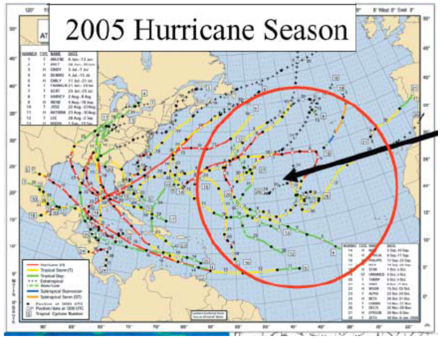

NASA Hurricane Science Research Program Science Team Meeting
[6 - 8 April 2009; Tallahassee, FL]

Current Issues with TRMM Satellite Precipitation Retrieval & Desired New Measurements from NASA HSRP

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Four Current Research Issues Concerning TRMM Satellite Precipitation Retrieval vis-à-vis Tropical Cyclones

Issue 1: There is continuing disagreement amongst three main Version-6 (V6) / Level-2 (L2) algorithms insofar as full-resolution / instantaneous precipitation rates: Radar-only (2a25), Combined Radar-Radiometer (2b31), and Radiometer-only (2a12).

Issue 2: Gross approximation methodologies are needed for retrieval of latent heat (LH) profile above freezing level.

Issue 3: Lack of understanding of precipitation diurnal cycle within tropical cyclones precludes testing existing V6/L2 retrieval algorithms for their capabilities in extracting diurnal signals.

Issue 4: Rainfall data assimilation driven deterministic numerical prediction experiments for highly convective regimes (*e.g.*, genesis / early development stages of tropical cyclones) ultimately fail to retain assimilation effects beyond very short forecast times (order 1 hour) if time scale of rainfall data (typically hours) is considerably longer than time scale of convective processes (typically minutes) -- and ultimately corrupts thermodynamic, dynamic, and hydrological control variables in seeking to produce "averaged" adjusted rainfall quantities over data time intervals that are inconsistent with "actual" mesoscale rainfall quantities.

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Issue 1: V6/L2 Algorithm Disagreement

Hurricane Katrina: 28 August 2005

generally strongest maxima throughout inner and outer bands

weaker maxima than 2a25, with generally similar pattern throughout inner and outer bands -- but there are striking exceptions

generally weaker outer environment rain rates but generally stronger eyewall rain rates

mm hr^{-1}

Radar-only (2a25)

mm hr^{-1}

Combined (2b31)

mm hr^{-1}

Radiometer-only (2a12)

ONE SPECIFIC EXAMPLE

2a25 indicates very weak local minimum along inner rain band

2b31 indicates very strong local maximum along same band at same place

2a12 breaks rain band precipitation into two stron pieces with moderate sector in between

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Issue 1: Likely Suspects

1. **Erroneous & inconsistent microphysics assumptions.** [Ongoing research by various PMM Science Team members including myself; Fovell et al. 2009 (JAS); Matyas 2009 (JAMC); Li & Pu 2008 (MWR); Zhu & Zhang 2006 (JAS); others]
2. **Insofar as radiometer algorithm -- ice loading above freezing level strongly impacts all retrieved rain rate estimates along vertical profile via Earth-directed passive backscatter and moderate ice emission effects, whereas insofar as radar and combined algorithms -- ice loading only weakly interacts with reflectivity-driven retrievals via minor attenuation effects.**
3. **Radar-only algorithm is based on deterministic, distance-dependent, time-delay RTE backscatter physics using high spatial resolution measurements, while combined algorithm is based on radiometer-generated attenuation correction to Bayesian radar method, and radiometer algorithm is based on steady state RTE path-accumulated attenuation physics using significantly lower spatial resolution measurements.**

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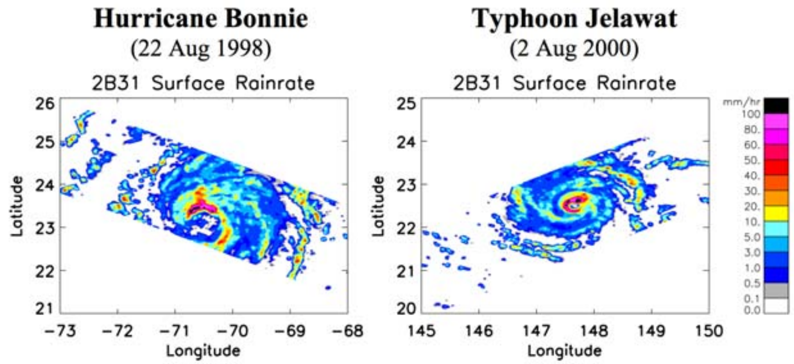
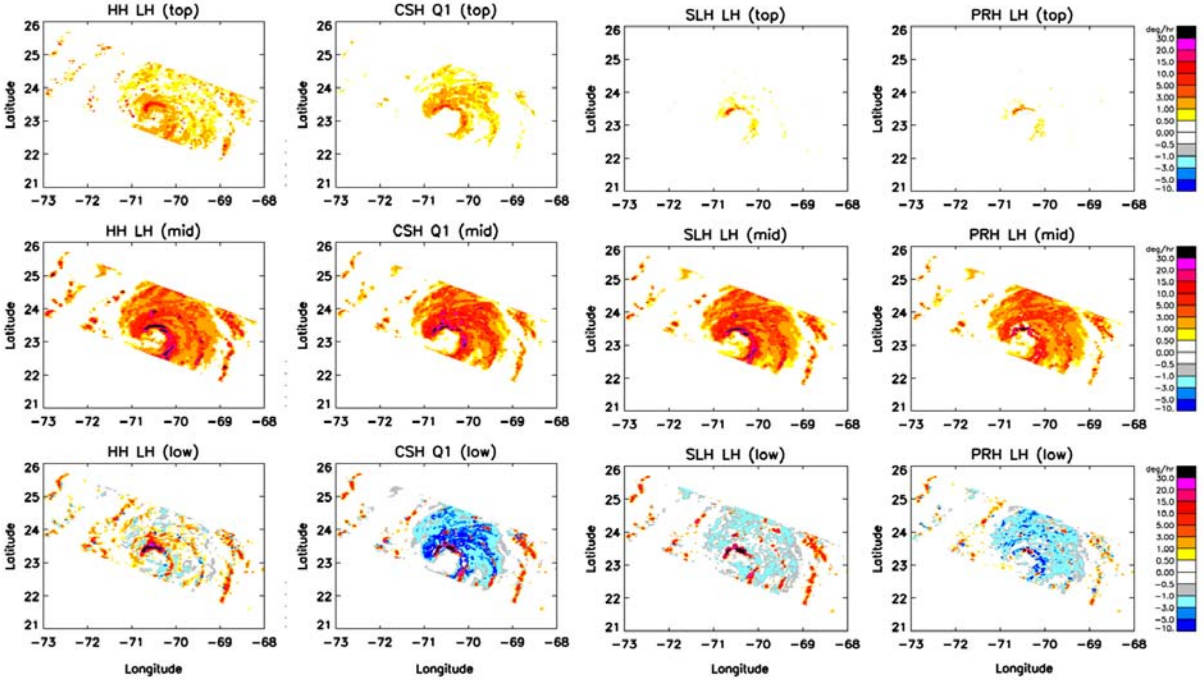
Issue 2: LH Retrieval Problems above Freezing Level



Hurricane Bonnie



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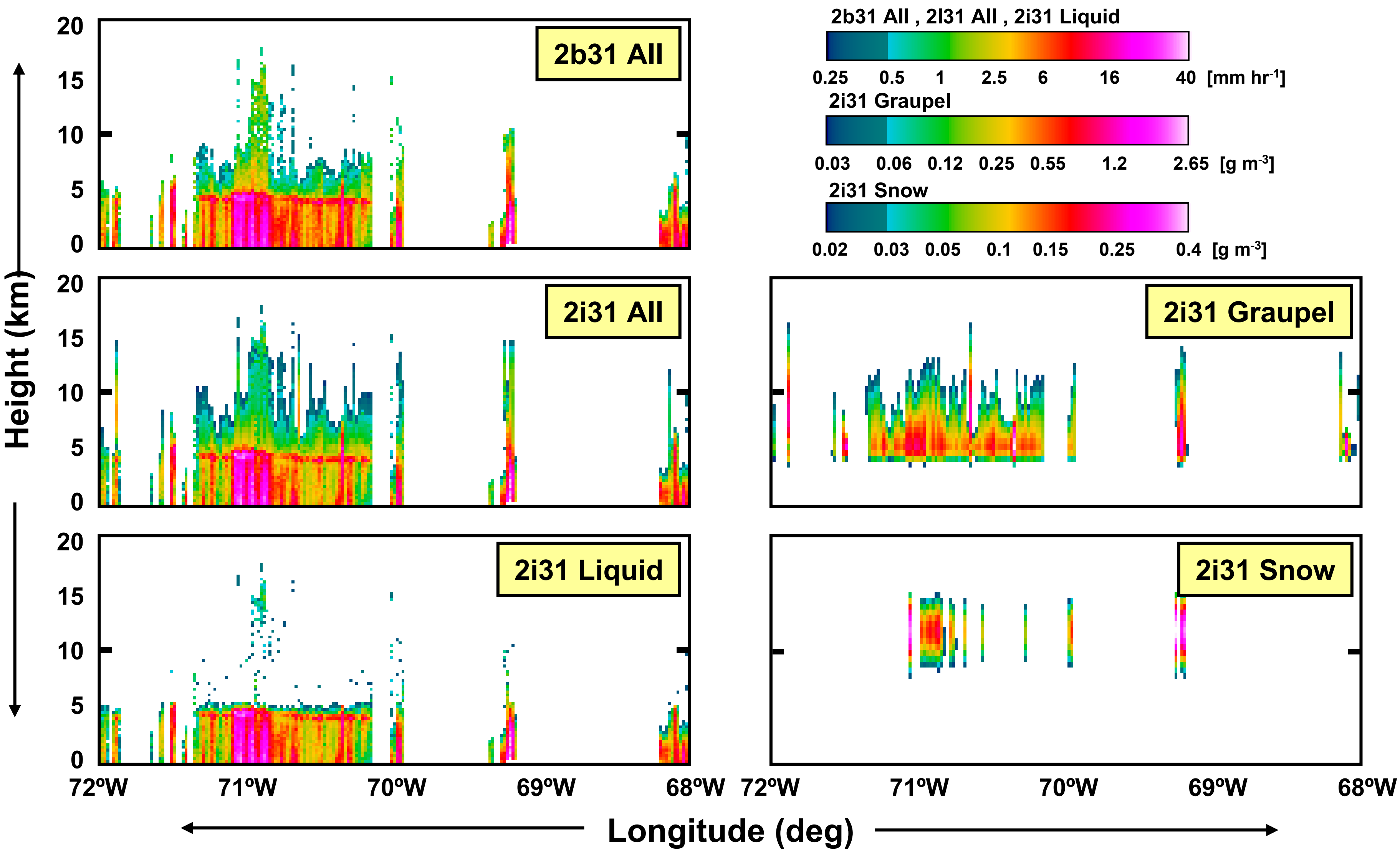
Comparison of Combined PR-TMI Algorithm Precipitation Retrieval for Hurricane Bonnie: 2b31 vs 2i31



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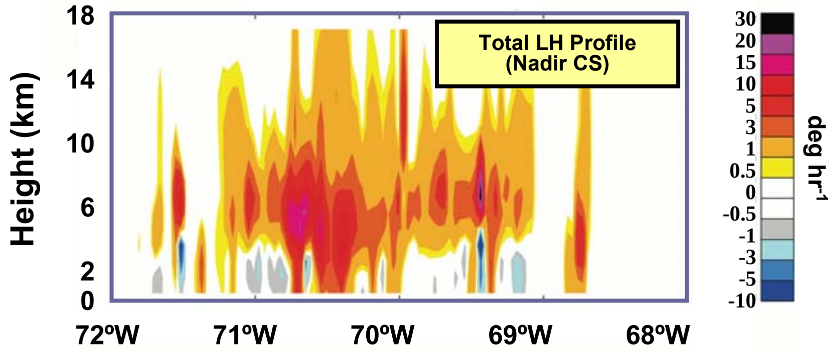
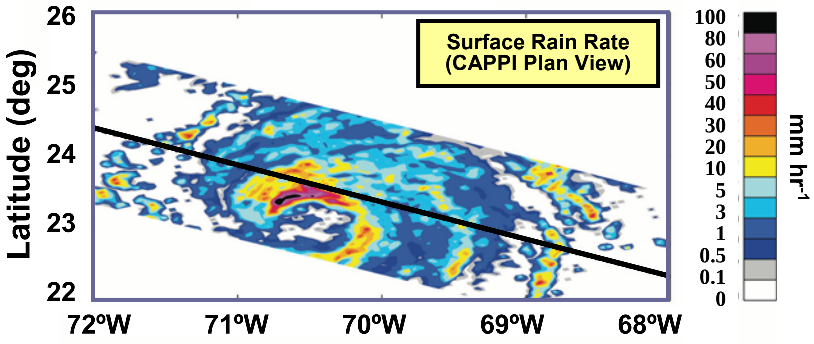
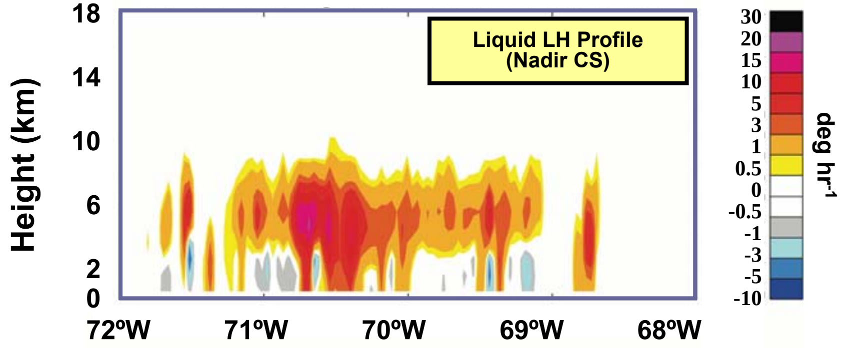
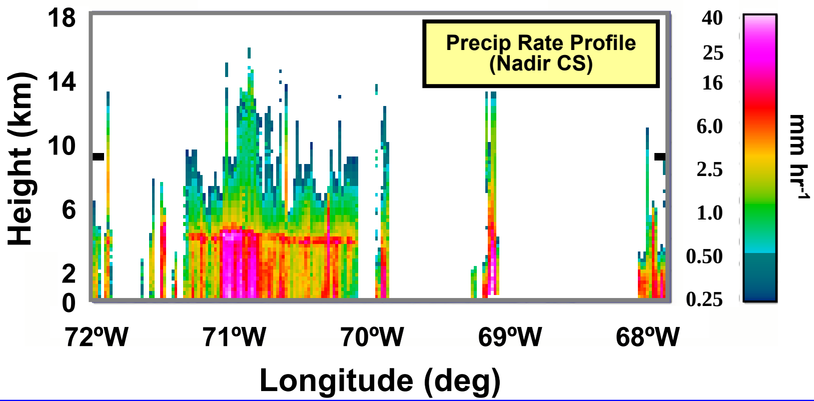
Hurricane Bonnie LH Rate Profile Retrievals from Vertical Derivatives of Water & Ice Mass Fluxes

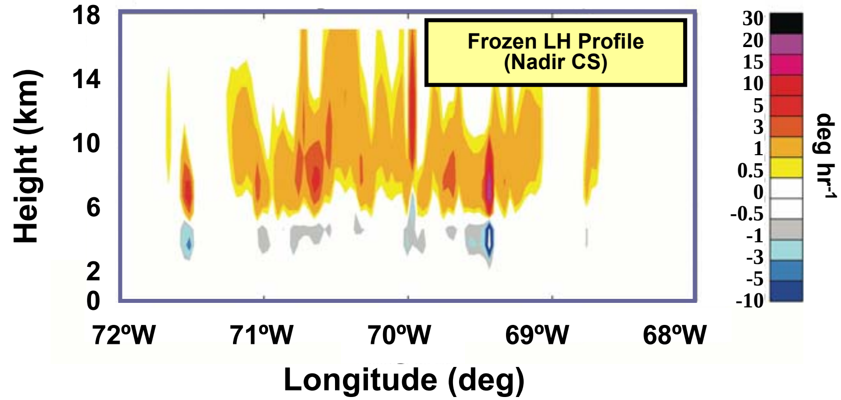
[water drop sizes / concentrations plus rain rates / water drop fall velocities & mass fluxes derived from original combined PR-TMI rain rate algorithm 2b31, while ice particle sizes / concentrations plus precipitation rates / ice particle fall velocities & mass fluxes along with total / liquid / frozen LH rate profiles derived from CRM-based precip rate / LH algorithm 2i31]











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Issue 2: Likely Suspect

1. There are two basic methods for retrieving LH profiles:

A. Pre-calculated CRM-generated LH profiles are correlated with small set of basic satellite data-recoverable parameters, *i.e.*, binary convective-stratiform index; surface RR; rain top height,

B. Calculating vertical derivatives of retrieved liquid and ice vertical mass fluxes, which are, under steady state microphysics assumption, proportional to LH magnitudes through use of appropriate latent heat of phase change coefficients.

Each method is highly sensitive to nature of ice profile above freezing level -- from CRM model in first case and from retrieval scheme in second case. CRMs are notoriously inaccurate in simulating ice microphysics; radar-only and combined algorithms cannot obtain ice layer retrievals because of PR sensitivity cuttoff (17 dBZ); radiometer-only algorithm's ice concentration retrievals have large uncertainty properties.

Smith, E.A., W.-K. Tao, Z.S. Haddad, A.Y. Hou, R.K. Kakar, M. Katsumata, T.N. Krishnamurti, S. Lang, W.S. Olson, S. Satoh, S. Shige, Y. Takayabu, G.J. Tripoli, and S. Yang, 2009: A review of TRMM satellite latent heating retrieval: Algorithm development, validation, and applications. *J. Meteor. Soc. Japan*, submitted.

Tao, W.-K., E.A. Smith, R.F. Adler, Z.S. Haddad, A.Y. Hou, T. Iguchi, R. Kakar, T.N. Krishnamurti, C.D. Kummerow, S. Lang, R. Meneghini, K. Nakamura, T. Nakazawa, K. Okamoto, W.S. Olson, S. Satoh, S. Shige, J. Simpson, Y. Takayabu, G.J. Tripoli, and S. Yang, 2006: Retrieval of latent heating from TRMM satellite measurements. *Bull. Amer. Meteor. Soc.*, 87, 1555-1572.

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Issue 3: Can We Retrieve Precipitation Diurnal Cycle Signal?

- ✓Emanuel and Rotunno (1986) initial vortex
- ✓302K SST
- ✓2 Experiments:
  - Control: No Sal sounding (moist)
  - Impact: SAL sounding (dry)
- ✓2 Nested grids:
  - Grid 1: 15 km resolution (125 points)
  - Grid 2: 3.75 km resolution (212 points)
- ✓65 levels of 500 m spacing to 32 km AGL
- ✓15 point absorbing layer on top
- ✓No mean flow

QuickTime™ and a
decompressor
are needed to see this picture.

Condensate Field Viewed from South

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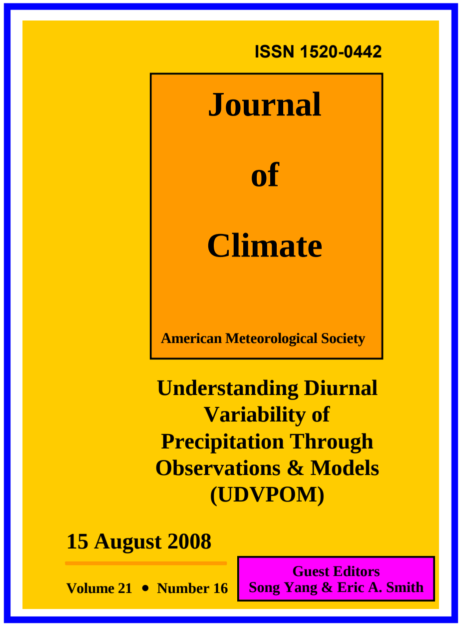
Issue 3: Likely Suspect

In recent numerical experiments conducted at the University of Wisconsin by G. J. Tripoli and his group in collaboration with myself and my group at NASA/GSFC in preparing papers for the UDVPOM Special Issue in JCLIM, we could not resolve whether apparent diurnal cycle during mature stage of simulated hurricane is actually an inertial oscillation whose time scale closely matches solar-heating diurnal cycle (*i.e.*, at 30° latitude, inertial oscillation frequency would equal *f*).

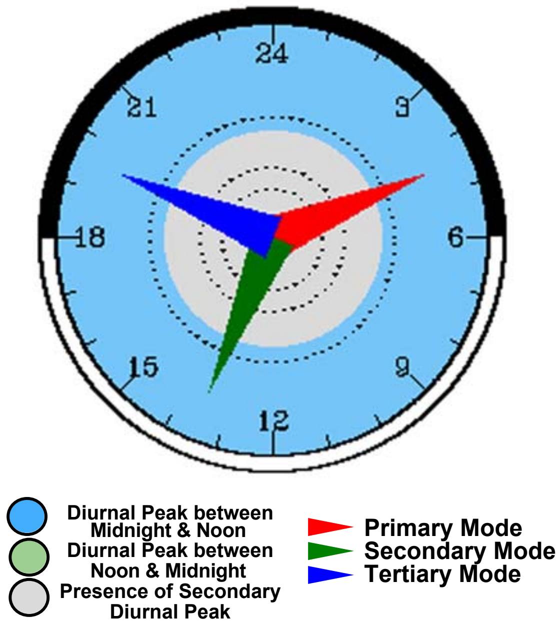
Smith E.A., and S. Yang, 2006: Diurnal variability of precipitation: Multiple modes & ambiguities. 27th Conference on Hurricanes and Tropical Meteorology 24-28 April 2006, Monterey, CA.

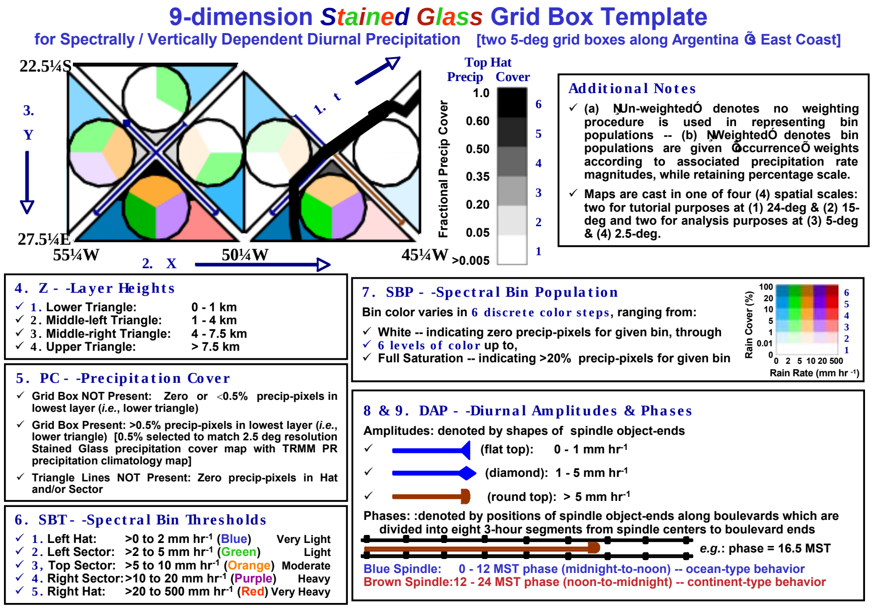
Tripoli, G.J., 2006: Diurnal modulation of tropical cyclone intensity. 27th Conference on Hurricanes and Tropical Meteorology 24-28 April 2006, Monterey, CA.



We have developed diurnal analysis tools for seeking obscure diurnal signatures in compositing framework:

Clock-face Graphic Display Analysis | **9-dimension Stained Glass Grid Box Analysis**





Yang, S., and E.A. Smith, 2006: Mechanisms for diurnal variability of global tropical rainfall observed from TRMM. *J. Clim.*, 19, 5190–5226.

Yang, S., and E.A. Smith, 2008: Convective - stratiform precipitation variability at seasonal scale from eight years of TRMM observations: Implications for multiple modes of diurnal variability. *J. Clim.*, 21, 4087-4114.

Yang, S., K.-S. Kuo, and E.A. Smith, 2008: Persistent nature of secondary diurnal modes of precipitation over oceanic and continental regimes. *J. Clim.*, 21, 4115-4131.

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Issue 4: Matching Time Scales for Data Assimilation Experiments

- **Deterministic numerical prediction experiments using precipitation data assimilation run with ARPS, NMS, and WRF CRMs, among others, have typically found for convective environments, that data assimilation effects do not “stick” for more than few hours.**
- **Because of this problem coupled with problem due to intrinsic inconsistency between non-linear growth and linear adjoints used in deterministic variational data assimilation, CRM modelers have already or are turning to ensemble EnKF-based data assimilation strategies -- without ever seeking to overcome underlying matched-time scale requirement.**

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Issue 4: Likely Suspect

Within highly convective systems, including genesis and early development stages of hurricanes, if assimilation time scale of characteristic satellite-retrieved / interval-averaged precipitation products (hours) mismatches convective time scale (minutes), assimilation process will corrupt thermodynamic, dynamic, and hydrologic control parameters in seeking average model rain rates that match interval-averaged observed rain rates -- in violation of actual convective time scale rain rates.

Experience of ARPS, NMS, and WRF modelers at Univ. of Oklahoma (K. Drogemeir; M. Xue), Univ. of Wisconsin (G. J. Tripoli), and NCAR (C. Davis et al.)

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Measurement Recommendations

Issue 1 (V6/L2 Algorithm Disagreement): Microphysics within convective regions; droplet fall rates; droplet DSDs including local spatial and temporal DSD variances over 10-km / 10-min scales.

Issue 2 (LH Retrieval Problems above Freezing Level): Ice concentrations at 4-5 levels between freezing level and 15 km altitude -- with coincident rain rate profiles below freezing level.

Issue 3 (Can We Retrieve Precipitation Diurnal Cycle Signal?): 4 to 8 time-per-day A/C radar-based, swath-merged rain layer precipitation maps along with pressure & wind observations sufficient to determine if geostrophic adjustment is occurring at background inertial oscillation frequency.

Issue 4 (Matching Time Scales for Data Assimilation Experiments): Many time-dependent, accurate rain rate observations throughout outer & inner storm environments.

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Thank You

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Backup Slides

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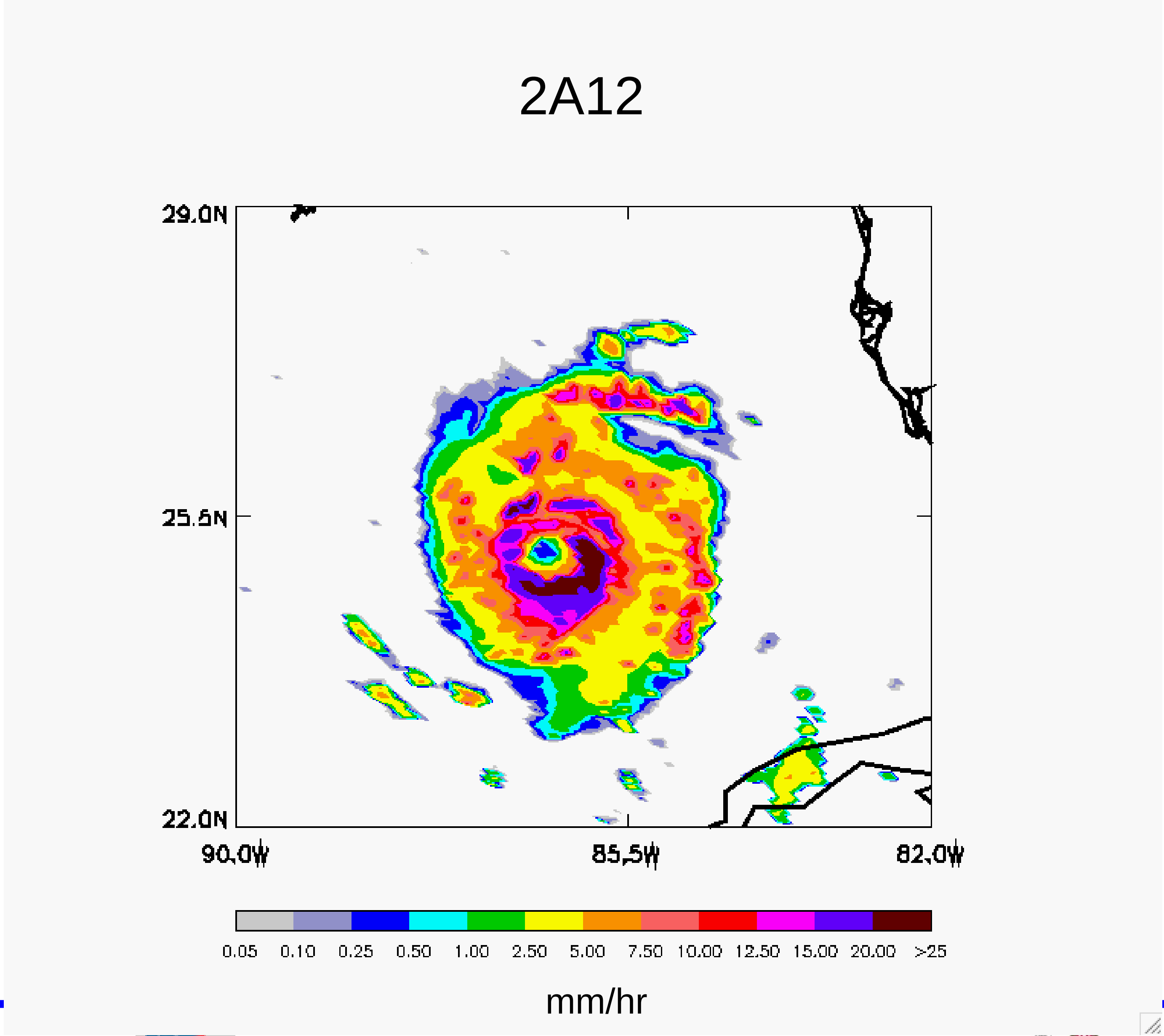
Hurricane Katrina: 28 August 2005



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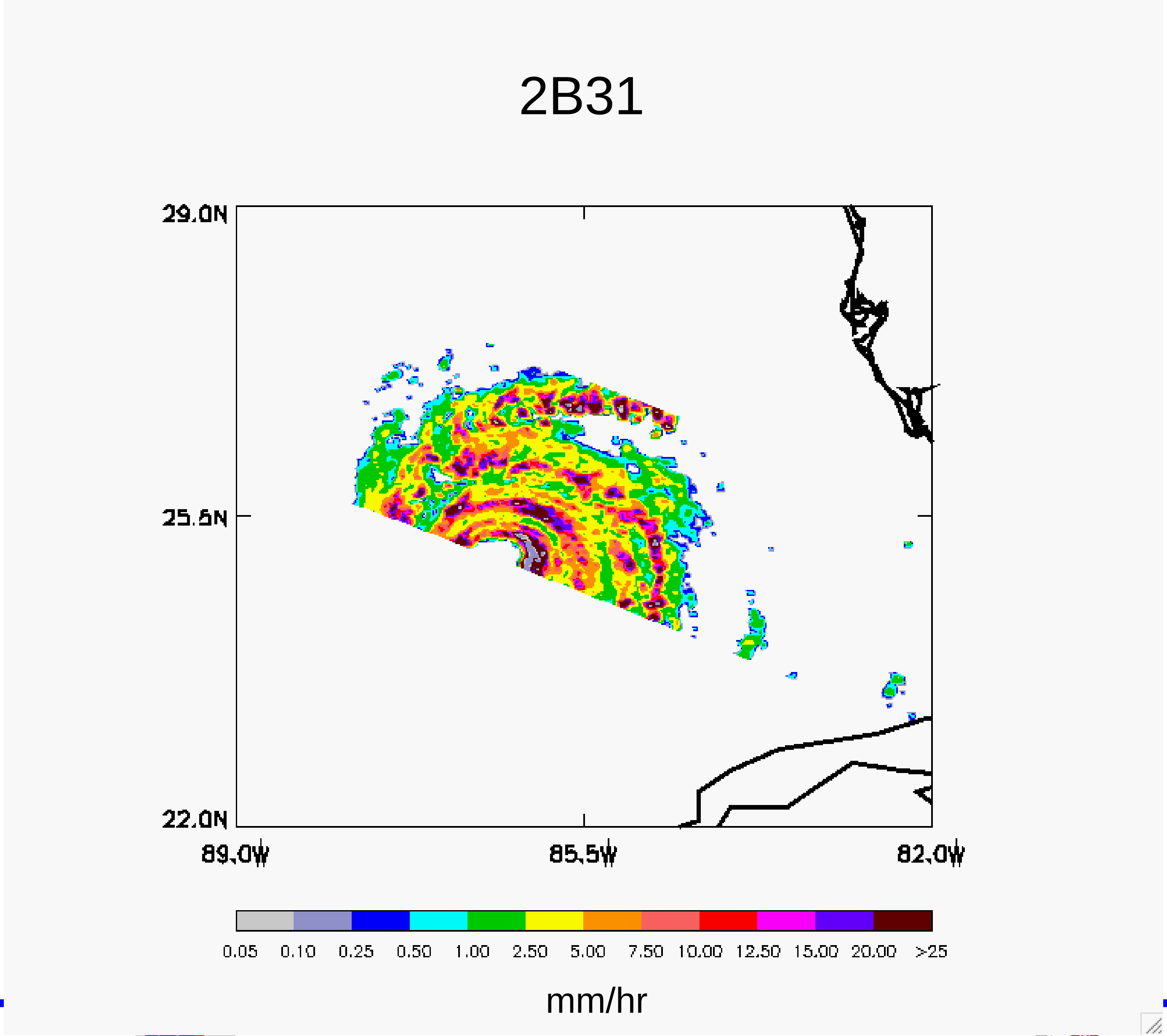
Hurricane Katrina: 28 August 2005



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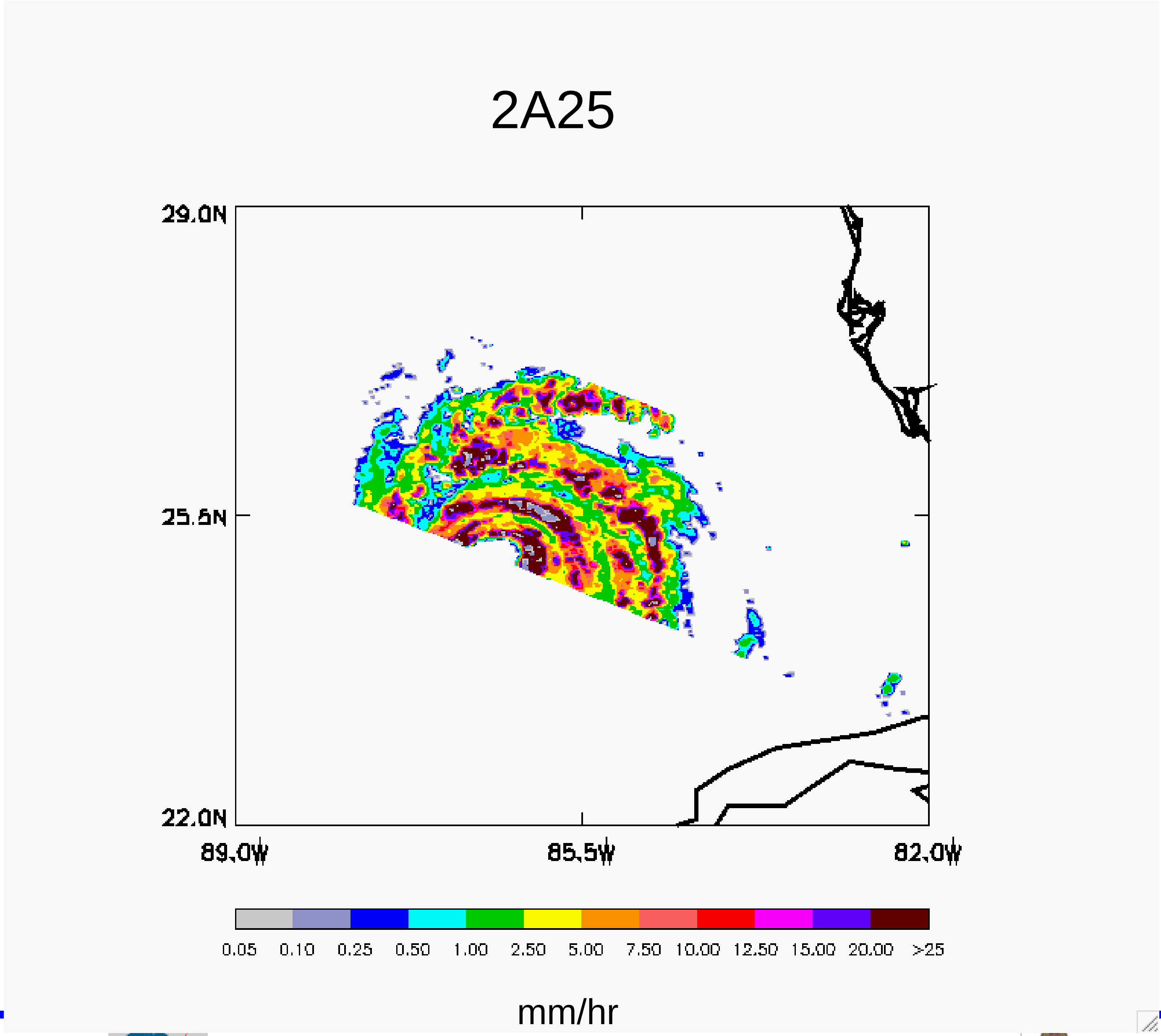
Hurricane Katrina: 28 August 2005



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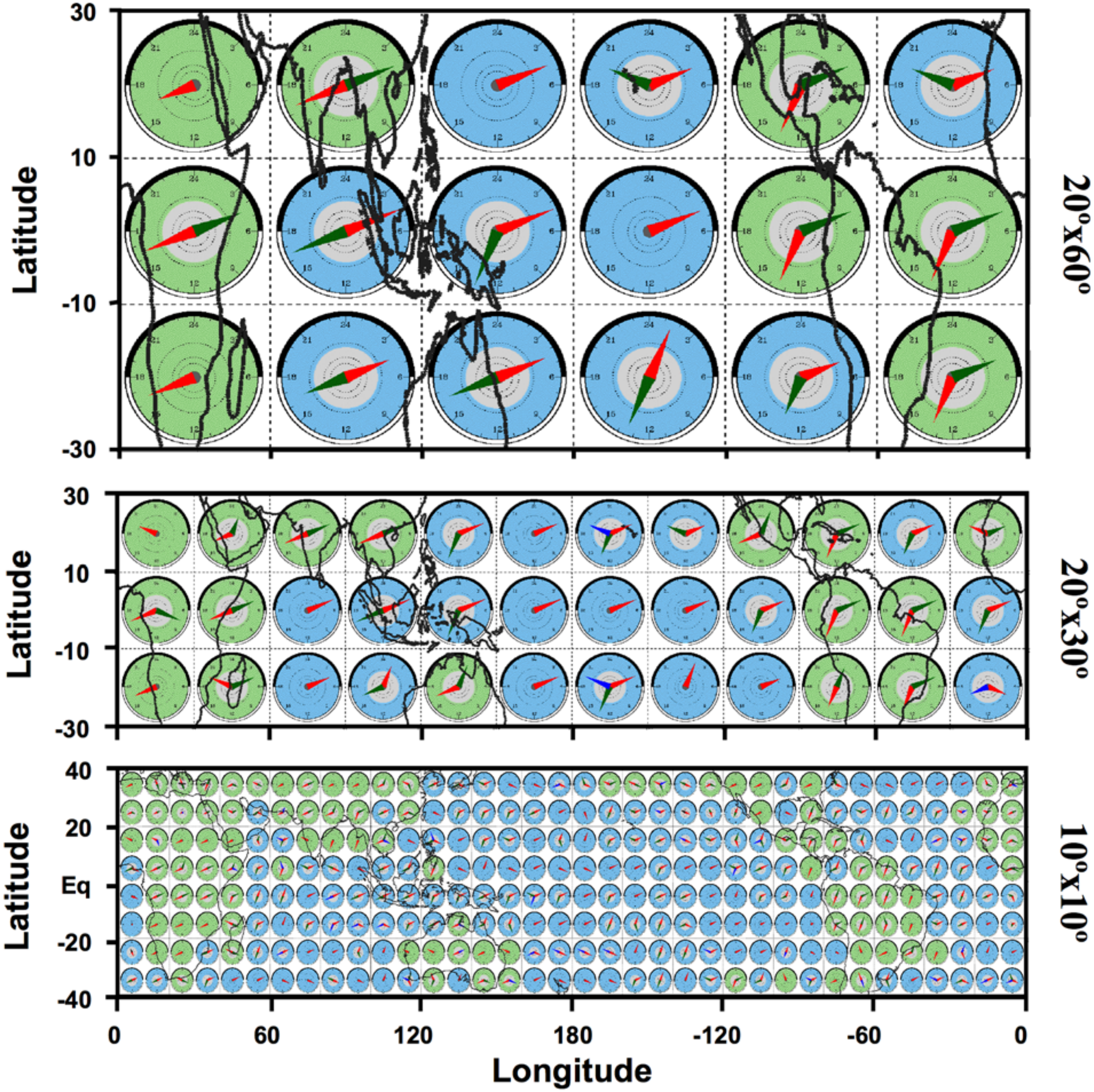

Fig 6-png

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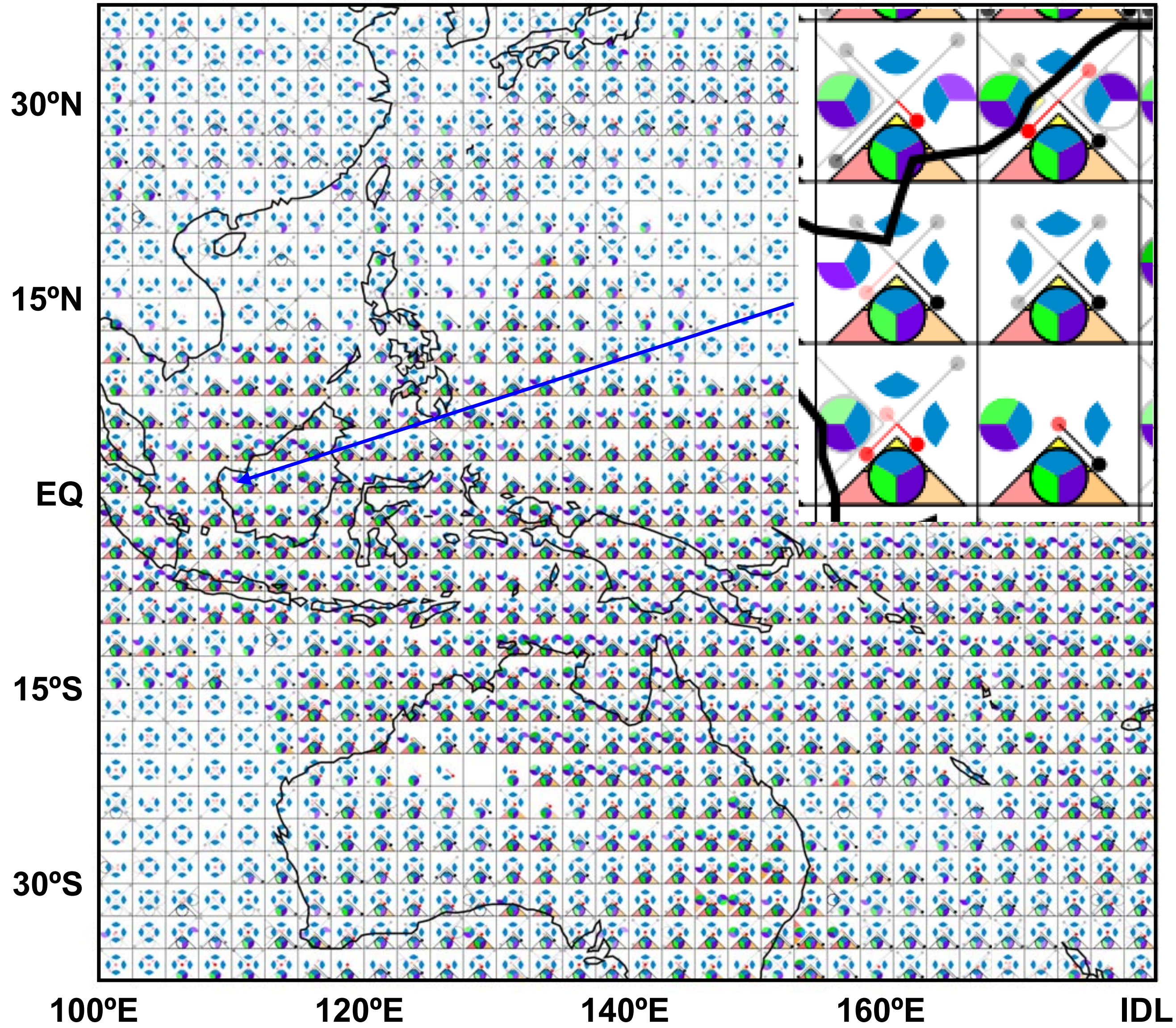
Explicit & Implicit Properties of Spectrally / Vertically Dependent Diurnal Precipitation: Jan 2007 [weighted -- 2.5-deg grid scale]



Map Properties

Explicit Properties

1. Vertical structure of spectrally dependent monthly rainfall
2. Vertical structure of diurnal amplitude & phase of monthly rainfall
3. Vertical structure of spectrally dependent diurnal amplitude & phase of monthly rainfall -- given in separate map

Implicit Properties

1. Location of significant monthly rainfall
2. Location of vertically deep monthly rainfall
3. Distribution of convective & stratiform monthly rainfall -- also explicitly given in separate maps
4. Distribution of morning (oceanic-type) & afternoon (continental-type) phase-mode of maximum-amplitude monthly rainfall
5. Distribution of spectrally similar monthly rainfall

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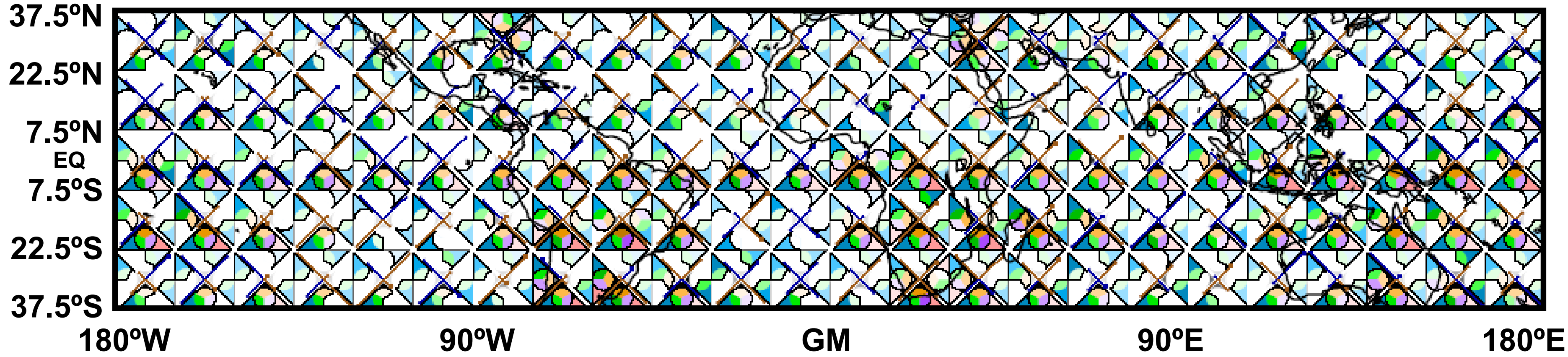
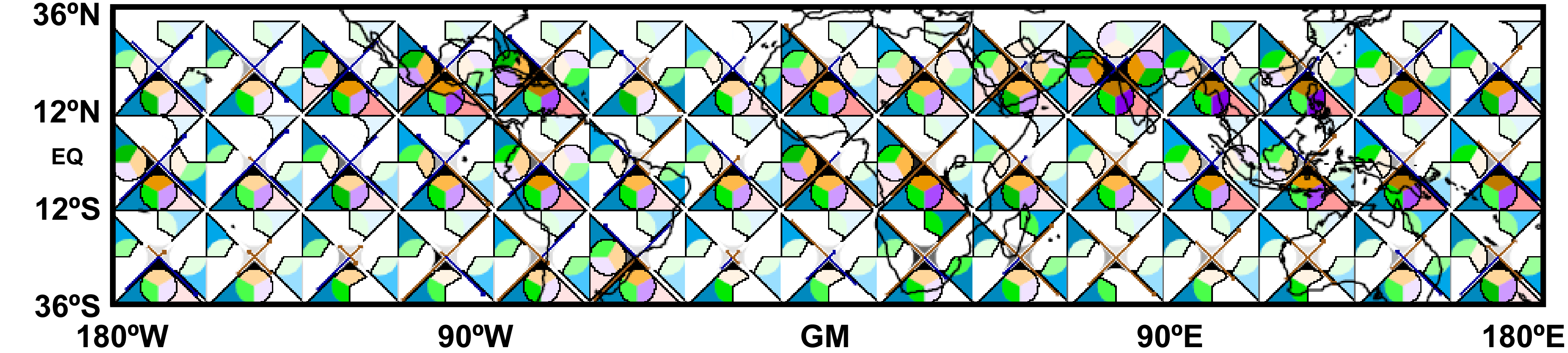
Tutorial View of Vertically / Spectrally Dependent Diurnal Precipitation: Jan 2007

15 Degree Grid Scale



24 Degree Grid Scale



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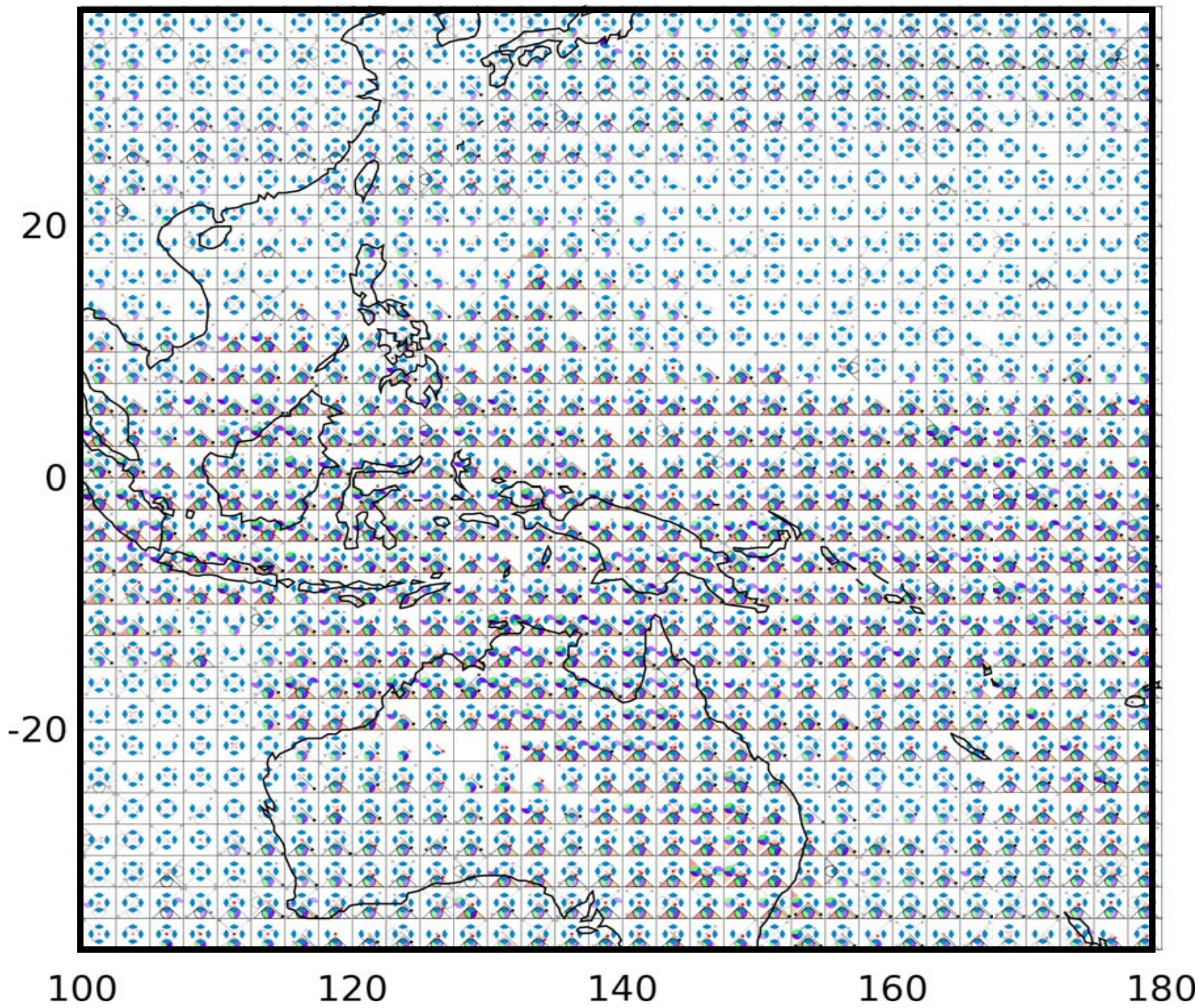
Un-weighted Spectrally / Vertically Dependent Diurnal Precipitation: Jan 2007 [2.5 deg Grid Scale]



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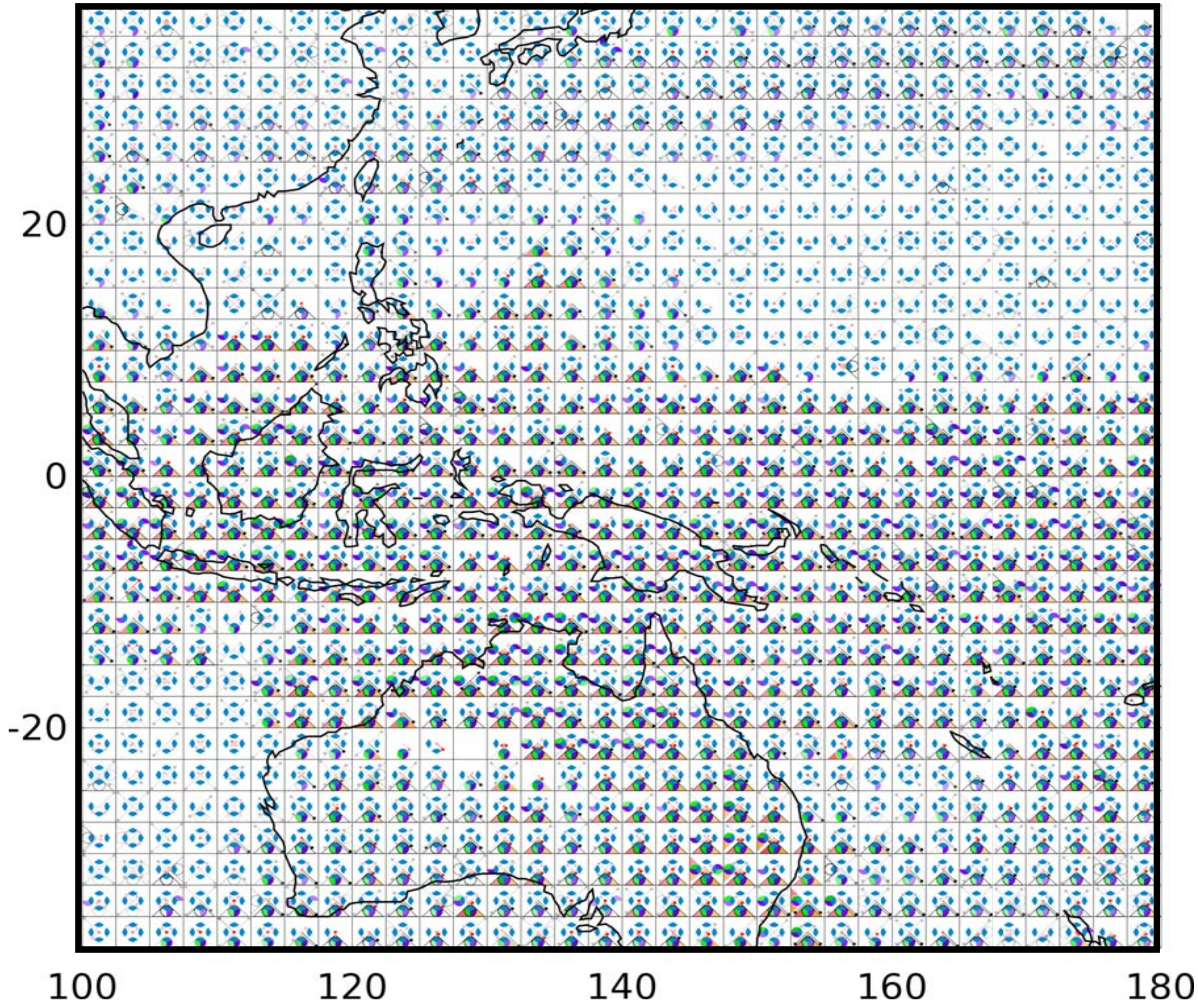
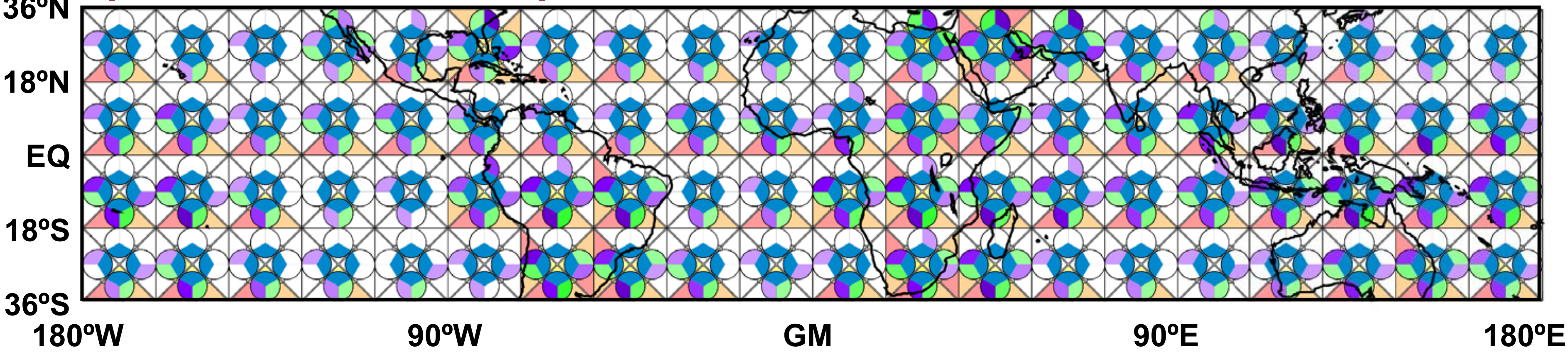
Weighted Spectrally / Vertically Dependent Diurnal Precipitation: Jan 2007 [2.5 deg Grid Scale]



Spectral Diurnal Precipitation: Jan 2007 (un-weighted -- 18-deg box scale)



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