

Variations of the Arctic Oscillation and its impact on East Asian winter

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Purpose

- Overview of the variation of the Arctic Oscillation
- Investigation of the impact on the climate in East Asia

INDEX

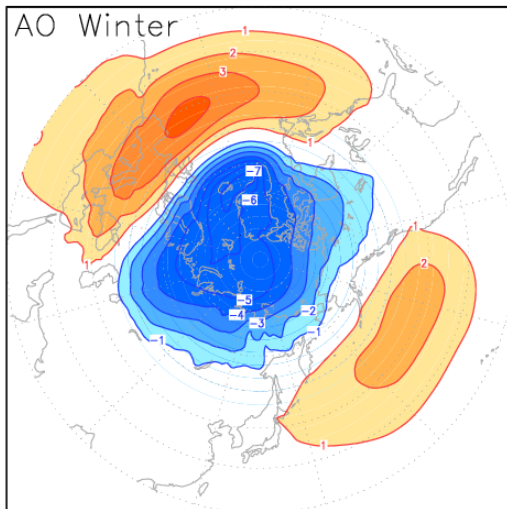
Arctic Oscillation (AO)

A large scale mode of climate variability

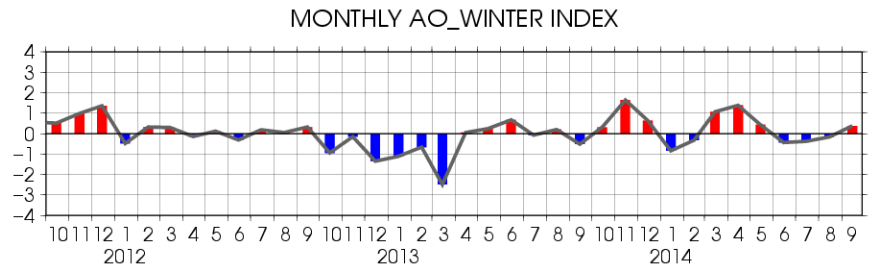
The phase of the SLP anomaly around the north pole different from the one around mid-latitude regions

AO index

The first mode of EOF analysis using the monthly Sea Level Pressure (SLP)



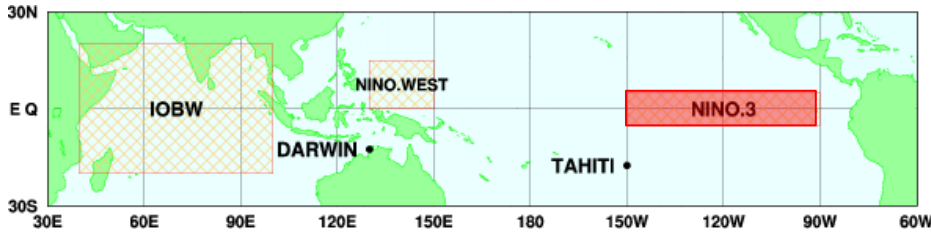
Projecting the AO leading pattern to the monthly anomaly SLP over 20N-90N latitude.



Period: December to February in 1958-2012

INDEX

ENSO index

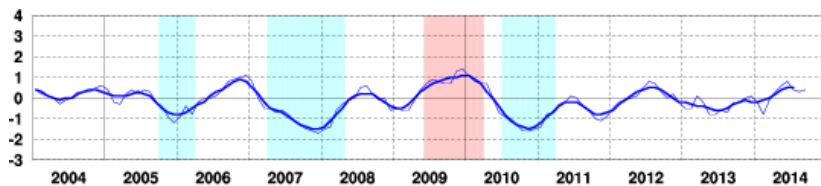


ENSO index:
Five-month moving averaged “NINO.3” SST anomaly

El Niño:
More than +0.5 for six consecutive months

La Niña:
Less than -0.5 for six consecutive months

Time series of ENSO index (Last 10 years)

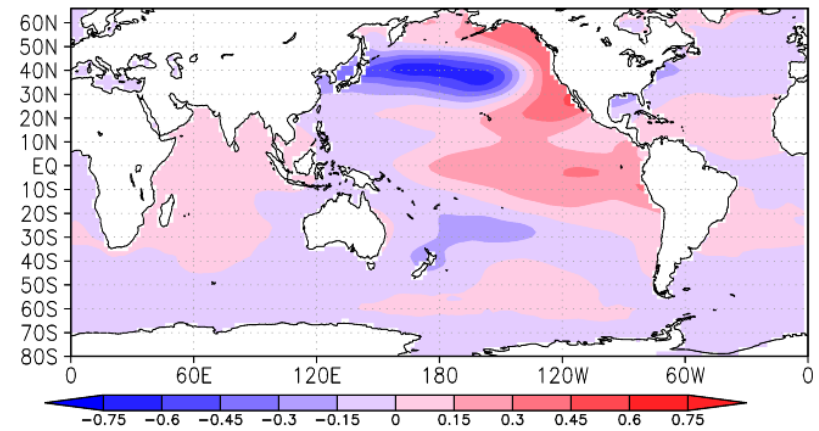


PDO index

The first mode of EOF analysis using the Sea Surface Temperature in the North Pacific (north of 20°N)

The distribution of winter mean SST anomalies linearly regressed on the PDO index.

Typical SST anomaly patterns (PDO+)



All indices have been calculated routinely.

Data

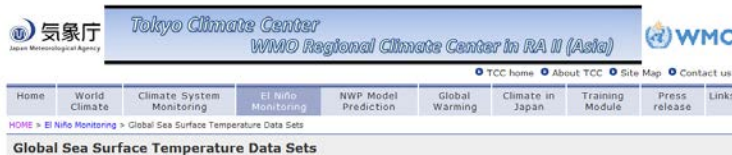
- Reanalysis Data: JRA-55 (Kobayashi et al., 2015)



- Sea Level Pressure
 - ➔ AO Index
- Surface Temperature
- Total Precipitation Rate
 - ➔ Climate in East Asia

http://jra.kishou.go.jp/JRA-55/index_en.html

- Sea Surface Data: COBE-SST (Ishii et al., 2005)



- Sea Surface Temperature
 - ➔ ENSO, PDO

We provide 1x1 degree resolution GPV data from January 1891 up to the latest month. Information about the SST analysis and explanation for SST-GPV file are available in following pages respectively.

- [Daily Sea Surface Analysis for Climate Monitoring and Predictions \(COBE-SST\)](#)
- [Explanation for SST-GPV file](#)

<http://ds.data.jma.go.jp/tcc/tcc/products/elniño/cobesst/cobe-sst.html>

About the Index Data in this Report:

- Three months (DJF) averaged data
- Period: Winter from 1958/1959 – 2013/2014

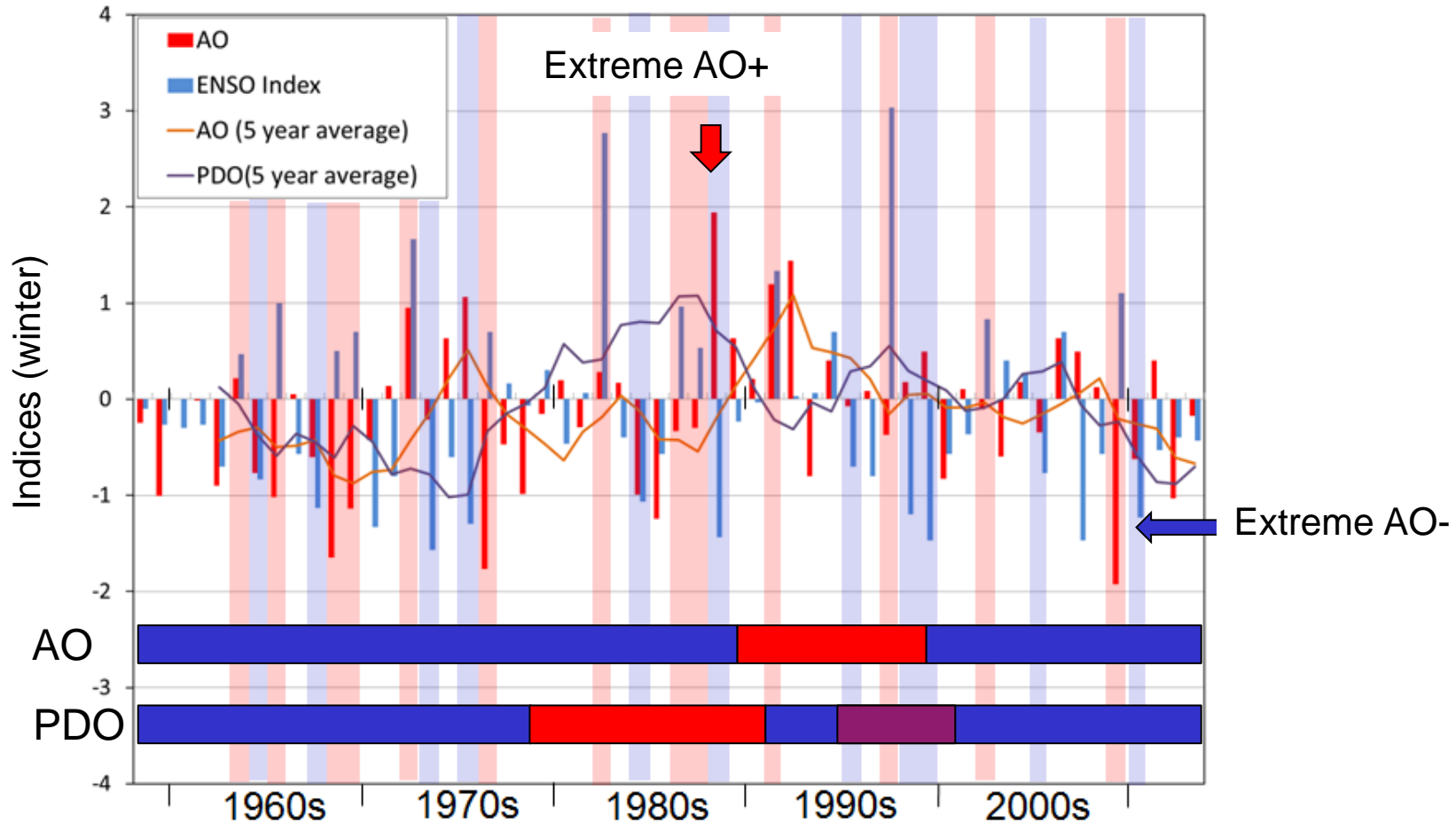
Note: “Precipitation” refers to “Total Precipitation Rate” after this slide

Historical Variability and Relationship

- Long-term trend for AO, ENSO and PDO Indices
- Classification of AO, ENSO and PDO (+ or -)
- Composite Analysis of AO under El Niño/La Niña years and PDO+/PDO- years



Historical Variability in AO/ENSO/PDO Indices



The AO- frequently appeared after late 1990s.

Correlation between AO and
ENSO: -0.1, PDO:-0.2
(No significant)

Classification of years (Winter)

AO

Positive (More than +0.1 (+0.5 in red))	Negative (Less than -0.1 (-0.5 in blue))
1972, 1974, 1975, 1988, 1989, 1991, 1992, 2006 1963, 1971, 1980, 1982, 1983, 1990, 1994, 1998, 1999, 2001, 2004, 2007, 2008, 2011	1959, 1962, 1964, 1965, 1967, 1968, 1969, 1976, 1978, 1984, 1985, 1993, 2000, 2003, 2009, 2010, 2012 1958, 1970, 1973, 1977, 1979, 1981, 1986, 1987, 1997, 2002, 2005, 2013

ENSO

El Niño (More than +0.5 for consecutive 6 months)	La Niña (Less than +0.5 for consecutive 6 months)
1965, 1968, 1969, 1972, 1976, 1982, 1986, 1987, 1991, 1997, 2002, 2009	1967, 1973, 1975, 1984, 1988, 1995, 1998, 1999, 2005, 2007, 2010

PDO

Positive (More than +0.5)	Negative (Less than -0.5)
1958, 1959, 1960, 1969, 1976, 1977, 1980, 1982, 1983, 1984, 1985, 1986, 1987, 1993, 1995, 1997, 2002, 2005	1961, 1964, 1967, 1968, 1970, 1971, 1973, 1975, 1988, 1990, 1994, 1999, 2001, 2007, 2008, 2010, 2011, 2012

The year of 2000 refers to the boreal 2000/2001.

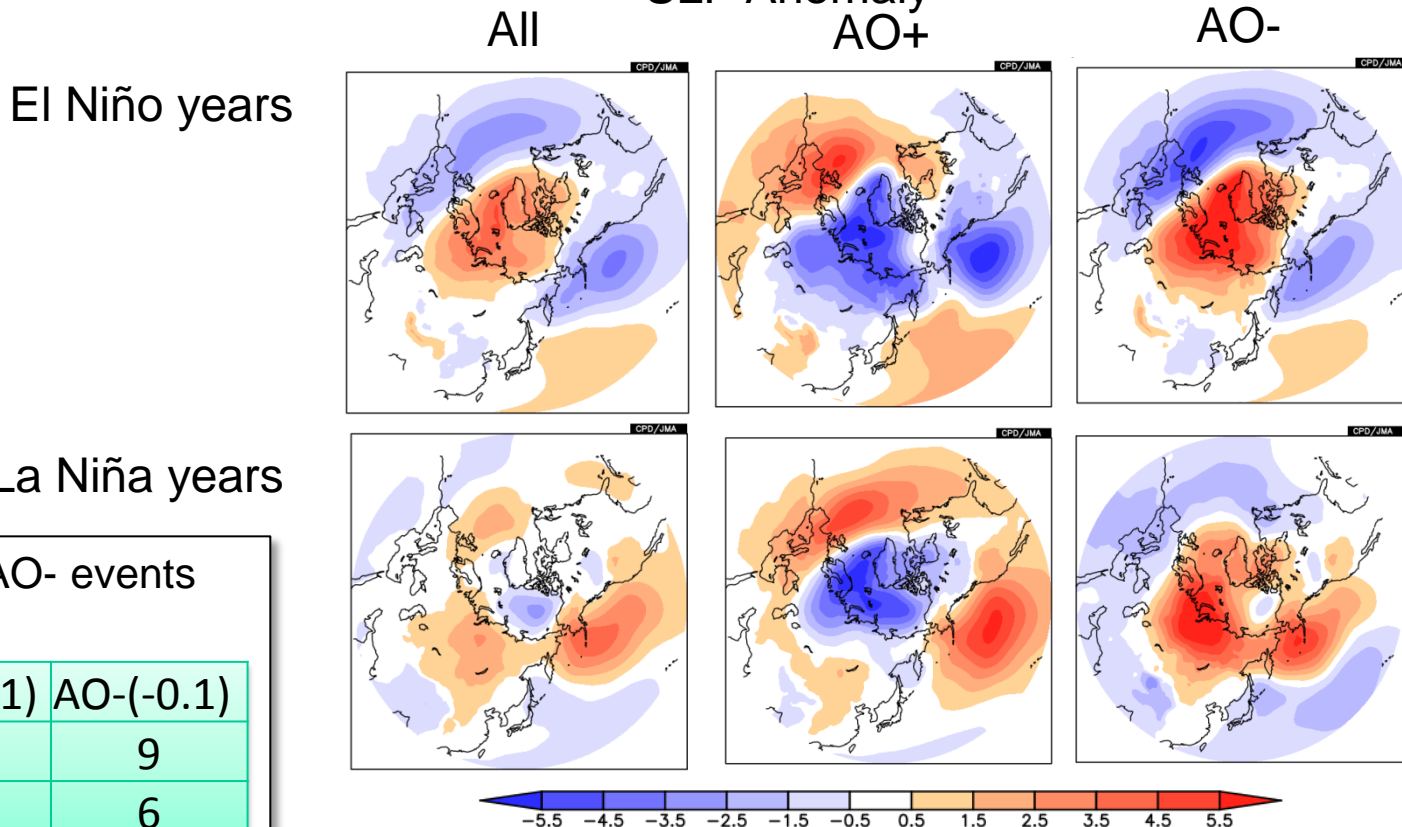


Relationship with ENSO

Composite Analysis

From the El Niño/La Niña years, the years of AO+/AO- is selected

SLP Anomaly



El Niño years

La Niña years

Classification of AO+/AO- events
in El Niño years

	AO+(+0.1)	AO-(-0.1)
El Niño years	3	9
La Niña years	5	6

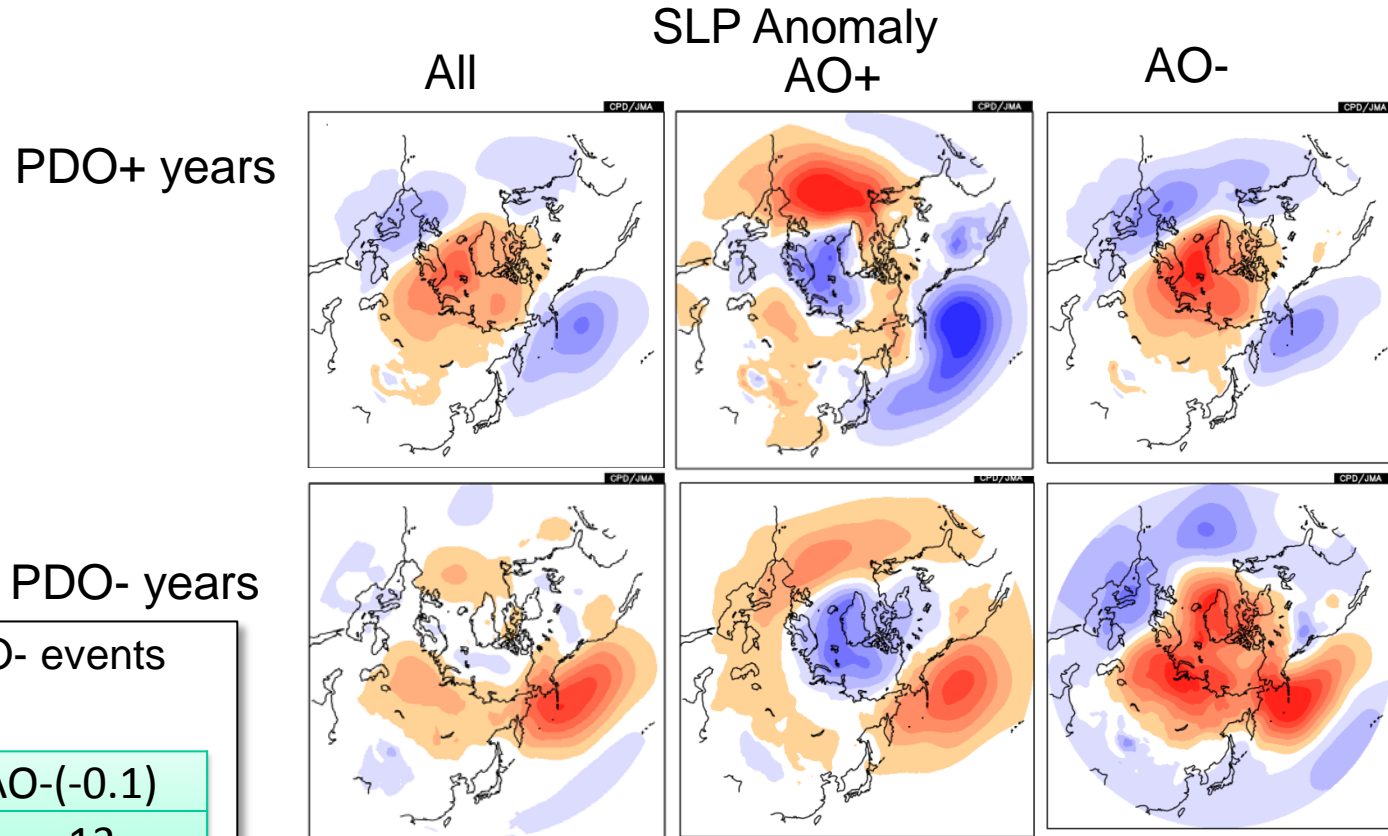
The value in “()” means threshold

- El Niño: AO- occurs more often than AO+
- Same anomaly around the Eastern Pacific under the different AO pattern and the same ENSO

Relationship with PDO

Composite Analysis

From the PDO+/PDO- years, the years of AO+/AO- is selected



Classification of AO+/AO- events
in PDO years

	AO+(+0.1)	AO-(-0.1)
PDO+ years	3	13
PDO- years	10	7

The value in “()” means threshold

- AO- occurs more often than AO+ under PDO+
- AO+ occurs under PDO- more often than PDO+

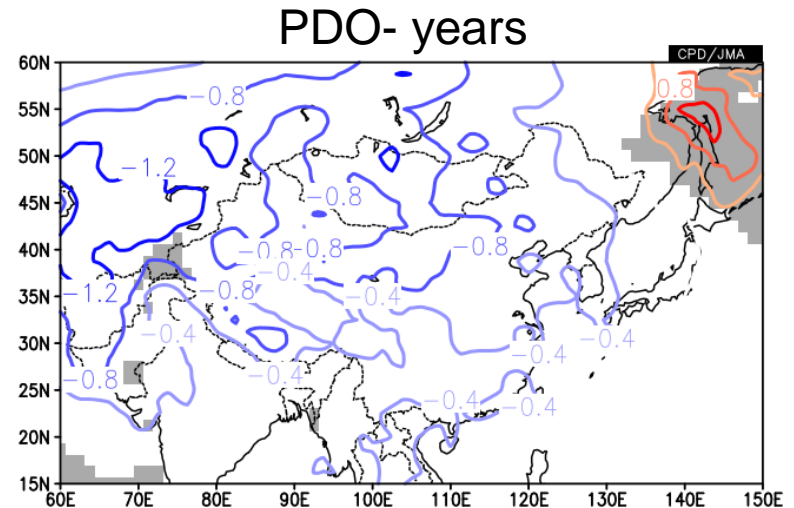
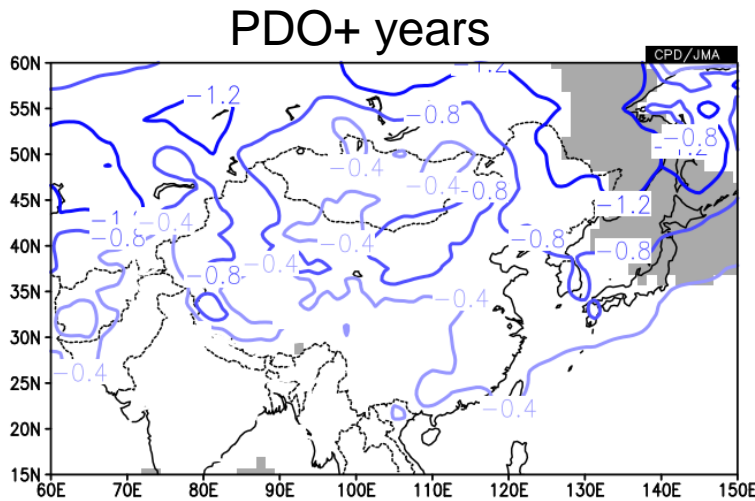
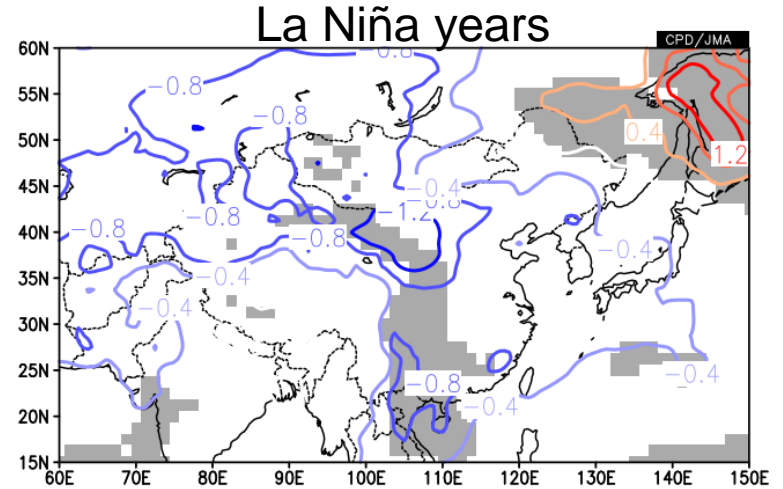
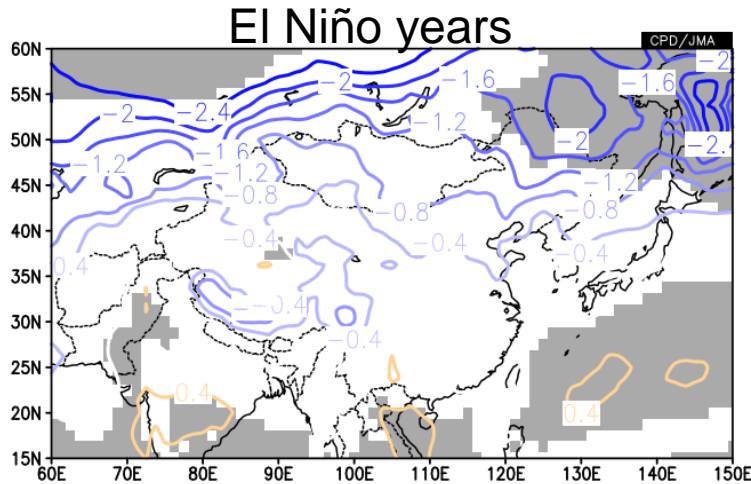
Relationship with Climate in East Asia

- Elements:
Surface temperature & Precipitation
- Composite Analysis:
 1. Case of El Niño/La Niña/PDO+/PDO-
(No concern about the phase of AO)
 2. Case of AO+/AO-
 3. Case of El Niño/La Niña/PDO+/PDO- under AO+/AO-
- Correlation between Indices and temperature/precipitation in several region

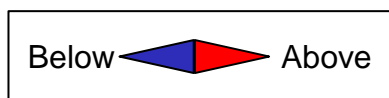
Note: The phase of AO is defined below after this slide:
AO+: more than 0.5 / AO-: less than -0.5

East Asia: Surface Temperature

ENSO composite and PDO Composite

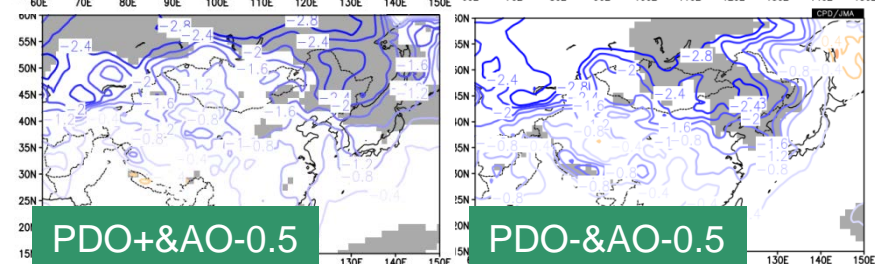
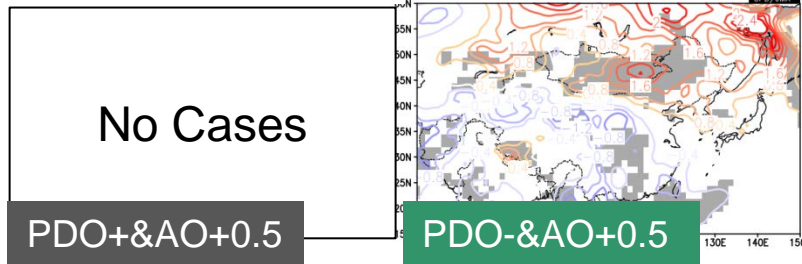
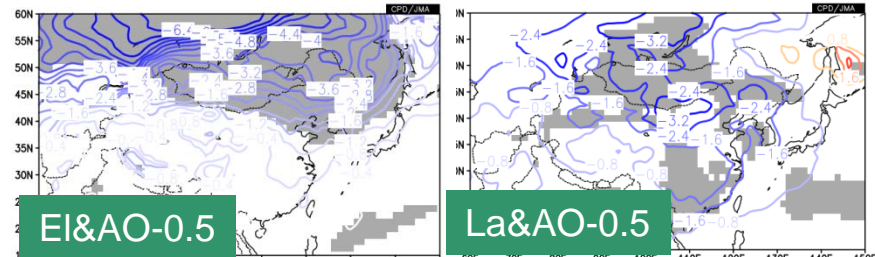
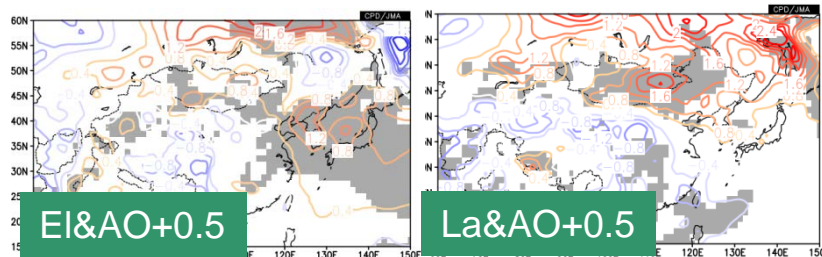
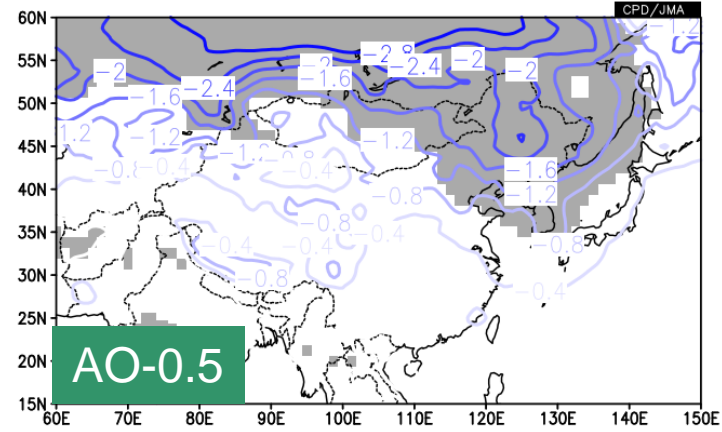
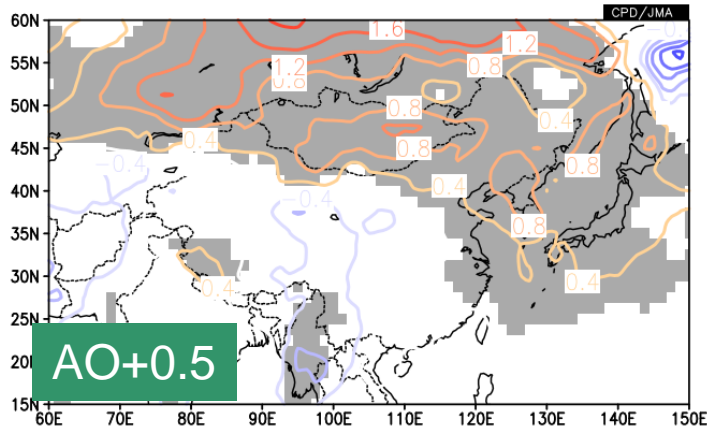


- Almost Below normal (Not Significant)

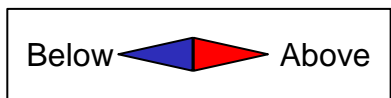


East Asia: Surface Temperature

AO Composite



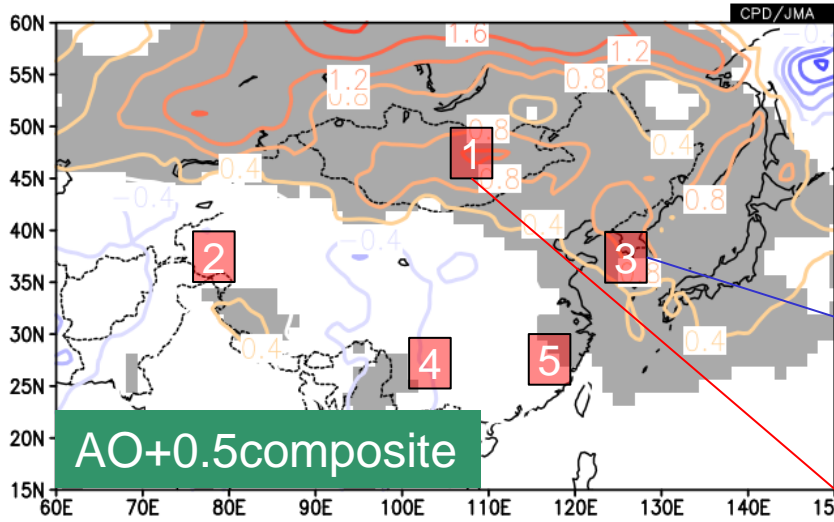
Gray: 90% significance



Around the northern East Asia

AO+: Above Normal, AO-: Below Normal

East Asia: Surface Temperature



Correlation (Period: All years)

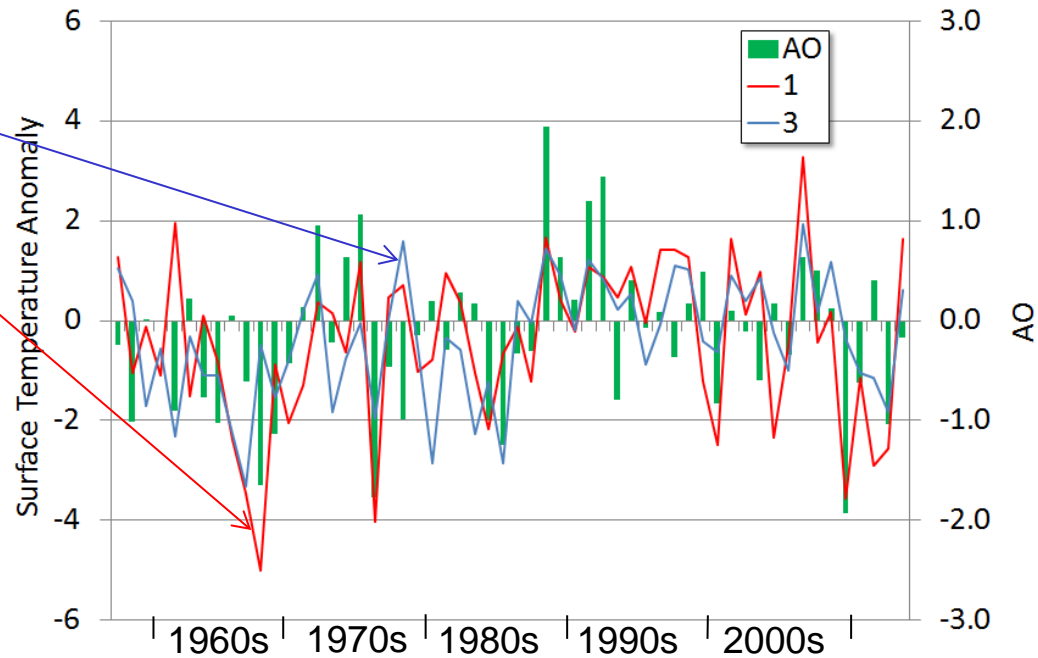
	AO	PDO	NINO3
1	0.50	0.08	0.08
2	0.03	0.10	0.21
3	0.41	-0.08	0.28
4	-0.18	0.08	0.08
5	0.04	-0.04	0.21

Black figures: No significant

Colored figures: 95% significance

- Region 1 and 3 has the significant correlation with AO index
- No significant correlation with NINO3 or PDO

Time Series for Winter

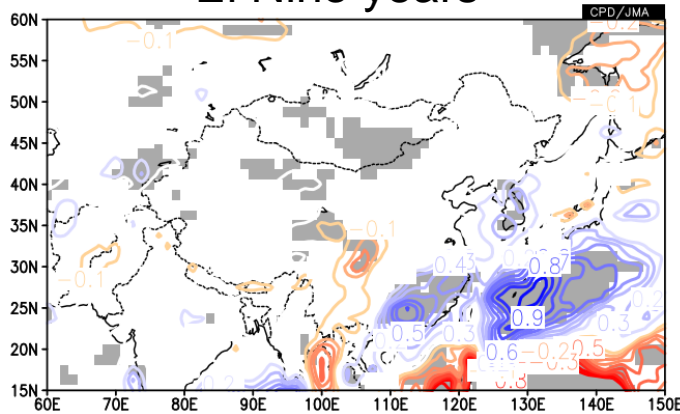


The color of the line graph corresponds to the color of figure in the left table

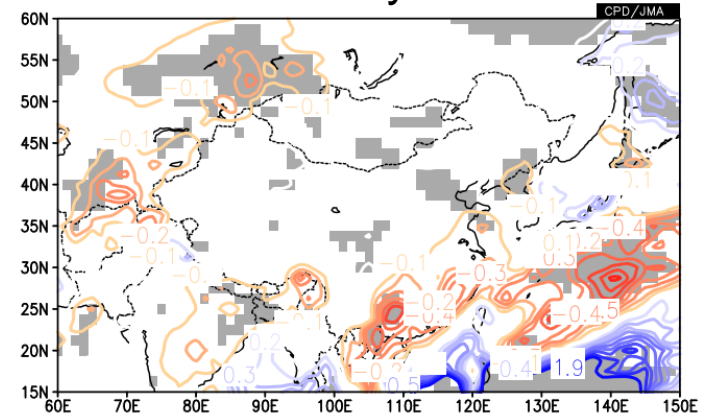
East Asia: Precipitation

ENSO composite and PDO Composite

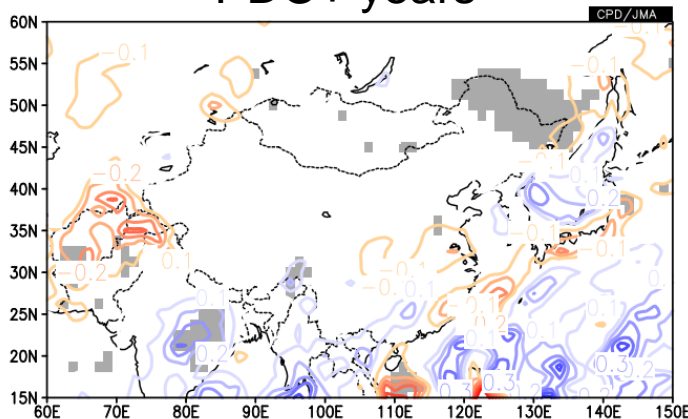
El Niño years



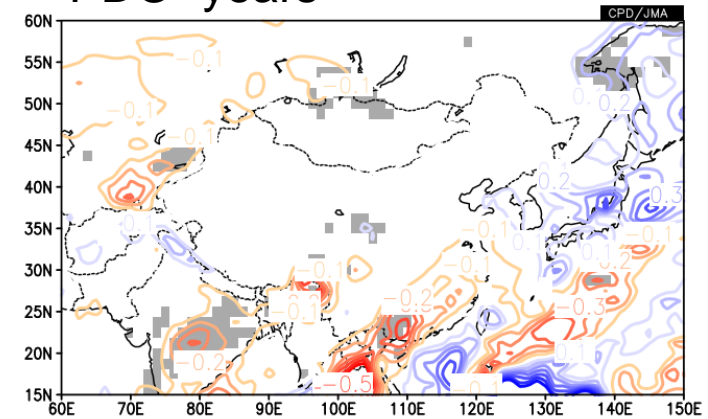
La Niña years



PDO+ years

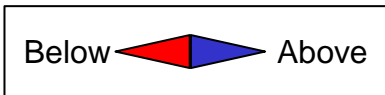


PDO- years



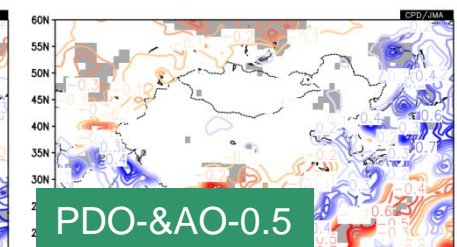
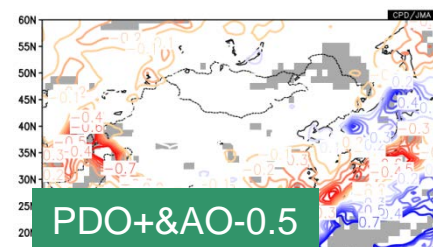
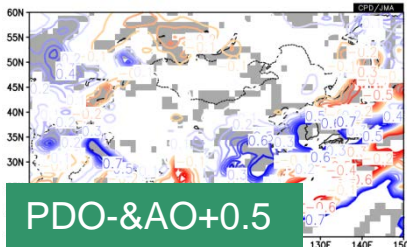
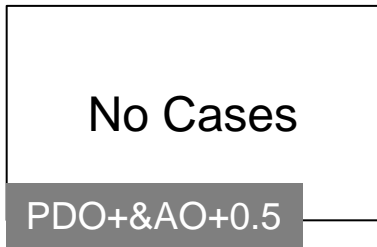
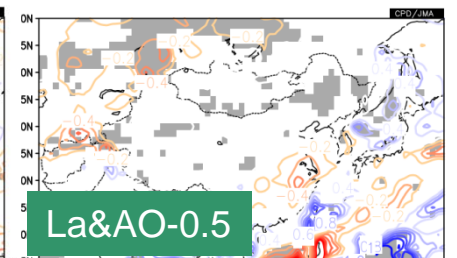
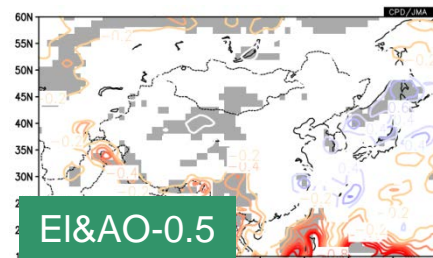
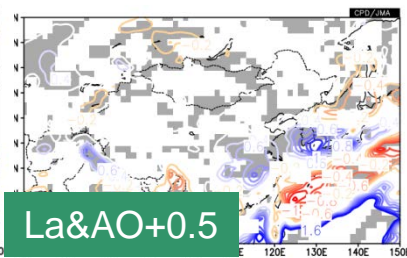
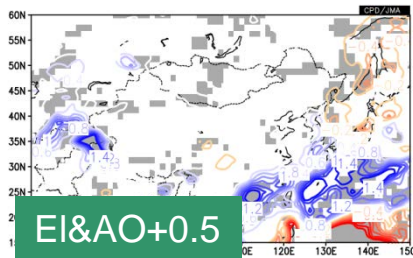
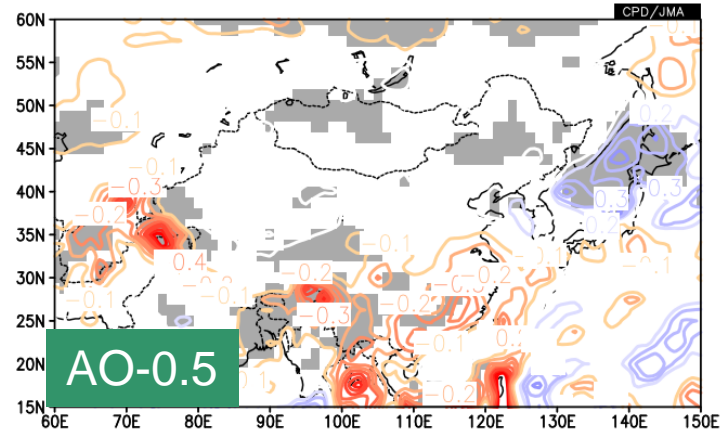
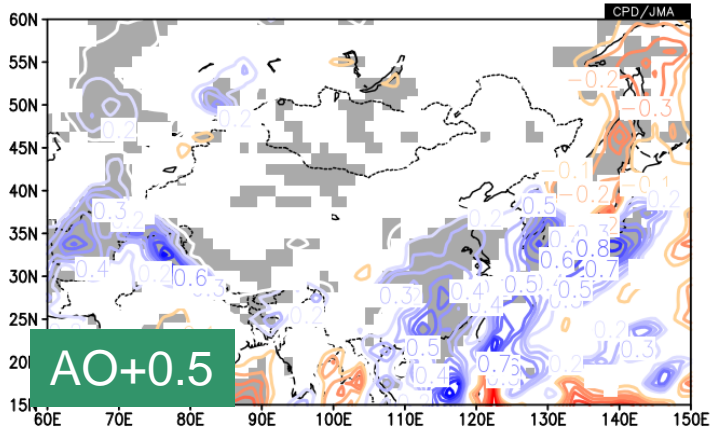
Around the southeastern East Asia

El Niño: Above Normal, La Niña : Below Normal

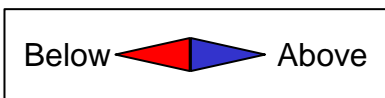


East Asia: Precipitation

AO Composite



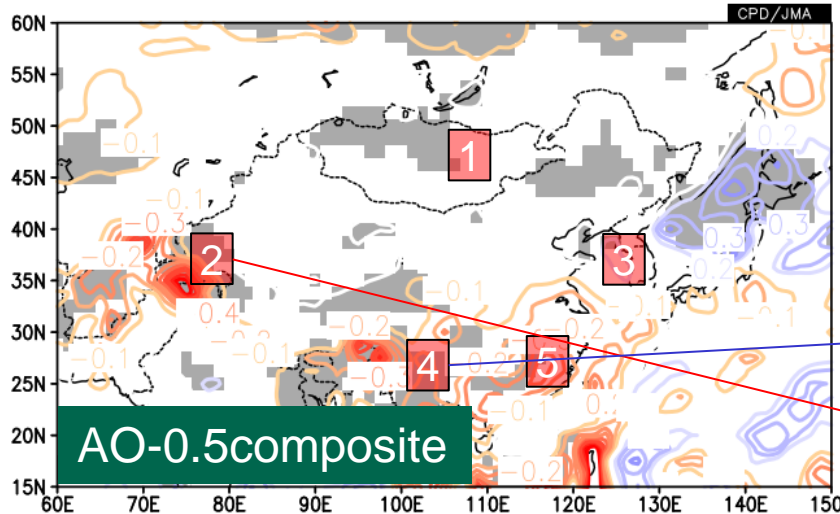
Gray: 90% significance



Around the south of East Asia

AO+: Above Normal, AO-: Below Normal

Precipitation



Correlation (Period: All years)

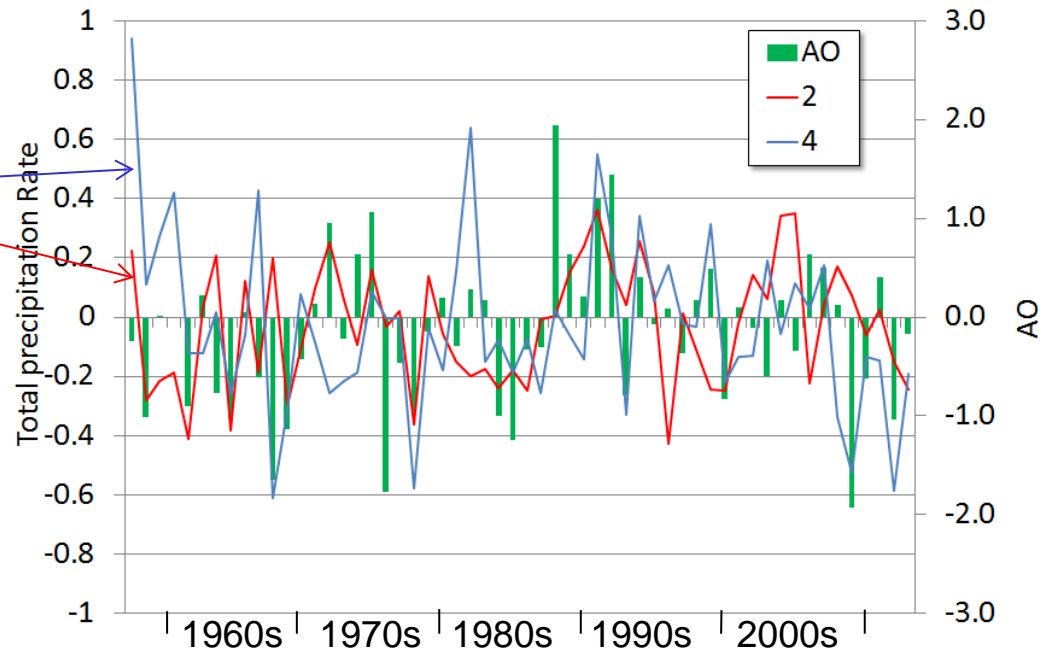
	AO	PDO	NINO3
1	-0.25	0.26	0.17
2	0.32	-0.13	0.12
3	0.03	-0.01	0.17
4	0.40	0.08	0.02
5	0.19	0.05	0.46

Black figures: No significant

Colored figures: 95% significance

- Region 2 and 4 has the significant correlation with AO index
- Region 5 has the significant correlation with NINO index

Time Series for Winter



The color of the line graph corresponds to the color of figure in the left table

Conclusion

- Negative AO more frequently appeared after late 1990s
- No statistically significant correlation with PDO or ENSO about the phase of AO
- However,
 - El Nino years: Occurrence of AO- is more than that of AO+
 - PDO+ years: Occurrence of AO- is more than that of AO+
 - AO+: Occurrence of AO+ is more often under PDO- years than PDO+ years

Conclusion: East Asia

Surface Temperature

- Larger correlation with AO rather than PDO or ENSO
- Around the northern East Asia

AO+ : Above normal, AO- : Below normal

Precipitation

- Significant Correlation with AO in the west and south of East Asia



Close Relationship

between AO index and the climate in East Asia

Thank you for your attention



Backup Slides

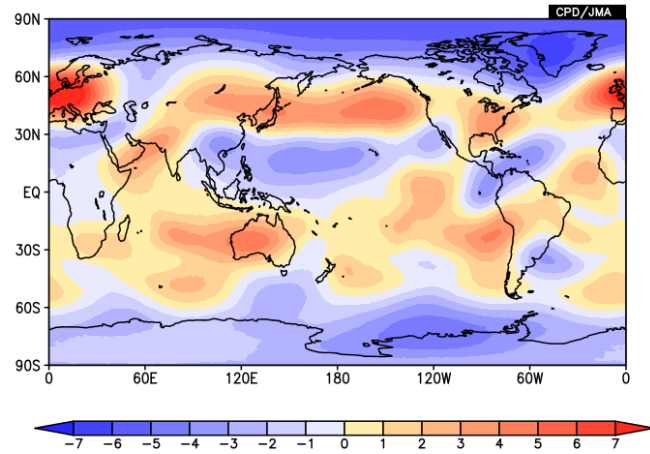
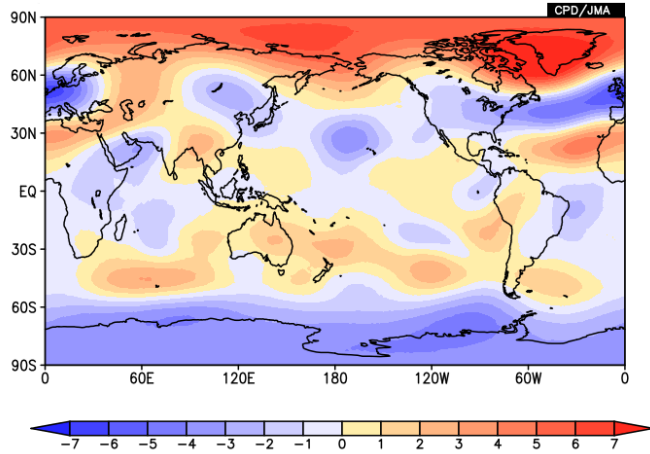


Composite

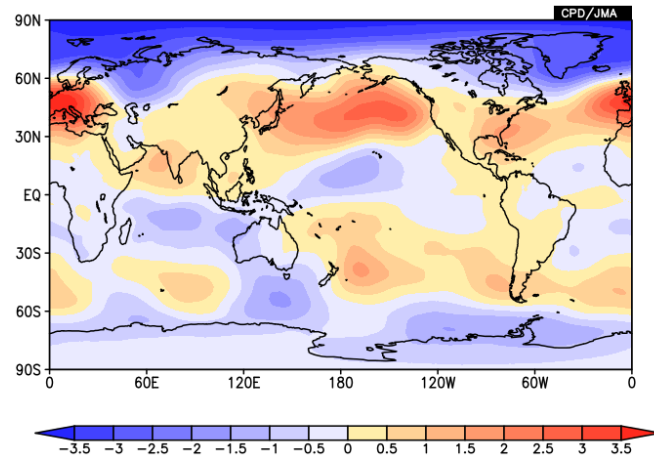
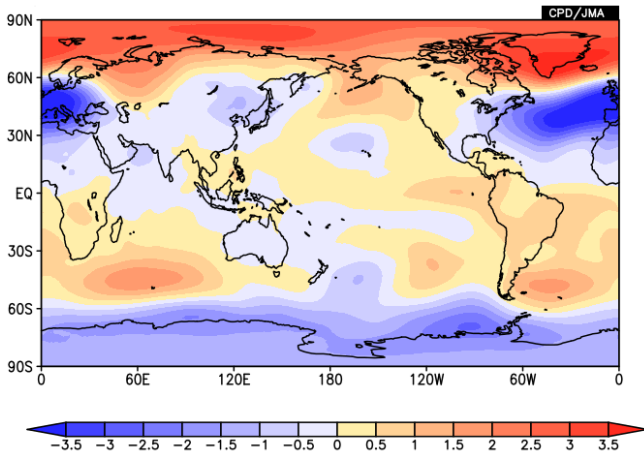
AO-

AO+

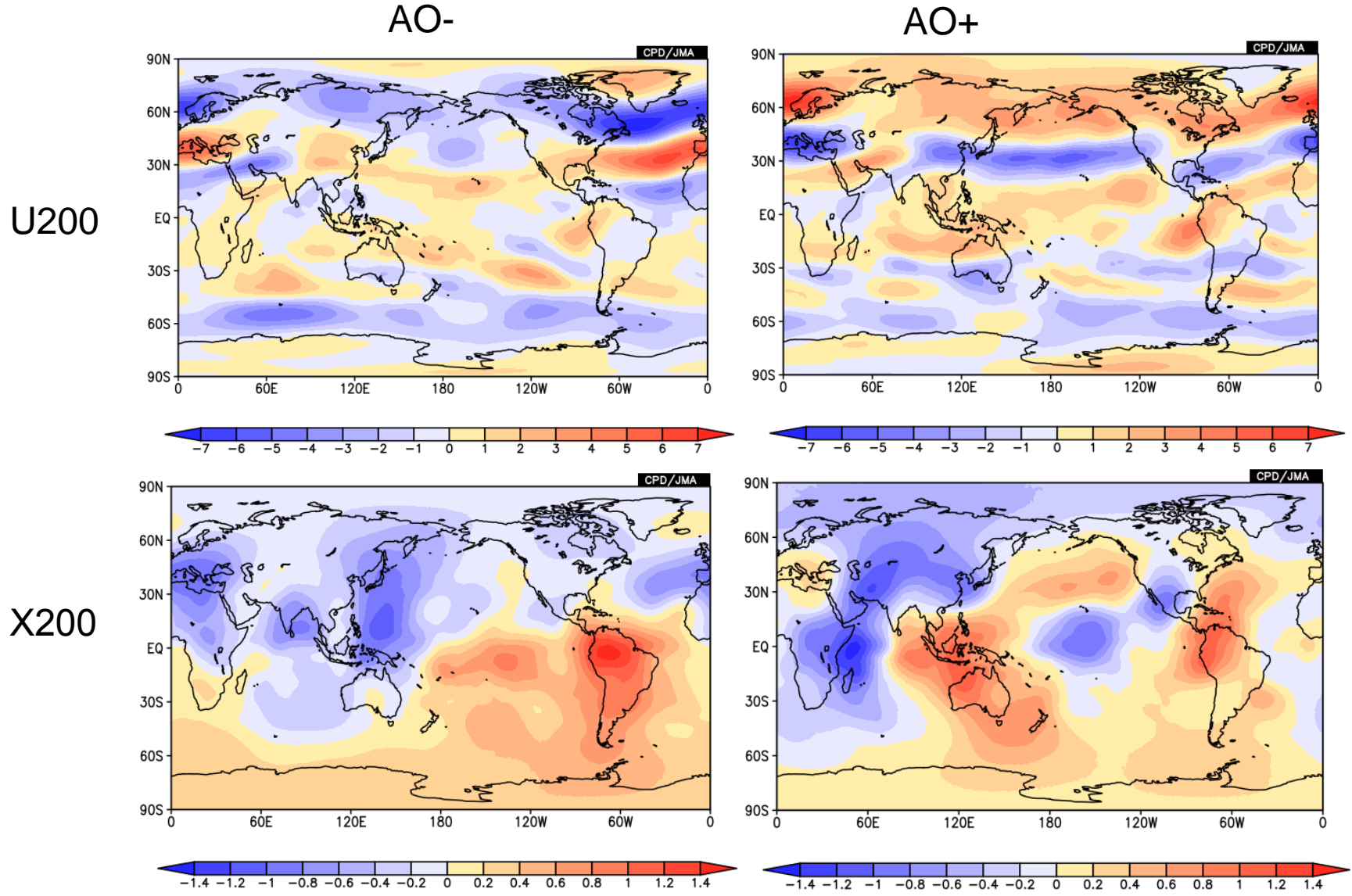
ψ_{200}



ψ_{850}



Composite



Composite Significance

Relationship with ENSO

SLP Anomaly

AO+

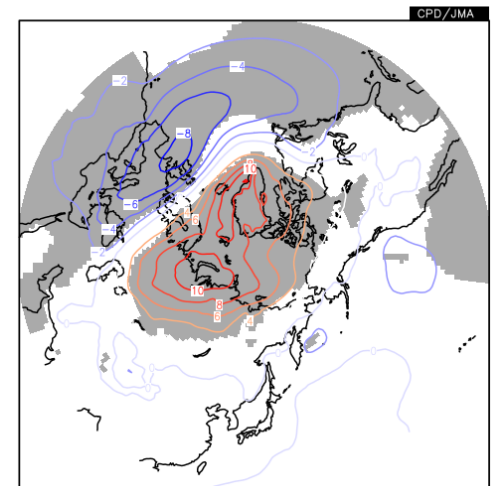
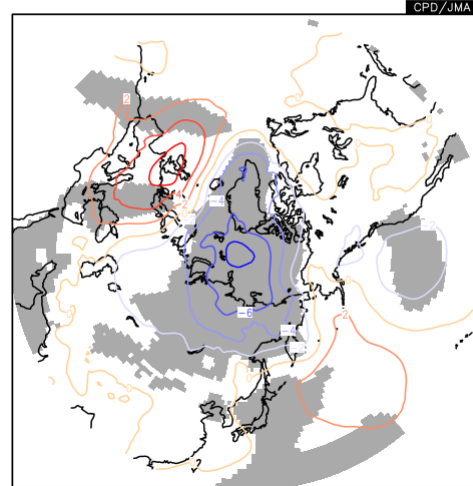
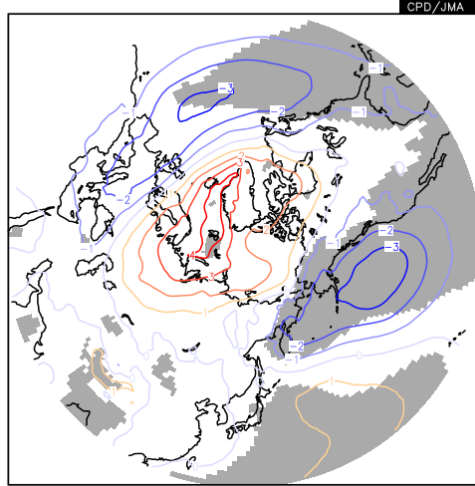
AO-

DATA1 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2015020100 ave = 12YR(3*1M0)
years = 1965, 1968, 1969, 1972, 1976, 1982, 1986, 1987, 1991, :
DATA2 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2014020100 ave = 44YR(3*1M0) analys

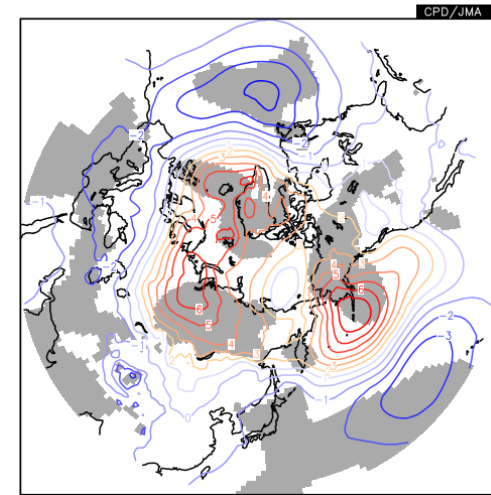
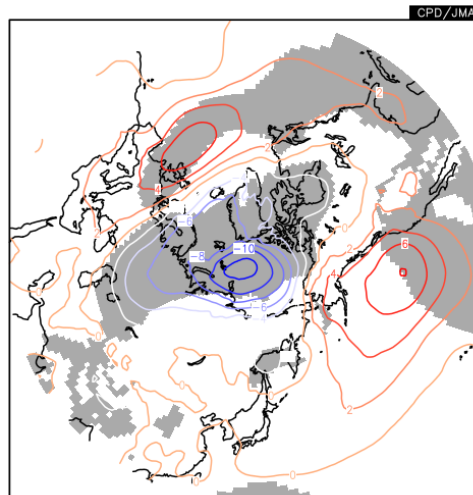
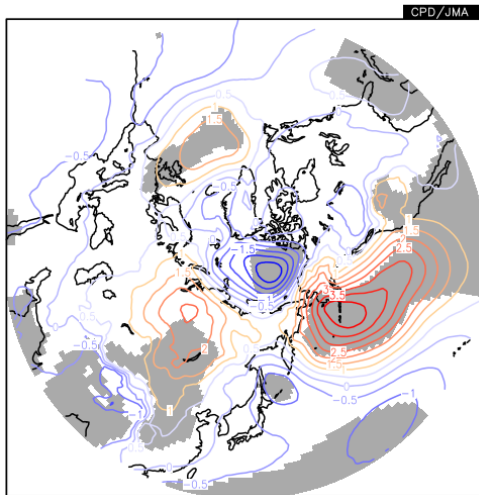
DATA1 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2015020100 ave = 2YR(3*1M0)
years = 1972, 1991
DATA2 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2014020100 ave = 54YR(3*1M0) analysis

DATA1 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2015020100 ave = 5YR(3*1M0)
years = 1965, 1968, 1969, 1976, 2009
DATA2 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2014020100 ave = 51YR(3*1M0) analys

El Niño



La Niña

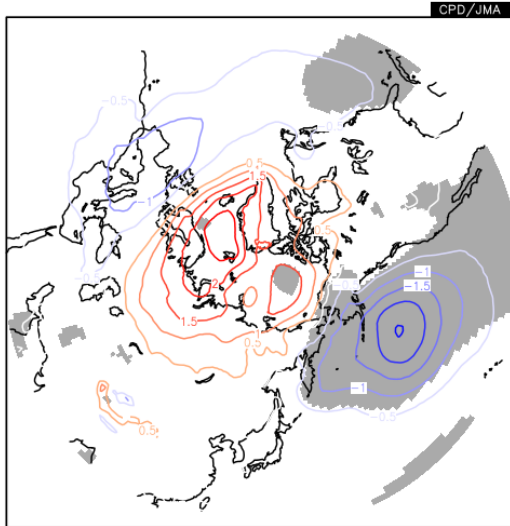


Relationship with PDO

SLP Anomaly

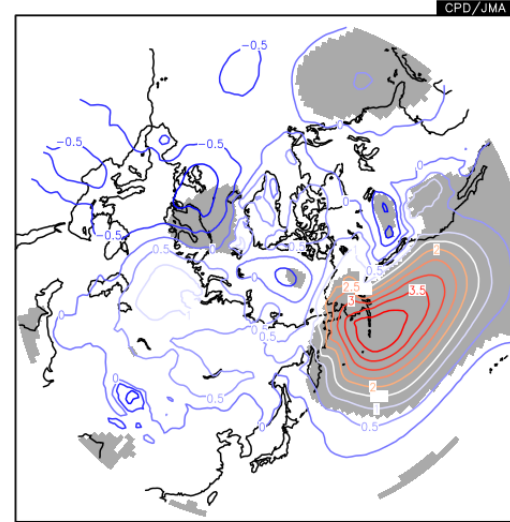
PDO+

DATA1 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2015020100 ave = 27YR(3*1MO)
years = 1958, 1959, 1960, 1963, 1969, 1976, 1977, 1979, 1980, 1981,
DATA2 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2014020100 ave = 29YR(3*1MO) analys



PDO-

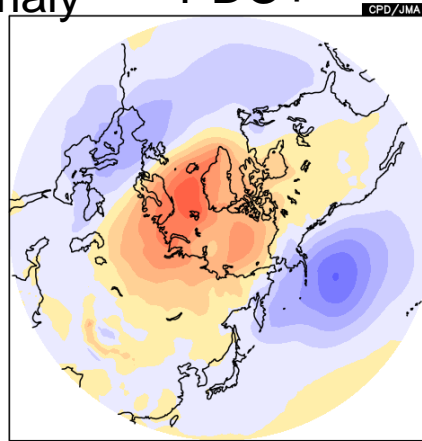
DATA1 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2015020100 ave = 29YR(3*1MO)
years = 1961, 1962, 1964, 1965, 1966, 1967, 1968, 1970, 1971, 1972,
DATA2 JRA-55 slp ANOM lat = 20:90 lon = -45:315 level = 1:1
time = 1958120100:2014020100 ave = 27YR(3*1MO) analys



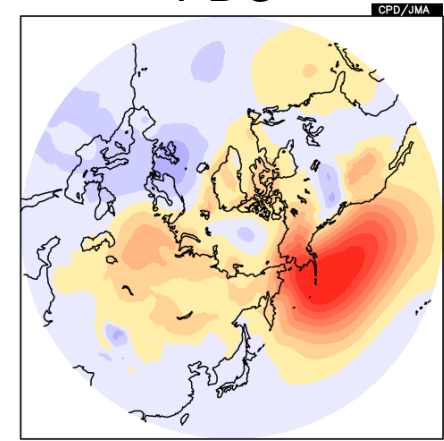
Relationship with PDO

SLP Anomaly

PDO+

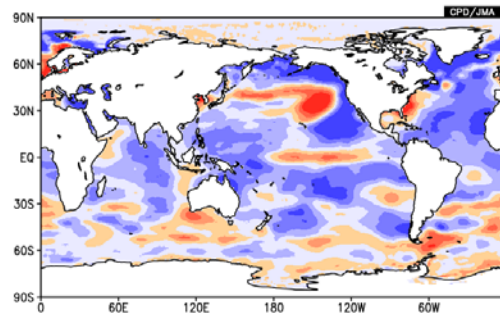


PDO-

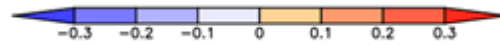
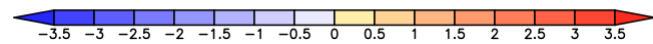
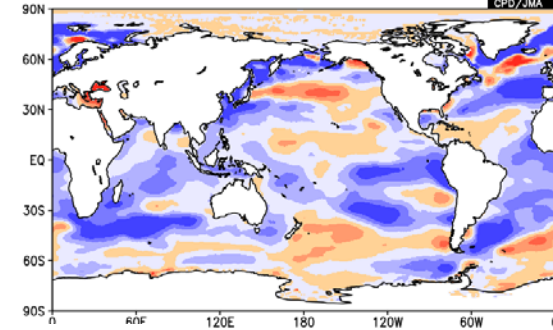


SST Anomaly

AO+



AO-



The number of Events

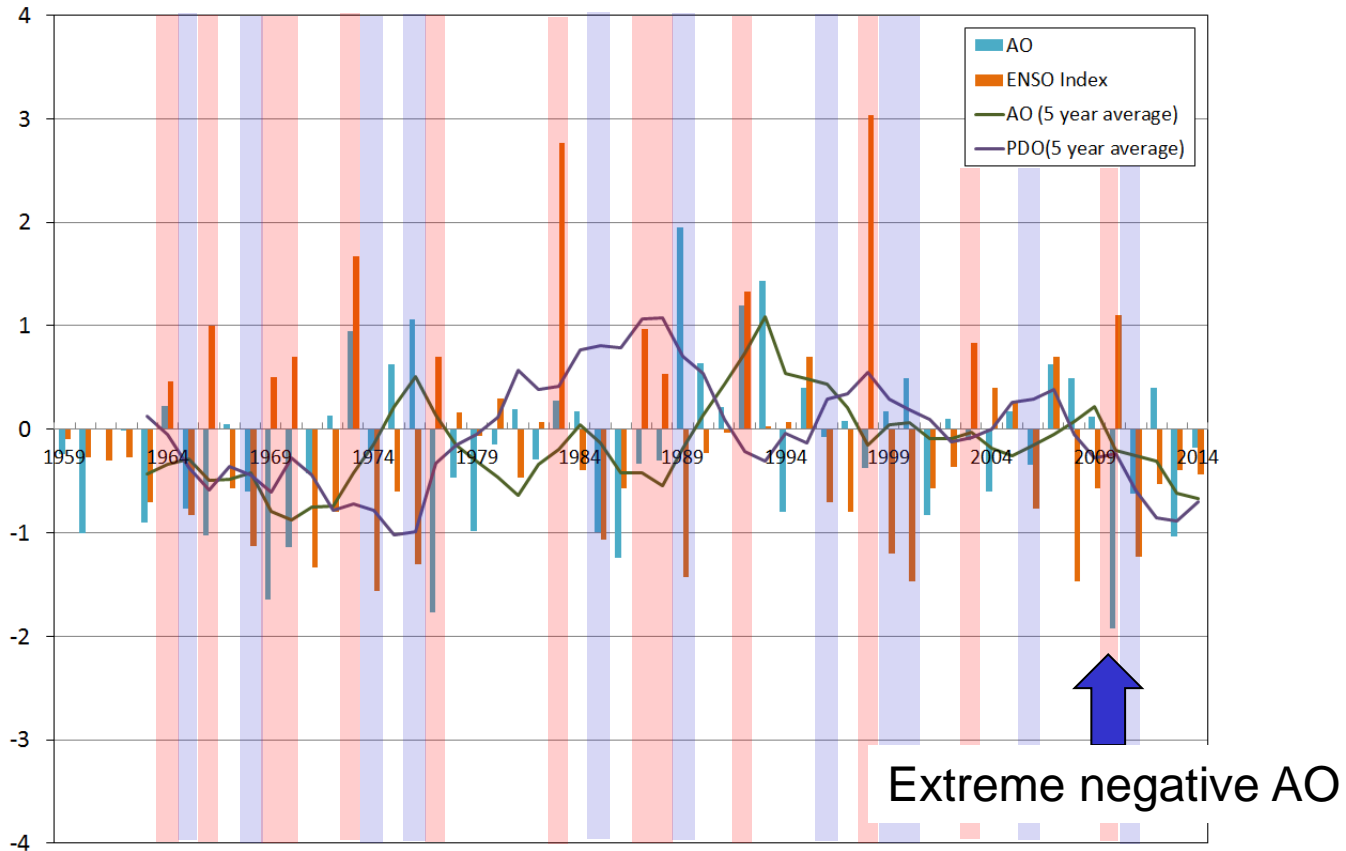
	AO+(+0.1)	AO-(-0.1)
PDO+	2(7)	8(17)
PDO-	6(15)	9(12)

(): Threshold of AO is ± 0.1

- AO+ occurs under PDO- more often than PDO+
- AO- occurs more often than AO+ under PDO+

Overview

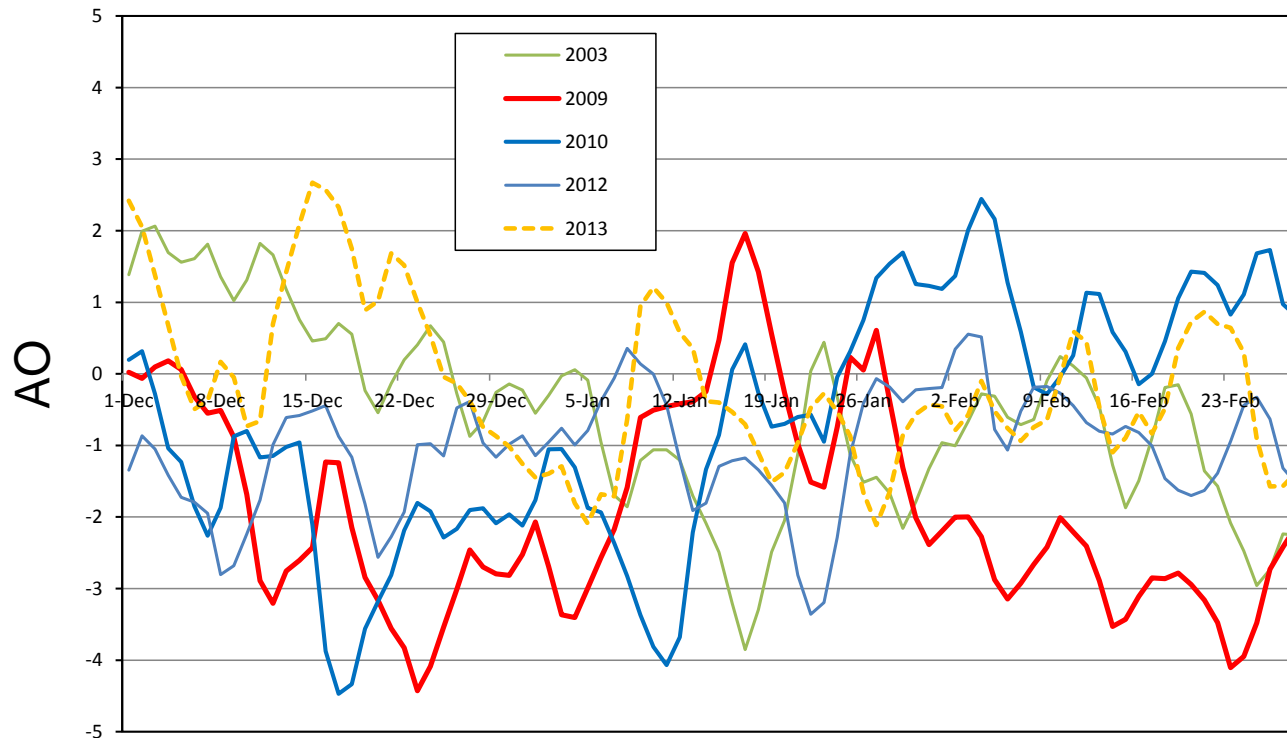
Time series of the AO index, ENSO index and PDO index (Winter season)



The negative AO frequently appeared after late 1990s.

Daily Variation

Consideration of the monthly or daily variation



SST

SST

AO+

AO-

