1

Seasonal forecast (One-month forecast)

Masayuki Hirai

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

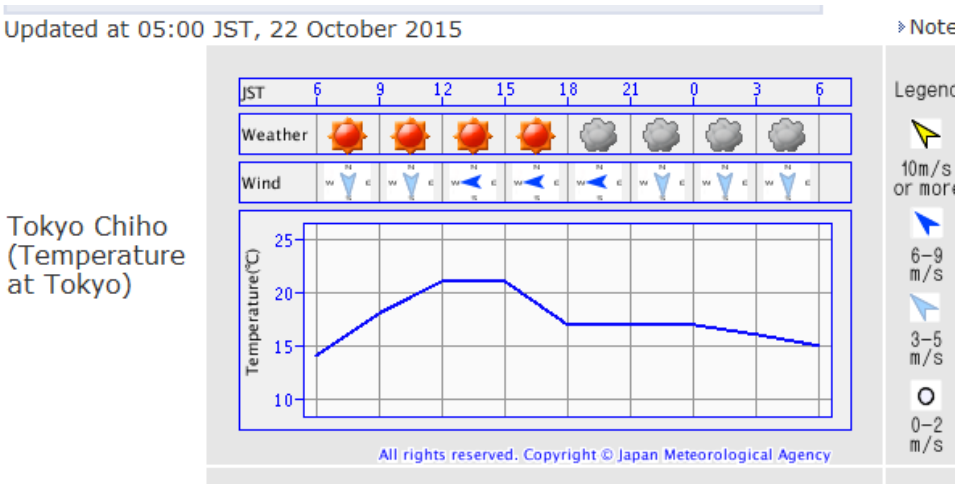
Outline

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

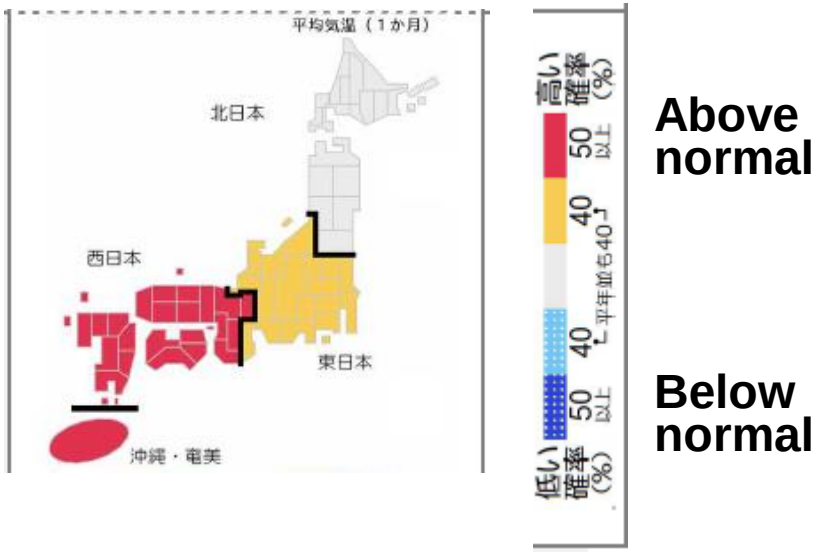
Introduction

Differences between short-range forecast and seasonal forecast

Short-range forecast



Seasonal prediction



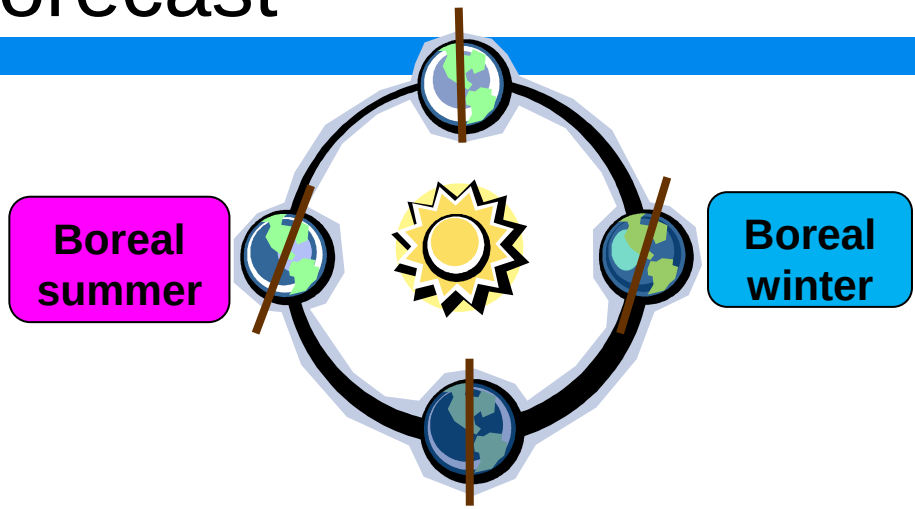
Describing <u>weather parameter variation itself</u>.

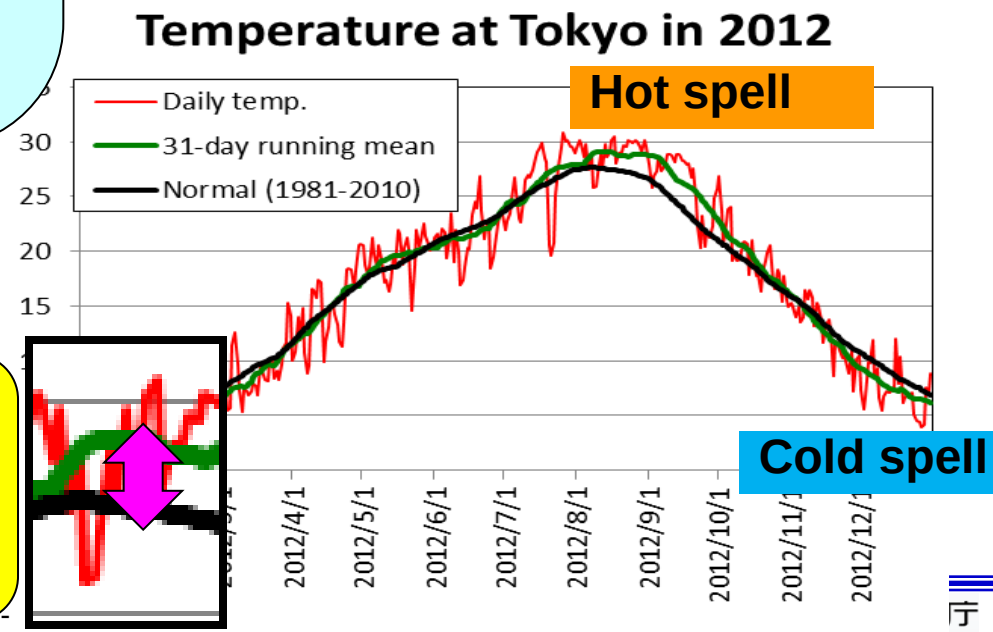
(not deviation, not averaged)

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

The meaning of describing “anomalies” in the seasonal forecast

- Four (Three?) seasons cycle annually.
- Seasonal cycle of the region depends on solar angle and land-sea distribution.
- Weather conditions averaged over a period is “normal”.
- Meanwhile, Weather conditions has some features every year.
- Anomalous climate may affects the lives of the people.

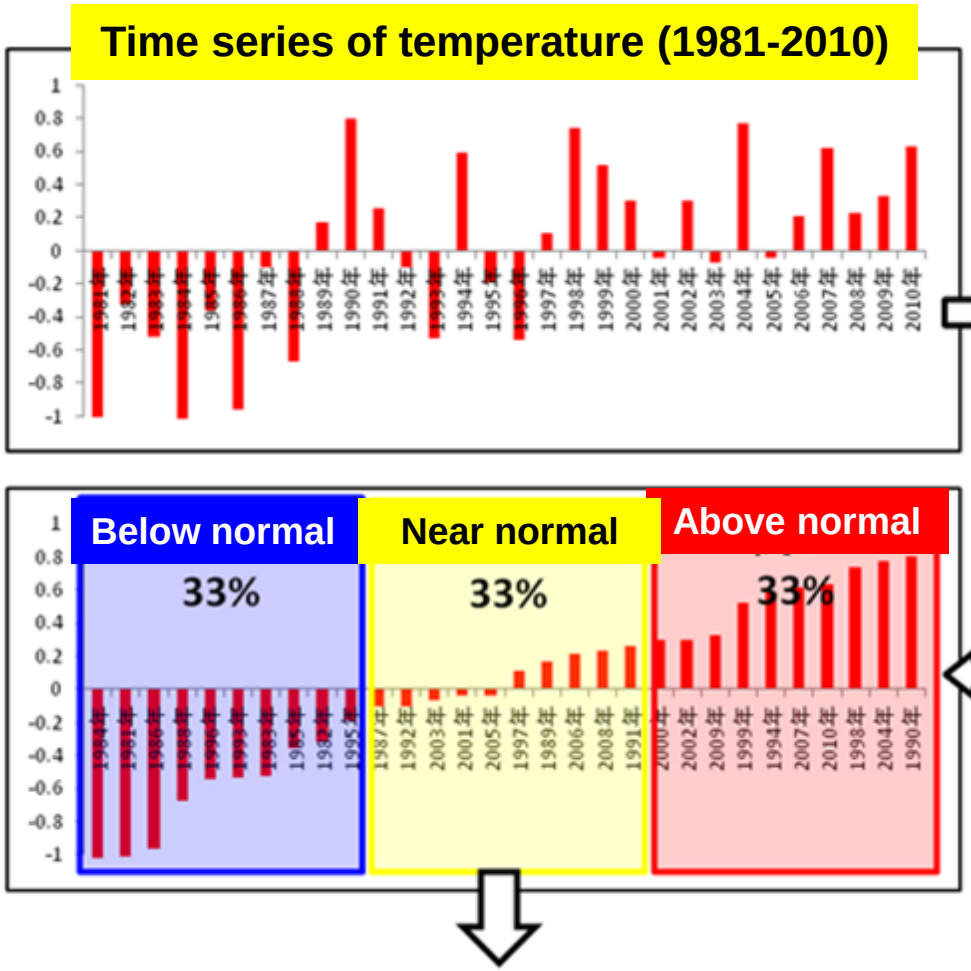




- **Anomaly from normal** is the target of seasonal forecasting.

What is the “normal” used in seasonal forecast?

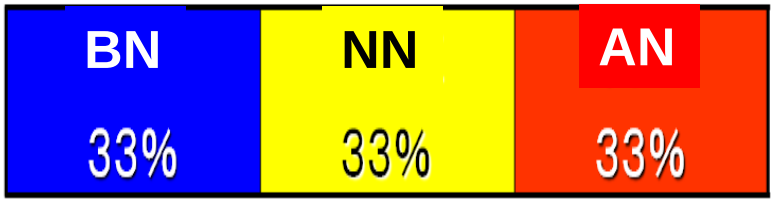
- Target of the seasonal forecast is departure from the “normal”.
- In JMA, period for “normal” is 30-year (1981 to 2010) as WMO recommends.
- Arranging historical data each year in ascending order,
  - <= 10th largest ; Below normal
  - 11th to 20th largest; Normal
  - 21th largest <= ; Above normal

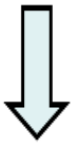


Tercile probabilistic forecast

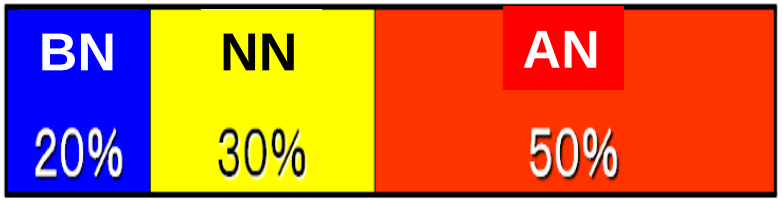
- In the seasonal forecast probability for each category is predicted.
- Occurrence rate for each category is expected 33%.
- In certain forecasting, deviation from the climatological occurrence is important.

Climatological occurrence



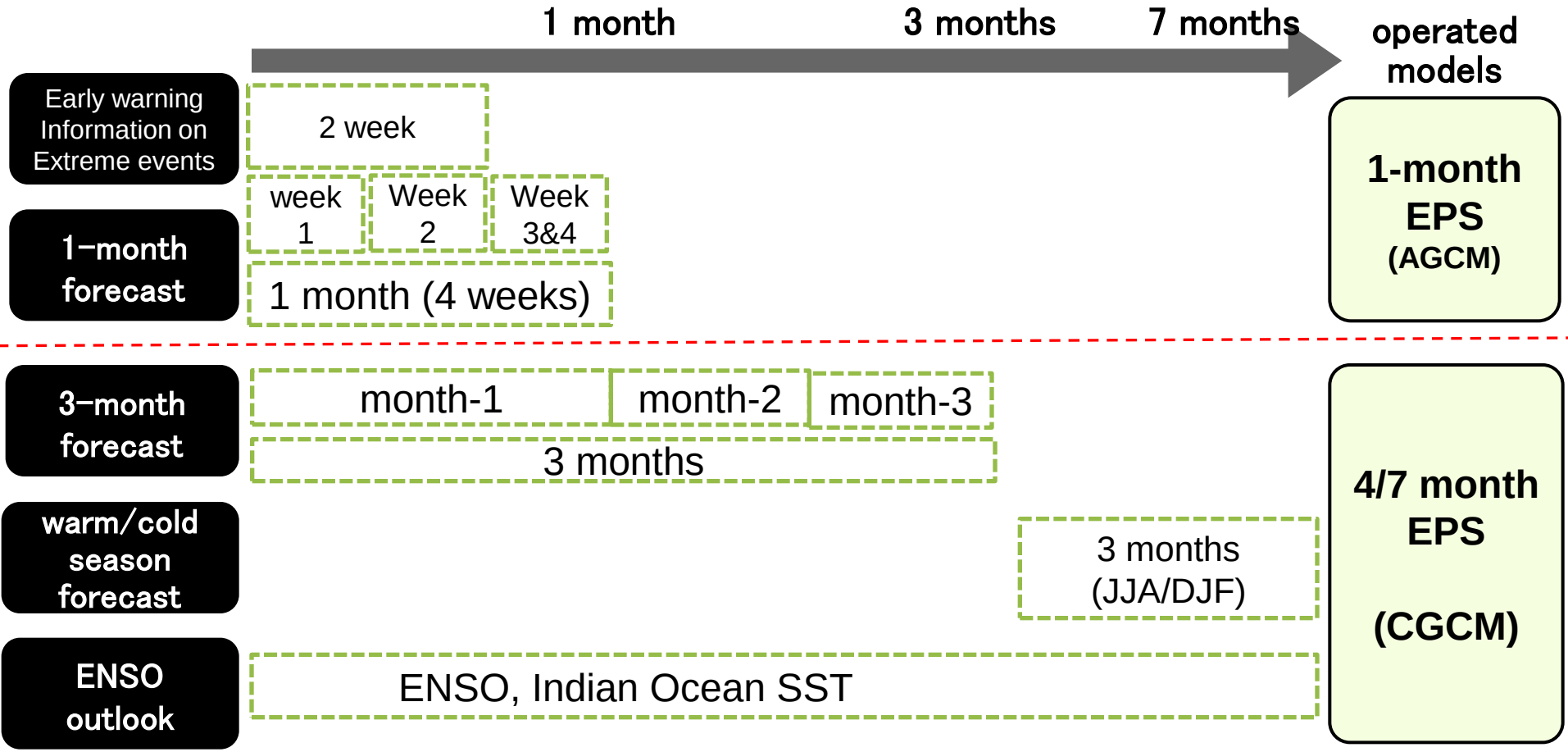


Certain forecast



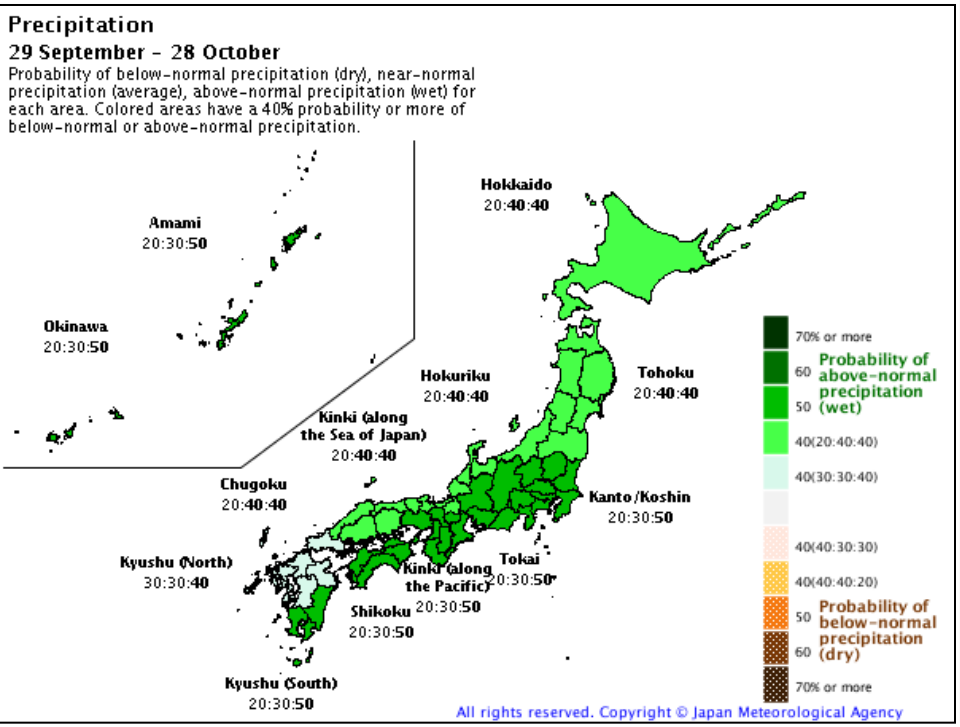
Seasonal forecasts in Japan

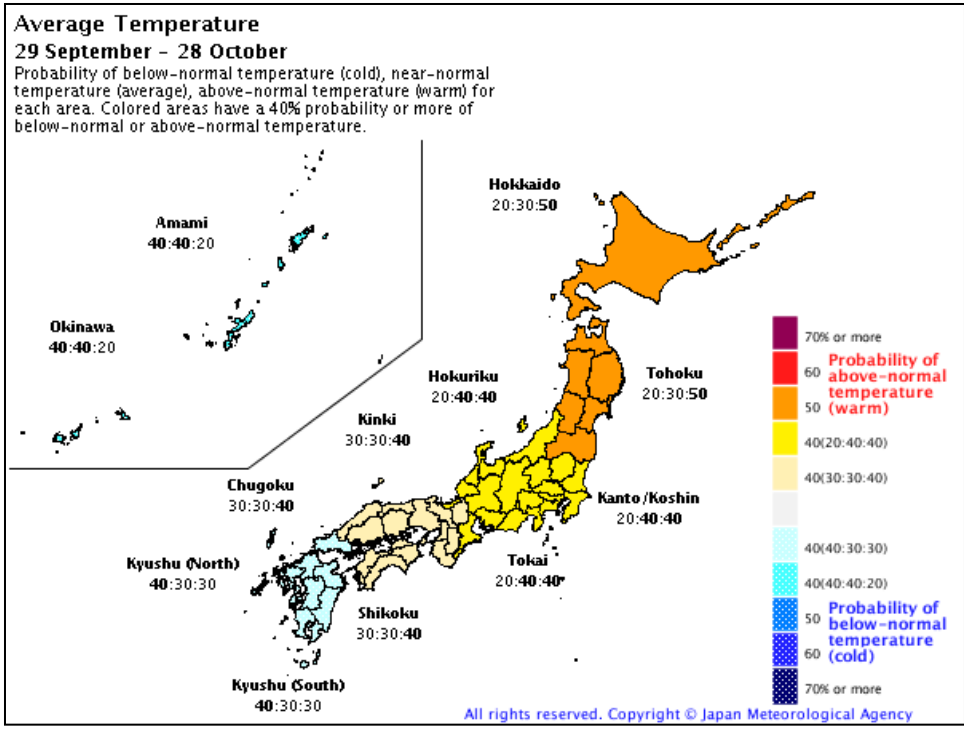
Overview of forecasts at CPD/JMA



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

One-month forecast
Seasonal Forecast Announcement (JMA Homepage)





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

Commentary of one-month forecast

向こう1か月の天候の見通し
（11月14日～12月13日）

気象庁地球環境・海洋部

予報のポイント

- 日本付近は北からの寒気の影響が小さいでしょう。このため、向こう1か月の気温は全国的に高く、期間の前半はかなり高くなる見込みです。
- 太平洋側を中心に低気圧や前線の影響を受けやすく、向こう1か月の降水量は、東日本太平洋側と西日本、沖縄・奄美で多いでしょう。東日本太平洋側と西日本では、向こう1か月の日照時間も少ない見込みです。

Headline

1か月の平均気温・降水量・日照時間

		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	低い 20 並 30 高い 50% 高い 見込み	少ない 30 並 40 多い 30% ほぼ平年並 の見込み	少ない 30 並 40 多い 30% ほぼ平年並 の見込み
	太平洋側		少ない 20 並 40 多い 40% 平年並か多い 見込み	少ない 40 並 40 多い 20% 平年並か少ない 見込み
東日本	日本海側	低い 10 並 20 高い 70% 高い 見込み	少ない 30 並 40 多い 30% ほぼ平年並 の見込み	少ない 30 並 40 多い 30% ほぼ平年並 の見込み
	太平洋側		少ない 10 並 30 多い 60% 多い 見込み	少ない 60 並 30 多い 10% 少ない 見込み
西日本	日本海側	低い 10 並 20 高い 70% 高い 見込み	少ない 20 並 30 多い 50% 多い 見込み	少ない 50 並 30 多い 20% 少ない 見込み
	太平洋側		少ない 10 並 30 多い 60% 多い 見込み	少ない 60 並 30 多い 10% 少ない 見込み
沖縄・奄美		低い 10 並 20 高い 70% 高い 見込み	少ない 20 並 30 多い 50% 多い 見込み	少ない 40 並 40 多い 20% 平年並か少ない 見込み

数値は予想される出現確率です

Probabilities (one-month mean)

週別の天候

（1週目）11／14～20	・北日本日本海側では、平年に比べ曇りや雨または雪の日が少ないでしょう。 ・東日本日本海側では、平年と同様に曇りや雨の日が多いでしょう。 ・西日本日本海側では、平年に比べ曇りや雨の日が多いでしょう。 ・北・東・西日本太平洋側では、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、平年に比べ曇りや雨の日が多いでしょう。
（2週目）11／21～27	・北日本日本海側では、平年に比べ曇りや雨の日が多いでしょう。 ・西日本日本海側では、平年と同様に曇りや雨の日が多いでしょう。 ・北日本太平洋側では、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、平年に比べ曇りや雨の日が多いでしょう。
（3～4週目）11／28～12／11	・北日本日本海側では、平年と同様に曇りや雨または雪の日が多いでしょう。 ・東・西日本日本海側では、平年と同様に曇りや雨の日が多いでしょう。 ・北日本太平洋側では、平年と同様に晴れの日が多いでしょう。 ・東・西日本太平洋側では、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、平年と同様に曇りや雨の日が多いでしょう。

Expected climate by week (week-1, -2, -3 and 4)

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（http://www.jma.go.jp/jp/week/）を参照してください。

週別の平均気温

	平均気温（1週目）11／14～20	平均気温（2週目）11／21～27	平均気温（3～4週目）11／28～12／11
北日本	低い 10 並 10 高い 80% 高い 見込み	低い 30 並 50 高い 20% 平年並 の見込み	低い 30 並 30 高い 40% ほぼ平年並 の見込み
東日本	低い 10 並 10 高い 80% 高い 見込み	低い 10 並 40 高い 50% 高い 見込み	低い 20 並 30 高い 50% 高い 見込み
西日本	低い 10 並 10 高い 80% 高い 見込み	低い 10 並 30 高い 60% 高い 見込み	低い 20 並 30 高い 50% 高い 見込み
沖縄・奄美	低い 10 並 10 高い 80% 高い 見込み	低い 10 並 30 高い 60% 高い 見込み	低い 20 並 30 高い 50% 高い 見込み

数値は予想される出現確率です

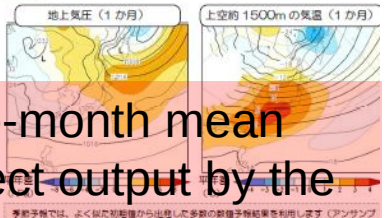
予報予報は、予測の確からしさに応じて、気温や降水量などを「低い（少ない）、平年並、高い（多い）」となる確率で表しています。「平年並」がどの程度の値になるのかについては、末尾の「参考データ（平年並の範囲）」をご覧ください。
確率をその大きさに応じ言葉で説明しています。詳しくは末尾の「参考データ（確率予報の説明）」をご覧ください。

Probabilities by week (temperature only)

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）では、オホーツク海から日本の東にかけて気圧が高く、冬型の気圧配置が弱い予測となっています。また、華中から本州南岸にかけて相対的に気圧が低く、日本の南岸を低気圧が通過しやすい見込みです。

上空約1500mの気温（右図）は、日本付近は平年より高い予測となっています。



One-month mean (direct output by the NWP model)

参考データ

●平均値の範囲

	平均気温（1か月）の平年値の範囲			降水量（1か月）の平年値の範囲	日照時間（1か月）の平年値の範囲
北日本	平年差：-0.5～0.6℃	北日本	日本海側	平年比：95～108%	平年比：88～108%
			太平洋側	平年比：73～114%	平年比：97～104%
東日本	平年差：-0.4～0.6℃	東日本	日本海側	平年比：87～112%	平年比：92～110%
			太平洋側	平年比：58～115%	平年比：96～106%
西日本	平年差：-0.4～0.5℃	西日本	日本海側	平年比：87～107%	平年比：93～108%
			太平洋側	平年比：66～113%	平年比：95～107%
沖縄・奄美	平年差：-0.2～0.5℃	沖縄・奄美		平年比：79～107%	平年比：91～107%

	平均気温（1週目）の平年値の範囲	平均気温（2週目）の平年値の範囲	平均気温（3-4週目）の平年値の範囲
北日本	平年差：-0.9～0.8℃	平年差：-0.9～0.8℃	平年差：-0.5～0.7℃
東日本	平年差：-0.7～0.5℃	平年差：-0.6～0.5℃	平年差：-0.4～0.6℃
西日本	平年差：-0.7～0.7℃	平年差：-0.7～0.6℃	平年差：-0.3～0.6℃
沖縄・奄美	平年差：-0.4～0.6℃	平年差：-0.3～0.7℃	平年差：-0.3～0.6℃

「平年並」の範囲は、現時期の過去30年間（1981-2010年）の値から統計的に求めています。30年間のデータの中で「高い（多い）」「平年並」「低い（少ない）」となるデータの数が等分になるように「平年並」の範囲を決めています。すなわち、30年間の30個のデータのうち、値が高い（多い）方から11～20番目となる10個のデータの値の範囲を、おおよそ「平年並」の範囲としています。

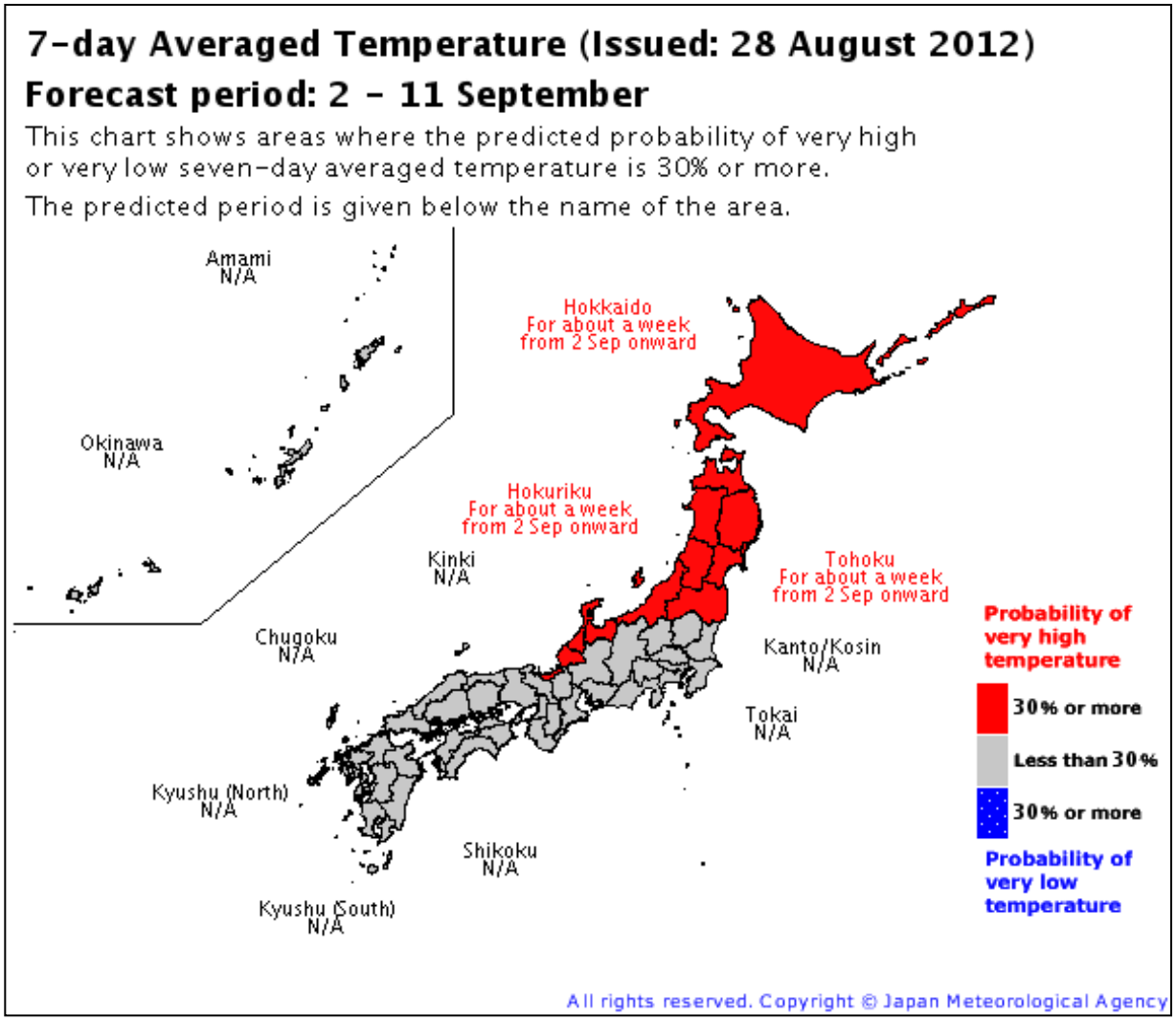
●確率予報

References (ex. range of near-normal)

気象庁 Japan Meteorological Agency

・Early Warning Information on Extreme Weather

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



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

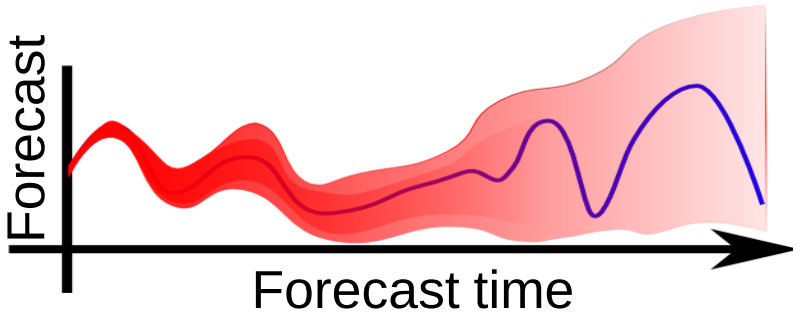
Climate information

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

Estimate of uncertainty (Ensemble prediction)

How to predict for longer time-scale

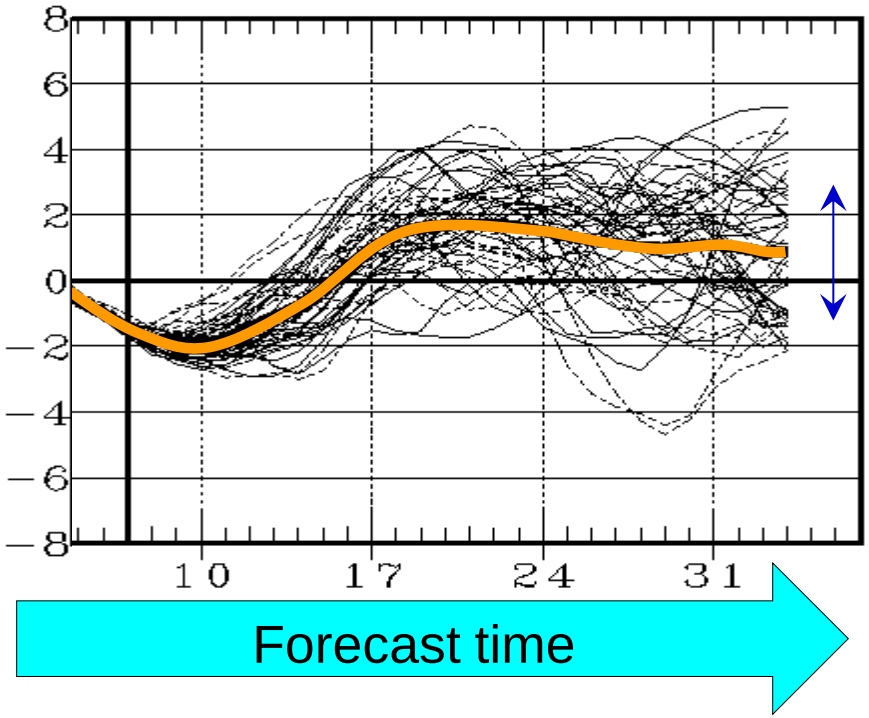
- Due to chaotic behavior of atmosphere, errors rapidly grow during period of prediction.



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

Estimating uncertainty with ensemble prediction

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

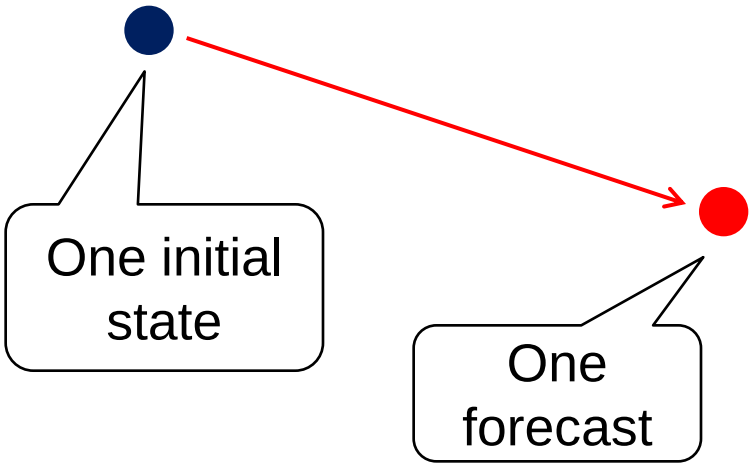


Ensemble spread = Standard dev., suggesting degree of uncertainty

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

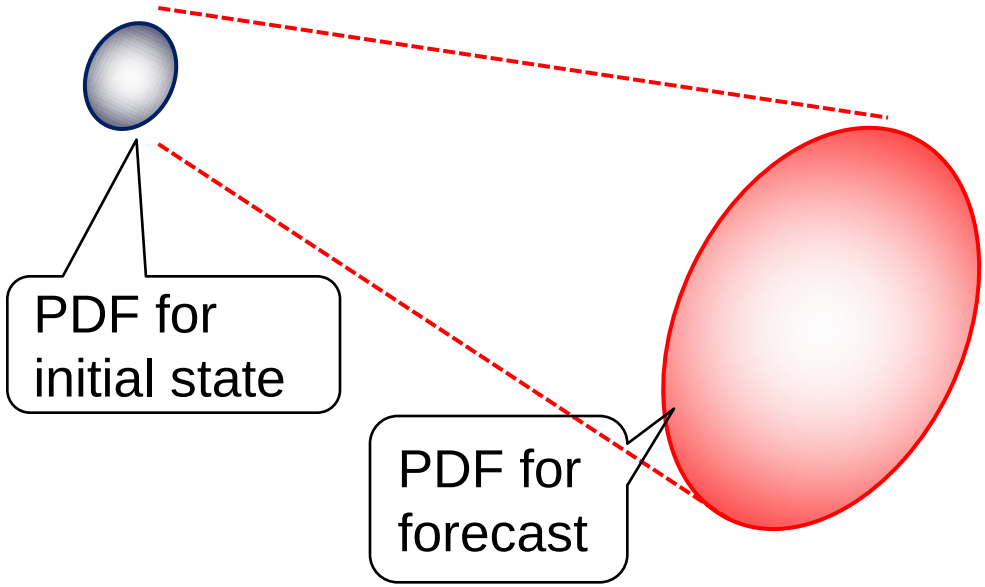
Deterministic and probabilistic forecast

Deterministic forecast



Calculate one forecast using one initial state

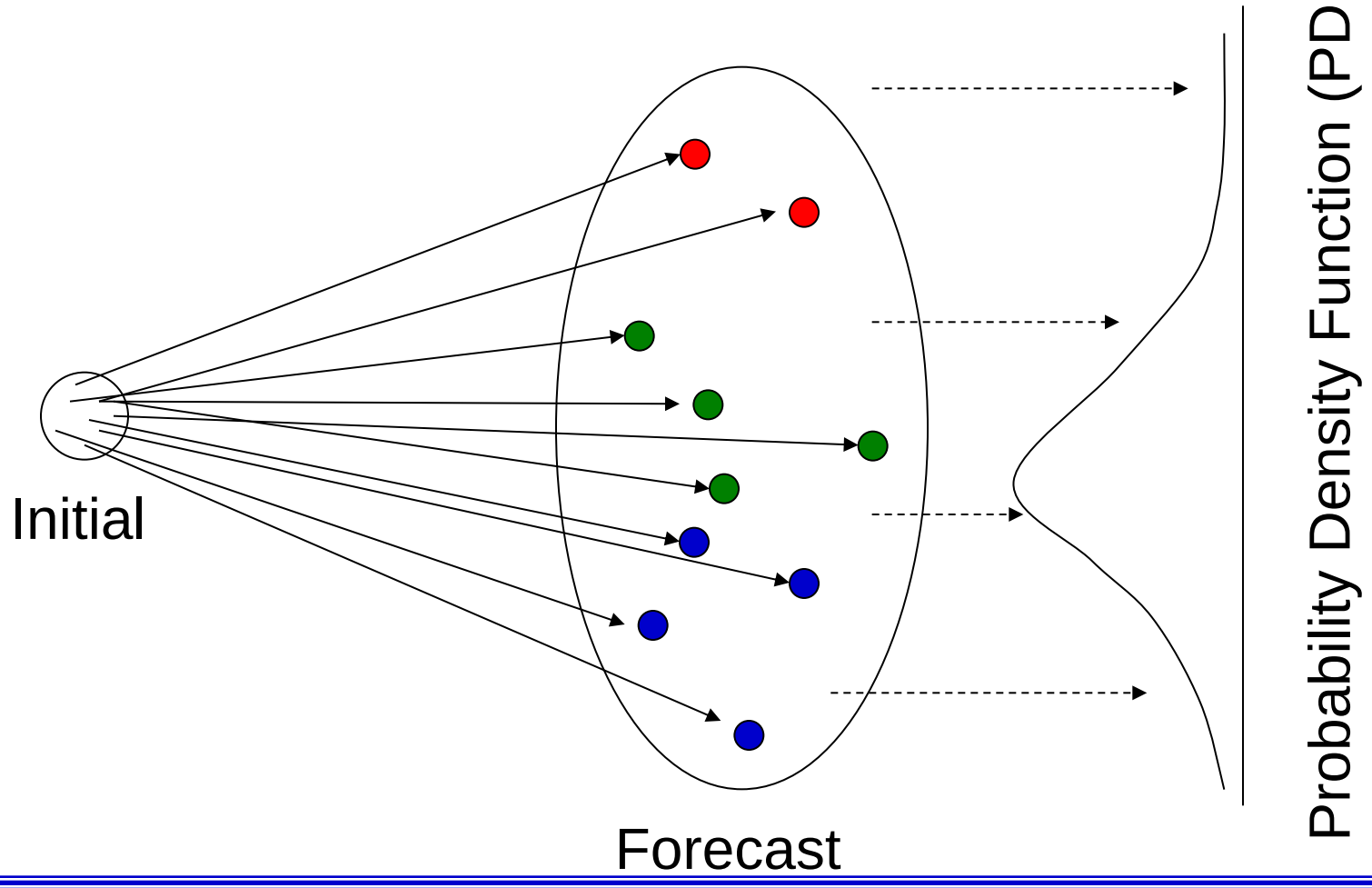
Probabilistic forecast



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

Probabilistic Forecast

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



WMO Classification of meteorological forecasting
(GDPFS Manual)

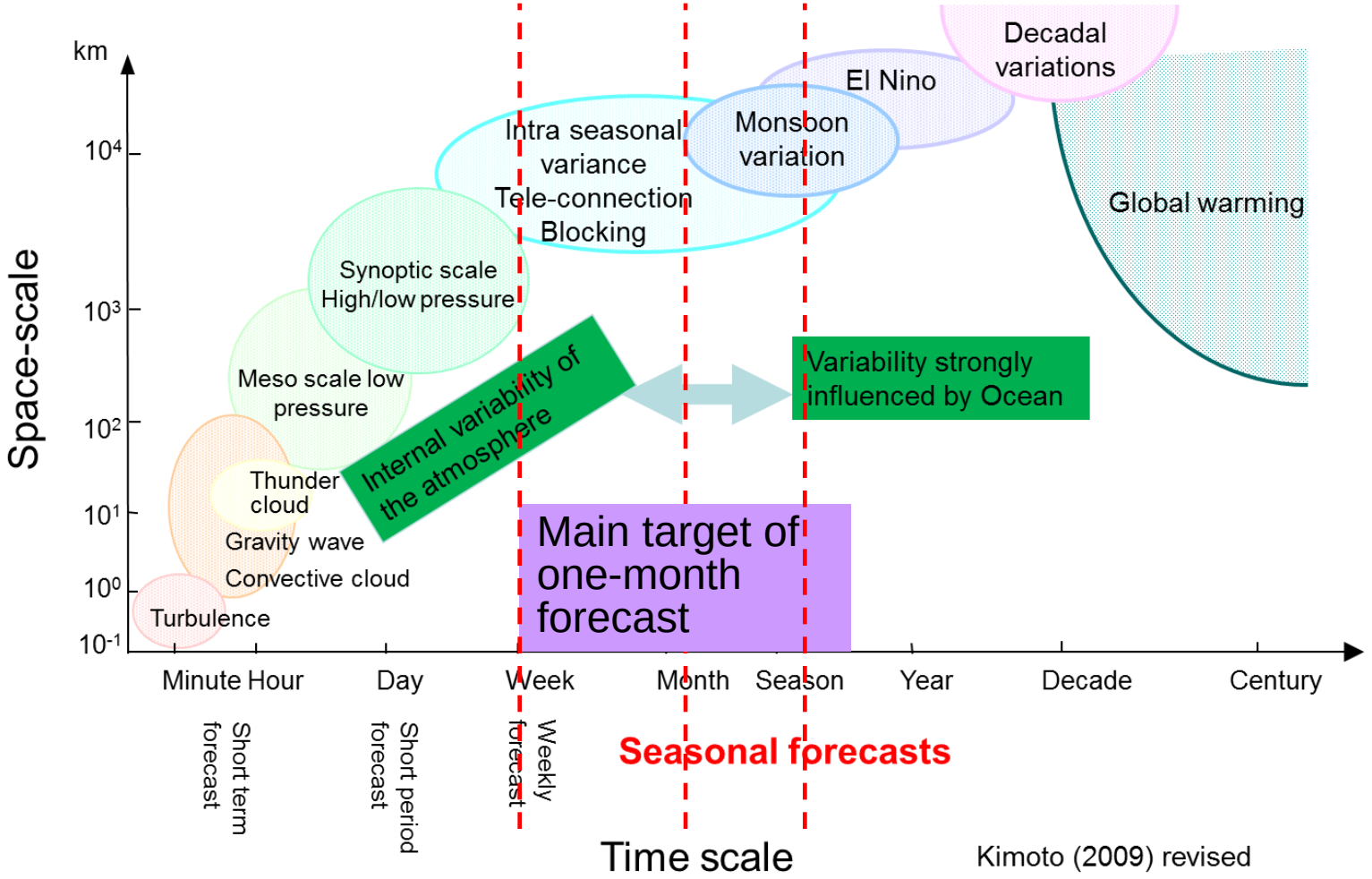
	Forecasting target period
Nowcasting	Up to 2 hours
Very short-range weather forecasting	Up to 12 hours
Short-range forecasting	Beyond 12 hours and up to 72 hours
Medium-range weather forecasting	Beyond 72 hours and up to 240 hours
Extended-range weather forecasting	Beyond 10 days and up to 30 days
Long-range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

Target of this seminar

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

Multiple structure in the atmospheric phenomena

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

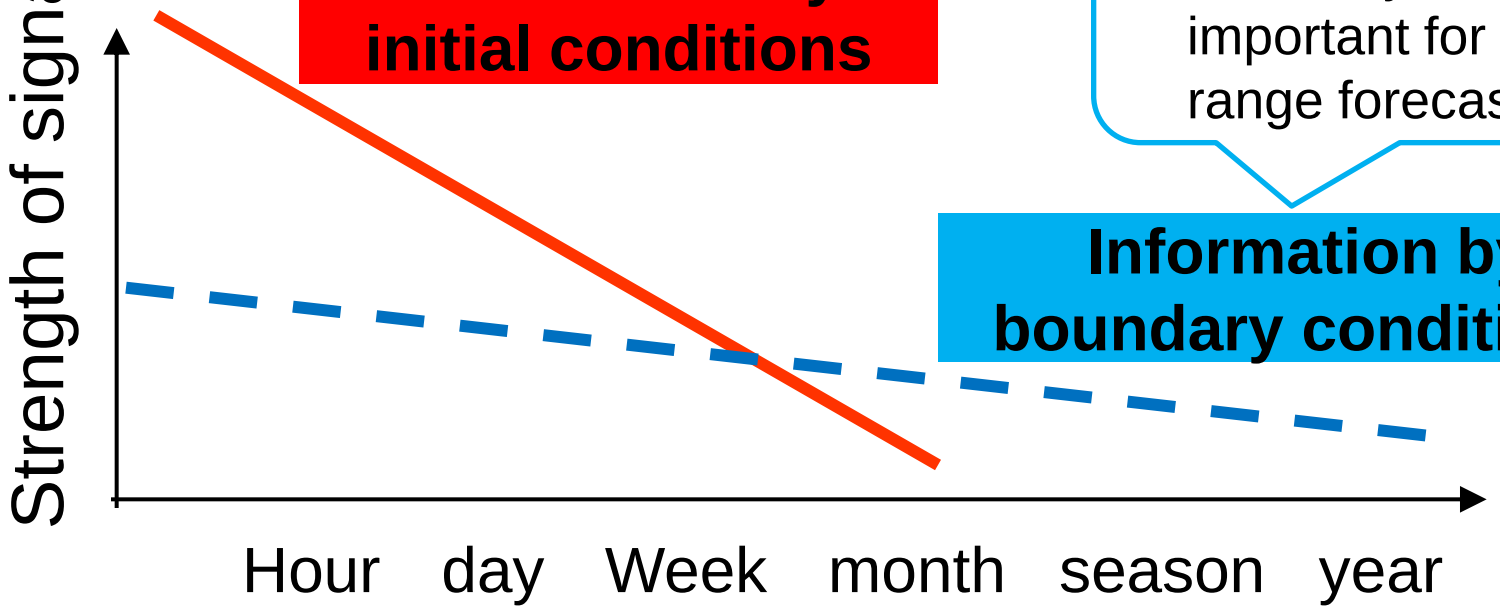


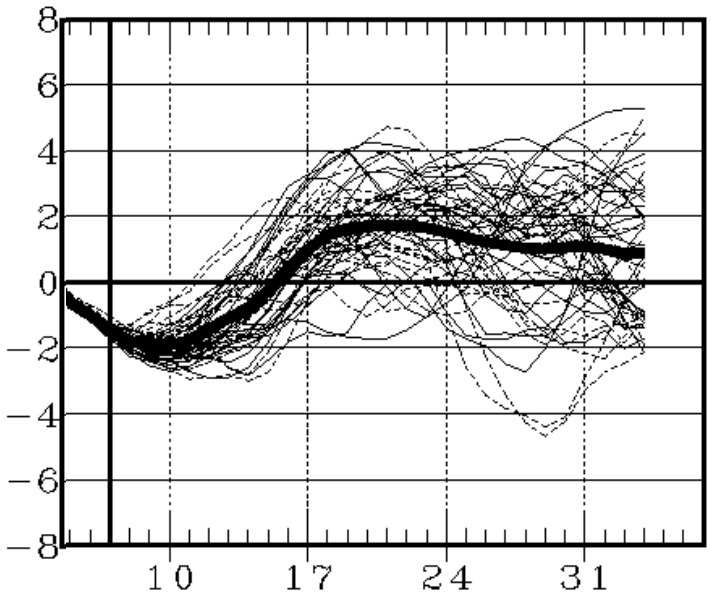
Kimoto (2009) revised

Importance of initial and boundary condition

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

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





Variation of predicted values consist of

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

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

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

How to make one–month Prediction

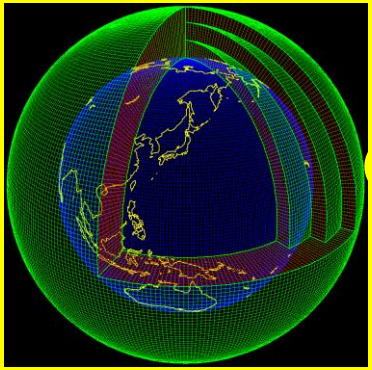
Typical flow of making one month forecast

Observed data

Atmospheric and Oceanic conditions

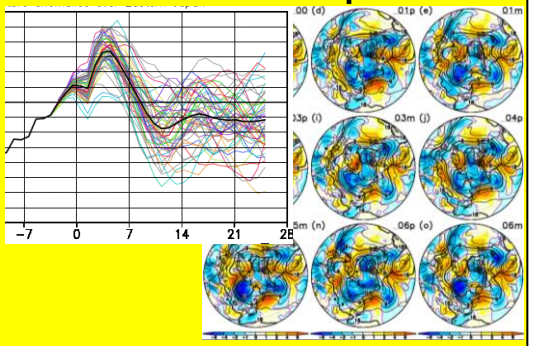
Analysis

Numerical model



Ensemble forecast

Model output



Statistical downscale

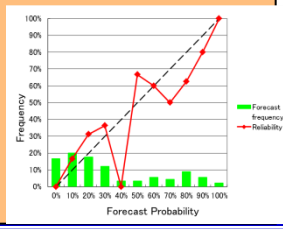
Evaluate predicted characteristic of atmospheric field

Diagnosis of current status

Basic data of probabilistic forecast

Guidance

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



Forecaster

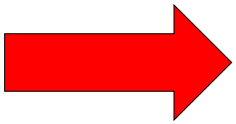
Comprehensive evaluation of the mode prediction

Official probabilistic forecasts

Procedure of the one-month forecast (1)

(1) Understanding **current status**

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



Refer to the “Climate System Monitoring”

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

Procedure of the one-month forecast (2)

(2) Estimate **predicted results**

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

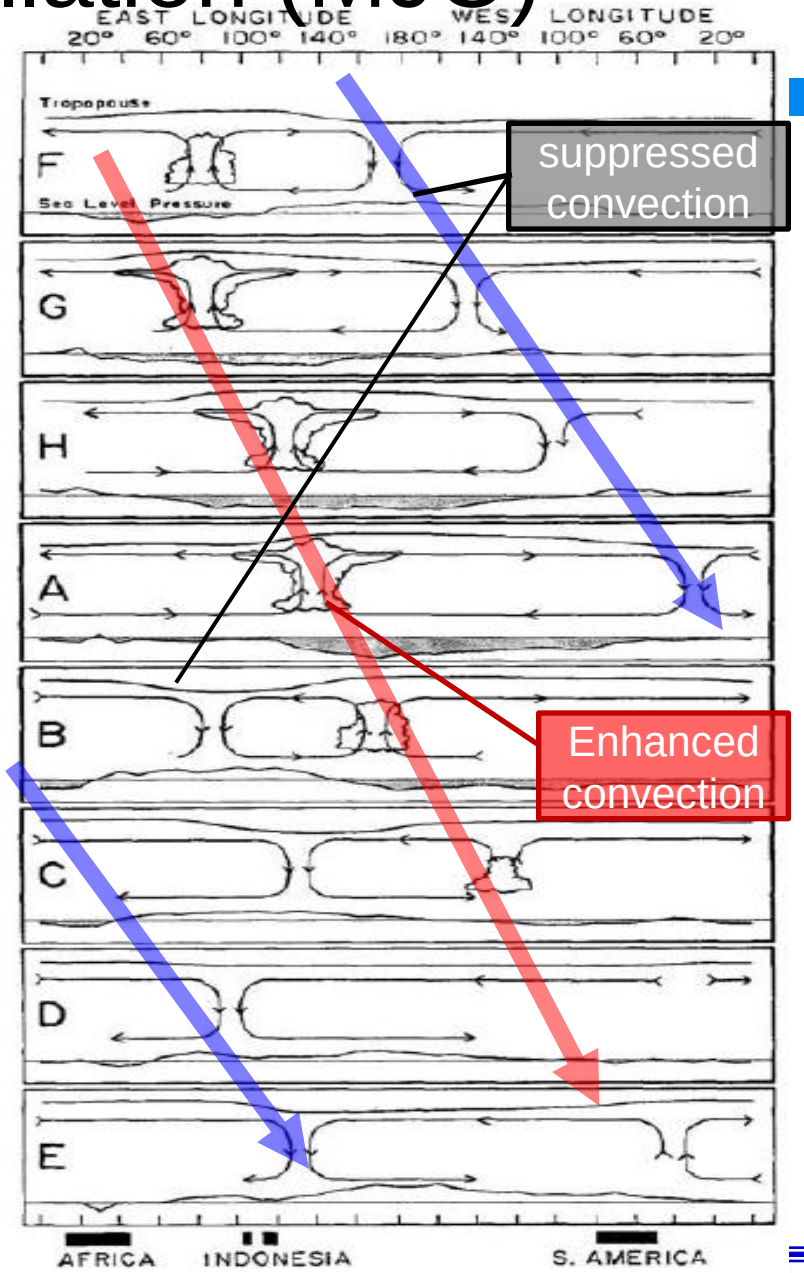
⇒Refer to the EPS products

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

(3) **Build one-month forecast**

Madden-Julian Oscillation (MJO)

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

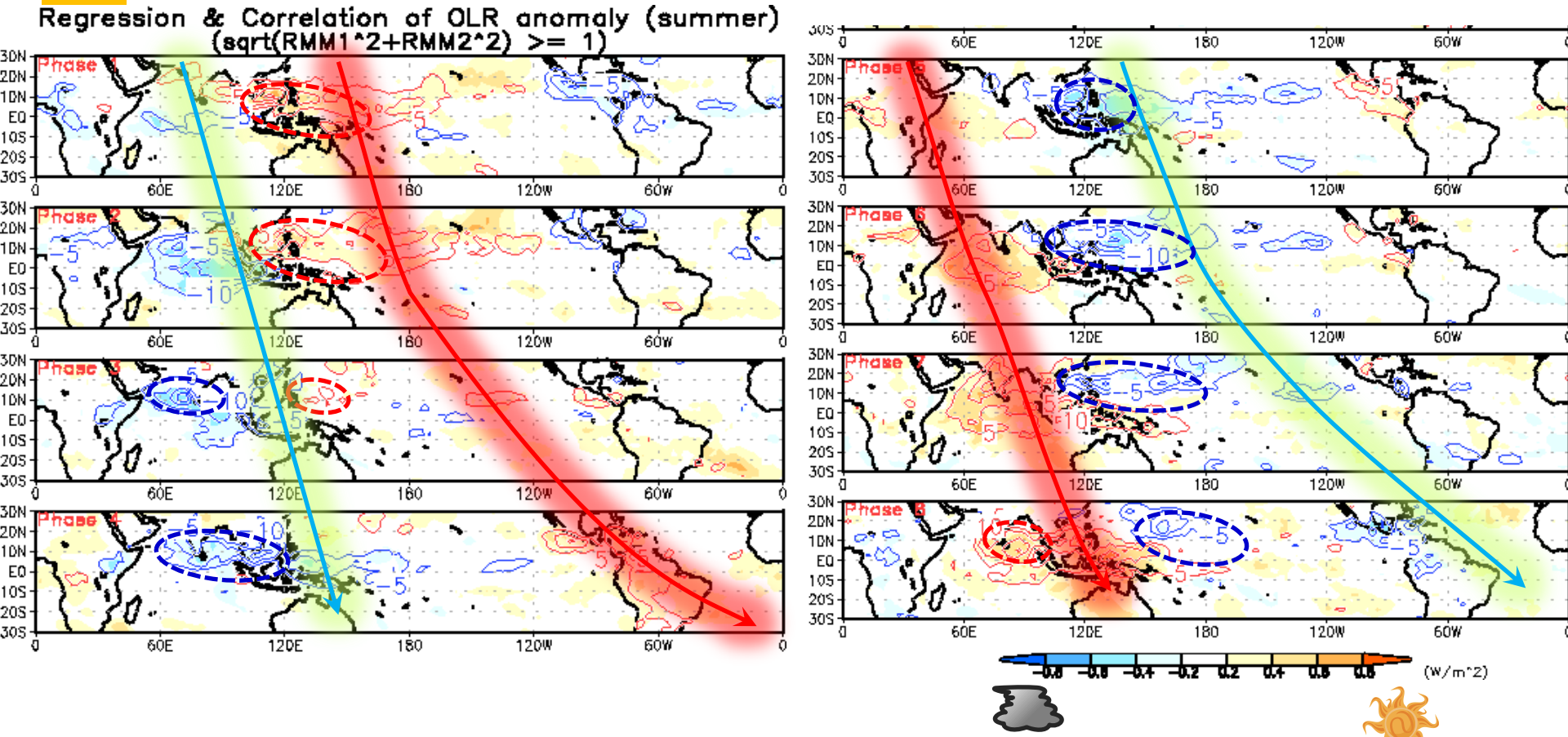


Original; Madden and Julian (1972) Fig.16

BSISO (Boreal Summer IntraSeasonal Oscillation)

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

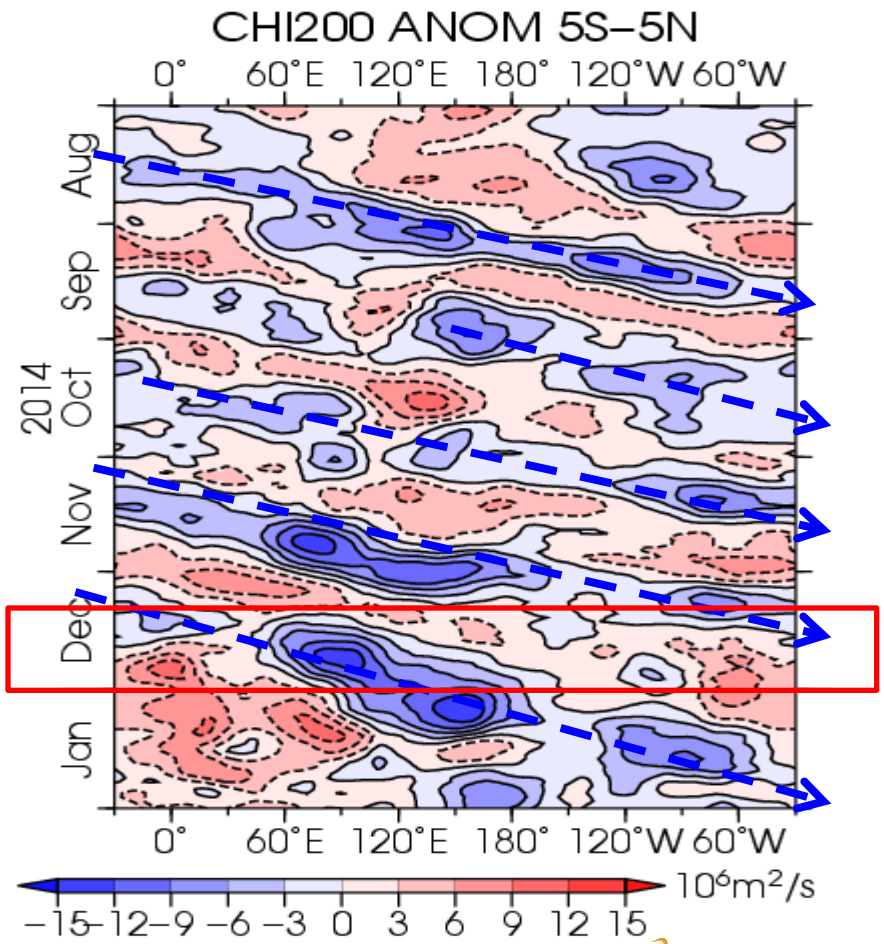
JJA



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

Upper Velocity potential (CHI 200) anomaly along EQ.

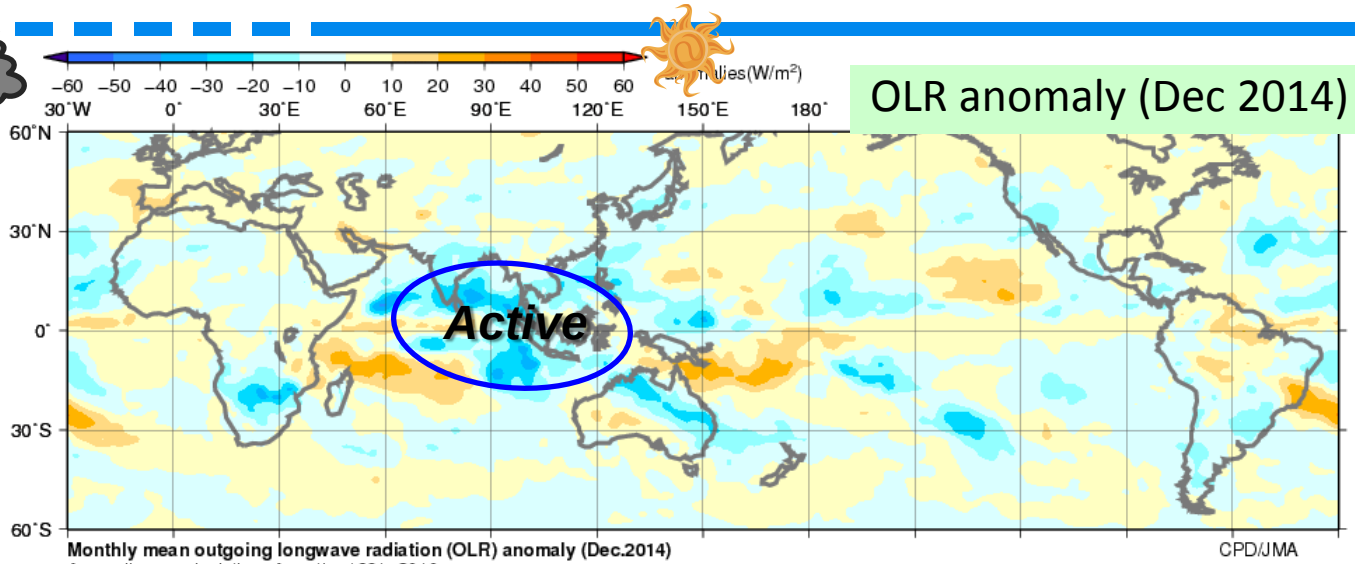
http://ds.data.jma.go.jp/gmd/tcc/tcc/products/clisys/ASIA_TCC/mjo_cross.html



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

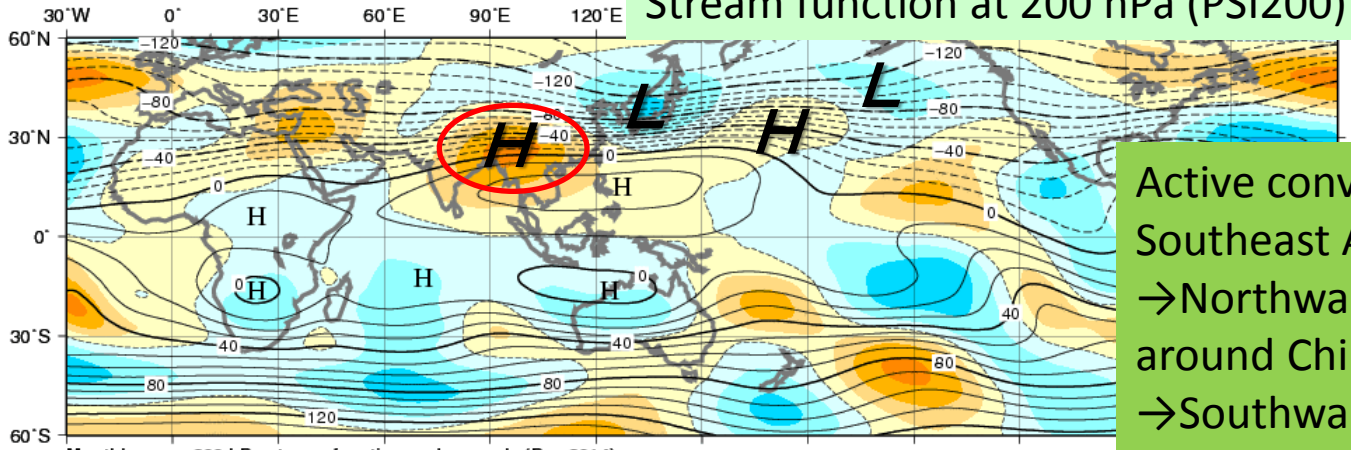
meanderings of the sub-tropical jet due to anomalous convection in the tropics (Dec. 2014)

OLR anomaly (Dec 2014)



Monthly mean outgoing longwave radiation (OLR) anomaly (Dec.2014)
Anomalies are deviations from the 1981–2010 average.
Original data provided by NOAA.

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



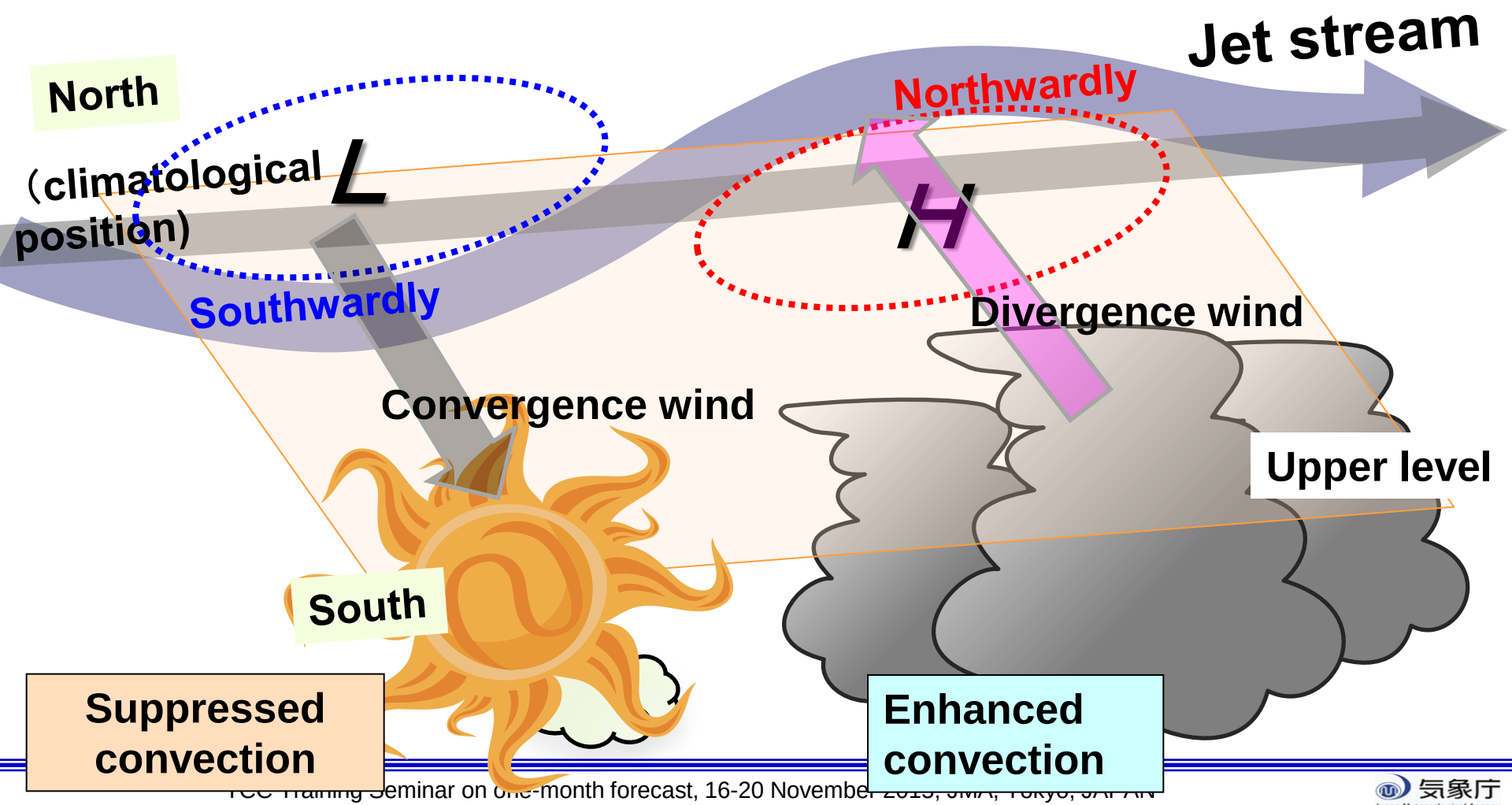
Monthly mean 200 hPa stream function and anomaly (Dec.2014)
The contours show the stream function at intervals of 10×10^6 m^2/s, and the shading shows stream function anomalies.
Anomalies are deviations from the 1981–2010 average.

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

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

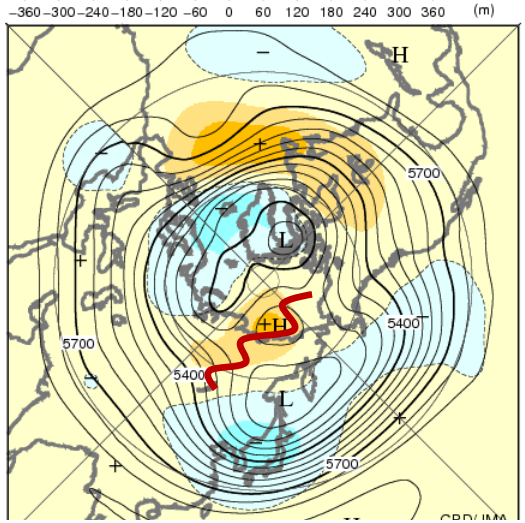
Meanderings of jet stream by anomalous convections in the tropics

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

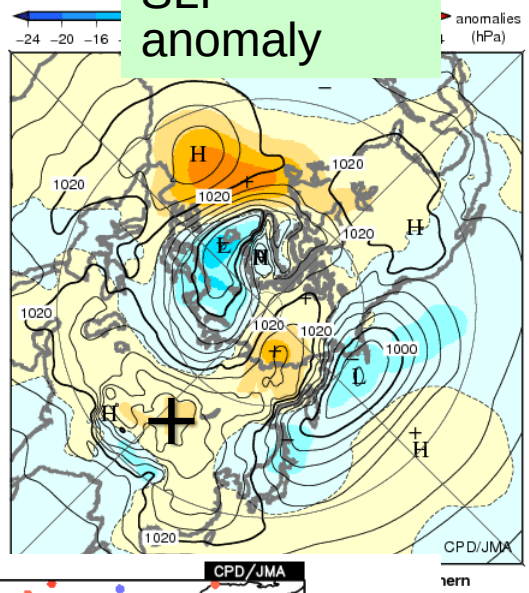


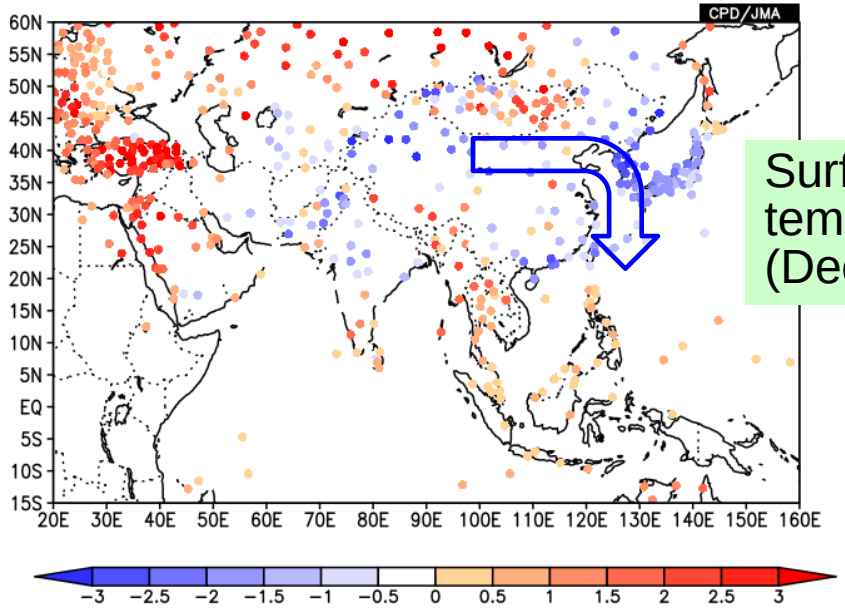
meanderings of the sub-tropical jet due to anomalous convection in the tropics (Dec. 2014)

500hPa height anomaly



SLP anomaly



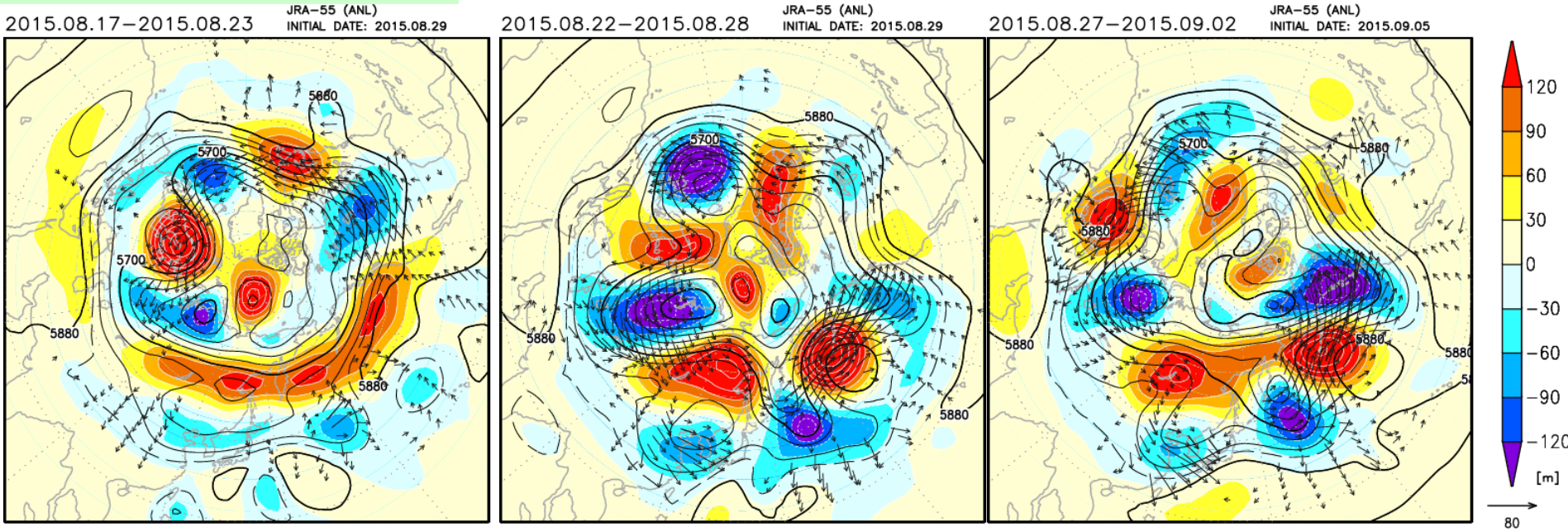


Surface temperature (Dec 2014)

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

Meanderings the upper westerlies, relating with Rossby wave propagation

500hPa height anomaly



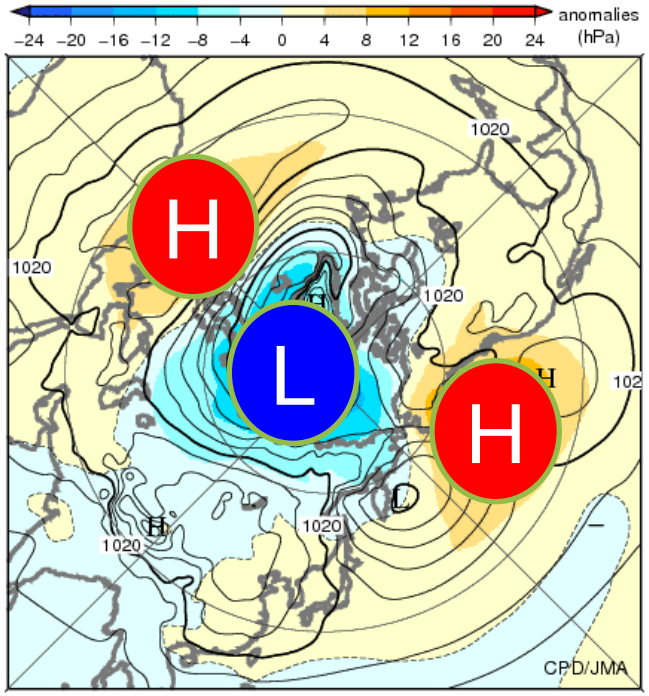
- Depending on propagation of Rossby wave packet, meanderings of the upper westerlies amplifies.
- In the above case, a blocking high developed in eastern Siberia, in association with propagation of wave packet along the polar jet stream. In the end of August 2015, the blocking high weakened emitting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

Arctic Oscillation (AO)

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

SLP anomalies (1988/89 DJF)

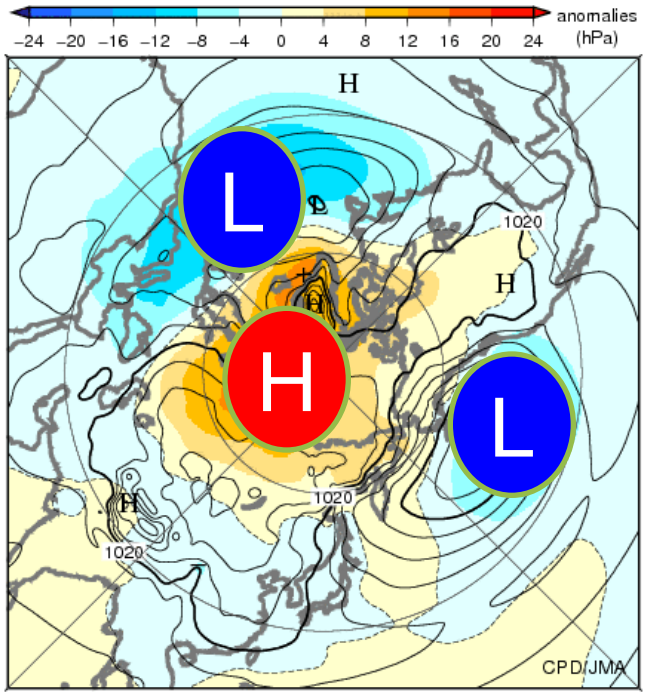
+AO



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

SLP anomalies (2009/10 DJF)

-AO



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

“Signal” and “Noise” depending on forecast

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

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

<Summary>
Viewpoint of the one month forecast

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

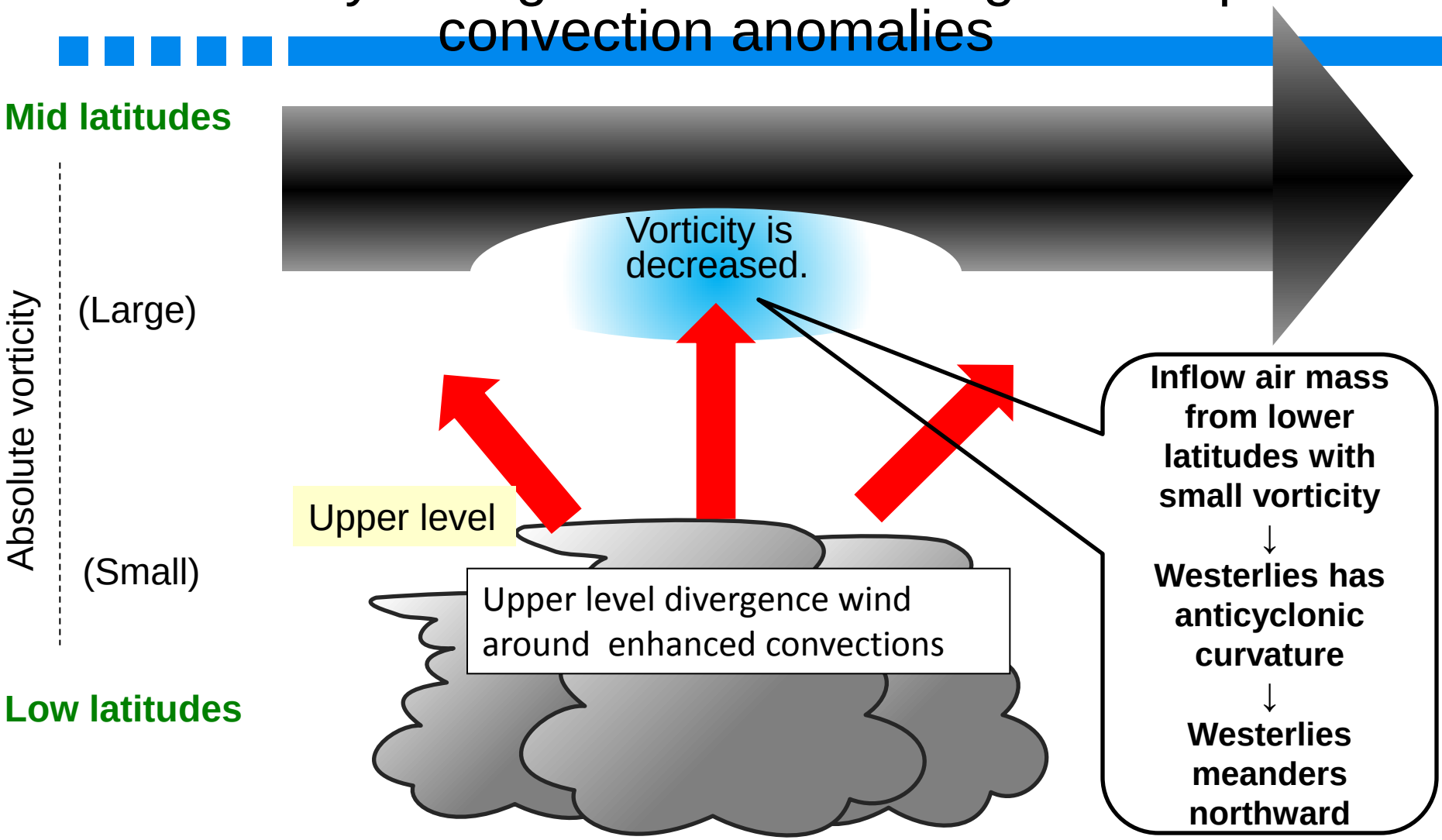
➢ Both “signal” and “noise” for building probabilistic prediction.

<Supplemental>

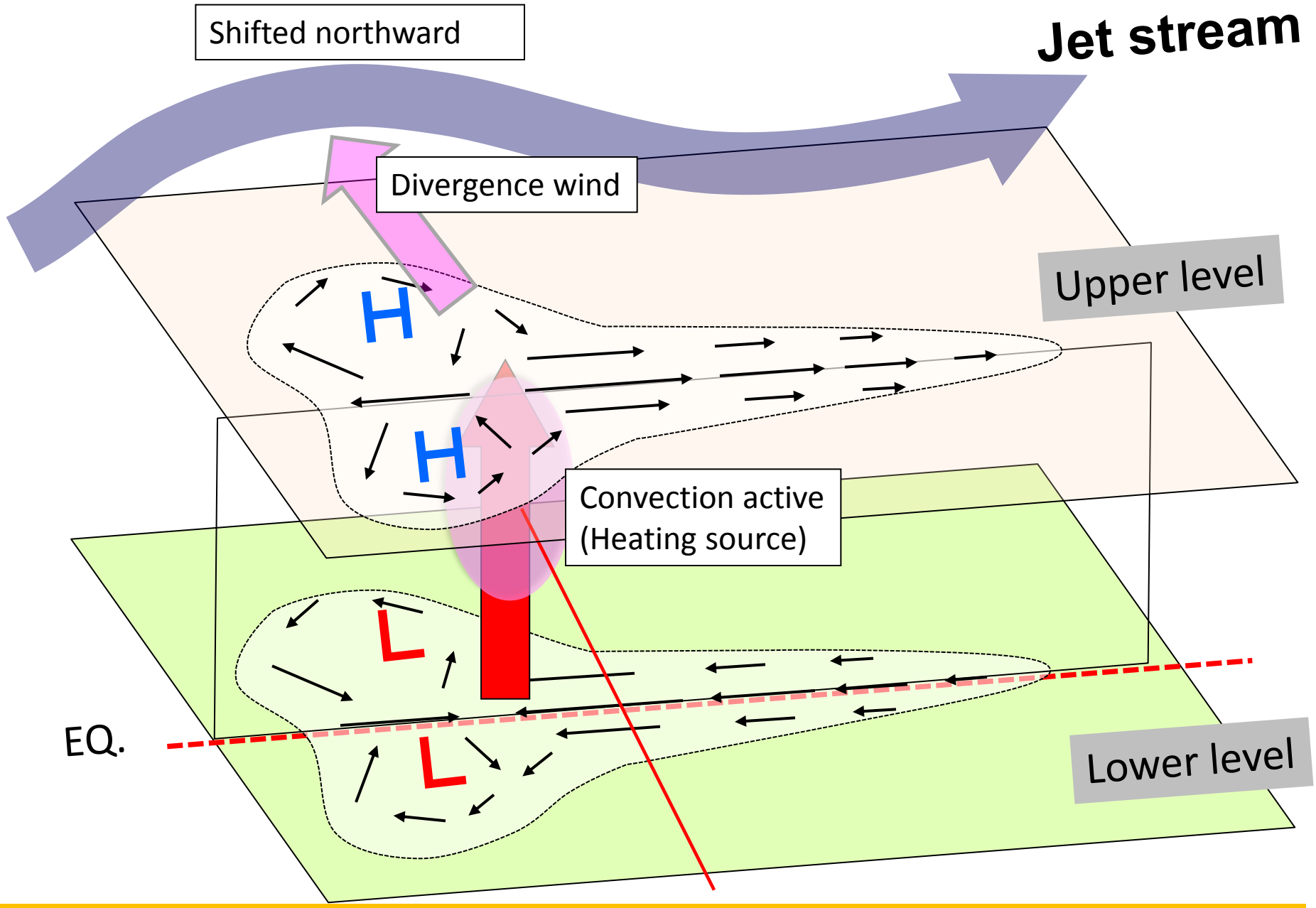
- General
  - Strongly anomalous probabilities are likely only up to 2 weeks.
- Tropics
  - MJO has some degree of predictability even in 3-4 weeks ahead. But, prediction of amplitude tends to be small.
  - The model tends to overconfidence (too small spread) especially in second half, partly because same boundary condition of SSTs (destiny of the AGCM)
  - Sometimes, boundary conditions of SST anomalies mislead prediction of convection anomalies, especially in 3-4 weeks ahead.
- Mid-high latitudes
  - Up to 2-week, large scale variations are generally predictable. But, occurrence/disappearance of a blocking phenomena is generally difficult.
  - Maintain of the AO or the large-scale anomaly pattern can be one reason of the forecast. However, phase change of those phenomena is generally difficult.

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

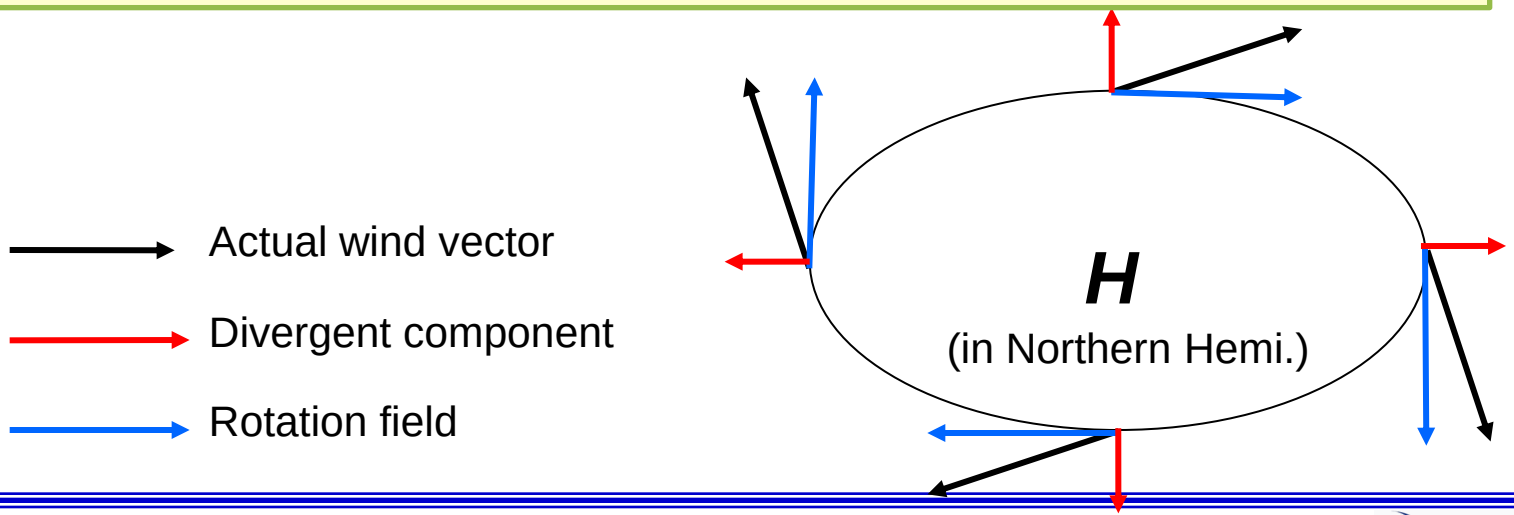
Ref. CHI (velocity potential),PSI (stream function)

- 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

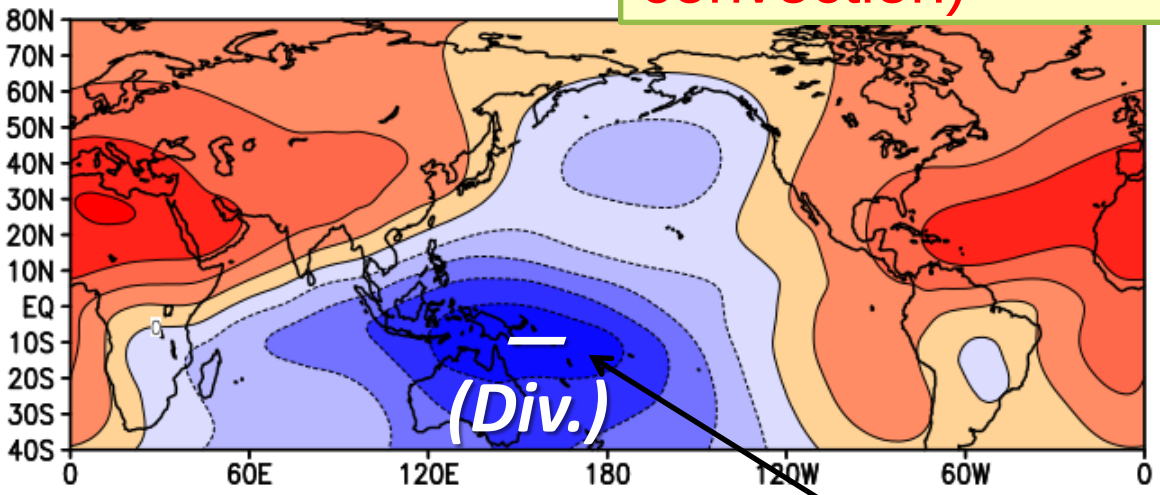
- Divergence component
  - ➢ Velocity potential (negative; more divergent)
- Rotation component
  - ➢ Stream function (negative; anticlockwise)

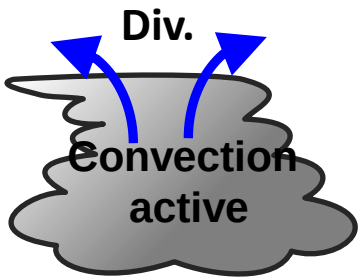


Velocity potential (Normal for January)

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

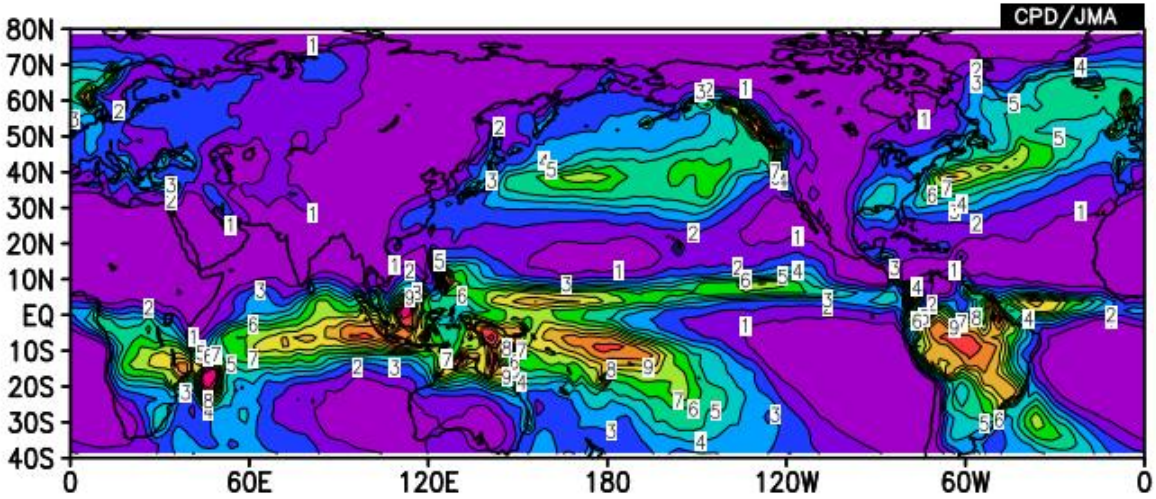
CHI (200hPa)





[× 10^6 m^2/s]

Precipitation (GPCP)



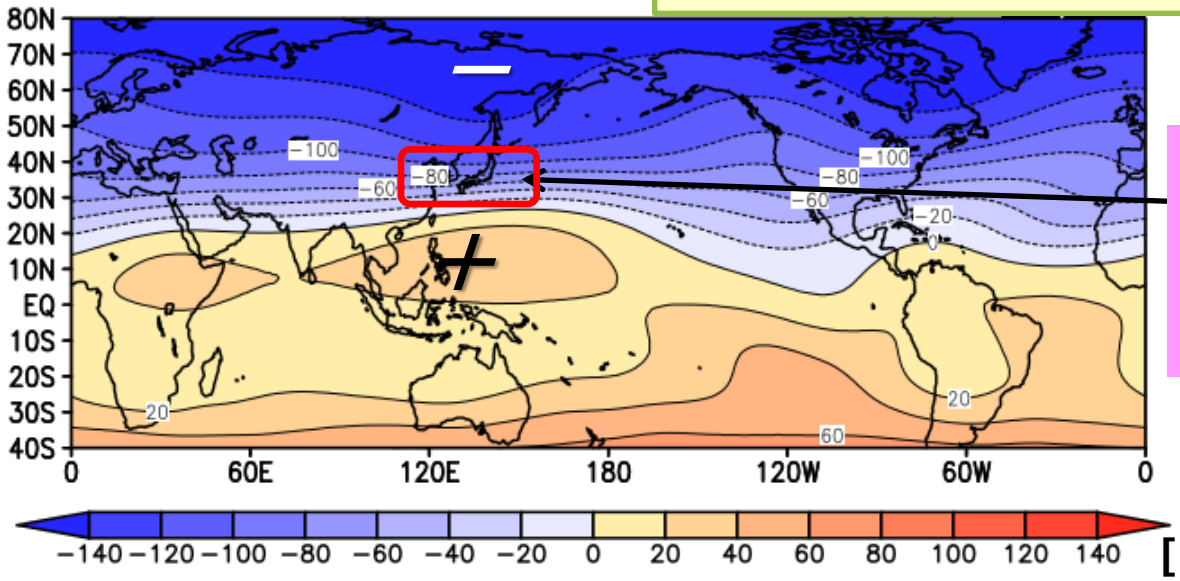
[mm/day]

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)

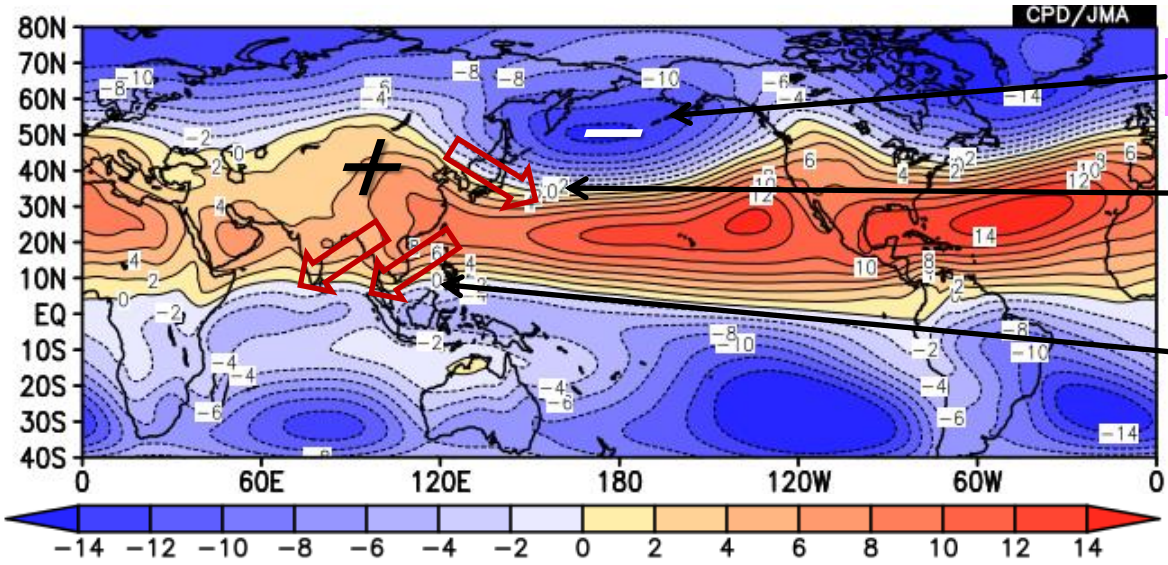
Upper (200hPa)



[×10⁶ m²/s]

Large contour dense
= strong flow
= jet stream

Lower (850hPa)



[×10⁶ m²/s]

Aleutian low

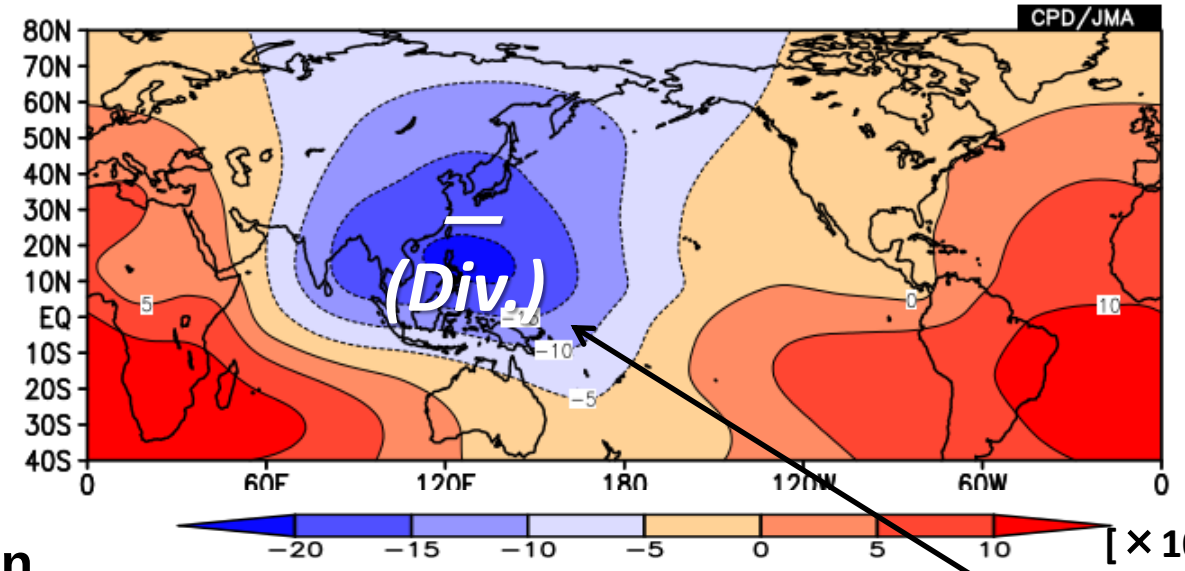
North-westerly monsoon

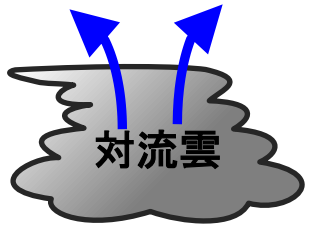
North-easterly monsoon

Velocity potential (Normal for August)

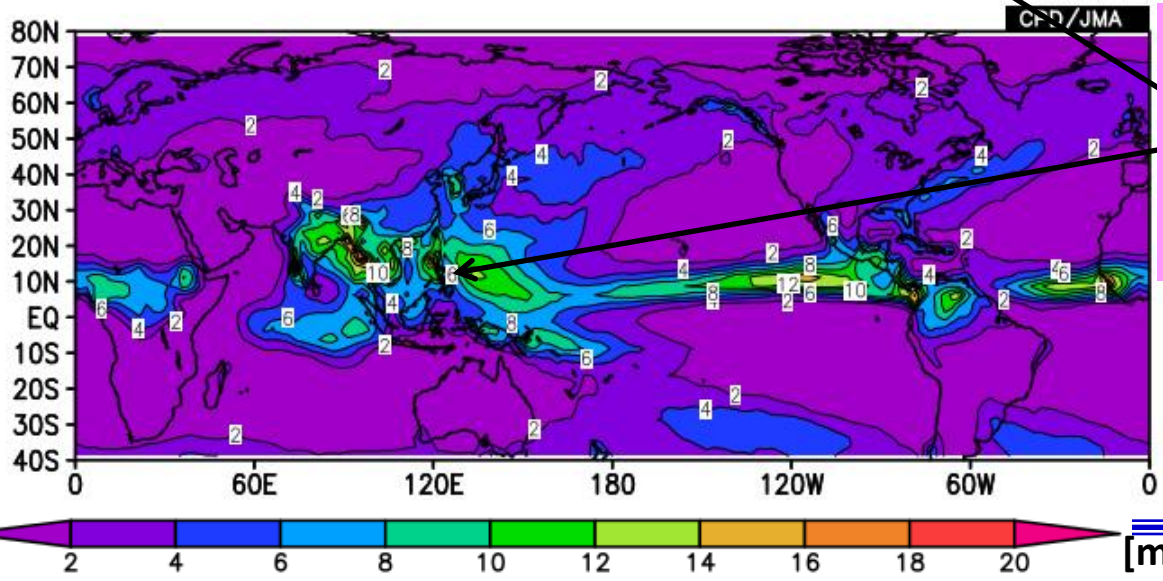
-: divergent (active convection)
+: convergent (inactive convection)

CHI (200hPa)





Precipitation (GPCP)

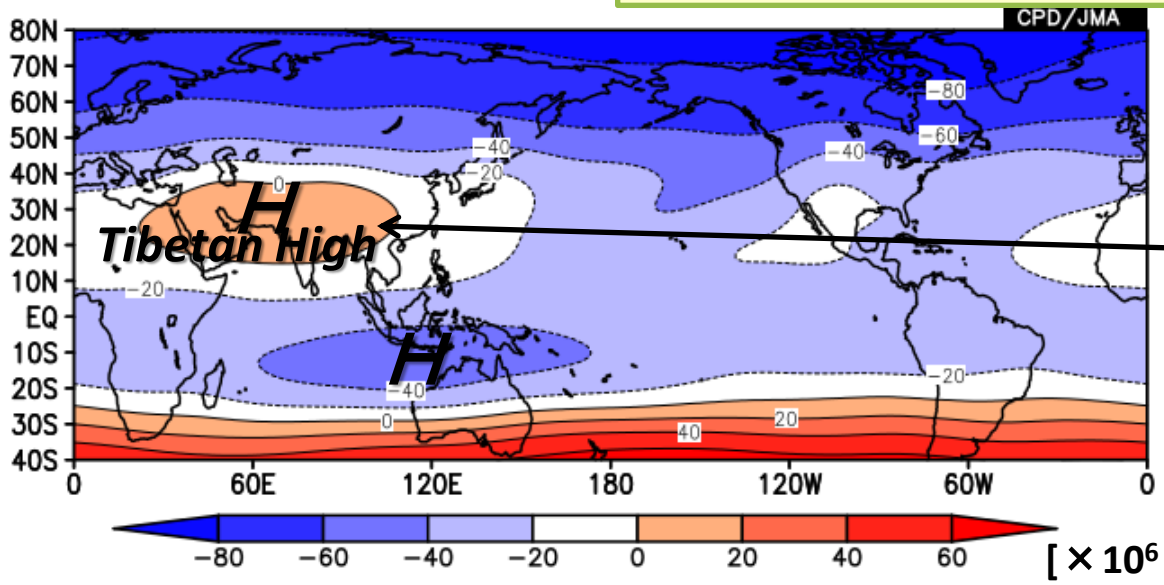


Divergence in the upper level over the Asian monsoon region, reflecting active convections.

Stream function (Normal for August)

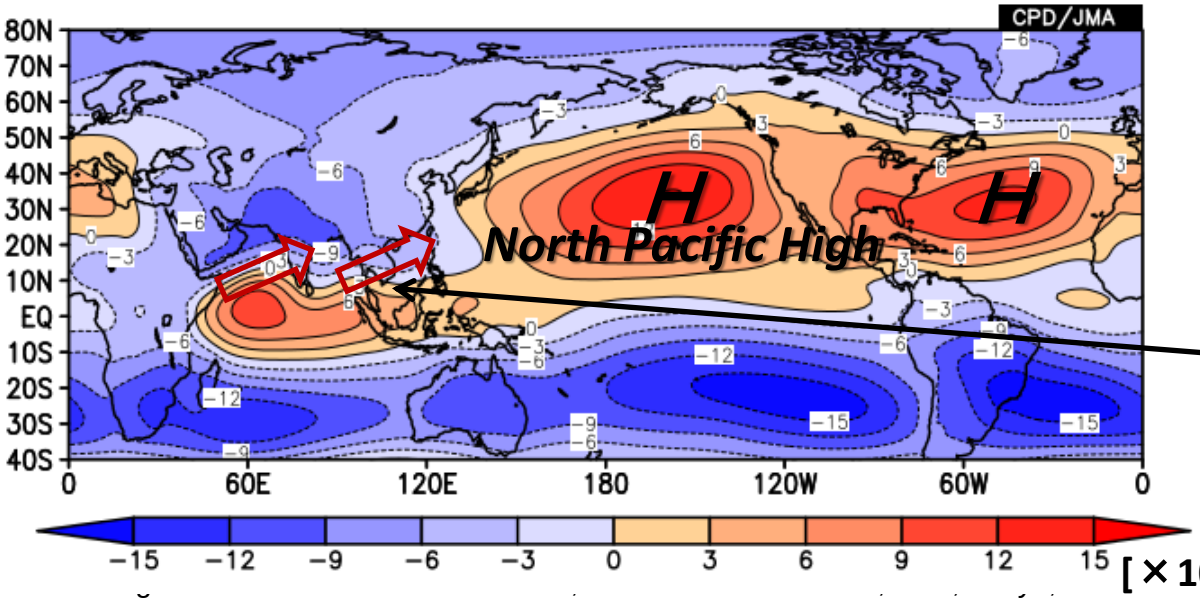
+: clockwise (anti-cyclonic)
-: anticlockwise (cyclonic)
(in Northern Hemisphere)

Upper (200hPa)



Large scale high in upper level (Tibetan high)

Lower (850hPa)



South-westerly monsoon