Gross moist stability

Raymond et al. , 2009: The mechanics of Gross Moist Stability

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SWAP 2

GMS

- Gross moist stability

$$\frac{\textit{vertically integrated horizontal divegence of some intensive quantity conserved in moist adiabatic processes}}{\textit{measure of the strength of moist convection per unit of area}}$$

•convective mass flux/A
•vertically integrated divergence of potential temperature flux
•vertically integrated convergence of water vapor

•moist static energy
•equivalent potential temperature
•specific moist entropy

Methods

$$\frac{\partial[s]}{\partial t} + \nabla \cdot [vs] = F_s - R$$

$$\frac{\partial[r]}{\partial t} + \nabla \cdot [vr] = E - P$$

$$\omega = 0|_{z=0}^{z_{trop}} ; \quad \frac{\partial \omega s}{\partial p} = 0$$

- Normalized GMS: $$\Gamma_R = -\frac{T_R[\nabla \cdot (sv)]}{L[\nabla \cdot (rv)]}$$
- Steady state: $$P - E = \frac{T_R(F_s - R)}{L\Gamma_R}$$

net precipitation

entropy forcing

- Raymond and Fuchs (2009)
  - Steady state +: $[\nabla \cdot (s v)] = [v \cdot \nabla s] + [s \nabla \cdot \mathbf{v}]$

$$\nabla \cdot v + \frac{\partial \omega}{\partial p} = 0 \qquad \cdot / \int_{p_0}^{p_t} dp / \cdot s$$

$$\omega = 0 \Big|_{z=0}^{z_{trop}} ; \ \frac{\partial \omega s}{\partial p} = 0$$

$$\Gamma_R = \underbrace{-\frac{T_R[v \cdot \nabla s]}{L[\nabla \cdot (r v)]}}_{\Gamma_H} \underbrace{-\frac{T_R[\omega \cdot \frac{\partial s}{\partial p}]}{L[\nabla \cdot (r v)]}}_{\Gamma_V}$$

Theory

- MOIST ENTROPY - conserved in a slow, moist and adiabatic processes
- MOIST STATIC ENERGY - not conserved,   depends on hydrostatic approximation

- NGMS over region
  - averging in space

$$[\overline{\nabla \cdot (sv)}] = \frac{1}{A}[\int_{\partial A} \nabla \cdot (sv) \cdot dA] = \frac{1}{A}[\oint_{\partial A} sv \cdot ndl]$$

$$\overline{\Gamma_R} = -\frac{[T_R \oint_{\partial A} sv \cdot ndl]}{[L \oint_{\partial A} rv \cdot ndl]}$$

$$s = \tilde{s} + s^*$$

$$\nabla \cdot v + \frac{\partial \omega}{\partial p} = 0 \qquad \cdot/(\overline{\ \ }) \cdot s$$

$$\omega = 0|_{z=0}^{z_{trop}} \ ; \ \frac{\partial \omega s}{\partial p} = 0$$

$$\frac{\partial \omega}{\partial p} = -\frac{1}{A}\oint_{\partial A} v \cdot ndl$$

$$\overline{\Gamma_R} = -\underbrace{\frac{AT_R[\overline{\omega}\frac{\partial \tilde{s}}{\partial p}]}{[L \oint_{\partial A} rv \cdot ndl]}}_{\Gamma_s} - \underbrace{\frac{[T_R \oint_{\partial A} s^* v \cdot ndl]}{[L \oint_{\partial A} rv \cdot ndl]}}_{\Gamma_A}$$

- NGMS in models
  - large scale models-low pass filtering s=<s>+s’, v=<v>+v’
    + Raynold decomposition <s’<v’>>=o etc.
  - averging over a relatively homogeneus region - differences betwwen two models small

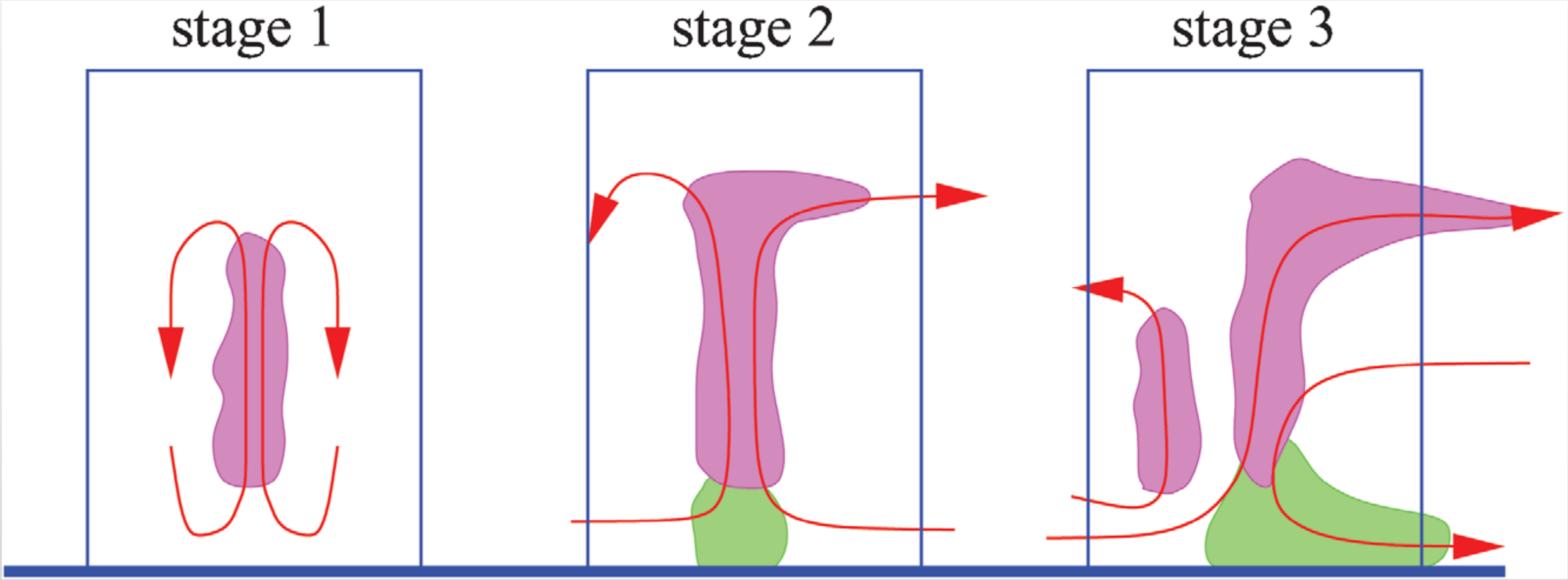
- Averging over time
  - alternative
  - total moist entropy:
    - term constructed of only timemean variable
    - term constructed from fluctuating parts of the velocity & entropy fields

GMS and environmental conditions

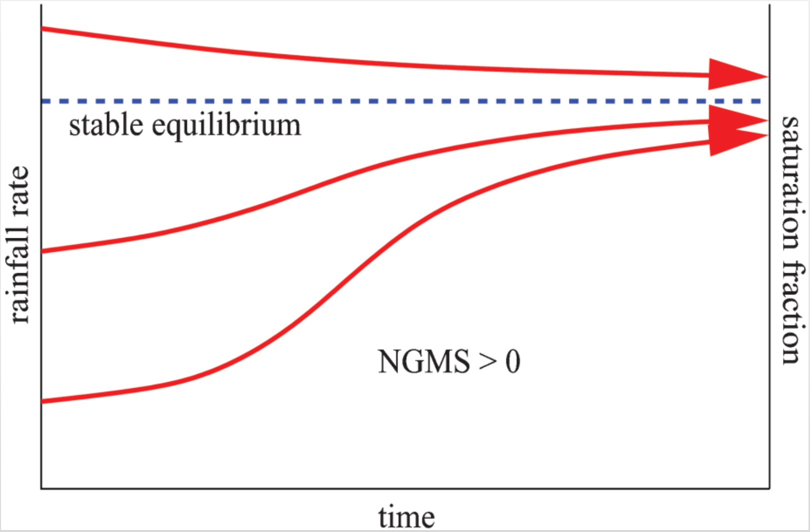
- 1. Neelin & Held (1987)
  - 2-layer model
  - postulate: $$\underset{convection\ \&\ precipitation}{low\ level\ convergence} \propto \frac{(MSEF)_{upper} - (MSEF)_{lower}}{(MSE)_{upper} - (MSE)_{lower}}$$
  - fixed - sea temp. difference
    - relative humidity
  - used to explain sensitivity to SST - climatology ok,; day-to-day not
- 2. Raymond (2000) hypothesis
  - preciputation over wram tropical pool function solely of column relative humidity or saturation fraction (SF)

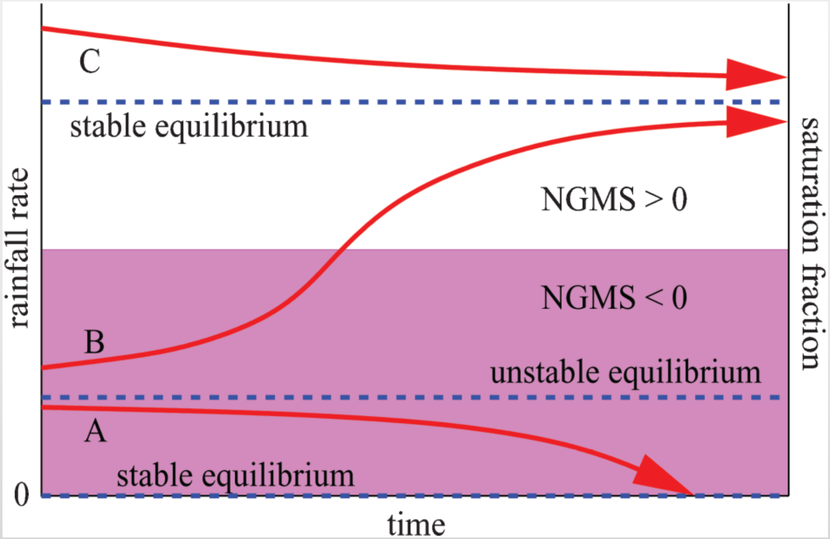
- Back & Bretheron (2005)
  - SF + surface wind speed - surface heat & moisture fluxes
  - column stability CIN or CAPE
- BUT dominant contributor to precipitation rates are SF variations

- 4. Transient flows
  - If precipitation rate & tropospheric humidity =F(t) → NGMS=f(t)



- 5. Multiple equilibria
  - Convective regions associated with smaller SF then stratiform regimes.
  - Moist entropy import, NGMS<0
  - saturation deficit, key parameter





Convective regimes tend to be associated with smaller SF then stratiform & import entropy - NGMS<0

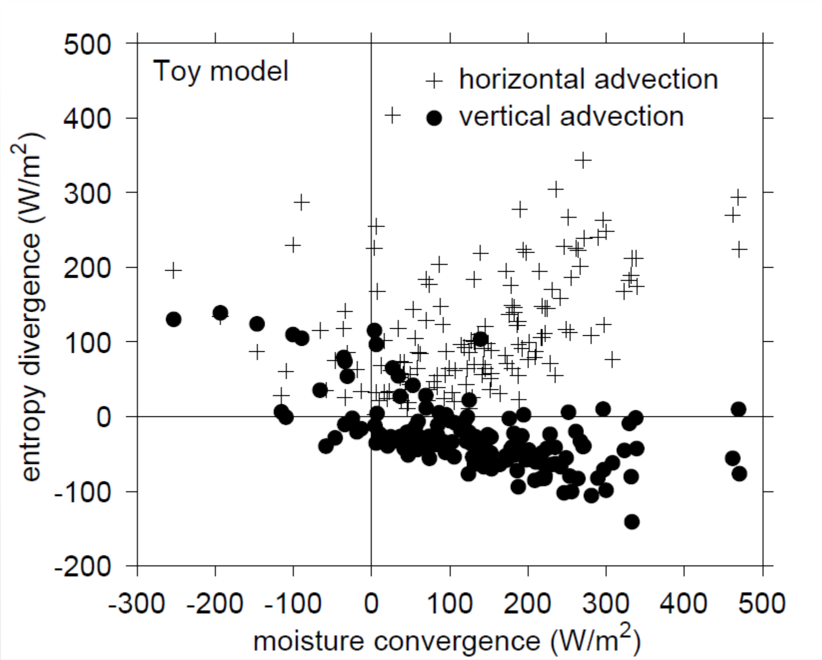
Results

- **G**lobal **F**orecasting **S**ystem
- Period: March 10th - May 22nd, 2010.
- Resolution: - time 6h

  - space 1°

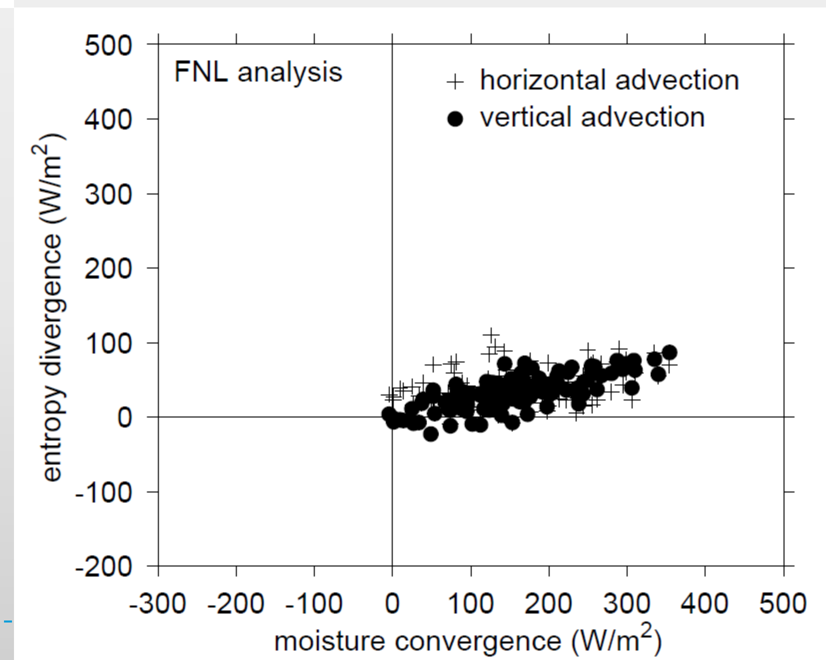
$$\Gamma_H = \frac{T_R[\vec{v} \cdot \nabla s]}{-\left\{L[\vec{v} \cdot \nabla r_t] + L[\omega \frac{\partial r_t}{\partial p}]\right\}}$$

$$\Gamma_V = \frac{T_R[\omega \frac{\partial s}{\partial p}]}{-\left\{L[\vec{v} \cdot \nabla r_t] + L[\omega \frac{\partial r_t}{\partial p}]\right\}}$$



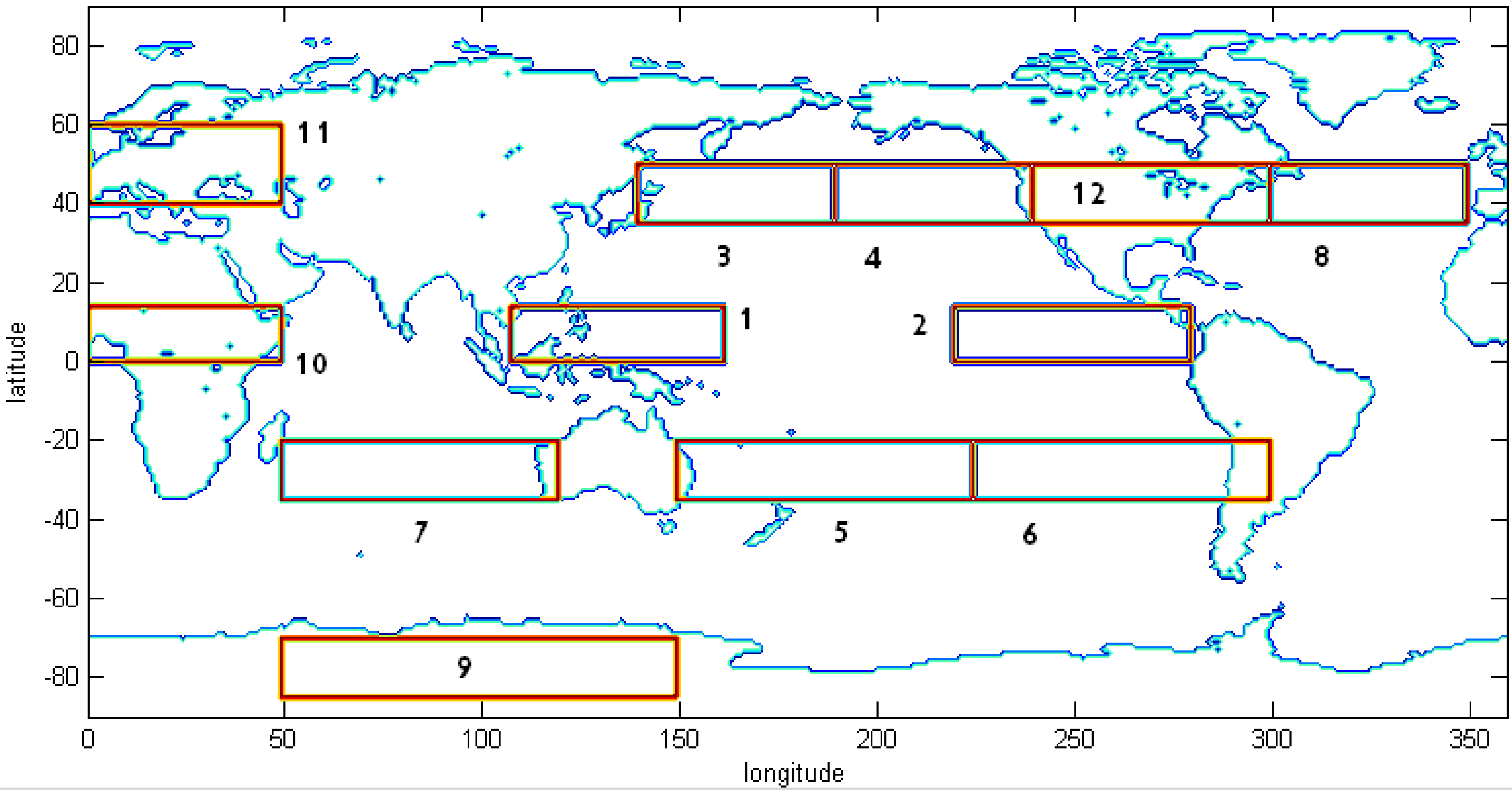
Toy
model

August



FNL

June-September 2005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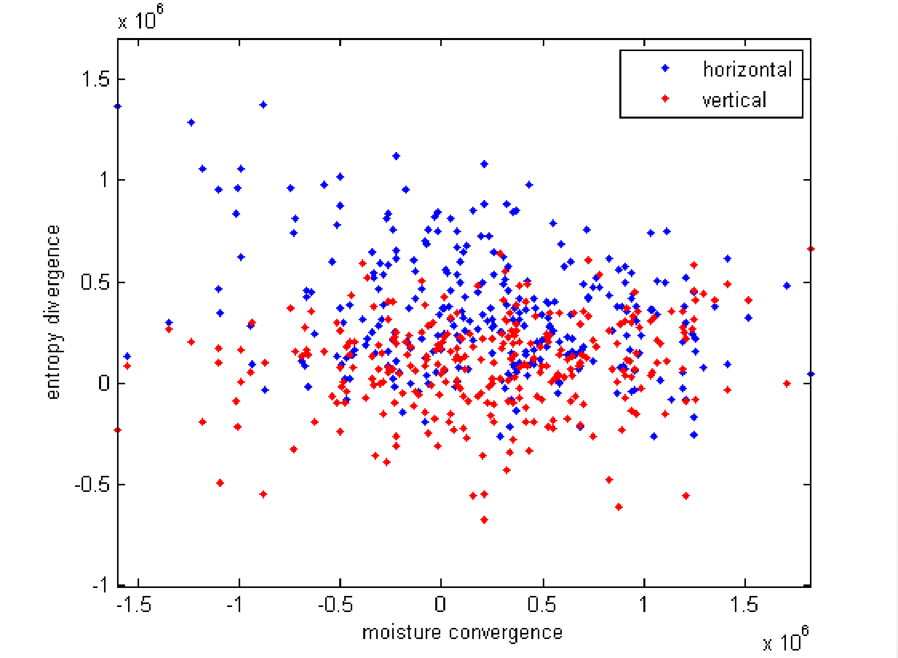
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moisture convergence
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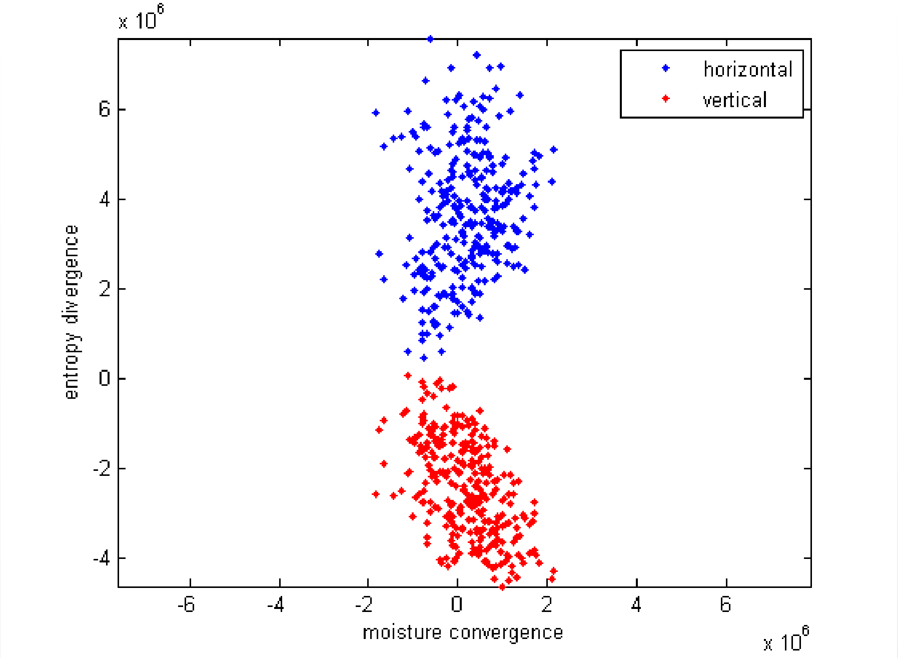
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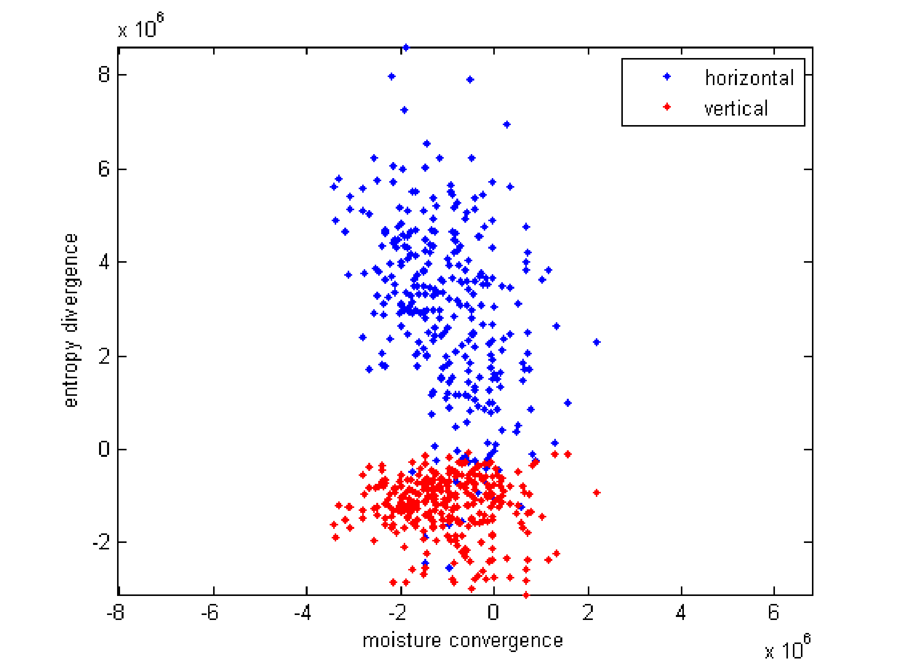
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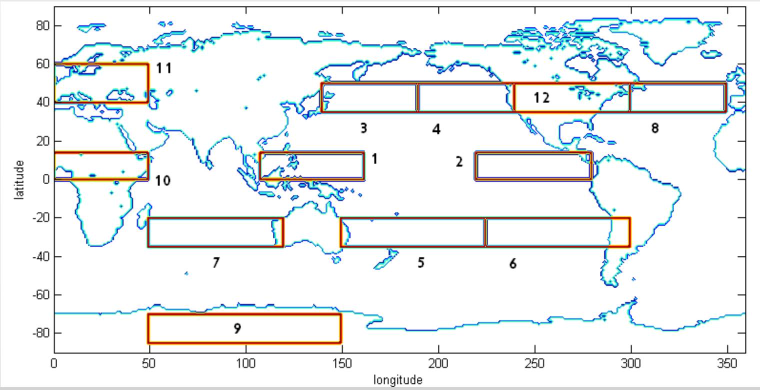
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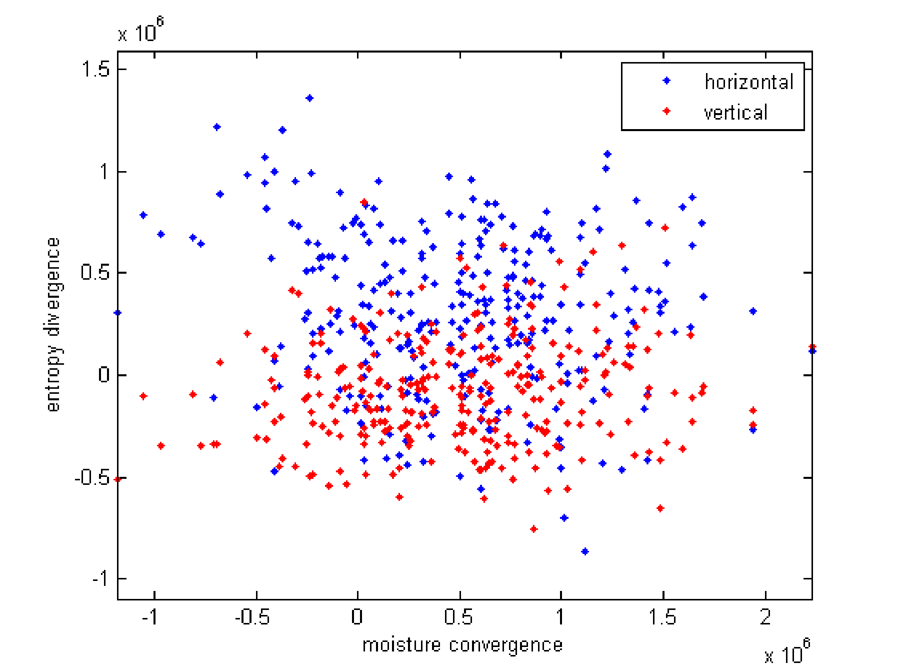
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entropy divergence
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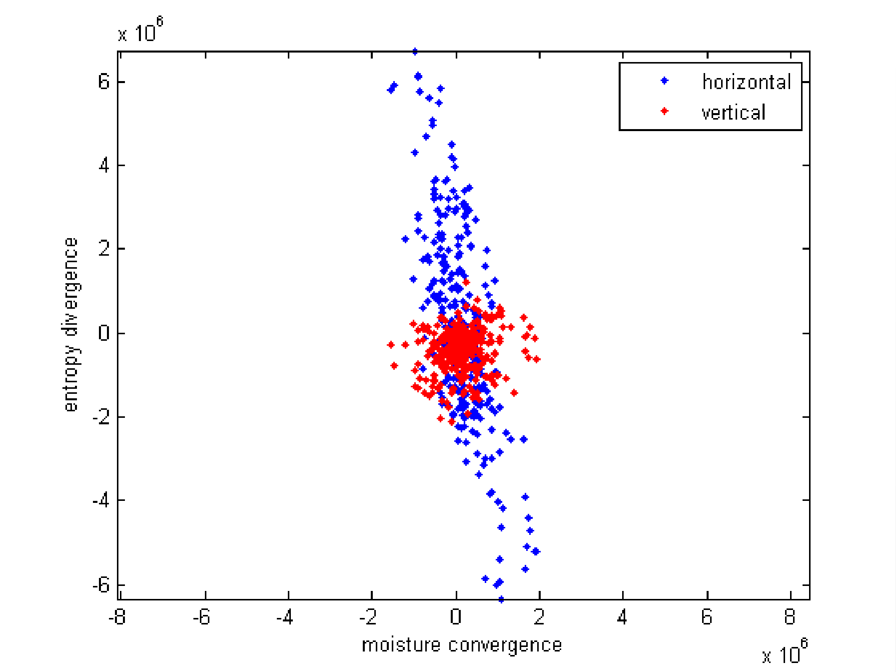
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entropy divergence
moisture convergence
x 10^6
horizontal
vertical

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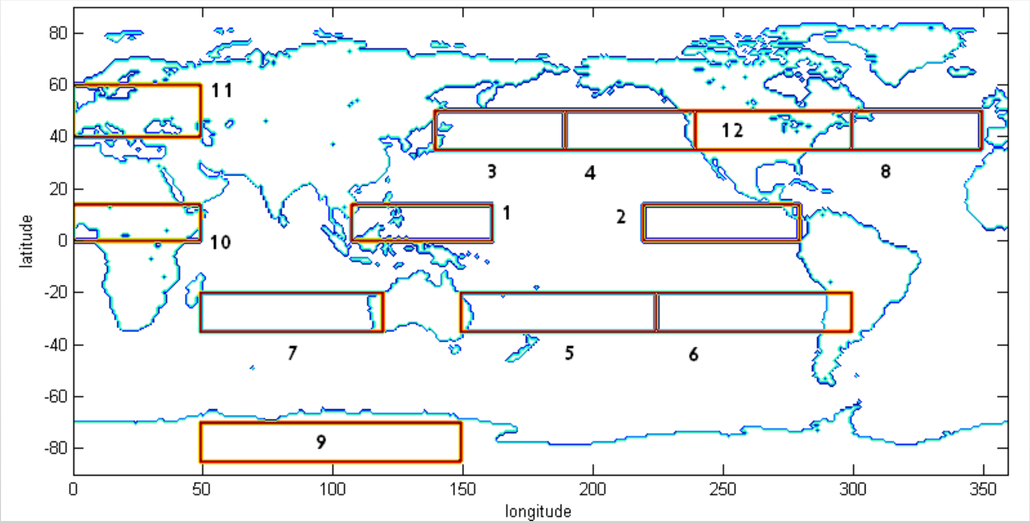
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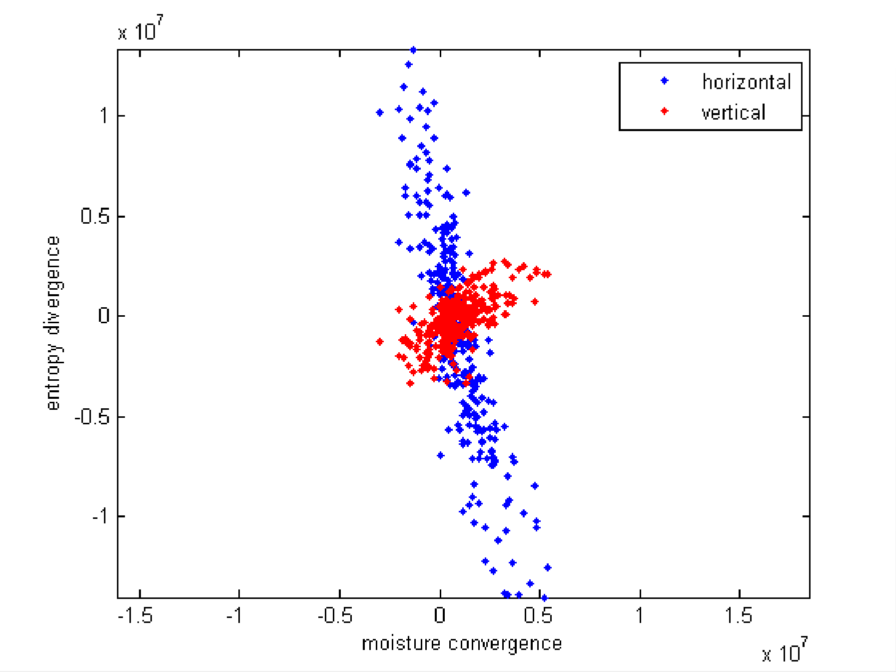
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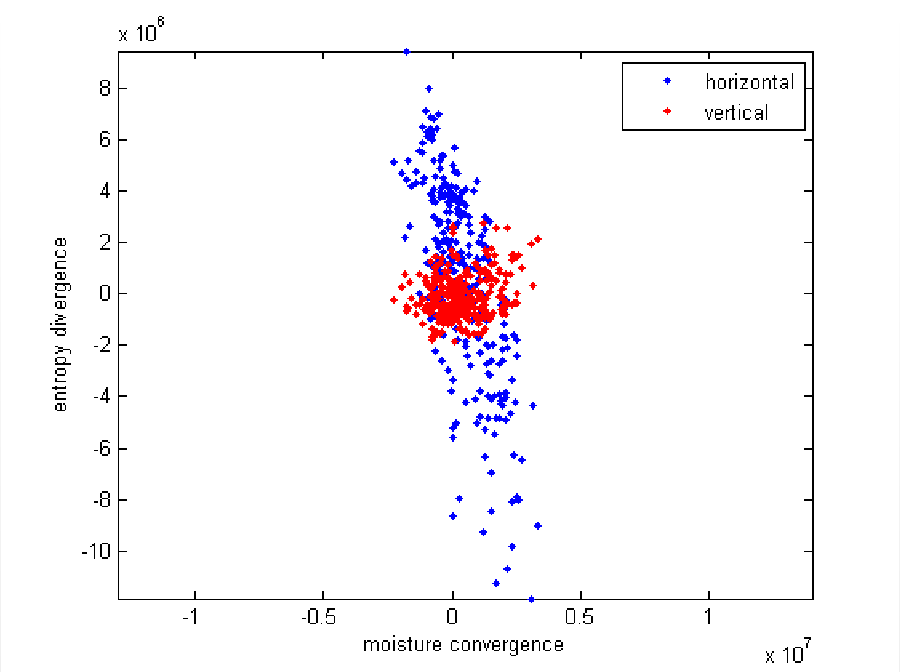
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x 10^7

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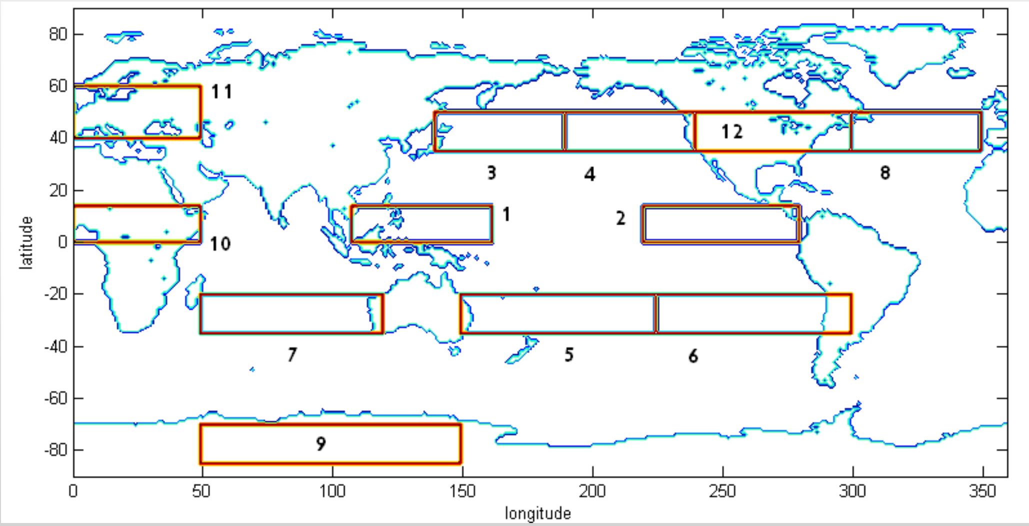
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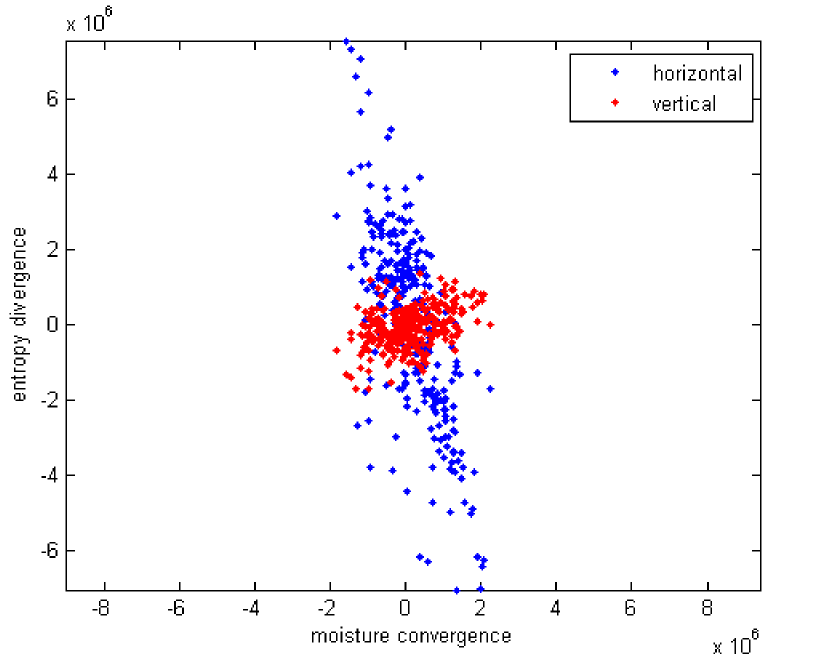
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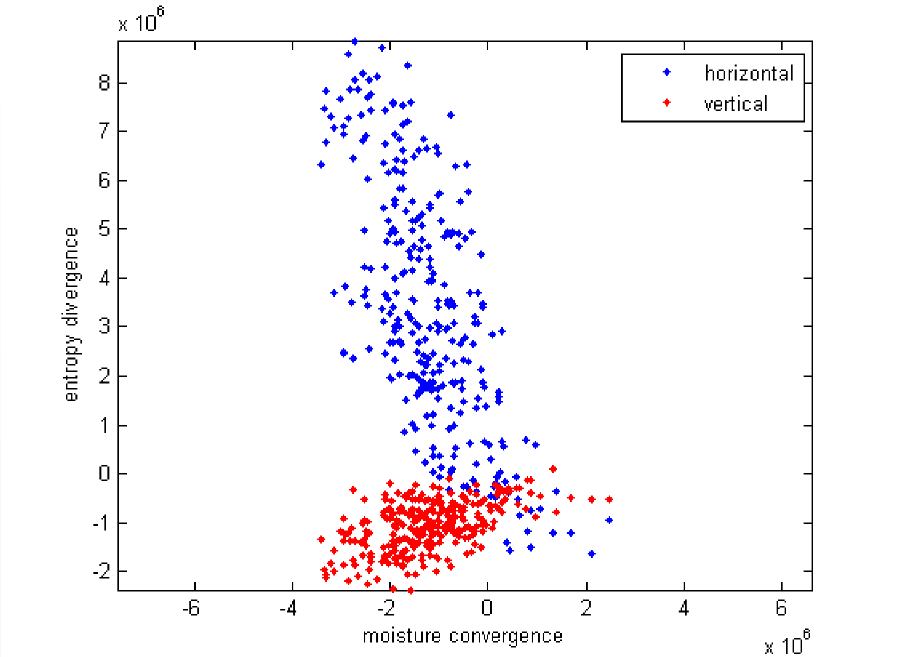
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moisture convergence
x 10^6

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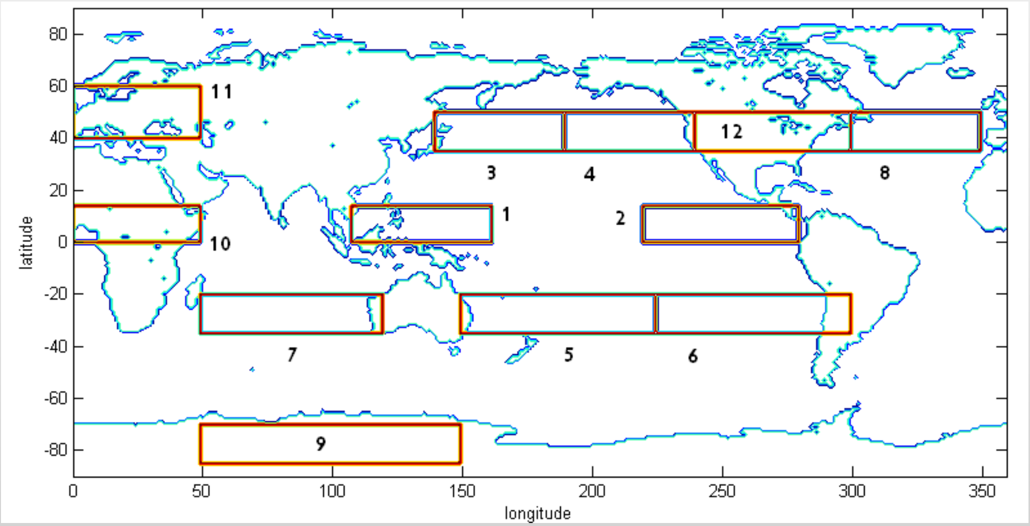
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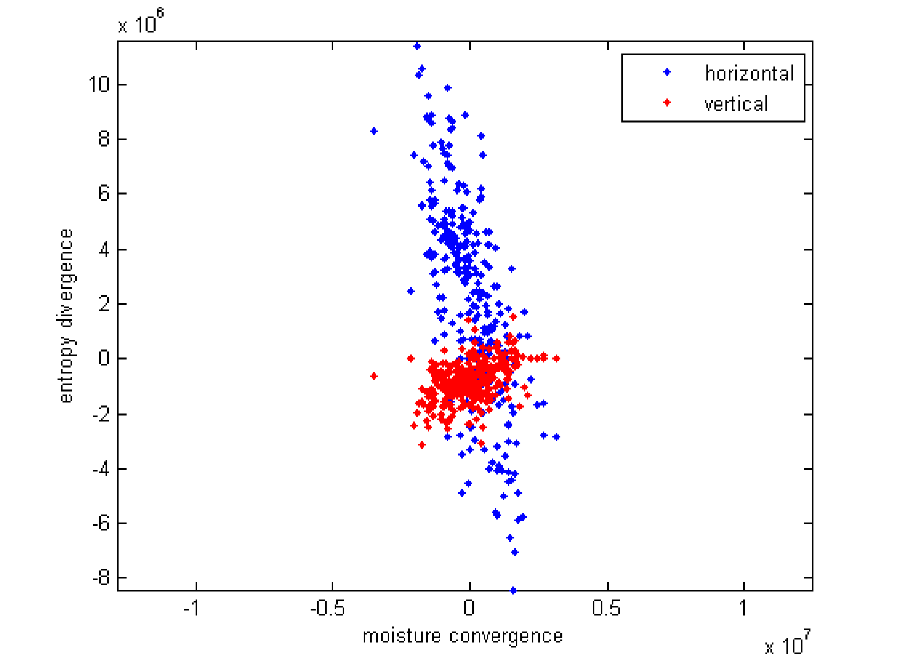
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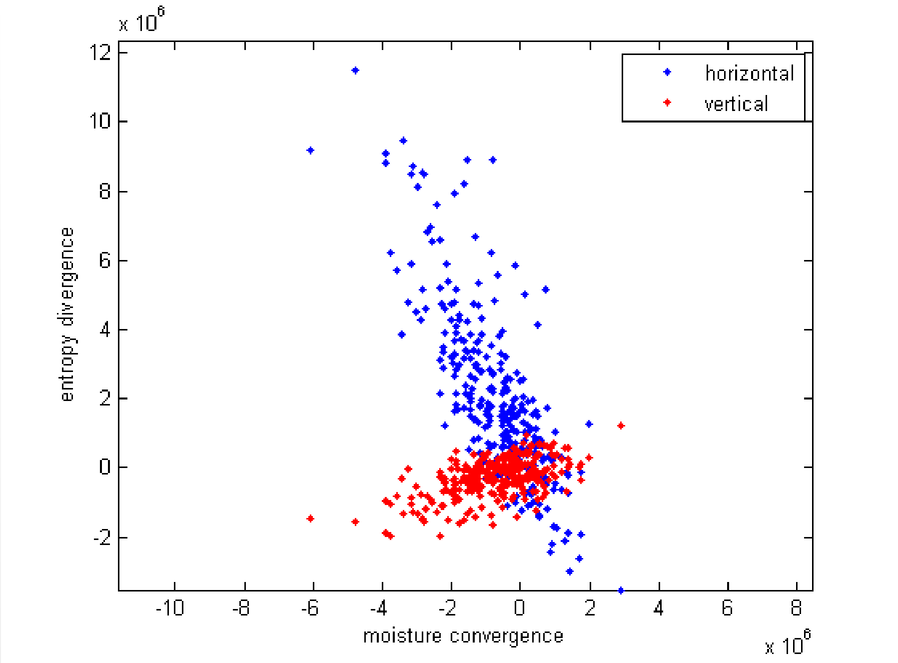
x 10^7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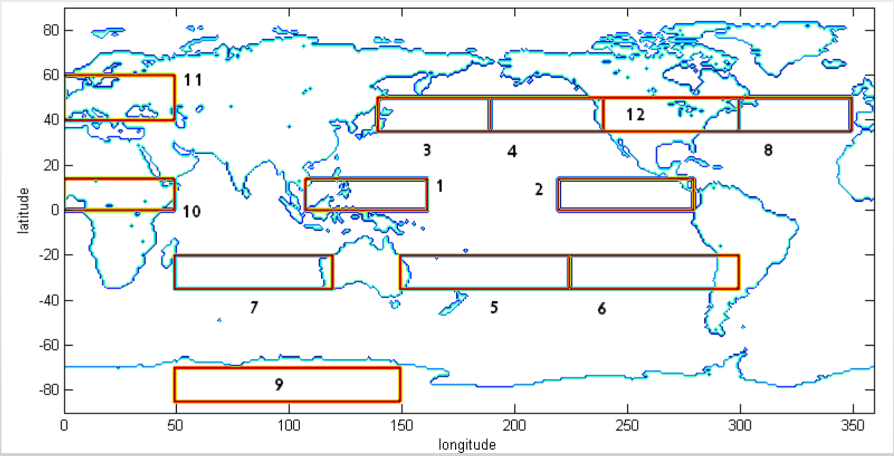
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Thank you for your attention!