

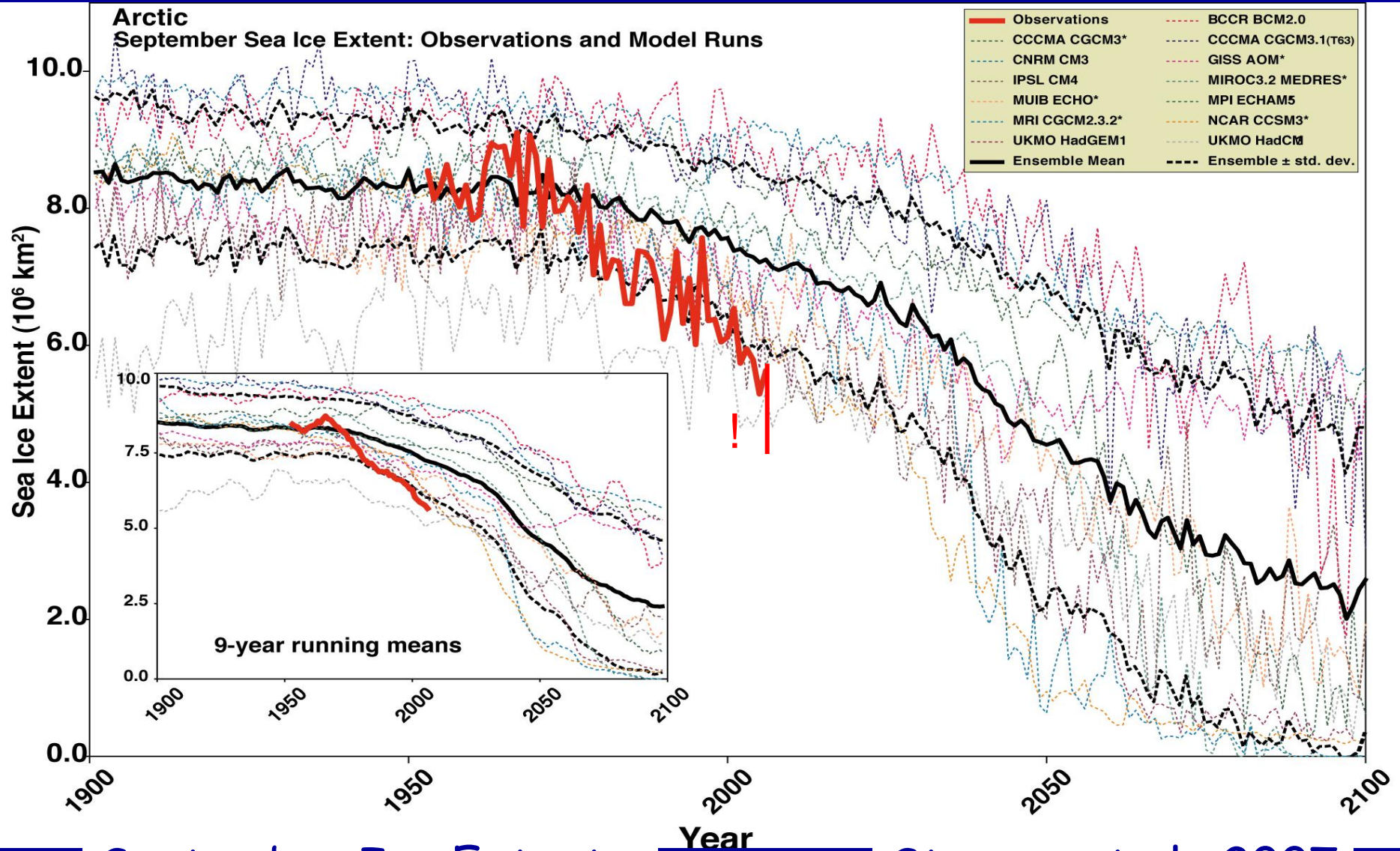
# Arctic Sea Ice Mass Budgets

We report, you decide.

Marika Holland  
NCAR



# Projected September Arctic Extent



September Ice Extent

Stroeve et al., 2007

# What causes the wide scatter in Arctic ice loss among models?

- Assess sea ice mass budgets across models
- Examine role of changing surface heat exchange
- Examine how changing mass budgets translate into inter-model scatter in September ice extent

# Assessing IPCC Mass Budgets

$$\frac{d\bar{h}}{dt} = \Gamma_h - \nabla \cdot (\vec{u}h)$$

Ice volume  
change

Thermodynamic  
source

Divergence

IPCC archive has: monthly averaged ice thickness, velocity

For 14 models, assess Arctic mean ice volume, transport through straits that define Arctic domain

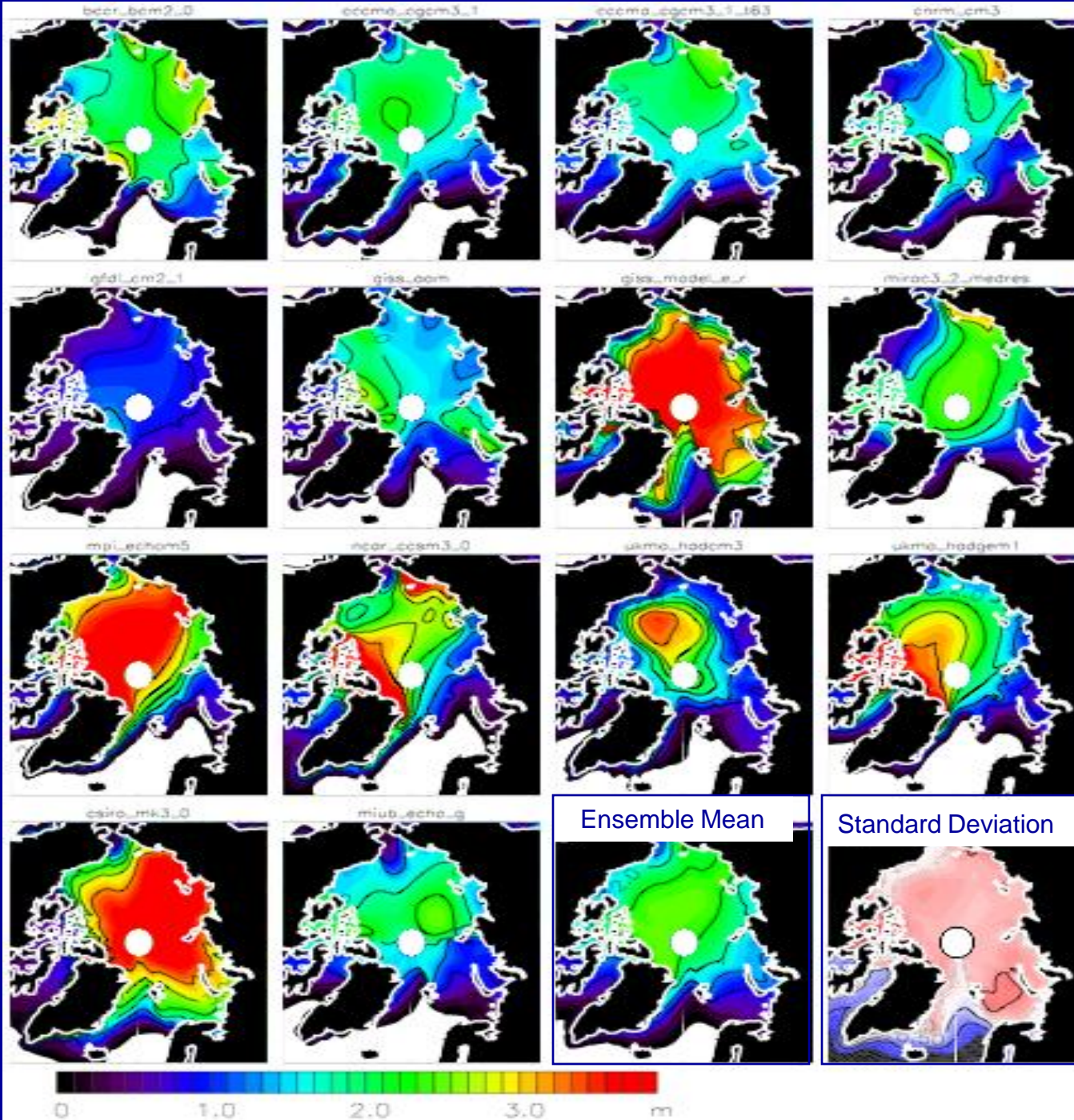
Allows us to solve for ice growth/melt as residual



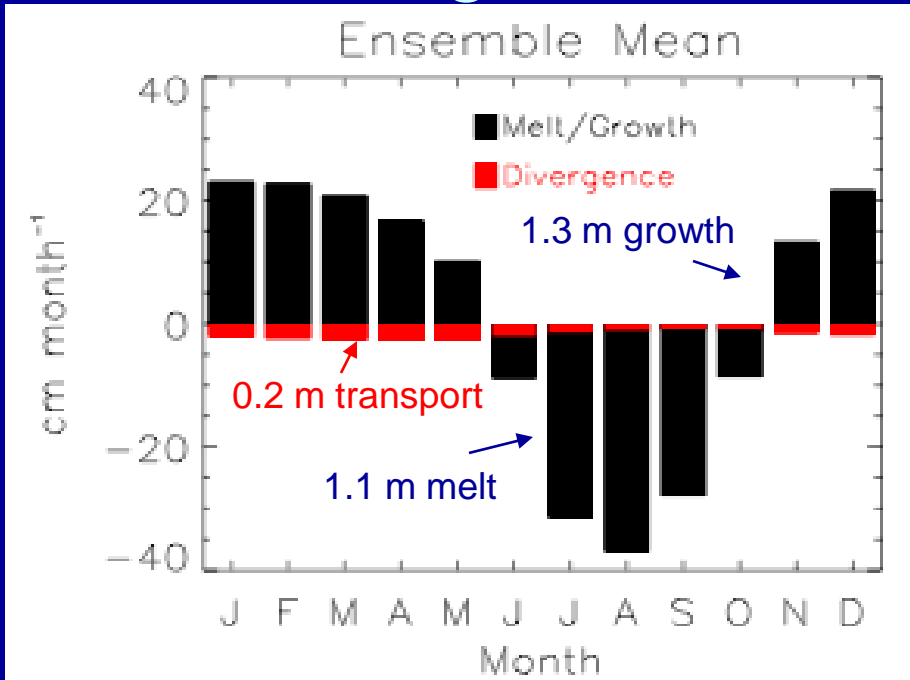
# Ice Thickness Climatology 1980-1999

Thickness varies  
considerably  
across models

Largest inter-  
model scatter is  
in the Barents  
Sea region

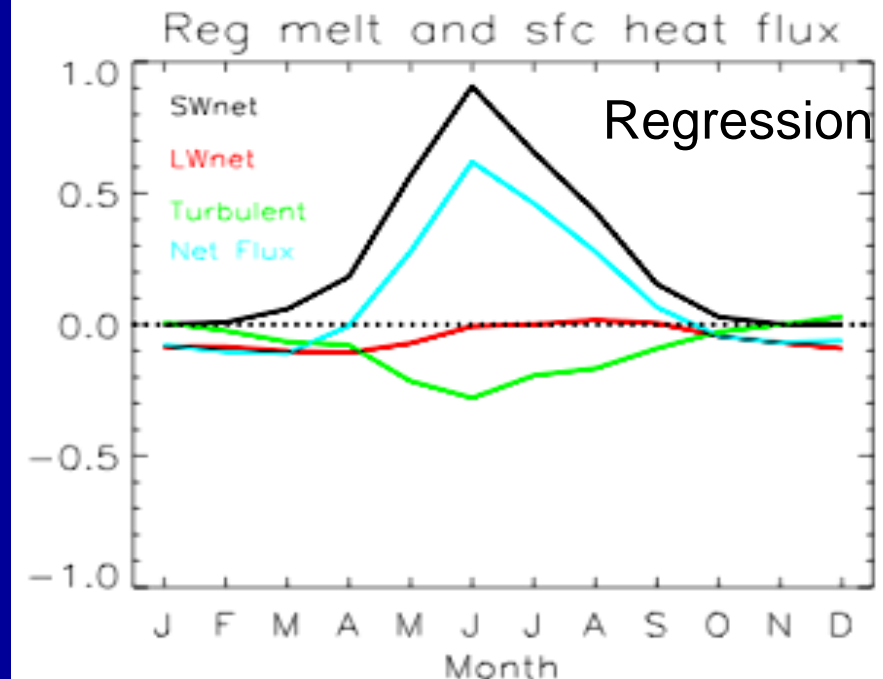
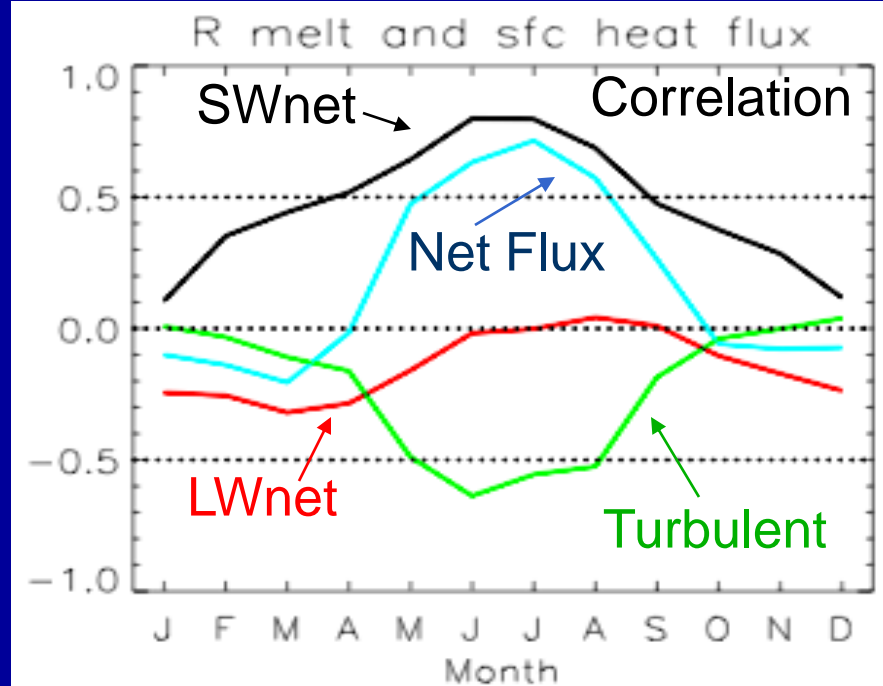


# Late 20th century mass budgets

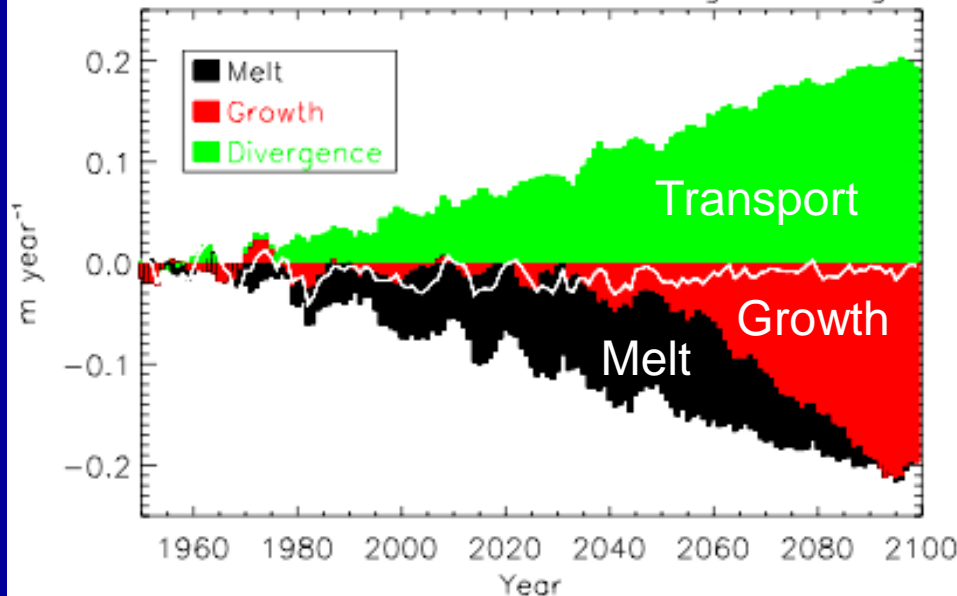


Intermodel scatter in ice melt strongly related to net SW flux with compensating changes in turbulent flux

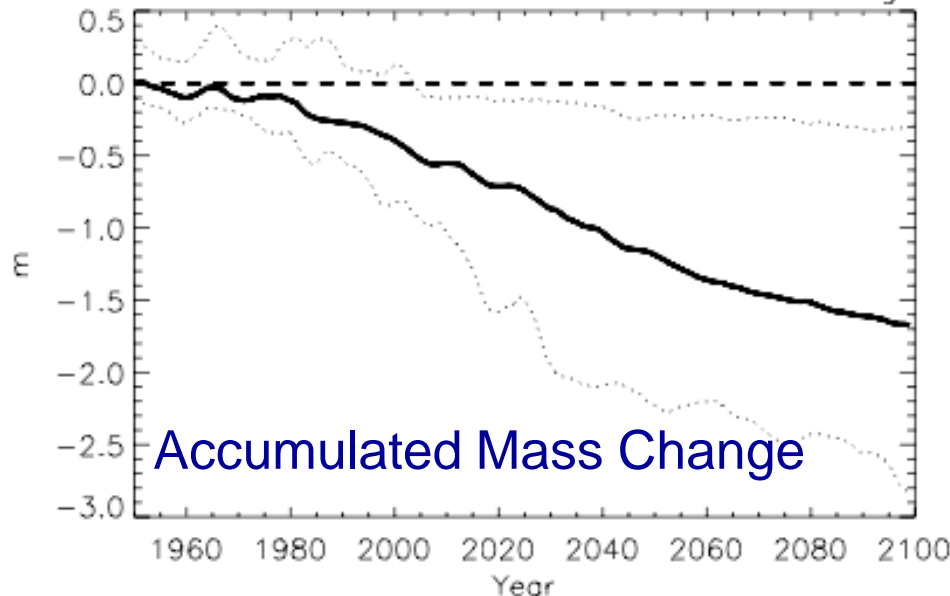
Ice divergence strongly related to mean thickness



Ensemble Mean Ice Mass Budget Change



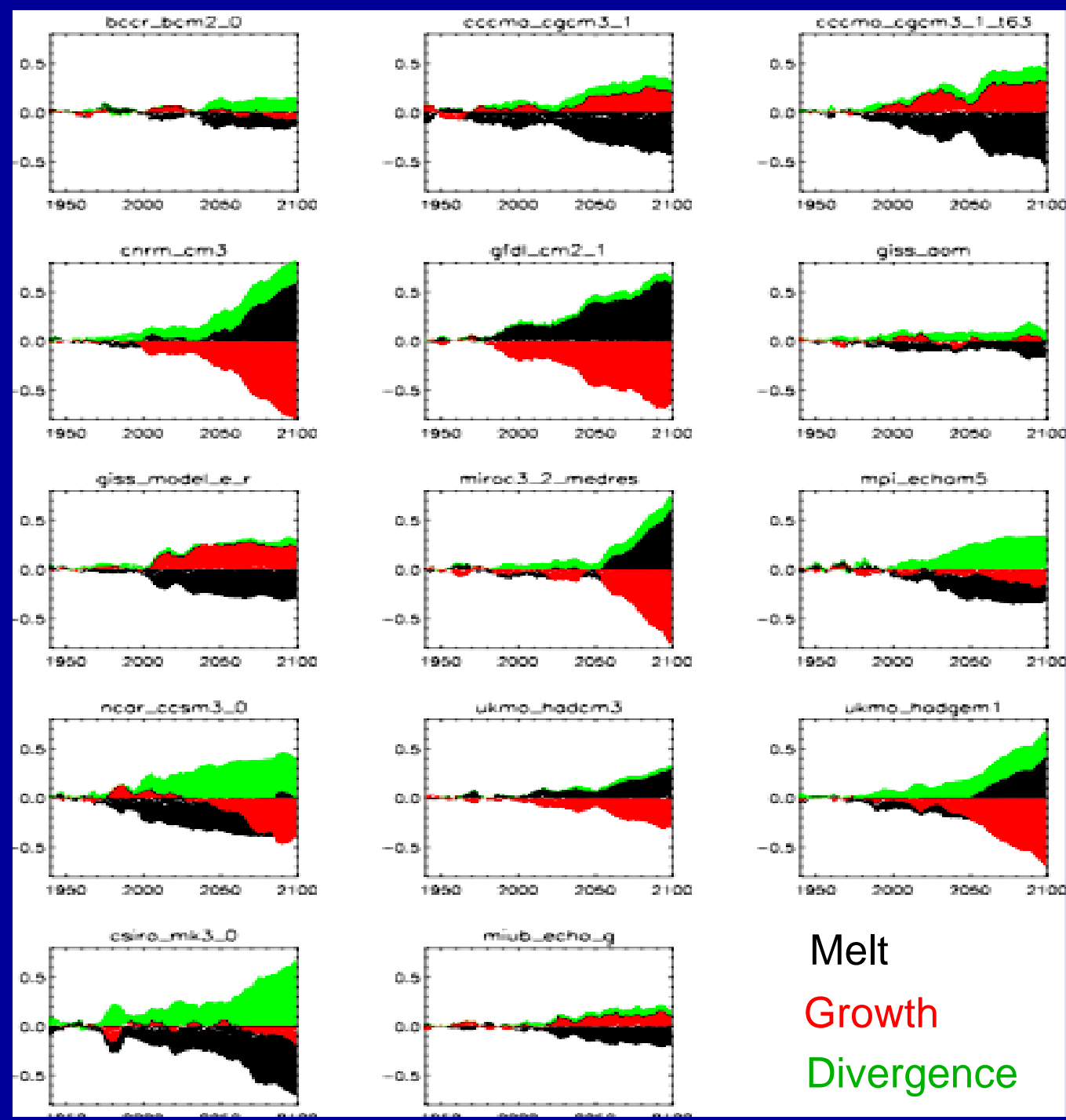
Ensemble Mean Accumulated Mass Change



Accumulated Mass Change

## Multi-Model Mean Ice Mass Budget Change

- Initial increases in melt
- Gives way to reductions in ice growth
- Partially compensated by reduced loss via ice transport
- By 2100, considerable ice volume loss of about 1.5m on annual avg



All models have a net reduction in ice mass in 21st century

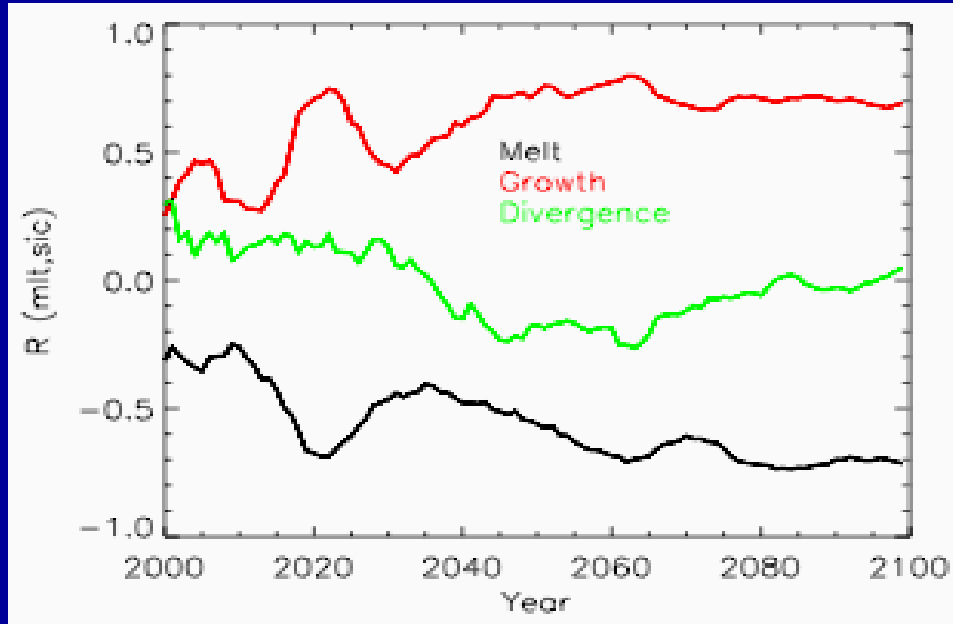
Nature of ice mass budget changes varies considerably across models

Both in the

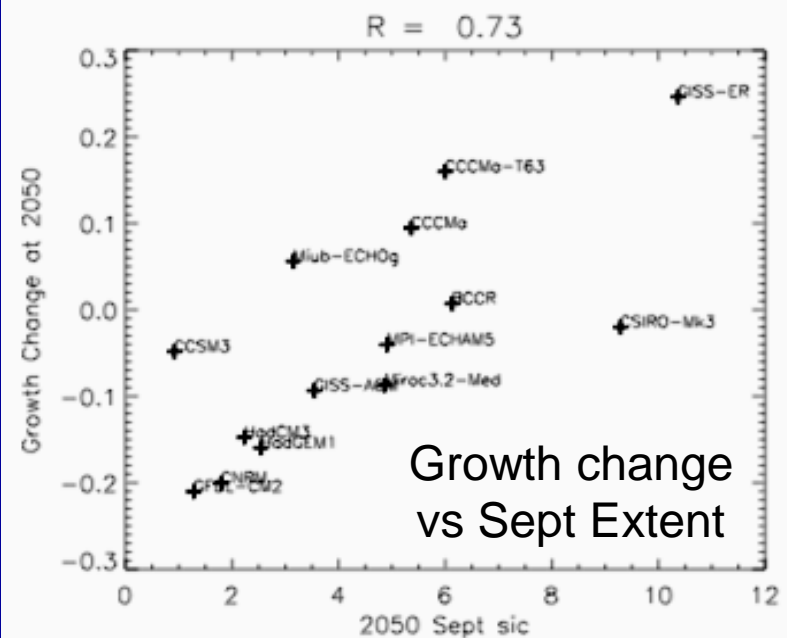
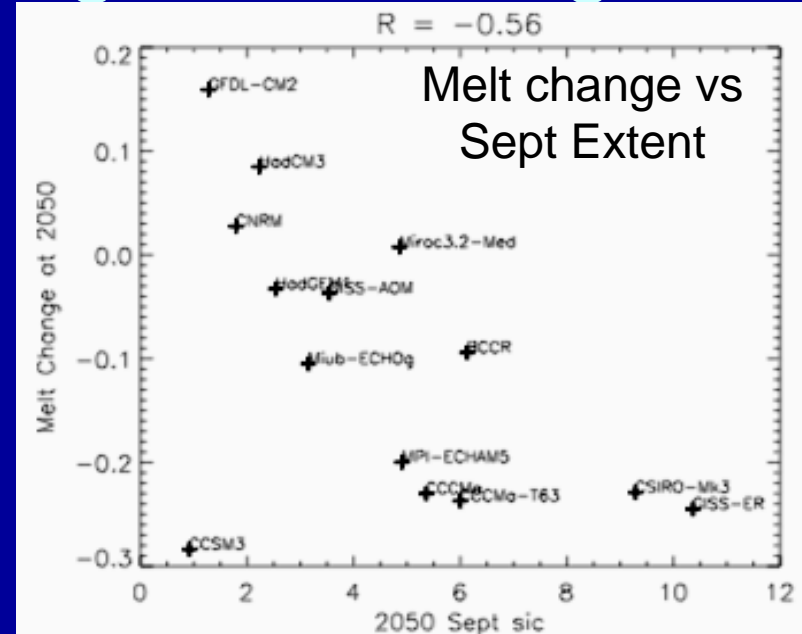
- Magnitude of net change
- Terms that produce change



# What determines evolving mass budgets



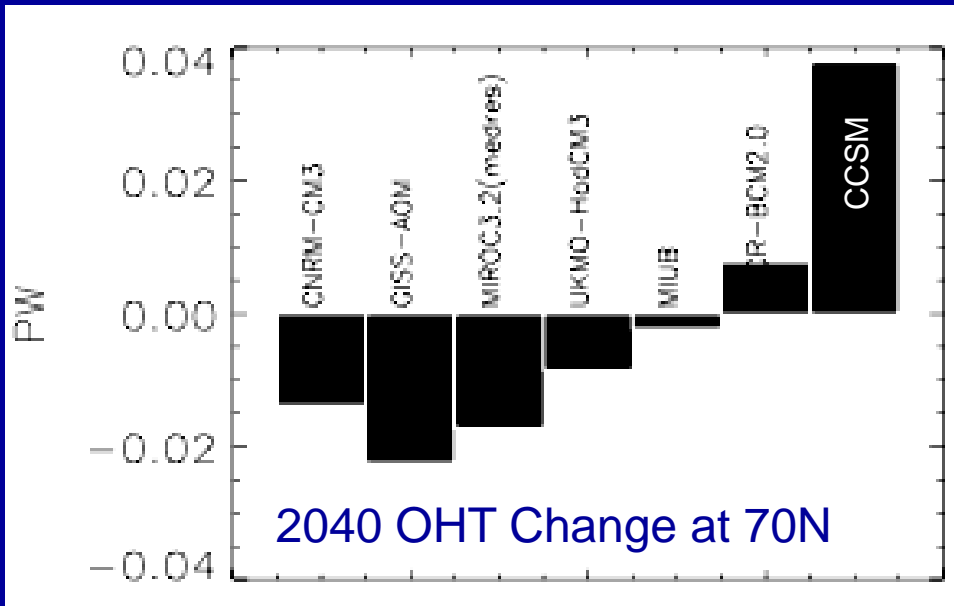
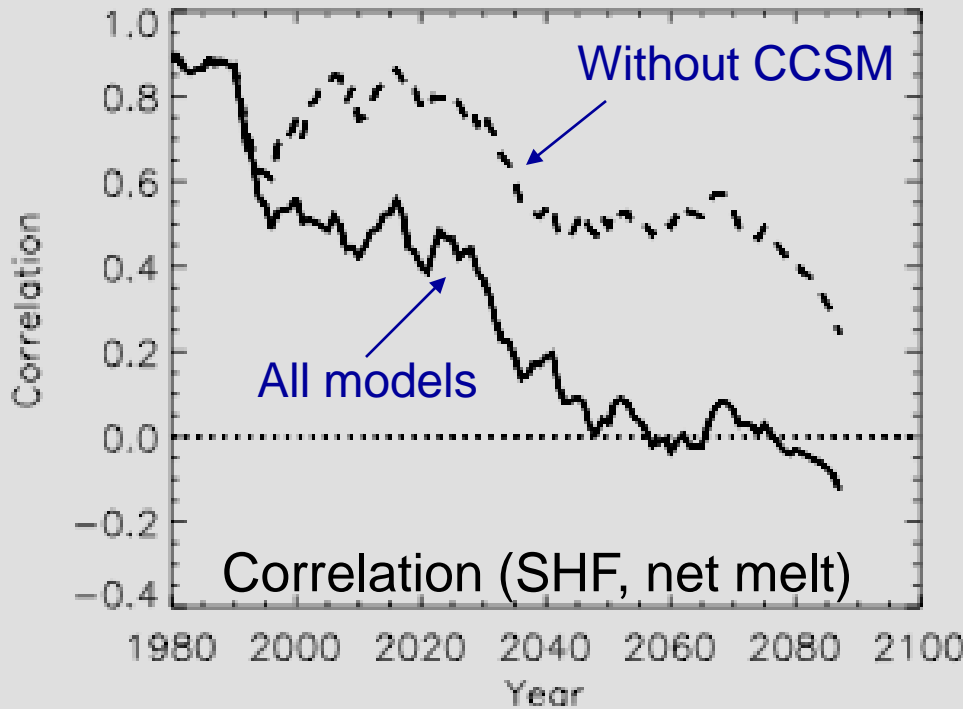
- Net melt increase strongly related to initial thickness (thicker models have more melt)
- Relative role of melt/growth change related to evolving September ice extent
- Ice transport change related to ice thickness decrease



# Role of changing SHF

Correlation of net ice melt change and SHF decreases with time.

Is much higher if CCSM is excluded



CCSM has among the largest increase in OHT.

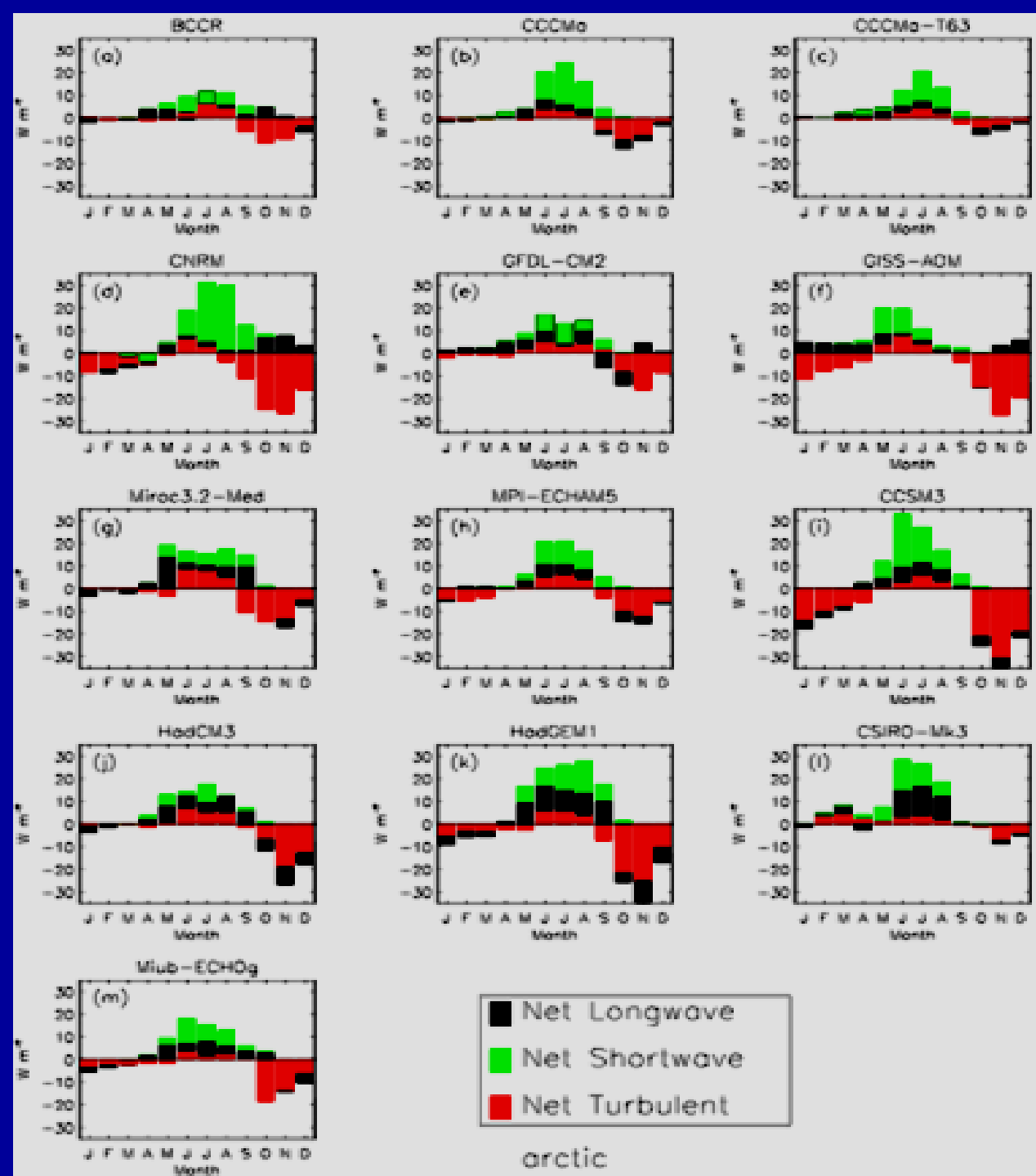
This will affect the net ice melt and can affect the relationship to SHF change

# 2040 SHF Change

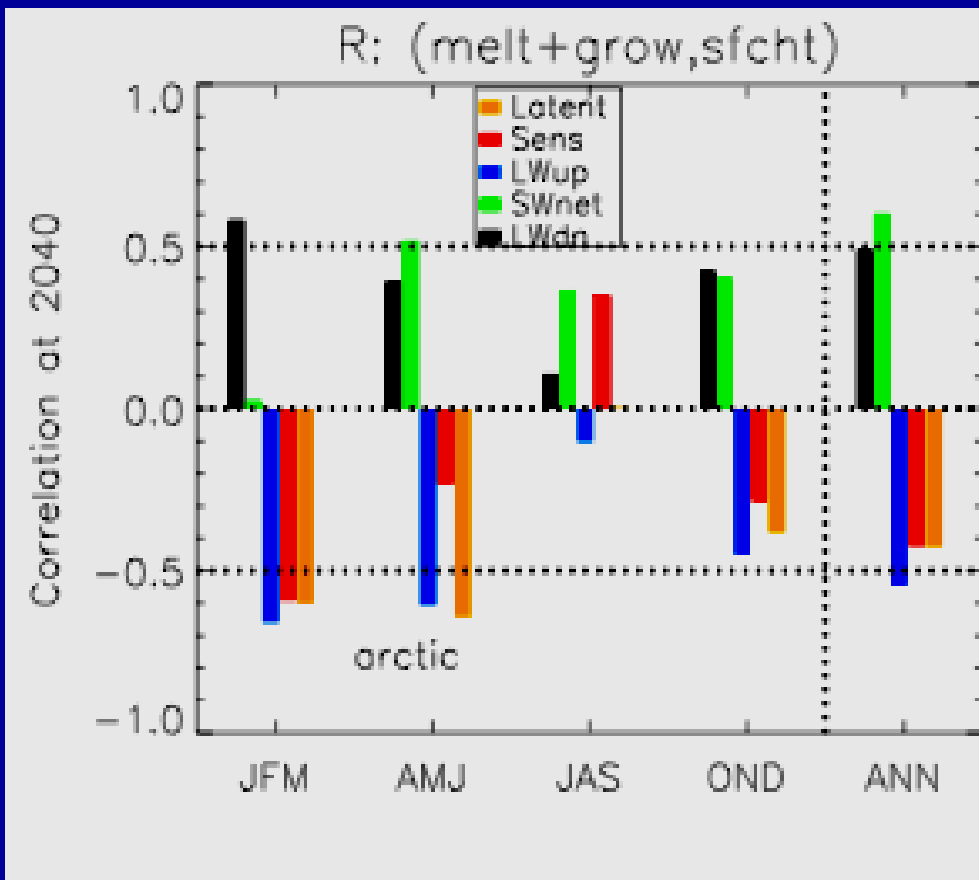
Models exhibit net warming of surface  
Summer increases, (net SW). Increase in turbulent heat loss in cold season.

Models with thicker ice have

- smaller increases in LW heat loss;
- smaller turbulent heat flux change



# Role of individual flux terms in changing net ice melt



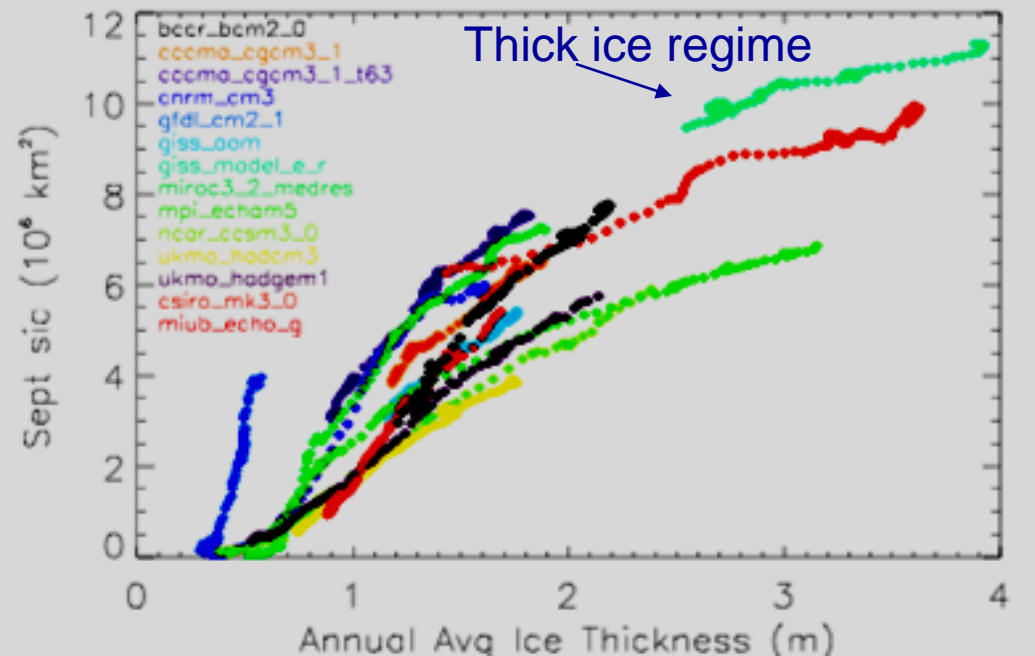
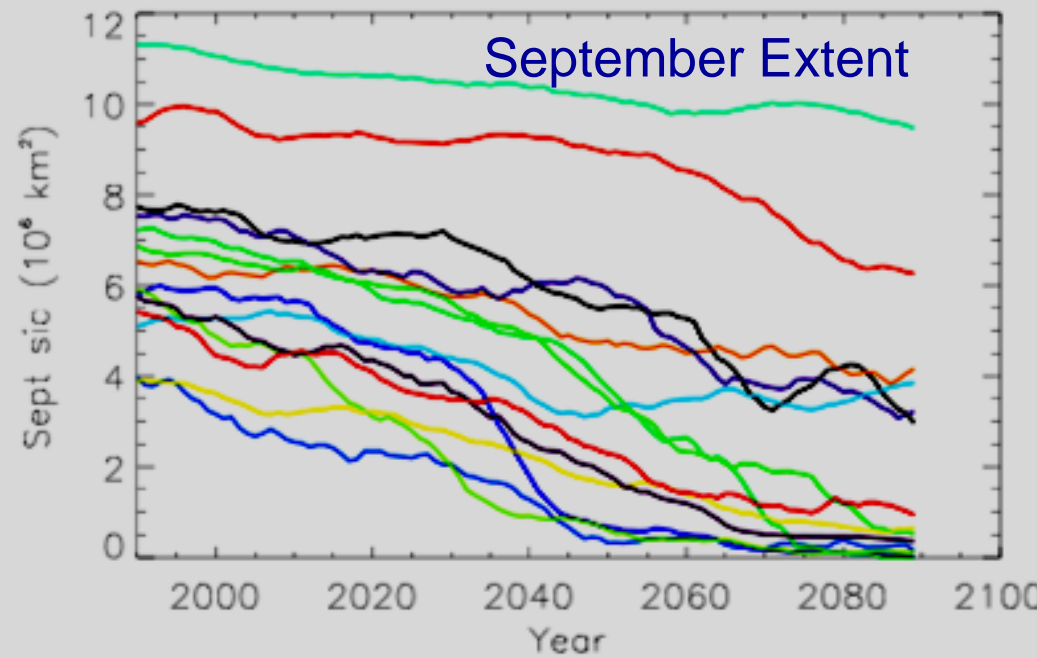
- Models with larger increase in net ice melt generally have
- Larger increases in net SW
  - Larger increases in downwelling longwave (winter)
  - Larger compensating increases in turbulent and longwave heat loss (cold season)

Correlation of net melt change and changing SHF terms at 2040

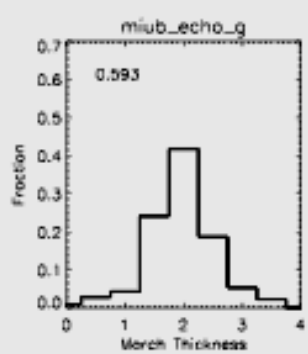
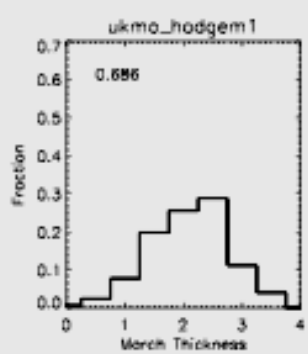
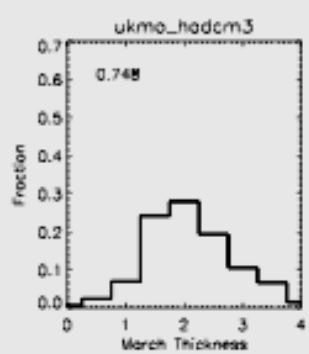
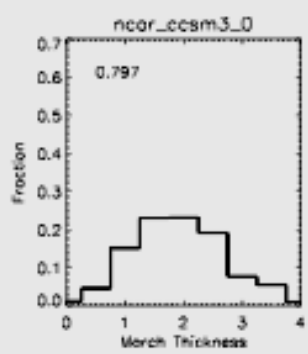
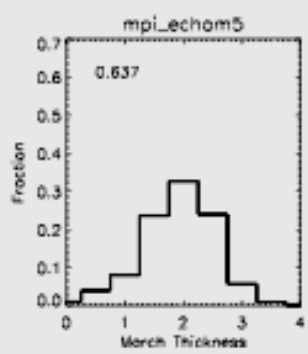
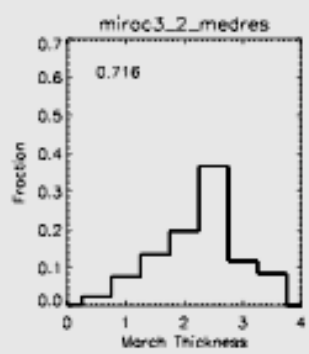
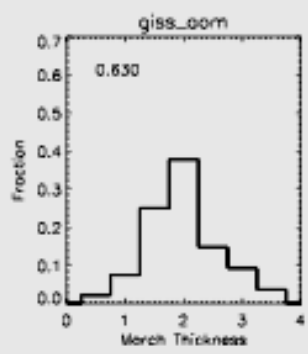
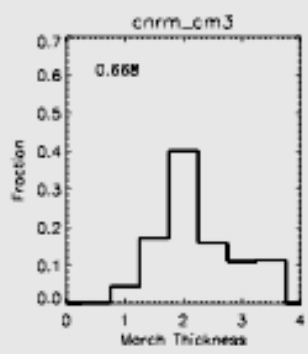
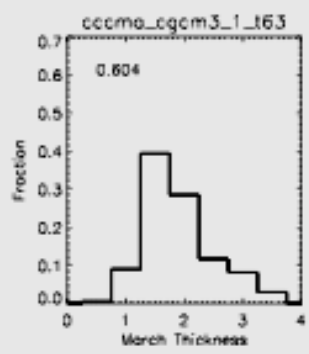
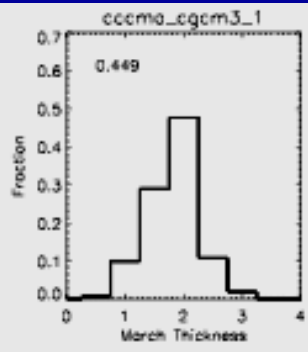
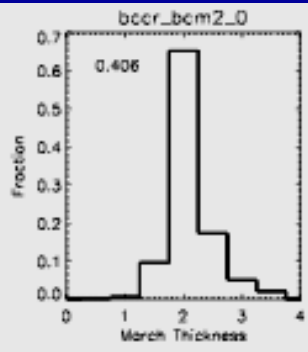
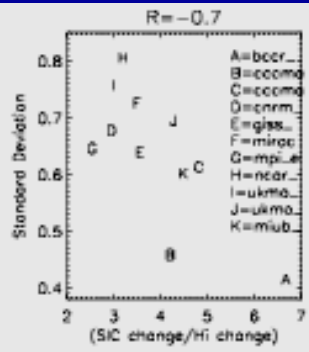
How do changes in ice volume translate into ice extent loss?

Smaller ice extent loss per meter of ice thickness loss for thicker sea ice

For 1-2m ice, large intermodel differences in how ice volume loss translates into ice extent change







# How do changes in ice volume translate into ice extent loss?

Relationship between ice extent loss per ice thickness change and the March ITD among the models for 1-2m ice

Models with a greater spread in the distribution generally have smaller ice extent loss per ice thickness change.

Stabilizing effect of thick ice regions?

# Summary

- Differences in climatological ice melt across models related to net SW heating
- Intermodel scatter in changing net ice melt associated with
  - The sea ice state: larger net melt for thicker ice; relative role of melt/growth related to Sept extent
  - SHF change: larger net melt in models with larger net SW, larger downwelling LW, larger LW loss, larger turbulent loss
- Ice mass budget changes translate into ice extent loss dependent on distribution of ice, initial thickness