Global implications of Arctic climate processes and feedbacks

Klaus Dethloff & the GLIMPSE group

Alfred Wegener Institute for Polar- and Marine Research
Research Unit Potsdam, Germany

e-mail : dethloff@awi-potsdam.de , http: //www.awi-potsdam.de

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The GLIMPSE group:

K. Dethloff, A. Rinke, M. Sempf, D. Handorf,
E. Sokolova, W. Dorn, S. Saha, S. Brand
Alfred Wegener Institute for Polar and Marine Research,
Potsdam, Germany

J. E. Haugen, M. Ø. Køltzow, J. Debernard, L. P. Røed
Norwegian Meteorological Institute, Oslo, Norway

J. H. Christensen, M. Stendel
Danish Meteorological Institute, Copenhagen, Denmark

B. Rockel, A. Benkel, H. von Storch,
GKSS Geesthacht, Germany

R. Döscher, K. Wyser, M. Meier
Rossby Centre, SMHI, Norrköping, Sweden

Associated project: GLIMPSE

Global Implications of Arctic climate processes and feedbacks

- The GLIMPSE project will address the deficiencies in our understanding of the Arctic by developing, in concert with ARCMIP, improved physical descriptions of Arctic climate feedbacks in atmospheric and coupled regional climate models.
- The improved parameterizations will be implemented into global climate system models, to determine their global influences and consequences for decadal-scale climate variations.
- These results will be used to assess the probability of abrupt climate changes on decadal time scales in the past and in the future.

Outline

1. Motivation

2. Arctic Focus

2.1 Regional atmospheric models

2.2 Atmospheric boundary layer

2.3 Improved snow and sea-ice albedo param.

2.4 Coupled regional models of the Arctic

3. Global atmospheric circulation pattern

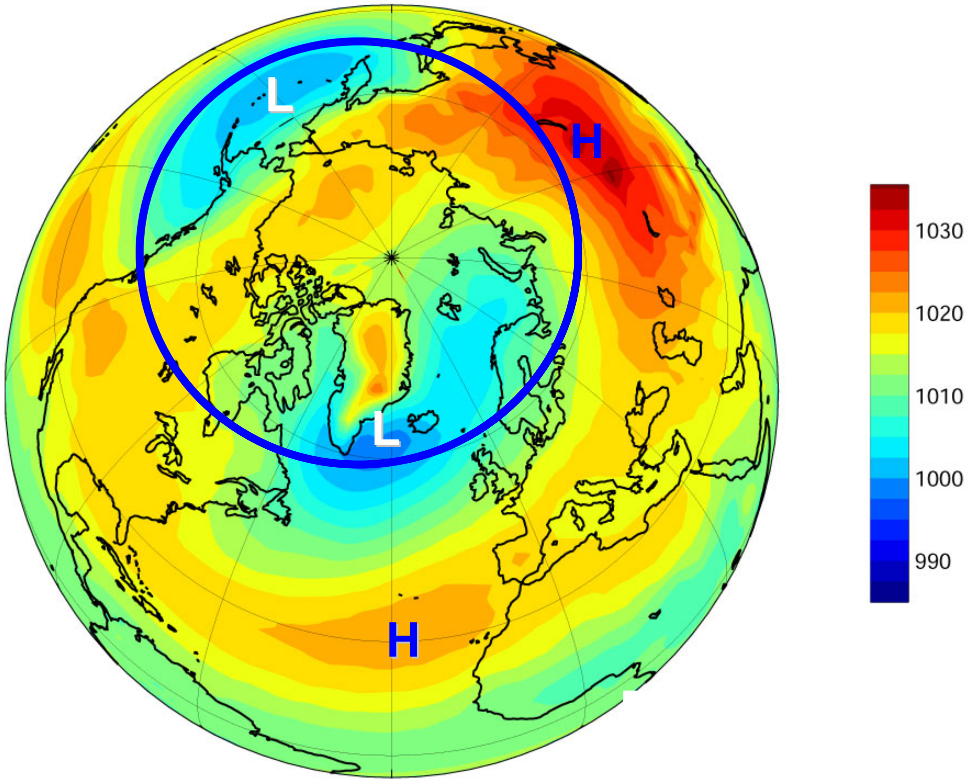
3.1 Global impacts of snow and sea-ice albedo param.

3.2 Global impacts of stratospheric ozone chem.-dynamics

4. Origin of circulation regimes and decadel variability

5. Summary and outlook

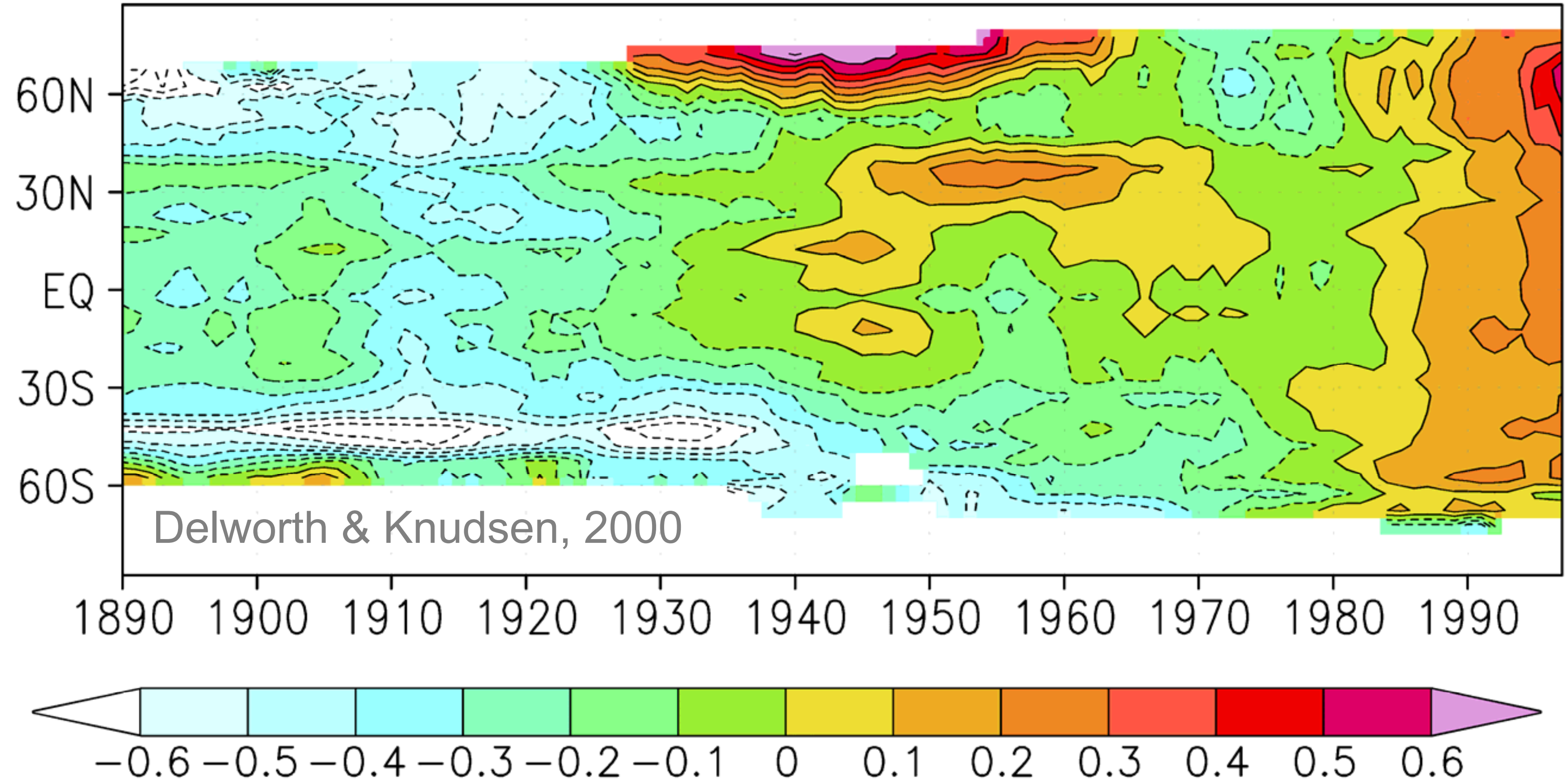
1. Motivation
Arctic → Integral part of the Earth System



Mean SLP (hPa) DJFM, 1948-2004, ERA40

Highs over the cold continents and Lows over the warmer oceans
Atmospheric and oceanic links between the Tropics and Arctic

Observed Atmospheric surface air temperatures (°C)

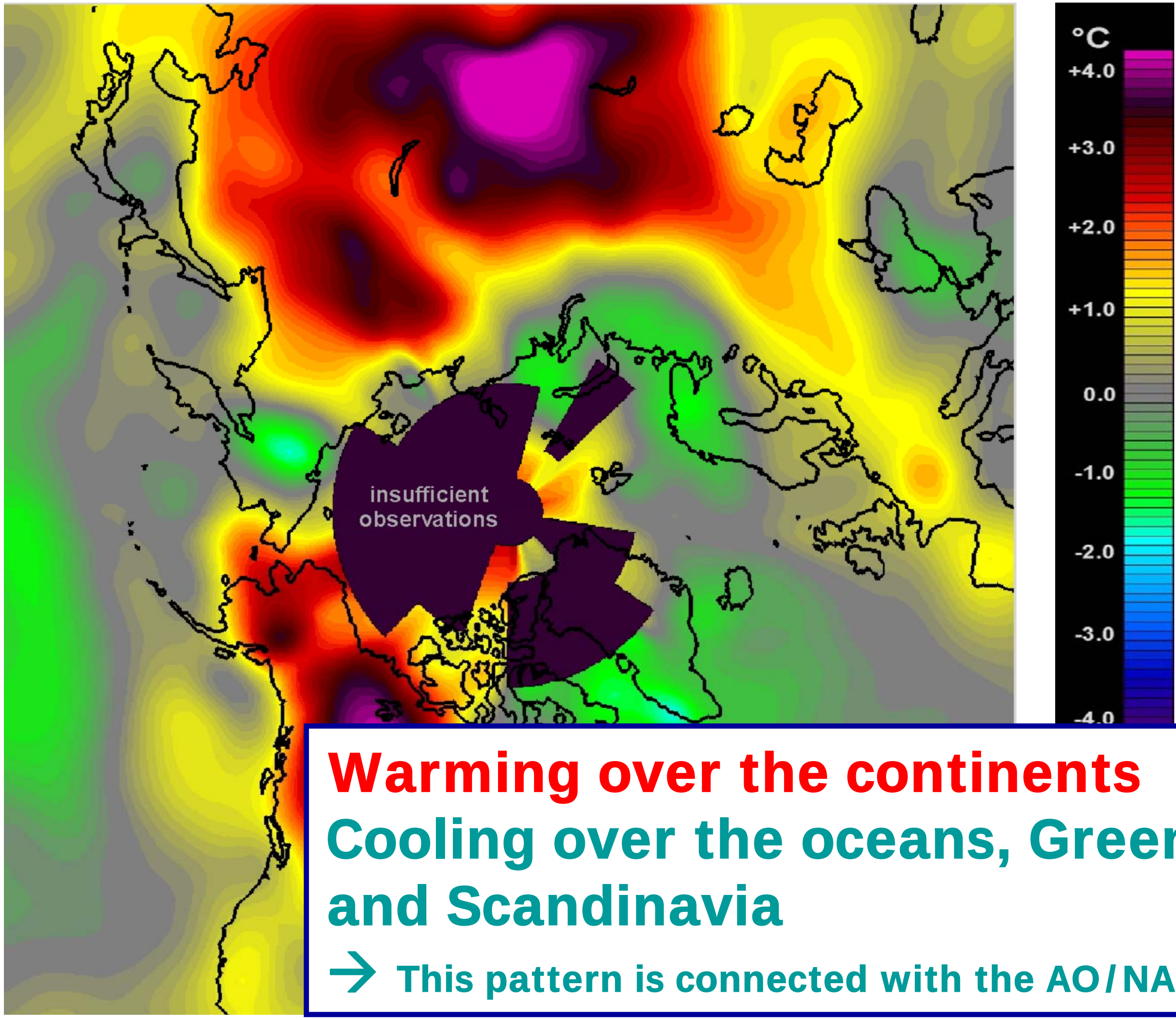


1) Early Arctic warming in the fourties → **Chaotic dynamics ?**
2) Last decades → Distribution of warming has become global, **GHG ?**
3) Pronounced decadal-scale climate variability in the Arctic.

Natural Variability or anthropogenic trends?

Arctic surface air temperature trends (°C) Winter (DJF) 1943-2002

Chapman and Walsh, http://zubov.atmos.uiuc.edu/ARCTIC



Warming over the continents

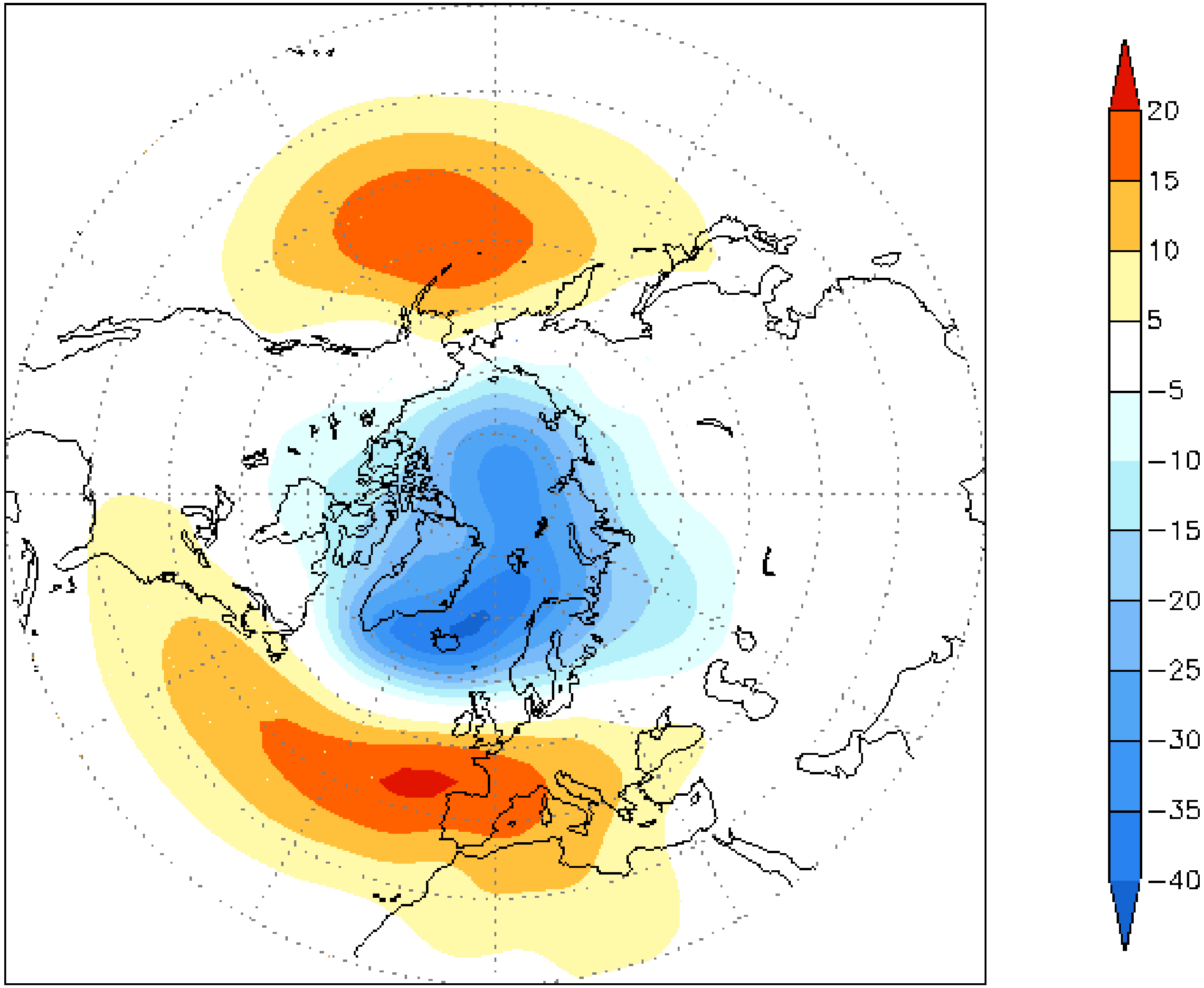
Cooling over the oceans, Greenland and Scandinavia

→ **This pattern is connected with the AO/NAO pattern (ca 50%)**

Arctic/North Atlantic Oscillation (winter)

Dominating spatial variability pattern of sea-level pressure or geopotential
Leading EOF (19%) of the geopotential height anomalies (m) at 1000 hPa

$$Geopotential : \phi = gz \rightarrow (1gpm = 9.81 m^2 s^{-2} = 9.81 ms^{-2} m)$$



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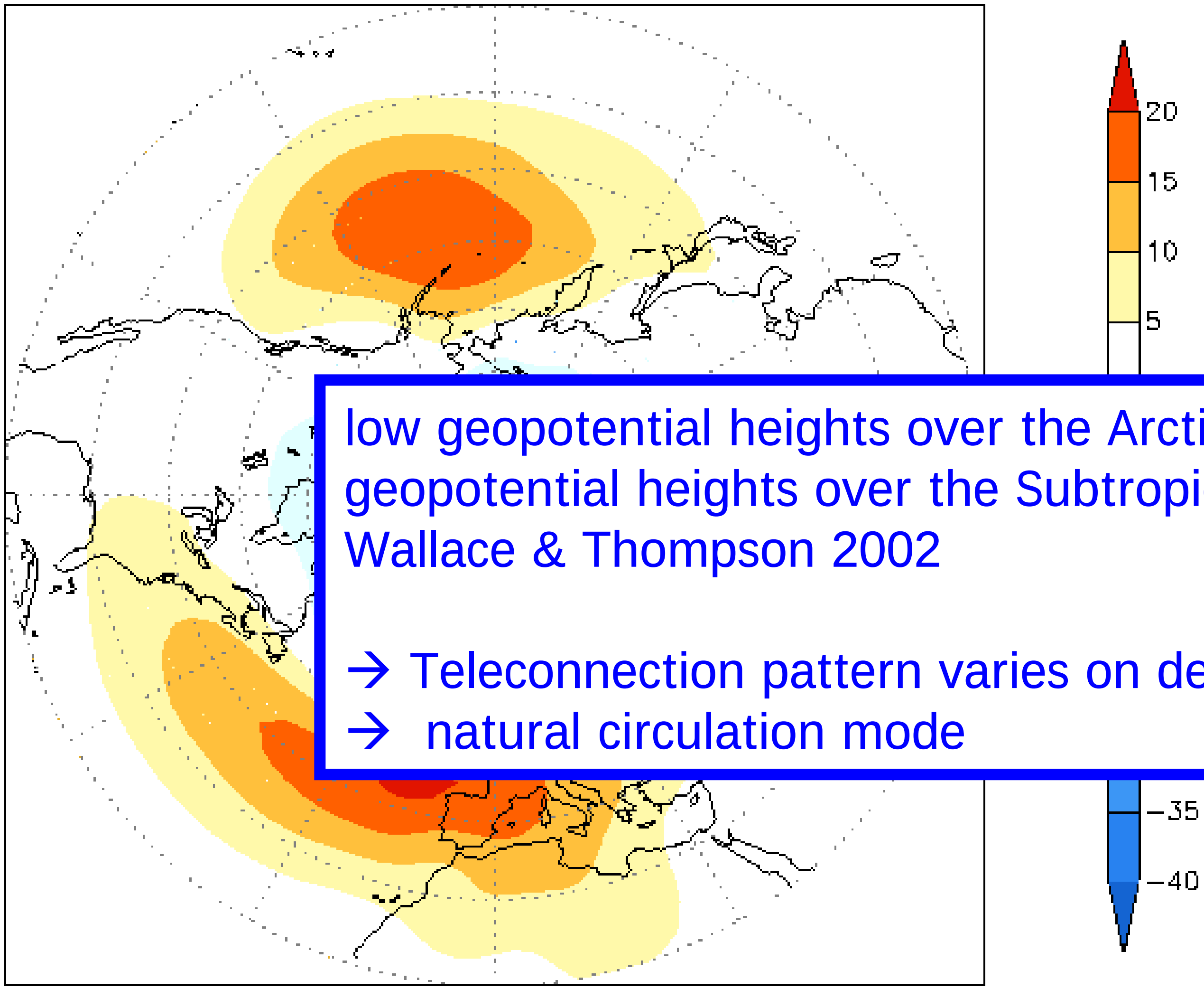


low geopotential heights over the Arctic ocean high geopotential heights over the Subtropics

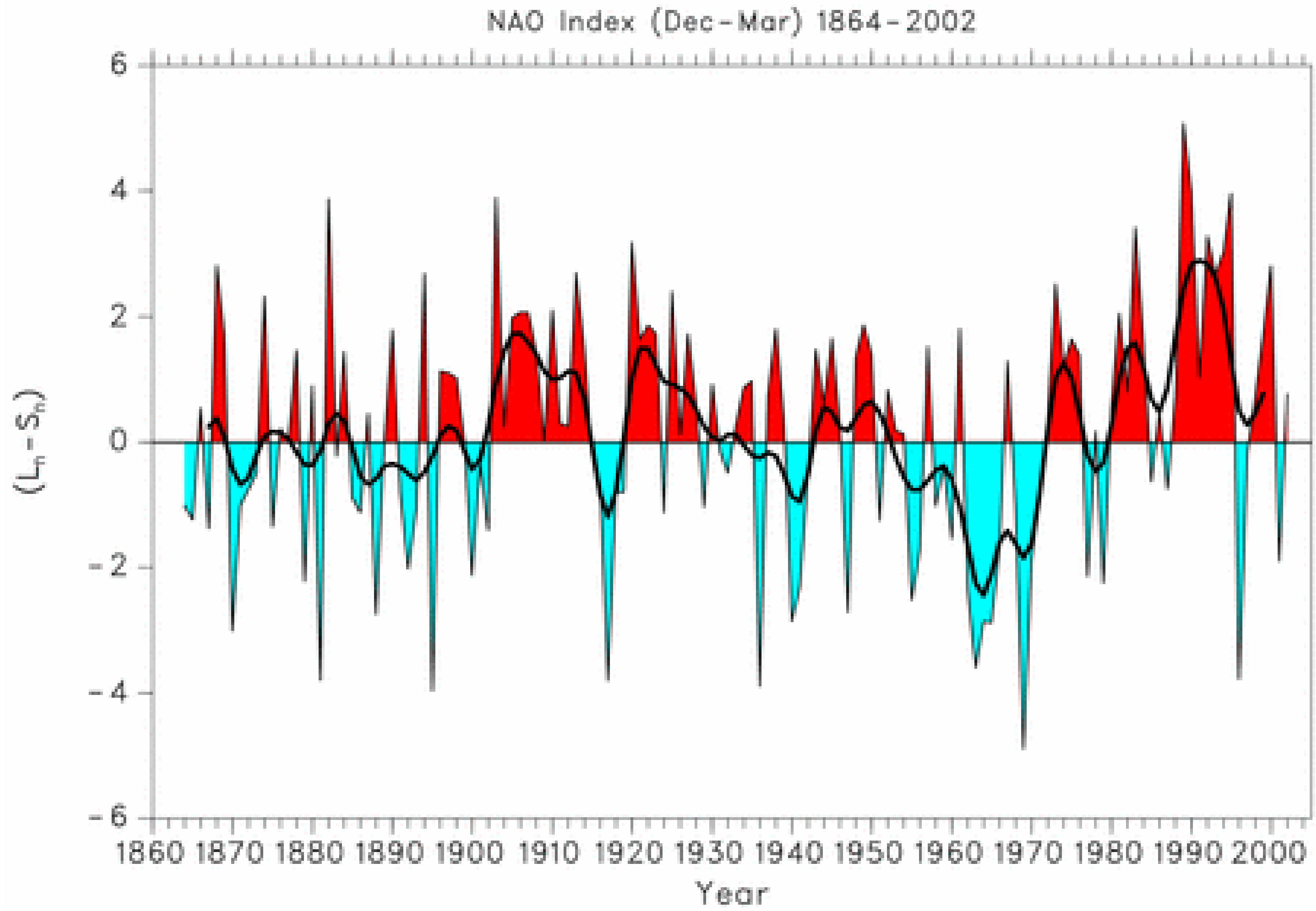
Wallace & Thompson 2002

→ Teleconnection pattern varies on decadel scales

→ natural circulation mode

Temporal variation of the NAO Index, Hurrell 2002

Normalized SLP difference between Azoric High (Lisbon) and Icelandic Low (Stykkisholmur)



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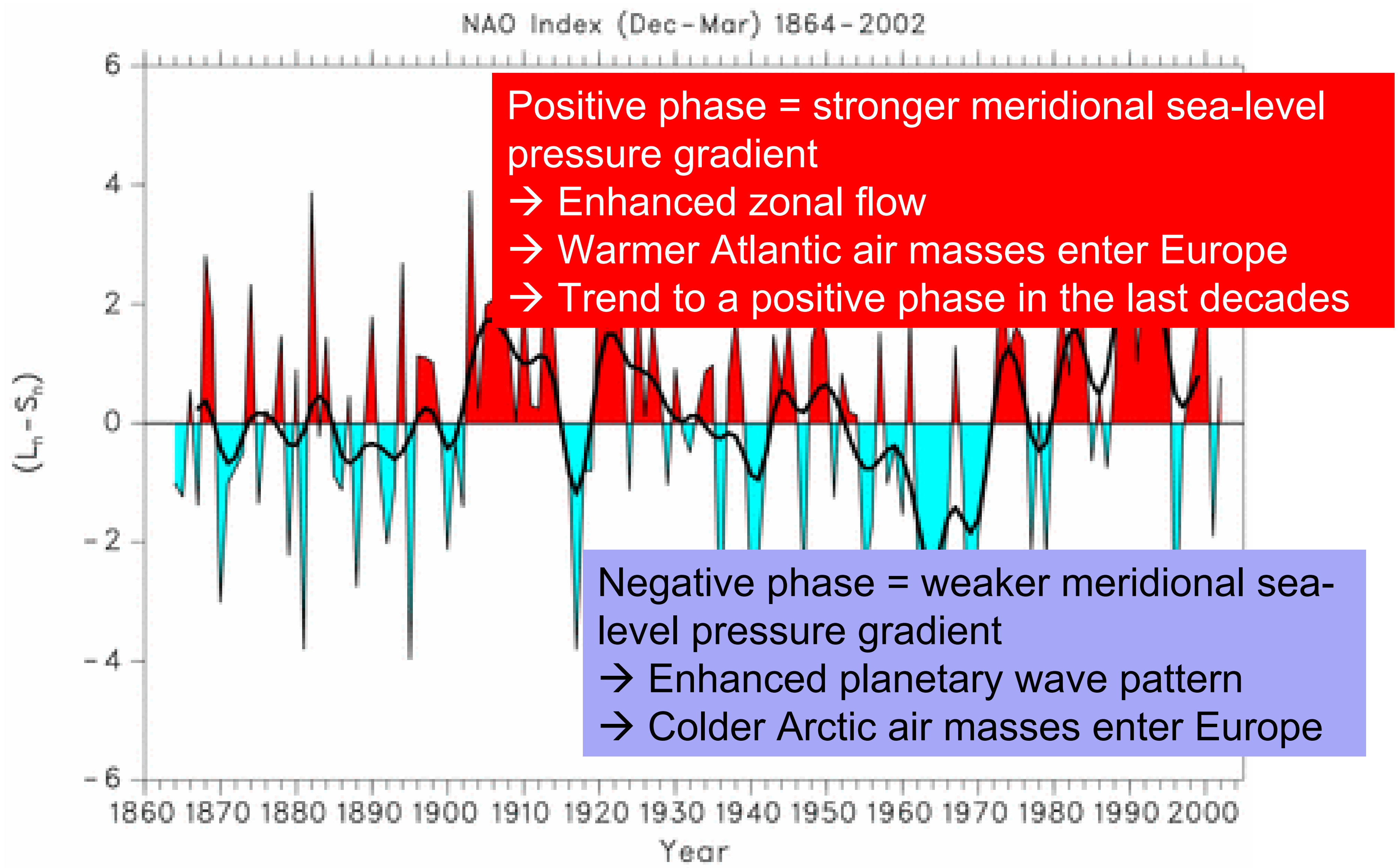
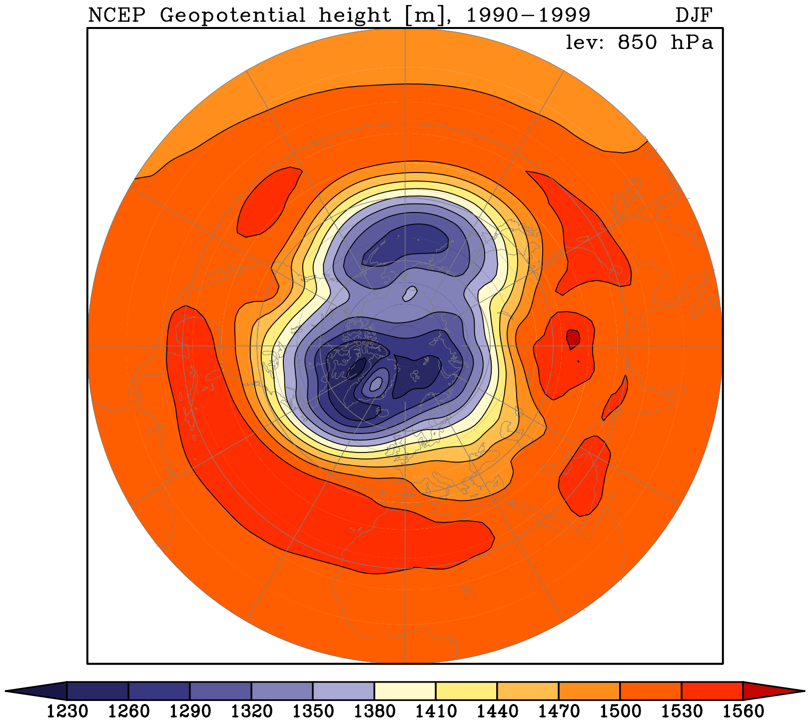


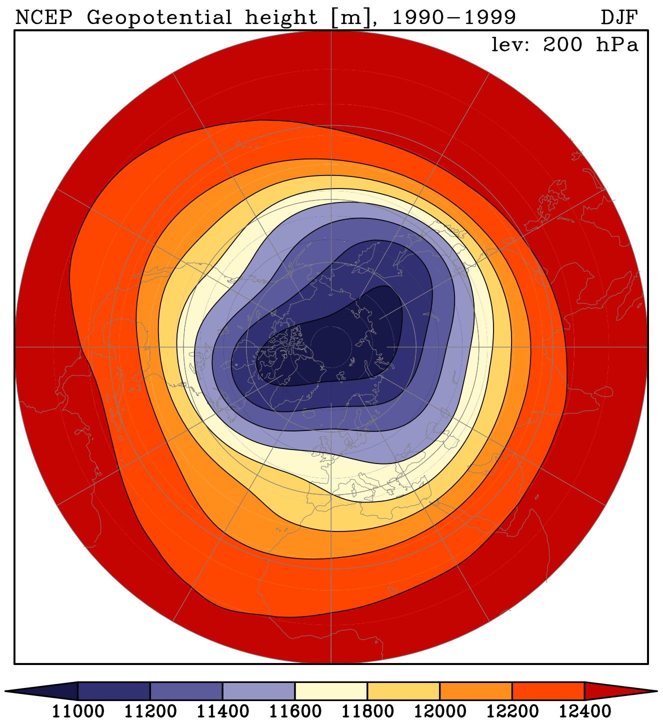
Quasi-Stationary planetary waves, NH winter

- Atmospheric circulation patterns → forced by orography of the surface, land-sea contrasts and baroclinic cyclones of mid-latitudes
- Global high and low pressure patterns are the fly wheels (Schwungrad) of the climate systems → determine climate variations on decadel scales
- Increase with height, propagate into the stratosphere and introduce radiation-dynamic feedbacks with the stratospheric ozone layer

DJF Geopotential field at 1.5 km height



DJF Geopotential field at 12 km height



Global and regional links

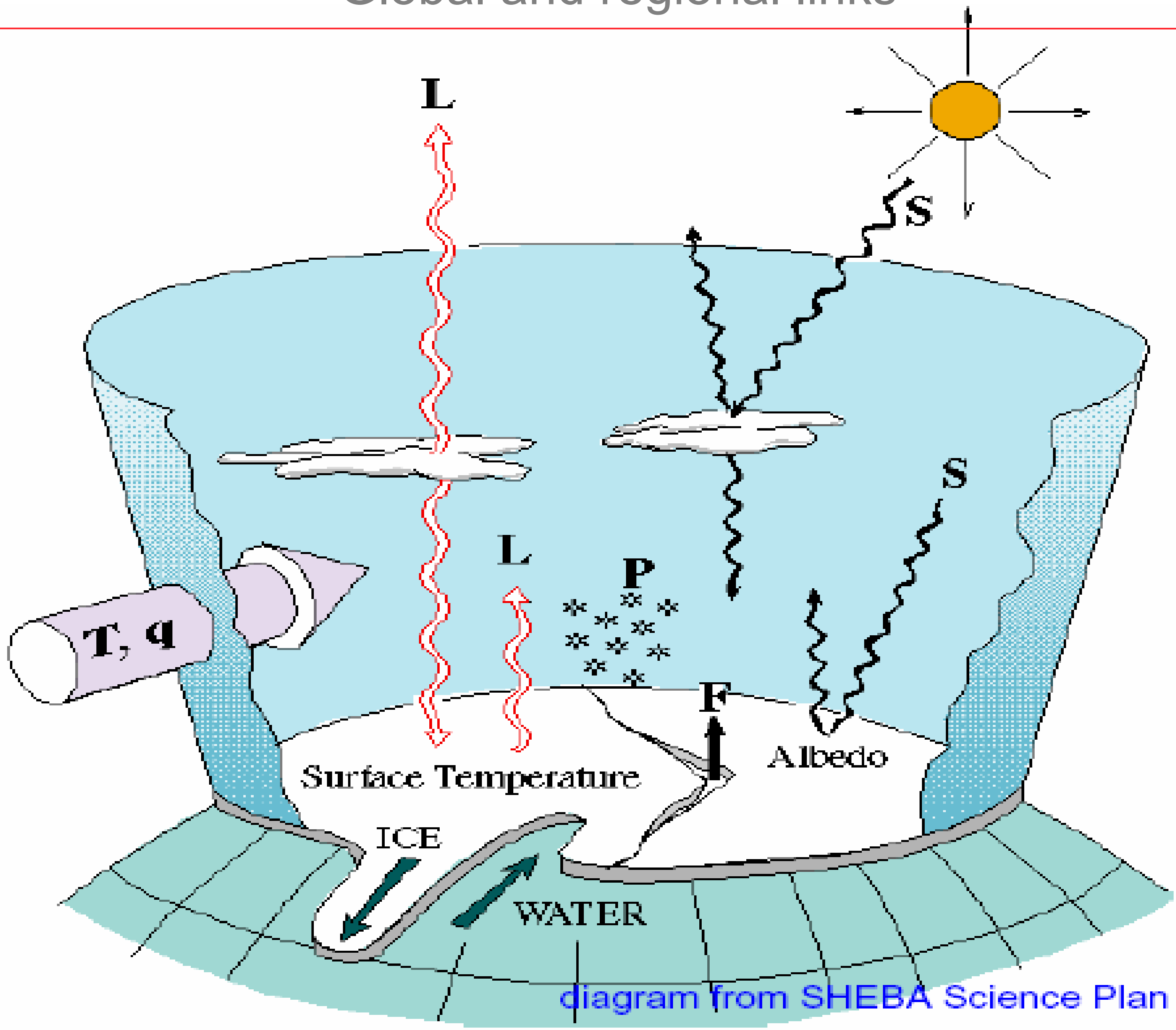
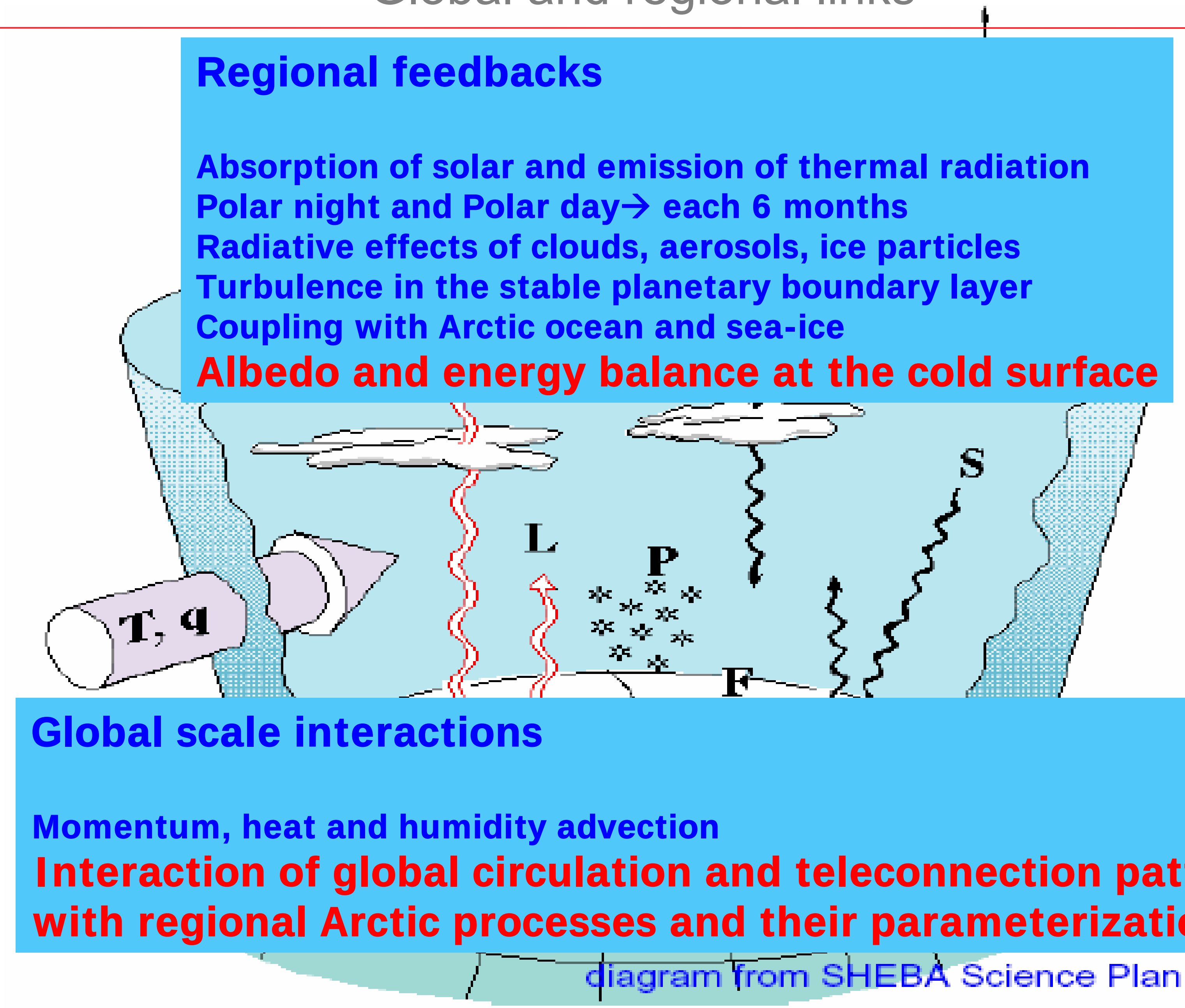


diagram from SHEBA Science Plan

Global and regional links

Regional feedbacks

Absorption of solar and emission of thermal radiation
Polar night and Polar day→ each 6 months
Radiative effects of clouds, aerosols, ice particles
Turbulence in the stable planetary boundary layer
Coupling with Arctic ocean and sea-ice
Albedo and energy balance at the cold surface



Global scale interactions

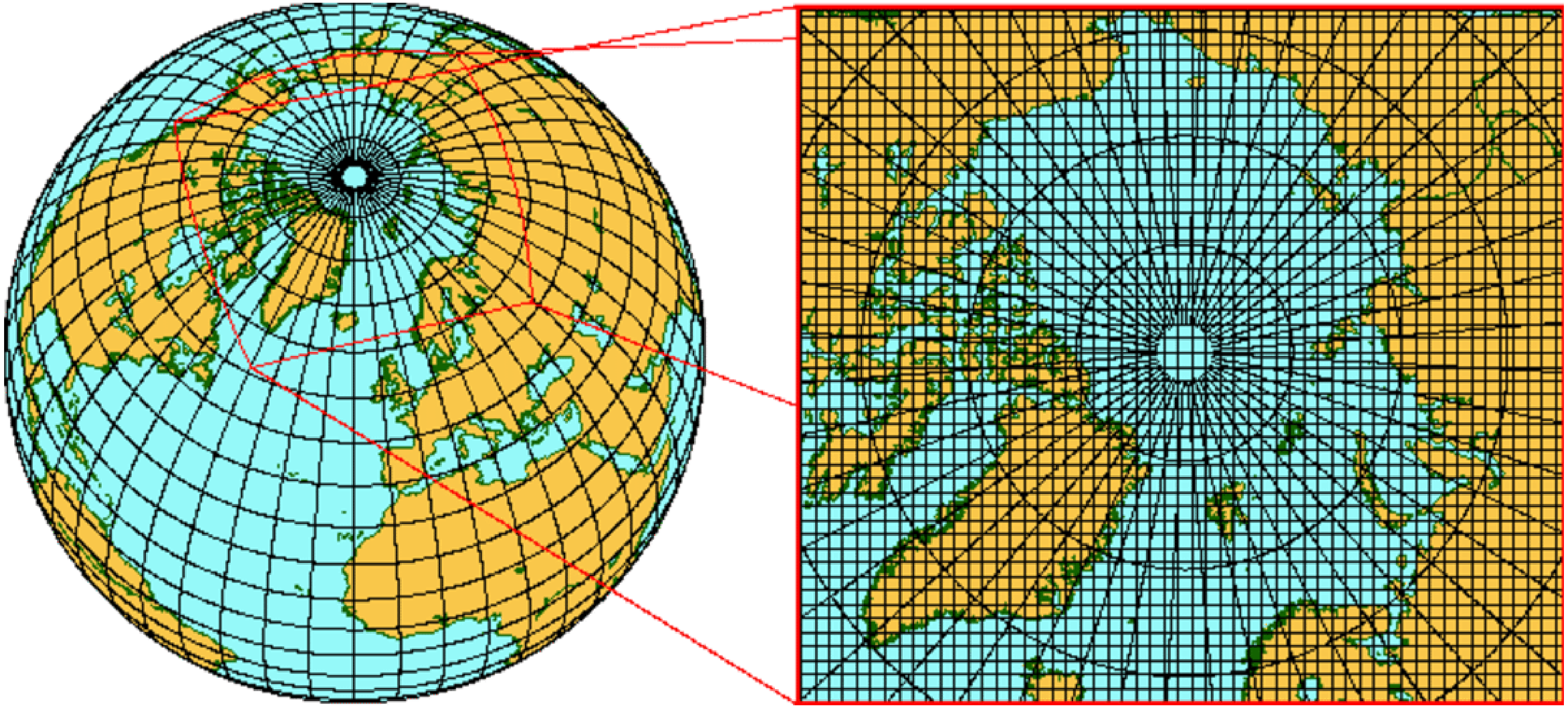
Momentum, heat and humidity advection
Interaction of global circulation and teleconnection pattern with regional Arctic processes and their parameterizations

diagram from SHEBA Science Plan

2.1 Regional atmospheric models

Regional climate modeling method

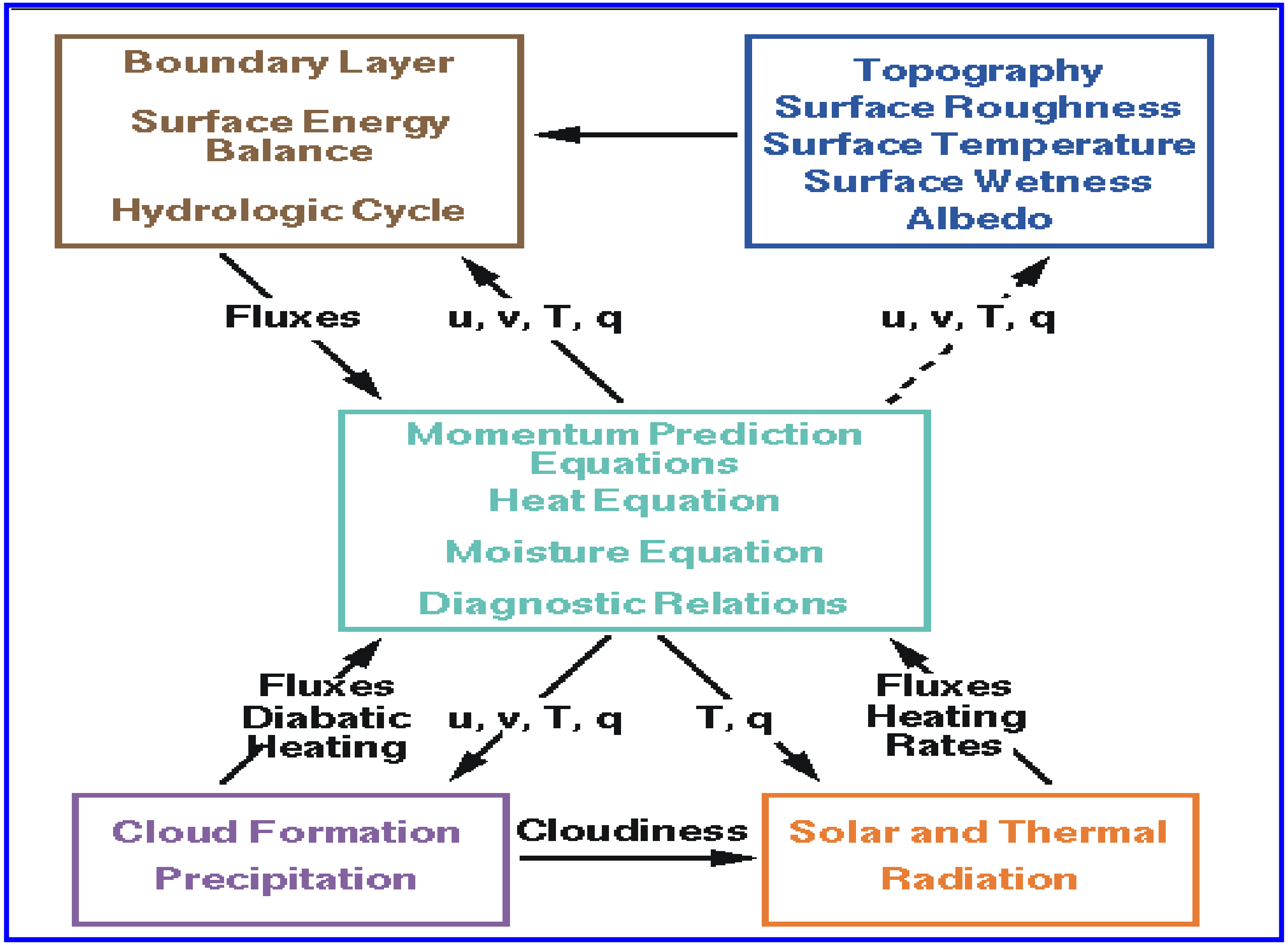
High horizontal resolution of regional topographic structures in the RCM, improved simulation of cyclones



GCM → RCM

Initial & boundary conditions for the RCM provided by GCM

Model simulations, parameterizations and measurements



ARCMIP - Arctic Regional Climate Model Intercomparison Project

Participating models

1. ARCSyM (USA)
2. COAMPS (S,USA)
3. HIRHAM (D,DK)
4. CRCM (C)
5. RCA (S)
6. RegCM (N)
7. REMO (D)
8. PolarMM5 (USA)

Experiment 1

- Simulations for one year SHEBA period Sept 1997-Sept 1998 have been carried out

Experimental set-up

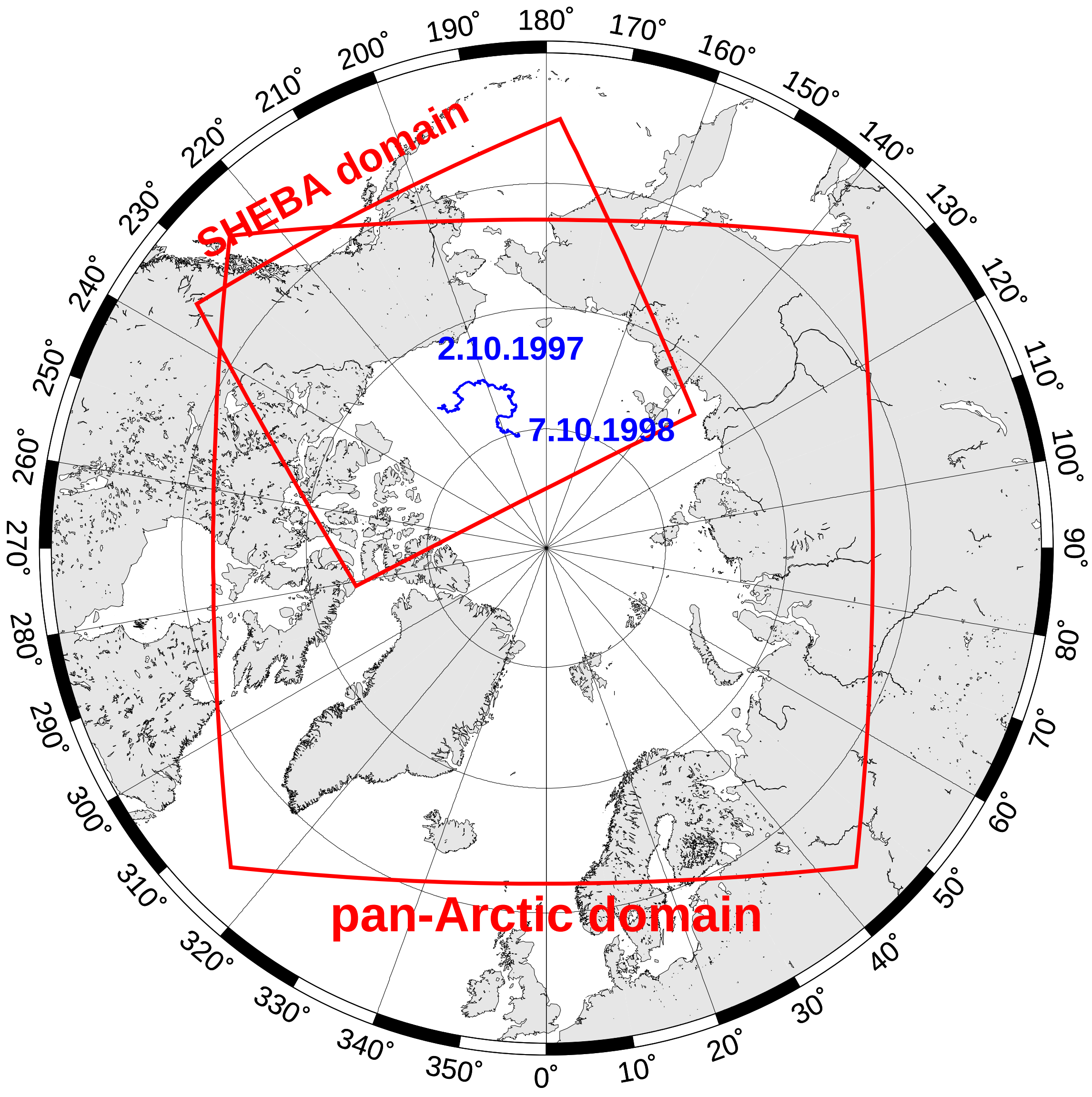
- Same domain
- Same horizontal resolution
- Same boundary conditions
- Different dynamics/physics

SHEBA 1997/98

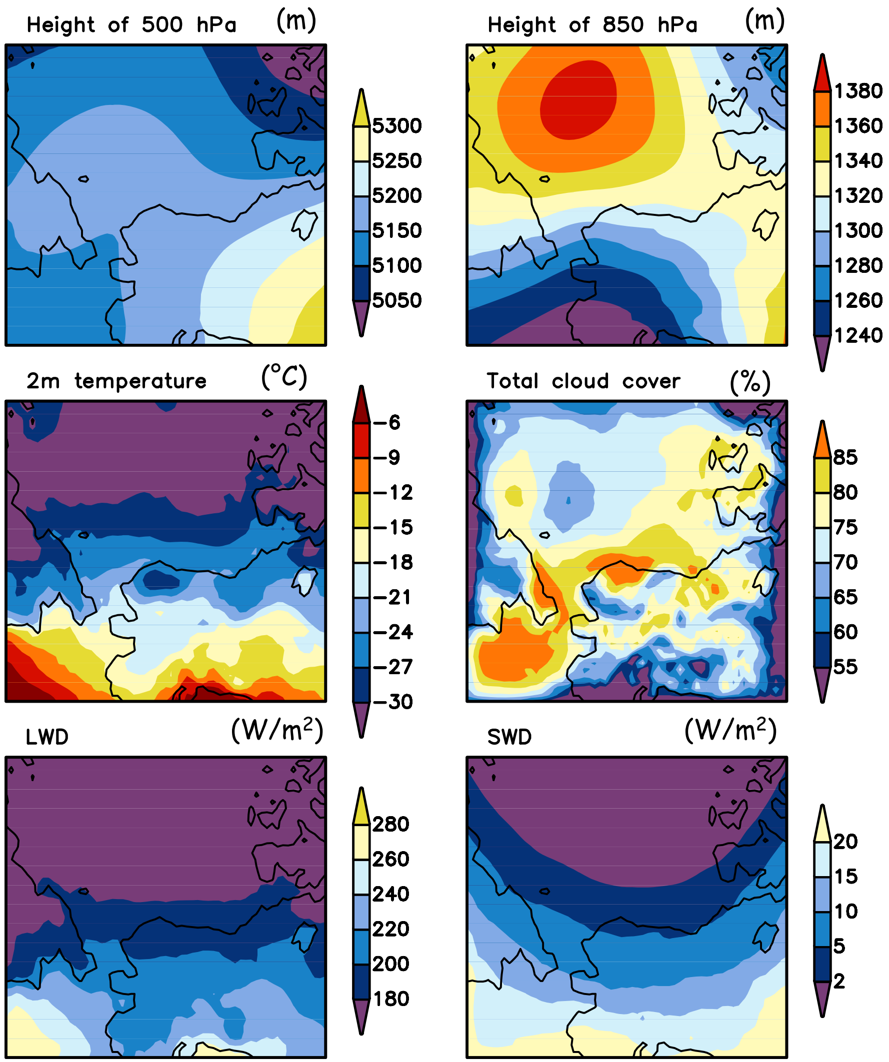
The surface heat budget components of the Arctic Ocean have been measured

Trajectory of the SHEBA ice camp in the Beaufort-Chukchi sea

Application of RCMs for the SHEBA subdomain and the pan-Arctic domain

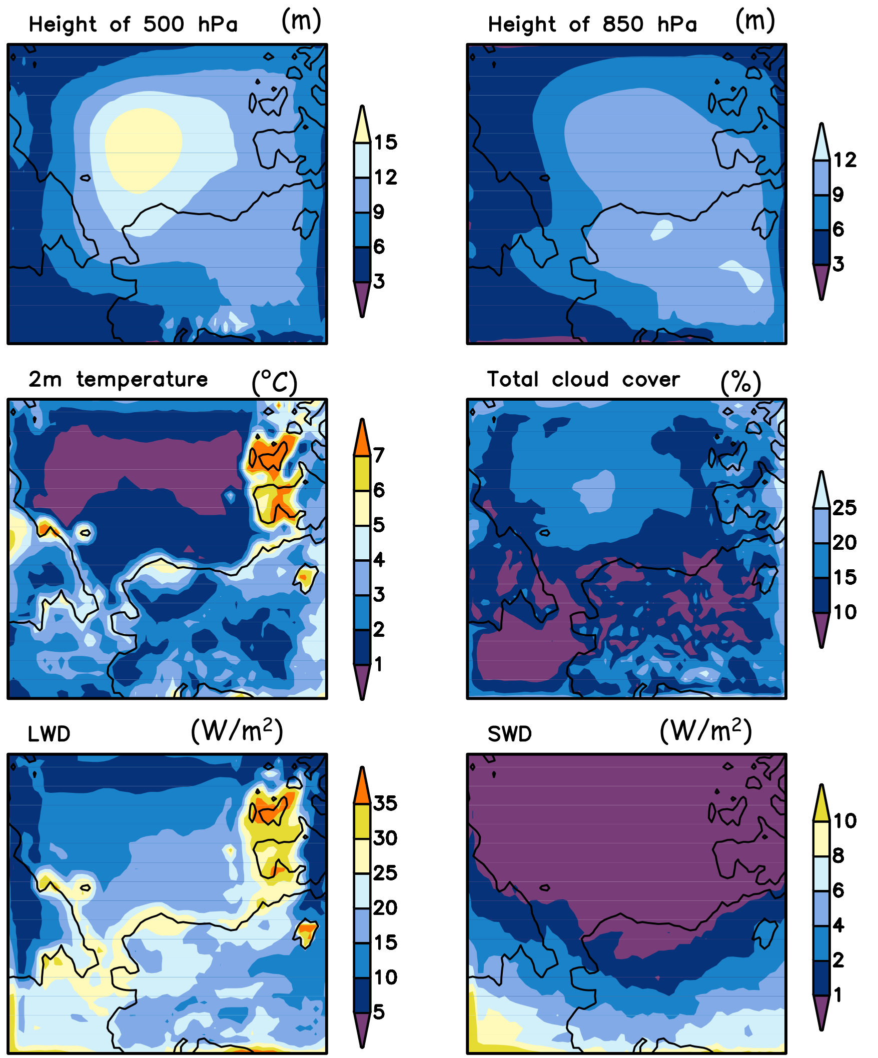


Winter ensemble mean



Realistic reproduction of the observed winter climate, geopotential height 850 & 500 hPa, 2 m temperature, total cloud cover, longwave and shortwave downward radiation,

Winter ensemble stdev.

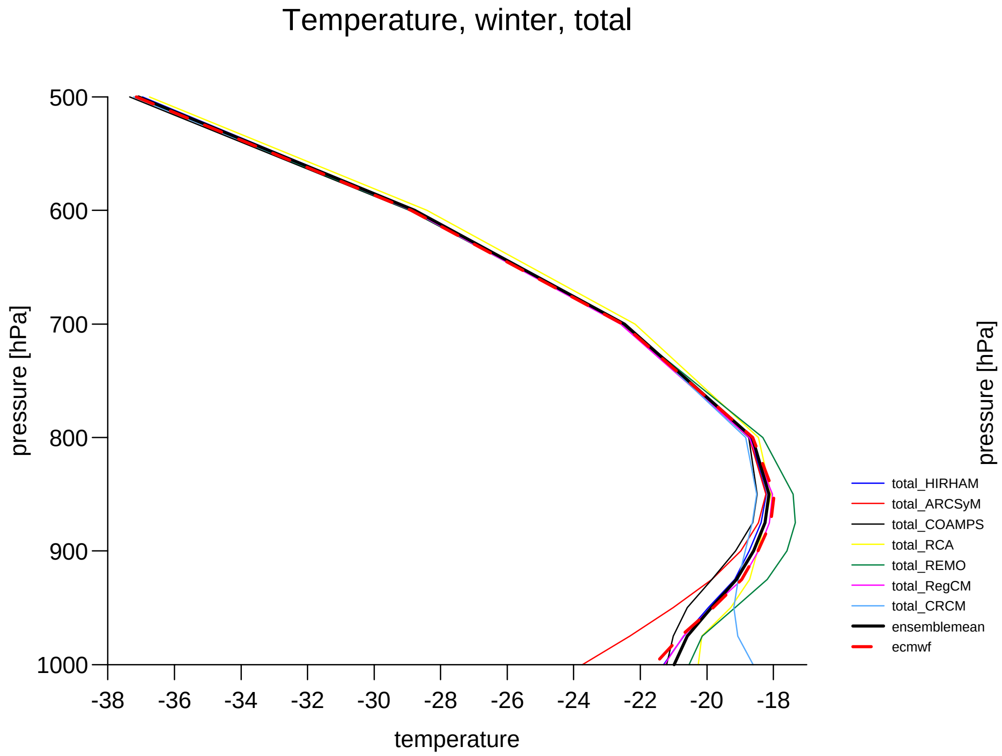


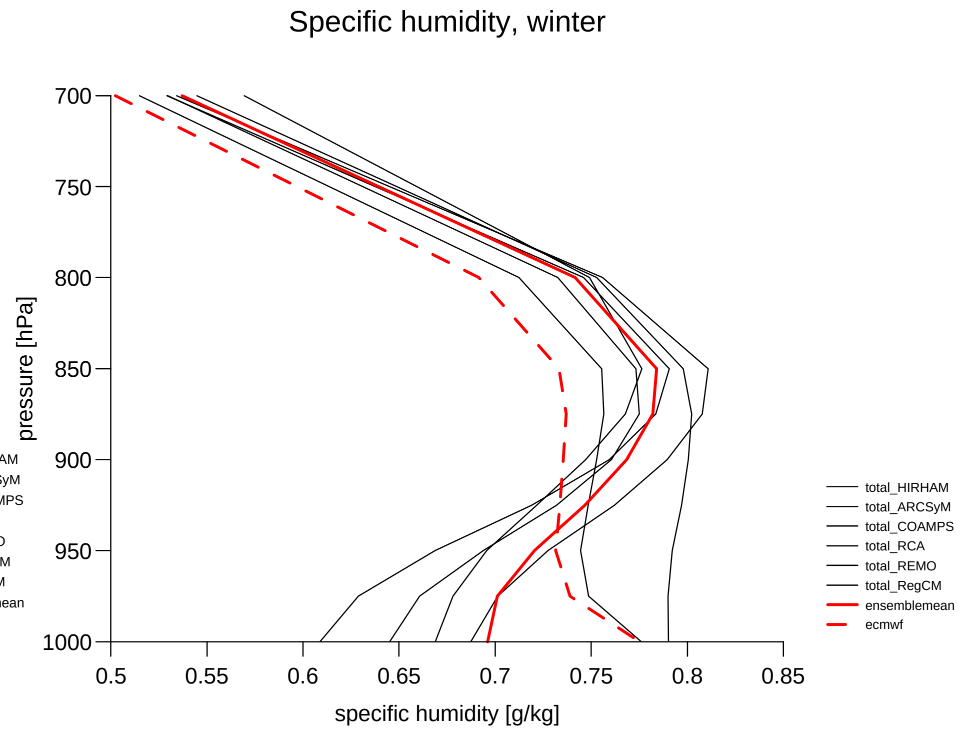
Scatter between the participating models

- **2m temperature over land up to 7 K**
- **surface radiation fluxes up to 35 W/m²**
- **cloud cover 25 %**

Intercomparison of temperature and humidity profiles for SHEBA domain and year

(Rinke et al., Climate Dyn., 2006)





→ **Remarkable scatter between model temperature and humidity profiles (due to different radiation, clouds, aerosols, PBL, soil and permafrost schemes)**

→ **Temperature scatter in the order of 3°C (in the range of climate change scenarios)**

→ **Need for improved parameterizations of Arctic climate processes**

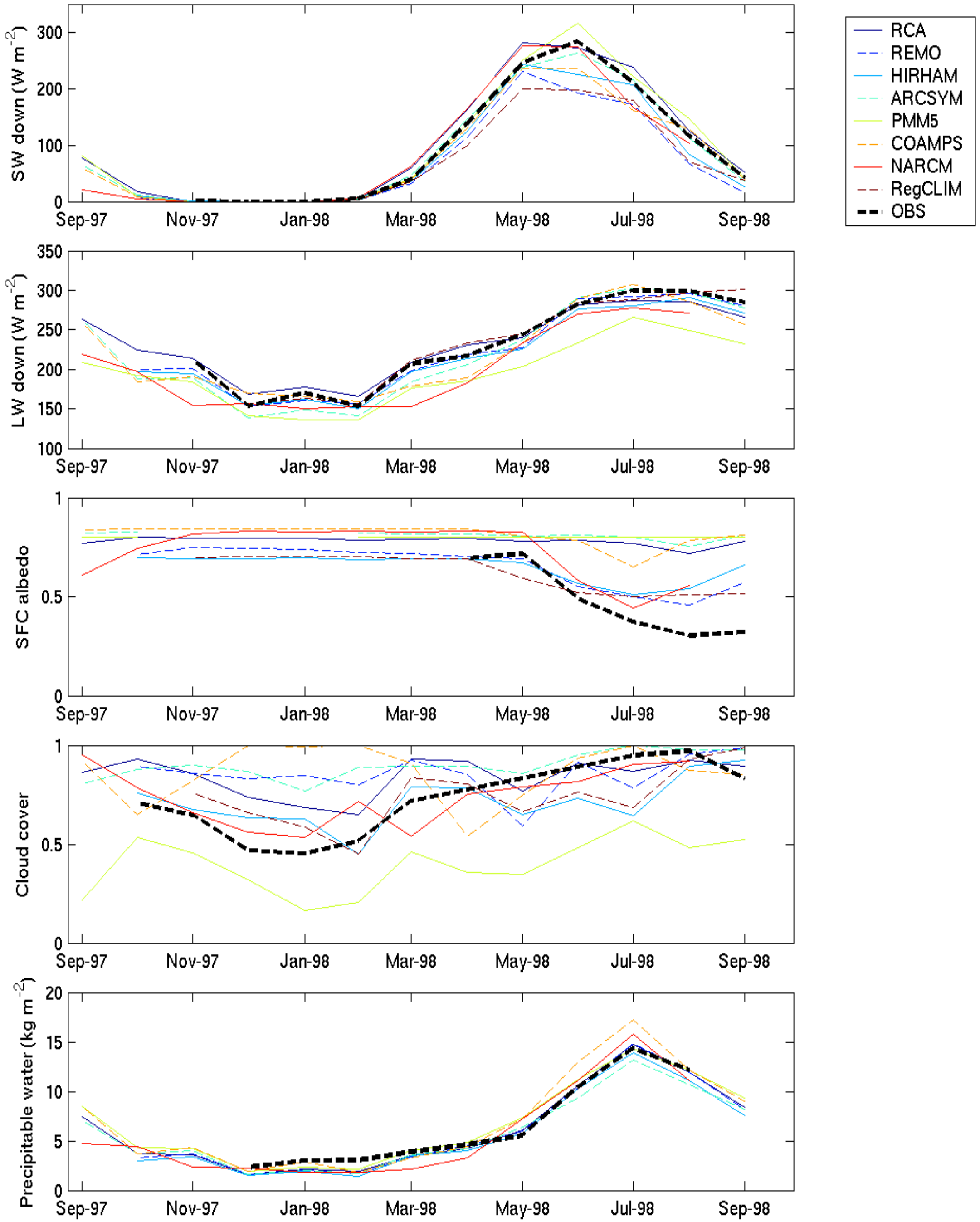
Measurements and modelling approach → IPY

Measurements are needed for the improved model description and parameterizations of:

1. **Surface radiative and turbulent fluxes**
2. **Stable Arctic boundary layer**
3. **Temperature and humidity inversions**
4. **Arctic Haze, aerosols and clouds**
5. **Low ice crystal clouds**
6. **Convective plumes due to leads in the sea-ice**
7. **Sea-ice dynamic and thermodynamic processes**

2.2 Atmospheric boundary layer

Monthly averages of the SHEBA year 1997/98 for the models participating in ARCMIP: Shortwave and longwave radiation, surface albedo, cloud cover, water content.



Big uncertainties in the Arctic climate simulations due to:

Surface albedo, clouds and PBL turbulence

Wyser and Jones 2004

Different turbulent closure schemes for the APBL in winter

ECHAM3_MO

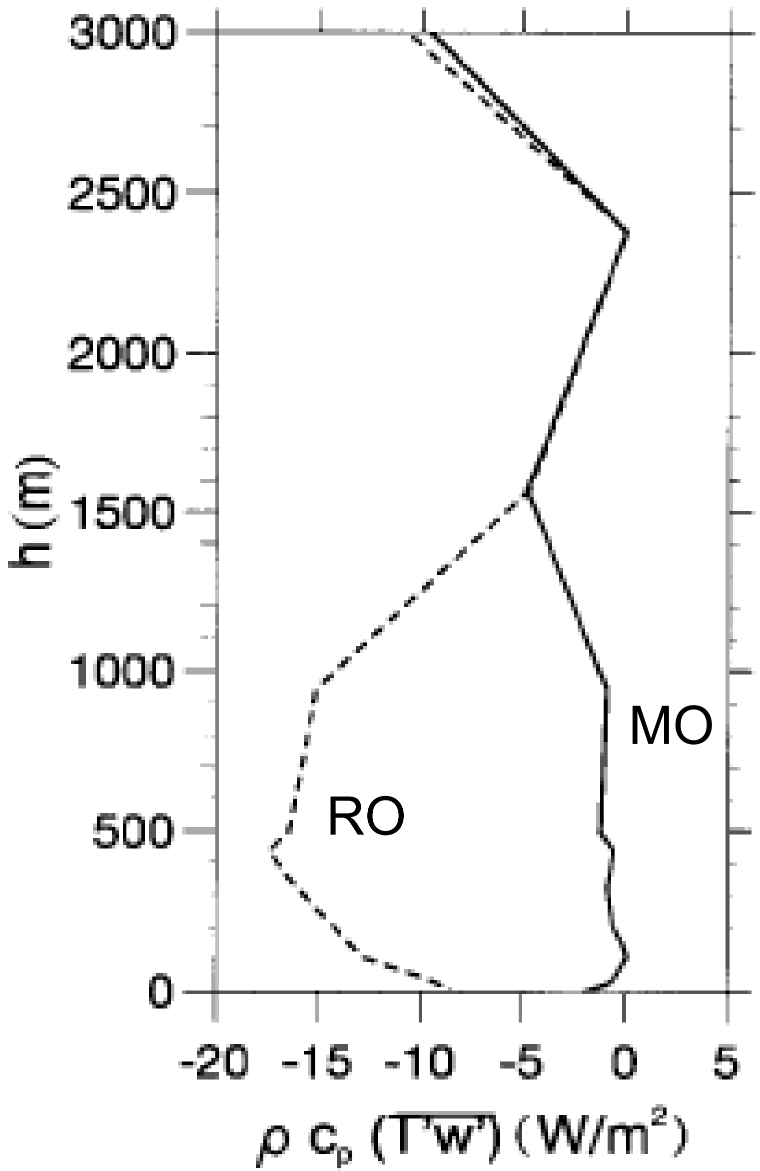
Monin Obukhov similarity theory in the surface layer
Mixing length approach in the Ekman layer

ECHAM3_RO

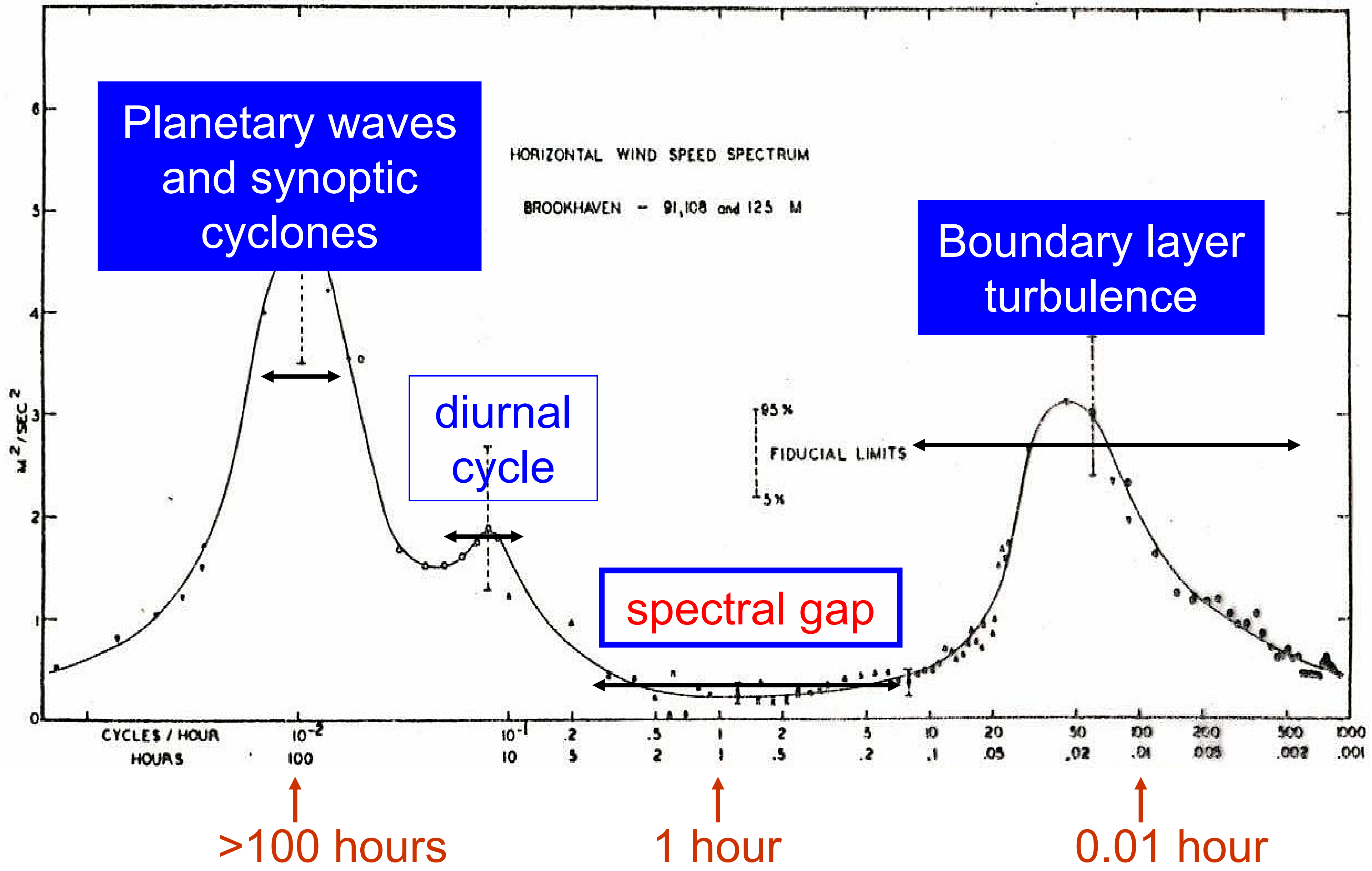
Extension of similarity theory to the whole planetary boundary layer
Coriolis force included

ECHAM4_TKE

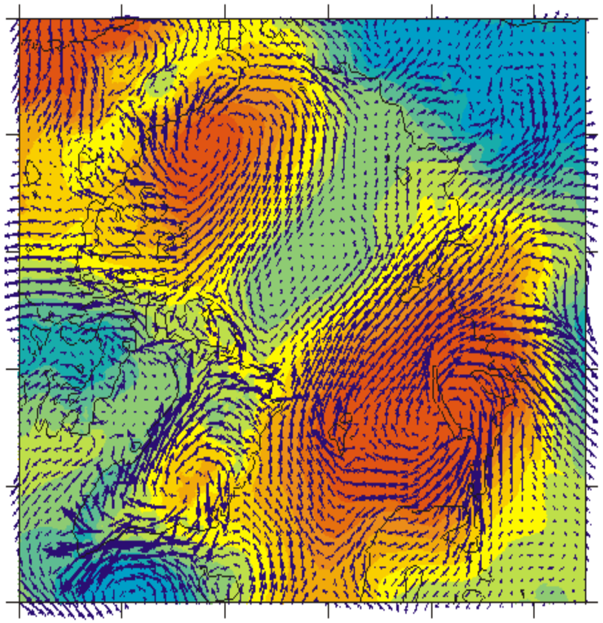
MO in the surface layer and TKE closure in the Ekman layer

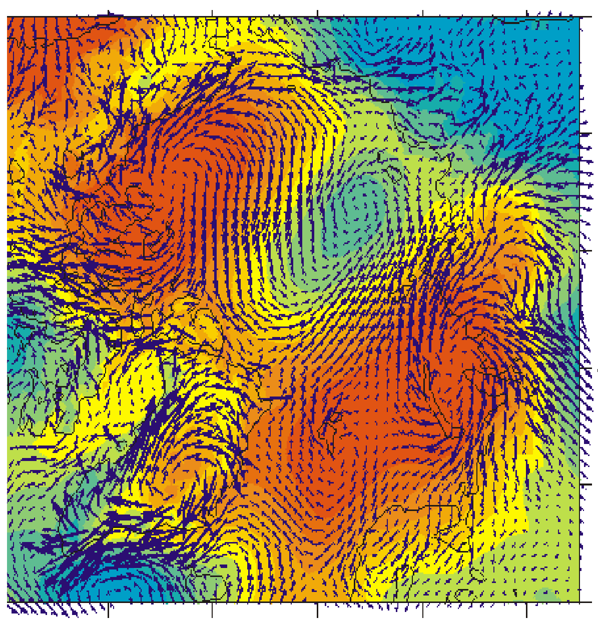


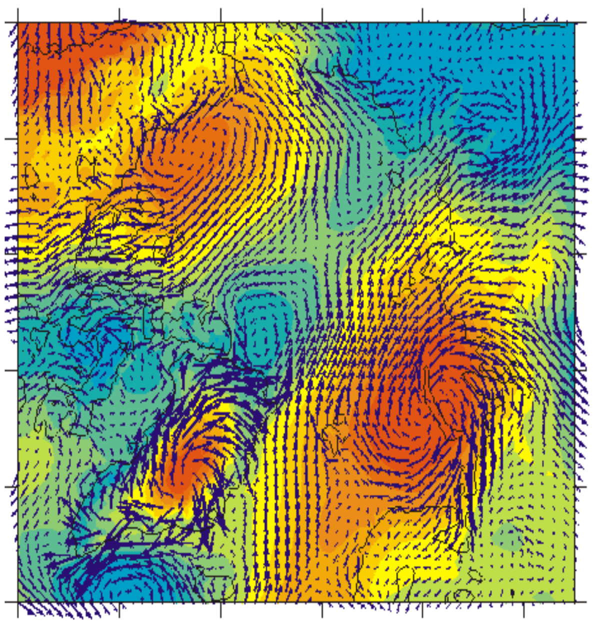
Nonlinear energy cascade of space and time scales in the atmosphere → atmospheric energy spectrum

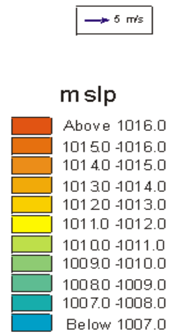


HIRHAM with ECHAM3_MO	HIRHAM with ECHAM3_RO	HIRHAM with ECHAM4_TKE







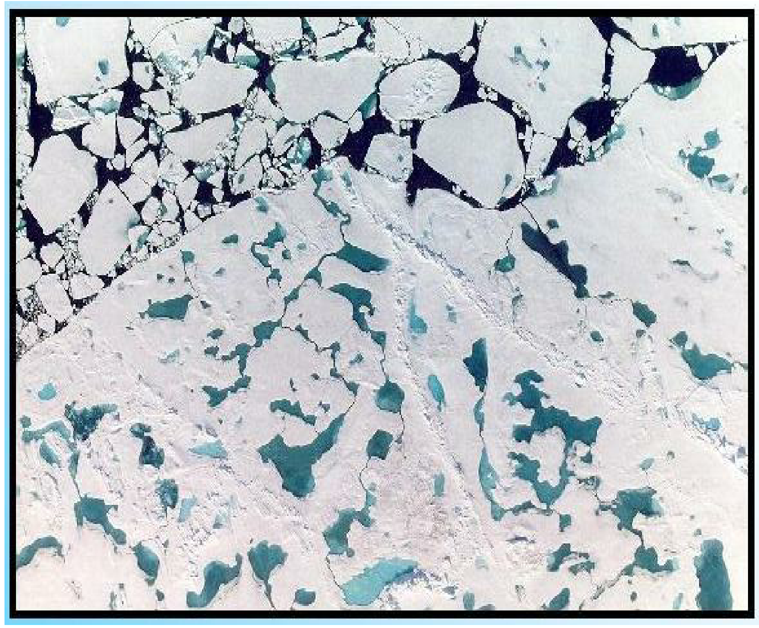


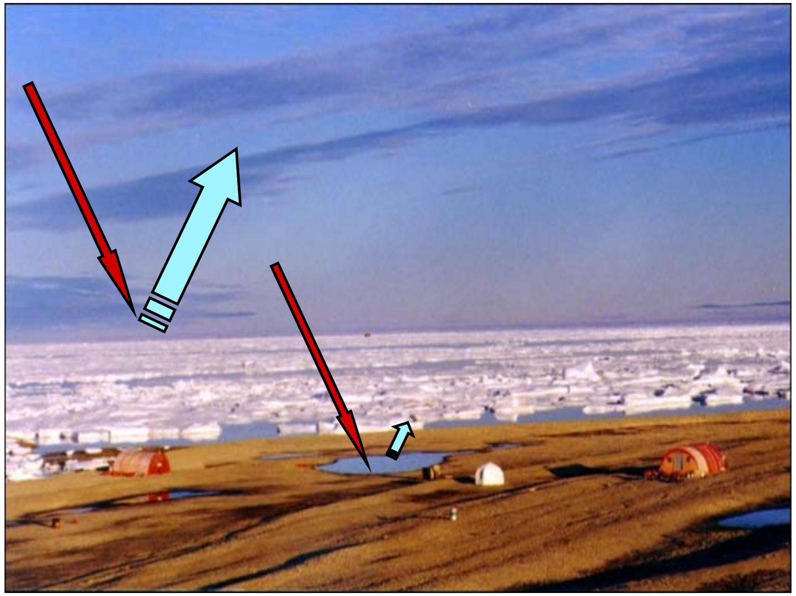
MSLP (hPa) and 10 m wind for July 1990 over sea-ice regions for atmospheric HIRHAM simulations with different turbulent PBL closure schemes, but identical lower and lateral boundary forcing

→ **Arctic PBL turbulence parameterization influences the regional circulation structures, Dethloff et al., Tellus, 2001**

2.3 Improved snow and sea-ice albedo parameterization

Snow and sea-ice albedo feedback





- Ice, snow and clouds are the stabilizer and brakes of the climate system
- They regulate atmospheric temperature by reflecting much of the incoming solar radiation
- Ice-albedo feedback: Self accelerating feedback loop

water-vapour-cloud feedbacks changes

- Temperature increase → melting ice and snow → open water forms → reduced solar reflection

New snow and sea ice albedo schemes from satellite and SHEBA data

(measured surface energy budget components)

Snow albedo:

- Surface temperature dependent scheme; different for forested (linear dependency) and non-forested (polynomial approach) areas → Roesch (2000) for Russian land stations

Sea ice albedo:

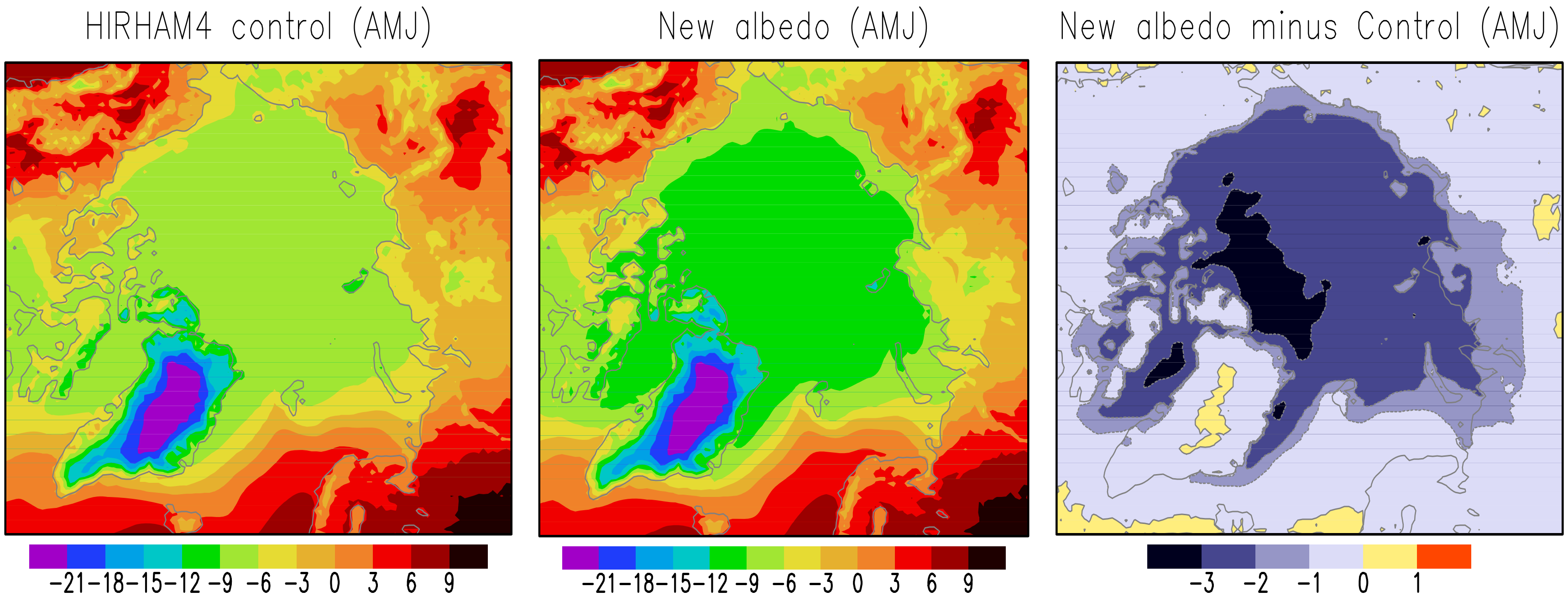
- 3 different surface types (snow covered ice, bare sea-ice, melt ponds and leads)
- Surface temperature dependent scheme; linear dependency → Køltzow et al. (2004)

→ The gross features of the annual surface albedo cycle are reproduced by using a surface temperature dependent scheme

→ Implementation into the RCM HIRHAM

New snow and ice albedo parameterization in HIRHAM

Mean spring (AMJ) 2m temperature (°C) in control and new albedo runs
(Saha et al., 2006)



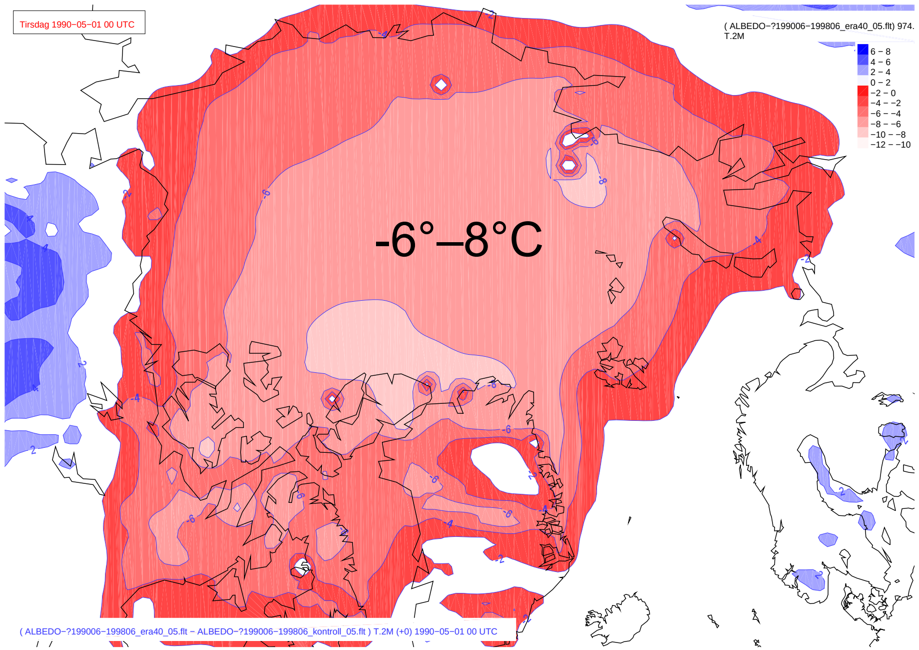
- → **New albedo scheme leads to temperature decrease over the Arctic Ocean**
- → **Increased temperature gradient between tropics and Arctic with potential global implications**
- → **Impact on Arctic sea-ice in coupled models expected**

New snow and ice albedo parameterization in HIRHAM

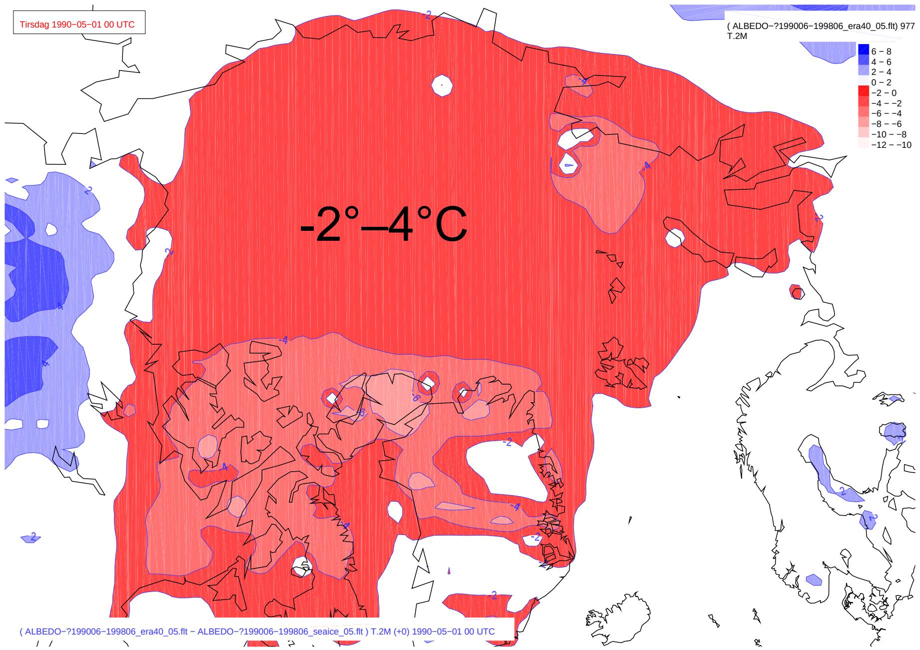
compared with ERA-40 → mean of 8 May months (1991-1998)

(Køltzow et al., 2005)

T2m: ERA-40 minus old albedo



T2m: ERA-40 minus new albedo

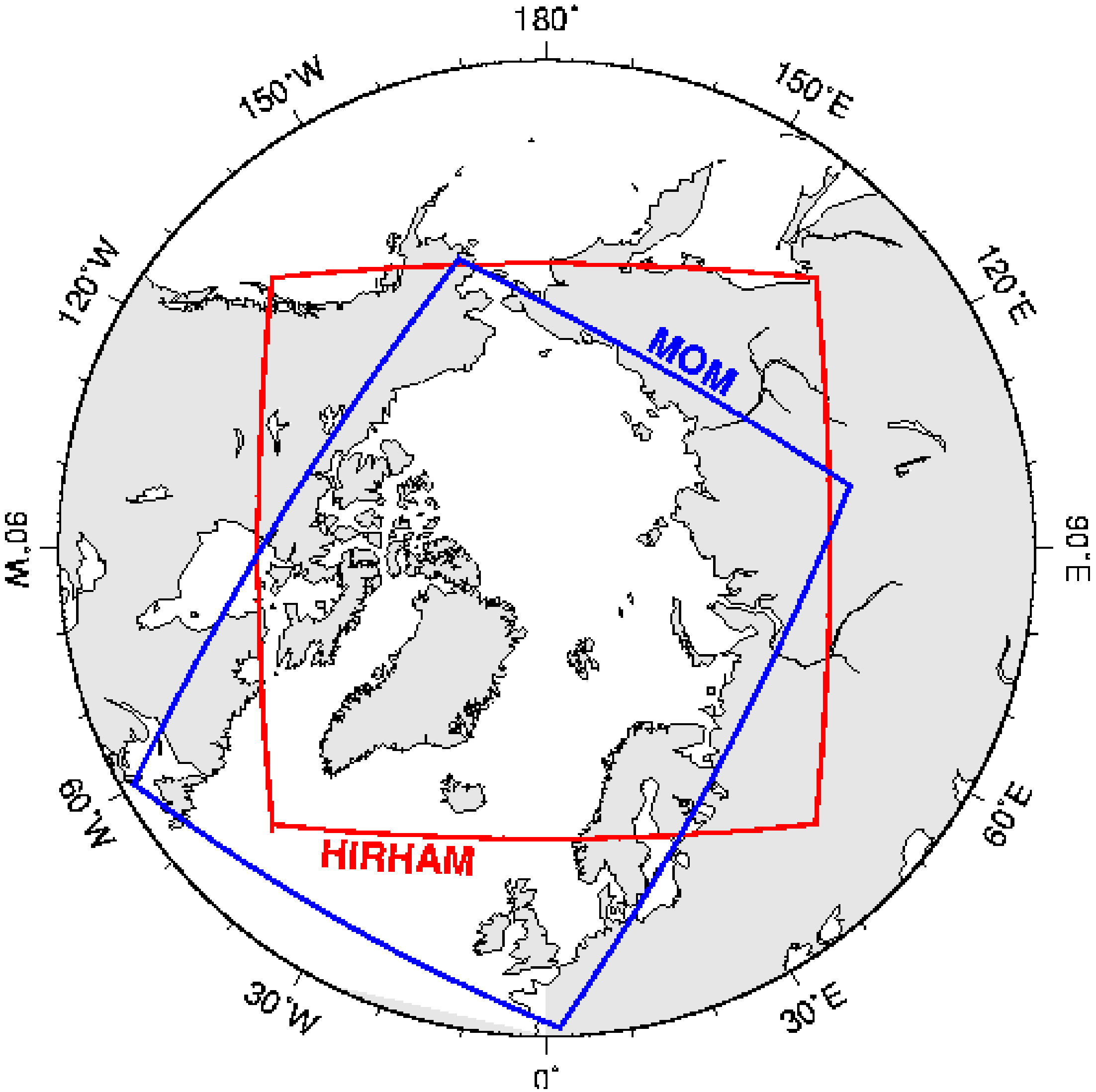


→ **New albedo scheme improves 2m temperatures in spring and autumn**

→ **Improved simulation of MSLP in spring and autumn (but not in mid-summer compared to ERA-40)**

2.4 Coupled regional models of the Arctic

Integration domain of the coupled A-O-I model HIRHAM-NAOSIM



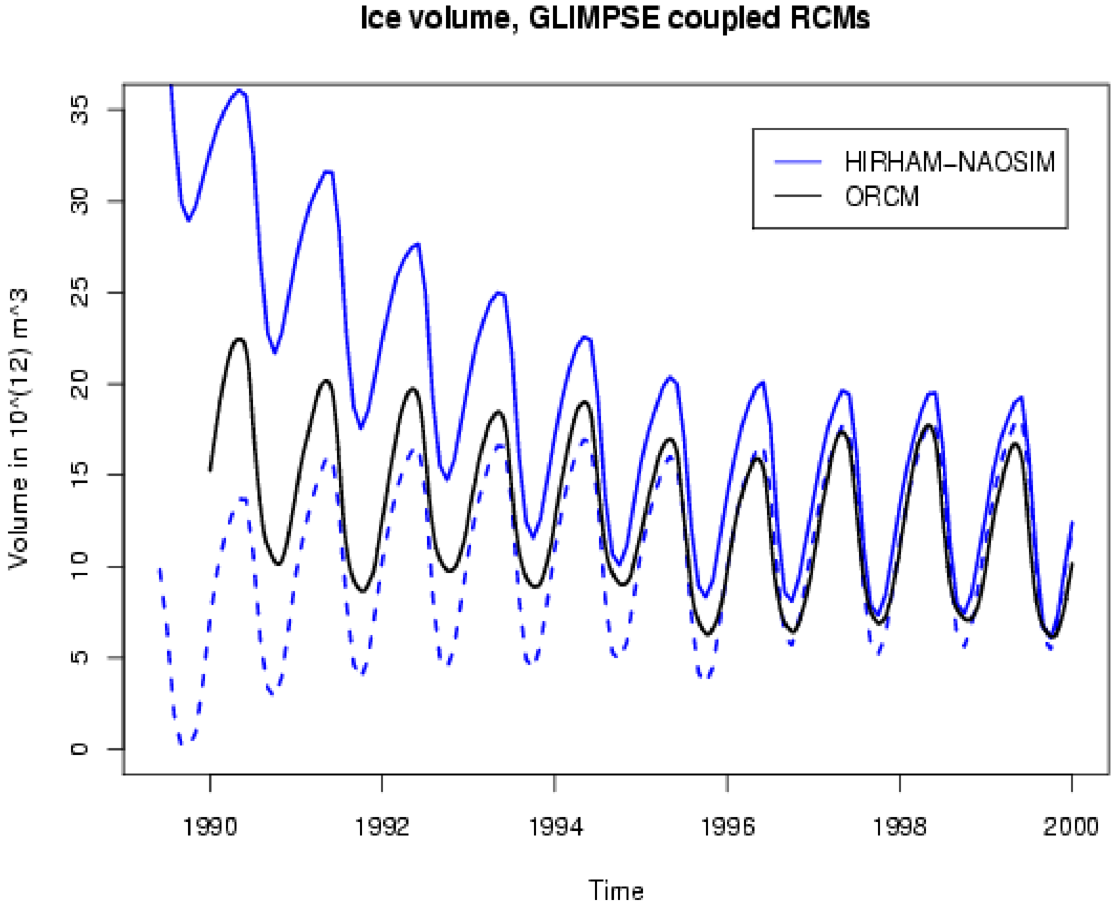
Atmosphere model HIRHAM

- parallelized HIRHAM
- 110×100 grid points
- horizontal resolution 0.5°

Ocean model (MOM +EVP)

- AWI's regional NAOSIM
- 242×169 grid points
- horizontal resolution 0.25°

Total volume of Arctic sea-ice 1989–2000



Blue: two HIRHAM–NAOSIM experiments with different initial sea-ice thickness
(Dorn et al., 2006)

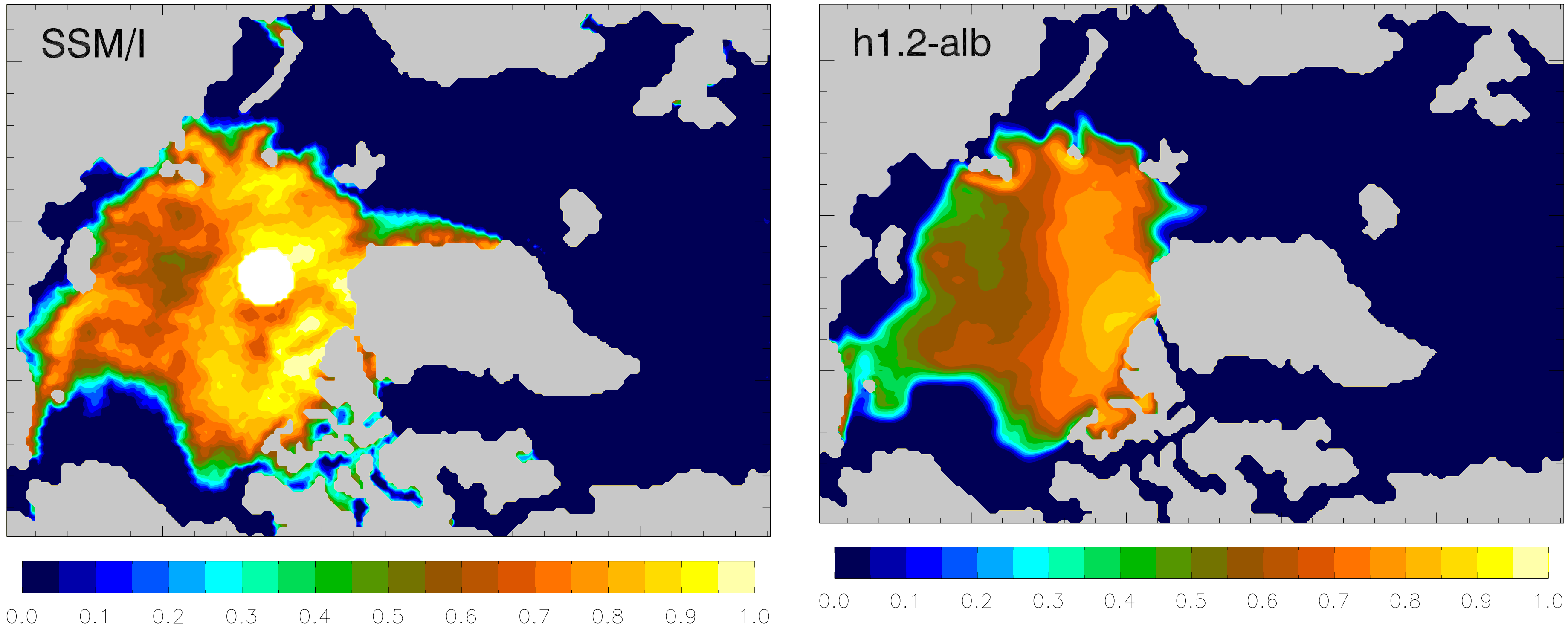
Black: ORCM experiment
(Debernard et al., 2006)

→ **Spin-up of about 6–10 years to reach quasi-stationary ice volume**

→ **Year to year variations in ice volume for HIRHAM–NAOSIM and ORCM shows similar fluctuations (consequence of variability in external atmospheric forcing)**

Sea-ice concentration (Big anomaly of September 1998)

from SSMI and sensitivity simulation with the coupled model HIRHAM-NAOSIM and the new ice albedo scheme



SSMI-Special Sensor Microwave Imager

Dorn et al., JGR 2006, submitted

Sea-ice concentration (Big anomaly of September 1998)

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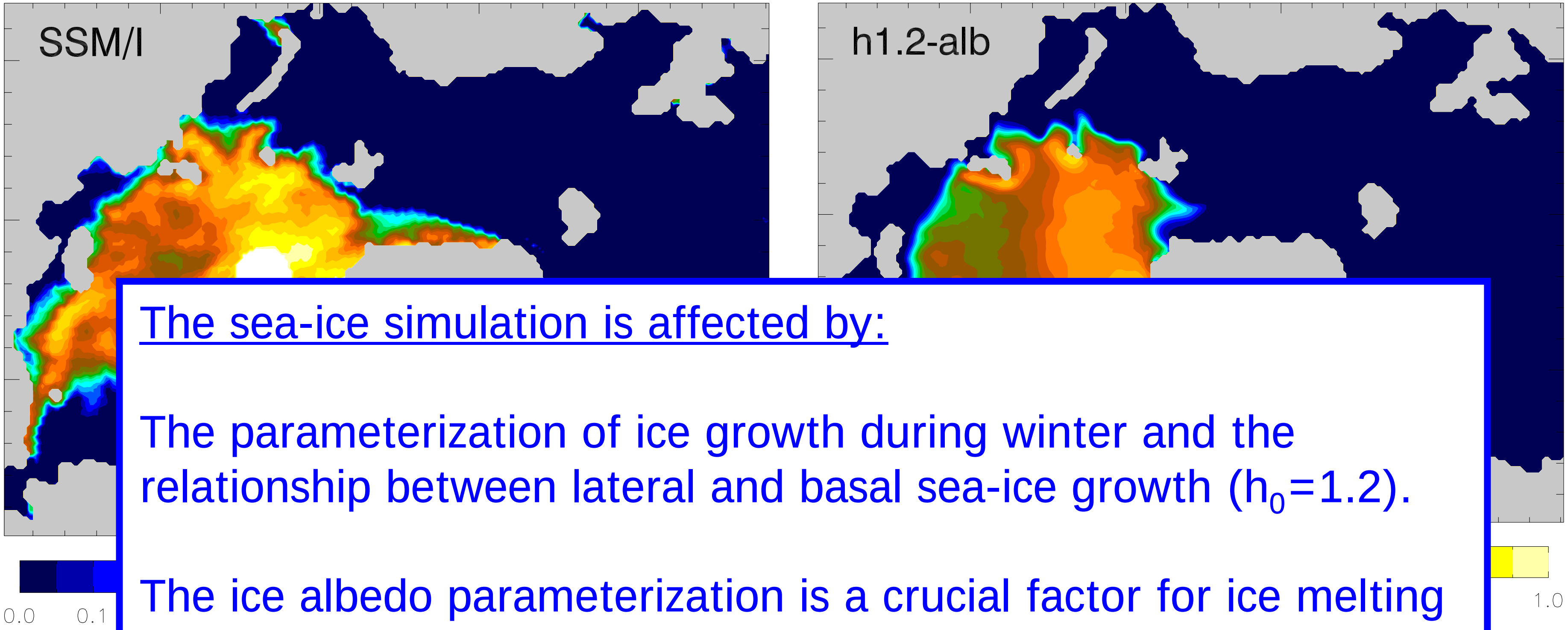


<u>The sea-ice simulation is affected by:</u>

The parameterization of ice growth during winter and the relationship between lateral and basal sea-ice growth (h_0=1.2).

The ice albedo parameterization is a crucial factor for ice melting during summer due to its impact on the energy fluxes via the ice–albedo feedback.

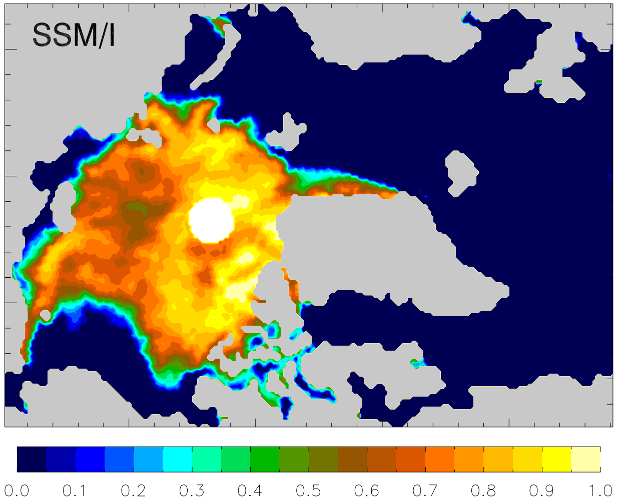
The regional sea-ice distribution during summer is modified by the regional atmospheric circulation and vice versa.

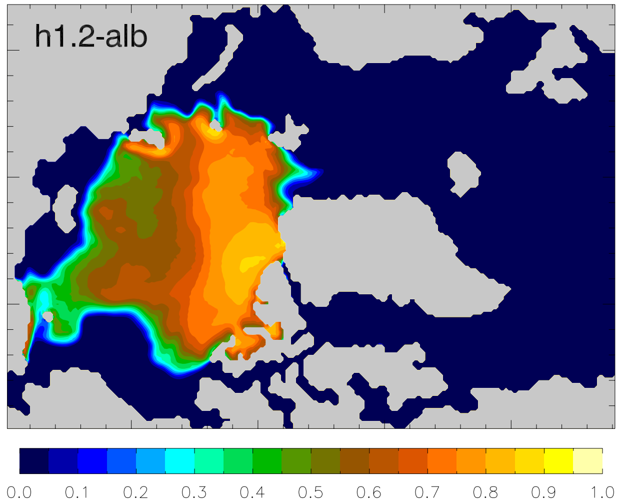
SSMI-Special Sensor Microwave Imager

Dorn et al., JGR 2006, submitted

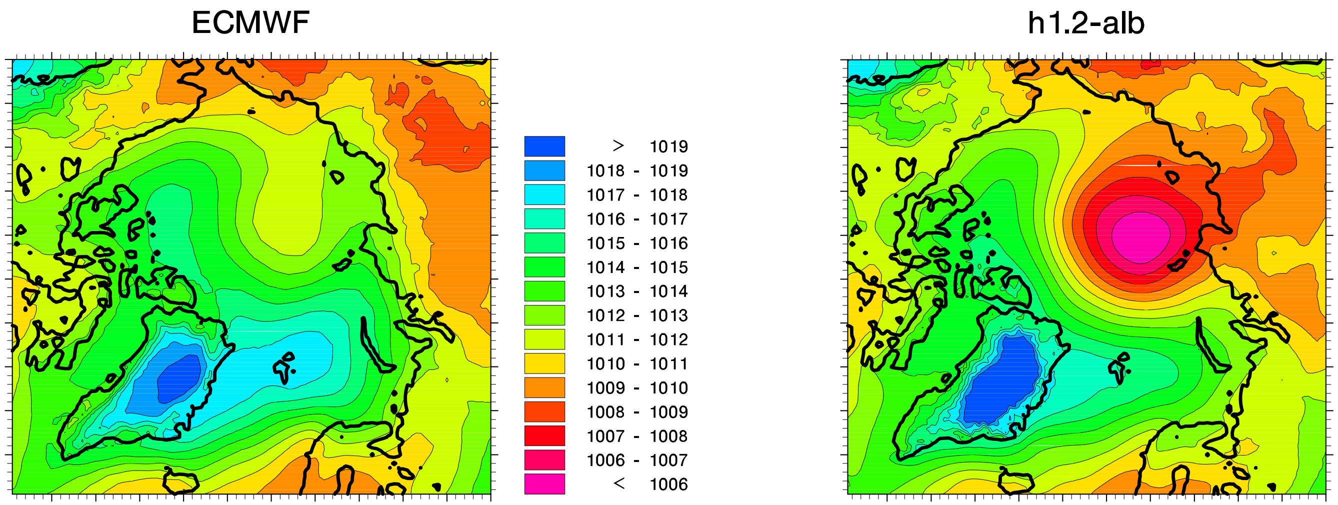
Sea-ice concentration (Big anomaly of September 1998)

from SSMI and two 10 year long simulations with the coupled model using a lead closing parameter of 1.2 and the new ice albedo scheme





Mean sea-level pressure in hPa (June-September 1998)



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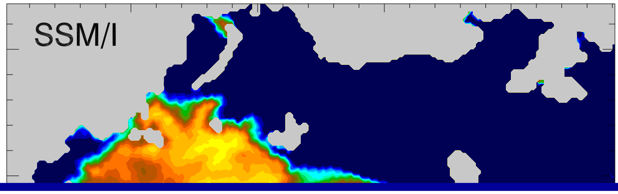
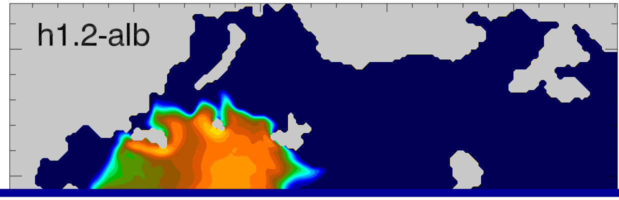


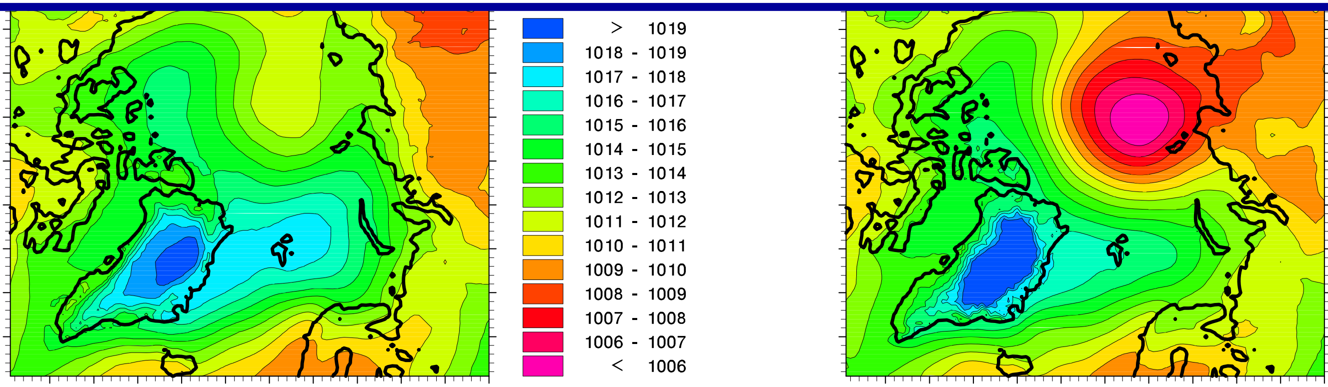


Bias in the cyclonic circulation of the atmosphere over the Kara sea.

Current biases for radiation in the range of 5 W/m² (Summer) and 20 W/m² (Winter) due to the influence of cloud feedbacks.

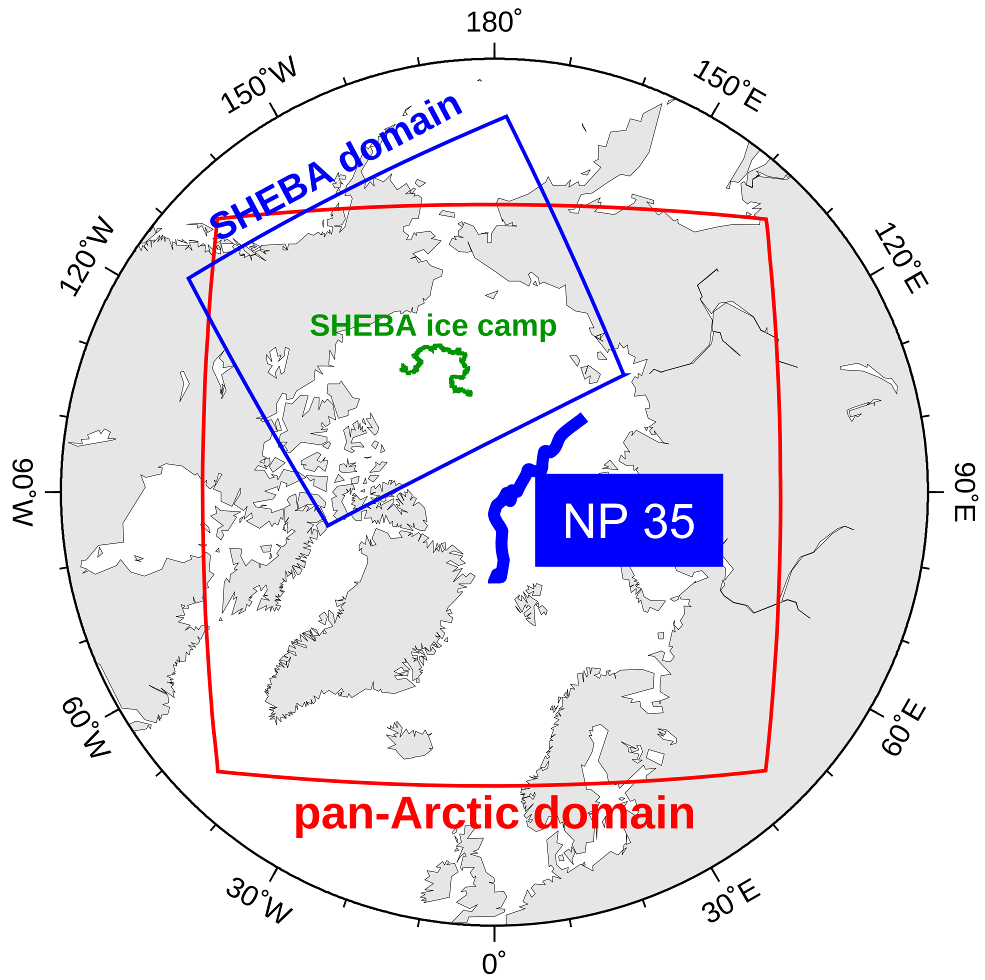
→ Radiative response in CO_2 scenario runs → 2.5 W/m² ?

Strong regional atmospheric-sea-ice feedbacks during summer which are not understood good enough.



SSMI Special Sensor Microwave Imager

NP 35 (August 2007-March2008) “Arctic PBL and synoptic cyclones”
ARCMIP and CARCMIP in the pan-Arctic domain



Measurements on Russian North Pole drifting station NP 35
Comparison against simulations with coupled and uncoupled RCMS

3. Global atmospheric circulation pattern

Global climate simulations with the coupled atmosphere-ocean model ECHO-G

- Atmosphere: ECHAM4/T30/L19 (~ 3.75°, 19 layers)
- Ocean: HOPE-G/T42er/L20 (~ 2.8°, 20 layers)

Zorita et al. (2004)

- Unforced (control) run over 1000 years with fixed solar constant (1365 W/m^2) and CO_2 (353 ppm)

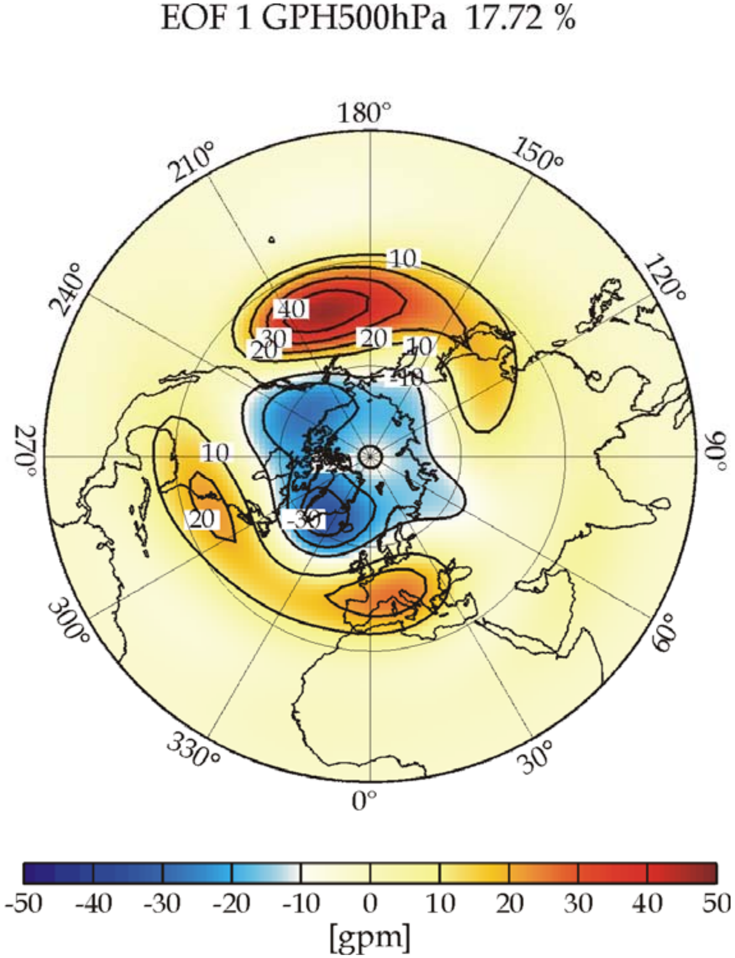
  → climate variations due to internal nonlinear dynamics

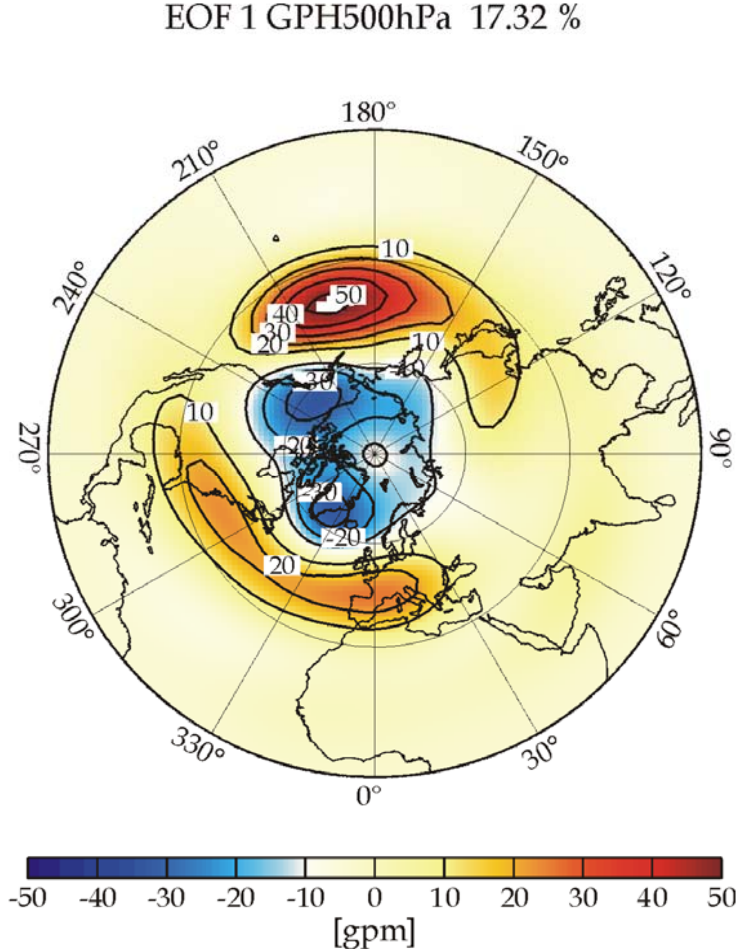
- Forced (historic) run over 500 years with reconstructed variations of solar irradiance, volcanic dust indices, and greenhouse gases

  → climate variations due to changes in external forcing <u>and</u> internal nonlinear dynamics

1000 yr run of ECHO-G with constant external forcing EOF1, 500 hPa, NH, DJF

500 yr run of ECHO-G with time dependent external forcing EOF1, 500 hPa, NH, DJF



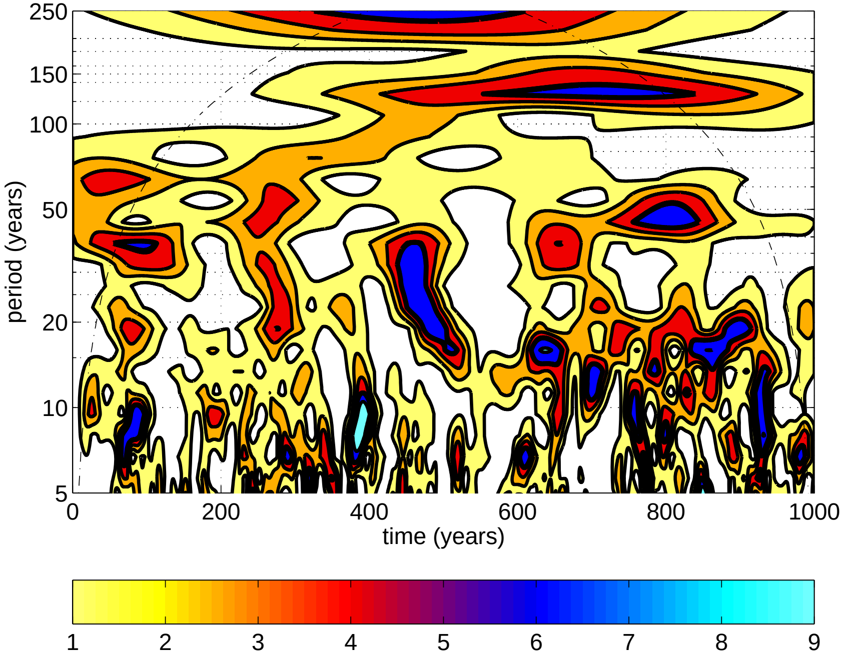


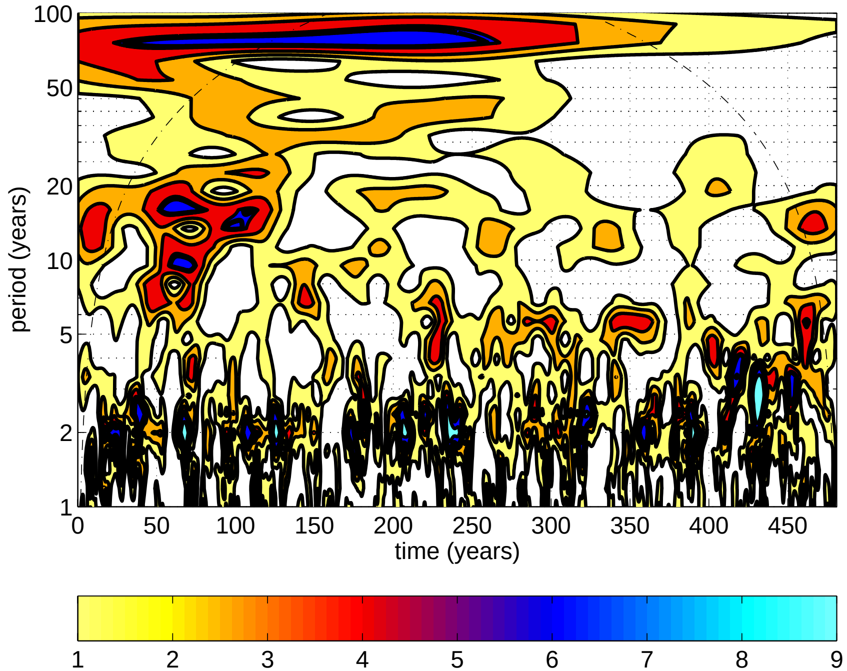
Arctic Oscillation, Strength of Aleutian high increases in the forced run
Projection of GHG & aerosols on natural circulation modes

1000 yr run of ECHO-G
constant external forcing
PC1, 500 hPa, NH, DJF

500 yr run of ECHO-G
time dependent external forcing
PC1, 500 hPa, NH, DJF

Wavelet transform spectra of PC1
Thick contour shows 95 % confidence level
for a corresponding red noise process
Dashed-dotted lines separate regions where
edge effects are important



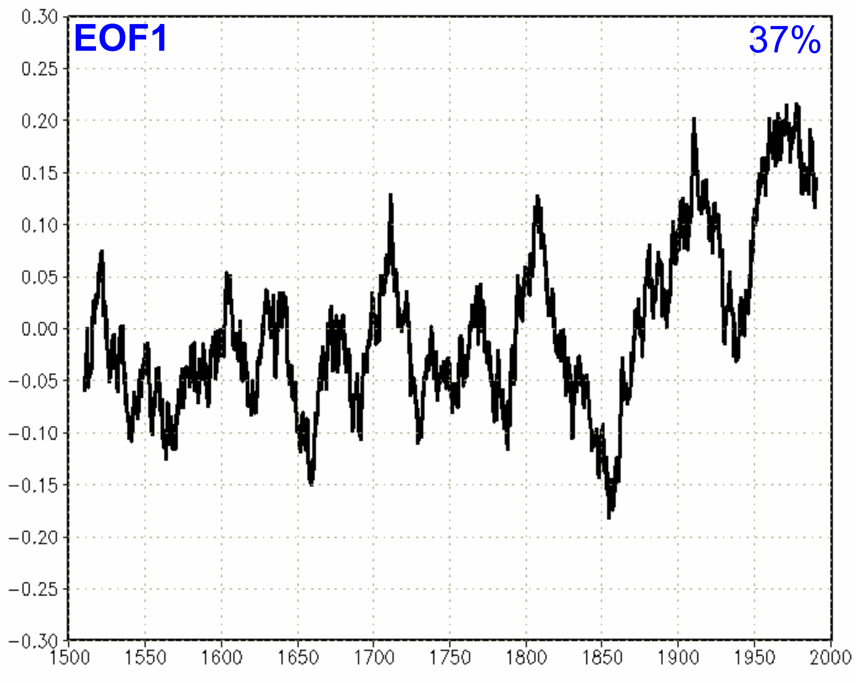


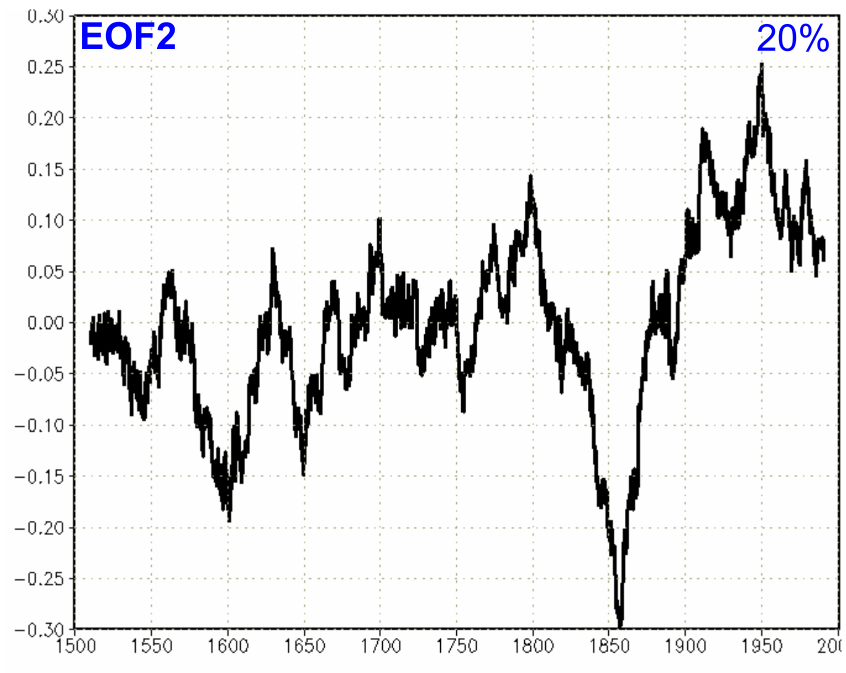
Large amount of energy on decadel time scales

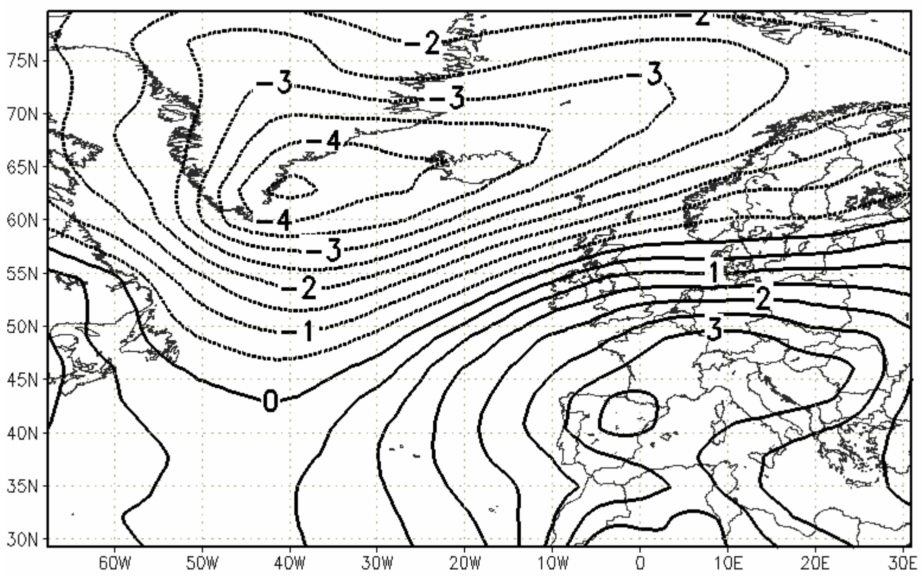
Decadel scale climate changes as a result of nonlinear dynamics,
Coupling of dynamics and external forcing, **Casty, C. et al., 2005**.

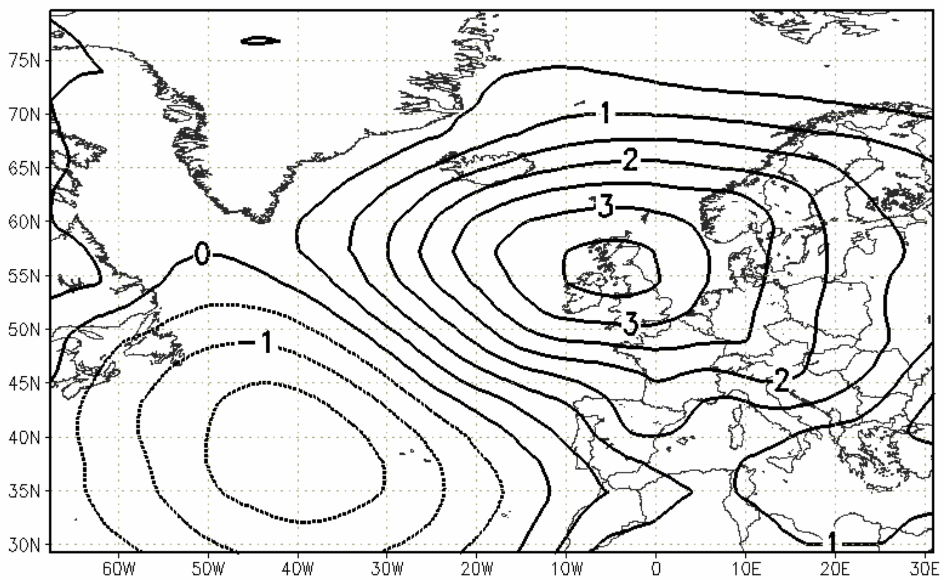
North Atlantic Oscillation in MSLP (hPa)

500 year long simulations with ECHAM4/OPYC, DMI



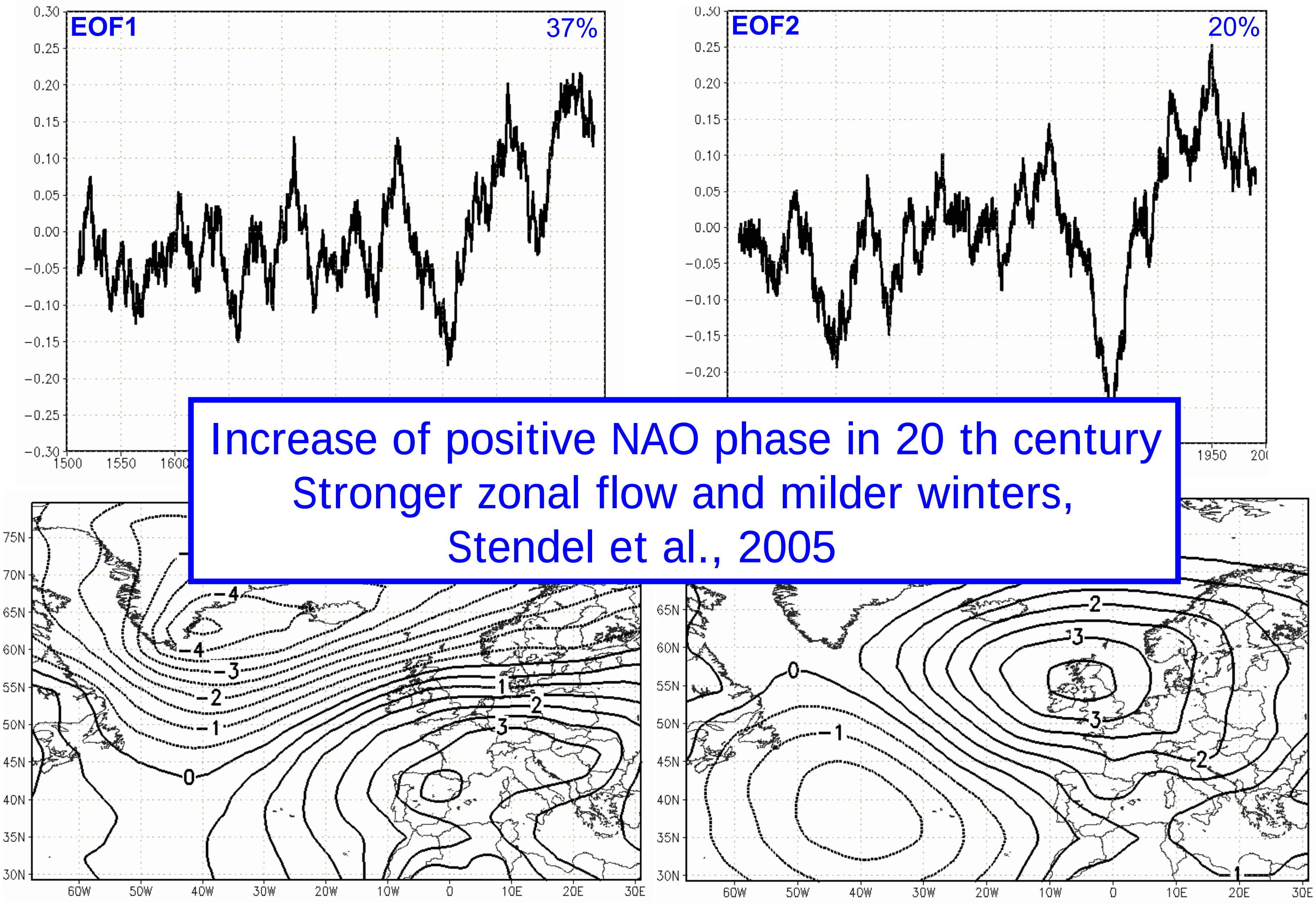






North Atlantic Oscillation in MSLP (hPa)

500 year long simulations with ECHAM4/OPYC, DMI



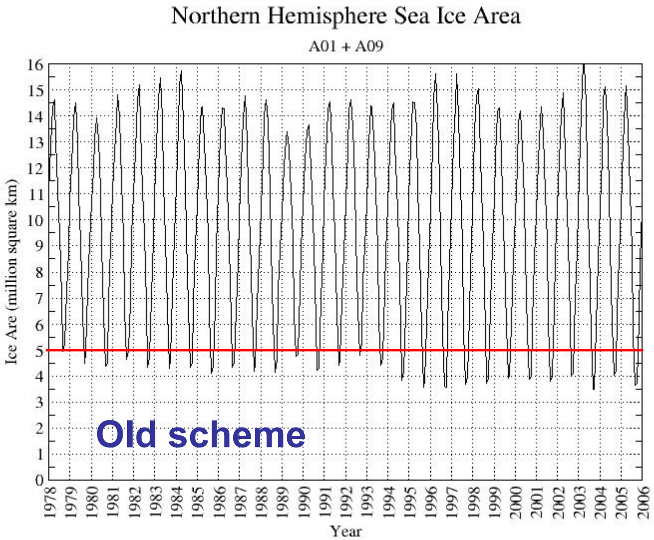
Increase of positive NAO phase in 20 th century
Stronger zonal flow and milder winters,
Stendel et al., 2005

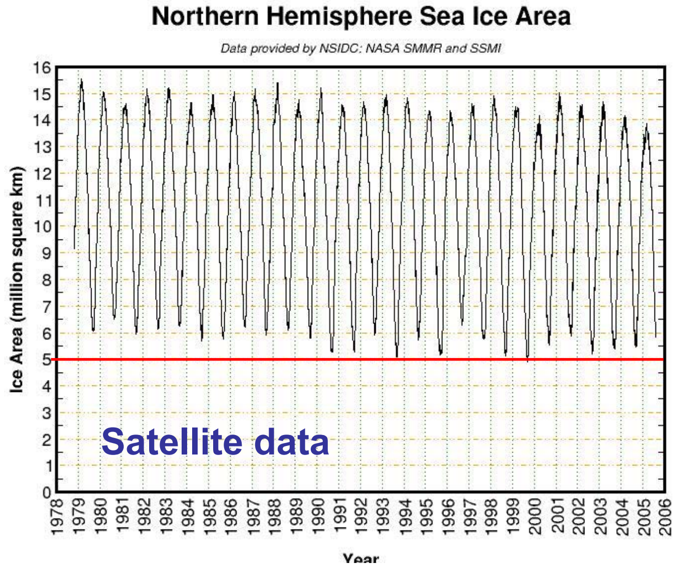
3.1 Global impacts of improved snow and sea-ice albedo parameterization

New snow and ice albedo parameterization in ECHO-G

(= global coupled atmosphere–ocean model ECHAM4/HOPE-G)

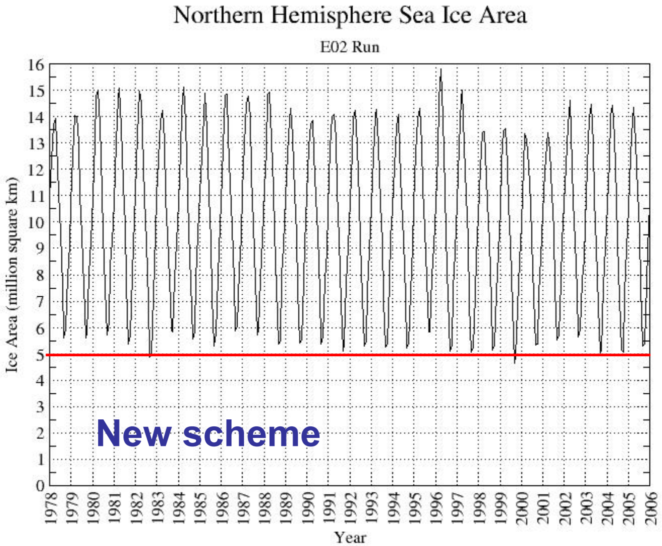
(Benkel et al., 2006)





Arctic (NH) sea-ice area 1978–2005

← Red lines: 5 mill. km^2



→ New albedo scheme improves Arctic sea-ice area and extent during summer (associated with increase in ice volume)

Diagnostic with localized Eliassen-Palm fluxes

Interaction between the time mean state and the transient eddies

$$\frac{D\bar{u}}{Dt} - fv^{*} = \nabla \cdot \vec{E}_u \qquad \frac{D\bar{v}}{Dt} + fu^{*} = \nabla \cdot \vec{E}_v$$

Divergence operator $\nabla = \left[\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{1}{\rho_o}\frac{\partial \rho_o}{\partial z}\right]$

$$\vec{E}_u = \left[\frac{1}{2}\left(\overline{v'^2} - \overline{u'^2}\right), -\overline{u'v'}, f\frac{\overline{v'\phi_z'}}{S}\right] \qquad \vec{E}_v = \left[-\overline{u'v'}, -\frac{1}{2}\left(\overline{v'^2} - \overline{u'^2}\right), -f\frac{\overline{v'\phi_z'}}{S}\right]$$

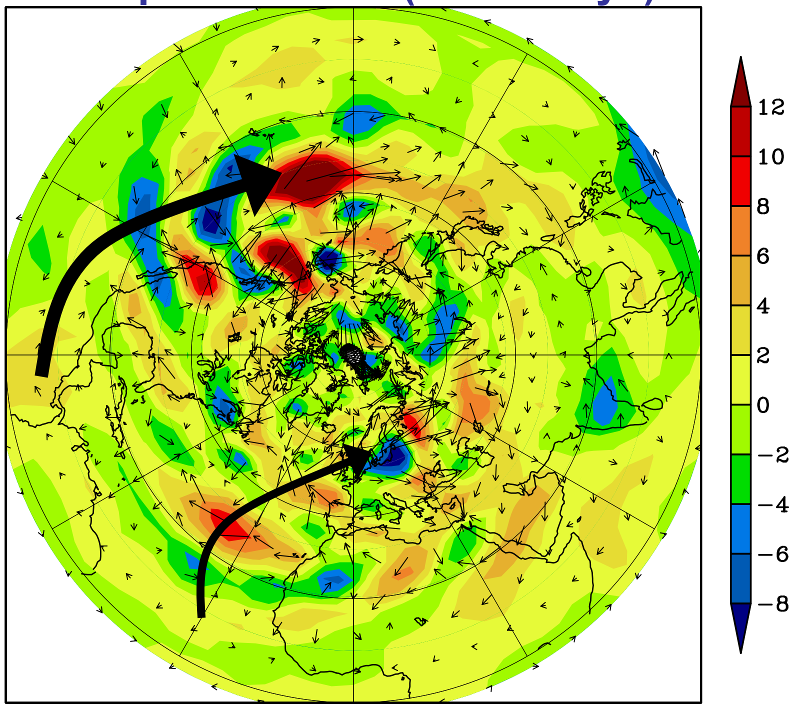
Barotropic component of EP fluxes
→ Decribes the barotropic feedback between the mean state and the transient waves due to momentum fluxes

Baroclinic component of EP fluxes
→ Decribes the baroclinic feedback between the mean state and the transient waves due to heat fluxes

Diagnostic with localized Eliassen-Palm Fluxes (EPF)
(interaction between the time mean state and the transient eddies)
(Sokolova et al., 2006)

EPF difference (m^2s^{-2}) ECHO-G “New albedo minus control run” for 8 years

low-pass filtered (10–90 days)



- **Colors: magnitude of the differences**
- **Arrows: differences in the EP vector propagation**

→ **Changes in the planetary wave trains over the Pacific and the Atlantic**

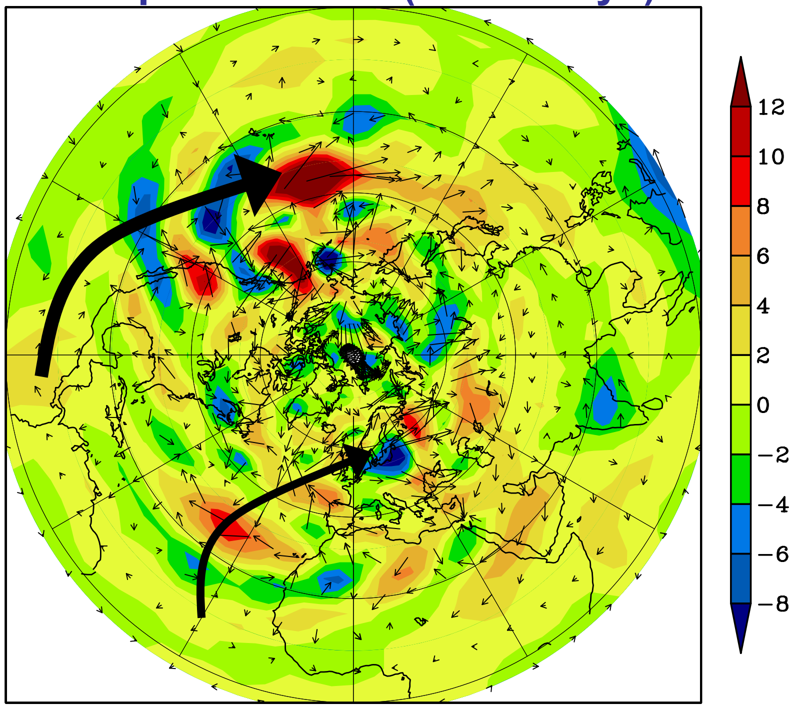
Diagnostic with localized Eliassen-Palm Fluxes (EPF)

(interaction between the time mean state and the transient eddies)

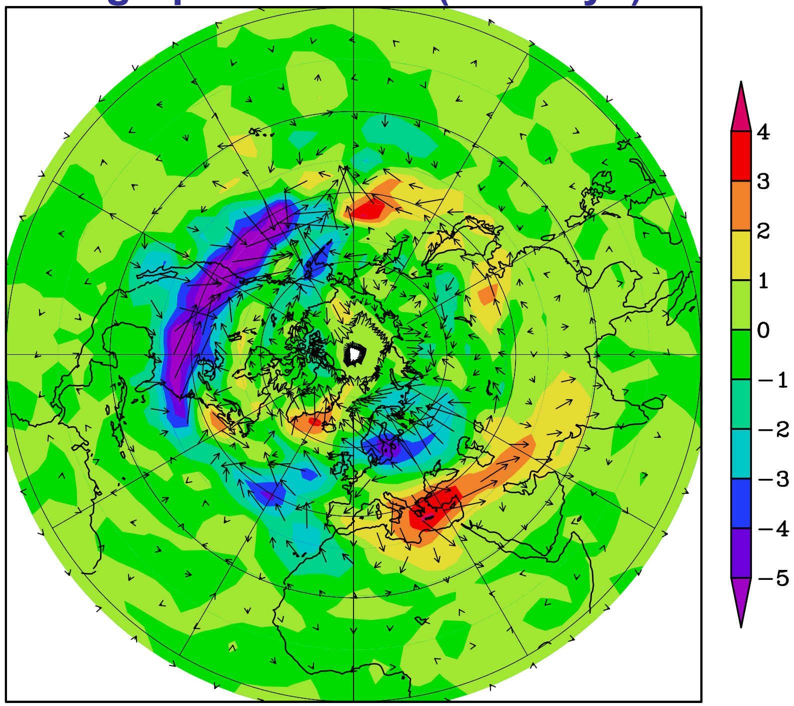
(Sokolova et al., 2006)

EPF difference (m^2s^{-2}) ECHO-G "New albedo minus control run" for 8 years

low-pass filtered (10–90 days)



high-pass filtered (2–6 days)

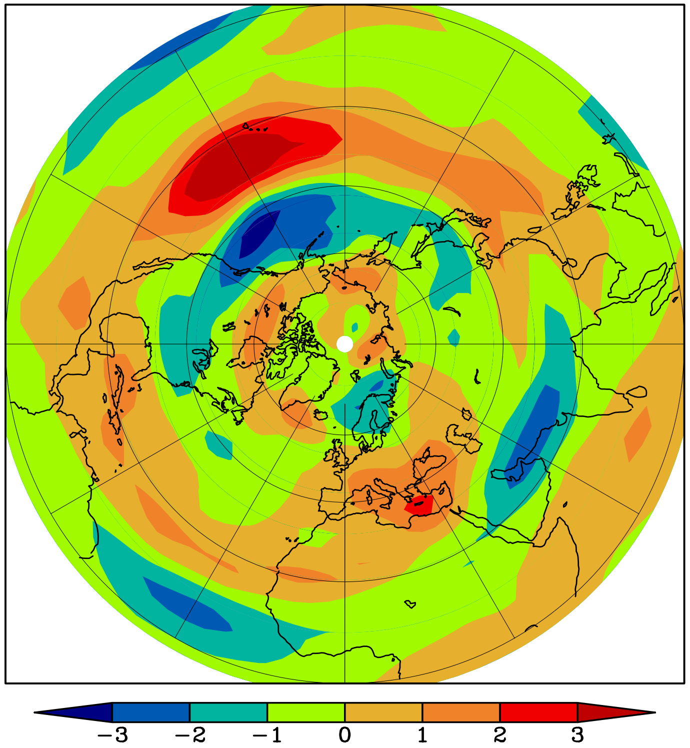


→ **Changes in the planetary wave trains over the Pacific and the Atlantic**

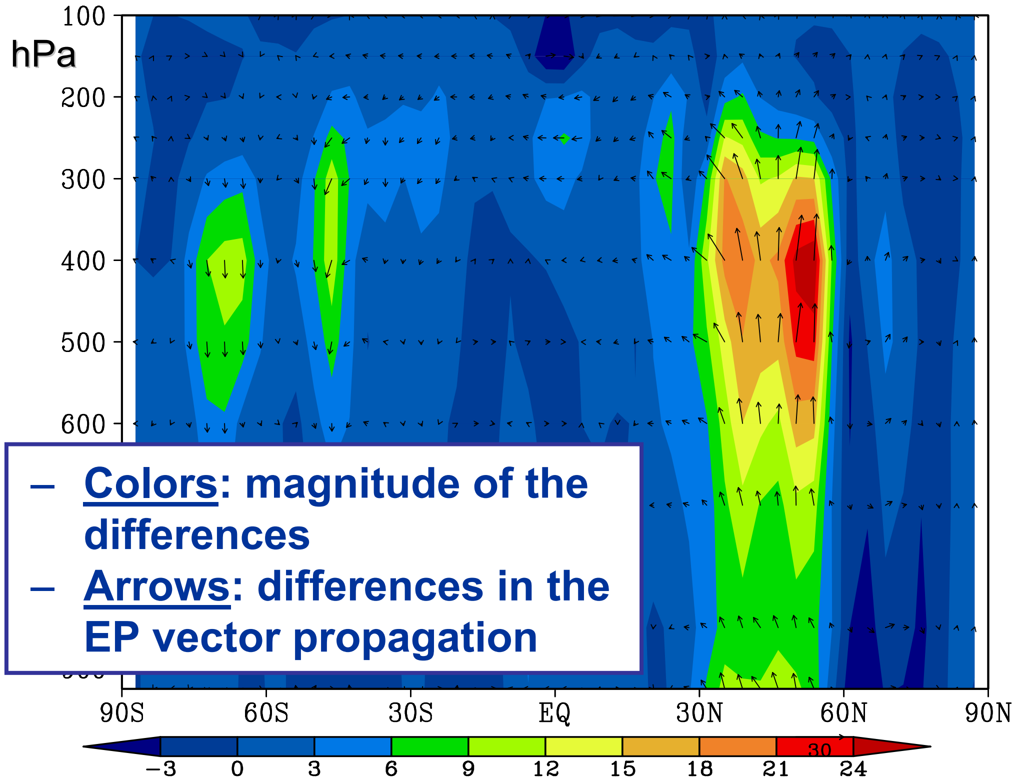
→ **Changes in the storm tracks over North America and Northern Europe**

Zonal wind changes and zonally averaged Eliassen-Palm Fluxes (EPF), (Dethloff et al., GRL 2006)

ECHO-G "New albedo minus control run" for 8 years



Zonal wind differences (ms^{-1})



Zonally averaged EPF differences (10^6 m^3s^{-2}) (10-90 days)

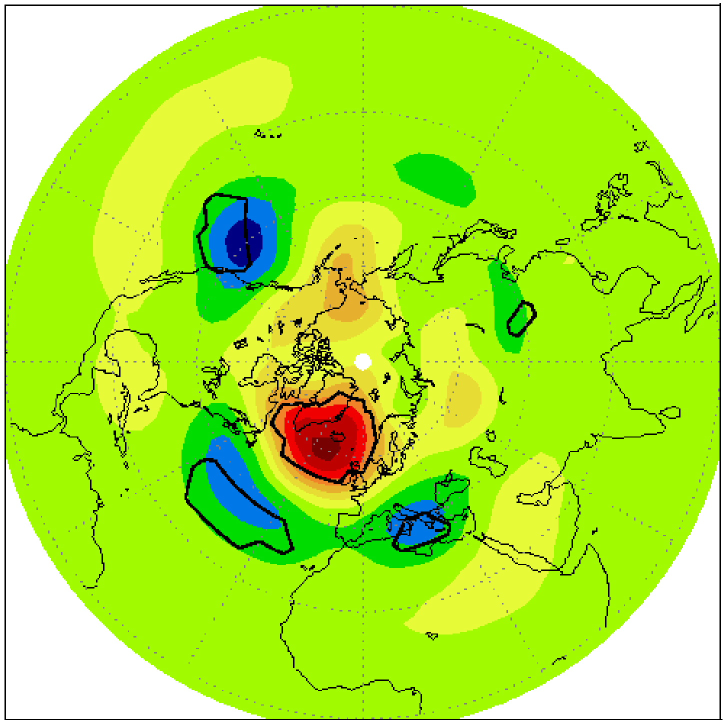
Wave-like wind changes and stronger EP Fluxes on seasonal time scales

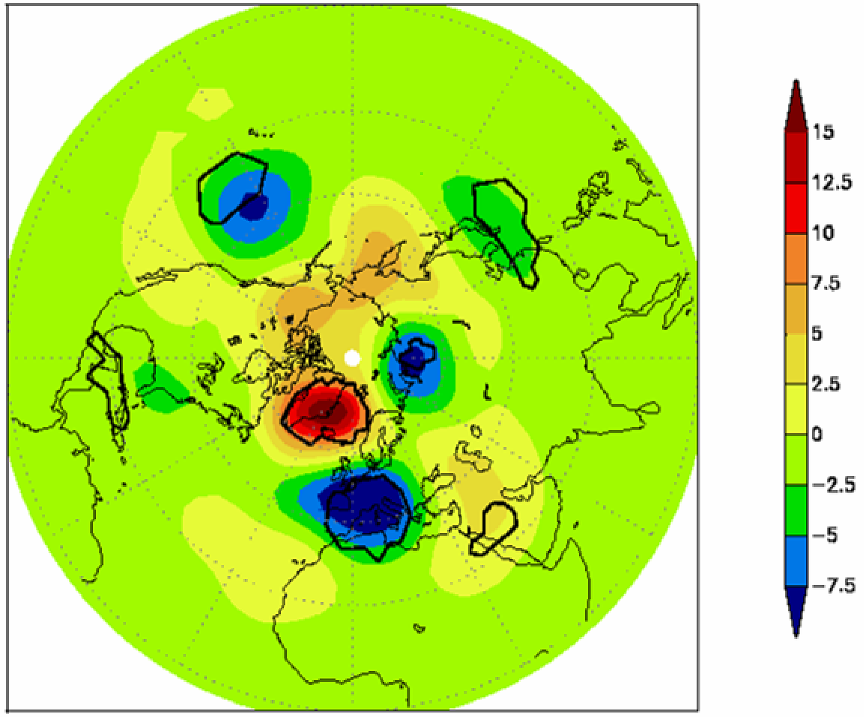
New snow and ice albedo parameterization in ECHO-G

500 hPa geopotential difference (gpm) "New albedo minus control run"
(thick black contours = 95% significance level)

Winter (DJF) diff.

1-250 year run **251-500 year run**





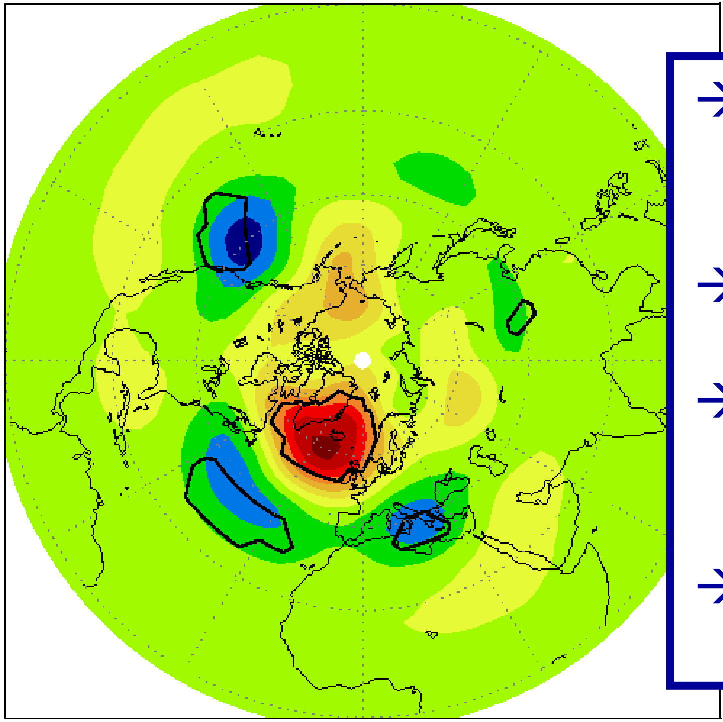
Non-Stationarity of the AO/NAO pattern, (Dethloff et al., 2006)

New snow and ice albedo parameterization in ECHO-G

500 hPa geopotential difference (gpm) "New albedo minus control run"
(thick black contours = 95% significance level)

Winter (DJF) diff.

1-250 year run | **251-500 year run**



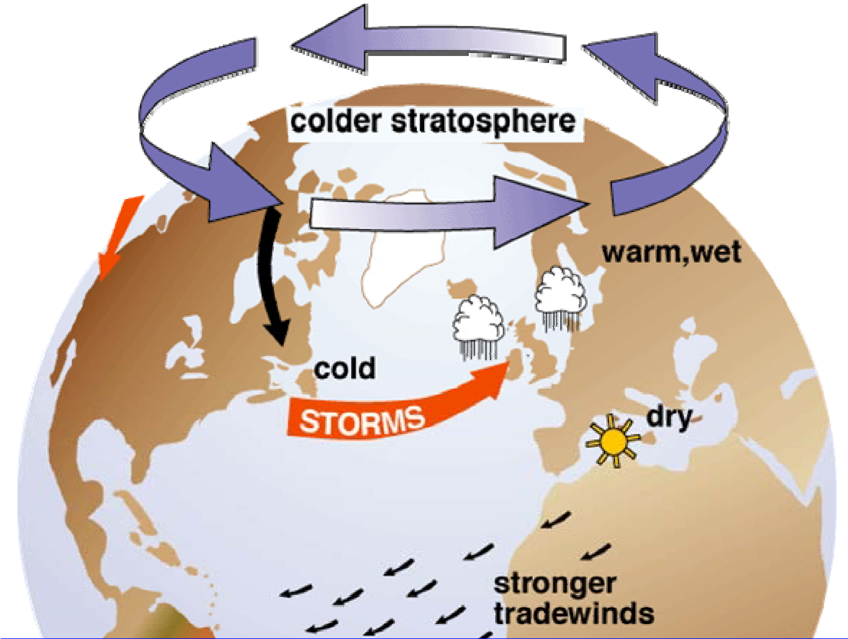
- → **New snow and ice albedo scheme affects global NAO teleconnection pattern**
- → **Increase of negative AO/NAO phases**
- → **Coupled A-O-I modes control climate changes**
- → **Implications for projections of the future climate?**

Non-Stationarity of the AO/NAO pattern, (Dethloff et al., 2006)

3.2 Global impacts of stratospheric ozone chemistry-dynamics

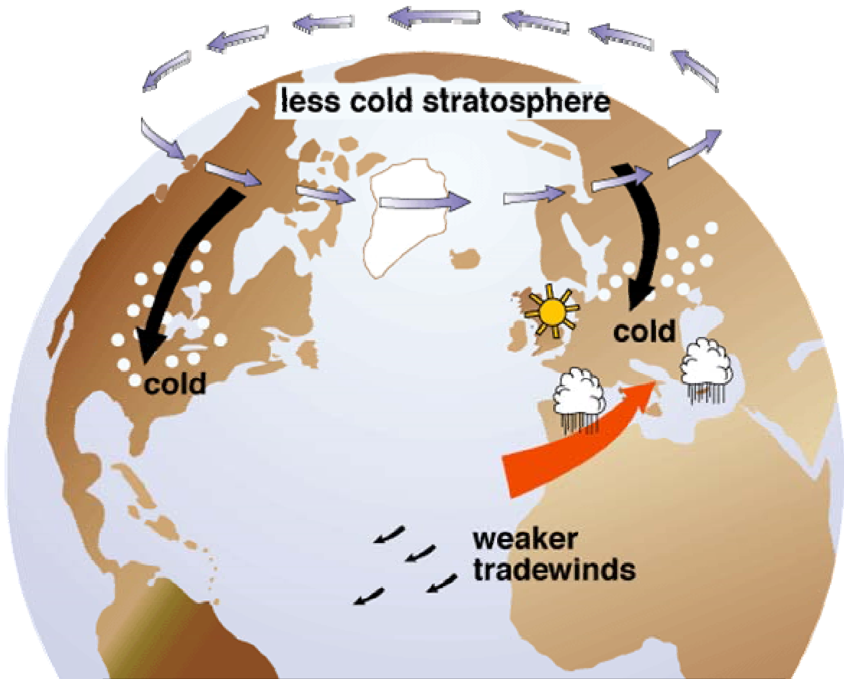
→ Funded by the virtual institute Pole-Equator-Pole
of the German Helmholtz-Association

Phases of the NAO in the stratosphere (Wallace 2000)



Stratosphere colder as usual
→ Enhanced ozone depletion
due to chlorine compounds FCKW
→ Less ozone in the Arctic

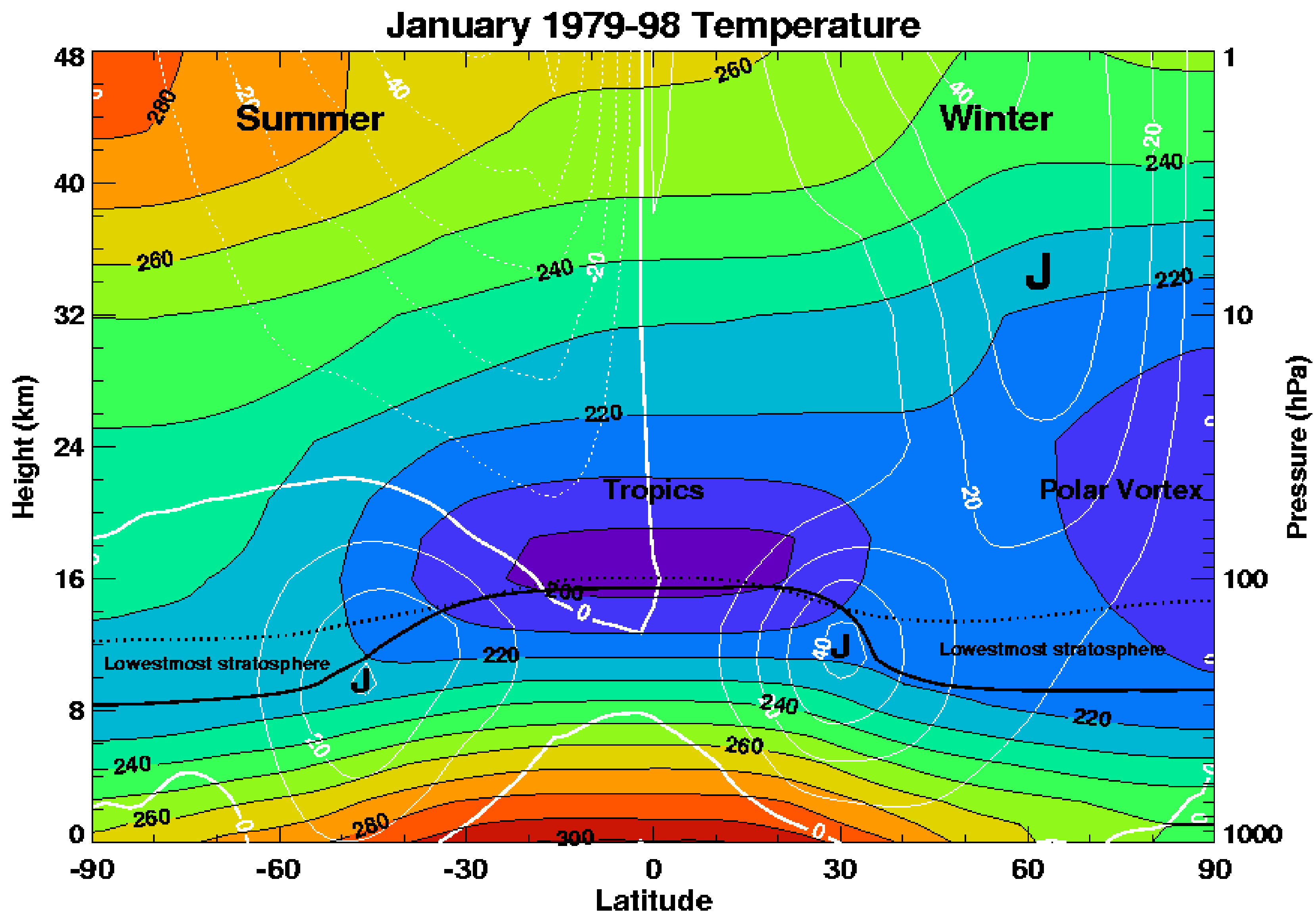
Positive phase
Colder stratosphere



Stratosphere
warmer as usual
→ Reduced ozon depletion
→ More ozone in the Arctic

Negative phase
Warmer (less cold) stratosphere

Wind (m/s) and temperature (K) in the stratosphere



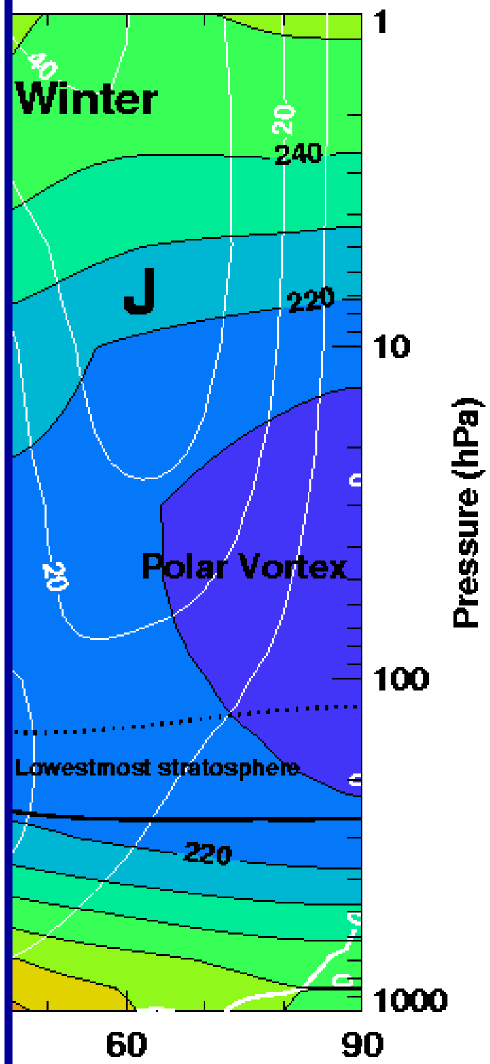
Wind (m/s) and temperature (K) in the stratosphere

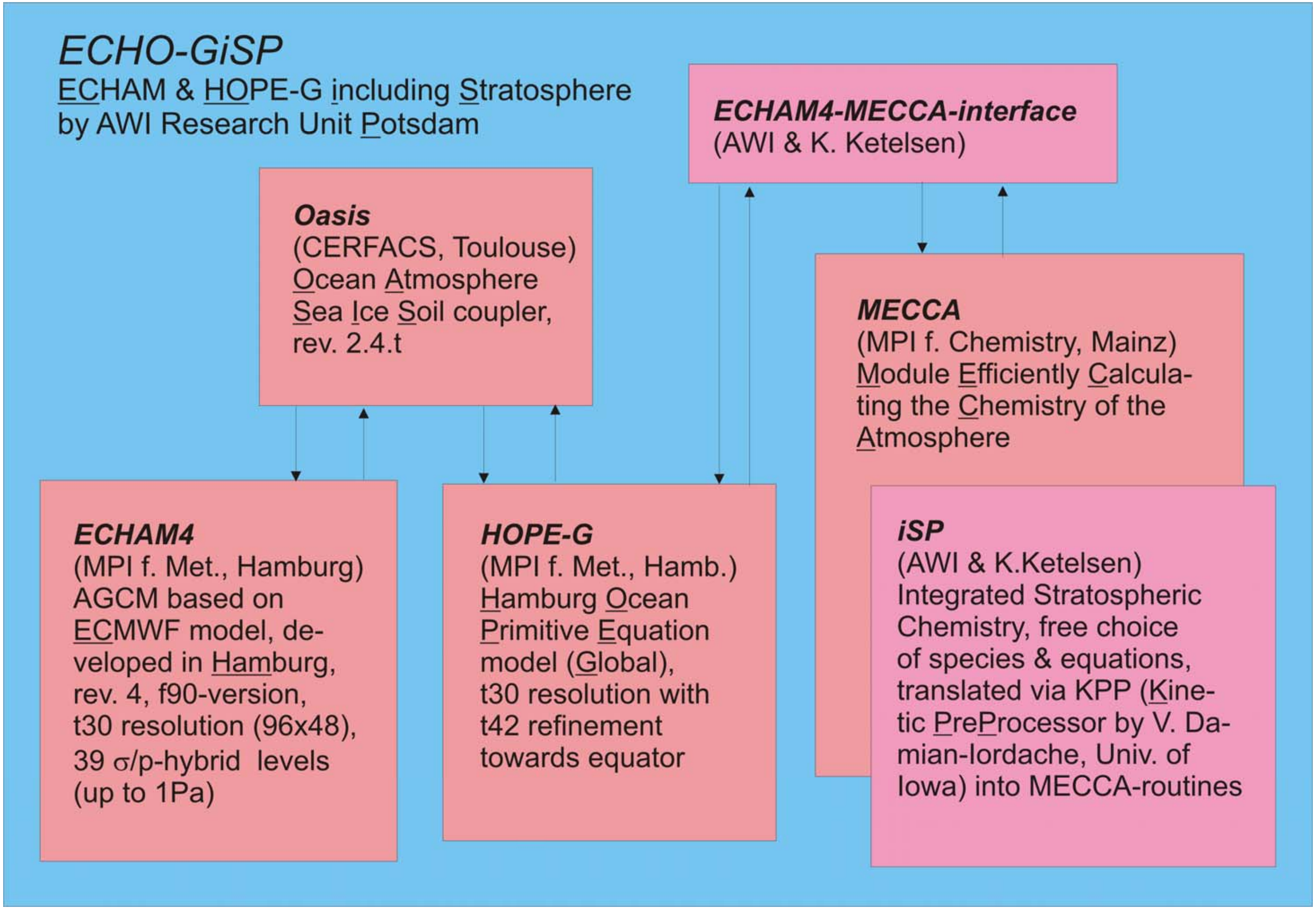
Expected greenhouse warming connected with:

→ Cooling of the polar stratosphere
→ Increased polar vortex with stronger zonal winds
→ Lowered stratospheric temperatures increases ozone depletion in the presence of chlorine compounds (FCKW)

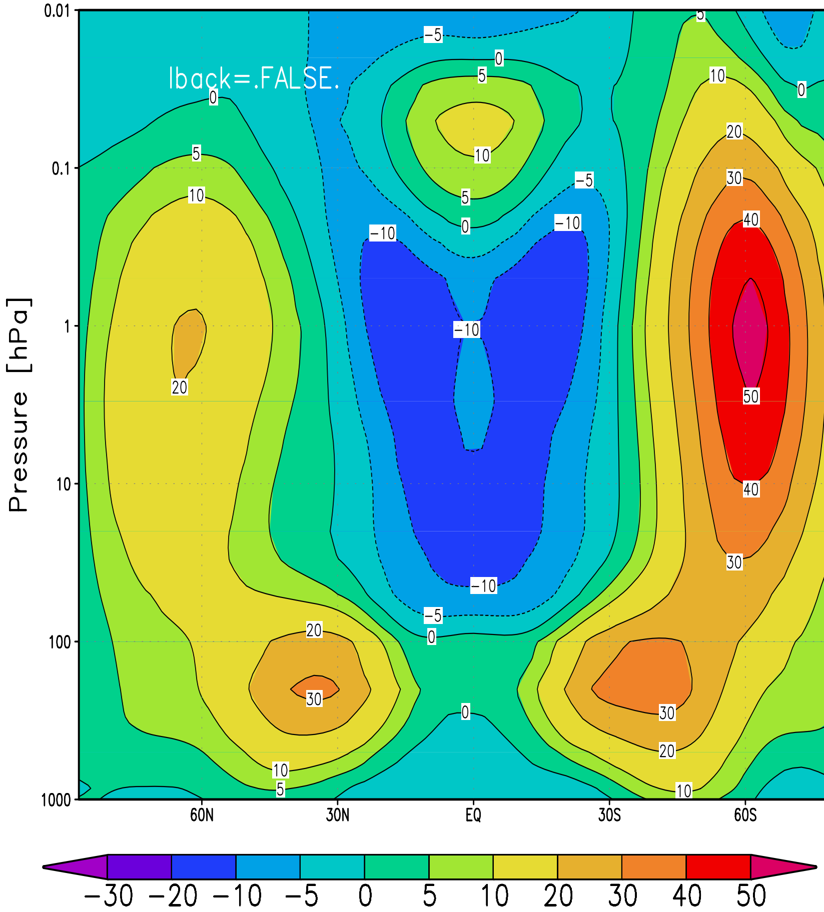
→ Ozone hole of polar stratosphere

→ Tropo-stratospheric feedback changes
→ Influence on AO?

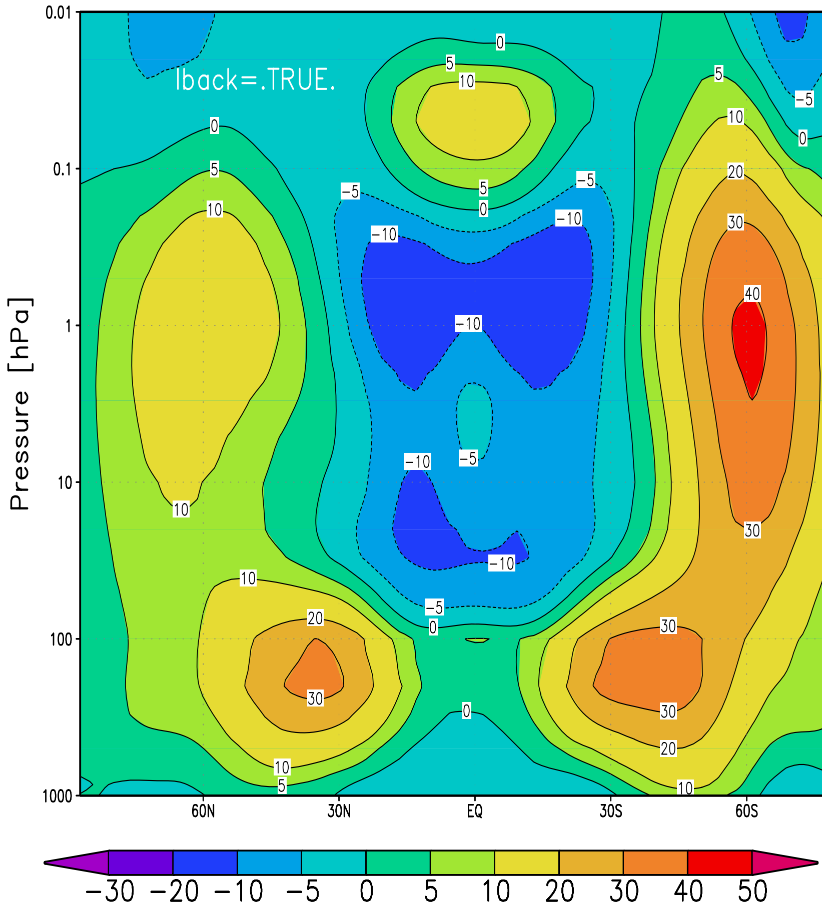



ECHO-GiSP
ECHAM & HOPE-G including Stratosphere
by AWI Research Unit Potsdam
ECHAM4-MECCA-interface
(AWI & K. Ketelsen)
Oasis
(CERFACS, Toulouse)
Ocean Atmosphere
Sea Ice Soil coupler,
rev. 2.4.t
MECCA
(MPI f. Chemistry, Mainz)
Module Efficiently Calcula-
ting the Chemistry of the
Atmosphere
ECHAM4
(MPI f. Met., Hamburg)
AGCM based on
ECMWF model, de-
veloped in Hamburg,
rev. 4, f90-version,
t30 resolution (96x48),
39 σ/p-hybrid levels
(up to 1Pa)
HOPE-G
(MPI f. Met., Hamb.)
Hamburg Ocean
Primitive Equation
model (Global),
t30 resolution with
t42 refinement
towards equator
iSP
(AWI & K.Ketelsen)
Integrated Stratospheric
Chemistry, free choice
of species & equations,
translated via KPP (Kine-
tic PreProcessor by V. Da-
mian-Iordache, Univ. of
Iowa) into MECCA-routines

Zonal wind (m/s) mean of years 11-25



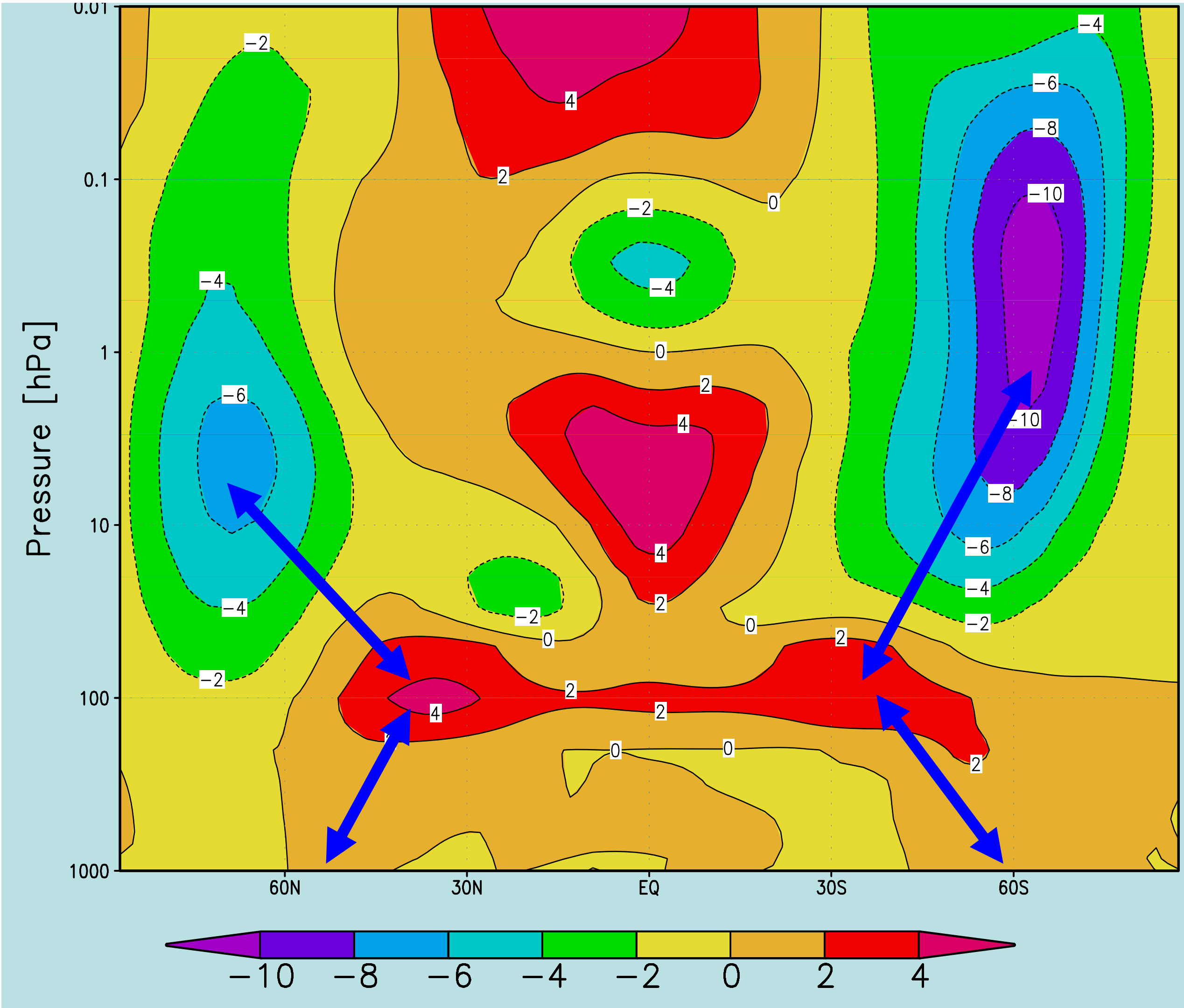
ECHO-GiSP
interactive Stratosphere, Potsdam
with prescribed Ozone (AWI Potsdam)



ECHO-GiSP with interactive Stratospheric Ozone chemistry (AWI Potsdam)

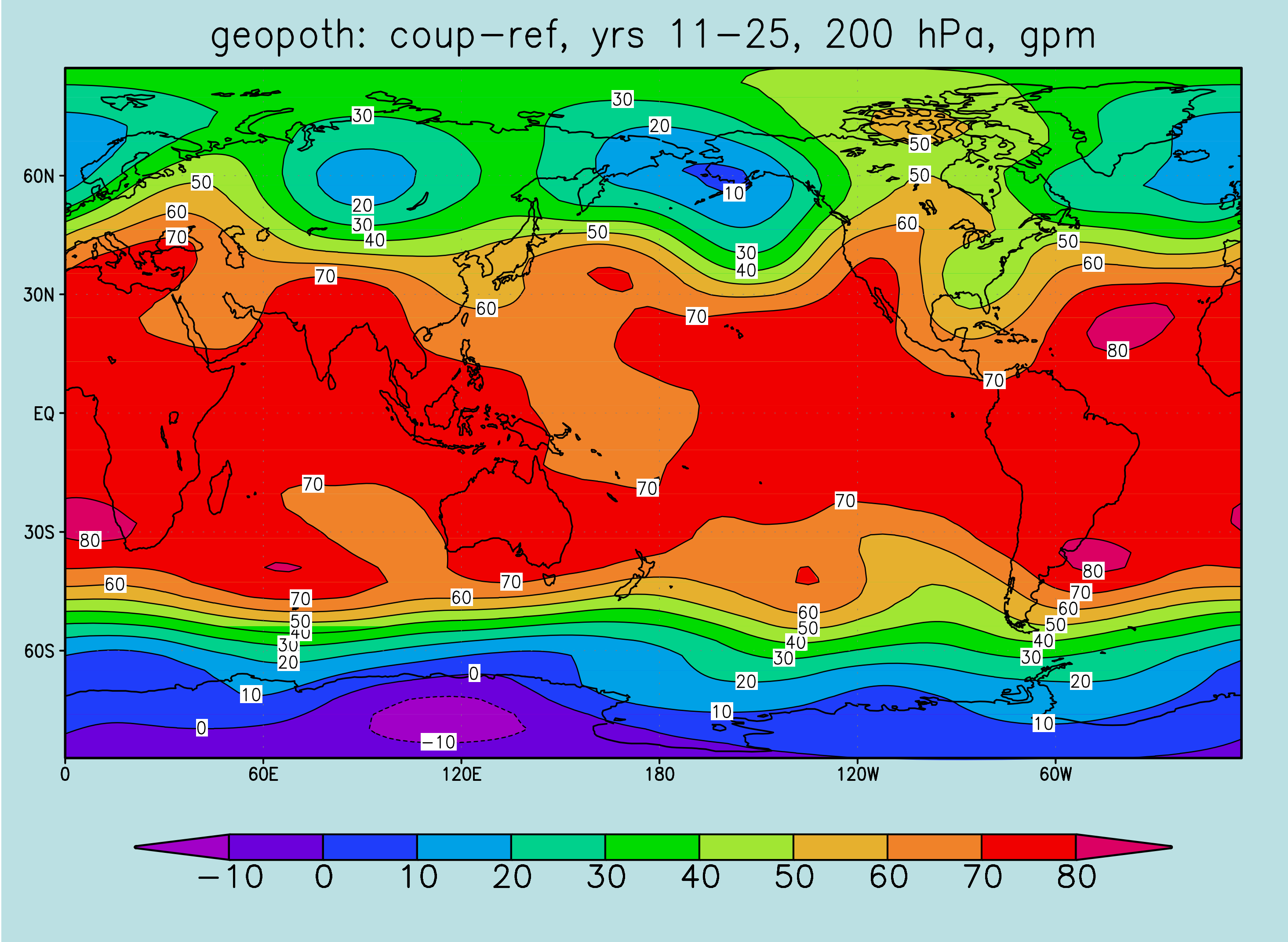
Brand et al., 2006, in preparation

Zonal wind differences (m/s) due to stratospheric Dynamic-Radiation-Chemistry feedbacks



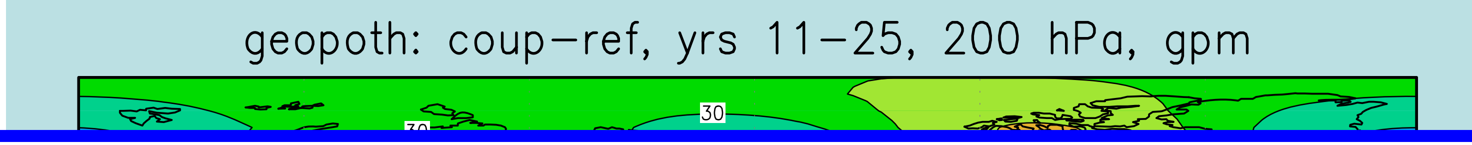
Wind changes in mid-latitudes during winter
tropo-stratospheric coupling → Asymmetries between NH and SH

Geopotential height differences (gpm) on 200 hPa



Geopotential and planetary wave changes in mid-latitudes during winter
→ vertical (Tropo-Strato) and meridional (Tropics-Polar) coupling

Geopotential height differences (gpm) on 200 hPa



Preliminary results:

→ Planetary wave activity in mid-latitudes enhanced in interactive AOGCM with stratospheric chemistry

→ Zonalwind reduction and planetary wave increase

→ Shift to a negative AO phase in the stratosphere?

→ Would warm the stratosphere and reduce ozone hole?

Geopotential and planetary wave changes in mid-latitudes during winter
→ vertical (Tropo-Strato) and meridional (Tropics-Polar) coupling

4. Origin of circulation regimes and decadel variability

Objectives

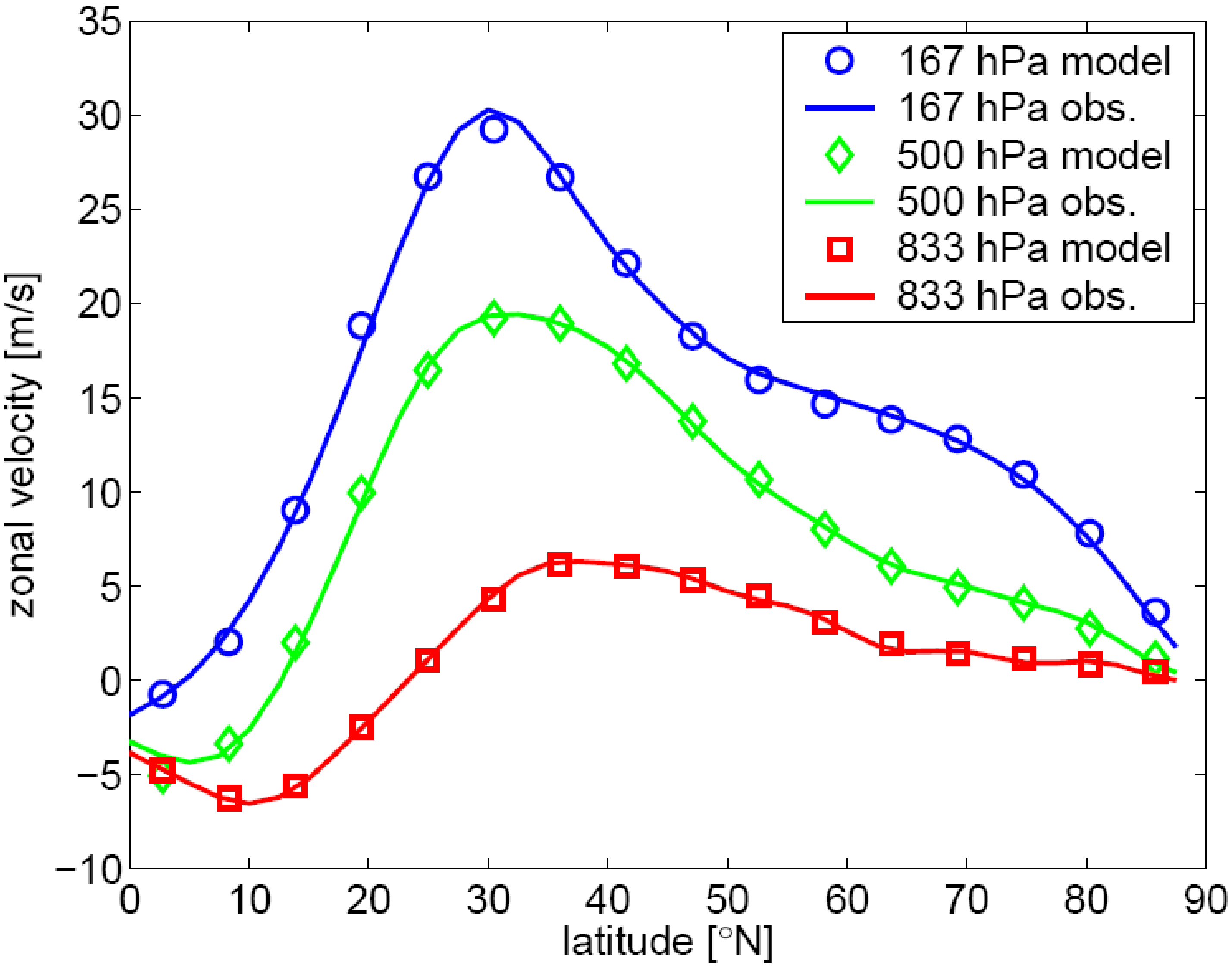
1. Reality-near model simulations of the climate state, its variability and regime behaviour of the atmospheric circulation

2. Understanding the origin of atmospheric regime behaviour and testing hypothesis

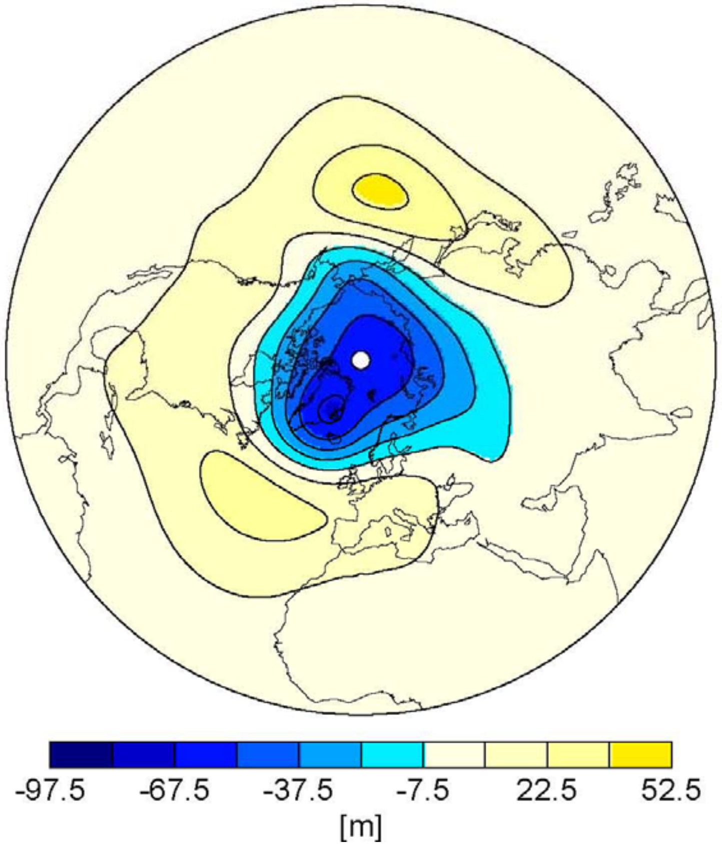
Requirements for the model:
Complex enough for topic 1, idealised enough for topic 2

→ **quasi-geostrophic three-layer model of the atmosphere**
T21 spectral model, 1000 year long simulations

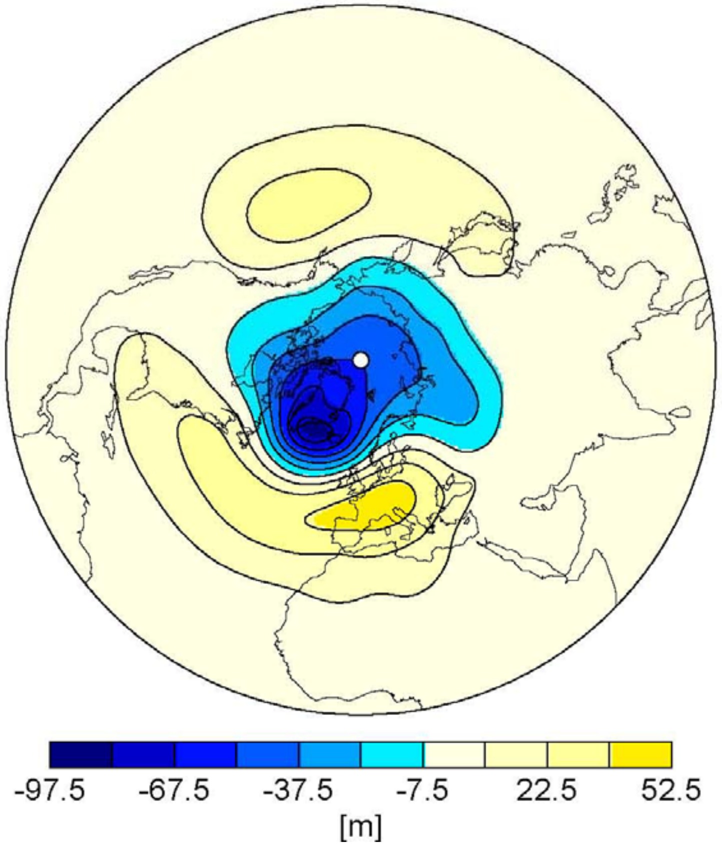
zonal wind profiles



First EOF of 833 hPa geopotential height: Arctic Oscillation



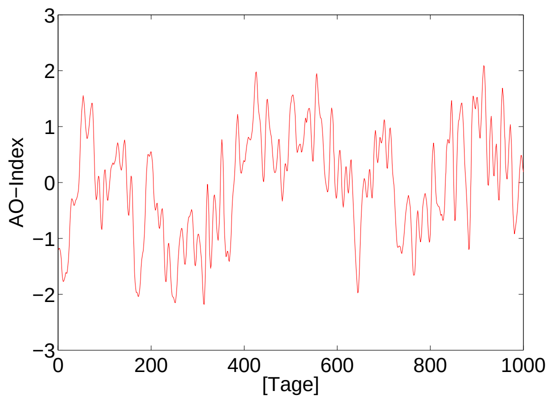
Model
simulations over 1000 years



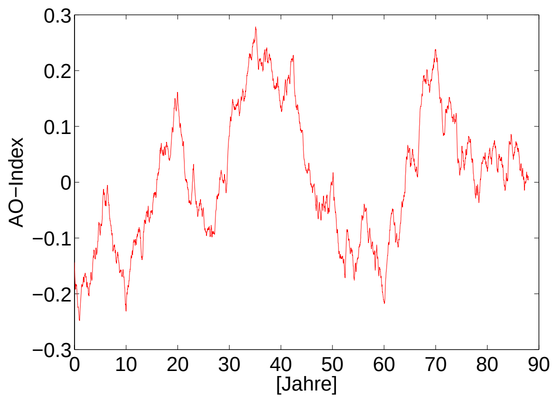
NCEP-Reanalysis data,
Mean over the lower level

AO-Index in a three-layer model

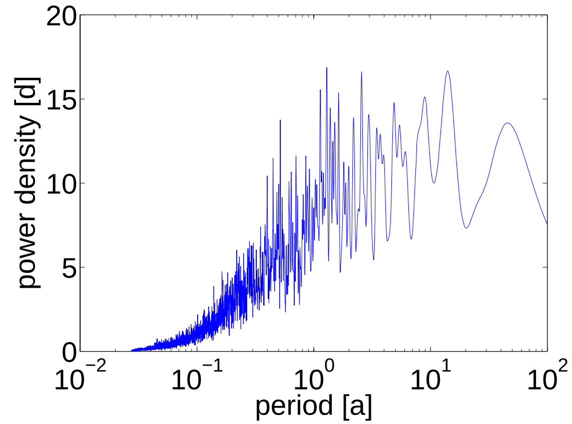
Daily AO-Index



10-year averaging mean



Power density spectrum
of AO index
1000-year simulations
constant external forcing



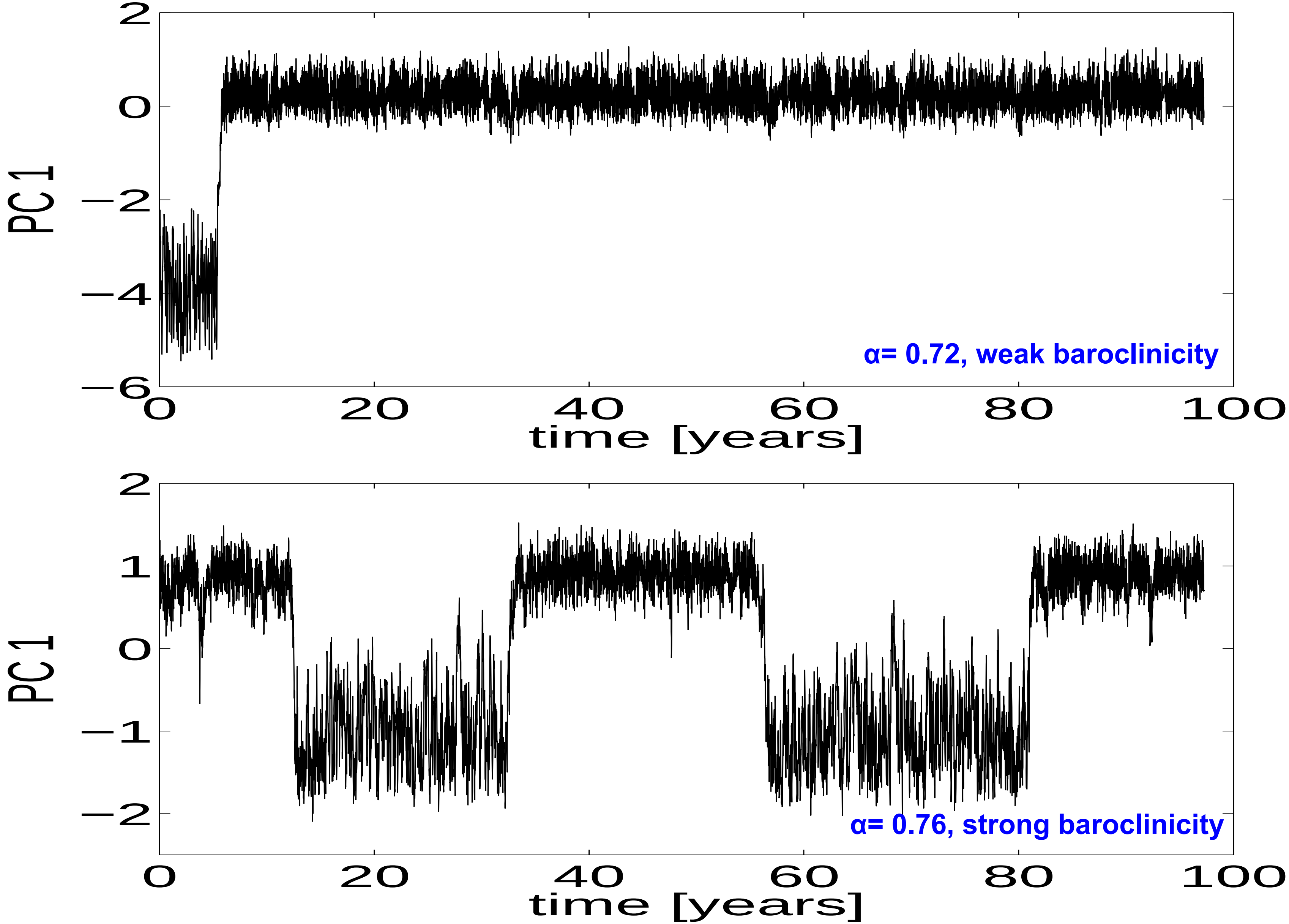
Decadel variations are due to the internal nonlinear dynamics of the model atmosphere!

Sempf et al., J. Atmos. Sci. 2006

PC1 time series of 833 hPa geopotential (normalised)

→ Sign corresponds to AO+ and AO-, two 100 year integrations

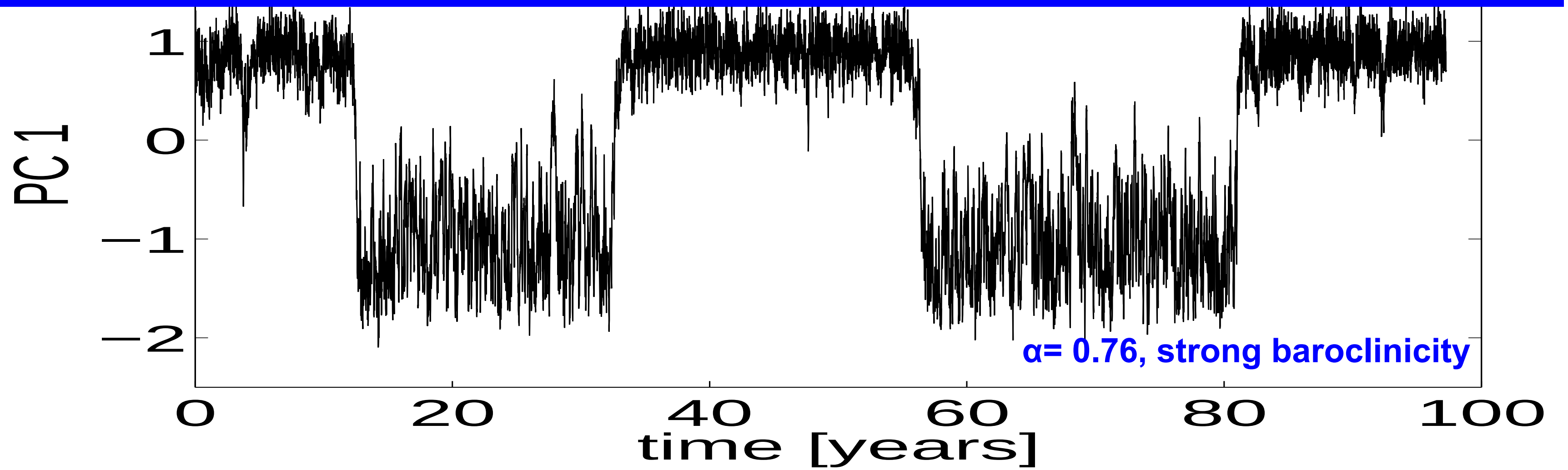
with a lower and a higher value for baroclinicity, α= 0.72 (top) and α= 0.76 (bottom)



PC1 time series of 833 hPa geopotential (normalised)
→ Sign corresponds to AO+ and AO-, two 100 year integrations
with a lower and a higher value for baroclinicity, α= 0.72 (top) and α= 0.76 (bottom)

Friction processes, PBL parameterizations and ratio between baroclinicity/barotropicity of atmospheric processes determines residence times in AO regimes

Changes in the residence times of regimes, high- and low-index regimes (AO+, AO-)
→ implications for climate change scenarios
→ paleoclimatic changes!



5. Summary and outlook

Feedbacks and parameterizations are key processes in the climate system and poorly understood

- → Decadel-scale climate variations are a result of nonlinear atmospheric dynamics and complex A-O-I feedbacks
- → Snow- and Sea-Ice albedo and stratospheric feedbacks trigger negative AO phases; GHG: positive AO phases
- → Improved understanding of feedbacks between natural and external/anthropogenic forcing factors needed.
- → Could deliver more reliable climate projections

To reduce uncertainties

- → Large-scale synoptic studies of Arctic key processes
- → Improved description of sea-ice dynamics, permafrost, PBL and cloud schemes and regional A-O-I feedbacks
- → Importance of IPY 2007- 08, Pan-Arctic coordination
- → Improved model formulation ARCMIP, CARCMIP
- → Synthesis of regional and global models & data

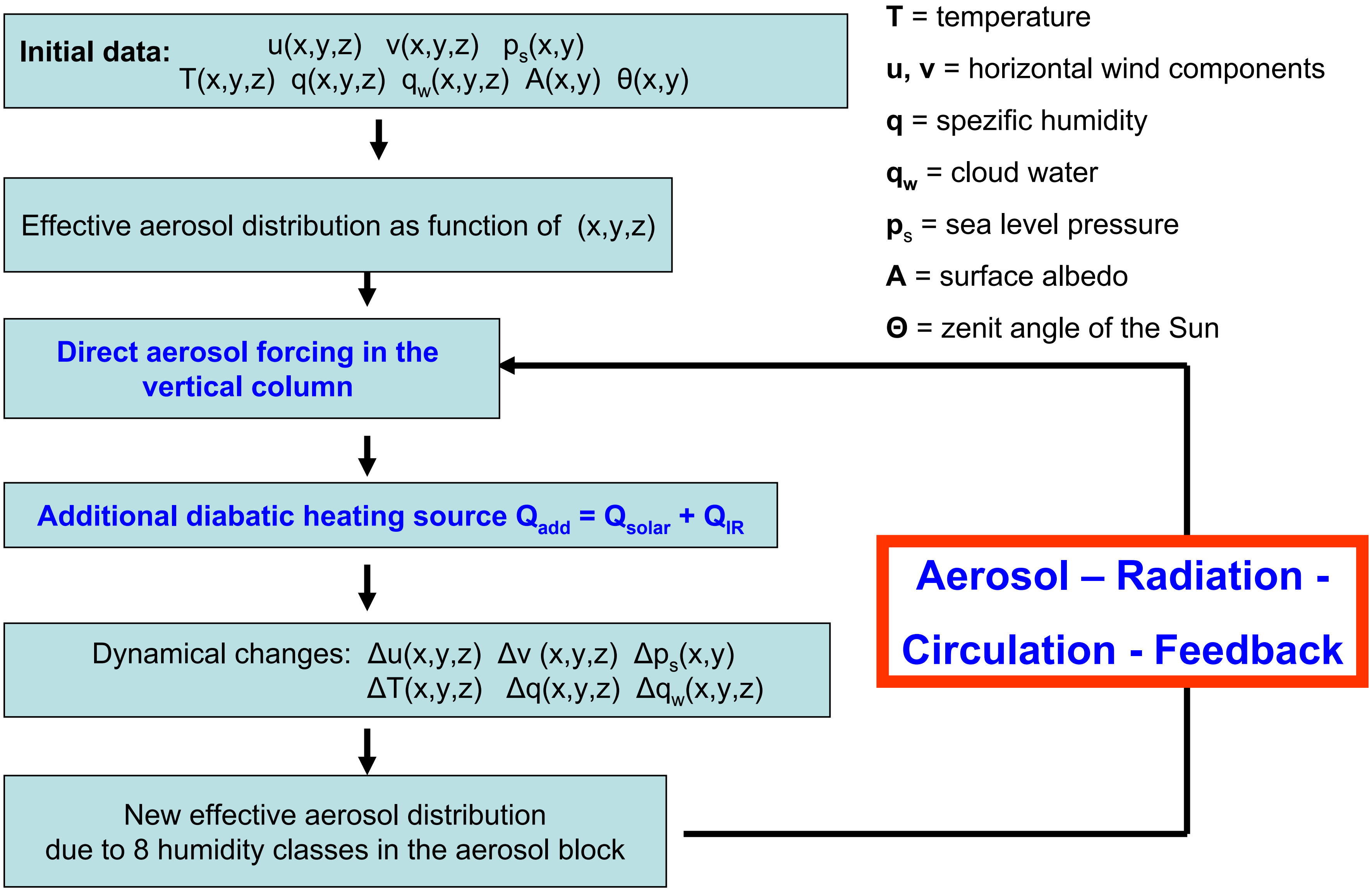
Selected GLIMPSE Papers

1. **Rinke, A. et al., (2004),** Regional climate effects of Arctic Haze, Geophys. Res. Lett., 31, L16202.
2. **Dethloff, K. et al., (2004),** The impact of Greenland's deglaciation on the Arctic circulation, Geophys. Res. Lett. 31, L19201, doi: 10.1029/2004GL020714.
3. **Stendel, M. et al., (2005),** Influence of various forcings on global climate in historical times using a coupled atmosphere-ocean general circulation model, Climate Dyn., 25, 10.1007/s00382-005-0041-4.
4. **Casty, C. et al., (2005).** Recurrent climate winter regimes in reconstructed and modelled 500 hPa geopotential height fields over the North Atlantic/European sector 1659-1990., Climate Dyn. ,24, 809-822, DOI: 10.1007/s00382-004-0496-8;
5. **Tjernström, M. et al., (2005),** Modelling the Arctic Boundary layer: An evaluation of six ARCMIP regional-scale models using data from the SHEBA project, Boundary-layer meteorology, 117, 337 – 381, DOI: 10.1007/s10546-004-7954-z.
6. **Dethloff, K. et al., (2005),** Global impacts of Arctic climate processes, EOS transactions, 86, 49, 6 December 2005, 511-512.
7. **Rinke, A. et al., (2006),** Evaluation of an ensemble of Arctic regional climate models: Spatiotemporal fields during the SHEBA year, Climate dynamics, 26, 459-472, DOI: 10.1007/s00382-005-0095-3.
8. **Dethloff, K. et al., (2006),** A dynamical link between the Arctic and the global climate system, Geophys. Res. Lett., 33, L03703,DOI: 10.1029/2005GL02524.
9. **Dorn, W. et al., (2006),** Sensitivities and uncertainties in a coupled regional atmosphere-ocean-ice model with respect to the simulation of Arctic sea-ice, JGR, submitted.
10. **Saha, S. K. et al., (2006),** Future winter extreme temperature and precipitation events in the Arctic, Geophys. Res. Lett., 33, L15818, DOI: 10.1029/2006GL026451.
11. **Sempf, M. et al. (2006),** Circulation Regimes due to Attractor Merging in Atmospheric Models, J. Atmos. Sci., accepted.

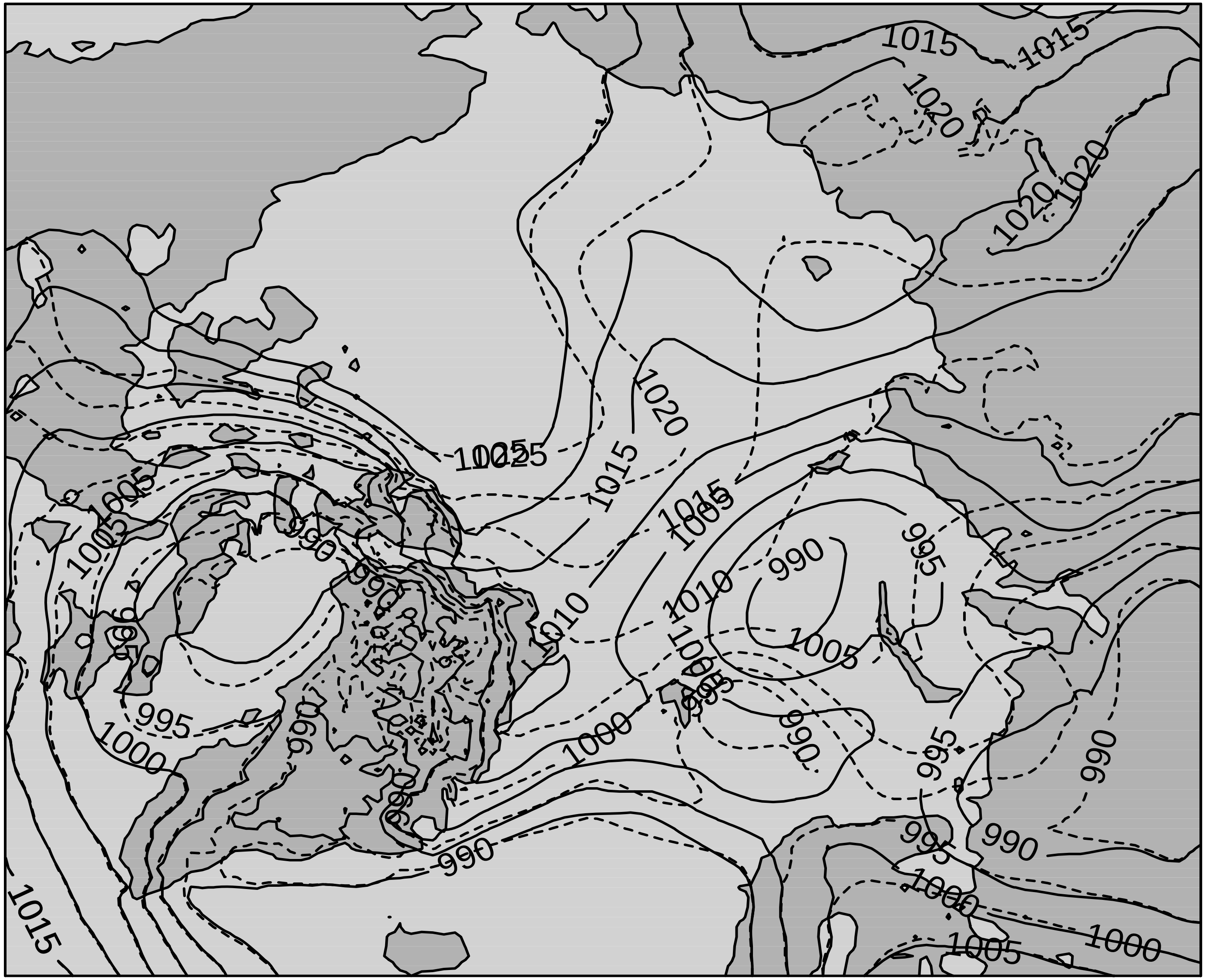
The End

Direct climatic effect of Arctic aerosols in HIRHAM4

(Implementation of an aerosol block without advection of aerosols, Strong Arctic aerosol loading in Spring → Arctic Haze)



MSLP fields (hPa) after 20 days of simulation for March 1990.
Control run (solid lines) and Aerosol run (dashed lines).



Rinke et al. (2004)

Changes in the development of cyclones over the Arctic Ocean

Direct radiative forcing effect of aerosols on the mean sea level pressure (Fortmann et al., 2004)

(ensemble of 8 March months)

(Aerosol run minus Control run)

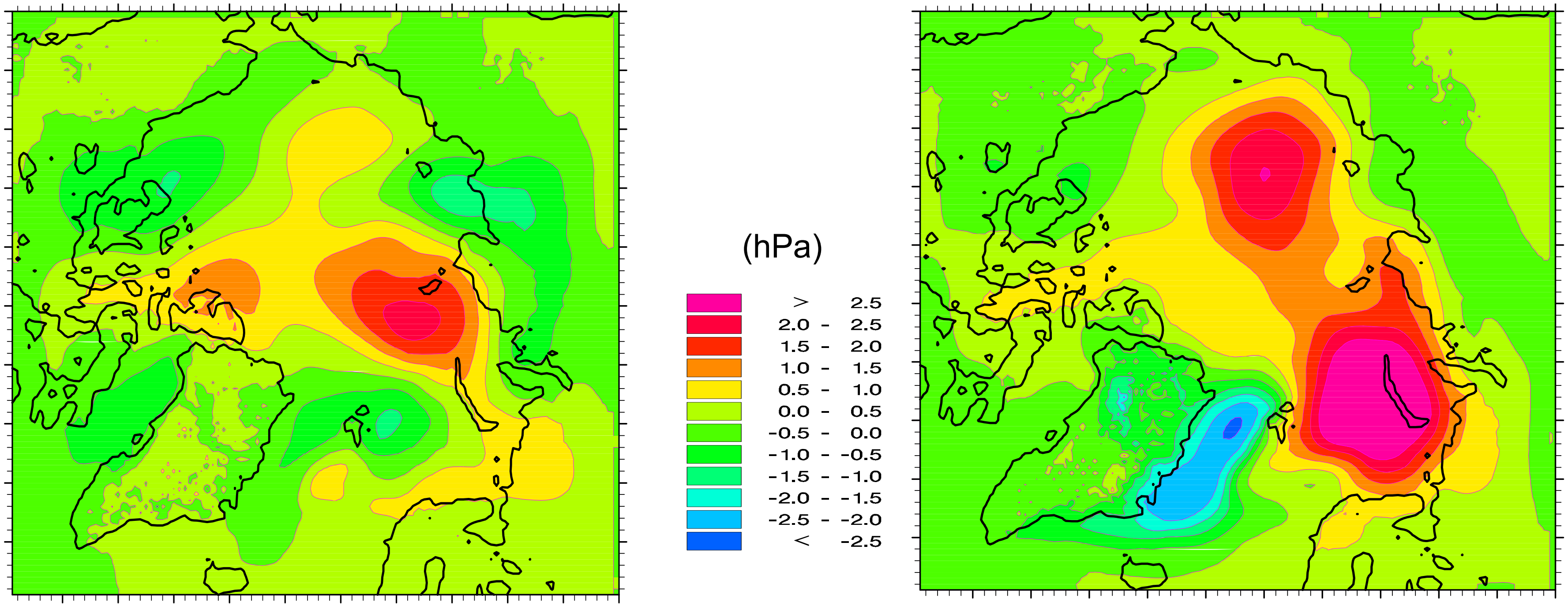
ECHAM4 cloud parameterization (Rockel et al., 1991)

Influence of cloud parameterizations on the mean sea level pressure as indirect aerosol effect

(Cloud run minus Control run)

Indirect aerosol effect taken into account Cloud droplet concentration depends on sulfate mass, (Boucher et al., 1995)

Changes in the optical properties of water and ice clouds

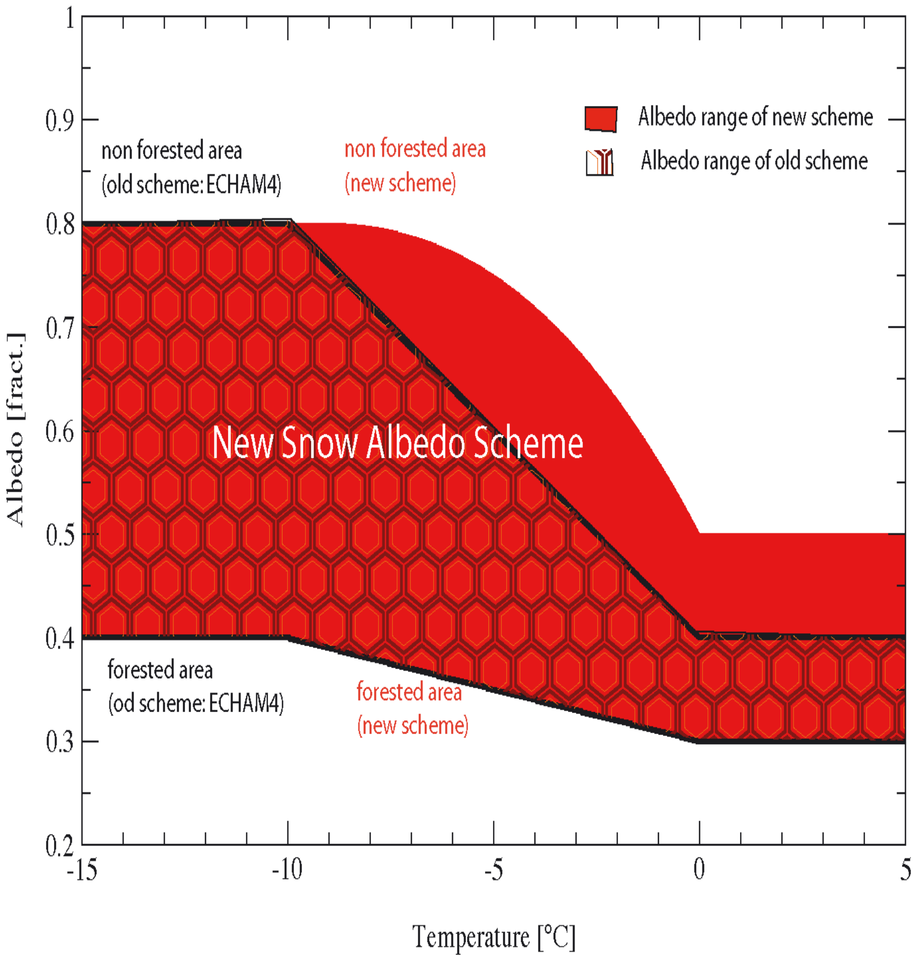


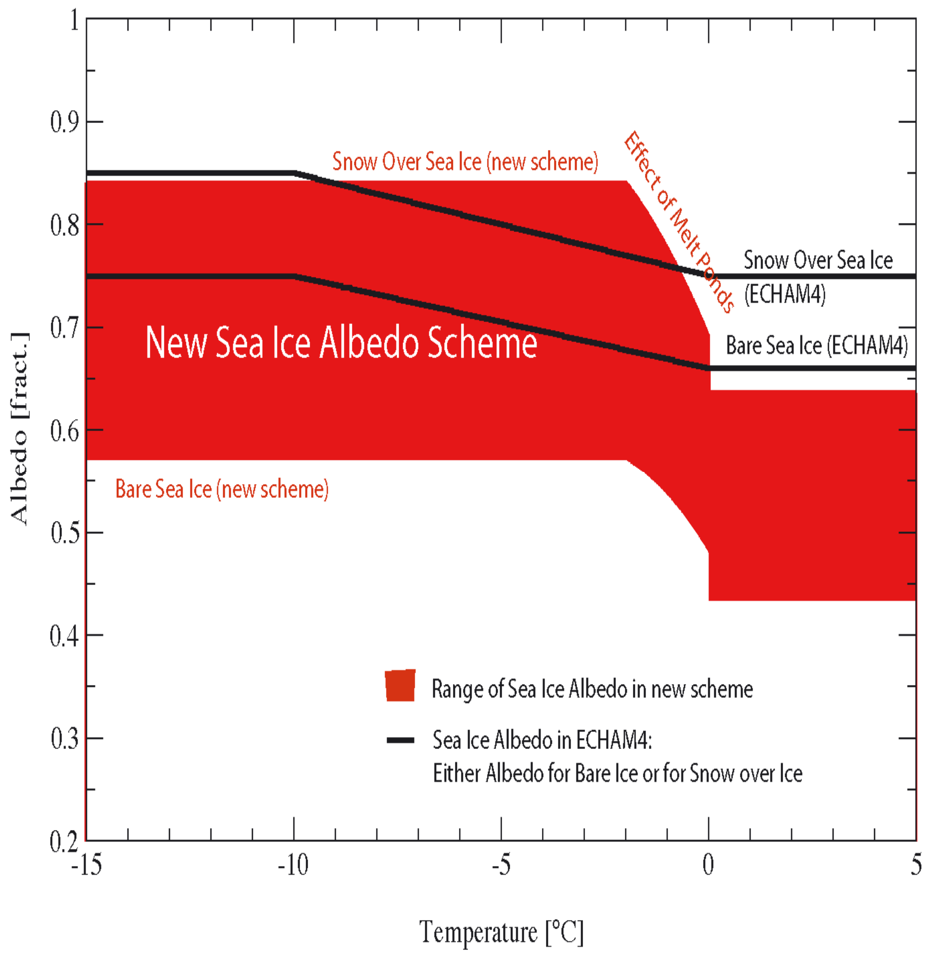
Impact of indirect aerosol effects on the Barents Sea Oscillation

Improved snow albedo scheme (left) and sea ice albedo scheme (right), Benkel et al., 2006

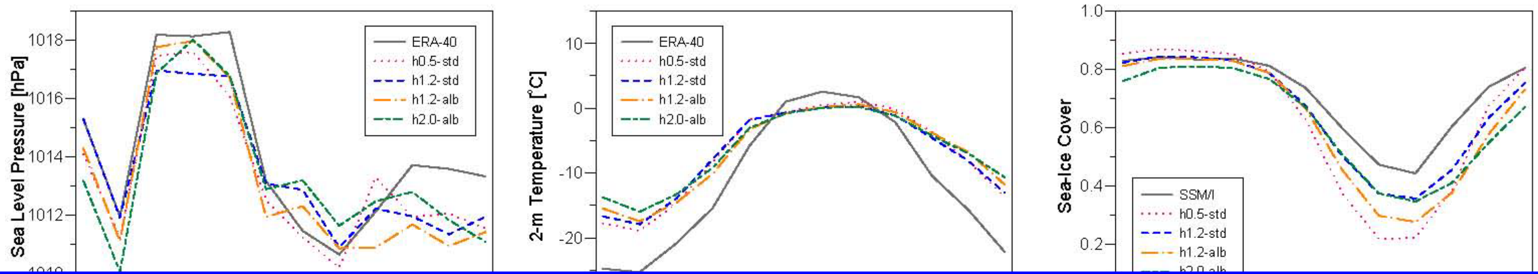
Black → Old albedo scheme

Red → New albedo scheme





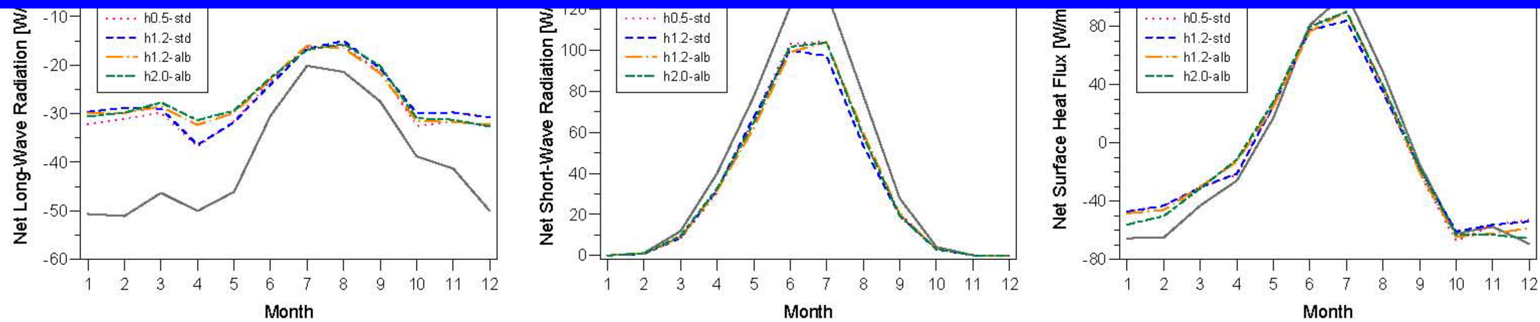
Mean seasonal cycle (1996-1999) of selected variables averaged over all sea areas north of 70°N from ERA-40 reanalysis data and simulations of HIRHAM–NAOSIM. Observed mean sea-ice cover is based on SSMI data instead of ERA-40. Fluxes are positive towards the ocean–ice surface, Dorn et al., 2006



Temperature, longwave radiative and cloud bias compared to ERA-40 reanalysis data for mean over period 1996-1999

Strong sensitivity of atmospheric and ice variables with respect to:

→ sea-ice albedo parameterization
→ relationship between lateral and basal sea-ice growth



Comparison to observational sea ice extend

Reference period for the observational data: 1979-1999.
Observational data from Parkinson and Cavalieri (2002).

	Obs.	Old	New
Sea Ice extend over Baffin Bay, Labrador Sea, Greenland Sea, and Gulf of St. Lawrence (MAM mean) [10^6 km^2]	**2.3**	**3.0**	**2.4**
NH sea ice extend (Sep) [10^6 km^2]	**6.9**	**6.2**	**7.2**
NH sea ice extend (Mar) [10^6 km^2]	**15.3**	**16.9**	**16.3**