Investigation of Southern Great Plains Atmospheric Moisture Budget for CLASIC

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ARM Science Team Meeting
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CLASIC

CLOUD AND LAND SURFACE INTERACTION CAMPAIGN

Southern Great Plains Site

ARM Climate Research Facility (ACRF)

June 9-30

2007

CLASIC Science Questions

(1) What are the roles of cumulus convection and spatial variations in land cover in depleting low-level water vapor as it is advected into the SGP region?

(2) What are the relationships between cumulus clouds and the soil-plant-atmosphere exchange of heat, carbon, and water at the site?

(3) How do land cover changes, such as agricultural harvesting, impact surface heat, carbon, and water fluxes, and can those changes affect local and regional cumulus cloud formation at the ACRF SGP site?

(4) How do land surface processes at the SGP affect atmospheric aerosol loading and chemistry and what are the resulting effects on the microphysical and macrophysical properties of cumulus cloud fields?

(5) How well do the long-term (15+ years) surface flux measurements made at specific locations within the ACRF SGP represent the actual distribution of the fluxes across the domain?

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HORIZONTAL MOISTURE ADVECTION versus VERTICAL MOISTURE FLUX
for
CUMULUS CONVECTION

CLASIC OBSERVATIONAL PLATFORMS

ROUTINE AND ENHANCED ACRF SGP MEASUREMENTS

Central Facility, Extended Facilities (23)

AIRPLANES (9)

Measurements made below, within, and above clouds

- ER-2 (DOE) -- cloud and surface properties from 65,000-70,000 feet
- Gulfstream-1 (DOE) -- aerosol measurements for CHAPS Experiment
- King Air B200 (NASA) -- aerosol measurements for CHAPS Experiment
- P-3 (NASA) -- soil moisture monitoring
- Jetstream-31 (NASA) -- solar radiation measurements within clouds
- Twin Otter (CIRPAS, DOE) -- aerosol, carbon cycle, and cloud measurements
- Twin Otter (International, NASA) -- soil moisture monitoring
- Cessna 206 (DOE) -- aerosol measurements
- Bell 206 Helicopter (Duke University, NASA) -- boundary layer fluxes (heat, moisture, carbon)

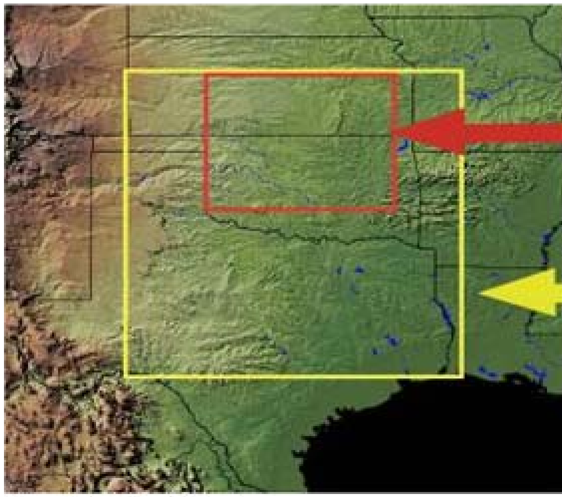
SURFACE SUPER SITES (3)

ACRF SGP Central Facility, Little Washita Watershed (USDA), Okmulgee (forest)
Heavily instrumented (flux towers) to link heat, moisture, and carbon fluxes to atmospheric structure

SATELLITE OVERPASSES

Airplane flights were timed to coincide with routine “A Train” satellite overpasses on selected days -- e.g., Terra, Calipso, Cloudsat, Aqua satellites -- with “stacking” of 3-5 airplanes under satellite on several days

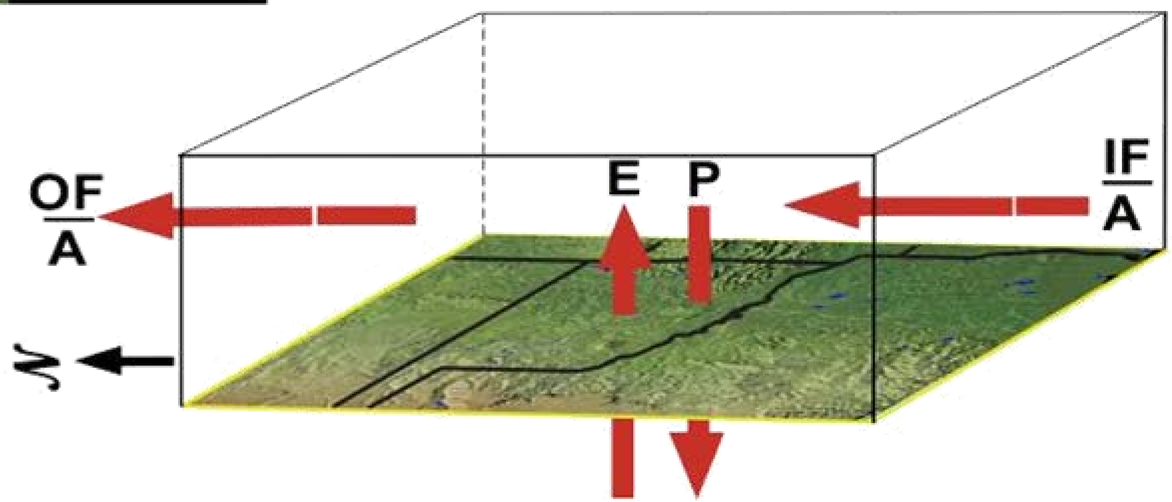
SOUTHERN GREAT PLAINS STUDY DOMAINS



CLASIC Field Campaign [ACRF SGP]

Study Area (0.83 x 10^6 km^2) [MOISTURE BUDGET]

"Tank Model"



ATMOSPHERIC MOISTURE BUDGET EQUATIONS

$$\frac{1}{g}\frac{\partial}{\partial t}\int_S^T q\,dp + \frac{1}{g}\int_S^T \mathbf{V}\cdot\nabla q\,dp + \frac{1}{g}\int_S^T q\nabla\cdot\mathbf{V}\,dp = E - P \qquad (1)$$

dPW ***HA*** ***HD***

$$HA + HD = \frac{1}{g}\int_S^T \nabla\cdot q\mathbf{V}\,dp = \frac{1}{Ag}\int_S^T \oint qV_n dl\;dp = \frac{OF}{A} - \frac{IF}{A} \qquad (2)$$

MFD ***MFD***

$$E - P = MFD + dPW$$

Conventional Form of Budget Equation (3)

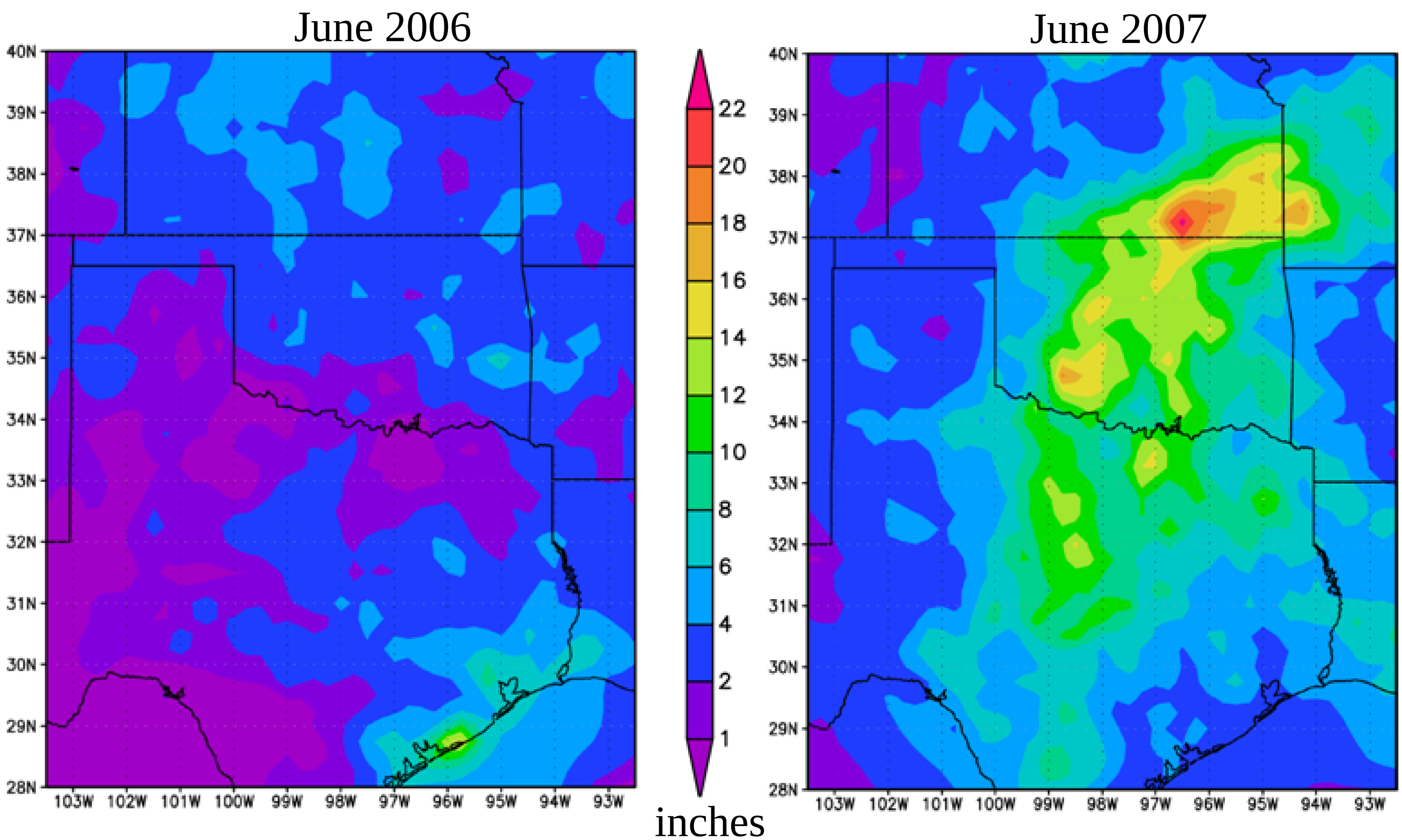
$$E - P = \frac{OF}{A} - \frac{IF}{A} + dPW$$

Bulk or Boundary Form of Budget Equation (4)

$$\frac{P_E}{P} = \frac{E}{E + \frac{IF}{A}}$$

Tank Model Recycling Ratio (5)

EXTREME WETNESS DURING CLASIC



DRY PRECEDING JUNE

OK $\overline{P}$ = 2.36" (−1.90")

May 2006: OK $\overline{P}$ = 3.03" (-2.18")

WET CLASIC MONTH

OK $\overline{P}$ = 9.10" (+4.84")

May 2007: OK $\overline{P}$ = 6.65" (+1.44")

MONTHLY ATMOSPHERIC MOISTURE BUDGET
MAY-JUNE 2006 (Very Dry) versus 2007 (Very Wet)

	E	– P	= HA	+ HD	+ dPW	MFD	P_E /P
June 2007	+4.93	+6.24	-2.16	+0.40	+0.45	-1.76	0.19
June 2006	+2.79	+2.21	-3.28	+4.23	-0.37	+0.95	0.22
May 2007	+3.39	+5.23	-1.15	-0.47	-0.22	-1.62	0.19
May 2006	+3.30	+2.52	-1.32	+1.37	+0.73	+0.05	0.15
May-June 2007	+4.16	+5.75	-1.66	-0.04	+0.11	-1.70	0.19
May-June 2006	+3.05	+2.37	-2.30	+2.80	+0.18	+0.50	0.19
	←		(mm d^{-1})		→	(mm d^{-1})	

Convergent HA strongly drove convergent MFD in wet 2007

Even more convergent HA offset strongly divergent HD in dry 2006

E much larger (but P_E /P smaller) in wet June 2007 than dry June 2006

P_E /P was consistent and only 0.19 for wet May-June 2007 (and dry 2006)

MOISTURE BUDGET CORRELATIONS -- MAY-JUNE 2006-2007

MONTHLY (4)/DAILY (122)

	P	E	HA	HD	MFD	dPW	IF/A	P_E /P
P		+0.84	+0.34	-0.78	-0.96*	+0.09	+0.71	-0.01
E	+0.23		+0.17	-0.57	-0.76	+0.50	+0.77	-0.16
HA	+0.21	+0.19		-0.85	-0.58	+0.46	+0.75	-0.82
HD	-0.80	-0.09	-0.52		+0.92	-0.34	-0.89	+0.54
MFD	-0.68	+0.08	+0.36	+0.61		-0.19	-0.82	+0.23
dPW	-0.09	+0.10	-0.66	+0.01	-0.60		+0.71	-0.83
IF/A	+0.31	+0.15	+0.01	-0.38	-0.41	+0.30		-0.70
P_E /P	-0.14	+0.50	+0.16	+0.21	+0.38	-0.14	-0.62	

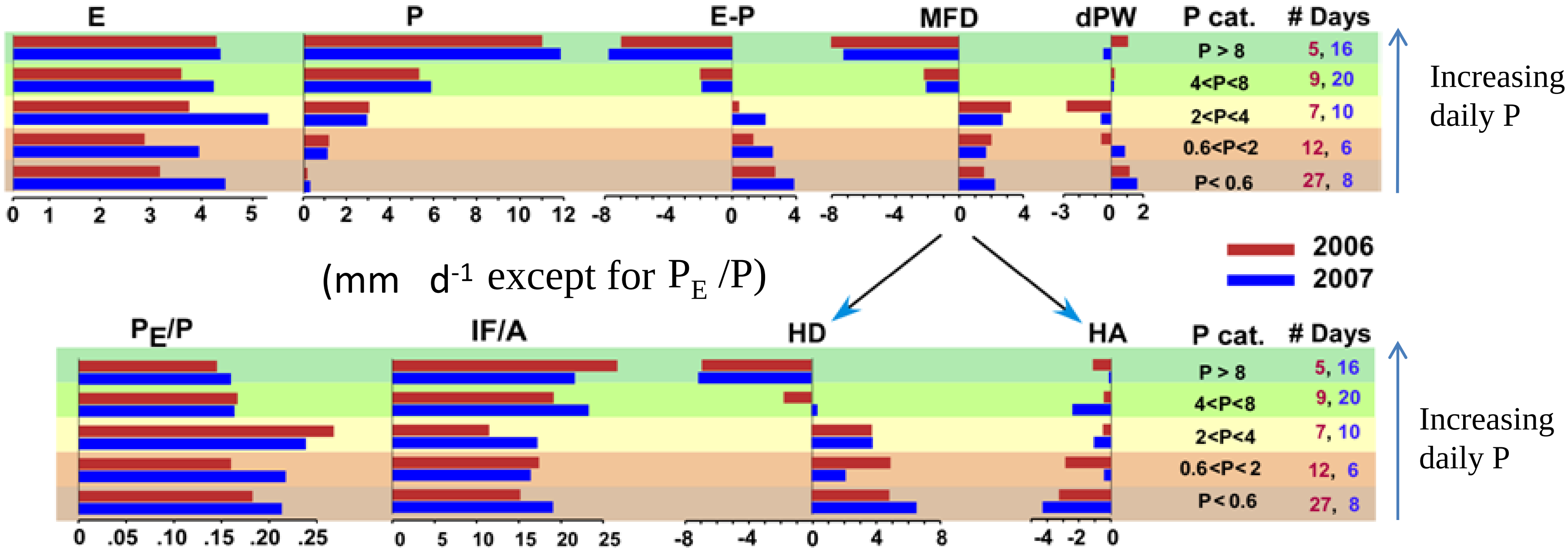
P strongly/moderately related (-ve) to HD and MFD (monthly, daily)

P weakly related (+ve) to HA (monthly, daily)

P not related to P_E /P (monthly), weakly related (-ve) to P_E /P (daily)

(for daily, 95%/99% confidence threshold is 0.15/0.12)

DAILY ATMOSPHERIC MOISTURE BUDGET
MAY-JUNE 2006 (Very Dry) versus 2007 (Very Wet)



Strong contrast between dry 2006/wet 2007 for numbers of days in least/most wet P categories

General consistency between dry 2006 and wet 2007 for same daily P category

P_E /P tends to decrease with increasing daily P except for 2 < P < 4mm

E considerably higher in wet 2007 for daily P < 8 mm and P_E /P higher in wet 2007 for daily P < 4 mm

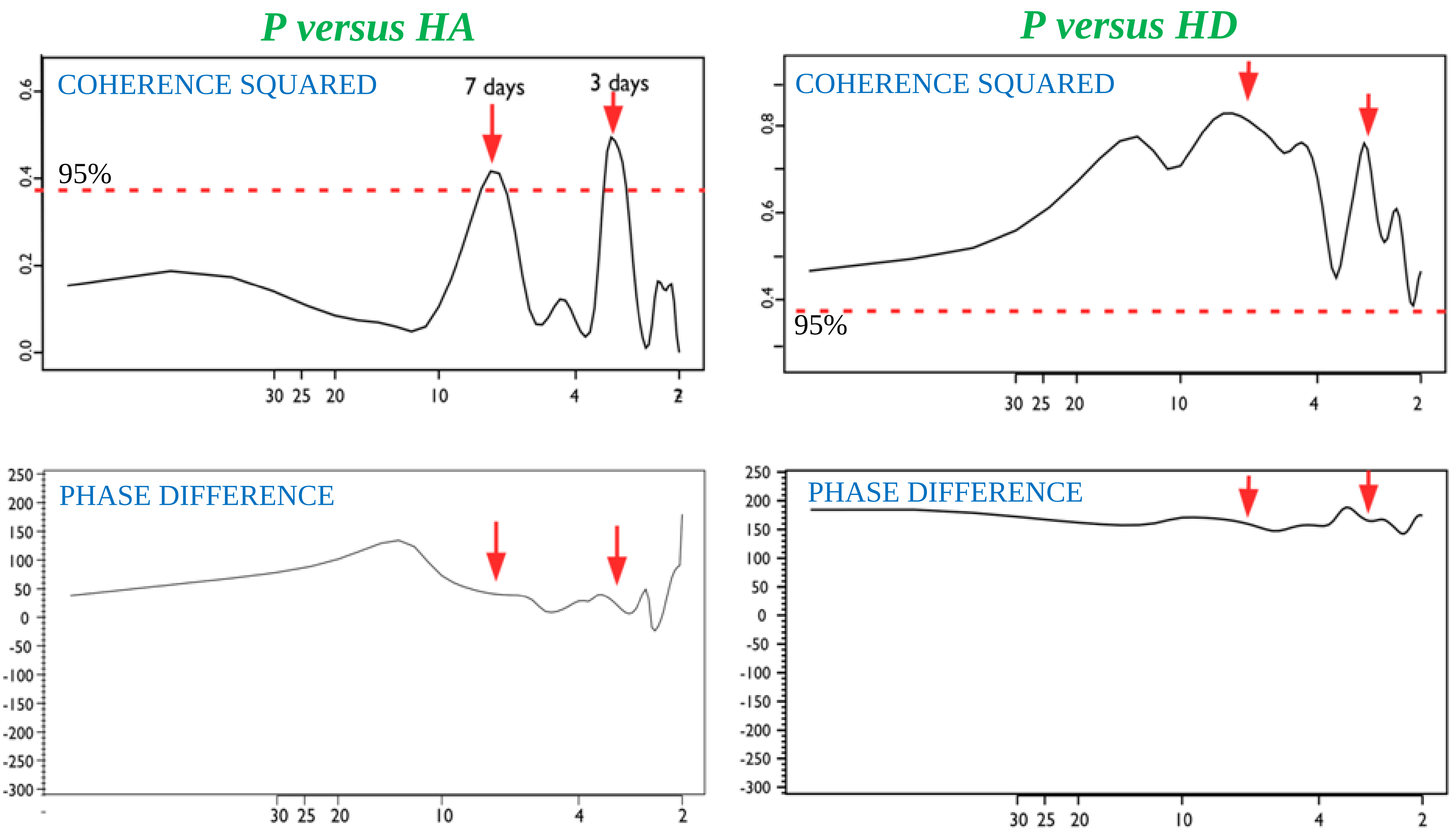
HA (not HD) is convergent contributor to MFD for daily P < 4 mm and (wet 2007) 4 < P < 8 mm (CLASIC!)

dPW depletion is important moisture source in dry 2006 for daily 2 < P < 4

HD is dominant convergent contributor to MFD for daily P > 8mm

IF/A generally substantially greater in wet 2007 for daily P < 8 mm

MOISTURE BUDGET CROSS-SPECTRAL ANALYSIS MAY-JUNE 2006-2007

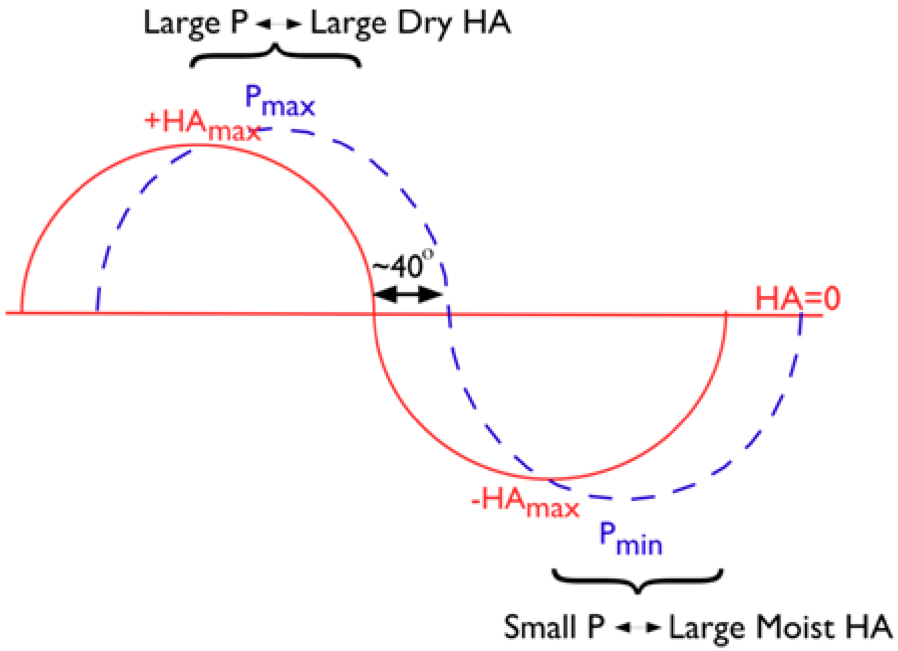


Covariance has pronounced 3- and 7- day periodicities

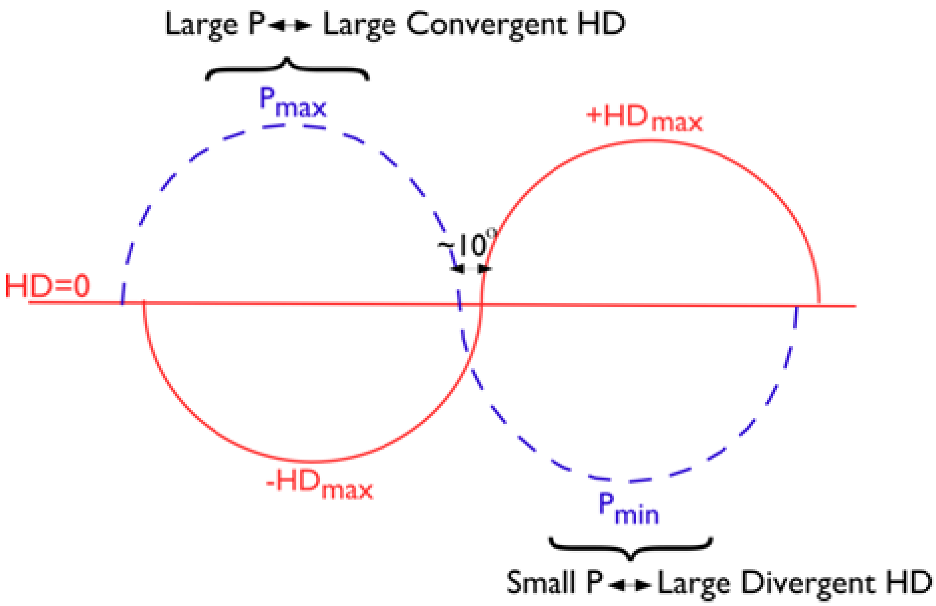
MOISTURE BUDGET CROSS-SPECTRAL WAVE MODEL MAY-JUNE 2006-2007

3- and 7-day cross-spectral peaks

P versus HA



P versus HD



Strongly convergent HA follows P minimum (and initiates moisture build-up for P maximum?)

Strongly convergent HD slightly precedes P maximum

CONCLUDING REMARKS

Original focus of CLASIC -- relative influences of land surface processes and horizontal moisture advection for evolution of cumulus convection from cumulus humilis (fair weather) to cumulus congestus (stormy).

Record breaking rainfall during CLASIC produced generally uniformly saturated land surface (one extreme).

Large-scale atmospheric moisture budget analyses document environment that supports cloud development.

Comparison of budget results for very wet CLASIC period with counterparts for very dry 2006 (other extreme) reveal fundamental commonalities.

Further comparative analyses are being performed for seasons of intermediate wetness (2002) and upstream dryness in Texas (1998).

Challenge for model simulation and prediction is to treat and interrelate moisture budget components on daily-to-interannual time-scales -- being investigated for CLASIC (2007) using WRF Model in collaboration with Larry Berg (PNNL).