Linking AIRS Water Vapor to Remote-Sensing Precipitation and Surface Evaporation: A Way to Understand Global Hydrological Cycle

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Collaborators: Eric Fetzer, Brian Kahn, Baijun Tian, William Olson, Tristan L'Ecuyer, Ju-Mee Ryoo, Xianan Jiang, Bjorn Lambrigtsen

(AIRS Science Team Meeting, April 2011)

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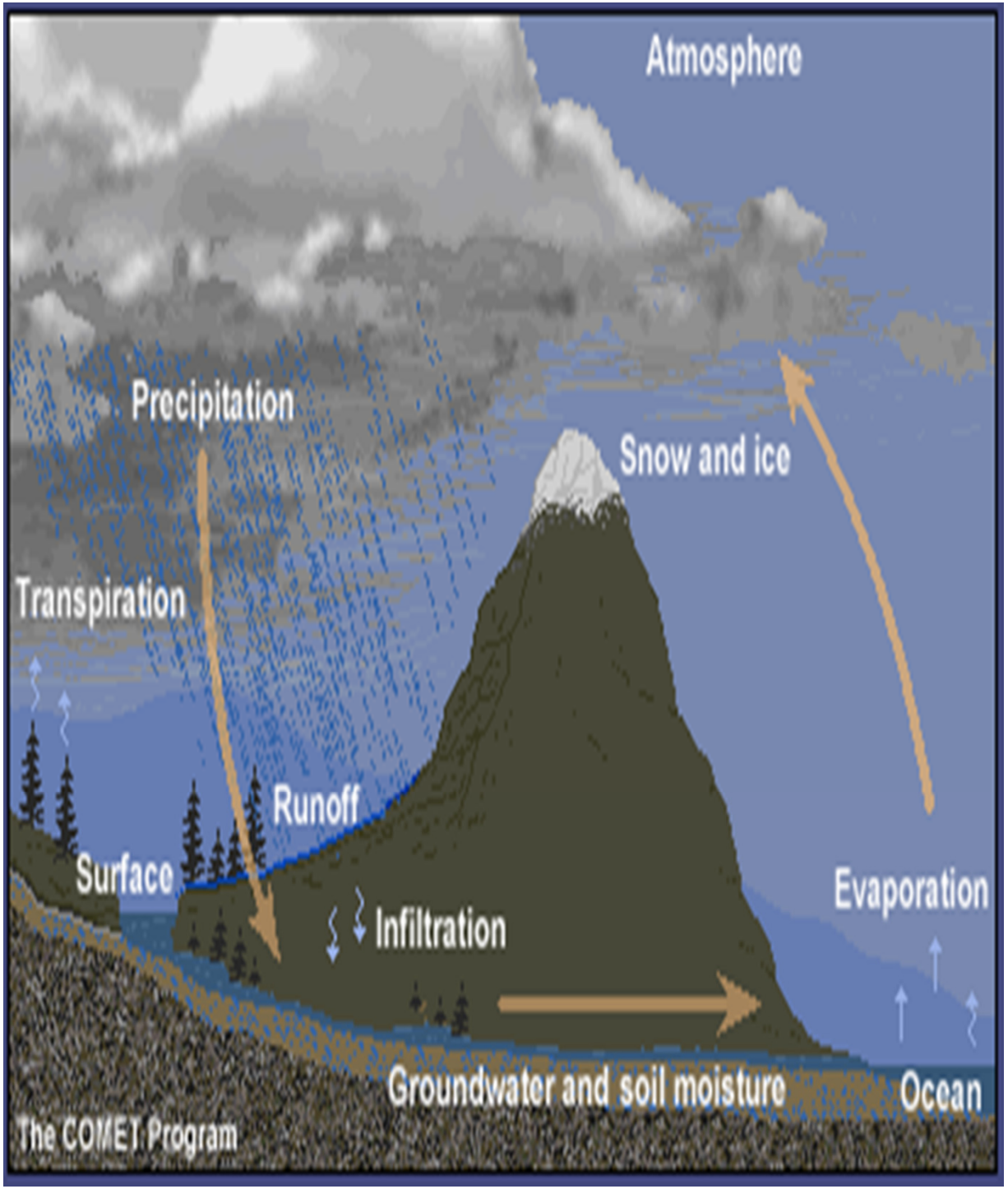

Precipitation:

TRMM, GPCP,…
MERRA, ECMWF,…

Surface evaporation:

GSSTF2b, OAFlux, …
MERRA, ECMWF….

Atmospheric water:

AIRS, IASI q retrievals,
MERRA, ECMWF

Question to Ask

- Are these independent estimates of components of hydrological cycle physically consistent with each others?

Local Balance for Hydrological Cycle (Yanai et al., 1973)

$$S = -(\partial[q]/\partial t + [u]\cdot\partial[q]/\partial x + [v]\cdot\partial[q]/\partial y + [\omega]\cdot\partial[q]/\partial p)$$

$$= C - E + \partial[\omega' q']/\partial p$$

q: AIRS specific humidity (g/kg)
x, y, p: longitude, latitude, pressure coordinates
[ ] : averaged over a 10°×5° grid
u, v, ω: winds from GEOS5 MERRA
E, C, $-\partial[\omega' q']/\partial p$: Evaporation, Condensation, eddy term
S : In literature, it's related to Q2

$$\int S \cdot dp/g = \int (C - E + \partial[\omega' q']/\partial p) \cdot dp/g$$

$$\approx \text{Precipitation} - \text{Surface Evaporation}$$

Local Balance for Hydrological Cycle

$\int S \cdot dp/g \approx$ Precipitation – Surface Evaporation

S : AIRS q profiles and MERRA or other reanalaysis winds

Precipitation: TRMM 3B42 (Huffman, 2007)

Surface Evaporation: GSSTF2b (Shie et al., 2009; Chou et al., 2003)

What to Test?

- Seasonal Climatologies of hydrological cycle (J. Climate under review)

- All-time scale variability of P–E

- Processes:

Indian Monsoon (Wong et al., 2011, J. Climate)

Atmospheric Rivers (on-going research)

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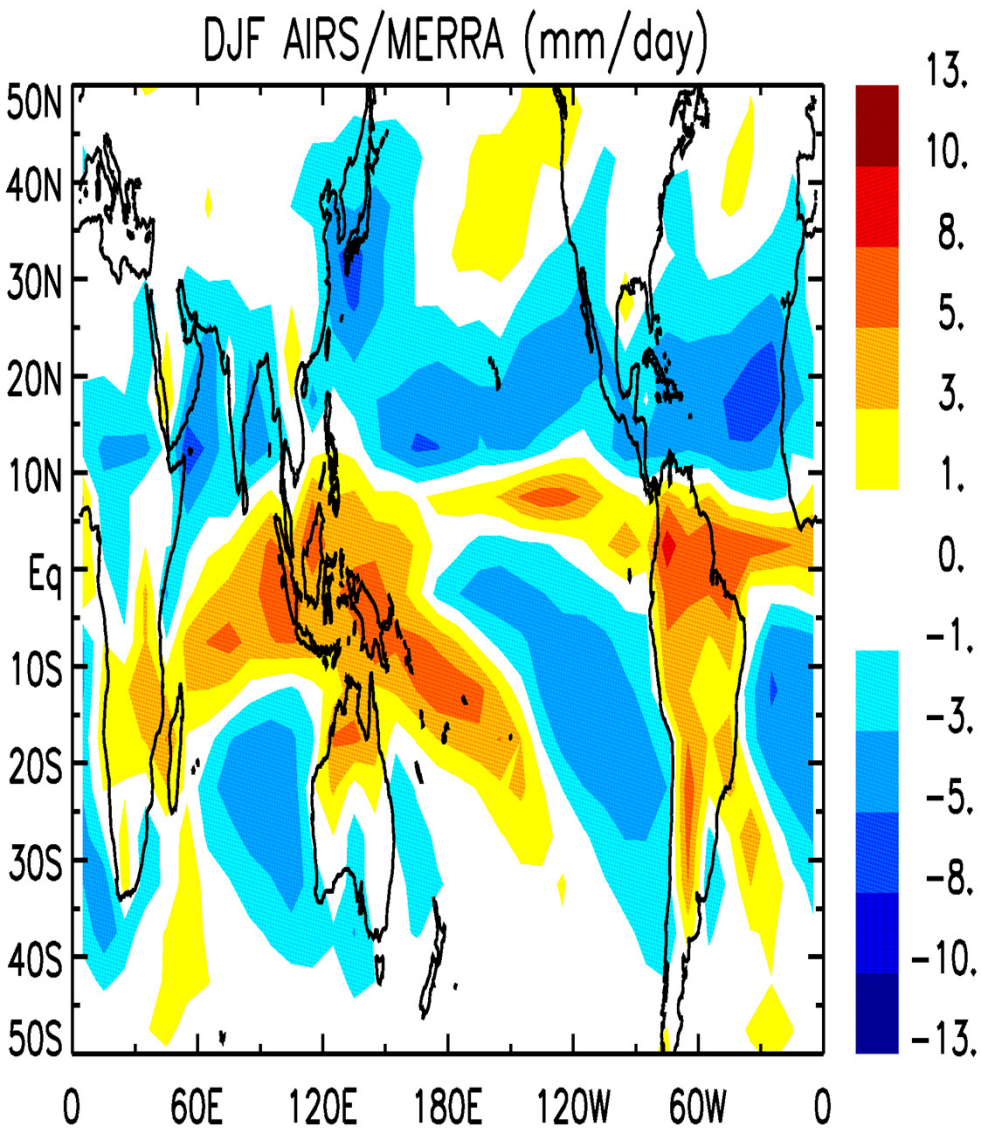
Seasonal Climatologies of ∫Sdp/g
(AIRS q + MERRA winds)

Winter 2004-2008



Seasonal Climatologies of ∫Sdp/g
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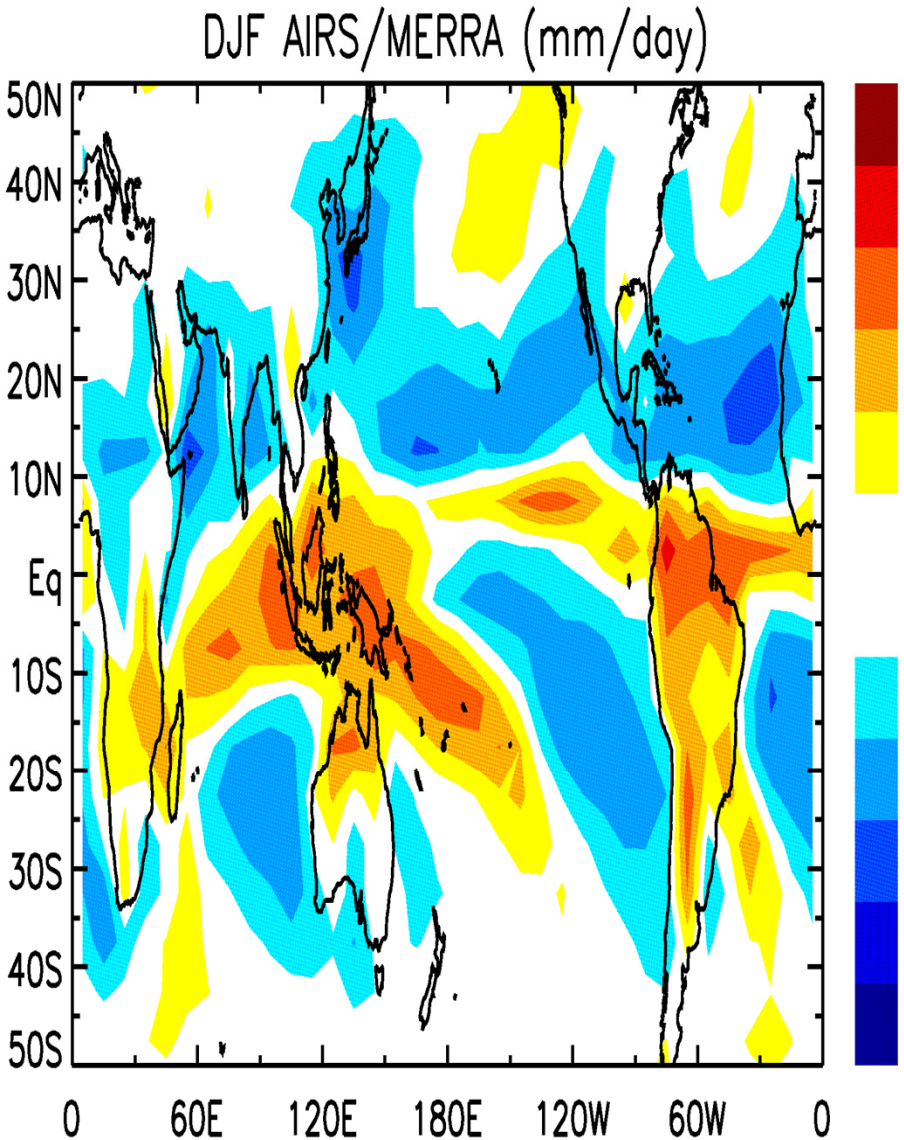
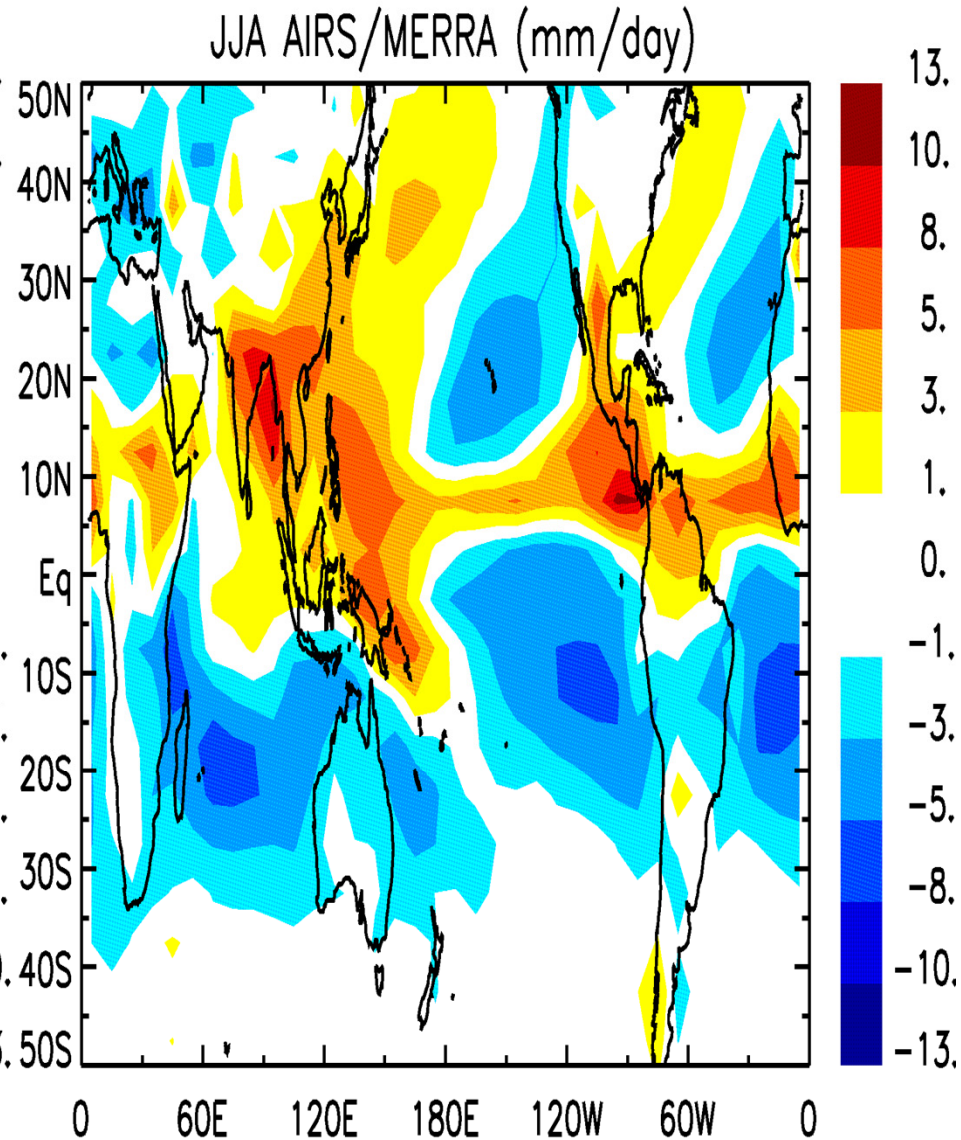
Winter 2004-2008



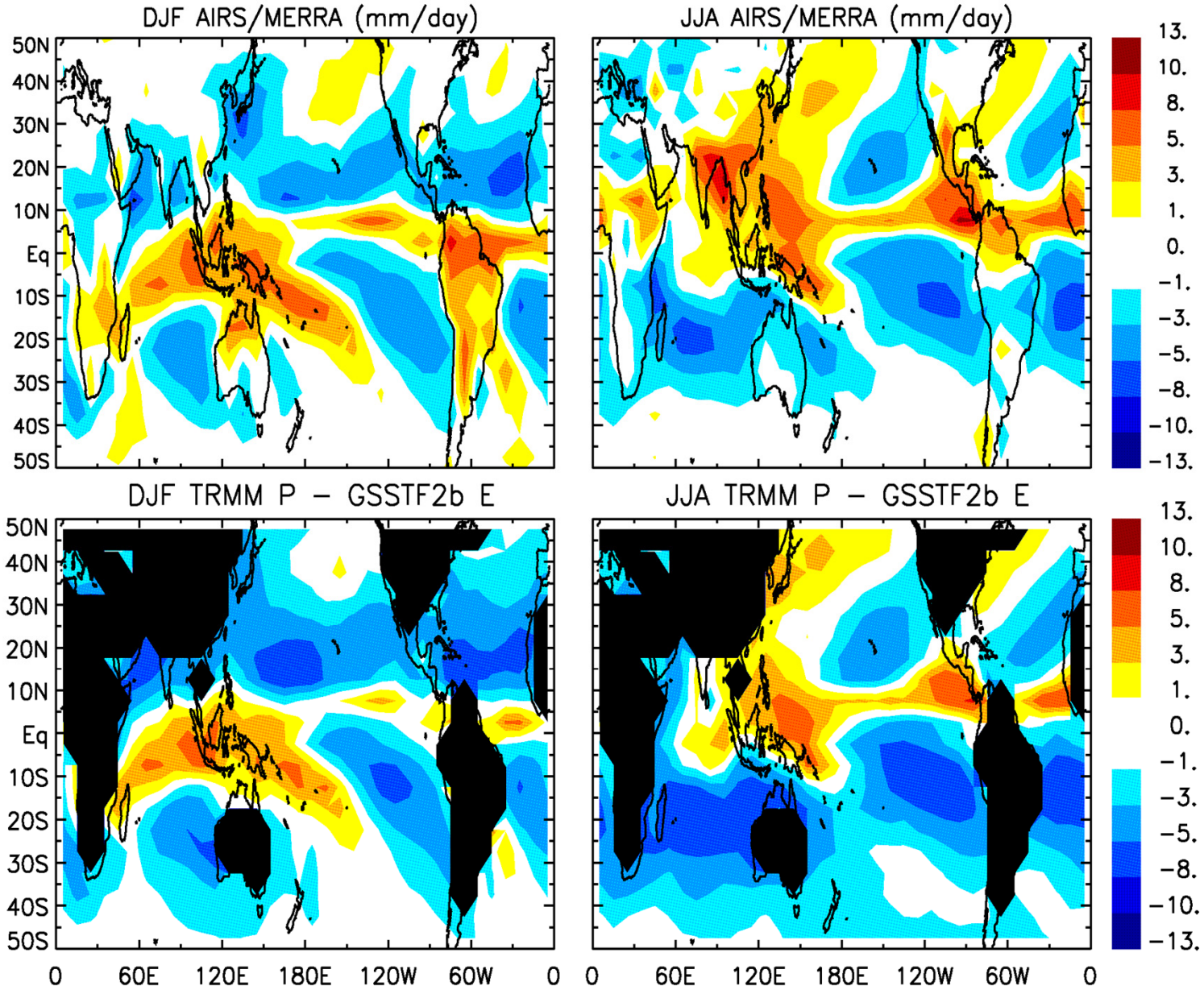
Summer 2004-2008



Comparison of ∫Sdp/g with P–E

Winter 2004-2008

Summer 2004-2008



∫Sdp/g

AIRS q
MERRA winds

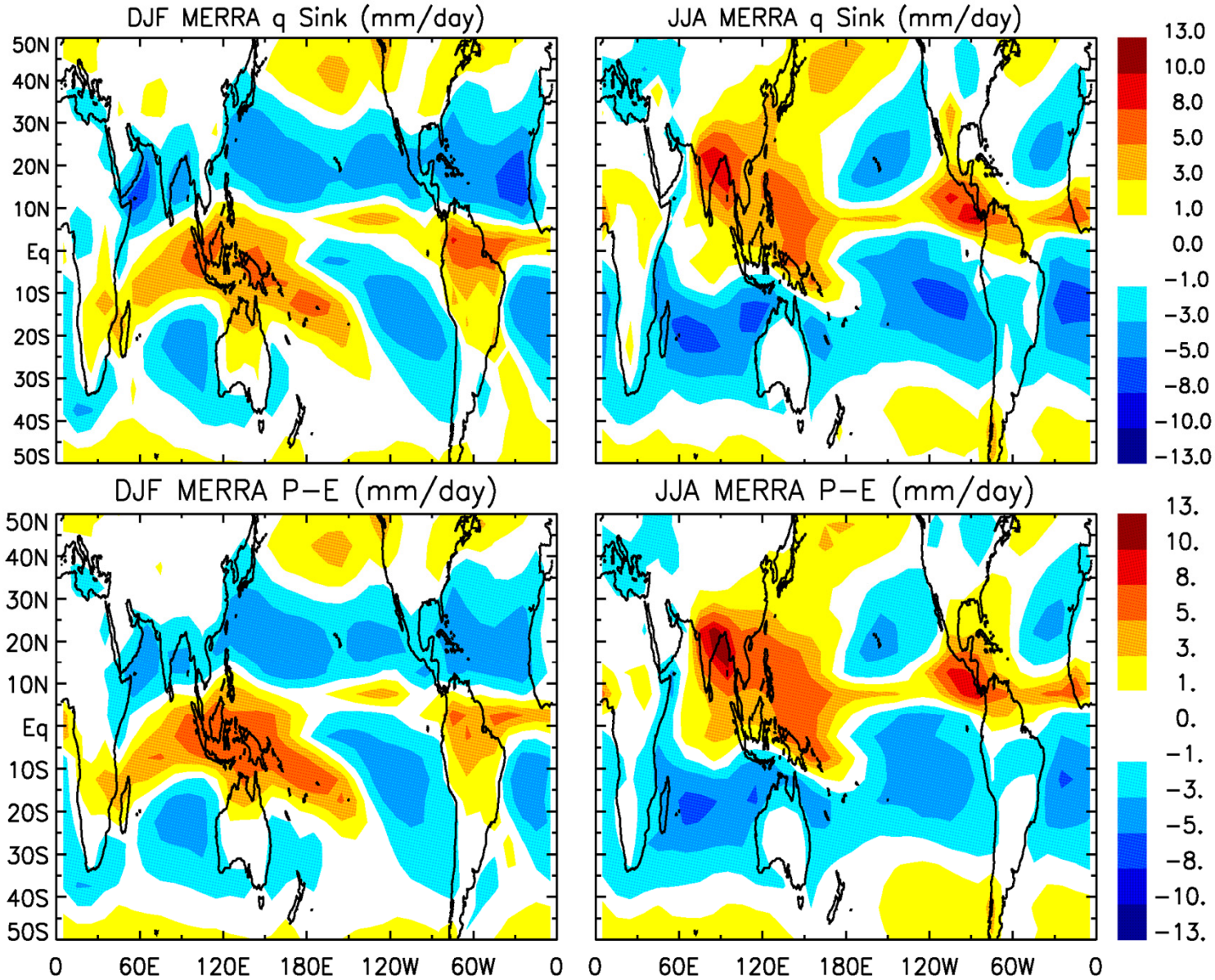
P–E

P: TRMM 3B412

E: GSSTF2b

Comparison of ∫Sdp/g with P–E for the MERRA

Winter 2004-2008 Summer 2004-2008



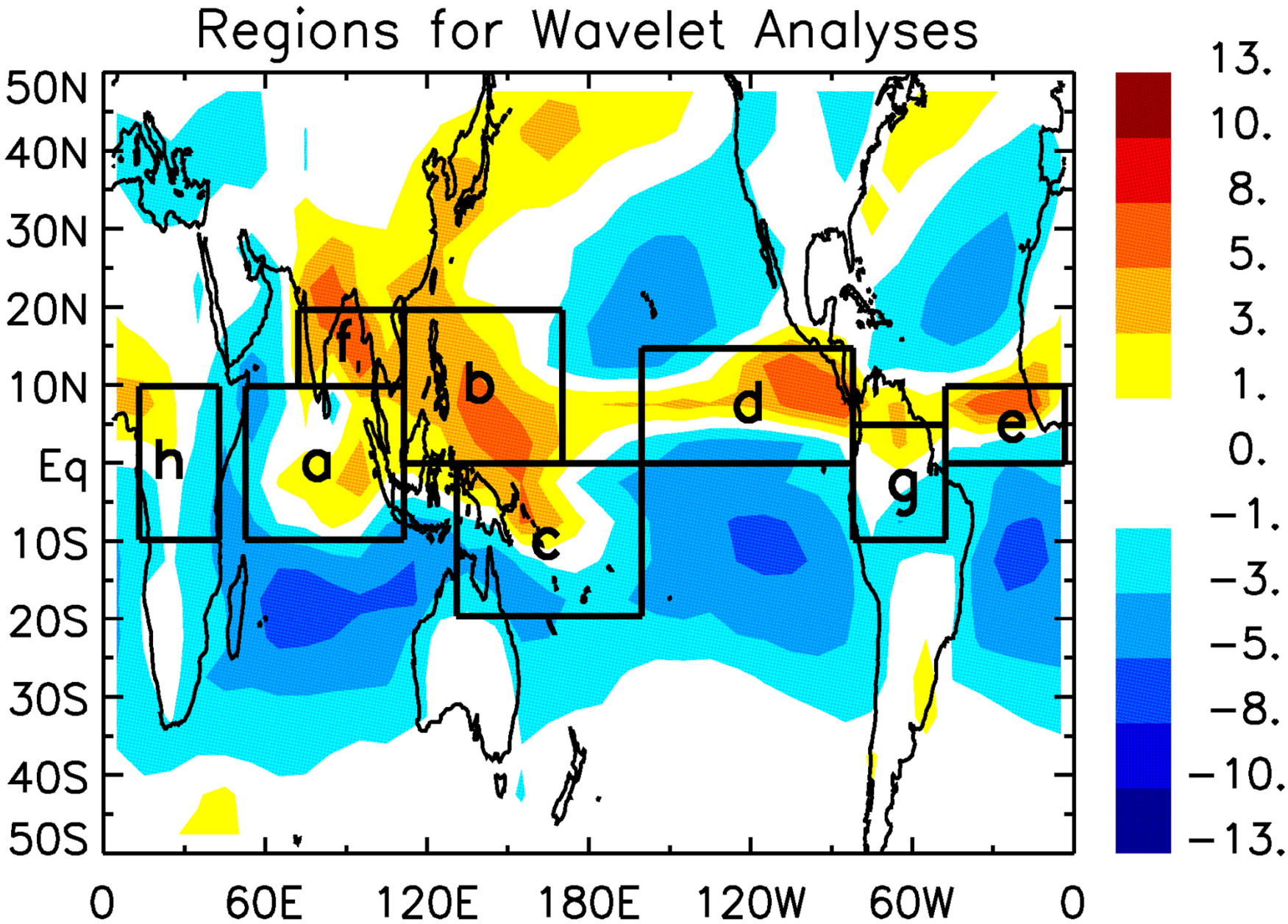
∫Sdp/g

MERRA q budget

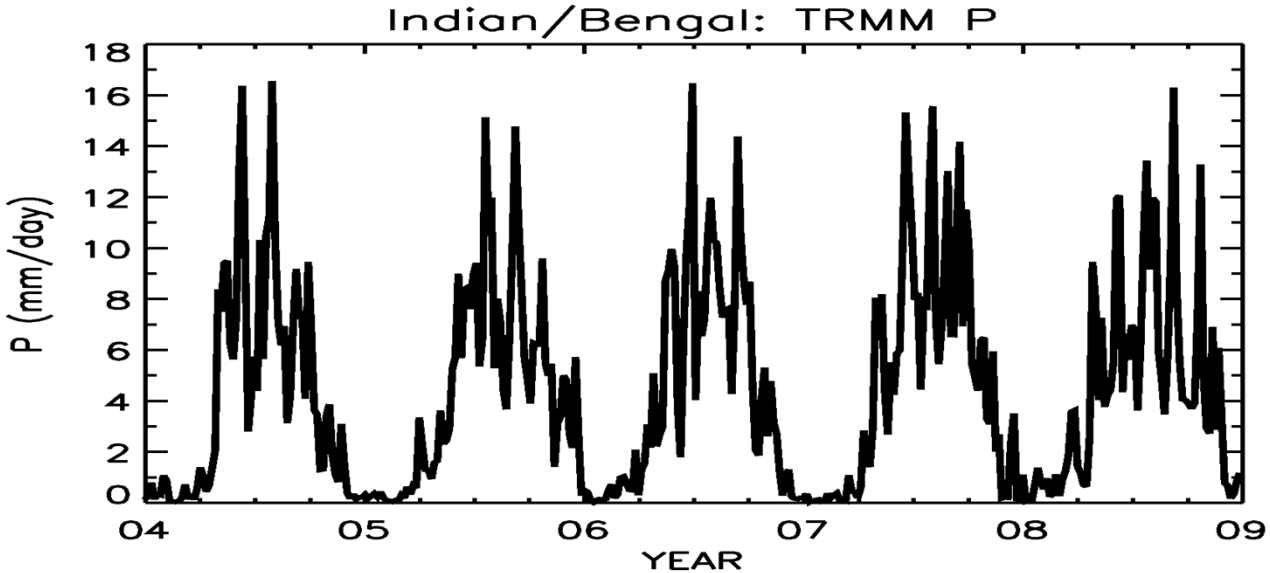
P–E

MERRA P and E modules

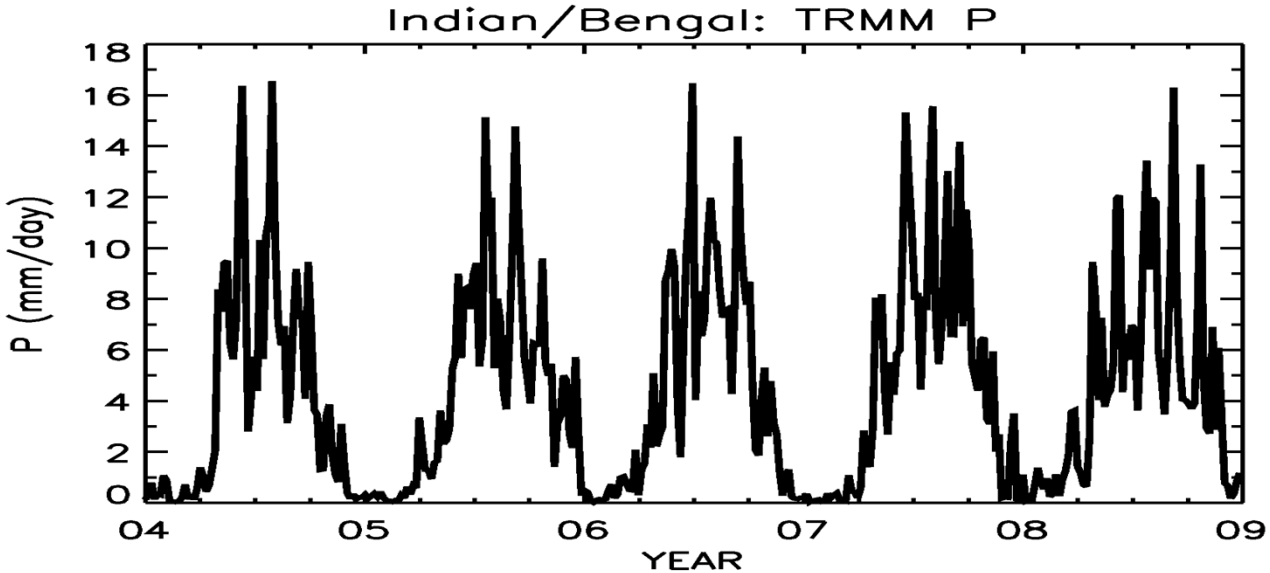
All Time-Scale Variability

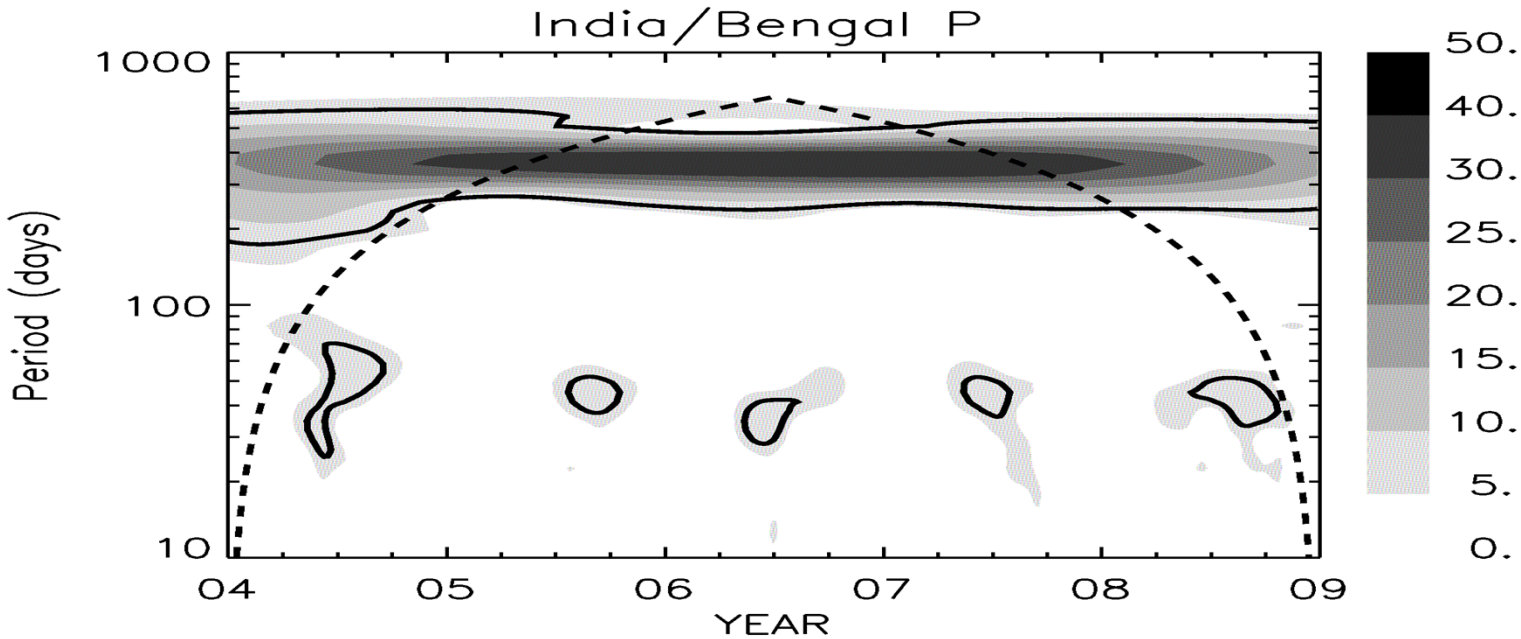


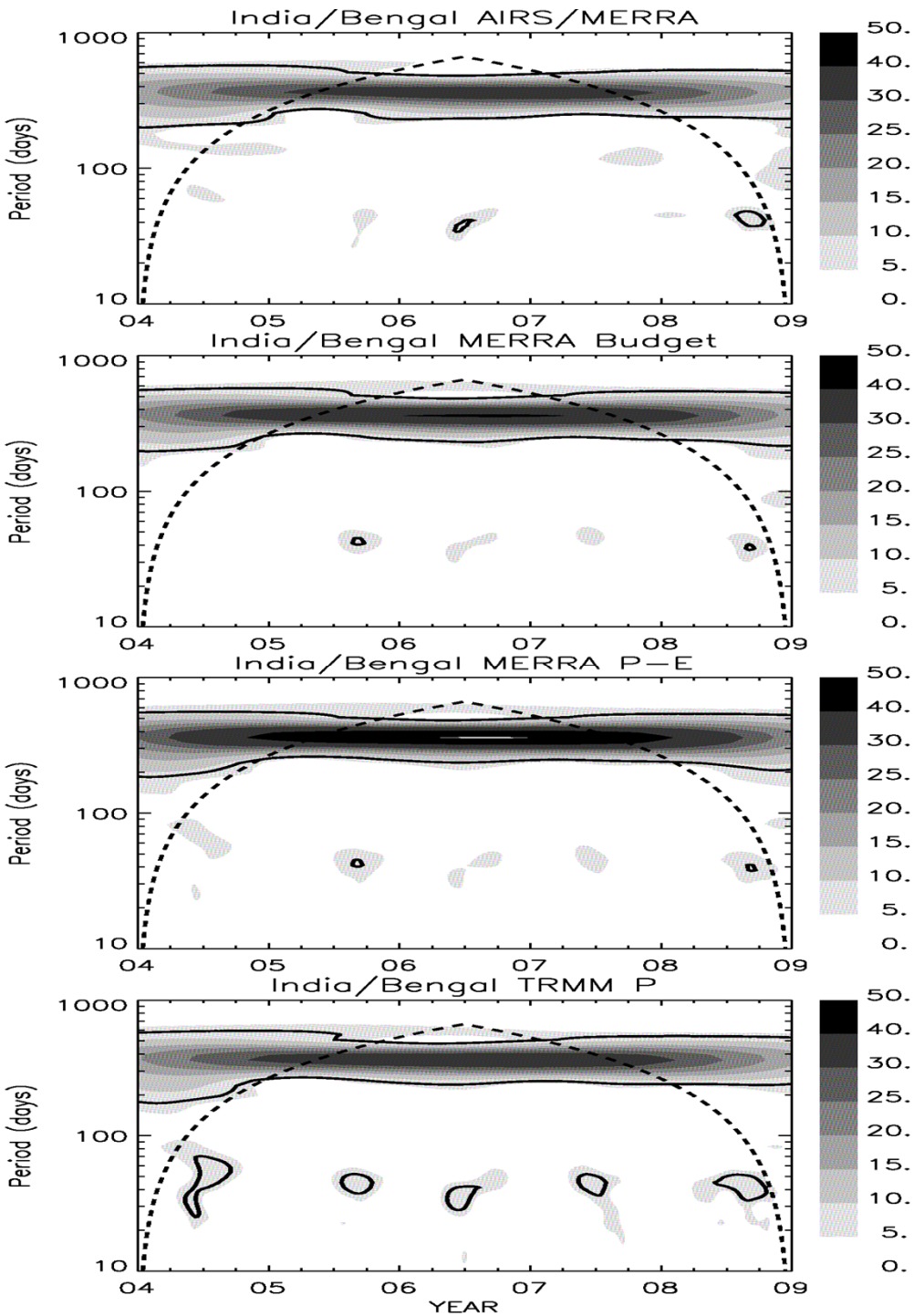
Indian Continent and Bay of Bengal Precipitation



Indian Continent and Bay of Bengal Precipitation







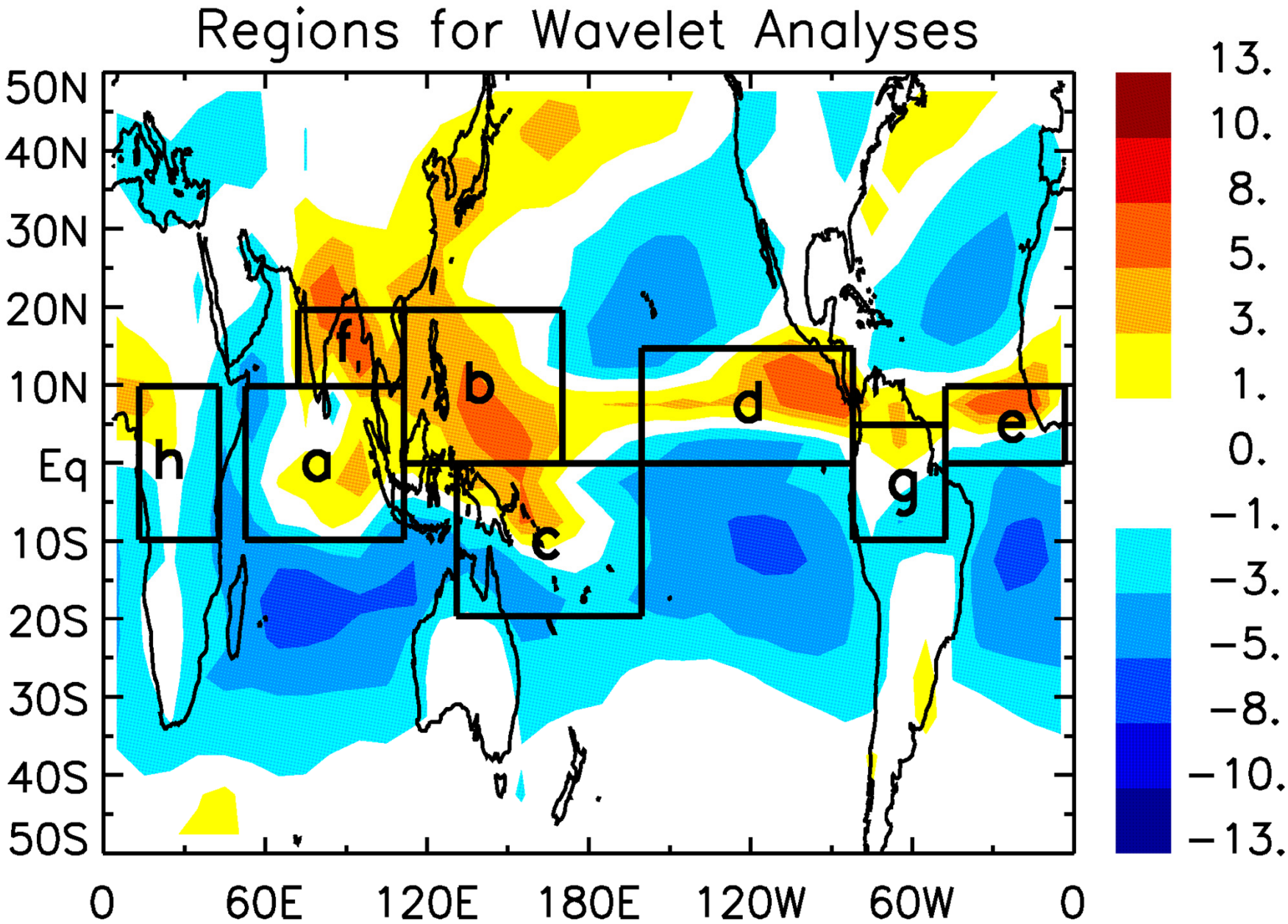
∫Sdp/g AIRS q and MERRA winds

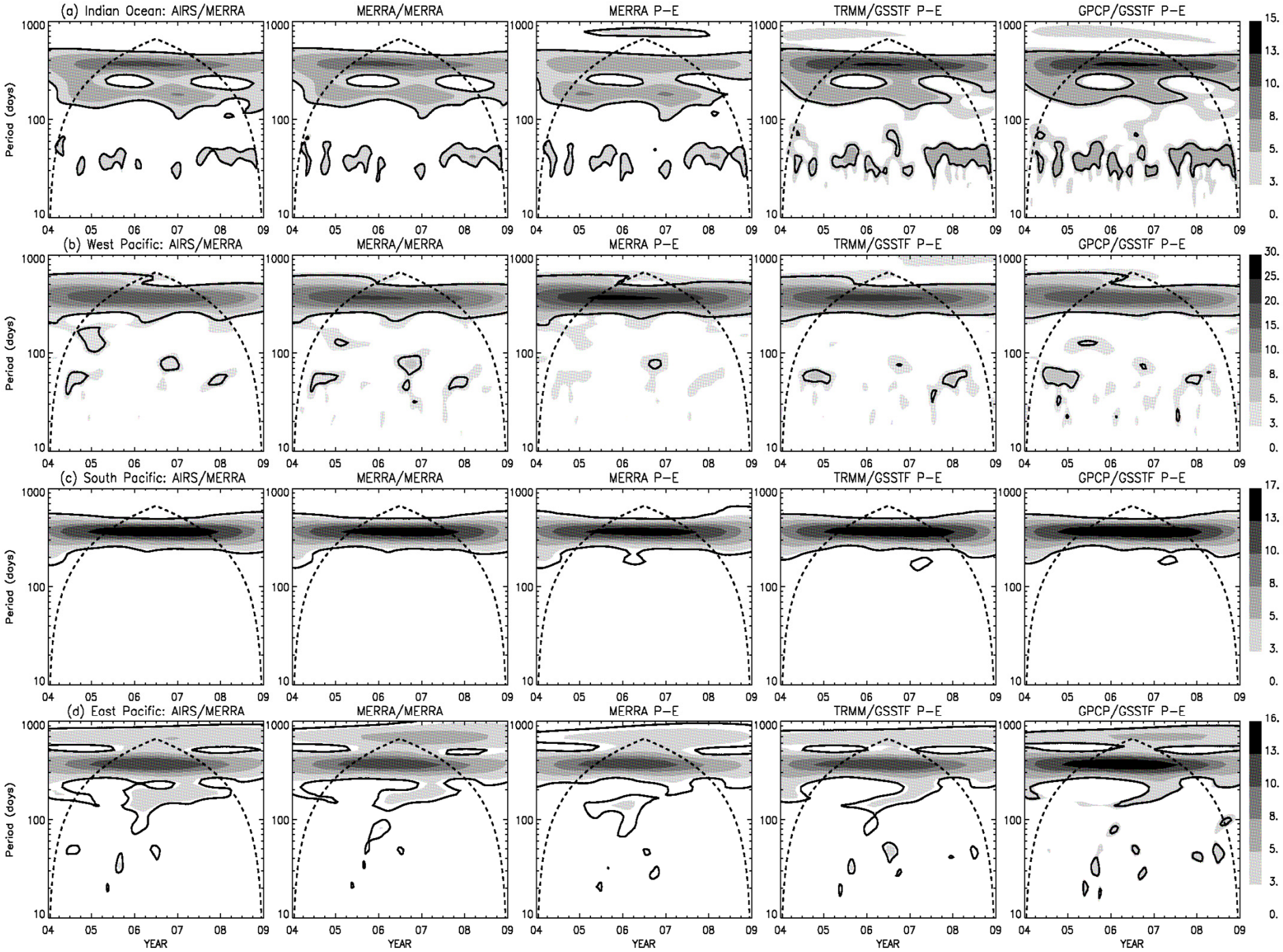
∫Sdp/g MERRA q budget

MERRA P–E

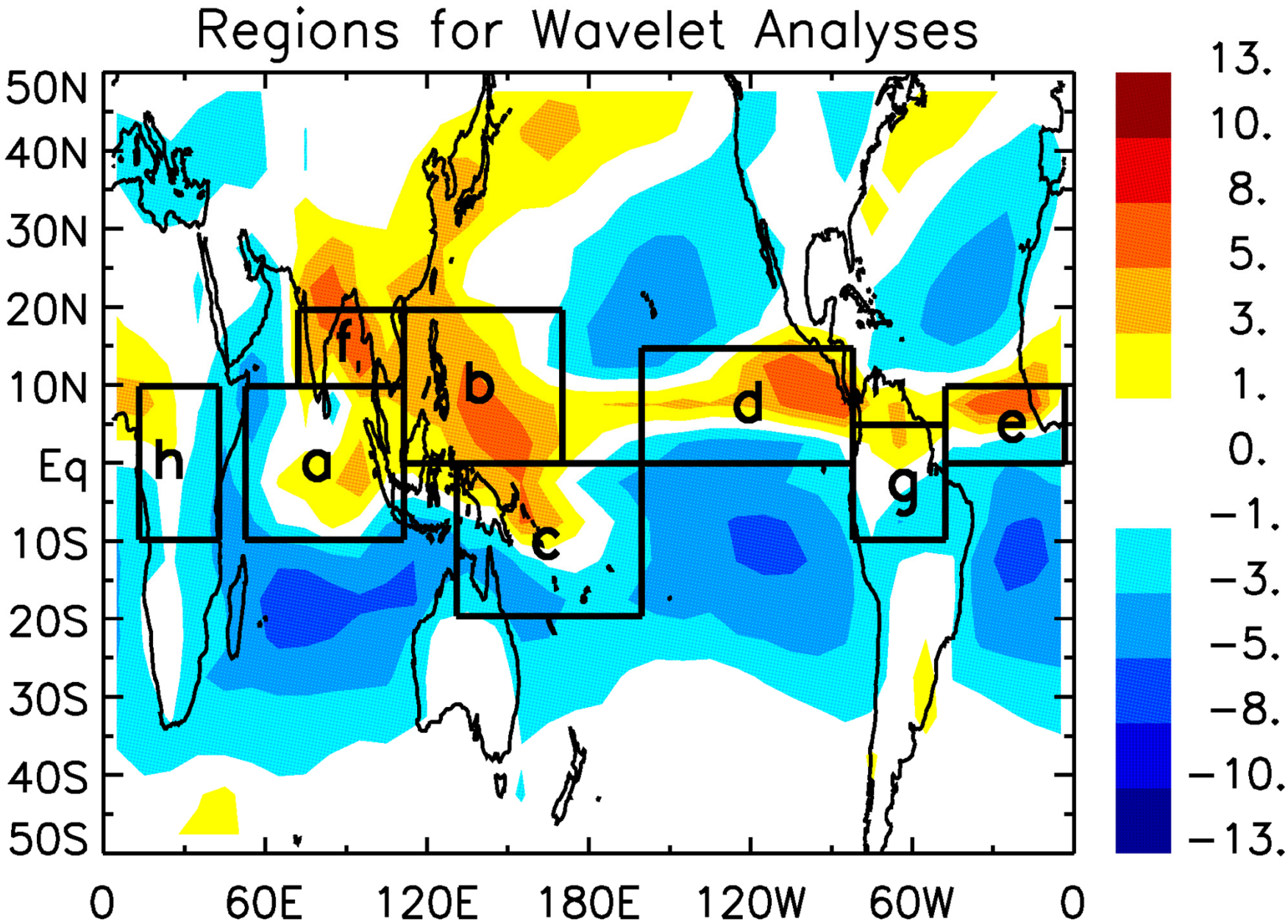
TRMM 3B42 P

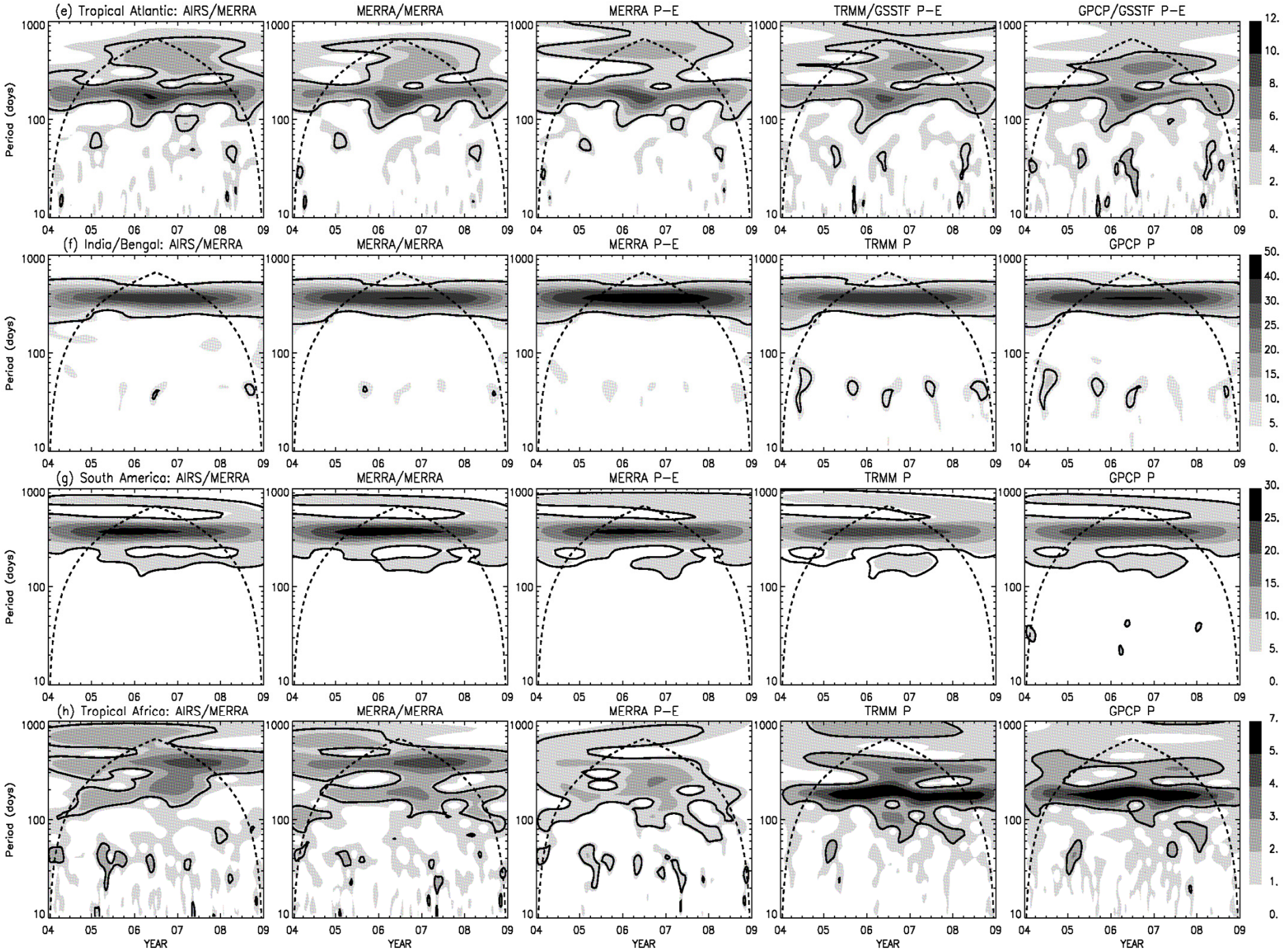
All Time-Scale Variability




(a) Indian Ocean: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM/GSSTF P−E
GPCP/GSSTF P−E
(b) West Pacific: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM/GSSTF P−E
GPCP/GSSTF P−E
(c) South Pacific: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM/GSSTF P−E
GPCP/GSSTF P−E
(d) East Pacific: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM/GSSTF P−E
GPCP/GSSTF P−E
Period (days)
1000
100
10
04
05
06
07
08
09
YEAR
15.
13.
10.
8.
5.
3.
0.
30.
25.
20.
17.
16.

All Time-Scale Variability




(e) Tropical Atlantic: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM/GSSTF P−E
GPCP/GSSTF P−E
(f) India/Bengal: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM P
GPCP P
(g) South America: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM P
GPCP P
(h) Tropical Africa: AIRS/MERRA
MERRA/MERRA
MERRA P−E
TRMM P
GPCP P
Period (days)
YEAR
1000
100
10
04
05
06
07
08
09
12.
10.
8.
6.
4.
2.
0.
50.
40.
30.
25.
20.
15.
10.
5.
0.
30.
25.
20.
15.
10.
5.
0.
7.
5.
4.
3.
2.
1.
0.

Conclusions:

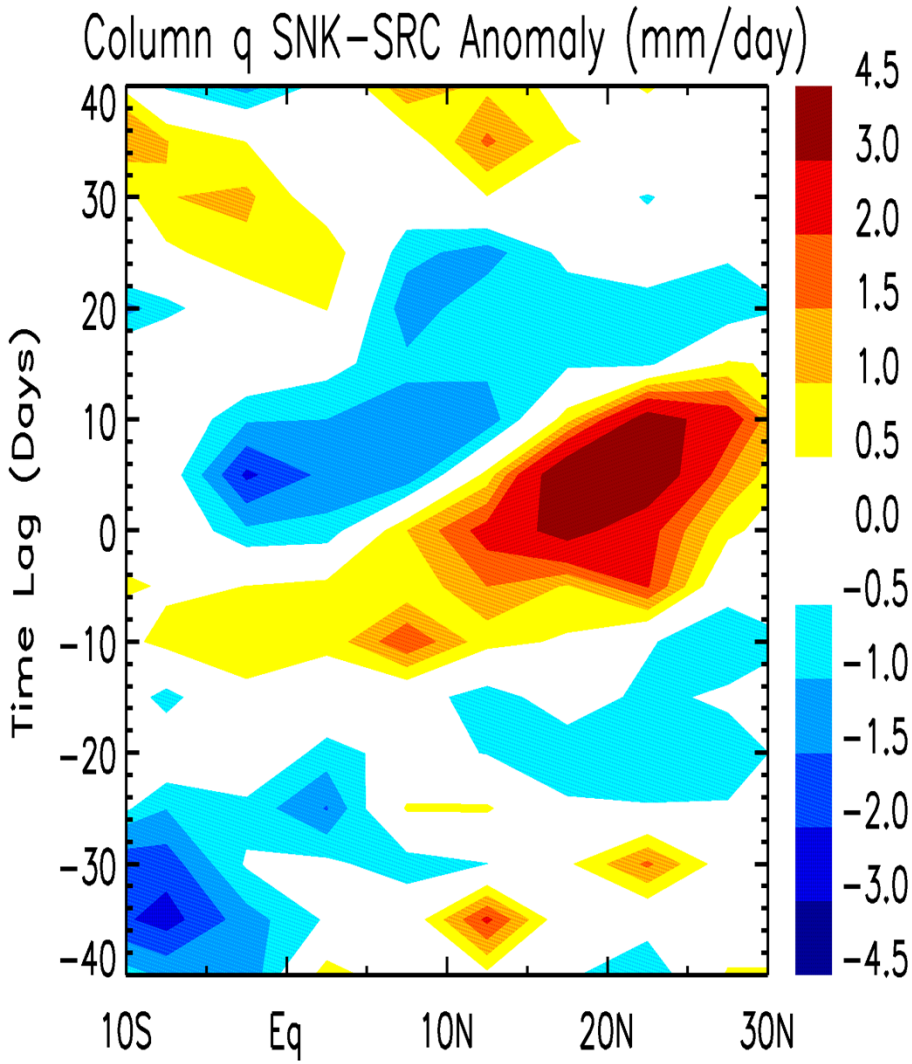
- AIRS q combined with the MERRA or ECMWF winds reproduces reasonable climatologies of P–E, compared to TRMM 3B42, GPCP, and GSSTF2b

- agreeable pattern of wavelet spectra over the ITCZ, martime continents, and Indian continent, but underestimates the intraseasonal time-scale variability

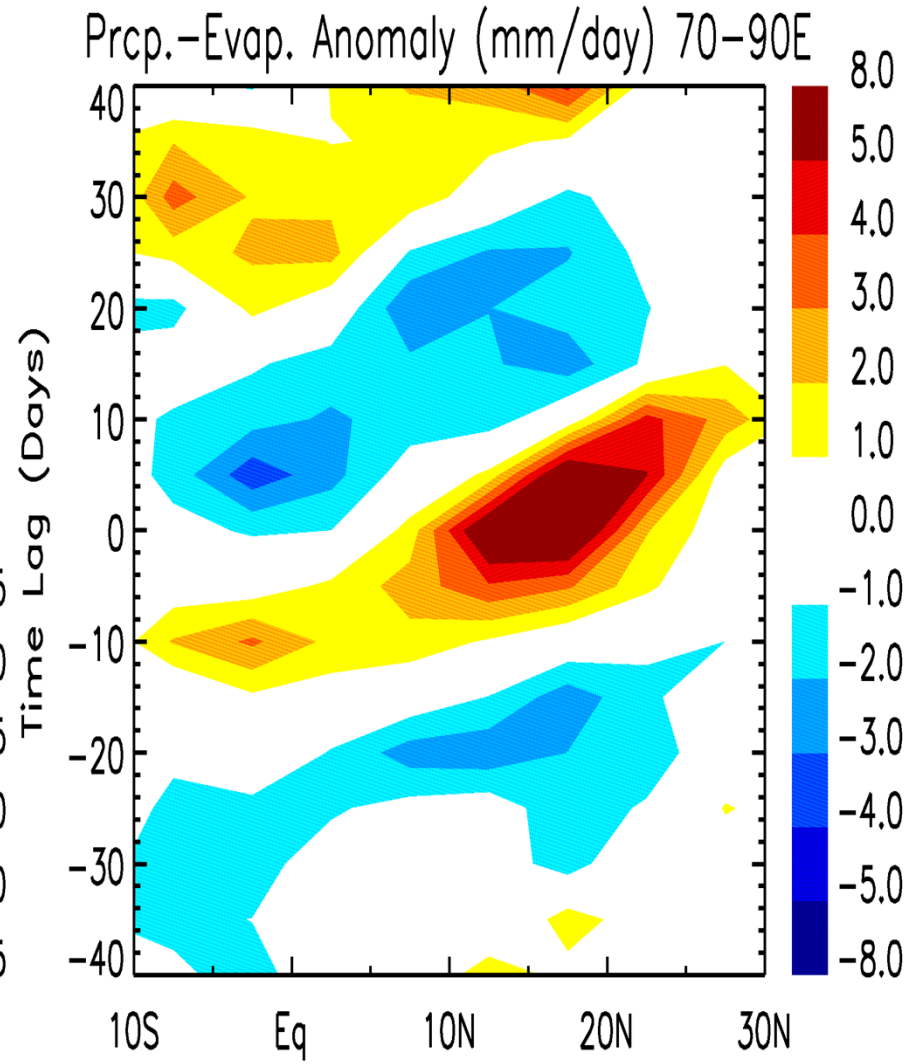
- wavelet spectra of AIRS and MERRA dynamically calculated q sink do not agree with the retrieved P over the Tropical Africa

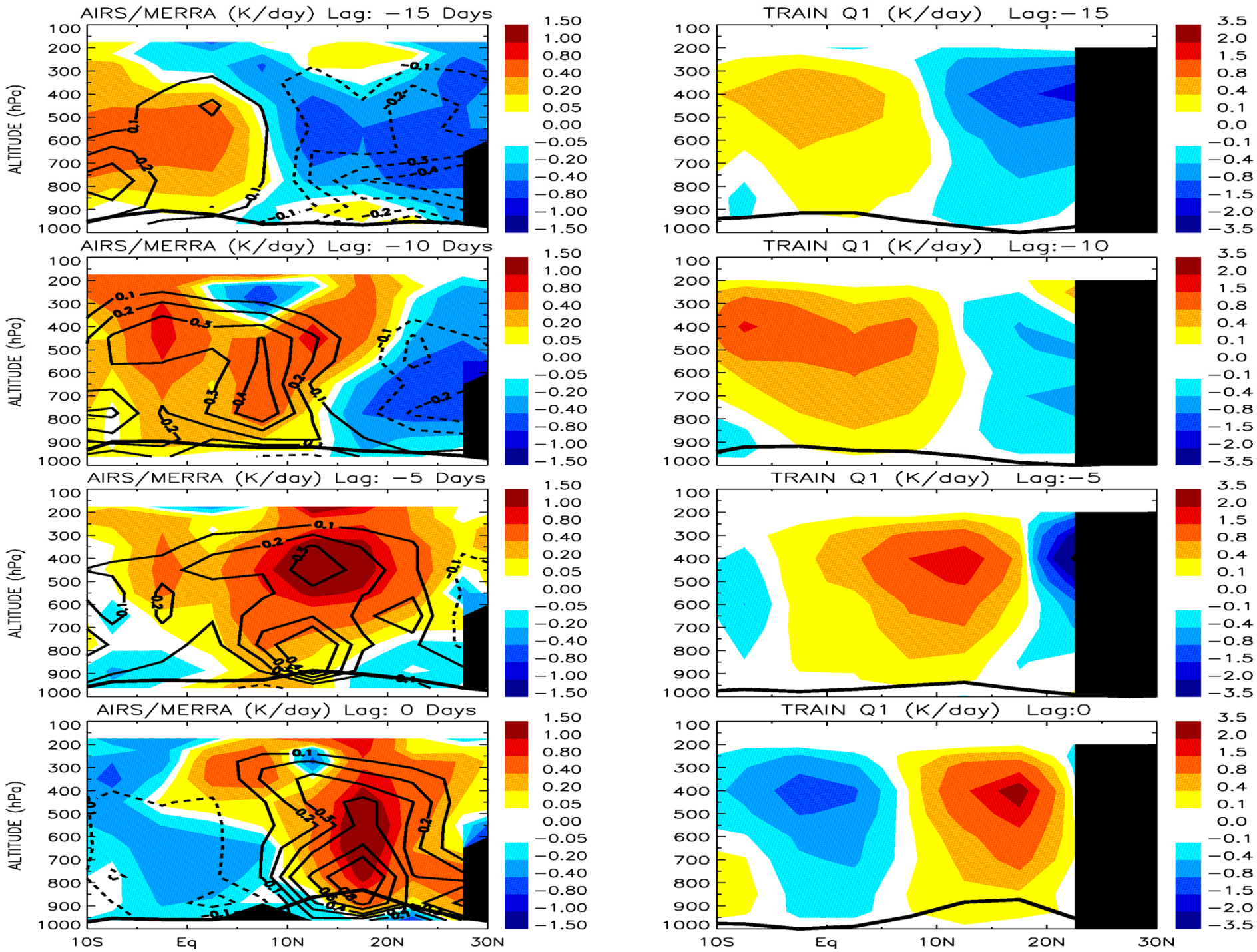
FFT Filter of Indian Precipitation 30-100 days
Hovmöller Diagram of Time Lag Composite of Anomalies

$-\int S \cdot dp/g$ from AIRS q and MERRA winds



TRMM 3b42 Precipitation –
OAFlux Surface Evaporation




AIRS/MERRA (K/day) Lag: −15 Days
AIRS/MERRA (K/day) Lag: −10 Days
AIRS/MERRA (K/day) Lag: −5 Days
AIRS/MERRA (K/day) Lag: 0 Days
TRAIN Q1 (K/day) Lag:−15
TRAIN Q1 (K/day) Lag:−10
TRAIN Q1 (K/day) Lag:−5
TRAIN Q1 (K/day) Lag:0
ALTITUDE (hPa)
100
200
300
400
500
600
700
800
900
1000
10S
Eq
10N
20N
30N
1.50
1.00
0.80
0.40
0.20
0.05
0.00
−0.05
−0.20
−0.40
−0.80
−1.00
−1.50
3.5
2.0
1.5
0.8
0.4
0.1
0.0
−0.1
−0.4
−0.8
−1.5
−2.0
−3.5

Local Balance for Hydrological Cycle

$\int S \cdot dp/g \approx$ Precipitation – Surface Evaporation

S : AIRS q profiles and MERRA or other reanalaysis winds

Precipitation: TRMM 3B42 (Huffman, 2007)

Surface Evaporation: GSSTF2b (Shie et al., 2009; Chou et al., 2003)

Local Balance for Atmospheric Energy Cycle

$\partial[T]/\partial t + [u]\cdot\partial[T]/\partial x + [v]\cdot\partial[T]/\partial y + [\omega]\cdot\partial[T]/\partial p - \kappa\omega T/p = Q1$ (diabatic heating)

L. H. S.: AIRS T retrievals, and MERRA winds

R. H. S.: TRAIN Q1 (L'Ecuyer and Stephens, 2007; Grecu and Olson, 2006)

What to Test?

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- All-time scale variability of P–E (J. Climate under review)

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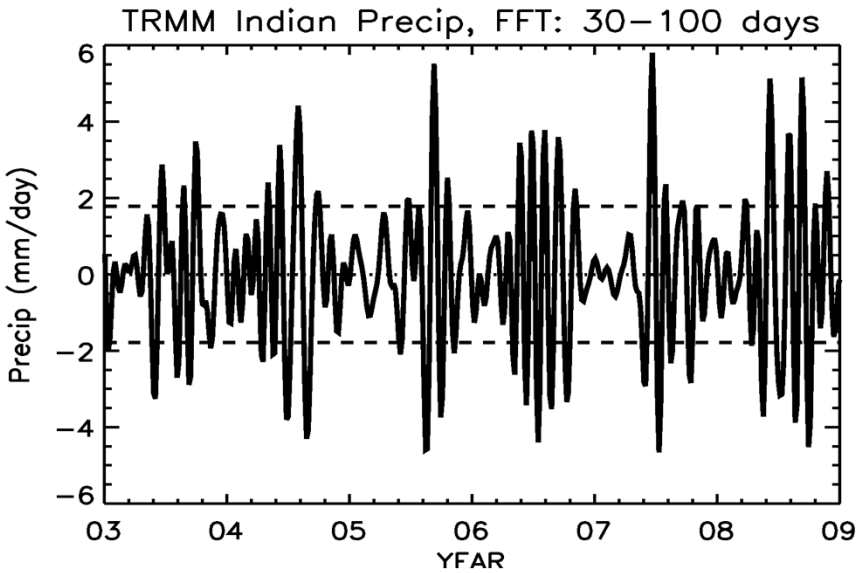
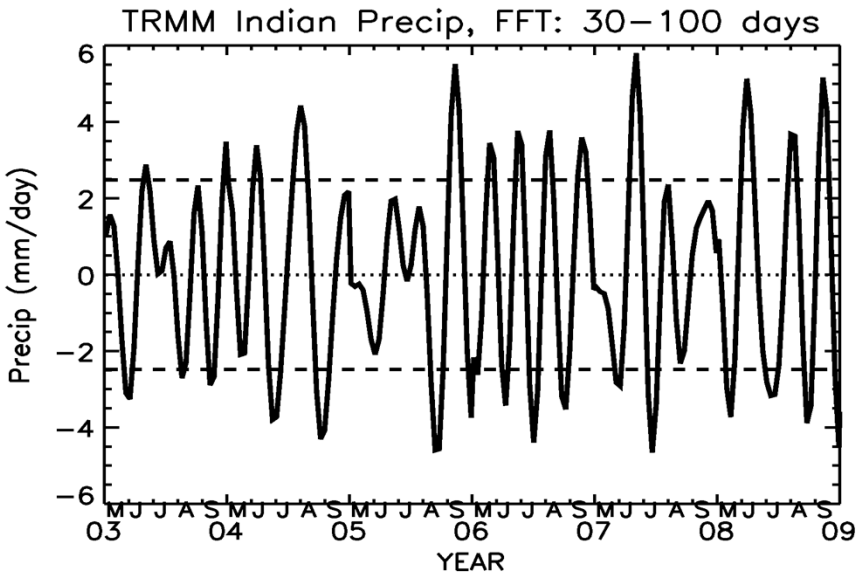
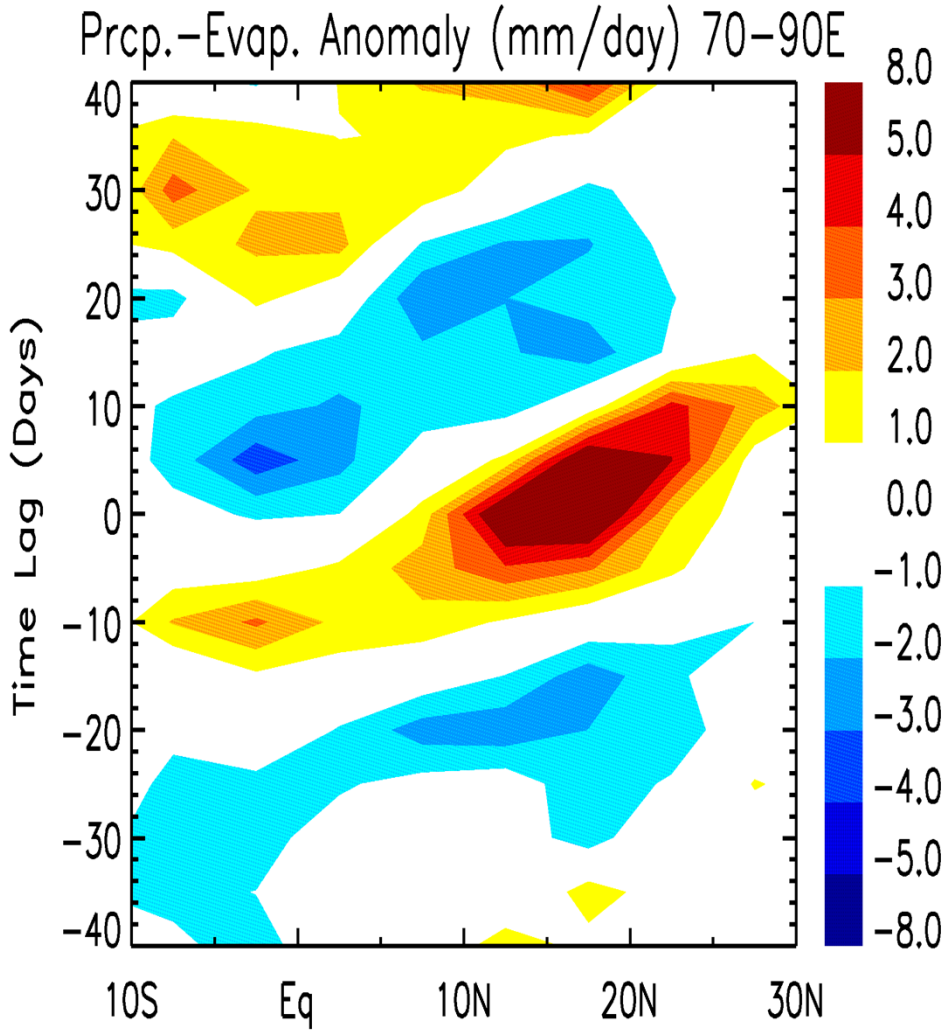
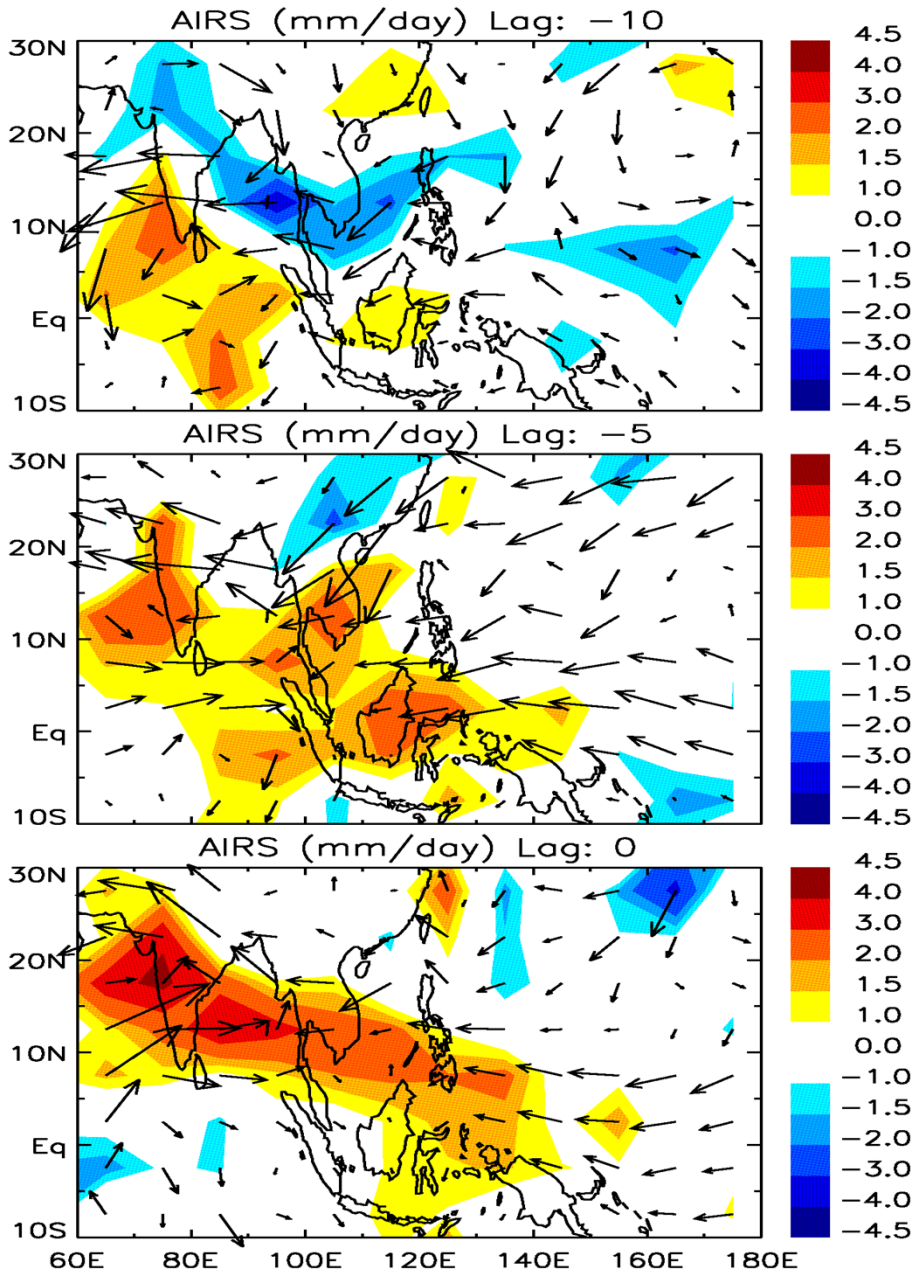




TRMM 3b42 Precipitation –
OAFlux Surface Evaporation



$-\int S \cdot dp/g$ from AIRS q and MERRA winds



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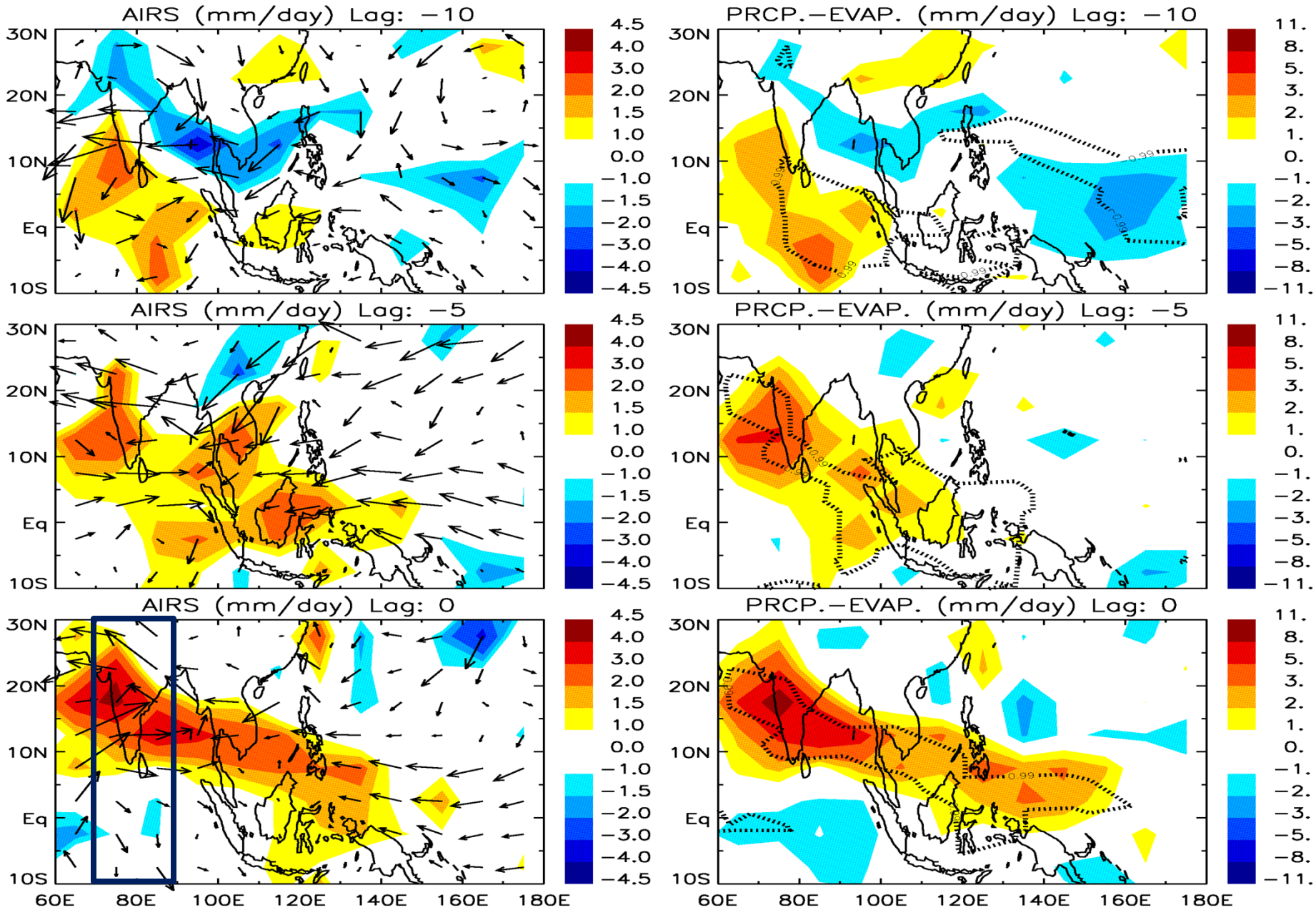
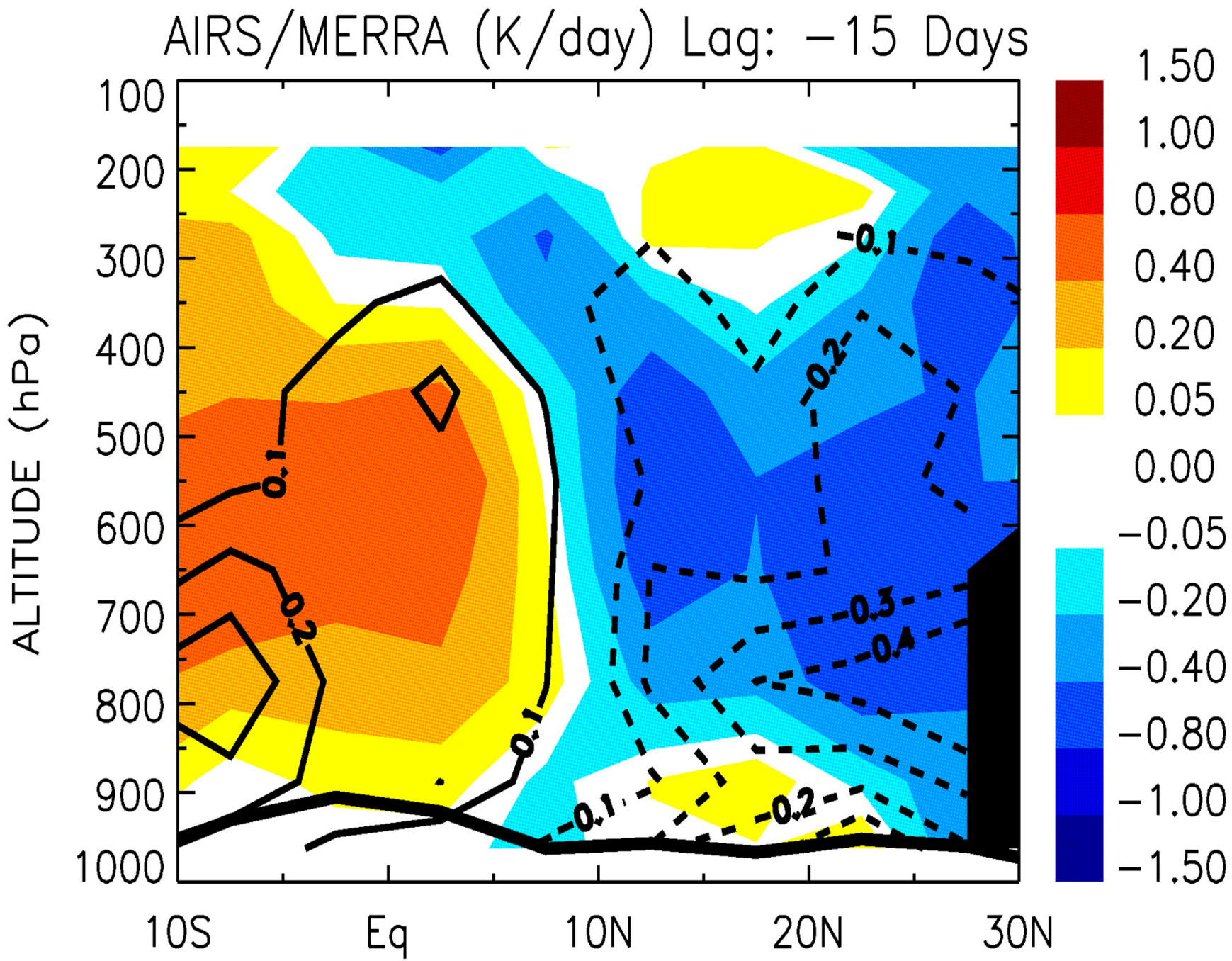
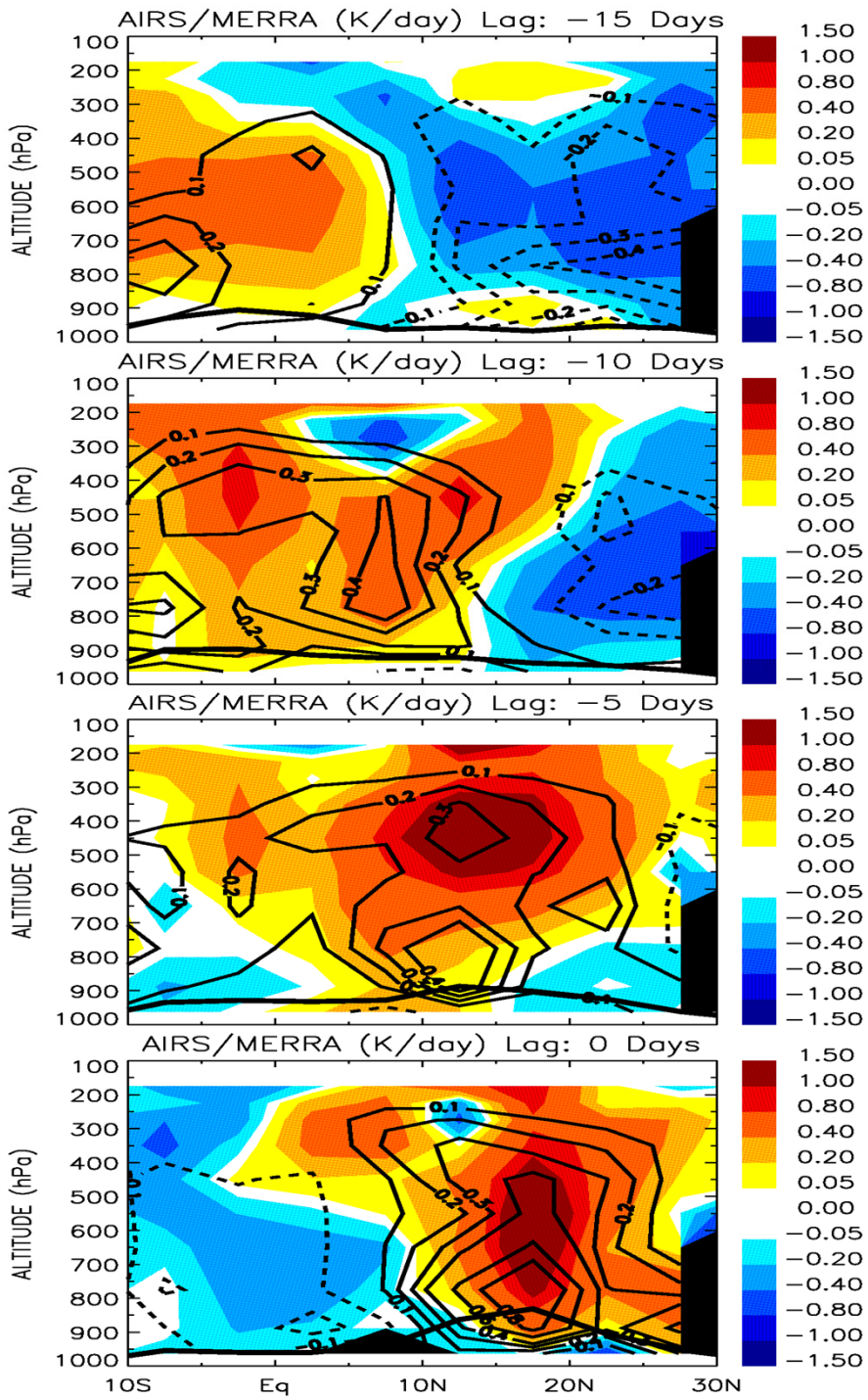
TRMM 3b42 Precipitation –OAFlux Surface Evaporation




AIRS/MERRA (K/day) Lag: −15 Days
ALTITUDE (hPa)
100
200
300
400
500
600
700
800
900
1000
10S
Eq
10N
20N
30N
1.50
1.00
0.80
0.40
0.20
0.05
0.00
−0.05
−0.20
−0.40
−0.80
−1.00
−1.50
0.1
0.2
0.1
0.1
−0.1
−0.2
−0.3
−0.4
−0.1
−0.2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ALTITUDE (hPa)
100
200
300
400
500
600
700
800
900
1000
10S
Eq
10N
20N
30N
1.50
1.00
0.80
0.40
0.20
0.05
0.00
−0.05
−0.20
−0.40
−0.80
−1.00
−1.50

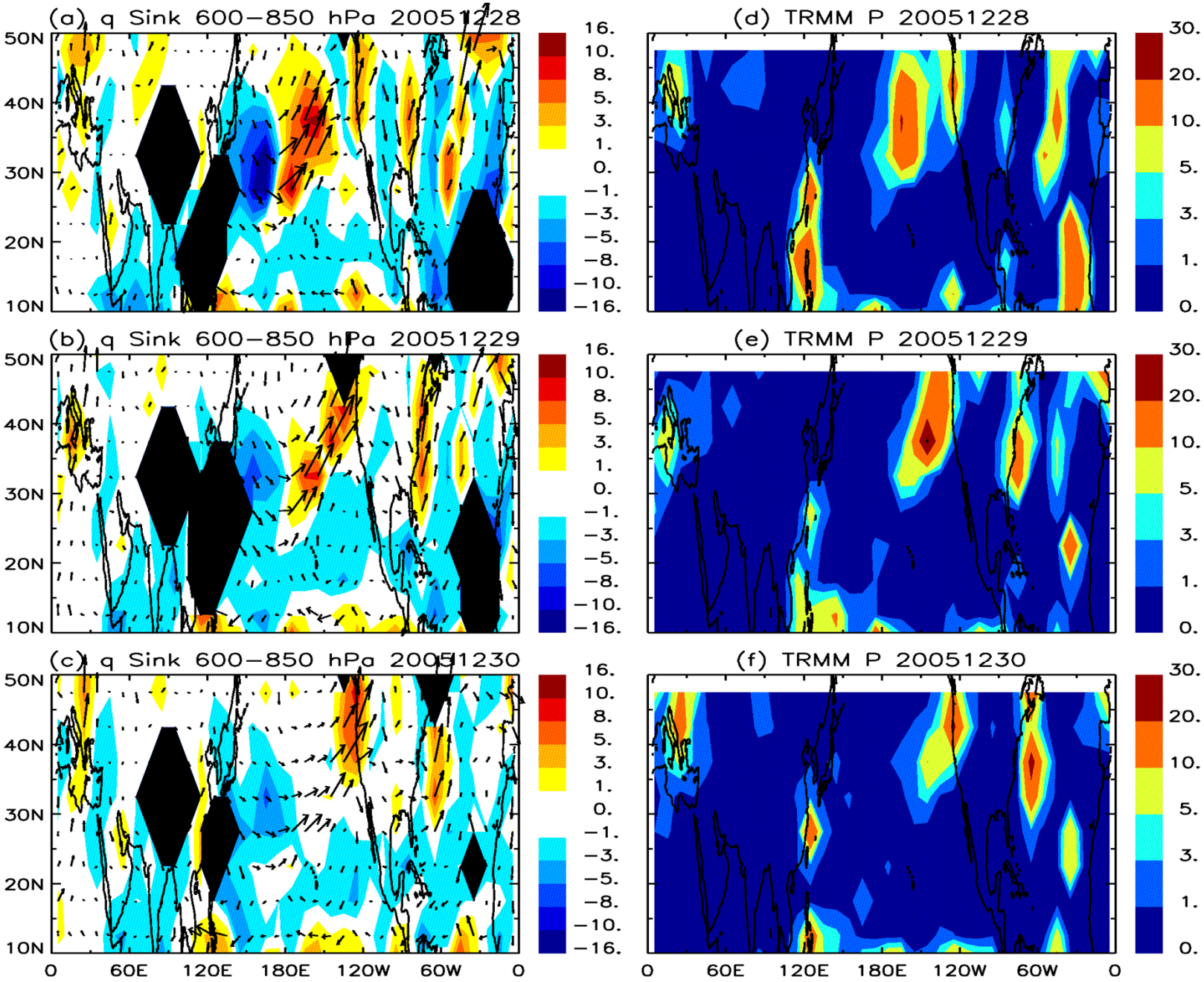
On-Going or Future Work:

- Validation the AIRS/MERRA heating sources with TRAIN Q1 on climatologies and all time-scale variability (Bill Olson and Tristan L'Ecuyer)

- Water vapor sinks and heat sources associated with the Atmospheric Rivers (Ju-Mee Ryoo)

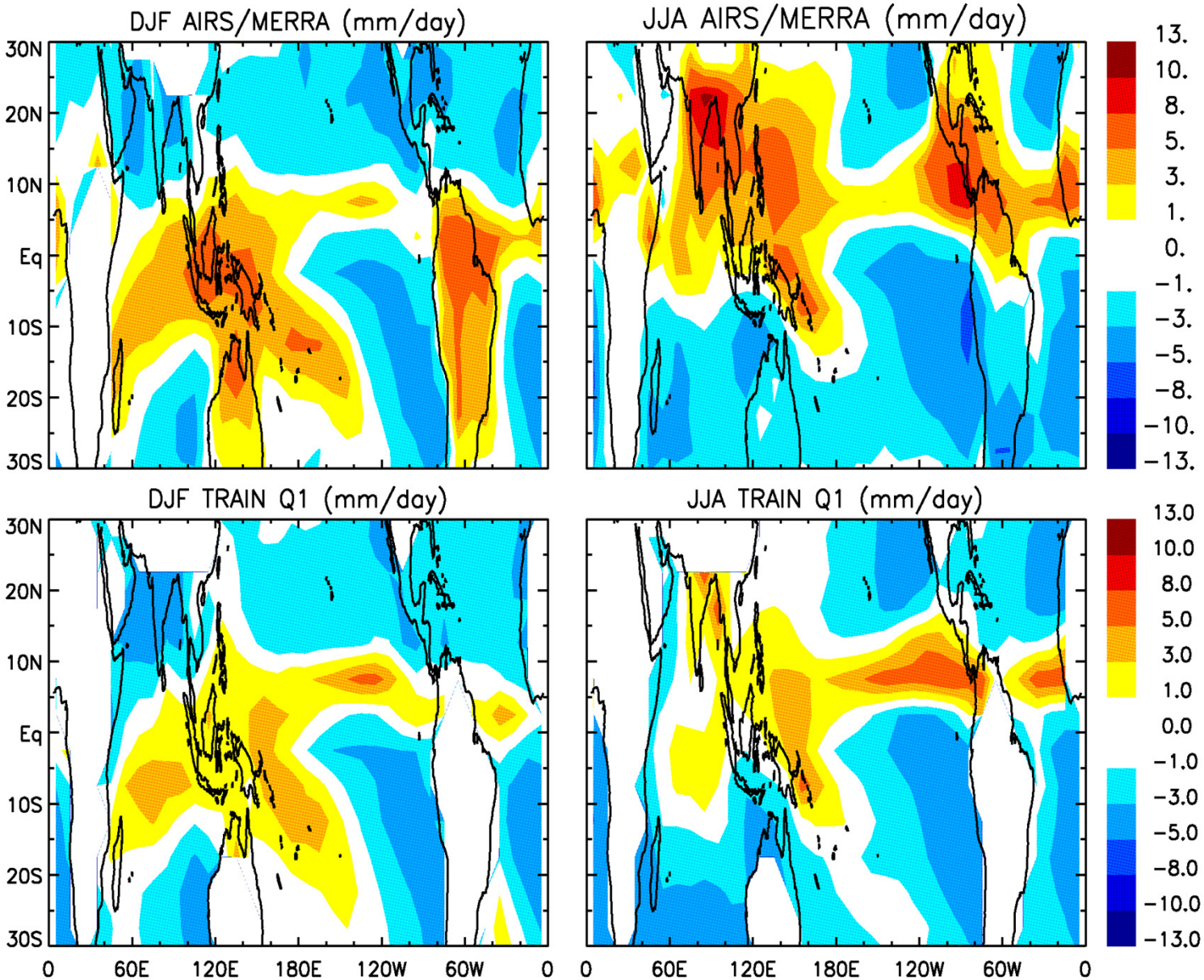
- Understanding the effect of clouds on biases of the q sinks and heat sources (Eric Fetzer)

Sneak Peek on Atmospheric River



Comparison of ∫Qdp/g (On-going Research)

Winter 2004-2008 | Sumer 2004-2008



∫Qdp/g / L

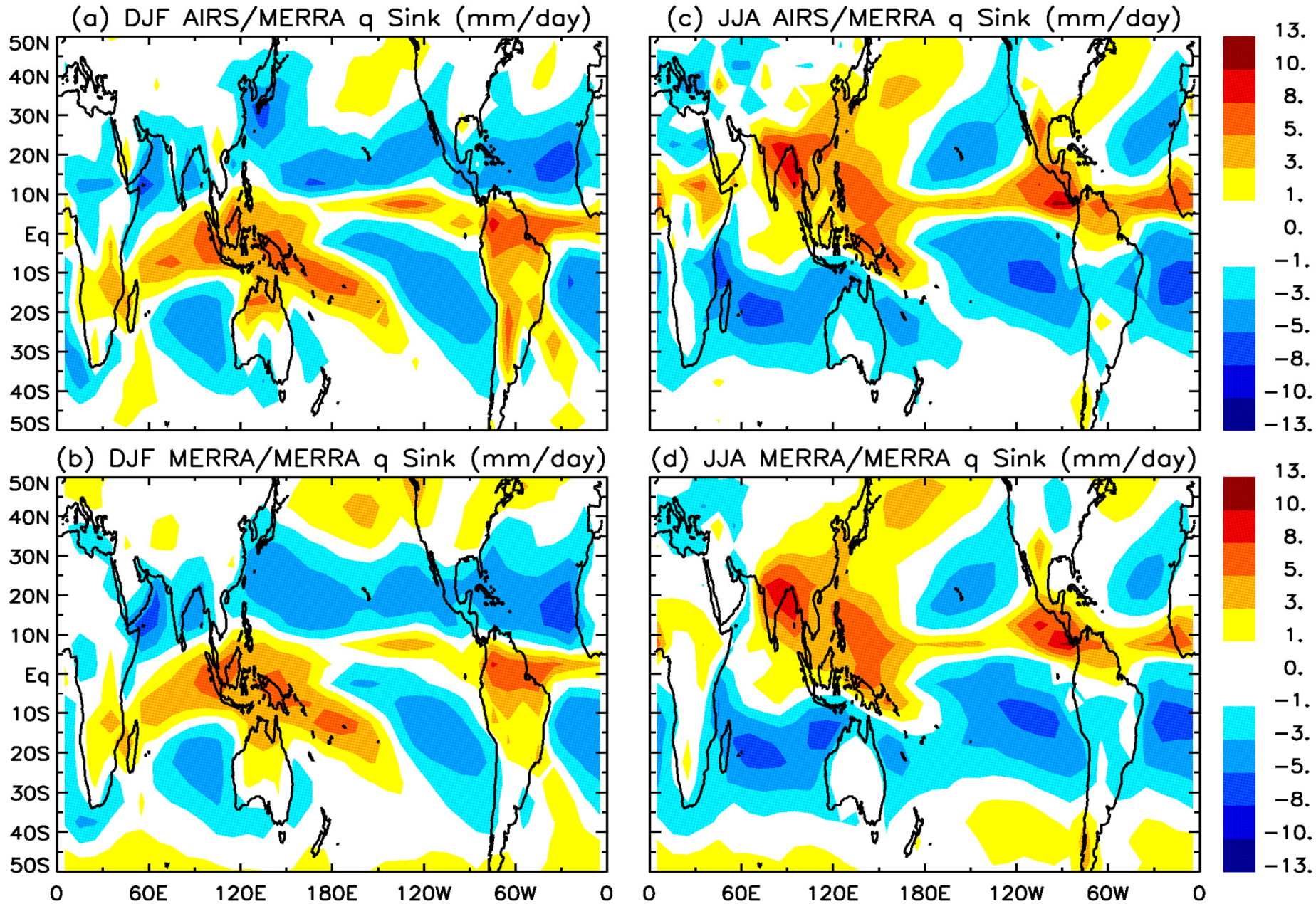
AIRS T

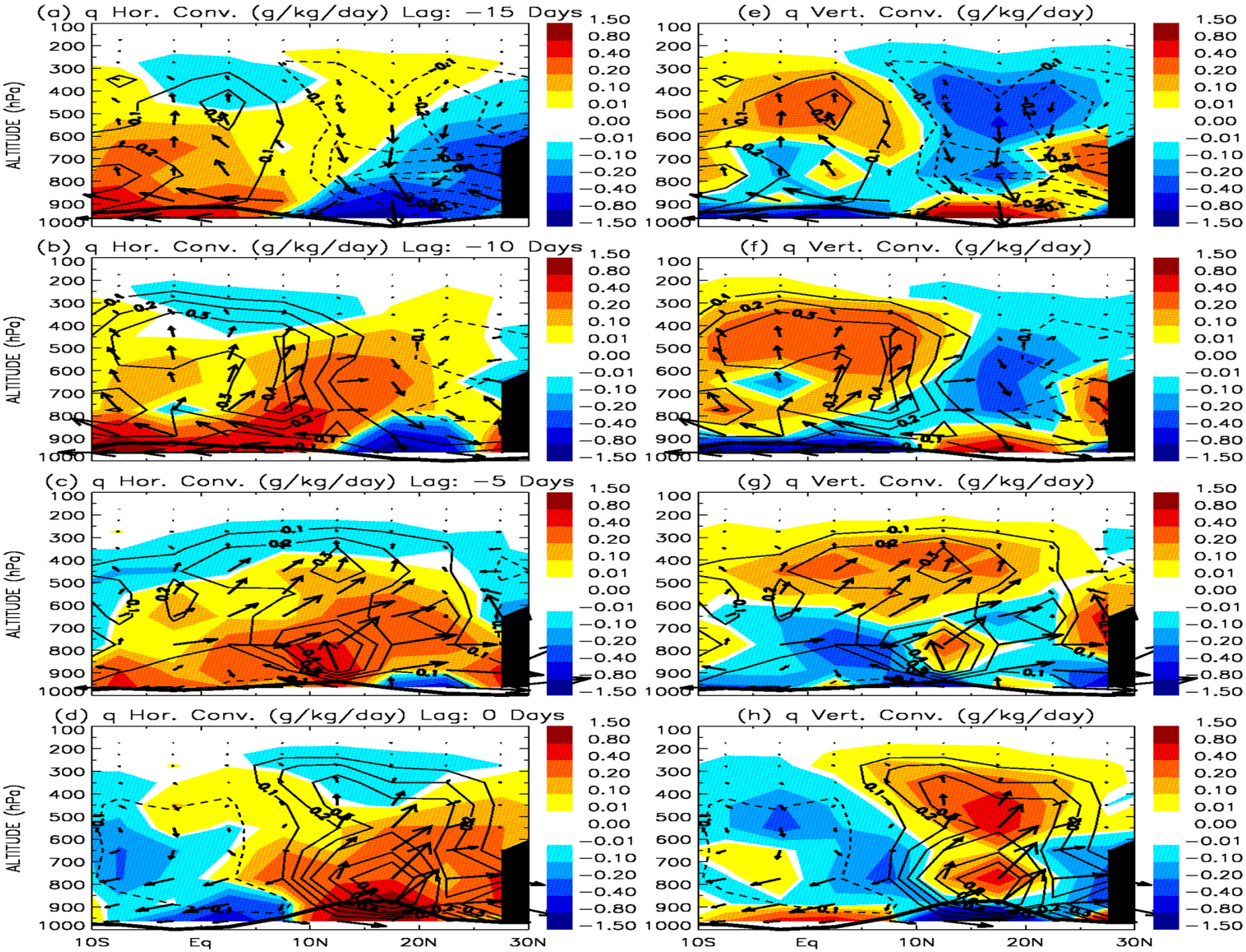
MERRA winds

∫Q1 dp/g /L

Q1: TRAIN Q1

Comparison of ∫Sdp/g between AIRS/MERRA and purely MERRA




(a) q Hor. Conv. (g/kg/day) Lag: −15 Days
(b) q Hor. Conv. (g/kg/day) Lag: −10 Days
(c) q Hor. Conv. (g/kg/day) Lag: −5 Days
(d) q Hor. Conv. (g/kg/day) Lag: 0 Days
(e) q Vert. Conv. (g/kg/day)
(f) q Vert. Conv. (g/kg/day)
(g) q Vert. Conv. (g/kg/day)
(h) q Vert. Conv. (g/kg/day)
ALTITUDE (hPa)
100
200
300
400
500
600
700
800
900
1000
1.50
0.80
0.40
0.20
0.10
0.01
0.00
−0.01
−0.10
−0.20
−0.40
−0.80
−1.50
10S
Eq
10N
20N
30N