Where does spread come from? Initial perturbations in decadal prediction

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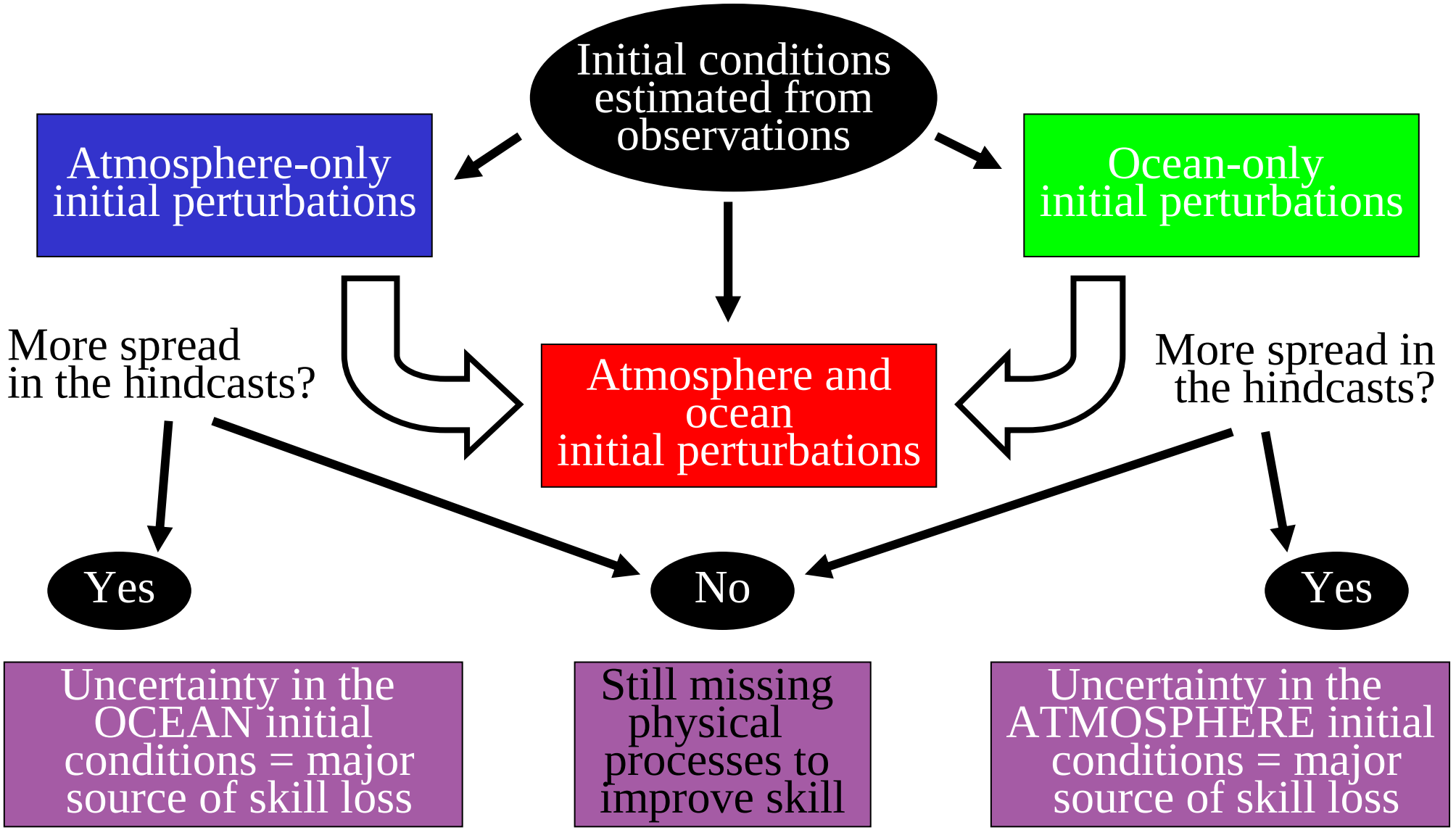
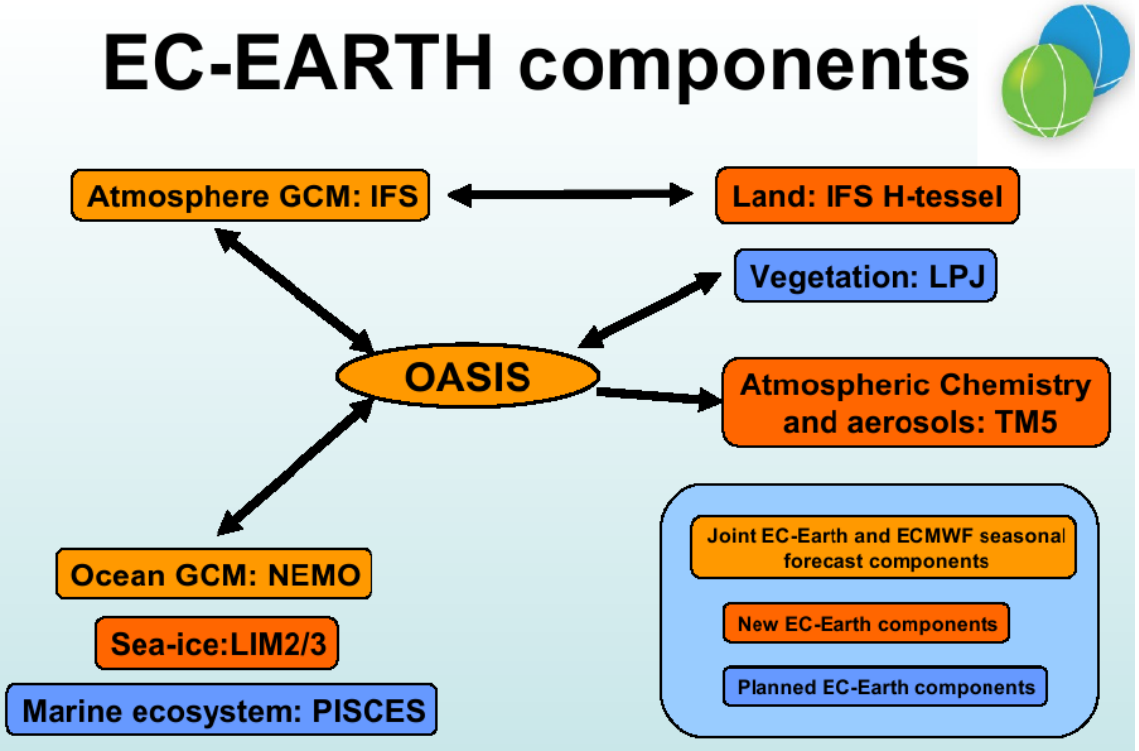
Introduction : the aim



Which tool ? EC-Earth

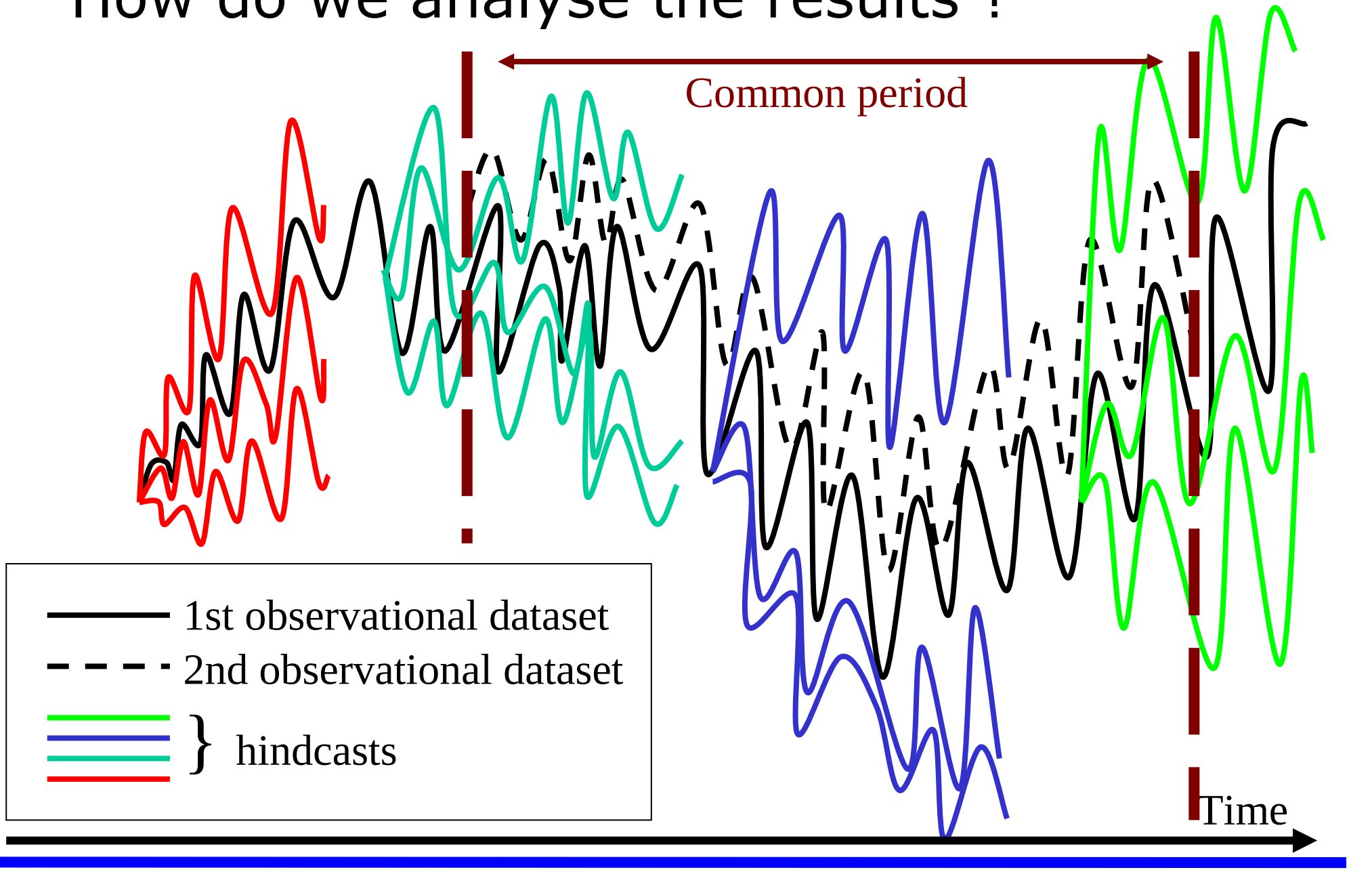
EC-Earth is an Earth System Model (ESM) with three major components: the atmosphere model IFS (ECMWF), the ocean model NEMO and coupler OASIS3.



Which experimental design ?

- Atmosphere and soil initial conditions: ERA40/ERAINT (five members, ECMWF)
- Ocean initial conditions: NEMOVAR (COMBINE, five members, ECMWF)
- Sea ice initial conditions: A single run of LIM2 forced with DFS4.3 (KNMI,SMHI)
- Three experiments are performed:
  - Atmospheric perturbation only
  - Ocean perturbation only
  - Both Atmospheric and ocean perturbation
- Simulations starting November 1 of 1960,1965,1970,1975,1980,1985,1990,1995, 2000 and 2005 with 60-month long run for each starting date.

How do we analyse the results ?



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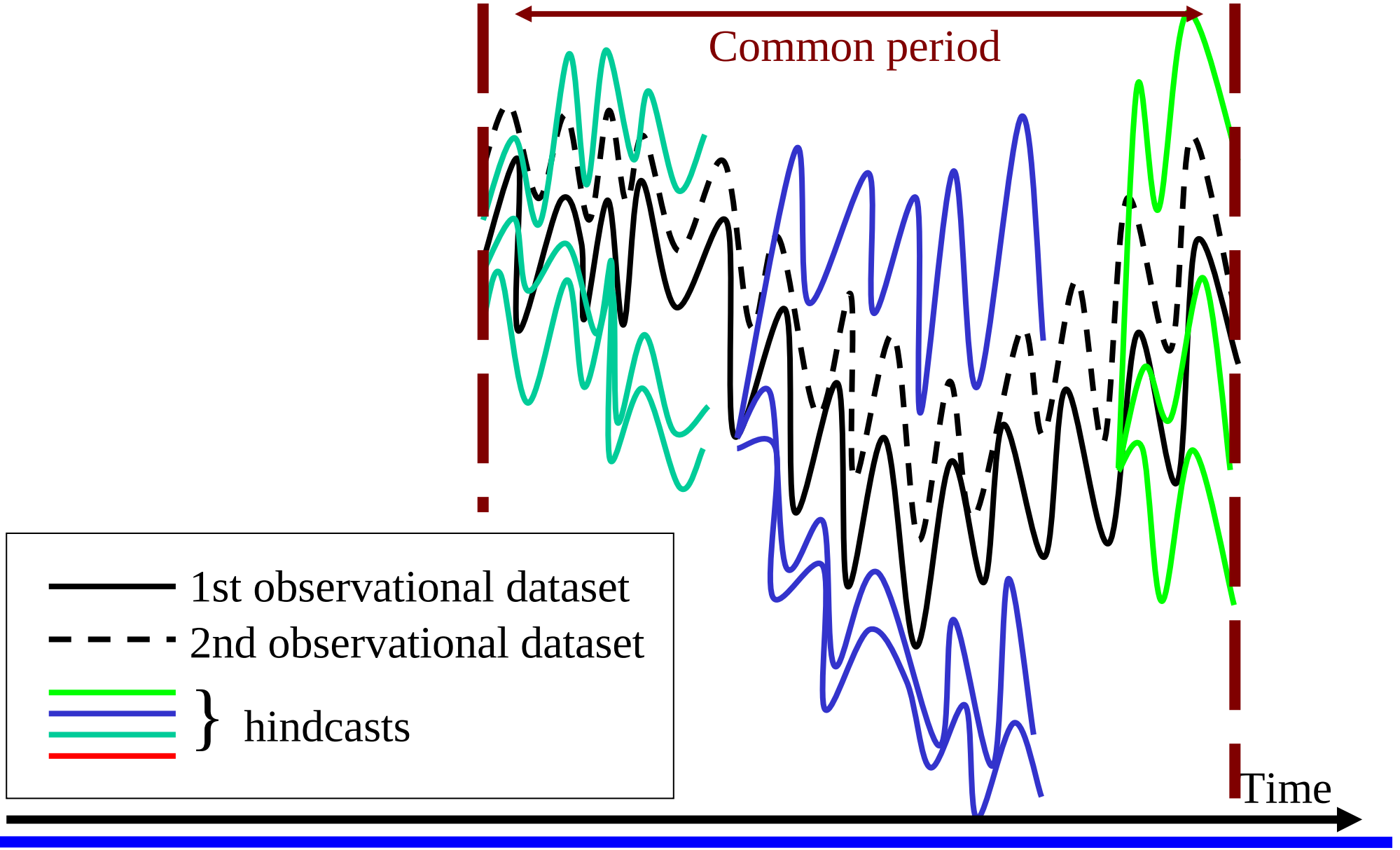

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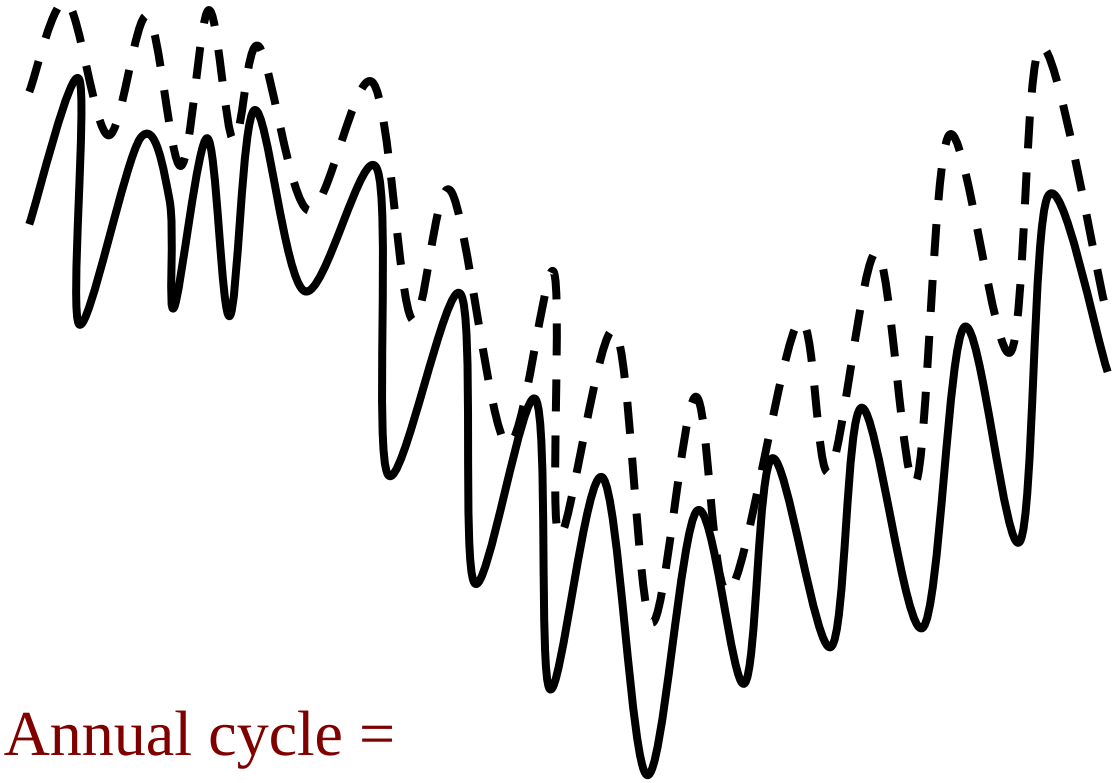
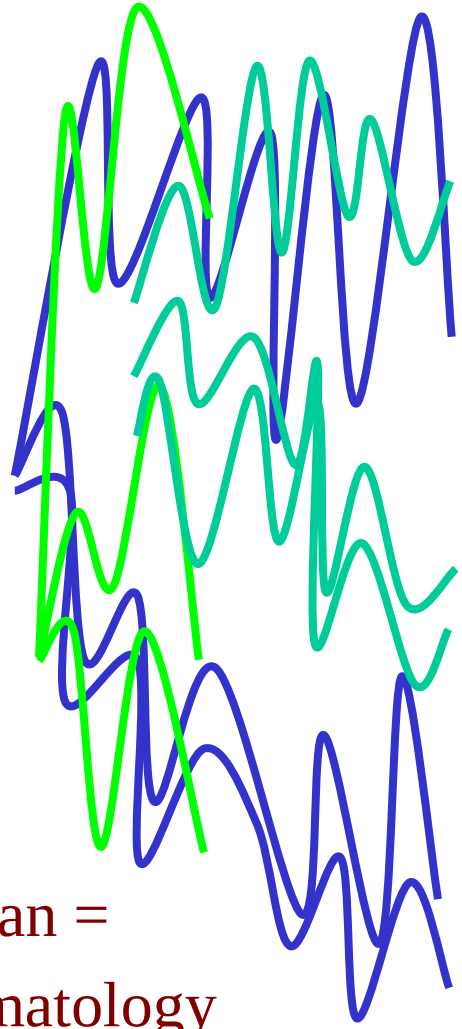


Annual cycle =

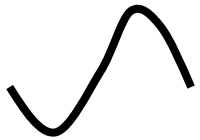
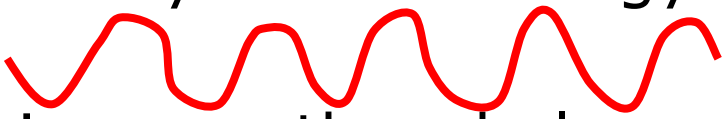
climatology
of the observations/reanalyses



Mean =

climatology
of the hindcasts

How do we analyse the results ?

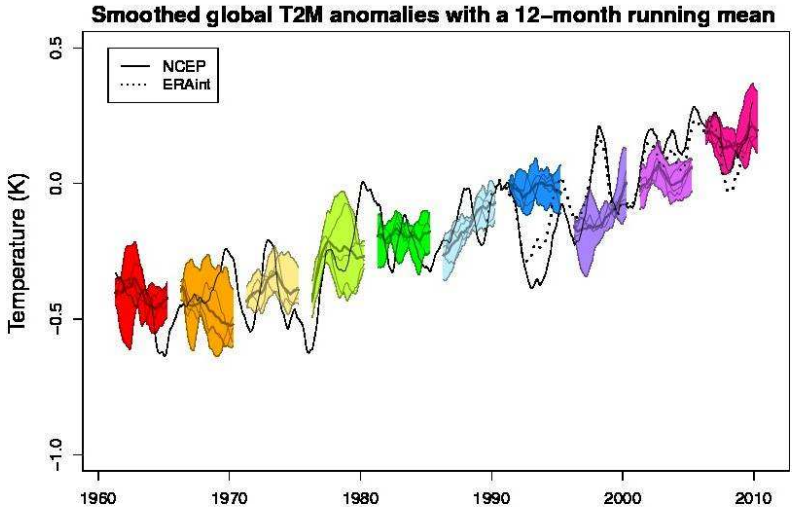
Observations/reanalyses climatology  and hindcasts climatology  are removed from the raw time-series over the whole period, not only the common one for :

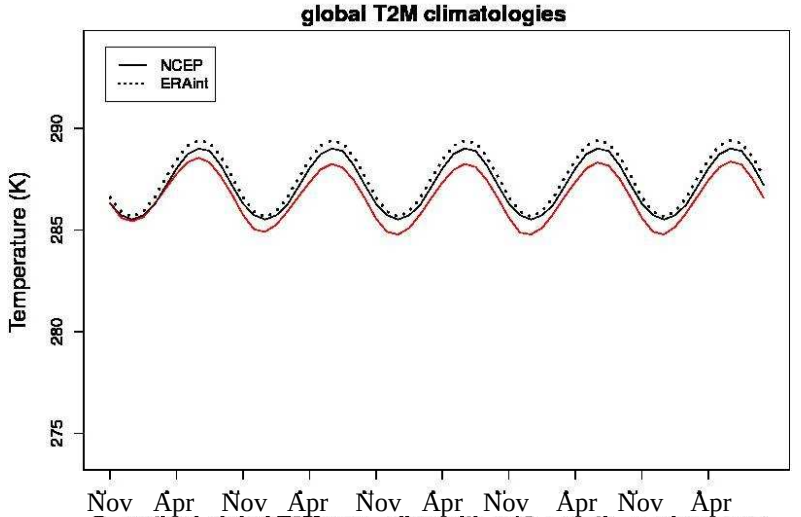
1) Two-meter temperature
2) Sea surface temperature
3) Sea ice area (Arctic/Antarctic)
4) Global ocean heat content (0-315m, 373-657m, 800m-bottom)
5) Atlantic Meridional Overturning Circulation maximum and latitude of this maximum

Two-metre air temperature

Global-mean temperature for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

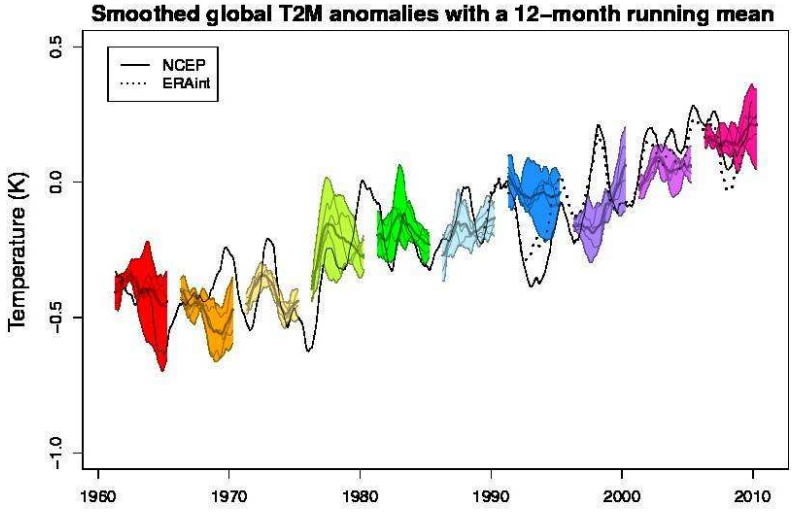
Atmosphere and ocean perturbations

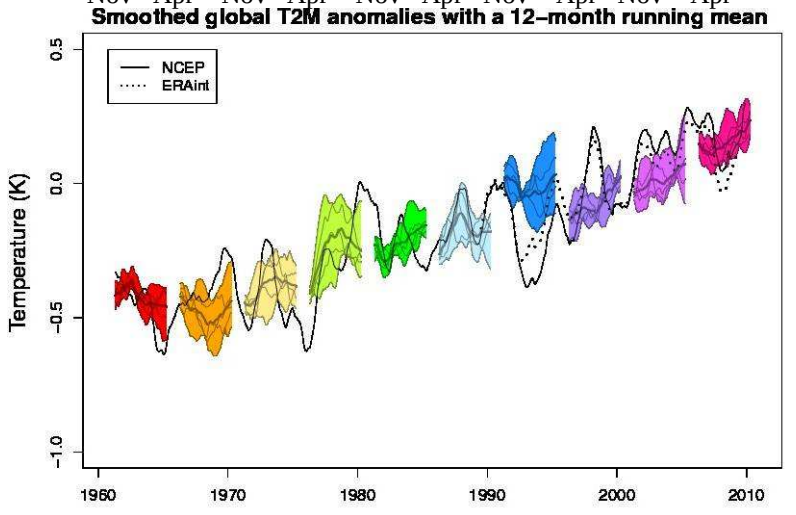




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

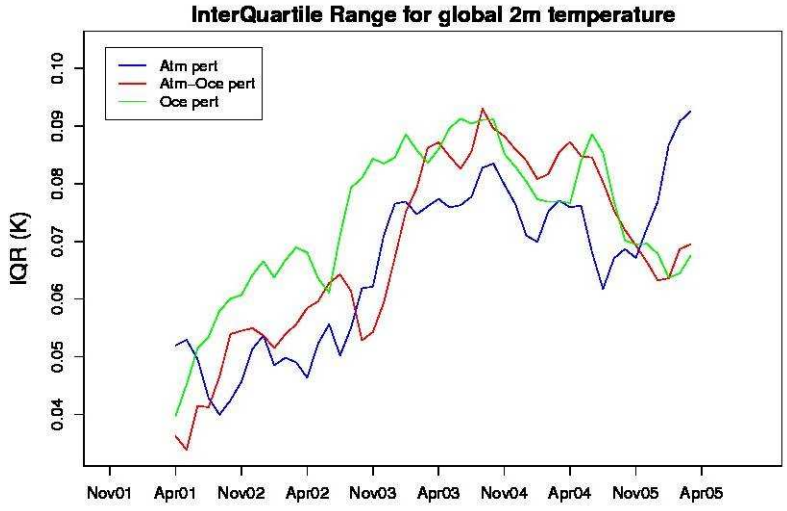


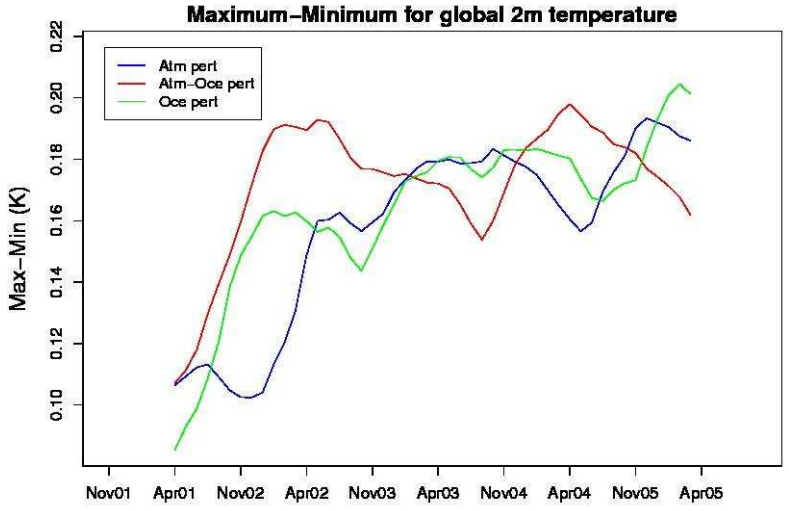


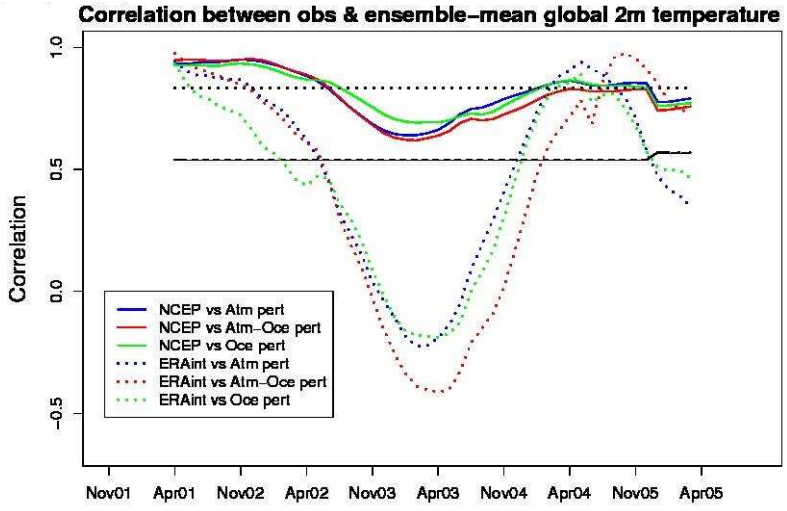
Ocean only perturbations

Two-metre air temperature

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations of smoothed anomalies with reanalyses



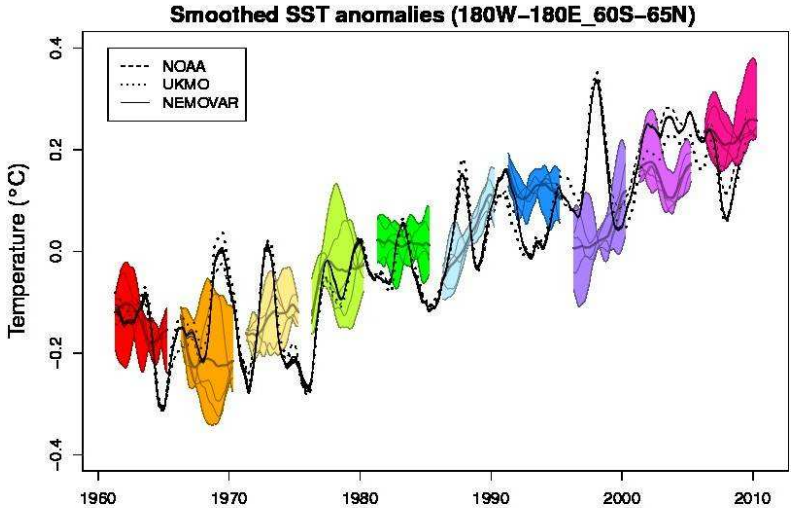


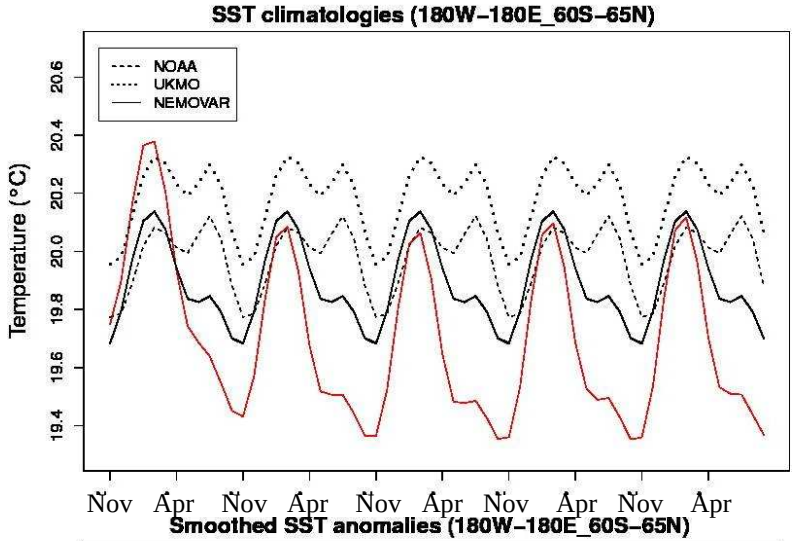


Sea Surface Temperatures

60°S-65°N global temperature for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

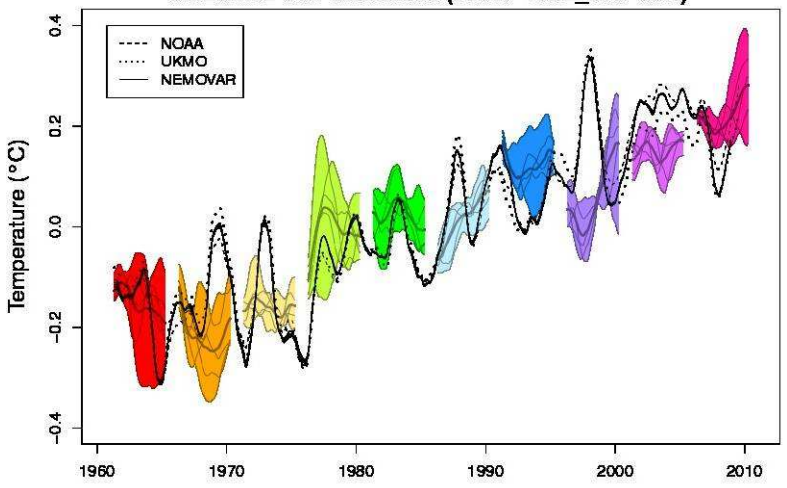
Atmosphere and ocean perturbations

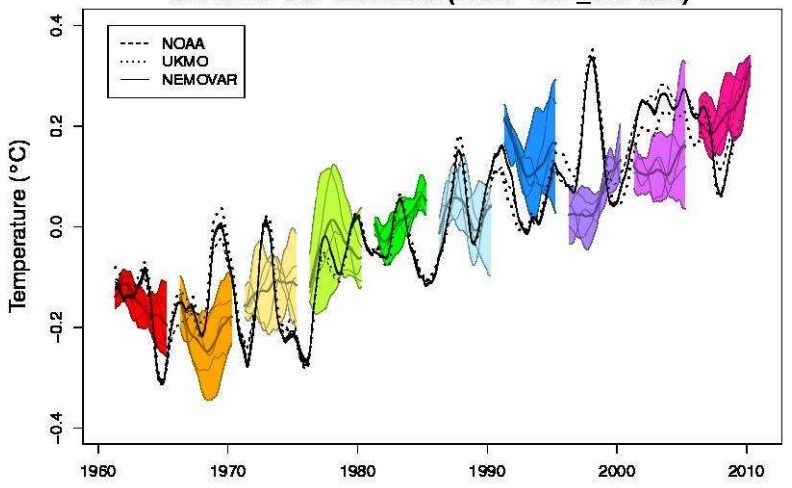




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations



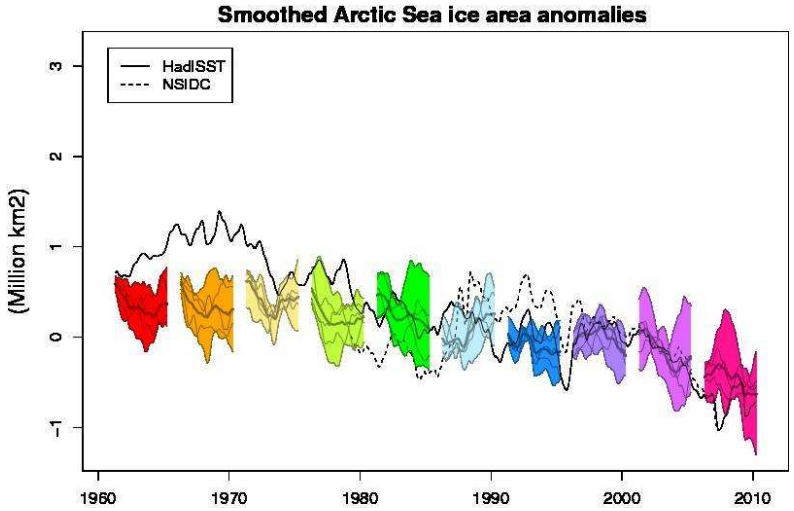


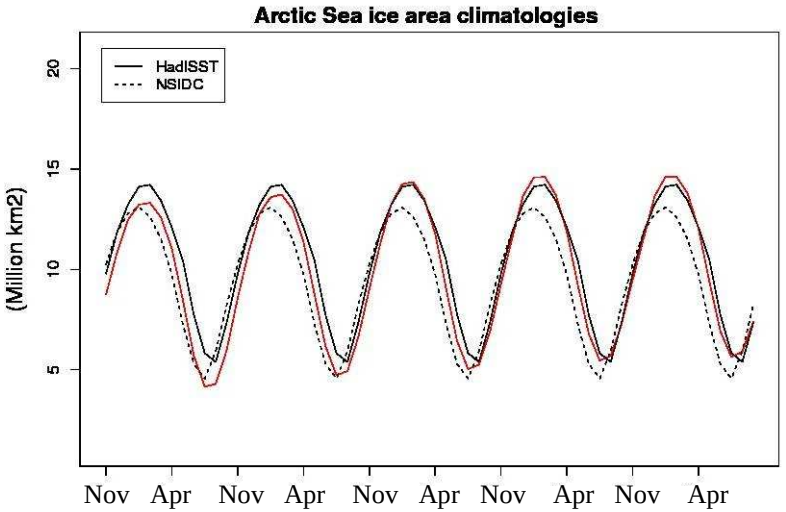
Ocean only perturbations

Arctic Sea ice area

Arctic sea ice area for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

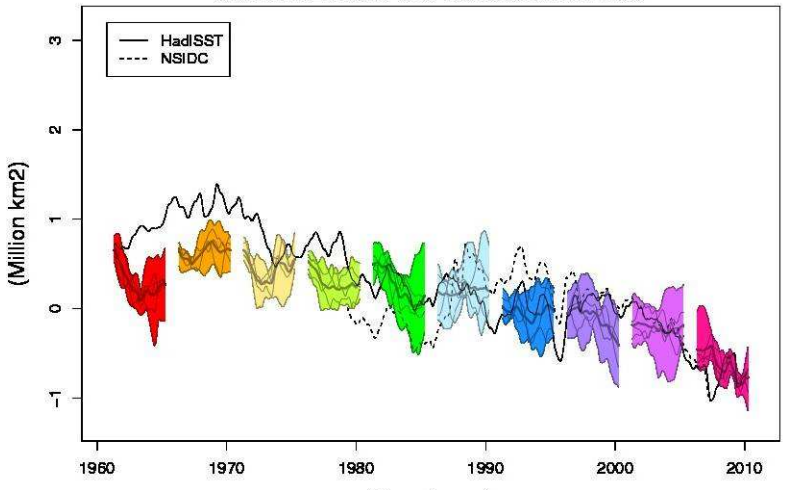
Atmosphere and ocean perturbations

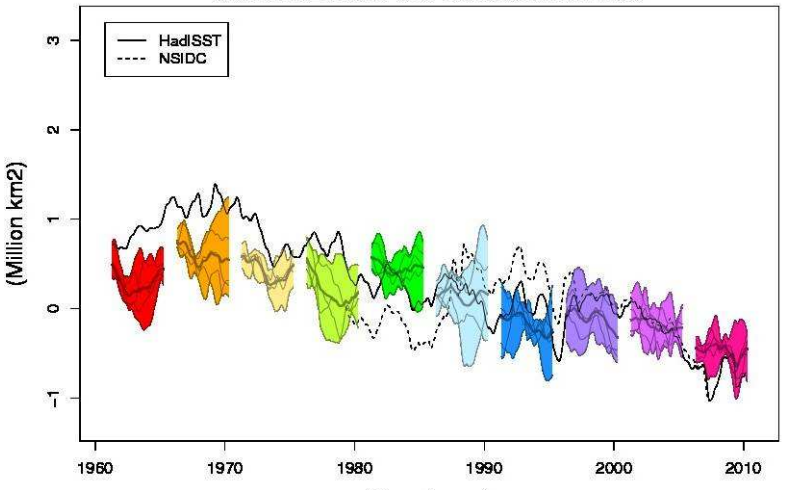




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations



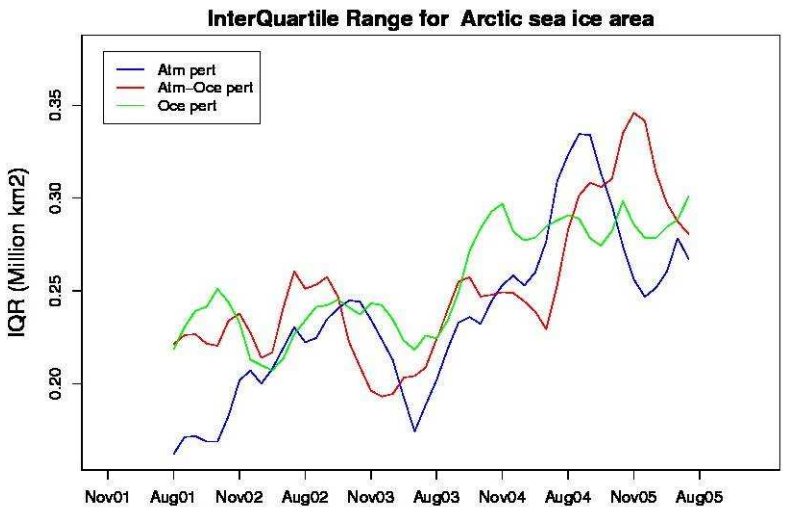


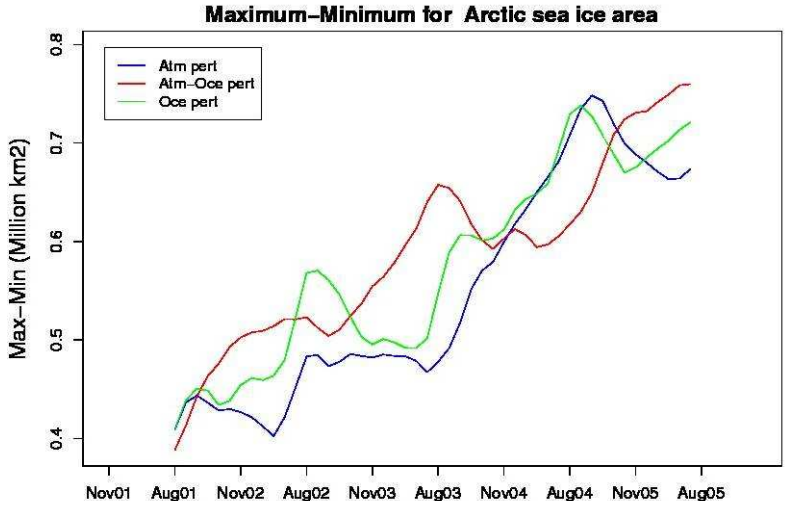
Ocean only perturbations

Arctic/Antarctic sea ice area

Average over the 10 starting dates of the interquartile range/ Maximum-minimum of smoothed anomalies

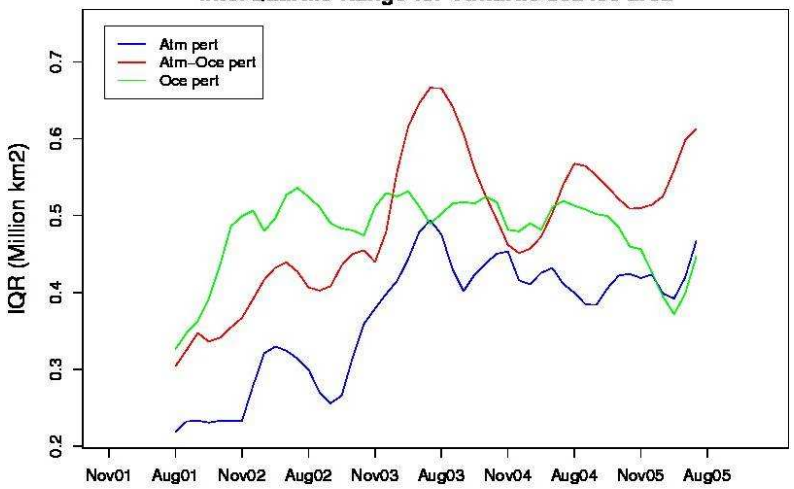
Arctic sea ice area

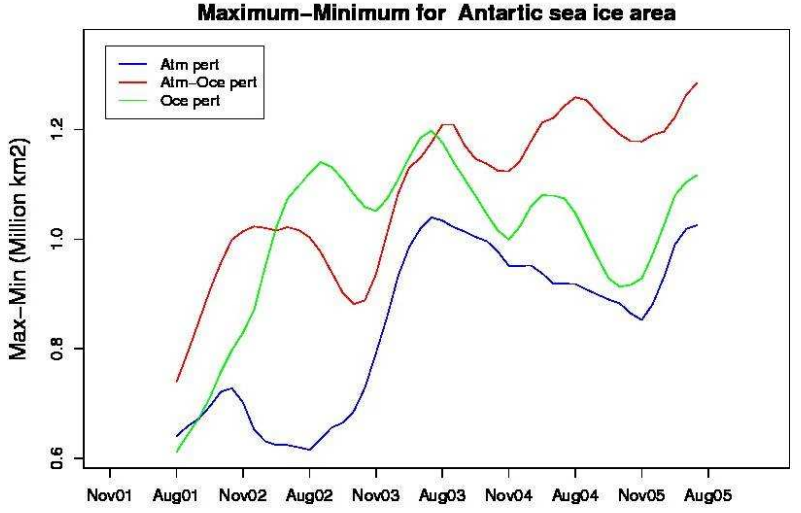




Arctic sea ice area

Antarctic sea ice area



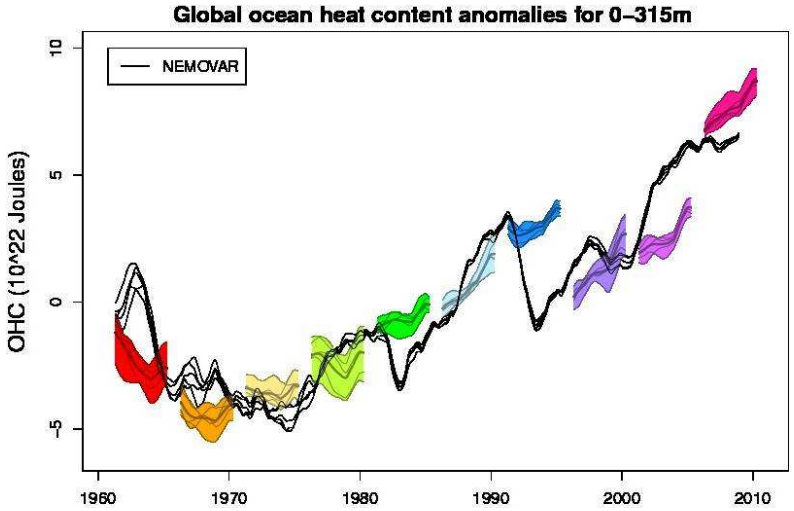


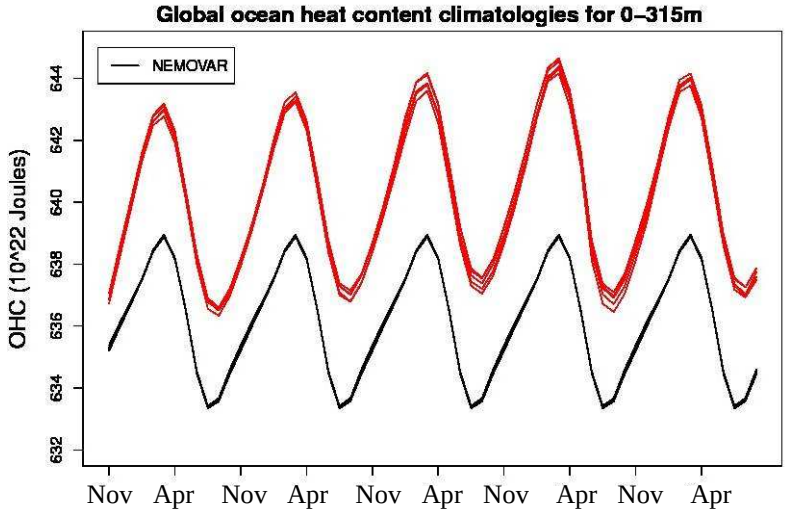
Antarctic sea ice area

Global ocean heat content 0-315m

Global-mean 0-315m OHC for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

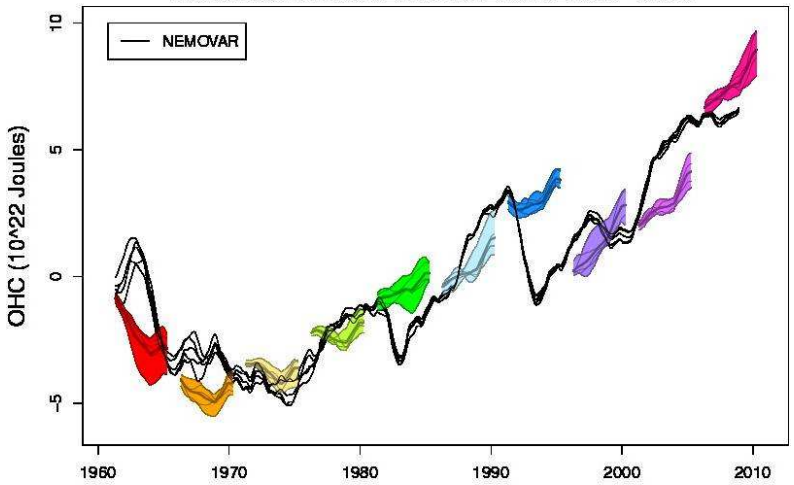
Atmosphere and ocean perturbations

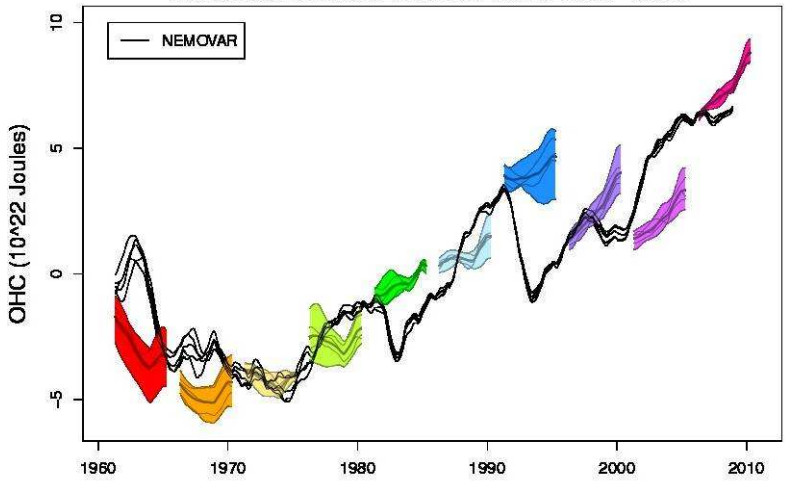




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations



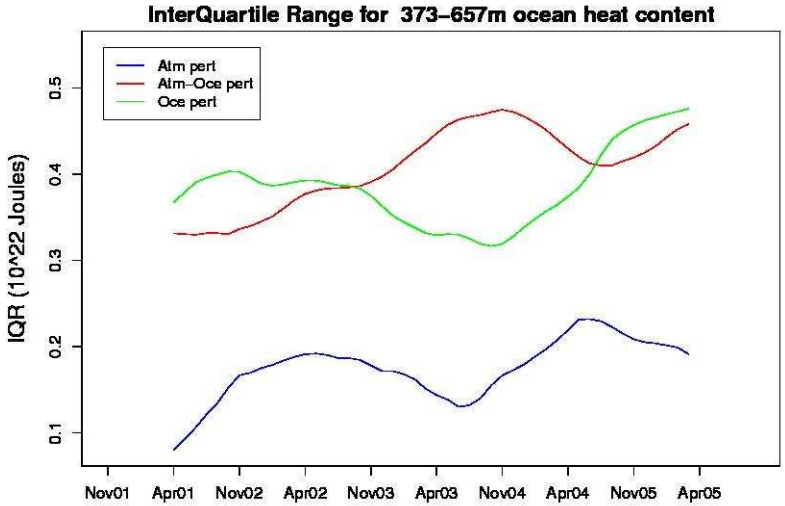


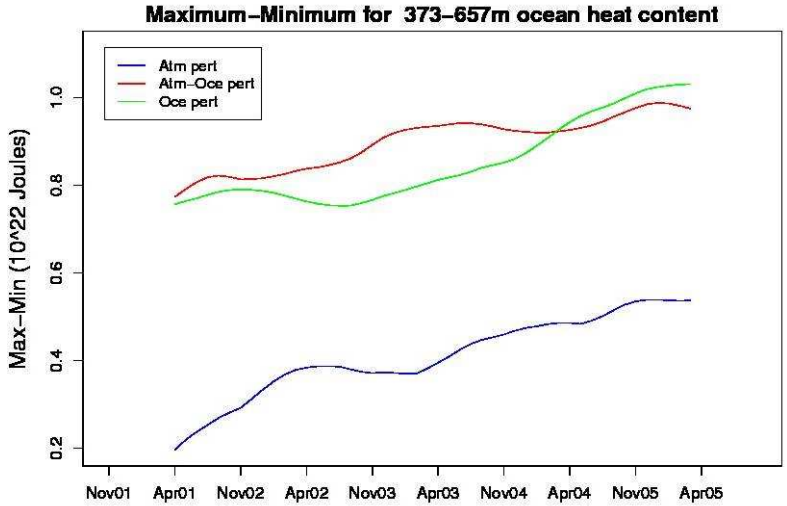
Ocean only perturbations

Global ocean heat content 373m-bottom

Average over the 10 starting dates of the interquartile range/ Maximum-minimum of smoothed anomalies

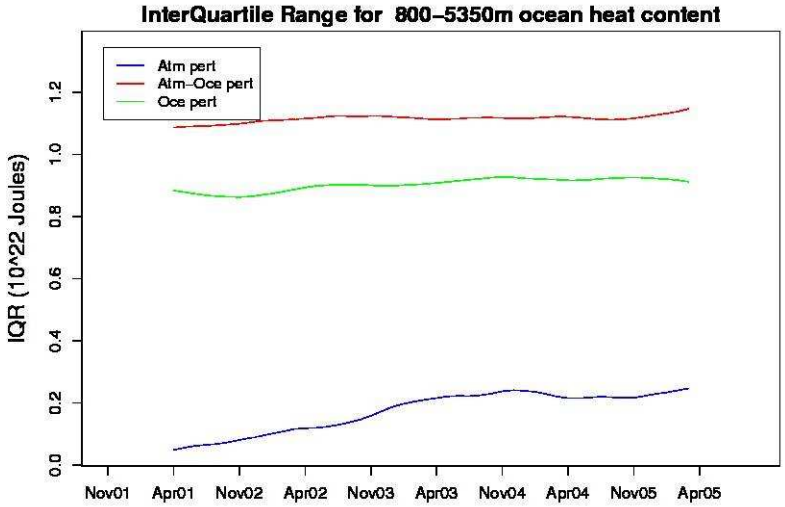
373-657m layer

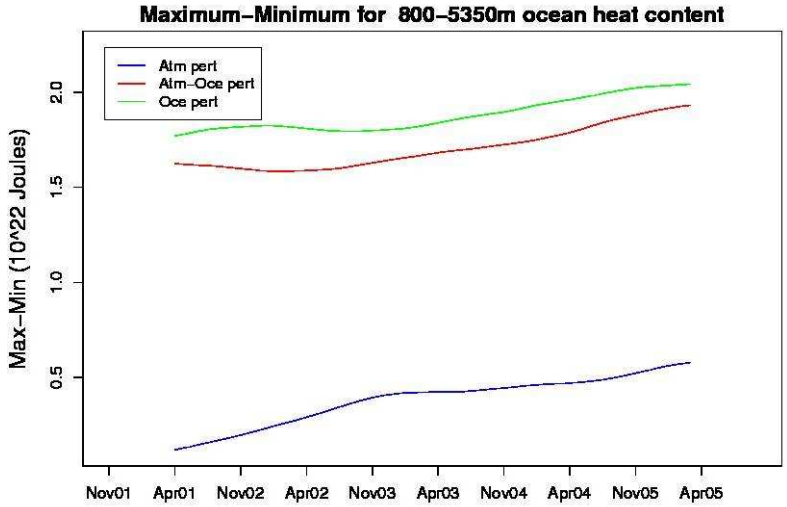




373-657m layer

800-5350m layer



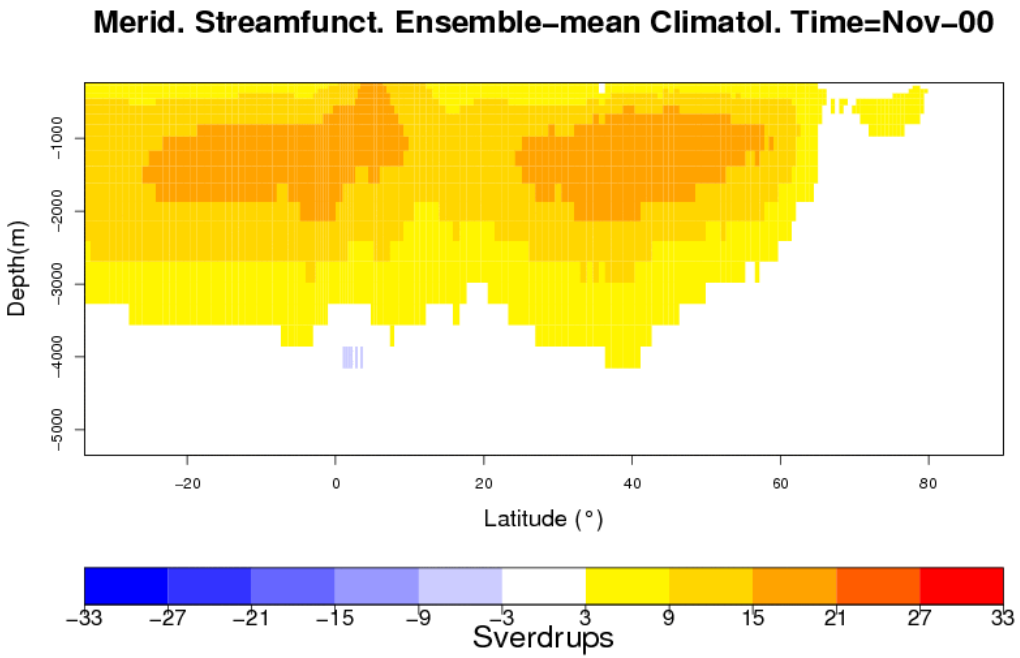


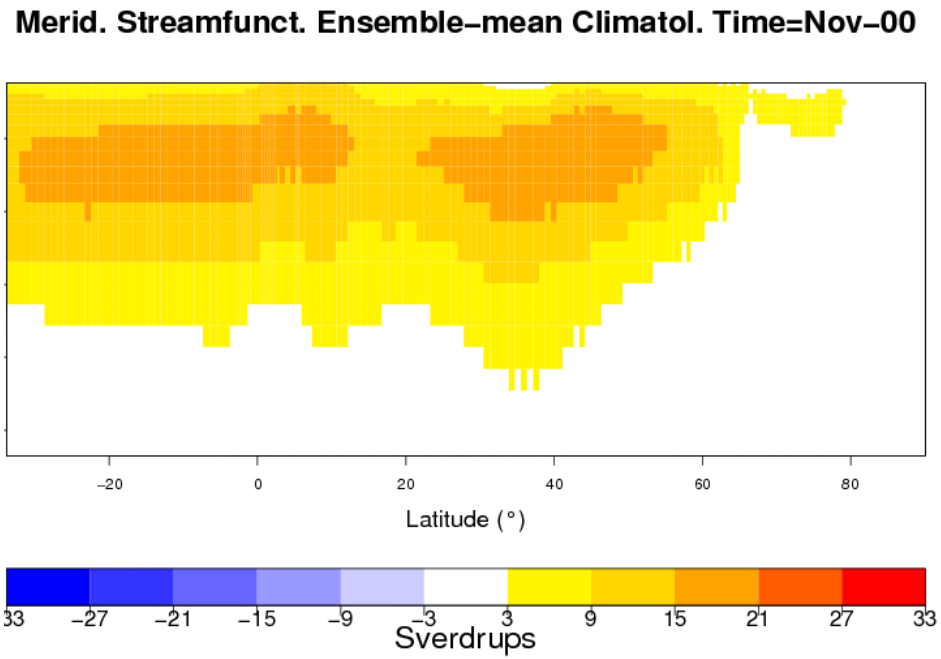
800m-5350m layer

Atlantic Meridional Overturning Circulation
ensemble-mean climatologies : 250m-bottom

Atmosphere and ocean perturbations

NEMOVAR





Conclusions

1) **Two-metre temperature and SST :** cool bias + better consistency model/reanalysis in 1st half of 20th century + more spread in year 1-3 (1-2) if ocean perturbations

2) **Sea ice cover :** more spread if ocean perturbations especially in the Antarctic

3) **Global ocean heat content :** warm bias in the upper layer, cold one in the deep ocean + more spread if ocean perturbations especially in the deep layers + bad consistency with reanalysis

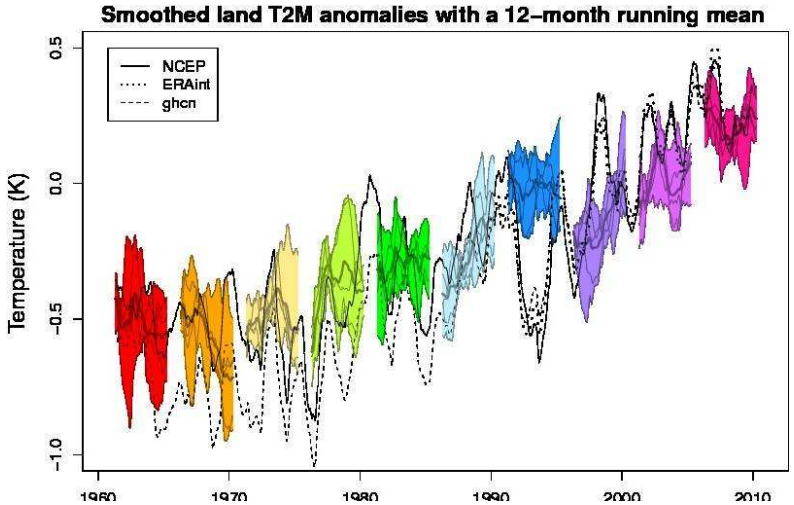
4) **Maximum of the AMOC :** slightly higher than NEMOVAR reanalysis, late summer maximum more pronounced + spread roughly the same in the 3 experiments + bad consistency with reanalysis

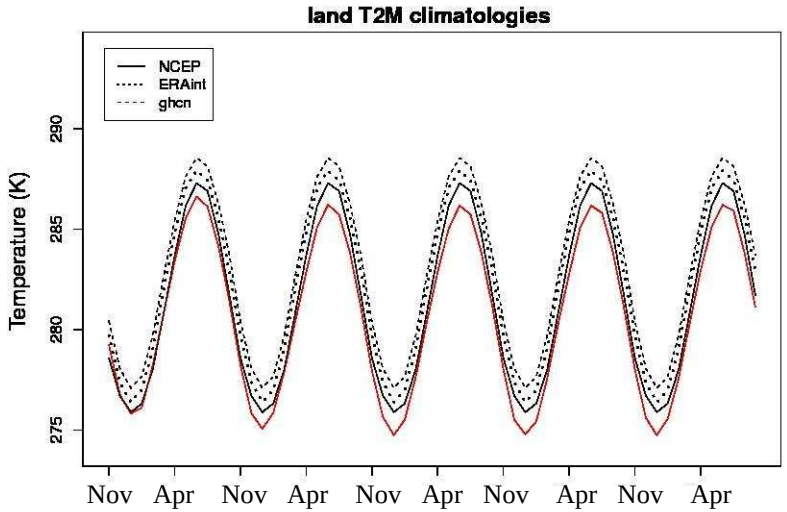
Thank you for your attention !

Land two-metre temperature

Land-only temperature for EC-Earth v2.2 (pre-SO4 fix).
Anomalies smoothed out with 12-month running mean.

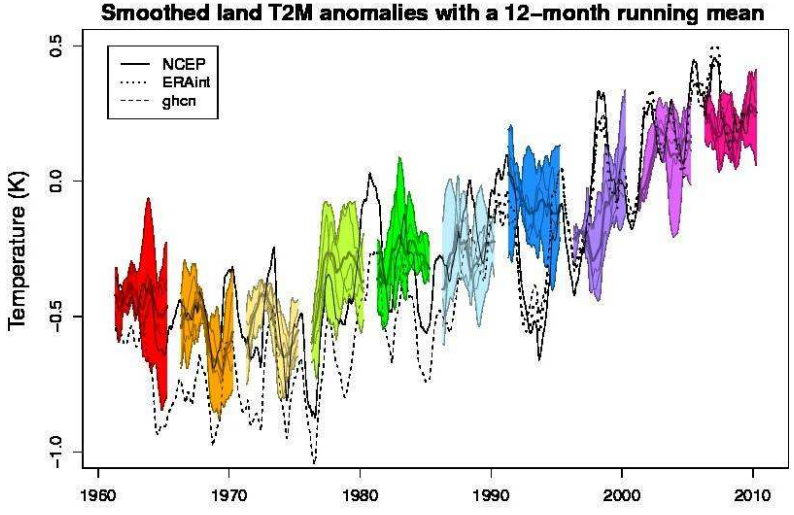
Atmosphere and ocean perturbations

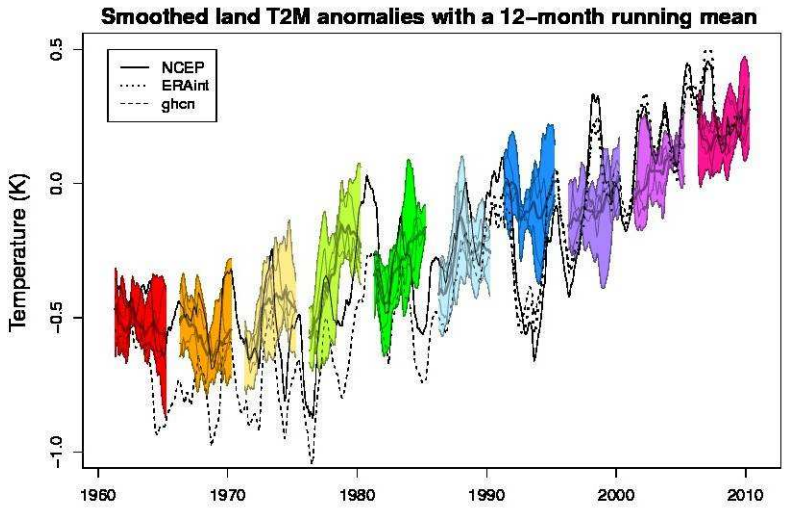




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

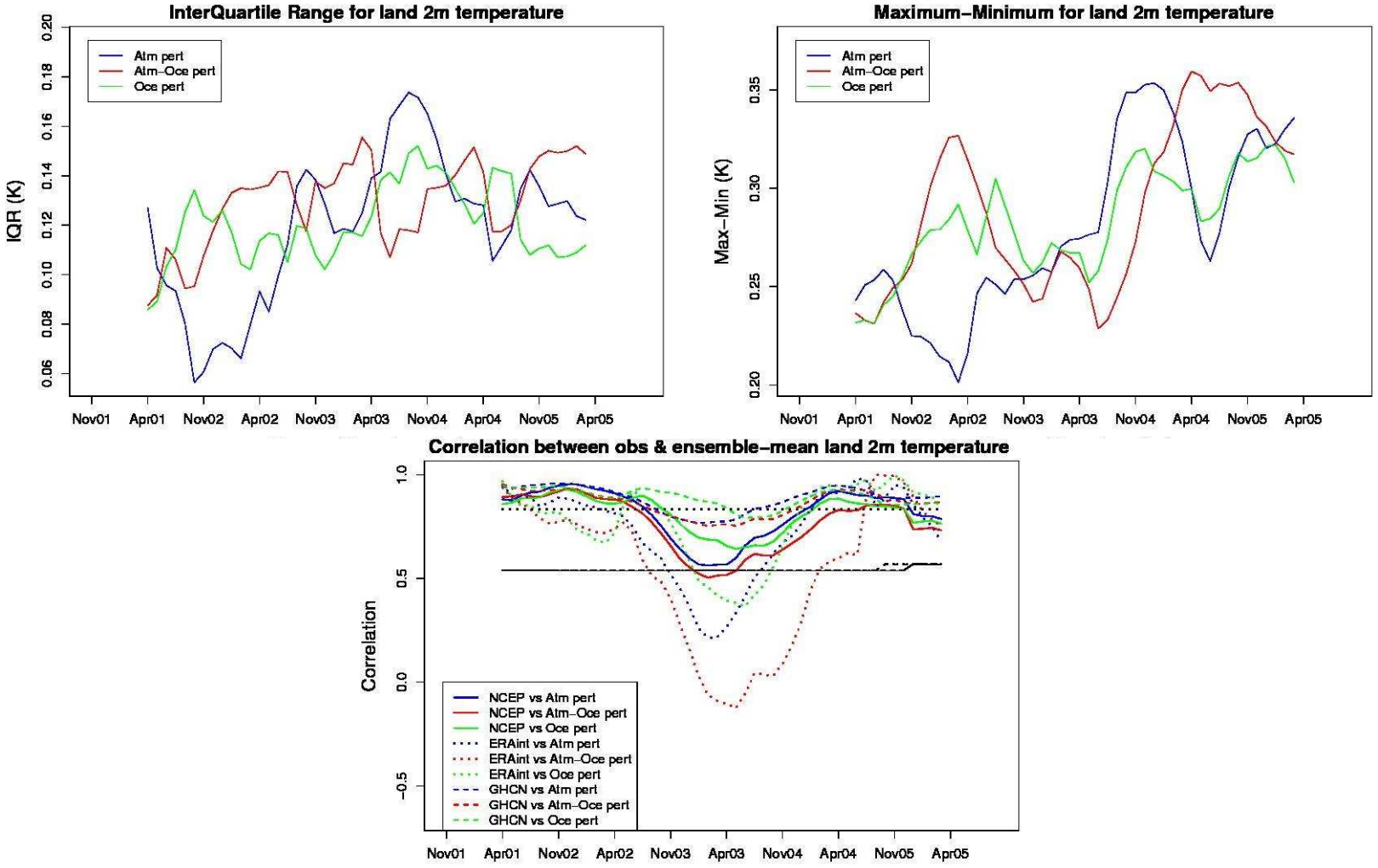




Ocean only perturbations

Land two-metre temperature

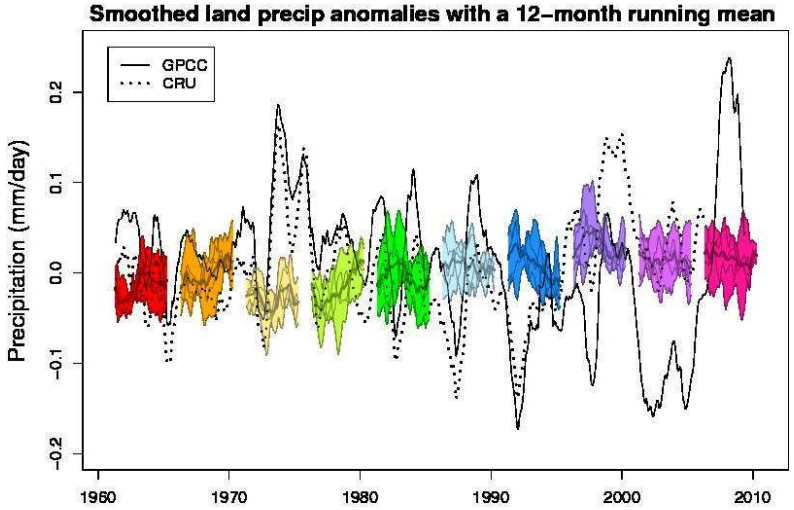
Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies

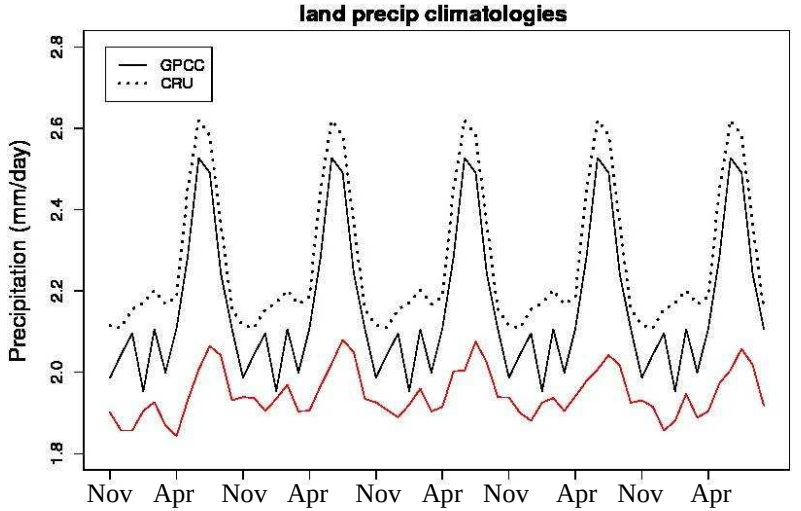


Land-only precipitation

Land-only precipitation for EC-Earth v2.2 (pre-SO4 fix).
Anomalies smoothed out with 12-month running mean.

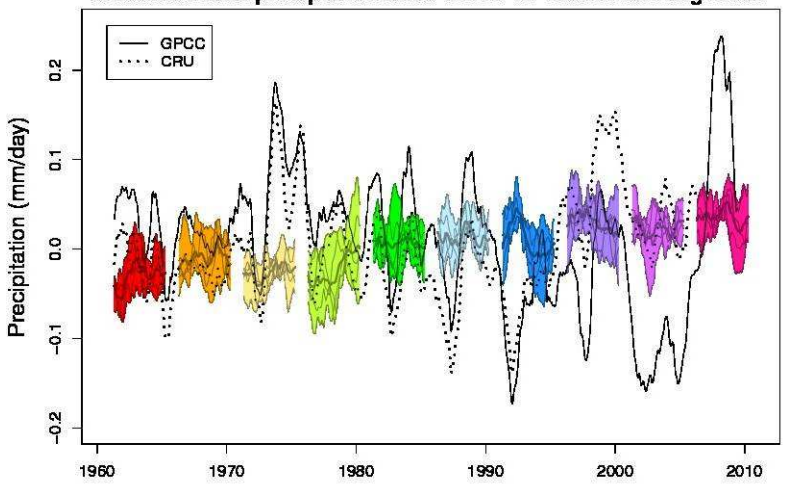
Atmosphere and ocean perturbations

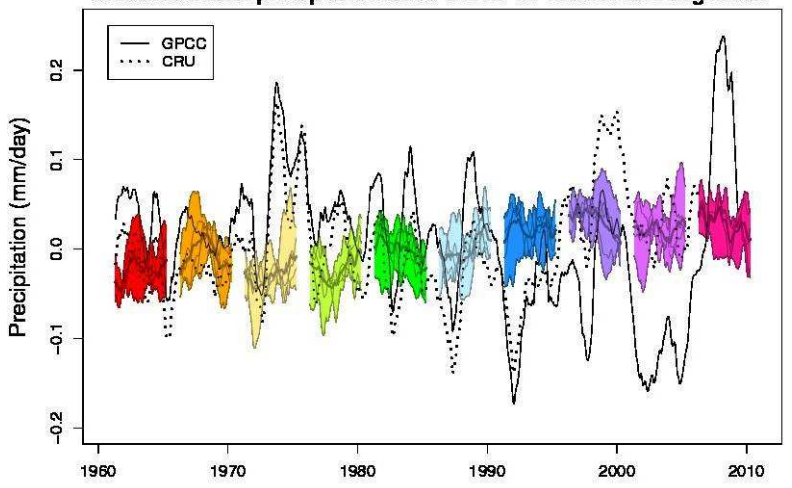




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

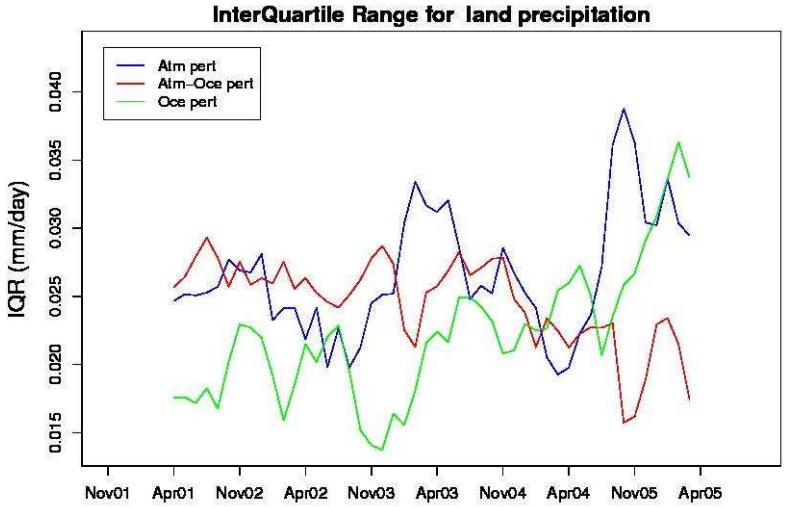


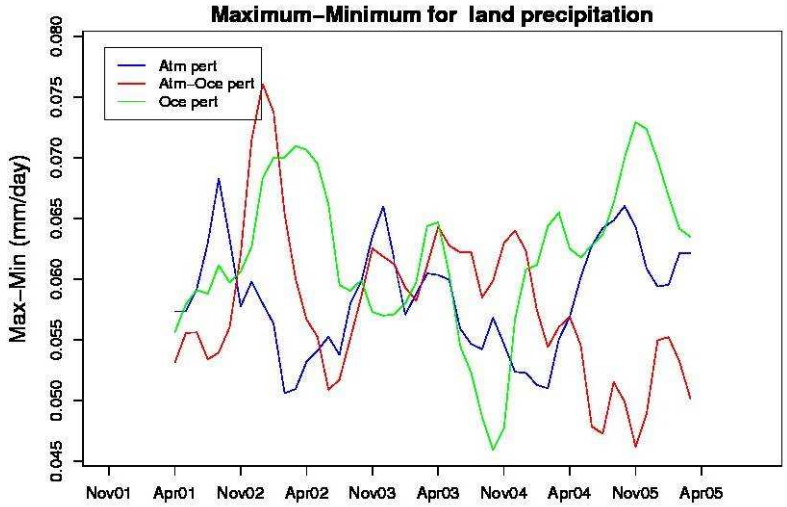


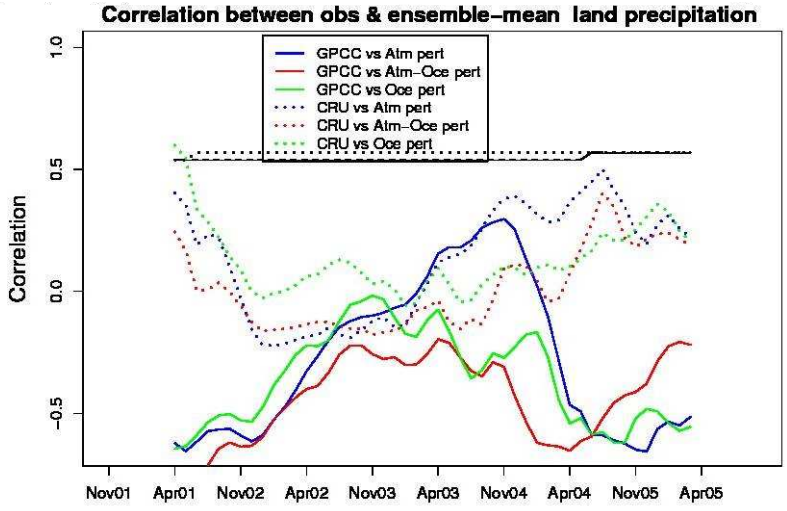
Ocean only perturbations

Land-only precipitation

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with observation of smoothed anomalies

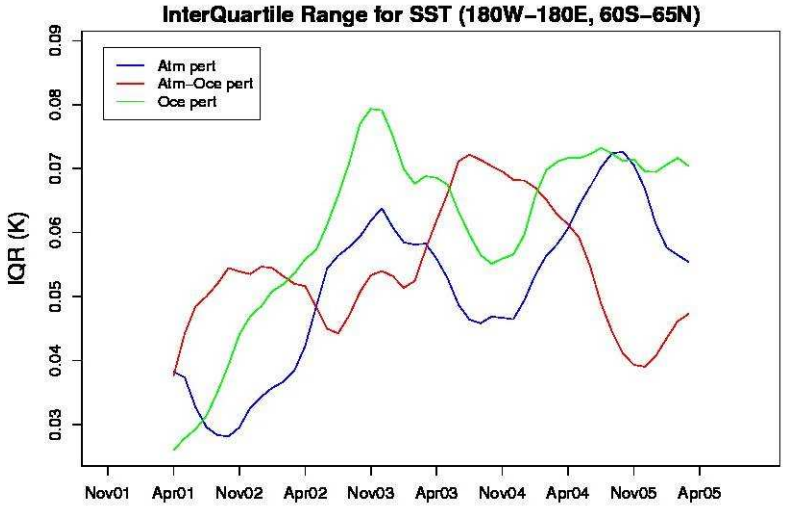


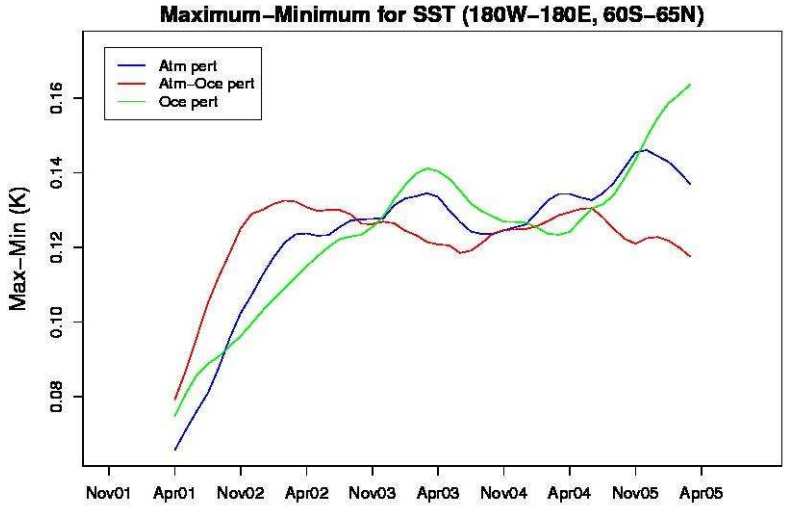


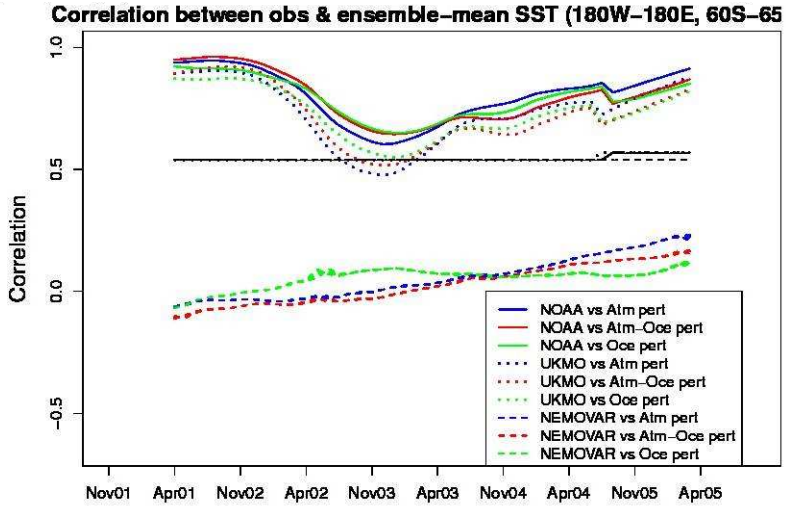


Sea Surface Temperatures

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with obs/reanal of smoothed anomalies

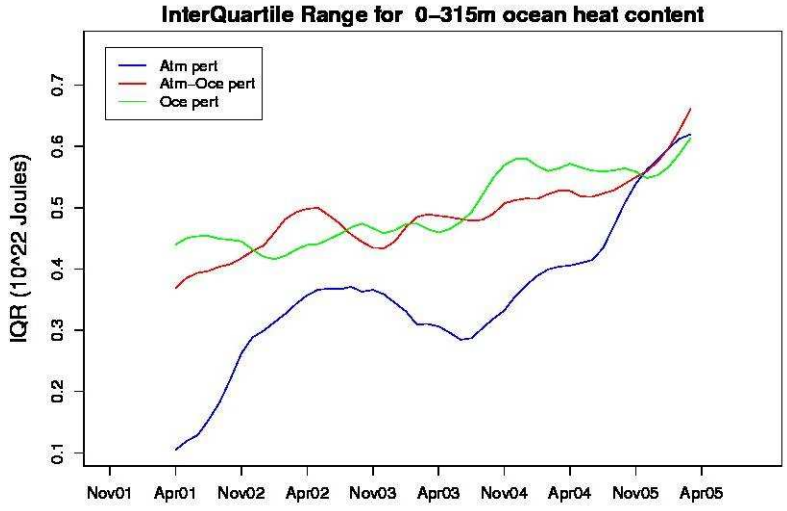


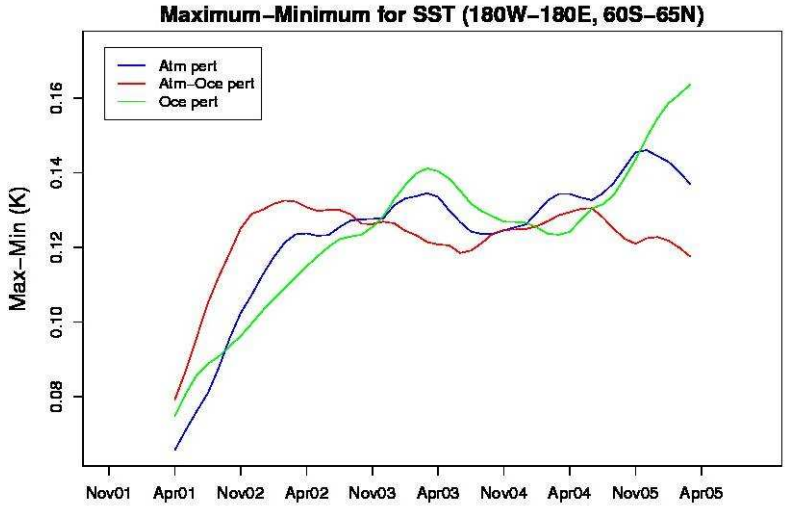


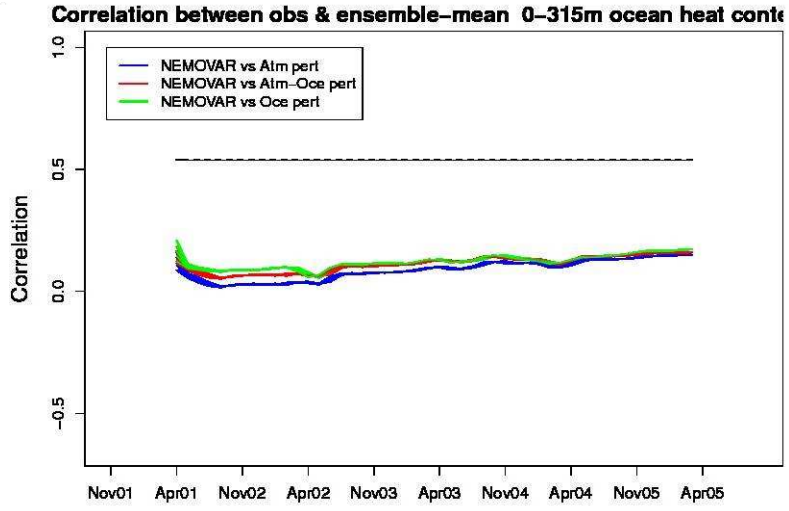


Global ocean heat content 0-315m

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations of smoothed anomalies with reanalyses



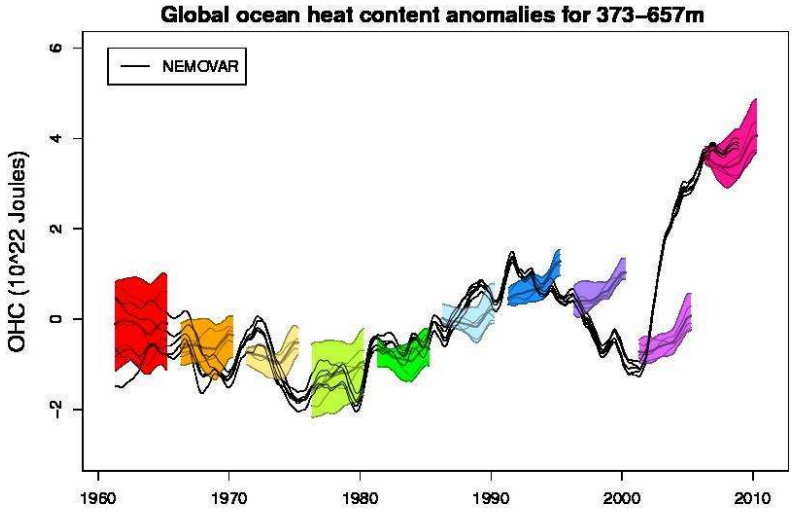


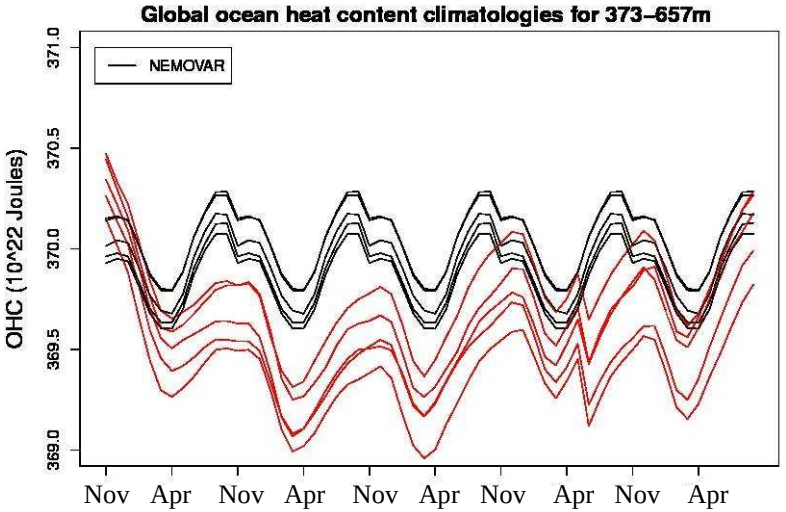


Global ocean heat content 373-657m

Global-mean 371-657m OHC for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

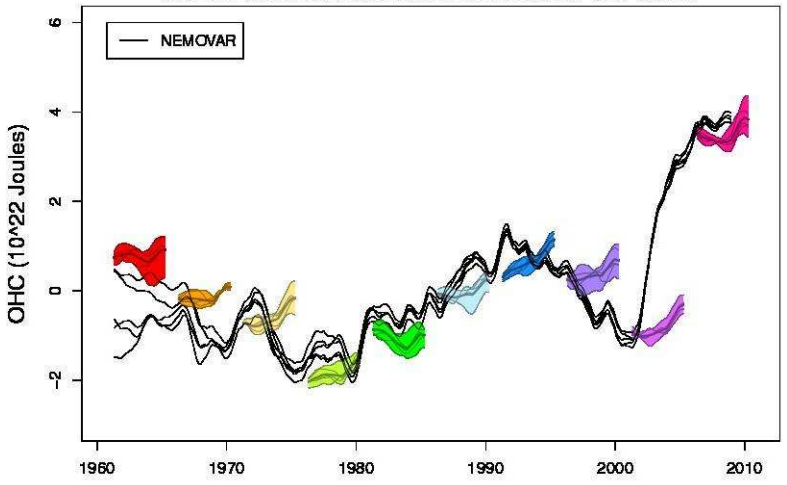
Atmosphere and ocean perturbations

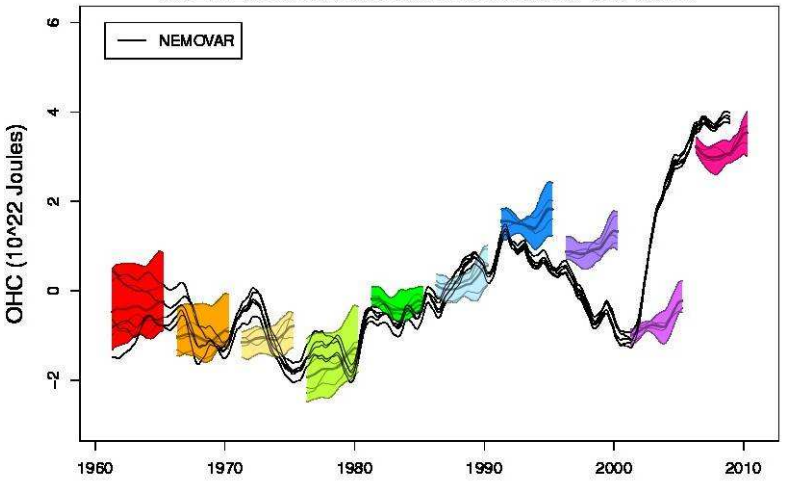




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

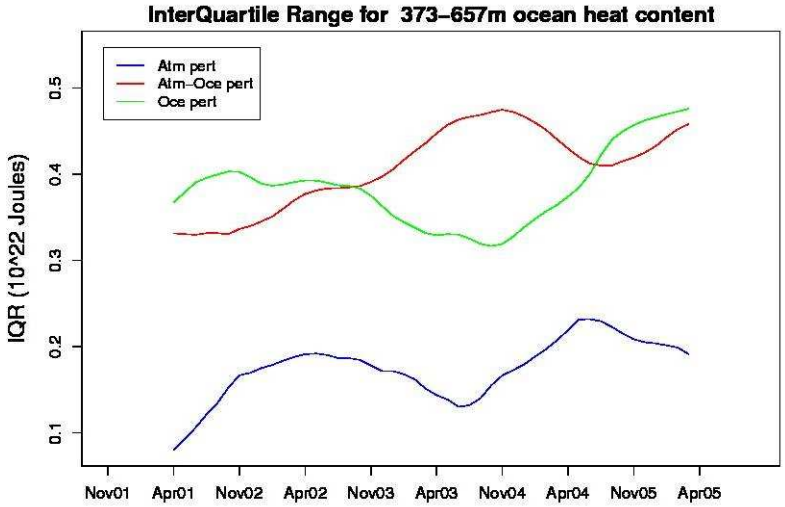


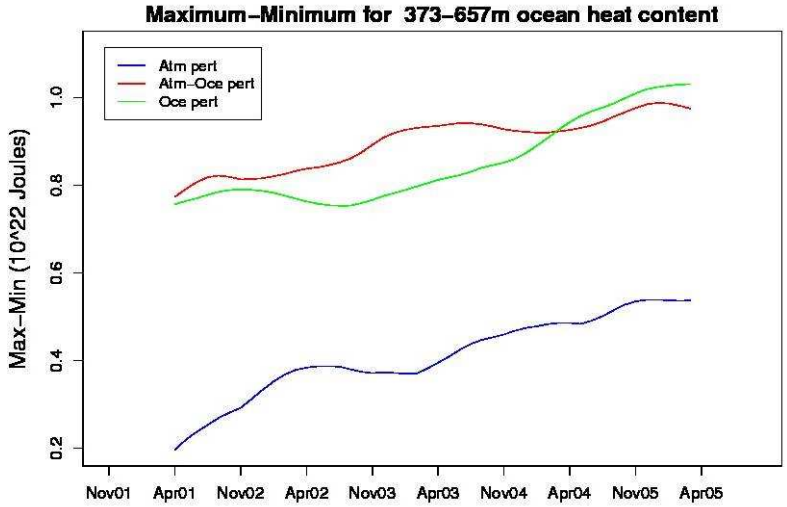


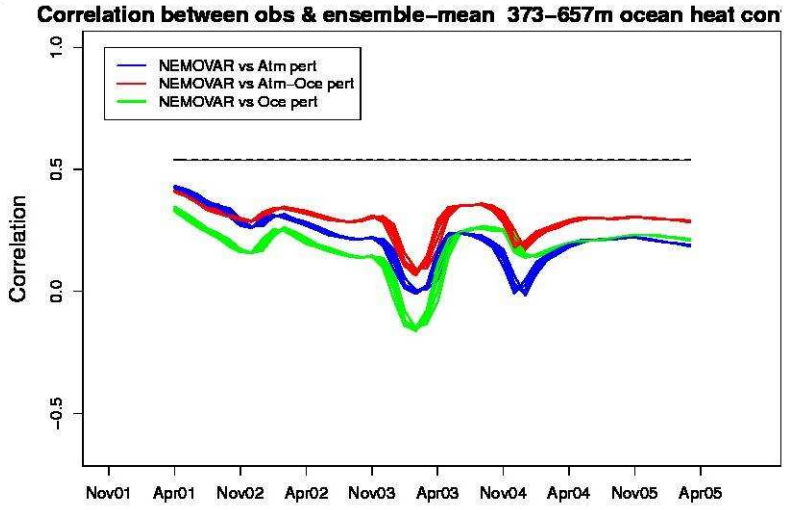
Ocean only perturbations

Global ocean heat content 373-657m

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies



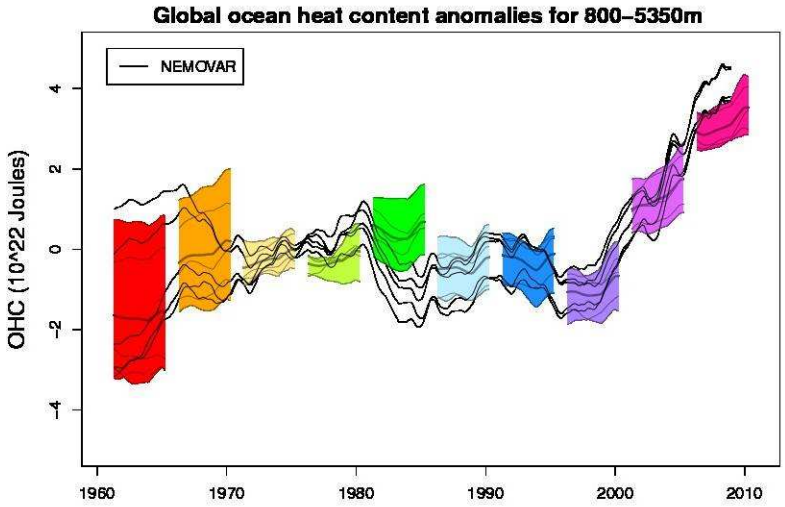


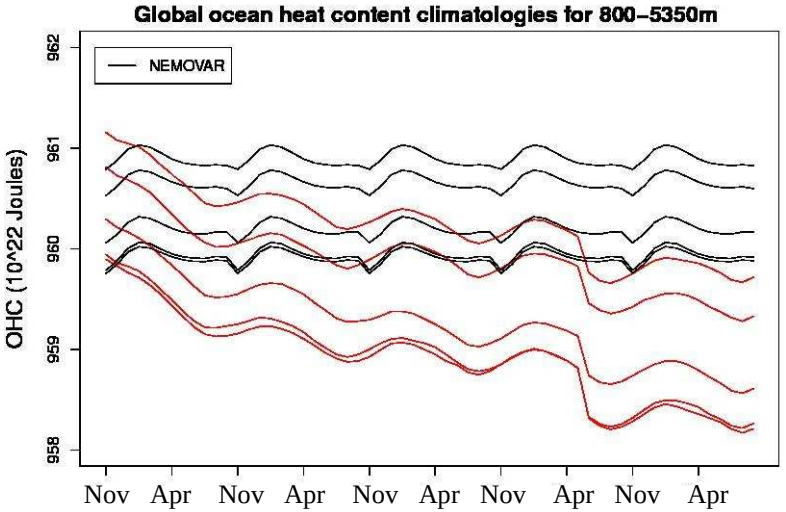


Global ocean heat content 800m-bottom

Global-mean 800m-bot OHC for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

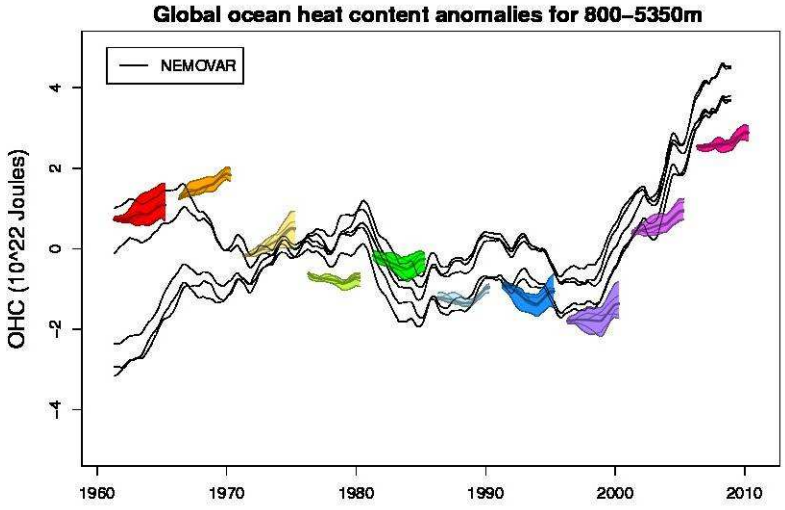
Atmosphere and ocean perturbations

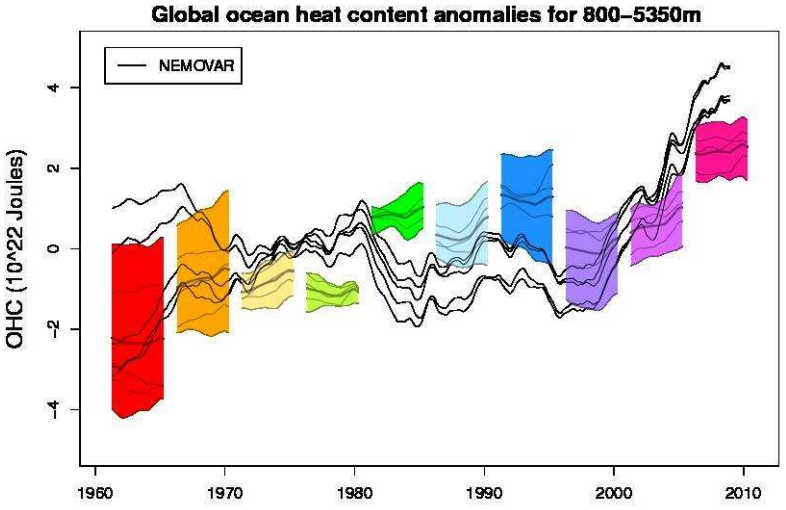




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

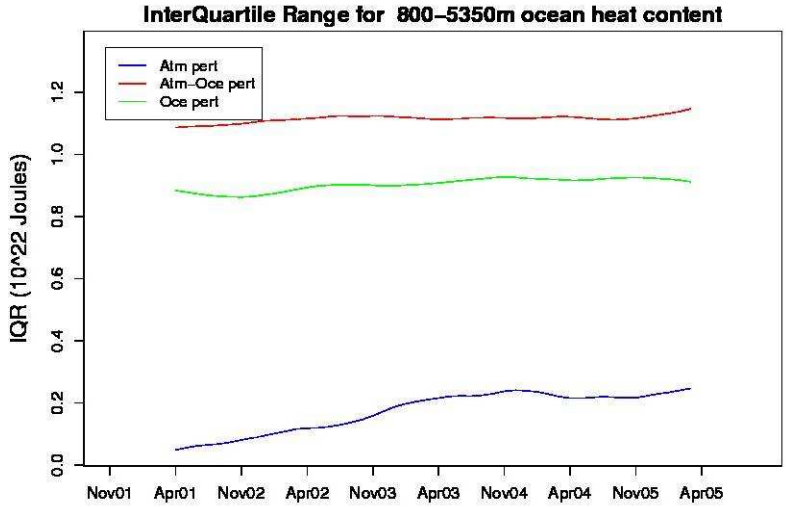


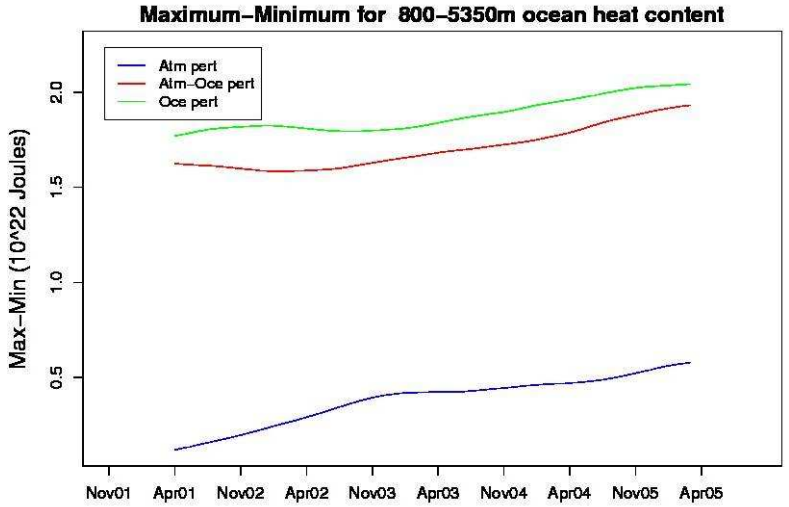


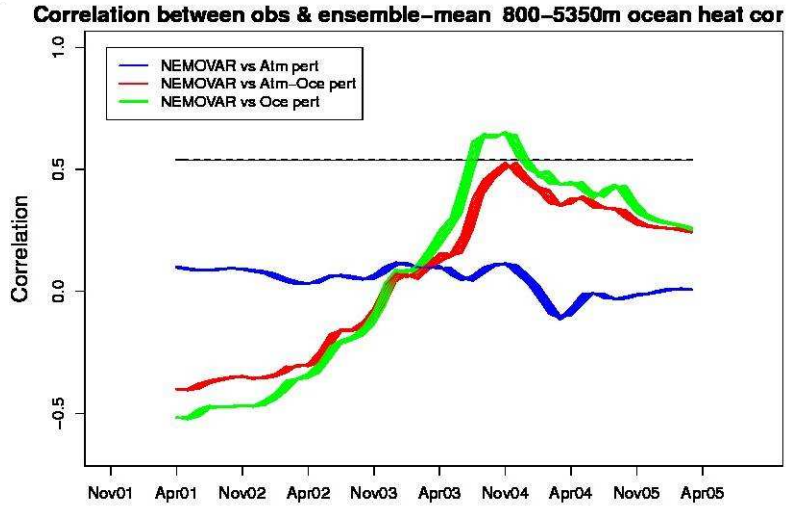
Ocean only perturbations

Global ocean heat content 800m-bottom

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies



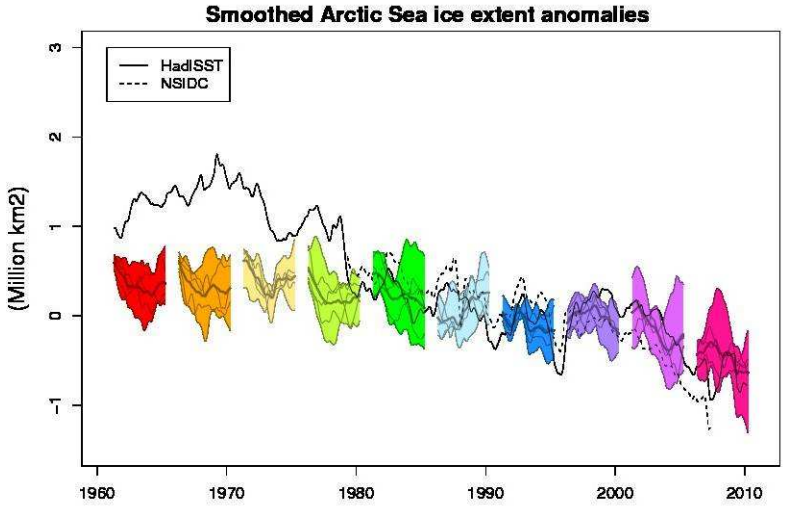


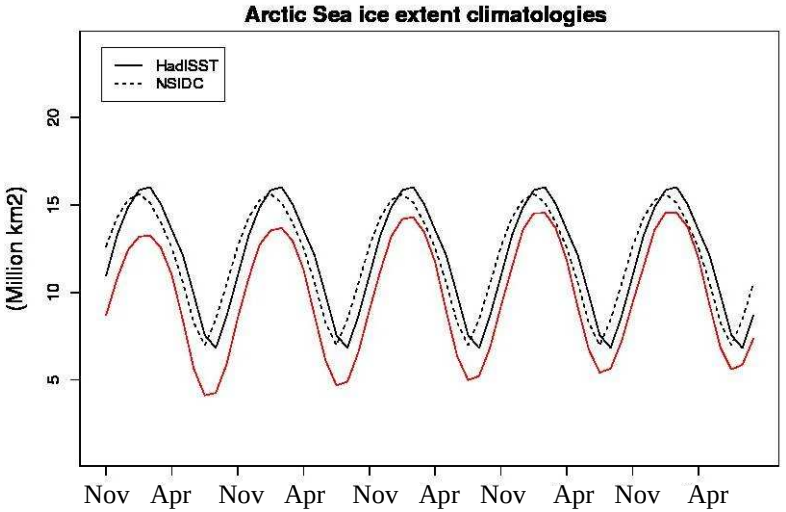


Arctic Sea ice extent

Arctic sea ice extent for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

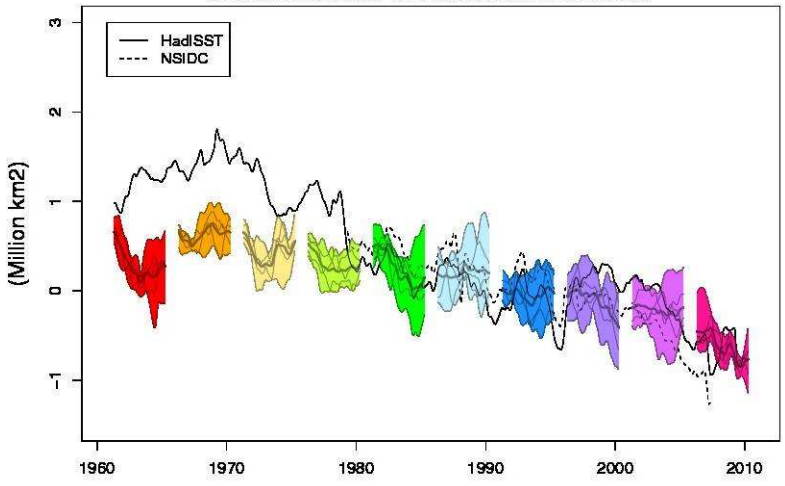
Atmosphere and ocean perturbations

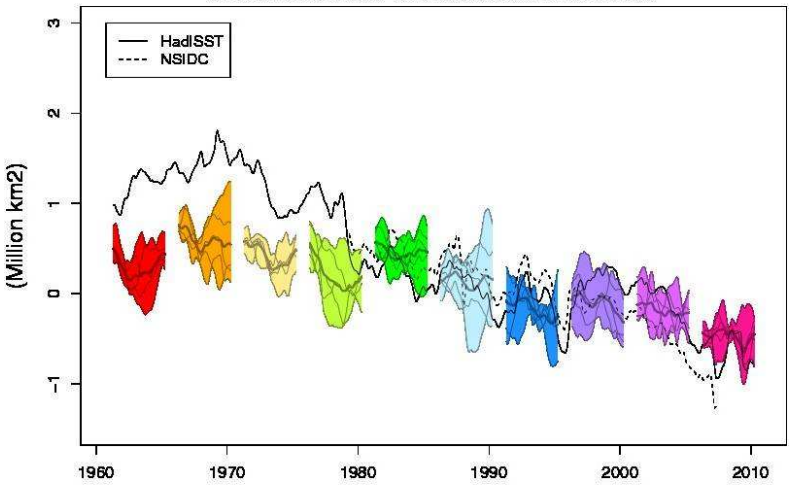




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

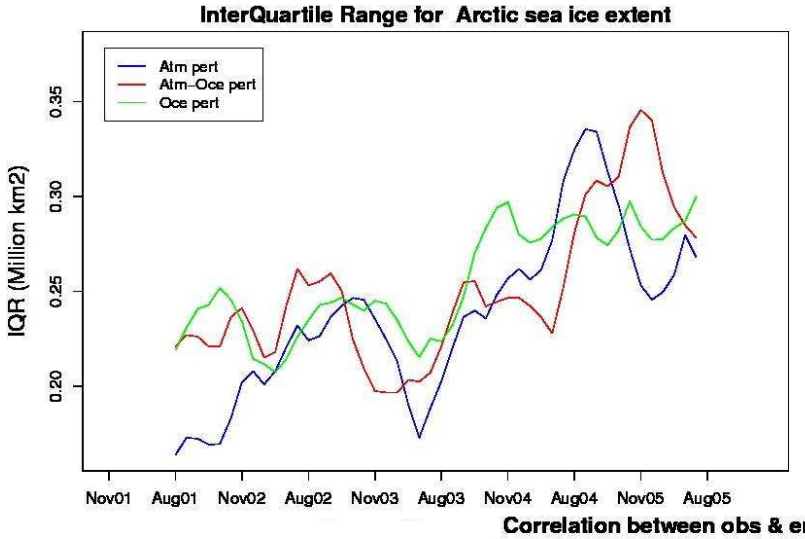


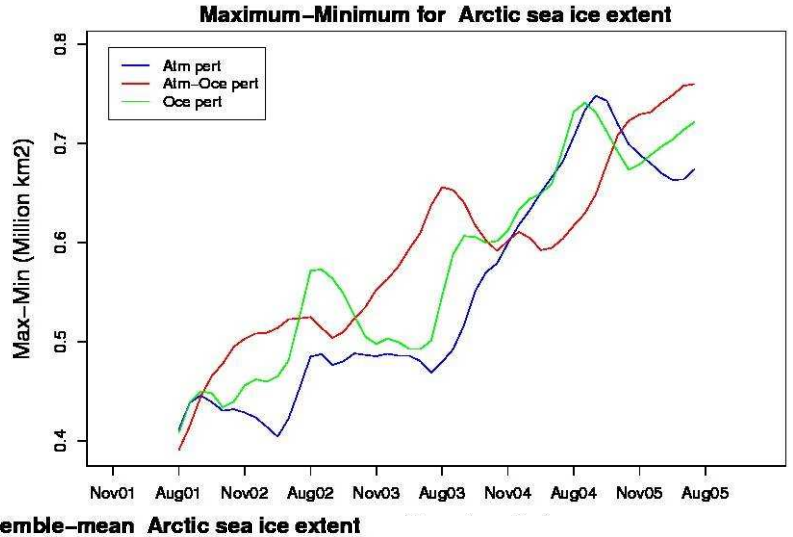


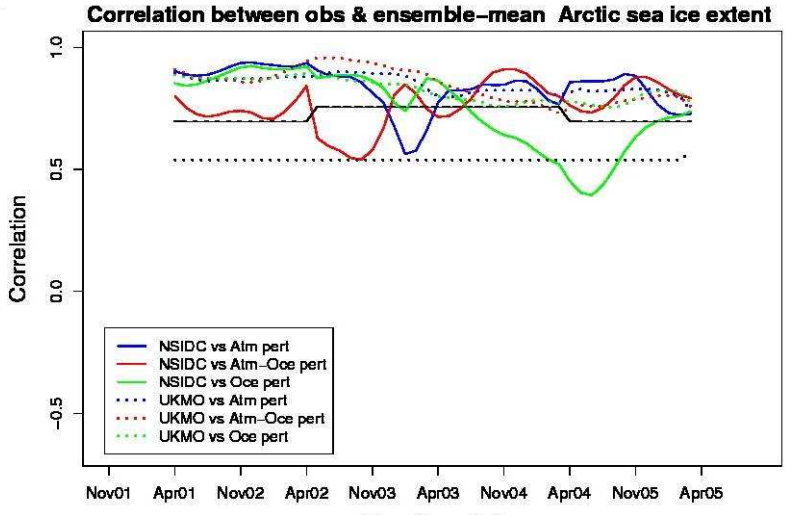
Ocean only perturbations

Arctic Sea ice extent

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with observation of smoothed anomalies

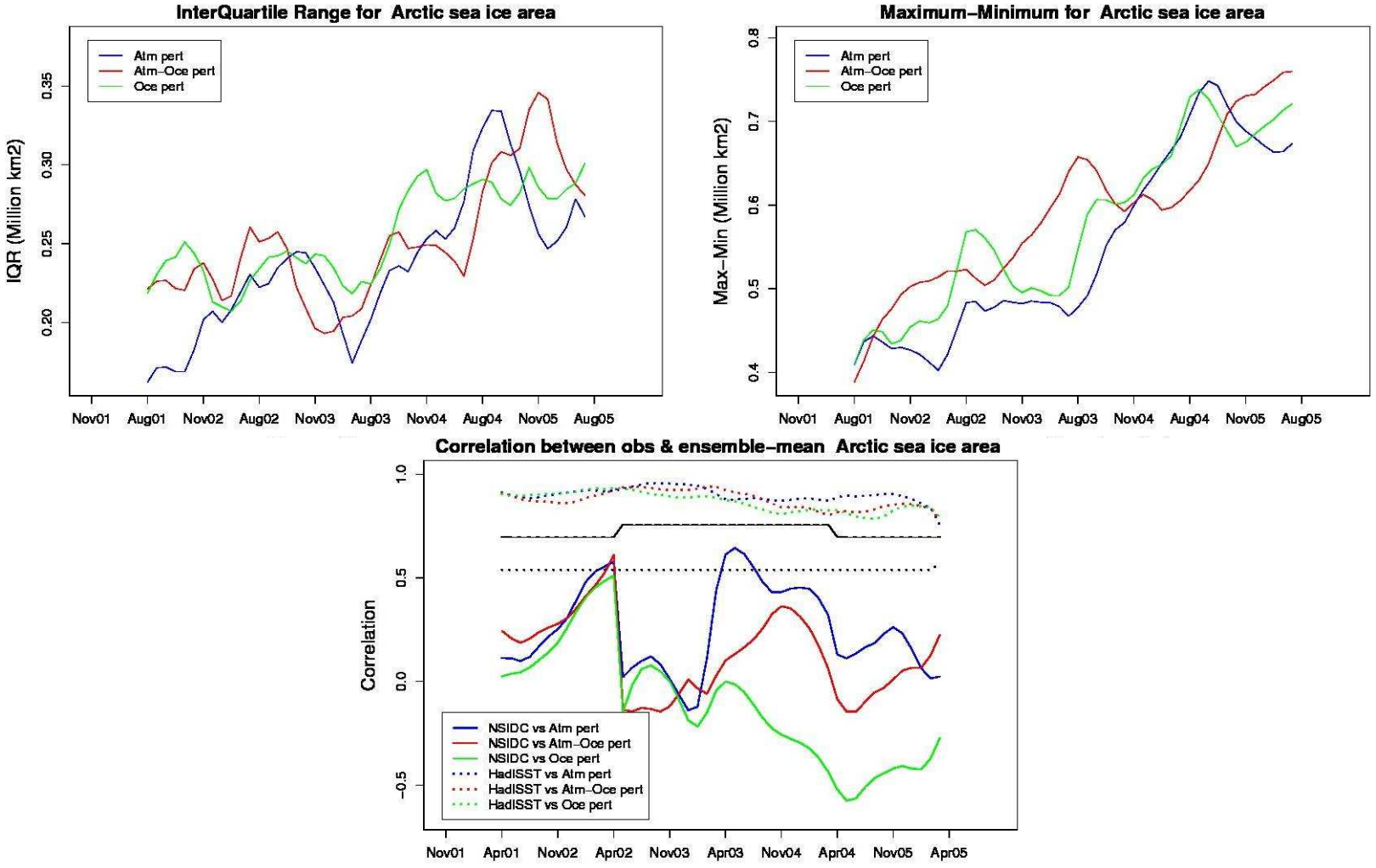






Arctic Sea ice area

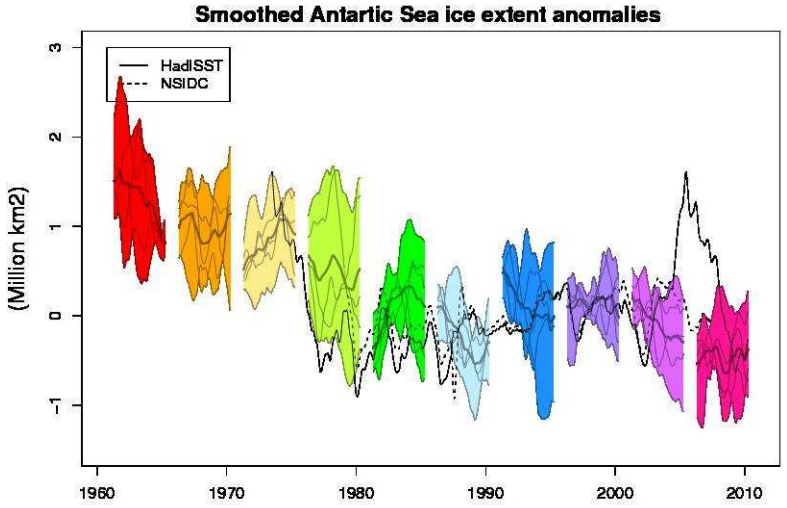
Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with observation of smoothed anomalies

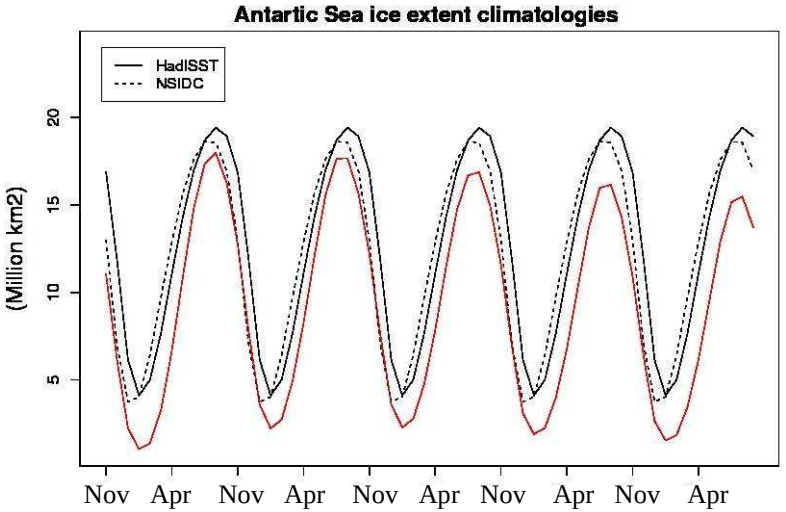


Antarctic Sea ice extent

Antarctic sea ice extent for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

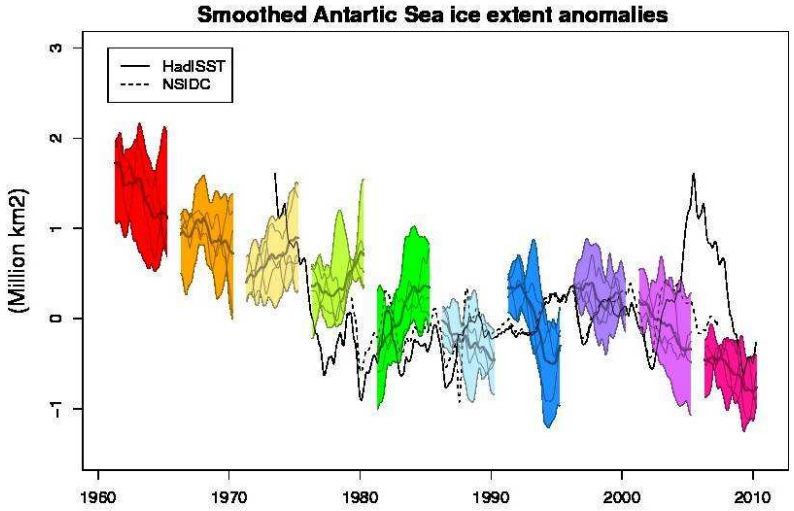
Atmosphere and ocean perturbations

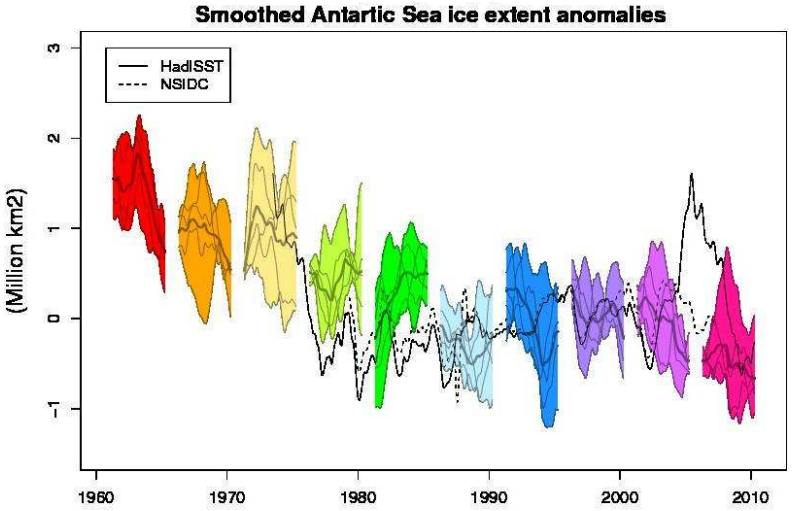




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

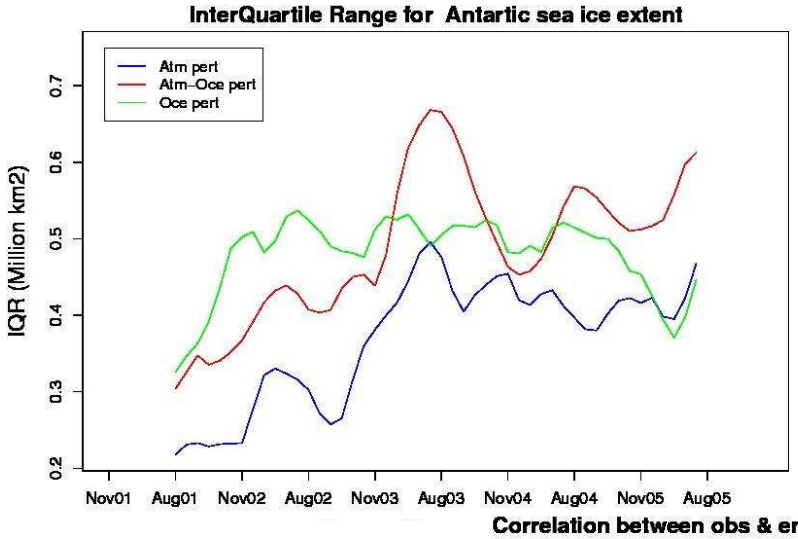


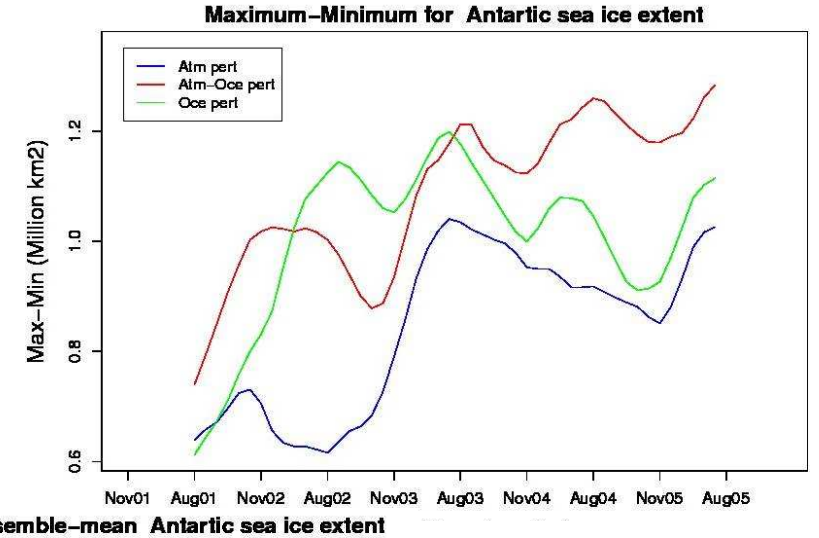


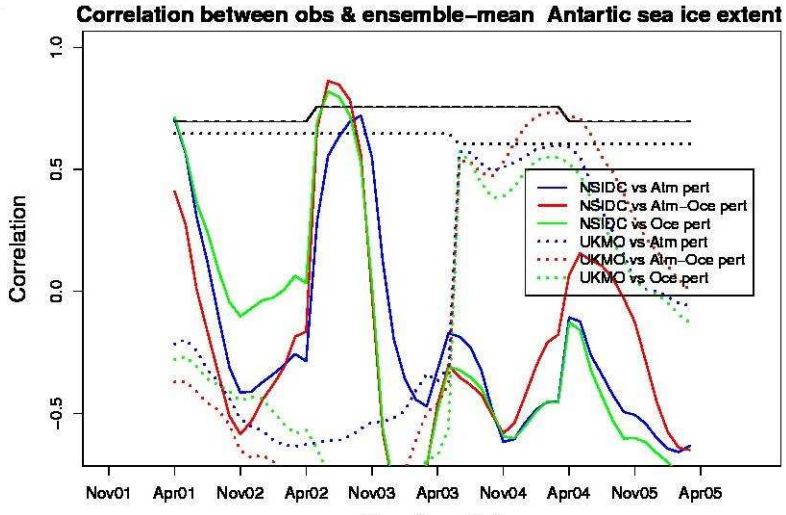
Ocean only perturbations

Antarctic Sea ice extent

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with observation of smoothed anomalies



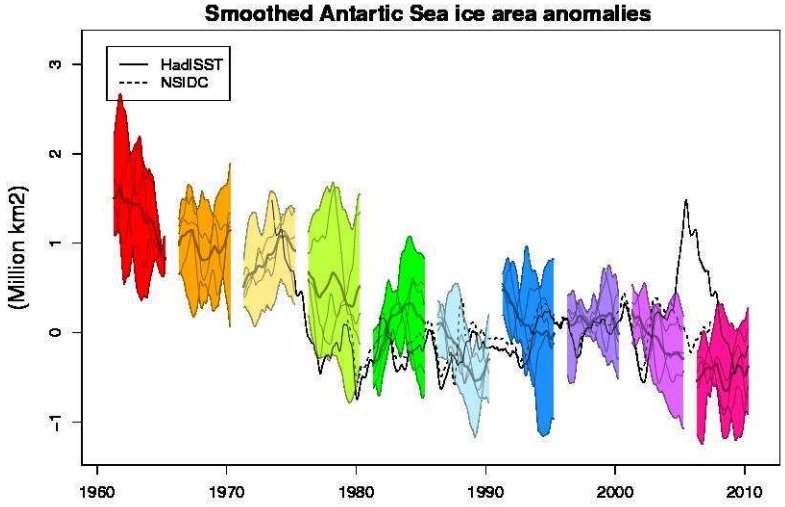


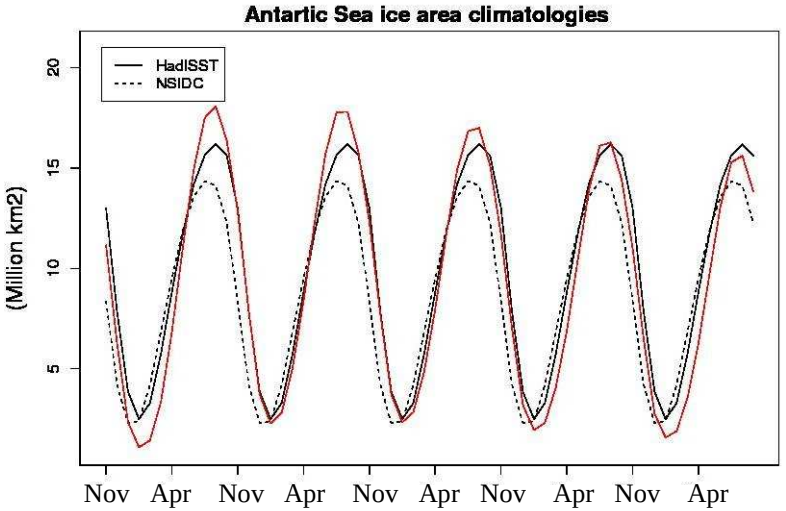


Antarctic Sea ice area

Antarctic sea ice area for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

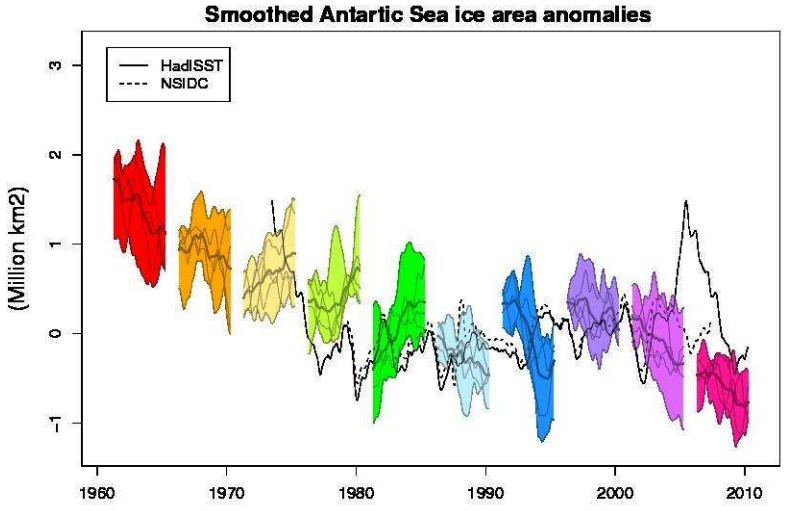
Atmosphere and ocean perturbations

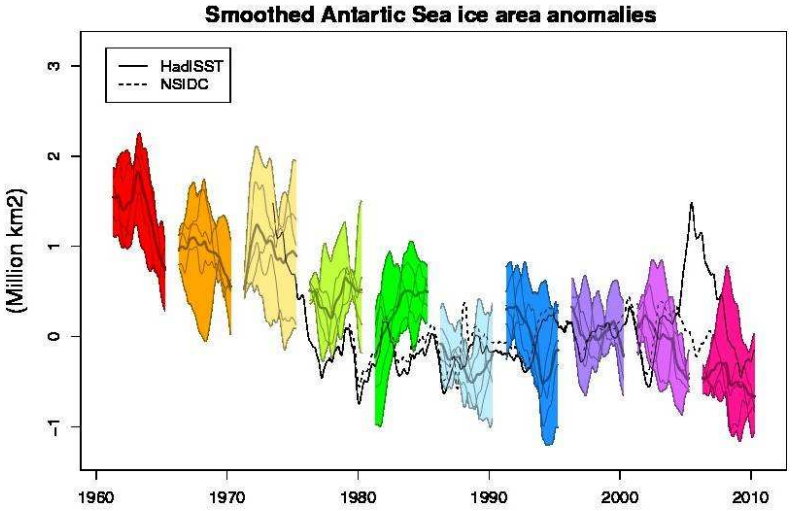




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

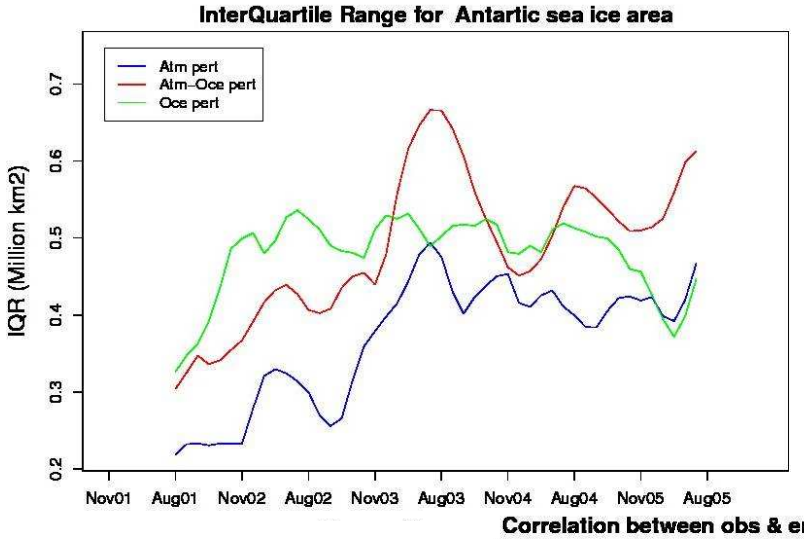


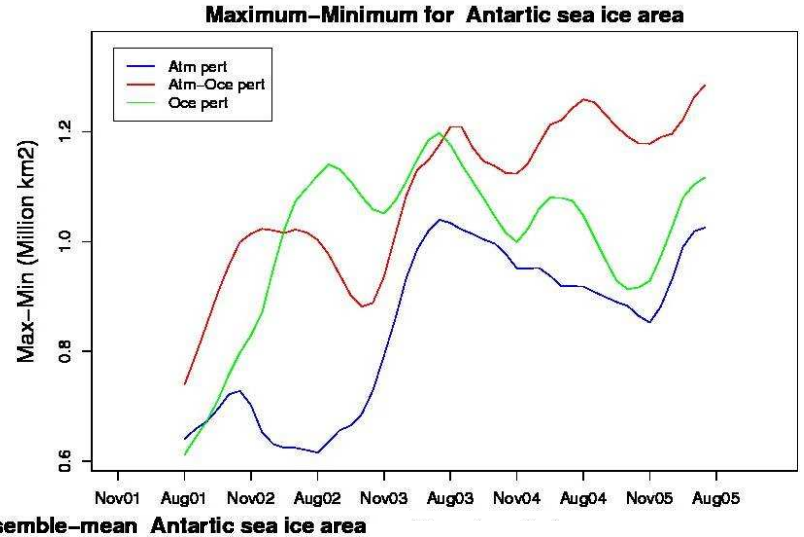


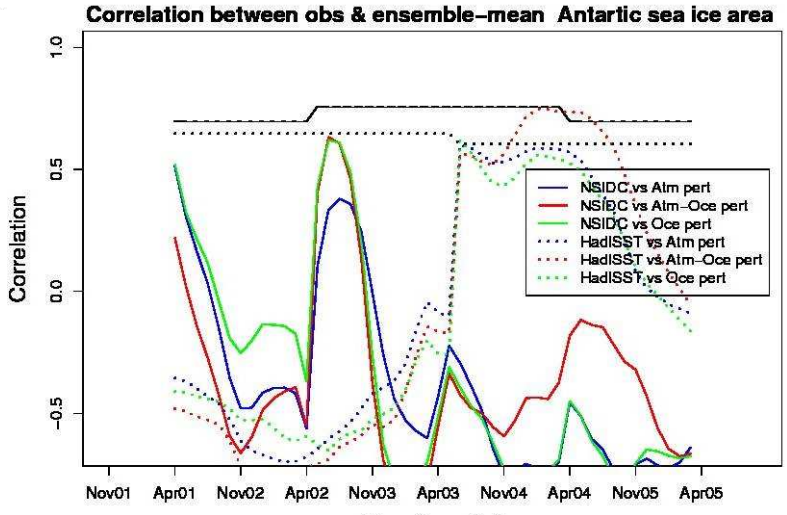
Ocean only perturbations

Antarctic Sea ice area

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with observation of smoothed anomalies



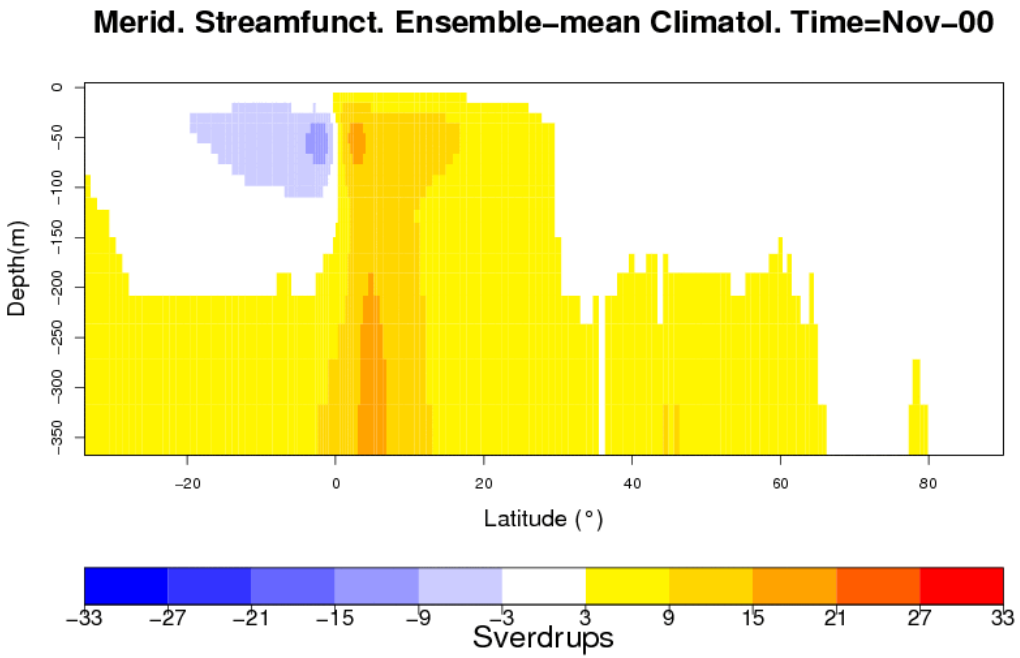


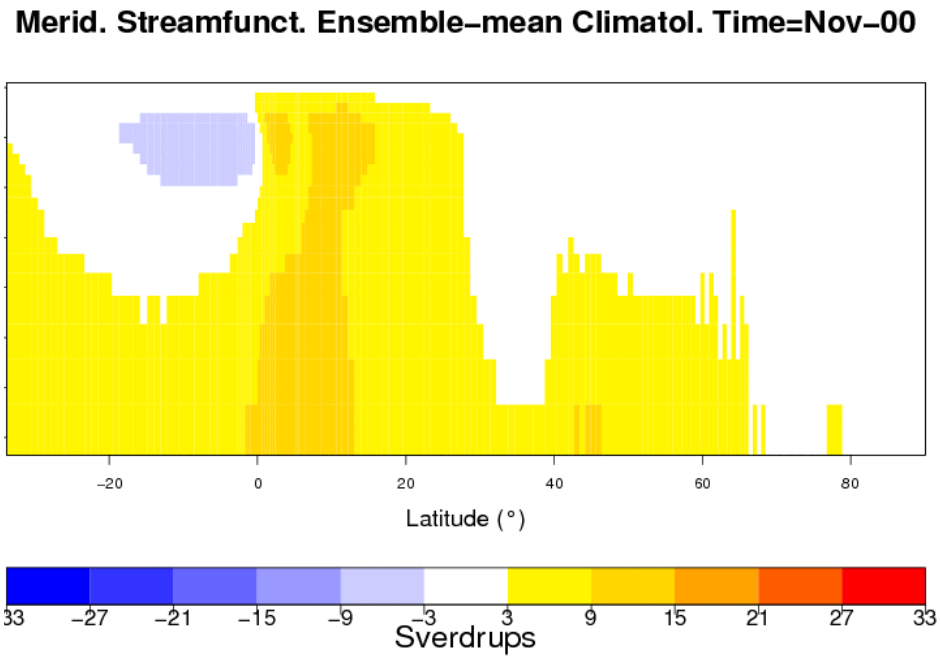


Atlantic Meridional Overturning Circulation
ensemble-mean climatologies : 0-400m

Atmosphere and ocean perturbations

NEMOVAR





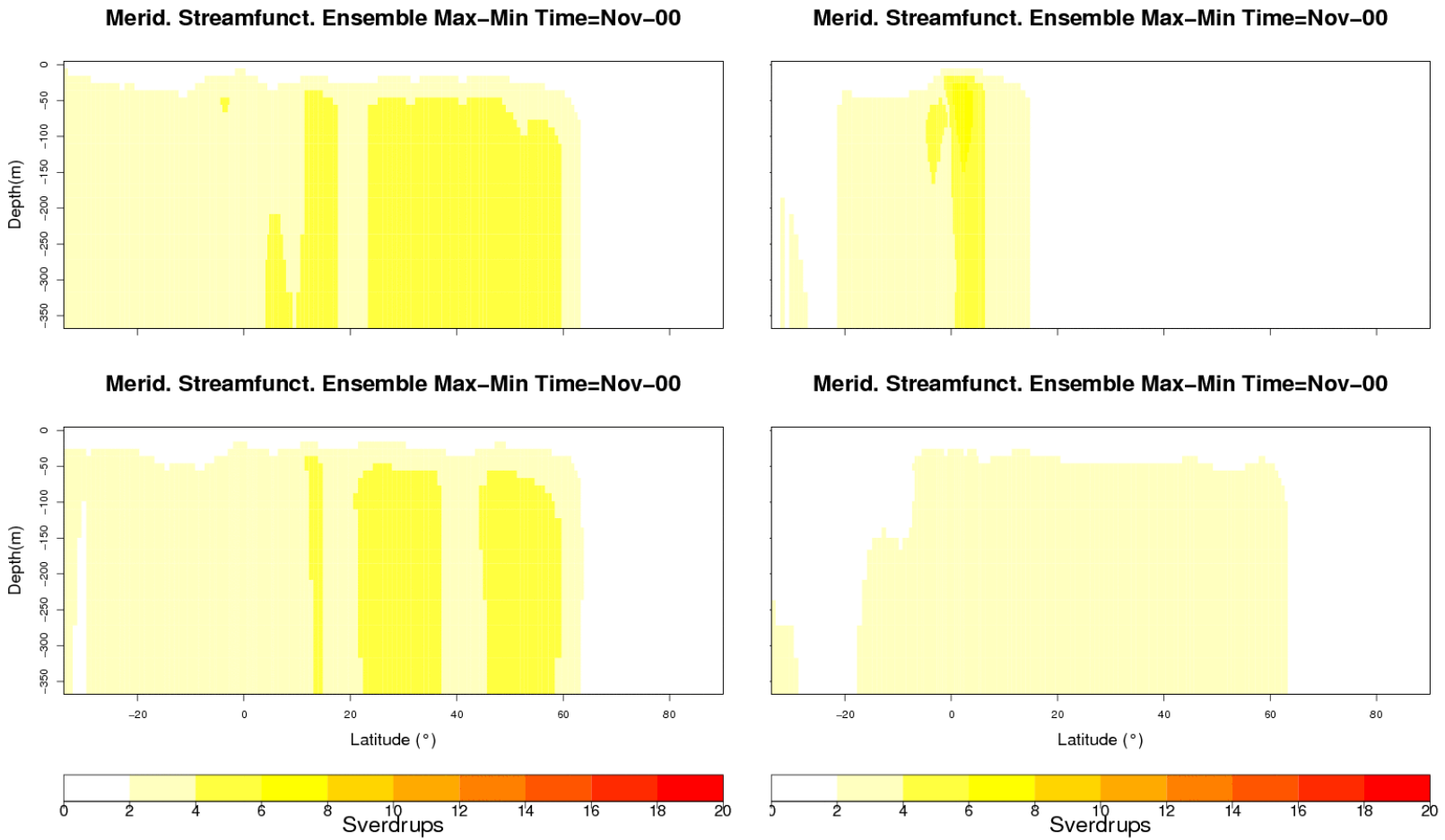
Atlantic MOC ensemble spread : 0-400m (Maximum-Minimum)

Atmosphere and ocean perturbations

NEMOVAR

Atmosphere only perturbations

Ocean only perturbations



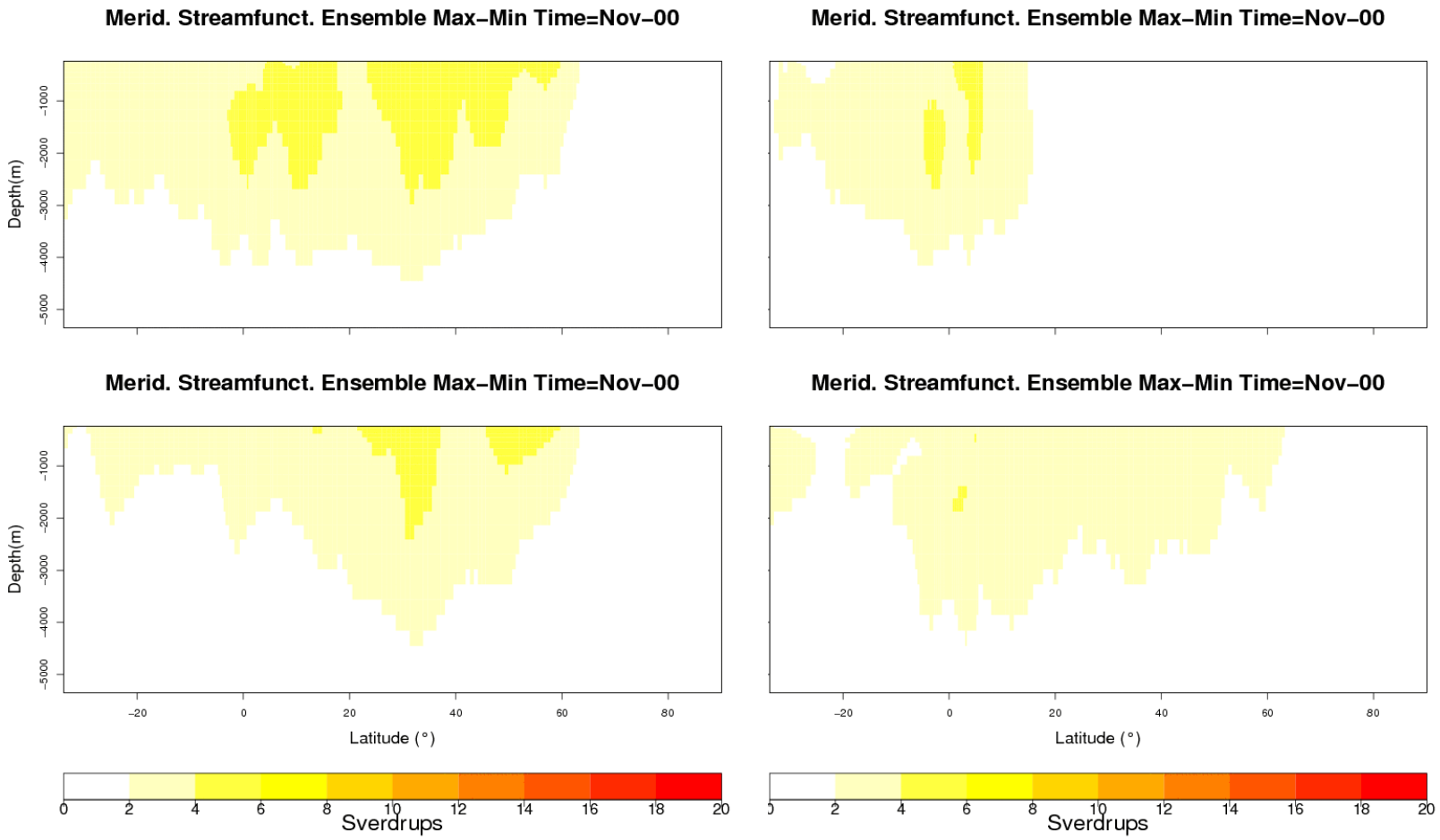
Atlantic MOC ensemble spread : 250m-bottom (Maximum-Minimum)

Atmosphere and ocean perturbations

NEMOVAR

Atmosphere only perturbations

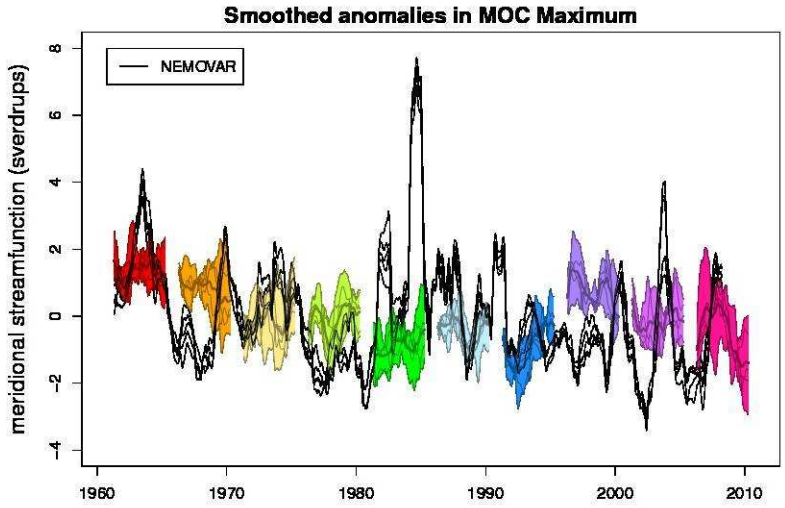
Ocean only perturbations

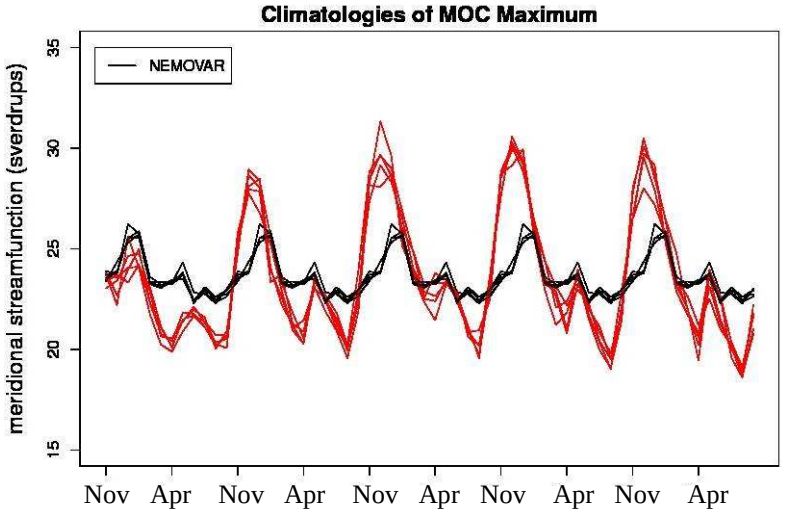


Atlantic MOC maximum

AMOC maximum for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

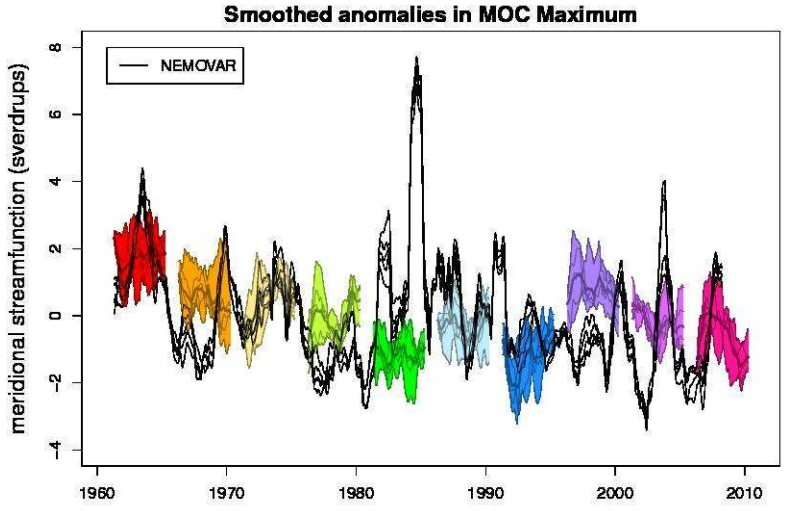
Atmosphere and ocean perturbations

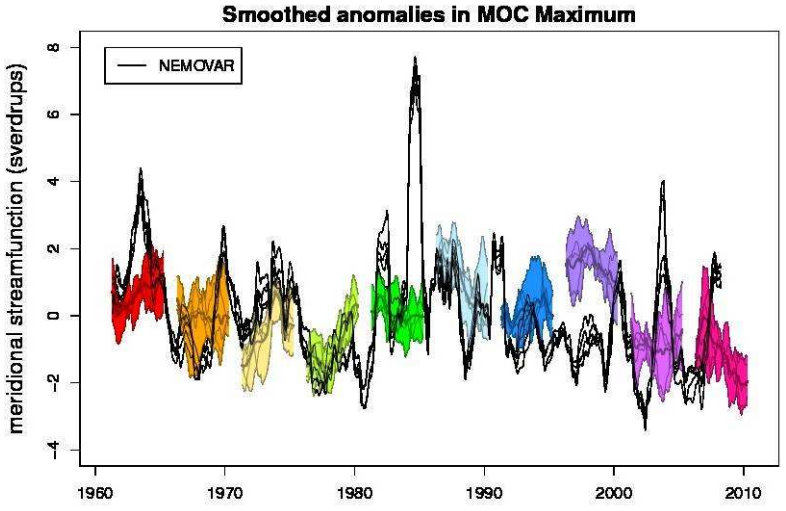




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

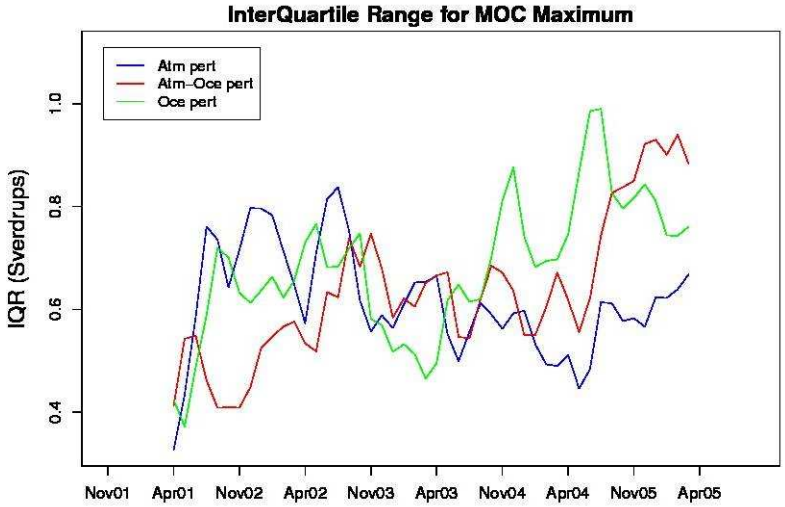


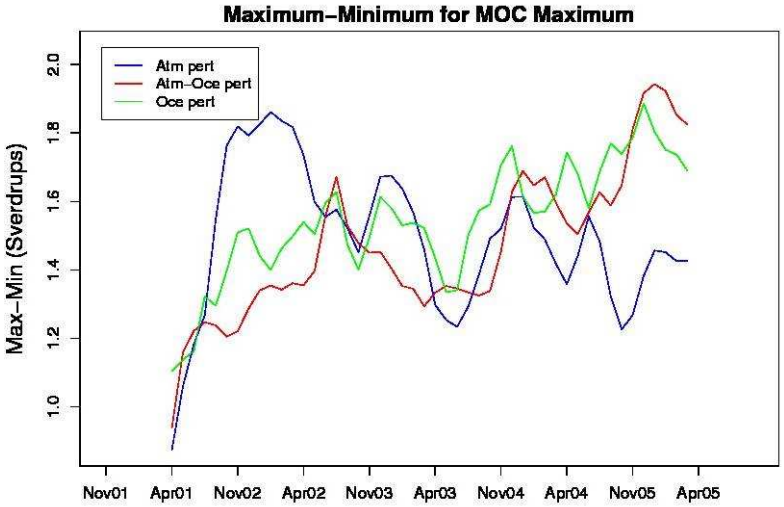


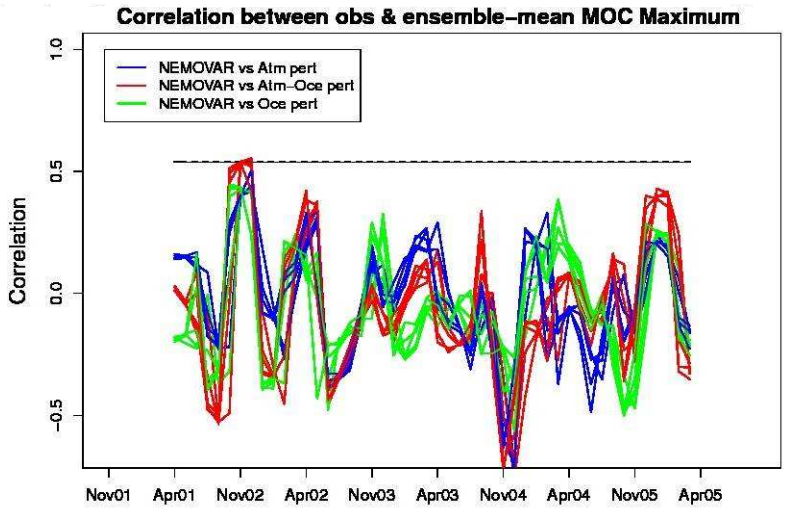
Ocean only perturbations

Atlantic MOC maximum

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies



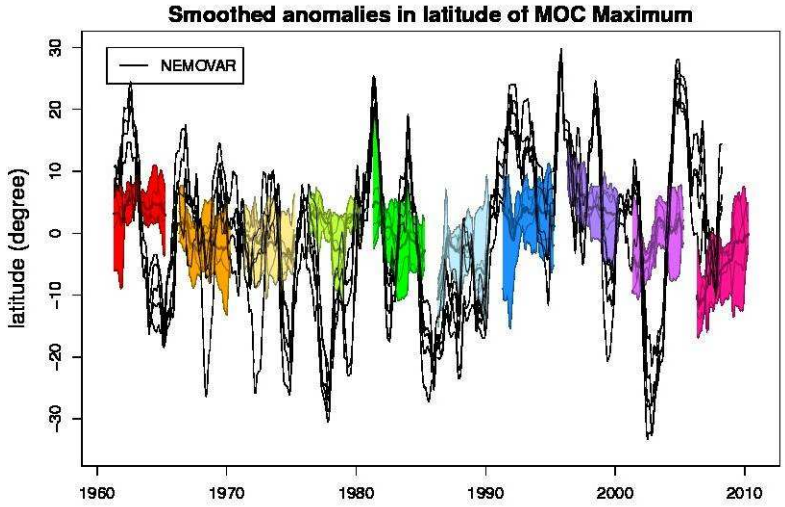


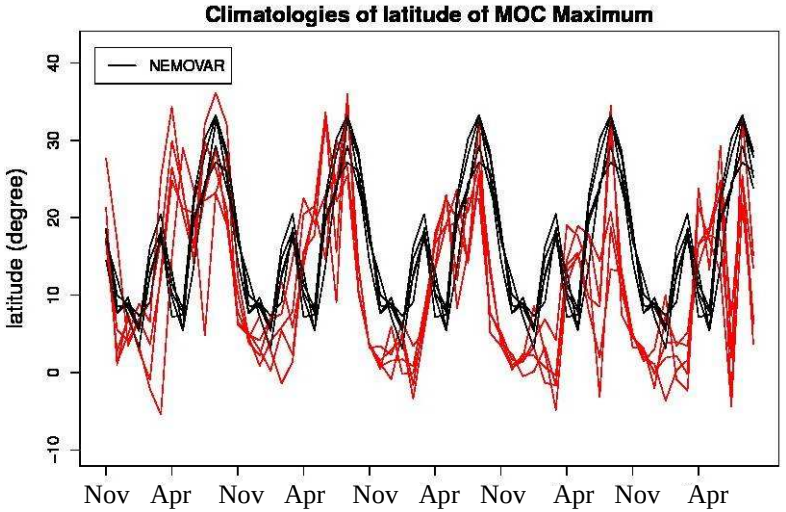


Latitude of the AMOC maximum

Latitude of AMOC maximum for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

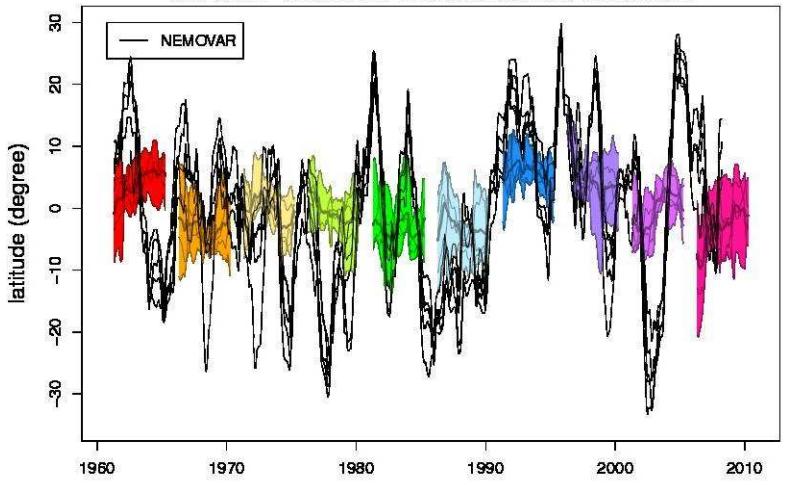
Atmosphere and ocean perturbations

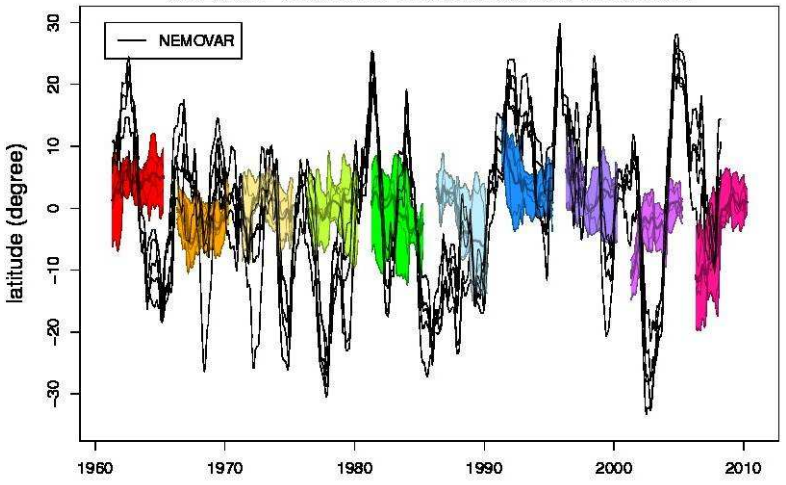




Pair Climatology Atm-Oc perturb

Atmosphere only perturbations

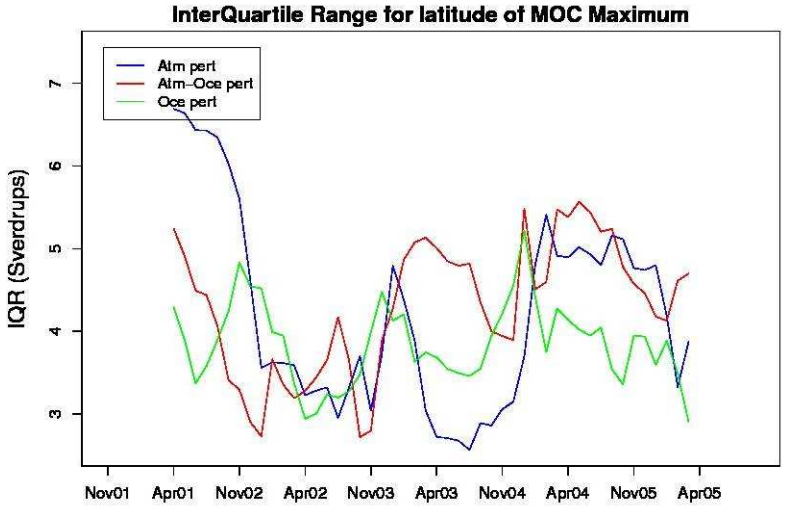


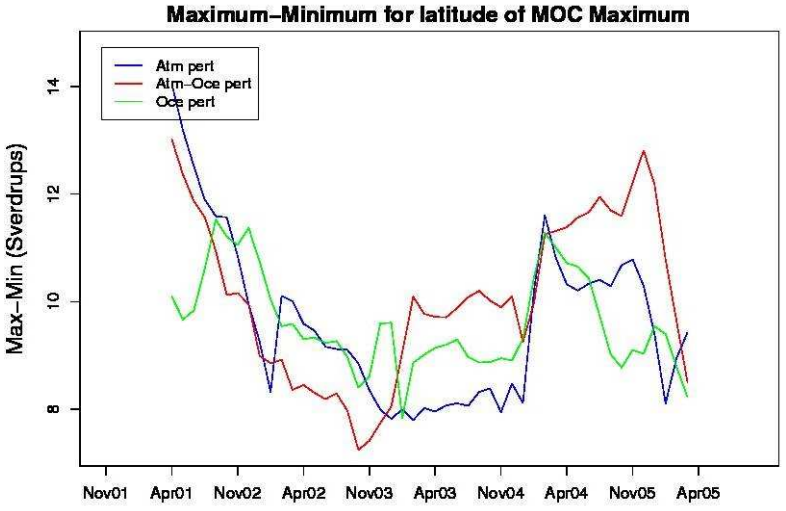


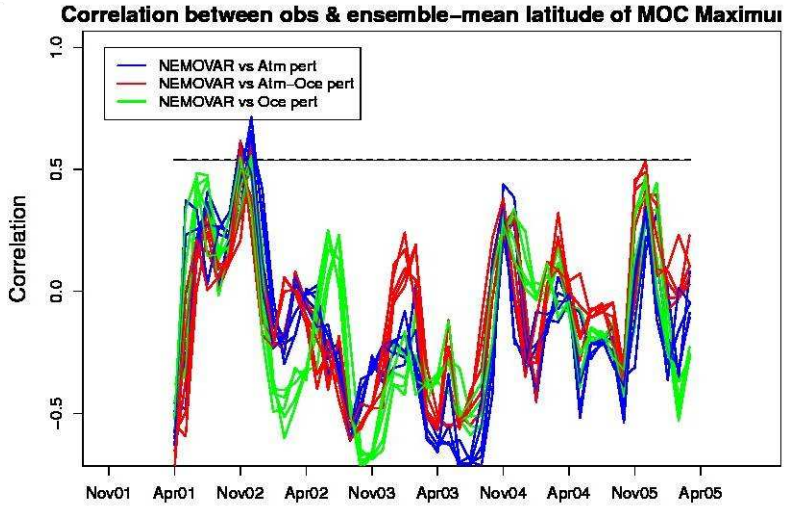
Ocean only perturbations

Latitude of the AMOC maximum

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies



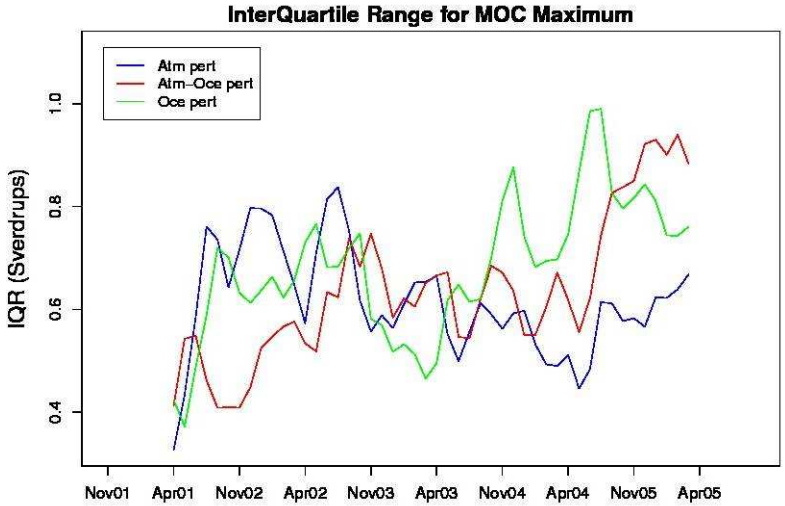


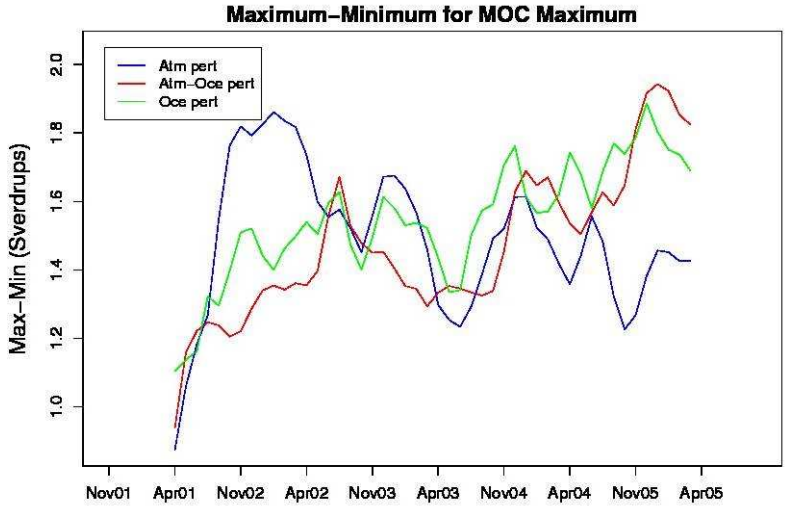


Atlantic MOC

Average over the 10 starting dates of the interquartile range/ Maximum-minimum of smoothed anomalies

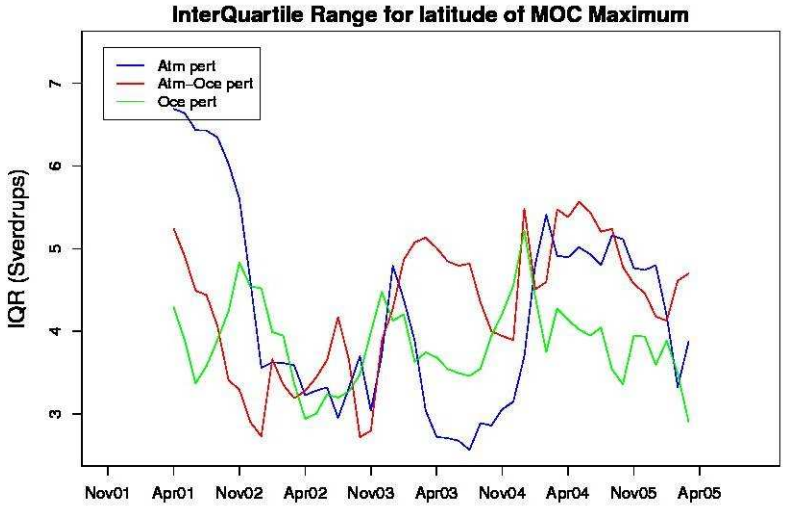
AMOC Maximum

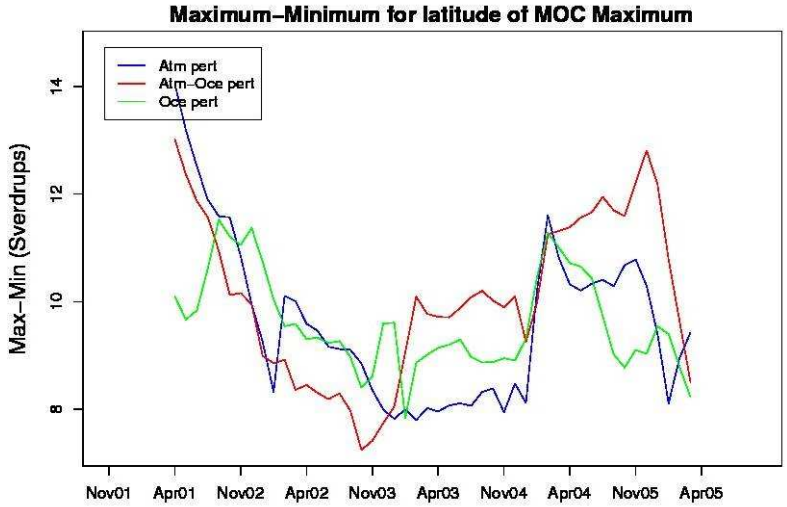




AMOC Maximum

Latitude of AMOC Maximum



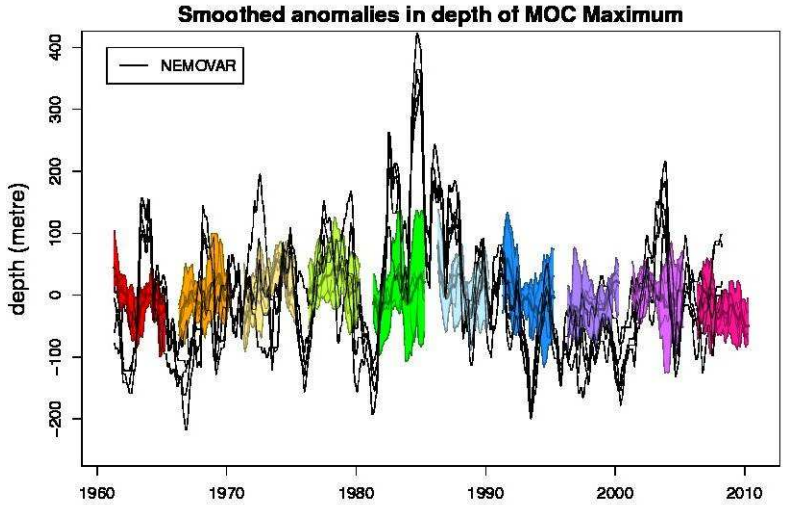


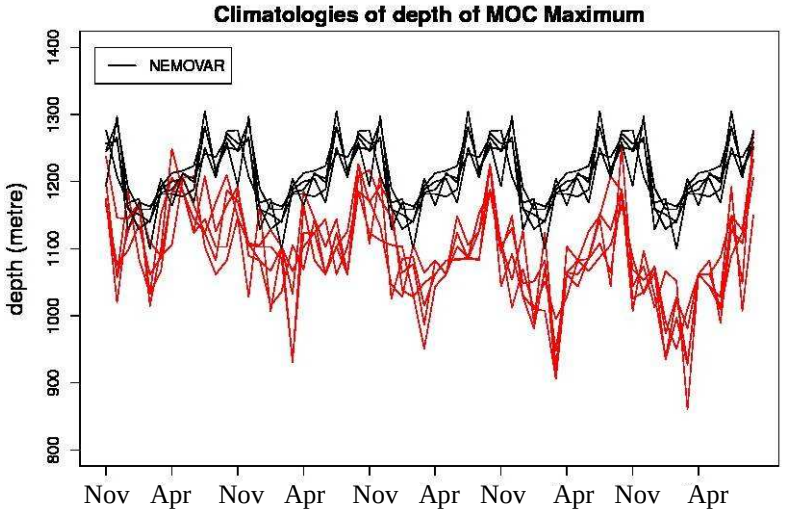
Latitude of AMOC Maximum

Depth of the AMOC maximum

Depth of AMOC maximum for EC-Earth v2.2 (pre-SO4 fix). Anomalies smoothed out with 12-month running mean.

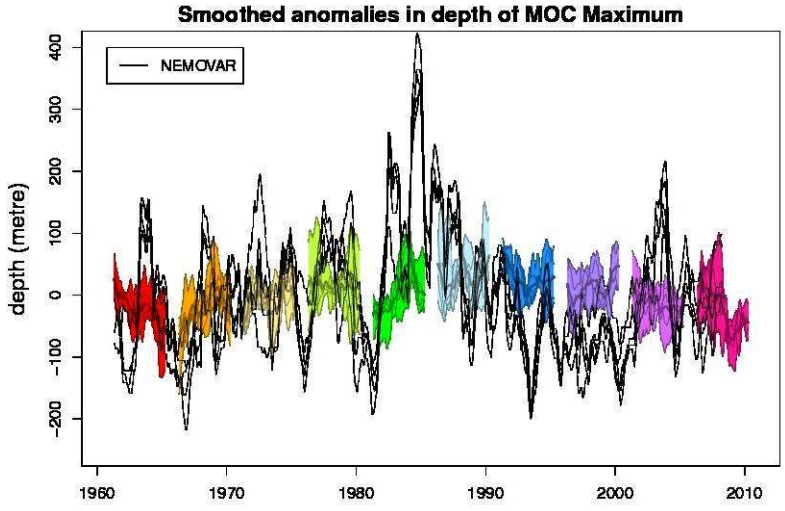
Atmosphere and ocean perturbations

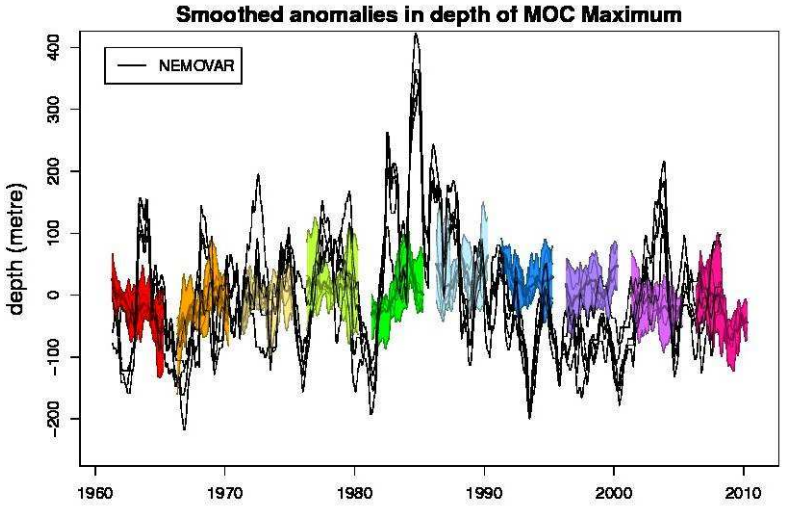




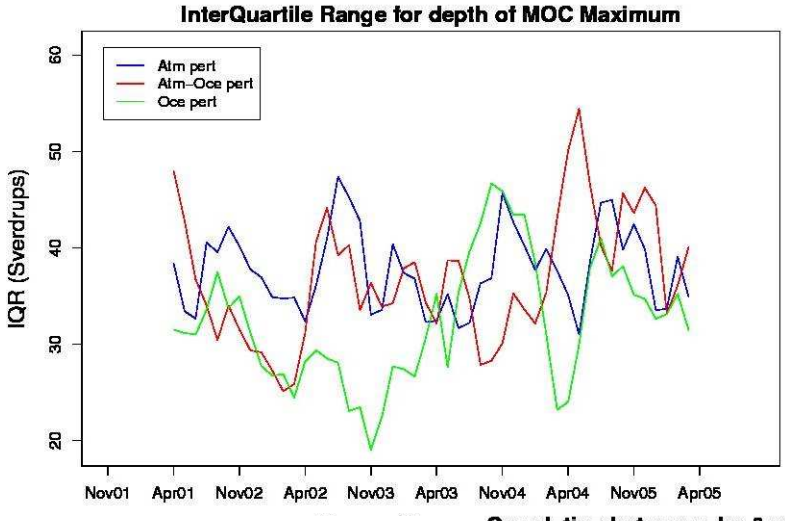
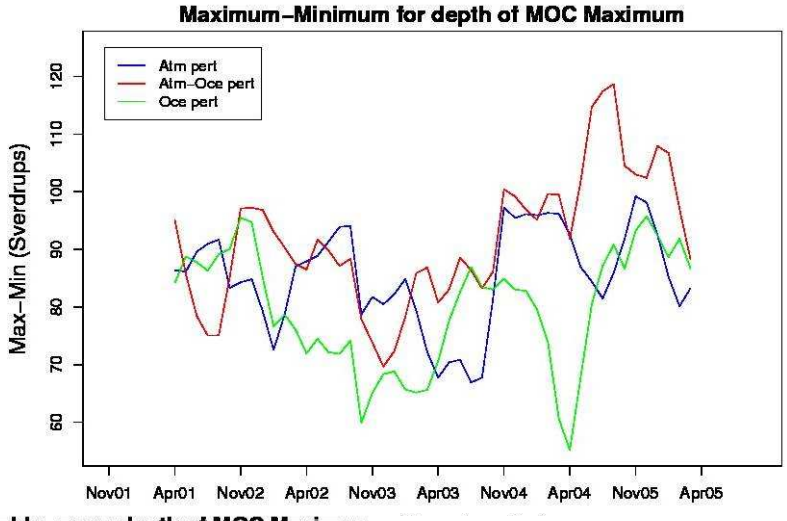
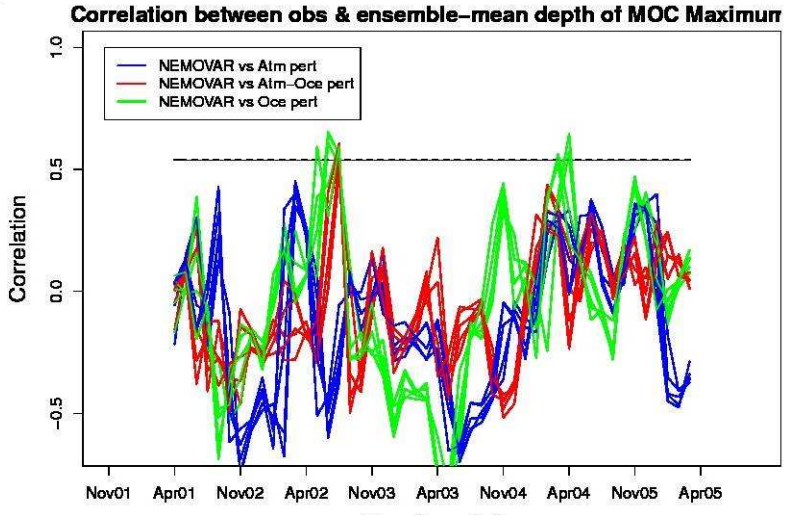
Pair Climatology Atm-Oc perturb

Atmosphere only perturbations





Ocean only perturbations

Depth of the AMOC maximum

Average over the 10 starting dates of the interquartile range/ Maxi-mini/correlations with reanalyses of smoothed anomalies