

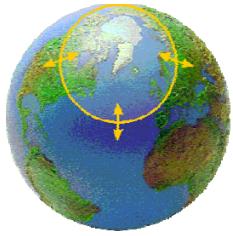
The Rossby Centre Ocean model applied to the Arctic Ocean using ERA-40

*H.E. Markus Meier, R. Döscher, K. Wyser
Rossby Centre/SMHI, Norrköping*

and

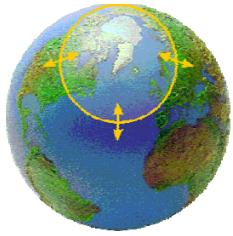
K. Döös

MISU, Stockholm University, Stockholm



Rossby Centre Ocean model (RCO)

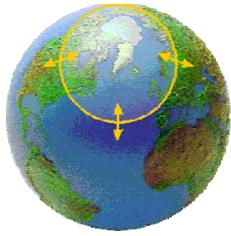
- based on the BRYAN-COX-SEMTNER code reorganised for running on parallel computer architectures (OCCAM, Webb et al., 1997)
- spherical rotated ARAKAWA B – grid, level model
- explicit free surface (Killworth et al., 1991)
- improved vertical and horizontal advection schemes (Webb, 1995; Webb et al., 1998)
- alternative: **FCT** (Zalesak, 1979; Gerdes et al., 1991)
- open boundary conditions (Stevens, 1990)
- $k-\varepsilon$ (k) **turbulence model** with improved flux boundary conditions and parameterization of internal waves (Meier, 2001)
- **bottom boundary layer model** (Beckmann & Döscher, 1997)



Rossby Centre Ocean model (RCO)

- HIBLER-type two-level dynamic-thermodynamic sea ice model (Hibler, 1979)
- elastic-viscous-plastic ice rheology (Hunke and Dukowicz, 1997)
- Semtner 3-layer model for ice thermodynamics (Semtner 1976)
- multi-category ice model (Haapala, 2000)

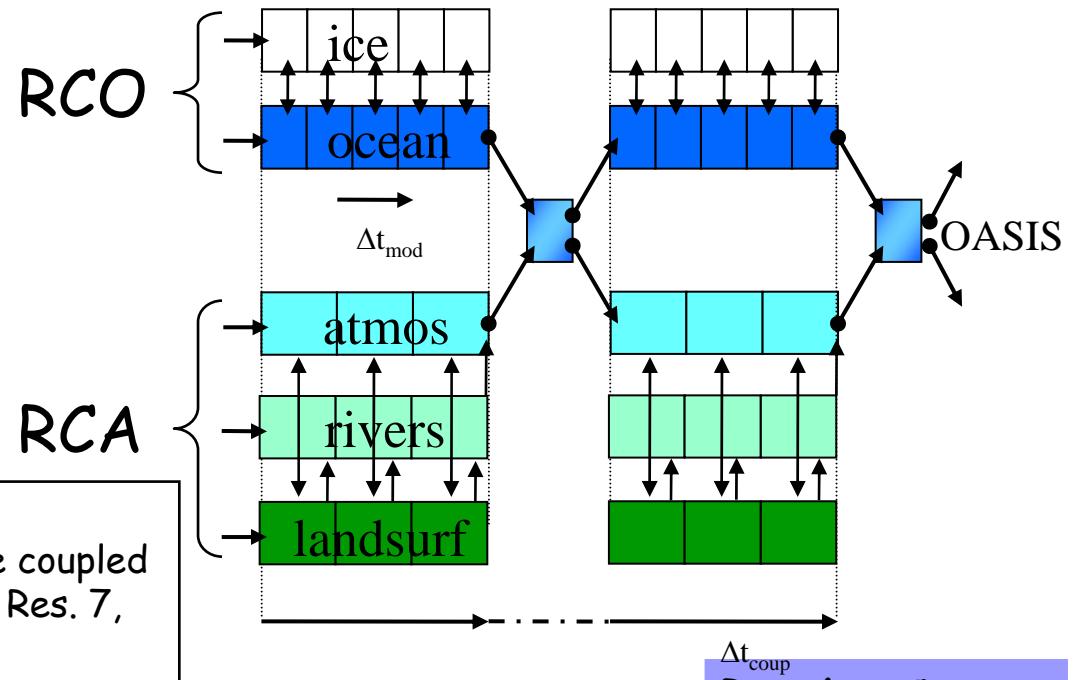
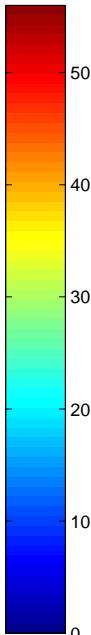
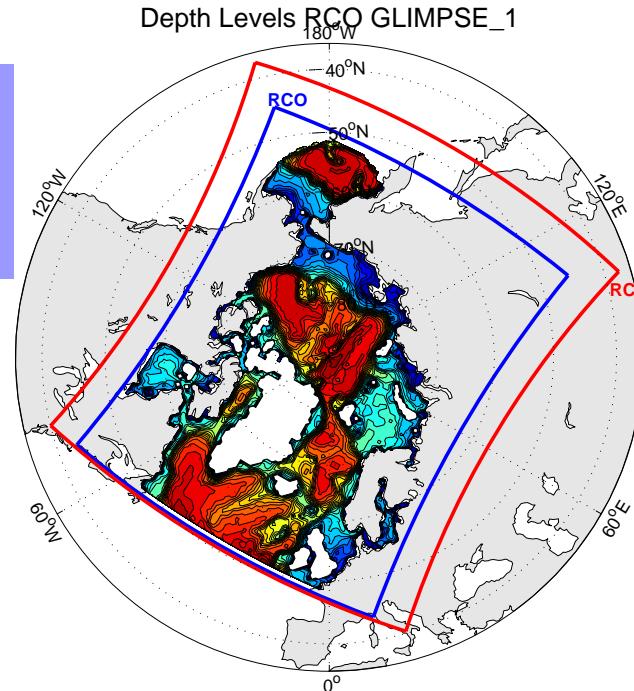
RCO described in:
Meier, Döscher and Faxen, 2003:
A multiprocessor coupled ice-ocean
model for the Baltic Sea: application to
salt inflow, JGR, 108 (C8), 3273



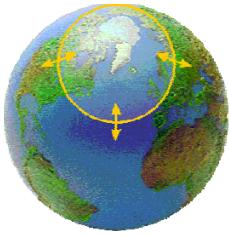
Development of RCAO-Arctic

Setup:

- Identical grids (0.5 degrees)
 - facilitates flux coupling
- Consistent coast definitions in both RCO and RCA
- OASIS 2.4
- Ocean sends
 - state variables
 - sea ice albedo
- Atmosphere responds with fluxes



RCAO described in:
Döscher et al. 2002: The development of the coupled ocean-atmosphere model RCAO. Boreal Env. Res. 7, 183-192.

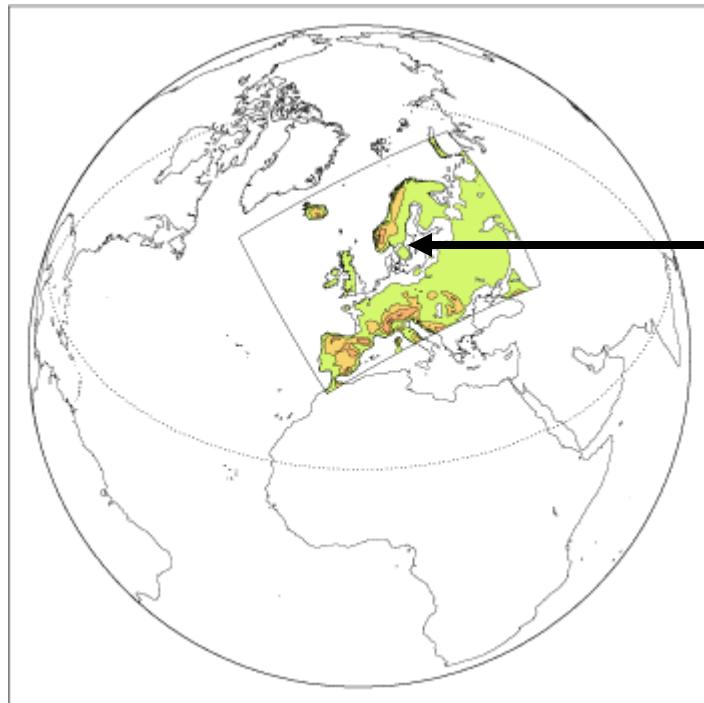


The coupled system RCAO

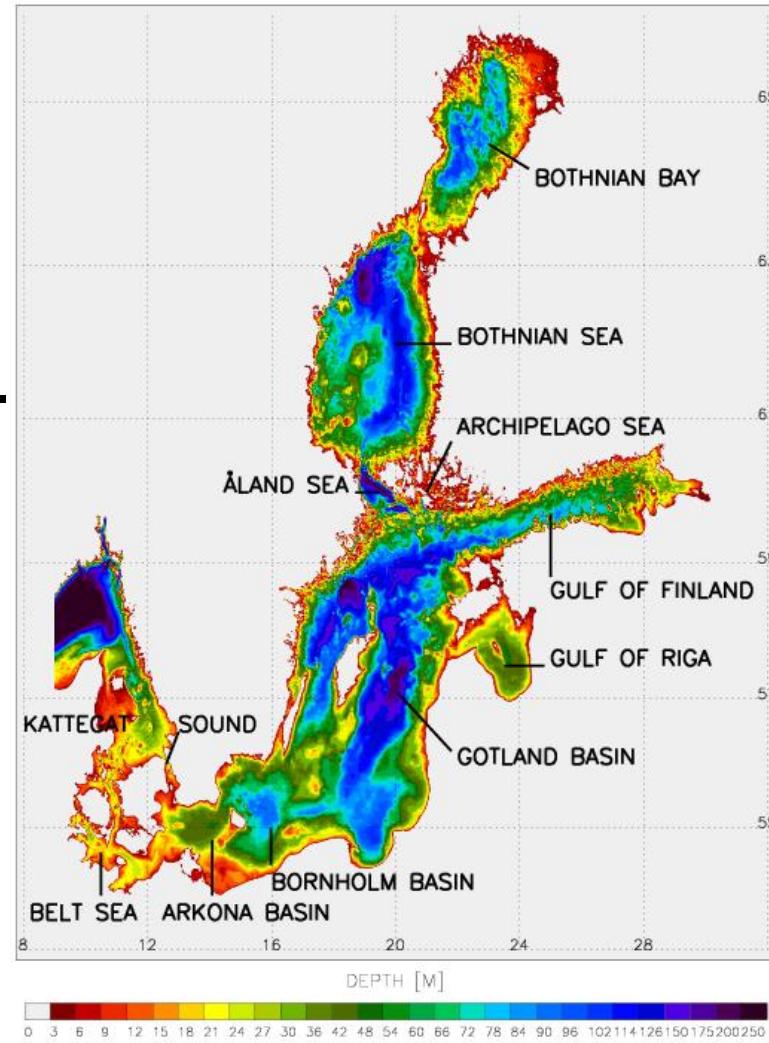
RCA: 44 km, 30 min

RCO: 11 km, 10 min

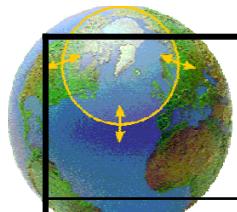
Coupling timestep: 3 h



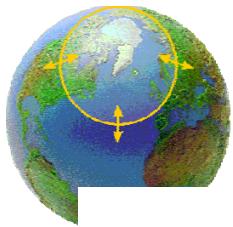
Model domain, covering most of Europe and parts of the North Atlantic Ocean and Nordic Seas. Only the Baltic Sea is interactively coupled.



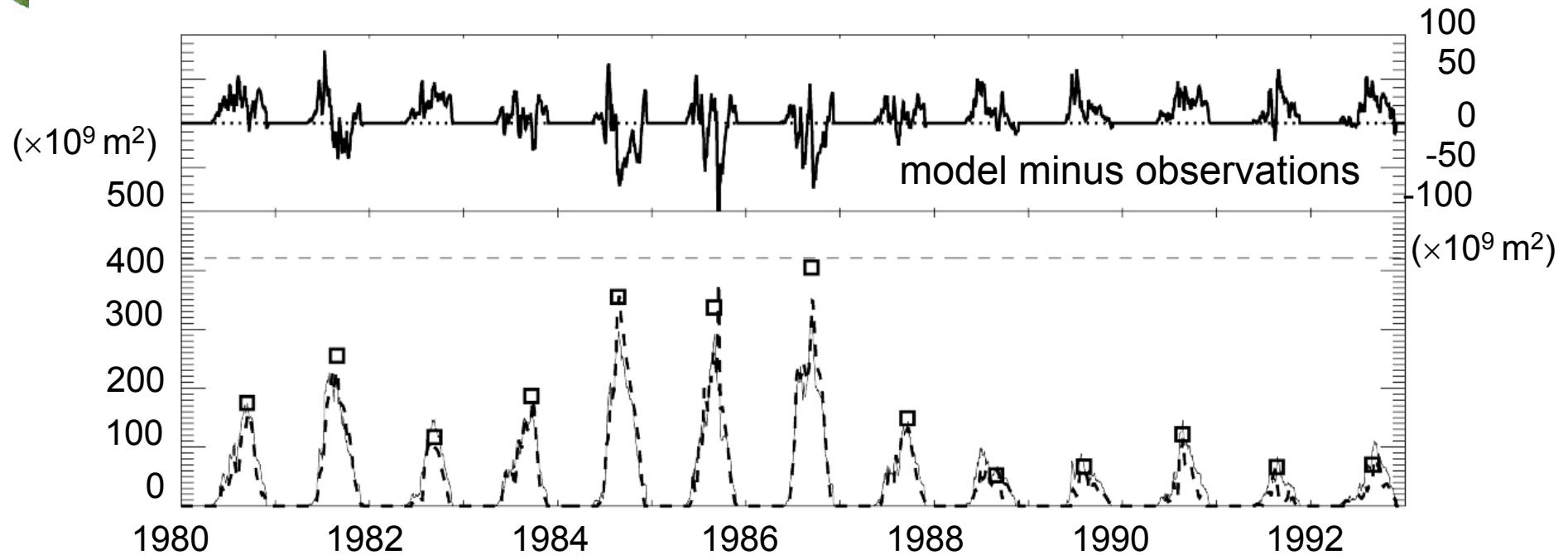
Döscher et al. (2002)



	RCO-Arctic	RCO-Baltic
maximum depth	5000 m	250 m
horizontal resolution	54 km	3.6 km
spherical grid	rotated	not rotated
vertical resolution	59 levels, 3 - 200 m	41 levels, 3 - 12 m
sea ice	multi-year	seasonal
tides	yes	no
freshwater supply	climatology (AWI), 3156 km ³ /yr	monthly, 444 km ³ /yr
open boundary	climatology (PHC), sea level (OCCAM)	T,S climatology, hourly sea level
initial conditions	climatology (PHC)	snapshots from observations
atmospheric forcing	ERA40 (6h, 1958 -2002)	SMHI (3h, 1980-2003), reconstructed (1d, 1902-1998)



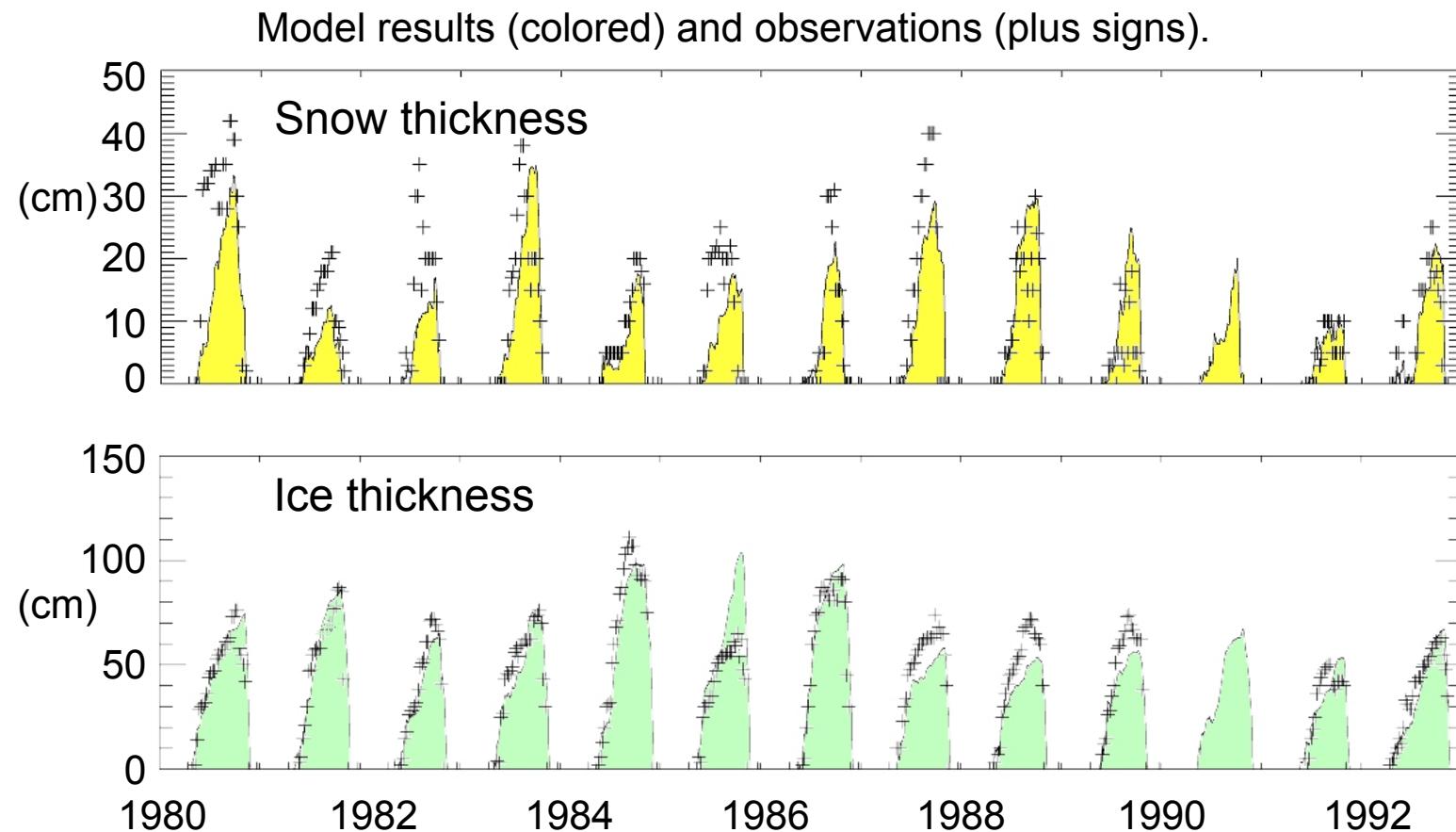
RCO: Baltic Sea ice cover

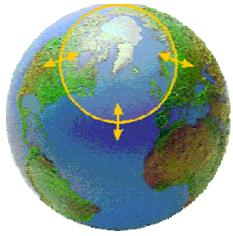


Simulated ice covered area for 1980-1993 (solid line). The Baltic Sea area is shown as dashed horizontal line. Squares denote observed maximum ice extent published by the Finnish Institute of Marine Research. The dashed line denotes calibrated data of the USA National Ice Center (see Schrum et al., 2000). The difference between RCO model results and observations is shown on top of the panel.

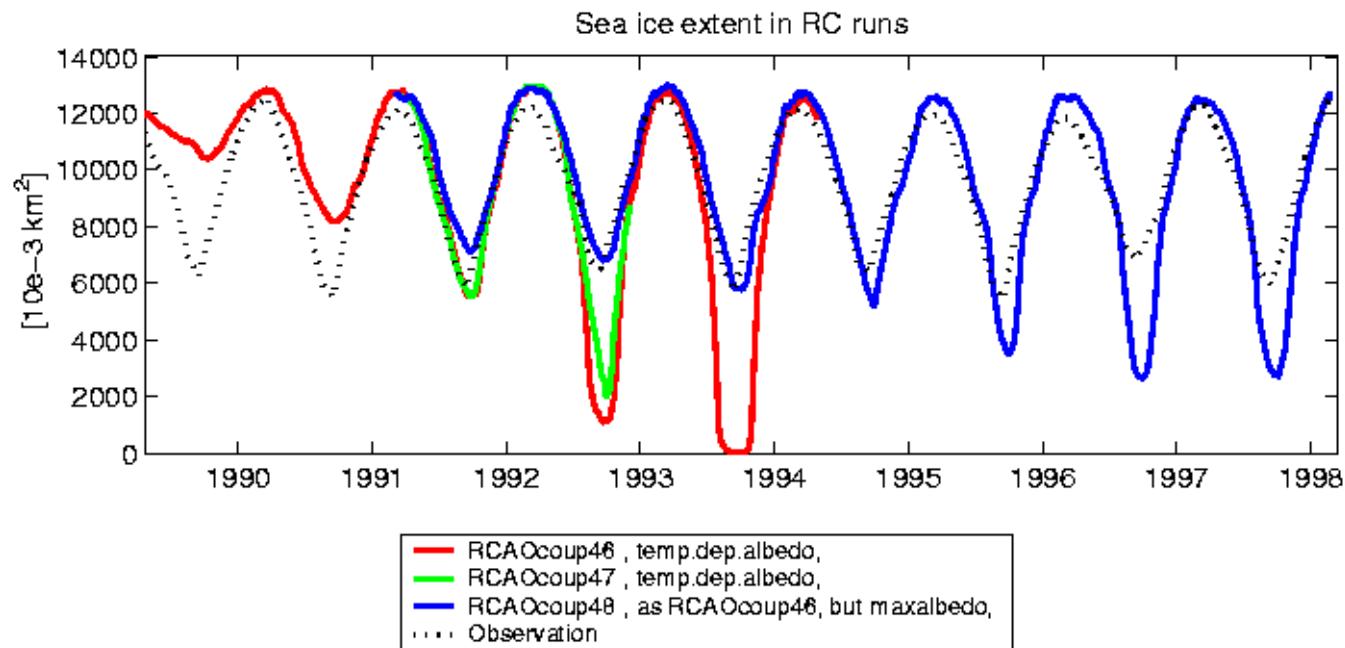


RCO: Snow and ice thickness at Kemi, Bay of Bothnia





RCAO decadal run: Sea Ice Extent

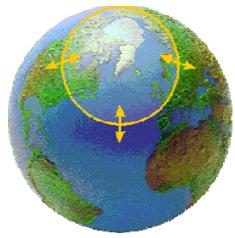


Albedo 1 (Perovich, 1996)

type	albedo
dry snow	0.87
wet snow	0.77
dry ice	0.7
wet ice	0.3

Albedo 2 (Køltzow et al.)

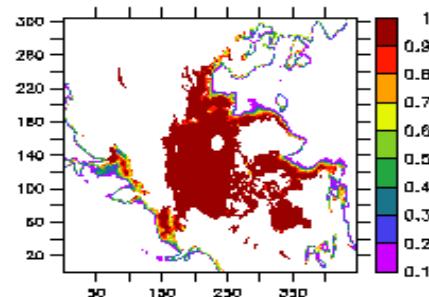
$$\begin{aligned}
 \alpha_{\text{seaice}} &= 0.84 && \text{if } (T_s \leq -2^\circ C) \\
 \alpha_{\text{seaice}} &= 0.84 - 0.145(2 + T_s) && \text{if } (-2^\circ C \leq T_s) \\
 \alpha_{\text{seaice}} &= 0.51 && \text{if } (T_s \geq 0^\circ C) \\
 \Delta_{\text{meltpond}} &= 0.11(2 + T_s) && \text{if } (T_s \geq -2^\circ C) \\
 \alpha_{\text{meltpond}} &= 0.36 - 0.1(2 + T_s) && \text{if } (T_s \geq -2^\circ C) \\
 \alpha_{\text{surface}} &= (1 - \Delta_{\text{meltpond}}) \cdot \alpha_{\text{seaice}} + \Delta_{\text{meltpond}} \cdot \alpha_{\text{meltpond}}
 \end{aligned}$$



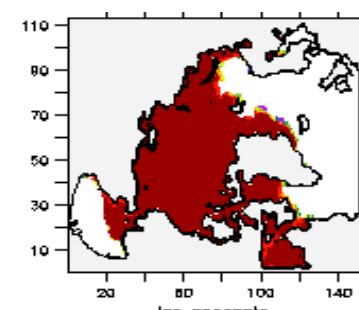
April 1991

ice
fraction

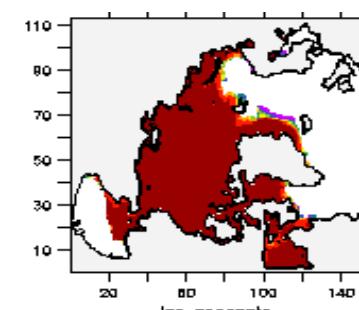
Obs



with
max-albedo

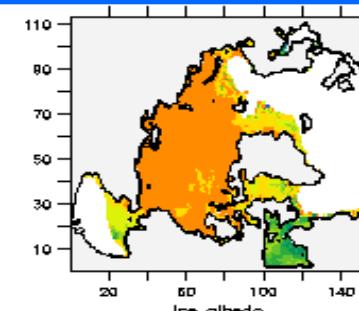
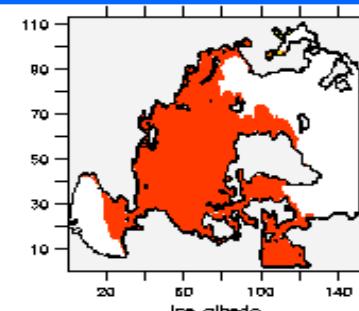
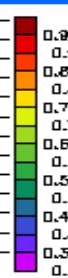
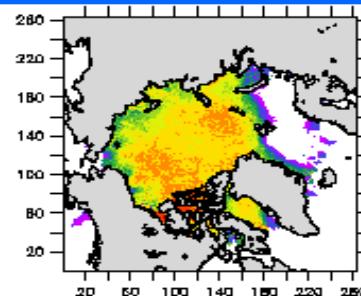


with Køltzow et al
albedo



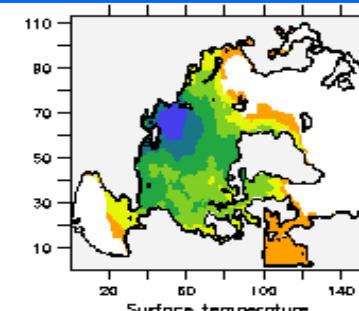
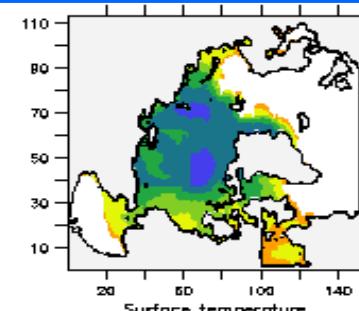
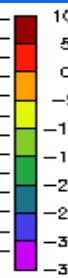
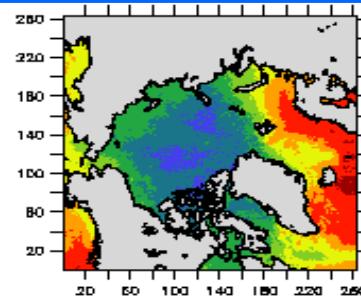
ice/snow
albedo

Sea ice concentration

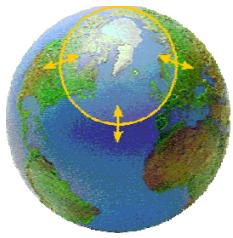


surf
temp

Sea ice albedo

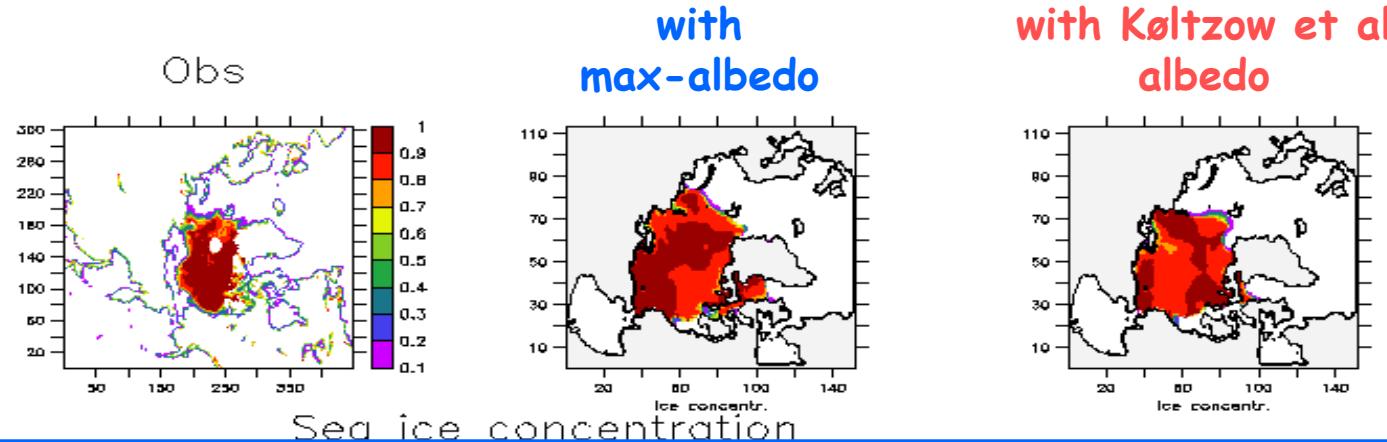


Surface temperature

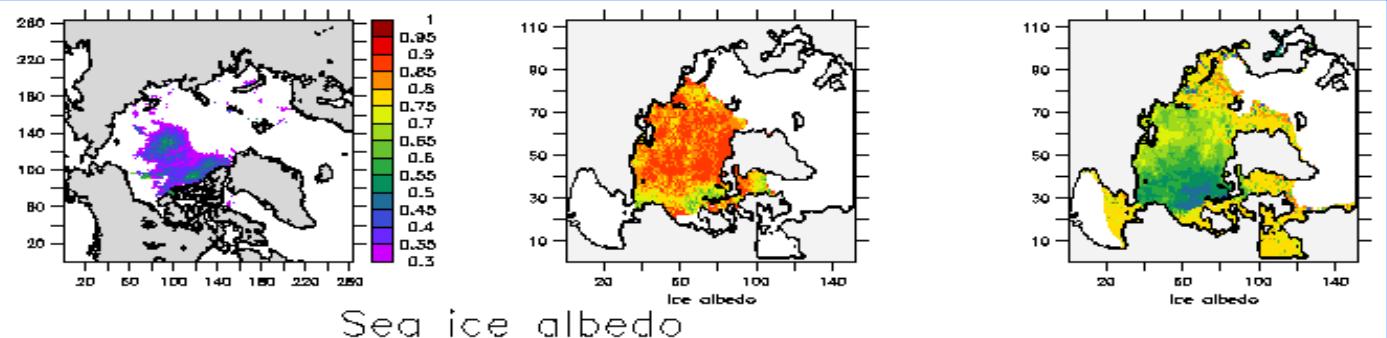


Sept 1991

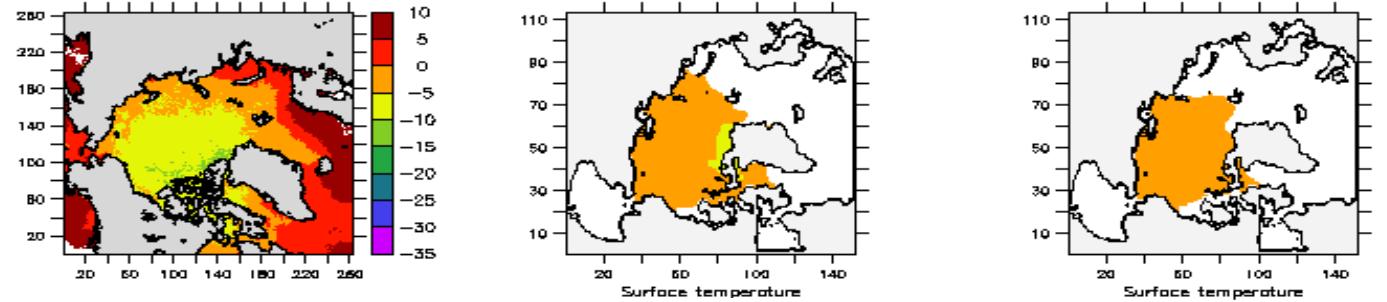
ice fraction



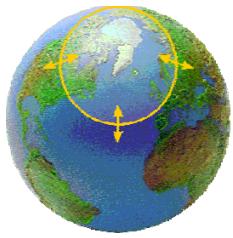
ice/snow albedo



surf temp

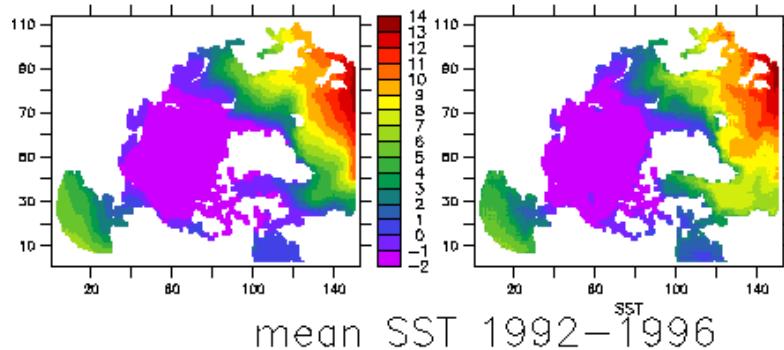


→ RCAO needs an albedo (likely) higher than observations
in order to prevent the ice extent from drifting



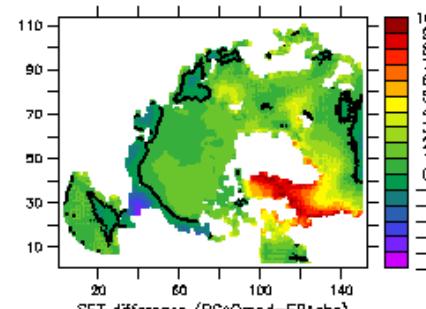
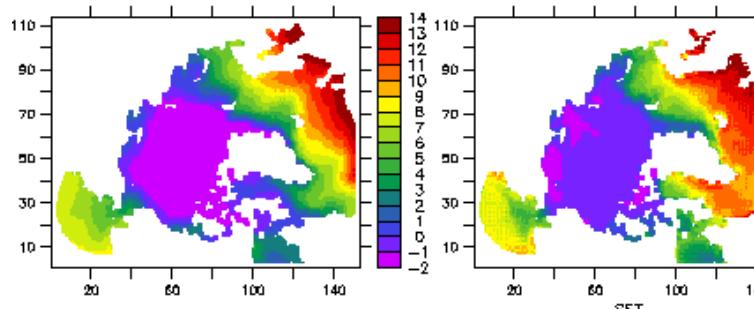
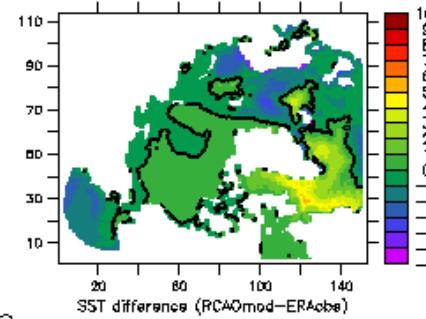
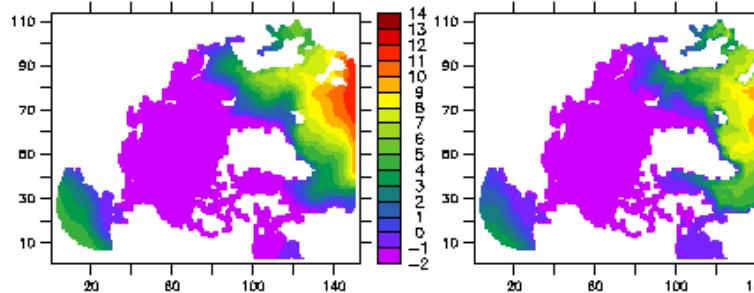
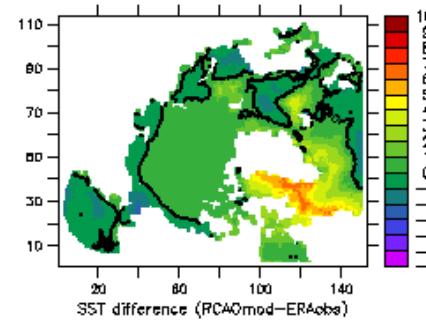
RCAO: SST

ERA obs



coup48

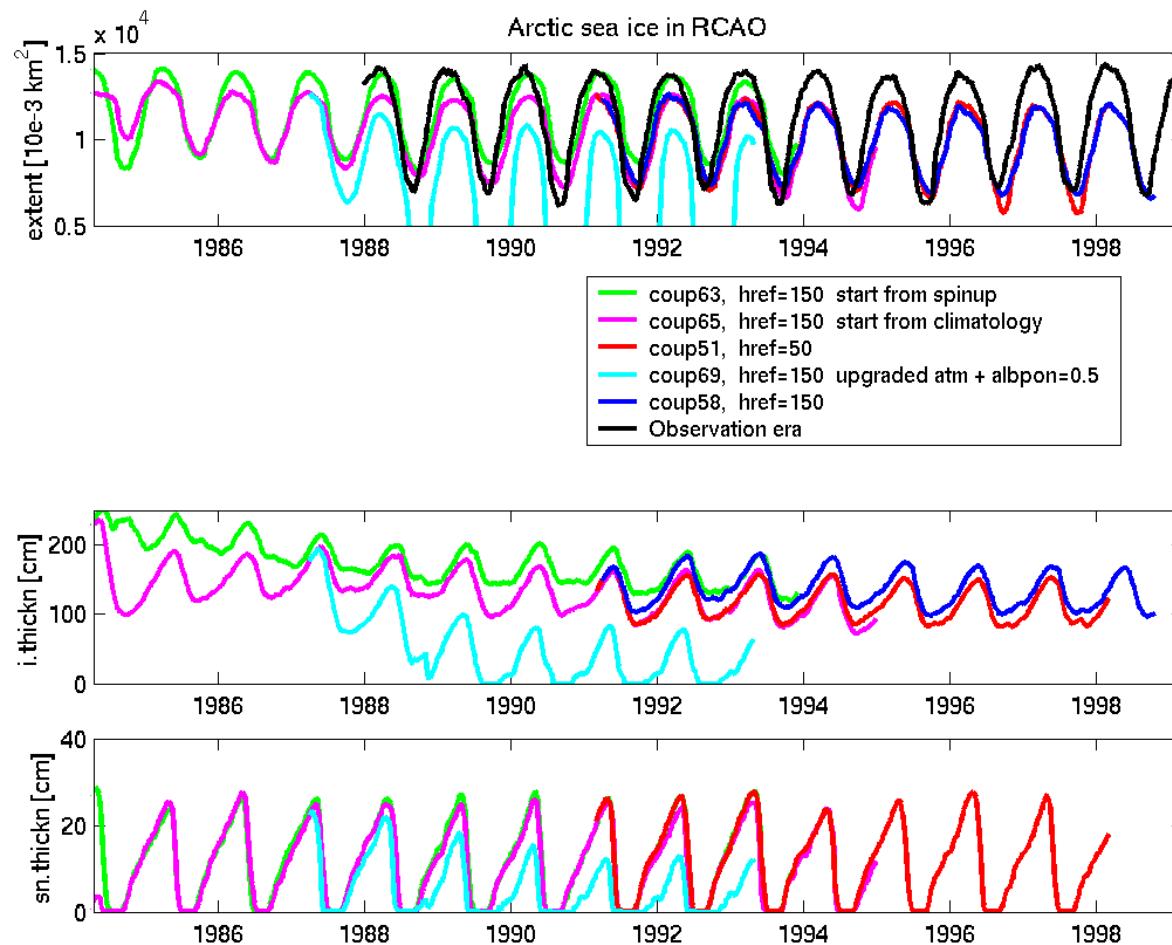
Difference

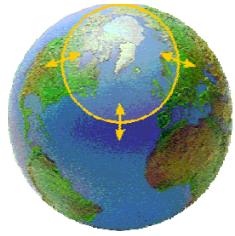


- Winter mean bias similar to the NAO influence pattern
- Summer is too warm consistent with too little sea ice

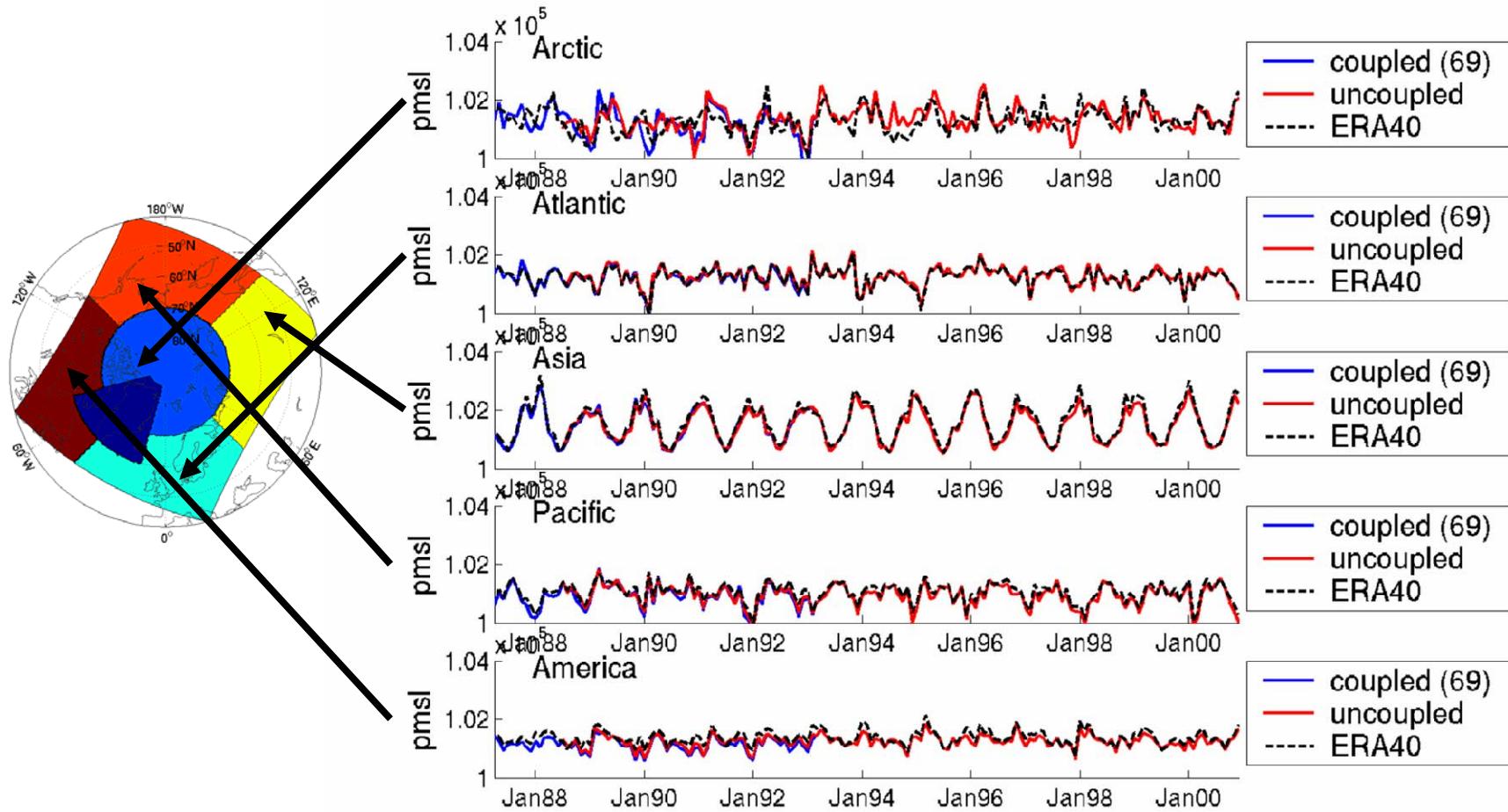


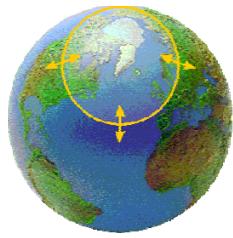
RCAO latest developments:



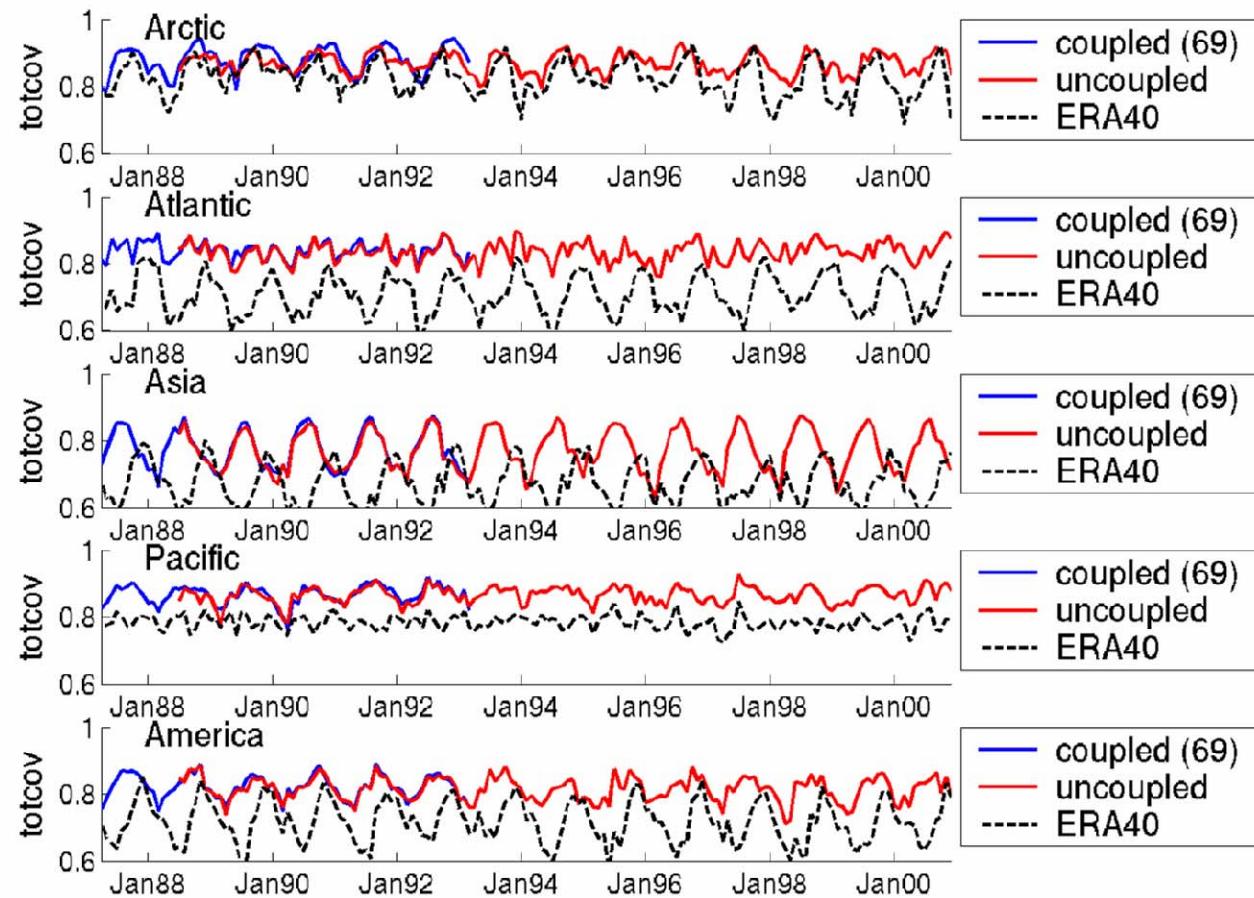


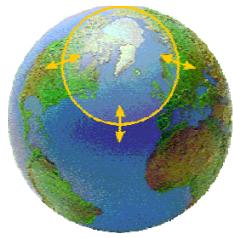
Monthly mean sea level pressure



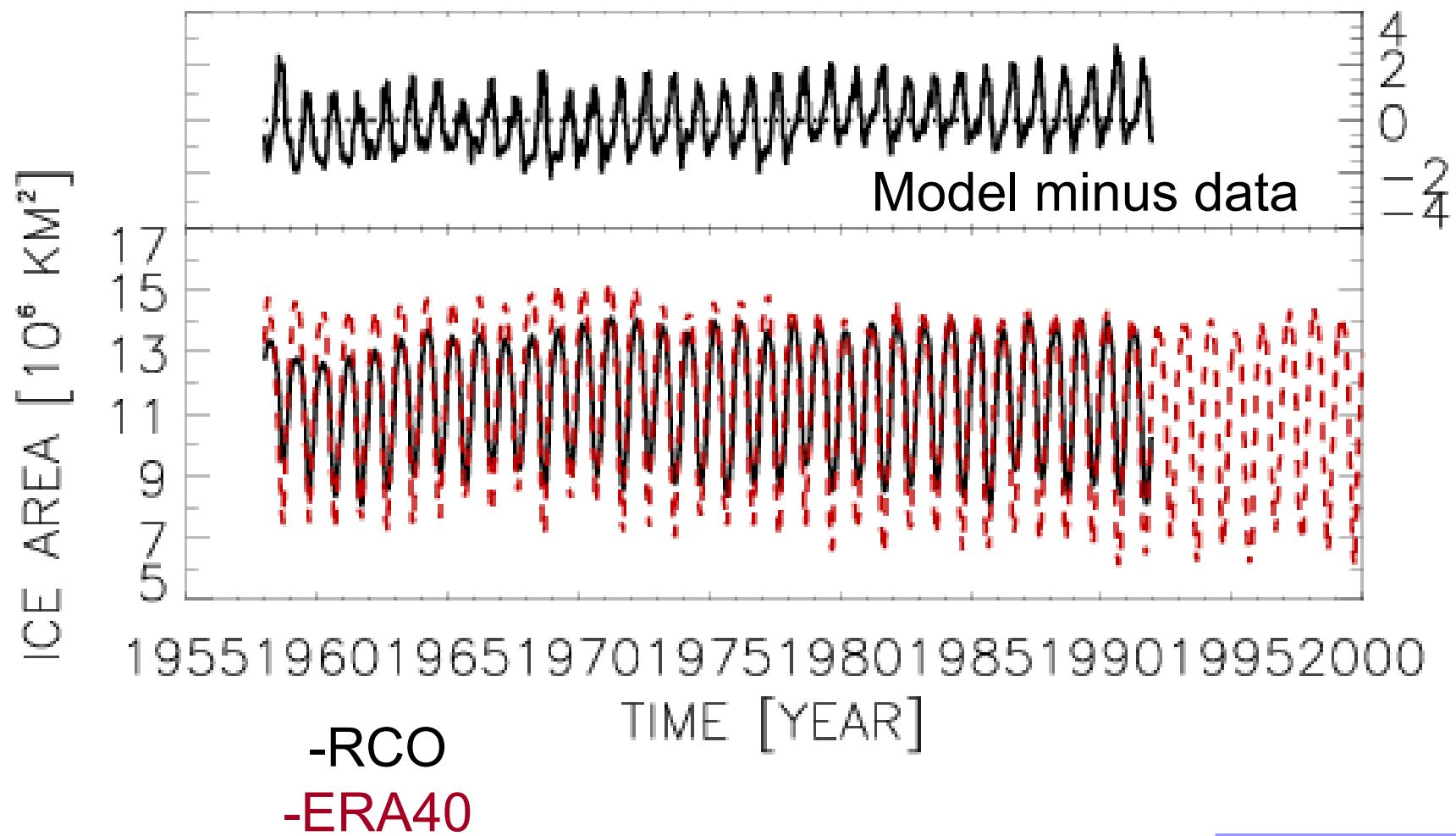


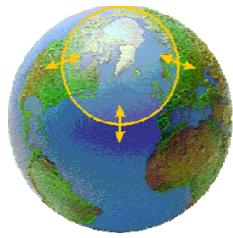
Monthly total cloudiness



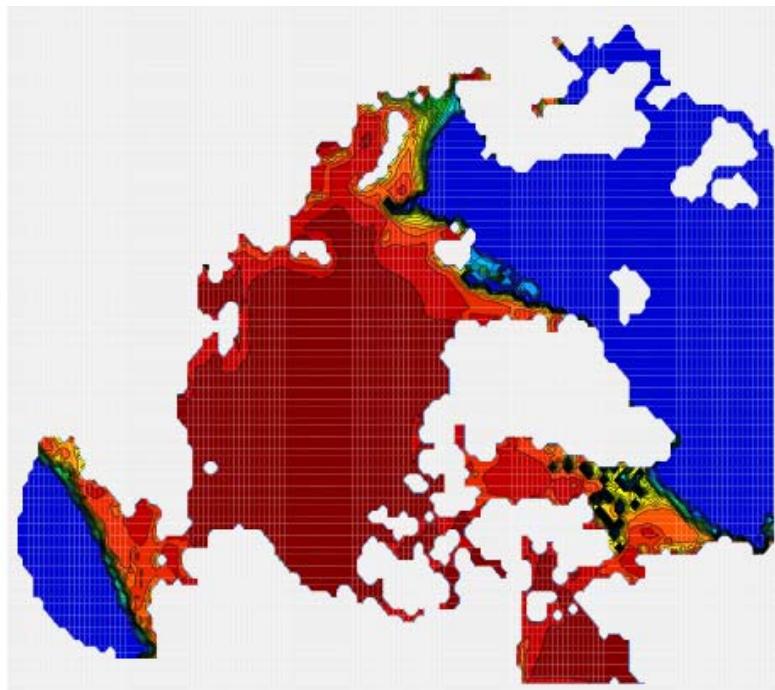


RCO forced with ERA40:

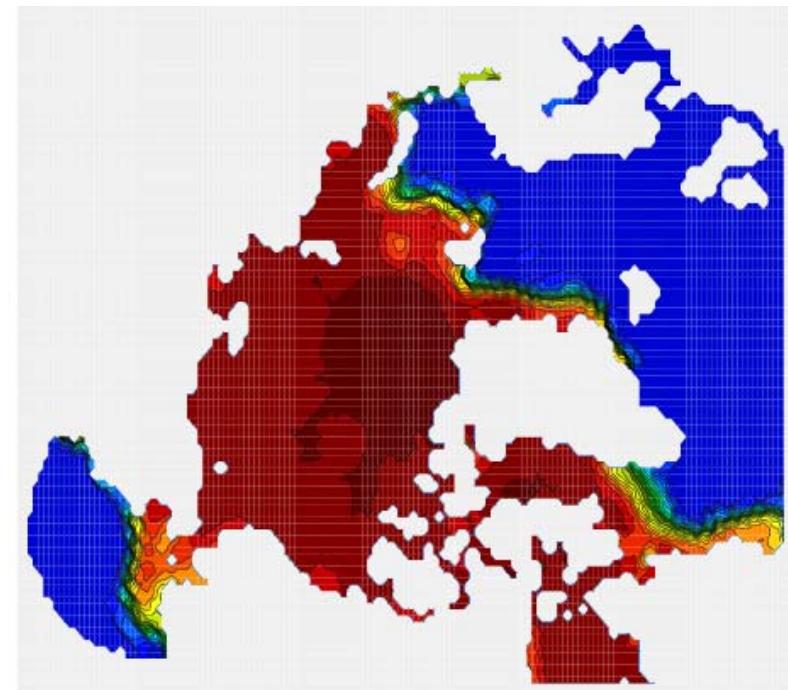




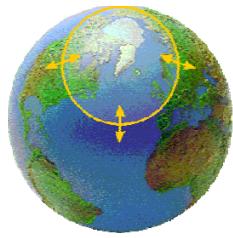
Ice concentration February 1990



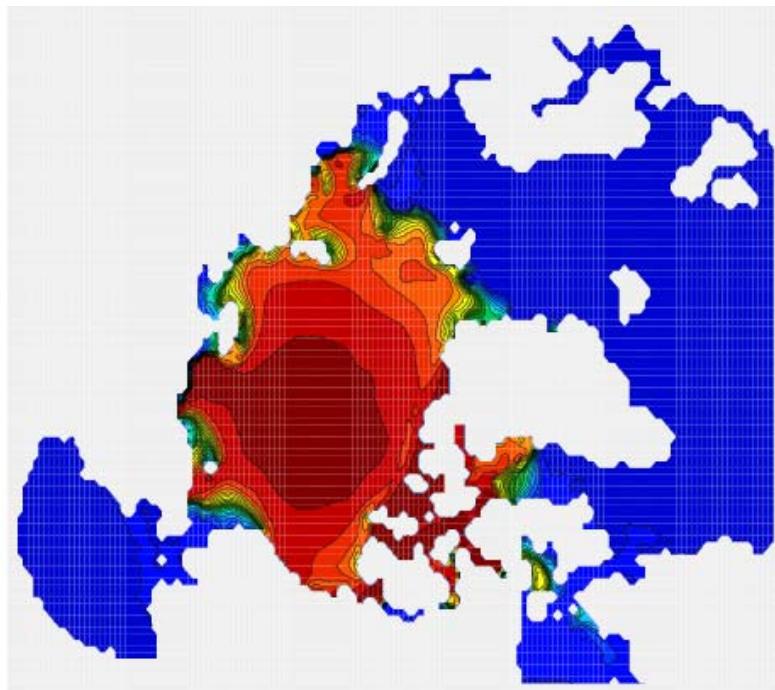
RCO



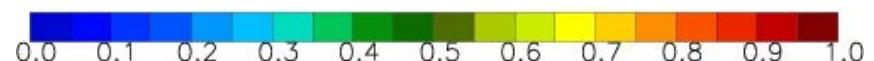
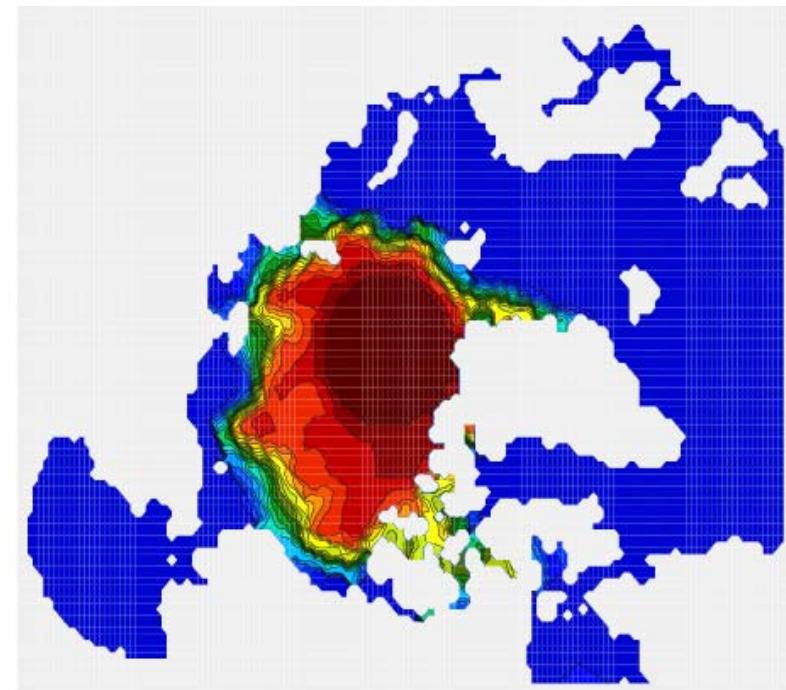
ERA40



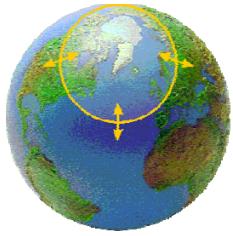
Ice concentration August 1990



RCO

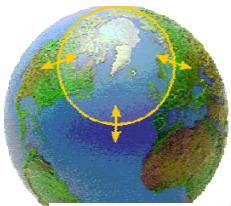


ERA40

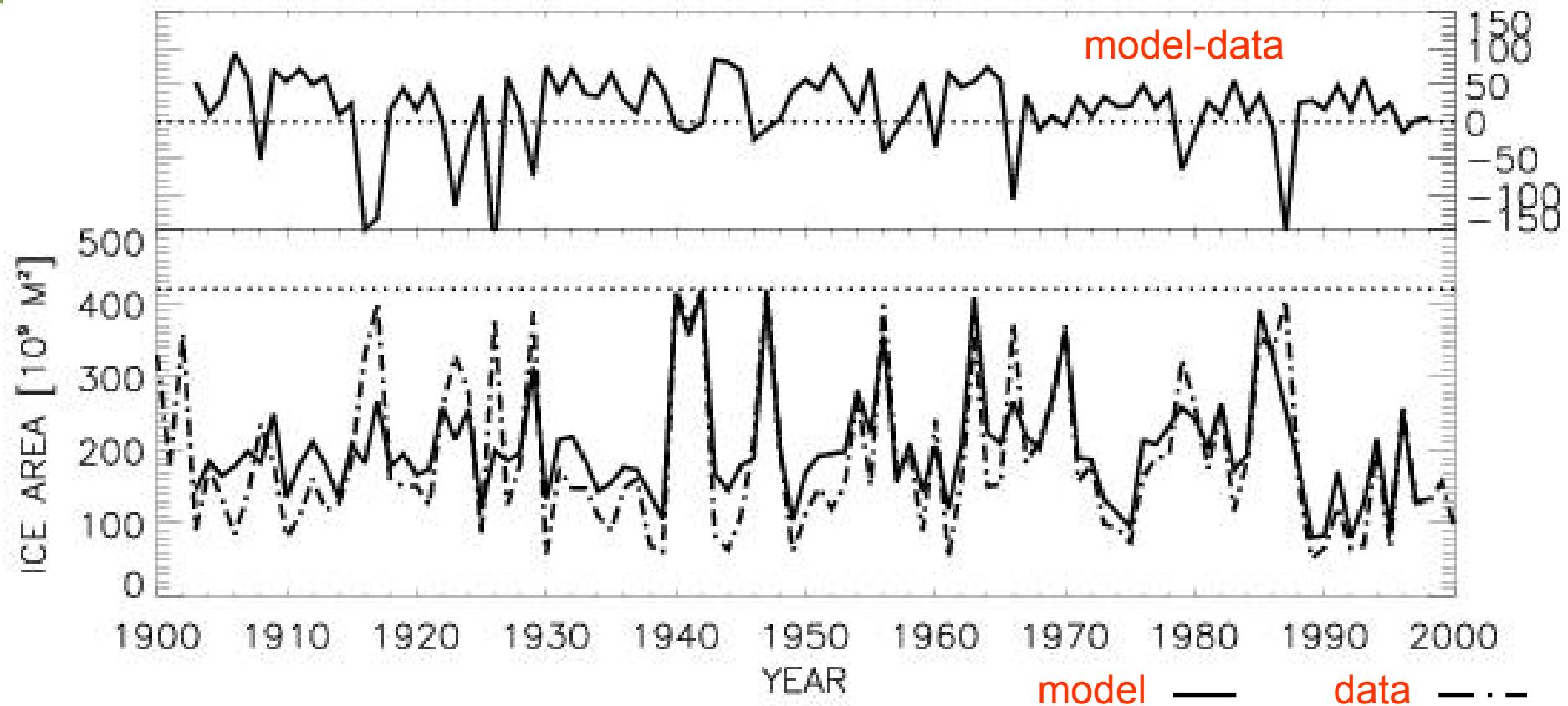


Conclusions and future plans:

- High sensitivity of sea ice against details of the radiative fluxes and albedo
- Further improvements in radiation and cloud parameterizations/cover are needed before conclusions with respect to albedo are possible
- Limited geographical portability of both RCAO and RCO
- Future plans: test of different mixing schemes, sensitivity studies



Annual maximum ice extent



Period	ME	RMSE	R	VAR
1903-98	16.8	55.2	0.87	0.71
1903-26	3.9	73.9	0.66	0.37
1927-66	29.1	52.8	0.94	0.79
1967-98	11.1	39.5	0.93	0.83

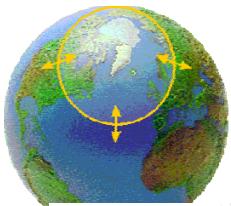
Model biases:

ME=mean error in 10^9 m^2 ,

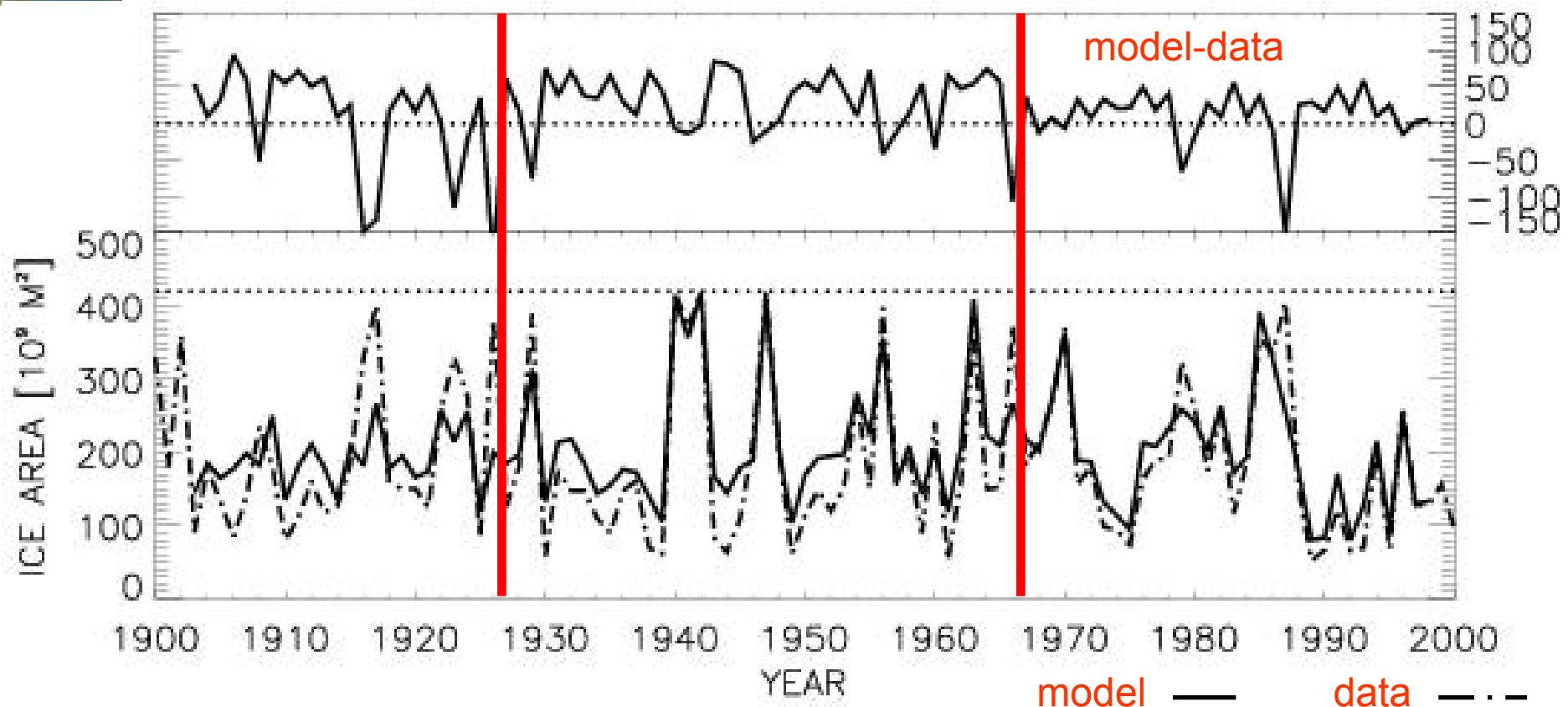
RMSE=root mean square error in 10^9 m^2 ,

R=correlation coefficient,

VAR=explained variance



Annual maximum ice extent



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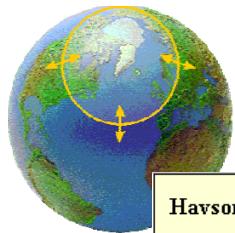
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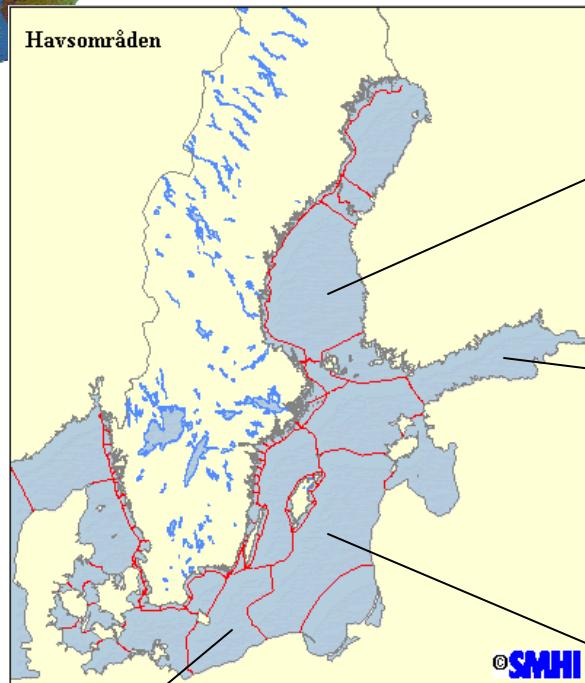
RMSE=root mean square error in 10^9 m^2 ,

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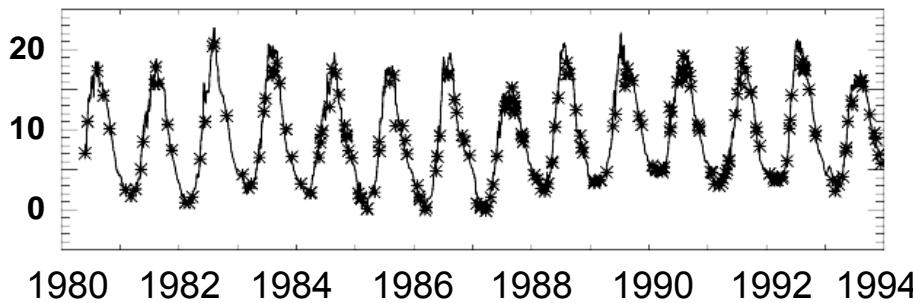
VAR=explained variance



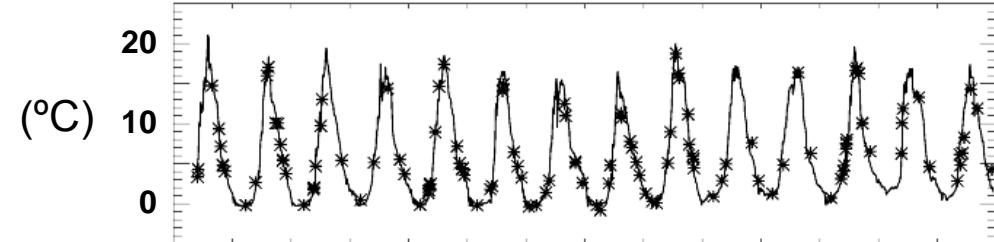
Sea surface temperature



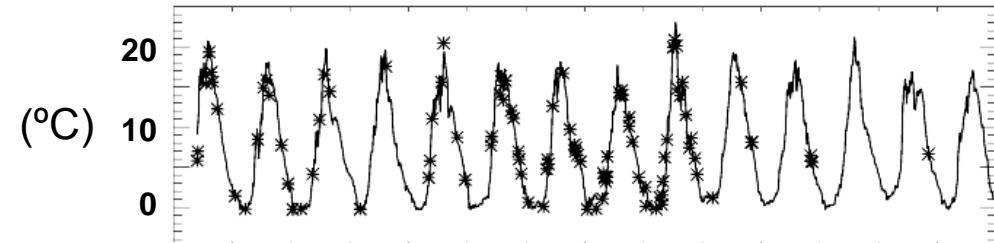
Bornholm Basin



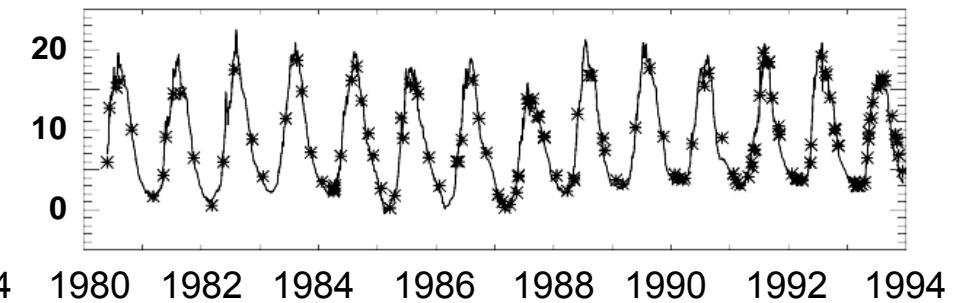
Bothnian Sea

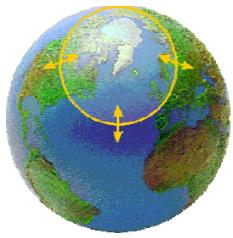


Gulf of Finland



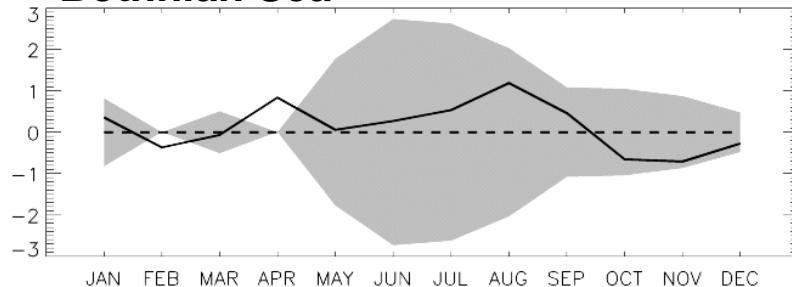
Gotland Basin



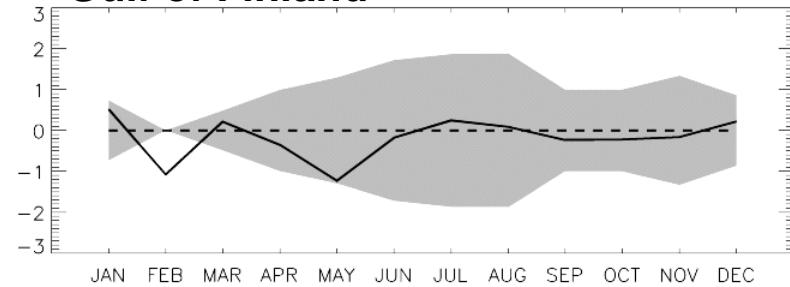


Monthly mean SST bias

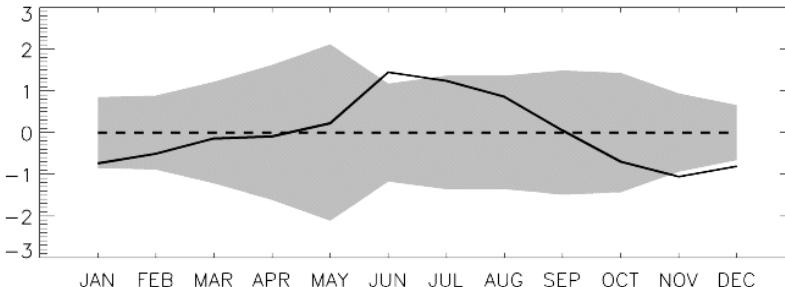
Bothnian Sea



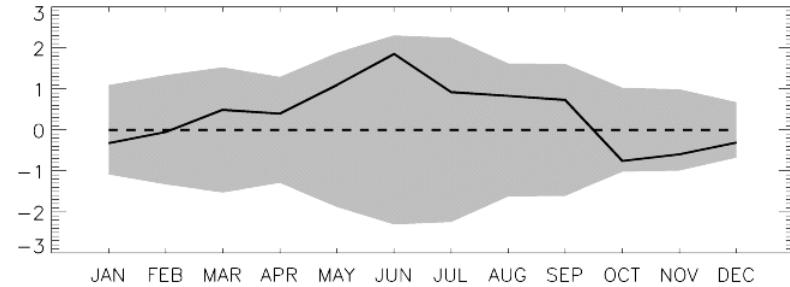
Gulf of Finland



Gotland Basin

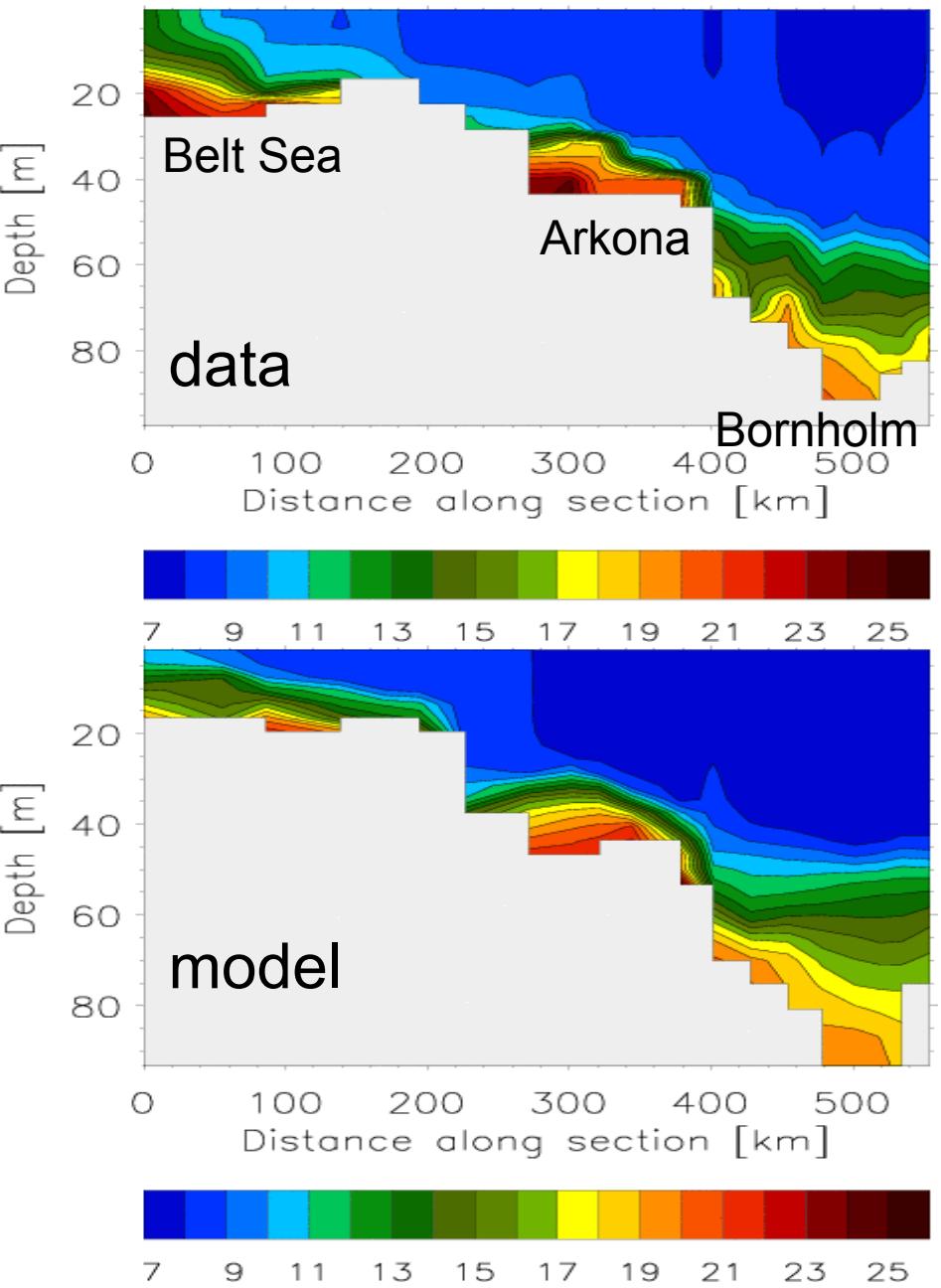
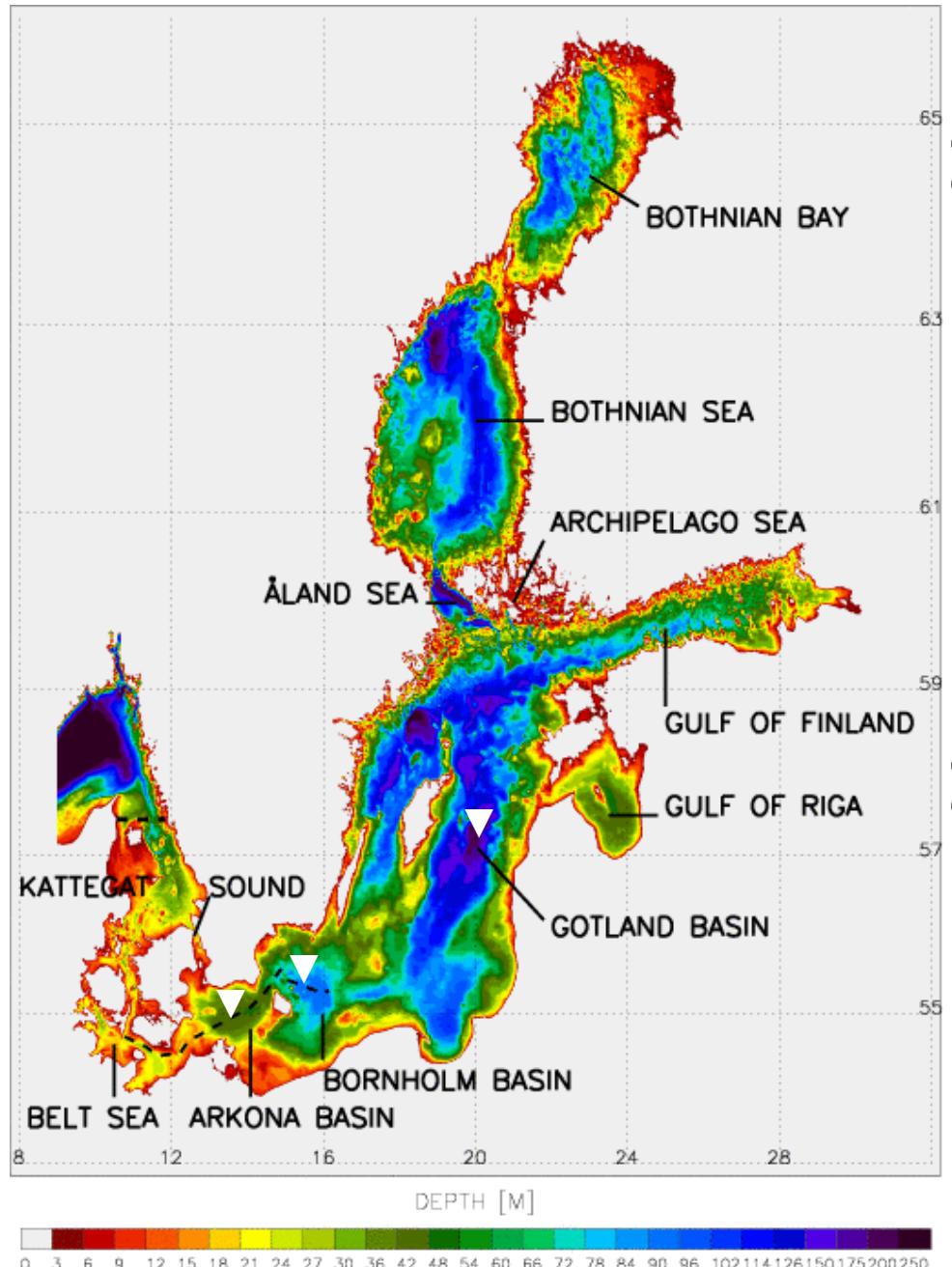


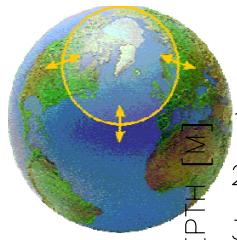
Bornholm Basin



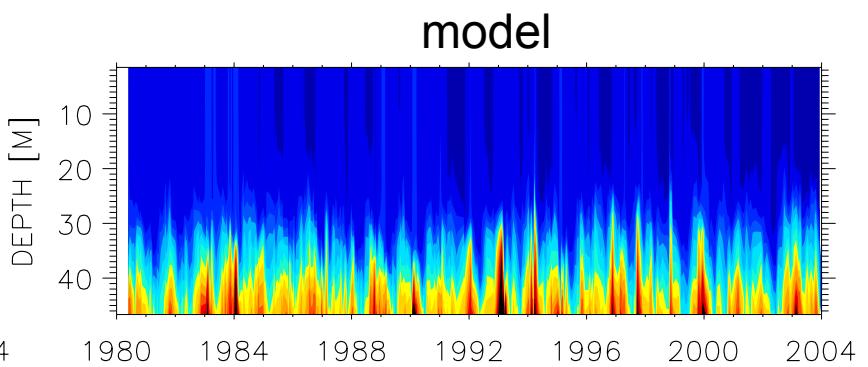
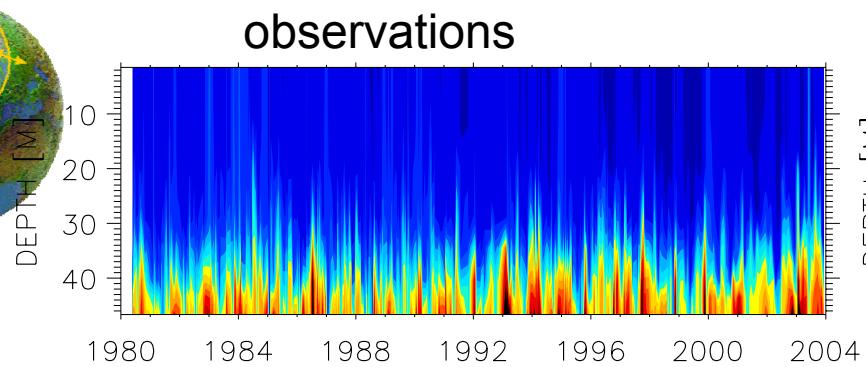
Simulated period
May 1980 – December 1993.

The shaded areas indicate observed natural variability indicated by two standard deviations.

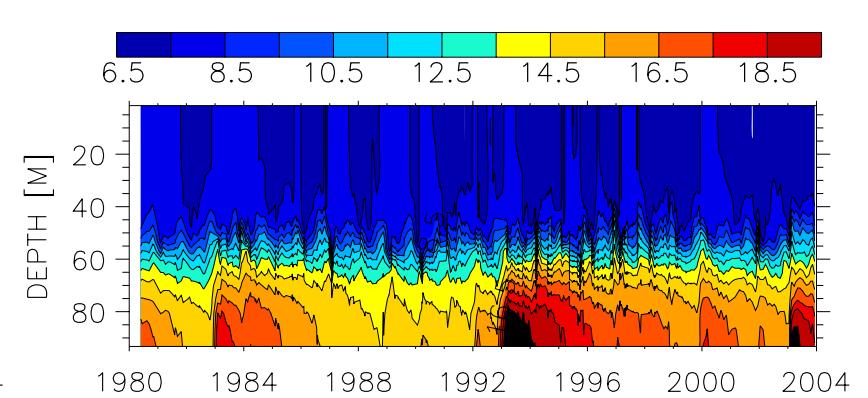
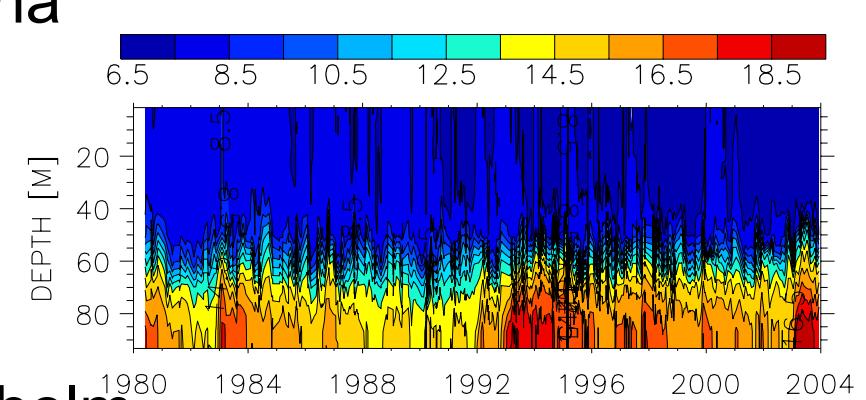




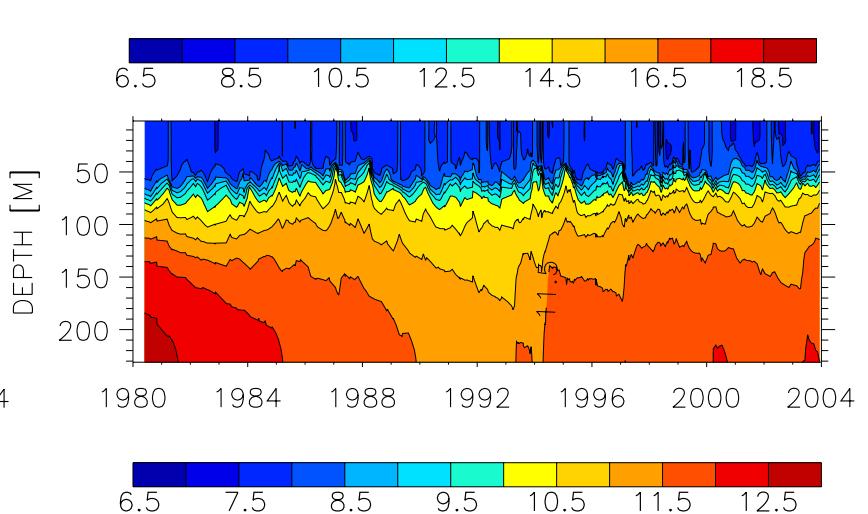
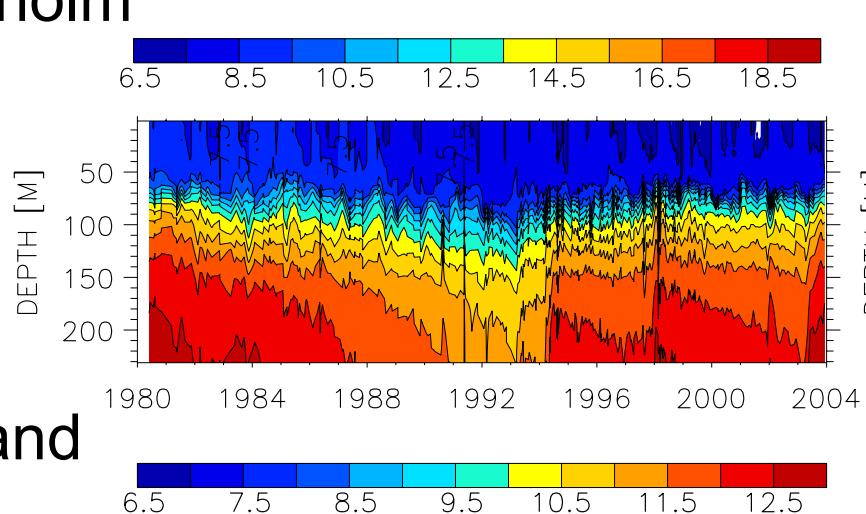
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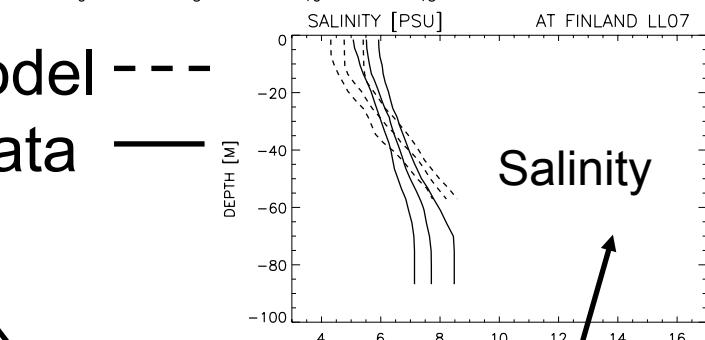
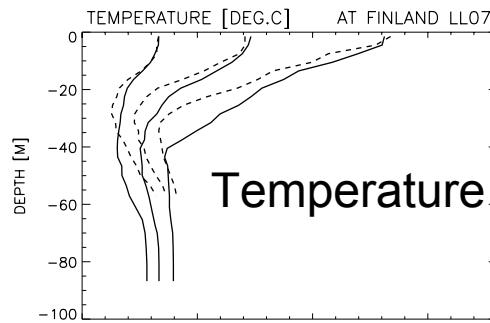
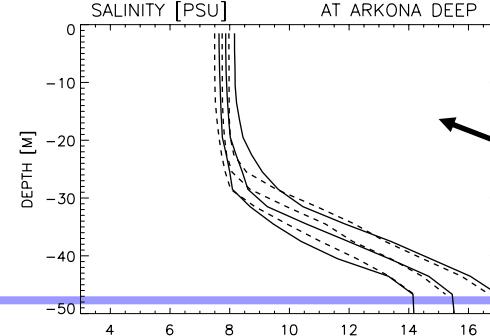
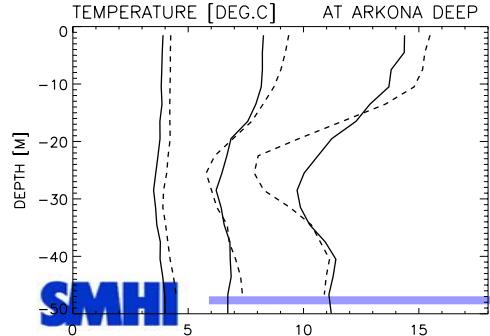
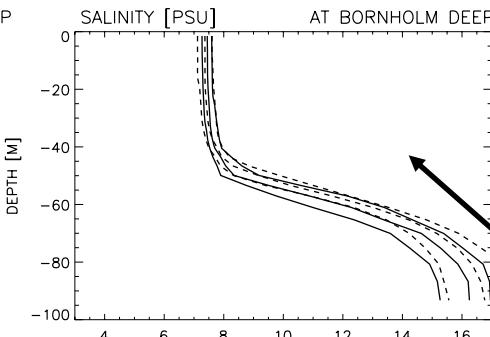
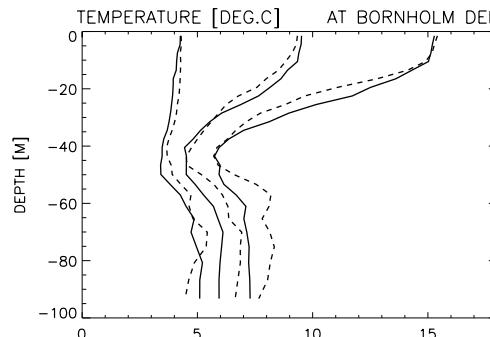
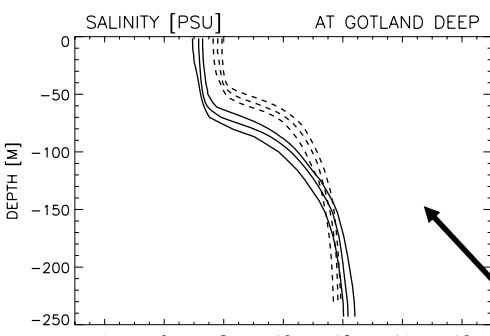
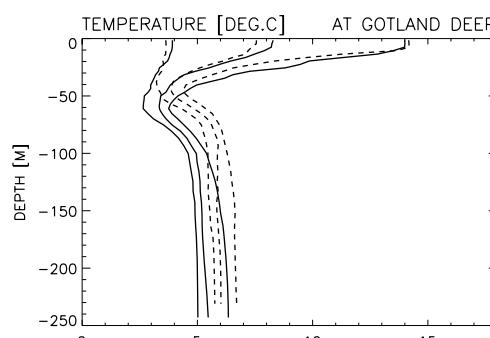
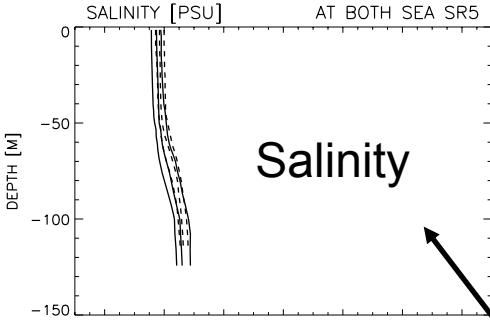
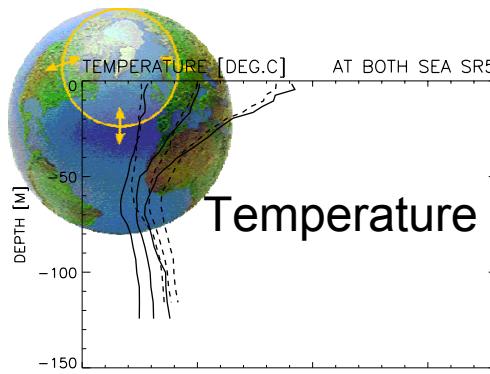


Bornholm

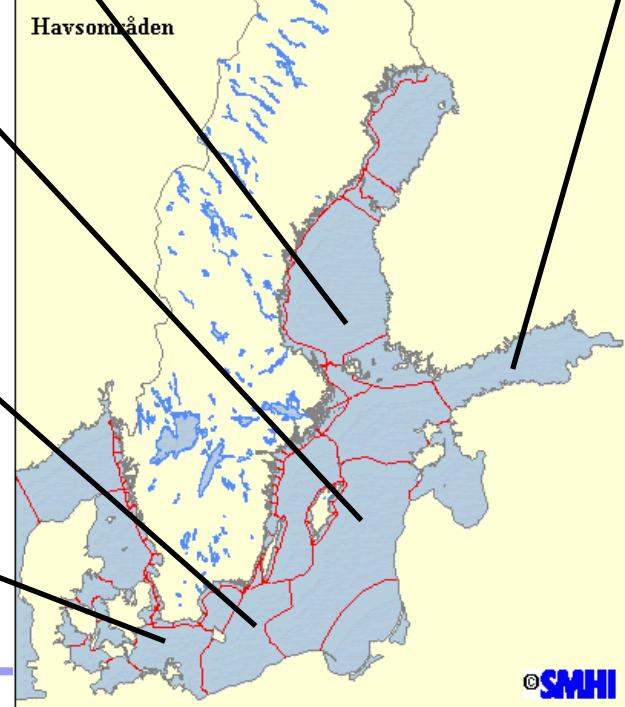


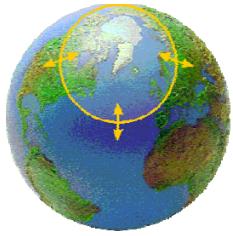
Gotland



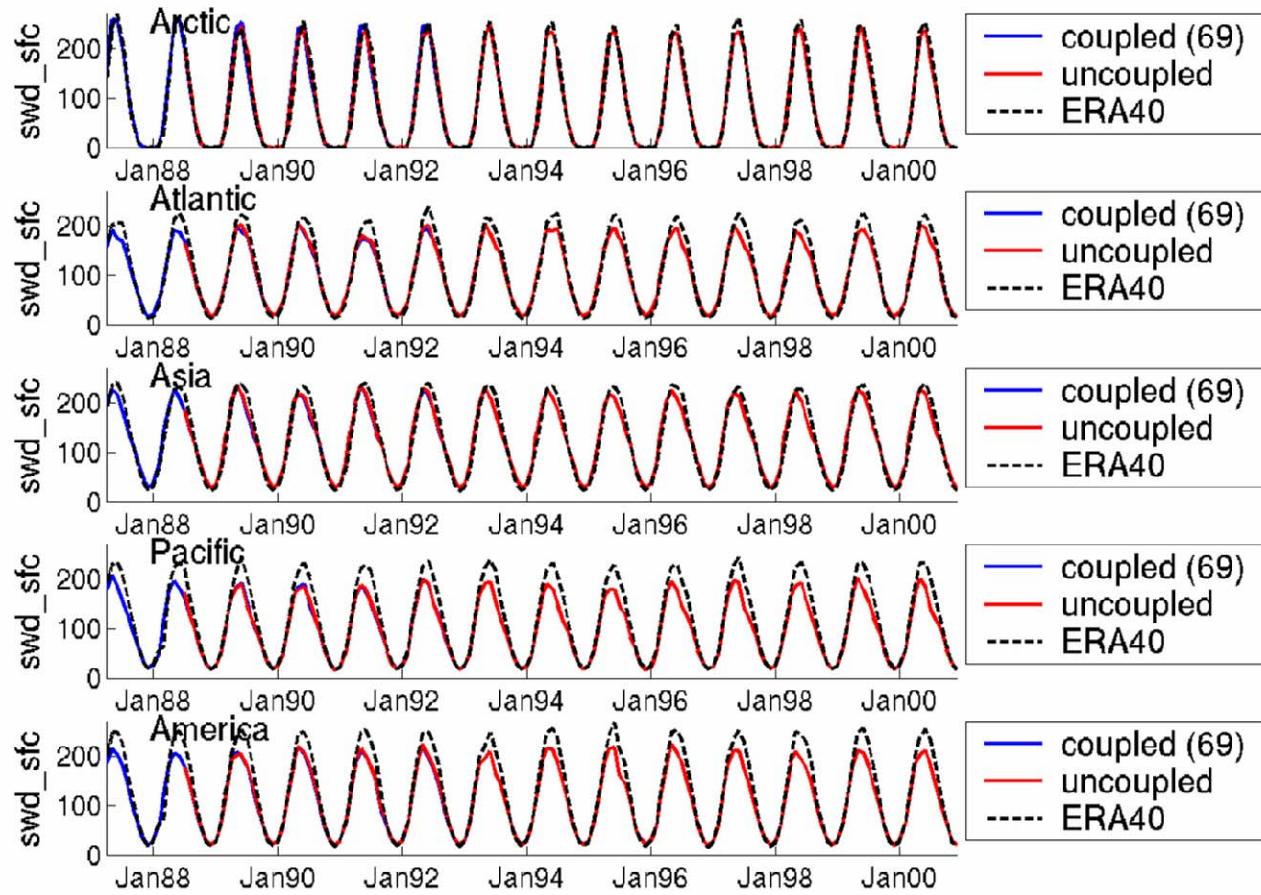


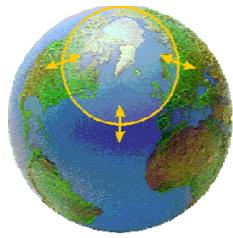
Model ---
Data —





Monthly shortwave radiation





Monthly longwave radiation

