Evaluation of GISS SCM Simulated Cloud and Radiative Properties Using Both Surface and Satellite Observations

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Objectives

1) To compare GISS SCM simulated radiation and cloud properties with GOES/CERES and ARM observations at the ARM SGP site. (03/2000 – 12/2001)

2) To evaluate the GISS SCM simulated cloud fractions using ARM-GOES observations and North American Regional Reanalysis (NARR) data. (1999-2001)

Data: ARM Surface Observations

ARM radar-lidar data have been averaged to derive monthly mean cloud fraction (CF) as:

$$CF = \frac{\text{Five minute samples containing cloud}}{\text{Total number of radar-lidar samples}}$$

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SW fluxes: Measured by up/down looking PSPs.

LW fluxes: Measured by up/down looking PIRs.

Data : GOES/CERES observations

- Cloud fraction and optical depth were derived from the multispectral GOES imager data using CERES cloud algorithms (VISST)
- TOA fluxes using NB (GOES) to BB (CERES) conversion
- 0.5° resolution (derived from 4-km pixel data)
- Separates cloud fraction (amount) into total, low (<2km), mid (2-6km), and high clouds (> 6km)

Data : CERES observations

- **Monthly TOA/Surface Flux Averages (SRBAVG) – GEO Edition 2D**
  - Mean flux from all SSFs within a 1°×1° grid box containing the SGP site (spatial average).
  - Gridded instantaneous fluxes are temporally interpolated daily using albedo directional models in the SW and linear LW interpolation
  - GEO product also includes normalized GOES-12 3 hourly data to capture diurnal signal.

- **Monthly mean cloud optical depth**
  - All log(tau) within the 1°×1° grid box are averaged
  - Log(tau) values are then averaged in time for the month
  - Monthly mean optical depth is then found by taking the antilog. This value is related to the monthly mean TOA albedo and surface transmission

Data: NASA GISS SCM Simulations

- 2°×2.5° centered on ARM SGP CF
  - 35 levels (25-mb vertical resolution)
  - Hourly output
- Driven by ARM hourly continuous forcing (Zhang et al. 2001, Xie et al. 2004)
- Radiation scheme is run in longer time steps due to computational demand and values interpolated in-between
- SCM prognostic cloud parameterizations
  - RH based parameterization for stratiform clouds (Sundqvist et al. 1989, Del Genio et al. 1996) with recent modifications to the scheme outlined in Schmidt et al. (2006). Threshold RH is designed to represent sub-grid scale variability of clouds
  - Convective scheme uses mass flux and is closed by moving enough mass to neutralize cloud-base instability (Del Genio and Yao 1993, Del Genio et al. 2005)
- Clouds can form in any layer and are overlapped in time rather than instantaneously in space with assumptions equivalent to mixed maximum-random overlapping

Objective One

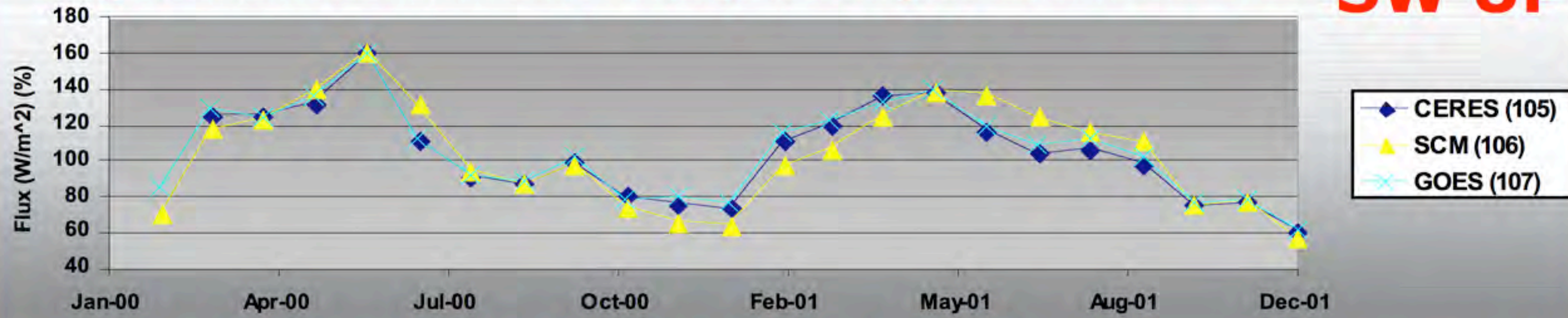
- To compare GISS SCM simulated radiation and cloud properties with GOES/CERES and ARM observations at the ARM SGP site.

- Based on all available data sets from March 2000 to December 2001.

TOA Fluxes

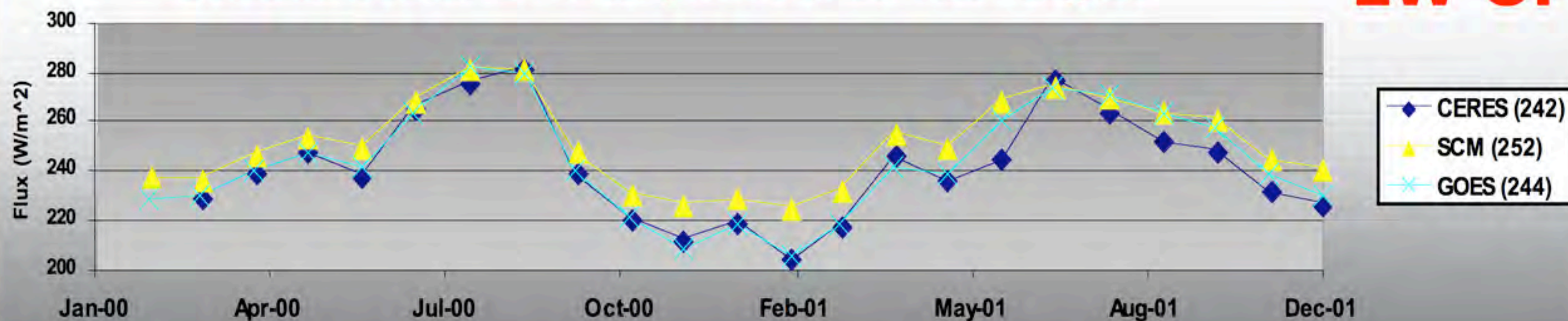
Despite month to month variations, fluxes agree within 2 W m^{-2}

SW UP

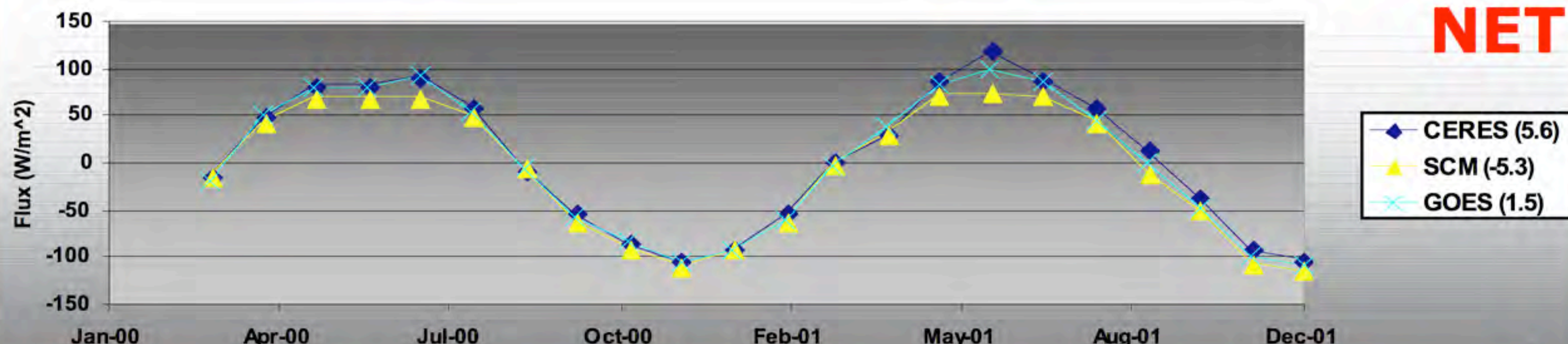


CERES/GOES ~2 W m^{-2}, SCM is 10 Wm^{-2} higher

LW UP

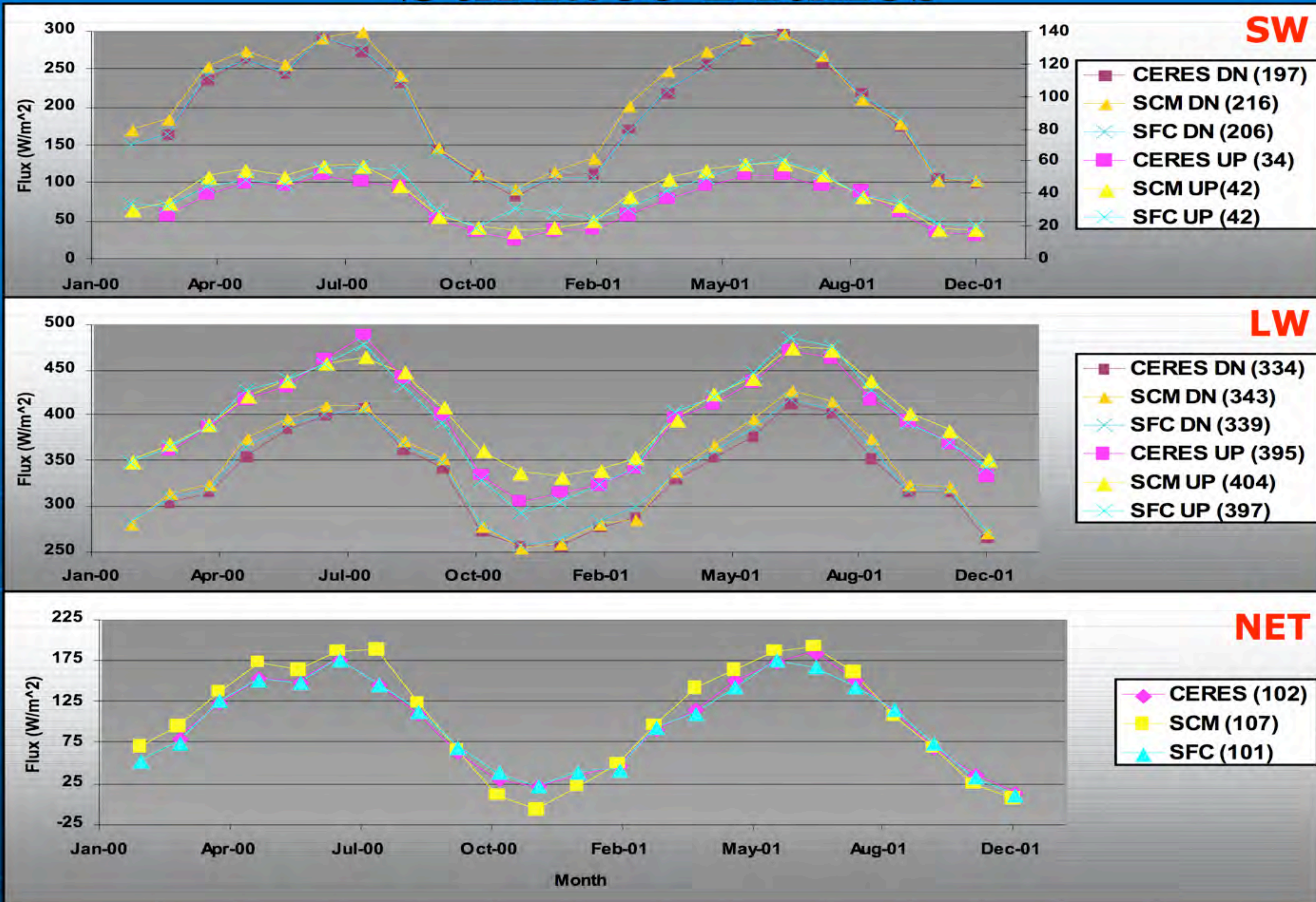


NET

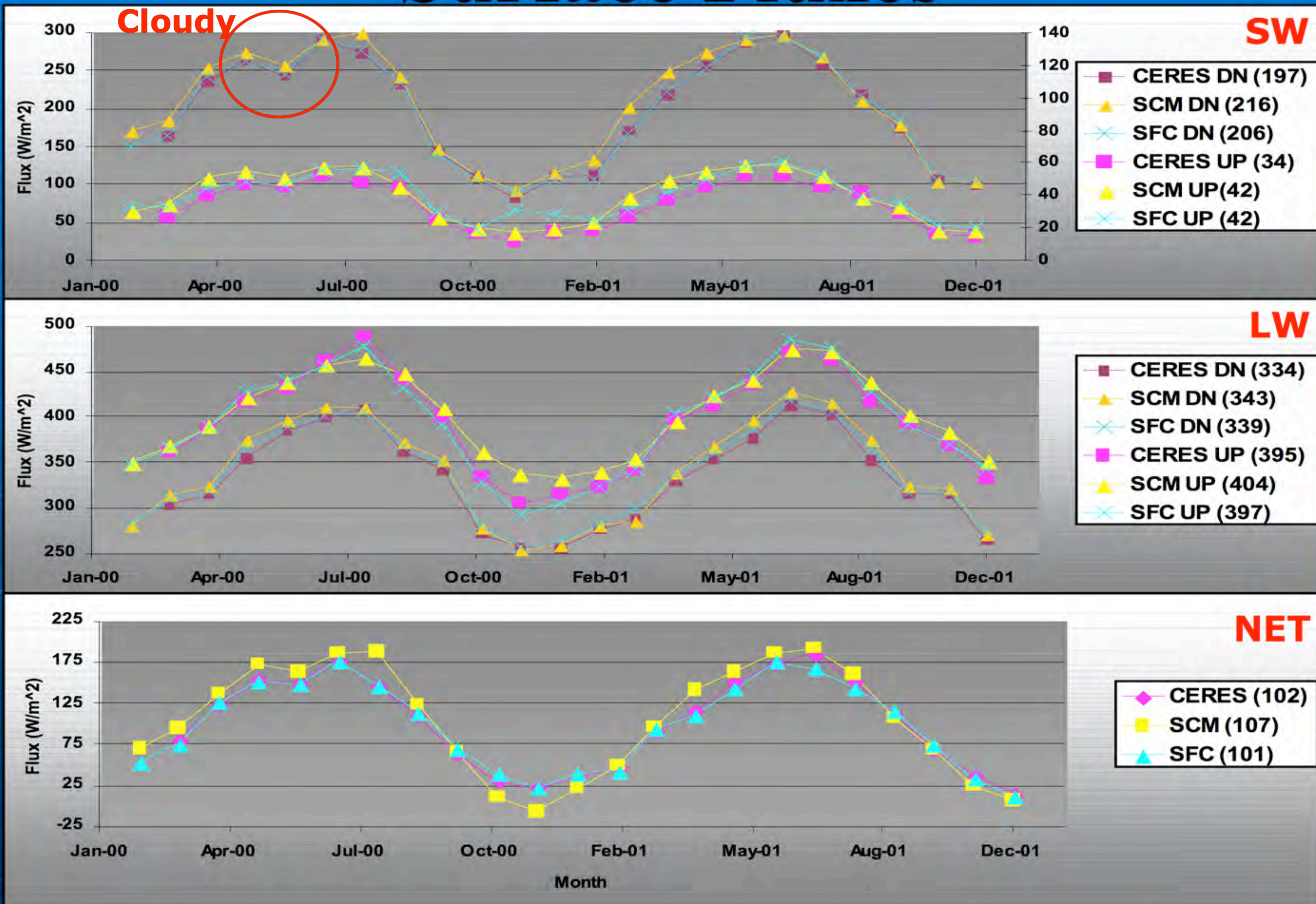


SCM simulations agree with CERES/GOES observations within 10 W m^{-2}

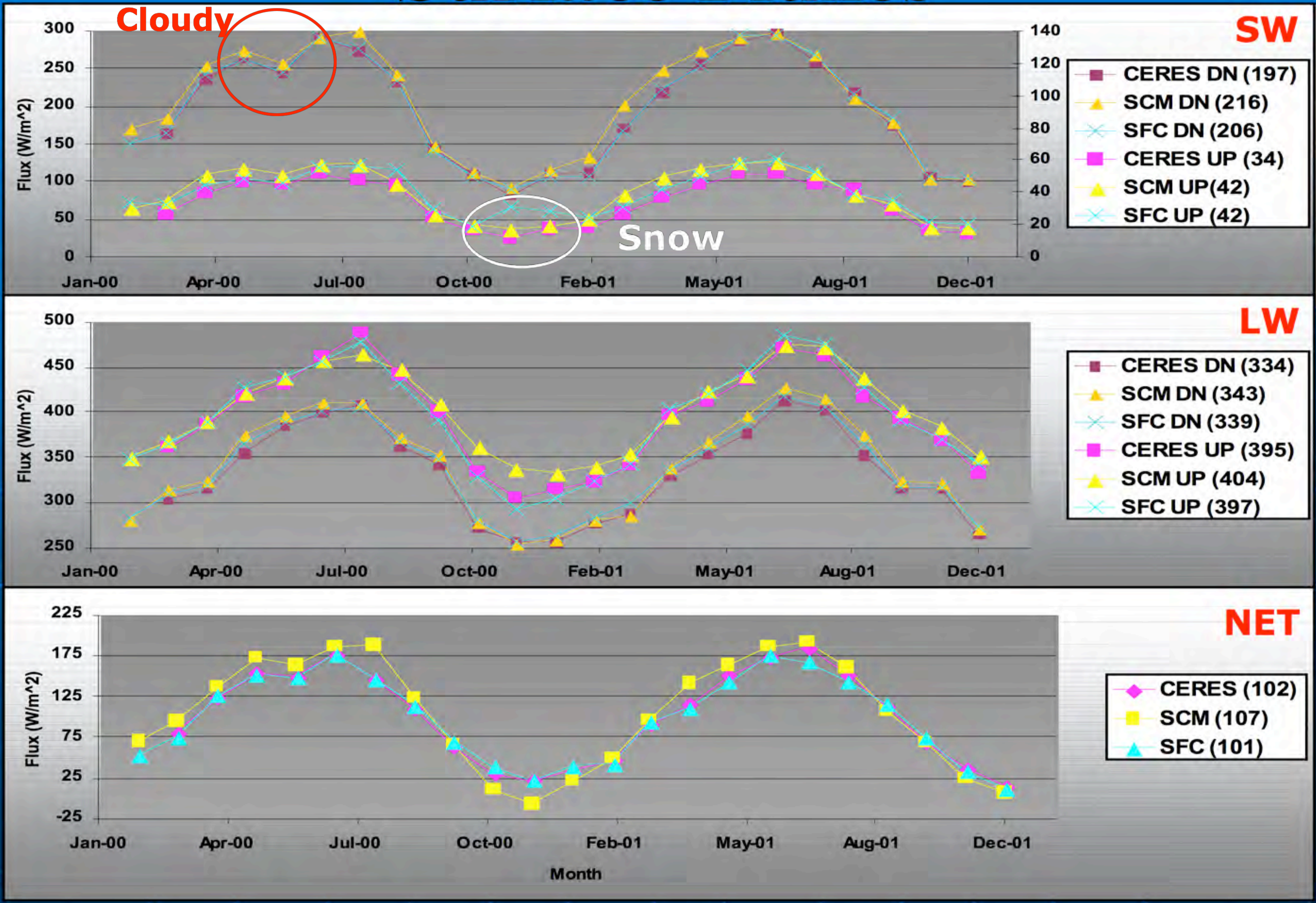
Surface Fluxes



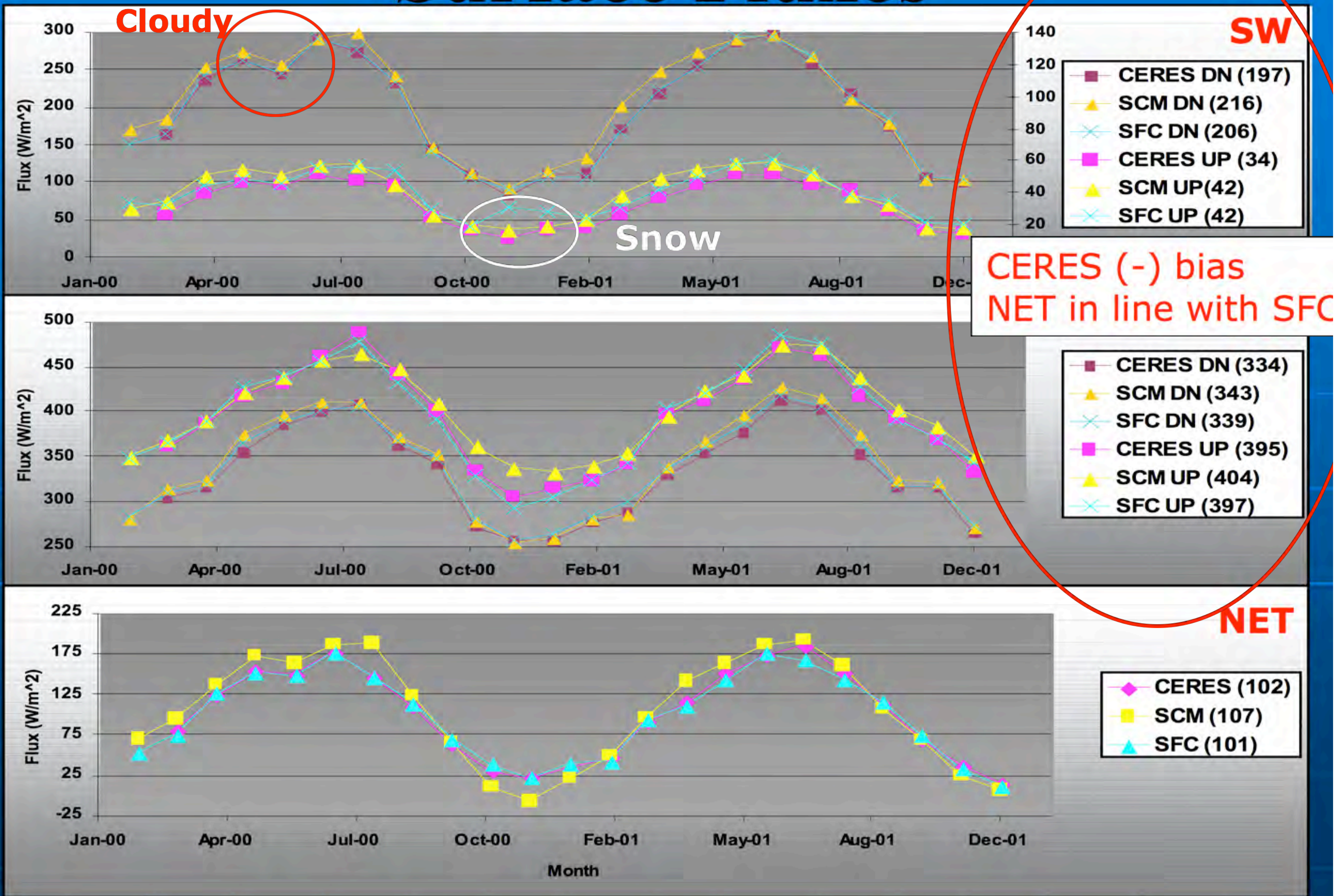
Surface Fluxes



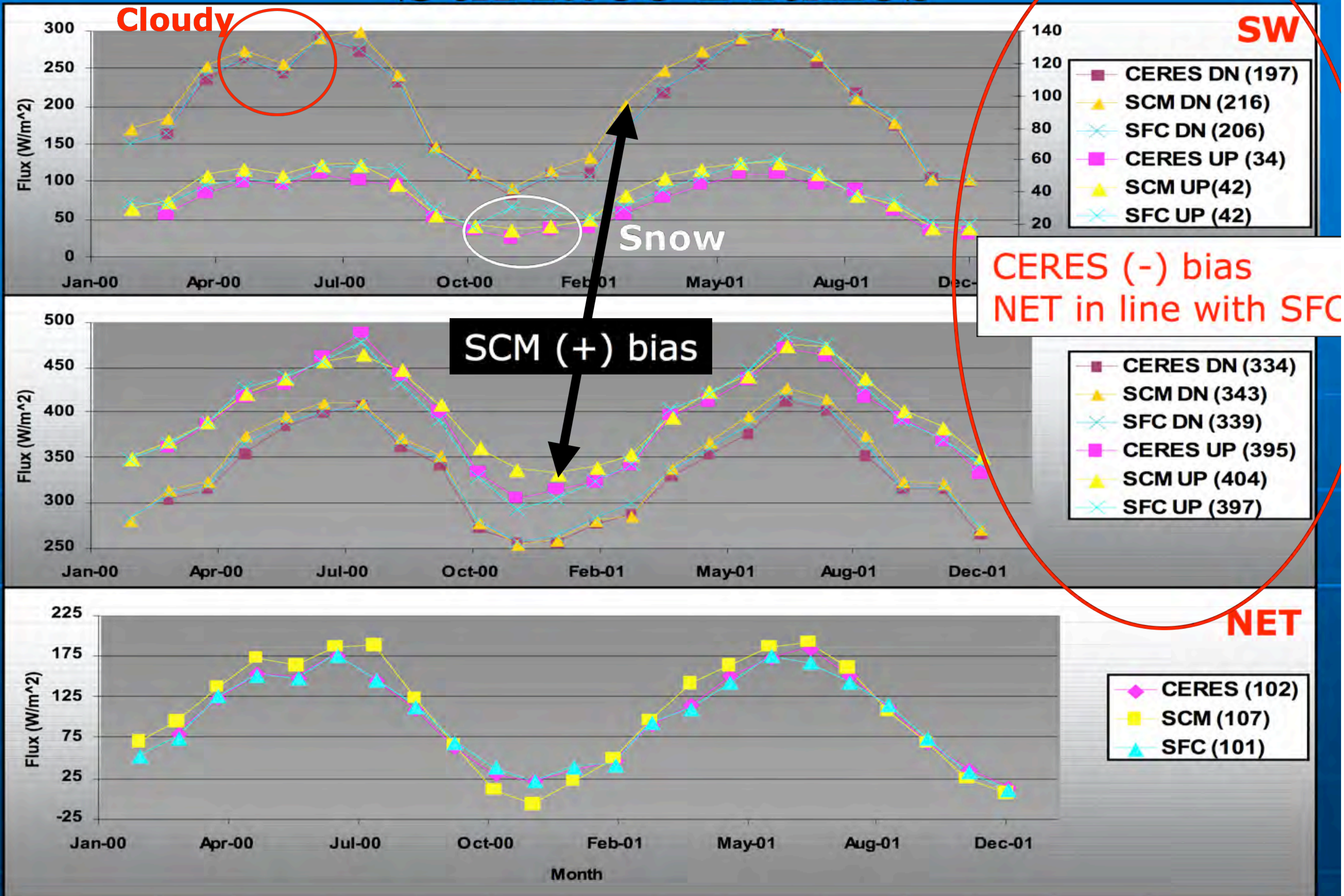
Surface Fluxes



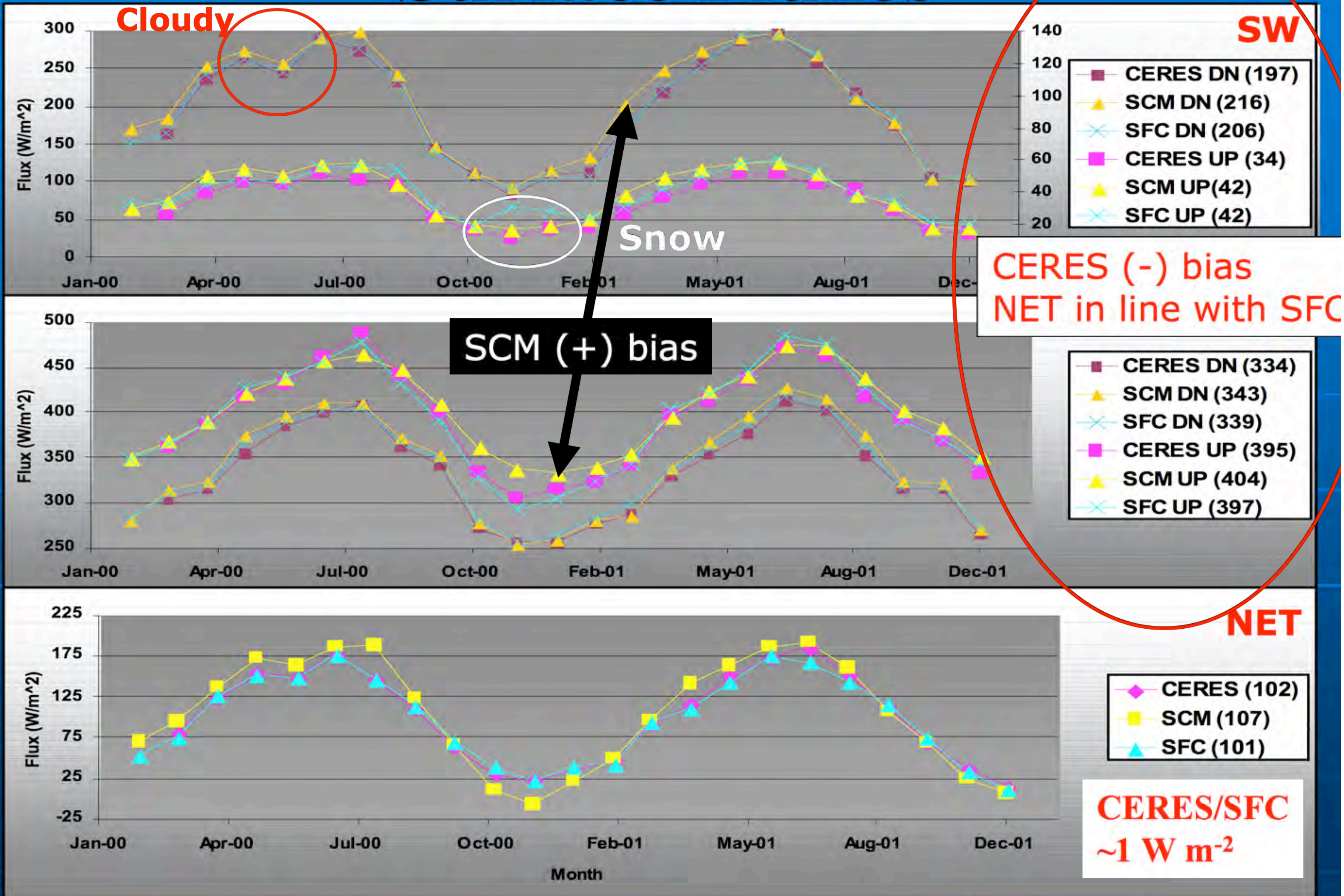
Surface Fluxes



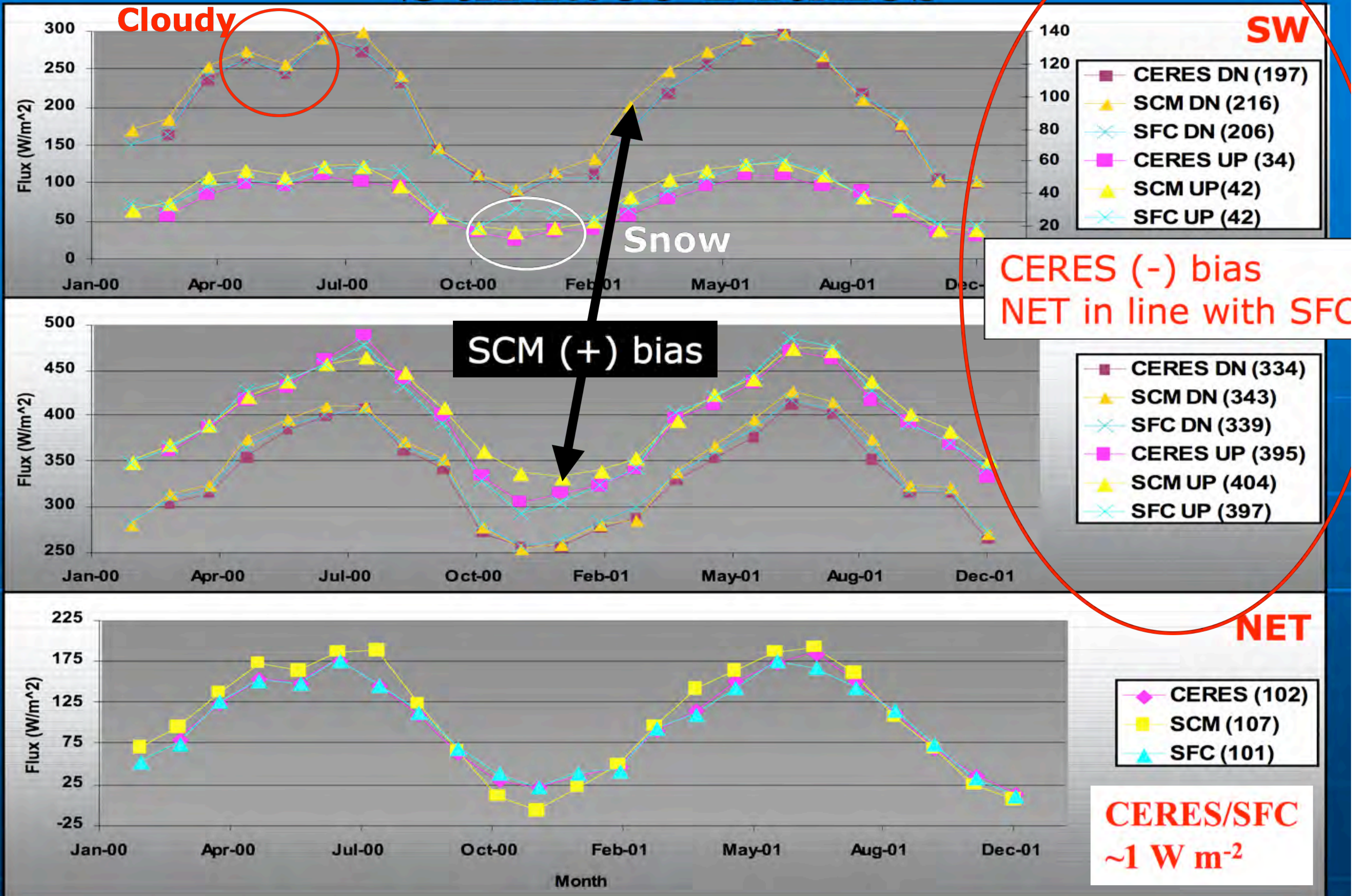
Surface Fluxes



Surface Fluxes

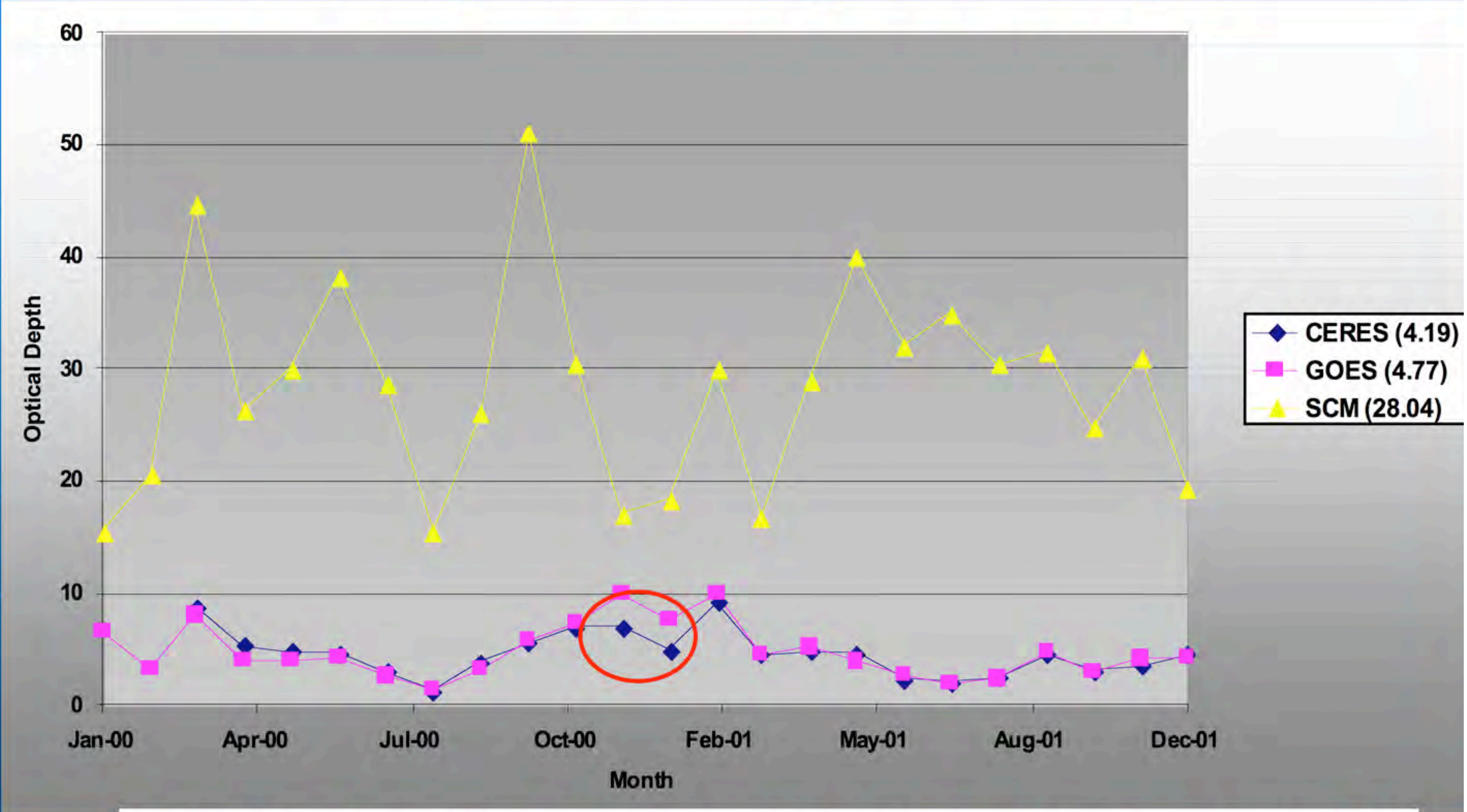


Surface Fluxes



SCM simulated NET surface flux agree with observations within 5-6 W m^{-2}.

Monthly Mean Optical Depth

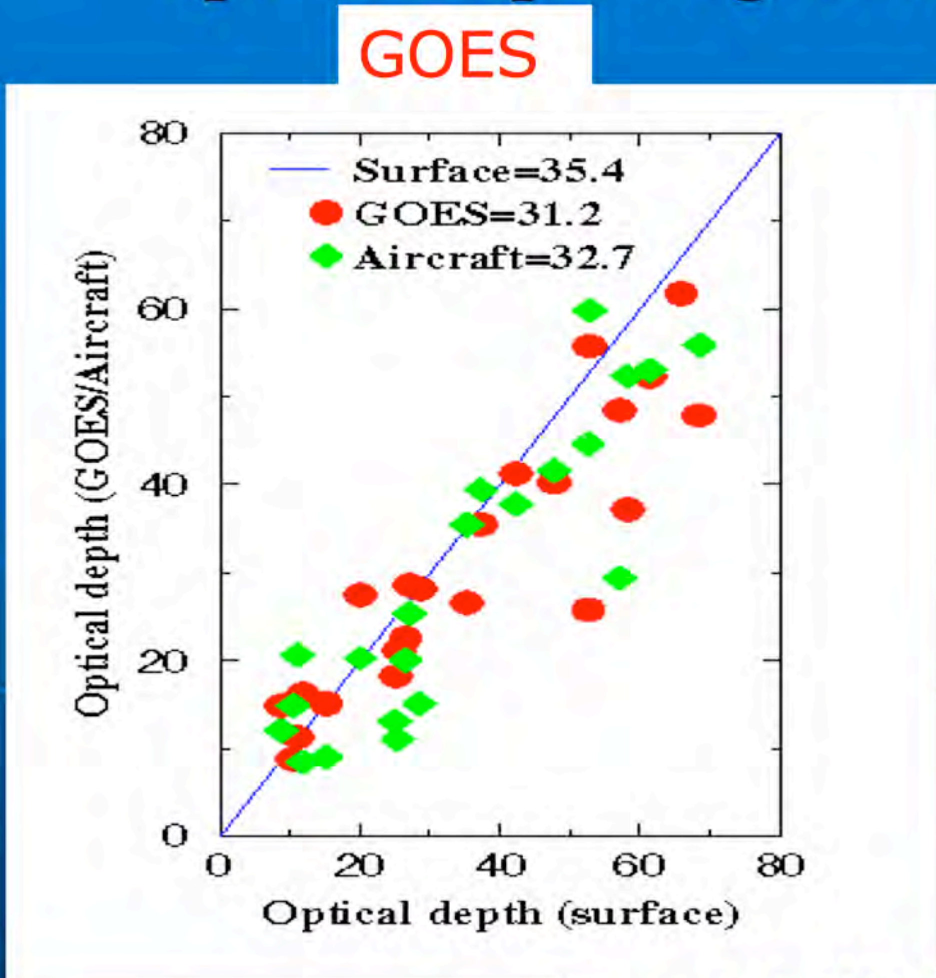


Satellites in excellent agreement except for snowy months

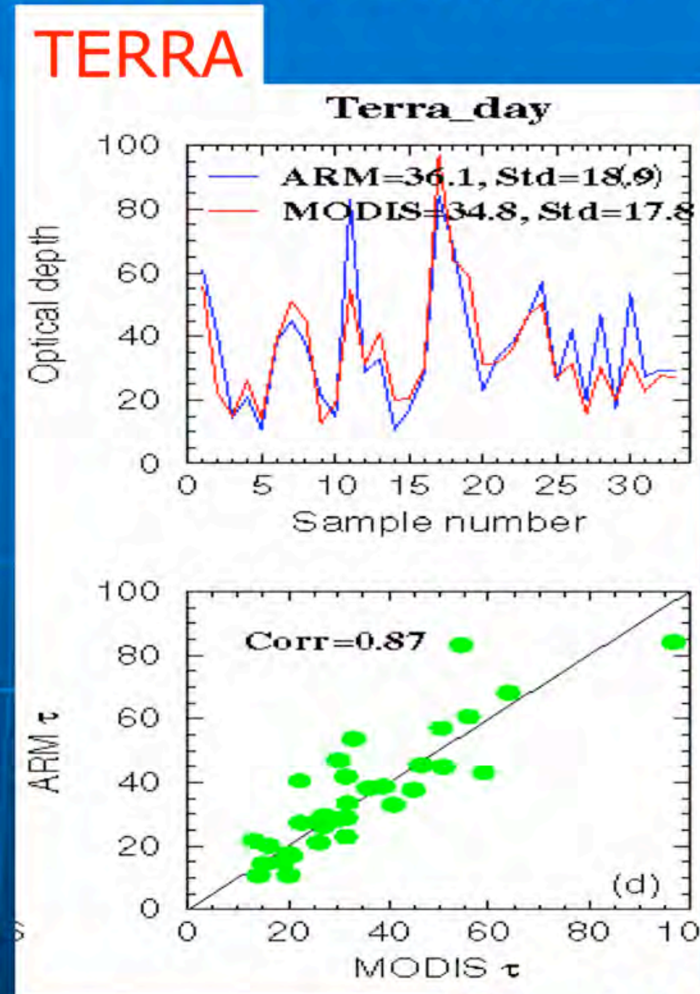
Log-Log averages used in both space and time

SCM optical depths are too large

How well do the GOES and CERES retrieved optical depths agree with ARM retrievals?



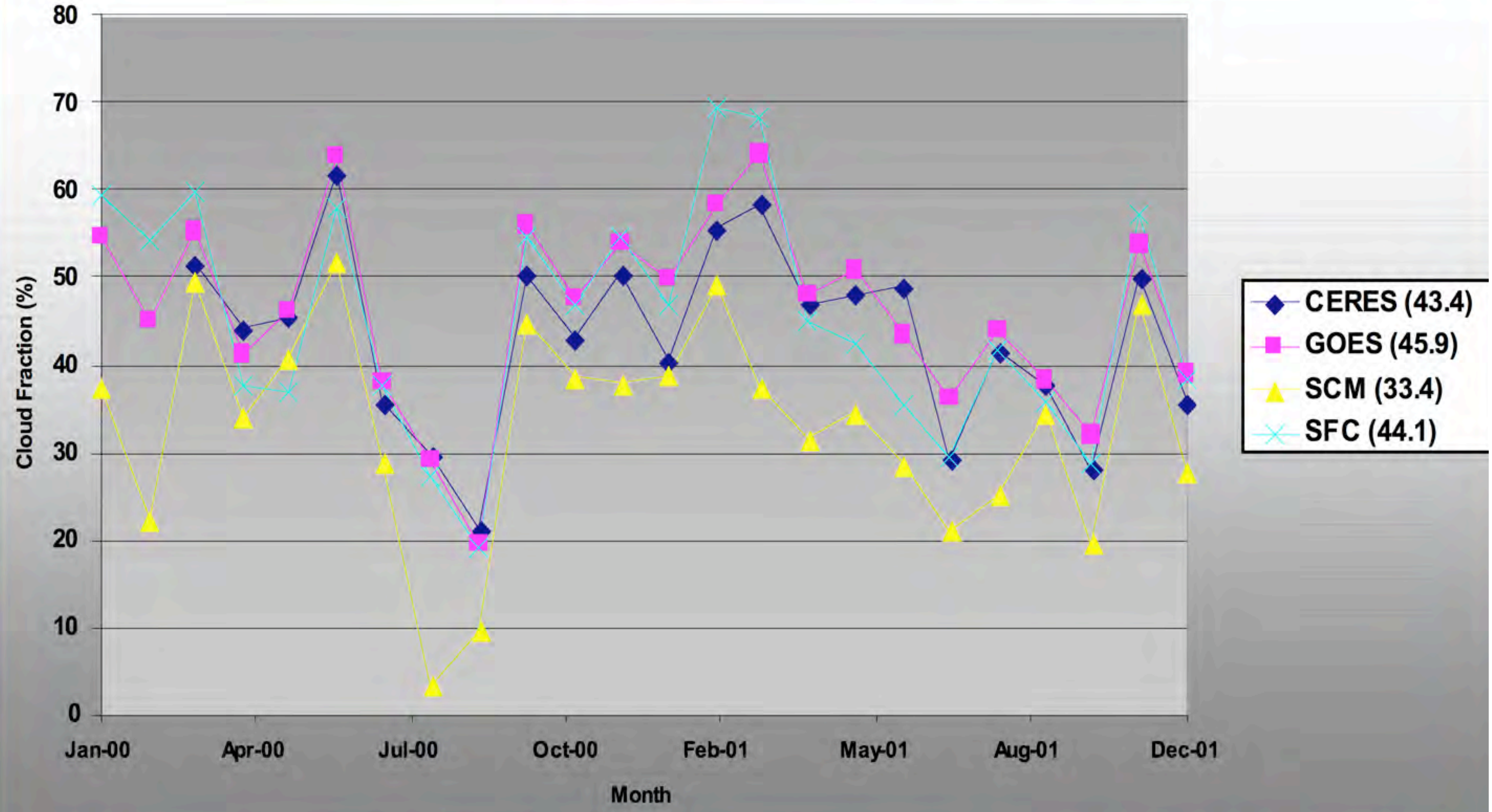
Dong et al (2002)



Dong et al. 2008

Both GOES and CERES retrieved optical depths have an excellent agreement with ARM retrievals for single layer stratus clouds.

Monthly Cloud Fraction



CERES and GOES derived cloud fractions agree well with ARM radar-lidar observations (~ 1%). SCM simulated clouds are ~10% lower.

Summary of Objective One

Objective 1: To compare GISS SCM simulated radiation and cloud properties with GOES/CERES and ARM observations at the ARM SGP site.

- ➔ **SCM simulated both TOA and Surface fluxes agree with observations within 10 Wm^{-2}.**
- ➔ **SCM overestimated cloud optical depth and underestimated cloud fraction, which results in decent agreement for the TOA and surface flux comparison.**

Objective Two

To evaluate the GISS SCM simulated cloud fractions using ARM-GOES observations and NARR data.

Based on all available data sets from January 1999 to December 2001.

Cloud Fraction by Height

	Radar	GOES(2.5°)	SCM(2.5°)
TOTAL	0.44	0.44	0.34
HIGH > 6 km	0.32	0.23	0.15
MID 2-6 km	0.20	0.11	0.17
LOW <2 km	0.16	0.10	0.24

➔SCM underestimated total and high clouds, and overestimated low clouds over the SGP during 1999-2001.

➔The radar/GOES discrepancies for individual levels are due to cloud height/base detection and multi-layer situations.

Possible causes for the biases

1) Forcing dataset biases

- EX: Too dry, too few clouds
- Difficult to quantify – forcing offers itself as a best estimate of reality due to its combination of observations (sounding, surface, satellite) and RUC-2 model assimilation

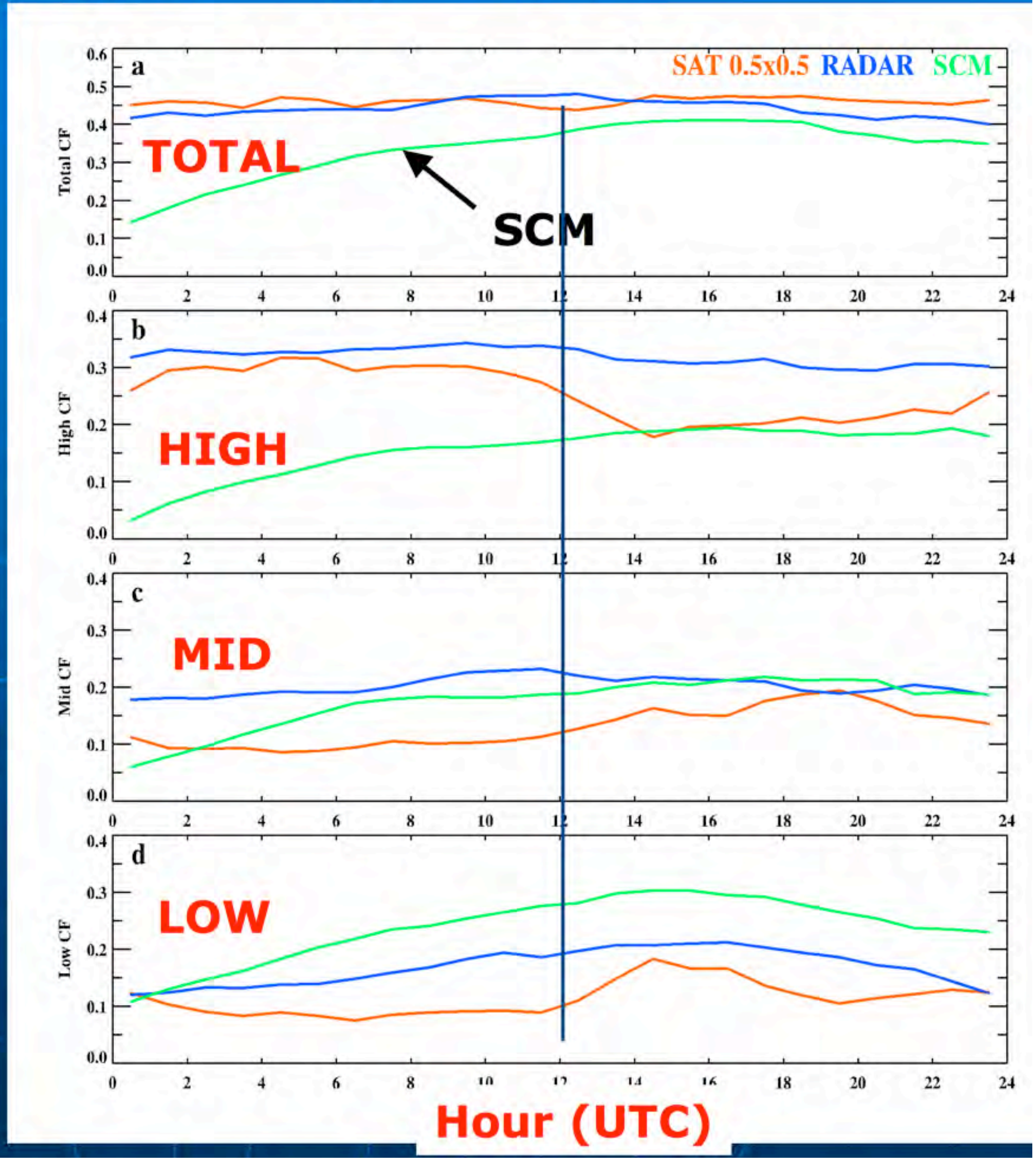
2) SCM

- Parameterizations
  - GCMs require relatively simplistic cloud parameterizations
  - Stratiform scheme uses a RH value to represent sub-grid scale variability
  - Convective scheme uses mass flux
- Model needs time to spin-up?

3) Combination – too many clouds occur due to sub-grid scale processes, stratiform threshold can't "catch up"

Model Spin-Up Time

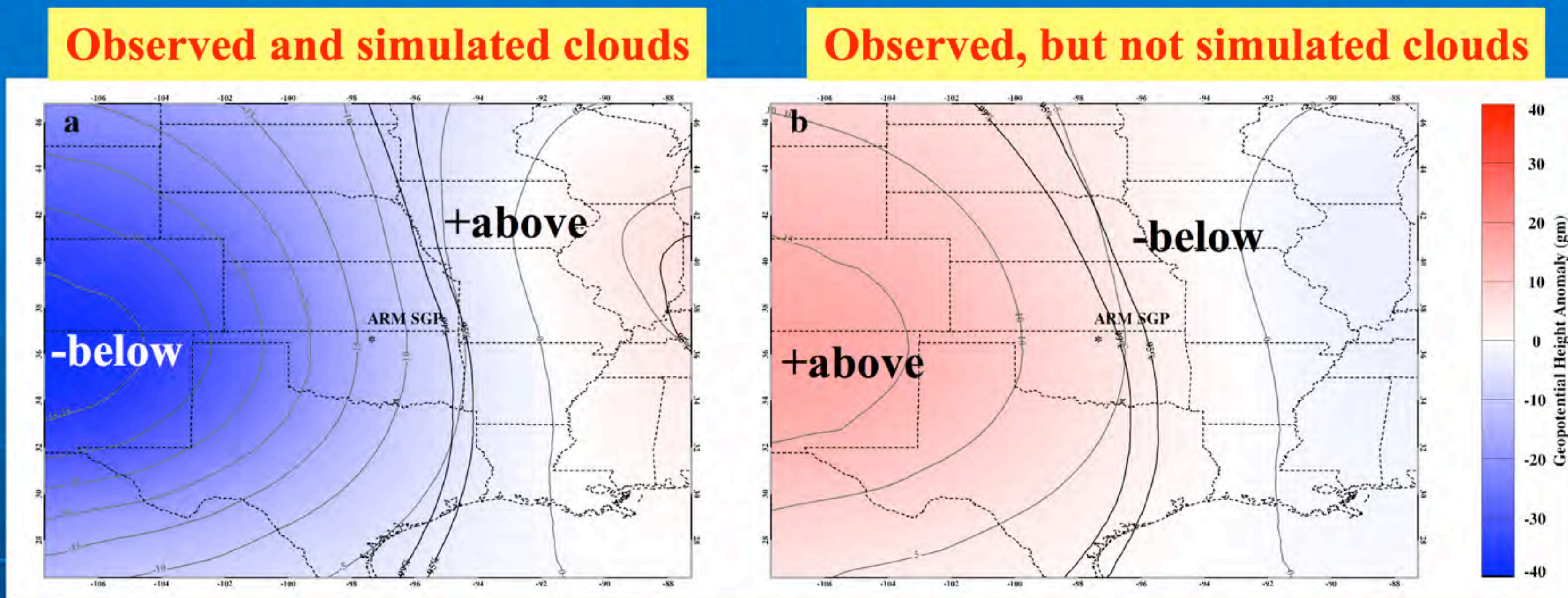
- There is no strong diurnal cycle from observations (except for low clouds)
- SCM needs ~12 hours to warm-up and produce a maximum amount of clouds
- For example, the SCM total cloud CF increases from 0.15 to 0.36, and high clouds CF increases to 0.18 after 12 hours



Climatology of simulated and observed clouds

- Analysis based off NARR data and combined GOES/ARM cloud mask.
- Resolution decreased to the three hourly NARR
- Goals:
  - Under what conditions is the model simulating clouds?
  - Is there a seasonal variation in cloud occurrence with large scale parameters?

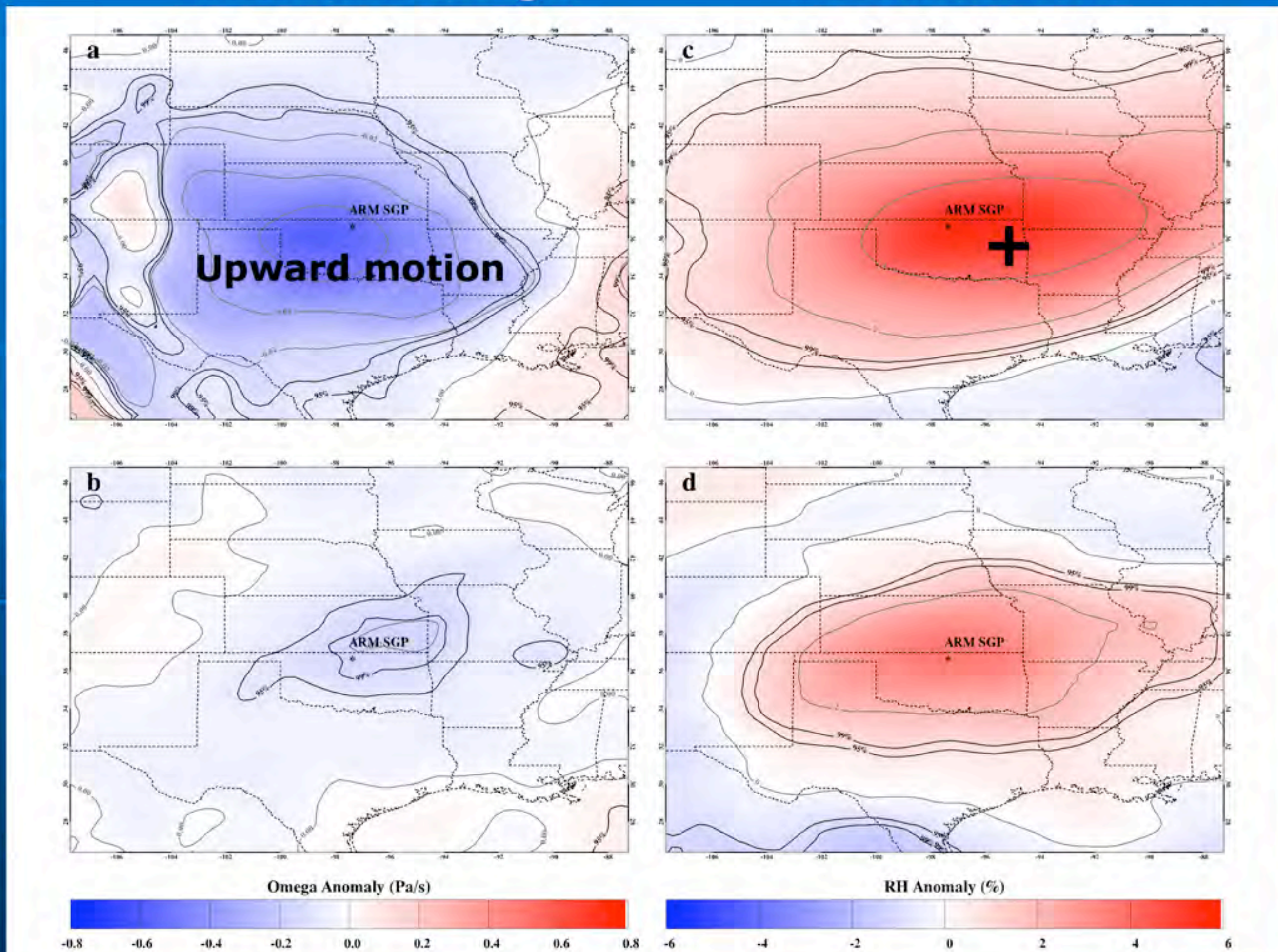
Model Evaluation by Synoptic Pattern (Using observed clouds as baseline at 500 mb)



- Model produces clouds when trough axis is west of SGP
  - Associated with rising motion and positive RH anomaly
  - Fits conceptual model of a baroclinic wave
- Reverse is true for missed clouds
  - Conditions have negative RH bias and sinking motion
- CAVEAT – Only 3 hour periods, so is this representative for a model designed to simulate monthly/yearly means?

500 mb Omega and 300 mb RH climatological anomalies for observed high clouds

500mb Omega **300mb RH**



Winter (DJF)

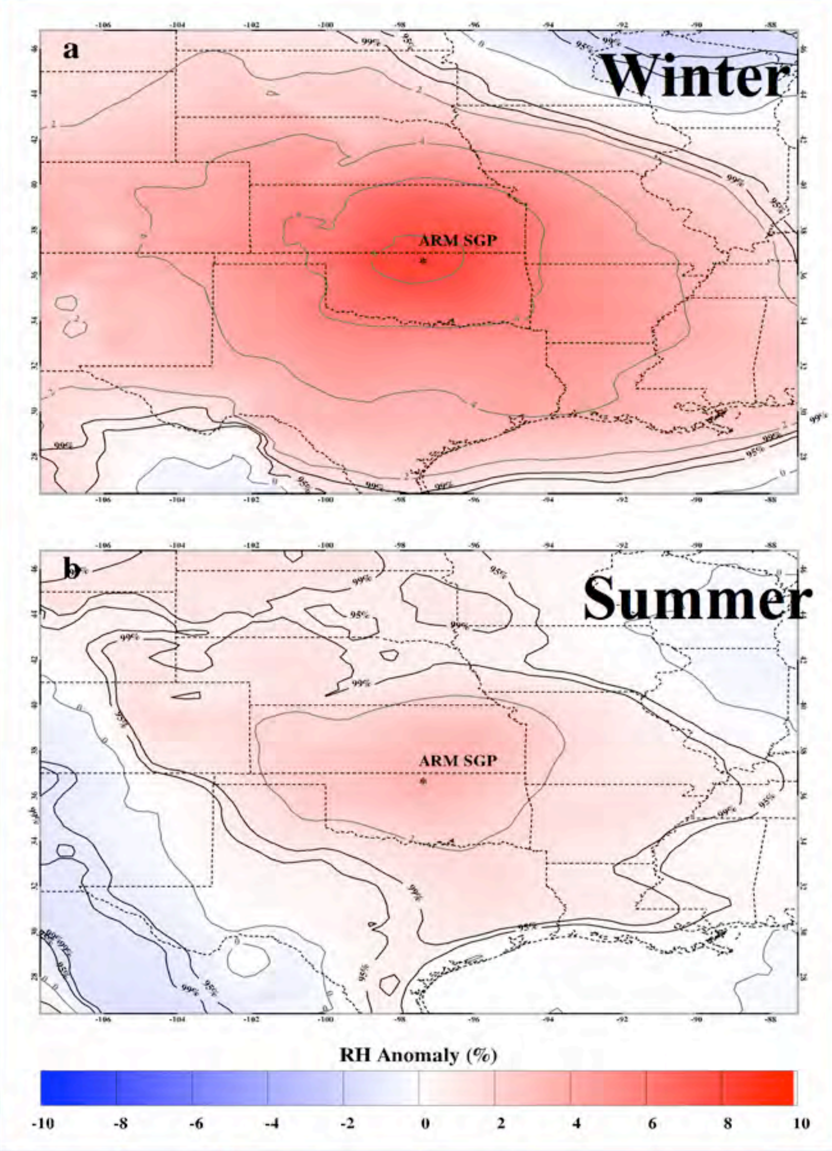
Summer (JJA)

Winter: clouds are associated with strong upward motion and positive RH anomalies
Summer: relationships are smaller in magnitude, more clouds forced due to sub-grid scale processes

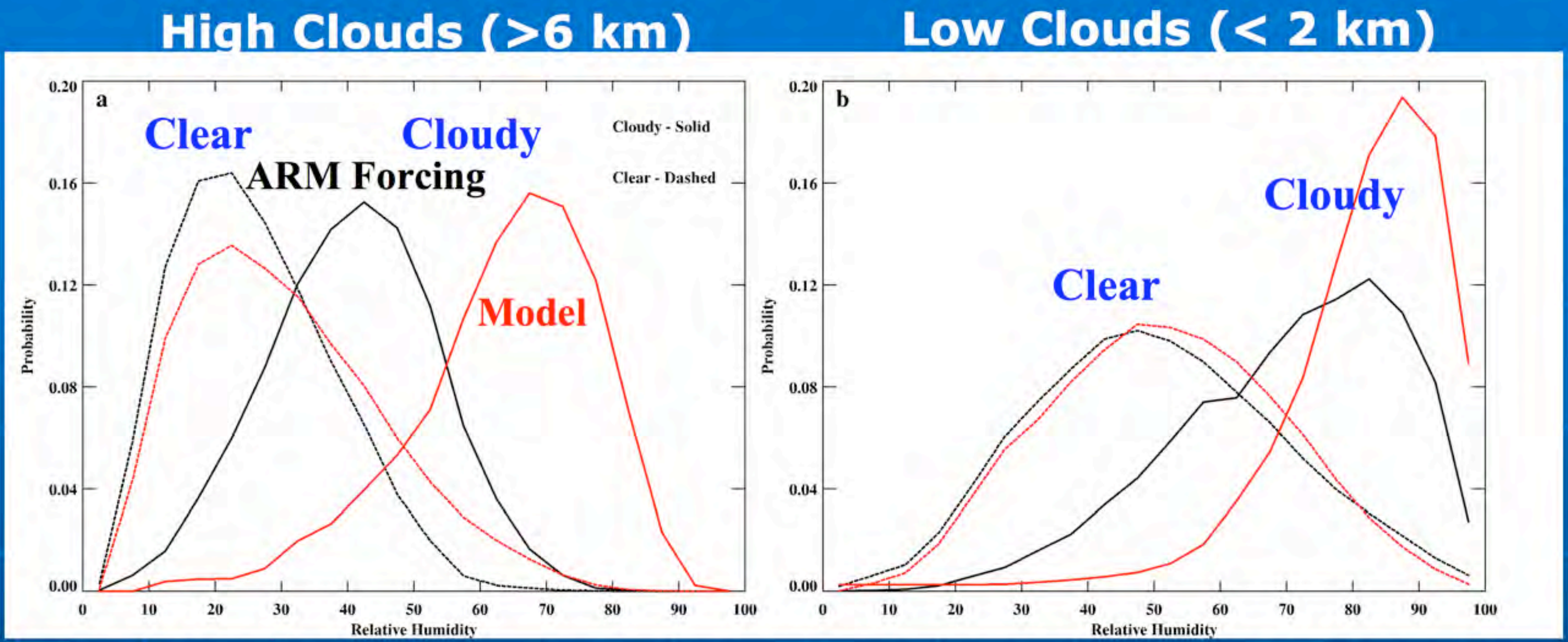
Climatology of Low Clouds

- 925mb RH
- Less relationship during summer -> over production of clouds

- **Climatology Summary**
  - Model does well for clouds with large-scale synoptic forcing (expected)
  - During summer (ridging/ subsidence), clouds are more often forced by sub-grid scale processes and are harder to capture

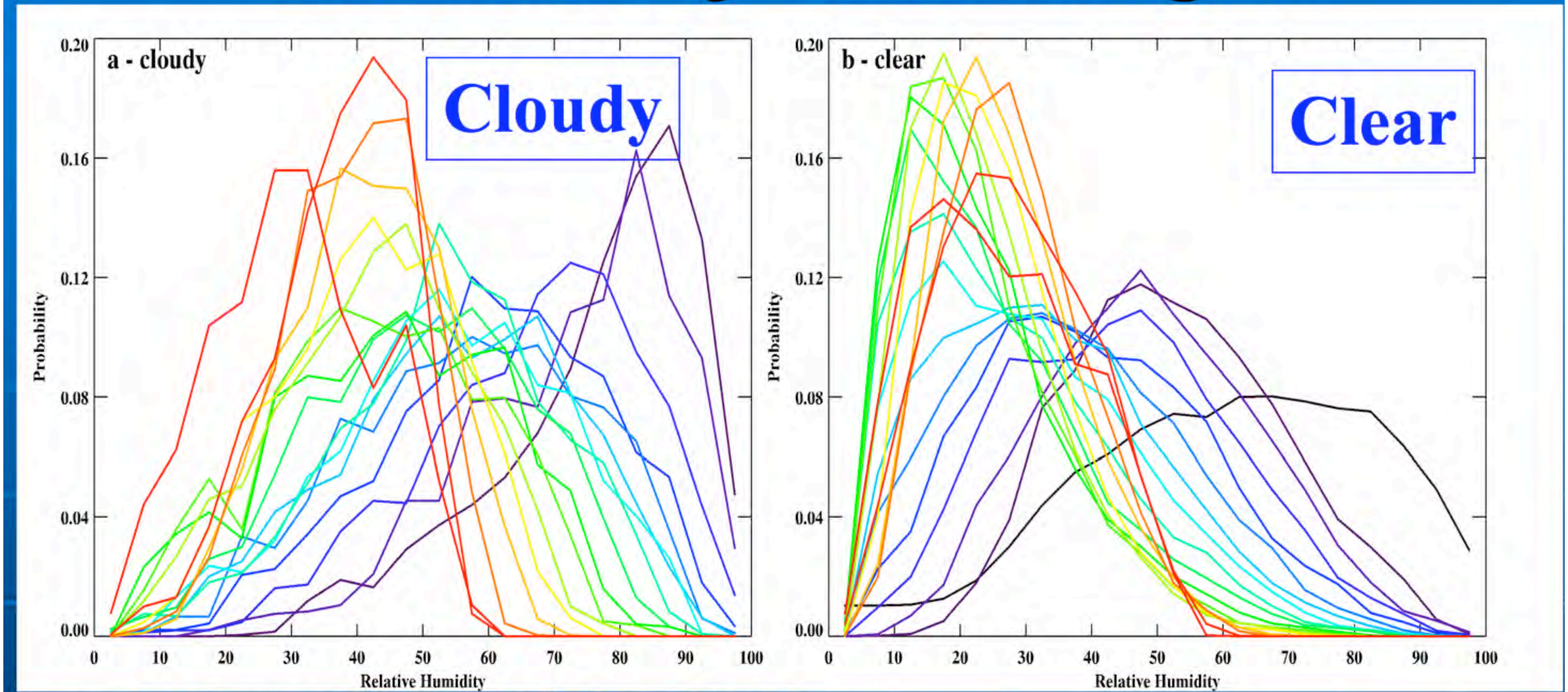


Cloud Occurrence with Forcing RH



- Stratiform conditions (ω > 0)
- Cloud relationship to large-scale mean RH is dependant on height
- For high clouds, many clouds occur at lower RH – large overlap between cloudy/clear conditions (to be expected)
- For low clouds, better agreement, however, easy to see why clouds overproduced for humid situations.
- 36% of clouds occur during stratiform conditions so this can be a significant issue.

Variability with Height



- **Warm colors = higher levels**
- **Cool colors = lower levels**
- **Can see "happy" medium in mid-levels where cloud/clear distributions are better separated**
- **For high clouds, distributions overlap**

Summary of Objective Two

SCM has negative/positive biases for high/low clouds due in part to:

- Model Spin-up (negative bias)
- Model captures large-scale synoptically evident clouds, however, sub-grid scale clouds are common over SGP, especially during summer
- Easy answer for coming up with correct cloud fraction is to simply to change the RH threshold representing sub-grid scale variability. Caveats abound!
  - Only for one location, one time
  - Leads to more tuning which is always frowned upon.
  - How accurate is the forcing?
  - Regardless, the forcing data show that cloudy RHs decrease with height. RH based parameterizations will have issues predicting sub-grid scale variability since this changes with height.

Future Work

- Additional work with forcing/satellite data…
  - This study has only looked at cloud occurrence with RH… what about cloud amount vs. RH?
- What percentage of convection is missed? How does this contribute to the cloud bias?
  - High clouds – anvil? or isolated cirrus?
  - What is the radiative impact of these clouds?
- Cloud microphysics evaluation

Questions?