A Global Model Investigation of MJO Initiation for DYNAMO

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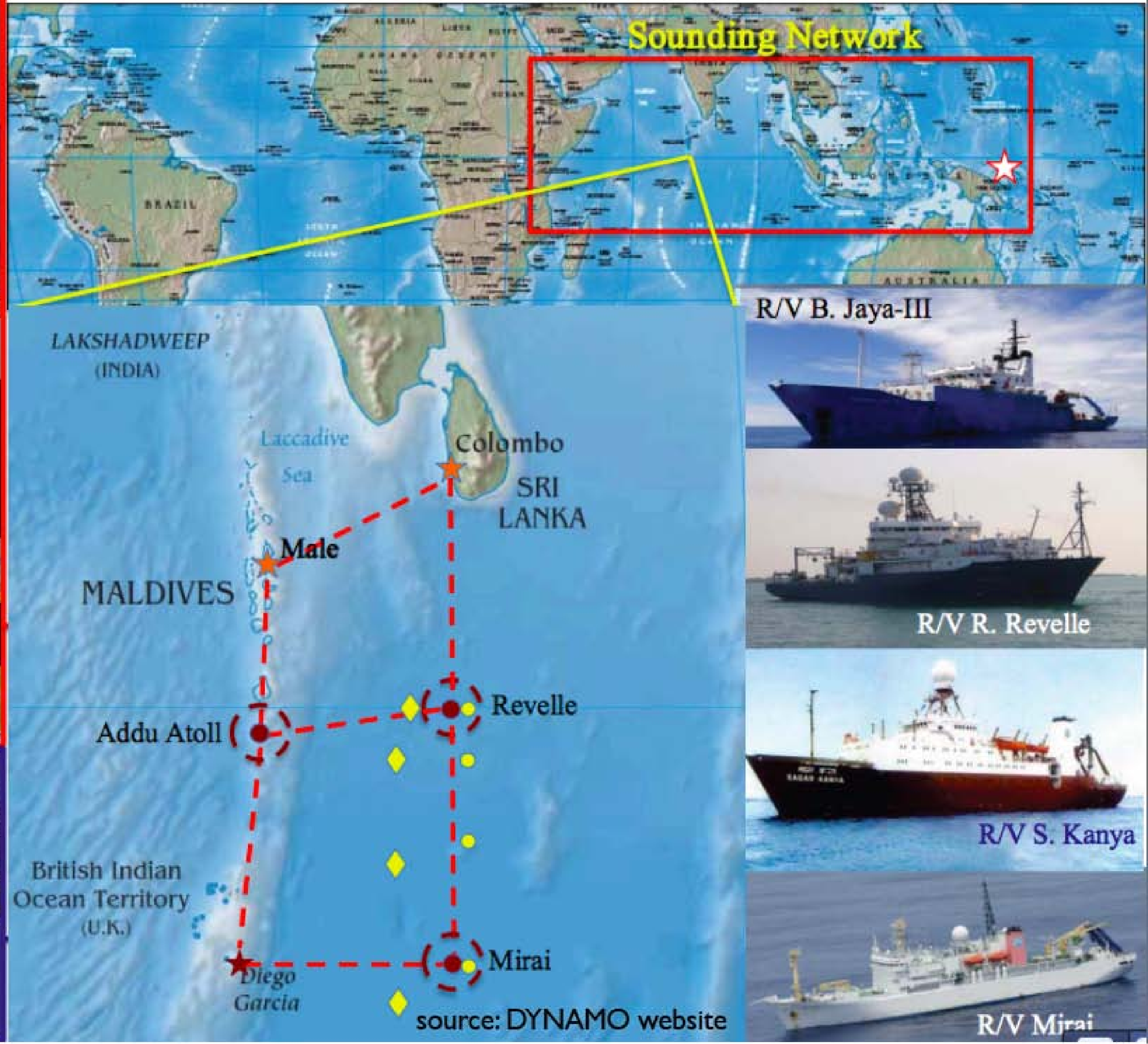
Subramanian and Zhang (2014, JGR)

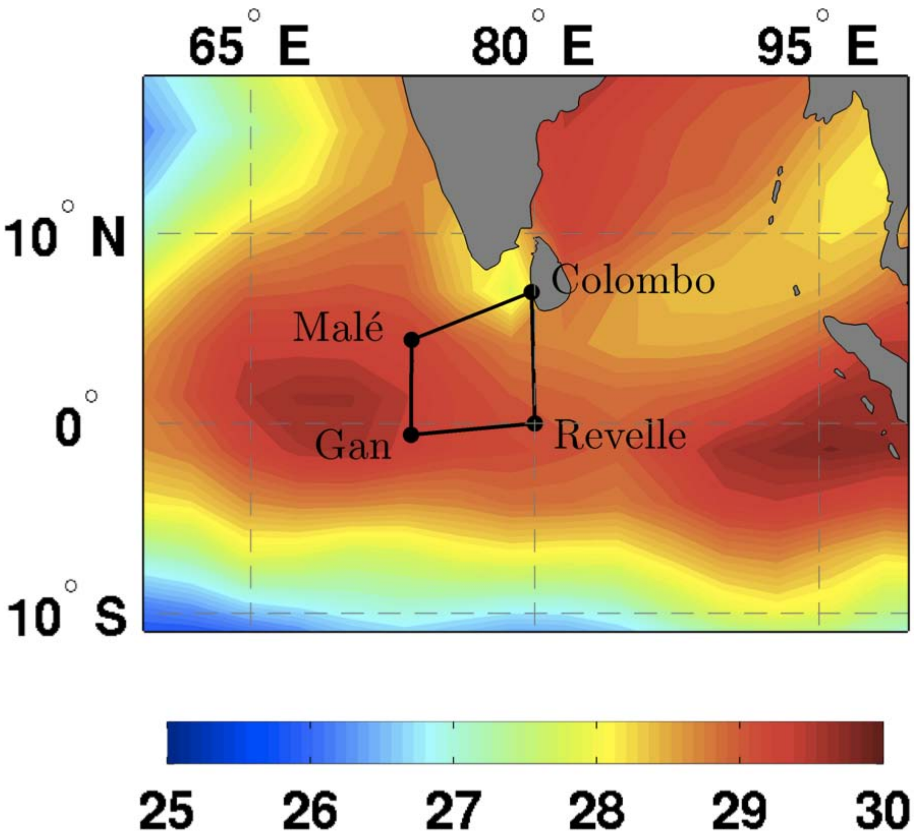
Objectives

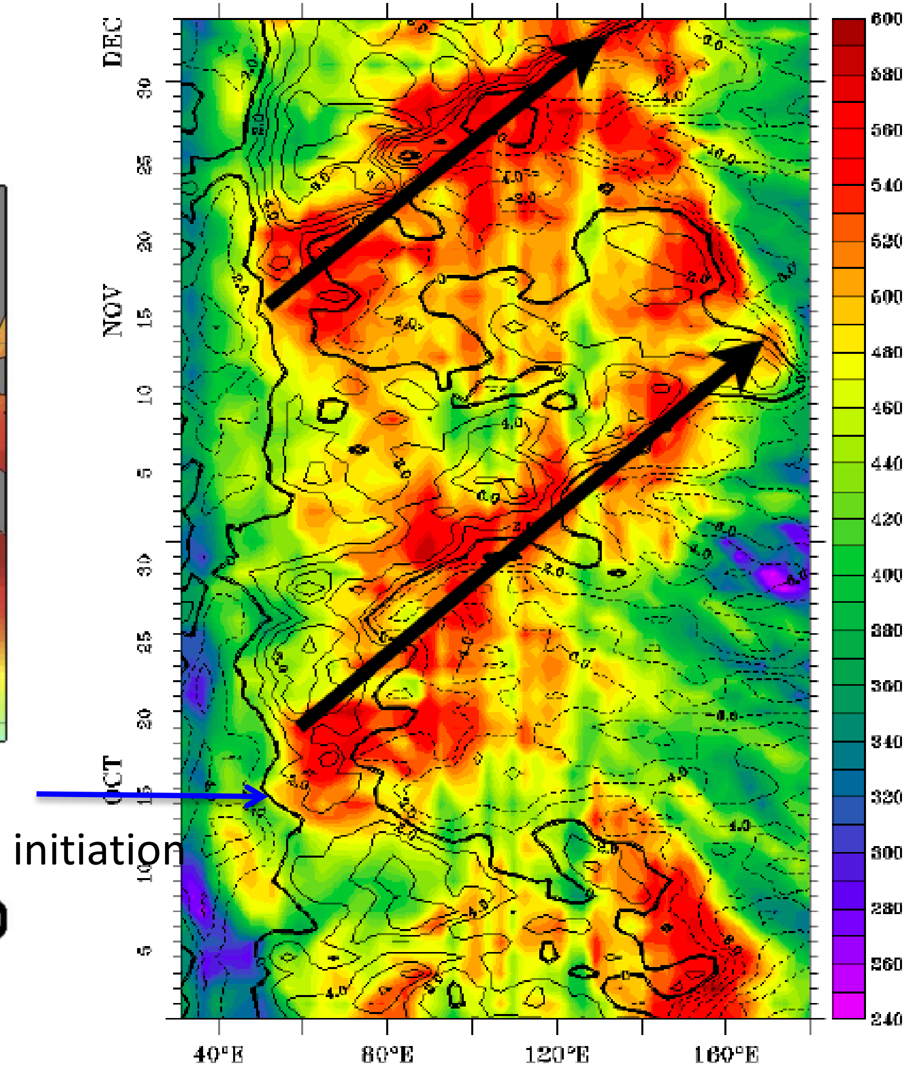
- To investigate the MJO initiation in the Indian Ocean using the NCAR CAM3 and the DYNAMO observations.
- To improve MJO simulation, and ultimately MJO prediction using global models.

DYNAMO Field Experiment (October 2011 – March 2012)



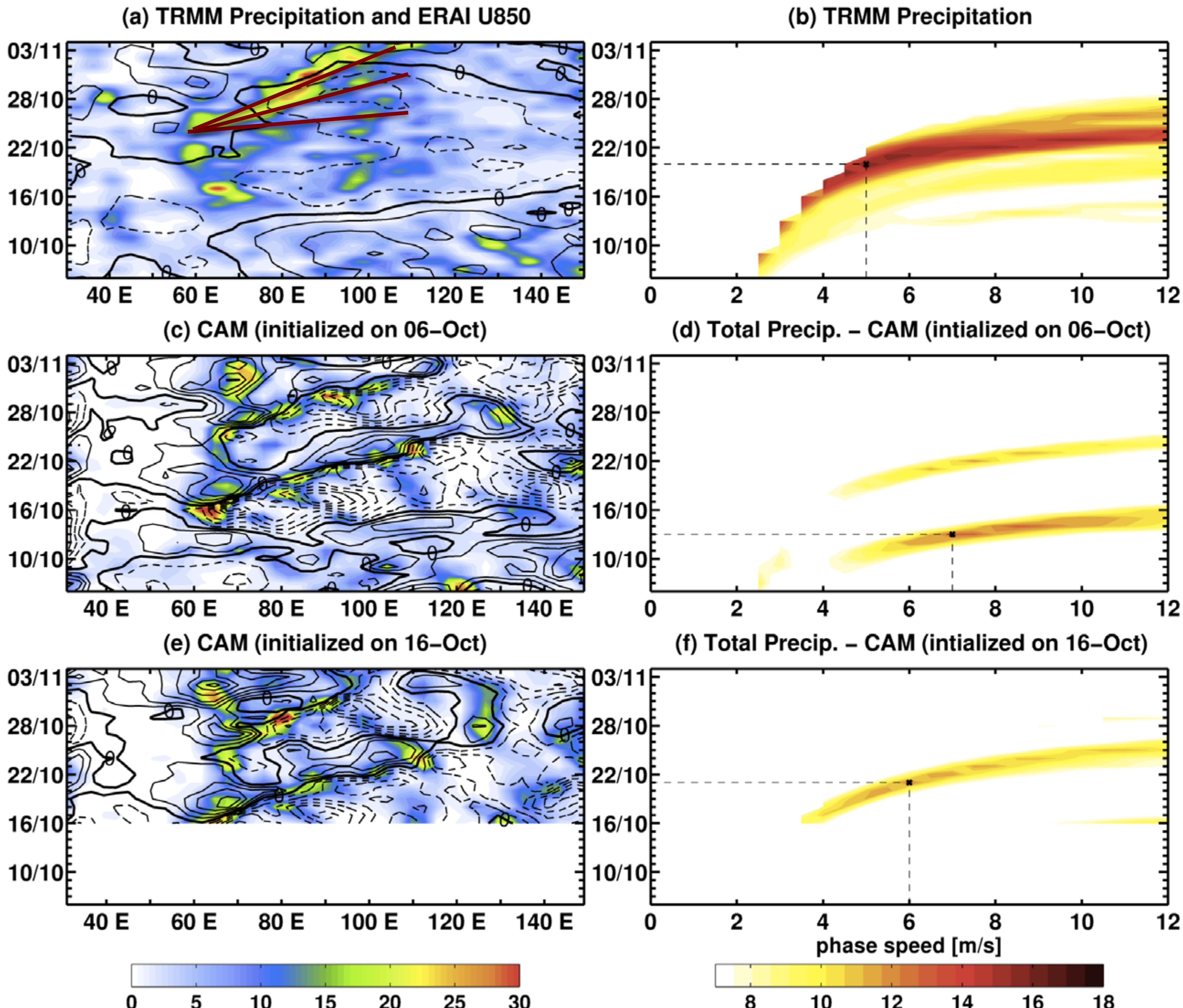
U850 anomalies and column water vapor from ECMWF Reanalyses for DYNAMO

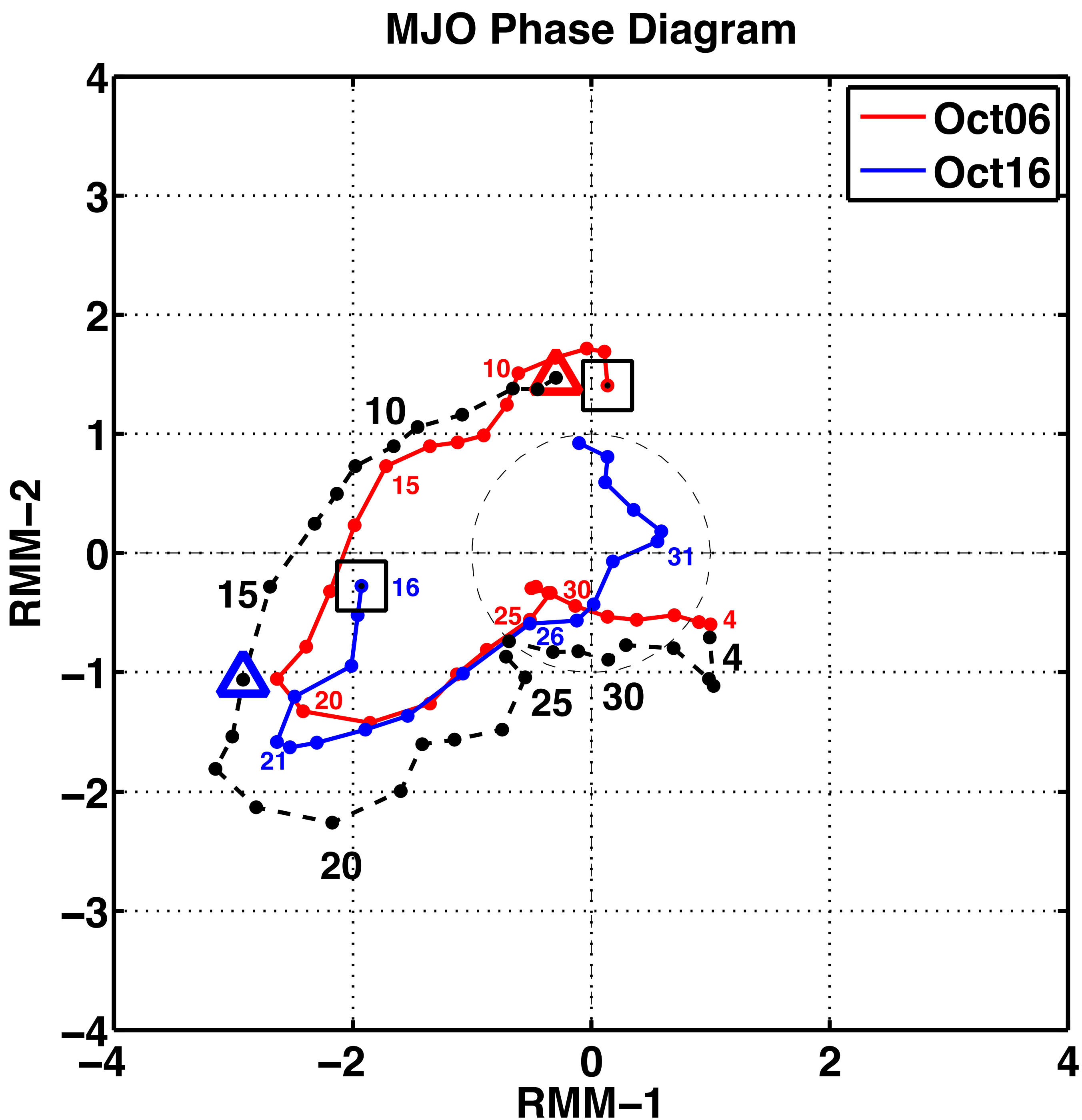




Experiments with NCAR CAM3

- Control Simulation: standard CAM3 with revised Zhang-McFarlane scheme
- 30 day hindcast initialized on Oct. 6 and Oct. 16, 2011
- Initial condition from ECMWF Reanalyses with DYNAMO data assimilated
- Boundary conditions use observed SST for the time period


(a) TRMM Precipitation and ERAI U850
(b) TRMM Precipitation
(c) CAM (initialized on 06-Oct)
(d) Total Precip. - CAM (intialized on 06-Oct)
(e) CAM (initialized on 16-Oct)
(f) Total Precip. - CAM (intialized on 16-Oct)
03/11
28/10
22/10
16/10
10/10
40 E
60 E
80 E
100 E
120 E
140 E
0
2
4
6
8
10
12
phase speed [m/s]
0
5
10
15
20
25
30
8
10
12
14
16
18


MJO Phase Diagram
Oct06
Oct16
RMM−1
RMM−2
4
3
2
1
0
−1
−2
−3
−4
−4
−2
0
2
4
10
15
20
25
30
4
10
15
20
25
30
4
16
21
26
31

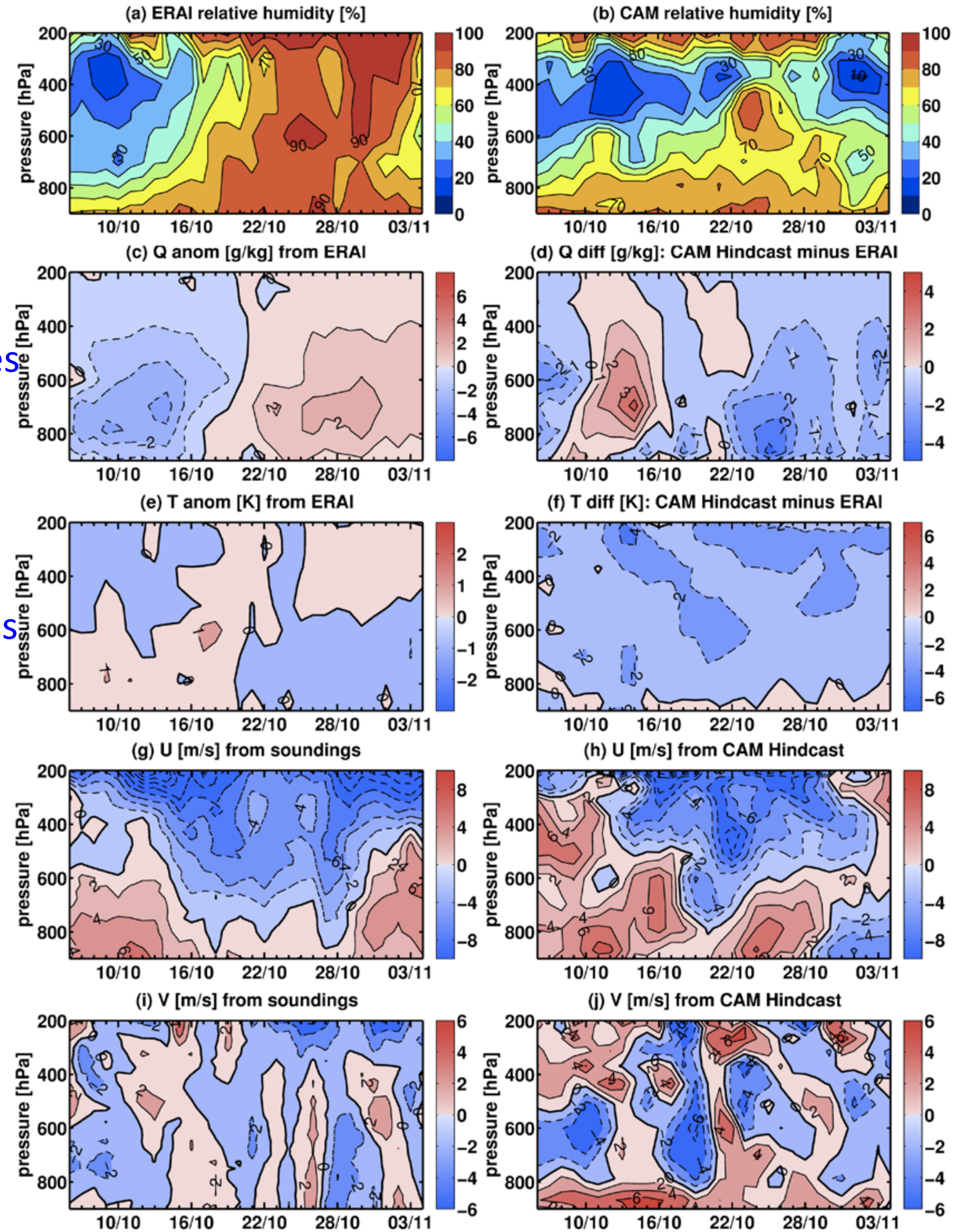
RH

q anomalies

T anomalies

u

v



Observed (left) and simulated (right) fields

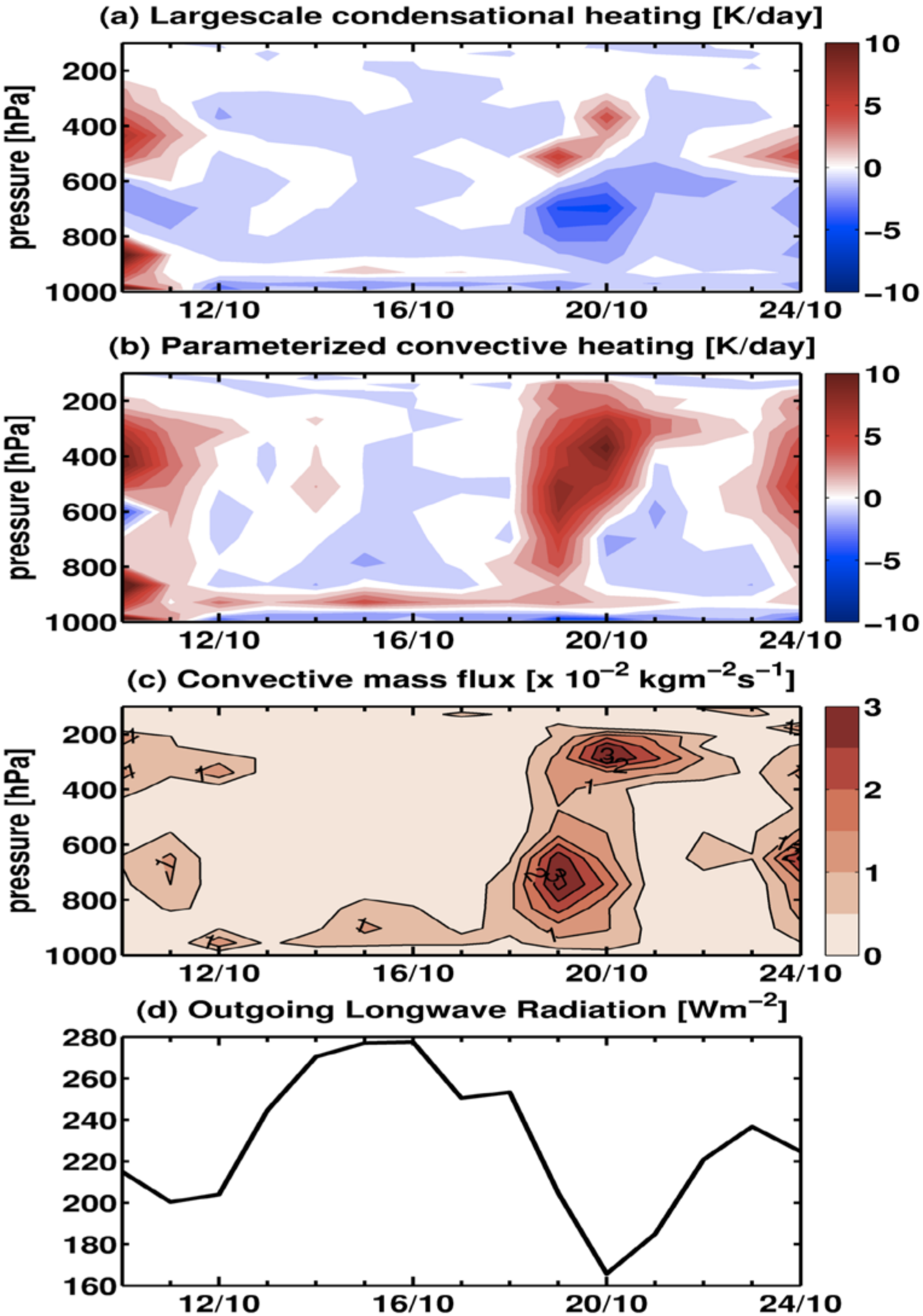
Evolution of model convection during MJO initiation

Large-scale condensation heating

Convective heating

Convective mass flux

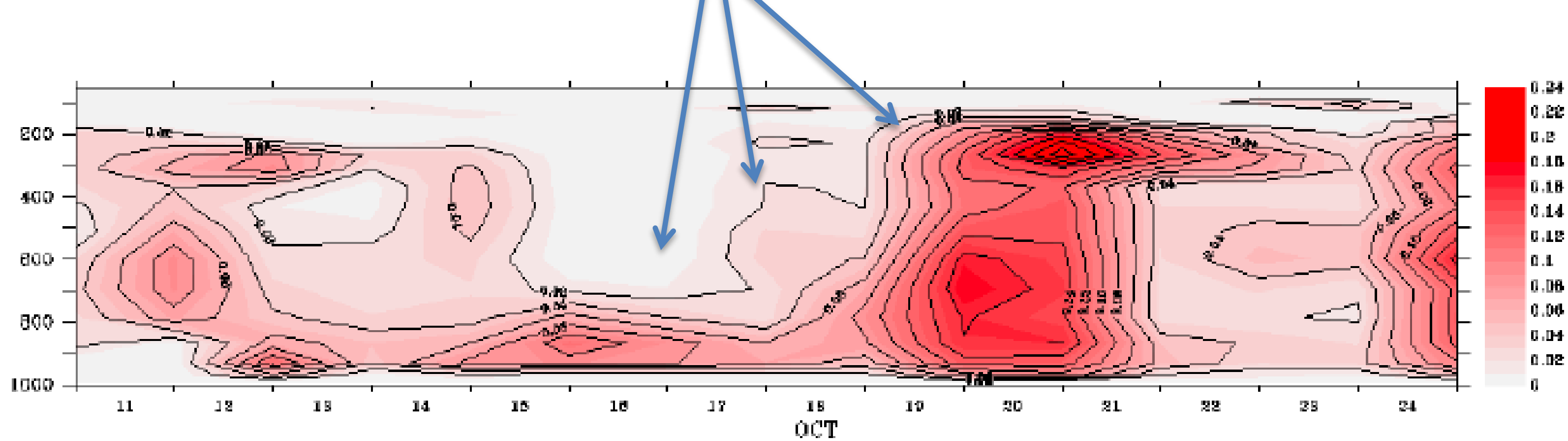
OLR



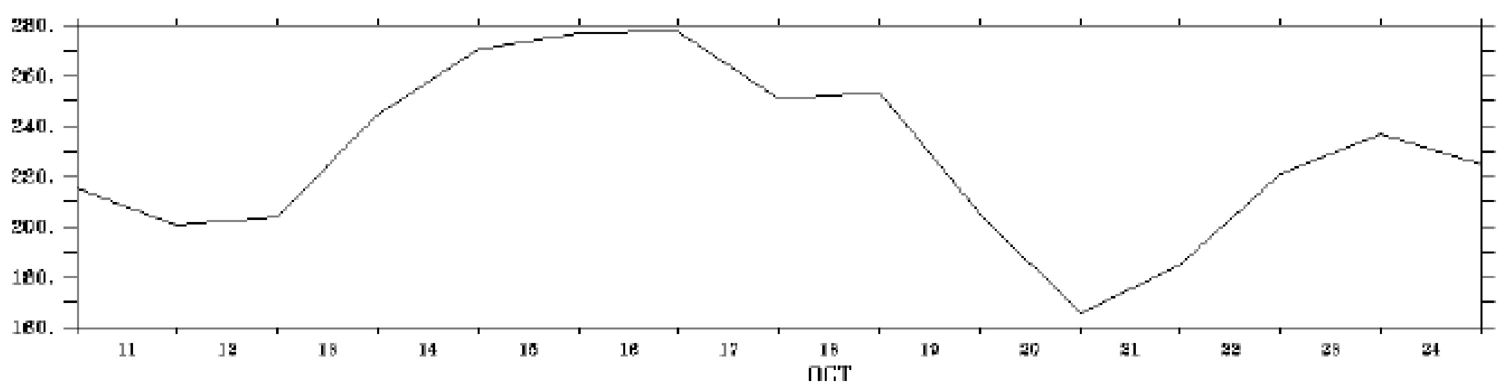
Convective cloud amount

Shallow convection leads deep convection during MJO initiation

72E:80E, 0N:7.5N



OLR



Experiments with NCAR CAM3: Nudging experiments

1. Nudge all fields (T, q, u, v)
2. Nudge all fields but one
3. Nudge one field a time

Why Nudging?

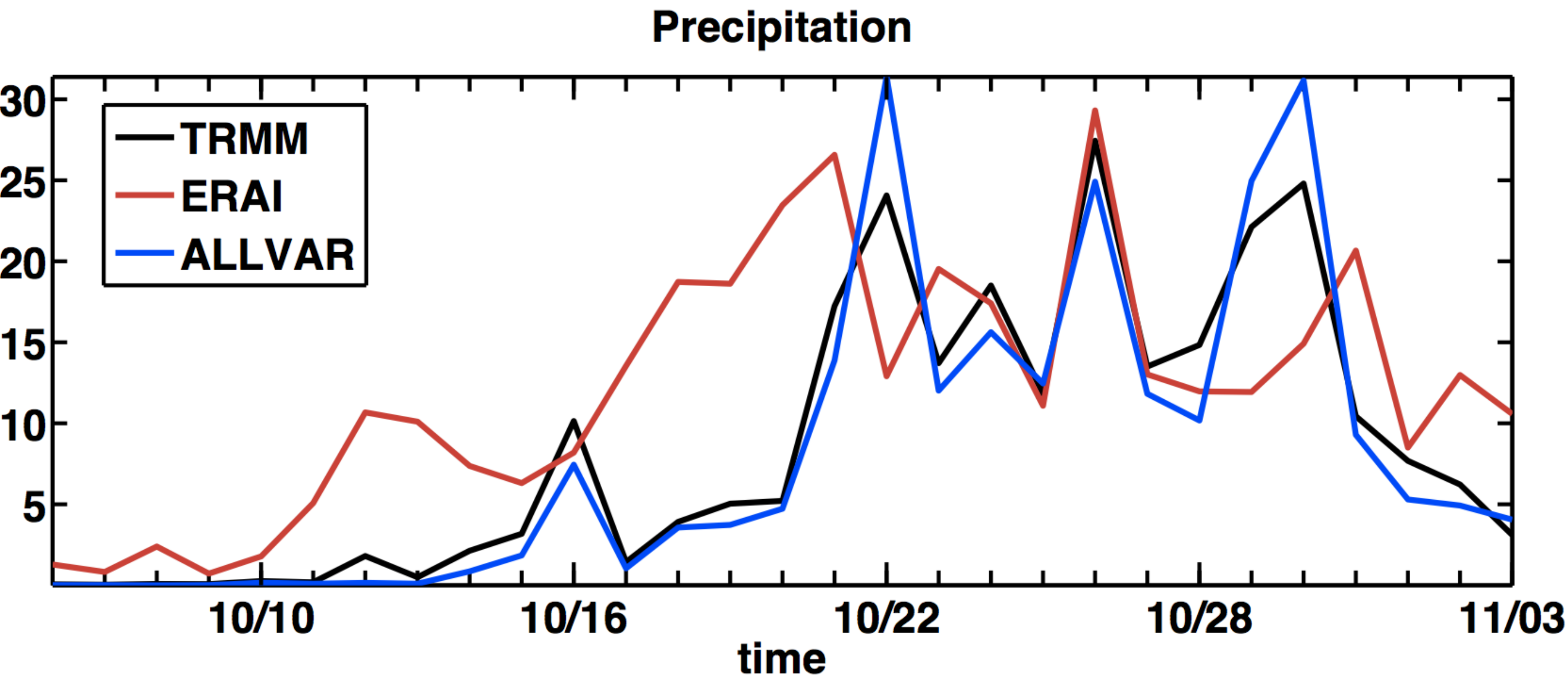
$$\frac{\partial X}{\partial t} = \ldots - \frac{X - X_a}{\tau}$$

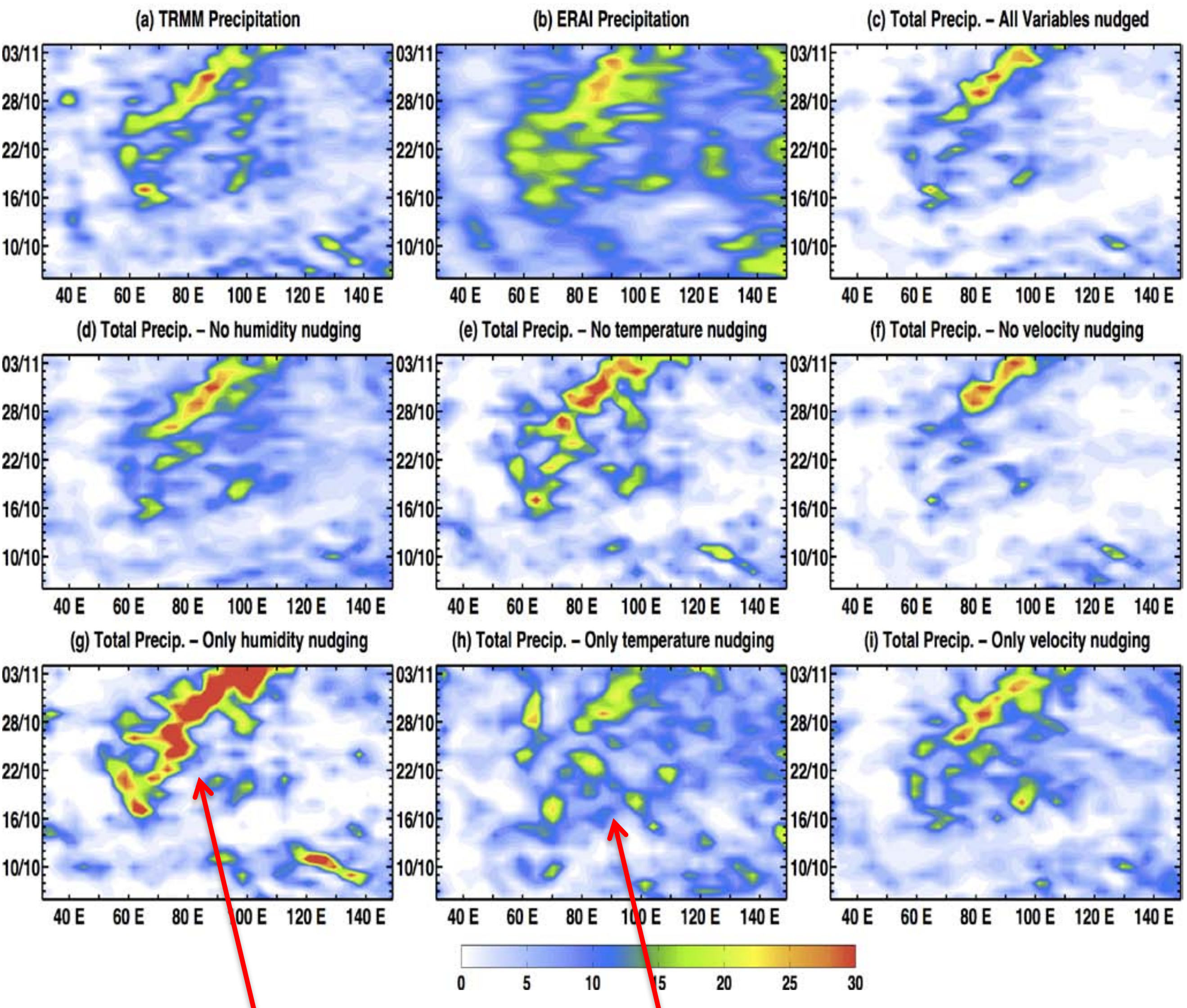
$$\left(\frac{\partial q}{\partial t}\right)_{\text{model}} = \left(\frac{\partial q}{\partial t}\right)_{dyn\_\text{model}} + \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{model}} + \left(\frac{\partial q}{\partial t}\right)_{nudge}$$

$$\left(\frac{\partial q}{\partial t}\right)_{\text{obs}} = \left(\frac{\partial q}{\partial t}\right)_{dyn\_\text{obs}} + \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{obs}}$$

$$\left(\frac{\partial q}{\partial t}\right)_{nudge} = \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{obs}} - \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{model}}$$

Precipitation averaged over the Northern Sounding Array of DYNAMO





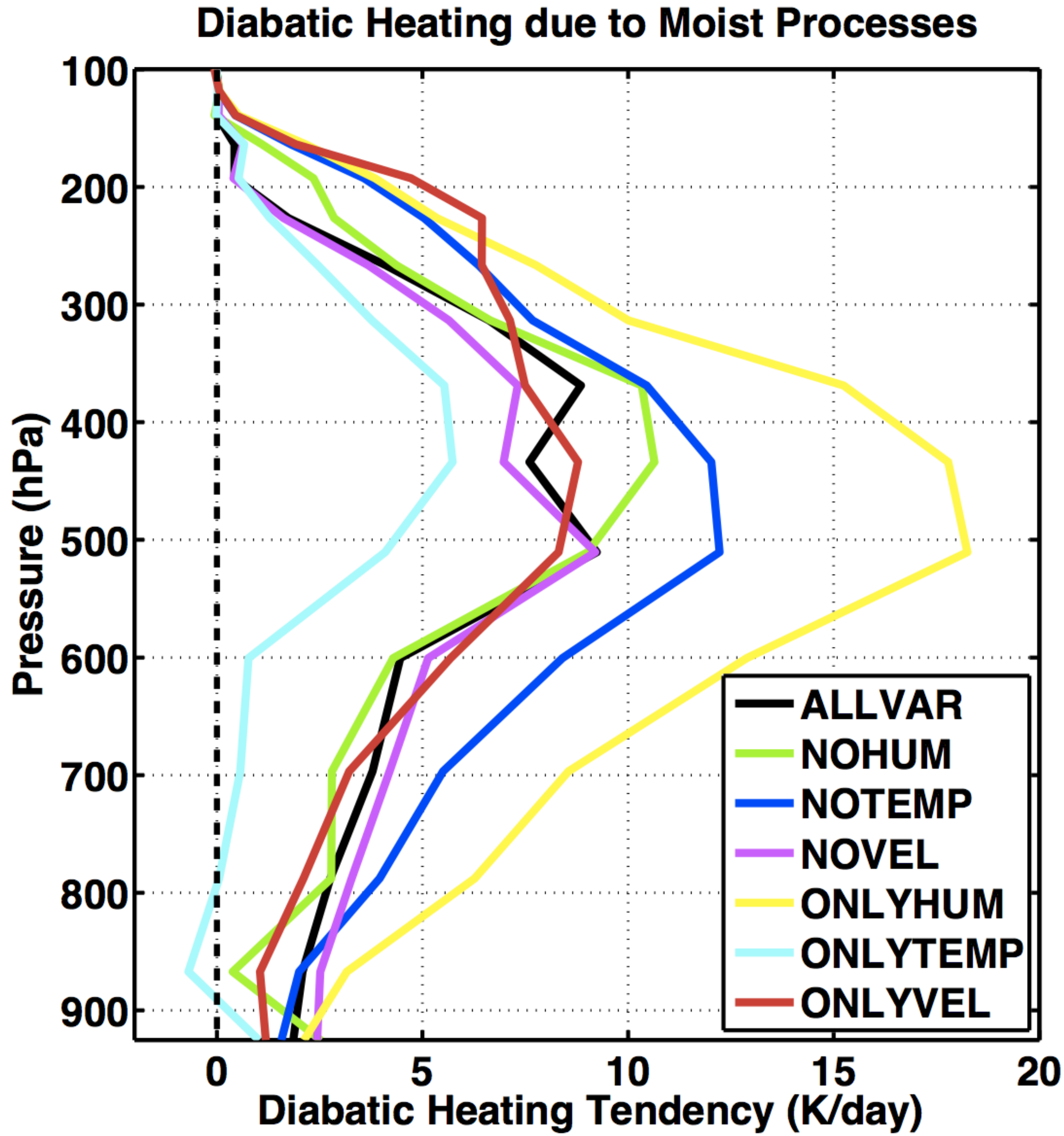
Of the three exp.
"no velocity nudging"
has the largest impact.

nudging velocity
is the most effective.

Strongest MJO precip

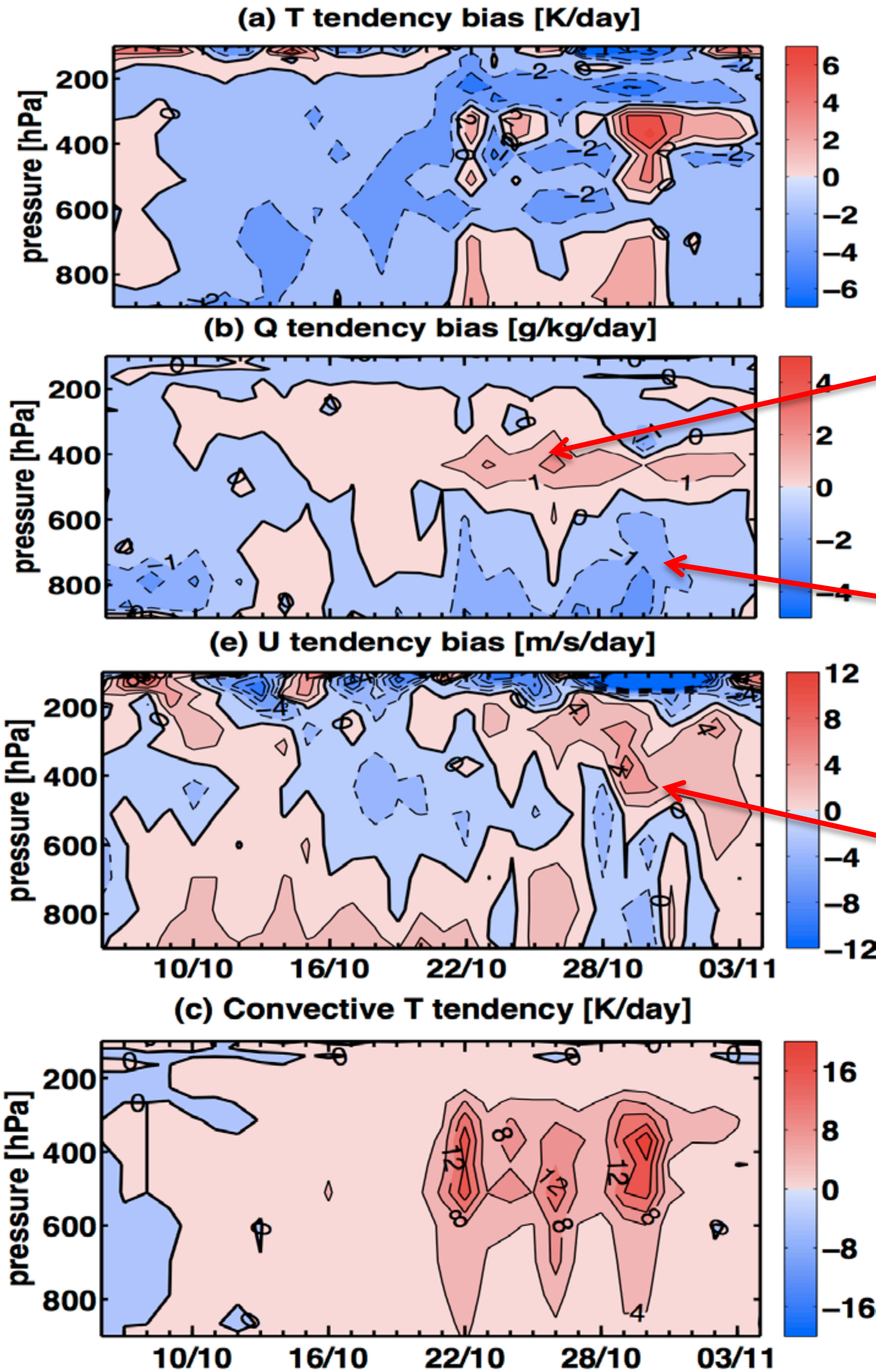
Weakest MJO precip

It is important to get the wind fields right



Diabatic Heating due to Moist Processes
Pressure (hPa)
100
200
300
400
500
600
700
800
900
0
5
10
15
20
Diabatic Heating Tendency (K/day)
ALLVAR
NOHUM
NOTEMP
NOVEL
ONLYHUM
ONLYTEMP
ONLYVEL

Nudging all fields

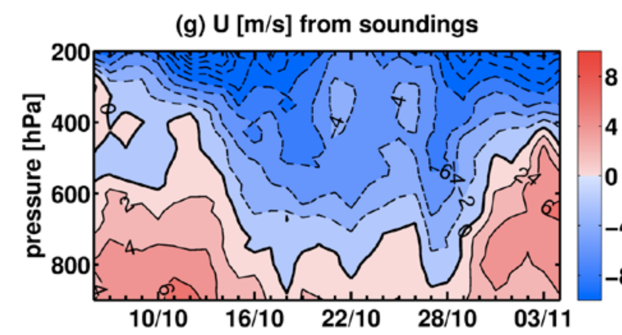


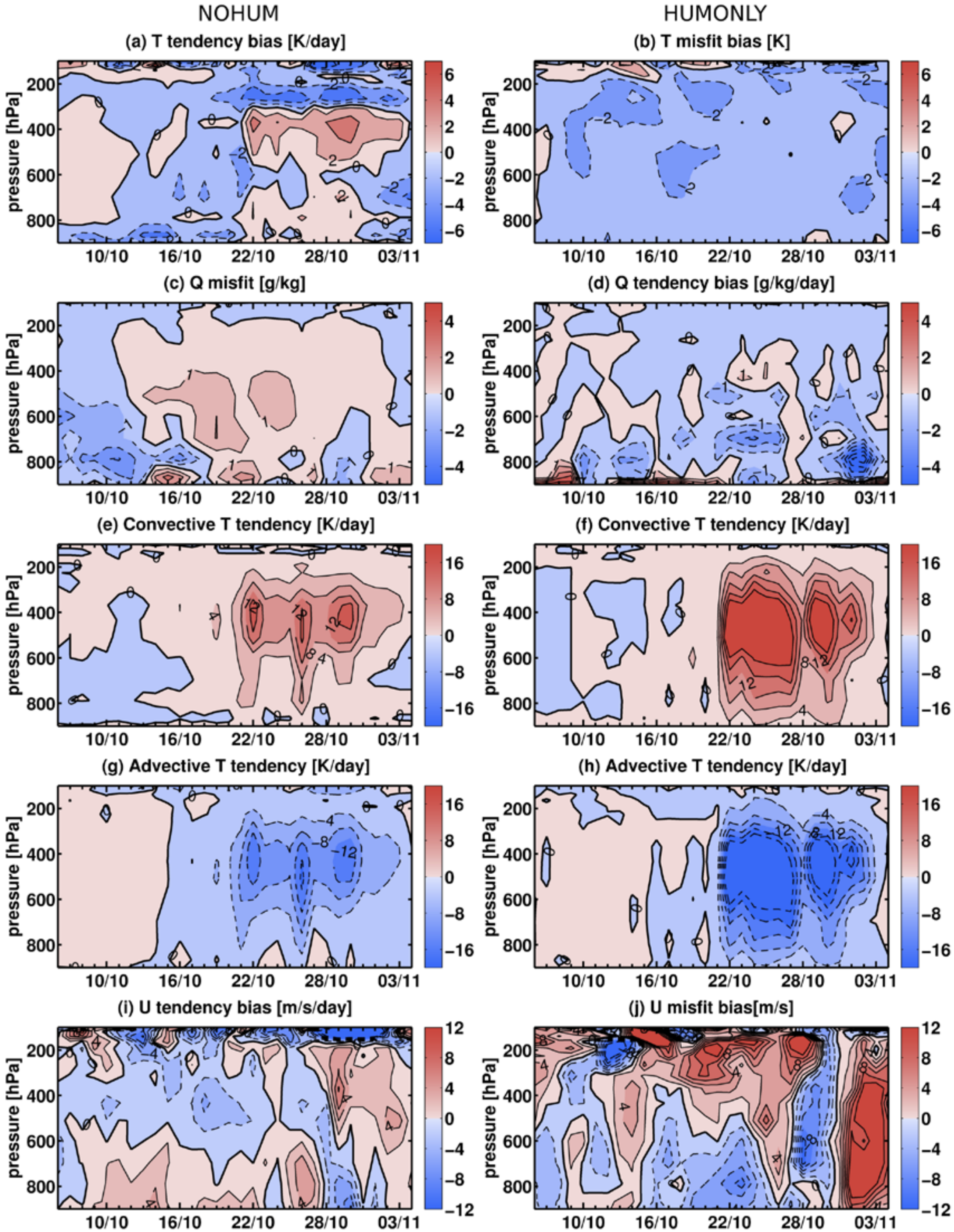
Too little condensation in the upper level

too little evaporation in the lower levels during active MJO convection (10/22-31).

Too much vertical transport of zonal momentum by convection.

Observed u

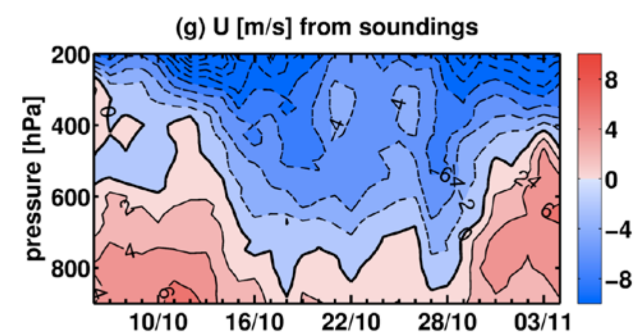


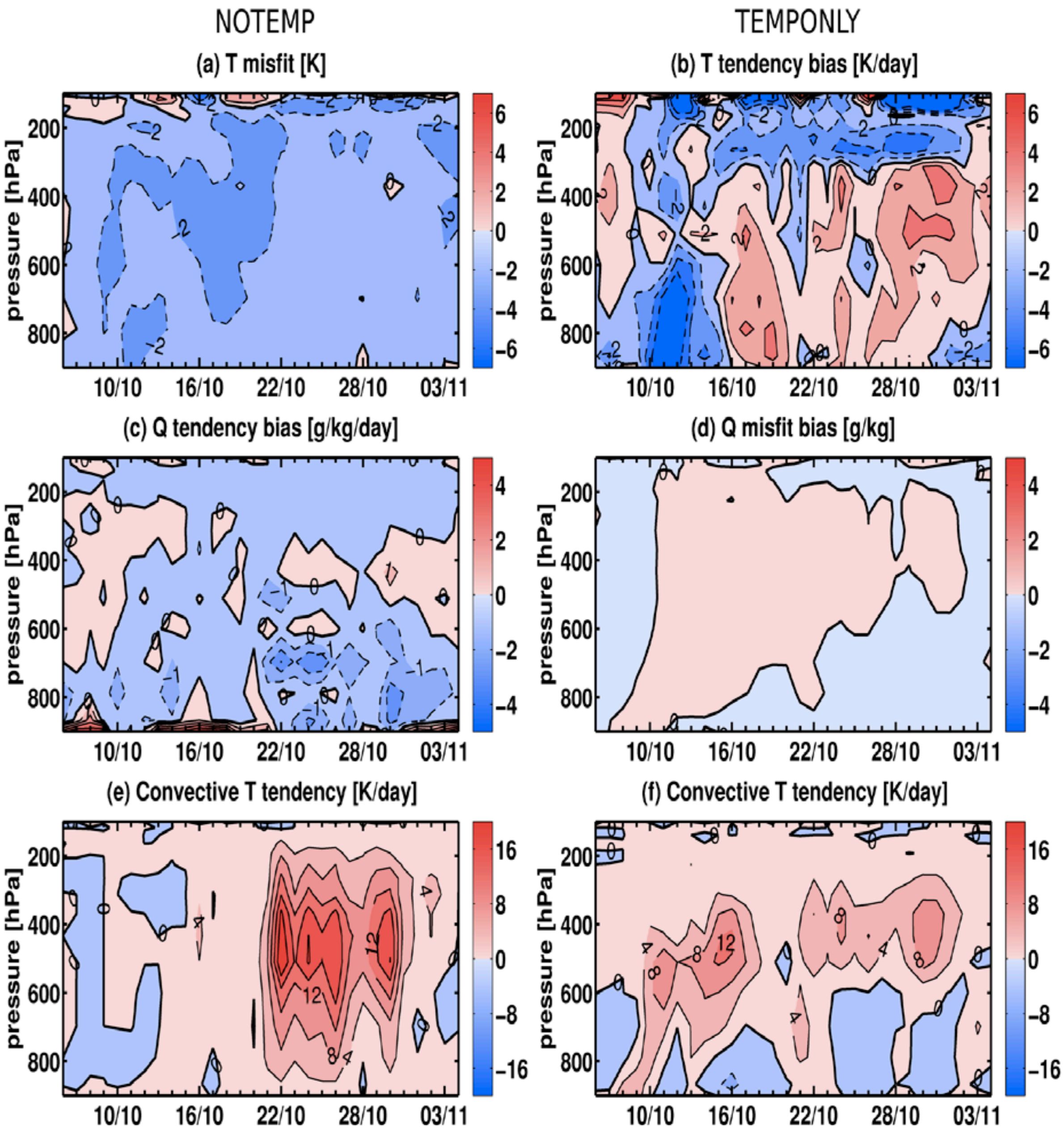


No humidity nudging is about the same as nudging all fields.

If only humidity is nudged, convection is too strong, and the atmosphere is too cold.

Observed u

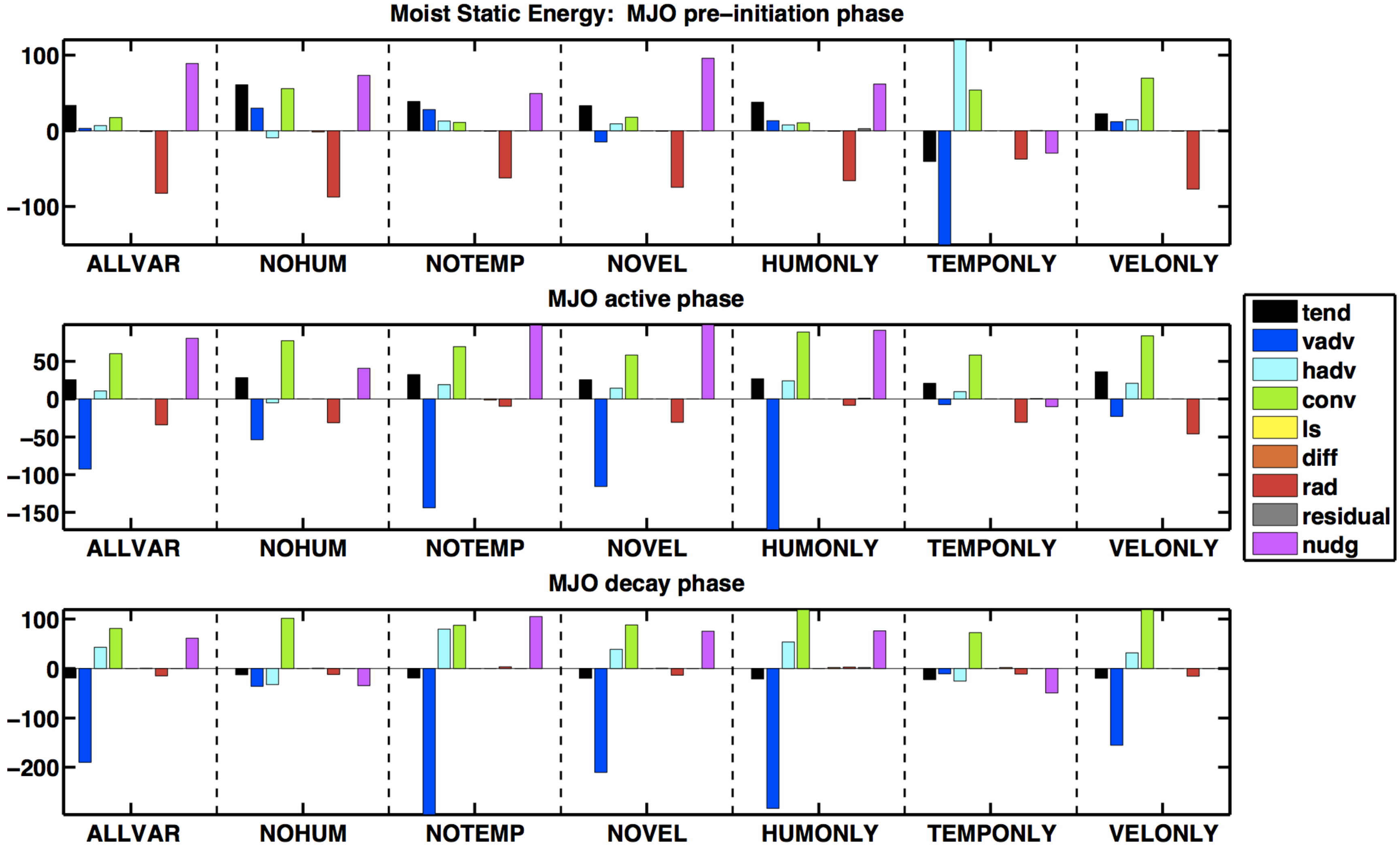


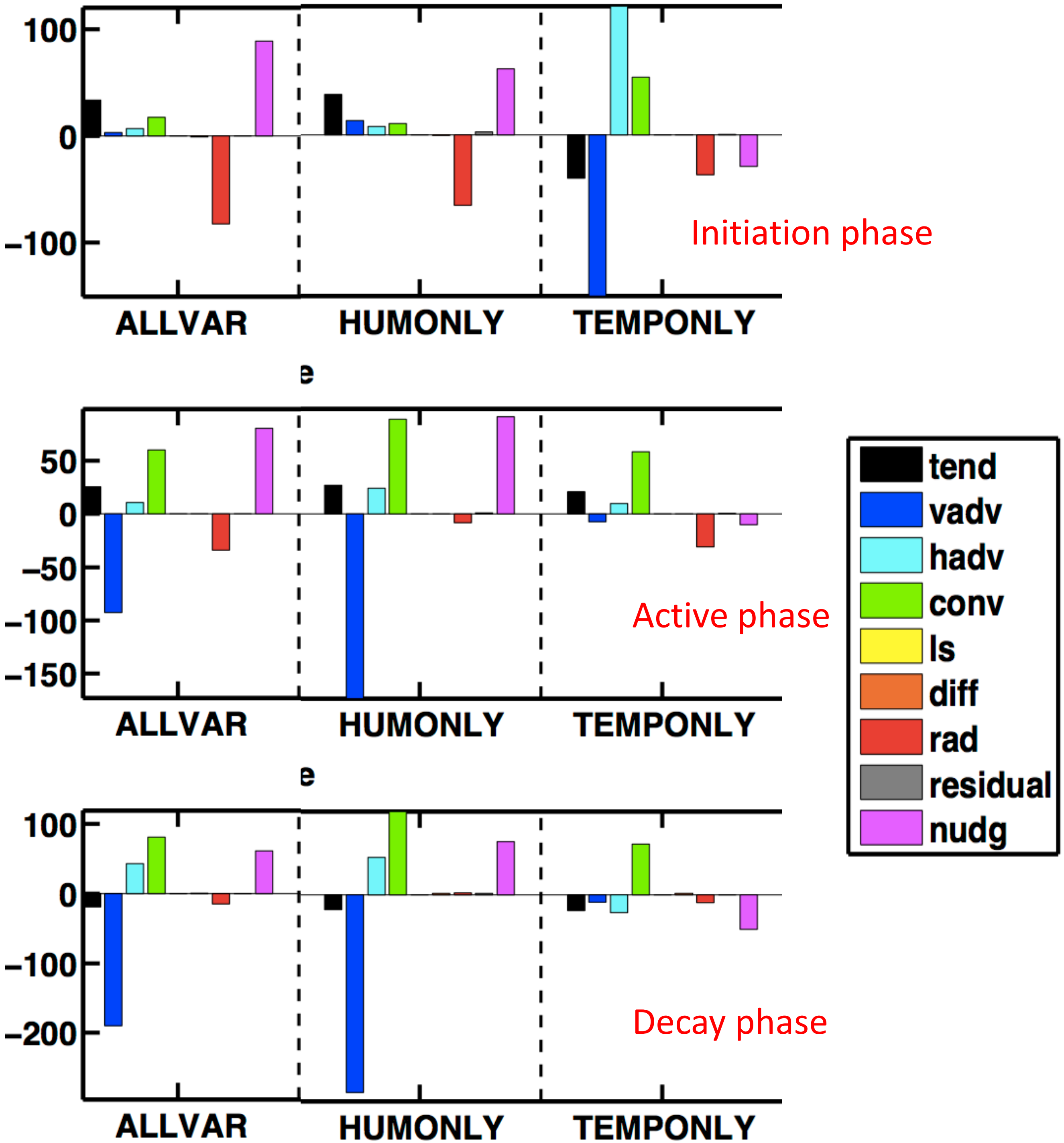


Without T nudging the atmosphere is too cold prior to MJO initiation, but q tendency shows smaller biases

With T nudging only, q biases are small, but convection starts too early

$$\underbrace{<h_t>}_{\text{tendency}} = -\underbrace{<v.\nabla h>}_{\text{advection}} + \underbrace{<h_{conv}>}_{\text{convective tendency}} + \underbrace{<h_{ls}>}_{\text{largescale tendency}} + \underbrace{<h_{diff}>}_{\text{diffusive tendency}} + \underbrace{<h_{rad}>}_{\text{radiative tendency}} + \underbrace{<h_{nud}>}_{\text{nudging tendency}}$$





100
0
−100
ALLVAR
HUMONLY
TEMPONLY
Initiation phase
e
50
0
−50
−100
−150
ALLVAR
HUMONLY
TEMPONLY
Active phase
e
100
0
−100
−200
ALLVAR
HUMONLY
TEMPONLY
Decay phase
tend
vadv
hadv
conv
ls
diff
rad
residual
nudg

Summary

- The initiation of the Oct. MJO is well captured by the CAM3 model; however, the propagation is too fast.
- The nudging experiments show that getting the wind fields right is the most important in the Oct. MJO hindcast.
- When T, q, u and v are all nudged, in the decaying phase of the MJO there is too little condensation in the upper troposphere and too little evaporation in the lower troposphere, indicative of too little stratiform cloud processes.
- There is too much downgradient vertical transport of zonal wind by convection.