Seasonal Forecast (One-month Forecast)

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Outline

- Introduction
- Predictability and Ensemble Prediction
- Signal for 1-month Forecast
- Seasonal Forecast in Japan
- Procedure of 1-month Forecast

Introduction

Classification of Meteorological Forecasting
(WMO 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)

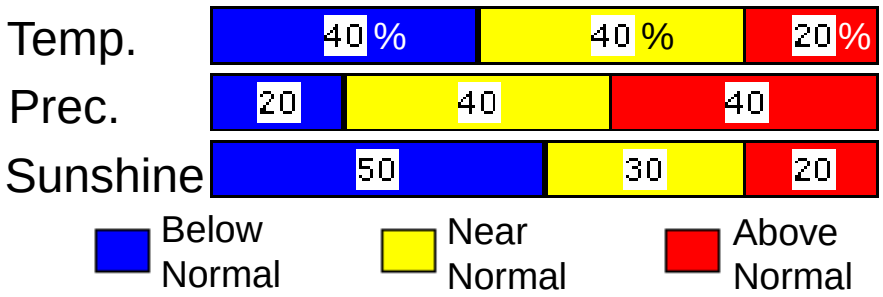
Short/Long Range Forecasts

Short range forecast

Date		30 Tue	31 Wed	1 Thu	2 Fri	3 Sat	4 Sun	5 Mon
Tokyo Daily Forecast								
Probability of precipitation (%)		0/0/20/20	20	60	60	30	10	10
Reliability		/	/	B	C	A	A	A
Tokyo	High (°C)	7	7 (6 - 9)	5 (3 - 7)	6 (4 - 9)	8 (7 - 11)	8 (6 - 11)	7 (5 - 8)
	Low (°C)	0	1 (-1 - 2)	1 (-1 - 2)	2 (0 - 4)	1 (0 - 3)	1 (-1 - 2)	0 (-1 - 2)

- Forecasting the actual weather parameters (e.g., weather, temp.)
- Deterministic forecast

Seasonal forecast



- Forecasting deviation from the climatological normal in categories (Not actual temp. or precip.)
- Probabilistic forecast (Not forecasting which category will happen, but forecasting probabilities of occurrence for each category)

Above example shows a forecast in 3 categories: **Below**, **Near** and **Above normal**.

Probabilities of both below and near normal temp. are **40%**, and above normal temp. is **20%**.

Anomaly

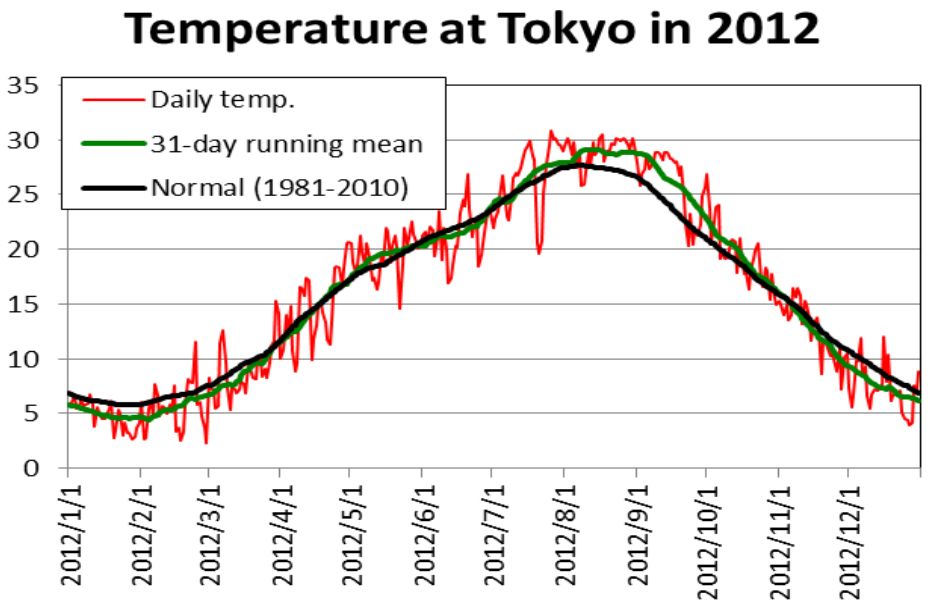
Normal: Defined as 30-year average for 1981 – 2010

Anomaly: Deviation from the normal

[Anomaly] = [Actual Value] – [Normal]

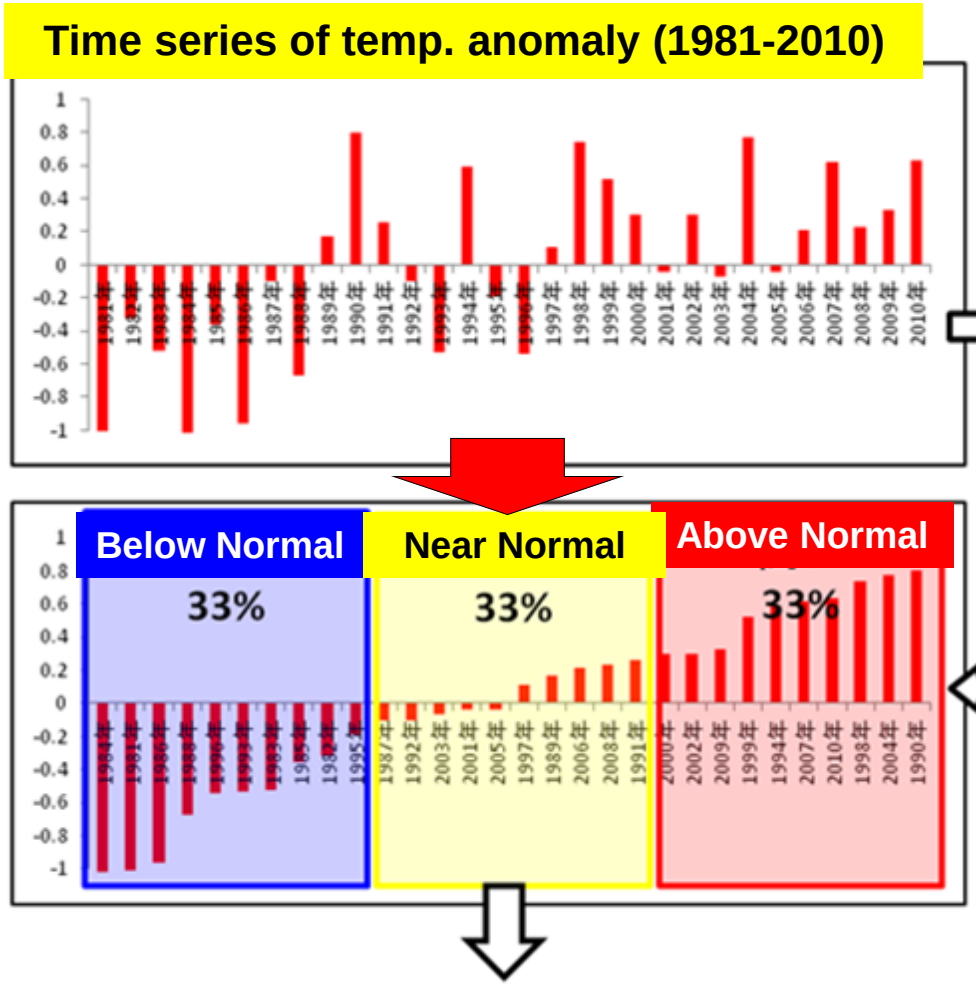
- Weather condition changes from year to year (interannual variability)
- Anomalous climate may affects the lives of society (e.g., drought, flood, and hot spell)

Anomaly is the target of seasonal forecasting.



Forecast Category

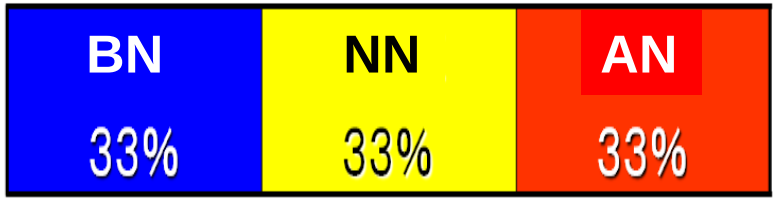
- JMA conducts seasonal forecast in **3 categories**: **Above**, **Near**, and **Below Normal**
- Arranging historical data for 30-year (e.g., 1981-2010) in ascending order,
  - 1 - 10th: **Below Normal**
  - 11 - 20th: **Near Normal**
  - 21 - 30th: **Above normal**



3-category Probabilistic Forecast

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

Climatological occurrence



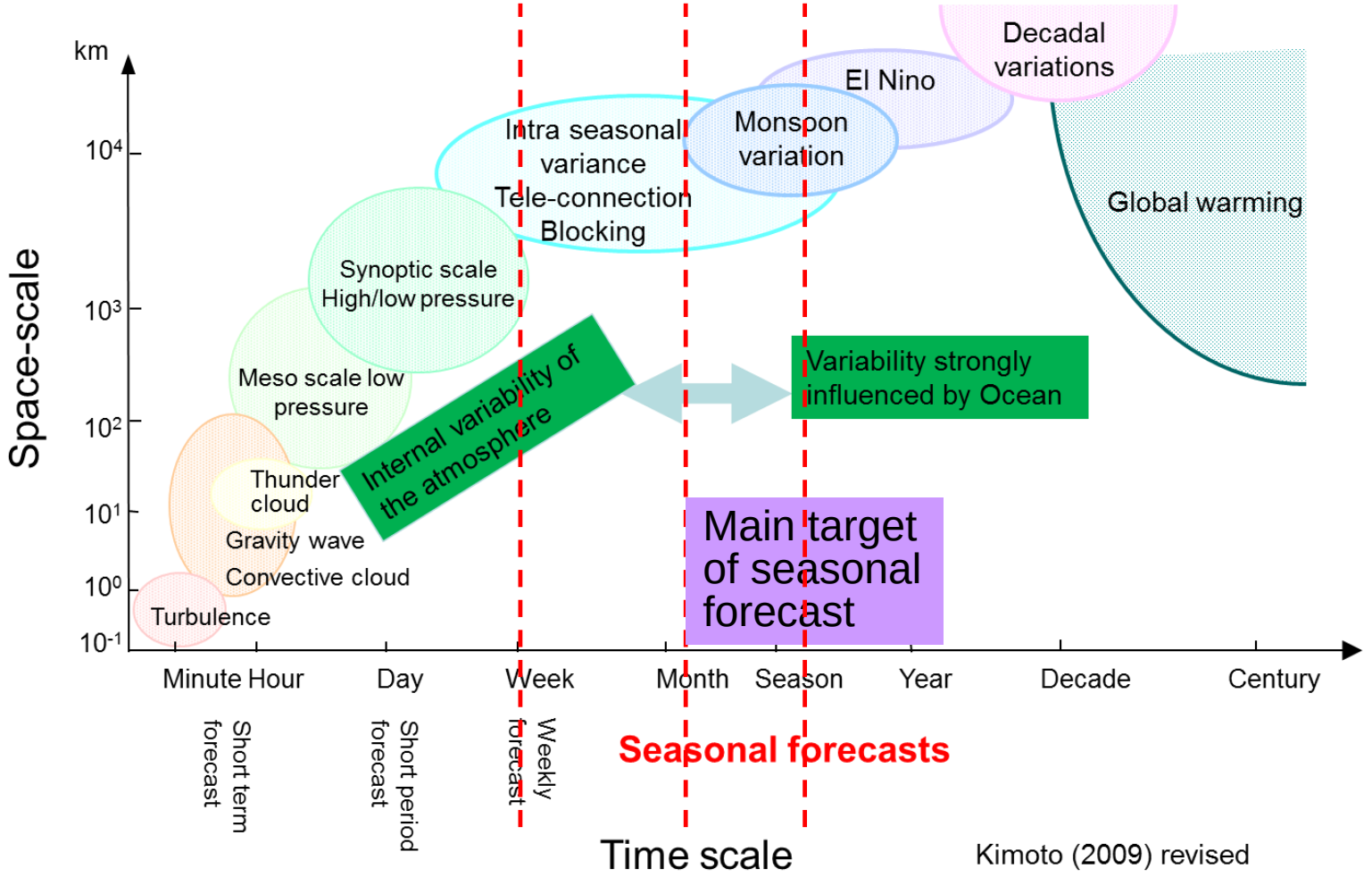
Certain forecast

This forecast shows that
above normal is ***more likely*** (50%), and
below normal is ***less likely*** (20%) to occur
than expected in climatology (33%).

Predictability and Ensemble Prediction

Multiple Structure of 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 a week).



Kimoto (2009) revised

Signal and Noise for Each Kind of Forecast

Green boxes show signal for short-range forecast and noise for one-month forecast

Kind of forecast	**Signal**	**Noise**
Medium-range (One-week forecast)	Shortwave disturbance dominating over daily variations of weather	
Extended –range (One-month forecast)	Low-frequency variation of atmosphere (meanderings of the jet, blocking, AO, MJO and so on)	Transient eddies (moving high, low)
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

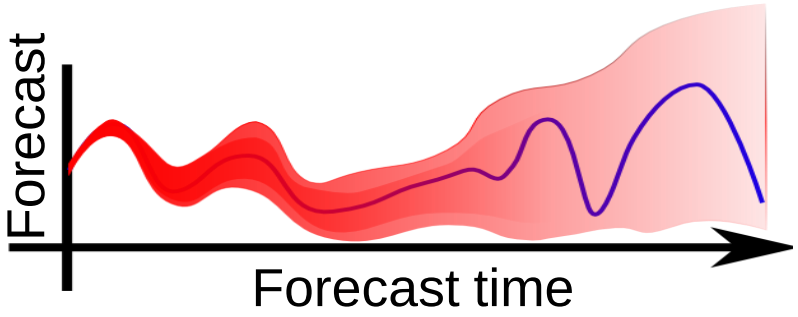
Blue box shows signal for seasonal forecast

Red boxes show signal for one-month forecast and noise for seasonal forecast

Noise can be reduced by time average (e.g., 1-month mean)

Chaos in Atmosphere

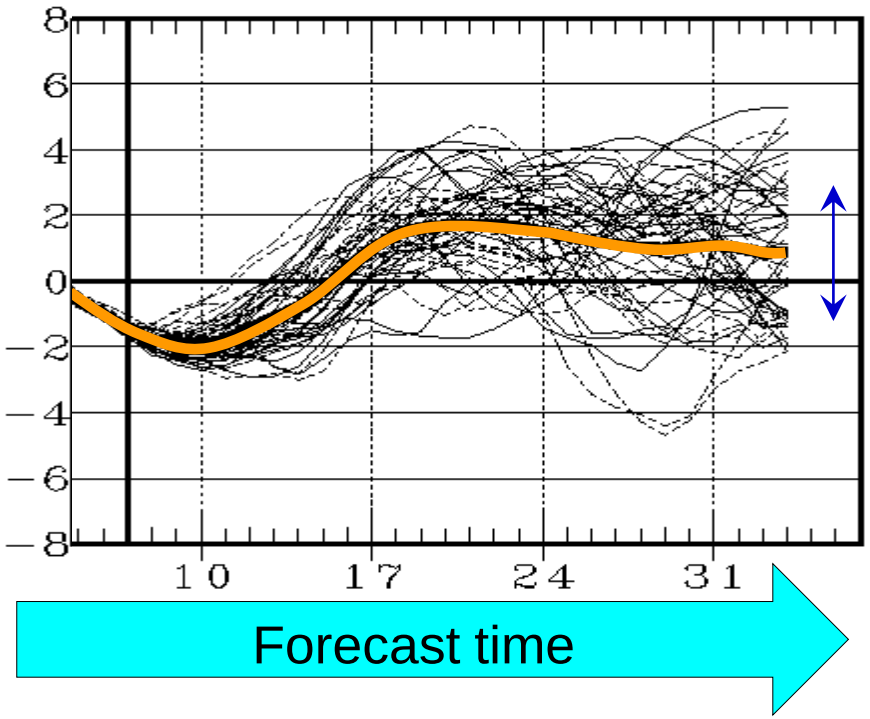
- Due to chaotic behavior of atmosphere, errors rapidly grow during period of prediction.



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

Ensemble Prediction

In **ensemble prediction**, the model is run many times from very slightly different initial conditions.



Ensemble Member = Individual solutions

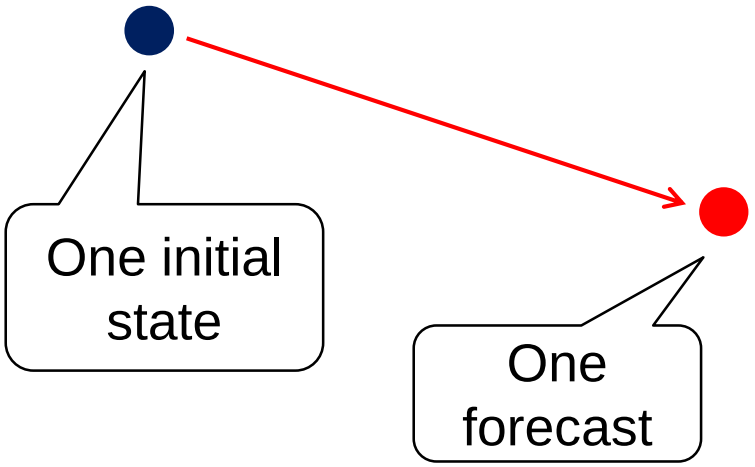
Ensemble spread = Standard dev. among members, suggesting degree of **uncertainty**

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

- Ensemble mean is statistically better than each member.
- The more the number of members is, the better the prediction is.

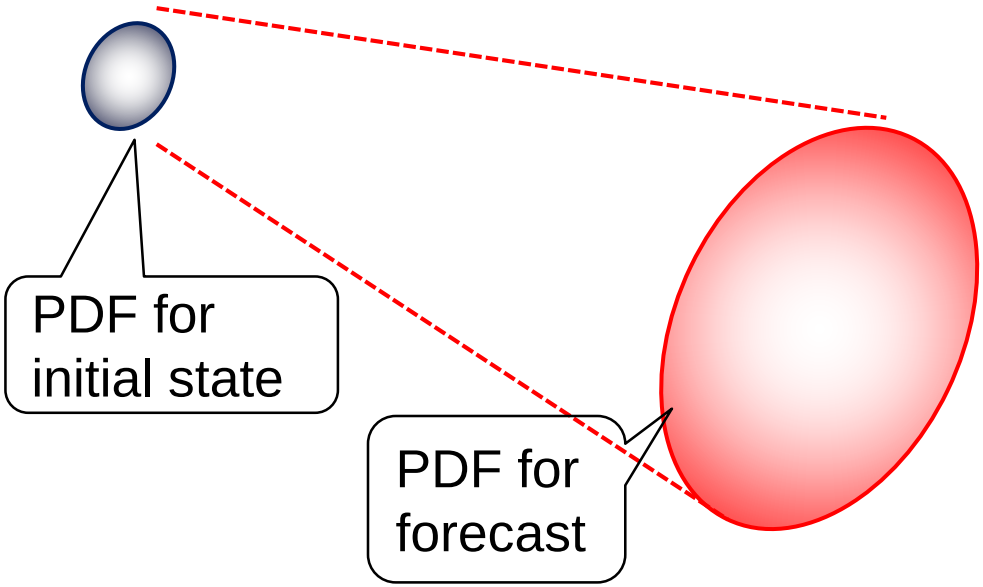
Deterministic and Probabilistic Forecast

Deterministic forecast



Calculate one forecast using one initial state

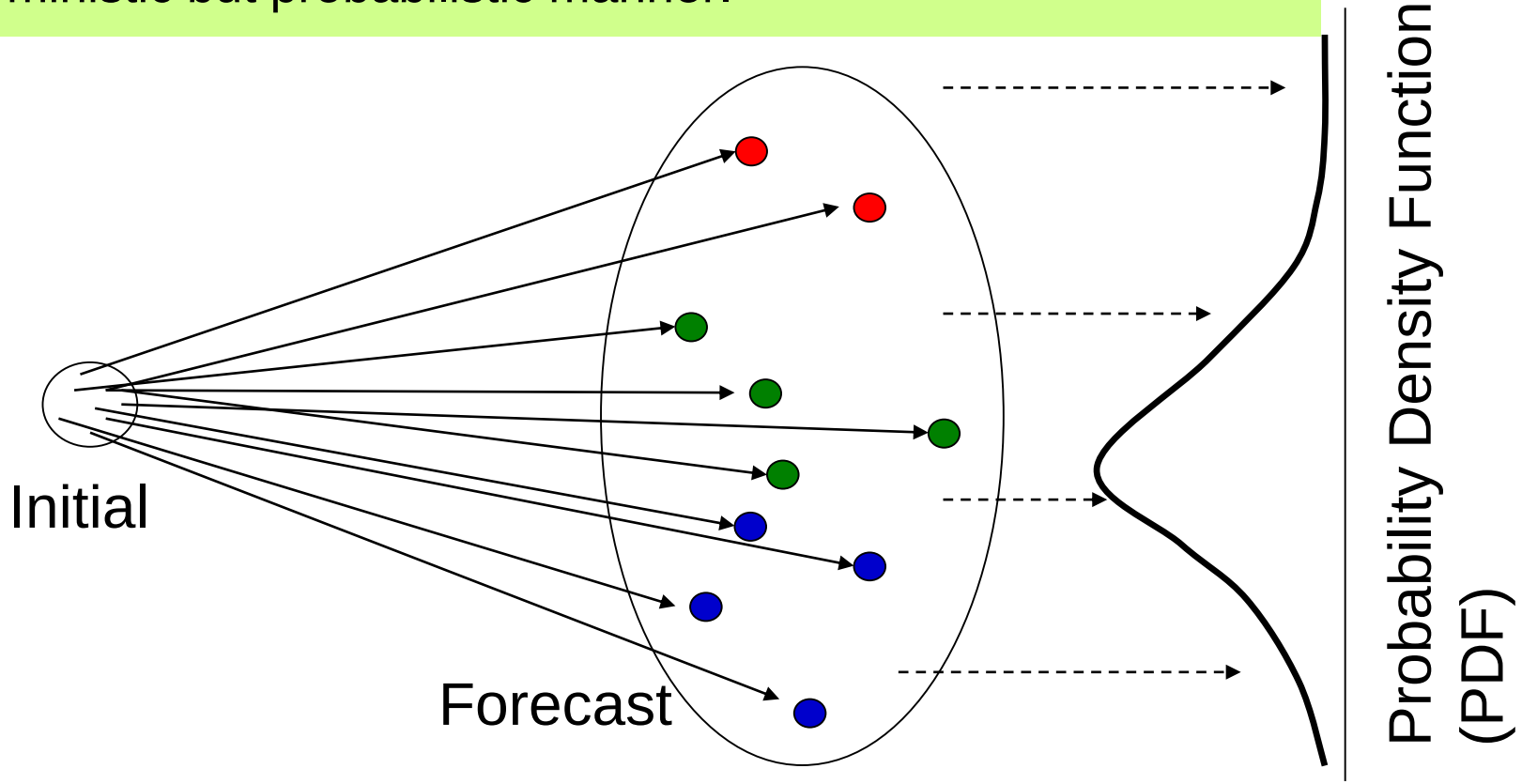
Probabilistic forecast



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

Probabilistic Forecast

- Ensemble prediction system (EPS) enables to derive PDF from the distribution of individual members.
- This denotes that long-range forecast is possible with not deterministic but probabilistic manner.

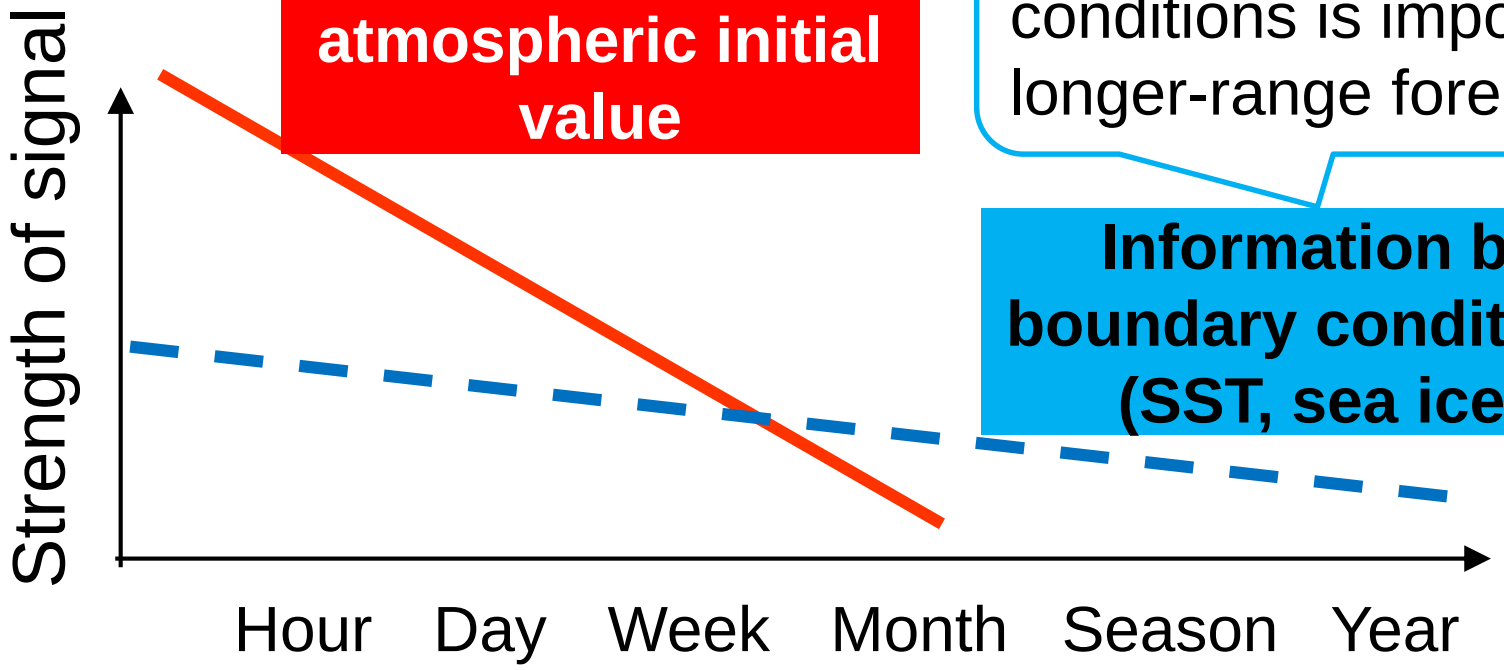


Initial and Boundary Condition

Due to the chaotic nature of the atmosphere, the limit for deterministic forecasting is about two weeks.

Second kind of predictability

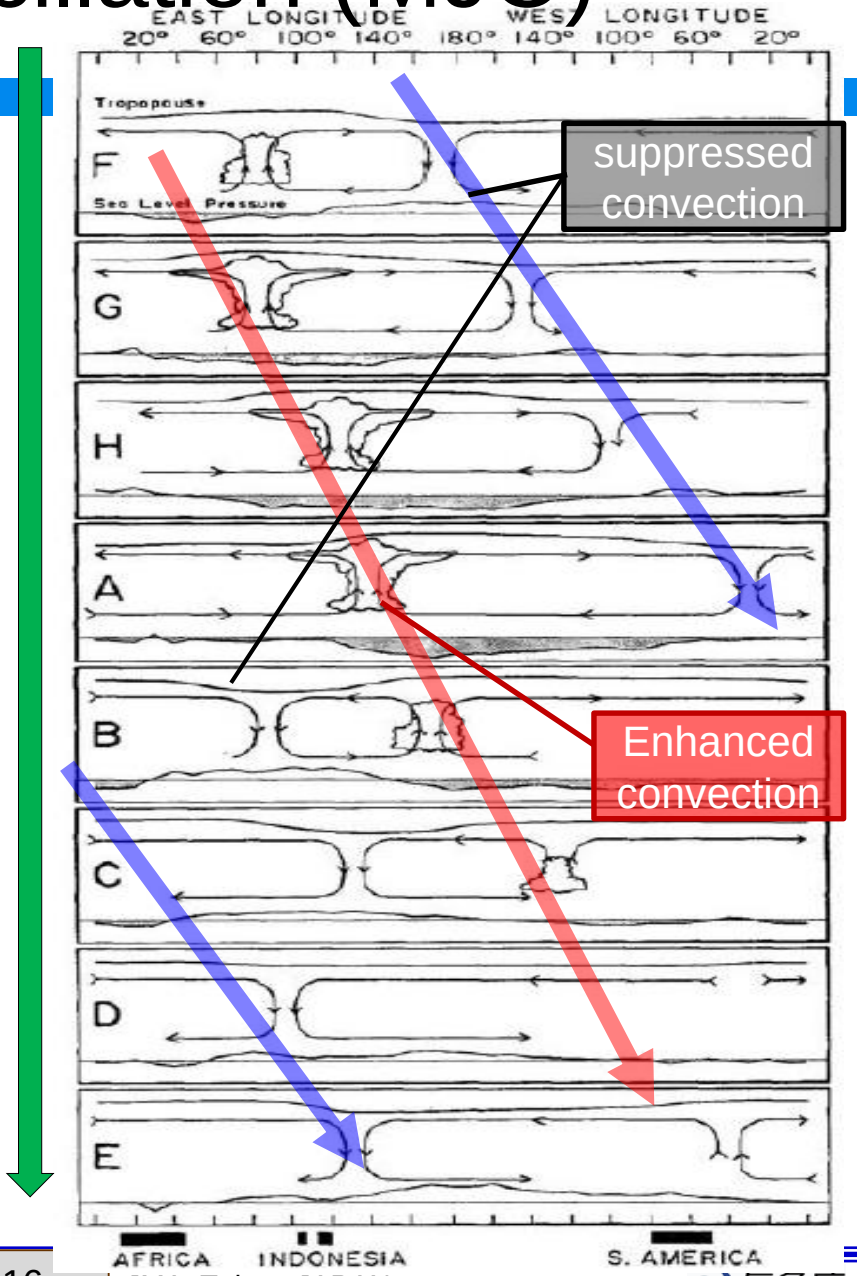
The influence of boundary conditions is important for longer-range forecasting



Signal for One-month Forecast

Madden-Julian Oscillation (MJO)

- Most dominant mode over the tropics in extended range timescale
- MJO propagates eastward along the equator with periods of 30 – 60 days
- A large-scale coupled pattern between deep convection and atmospheric circulation
- Clear signal of convection is seen over the Indian Ocean and the western Pacific
- Its convective activity makes an impact on mid-high latitude through the meandering of the jet stream
- MJO is monitored with 200hPa velocity potential (upper-level divergence) field
- Possible to predict its evolution up to 2-3 weeks (Important signal for 1-month forecast)

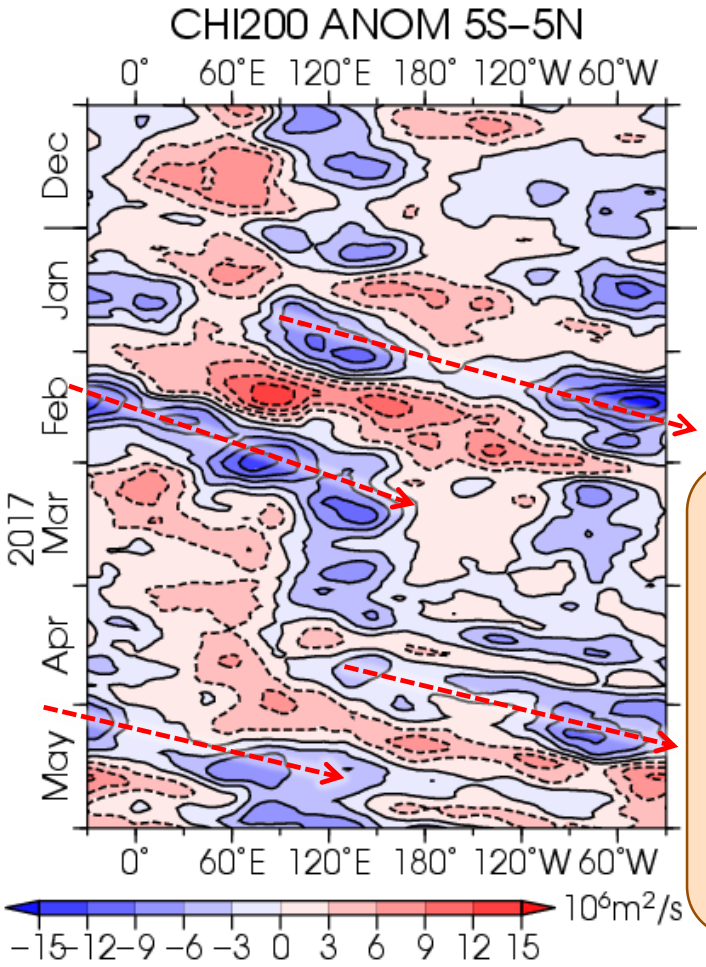


Original; Madden and Julian (1972) Fig.16

Monitoring of MJO

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

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

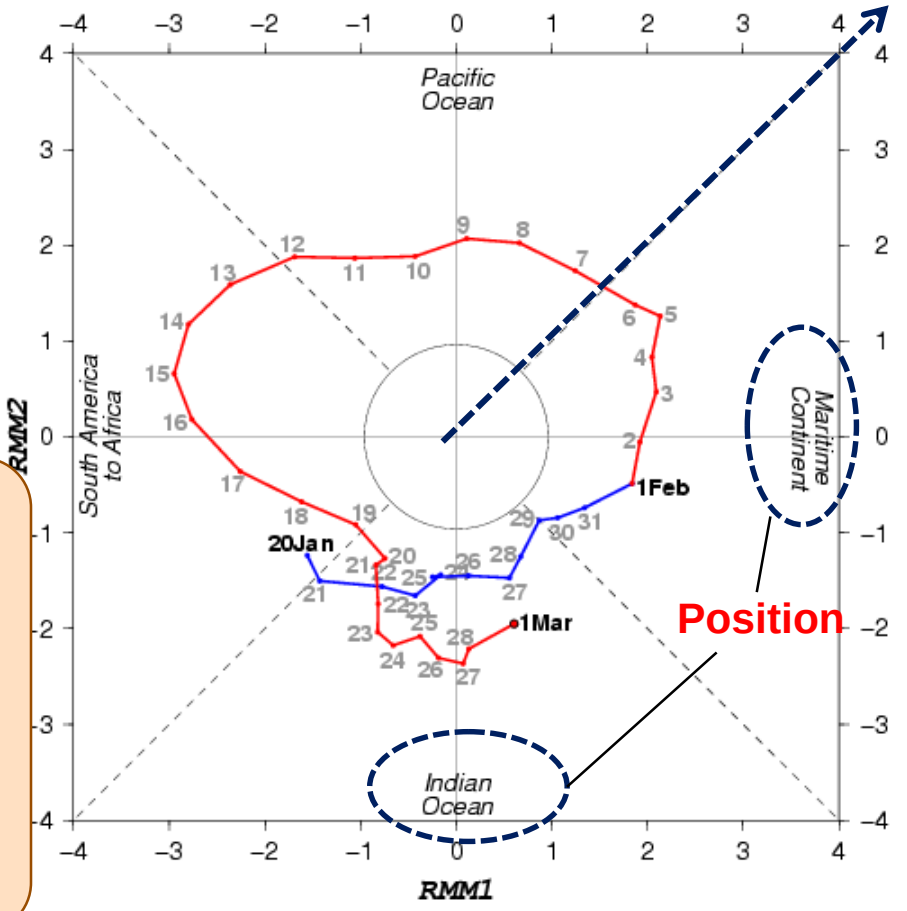


Blue: Upper-level Divergent anomaly

Red: Convergent anomaly

MJO's phase and amplitude diagram

Amplitude: distance from the center



気象庁 Japan Meteorological Agency

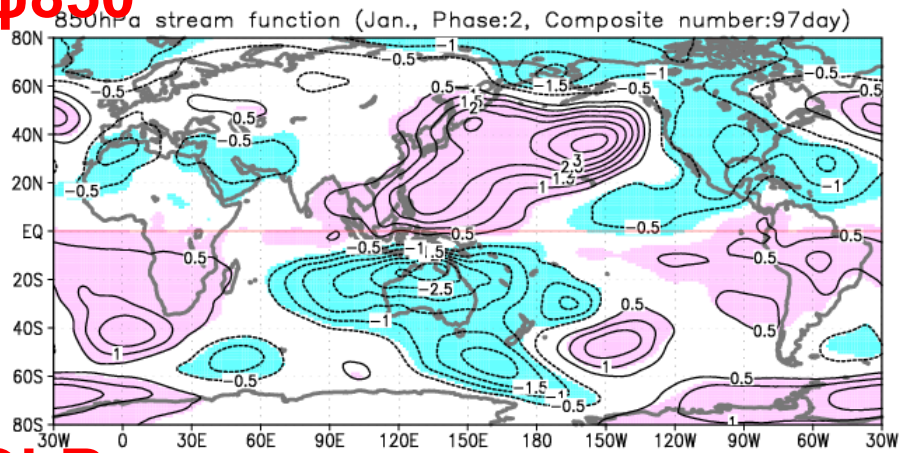
Atmospheric Response to MJO

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

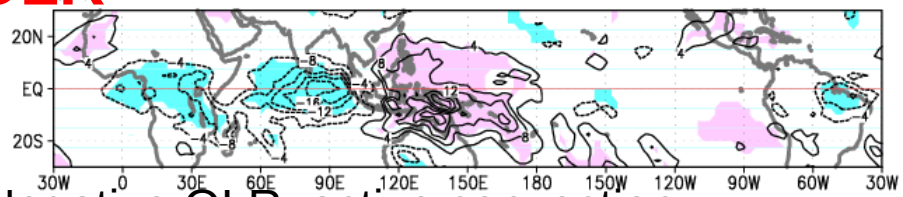
Composite maps for each MJO phase in January

Phase 2: Active in the Indian Ocean

ψ850

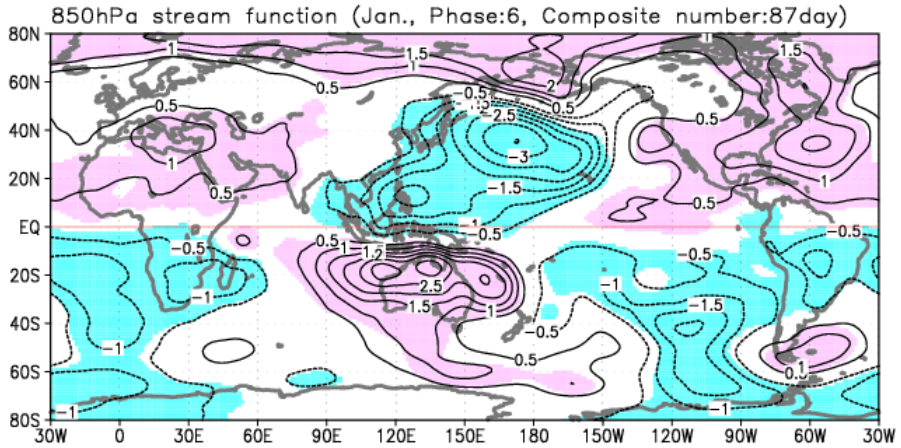


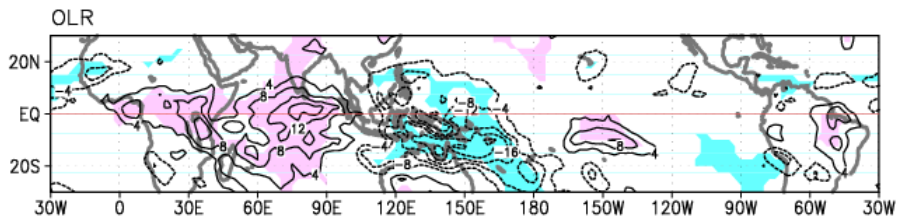
OLR



Negative OLR: active convection

Phase 6: Active in MC – the western Pacific





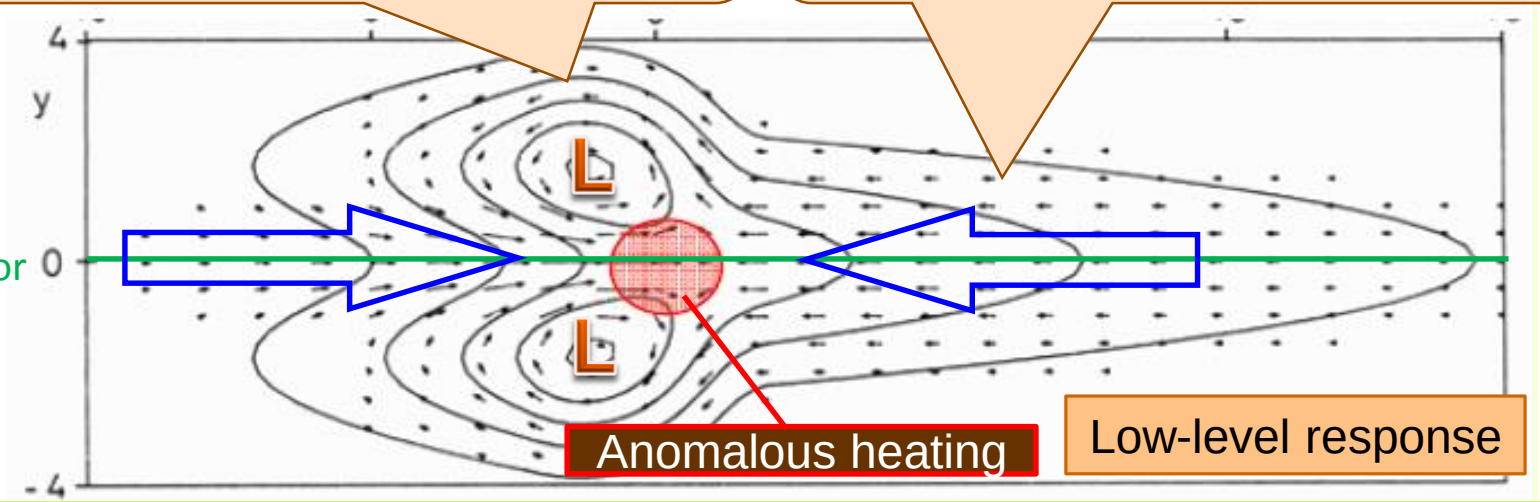
Response is dependent on season and the position of MJO

Matsuno-Gill pattern

Basic features of the response of the tropical atmosphere to convective activity (heating).

A pair of cyclonic circulation straddling the equator on the western side of the heating (equatorial Rossby wave).

Low pressure and easterly winds along the equator east of the heating (equatorial Kelvin wave).



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

Contours indicate perturbation pressure, and vectors denote velocity field.

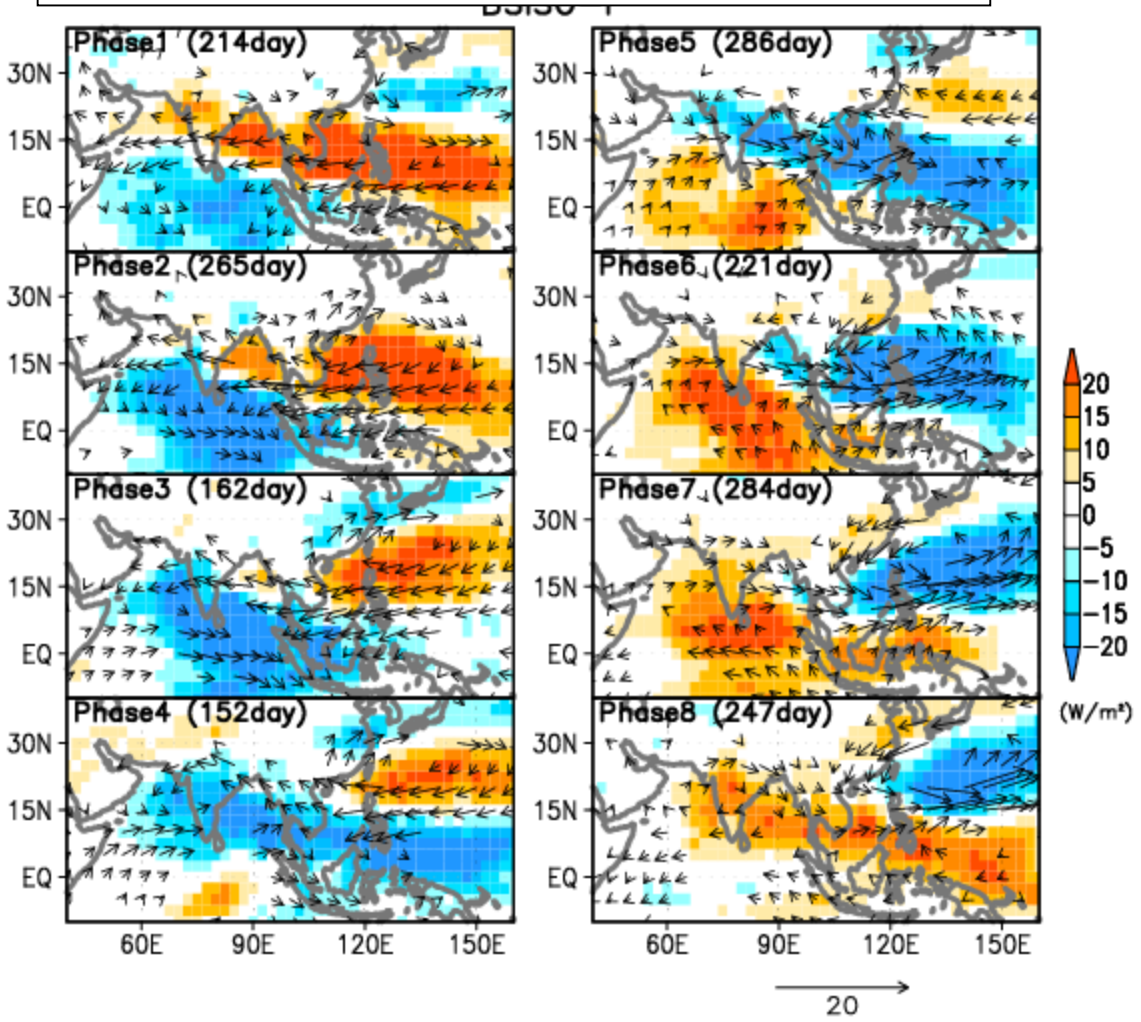
Red circle indicates the position of the heating. (Source: Gill 1980)

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

BSISO

- In boreal summer, northward propagation is also seen over the Indian Ocean and the western Pacific
- BSISO hugely affects the Asian monsoon activity

One of the typical evolutions of BSISO



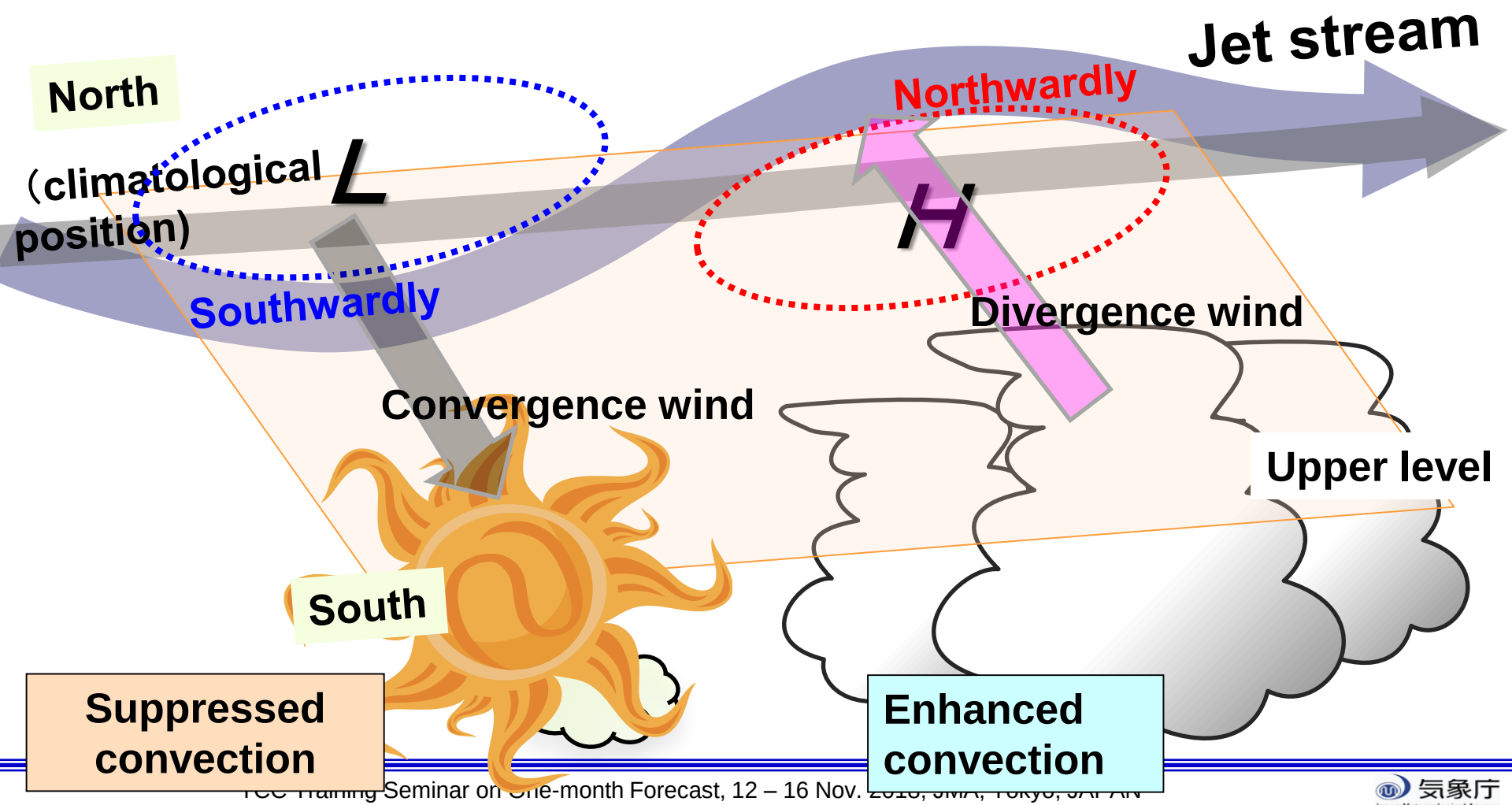
Blue: Negative OLR (active convection)

Red: Positive OLR (inactive convection)

Arrows: 850-hPa wind

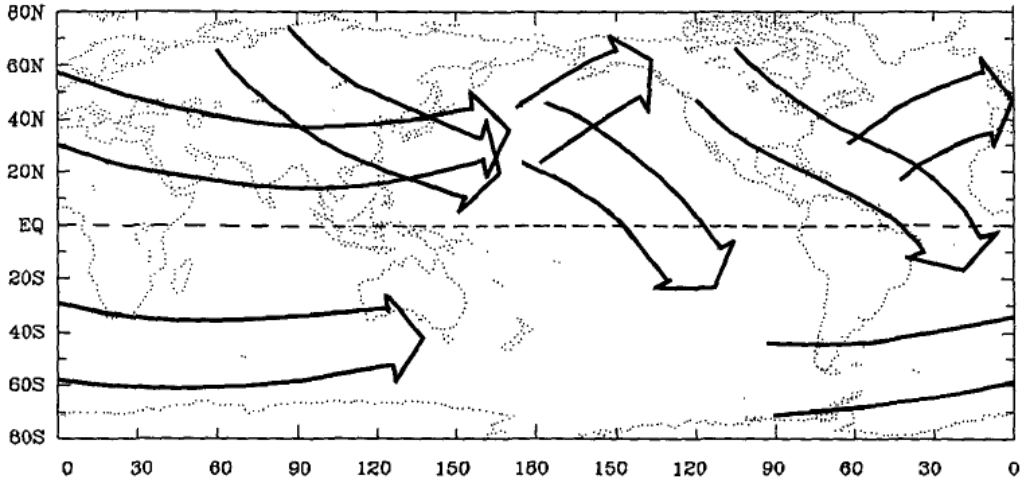
Meanderings of jet stream by anomalous convections

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



Quasi-stationary Rossby Wave

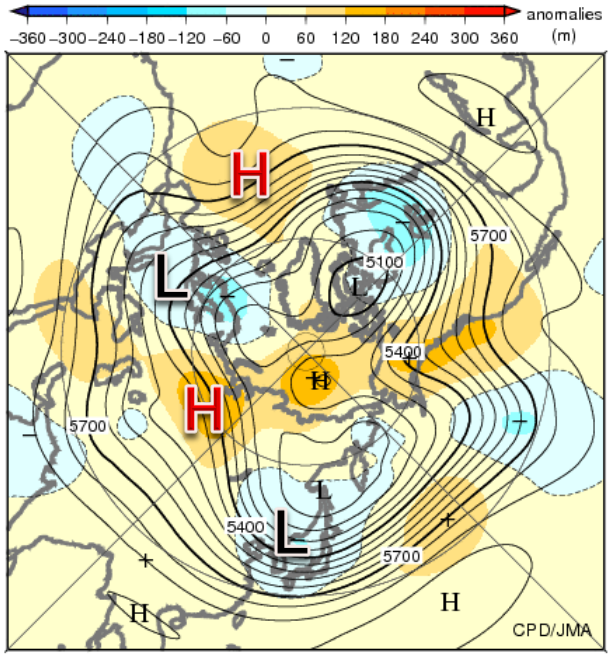
- Meandering of the westerly wind often persists for more than a week due to (quasi-)stationary Rossby wave.
- Stationary Rossby wave often causes extreme weather (ex. hot/cold spell, drought…)
- The wave energy propagates eastward often along the sub-tropical and polar front jet streams (teleconnection).
- Stationary Rossby wave is one of the important phenomena in 1-month forecast.



Typical path of Rossby wave energy propagation

(Hsu and Lin, 1992)

Quasi-stationary Rossby Wave

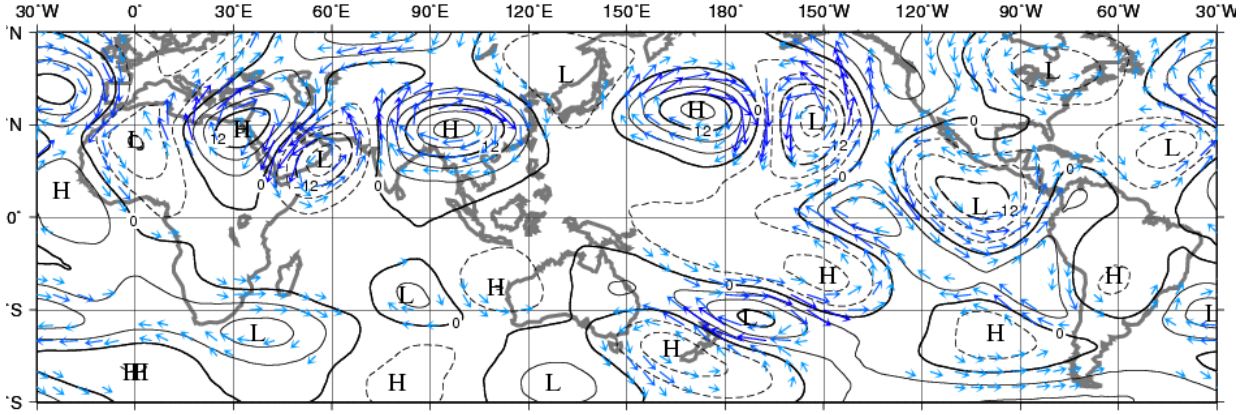


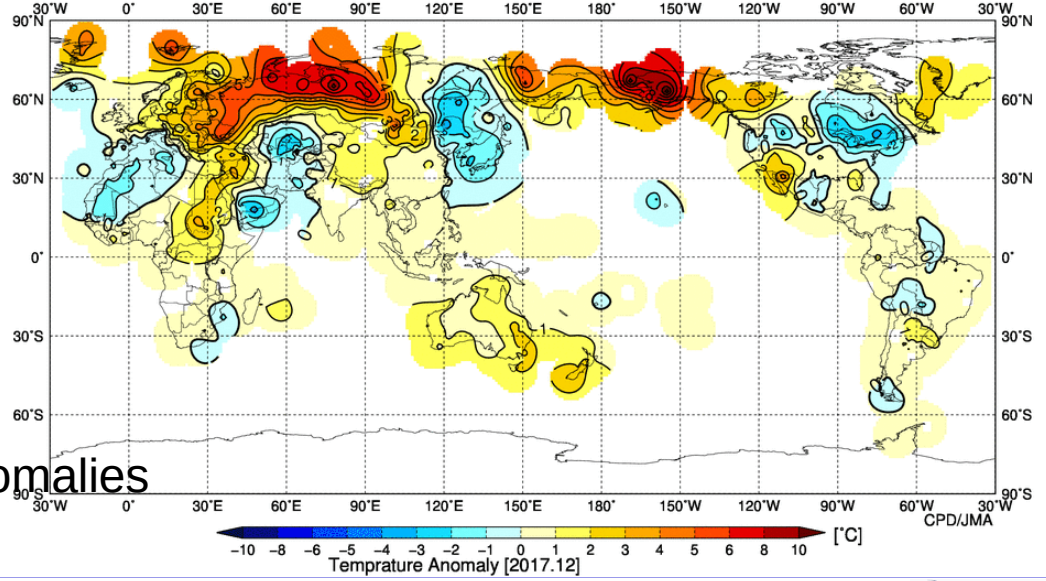
Z500 in Dec. 2017

Rossby wave trains are seen along the polar front jet stream

200-hPa stream function anomaly in Dec. 2017

Wave trains are seen along the sub-tropical jet stream



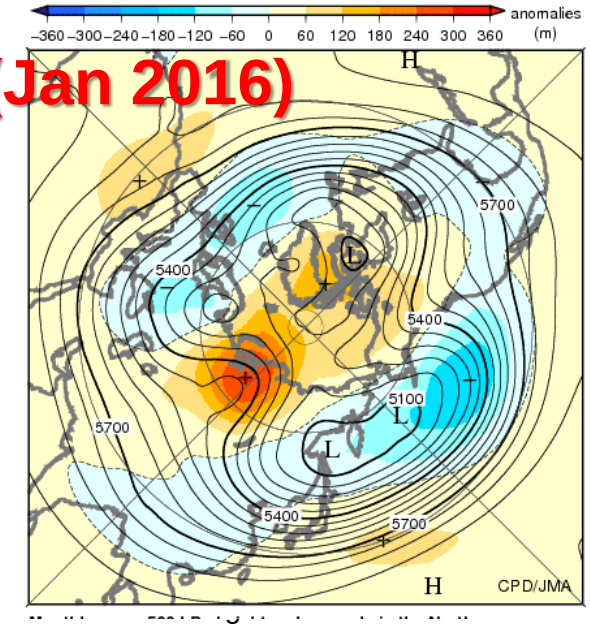


Monthly mean temperature anomalies in Dec. 2017

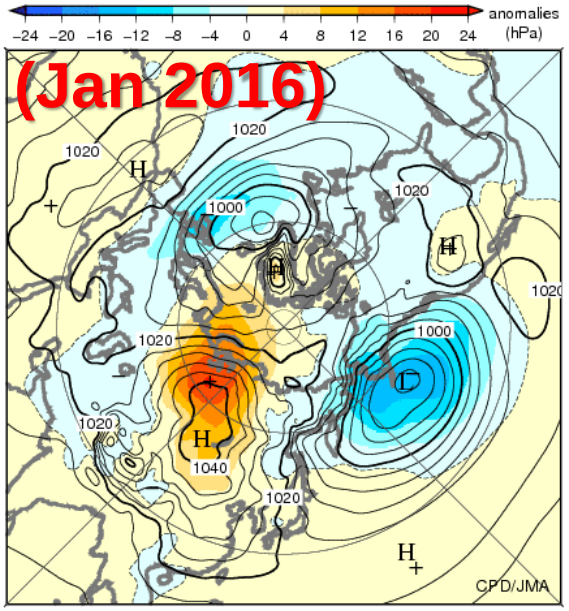
Eurasia (EU) Pattern

- The EU pattern is shown as a Rossby wave train along the polar front jet stream.
- The positive EU pattern is associated with an enhanced ridge over Siberia and intensification of the Siberian High.
- Hence the positive EU is often connected to a cold air outbreak and leads to an unusually freezing episode over East Asia and sometimes Southeast Asia as well.

Z500 (Jan 2016)



SLP (Jan 2016)

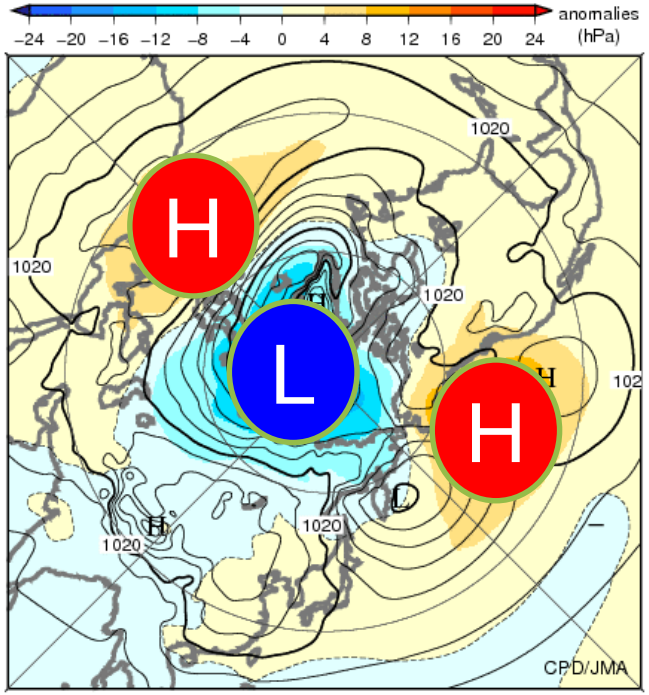


Arctic Oscillation (AO)

- 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)

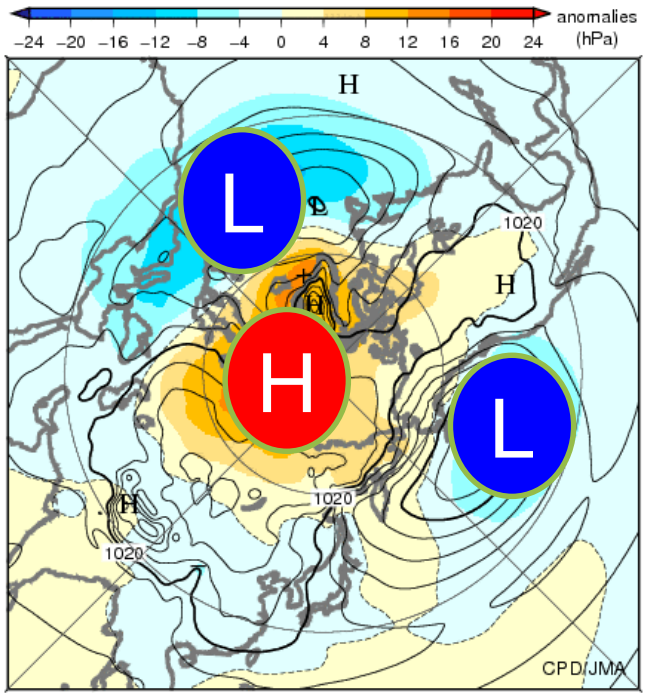
+AO



Three month mean sea level pressure and anomaly in the Northern Hemisphere (Dec.1988–Feb.1989)
The contours show sea level pressure at intervals of 4 hPa.
The shading indicates sea level pressure anomalies.

SLP anomalies (2009/10 DJF)

-AO



Three month mean sea level pressure and anomaly in the Northern Hemisphere (Dec.2009–Feb.2010)
The contours show sea level pressure at intervals of 4 hPa.
The shading indicates sea level pressure anomalies.

Seasonal Forecasts in Japan

Japan’s seasonal forecast started in 1942 for the purpose to reduce agricultural damages associated with cooler summers.

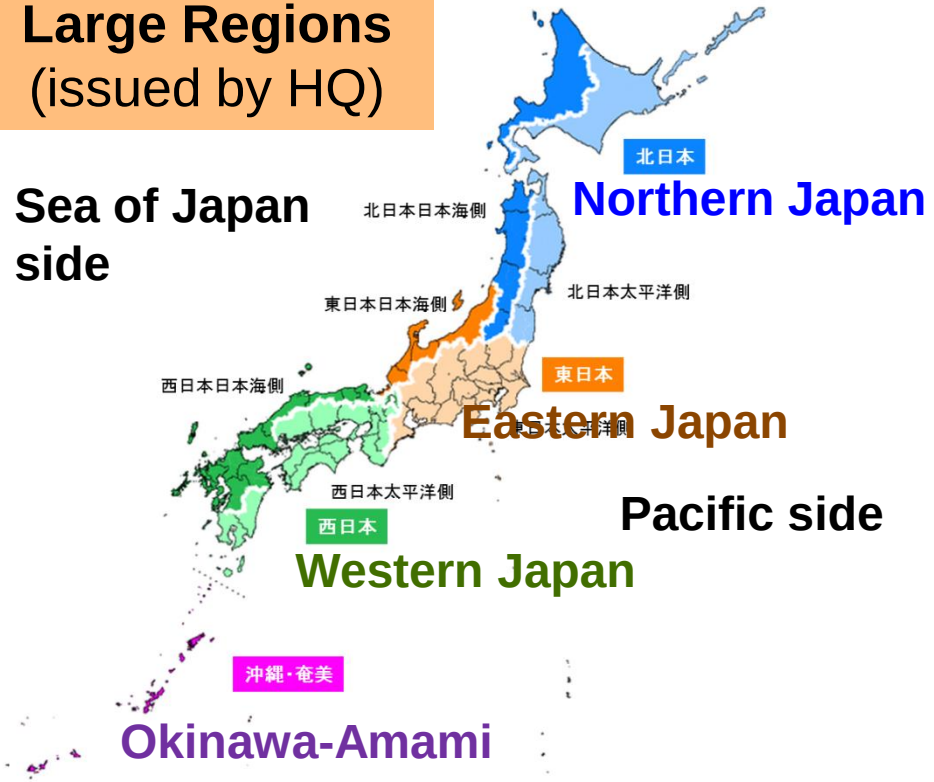
Seasonal Forecast at JMA

	Date of issue	Forecast Period	Forecast Item
1-month Forecast	Every Thursday	1-month mean	Temperature, Precipitation, Sunshine, Snowfall
		Weekly mean (1^{st}, 2^{nd}, 3^{rd}-4^{th} week)	Temperature
3-month Forecast	Around 25^{th} of every month	3-month mean,	Temperature, Precipitation, Snowfall
		Monthly mean (1^{st}, 2^{nd}, 3^{rd} month)	Temperature, Precipitation
Warm Season Forecast	Around 25 Feb.	3-month mean (Jun. – Aug.)	Temperature, Precipitation
		Rainy season (Jun. – Jul.)	Precipitation
Cold Season Forecast	Around 25 Sep.	3-month mean (Dec. – Feb.)	Temperature, Precipitation, Snowfall

Forecast Region

- Forecast is issued for sub-regions divided based on the climate characteristics.

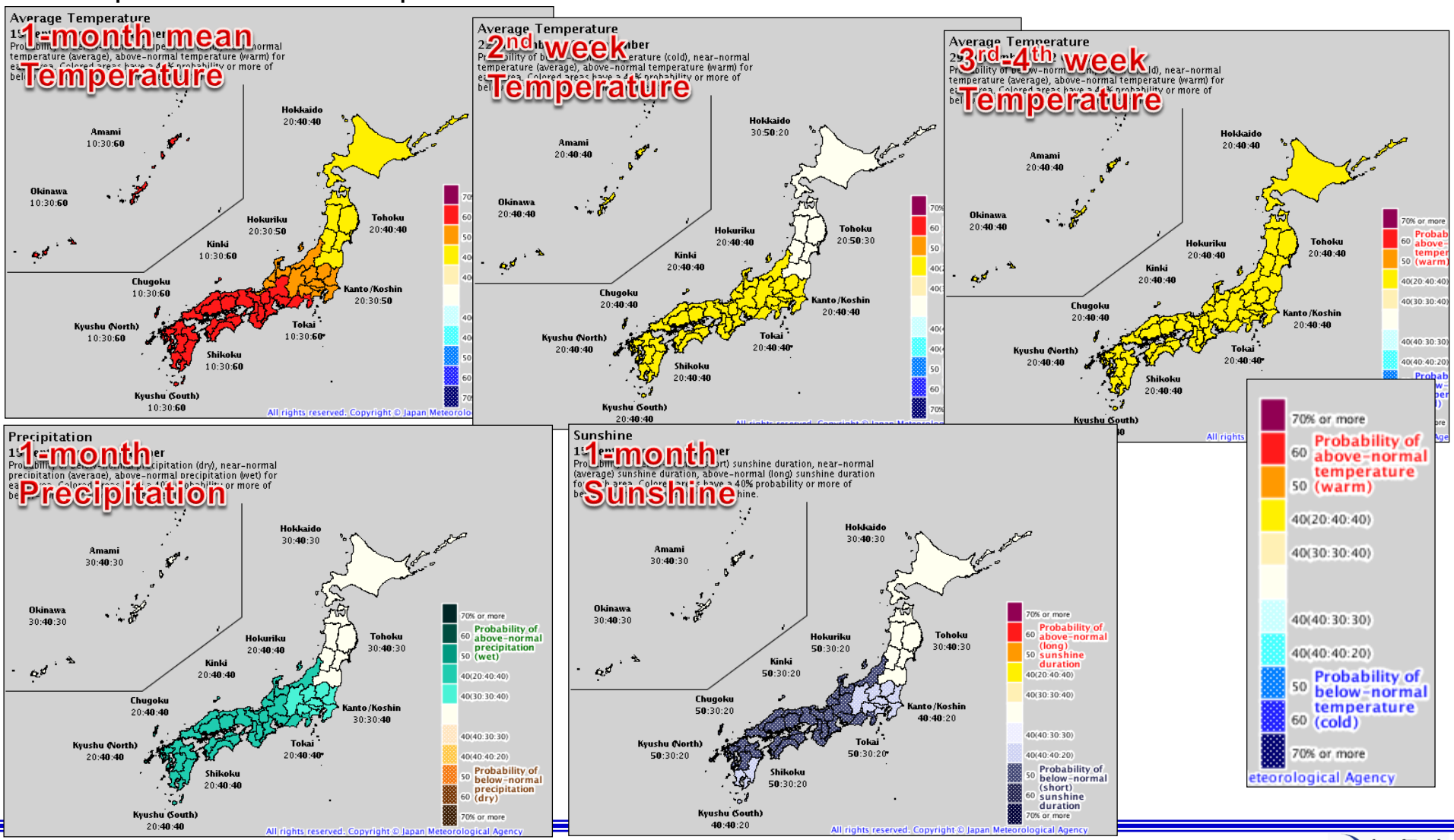
Large Regions
(issued by HQ)



Small Regions
(issued by the regional offices)

One-month Forecast

Example issued on 13 Sep. 2018



気象庁 Japan Meteorological Agency

Commentary on 1-month Forecast

1か月予報（平成30年9月13日発表）の解説

向こう1か月の天候の見通し

（9月15日～10月14日）

気象庁地球環境・海洋部

予報のポイント

Summary of the forecast

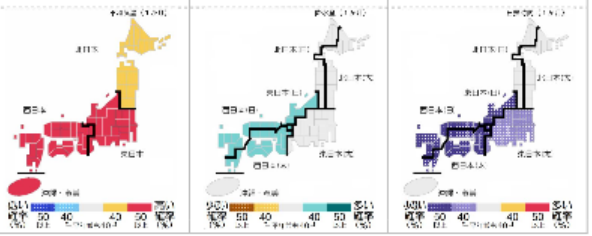
- 全国的に暖かい空気が流れ込みやすく、向こう1か月の気温は東・西日本と沖縄・奄美で高く、北日本でも平年並か高いでしょう。特に、西日本と沖縄・奄美では、期間のはじめは気温がかなり高くなる所がある見込みです。
- 東・西日本では、前線や湿
日本日本海側と西日本では、向こ
1か月の降水量は平年並か多いでし
1か月の日照時間は平年並か少ない見

In western/eastern Japan, cloudy/rainy weather is expected due to the active front and humid airflow...

1か月の平均気温・降水量・日照時

1-month forecast (probability)

		平均気温（1か月）	降水量（1か月）	日照時間（1か月）
北日本	日本海側	低20 並30 高50% 平年並か高い 見込み	少30 並40 多30% ほぼ平年並 の見込み	少30 並40 多30% ほぼ平年並 の見込み
	太平洋側		少30 並40 多30% ほぼ平年並 の見込み	少30 並40 多30% ほぼ平年並 の見込み
東日本	日本海側	低20 並30 高50% 高い 見込み	少30 並40 多30% 平年並か多い 見込み	少50 並30 多20% 少ない 見込み
	太平洋側		少30 並40 多40% ほぼ平年並 の見込み	少40 並40 多20% 平年並か少ない 見込み
西日本	日本海側	低10 並30 高60% 高い 見込み	少20 並40 多40% 平年並か多い 見込み	少50 並30 多20% 少ない 見込み
	太平洋側		少20 並40 多40% 平年並か多い 見込み	少50 並30 多20% 少ない 見込み
沖縄・奄美		低10 並30 高60% 高い 見込み	少30 並40 多30% ほぼ平年並 の見込み	少30 並40 多30% ほぼ平年並 の見込み



数値は予想される出現確率です

Commentary material is also provided from JMA HP

週別の天候

Expected weather

（1週目）9/15～21	・北日本と東日本太平洋側では、天気は数日の周期で変わるでしょう。 ・東日本日本海側では、天気は数日の周期で変わりますが、前線や湿った空気の影響を受けやすく、平年に比べ曇りや雨の日が多いでしょう。 ・西日本では、天気は数日の周期で変わりますが、前線や湿った空気の影響を受けやすく、平年に比べ晴れの日が少ないでしょう。 ・沖縄・奄美では、天気は数日の周期で変わりますが、高気圧に覆われやすく平年に比べ晴れの日が多いでしょう。
（2週目）9/22～28	・北日本では、天気 ・東日本では、天気は く、平年に比べ曇り ・西日本と沖縄・奄美では 雪を受けやすく、平年に
（3～4週目）9/29～10/12	・北日本では、天気は数日 ・東日本では、天気は数日 く、平年に比べ曇りや雨 ・西日本では、天気は数日 く、平年に比べ晴れの日が少ないでしょう。 ・沖縄・奄美では、天気は数日の周期で変わり、平年と同様に晴れの日が多いでしょう。

明日から1週間の、日別の天気や気温などは、週間天気予報（https://www.jma.go.jp/jp/week/）を参照してください。

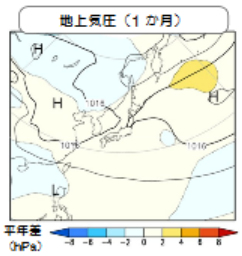
In 2nd week (22-28 Sep.), eastern/western Japan, cloudy/rainy days will be more likely to appear than normal due to active front and humid airflow.

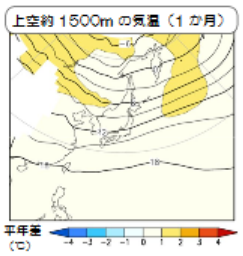
Numerical model's forecast maps (SLP and T850)

数値予報モデルによる予測結果

1か月平均の地上気圧（左図）は、華北から朝鮮半島付近と日本の東海上で高気圧が強い一方、西日本から東日本にかけては相対的に気圧が低い予測となっています。

上空約1500mの気温（右図）は、全体的に高い予測となっています。

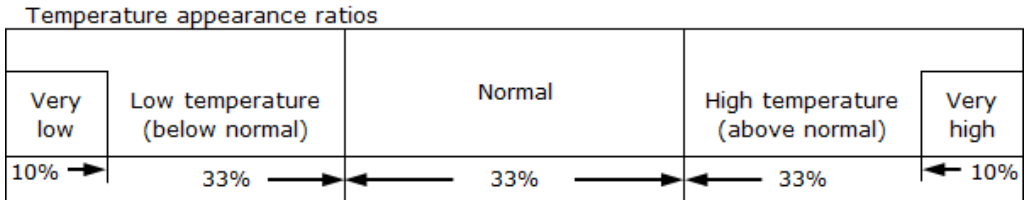




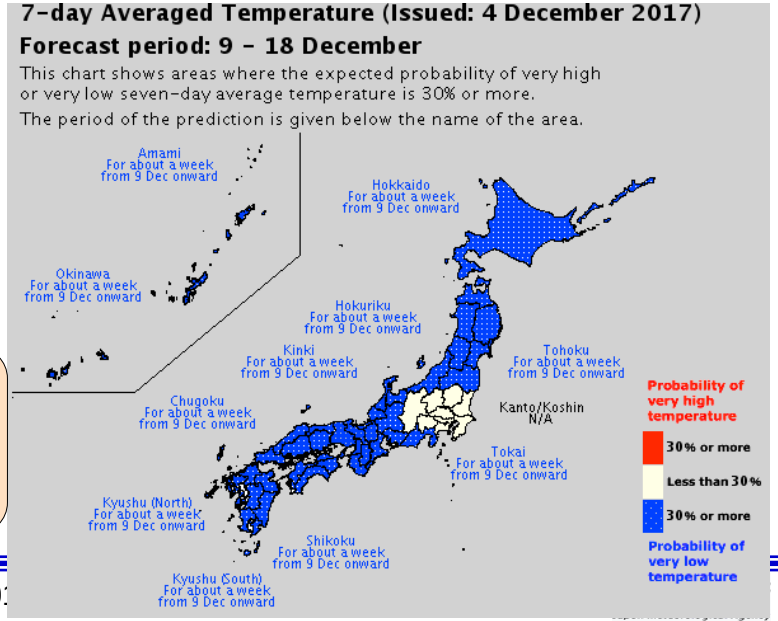
気象庁 Japan Meteorological Agency

Early Warning Information for Extreme Weather

- **Objective:** Mitigation of the adverse impacts from extreme weather events (hot/cold spell, heavy snow) on socio-economic activities such as agriculture and disaster prevention in early stage (1-2-week ahead).
- **Targeted event:** An extreme 7-day averaged temperature or 7-day snowfall amounts event which appears once per decade in climatology (i.e., 10%).
- **Timing of issuing:** When targeted event is expected to happen 5-14-day ahead with the probability of 30% or more (i.e., 3 times more likely to happen than normal).

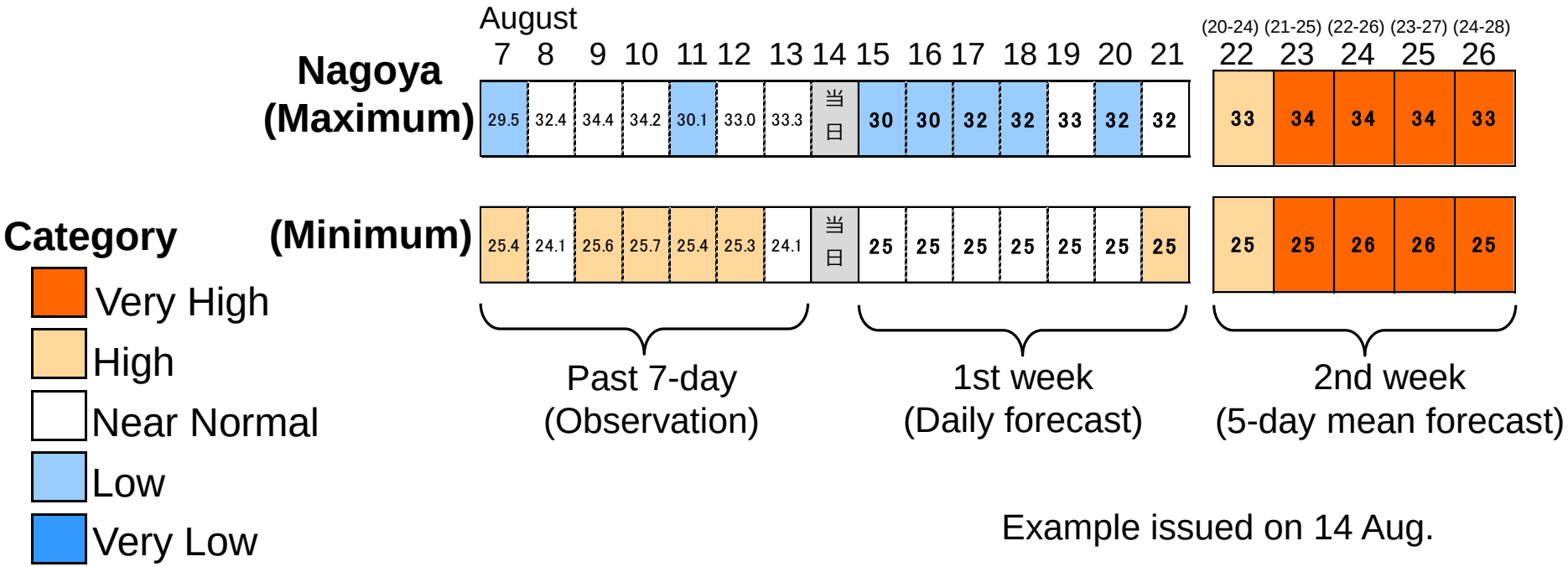


In this example, information for significantly cold weather from 9 Dec. onward was issued on 4 Dec.



2-week Temperature Forecast

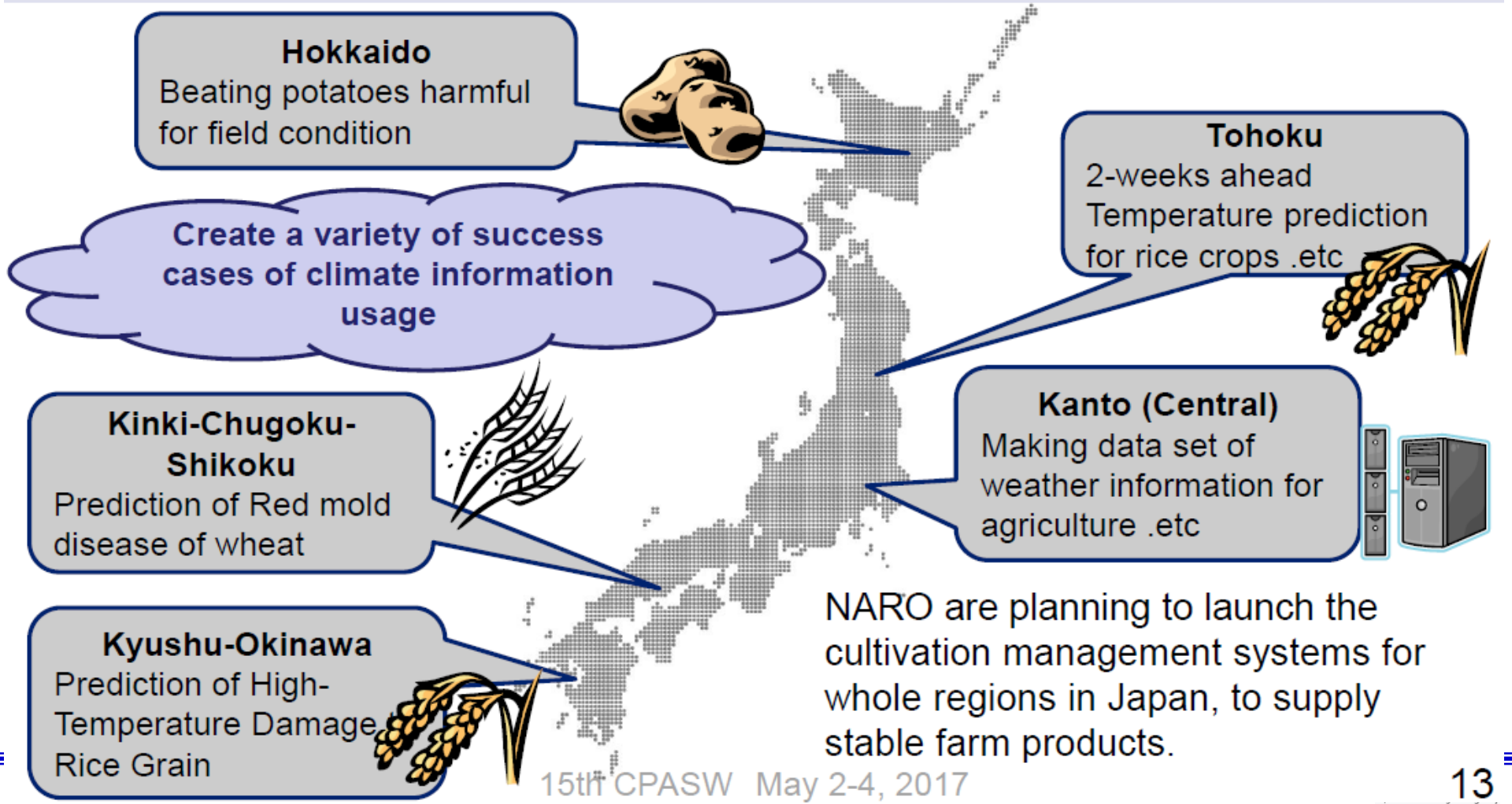
- From June 2019, new information of temperature outlook for the next 2-week will be provided.
- On JMA-HP, observation data for the past week and forecast for the next 2-week are summarized in one page so that users can easily check the temporal change of temperature.



Example issued on 14 Aug.

Utilization of Seasonal Forecast

JMA conducted joint researches with agricultural research Institutes（NARO）all over Japan.



NARO are planning to launch the cultivation management systems for whole regions in Japan, to supply stable farm products.

Future issues for practical use

Expansion is one of future issues for practical use

JMA makes effort to continue dialogue with local agricultural organization to promote a use of climate information in agricultural decision-making.

Meteorological Office

Climate Services

local agricultural organization (research center and government agricultural association)

Farming information with agromet Advisories

Farmers

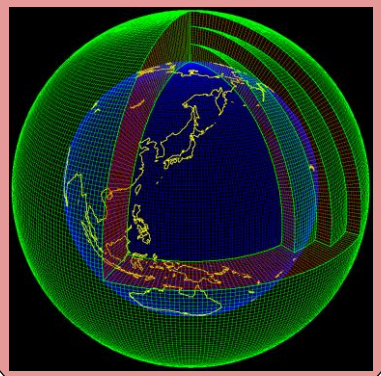
- Dialogue & Sharing knowledge
- Joint technology development

They usually have close contact with farmers in their territory

Procedure of 1-month Forecast

Flow of Making 1-month Forecast

Numerical Model



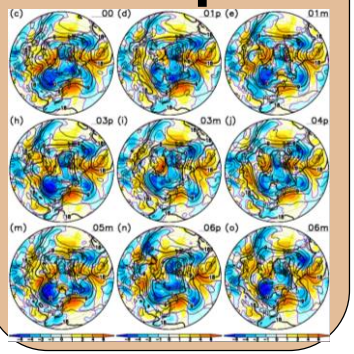
Hindcast

Ensemble Forecast

Verification Map

- Verification of model results

Forecast Map



- ENSO
- Precipitation
- Atmospheric response

Statistical Downscale

Guidance

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

- Probability

Forecaster

1-month Forecast

Procedure of 1-month Forecast

1. Understand the current status of ocean and atmosphere
2. Check the numerical model results
   - Convective activity (Precipitation)
   - Atmospheric circulation (response to the convection)
3. Check the prediction skill of the numerical model
4. Check the **guidance** to estimate probability
5. Decide forecast

Next lecture

Lecture on Wednesday

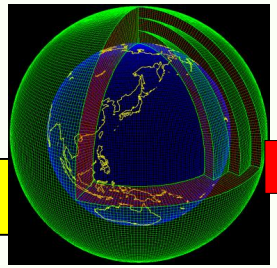
Exercise on Wednesday

Goal of this seminar

Guidance is an application to translate model output values into target of forecasting with statistical relationship between forecast and observation

INPUT

Numerical model



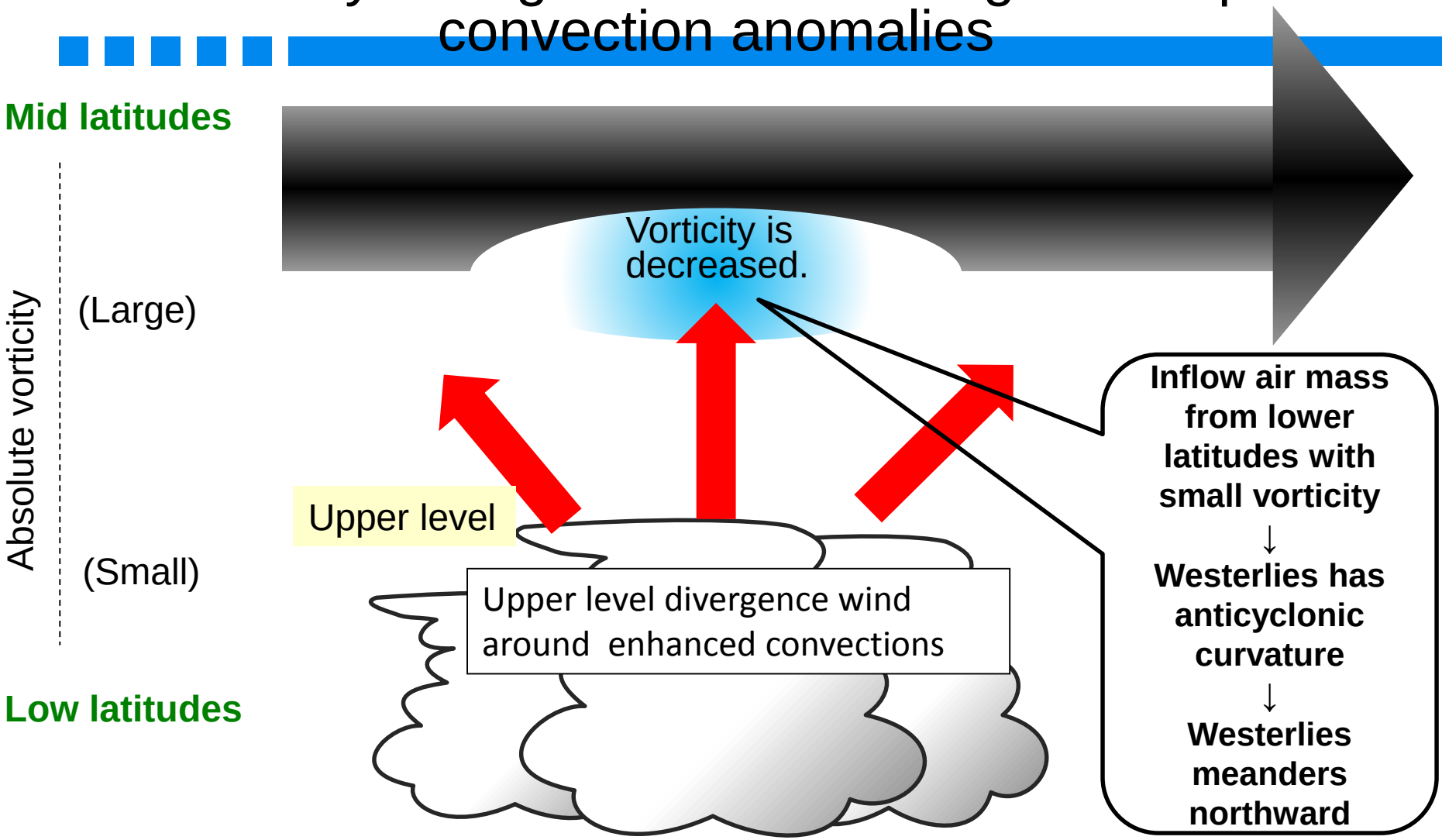
Statistical downscale

OUTPUT

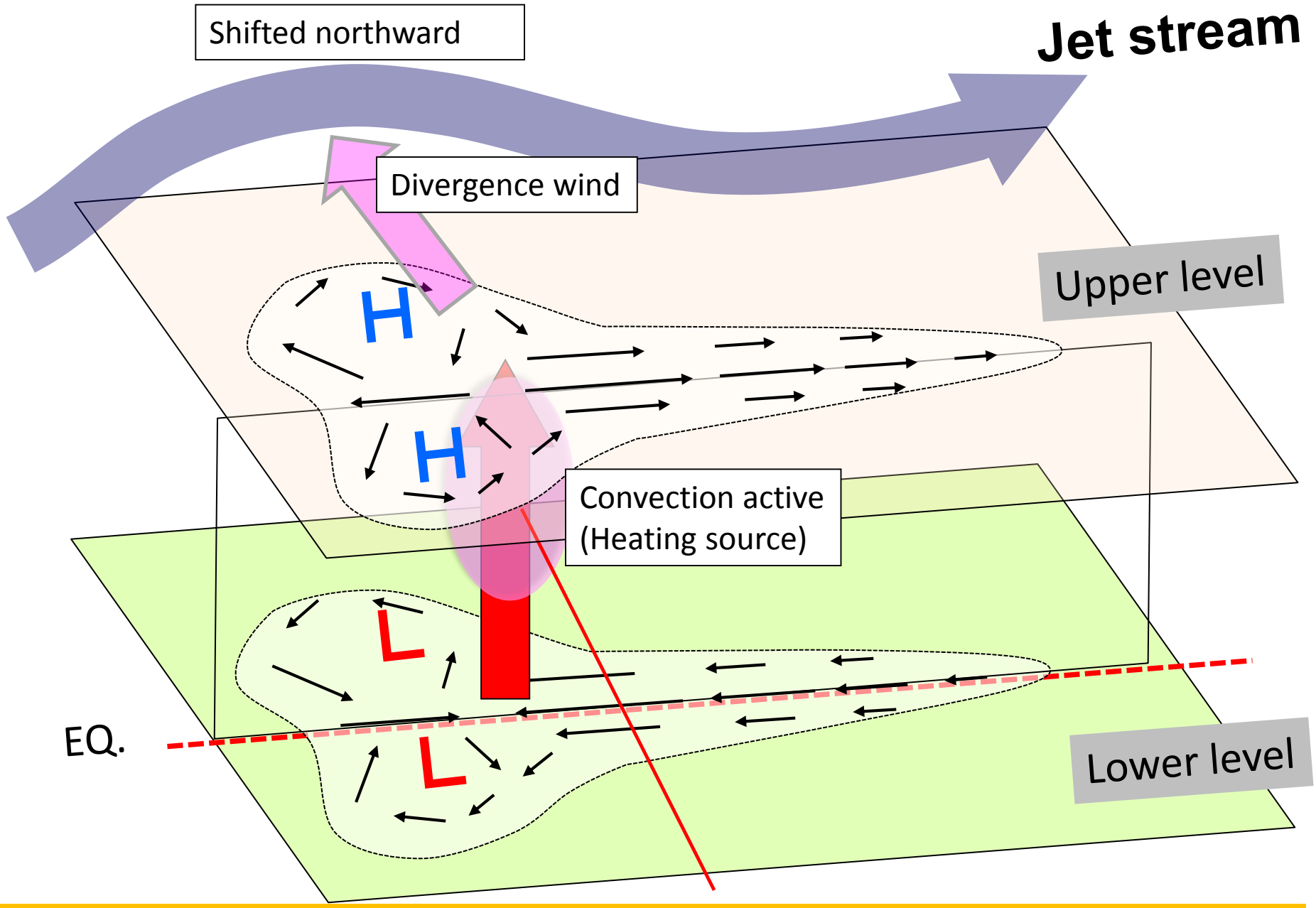
Probabilistic forecast

Backup Slides

Meandering of the jet stream induced by divergence wind relating with tropical convection anomalies



Absolute vorticity is generally low in lower latitudes.
When upper level divergence wind (enhanced convections) flows into the mid latitudes, relatively small absolute vorticity is supplied.



Response to heating source on EQ

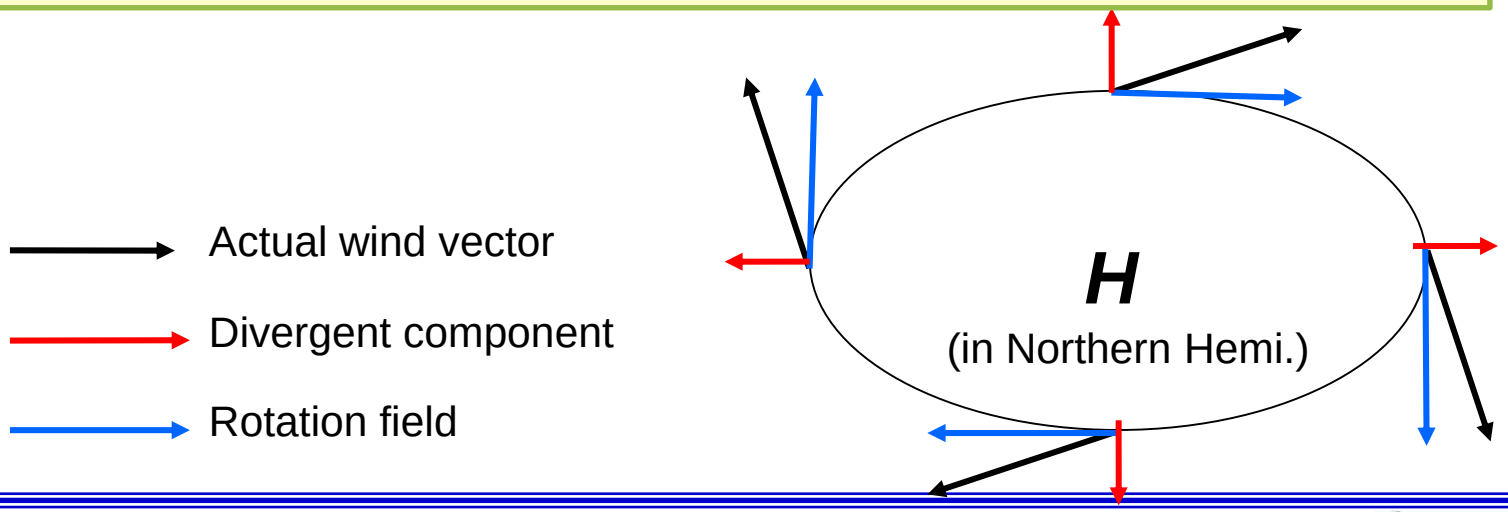
Ref. CHI (velocity potential),PSI (stream function)

- CHI and PSI are more helpful for monitoring large-scale atmospheric fields, comparing with [U,V].

✓ CHI and PSI represent larger spatial distribution than divergence and vorticity, according to those definitions (refer to the note for details).

Decomposition of the wind fields into divergence and rotation

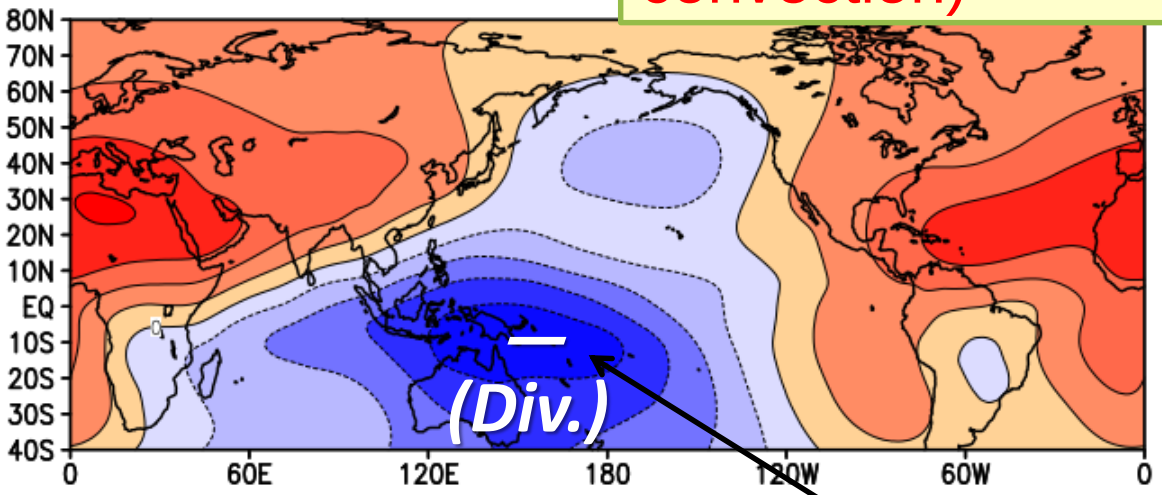
- Divergence component
  - ➢ Velocity potential (negative; more divergent)
- Rotation component
  - ➢ Stream function (negative; anticlockwise)

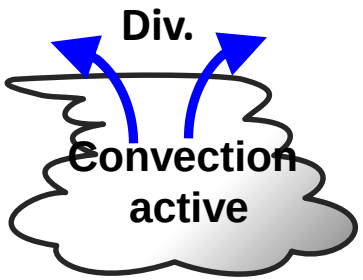


Velocity potential (Normal for January)

-: divergent (active convection)
+: convergent (inactive convection)

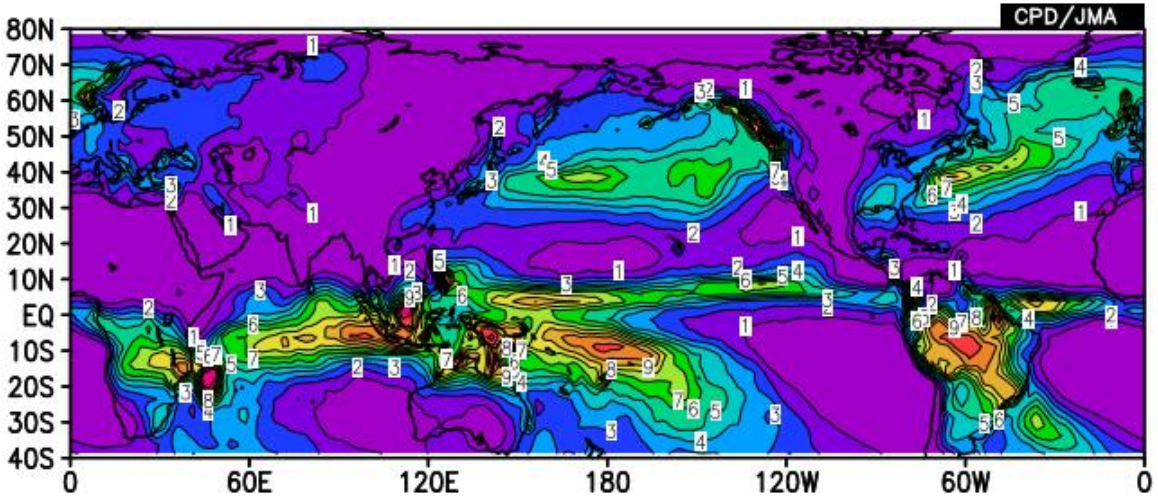
CHI (200hPa)





[× 10^6 m^2/s]

Precipitation (GPCP)



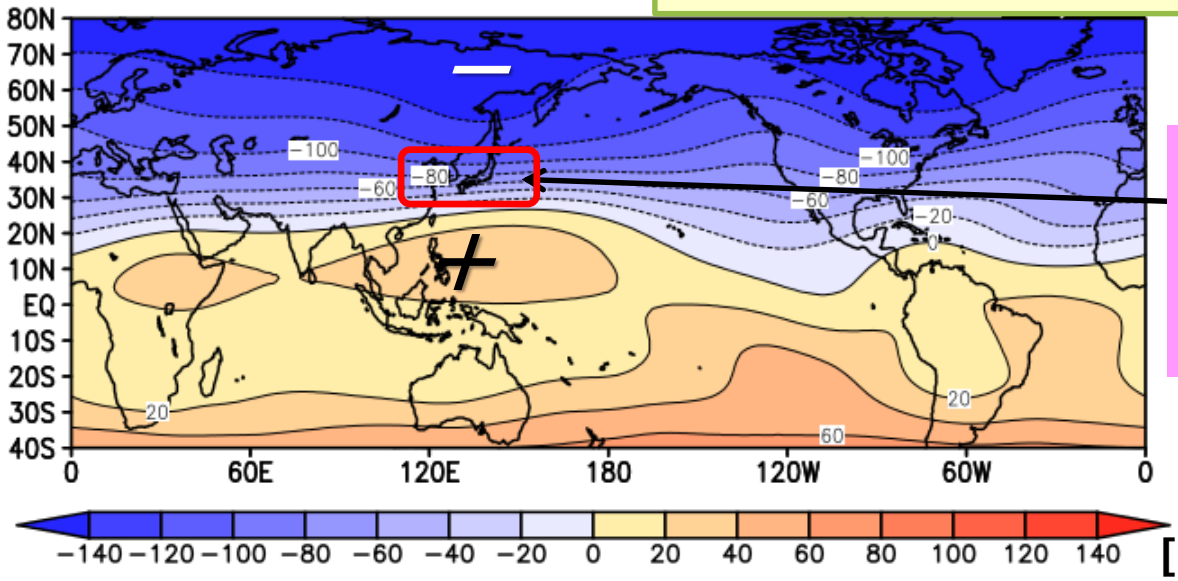
[mm/day]

Divergence in the upper level in the western Pacific, reflecting active convections.

Stream function (Normal for January)

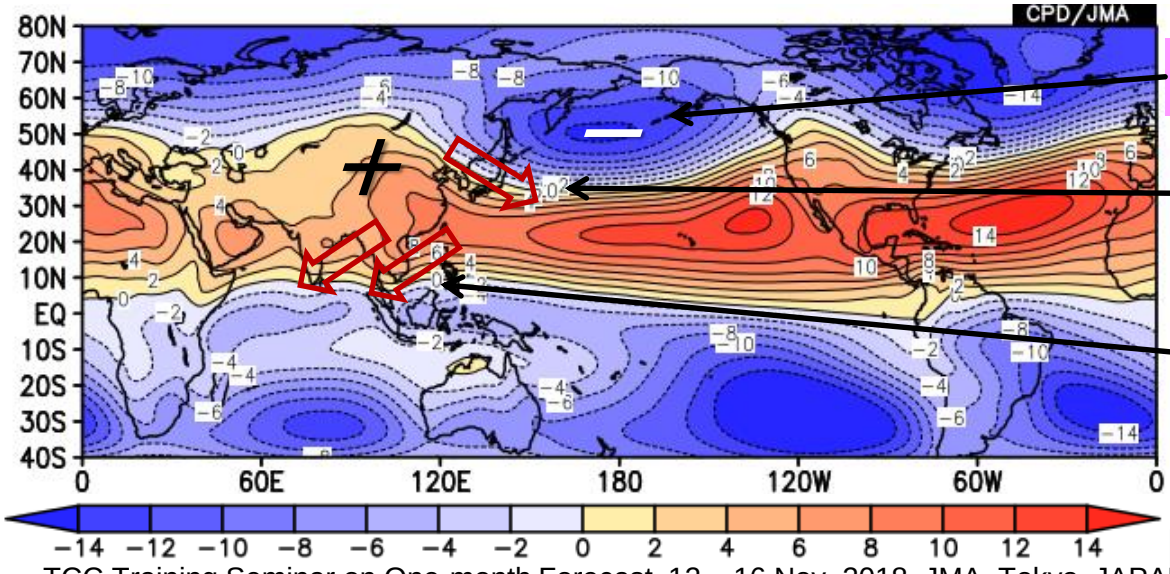
+: clockwise (anti-cyclonic)
-: anticlockwise (cyclonic)
(in Northern Hemisphere)

Upper (200hPa)



Large contour dense
= strong flow
= jet stream

Lower (850hPa)



Aleutian low

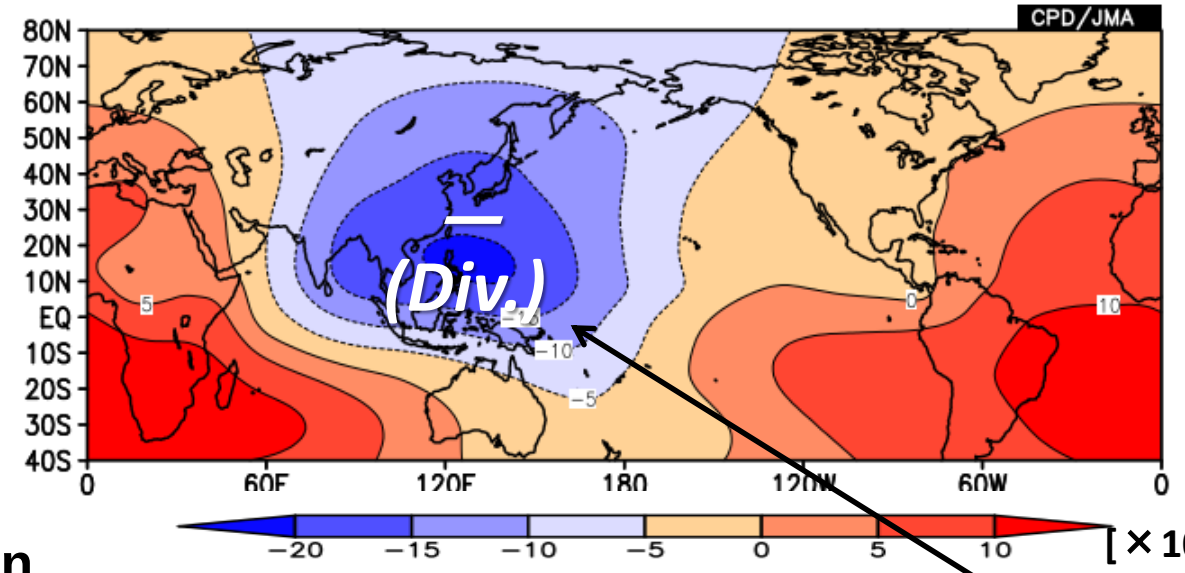
North-westerly monsoon

North-easterly monsoon

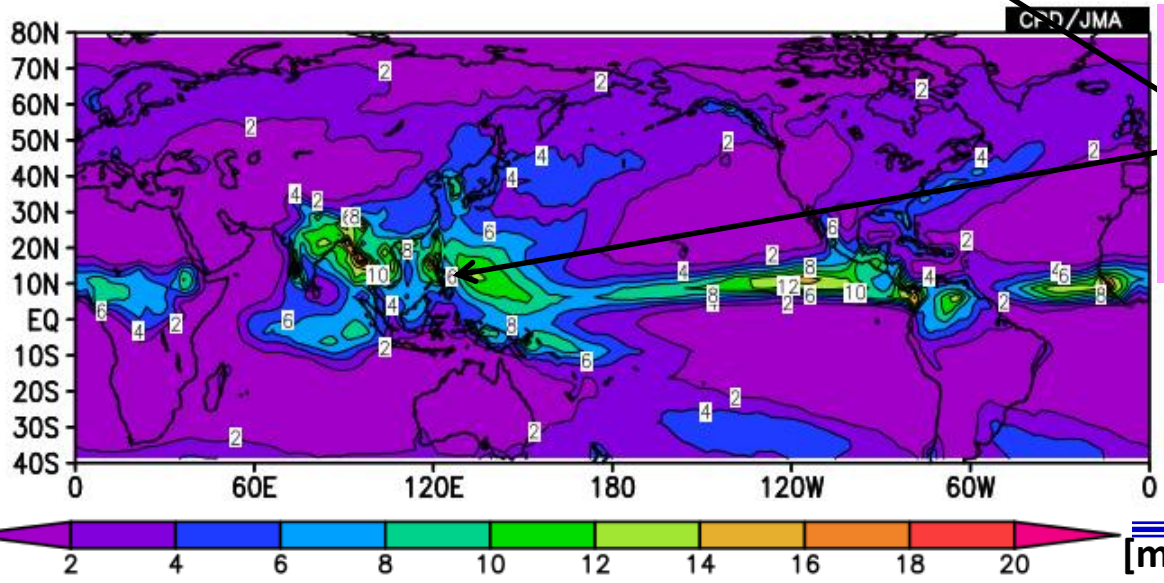
Velocity potential (Normal for August)

-: divergent (active convection)
+: convergent (inactive convection)

CHI (200hPa)



Precipitation (GPCP)

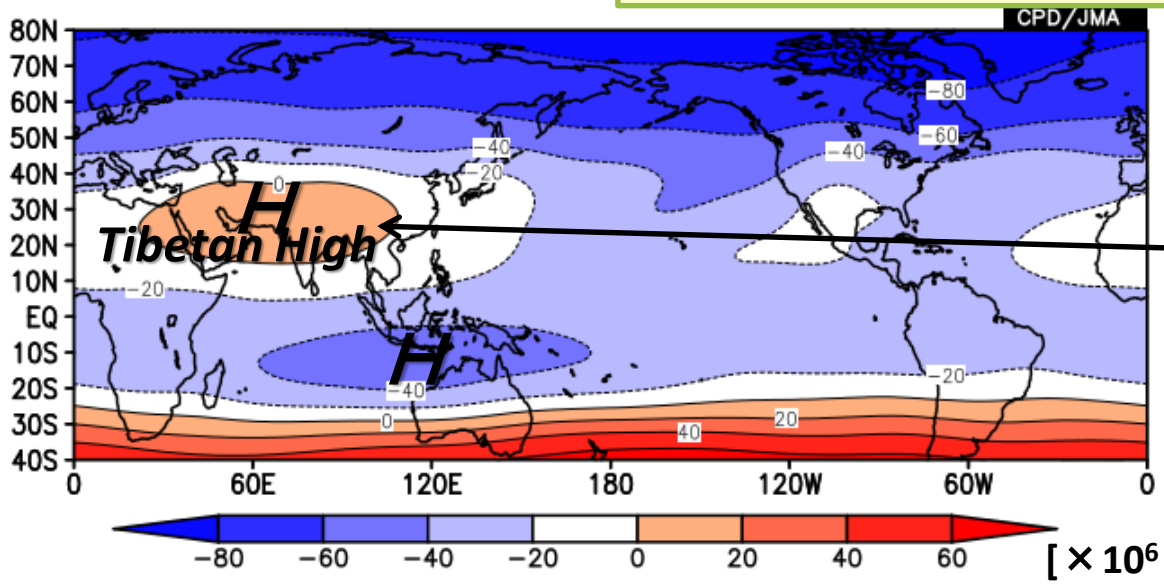


Divergence in the upper level over the Asian monsoon region, reflecting active convections.

Stream function (Normal for August)

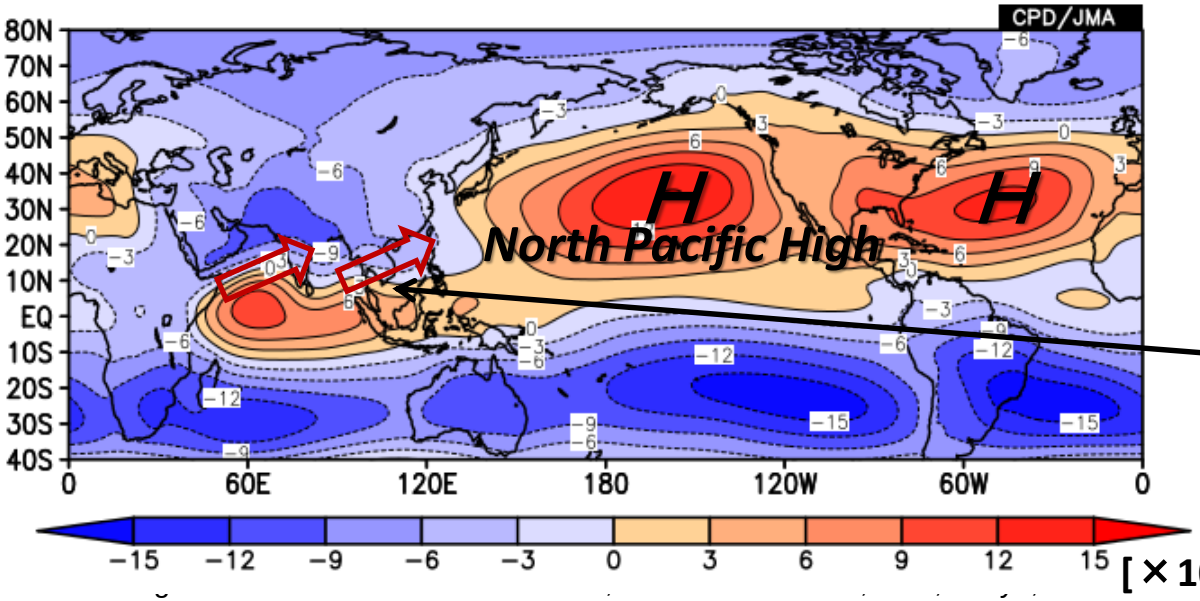
+: clockwise (anti-cyclonic)
-: anticlockwise (cyclonic)
(in Northern Hemisphere)

Upper (200hPa)



Large scale high in upper level (Tibetan high)

Lower (850hPa)



South-westerly monsoon