NCAR, Feb. 11, 2013

The CCSM4-based Norwegian Earth System Model (NorESM) - selected validation and scenario projections.

Trond Iversen

- NorESM1-M development team in Norway, i.a.:
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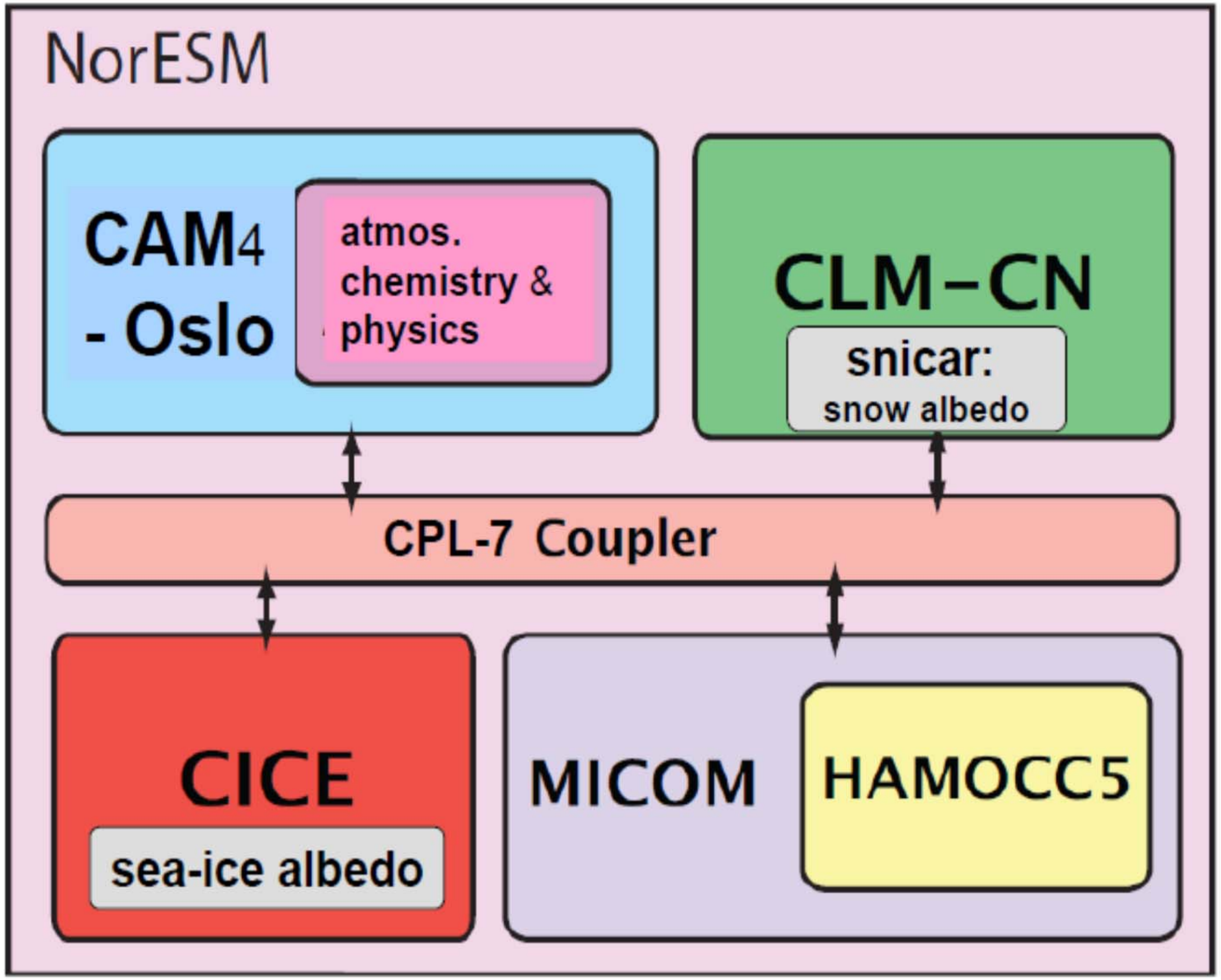
- Co-operation with Stockholm University:
  A. Ekman, E. D. Nilsson, H. Struthers (CRAICC)
- More recently with Univ. Helsinki: **R. Makkonen (CRAICC**)
- **CCSM / CESM**, NCAR, PNNL, and others

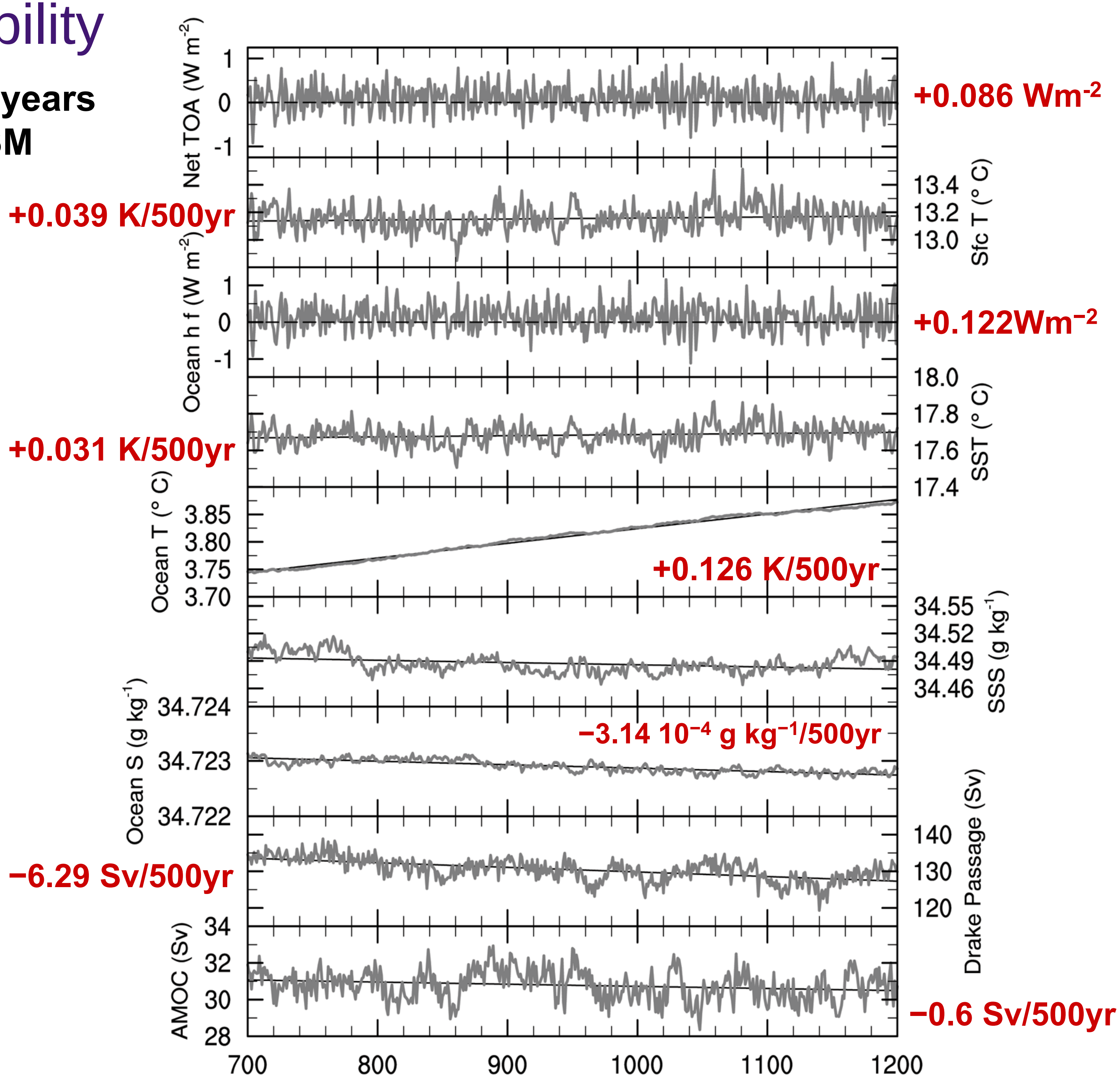
Bjerknes Centre for Climate Research · NILU · Meteorologisk institutt met.no · CICERO Senter for klimaforskning · Norwegian Climate Center

NorESM
components and interactions

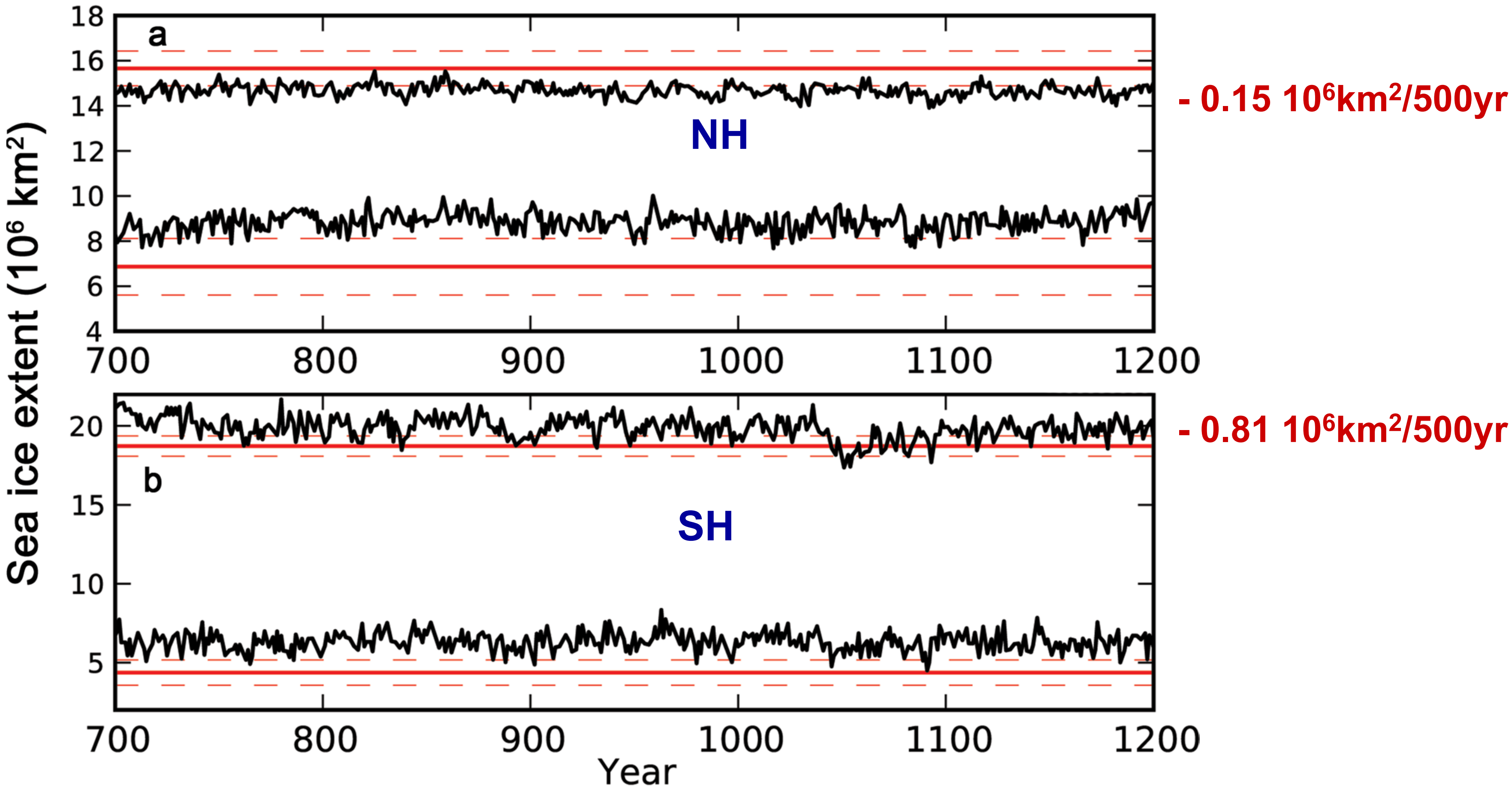


Climate stability

Annual means for years 700-1200 of NorESM **piControl.**



Climate stability



Northern and Southern Hemispheric sea-ice extent (10^6 km^2) for March and September in piControl.

Black lines: **piControl;**

Red lines: **OBS-data**, annual mean and ±2std for the years **1979–2005** (data from NSIDC, Fetterer et al., 2009).

Climate stability

Clouds and fresh water budget,

No significant trends.

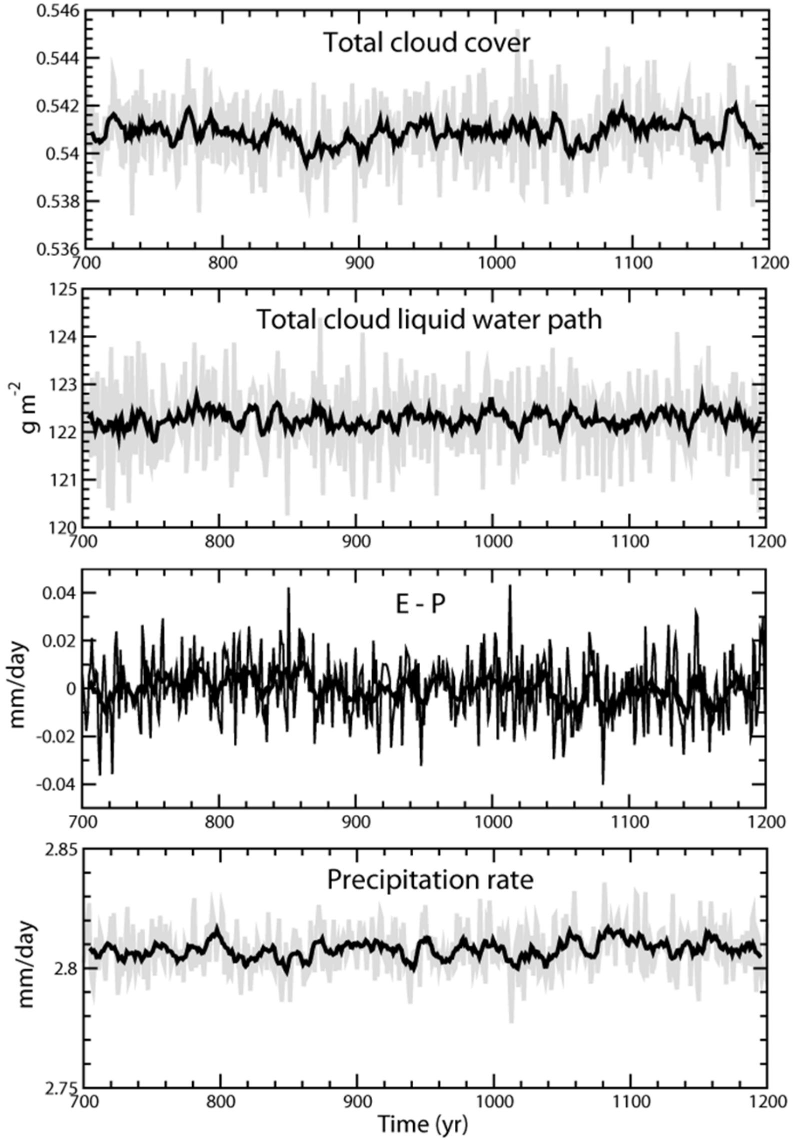
SW_cloud-forcing: −54.83Wm^{-2}

LW_cloud-forcing: +30.91Wm^{-2}

SW_net-rad: +232.43Wm^{-2}

LW_net-rad: -232.33Wm^{-2}

- Oceanic Evaporation:
  ~ 4% too large
- (E-P)_ocean: ~8% too large.
- Recycling oceanic water, (P/E)_ocean:
  ~0.4% under-estimated.



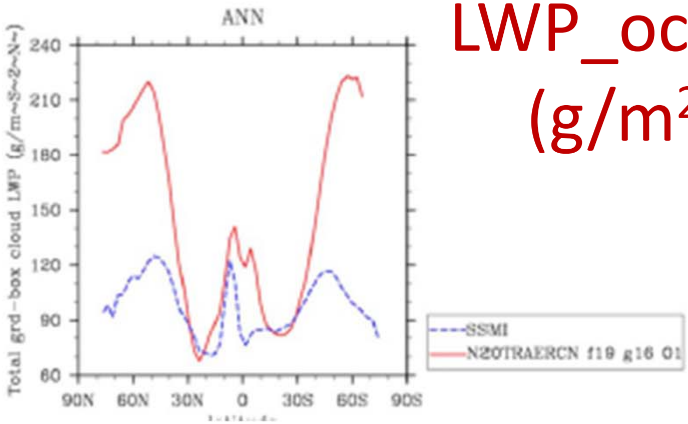
~0.541

~122.3 gm^{-2}

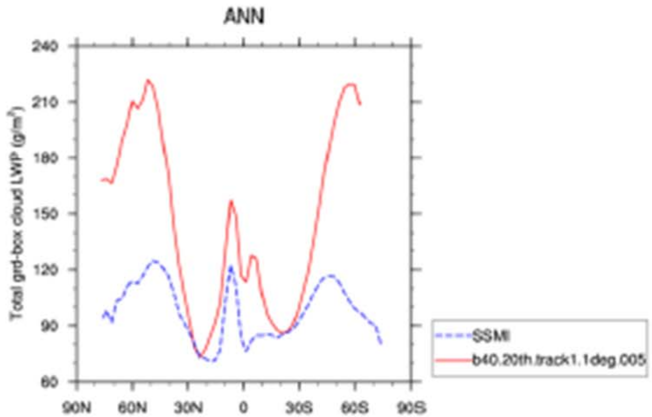
0.00 mmd^{-1}
(-0.02 - +0.02)

2.81mm d^{-1}

NorESM1-M_m1 1976-2005
SSMI

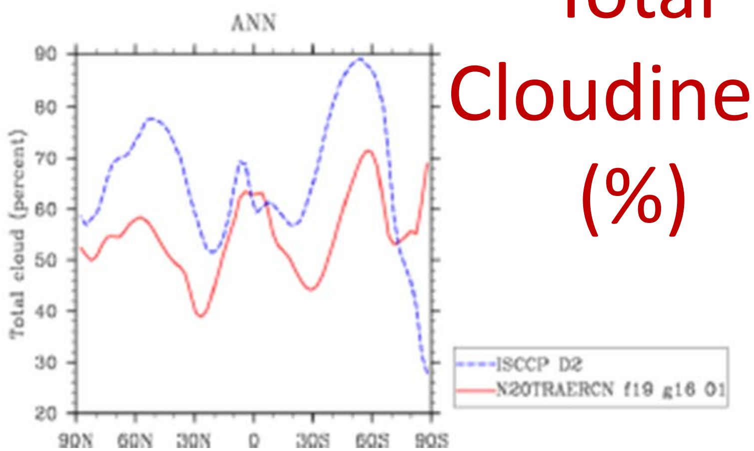


CCSM4_m1 1981-2005
SSMI

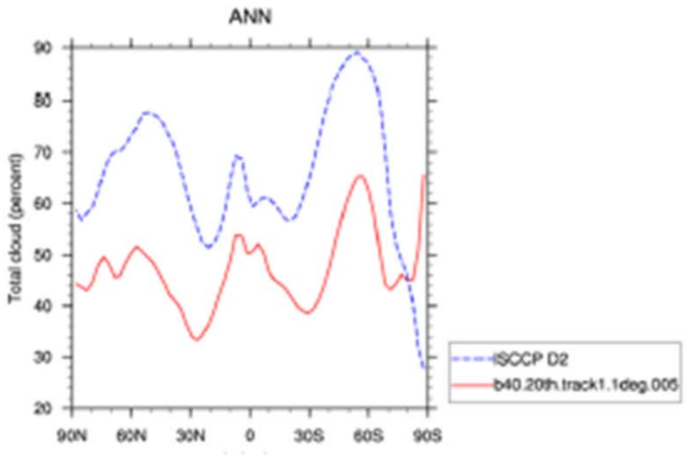


LWP_ocean
(g/m²)

NorESM1-M_m1 1976-2005
ISCCP_vis/ir/nir



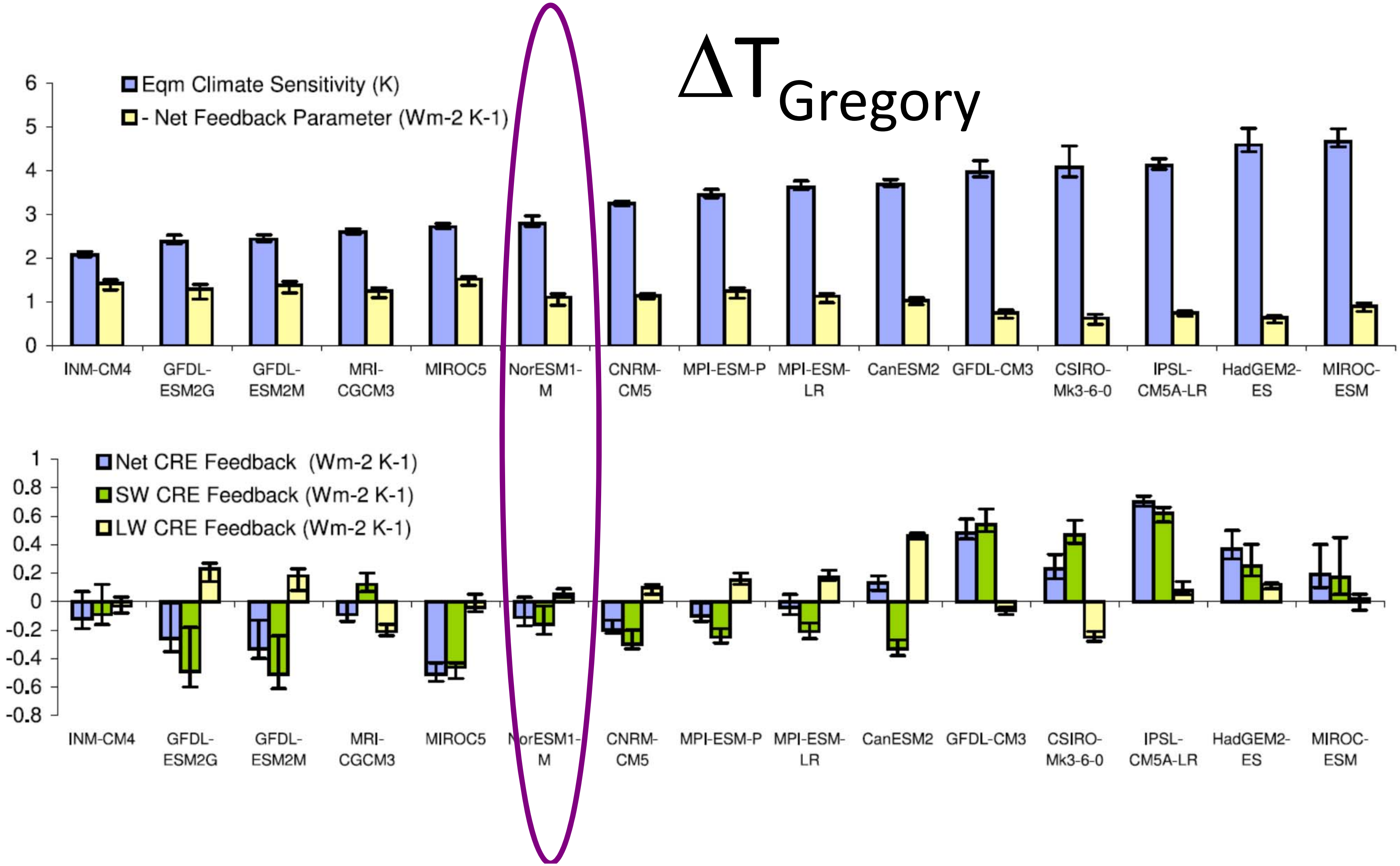
CCSM4_m1 1981-2005
ISCCP_vis/ir/nir



Total
Cloudiness
(%)

Equilibrium Climate Sensitivity
for CO2 doubling
Comparisons (Andrews et al, 2012)

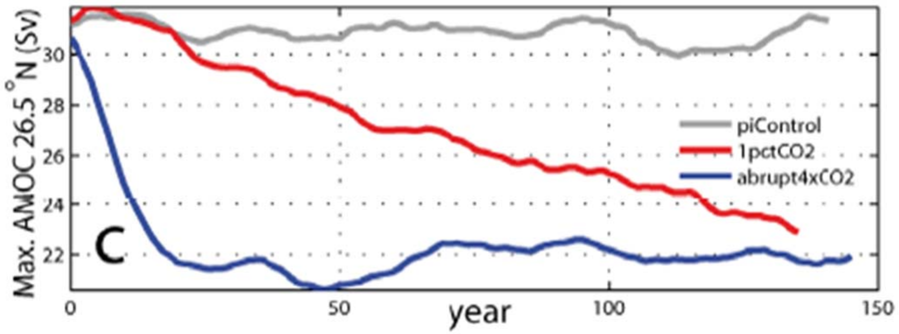
$\Delta T_{Gregory}$



	ΔT_{eq} K	ΔT_{eff} K	ΔT_{reg} K	R_{f_reg} Wm^{-2}	λ_{reg} $Wm^{-2}K^{-1}$	ΔT_{TCR} K	$\Delta T_{TCR,eff}$ K
NorESM1-M 2 deg	not calc.	2.86	2.87	3.16	1.101	1.39	2.32
CCSM4, 1 deg.	3.20	2.78	2.80	2.95	1.053	1.72	2.64

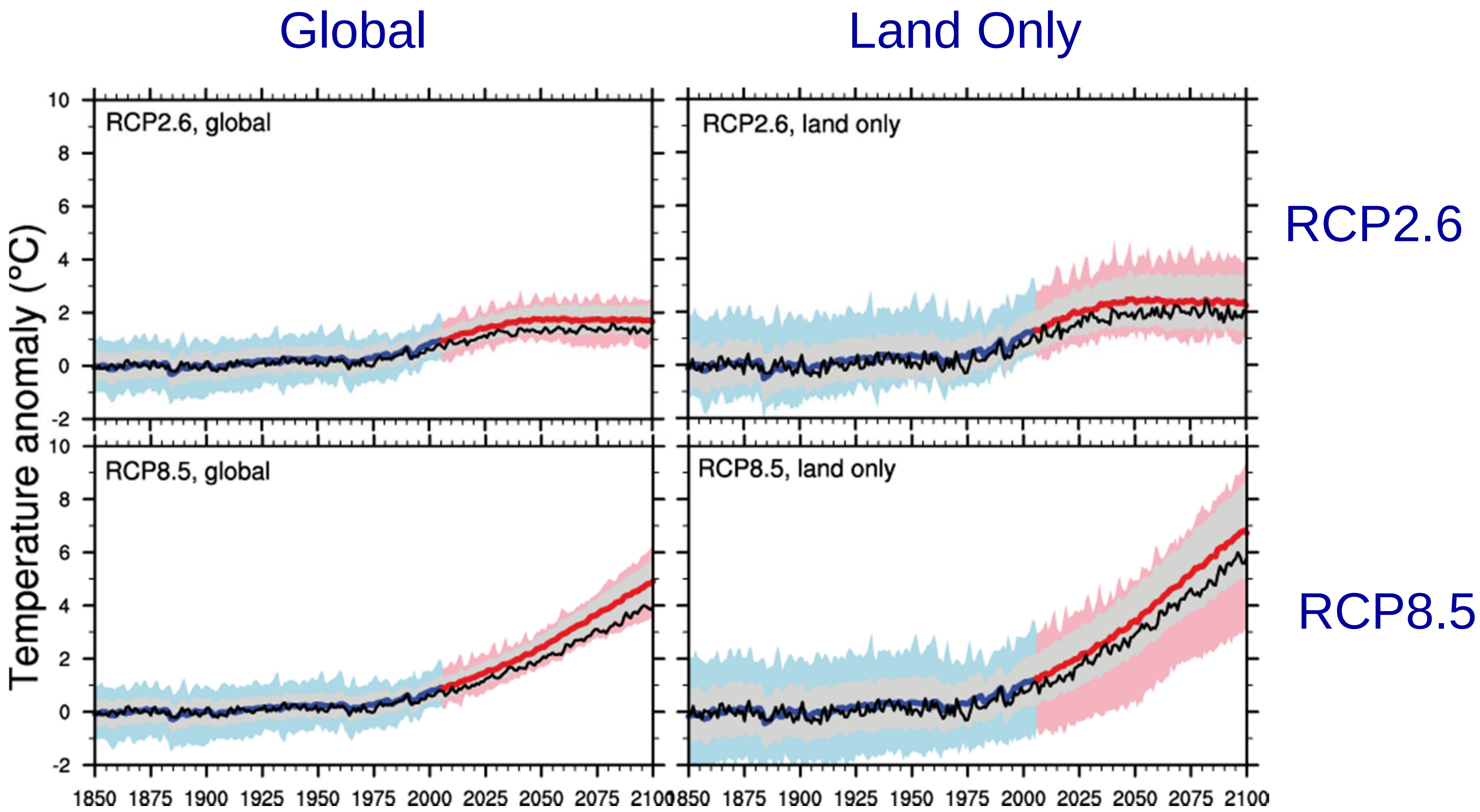
ΔT_{reg}= 2.87 K
CCSM4: 2.80 K

ΔT_{TRC}= 1.39 K
CCSM4: 1.72 K



NorESM1-M:
RCP scenario projections

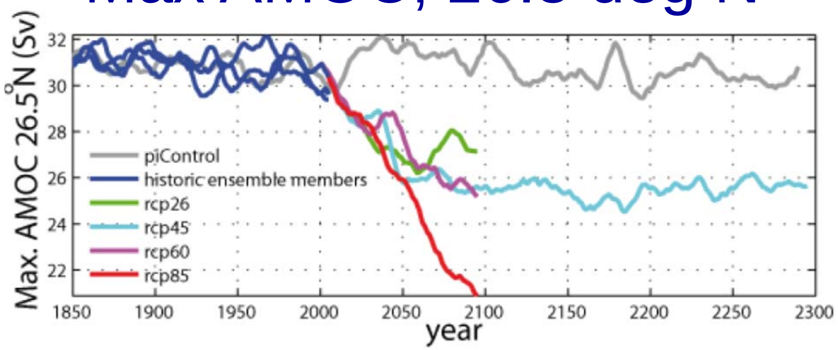
Compared to 15 CMIP5 models



NorESM1-M: RCP scenario projections

(P-E)_Land = (E-P)_Ocean
P_Land increases
But
E_Land = const (approx)

Max AMOC, 26.5 deg N

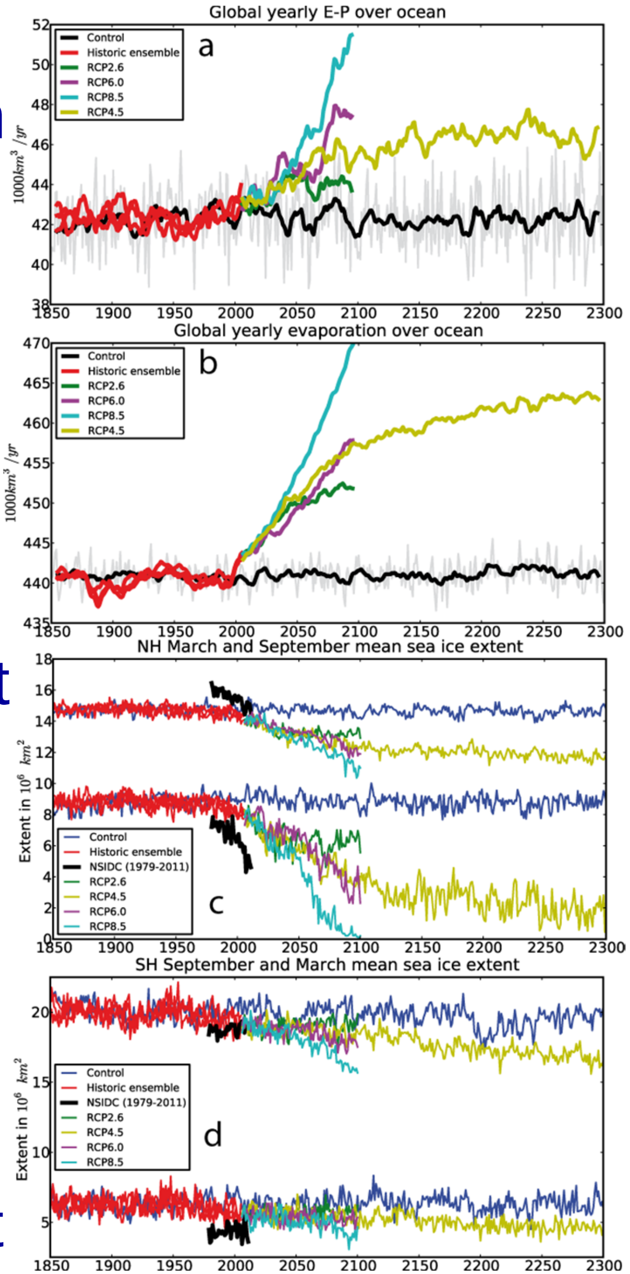


(E-P)_Ocean

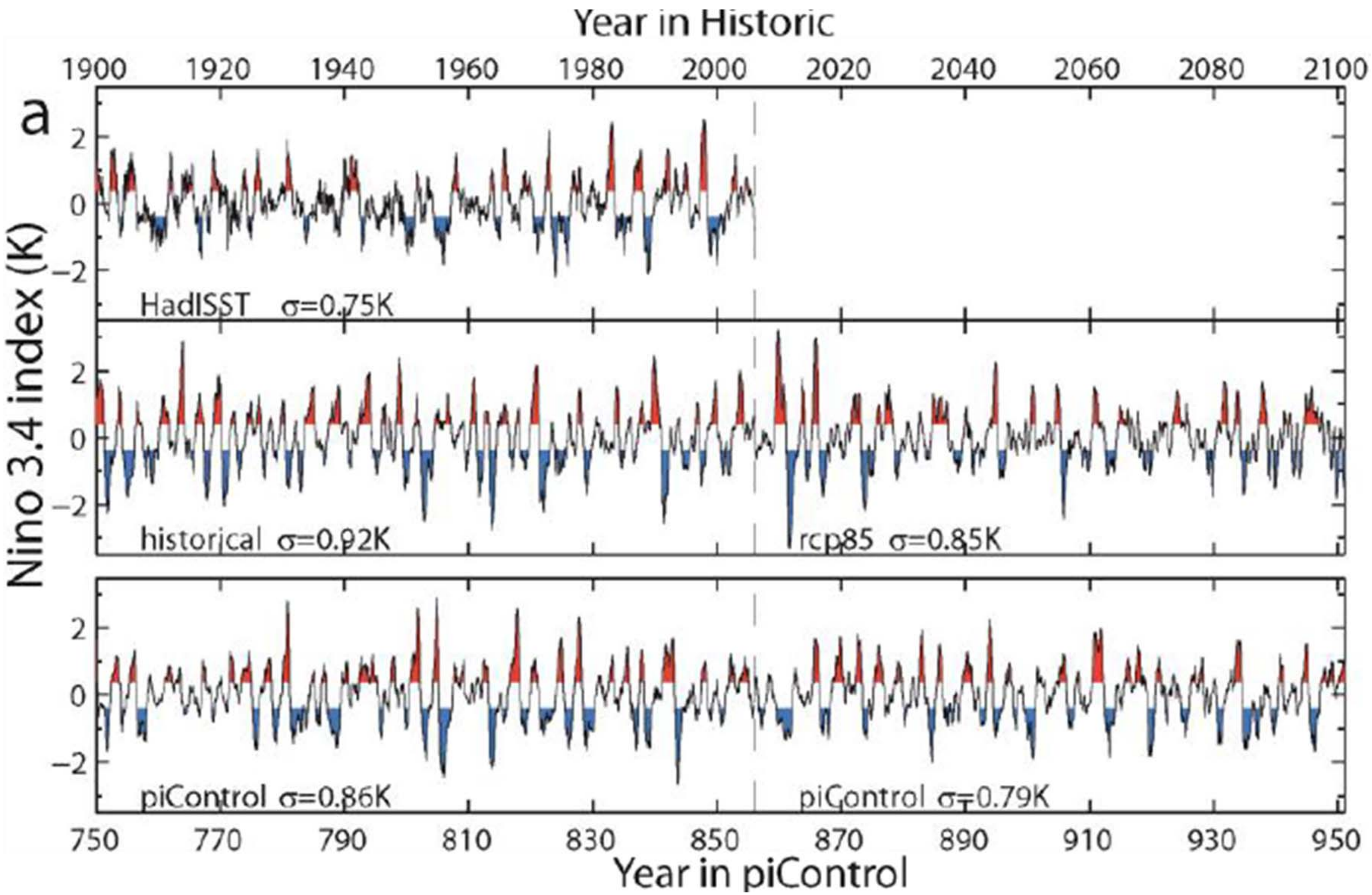
E_Ocean

NH sea-ice ext

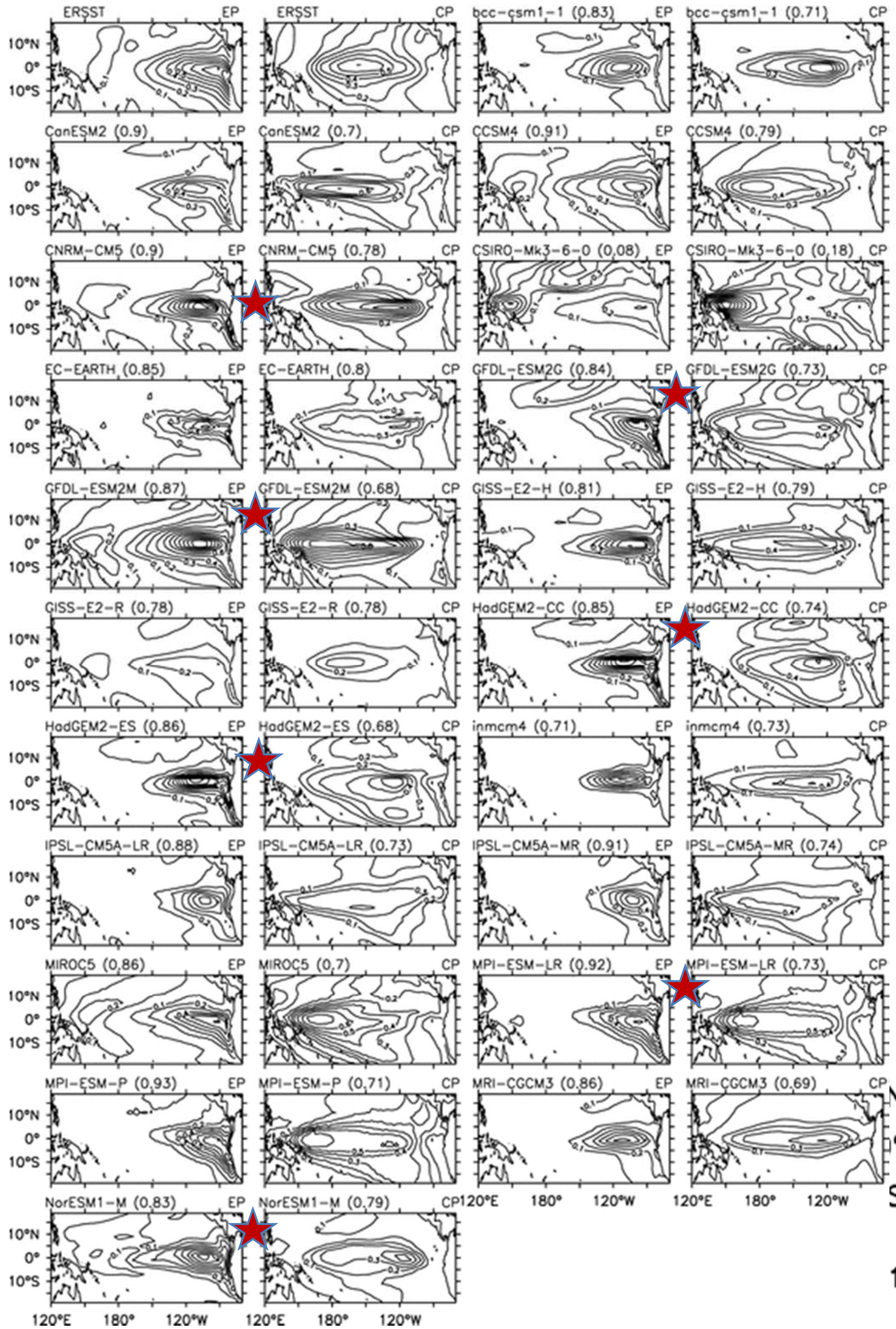
SH sea-ice ext



El Niño-Southern Oscillation



Time series of detrended monthly SST anomalies of the NINO3.4 region.

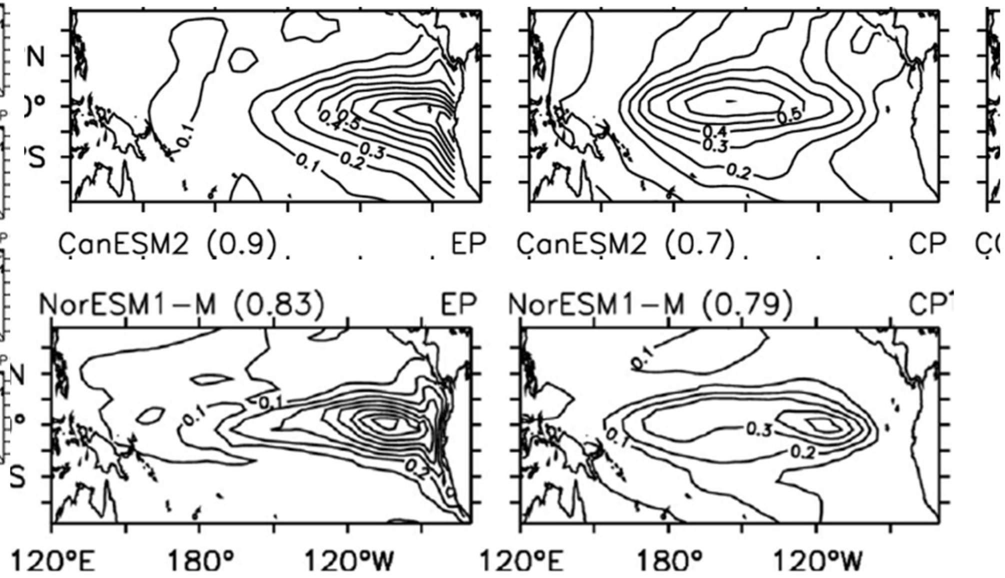


Kim & Yu, 2012:

The Two Types of ENSO in CMIP5 Models,

GRL, 39, L11704,
doi:10.1029/2012GL052006, 2012

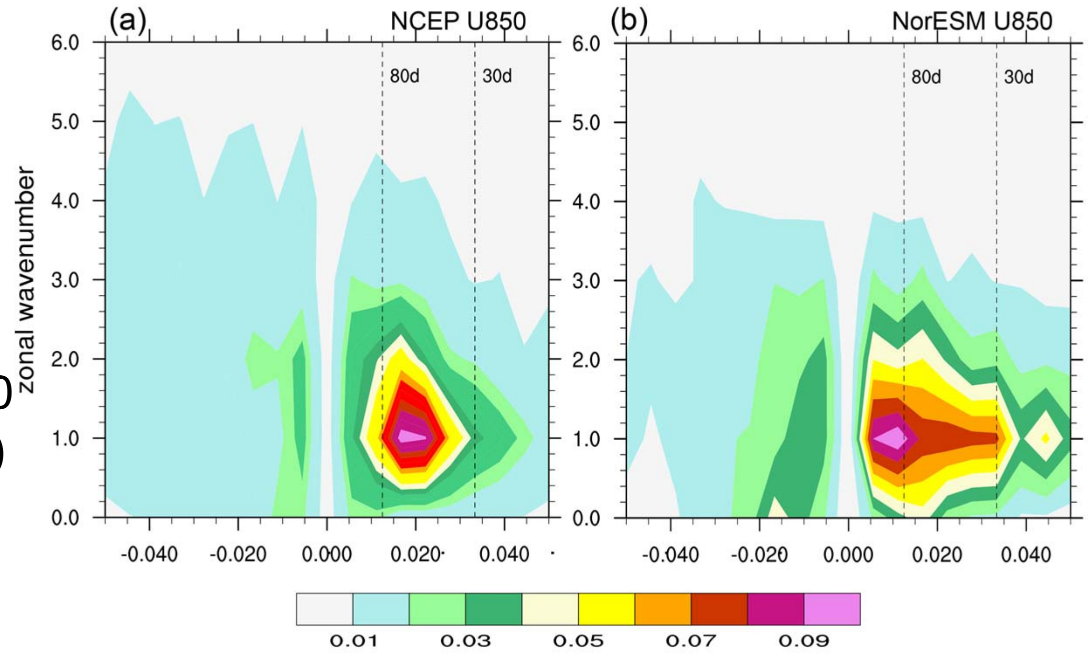
Spatial patterns of the standard deviations of the first EOF mode for **CP ENSO and EP ENSO** calculated from observations (ERSST) and 20 CMIP5 models.



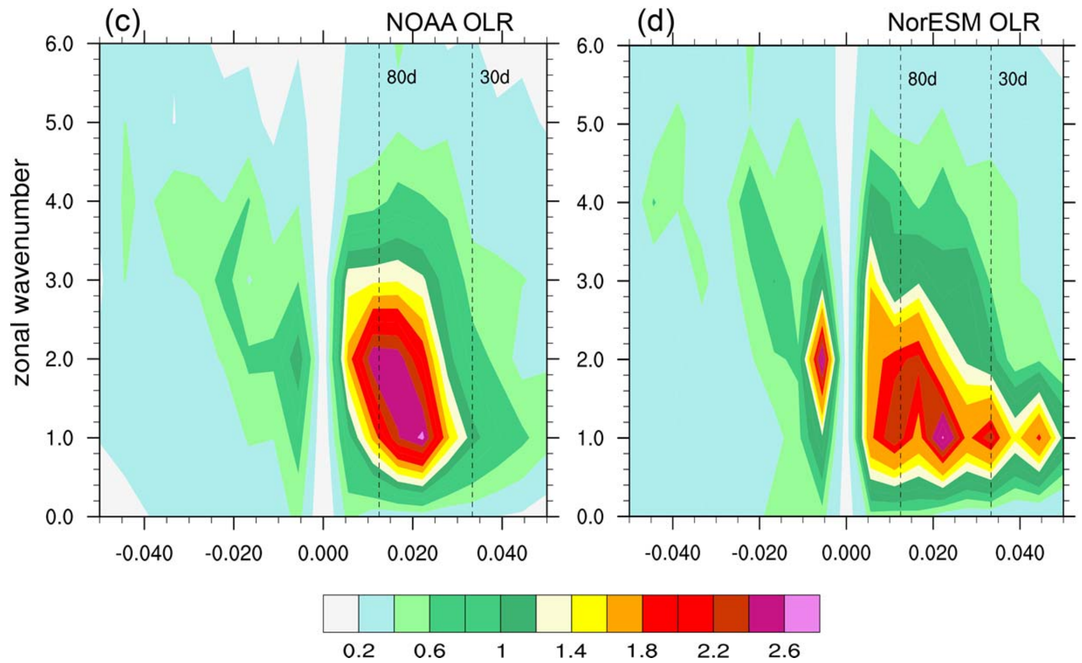
Madden-Julian oscillation

November-April wavenumber-frequency spectra of

10°S-10°N averaged daily zonal 850 hPa winds of (a) NCEP (1979-2008) and (b) NorESM (1976-2005),

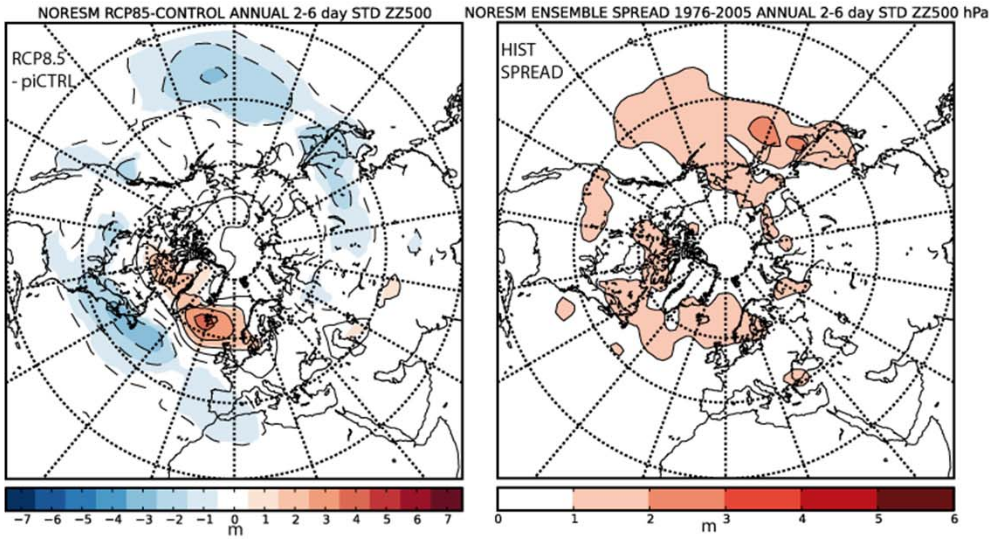


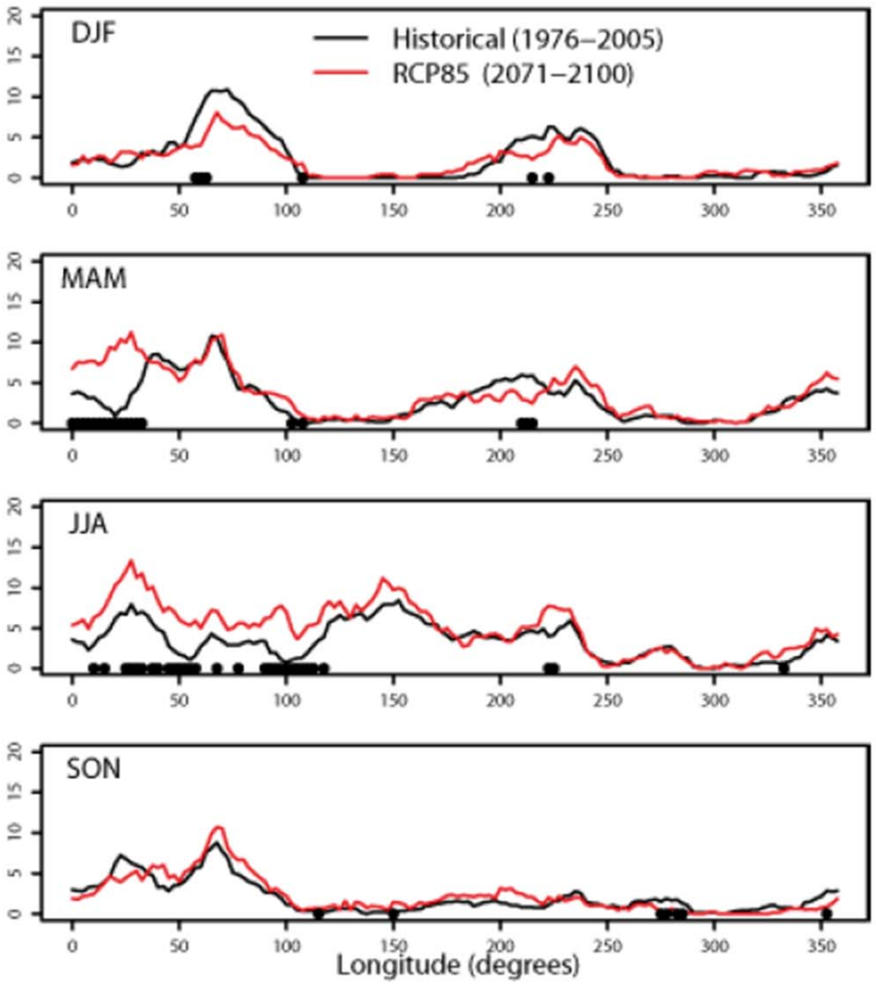
and daily OLR fields of (c) NOAA satellite OLR (1979-2008) and (d) NorESM (1976-2005).



NorESM1-M:

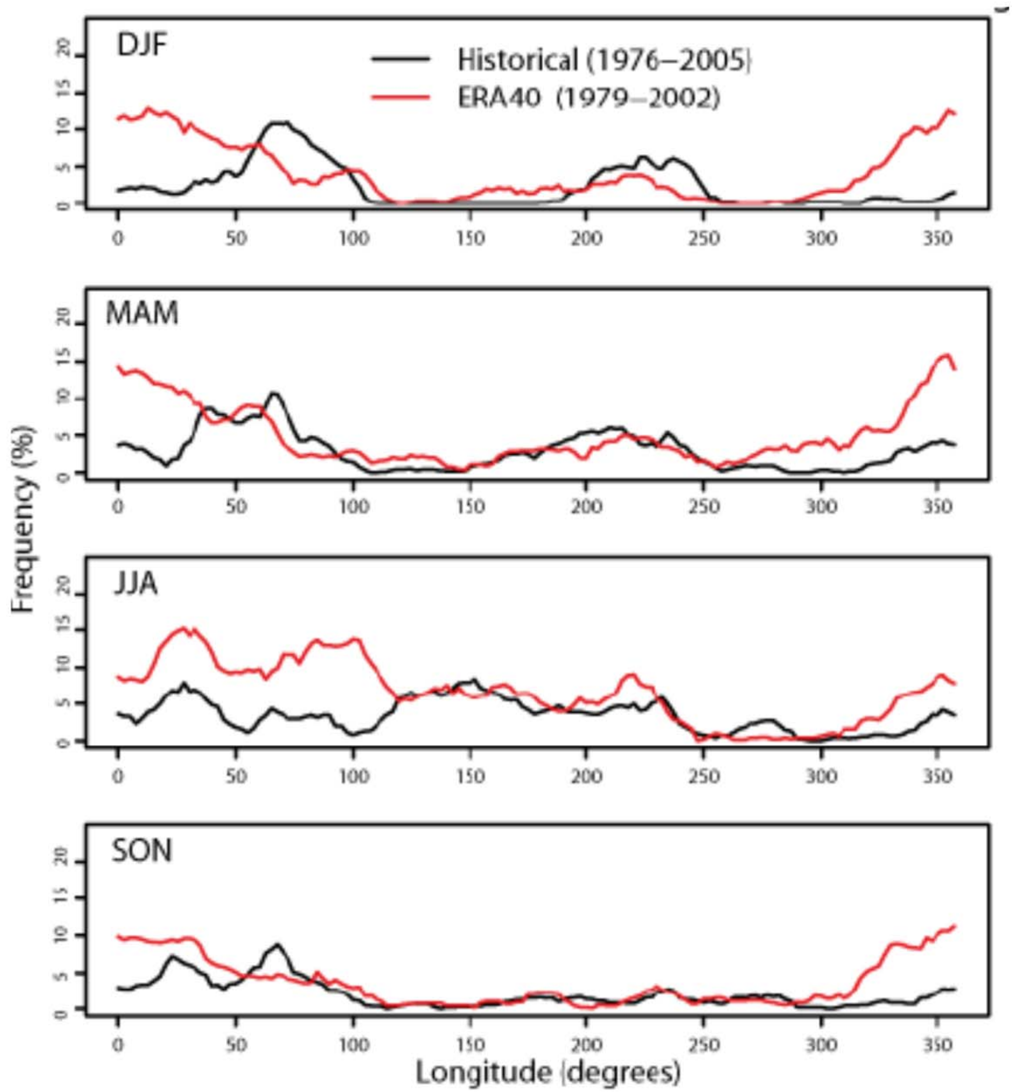
RCP scenario projections: Storminess and blocking





NorESM1-M:

However: Too zonal, and to few Atlantic blocking



Concluding Remarks

- Many aspects of NorESM1-M is related to CCSM4.
- AMOC is probably too strong
- Cloudiness is under-estimated and liquid water over-estimated
- Too cold climate; Artic sea-ice is too thick.
- ENSO and MJO have favorable properties
- NH cyclone activity is too zonal and Euro-Atlantic blocking under-estimated
- RCP-scenarios imply structural changes in precipitation over land:
  High intensity incidents increase, dry spells increase
- AMOC is reduced with up to 1/3 for RCP8.5
- NH Storminess is displaced polewards
- Eur-Asian blocking frequency increases in spring and summer
  BUT: their simulation quality is highly uncertain,
  (2 degrees is too low resolution ?)

What's next ?

Atmospheric part of NorESM2 based on CAM5 (or later)?

1. Reduce complexity, increased resolution and improved transport ?
   - Requires further aerosol simplifications?

2. Increased complexity,
   Missing components and processes
   - Nitrates and anthropogenic SOA,
   - On-line oxidant chemistry,
   - Nucleation of new particles
   - Prognostic, non-SS oceanic emissions (DMS, OM)
   - Prognostic aerosols in cloud droplets / ice
   - Interactions with microphysics in convective clouds
   - Missing soil dust sources, prognostic dust emissions
   - Aerosol – ice & mixed-phase clouds interactions,

Scientfific documentation

Special NorESM-issue of *Geoscientific Model Developments*

- Kirkevåg et al. [2012, GMDD]: Aerosol-climate interactions in the Norwegian Earth System Model NorESM **Published in GMD**
- Bentsen et al. [2012, GMDD]: The Norwegian Earth System Model, NorESM1-M – Part 1: Description and basic evaluation **Minor review for GMD**
- Iversen et al. [2012, GMDD]: The Norwegian Earth System Model, NorESM1-M – Part 2: Climate response and scenario projections **Accepted and in print for GMD**
- Tjiputra et al. [2012, GMDD]: Evaluation of the carbon cycle components in the Norwegian Earth System Model (NorESM) **Under review for GMD**

Low-resolution, paleo-version without interactive aerosols:

- Zhang et al. [2012, GMD]: Pre-industrial and mid-Pliocene simulations with NorESM-L
- Zhang and Yan [2012, GMD]: Pre-industrial and mid-Pliocene simulations with NorESM-L: AGCM simulations

Thank You!

Acknowledgements

The development of both versions of NorESM1 has been possible because of the granted early access to the later public versions of the CCSM4 and CESM1.

We are particularly grateful to

P. J. Rasch, A. Gettelman, J. F. Lamarque, S. Ghan, M. Vertenstein, B. Eaton, M. Flanner, and others,

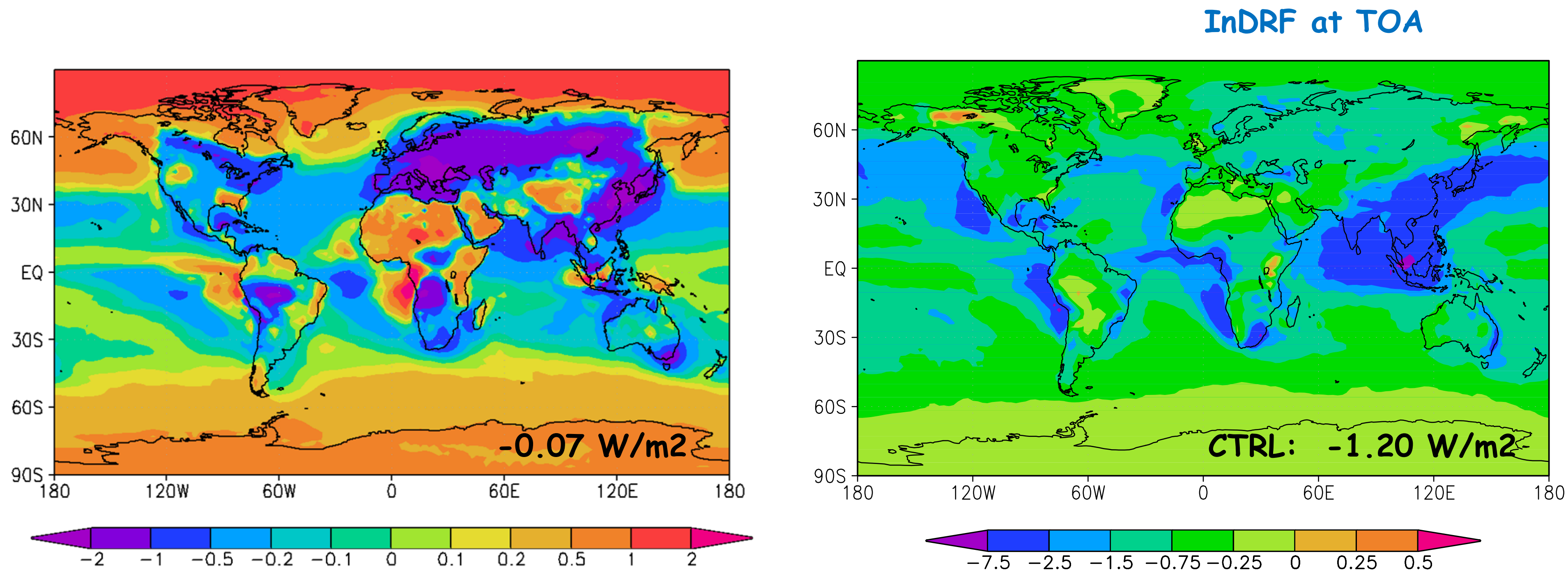
for invaluable advice on numerous scientific and technical issues, and the support by the CESM program directors during the development period,

P. Gent and J. Hurrel.

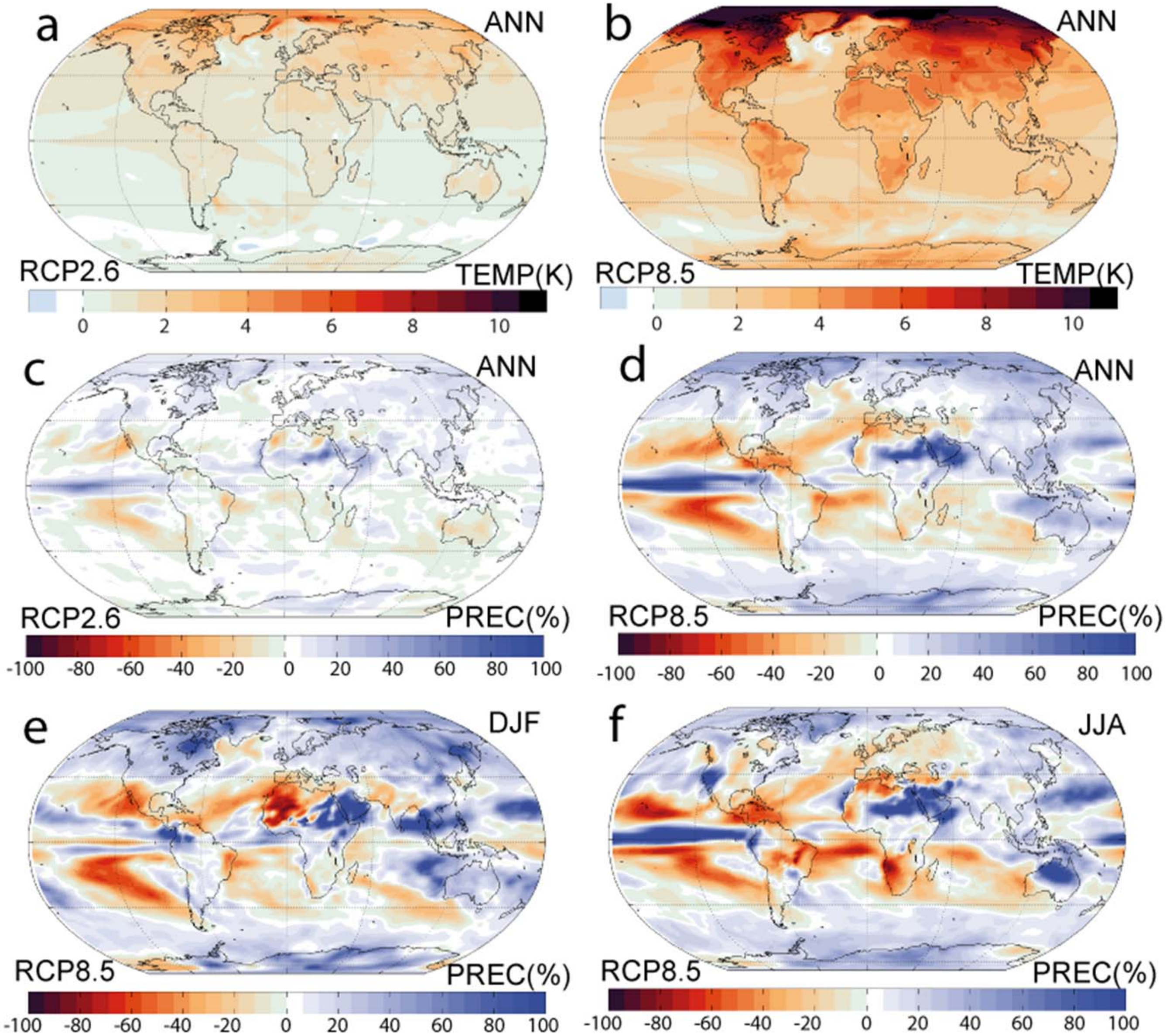
Extra Slides

Aerosol Life-cycling

-20 mass tracers, 11 emitted/produced, 9 transformed
- Tabulations for optics and CCN-activation
- IN-activation not estimated from aerosols
- details in CCWG-talks by Alf Kirkevåg and Dirk Olivié

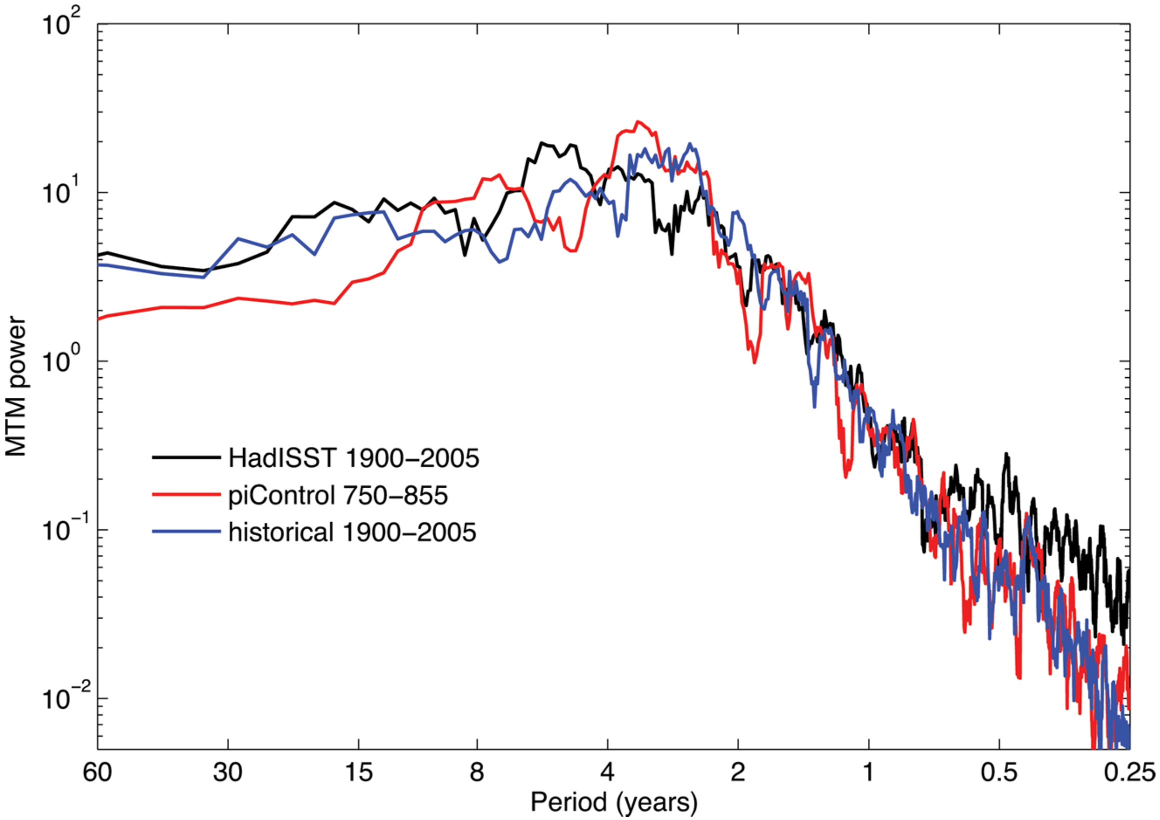


NorESM1-M:
RCP scenario projections



ENSO spectra,

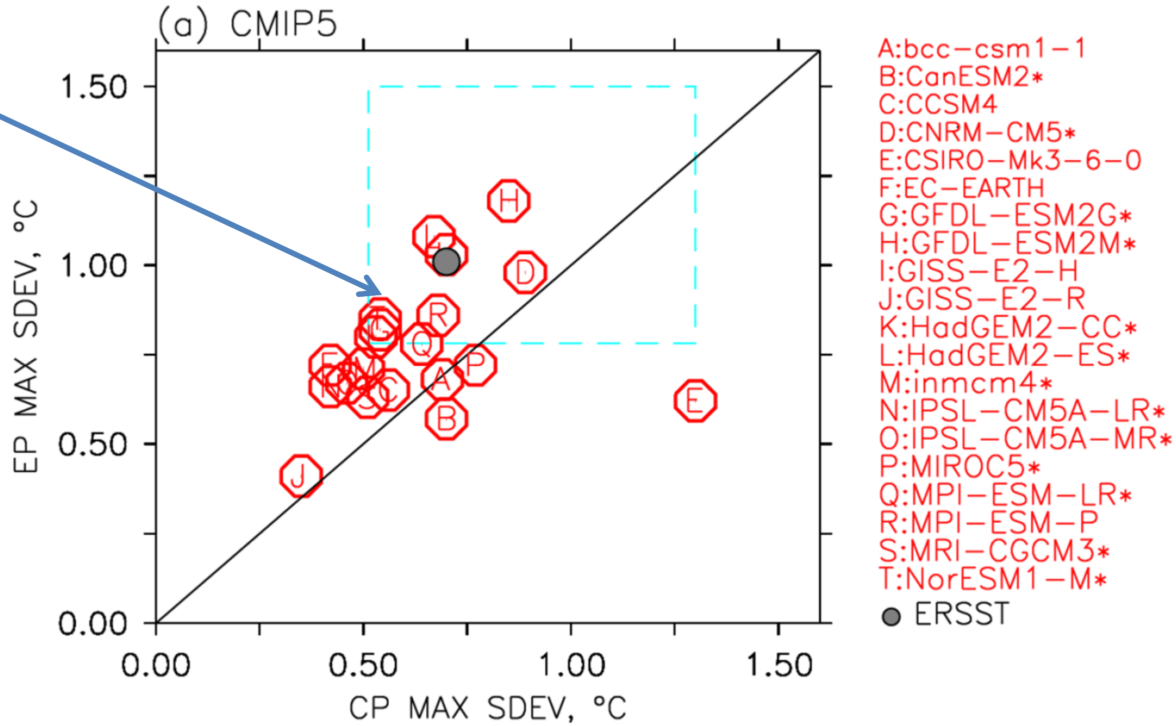
Bentsen et al, 2013, GMD in prep



Power spectra of the NINO3.4 index (the SST anomalies of previous figure normalized with the standard deviation) using a multitaper method.

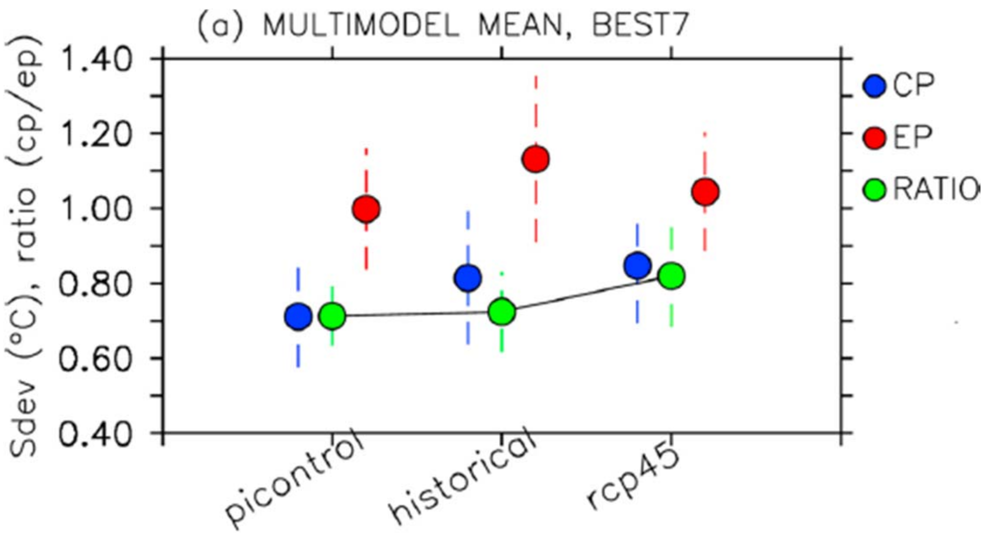
Kim & Yu, 2012,GRL

Scatter plots of maximum standard deviation from CMIP5. The blue dashed lines indicate the lower limit of the 95% significance interval of the observed ENSO intensities based on an F-test.



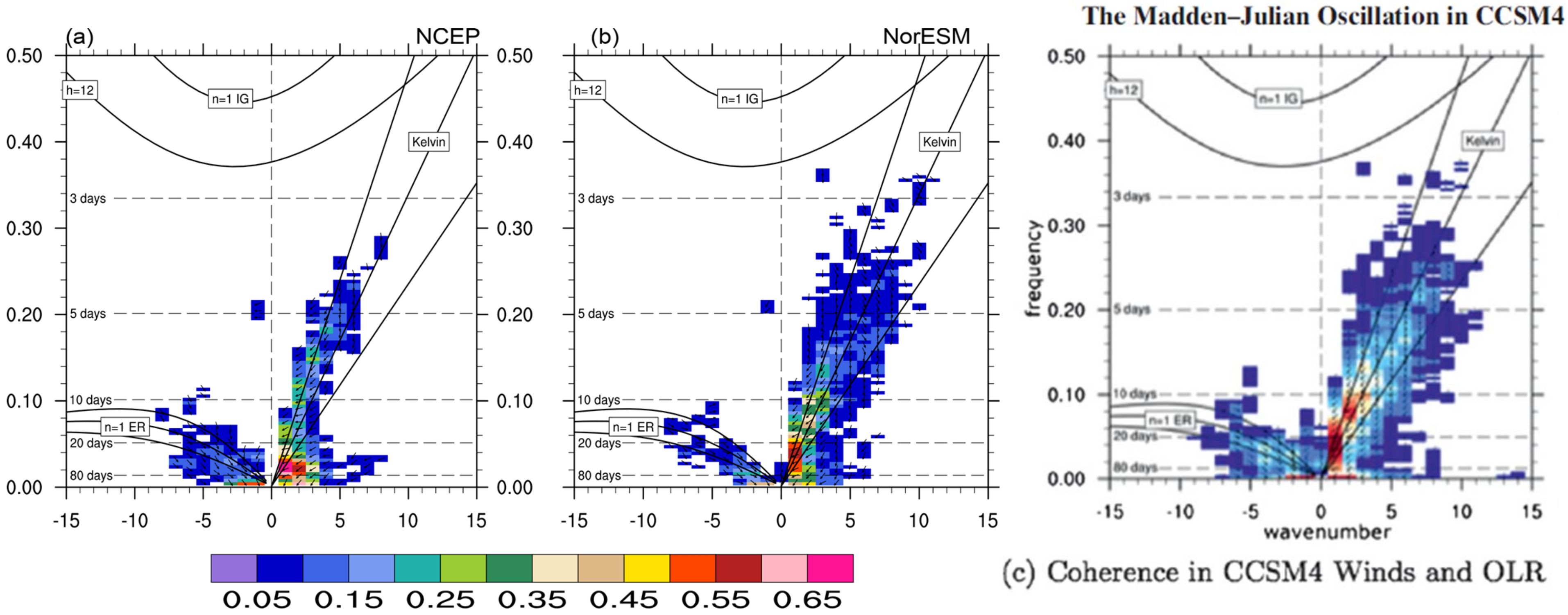
CNRM-CM5, GFDL-ESM-208 2G, GFDL-ESM2M, HadGEM2-CC, HADGEM2-ES, MPI-ESM-LR, and Nor-ESM1-M
produce strong EP and CP ENSOs.

The “best model ensemble” for projecting the response of the two types of ENSO to the ongoing and possible future global warming.



MJO, Coherence

Subramanian et al, J. Cli. 2011



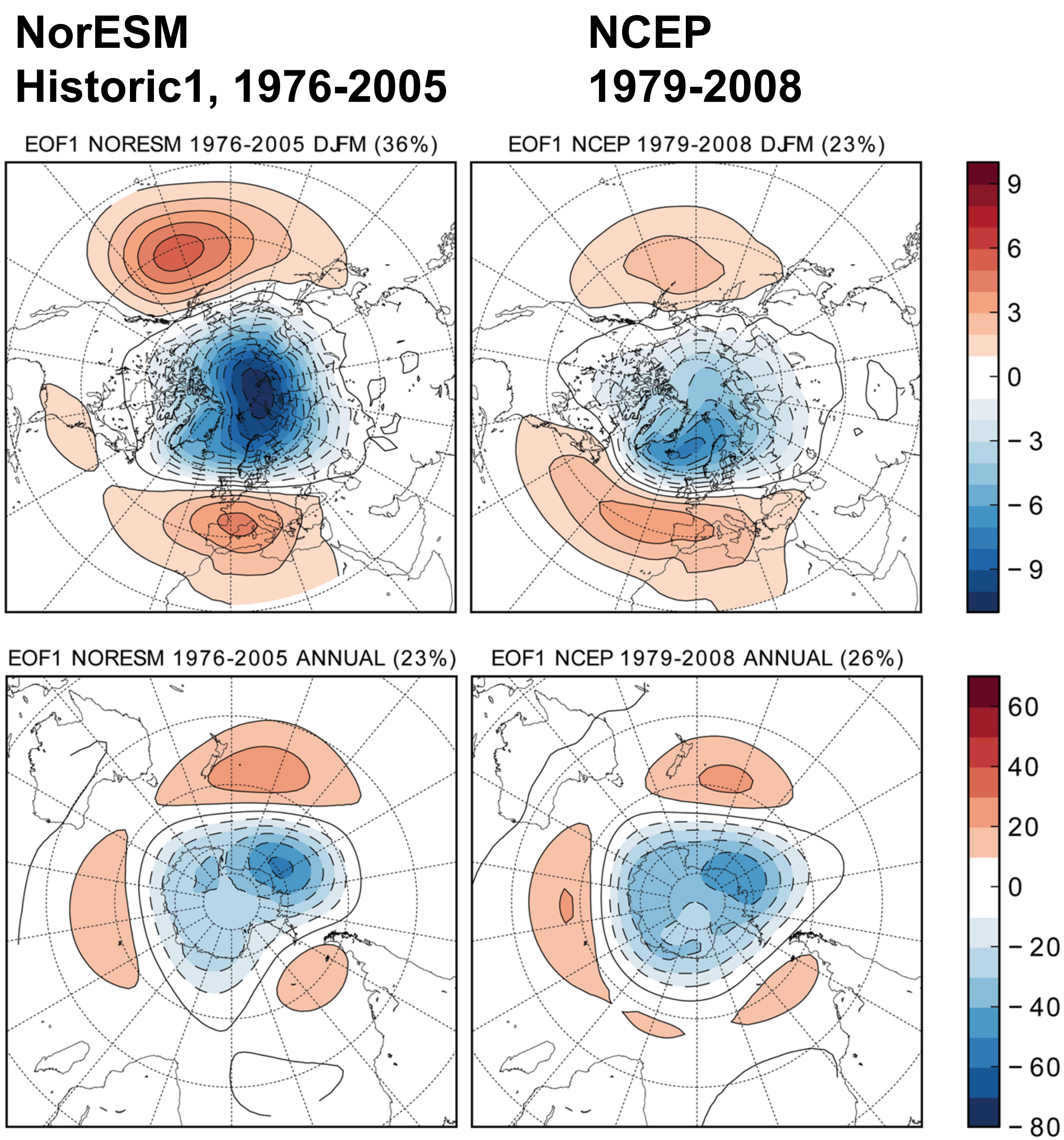
(c) Coherence in CCSM4 Winds and OLR

Coherence squared (colors) and phase lag (vectors) between zonal winds at 850 hPa and OLR are shown for (a) NCEP winds and NOAA satellite OLR, (b) NorESM, and (c) CCSM4 (Subramanian et al, J. Cli. 2011).

NH Annular modes

NAM:
Leading EOF of winter (DJFM) monthly mean sea level pressure anomalies).

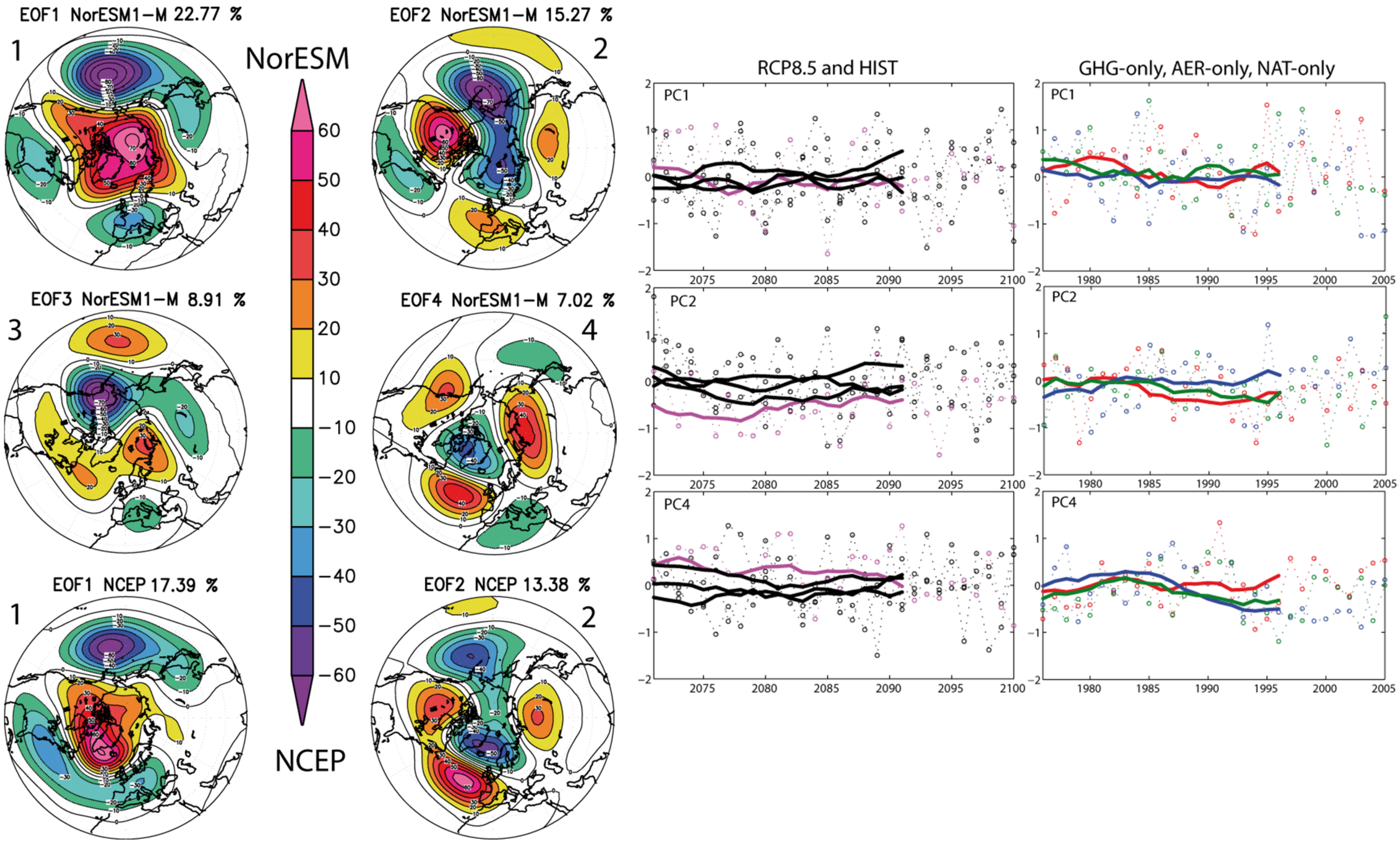
SAM:
Leading EOF of monthly mean 850 hPa geopotential height anomalies (m)



NorESM1-M:

RCP scenario projections: Flow regimes

Iversen et al., 2013 in press



NorESM1-M:

RCP scenario projections: Global numbers

	RCP8.5 – Historic1	RCP6.0 – Historic1	RCP4.5 – Historic1	RCP2.6 – Historic1	Historic1 1976-2005	Historic1 – piControl
T_{2m} / K	+3.07	+1.86	+1.65	+0.94	286.78	+0.50
SST / K	+1.76	+1.06	+0.95	+0.59	282.92	+0.34
$AREA_{SeaIce}$ / $10^6 km^2$	-6.24	-3.48	-2.97	-1.43	20.76	-1.14
P_{GLOBAL} / $1000 km^3 yr^{-1}$	+27	+17	+17	+12	521	0
E_{OCEANS} $1000 km^3 yr^{-1}$	+25	+15	+14	+10	442	+1
$(E-P)_{OCEANS}$ $1000 km^3 yr^{-1}$	+8	+4	+2	+1	43	+1
P_{OCEANS}* / $1000 km^3 yr^{-1}$	+17	+11	+12	+9	399	0
P_{LAND}* / $1000 km^3 yr^{-1}$	+10	+6	+5	+3	122	0
E_{LAND}* / $1000 km^3 yr^{-1}$	+2	+2	+3	+2	79	-1