Estimation of a Non-Flux Component of Moisture Flux Divergence and its Relation to CLASIC Rainfall and Clouds

Diane H. Portis[1], Peter J. Lamb[1,2], Abraham Zangvil[3]

[1]Cooperative Institute for Mesoscale Meteorological Studies, [2]School of Meteorology, The University of Oklahoma,
[3]Blaustein Institute for Desert Research, Ben Gurion University of the Negev, Israel

ARM CLIMATE RESEARCH FACILITY

CLASIC Campaign

The Cloud Land And Surface Interaction Campaign was conducted over the Southern Great Plains (SGP) ARM Climate Reasearch Facility in June 2007. A primary goal of CLASIC is to understand the interactive roles of horizontal moisture advection and land surface processes in the evolution of cumulus convection.

Study Overview

Our ongoing study is providing the larger-scale (Oklahoma-Texas; 0.83 x 106 km2) atmospheric moisture budget background for the interpretation of results derived from the CLASIC observational platforms. Extremely wet conditions prevailed during CLASIC, when Oklahoma experienced its wettest June since recording began in 1895. Three other contrasting May-June periods were chosen for analysis: 2006 (very dry), 2002 (intermediate wetness), and 1998 (very dry especially upstream in Texas). By Green's Theorem, in the 2D case, the moisture flux divergence term in the budget (MFD = horizontal advection HA + horizontal divergence HD) is equal to the net flux around the region's boundaries. For the 1D case shown below, both HA and HD have identical boundary flux terms with the same sign and identical non-flux terms with opposite signs. The flux terms are proportional to the net flux around the region's boundary, whereas the non-flux terms are equal to HA – HD. This interesting finding encouraged us to examine these non-flux terms over our SGP study region, including its association with cloud cover and factors related to its magnitude. Except for precipitation, we used the North American Regional Reanalysis (NARR) data for our SGP calculations.

Non-Flux Component of the Moisture Flux Divergence

The one dimensional case *

Consider the Water Vapor Budget Equation (WVBE):
E-P = MFD + dPW = HA +HD +dPW
where E is Evapotranspiration, P is Precipitation, MFD is Moisture Flux Divergence with its components HA (horizontal moisture advection) and HD (horizontal velocity divergence in the presence of moisture), dPW is the change in atmospheric moisture storage.

In one dimension:

$$\mathrm{MFD} = \nabla \cdot qu = u \cdot \nabla q + q\, \nabla \cdot u = \mathrm{HA} + \mathrm{HD} \qquad (1)$$

where
u is the zonal wind
q is the specific humidity.

In finite difference form:

$$\mathrm{HA} = 0.5K\,(u_2q_2 - u_2q_1 + u_1q_2 - u_1q_1) \qquad (2)$$

$$\mathrm{HD} = 0.5K\,(u_2q_2 + u_2q_1 - u_1q_2 - u_1q_1) \qquad (3)$$

where
K is a constant depending on dx – the distance between two adjacent points on the x axis
(u_1q_1, u_2q_2) are the flux terms and represent the inflow and outflow
(u_2q_1, u_1q_2) are the non-flux terms

When HA and HD are added, the non-flux terms cancel out, yielding:

$$\mathrm{HA} + \mathrm{HD} = 0.5K\,(u_2q_2 - u_2q_1 + u_1q_2 - u_1q_1) + 0.5K\,(u_2q_2 + u_2q_1 - u_1q_2 - u_1q_1)$$

$\Rightarrow$ $\mathrm{MFD} = \mathrm{HA} + \mathrm{HD} = K\,(u_2q_2 - u_1q_1)$ = Outflow - Inflow ***Basic term of the WVBE***

When HD is subtracted from HA, the flux terms cancel out, yielding:

$$\mathrm{HA} - \mathrm{HD} = 0.5K\,(u_2q_2 - u_2q_1 + u_1q_2 - u_1q_1) - 0.5K\,(u_2q_2 + u_2q_1 - u_1q_2 - u_1q_1)$$

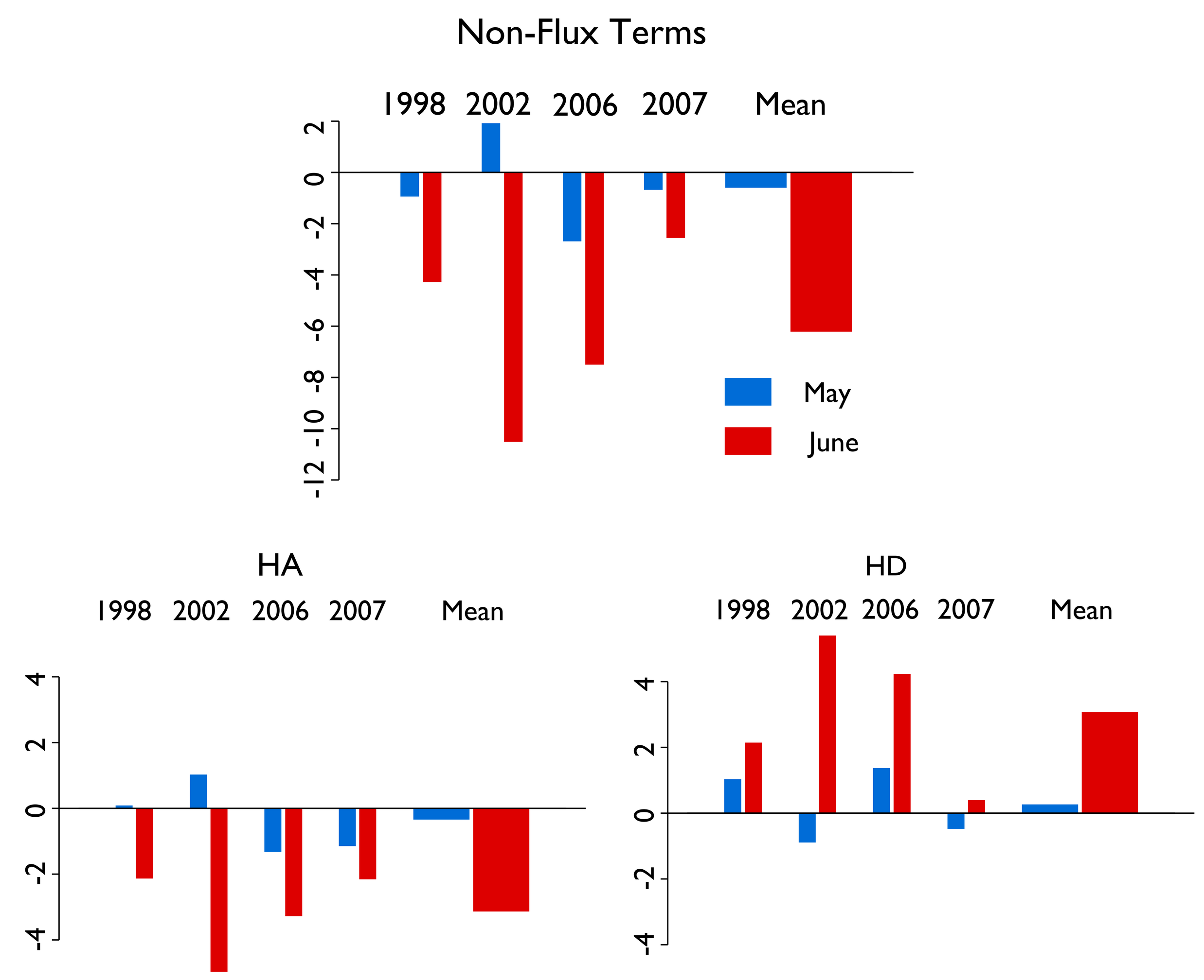
$$\Rightarrow \mathrm{HA} - \mathrm{HD} = K\,(-u_2q_1 + u_1q_2)$$

Thus, the expression HA - HD is a measure of the size of the non-flux components or non linearity in HA and in HD.

* Contributed by Abraham Zangvil

Size of the Non-Flux Terms

May vs June



The significant size of the non-flux terms over the SGP in June is due to the strength of horizontal moisture advection and horizontal divergence. The opposition of these budget terms increases the size of the non-flux terms. Their strength in June is associated with 1) the location of the subtropical high; 2) a drier land surface after the harvesting of the winter wheat crop.

For CLASIC, the size of the non-flux term is small. The horizontal divergence term is weak due to anomalous convergence over the region.

Dominance of Moist Advection (-HA) with Horizontal Divergence (+HD) in the Daily June Moisture Budget

	# of Cases
Moist advection (-HA); Horizontal Divergence (+HD)	77
Dry advection (+HA); Horizontal Convergence (-HD)	15
Moist Advection (-HA); Horizontal Convergence (-HD)	15
Dry Advection (+HA); Horizontal Divergence (+HD)	13

Mean Budget when HA/HD have Opposite Signs

	HA	HD	Non-Flux	E	P	MFD	dPW
-HA/+HD	-5.97	6.25	-12.22	3.30	1.79	0.28	1.23
+HA/-HD	6.43	-7.05	13.48	4.07	7.85	0.62	-3.15

Mean Budget when HA/HD have Same Signs

	HA	HD	Non-Flux	E	P	MFD	dPW
-HA/-HD	-3.03	-3.60	0.57	3.45	7.23	-6.63	2.85
+HA/+HD	2.51	3.64	-1.13	3.62	1.83	6.16	-4.37

Opposite Sign:

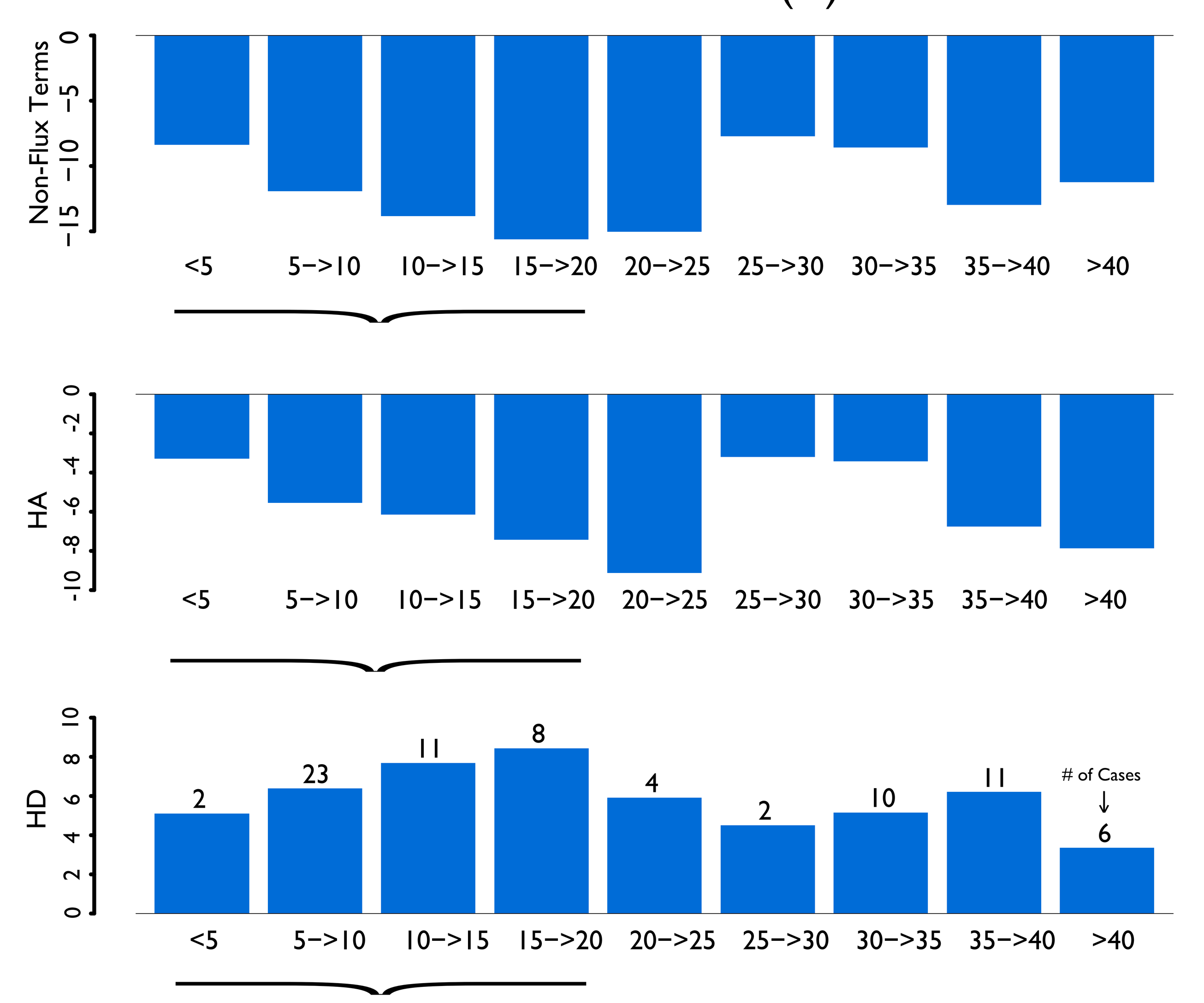
$\Rightarrow$-HA/+HD: surplus of E over P is balanced by an increase in storage; net boundary flux is minimal; large negative non-flux component.
$\Rightarrow$ +HA/-HD: large deficit of E over P is balanced by a large depletion in storage; net boundary flux is minimal; large positive non-flux component

Same Sign:

$\Rightarrow$-HA/-HD: large deficit of E over P is balanced by large net inflow boundary flux (which also increases the storage); minimal non-flux component.
$\Rightarrow$+HA/+HD: surplus of E over P is balanced by large net outlfow boundary flux (which also decreases the storage); minimal non-flux component.

Association of Non-Flux Terms with Cloud Cover for June cases with -HA, +HD

Total Cloud Cover (%)

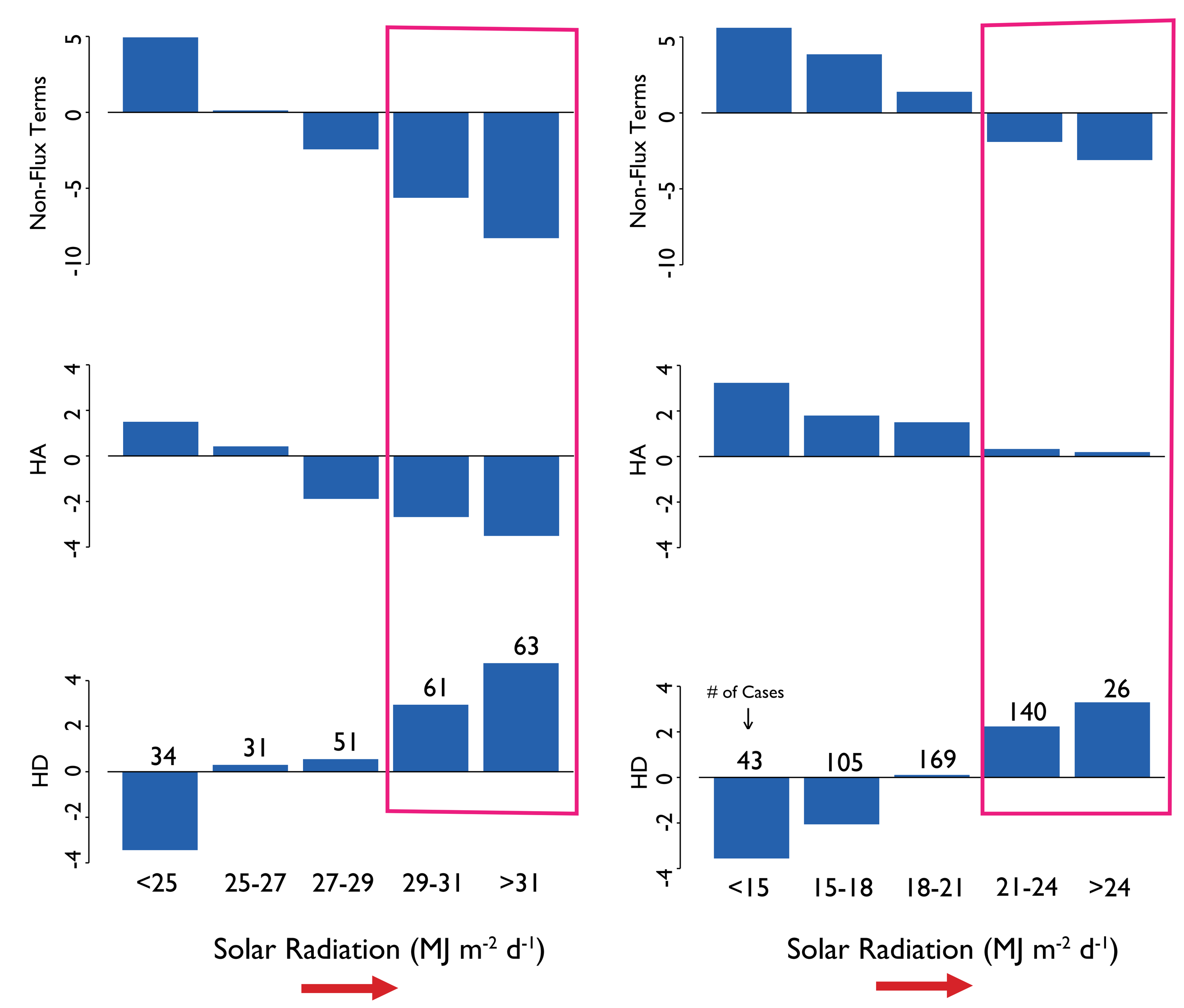


For the daily June budget, when there was moist advection and horizontal divergence, larger non-flux terms are associated with increasing cloud coverage through ~20%.

Non-FluxTerms & Solar Radiation SGP vs Midwest

SGP (240 Cases) May - June

Midwest (488 Cases) May-August



The size of the non-flux terms in the SGP under partly cloudy to mostly sunny skies is significantly larger than in the Midwest due to the limited moist horizontal advection in the Midwest.