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Sparks of Life, Fixers of N:
Rivers of Lightning

Focus for a second on the amazing photo above, taken in the ancient Arbuckle Mountains of Oklahoma[1]. Consider the pattern, texture and structure of the lightning as it crosses the landscape, making contact with the Earth's surface. Does it not resemble the aerial photos of river systems as we now know them, or the Amazon itself? Perhaps it resembles the human vascular system, or mountain streams and tributaries? Few outside of the Midwest can believe that such lightning storms are extremely common, and so spectacular. However, is there a function to this conduction?

Splitter of N_2

Sources of nitrogen fixation within the biospheric cycle are well known, but the extent of their contribution to the global cycle is still under debate. Smil (2002) states that the nitrogen cycle is "nearly completely dominated by bacteria", with biofixation accounting for "two orders of magnitude more N than lightning" (137). However, Liaw et al. (1990) argued that lightning may indeed by the largest fixer of nitrogen and that earlier fixation rates have been underestimated. Thus, lightning may make a larger contribution to the global N budget than previously understood (22,489).

Liaw et al (1990)

In short, this study reviewed theoretical, laboratory and field estimates of global fixation of N by lightning. They recalculated each study's results with modern, more accurate calculations of N fixation. In conclusion, it was estimated that fixation by lightning was previously underestimated, and field observations indicated that lightning could account for as much as 74-220 Tg N y-1. This range bears striking resemblance biofixation estimates by Smil's of "100-290 Mt N, with 150-190 Mt N per year more likely" and Turner's estimate of 170 Mt N per year (Lecture 9). In comparison, it would seem that lightning could account for about ***half*** of annual nitrogen fixation.

US National Lightning Detection Network Database (NLDN)

Enter: The NLDN. In 1989, Vaisala Inc. began operating the communications network and satellite systems necessary to record information on the location, time, polarity and amplitude of each lightning strike. The NLDN provides real time data for the 48 contiguous states and their archive includes over 160 million flashes from 1989 to present.[2]

After studies revealed that there can be as many as 20 return strokes in a single flash, and about half of the flashes contain subsequent strokes that terminate at more than one location, the NLDN revised its data collection process. Beginning in 1995, flash data was expanded to include stroke characteristics of each strike. The NLDN states, "The stroke data set provides such detail that a whole new level of analyses and in-depth lightning exposure investigations can now be performed" (Flash/Stroke Data Section). However, nitrogen fixation doesn't seem to have been one of them!

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[1] http://www.chaseday.com/lightning.htm
[2] http://gcmd.nasa.gov/records/GCMD_NLDN.html

Implications

As previously illustrated, Liaw's (1990) assumption was enough to model, with field observations, that lightning just may fix more N than terrestrial biofixation. This conclusion was reached with the assumption that lightning averaged only 2 return strokes per flash (abstract). In light of more accurate estimates of up to 20 return strokes per flash, it seems that Liaw's analysis may have drastically underestimated the amount of N fixed by lightning.

1. NLDN's data can be exported for statistical analysis and charting. The data provided could be easily utilized to provide the most accurate calculation of annual N fixed to date
2. Lightning is a natural source of nitrogen oxides (NO & NO2), which forms easily utilized nitrates (NO3) for flora (instead of biofixed ammonia NH3) (Smil 137)
3. Relationship between evapotranspiration/NPP, cloud formation and lightning needs research
4. Nitrogen is the factor most important for limiting photosynthesis, heterotrophic growth (Smil 137), and terrestrial ecosystems (Navarez-Gonzales, et al., 2001); the supply of which is a major concern for agricultural crop production and ecosystem restoration (Smil 137)
5. Anthropogenic involvement in the nitrogen cycle, fixation of nitrogen for fertilizers (Mosier, et al., 2005) and fossil fuel combustion (Lecture 9), essentially replicates the natural process of nitrogen fixation by lightning
6. In 1998, NASA first realized that lightning likes land[3], Figure 2. Subsequent research reveals interesting patterns and high concentration of lightning activity, Figure 3. The proximity of this activity to forests, or other vegetative areas and topography should be evaluated (the most intense areas of lighting activity occur around Midwestern forests of the US, south of the Amazon in South America, immediately over the Congo of Africa and immediately west of the Himalayan Mountain Range)

[3] http://thunder.nsstc.nasa.gov/bookshelf/news/lightning_likes_land.html

Resources

Liaw, YP; Sisterson, DL; Miller, NL. “Comparison of Field, Laboratory and Theoretical Estimates of Global Nitrogen Fixation by Lightning” *Journal of Geophysical Research*, Vol. 95, No. D13, Pages 22,489-22,494, December 20, 1990.

Mosier, Arvin R.; Syers, J. Keith; Freney, John R. “Global assessment of nitrogen fertilizer: The SCOPE/IGBP Nitrogen Fertilizer Rapid Assessment Project” *Science in China Series C: Life Sciences.* Volume 48, Supplement 2, 759-766, 2005

Navarro-González, R; McKay, C P; Mvondo, D N, “A possible nitrogen crisis for Archaean life due to reduced nitrogen fixation by lightning” *Nature*, 07/2001, Volume 412, Issue 6842, pp. 61 – 64

Smil, Vaclav, “The Earth’s Biosphere: Evolution, Dynamics, and Change” *MIT Press,* 2002

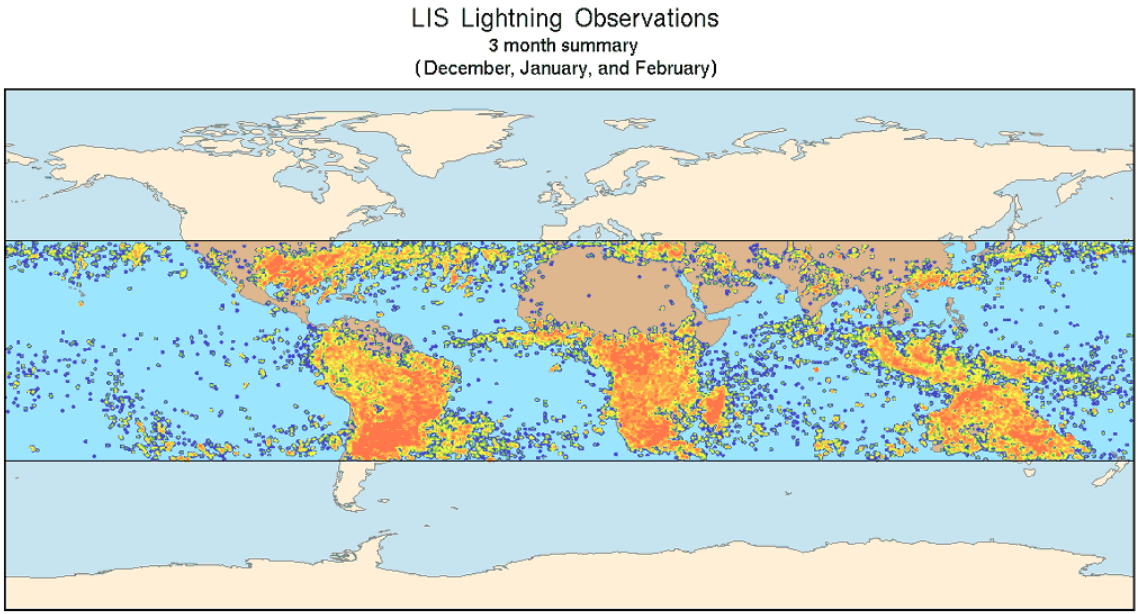

FIGURE 1[4] – First published lightning map from the Lightning Imaging Sensor (LIS) after first three months of data collection, Dec. 1997 to Feb. 1998. "This composite from three months of LIS data dramatically shows that most lightning occurs over land. .Areas over sea match major circulation patterns that carry storms over water. Credit: NASA/Marshall Space Flight Center."

[4] http://thunder.nsstc.nasa.gov/bookshelf/news/lightning_likes_land.html

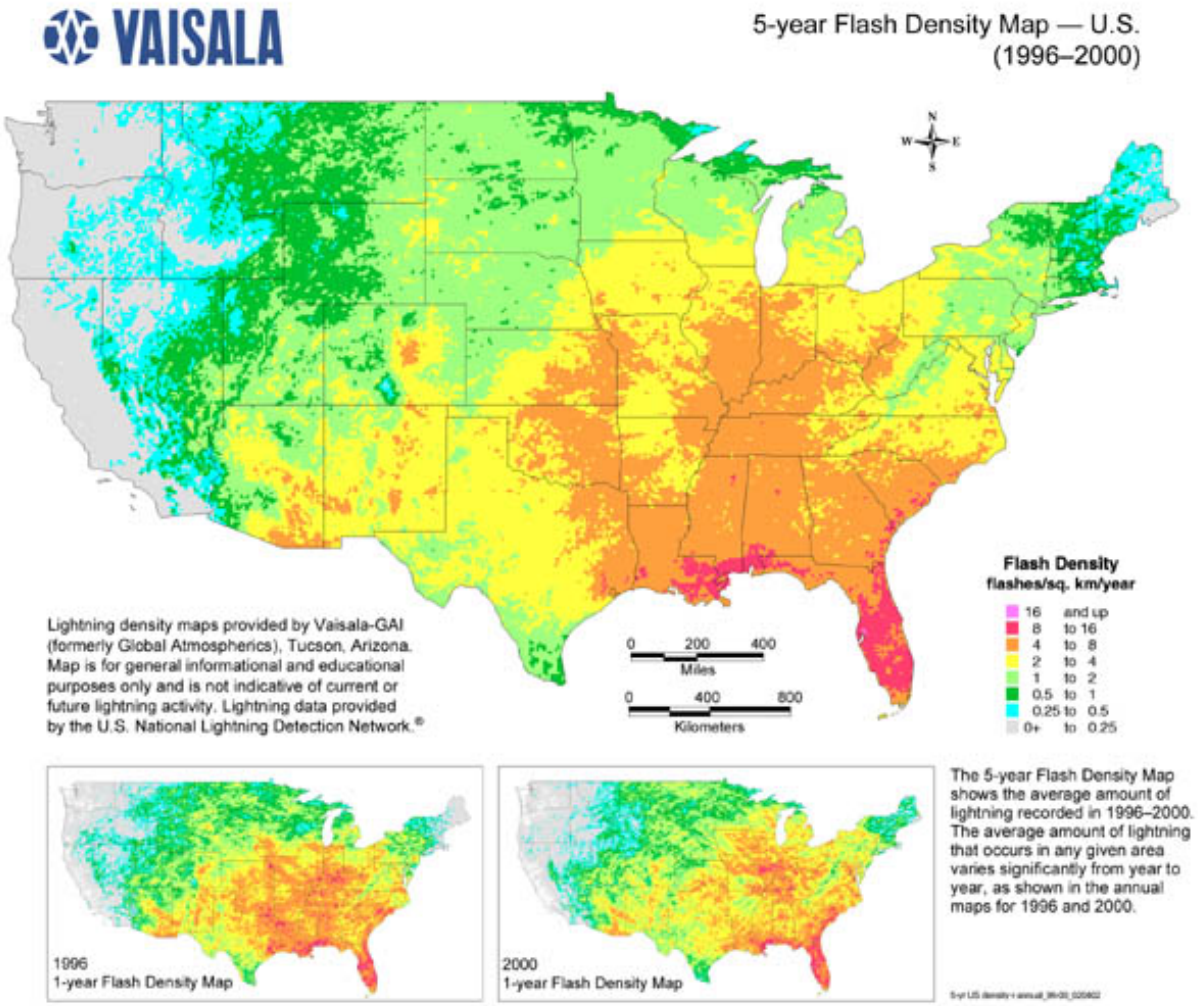

Figure 2 – 1996-2000 Flash Density in the US[5]

[5] http://www.lightningsafety.noaa.gov/lightning_map.htm

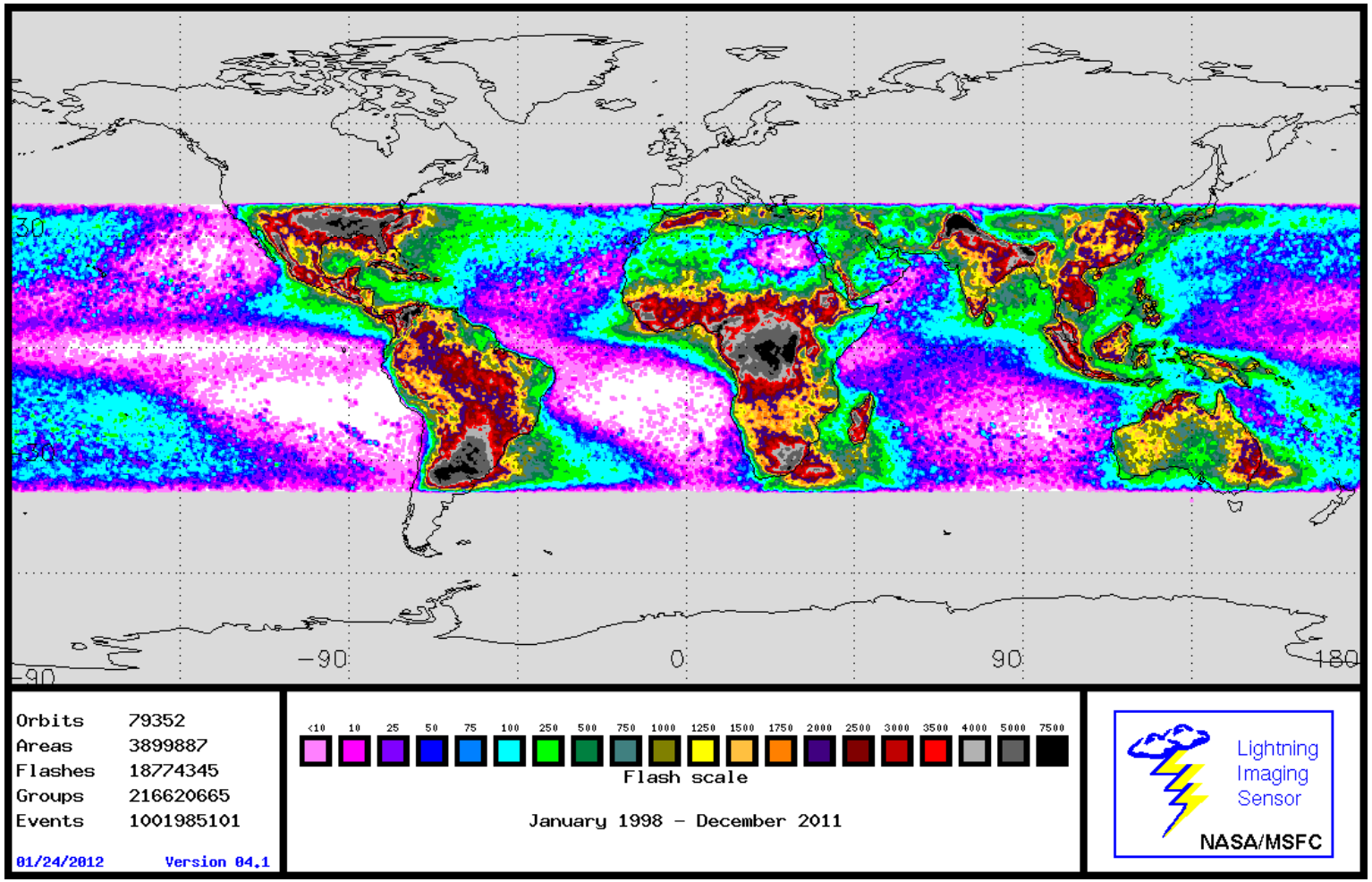

Figure 3 – 1998 thru 2011 global flash counts from the LIS.[6]

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[6] http://thunder.nsstc.nasa.gov/data/query/mission.png