ENSO, AO, and climate in Japan

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Aims of this lecture

At the end of the yesterday's lecture, Hare-run said,

- In the exercise session of this seminar, participants are requested to research on a relationship between a primary mode of variability of their choice and climate conditions in their own country.

- So please remind that you are going to discover the mode of variability which is of the greatest concern to your country's climate.

Aims of this lecture

- Before going on to the exercise session, some results from JMA's research into relationship between a primary mode of variability and climate in Japan will be presented in this lecture.

- The expectation is that these results provide some tips for participants and help them in planning and conducting their own research.

Preparatory discussions

Stream function and velocity potential

- Decomposing wind into a rotational part and a divergent part (stream function and velocity potential) is useful to analyze atmospheric circulation.

$$\vec{v} = \vec{v}_{\psi} + \vec{v}_{\chi}$$

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 >

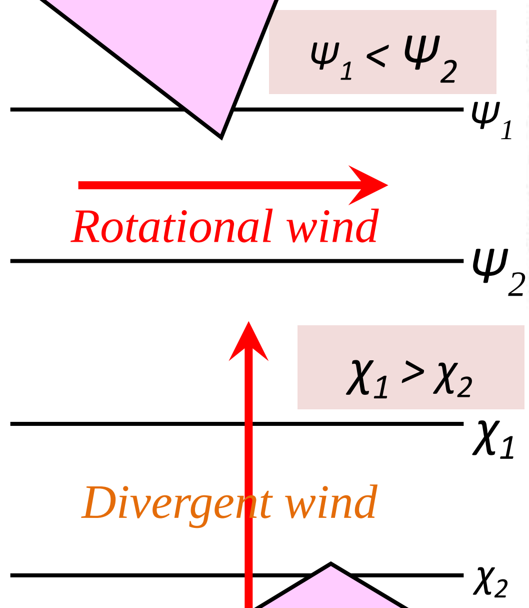
$$u_{\psi} = -\frac{\partial \psi}{\partial y}, v_{\psi} = \frac{\partial \psi}{\partial x}$$

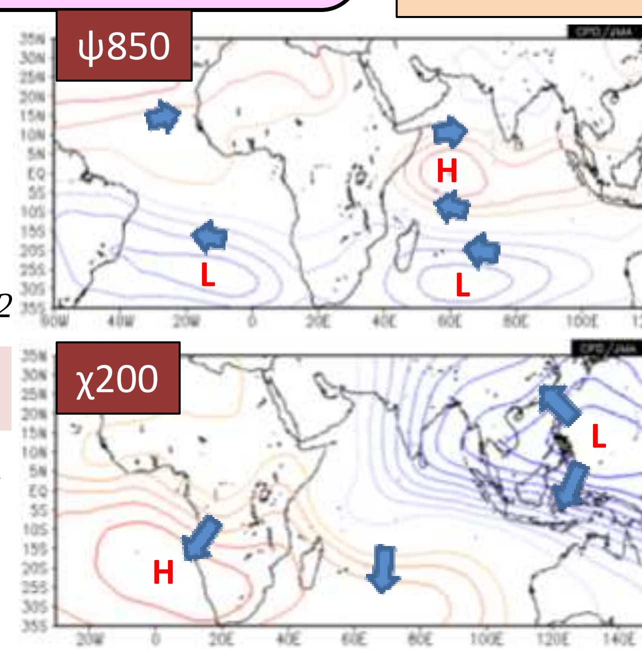
***Ψ*: Stream function**

< Divergent wind >

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

***χ*: Velocity potential**

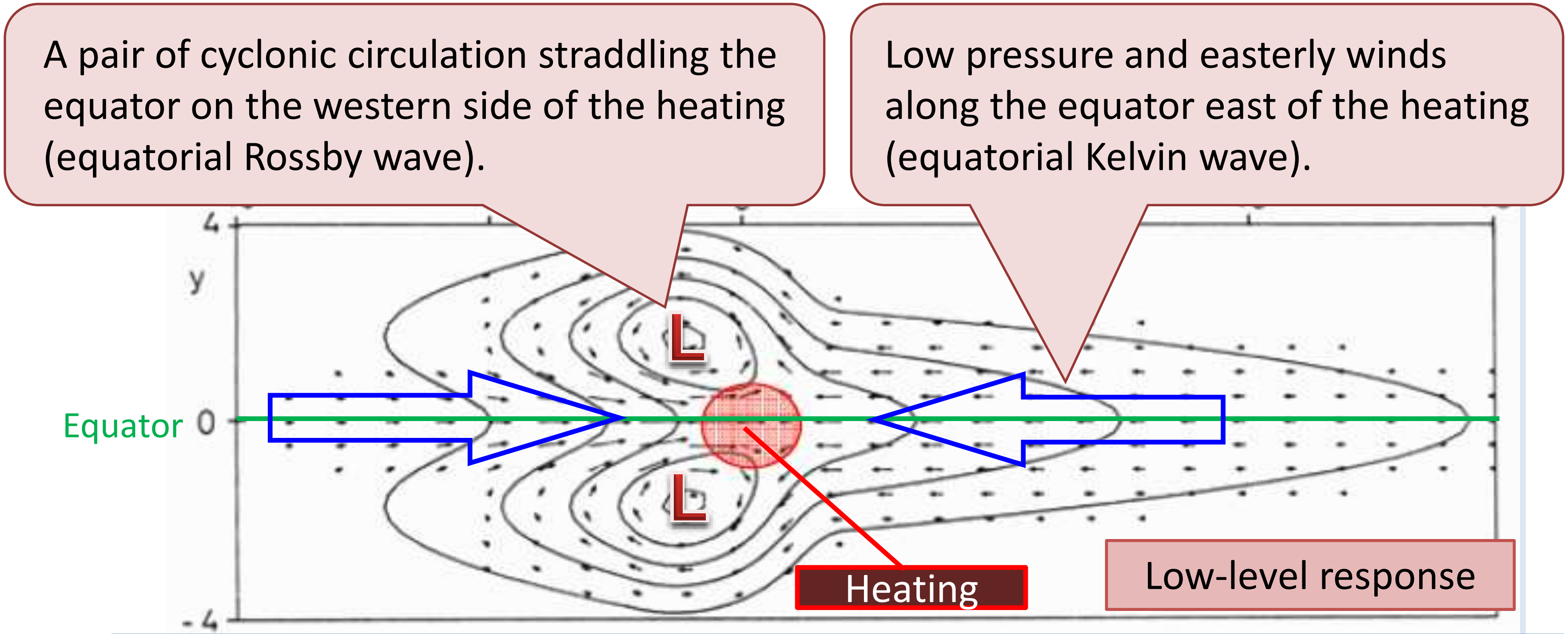




Divergent wind blows across contours of velocity potential, from areas of low to high velocity potential, regardless of the hemisphere.

Matsuno-Gill pattern

- Gill (1980) elucidated some basic features of the response of the tropical atmosphere to diabatic heating (related to 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.

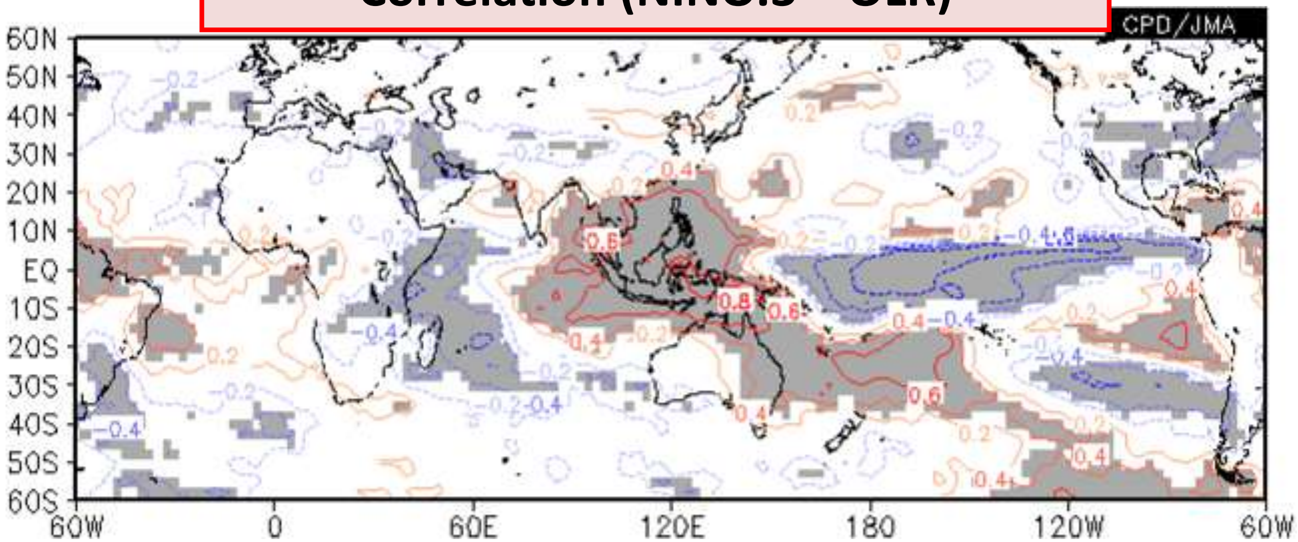
Correlation analysis

• This technique is used to investigate the linear relationship between two variations.

• Correlation coefficients range between -1 and 1. High (low) absolute values indicate strong (little) linear relationship.

r < 0 : Negative correlation
r = 0 : No correlation
r > 0 : Positive correlation

Correlation (NINO.3 – OLR)



Correlation coefficients between NINO.3 SST indices and OLR (Sep. – Nov.)

The base period for the analysis is 1979 – 2011. This is drawn by the ITACS.

Regression analysis

• Single regression analysis is used to investigate <u>quantitatively</u> to what extent a response variable is explained by a explanatory variable.

• Regression coefficient shows the anomaly of a response variable in one standard deviation of a explanatory variable.

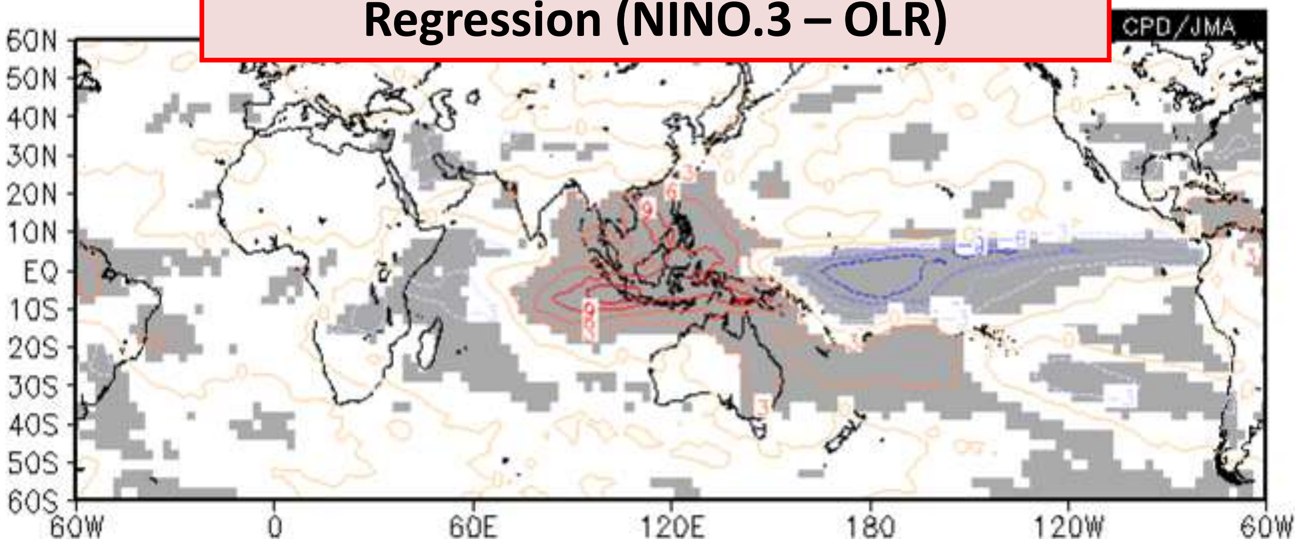
$$y = a\,x + b$$

Regression coefficient

Intercept

y: Response variable (e.g., stream function)
x: Explanatory variable (e.g., NINO.3 SST index)

Regression (NINO.3 – OLR)



Regression coefficients of OLR (W/m^2) onto NINO.3 SST indices (Sep. – Nov.)
The base period for the analysis is 1979 – 2011. This is drawn by the ITACS.

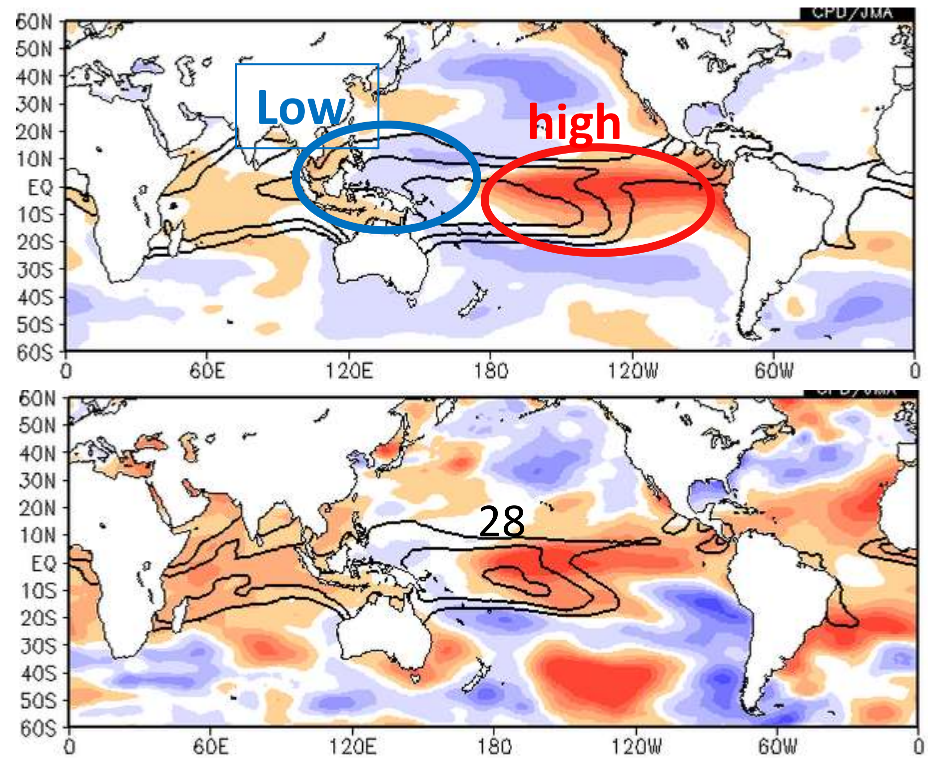
Composite analysis

- Composite analysis is a statistical technique to extract the common characteristics in past events of a targeted phenomenon (e.g., El Niño and La Niña events) from the other phenomena.

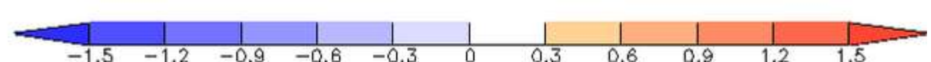
SST Composite Map
In El Nino Phase (DJF)

Contours: analysis, Shadings: anomaly,
Statistical period: 1979 – 2009
(Composite year :
82/83,86/87,87/88,91/92,97/98,02/03)

SST for DJF 2009/10



3-month mean SST and anomalies (˚C)



Tips for statistical analysis

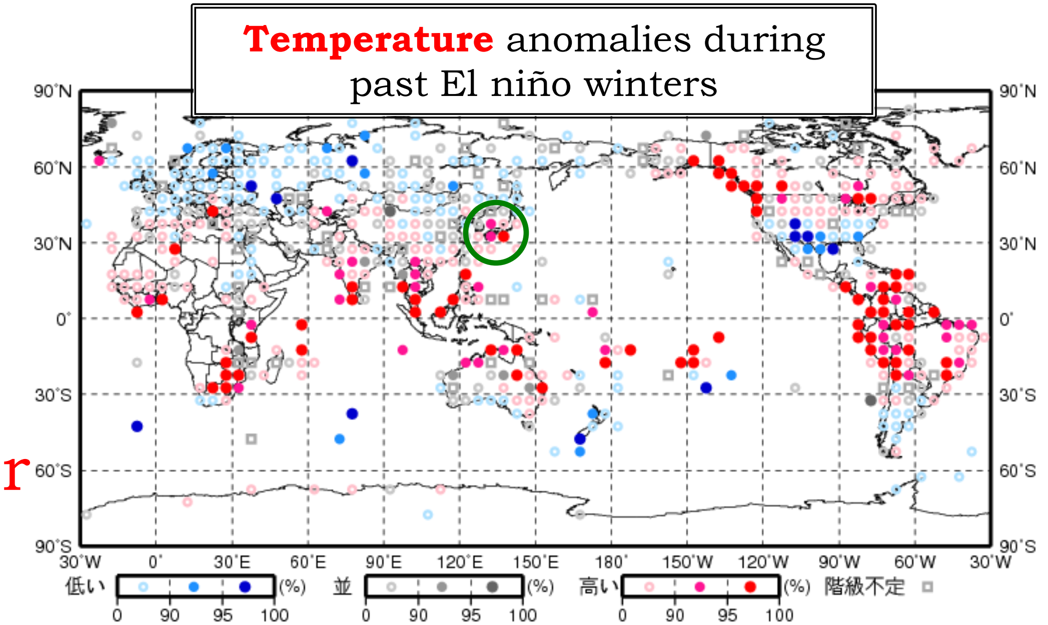
- If a target climate variable (e.g., temperature) does not have a linear relationship with other variables (e.g., El Nino indices), composite analysis will be useful.
- If a target climate variable has a linear relationship with other variables and there are not enough samples available to conduct statistically reliable composite analysis, regression and correlation analyses will be better suited.

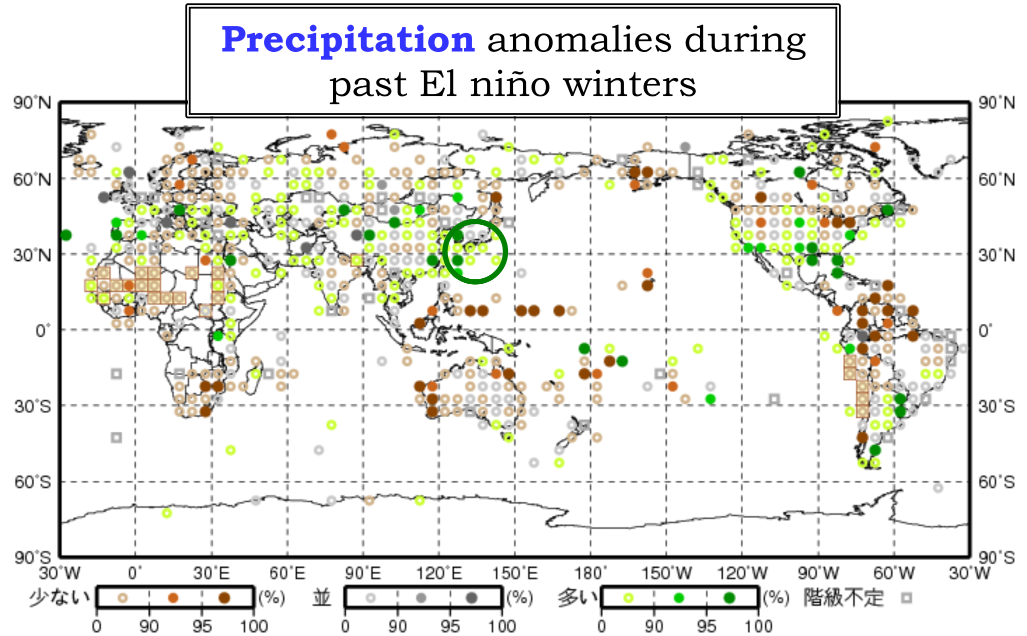
ENSO, AO and climate in Japan

ENSO and climate in Japan (El Niño winter (DJF))

- Statistical analysis indicates that in winters with El Niño conditions, it is likely that parts of Japan experience warmer and wetter than normal conditions.

- But how do we explain this pattern of anomalies in terms of climatology?



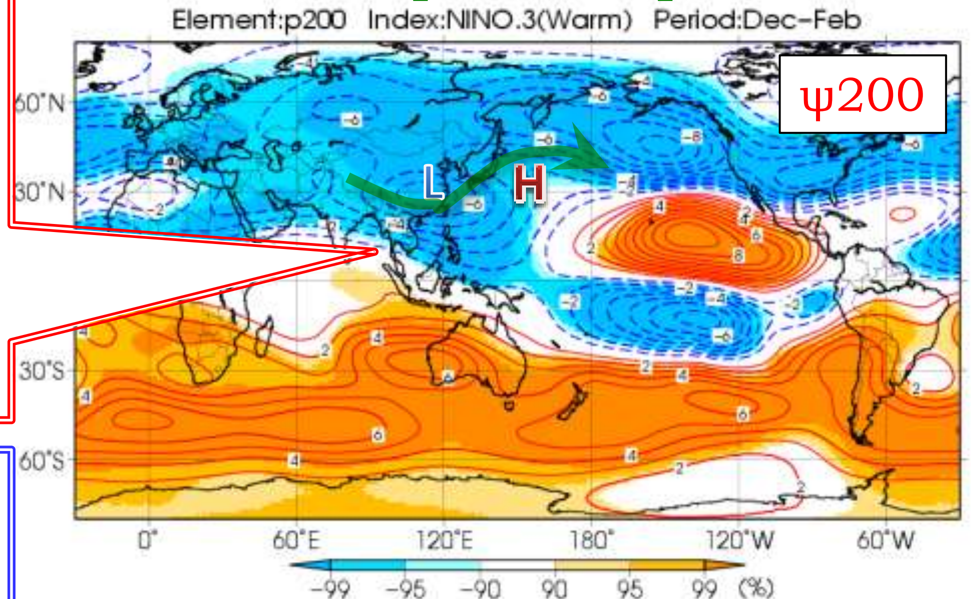


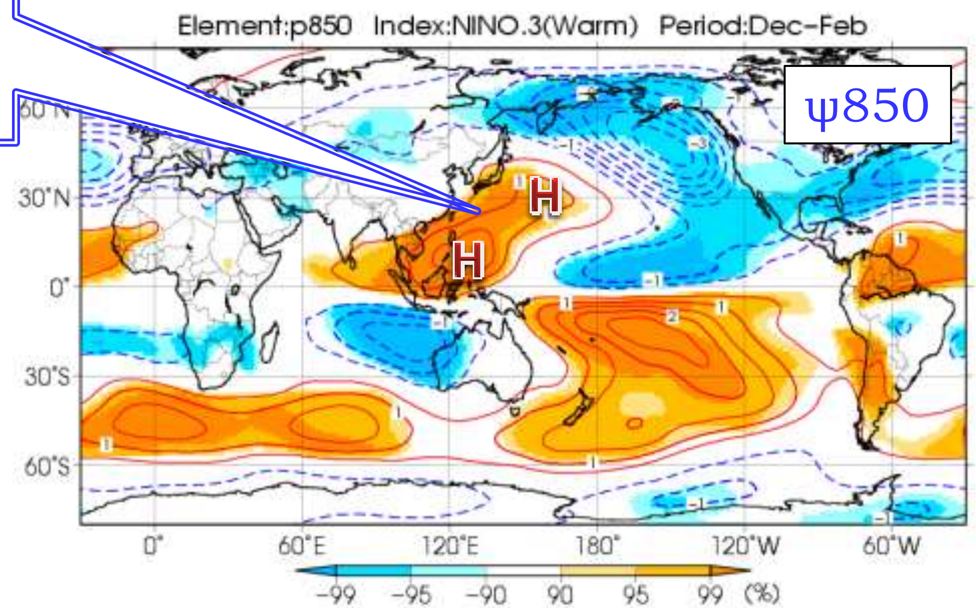
ENSO and climate in Japan (El Niño winter (DJF))

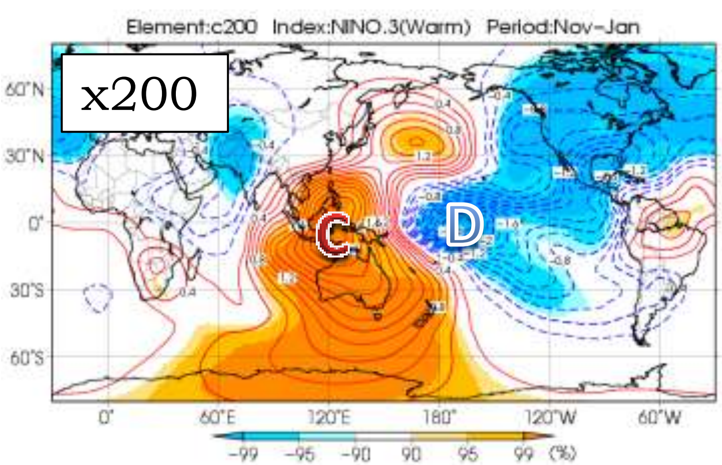
- **In the upper troposphere**, cyclonic anomalies centered over southeastern China and anticyclonic anomalies to the east of Japan, as a result of the convergence anomalies over the Maritime Continent and Rossby wave propagation.
- In association, the subtropical jet stream is displaced southward over China and northward to the east of Japan.
- This induces barotropic anticyclone to the east of Japan as well as anomalous southwesterly warm air advection which leads to enhanced extratropical cyclone activity.

- **In the lower troposphere**, anticyclonic anomalies develop centered over the Philippines and to the east of Japan in response to convection anomalies and upper-tropospheric circulation.
- This induces anomalous warm and wet air advection toward Japan, and leads to weaker northwestern winter monsoon.

Composite map





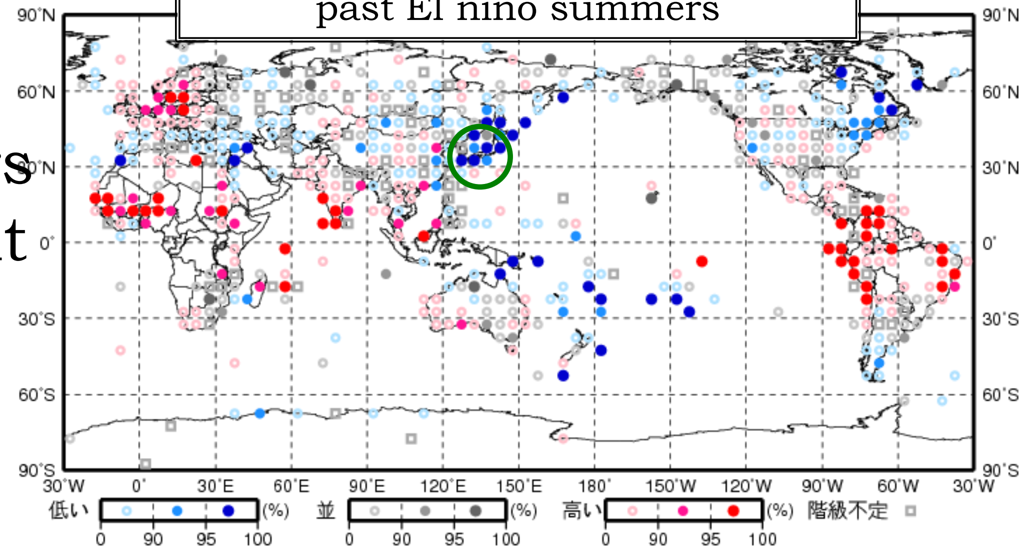


ENSO and climate in Japan (El Niño summer (JAS))

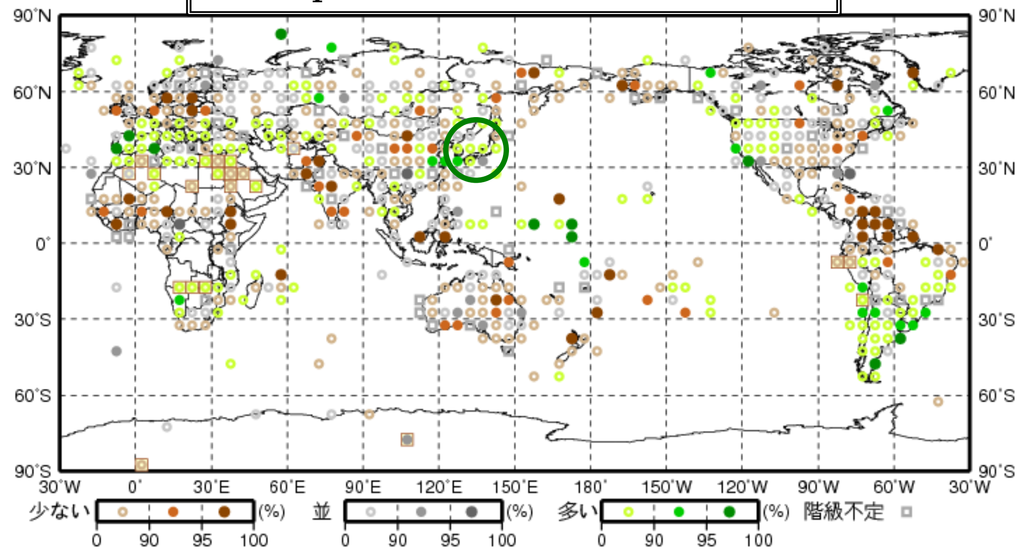
- Statistical analysis indicates that in summers with El Niño conditions, it is likely that parts of Japan experience cooler and slightly wetter than normal conditions.

- But how do we explain this pattern of anomalies in terms of climatology?

Temperature anomalies during past El niño summers



Precipitation anomalies during past El niño summers

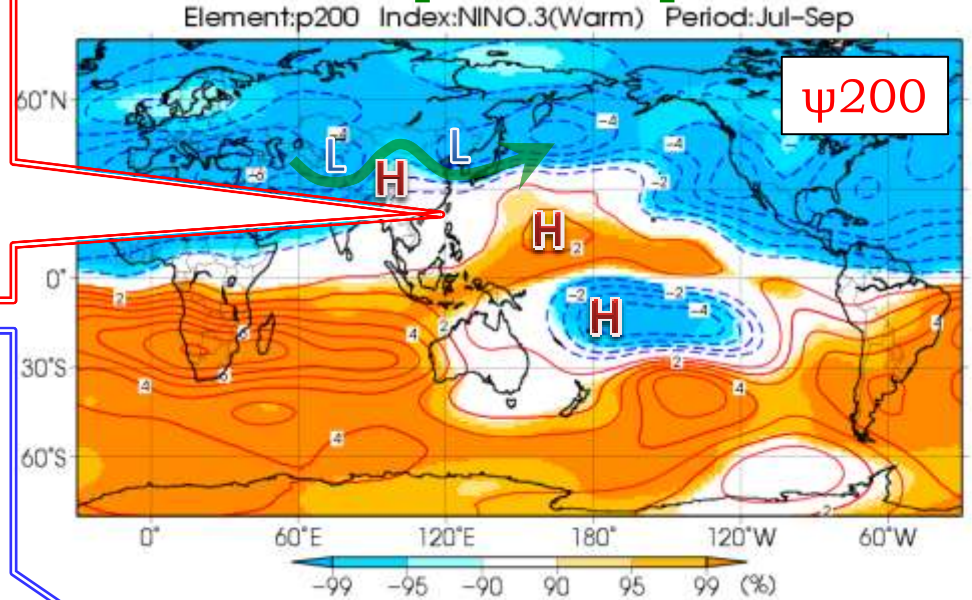


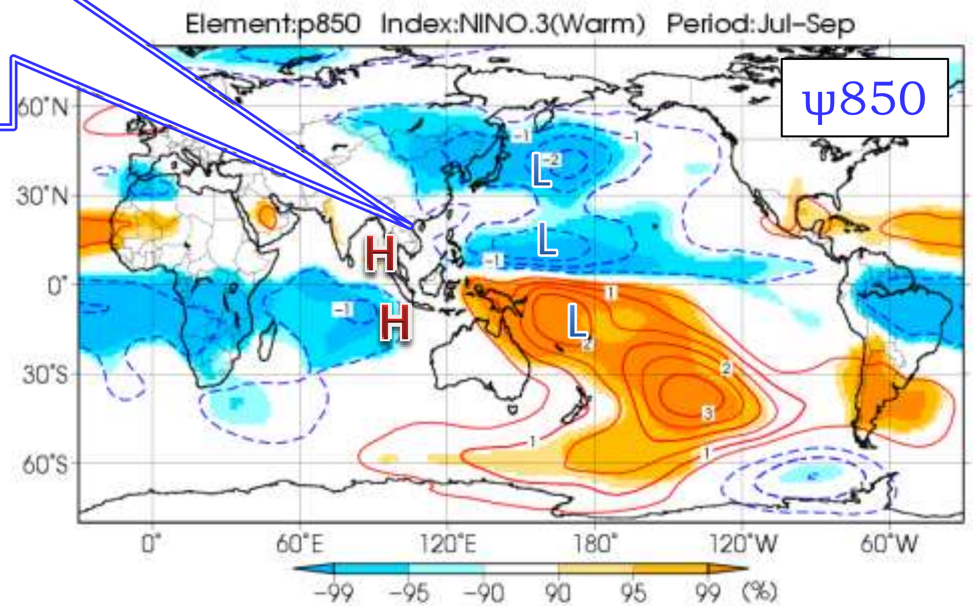
ENSO and climate in Japan (El Niño summer (JAS))

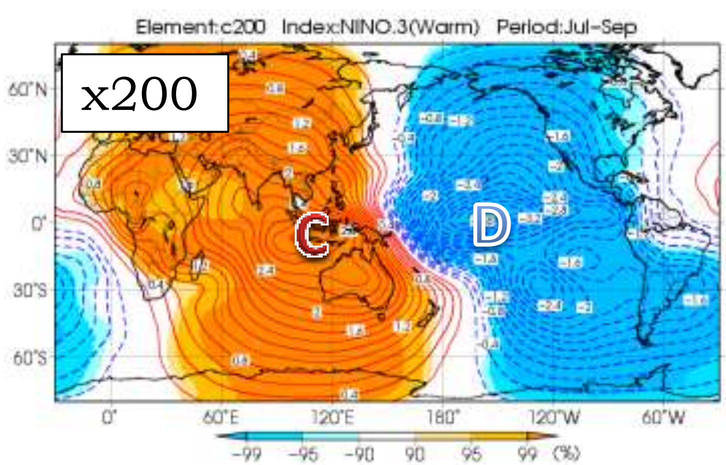
- **In the upper troposphere**, the subtropical jet stream is displaced southward and becomes wavy in relation to suppressed Asian monsoon, with cyclonic anomalies to the west of Japan.
- This induces anomalous southwesterly warm air advection and upward vertical flow over Japan, which leads to enhanced extratropical cyclone activity.

- **In the lower troposphere**, equatorial symmetric anticyclonic and cyclonic anomalies develop in the eastern Indian Ocean and the western Pacific, respectively, in response to convection anomalies. These anomalies indicate weaker-than-normal Asian summer monsoon.
- In the proximity of Japan, the North Pacific Subtropical High (which extends toward Japan in a normal summer) is so weak that it fails to bring hot and sunny days.

Composite map





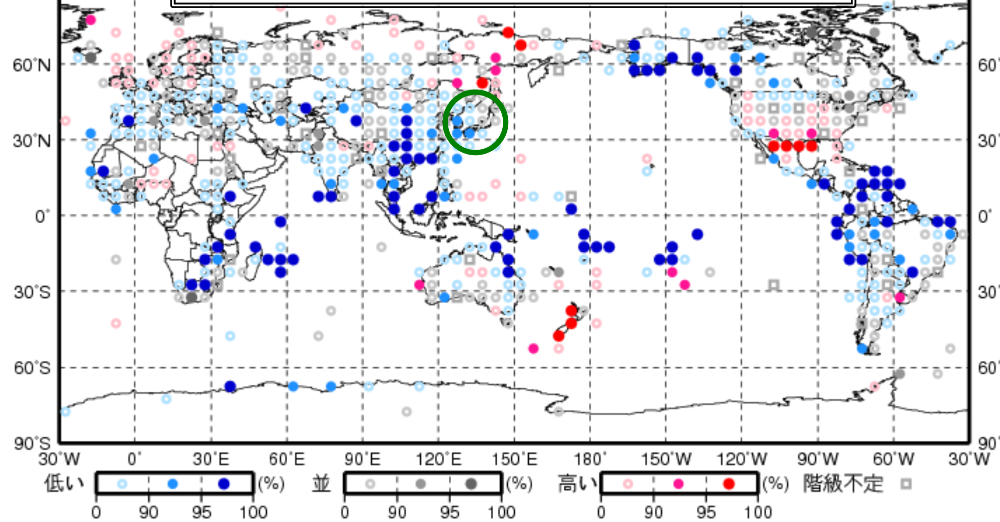


ENSO and climate in Japan (La Niña winter (DJF))

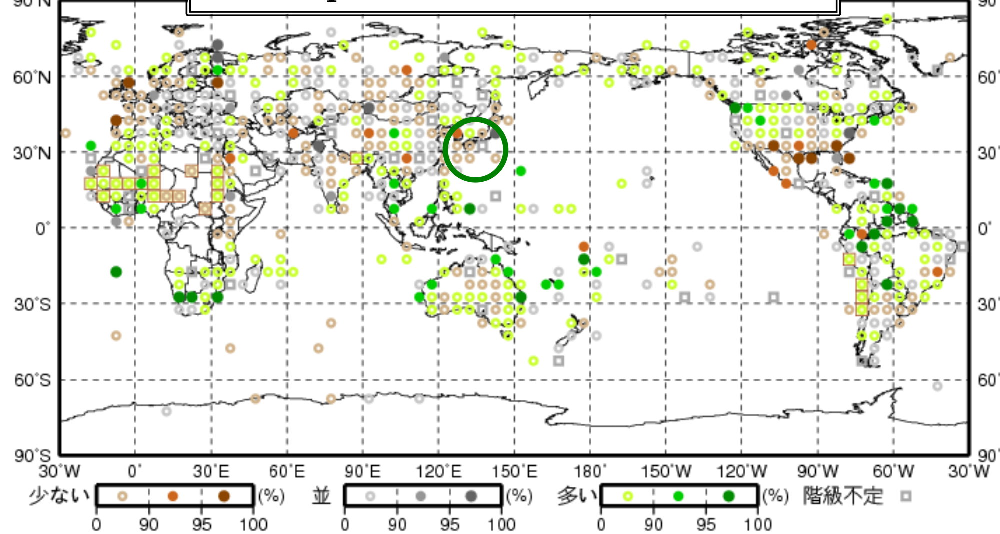
- Statistical analysis indicates that in winters with La Niña conditions, it is likely that parts of Japan experience slightly colder than normal conditions.

- But how do we explain this pattern of anomalies in terms of climatology?

Temperature anomalies during past La niña winters



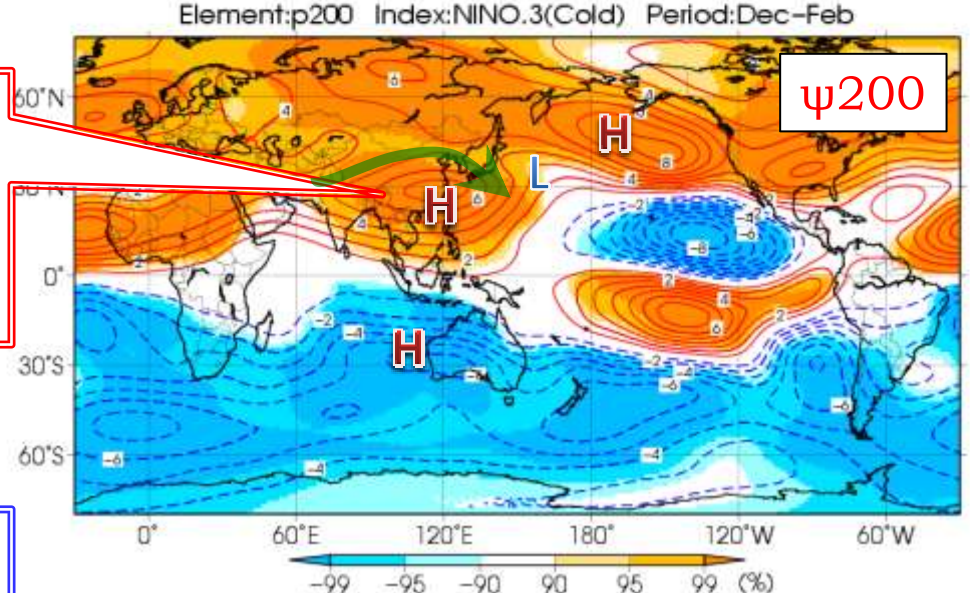
Precipitation anomalies during past La niña winters



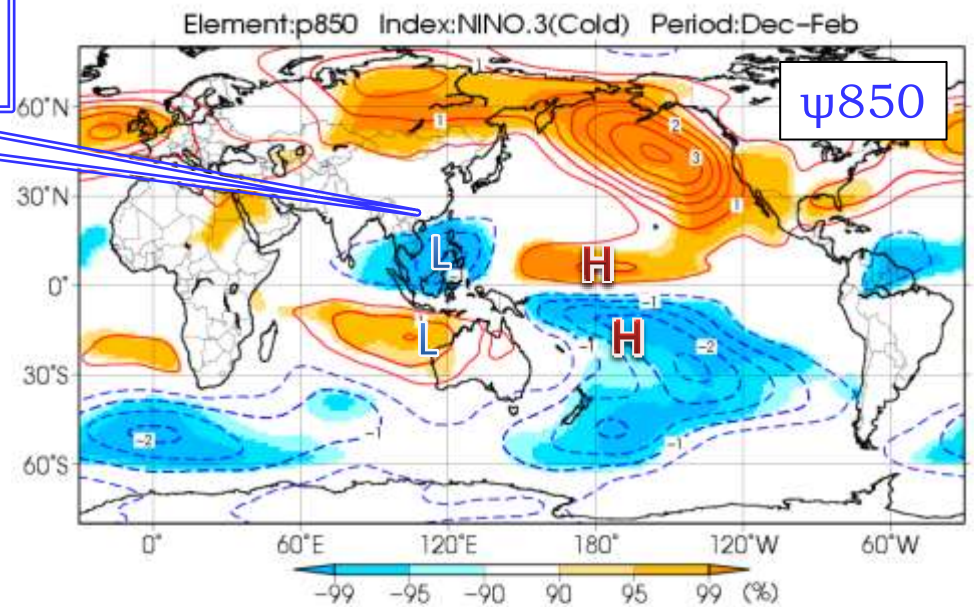
ENSO and climate in Japan (La Niña winter (DJF))

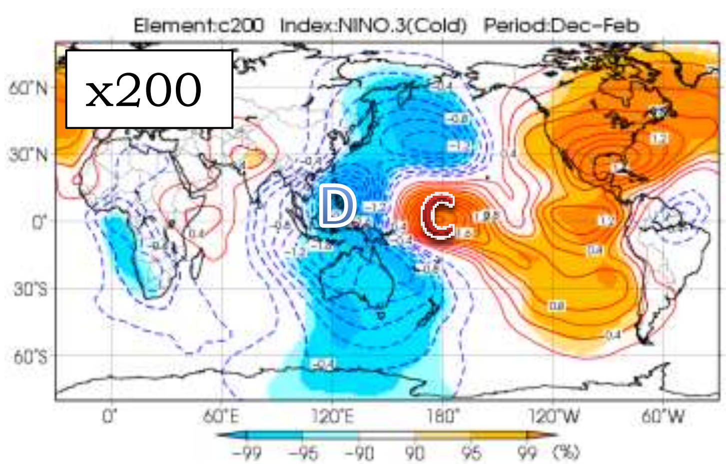
Composite map

- **In the upper troposphere**, pronounced anticyclonic anomalies are centered over southeastern China as a result of the divergence anomalies over the Maritime Continent.
- This induces anomalous northwesterly cold air advection toward Japan.



- **In the lower troposphere**, equatorial symmetric cyclonic and anticyclonic anomalies develop in the Maritime Continent and the central Pacific, respectively, in response to convection anomalies.

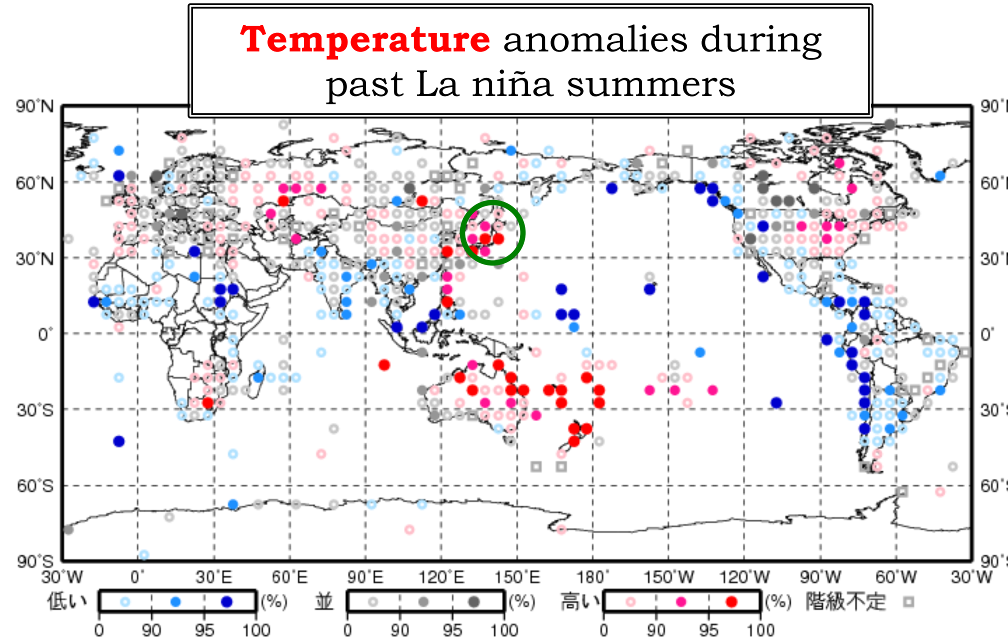


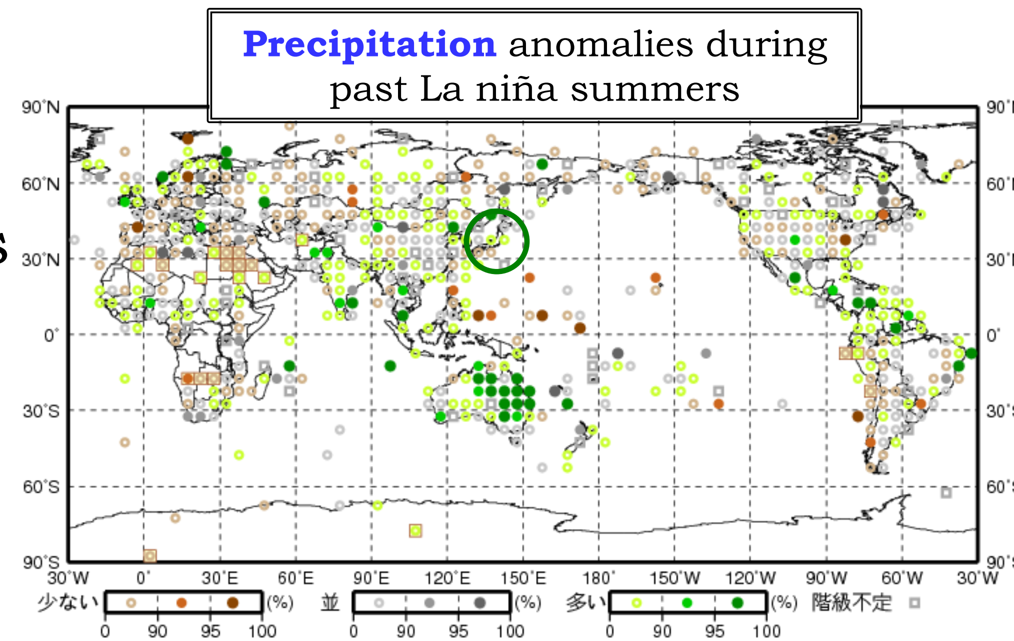


ENSO and climate in Japan (La Niña summer (JAS))

- Statistical analysis indicates that in summers with La Niña conditions, it is likely that parts of Japan experience hotter than normal conditions.

- But how do we explain this pattern of anomalies in terms of climatology?



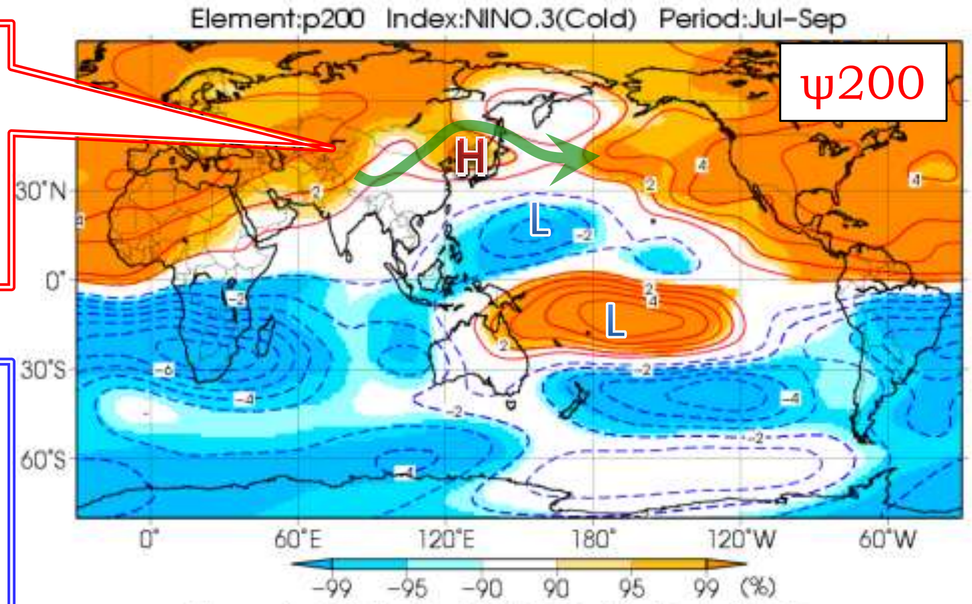


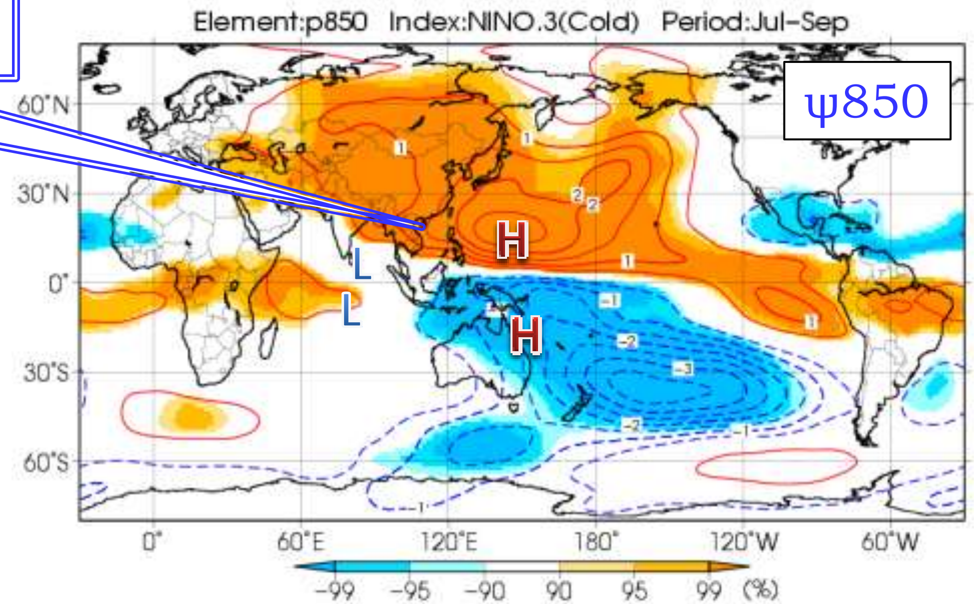
ENSO and climate in Japan (La Niña summer (JAS))

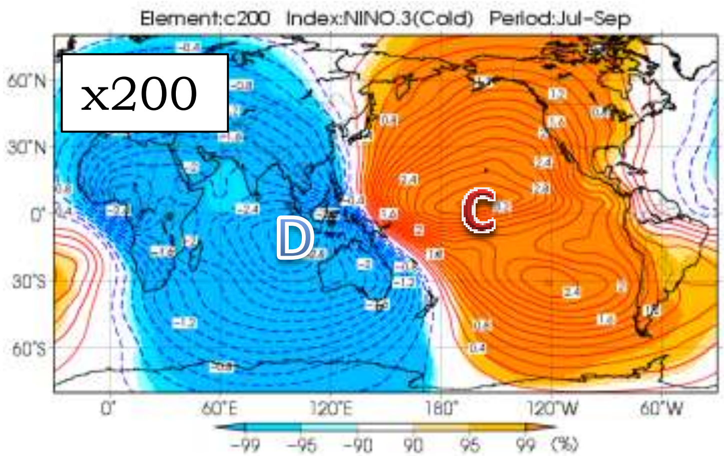
- **In the upper troposphere**, the Tibetan High is overall stronger than normal in response to active convection in the Asian summer monsoon region and anticyclonic anomalies are dominant over Japan.

- **In the lower troposphere**, equatorial symmetric anticyclonic anomalies develop in the western Pacific. The Subtropical High is enhanced in the western North Pacific and over Japan.
- In the Indian Ocean, equatorial symmetric cyclonic anomalies are associated with enhanced Asian summer monsoon.

Composite map

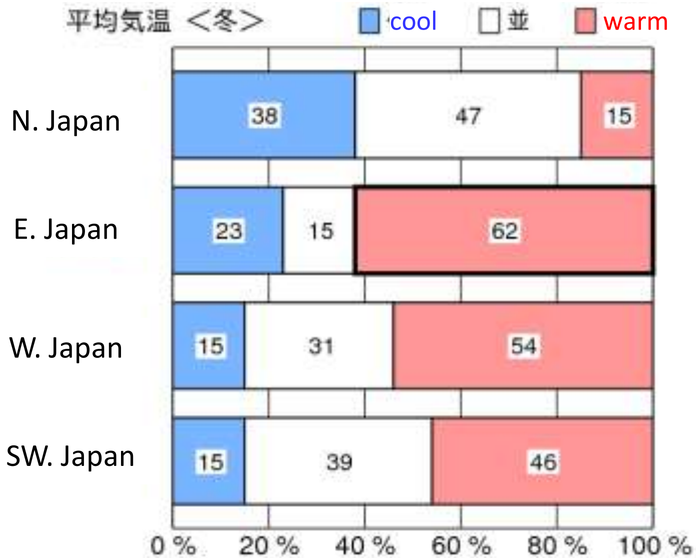




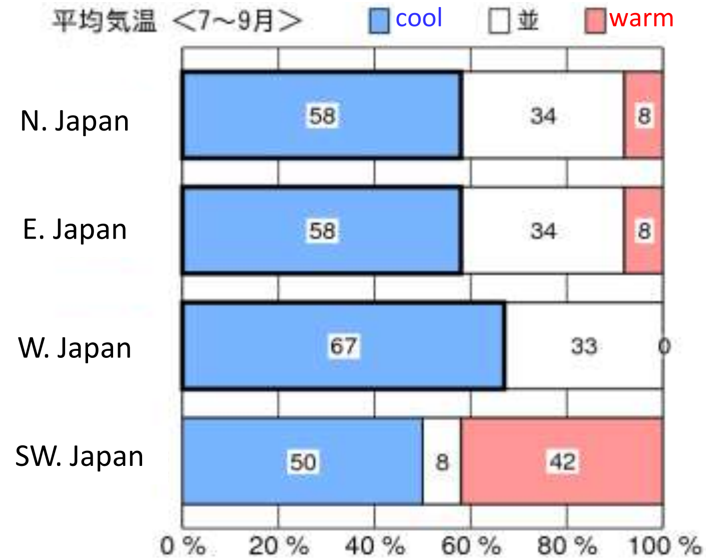


Summary of ENSO and climate in Japan (El Niño)

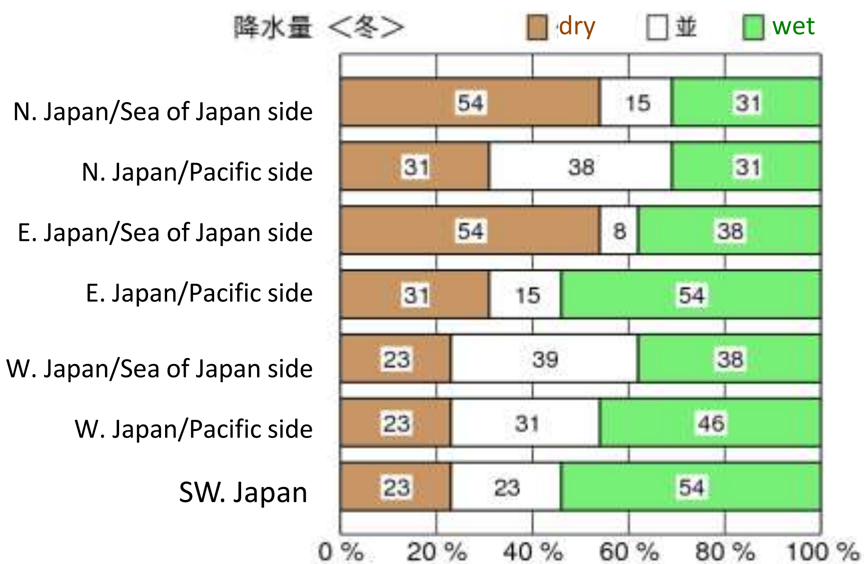
Probability of winter temperature



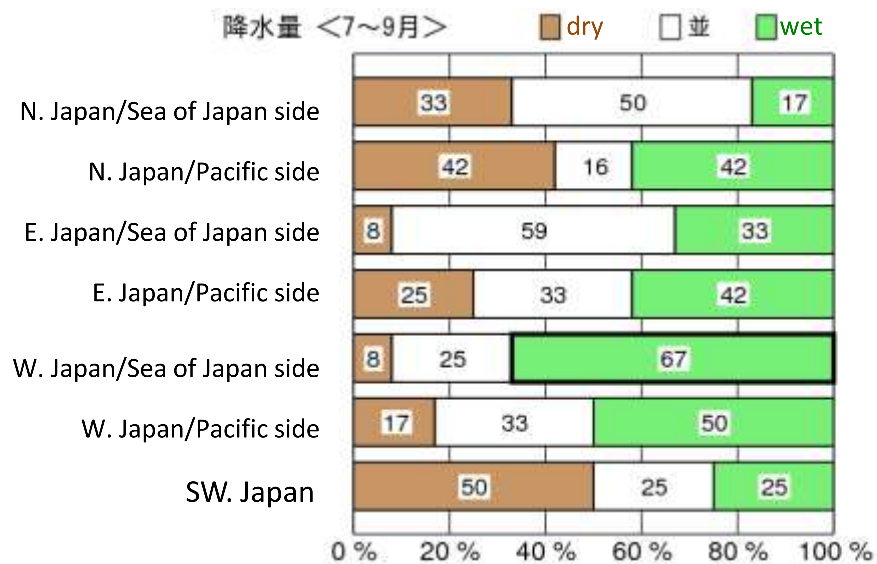
Probability of summer temperature



Probability of winter precipitation

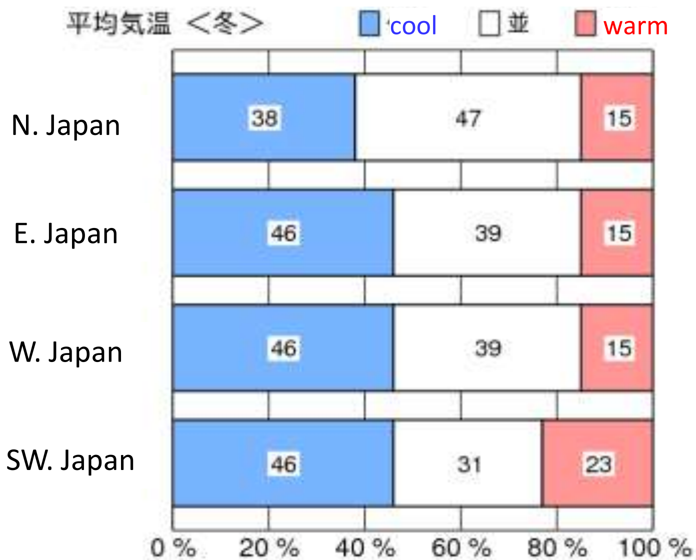


Probability of summer precipitation

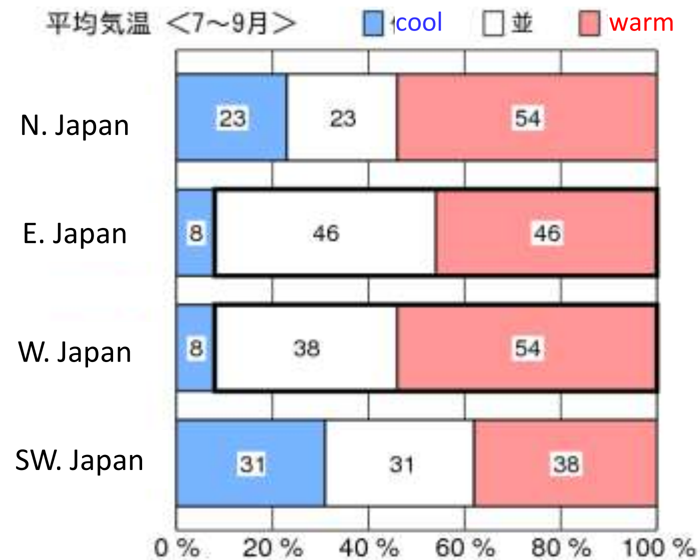


Summary of ENSO and climate in Japan (La Niña)

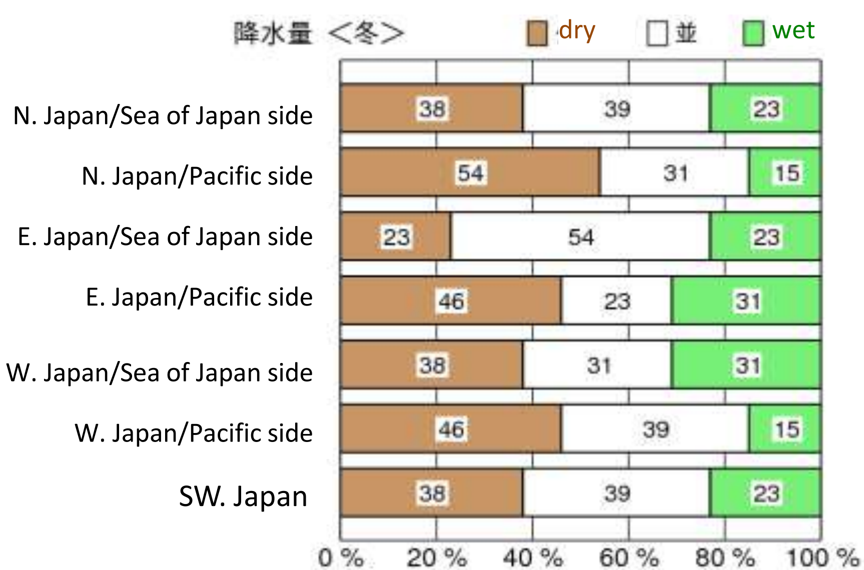
Probability of winter temperature



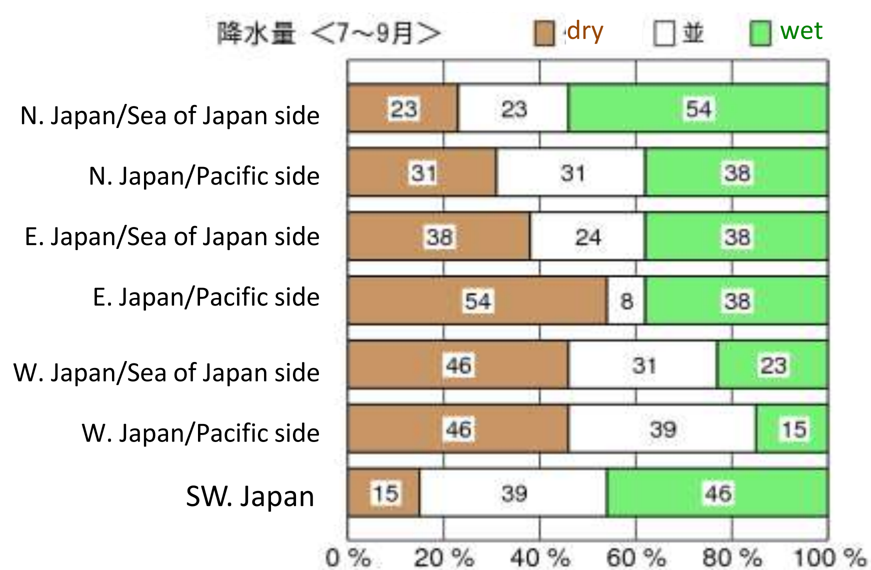
Probability of summer temperature



Probability of winter precipitation



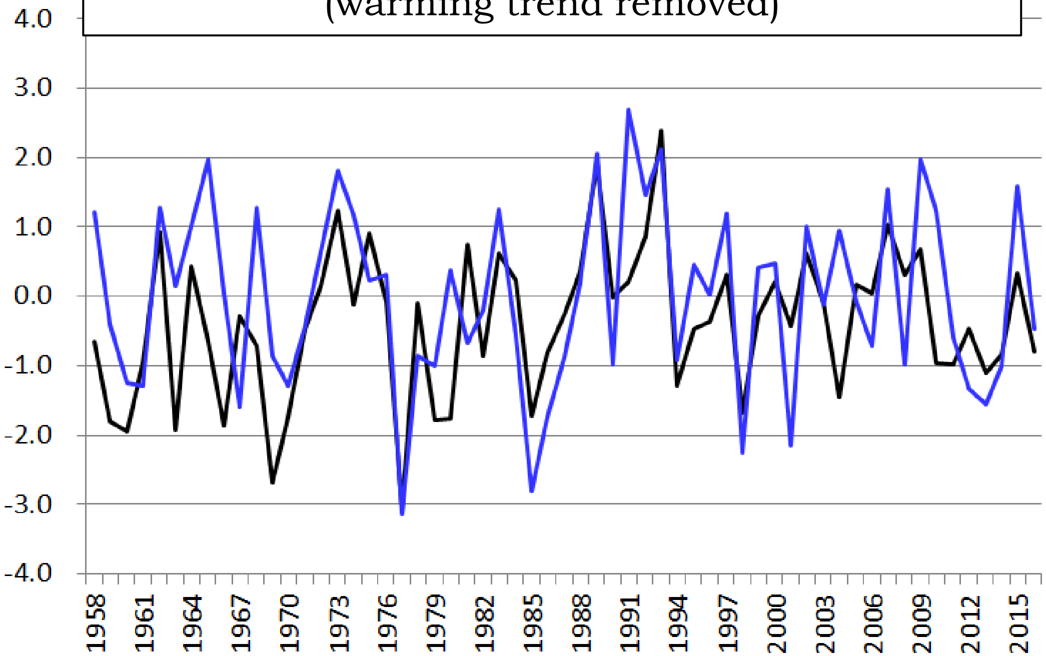
Probability of summer precipitation



AO and climate in Japan

- Statistical analysis indicates that January temperatures at Sapporo (a big city in northern Japan) are highly correlated with the AO index (cor >0.61).
- How is this correlation explained in terms of the atmospheric circulation pattern?

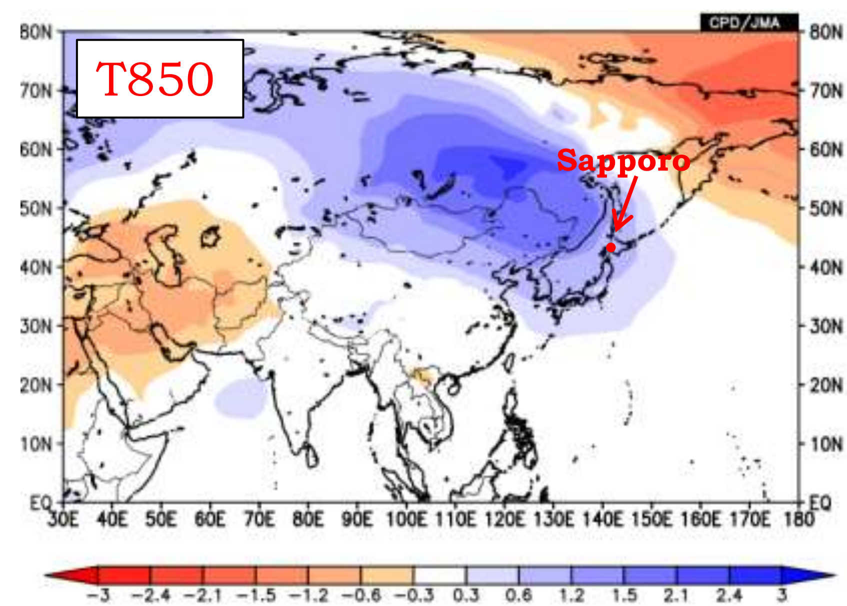
Correlation between AO index and temperature for January1958-2016 at Sapporo (warming trend removed)



Monthly AO index for January

January temperature anomalies at Sapporo

January temperature at 850hPa regressed on the AO index

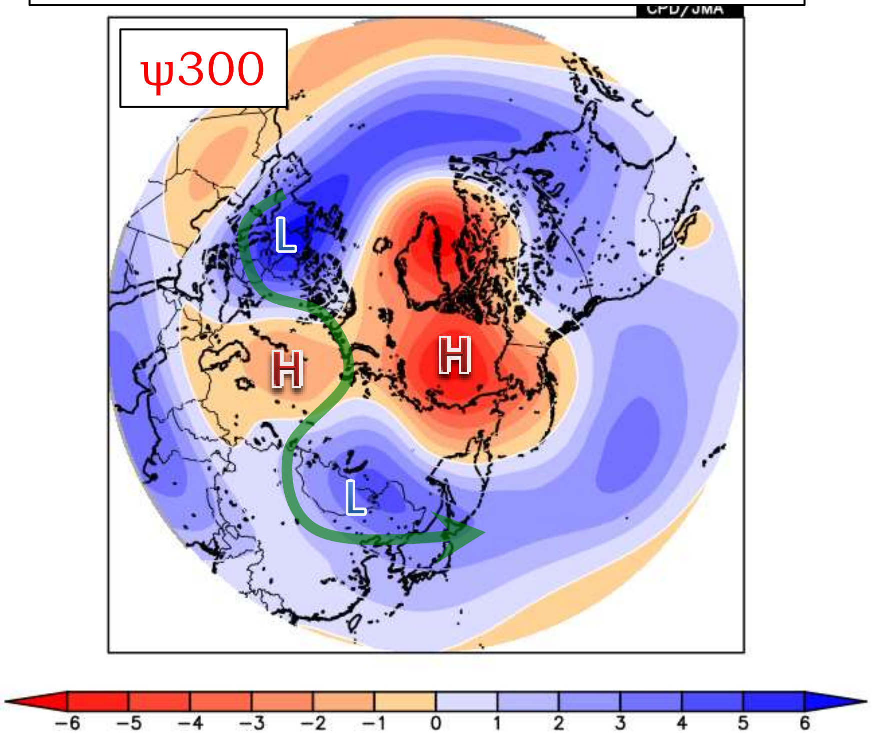


cold/warm colors reversed to indicate anomalies for the negative phase of AO

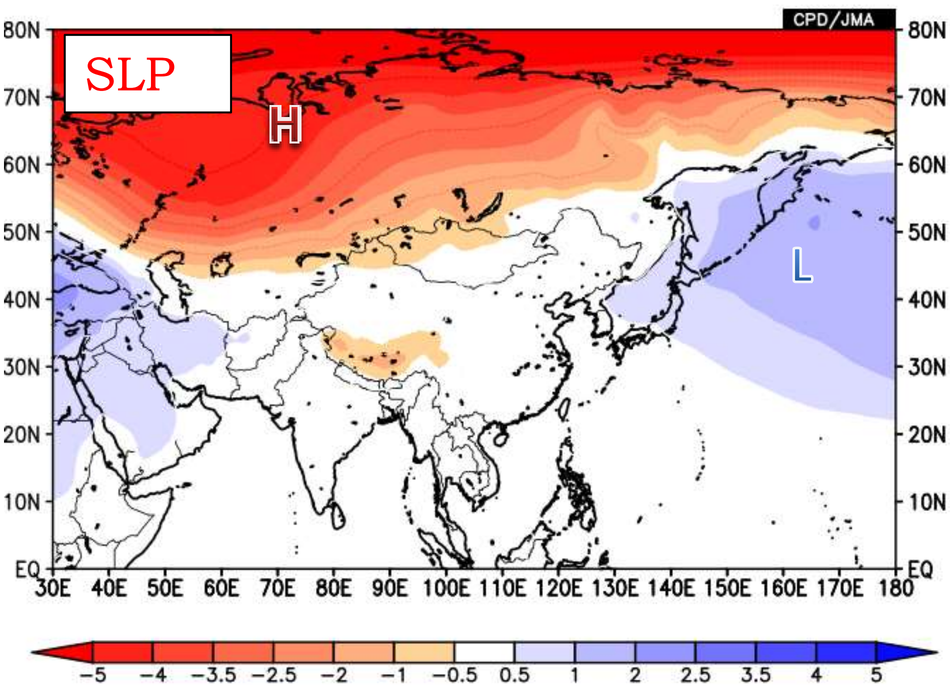
AO and climate in Japan

- In January of negative AO, anticyclonic anomalies prevail over the Arctic. This is associated with a weak polar vortex and a wavy polar jet.
- A Rossby wave train extends from Europe to East Asia in the upper troposphere, with a blocking-like ridge over Western Siberia and a trough over East Asia.
- In relation to the ridge over Western Siberia, the Siberian High is significantly intensified and enhances cold air advection into East Asia.

January streamfunction anomalies at 300hPa regressed on the AO index

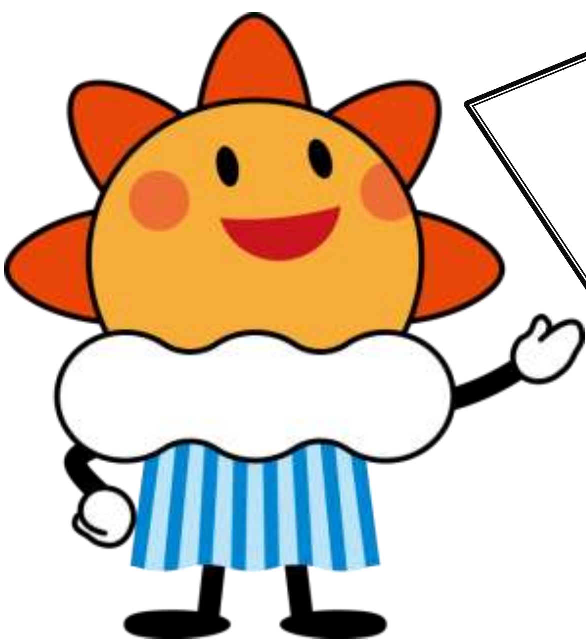


January SLP anomalies regressed on the AO index



cold/warm colors reversed to indicate anomalies for the negative phase of AO

Concluding remarks



In the exercise session starting tomorrow, participants are requested to research on a relationship between a primary mode of variability and climate in their country, according to the following steps:

(1) Seek and establish a statistical relationship between a mode of variability and a climate variable (observed records of temperature or precipitation) of their country, using an Excel-based tool prepared by TCC.

(2) Conduct an analysis of global circulation anomalies related to the results from (1), using iTacs.

(3) Try to come up with a good explanation that traces causal relationship as far back as possible.

(4) Give a presentation of the research results at the final session of the seminar.

Thank you for your attention.