

Thoughts to Consider Regarding Global Satellite-Based Climate Data Records (CDRs) of Hazardous Storm Event Detections

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TO GENERATE SATELLITE CDRs, ONE NEEDS TO CONSIDER

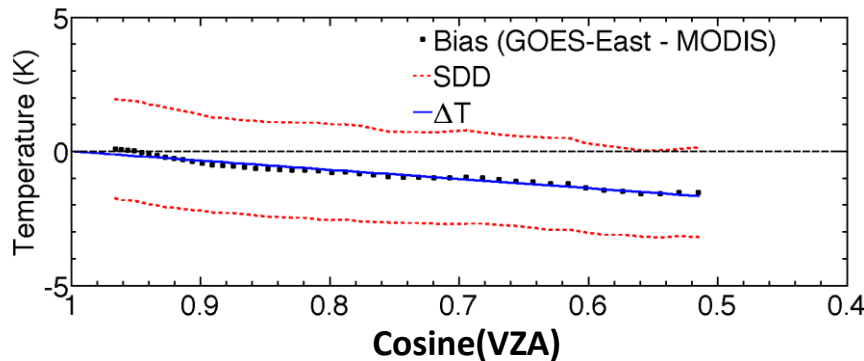
- **Fast and efficient input satellite image and ancillary data access**
- **Account for variation in sensor resolution and view angle dependencies**
- **Visible and IR sensor calibration**
 - Spectral channel differences between satellites (e.g. GOES vs 1st Gen and 2nd Gen Meteosat)
 - Historical GEO imagers have no on board visible calibration, must use vicarious calibration to account for degradation (SNO, desert, ice, deep convection)
 - Ensure no trend in IR radiances throughout the time series
 - “Midnight effect” in IR for 3-axis stabilized imagers produces bias of up to 1 K. Use TRMM VIRS (referenced to MODIS) to develop correction for this
- **False trends within reanalysis data**
- **AVHRR: Orbit drift from original satellite equatorial overpass time**
- **Widely accessible output data formats (e.g. NetCDF/HDF5, not XSQWTYB format) including metadata and efficient data distribution/subsetting tools**
- **Satellite cloud top observations does not necessarily provide enough information about weather hazards or risk. Need to constrain detection data with NWP information and ground reports / insured loss data to estimate hazards**

Sensor Calibration



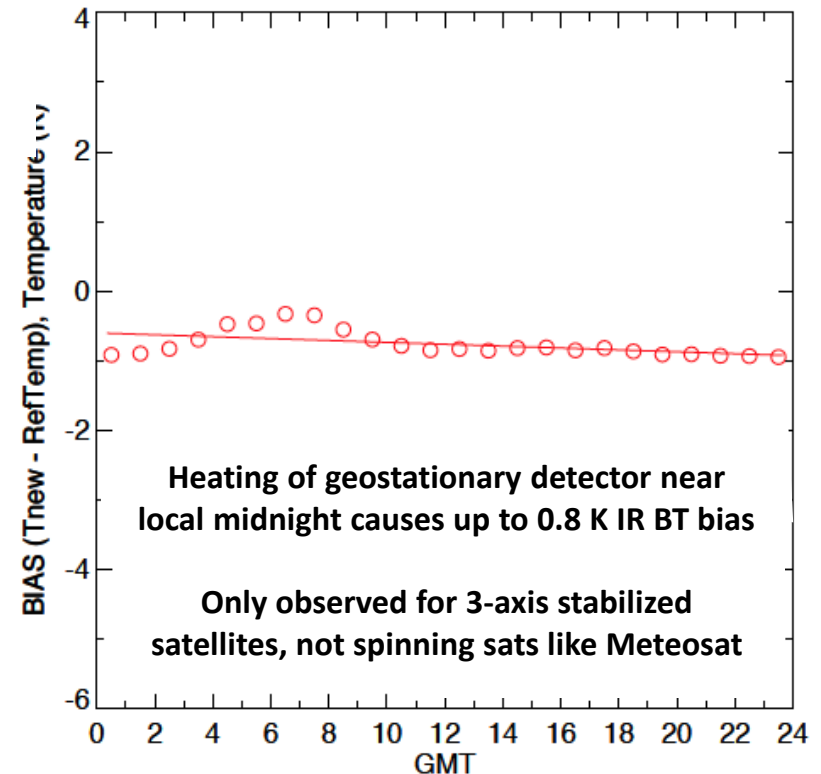
- Climate change effect on hazardous storm frequency may maximize at 1-2% per decade
- Sensor artifacts if not accounted for can induce trends at or exceeding this magnitude, therefore we must account for them before deriving satellite storm climatologies

IR Viewing Angle Dependency: "Limb Darkening"

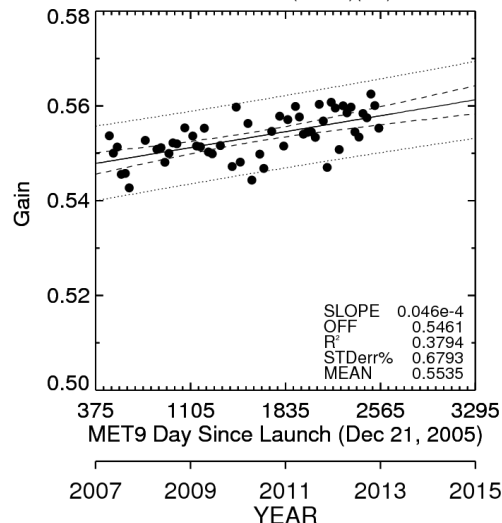


GOES IR Diurnal Dependency

G13 vs TRMM, GMT 0-24, OCEAN_ONLY
IR, 10.7um

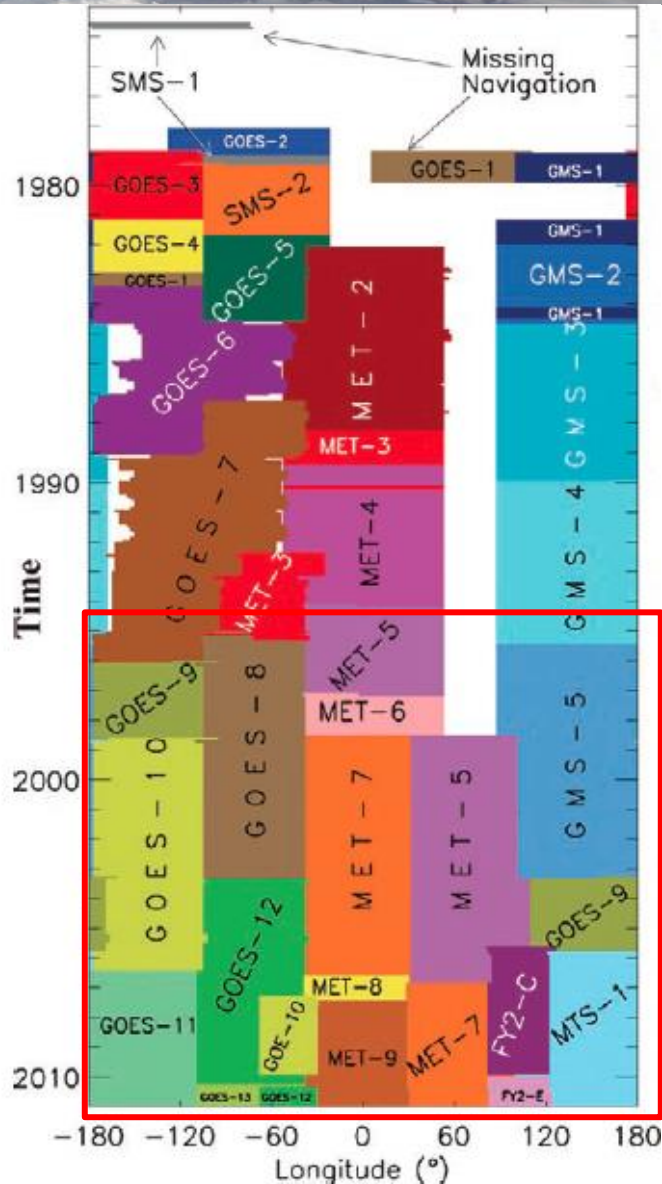


MET9 vs AQUA, 2007-2015, OCEAN_ONLY
VIS, 0.64um (SBAF)(C6)



Visible Channel
Degradation
As a Function
of Days Since
Satellite
Launch
Using GSICS
Methods

Global GEO Satellite Imager History From Knapp et al. (BAMS, 2011)



Long-Term Regional or Global Hazardous Storm Event Databases

- The global constellation of geostationary (GEO) imagers have been collecting high resolution (< 5 km) imagery since the mid-1990's
- NASA LaRC has immediate access to the entire GEO satellite image data archive via UW-Madison SSEC as well as a long-term database of reanalysis data
- An image covering an entire GEO satellite view can be acquired from a remote server and processed within minutes, enabling rapid development of long-term satellite-based hazardous storm event databases

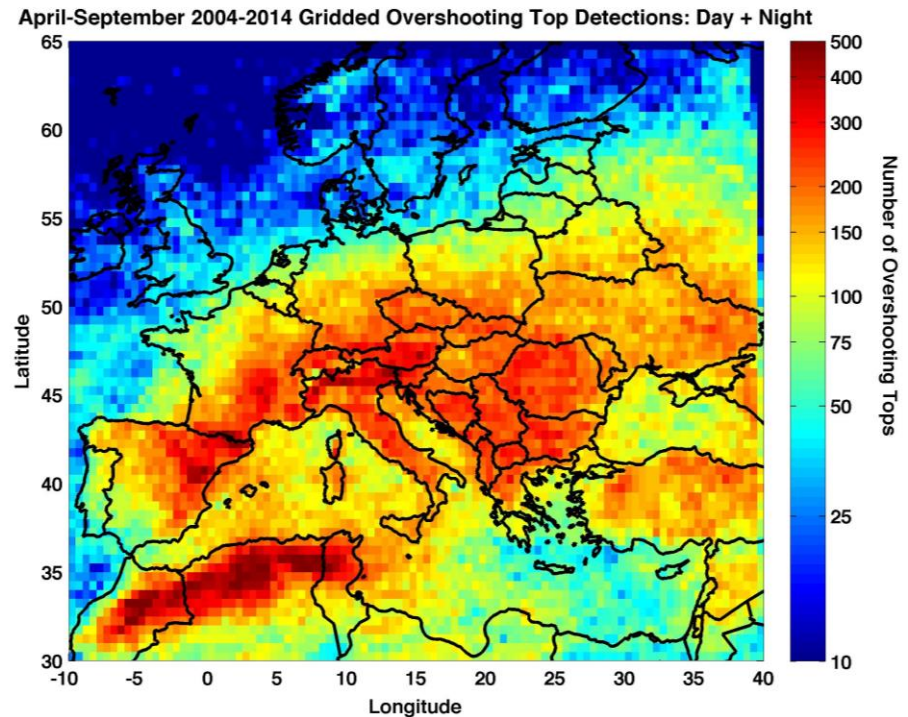
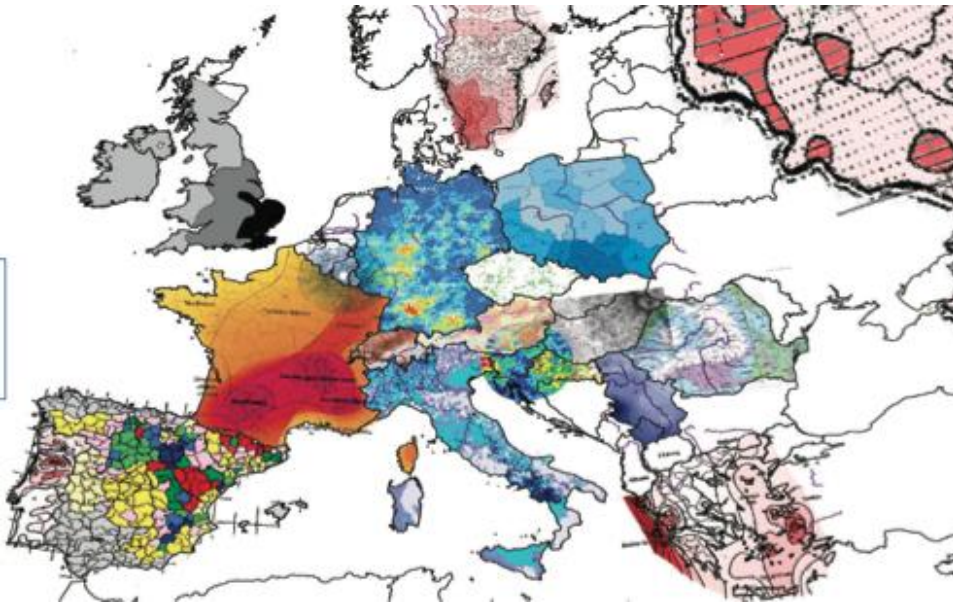
≤ 5 km Nadir IR
Spatial Resolution

European Severe Hail Climatology

Punge et al. (Natural Hazards, 2014)



European Hail Risk From Published Literature



(left panel) A map of severe hail risk assessments for various European nations from published literature. Methods used to derive them are inconsistent, resulting in an incoherent map that cannot be used effectively to assess hail risk.

(right panel) A map of severe hail risk derived by Willis Re and KIT (H. Punge) from a combination of 1) an 11-year database of Meteosat Second Generation SEVIRI overshooting top detections, 2) hail-induced insured loss data, 3) ground-based observations of severe hail, and 4) a set of NWP parameters. Darker shading indicates a greater climatological risk for severe hail. Adapted from the work of Punge et al. (Natural Hazards, 2014).

Filter Approach: Eliminate OTs where hail is less likely

1. Evaluate atmospheric conditions for each large hail event reported in the European Severe Weather Database (ESWD) from ERA-INTERIM reanalysis
2. For each variable v_i , define **lower** and **upper** thresholds :

$$v_i^{\text{low}} = p_5(v_i) - [p_{10}(v_i) - p_5(v_i)]$$

$$v_i^{\text{high}} = p_{95}(v_i) + [p_{95}(v_i) - p_{90}(v_i)]$$

where p_k is the k^{th} percentile of the distribution

3. Evaluate conditions at OT occurrences v_i^{OT}
4. Filter OTs below/above thresholds (**22% in total**)

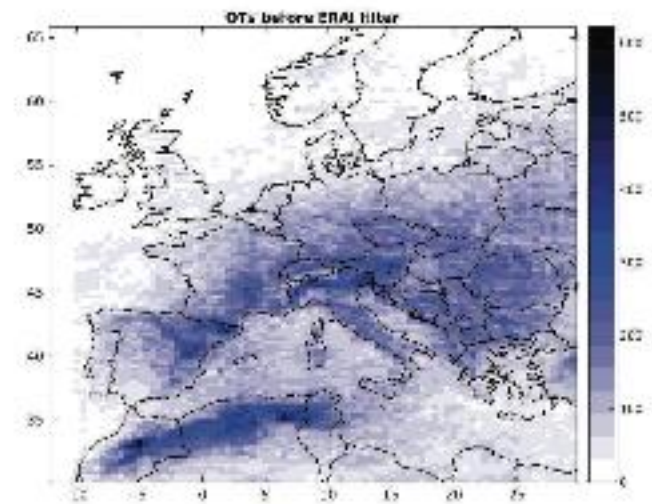
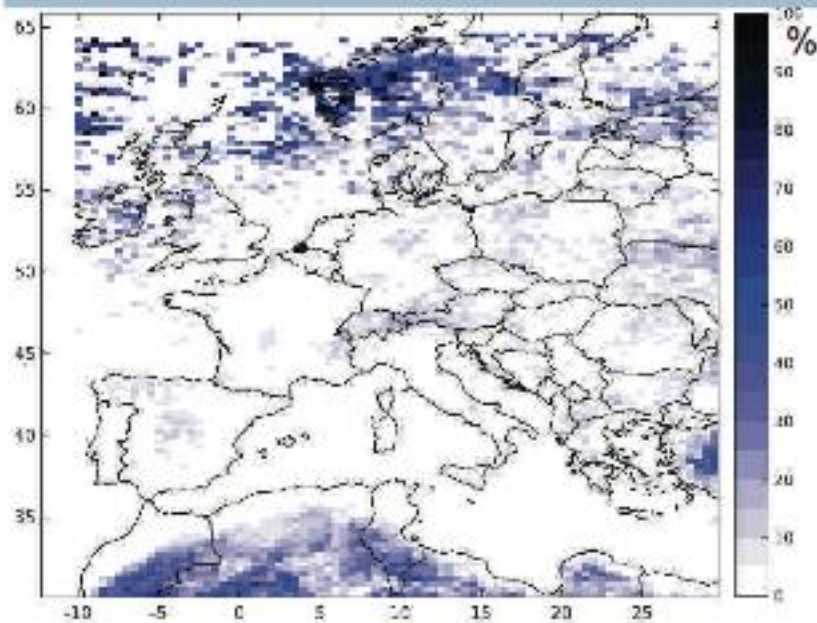
Lower thresholds ($v_i^{\text{OT}} < v_i^{\text{low}}$) for:
height of PV=2 tropopause,
dew point @ 2m,
total column water vapor,
eq. potential temperature @ 850hPa,
zero degree height

Upper thresholds ($v_i^{\text{OT}} > v_i^{\text{high}}$) for:
height of PV=2 tropopause,
temperature @ 700hPa
humidity @ 300hPa ,
eq. potential temperature @ 500hPa,
zero degree height

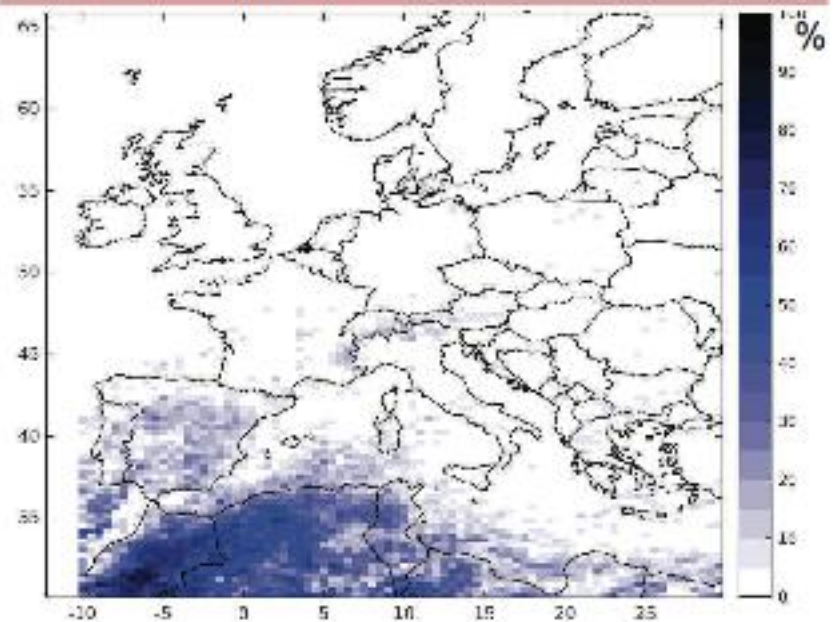
Filter examples:

Percentage of OTs filtered for:

Low dew point temperature

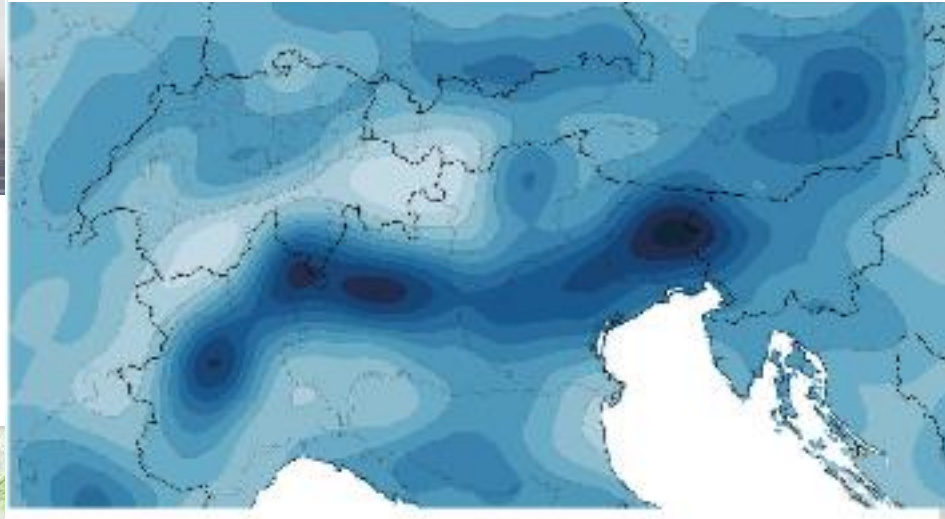


High freezing level



Courtesy of Heinz Jurgen Punge (KIT)

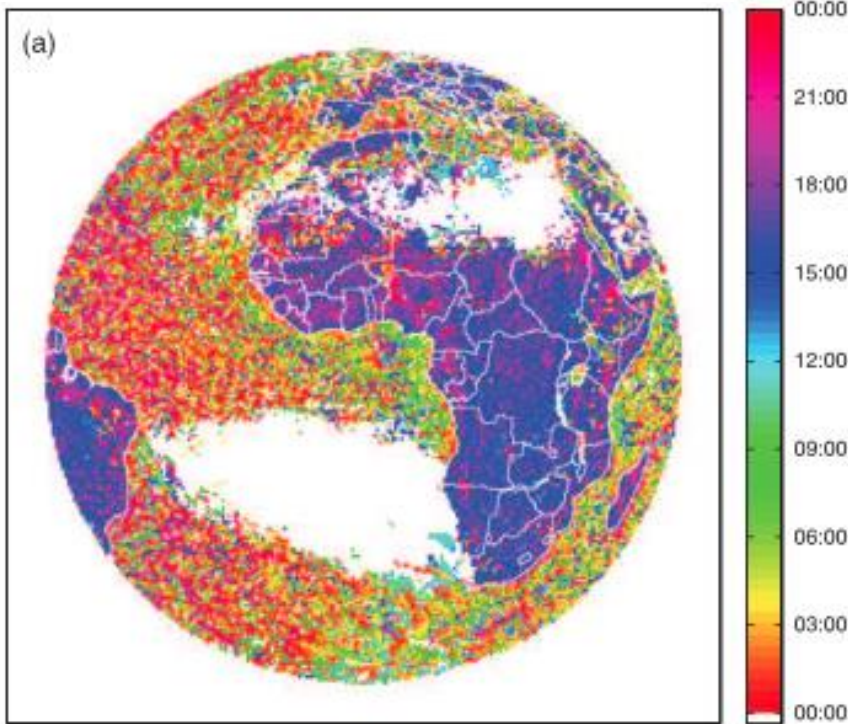
Hail Hazard Map Based on Filtered OT Dataset



5-Year Full-Disk SEVIRI OT Database



Local Time of Peak OT Activity



Month of Peak OT Activity

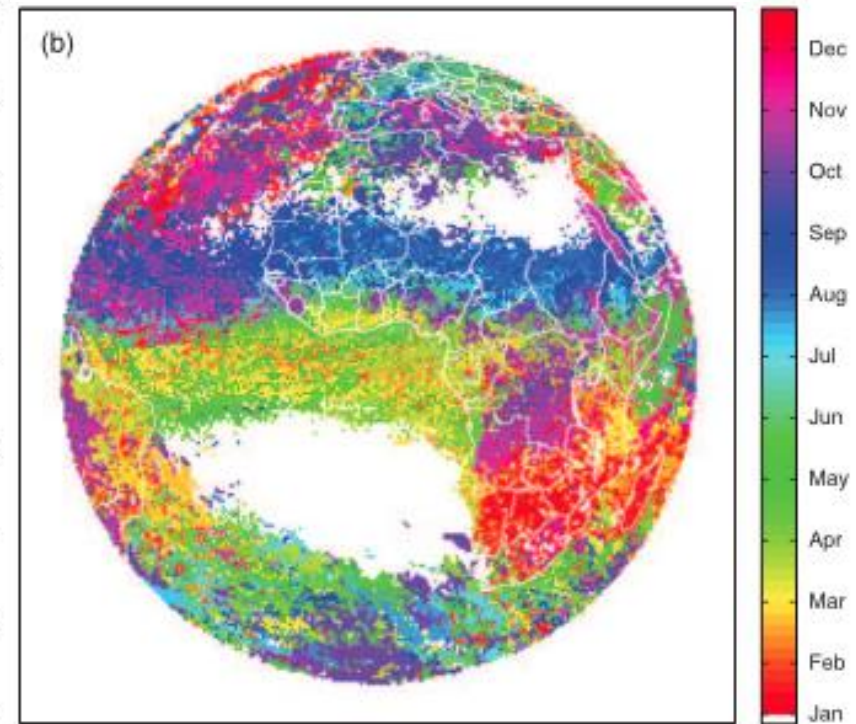
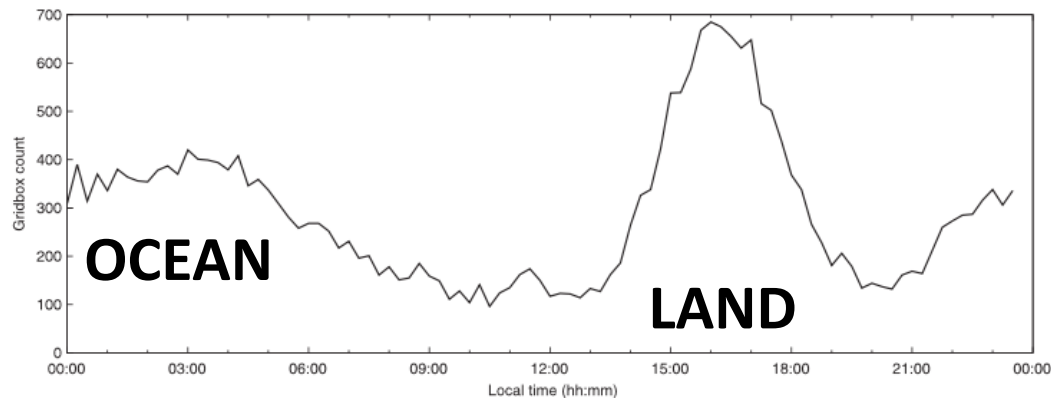


Figure 3. The (a) time of day (adjusted to local solar time) and (b) time of year for which the OT detection count peaked across the SEVIRI disk. In (b) the year is divided into 36 decades in order to reduce the amount of noise in the figure. There are three decades per month representing days 1–10, 11–20 and 21–end of month.



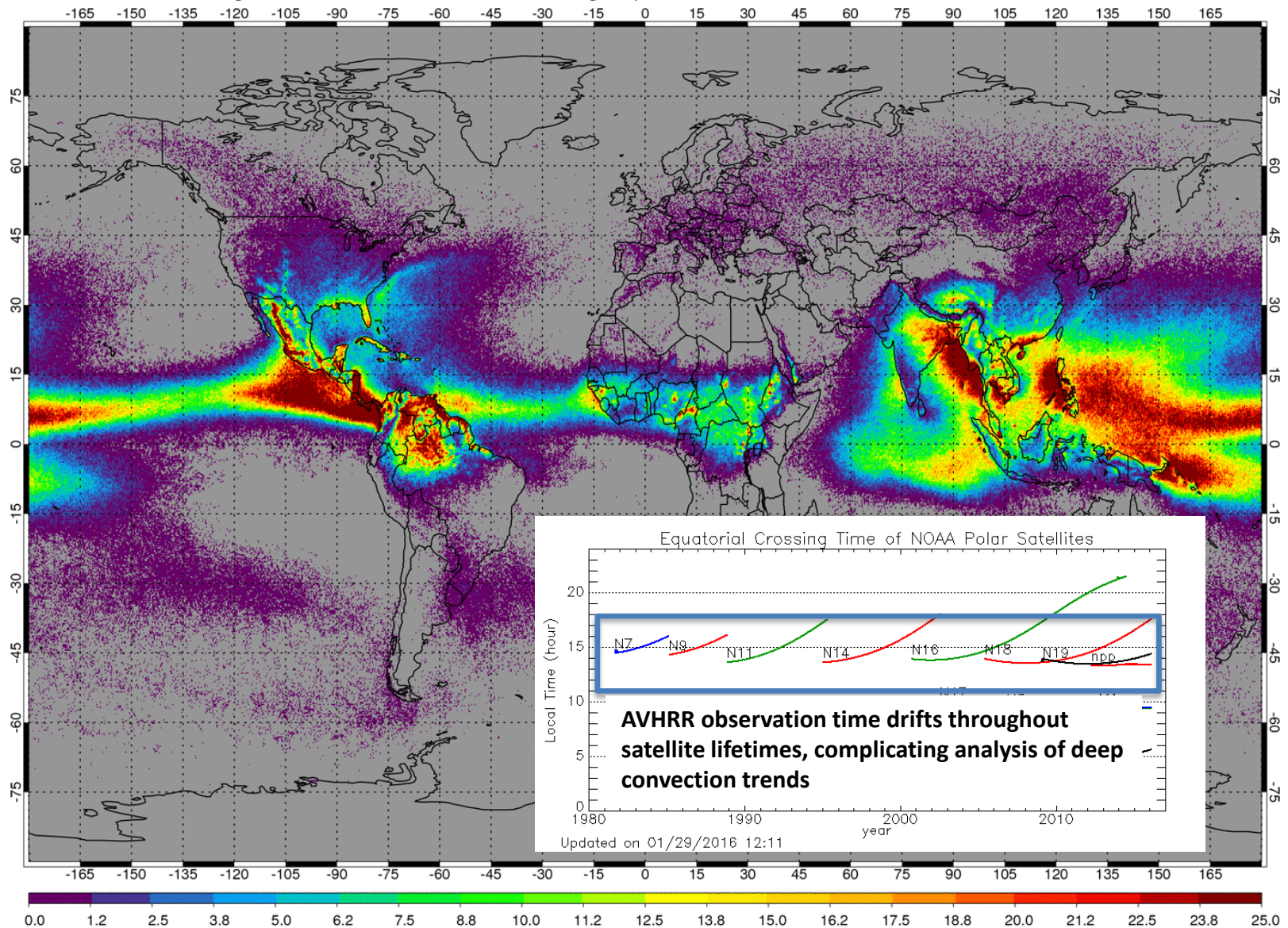
Proud (QJRMS, 2015)

Figure 4. A histogram showing the number of grid boxes that show peak OT activity at a particular time of day.

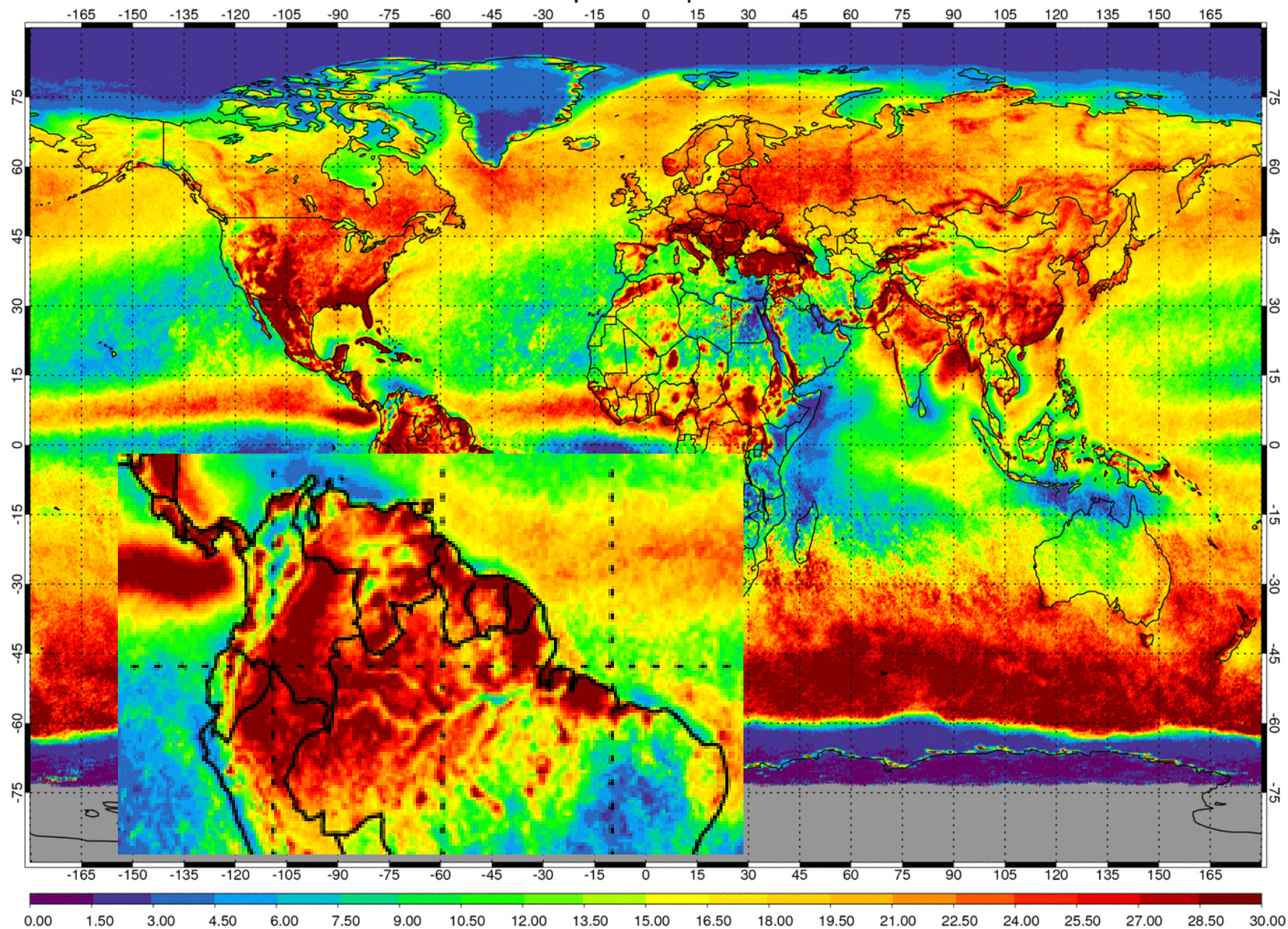
33-Year AVHRR Overshooting Top Climatology Northern Hemisphere Summer, "2 AM/PM" Observations



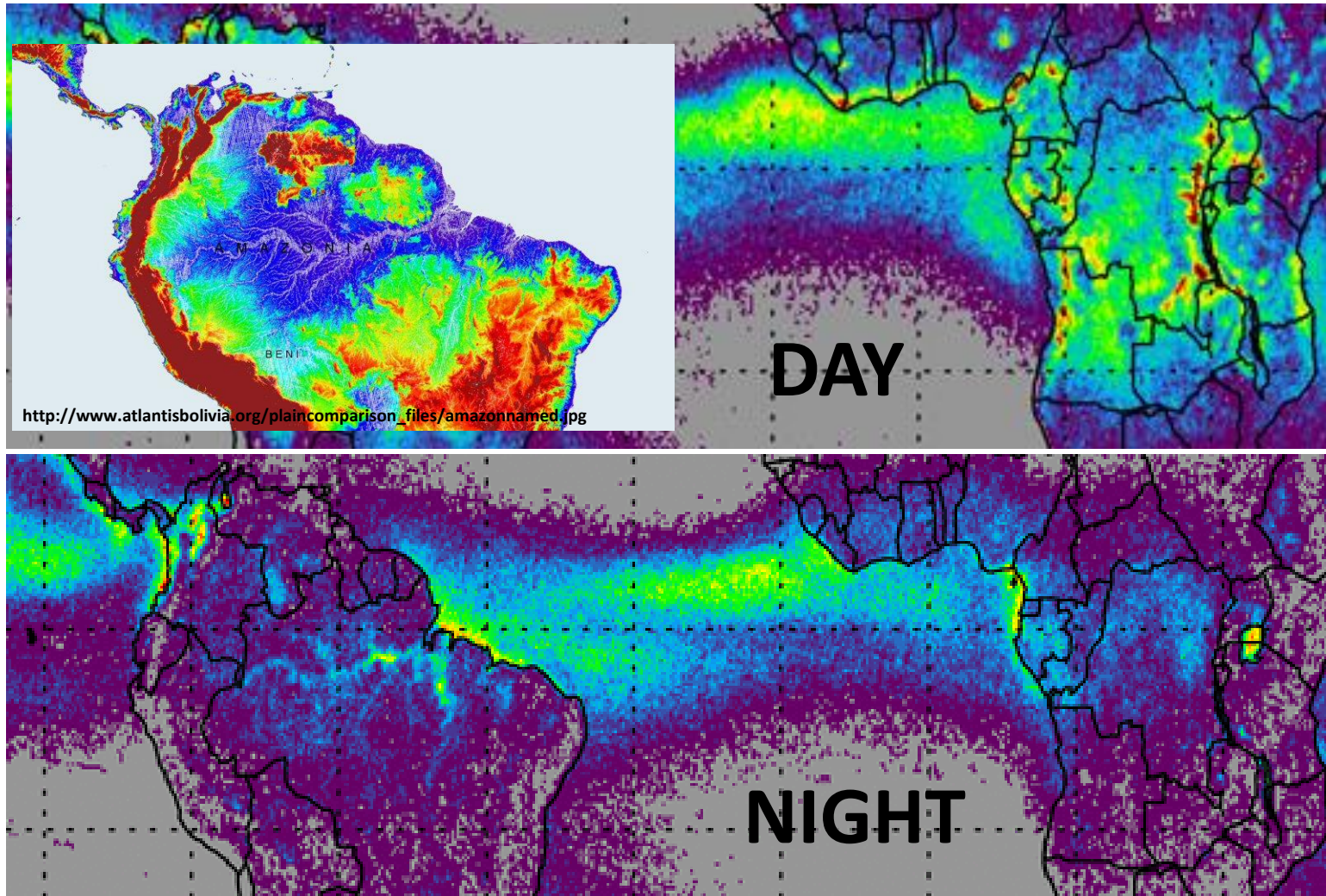
NASA LARC 0.25-Degree Gridded AVHRR Overshooting Top Pixel Count Mean Per Season: 1982-2014 N. Hemi. Summer



NASA LARC AVHRR Ice Cloud Optical Depth: SUMMER DAY NOAA-09 to -19



AVHRR 1982-2014 Northern Hemisphere Spring OT Climatology, Day vs. Night



0.0 1.2 2.5 3.8 5.0 6.2 7.5 8.8 10.0 11.2 12.5 13.8 15.0 16.2 17.5 18.8 20.0 21.2 22.5 23.8 25.0

Overshooting Cloud Top Detection Pixel Counts Per Year

9-Year Hazardous Storm Database over the African Great Lakes Region Using Bedka et al. (2010) Approach



Lethal weather on 'world's most dangerous lake'

From Errol Barnett, CNN
updated 9:48 AM EST, Thu January 17, 2013

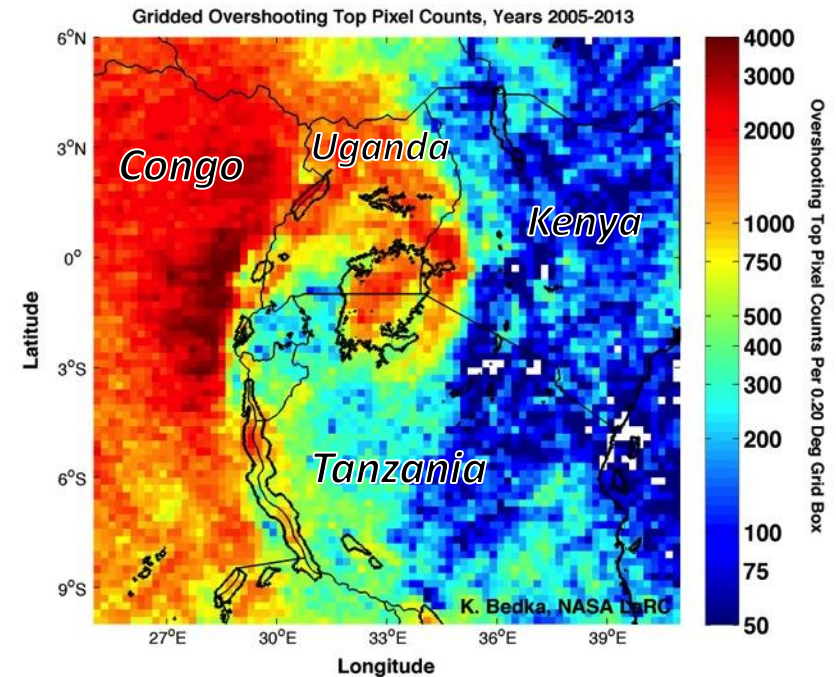
CNN World



Hundreds of thousands of people, mainly fishermen, depend on Lake Victoria for their livelihood.

Lake Victoria

HIDE CAPTION



5000+ people are killed on the African Great Lakes every year, most often due to severe weather

NASA LaRC and international partners are analyzing

- 1) The controlling factors for the occurrence of hazardous storms over the African Great Lakes region
- 2) How climate change could affect future storm activity via a regional climate model and satellite-based OT detection analysis

Thiery et al. (Under review Nature Communications, 2016)

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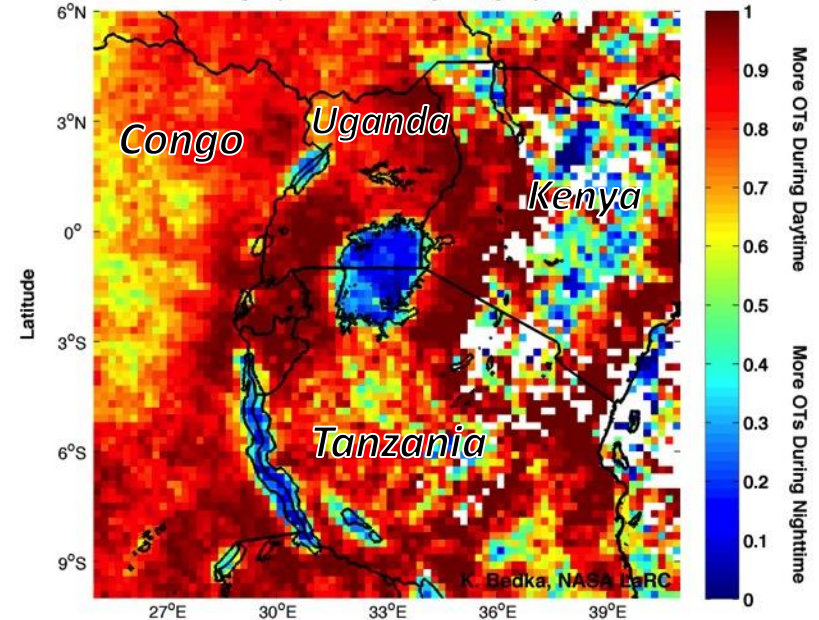
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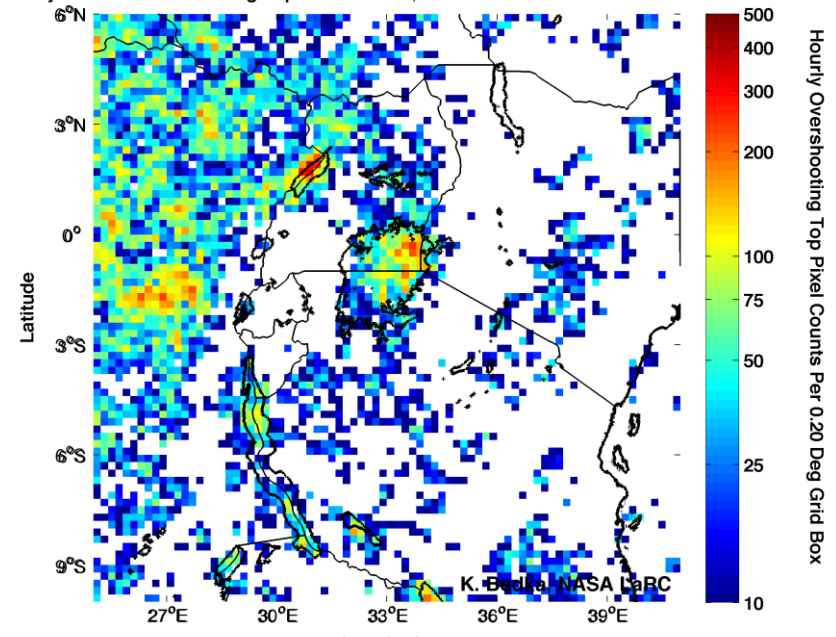
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Fraction of Overshooting Top Pixels Occurring During Daytime, Years 2005-2013



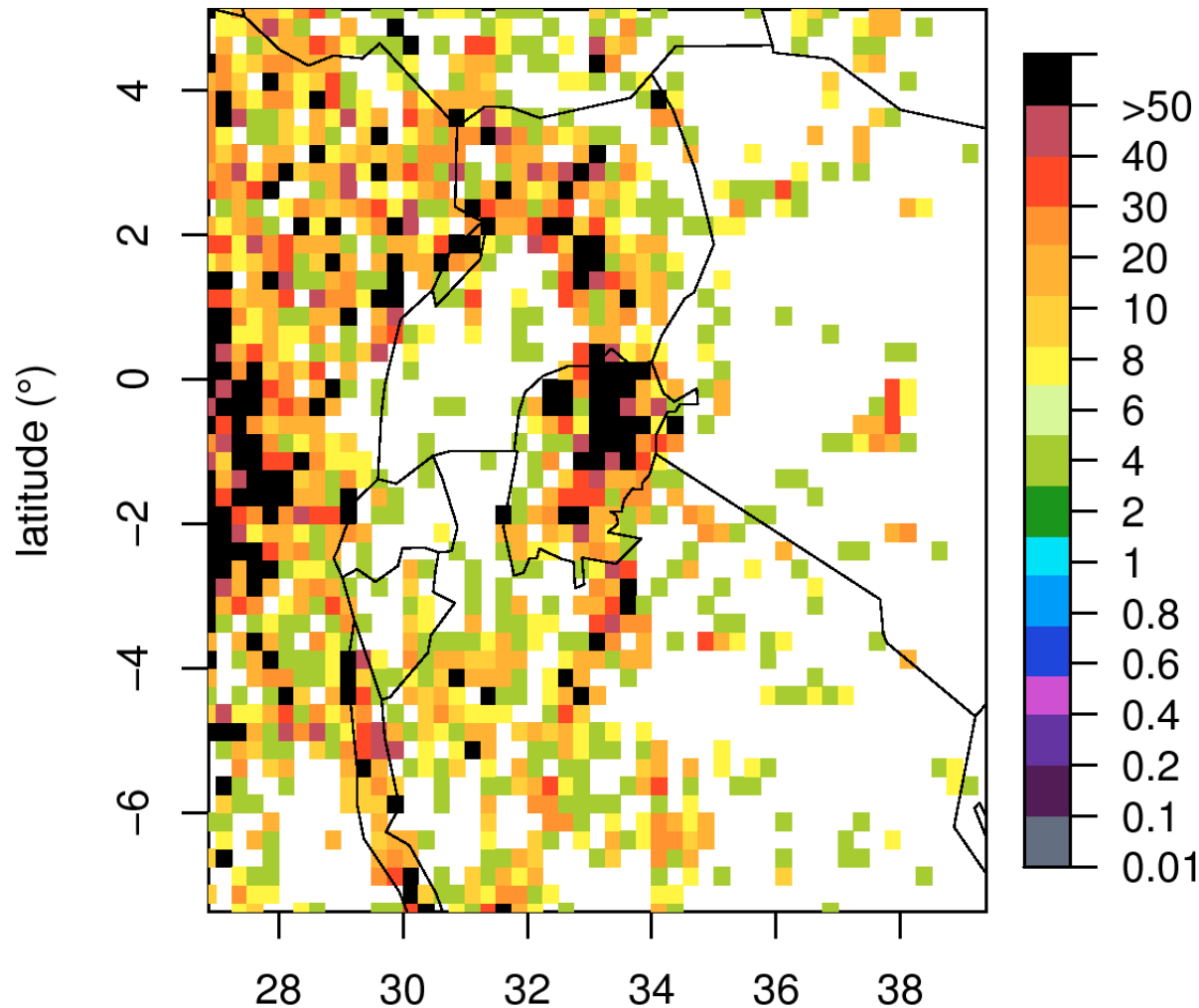
Hourly Gridded Overshooting Top Pixel Counts, Years 2005-2013: 0000-0045 Local Time



TRMM LIS Flash Detection Climatology Over The African Great Lakes



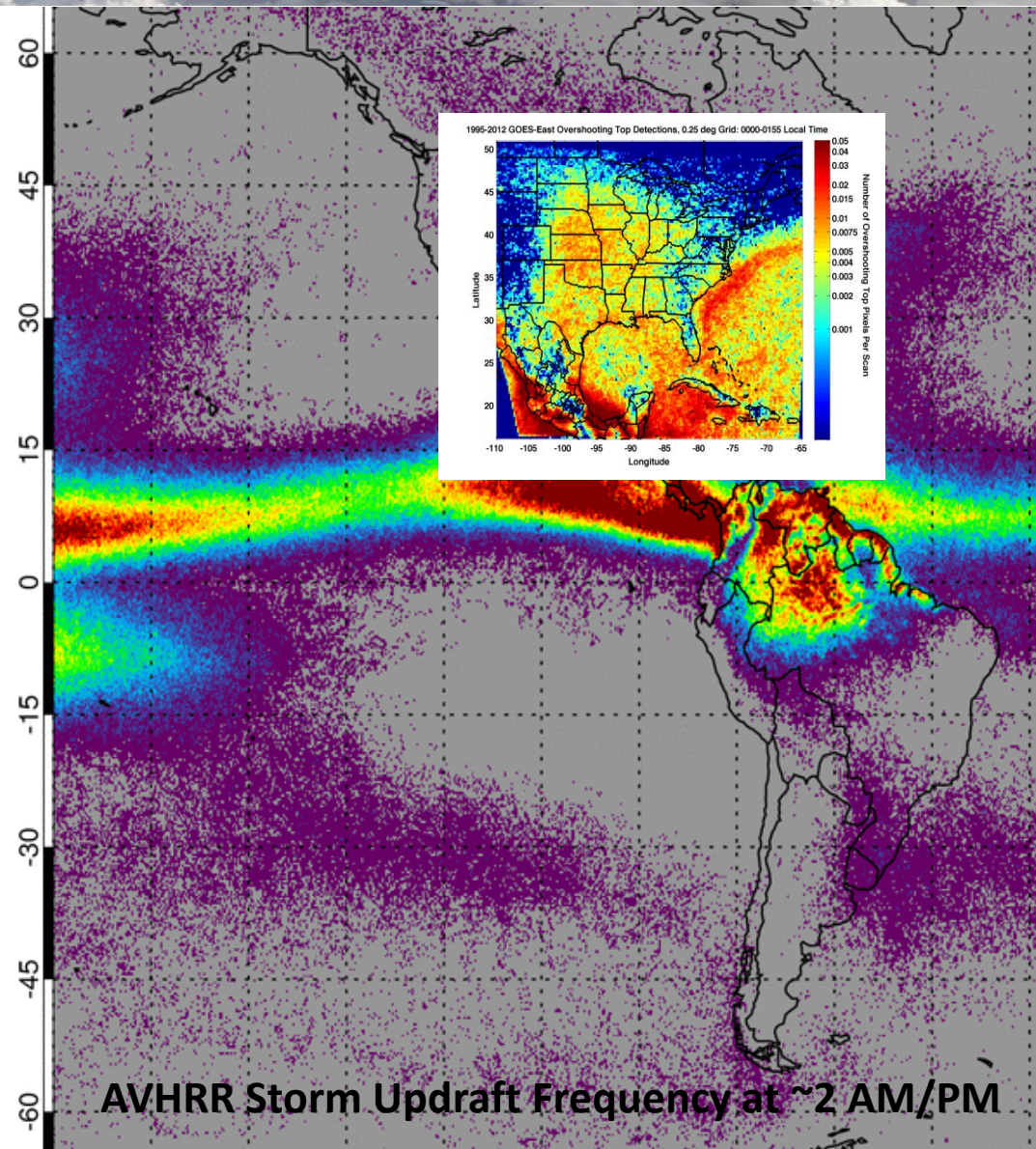
00 LST flash rate density ($\text{fl km}^{-2}\text{yr}^{-1}$)



longitude (°)

Animation Courtesy of Steve Goodman

20+ Year GOES Hazardous Storm Climatology Under Development at NASA LaRC



- The entire GOES record since 1995 is being processed within the NASA LaRC hazardous storm detection algorithms, supported by the NASA Science Innovation Fund
- The GOES climatology will provide 24x the sampling of the AVHRR climatology
- ~10 trillion pixels to be processed
- Updraft/anvil detections and MERRA severe weather reanalysis fields will be provided every 30 mins
 - 30-180° West, 65 North/South latitude,
 - 5 km daily and 25 km monthly products
- Frequent observations will allow for a range of applications, from defining historical storm events and storm tracks to analysis of climatological storm distributions/trends
- Processing to be complete by Spring 2017