Responses of Cloud Type Distributions to the Large-Scale Dynamical Circulation:
Water Budget-Related Dynamical Phase Space and Dynamical Regimes

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Goals:

- Water budget-related dynamical phase space
- Connect large-scale dynamical conditions to atmospheric water budget (including precipitation)
- Connect atmospheric water budget to cloud type distributions

Q Convergence and Q Advection

$$P - E + \frac{\partial Q}{\partial t} = -Q\nabla \cdot \vec{V} - \vec{V} \cdot \nabla Q$$

$$where$$

$$Q = \int_{ptop}^{psrf} q \frac{dp}{g}$$

$$\vec{V} = \frac{1}{Q} \int_{ptop}^{psrf} (q\vec{v}) \frac{dp}{g}$$

P: Precipitation

E: Evaporation

Dynamical Phase Space ≡ QCONV X QADVT

$$P - E + \frac{\partial Q}{\partial t} = -Q\nabla \cdot \vec{V} - \vec{V} \cdot \nabla Q$$

QCONV

QADVT

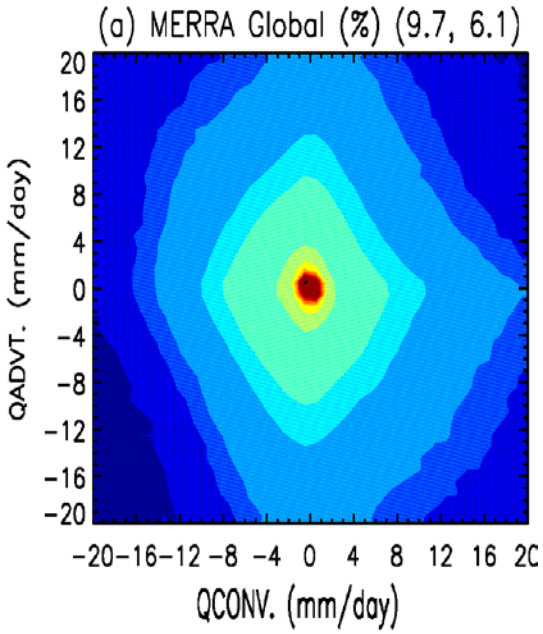
where

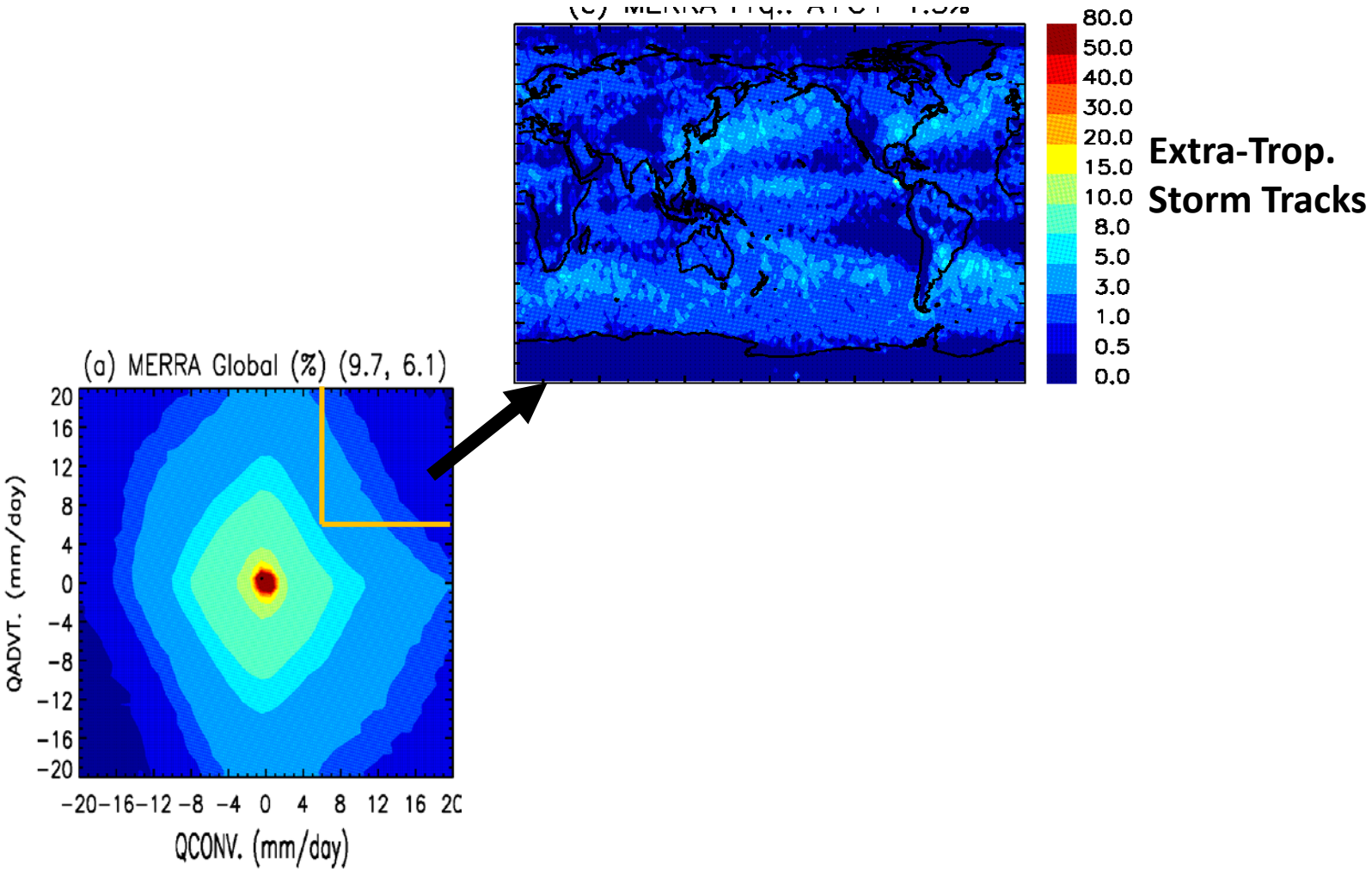
$$Q = \int_{ptop}^{psrf} q \frac{dp}{g}$$

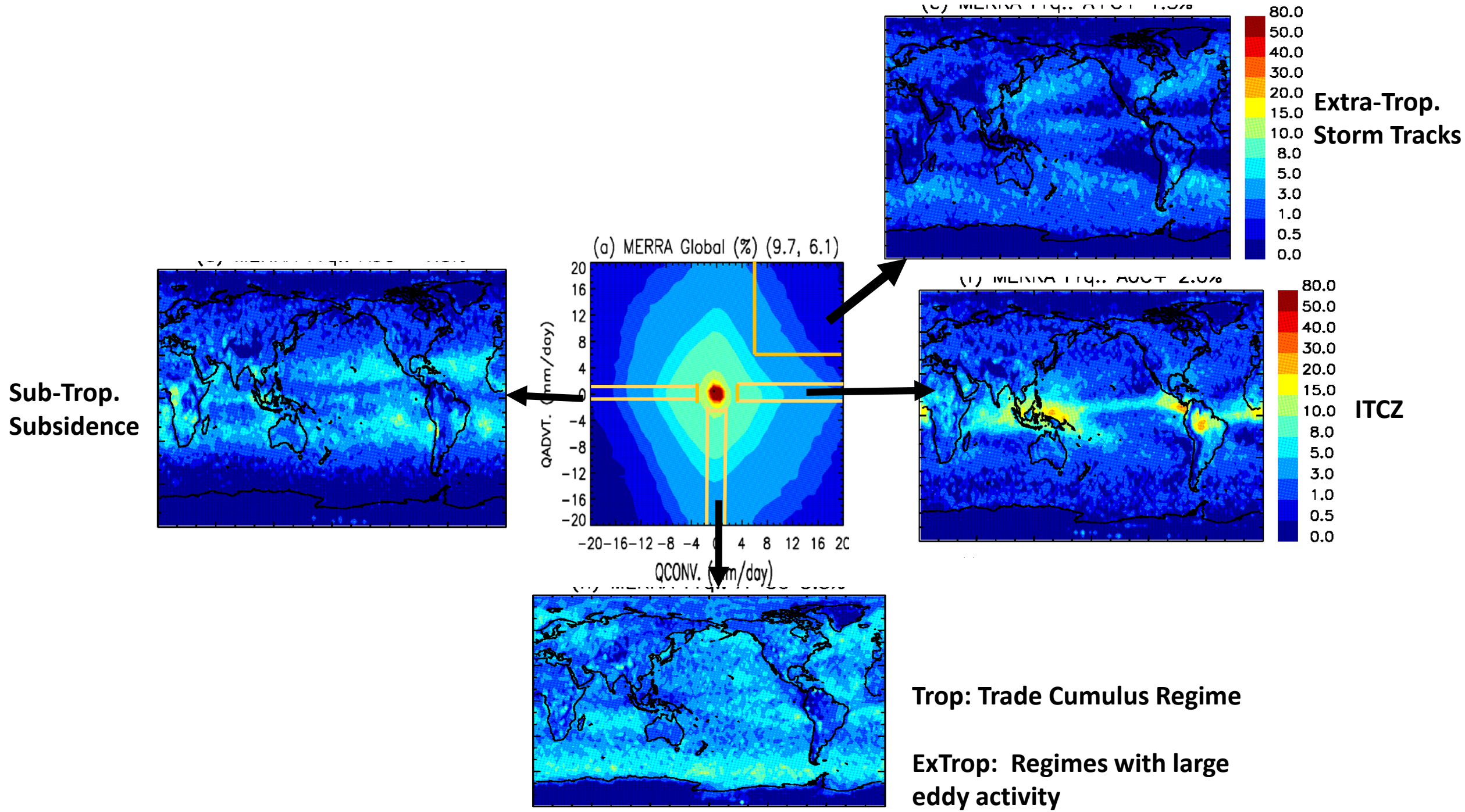
$$\vec{V} = \frac{1}{Q} \int_{ptop}^{psrf} (q\vec{v}) \frac{dp}{g}$$

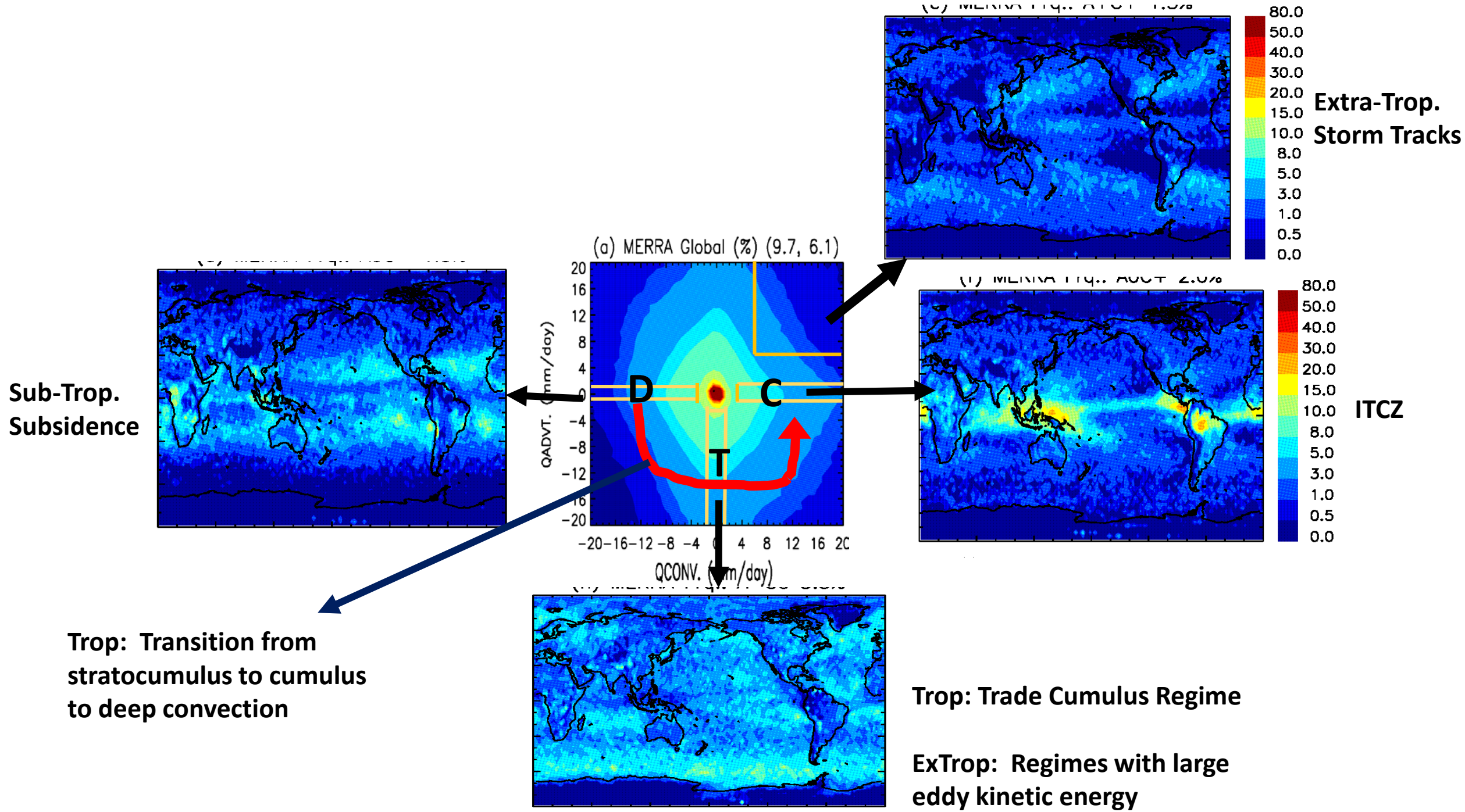
P: Precipitation

E: Evaporation


(a) MERRA Global (%) (9.7, 6.1)
QADVT. (mm/day)
20
16
12
8
4
0
−4
−8
−12
−16
−20
−20 −16 −12 −8 −4 0 4 8 12 16 20
QCONV. (mm/day)

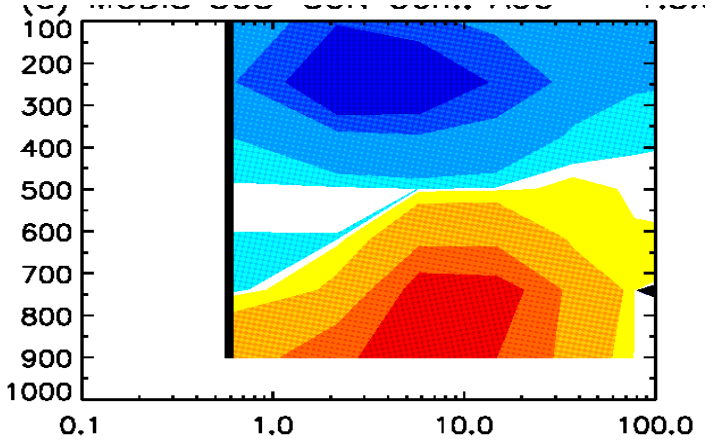

(a) MERRA Global (%) (9.7, 6.1)
QADVT. (mm/day)
QCONV. (mm/day)
20
16
12
8
4
0
−4
−8
−12
−16
−20
80.0
50.0
40.0
30.0
20.0
15.0
10.0
8.0
5.0
3.0
1.0
0.5
0.0
Extra-Trop.
Storm Tracks

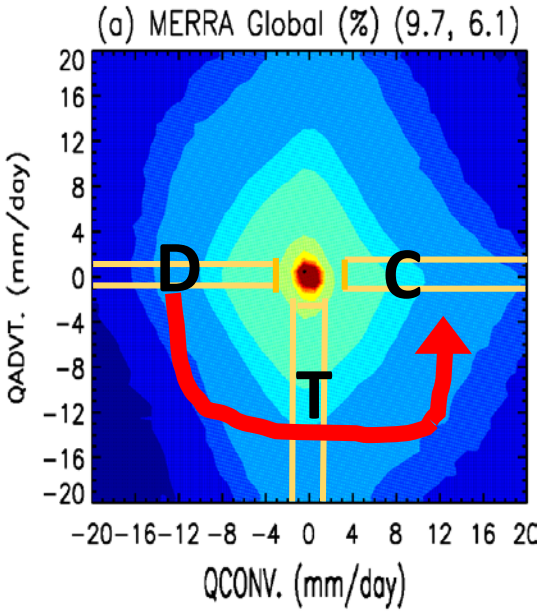

Extra-Trop.
Storm Tracks
Sub-Trop.
Subsidence
ITCZ
(a) MERRA Global (%) (9.7, 6.1)
QADVT. (mm/day)
QCONV. (mm/day)
80.0
50.0
40.0
30.0
20.0
15.0
10.0
8.0
5.0
3.0
1.0
0.5
0.0
Trop: Trade Cumulus Regime
ExTrop: Regimes with large eddy activity


Extra-Trop.
Storm Tracks
80.0
50.0
40.0
30.0
20.0
15.0
10.0
8.0
5.0
3.0
1.0
0.5
0.0
(a) MERRA Global (%) (9.7, 6.1)
QADVT. (mm/day)
QCONV. (mm/day)
D
C
T
Sub-Trop.
Subsidence
ITCZ
Trop: Transition from
stratocumulus to cumulus
to deep convection
Trop: Trade Cumulus Regime
ExTrop: Regimes with large
eddy kinetic energy

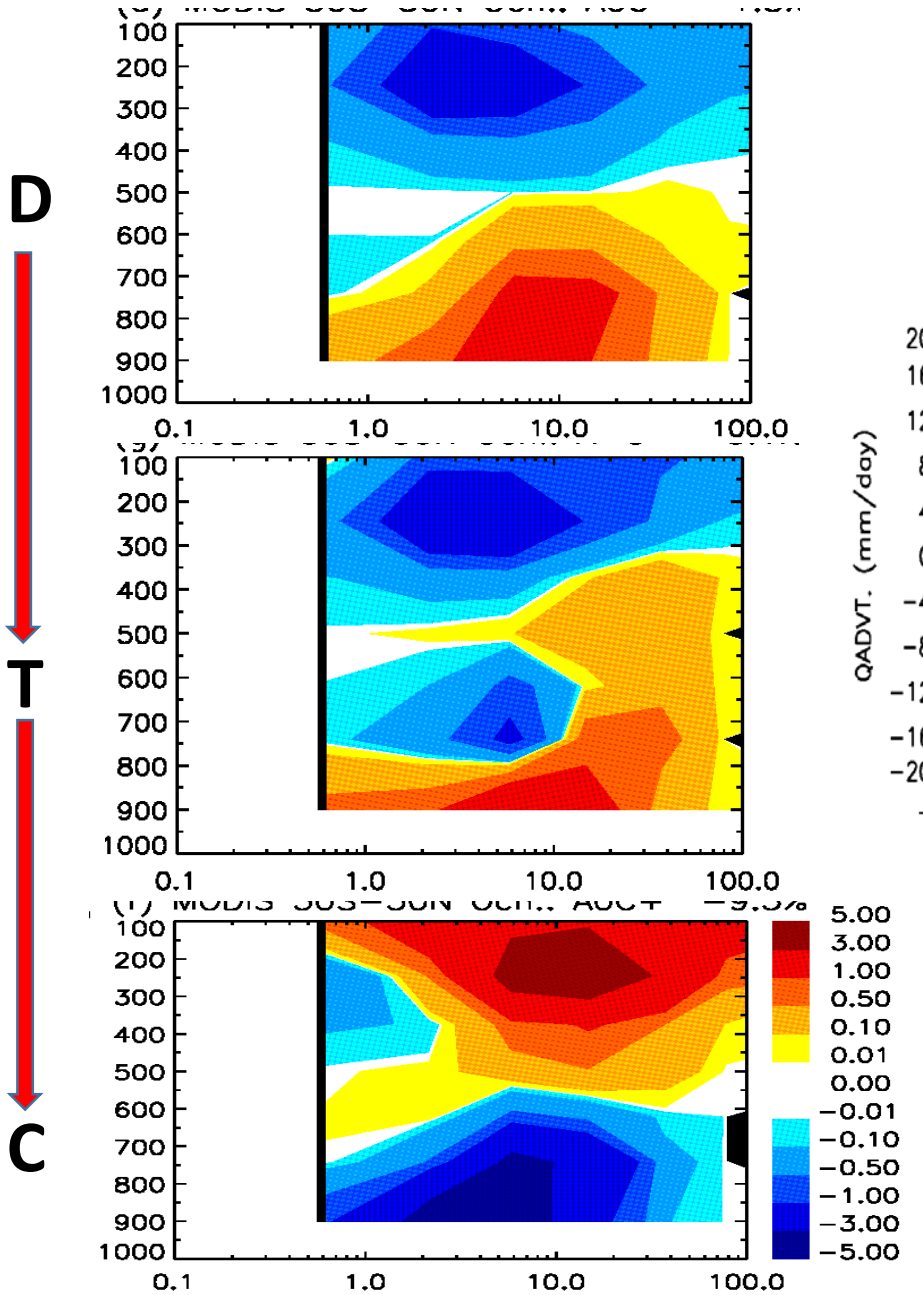
MODIS CTP-COD Histogram Anomalies

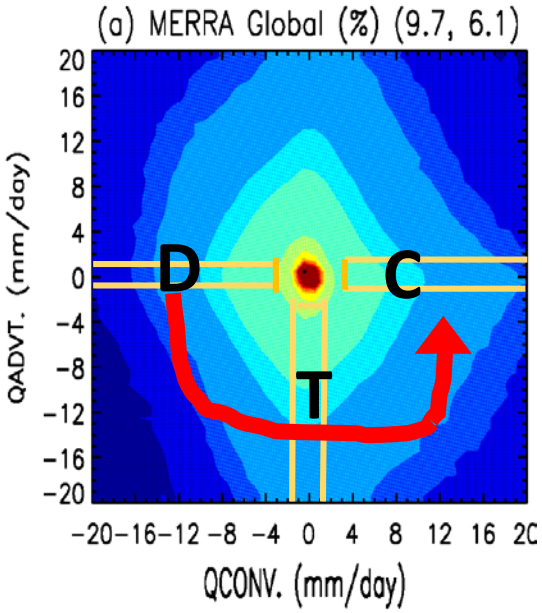
D





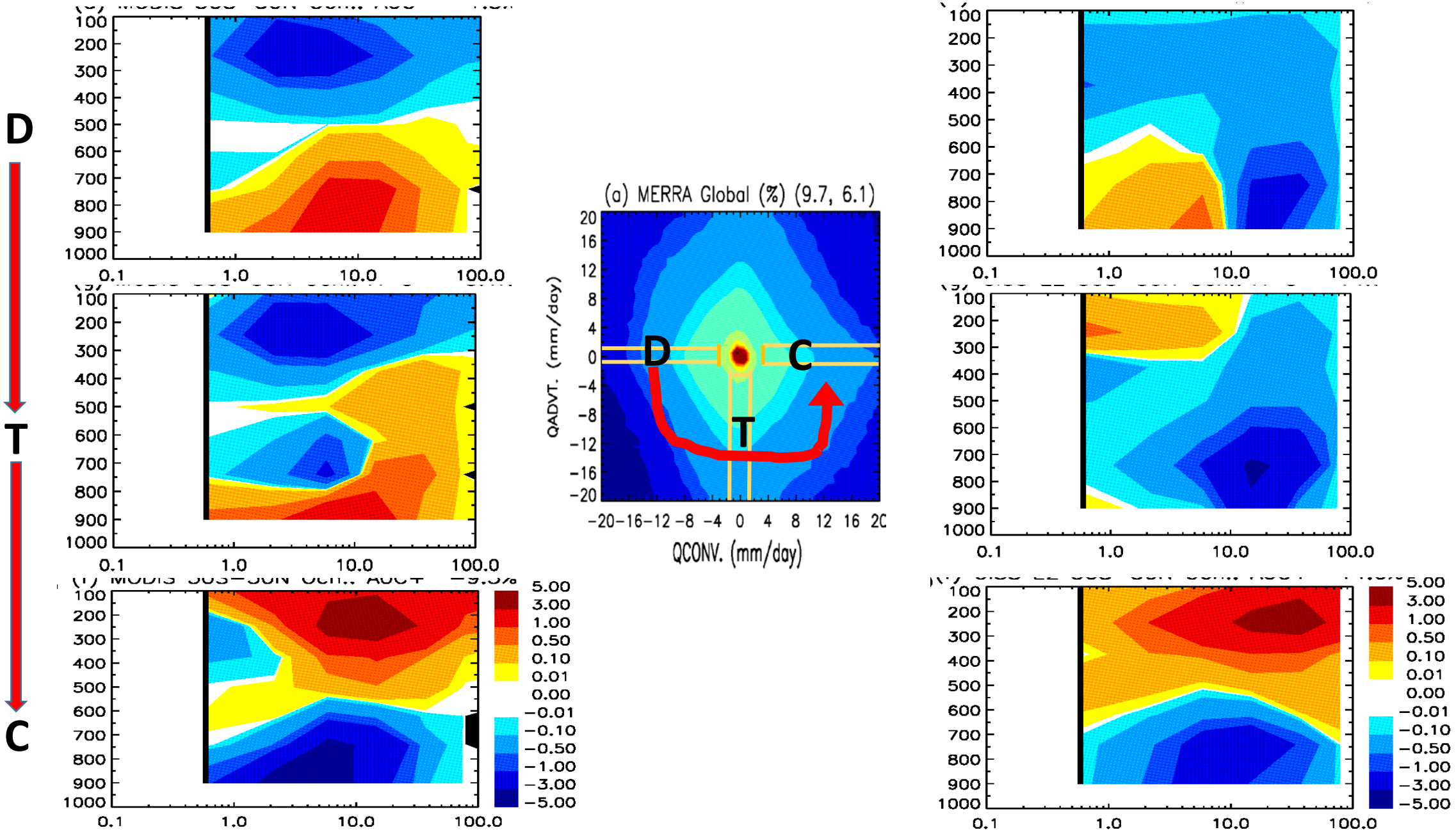
MODIS CTP-COD Histogram Anomalies





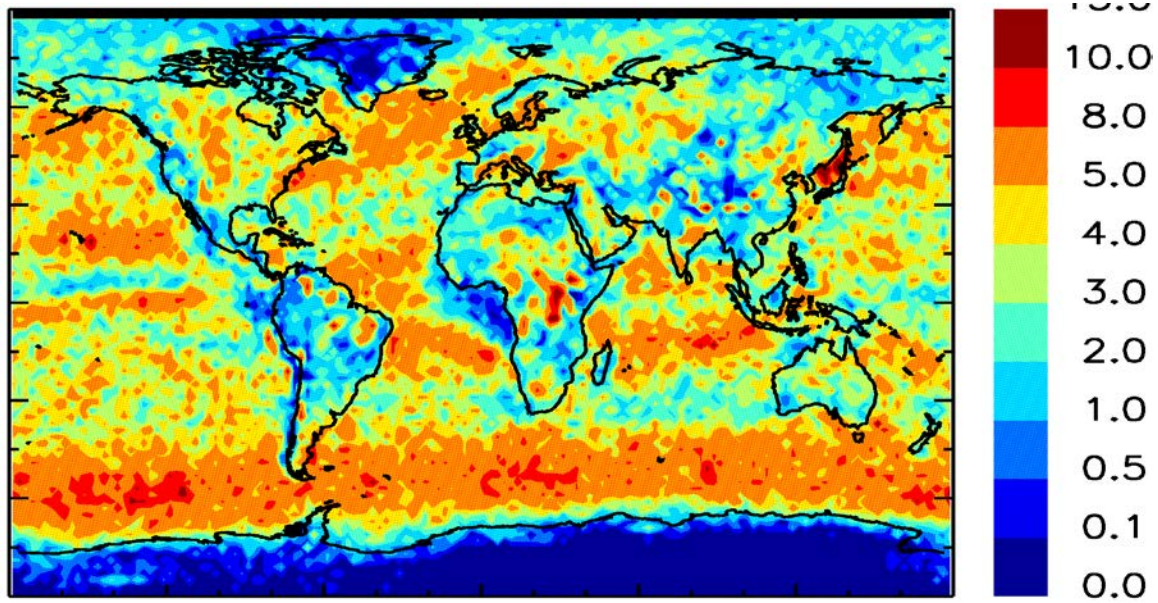
MODIS CTP-COD Histogram Anomalies

GISS E2 with MODIS Simulator

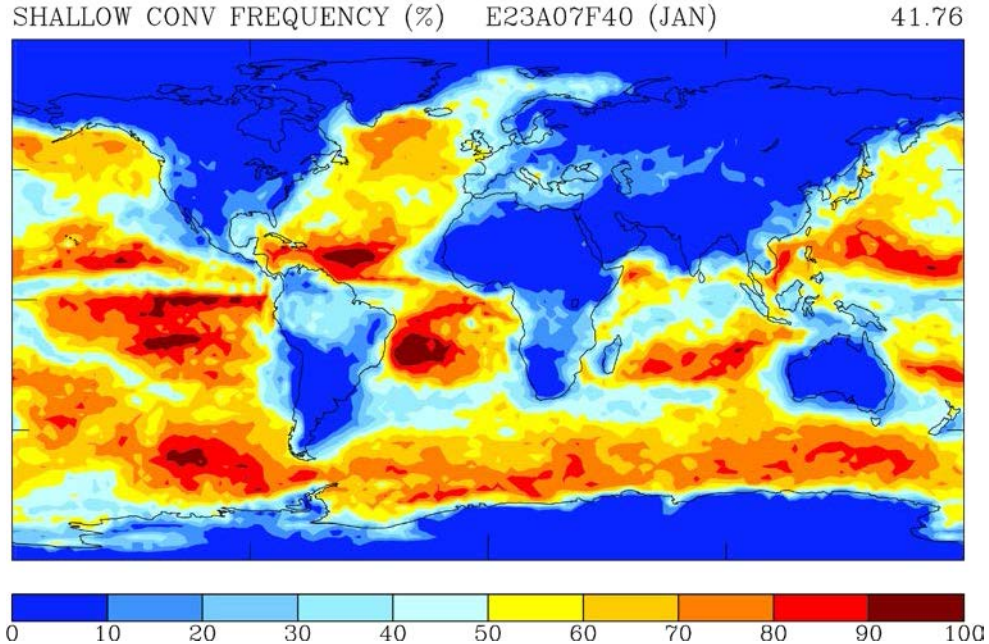


GISS E2 Does Have Shallow Convection

Freq. of Occurrence of Dynamical Regime T

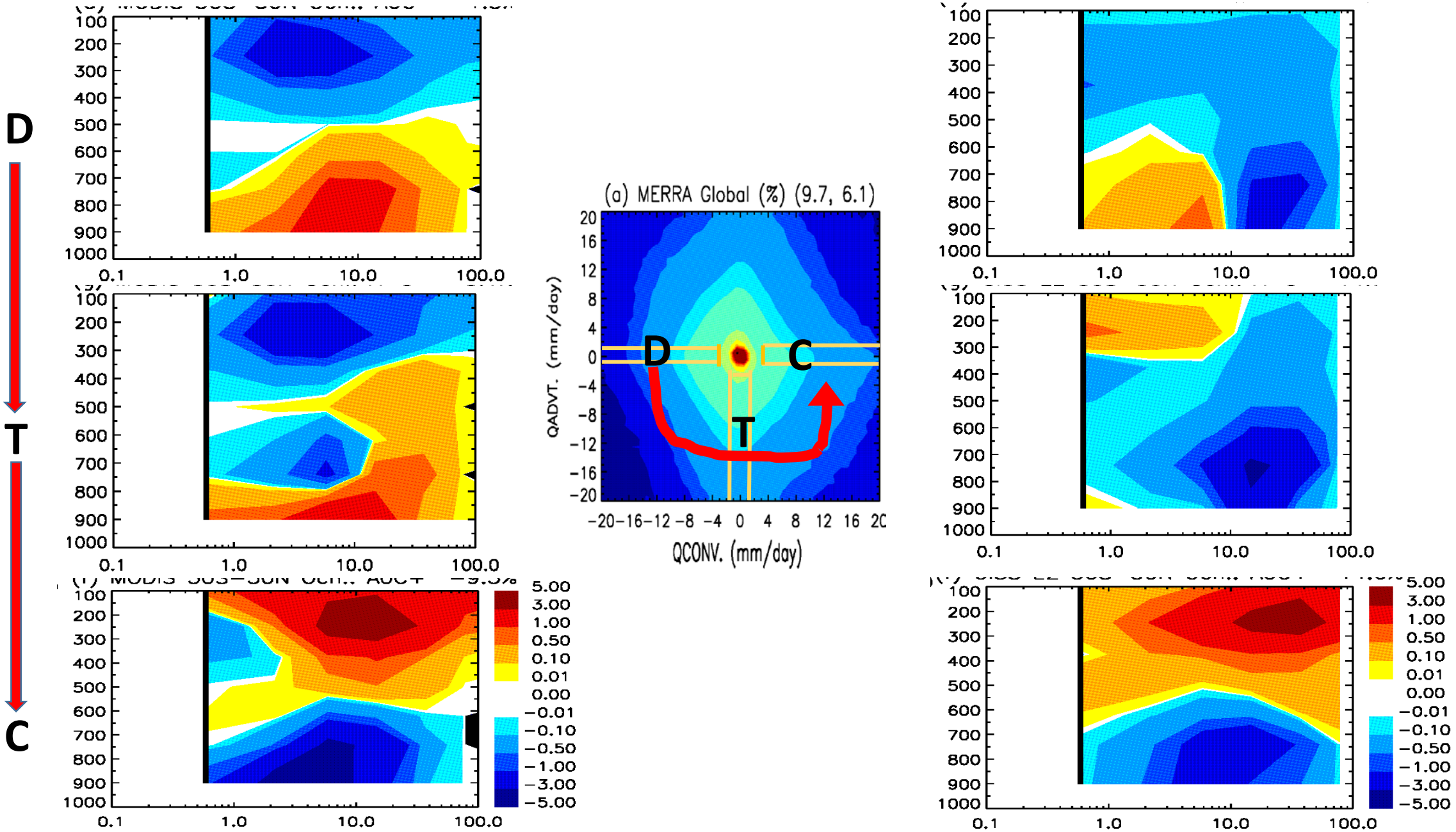


Freq. of Occurrence of GISS E2 Shallow Convection



MODIS CTP-COD Histogram Anomalies

GISS E2 with MODIS Simulator

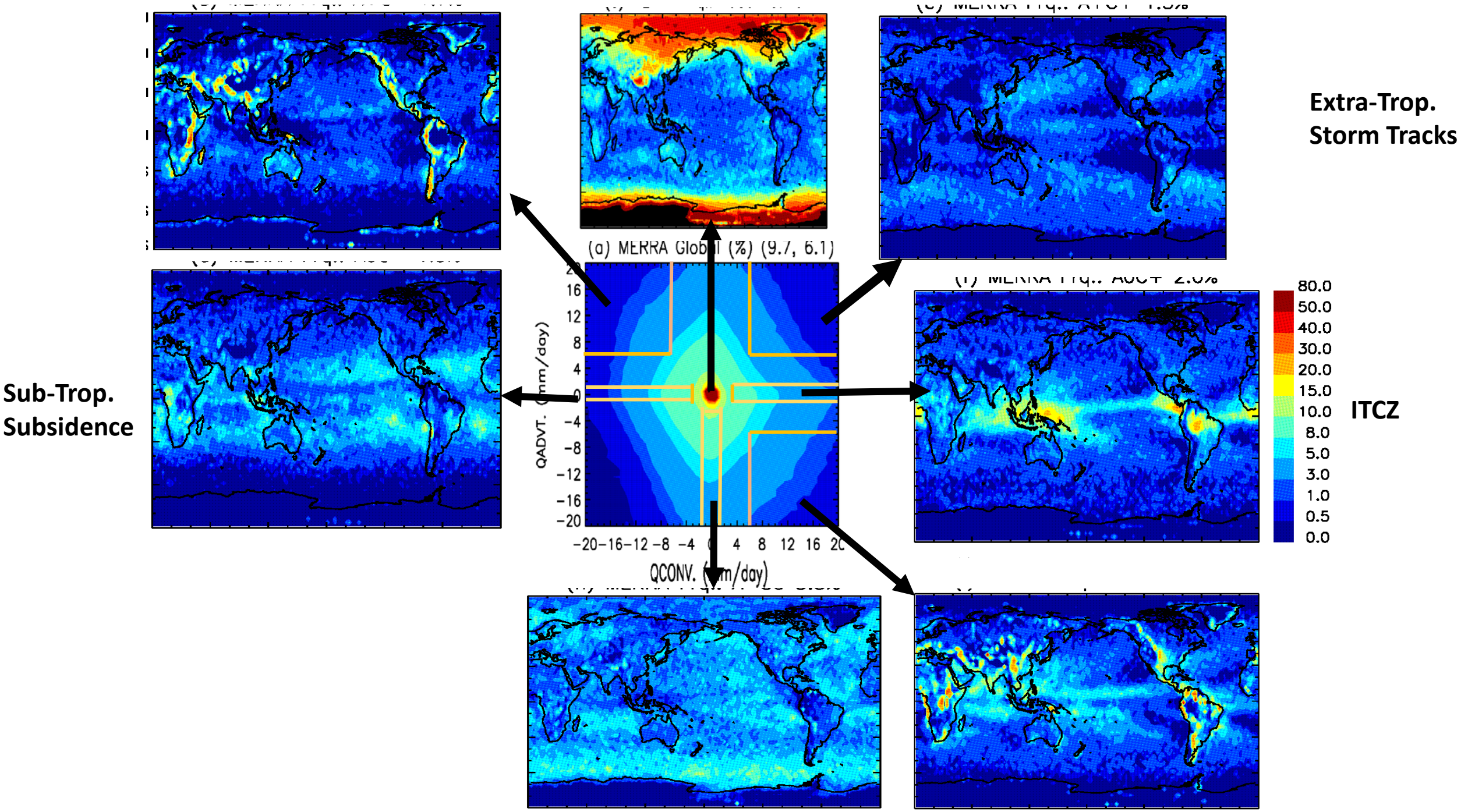


Conclusions

- Dynamical phase space is an efficient tool to (1) summarize large-scale dynamical conditions, (2) simultatneous links them to atmospheric water budget, (3) identify circulation systems.

- GISS E2 has the skills to simulate the shallow convection and deep convection in the right dynamical regimes, but misses the low-level thick clouds in the divergence regime

- Passive sensor cloud simulators (e.g. MODIS) may mask low level clouds in the GCMs when the models have more high level clouds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50.0
40.0
30.0
20.0
15.0
10.0
8.0
5.0
3.0
1.0
0.5
0.0

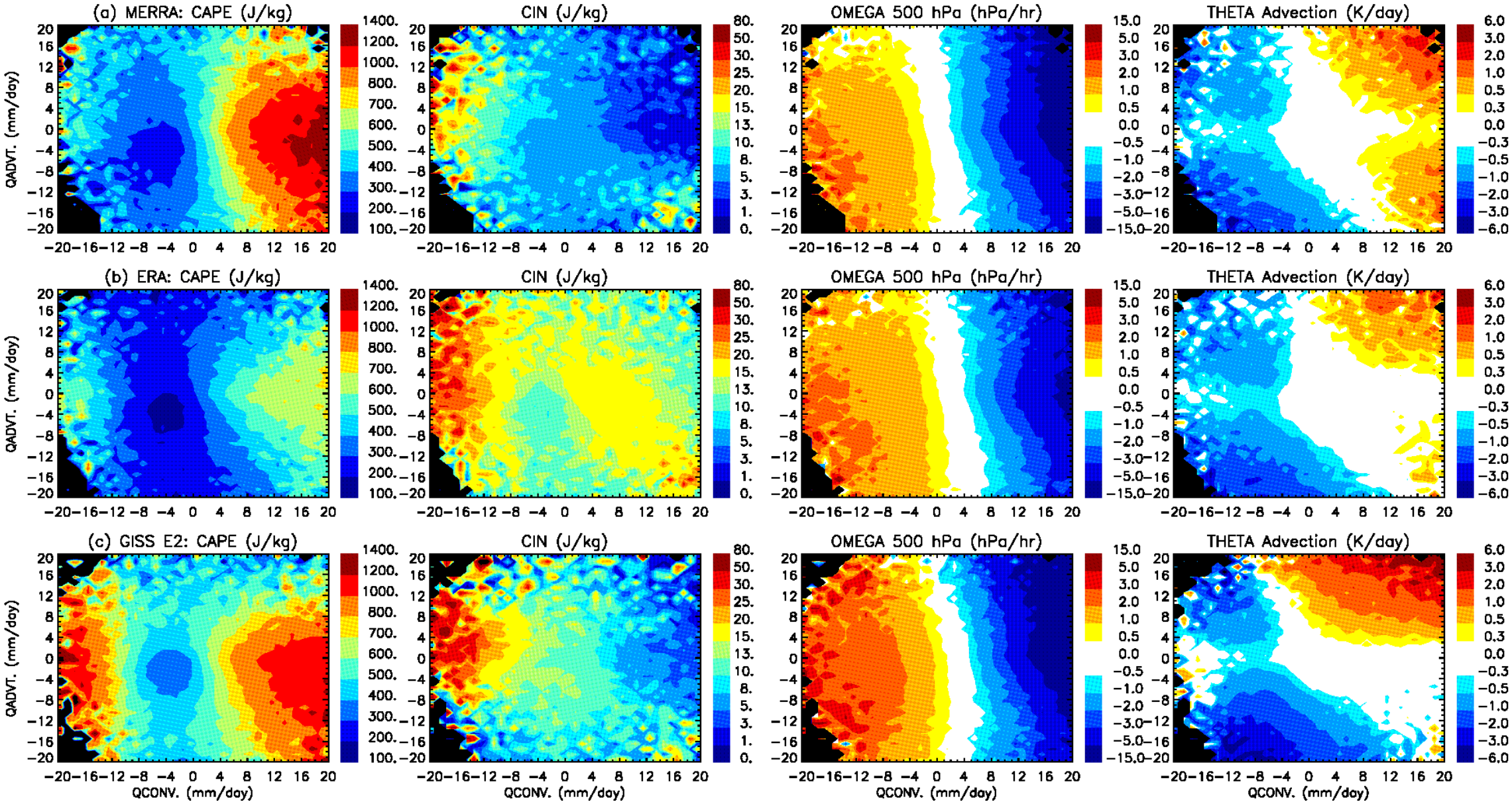
Tropical Large-Scale Dynamical Conditions in Dynaical Phase Space

CAPE | CIN | ω-500 hPa | $-v^*\nabla\theta$(850 hPa)

MERRA

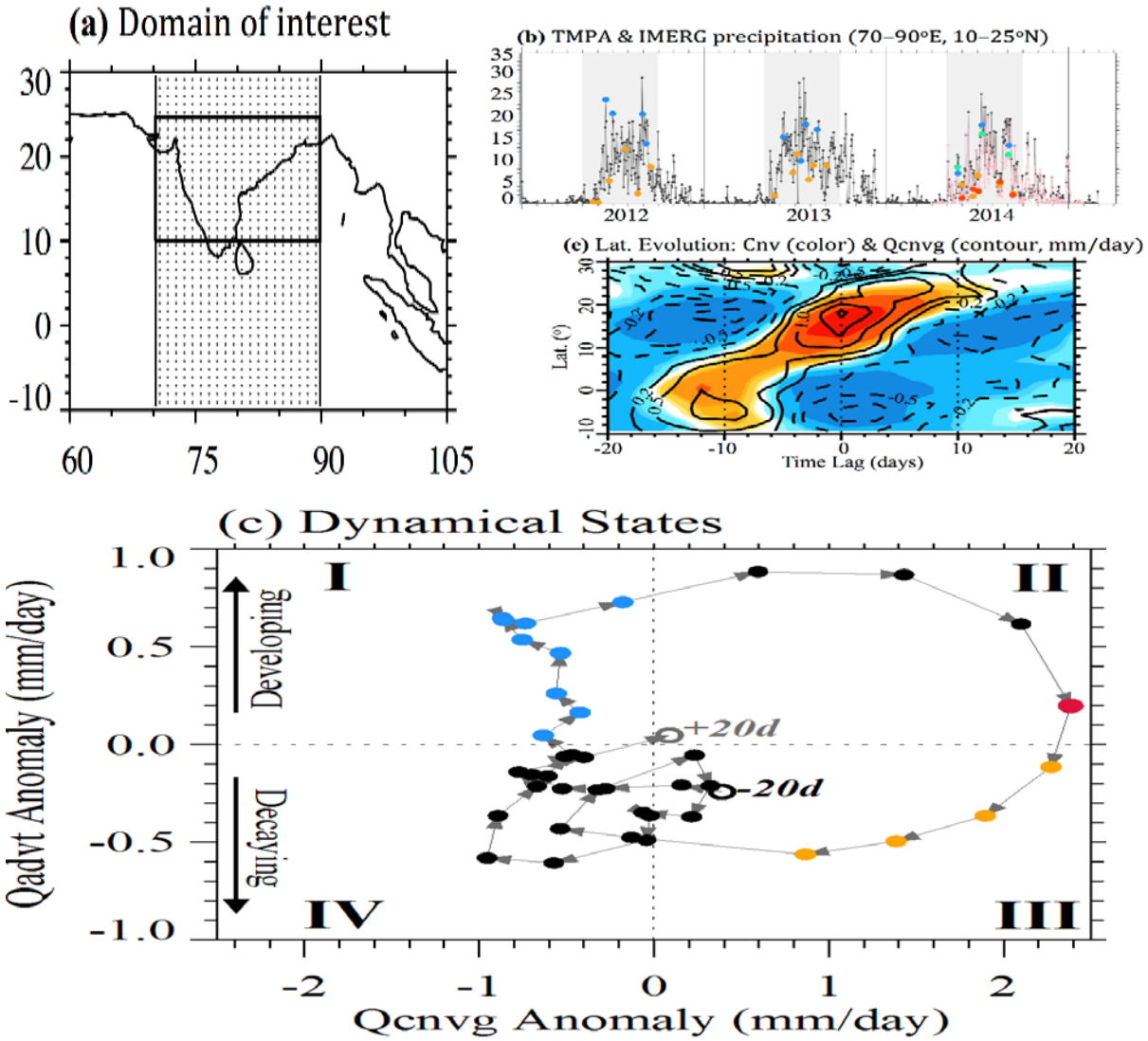
ERA-I

GISS E2

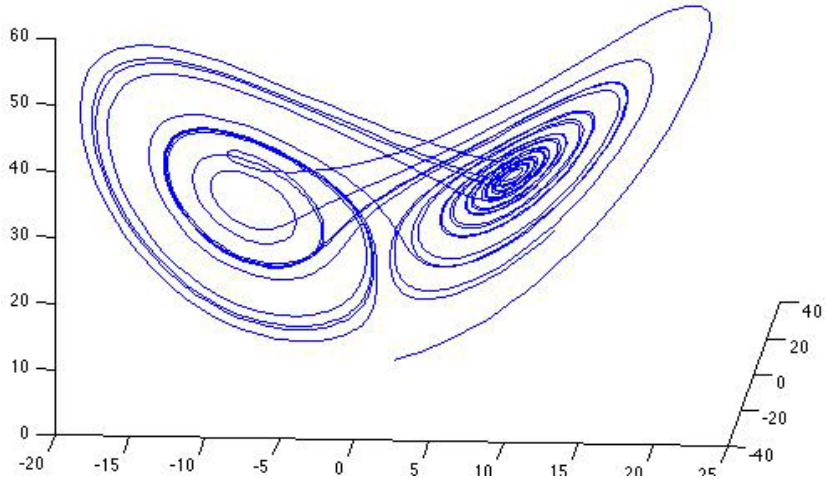


Why Call it "Dynamical Phase Space"?

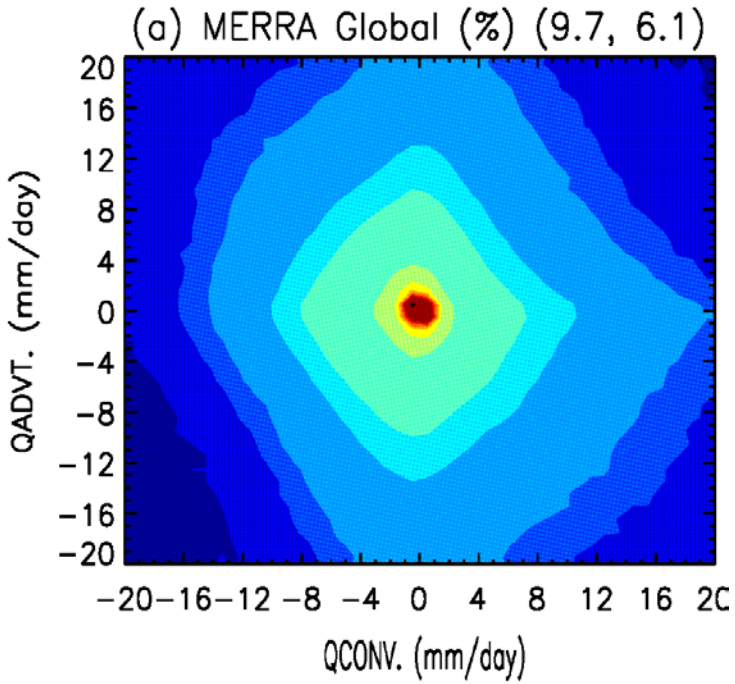
Orbit of Indian Monsoon ISO



Inspiration from Non-Linear Dynamics



Lorentz loves this butterfly. Poincaré wanted to cut it in 2-d sections



I don't have butterflies, but a Christmas star