Lessons learned from evaluating the 2007 Arctic sea ice loss in observations, atmospheric reanalysis, and CAM4

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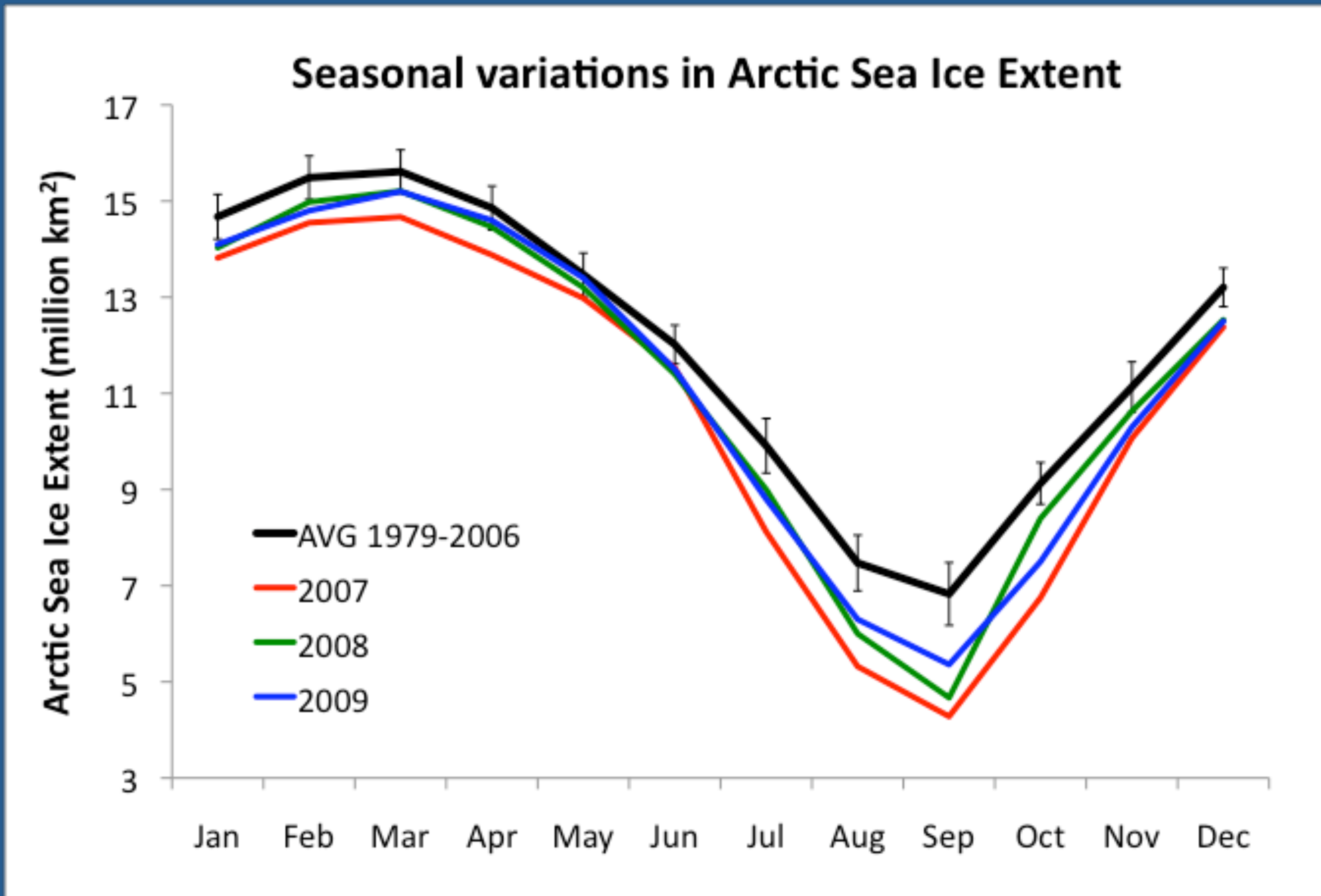
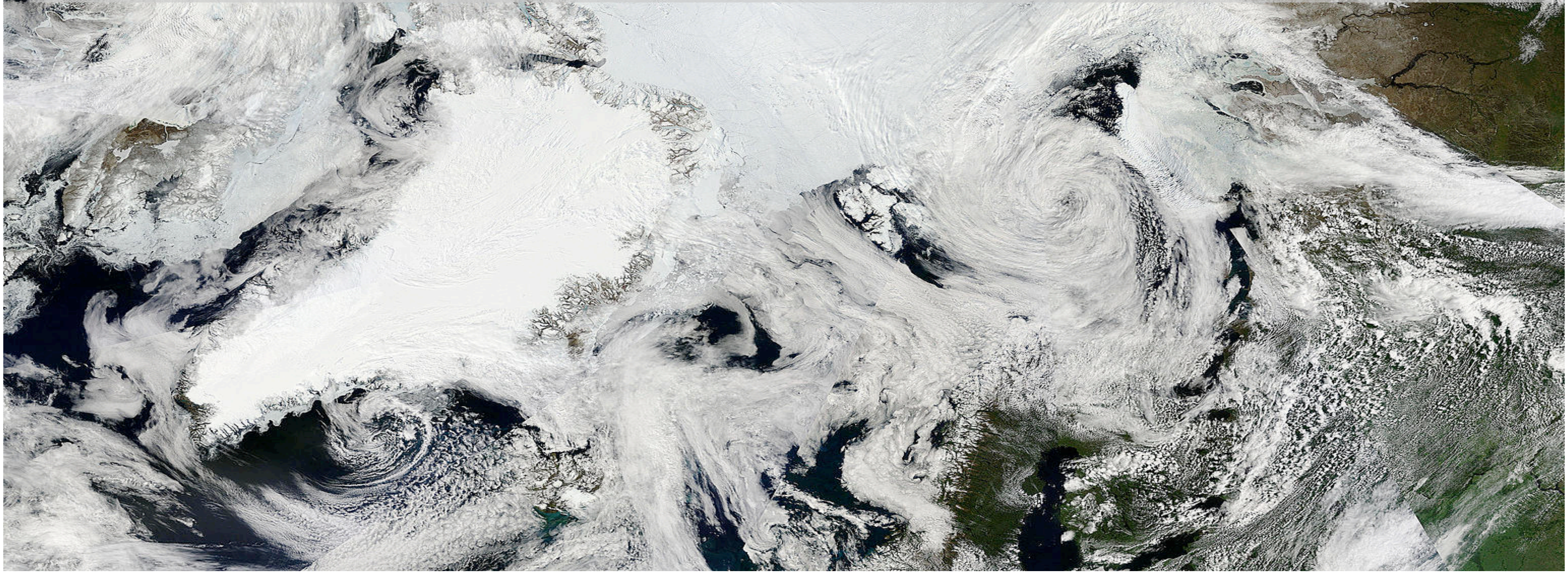
Recent Arctic ice loss has caught us off guard, especially 2007.



Ice extent data from NSIDC

talk outline

1. Observations during 2007 sea ice melt
2. Model evaluation during 2007 sea ice melt
3. Flux user requirements



Why so much sea ice loss in 2007?

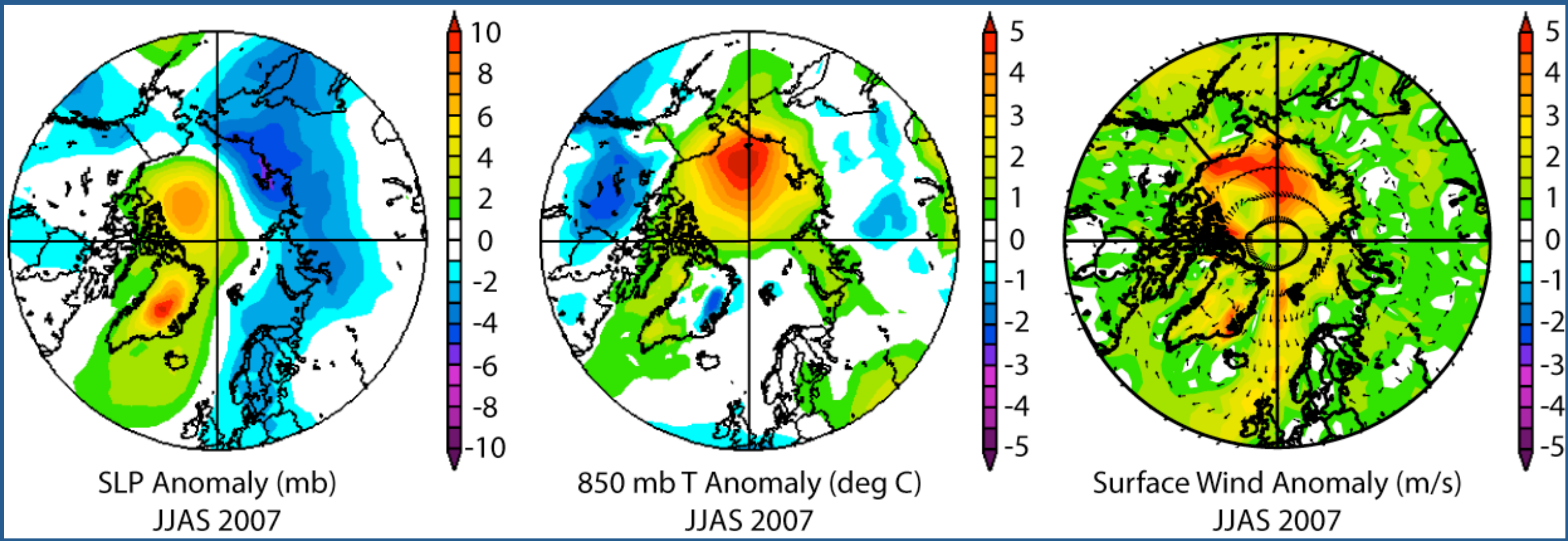
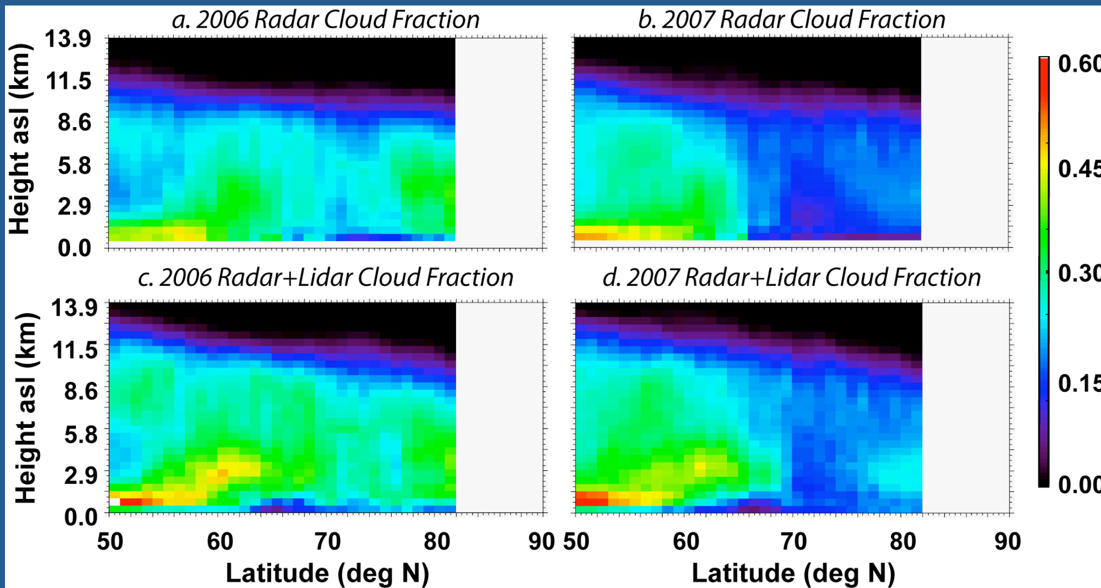


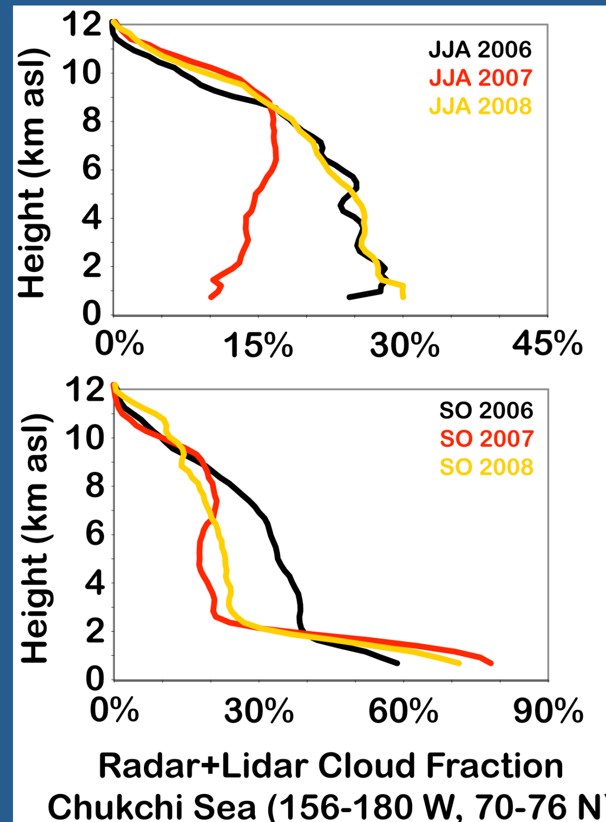
Figure 4, Kay et al. (2008)

Record-breaking 2007 sea ice loss was driven by an anomalous but not unprecedented atmospheric circulation pattern (Kay et al. (2008), Zhang et al. (2008), L'Heureux et al. (2008), Kay and Gettelman (2009)).

New data + Large ice loss = New discoveries



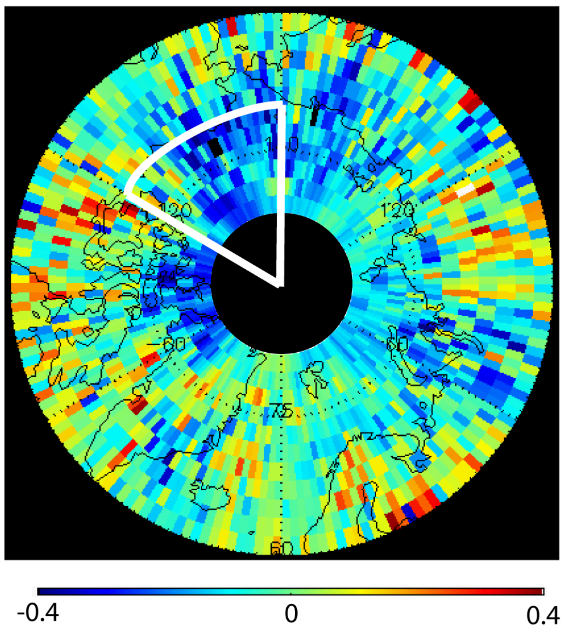
A-train observations of Arctic clouds helped quantify the contribution of cloud reductions to the 2007 sea ice loss (Kay et al. 2008)



Cloud response to sea ice loss depends on the efficiency of the air-sea coupling (Kay and Gettelman, 2009)

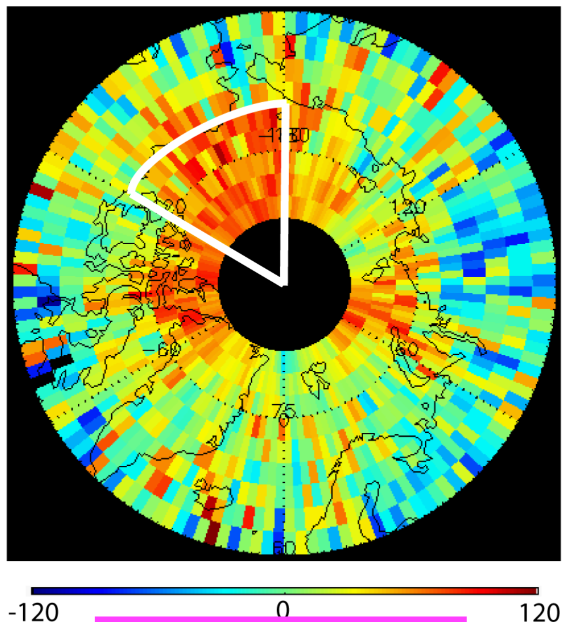
Did anomalous fluxes contribute to the record-breaking sea ice loss?

CloudSat/CALIOP Cloud Fraction



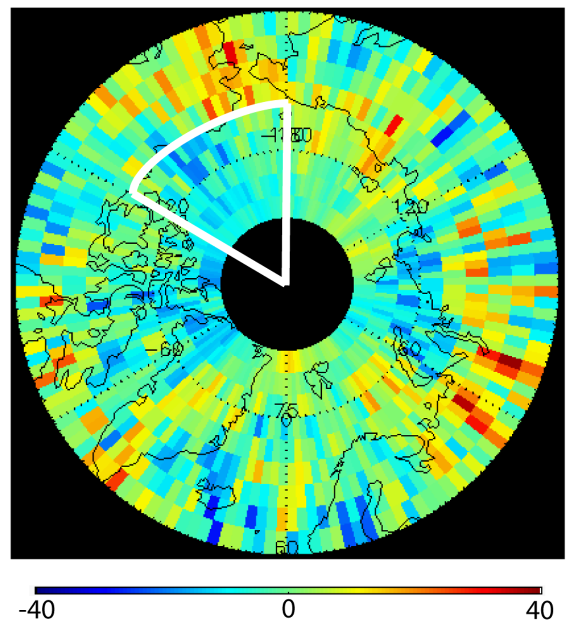
Western Arctic: -16%

Downwelling SW Radiation (W m^{-2})



Western Arctic: + 32 W m^{-2}

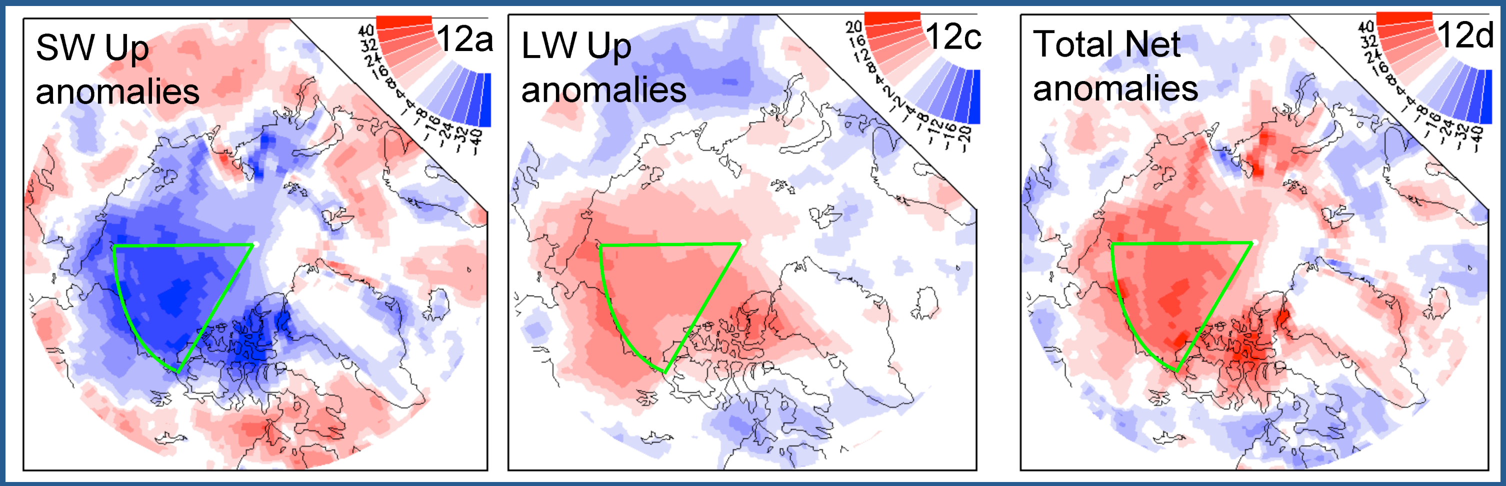
Downwelling LW Radiation (W m^{-2})



Western Arctic: - 4 W m^{-2}

Summer 2007 – Summer 2006 cloud and surface flux differences from Kay et al. (2008)

What about CERES-derived fluxes?

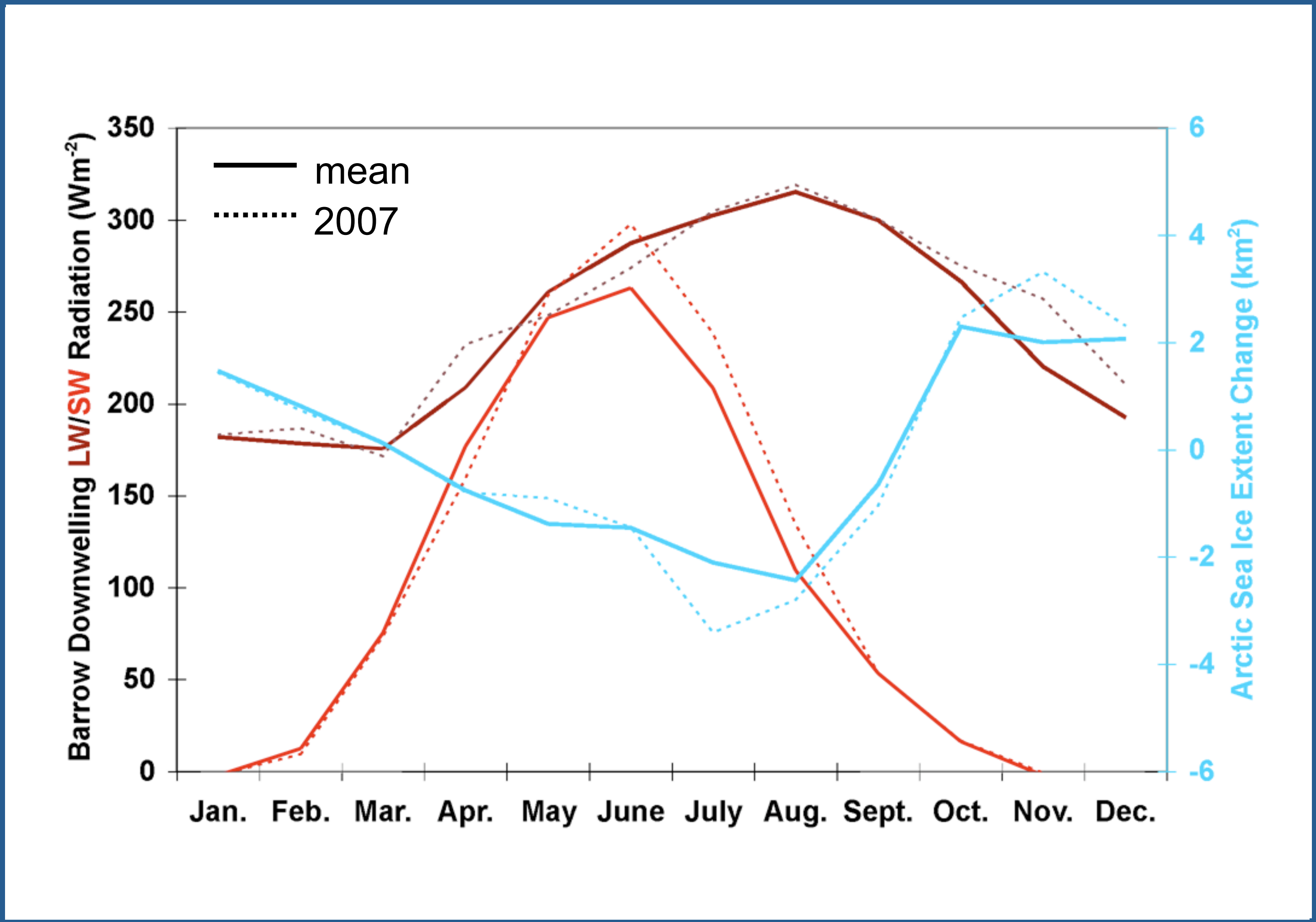


TOA Fluxes (Wm^{-2})	2007	2007-avg(2000-4)
Net	12	25
LW up	231	9
SW up	183	-34

Summary of AMS09 analysis of CERES FlashFlux (Stackhouse et al):
- Analysis to date consistent with Kay et al. (2008) GRL
- “Oddities” with CERES surface shortwave fluxes still being resolved
- Climatological surface albedo assumed, not appropriate for 2007!

What about direct flux measurements?

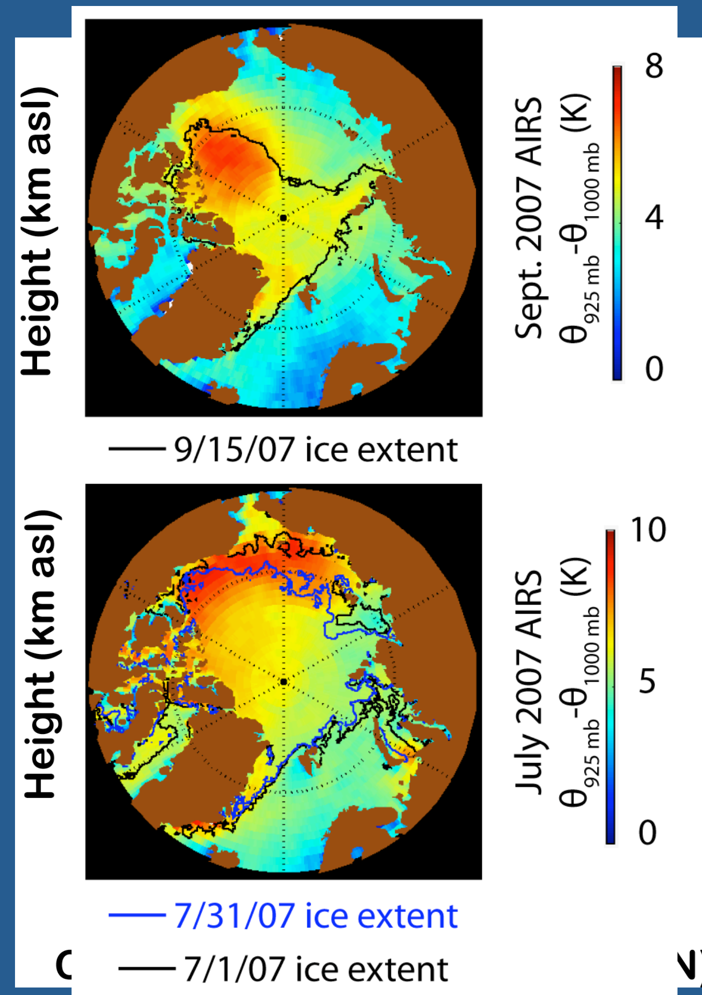
(Barrow, AK data)



Early ice loss and cloud reductions led to strong shortwave feedbacks during the 2007 melt season.

What about turbulent fluxes?

Atmosphere-ocean coupling (via turbulent fluxes) is enhanced when a warm open-ocean underlies a rapidly cooling atmosphere.



Figures adapted from Kay and Gettelman (2009)

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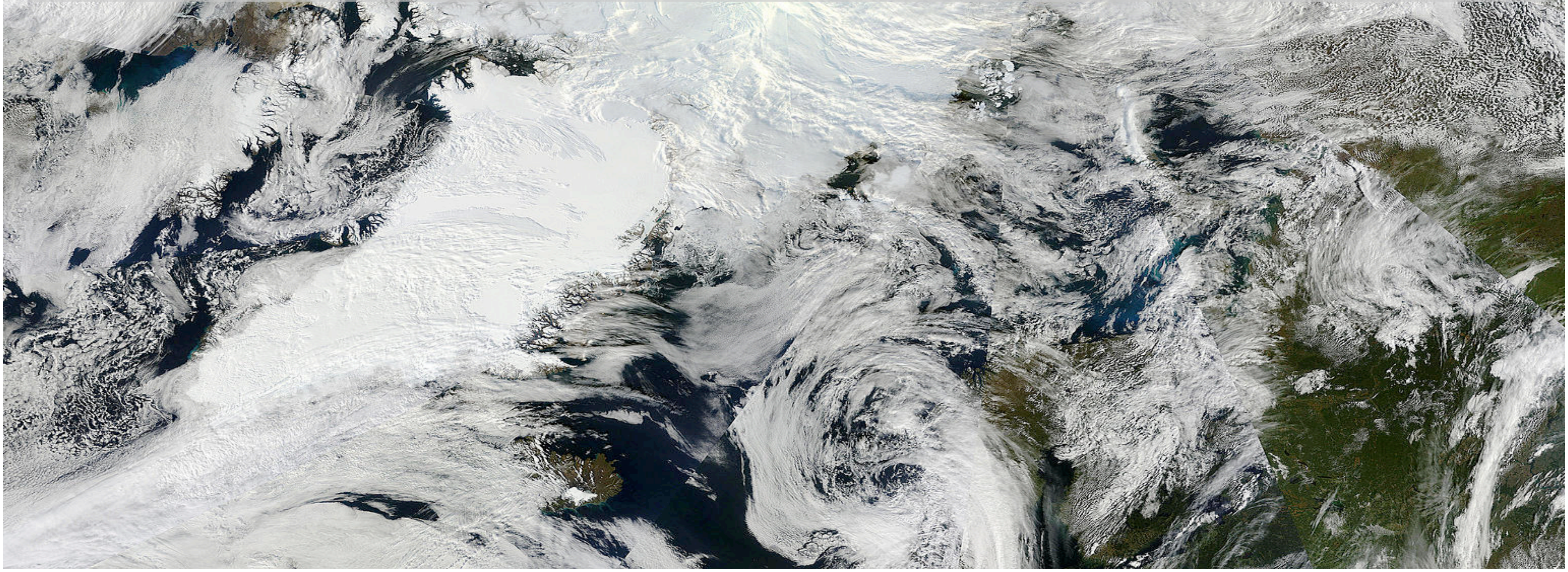
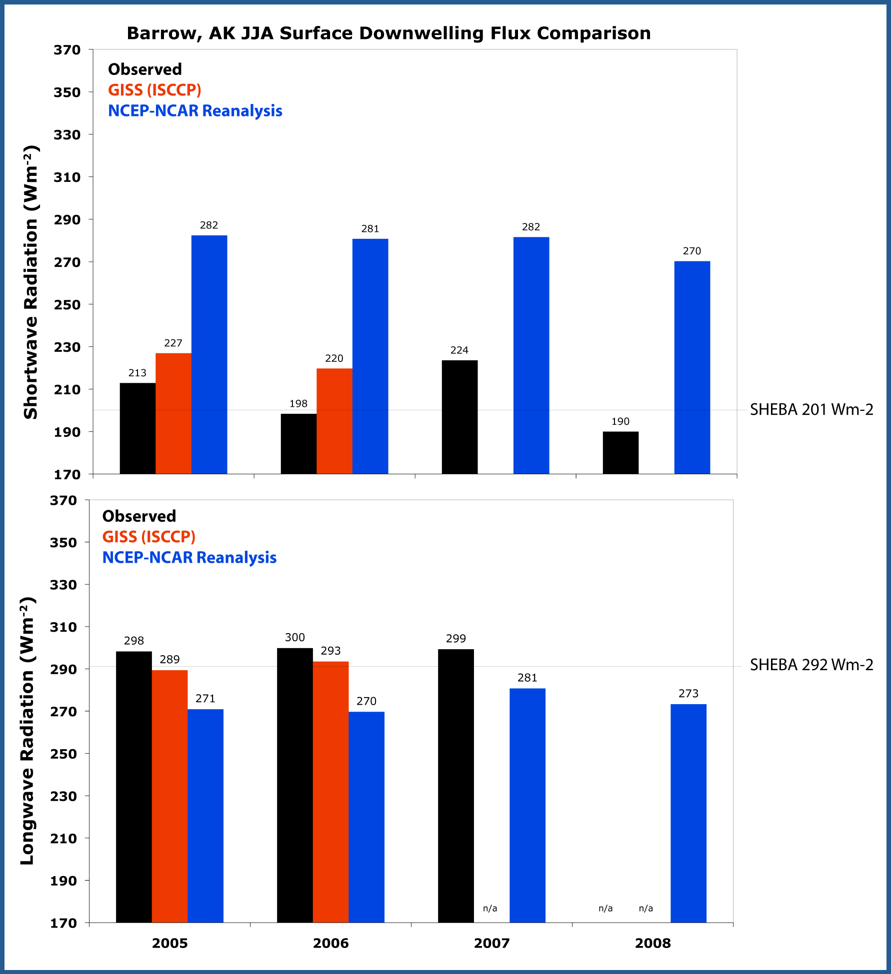


Many studies have pointed to large model discrepancies in Arctic fluxes…



Recent comparisons with Barrow observations consistent with Serreze et al (1998):

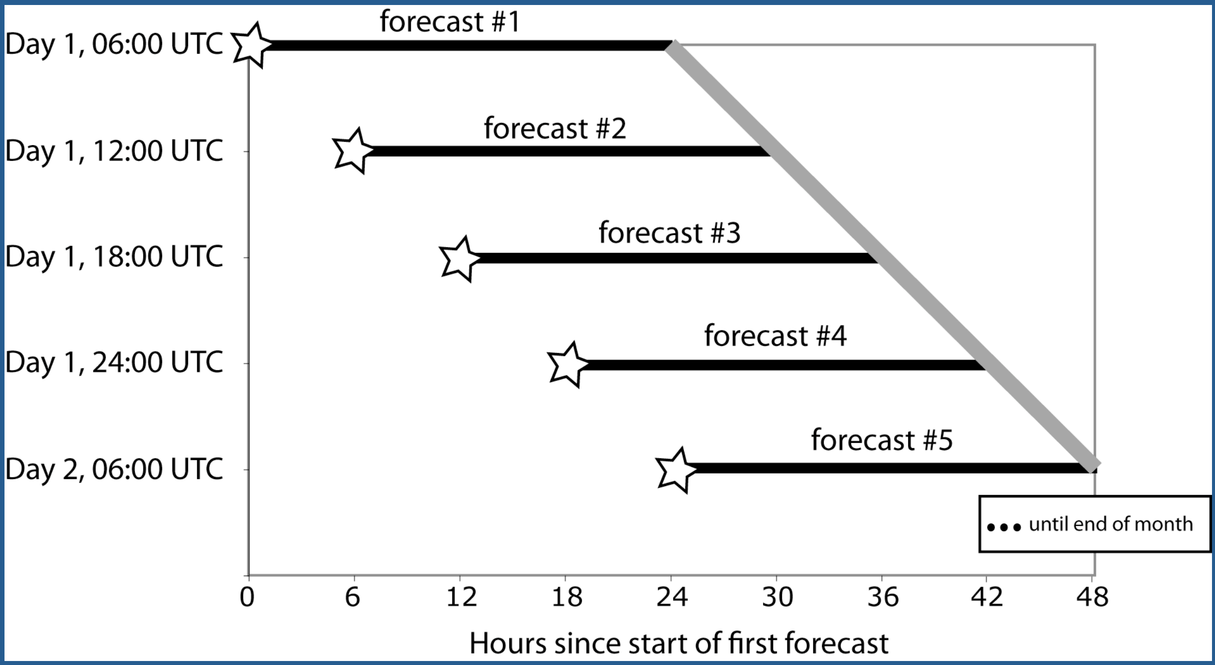
-NCEP has excessive downwelling SW and too little downwelling LW (cloud deficit).

-GISS (ISCCP) closer to observed fluxes.

I have been evaluating CAM4 during 2007 using observationally constrained forecasts

CAM4 = Community Atmosphere Model, version 4 (IPCC AR5 model)
DART = Data Assimilation Research Testbed (Anderson et al. 2009 BAMS)

Forecast averaging to produce monthly mean values

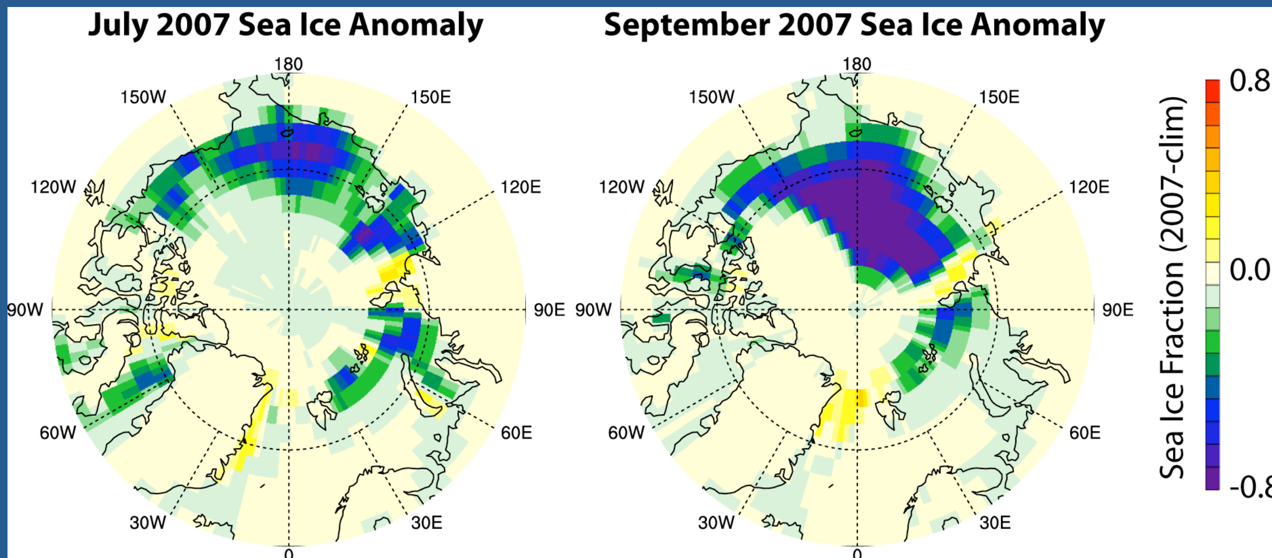


CAM4-forecasted values over the newly ice-free Arctic Ocean

	July 2007	September 2007
Net TOA radiation	54 Wm^{-2}	-156 Wm^{-2}
Net surface energy	148 Wm^{-2}	-27 Wm^{-2}
Low cloud (Total cloud)	72% (74%)	71% (73%)
TOA Cloud Forcing	-77 Wm^{-2}	-11 Wm^{-2}
Surface Cloud Forcing	-56 Wm^{-2}	28 Wm^{-2}

How do we evaluate these forecasts with observations?

CAM4 response to prescribed 2007 sea ice loss



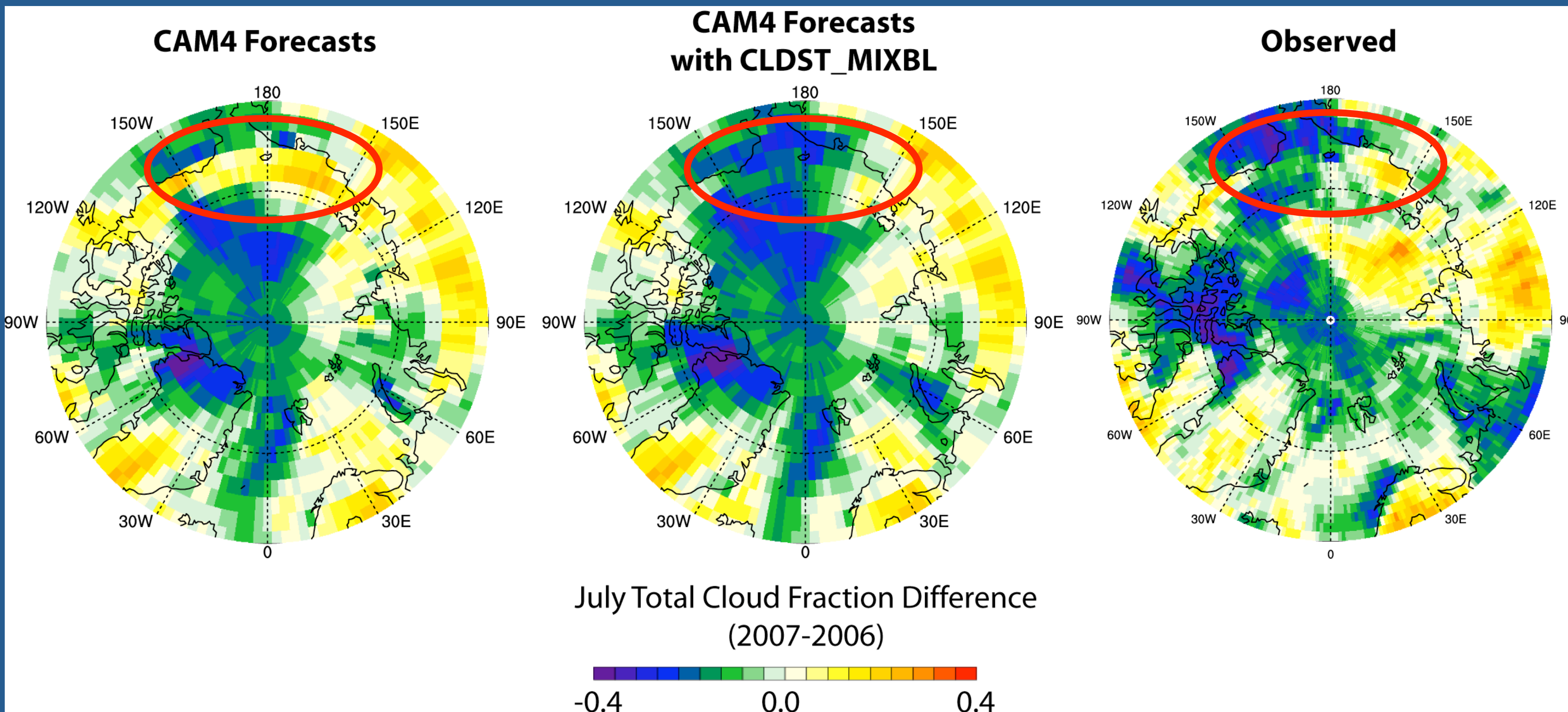
Change associated with sea ice loss (2007 – climatology)

	July 2007	September 2007
Low cloud	+30%	+12%
Net TOA radiation	+21.0 Wm^{-2}	+1.4 Wm^{-2}
Net surface energy	+19.4 Wm^{-2}	-17.9 Wm^{-2}

Again, how do we evaluate these forecasts with observations?

Evaluating and improving the CAM4-forecasted cloud response to sea ice loss

Kay et al. (submitted to J. Climate)



A physically motivated change to the stratus cloud parameterization (CLDST_MIXBL) improved the cloud response to sea ice loss and increased surface energy budgets in July 2007 by 11 Wm^{-2}.

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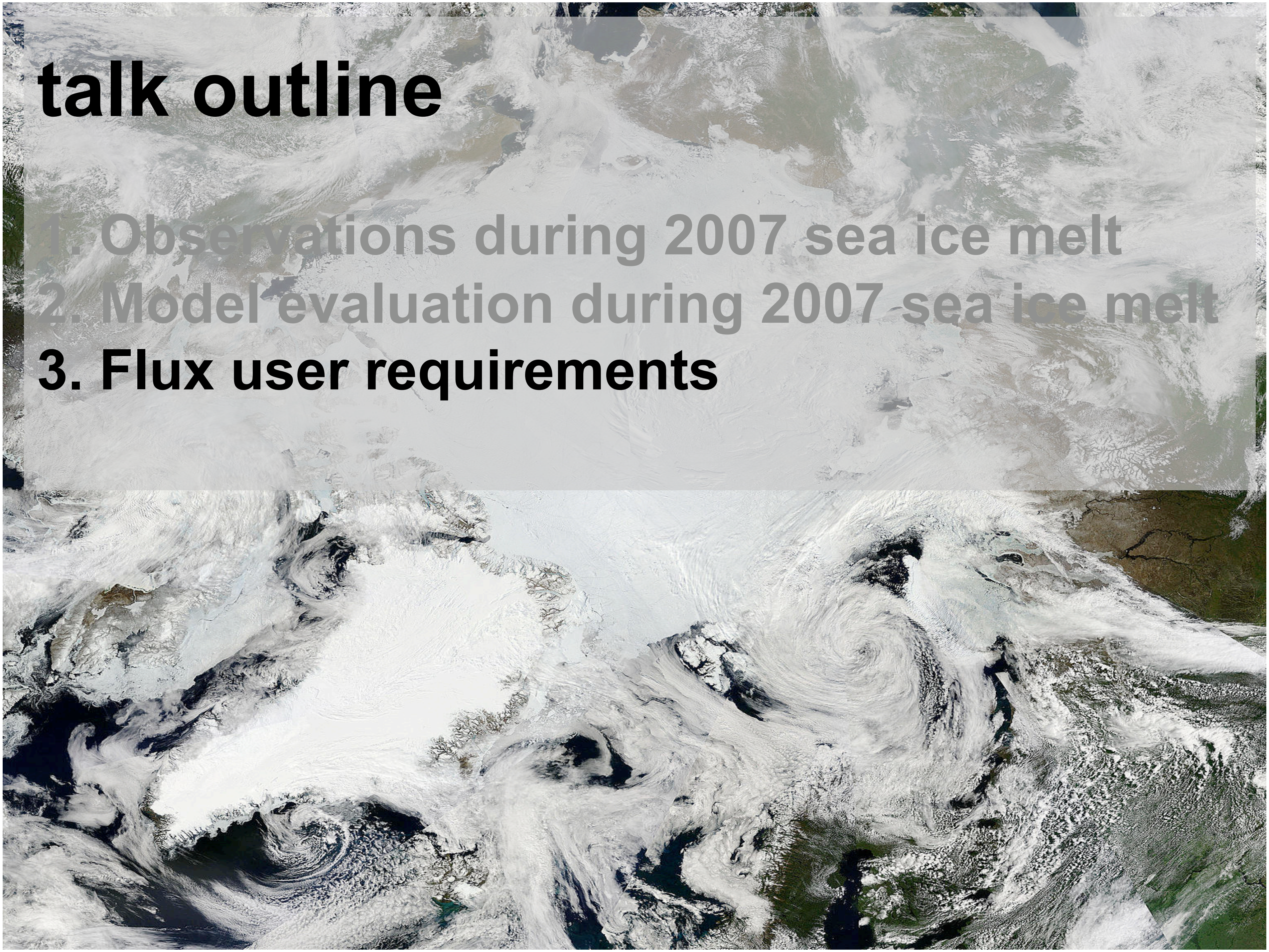

Discussion about forcing datasets used for ice-ocean hindcasts in a recent paper…

"Given the well-documented NCEP biases with respect to clouds and radiation [Liu et al., 2005; Makshtas et al., 2007; Serreze et al., 1998], the use of NCEP forcing fields to investigate the role of clouds may appear to be a rather poor choice. However, since the other alternative (ERA-40) ends in August of 2002, there currently is no other viable choice that would not require the construction of forcing fields from disparate sources and demand laborious retuning of the model. … NCEP forcing fields are adequate because cloud variability for the summer of 2007 is represented surprisingly well by the NCEP/NCAR reanalysis, as shown below."

We all know that validating with cloud fraction does not guarantee reasonable radiative fluxes!

Evaluation of the fluxes used to drive the hindcasts was lacking…

Observations I have worked with during 2007 Arctic sea ice loss

Data source	Atmospheric variable
AIRS, infrared sounder	Temperature (T), moisture (Q) and near-surface stability (S)
CloudSat/Calipso, spaceborne radar/lidar	Cloud occurrence and vertical structure, broadband fluxes
CERES (FlashFlux)	Broadband fluxes at TOA and surface
MODIS	Cloud occurrence
Barrow, Alaska, heavily instrumented site	Cloud occurrence, surface fluxes
Radiosondes, over land only	T, Q, S, inversion statistics
SHEBA, one year over sea ice only	Surface fluxes, clouds
Reanalysis products	Large-scale atmospheric structure (SLP, T)

What else could be added?
Need for observations over the Arctic Ocean, especially over newly open water.

USER REQUIREMENTS/REQUEST GUIDANCE

Sampling:
-Temporal = at least seasonal, monthly meets many needs
-Spatial resolution and coverage = at least 3x5 degrees
-Spatial coverage = 65-90 N

Precision/accuracy:
- Precision << 5 Wm^{-2}
- Absolute accuracy within 5 Wm^{-2}

Additional requests:
-Don’t assume a climatological surface.
-Don’t assume the Arctic is one environment.
-Discriminate between “easy” and “hard” fluxes
(e.g., TOA broadband radiative fluxes vs. surface fluxes)