Exercise

Finding statistical relationship between primary modes of variability and atmospheric circulation

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16 November 2016, 11:20-12:30, 14:00-16:00

Objective of this exercise

Finding statistical relationship between ***primary modes of variability*** (ENSO index, AO, EU, …) and ***atmospheric circulation***

- Climate system has primary modes of variability. These modes influence global atmospheric circulations and climate.
- It is important in understanding climate characteristics of your country to know the statistical relationship between primary modes of variability and atmospheric circulation.
- We consider the mechanism of the relationship ***in the following exercise***.

Outline

1. Introduction
2. Relationship between ENSO index and atmospheric circulation (referring to TCCHP)
3. Procedure of this exercise
4. Introduction of TCC products and tools
5. Exercise (using iTacs)

Program of this exercise

Day 3 - Wednesday, 16 November		
9:30-11:00	10. Exercise: Finding climate characteristics associated with primary modes of	
11:00-11:20	Coffee Break	
11:20-12:30	11. Exercise: Finding statistical relationship between primary modes of variability and atmospheric circulation	
12:30-14:00	Lunch	
14:00-16:00	11. Exercise: Finding statistical relationship between primary modes of variability and atmospheric circulation	
16:00-16:20	Coffee Break	
16:20-18:00	12. Exercise: Considering mechanisms of the relationship between primary modes of climate variability and atmospheric circulation	

11:20-12:30

1. Introduction
2. Relationship between ENSO index and atmospheric circulation (referring to TCCHP)
3. Procedure of this Exercise

1400-1600

4. Introduction of TCC products and tools
5. Exercise (using iTacs)

Outline

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2. Relationship between ENSO index and atmospheric circulation (referring to TCCHP)
3. Procedure of this exercise
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Primary modes of variability

- atmosphere-ocean variability in tropical region
  - El Nino and Southern Oscillation (ENSO)
  - ENSO influence atmospheric circulations and climate not only in tropical region, also in the global area.
- variability mode in the mid- and high latitudes
  - Teleconnections pattern (AO, EU, PNA …)

Relationship between ENSO index and atmospheric circulation

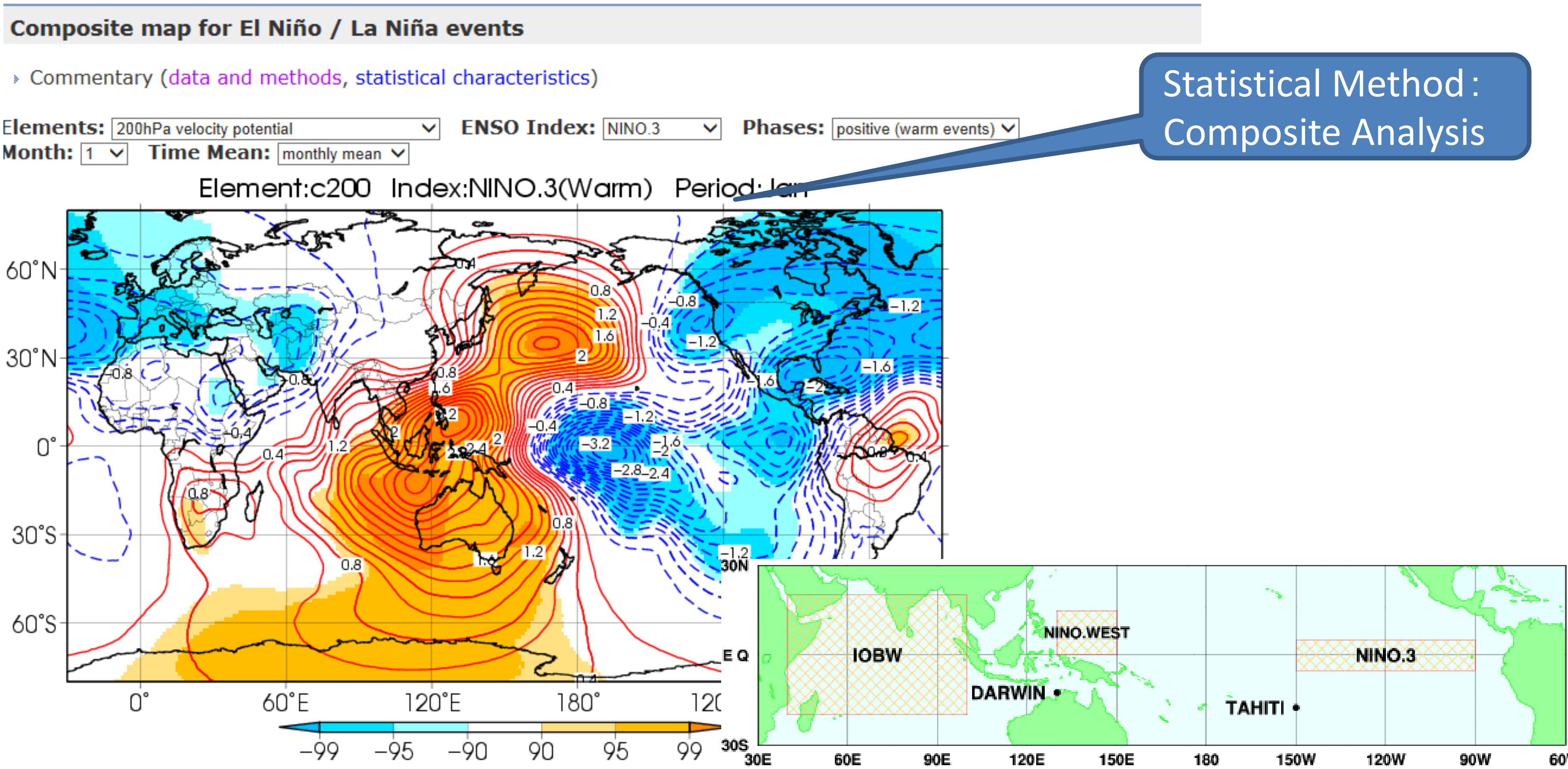
- El Niño and Southern Oscillation (ENSO) is the most dominant mode of variability in the Earth’s climate system.

- In this section, I introduce the TCC product “Composite map for El Nino/La Nina event” providing the statistical relationship between ***El Nino/La Nina event*** and ***global atmospheric circulation***.

- This product is an example of statistical relationship between ***primary modes of variability*** and ***atmospheric circulation***, and will be useful reference for this exercise.

[TCCHP] Composite map for El Nino/La Nina event

This product provides the statistical analysis on the relationship between ***warmer/cooler SST event in the areas of NINO.3, NINO.WEST and IOBW*** and ***atmospheric circulation***.



Monthly mean composite of 200-hPa velocity potential anomalies in the positive phase of NINO.3 (Jan.)

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

[TCCHP] Composite map for El Nino/La Nina event

This product also outlines ***the characteristics of seasonal mean composite anomalies*** in the positive and negative phases of the ENSO indices.

Statistical characteristics

This section outlines the characteristics of seasonal mean composite anomalies in the positive and negative phases of the ENSO indices.

1. Atmospheric circulation in the El Niño (positive) phase of NINO.3

Contents

- Data and methods
- Statistical characteristics
  - El Niño phase of NINO.3
  - La Niña phase of NINO.3
  - El Niño phase of NINO.WEST
  - La Niña phase of NINO.WEST
  - El Niño phase of IOBW
  - La Niña phase of IOBW
- References

Winter (December - February)

OLR and precipitation anomalies indicate that convective activity is enhanced over the central to e Pacific. Enhanced convective activity is seen over the Gulf of Mexico, and suppressed convective a Convergence Zone (ITCZ) exhibits equatorward shift.

In the lower troposphere, cyclonic (anti-cyclonic) circulation anomalies straddling the equator are and the Atlantic). These patterns are consistent with those of the gMatsuno - Gillh response (Mats lower troposphere. Zonal wind anomalies in the lower and upper troposphere indicate weaker-tha

The subtropical jet stream demonstrates a southward shift over the area from the Middle East to E hPa height field, wave trains such as the Pacific - North American (PNA) pattern (Wallace and Gut anomalies, negative sea-level pressure anomalies are seen to the south of Alaska, indicating enha

Spring (March - May)

OLR and precipitation anomalies indicate that convective activity is enhanced over the central to e Pacific. Suppressed convective activity is seen over the equatorial Atlantic and the north Indian Ocean.

In the lower troposphere, cyclonic (anti-cyclonic) circulation anomalies straddling the equator are seen, and westerly (easterly) wind anomalies a Atlantic). In the upper troposphere, the signs of anomaly patterns are opposite to those observed in the lower troposphere, indicating weaker-tha

The subtropical jet stream exhibits a southward shift over the area from the Middle East to southern China. In the 500-hPa height field, positive ar

Summer (June - August)

OLR and precipitation anomalies indicate that convective activity is enhanced over the equatorial Pacific and suppressed over the Maritime Contine activity is seen over India, indicating an inactive Indian monsoon. The coefficient of correlation between the NINO.3 index and the intensity of the normal Asian monsoon circulation seen in El Niño events (not shown).

In the lower troposphere, cyclonic circulation anomalies straddling the equator are seen, and westerly wind anomalies are dominant over the Paci troposphere. Cyclonic circulation anomalies are seen over vast areas of southern Eurasia, indicating a weaker-than-normal Tibetan High in its nort

In the 500-hPa height field, negative anomalies are seen over Japan and the North Pacific in line with southward meandering and enhancement of function fields, negative anomalies are seen over vast areas of the North Pacific, indicating a weaker-than-normal subtropical high.

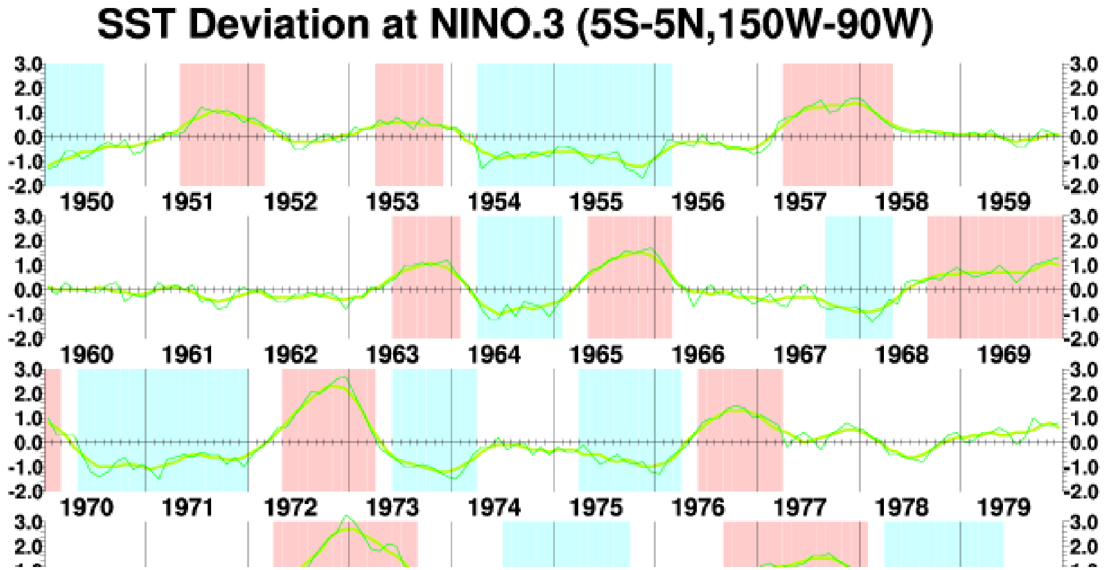
http://ds.data.jma.go.jp/tcc/tcc/products/clisys/enso_statistics/explanation.html#statistics

[TCCHP] Composite map for El Nino/La Nina event

- Data
  - COBE-SST analysis dataset for SST
  - JRA-55 reanalysis dataset for Atmospheric Circulation Data
  - satellite observation data for Outgoing Longwave Radiation
- Base period
  - 1958 - 2012 for SST and JRA-55 dataset
  - 1979 - 2012 for OLR
- Definition of positive/negative phase
  - The five-month running mean SST deviation* satisfies the threshold requirements (see the Table) for at least six consecutive months

* deviation from the sliding 30-year base period average

ENSO Index	Threshold (five-month running mean)	
	Negative Phase	Positive Phase
NINO.3	<= -0.5	>= +0.5
NINO.WEST	<= -0.15	>= +0.15
IOBW	<= -0.15	>= +0.15

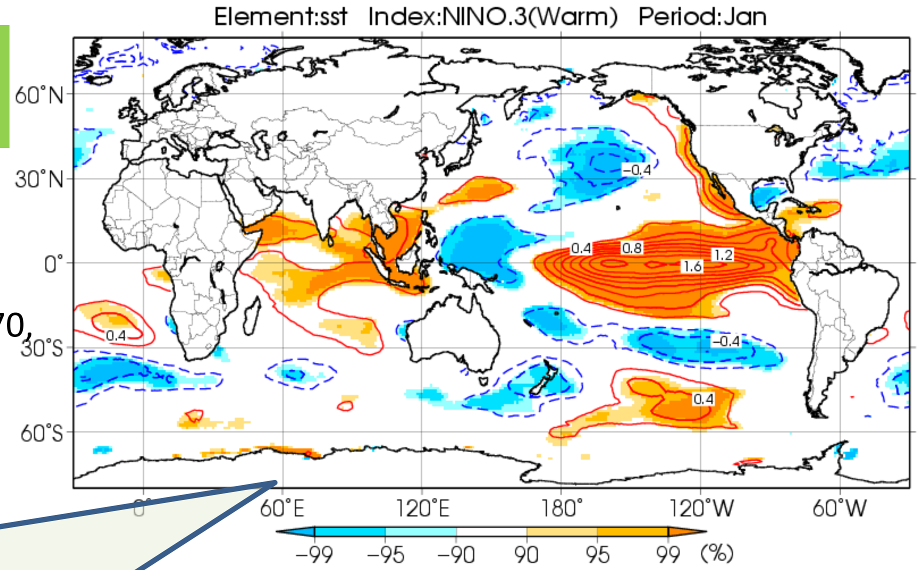


[Review] Composite analysis

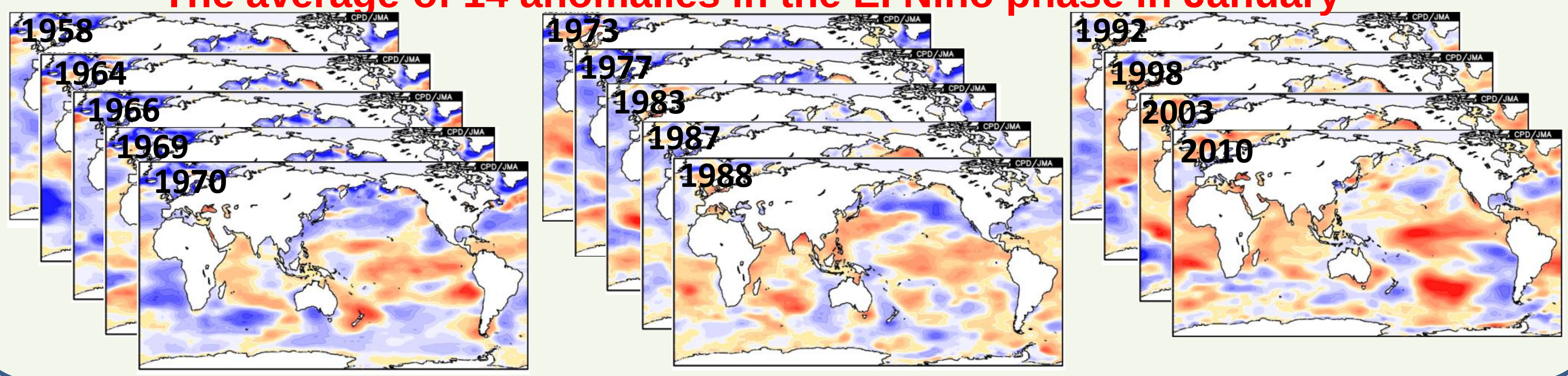
Composite analysis is a statistical technique to extract the common characteristics in past events of a targeted phenomenon (e.g., El Niño and La Niña events) from the other phenomena.

SST Composite Map In El Nino Phase (Jan.)

Contours: composite anomaly,
Shadings: confidence level,
Statistical period: 1958 – 2012
(Composite year : 1958,64,66,69,70, 73,77,83,87,88,92,98,2003,2010)



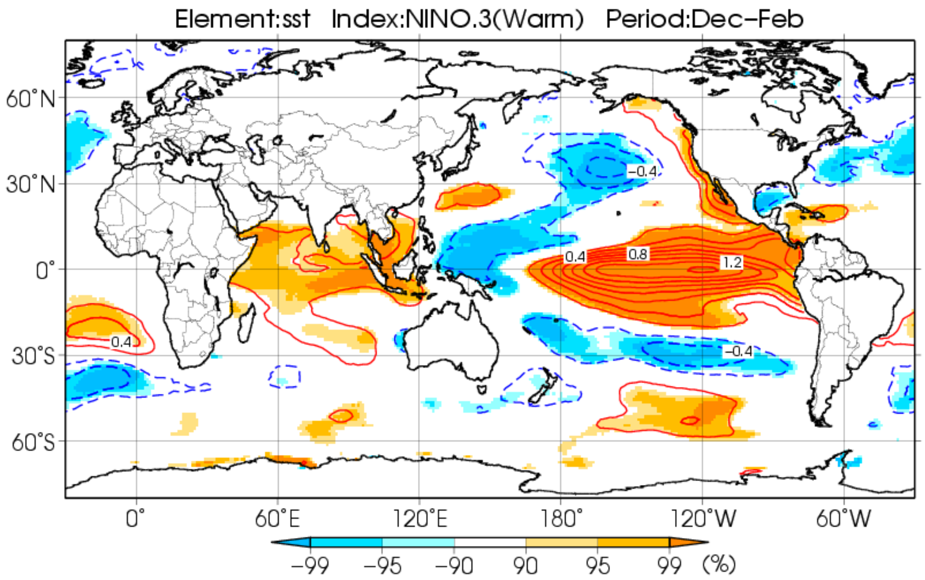
The average of 14 anomalies in the El Nino phase in January



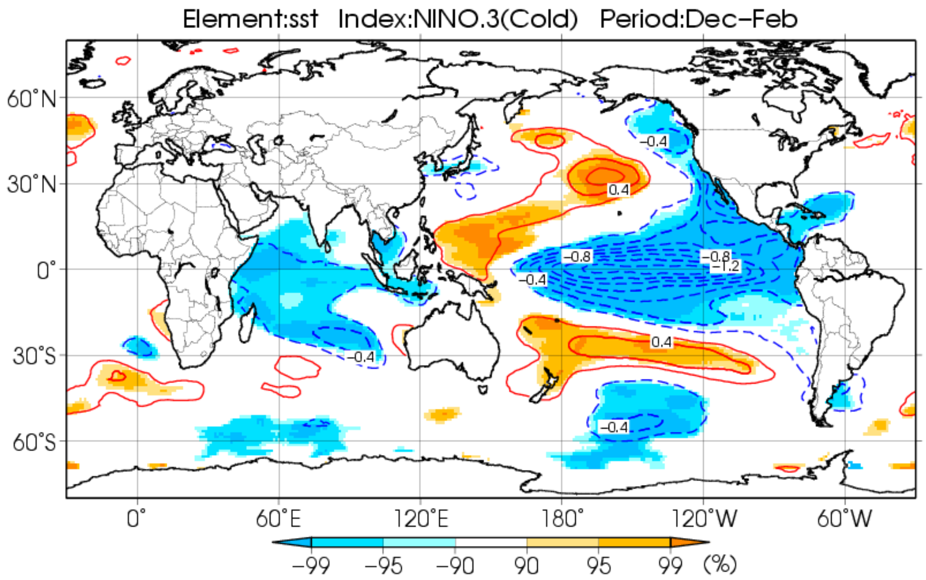
Sea Surface Temperature (DJF)

- In the El Nino phase, positive SST anomalies were seen over the central to eastern Pacific and Indian Ocean, and negative SST anomalies were seen over the western Pacific.

El Niño phase



La Niña phase



<u>Three-month mean composite of sea surface temperature anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 0.2 C.

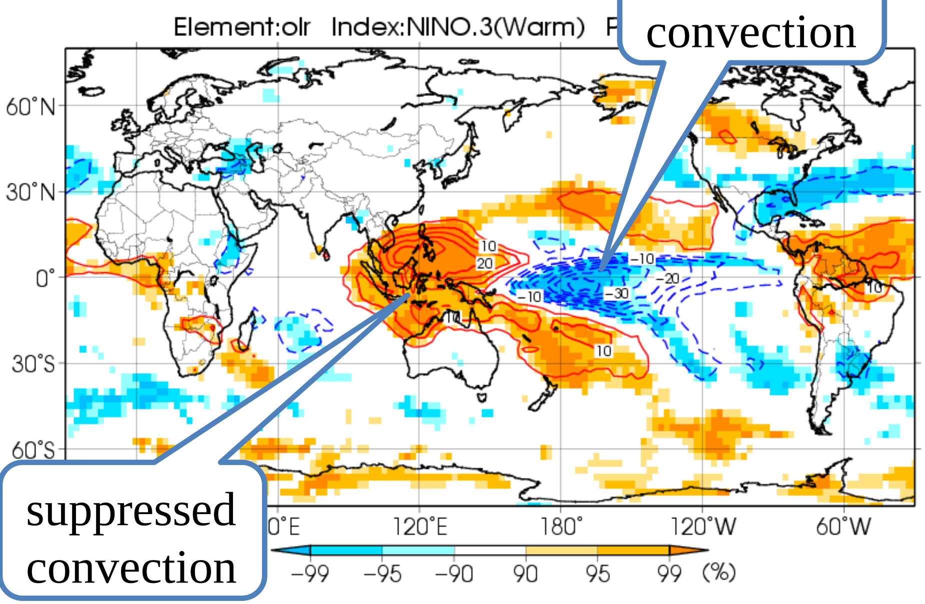
Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

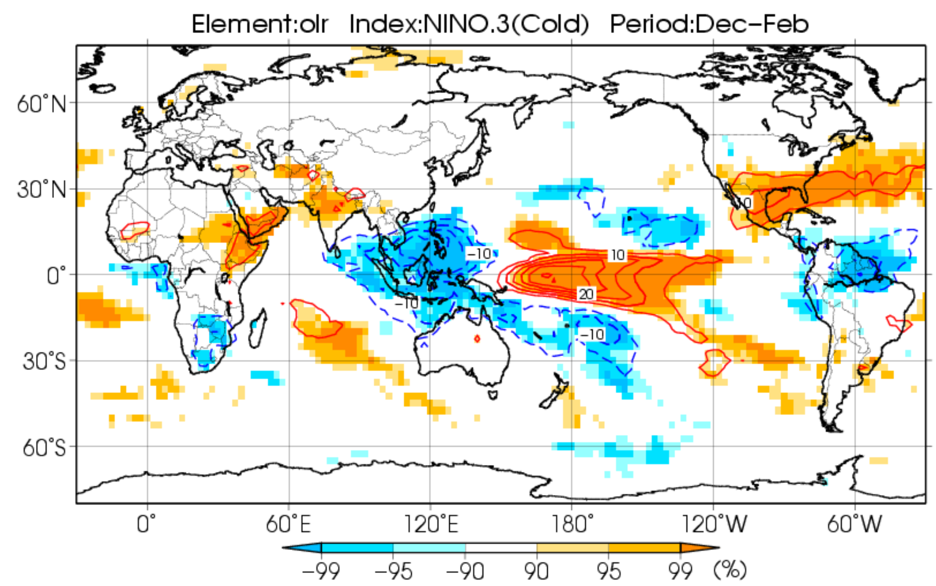
Convective Activity (DJF)

- In the El Nino phase, convective activity is enhanced over the central to eastern equatorial Pacific, and suppressed over and around the Maritime Continent in response to the east-west contrast of SST anomalies over the equatorial Pacific.

El Niño phase



La Niña phase



<u>Three-month mean composite of outgoing longwave radiation anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 5 W/m^2.

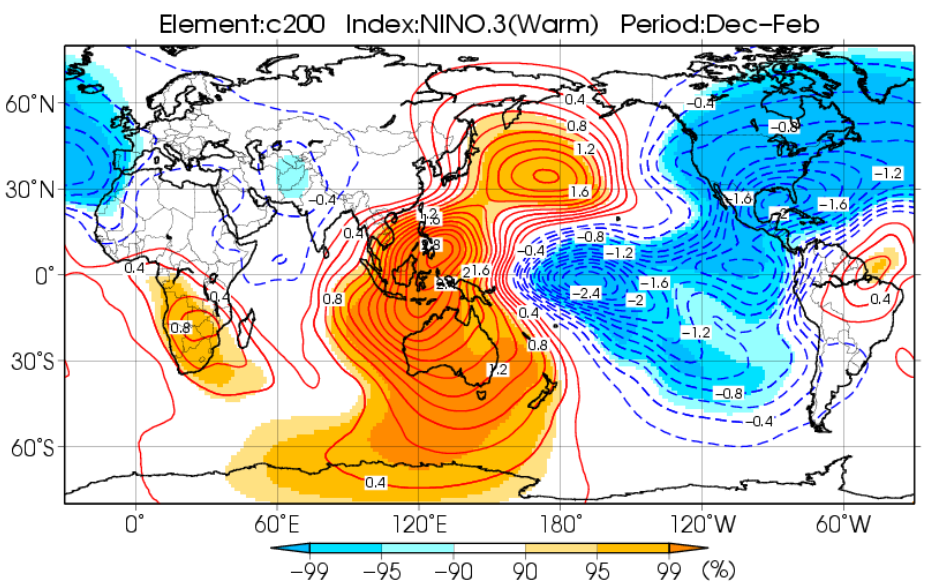
Shading indicates the confidence level.

The base period for composite analysis is 1979- 2012.

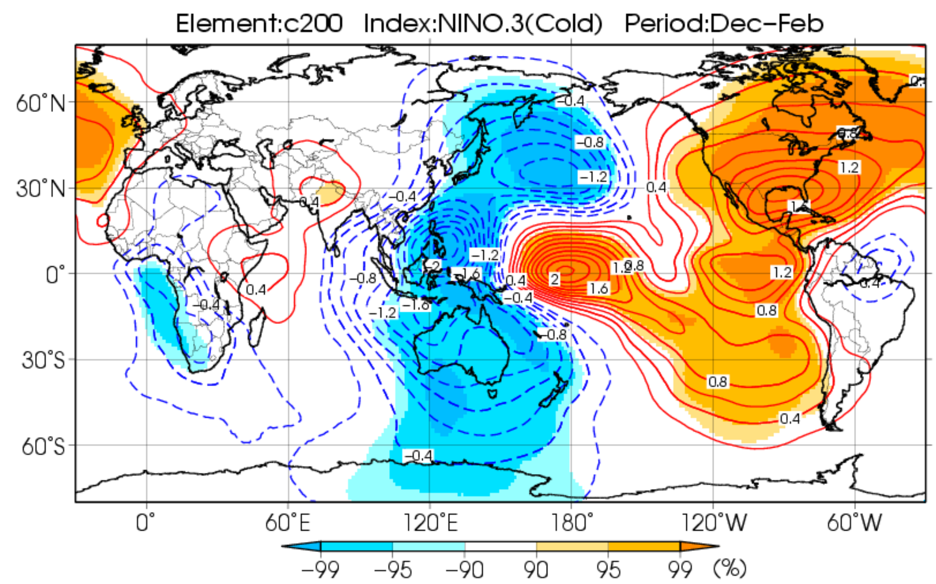
Upper-level Divergence/Convergence (DJF)

- In the El Nino phase, large-scale divergence anomalies were seen central to eastern Pacific, and large-scale convergence anomalies were seen over the Maritime Continent.

El Niño phase



La Niña phase



<u>Three-month mean composite of 200-hPa velocity potential anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 0.2×10^6 m^2/s.

Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

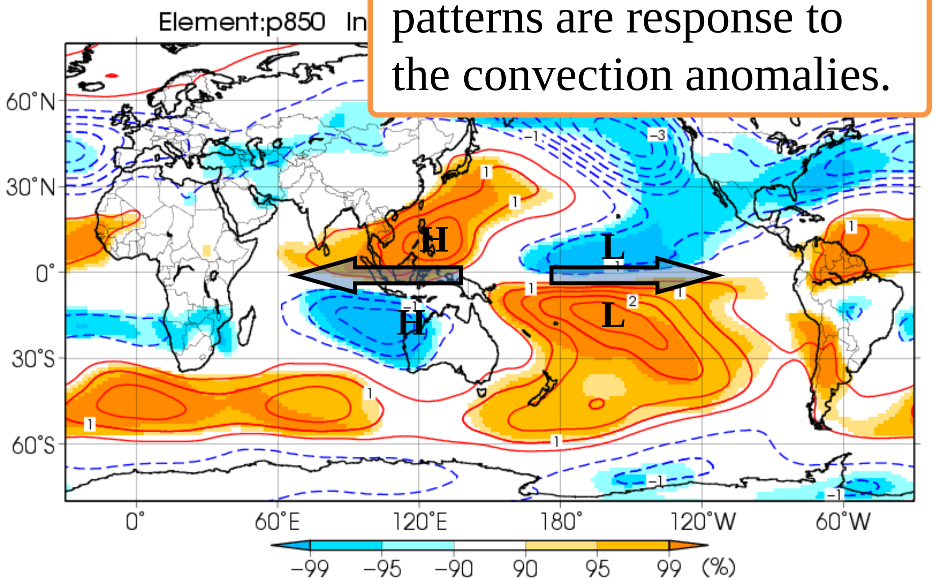
Low-level Circulation (DJF)

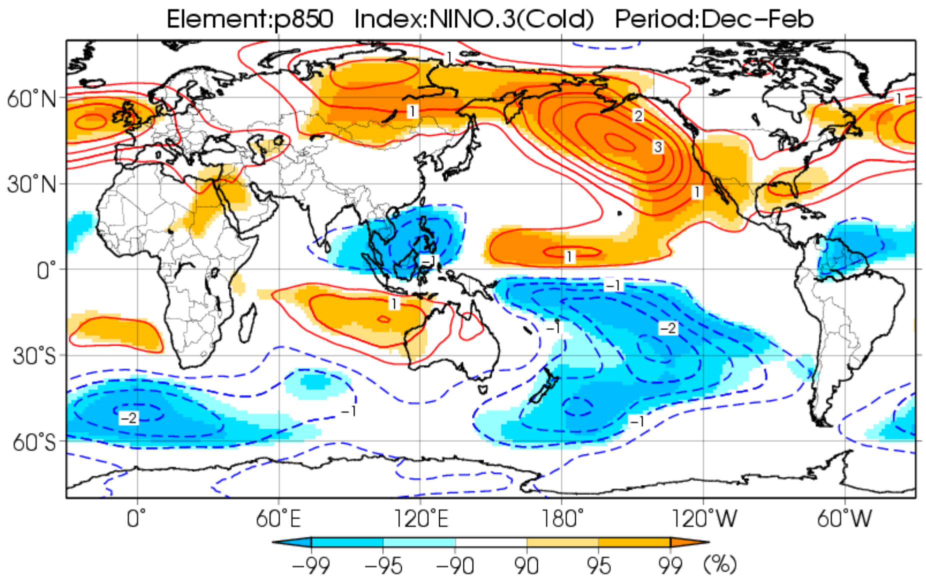
- In the El Nino phase, cyclonic (anti-cyclonic) circulation anomalies straddling the equator are seen over central Pacific (around the Maritime Continent), and westerly (easterly) wind anomalies are dominant over the equatorial area.

El Niño phase

Tropical circulation patterns are response to the convection anomalies.

La Niña phase





<u>Three-month mean composite of 850-hPa stream function anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 0.5×10^6 m^2/s.

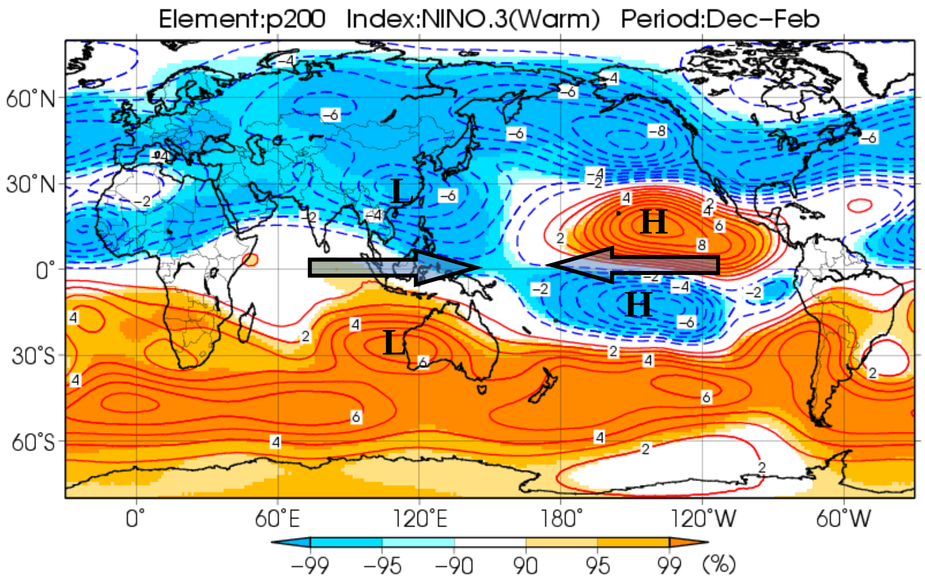
Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

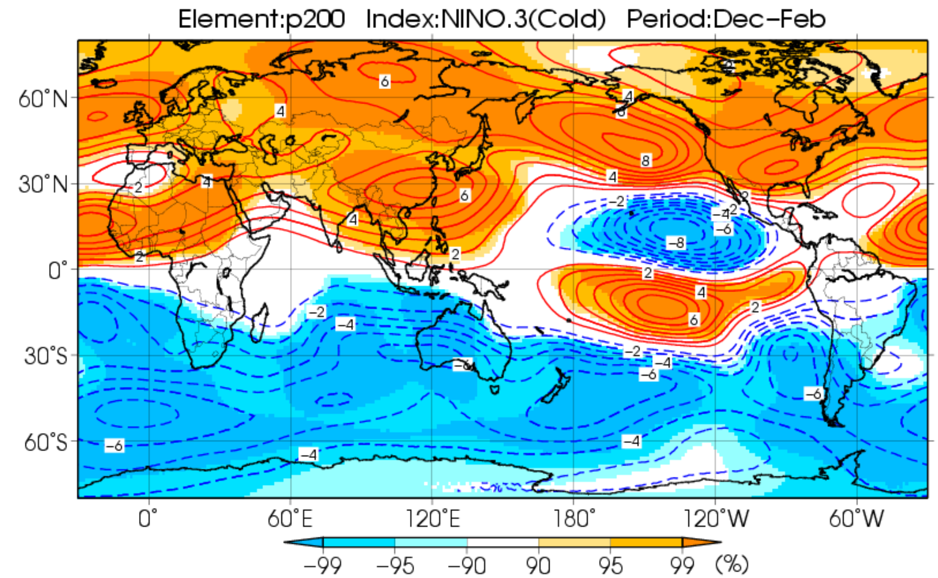
Upper-level Circulation (DJF)

- The signs of anomaly patterns are opposite to those observed in the lower troposphere. In the El Nino phase, zonal wind anomalies in the lower and upper troposphere indicate weaker-than-normal Walker Circulation.

El Niño phase



La Niña phase



Three-month mean composite of 200-hPa stream function anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)

Contours show composite anomalies at intervals of $1x10^6$ m^2/s.

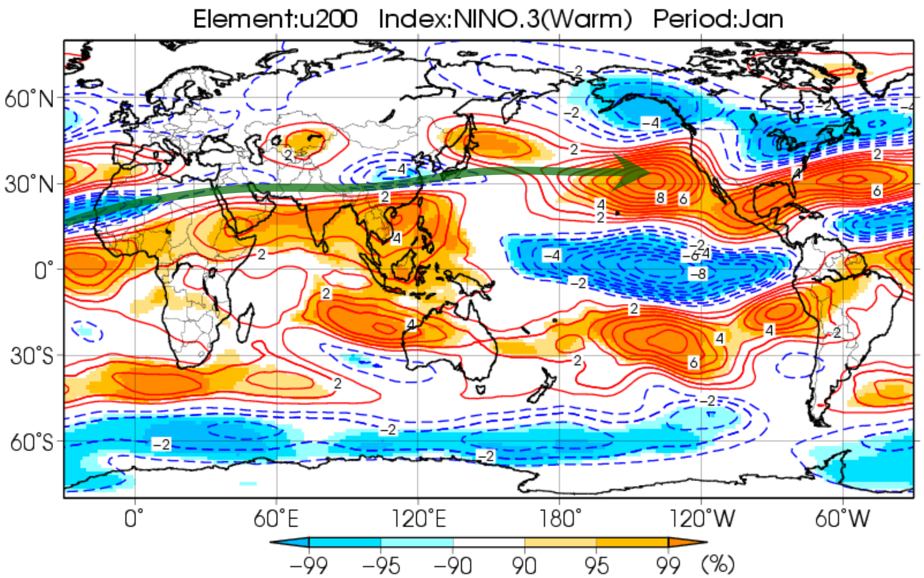
Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

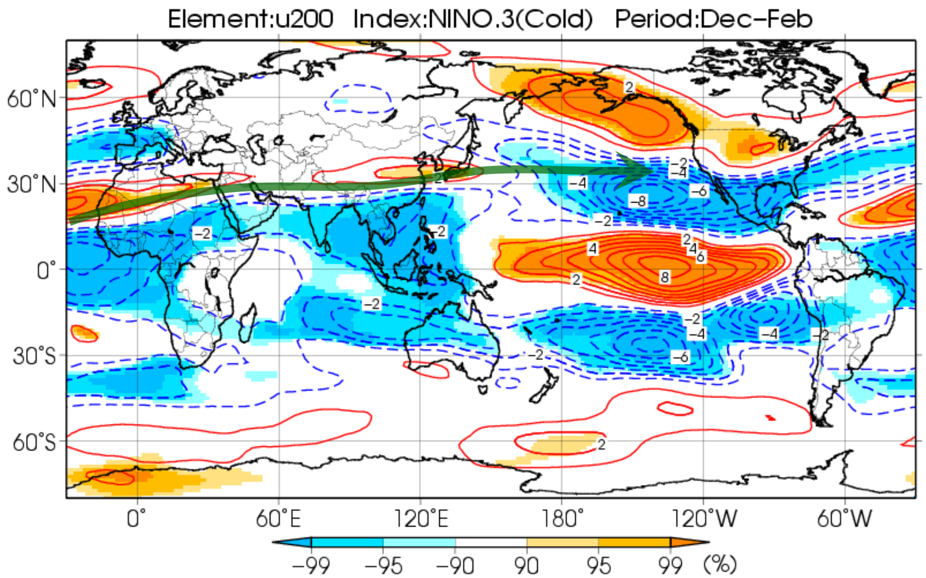
Jet Stream (DJF)

- In the El Nino phase, the subtropical jet stream demonstrates a southward shift over the area from the Middle East to East Asia in line with cyclonic circulation anomalies in the upper troposphere.

El Niño phase



La Niña phase



<u>Three-month mean composite of 200-hPa zonal wind anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 1 m/s.

Shading indicates the confidence level.

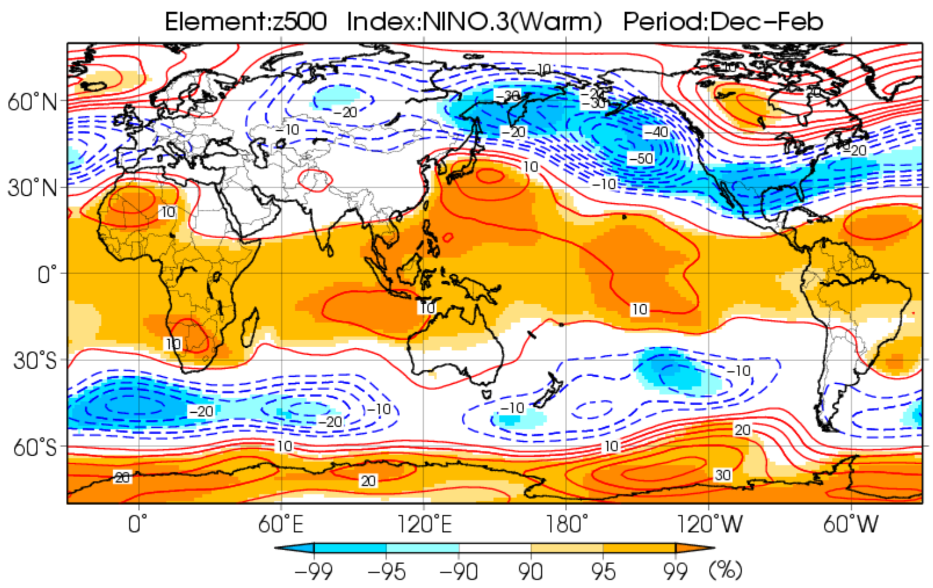
The base period for composite analysis is 1958 - 2012.

The green solid line represents the normal position of the subtropical jet stream.

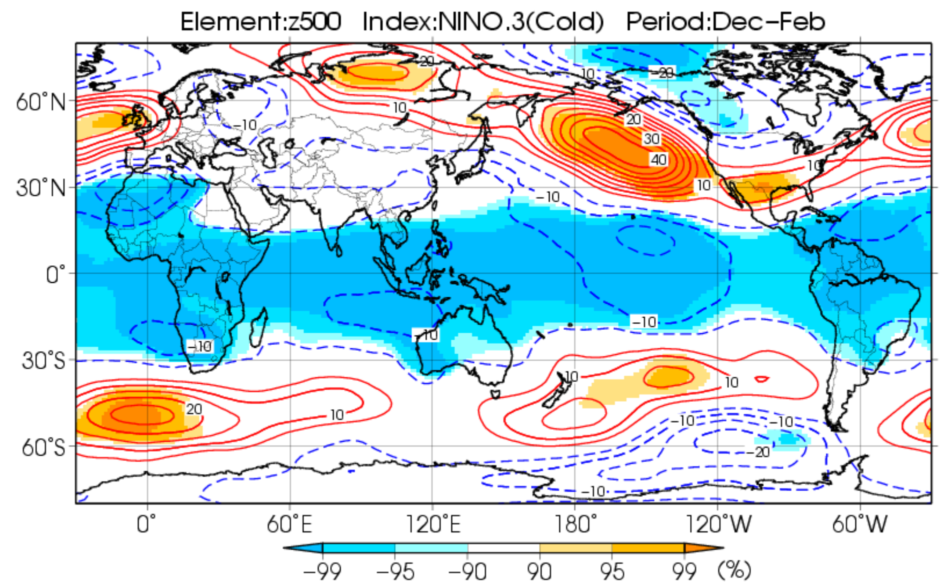
500hPa Height Field (DJF)

- In the El Nino phase, positive anomalies extend in the global tropics and to the southeast of Japan, and negative anomalies in the northern North Pacific.

El Niño phase



La Niña phase



<u>Three-month mean composite of 500-hPa height anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 5 m.

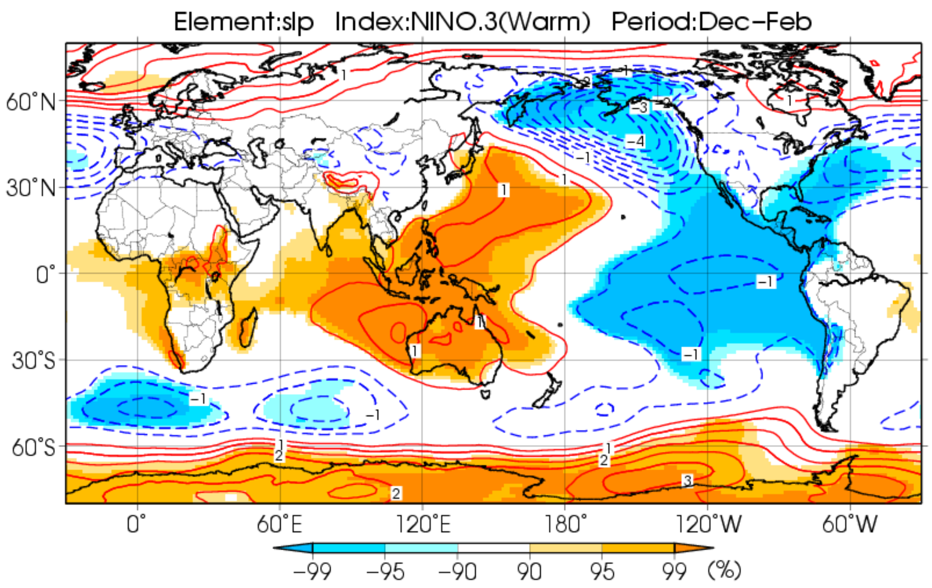
Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

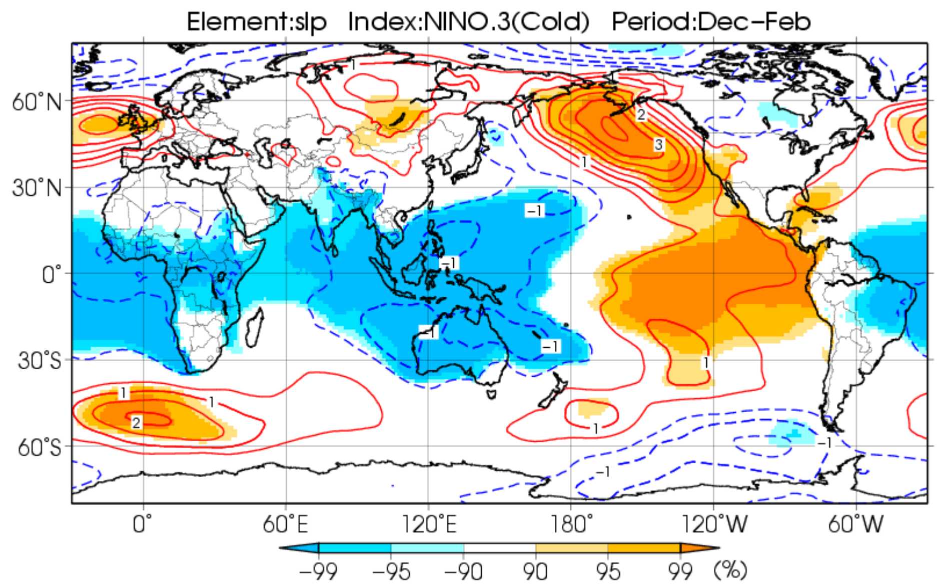
Sea-level Pressure (DJF)

- In the El Nino phase, positive anomalies extend from the eastern Indian Ocean to the western Pacific and negative anomalies in the eastern Pacific.

El Niño phase



La Niña phase



<u>Three-month mean composite of sea level pressure anomalies in the positive (left) and negative (right) phase of NINO.3 (Dec.-Feb.)</u>

Contours show composite anomalies at intervals of 0.5 hPa.

Shading indicates the confidence level.

The base period for composite analysis is 1958 - 2012.

Outline

1. Introduction
2. Relationship between ENSO index and atmospheric circulation (referring to TCCHP)
3. Procedure of this exercise
4. Introduction of TCC products and tools
5. Exercise (using iTacs)

Procedure of this exercise

Finding statistical relationship between ***primary modes of variability*** (ENSO index, AO, EU, …) and ***atmospheric circulation***

1. Select a mode for your statistical analysis.
2. Decide the target months of your statistical analysis.
3. Try the statistical analysis between ***the selected mode*** and ***atmospheric circulation*** using iTacs.
4. Make a PPT materials about your statistical analysis.

Procedure of this exercise (1)

1. Select a mode for your statistical analysis.
   - The mode which is closely related to your country’s climate is recommended.
   - Please refer to the previous exercise materials (“Finding Climate Characteristics Associated with Primary Modes of Global Climate Variability”).

Procedure of this exercise (2)

2. Decide the target months of your statistical analysis.
   - Take into climatic features of your country (summer, winter, monsoon season, post-monsoon, …).
   - For example, January (July) is representative month of winter (summer) in Japan.

Procedure of this exercise (3)

3. Try the statistical analysis between ***the selected mode*** and ***atmospheric circulation*** using iTacs .
   – We do ***the regression analysis*** in this exercise.
   – iTacs is very convenient and useful tool for regression analysis. Regression analysis and significance testing based on t-testing can be performed at the same time.

Procedure of this exercise (4)

4. Make PPT materials about your statistical analysis.
   - execute step 3 for various elements
     - SST, OLR, velocity potential, stream function, geopotential height, sea level pressure, temperature, …
   - make PPT materials
     - **<u>You will need figures that you make here</u>** for the following exercise.
   - If you have time to spare
     - You can change month, average period (e.g., DJF for winter) and the climate variability mode's index (e.g., IOBW SST index (tropical Indian Ocean), Arctic Oscillation(AO), and others).
     - You can try another statistical method (e.g., composite analysis) .

[Review] 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.

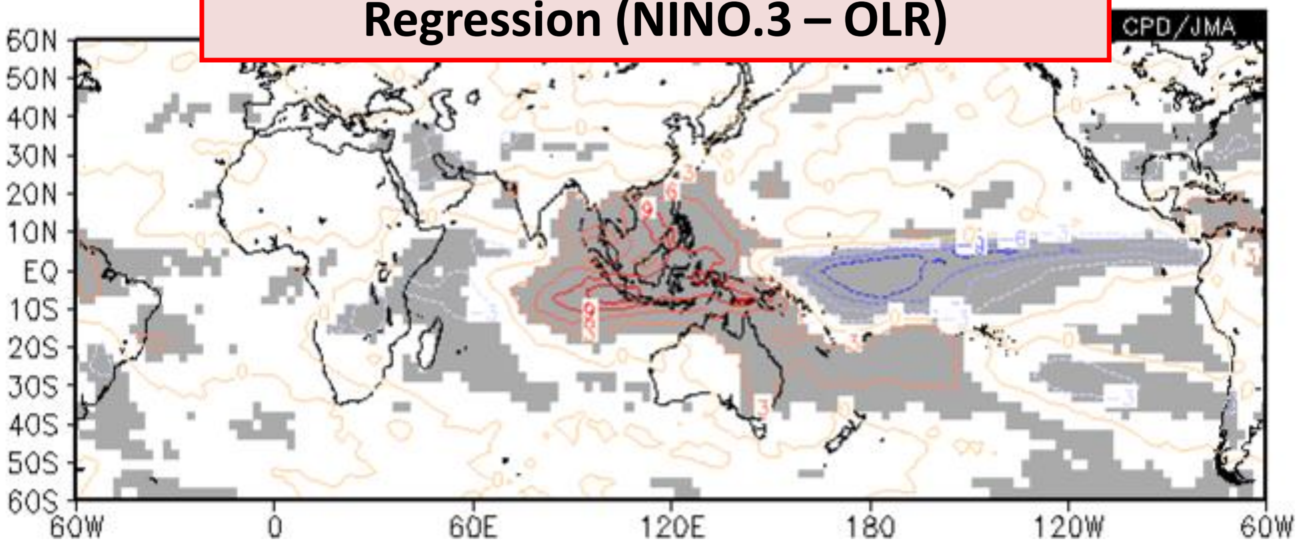
$$y = a x + b$$

Regression coefficient

Intercept

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

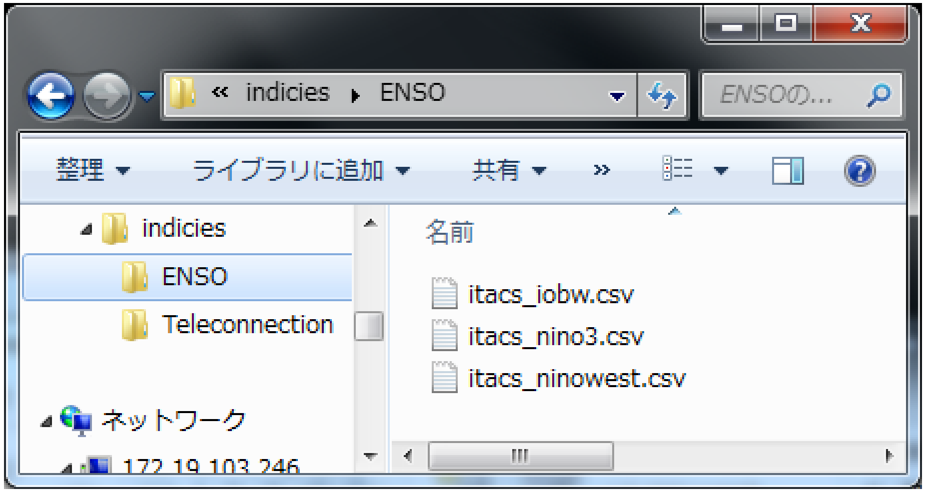
Regression (NINO.3 – OLR)

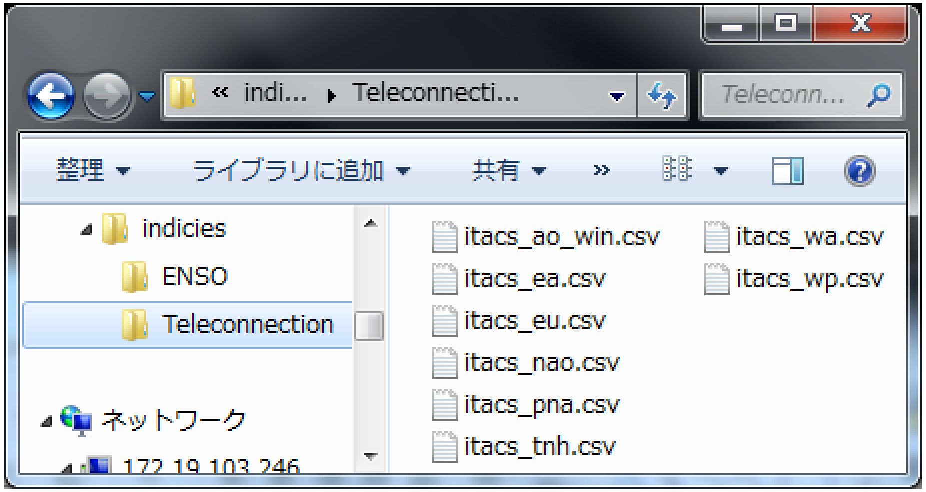


<u>Regression coefficients of OLR (W/m^2) onto NINO.3 SST indices (Sep. – Nov.)</u>
The base period for the analysis is 1979 – 2011. This is drawn by the ITACS.

Regression analysis using iTacs

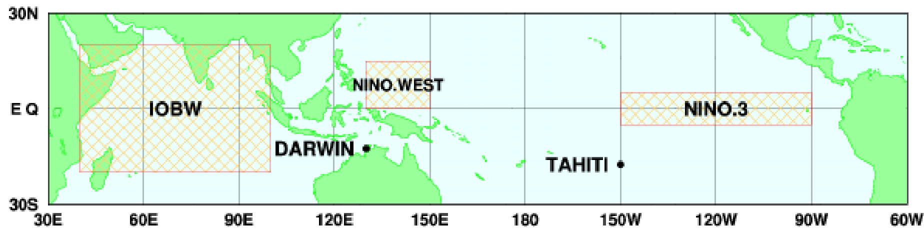
- We can do regression analysis for any indices using “USER INPUT” function on iTacs.
- For this exercise, the text files of major indices (NINO3, IOBW, AO, EU, …) are prepared.
- Please copy the text files from shared folder to your PC.





Primary mode's indices for this exercise

- Indices
  - ENSO monitoring Indices



    - Sea surface temperatures for ***NINO.3***, ***NINO.WEST*** and ***IOBW***
    - The five-month running mean SST deviation from the sliding 30-year base period average.
    - You can download these Indices from TCC website.
      http://ds.data.jma.go.jp/tcc/tcc/products/elnino/index/
  - Teleconnection indices
    - ***AO, EA, EU, NAO, PNA, TNH, WA, WP***
    - These indices are used in the operational analysis at JMA.
    - *Now we are preparing to provide these indices on TCC website.*

Atmospheric circulation data for this exercise

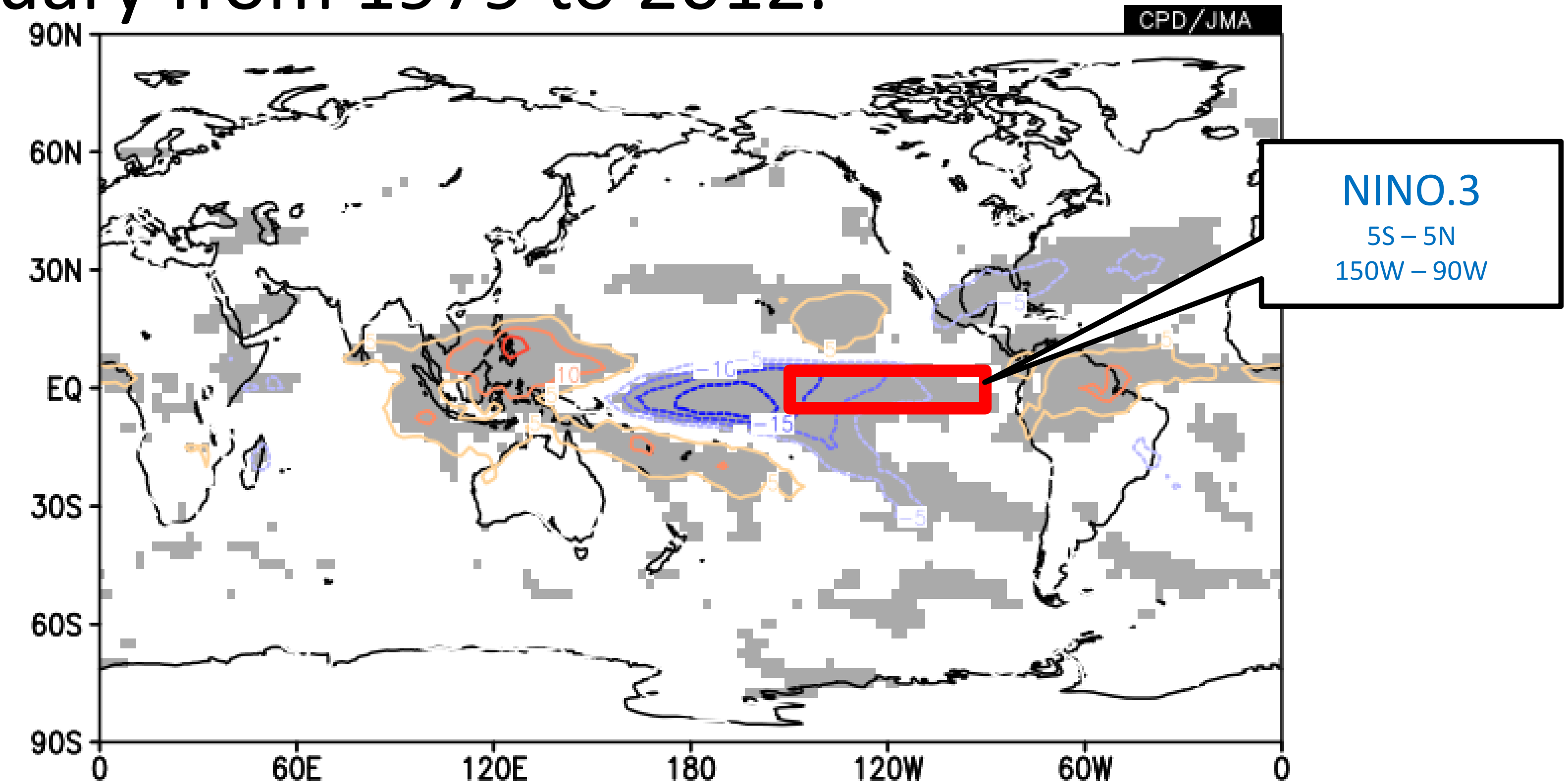
Dataset for this exercise are available without any preparation on the iTacs.

- Dataset
  - COBE-SST analysis dataset for sea surface temperature
  - JRA-55 reanalysis dataset for Atmospheric Circulation Data
  - satellite observation data for Outgoing Longwave Radiation (OLR)
- Period for this exercise
  - 1958 - 2012 for COBE-SST and JRA-55 dataset
  - 1979 - 2012 for OLR dataset

OLR data in 1978 is partially missing.

[sample] Regression analysis using iTacs

- Regression coefficient of ***outgoing longwave radiation (OLR)*** onto ***NINO.3 SST index*** for January from 1979 to 2012.

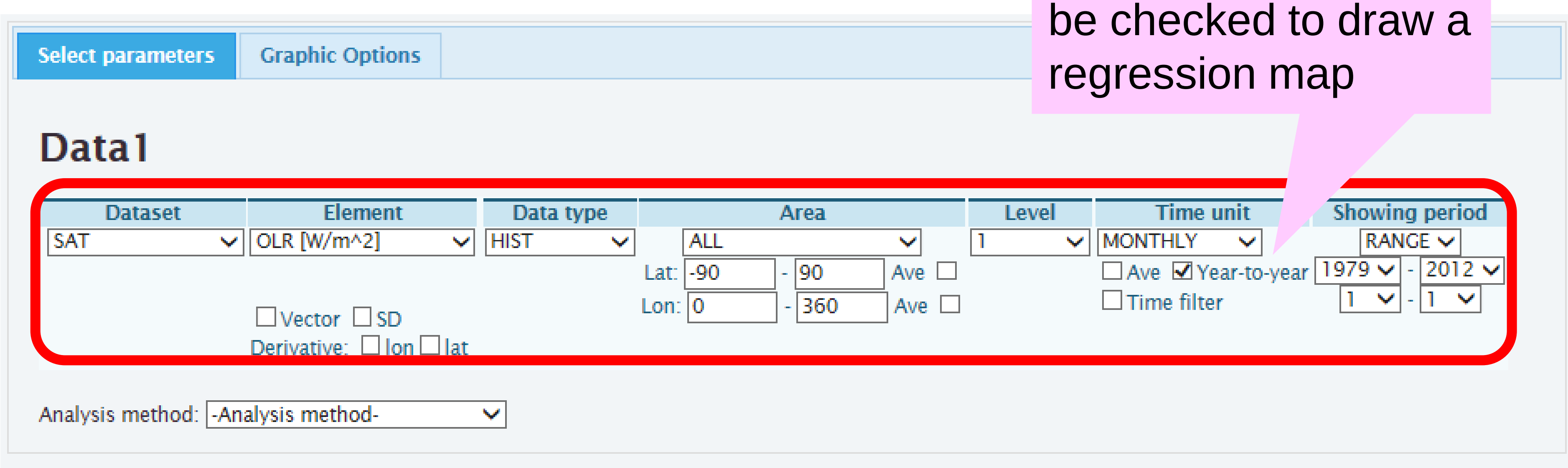


Contour: regression coefficients
Gray shade: the area where regression coefficient is significant at 95% confidence level by t-testing

Regression analysis (1)

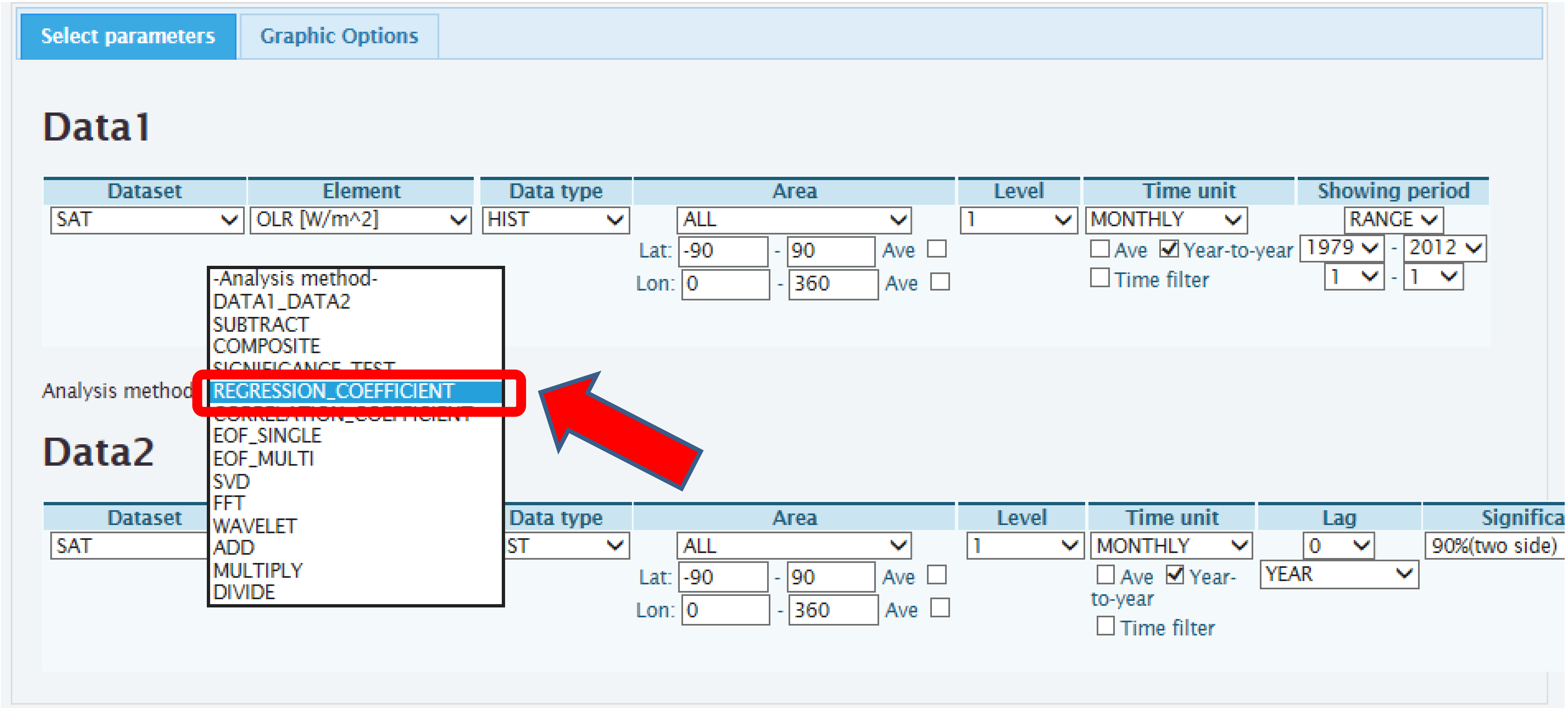
- "Data1" is a response variable (OLR in this case).
  - Dataset: SAT
  - Element: OLR
  - Data type: HIST
  - Area: ALL (Lat:-90 – 90, Lon:0 - 360)
  - Level: 1
  - Time unit: MONTHLY checking "Year-to-year"
  - Showing period: 1979 – 2012; 1 – 1

"Year-to-year" must be checked to draw a regression map



Regression analysis (2)

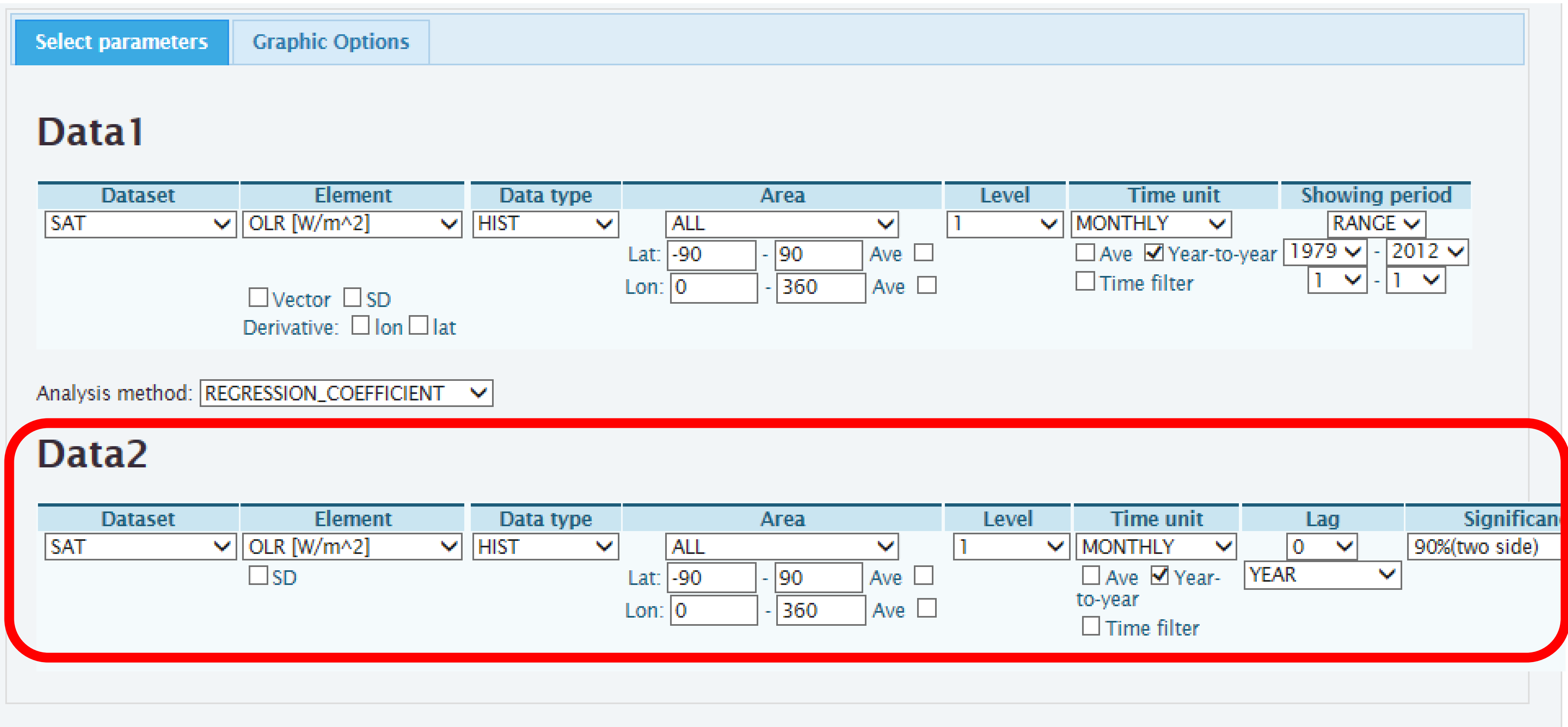
- Select “REGRESSION_COEFFICIENT” in the Analysis method box.



Regression analysis (3)

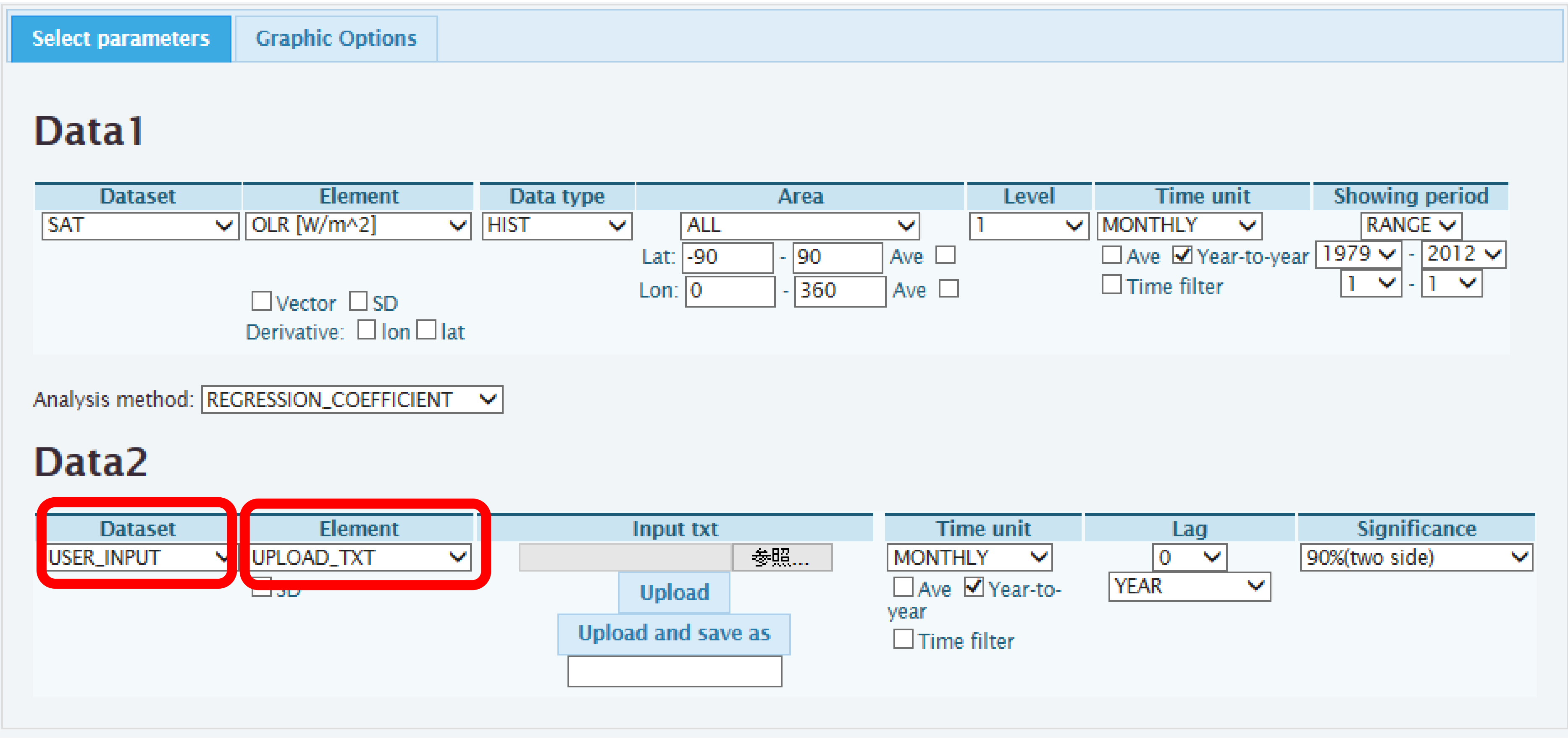
Setting an explanatory variable

- You can see “Data2” open.
- “Data2” is an explanatory variable (NINO.3 SST index in this case).



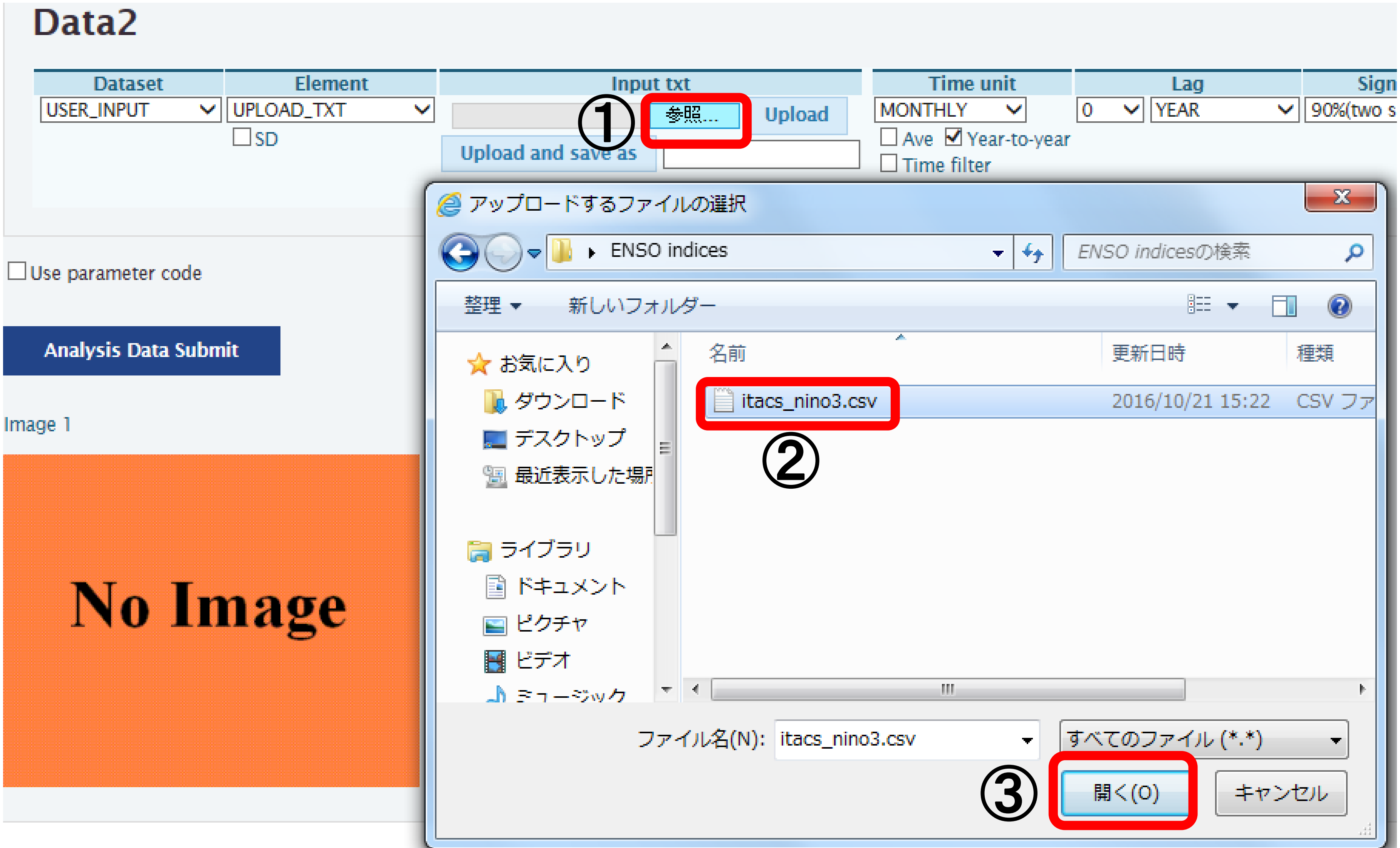
Regression analysis (4)

- Select “USER_INPUT” in the Dataset box and “UPLOAD_TXT” in the element box of Data2.



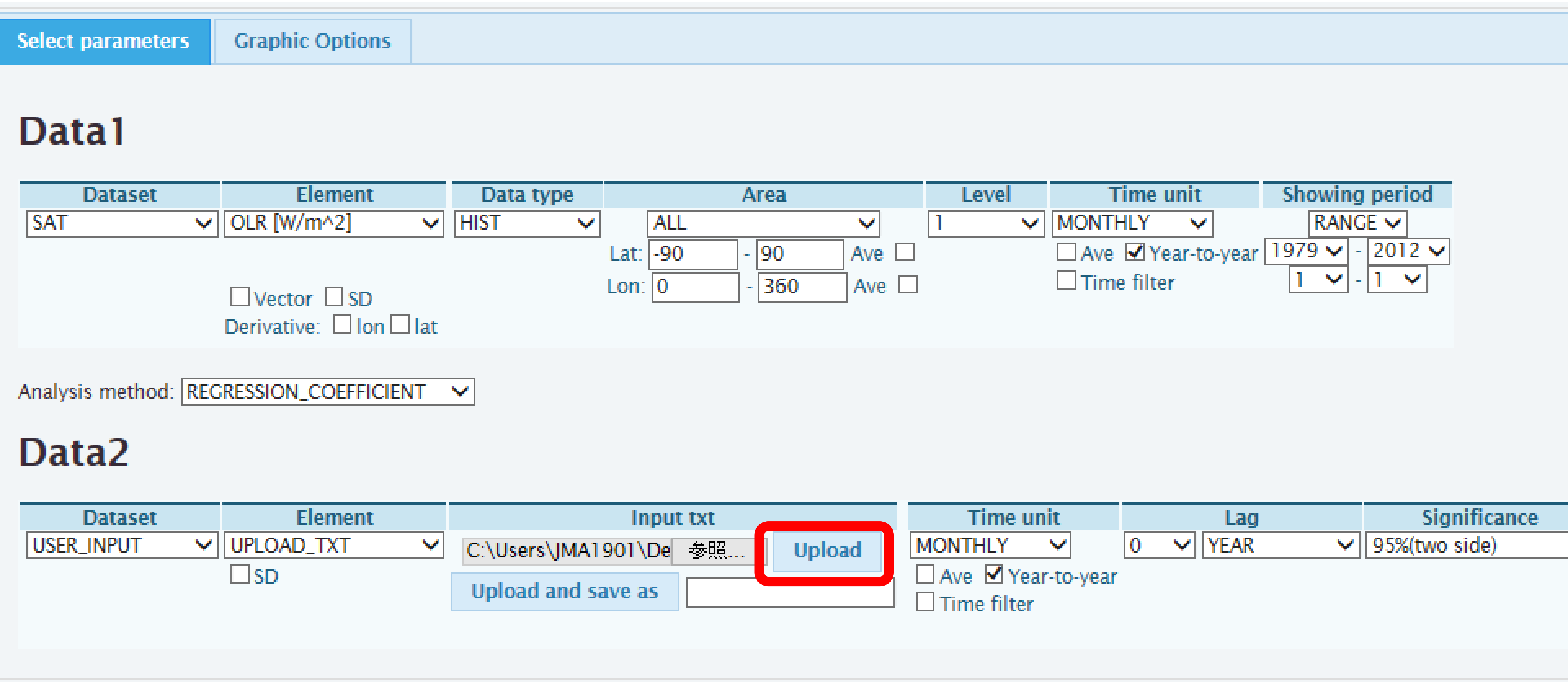
Regression analysis (5)

- Click the "reference" button, select the NINO.3 index file and click the "Open" button in the Input txt box.



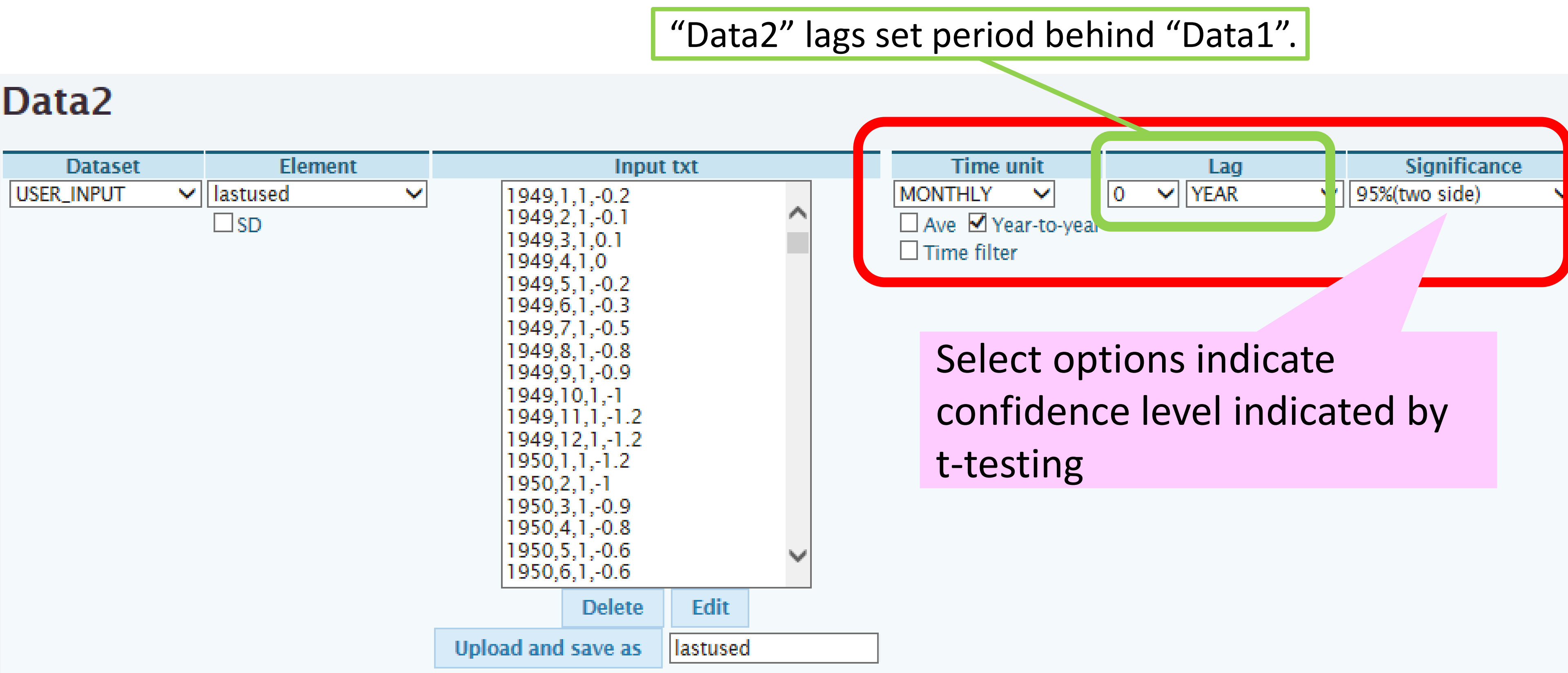
Regression analysis (6)

- Click the “Upload” button in the Input txt box.



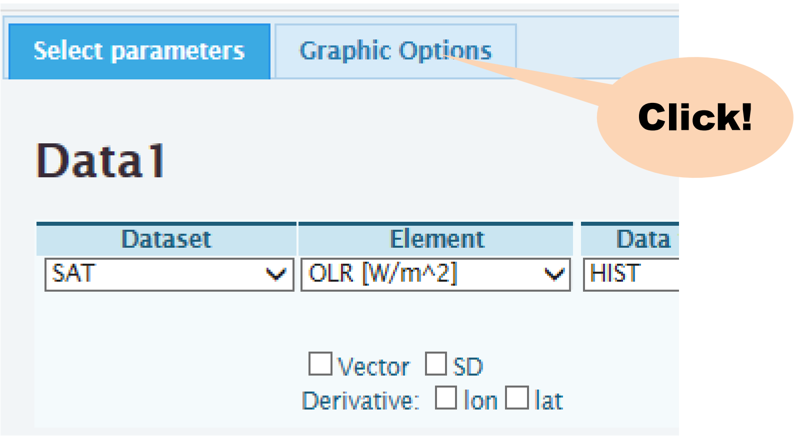
Regression analysis (7)

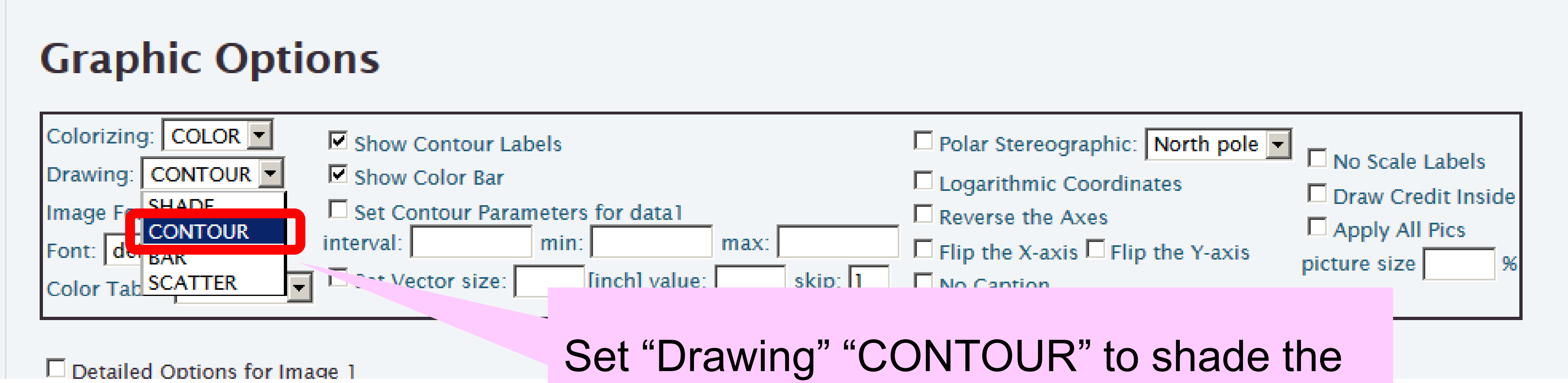
- Set each of the remaining items in data2 as shown below.
  - ➢Time unit: MONTHLY checking “Year-to-year”
  - ➢Lag: 0; YEAR *simultaneous regression
  - ➢Significance: 95% (two side)



Regression analysis (8)

- Click “Graphic Options” and select “CONTOUR” in the Drawing box of Graphic Option.

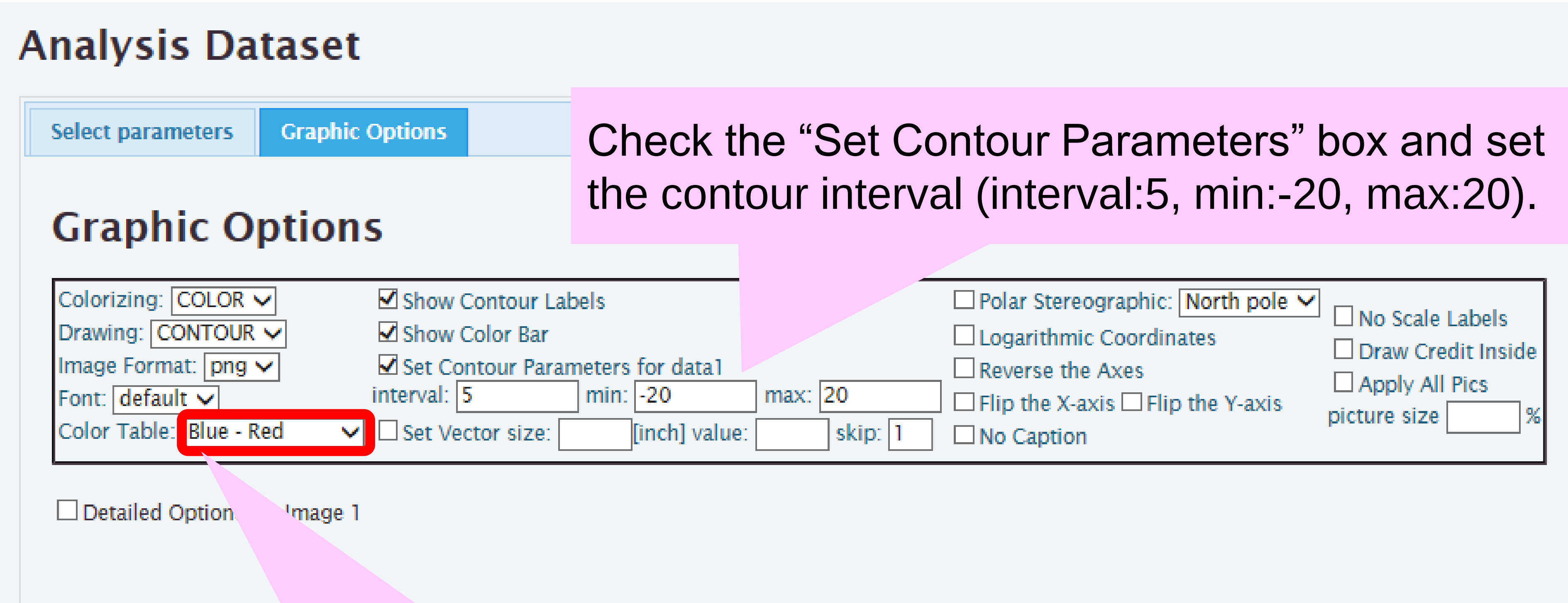




Set “Drawing” “CONTOUR” to shade the grids exceeding confidence level in gray.

Regression analysis (9)

- Select “Blue - Red” in the Color Table box to display negative and positive values with blue and red contours, respectively.

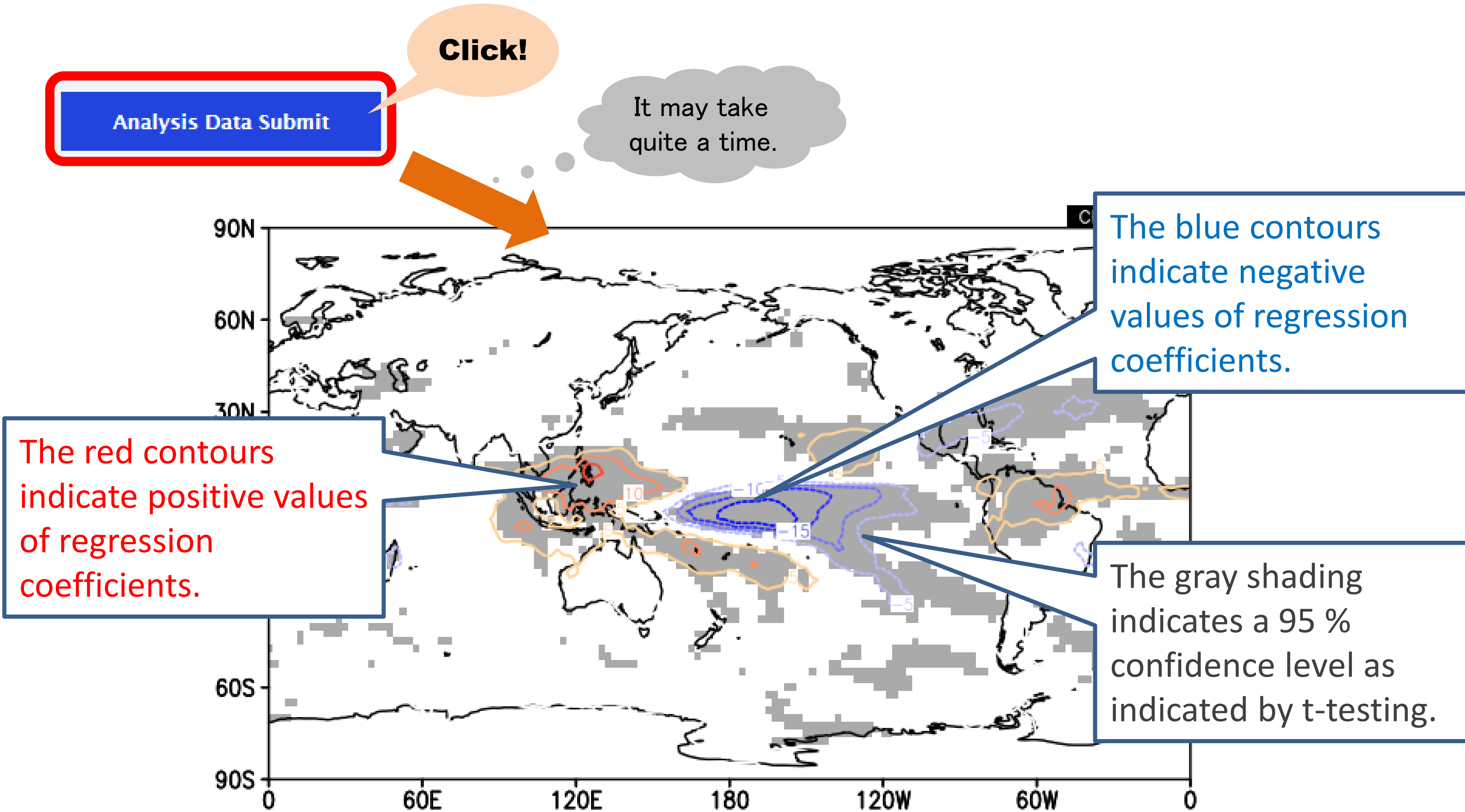


Check the “Set Contour Parameters” box and set the contour interval (interval:5, min:-20, max:20).

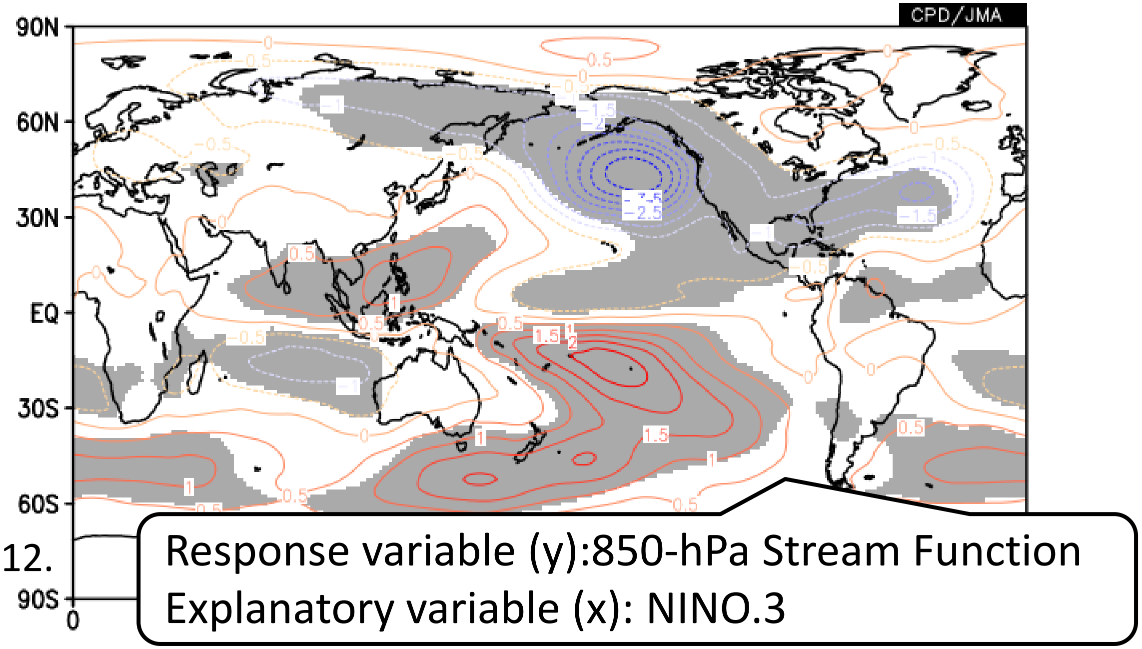
“Blue – Red” >> Blue: Lower, Red: Higher

Regression analysis (10)

- You can draw the following chart.

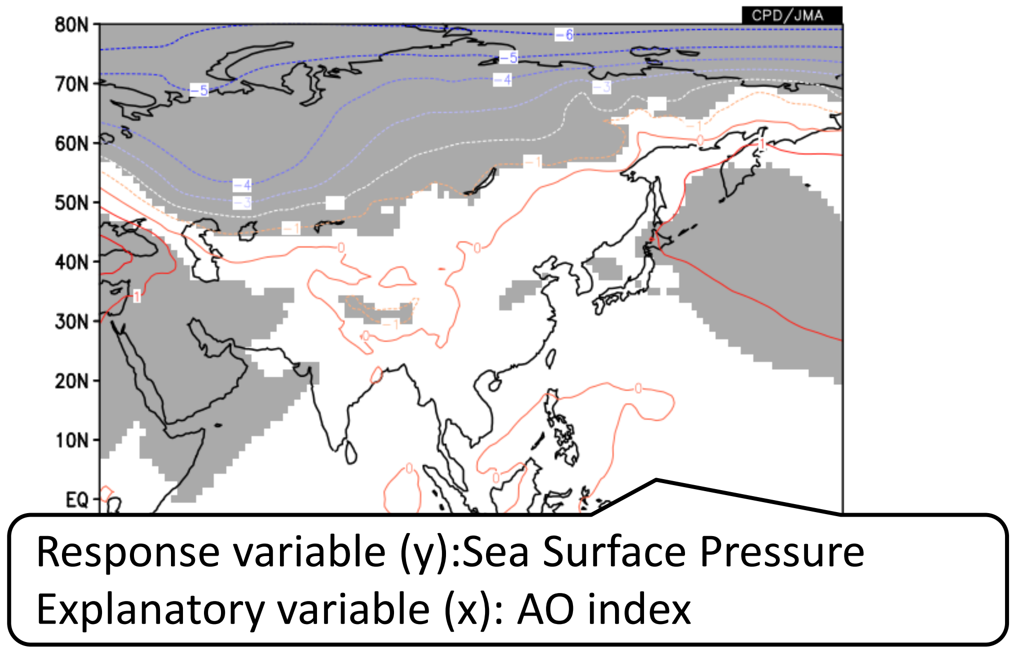


[sample] Various regression analysis



<u>Regression coefficients of 850-hPa Stream function (x10^6 m^2/s) onto **NINO.3** SST indices (**Jan.**)</u>

The base period for the analysis is 1958 – 2012.



<u>Regression coefficients of Sea Surface Pressure (hPa) onto **AO** index (**Jan.**)</u>

The base period for the analysis is 1958 – 2012.

Outline

1. Introduction
2. Relationship between ENSO index and atmospheric circulation (referring to TCCHP)
3. Procedure of this exercise
4. Introduction of TCC products and tools
5. Exercise (using iTacs)

Introduction of TCC products and tools

- Interactive Tool for Analysis of the Climate System (iTacs)
  http://extreme.kishou.go.jp/tool/itacs-tcc2015/
- ENSO Impacts ***on Global Climate***
  "Impacts of Tropical SST Variability on the Global Climate"
  http://ds.data.jma.go.jp/tcc/tcc/products/climate/ENSO/index.htm
- ENSO Impacts ***on Atmospheric Circulation***
  "Composite analysis of atmospheric circulation"
  http://ds.data.jma.go.jp/tcc/tcc/products/clisys/enso_statistics/index.html

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Let's try!

Try the statistical analysis between *the selected mode* and *atmospheric circulation* using iTacs and make a PPT materials.
Please feel free to ask TCC staff your question.