Introduction to Seasonal Forecast

Hiroaki Natori
Senior Forecaster for Seasonal Forecast
Tokyo Climate Center
Japan Meteorological Agency

Janualy 30, 2024
TCC training course

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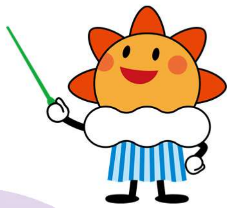


What a seasonal forecast is

Classification of weather and climate forecasts

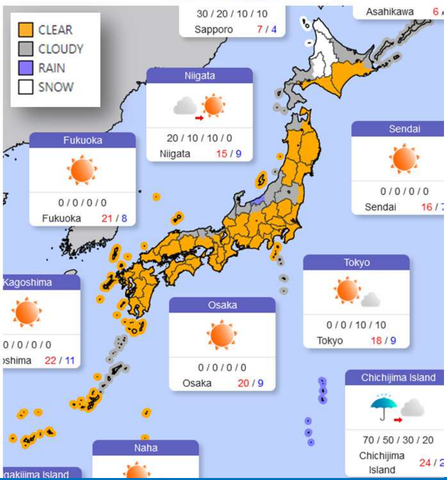
According to WMO's ***Manual on Global Data-processing and Forecasting System***,

Class	Target forecast range
Nowcasting	Current and forecasted weather up to 2 hours ahead
Very short-range weather forecasting	Up to 12 hours ahead
Short-range forecasting	From 12 hours to 72 hours ahead
Medium-range weather forecasting	From 72 hours to 240 hours ahead
Extended-range weather forecasting	From 10 days to 30 days ahead, usually averaged and expressed as a departure from climate values for that period
Long-range forecasting	From 30 days up to two years (Monthly, three-month or seasonal outlook of averaged weather parameters)
Climate forecasting	Beyond 2 years (Annual, decadal and beyond, including human-induced climate change projection)

Images of short-range forecasts and long-range forecasts

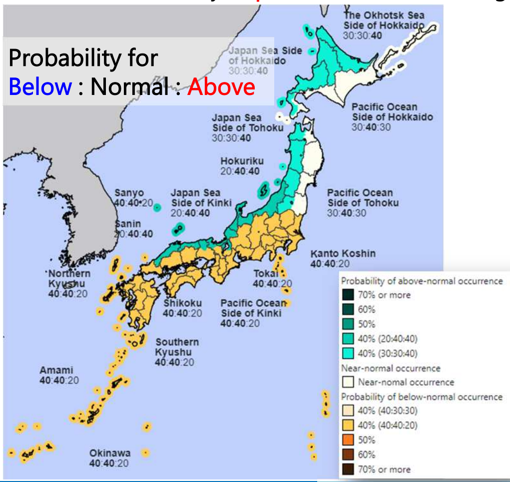
Short-range forecast

- States weather parameters (temperatures, precipitation, …) as they are expected
- Achievable in deterministic way



Seasonal forecast

- States expected deviations from climate values
- Achievable only in probabilistic forecasting



(from the website of JMA)

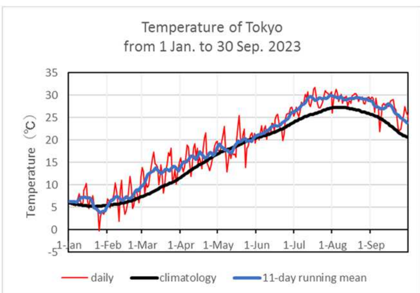
Anomaly is descripted in long-range forecast

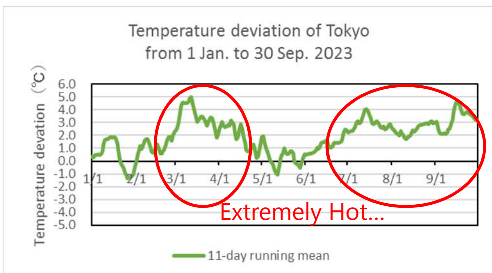
Climatological normal is defined as 30-year average for 1991–2020

Anomaly is deviation from the Climatology

[Anomaly] = [Actual Value] – [Normal]

- Climate is what we expect, anomaly is what we forecast.
- ***Anomalies*** often 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's seasonal forecasts state probabilities of 3 categories, namely,

  Above/Near/Below normal

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

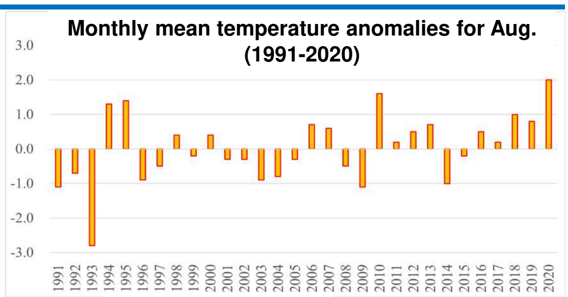
- Seasonal forecasts state probabilities of weather parameter (e.g. temperature) anomalies falling within

  1-10th(Below normal; BN)

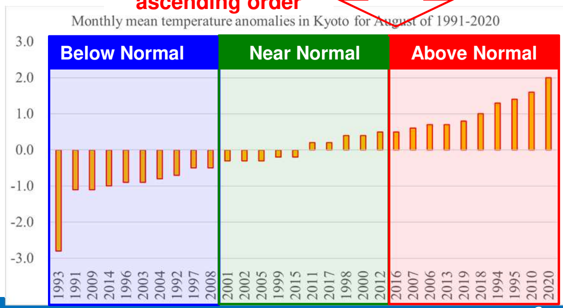
  11-20th (Near normal; NN)

  21-30th (Above normal; AN)

Ex. | BN 20% | NN 30% | AN 50% |

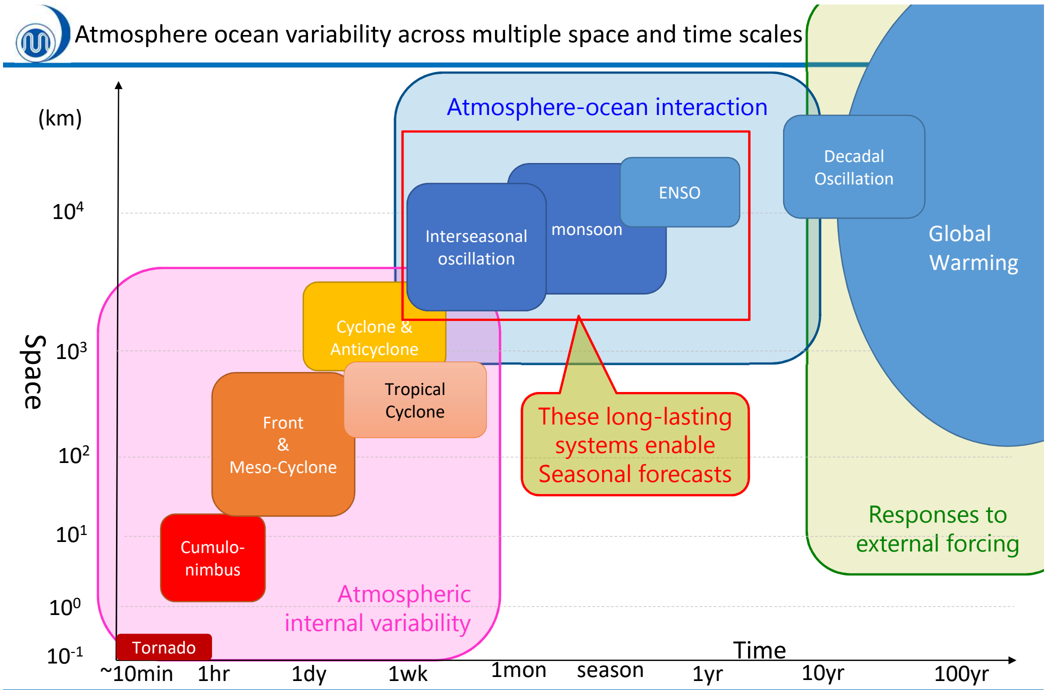


Sort by anomalies in ascending order



Brief introduction to climate dynamics

Atmosphere ocean variability across multiple space and time scales



Anomaly Correlation Coefficient

- Anomaly Correlation Coefficient (ACC) is one of measures in the verification of spatial fields (Jolliffe and Stephenson 2003), and is the correlation between anomalies of forecasts and those of verifying values with the reference values, such as climatological values. ACC is defined as follows:

$$\mathrm{ACC} \equiv \frac{\sum_{i=1}^{n} w_i (f_i - \overline{f})(a_i - \overline{a})}{\sqrt{\sum_{i=1}^{n} w_i (f_i - \overline{f})^2 \sum_{i=1}^{n} w_i (a_i - \overline{a})^2}}, \quad (-1 \le \mathrm{ACC} \le 1),$$

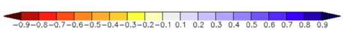
- where n is the number of samples, and f_i, $\overline{f}$, a_i and $\overline{a}$ are given by the following equations:

$$f_i = F_i - C_i, \quad \overline{f} = \left(\sum_{i=1}^{n} w_i f_i\right) \Big/ \sum_{i=1}^{n} w_i,$$

$$a_i = A_i - C_i, \quad \overline{a} = \left(\sum_{i=1}^{n} w_i a_i\right) \Big/ \sum_{i=1}^{n} w_i,$$

- where F_i, A_i, and C_i represent forecast, verifying value, and reference value such as climatological value, respectively. Also, $\overline{f}$ is the mean of f_i, $\overline{a}$ is the mean of a_i, and w_i represents the weighting coefficient*. If the variation pattern of the anomalies of forecast is perfectly coincident with that of the anomalies of verifying value, ACC will take the maximum value of 1. In turn, if the variation pattern is completely reversed, ACC takes the minimum value of -1.

$$* \quad w_i = \frac{1}{n} \text{ (or } \cos\phi_i \text{, and so on)}$$



Perfectly reversed   No skill   Perfect skill

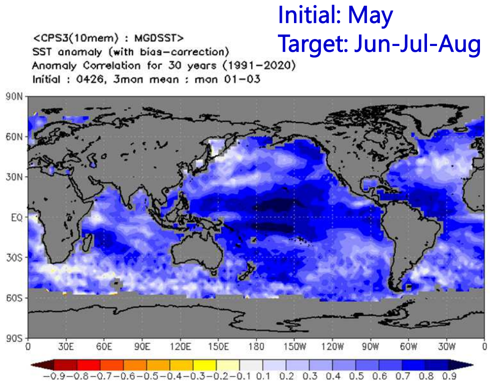
Anomaly Correlation Coefficient of CPS3 products

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

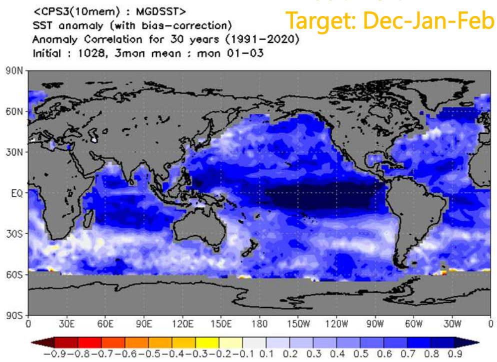
Forecasters should note where and how numerical model skills are good and poor.

Anomaly correlation for Sea Surface Temperatures for 3-month forecasts

Initial: May
Target: Jun-Jul-Aug



Initial: Nov.
Target: Dec-Jan-Feb



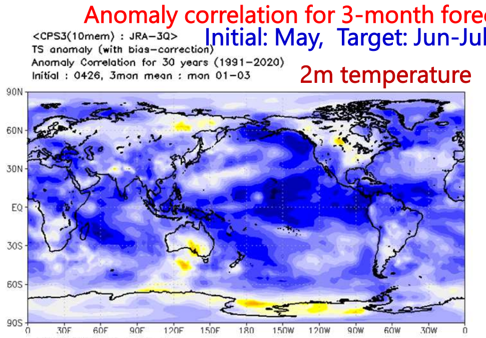
Verification of JMA Seasonal Prediction System

Anomaly correlation for 3-month forecasts

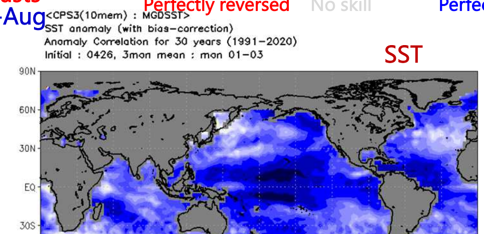
Initial: May, Target: Jun-Jul-Aug

Perfectly reversed   No skill   Perfect skill

2m temperature

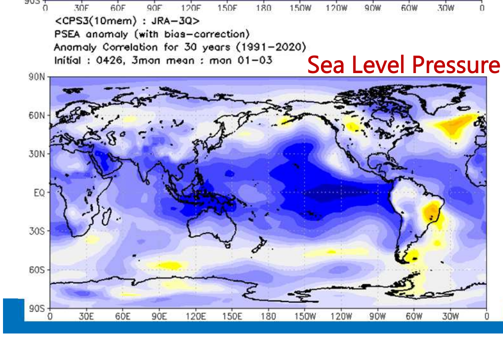


SST

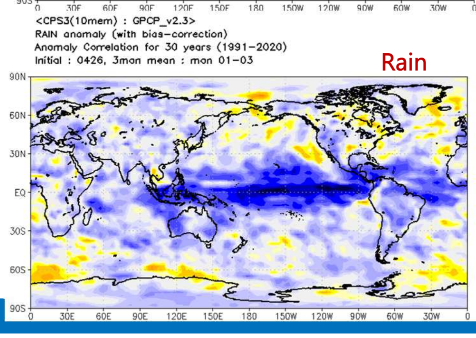


Tropical ocean SST is the most important source of signals available in seasonal forecasts.

Sea Level Pressure

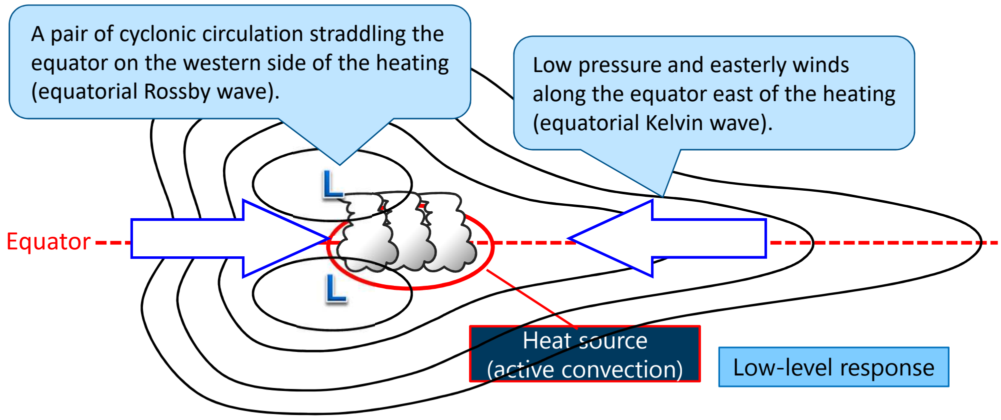


Rain



Matsuno-Gill response (in the lower troposphere)

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



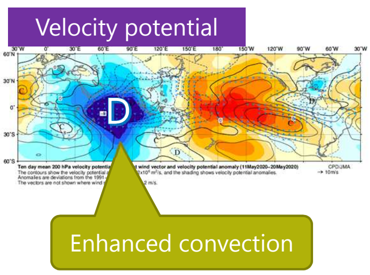
Atmospheric response to the heating in the lower troposphere, which is symmetric over the equator
Contours indicate perturbation pressure, and vectors denote velocity field.
Red circle indicates the position of the heating

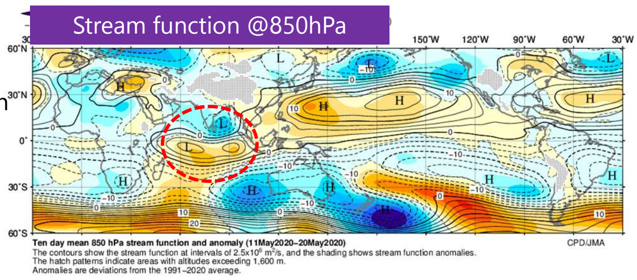
Upper-level response shows the reverse of the low-level response.

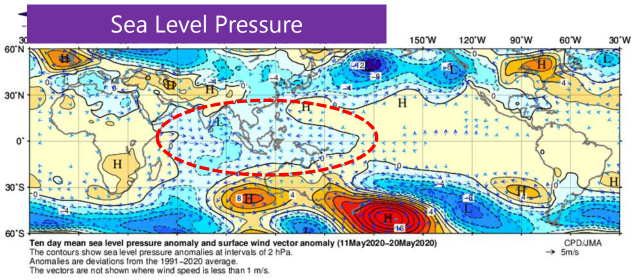
Example of Matsuno-Gill response

Atmospheric circulation anomalies averaged over 11-20 May, 2020

- Convective activities were enhanced over the Indian Ocean
- In response, cyclonic circulation anomalies are formed in the lower troposphere
- Low pressure area extended along the equator into the western Pacific



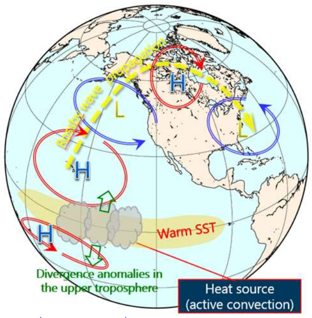


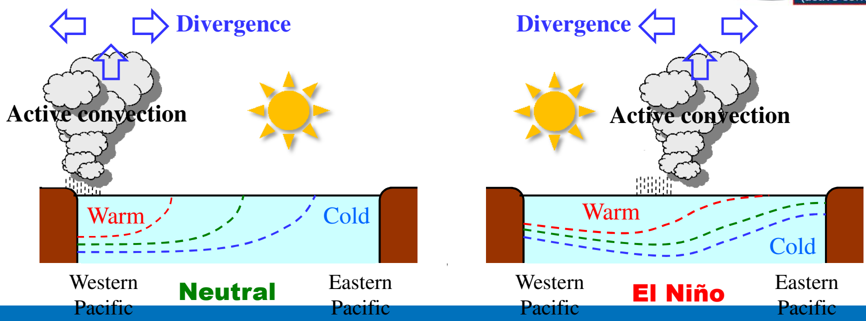


http://www.data.jma.go.jp/tcc/tcc/products/clisys/figures/db_hist_jun_tcc.html

El Nino Southern Oscillation

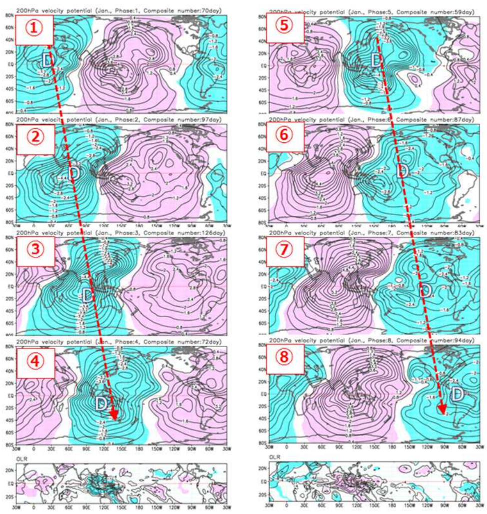
- During an El Niño event, SST over the central to eastern equatorial Pacific gets warmer significantly.
- The warmer SSTs induce active convection to shift eastward along the equator.
- These convection anomalies give rise to Rossby waves (Matsuno-Gill response!)
- Rossby waves propagate over a large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





Madden-Julian Oscillation (MJO)

- MJO is a planetary scale wave consisting of enhanced and suppressed convection extending east-west along the equator
- MJO is the most dominant signal over the tropics on weekly to monthly timescale.
- MJO propagates eastward along the equator, going around the globe in 30 – 60 days.
- 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

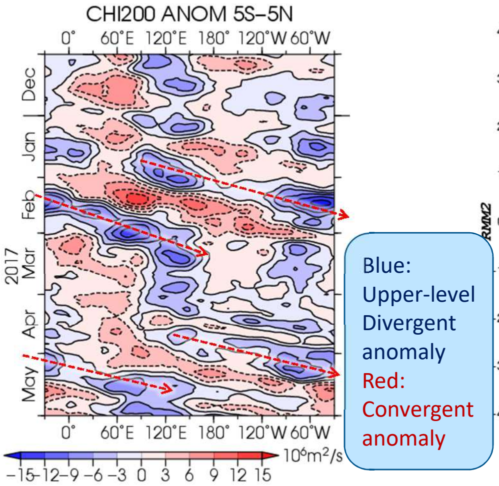


Enhanced phases of convection are denoted as "D" in this figure

How to detect MJO?

Propagation of MJO is visualized through Hovmöller diagram and phase diagram

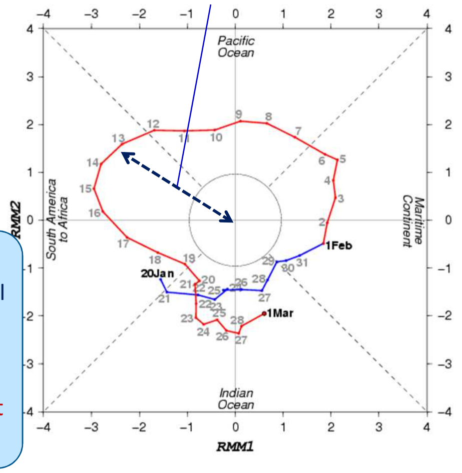
Time-longitude section of **chi200** anomaly along the EQ.



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

phase diagram

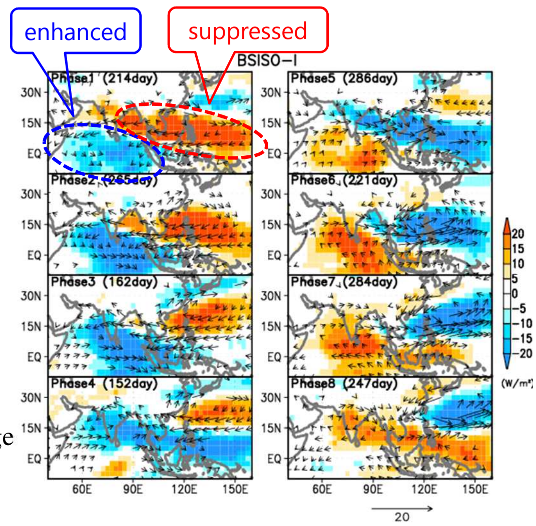
Amplitude: distance from the center



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

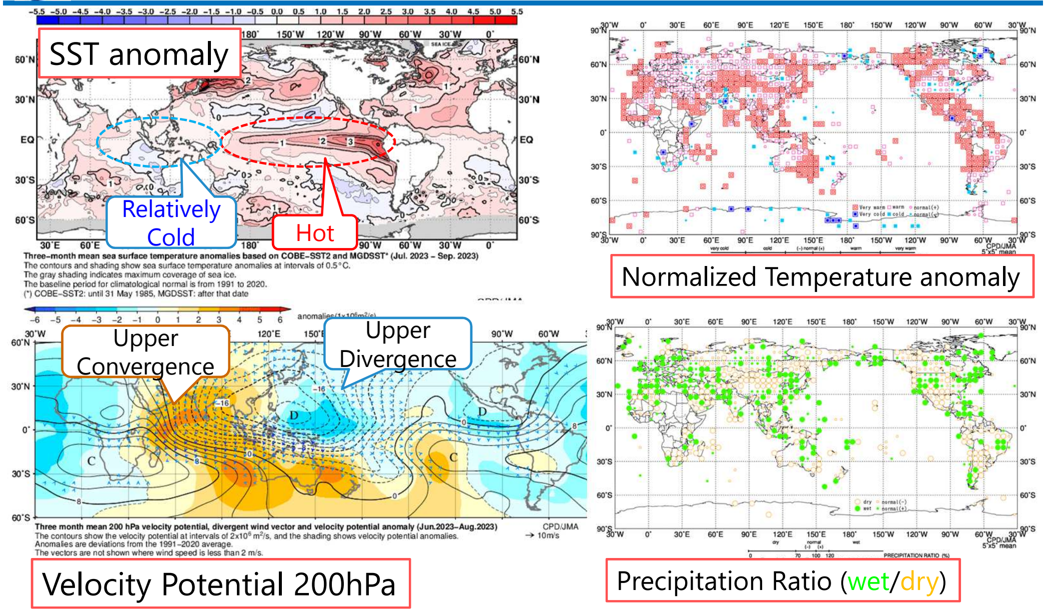
Another "Oscillation" - BSISO

- During summer in northern hemisphere, 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.



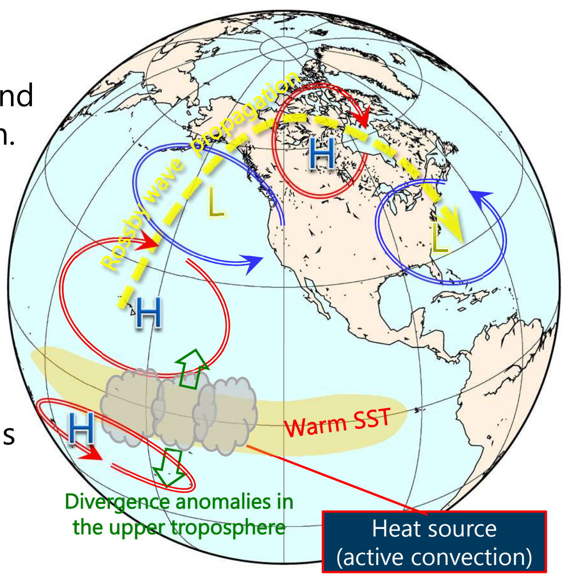
typical time evolution of BSISO

(JJA 2023) El Nino, Positive IOD like, Globally hot



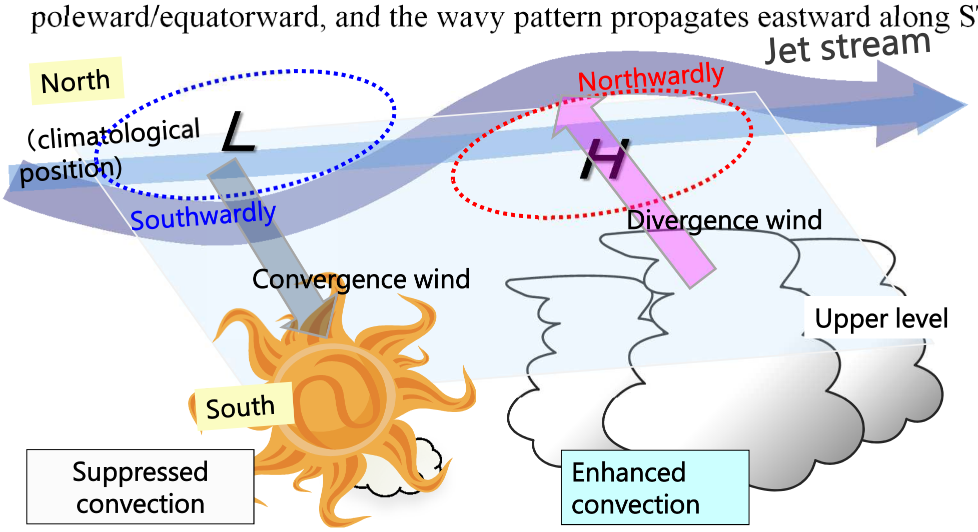
Matsuno-Gill response in the upper troposphere

- 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.



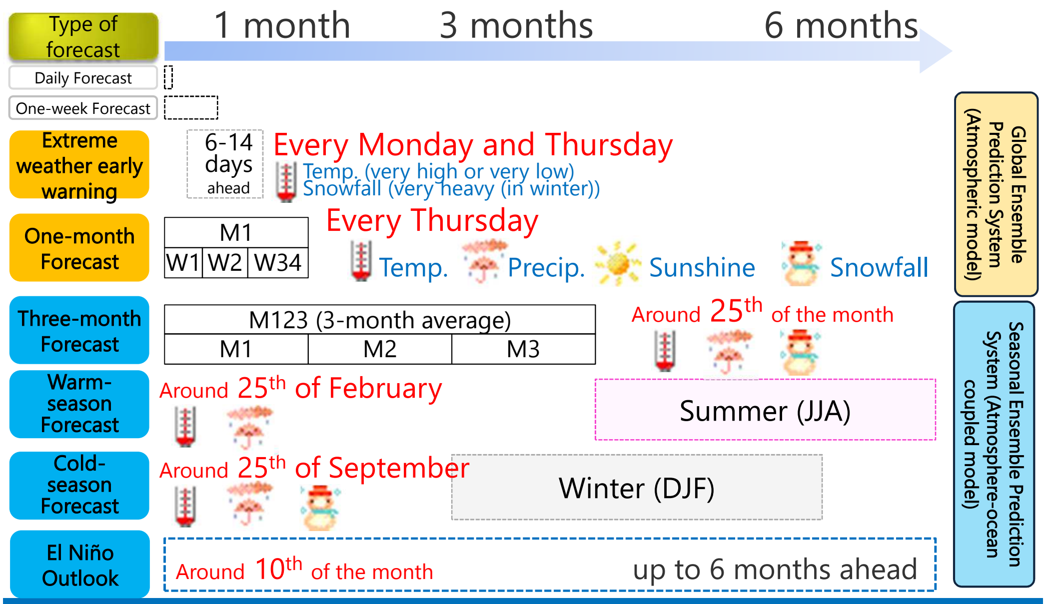
Convection changes jet stream

- 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.



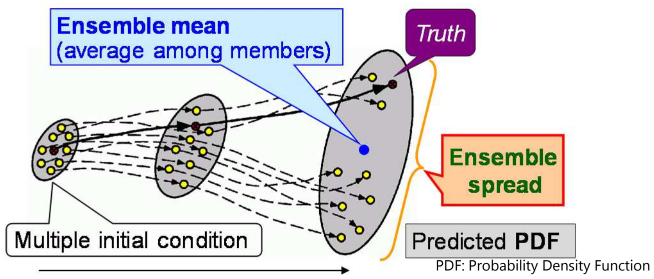
Methodology for JMA's seasonal forecast

JMA's extended and long-range forecast models



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 ensemble mean as the most likely atmospheric conditions in future, along with ensemble spread, an estimation of degree of uncertainty.



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

Stream function and velocity potential

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

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

< Rotational wind >

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

***Ψ*: Stream function**

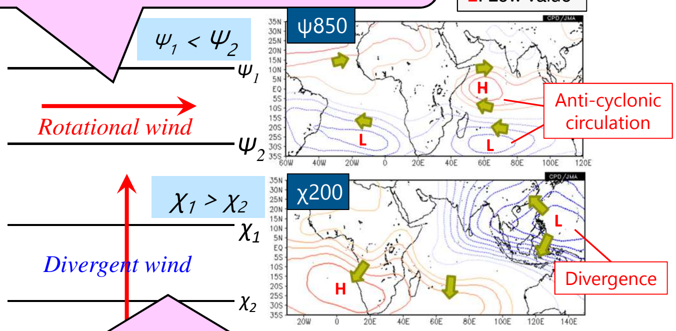
< Divergent wind >

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

***χ*: Velocity potential**

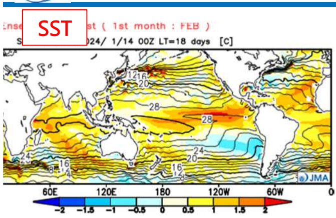
Rotational wind blows parallel to contours of stream function, with low values of stream function to the left, regardless of the hemisphere.

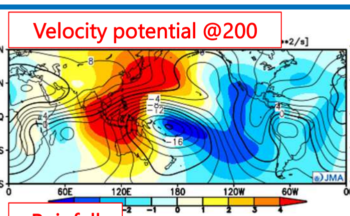
H: high value
L: Low value

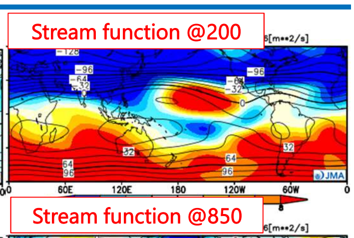


Divergent wind blows across contours of velocity potential, from areas of low to high velocity potential, regardless of the hemisphere.

Samples of Products from EPS





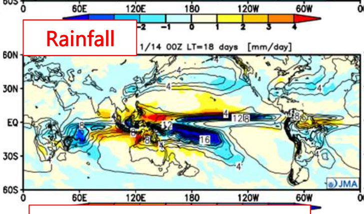


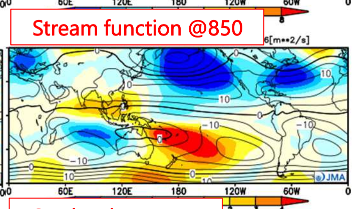
Forecast Maps

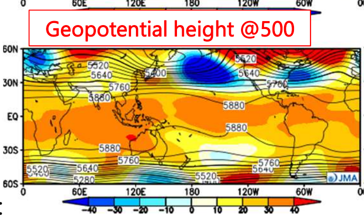
forecast period
the first month

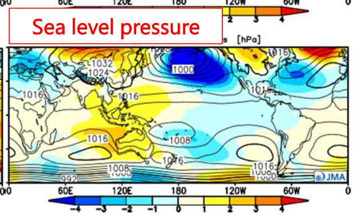
initial date
2024.01.14.00Z

[forecast]
Contour show forecast, and shaded pattern and vector show anomalies. Contour interval
CHI200 : 2x1.0E6m²/s
RAIN : 2mm/day
Z500 : 60m(area:60N-60S), 20m(area:Asia)
TS : 4C
SST : 2C
PSI200 : 16x1.0E6m²/s(area:60N-60S),
4x1.0E6m²/s(area:Asia)
PSI850 : 5x1.0E6m²/s(area:60N-60S),
2x1.0E6m²/s(area:Asia)
PSEA : 4hPa



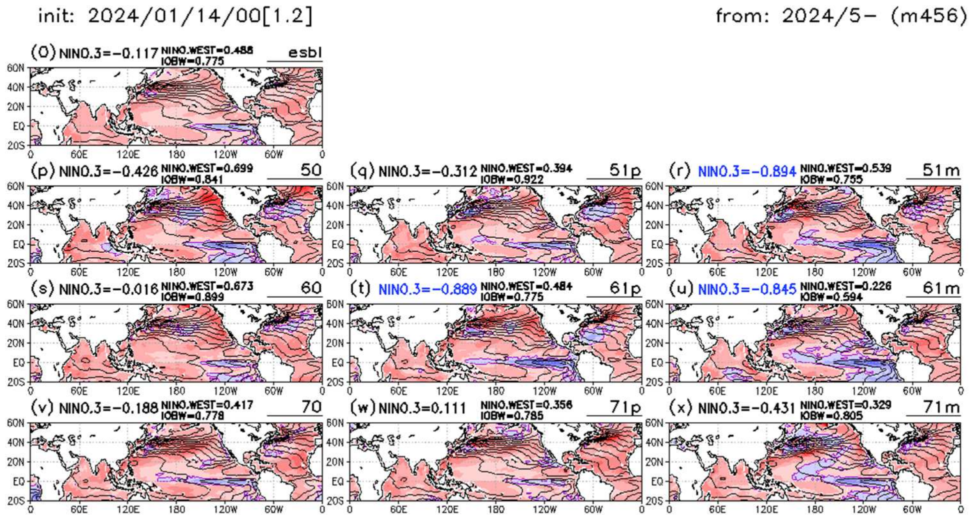






These figures are available at:
https://www.data.jma.go.jp/tcc/tcc/products/model/map/4mE/map1/zpcmap.php

Sample of individual ensemble members



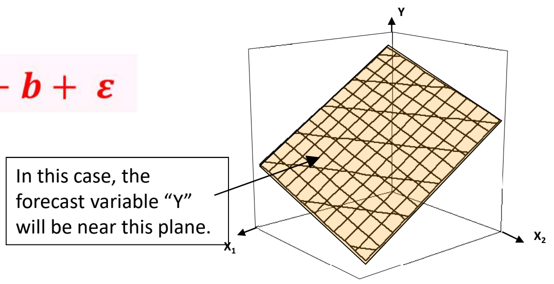
Sea Surface Temperature of the ensemble mean and 9 members（3 days, 3 members per a day）out of 51 (17 days : initialized on 28,Dec ~ 14, Jan.) and its anomaly (shaded) forecasted for May-Jun-Jul 2024 .

Statistical Post-processing for Seasonal forecast

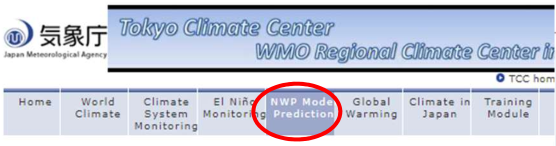
- Statistical post-processing methods and tools which translate direct model outputs into variables seen in forecasts (e.g. temperature, precipitation, …) is referred to as “guidance” in JMA.
- Guidance tools exploit statistical relations between past forecasts and observations.
- Typically, these statistical relations are represented in multiple regression equation.

$$Y = a_1 X_1 + a_2 X_2 + b + \varepsilon$$

a_1, a_2: regression coefficient
b: constant
ε: error term



Verification of JMA Seasonal Prediction System



- We can check major verification products of CPS3 and Global Ensemble Prediction System (GEPS; Atmospheric model), including hindcast products such as RMNSs, Anomaly correlation coefficients, … through NWP Model Prediction page in Tokyo Climate Center (TCC)
- JMA's guidance are also based on the hindcast products and statistics of stations' data.

CPS3 verification is available as same as Three-month Prediction

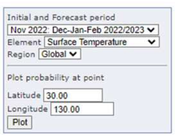
https://www.data.jma.go.jp/tcc/tcc/products/model/index.html

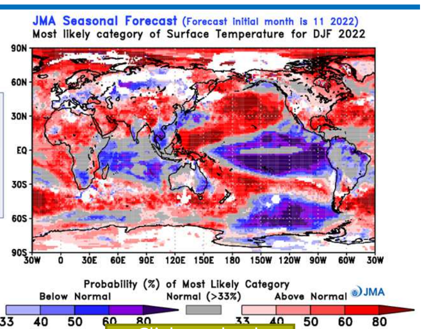
Probabilistic Forecast and Verification contents of TCC

- Probabilistic forecast (model result) and verification products are available through NWP Model Prediction page in Tokyo Climate Center (TCC)

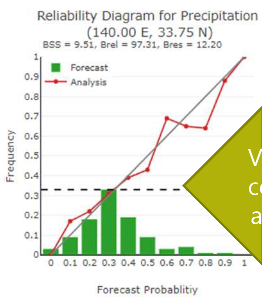
  *: 1.25 degree grid contents

Probabilistic Forecast Map

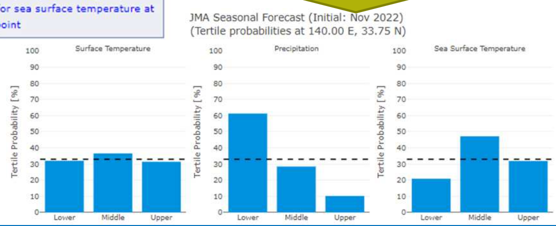


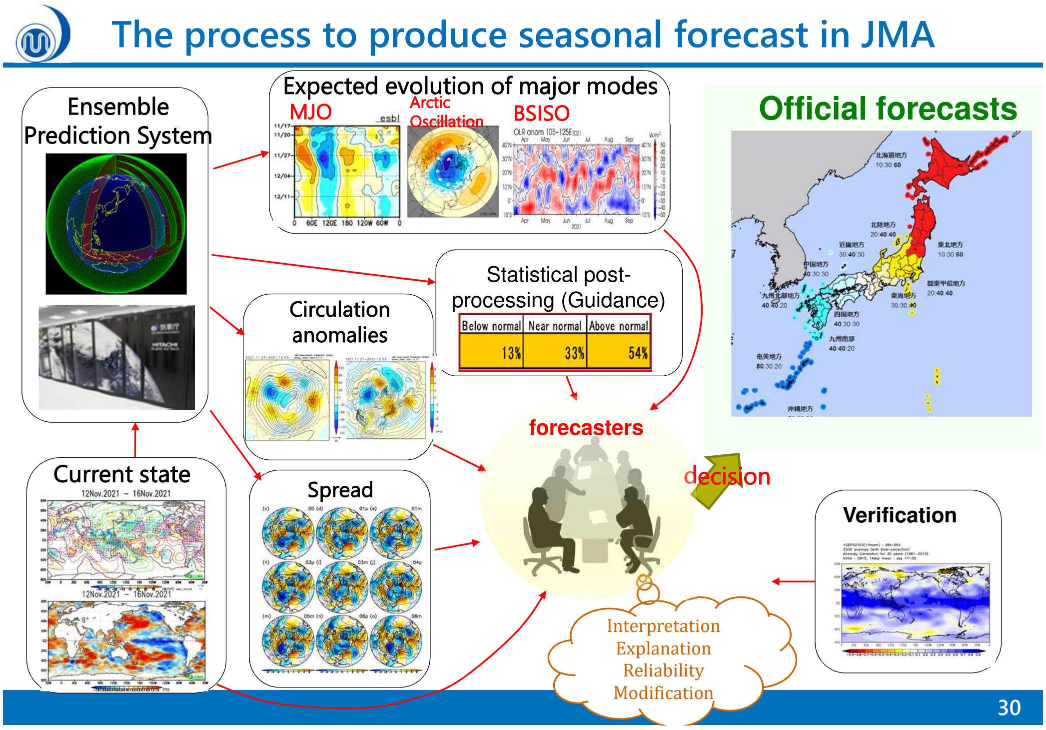


Click to check probability at any* point



Verification contents at any point !




The process to produce seasonal forecast in JMA
Ensemble Prediction System
Expected evolution of major modes
MJO
Arctic Oscillation
BSISO
Official forecasts
Statistical post-processing (Guidance)
Below normal
Near normal
Above normal
13%
33%
54%
Circulation anomalies
forecasters
decision
Current state
12Nov.2021 – 16Nov.2021
Spread
Verification
Interpretation
Explanation
Reliability
Modification
30


Thank you