Prediction skill of the seasonal prediction model

- Cautions about interpretation of numerical prediction data

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The purpose of this lesson

- Difference between analysis and prediction
  - Analysis (Reanalysis);
    - True (Error is minim comparing with the model prediction.)
      - Of cause, strictly speaking, it includes analysis error.
    - Statistical relations among variables are “real”.
  - Prediction by model
    - need to take into account prediction skill.

- In this lesson, we will be consider cautions about interpretation of model data.

•Real-time predictions
•Hindcast datasets

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- Uncertainty of prediction and concept of the ensemble prediction system (EPS)
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  - replace EPS system for seasonal prediction in February 2010.
    - (AGCM --> CGCM)

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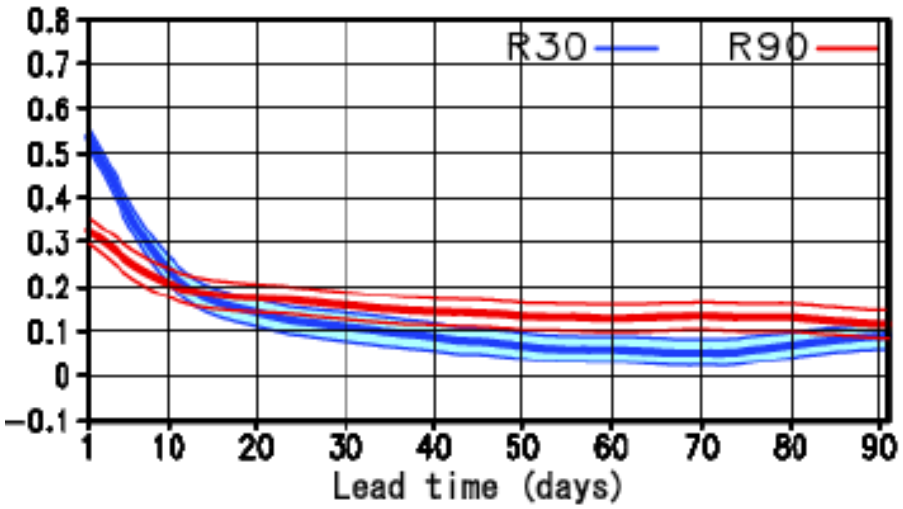
Lead time dependency of the prediction skill

As lead time increases, prediction skill decreases.

Anomaly Correlation of Z500 in NH (20N-90N)



30 days averaged prediction

90 days averaged prediction

- Initial date; every months from 1984 to 2005
- 5% significant levels are also shown.

Uncertainty of prediction

- Causes of prediction error
  - Uncertainty of an initial condition
    - limitation of observation data (especially in ocean)
    - observation error
    - Errors in the objective analysis procedure
  - Uncertainty of the boundary conditions

    (ex. SSTs for AGCM)
  - Uncertainty of an NWP model
    - certain limits of resolution
    - Many approximations in the physical processes (Parameterization)

- Considering with the prediction error, deterministic prediction fails if leadtime increases.

- Probabilistic prediction using ensemble prediction system (EPS)

Often-used technical terms on EPS

Member x^m Individual prediction in the EPS

Ensemble size m Number of the member

Control run x^0 prediction with non-perturbation

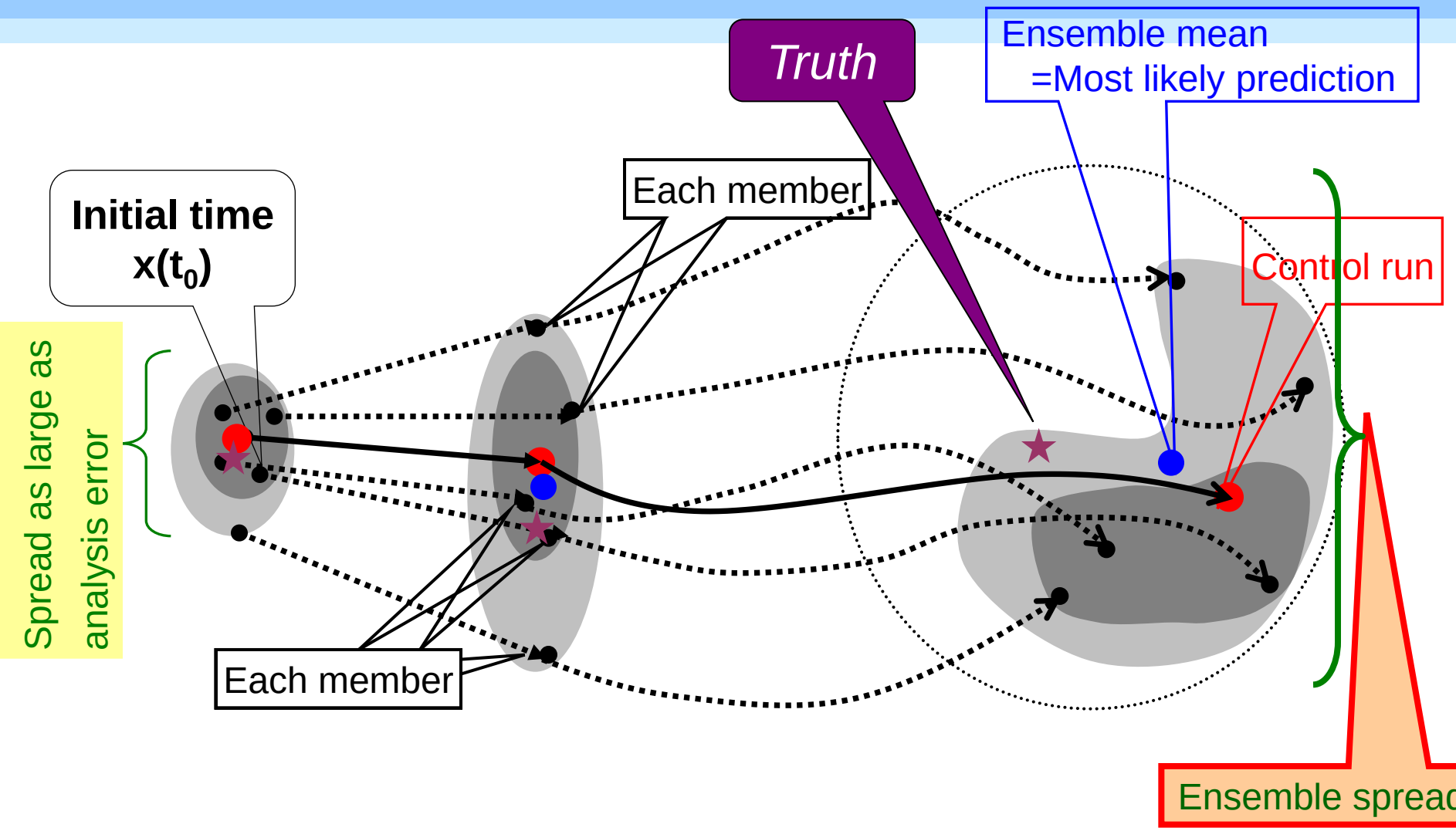
Ensemble mean $\bar{x}_i = \frac{1}{M}\sum_{i=1}^{m} x_i^m$ Average of the all member

(Most likely prediction)

(Ensemble) spread $\sqrt{\frac{1}{M}\sum_{i=1}^{m}\left(x_i^m - \bar{x}_i\right)^2}$ index of the variability among each member

(degree of Uncertainty)

Concept of ensemble prediction



(Ref.)
Ensemble mean and Ensemble spread

- Basics of the ensemble prediction statistics
  - Ensemble mean : average of the all member results
  - Ensemble spread :
    - corresponding to standard deviation in statistics
    - indicate variability of predictions

Spread:

$$s = \sqrt{\frac{1}{M}\sum_{i=1}^{m}\left(x_i^m - \overline{x}_i\right)^2}$$

X_i : predictions by each member,
$\overline{X}$: ensemble mean

((Hopefully)) comparable

RMSE of ensemble prediction

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

fi : predictions, ai : truths

- Idealized ensemble prediction system:
  (error of ensemble mean) = (ensemble spread)

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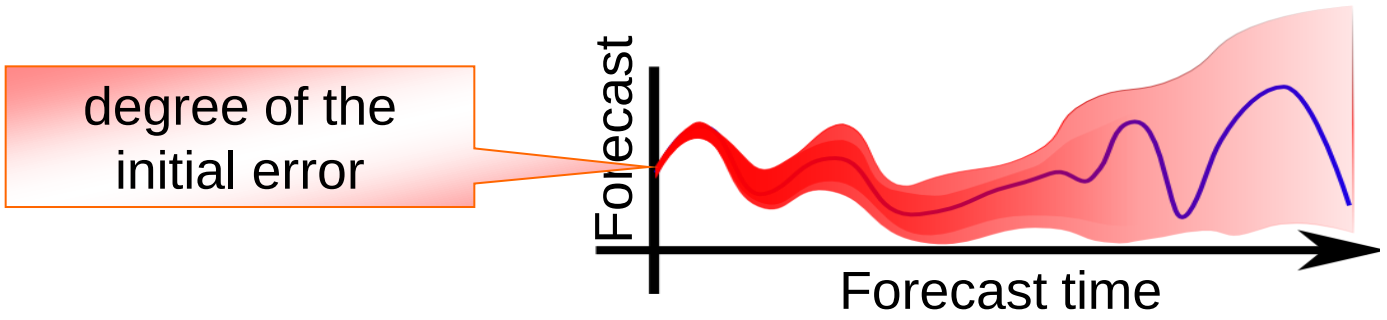
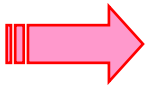
Grow of prediction error

Even if the prediction error amplifies,
it is possible to identify rough tendency.



Two kinds of Predictability

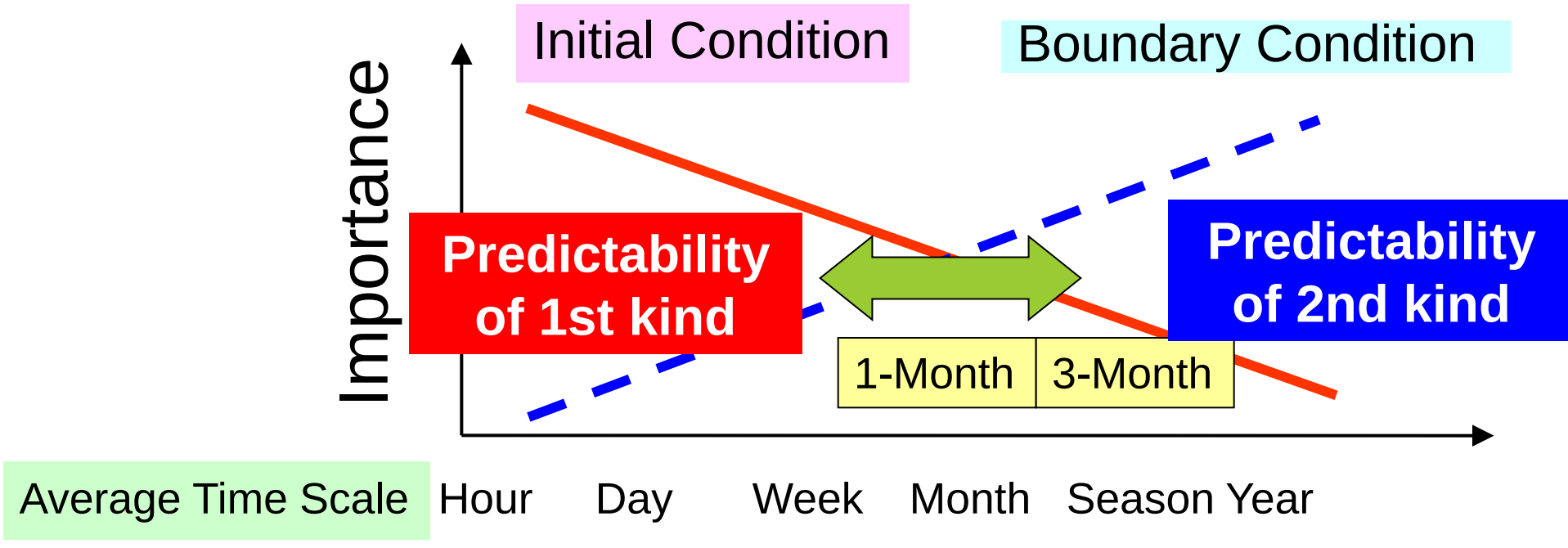
- Predictability of 1st kind
  - Originates from initial condition
    - Errors contained in the initial states rapidly grows in the beginning of the prediction due to chaotic behavior of atmosphere.
- Predictability of 2nd kind
  - Originates from lower boundary condition
  - Even long range prediction, “signals” associated with lower boundary condition, such as SSTs, remains.



Support of the seasonal prediction

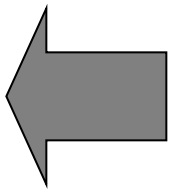
Relative importance of initial condition and boundary condition

- 1-month prediction; both initial and boundary condition are important.
- 3-month prediction; boundary condition is important



Lower boundary condition of atmosphere

- **Ocean**
  - Sea Surface Temperature (SST)
  - Sea Ice
- **Land Surface**
  - Soil Temperature
  - Soil Moisture
  - Snow Cover, Snow Depth
  - Vegetation (Grass, Tree etc.)



For AGCM,

SSTs are most important boundary condition.

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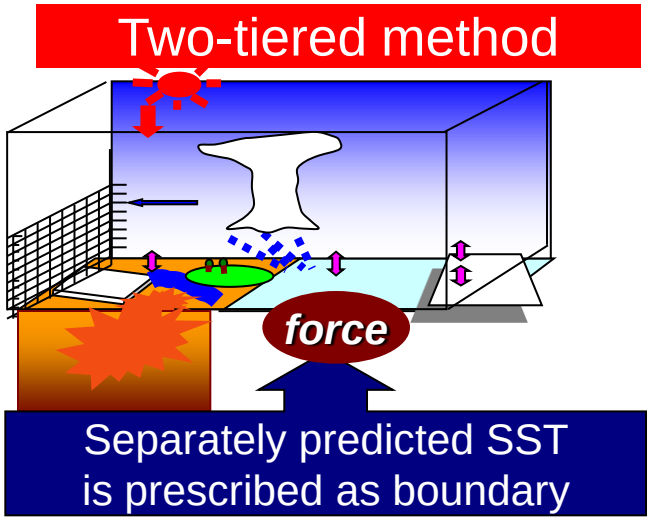
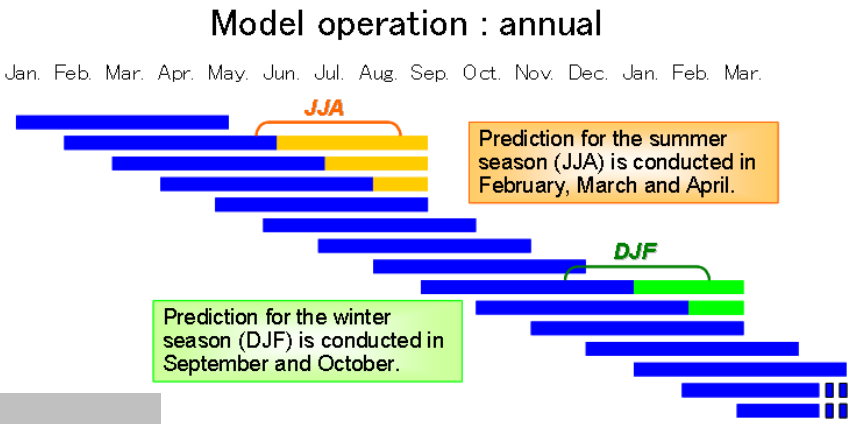
Outline of the JMA EPS for seasonal prediction

- **AGCM with two-tired method**
  - SSTs as boundary condition for AGCM is "prescribed" using persisted anomaly, climatology and ENSO prediction by CGCM.
- Specifications of the AGCM
  - resolution: horizontally 1.875 deg., vertically 40 levels
  - ensemble size: 51 members
  - frequency: once a month
  - prediction period: 4 to 7months

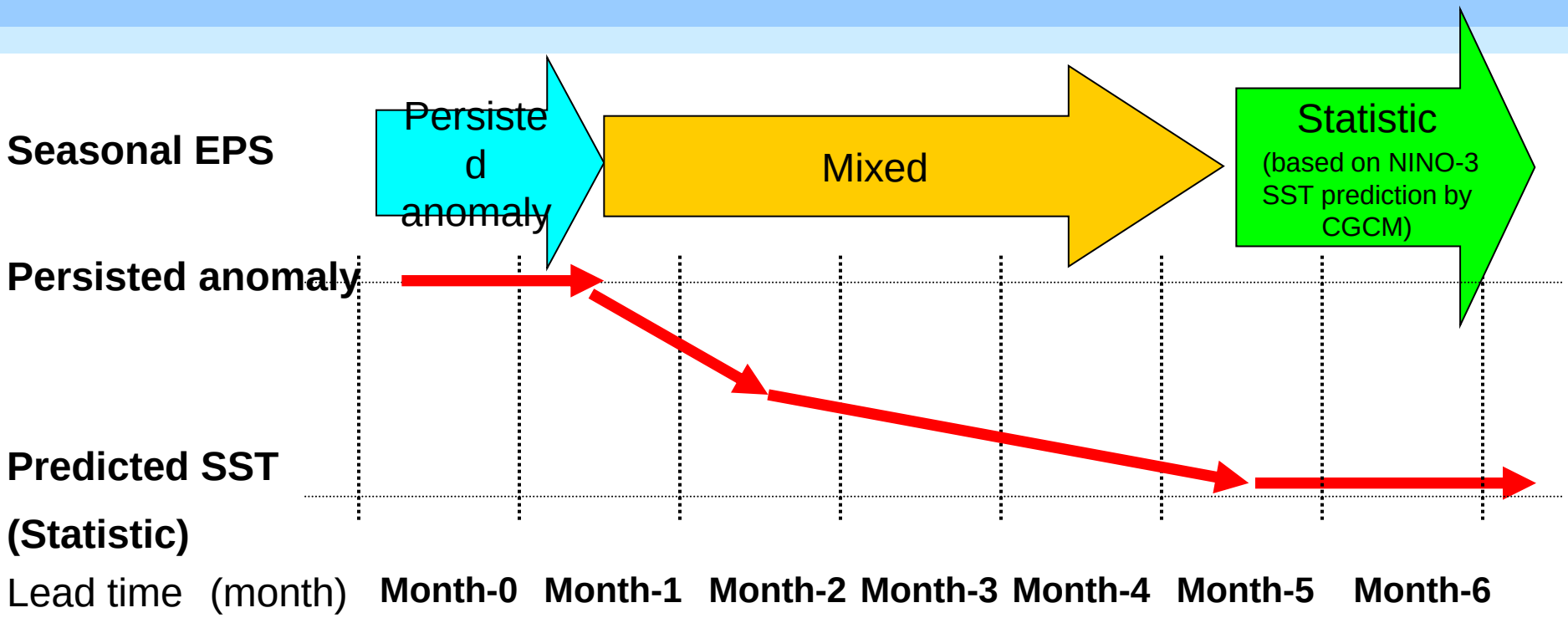




For details;

- http://ds.data.jma.go.jp/tcc/tcc/products/model/outline/index.html.
- http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline-nwp/index.htm

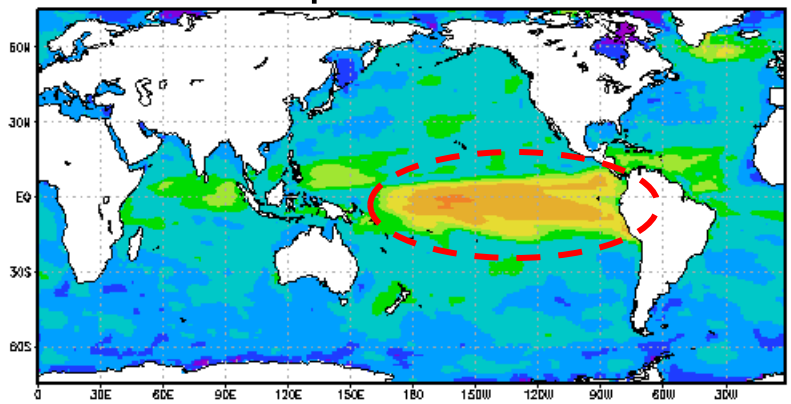
Prescribed SSTs for seasonal prediction model



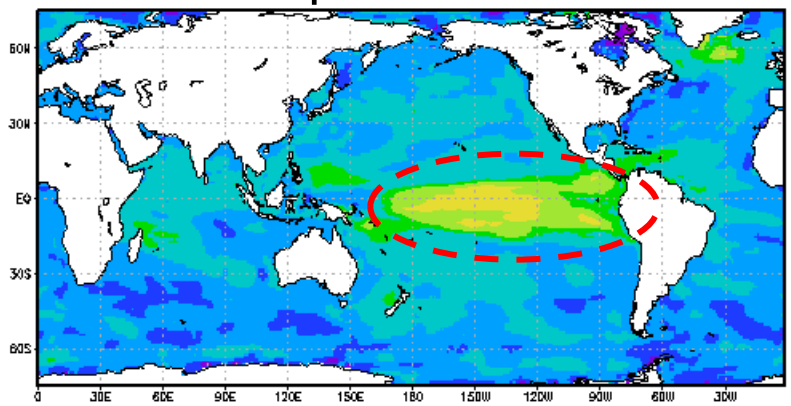
- Predicted SST
  - Persisted anomaly (for the beginning of prediction)
  - Statistical prediction:
    - regression upon NINO.3 SST outlook by CGCM
    - linear trend of 1971-2000

Anomaly correlation of SSTs in the JMA's CGCM

3-month prediction



6-month prediction



- Anomaly correlation is high in the central-eastern equatorial Pacific, in which El Niño /La Niña phenomena directly links.
- In the tropics, anomaly correlation relatively high comparing with high latitudes, in which atmospheric influence tends to dominated.

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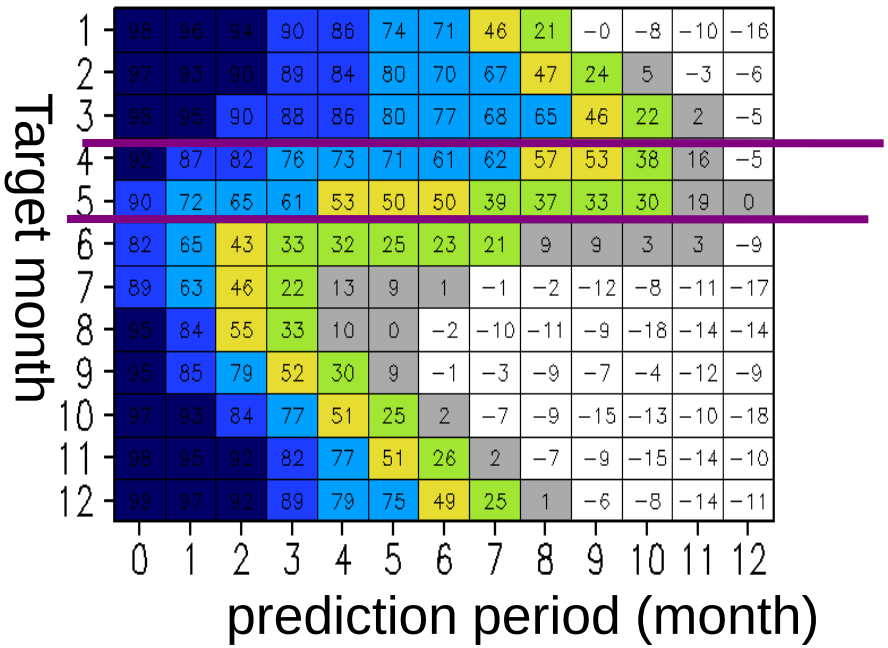
Anomaly Correlation of NINO.3.4 SST in the JMA's CGCM

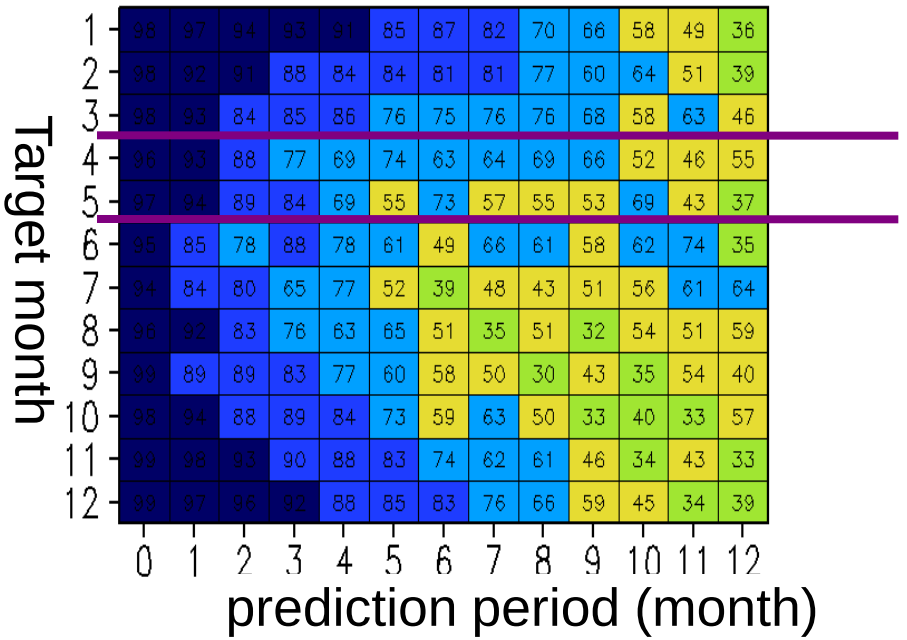
Prediction skill has target month dependency.

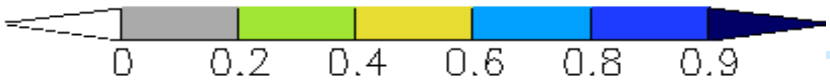
- Persistence barrier from spring to summer
- Anomaly correlation is small for model from spring to summer.
  = "**spring barrier**" ; common issues for all numerical model

Persisted anomaly



CGCM

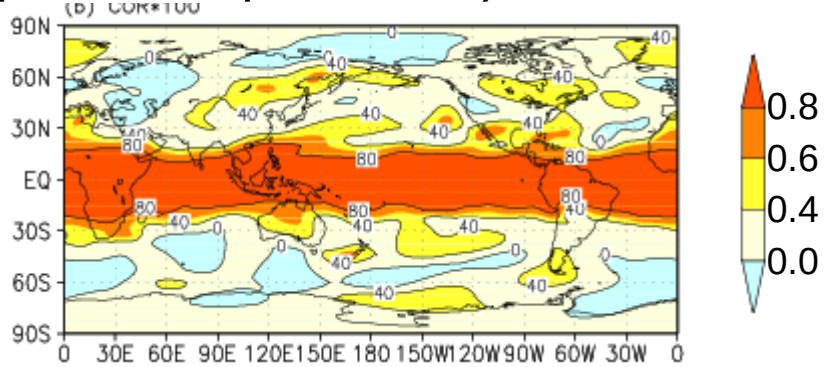




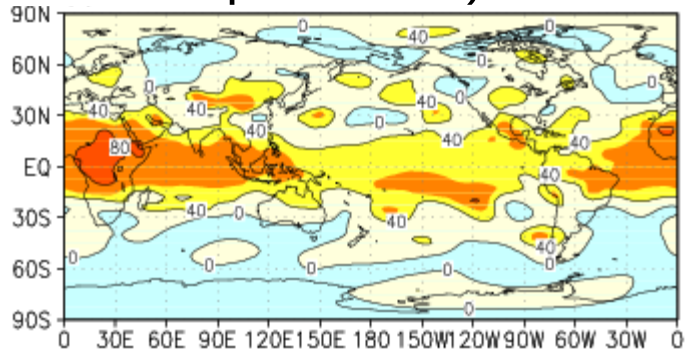
period: 1979～2007

Anomaly correlation of Z500 in the JMA EPS for seasonal prediction

MAM prediction (init. month of Feb.)
(prediction period 1-3)



JJA prediction (init. month of Feb.)
(prediction period 4-6)

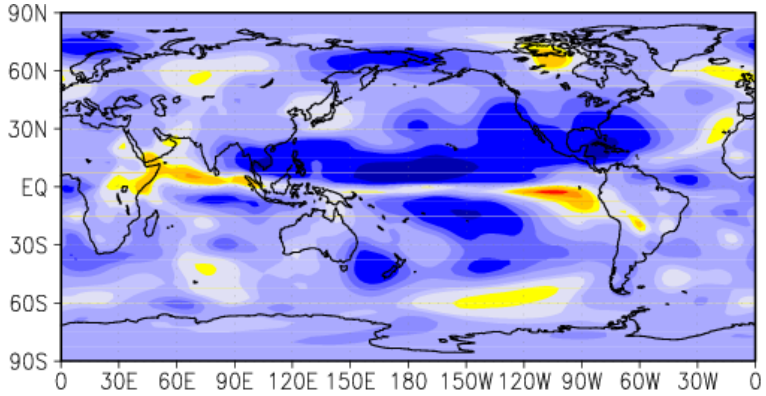


http://ds.data.jma.go.jp/tcc/tcc/products/model/index.html

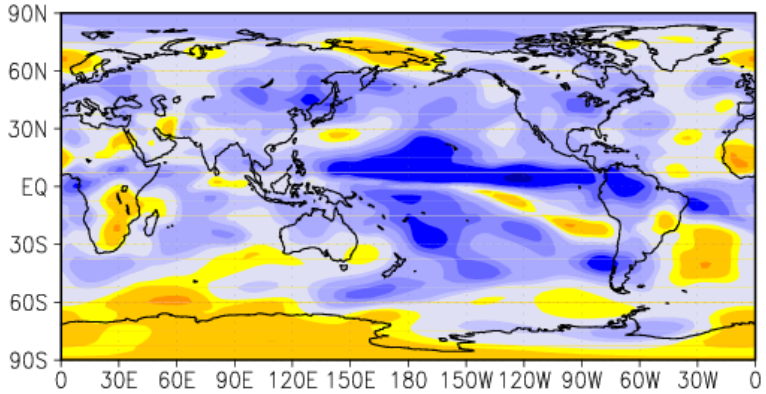
- Anomaly correlation is high in the tropics reflecting tropical ocean variability.
- In the mid-high latitudes, anomaly correlation is small due to dominant of the atmospheric internal variability.

Anomaly correlation of PSI850 (stream function of 850 hPa)

MAM prediction (init. month of Feb.)
(prediction period 1-3)



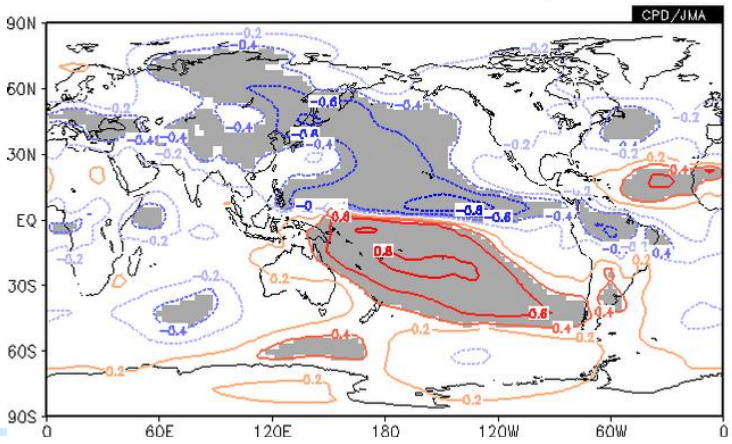
JJA prediction (init. month of Feb.)
(prediction period 4-6)



- Anomaly correlation is high in the tropical Pacific.

High correlation region is similar to the atmospheric response with ENSO.

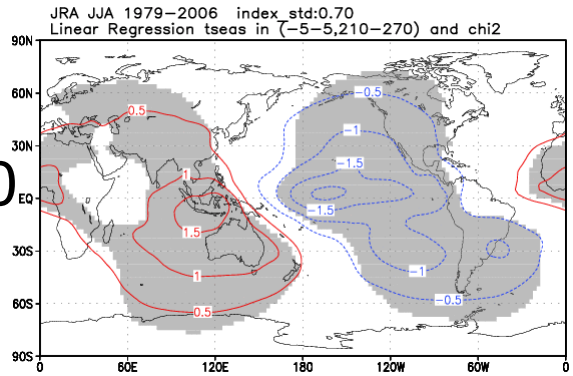
Correlation between PSI850 and NINO.3 SST in JJA

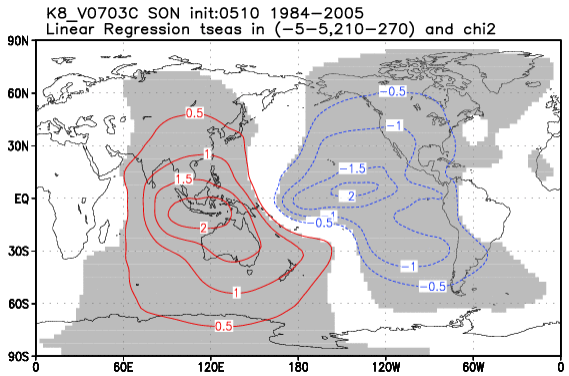


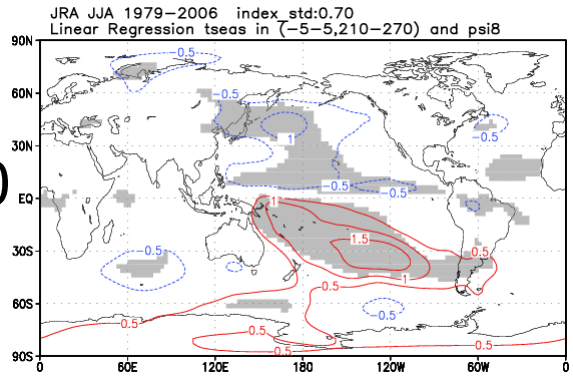
Regression coefficient of CHI200 and PSI850 upon NINO.3 SST (JJA)

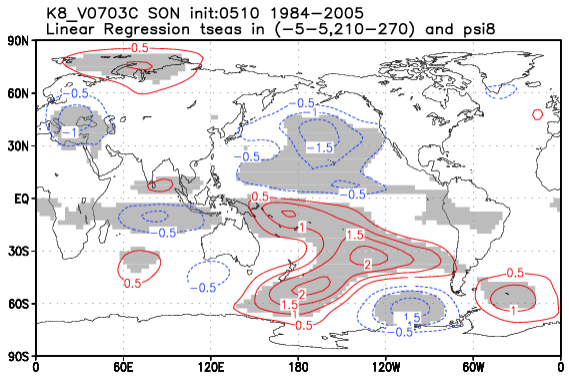
CHI200

PSI850









Atmospheric response associated with ENSO is generally reproduced in the model.

Analysis(JRA-25)

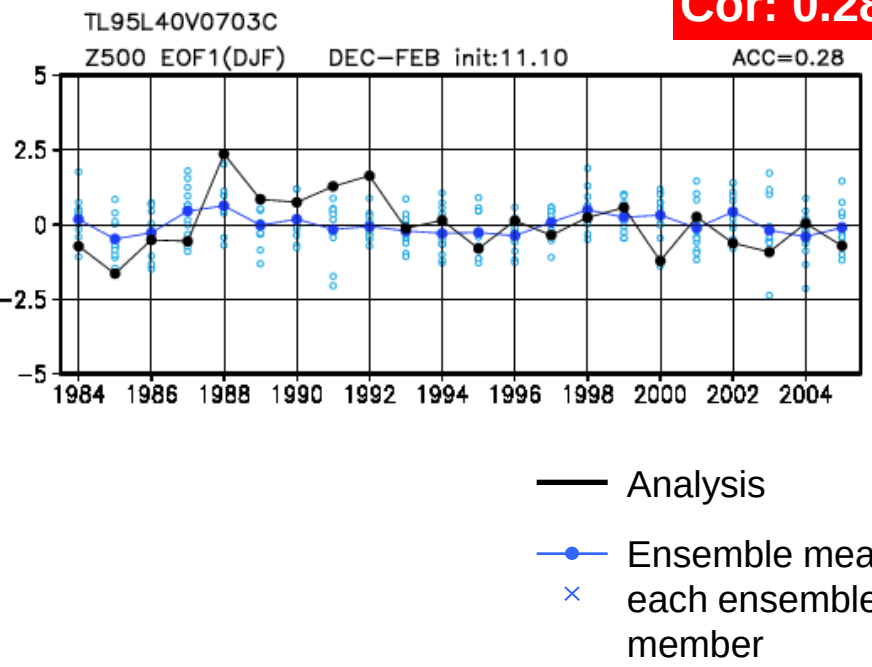
seasonal model (init. month of May)

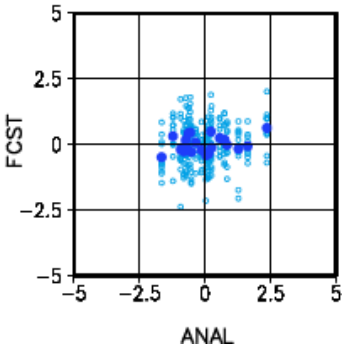
Difficulty of the prediction of the AO for seasonal timescale

Verification of the AO index in DJF with the initial month of **November.**

(from the hindcast of 1984-2005 (22years).

Cor: 0.28





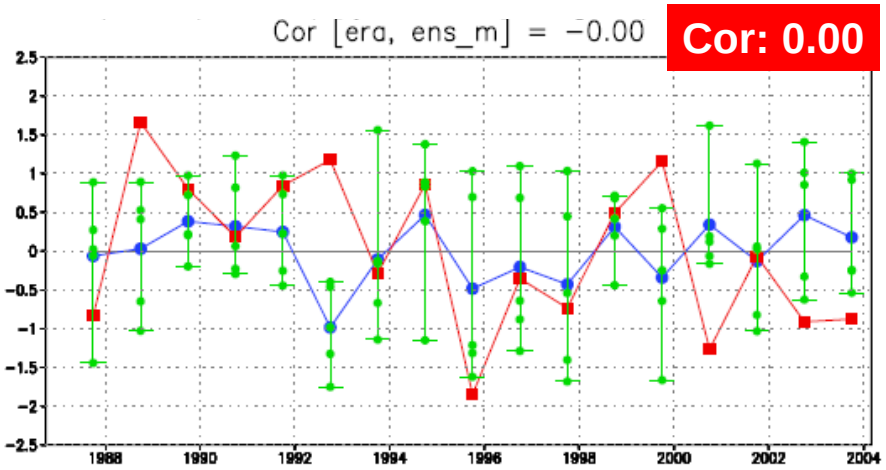
Anomaly correlation of the AO index in DJF for the seasonal EPS

Initial month	
September	-0.07
October	0.23
November	0.28

In case of the System 3 of ECMWF…

(From the figure 28 in the ECMWF Technical Memorandum No. 503)

Verification of the NAO index for DJF with the initial month of Sep by the system-3 of ECMWF. (from the Preliminary hindcast experiment for 1987-2005)



Difficulty of predicting the AO(/NAO) is common to all of the NWP models.

•The AO is an internal variability of the atmosphere in the mid-high latitudes.

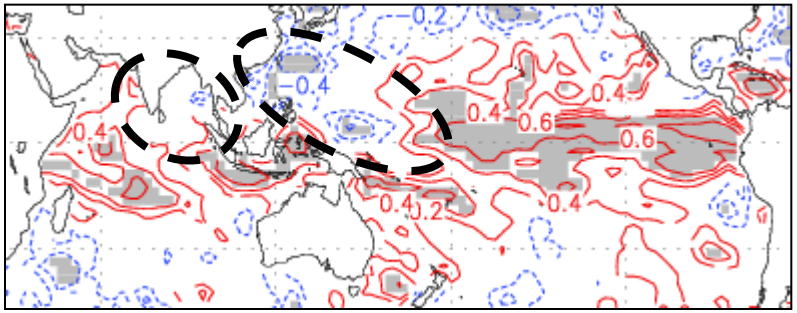
-->prediction of the AO(/NAO) is difficult for the seasonal timescale.

Excess response to precipitation with SST anomaly in AGCM

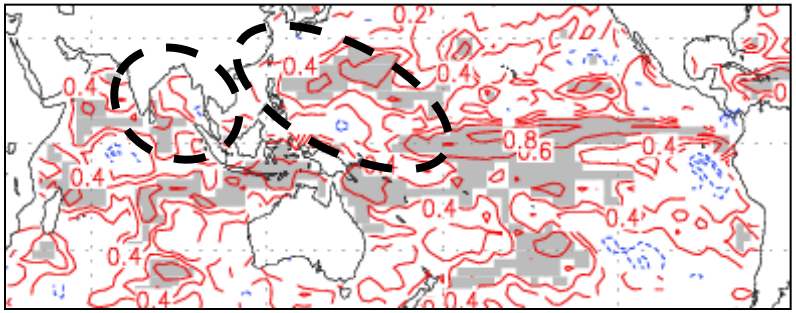
- In the AGCM, precipitation is sensitive to local SST anomaly.

Correlation between precipitation and SST anomaly in JJA

Analysis(JRA-25)



seasonal model (init. month of May)



- positive correlation is excess in the model.
- Negative correlation in the western North Pacific region is not found in the AGCM.

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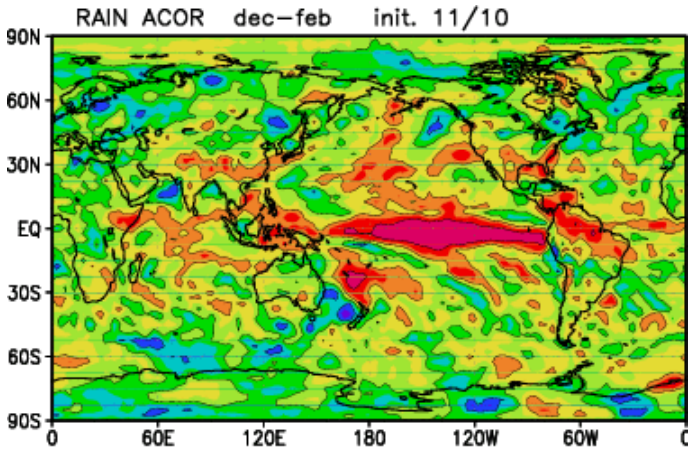
Example: Interpretation of seasonal prediction model results considering with the prediction skill

- Initial date: 13 Nov 2009
- Target: Temperature anomalies in DJF 2009/2010 in Japan

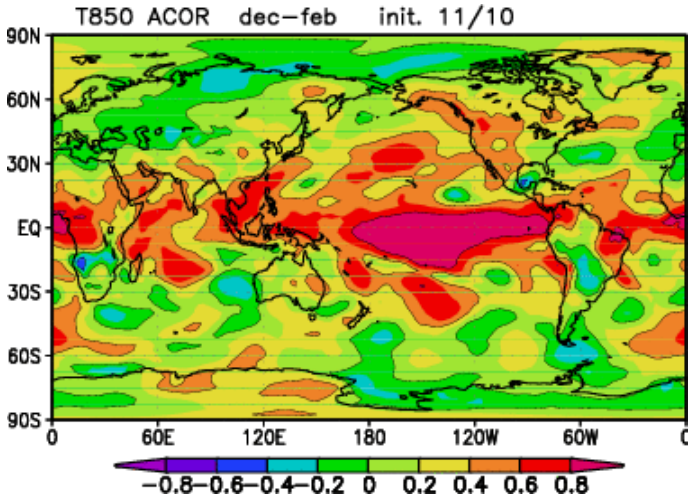
- methodology
  - Prediction skill according to the hindcast
  - prediction of SSTs especially in the tropics
  - prediction of convective activity in the tropics comparing to SST anomaly
  - prediction of the atmospheric circulation in the tropics (CHI200, PSI200, PSI850)
  - prediction in the mid-high latitude

Anomaly Correlation of precipitation for DJF
(init. month of Nov.)

Rain



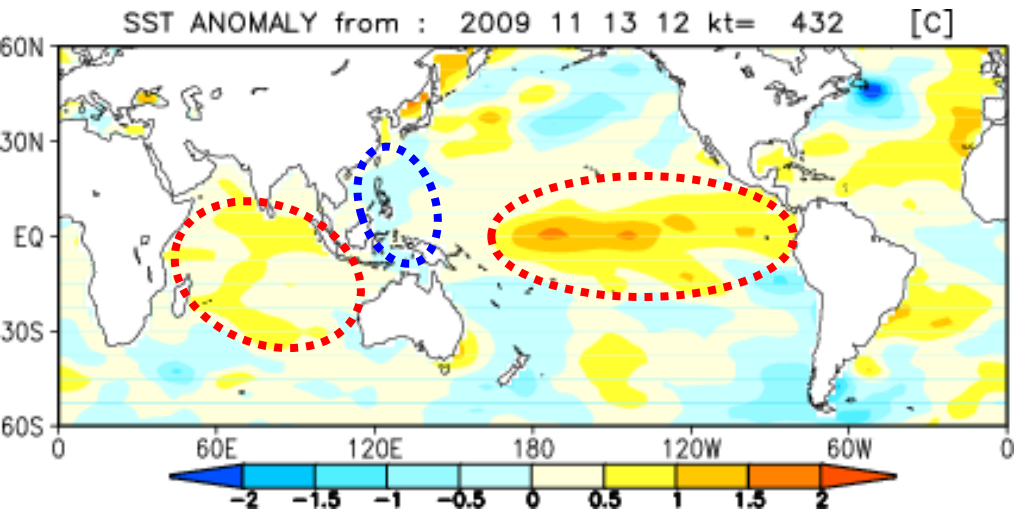
T850



- high anomaly correlation in the tropics, especially in the Pacific.
- While anomaly correlation is relatively high in the equatorial Indian Ocean, it is small over bay of Bengal and Arabian Sea.

Prediction of SST (DJF 2009/2010)

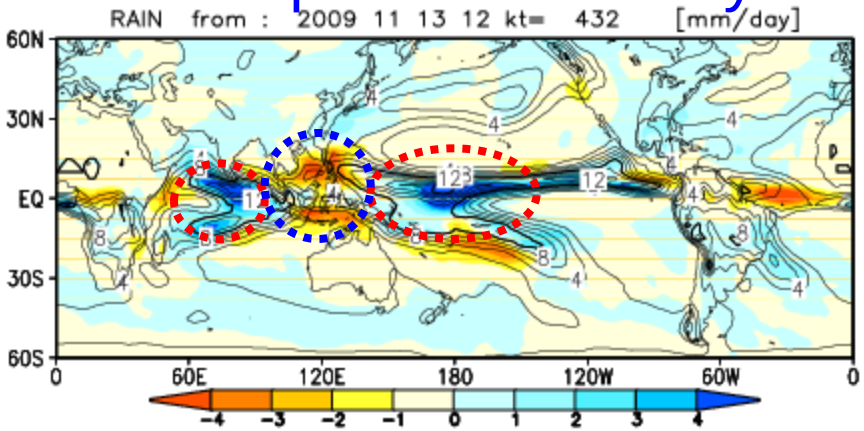
SST anomaly



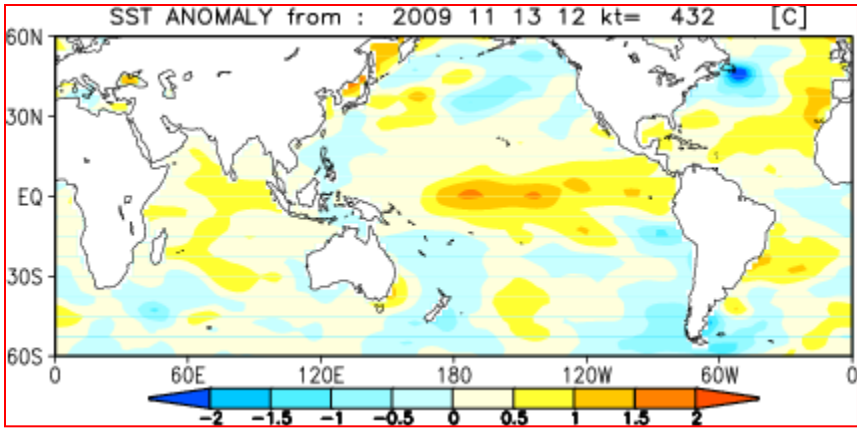
- Above normal SST will be continue in most part of the tropics.
- Particularly, in the eastern part of the equatorial pacific, large positive anomalies are found reflecting El Niño conditions.
- Around the Philippines, negative anomalies are found.
- Large positive anomalies are found in the tropical Indian Ocean.

Precipitation and CHI200 (200hPa velocity potential)

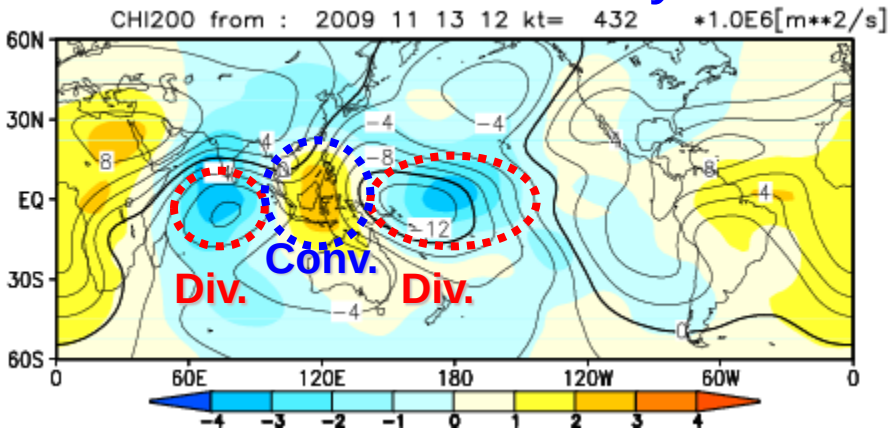
Precipitation anomaly



SST anomaly



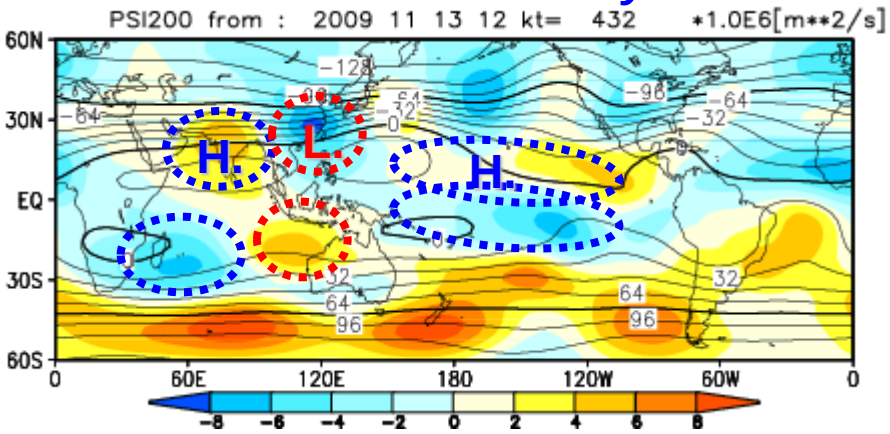
CHI200 anomaly



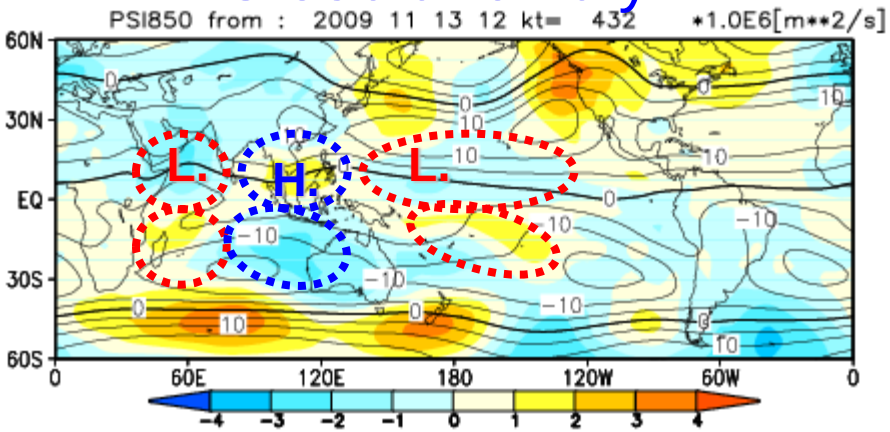
- Active convections in the central part of equatorial Pacific and central part of tropical Indian Ocean
  - (near high SST anomaly)
- Inactive convection over Maritime continent
  - (negative SST anomaly)

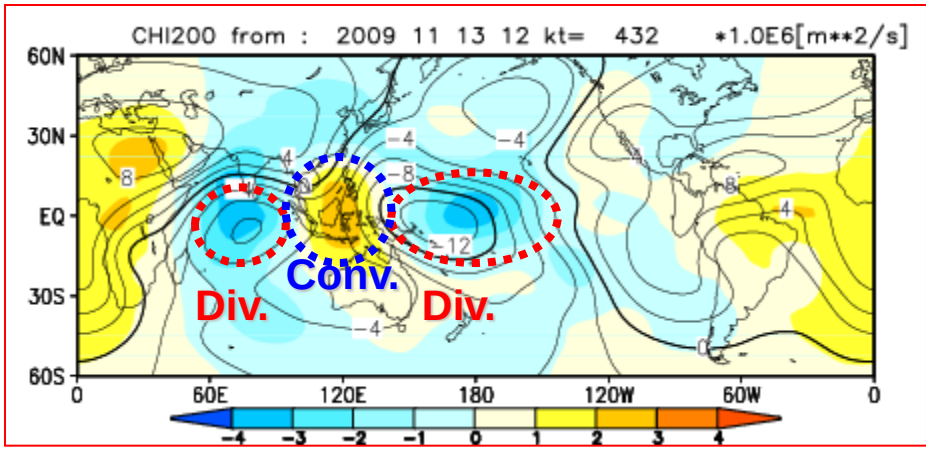
PSI200 and PSI850 (200/850hPa stream function)

PSI200 anomaly

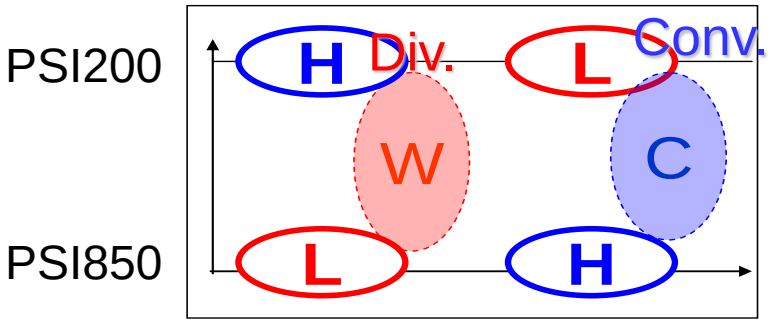


PSI850 anomaly





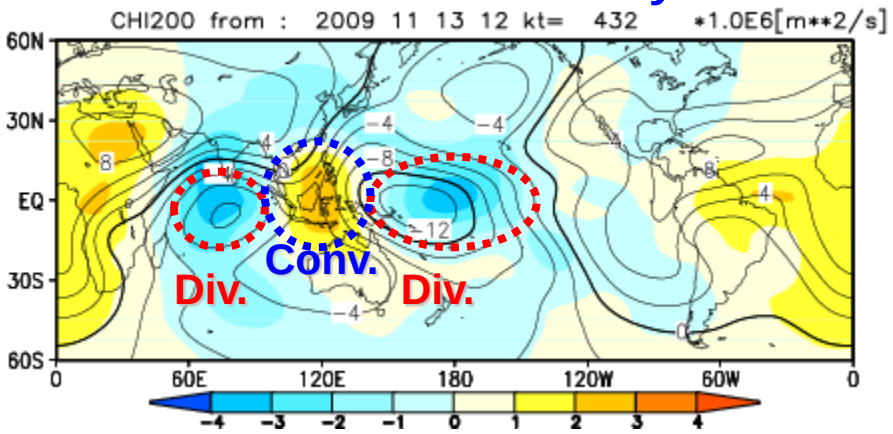
Reference; relationship warm (cool) anomaly and PSI fields



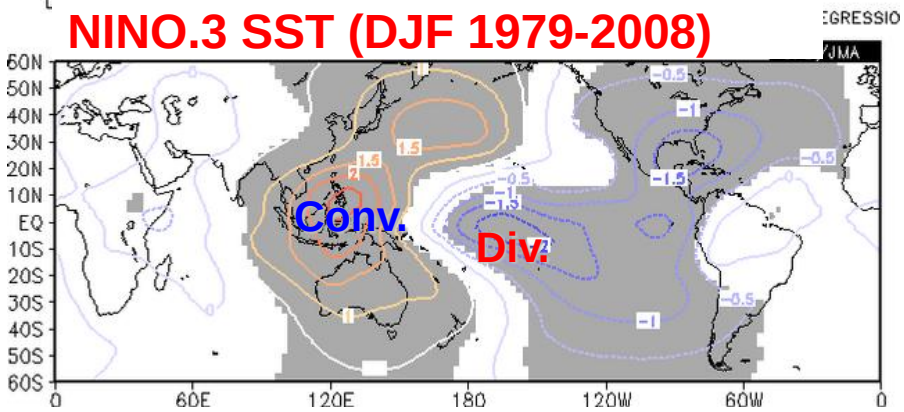
How much does El Niño conditions influence affect predicted anomaly fields? (CHI200)

(JRA-25/JCDAS)

CHI200 anomaly



Regression of CHI200 upon NINO.3 SST (DJF 1979-2008)



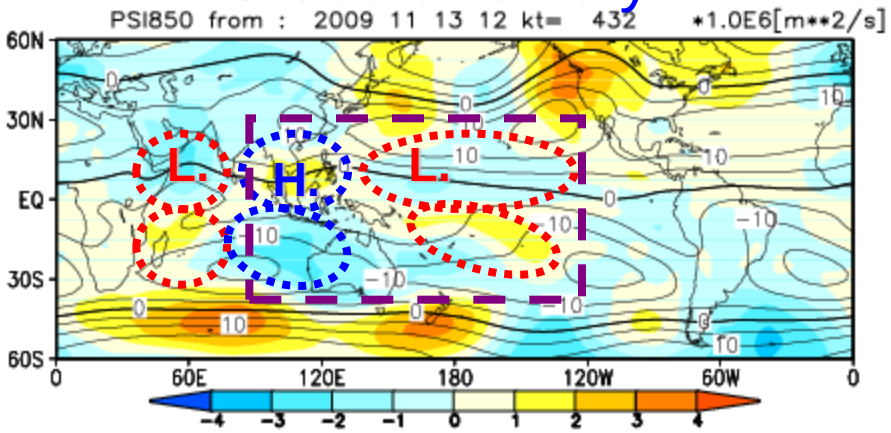
gray; 5% significant level

- Common point with climate statistics
  - Contrast of CHI200 anomalies between Maritime continent and central part of equatorial Pacific is similar to climate statistics.
- Difference from climate statistics
  - Negative anomaly in the tropical Indian Ocean is clear, reflecting high SSTs.
  - Negative anomalies in the central part of the equatorial Pacific shifts westward, but it is small.

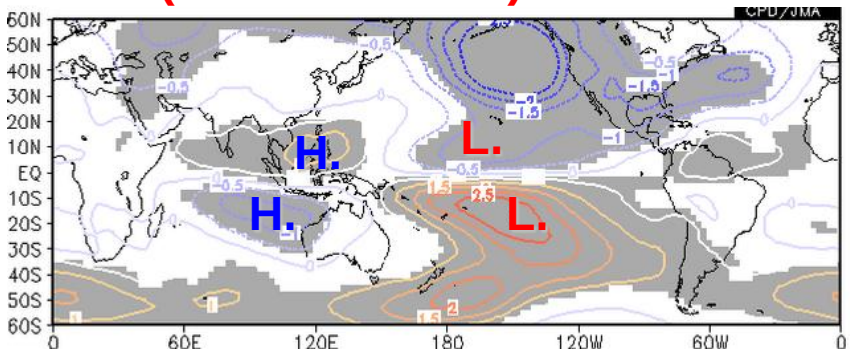
How much does El Niño conditions influence prediction fields? (PSI850)

(JRA-25/JCDAS)

PSI850 anomaly



Regression of PSI850 upon NINO.3 SST (DJF 1979-2008)



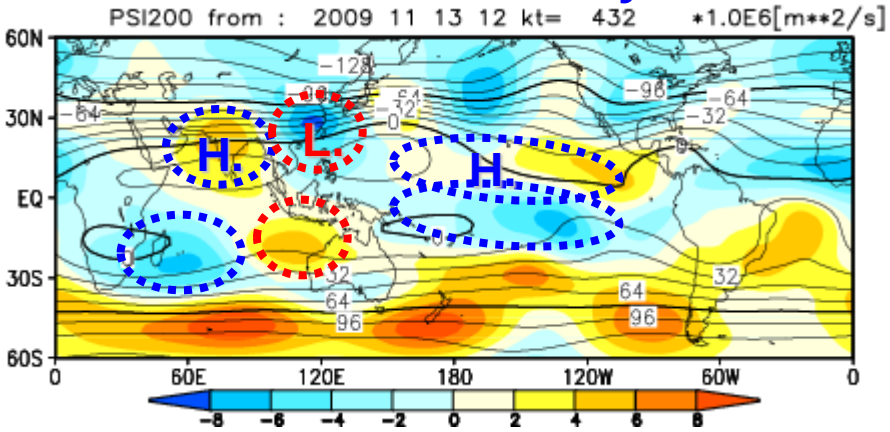
gray; 5% significant level

- Common point with climate statistics
  - PSI850 anomalies in Pacific and Maritime continent are generally similar to the climate statistics.
- Difference from climate statistics
  - Cyclonic anomalies over western Indian Ocean cannot be found in the climate statistics.

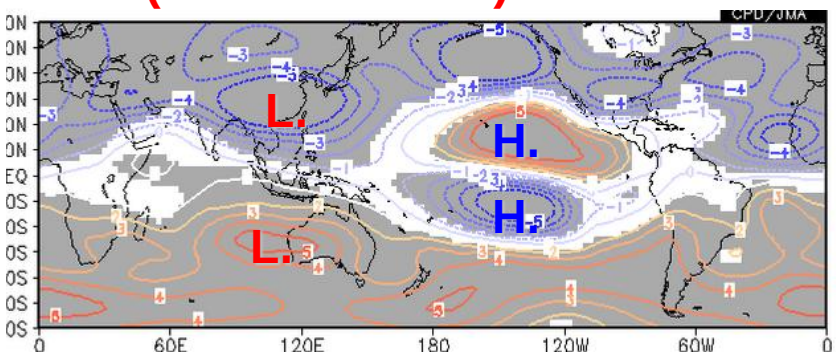
How much does El Niño conditions influence prediction fields? (PSI200)

(JRA-25/JCDAS)

PSI200 anomaly



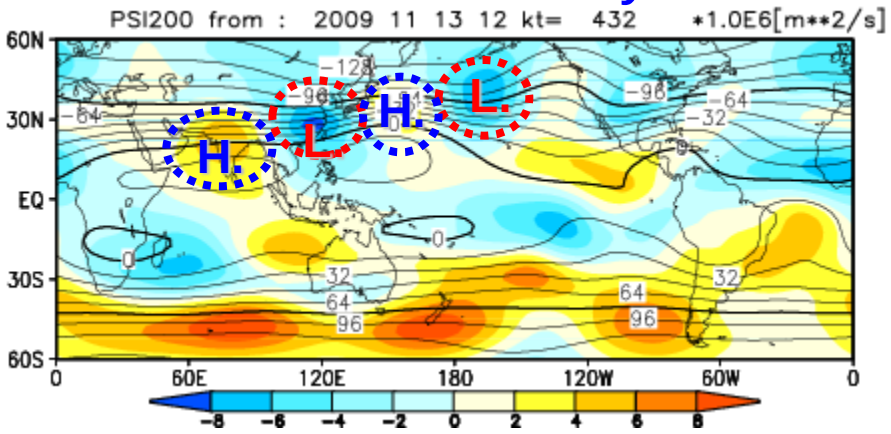
Regression of PSI200 upon NINO.3 SST (DJF 1979-2008)



- Common point with climate statistics
  - PSI200 anomalies in Pacific and in East Asia are generally similar to the climate statistics.
- Difference from climate statistics
  - Cyclonic anomalies in the western Indian Ocean cannot be found in the climate statistics.

Indirect effect of convective activities in the Indian ocean against East Asia

PSI200 anomaly



- Quasi-stationary Rossby-wave packet, originated by active convection in the tropical Indian Ocean, forced both cyclonic anomalies in East Asia and anticyclonic anomalies east of Japan.

  -> Inflow the cold air mass may be weaker than normal in East Asia.

((Caution!))

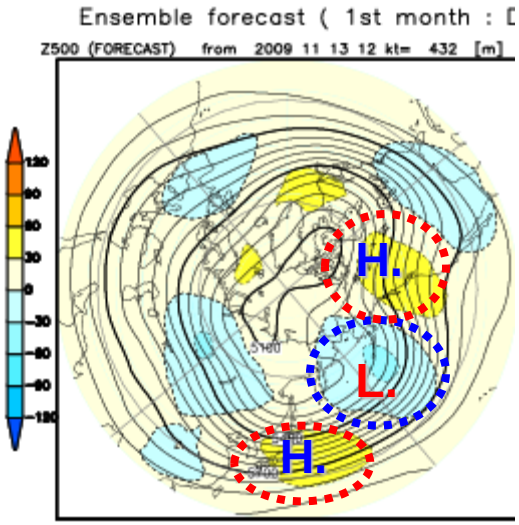
- How much reliability is predicted convection in the tropical Indian Ocean?

  ((The model may overestimate precipitation in the Indian Ocean due to excess response with high SSTs.))

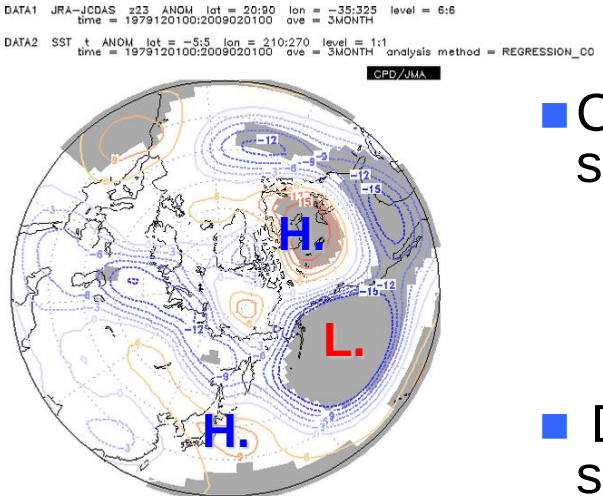
- Cyclonic anomalies East Asia and anticyclonic anomalies east of Japan may be too clear.

Z500

Z500



Regression of Z500 upon NINO.3 SST (DJF 1979-2008)



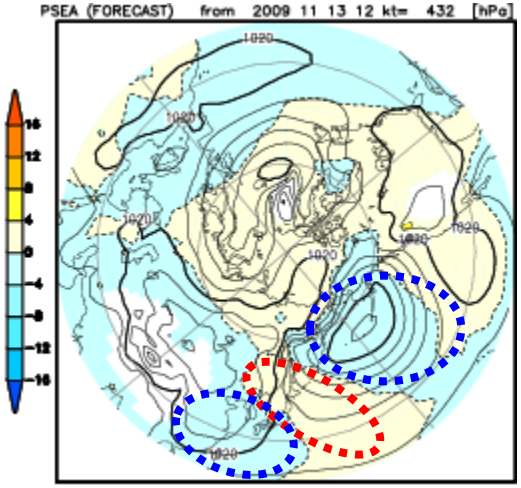
- Common point with climate statistics
  - Anomaly patterns from Pacific to North America are similar to the climate statistics (TNH pattern).
- Difference from climate statistics
  - Positive anomalies over Japan may be more remarkable than the statistics.
  - Anomaly patterns in Siberia are different from statistics.

enhanced by active convection in the Indian Ocean?

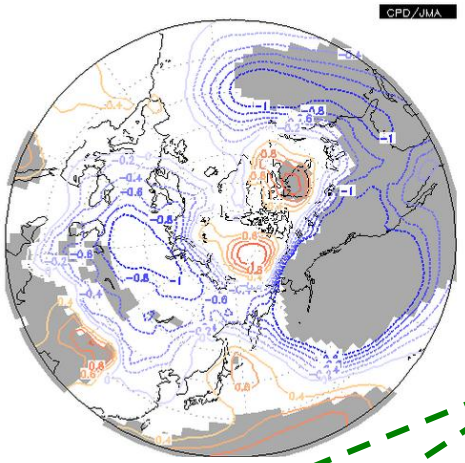
Uncertainty of internal variations in atmosphere?

SLP (Sea level pressure)

SLP



Regression of SLP upon NINO.3 SST (DJF 1979-2008)



- Common point with climate statistics
  - Negative anomalies in the east part of the Aleutian Low region
  - Positive anomalies over Japan
- Difference from climate statistics
  - Negative anomalies slightly clear over China.

The Aleutian Low tends to be strong, but it shifts eastward.

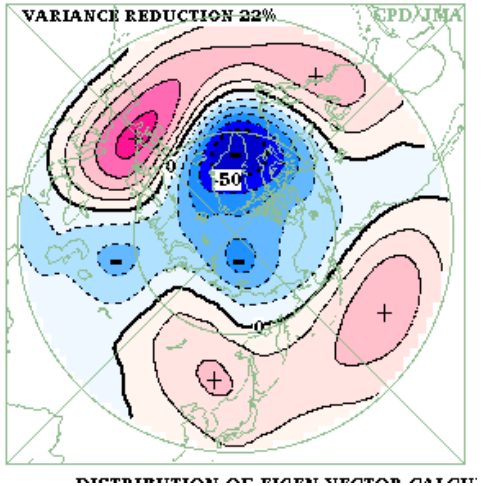
(In East Asia, inflow of cold air mass tends to be weak)

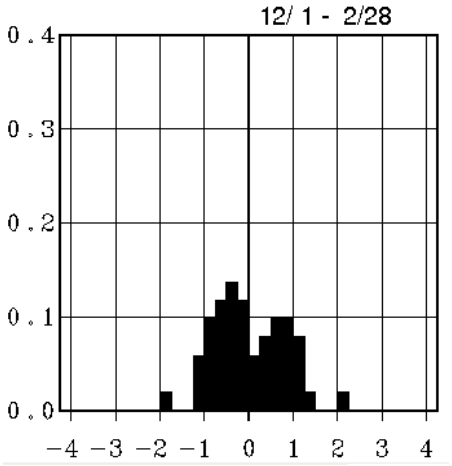
enhanced by active convection in the Indian Ocean?

AO index

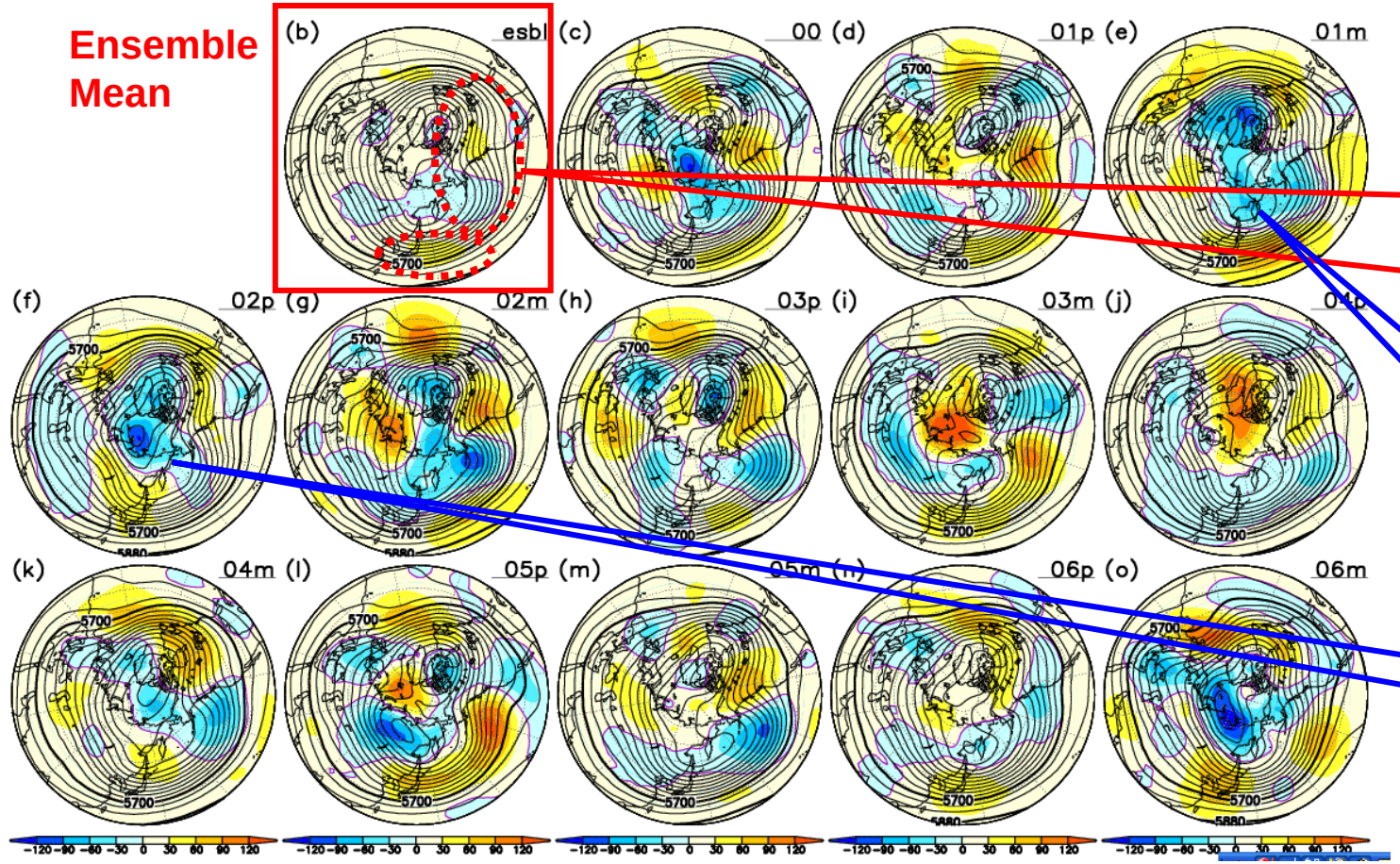
- Difficult to predict AO variations
  - Insufficient prediction skill (hindcast)
  - Large spread of AO index predictions

Histogram of AO index (DJF)





How much does anomaly patterns are same among ensemble members?
(13/53 members are shown here.)



Anomaly pattern associated with ENSO is generally common

Like negative AO

Like positive AO

Forecaster's Interpretation
(quote from directive document to district observatories on 29 Nov 2009)

- (Base for prediction)
  - El Niño conditions is likely to continue during DJF 2009/2010.
  - In the tropics, atmospheric circulation anomalies fields, (CHI200, PSI200, PSI850) are similar to the atmospheric response associated with El Niño conditions.
  - The Aleutian Low develops, but it shifts eastward. Winter monsoon tends to be weak. This is also common with to the atmospheric response associated with El Niño conditions.
    - **Numerical guidance, that says the above-normal temperature is most-likely category, is agreeable.**
  - As for the AO, any signals cannot be identified. Reliability of AO prediction is currently insufficient. Therefore, it is necessary to consider possibility of cold air inflow from Siberia especially in the Northern Japan.
    - **Probability of above-normal temperature is reduced especially in the Northern Japan.**
  - Positive anomalies of Z500 in the east of Japan may be enhanced by active convections in the Indian Ocean. But, its reliability is not sufficient.
    - **Probability of above-normal temperature is reduced.**

Three-month Outlook
(issued on 25 Nov. 2009)

Forecast Period	3 months		
	Dec-Feb		
category	–	0	+
Northern Japan	30	30	40
Eastern Japan	20	30	50
Western Japan	10	40	50
Okinawa and Amami	10	30	60

The more northern part, the higher possibility for below-normal temperature.

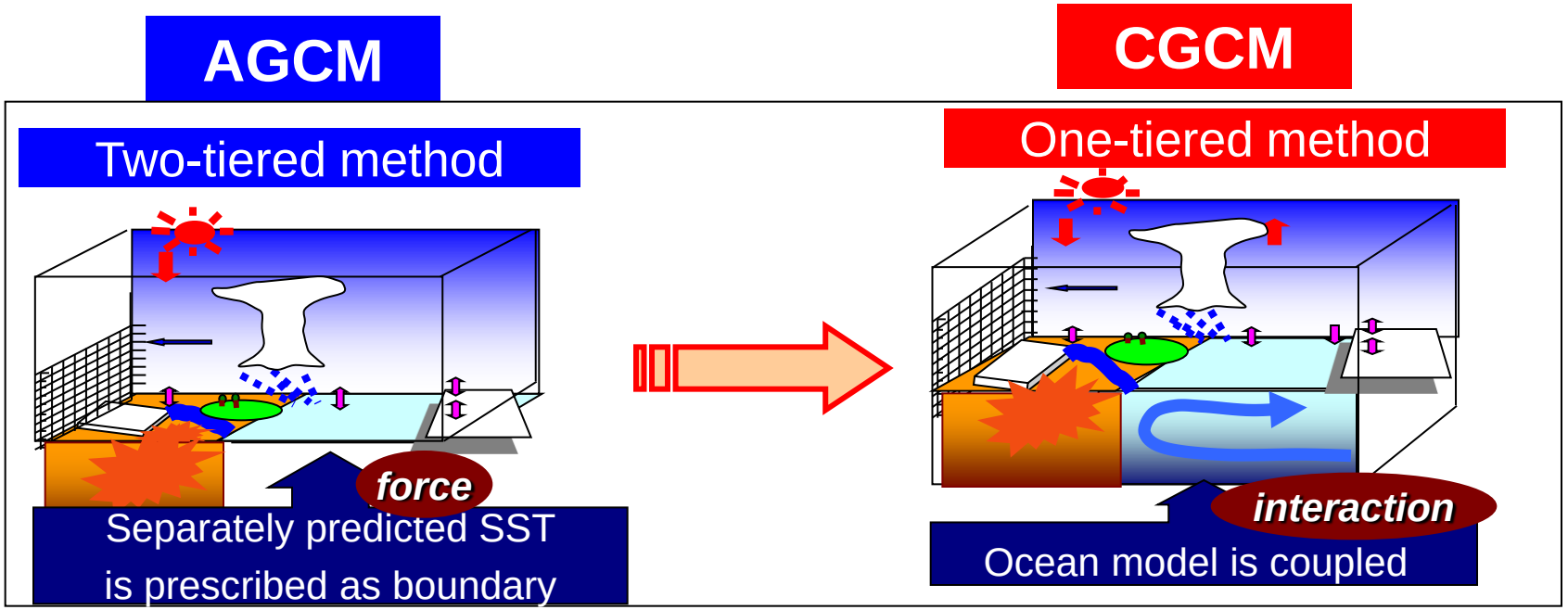
(category – : below normal, 0 : near normal, + : above normal, Unit : %)

Contents

- Uncertainty of prediction and Concept of the ensemble prediction system (EPS)
- Predictability
- Outline of the JMA's EPS for seasonal prediction
- Prediction skill (JMA's EPS for seasonal prediction)
- Practice
  - Interpretation of seasonal prediction model results considering with the prediction skill
- Announcement
  - replace EPS system for seasonal prediction in February 2010.
    - (AGCM --> CGCM)

Replace EPS for seasonal predictions in February 2010

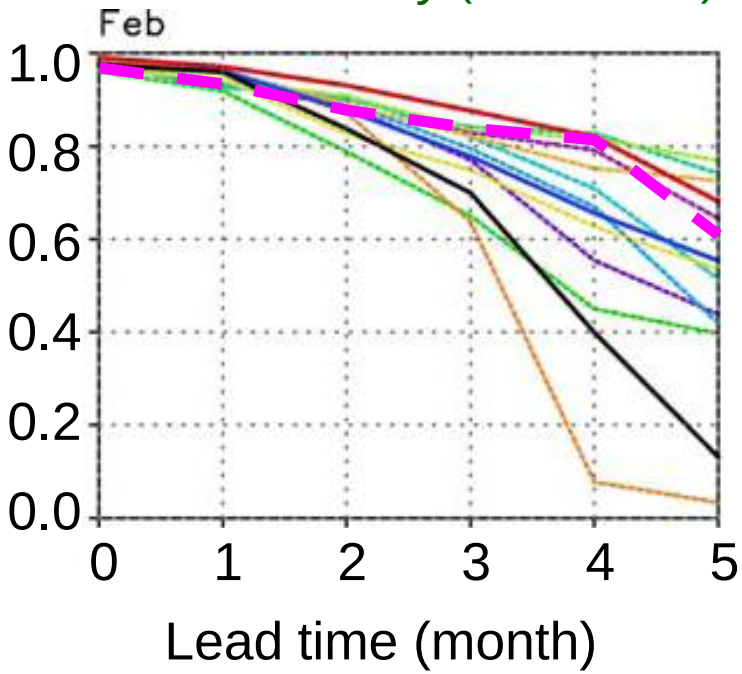
- Introducing the atmosphere-ocean coupled model (CGCM) into operational seasonal prediction



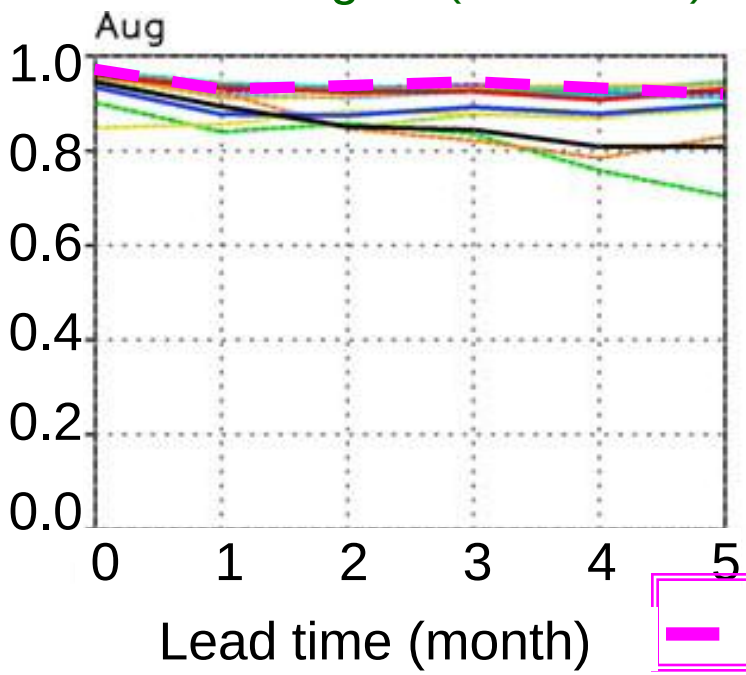
NINO.3.4 SST ACC: dependency on lead time

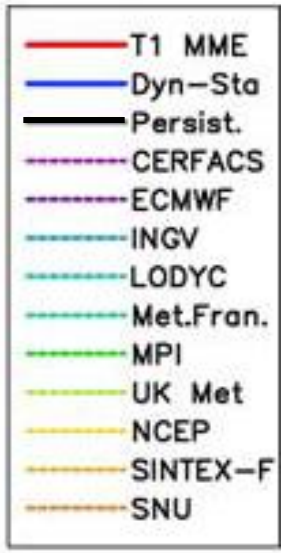
（quote from Fig. 8 of Jin et al. 2008）

Initial: February (1980-2001)



Initial: August (1980-2001)





(JMA/MRI-CGCM)

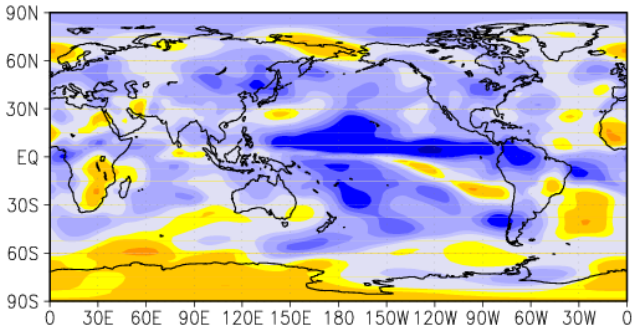
NINO.3.4 region: 120W-170W, 5S- 5N

Jin E. K., James L. Kinter III, B. Wang, C.-K. Park, I.-S. Kang, B. P. Kirtman, J.-S. Kug, A. Kumar, J.-J. Luo, J. Schemm, J. Shukla and T. Yamagata, 2008: Current status of ENSO prediction skill in coupled ocean–atmosphere models. Clim. Dyn., **31**, 647–666.

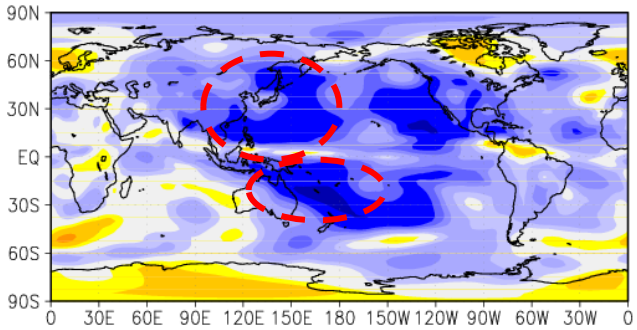
Improvement of atmospheric circulation
(JJA predictions, init. month of Feb.)

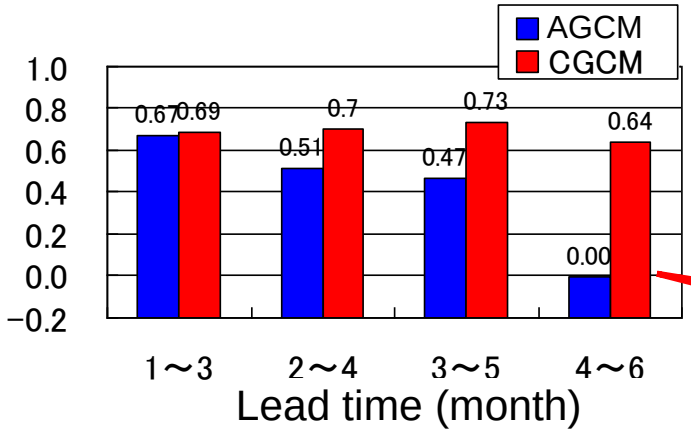
Anomaly correlation of PSI850 (1984-2005)

AGCM



CGCM





Anomaly correlation of precipitation over WNPM region

Western North Pacific Monsoon region; (10N-20N, 110E-160E)

Prediction skill of CGCM hardly decrease even transit of monsoon.

Appendix

- Some terms
  - Verification scores, such as ACC
  - Stream function, velocity potential
- NWP contents on the TCC web

Verification of the JMA EPS for seasonal prediction

Root Mean Square Error

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

F : forecast
O : observation
N : sample size

Range: 0 to infinity. Perfect score: 0.

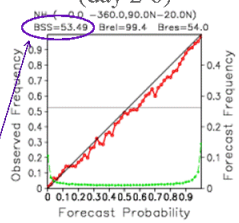
RMSE measures average magnitude of the forecast error, weighted according to the square of the error.

It does not indicate the direction the error.

Interpretation of Reliability diagram and BSS

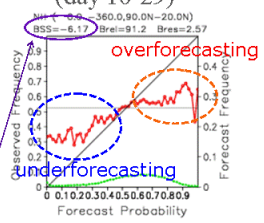
Event : Z500 Anomaly > 0
Northern Hemisphere
Spring of 2008 (2008/2/28 ~2008/5/29)

First week forecast (day 2-8)



BSS>0
better than climatology

Third and fourth week (day 16-29)



BSS<0
inferior to climatology

Verification at JMA on Ensemble Prediction

Anomaly Correlation

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

F : forecast
O : observation
C : climatology

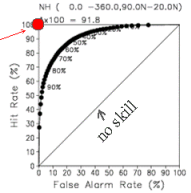
Range: -1 to 1. Perfect score: 1.

AC measures correspondence or phase difference between forecast and observation, subtracting out the climatological mean at each point.

Interpretation of ROC curves

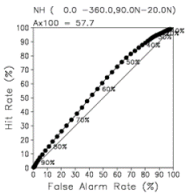
Event: Z500 anomaly > 0
Spring 2008

1st week forecast



high resolution
(high potential skill)

3rd and 4th week forecast

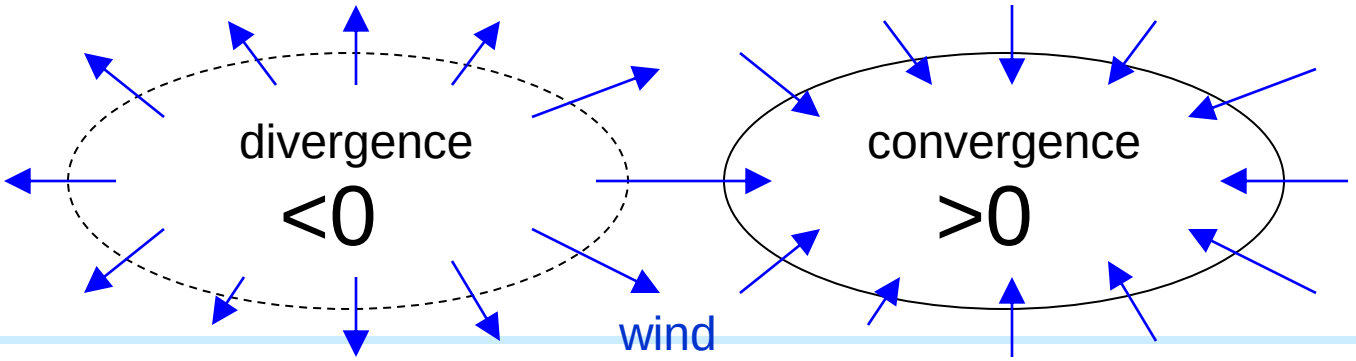


low resolution
(low potential skill)

- ROC is not sensitive to bias in the forecast. A biased forecast may still have good resolution and produce a good ROC curve, which means that it may be possible to improve the forecast through calibration.
  Thus, the ROC can be considered as a measure of potential usefulness.
- On the other hand, reliability diagram measures bias. It is a good partner to the ROC.

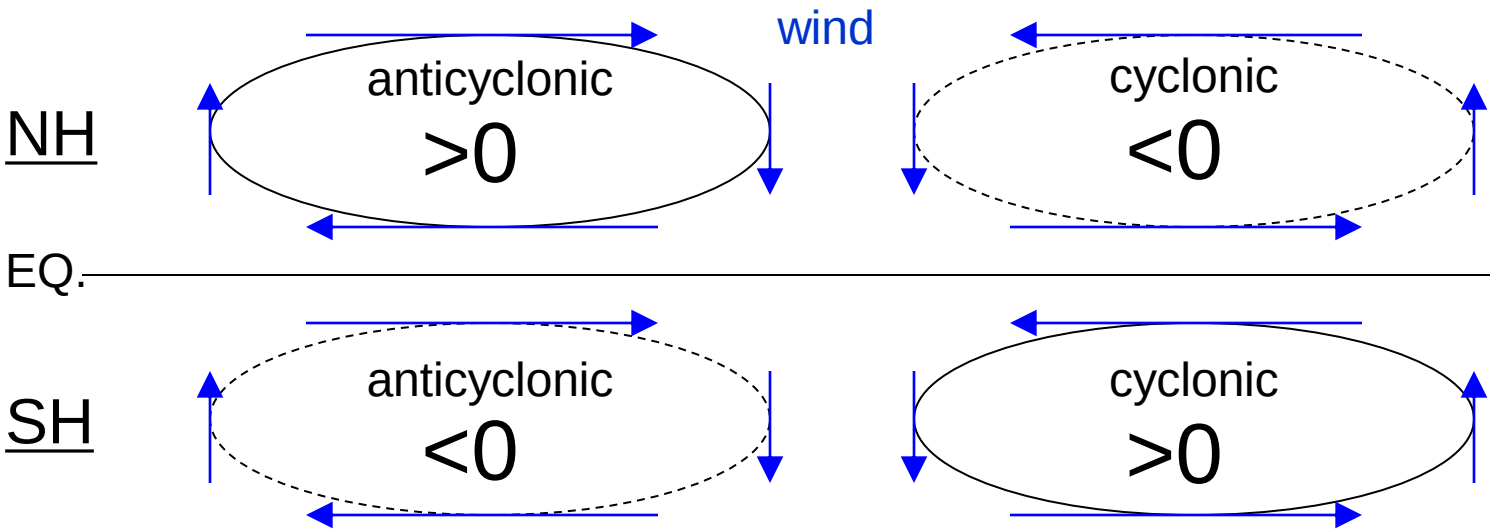
Velocity potential

- A velocity potential indicates a large scale divergence or convergence.
- The maximum (minimum) portions of positive (negative) velocity potential indicate centers of large scale convergence (divergence).
- At the upper troposphere (e.g. 200hPa), divergence is considered to be related to an active convective area.



Stream function

- A stream function is an indicator for non-divergent winds.
- In an area with an anticyclonic circulation, the stream function is positive (negative) in the northern (southern) hemisphere.



Appendix

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  - Stream function, velocity potential
- NWP contents on the TCC web

TCC-Web

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

Climate Monitoring

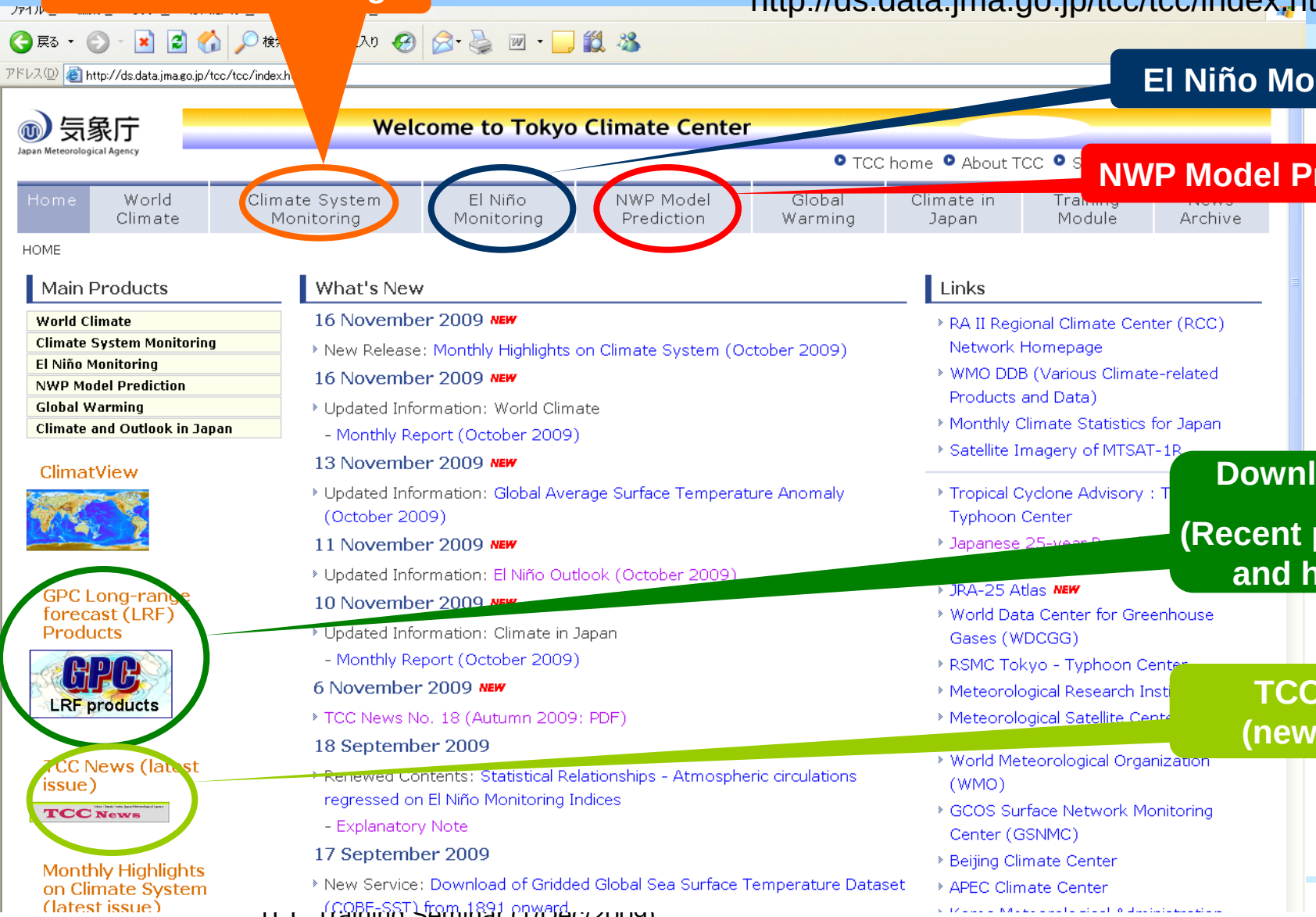
El Niño Monitoring

NWP Model Prediction

Download GPV

(Recent predictions and hindcast

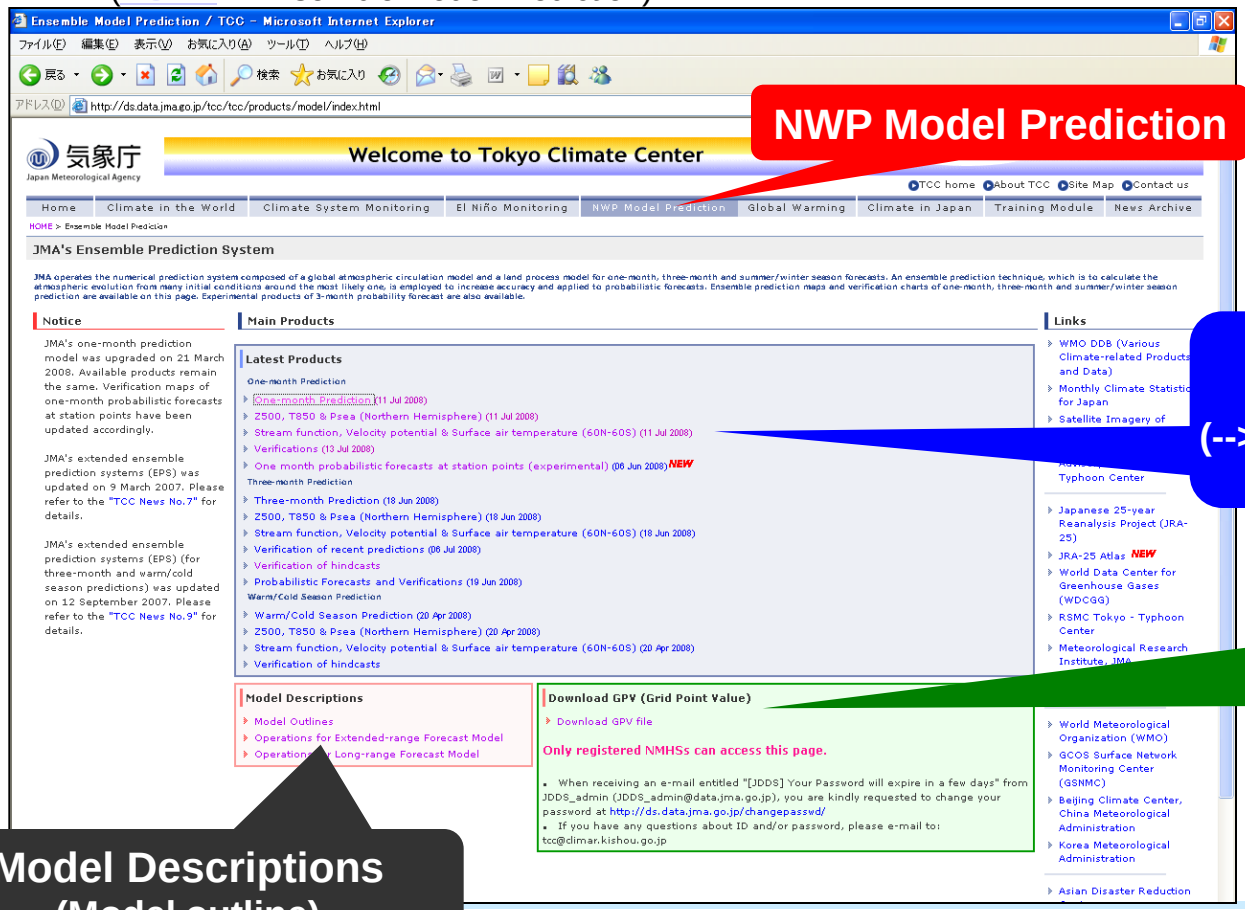
TCC news (newsletter)



NWP model products in the TCC-Web

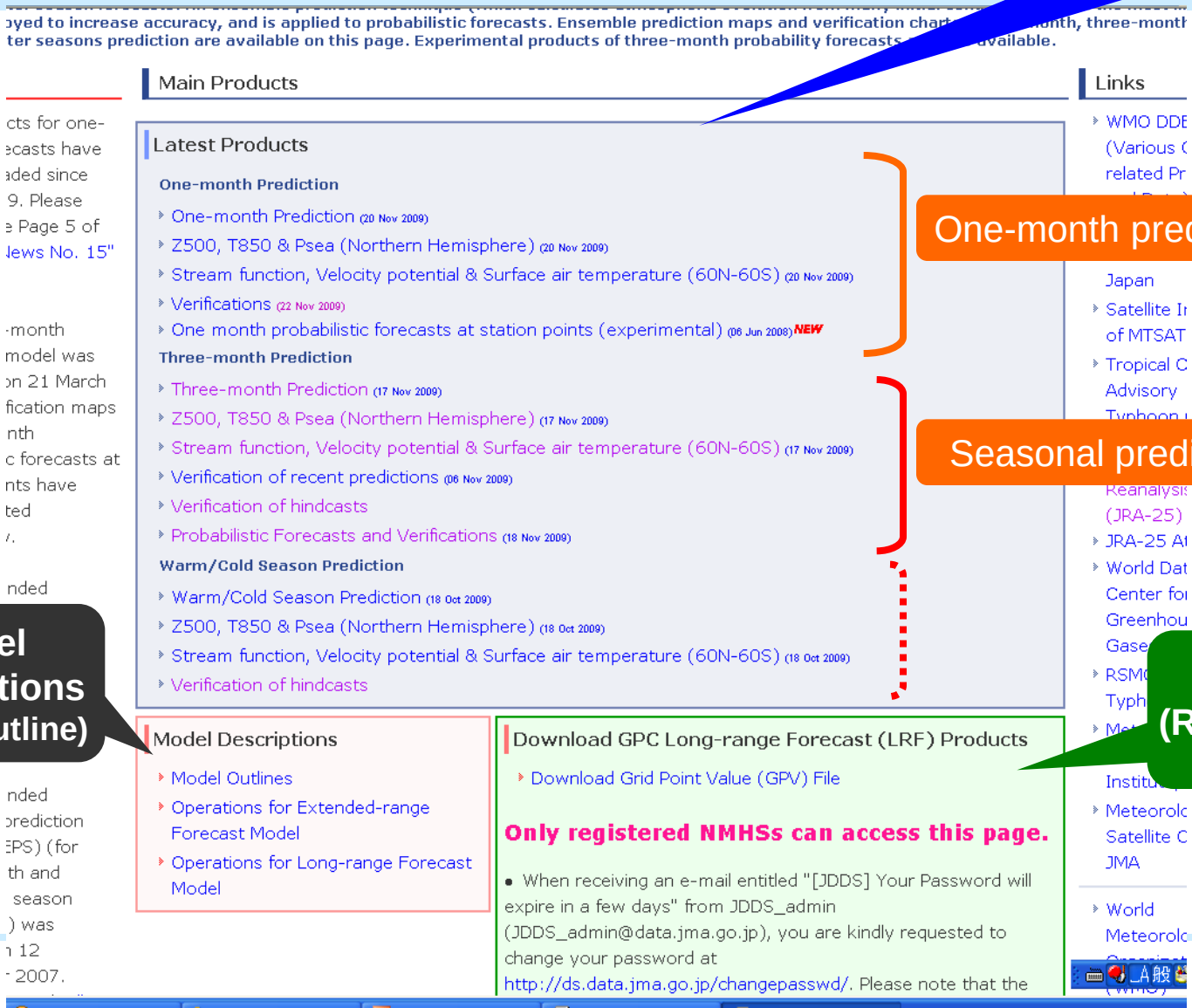
http://ds.data.jma.go.jp/tcc/tcc/products/model/index.html

(HOME > Ensemble Model Prediction)



Latest Products

(--> Various predictions maps)



oyed to increase accuracy, and is applied to probabilistic forecasts. Ensemble prediction maps and verification char… …onth, three-month
ter seasons prediction are available on this page. Experimental products of three-month probability forecasts … available.

Main Products

Latest Products

One-month Prediction

- One-month Prediction (20 Nov 2009)
- Z500, T850 & Psea (Northern Hemisphere) (20 Nov 2009)
- Stream function, Velocity potential & Surface air temperature (60N-60S) (20 Nov 2009)
- Verifications (22 Nov 2009)
- One month probabilistic forecasts at station points (experimental) (06 Jun 2008) NEW

Three-month Prediction

- Three-month Prediction (17 Nov 2009)
- Z500, T850 & Psea (Northern Hemisphere) (17 Nov 2009)
- Stream function, Velocity potential & Surface air temperature (60N-60S) (17 Nov 2009)
- Verification of recent predictions (06 Nov 2009)
- Verification of hindcasts
- Probabilistic Forecasts and Verifications (18 Nov 2009)

Warm/Cold Season Prediction

- Warm/Cold Season Prediction (18 Oct 2009)
- Z500, T850 & Psea (Northern Hemisphere) (18 Oct 2009)
- Stream function, Velocity potential & Surface air temperature (60N-60S) (18 Oct 2009)
- Verification of hindcasts

Model Descriptions

- Model Outlines
- Operations for Extended-range Forecast Model
- Operations for Long-range Forecast Model

Download GPC Long-range Forecast (LRF) Products

- Download Grid Point Value (GPV) File

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Links

- WMO DDE (Various … related Pr…
- Japan
- Satellite I… of MTSAT
- Tropical C… Advisory
- Typhoon …
- Reanalysis (JRA-25)
- JRA-25 A…
- World Dat… Center for Greenhou… Gase…
- RSM… Typh…
- M…
- Institut…
- Meteorolo… Satellite C… JMA
- World Meteorolo…

One-month prediction

Seasonal prediction

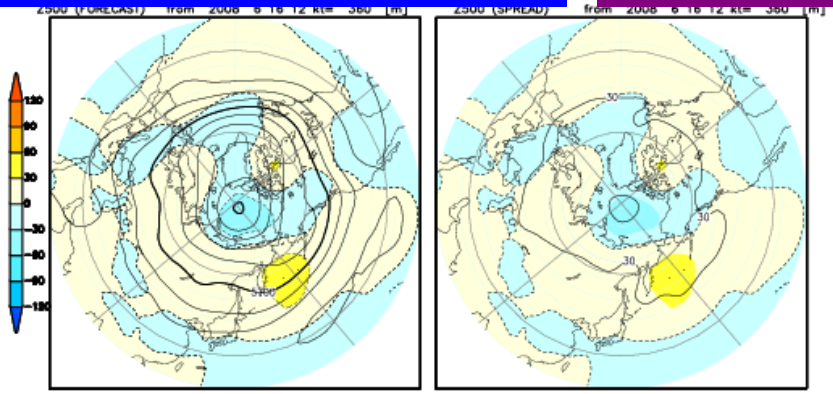
Model Descriptions (Model outline)

Download GPV (Recent predictions and hindcast)

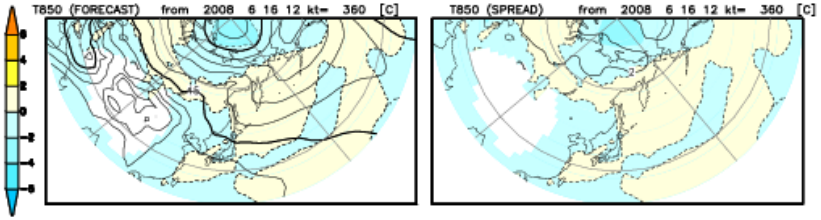
Various predictions maps in the TCC Web (1) prediction Map (Z500, T850, PSEA)

Ensemble mean & anomaly | **Ensemble spread**

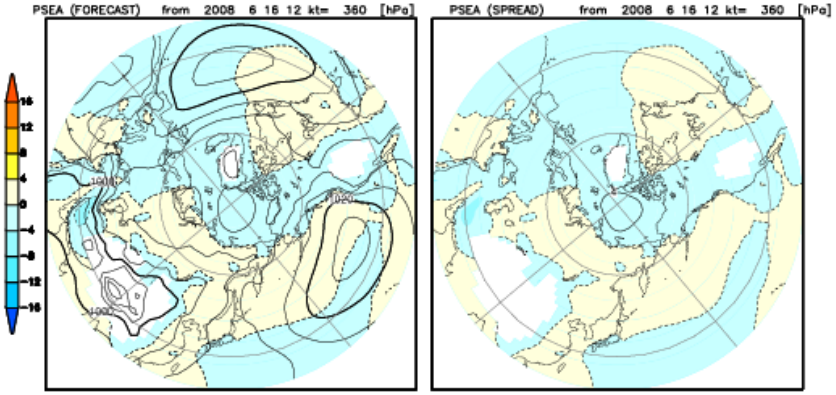
Z500



T850



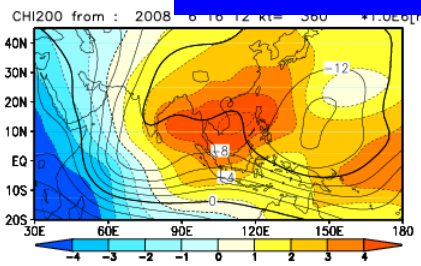
PSEA



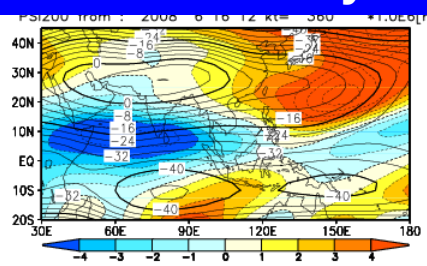
Various predictions maps in the TCC Web (2) prediction Map (CHI, PSI and the others)

Ensemble mean & anomaly

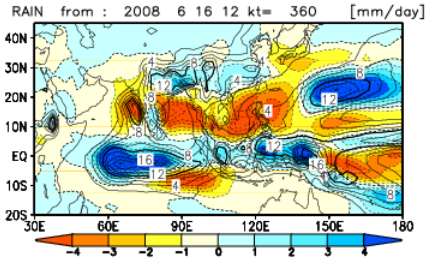
CHI200



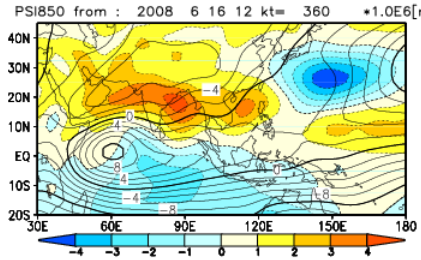
PSI200



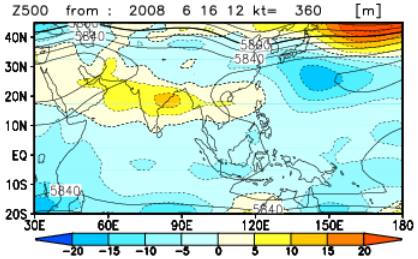
RAIN



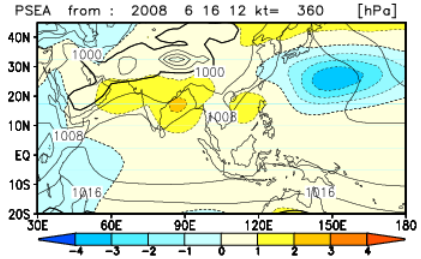
PSI850



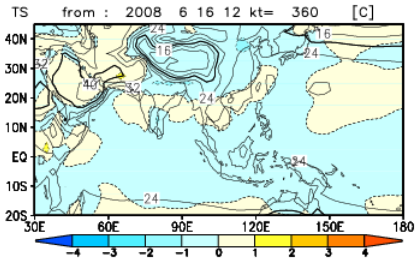
Z500



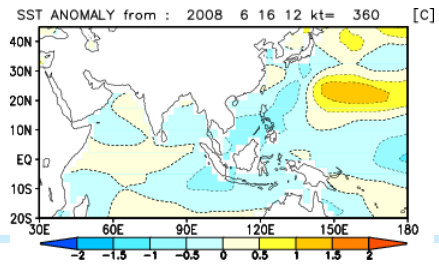
SLP



TS



SST

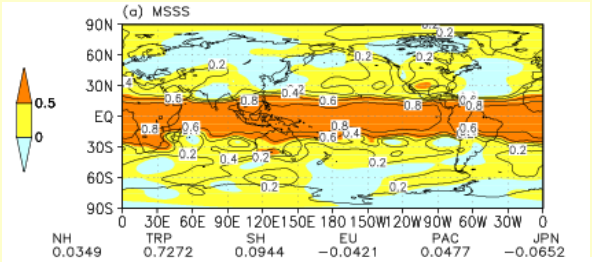


Various predictions maps in the TCC Web (3) Verification of hindcast

Verification of hindcast based on WMO Standard Verification System (SVS)

Verification of deterministic forecasts

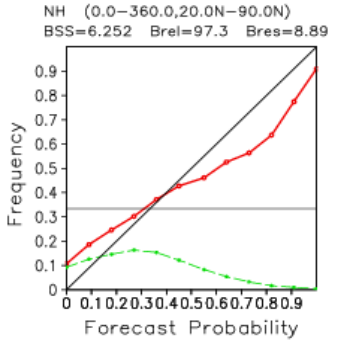
- Mean Square Skill Score
  RAIN | T2m | PSEA | Z500 | T850
  Dependence of MSSS on Initial date



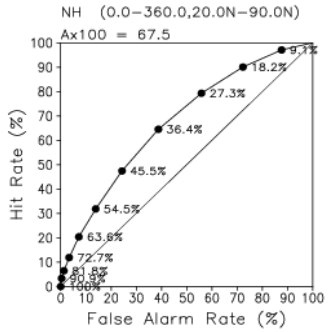
- 3 by 3 contingency tables (in Japan)
  (Category : Below Normal, Near Normal, Above Normal)
  RAIN | T2m | PSEA | Z500 | T850

Verification of Probabilistic forecasts

- Reliability diagrams (Aggregated verification)
  (Anomaly > 0, Below Normal, Near Normal, Above Normal)
  RAIN | T2m | PSEA | Z500 | T850

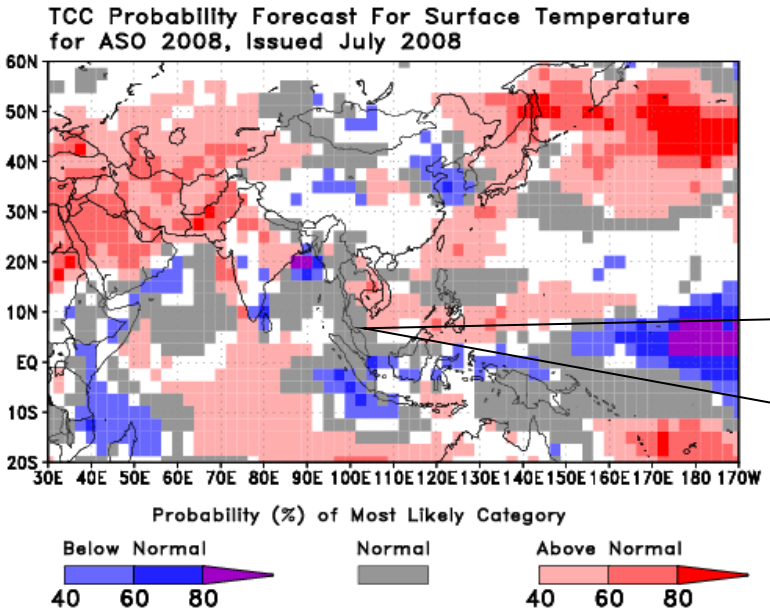


- Relative Operating Characteristics
  - ROC curves, ROC areas (Aggregated verification)
    (Anomaly > 0, Below Normal, Near Normal, Above Normal)
    RAIN | T2m | PSEA | Z500 | T850
    Dependence of ROC areas on Initial date
  - ROC areas (Grid point verification)
    (Anomaly > 0, Below Normal, Near Normal, Above Normal)
    RAIN | T2m | PSEA | Z500 | T850

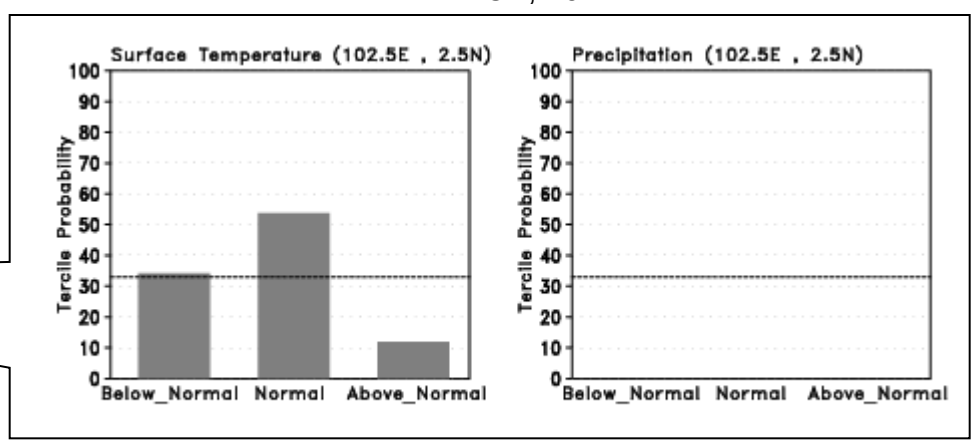


Various predictions maps in the TCC Web (4) Probability predictions

Most Likely Category



Probability in three categories at near Kuala Lumpur (3N 102E)



--> This products includes whole members information