Importance of snow initial condition in seasonal forecasting

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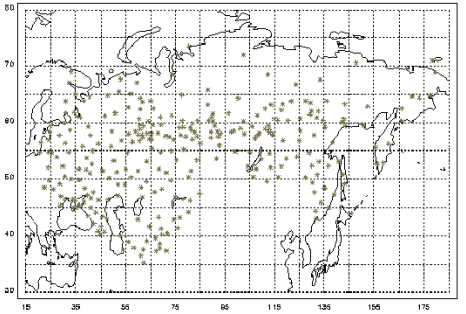
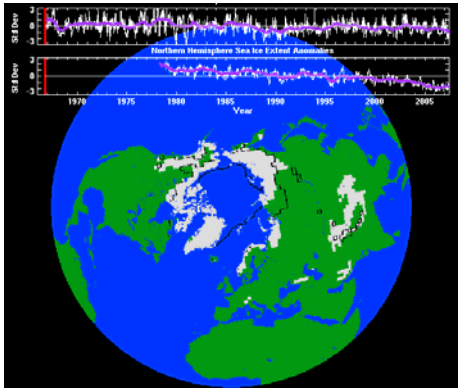
Snow cover (SC) & snow depth (SD) datasets

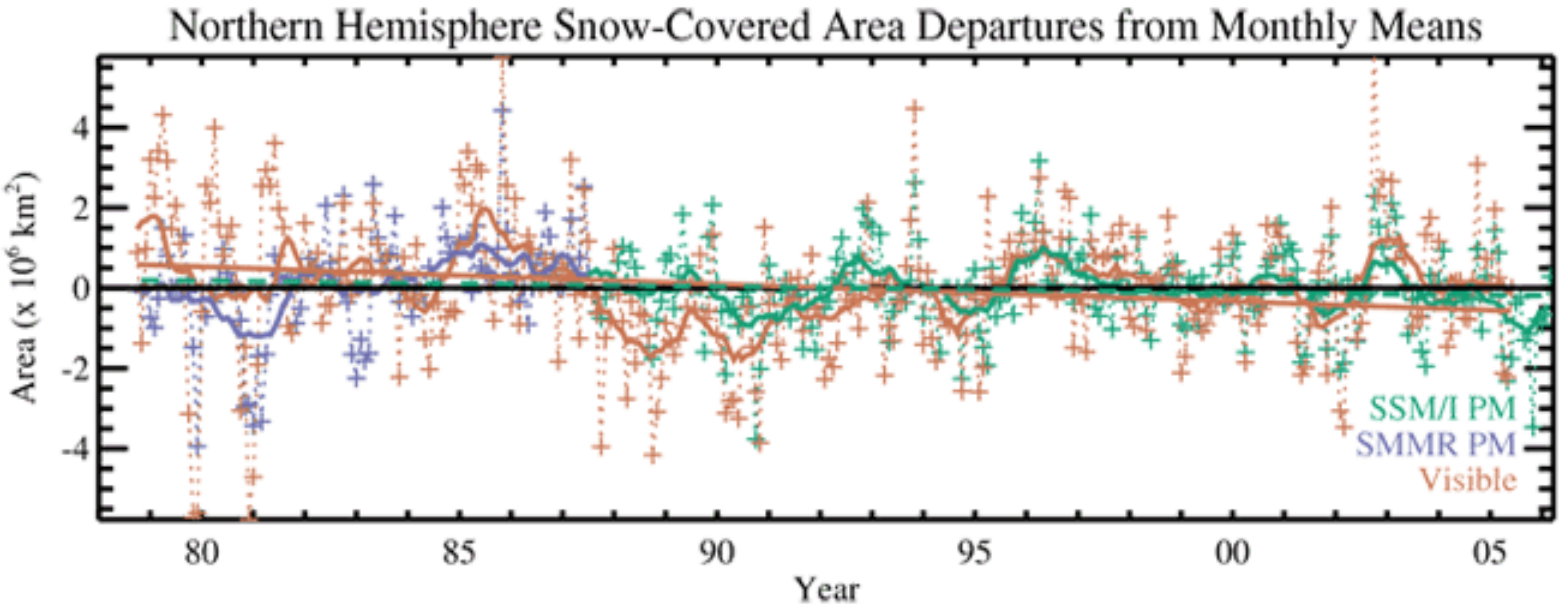
- ✓ USAF global SD monthly climatology (*Foster and Davy 1988*)
- ✓ Historical Soviet Union daily SD (1936-1995)
- ✓ NSIDC v3 NH weekly/daily SC (1967-2006)
- ✓ SMMR+SSM/I SD (since 1978)
- ✓ MODIS SC (since 2000)
- ✓ GRACE SD (since 2002, e.g. *Niu et al. 2007*)





- ✓ On-line assimilation schemes (e.g. CMC *Brasnett 1999*; ECMWF, *Drusch et al. 2004*)
- ✓ Off-line land surface simulations driven by « observed » atmospheric forcings (e.g. GSWP2 1986-1995; Princeton Univ. 1950-2006, *Sheffield et al. 2006*)

Variability of NH snow cover area



Northern Hemisphere snow-covered area anomalies: This shows Northern Hemisphere snow-covered area departures from monthly means, 1978-2005, from NOAA snow charts (orange) and microwave satellite (purple/green) data sets. The NOAA time series for this period exhibits a significant decreasing trend of -2.0 percent per decade (solid orange line); the microwave snow cover time series exhibits a decreasing trend of -0.7 percent per decade that is not significant at a 90 percent level (dashed green line). Image by Richard Armstrong and Mary Jo Brodzik, National Snow and Ice Data Center, University of Colorado, Boulder.

http://nsidc.org/sotc/snow_extent.html

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Snow depth versus snow extent variability

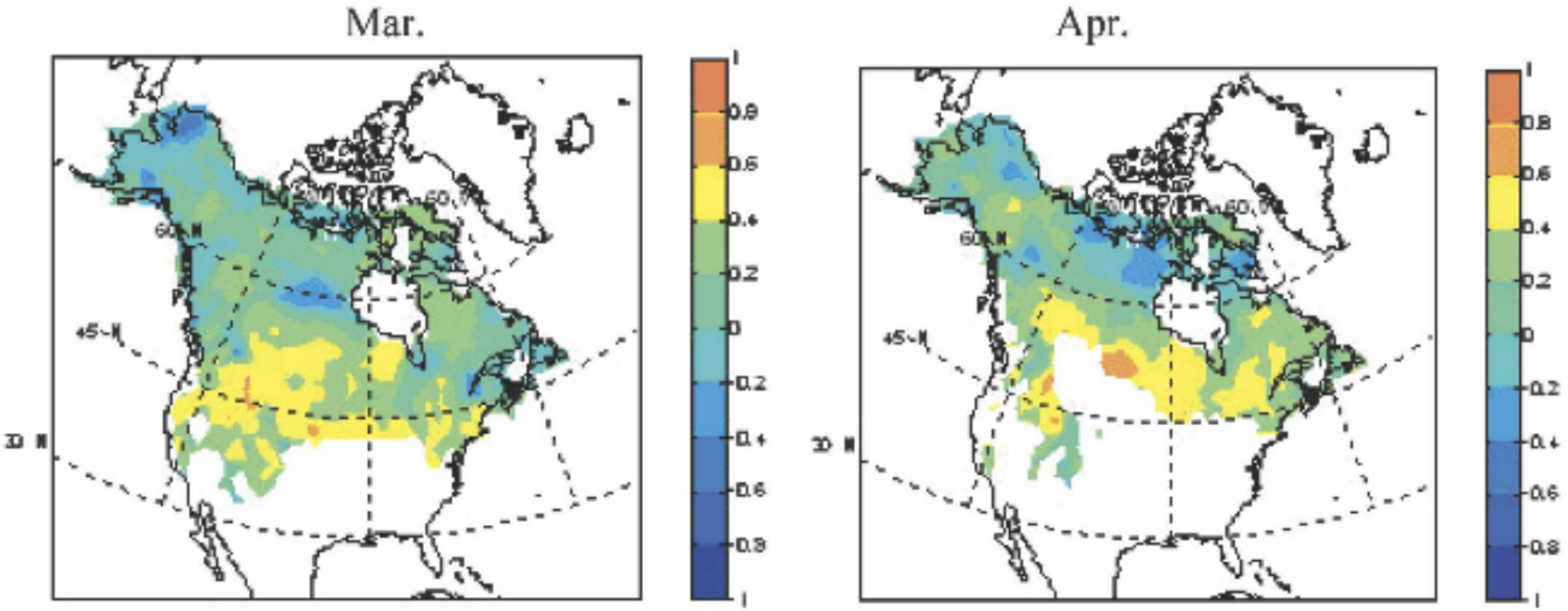


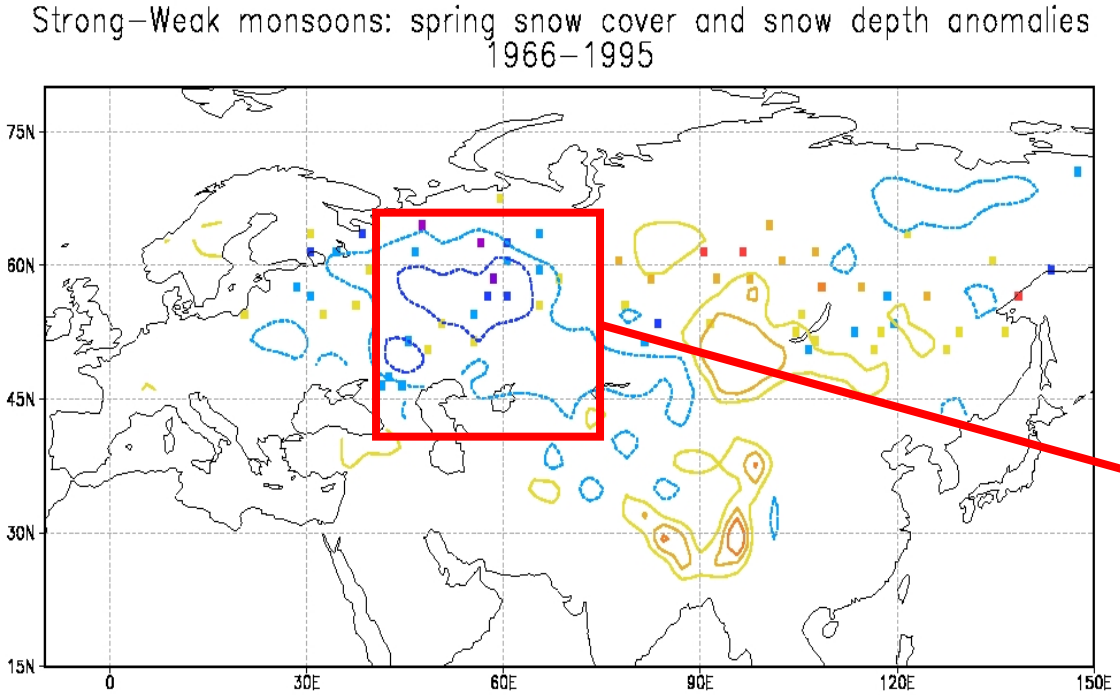
FIG. 4. Correlation maps between gridded snow depth (Dyer and Mote 2006) and North American snow extent (Brown 2000) from 1956 to 1997. Absolute values greater than 0.30 (0.39) are significant at the 5% (1%) level for a sample size of 42 yr.

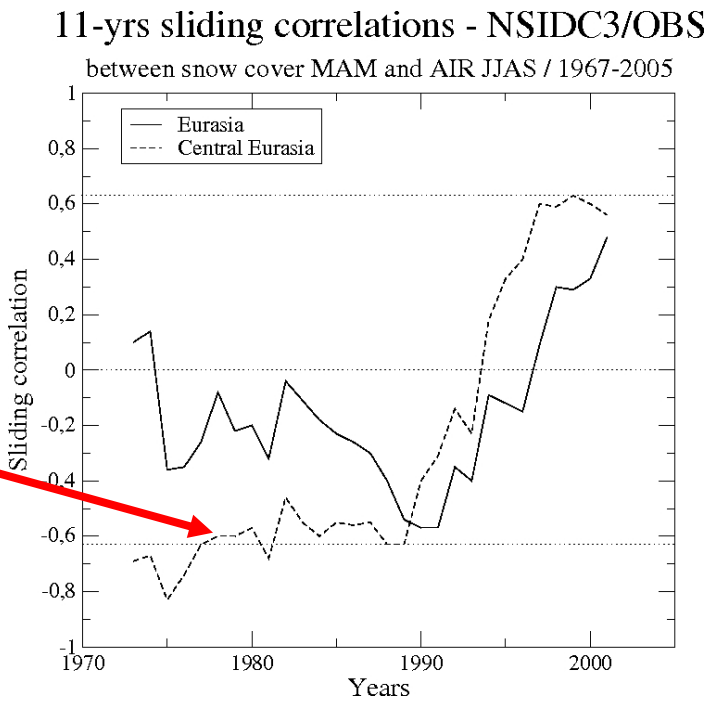
Ge and Gong, J. Climate 2008

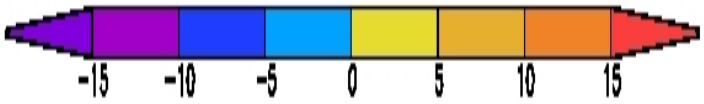
Potential impact on Indian summer monsoon

- ✓ Observational studies: Blanford (1884), Hahn and Shukla 1976, Dickson 1984, Yang 1996, Bamzai and Shukla 1999, Robock et al. 2003, Fasullo 2004, etc…
- ✓ GCM sensitivity experiments: Barnett et al. 1988, Yasunari et al. 1991, Douville and Royer 1996, Ferranti and Molteni 1999, etc…
- ✓ CMIP3 20th century simulations: Peings and Douville 2009
- ✓ Summary:
  - ✓ Statistical relationship between winter/spring Eurasian snow cover and subsequent Indian summer monsoon rainfall
  - ✓ Reproduced by different AGCM sensitivity experiments
  - ✓ Two possible mechanisms: modulation of the land-sea temperature contrast through both radiative and hydrological effects, modulation of tropical Pacific SST
  - ✓ Not consistent in CMIP3 models
  - ✓ No longer observed over recent decades

Strong minus Weak monsoon composites







snow mass (pixels in kg/m²)
and snow cover (isolines in %)

Collapse of the snow-monsoon relationship since the mid 1990's

Peings and Douville, Climate Dyn. 2009

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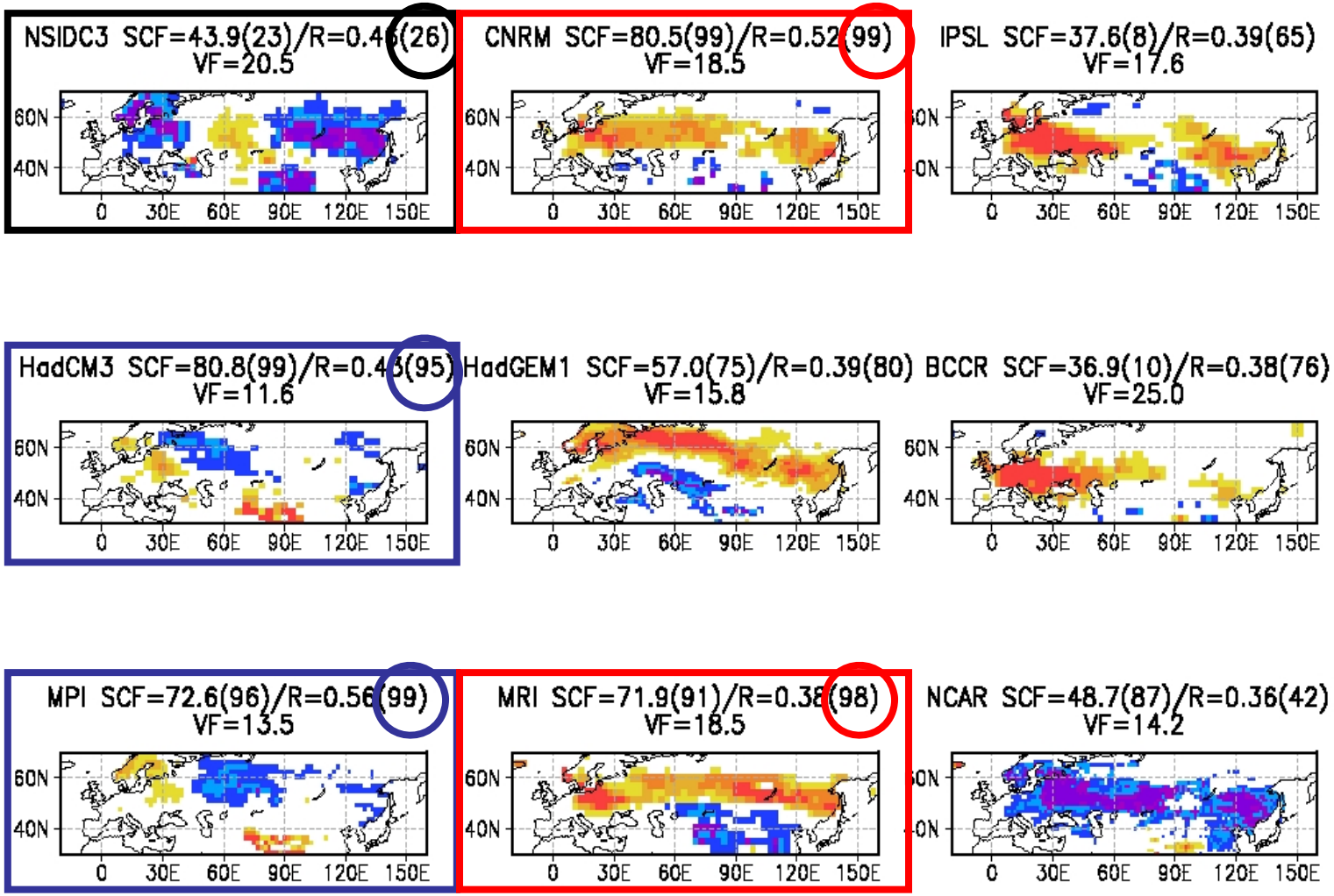
Maximum Covariance Analysis MAM SC / JJAS P

Peings and Douville, Climate Dyn. 2009



Potential impact on winter AO/NAO

- ✓ Observational studies: Cohen and Entekhabi 1999, Cohen et al. 2001, Saito et al. 2001, Saito and Cohen 2003, Qian and Saunders 2003, Cohen 2007
- ✓ GCM sensitivity experiments: Walland and Simmons 1997, Watanabe and Nitta 1998, Gong et al. 2003, Fletcher et al. 2007, Fletcher et al. 2009
- ✓ CMIP3 pre-industrial simulations: Hardiman et al. 2008
- ✓ Summary:
  - ✓ Statistically robust relationship between october snow cover over Siberia and winter AO/NAO variability in the northern extratropics
  - ✓ Reproduced by few AGCM sensitivity experiments
  - ✓ Two-part mechanism: snow-forced vertical propagation of Rossby waves, interaction with the lower stratosphere zonal circulation and downward propagation
  - ✓ Not clear in CMIP3 models

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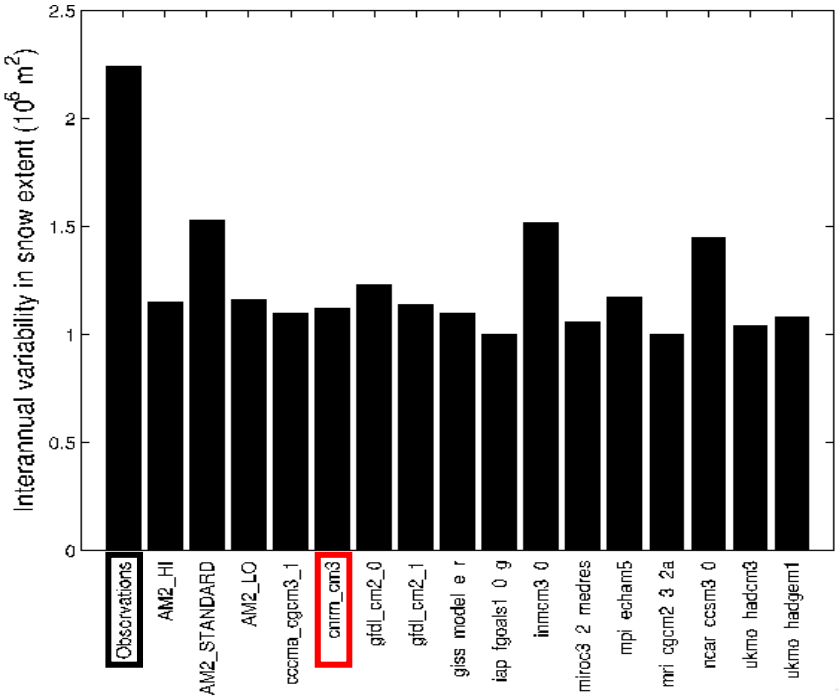
Analysis of pre-industrial CMIP3 simulations

- CMIP3 models fail to capture the observed relationship between October Eurasian snow cover and DJF AO/NAO
- The snow variability is weaker than observed
- The snow forcing of planetary waves is too localized longitudinally
- Need of a well-resolved stratosphere ?

Standard deviation of October interannual variability in Eurasian snow extent



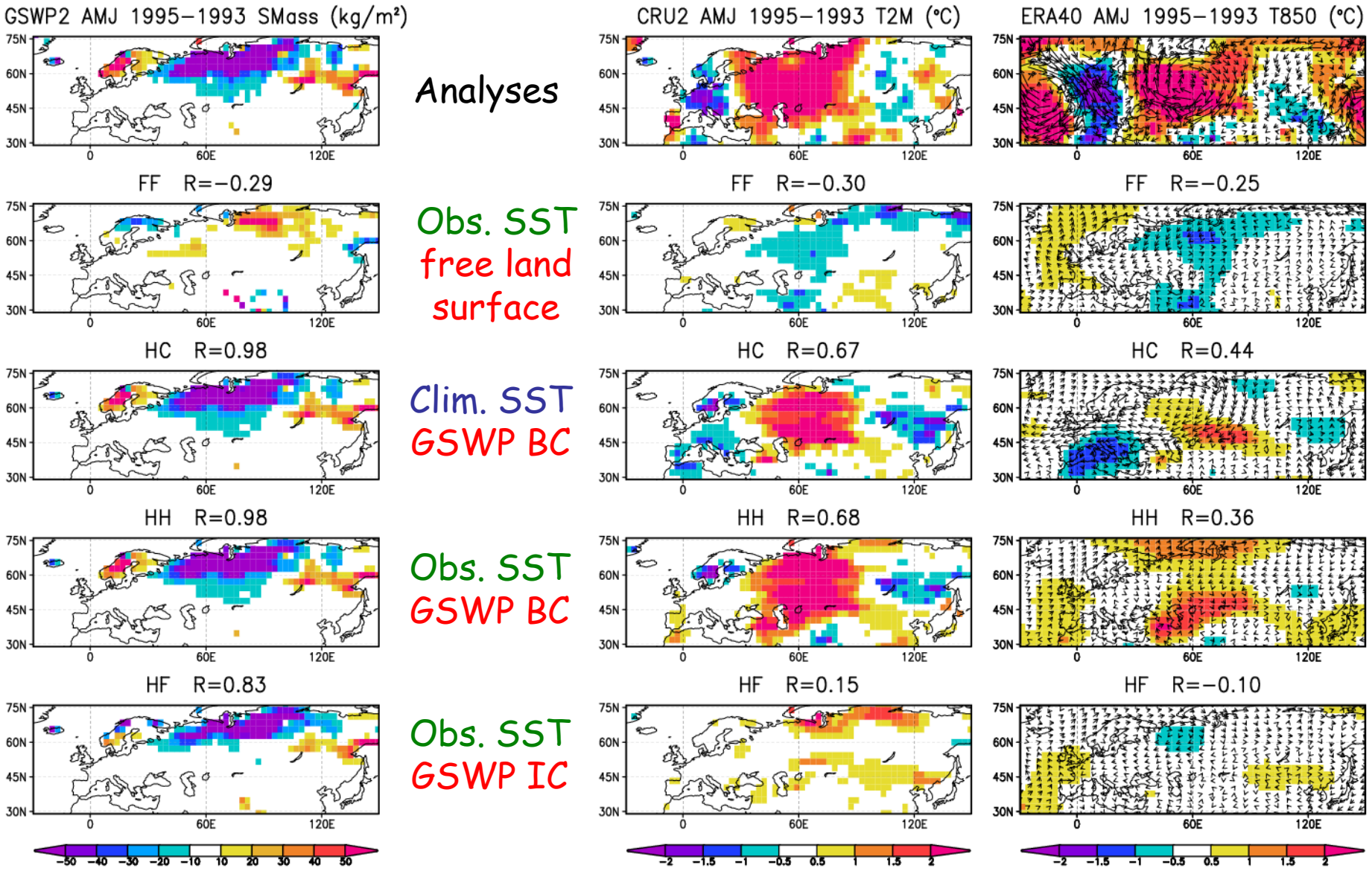
Hardiman et al., JGR 2008

Potential impact on seasonal predictability

- ✓ Statistical hindcasts: e.g. Cohen and Fletcher 2007
- ✓ Dynamical « hindcasts »: Kumar and Yang 2003, Schlosser and Mocko 2003, Orsolini and Kvamsto 2009, Douville 2009
- ✓ Summary:
  - ✓ Lack of global snow mass observations for an accurate initialization of dynamical models
  - ✓ Most AGCM sensitivity experiments explored the influence of boundary conditions rather than initial conditions
  - ✓ They showed positive impacts on low-level temperatures but no clear improvement of large-scale circulation
  - ✓ Need of a GLACE-like intercomparison project
  - ✓ No sensitivity test with real dynamical seasonal forecasting systems (coupled OAGCM with data assimilation)

Dynamical hindcasts with prescribed SSTs

Douville, Climate Dyn. 2009

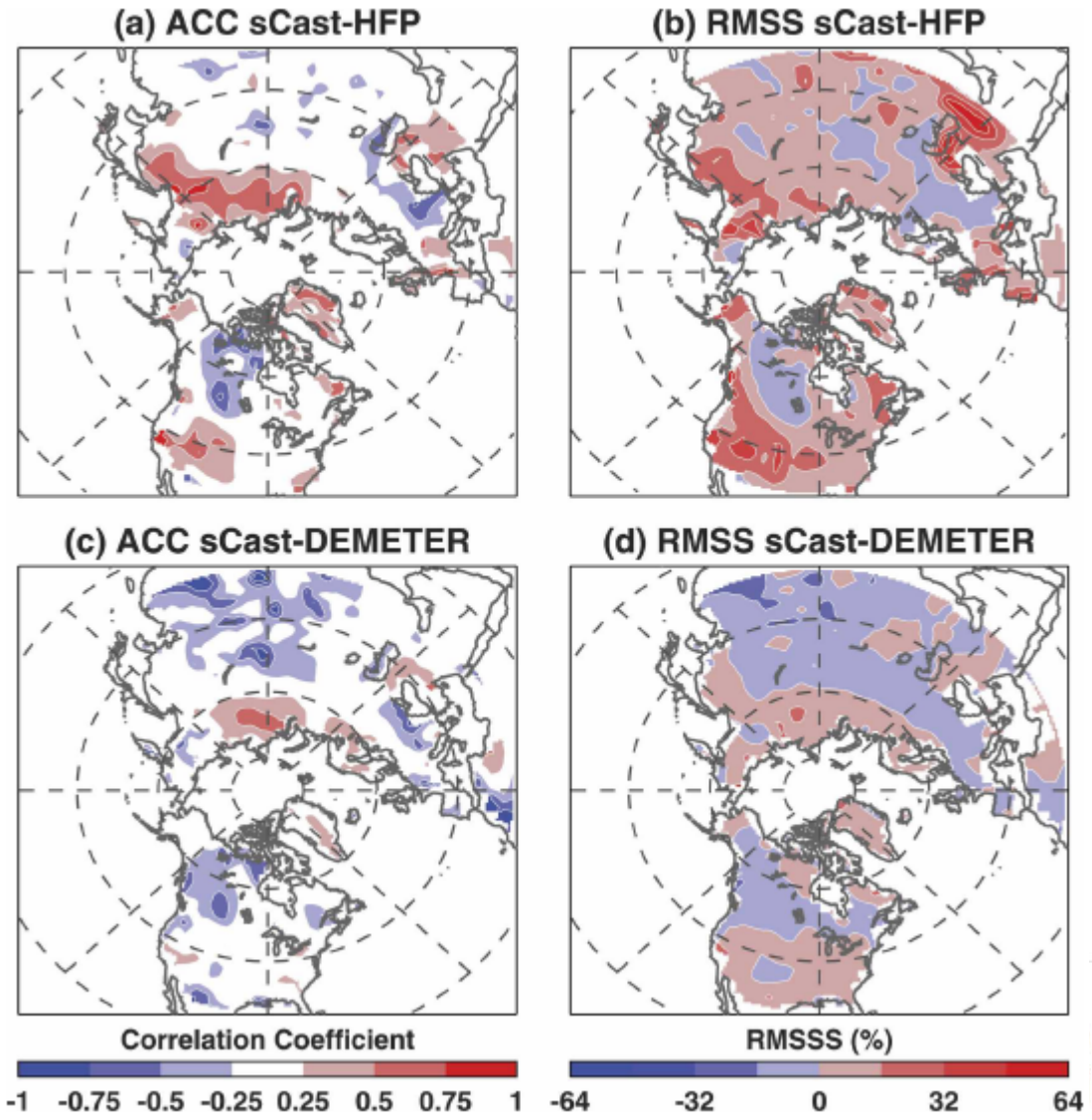


Statistical versus dynamical hindcasts

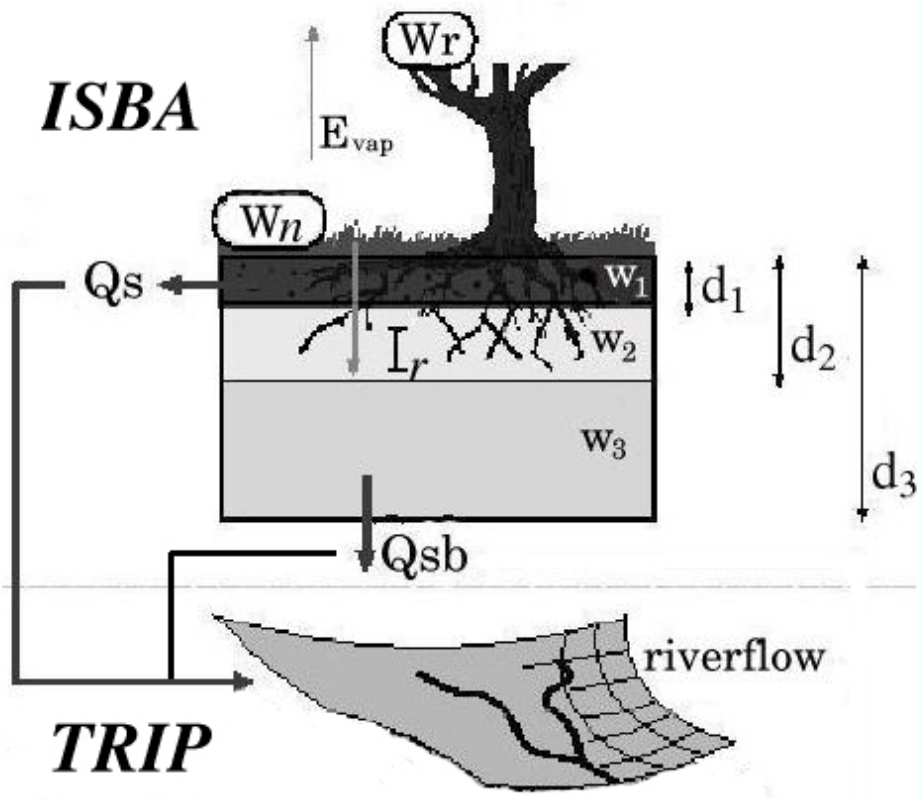
Cohen and Fletcher, J. Climate 2007

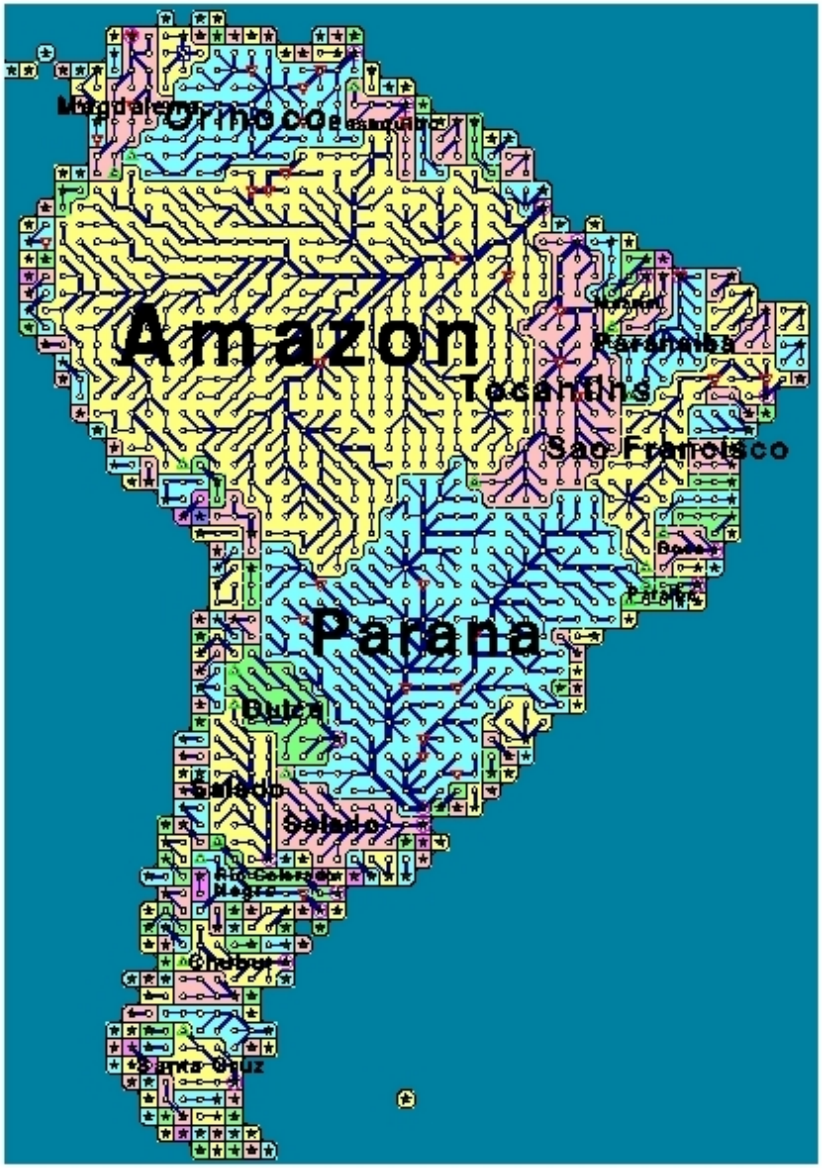
Anomaly correlation coef. (ACC) and root-mean skill score values (RMSS) for DJF surface temperature hindcasts (1972/73 to 1992/93)

Difference between the simplified sCast model and two dynamical forecasting systems (red means sCast has greater skill)



The ISBA-TRIP land surface hydrology





Noilhan and Planton 1989, Douville et al. 1995, Oki and Sud 1998, Boone et al. 1999, Decharme et al. 2006, Alkama et al. (submitted)

Local « off-line » evaluation: e.g. SnowMIP2

Rutter et al. 2009

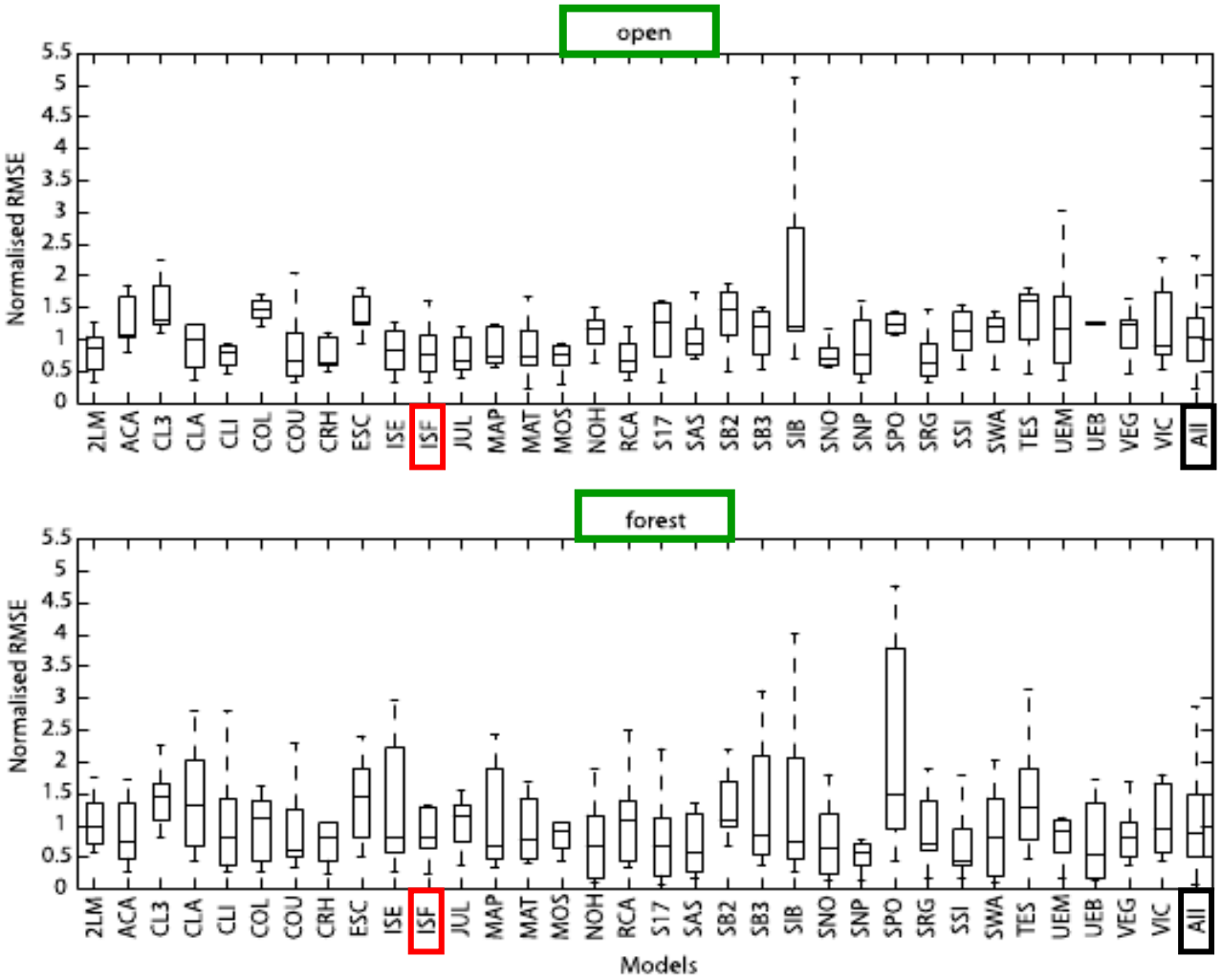
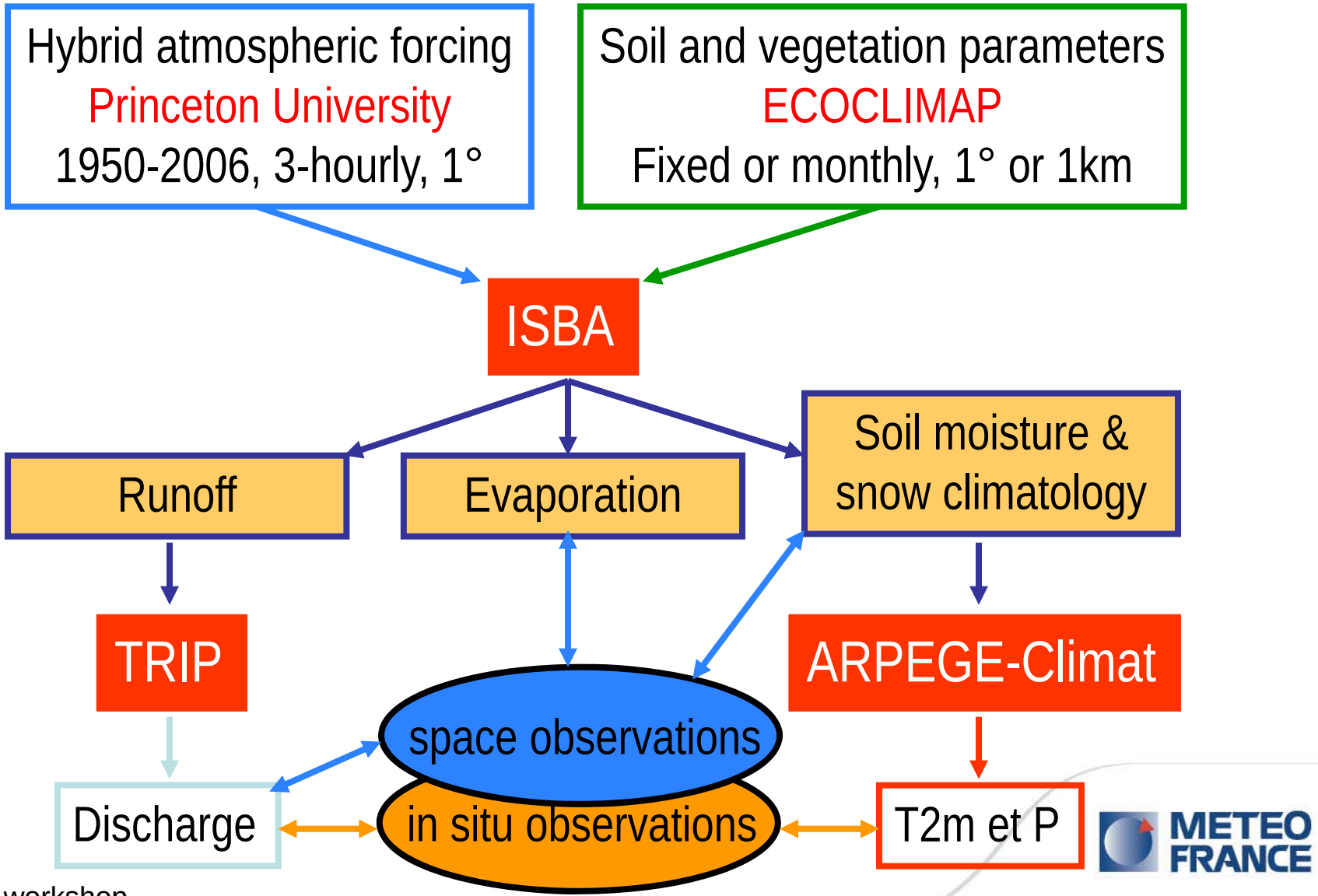
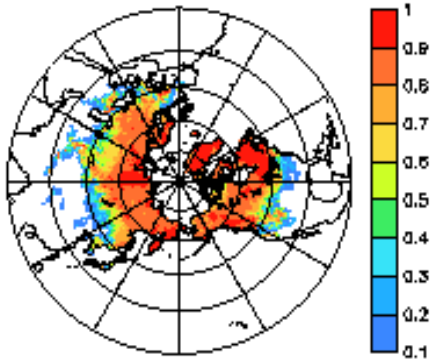


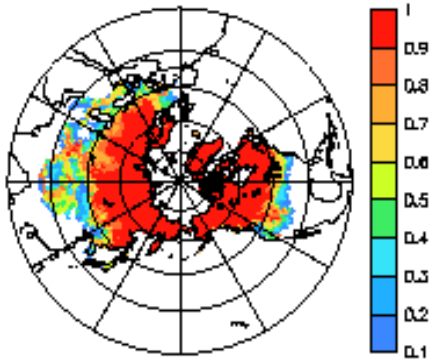
Figure 6. Box plot summaries [*Tukey*, 1977] describing the performance of individual models and all models, combined at all locations and years at open sites and forest sites. Each box has horizontal lines (solid) at lower quartile, median, and upper quartile values; whiskers (dashed lines) extend from the end of each box to 1.5 times the interquartile range; outliers beyond this range are omitted.

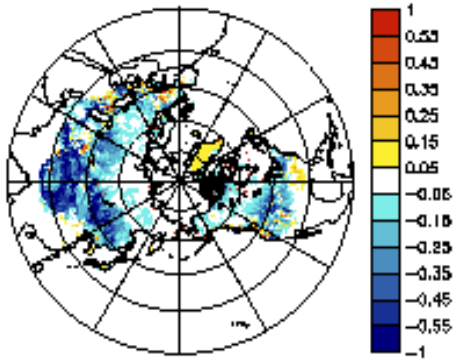
Production of a global snow climatology

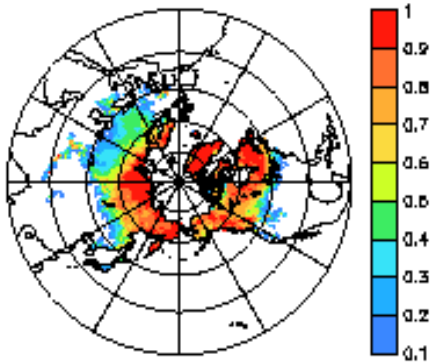


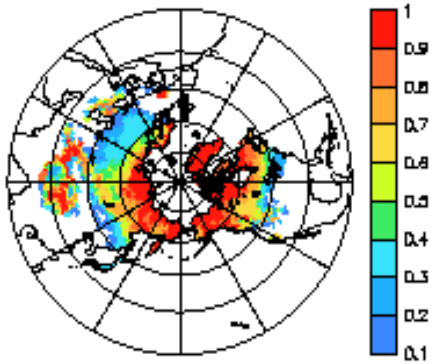
Northern Hemisphere snow cover fraction DJF and MAM climatology


DJF SIM


DJF OBS


DJF SIM−OBS


MAM SIM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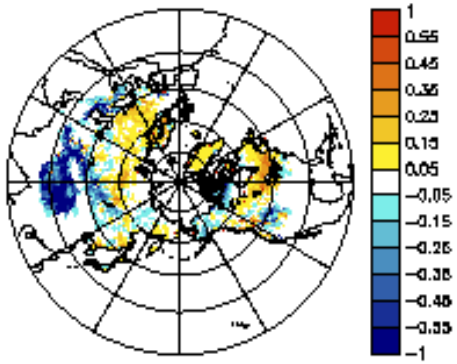
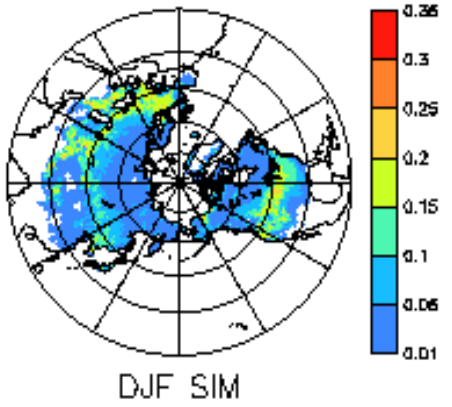
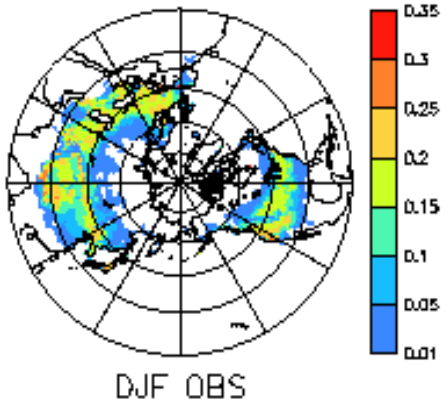

MAM SIM−OBS

Northern Hemisphere snow cover fraction DJF and MAM interannual variability



DJF SIM



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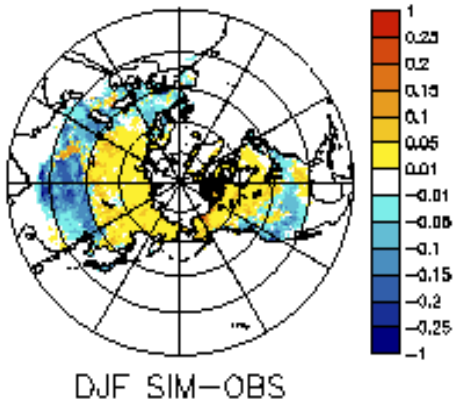

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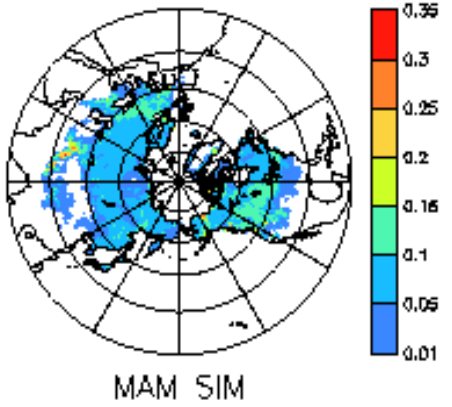
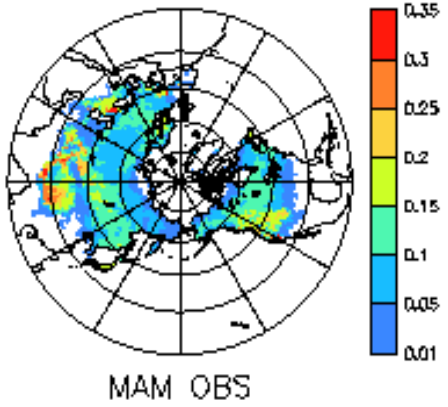
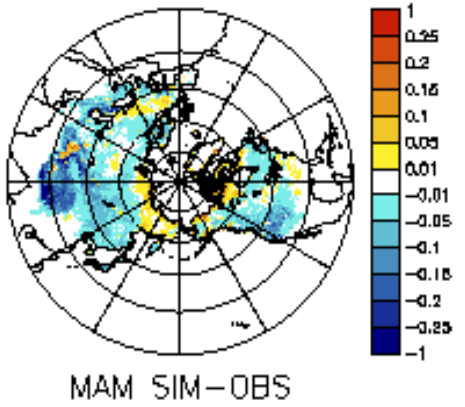


MAM SIM



MAM OBS



MAM SIM−OBS

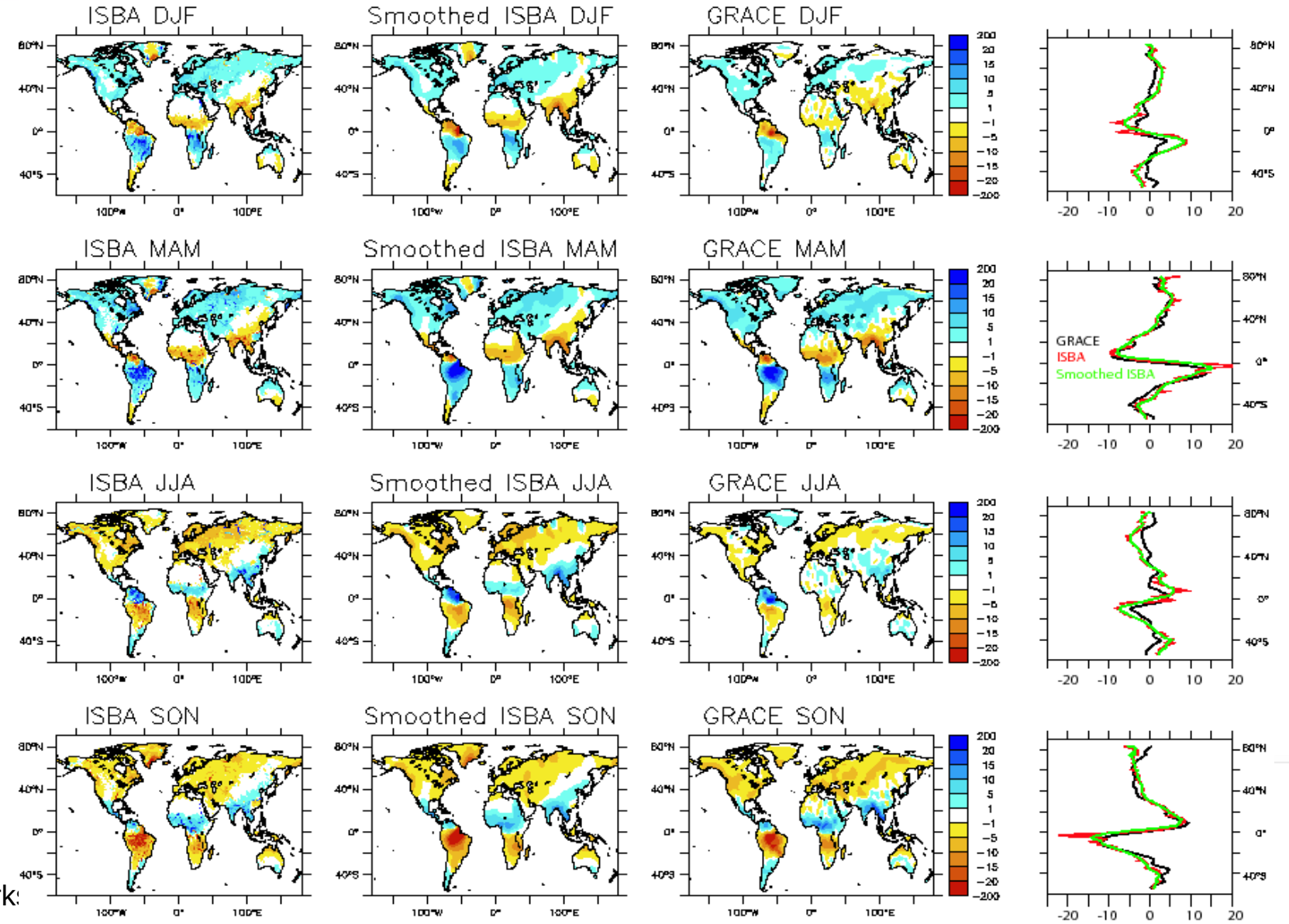
Seasonal variations of total water storage (kg/m²)

DJF

MAM

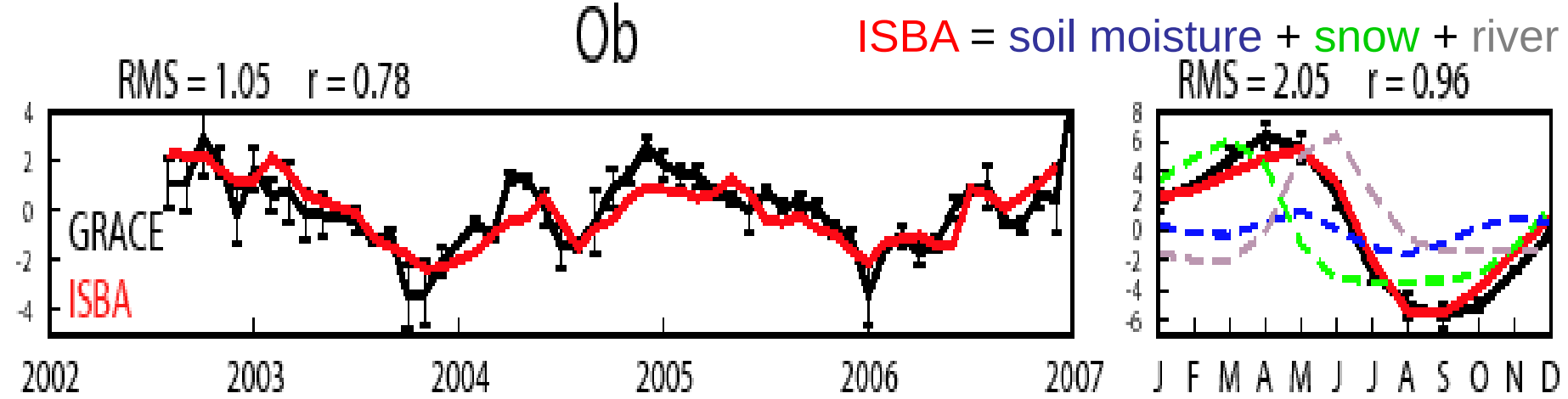
JJA

SON

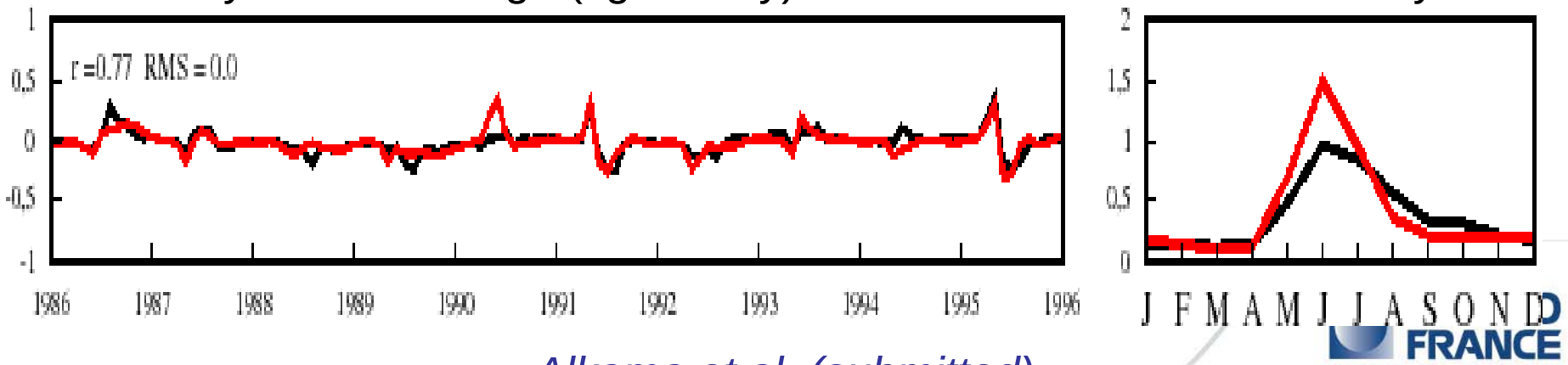


Basin-scale validation vs GRACE and GRDC data

Monthly water storage variation (kg/m²/day) anomalies and mean annual cycle



Monthly river discharge (kg/m²/day) anomalies and mean annual cycle



Alkama et al. (submitted)

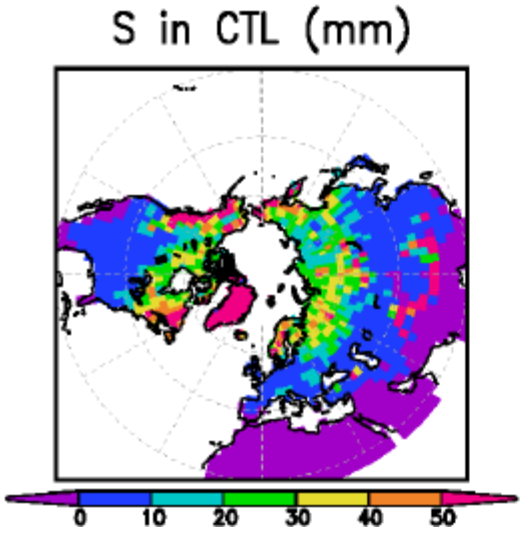
Assessing snow impact on climate variability

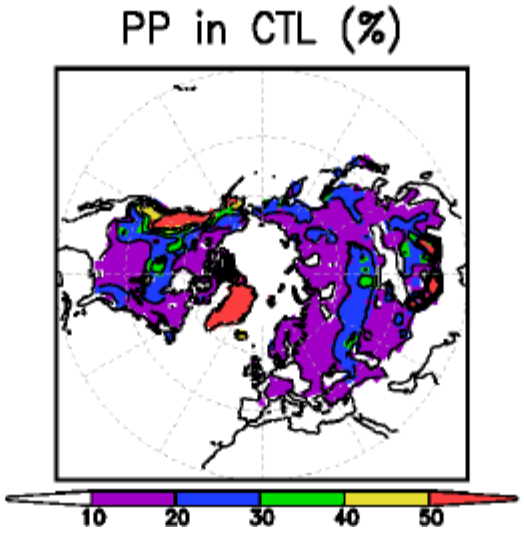
(Peings et al. 2009, in preparation)

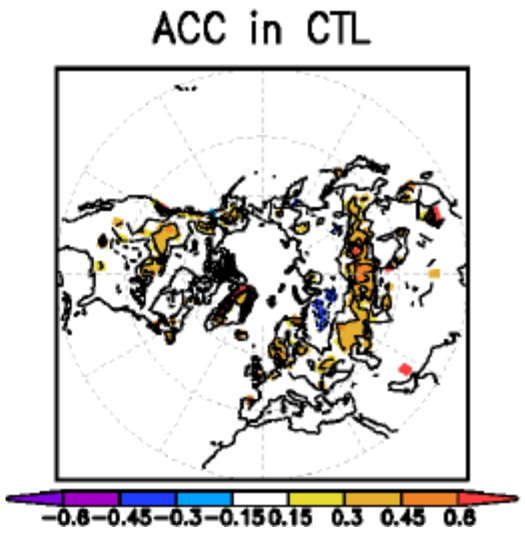
- ✓ Ensembles of 10-member AMIP-like (HadISST monthly mean SST and sea ice) simulations from 1951 to 2000
- ✓ Nudging towards the ISBA off-line monthly climatology to prescribe *realistic* snow mass boundary conditions or initial conditions (March 1st)
- ✓ Three ensembles:
  - **CTL**: Control experiment (interactive snow)
  - **SS**: Nudging towards the ISBA climatology
  - **SI**: Same as SS, but no nudging after March 1st
- ✓ No initialization of other land surface and atmospheric variables !

MAM snow mass predictability (Ref=ISBA)

CTL







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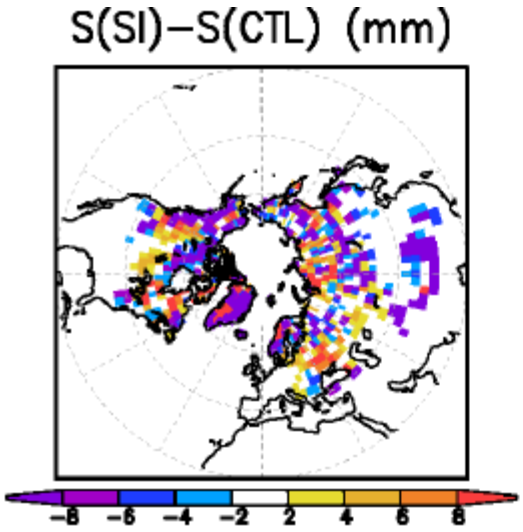
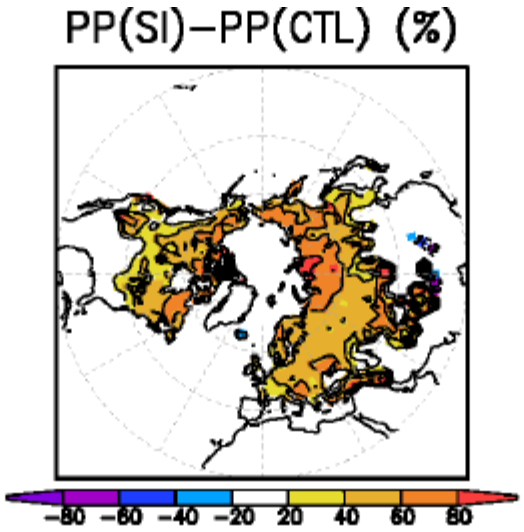
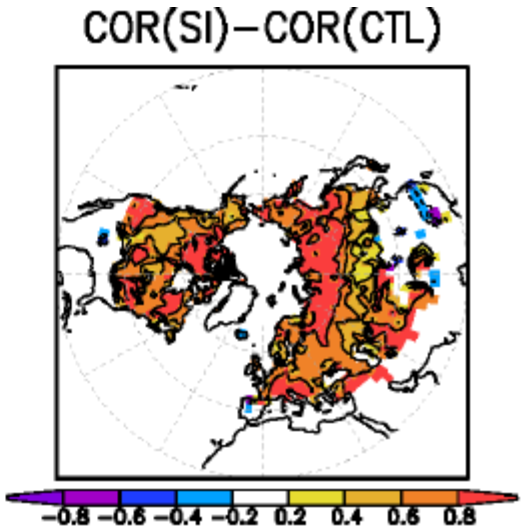
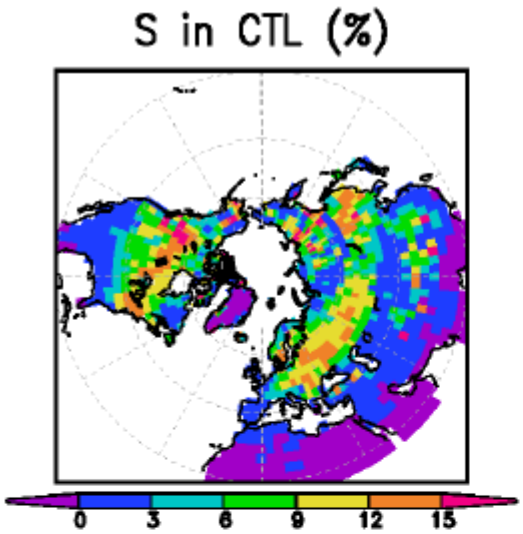


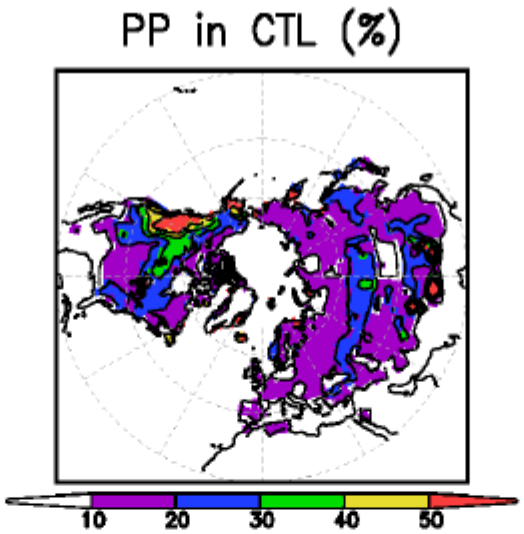


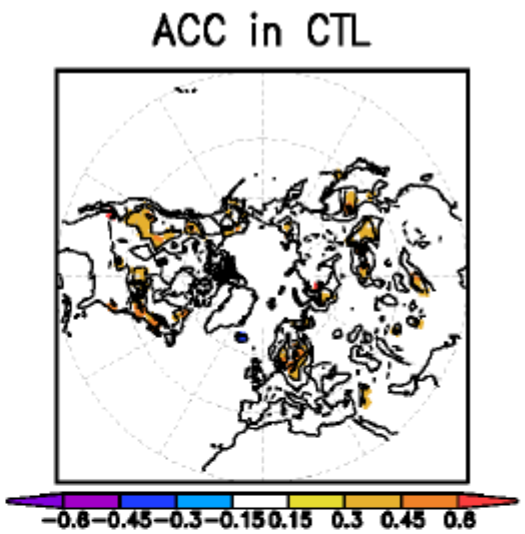


MAM snow cover predictability (Ref=NSIDC)

CTL







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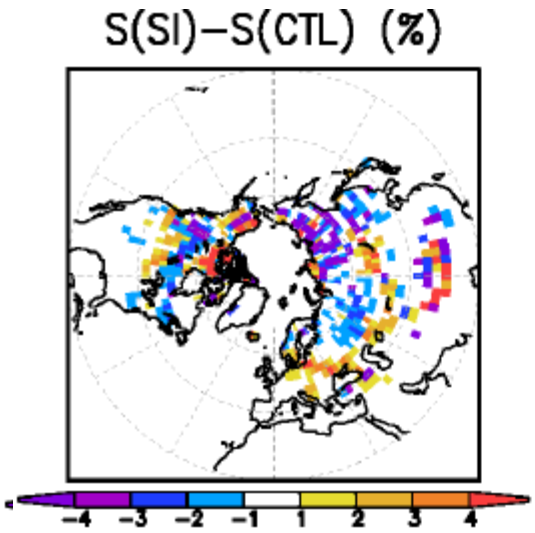
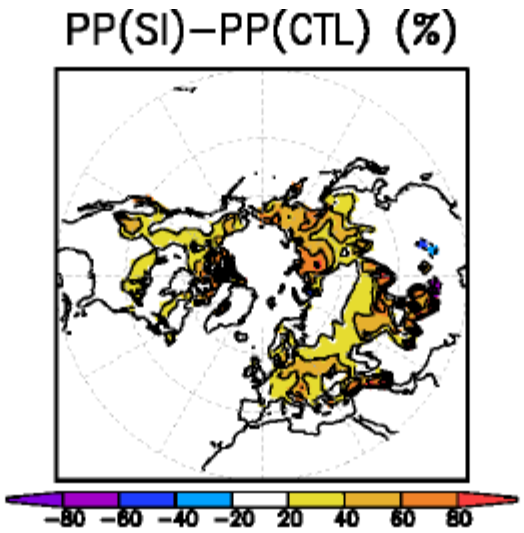
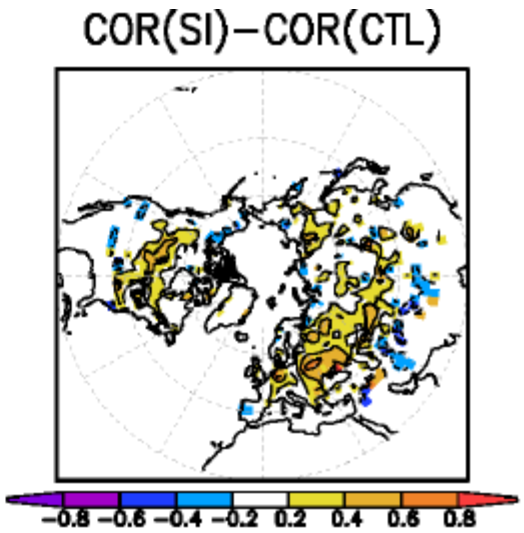
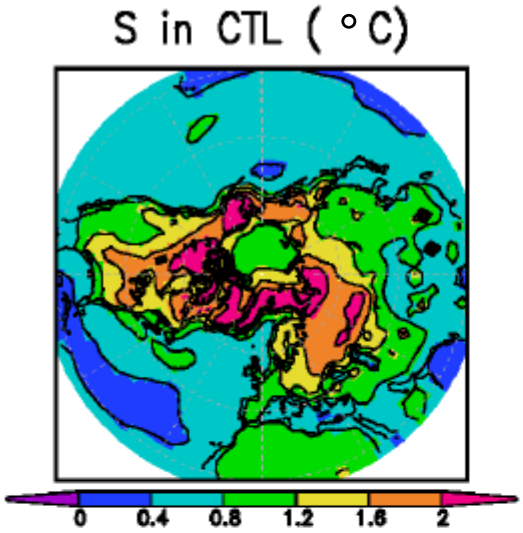


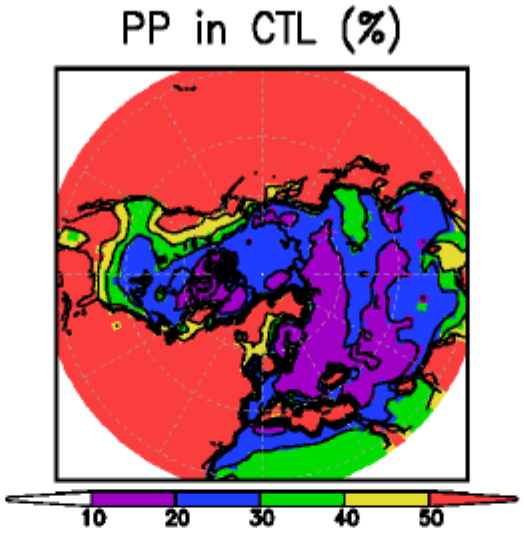


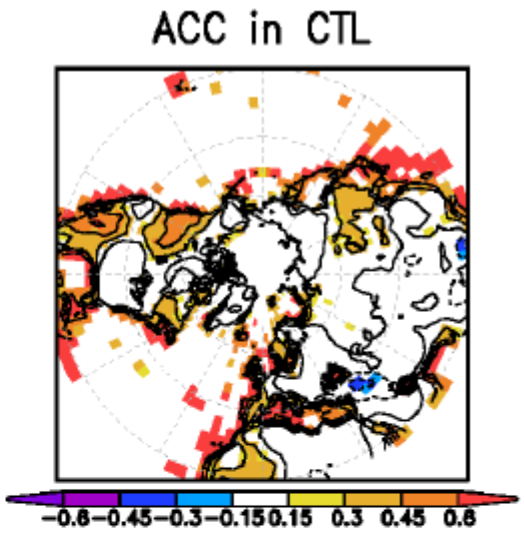


MAM T2m predictability (Ref=CRU)

CTL







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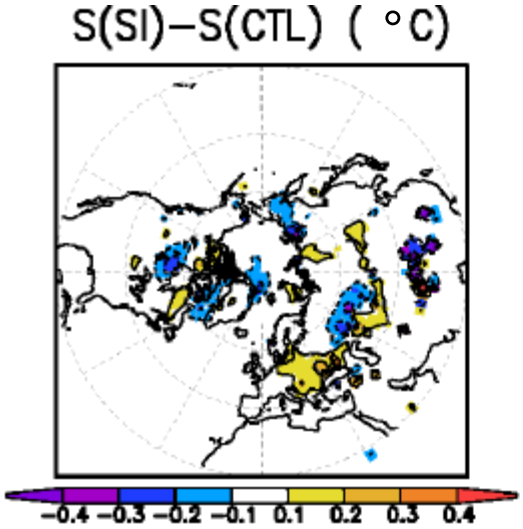
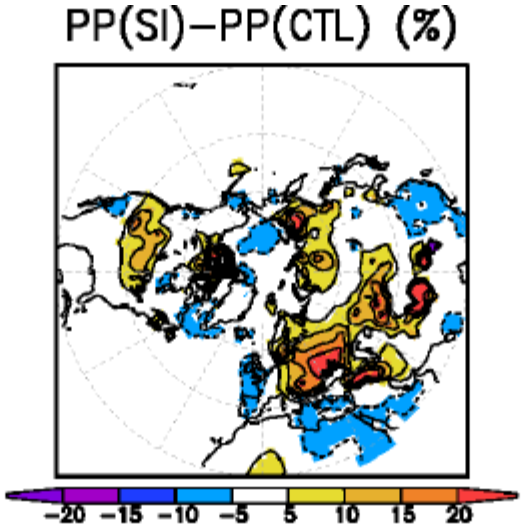
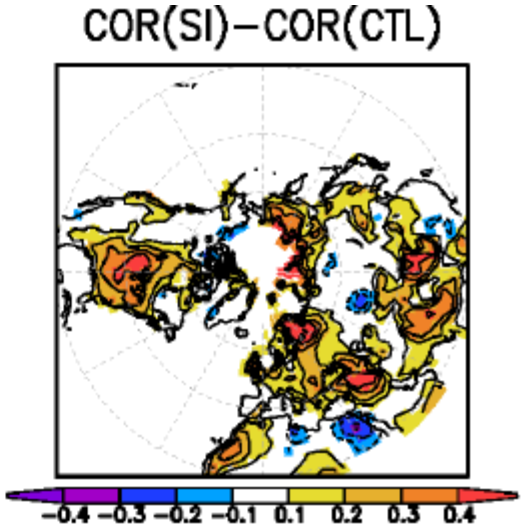
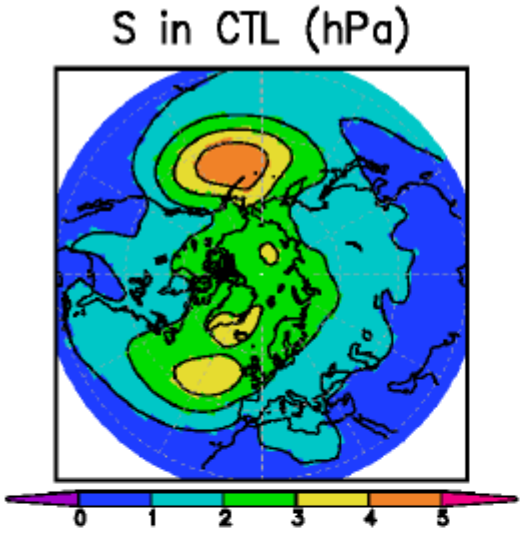


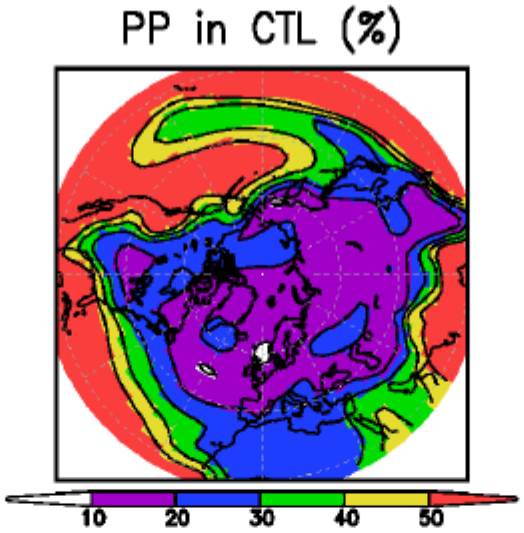


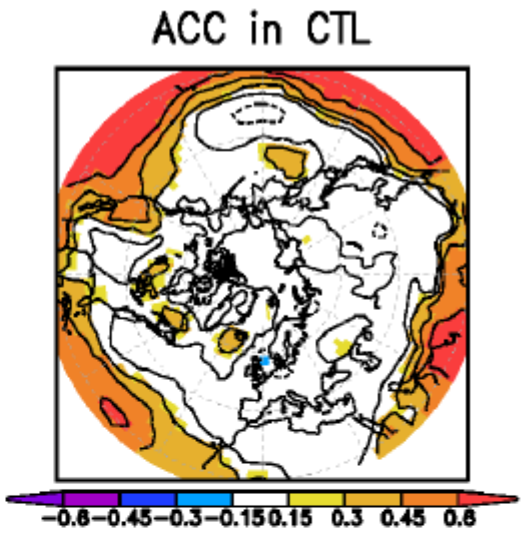


MAM SLP predictability (Ref=ERA40)

CTL







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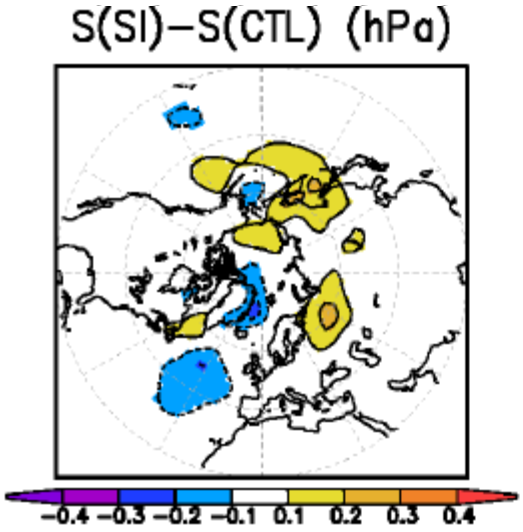
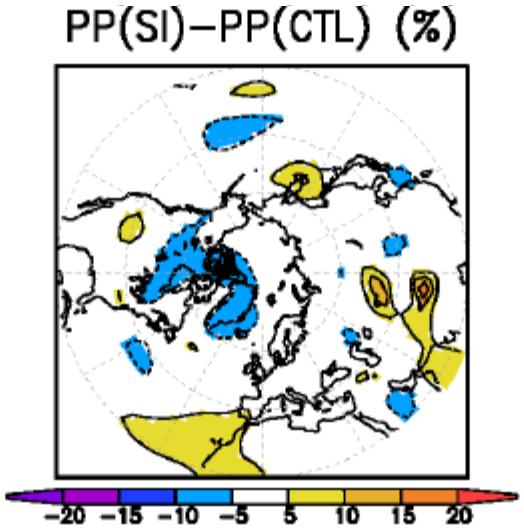
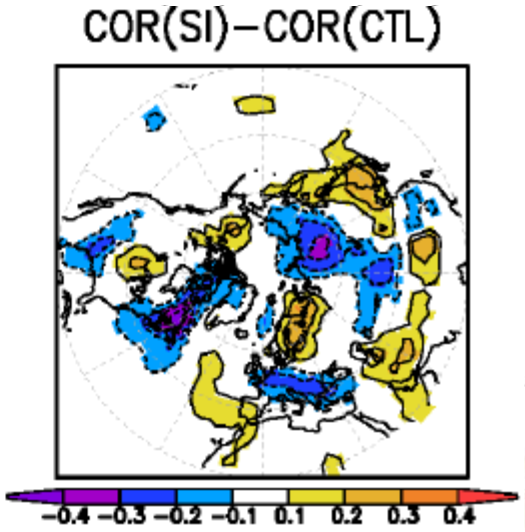


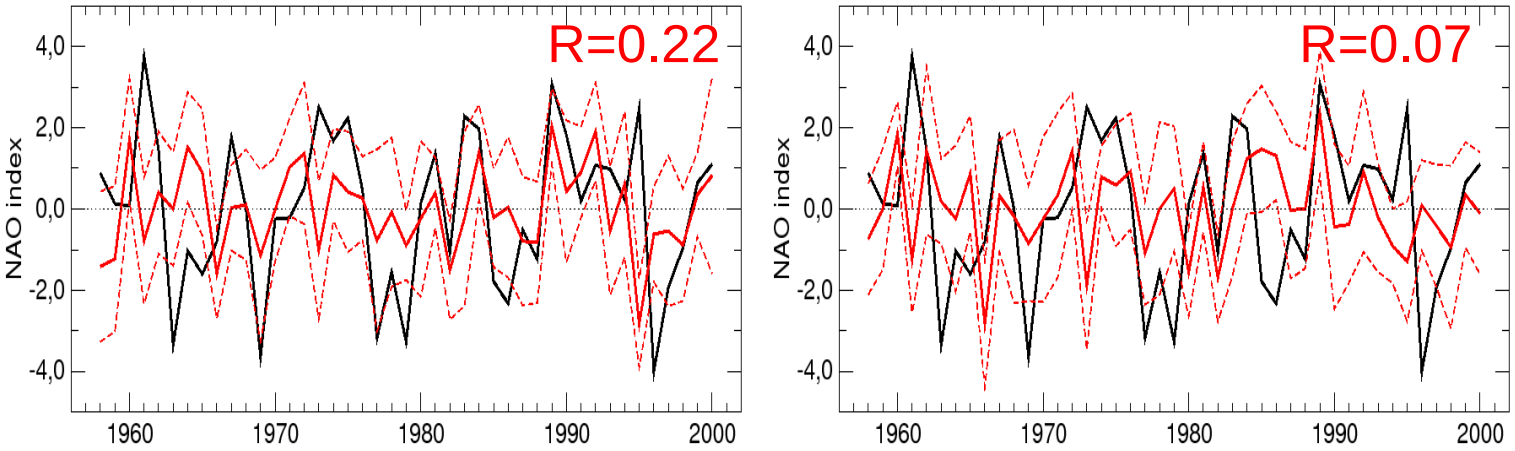




DJF NAO variability (Ref=ERA40)

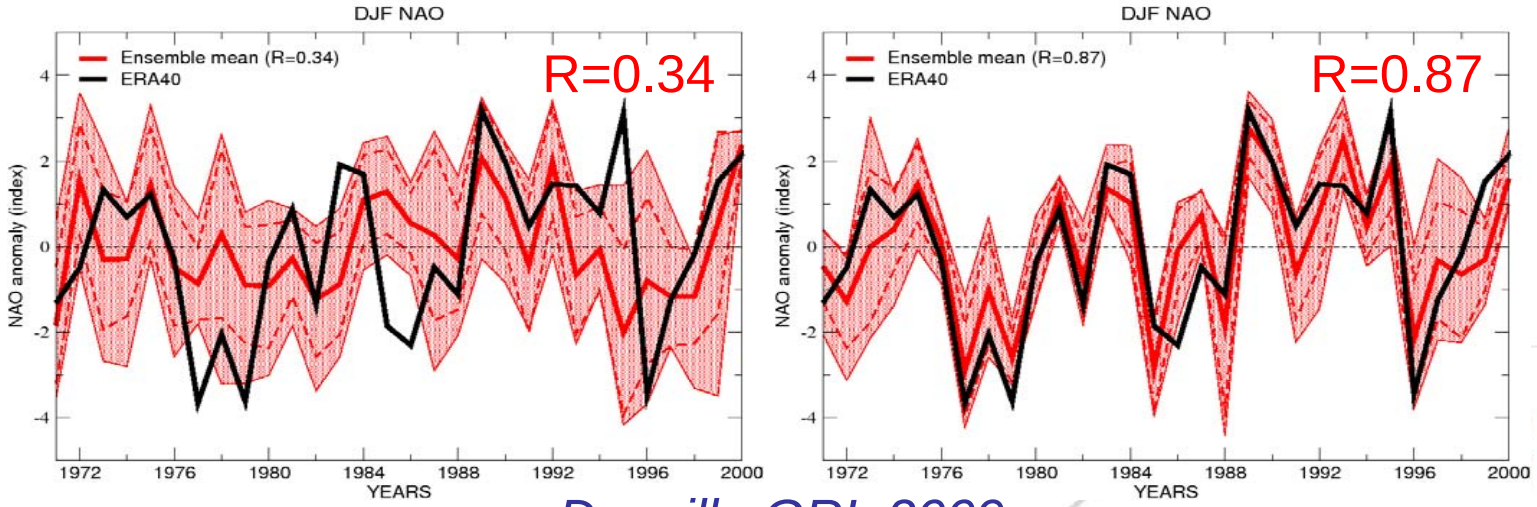
DJF NAO index anomalies over 1958-2000

Snow nudging



DJF NAO index anomalies over 1971-2000

Strato. nudging



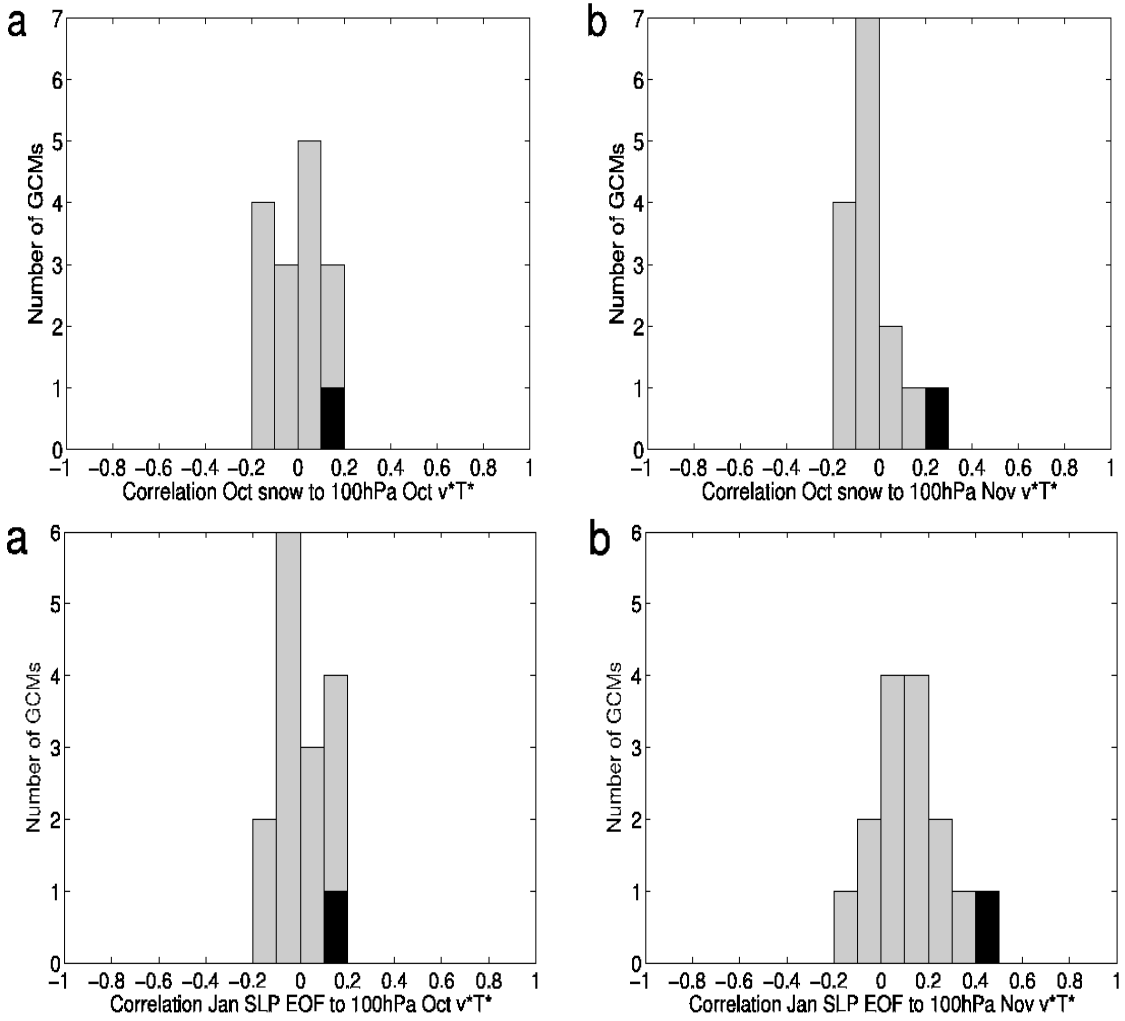
Douville GRL 2009

Summary

- ✓ Snow cover shows year-to-year variability and month-to-month persistence and is therefore a potential source of predictability
- ✓ Such a potential has been suggested by both observational studies and numerical sensitivity experiments
- ✓ Improved real-time SWE observations and data assimilation systems would be necessary for a thorough assessment of this potential
- ✓ Preliminary AGCM experiments suggest a significant contribution to the predictability of temperature (especially in spring), but confined to the lower troposphere and with little impact on the mid-and-upper troposphere circulation
- ✓ Remote impacts have been suggested by observational studies and numerical experiments, but have not been found in CMIP3 models
- ✓ A realistic simulation of the lower stratosphere might be necessary for a good evaluation of snow-driven circulation anomalies

METEO FRANCE

Analysis of CMIP3 preindustrial simulations

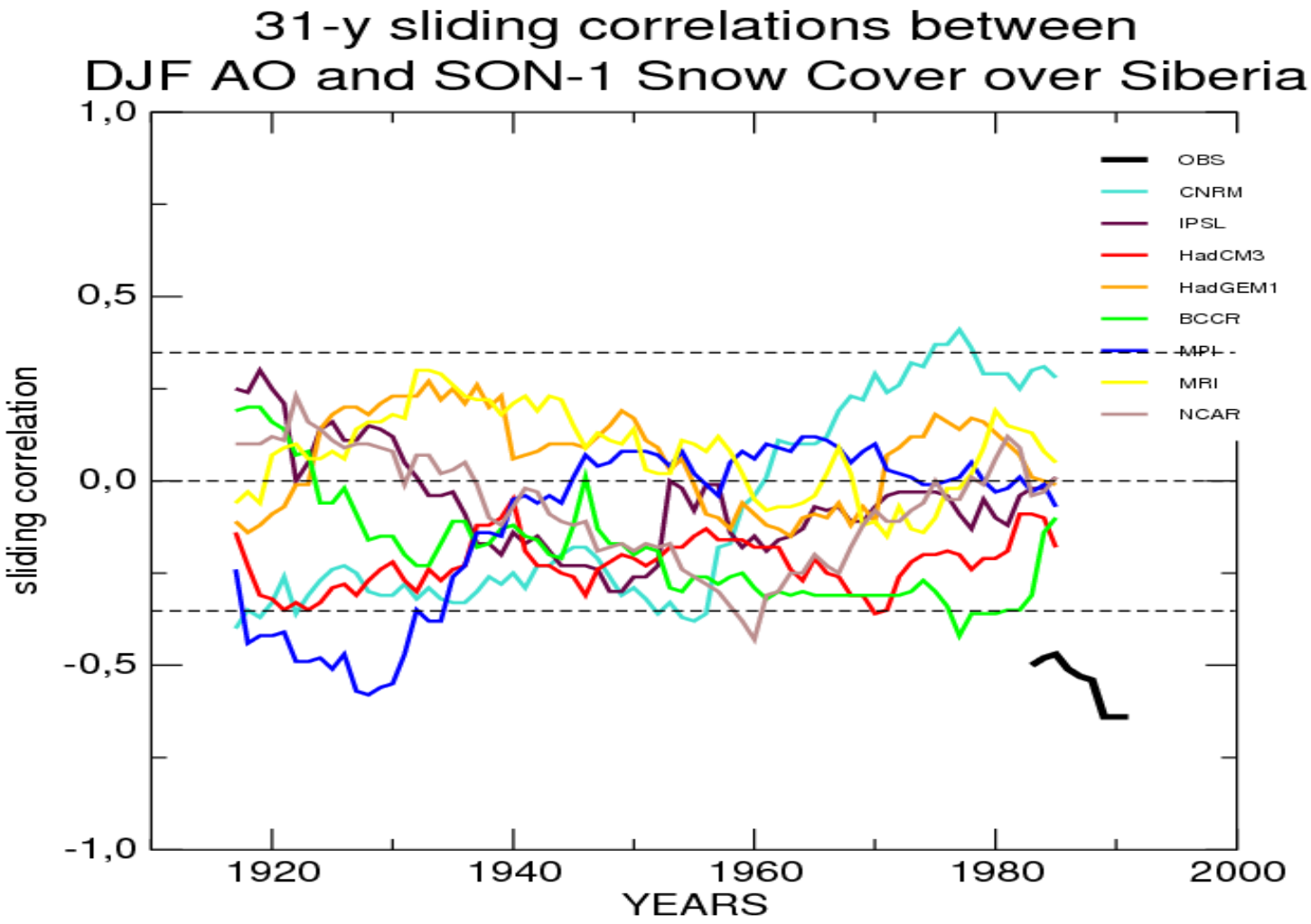


Frequency distribution of the correlation between the October snow index and 40-80°N v*T* at 100 hPa in a) October and b) November

Frequency distribution of the correlation between the January AO index and 40-80°N v*T* at 100 hPa in a) October and b) November

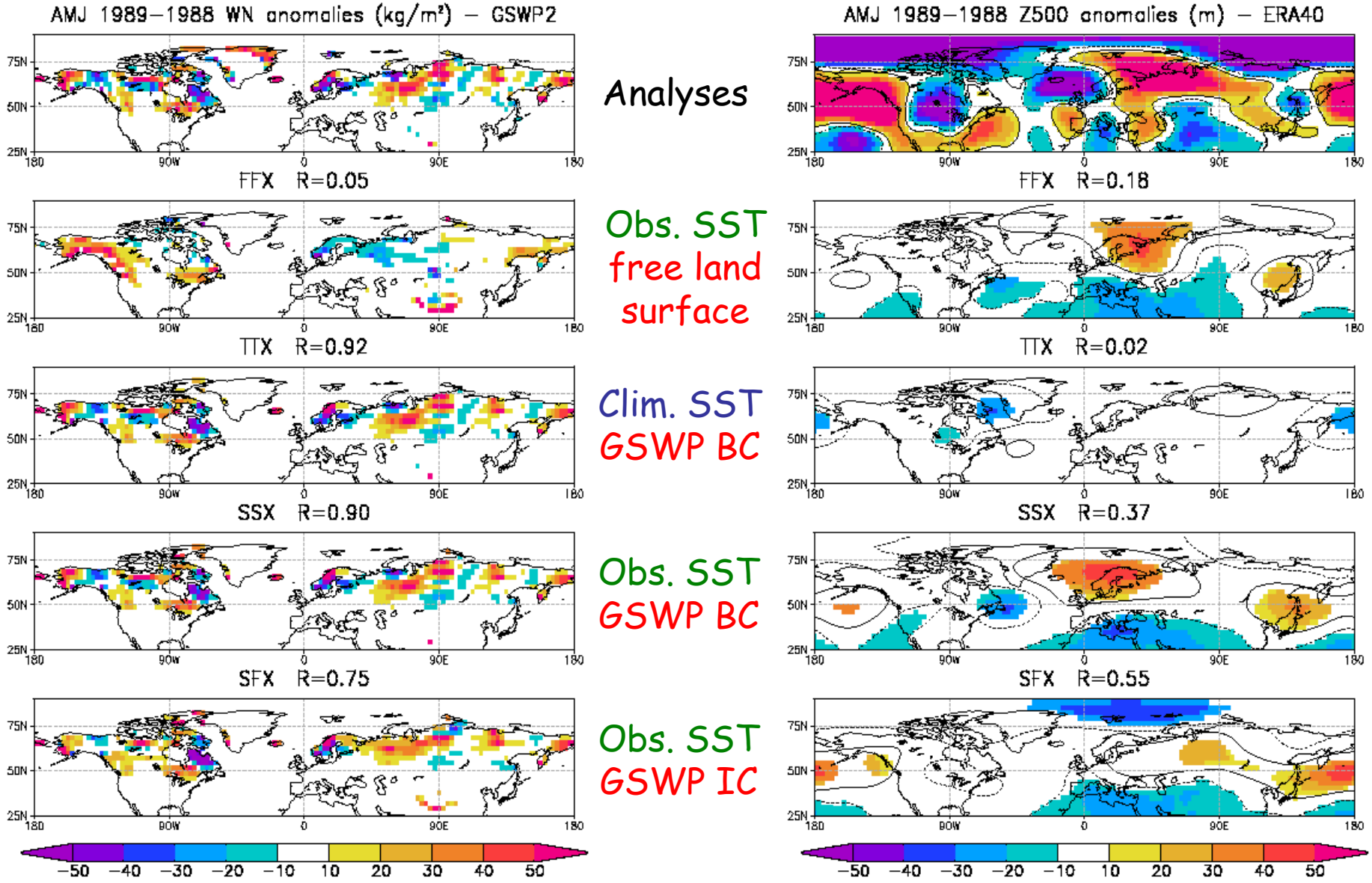
Hardiman et al., JGR 2008

SON SC / DJF AO in CMIP3 vs observations



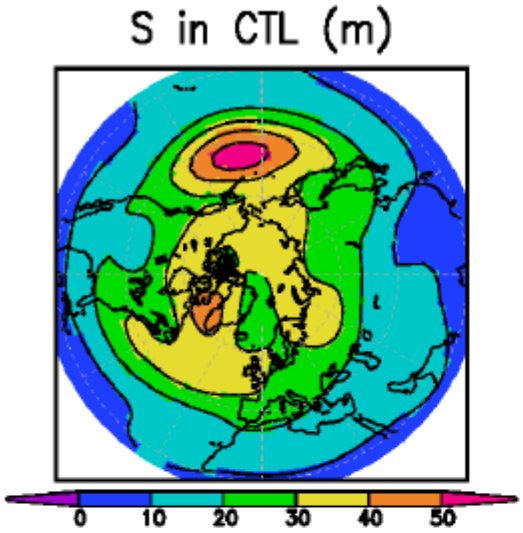
April-May-June 1989 minus 1988

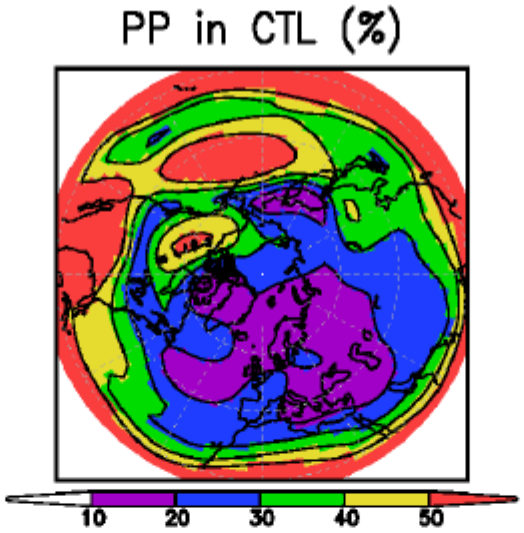
(shading denotes statistical significance at a 5% level)

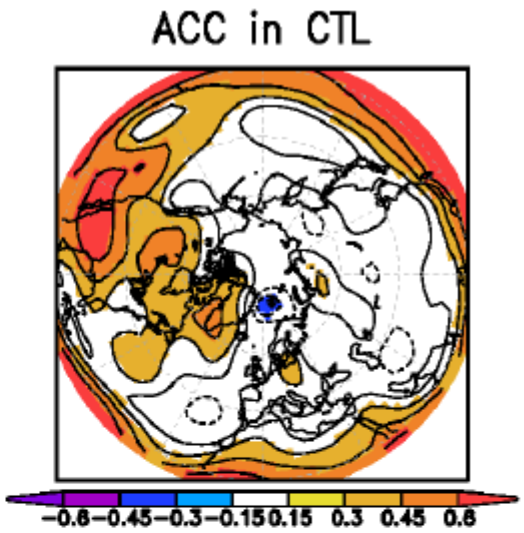


Z500 predictability in MAM (Ref=ERA40)

CTL







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