Characterization of the Present-Day Arctic Atmosphere in CCSM4

Gijs de Boer[1], Bill Chapman[2], Jennifer Kay[3], Brian Medeiros[3], Matthew Shupe[4], Steve Vavrus[5], and John Walsh[6]

(1) BERKELEY LAB (2) ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN (3) NCAR

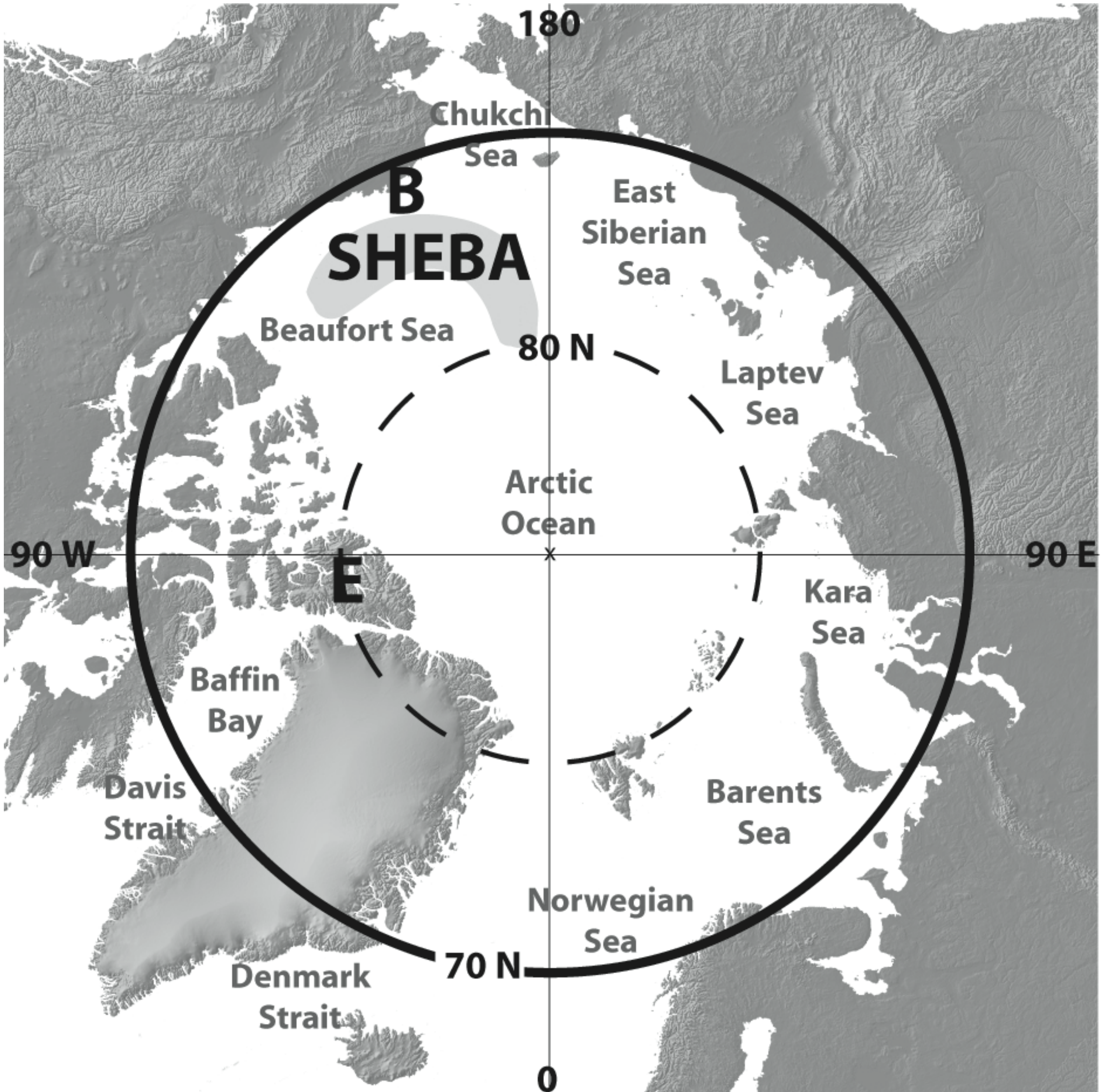
(4) NOAA ESRL (5) THE UNIVERSITY of WISCONSIN MADISON (6) UAF UNIVERSITY OF ALASKA FAIRBANKS

CCSM Polar Climate Working Group Meeting, Boulder, CO, February 28 - March 1, 2011

Goals:

- Document the ability of CCSM4 to simulate the present-day Arctic atmosphere via evaluation of several key variables
  - SLP
  - T_{sfc}
  - Cloudiness
  - Atmospheric Energy Budget
  - Precipitation/Evaporation
  - Boundary Layer Stability
- Document the ability of CCSM4 to correctly simulate variability within the system for some variables

Area of Study:

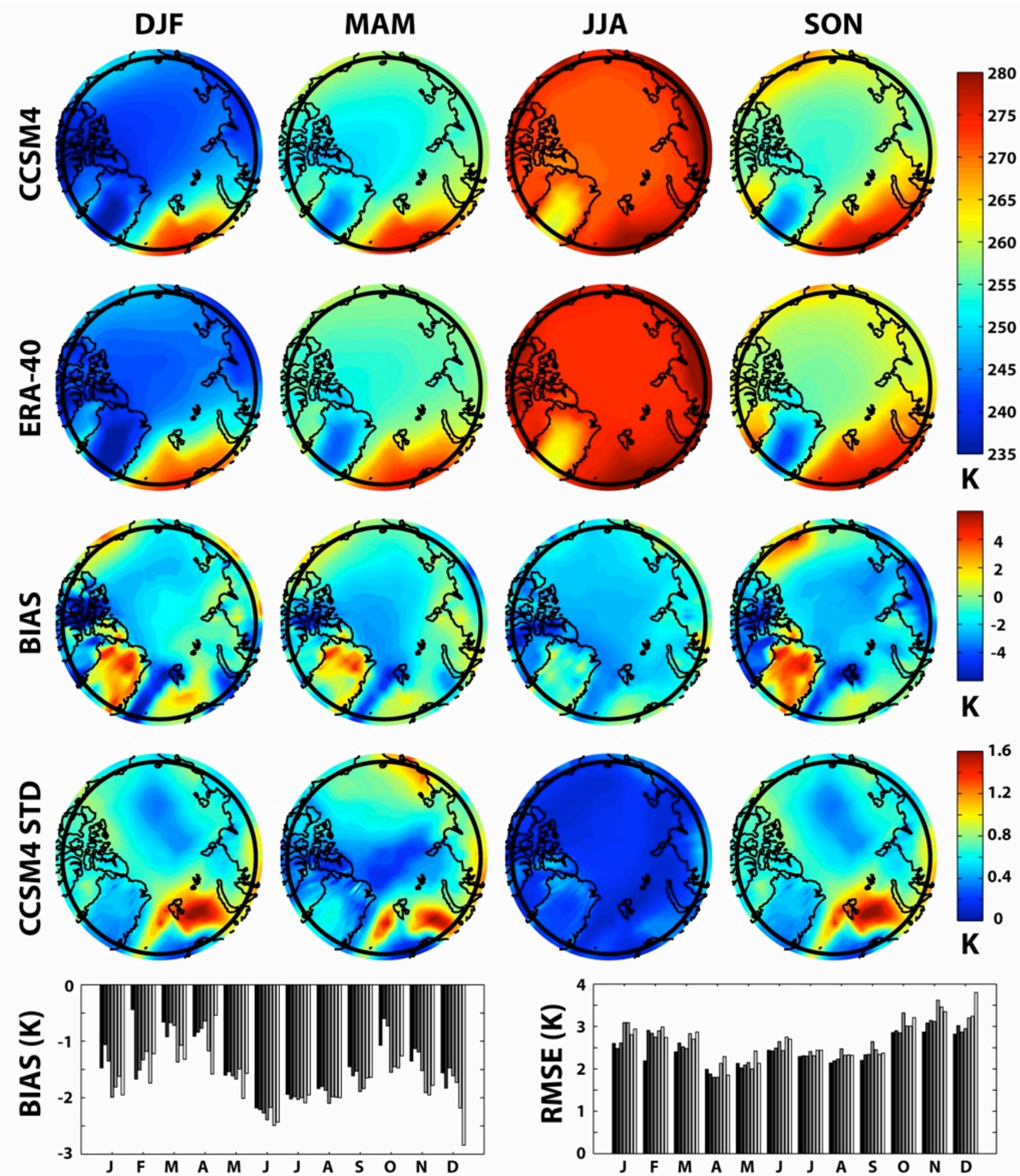


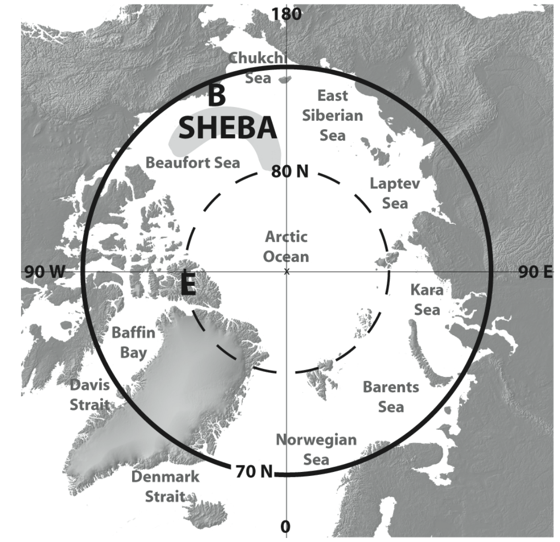
Map courtesy of NOAA (modified)

Simulations:

- Seven "present-day" AR5 CCSM4 simulations (6 ensemble members + MOAR)
- MOAR ("Mother Of All Runs") has high frequency output (up to 3 hourly for some variables), allowing for evaluation extremes, and monthly distributions
- All simulations run at f09_g16 (0.9°x1.25°) atmosphere and land grids, gx1v6 displaced pole ocean and sea ice grids

Surface Temperature:

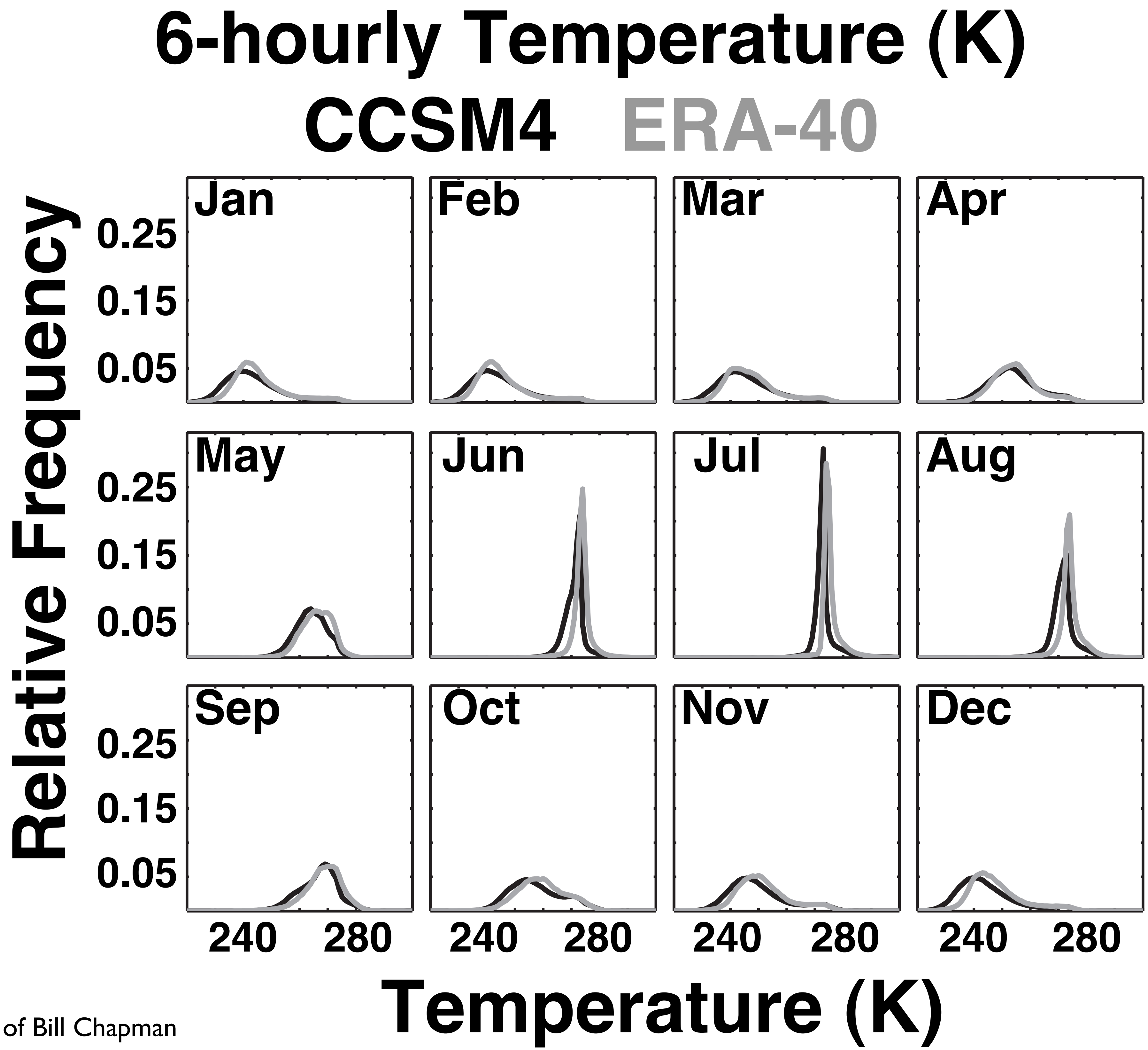




- Spatial patterns simulated very well
- Small but potentially important negative bias across most of Arctic
- Largest negative biases east of Greenland
- Largest variability between ensemble members along Barents Sea
- Largest biases and smallest standard deviation during JJA
- Smallest biases during FMA
- RMSE of ~2-3.5 K

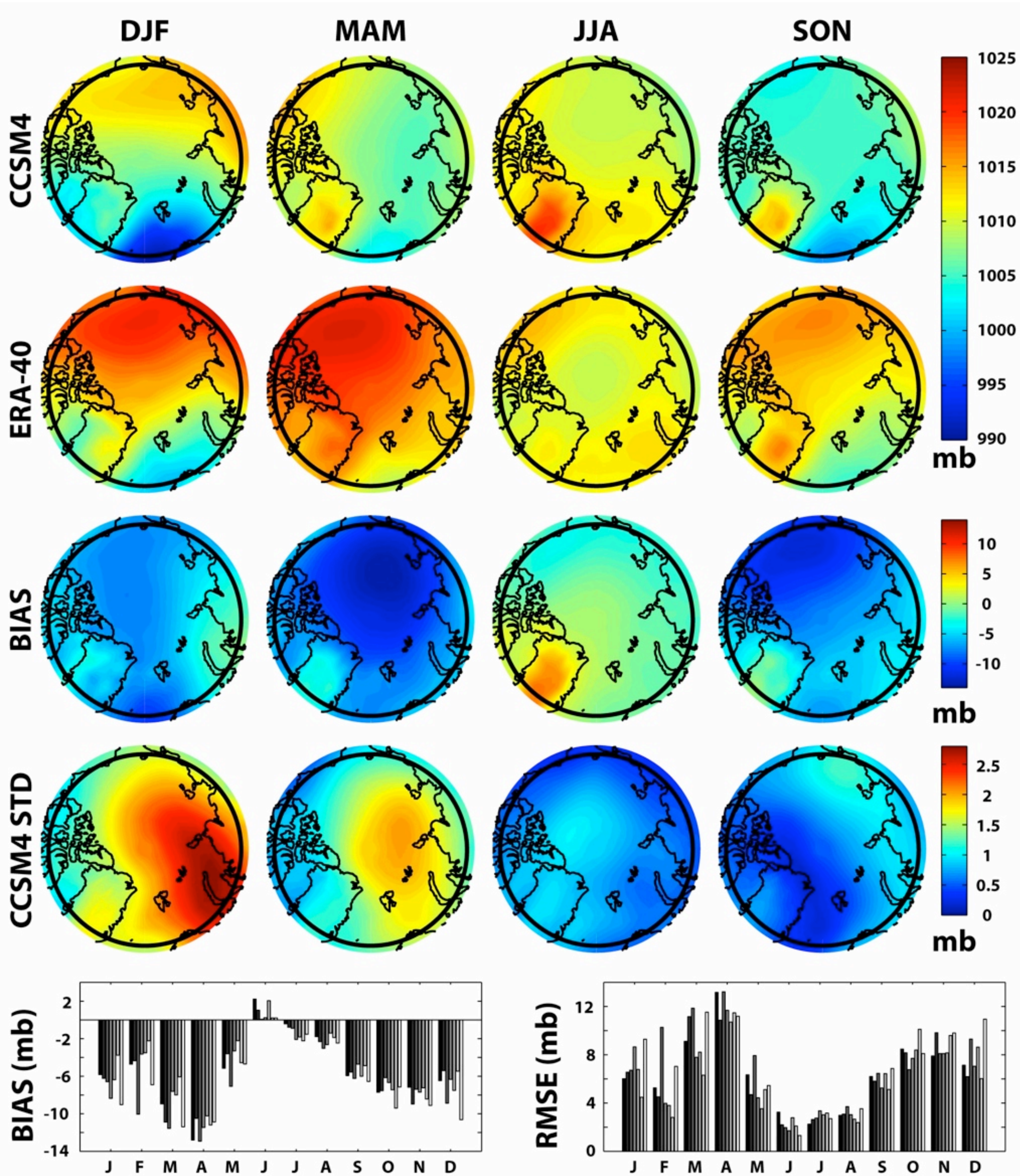
-**ERA-40** courtesy of Bill Chapman

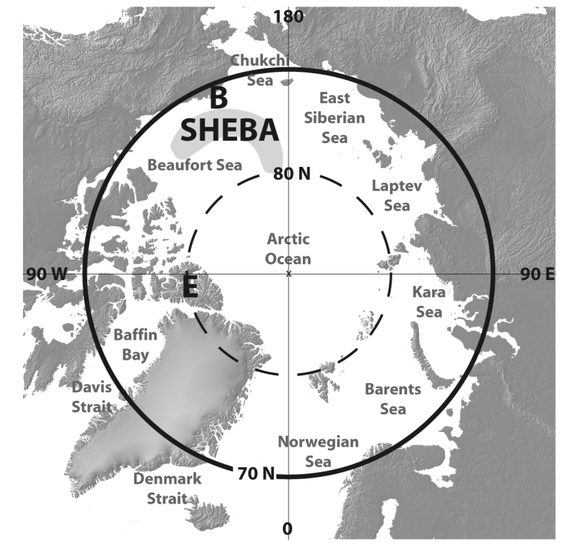
Surface Temperature Variability:



-**ERA-40** courtesy of Bill Chapman

Sea Level Pressure:





- Beaufort High (-15 mb bias)!!
- Generally negative biases throughout Arctic (except for June)
- Largest variability between ensemble members along Barents and Kara Seas during winter and spring
- Largest biases and largest standard deviation during spring
- Very small biases during JJA
- RMSE of ~2-13 mb

-**ERA-40** courtesy of Bill Chapman

Clouds:

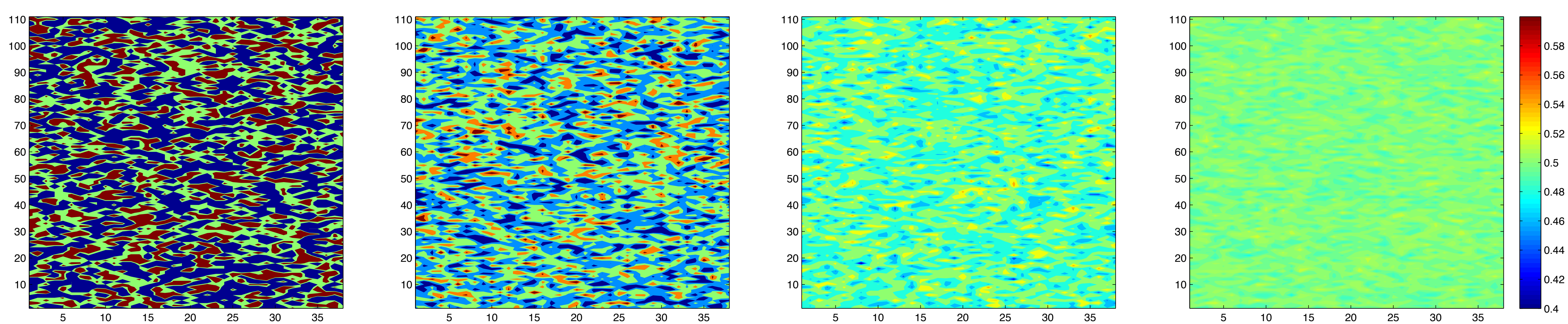
** Clouds are challenging to evaluate **

- Short datasets (1-2 years at a given location)

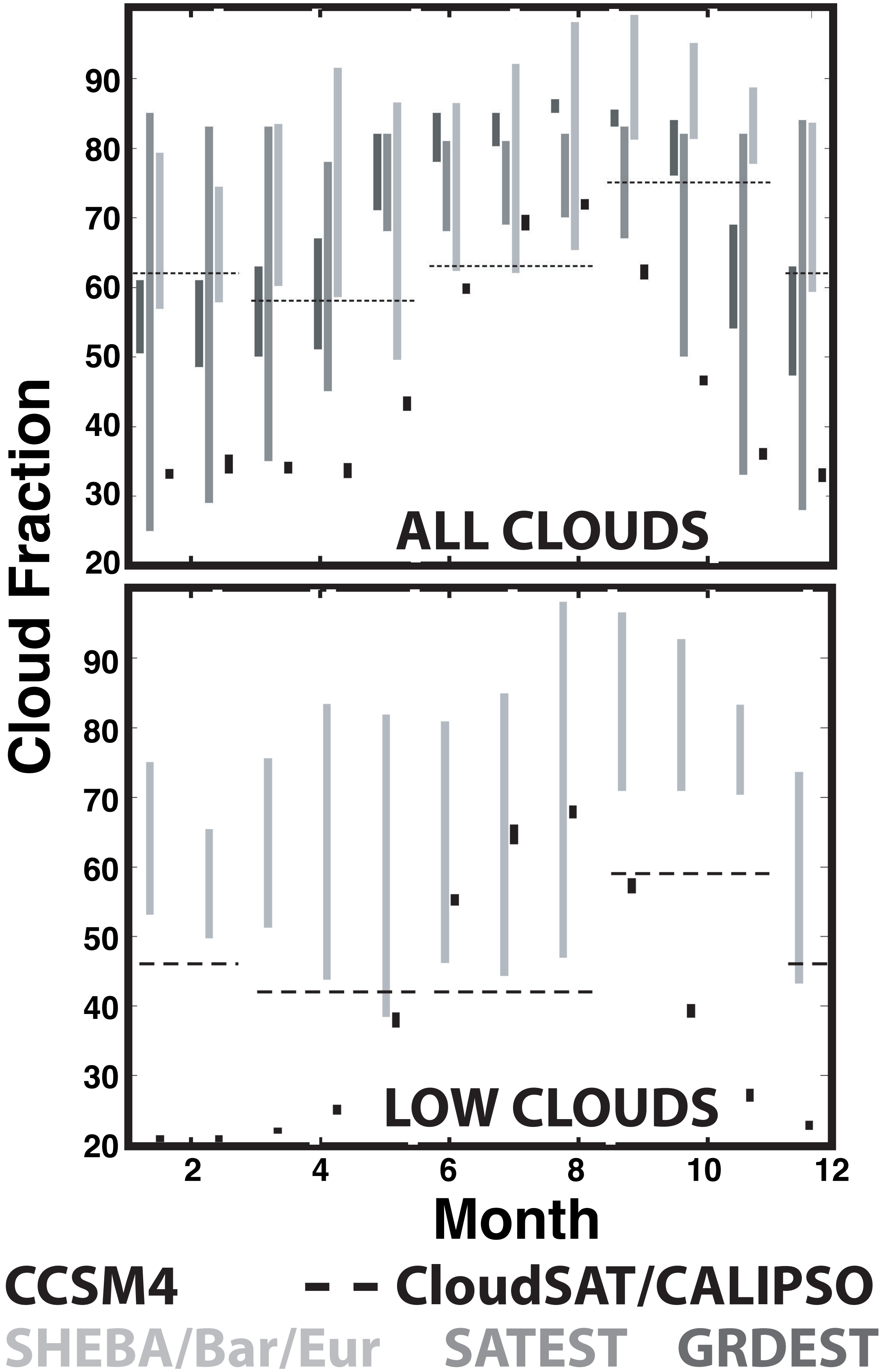
- "Cloud Fraction" definition is not standardized, and sampling issues exist

  - Different thresholds used by different sensors, so we included a wide range of estimates including human, satellite and ground-based observations

  - Sampling -- "Quick and dirty" evaluation of station sampling errors provides estimate of sampling induced error (~5%), but more thorough evaluation is needed and planned



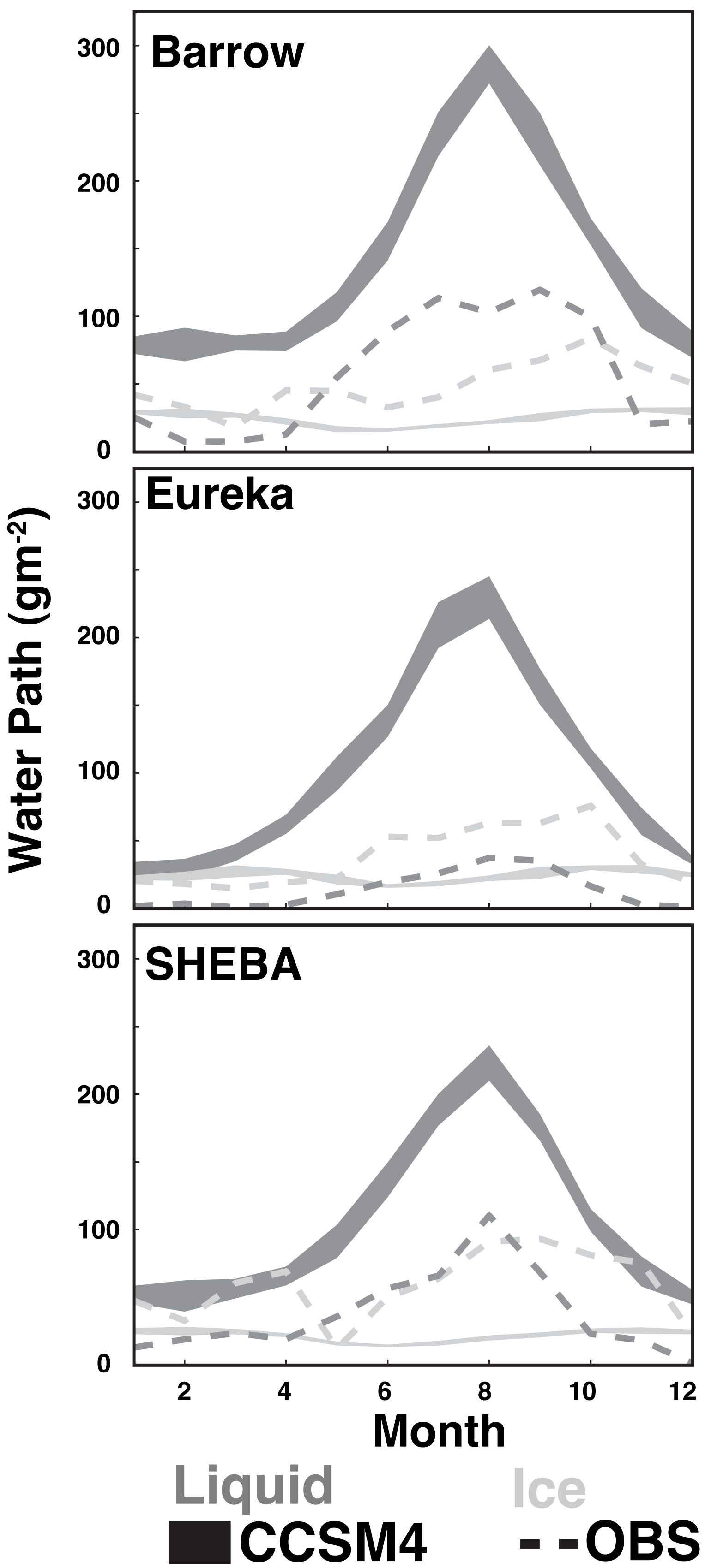
Clouds:



- Observational datasets peak during different times.
- CCSM4 tends to underestimate cloud occurrence during most of the year (except summer months)
- Low clouds are particularly underestimated during all but summer months (Impact of FREEZEDRY not yet fully evaluated)

-**CloudSAT/CALIPSO** dataset courtesy of Jennifer Kay
-**SATEST** courtesy of Steve Vavrus (includes estimates from ISCCP, TOVS Path-B, HIRS, MODIS, PATMOS, Wang and Key, and CERES)
-**GRDEST** courtesy of Steve Vavrus (includes COADS, Huschke, Hahn et al. and Makshtas et al.)
-**SHEBA/Bar/Eur** courtesy of Matthew Shupe

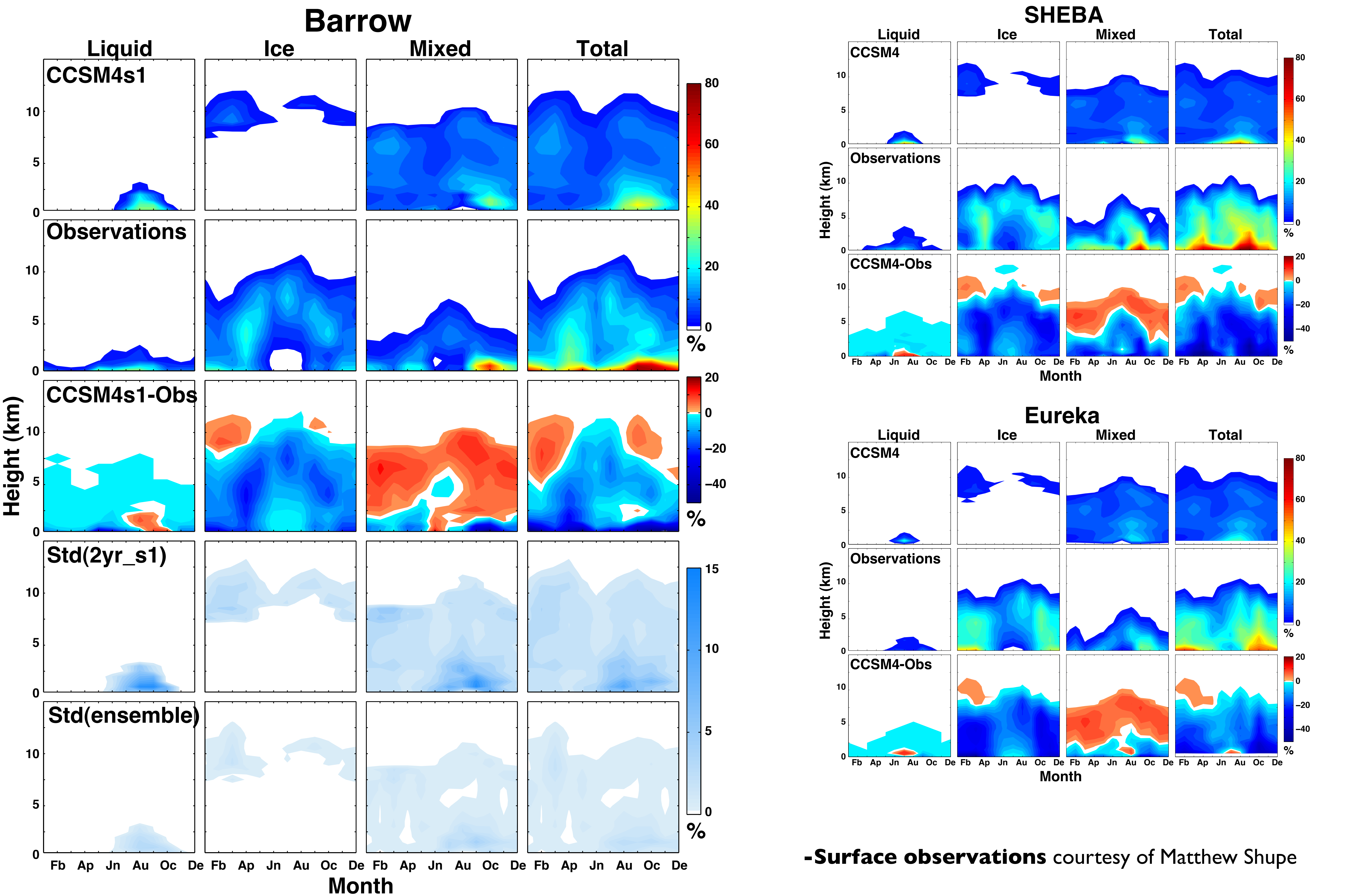
Clouds:



- All-sky cloud liquid/ice water paths compared to surface observation stations
- CCSM4 liquid water path is too high for all locations, though seasonal cycle is captured
- CCSM4 ice water path is generally too low (except for Eureka winter)
- IWP seasonal cycle does not appear to be captured in the simulations
- Despite a "lack" of clouds (CF), liquid clouds that are present are found to be too thick, particularly during summer

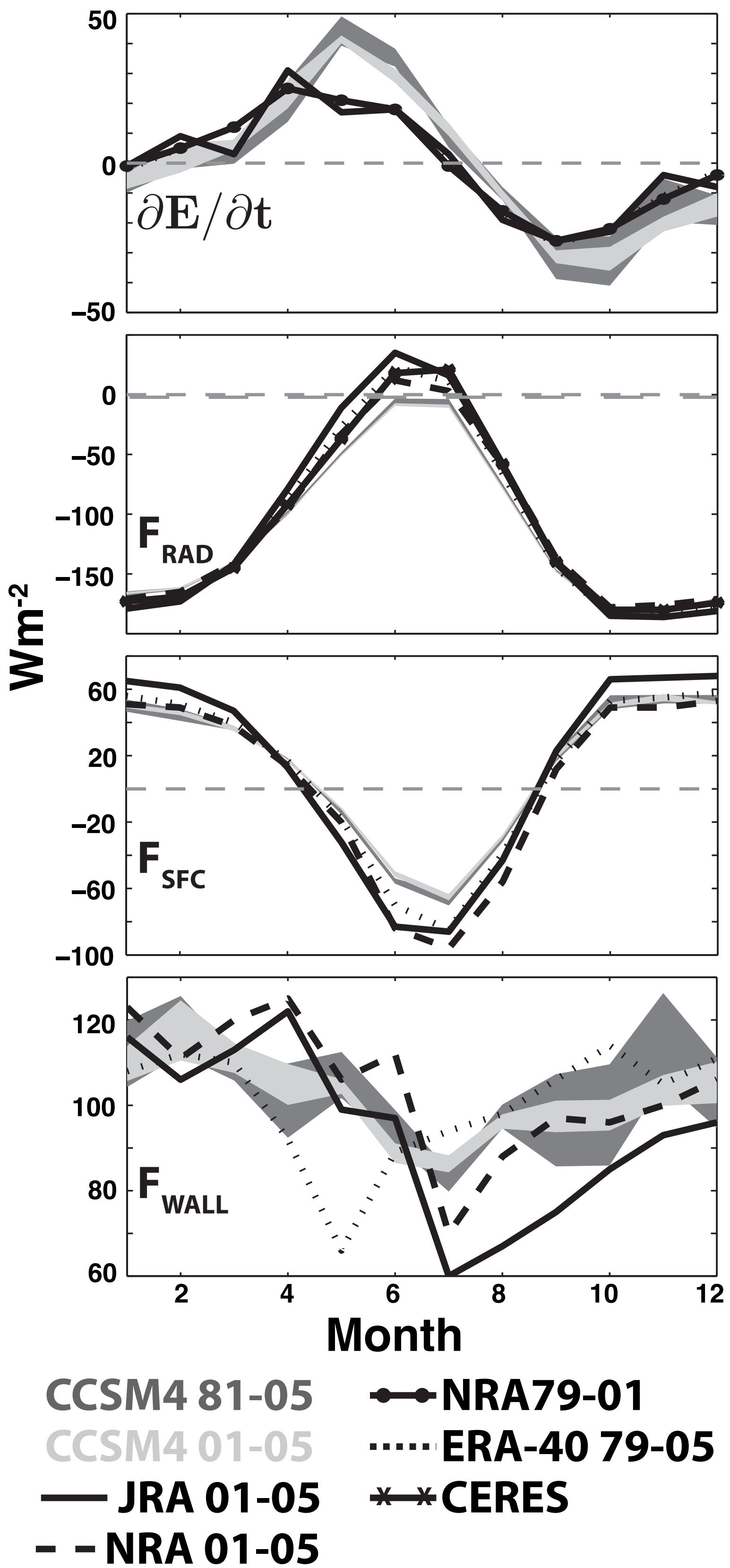
-**Surface observations** courtesy of Matthew Shupe

Clouds:



-**Surface observations** courtesy of Matthew Shupe

Energy Budget:

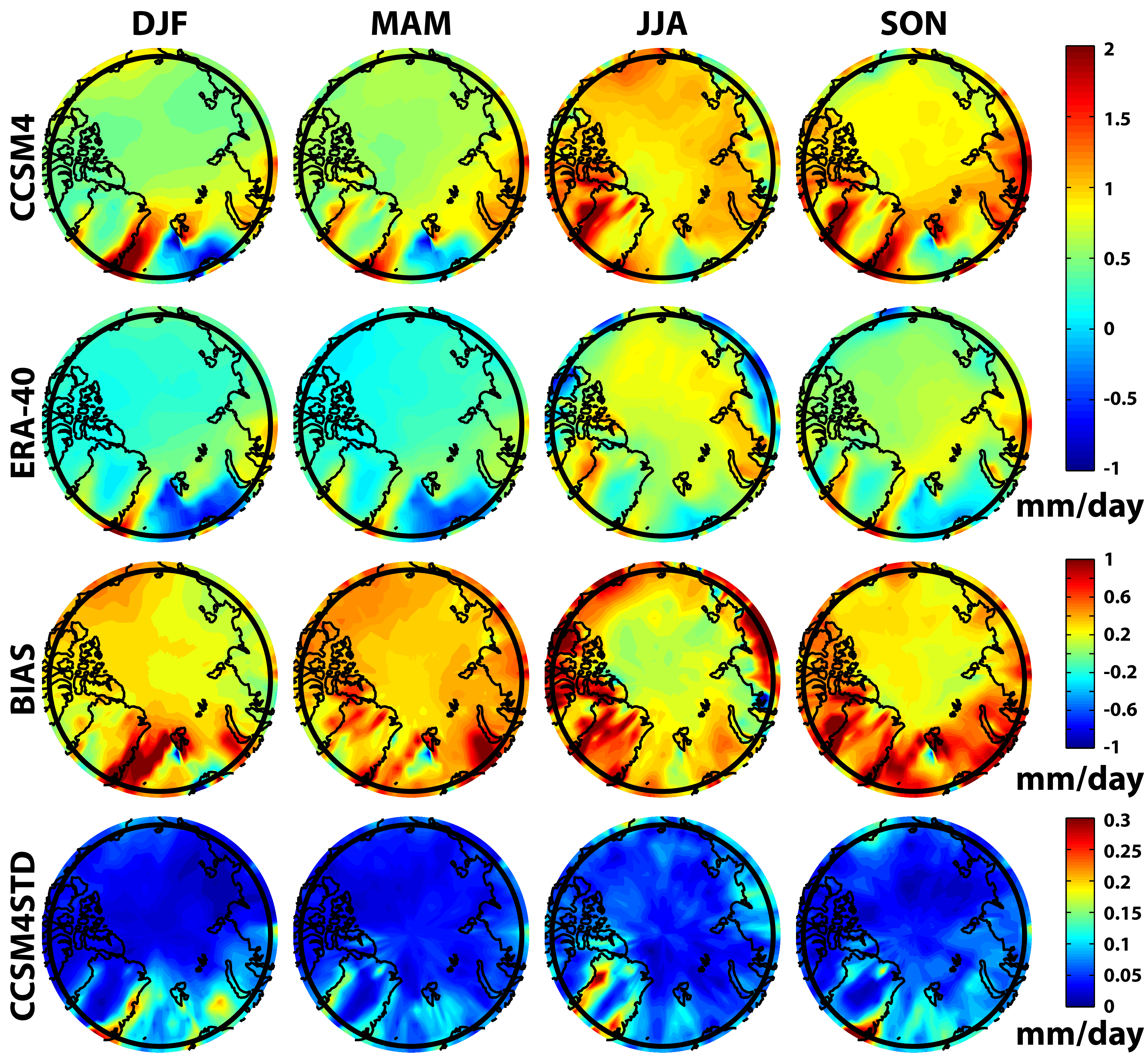


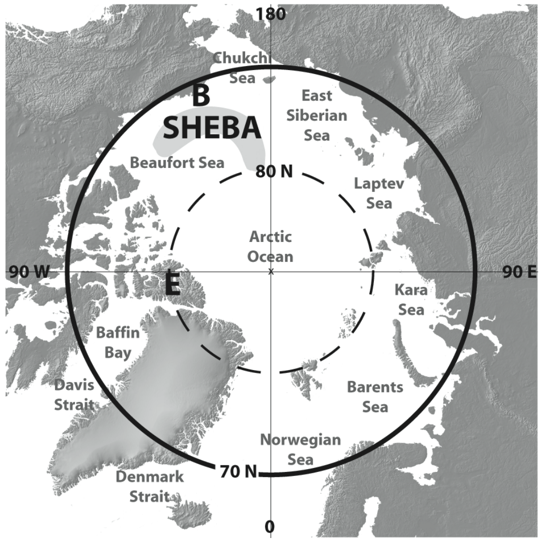
$$\frac{\partial E}{\partial t} = F_{rad} + F_{sfc} + F_{wall}$$

- General temporal patterns well simulated
- Small differences between 5 year period and 25 year period.
- TOA radiation is under-predicted during summer months, while SFC radiation is over predicted. Too much outgoing LW at TOA (assuming incoming SW is correct).
- Atmospheric energy storage during late spring/early summer is too high due in part to under-simulated fluxes into the earth's surface.

-JRA/NRA 2001-2005 and CERES from Porter et al. (2010)
-NRA (1979-2001) and ERA-40 (1979-2005) from Serreze et al. (2007)

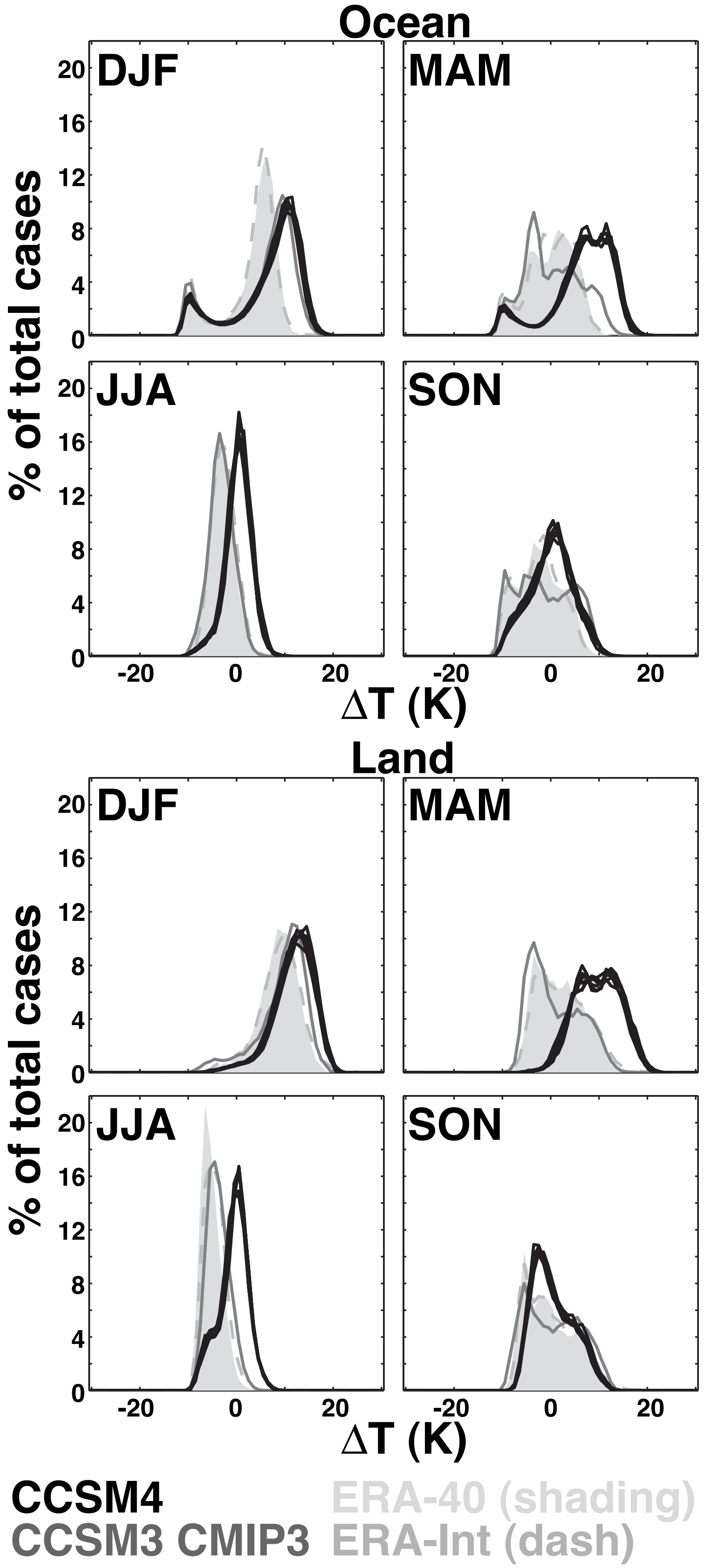
Precipitation/Evaporation:





-ERA-40 courtesy of Bill Chapman

Lower Tropospheric Stability:



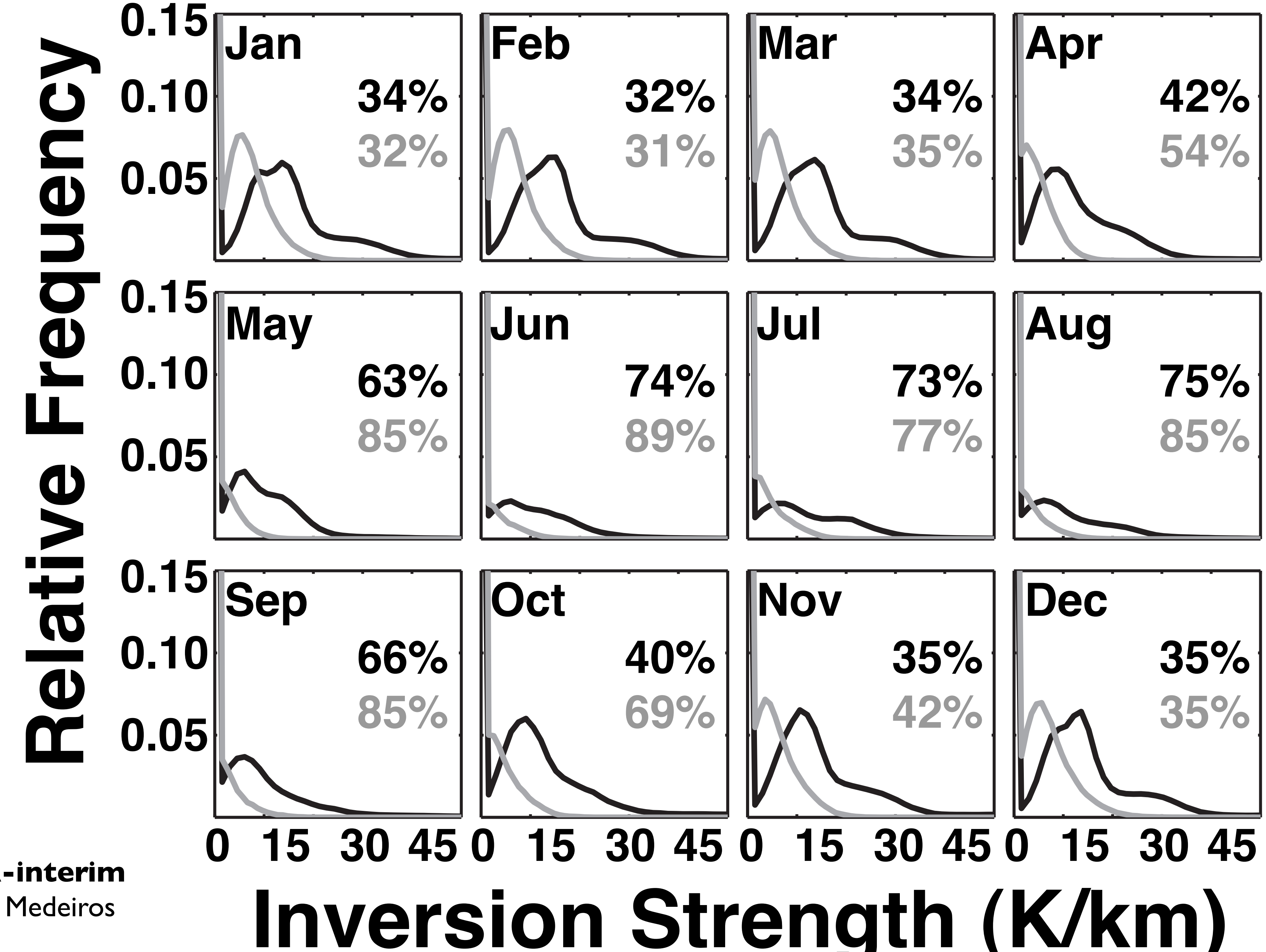
- Difference between monthly mean T_{850} and T_{2m} is plotted here
- The atmosphere is demonstrated to be too stable for all seasons besides fall over land and ocean and possibly winter over land surfaces.
- Not limited to extremely stable air (e.g. summer)
- Left edge is almost always captured (exception Spring over land), but is usually under-represented.

-ERA-40/ERA-interim courtesy of Brian Medeiros

Lower Tropospheric Stability:

6-hourly Inv. Strength (K/km)

CCSM4 ERA-40



-ERA-40/ERA-interim
courtesy of Brian Medeiros

Summary:

The good:

- Surface temperature, both spatial distribution and variability

- Seasonal representation of overall energy budget

The bad:

- Lower tropospheric stability. Much too stable, too often

- Cloud phase based on temperature dependent partitioning (gone in CESM1/CAM5)

- Cloud liquid water path -- severely over-simulated during summer months

- Cloud ice water path -- generally under-simulated

The Ugly:

- “Cloud fraction” -- both evaluation and simulated quantity

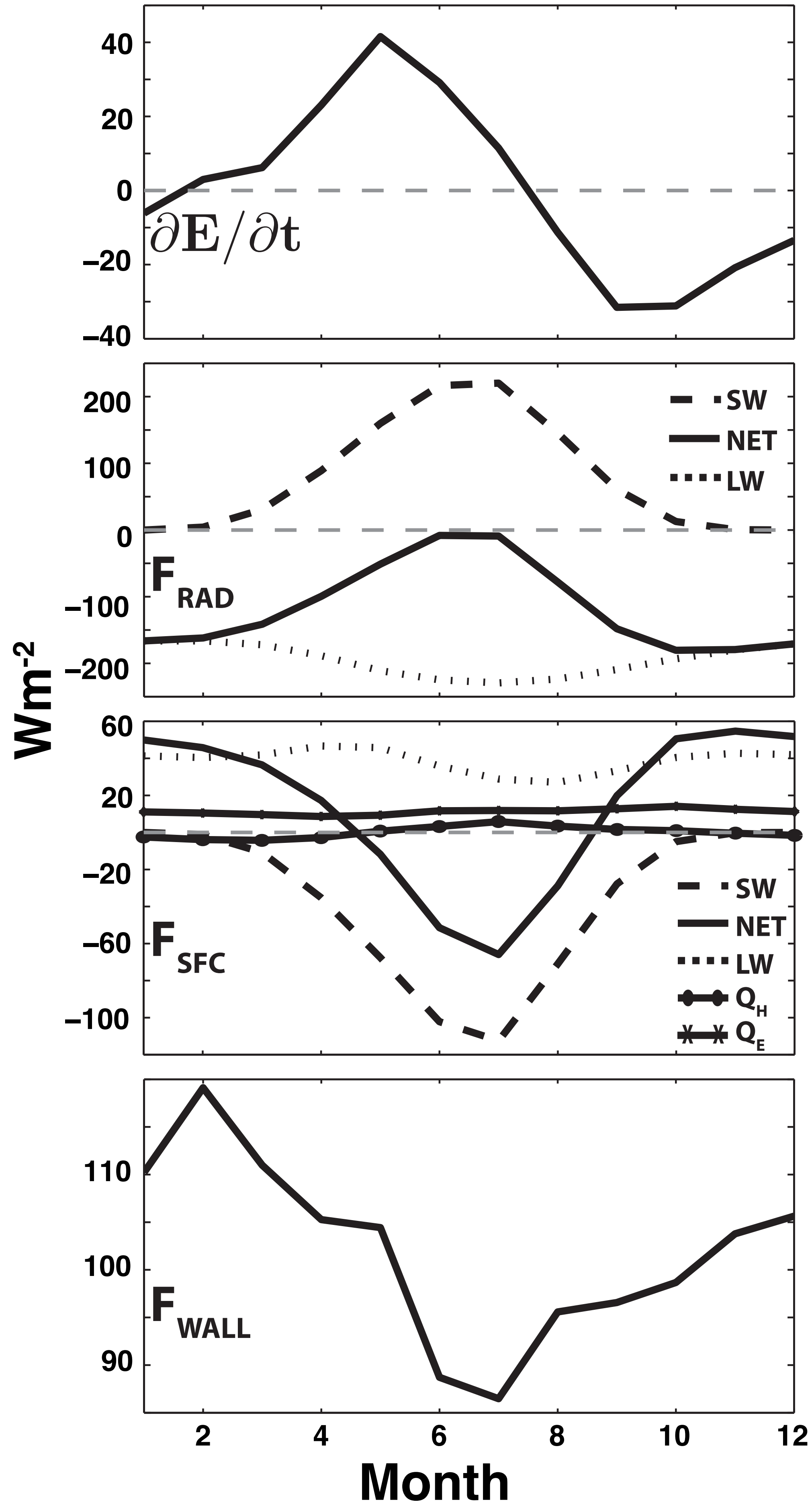
- P-E evaluation (measurements/datasets need improvement)

- SLP fields demonstrating missing Beaufort High

EXTRA SLIDES

|

V



40
20
0
−20
−40
$\partial E/\partial t$
200
100
0
−100
−200
SW
NET
LW
F_{RAD}
60
20
−20
−60
−100
SW
NET
LW
Q_H
Q_E
F_{SFC}
110
100
90
F_{WALL}
Wm^{-2}
2
4
6
8
10
12
Month