Estimating SGP land-atmosphere coupling strength: Sensitivity to diverse soil-moisture measurements

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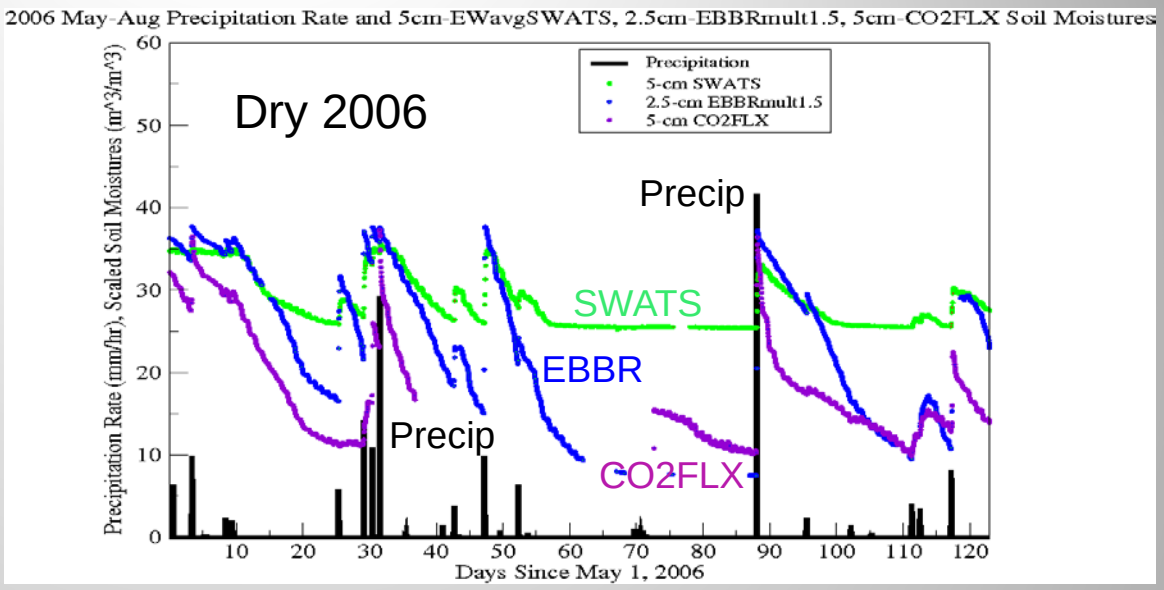
SGP Central Facility hourly soil moisture time series

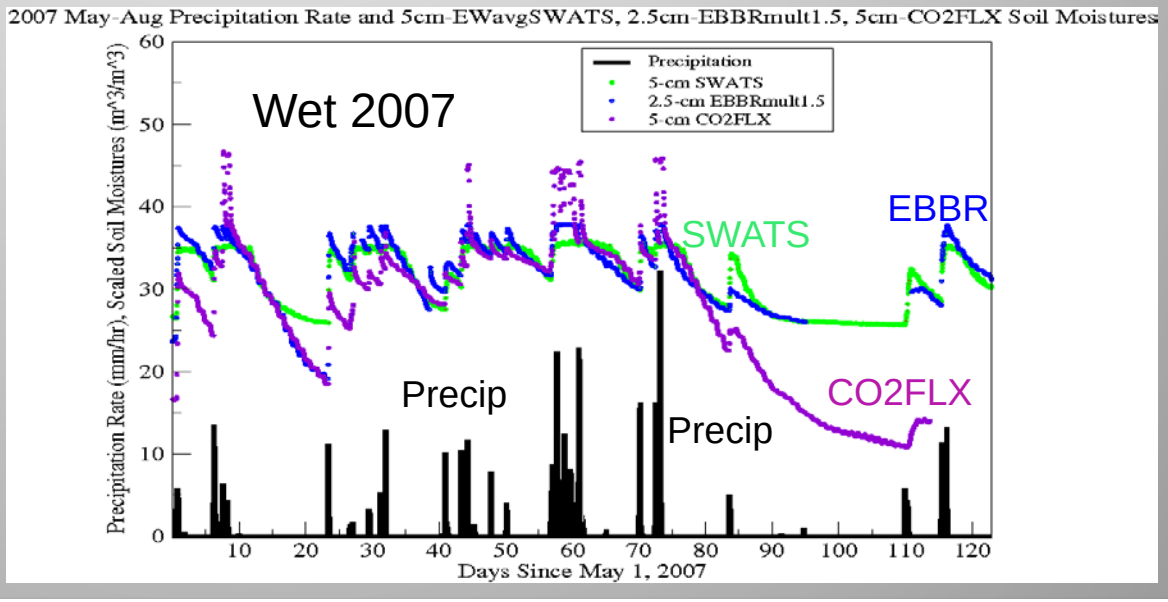
Example: Dry 2006 vs Wet 2007

Precipitation events (mm/hr),
SWATS, EBBR, CO2FLX (100 m^3/ m^3)

Due to sensor limitations, *reported* SWATS measurement are "truncated" at a lower bound of ~ 0.25 m^3/m^3 and an upper bound of ~ 0.35 m^3/m^3 .

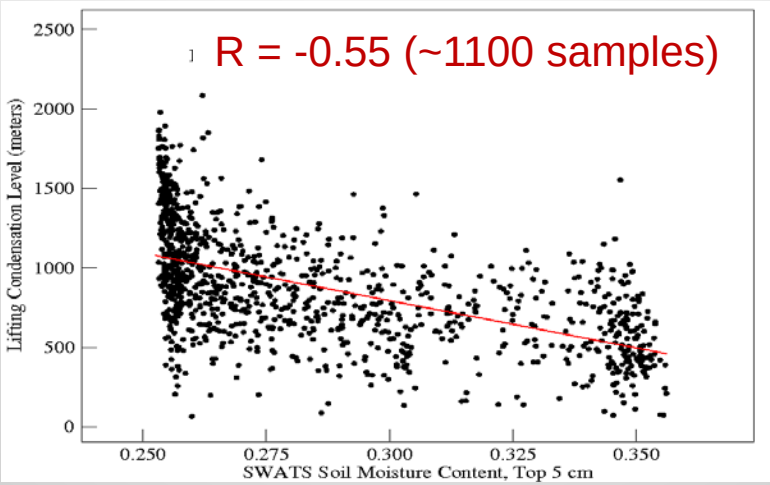
EBBR and CO2FLX display a fuller range of moisture values than SWATS; however, there are many more missing data points .



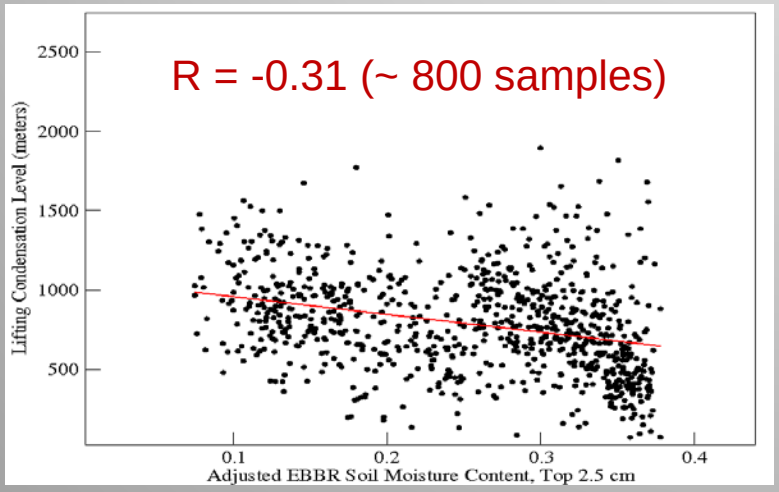


Soil Moisture-LCL correlations: 3 cases

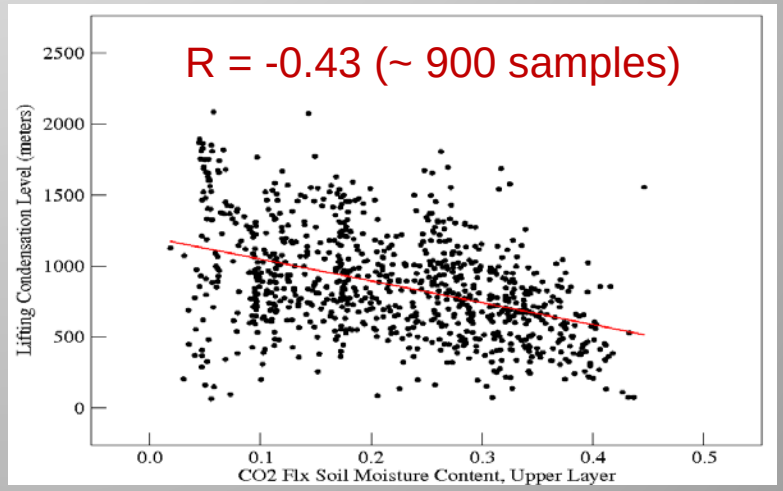
LCL vs 5-cm SWATS



LCL vs 2.5-cm EBBR



LCL vs 5-cm CO2FLX



Statistically significant (p = 0.05) correlations R

Surface Evaporative Fraction (EF) =
Latent Heat Flux/(Latent + Sensible Heat Fluxes)

Data Set	LCL	RH_s	T_s	EF
SWATS	-0.55	0.55	-0.36	0.50
EBBR	-0.31	0.30	-0.18	0.34
CO2FLX	-0.43	0.42	-0.32	0.39

For each variable:
Maximum |R|
Minimum |R|

The land-atmosphere coupling strength (R value) of each atmospheric variable ranges fairly widely, depending on which soil moisture data set is chosen. The largest absolute correlations |R| are associated with SWATS soil moisture, and the smallest with EBBR.

Reduced sampling of SWATS data

Data Set	LCL	RH_s	T_s	EF
$SWATS_{red}$	-0.47, -0.55	0.47, 0.54	-0.22, -0.38	0.42, 0.52
EBBR	-0.31	0.30	-0.18	0.34
CO2FLX	-0.43	0.42	-0.32	0.39

For each variable:
Maximum |R|
Minimum |R|

The largest absolute correlations |R| are still mostly associated with the SWATS data

Other sub-sampling schemes for EBBR and CO2FLX data also were tried:

- Include data sample only when W > 0.25 m^3/m^3 (match SWATS lower bound)
- Include data sample only when W < ~ 0.35 m^3/m^3 (avoid cases of saturated soil)

Neither scheme substantially or consistently "boosted" the EBBR and CO2FLX correlations

Summary

- Given current technologies, it is challenging to measure SGP soil moisture *accurately and consistently over its entire observed range*

- Estimates of SGP land-atmosphere coupling strength appear to be sensitive to the different choices of soil moisture data sets that are available

- The SWATS soil moisture yields the highest estimates of L-A coupling strength, but this *may* result from biases introduced by the “truncation” of the reported data under conditions of either very dry or very wet soils

Thanks—Comments Welcome!

Background

- The atmosphere exerts a lot of influence on the land surface, but the land can also feed back significantly on atmospheric surface and BL variables
- This land-atmosphere coupling (generally strongest in summer) is usually *modulated by soil moisture*
- *One way* to estimate aspects of the L-A coupling strength is to calculate the magnitude of the correlations between soil moisture and atmospheric variables

Available soil moisture data sets at SGP CF

- At the SGP Central Facility, 3 observational soil moisture data sets are available for comparison *at shallow depths* in the years 2003-2011:

> Soil Water and Temperature System (SWATS) soil moisture at 5-cm depth
inferred from soil-water potential, estimated from sensor $\Delta T/\Delta t$ heating pulse

> Energy Balance Bowen Ratio (EBBR) soil moisture at 2.5-cm depth
inferred from electrical 'resistance-type' sensor probes

> Carbon Flux (CO2FLX) soil moisture at 5-cm depth
inferred from dielectric constant of soil, estimated by sensor probes

One method for estimating L-A coupling strength

For the 2003-2011 May-August warm seasons at the SGP Central Facility:

- For *each soil moisture dataset*: Construct *daily averages* of soil moisture *W* from the hourly samples
- Construct *daily averages* of an ARM Best Estimate (ARMBE) atmospheric variable A (also sampled hourly)
- Plot the scatter of A vs W over the 2003-2011 warm seasons
- As a measure of their coupling strength, compute the correlation coefficient **R** over all warm-season days **d**

$$\mathbf{R} = \sum_d (A'W')/(\sigma_A \sigma_W)$$

where A' and W' are daily departures from the climatologies of A & W, and σ_A & σ_W are their standard deviations

Example: Correlation of LCL with SWATS soil moisture

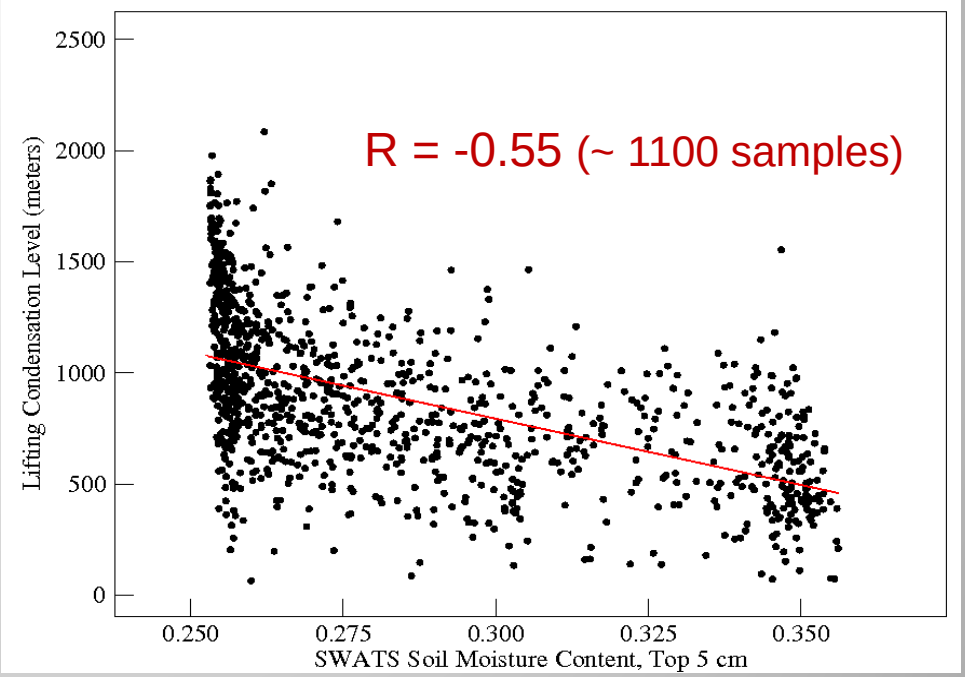
$LCL \sim (20 + T_s)*(100 - RH_s)$

T_s = *surface* temp. (deg C)

RH_s = *surface* rel. humidity (%)

Because increasing soil moisture is associated with a cooler and moister PBL (decreased T_{sfc} and increased RH_{sfc}), the LCL *decreases* as soil moisture *increases*.

LCL versus 5-cm SWATS soil moisture



Sampling issues

Might differences in estimated soil-moisture coupling strength be explained by fewer EBBR or CO2FLX samples compared to SWATS?

Test this, as follows:

- remove samples from the SWATS dataset wherever they are missing from *either* the EBBR *or* the CO2FLX time series, then
- re-compute the R measures of coupling strength for the reduced SWATS data in years 2003-2011.
- compare R values for reduced SWATS data with those from EBBR and CO2FLX