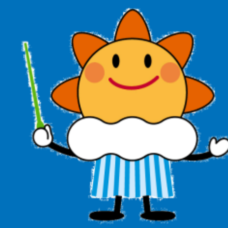


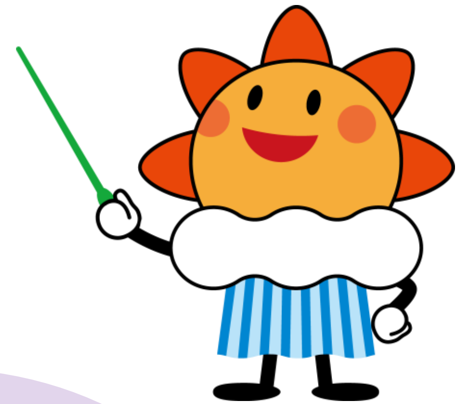
One-month Forecast

Yoshinori Oikawa
Senior Scientific Officer for Seasonal Forecast
Tokyo Climate Center
Japan Meteorological Agency

December 1, 2021
TCC training seminar

Structure

- What is one-month forecast?
- Brief introduction to climate dynamics
- Methodology for JMA's one-month forecast



What is one-month forecast ?

Classification of weather and climate forecasts

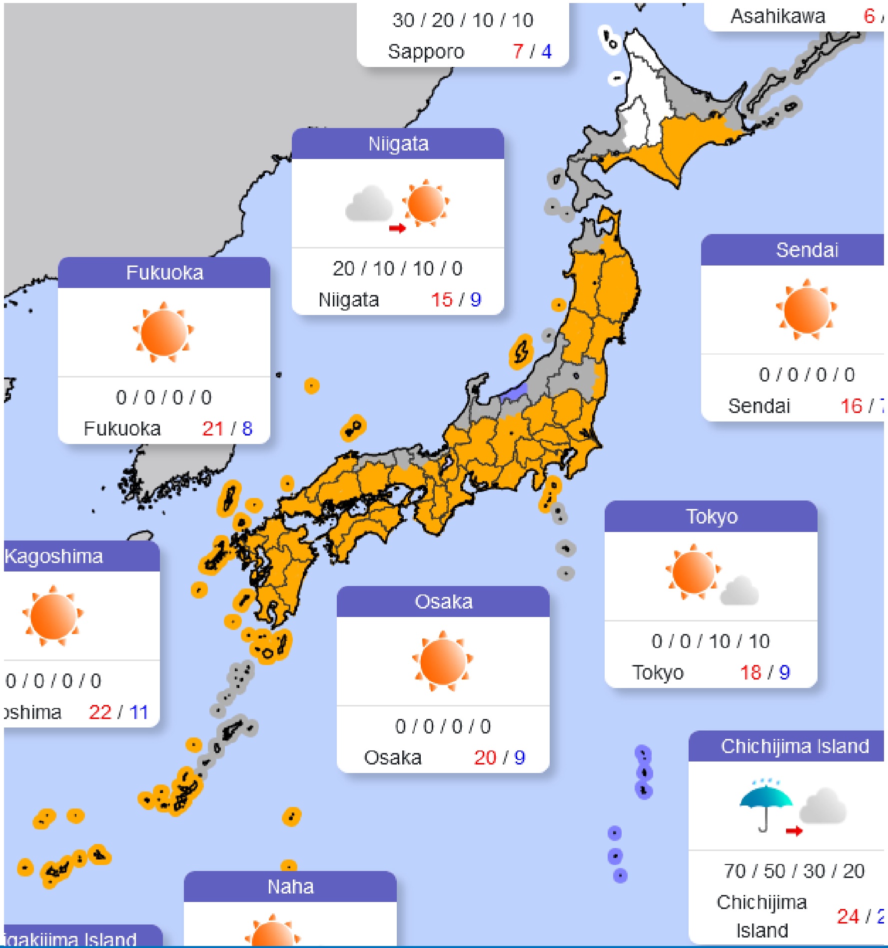
According to WMO's ***Manual on Global Data-processing and Forecasting System***,

Class	Target forecast range
Nowcasting	Current and forecasted weather up to 2 hrs ahead
Very short-range weather forecasting	Up to 12 hrs ahead
Short-range forecasting	Beyond 12 hrs up to 72 hrs
Medium-range weather forecasting	Beyond 72 hrs up to 240 hrs
Extended-range weather forecasting	Beyond 10 days up to 30 days
Long-range forecasting	Monthly, three-month or seasonal outlook for averaged weather parameters as departure from climate
Climate forecasting	Annual, decadal and beyond, including human-induced climate change projection

What's different between short- and extended- range forecasts?

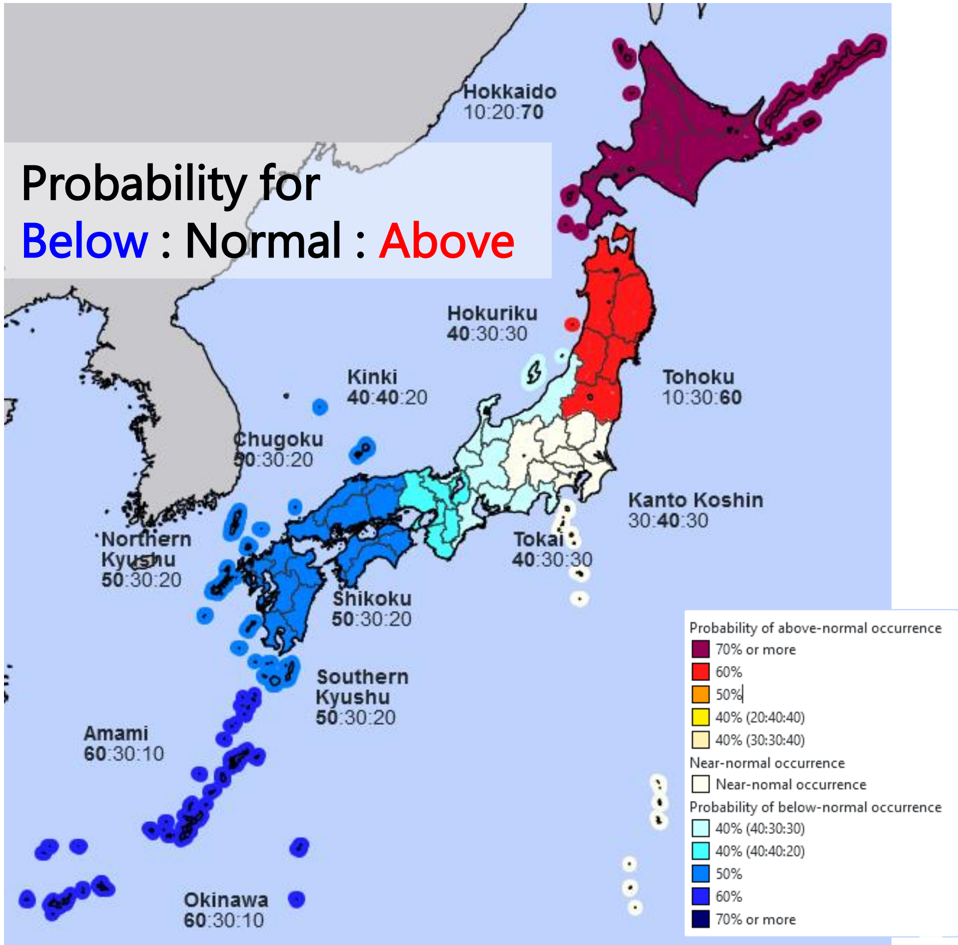
Short-range forecast

- Provides weather parameters (temperatures, precipitation, …) as they are expected
- Possible to forecast in **deterministic** way



One-month forecast

- Provides expected **deviations** from climatology
- Possible to forecast only in **probabilistic** way



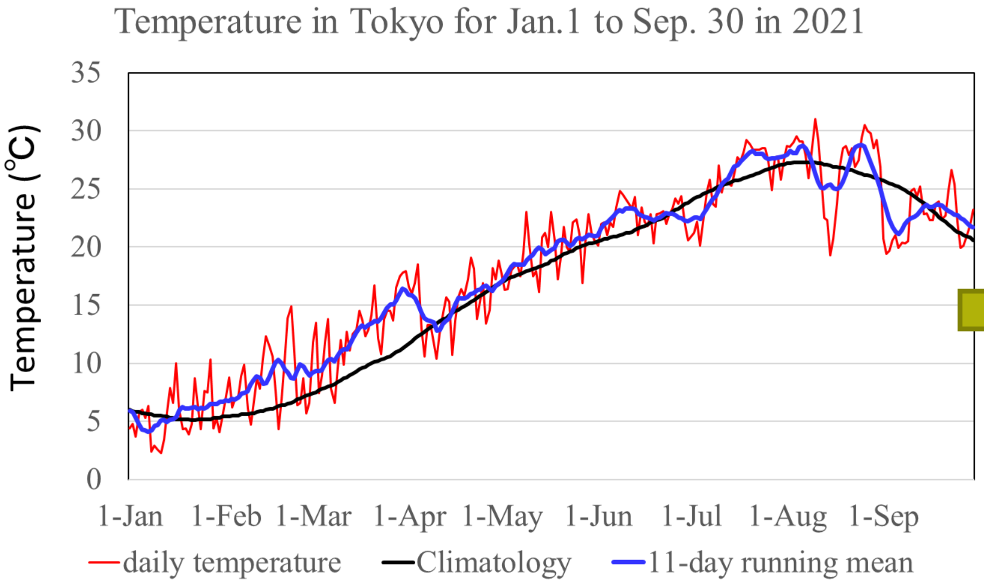
Anomaly is what we forecast

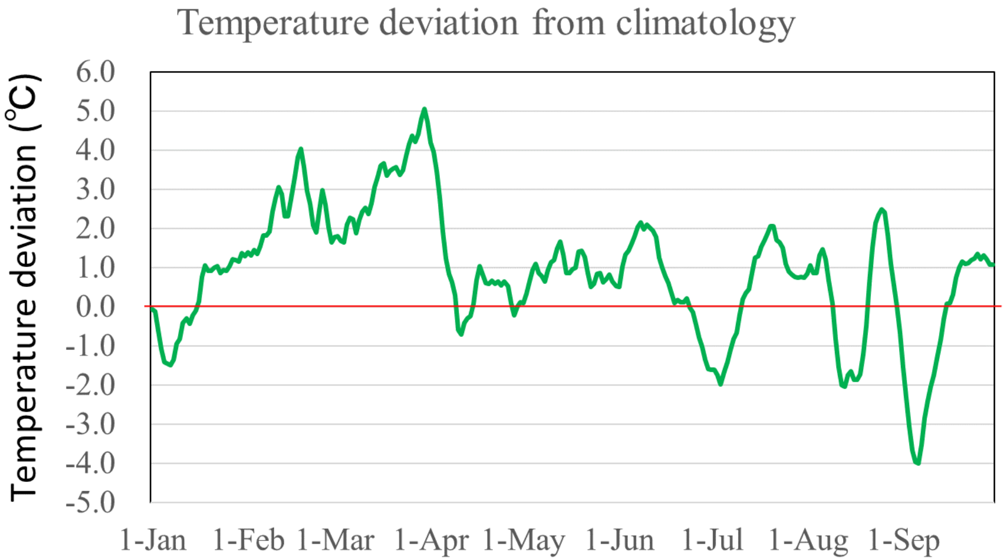
Climatological normal: Defined as 30-year average for 1991–2020

Anomaly: Deviation from the Climatology

[Anomaly] = [Actual Value] – [Normal]

- Climate is what we expect, anomaly is what we forecast.
- It's often ***anomalies*** that matter most to industries, societies and economies, because ***unseasonable*** weather conditions could bring adverse effects across multiple sectors, including agriculture, tourism, water resource, and so on.





3-category probabilistic forecast

- JMA provides one-month forecasts in 3 probabilistic categories, namely,

  Above/Near/Below normal

- The 3 categories are defined from historical observations for the 30-year period of 1991-2020, by sorting them in ascending order and dividing into 3 categories.

- One-month forecasts are provided as probability of weather parameter (e.g. temperature) anomalies falling within

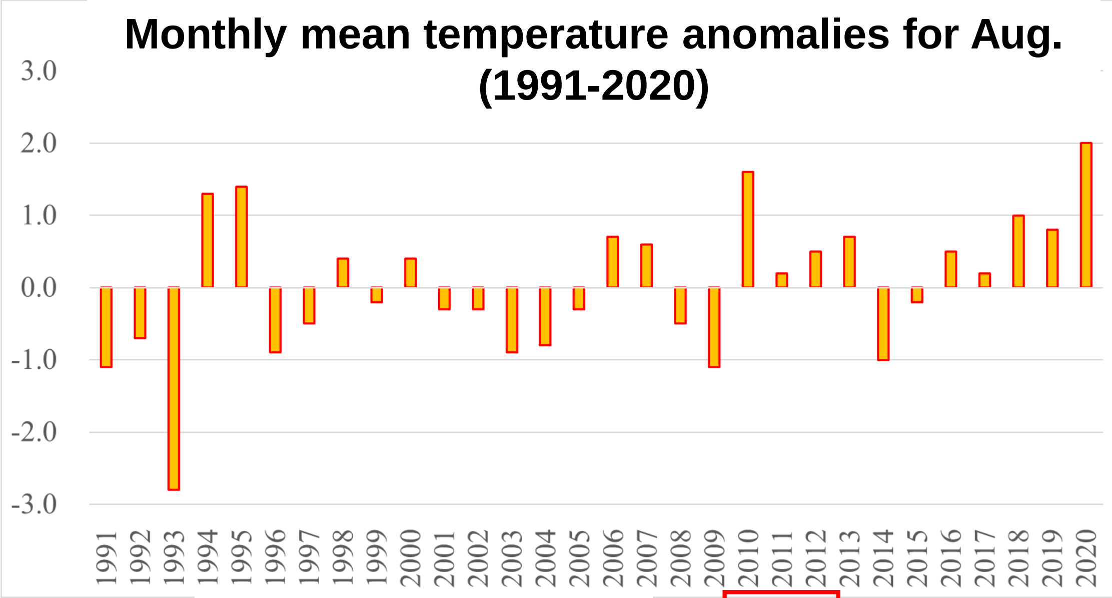
  1-10th(Below normal; BN)

  11-20th (Near normal; NN)

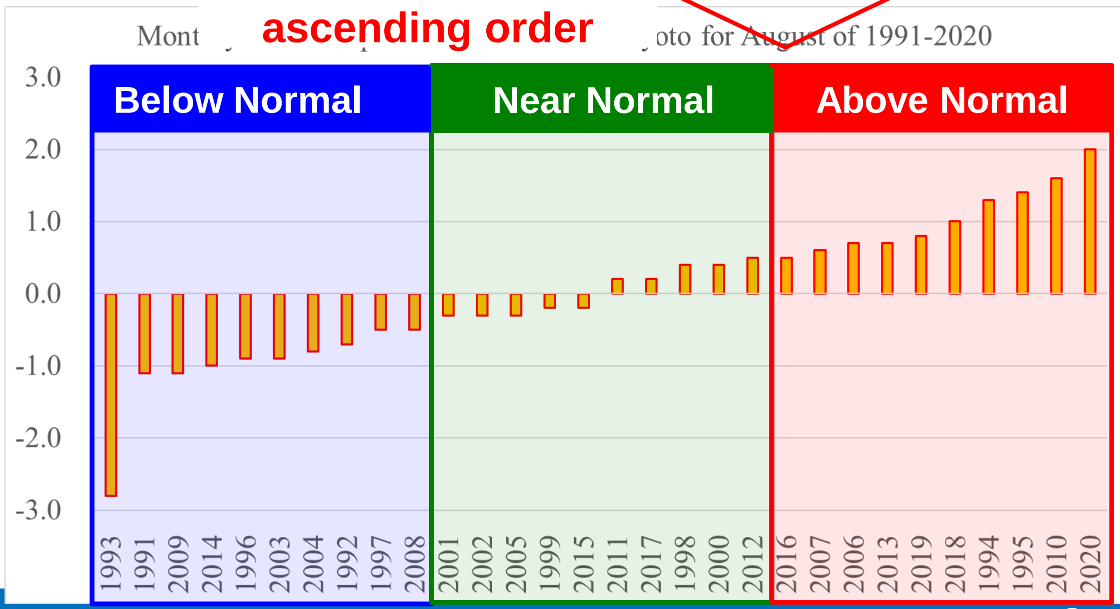
  21-30th (Above normal; AN)

Ex.

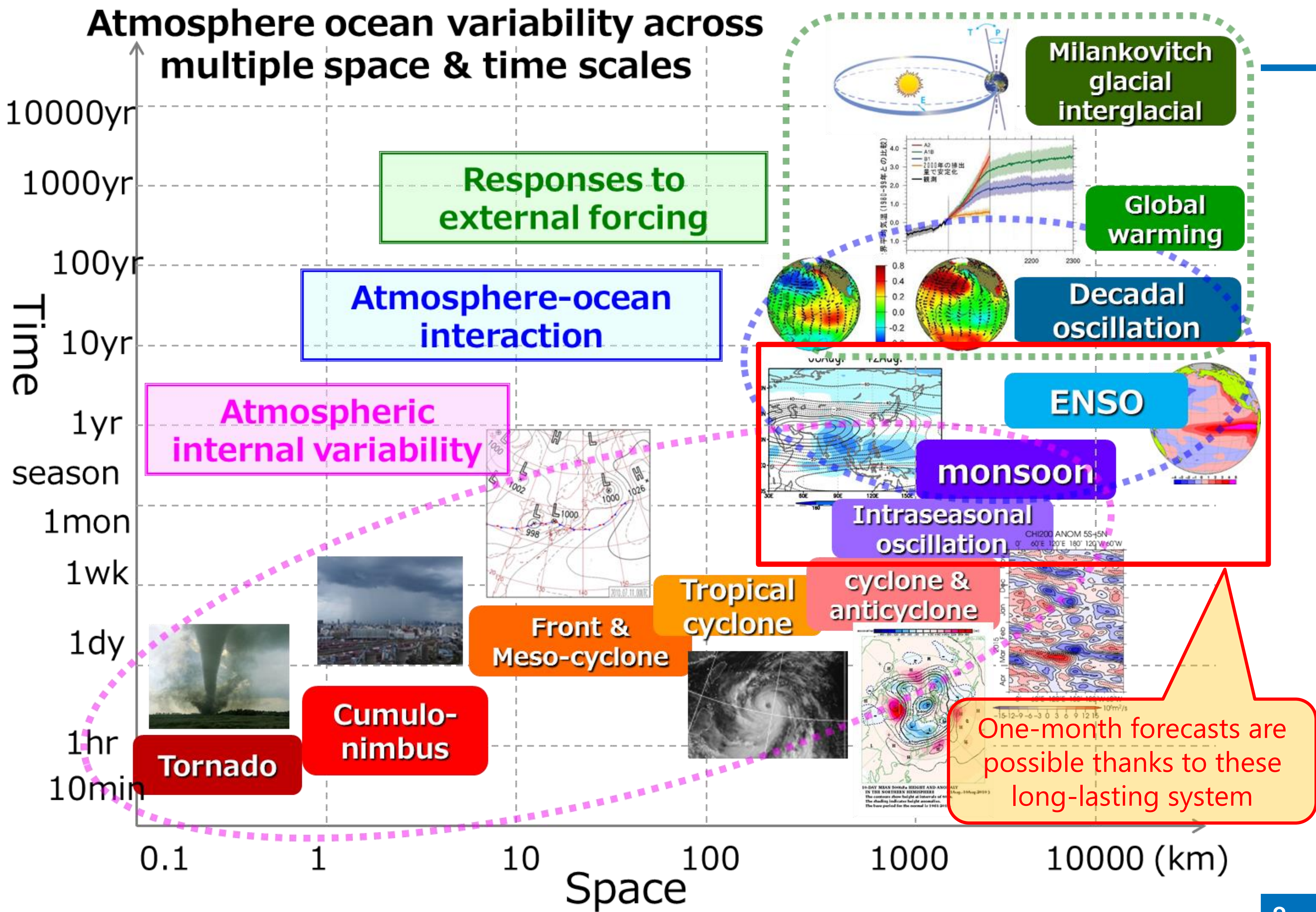
BN	NN	AN
20%	30%	50%



Sort by anomalies in ascending order



Brief introduction to climate dynamics



Atmosphere ocean variability across multiple space & time scales
Time
10000yr
1000yr
100yr
10yr
1yr
season
1mon
1wk
1dy
1hr
10min
Space
0.1
1
10
100
1000
10000 (km)
Responses to external forcing
Atmosphere-ocean interaction
Atmospheric internal variability
Milankovitch glacial interglacial
Global warming
Decadal oscillation
ENSO
monsoon
Intraseasonal oscillation
cyclone & anticyclone
Tropical cyclone
Front & Meso-cyclone
Cumulo-nimbus
Tornado
One-month forecasts are possible thanks to these long-lasting system

Stream function & velocity potential

- In discussing one-month forecast, we often encounter these figures.
- Decomposing wind into a rotational part and a divergent part (stream function and velocity potential) is useful to analyze atmospheric circulation.

$$v = v_{\psi} + v_{\chi}$$

Rotational wind blows parallel to contours of stream function, with low values of stream function to the left, regardless of the hemisphere.

H: high value
L: Low value

< Rotational wind >

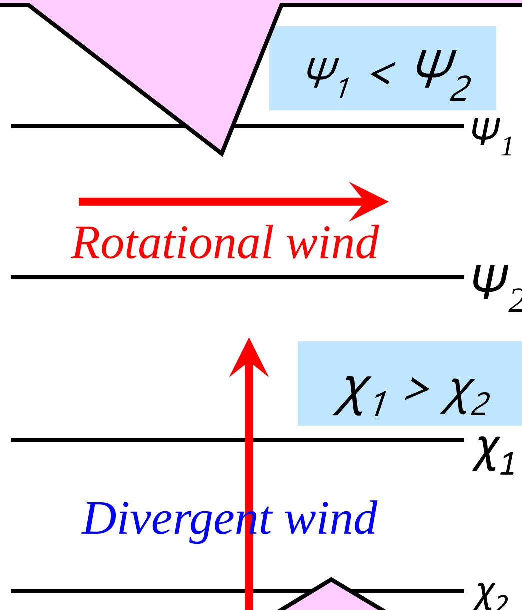
$$u_{\psi} = -\frac{\partial \psi}{\partial y}, v_{\psi} = \frac{\partial \psi}{\partial x}$$

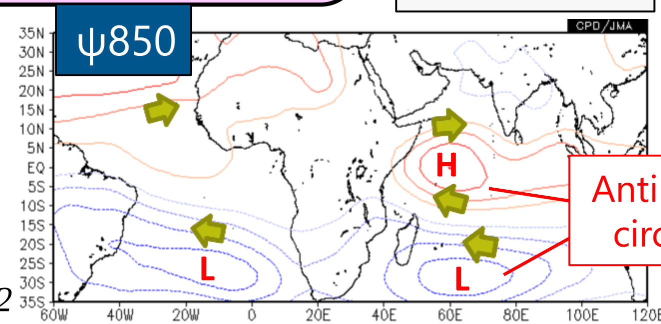
***Ψ*: Stream function**

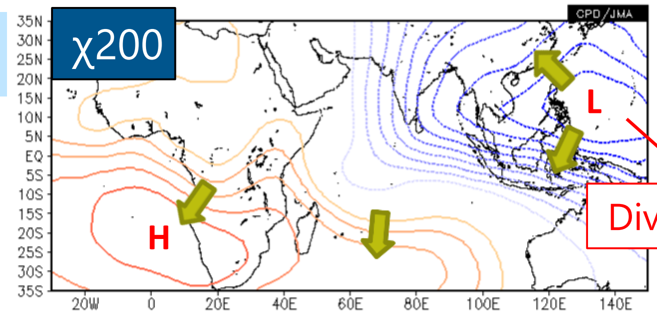
< Divergent wind >

$$u_{\chi} = \frac{\partial \chi}{\partial x}, v_{\chi} = \frac{\partial \chi}{\partial y}$$

***χ*: Velocity potential**



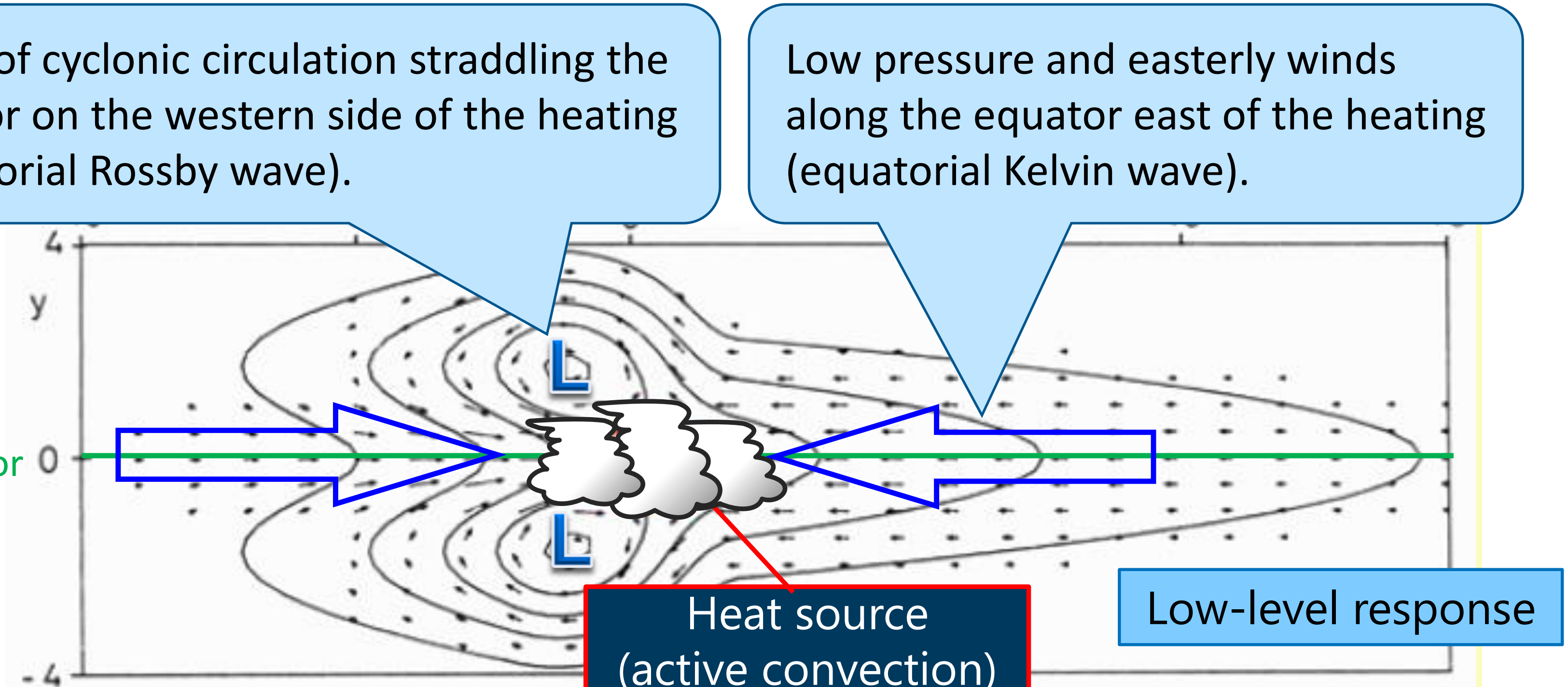




Divergent wind blows across contours of velocity potential, from areas of low to high velocity potential, regardless of the hemisphere.

Matsuno-Gill response (in the lower troposphere)

- Gill (1980) found how the tropical atmosphere responds to **diabatic heating** (i.e. convective activity).



Atmospheric response in the lower troposphere to the heating symmetric about the equator

Contours indicate perturbation pressure, and vectors denote velocity field.

Red circle indicates the position of the heating. (Source: Gill 1980)

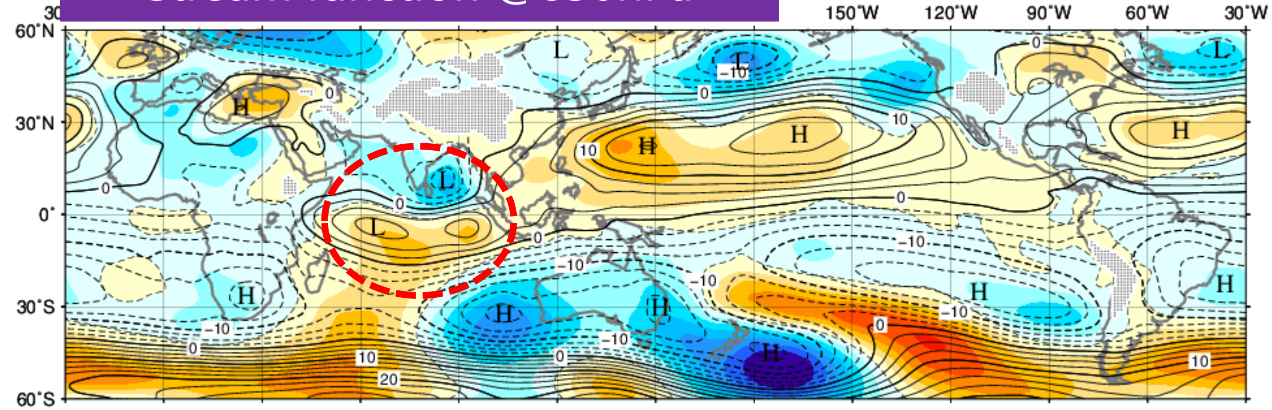
Upper-level response shows the reverse of the low-level response.

Example of Matsuno-Gill response

Atmospheric circulation anomalies averaged over 11-20 May, 2020

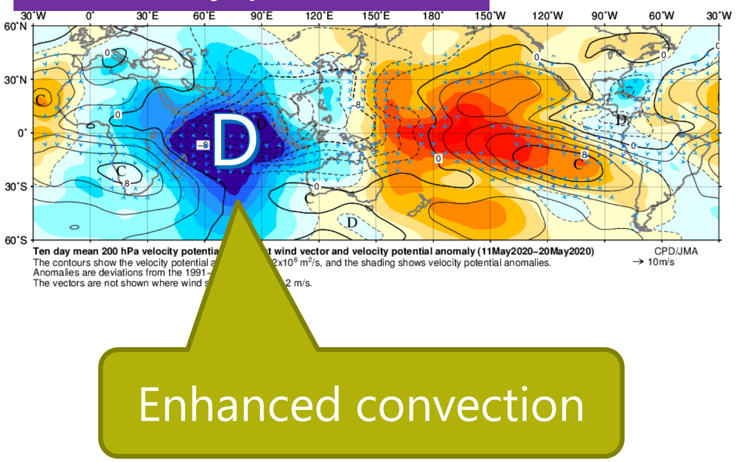
- Enhanced convective activity over the Indian Ocean
- In response, cyclonic circulation anomalies formed in the lower troposphere
- Low pressure area extended along the equator into the western Pacific

Stream function @850hPa

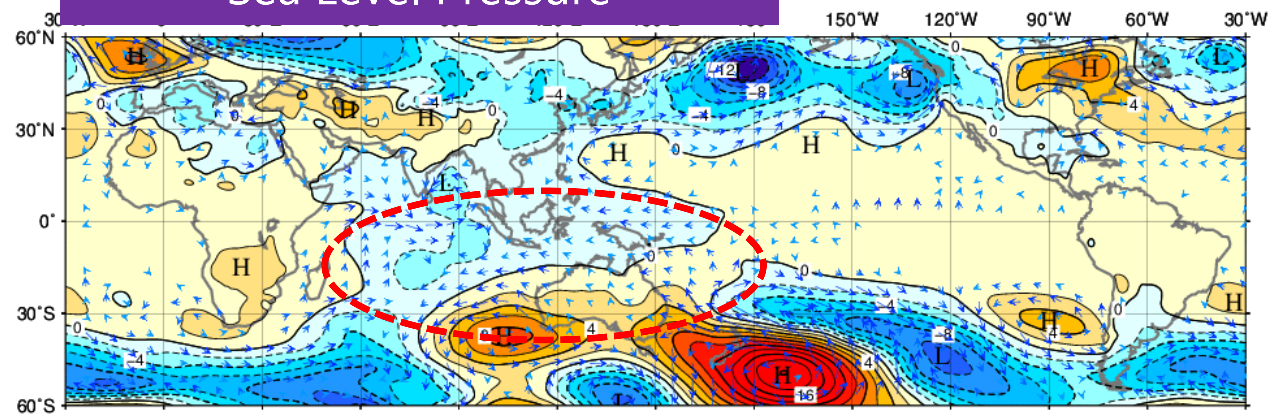


Ten day mean 850 hPa stream function and anomaly (11May2020–20May2020) CPD/JMA
The contours show the stream function at intervals of 2.5×10^{6} m^2/s, and the shading shows stream function anomalies.
The hatch patterns indicate areas with altitudes exceeding 1,600 m.
Anomalies are deviations from the 1991–2020 average.

Velocity potential



Sea Level Pressure

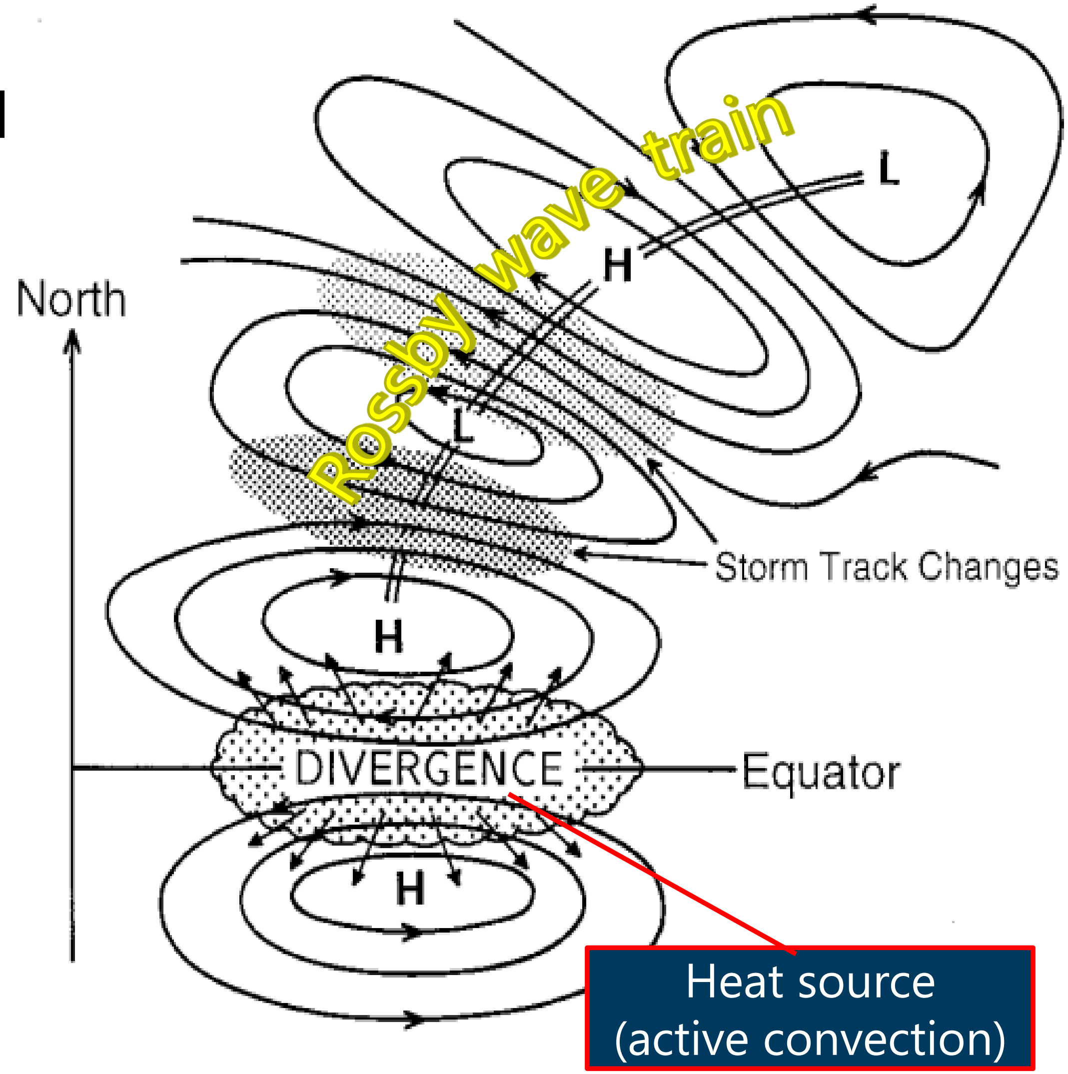


Ten day mean sea level pressure anomaly and surface wind vector anomaly (11May2020–20May2020) CPD/JMA
The contours show sea level pressure anomalies at intervals of 2 hPa. → 5m/s
Anomalies are deviations from the 1991–2020 average.
The vectors are not shown where wind speed is less than 1 m/s.

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

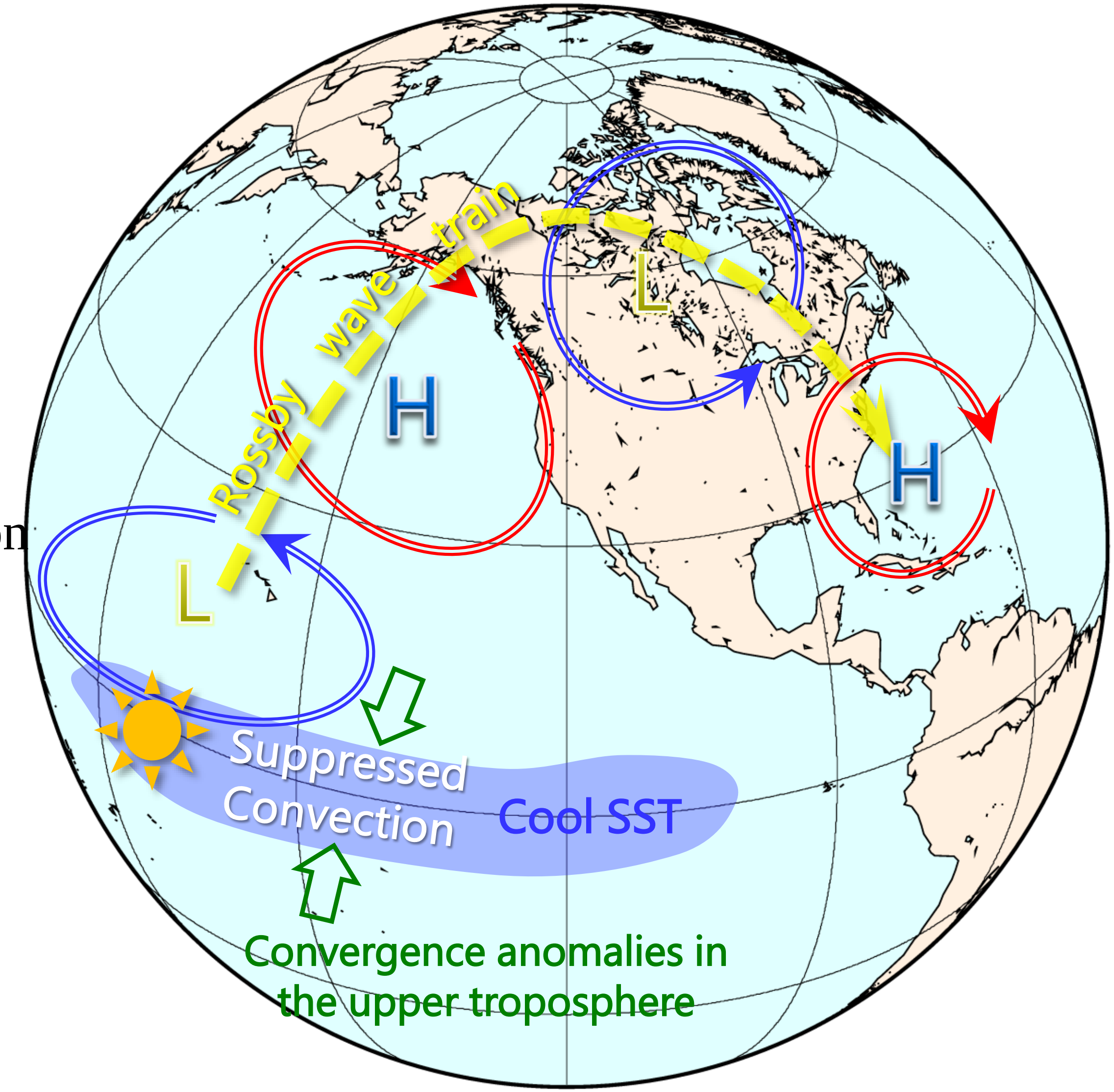
Response in the upper troposphere

- In the upper troposphere, an anti-cyclonic circulation anomaly forms to the north and south of enhanced convection.
- The circulation anomaly propagates poleward as a Rossby wave train.
- This sometimes causes anomalous weather conditions in remote areas in subtropics and higher latitudes.



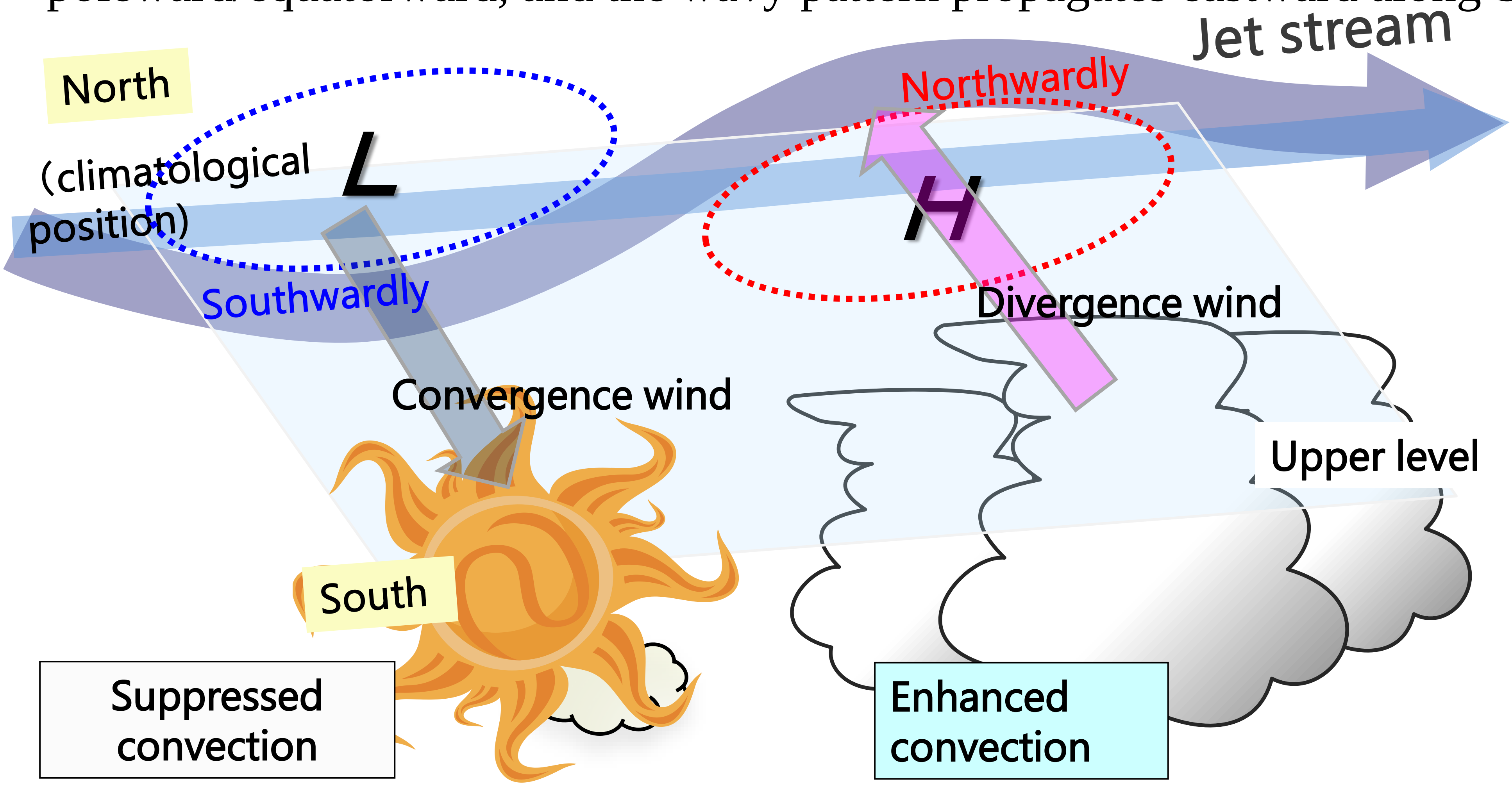
Response to suppressed convection

- Conversely, a **cyclonic circulation anomaly** forms to the north and south of **suppressed** convection
- This propagates poleward as a Rossby wave train and brings anomalous weather in higher latitudes.
- In other words, near-equator convection activity (whether enhanced or suppressed) provides a good signal for long-range forecasts
- In jargon of climate dynamics, this is called "**teleconnection**"



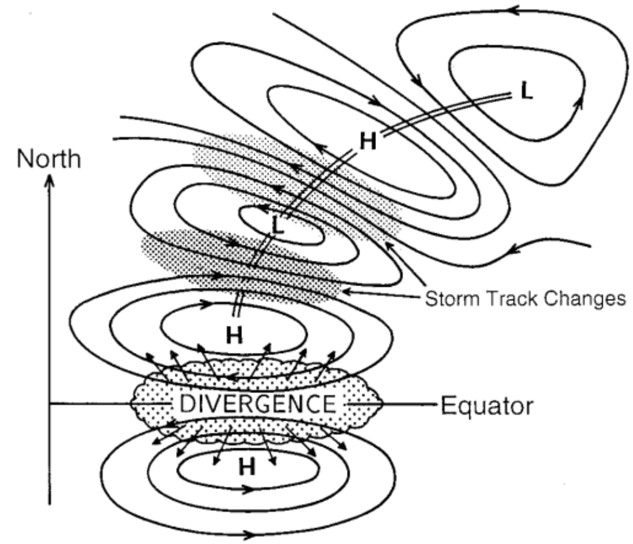
Convection changes jet stream

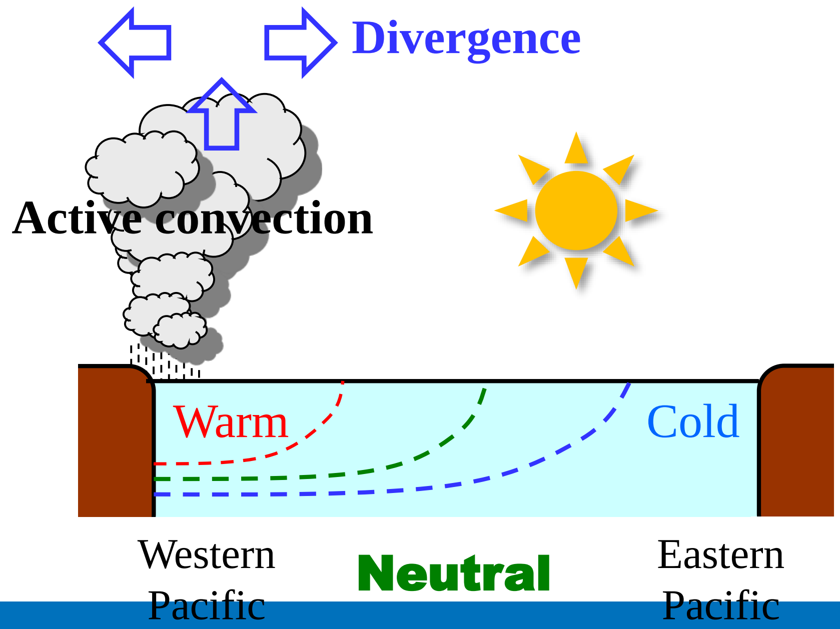
- The **subtropical jet stream (STJ)** flows poleward of tropics.
- In response to enhanced/suppressed convection, STJ meanders poleward/equatorward, and the wavy pattern propagates eastward along STJ.

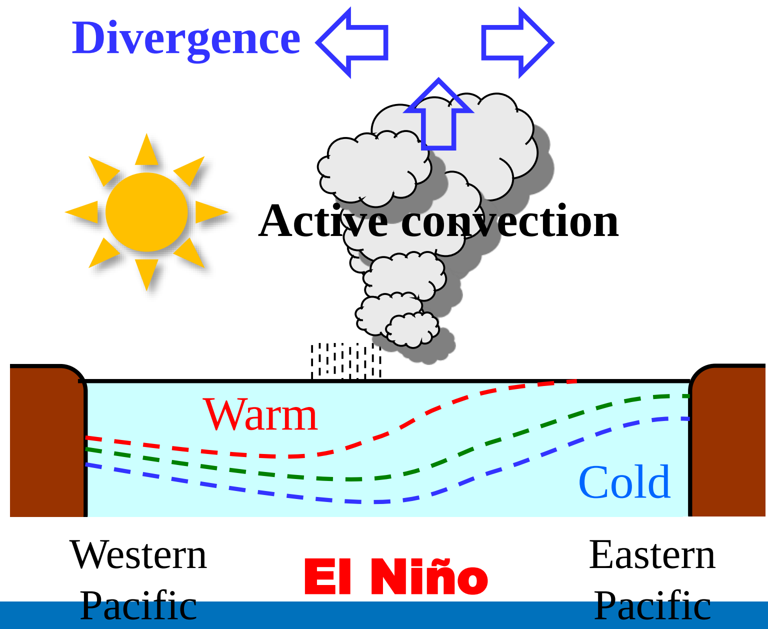


El Nino Southern Oscillation

- During an El Niño episode, a significant increase in SST over the central to eastern equatorial Pacific is observed.
- The warmer SSTs induce active convection to shift eastward along the equator.
- These convection anomalies give rise to Rossby waves (Matsuno-Gill!)
- Rossby waves propagate over a large distance and influence the global atmosphere

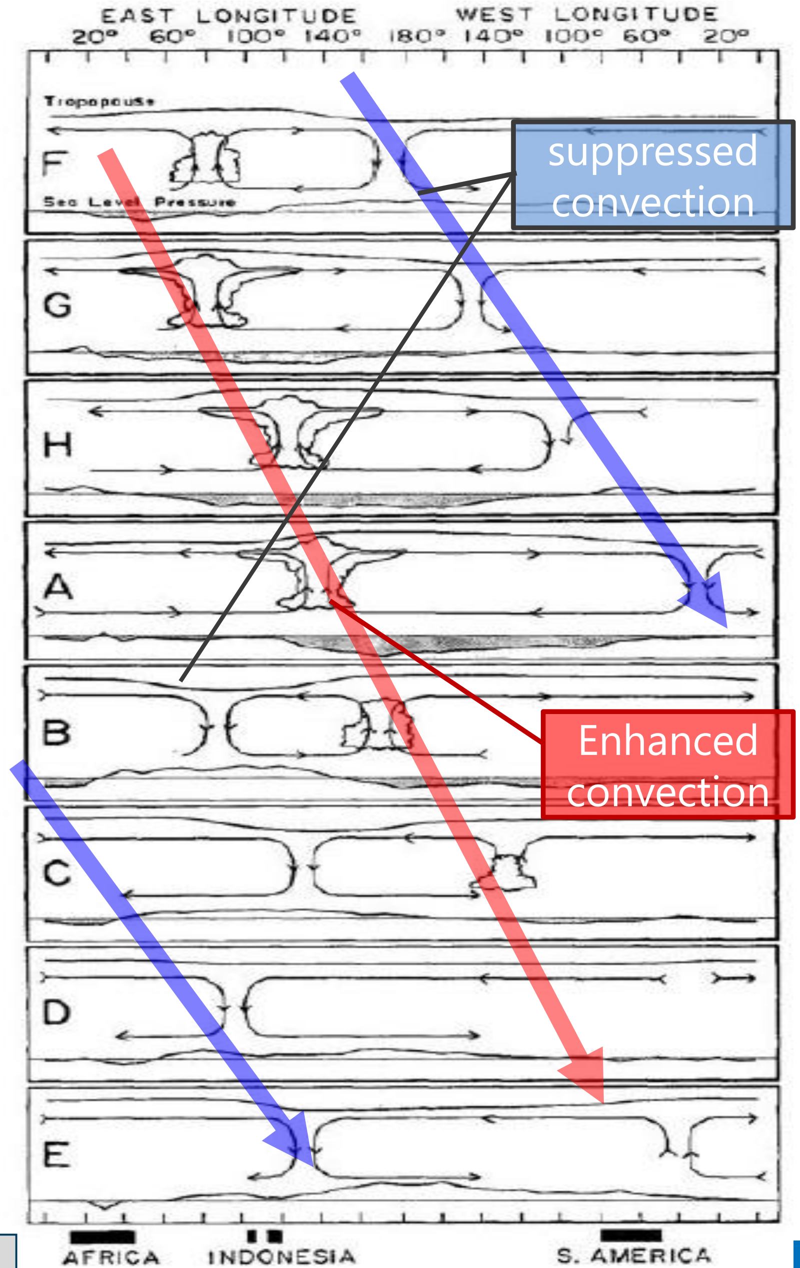






Madden-Julian Oscillation (MJO)

- MJO is a planetary scale wave of enhanced and suppressed convection extending east-west along the equator
- The most dominant signal over the tropics on weekly to monthly timescale.
- MJO propagates eastward along the equator, taking 30 – 60 days to go around the globe.
- In response to MJO, circulation anomalies form and propagate poleward or eastward. This provides key to one-month forecasts
- MJO is monitored with 200hPa velocity potential (upper-level divergence) field

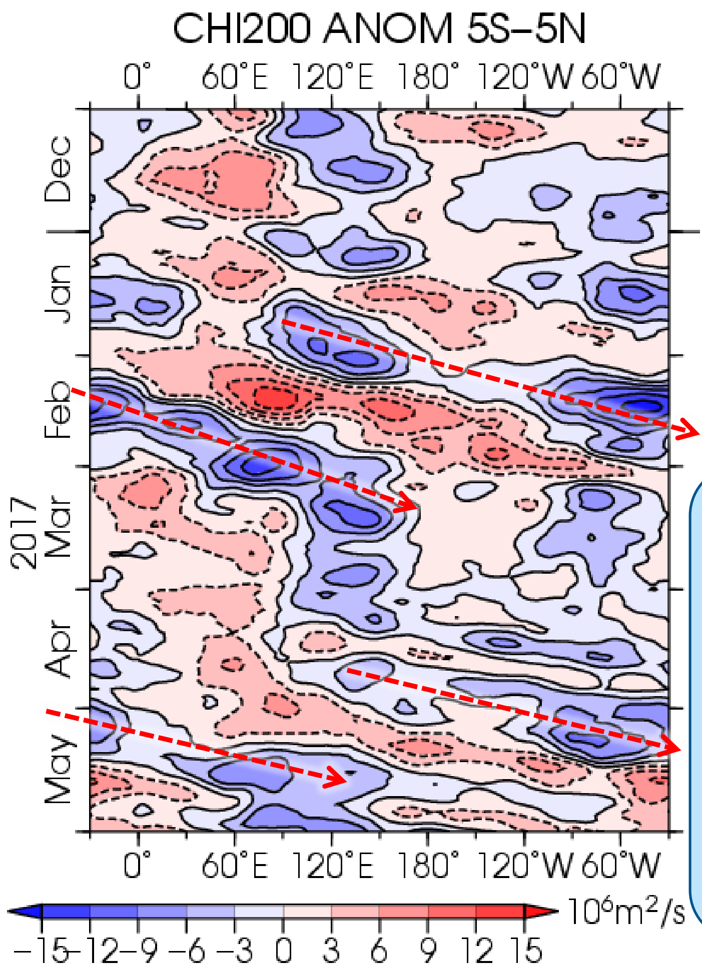


Original; Madden and Julian (1972) Fig.16

How to detect MJO?

Propagation of MJO is visualized through Hovmöller diagram and phase diagram

Time-longitude section of **chi200** anomaly along the EQ.

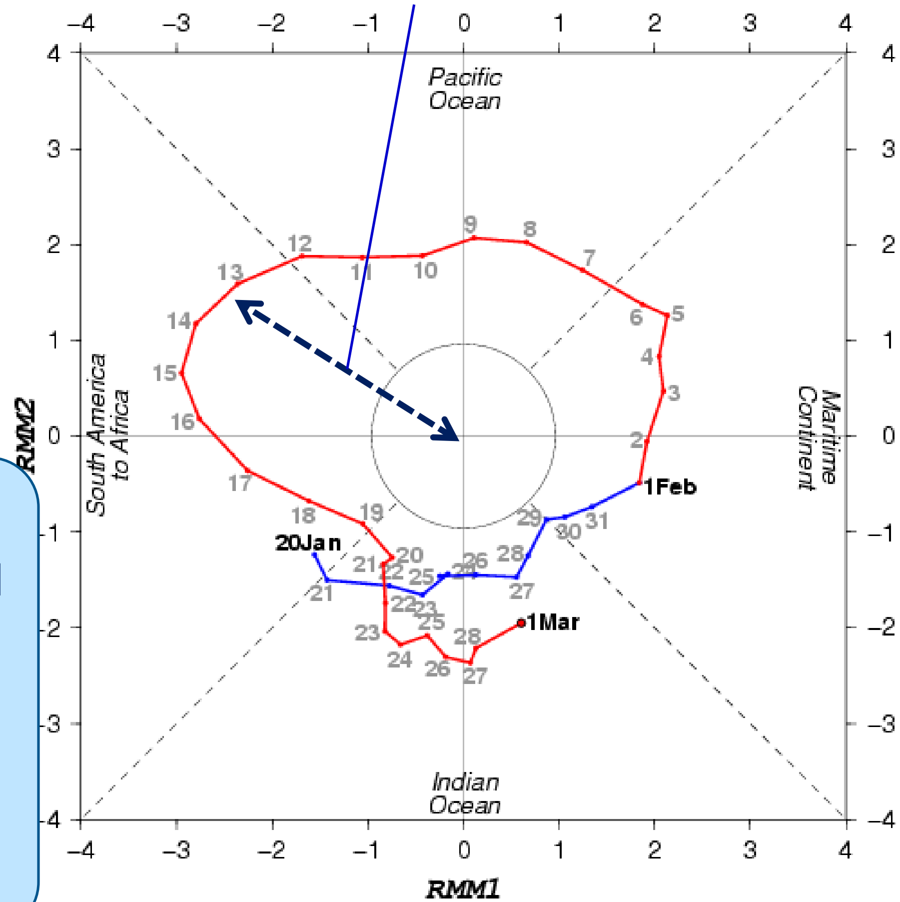


Blue: Upper-level Divergent anomaly
Red: Convergent anomaly

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

phase diagram

Amplitude: distance from the center



http://ds.data.jma.go.jp/tcc/tcc/products/clisys/mjo/monitor.html

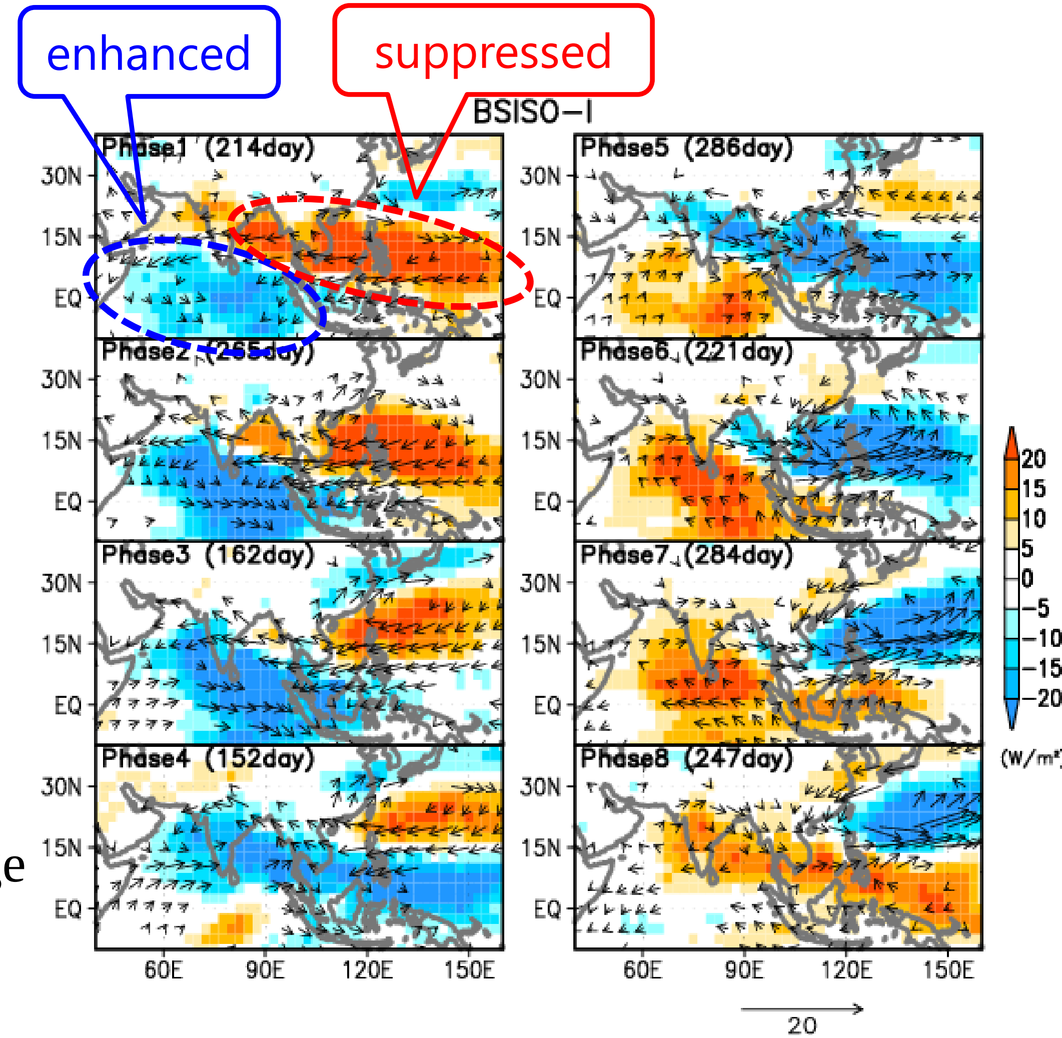
Another "Oscillation" - BSISO

- During (northern hemisphere) summer, enhanced or suppressed convection is seen to **propagate northward**, instead of eastward, over the Indian Ocean and the western Pacific

- This is called "**B**oreal **S**ummer **I**ntra-**S**easonal **O**scillation".

- BSISO can have as much impact on weather conditions as MJO across Asia

- This is another factor key to extended-range forecasts

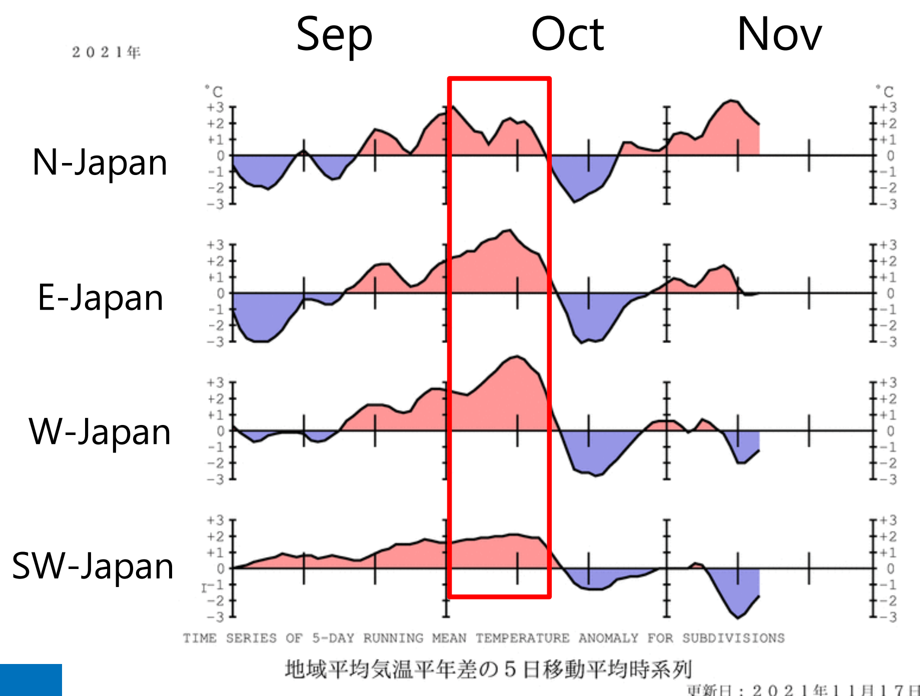


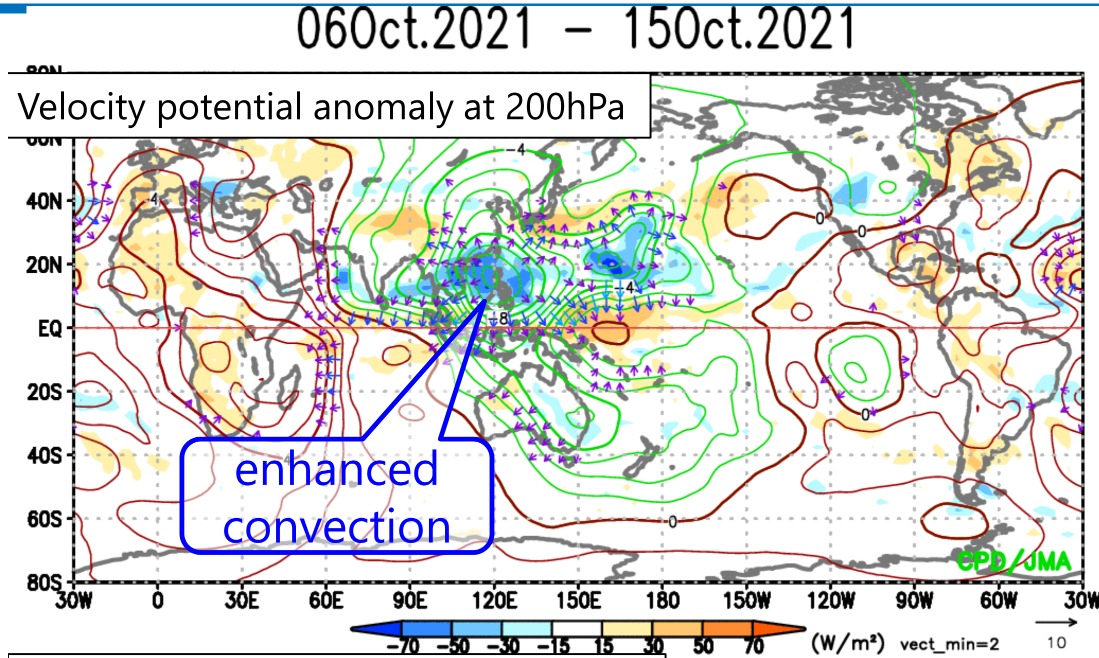
typical time evolution of BSISO

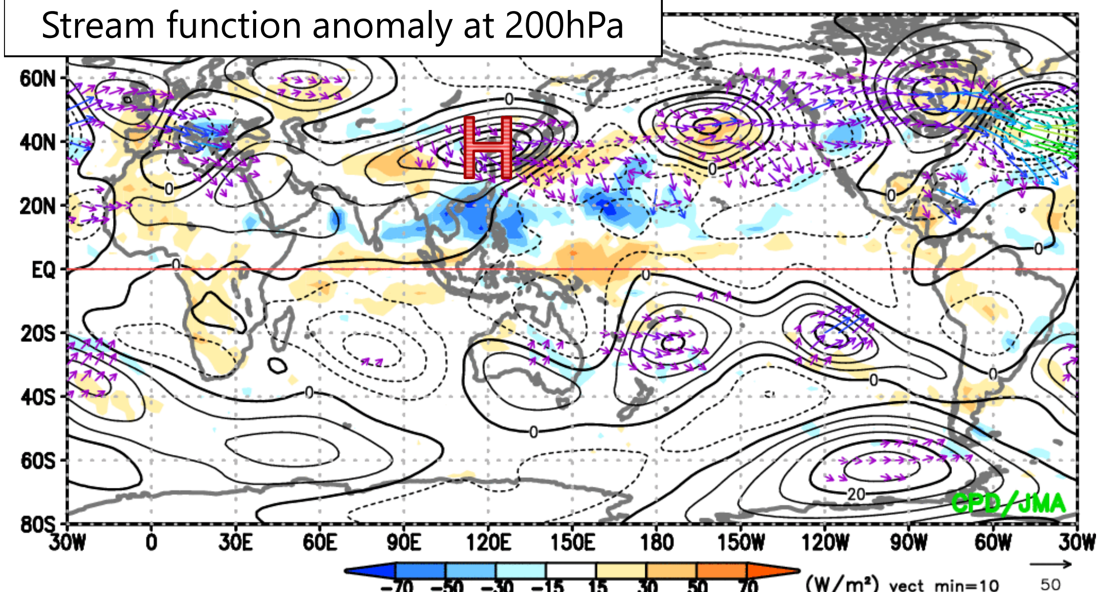
Recent notable weather events

- Early last October, Japan experienced very warm weather exceptionally for the time of the year.
- This is due to anti-cyclonic anomalies persistent over the country
- The cause of these anomalies is traced back to enhanced convection over the South China Sea to the western Pacific.

5-day running average temperature anomalies

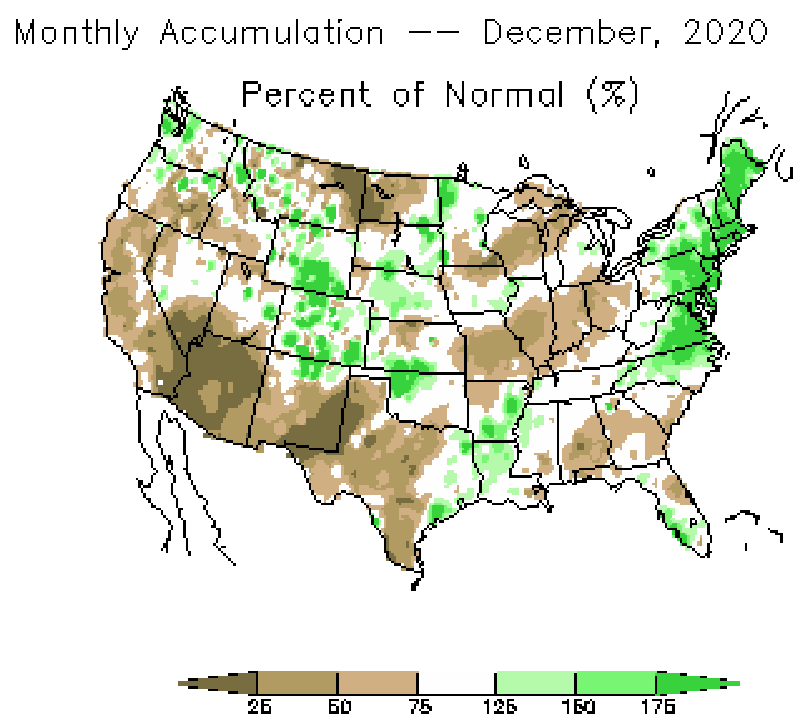




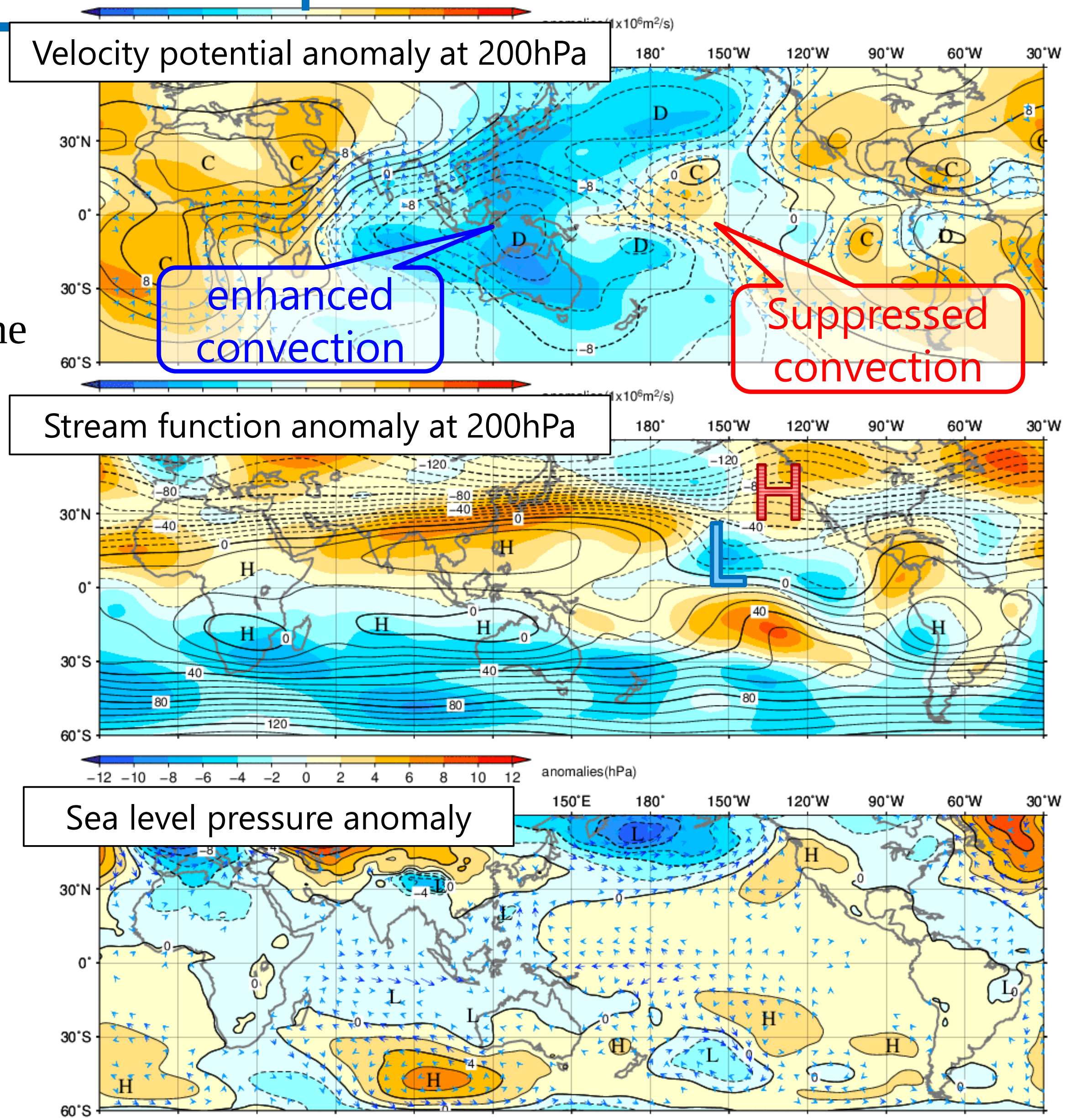


Recent examples

- Dec. 2020 brought notably dry weather to the southwest U.S.
- This is attributable to intense anti-cyclone persistent over the region.
- The cause of the anomalous anti-cyclone can be traced back to the suppressed convection in the tropics.



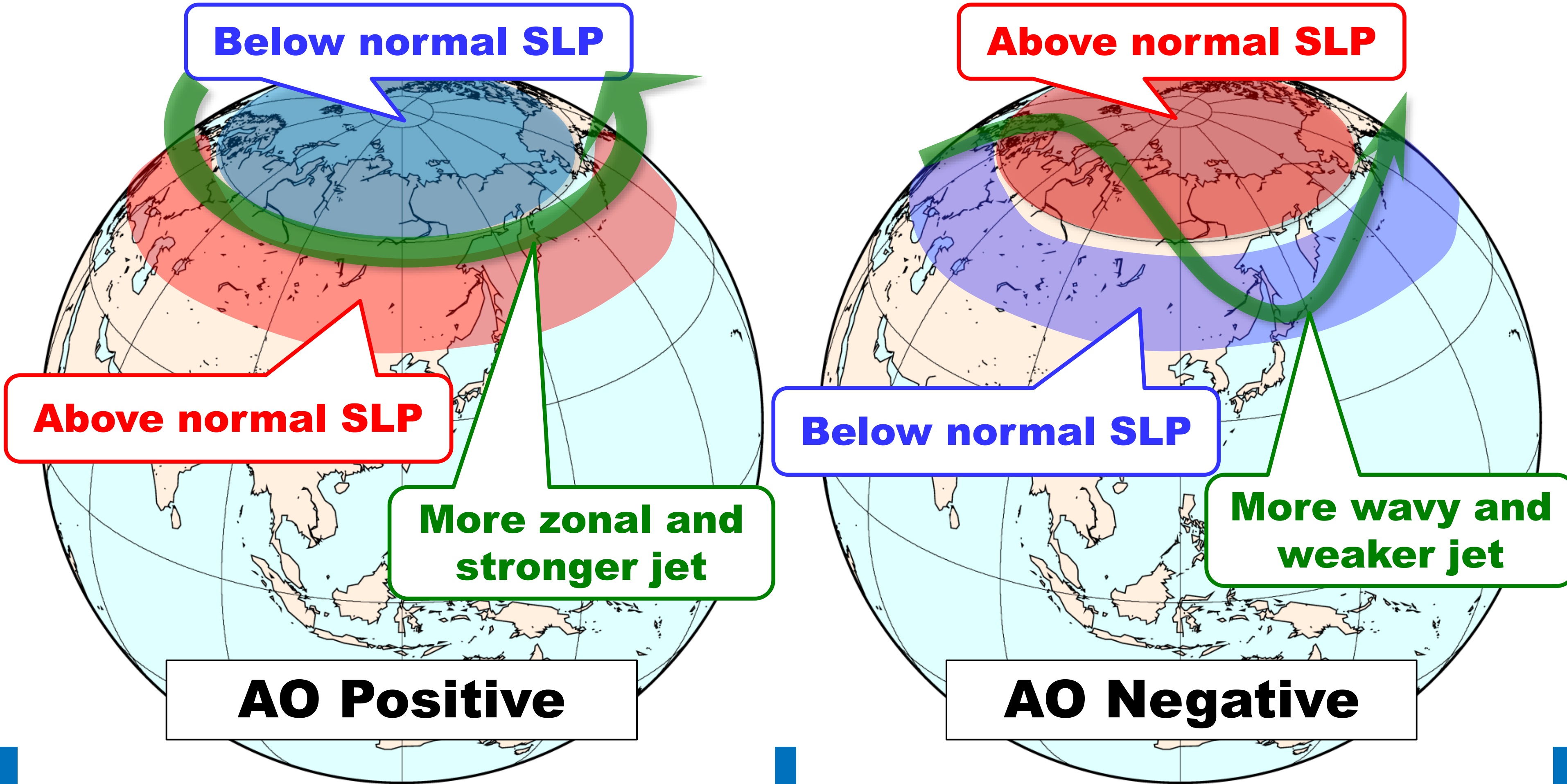
From NOAA CPC



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

Oscillation in mid- and high latitudes (AO)

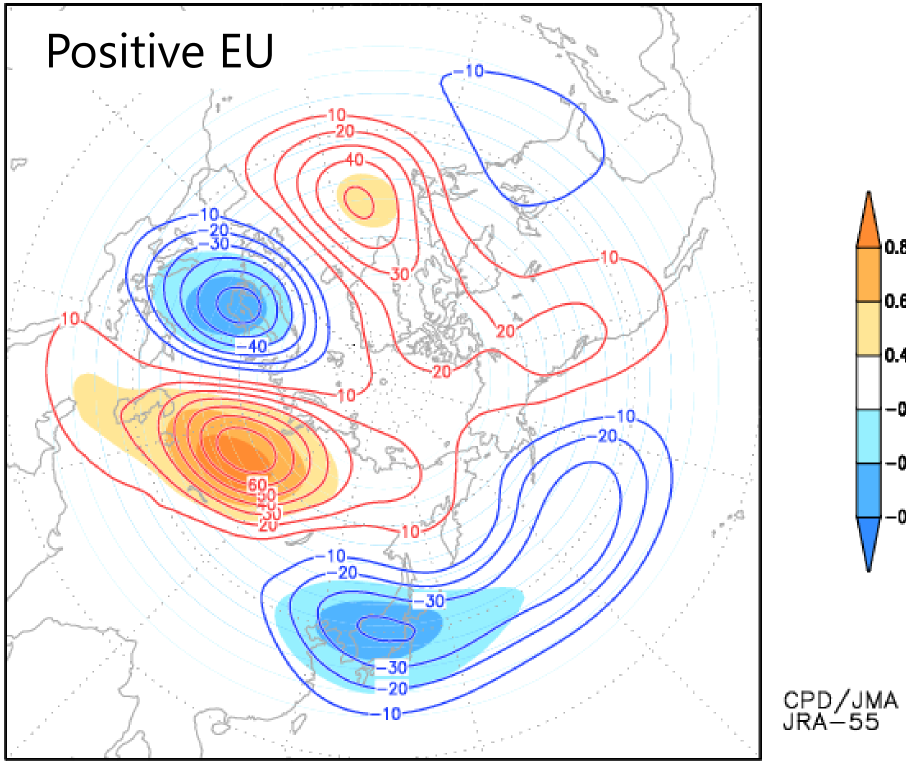
- A seesaw-like oscillation of pressure anomalies between the Arctic and mid-latitudes which dominates climate variability in boreal winter.
- In a positive phase of AO, cold air mass tends to be confined in the Polar region, leading to a warm winter in mid-latitudes.
- In a negative phase of AO, cold air mass flows southward from the Polar region, leading to a cold winter in mid-latitudes.

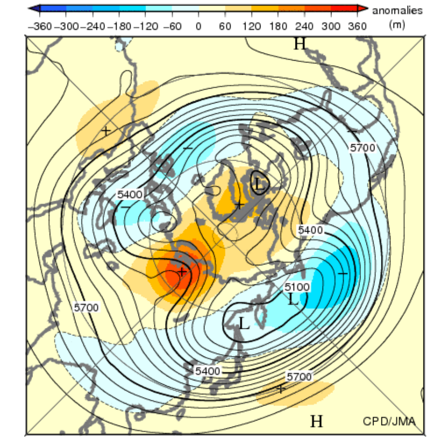


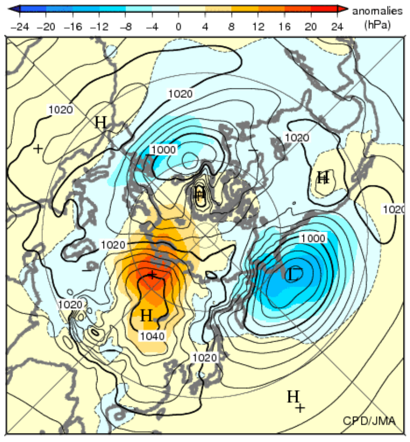
Eurasia (EU) pattern

- Rossby wave train along the Polar Front Jet (PFJ), with a ridge over western Siberia and troughs over Europe and East Asia.

- When this pattern appears, Siberian High intensifies and brings cold air outbreak to East and Southeast Asia.







Methodology for JMA's one-month forecast

JMA's extended & long-range forecast models

Type of forecast	1 month	3 months	6 months
Daily Forecast			
One-week Forecast			

Extreme climate early warning
5-14 days ahead
Every Monday and Thursday
Temp. (very high or very low)
Snowfall (very heavy (in winter))

One-month Forecast

M1		
W1	W2	W34

Every Thursday
Temp. Precip. Sunshine Snowfall

Three-month Forecast

M123 (3-month average)		
M1	M2	M3

Around 25th of the month

Warm-season Forecast
Around 25th of February
Summer (JJA)

Cold-season Forecast
Around 25th of September
Winter (DJF)

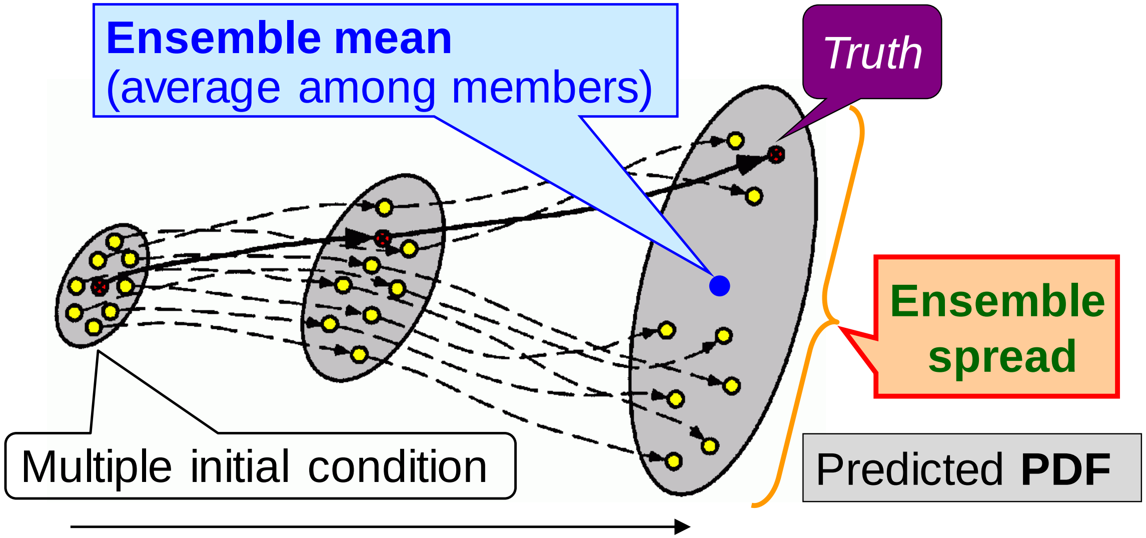
El Niño Outlook
Around 10th of the month
up to 6 months ahead

Global Ensemble Prediction System (Atmospheric model)

Seasonal Ensemble Prediction System (Atmosphere-ocean coupled model)

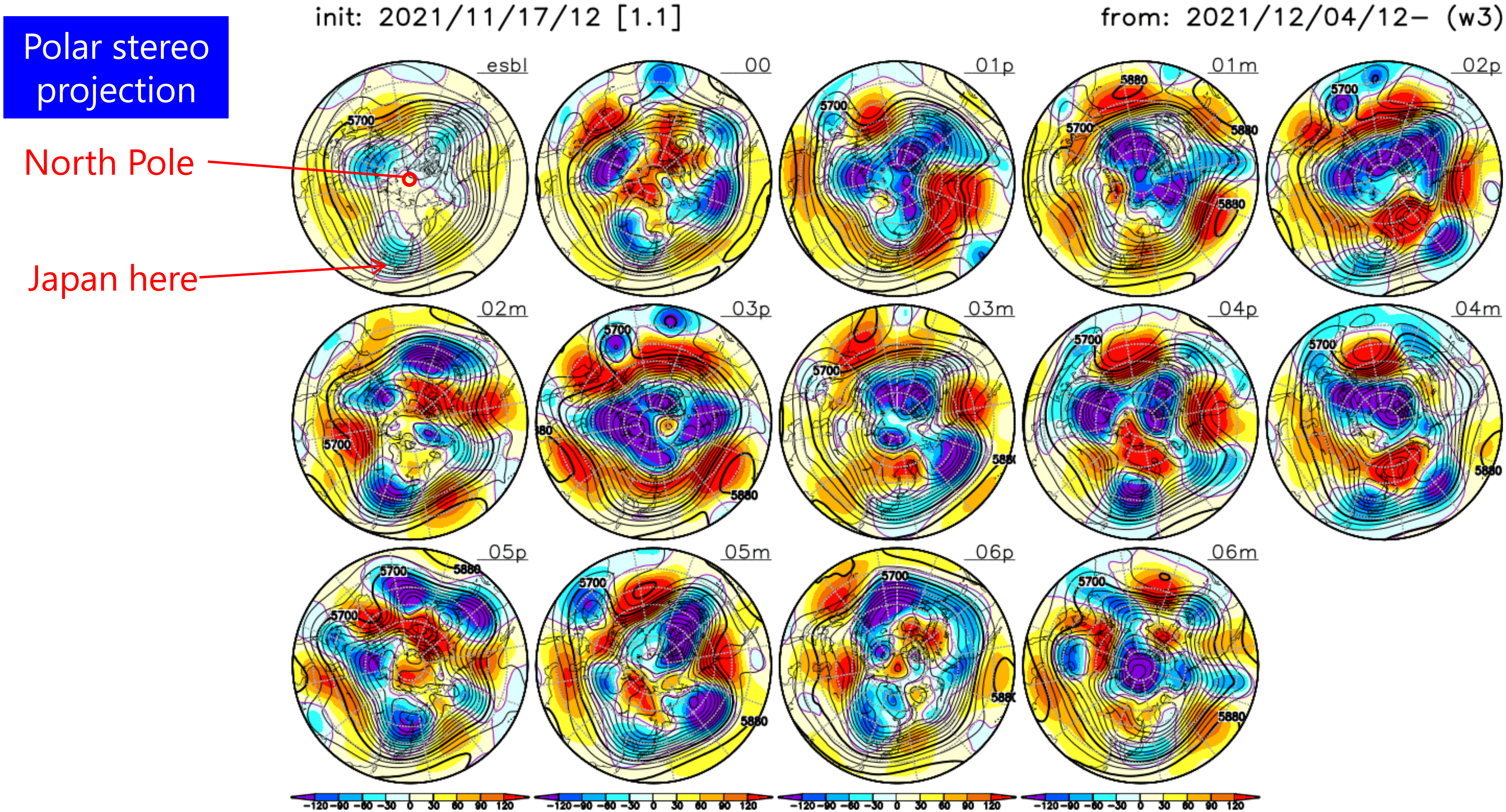
Concept of ensemble prediction

- The atmosphere and ocean is a chaotic system
- Even the tiniest error in an initial condition grows rapidly and errors are unavoidable
- This nature disrupts deterministic numerical prediction beyond about two weeks
- To produce a seasonal forecast, "**ensemble prediction**" is indispensable.
- Ensemble prediction system (EPS) starts with similar, but slightly different, multiple initial conditions, and produces multiple forecasts.
- With the results from EPS, we can get the most likely atmospheric conditions (ensemble mean) in future, along with an estimation of degree of uncertainty (spread)



The individual calculation is called "Ensemble member" and the standard deviation among all members is called "Ensemble spread".

Example of individual ensemble members

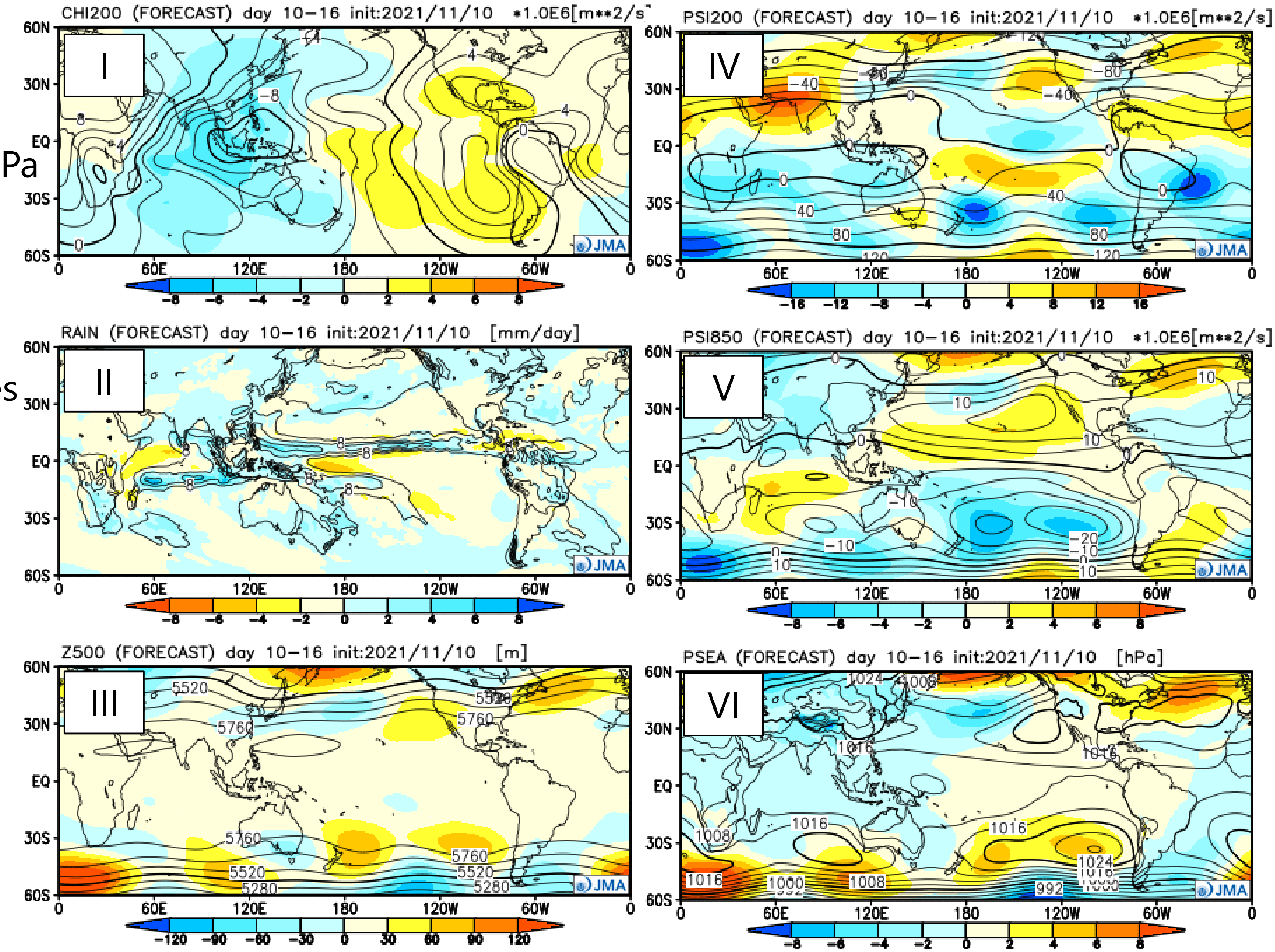


Geopotential height anomalies at 500hPa for the week-3 forecast of 1-month prediction run, initialized on 17, Nov. 2021. The ensemble mean and 13 members out of 51 are shown.

Ensemble means of :

I : Velocity potential at 200hPa
II: Precipitation
III: Geopotential height at 500hPa
IV: Stream function at 200hPa
V: Stream function at 850hPa
VI: Sea level pressure

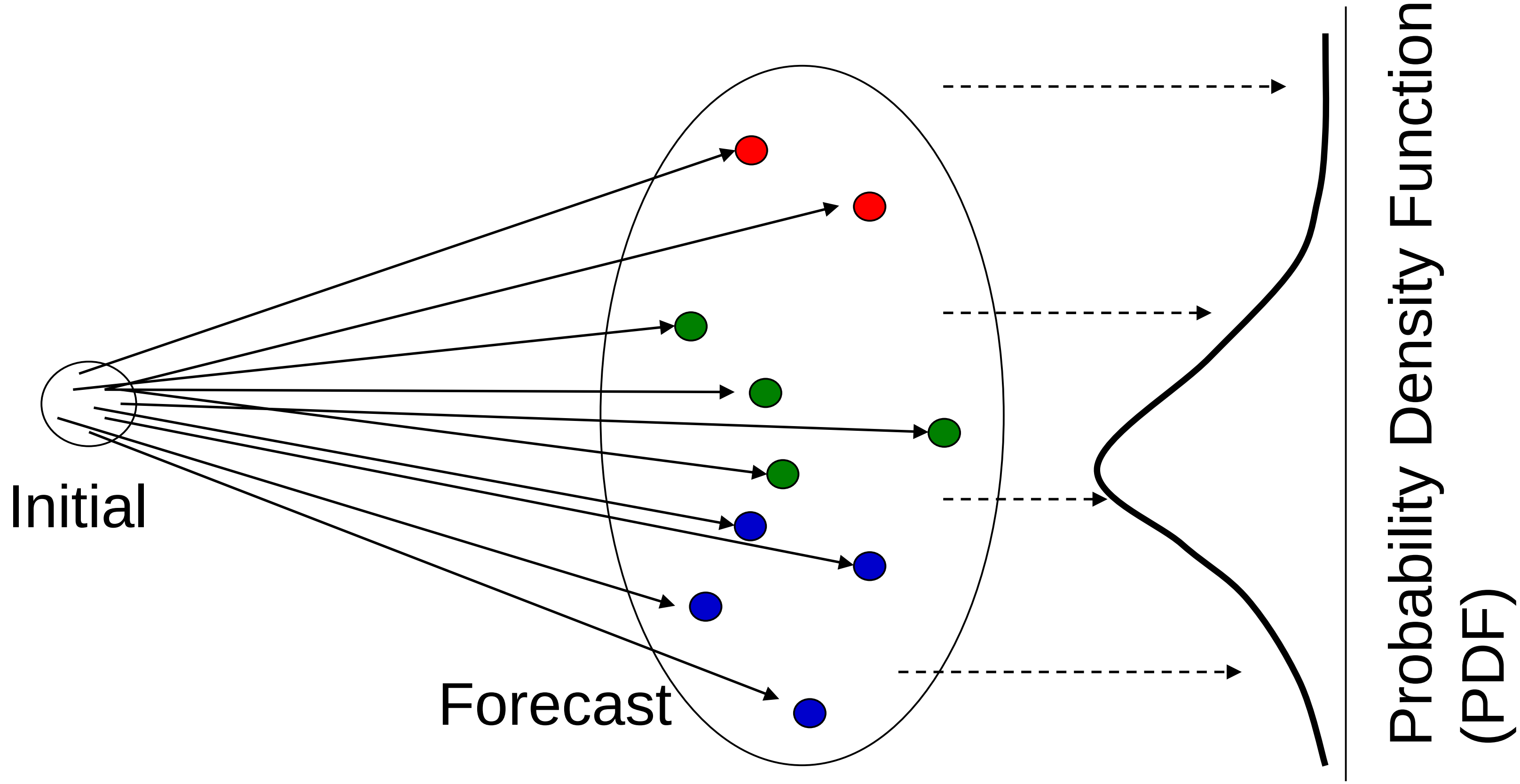
Color shades indicate anomalies



Available at: https://ds.data.jma.go.jp/tcc/tcc/products/model/index.html

From ensemble to probability forecast

- From results of EPS, a probability distribution can be derived
- The probability distribution can be translated into, say, a three-category forecast in the form of above/near/below normal.



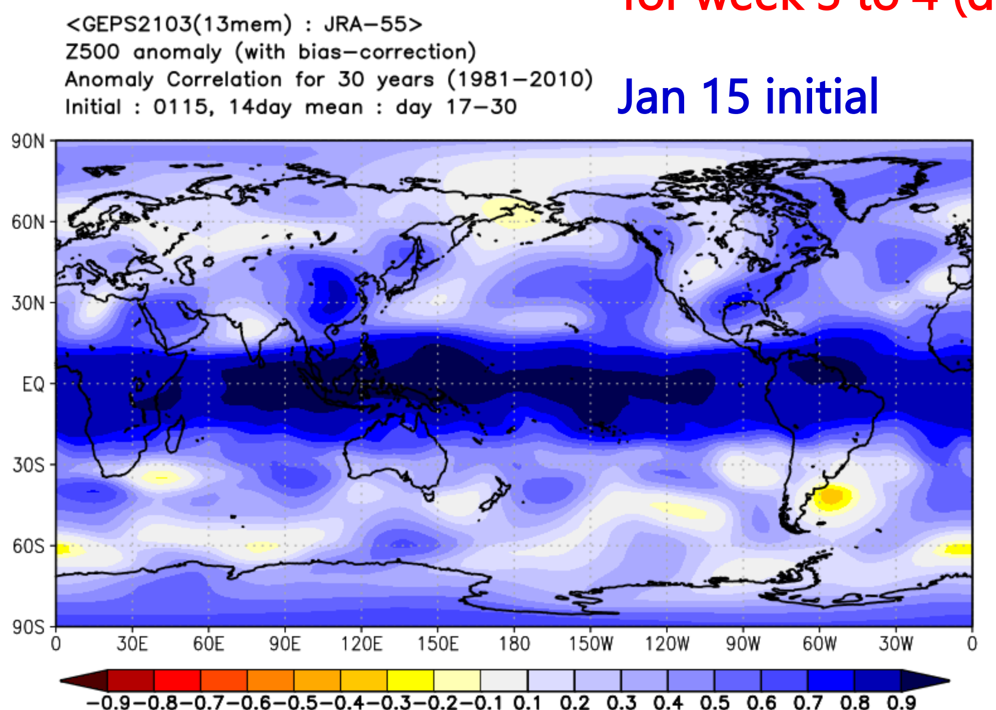
Verification of JMA Ensemble Prediction System

In general,
- Better forecast skill in (boreal) winter than in summer
- Better forecast skill in tropics than in higher latitudes

Forecasters need to be aware of where and how numerical model skills are good and poor!

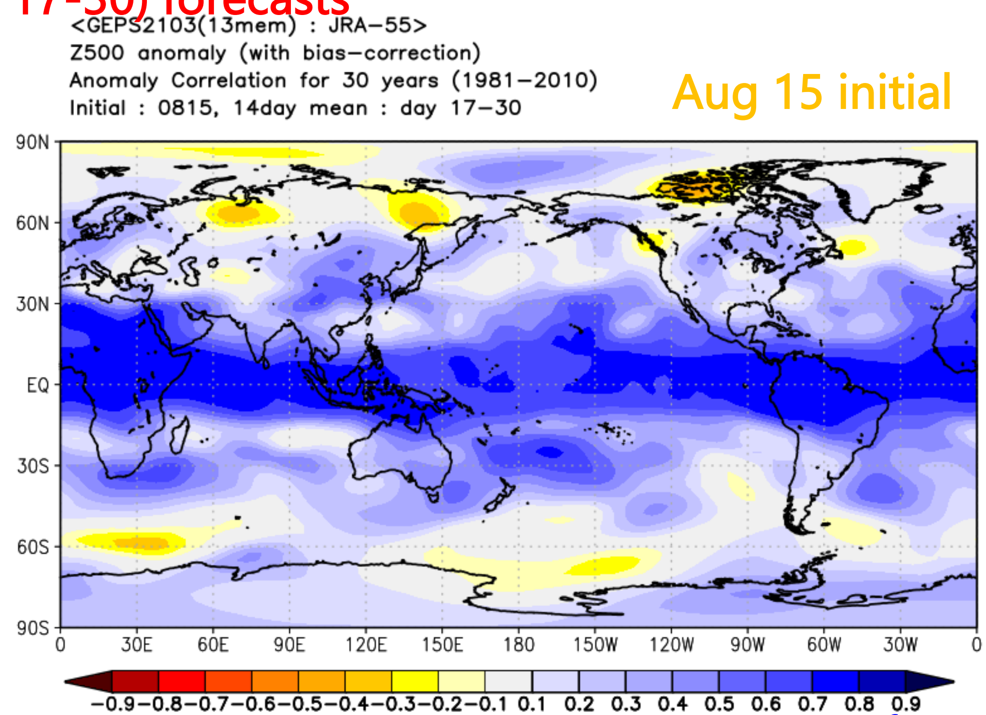
Anomaly correlation for geopotential height at 500hPa for week 3 to 4 (day 17-30) forecasts

Jan 15 initial



Poor Perfect

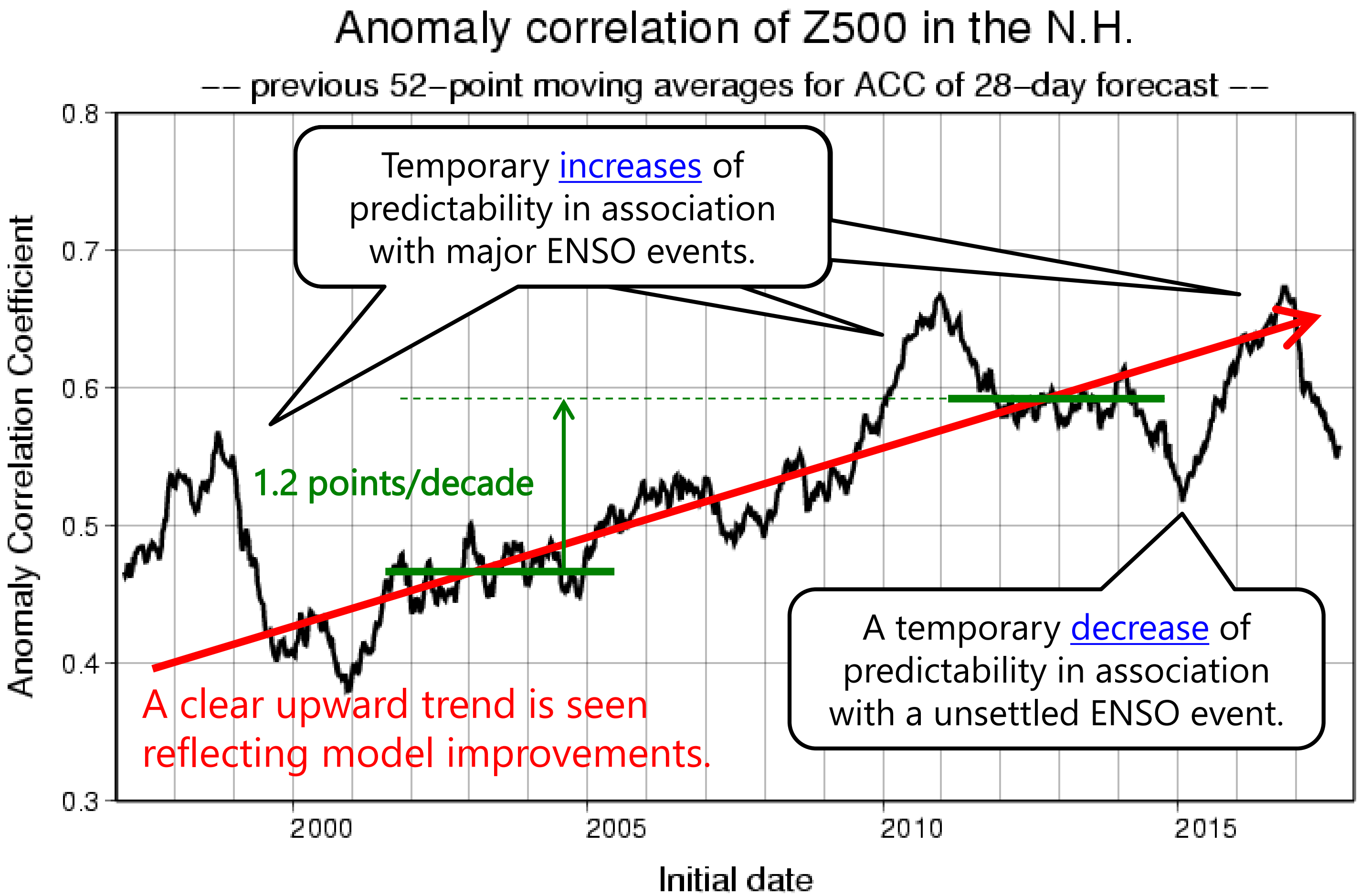
Aug 15 initial



Poor Perfect

https://ds.data.jma.go.jp/tcc/tcc/products/model/hindcast/1mE.GEPS2103/tro_acor.html

Model skill gradually gets better

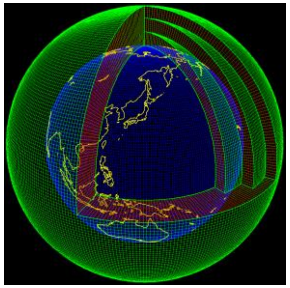


0.6 is the limit for deterministic forecast.

0.3 is the limit for probabilistic forecast.

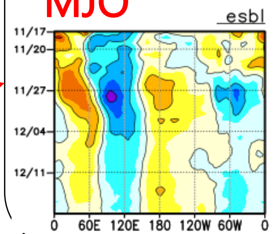
Steps in the process to produce one-month forecast

Ensemble Prediction System

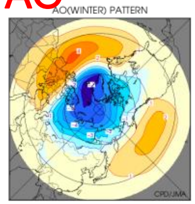


Expected evolution of major modes

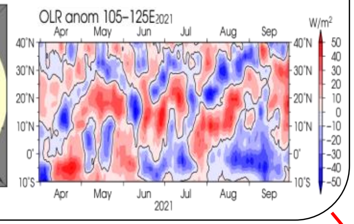
MJO



AO



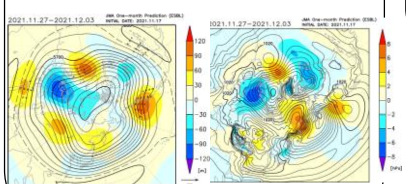
BSISO



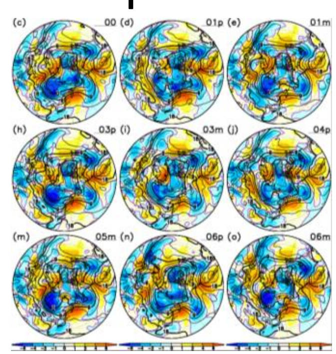
Guidance

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

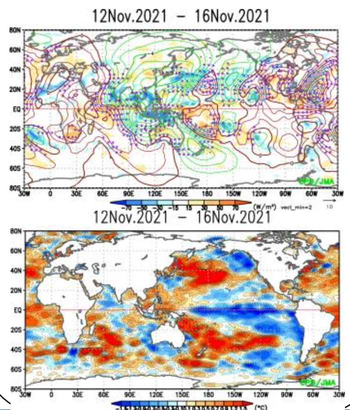
Circulation anomalies



Spread



Current state

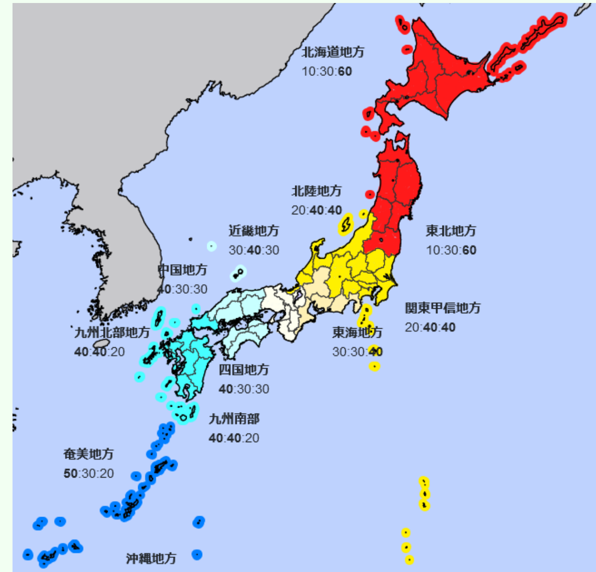


forecasters

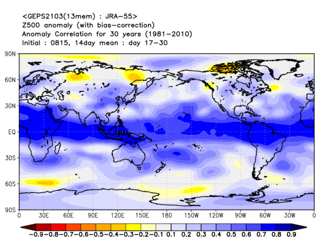
Interpretation
Explanation
Reliability
Modification

decision

Official forecasts



Verification



Steps to produce one-month forecast (in text)

0. Before starting to think about forecasts, be aware of what's going on in the current atmosphere and ocean.

1. See results from the numerical model prediction;

- Expected evolution of the major oscillation modes; ENSO, MJO, BSISO, AO, …
- Atmospheric circulation anomalies globally and over your country
- Degree of uncertainty (spread among individual ensemble members)

2. Think how do you interpret and explain these predicted modes and anomalies.

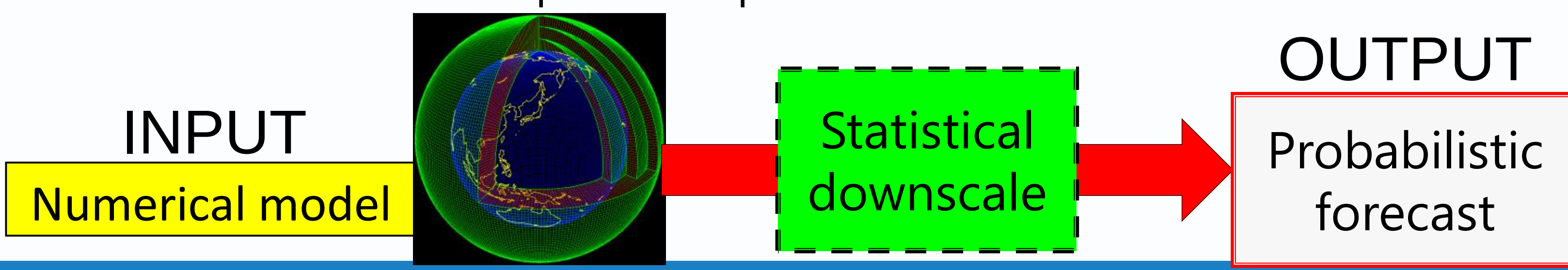
- Judging from the verification data, model prediction skill is sufficient or poor?
- Are you sure the model prediction is sufficiently reliable? If not, what aspect is questionable and why?
- Can the predicted anomalies be interpreted and explained in terms of climate dynamics?

3. Look to guidance (this is a topic of next day's lecture)

4. Adjust and modify the prediction if needed.

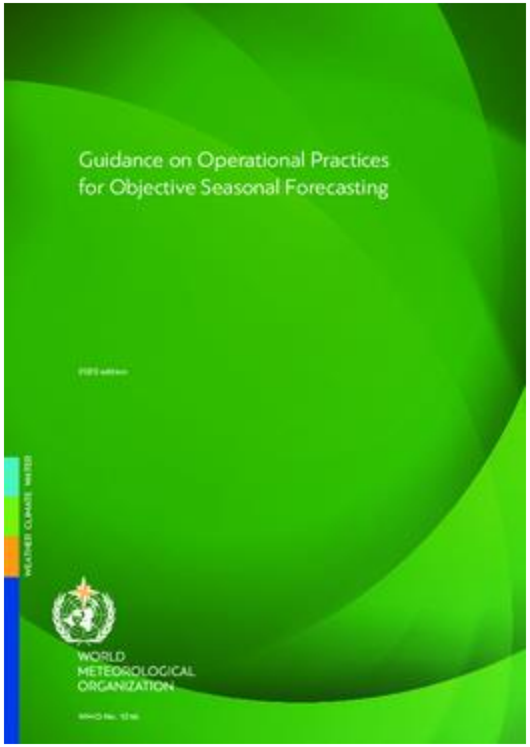
5. Assign probability to above/near/below normal categories.

- Guidance is used to translate raw model outputs into forecasts more understandable and manageable to human forecasters
- This relies on statistical relationship between past forecasts and observations.



Objective forecast? Need forecaster's intervention?

WMO's Guidance on Operational Practices for Objective Seasonal Forecasting



https://library.wmo.int/index.php?lvl=notice_display&id=21741#.YZYmpbpUuUk

In the seasonal process recommended above, while it has been a routine practice to take forecast products from GPCs-LRF or LC-LRFMME and ***frequently modify these products manually, this practice is not encouraged without (a) strong justification, (b) relevant expertise and (c) proper documentation***. If the above-mentioned forecast products are modified manually, the modifications should be carried out using methods which have been previously documented and have led to improvements in seasonal forecasts. A manual modification of a forecast should be supported by a detailed and transparent discussion of climate drivers, and all forecasts should be verified as per standard practices; this verification should include documenting the skill of the MME and using statistical forecasts as the baseline over which manual intervention shows improvement. ***The process of manual intervention requires significant knowledge and expertise to be able to improve on the MME and statistical forecasts and detailed knowledge of global, regional and local drivers of climate variability and teleconnections.***


Thank you