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DROP SIZE DISTRIBUTION MODEL ESTIMATION BY COMPARING CLOUDSAT/CPR AND TRMM/PR

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An analysis method to estimate the climatological drop size distribution (DSD) parameter using spaceborne radars (CloudSat's w-band radar and TRMM's Ku-band radar) is proposed in this study and a global maps of estimated DSD parameters (e.g. median diameter, D0) are demonstrated. The basic idea of the analysis method is to compare the histogram of radar reflectivity factor (Z) at near-surface range bin in the over-lapping Z range (weak to moderate rain echo). Because of the Mie effect, the Z value of rainfall is different between w- and Ku-band and it reflects the difference in the histograms of w- and Ku-band.

A general characteristic of global maps of D0 through the year and local time is apparent land-ocean contrast; larger D0 appears over land and smaller D0 appears over ocean except for relatively small D0 over southeastern Asia to China. Also, relatively larger D0 appears in tropical area and mid latitude summer. Diurnal change of D0 can be seen by comparing the day/night time D0; D0 is larger in the night time over ocean while day time D0 is larger over land. Tropical Ocean shows smaller seasonal change, while larger change are seen over mid-latitude area.

Introduction (Motivation of this study: goal)

- Algorithm validation for GPM/DPR, especially for DSD estimation.
  - **Utilization of W-band radar data (CloudSat and future EarthCARE)**
  - **Current target is validation of DSD estimation by TRMM/PR .**

Key idea

- Difference in histogram of Z between CloudSat and TRMM/PR comes from the Mie scattering effect and attenuation.
  - **Mie scattering correction closely relating to the DSD (model).**
  - **Attenuation correction can be done using surface echo (sigma zero) if we consider only surface rain. Reference sigma zero data are prepared using no-cloud data (1 x 1 deg.)**
  - Note: this study is targeting the weak to moderate rain where the both radar can observe with certain quality.

Equations

$$k=\alpha Z^{\beta}$$ k-Z relationship (α, β: constant) *--- Start point of DSD model*

$$k=\int Q_t(D)N(D)dD=N_0\int Q_t(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD$$

$$Z=\int \sigma(D)N(D)dD=N_0\int \sigma(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD$$

--- Gamma DSD model is used

Qt: extinction cross section, N(D): number concentration, D: diameter
sigma: backscattering cross section

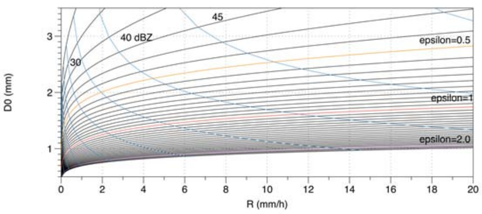
$$N_0\int Q_t(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD=\alpha\left[N_0\int \sigma(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD\right]^{\beta}$$

$$N_0^{1-\beta}=\frac{\alpha\left[\int \sigma(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD\right]^{\beta}}{\int Q_t(D)D^{\mu}e^{-(3.67+\mu)/D_0}dD}$$

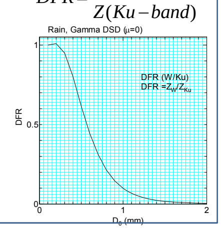
--- equation to determine N0 (function of D0 or mu)

k-Z adjustment equation in TRMM 2A25 (ε-k-Z relationship) $$k=\varepsilon\alpha Z^{\beta}$$ *---ε adjusts the α in k-Z relationship*

Relationship among D0, R, Z and ε



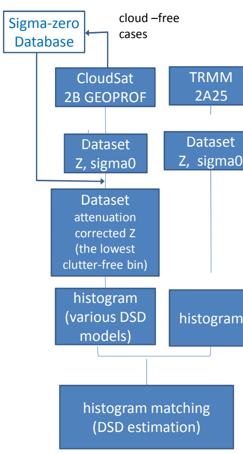
$$DFR=\frac{Z(w-band)}{Z(Ku-band)}$$

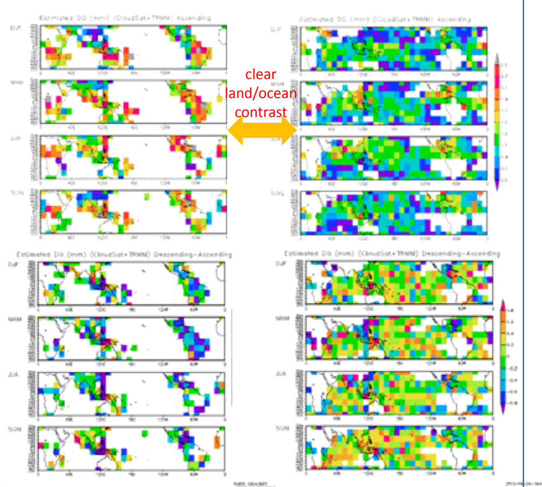


Result (Example of estimated D0)

Global dataset:
3-month average, 10 x 10 degree grid (40S to 40N), Land/Ocean, daytime/nighttime
December 2006 to November 2007

(Top) Afternoon (0-3 P.M.= ascending node of CloudSat)
(Bottom) Descending – Ascending





larger diurnal change (day/night contrast) over maritime continent and Amazon

smaller diurnal change except for several area (e.g Indian ocean in SON)

Purpose of this study

- Establish a DSD parameter estimation method by combining both CloudSat and TRMM/PR data with statistical method.
- Demonstrate a visualization method of global microphysical data
  - **Climate map of DSD parameter as well as other meteorological parameters.**
- To see the climatological characteristics in term of cloud and precipitation interaction
  - 10 x 10 deg. box

Data

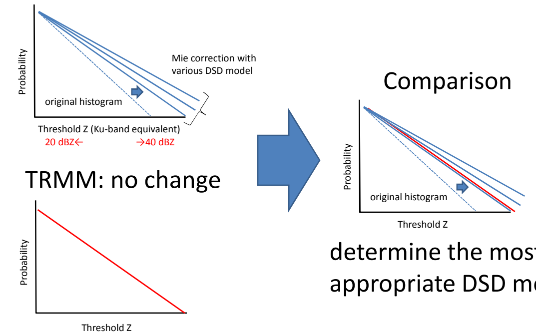
Major specifications of CloudSat/CPR and TRMM/PR

	CloudSat/CPR	TRMM/PR
Orbit	Sun-synchronous orbit Altitude about 700 km (local time 1:30)	Non sun-synchronous orbit (Inclination = 35 degrees) Altitude about 400 km
Swath width (footprint size)	Nadir (1.3 km)	about 240 km (5 km)
Vertical resolution	500 m (240 m sampling)	250 m (partially 125 m sampling)
Frequency	94 GHz	13.8 GHz
Minimum detectable echo	-30 dBZ	17 dBZ
Product used in this study	2BGROPROF	2A25 Ver. 6
Data available	2006.8-2011.1 2011.12-current	1997.12-current

Histogram matching

Compare the Z-histogram of Ku-band.

CloudSat : convert W-band histogram to Ku-band histogram with various DSD models (Mie correction)

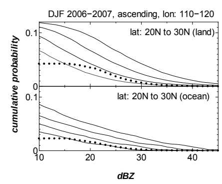


determine the most appropriate DSD model

DSD models

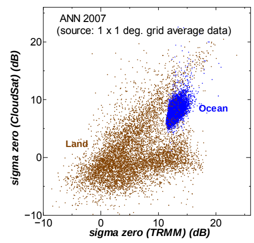
DSD model defined by k-Z (and ε) relationship
gamma DSD with various μ factors
(single D0 in fixed gamma DSD model)

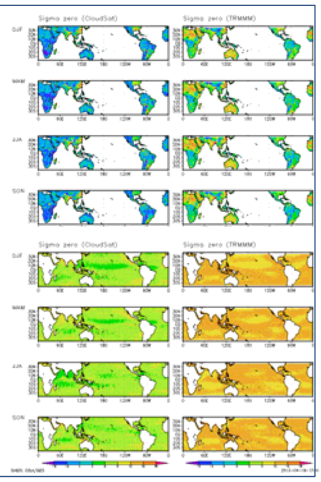
Fitting result and coverage of DSD model, sing le D0 model is the most appropriate → simply offset the histogram of CloudSat.



σ0 database

In order to estimate the path integrated attenuation, no-cloud (no-rain) sigma zero databases are created from CloudSat (TRMM) data.



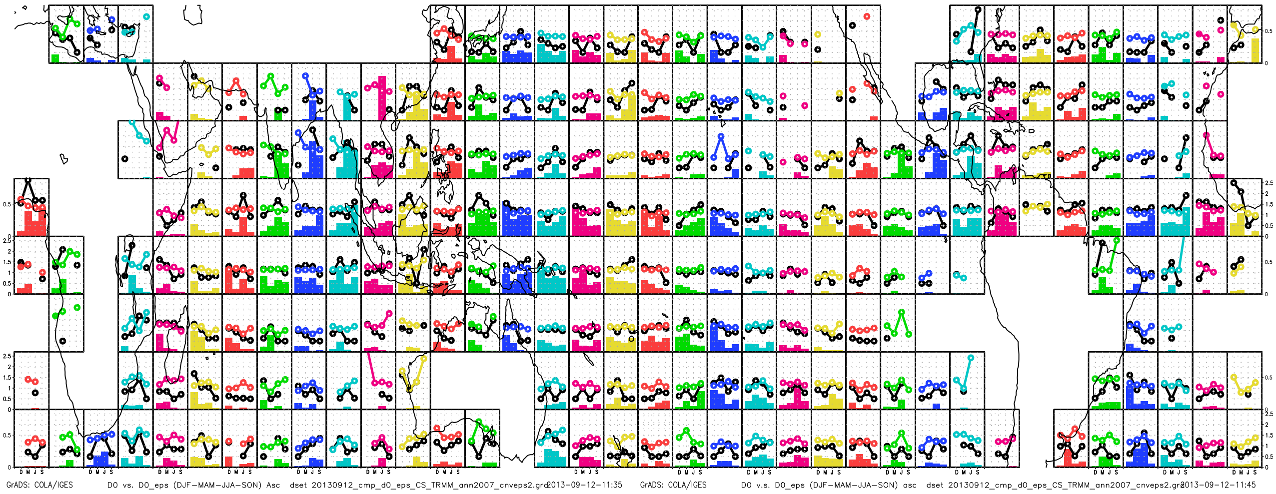


Evaluation (Comparison of D0 with single frequency precut = TRMM/PR only)

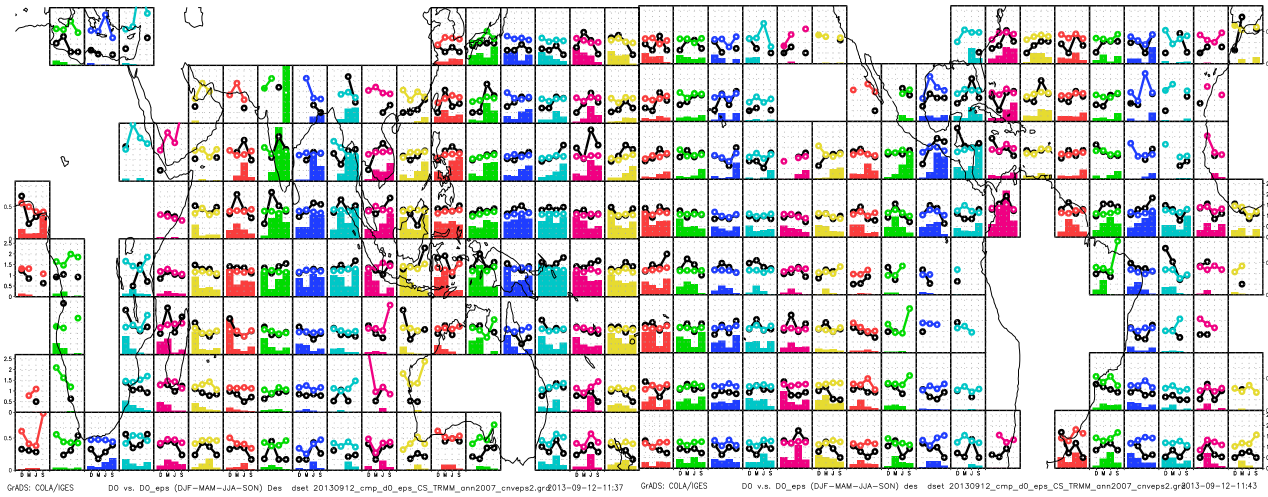
- Seasonal change (DJF, MAM, JJA, SON) of climatological D0 and rain rate (December 2006 to November 2007)

- D0 (CloudSat & TRMM) : black circles
- D0 (TRMM only) : colored circles
- bars: rain rate (mm/h)

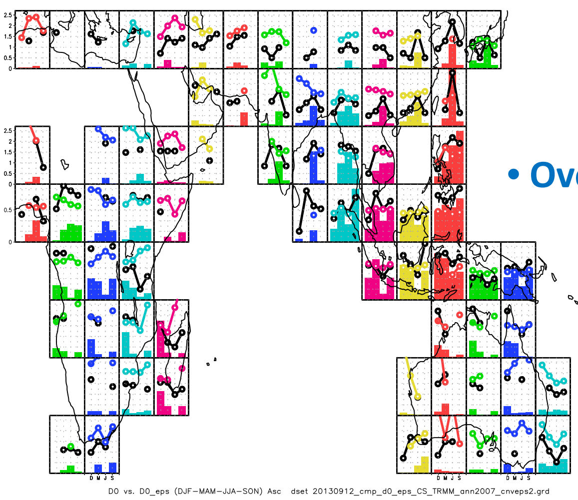
• Over water/Daytime

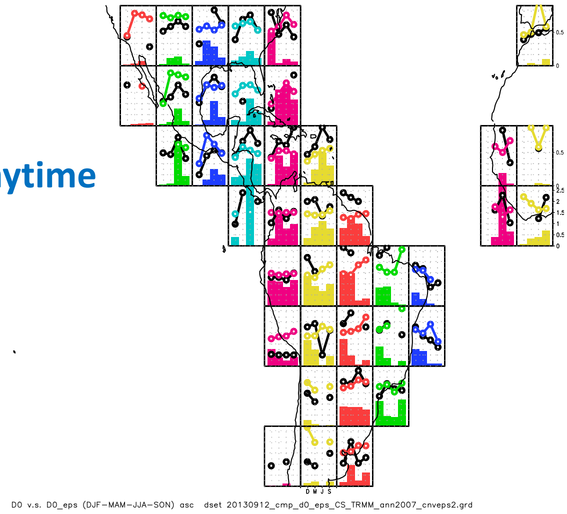


• Over water/Nighttime

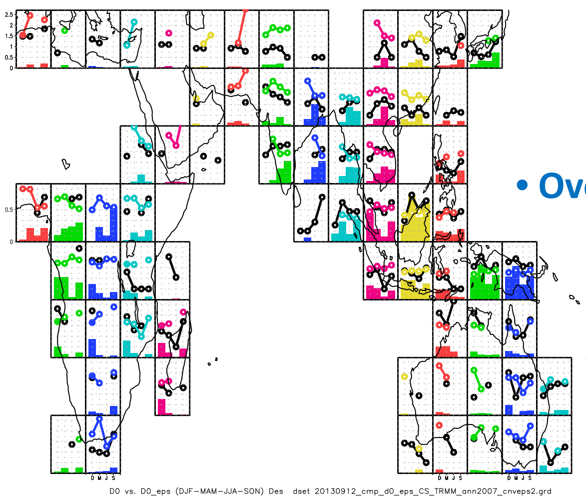


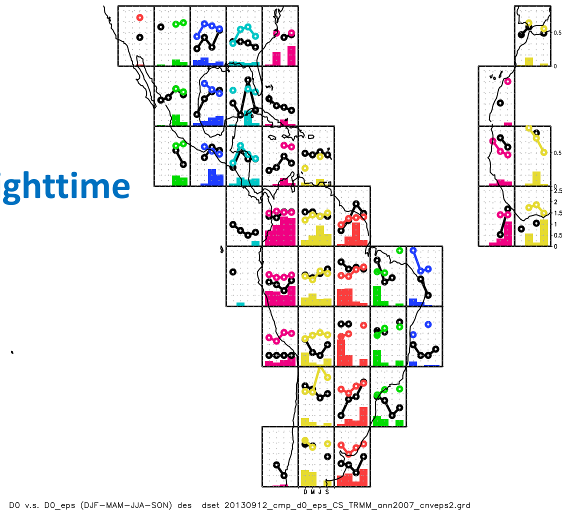
• Over land/Daytime

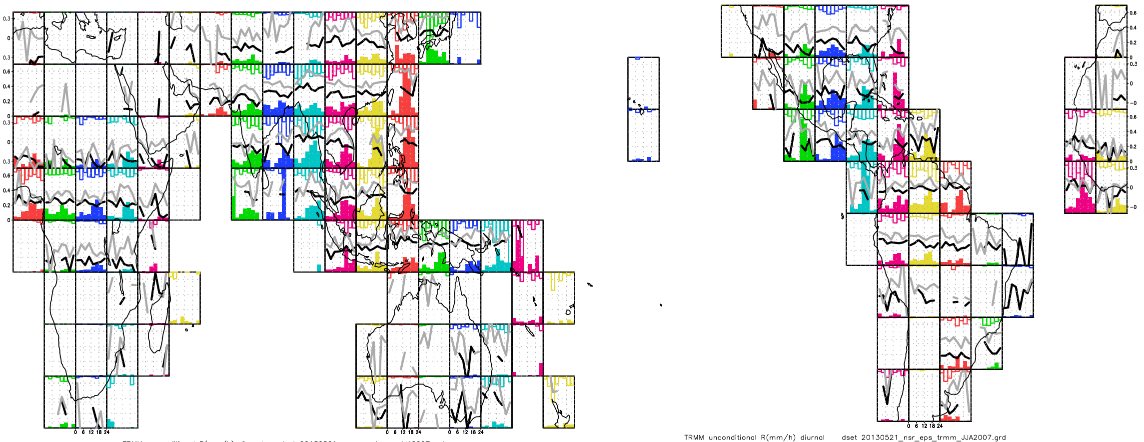




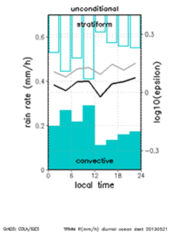
• Over land/Nighttime

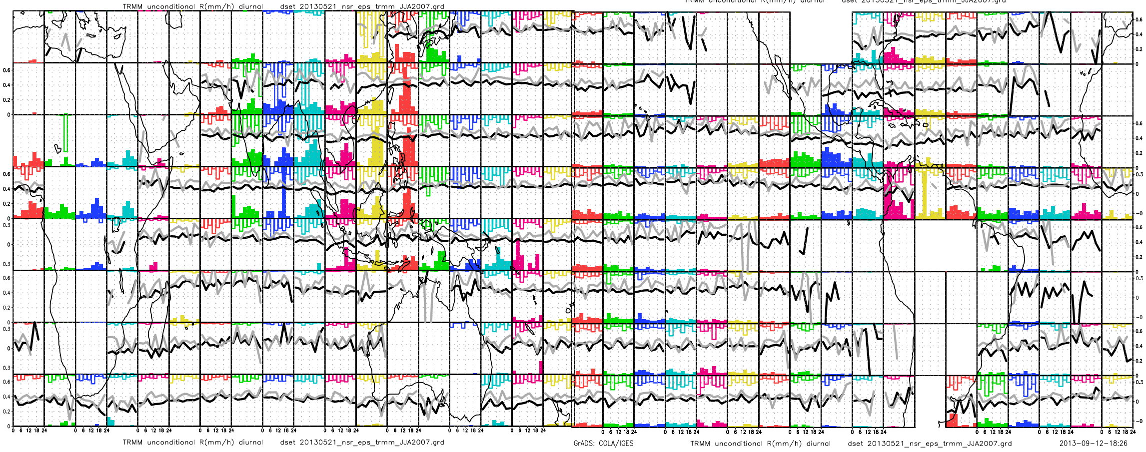




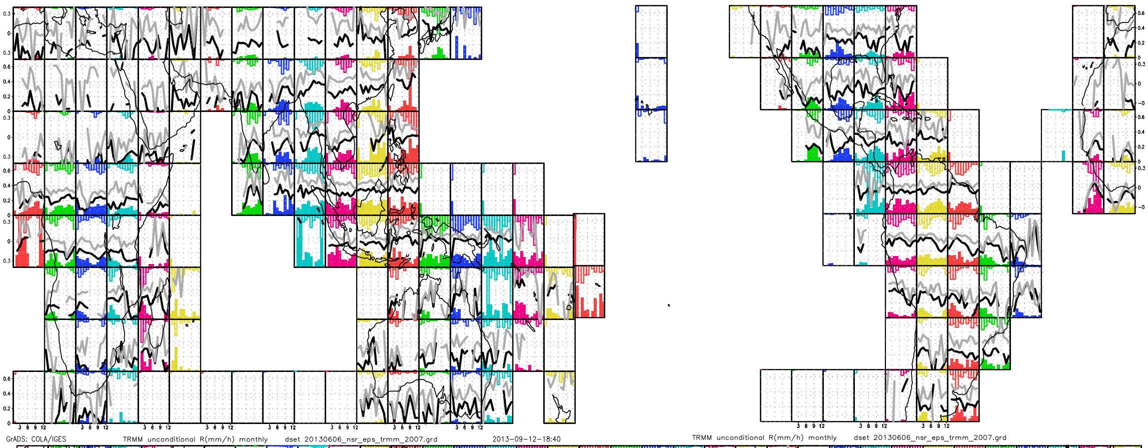


- Diurnal change
  - TRMM only
  - Convective vs. Stratiform
  - over land
  - 2007

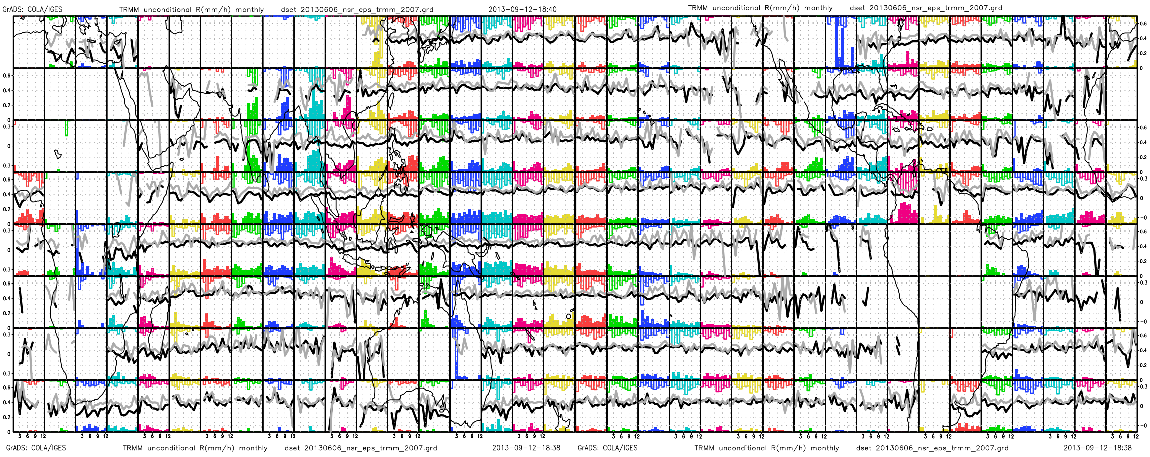




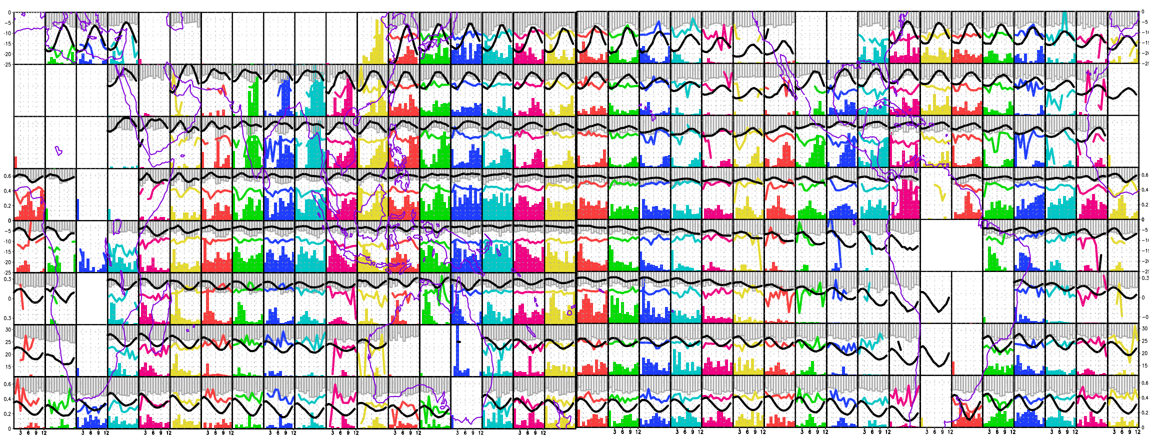
- Diurnal change
  - TRMM only
  - Convective vs. Stratiform
  - over water
  - 2007



- Monthly change
  - TRMM only
  - Convective vs. Stratiform
  - over land
  - 2007



- Monthly change
  - TRMM only
  - Convective vs. Stratiform
  - over water
  - 2007



- Monthly change
  - TRMM (rain)
  - NOAA (SST)
  - J-OFURO (Sea surface wind)
  - over water
  - 2007