Regional Arctic processes and interactions

Potential importance for predictability on seasonal scale?

Annette Rinke and Klaus Dethloff,

Wolfgang Dorn, Dörthe Handorf

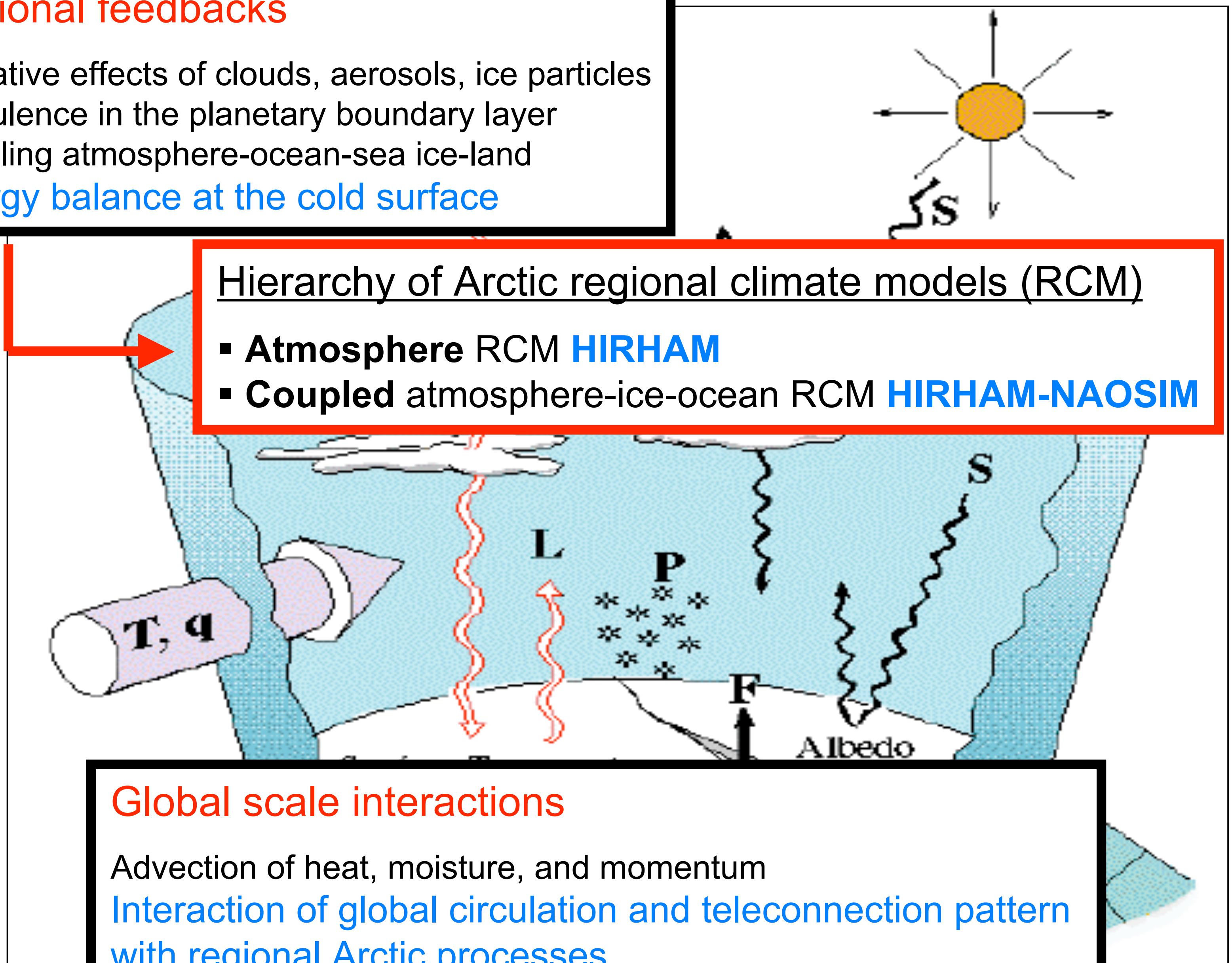
Alfred Wegener Institute for Polar and Marine Research (AWI)
Potsdam, Germany

Regional feedbacks

Radiative effects of clouds, aerosols, ice particles
Turbulence in the planetary boundary layer
Coupling atmosphere-ocean-sea ice-land
Energy balance at the cold surface

Hierarchy of Arctic regional climate models (RCM)

- **Atmosphere** RCM **HIRHAM**
- **Coupled** atmosphere-ice-ocean RCM **HIRHAM-NAOSIM**



Global scale interactions

Advection of heat, moisture, and momentum
Interaction of global circulation and teleconnection pattern with regional Arctic processes

diagram from SHEBA science plan

Part I

Two selected regional processes/feedbacks in the Arctic

- Physical parameterizations for key Arctic atmospheric processes (atmospheric boundary layer - ABL)
- Interactions/feedbacks between atmosphere and sea ice

Part I

Two selected regional processes/feedbacks in the Arctic

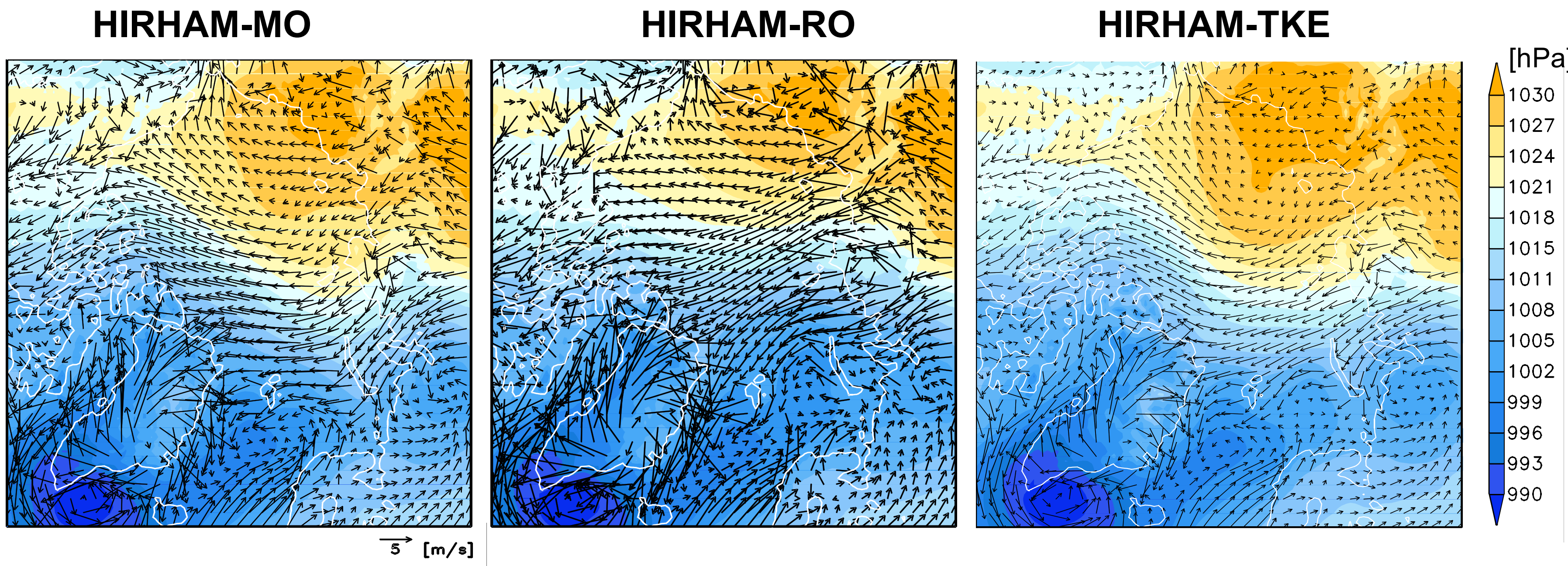
- Physical parameterizations for key Arctic atmospheric processes (**atmospheric boundary layer - ABL**)
- Interactions/feedbacks between atmosphere and sea ice

Sensitivity to atmospheric boundary layer (ABL) parameterization

Exp.: **HIRHAM** simulations with 3 **different ABL schemes**

MO: Monin-Obukhov similarity theory in srfc layer, mixing length approach above
RO: Rossby-number similarity theory in whole ABL (Monin-Zilintikevich)
TKE: Monin-Obukhov similarity theory in srfc layer, turbulent kinetic energy closure

Mean sea level pressure (hPa; color) and near-srfc. **wind** (m/s); winter



- HIRHAM-RO most successful in simulation of vertical exchange and srfc. temperature for cold and stable ABL conditions
- different energy fluxes srfc/atm - different baroclinic structures - strong regional differences in atmospheric circulation and wind → impact on Transpolar drift and sea ice export

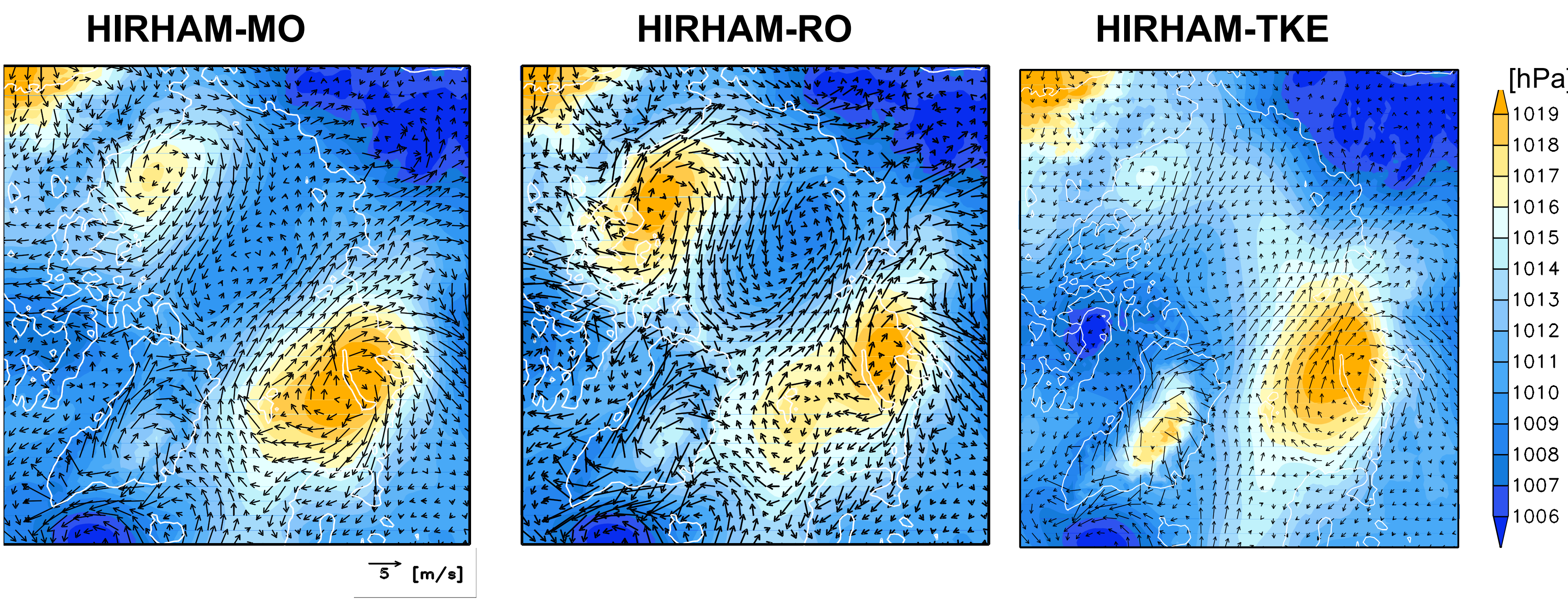
Dethloff, et al. 2001

Sensitivity to atmospheric boundary layer (ABL) parameterization

Exp.: **HIRHAM** simulations with 3 **different ABL schemes**

MO: Monin-Obukhov similarity theory in srfc layer, mixing length approach above
RO: Rossby-number similarity theory in whole ABL (Monin-Zilintikevich)
TKE: Monin-Obukhov similarity theory in srfc layer, turbulent kinetic energy closure

Mean sea level pressure (hPa; color) and near-srfc. **wind** (m/s); **summer**



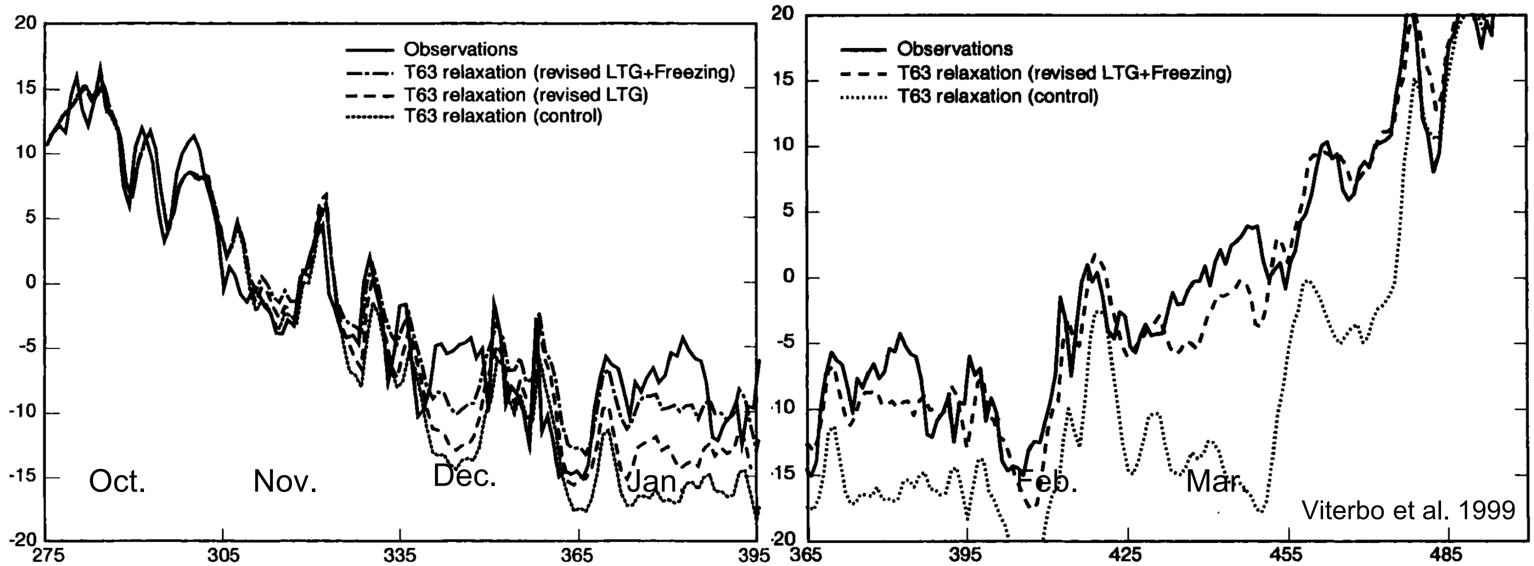
- Especially pronounced pressure differences in Beaufort and Barents/Kara Seas
- Strong regional wind differences and influence on atmospheric circulation
  → strong impact on sea ice circulation

Dethloff, et al. 2001

Sensitivity to atmospheric boundary layer (ABL) parameterization

Exp.: **HIRHAM** simulations with **different stability functions** (Viterbo et al., 1999)

Time series of 2m air temperature (˚C) over Russia, winter 1995/96



ECMWF model: turbulent diffusion above the surface layer → eddy diffusivity concept (Louis et al., 1982)

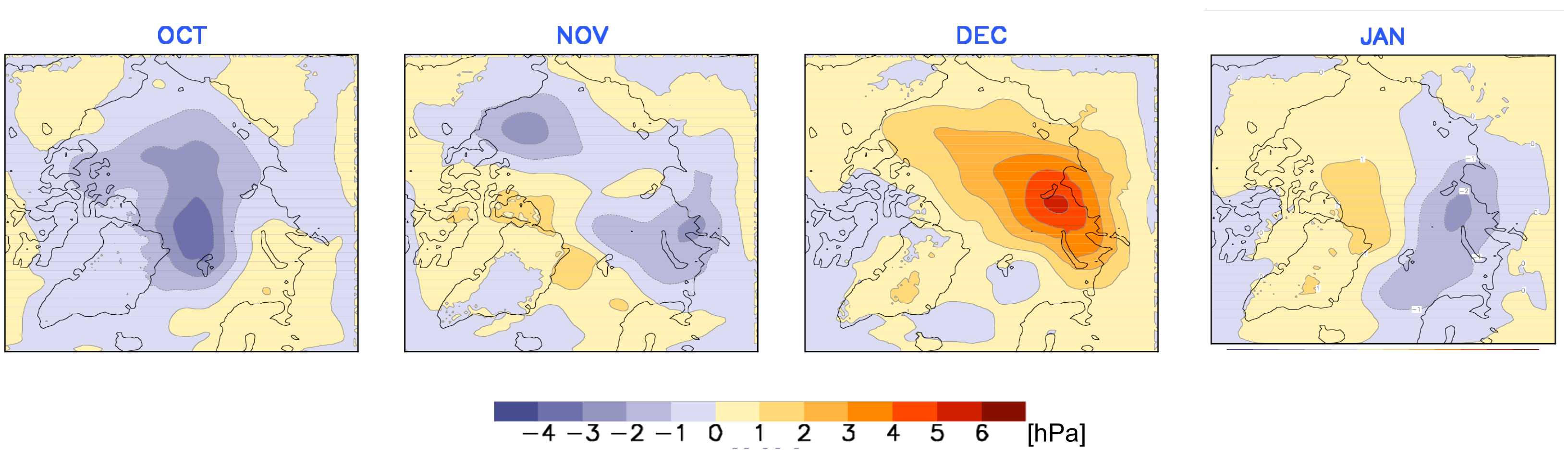
K=f(wind shear, turbulent length-scales for momentum/heat, prescribed **stability functions**)

LTG: revised stability functions to increase turbulent heat diffusion in stable situations, which increases the coupling between atmosphere and surface

<u>Sensitivity to atmospheric boundary layer (ABL) parameterization</u>

<u>**Exp.:**</u> **HIRHAM** simulations with **different stability functions** (Viterbo et al., 1999)

Mean sea level pressure (hPa); **difference "Viterbo-run minus CTRL"**; **1979-1993**



Dethloff, Rinke, et al. 2010

Part I

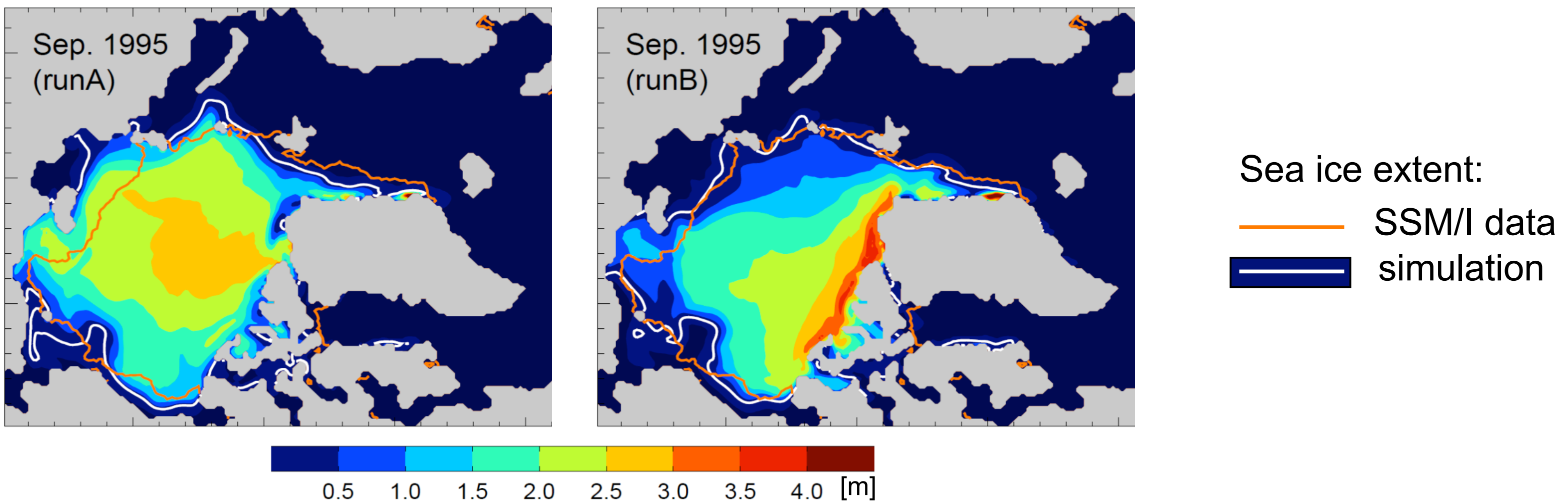
Two selected regional processes/feedbacks in the Arctic

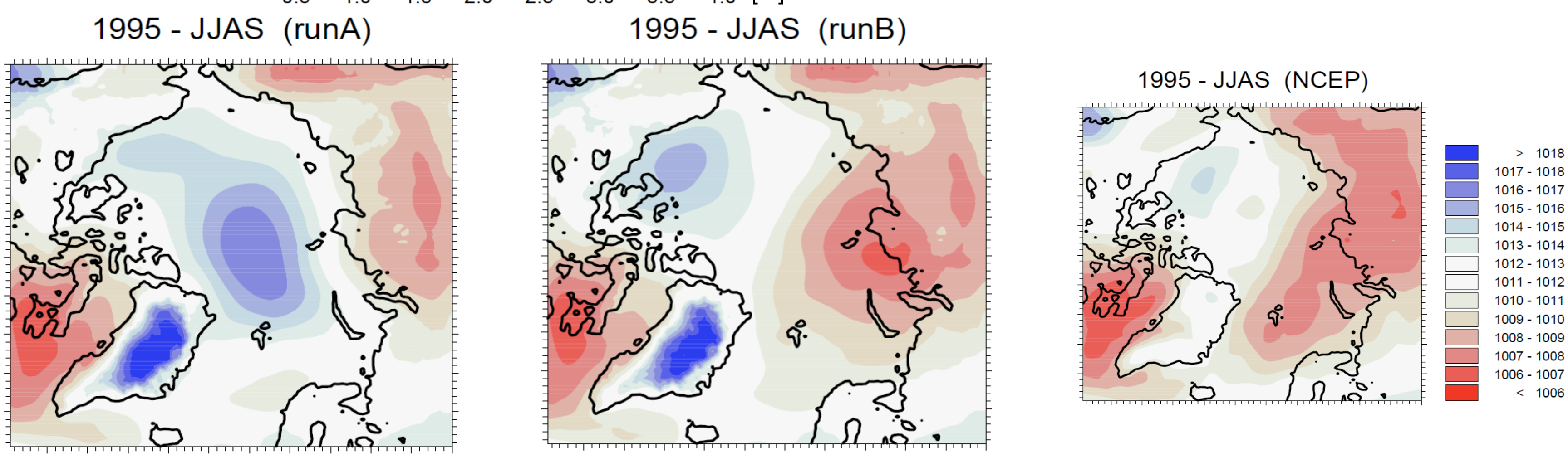
- Physical parameterizations for key Arctic atmospheric processes (atmospheric boundary layer - ABL)
- **Interactions/feedbacks between atmosphere and sea ice**

Sensitivity of sea ice simulation to atmospheric forcing

Exp.: **HIRHAM-NAOSIM** ensemble simulations; 1948-2008

Sea ice extent/thickness and mean sea level pressure (hPa), summer 1995





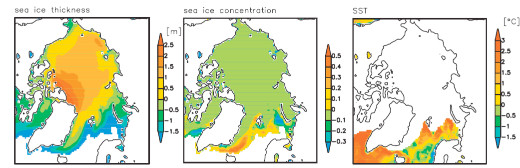
Dorn, et al. 2010

Sensitivity of atmosphere to sea ice/SST forcing

Exp.: **HIRHAM** simulations with 2 **different sea ice/SST data sets**

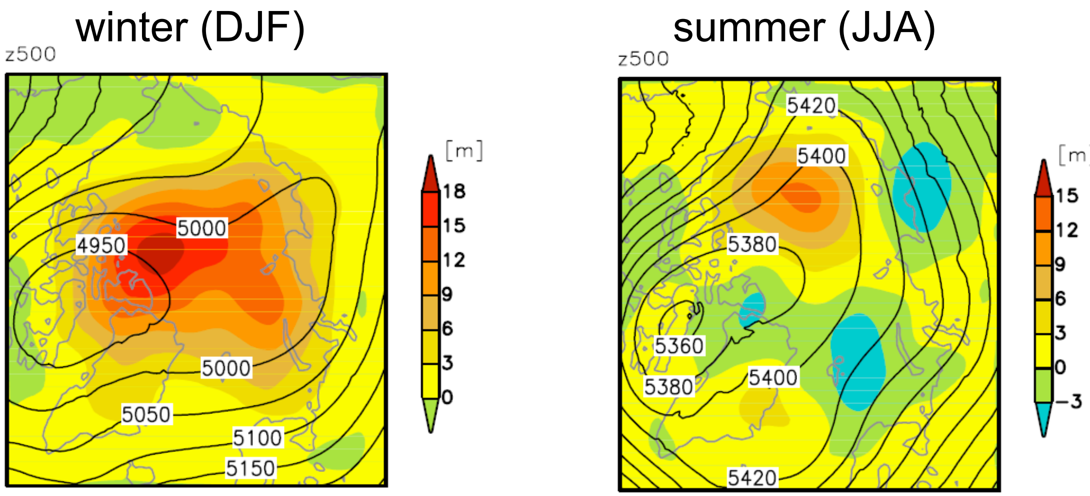
ERA15: SST, sea ice fraction, ice thickness=2m

NPS ocean-ice model: SST, sea ice concentration and thickness



Impact on atmosphere ("HIRHAM.nps minus HIRHAM.era"); 1979-1993

500 hPa geopotential height



- dynamical large-scale response is modest, but of similar magnitude in the seasons
- more regional pattern in summer
- less accurate sea ice /SST data leads to deviations of modeled atm. pressure patterns

Rinke, Maslowski, Dethloff, et al. 2006

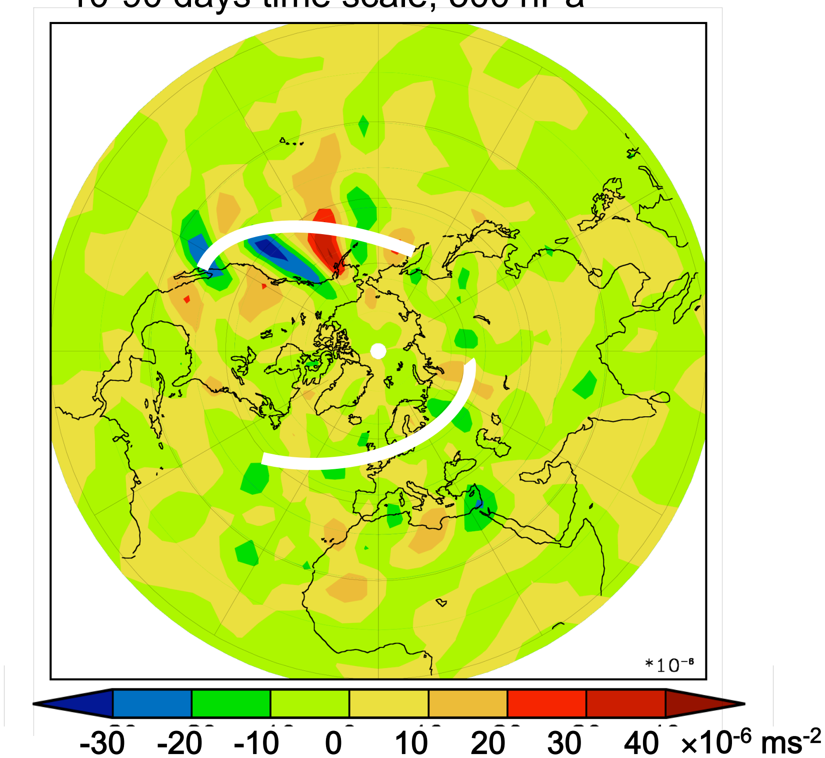
Sensitivity of atmosphere to sea ice and snow albedo changes

Exp.: **ECHO-G** simulations with 2 **different surface albedo parameterizations**

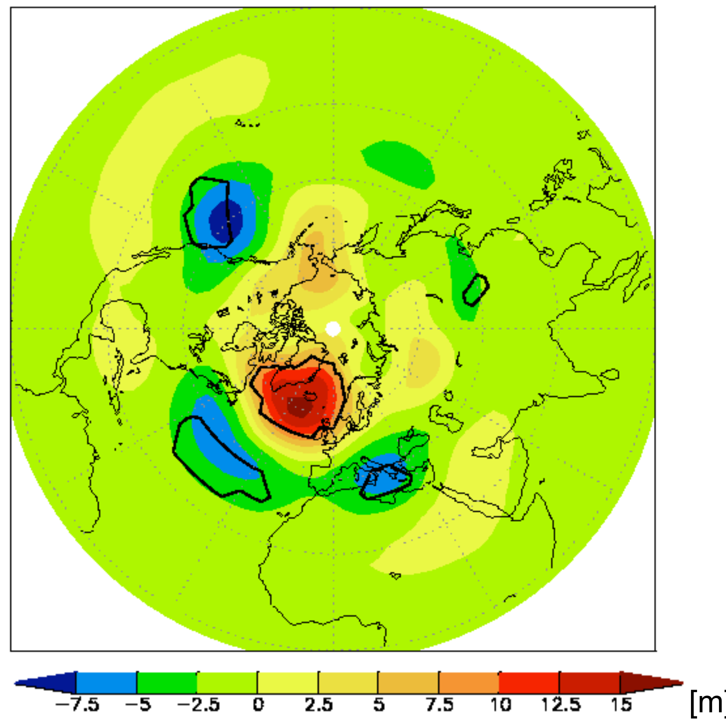
Ctrl: from Echam4
Koltzøw (2007): improved parameterization of melt ponds, snow cover, etc

Impact on atmosphere ("ECHO-G.koltzøw minus ECHO-G.ctrl"); winter

Divergence of Eliassen-Palm fluxes
10-90 days time scale, 500 hPa



500 hPa geopotential height



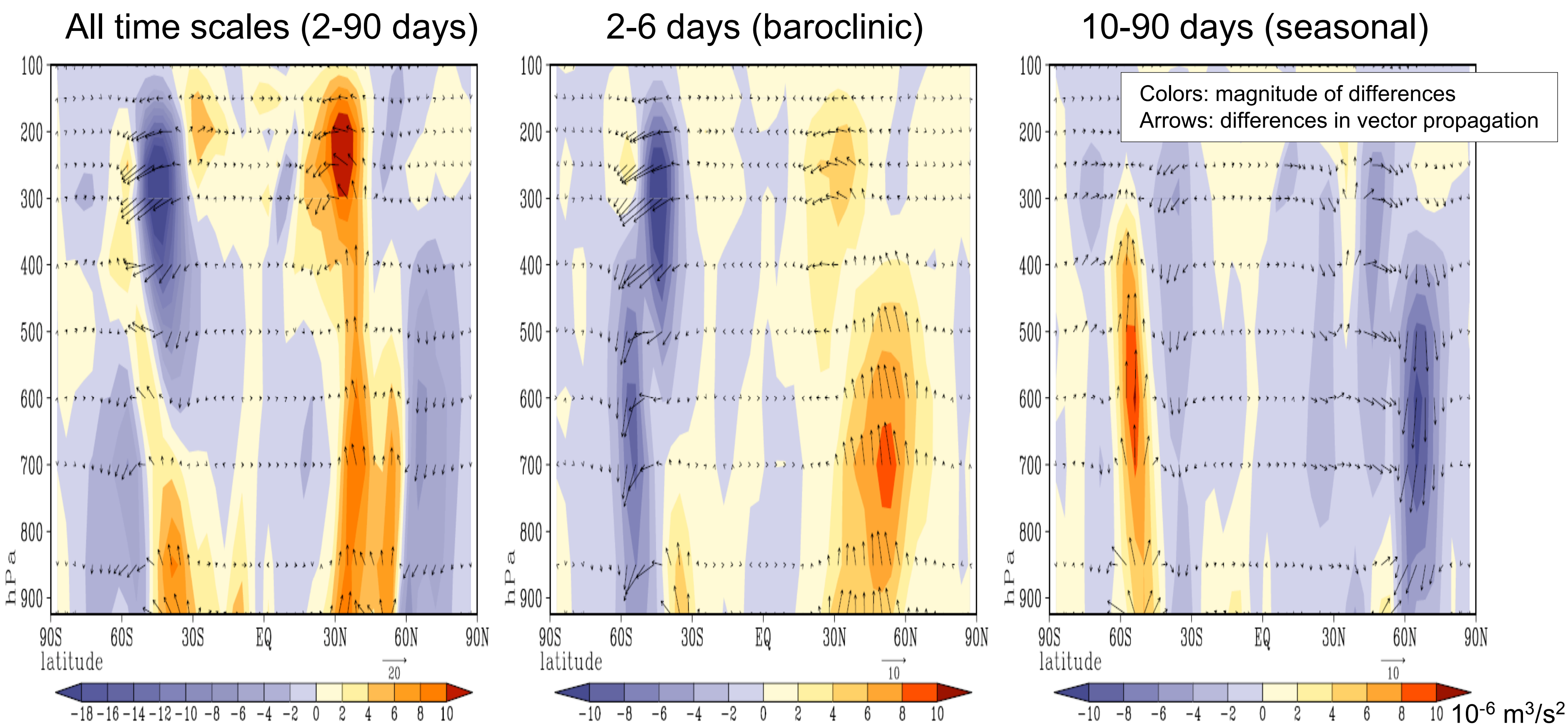
- change in planetary wave trains
- impact on global teleconnection patterns (NAO-/AO-)

Dethloff, et al. 2006

Sensitivity of atmosphere to sea ice cover changes

Exp.: **ECHO-G** simulations; **different phases of sea ice cover**

Impact on atmosphere (**“high ice minus low ice”**); **winter**; Eliassen-Palm flux differences



- Sea ice impacts atmospheric planetary and baroclinic waves
- EP fluxes change in opposite direction

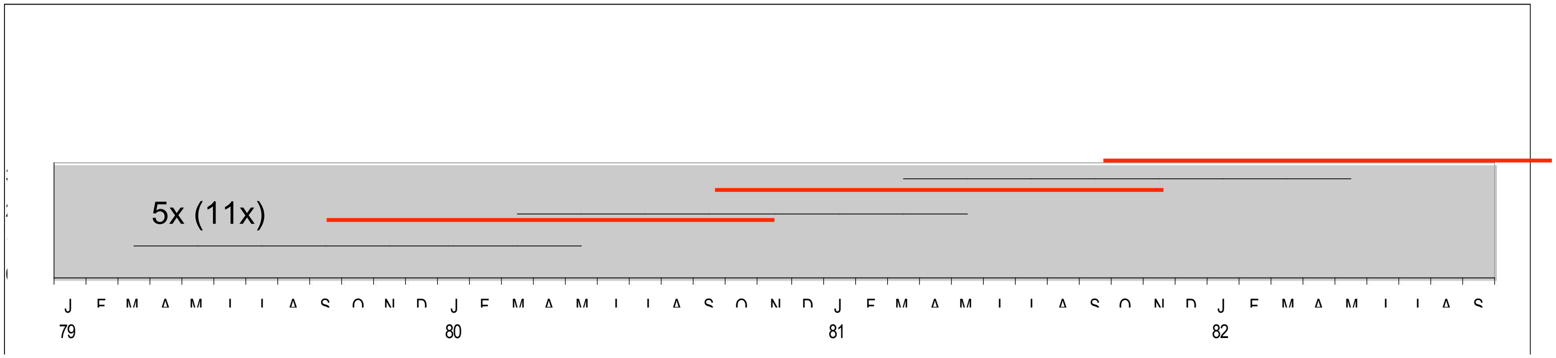
Sokolova, Dethloff, et al. 2007

Part II

Predictability on seasonal scale

Hindcast ensemble simulations with HIRHAM over last 30 years 1979-2009 (each run is over 15 months, each with start in Mar. and Sep.)

- atmospheric initialization
- sea ice/SST initialization
- sea ice/SST forcing
- snow initialization



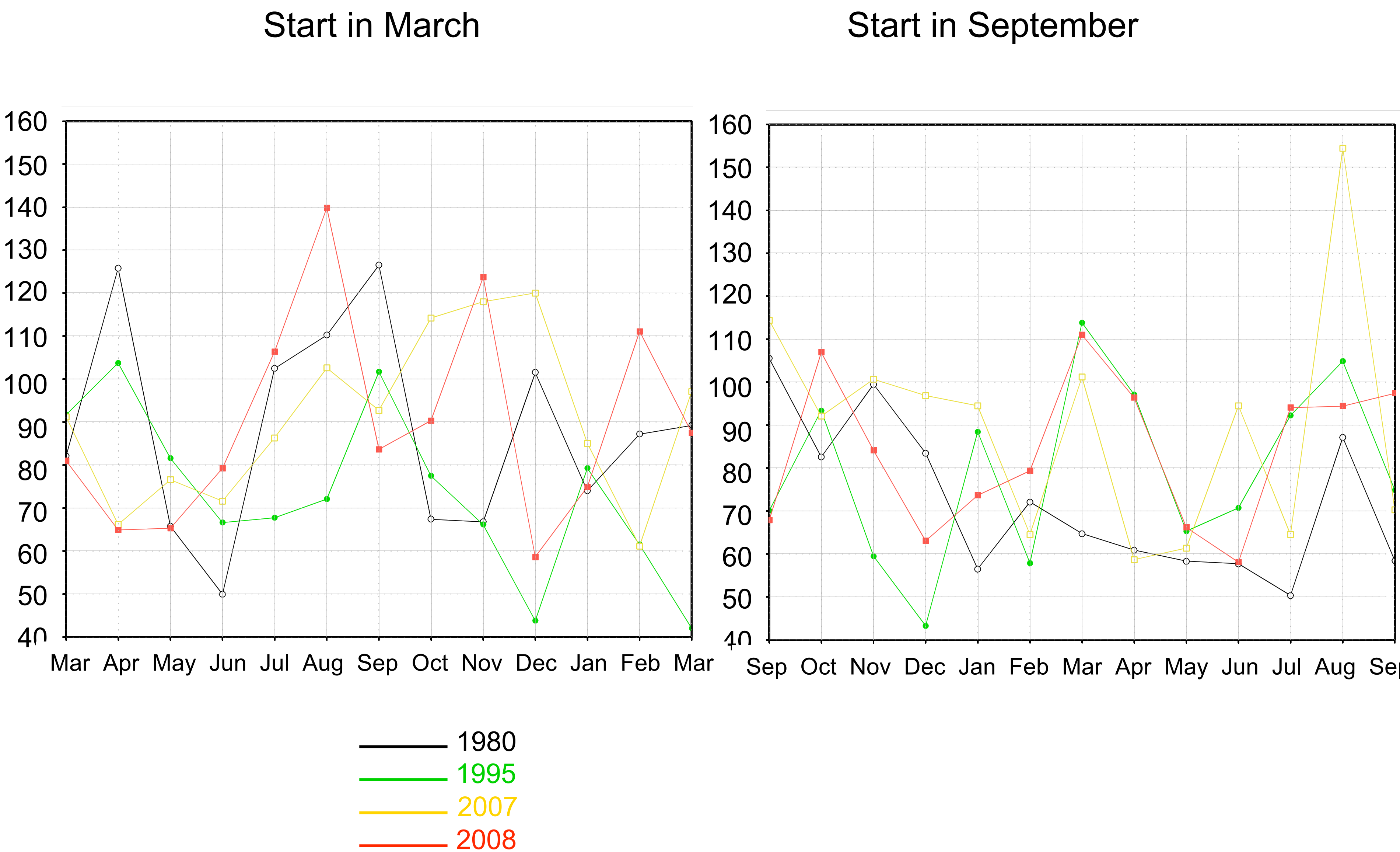
Part II

Predictability on seasonal scale

Hindcast ensemble simulations with HIRHAM over last 30 years 1979-2009 (each run is over 15 months, and start in Mar. and Sep.)

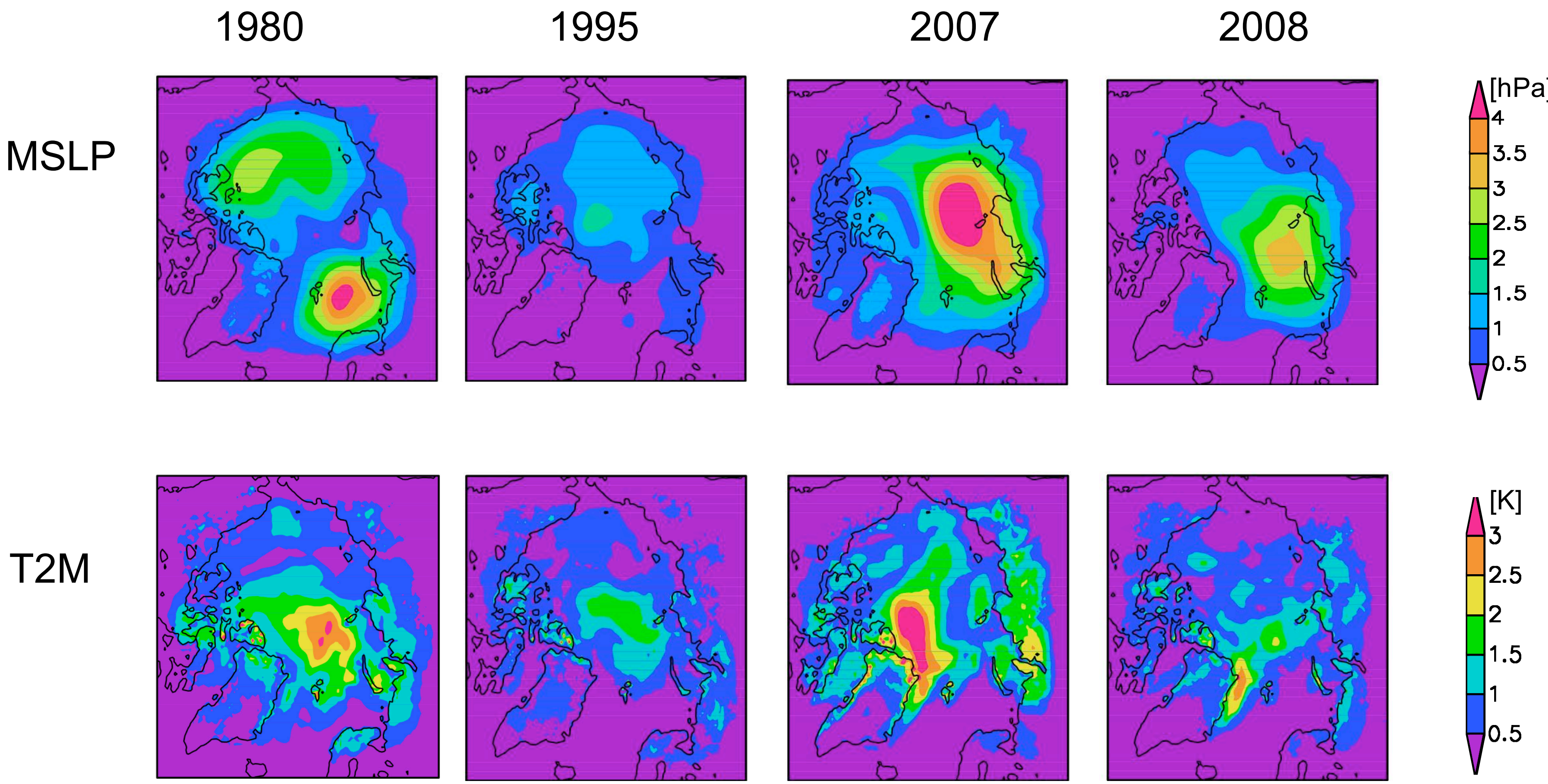
- atmospheric initialization
- sea ice/SST initialization
- sea ice/SST forcing
- snow initialization

Temporal development of area-averaged hindcast spread of MSLP (Pa)



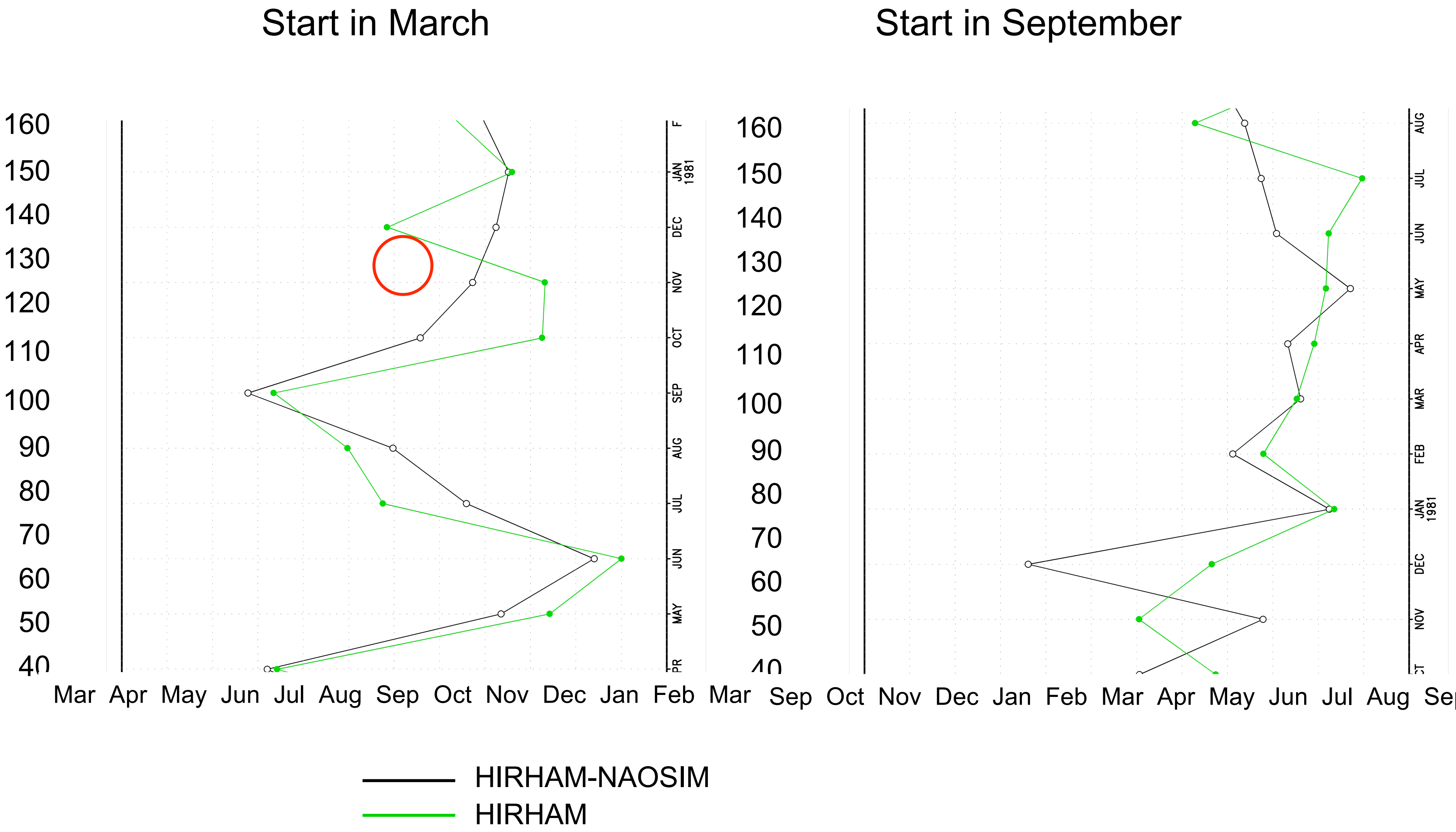
Spatial patterns of hindcast spread of MSLP (hPa) and T2M (K)

December (start in September, after 3 months)



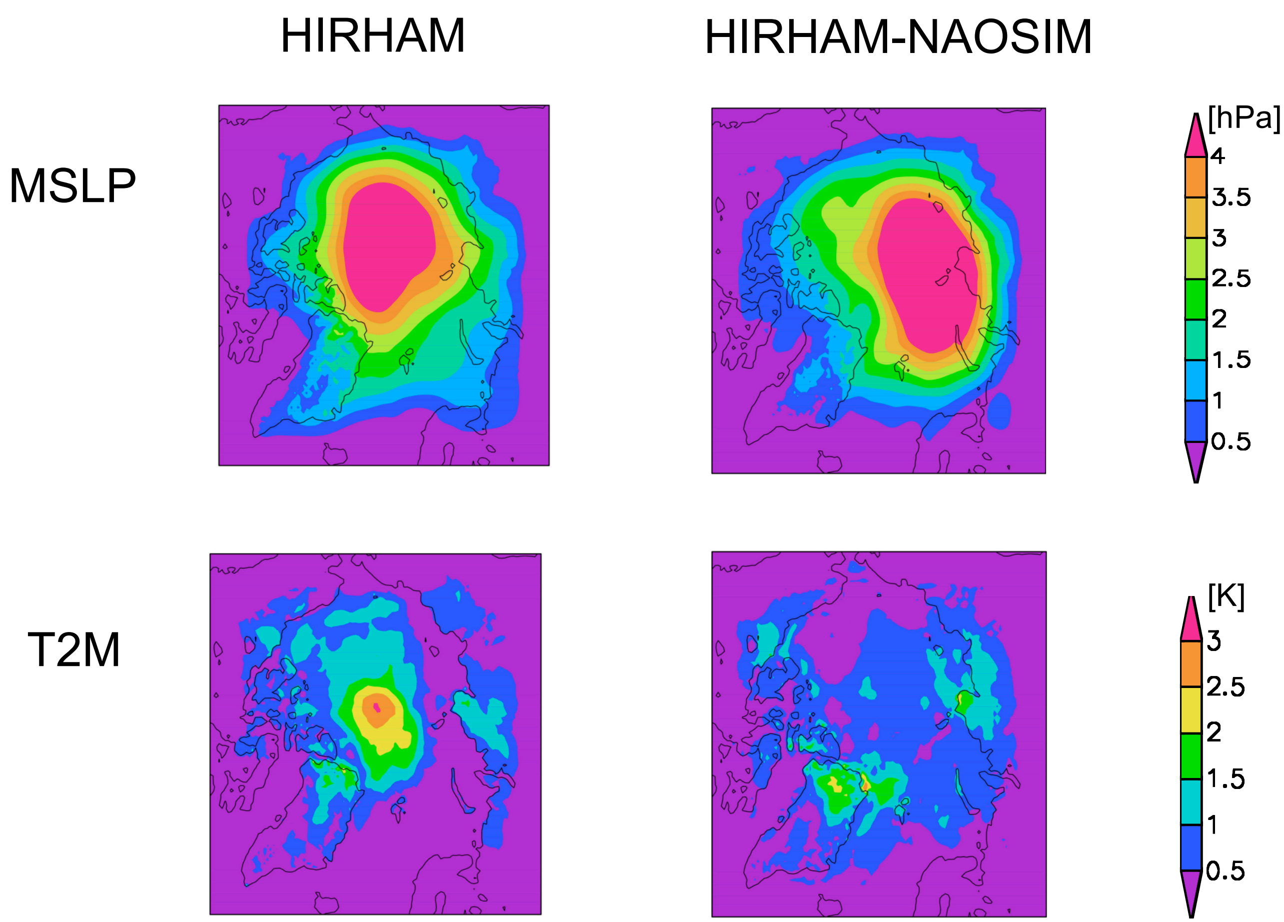
Temporal development of area-averaged hindcast spread of MSLP (Pa)

1980



Spatial patterns of hindcast spread of MSLP (hPa) and T2M (K)

September (start in March, after 6 months), 1980



Summary

- Key Arctic processes (ABL, sea ice, land) and associated interactions & feedbacks are relevant; influence on atm. regional & large-scale circulation

- Connection of Arctic sea ice (snow) changes and quasi-stationary planetary waves and transient systems on synoptic to seasonal scales

  - complex interactions between baroclinic & planetary waves
  - September sea ice cover important for winter atm. large-scale circulation

- Seasonal predictability: initial value problem; external forcing important

  winter: response of atmosphere largely determined by large-scale forcing;
  enhanced predictability
  summer: regional feedbacks & baroclinic wave systems are more important