Polar Climate Working Group Update

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http://www.cesm.ucar.edu/working_groups/Polar/

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Polar-relevant CCSM4/CESM1
J. Climate Special Issue Papers

http://journals.ametsoc.org/page/CCSM4/CESM1

All papers below have been accepted. Congrats!

Holland: **Improved sea ice shortwave radiation physics in CCSM4: The impact of melt ponds and aerosols on Arctic sea ice**

Jahn: **Late 20th century simulation of Arctic sea ice and ocean properties in the CCSM4**

de Boer: **A Characterization of the Present-Day Arctic Atmosphere in CCSM4**

Vavrus: ***21st-Century Arctic climate change in CCSM4***

Lawrence: ***Simulation of present-day and future permafrost and seasonally frozen ground conditions in CCSM4***

Landrum: ***Antarctic sea ice climatology, variability and late 20th-Century change in CCSM4***

Weijer: ***The Southern Ocean and its climate in CCSM4***

Kay: ***The influence of local feedbacks and northward heat transport on the equilibrium Arctic climate response to increased greenhouse gas forcing in coupled climate models***

Polar Climate Working Group Observational Needs/Uses

Atmosphere (Kay, de Boer)

Sea ice (Massonet, Jahn)

Polar Climate Working Group CSL Request for Yellowstone (development)

- Unify LANL and CESM CICE code base, Test climate impacts in CESM
(melt ponds, ridging, anisotropic dynamics, multi-phase physics, and biogeochemistry)

- Evaluation and improvement of CAM physics for polar regions

a) Data assimilation and atmospheric reanalysis for CAM5.1 (SHEBA, atmospheric response to extreme Arctic ice loss)
b) Impact of unresolved atmospheric dynamics on polar atmospheric circulation and sea ice distributions in CAM SE (TMS, gravity waves)
c) Moist physics processes (clouds, precipitation, boundary layer, turbulence) in CAM5.1 and next-generation CAM versions
d) Snow parameterization sensitivity experiments

Polar Climate Working Group CSL Request for Yellowstone (production)

- Long control run and 300-year long 2xCO_2 climate sensitivity experiment with fully coupled 1-degree CESM-CAM5

-21st century ensembles to evaluate climate impacts of methane release and artificially reduced Arctic sea ice albedos

- Sea ice predictability experiments (inherent predictability, sensitivity to inaccurate, sparse, or incomplete initial conditions)

- Eddy-resolving (1/10th degree) ice-ocean 60-year 20th century hindcast with CORE atmospheric forcing

- High-resolution (1/10th degree ocean, ½ degree atmosphere/land)coupled studies of Antarctic ocean circulation

PCWG-relevant CESM development update

- CAM Atmosphere

a) CAM spectral element dynamical core: orography affects polar atmospheric biases via TMS/gravity wave parameterizations. (Bailey talk). CAM5 SE with climate similar to CAM5 FV expected mid-2012.

b) CAM5.1 prescribed aerosols: too few Arctic aerosols, JJA cloud and flux differences from prognostic aerosols

- CICE Sea ice (Hunke talk, public release mid-2013)

a) Multi-phase physics, melt ponds, anisotropic dynamics, mechanical deformation/ridging, sea ice-ocean coupling, icebergs

b) Biogeochemistry

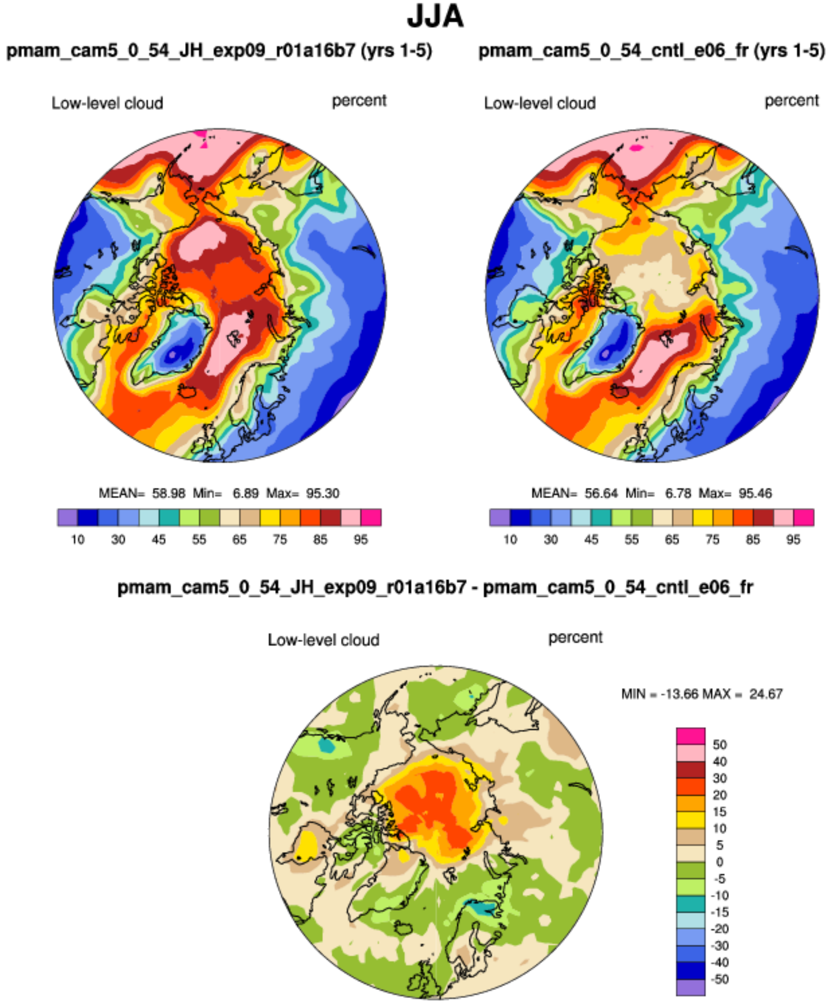
c) Infrastructure, MPAS-CICE

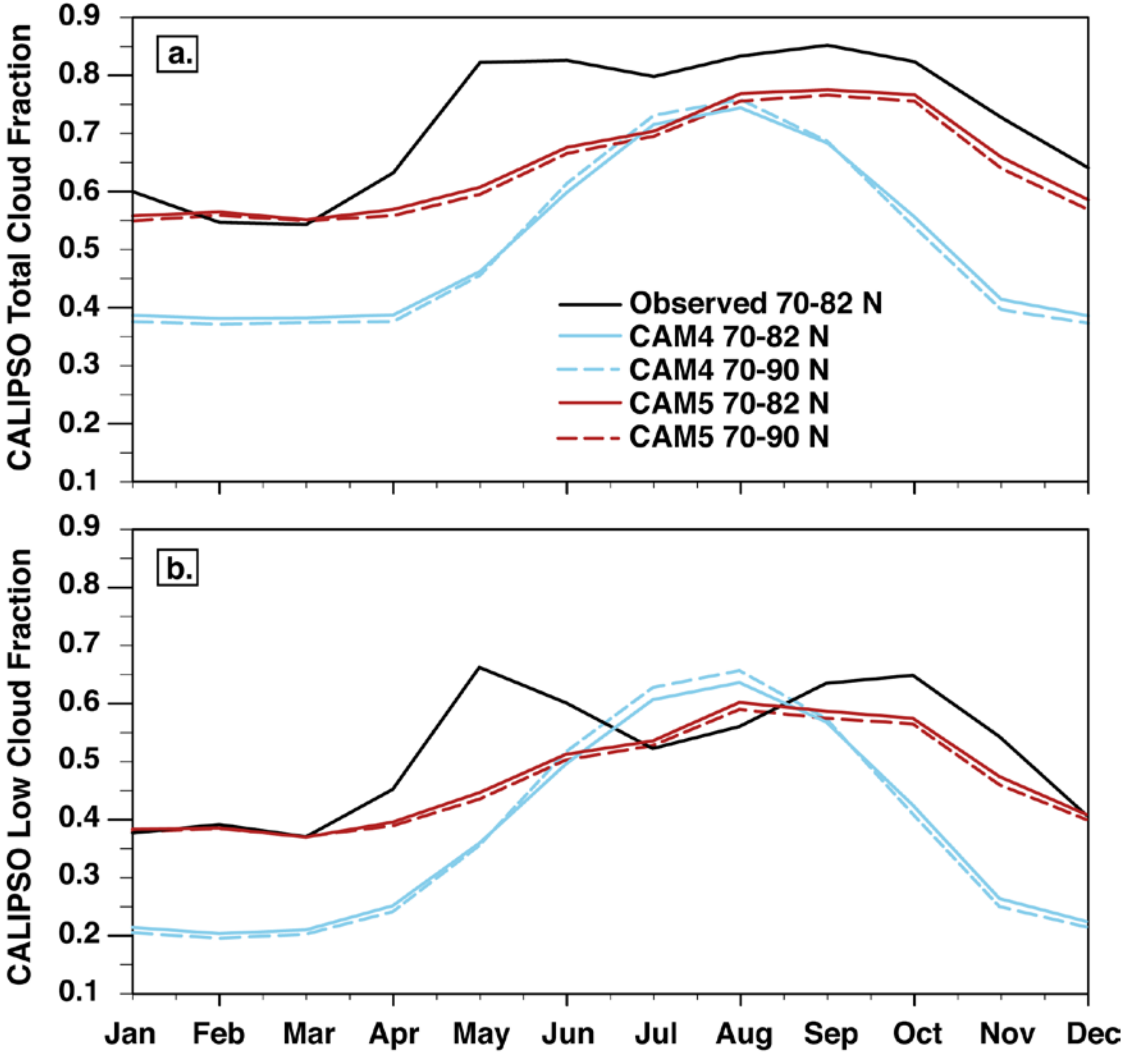
- High resolution runs (are we ready for Yellowstone?)

- Regional Arctic Climate Model (RACM) collaboration

Aerosol issues in the Arctic
(contact: Phil Rasch, PNNL)

- ***Unrealistically low aerosol numbers and mass*** in the predicted aerosol runs
  - Unrealistic values of aerosols < $0.1/cm^3$ are simulated in the Arctic during northern summer
  - The monthly prescribed aerosols, do not show these low aerosol numbers, and have too many clouds (see figure on right)
  - As soon as we have more aerosols, more cloud will be created. We think it will reduce discrepancy between prescribed and predicted aerosols.





Improved Arctic cloud seasonal cycle in CESM-CAM5 (despite known low aerosol issues…)

Kay et al. 2012: Exposing global cloud biases in the Community Atmosphere Model (CAM) using satellite observations and their corresponding instrument simulators, *J. Climate*, in press.

Polar biogeochemistry work

Ice Algal Biogeochemistry for Full Arctic, with DMS Release

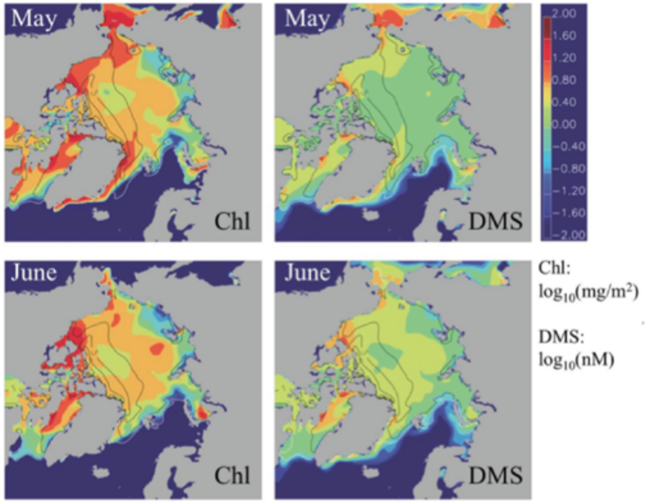
Objective

Marine ecodynamics influence high latitude climate via greenhouse gases and aerosol precursors, emitted from both ocean and ice. We present the first regional scale model of sea ice sources for dimethyl sulfide (DMS), primary natural carrier of sulfur to the atmosphere.

Approach

- Driven by ice algae & nutrients in CICE
- N, Si, C, pigments alongside S cycle
- Large DMS fluxes from ice into margins, leads and peripheral seas
- But data for comparison very sparse
- Renewed measurement activity recommended for all Arctic waters

Chlorophyll & DMS produced by CICE algae: Pigments in ice, trace gas below and in margins



Impact

Simulations of marine aerosol precursors will enable uncertainty quantification for cloud optical effects across Arctic system

Elliott, S., Deal, C., Humphries, G., Hunke, E., Jeffery, N., Jin, M., Levasseur, M. and Stefels, J. 2012. Pan-Arctic simulation of coupled nutrient-sulfur cycling due to sea ice biology. Journal of Geophysical Research, doi:10.1029/2011JG001649.

Polar climate in CESM-CAM5

- Initial evaluation of the late 20th century
  *Mean state (Bailey talk Thursday)
  *Atmospheric regimes and clouds (Barton talk Thursday)
  *Temperature and sea ice trends
- Sensitivity to $2xCO_2$: forcing and feedbacks

- your idea here… let us know how we can help!
- 3 RCP runs are currently being completed with CESM-CAM5, many new community simulations with CESM-CAM5 proposed for Yellowstone (Holland talk)

Like CCSM4, CESM-CAM5 can qualitatively reproduce observed late 20th century Arctic sea ice extent loss but has large internal variability.

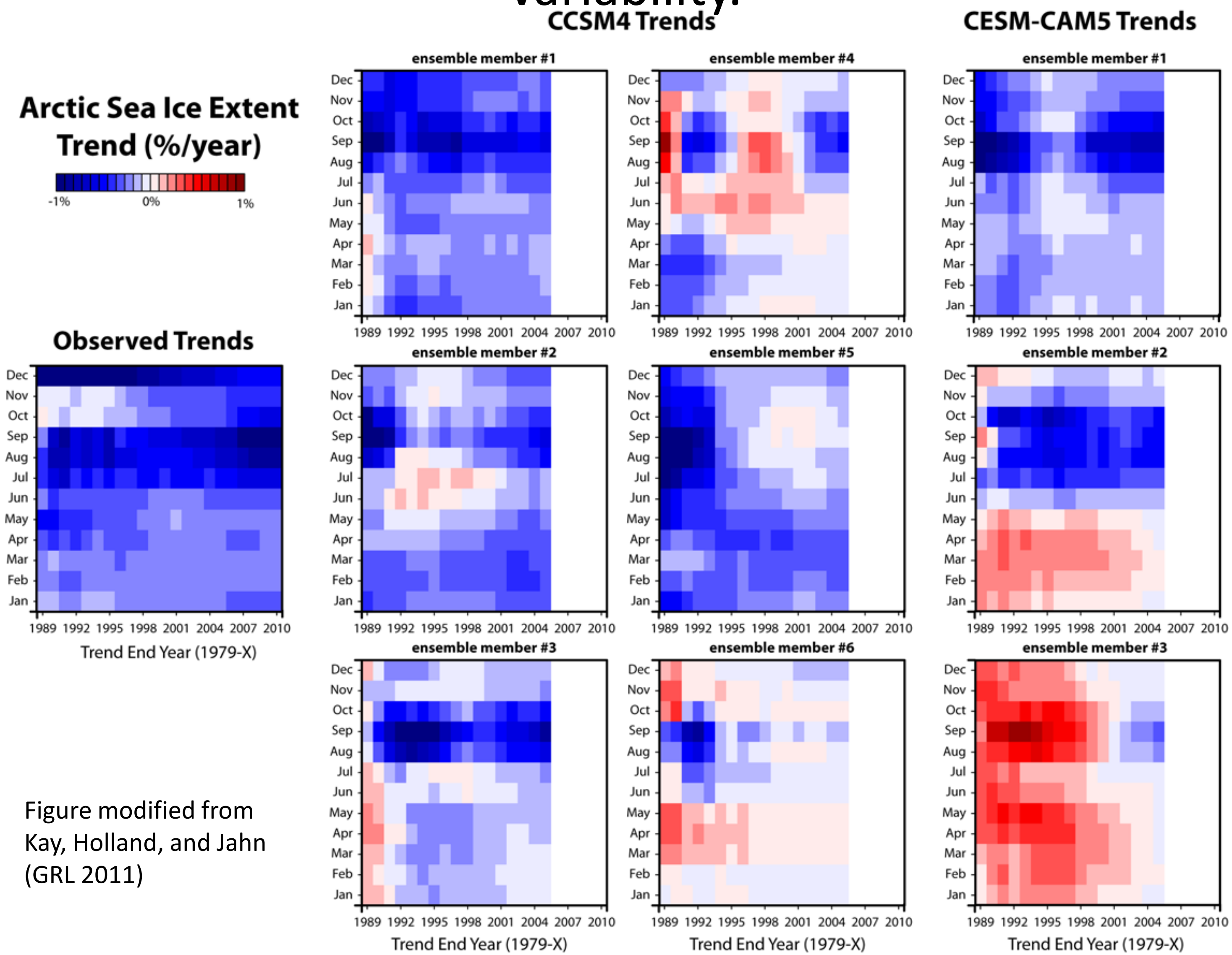
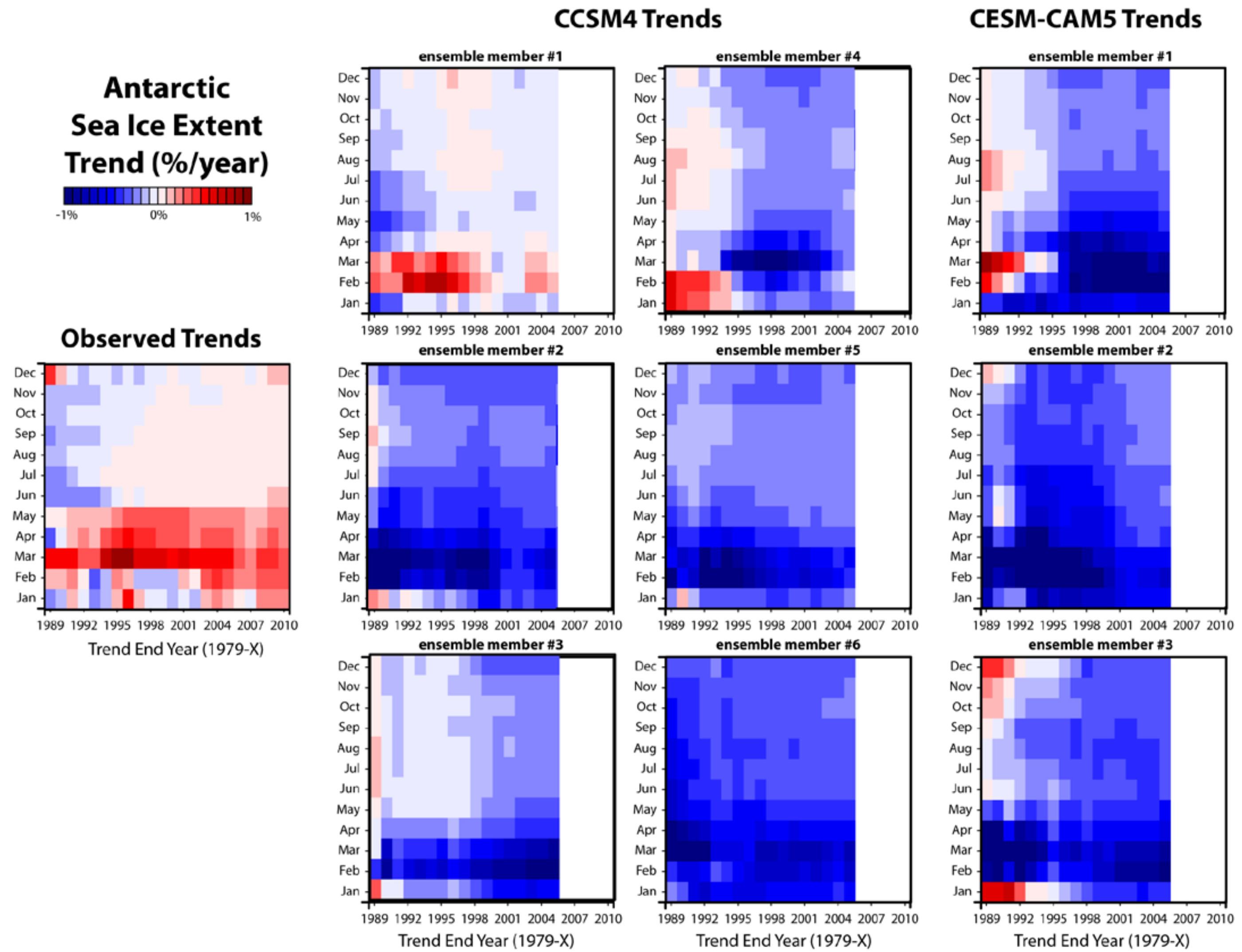


Figure modified from Kay, Holland, and Jahn (GRL 2011)

Like CCSM4, CESM-CAM5 Antarctic sea ice extent trends are mostly large and negative, while observations show small positive trends.



$2xCO_2$ climate response: CESM-CAM5 > CCSM4

($2xCO_2$ forcing and shortwave cloud feedbacks responsible)

	CAM4 (CCSM4)	CAM5 (CESM-CAM5)
$2xCO_2$ global radiative forcing	3.5 Wm^{-2}	3.8 Wm^{-2}
Equilibrium global surface air temperature response ("climate sensitivity")	3.2 K	4.0 K
Equilibrium Arctic surface air temperature response	7.0 K	10.2 K

More information in special issue papers:

Gettelman et al. 2012: The evolution of climate feedbacks in the Community Atmosphere Model, *J. Climate*, in press.
Bitz et al. 2012: Climate sensitivity of the Community Climate System Model Version 4, *J. Climate*, in press.
Kay et al. 2012: The influence of local feedbacks and northward heat transport on the equilibrium Arctic climate response to increased greenhouse gas forcing in coupled climate models, *J. Climate*, in press.

Summary

- Ongoing research and development: CICE, CAM, high resolution collaborations (your idea here!)

- CESM-CAM5: (2xCO_2 ΔT = 4.0 K)

☺ Better clouds globally and in the Arctic

☺ Better late 20th century temperature trends

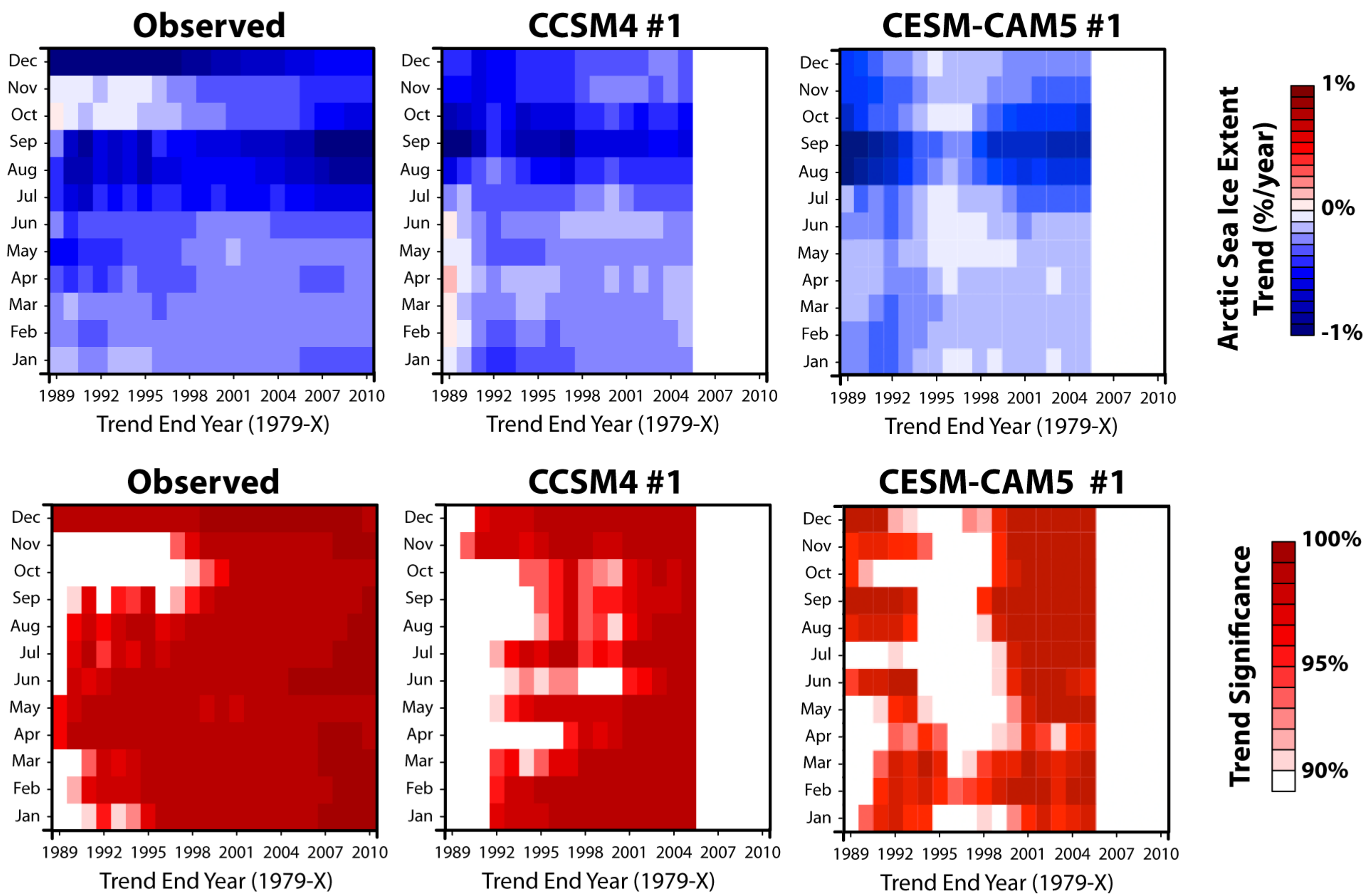
☺ Reproduces observed negative Arctic sea ice trends

☹ Large unobserved negative Antarctic sea ice trends

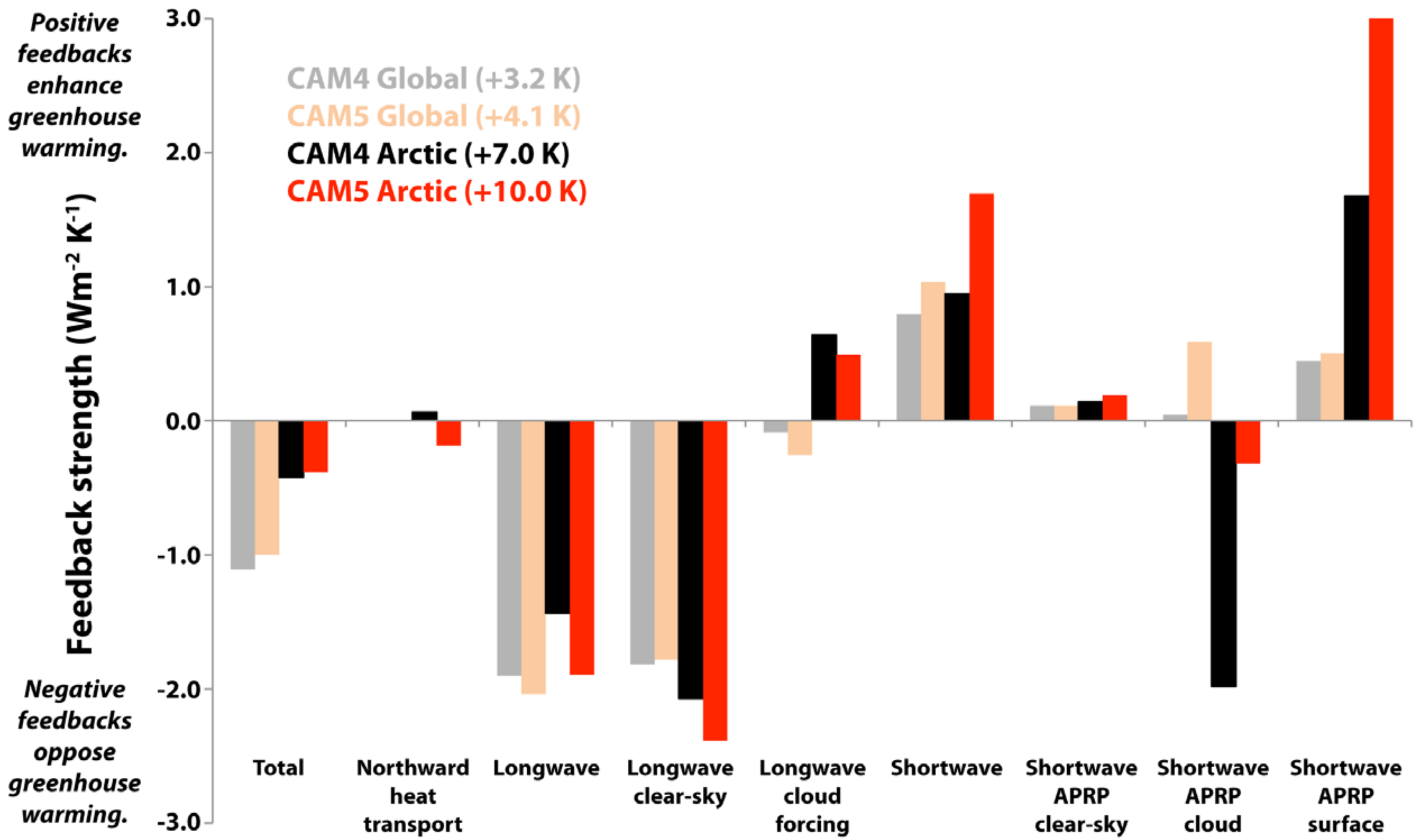
☹ Too few aerosols in the Arctic summer months

EXTRA

Like CCSM4, CESM-CAM5 can qualitatively reproduce observed late 20th century Arctic sea ice extent loss…

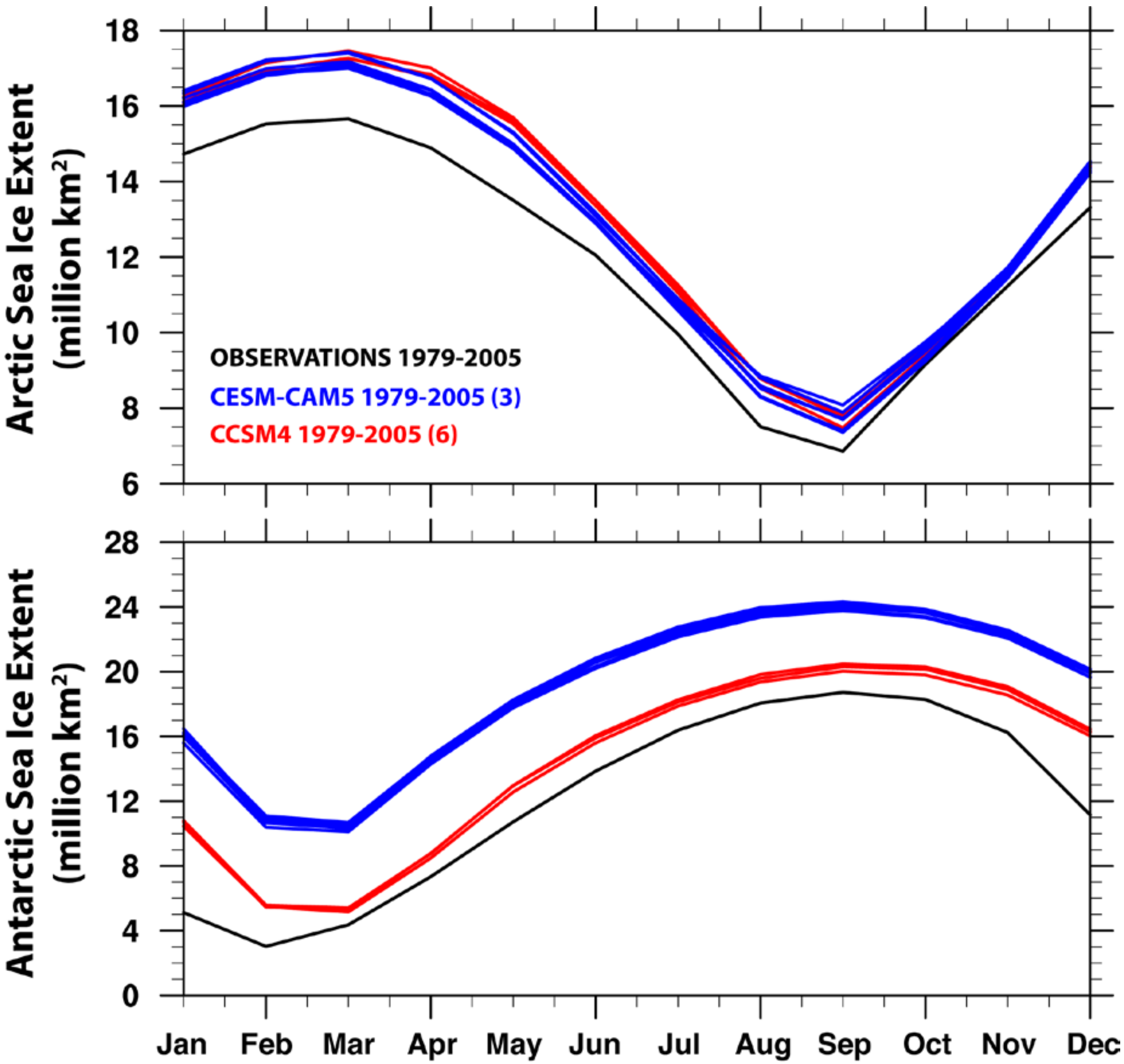


CESM-CAM5 has greater sensitivity to $2xCO_2$ forcing than CCSM4: both globally and in the Arctic

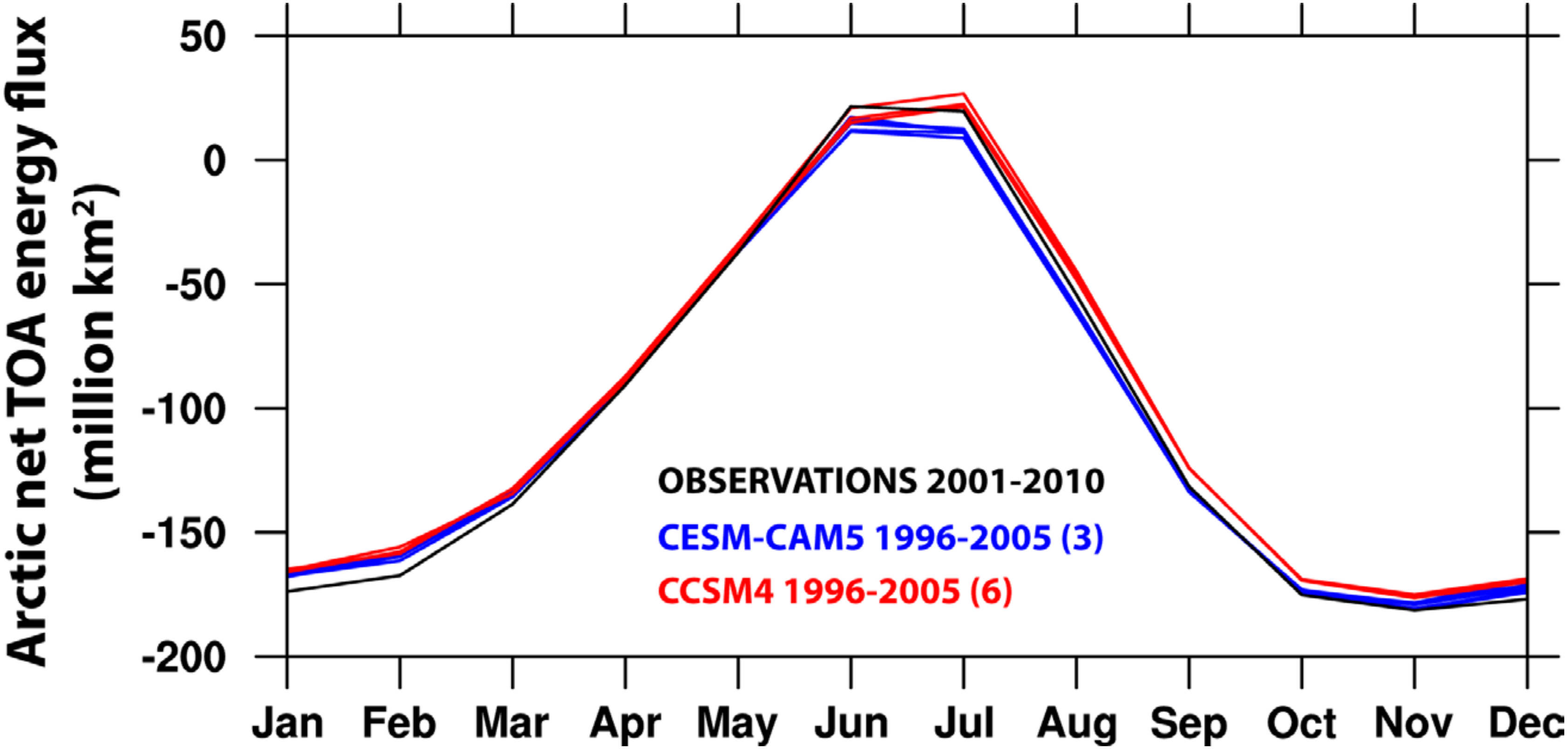


Kay et al. 2012b

Mean seasonal cycle: Sea ice extent

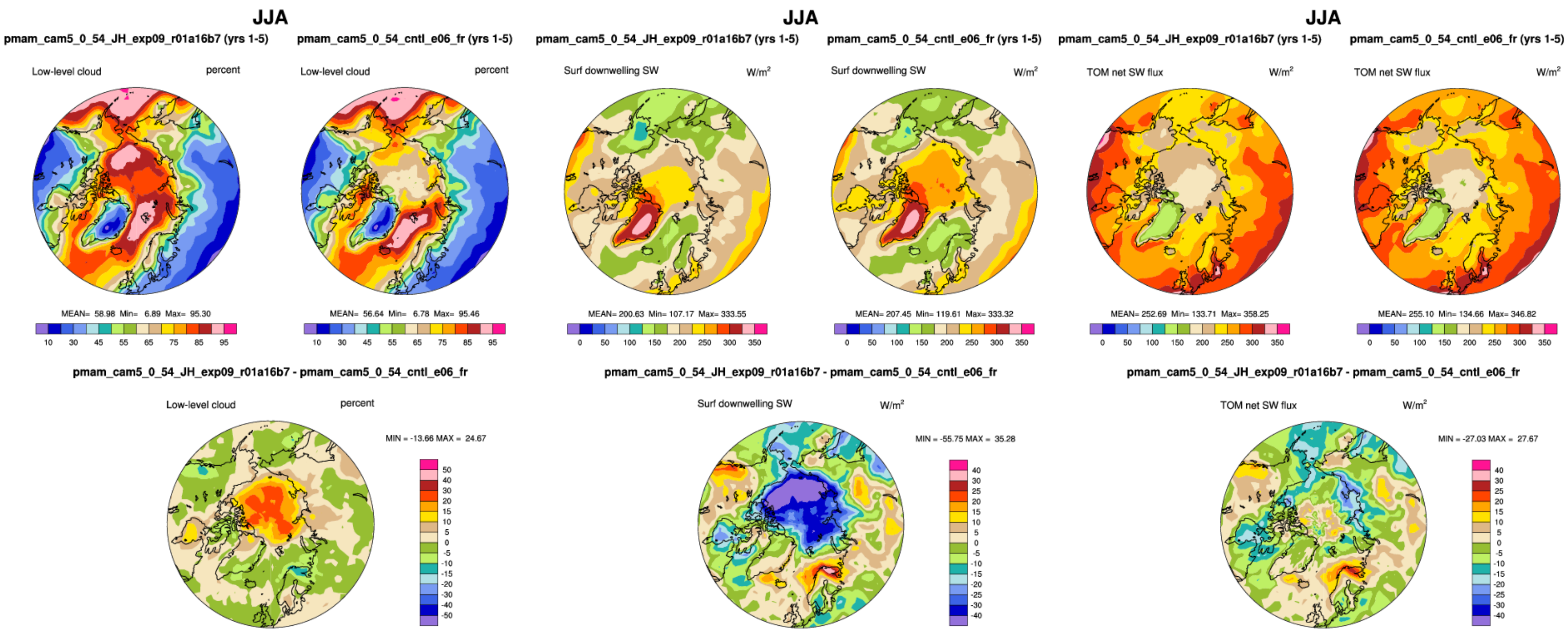


Mean seasonal cycle: Arctic top-of-atmosphere fluxes



Note: Despite known aerosol issues, CESM-CAM5 has more realistic Arctic cloud amounts than CCSM4 (Kay et al. 2012a Figure 11).

Aerosol issues in the Arctic
(contact: Phil Rasch, PNNL)



Large impacts on downwelling shortwave radiation at the surface… impacts smaller on net TOA (restricted to open water areas where the cloud increases affect TOA albedo).

CCSM4/CESM-CAM5 late 20th C Global and Arctic Temperature Trends

Hunke talk outline

Outline

1. LANL Development Thrusts
   - Biogeochemistry
   - Multiphase Physics
   - Melt Ponds
   - CICE Release
2. External/Collaborative Development Projects
   - Melt Ponds
   - Topography/Mechanical Redistribution
   - Rheologies
3. Future Plans