TCC Training Seminar on One-month Forecast

16 – 20 November 2015
Tokyo, Japan

Contents

Schedule

TCC Training Seminar on One-month Forecast

Tokyo, Japan, 16 -20 November 2015

Draft Schedule

Day 1 - Monday, 16 November		
10:00-10:30	1. Opening - Welcome Address - Self-introduction by participants - Group photo shooting - Courtesy call on JMA's Director-General	
10:30-10:45	Coffee Break	
10:45-11:00	2. Introduction: Outline and scope of the Training Seminar	
11:00-12:45	3. Lecture: "Introduction to Climatology" for experts on seasonal forecasting	
12:45-14:15	Lunch	
14:15-16:15	3. Lecture: "Introduction to Climatology" for experts on seasonal forecasting	
16:15-16:30	Coffee Break	
16:30-16:50	4. Lecture: Introduction to JRA-55	
16:50-18:15	5. Lecture and Exercise: Introduction and Basic Operation of iTacs	
18:30-20:00	Reception	at KKR Hotel Tokyo
Day 2 - Tuesday, 17 November		
09:30-09:50	6. Lecture: Introduction of products for Climate System Monitoring	
09:50-11:20	7. Lecture: JMA's Ensemble Prediction Systems (EPS) and their products for Climate Forecast	
11:20-11:30	Coffee Break	
11:30-12:30	8. Lecture: Seasonal Forecast (One-month Forecast)	
12:30-14:00	Lunch	
14:00-15:15	9. Lecture: Concept of numerical guidance, Overview of the guidance tool	
15:15-15:30	Coffee Break	
15:30-18:00	10. Exercise: How to use guidance tool	
Day 3 - Wednesday, 18 November		
9:30-12:30	10. Exercise: How to use guidance tool	
Around 11:00	Coffee Break	
12:30-14:00	Lunch	
14:00-18:00	10. Exercise: How to use guidance tool	
Around 16:00	Coffee Break	
Day 4 - Thursday, 19 November		
9:30-12:30	10. Exercise: How to use guidance tool	
Around 11:00	Coffee Break	
12:30-14:00	Lunch	
14:00-15:30	11. Presentation by participants	Presentation (15 min.) followed by Q&A (5 min.)
15:30-15:45	Coffee Break	
15:45-18:00	11. Presentation by participants	
Day 5 - Friday, 20 November		
09:30-12:10	11. Presentation by participants	
Around 11:00	Coffee Break	
12:10-12:30	12. Wrap up and Closing	
12:30-14:00	Lunch	
14:00-18:30	Technical Tour	

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Provisional List of participants

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“Introduction to Climatology”
for experts on seasonal forecasting

"Introduction to Climatology" for experts on seasonal forecasting

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1. Climate and Climate system

According to WMO website, "on the simplest level the weather is what is happening to the atmosphere at any given time. Climate, in a narrow sense, can be considered as the 'average weather,' or in a more scientifically accurate way, it can be defined as 'the statistical description in terms of the mean and variability of relevant quantities over a period of time.'" Although climate is the synthesis of the weather, climate is not maintained only by atmosphere itself but is formed in the interactions among many components of the Earth. This system is named as a climate system. The global climate system consists of atmosphere including its composition and circulation, the ocean, hydrosphere, land surface, biosphere, snow and ice, solar and volcanic activities (Fig.1). These components interact on various spatial and temporal scales through the exchanges of heat, momentum, radiation, water and other materials.

The purpose of the lecture is to know how climate is formed and its variability is caused. In the lecture, anthropogenic "climate change" defined by UNFCCC is not explicitly included. As for "climate change", please refer to other text books or the item 5 of last year's TCC seminar text book written by Dr Ose.

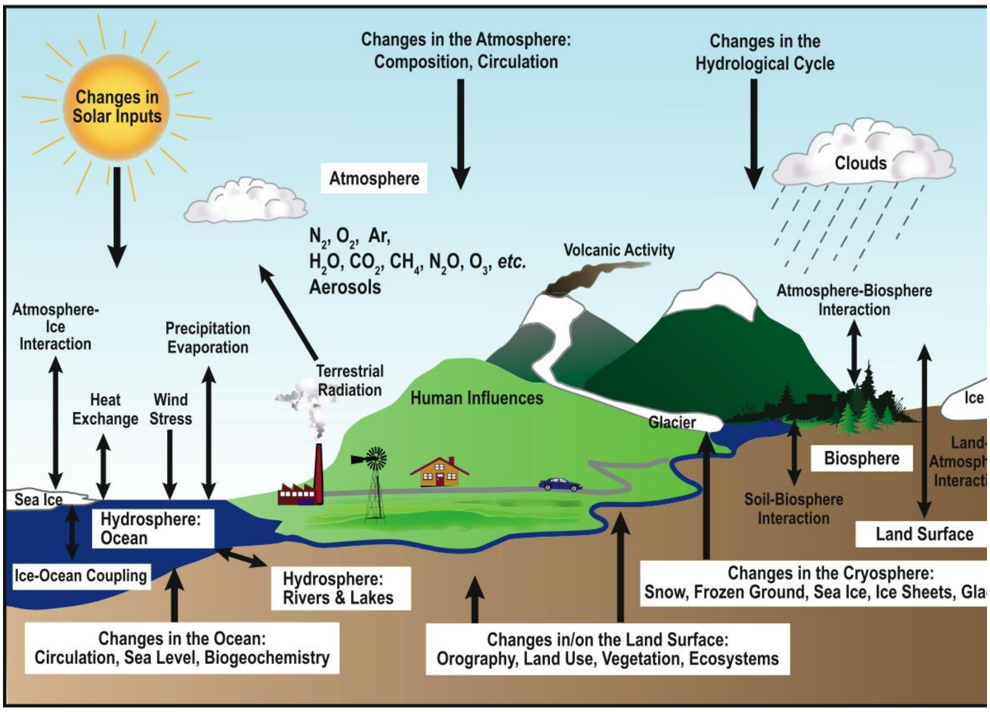


Figure 1 Schematic view of the components of the climate system, there processes and interactions. From IPCC (2007).

2. Global mean temperature and Radiative balance

Global mean temperature of planets, which is the temperature "observed from space", is estimated by global radiation balance between absorbed solar radiation and terrestrial emission from the planet. Incoming solar radiation is reflected back to space by a fraction of the planetary albedo. For the Earth, the observed mean ground temperature (15°C) is warmer by 34°C than the estimated temperature (-19°C). The reason is suggested by comparing other planet cases. The mean ground temperature for Mars with thin atmosphere is warmer only by 1°C than the estimated temperature. For Venus with thick atmosphere, the difference is 503°C. Radiative absorption by greenhouse gas in atmosphere is an important factor to determine mean ground temperature as well as planetary albedo.

The Earth's atmosphere has different characteristics for shortwave and longwave radiations (Fig.2). It is transparent (about 50%) for shortwave radiative flux from the sun as an approximation except for the reflection due to clouds (about 20%). On the other hand, the longwave radiation flux emitted from the Earth's ground is absorbed (about 90%) once in the atmosphere approximately and then mostly emitted back to the ground (greenhouse effect). Upper cold atmosphere and clouds emit less longwave flux to space than the ground emits. As a net, surface ground is heated by shortwave radiation from the sun, and atmosphere is cooled by longwave emission to space. The vertical contrast of the heating between ground and atmosphere creates thermal instability, which is compensated by vertical transport processes of sensible and latent heat energy due to turbulences, convections and waves.

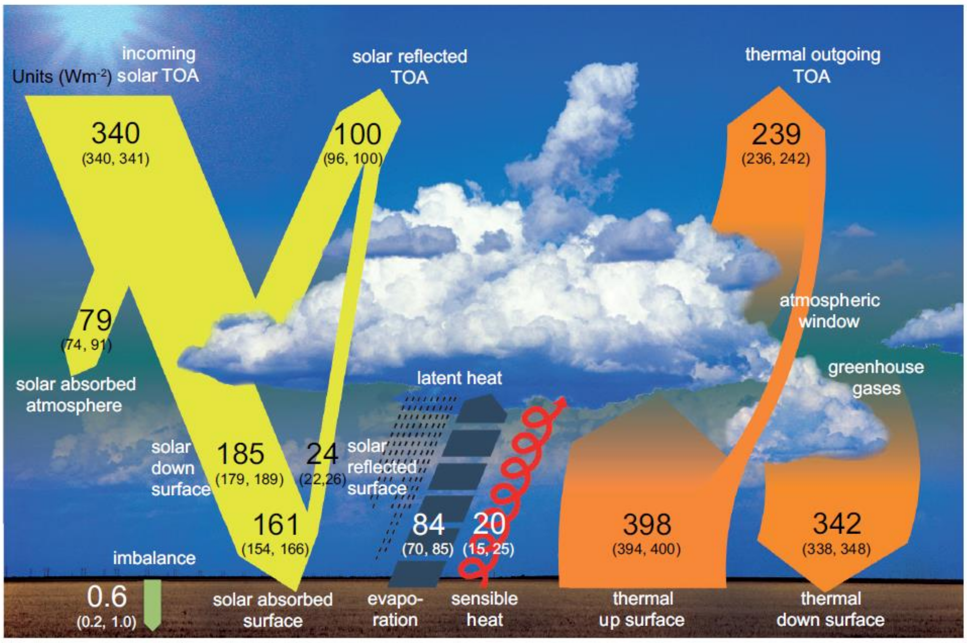


Figure 2 Schematic diagram of the global mean energy balance of the Earth. Numbers indicate best estimates for the magnitudes of the globally averaged energy balance components together with their uncertainty ranges, representing present day climate conditions at the beginning of the twenty first century. Units W/m^2. From IPCC (2014).

3. Annual mean circulation and Horizontal heating contrast

Longitudinal contrast of radiative heating is created between day and night (Fig.3). But, generally, as compared with the annual cycle, the diurnal heating contrast does not produce significant temperature differences between day and night and related global circulations because a relaxation time to a radiative equilibrium is estimated as 30 days for the Earth (James, 1995), which is much longer than a day scale. Latitudinal heating contrast on the Earth is created on seasonal time-scale by the different incoming shortwave radiation between near the poles and the tropics (Fig.3). Local surface temperature determining outgoing longwave radiation is not adjusted instantly enough to compensate for the shortwave radiation contrast. A part of absorbed radiative energy in low latitudes is transported poleward by meridional circulations and waves in atmosphere and ocean, and these heat transports keep high-latitudes warmer than the radiative equilibrium.

Poleward/equatorward air motions form westerly/easterly wind in the upper/lower subtropics (Fig.4) through Coriolis force due to the rotation of the Earth (or the angular momentum conservation about the Earth's rotation axis). Extra-tropical waves are also responsible for creating mid- to high latitude's westerly jets.

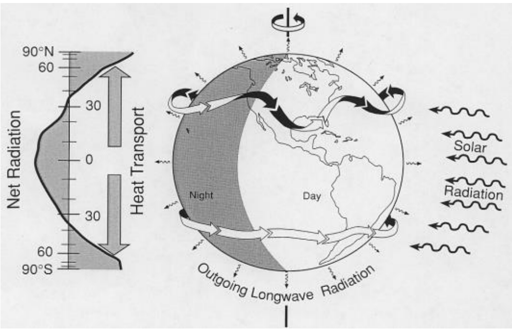


Figure 3 Horizontal radiative imbalance and energy transport by the atmosphere and ocean. From IPCC (1995).

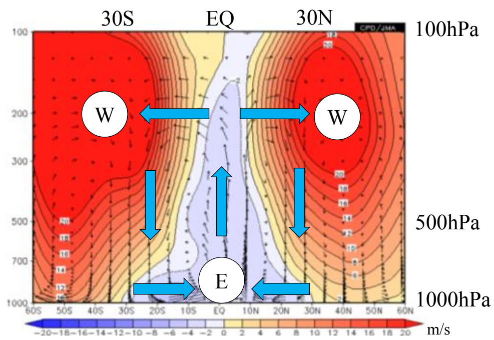
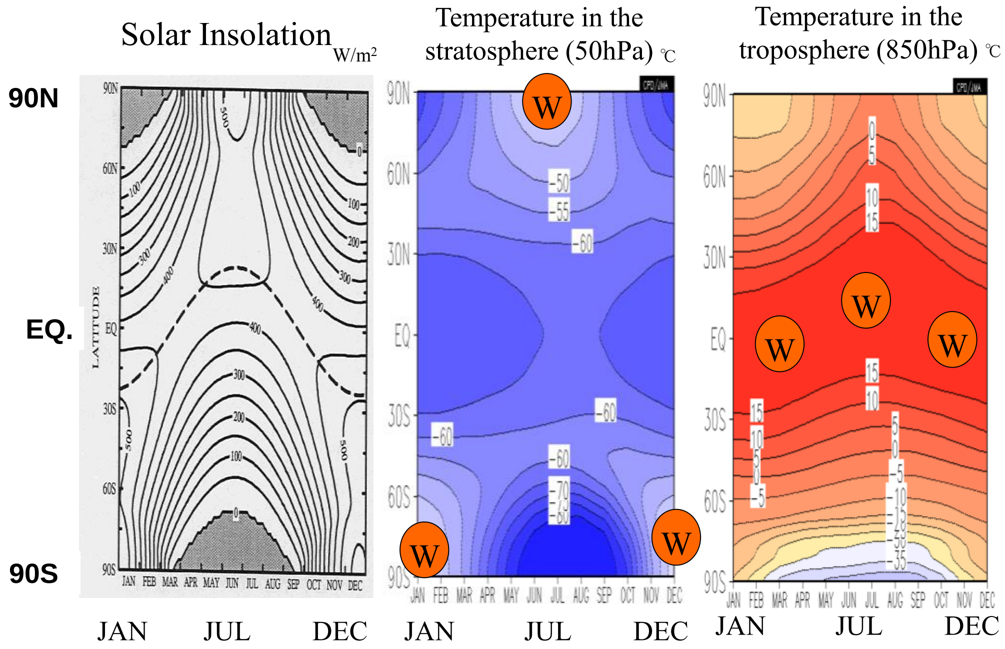


Figure 4 Annual and zonal mean wind. Shade: zonal wind, and arrow: meridional and vertical wind.

4. Seasonal change and Heat capacity

Seasonal change is definitely produced by the seasonally changing solar incidence with its maxima at the South Pole in December and at the North Pole in June. However, zonally averaged features of temperature are not drastically changed in the troposphere (lower than about 100hPa) through the whole year, hot tropics and cold poles (Fig.5). This fact is attributed to basically unchanged distribution of sea surface temperature (SST) due to large heat capacity of the oceans; in the Earth, heat capacity of the ocean is about 1,000 times of that of the atmosphere. SSTs roughly determine the location of deep cumulus occurrences, which leads to vertical energy mixing in the troposphere and drives global circulations (Webster, 1994). Stratospheric climate above 100hPa varies following the seasonal march of the sun (Fig.5) because of the seasonal change of ozone-related shortwave heating and small heat capacity of thin stratospheric atmosphere; cold around a winter pole, warm around a summer pole. Atmospheric circulations also contribute to the stratospheric climate; a cold tropopause in the tropics is steadily created by upward motion.



Figue 5 Seasonal change of (left)solar insolation, zonally averaged temperature (middle) at 50hPa and (right) at 850hPa. The figure for solar insolation is from IPCC (1995).

Heat capacity of land surface is small as compared with that of the oceans. Surface air temperature over the northern continents is much higher than SSTs at the same latitudes in the northern summer (especially in daytime) and much colder in the northern winter (Fig.6). The large contrasts of surface air temperature between continents and the oceans add a significant feature to regional seasonal changes of rainfall and wind around the continents in low and mid-latitudes, which is named as monsoon. A concentrated subtropical rainfall forms a typical summer monsoon system consisting of an upper-level anti-cyclonic circulation, a monsoon trough, a low-level jet, a subtropical rainfall band expanding north eastward (south eastward) and extensive downward motions causing dry region in the north westward (south westward) area of the Northern (Southern) Hemisphere (Rodwell and Hoskins, 1996), as shown in the Asian region of Fig.6 and Fig. 7.

Jan-Jul contrast of surface temperature/precipitation

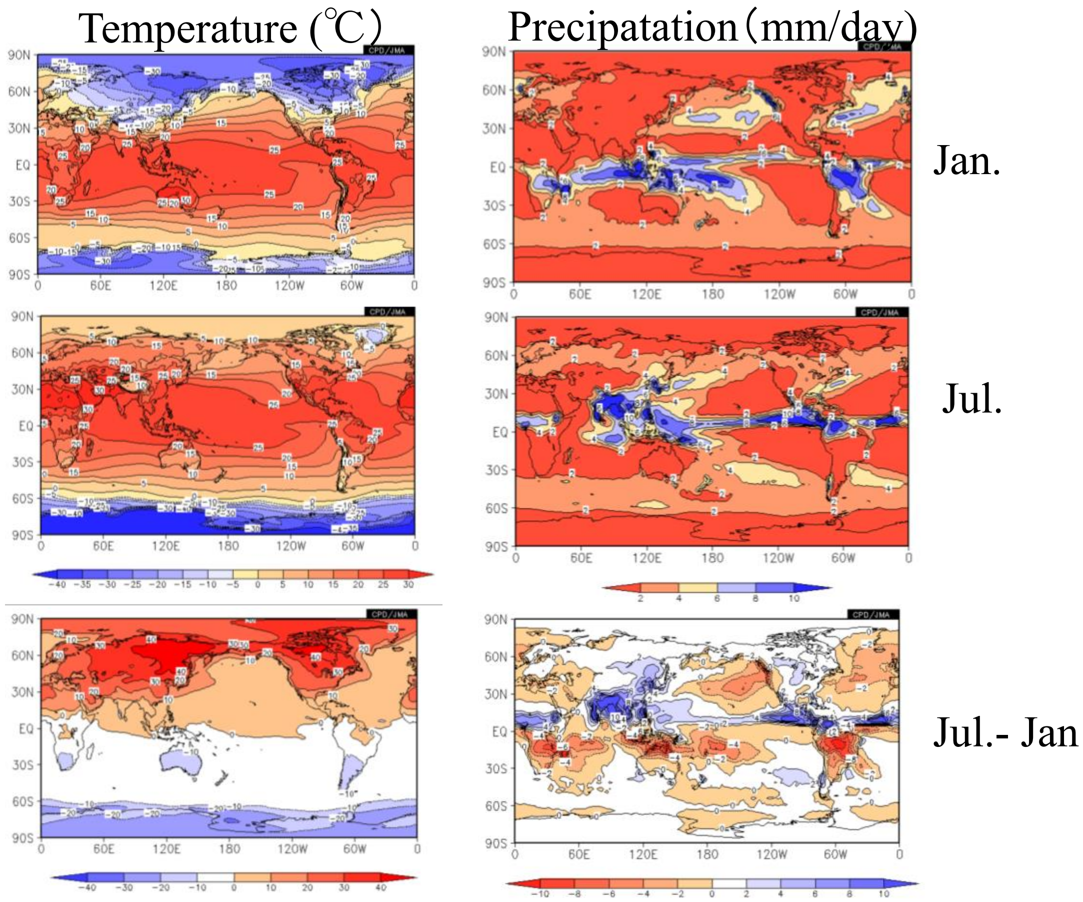


Figure 6 (Left) surface are temperature and (right) precipitation in (upper) January, (middle) July, and (bottom) deference between the two months.

Northern Summer Monsoon circulation

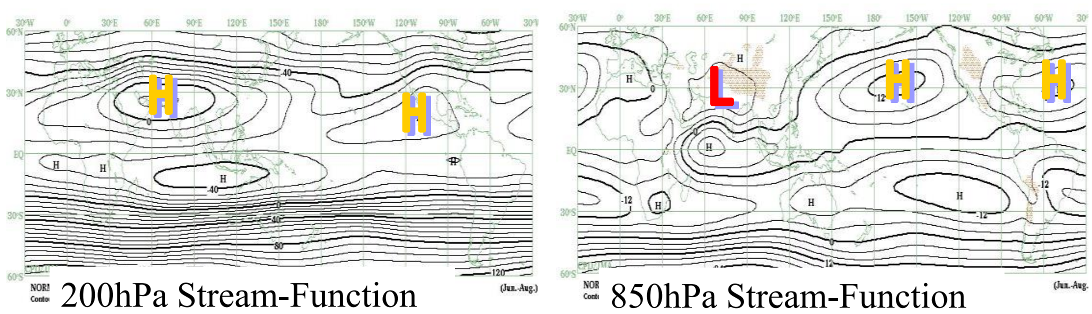


Figure 7 (Left) 200hPa stream function and (right) 850hPa stream function in JJA.

Mountains have also impact on seasonal changes in local climate through thermal and dynamical processes. A good way to understand climate system is to modify or remove some elements of the climate system (Fig. 1). It is not easy to modify a real climate system of the Earth by changing the Earth orbit or removing mountains. Instead, we can easily modify virtual climate systems simulated numerically in climate models based on physics and other fundamental sciences. From the comparison between with/without mountain model experiments (Fig. 8), we can see that mountains would be responsible for the real world climate of humid summer and somewhat cold winter in the eastern parts of the continents.

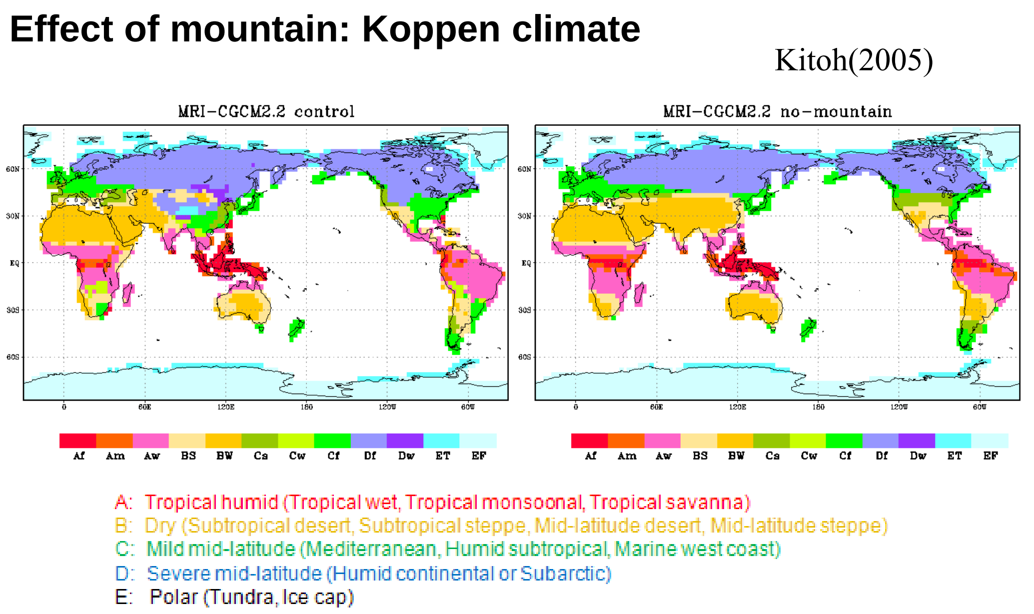


Figure 8 Koppen climate maps simulated by a climate model (left) with mountains and (right) without mountains. From Kitoh (2005) in Japanese.

6. Intra-seasonal to Interannual variability

Climate varies naturally with time. Atmosphere itself includes internal instability mechanisms, typically the baroclinic instability around the extratropical westerly jets, so that it may be considered as chaotic or unpredictable beyond a few weeks. However, some atmospheric low-frequency (>10days) teleconnections are analyzed such as wave patterns along the westerly jet waveguides and other ones from the northern mid-latitudes across the equatorial westerlies (Fig. 9), which are consistent with the Rossby-wave propagation theory. Also, teleconnections of another type are analyzed such as meridional displacements of the westerly jet (Fig.10), which are maintained by the wave-mean flow interaction (Vallis, 2006). Numerical ensemble predictions from many disturbed atmospheric initials are a reasonable tool to capture mean weathers in next few weeks.

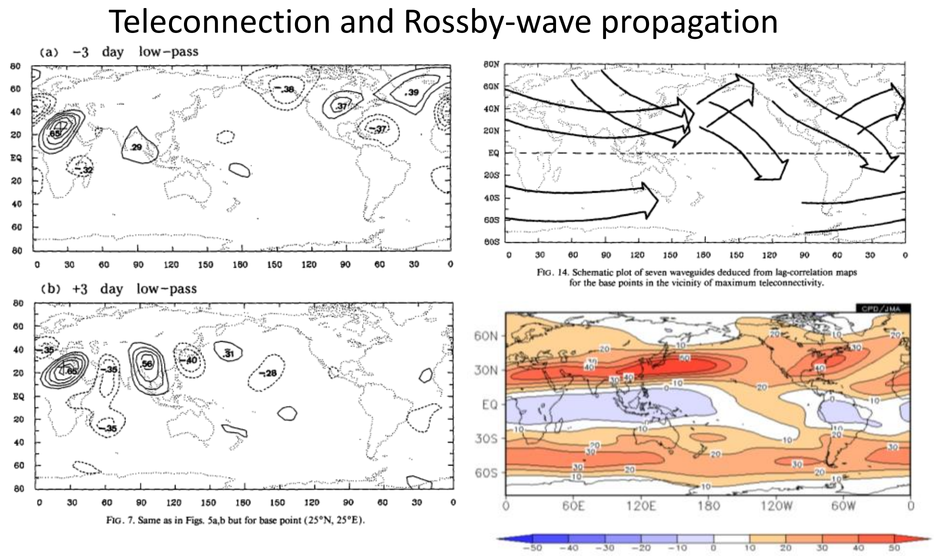


Figure 9 (Left) a teleconnection pattern of 250hPa stream function in boreal winter, (upper-right) various propagations of Rossby-wave and (lower-right) 250hPa climatological zonal wind in DJF. Left and upper-right panels are from Hsu and Lin (1992).

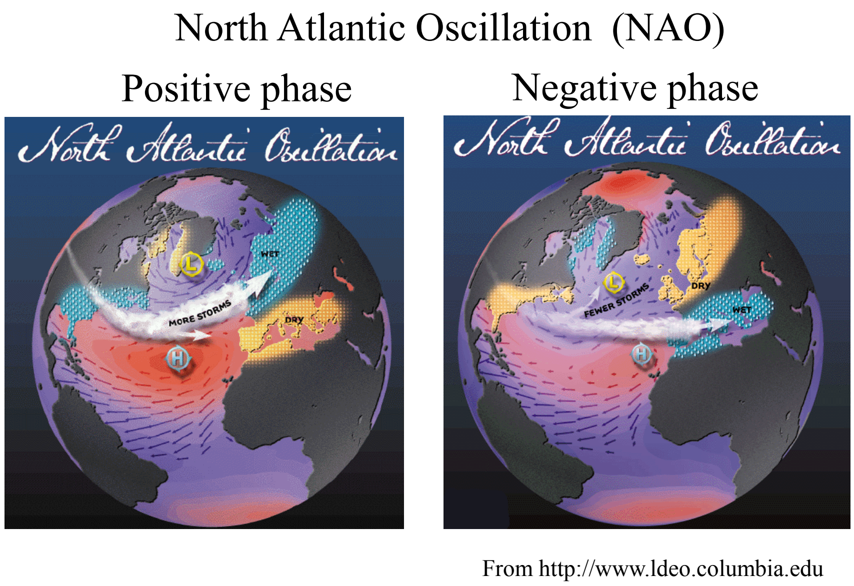


Figure 10 (Left) positive and (right) negative phase of North Atlantic Oscillation (NAO). NAO is one of teleconnections with meridional displacements of the westerly jet. Panels are from http//www.ldeo.columbia.edu.

Some peaks in spatial and temporal power-spectrums, indicating organized atmospheric variability coupled with convective activity, are imbedded in red noise backgrounds in the tropics. Variability of outgoing longwave radiation (OLR) associated with equatorial waves, such as Kelvin waves, equatorial Rossby waves (ER) and mixed Rossby-Gravity waves (MRG), can be detected, as well as tropical depressions and easterly waves (TD-type) in Fig. 11.

Wheeler, M., and G. N. Kiladis, 1999: Convectively coupled equatorial waves: Analysis of clouds in the wavenumber frequency domain. *J. Atmos. Sci.,* **56,** 374–399.

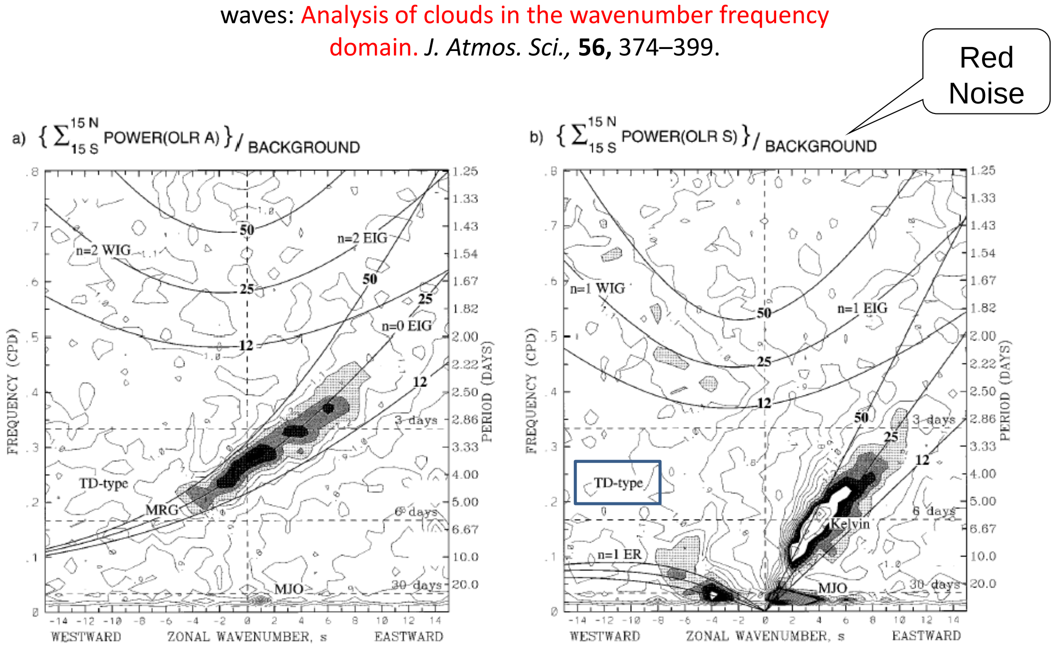


FIG. 3. (a) The antisymmetric OLR power of Fig. 1a divided by the background power of Fig. 2. Contour interval is 0.1, and shading begins at a value of 1.1 for which the spectral signatures are statistically significantly above the background at the 95% level (based on 500 dof). Superimposed are the dispersion curves of the even meridional mode-numbered equatorial waves for the three equivalent depths of h = 12, 25, and 50 m. (b) Same as in panel a except for the symmetric component of OLR of Fig. 1b and the corresponding odd meridional mode-numbered equatorial waves. Frequency spectral bandwidth is 1/96 cpd.

Figure 11 Spatial and temporal power-spectrums in the tropics of (left) asymmetric and (right) symmetric OLR variability about the equator. (From Wheeler and Kiladis 1999).

The Madden-Julian Oscillation (MJO) is an eastward-moving oscillation of surface pressure, precipitation and winds along the equator with the period of 30-60 days and planetary scale wavenumbers (Fig. 12). Monitoring MJO or watching OLR and velocity potential anomalies may be very helpful for intra-seasonal prediction in the tropics to the subtropics and even in the mid-latitudes (Fig. 12). Improvement of MJO prediction skill is one of key topics for operational numerical prediction centers in the world.

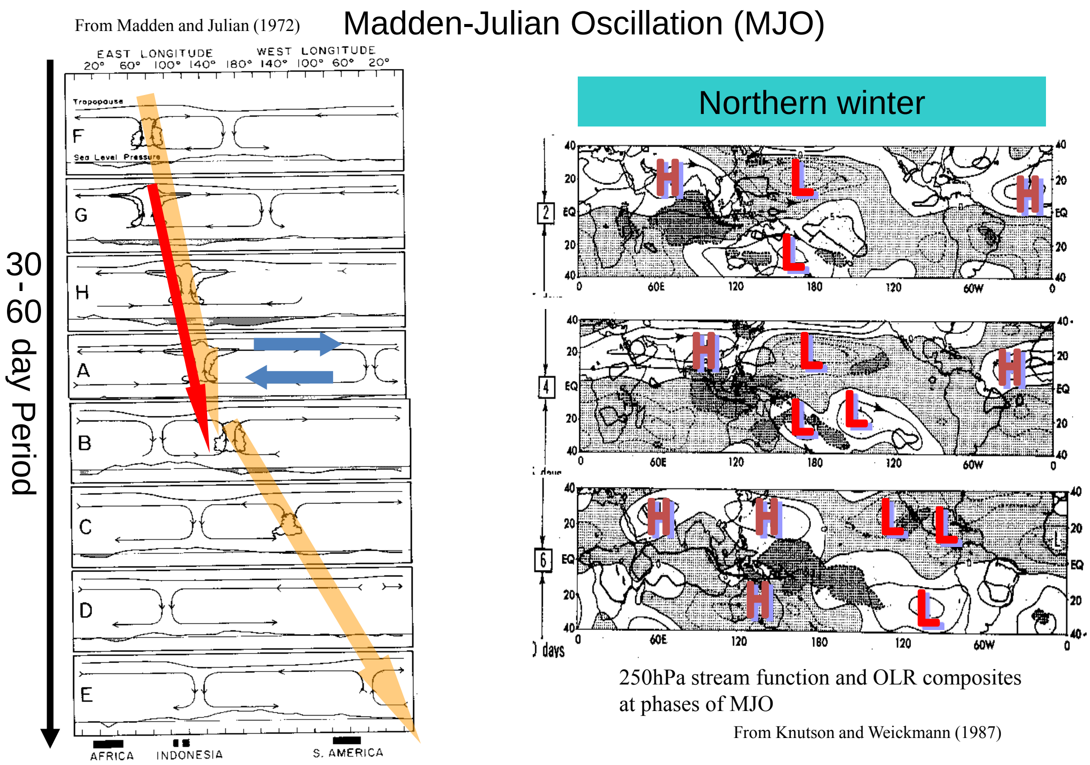


Figure 12 (Left) schematic time-sequence of Madden-Julian Oscillation (MJO) along the equator (from Madden and Julian, 1972). (Right) composite maps of OLR and 250hPa stream function anomaly at MJO phases (from Knutson and Weickmann 1987).

Atmosphere-ocean interactions are able to produce longer time-scale natural variability in atmosphere with periods beyond months up to several and decadal years. A typical example is ENSO (El Niño / Southern Oscillation) with the period of 2-7 years, which is influential to worldwide climate even out of the tropical Pacific. El Niño events themselves, and related surface air temperature and precipitation anomalies are predicted successfully on seasonal to inter-annual scales (Fig.13). The SST anomalies with El Niño tend to keep seasonally steady precipitation (heating) anomalies over the equatorial central Pacific. The response of the upper and lower-level tropical atmosphere to these steady heating anomalies can be explained based on forced equatorial waves or the Gill-pattern (or Matsuno-Gill pattern) (Fig. 14).

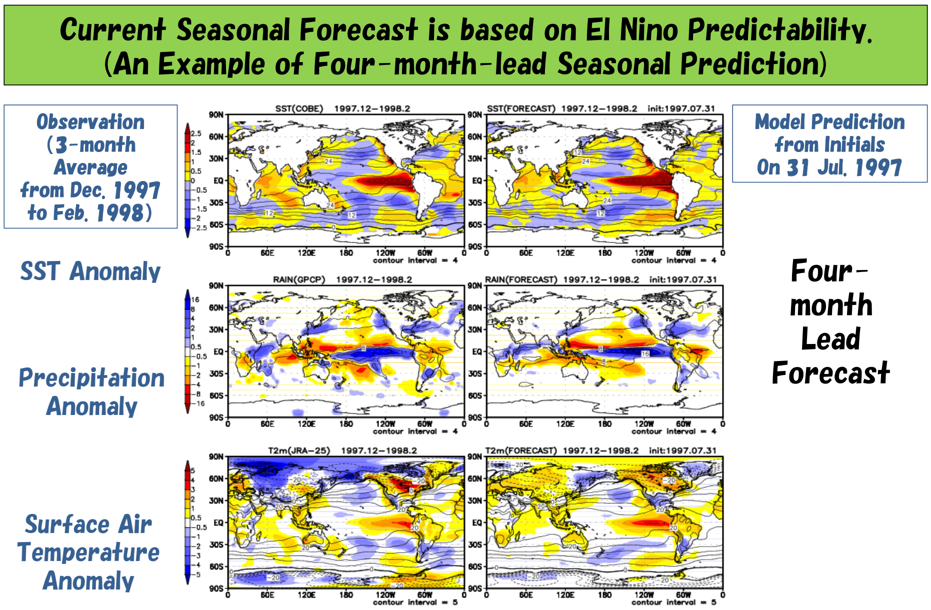


Figure 13 (Left) observed SST, precipitation and surface air temperature anomalies for DJF 1997-98. (Right) the same except for four-month lead prediction.

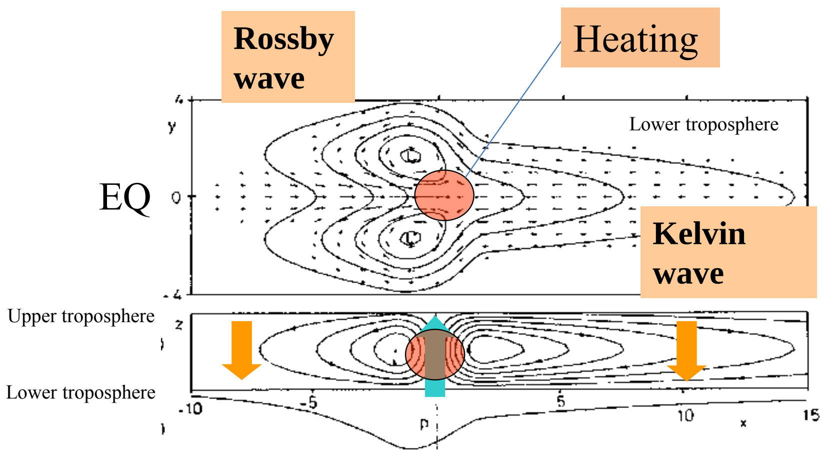


Figure 14 Tropical atmospheric responses to equatorially symmetric heating anomalies. (from Gill 1980).

Recently, terms of "El Niño Modoki" or "Central Pacific (CP)-El Niño" are used to distinguish them from normal El Niño events or Eastern Pacific (EP)-El Niño. They consist of the equatorial Pacific phenomena with warm SST anomalies and enhanced precipitation in the central Pacific, and cold SST anomalies and suppressed precipitation in the eastern Pacific, on contrast. The remote effect of El Niño during the mature stage is stored in the Indian Ocean capacity and still influential to the Indo-western Pacific climate even during summer following the ENSO (Fig.15). A dipole mode with an east-west SST anomaly contrast sometimes occurs around September and October in the tropical Indian Ocean, which is at least partially independent from ENSO events (Fig. 16). Occurrence of this mode affects climate over various regions including tropical eastern Africa and the maritime continent.

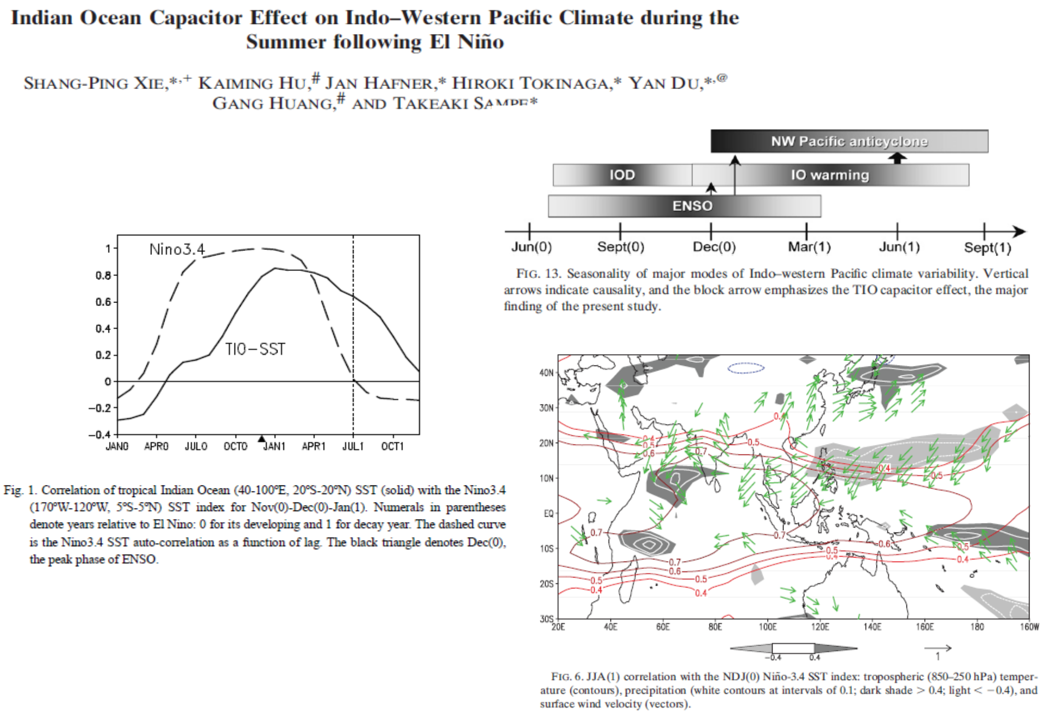


Figure 15 Indian Ocean capacitor effect. (Left) lagged correlation of tropical Indian Ocean SST with Nino 3.4 SST for NDJ. (Upper-right) seasonality of major modes. (Lower-right) correlation of the NDJ Nino3.4 SST with the following JJA climate. From Xie et al. (2009).

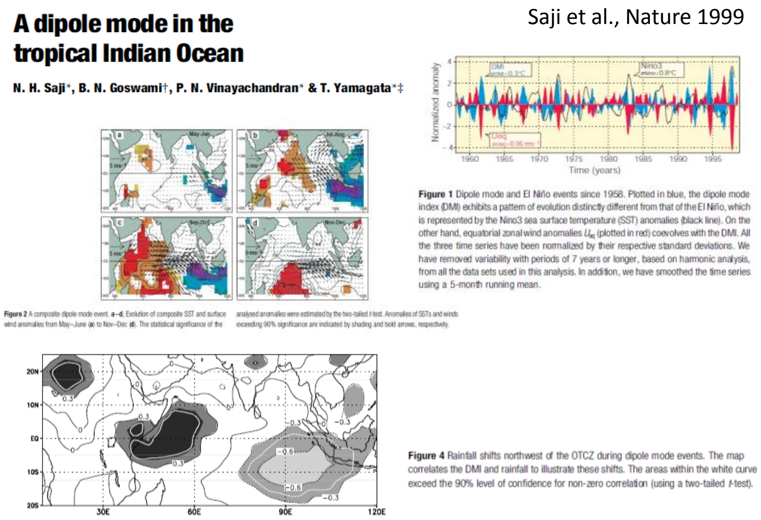


Figure 16 A dipole mode in the tropical Indian Ocean. (Upper-left) time-evolution of the dipole mode SST anomaly, (lower-left) rainfall shift during the dipole mode, (right) historical records for dipole mode and El Niño events. From Saji et al. (1999).

7. Decadal variability

Decadal variability and climate change involve feedbacks from other elements of the climate system. Changes of vegetation and soil moisture amplify the dramatic drying trend in 1980's in Sahel region, which is basically forced by a southward precipitation shift of the Inter-tropical Convergence Zone due to cooler/warmer SST anomaly in the northern/southern Atlantic Ocean (Fig. 17).

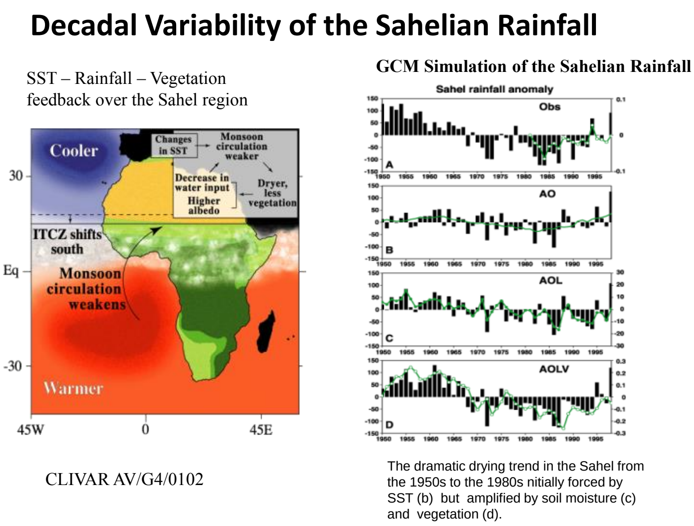
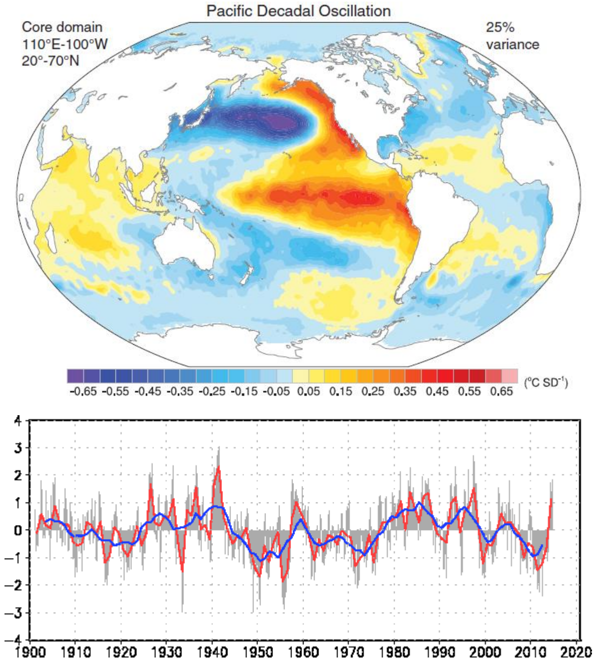


Figure 17 Decadal variability of the Sahel Rainfall. (Left) a possible mechanism, (Right) observed historical Sahel rainfall anomaly and GCM simulations . From Zeng et al. 1999.

Decadal variabilities are also found in SST anomaly from the North Pacific to the tropics(Fig. 18) which is named Pacific Decadal Oscillation (PDO) or Interdecadal Pacific Oscillation (IPO) . A possible mechanism of PDO is the subduction hypothesis; high latitudes' cold surface water is subducted in the North Pacific and flows into the subtropical deeper ocean along the surfaces of constant density, then emerges again to the surface of the equatorial Pacific by upwelling. This is consistent with the analysis showing that the decadal SST variability in the central North Pacific spreads into the deep ocean. PDO has impact on ENSO characteristics and regional climate. Several studies indicated that the negative phase of PDO played the major role in the slowdown of the global averaged surface air temperature raise in recent years (Meehl, 2015).

Pacific Decadal Oscillation



Trenberth and Fasullo (2013)

PDO index (From JMA HP)

Figure 18 (Upper) SST anomaly pattern in the positive phase of Pacific Decadal Oscillation (PDO)(from Trenberth and Fasullo, 2013) and (lower) PDO index (from http://ds.data.jma.go.jp/tcc/tcc/products/elnino/decadal/pdo.html).

8. Summary

Unusual weather and climate are attributed to unusual atmospheric flows, storms and convective disturbance. Diagnostic analysis shows that those disturbances are often related to atmospheric intrinsic waves and phenomena. However, atmospheric environment is maintained and influenced by other elements consisting of the climate system. Sometimes, and unusual and steady convective activity is connected to long-term SST anomalies related to ocean variability. Numerical ensemble simulations starting from many disturbed atmospheric and oceanic initials are a reasonable tool to capture the mean state of weathers and climate in a timescale from weeks to seasons. Radiative processes including longwave absorption by greenhouse gases and shortwave reflection by snow, ice, clouds and aerosols determine the local Earth's ground temperature. The distribution of ground temperature is influential to vertical and horizontal atmospheric and oceanic stabilities, the amount of water vapor and the speed of water cycle. Then, those can affect atmospheric and oceanic flows, the features of storms and convections and eventually our daily lives. Therefore, we need to continue careful watches and diagnostics for global and local climate systems (Fig.1), as well as its prediction.

References

Deser, C., M. A. Alexander and M. S. Timlin, 1996: Upper-ocean thermal variations in the North Pacific during 1970-1991. *J. Climate,* **9**, 1840-1855.

Gill, A. E., 1980: Some simple solutions for heat-induced tropical circulation. *Quart. J. Meteor. Soc.*,**106**, 447-462.

Hsu, H.-H., and S.-H. Lin, 1992: Global teleconnections in the 250-mb streamfunction field during the Northern Hemisphere winter. *Mon. Wea. Rev.*, **120**, 1169-1190.

IPCC Second Assessment Report (SAR) Climate Change 1995: The Science of Climate Change.

IPCC Fourth Assessment Report (AR4) Climate Change 2007: The Physical Science Basis.

IPCC Fifth Assessment Report (AR5) Climate Change 2014: The Physical Science Basis.

Kitoh, A., 2005: Climate model simulation on the role of mountain uplift on Asian monsoon. The Geological Society of Japan, 111, XIX.

Knutson, T. R. and K. M. Weickmann, 1987: 30-60 day atmospheric oscillations: composite life cycles of convection and circulation anomalies. *Monthly Wea. Rev.* **115**, 1407-1436.

Madden, R. A. and P. R. Julian, 1994: Observations of the 40–50-day tropical oscillation—A review, *Monthly Wea. Rev.*, **122**, 814–37.

Meehl G. A., 2015: Deacadal climate variability and the early-2000s hiatus. US CLIVAR, 13, No.3, 1-6.

Saji, N. H., B. N. Goswami, P. N. Vinayachandran and T. Yamagata, 2009: A dipole mode in the tropical Indian Ocean. *Nature*, **401**, 360-363.

Trenberth, K.E and J. T. Fasllo, 2013: An apparent hiatus in global warming?. Earth's Future 1, 19-32.

Rodwell, M.J. and B. I Hoskins, 1996: Monsoons and the dynamics of deserts. *Q. J. R. Meteor. Soc.*, **122**, 1385-1404.

Webster, P. J., 1994: The role of hydrological processes in ocean-atmosphere interactions, *Review of Geophysics,* **32**,427-476.

Weng, H., K. Ashok, S. Behera, S. A. Rao and T. Yamagata, 2007: Impacts of recent El Nino Modoki on dry/wet conditions in the Pacific rim during boreal summer. *Clim Dyn.*, **29**, 113-129.

Wheeler, M., and G. N. Kiladis, 1999: Convectively coupled equatorial waves: Analysis of clouds in the wavenumber frequency domain. *J. Atmos. Sci.*, **56,** 374–399.

Xie, S.-P., K. Hu, J. Hafner, H. Tokinaga, Y. Du, G. Huang and T. Sampe, 2009: Indian Oceancapacitor effect on Indo-western Pacific climate during the summer following El Niño. *J. Climate*, **22**, 730-747.

Zeng, N., J. D. Neelin, K.-M. Lau and C. J. Tucker, 1999: Enhancement of interdecadal climate variability in the Sahel by vegetation interaction. *Science*, **286**, 1537-1540.

Text books

James, I. N., 1995: Introduction to Circulating Atmospheres. Cambridge University Press, 422pp.

Trenberth, K.E.(ed.), 1992: Climate System Modeling. Cambridge University Press, 788pp.

Valls G. K., 2006:Atmospheric and oceanic fluid dynamics. Cambridge University Press, 7454pp.

Wallace, J.M. and P. V. Hobbs, 2006: Atmospheric Science. Academic Press, 483pp.

Introduction to JRA-55

Introduction to JRA-55

Kazutoshi ONOGI

1 Approaches in researches on the past climate

(1) Direct use of observational data

Historical in situ surface observational data have been accumulated for more than 100 years and upper air data for several decades, which can be a reliable data source to estimate the past climate quantitatively. In fact the Climatic Research Unit TEMperature (CRUTEM4, latest version) data (Jones et al., 2012) was produced as a reliable temperature database of land surface temperatures. The Global Climate Observing System (GCOS) established in 1992 organized the climate observing networks for surface (GCOS Surface Network; GSN) and for upper air (GCOS Upper Air Network; GUAN), each of which consists of selected high-quality observing stations. The GSN and GUAN data are quality controlled and accumulated in their data archive centers. Climate statistics using GUAN and other data (HadAT; Thorne et al. 2005) has been produced by United Kingdom Meteorological Office (UKMO) and National Climatic Data Center (NCDC), and a long-term tendency in radiosonde observations of GUAN was detected. However, even the best organized observational dataset covers mainly land areas and the observed meteorological variables are limited. Generally in many cases, past observational data were not well organized; they were accumulated separately in many countries and organizations with various data formats and units. These data can be used only locally even if they are available. The data as they are may not be adequate for a global climate study because the observational data are not distributed uniformly to represent global atmospheric situation homogeneously.

(2) Use of numerical assimilation and prediction techniques

On the other hand, in the advanced national meteorological centers in the US, Europe and Japan, global observational data are acquired via the global telecommunication system (GTS) and assimilated into numerical weather prediction (NWP) models. The global atmospheric status at a certain time can be assimilated to every grid point of the NWP model, as an analysis. The future atmospheric state is then predicted from the analysis. In consequence, global Data Assimilation (DA) systems were developed rapidly in major NWP centers. DA cycles have been operated since the 1980s.

The DA cycle is a core system of NWP system. In the DA cycle, data assimilation gives an initial condition for a forecast model, and short term forecast is performed and gives a first guess field to DA. The DA cycle is a continuous repetition of data assimilation and short-term forecasts. It is a quite important method for representing the global atmospheric situation in detail and to improve the forecast. The accumulated operational analysis data are useful data which give frequent three-dimensional high quality global grid point values (GPV) of many kinds of meteorological variables with a system specific resolution. It gives the most reliable data for meteorological and climate researches at the time. In particular, for operational climate monitoring and climate research, daily global atmospheric data with many kinds of variables for several decades are essential and necessary as basic data. The operational numerical analysis archives have been used as the basic data to calculate climate normal values of average for the past 30 years.

However, there are serious problems to use an operational analysis data as basic data for climate monitoring. About a half century has passed since the beginning of operational NWP at the major NWP centers in the world. During the years, operational NWP system and supercomputer system have developed significantly. The quality of numerical analysis largely depends on the techniques of data assimilation and the power of supercomputer system at the time of production. Therefore the quality of the latest operational analysis is quite different from older analyses. Obviously consistent climate monitoring for several decades is impossible if we use operationally archived analysis data.

2 Introduction to JRA-55 reanalysis

The Japan Meteorological Agency (JMA) conducted the second Japanese global atmospheric reanalysis, called the Japanese 55-year Reanalysis or JRA-55 (Kobayashi et al. 2015). It covers the period starting in 1958, when regular radiosonde observations began on a global basis. JRA-55 is the first comprehensive reanalysis that has covered the last half-century since the European Centre for Medium-Range Weather Forecasts 45-year Reanalysis (ERA-40, Uppala et al. 2005), and is the first one to apply four-dimensional variational analysis to this period. The main objectives of JRA-55 were to address issues found in previous reanalyses and to produce a comprehensive atmospheric dataset suitable for studies of multidecadal variability and climate change. This paper describes the observations, data assimilation system and forecast model used to produce JRA-55 as well as the basic characteristics of the JRA-55 product.

JRA-55 has been produced with the TL319 version of JMA's operational data assimilation system as of December 2009, which was extensively improved since the Japanese 25-year Reanalysis (JRA-25, Onogi et al. 2007). It also uses many newly available and improved past observations. The resulting reanalysis products are considerably better than the JRA-25 product. Two major problems of JRA-25 were a cold bias in the lower stratosphere, which has been diminished, and a dry bias in the Amazon basin, which has been mitigated. The temporal consistency of temperature analysis has also been considerably improved compared to previous reanalysis products. Our initial quality evaluation revealed problems such as a warm bias in the upper troposphere, a large upward imbalance in the global mean net energy fluxes at the top of the atmosphere and at the surface, excessive precipitation over the tropics, and unrealistic trends in analyzed tropical cyclone strength. This paper also assesses the impacts of model biases and changes in the observing system, and it mentions efforts to further investigate the representation of low-frequency variability and trends in JRA-55.

3. Data assimilation system and forecast model used in JRA-55

The JRA-55 data assimilation system is based on the low-resolution (TL319) version of JMA's operational data assimilation system as of December 2009 (JMA 2013), which has been improved extensively since JRA-25 as shown in Table 1.

Table 1. Data assimilation systems used for JRA-25 and JRA-55.

	JRA-25	JRA-55
Base system	JMA's operational system as of March 2004 (JMA 2002)	JMA's operational system as of December 2009 (JMA 2007, 2013b)
Horizontal grid system	Gaussian	Reduced Gaussian
Horizontal resolution	T106 (~110 km)	TL319 (~55 km)
Atmospheric analysis		
Vertical levels	Surface and 40 levels up to 0.4 hPa	Surface and 60 levels up to 0.1 hPa (Iwamura and Kitagawa 2008; Nakagawa 2009)
Analysis scheme	3D-Var with the T106 inner resolution	4D-Var with the T106 inner resolution
Background error covariances	Static	Static with the simple inflation factor of 1.8 applied before 1972
Bias correction for satellite radiances	*TOVS* Adaptive scheme using 1D-Var analysis departures (Sakamoto and Christy 2009) *ATOVS* Static (until July 2009) and adaptive (thereafter) schemes using radiosonde and supplemental background fields (Kazumori et al. 2004)	VarBC (Derber and Wu 1998; Dee and Uppala 2009; JMA 2013b)
Radiative transfer model for satellite radiances	*TOVS:* RTTOV-6 *ATOVS:* RTTOV-7	RTTOV-9.3
Surface analysis		
Screen-level analysis	2D-OI	2D-OI with the FGAT approach
Land surface analysis	Offline SiB with 6-hourly atmospheric forcing	Offline SiB with 3-hourly atmospheric forcing
Snow depth analysis	2D-OI	2D-OI

The forecast model used for JRA-55 is based on the TL319 spectral resolution version of the JMA global spectral model (GSM) as of December 2009 (JMA 2013), which has been extensively improved since JRA-25 as shown in Table 2.

Table 2. Forecast models used for JRA-25 and JRA-55.

	JRA-25	JRA-55
Base model	JMA GSM as of March 2004 (JMA 2002)	JMA GSM as of December 2009 (JMA 2007, 2013b)
Horizontal resolution	T106 (~110 km)	TL319 (~55 km)
Vertical levels	Surface and 40 levels up to 0.4 hPa	Surface and 60 levels up to 0.1 hPa (Iwamura and Kitagawa 2008; Nakagawa 2009)
Dynamics		
Horizontal grid system	Gaussian	Reduced Gaussian
Advection scheme	Euralian	Semi-Lagrangian
Radiation		
Longwave radiation	*Line absorptions* Random band model of Goody (1952) *Water vapor continuum (e-type)* Roberts et al. (1976) *Radiatively active gases* H_2O, O_3 and CO_2 (constant at 375 ppmv)	*Line absorptions* Pre-computed transmittance tables and *k*-distribution (Chou et al. 2001) *Water vapor continuum (e-type and p-type)* Zhong and Haigh (1995) with MK_CKD (Clough et al. 2005) *Radiatively active gases* H_2O, O_3, CO_2, CH_4, N_2O, CFC-11, CFC-12 and HCFC-22
Shortwave radiation	*Absorptions by* H_2O, O_2, O_3 *and* CO_2 Briegleb (1992)	*Absorptions by* H_2O Briegleb (1992) *Absorptions by* O_2, O_3 *and* CO_2 Freidenreich and Ramaswamy (1999)
Cloud radiation	*Longwave* Maximum-random overlap *Shortwave* Random overlap	*Longwave* Maximum-random overlap with the method of Räisänen (1998) *Shortwave* Random overlap
Aerosols	Atmospheric aerosol profiles from WMO (1986) (CONT-I over land and MAR-I over sea)	Atmospheric aerosol profiles from WMO (1986) (CONT-I over land and MAR-I over sea) with optical depths adjusted to 2-dimensional monthly climatology
Cumulus convection	Prognostic Arakawa-Schubert	Prognostic Arakawa-Schubert with DCAPE
Initialization	Nonlinear normal mode initialization	Not used
Boundary conditions and forcing fields		
SST and sea ice	COBE-SST (Ishii et al. 2005)	COBE-SST (Ishii et al. 2005)
Ozone	T42L45 version of MRI-CCM1 (Shibata et al. 2005)	*Until 1978* Climatology *From 1979 onward* T42L68 version of MRI-CCM1 (Shibata et al. 2005)

4. Basic performance of JRA-55

(1) Two-day forecast scores

To evaluate the temporal consistency of the product and the impact of changes in observing systems, a short-range forecast was carried out in JRA-55 from 12 UTC every day. Figure 1 shows the time series of RMS errors in these 2-day forecasts at a geopotential height of 500 hPa averaged over the extratropical northern and southern hemisphere from JRA-25, JRA-55, and the JMA operational system, as verified against their own analyses. Because the forecasts were carried out with their own forecast models, the comparison is not made based on a common standard; nevertheless, it can provide useful insights regarding the temporal consistency of each product.

The JMA operational system has been improved in many aspects since JRA-25, including a revision of the longwave radiation scheme and the introduction of 4D-Var and VarBC. The JRA-55 data assimilation system, which is based on the TL319 resolution version of the operational system as of December 2009, incorporates these improvements and has been used consistently throughout the reanalysis period. Thus, variations in the forecast scores of JRA-55 can be attributed solely to the changes in observing systems and natural variations of atmospheric predictability, whereas forecast scores of the operational system clearly show the effect of these improvements. These are evidence of the greater temporal consistency of the JRA-55 product. The forecast scores of the JRA-55 system are considerably better than those of the JRA-25 system, which is based on the T106 resolution version of the operational system as of March 2004. The improvement of forecast scores is particularly significant in the southern hemisphere, which is most likely because of the availability of new satellite observations as well as the improvement of the data assimilation system.

The forecast scores of JRA-55 show relatively large variations that correspond to the introduction of VTPR in 1973; the advent of satellite observing systems in the late 1970s, ATOVS in 1998, and GNSS-RO in 2006; and variations in coverage of TOVS observations, suggesting that performance under sparse observations is an important concern for future reanalyses. It should be noted that the forecast scores in the southern hemisphere tend to be degraded during the pre-satellite era, whereas the number of used obsevations rather increased (Fig 2d, 2e). This inconsistency may indicate that the JRA-55 data assimilation system did not perform well during this period.

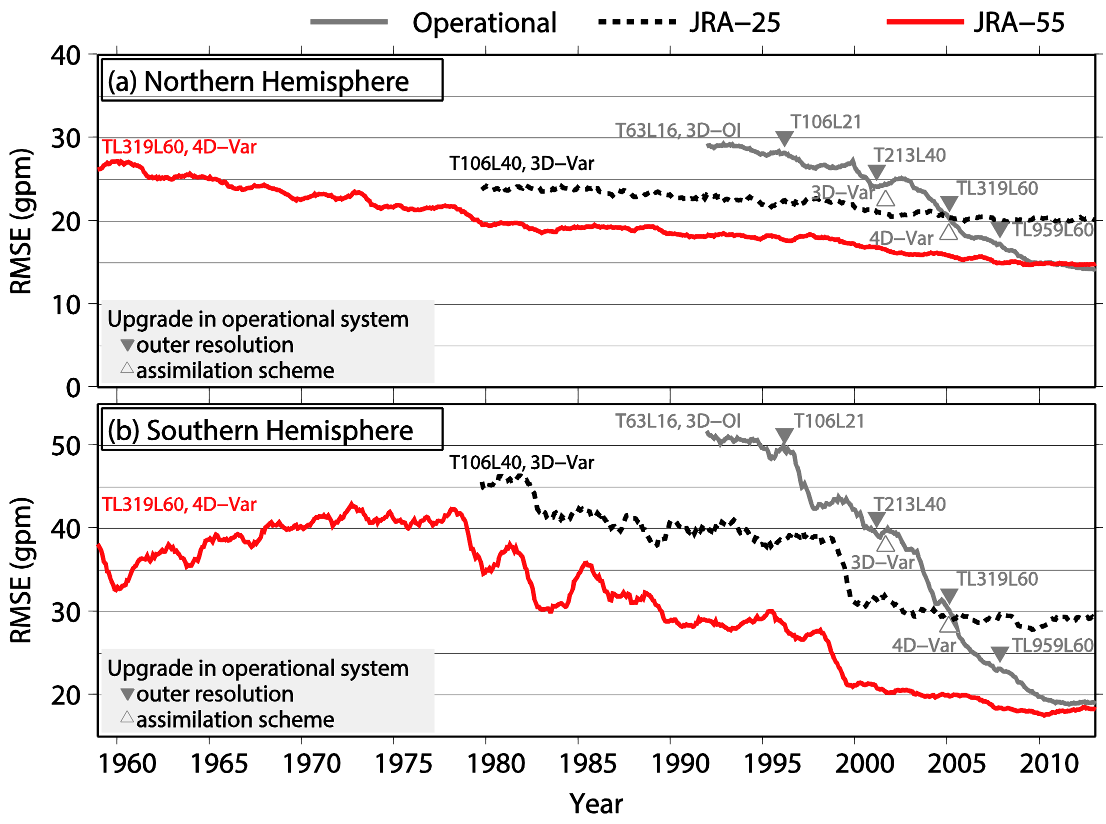


Figure 1 RMS errors of 2-day forecasts of the geopotential height at 500 hPa averaged over the extratropics of the (a) Northern and (b) Southern Hemispheres from JRA-25, JRA-55 and JMA operational system, verified against their own analyses. Changes in the assimilation scheme and resolution of the outer model are also noted. Each value represents the average for the last 12 months.

(2) Precipitation

Figure 2 shows the climatology of global precipitation distributions in JRA-55, JRA-25, ERA-Interim, ERA-40, the Modern-Era Retrospective Analysis for Research and Applications (MERRA, Rienecker et al. 2011), and GPCP (Adler et al. 2003) as an observational dataset. While precipitation in middle and high latitudes are underestimated in most reanalyses, this feature is improved in JRA-55, especially in the Pacific and Atlantic Oceans north of 30°N. On the other hand, JRA-55 overestimates precipitation in the tropics compared with GPCP. The regions where JRA-55 overestimates precipitation tend to exhibit the spin-down problem (precipitation is excessive immediately after the start of forecasts and then gradually decreases) (not shown). Therefore, the excessive precipitation in the tropics in JRA-55 is most likely related to the dry bias and the spin-down problem of the forecast model in regions of deep convection.

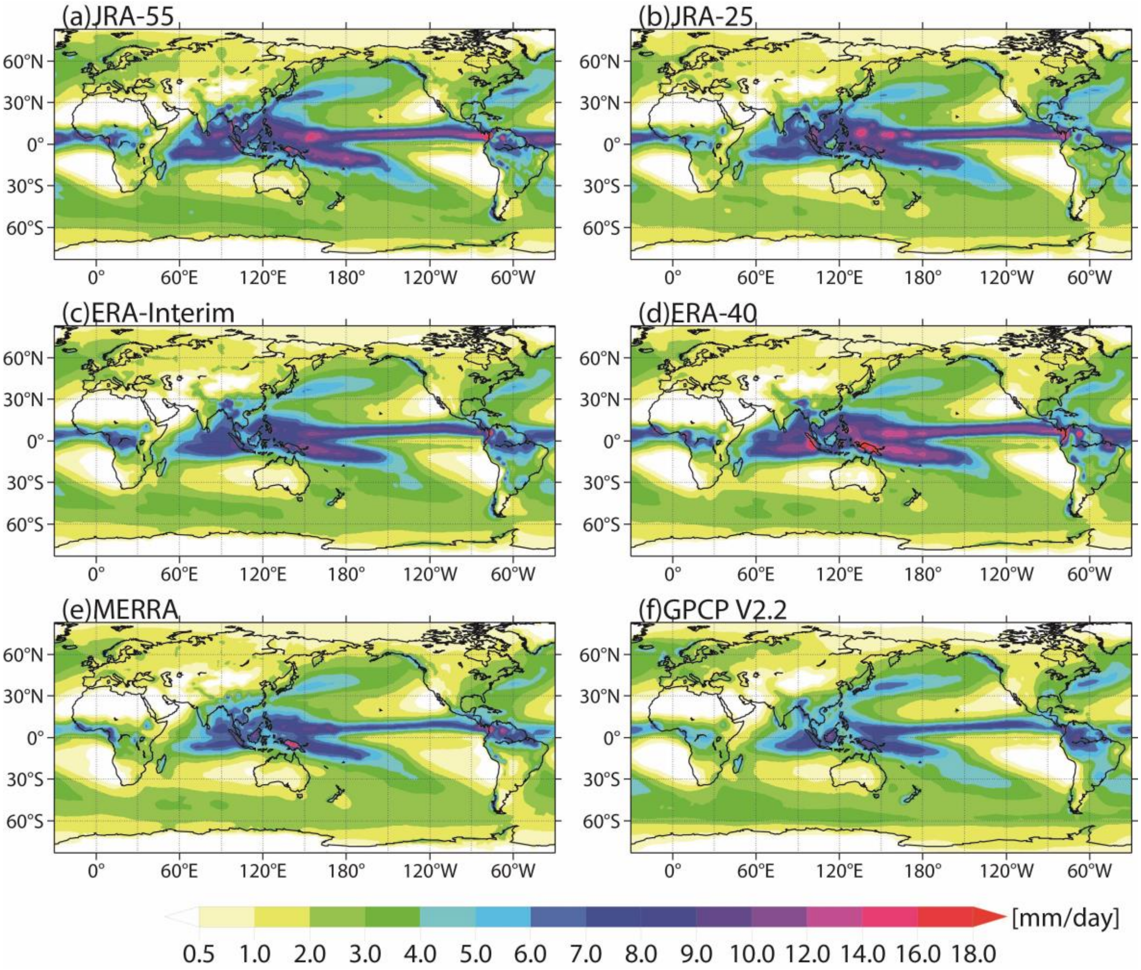


Figure 2 Climatological annual mean precipitations in (a) JRA-55, (b) JRA-25, (c) ERA-Interim, (d) ERA-40, (e) MERRA, and (f) GPCP V2.2, averaged over 1980–2001.

5. JRA-55C and JRA-55AMIP

As a subset of the Japanese 55-year Reanalysis (JRA-55) project, the Meteorological Research Institute of the Japan Meteorological Agency is conducting a global atmospheric reanalysis that assimilates only conventional surface and upper air observations, with no use of satellite observations, using the same data assimilation system as the JRA-55. The project, named the JRA-55 Conventional (JRA-55C, Kobayashi et al. 2014), aims to produce a more homogeneous dataset over a long period, unaffected by changes in historical satellite observing systems. The dataset is intended to be suitable for studies of climate change or multi-decadal variability. The reanalysis period of the JRA-55C is from 1958 to 2012. Note, however, that the data for the period from 1958 to Oct 1972 are exactly the same of JRA-55. We recommend to use together with the JRA-55 data in the period.

As another subset of the Japanese 55-year Reanalysis (JRA-55) project, an experiment using the global atmospheric model of the JRA-55 was conducted by the Meteorological Research Institute of the Japan Meteorological Agency. The experiment, named the JRA-55AMIP, has been carried out by prescribing the same boundary conditions and radiative forcing of JRA-55, including the historical observed sea surface temperature, sea ice concentration, greenhouse gases, etc., with no use of atmospheric observational data. This sub-project is intended to assess systematic errors of the model.

6. JRA-55 homepage

The JRA-55 data can be downloaded from the JRA-55 homepage (http://jra.kishou.go.jp/JRA-55/index_en.html) as shown in Figure 3. The data can be downloaded not only from JMA Data Distribution System (JDDS) but also DIAS managed by University of Tokyo, CCS of Tsukuba university, NCAR in the US, and ESGF of NASA. Please see details in the page. ECMWF and University of Cantabria in Spain are now in preparation for JRA-55 data services. You are required only registration on each suite.

Figure 3 JRA-55 Homepage in English

References

Adler, R. F., G. J. Huffman, A. Chang, R. Ferraro, P.-P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, P. Arkin, and E. Nelkin, 2003: The Version-2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (1979-present). J. Hydrometeor., 4, 1147-1167.

Dee, D. P., S. M. Uppala, A. J. Simmons, P. Berrisford, P. Poli, S. Kobayashi, U. Andrae, M. A. Balmaseda, G. Balsamo, P. Bauer, P. Bechtold, A. C. M. Beljaars, L. van de Berg, J. Bidlot, N. Bormann, C. Delsol, R. Dragani, M. Fuentes, A. J. Geer, L. Haimberger, S. B. Healy, H. Hersbach, E. V. Hólm, L. Isaksen, P. Kållberg, M. Köhler, M. Matricardi, A. P. McNally, B. M. Monge-Sanz, J.-J. Morcrette, B.-K. Park, C. Peubey, P. de Rosnay, C. Tavolato, J.-N. Thépaut, and F. Vitart, 2011: The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Quart. J. Roy. Meteor. Soc., 137, 553-597.

JMA, 2013: Outline of the operational numerical weather prediction at the Japan Meteorological Agency. Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research, JMA, Japan, 188 pp. Available at http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/nwp-top.htm.

Jones, P. D., D. H. Lister, T. J. Osborn, C. Harpham, M. Salmon, and C. P. Morice, 2012: Hemispheric and large-scale land surface air temperature variations: An extensive revision and an update to 2010. J. Geophys. Res., 117, D05127, doi:10.1029/2011JD017139.

Onogi, K., J. Tsutsui, H. Koide, M. Sakamoto, S. Kobayashi, H. Hatsushika, T. Matsumoto, N. Yamazaki, H. Kamahori, K. Takahashi, S. Kadokura, K. Wada, K. Kato, R. Oyama, T. Ose, N. Mannoji, and R. Taira, 2007: The JRA-25 reanalysis. J. Meteor. Soc. Japan, 85, 369-432.

Kobayashi, C., H. Endo, Y. Ota, S. Kobayashi, H. Onoda, Y. Harada, K. Onogi and H. Kamahori, 2014: Preliminary results of the JRA-55C, an atmospheric reanalysis assimilating conventional observations only. , SOLA, 10, 78-82, doi: 10.2151/sola.2014-016.

Kobayashi, S., Y. Ota, Y. Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi: The JRA-55 Reanalysis: General Specifications and Basic Characteristics, DOI:10.2151/jmsj.2015-001.

Rienecker M. M., M. J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M. G. Bosilovich, S. D. Schubert, L. Takacs, G.-K. Kim, S. Bloom, J. Chen, D. Collins, A. Conaty, A. da Silva, W. Gu, J. Joiner, R. D. Koster, R. Lucchesi, A. Molod, T. Owens, S. Pawson, P.

Pegion, C. R. Redder, R. Reichle, F. R. Robertson, A. G. Ruddick, M. Sienkiewicz, and J. Woollen. 2011: MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. J. Climate, 24, 3624-3648.

Thorne, P. W., D. E. Parker, S. F. B. Tett, P. D. Jones, M. McCarthy, H. Coleman, and P. Brohan 2005: Revisiting radiosonde upper air temperatures from 1958 to 2002. Journal of Geophysical Research, 110, D18105, doi:10.1029/2004JD005753.

Uppala, S. M., P. W. Kållberg, A. J. Simmons, U. Andrae, V. Da Costa Bechtold, M. Fiorino, J. K. Gibson, J. Haseler, A. Hernandez, G. A. Kelly, X. Li, K. Onogi, S. Saarinen, N. Sokka, R. P. Allan, E. Andersson, K. Arpe, M. A. Balmaseda, A. C. M. Beljaars, L. Van De Berg, J. Bidlot, N. Bormann, S. Caires, F. Chevallier, A. Dethof, M. Dragosavac, M. Fisher, M. Fuentes, S. Hagemann, E. Hólm, B. J. Hoskins, L. Isaksen, P. A. E. M. Janssen, R. Jenne, A. P. McNally, J.-F. Mahfouf, J.-J. Morcrette, N. A. Rayner, R. W. Saunders, P. Simon, A. Sterl, K. E. Trenberth, A. Untch, D. Vasiljevic, P. Viterbo, and J. Woollen, 2005: The ERA-40 re-analysis. Quart. J. Roy. Meteor. Soc., 131, 2961-3012.

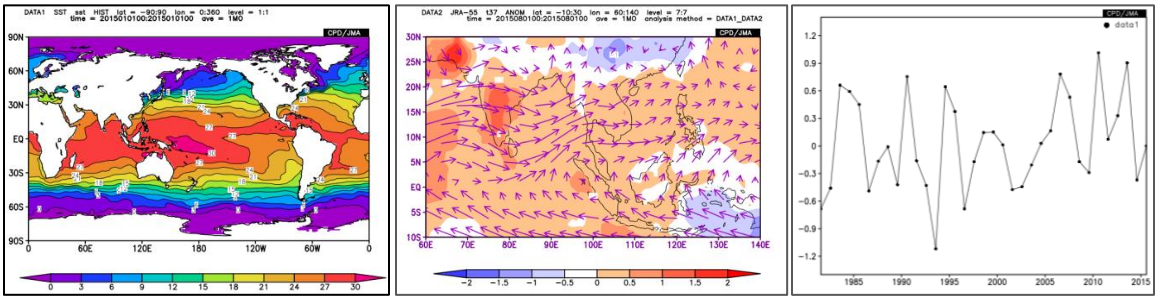
Introduction and Basic Operation of iTacs

Introduction and Basic Operation of iTacs

Chapter 1 Introduction to the iTacs

What is the iTacs?

The iTacs is a web-based application for climatological analysis.
“iTacs”, is an acronym of “Interactive Tool for Analysis of the Climate System”.
It’s very convenient and useful and it will strongly help you to understand climate systems.



Samples of charts

Features of the iTacs

Various climatological datasets (atmospheric and oceanographic) are available.

Atmospheric analysis data (JRA-55), outgoing longwave radiation (provided by NOAA), sea surface temperature (COBE-SST), ocean analysis data (MOVE/MRI.COM-G), JMA 1-month forecast data, etc.

Various types of charts are supported.

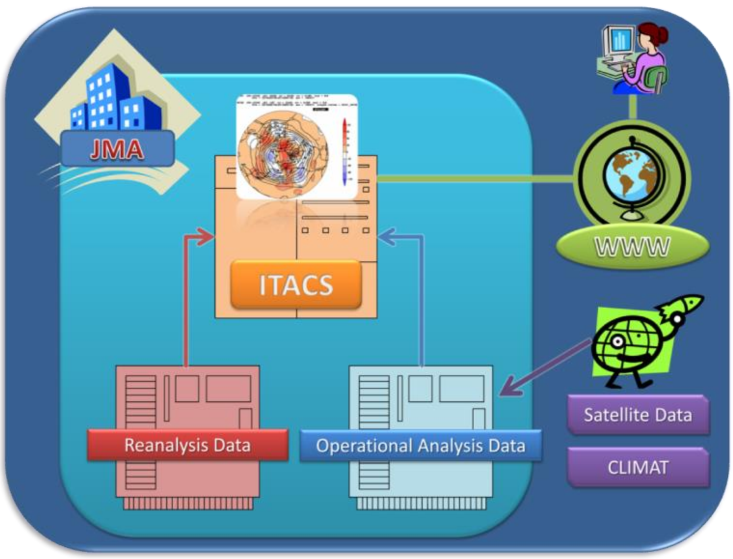
Plain longitude-latitude map, polar stereographic map, cross section, time series graph, etc.

Various statistical functions are built in.

Linear regression, correlation coefficient, EOF, SVD, FFT, etc.

Requirement to use the iTacs is only a web browser with accessibility to the World Wide Web.

Conceptual Outline of the iTacs



Chapter 2 Basic Operation

How to access to the iTacs

Start a web browser and access the following URL.

http://extreme.kishou.go.jp/tool/anatools/analyze4.0-pub/index1.php

Input ID and Password provided.

So, you will see main display of the iTacs as shown below.

Setting parameters

The procedure for drawing a chart by the iTacs is as shown below.

Select data-set, element, and data-type.

Set geophysical parameters:

Plotting area (latitude and longitude)

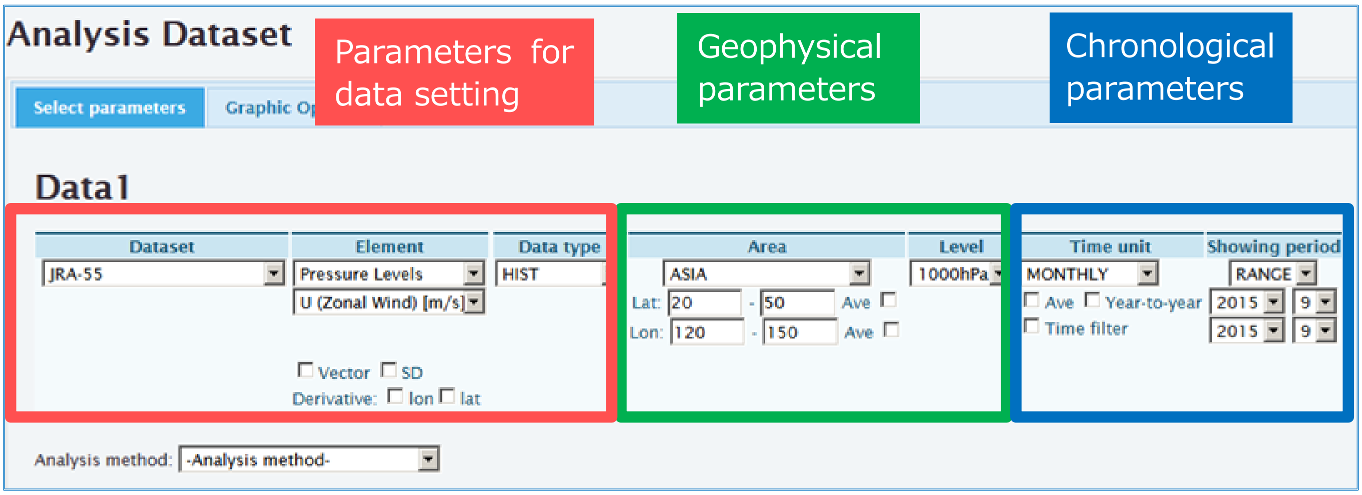
Pressure level (for atmospheric data) or depth (for oceanographic data).

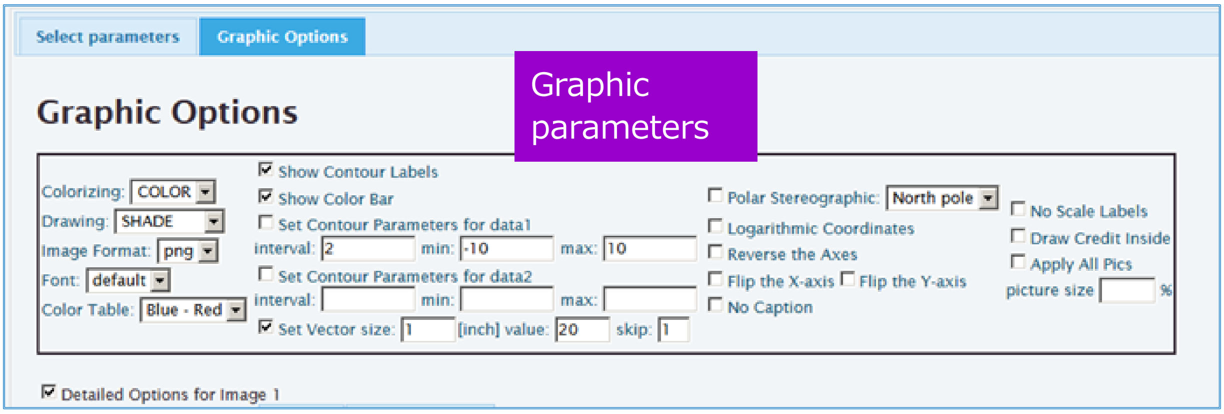
Set chronological parameters:

Average period (e.g., daily, monthly) and period to show (e.g., year, month)

Select analysis method (depending on intended use).

Set graphic parameters (depending on intended use).





The main display of the iTacs

An example of drawing a latitude-longitude map for one element

As the first step in using the iTacs, let’s try to draw a distribution map of 200-hPa stream function in October 2010.

Set parameters as shown below.

“Data1”

Dataset: JRA-55

Element: Pressure-levels - Stream function

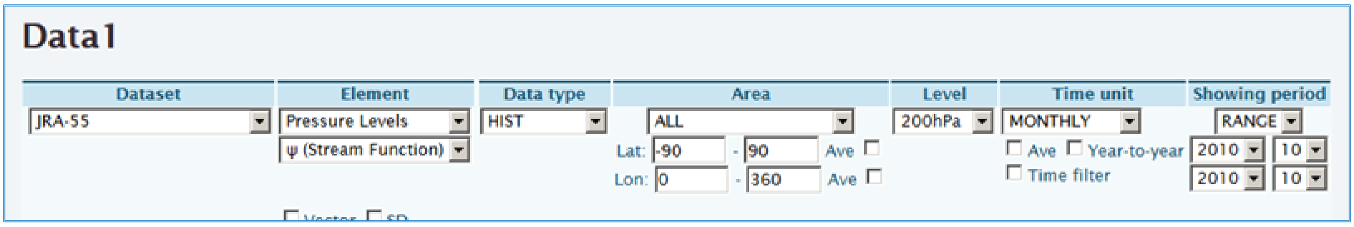
Data type: HIST (“Hist” means historical actual observation or analysis data)

Area: ALL (90°S – 90°N latitude, 0° – 360° longitude)

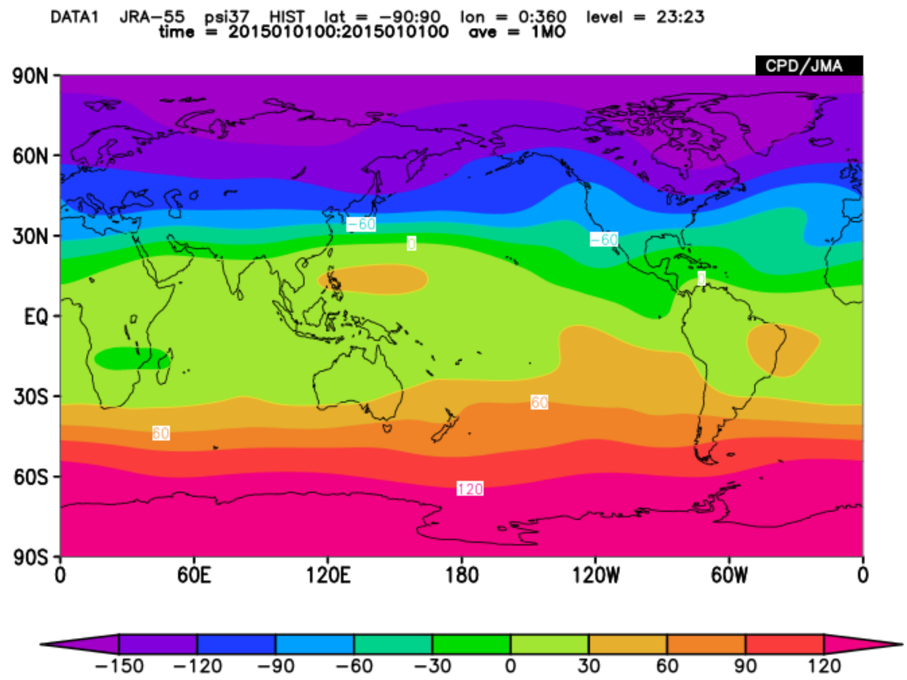
Level: 200 hPa

Time unit: MONTHLY

Showing period: RANGE, 2010 10



Press “Analysis Data Submit” button, and the following chart will be shown.



An example for drawing a latitude-longitude map for two-element

The second step is to make a distribution map of 3-month mean 200-hPa stream function with anomaly from September to November 2010.

Set parameters as followings.

“Data1”

Dataset: JRA-55

Element: Pressure-levels - Stream function

Data type: ANOM (“ANOM” means anomaly)

Area: ALL Level: 200 hPa

Time unit: MONTHLY, and check “Ave” box

Showing period: RANGE, 2010 09 - 2010 11

Analysis method

DATA1_DATA2

“Data2”

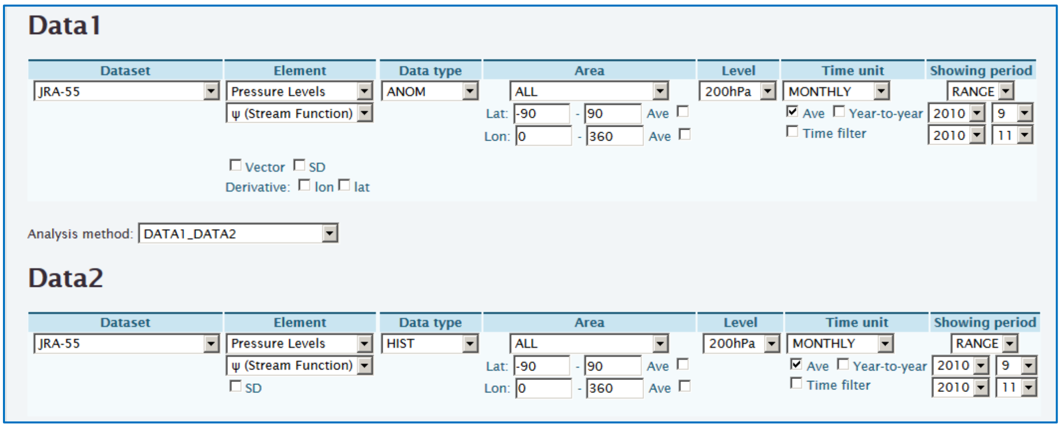
Data type: HIST Other parameters are the same as for data1.

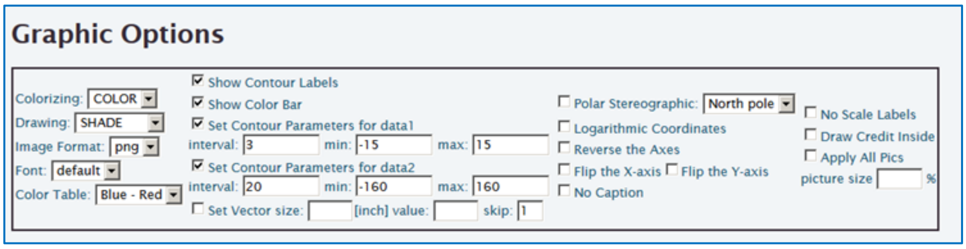
“Graphic Option”

Set Contour Parameters for data1 interval: 3 min: -15 max: 15

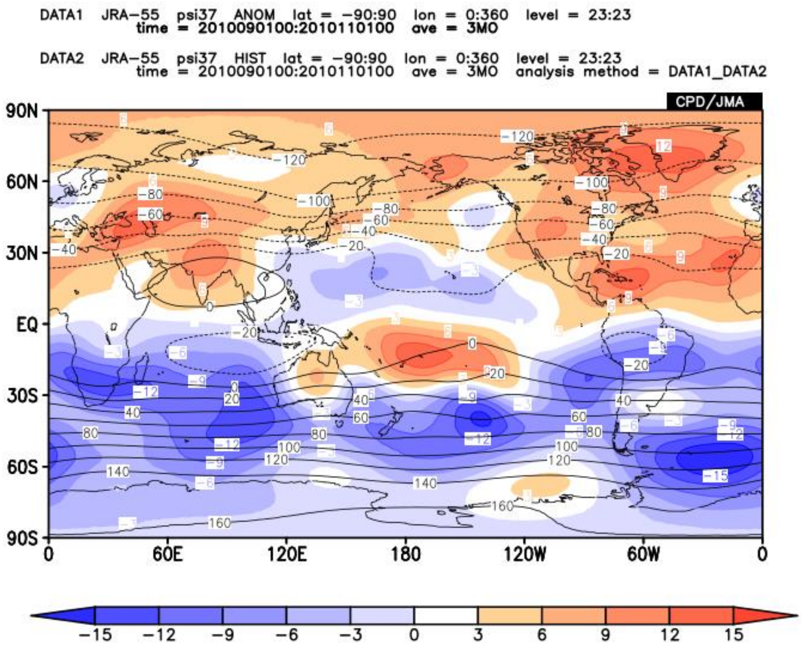
Set Contour Parameters for data2 interval: 20 min: -160 max: 160

Color Table: Blue-Red





Press “Analysis Data Submit” button, and the following chart will be shown.



Chapter 3: Regression Analysis

How to perform regression analysis on the iTacs

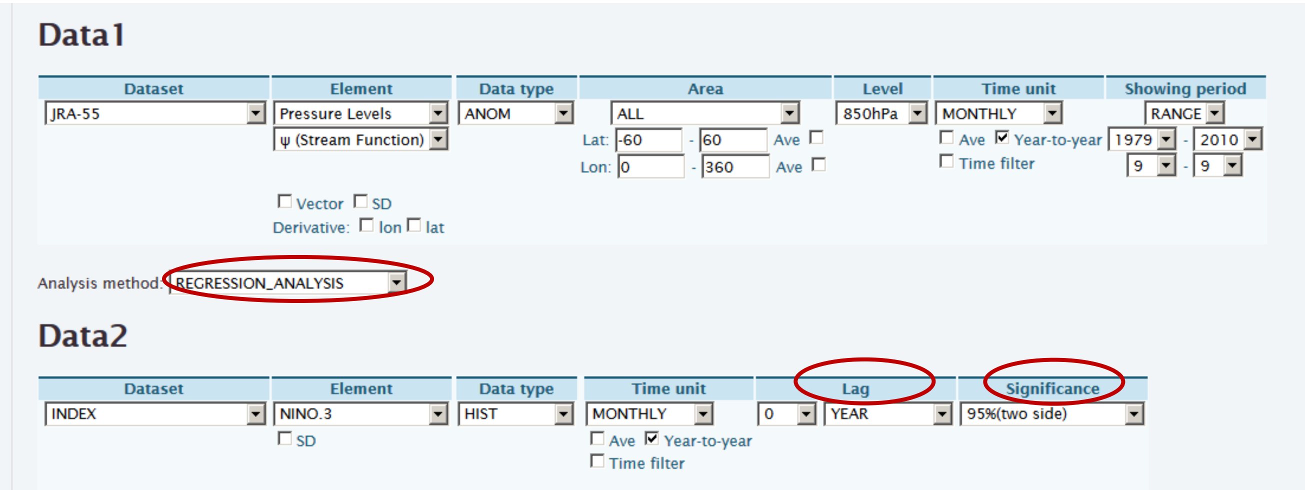
Select “REGRESSION COEFFICIENT” in “analysis method”.

Parameters for regression (or correlation) analysis

Lag: data2 lags behinds data1

For example, setting “Showing period in data1: 7 (July)” and “Lag: -6 month in data2” means data2 leads 6 months to data1, namely data2: January.

significance: confidence level based on t-test



Important notice for regression analysis by the iTacs

“Data2” is for independent variable.

“Data1” is for dependent variable.

An example of regression analysis by the iTacs

When you try to draw a distribution map of regression coefficient between sea surface temperature for NINO.3 region and 850-hPa stream function, please set parameters as shown below.

For data1 (dependent variable)

Dataset: JRA-55, Element: Stream-function, Data type: ANOM

Lat: -60 – 60, Lon: 0 – 360, Level: 850hPa

Time unit: Year-to-year

Showing period: RANGE, 1979/09 – 2010/09

“Year-to-year” means sampling data in the same month of consecutive years. In this case, data in all Septembers from 1979 to 2010 are extracted as samples for the analysis.

For analysis method

REGRESSION COEFFICIENT

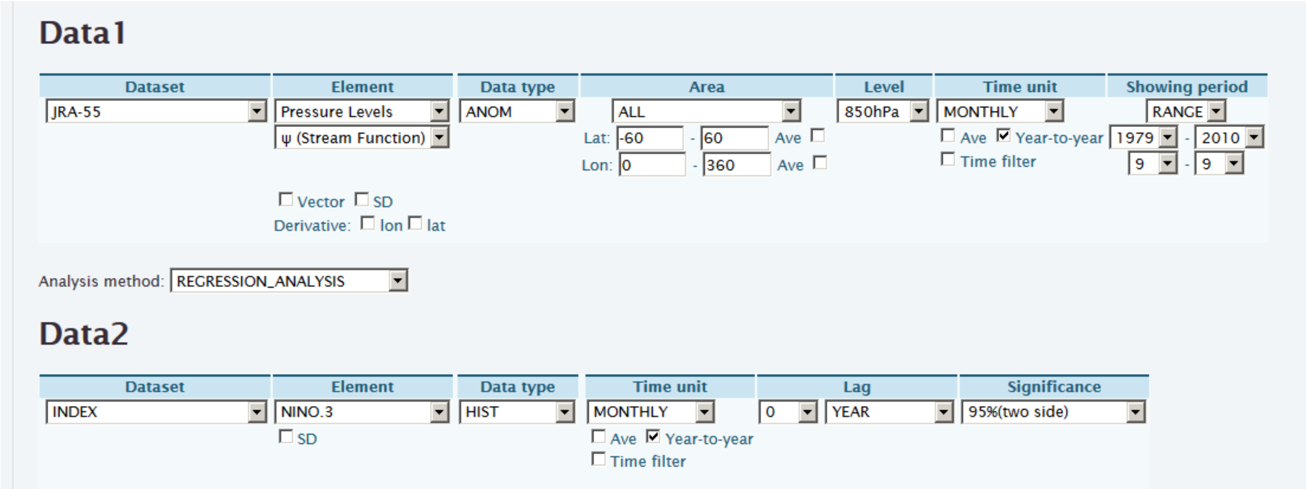
For data2 (independent variable)

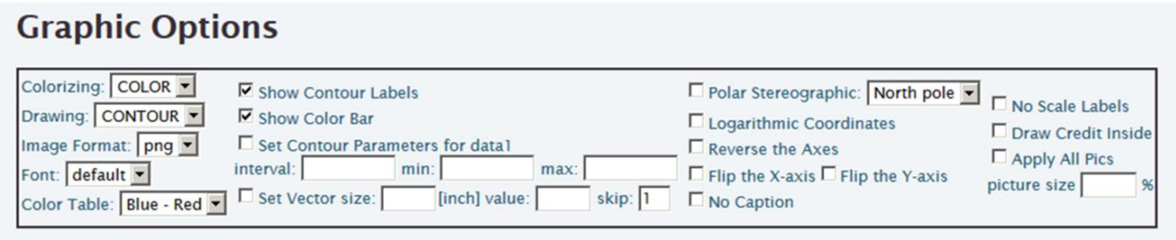
Dataset: INDEX, Element: NINO3, Data type: HIST

Significance: 95%(two side)

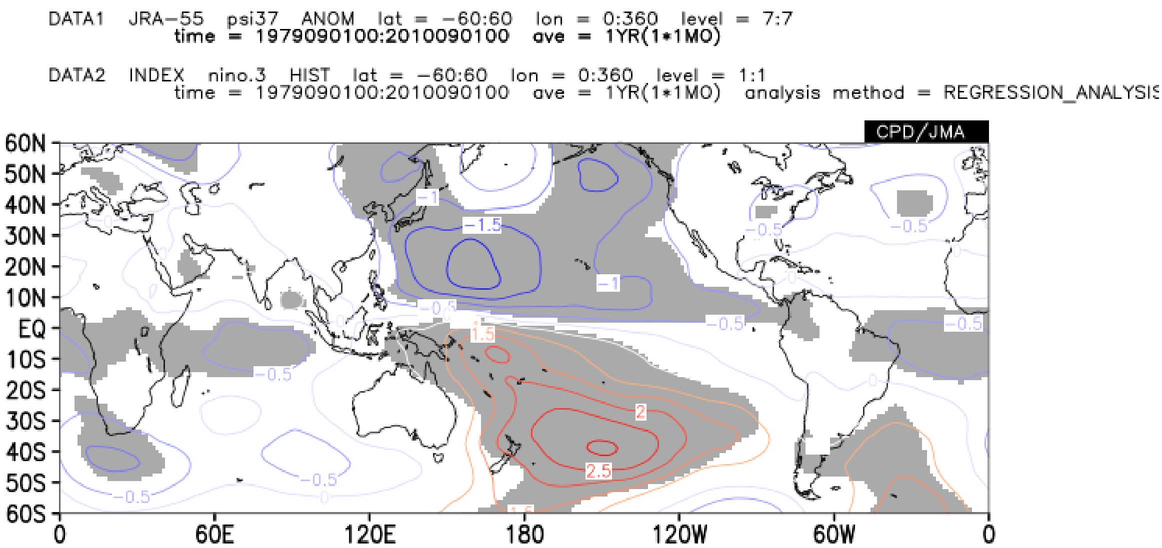
For graphic option

Coloring: COLOR,   Drawing: CONTOUR,   Color Table: Blue-Red





Press “Analysis Data Submit” button, and then the following picture will be shown.
Gray shading indicates 95% confidence level (same as 5% significance level).



Chapter 4: How to use the data prepared by users on the iTacs

Requirements on the data file for user input

The data file must be a text file in CSV (Comma Separated Values) format.

Time series data of one element is supported.

Only single station data is supported, not multi stations or GPV data set.

The order of fields in one record should be as below.

<year>, <month>, <day>, <data value>

See Appendix I for details.

How to input data by users to the iTacs

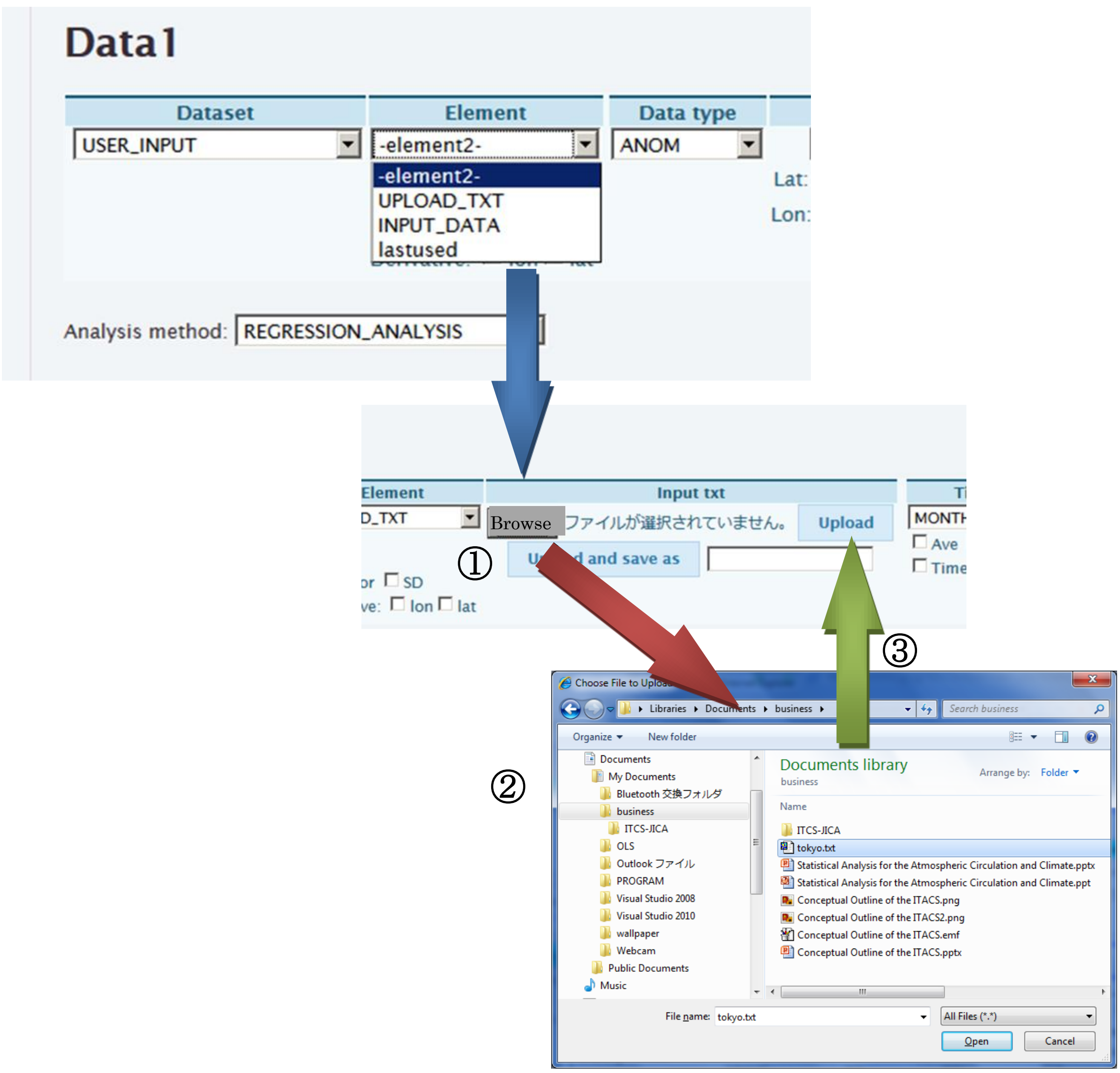
There are two methods, and “UPLOAD TXT” is suitable for usual purpose.

The procedure of “UPLOAD TXT” is as follows.

Select “USER INPUT” for “Dataset”

Select “UPLOAD TXT” in “element”.

Press “Browse…” button in “input txt” dialogue box, select the data file (“tokyo.txt” in this example) and press “upload” button.



<u>An example of correlation analysis using user prepared data</u>

When you try to draw a distribution map of correlation coefficient between temperature of Tokyo (user prepared data) and 500-hPa geopotential height (JRA-55), please set parameters as shown below.

For data1 (dependent variable)

Dataset: JRA-55, Element: Geopotential height, Data type: ANOM

Area: ALL, Level: 500hPa

Time unit: Year-to-year

Showing period: RANGE, 1979/09 – 2010/09

For analysis method

CORRELATION COEFFICIENT

For data2 (independent variable)

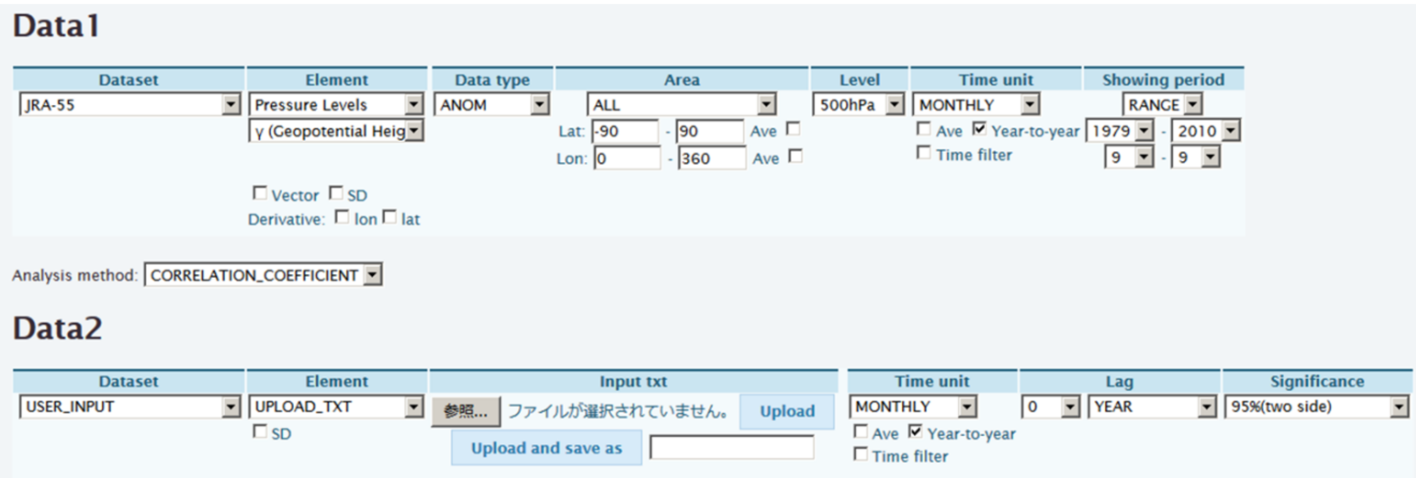
Dataset: USER INPUT

Element: UPLOAD_TEXT (upload a user-prepared-data file of Tokyo temperature)

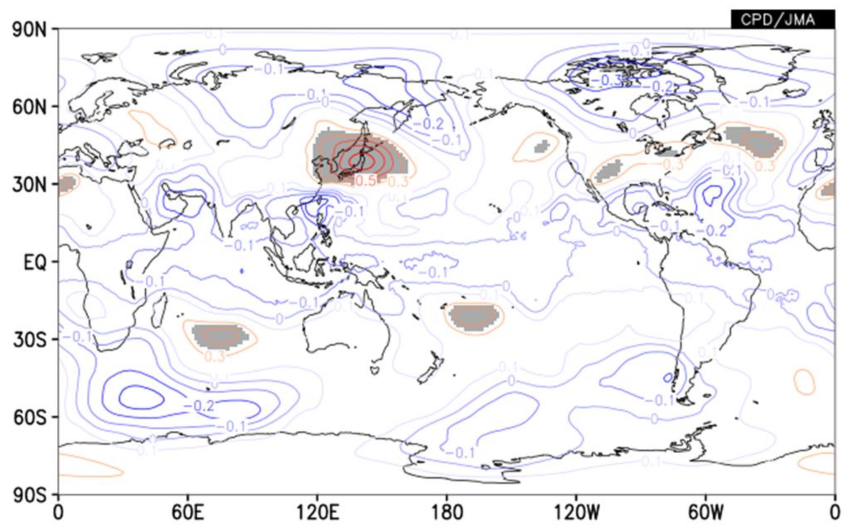
Significance: 95%

For graphic option (same as Chapter 3)

Coloring: COLOR, Drawing: CONTOUR, Color Table: Blue-Red



Please press "Analysis Data Submit", and then the picture below will be shown.



Appendix I: Application for using iTacs

First of all, you are advised to access the following URL for the application.

http://extreme.kishou.go.jp/tool/iTacs-tcc2011/

ITACS : Interactive Tool for Analysis of the Climate System

Announcement

31 October 2011
ITACS version 4.0 has been launched. This new version of ITACS has more graphic options than its version 3.0 and makes available one-month prediction dataset experimentally. The user IDs and passwords for ITACS version 3.0 can be used to access the new version. Please note that any IDs left unused for more than one year have been disabled and that new application is required in such a case.

You can see "Application for using the iTacs" section as shown below, clicking "application" in "Announcement" section as shown above or scrolling down this web page. Please carefully read the conditions of use and disclaimer. If you agree to them, please applying to TCC (tcc@met.kishou.go.jp) by e-mail completely filling the five items up.

Application for using the ITACS

Please read the Conditions of Use outlined below before applying to JMA to use the Interactive Tool for Analysis of the Climate System (ITACS). The Japan Meteorological Agency (JMA) will examine applications and, if the application is accepted, issue ID and password. JMA permits persons at National Meteorological and Hydrological Services to use the ITACS.

Application Form

Please enter the following items (Name, Affiliation, e-mail Address of affiliation and Purpose of use) in your e-mail and send us with "Application for ITACS" as the subject. A guidance mail will be sent to the applied e-mail address within a few days.

1. First name: Last name:
2. Affiliation (e.g. Climate Prediction Division, Japan Meteorological Agency):
3. Address of affiliation (e.g. 1-3-4 Otemachi, Chiyoda-ku, Tokyo, Japan):
4. E-mail address:
5. Purpose of use (Simply giving "study" or "research" is not acceptable.):

Conditions of Use

1. Users should provide user information including name, affiliation, e-mail address and purpose of data use.
2. The use of figures and/or data produced by ITACS for commercial purposes is prohibited.
3. Users should not let any third party use the ID/password information issued, and should keep this information private at all times.
4. The use of ITACS should be duly acknowledged in scientific or technical papers, publications, press releases or other communications.
   Sample of citation:
   The figures and statistical analysis in this study were made using ITACS data provided by the Japan Meteorological Agency.
5. The data source used in ITACS should be checked, and acknowledged if necessary, in scientific or technical papers, publications, press releases or other communications.
6. Users should provide JMA with a copy of their scientific or technical papers, publications, press releases or other communications involving ITACS.
7. Users must agree to the following operation policy:
   JMA will send a warning message in the event of inappropriate use, e.g., if a user causes excessive server load. In the event of failure to comply, the Japan Meteorological Agency will disable the offending ID.
   JMA will disable any IDs left unused for more than one year. Those wishing to reactivate IDs should inform JMA accordingly.

Disclaimer

Please note that although JMA has taken the utmost care in creating the functions of ITACS, it assumes no responsibility regarding the system's reliability. JMA accepts no responsibility for any damage that may result from the use of ITACS. JMA reserves the right to change or delete information on this site without prior notice. JMA accepts no responsibility for any inconvenience that may result from such changes or deletion.

Climate Prediction Division
Global Environment and Marine Department
Japan Meteorological Agency
Postal Address: 1-3-4 Otemachi, Chiyoda-ku, Tokyo, 100-8122 Japan

E-mail: tcc@met.kishou.go.jp

Appendix I: A sample for user input data

```
#Monthly mean temperature of Tokyo
#element=Temperature_of_Tokyo
#undef=9999
#year,month,day,temp.
1979,1,1,6.6
1979,2,1,8.4
1979,3,1,9.9
1979,4,1,13.9
1979,5,1,18.6
1979,6,1,24.4
1979,7,1,25.2
1979,8,1,27.4
1979,9,1,24.1
1979,10,1,19.6
1979,11,1,14.3
1979,12,1,10.1
1980,1,1,5.6
1980,2,1,5.2
```

Commentary

A line beginning with "#undef" is used for the definition of undefined value (default value: -9999).

A line beginning with "#element" is used for denoting element name (not required).

A line beginning with "#" except for "#undef" and "#element" is treated as comment line.

Every line must be terminated with a newline code.

Appendix II: Detailed tutorial for the iTacs

The present quick tutorial explains minimum operation of the iTacs that is required for exercises of the training seminar on seasonal prediction products. For persons who want to learn moreover about climatological analysis by the iTacs, comprehensive tutorials are available at the iTacs website (following URL).

http://extreme.kishou.go.jp/tool/iTacs-tcc2011/

Tools and documents

ITACS ver 4.0
ITACS ver 3.0

Sample images for ITACS ver.4.0
Tutorial for ver.4.0

- Sea surface temperature(SST)
- Average of SST anomaly
- Stream function of historical data on 850hPa
- Stream function of historical data and anomaly data on 850hPa
- Subtraction of monthly SST
- 500-hPa height and anomaly
- Time-longitude cross section of 200-hPa velocity potential
- Water vapor flux(vector) anomaly and specific humidity anomaly
- Interannual variation of monthly mean 850-hPa air temperature
- SST composite of La Nina years
- Regression Analysis : NINO.3 SST and 850hPa Stream Function / Correlation analysis
- boundaries +

Tutorial of the ITACS ver 3.0 (2.85MB)

Introduction of products
for Climate System Monitoring

Introduction of products for Climate System Monitoring

It is important for seasonal forecast to figure out current condition of atmospheric condition and convective activity. On the TCC website, various products for climate system monitoring and seasonal forecast are available. In this document, we introduce the following 6 products.

1. Animation Maps
2. Asian Monsoon Monitoring Indices (daily)
3. Time-Longitude Cross Section
4. Madden-Julian Oscillation (MJO) Phase and Amplitude monitor
5. Statistical analysis related to ENSO
6. Sea Surface Temperature

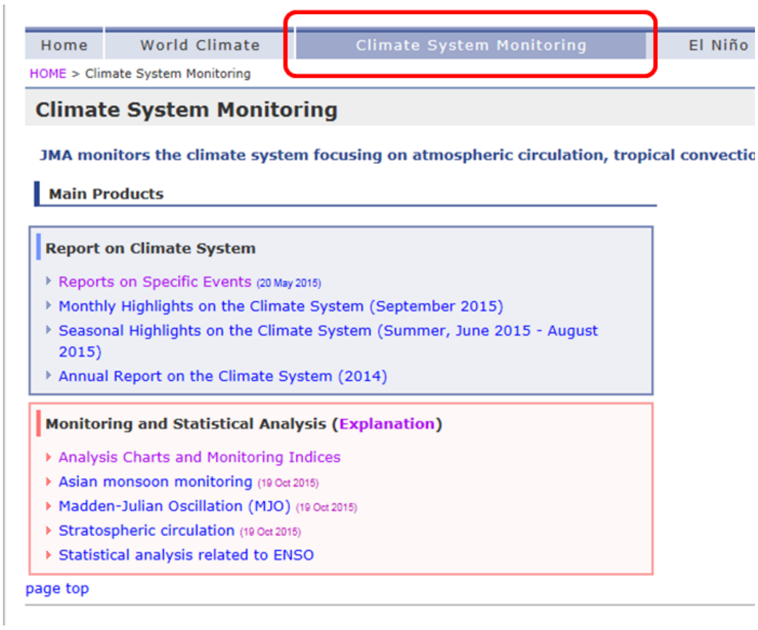


Figure 1 Climate System Monitoring web page on the TCC website
(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/index.html)

1. Animation Maps

The Animation Maps web pages are useful to analyze the time evolution of atmospheric circulation and tropical convective activity.

The web pages cover four areas: the Asian Region, the Northern Hemisphere, the Southern Hemisphere and the Global Area. Data on major elements for use in monitoring extratropical circulation (such as sea level pressure, 500-hPa geopotential height and 850-hPa temperature) shown on polar stereographic charts are available on the Northern Hemisphere and Southern

Hemisphere pages, and data for use in monitoring tropical convective activity and circulation (such as outgoing longwave radiation (OLR), velocity potential and stream function) are available on the Asian Region and Global Area pages. Daily, 5-day, 7-day, 10-day and 30-day average charts are available for all elements. Animation Maps are available for the period from 1958 to two days prior, and are updated every day.

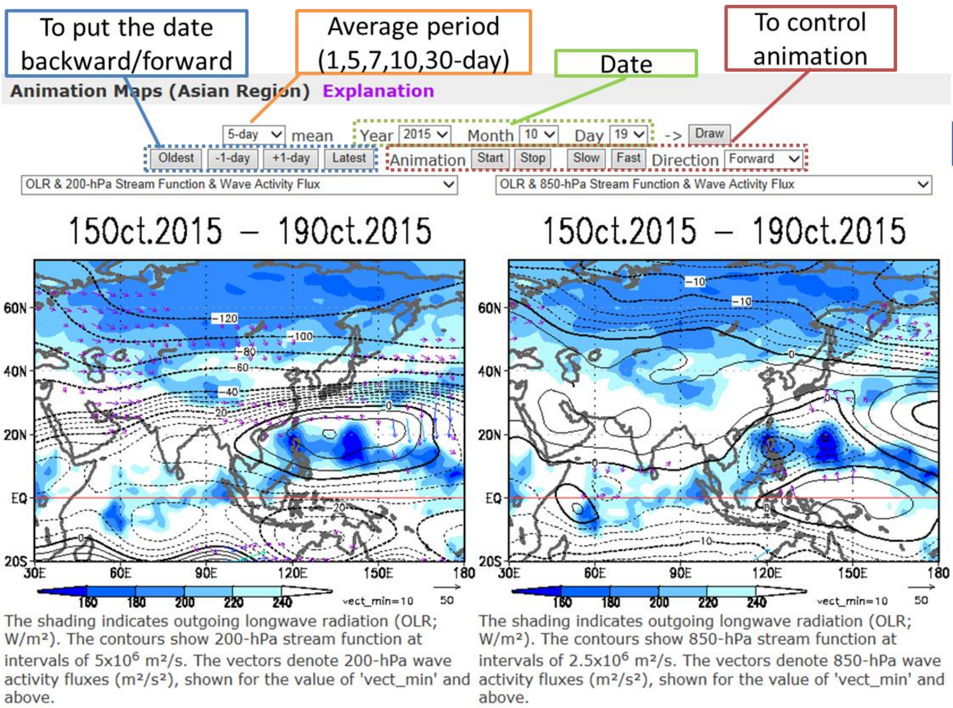


Figure 2 Animation Map page layout (Asian region)

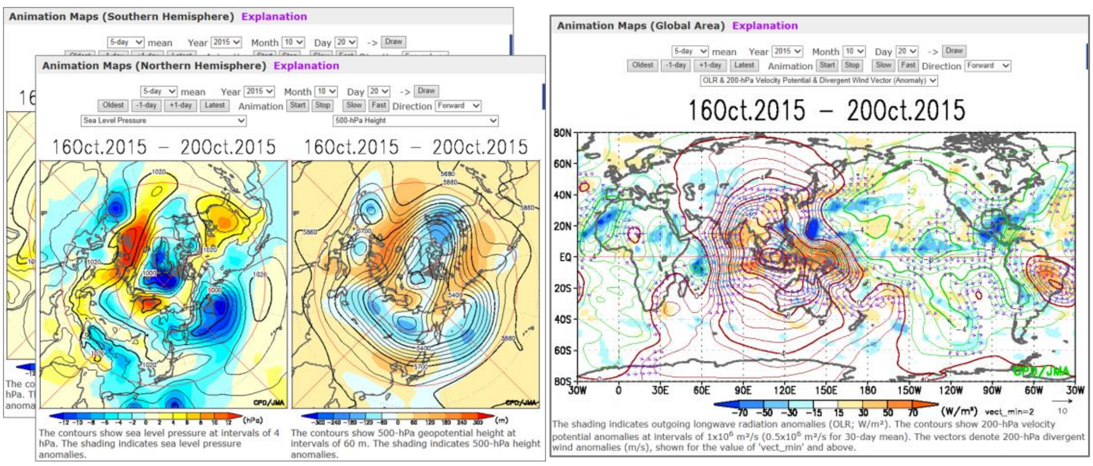


Figure 3 Animation Map page layout

(Left: Northern and Southern Hemisphere, Right: Global Area)

Animation Maps is available from Analysis Charts and Monitoring Indices page on the TCC website.

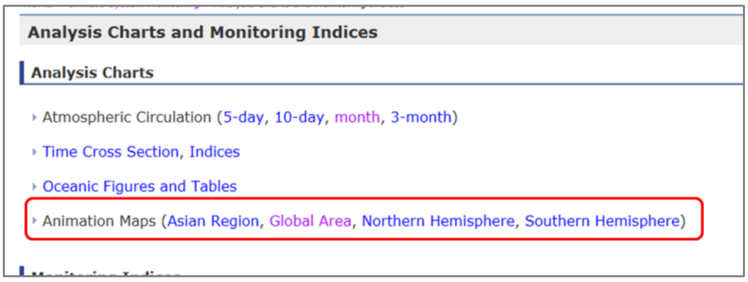


Figure 4 Analysis Charts and Monitoring Indices page on the TCC website

(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/acmi.html)

2. Asian Monsoon Monitoring Indices (daily)

This web page provides the daily time series of Asian Monsoon Monitoring Indices (such as area averaged vertical zonal wind shear (Webster and Yang 1992) and OLR (Wang and Fan 1999)). These indices are useful in monitoring the strength and expansion of the Asian summer monsoon, and are updated every day.

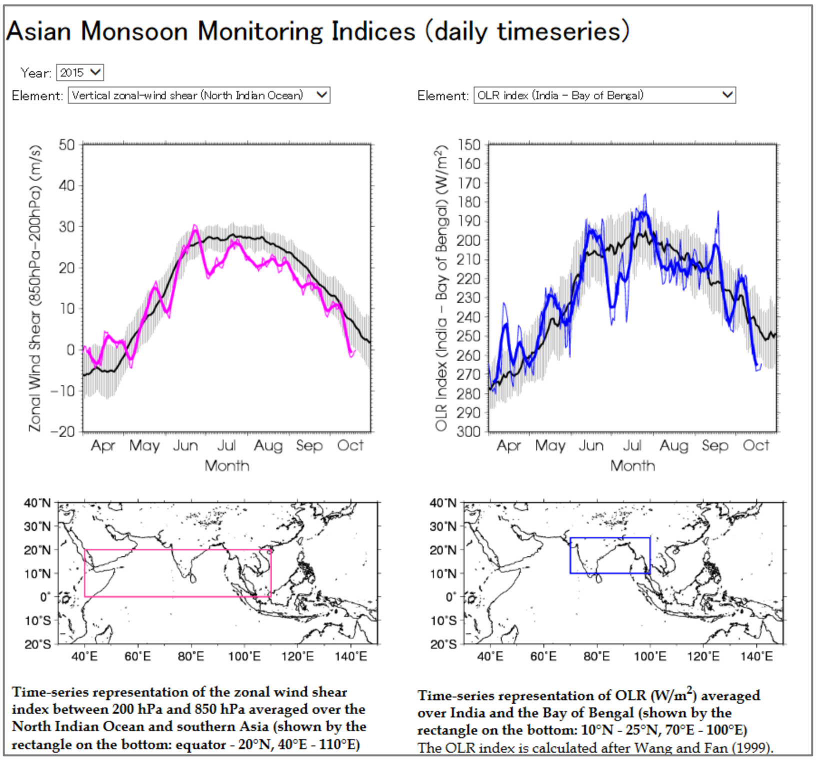


Figure 5 Asian Monsoon Monitoring Indices (daily) page

(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/ASIA_TCC/monsoon_index.html)

3. Time-Longitude Cross Section

This web page provides time-longitude cross sections of three and seven day mean OLR, velocity potential, zonal wind and sea surface temperature. These charts are useful in monitoring intraseasonal oscillations such as Madden-Julian Oscillation (MJO). This web page are available for the period since 1979, and are updated every day.

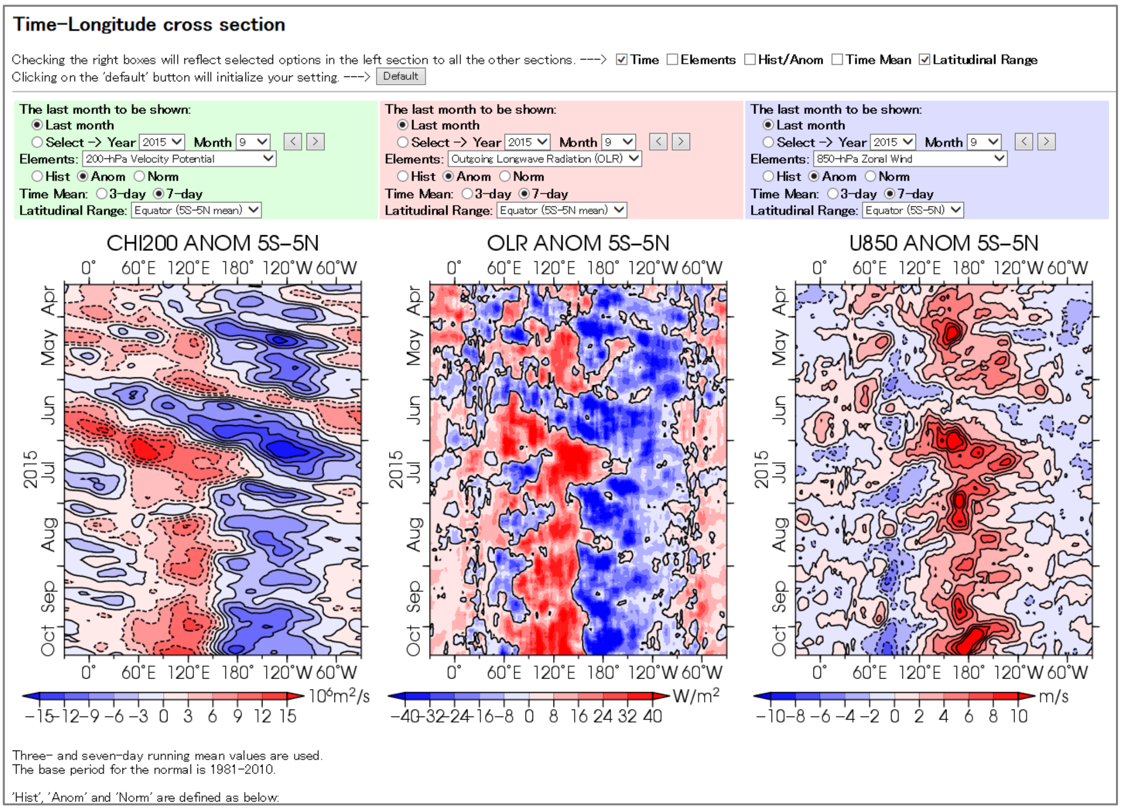


Figure 6 Time-Longitude Cross Section page
(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/ASIA_TCC/mjo_cross.html)

4. Madden-Julian Oscillation (MJO) Phase and Amplitude monitor

Madden-Julian Oscillation (MJO) web page provides indices for MJO monitoring defined by Wheeler and Hendon (2004). MJO Phase and Amplitude monitor (last 40-day) is convenient for MJO monitoring.

Two principal component time series from multivariate EOF of the MJO components are defined as RMM1 and RMM2. Two-dimensional phase space is defined by RMM1 and RMM2. In the phase space, the equatorial zones are divided into 8 phases and each phase indicates the active phase of the MJO propagation. In association with the eastward propagation of MJO, trajectory of RMM1 and RMM2 draws anti-clockwise circles in the phase space.

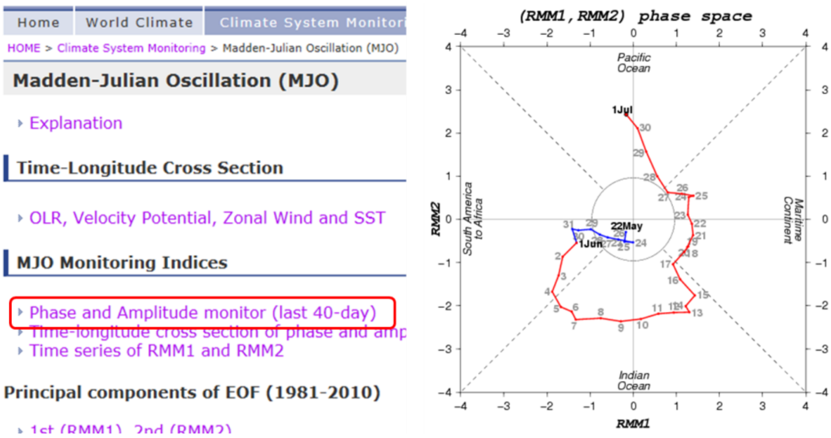


Figure 7 MJO page layout (left) and MJO Phase and Amplitude monitor (right)

(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/mjo/moni_mjo.html)

5. Statistical analysis related to ENSO

El Ninõ / Southern Oscillation (ENSO) events influence global atmospheric circulations and convective activities.

This web page provides the statistical analysis on the relationship between ENSO monitoring indices (such as NINO.3, NINO.WEST and IOBW） and atmospheric circulation (such as OLR, 850-hPa and 200-hPa stream function anomalies). The base period for the analysis is 1979 – 2008. Atmospheric circulation data (except OLR) are based on JRA-25 reanalysis dataset and the JCDAS which is consistent in quality with the JRA-25.

Now we are preparing to provide the renewed statistical analysis using the JRA-55 atmospheric data (base period: 1958 – 2012).

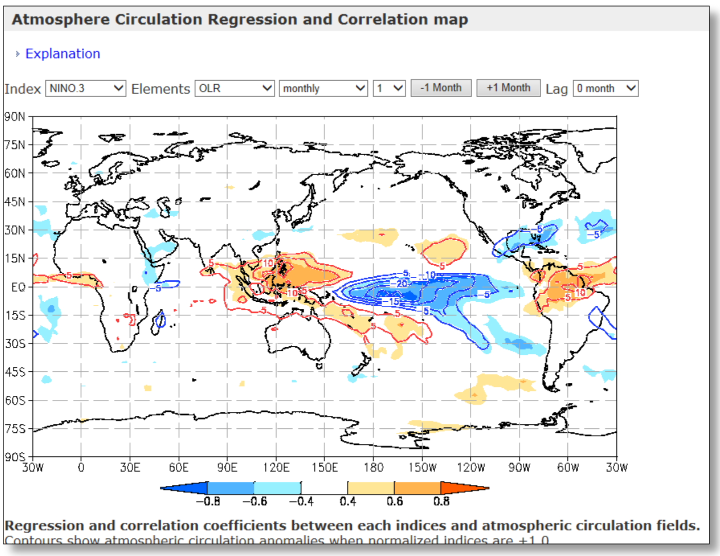


Figure 8 Statistical analysis related to ENSO

(http://ds.data.jma.go.jp/tcc/tcc/products/clisys/newoceanindex/index.html)

6. Sea Surface Temperature

In this document, we introduce the following 2 web pages for oceanographic condition monitoring on the TCC website.

(1) Monthly oceanographic condition

http://ds.data.jma.go.jp/gmd/tcc/tcc/products/elnino/ocean/index_tcc.html

Various monthly charts and tables, such as sea surface temperature, ocean heat content and surface zonal wind stress, are available.

(2) Current sea surface temperature anomaly

http://ds.data.jma.go.jp/tcc/tcc/products/model/map/1mE/map1/zpcmap.php

Chart of current sea surface temperature anomaly is available in the Forecast Maps for One-month Prediction web page. The sea surface temperature anomaly displayed in this map is used as the lower boundary condition of ensemble prediction systems for the one-month prediction (the atmospheric general circulation model).

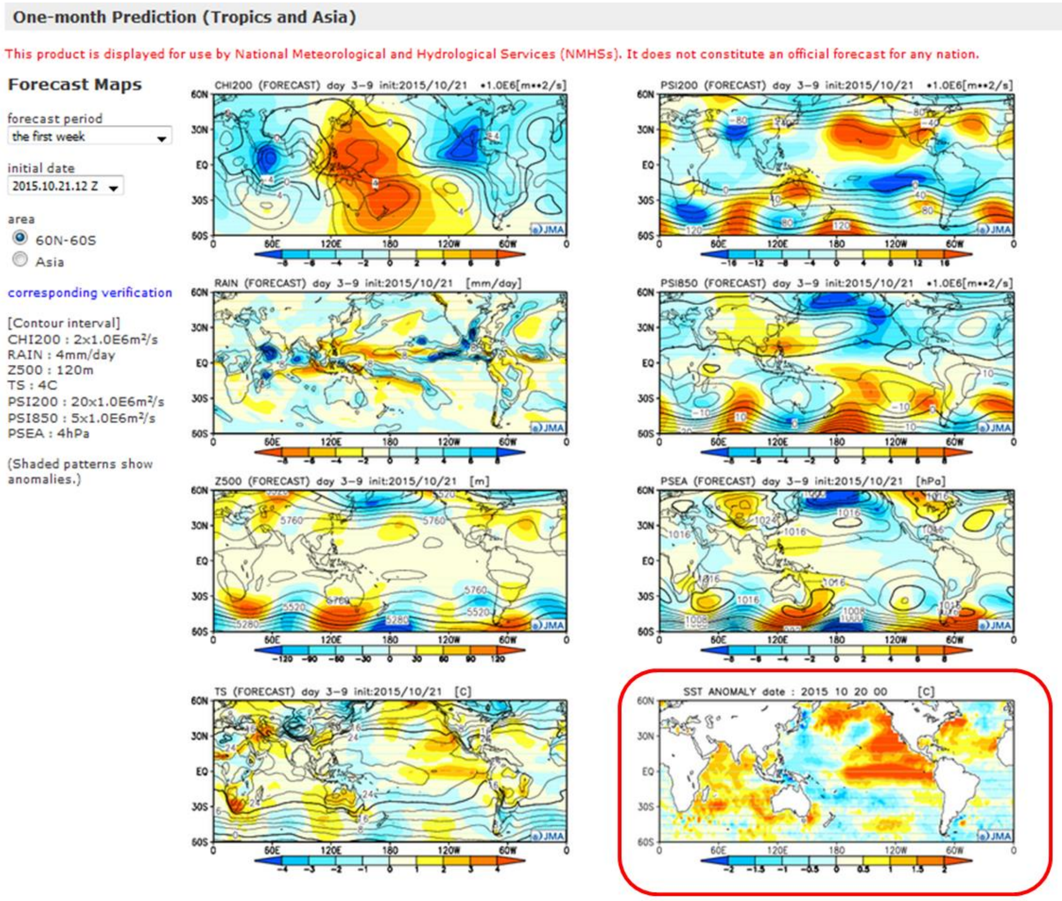


Figure 9 Forecast Maps for One-month Prediction (Tropics and Asia) page

(Bottom right: sea surface temperature anomaly)

JMA's Ensemble Prediction Systems (EPS) and their products for Climate Forecast

JMA's Ensemble Prediction Systems (EPS) and their products for Climate Forecast

1. Numerical Prediction

Figure 1 shows a simplified conceptual chart of "Numerical Prediction". A numerical model is made from many kinds of physical laws and a large number of grids. If you input an initial atmospheric condition and boundary conditions to a numerical model, you can get to know a future atmospheric condition as an output.

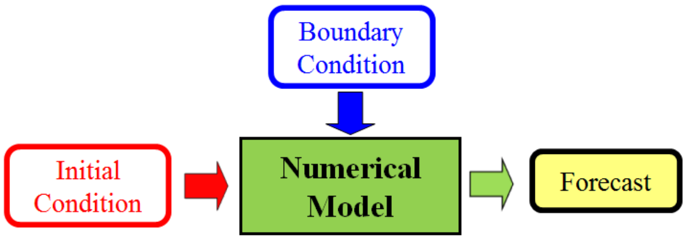


Figure 1 Conceptual Chart of Numerical Prediction

In this case, boundary conditions mean many kinds of seasonal variable natural factors except for atmosphere such as sea surface temperatures (SSTs), sea ices and snow covers. In general, variations of boundary conditions are much slower than a variation of atmosphere.

2. Predictability

Figure 2 shows a simplified conceptual chart of "Predictability". There are mainly 2 types of predictabilities. "Predictability of 1^{st} kind" depends on an initial atmospheric condition. Because a variation of atmosphere is fast, information which an initial atmospheric condition has are lost rapidly. On the other hand, "Predictability of 2^{nd} kind" depends on boundary conditions. Because variations of boundary conditions are slow, they make a long-range forecast possible.

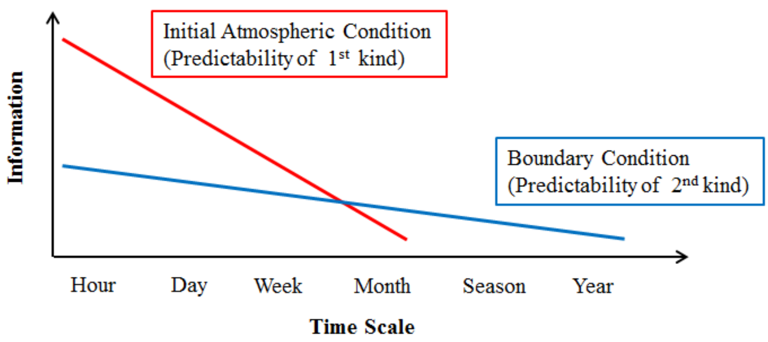


Figure 2 Conceptual Chart of Predictability

By the way, atmospheric phenomena have their own temporal and spatial scale (Figure 3). Regarding short-life and small-scale phenomena such as tornadoes and cyclones, long-range forecast is impossible because they are sensitive to an initial atmospheric condition. Conversely, regarding long-life and large-scale phenomena such as seasonal oscillations and monsoons, long-range forecast is possible, because they are sensitive to boundary conditions rather than an initial atmospheric condition.

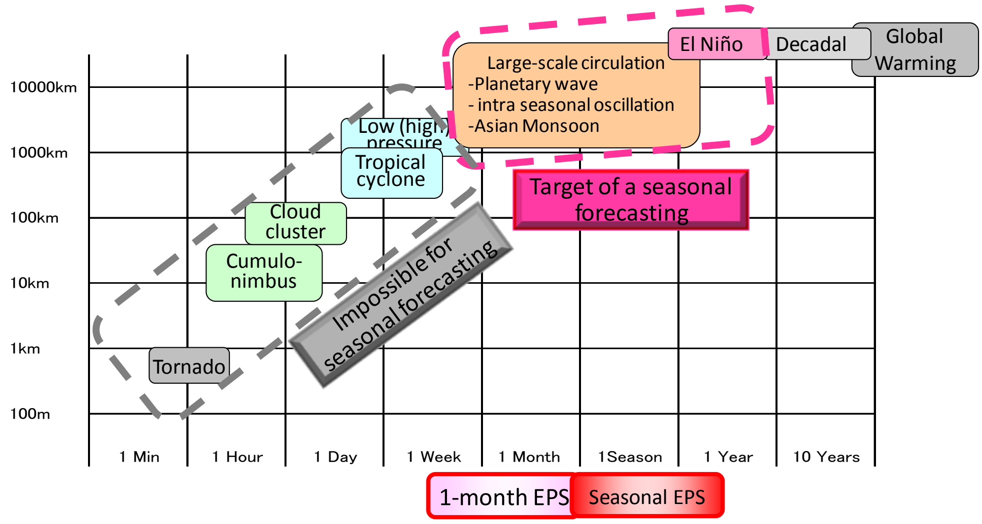


Figure 3 Temporal and Spatial Scale of Atmospheric Phenomena

3. Uncertainty and Ensemble Prediction

Because atmosphere has chaotic nature, a small error in an initial condition grows rapidly. However, it is impossible to know a perfect initial condition even with the use of high accurate observations. Therefore, it is essential to consider uncertainty when forecasting. Ensemble prediction makes it possible to estimate uncertainty caused by initial condition errors with similar calculations from a little bit different multiple initial conditions. The individual calculation is called “Ensemble member” and the standard deviation among all members is called “Ensemble spread” (Figure 4).

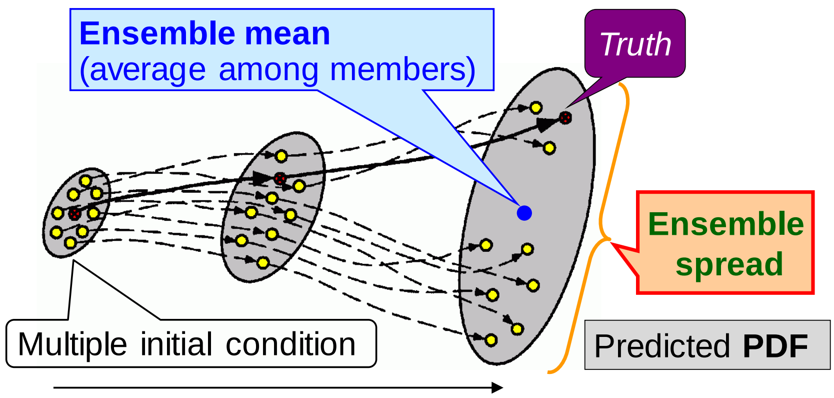


Figure 4 Conceptual Chart of Ensemble Prediction

Lagged Average Forecasting (LAF) is one of the ensemble prediction techniques. LAF ensemble prediction is calculated with the combination of ensemble predictions from not only latest initial condition but also older initial conditions (Figure 5). LAF is easy method for ensemble prediction and make it possible to share computer resources between some days. It is also possible to get a significant ensemble spread even at initial time. However, the accuracy of prediction from older initial conditions is generally worse than that from latest initial condition.

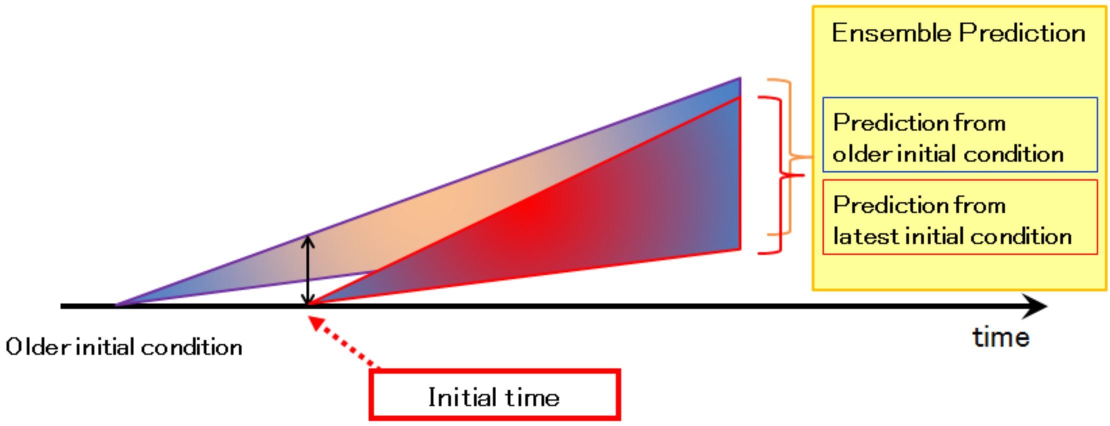


Figure 5 Conceptual Chart of Lagged Average Forecasting (LAF)

Actually uncertainty is caused by imperfection of not only initial conditions but also numerical prediction models. In order to consider uncertainty caused by imperfection of numerical prediction models, multi-model ensemble (MME) system and stochastic physics scheme are often used. MME is an EPS using some different numerical ensemble prediction models. Stochastic Physics Scheme is a calculation method which controls some physical calculations with random numbers (Figure 6).

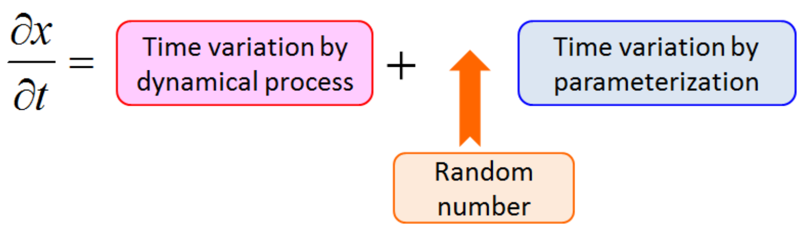


Figure 6 Conceptual Chart of Stochastic Physics Scheme

4. WMO Forecast Classification

In line with "WMO's Manual on the Global Data-Processing and Forecasting System"[1], forecasts are classified by their ranges as Table 1. Seasonal forecasting, which is the main topic of the TCC seminar, corresponds to extended- and long-range forecasting (shaded in table 1).

Table 1 Definitions of meteorological forecasting range classified by WMO

	Forecasting target period
Nowcasting	Up to 2 hours
Very short-range weather forecasting	Up to 12 hours
Short-range forecasting	Beyond 12 hours and up to 72 hours
Medium-range weather forecasting	Beyond 72 hours and up to 240 hours
Extended-range weather forecasting	Beyond 10 days and up to 30 days
Long-range forecasting	Beyond 30 days up to two years
Climate forecasting	Beyond two years

5. JMA's One-month and Seasonal Ensemble Prediction System

JMA uses a high-resolution atmospheric general circulation model (AGCM) in operational as one-month ensemble prediction system (EPS), because predictability of 1st kind is important for extended-range weather forecasting. JMA also uses a coupled ocean-atmosphere general circulation model (CGCM) in operational as seasonal EPS, because predictability of 2nd kind is important for long-range forecasting. The specifications of these two EPSs are listed as table 2. Actually the model resolution for seasonal EPS is lower than that for one-month EPS, because CGCM requires more computer resources than AGCM to calculate not only atmospheric component but also oceanic component. Both models use the combination of Breeding of Growing Modes (BGM) and LAF method to make initial perturbations. They also adopt Stochastic Physics Scheme to consider uncertainty caused by model's imperfection. The last major upgrades are March 2014 for one-month EPS and June 2015 for seasonal EPS. JMA normally upgrades one month EPS every few years and seasonal EPS about every half decade.

If you need more detailed information, see the "Numerical Weather Prediction of JMA" website (http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/nwp-top.htm).

[1] http://www.wmo.int/pages/prog/www/DPS/Publications/WMO_485_Vol_I.pdf

Table 2 Specification of the One-month and Seasonal EPS (as of November 2015)

	One-month EPS	Seasonal EPS
Upgrade	Last: March 2014 Frequency: Every few years	Last: June 2015 Frequency: About every half decade
Model	AGCM (Atmospheric General Circulation Model)	CGCM (Coupled Ocean-atmosphere General Circulation Model)
Resolution	Horizontal: approx. 55 km (TL319) Vertical: 60 levels up to 0.1 hPa	* Atmospheric component Horizontal: approx. 110 km (TL159) Vertical: 60 levels up to 0.1 hPa * Oceanic component Horizontal: 1.0º longitude, 0.3–0.5º latitude (with Tri-pole grid) Vertical: 52 levels+Bottom Boundary Layer
Forecast range	Up to 34 days	7-month (initial month of Sep., Oct., Feb., Mar., Apr) 4 months (the other initial month)
Ensemble method	Combination of Breeding of Growing Modes (BGM), Lagged Average Forecast (LAF), Stochastic physics scheme	
Ensemble size	50 (25 BGMs & 2 days LAF with 1-day interval)	51 (13 BGMs & 4 days LAF with 5-day interval)
Frequency of operation	Every Tuesday and Wednesday	Every 5 days
Frequency of model product creation	Once a week Every Thursday	Once a month Around 20th (no later than 22nd) of every month

6. Hindcast

Hindcasts are systematic forecast experiments for past cases. Hindcast experiments are performed with the use of the operational model. Hindcast datasets are used not only to estimate the systematic biases and prediction skills but also to develop statistical models.

In order to calculate a large number of past events, huge computer resources are required. Because of the limited computer resources, ensemble size and calculation frequency for hindcasts are less than those for operational forecasts. The detailed differences between hindcasts and operational forecasts are listed as table 3.

Table 3 Differences between hindcasts and operational forecasts

* One-month EPS

	Hindcast	Operational system
Initial Condition	JRA-55	Global Analysis (Newer System than JRA-55)
Ensemble size	5 (5 BGMs, not using LAF)	50 (25 BGMs & 2 days LAF with 1-day interval)
Forecast range	Initial date + 40 days	2, 3, 4,...31, 32 days from the latest initial date (Wednesday)
Initial date	10th, 20th, end of month	Every Tuesday and Wednesday
Target period for hindcast	Available : 1981-2012 Verification: 1981-2010	–

* Seasonal EPS

	Hindcast	Operational system
Initial Condition	JRA-55	JRA-55
Ensemble size	5 (5 BGM)	51 (13 BGMs & 4 days LAF with 5-day interval)
Forecast range	Lead time from 0 to 6 months as shown in the correspondence table below	(4-month EPS) Lead time from 1 to 3 as shown in the correspondence table below (7-month EPS) DJF (initial month of Sep., Oct.) JJA (initial months of Feb., Mar. and Apr.)
Initial date	24 initial dates a year (16th Jan., 31th Jan., 10th Feb., 25th Feb., ,... 12th Dec. and 27th Dec.)	Once a month
Target period for hindcast	Available : 1979-2014 Verification: 1981-2010	–

Correspondance between lead times (months) and initial dates

Target Month Initial Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
27-Dec, 12-Dec	0	1	2	3	4	5	6					
31-Jan, 16-Jan		0	1	2	3	4	5	6				
25-Feb, 10-Feb			0	1	2	3	4	5	6			
27-Mar, 12-Mar				0	1	2	3	4	5	6		
26-Apr, 11-Apr					0	1	2	3	4	5	6	
31-May, 16-May						0	1	2	3	4	5	6
30-Jun, 15-Jun	6						0	1	2	3	4	5
30-Jul, 15-Jul	5	6						0	1	2	3	4
29-Aug, 14-Aug	4	5	6						0	1	2	3
28-Sep, 13-Sep	3	4	5	6						0	1	2
28-Oct, 13-Oct	2	3	4	5	6						0	1
27-Nov, 12-Nov	1	2	3	4	5	6						0

7. Products

(1) TCC Website for Numerical Model Prediction

If you access TCC's numerical model prediction website, you can see and get many kinds of numerical prediction model products (Figure 7). The some products such as extreme weather prediction and gridded data require authentication. These products are displayed for use by National Meteorological and Hydrological Services (NMHSs). It does not forecast for any nation.

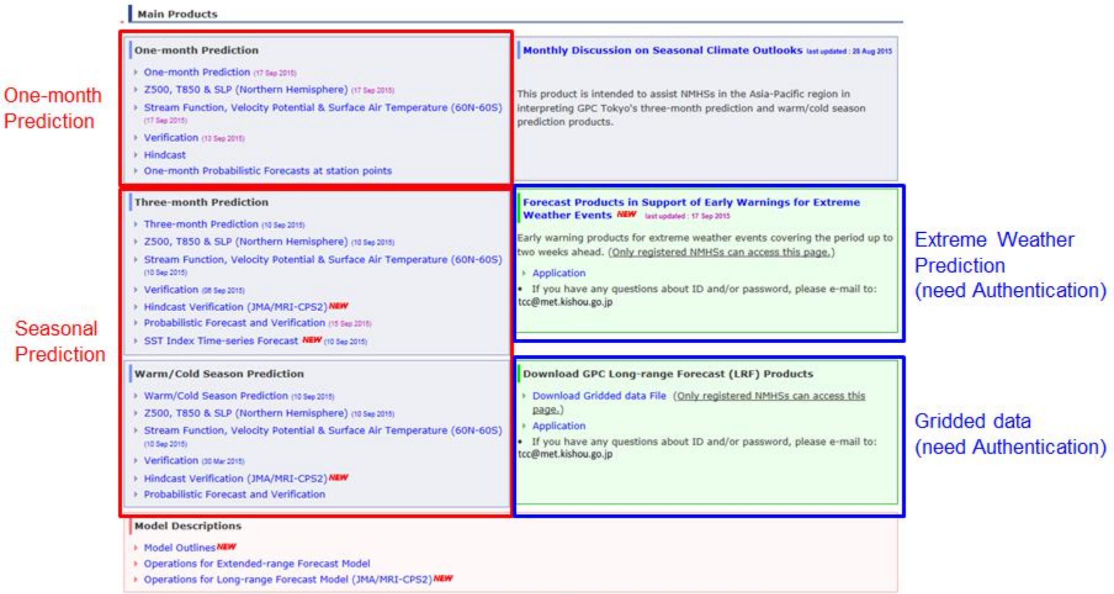


Figure 7 TCC's numerical weather prediction website
http://ds.data.jma.go.jp/tcc/tcc/products/model/index.html

(a) One-month EPS Products

・Forecast maps

・Animated forecast maps (available since 13 May 2015 high-speed internet access and authentication are required)

・Extreme forecast index (available since 27 August 2014, authentication is required)

・Real-time verification of routine model forecasts

・Hindcast verification charts

・Probabilistic forecasts at station points in Southeast Asia.

・Gridded data of operational forecasts and hindcasts (authentication is required)

(b) Seasonal EPS Products

・Forecast maps

・SST index time-series forecast (available since June 2015, authentication is required)

・Hindcast verification charts

・Probabilistic forecasts

・Gridded data of operational forecasts and hindcasts (authentication is required)

(2) Forecast Maps

Various kinds of forecast maps are available on the numerical model prediction website of TCC. The period for forecast maps are 1st week, 2nd week, 3-4 week and 28 days average for one month prediction and 1-month and 3-month average for seasonal prediction. The elements are as follows.

(a) Tropical Maps (60S-60N)

- Daily mean precipitation (RAIN)
- Velocity Potential (CHI200)
- Stream Function at 200hPa (PSI200)
- Stream Function at 850hPa (PSI850)
- Geo-potential height at 500hPa (Z500)
- Sea Level Pressure (PSEA)
- Surface Temperature (TS)
- Sea Surface Temperature (SST)
- Stream Function and wind at 850hPa (for only seasonal EPS)

(b) Northern Hemisphere Maps

- Geo-potential height at 500hPa (Z500)
- Temperature at 850hPa (T850)
- Sea Level Pressure (PSEA)

In addition to this, animation maps for one-month forecast are also officially available since 13 May 2015 (Figure 8). However, high speed internet access is required for smooth animation.

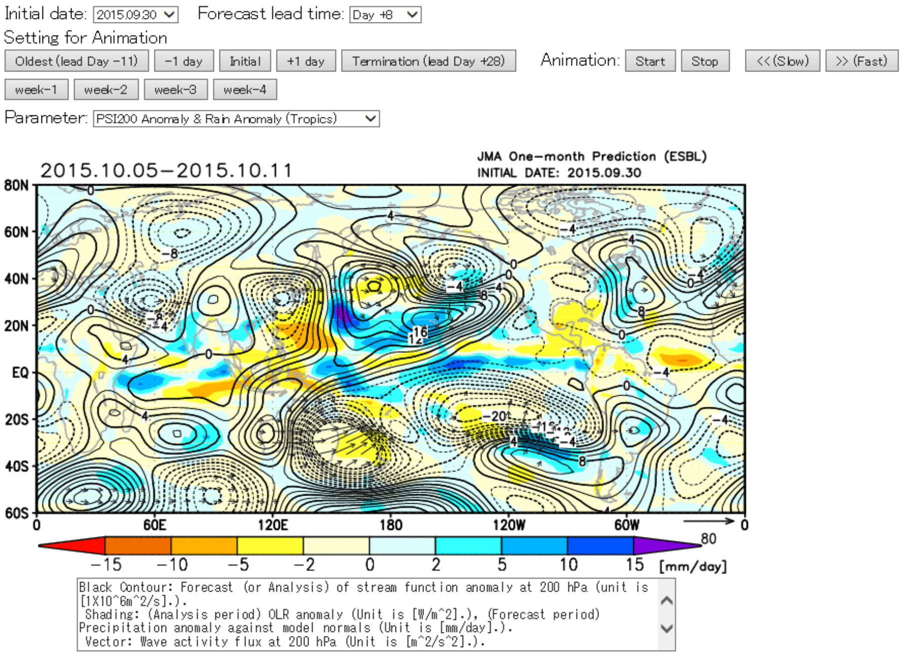


Figure 8 Animation Maps of One-month EPS
http://ds.data.jma.go.jp/tcc/tcc/gpv/model/Anime.1mE.experiment/anime.e.php

(3) Extreme Forecast Index

Extreme Forecast index (EFI) is a measure of EPS forecast deviation from climatological probability distribution. Especially, TCC uses the revised version of EFI (Figure 9). It is useful for the early detection of extreme climatic event risks. If you access "Forecast Products in Support of Early Warnings for Extreme Weather Events" website, you can see not only EFI warning maps but also probability maps and EPS meteograms. In combination with these products, you can get to know the risks of various extreme weather events in advance.

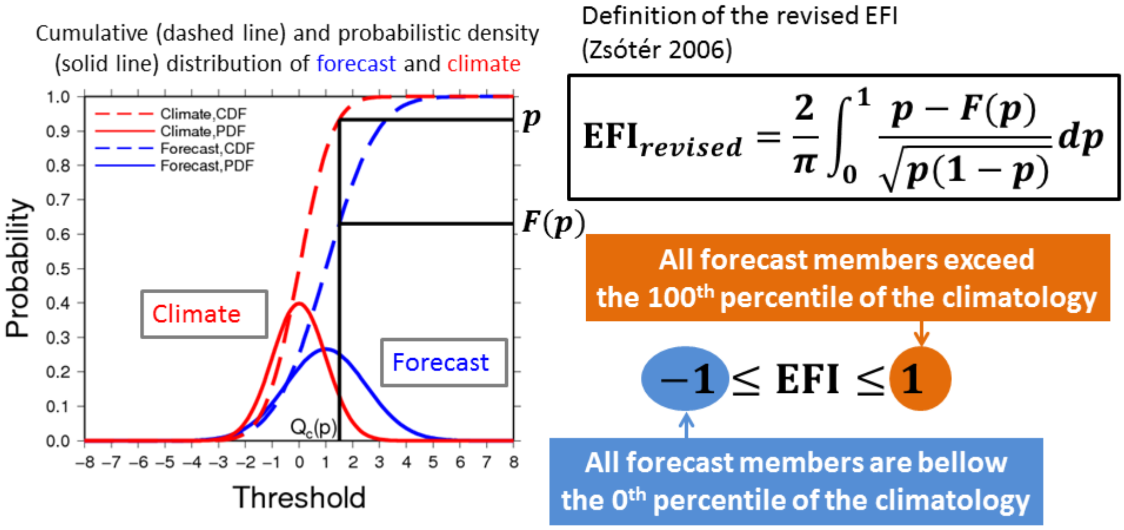


Figure 9 Definition of revised Extreme Forecast Index (EFI)

Figure 10 shows an example succeeded to forecast extreme weather. A heat wave hit Karachi city in Pakistan on 19-23 June 2015. Then the 3-day mean EFI warned "very warm" condition and the 3-day mean EPS meteogram also indicated extreme hot temperature at Karachi.

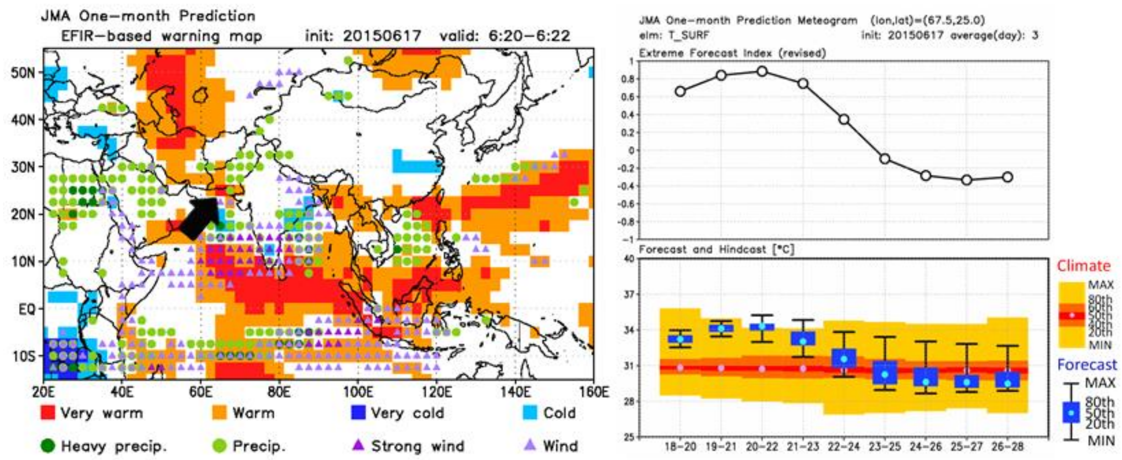


Figure 10 EFI warning map (left) and EPS Meteogram at Karachi (right)

(4) Probabilistic forecast

JMA provides calibrated tercile probabilistic forecasts for 3-month-averaged sea surface temperature, surface temperature and precipitation over the global based on the seasonal EPS. The ordered probit model is used to calibrate tercile probabilistic forecasts using 30-year hindcasts (1981-2010). The thresholds of tercile are determined so that the climatological chance of occurrence for each category is 33.3 % for the hindcast period from 1981 to 2010.

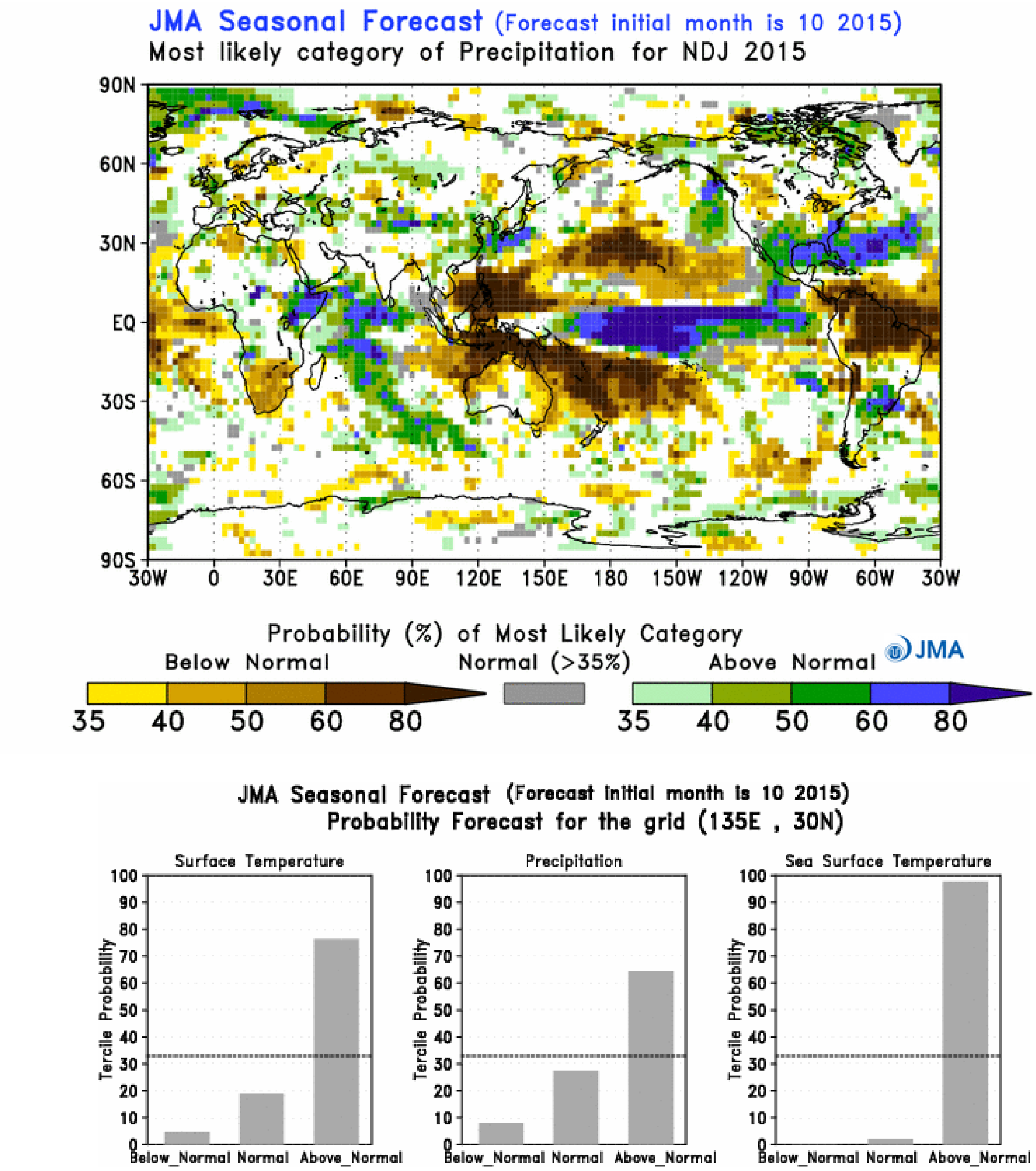


Figure 11 Probabilistic forecast map (top) and tercile probability of a point (bottom)

http://ds.data.jma.go.jp/tcc/tcc/products/model/probfcst/3-mon/index.html

http://ds.data.jma.go.jp/tcc/tcc/products/model/probfcst/warm_cold_season/index.html

Seasonal Forecast (One-month Forecast)

Seasonal forecast
(One-month forecast)

Masayuki Hirai

Tokyo Climate Center (TCC)/
Climate Prediction Division of
Japan Meteorological Agency (JMA)

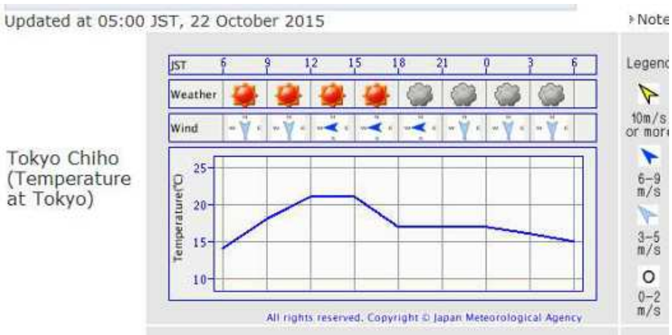
Outline

- Introduction
- Outline of the JMA seasonal prediction system
  - Specifications
  - Hindcast and Verification
  - History (effect of introduction of CGCM)
  - Future subjects
- Introduction of the TCC website

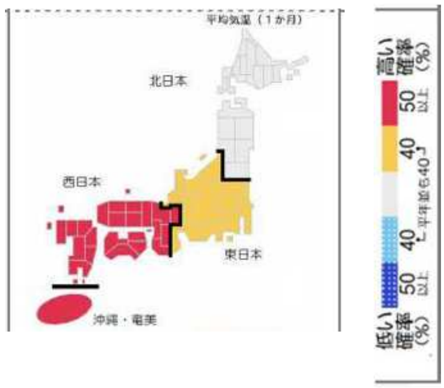
Introduction

Differences between short-range forecast and seasonal forecast

Short-range forecast



Seasonal prediction



Above normal

Below normal

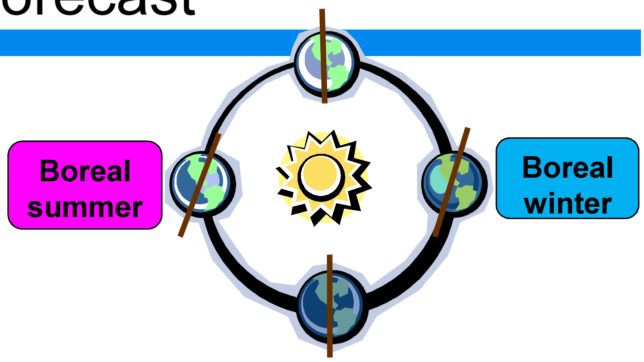
Describing weather parameter variation itself.

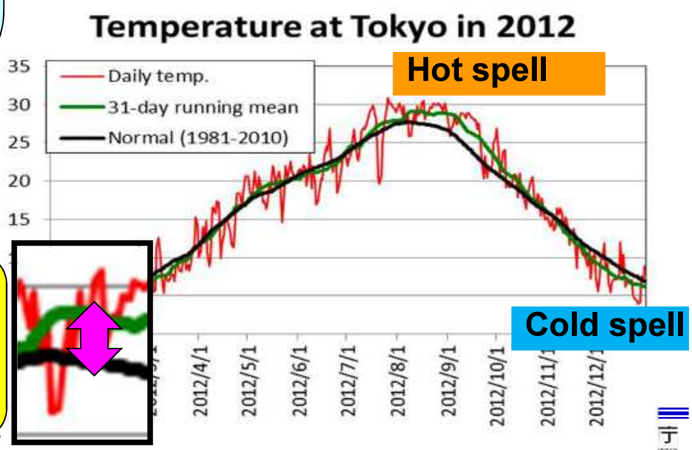
(not deviation, not averaged)

describing **averaged** weather parameters, expressed as a departure from climate values (anomaly) for that period.

The meaning of describing "anomalies" in the seasonal forecast

- Seasons cycle annually.
- Seasonal cycle of the region depends on solar angle and land-sea distribution.
- Weather conditions averaged over a period is "normal".
- Weather conditions has some features every year.
- Anomalous climate may affects the lives of the people.

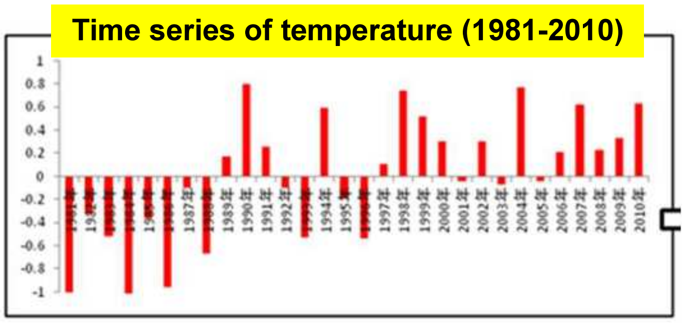


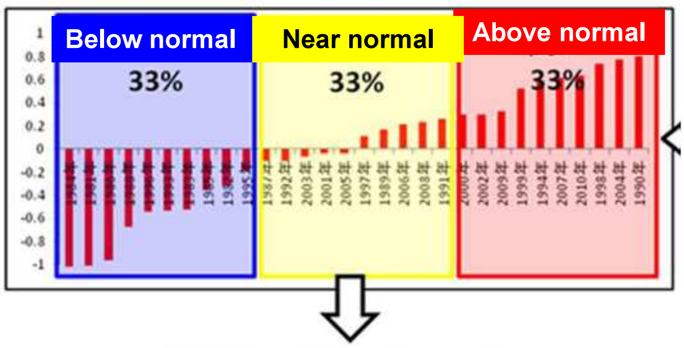


- **Anomaly from normal** is the target of seasonal forecasting.

What is the "normal" used in seasonal forecast?

- Target of the seasonal forecast is departure from the "normal".
- In JMA, period for "normal" is 30-year (1981 to 2010) as WMO recommends.
- Arranging historical data each year in ascending order,
  - <= 10th largest ; Below normal
  - 11th to 20th largest; Normal
  - 21th largest <= ; Above normal
- In the seasonal forecast, probability for each category is predicted.

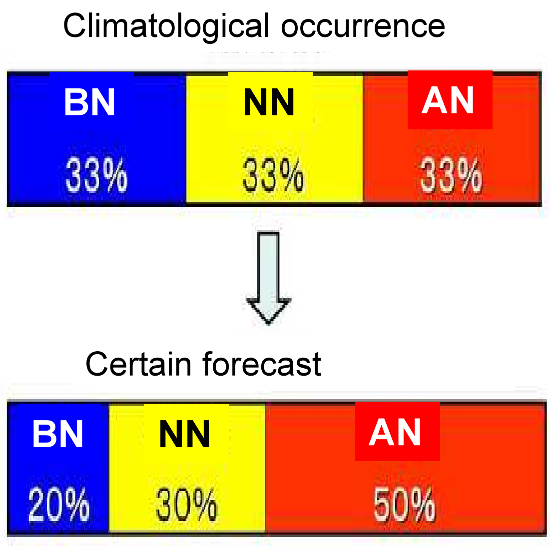




Range of Near normal: -0.1 to +0.3 ℃

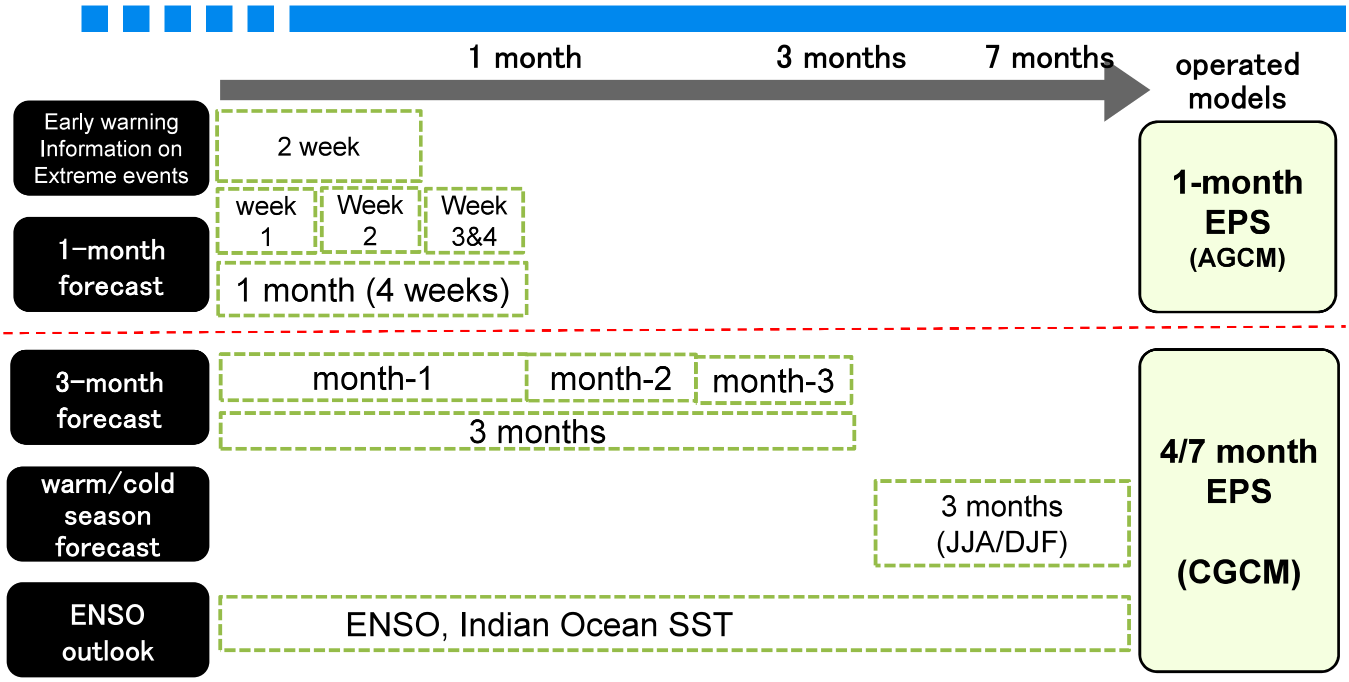
Tercile probabilistic forecast

- In the seasonal forecast probability for each category is predicted.
- Occurrence rate for each category is expected 33%.
- In certain forecasting, deviation from the climatological occurrence is important.



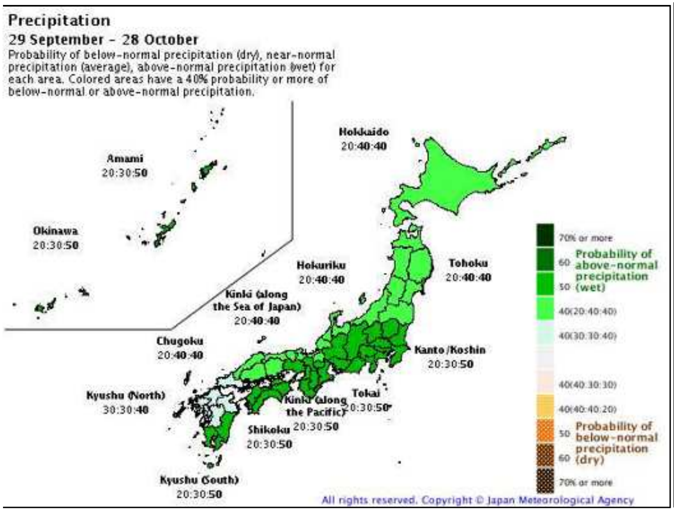
Seasonal forecasts in Japan

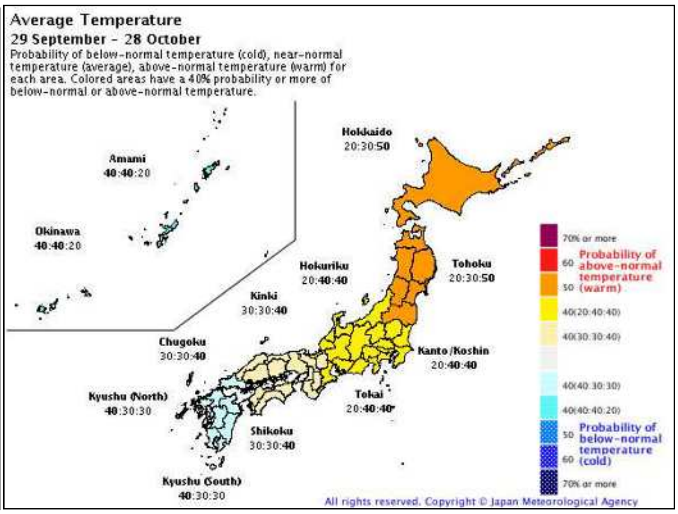
Overview of forecasts at CPD/JMA



In order to support seasonal forecast, two ensemble prediction systems (EPSs) are operated; 1-month EPS and the 4/7-month EPS

One-month forecast
Seasonal Forecast Announcement (JMA Homepage)

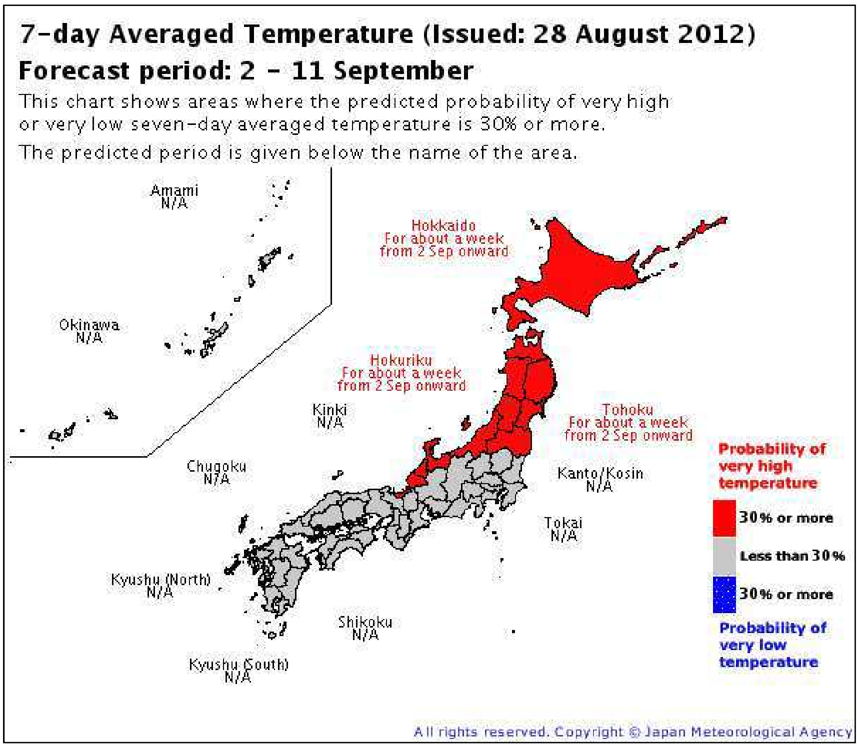




National monthly forecast
(weather outlook for Sept 29 through Oct 28)
Sept 28 2012 Meteorological Agency Global Environment and Marine Department Announcement
＜Items requiring special care＞
Outlook for very high temperatures in Northern and Eastern Japan for the beginning of the period.
＜Weather forecast for the coming one month period＞
Most probably weather, special temperatures, precipitation, etc for the coming month are as follows.
Across the whole country, weather is expected to change in the period of a few days. The Northern area on the Pacific side, in Western Japan, and Okinawa-Amami should see seasonal average large number of clear days Average temps for the coming month: 50% probability of high temps for North Japan; East Japan 40% chance of both seasonal average and high temps; Okinawa-Amami equal 40% chance of normal and low temps. Precipitation 40% chance for normal and high amounts in North and in East and West on the Sea of Japan side, with a 50% chance of high rain for East and West Japan on the Pacific side as well as Okinawa-Amami.
Weekly temperature outlook: in the first week, 80% chance of high temps in North Japan and 60% in Eastern Japan, 50% chance of seasonally average temps in Western Japan, with 60% chance of low temps in Okinawa-Amami. In the 2nd week 40% chance for both normal and high temps in North Japan and equal 40% chance of normal and low temperatures in Okinawa-Amami

・Early Warning Information on Extreme Weather

～1-2 weeks advanced
information is provided for marked high or low temperatures～



Early Warning Information on Extreme Weather is issued at 14:30 JST every Monday and Thursday when a high probability (30% or more) of a *very high* or *very low* seven-day average temperature is predicted in the week starting from five to eight days ahead of the date of announcement.
If information was issued on the preceding announcement date, follow-up information is issued on the next announcement date.
The terms very high and very low refer to high or low seven-day average temperatures in the top 10% of all samples.

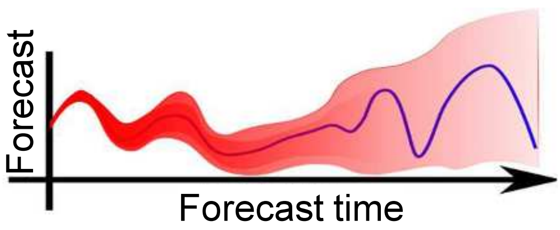
Climate information

When extreme climate condition, such as hot (cold) spell, drought, poor sunshine, with social impact is anticipated, JMA issues the climate information.

Estimate of uncertainty (Ensemble prediction)

How to predict for longer time-scale

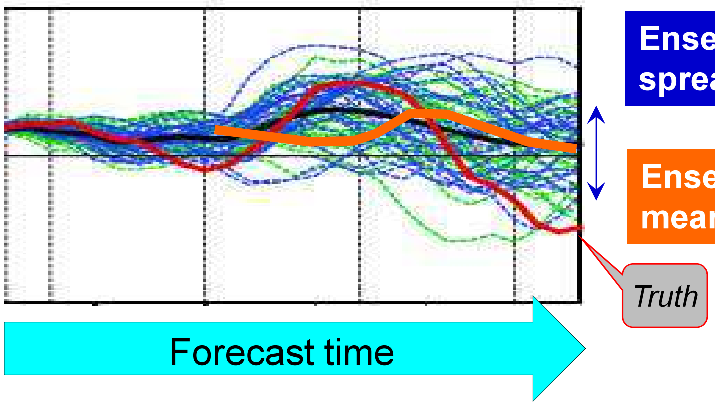
- Due to chaotic behavior of atmosphere, errors rapidly grow during period of prediction.



- To address this issue, ensemble prediction is essential for long-range forecasting.

Estimating uncertainty with ensemble prediction

Ensemble prediction:
Probabilistically predicting with aggregation of the multiple prediction results.

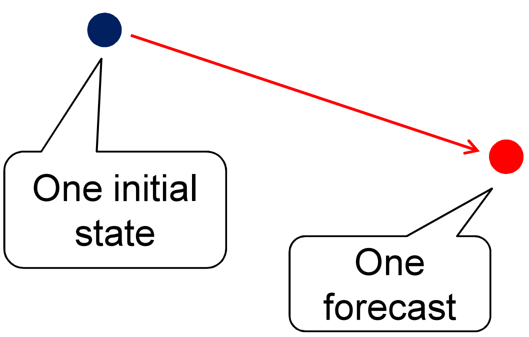


Ensemble spread = Standard dev., suggesting degree of uncertainty

Ensemble mean = Average of ensemble members outputs, suggesting degree of signal

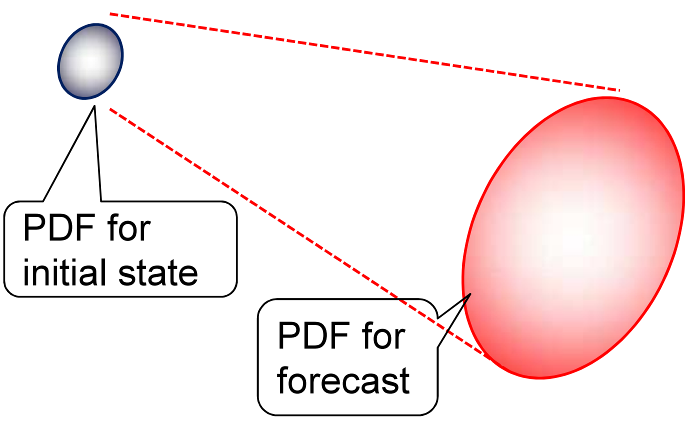
Deterministic and probabilistic forecast

Deterministic forecast



Calculate one forecast using one initial state

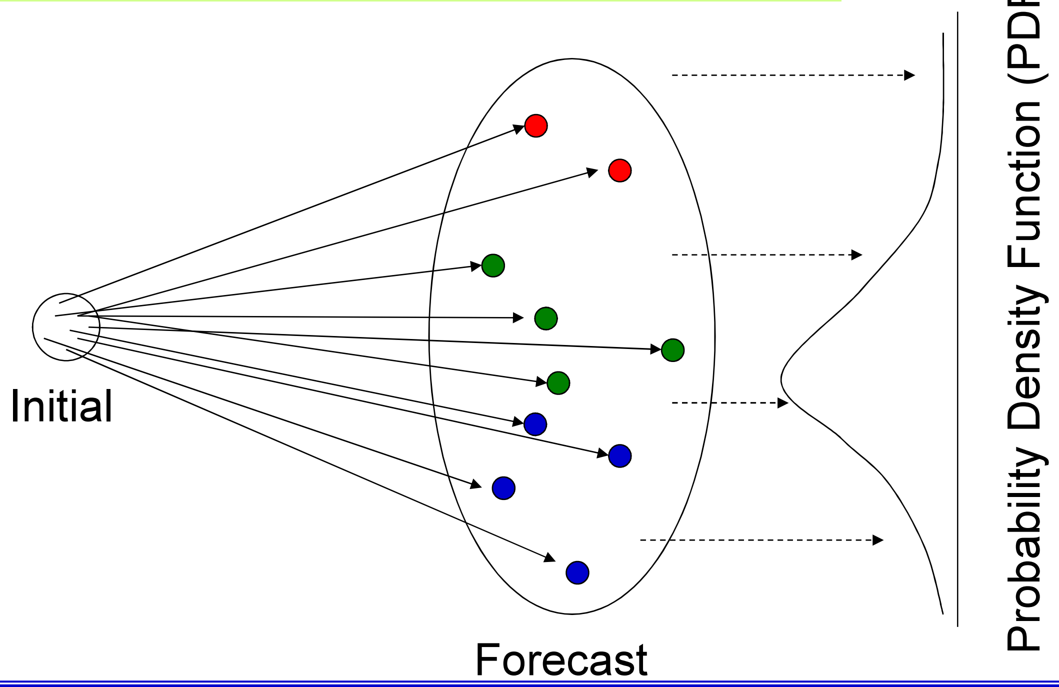
Probabilistic forecast



- EPS derives PDF for forecast.
  - Possible to predict probability of the targeted phenomena, which add degree of reliability to deterministic forecasting.

Probabilistic Forecast

- EPS enable to derive PDF, which denotes reliability for target phenomena.



WMO Classification of meteorological forecasting (GDPFS Manual)

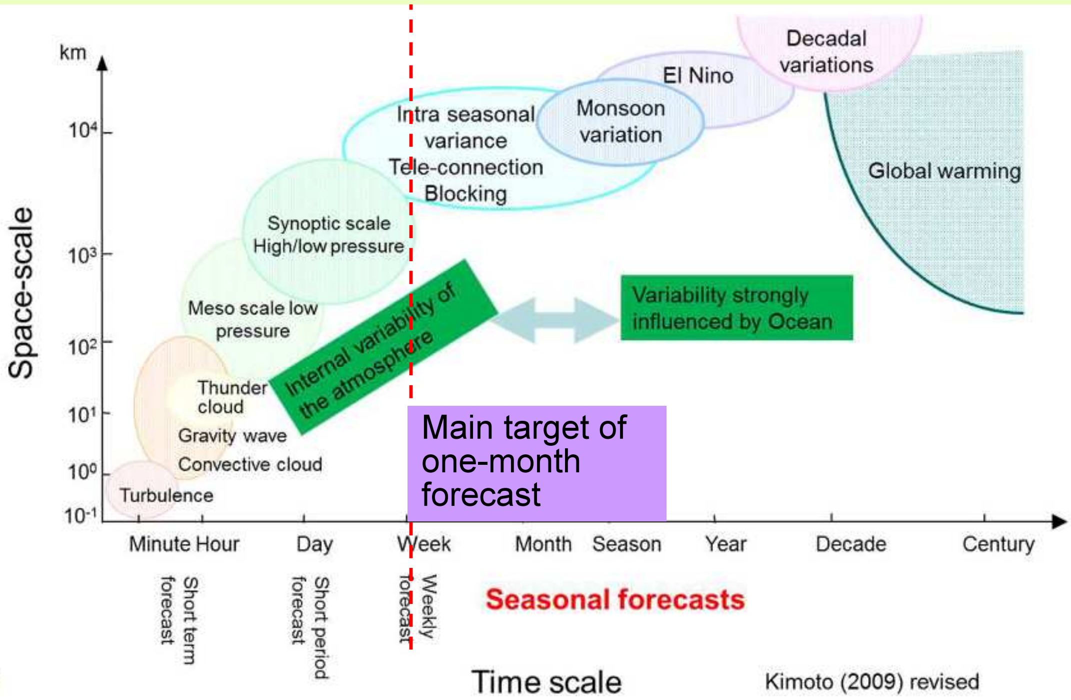
	Forecasting target period
Nowcasting	Up to 2 hours
Very short-range weather forecasting	Up to 12 hours
Short-range forecasting	Beyond 12 hours and up to 72 hours
Medium-range weather forecasting	Beyond 72 hours and up to 240 hours
Extended-range weather forecasting	Beyond 10 days and up to 30 days
Long-range forecasting	Beyond 30 days up to two years
Climate forecasting	Beyond two years

Target of this seminar

Manual on the Global Data-processing and Forecasting System, Appendix I-4
(https://www.wmo.int/pages/prog/www/DPFS/documents/485_Vol_I_en_colour.pdf)

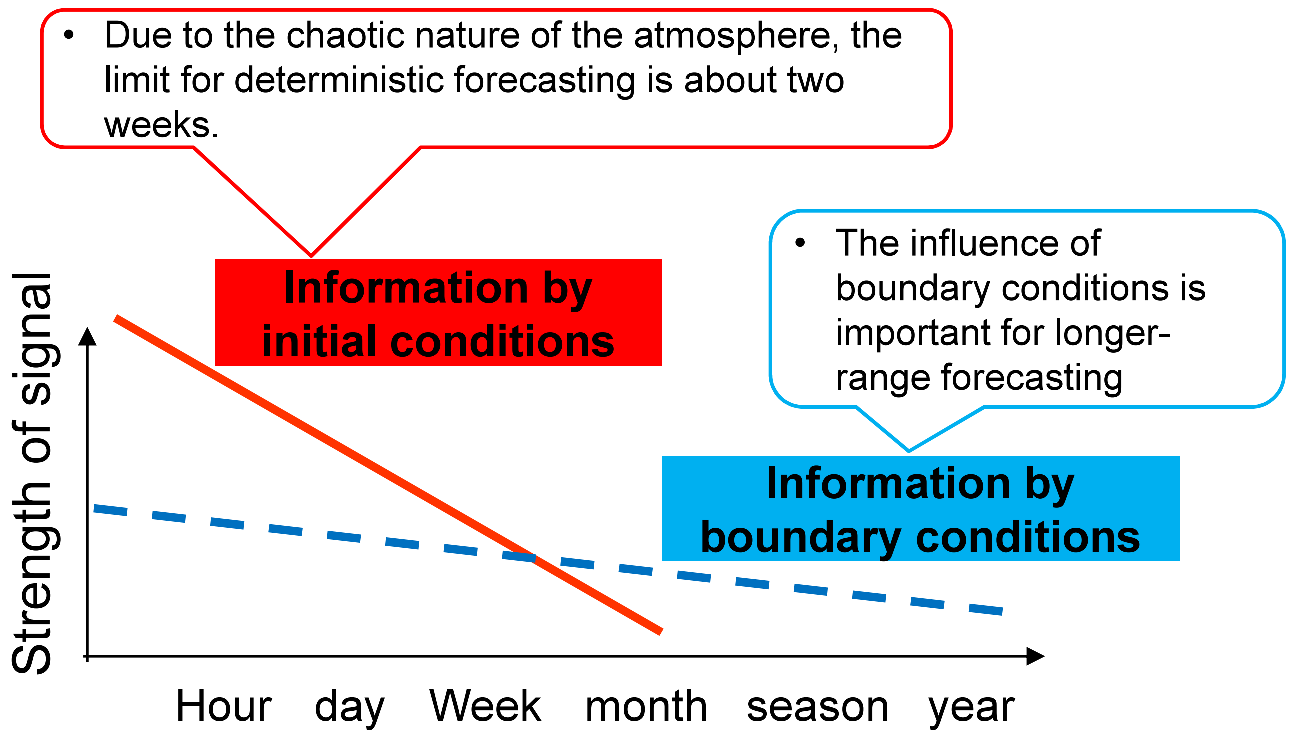
Multiple structure in the atmospheric phenomena

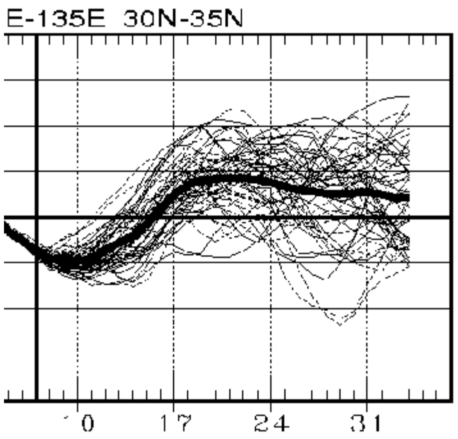
- Variations in atmosphere consist various space- and time-scale phenomena.
- Targets for seasonal prediction are phenomena with large time- and space-scale (over about one week).



Kimoto (2009) revised

Importance of initial and boundary condition





Variation of predicted values consist of

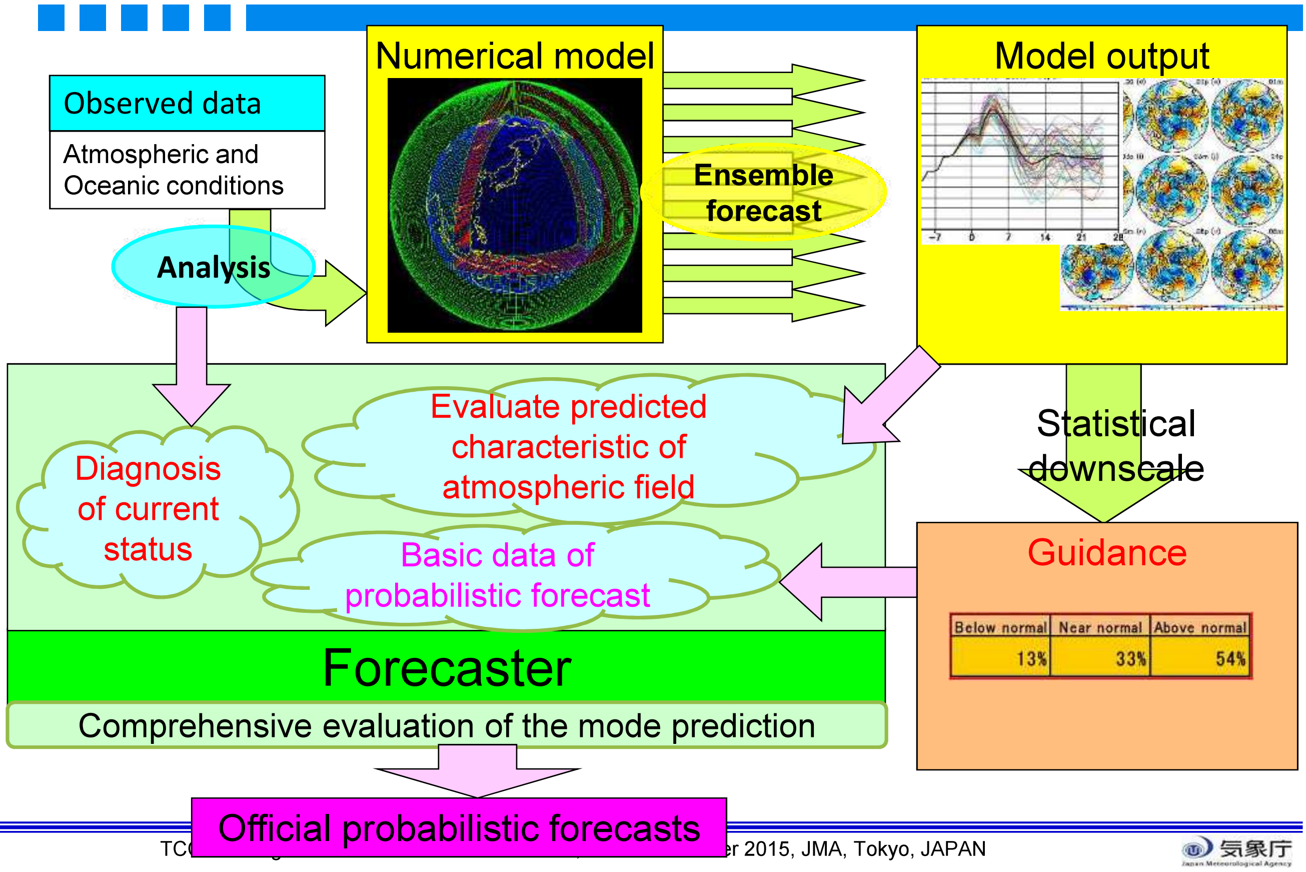
- Predictable variation (signal)
- Unpredictable variation (noise)

Forecasters are required to estimate degree of uncertainty (i.e. both signal and noise).

- EPS is essential to estimate signal/noise.
- Numerical guidance, which is the application tool of EPS, enable to support the estimation.

How to make one–month Prediction

Typical flow of making one month forecast



Procedure of the one-month forecast (1)

(1) Understanding current status

- SST (ENSO, anomalies over the tropics)
- Atmosphere in the tropics
  - ISO (MJO, BSISO) active/inactive, phase
  - Convective activity over the tropics
  - Influence of the anomalous convection on the sub-tropical (mid-latitude) atmosphere
- Atmosphere in the mid-high latitudes
  - Position and meandering of the sub-tropical jet or polar front jet
  - Rossby wave propagation along the jet streams
  - Subtropical High? Siberian High? Aleutian Low

Refer to the “Climate System Monitoring”

http://ds.data.jma.go.jp/gmd/tcc/tcc/products/clisys/index.html

Procedure of the one-month forecast (2)

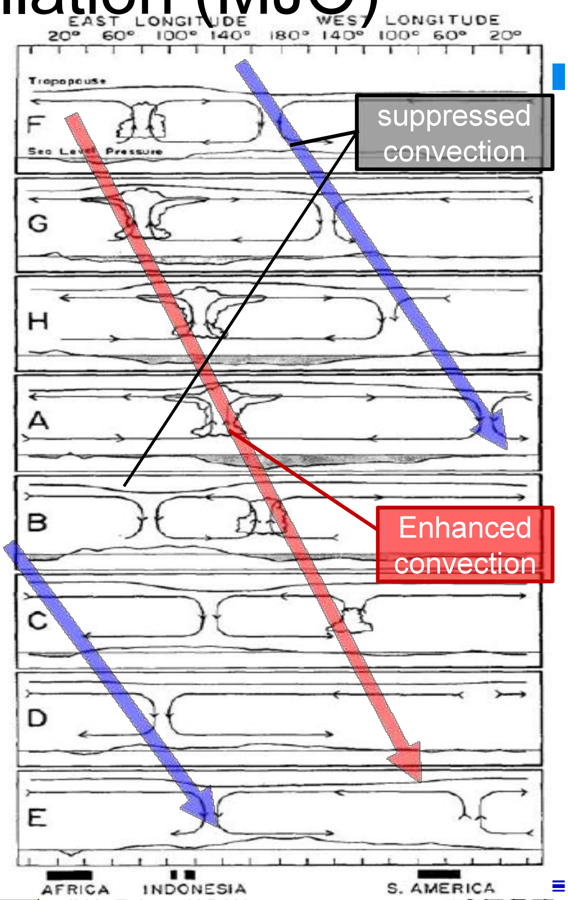
(2) Estimate predicted results
- NWP model results are basic
  - Forecast map
    - Convective activity in the tropics
    - Influence of atmospheric field by tropical convection in the tropics
    - Variations in the mid/high latitudes
  - Early warnings product (e.g. EFI)
- Estimate degree of uncertainty
  - Prediction skill of model (hindcast verification)
  - Prediction skill of created guidance

⇒Refer to the EPS products http://ds.data.jma.go.jp/gmd/tcc/tcc/products/model/index.html

(3)Build one-month forecast

Madden-Julian Oscillation (MJO)

- Most dominant mode over the tropics in extended range timescale
- propagates eastward along the equator with periods of 30 – 60 days
- a large-scale coupled pattern between deep convection and atmospheric circulation
- clearer signal in convection over the Indian Ocean and the western Pacific than other regions
- Make an impact on mid-high latitude through variations of sub-tropical high or meandering of the jet stream
- Often monitor using OLR and velocity potential (divergence field)
- Possible to predict about 2 to 3 weeks => important signal for one-month forecast

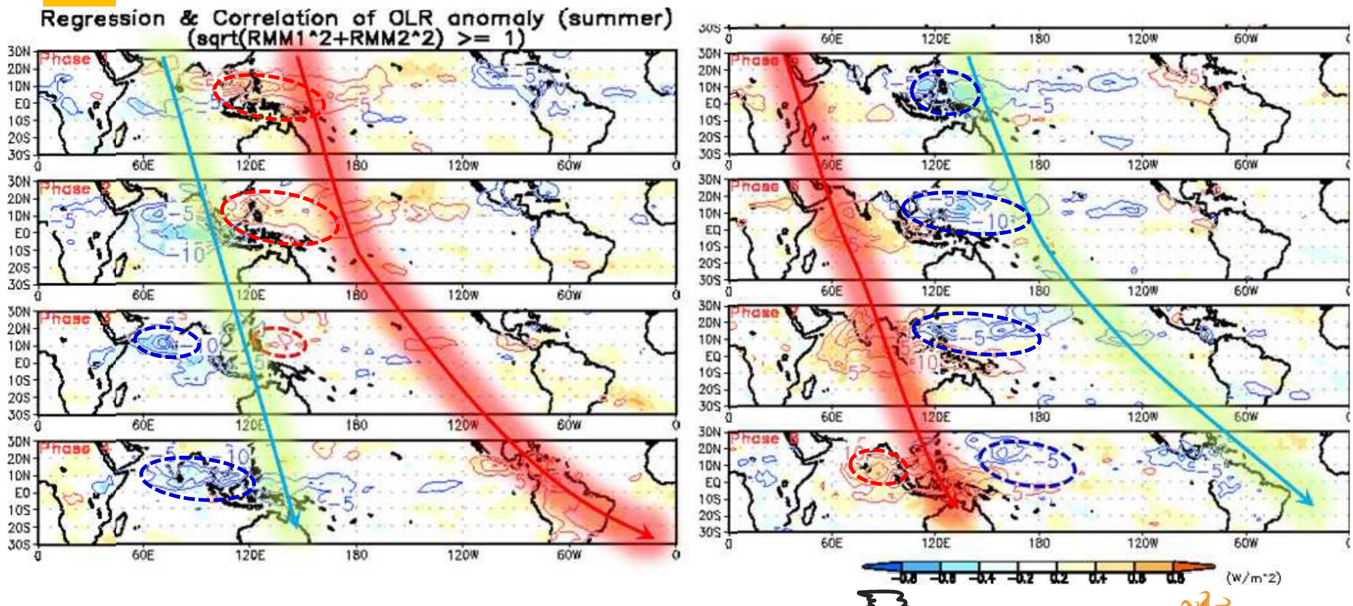


Original; Madden and Julian (1972) Fig.16

BSISO (Boreal Summer IntraSeasonal Oscillation)

In boreal summer, northward propagation is seen over the Indian Ocean and western Pacific, in addition to eastward propagation component.

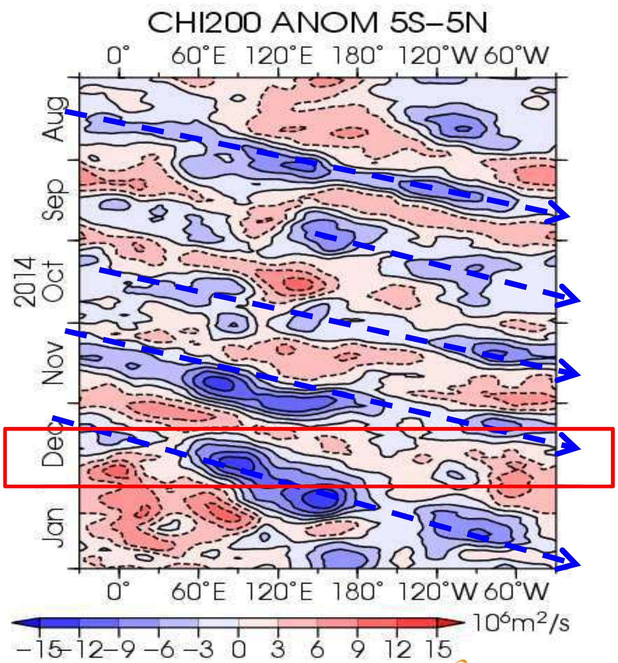
JJA



Example of influence of MJO on mid-latitude (Dec. 2014)

Upper Velocity potential (CHI 200) anomaly Along EQ.

http://ds.data.jma.go.jp/gmd/tcc/tcc/products/clisys/ASIA_TCC/mjo_cross.html

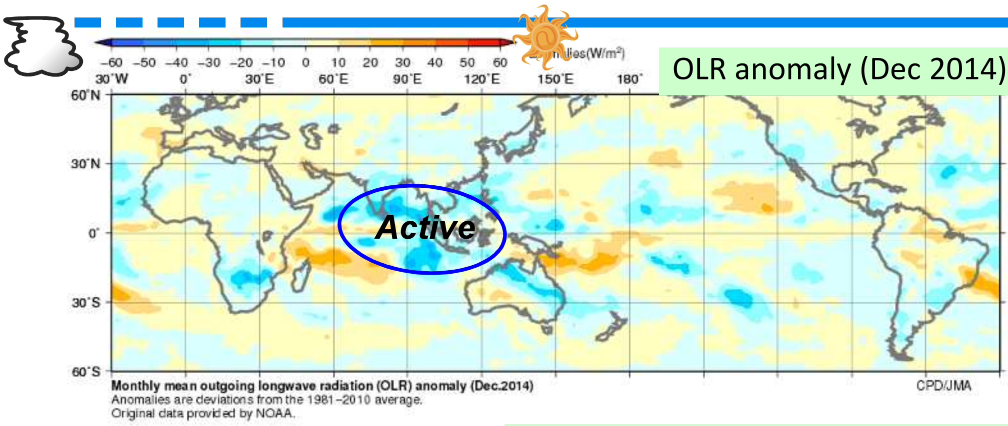


- Eastward propagation of convection activity anomaly pattern relating with MJO is generally clear.
- Around mid Dec. 2014, active phase of amplified MJO propagated from the Indian Ocean to the Maritime continent.

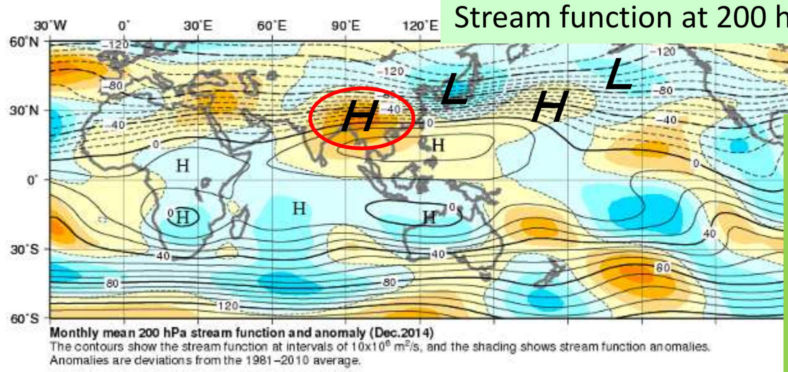
TCC Training Seminar on one-month forecast, 16-20 November 2015, JMA, Tokyo, JAPAN

Meandering of the sub-tropical jet due to anomalous convection in the tropics (Dec. 2014)

OLR anomaly (Dec 2014)



Stream function at 200 hPa (PSI200) (Dec 2014)

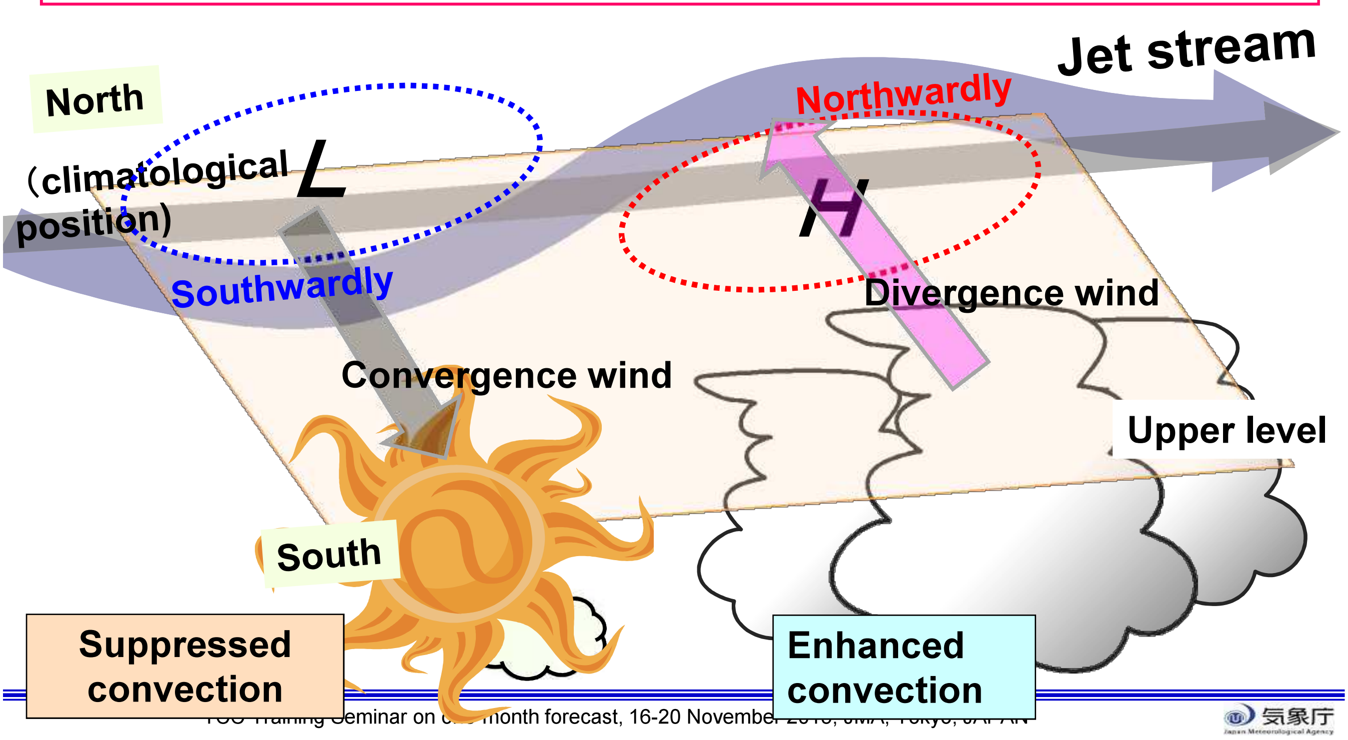


Active convection around Southeast Asia
→Northwardly shifted jet stream around China (Positive anomaly)
→Southwardly shifted jet stream around Japan (Negative anomaly)
→Cold spell around Japan

http://ds.data.jma.go.jp/gmd/tcc/tcc/products/clisys/figures/db_hist_mon_tcc.html

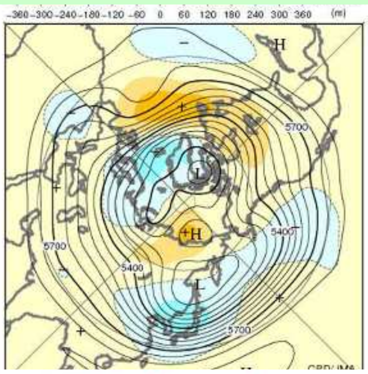
Meandering of jet stream by anomalous convections in the tropics

Shifted **northwardly** (north side of enhanced convections)
Shifted **southwardly** (north side of suppressed convections)

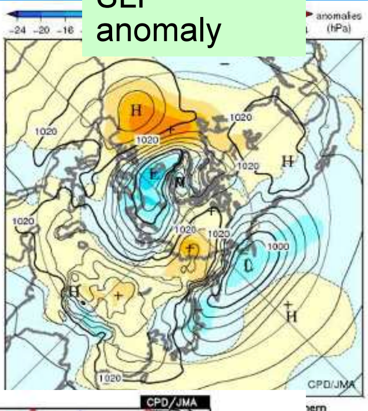


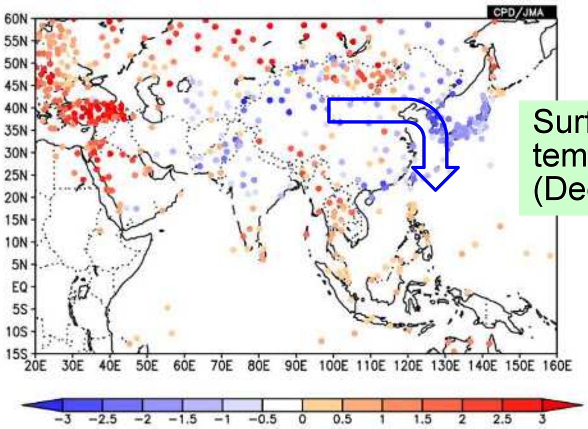
Meandering of the sub-tropical jet due to anomalous convection in the tropics (Dec. 2014)

500hPa height anomaly



SLP anomaly



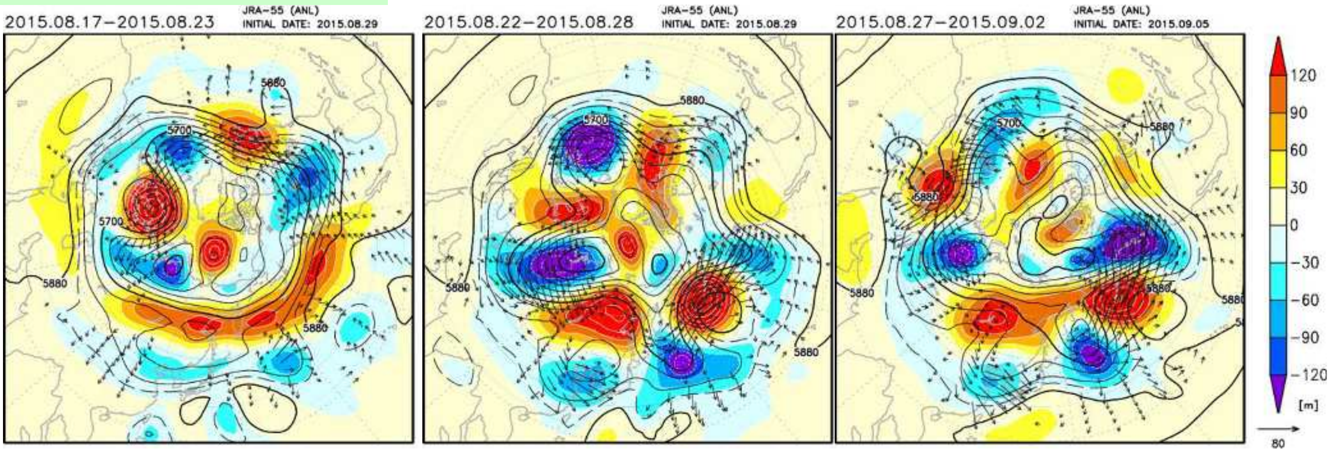


Surface temperature (Dec 2014)

- Ridge in west of Lake Baikal, relating to EU pattern, brought development of the Siberian high.
- In association with development of the Siberian high, cold air outflowed over the East Asia.

Meandering the upper westerlies, relating with Rossby wave propagation

500hPa height anomaly



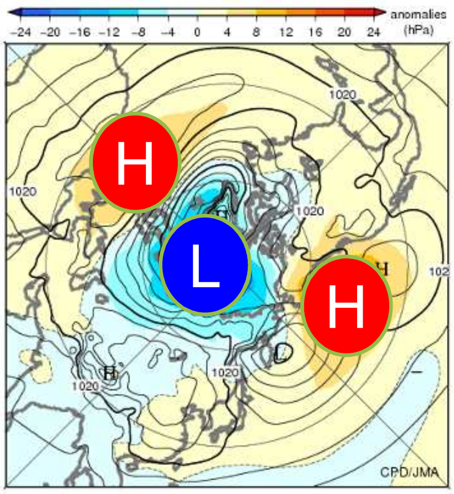
- Depending on propagation of Rossby wave packet, meandering of the upper westerlies amplifies.
- In the above case, a blocking high developed in eastern Siberia, in association with propagation of wave packet along the polar jet stream. In the end of August 2015, the blocking high weakened emitting wave packet southeastward, which enhanced trough in west of Japan.

Arctic Oscillation (AO)

- Meridionally asymmetric anomalies pattern of pressure (temperature) between arctic and mid-latitudes
- most dominant variations in the boreal winter
- ➢ Once the AO happens, it may persist and its influence may become large.

SLP anomalies (1988/89 DJF)

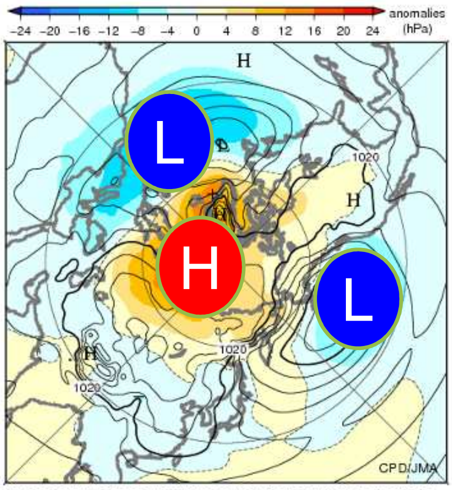
+AO



Three month mean sea level pressure and anomaly in the Northern Hemisphere (Dec.1988–Feb.1989)

SLP anomalies (2009/10 DJF)

-AO



Three month mean sea level pressure and anomaly in the Northern Hemisphere (Dec.2009–Feb.2010)

Novembe

気象庁

"Signal" and "Noise" depending on forecast

- Those are targets for short-range forecast.
- It is the difference between short-range and seasonal forecast!

Kind of forecast	Signal	Noise	Reduction of noise
Medium-range (One-week forecast)	Shortwave disturbance dominating over daily variations of weather		
Extended –range (One-month forecast)	Low-frequency variation of atmosphere (meandering of the jet, blocking, AO, MJO and so on)	Transient eddies (moving high, low)	* Forecast time averaged field, such as weekly or one-month average
Long-range (Three-month, Warm/Cold season forecast)	Low-frequency variation of tropical ocean and its influence, such as ENSO and Indian Ocean variation	Low-frequency variation of atmosphere	* Forecast time averaged field, such as one or three-month average

<Summary> Viewpoint of the one month forecast

- NWP model results are basic.
  - Forecast map (ensemble mean) **-> Signal**
- Predict convective activity in the tropics
  - ISO(MJO, BSISO), influence by SST (ENSO)
- Predict influence of atmospheric field by tropical convection in the tropics
- Predict variations in the mid/high latitudes
  - Meanderings of the westerlies (large-scale troughs and ridges)
- Estimate degree of uncertainty **-> Noise**
  - Numerical guidance
  - Prediction skill (verification using hindcast)

➢ Both "signal" and "noise" for building probabilistic prediction.

<Supplemental>

- Up to 2-week, large-scale variations are generally predictable.
- Strongly anomalous probabilities are likely only up to 2 weeks.
- MJO has some degree of predictability even in 3-4 weeks ahead.
- Maintain of the AO or the large-scale anomaly pattern can be one reason of the forecast. However, phase change of those phenomena is generally difficult.
- Occurrence/disappearance of a blocking phenomena is generally difficult.

Concept of numerical guidance

Concept of numerical guidance

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Climate Prediction Division of
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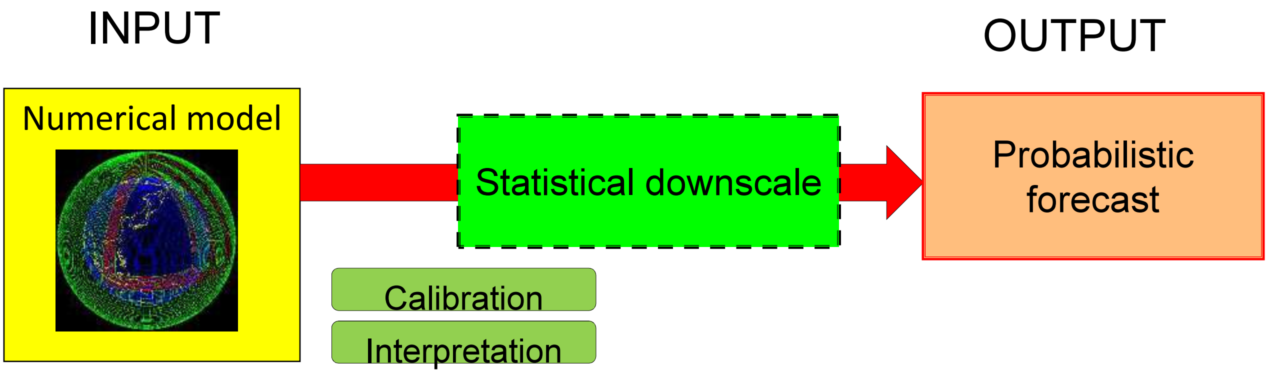
Outline

- Outline of guidance
  - Role
  - Principle
    - Regression model
    - Estimation of probability
- Verification
  - Verification score

Outline of guidance

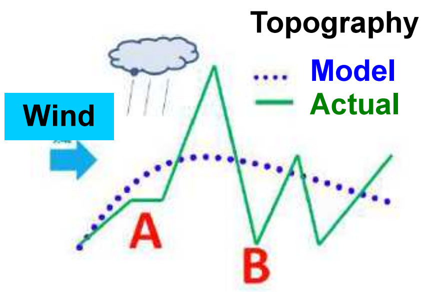
Guidance



- "Guidance" is an application to translate model output values into target of forecasting.
- Principle of guidance is to predict future values based on statistical relationship using model forecasts and observation data for past cases.

Role of guidance

- To extract effect of sub-grid scale topography
  - Model may not reproduce effect of local topography due to limited resolution, while enable to reproduce large-scale field.
- To Reduce imperfection of the model, such as systematic error (bias error).
- To estimate degree of uncertainty, considering prediction skill



A: Upwind side
- Model may underestimate precipitation

B: Bottom of the valley
- Model may have warming bias

"Guidance" enable to improve prediction skill comparing with direct model output.

Principle of guidance (MOS technique)

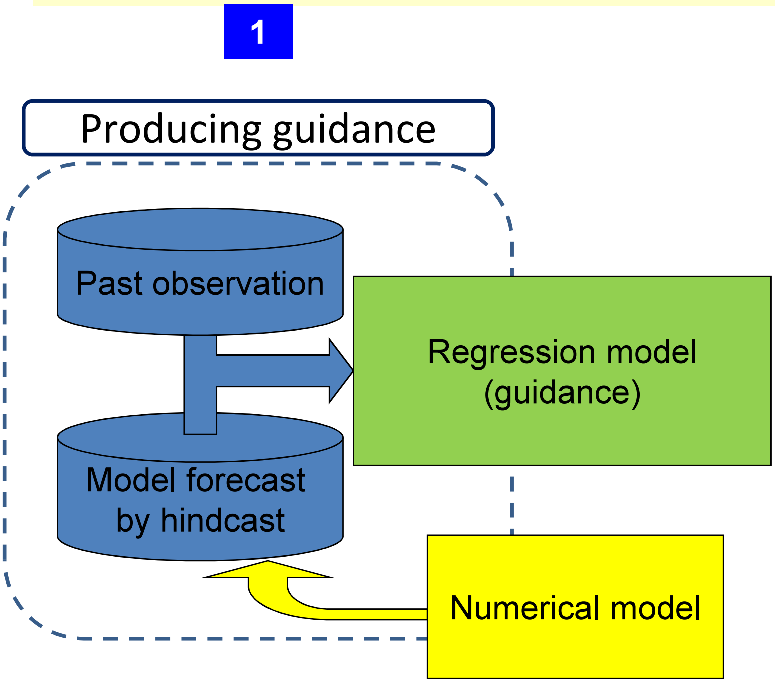
MOS (Model Output Statistics);

Calculation of statistical relationship between observation and model forecast for past cases, and apply to the real-time forecast

- Two types of the time series data are needed in order to produce guidance.
  - 1. Past observation (i.e., Predictands) ← Create by users
  - 2. Past model forecast by hindcast (i.e., Predictors) ← On ITACS

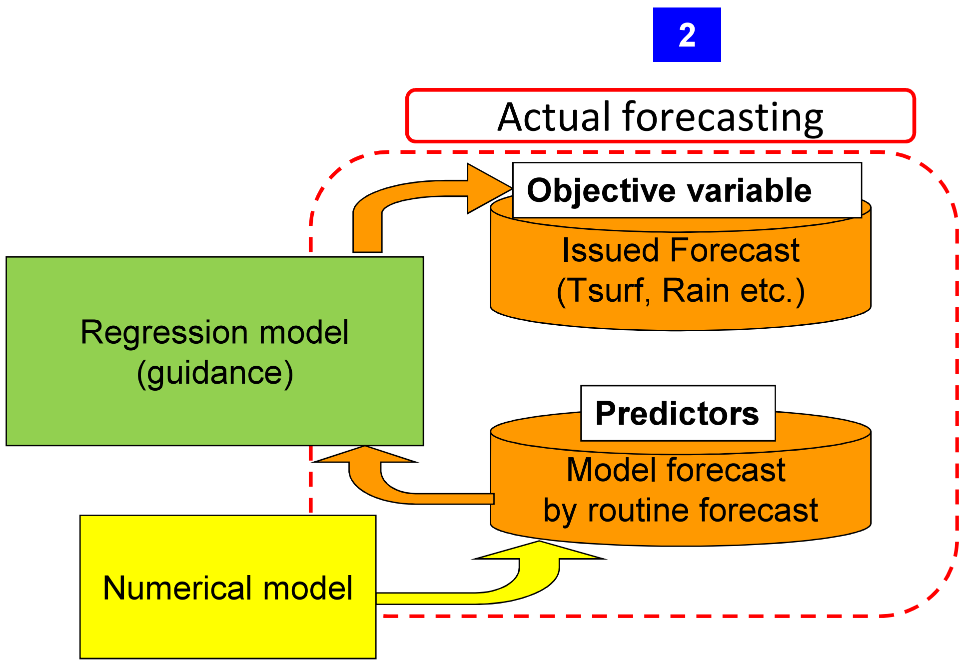
Concept of the guidance adopting MOS technique (1)

- **Statistical relationship** is estimated using observation and model forecast for past cases.



Concept of the guidance adopting MOS technique (2)

- In the real-time forecast, predicted value is calculated applying to the statistical relationship.

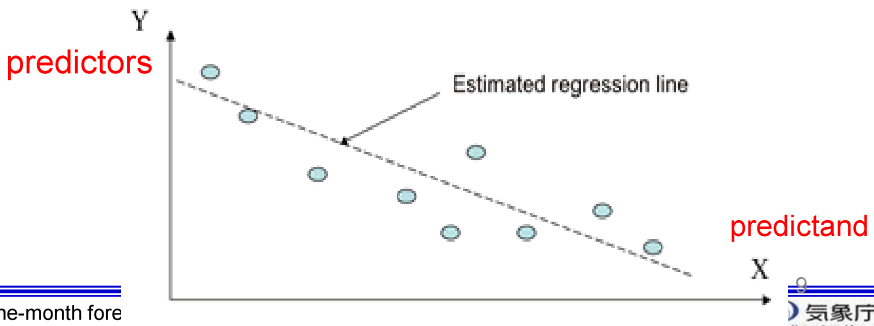


Single regression

- Single regression is modeled the relationship between one explanatory variable (predictors) and objective variable (ex. temp. rainfall).
- Single regression model is written as

$$Y = a_x + b + \varepsilon$$

Y: predictand X: predictor
a: regression coefficient b: constant,
ε: error term



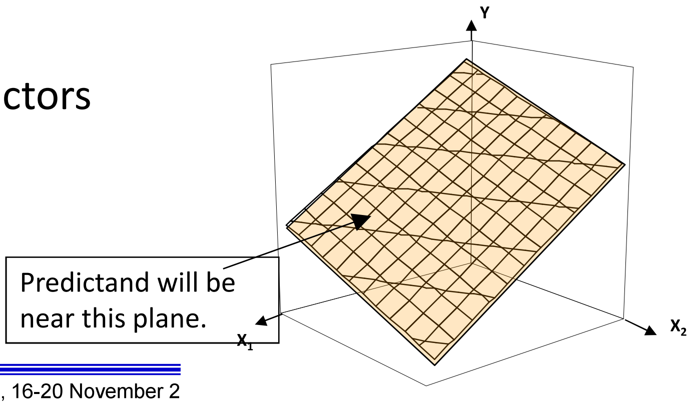
Multiple regression

- Multiple regression is assumed that the objective variable is the sum of a linear combination of plural predictors.
- Multiple regression model is written as

$$Y = \sum_k (a_k X_k) + b + \varepsilon$$

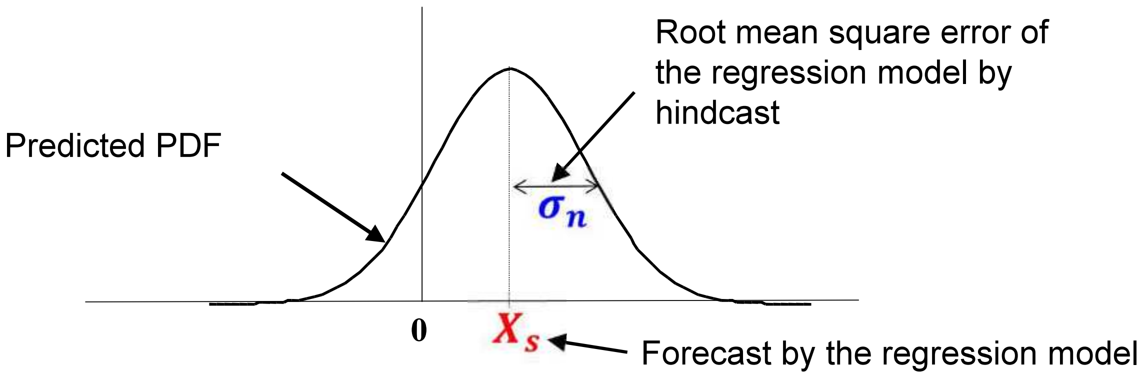
k=1,2,…,n
Y: predictand X: predictors
a: regression coefficient
b: constant
ε: error term

Example: two predictors



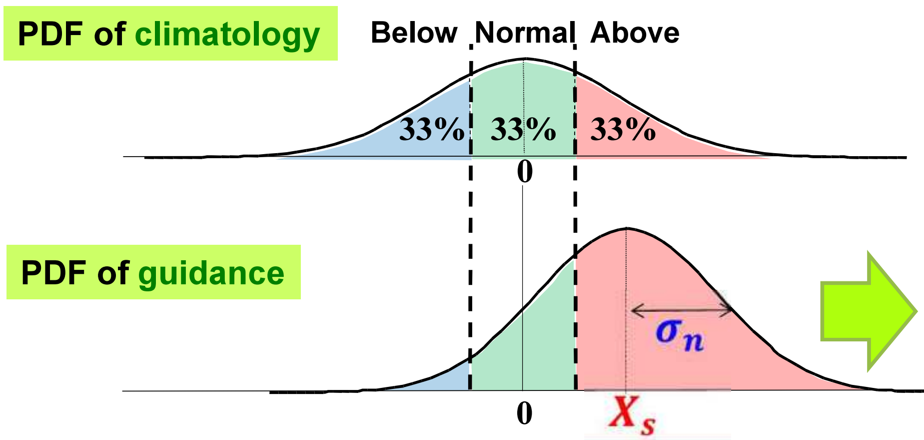
Translation to PDF in the regression model

- In the guidance tool, Probability Density Function (PDF) is assumed to be a **normal distribution.**
  - **Mean (x_s)** : prediction value by the regression model
  - **Standard deviation (σ_n)** is error of the regression model, which is assumed to be RMSE of the regression model using hindcast.



Estimation of Tercile probability with regression model

- The threshold values for tercile categories determined from the past observation (1981 to 2010).
- Probability for each Tercile category (below-, near-, above-normal) is calculated by referring to the PDF of guidance and the threshold values for tercile categories.



Issued Forecast		
Below	Normal	Above
10%	30%	60%

Normalization of precipitation data

- **Normal distribution** is assumed in the regression model.
- As for temperature, its distribution is generally approximated by a normal distribution.

Meanwhile,

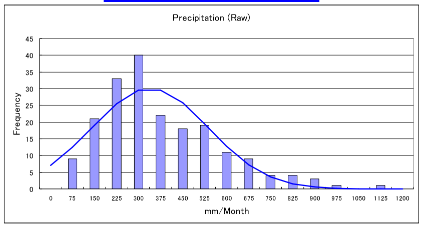
- As for precipitation, its distribution does not represent a normal distribution, and it's usually approximated by a gamma distribution.

- In order to create guidance, precipitation data need to be normalized.

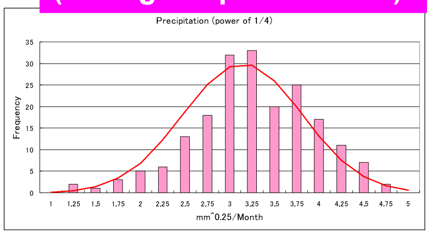
- Power of 1/4 for precipitation ($RAIN^{1/4}$) is approximated by a normal distribution.

Ex. Precipitation over Japan

(Row value)



(Taking the power of 1/4)



Verification

Verification for deterministic forecast (1 of 2)

- Mean Square Error (MSE)
- Root Mean Square Error (RMSE)

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$$

F :forecast
O :observation
N :sample size

- MSSS

$$MSSS = 1 - \frac{MSE_{(forecast)}}{MSE_{(climatology)}}$$

Skill score of MSE, comparing with climatology

Verification for deterministic forecast (2 of 2)

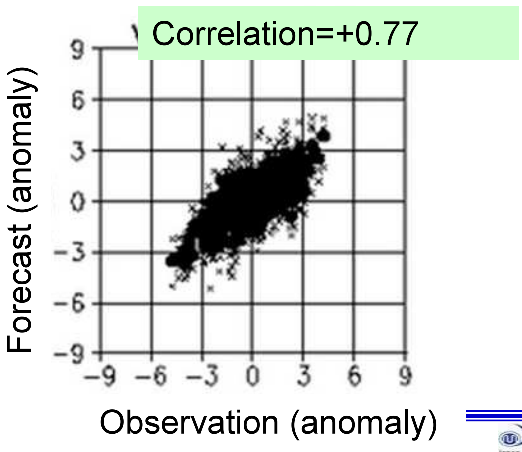
- Anomaly Correlation Coefficient (ACC)

$$AC = \frac{\sum_{i=1}^{N}(F_i - C_i)(O_i - C_i)}{\sqrt{\sum_{i=1}^{N}(F_i - C_i)^2}\sqrt{\sum_{i=1}^{N}(O_i - C_i)^2}}$$

F :forecast
O :observation
C :climatology

Range: -1 to 1.
Perfect score: 1.

Forecast data is calibrated

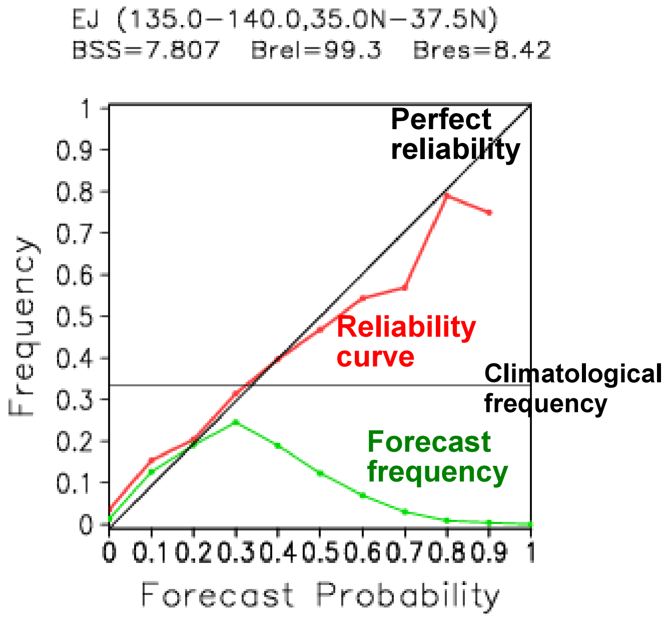


Verification for probabilistic forecast (1)
Reliability diagram

- Red line (reliability curve);
  plotted the observed frequency(Y-axis) against the forecast probability(X-axis)

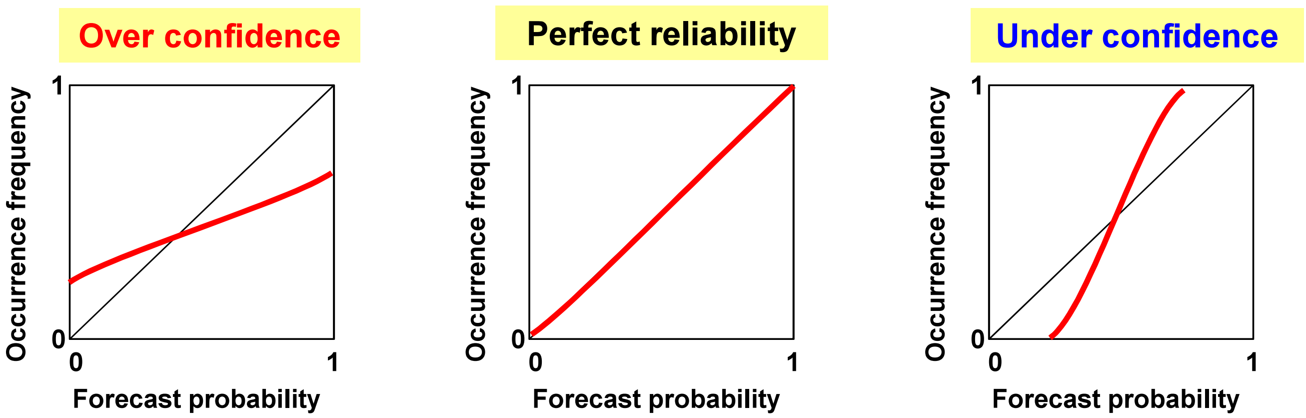
Probabilistic forecast becomes better the more the reliability curve fit to 45° line (perfect reliability).

- Green line denotes forecast frequency (sharpness diagram);
  - •If most of the forecast probabilities are near the climatological frequency = unsharp
  - •If probabilities near 0 and 1 (100%) are often used = sharp



- probabilistic forecast

Over/under confidence



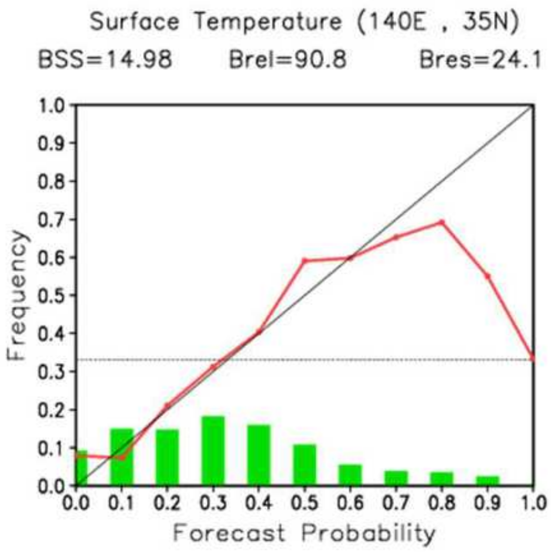
✓ Predicted probabilities are overestimated comparing with actual

✓ Predicted probabilities are underestimated comparing with actual

● probabilistic forecast

Interpretation of reliability diagram

Example



- The forecast is generally reliable for below 60%, while over-confident over 70%.

✓ Maximum probability should be suppressed under 60%

● probabilistic forecast

Brier skill score (BSS)

- Brier score is mean squared error of the probability forecasts.

$$BS = \frac{1}{2N}\sum_{i=1}^{N}\sum_{m=1}^{3}(p_i^m - o_i^m)^2$$

p_i^m : forecast probability

o_i^m : observed occurrence (0 or 1)

N : forecast frequency

m : category

Range: 0 to 1. Perfect score: 0

- Brier skill score is ***skill*** relative to a reference forecast (usually climatology).

$$BSS = 1 - \frac{BS}{BS_{reference}}$$

- Perfect score: 1
- BSS>0 : better than the climatology.
- BSS=0 indicates no skill when compared to the climatology.
- BSS<0 : worse than the climatology.

Overview of the guidance tool

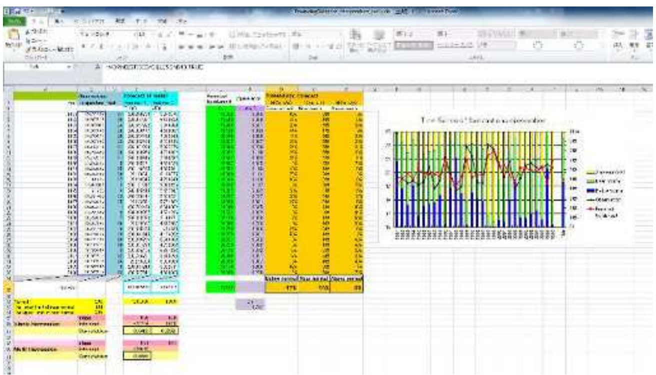
Overview of the guidance tool

For concrete method of the guidance tool, please refer to "How to use guidance tool .ppt".

Overview of the guidance tool

- EXCEL base … Simple
  - Regression analysis is executed using the EXCEL functions, not macro
    - easy to understand the principle of guidance
    - good portability
    - easy to customize

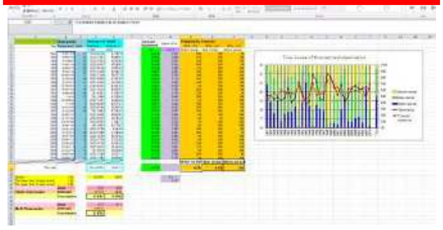
Worksheet



Structure … Three worksheet

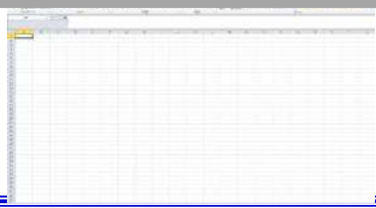
- "Calc_guidance" — Main part of the tool
  - Creation of guidance; regression analysis using past observation and model forecast (hindcast)
  - application to the real-time forecast
    - ➢ Provision of guidance output
- "Verification"
  - confirm prediction skill of guidance
- "Memopad"
  - Free space for cut and paste of data

Worksheet "Calc_guidance"

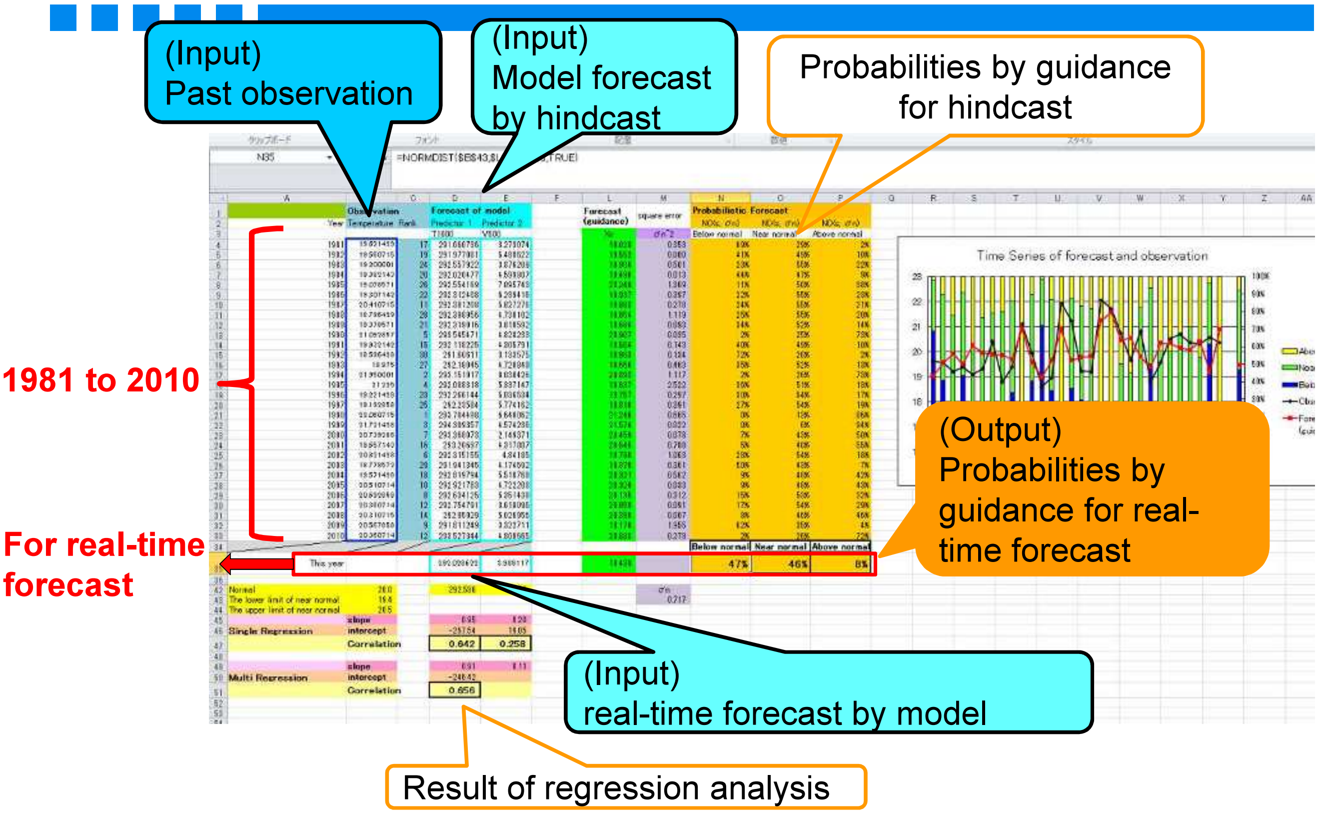


Worksheet "Verification"

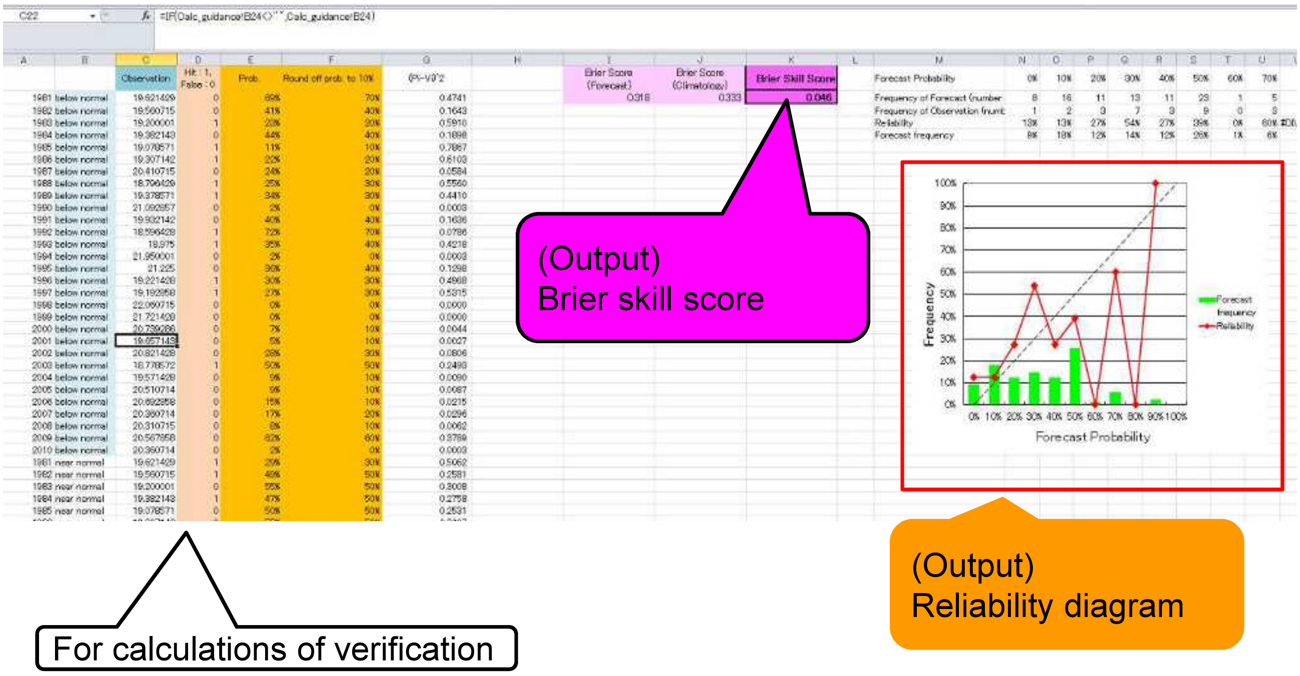
Worksheet "Memopad"



Worksheet "Calc_guidance"



Worksheet “Verification”



Specifications of the guidance tool

Climate baseline is 1981-2010.

- Threshold of tercile categories
  - Observation data in 30 years (1981 to 2010)
- Method of guidance
  - Multi regression (two elements) between model forecast (ensemble mean) and observation for the past cases
    - Single regression (one element) is also supported
- Estimation of uncertainty
  - Uncertainty is estimated based on forecast error (RMSE) of guidance during hindcast (1981 to 2010).
  - PDF is assumed a normal distribution.

Necessaries for producing guidance

- Past observation (Objective variables)
  - target of forecast
  (ex. Temperature, rainfall)

Create by users.
(You have prepared.)

- Model forecast (Predictors)
  - past cases (hindcast)
  - real-time forecast

Using iTacs

For concrete method of the guidance tool, please refer to "How to use guidance tool .ppt".

Workflow of the guidance tool

1. (Preparation)
   1. Create the past observation file (csv format)

Input of the guidance tool
(We have already prepared.)

2. (using EXCEL file and iTacs)
   1. Check the initial date and target period
   2. Production of guidance and verification
      (1) Get past observation data
      (2) Get hindcast data
      (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

For concrete method of the guidance tool, please refer to "How to use guidance tool .ppt".

Exercise: How to use guidance tool

How to use guidance tool
(Producing Guidance and Verification)

Masayuki Hirai

Tokyo Climate Center (TCC)/
Climate Prediction Division of
Japan Meteorological Agency (JMA)

Workflow of the guidance tool

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      Obtaining solution of probabilistic forecast by the guidance

Workflow of the guidance tool

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      (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

1. Past observation data

- Element: Mean temperature and precipitation (daily)
  - Create the files separately between temperature and precipitation
- File format: csv
- Period: Every day from 1 January 1981 to 31 January 2011
- Describe some information on observation point in the beginning five lines
- Embedded undefined value in case of missing data

The next slide illustrates the example

Example of the observation data file

	A	B	C	D
1	#station=TOKYO/JAPAN			
2	#undef=-9999			
3	#elname=precipitation			
4	#lon=140.0			
5	#lat=35.0			
6	1981	1	1	0
7	1981	1	2	2
8	1981	1	3	0
9	1981	1	4	0
10	1981	1	5	0
11	1981	1	6	0
10986	2011	1	24	3.5
10987	2011	1	25	0
10988	2011	1	26	0
10989	2011	1	27	0
10990	2011	1	28	-9999
10991	2011	1	29	-9999
10992	2011	1	30	0
10993	2011	1	31	0
10994				

Line -1: #station={station name}
-2: #undef={undefined value}
-3: #elname={temperature or precipitation}
-4: #lon={longitude of the observation point}
-5: #lat={latitude of the observation point}

1 January 1981 to 31 January 2011

After line-6: observation data

{Year}, {Month}, {Day}, {Observational value}

Embedded undefined value in case of missing data

Workflow of the guidance tool

1. (Preparation)
   1. Create the past observation file (csv format)

Input of the guidance tool
(We have already prepared.)

2. (using EXCEL file and iTacs)
   1. Check the initial date and target period
   2. Production of guidance and verification
      - (1) Get past observation data
      - (2) Get hindcast data
      - (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

2.1. Specification of initial date and target period

Note:
The initial time and the forecast target period are different between verification of guidance by hindcast and real-time forecast, because operation procedures of NWP model are different between real-time and hindcast.

	Hindcast	Real-time forecast
Initial date	10th, 20th and the end of month (10 Jan, 20 Jan, 31 Jan, 10 Feb, …, 31 Dec)	Every Wednesday

2.1. Specification of initial date and target period

Example

	Hindcast		Real-time forecast
1	**31 Jul**	←	29 Jul
2	~~20 Dec~~ **30 Dec**	←	25 Dec

1. Basically, the initial date for hindcast is the nearest to that for real-time forecast.
2. When the initial date for real-time forecast is just middle of the hindcast initial dates, later date is referred.

	Hindcast	Real-time forecast
Initial time	31 Jul. 2015	29 Jul. 2015
Target period	3 Aug. to 1 Sep. 2015	1 to 30 Aug. 2015

+2day

Target period for hindcast are shifted from those for real-time forecast according to the difference of initial date.

Workflow of the guidance tool

1. (Preparation)
   1. Create the past observation file (csv format)

Input of the guidance tool
(We have already prepared.)

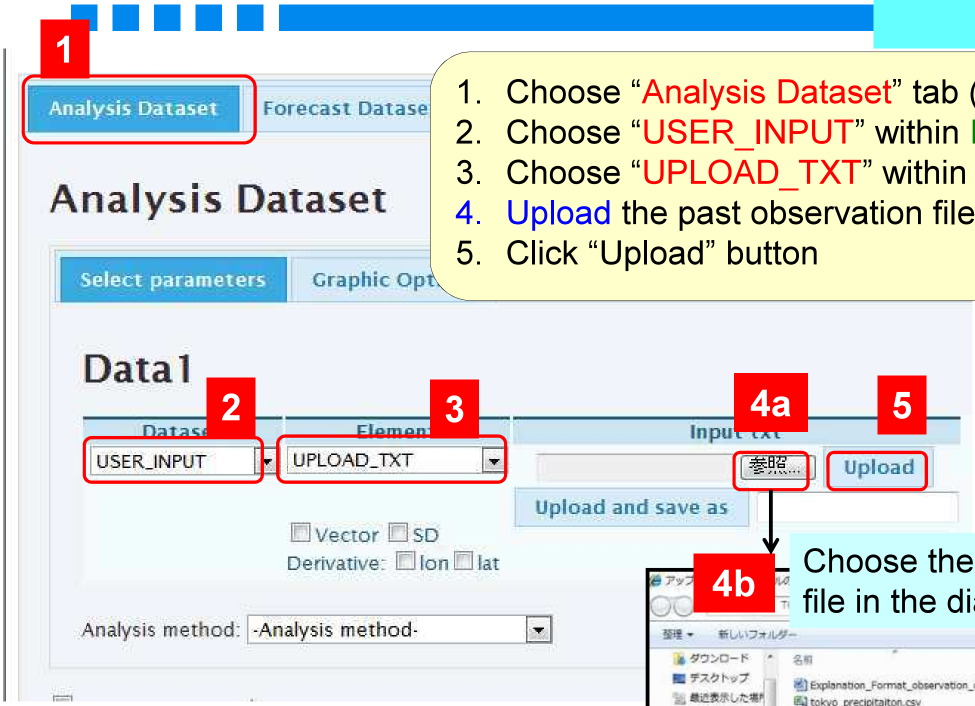
2. (using EXCEL file and iTacs)
   1. Check the initial date and target period
   2. Production of guidance and verification
      - (1) Get past observation data
      - (2) Get hindcast data
      - (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

2.2 Input past observation data
(1) Get past observation data (1 of 5)

iTacs

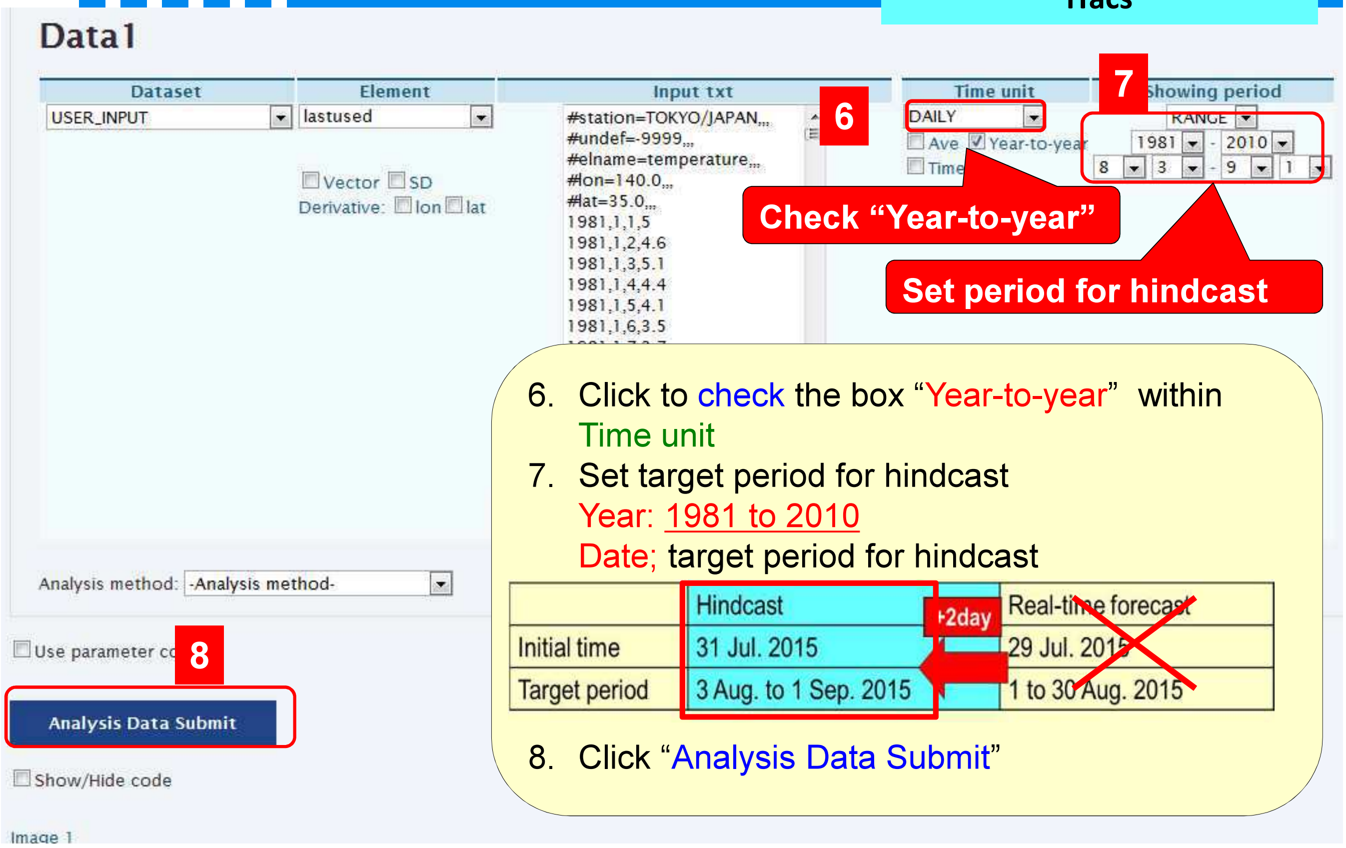
1. Choose "Analysis Dataset" tab (default tab)
2. Choose "USER_INPUT" within Dataset for Data1
3. Choose "UPLOAD_TXT" within Element for Data1
4. Upload the past observation file created by users
5. Click "Upload" button



Choose the past observation file in the dialog box

2.2 Input past observation data
(1) Get past observation data (2 of 5)

iTacs



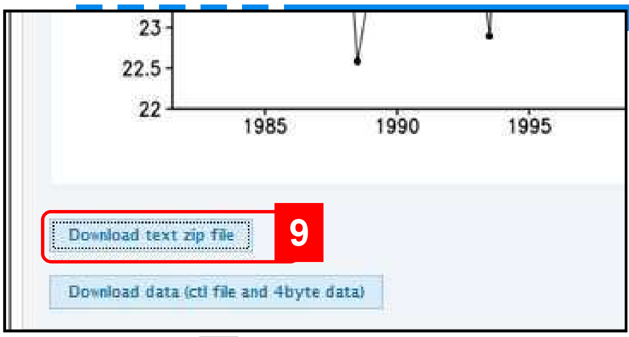
6. Click to check the box "Year-to-year" within Time unit
7. Set target period for hindcast
   Year: 1981 to 2010
   Date; target period for hindcast

	Hindcast		Real-time forecast
Initial time	31 Jul. 2015	+2day	29 Jul. 2015
Target period	3 Aug. to 1 Sep. 2015		1 to 30 Aug. 2015

8. Click "Analysis Data Submit"

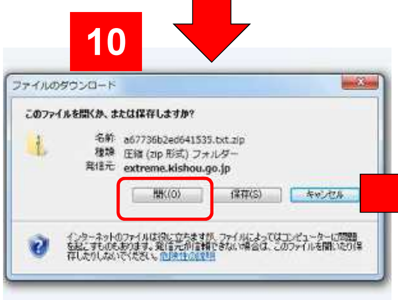
2.2 Input past observation data
(1) Get past observation data (3 of 5)

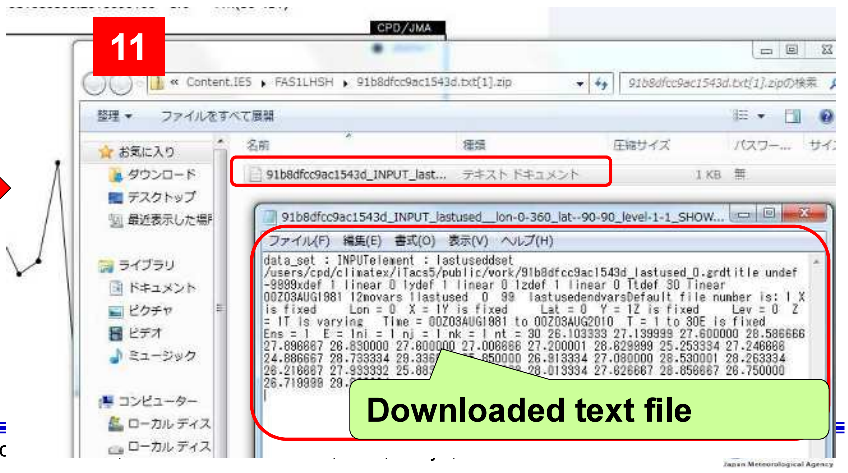
iTacs



(After "Analysis Data Submit", time sequence graph is displayed.)

9.Click "Download text zip file" below the graph
10. Download the text file
11. Open the downloaded text file





2.2 Input past observation data
(1) Get past observation data (4 of 5)

Downloaded text file

91b8dfcc9ac1543d_INPUT_lastused__lon-0-360_lat--90-90_level-1-1_SHOW...

ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)

```
Data_set : INPUTelement : lastuseddset
/users/cpd/climatex/iTacs5/public/work/91b8dfcc9ac1543d_lastused_0.grdtitle undef
-9999xdef 1 linear 0 1ydef 1 linear 0 1zdef 1 linear 0 1tdef 30 linear
00Z03AUG1981 12movars 1lastused  0  99  lastusedendvarsDefault file number is: 1 X
is fixed     Lon = 0  X = 1Y is fixed     Lat = 0  Y = 1Z is fixed     Lev = 0  Z
= 1T is varying   Time = 00Z03AUG1981 to 00Z03AUG2010  T = 1 to 30E is fixed
Ens = 1   E = 1ni = 1 nj = 1 nk = 1 nt = 30 26.103333 27.139999 27.600000 28.586666
27.896667 26.830000 27.600000 27.006666 27.200001 28.629999 25.253334 27.246666
24.886667 28.733334 29.336666 25.850000 26.913334 27.080000 28.530001 28.263334
26.216667 27.933332 25.883333 27.143333 28.013334 27.626667 28.856667 26.750000
26.719999 29.663334
```

Time sequence data is described atfer “nt = **”.

2.2 Input past observation data
(1) Get past observation data (5 of 5)

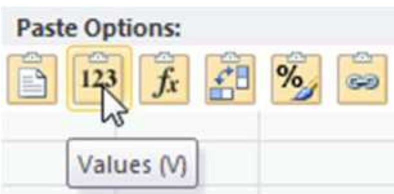
Worksheet “Calc_guidance”

91b8dfcc9ac1543d_INPUT_lastused__lon-0-360_lat--90-90_level-1-1_SHOW...

ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)

```
Data_set : INPUTelement : lastuseddset
/users/cpd/climatex/iTacs5/public/work/91b8dfcc9ac1543d_lastused_0.grdtitle undef
-9999xdef 1 linear 0 1ydef 1 linear 0 1zdef 1 linear 0 1tdef 30 linear
00Z03AUG1981 12movars 1lastused  0  99  lastusedendvarsDefault file number is: 1 X
is fixed     Lon = 0  X = 1Y is fixed     Lat = 0  Y = 1Z is fixed     Lev = 0  Z
= 1T is varying   Time = 00Z03AUG1981 to 00Z03AUG2010  T = 1 to 30E is fixed
Ens = 1   E = 1ni = 1 nj = 1 nk = 1 nt = 30 26.103333 27.139999 27.600000 28.586666
27.896667 26.830000 27.600000 27.006666 27.200001 28.629999 25.253334 27.246666
24.886667 28.733334 29.336666 25.850000 26.913334 27.080000 28.530001 28.263334
26.216667 27.933332 25.883333 27.143333 28.013334 27.626667 28.856667 26.750000
26.719999 29.663334
```


12. Copy and paste with the paste values option to the Excel file



12

Year	Temperature	Rank	Predictor 1	Predictor 2
	(Set blank for missing)			
	26.103333	26		
1982	27.139999	18		
1983	27.6	13		
1984	28.586666	6		
1985	27.896667	11		
1986	26.83	22		
1987	27.6	13		
1988	27.006666	20		
1989	27.200001	16		
1990	28.629999	5		
1991	25.253334	29		
1992	27.246666	15		
1993	24.886667	30		
1994	28.733334	4		
1995	29.336666	2		
1996	25.85	28		
1997	26.913334	21		
1998	27.08	19		
1999	28.530001	7		
2000	28.263334	8		
2001	26.216667	25		
2002	27.933332	10		
2003	25.883333	27		
2004	27.143333	17		
2005	28.013334	9		
2006	27.626667	12		
2007	28.856667	3		
2008	26.75	23		
2009	26.719999	24		
2010	29.663334	1		
This year				

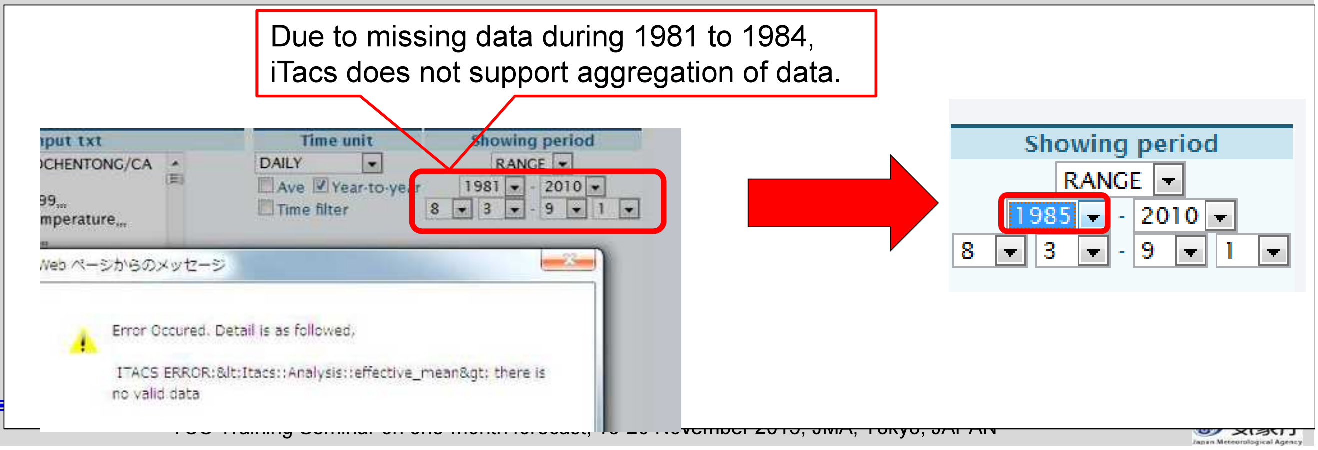
(Ctrl)

(Note) In case of continuous missing data in the past observation file

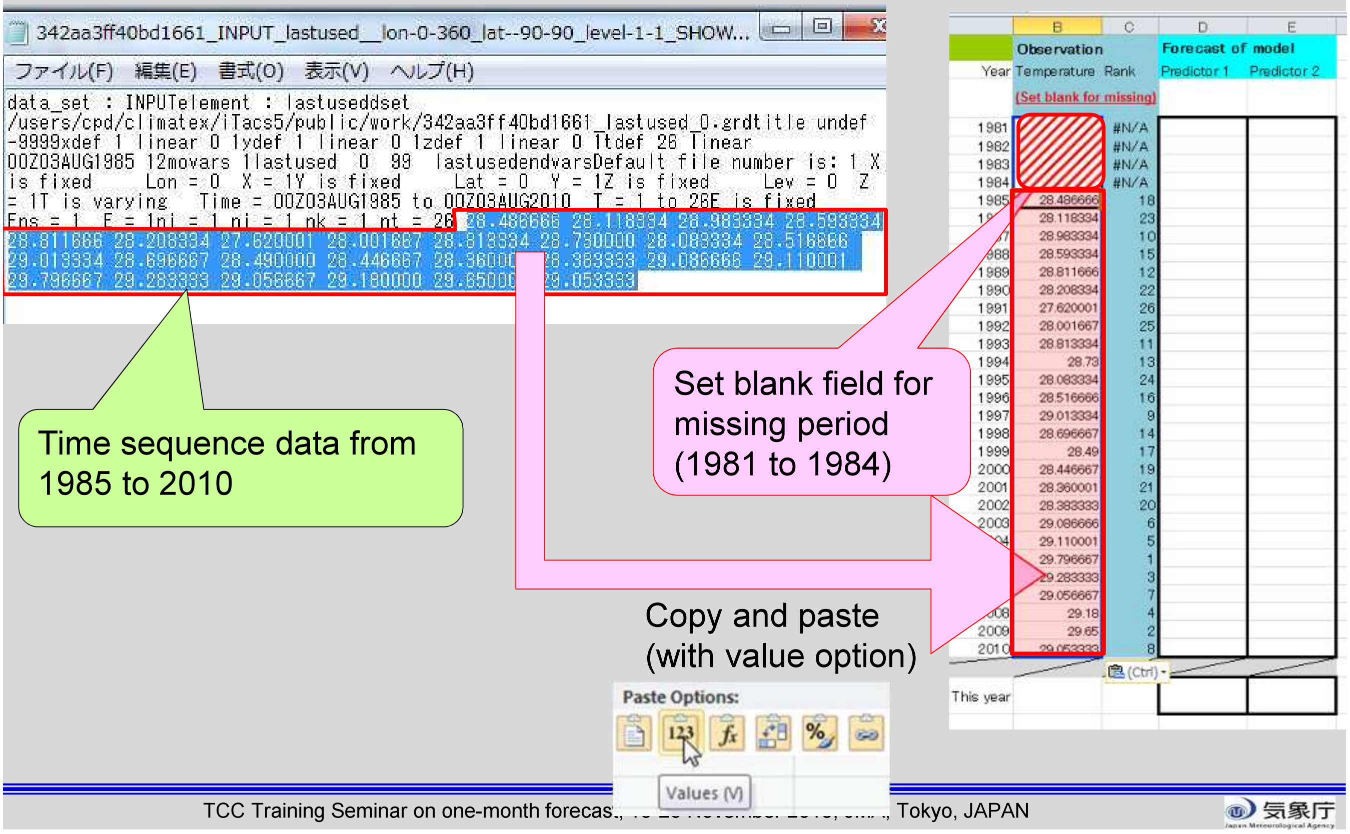
- If observation data for whole target period is missing, it is impossible to aggregate on iTacs.
  - ➢ If so, target year (i.e. "Showing period") should be set with the exception of missing-data year.

(Example)

✓ Including missing data during 1981 to 1984;
  - ➢ Aggregate 1985 to 2010



(Note) In case of continuous missing data in the past observation file



Workflow of the guidance tool

1. (Preparation)
   1. Create the past observation file (csv format)

   Input of the guidance tool
   (We have already prepared.)

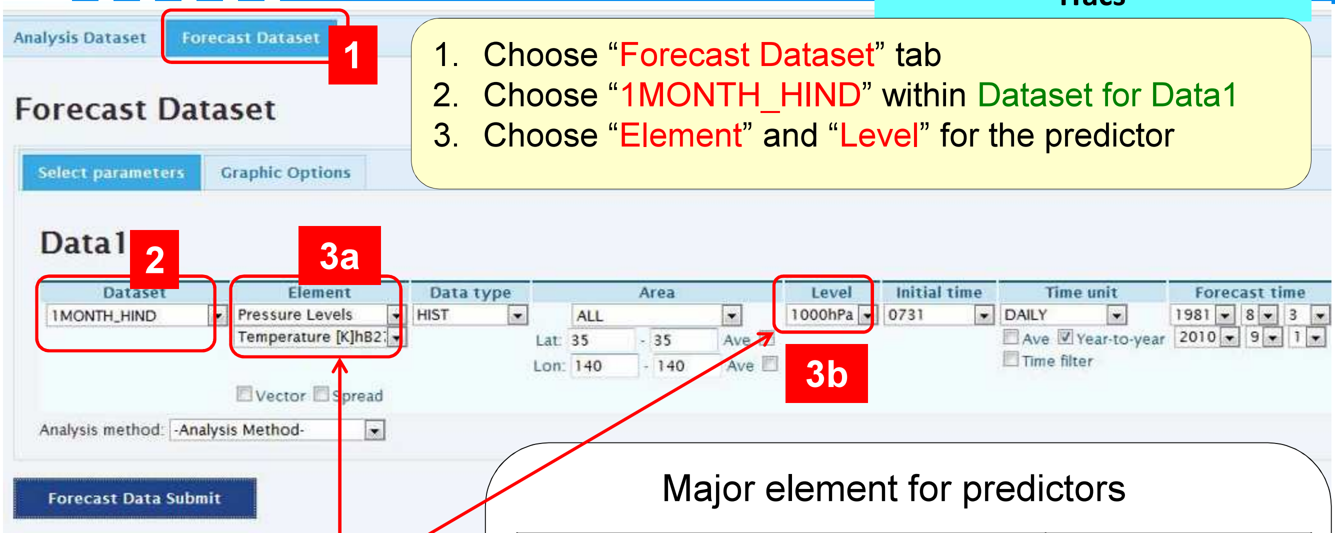
2. (using EXCEL file and iTacs)
   1. Check the initial date and target period
   2. Production of guidance and verification
      - (1) Get past observation data
      - (2) Get hindcast data
      - (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

2.2 Input past observation data
(2) Get hindcast data (1 of 5)

iTacs

1. Choose "Forecast Dataset" tab
2. Choose "1MONTH_HIND" within Dataset for Data1
3. Choose "Element" and "Level" for the predictor



Ex. 1000hPa temp.

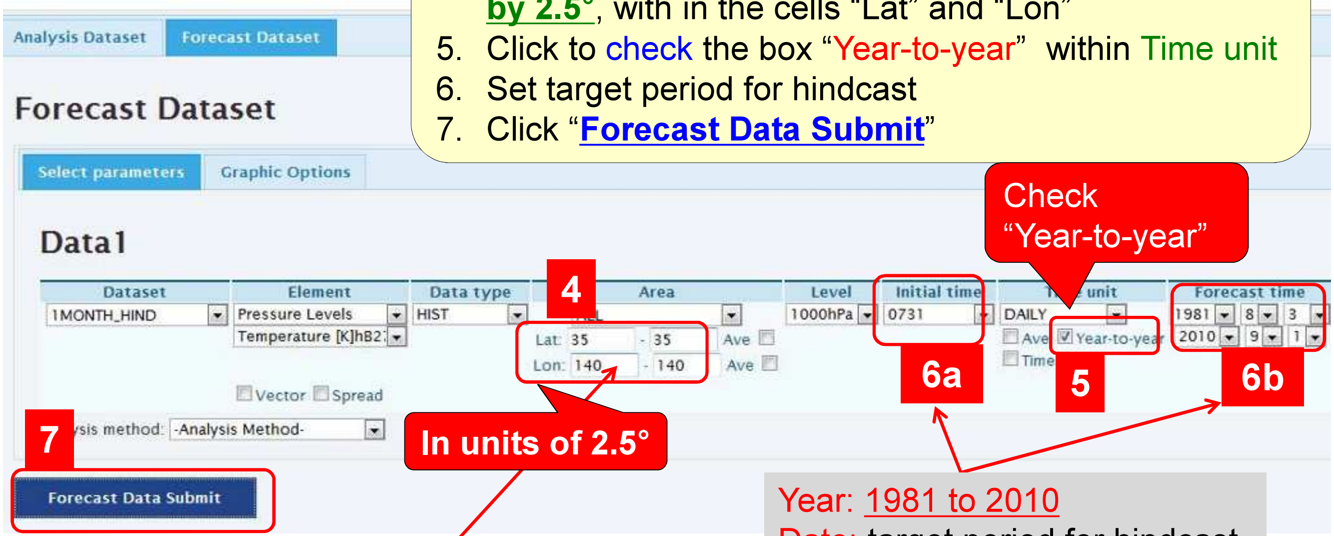
Major element for predictors

Isobatic (pressure levels) (1000,850,700,500,… hPa)	Surface
Temperature Dew-point depression (=T-Td) Wind (U or V) Geopotential height	Temperature Rain

2.2 Input past observation data
(2) Get hindcast data (2 of 5)

iTacs

4. Input the nearest grid point from the observation site **by 2.5°**, with in the cells “Lat” and “Lon”
5. Click to check the box “Year-to-year” within Time unit
6. Set target period for hindcast
7. Click “**Forecast Data Submit**”



Year: 1981 to 2010
Date; target period for hindcast

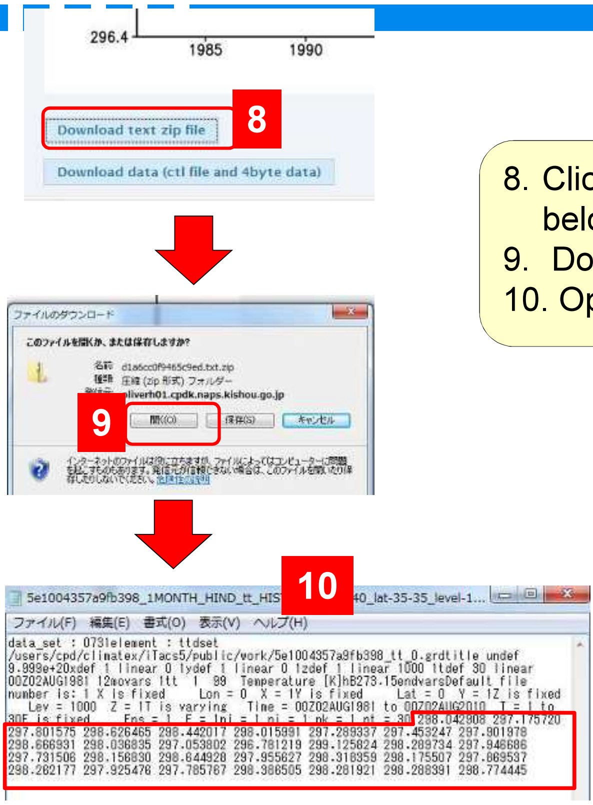
Ex.
Tokyo 35.7°N --> 35°N
139.8°E --> 140°E

	Hindcast	Real-time forecast
Initial time	31 Jul. 2015	29 Jul. 2015
Target period	3 Aug. to 1 Sep. 2015	1 to 30 Aug. 2015

+2day

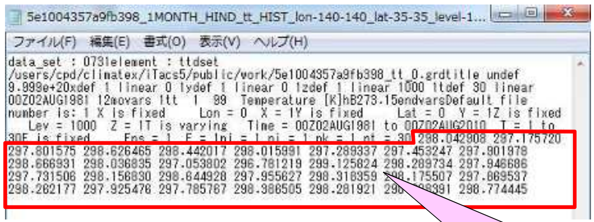
2.2 Input past observation data
(2) Get hindcast data (3 of 5)

iTacs



8. Click “Download text zip file” below the graph
9. Download the text file
10. Open the downloaded text file

2.2 Input past observation data
(2) Get hindcast data (4 of 5)

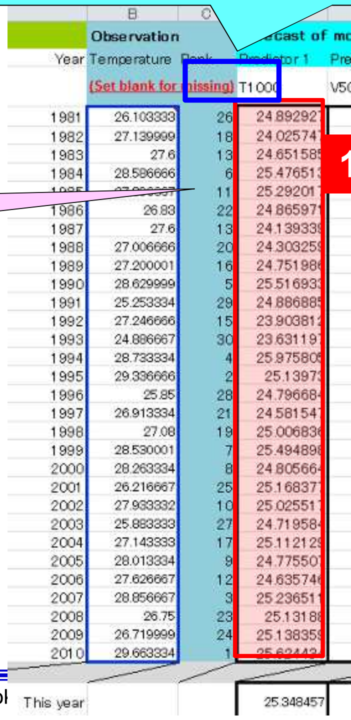



```
data_set : 0731element : ttdset
/users/cpd/climatex/iTacs5/public/work/5e1004357a9fb398_tt_0.grdtitle undef
9.999e+20xdef 1 linear 0 1ydef 1 linear 0 1zdef 1 linear 1000 1tdef 30 linear
00Z02AUG1981 12movars 1tt  1  99  Temperature [K]hB273.15endvarsDefault file
number is: 1 X is fixed     Lon = 0  X = 1Y is fixed     Lat = 0  Y = 1Z is fixed
   Lev = 1000  Z = 1T is varying   Time = 00Z02AUG1981 to 00Z02AUG2010  T = 1 to
30E is fixed     Ens = 1  E = 1ni = 1 ni = 1 nk = 1 nt = 30 298.042908 297.175720
297.801575 298.626465 298.442017 298.015991 297.289337 297.453247 297.901978
298.666931 298.036835 297.053802 296.781219 299.125824 298.289734 297.946686
297.731506 298.156830 298.644928 297.955627 298.318359 298.175507 297.869537
298.262177 297.925476 297.785767 298.386505 298.281921 298.?98391 298.774445
```

Copy and paste with paste values option

Worksheet "Calc_guidance"

(Recommendation)
The element name should be memorized

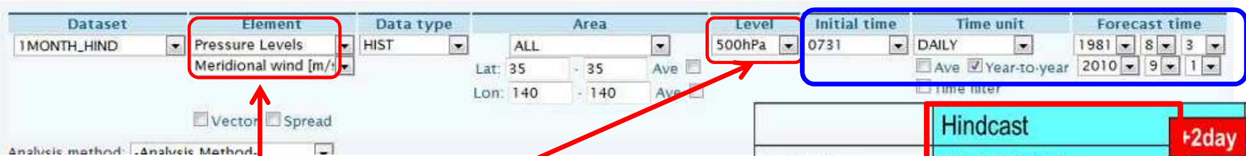


	B	C		
	Observation		...ecast of mo...	
Year	Temperature	Rank	Predictor 1	Pre...
	(Set blank for missing)		T1000	V50...
1981	26.103333	26	24.89292...	
1982	27.139999	18	24.02574...	
1983	27.6	13	24.65158...	
1984	28.586666	6	25.47651...	
1985	[illegible]	11	25.29201...	
1986	26.83	22	24.86597...	
1987	27.6	13	24.13933...	
1988	27.006666	20	24.30325...	
1989	27.200001	16	24.75198...	
1990	28.629999	5	25.51693...	
1991	25.253334	29	24.88688...	
1992	27.246666	15	23.90381...	
1993	24.886667	30	23.63119...	
1994	28.733334	4	25.97580...	
1995	29.336666	2	25.13973...	
1996	25.85	28	24.79668...	
1997	26.913334	21	24.58154...	
1998	27.08	19	25.00683...	
1999	28.530001	7	25.49489...	
2000	28.263334	8	24.80566...	
2001	26.216667	25	25.16837...	
2002	27.933332	10	25.02551...	
2003	25.883333	27	24.71958...	
2004	27.143333	17	25.11212...	
2005	28.013334	9	24.77550...	
2006	27.626667	12	24.63574...	
2007	28.856667	3	25.23651...	
2008	26.75	23	25.1318...	
2009	26.719999	24	25.13835...	
2010	29.663334	1	25.6244...	
This year			25.348457	

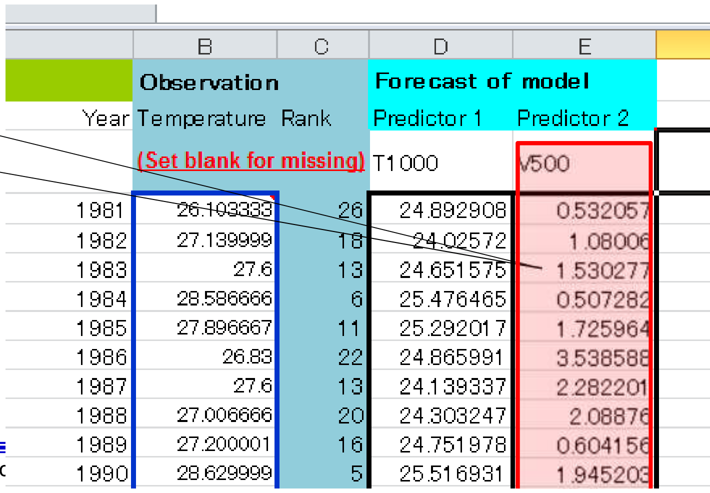
11. Copy and paste with the paste values option to the Predictor (1 or 2) field in the Excel file

2.2 Input past observation data
(2) Get hindcast data (5 of 5)

- Select the second predictors and paste the hindcast data



In this example, "Meridional wind at 500hPa" is selected as the second element.



	B	C	D	E
	Observation		Forecast of model	
Year	Temperature	Rank	Predictor 1	Predictor 2
	(Set blank for missing)		T1000	V500
1981	26.103333	26	24.892908	0.532057
1982	27.139999	18	24.02572	1.08006
1983	27.6	13	24.651575	1.530277
1984	28.586666	6	25.476465	0.507282
1985	27.896667	11	25.292017	1.725964
1986	26.83	22	24.865991	3.538588
1987	27.6	13	24.139337	2.282201
1988	27.006666	20	24.303247	2.08876
1989	27.200001	16	24.751978	0.604156
1990	28.629999	5	25.516931	1.945203

Workflow of the guidance tool

1. (Preparation)
   1. Create the past observation file (csv format)

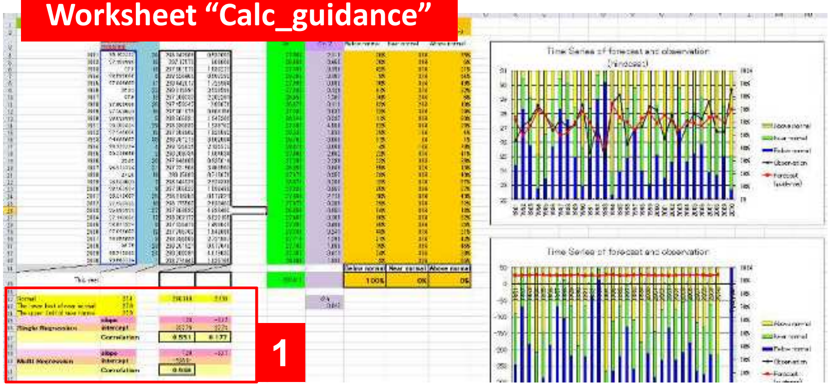
Input of the guidance tool
(We have already prepared.)

2. (using EXCEL file and iTacs)
   1. Check the initial date and target period
   2. Production of guidance and verification
      - (1) Get past observation data
      - (2) Get hindcast data
      - (3) Confirmation of prediction skill of guidance
   3. Application to the real-time forecast
      - Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

2.2 Input past observation data
(3) Confirmation of prediction skill of guidance (1 of 3)

Worksheet “Calc_guidance”



1. Check up correlation

✓ Whether the correlation score of multi-regression better than that of single-regression?

Normal		27.4	298.040	2.036
The lower limit of near normal		27.0		
The upper limit of near normal		27.9		
	slope		1.23	-0.17
Single Regression	intercept		-337.76	27.74
	Correlation		0.551	0.177
	slope		1.20	-0.11
Multi Regression	intercept		-308.01	
	Correlation		0.563	

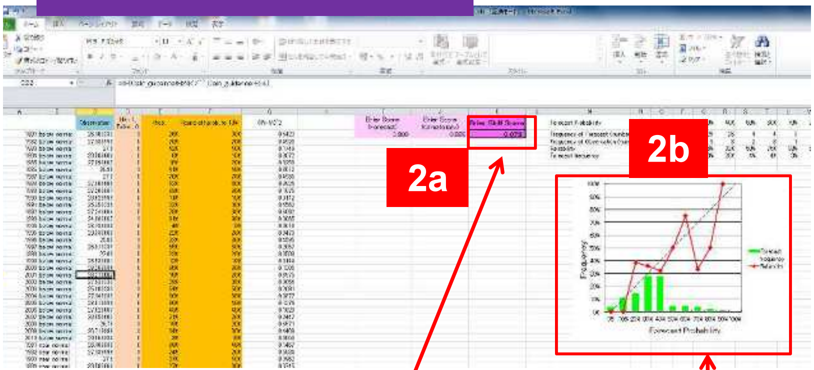
Correlation with the single- regression (predictor-1,-2, respectively)

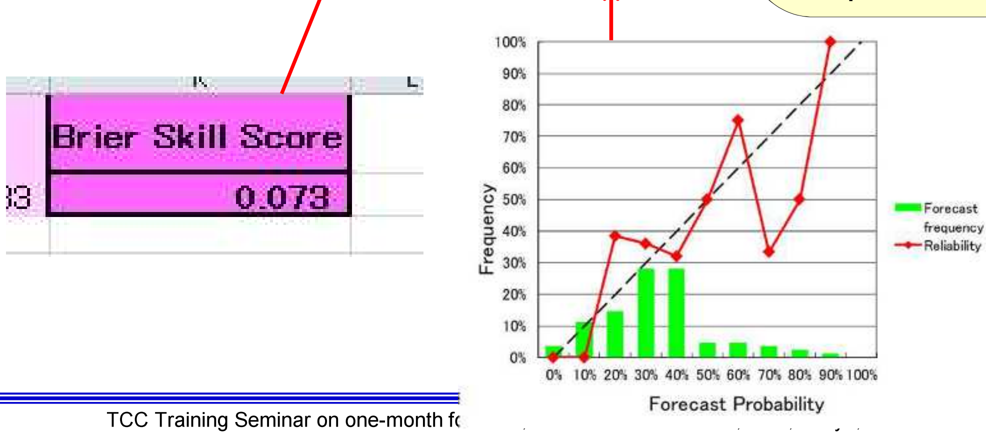
∧ (preferable)

Correlation of guidance (multi-regression)

2.2 Input past observation data
(3) Confirmation of prediction skill of guidance (2 of 3)

Worksheet "Verification"





2. Check up probabilistic verification

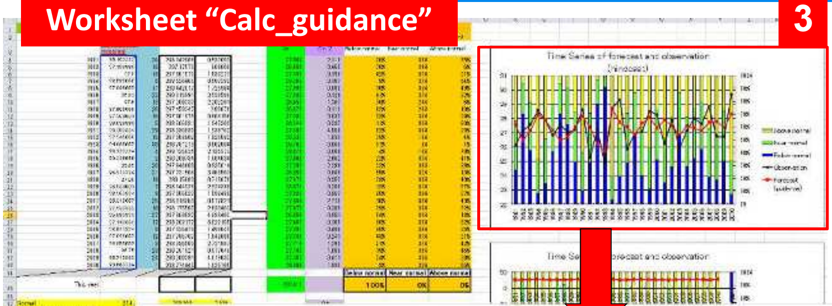
(2a) BSS (preferable >0)

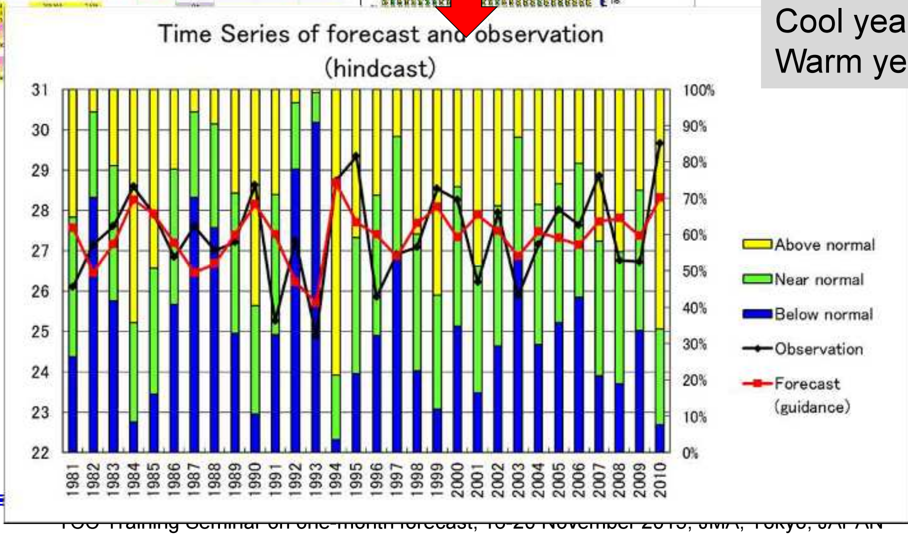
(2b) reliability diagram

✓ Whether the reliability curve has a positive slope?

2.2 Input past observation data
(3) Confirmation of prediction skill of guidance (3 of 3)

Worksheet "Calc_guidance"





3. Check up prediction result for the noticeable year

Example;
Cool year; 1991, 1993
Warm year; 1985, 2010

An example

Prediction skill of guidance

Objective variable	Temperature
Predictors	1000 hPa temperature 850hPa meridional wind
Correlation	0.563
Brier Skill Score	0.073

- Check up the skill of guidance selected two elements (predictors)
- Look for the more effective combination of variables

Hint; Recommended combination of predictors

◆(Forecast of temperature)

– One predictor is selected among **temperature**
  - Lower troposphere temperature (1000, 850 hPa) or surface temperature
  - As for the island point, to avoid surface temp. might be better (i.e. using 850hPa temp.).

– Another predictor is selected except for temperature, such as **wind, TTD**.
  - ✓In statistics, if two or more predictor variables in a multiple-regression are remarkably correlated, reliability of regression analysis become poor (multicollinearity).

Example;
(o) T1000 and V850, (x) T1000 and Tsurface

Hint; Recommended combination of predictors

◆(Forecast of precipitation)

– One predictor is selected **precipitation**

– Another predictor is selected depending on regionality

Example;
•Temperature or geopotential height in consideration of temperature-precipitation correlation
•Lower wind (U or V) in consideration of terrain condition

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(1) Get past observation data
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(3) Confirmation of prediction skill of guidance

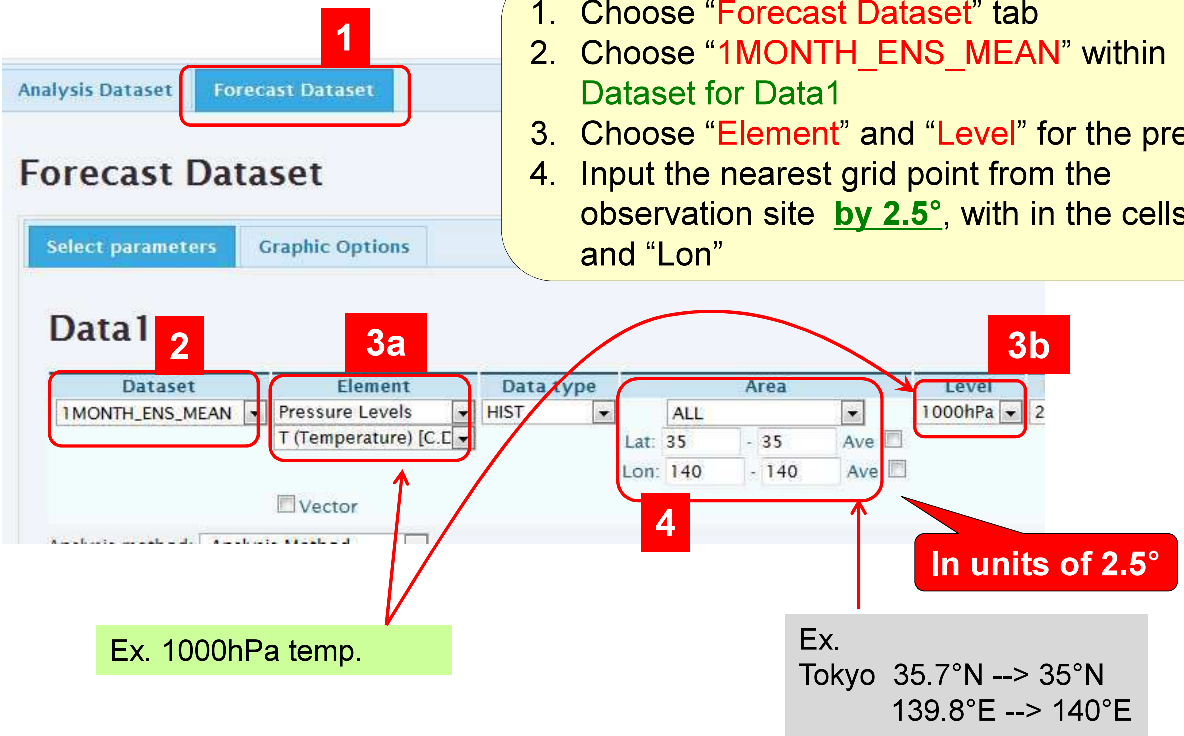
   3. Application to the real-time forecast
      • Input of real-time forecast of model

      Obtaining solution of probabilistic forecast by the guidance

3 Application to the real-time forecast (1 of 5)

iTacs

1. Choose "Forecast Dataset" tab
2. Choose "1MONTH_ENS_MEAN" within Dataset for Data1
3. Choose "Element" and "Level" for the predictor
4. Input the nearest grid point from the observation site <u>**by 2.5°**</u>, with in the cells "Lat" and "Lon"



3 Application to the real-time forecast (2 of 5)

iTacs

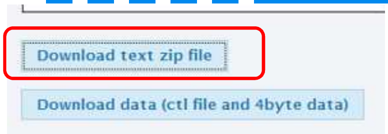
5. Click to check the box "Ave" within Time unit
6. Set target period for forecast
7. Click "<u>**Forecast Data Submit**</u>"

	Hindcast	Real-time forecast
Initial time	31 Jul. 2015	29 Jul. 2015
Target period	3 Aug. to 1 Sep. 2015	1 to 30 Aug. 2015

+2day

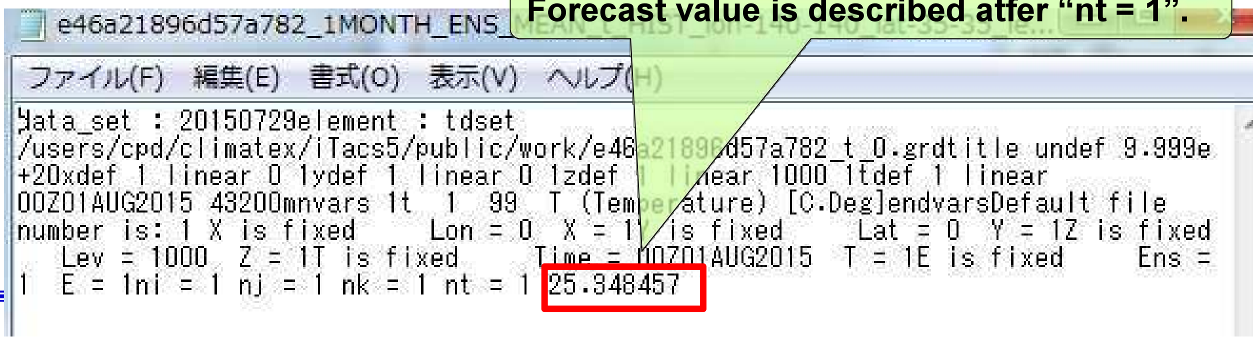
3 Application to the real-time forecast (3 of 5)

iTacs



8. Click "Download text zip file"
9. Download the text file
10. Open the downloaded text file

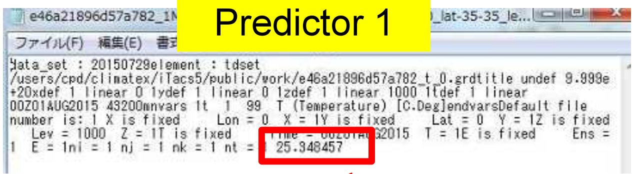
Forecast value is described atfer "nt = 1".



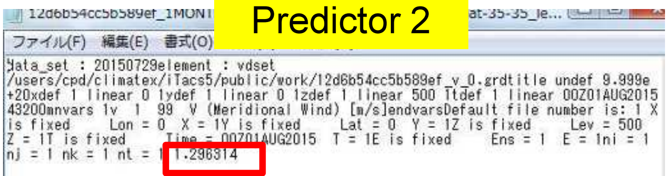
3 Application to the real-time forecast (4 of 5)

Worksheet "Calc_guidance"

Predictor 1



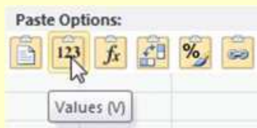
Predictor 2



1999	28.530001	7	25.494928	2.324338
2000	28.263334	8	24.805627	1.598438
2001	26.216667	25	25.168359	0.577821
2002	27.933332	10	25.025507	2.630462
2003	25.883333	27	24.719537	4.833402
2004	27.143333	17	25.112177	3.622155
2005	28.013334	9	24.775476	1.499049
2006	27.626667	12	24.635767	1.542086
2007	28.856667	3	25.236505	2.721867
2008	26.75	23	25.131921	0.977643
2009	26.719999	24	25.138391	4.819633
2010	29.663334	1	25.624445	1.626705
This year			25.348457	1.296314

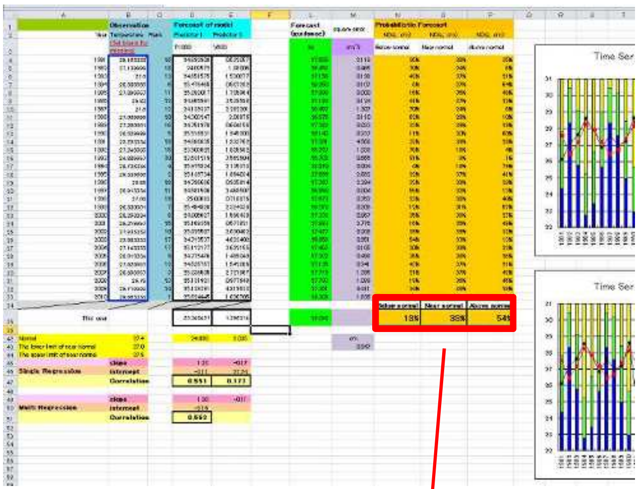
11a 11b

11. Copy and paste with the paste values option to the Predictor (1 or 2) field in the Excel file



3 Application to the real-time forecast (5 of 5)

Worksheet “Calc_guidance”



Below normal	Near normal	Above normal
13%	33%	54%

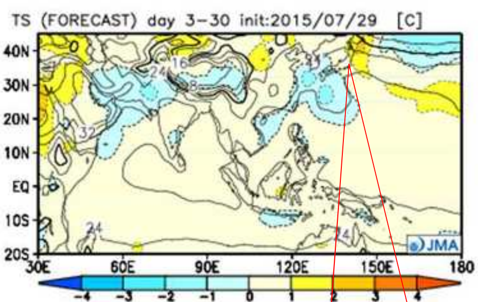
(Output)
Probabilities by guidance for real-time forecast

Confirmation of the output guidance

✓ In order to validate the output of guidance, it is recommended that guidance is compares with forecast of model.

◆Forecast map

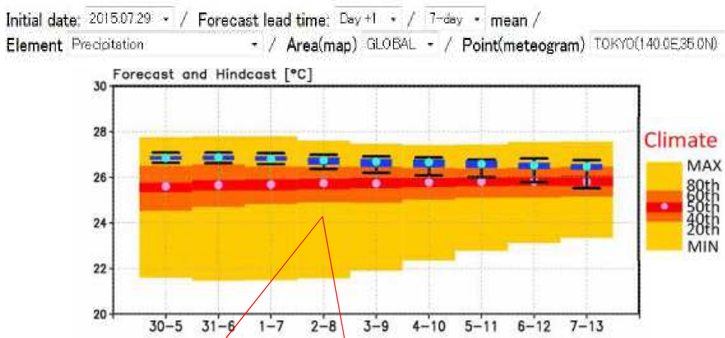
➢http://ds.data.jma.go.jp/gmd/tcc/tcc/products/model/index.html



Positive anomalies are predicted around Tokyo

◆Meteogram

➢http://ds.data.jma.go.jp/gmd/tcc/tcc/gpv/EFI/index.php



Although it covers the beginning of two weeks, extremely above normal temp. (more than 80 percentile) are predicted.