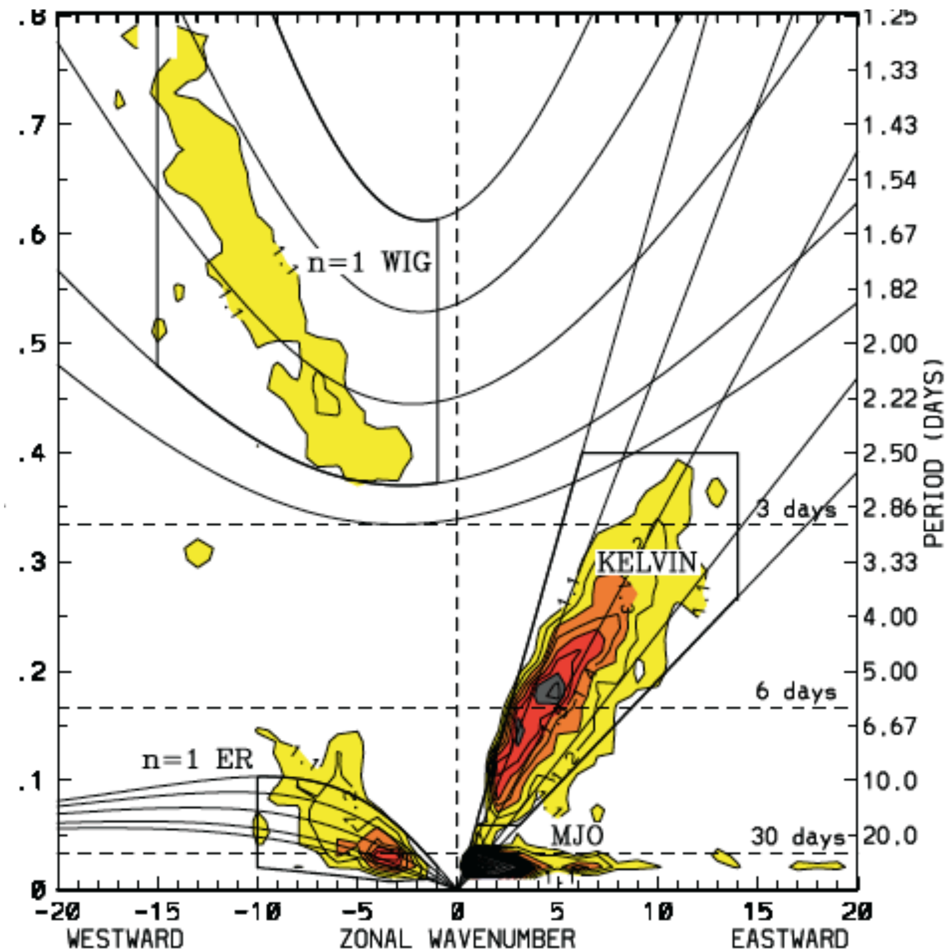
Some thoughts on MJO theory and AMIE/DYNAMO observations

Zhiming Kuang

The MJO

- is believed to have different dynamics from the convectively coupled waves.



A framework based on column integrated moist static energy

(e.g .Neelin and Yu, 1994; Sobel et al., 2001; Fuchs and Raymond 2002; Maloney, 2009; Sugiyama, 2009ab, and many others)

- Spectra of precipitable water show a strong MJO signal but weaker Kelvin waves (Roundy and Frank, 2004, Yasunaga and Mapes 2011). (Observational, but indirect)
- In idealized SPCAM simulations, damping column MSE anomalies eliminates the "MJO-like" signals but not Kelvin waves (Andersen and Kuang, 2012). (More direct, but in a model)

A framework based on column integrated moist static energy budget

$$\langle \partial_t h \rangle_{budget} = -\langle \omega \partial_p h \rangle - \langle v \cdot \nabla h \rangle + LH + SH + \langle LW \rangle + \langle SW \rangle,$$

Contribution to growth
(fractional growth per time)

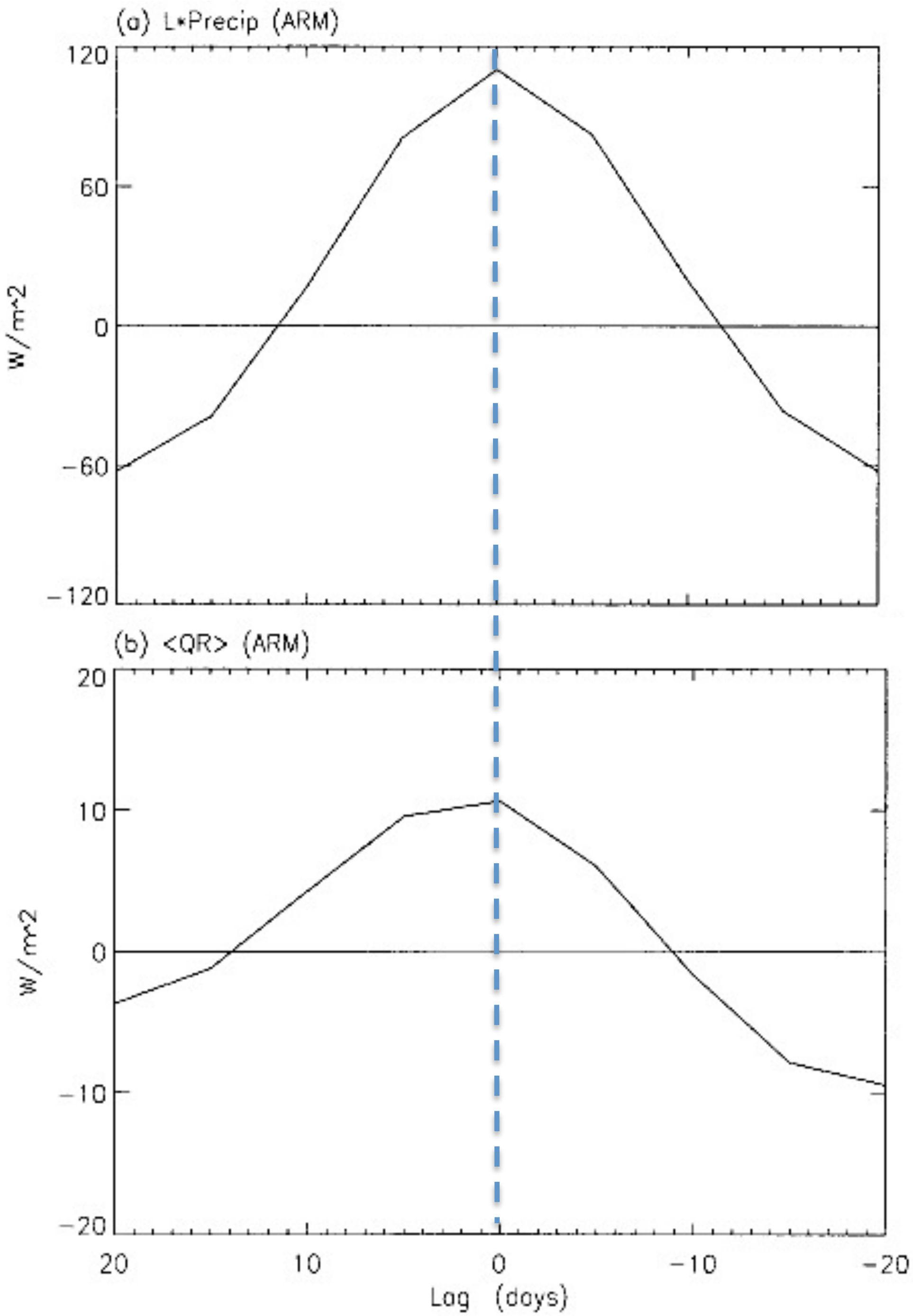
$$\frac{\| x \cdot \langle h \rangle \|}{\| \langle h \rangle^2 \|}$$

Contribution to propagation

$$\frac{\| x \cdot \langle dh/dt \rangle \|}{\| \langle dh/dt \rangle^2 \|}$$

where $\|y\| = \iint_{ITCZ} y\, dA$ is the integral over the ITCZ

(Andersen and Kuang, J. Climate 2012)

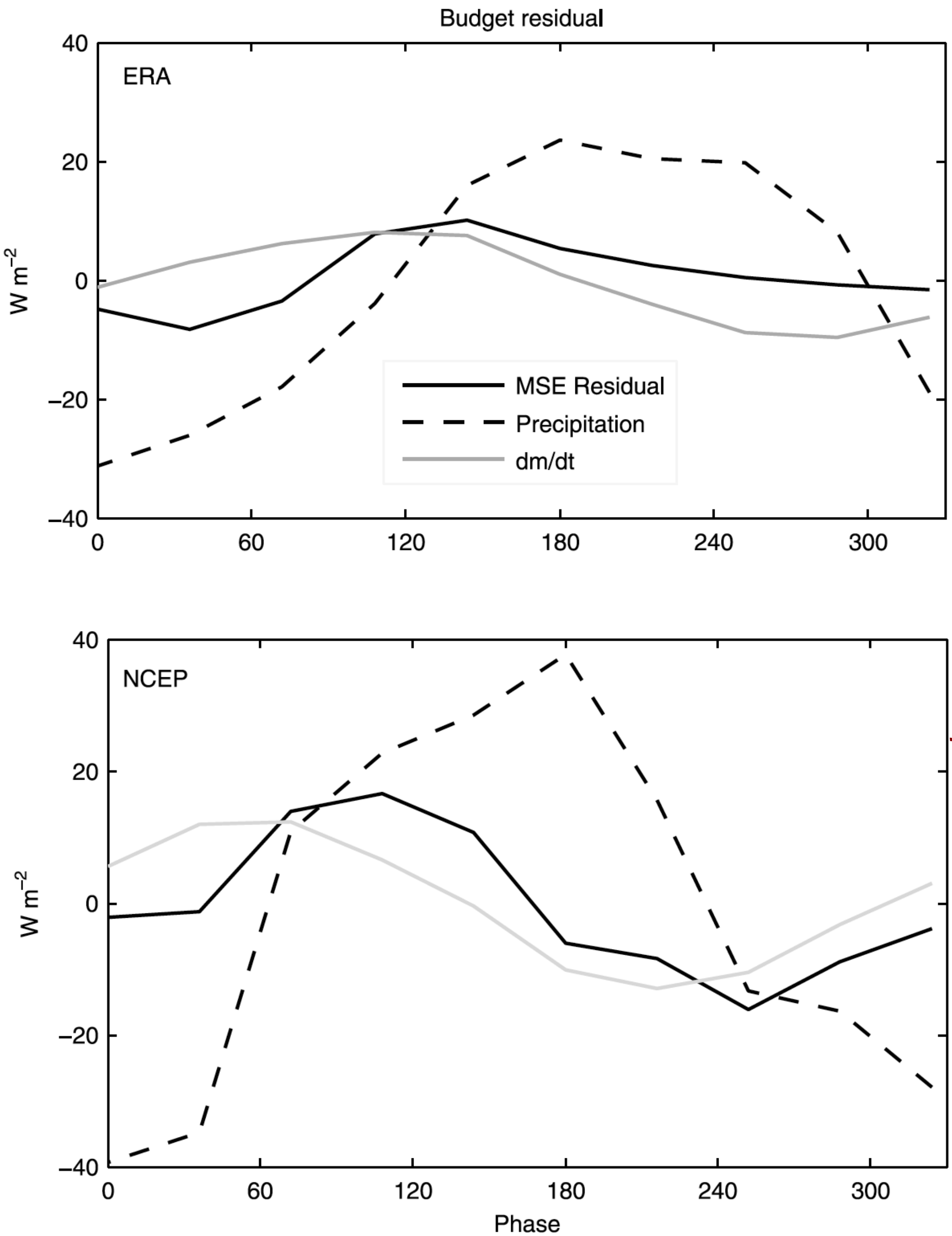


Lin and Mapes (2004)

<QR>'~10-15%LP'

and dominated by OLR

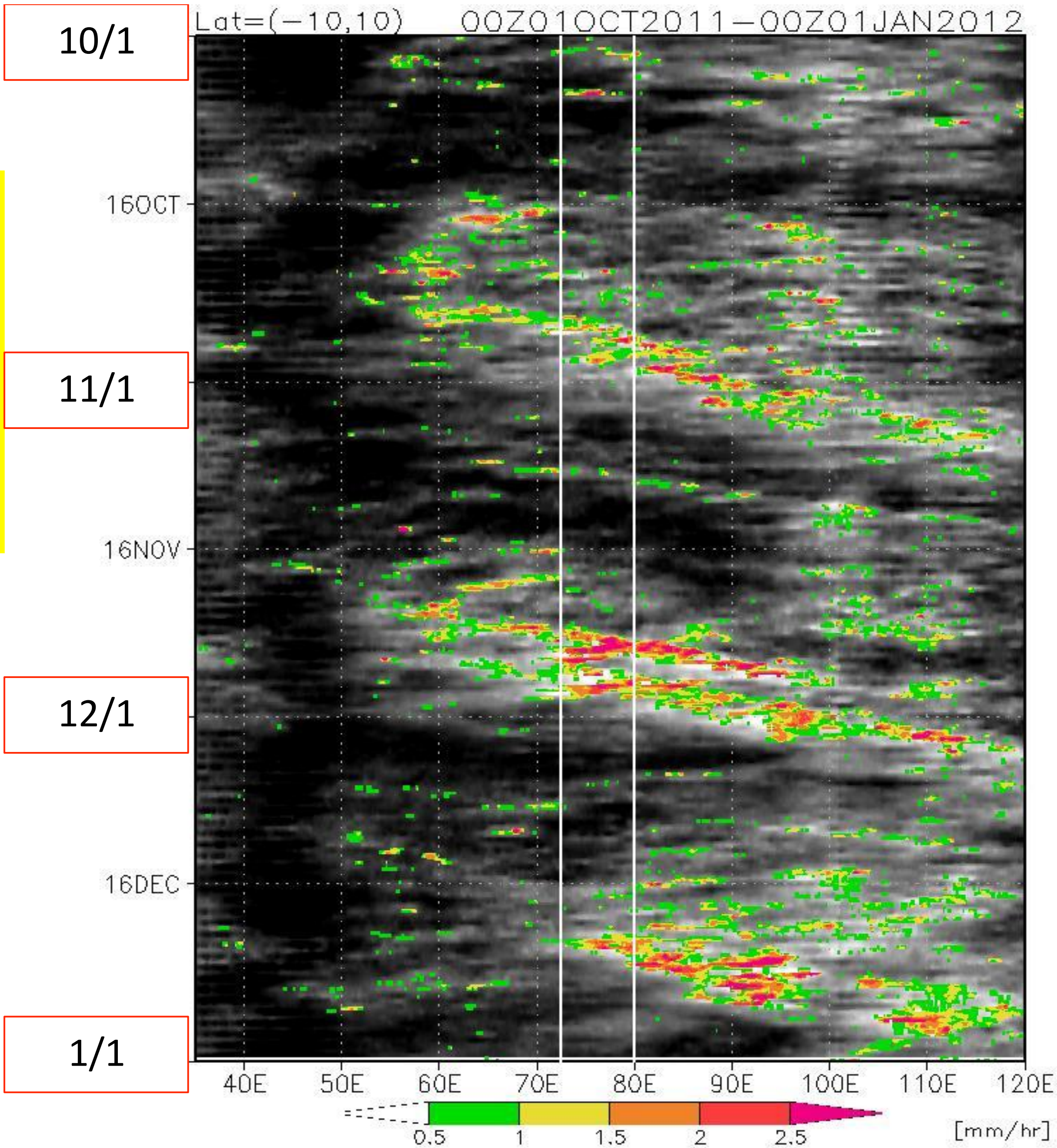
In the SPCAM results, <QR>'~20%LP'



MSE budgets using reanalyses have large residues

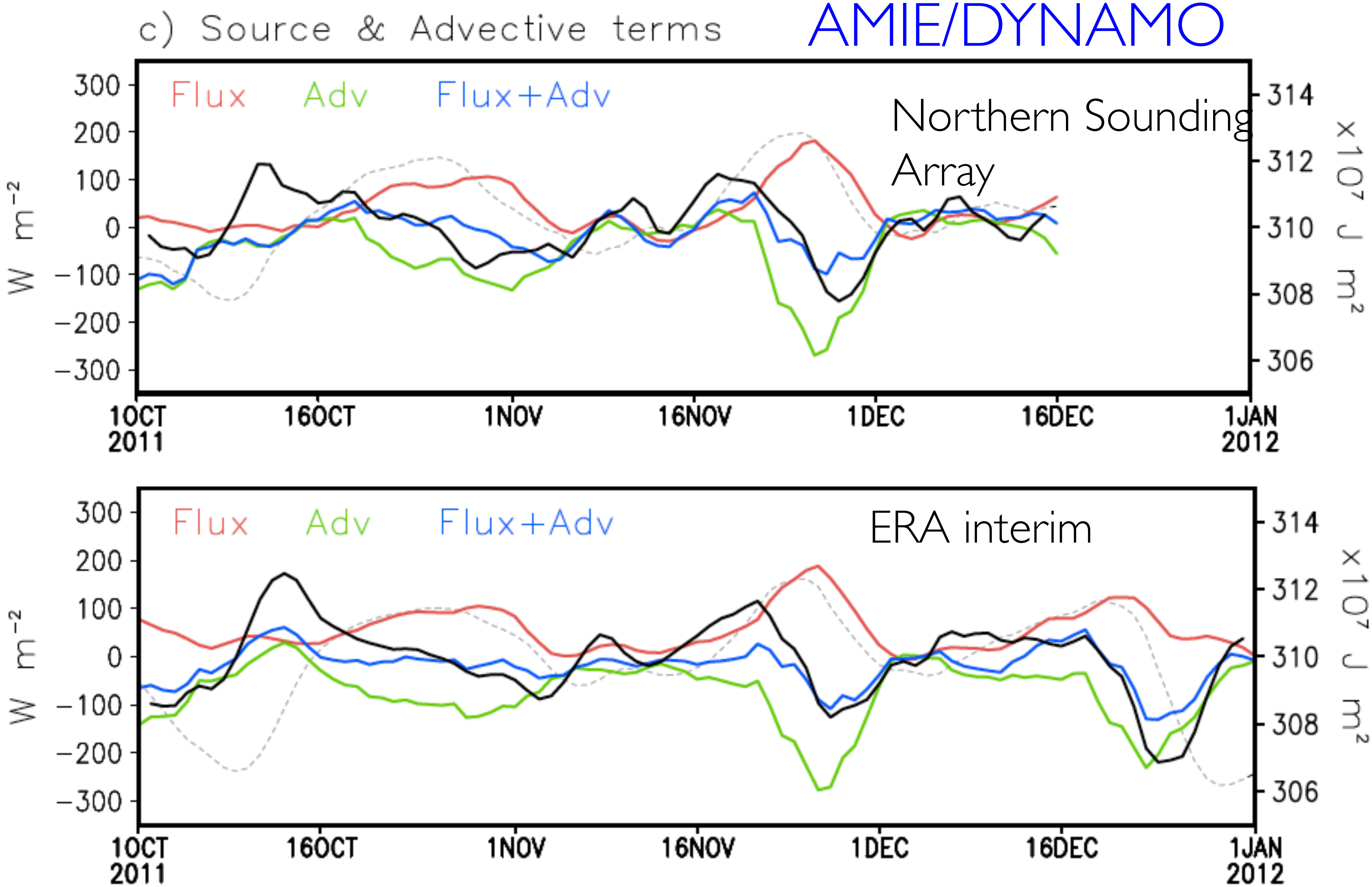
Kiranmayi and Maloney, JGR, 2011

Precip from DYNAMO/ CINDY/AMIE



Courtesy of Chidong Zhang and Kunio Yoneyama

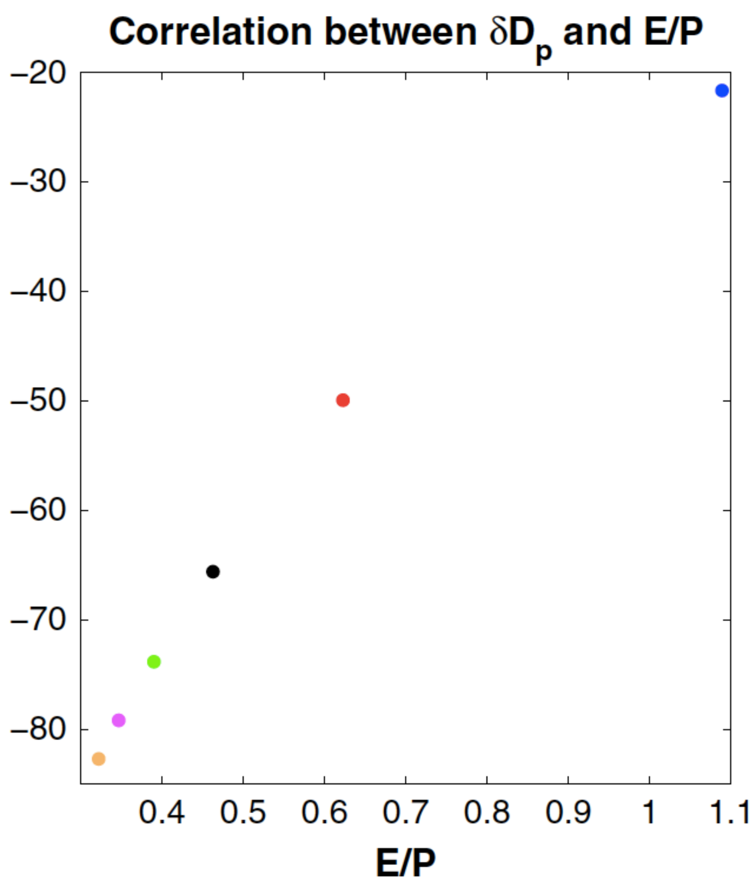
AMIE/DYNAMO



Sobel et al., submitted

How to better constrain the MSE budget observationally?

- Additional constraints (e.g. isotopic compositions)?

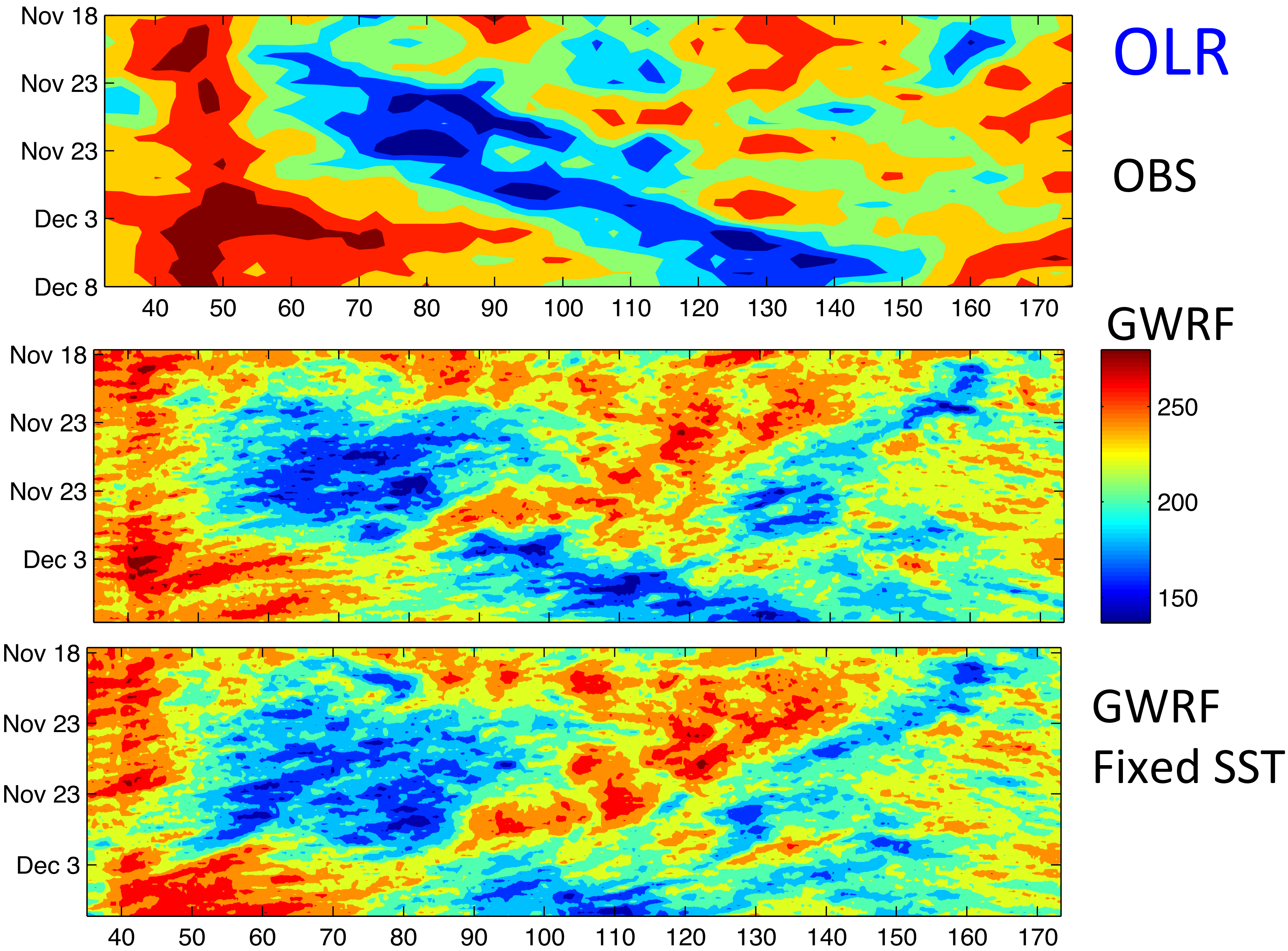


Deuterium content in rain *versus* moisture convergence

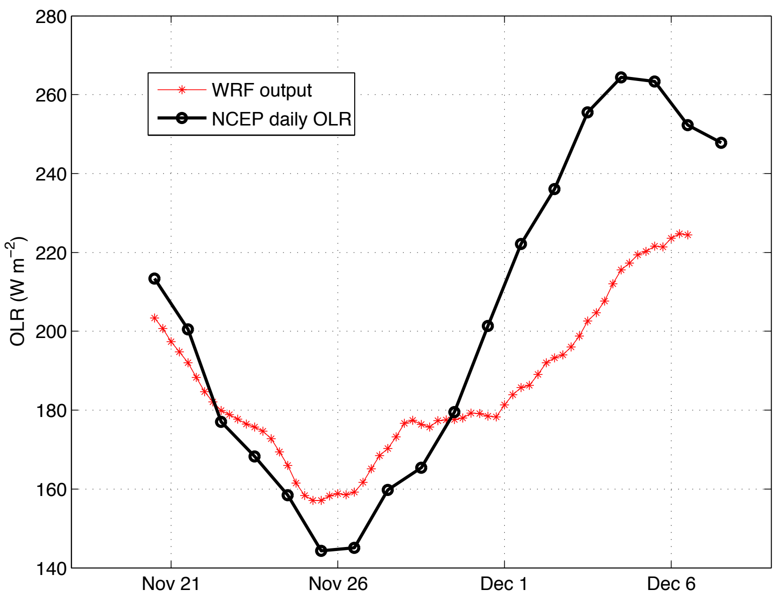
Moore, Kuang, and Blossey, GRL, 2014

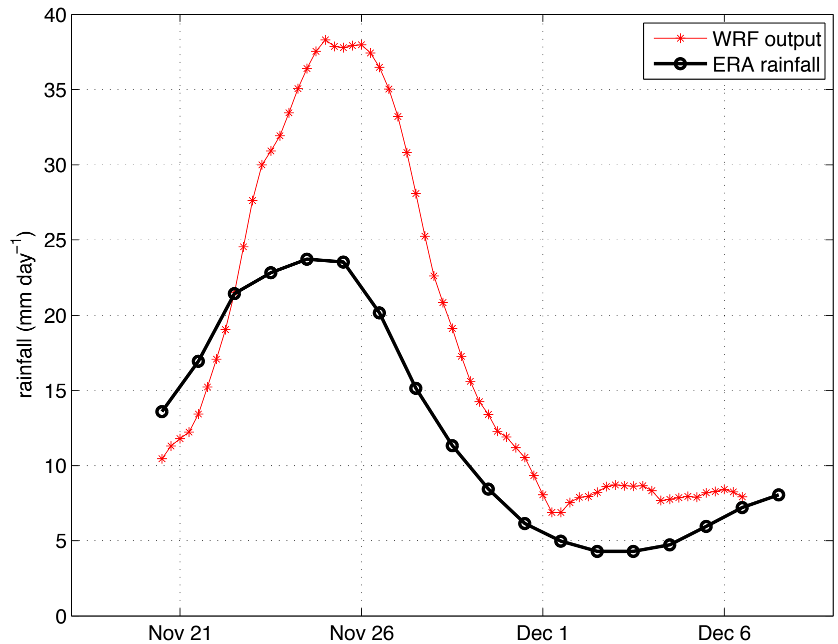
Global WRF runs

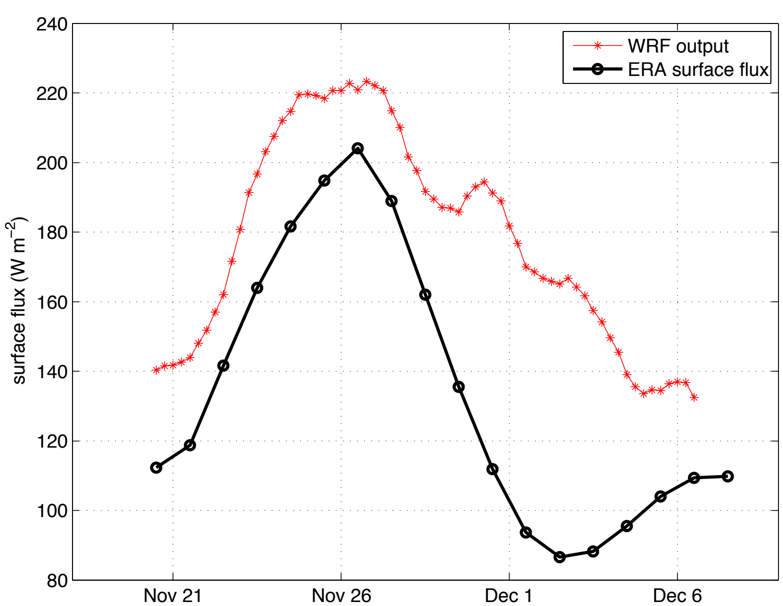
- WRF3.4.1,
- global run initialized with NCEP GFS,
- 13km horizontal resolution and 40 stretched vertical layers
- WSM 6-class microphysics, RRTM longwave, Goddard SW, thermal diffusion land surface
- Starting from Nov. 18 with and without temporal SST variations.



OLR
OBS
GWRF
GWRF
Fixed SST
Nov 18
Nov 23
Nov 23
Dec 3
Dec 8
40
50
60
70
80
90
100
110
120
130
140
150
160
170
250
200
150







Averages over the northern array (70-80E, 0-5N)
5-day running mean

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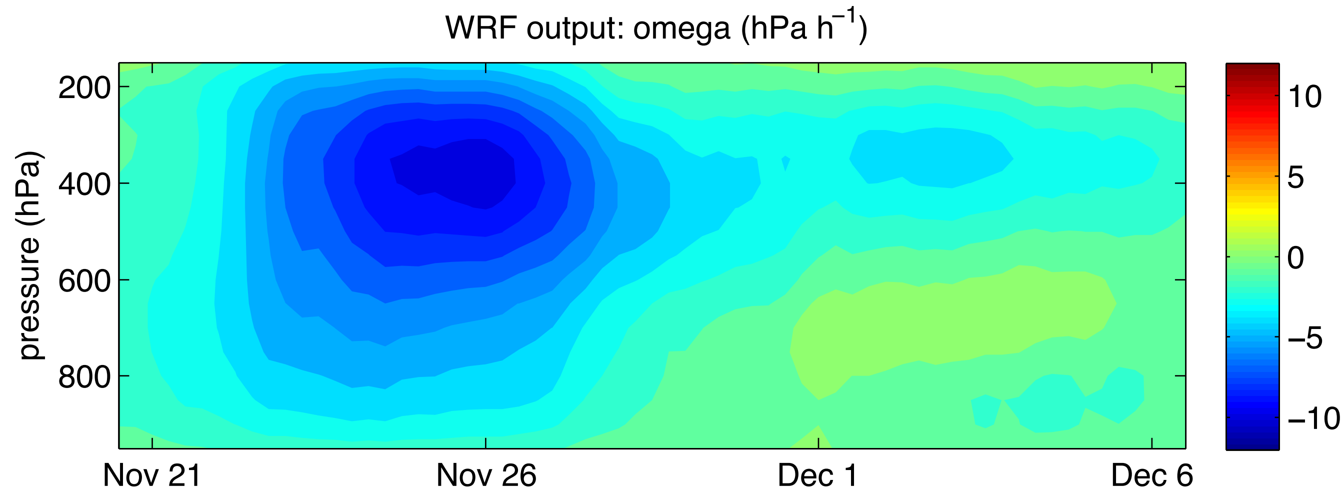
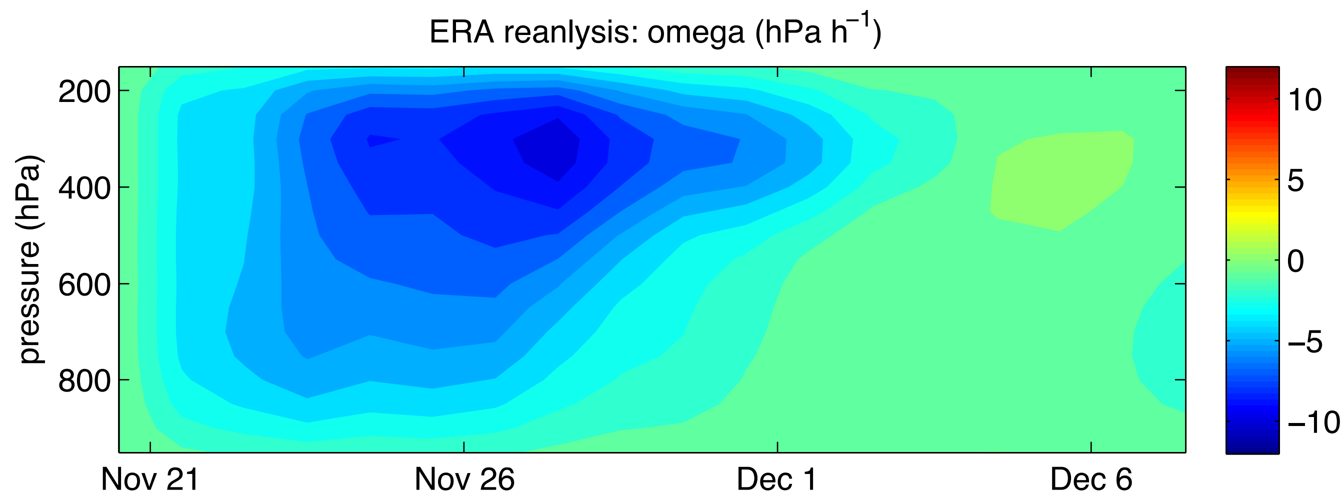
5-day running mean



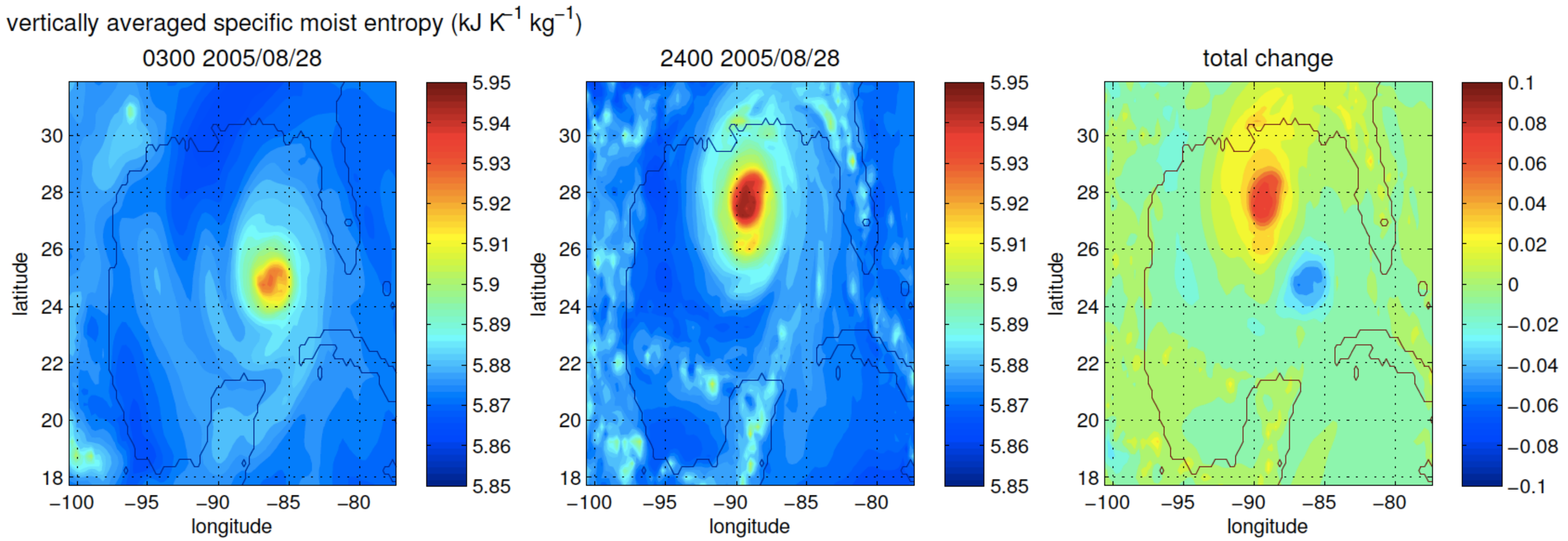


Adding moist entropy budget to WRF

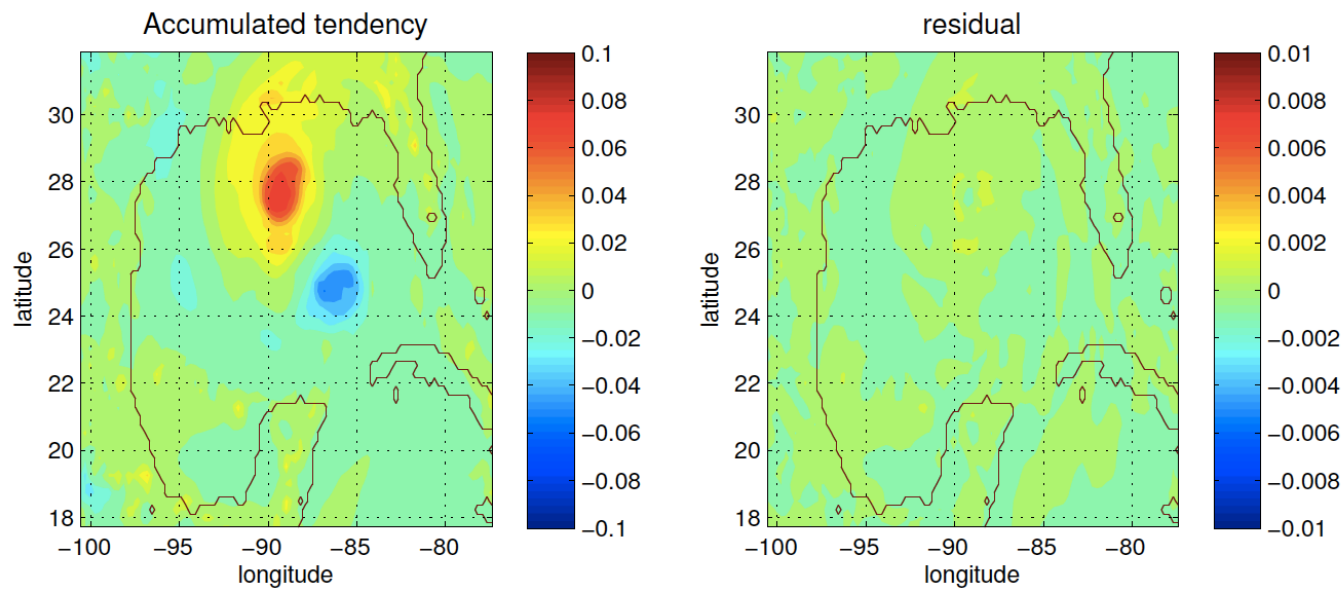
$$s = C_p \ln\theta + \frac{L_v q_v}{T}$$

Since $\left(\frac{L_v q_v}{T}\right)$ is not a prognostic model variable, we make the approximation:

$$\delta\left(\frac{L_v q_v}{T}\right) \approx \frac{L_v}{T}\delta\left(q_v\right)$$



Applied to Katrina



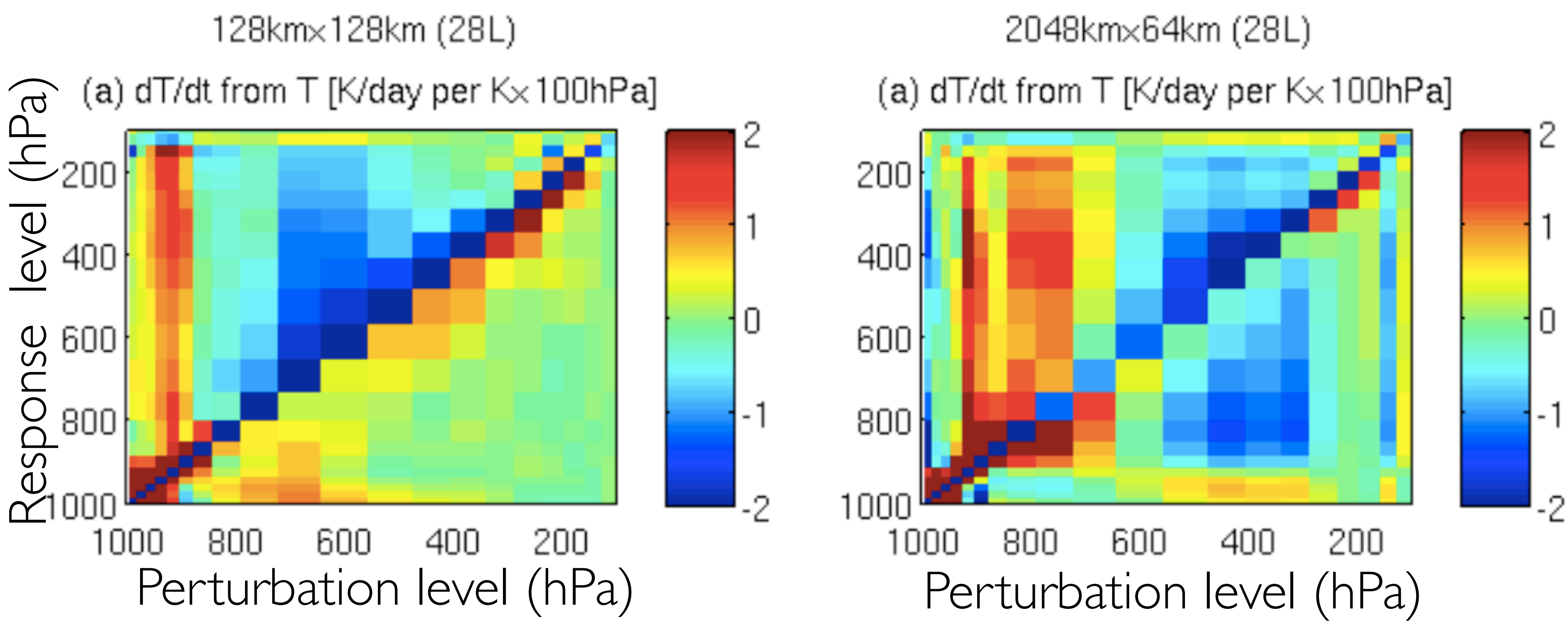
Beyond column MSE budget

1. Diagnosing a forcing dataset from the global WRF run over the sounding arrays and compare that with the observations.
2. Use that forcing dataset to drive a limited domain WRF with parameterized large-scale dynamics (along the lines of Wang, Sobel, Kuang JGR 2013) to see how well such methods reproduce the full model results.

Convective organization affects responses to large-scale temperature and moisture perturbations

Do models get it right?

Unorganized convection (parcel mode) | Organized convection (layer mode)



Kuang, JAS, 2012

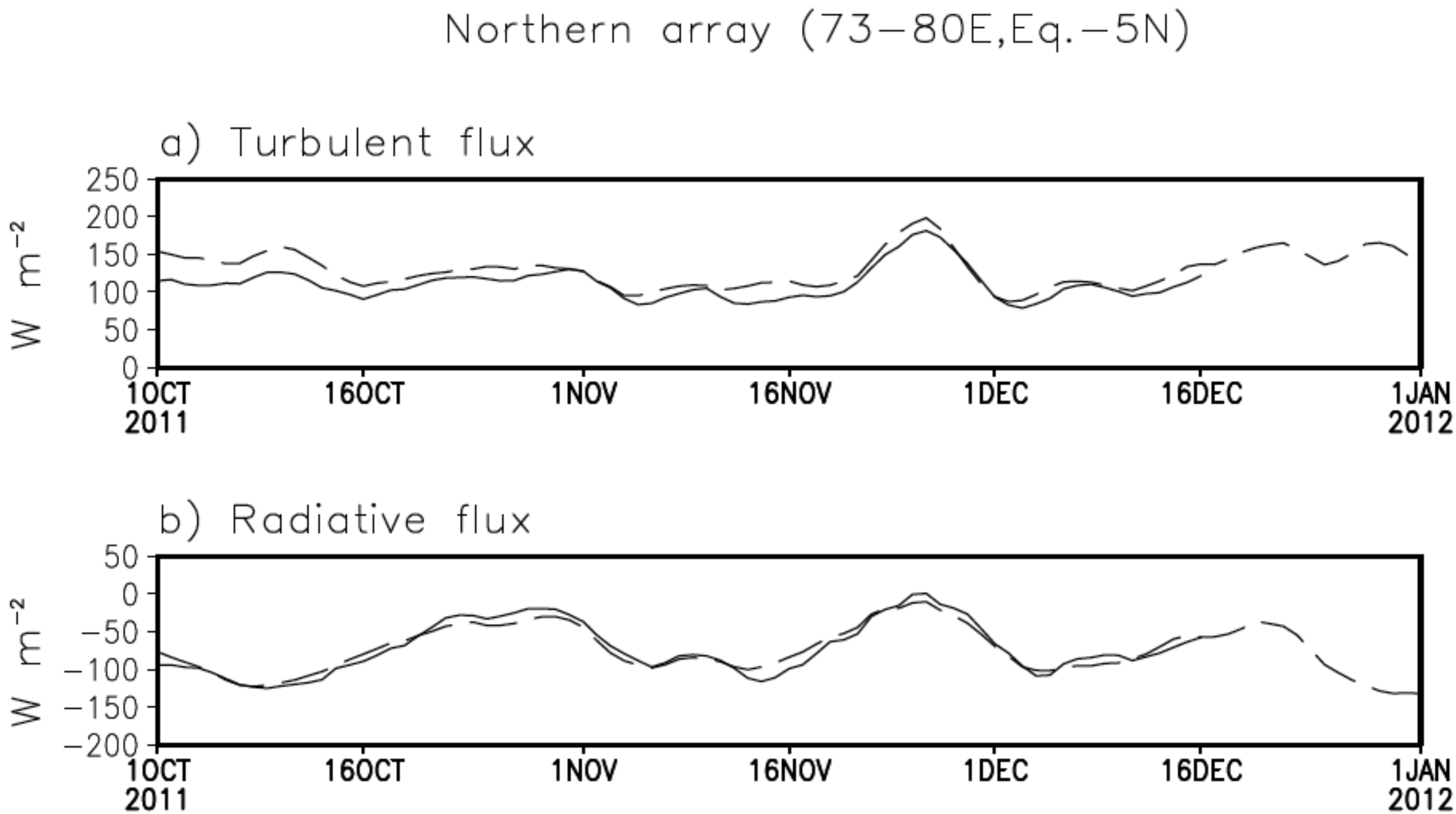
Observations to compare with

Cold pool characteristics, statistics of size and duration of convective systems, convective population (like in Zuluaga and Houze 2013), stratiform-to-convective rain ratio, morphology…

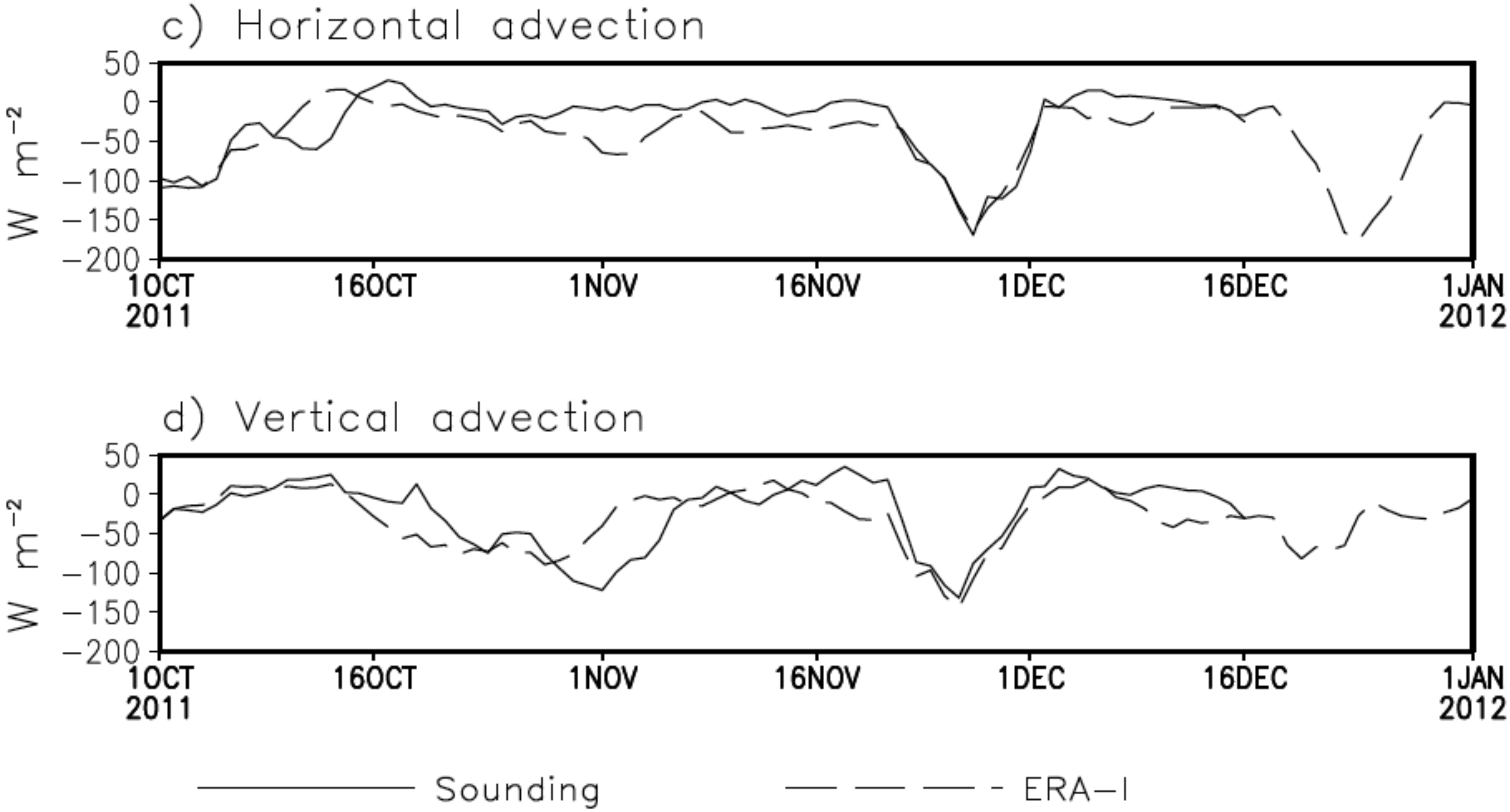
The models can then be used to examine how cold pools organize convection (see poster tomorrow) and how mesoscale organization affects convection's response to large-scale temperature/moisture perturbations.

Summary

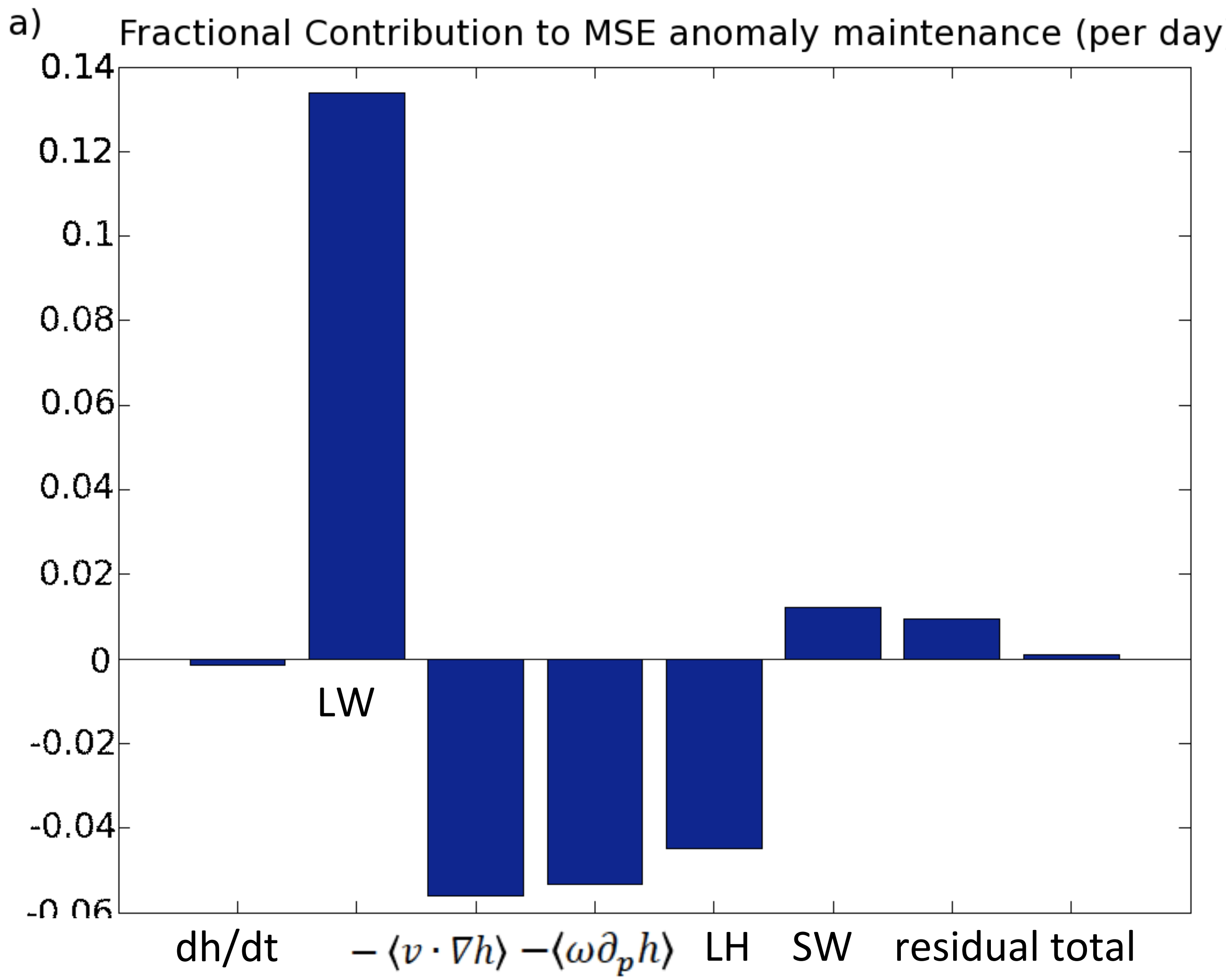
1. A global version of WRF is used to simulate the AMIE/DYNAMO MJO events with a detailed MSE (moist entropy) budget included.
2. The observations can be used to evaluate the modeled MSE budget and convective organization, which are important aspects of MJO dynamics.
3. Modeled derived forcing can complement observation/reanalysis derived forcing in driving single column models



Sobel et al., submitted

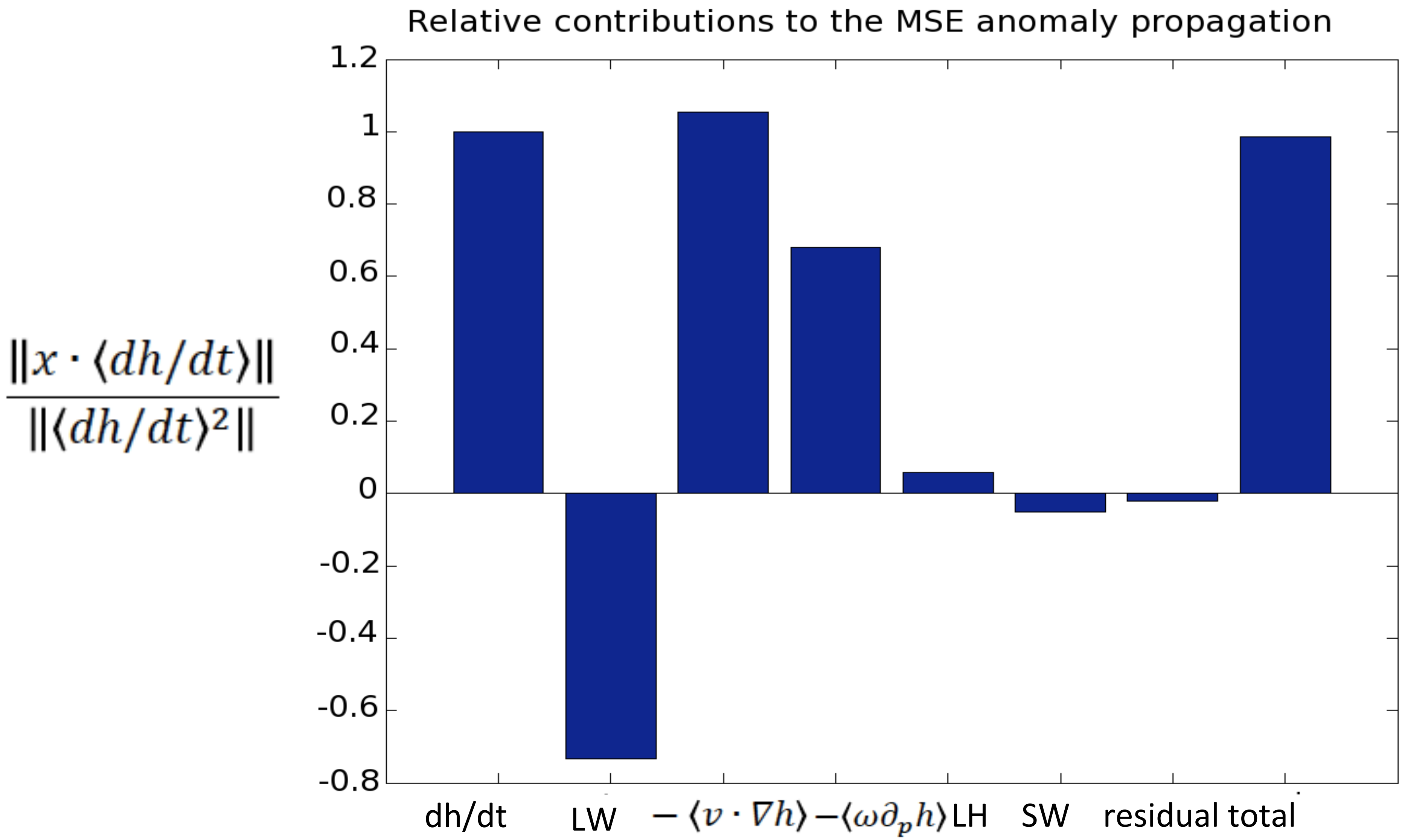


Sobel et al., submitted



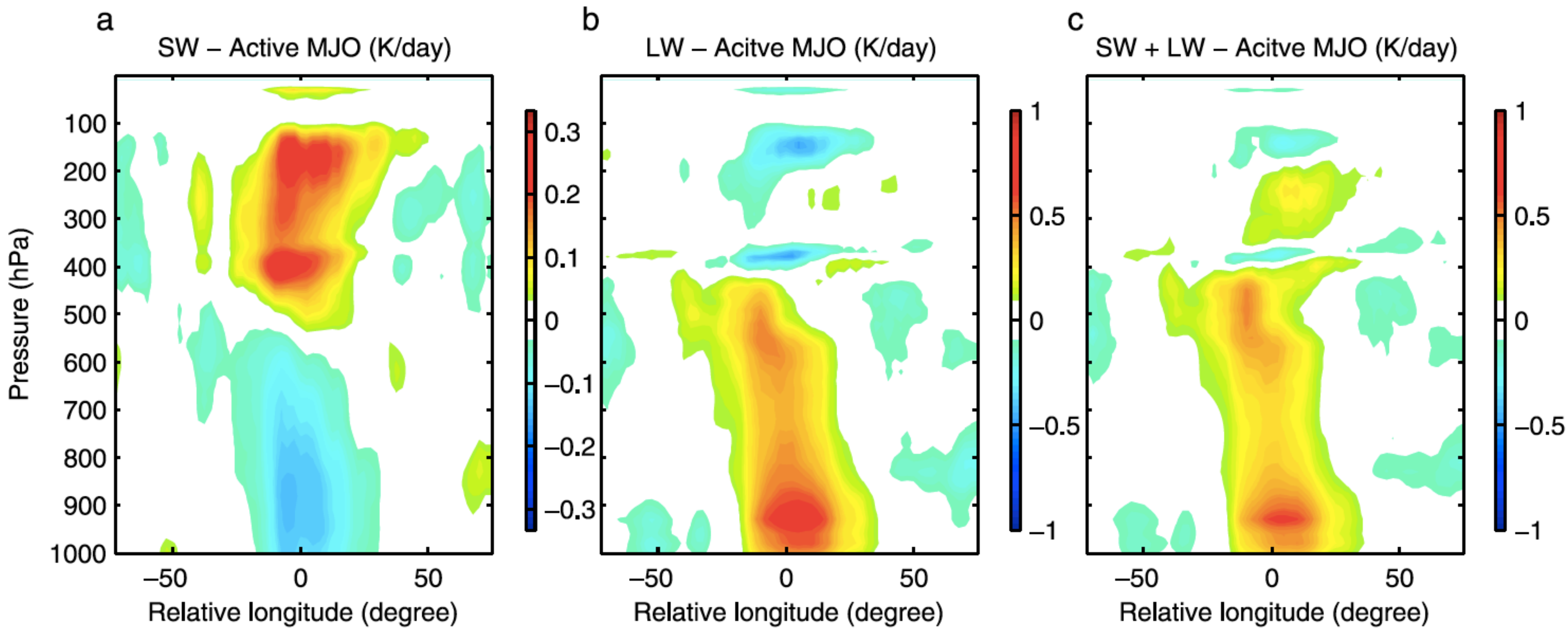
$$\frac{\|x \cdot \langle h \rangle\|}{\|\langle h \rangle^2\|}$$

where $\|y\| = \iint_{ITCZ} y dA$ is the integral over the ITCZ


Relative contributions to the MSE anomaly propagation
$\frac{\|x \cdot \langle dh/dt \rangle\|}{\|\langle dh/dt \rangle^2\|}$
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
dh/dt
LW
$-\langle v \cdot \nabla h \rangle$
$-\langle \omega \partial_p h \rangle$
LH
SW
residual
total

Vertical structure

Results using CloudSAT 2B-FLXHR (Ma and Kuang, GRL, 2011)



Caveat: radiative heating profile is a highly derived product