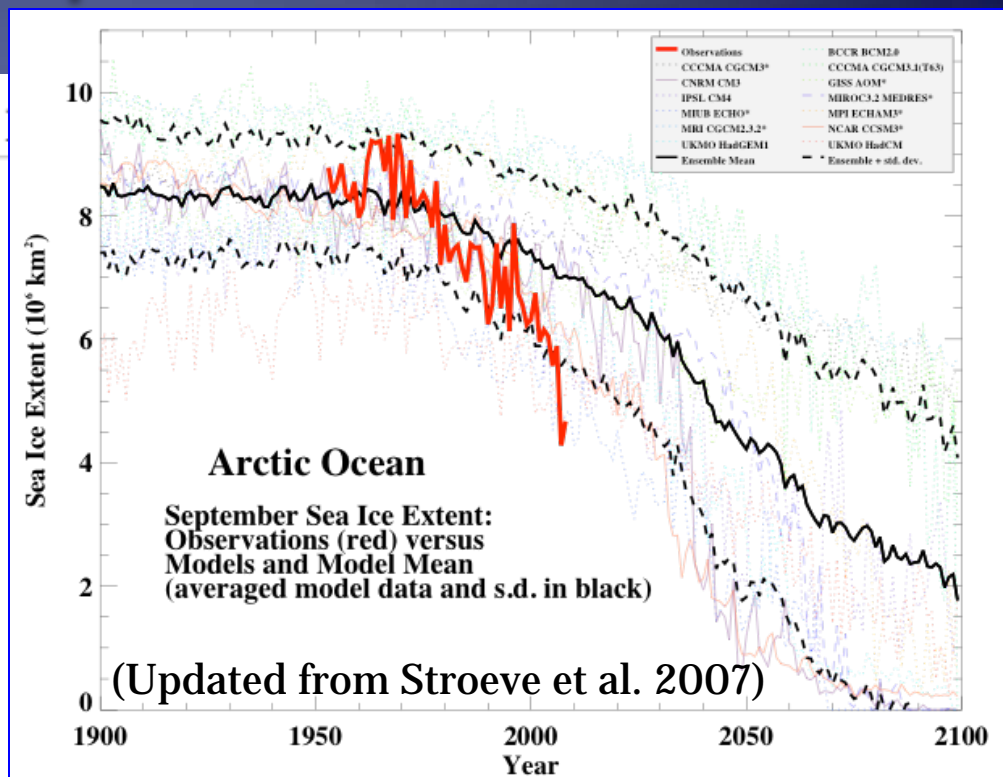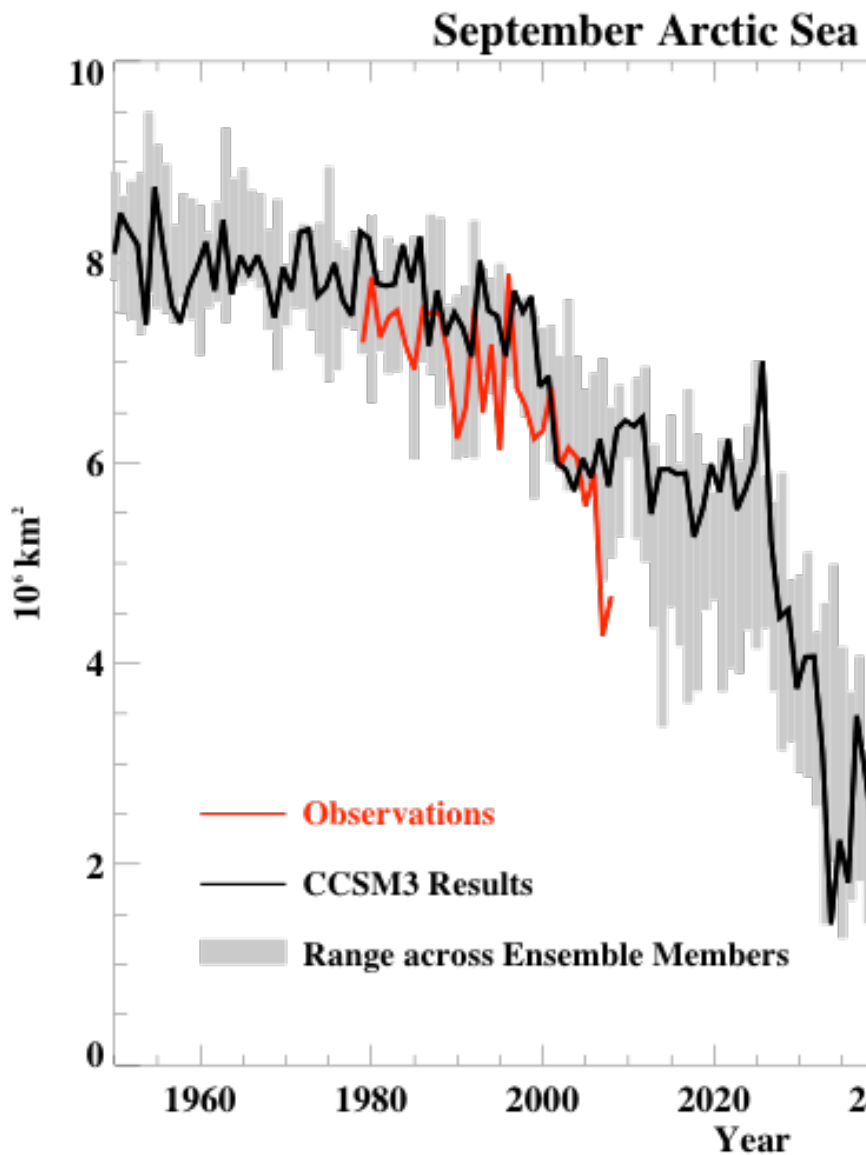# The Loss and Possible Recovery of Perennial Arctic Sea Ice
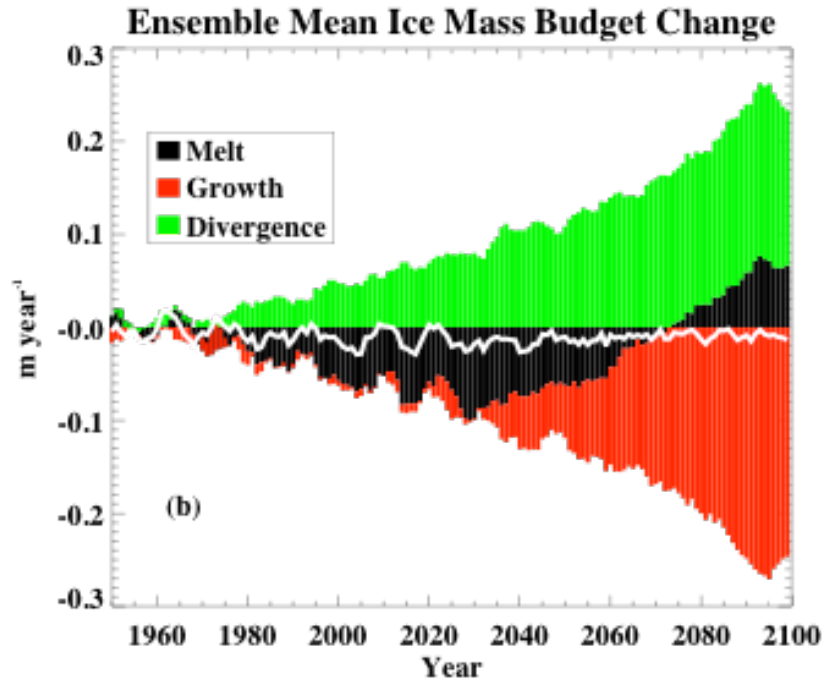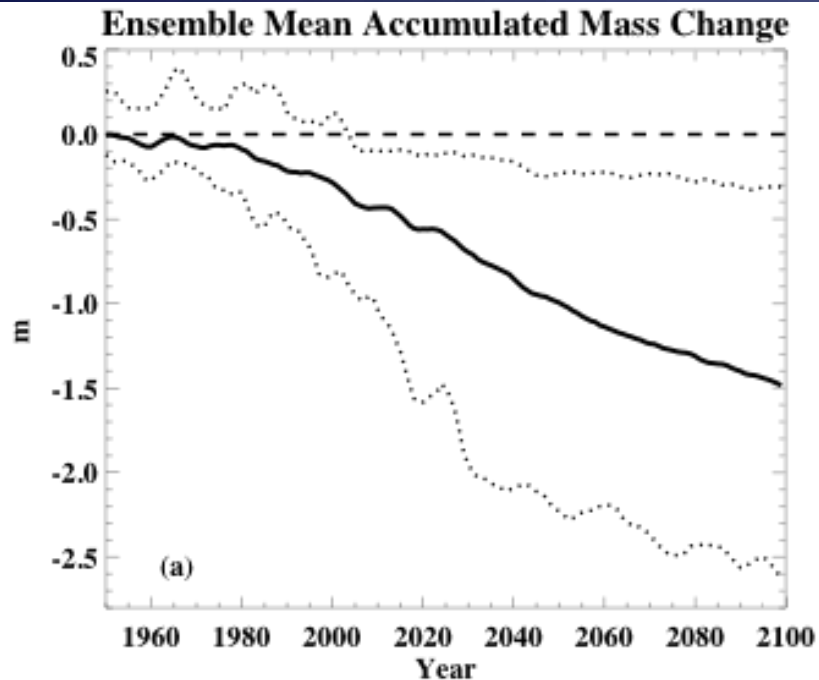
Marika Holland and David Bailey,
National Center for Atmospheric Research

Projected loss of perennial sea ice

September Arctic Sea Ice

Observations — *red*
CCSM3 Results — *black*
Range across Ensemble Members — *gray*

Arctic Ocean

September Sea Ice Extent:
Observations (red) versus
Models and Model Mean
(averaged model data and s.d. in black)
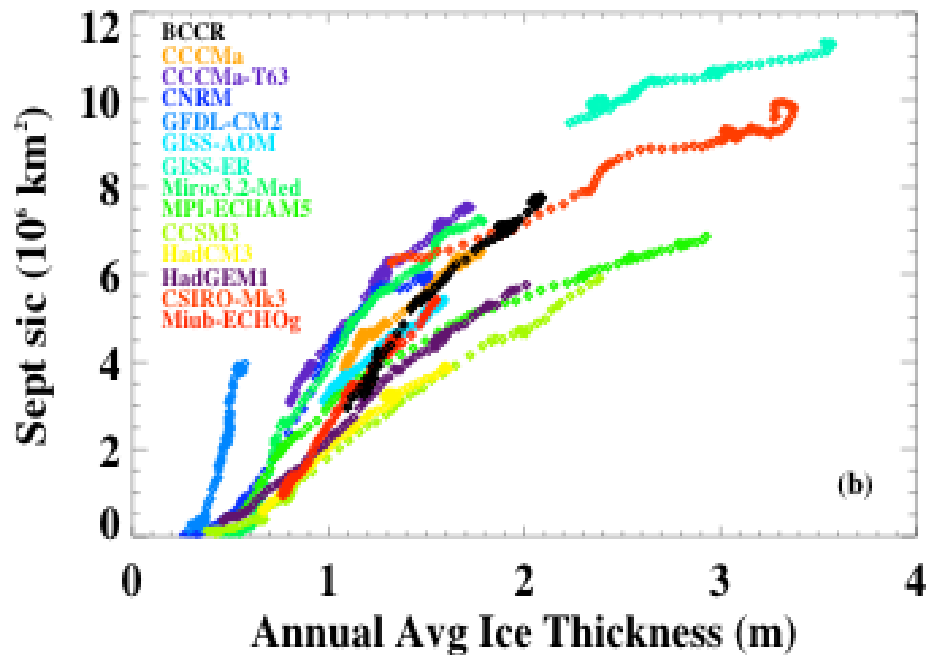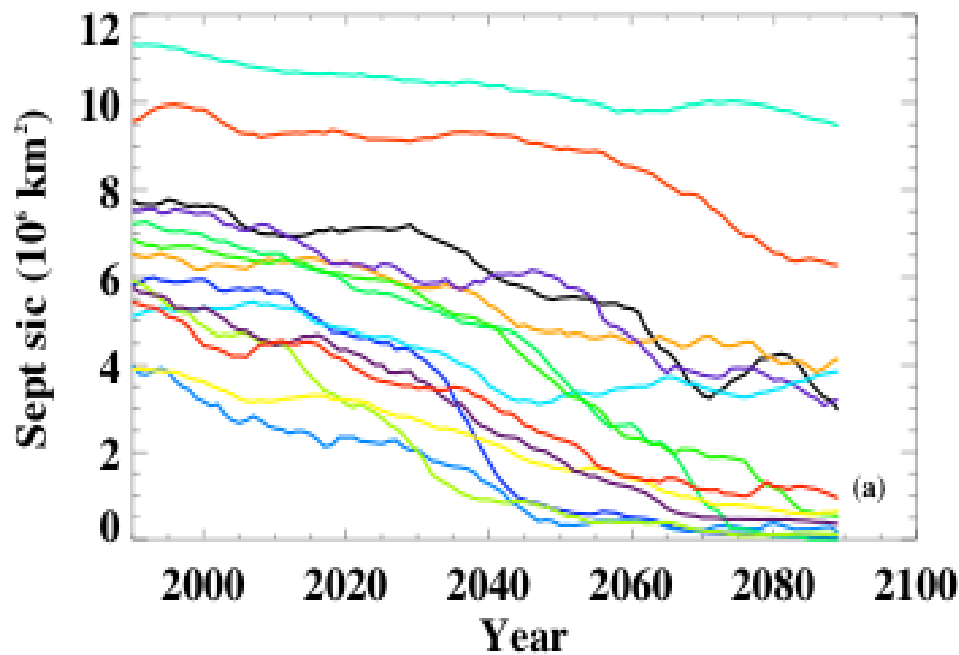
(Updated from Stroeve et al. 2007)

Diagnosing Ice Loss

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

(Holland et al., 2008)

# Translating ice volume change to ice extent loss

For thick ice: small extent loss per meter of ice thickness loss

For 1-2m ice, large ice extent loss per ice volume change; variable across models; related to spatial distribution of ice within the Arctic
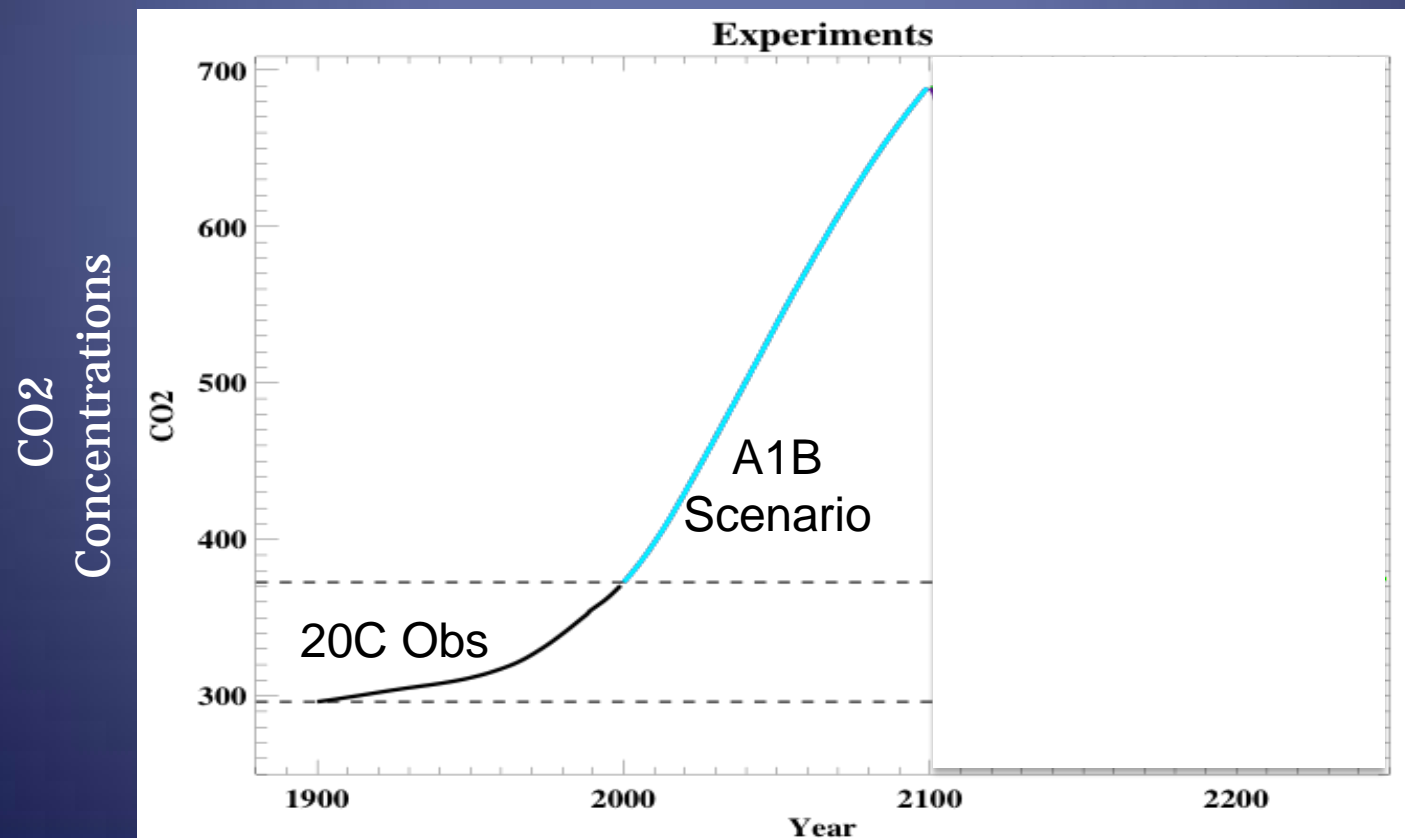
In general, models with more realistic ice, lose Sept extent earlier

(Holland et al., 2008)

Observations and models suggest the loss of perennial sea ice may be unavoidable
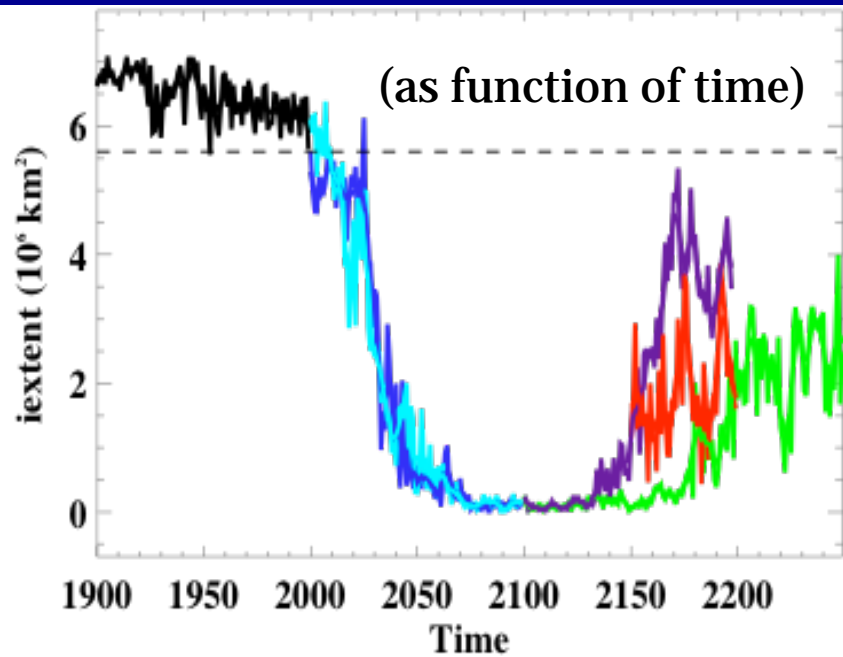
- Would this change be irreversible?
- If CO2 levels decrease would the perennial Arctic ice recover?
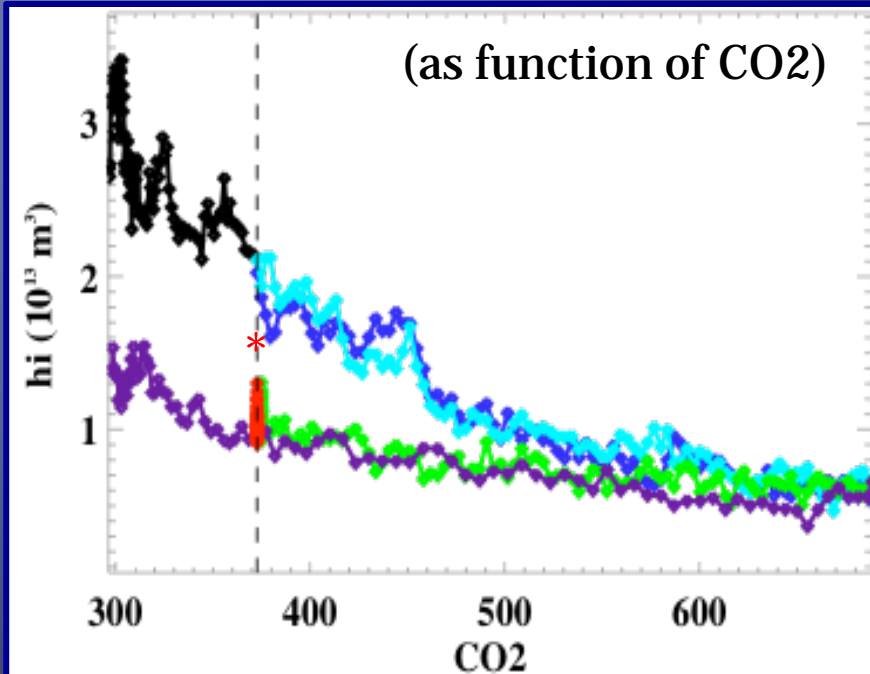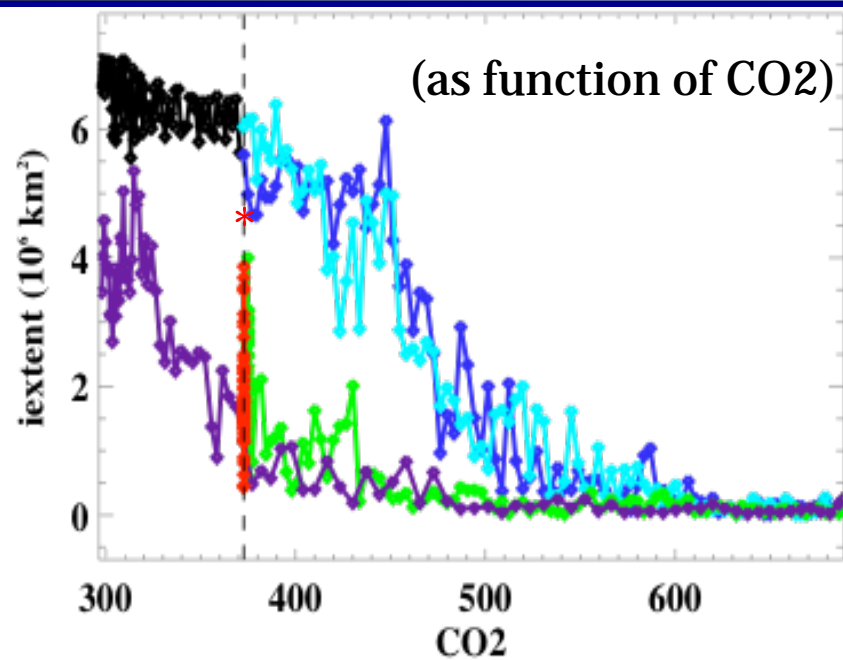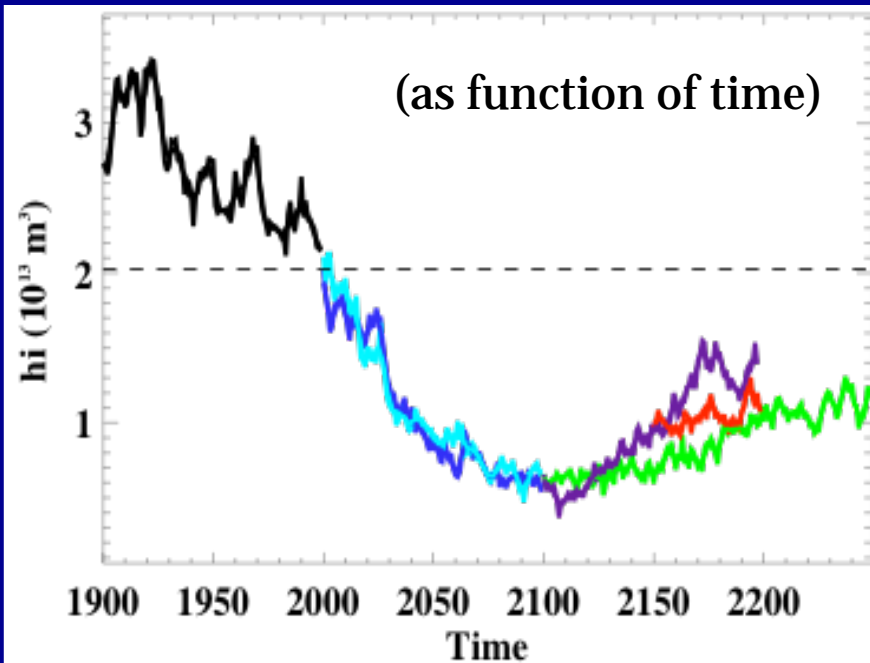- If so, what mechanisms would influence this recovery?
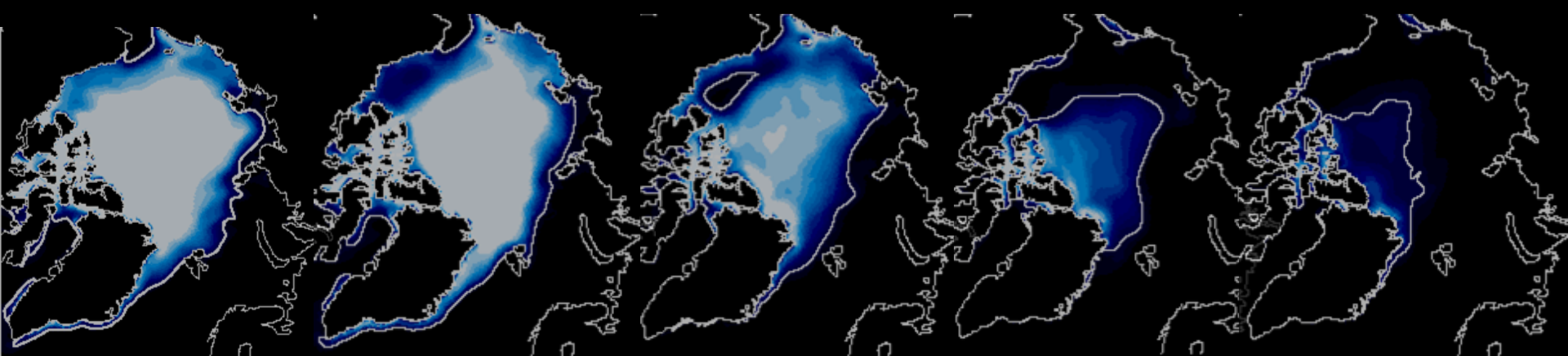
- Performed highly idealized experiments using CCSM3
- Runs initialized with 2100 CCSM3 conditions (seasonally ice free Arctic state)
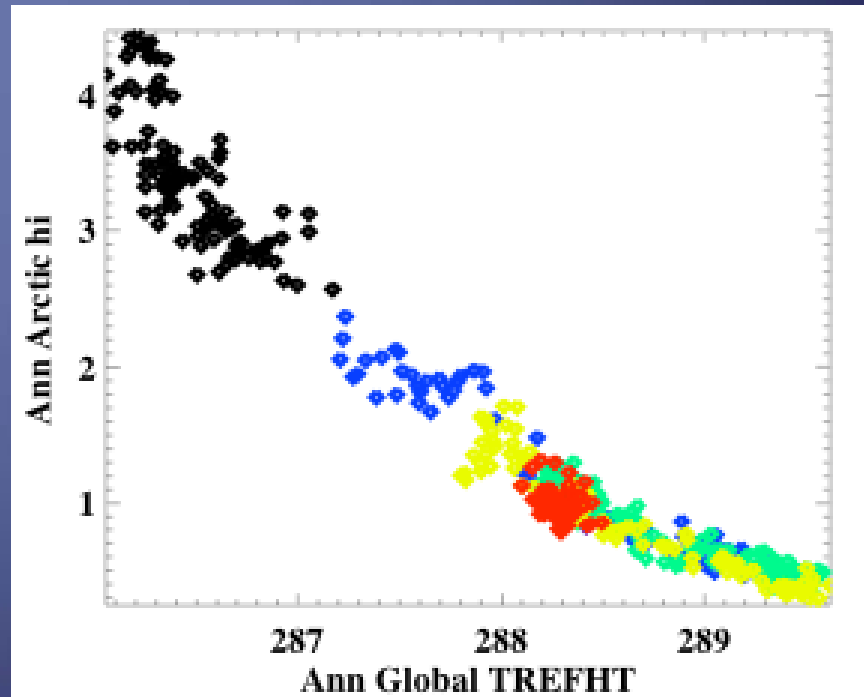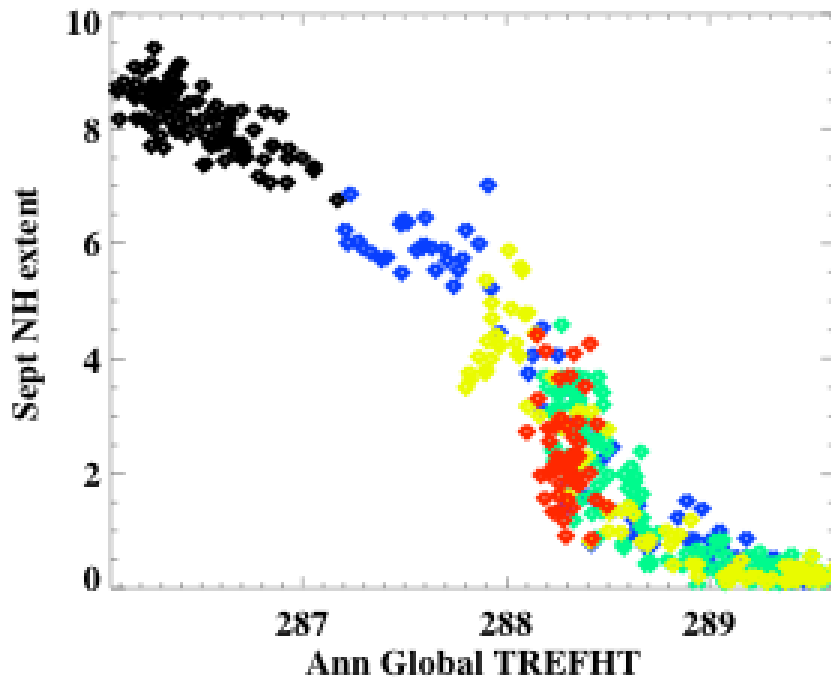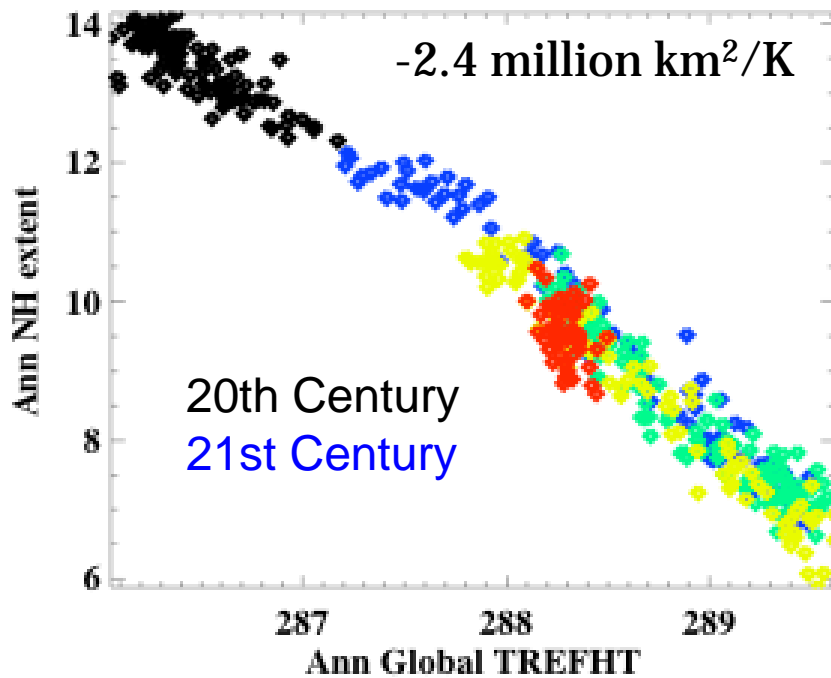- Reductions in CO_2 concentrations applied

September Extent

(as function of time)

(as function of CO2)

March Thickness

(as function of time)
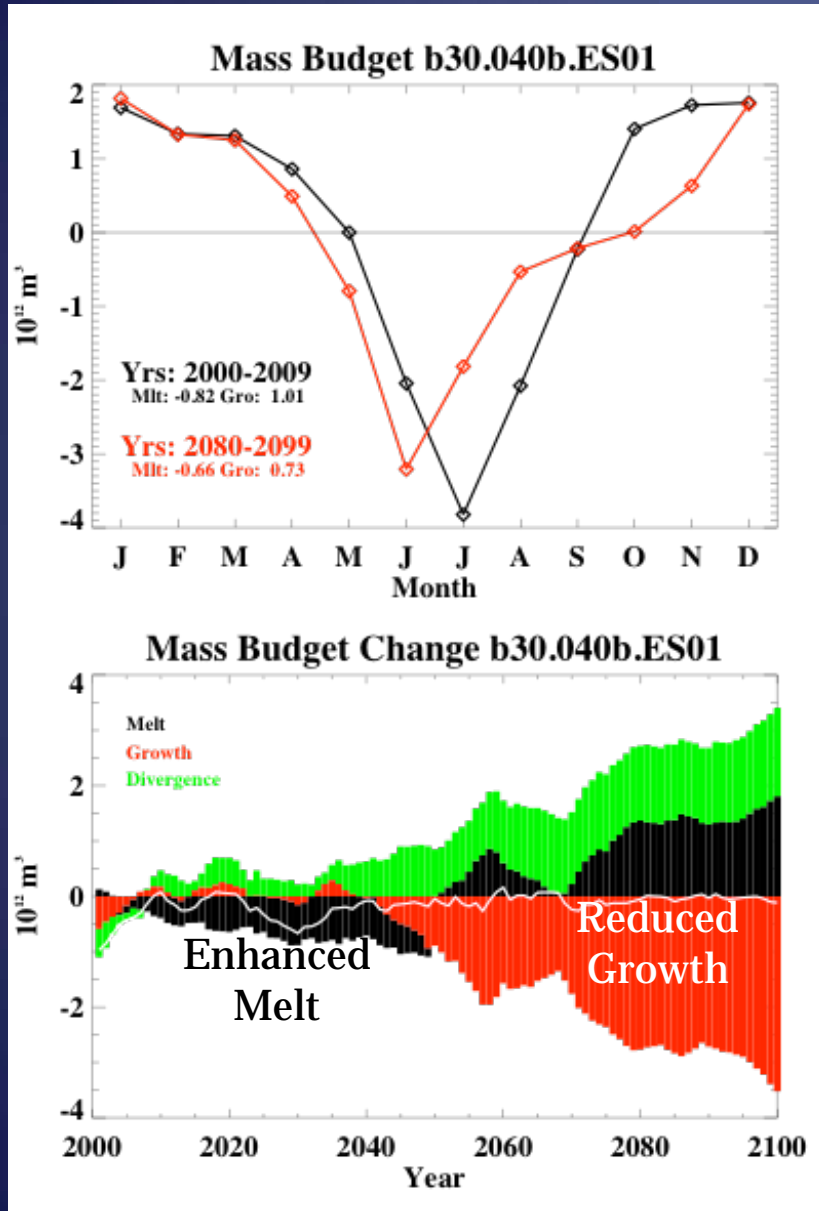
(as function of CO2)
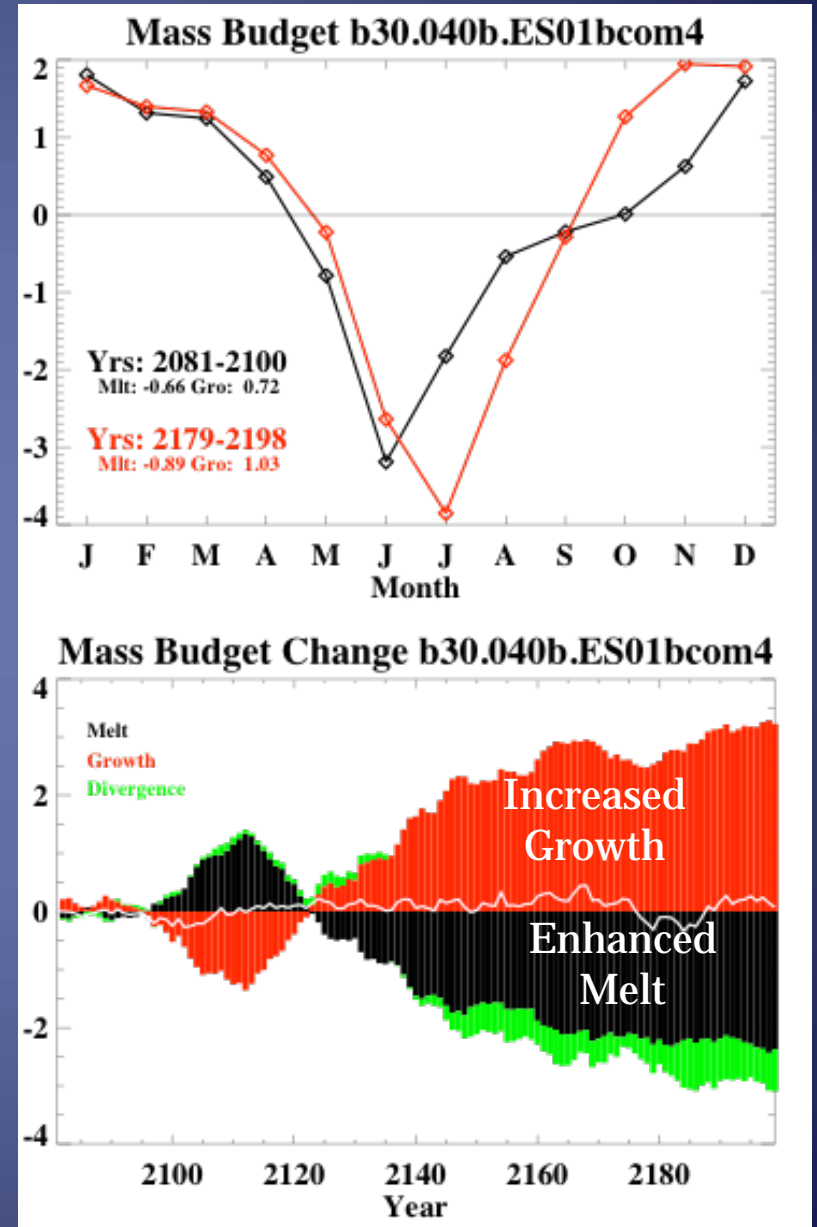
Relationship to global surface air temperature

- Linear relationship of annual NH ice extent and global SAT
- Relationship with September extent and ice thickness not linear
- Relationship nearly identical for the ice loss and ice recovery simulations

-2.4 million km^2/K

20th Century
21st Century

Sea ice mass budget changes

Mass Budget b30.040b.ES01

Yrs: 2000-2009
Mlt: -0.82 Gro: 1.01

Yrs: 2080-2099
Mlt: -0.66 Gro: 0.73

Mass Budget b30.040b.ES01bcom4

Yrs: 2081-2100
Mlt: -0.66 Gro: 0.72

Yrs: 2179-2198
Mlt: -0.89 Gro: 1.03

Mass Budget Change b30.040b.ES01

Melt
Growth
Divergence

Enhanced Melt

Reduced Growth

Mass Budget Change b30.040b.ES01bcom4

Melt
Growth
Divergence

Increased Growth

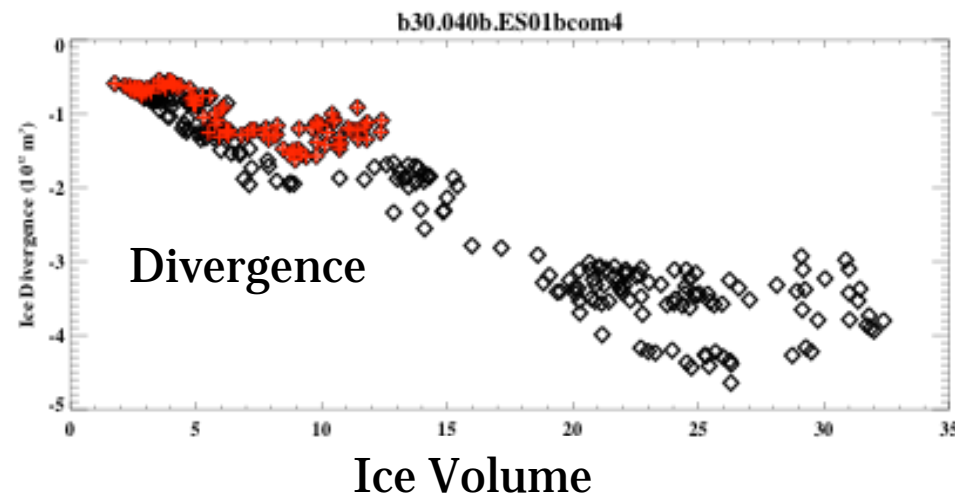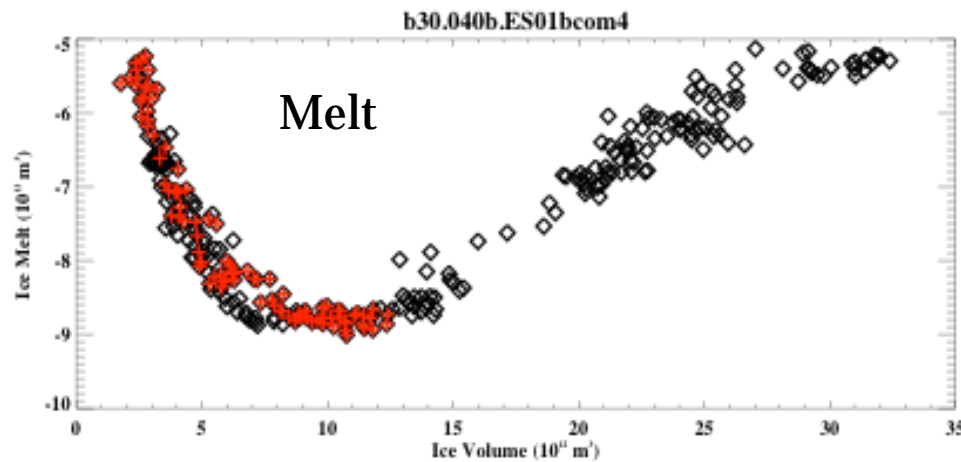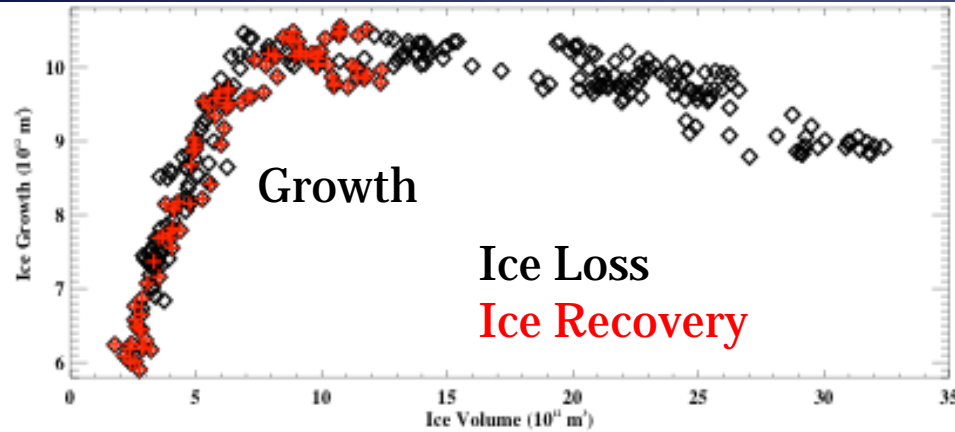Enhanced Melt

Ice loss transition

Ice recovery

Mass budget

Characteristics as a function of ice state are similar during the ice loss and ice recovery simulations

Hints of a difference with ice divergence response (more obvious in other run), but unsure how robust/significant

SAT (2080-2099 minus 1980-1999)

2080-2099 minus Present Day

Arctic amplification

Arctic amplification has similar characteristics for the loss and recovery of perennial sea ice
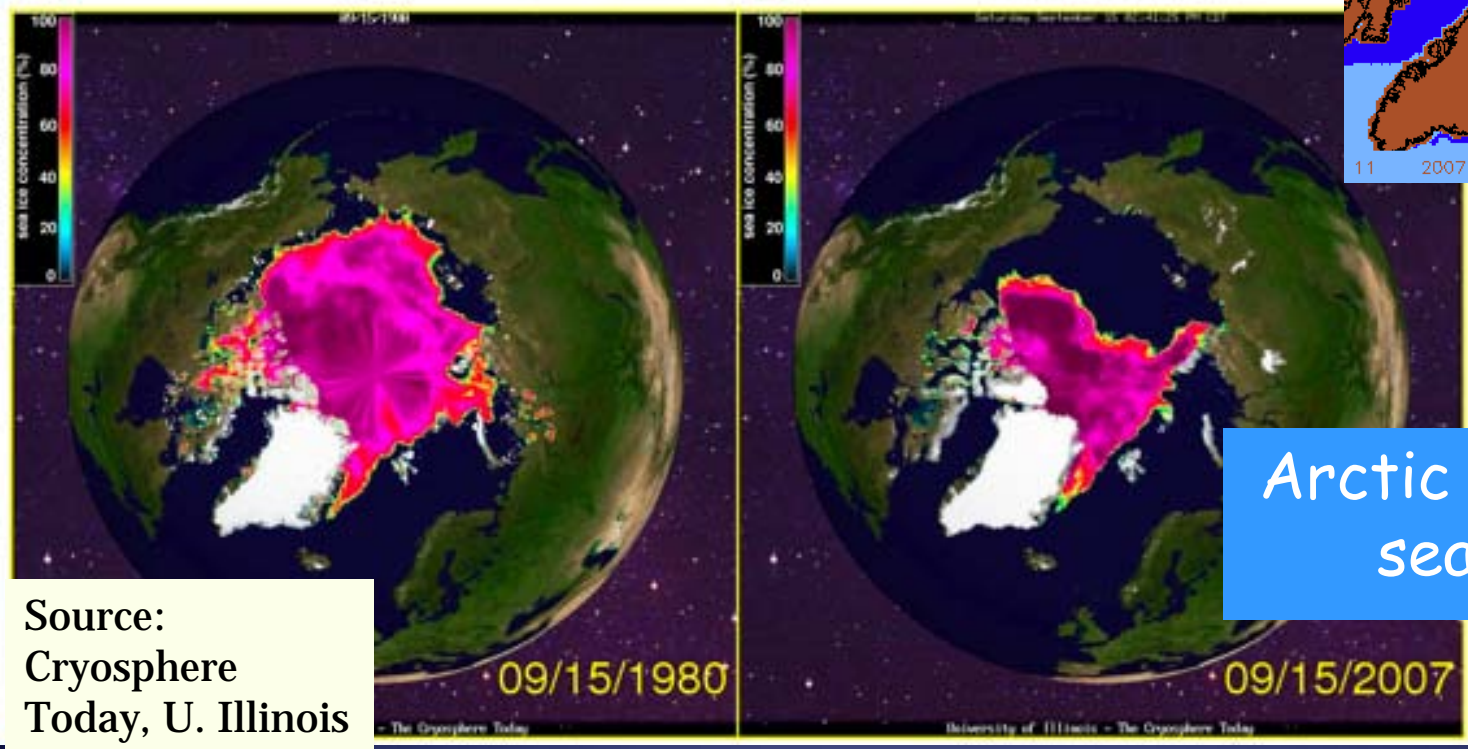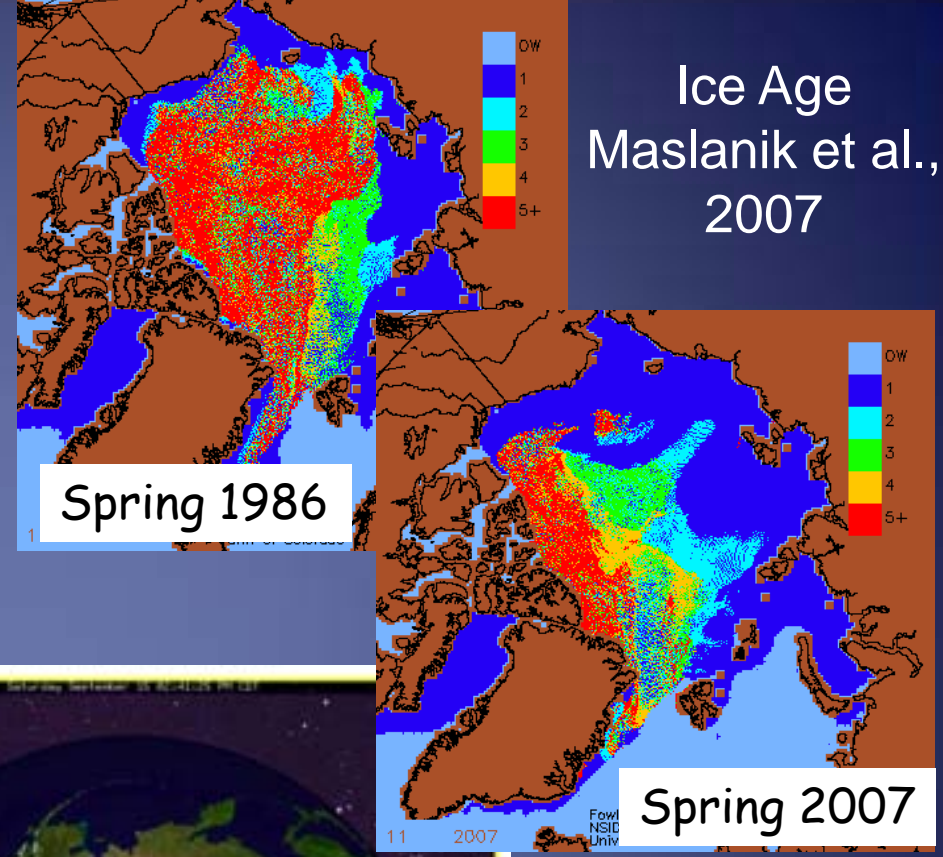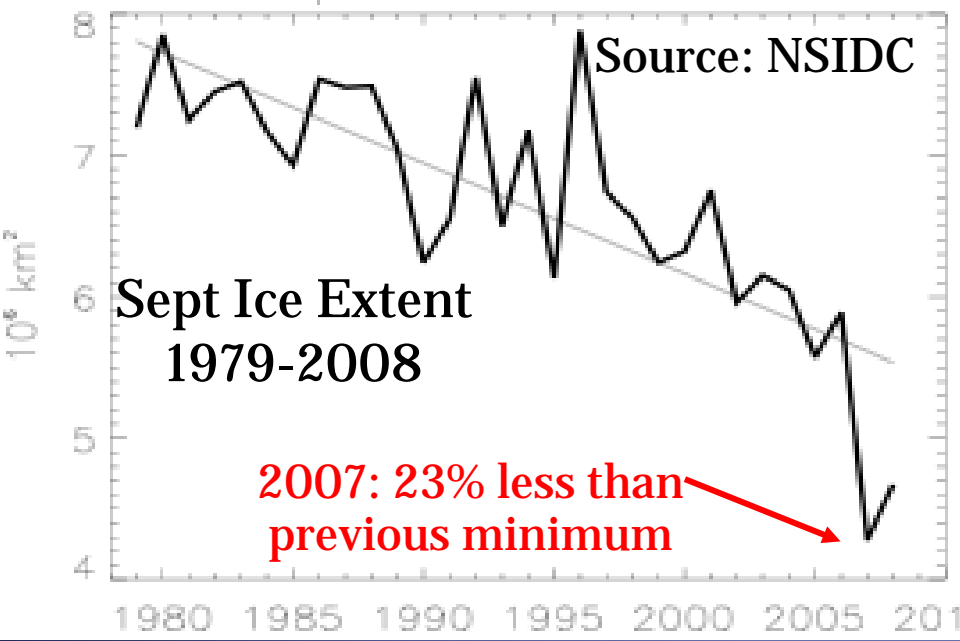
In CCSM3, the Arctic surface air temperature change is about 3Xs that of the global change
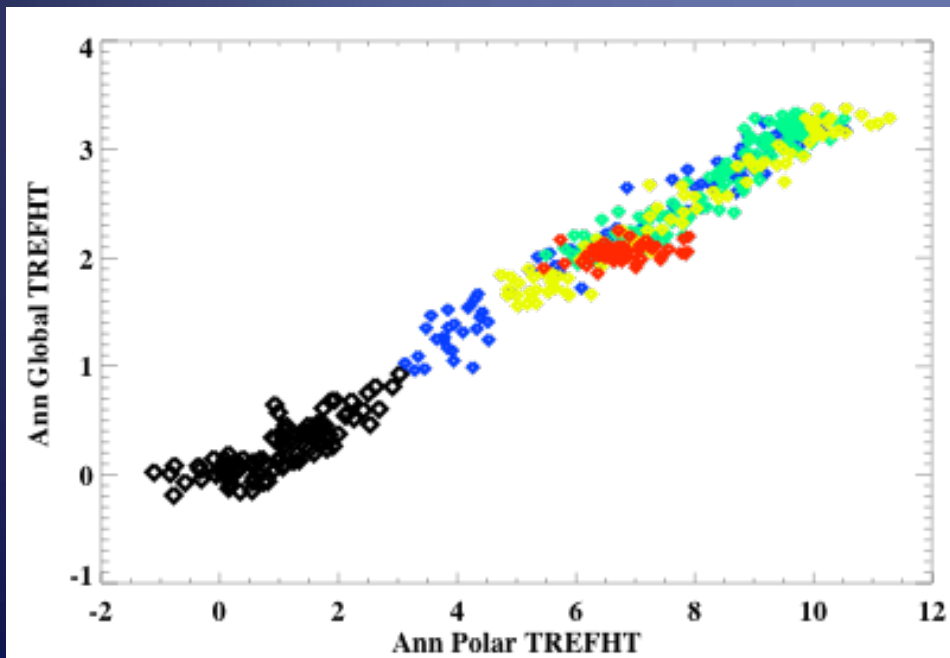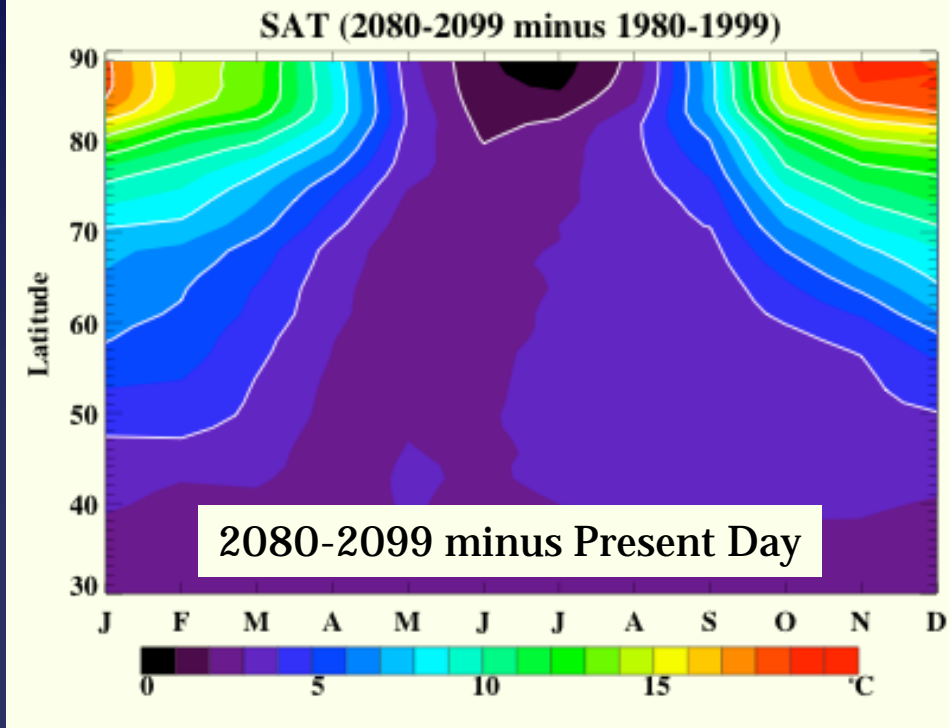
Preliminary Conclusions

- Initialized climate simulations from seasonally ice free (2100) state and applied reductions in CO_2 (from 2100 A1B levels)

- Arctic recovers a perennial ice pack with some time lag

- Relationship of sea ice conditions (state, mass budget) to atmospheric temperature is nearly identical for the loss and recover of perennial sea ice

- Suggests that loss of perennial sea ice is reversible

Questions?

Source: NSIDC

Sept Ice Extent
1979-2008

2007: 23% less than
previous minimum

Ice Age
Maslanik et al.,
2007

Spring 1986

Spring 2007

Arctic summer
sea ice

Source:
Cryosphere
Today, U. Illinois

09/15/1980

09/15/2007