

Assessing the effect of the relative AAM on LOD variations under climate warming

E. Lehmann, F. Hansen

U. Ulbrich, P. N  vir, G.C. Leckebusch,
Institute of Meteorology, Freie Universit  t Berlin,
Berlin, Germany

EGU Vienna 2009

Motivation ...

Present times –

- What determines varying relation relative AAM – observed LOD in the atmosphere-ocean system on interannual time scales ?
- Does the effect of the relative AAM on observed LOD variations relate to specific changes in large-scale atmospheric circulation ?

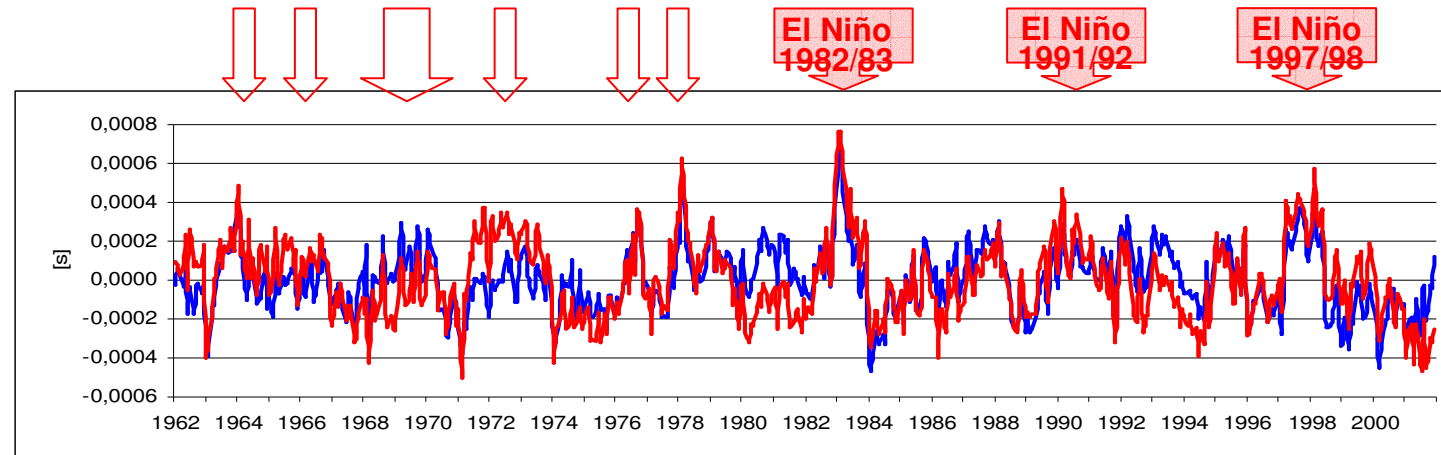
Future climate warming –

- Can a coupled ocean-atmosphere model (ECHAM5-OM1) reproduce findings from observations ?
- Assessing the effect of the relative AAM on length-of-day variations under climate warming.

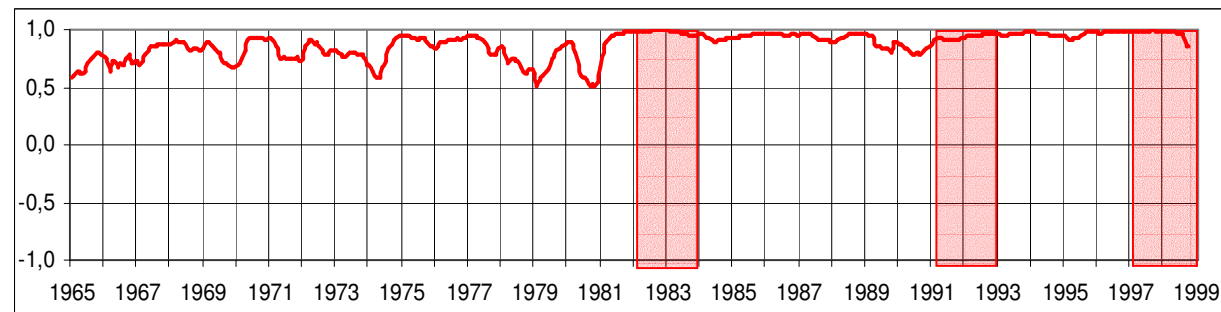
Relation interannual observed LOD and AAM variations

**LOD and
AAM
variations
[s]**

1962-2000



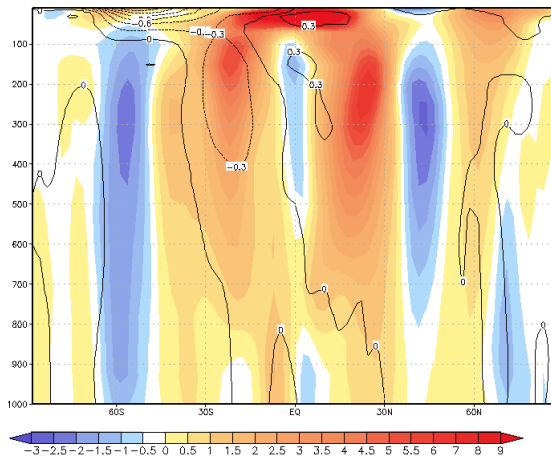
**Running
2-yr
correlation
LOD vs AAM**



- AAM and observed LOD highly correlated: $r = 0.8$
- El Niño events: Maxima of 2-year moving correlations

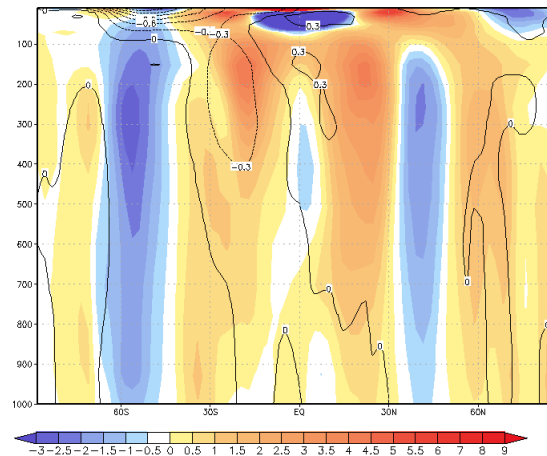
- ERA40 reanalyses (observations) - El Niño events associated with anomalies in zonal winds

El Niño 1982/83



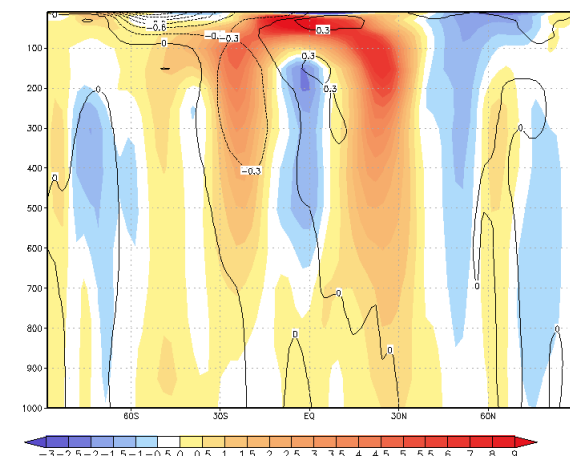
Contours: Climate mean (1971-2000) zonal wind (m/s).

El Niño 1991/92



Colors: Zonal wind anomalies (m/s) for peak El Niño months (ONI-index > 1.4).

El Niño 1997/98

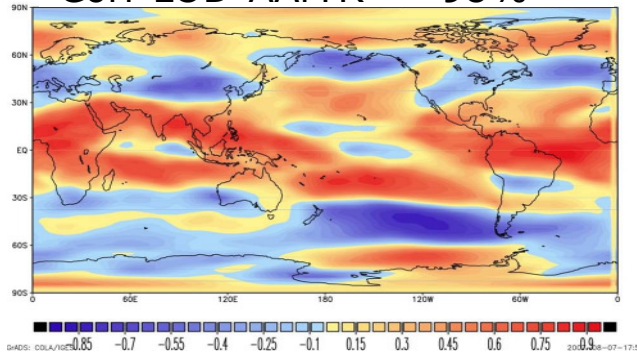


Data: **ERA40 reanalyses**, monthly means removed

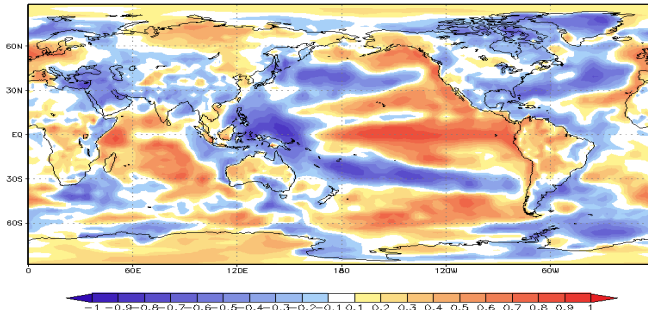
Interannual relations - Observed LOD-AAM and AAM-SST

El Niño 1997/98

Corr LOD-AAM $R^2 = 98\%$

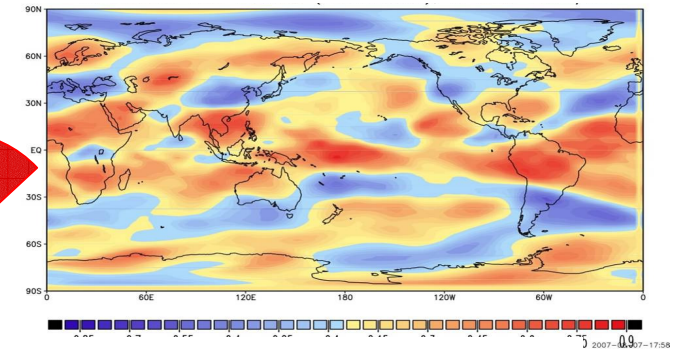


Corr AAM-NINO3.4 SST $R^2 = 56\%$

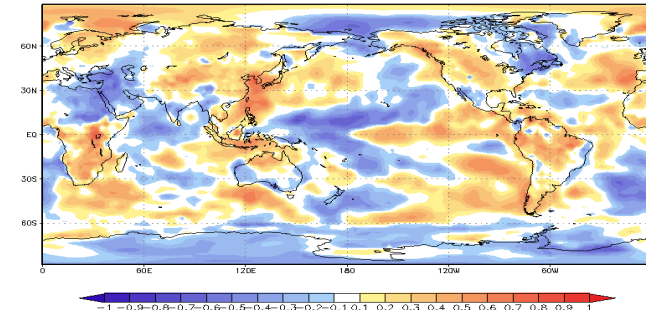


El Niño 1991/92

Corr LOD-AAM $R^2 = 71\%$



Corr AAM-NINO3.4 SST $R^2 = 18\%$

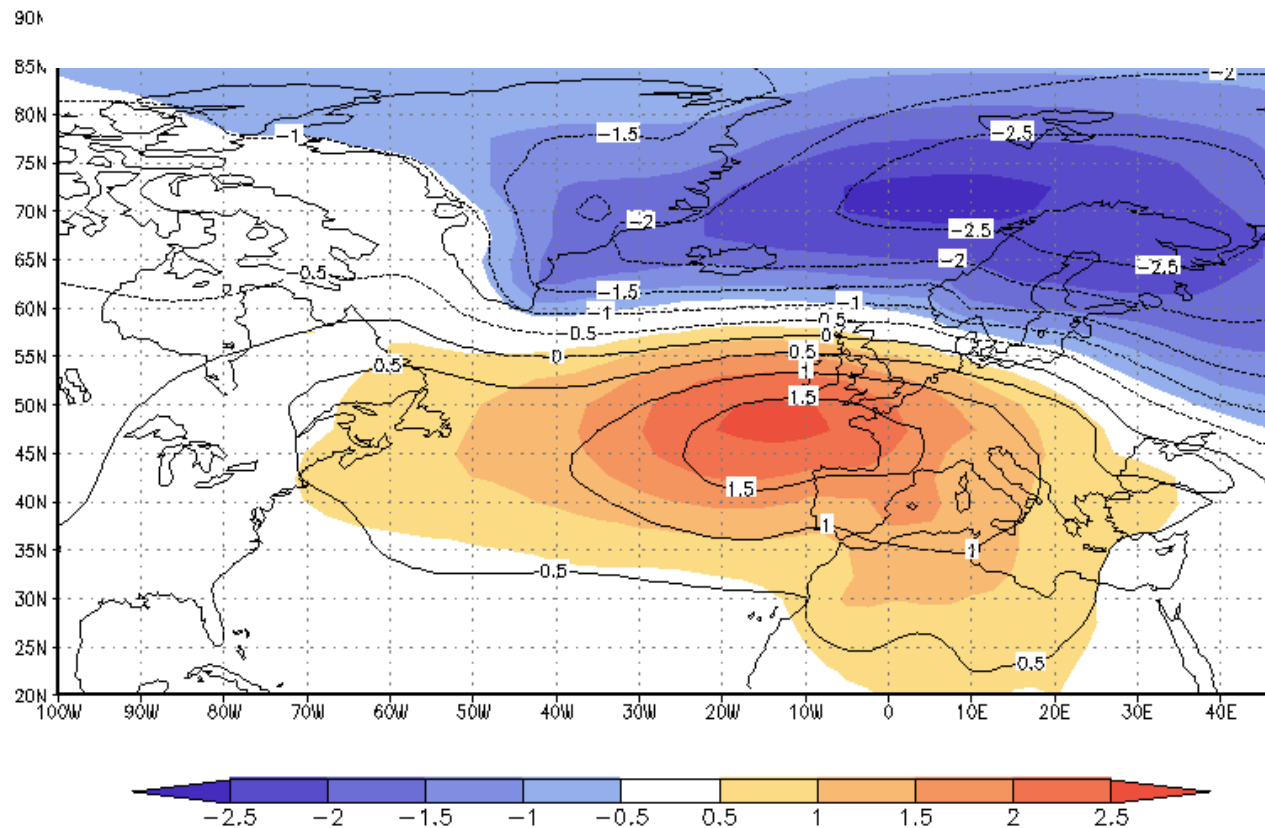


Correlation between AAM and observed LOD and AAM and NINO3.4 SSTs (sea surface temperatures) for two strong El Niño events (2-year period).

Data: ERA40 reanalyses, monthly means removed.

Large-scale atmospheric circulation with $R^2 \text{ AAM-SST} > 50\%$

North Atlantic Oscillation (NAO)



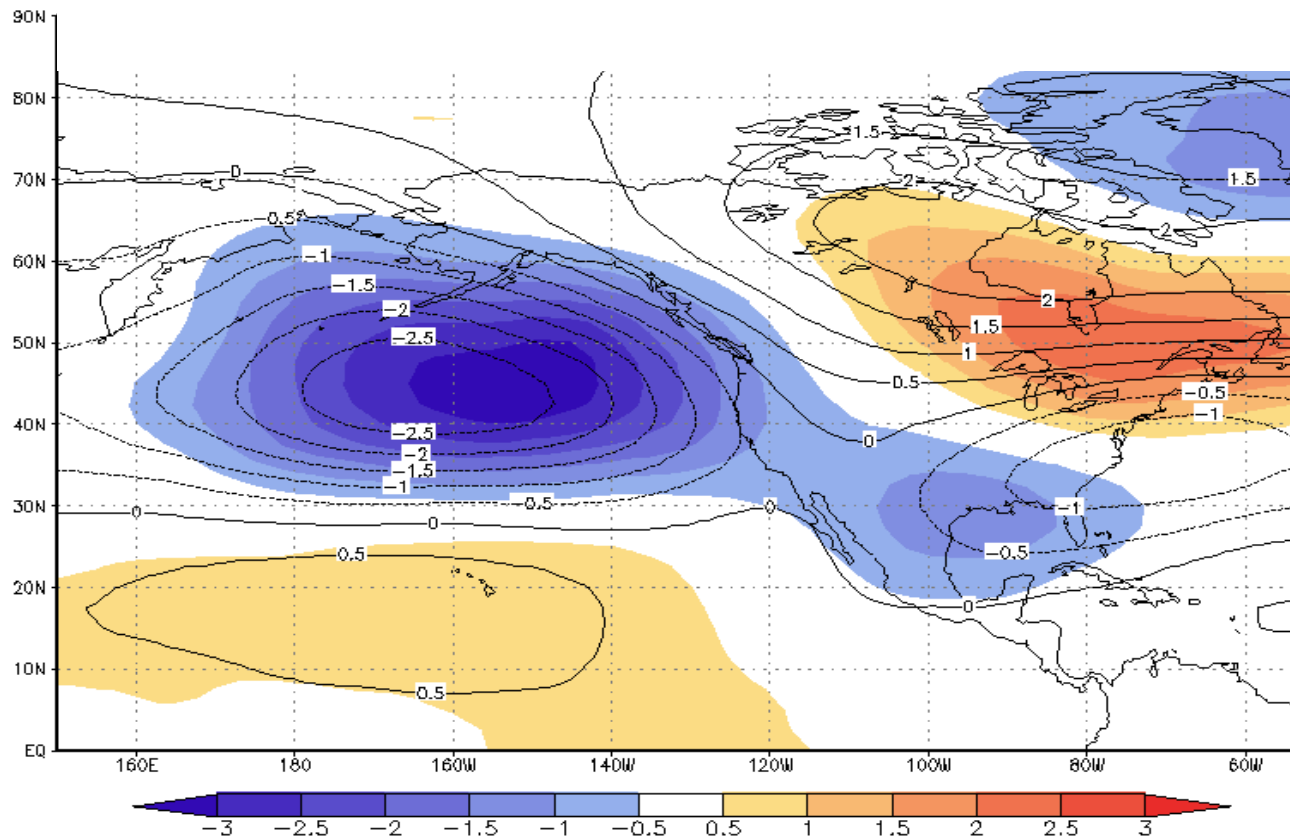
Contours: 1st EOF
mean sea level
pressure (NAO) climate
mean 1971-2000.

Colors: 1st EOF mean
sea level pressure
(NAO) for El Niño
periods with $R^2(\text{AAM-SST}) > 50\%$
(1982/83, 1997/98)

Data: mean sea level
pressure ERA40
reanalysis, ECMWF

Large-scale atmospheric circulation with R^2 AAM-SST > 50%

Pacific North America Oscillation (PNA)



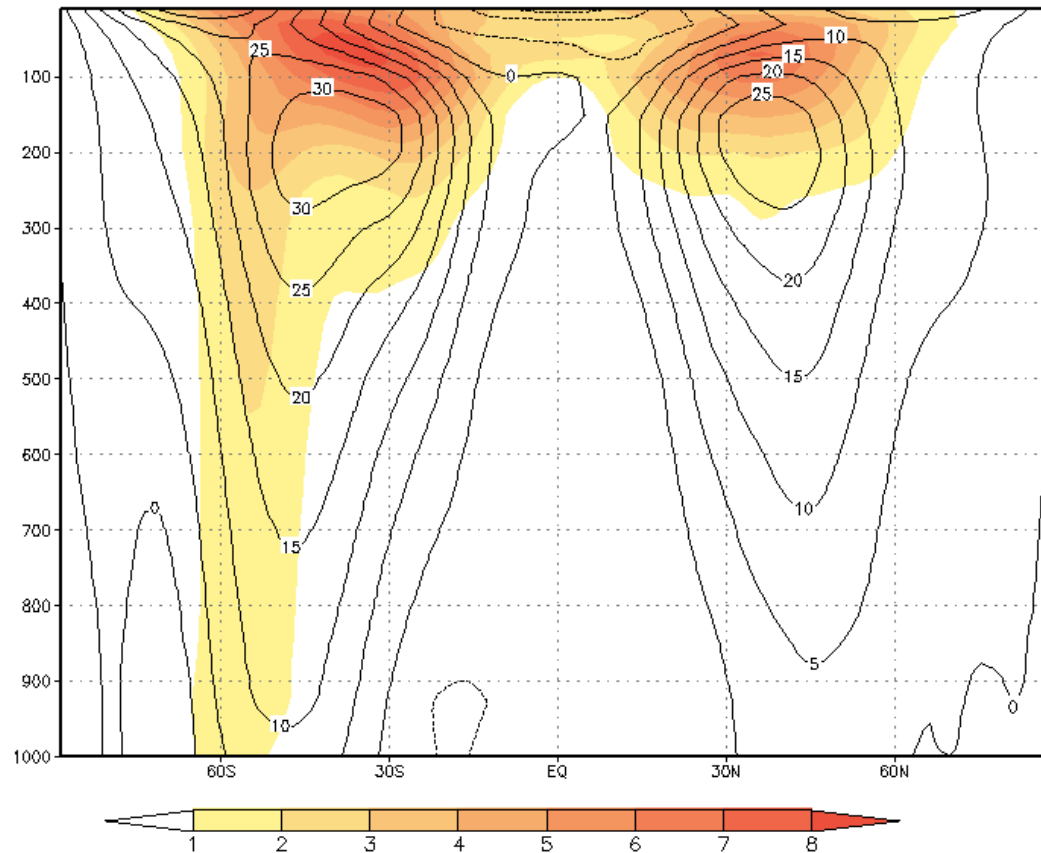
Contours: 1st EOF
geopotential height
500 hPa (PNA)
climate mean 1971-
2000.

Colors: 1st EOF
geopotential height
500 hPa (PNA) for
El Niño periods with
 $R^2(\text{AAM-SST}) > 50\%$
(1982/83, 1997/98)

Data: geopotential
height 500hPa,
ERA40 reanalysis,
ECMWF

Coupled model simulations ECHAM5-OM1

Greenhouse Gas Scenario A1B: Increasing jets



Contours: zonal wind in m/s
climate mean 1971-2000.

Colors: Difference between zonal
wind climate mean 2071-2100
and climate mean 1971-2000.

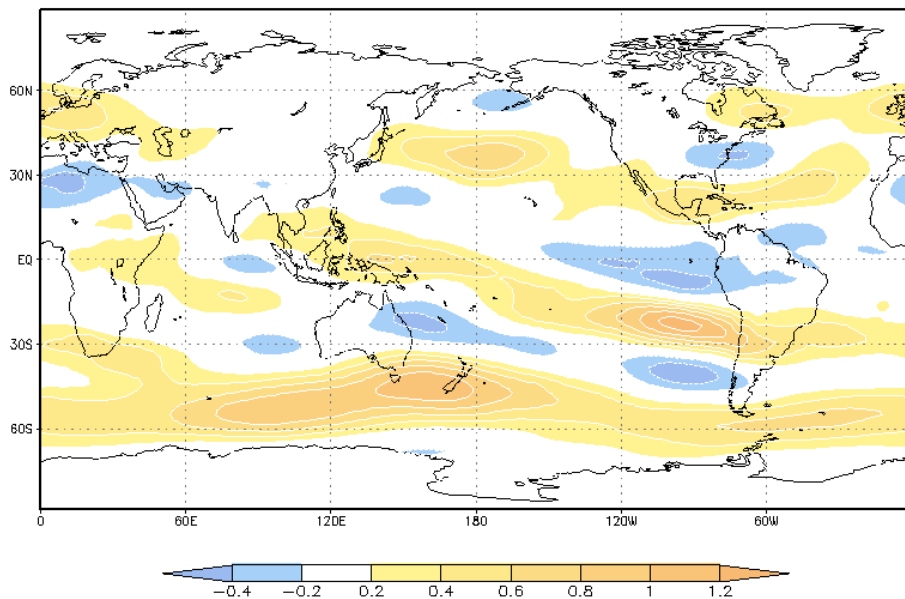
Data: ECHAM5-OM1-20C,
ECHAM5-OM1-A1B.

Coupled model simulations ECHAM5-OM1

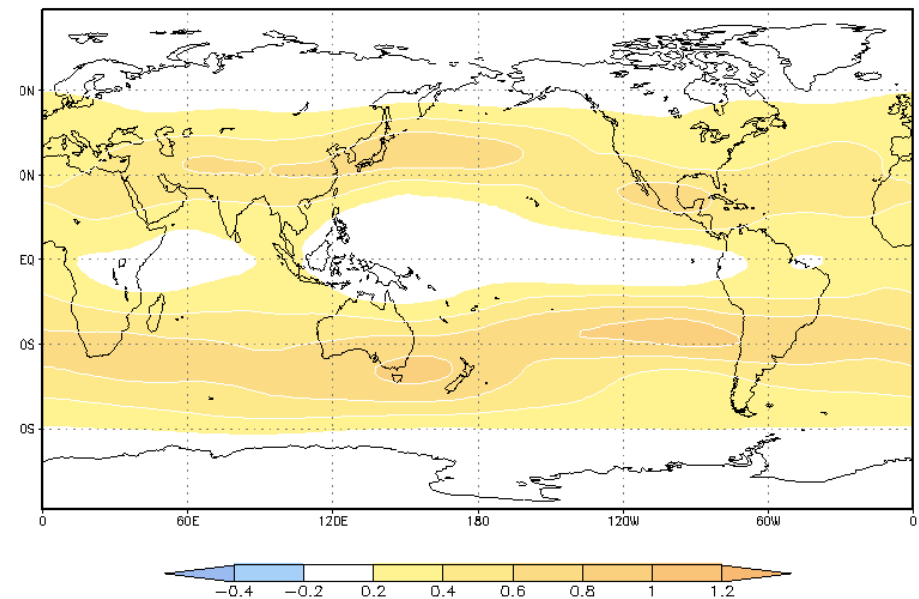
Greenhouse Gas Scenario A1B: Increasing AAM

AAM climate mean 2071-2100 (A1B) minus 1971-2000 (20C)

AAM (1000 – 200 hPa): +3.4%



AAM (200 – 10 hPa): **+31 %**

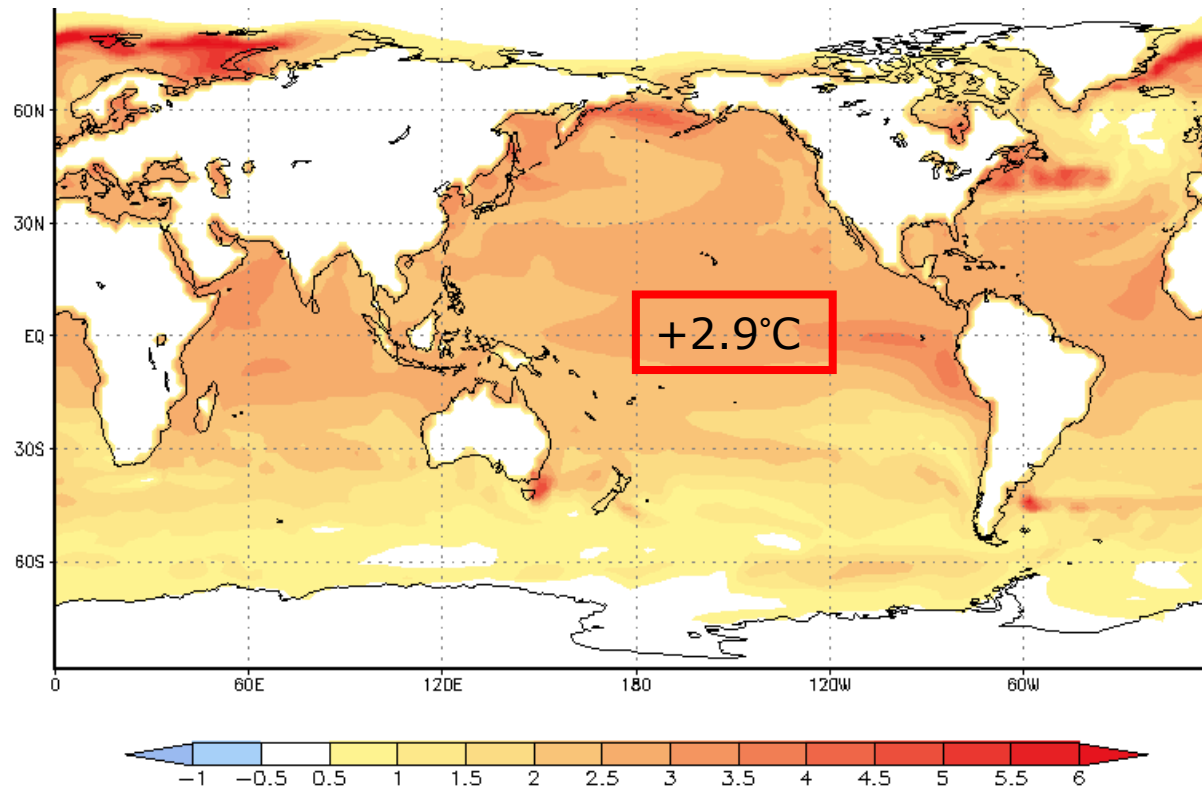


Data: ECHAM5-OM1 projections 20C, A1B,
monthly means removed.

Coupled model simulations ECHAM5-OM1 Greenhouse Gas Scenario A1B: Increasing SSTs

Difference climate mean A1B (2071-2100) – 20C (1971-2000)

Global warming +1.3°C



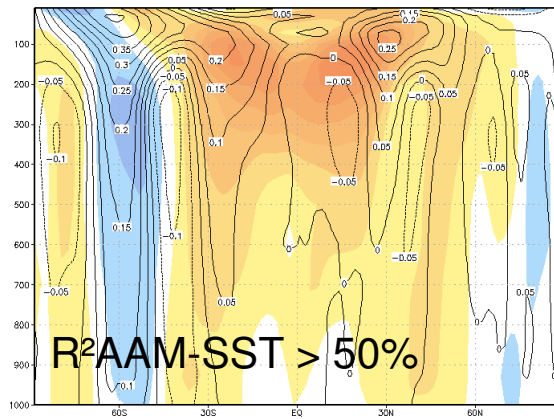
El Niño in coupled model simulations (ECHAM5-OM1)

Class	Years	Present time		Warming	Variability	Total episodes
		ERA40 40	20C 40	A1B 101	PICTRL 506	/class 687
90 < r^2 <= 100						
80 < r^2 <= 90				1		1
70 < r^2 <= 80			1	7	1	9
60 < r^2 <= 70		1		5	9	15
50 < r^2 <= 60		1	1	2	11	15
40 < r^2 <= 50			1	4	12	17
30 < r^2 <= 40					6	6
20 < r^2 <= 30					4	4
10 < r^2 <= 20		1			4	5
0 <= r^2 <= 10				1	4	5
Total episodes/ data set		3	3	20	51	77

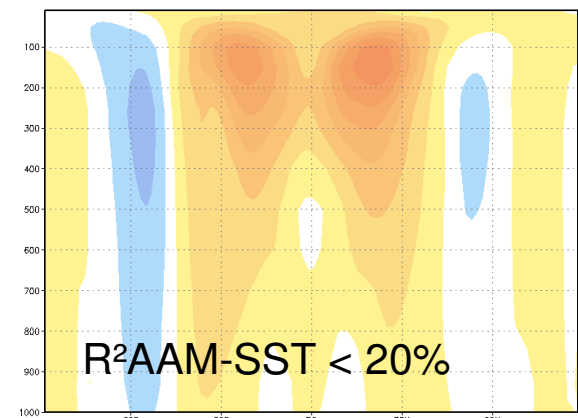
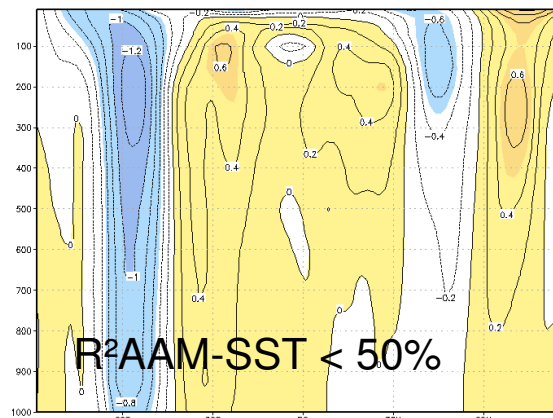
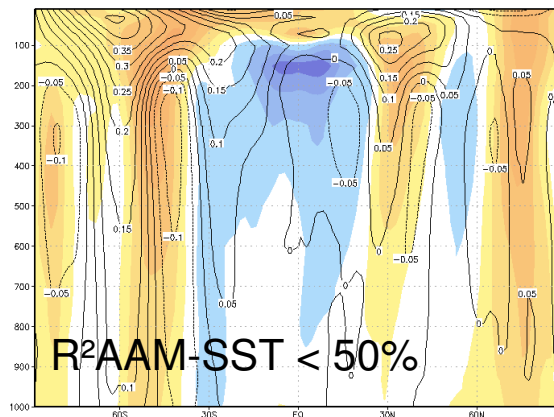
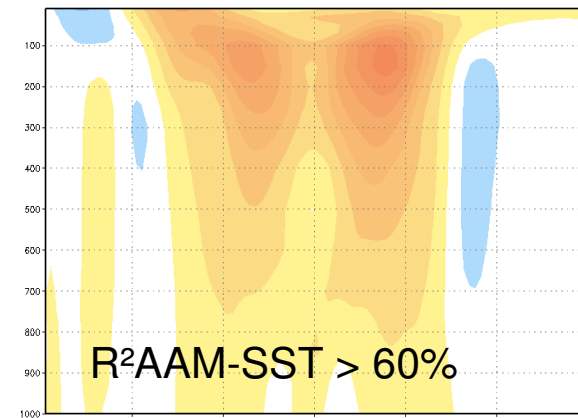
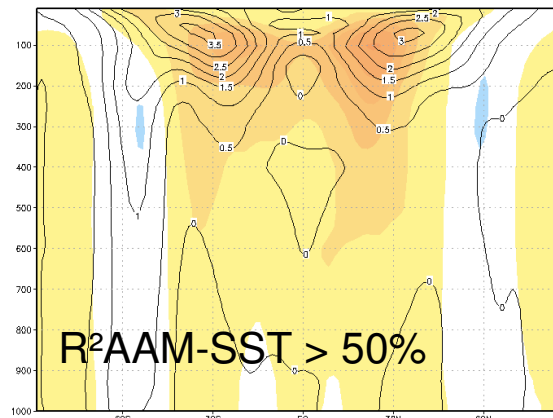
Coupled ECHAM5-OM1 model simulations

El Niño events associated with anomalies in zonal winds

20th century (20C)

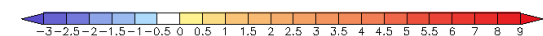


Climate warming (A1B) Climate variability (CTRL)



Contours: climate mean (20C: 1971-2000, A1B: 2071-2100, CTRL: 2150-2655) zonal wind (m/s).

Colors: Zonal wind anomalies (m/s) for peak El Niño months (ONI-index > 1.4 in climate mean).

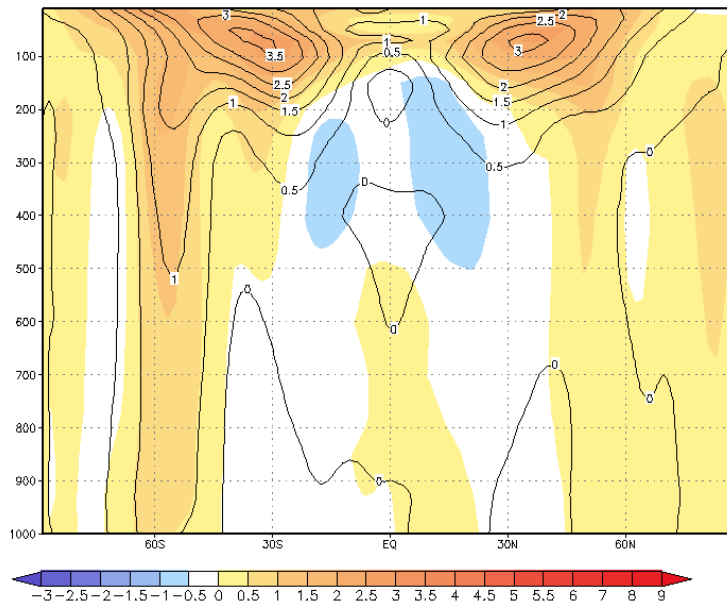


Data: ECHAM5-OM1, monthly means removed.

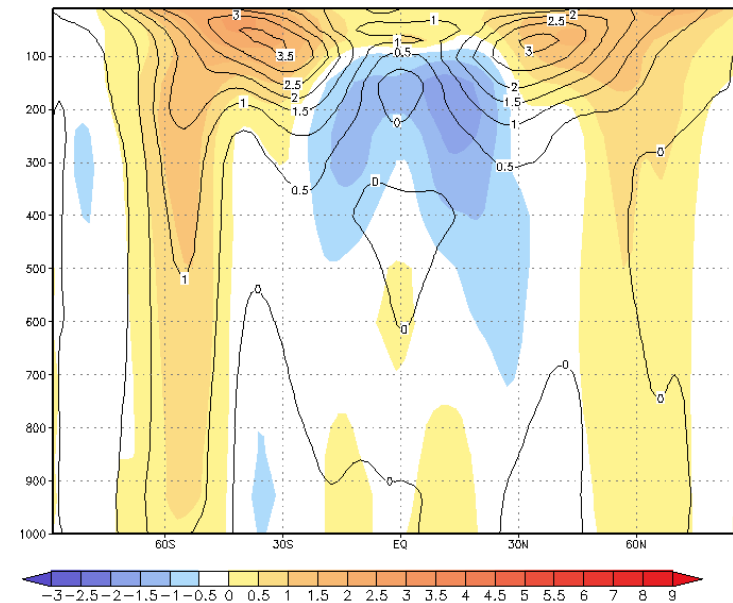
Coupled ECHAM5-OM1 model simulations

Climate warming in zonal winds

A1B-CTRL, $R^2\text{AAM-SST} > 60\%$



A1B-CTRL, $R^2\text{AAM-SST} < 20\%$



Contours: Climate warming (A1B) minus climate variability (CTRL) mean zonal winds (m/s) for simulation years 2150-2655.

Colors:

Left: A1B-CTRL mean zonal winds El Niño episodes $R^2\text{AAM-SST} > 60\%$ (5 events)

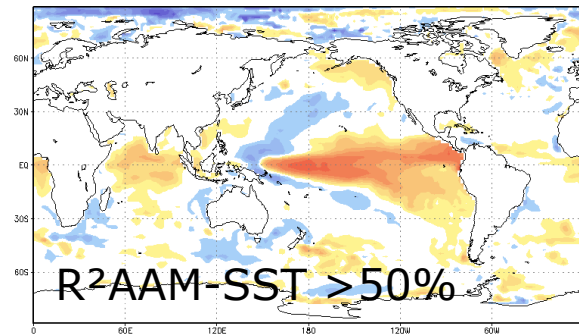
Right: A1B-CTRL mean zonal winds El Niño episodes $R^2\text{AAM-SST} < 20\%$ (8 events)

Data: Monthly means removed.

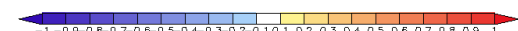
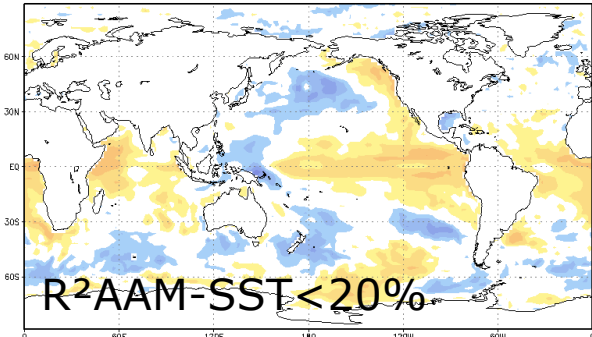
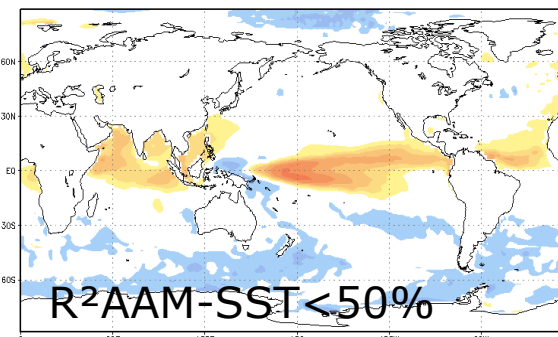
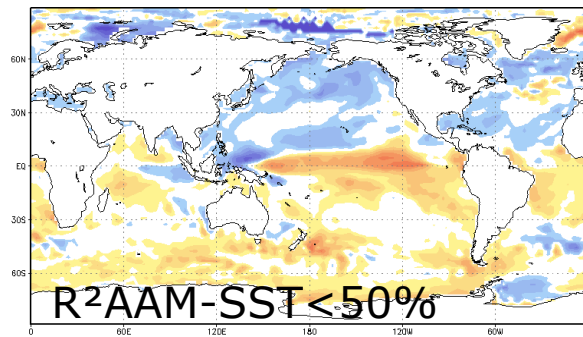
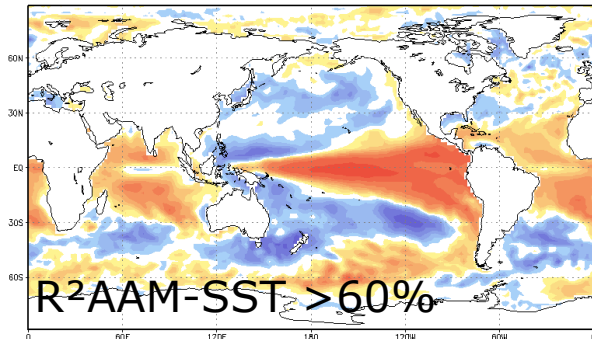
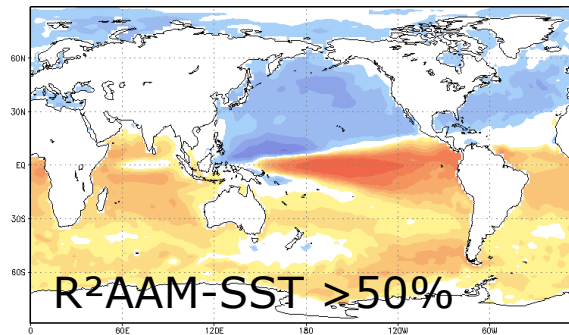
Coupled ECHAM5-OM1 model simulations

Climate warming in AAM-SST relation

20th century (20C)



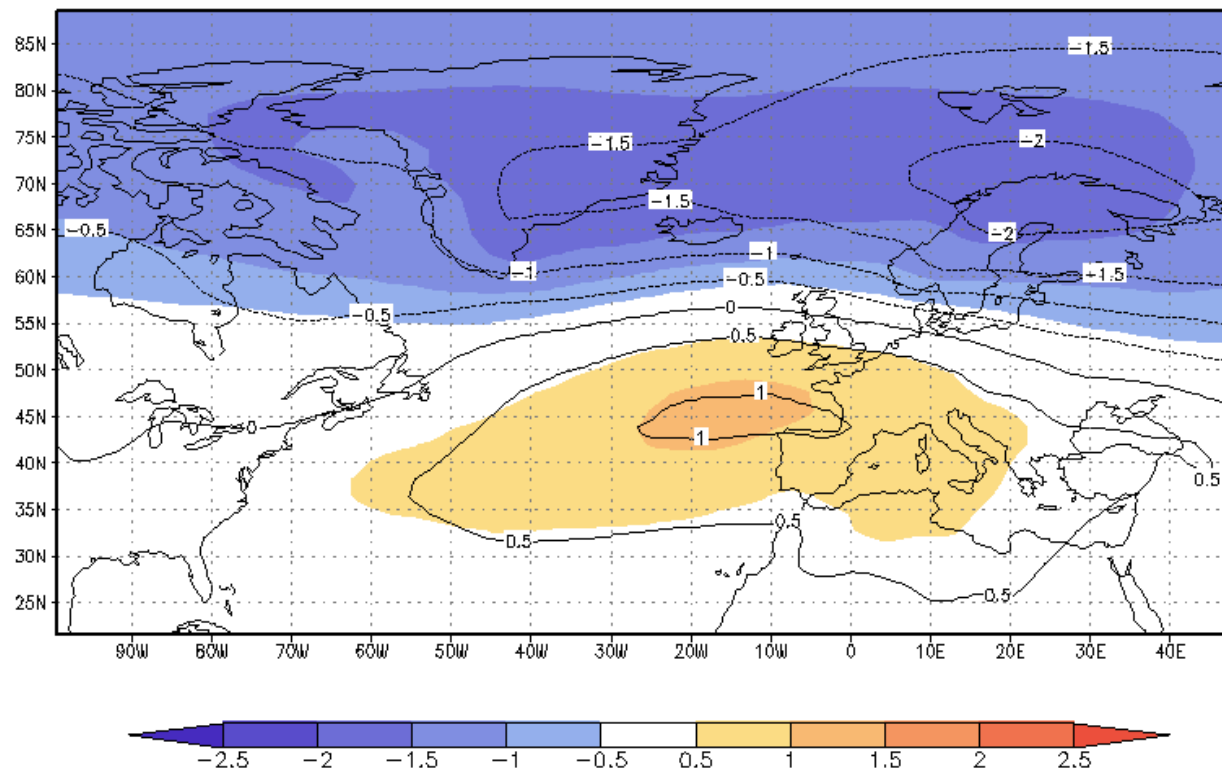
Climate warming (A1B) Climate variability (CTRL)



AAM and SST (sea surface temperature): ECHAM5-OM1, monthly means removed

Large-scale atmospheric circulation with R^2 AAM-SST > 50%

North Atlantic Oscillation (NAO)



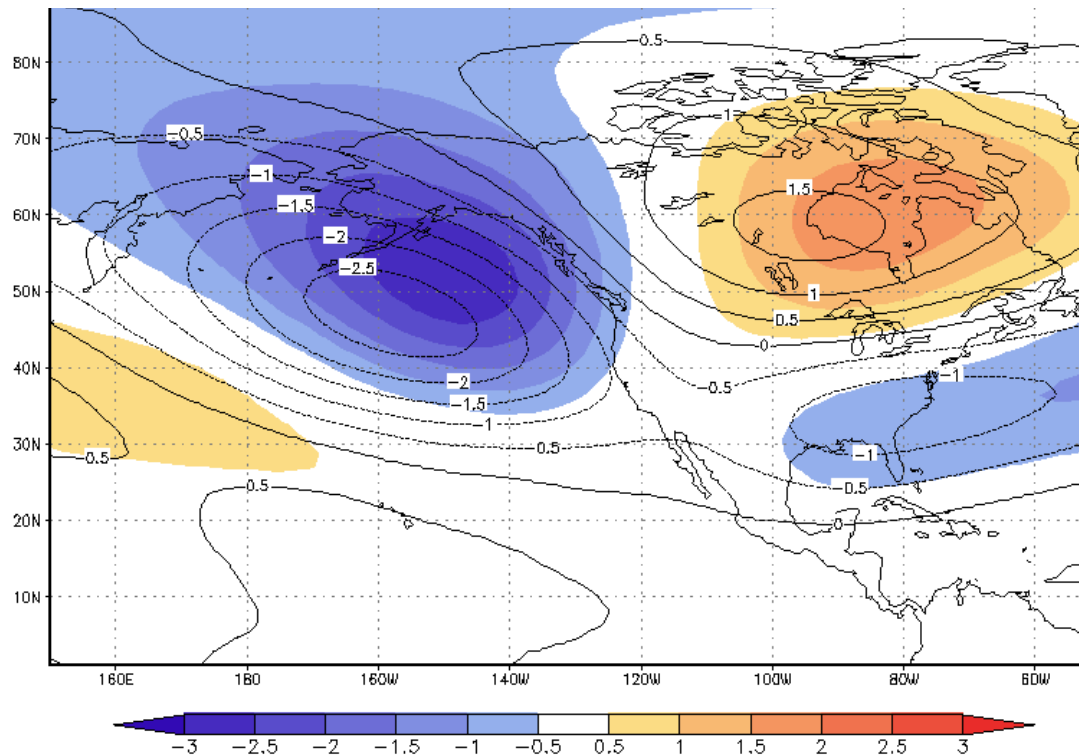
Contours: 1st EOF
mean sea level
pressure (NAO) climate
mean 2071-2100.

Colors: 1st EOF mean
sea level pressure
(NAO) for El Niño
periods with R^2 (AAM-
SST) > 50%

Data: mean sea level
pressure ECHAM5-
OM1, A1B projection

Large-scale atmospheric circulation with R^2 AAM-SST > 50%

Pacific North America Oscillation (PNA)



Contours: 1st EOF
geopotential height 500
hPa (PNA) climate mean
2071-2100.

Colors: 1st EOF
geopotential height 500
hPa (PNA) for El Niño
periods with $R^2(\text{AAM-SST}) > 50\%$

Data: geopotential
height 500 hPa,
ECHAM5-OM1, A1B
projection

Summary & Conclusions

➤ **Present times observations (ERA40 reanalyses)**

Main source of varying El Niño signal on AAM-SST relation associated with different zonal wind anomalies related to

- Troposphere in subtropics ($\sim 30^\circ$)
- Upper troposphere at equator

R^2 AAM-SST > 50%

- **NAO:** pronounced positive high pressure center
- **PNA:** NW and NE centers shift eastwards

➤ **Coupled ocean-atmosphere (ECHAM5-OM1) simulations**

- Location and strength of zonal wind anomalies associated with El Niño compare to observations

➤ **Future climate warming (ECHAM5-OM1 A1B)**

- Increasing zonal winds in extratropics, subtropics in upper troposphere
- Increase of global SSTs with as twice as much increase in NINO3.4 region
- More El Niños with a strong effect on AAM variations: R^2 AAM-SST > 50%



Thank you for your attention.