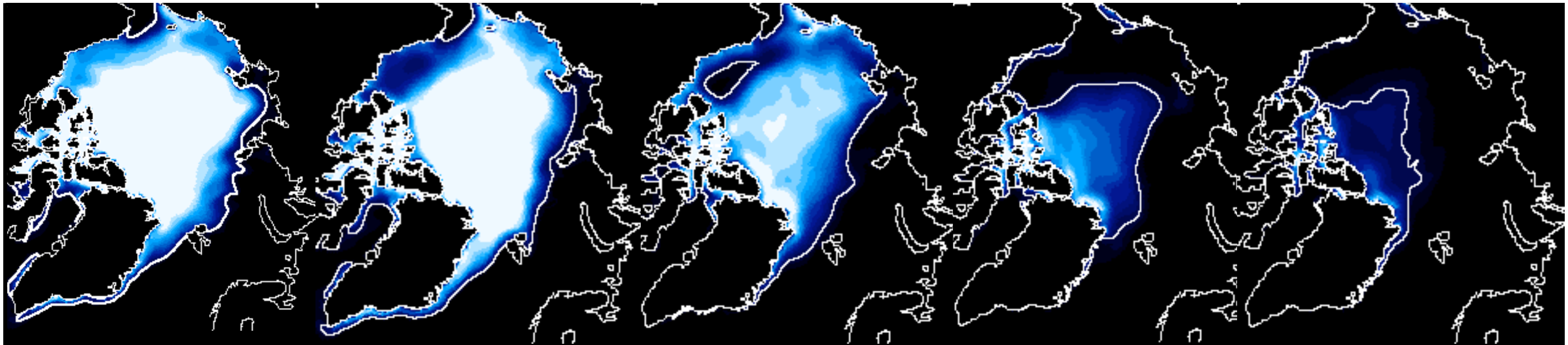
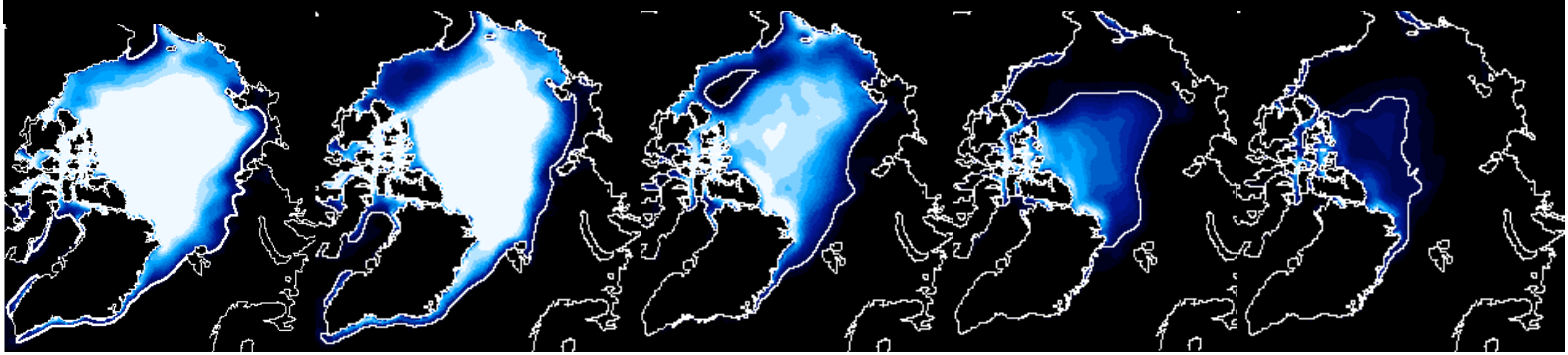


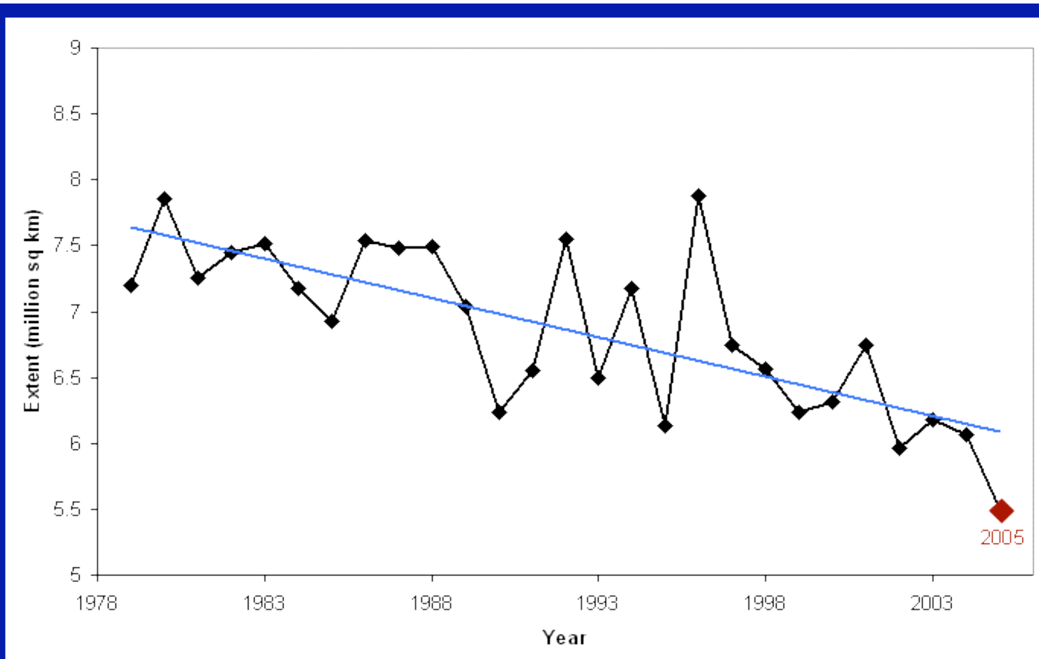
Arctic climate projections and progress towards a new CCSM

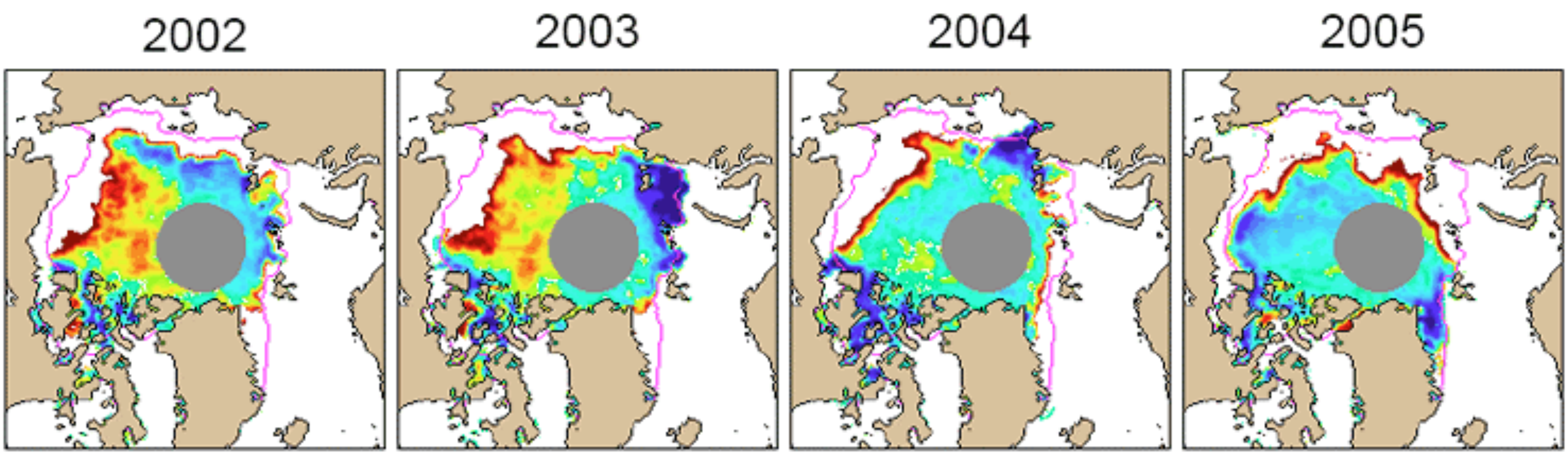
Marika Holland
NCAR



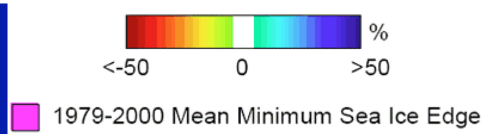
The Arctic is changing!

Loss of Sept Arctic Sea Ice





Loss of about 8% per decade Or >20% since 1979

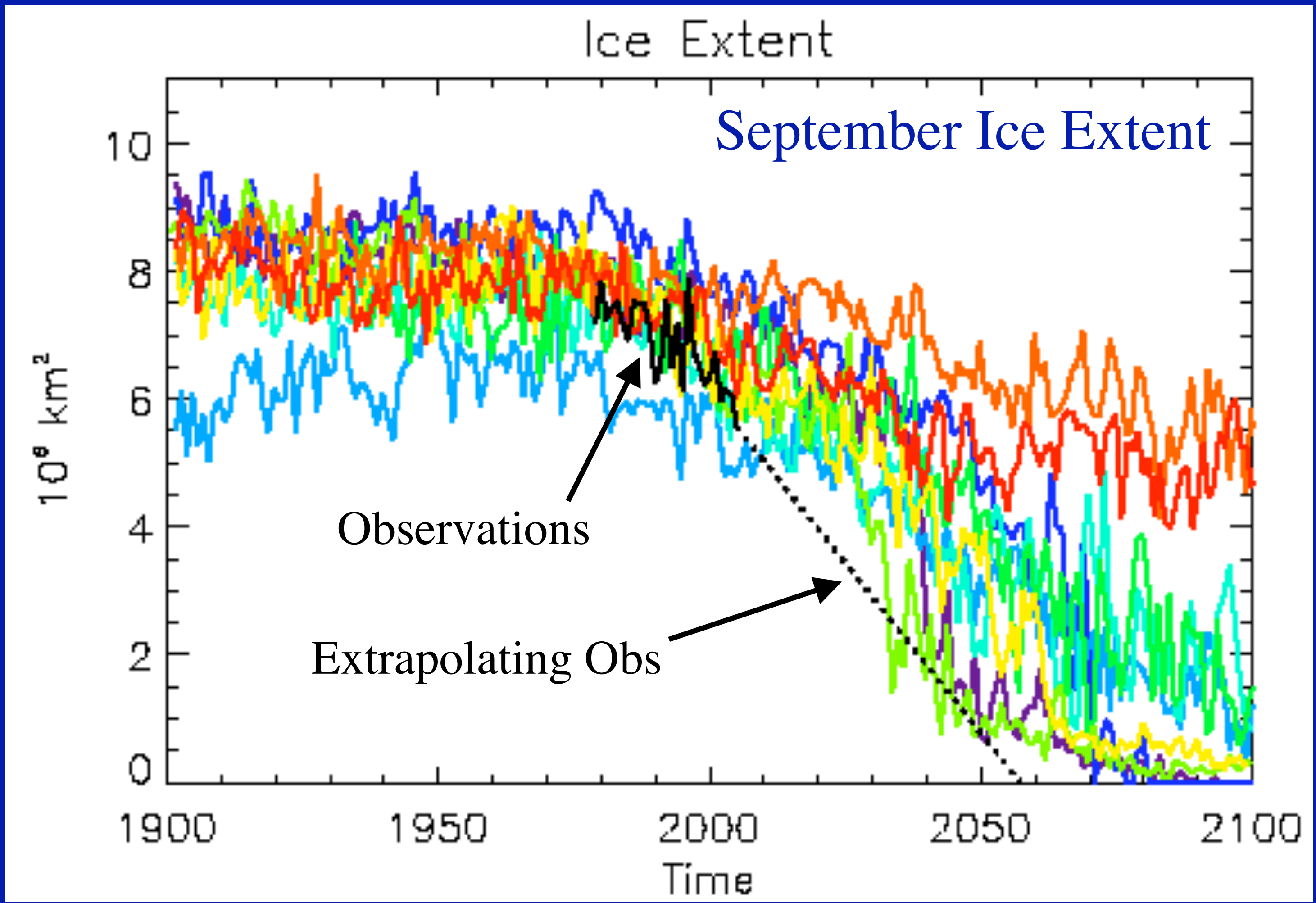


(Courtesy I. Rigor and Stroeve et al. 2005)

What does the near future hold?
Transition to September Ice Free Conditions?

~50% of 17 IPCC AR4 models are ice-free by 2100

Increases if models with unrealistic ice extents are excluded



Why is there large model scatter?

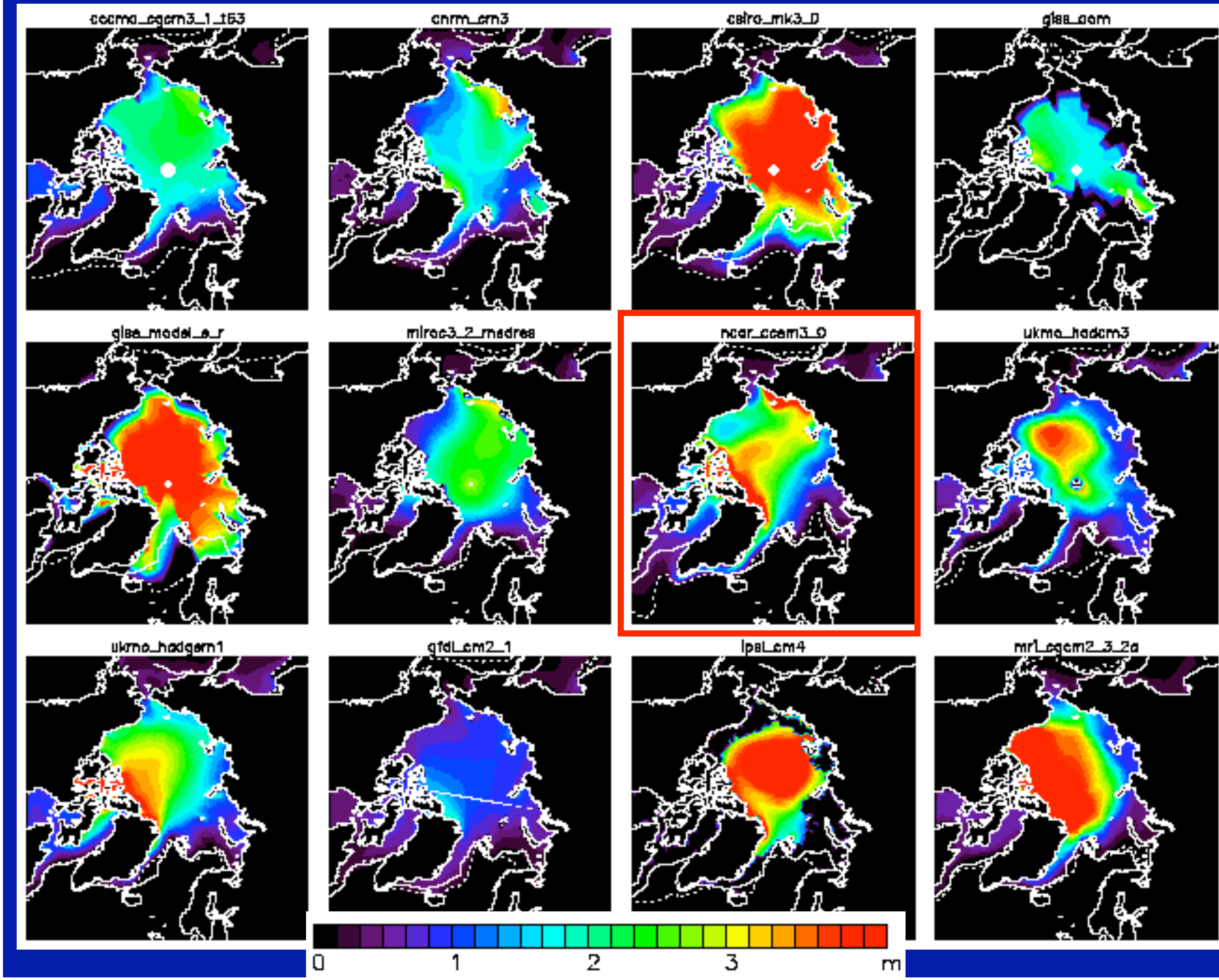
In the models, changes in sea ice largely driven by changing surface heat budgets

Heat budget changes directly affect ice growth/melt and hence, the volume of ice

Changes in September ice extent are related to:

- Initial ice thickness
- Change in ice thickness (and hence changing heat budgets)
- How ice thickness relates to OW production over the melt season

Late 20th Century Simulated Ice Thickness



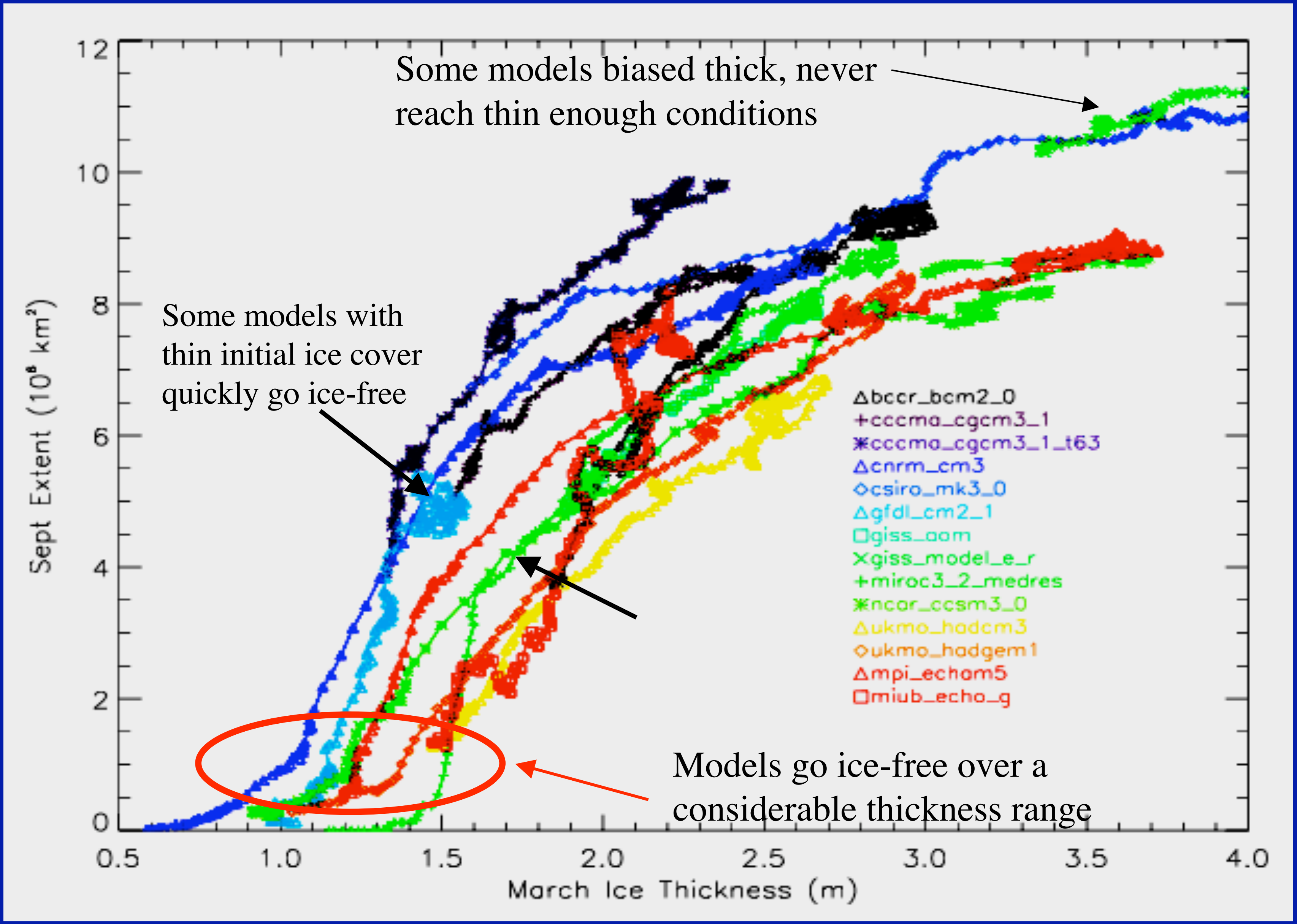
IPCC AR4

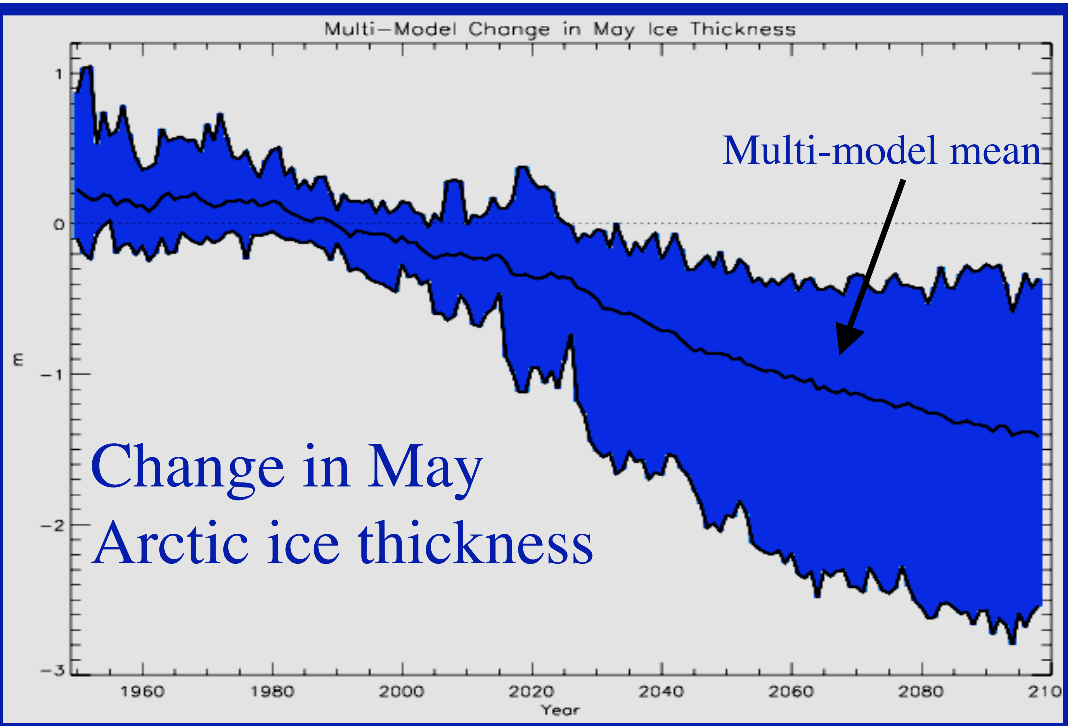
1980-1999 ice thickness

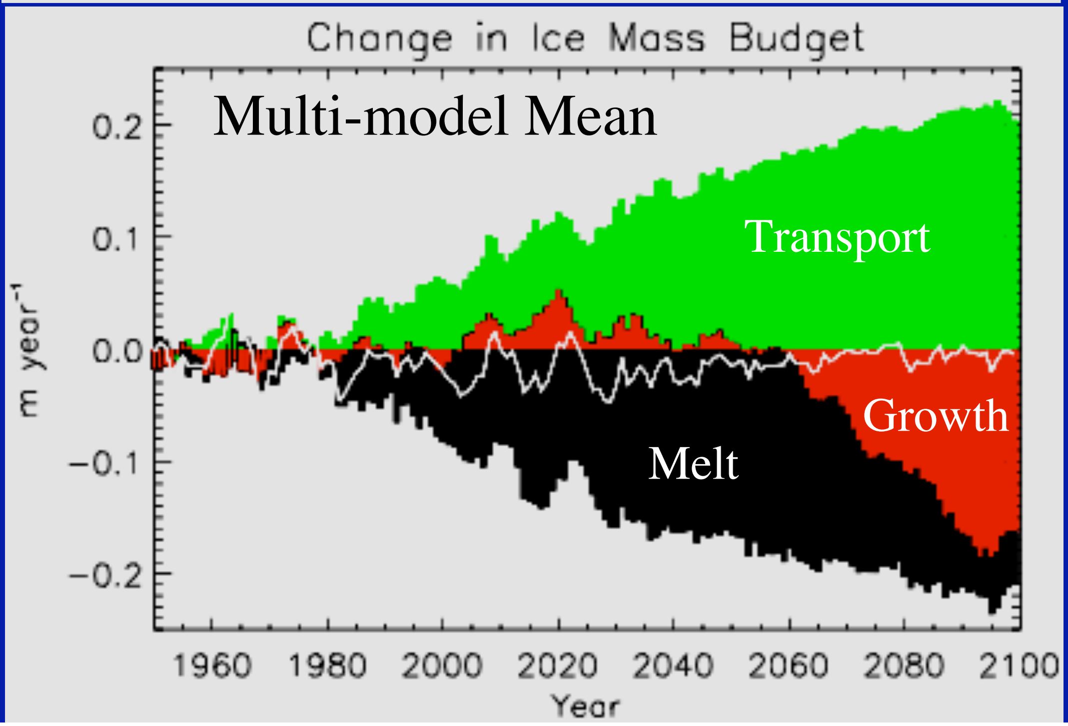
Dashed line=March extent

White line=Obs Extent

Sept Extent evolution as a function of Ice Thickness







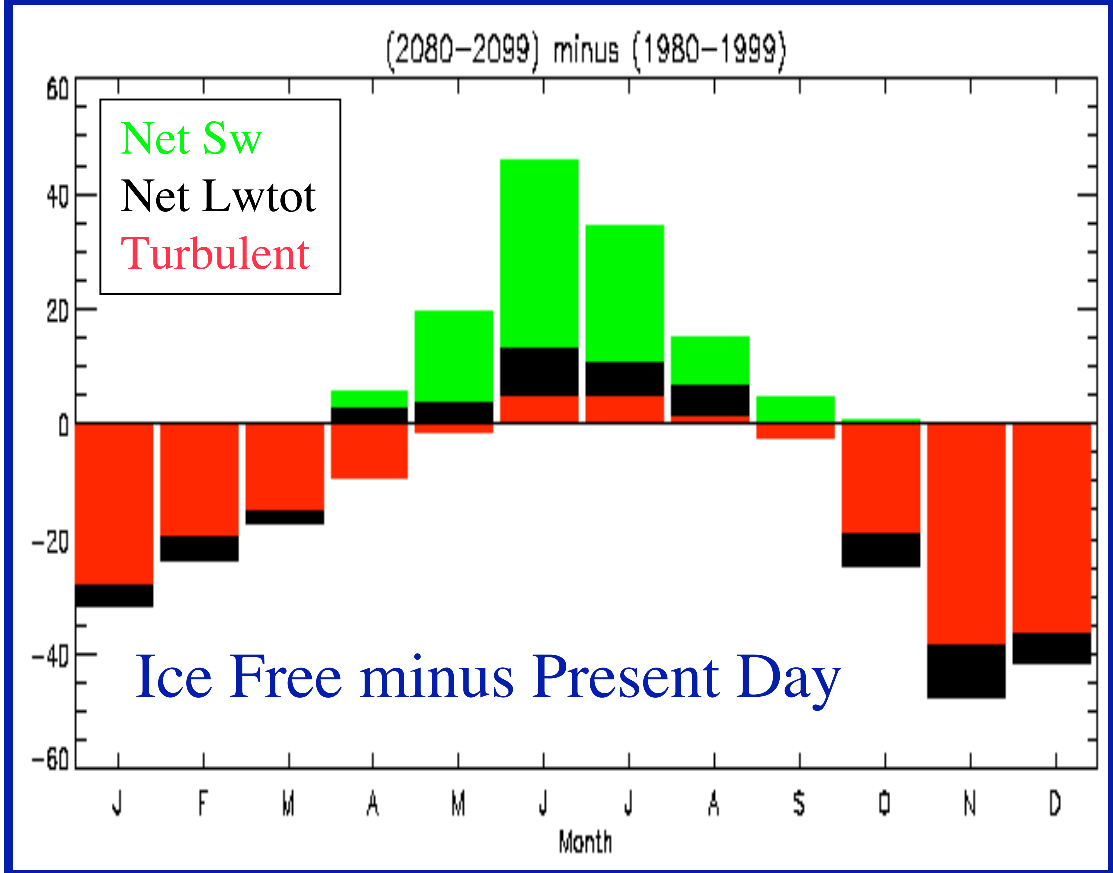
Sea Ice Mass Budget

For multi-model mean

- Increased melt partly compensated by larger growth, reduced transport
- Change in ice mass budget strongly dependent on initial ice thickness (Rmelt=-0.8; Rgrowth=0.7)

Models with thicker initial ice have larger ice volume loss

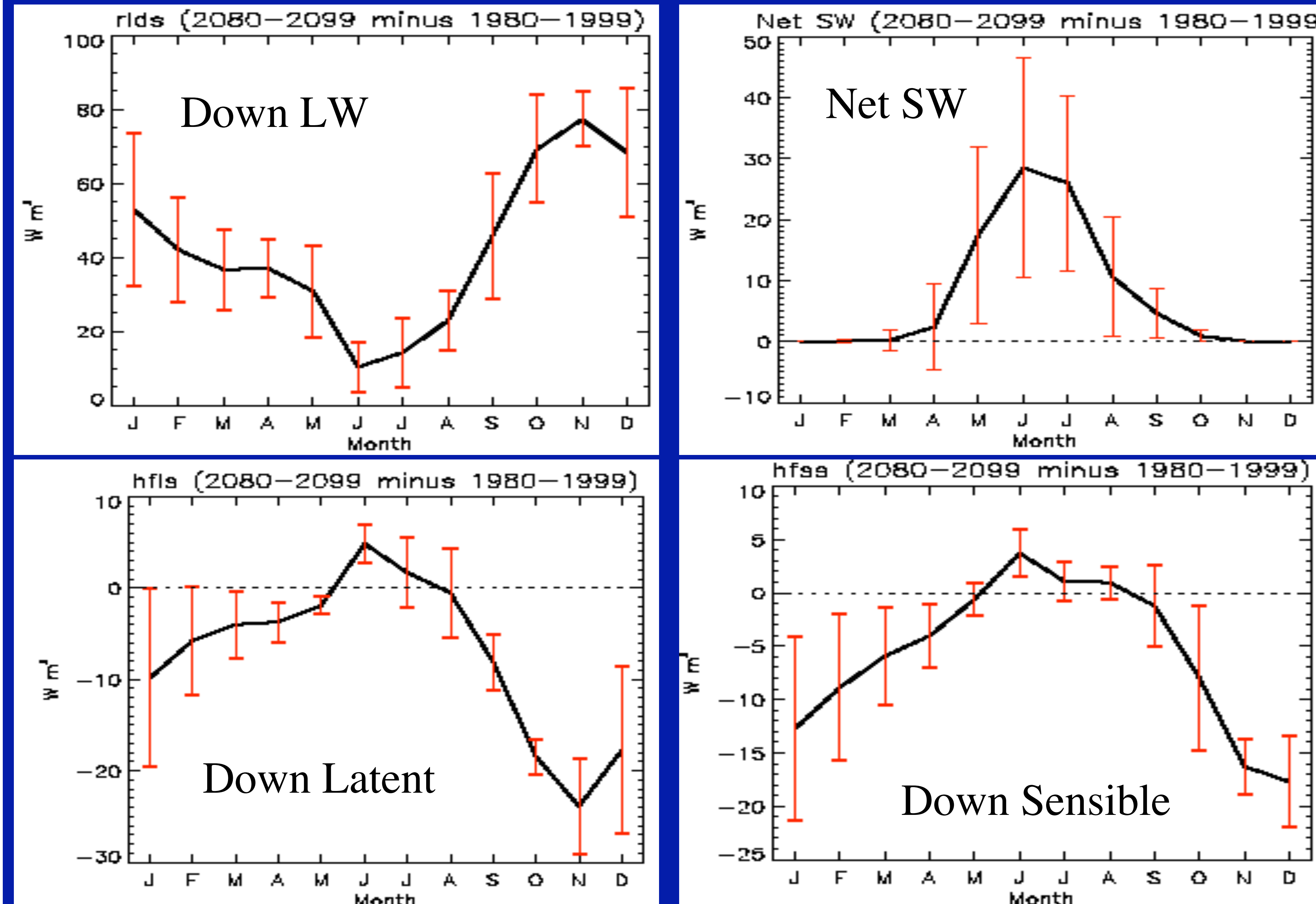
Change in Annual Cycle of Arctic Surface Heat Budget



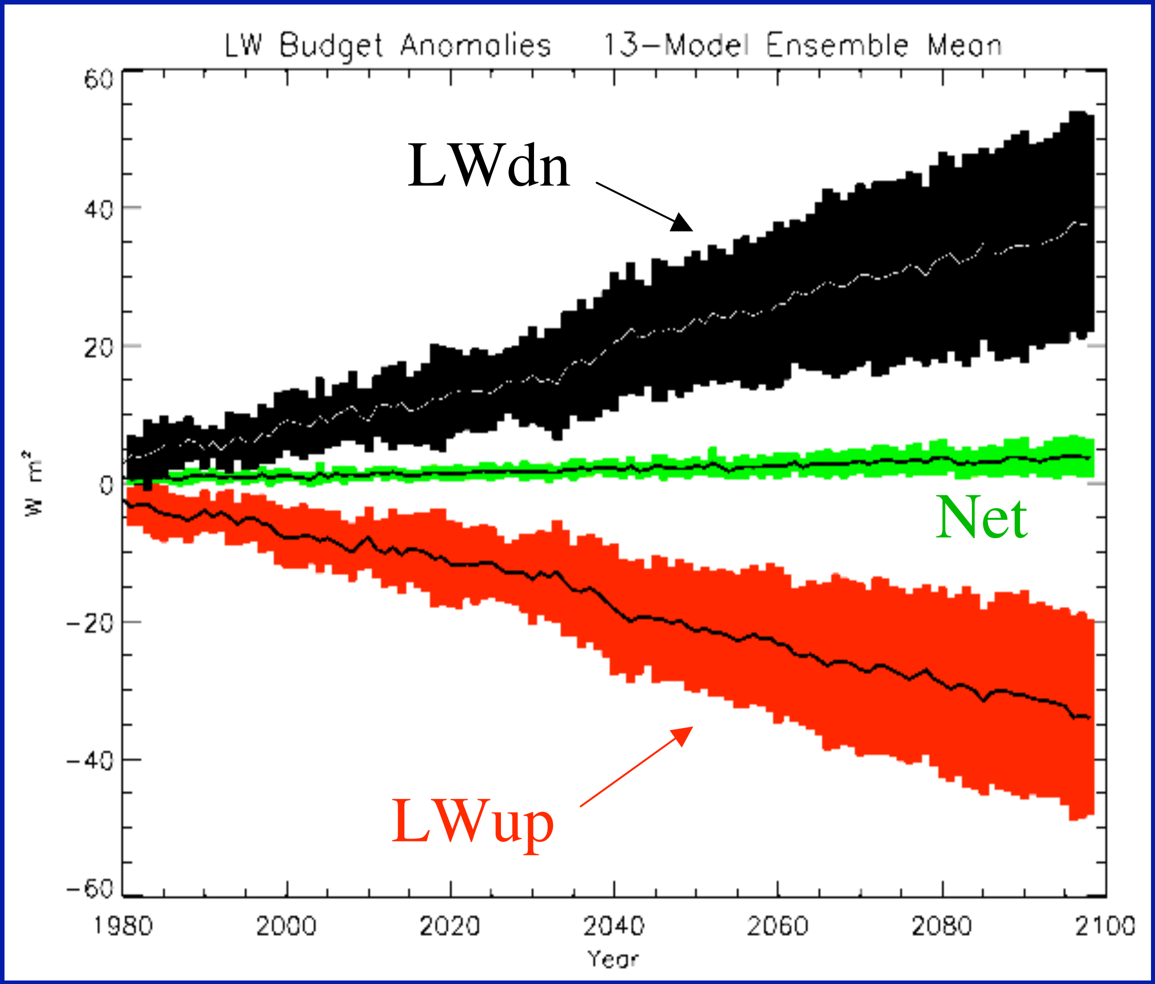
Annual cycle changes

- Surface gains more heat in summer
  - Goes to melting ice/warming ocean
- Surface loses more heat during winter
- Models have similar qualitative behavior, but differ in magnitude, timing

Magnitude of changes differs considerably



Changing Surface Longwave Fluxes



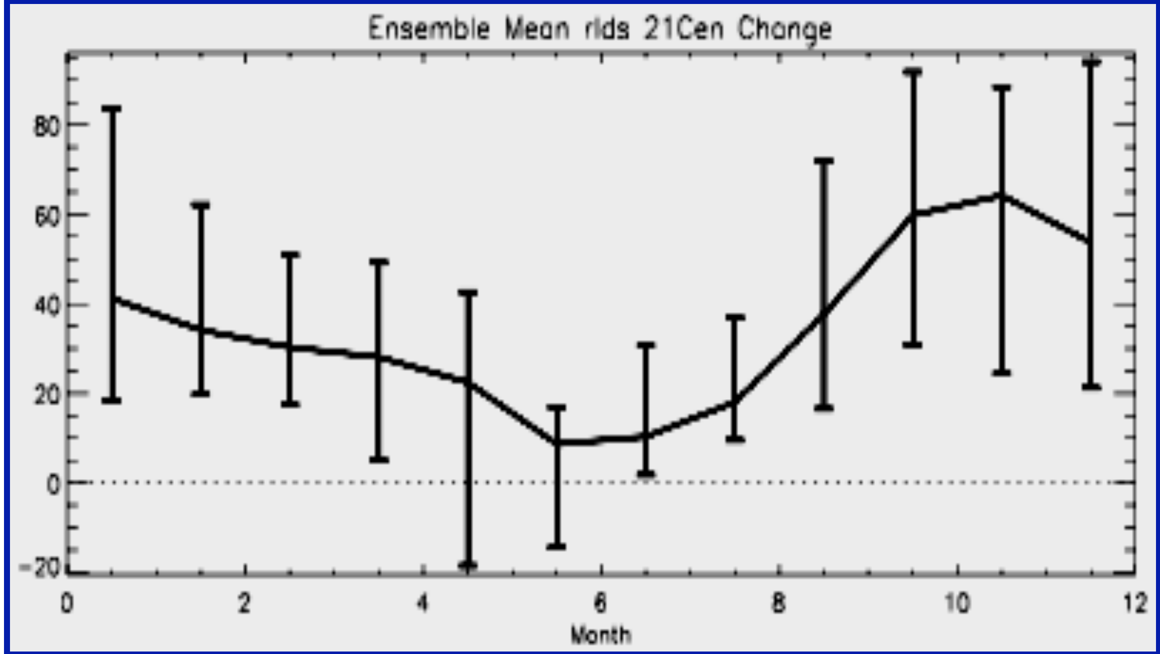
Small net change due to

Increased LWdn By 2100, Ann avg change varies by 30 W/m2 across models

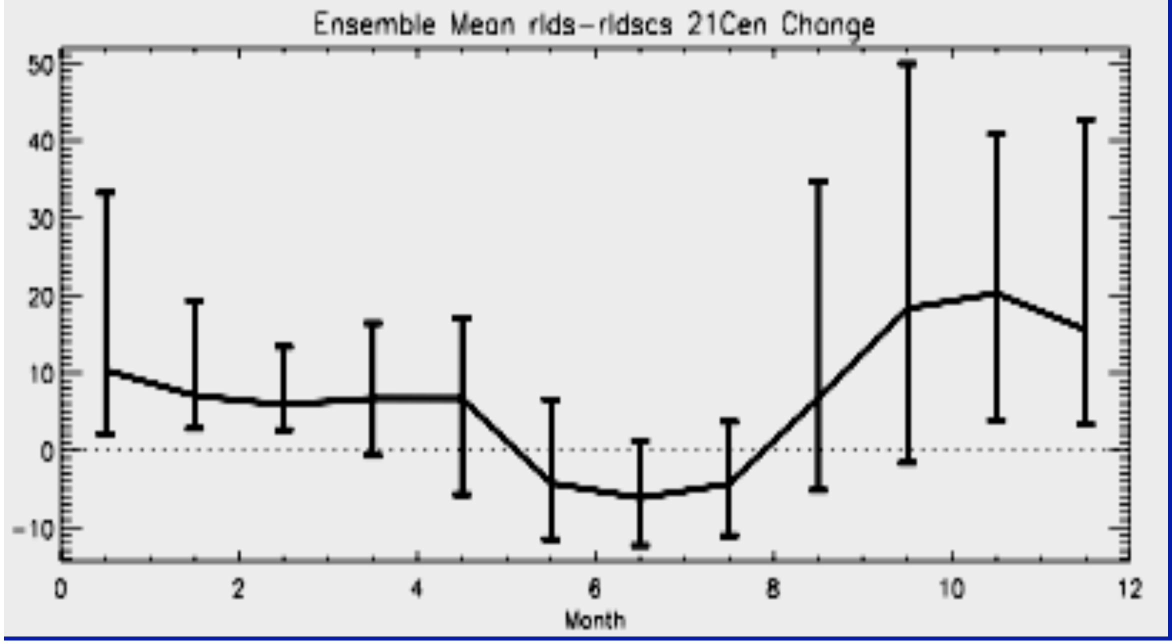
Offset by increasing LWup as the surface warms

LWdn increase partly due to increases in LW cloud forcing

Influence of clouds for changing LWdn



Change in monthly LWdn by end of 21st century

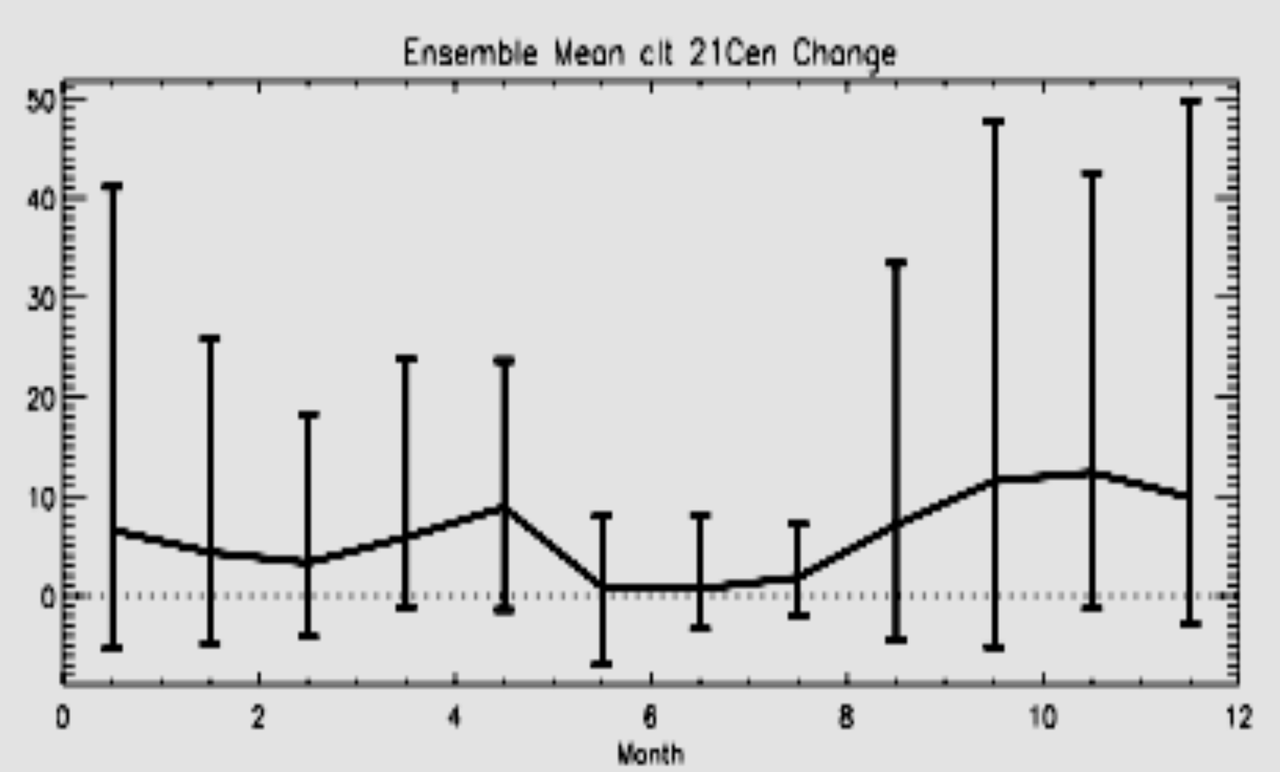


ΔLWCF at surface

Explains a fraction of the LWdn change.

ΔLWCF highly correlated to Δclt in May,June,Sept,Oct

Arctic Cloud changes



(non-summer) Cloud cover changes

- vary dramatically across models (-5 to +40% in Jan),
- Changes are highly related to initial cloud cover
- models with low initial cloud cover have larger cloud cover changes.

Projected Arctic change quite dependent on present day simulation

Ice area response affected by initial ice thickness

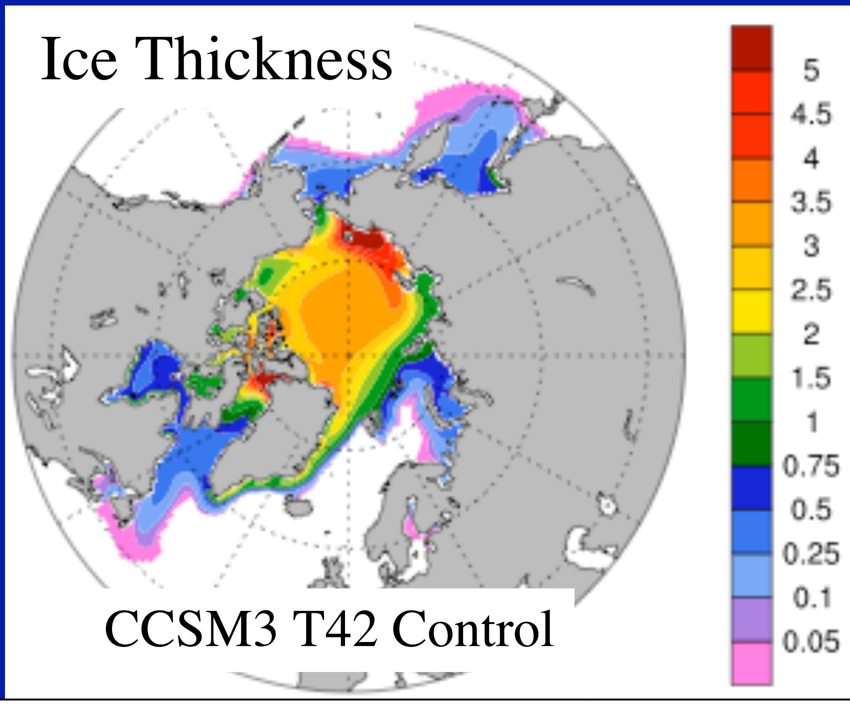
Changes in ice melt/growth depend on initial ice thickness

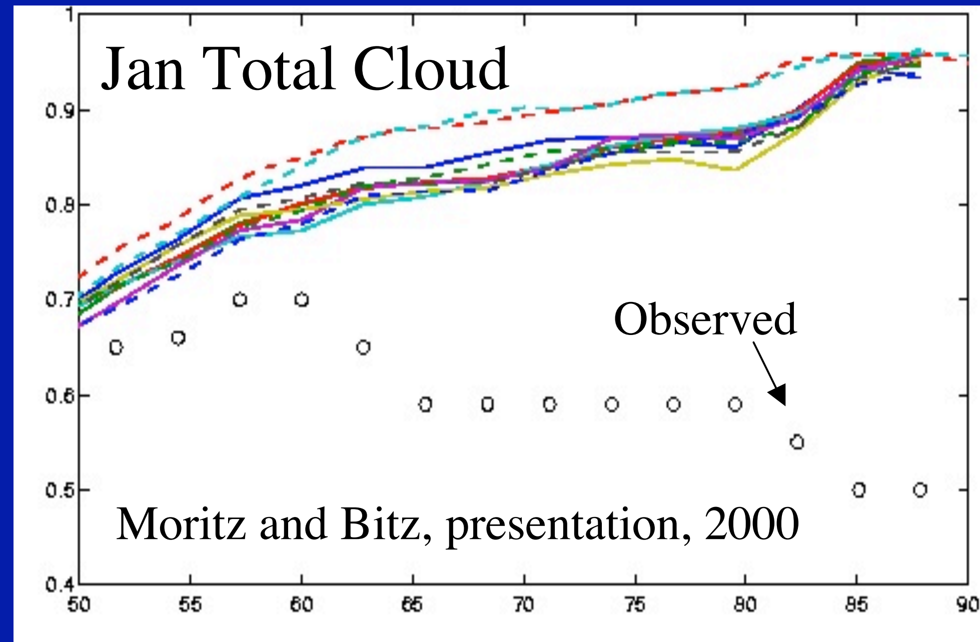
Changes in cloud cover (and consequent effects on changing radiative fluxes) depend on initial cloud conditions

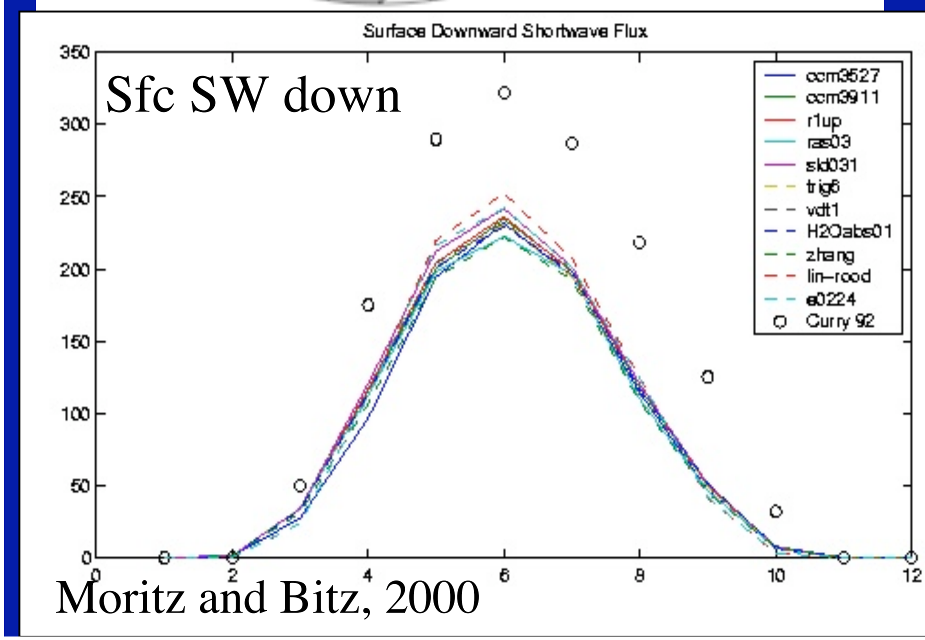
Results are consistent with studies using earlier models

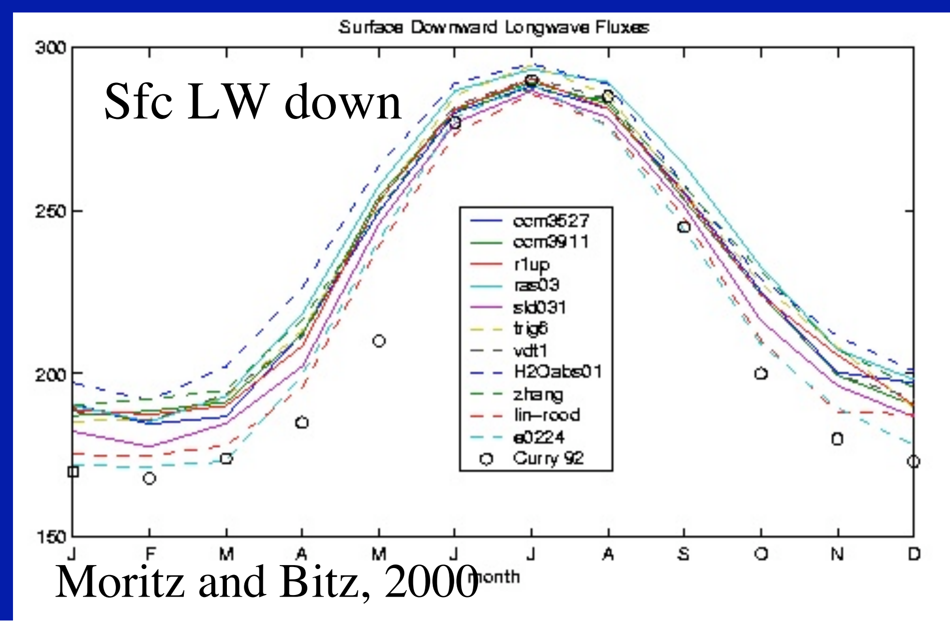
In order to improve projections of Arctic climate, it is important to improve the present day polar simulations

Long-standing Arctic biases in CCSM









An interim step forward - CCSM3.5

Ice model: CICE4.0, SE enhancements, improved ridging, improved snow treatment

Ocean Model: near sfc eddy flux scheme, reduced viscosity, 60 levels

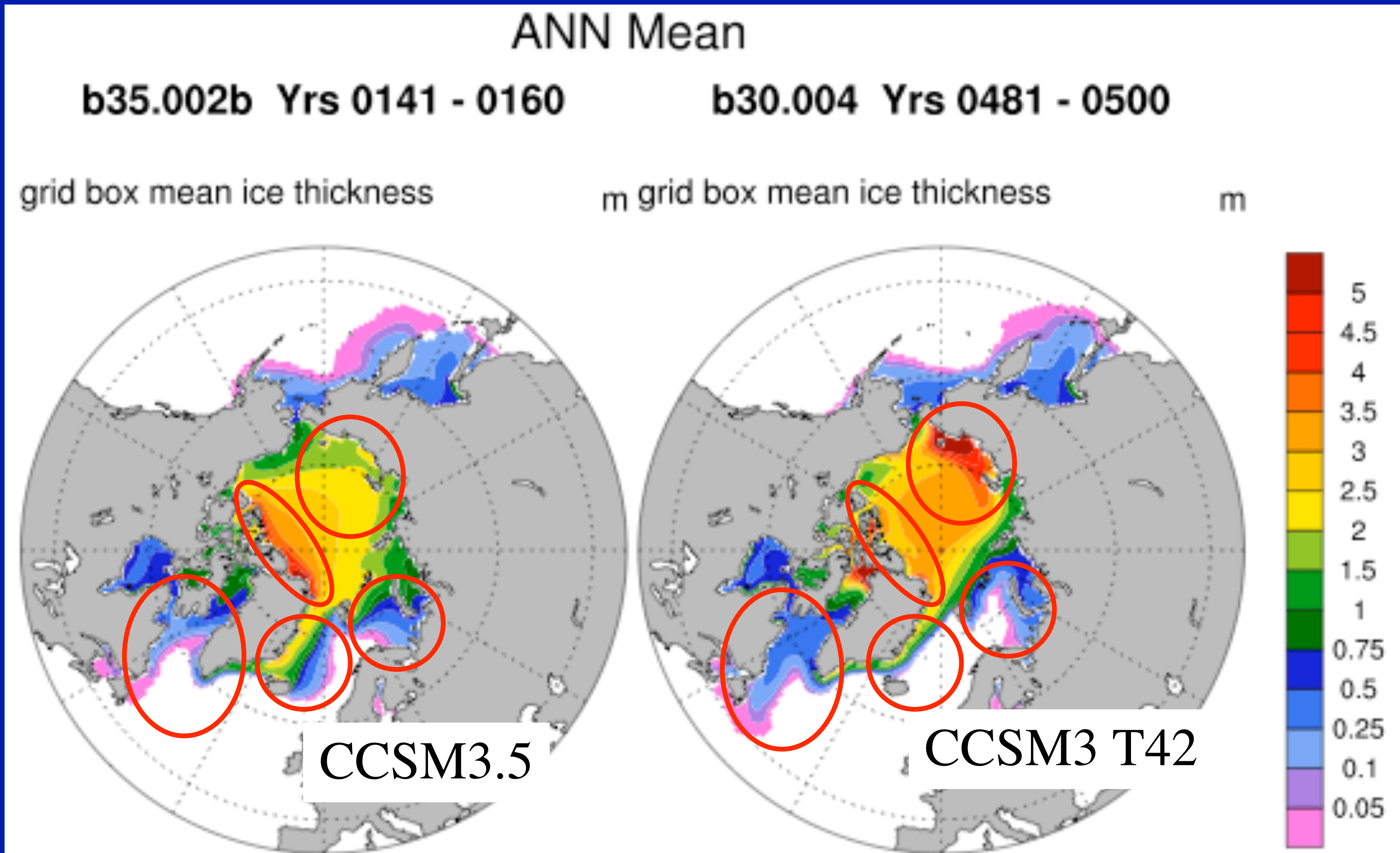
Atmospheric Model: FV dynamical core (1.9x2.5), deep convection modifications, polar cloud changes (thanks largely to Steve Vavrus)

Land Model: improved hydrology, new sfc datasets, other modifications

Purpose: Tuning, BGC Spin Up

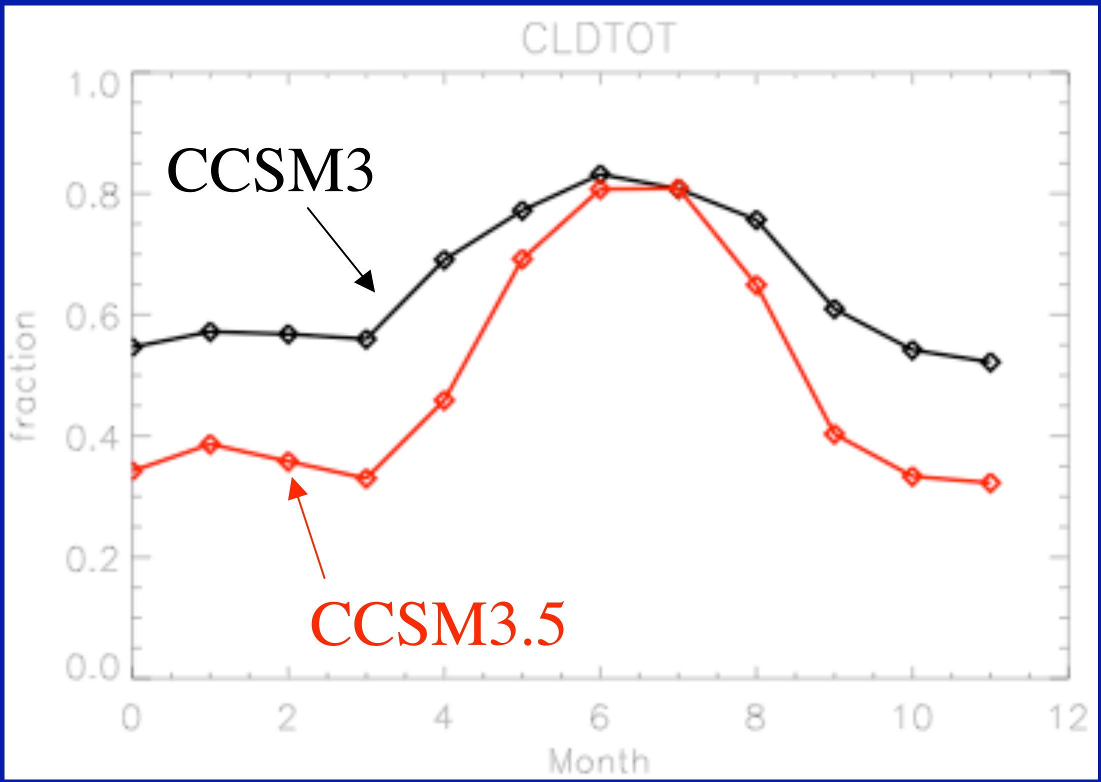
Additional changes underway for CCSM4

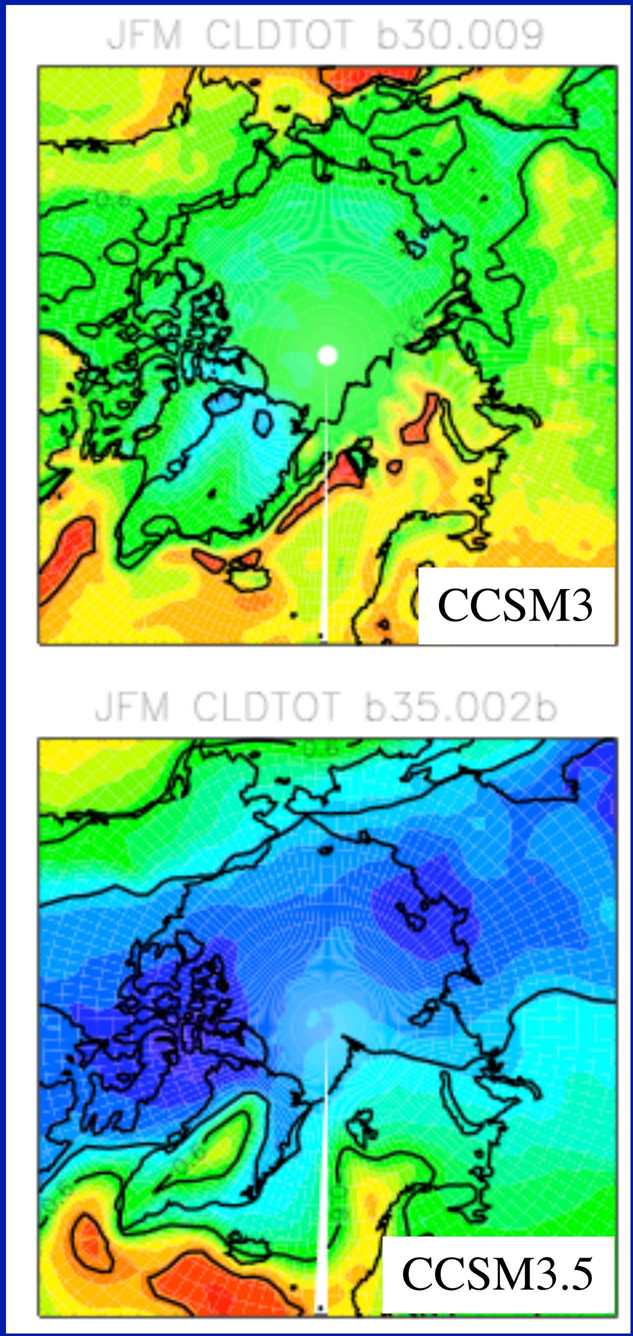
An interim step forward
CCSM3.5

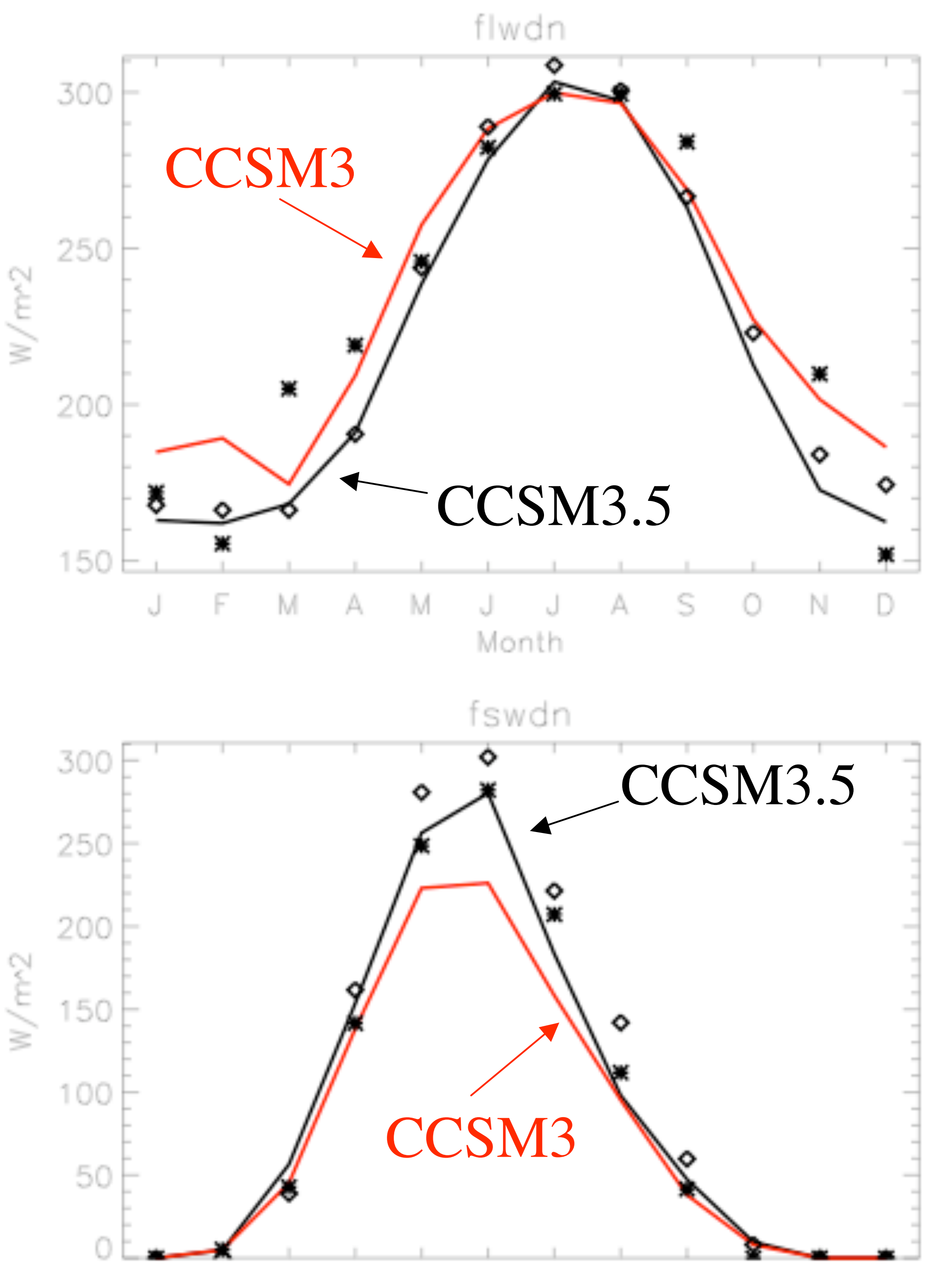


Arctic Sea Ice Thickness

CCSM3.5 Arctic Clouds







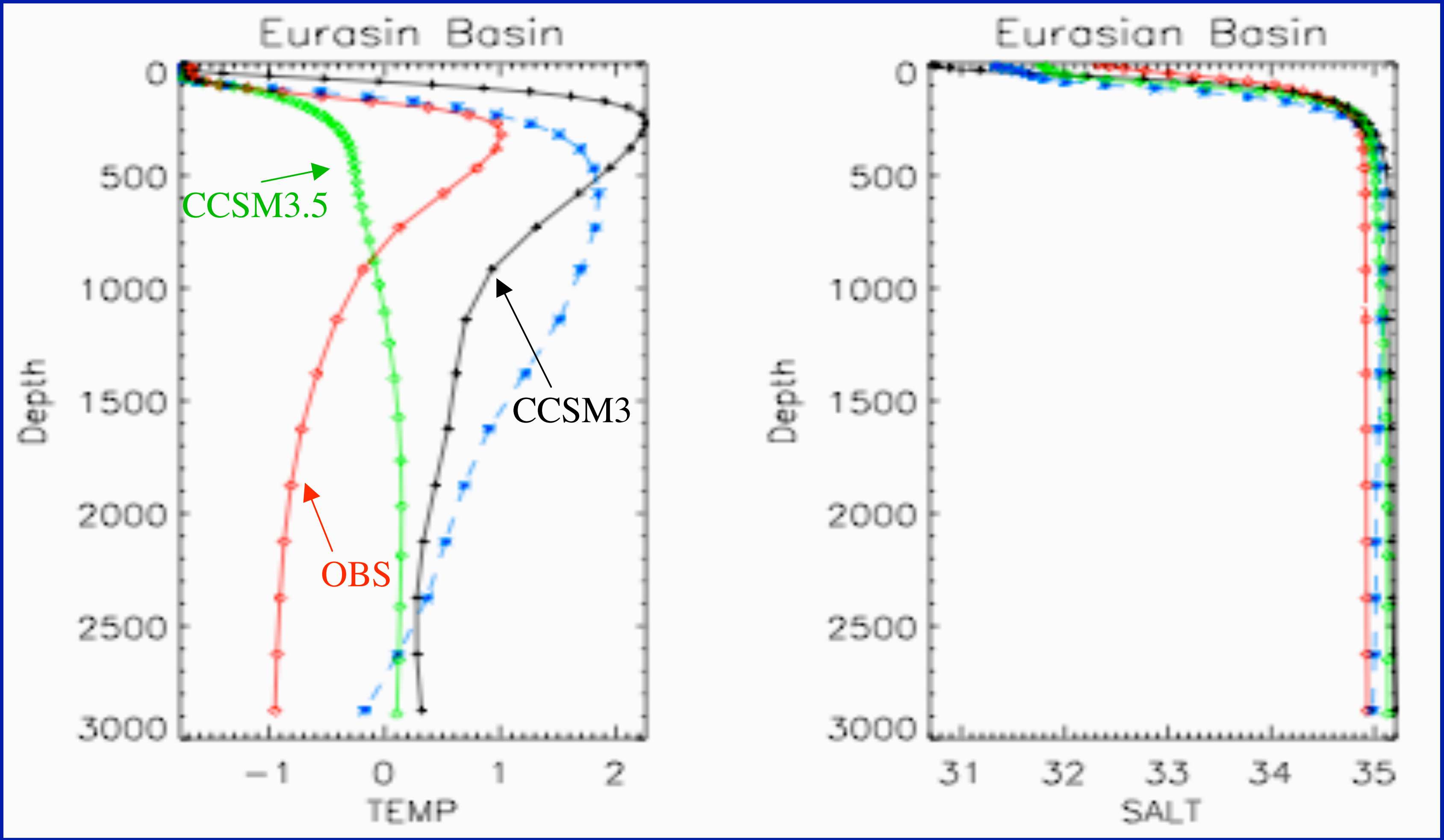
CCSM3.5 Arctic Surface Radiation

Values shown for a "SHEBA location" 20-yr climatology

*=SHEBA data

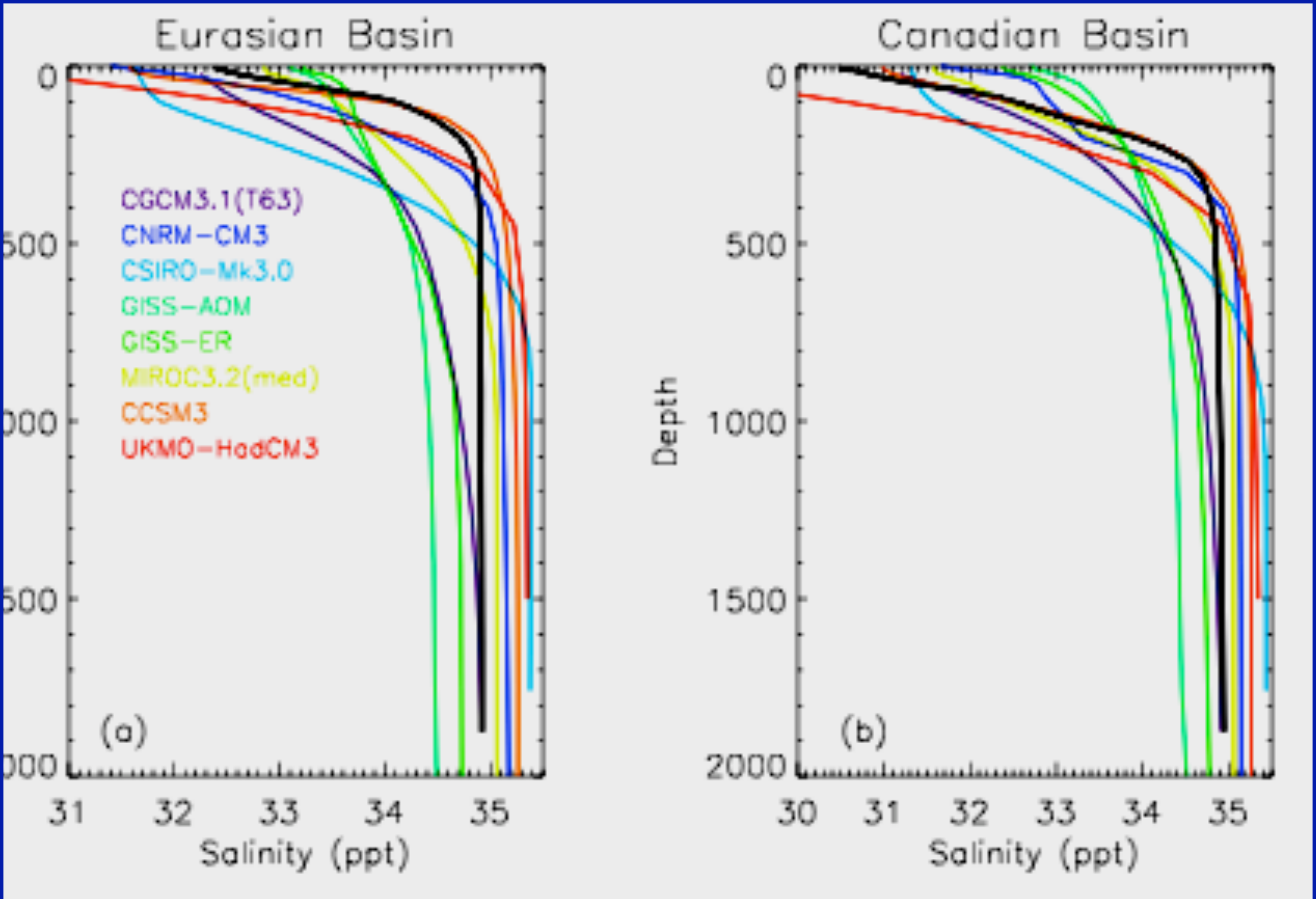
Diamonds=other observations

Not all good news - Arctic Ocn Profiles



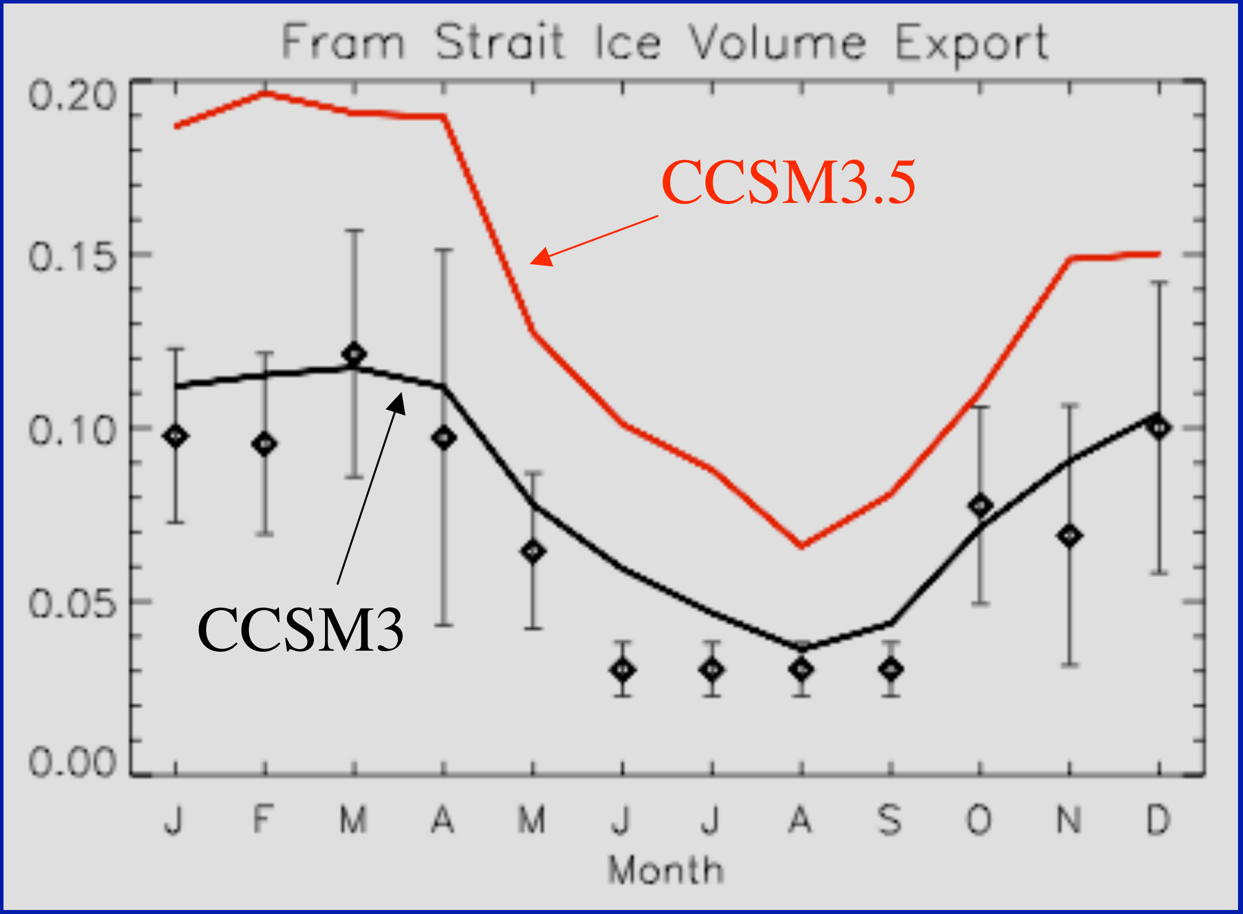
Distinct Atlantic layer missing in CCSM3.5 Runs.
Does not appear to be related to ocn or ice model changes
Considerable cooling of waters at depth compared to CCSM3
Salinity profiles still look quite good.

Ocean conditions



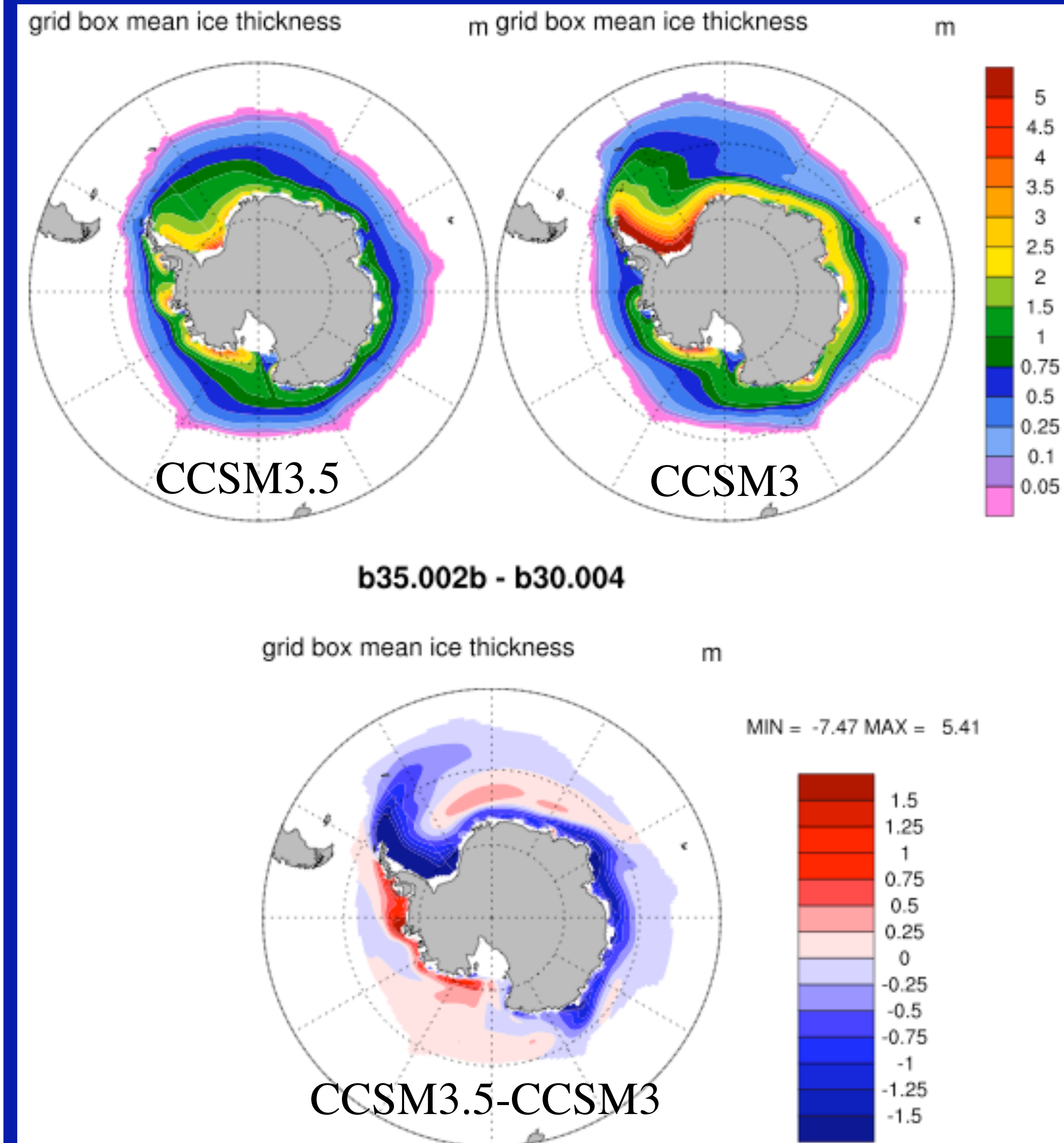
Simulated Salinity Profiles - large differences in strength of halocline, properties of Atlantic layer among models.

Fram Strait Ice Transport



Fram Strait ice transport appears quite high in CCSM3.5 Run

Perhaps related to excessive ice in GIN Seas and cold Atlantic waters within Arctic?

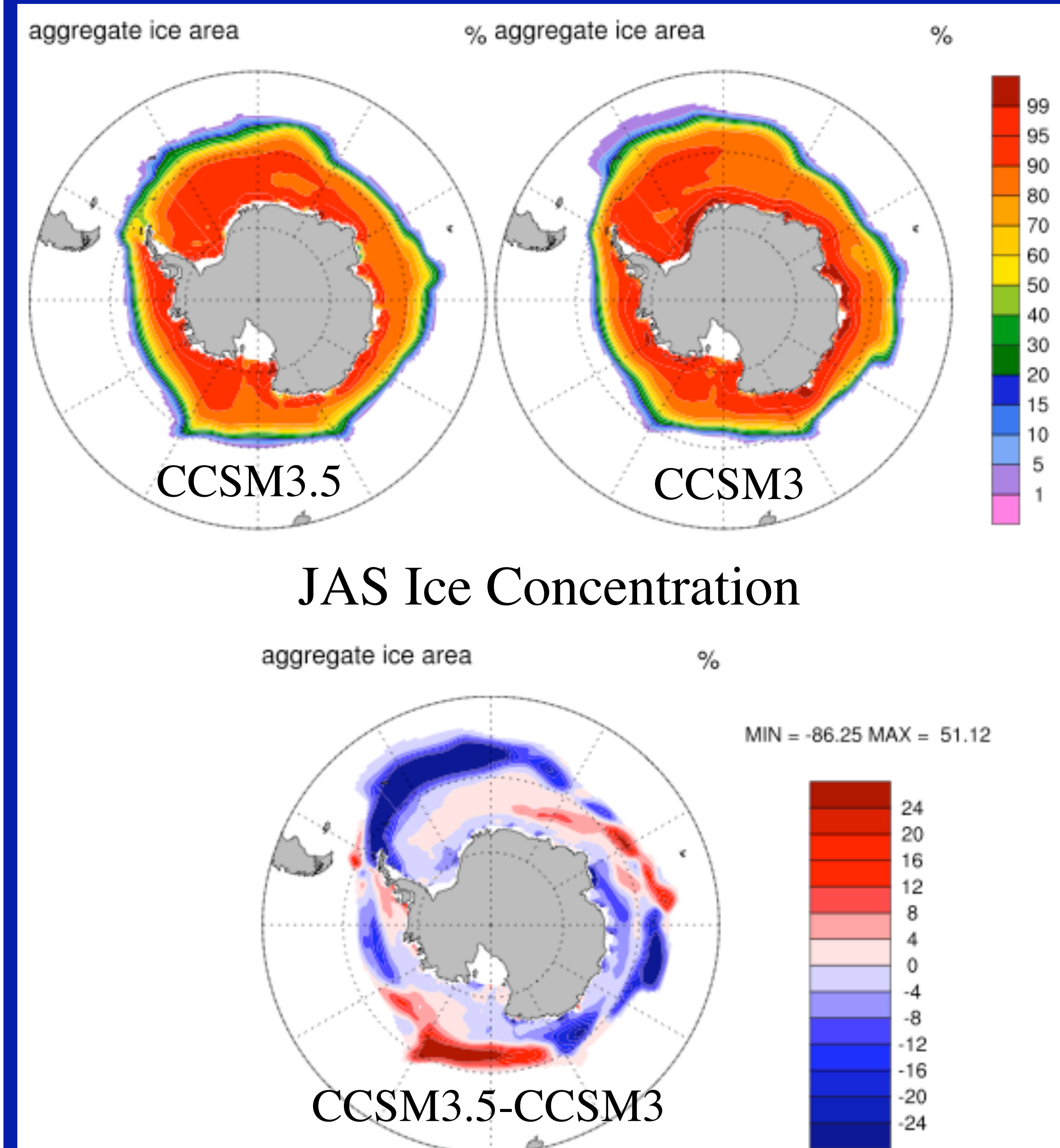


CCSM3.5 Antarctic Sea Ice

Generally improved

Thinner Weddell Sea ice

Less Extensive in Atlantic sector



CCSM3.5 Antarctic Sea Ice

Generally improved

Thinner Weddell Sea ice

Less Extensive in Atlantic sector

Conclusions

Arctic climate projections vary widely among models and are quite dependent on present day simulated state

CCSM3.5, an interim step forward in model development, improves a number of long-standing Arctic biases

- Arctic ice thickness distribution, Labrador Sea ice conditions
- Arctic cloud and radiation biases

Some aspects of the simulations still require work

CCSM3.5 also shows improved Antarctic sea ice thickness and extent

Development is underway for the CCSM4