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SEASONALITY OF THUNDERSTORMS SEEN BY TRMM

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1. INTRODUCTION

The Tropical Rainfall Measuring Mission (TRMM) satellite has collected ten years of measurements for the global tropics and subtropics (35 S – 35 N). Precipitation features (Nesbitt et al. 2000) have been defined as contiguous areas with rain indicated by the TRMM Precipitation Radar (PR) and / or TRMM Microwave Imager (TMI). For each of these Precipitation Features (nearly two million per year, so near twenty million total), the Lightning Imaging Sensor measures a flash rate in addition to the numerous properties measured by the other instruments (see Zipser et al. 2006 for examples).

Precipitation Features have been grouped into numerous low flash rate and high flash rate categories and examined. This paper will focus on two groupings: "all thunderstorms" observed by the Lightning Imaging Sensor (LIS,) and "intense thunderstorms" with at least 128 flashes per minute during the LIS observation period. Because LIS observes a particular spot for around 90 seconds, the "all thunderstorms" category certainly misses many of the low flash rate storms (less than ~1 flash per minute). The observed distribution of LIS thunderstorms is dominated by those with the lowest measurable flash rates (Cecil et al. 2005), so the "all thunderstorm" category best represents the low flash rate storms. The "intense thunderstorm" threshold of 128 flashes per minute follows the methodology from Cecil et al. (2005), using the top 0.01% level of Precipitation Feature flash rates. Cecil et al. (2005) estimated that roughly 10% of the Precipitation Features are likely to have any lightning (though only 2.4% have flashes frequently enough to be detected by LIS), so this would equate to about the top 0.1% of all thunderstorm flash rates.

Because the TRMM satellite has lasted so long, we are now able to examine monthly composites of storm populations. Data shown here is from Jan. 1998 through Dec. 2007. The "all thunderstorm" category has enough thunderstorms that it will be shown at 1x1 degree horizontal resolution. The "intense thunderstorm" category is shown at 4x4 degree resolution. This resolution appears somewhat noisy, but reveals some meaningful details of where the intense thunderstorms occur.

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2. DATA AND METHODS

The dataset and approach are similar to that described by Cecil et al. (2005). Precipitation Features are essentially defined as contiguous areas of precipitation with at least ~75 km^2 horizontal size and no upper limit on size (other than the limited observational swath, <250 km wide for the PR). Here, a thunderstorm is defined as any Precipitation Feature with lightning observed by LIS.

Uneven sampling (either spatially or temporally) is accounted for by counting the number of times data is successfully recorded for each grid box each month. The higher latitudes (30-35°) are sampled more often than others. Even after normalizing for the number of observations, a non-zero storm population is more likely to be observed in these higher latitudes. That is, the minimum observable population size is larger in the tropics than the subtropics.

Since TRMM's sampling of a particular location is intermittent (from low earth orbit), the number of observations are scaled as if there are 12 observations of each location per day. This is somewhat arbitrary, but consistent with the idea that observations timed two hours apart would feature populations of distinct convective-scale thunderstorms. This scaling is more appropriate for the "all thunderstorms" category (Fig. 1) than for the "intense thunderstorms" category (Fig. 2), since the intense thunderstorms are typically long-lived mesoscale convective systems. The actual numbers in Fig. 2 therefore are likely too high, perhaps by a factor of ~5. Nevertheless, the locations and relative magnitudes of thunderstorm maxima and minima can be seen in these figures.

For comparison with the TRMM measurements, NCEP/NCAR Reanalysis six-hourly data (Kalnay et al. 1996) is examined here. For a quick initial examination, the "best 4-layer lifted index" is considered in Fig. 3-4. This takes the lowest value of lifted index, computed using parcels from four different layers near the surface.

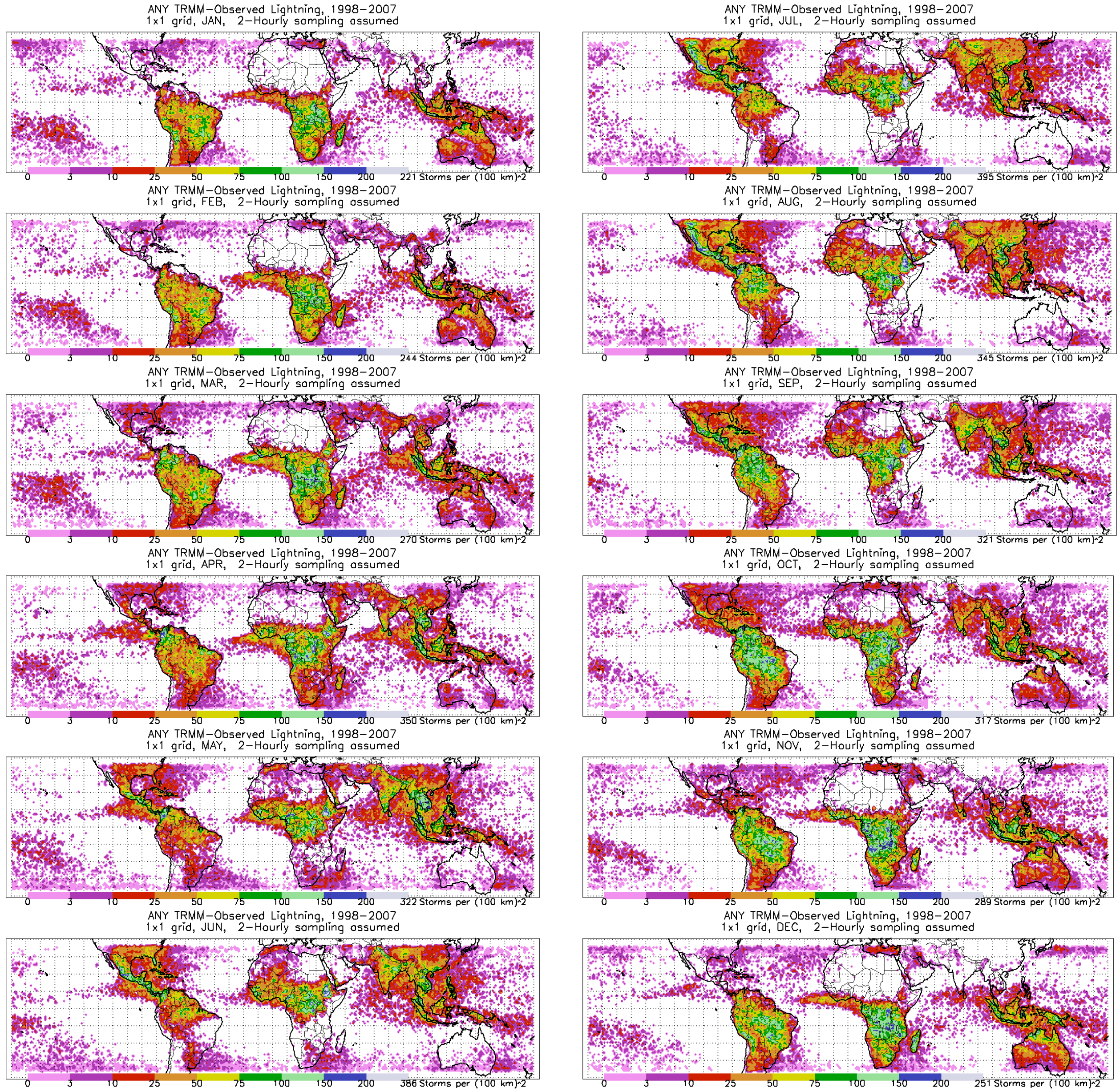

Figure 1. Monthly maps of thunderstorm frequency-of-occurrence as observed by TRMM LIS. Since TRMM's low earth orbit sampling of a particular location is intermittent, the number of observations are scaled as if there are 12 observations of each location per day. Grid spacing is 1x1°, with scaling per 100 km^2 per month. January – June on left, July – December on right.

3. Results

The spatial distribution of thunderstorms throughout the year (Fig. 1) is similar to the distribution of lightning flashes. At a first glance, much can be explained by simple evolution through the seasons, with many thunderstorms in the summer hemisphere and few in the winter hemisphere. There are some exceptions, for example the November – January maximum over the eastern and southern Mediterranean.

The locations with the most thunderstorms are over the deep tropical landmasses (Central Africa, northern South America and Central America, the Maritime Continent). Most of the local maxima are linked to orographic features, which enhance the forcing.

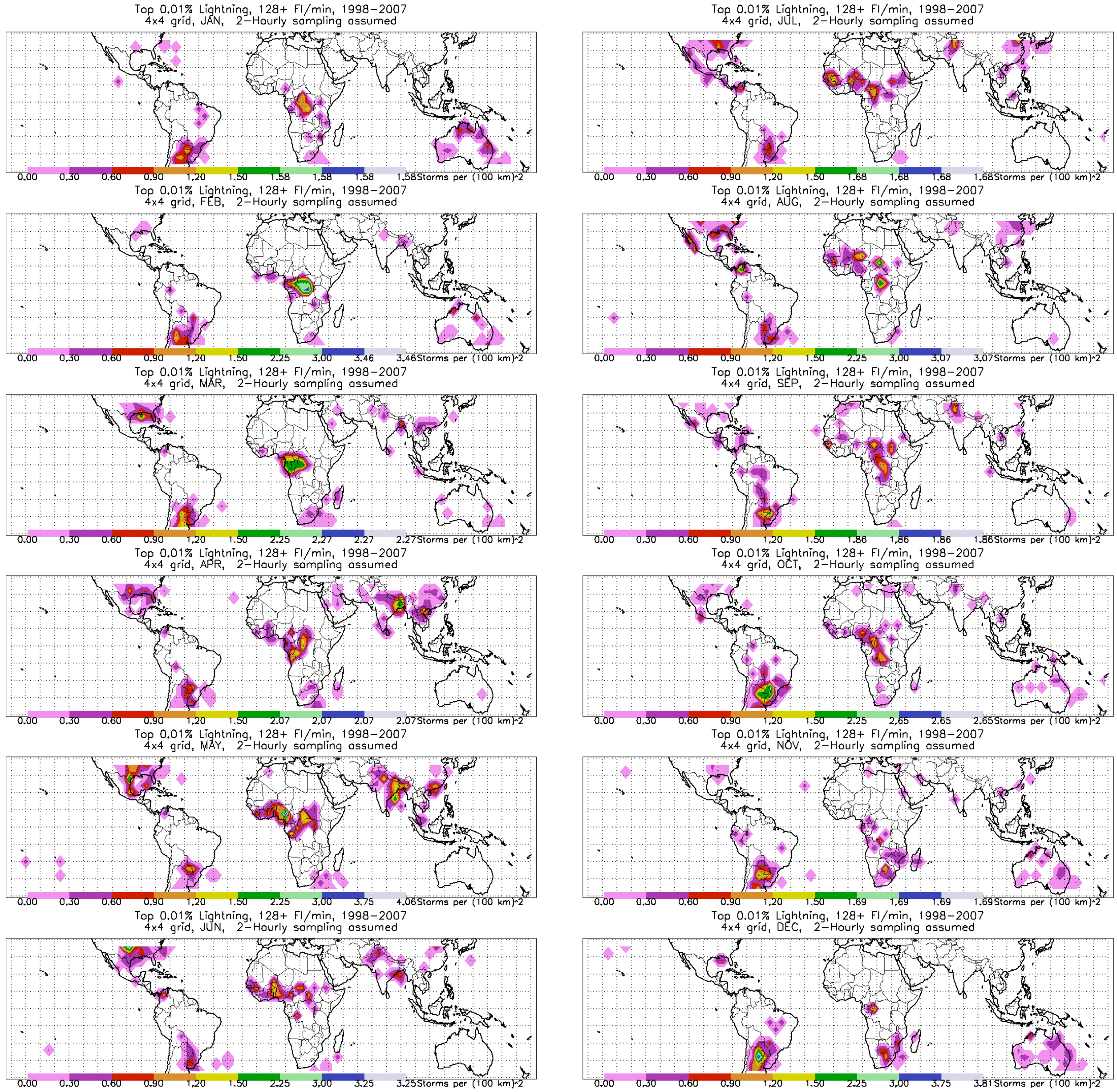

Figure 2. As in Figure 1, but for the intense thunderstorms (at least 128 flashes per minute). Grid spacing is 4x4°. Note that the lowest frequencies of occurrence (light purple shades) can only be observed in the higher latitudes, where TRMM's sampling is greatest.

Looking at the more intense thunderstorms (with at least 128 flashes per minute), Fig. 2 highlights more of the subtropical continental locations instead of the deep tropics. Central Africa and the Sahel are actually the only deep tropical locations with many of these very high flash rate storms. Subtropical locations have most of their intense thunderstorms during the spring and summer, with some also showing up during the autumn. Subtropical South America (northern Argentina and adjacent regions to the northeast) is notable for having several of these intense thunderstorms throughout the year. Although it experiences its most storms during October through December, there is less of an "off season" there than in other regions. The seasonal variability along the Indian subcontinent is also interesting. In the east, the Bangladesh region has numerous intense thunderstorms in April and May, before onset of the monsoon. The local maxima for intense thunderstorms shifts to the Pakistan region for July – September.

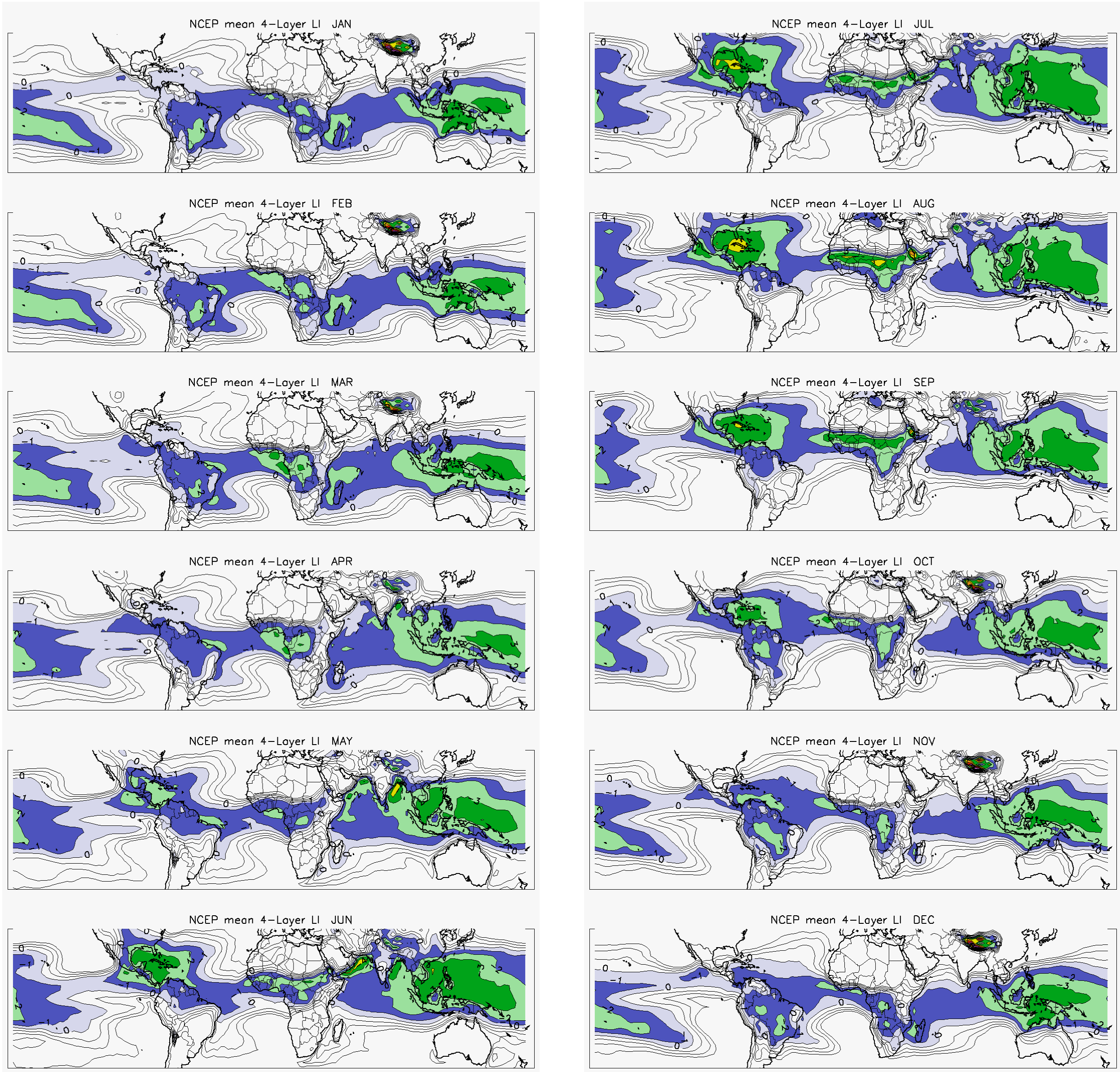

Figure 3. Monthly mean "best 4-layer lifted index" from NCEP/NCAR Reanalysis. Negative values are shaded, with 1° contour interval. Taken from 1998-2007, during the TRMM mission.

For a first look at the environmental forcing, we examine the monthly mean Lifted Index in Figure 3. This gives a simple idea of the updraft buoyancy available from the large scale environment. This certainly does not capture the well known land-ocean differences in observed lightning (Fig. 1). The intense thunderstorms in Fig. 2 are relatively rare, so we check the 99th percentile of Lifted Indices in Fig. 4. The reasoning is that these uncommon storms should be supported by uncommonly unstable environments. It is surprising (to the author, at least) how welll this measure does identify some of the local maxima in intense thunderstorm occurrence. Of course, there are also several regions where strong thermodynamic instability is depicted but intense thunderstorms are not observed.

This examination of the reanalysis Lifted Index is only a crude first look at the environment. Future work will look more specifically at the environmental conditions for specific thunderstorm cases, as opposed to monthly means or a simple 99th percentile. Lifted Index was chosen in part because it is readily available for download (see acknowledgements for website). More detailed analysis will follow in the future.

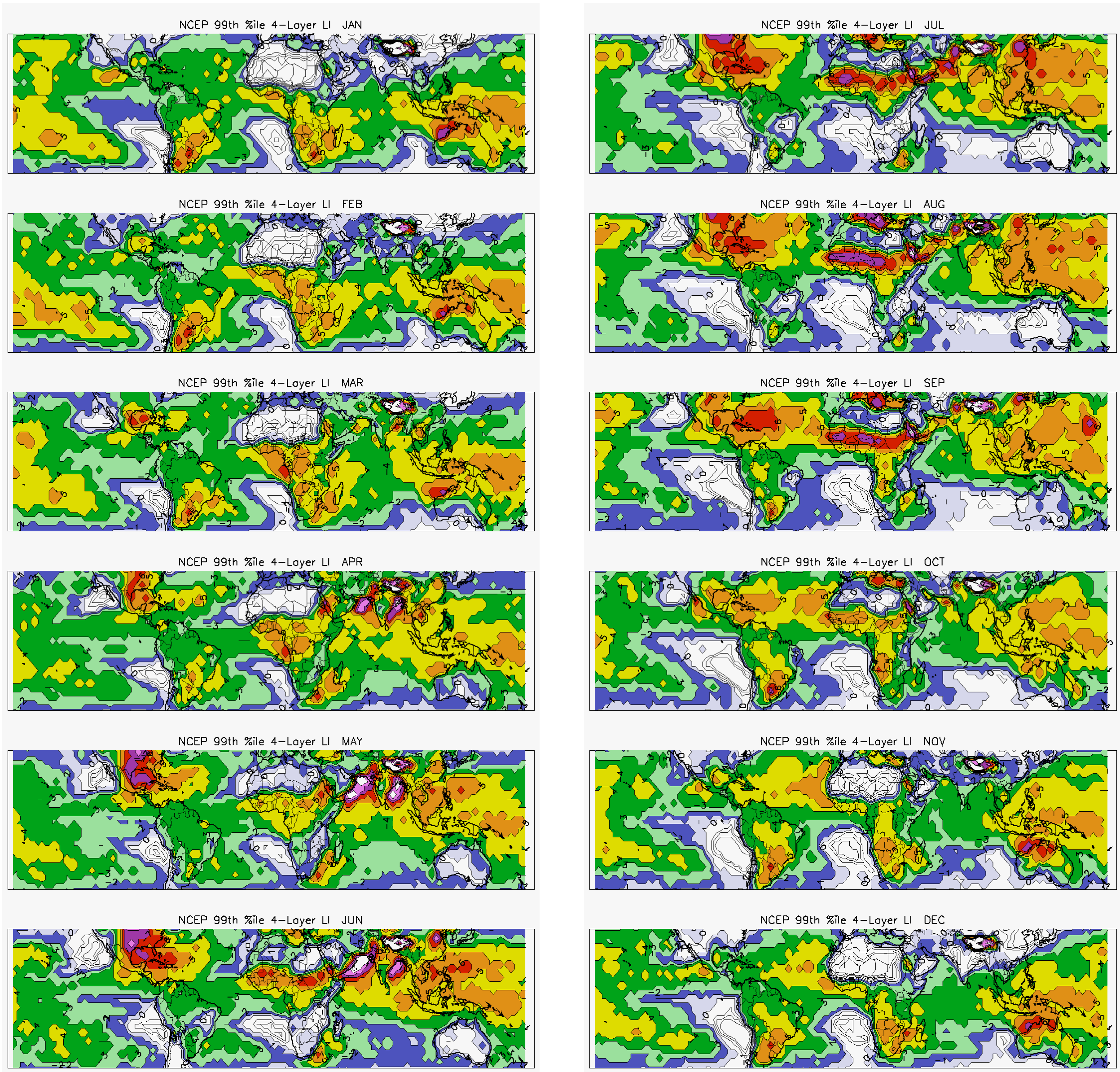

Figure 4. As in Figure 3, but for the 99th percentile lowest Lifted Indices.

REFERENCES

Cecil, D.J., S.J. Goodman, D.J. Boccippio, E.J. Zipser, S.W. Nesbitt, 2005: Three years of TRMM precipitation features. Part I: Radar, radiometric, and lightning distributions. *Mon. Wea. Rev.*, **133**, 543-566.

Kalnay, E. and co-authors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-471.

Nesbitt, S.W., E.J. Zipser, and D.J. Cecil, 2000: A census of precipitation features in the Tropics using TRMM: Radar, ice scattering, and lightning observations. *J. Climate*, **13**, 4087-4106.

Zipser, E.J., D.J. Cecil, C. Liu, S.W. Nesbitt, and D.P. Yorty, 2006: Where are the most intense thunderstorms on earth? *Bull. Amer. Meteor. Soc.*, **87**, 1057-1071.

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