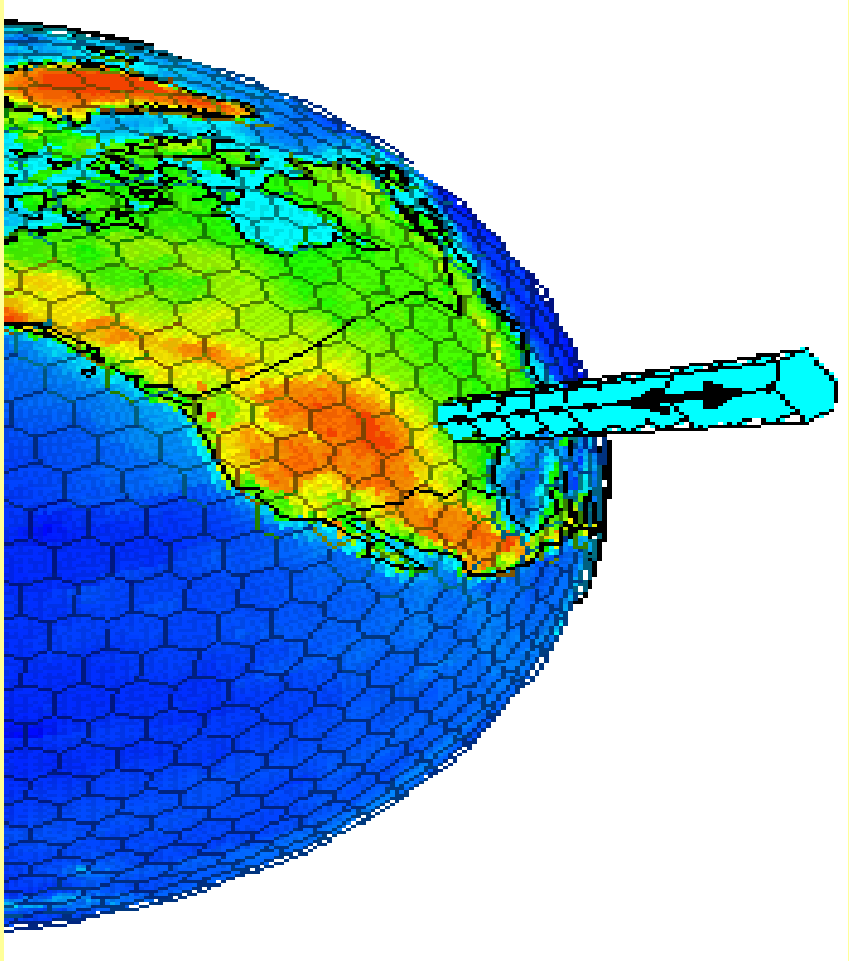
Analysis of Land-Atmosphere Interactions at the ARM SGP Site

Tom Phillips
February 26, 2008



Outline

- Motivation
- Approach
- Model validation (single variables)
- Covariance relationships (preliminary)
- Future work plans

Motivation

- Given the short time scales and high spatial heterogeneity of land processes, a MOLTS framework is a potentially useful framework for fine-grained validation of land-atmosphere interactions in climate GCMs

- Analysis of *relationships* (e.g. covariances, coupling strengths) among land-surface/ABL processes may yield new insights on parameterization deficiencies in present-day climate GCMs

Approach

- Utilize hourly observations and AM2/CAM3 model forecasts post-processed at the ARM SGP site for the year 2000

- Use ARM observations to validate atmospheric model *forcings* (e.g. radiative fluxes and precipitation) and land model *responses* (e.g. surface turbulent fluxes, temperature & humidity) at hourly to seasonal time scales → **Neglects coupled feedbacks**

- Also analyze covariances of land-atmosphere variables to gain insights into coupled processes/feedbacks in models vs. observations

- Today, discussion of results will be limited to the July-August-September (JAS) season when AM2 and CAM3 errors are both most stark and different--further details on other seasons can be found in the write-up on our internal website at

  http://www-pcmdi.llnl.gov/projects/capt/protected/index.html

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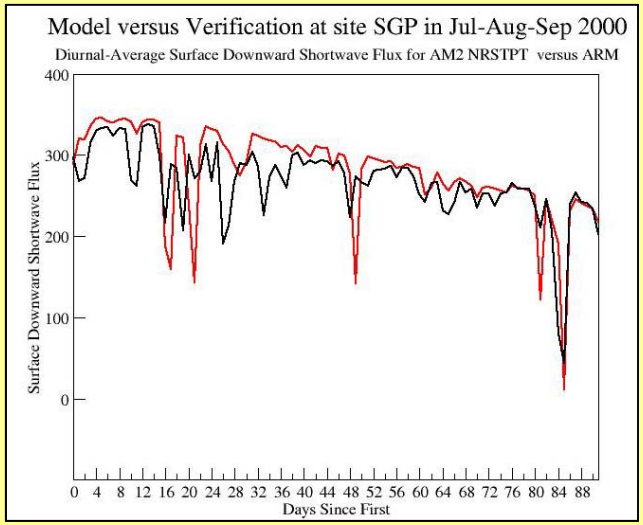
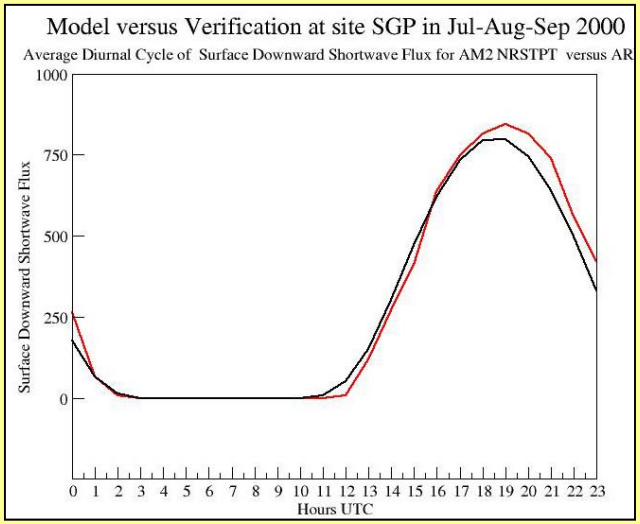
Validation of Atmospheric Model Forcing: JAS Downward Sfc Shortwave

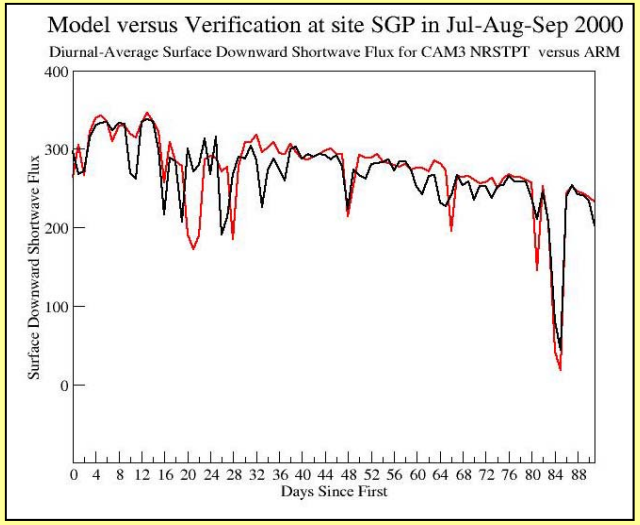
Daily Averages **AM2** vs. **Obs**



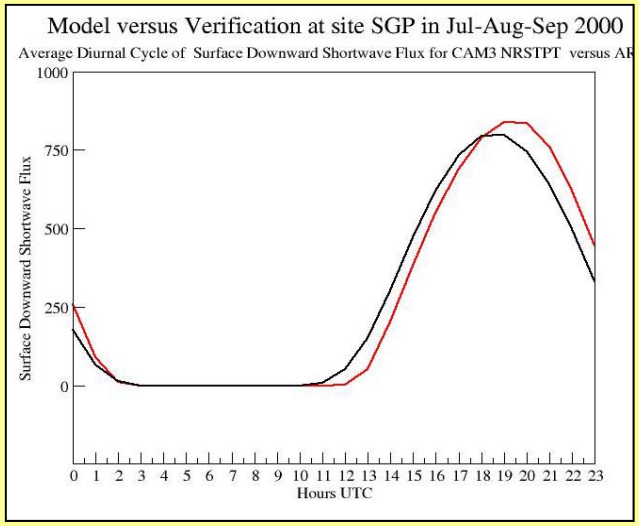
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

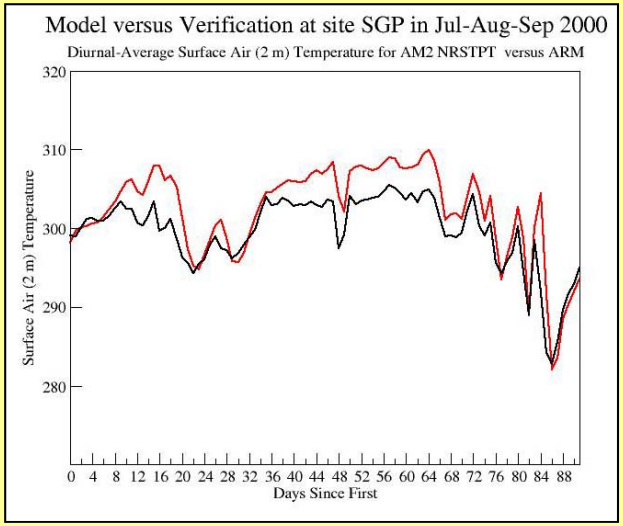


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

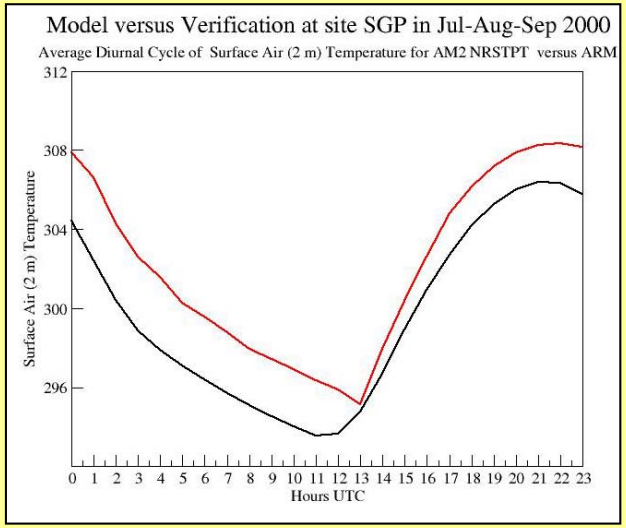


Validation of Land Model Response: JAS 2-Meter Temperature

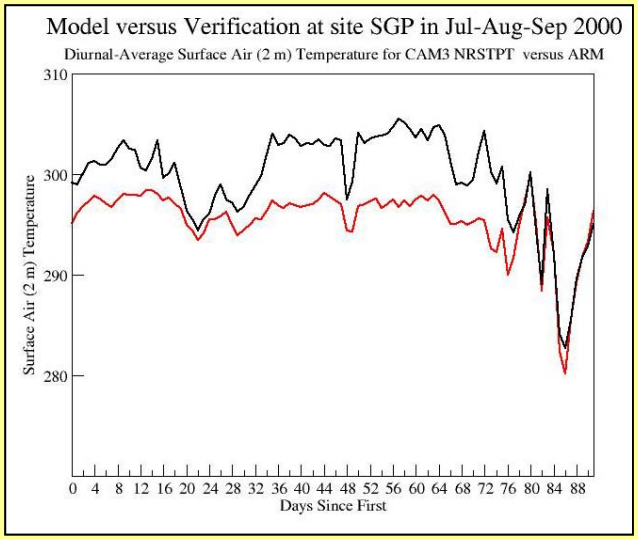
Daily Averages **AM2** vs. **Obs**



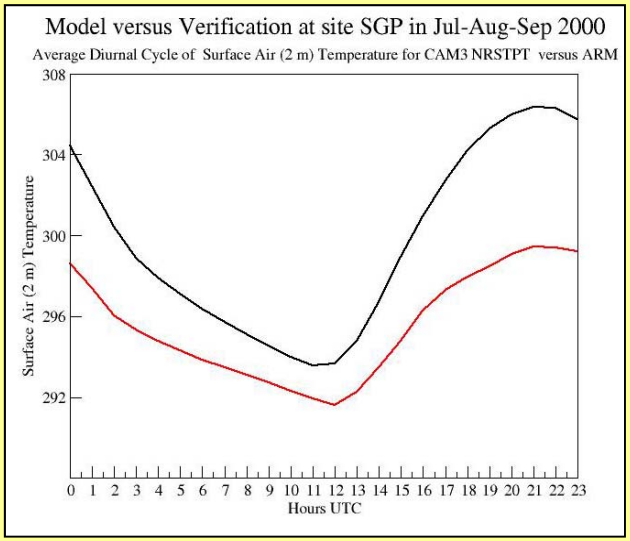
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

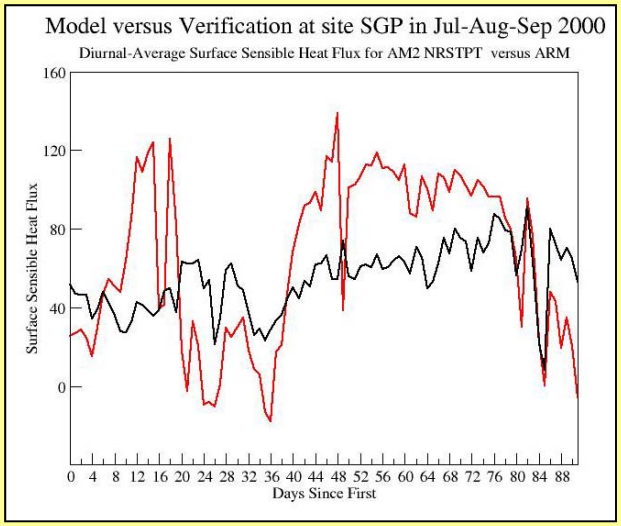


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

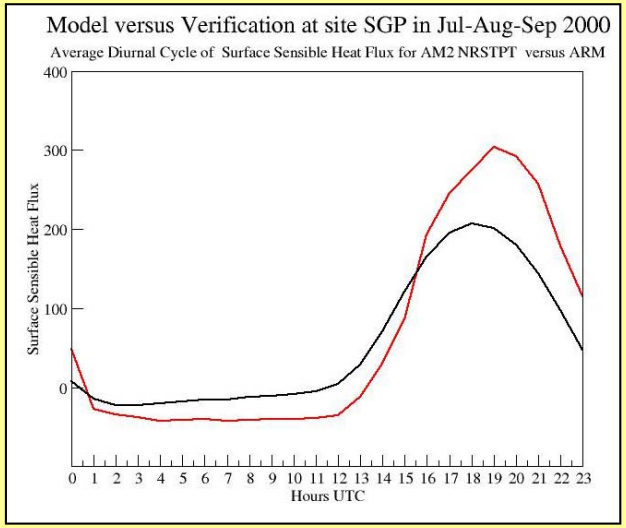


Validation of Land Model Response: JAS Surface Sensible Heat Flux

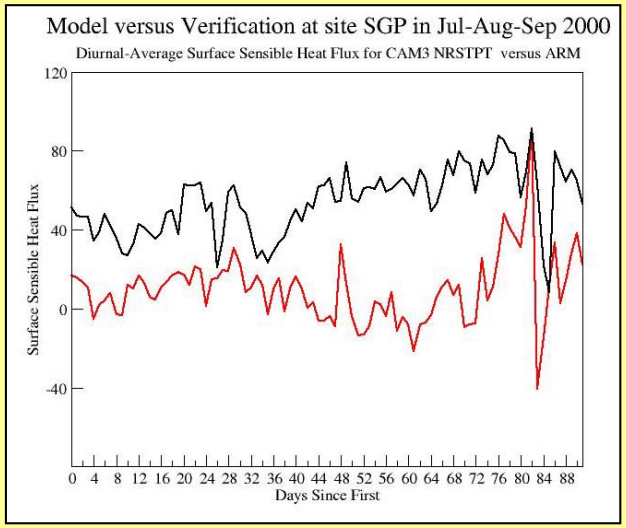
Daily Averages **AM2** vs. **Obs**



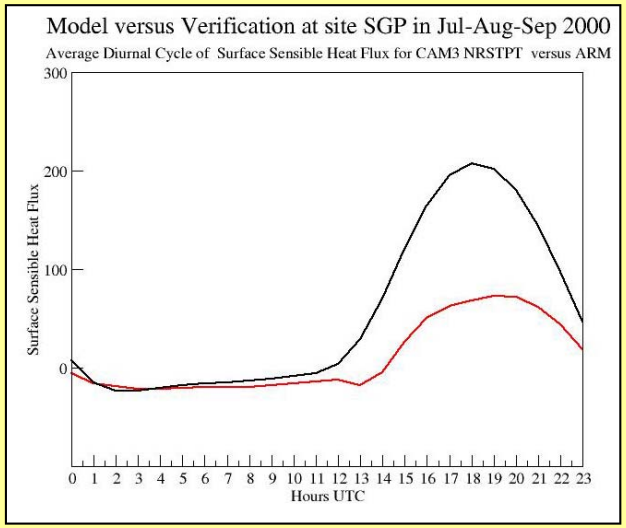
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

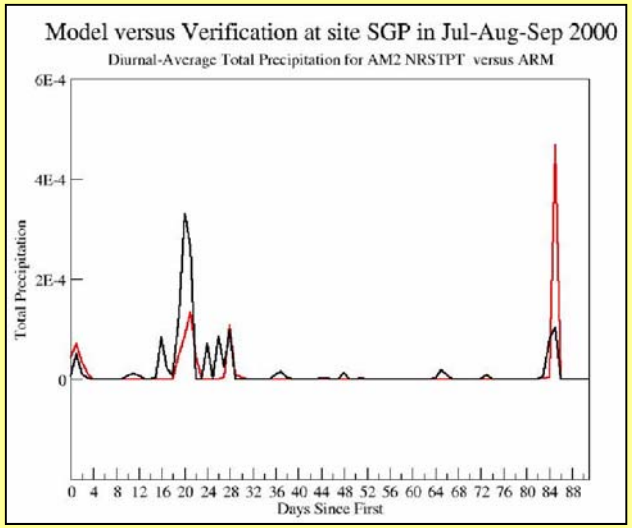


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

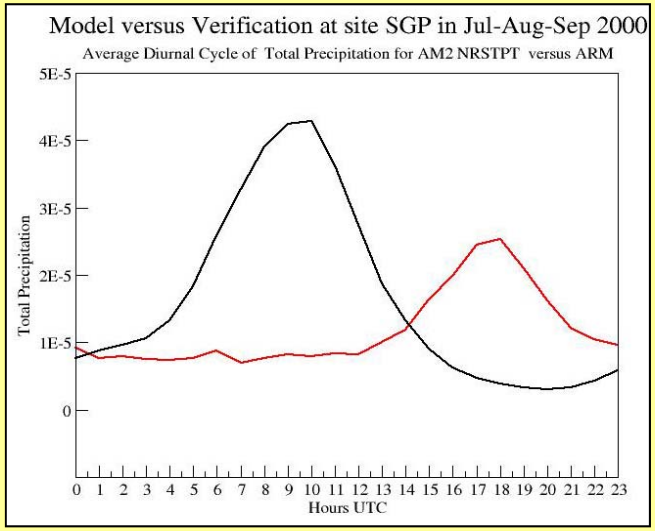


Validation of Atmospheric Model Forcing: JAS Precipitation

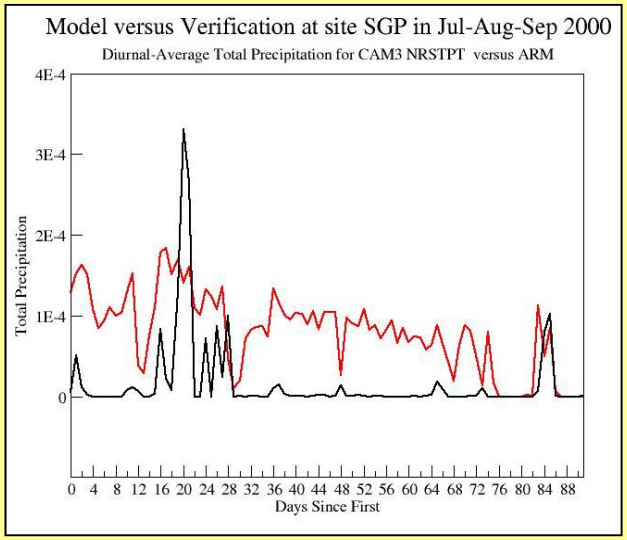
Daily Averages **AM2** vs. **Obs**



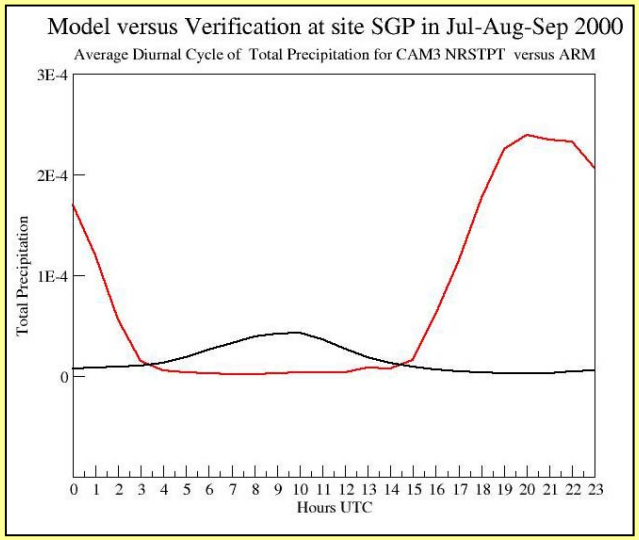
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

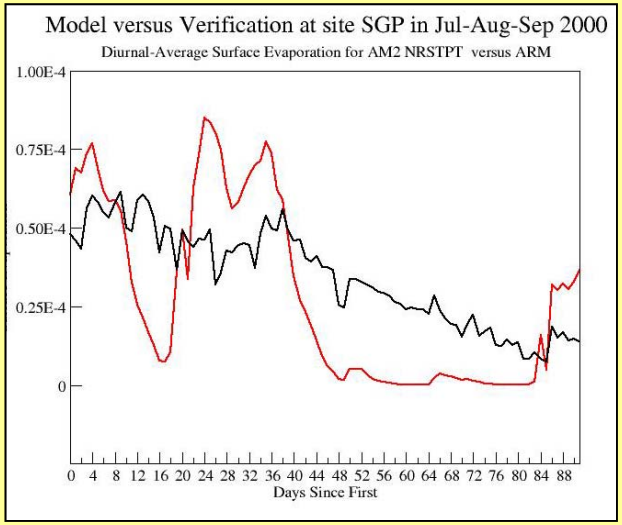


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

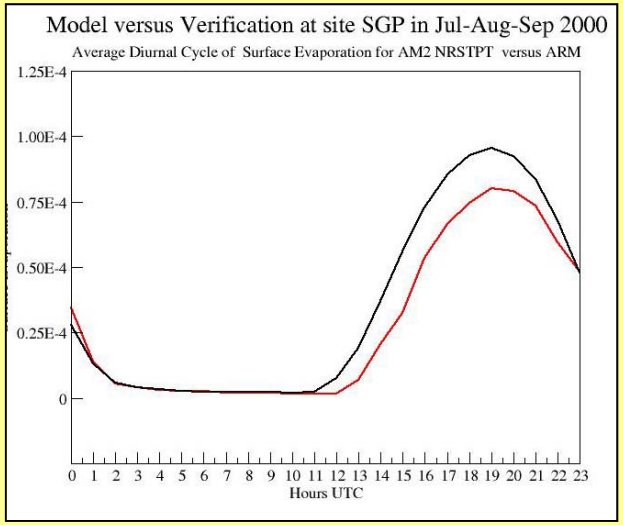


Validation of Land Model Response: JAS Surface Evaporative Flux

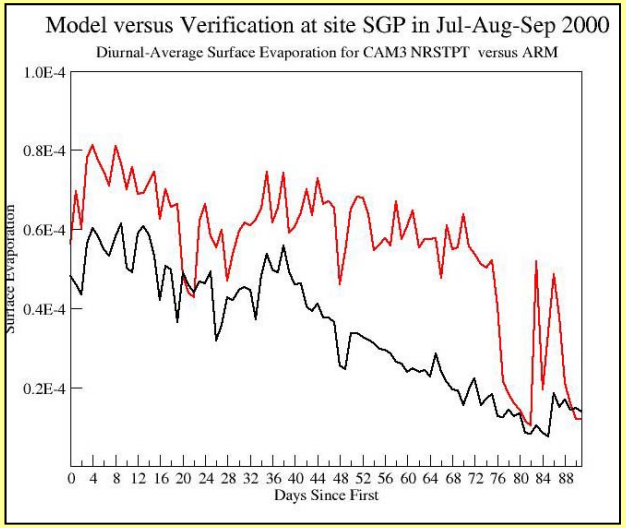
Daily Averages **AM2** vs. **Obs**



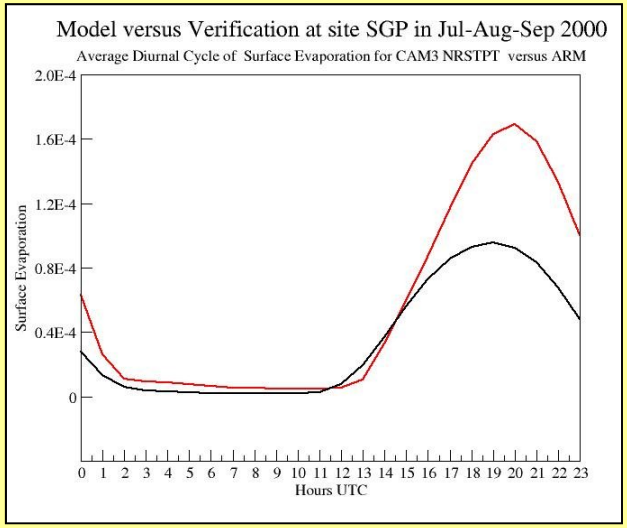
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

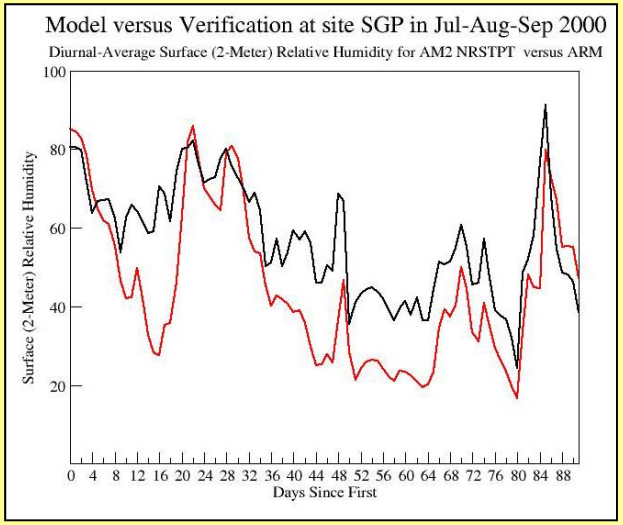


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

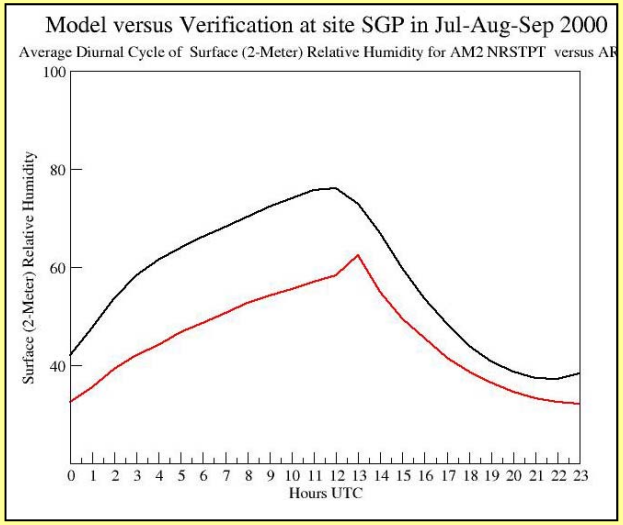


Validation of Land Model Response: JAS Surface Relative Humidity

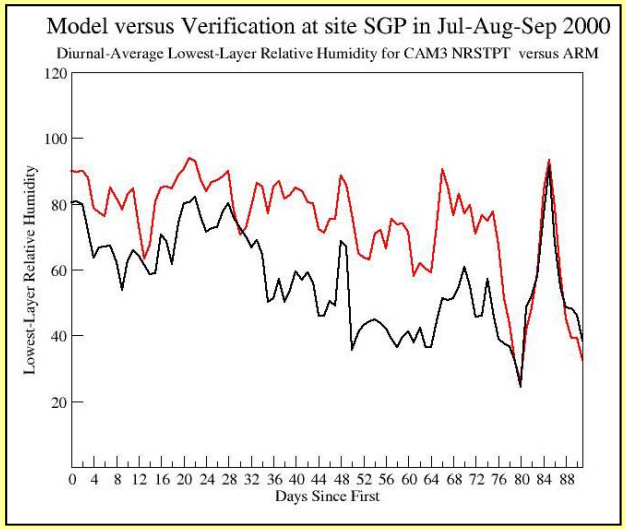
Daily Averages **AM2** vs. **Obs**



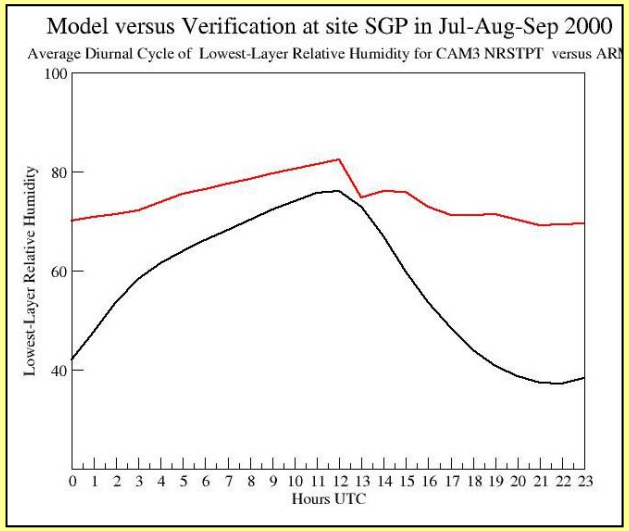
JAS-Avg Diurnal Cycle **AM2** vs. **Obs**



Daily Averages **CAM3** vs. **Obs**

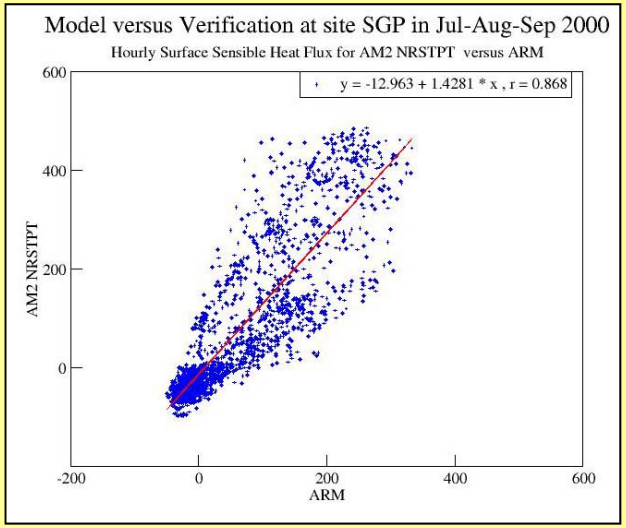


JAS-Avg Diurnal Cycle **CAM3** vs. **Obs**

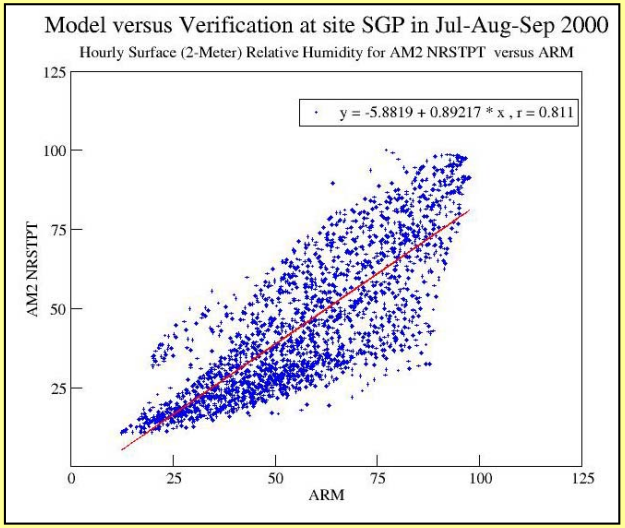


Model Errors Can Be Quantified: Examples at Hourly Time Scales

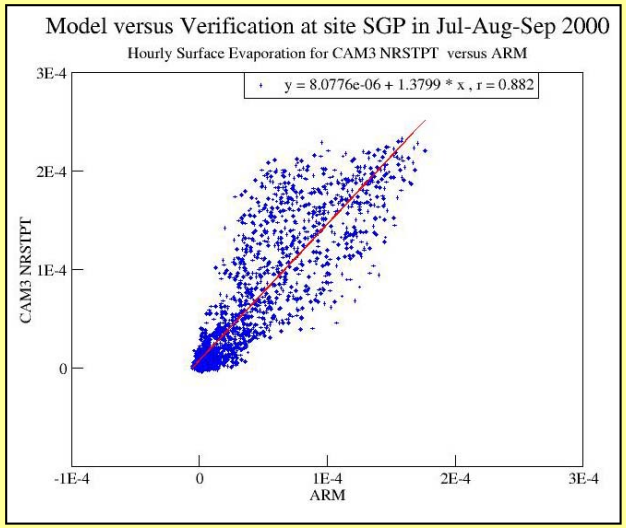
Hourly Sensible Ht Flux: **AM2** vs. **Obs**



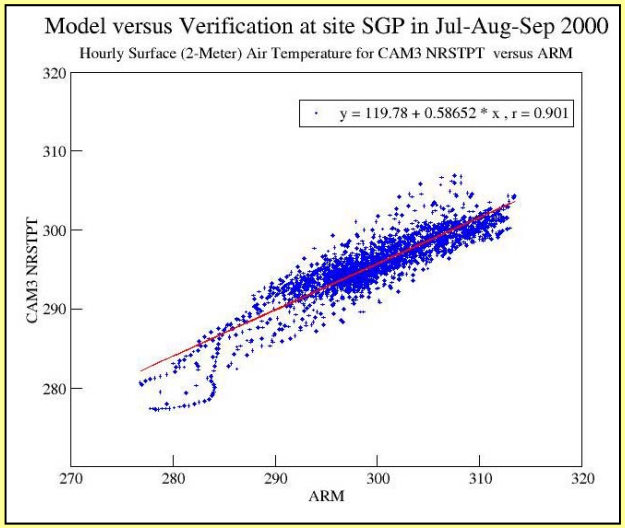
Hourly Rel Humidity: **AM2** vs. **Obs**



Hourly Evap Flux: **CAM3** vs. **Obs**



Hourly Sfc Temp: **CAM3** vs. **Obs**



Model Validation in JAS:

- Both AM2 and CAM3 show relatively good agreement with observed downward SW radiation (and other radiative fluxes)

- AM2 forecasts the timing of precipitation events fairly well, but with generally too low magnitudes → too dry soil, too low surface evaporation and humidity, too high surface sensible heating and temperature

- CAM3 forecasts nearly continuous precipitation, much in excess of observations → too wet soil, too high surface evaporation and humidity, too low surface sensible heating and temperature

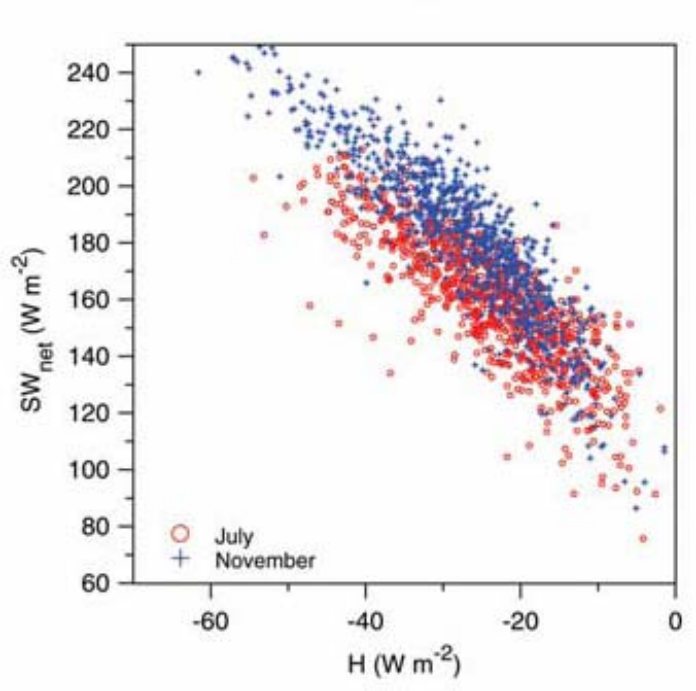
- These JAS systematic errors are probably consequences of deficient convective mechanisms in both models

Covariance relationships

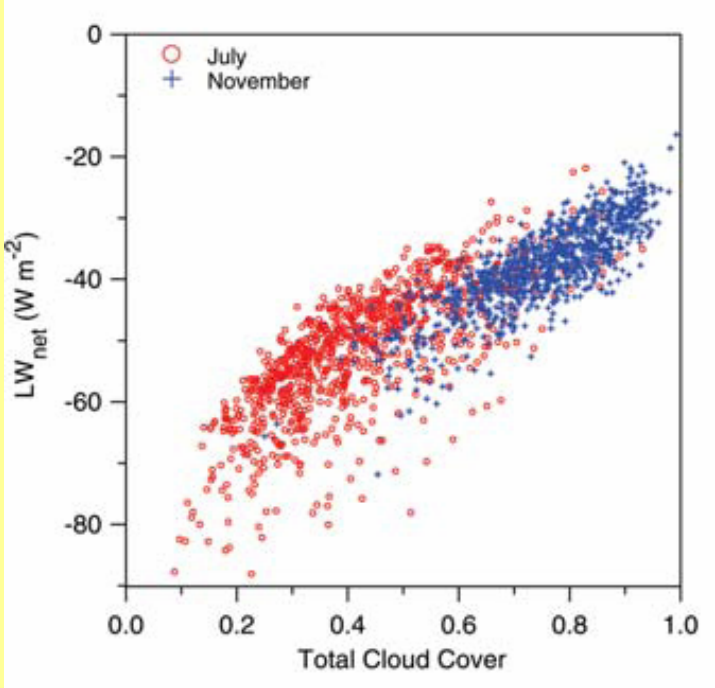
- Alan Betts' perspective (from analysis of field data & reanalyses) is that land-atmosphere processes are tightly coupled.
- Covariances of land-atmosphere variables provide insights into coupled processes/feedbacks

At an Amazonian site, July vs. November samples

Net SW vs. Sensible Htng



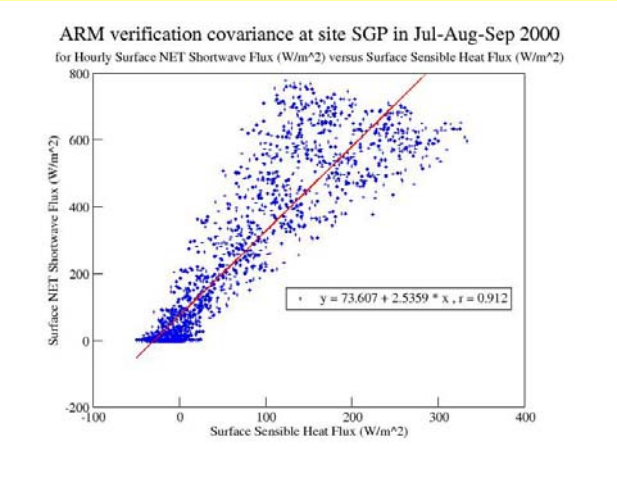
Net LW vs. Total Cloud



Covariances at ARM SGP in JAS:

- Find qualitatively similar relationships for ARM obs and models, e.g. CAM3:

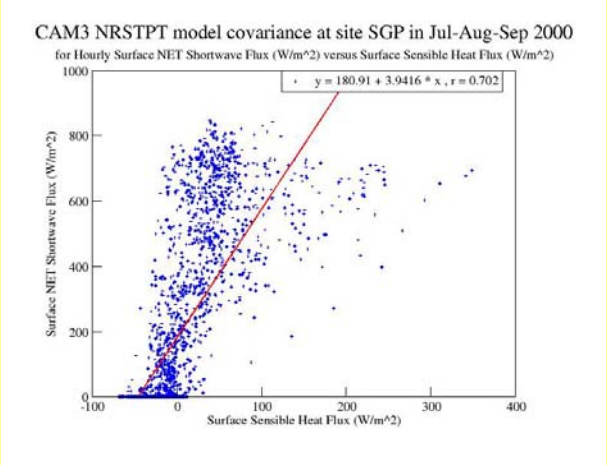
OBS: Sensible Htng vs. net SW



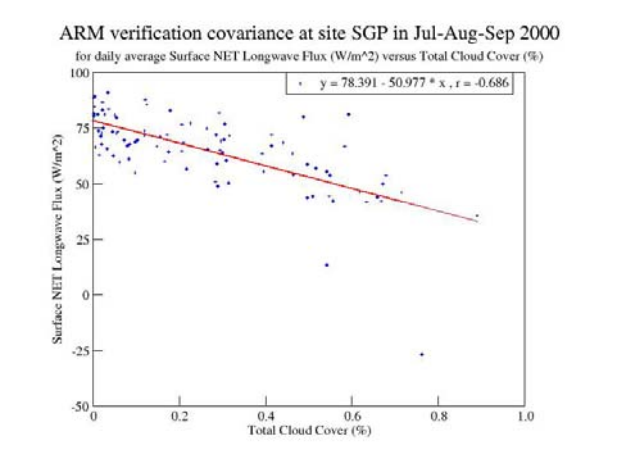
Hourly Samples

←→

CAM3: Sensible Htng vs. net SW



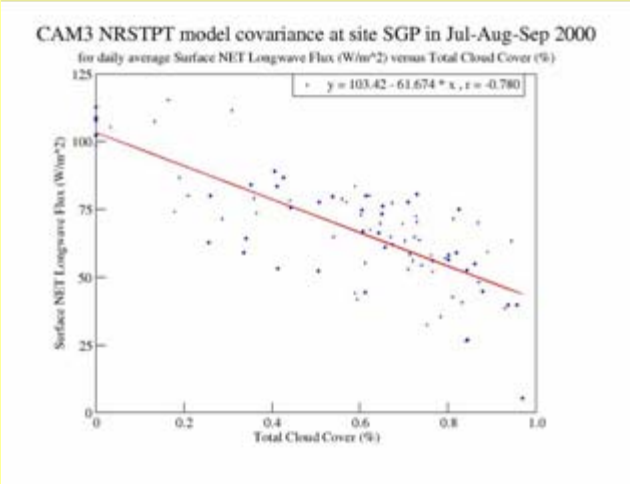
OBS: Net LW vs. Total Cloud



Daily Samples

←→

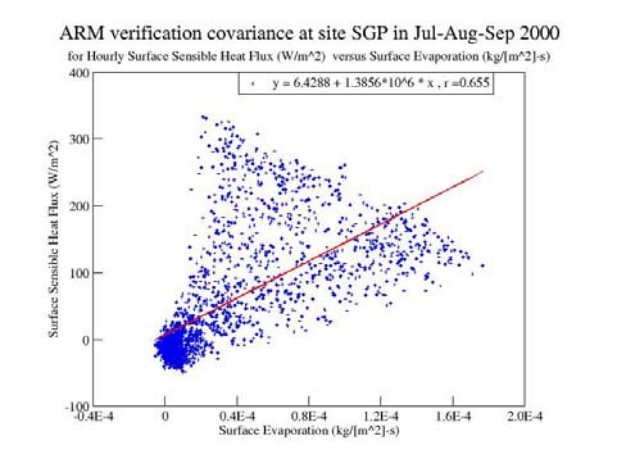
CAM3: Net LW vs. Total Cloud



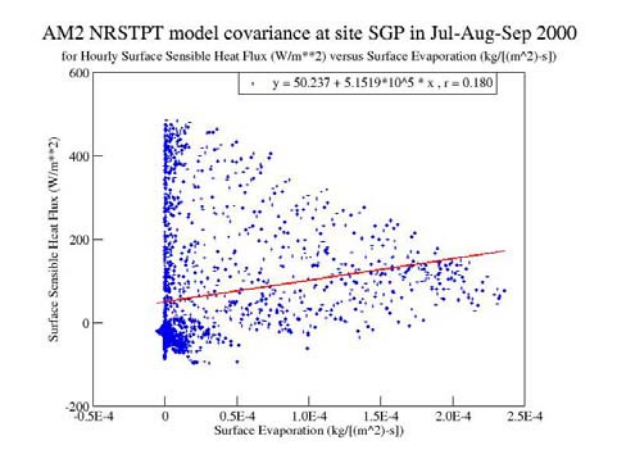
Covariance relationships at ARM SGP in JAS

- In general, covariances of *hourly* samples are found to obscure physically meaningful relationships that may exist among variables (Betts emphasizes covariances of daily or 5-day averages):

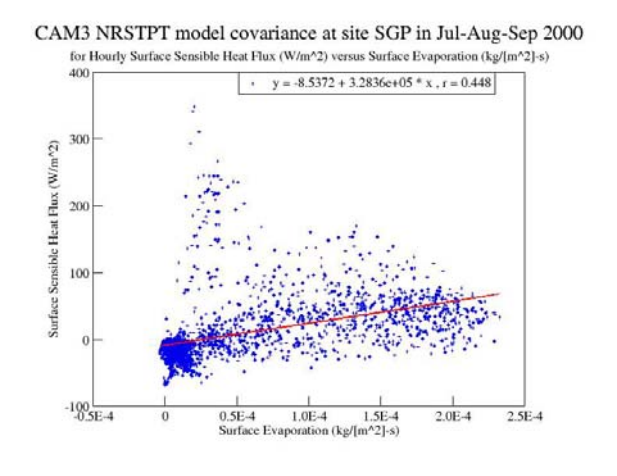
OBS



AM2



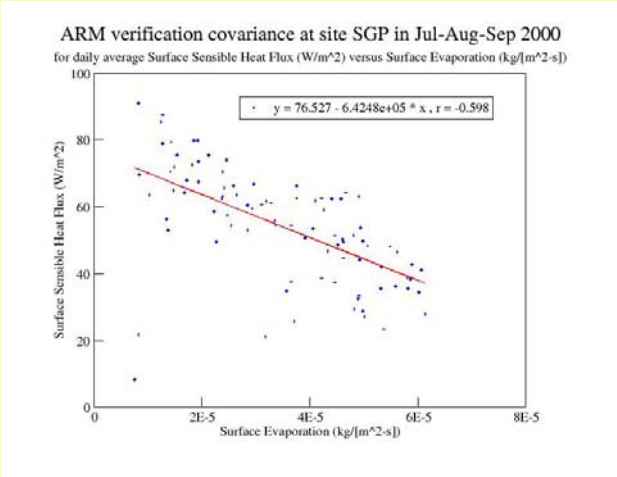
CAM3



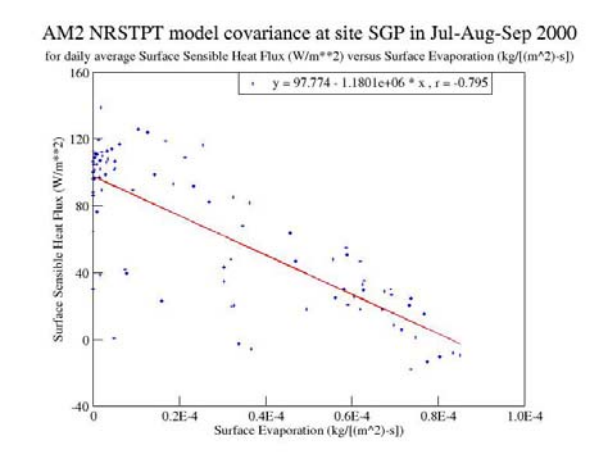
Covariance relationships at ARM SGP in JAS

- A covariance relationship that is robust across obs and models: *daily averages* of fluxes of sensible heat vs. evaporation*:*

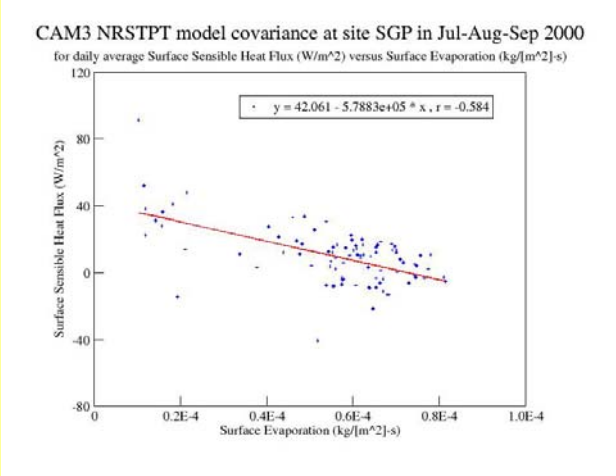
OBS



AM2



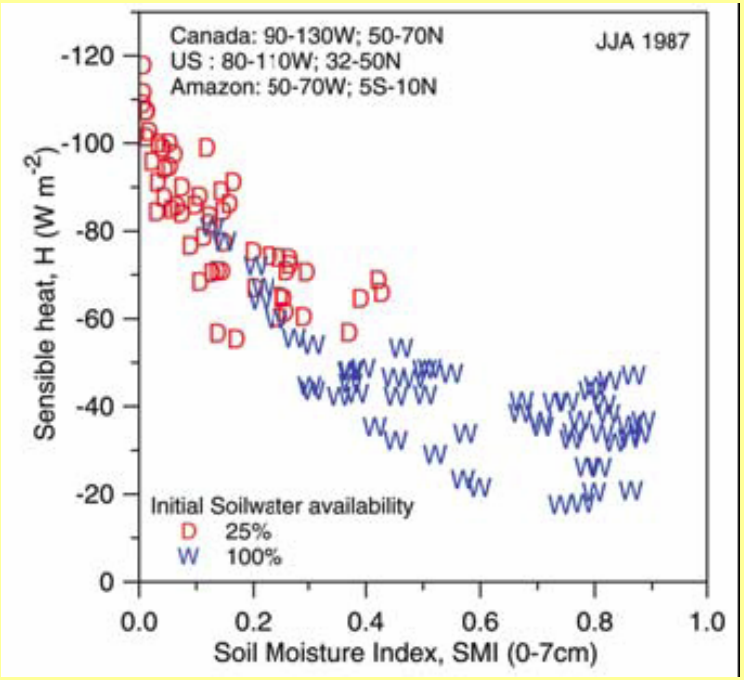
CAM3



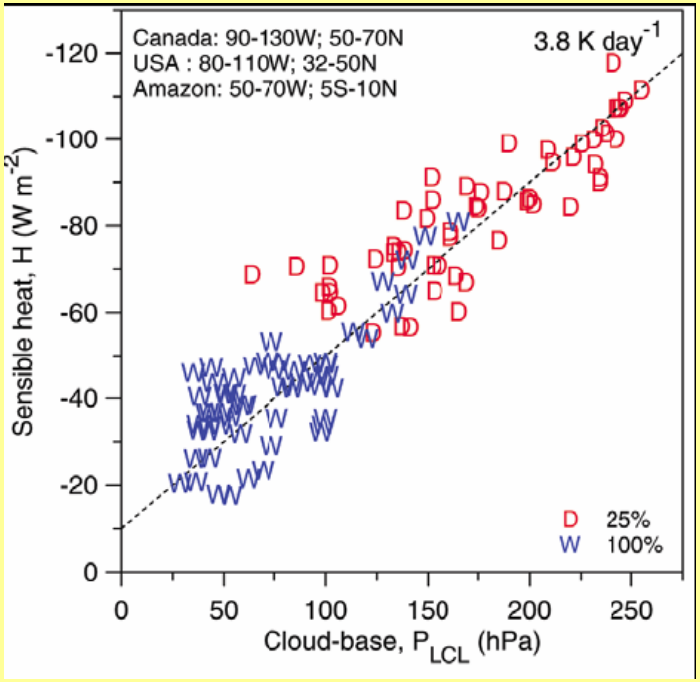
Covariance relationships: Land and ABL variables

- Betts emphasizes covariances among soil moisture, surface fluxes, and cloud base (LCL) as evidence of land-atmosphere coupling:

Sensible Heat Flux vs. Soil Moisture



Sensible Heat Flux vs. LCL Pressure



Future work plans

- Will acquire ARM soil moisture observations for additional model validation and covariance analysis

- Will investigate covariances between surface variables and boundary layer processes (e.g. between surface fluxes and LCL pressure level) to compare with Betts' results for other sites

- Will also stratify results for dry vs. wet conditions in observations and models