# Land-Atmosphere Coupling Manifested in Warm-Season Observations at the ARM Southern Great Plains Site

**Thomas Phillips**
**U.S. Department of Energy CAPT Project***
**Lawrence Livermore National Laboratory**

## Abstract

This study investigates some features of land-atmosphere coupling at the ARM SGP site during the May-August warm season, when such interactions tend to be strongest. Following the perspective of boundary-layer meteorologist Alan Betts, the land-atmosphere coupling should be manifest in the covariation of surface moisture/energy fluxes and related variables. The ARM Climate Modeling Best Estimate (CMBE) data sets presently provide the requisite surface observations at hourly sampling intervals for the years 1997-2008, thus allowing detailed investigation of the characteristics of the SGP land-atmosphere coupling. *Atmospheric models, when operating realistically, should exhibit similar covariance relationships.*

## Background

In a series of review papers (see **References** below), Alan Betts presents a physically based perspective on the interactions between warm-season land and lower-atmospheric processes, with supporting observational evidence from a number of different locales (but *not* the ARM SGP site) that exemplify various microclimates. Some of these coupled interactions are found to be quite coherent, e.g. as illustrated by scatter plots of atmospheric variable **A** vs land-surface variable **L.**

In elaborating his perspective, Betts makes use of several derived dimensionless quantities such as the following

- Effective shortwave (**SW)** cloud albedo **α** :

**α = 1 -- sfc dwnwrd SW / sfc dwnwrd *clear-sky* SW**

- Surface evaporative fraction **EF**:

**EF** = **LH** / (**LH** + **SH**)
where **LH** = sfc Latent Heat Flux
**SH** = sfc Sensible Heat Flux

Betts uses such dimensionless quantities to gauge the basic character of the land or atmospheric synoptic state at a given time, e.g. with respect to the availability of moisture sources.

## References

Betts, A.K., 2004: Understanding hydrometeorology using global models. *Bull. Amer. Meteor. Soc.*, **85**, 1673-1688.

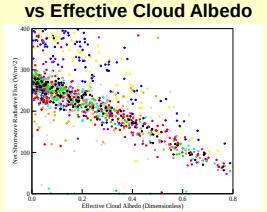
Betts, A.K., 2007: Coupling of water vapor convergence, clouds, precipitation, and land-surface processes. *J. Geophys. Res.*, **112**, **D10108**.

Betts, A.K., 2009: Land-surface-atmosphere coupling in observations and models. *J. Adv. Mod. Earth Systems*, **1**, **#4**, DOI: 10.3894/JAMES2009.1.4.

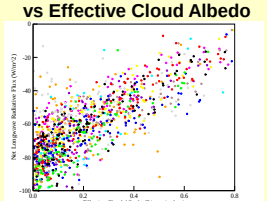
## Observational Examples

For observations during May to August of 1997-2008 at the SGP site, scatter plots illustrate the covariance of hourly or daily-average values of selected surface/atmospheric variables, or of their average diurnal cycles (color-coded, by year):

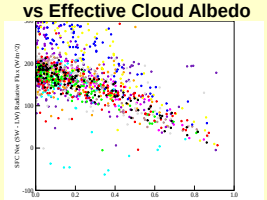
**Daily Avg sfc Net SW Flux vs Effective Cloud Albedo**



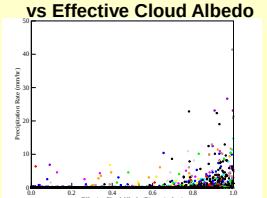
**Daily Avg Sfc Net LW Flux vs Effective Cloud Albedo**



**Daily Avg Sfc Net Total Radn vs Effective Cloud Albedo**

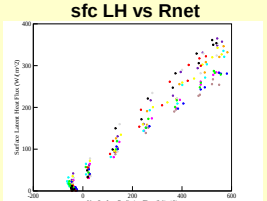


**Hourly Daytime Precipitation vs Effective Cloud Albedo**

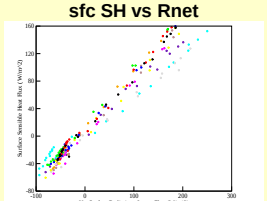


As expected, the net surface shortwave flux (**Swnet**) decreases with cloud albedo **α**, while the surface net longwave flux (**LWnet**) increases, owing to the added downward longwave emission from clouds. Like **Swnet,** the surface total net radiation **Rnet** (**SWnet – LWnet**) decreases with **α**, indicative of the dominance of the shortwave component **Swnet** in **Rnet**. The hourly rate of daytime precipitation increases sharply as **α** approaches its maximum value of 1, owing to increasing cloud cover and/or thickness.

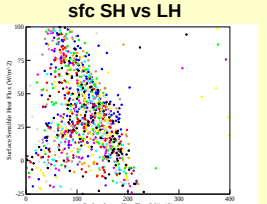
**Avg Diurnal Cycle of sfc LH vs Rnet**



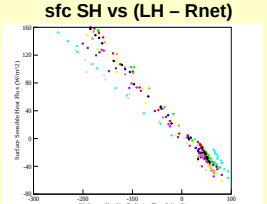
**Avg Diurnal Cycle of sfc SH vs Rnet**



**Daily Average sfc SH vs LH**

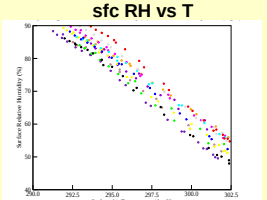


**Avg Diurnal Cycle of sfc SH vs (LH – Rnet)**

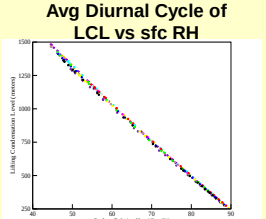


The average intra-diurnal magnitudes of surface **LH** and **SH** both increase with **Rnet**. However, daily average **SH** varies inversely with **LH** for a given daily average **Rnet** (assuming inconsequential ground heat storage **G**) , an inverse relationship that is more cleanly illustrated by the average diurnal cycle of **SH** vs **LH – Rnet**.

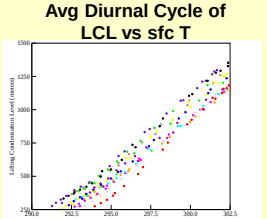
**Avg Diurnal Cycle of sfc RH vs T**



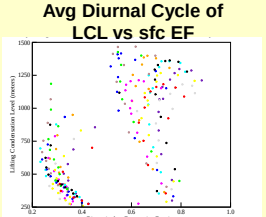
**Avg Diurnal Cycle of LCL vs sfc RH**



**Avg Diurnal Cycle of LCL vs sfc T**



**Avg Diurnal Cycle of LCL vs sfc EF**



On average, the diurnal cycles of surface relative humidity (**RH**)and temperature (**T**) vary inversely for a diurnal value of absolute humidity that remains roughly constant. The diurnal cycle of the lifting condensation level (**LCL**) which indicates the potential cloud base level varies directly with surface **T** but inversely with surface **RH**. The **LCL** also tends to decrease (weakly) with increasing evaporative fraction **EF**, but with distinctly different characteristics for nightime vs daytime conditions.

## Summary

For 1997-2008 warm-season observations at the ARM SGP site, scatter plots illustrate coupling relationships between selected land-surface and lower-atmosphere variables. In particular, coherent land-atmosphere interactions are observed,among low-level clouds and the surface radiative, sensible, and latent heat fluxes or related state variables. ..

*The Cloud-Associated Parameterization Testbed (CAPT) project operates under the auspices of the U.S. Department of Energy's Atmospheric System Research (ASR) Program, and conducts its work at Lawrence Livermore National Laboratory under general contract DE-AC52-07NA27344 .

LLNL-POST- 475240