Representativeness of the HAIC/HIWC Darwin + Cayenne Database

…in the context of global satellite data.

Ed Zipser, Univ. of Utah

We should ask "representative of what?"

- Of all known engine events?
- Of the largest and strongest storms likely to be penetrated by commercial aircraft anywhere?
- Or should we ask how Darwin and Cayenne storms compare to those elsewhere?
- Or should we ask whether the database in Darwin and Cayenne is representative of storms in those two regions?

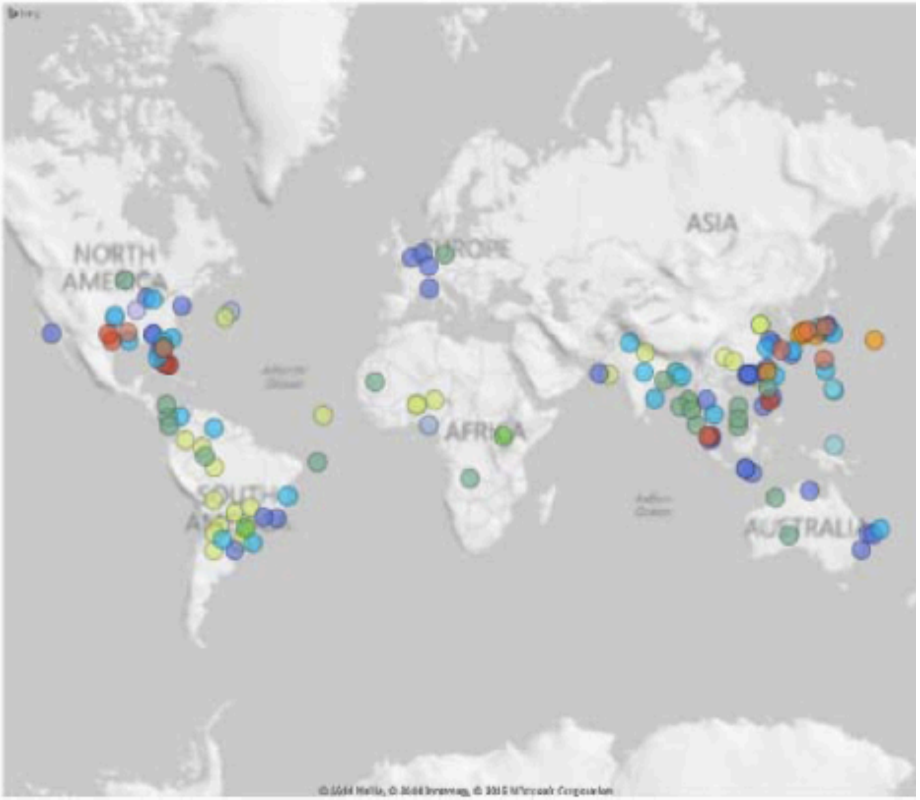
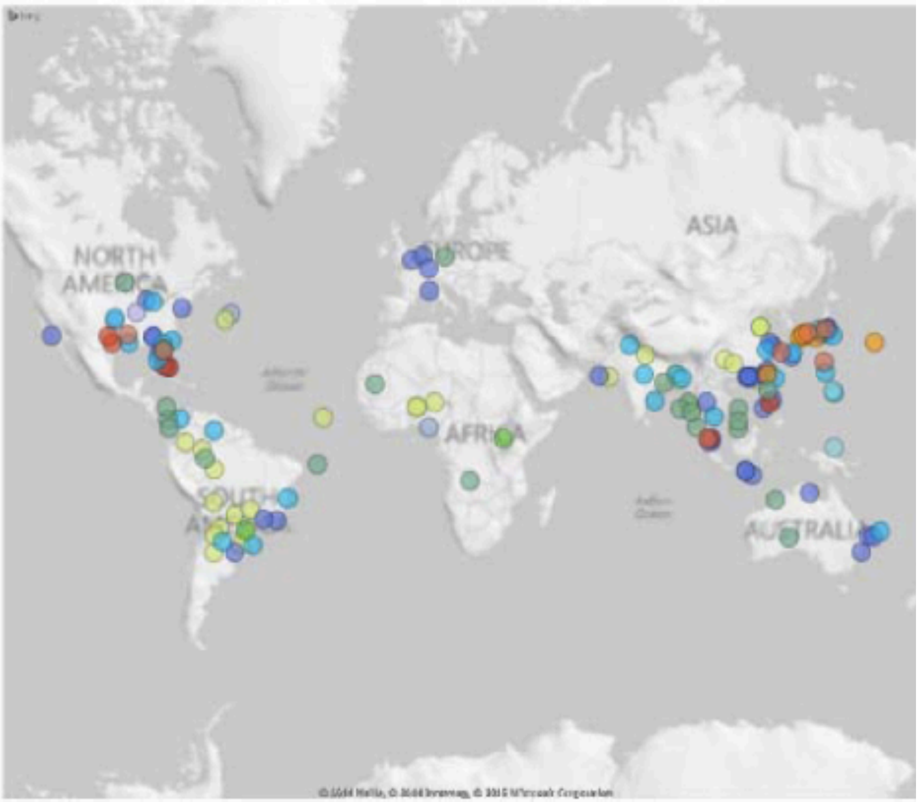


Figure 1. Locations of 162 engine events in current database. Different colored icons represent different types of engine events (e.g. powerloss, compressor damage).

Table 3. Events by Time of Day, by Region. Times are Local Solar Time (see footnote 3), and categorized as follows: 18:01-24:00 (evening to midnight), 00:01-06:00 (midnight-early morning), 06:01-12:00 (morning to noon), 12:01-18:00 (afternoon to evening).

Events per Time of Day, by Region				
Region	**18:01-24:00**	**00:01-06:00**	**06:01-12:00**	**12:01-18:00**
1 - North America North	8	3	5	4
2 - North America South	2	2	1	2
3 - South America North	2	5	3	1
4 - South America South	2	0	9	1
5 – Europe	1	1	1	1
6 - India/Thailand	1	3	5	3
7 – Africa	4	4	1	0
8 - Australia/ Indonesia	1	2	3	2
9 – Japan	4	6	7	4
10 - South East Asia/South China Sea	7	5	4	9
11 - Continental China	1	2	0	2

From Bravin, M., Strapp, J., and Mason, J., "An Investigation into Location and Convective Lifecycle Trends in an Ice Crystal Icing Engine Event Database," SAE Technical Paper 2015-01-2130, 2015, doi:10.4271/2015-01-2130



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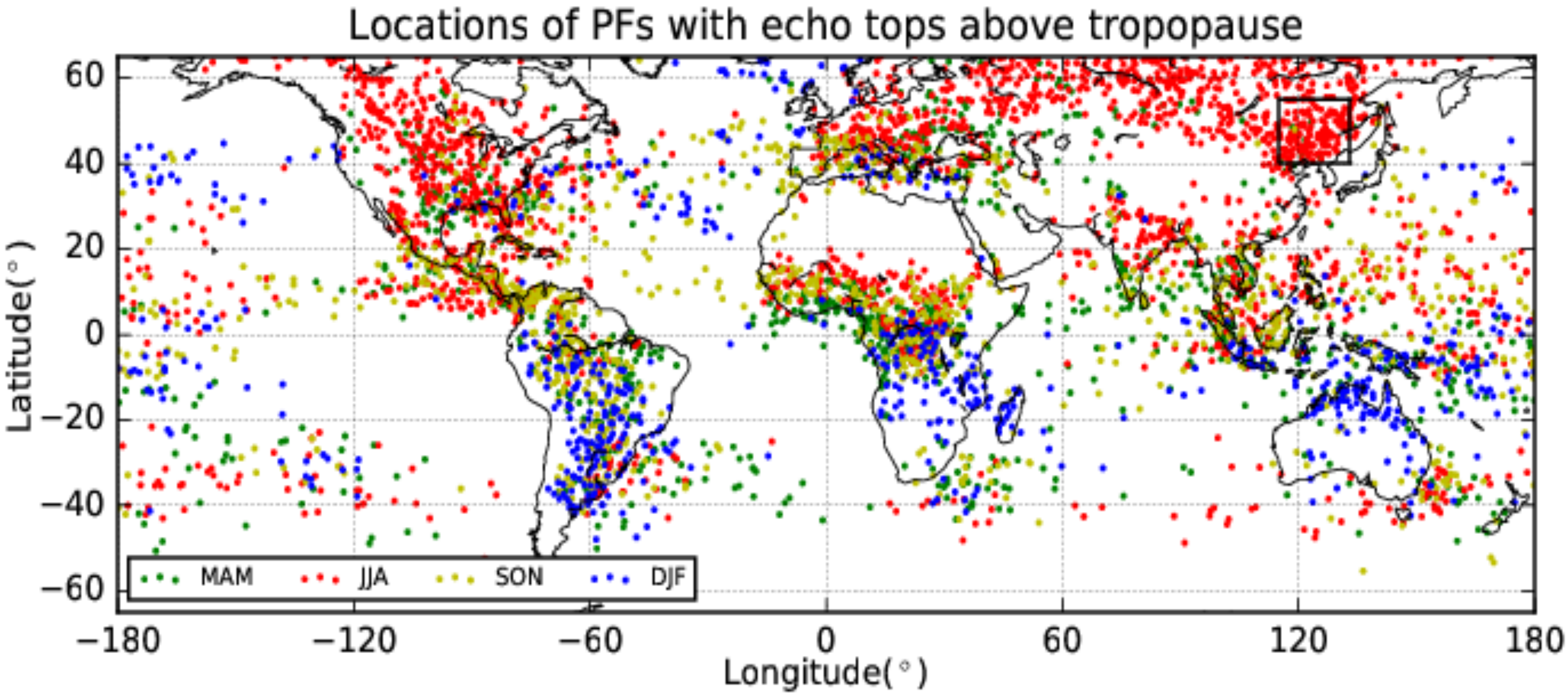
Question: To what extent do these distributions represent the global distribution of HIWC conditions, and to what extent do they represent density of air traffic in space and in time?

Convection reaching above lapse rate tropopause detected by GPM (201404-201603)

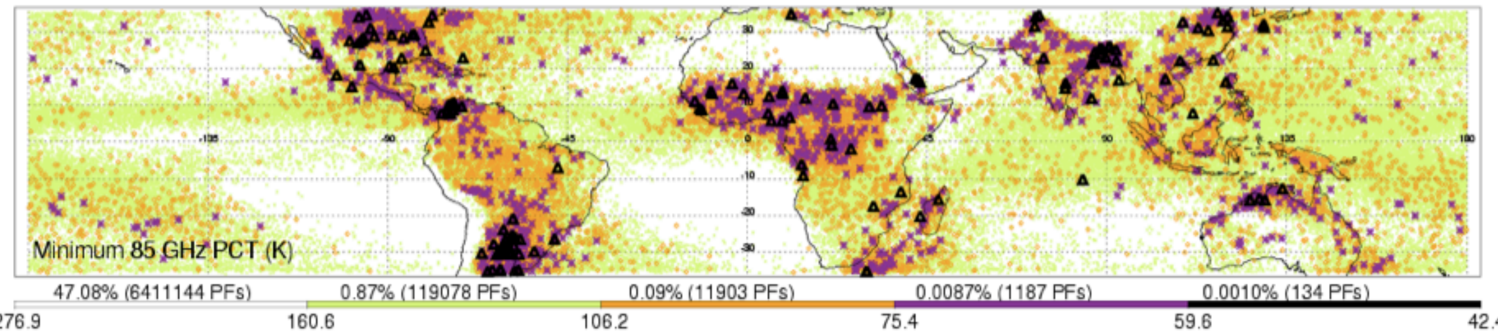


Courtesy Chuntao Liu, TAMU-CC

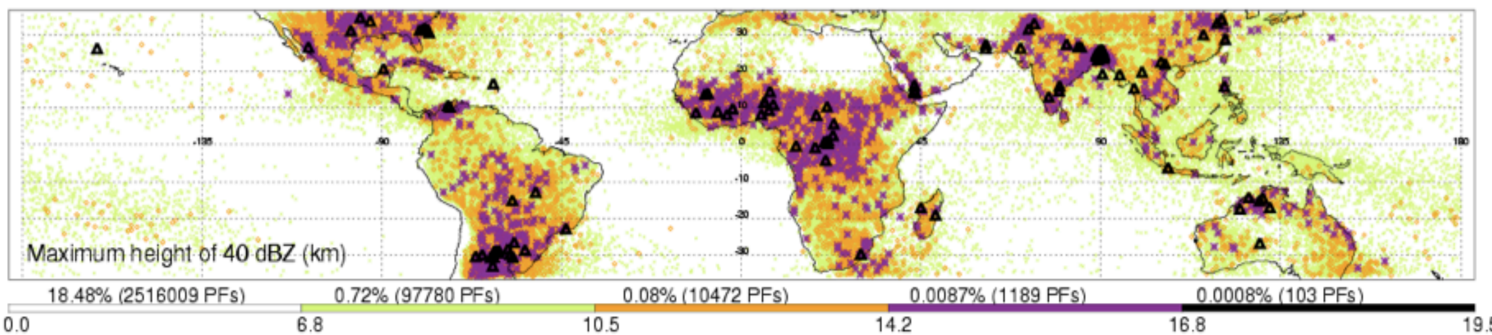
Where are the *most* "intense" storms?

Orange, purple, black: Very strong (0.1%) Even stronger(.01%), TOP 0.001%

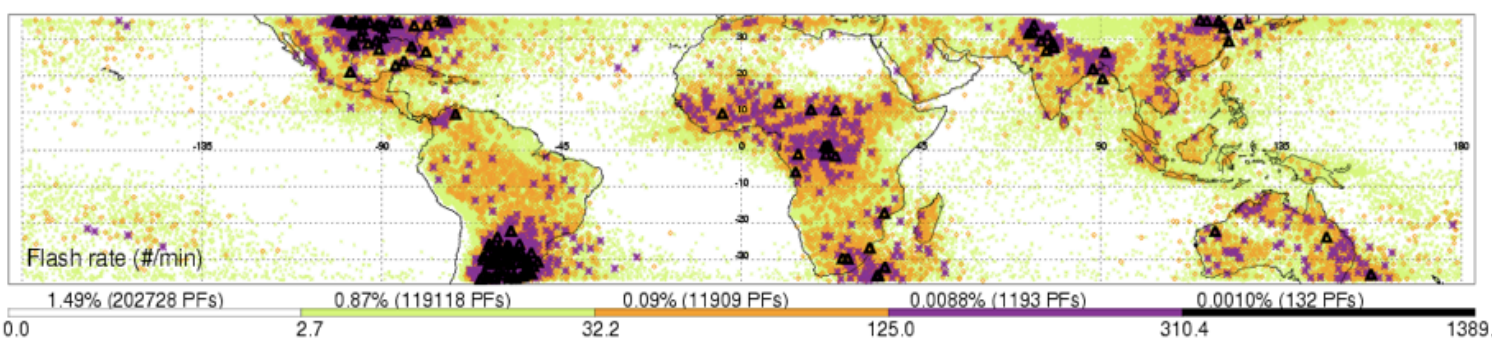
(Zipser et al., BAMS 2006)



Minimum 85 GHz PCT (related to ice water path)



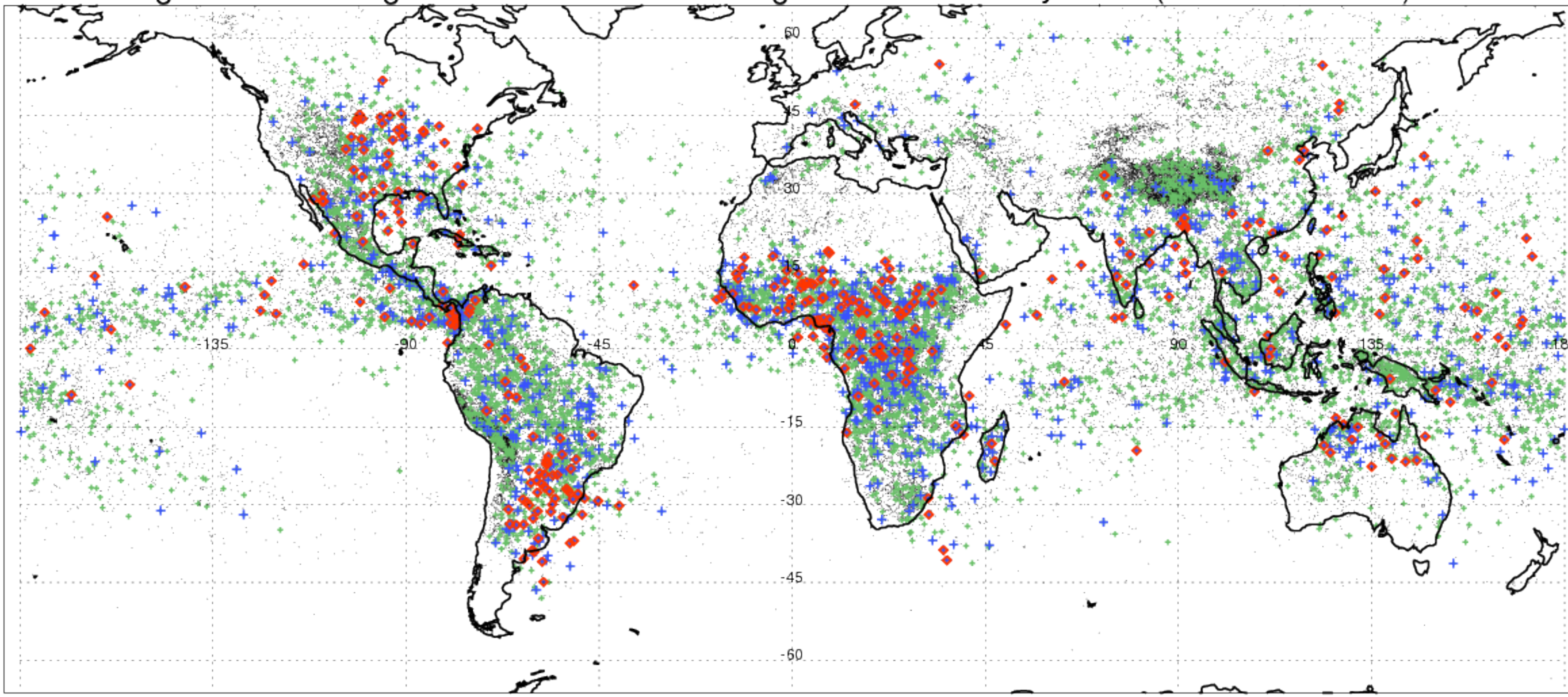
Max height of 40 dBZ echo (a very strong echo for the ice region – large graupel likely)



Lightning flash rate Purple is >125/min Black is >310/min

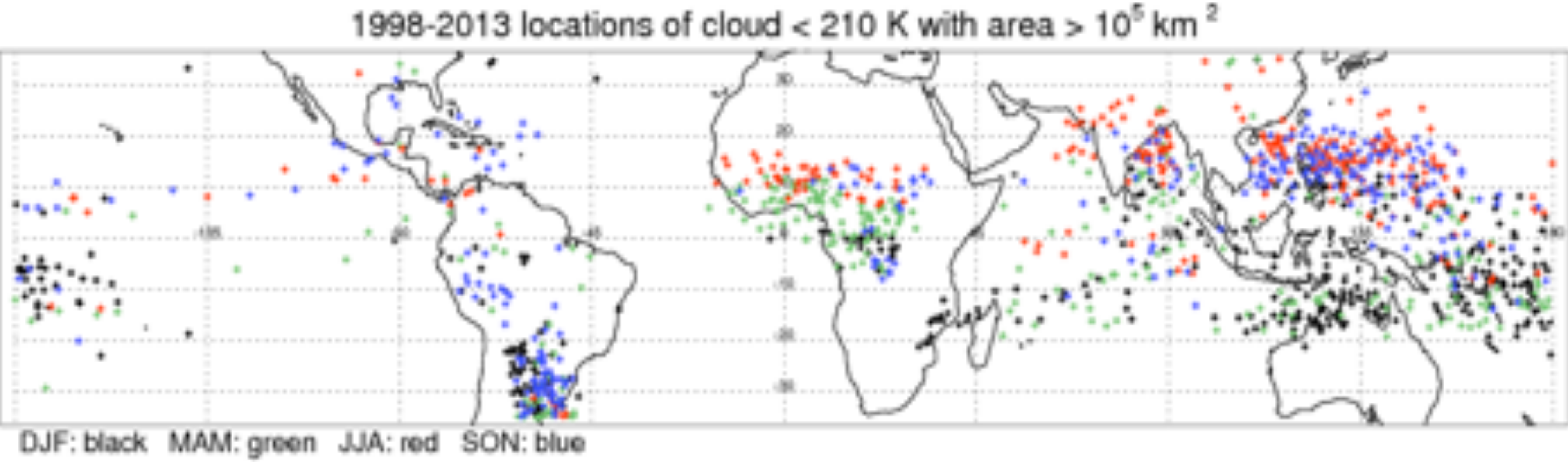
Extensive stratiform regions detected by the GPM

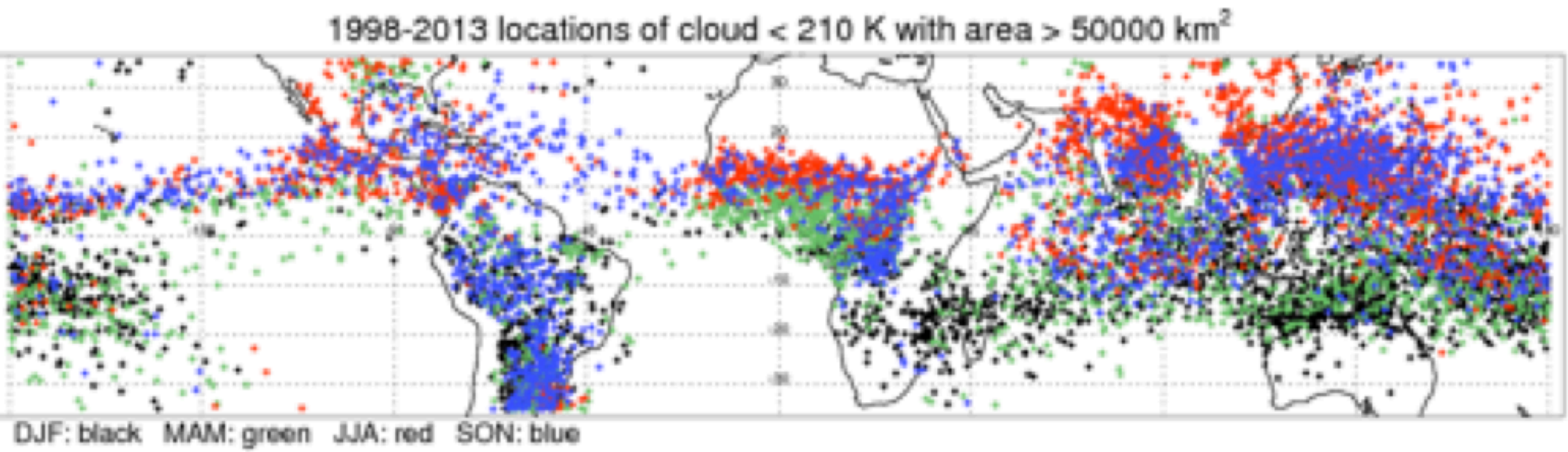
Large stratiform regions with 20 dBZ reaching 8 km detected by GPM (201404-201603)



green: > 1000 km^2 blue: > 5000 km^2 red: > 10000 km^2

Courtesy Chuntao Liu, TAMU-CC

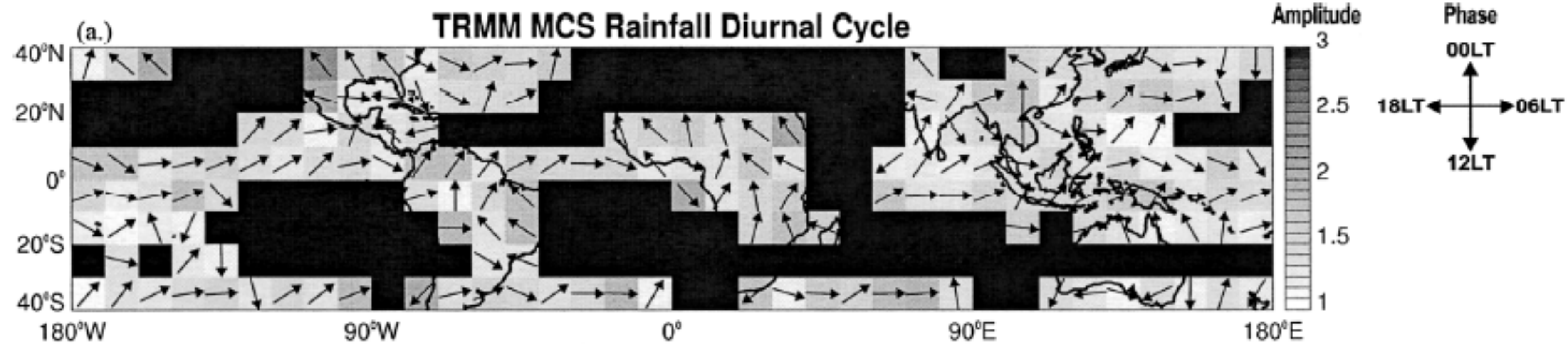




Note: Similar distribution, but less extensive cold cloud areas are much more common

Next set of slides highlights diurnal cycle of conditions likely associated with HIWC events

15 MAY 2003 NESBITT AND ZIPSER 1469



Note that rainfall from MCSs over tropical oceans typically reaches its peak between 03 and 06 local time.

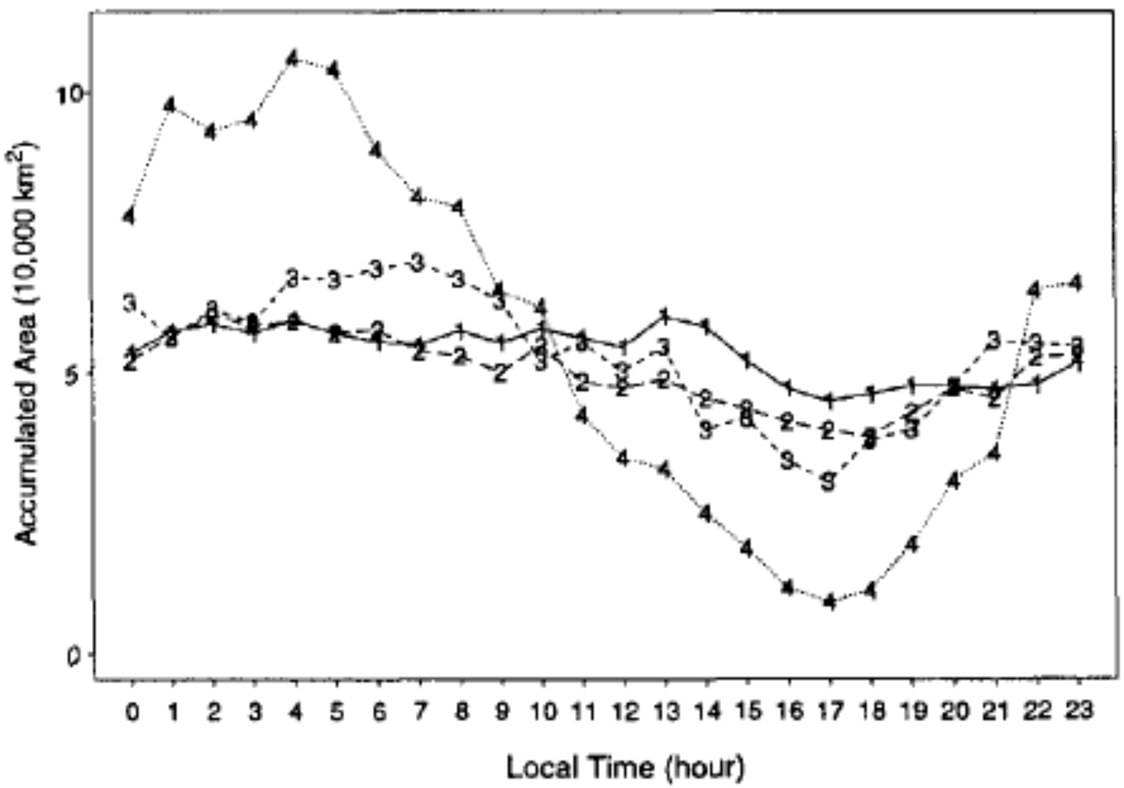


Figure 8. The diurnal cycle of the accumulated cloudy area covered by the 208 K cloud clusters over the domain of 152°–180°E and 10°N–10°S, for each of the four size classes defined in Fig. 6(a). (From Chen *et al.* 1996.)

More evidence: Cold cloud area in large MCSs increases rapidly between 21 and 01 LT, remains high until 05 LT, then decreases

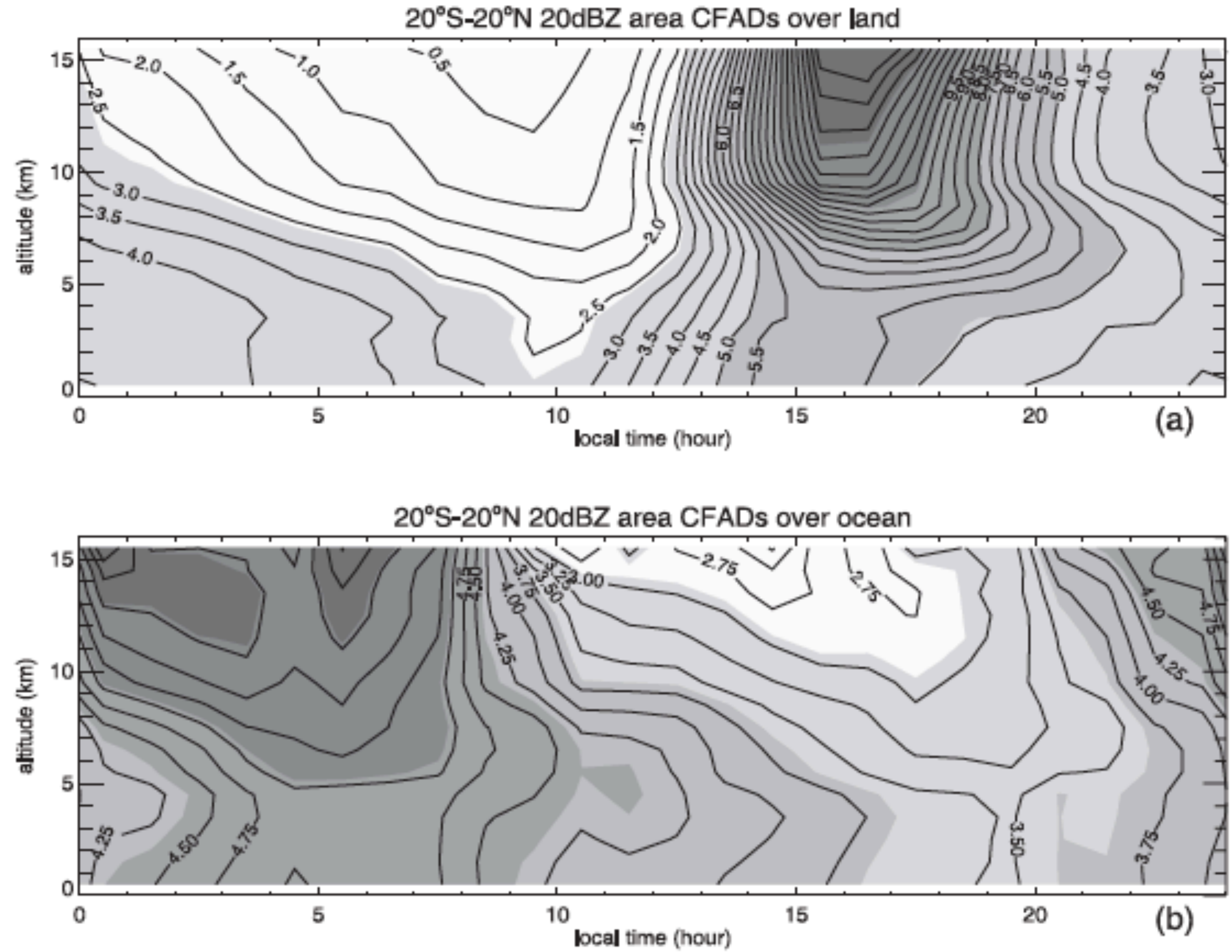


Figure 2. Contoured frequency of area with PR reflectivity greater than or equal to 20 dBZ with altitude vs. time over (a) land and (b) ocean. Units are in %.

This study shows peak in 20 dBZ radar echo at ~ 10 km between 03 – 06 LT

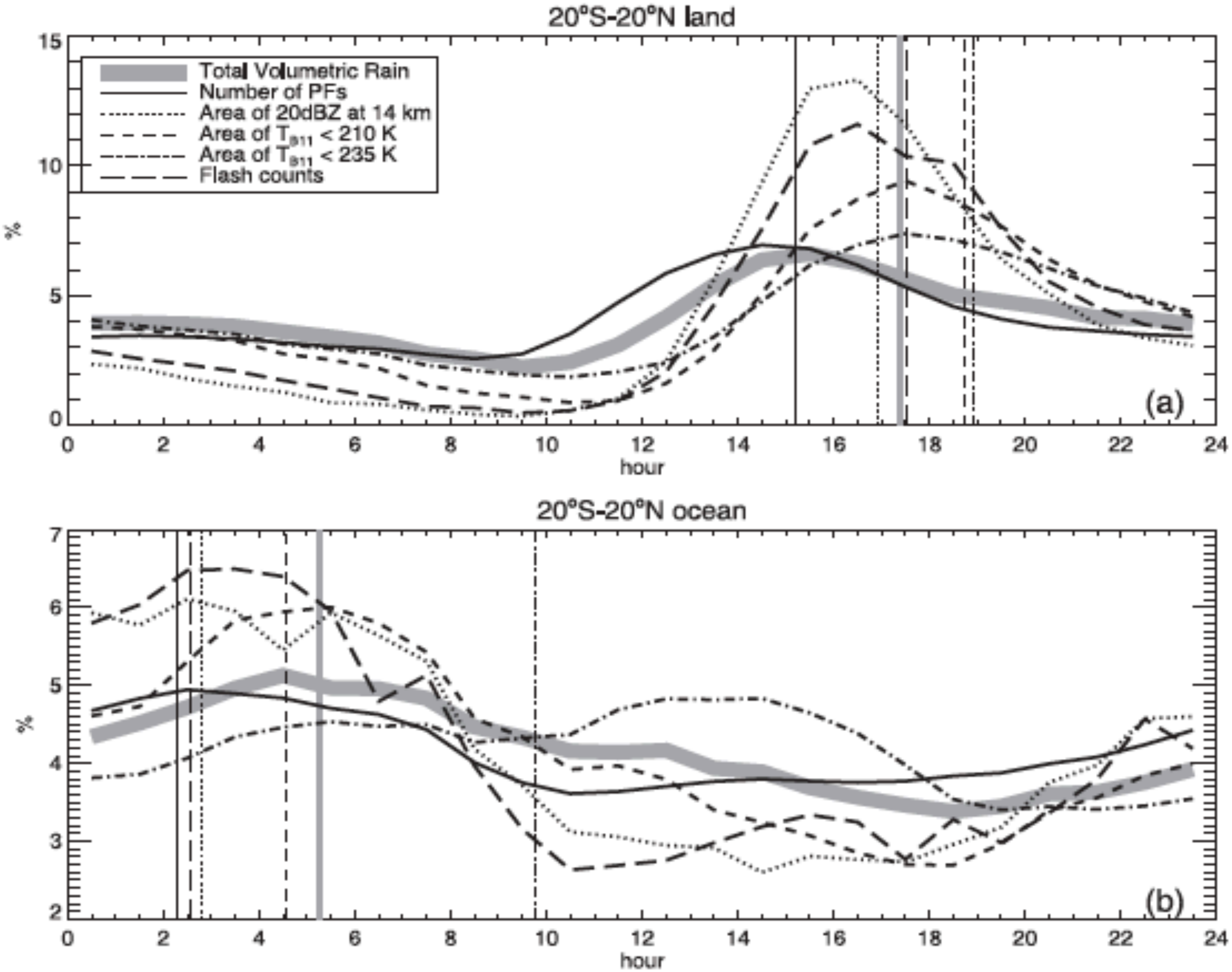


Figure 3. Diurnal variation of total volumetric rainfall, population of precipitation systems, area of 20 dBZ reaching 14 km, area of cold clouds with $T_{B11} < 210$ K and 235 K, and flash counts over (a) land and (b) ocean in 20°S–20°N. The vertical lines represent the location of the diurnal harmonic phase (S1). Diurnal cycles over land are stronger than over ocean with a larger scale range in Figure 3a.

…and still more evidence that oceanic MCSs typically are decaying at 06 LT

Tentative Summary:
Representativeness of the Darwin and Cayenne datasets of conditions responsible for engine events

- Cayenne region has weaker convection and less extensive stratiform and cold cloud regions than Darwin, but our sample there was as good as could be expected.
- Oceanic regions near Darwin are probably representative of many areas of tropical oceans with engine events such as those near SE Asia.
- Oceanic convection and its associated large MCSs have a clear diurnal peak before 06 LT; the lack of HIWC sampling before sunrise is an issue, because the statistics of both convective regions and stratiform regions (long legs under high cold cloud tops) are likely biased toward lower IWC.
- Large and intense MCSs over continents (such as the Minnesota event of June 2013) produce high cold clouds and stratiform MCSs that are most likely different from anything we have sampled during HAIC/HIWC. For example, these intense systems may have small ice from homogeneous freezing.

Compare this group of oceanic ITCZ cumulonimbus with the examples over continents in the next slide.

Some examples of strong storms over land. Notice the difference from ITCZ ocean storms? FORCING!

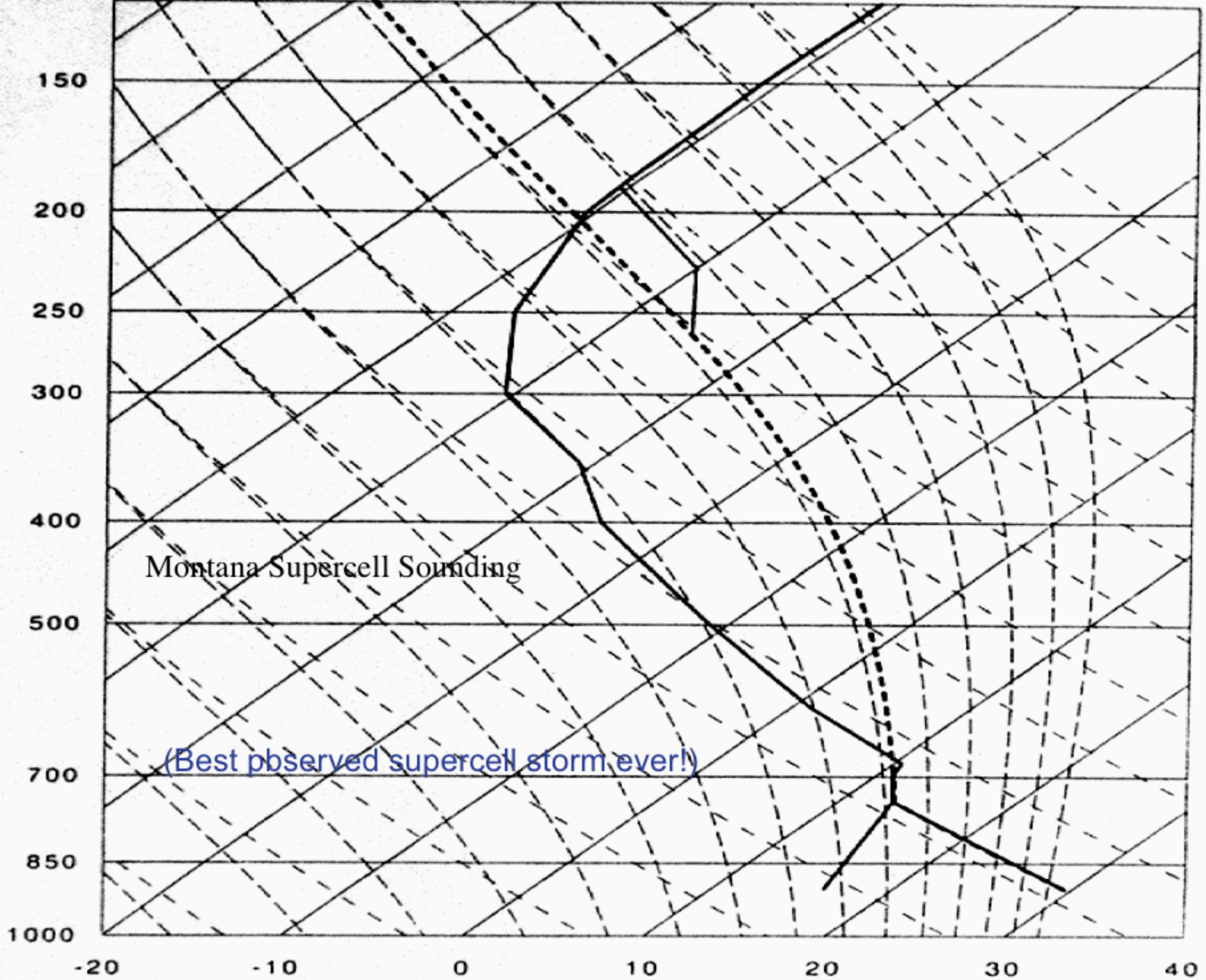


Figure 1. Sounding adapted from Miller et al. (1988) representing the properties of the environment of a severe hailstorm (solid) and hypothetical pseudoadiabatic ascent from cloud base (dashed). The thin solid line near storm top shows the temperature increase from freezing of adiabatic water content between -35 and -40C. See Fig. 2 and text.

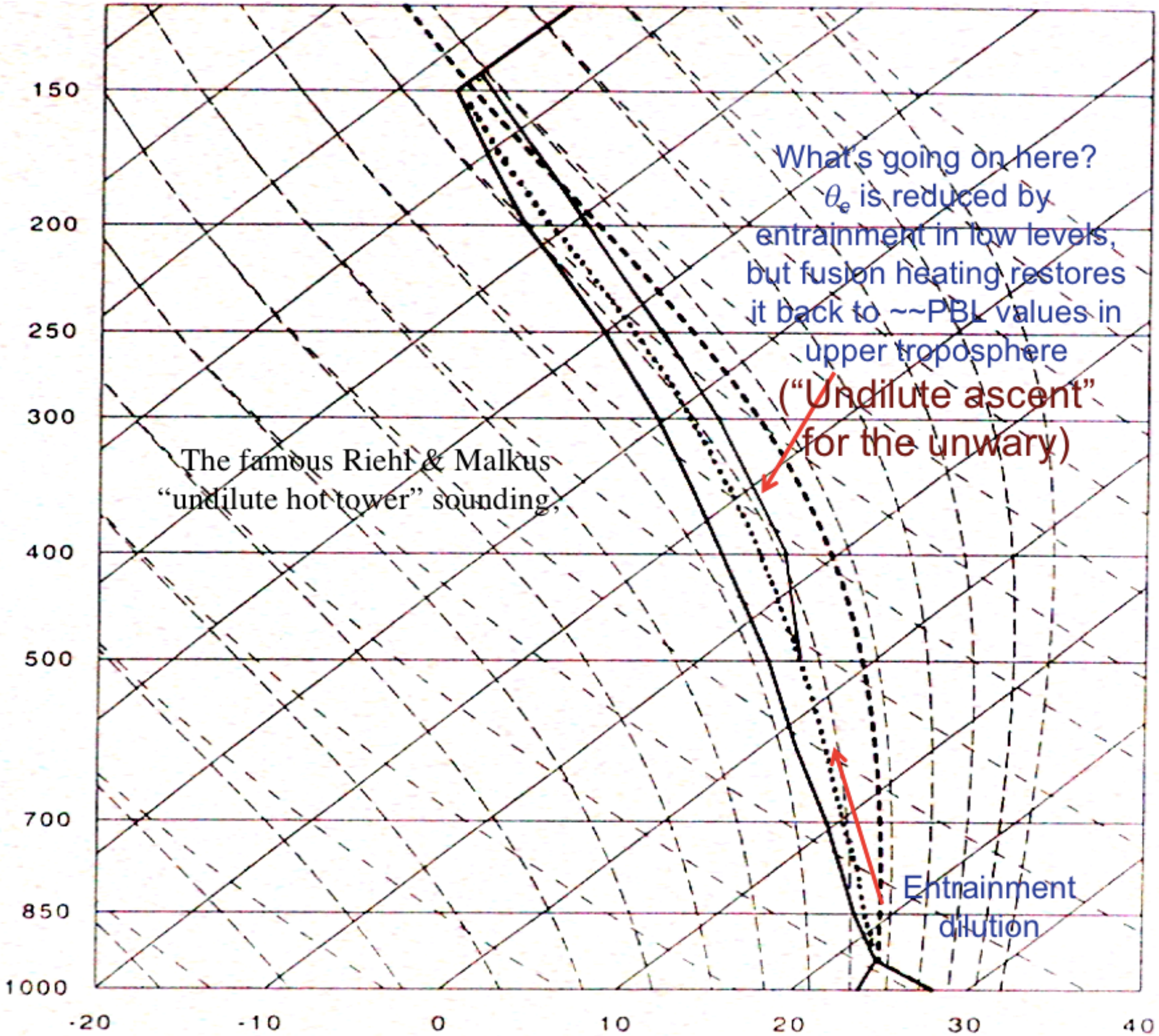


Figure 3. Sounding adapted from Riehl and Malkus (1958) representing the properties of the environment in the equatorial trough zone (solid) and hypothetical pseudoadiabatic ascent from cloud base (dashed). The dotted curve represents the actual temperature of the ascent at one-third pseudoadiabatic buoyancy. The thin solid curve shows the temperature increase from that