

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



# Motivation ...

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## Present times –

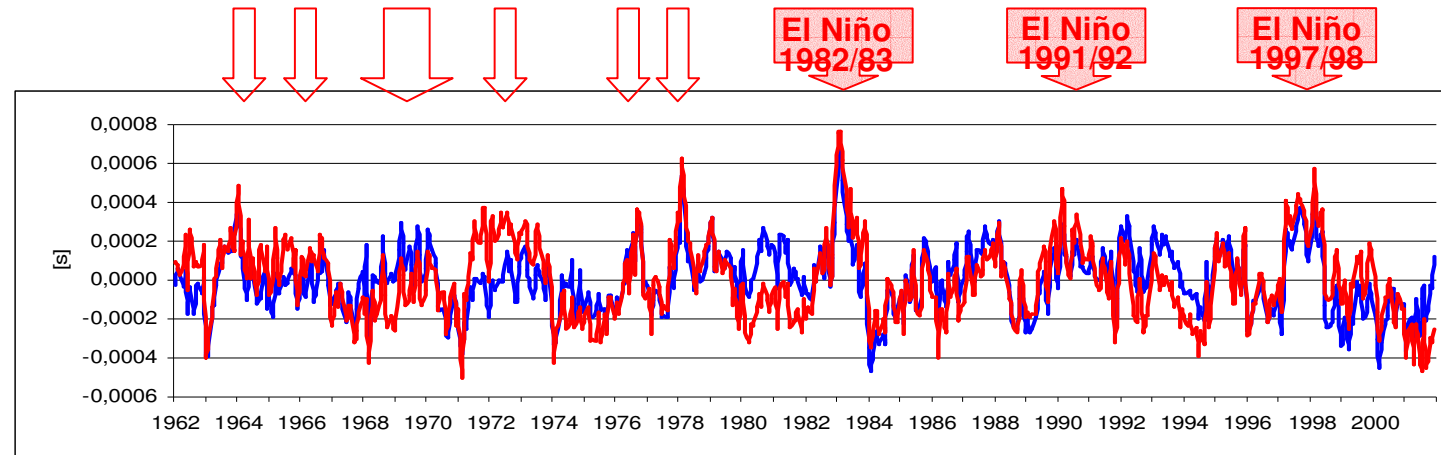
- What determines varying relation relative AAM – observed LOD in the atmosphere-ocean system on interannual time scales ?
- Does the effect of the relative AAM on observed LOD variations relate to specific changes in large-scale atmospheric circulation ?

## Future climate warming –

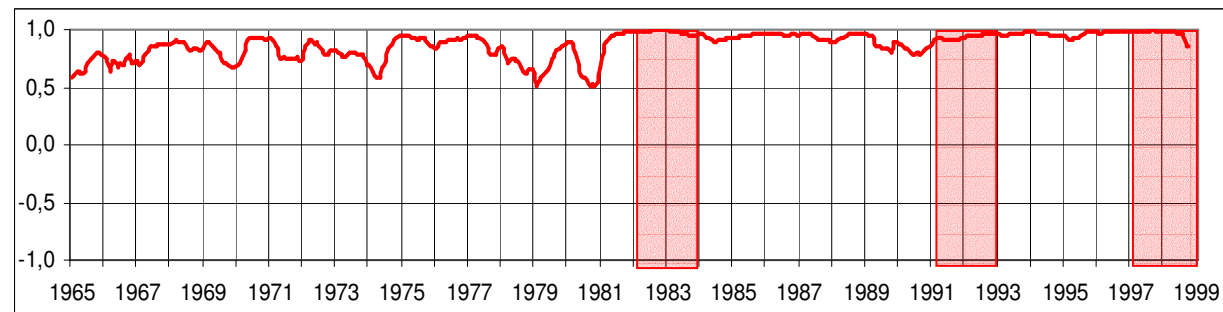
- Can a coupled ocean-atmosphere model (ECHAM5-OM1) reproduce findings from observations ?
- Assessing the effect of the relative AAM on length-of-day variations under climate warming.

# Relation interannual observed LOD and AAM variations

**LOD and  
AAM  
variations  
[s]**  
1962-2000



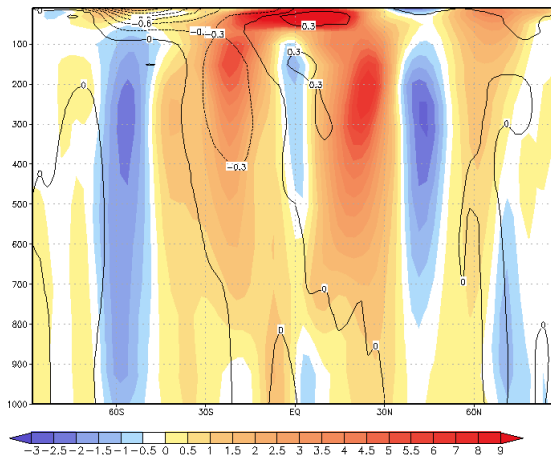
**Running  
2-yr  
correlation  
LOD vs AAM**



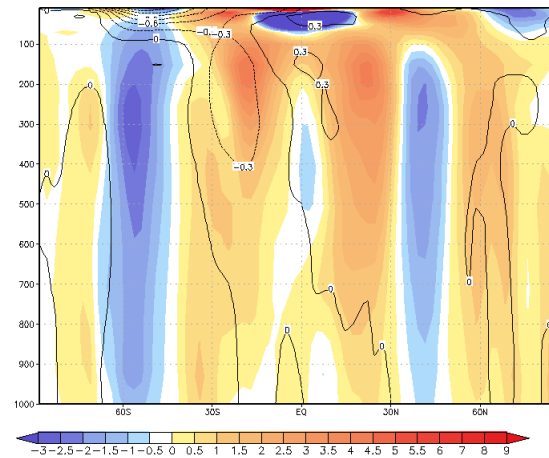
- AAM and observed LOD highly correlated:  $r = 0.8$
- El Niño events: Maxima of 2-year moving correlations

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

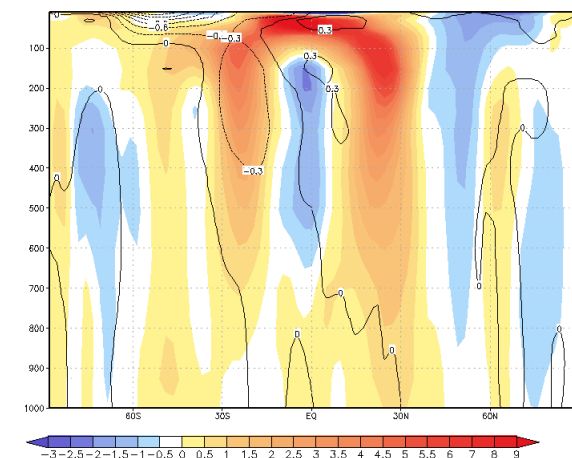
El Niño 1982/83



El Niño 1991/92



El Niño 1997/98



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

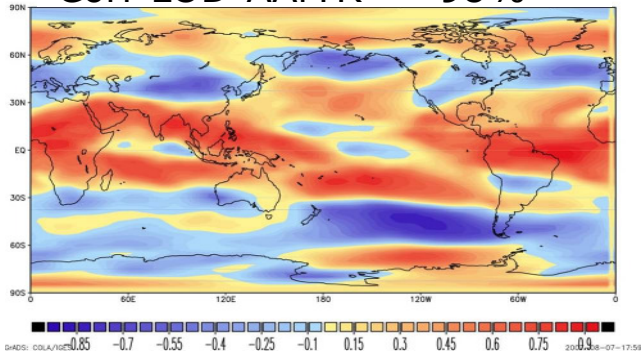
**Colors:** Zonal wind anomalies (m/s) for peak El Niño months (ONI-index > 1.4).

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

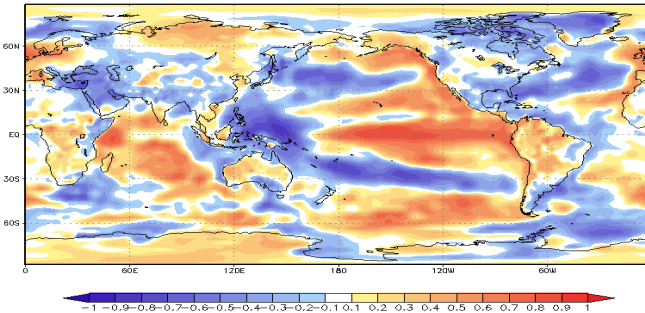
# Interannual relations - Observed LOD-AAM and AAM-SST

El Niño 1997/98

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

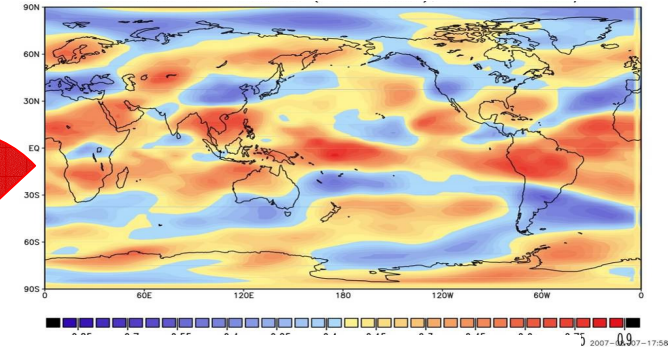


Corr AAM-NINO3.4 SST  $R^2 = 56\%$

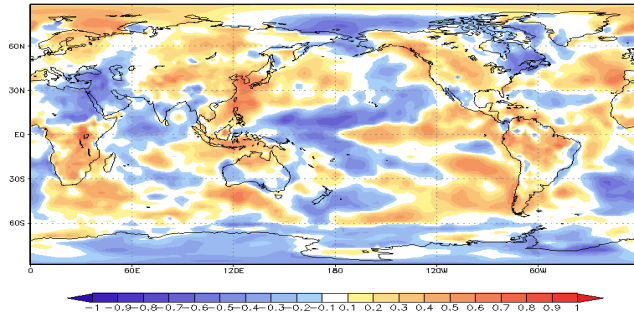


El Niño 1991/92

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



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

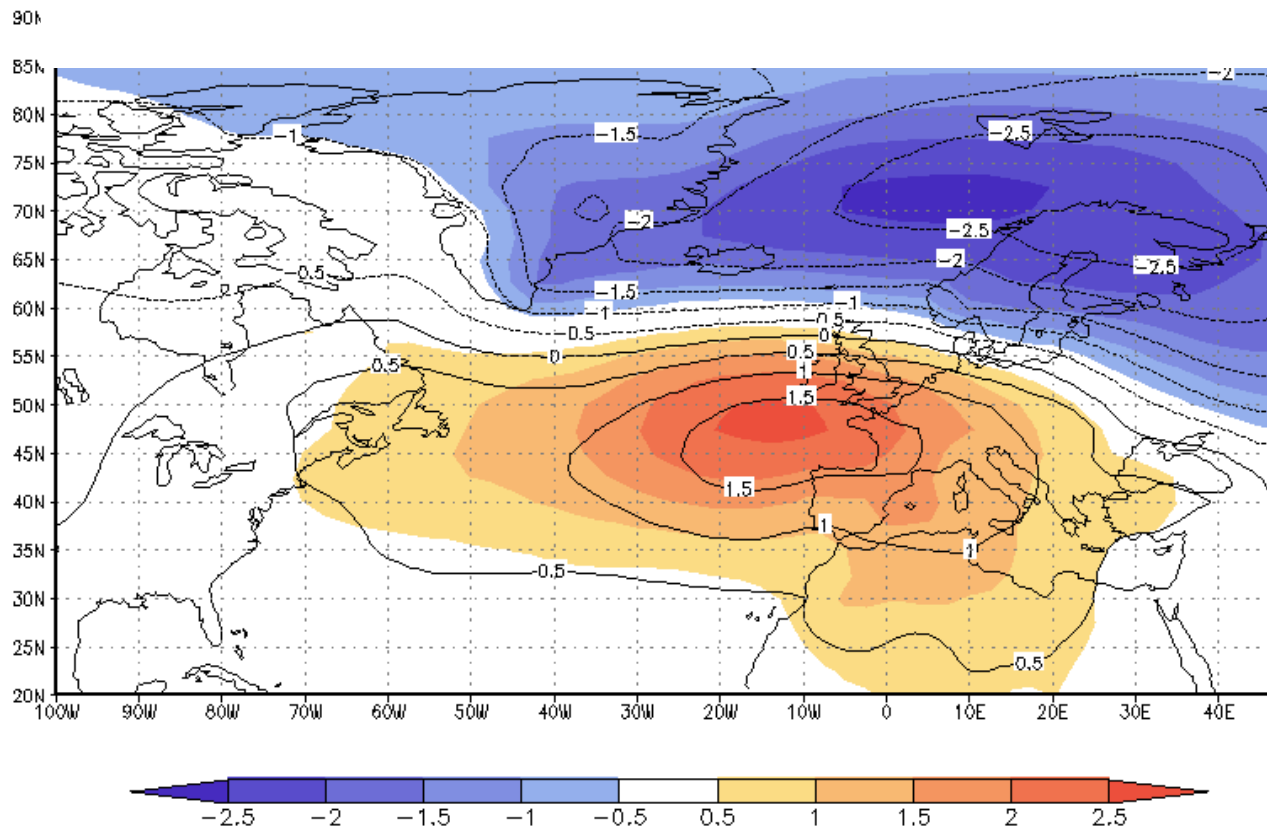


Correlation between AAM and observed LOD and AAM and NINO3.4 SSTs (sea surface temperatures) for two strong El Niño events (2-year period).

Data: ERA40 reanalyses, monthly means removed.

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

## North Atlantic Oscillation (NAO)



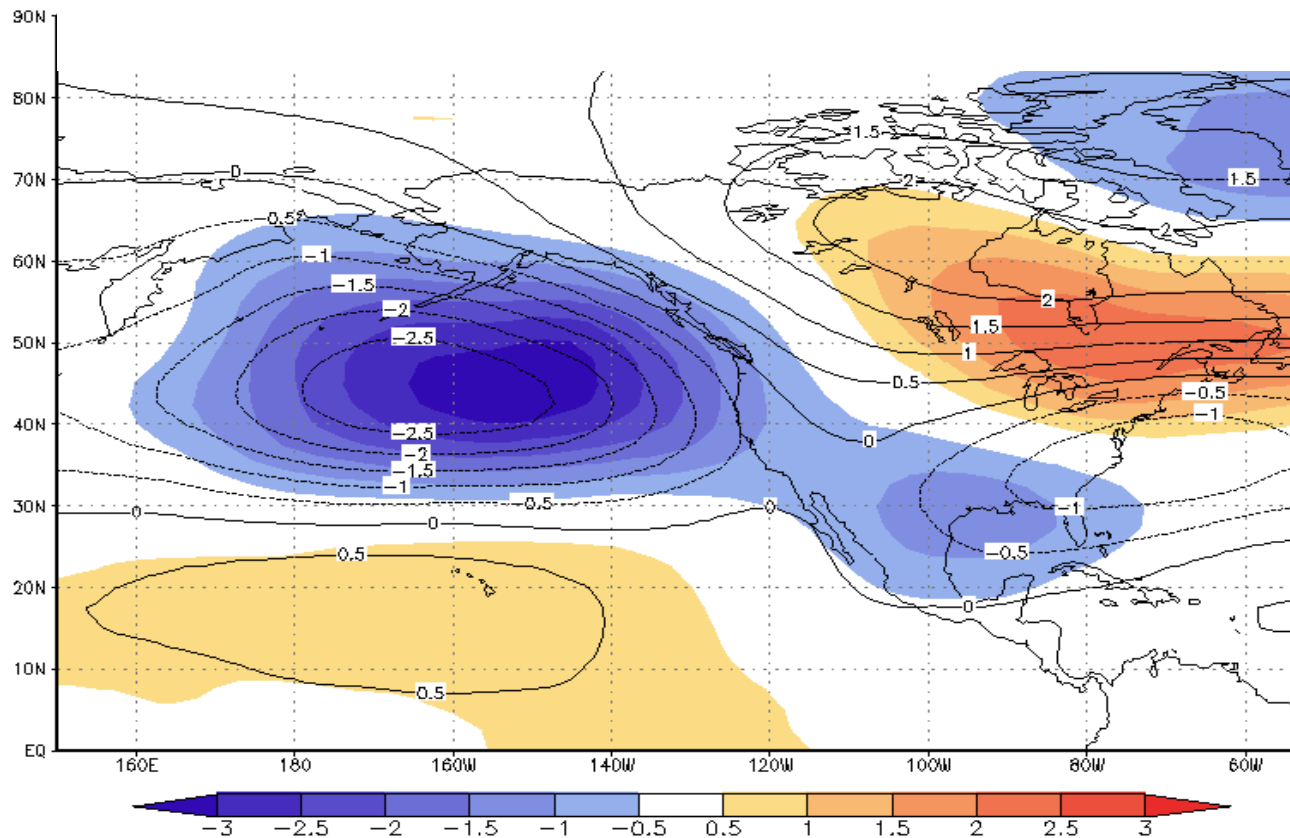
**Contours:** 1<sup>st</sup> EOF mean sea level pressure (NAO) climate mean 1971-2000.

**Colors:** 1<sup>st</sup> 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)

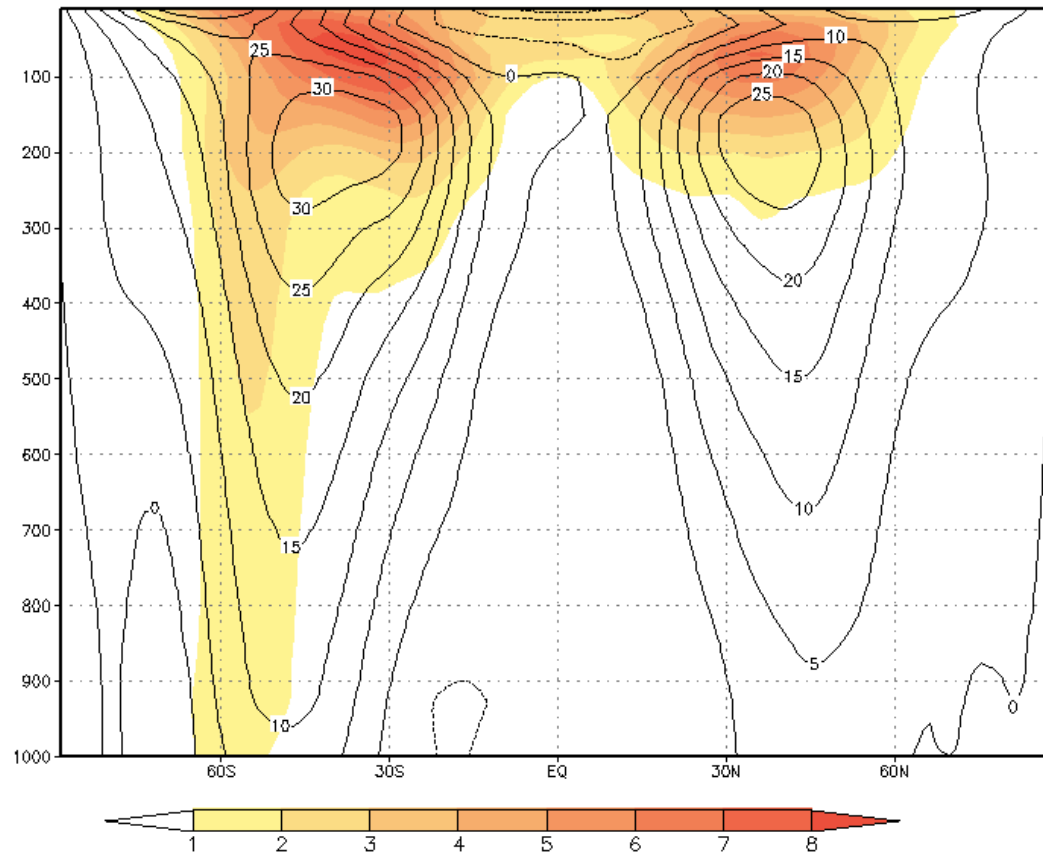


**Contours:** 1<sup>st</sup> EOF geopotential height 500 hPa (PNA) climate mean 1971-2000.

**Colors:** 1<sup>st</sup> 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.

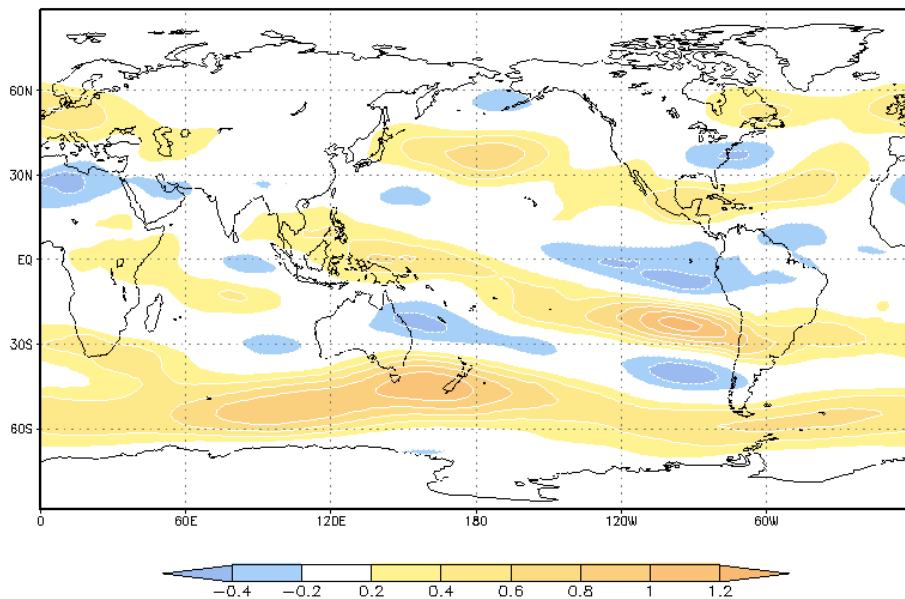
Data: ECHAM5-OM1-20C,  
ECHAM5-OM1-A1B.



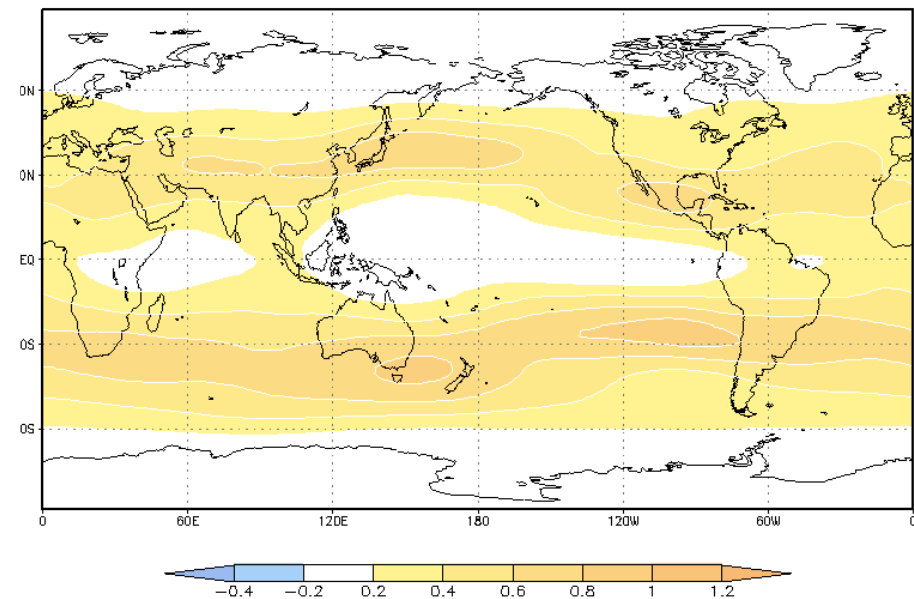
# Coupled model simulations ECHAM5-OM1 Greenhouse Gas Scenario A1B: Increasing AAM

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

AAM (1000 – 200 hPa): +3.4%



AAM (200 – 10 hPa): **+31 %**

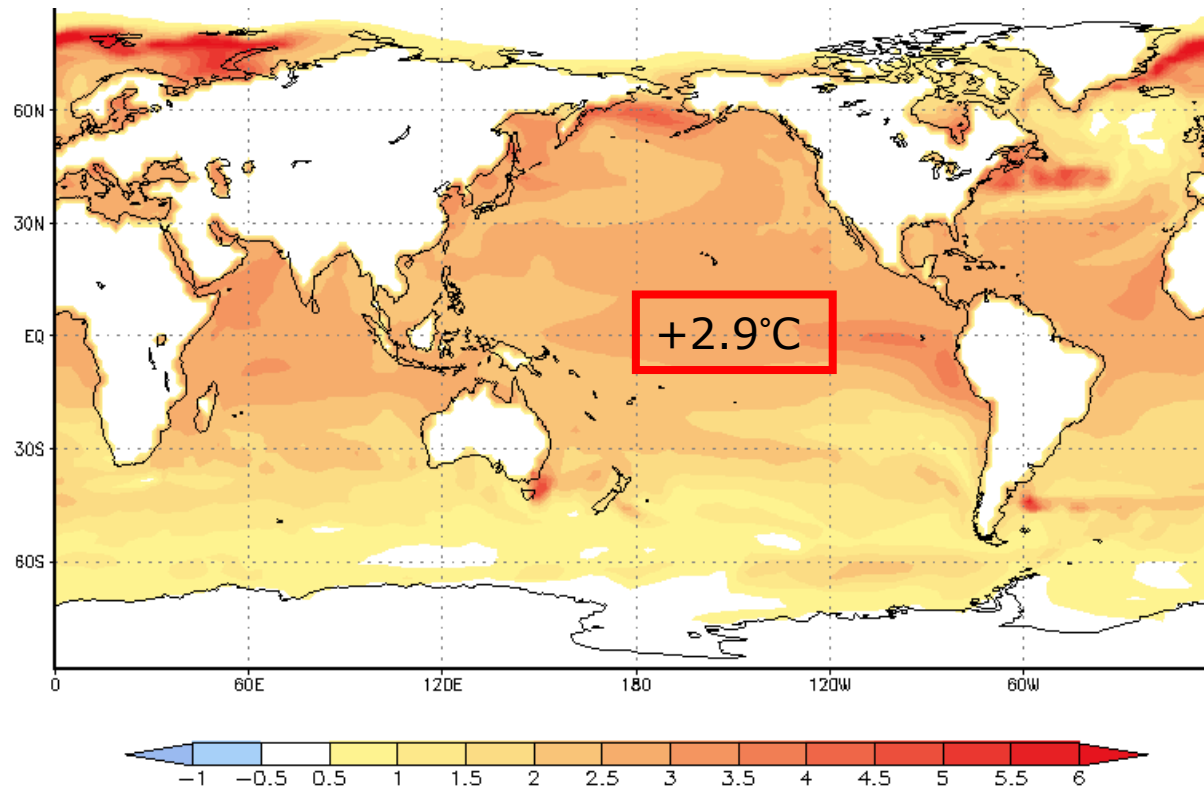


Data: ECHAM5-OM1 projections 20C, A1B,  
monthly means removed.

# 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



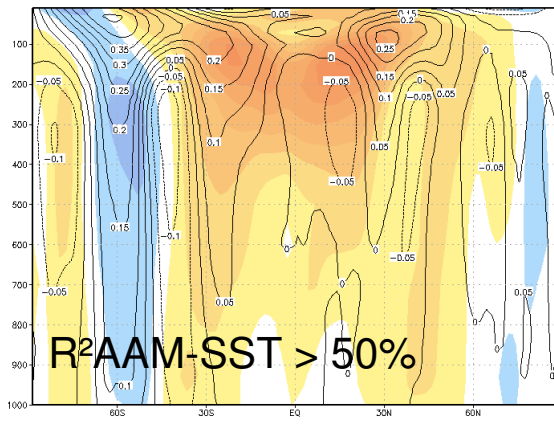
# El Niño in coupled model simulations (ECHAM5-OM1)

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

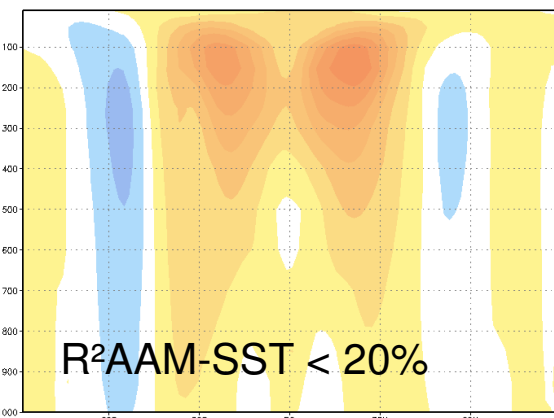
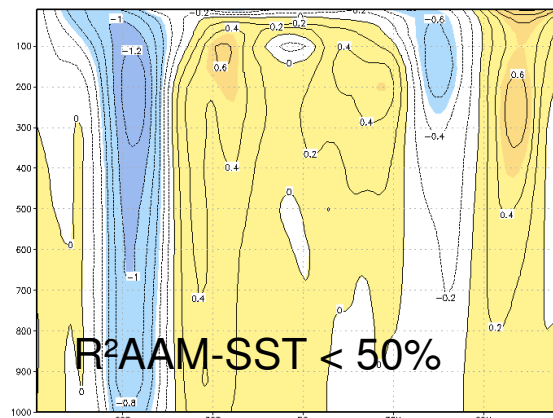
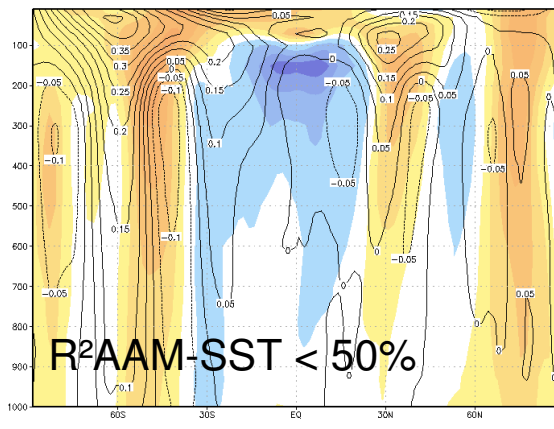
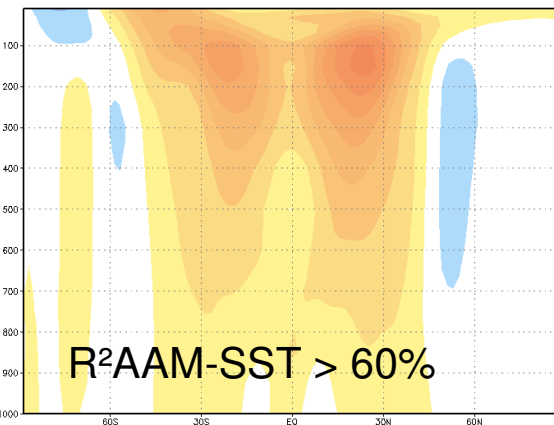
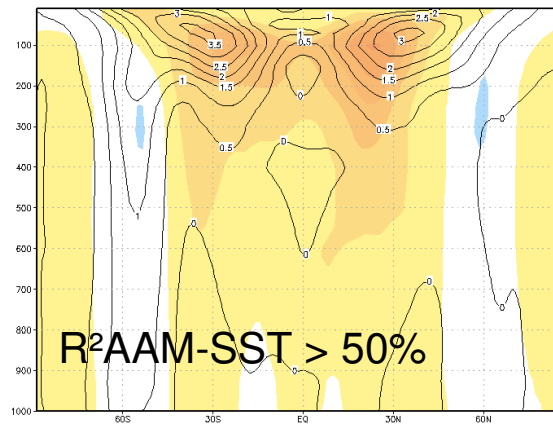
# Coupled ECHAM5-OM1 model simulations

## 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).

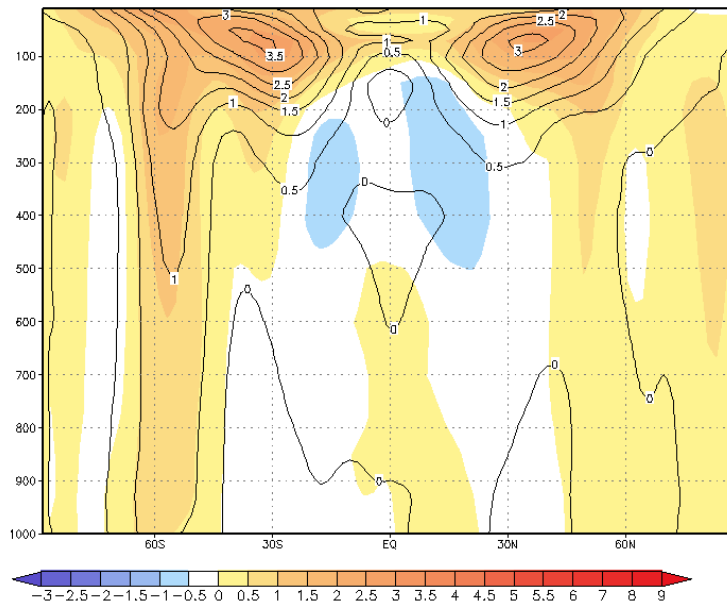
**Colors:** Zonal wind anomalies (m/s) for peak El Niño months (ONI-index > 1.4 in climate mean).

**Data: ECHAM5-OM1,** monthly means removed.

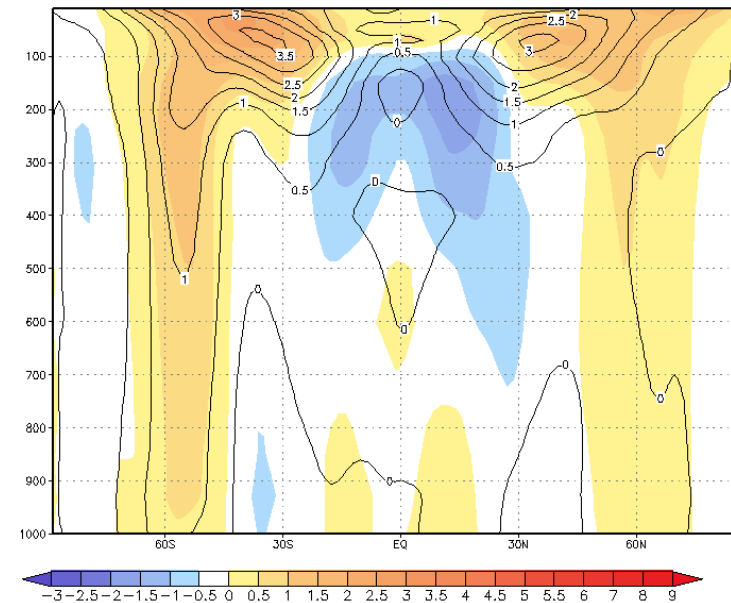
# Coupled ECHAM5-OM1 model simulations

## 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)

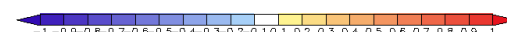
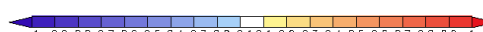
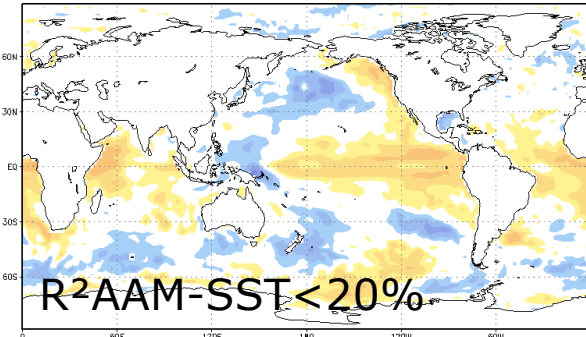
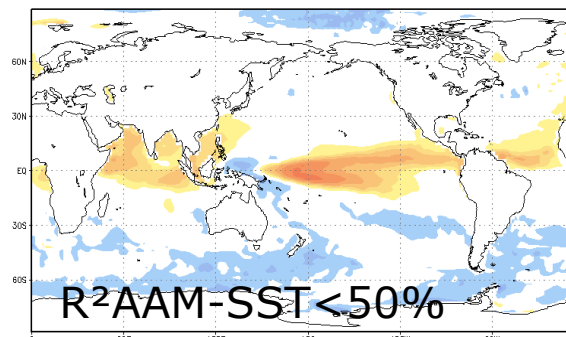
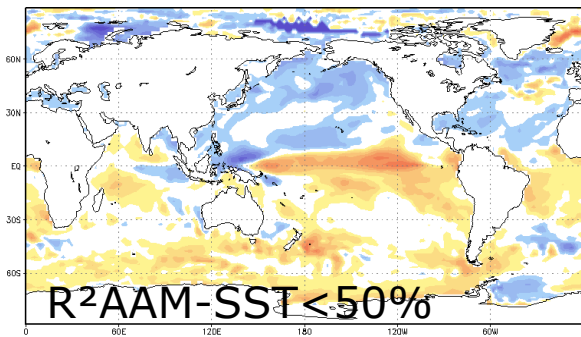
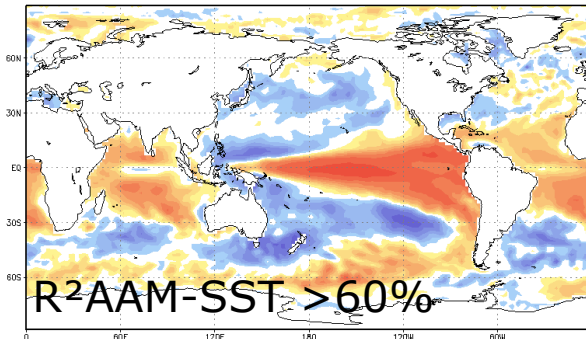
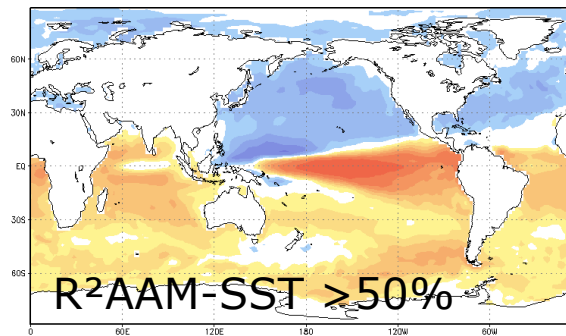
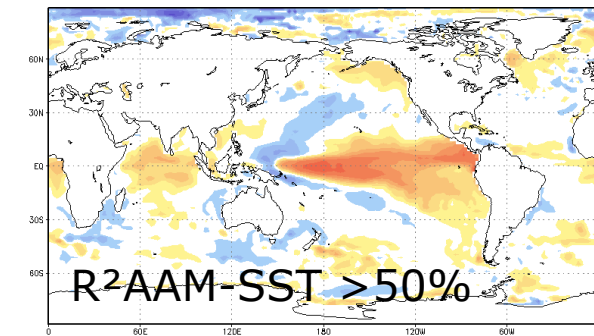
Data: Monthly means removed.

# Coupled ECHAM5-OM1 model simulations

## Climate warming in AAM-SST relation

20th century (20C)

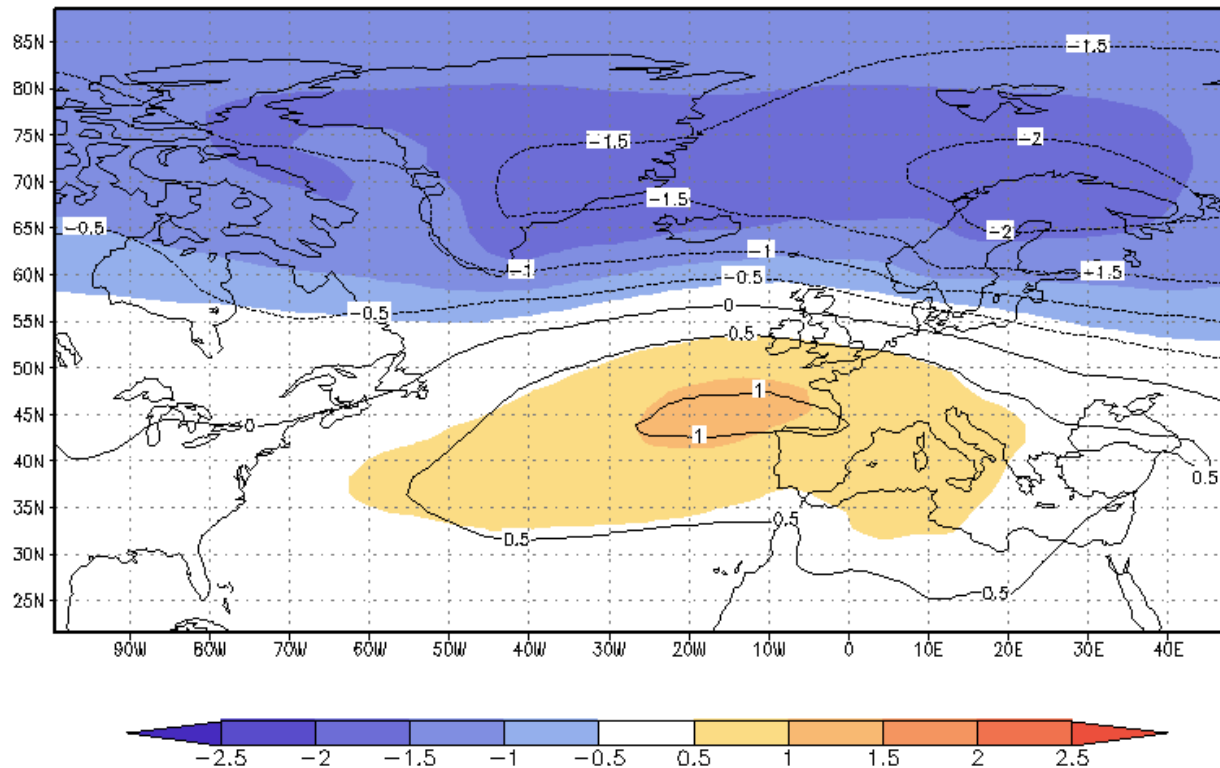
Climate warming (A1B) Climate variability (CTRL)



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)



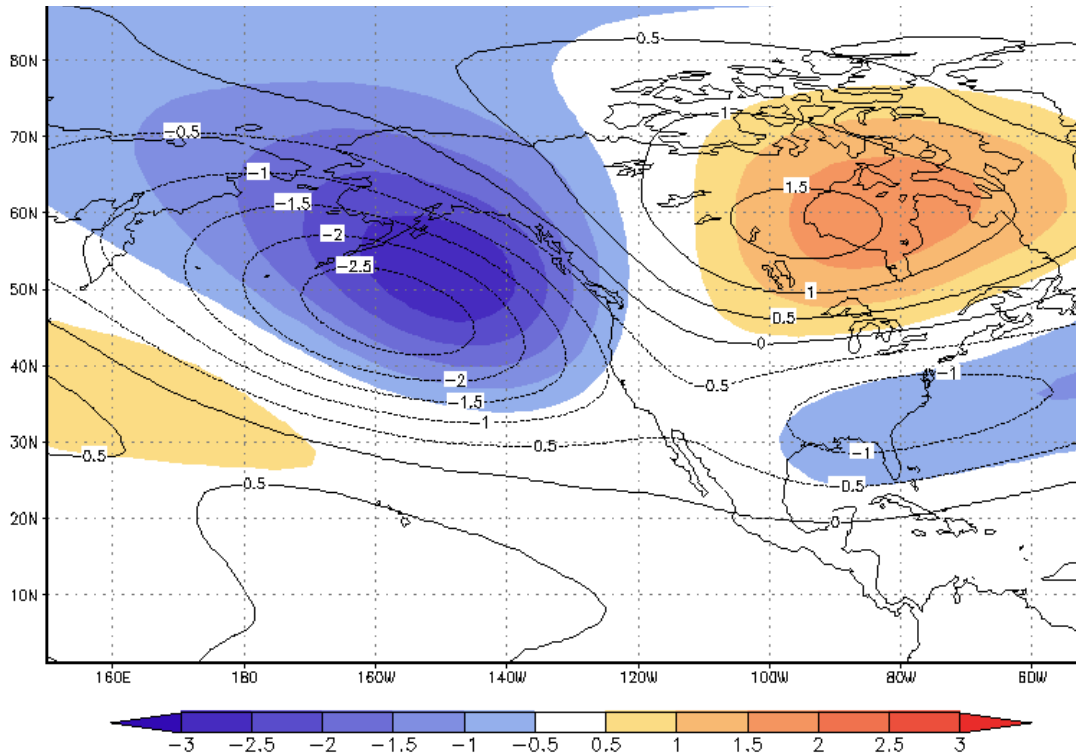
**Contours:** 1<sup>st</sup> EOF mean sea level pressure (NAO) climate mean 2071-2100.

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

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:** 1<sup>st</sup> EOF geopotential height 500 hPa (PNA) climate mean 2071-2100.

**Colors:** 1<sup>st</sup> 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.**