Is the Loss of Perennial Arctic Sea Ice Reversible?

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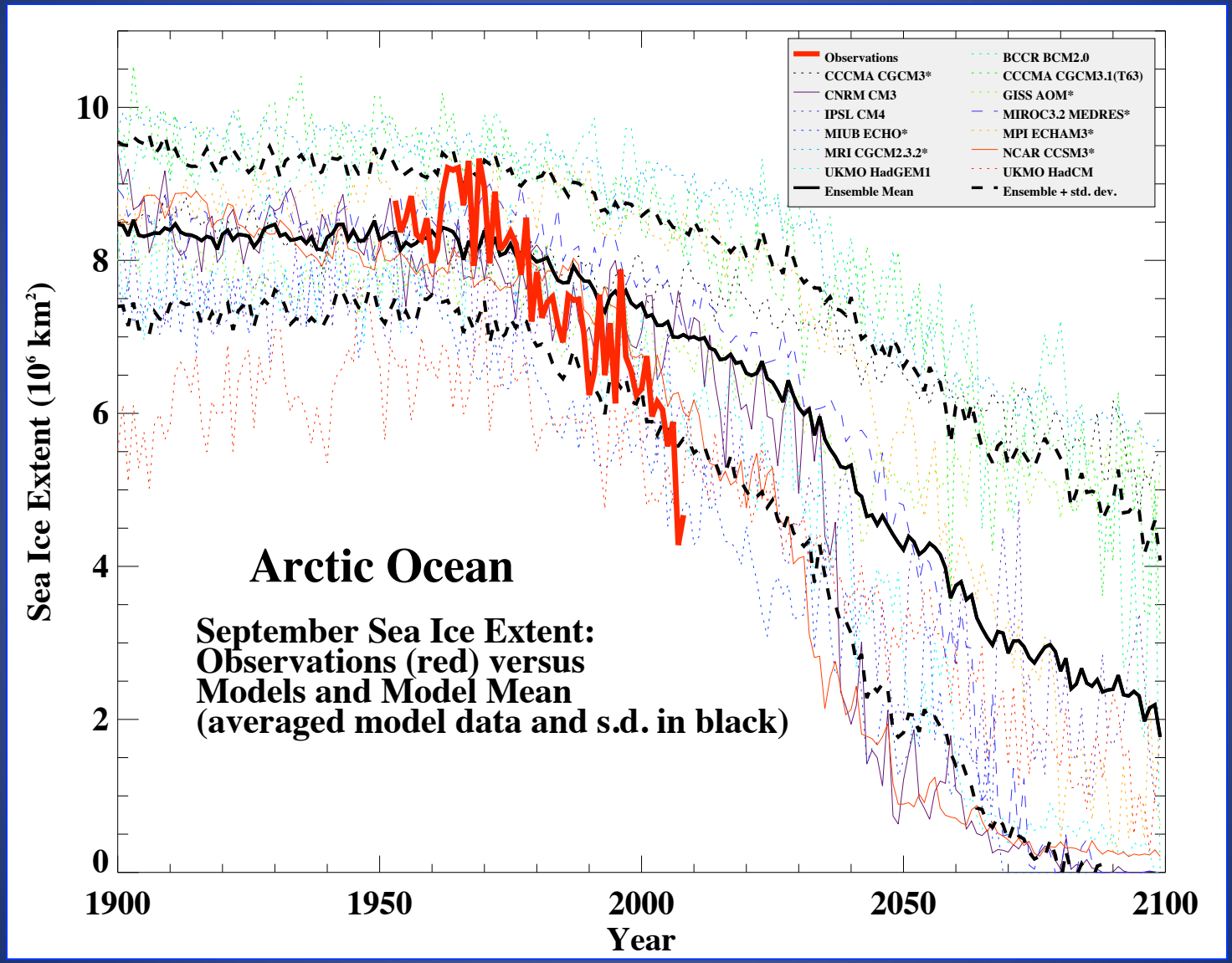
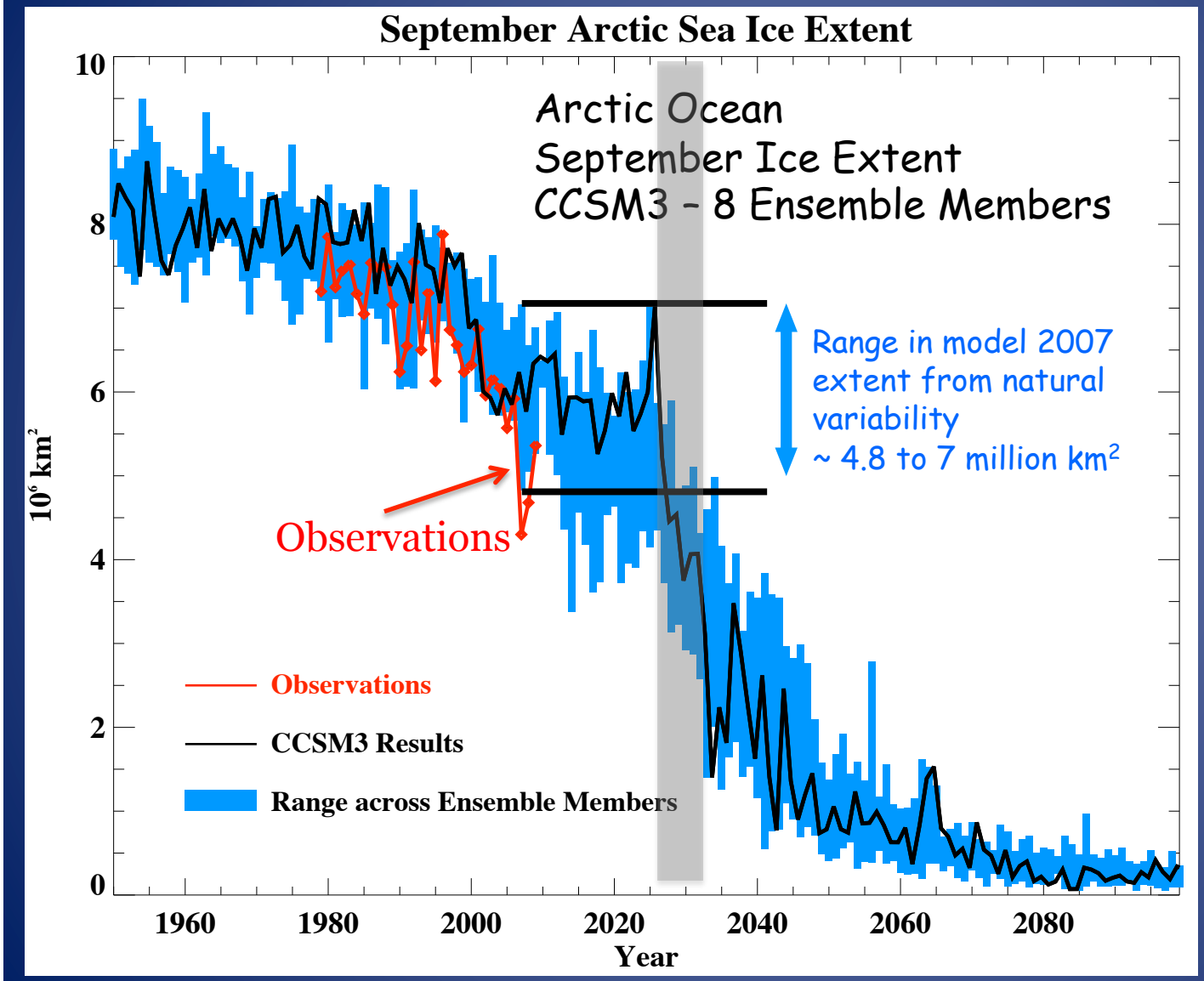
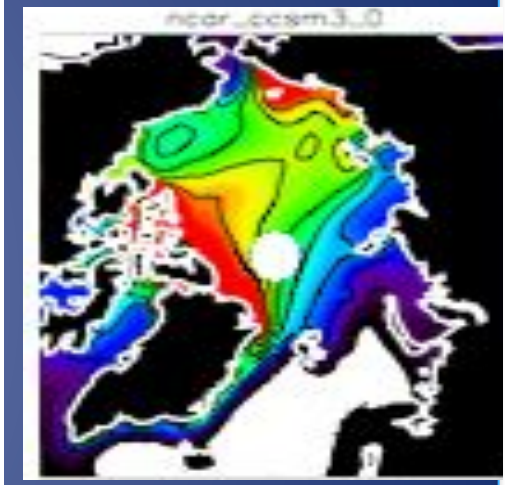
Projected loss of perennial sea ice



(Updated from Stroeve et al. 2007)

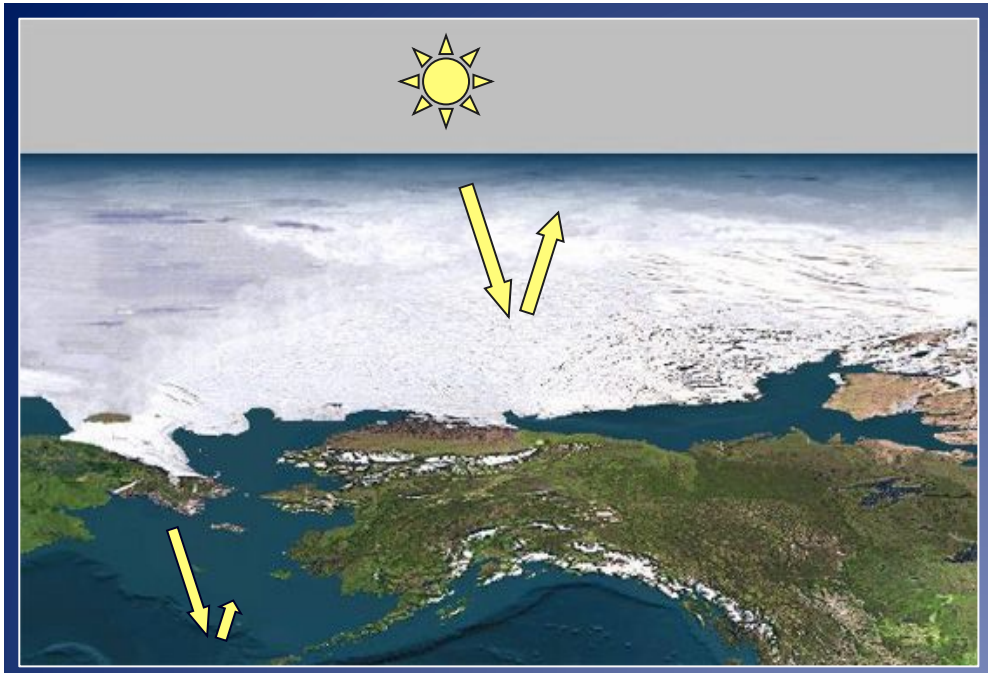
Projected loss of perennial sea ice

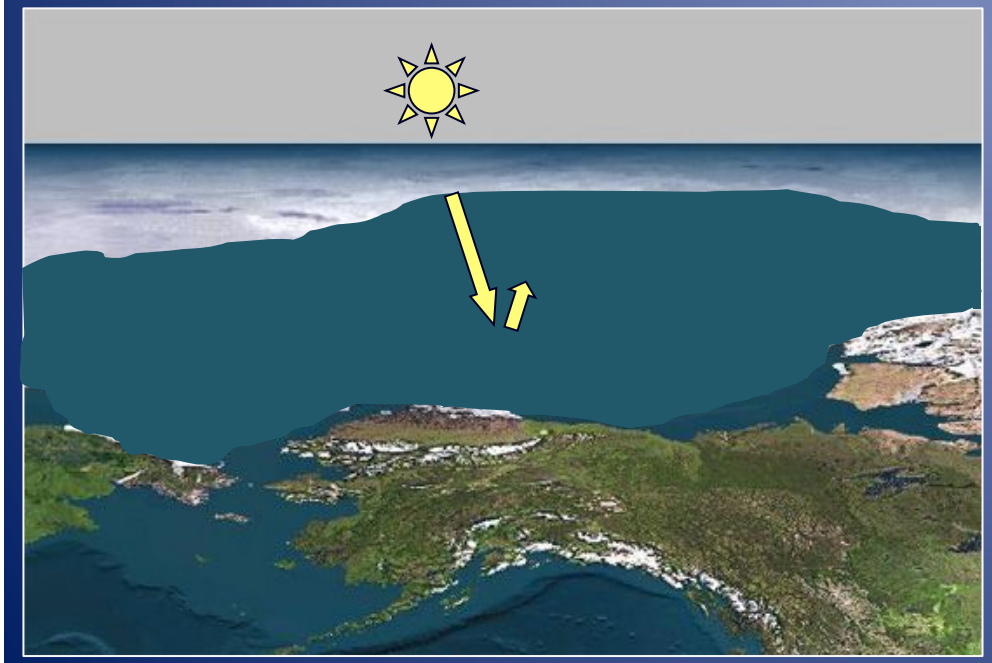




Thickness

(Holland et al., 2006)

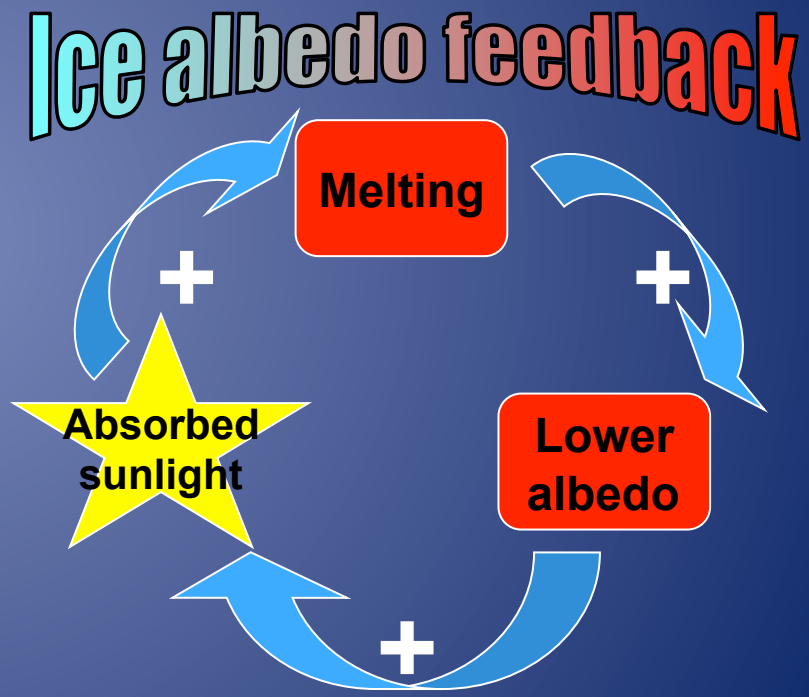




(Courtesy of Don Perovich)

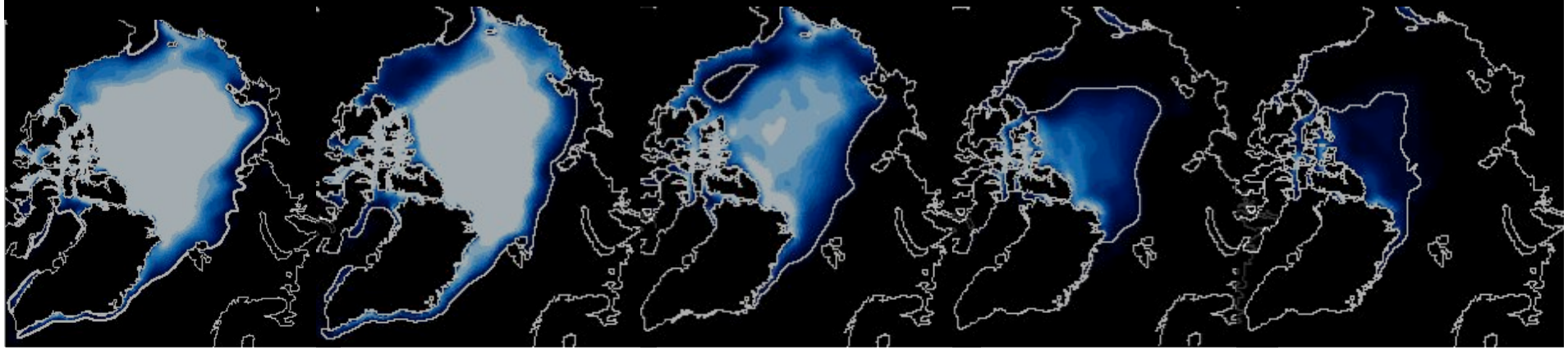
Possibility of a Tipping Point?

Could ice loss be irreversible?

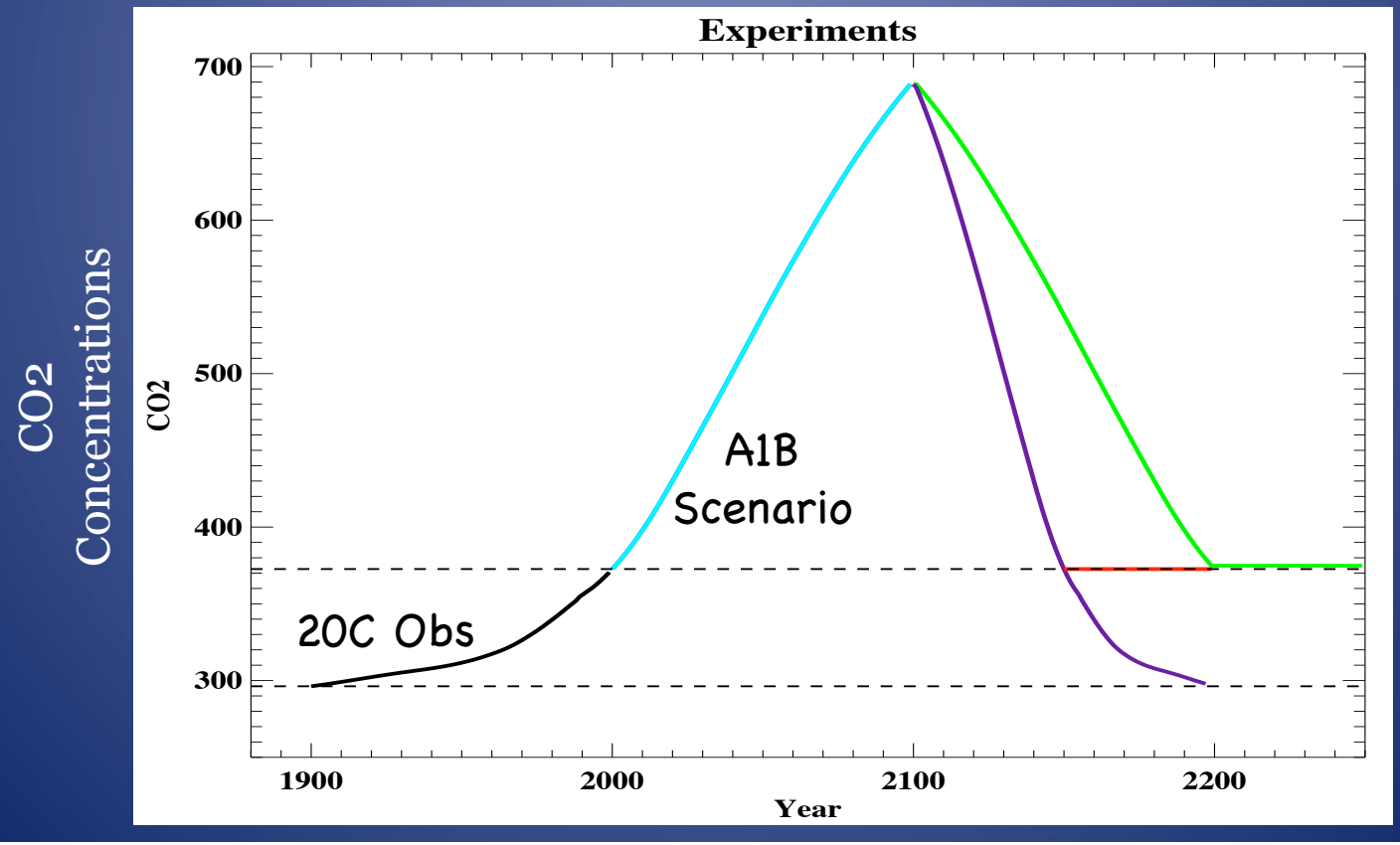


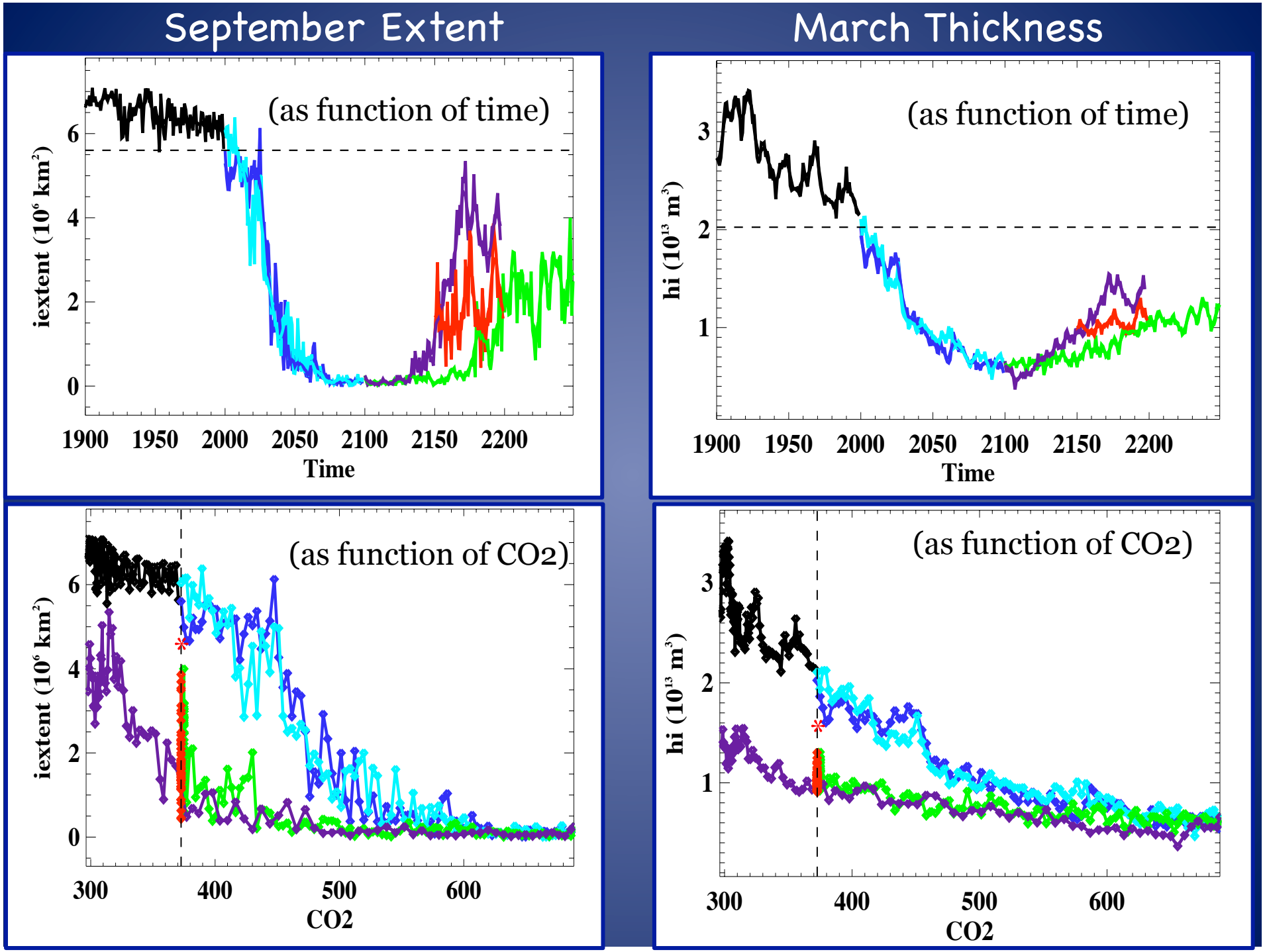
Observations and models suggest the loss of perennial sea ice may be unavoidable

- Would this change be irreversible?
- If global forcing change is removed (CO2 levels decrease) would the perennial Arctic ice recover?
- If so, what mechanisms would influence this recovery?

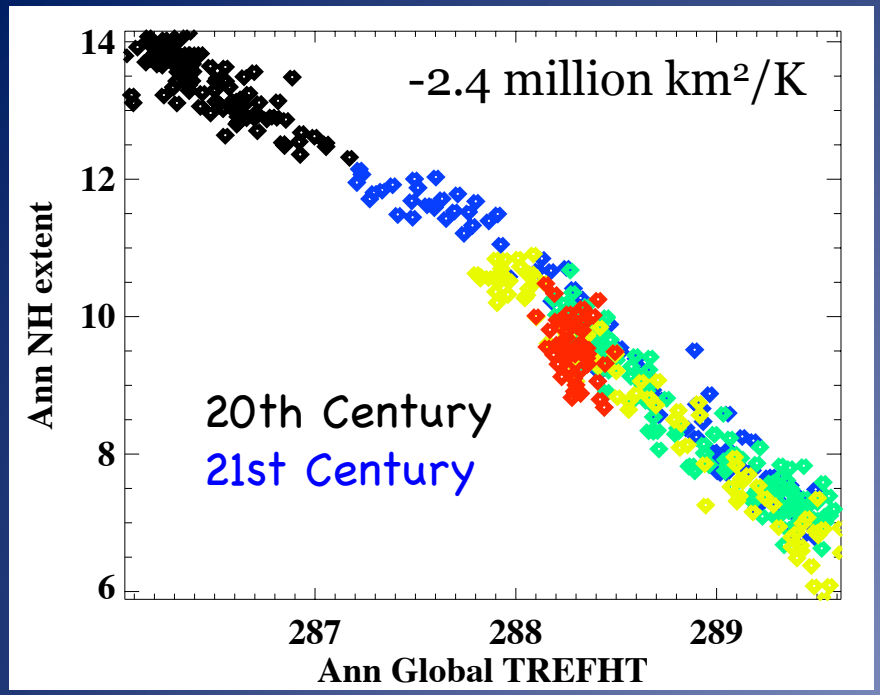


- Performed highly idealized experiments using CCSM3
- Runs initialized with 2100 CCSM3 conditions (seasonally ice free Arctic state)
- Reductions in CO_2 concentrations applied

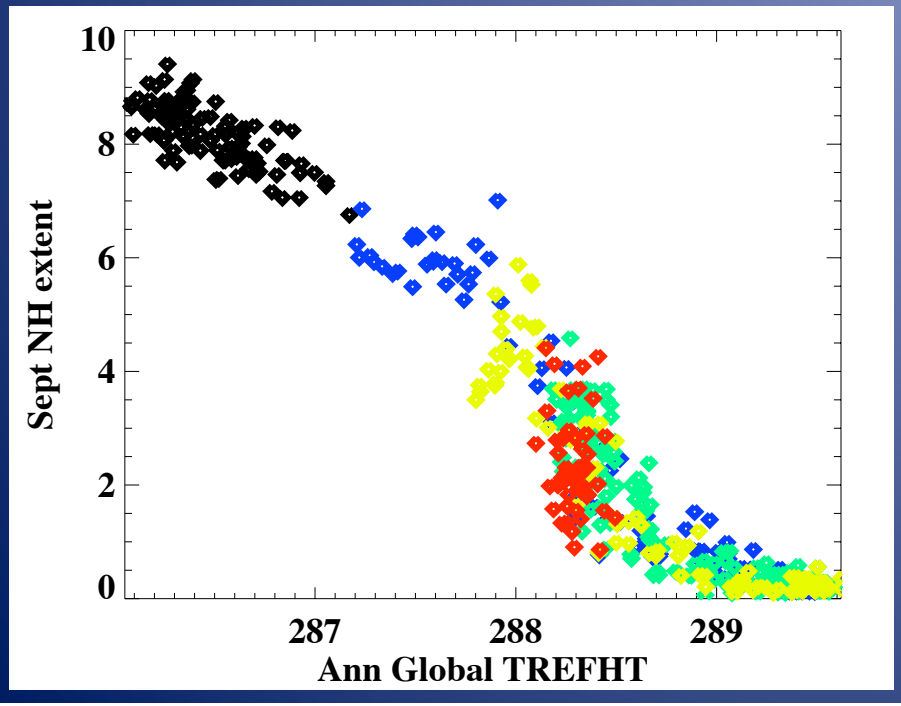


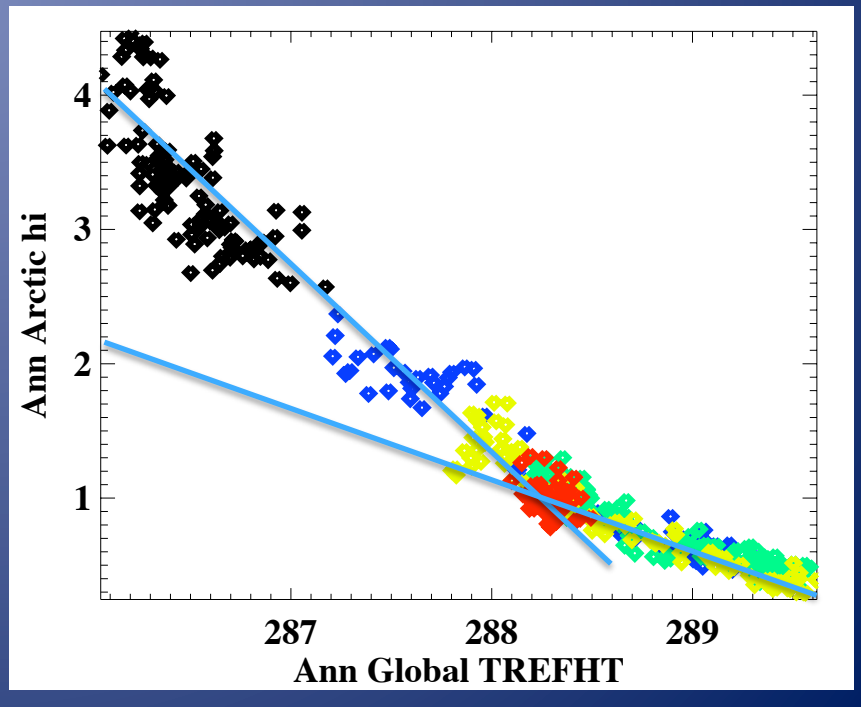

September Extent
March Thickness
(as function of time)
iextent (10^6 km^2)
Time
(as function of time)
hi (10^{13} m^3)
Time
(as function of CO2)
iextent (10^6 km^2)
CO2
(as function of CO2)
hi (10^{13} m^3)
CO2

Relationship to global surface air temperature



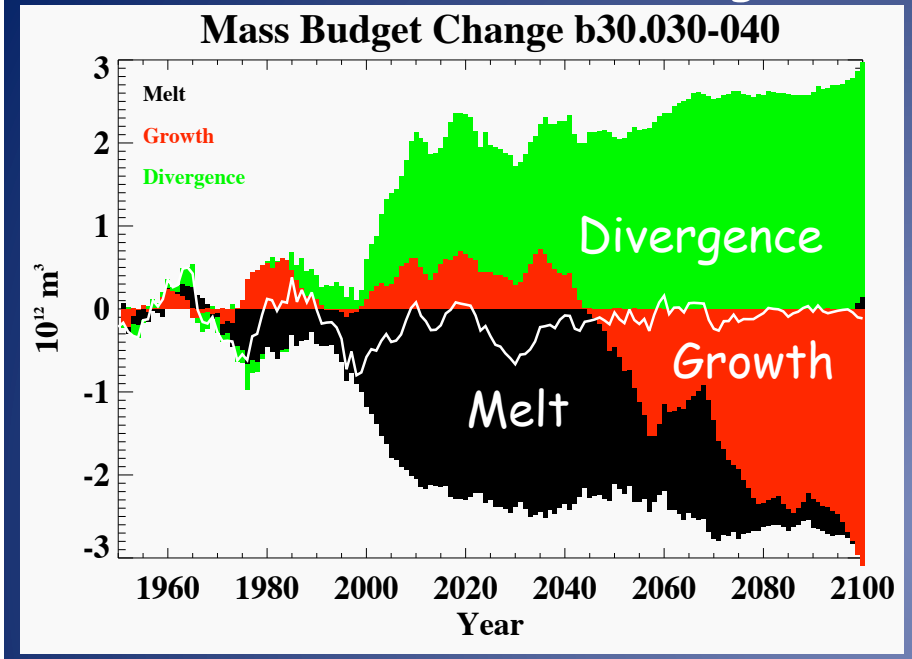
- Linear relationship of annual NH ice extent and global SAT
- Relationship with September extent and ice thickness not linear
- Relationship nearly identical for the ice loss and ice recovery simulations



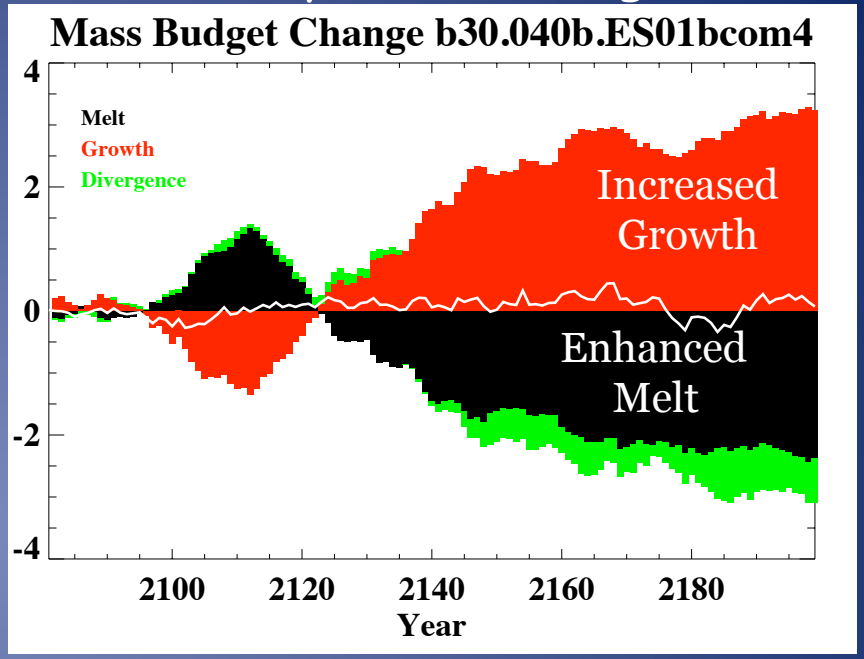


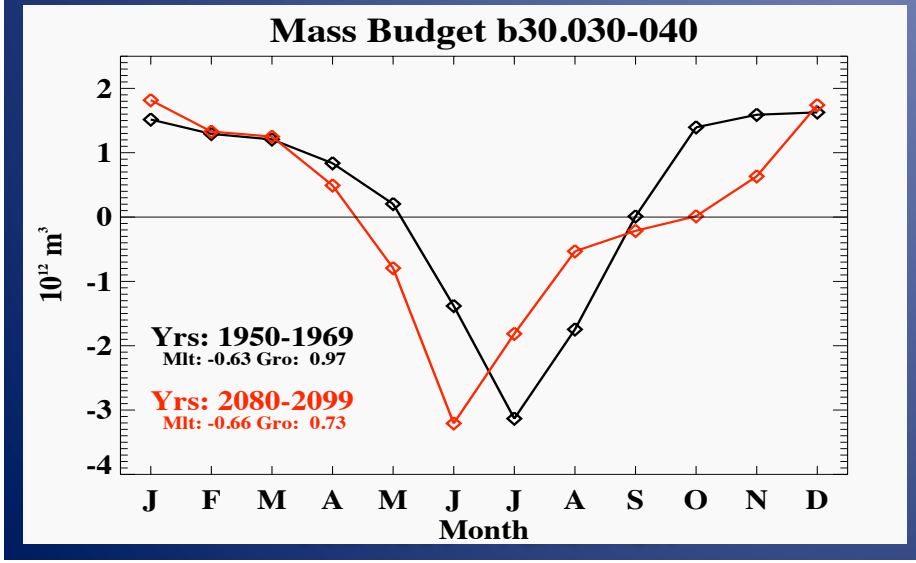
What allows sea ice recovery?

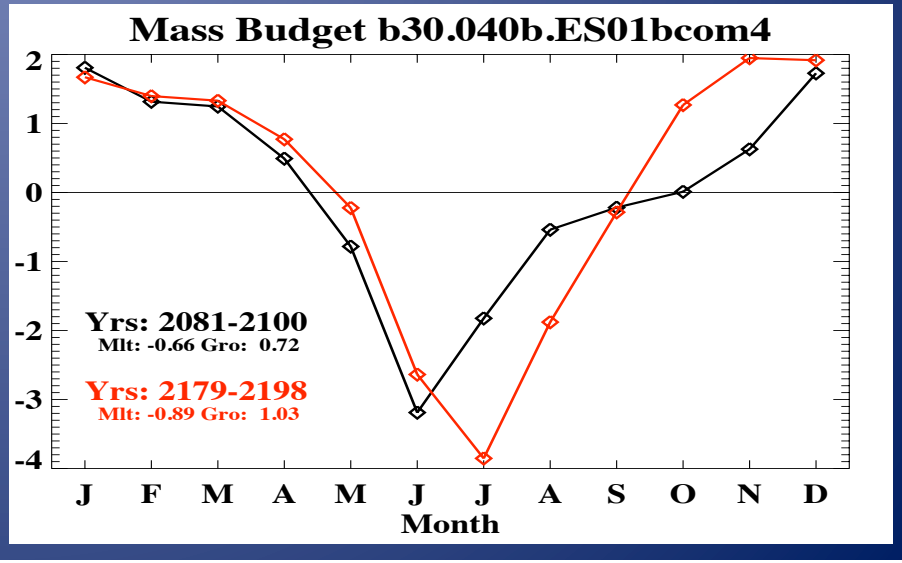
Ice Loss - Run with increasing GHG

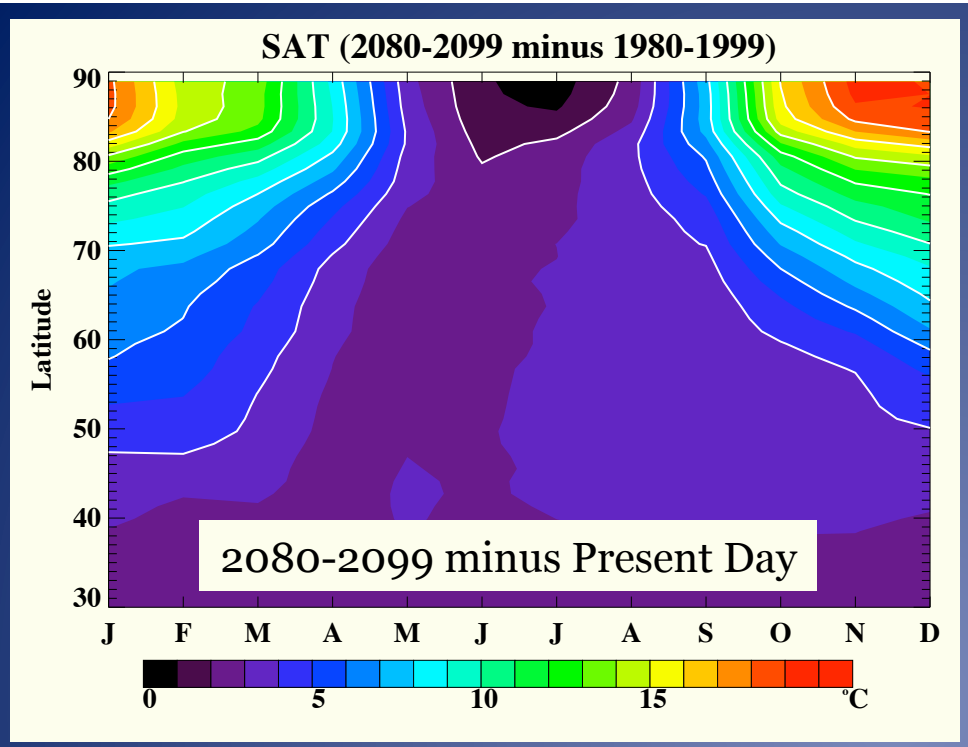


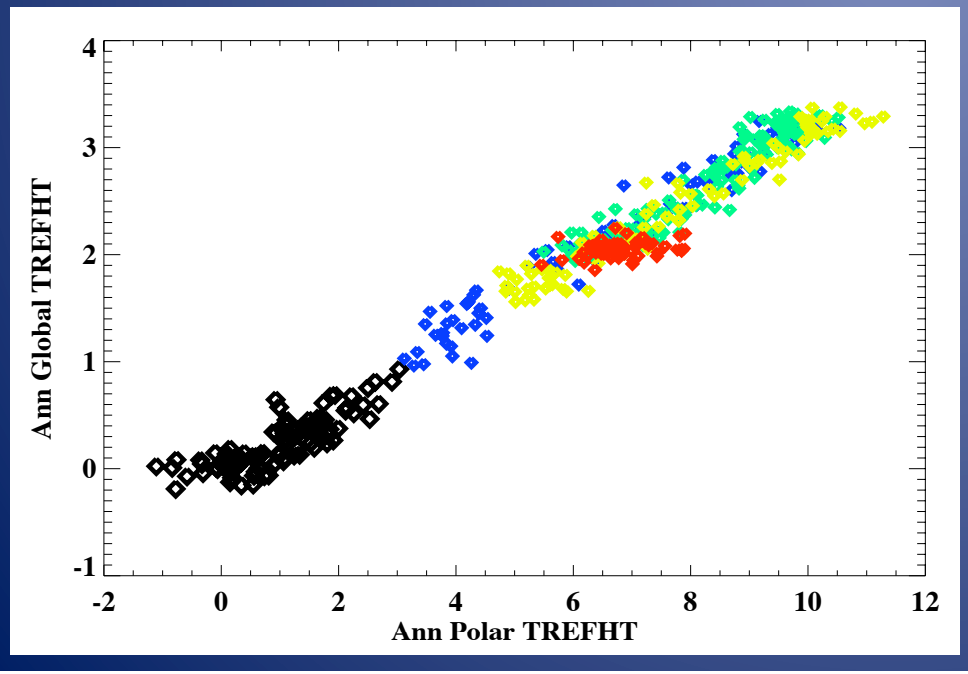
Ice Recovery - decreasing GHG











Arctic amplification

Arctic amplification has similar characteristics for the loss and recovery of perennial sea ice

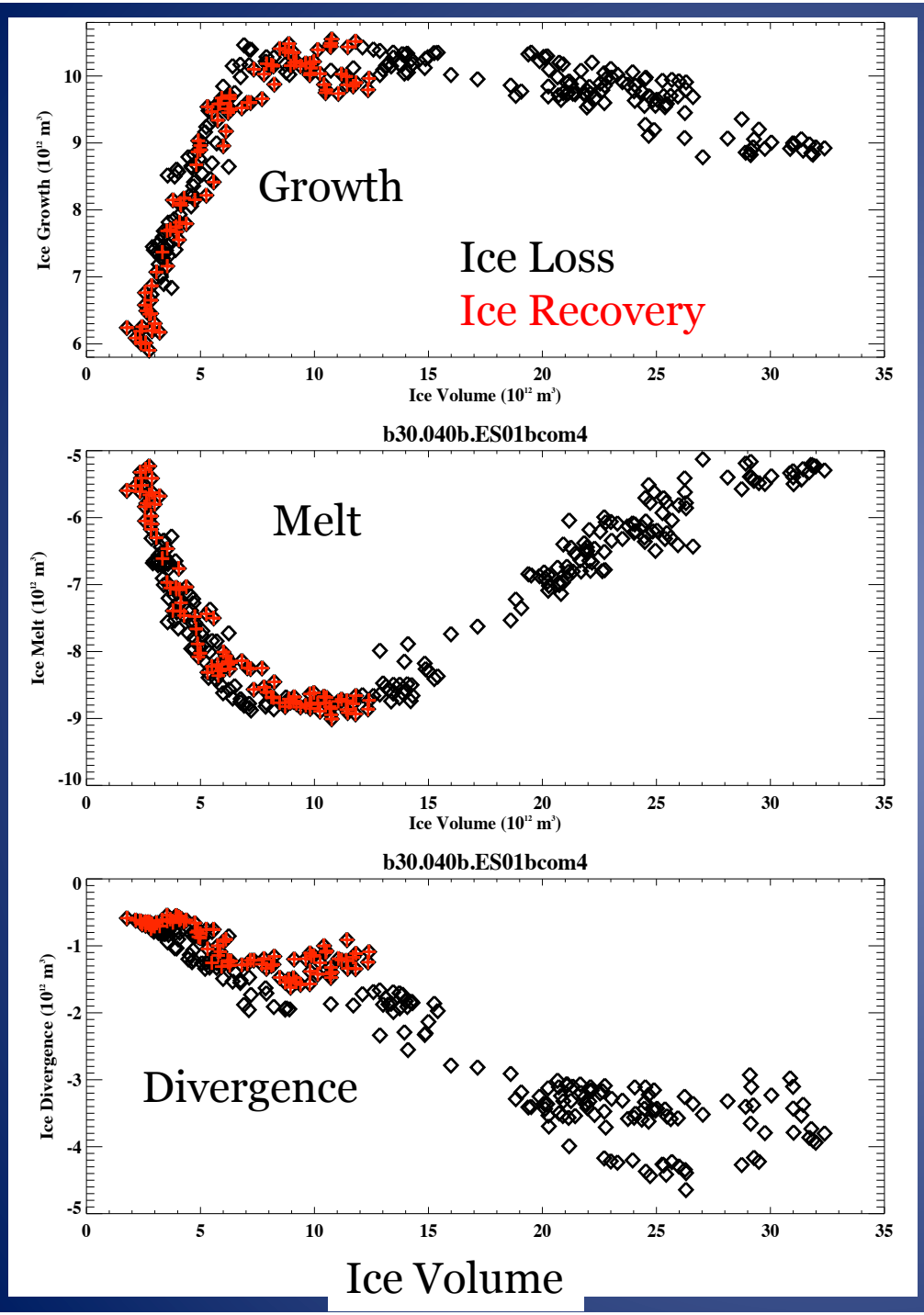
In CCSM3, the Arctic surface air temperature change is about 3Xs that of the global change

Conclusions

- Climate simulations were initialized from seasonally ice free (2100) state with applied reductions in CO2 (from 2100 A1B levels)
- Arctic recovers a perennial ice pack with some time lag
- Relationship of sea ice conditions (state, mass budget) to global air temperature is nearly identical for the loss and recover of perennial sea ice
- Suggests that loss of perennial sea ice is reversible

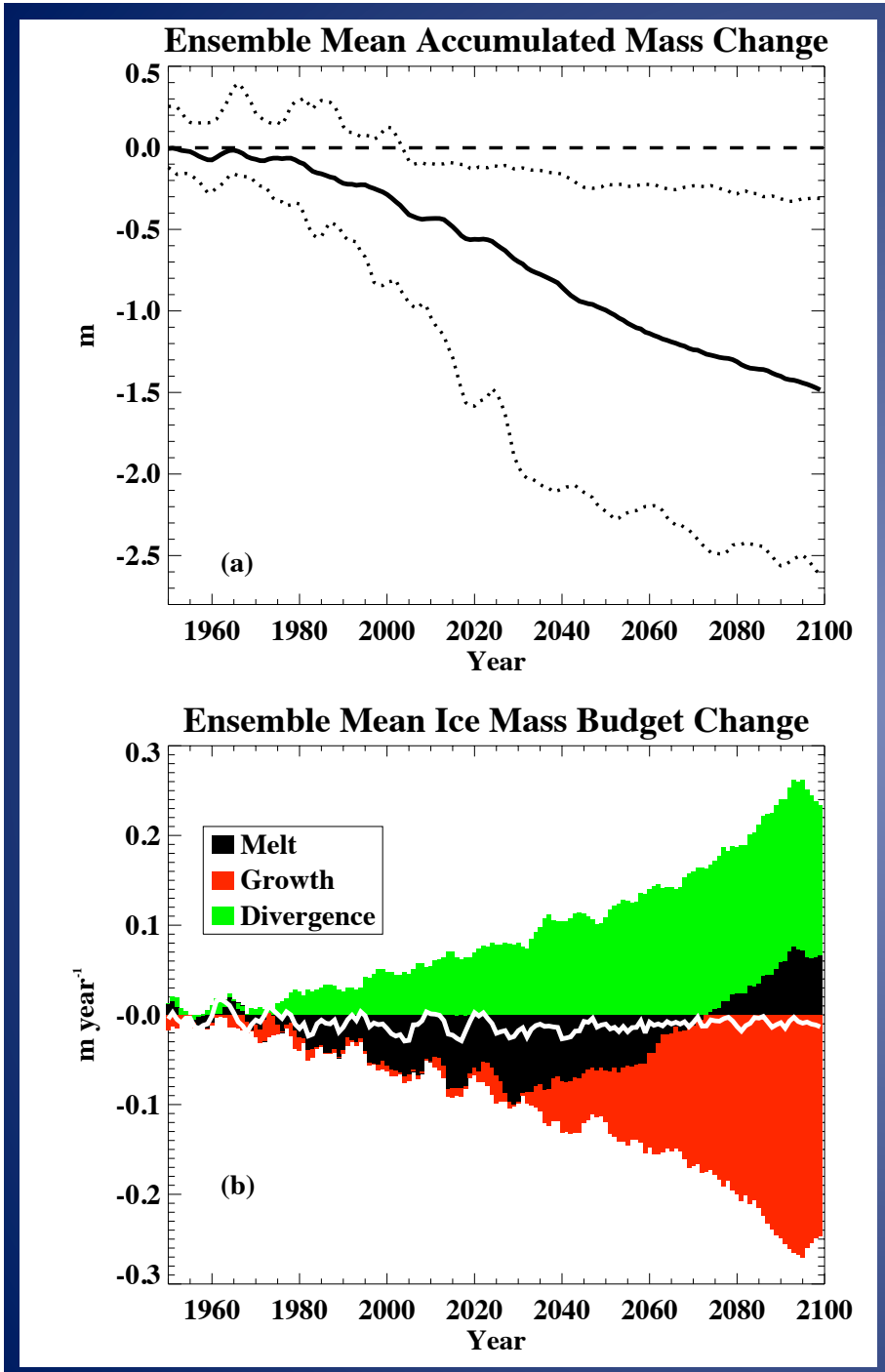
Questions?

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 not clear how robust/significant



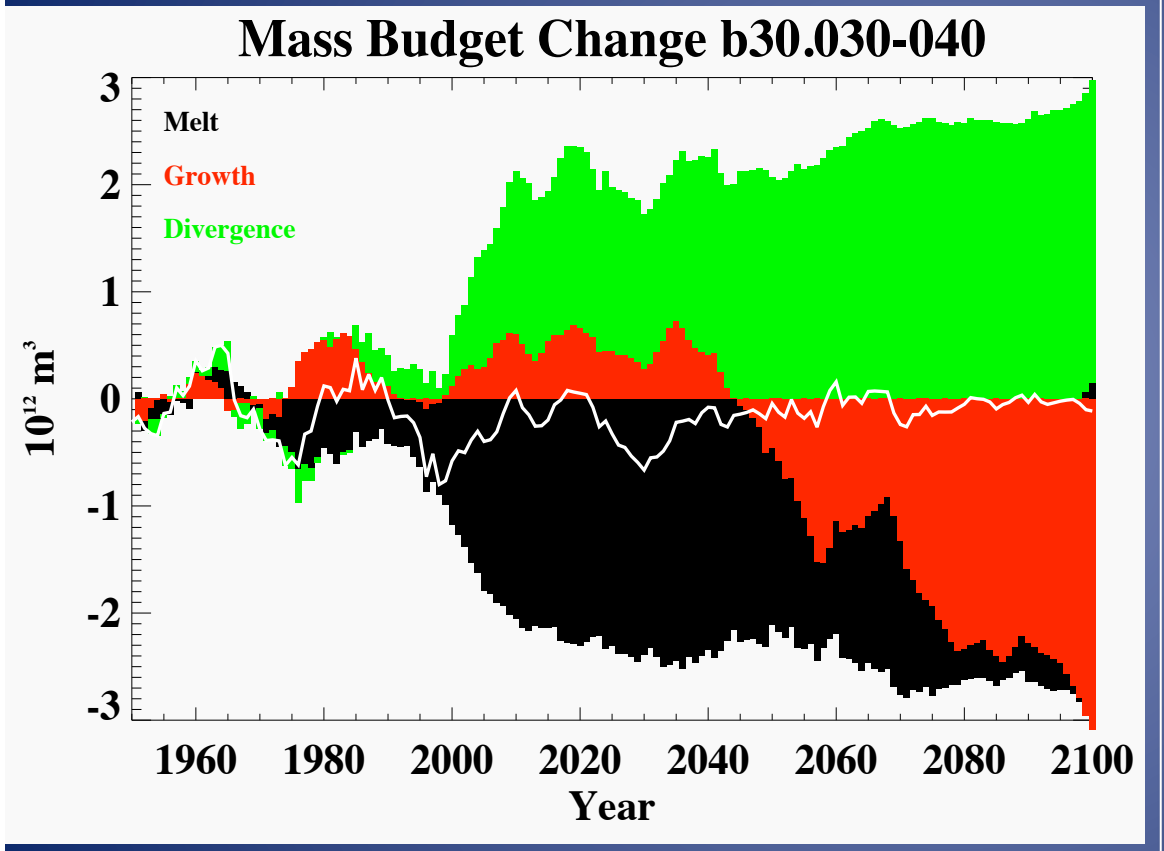
Diagnosing Ice Loss

Multi-model Sea 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., 2010)

Diagnosing Ice Loss

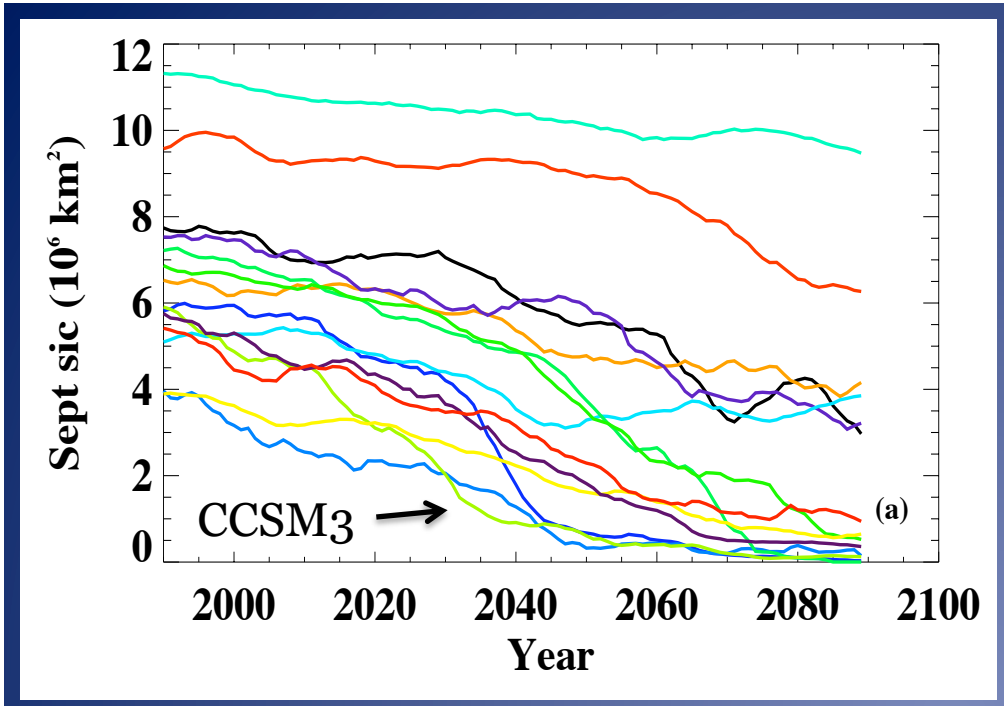


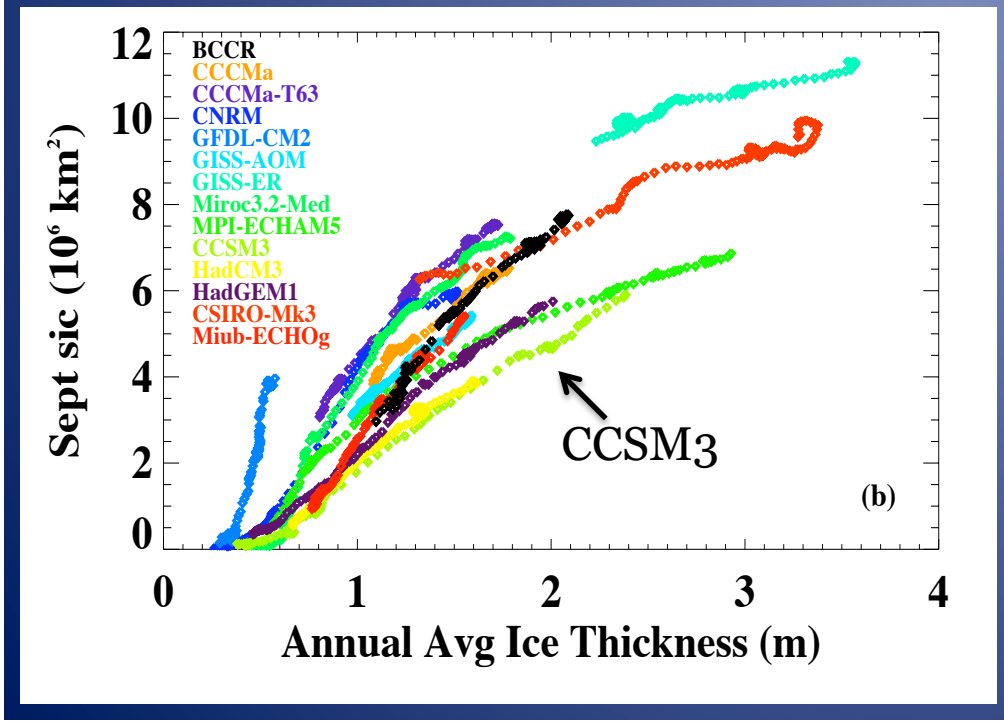
(Holland et al., 2010)

CCSM3 Sea Ice Mass Budget Change

- Initial increases in melt (and increases in ice growth)
- Gives way to reductions in ice growth
- Partially compensated by reduced loss via ice transport
- Results in ~2m of thinning

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., 2010)