Lightning Detection Systems

Roger Carter,

Spectrum Manager, UK Met Office

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ITU/WMO SEMINAR ON USE OF RADIO SPECTRUM FOR METEOROLOGY.

16 – 18 September 2009

Lightning Detection Systems

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  - Optical measurements from satellite [+VHF?]
  - Ground based observing systems, VLF/LF/VHF
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- Summary

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Reasons for operational lightning observing systems

- Managing electricity generation and supply, and the repair of supply lines
- Safety for handling of explosives
- Aviation safety/ operating costs
- Fighting forest/ bush fires
- Public safety and forecasting of severe weather
- Improving representation of convection in numerical weather prediction
- Scientific investigations such as :-
  - Understanding changes in global distribution of lightning and relation to climate change,
  - Production of important trace chemicals.

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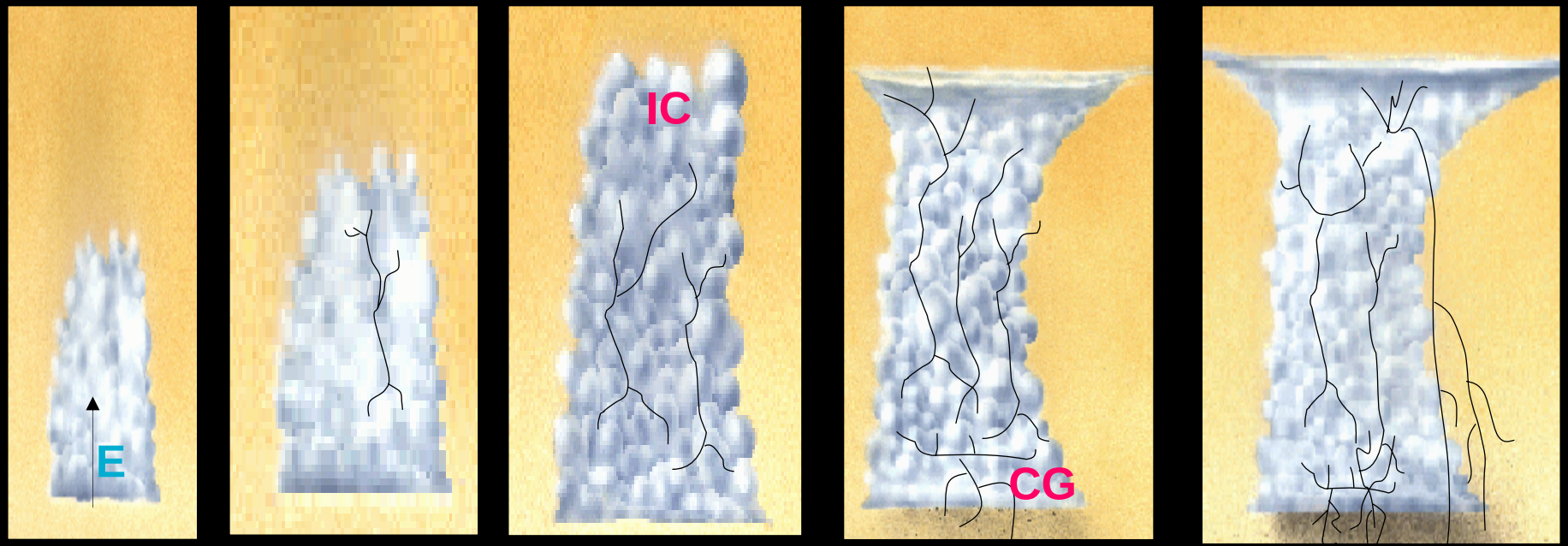
TOTAL LIGHTNING MEASUREMENTS



TLM technology combines :

Dual Electromagnetic detection

VHF for Total lightning detection

LF for CG characterisation

Based on information from Vaisala Oy

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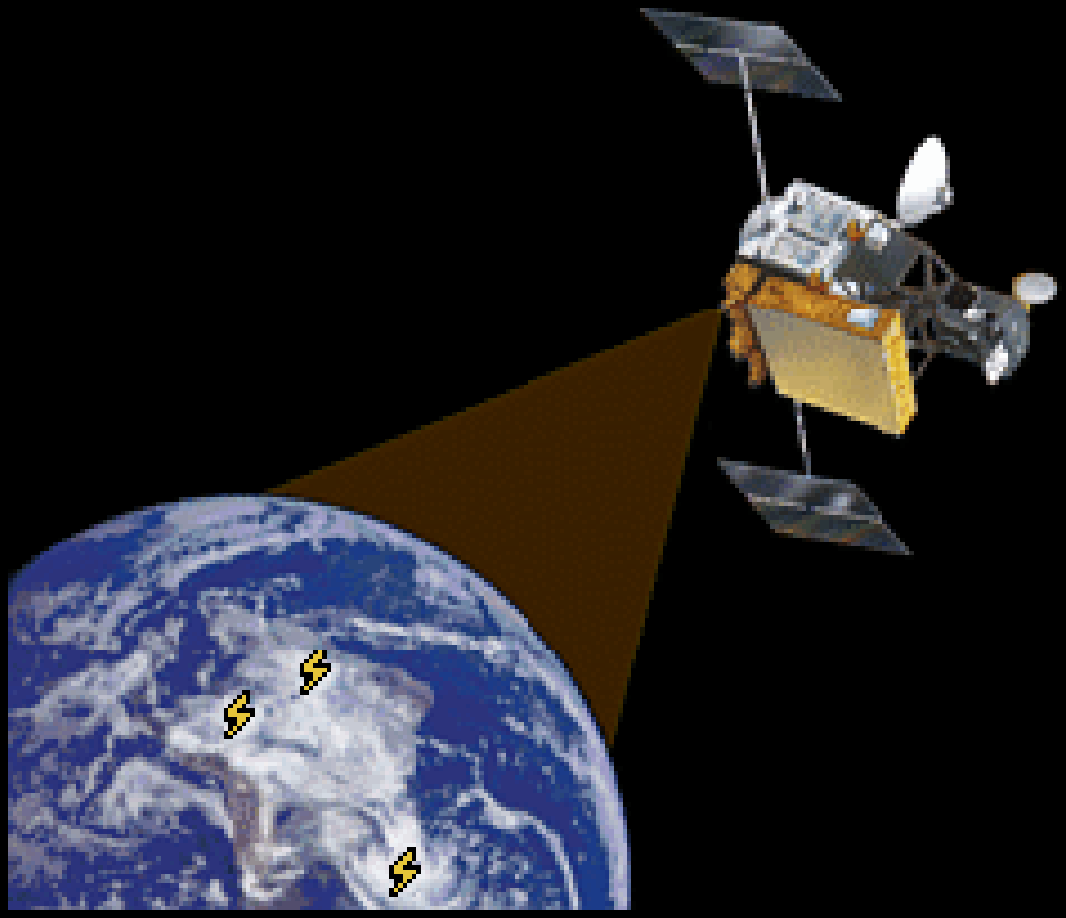
Lightning Imaging System [LIS] on TRMM satellite [NASA/MSFC]



4 to 7 km resolution

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Typical specification for satellite lightning detection

Detection efficiency [DE]: 90 per cent day and night

DE specified as the probability of detecting a lightning event for the specified event energy range, where a lightning event is defined as a spatially uniform optical signal produced by an electric discharge, within or below clouds with the following mean characteristics:

Energy	4.0 to 400 μJ.m-2.sr-1;
Spatial shape :	Square of 10 km.
Temporal width :	0.5 ms.

The occurrence of a lightning event is defined as any time the total signal from a given pixel exceeds the average signal for the pixel by a predetermined amount called the threshold.

The case when a random signal exceeds the threshold level with no lightning signal present is defined as a false alarm.

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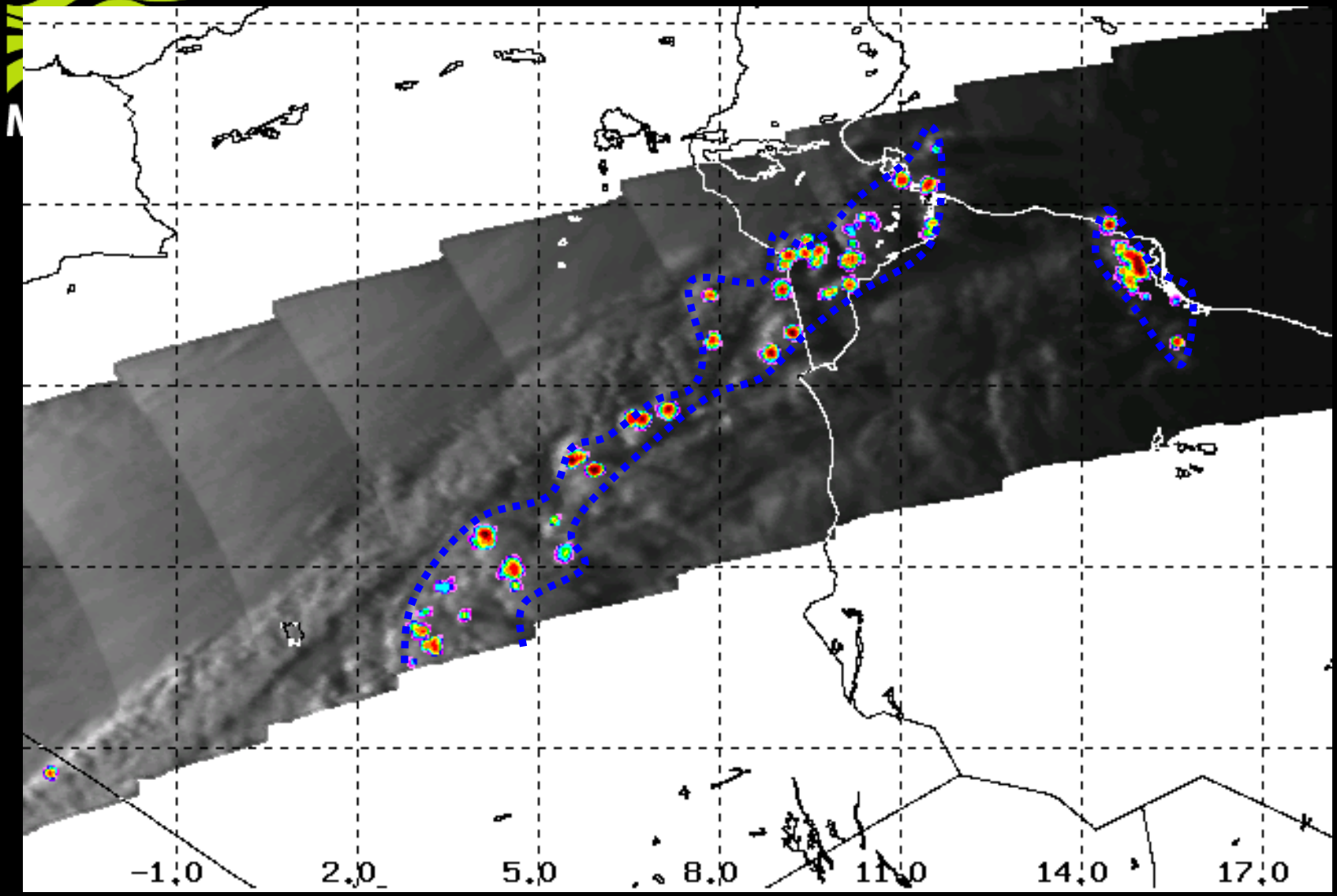
LIS, satellite, NASA MSFC



Algeria / Libya 17.15 UTC 11 April 2002, LIS

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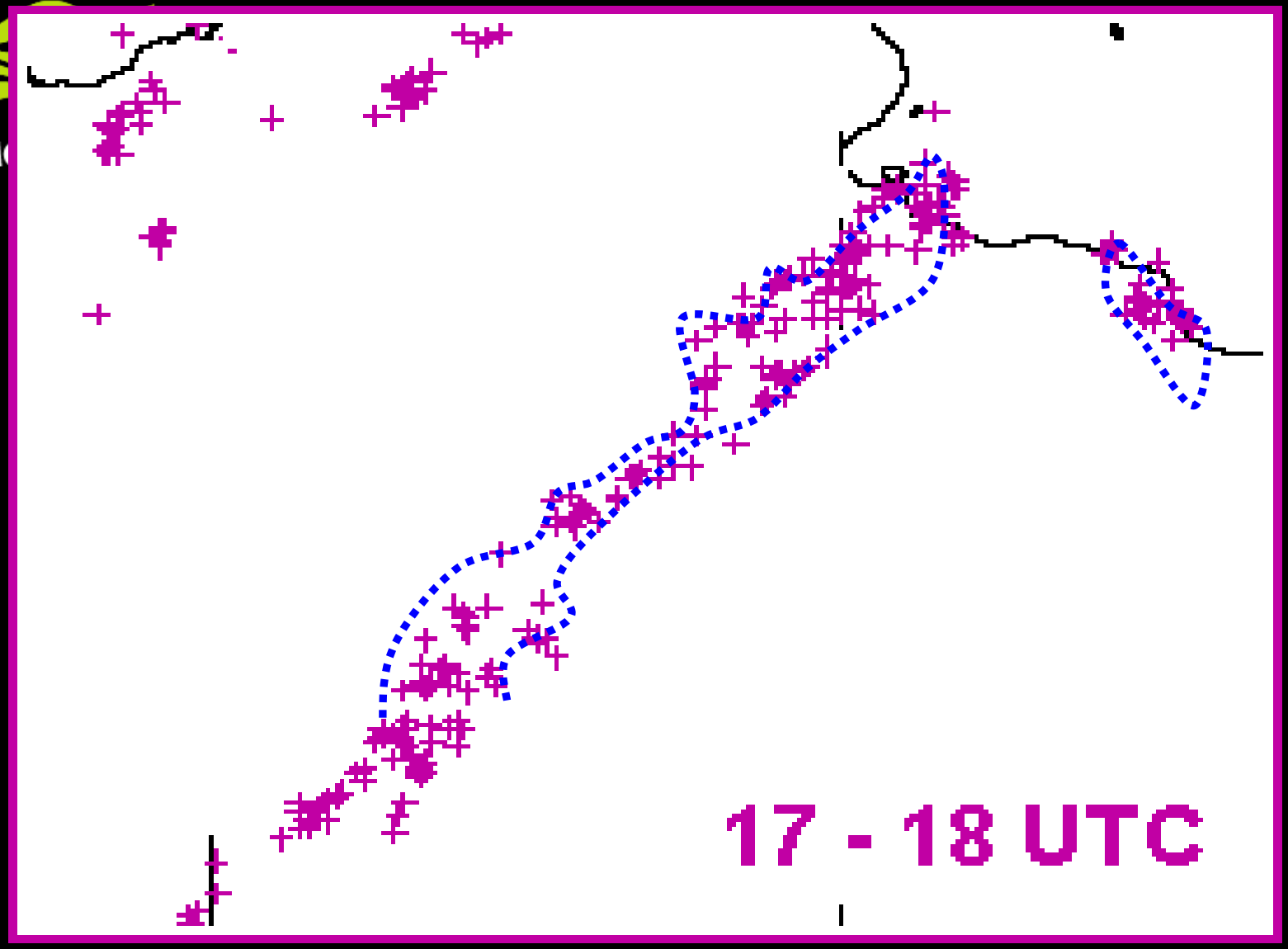
Ground-based long range lightning, Met Office



Algeria / Libya 17.15 UTC 11 April 2002, ATD

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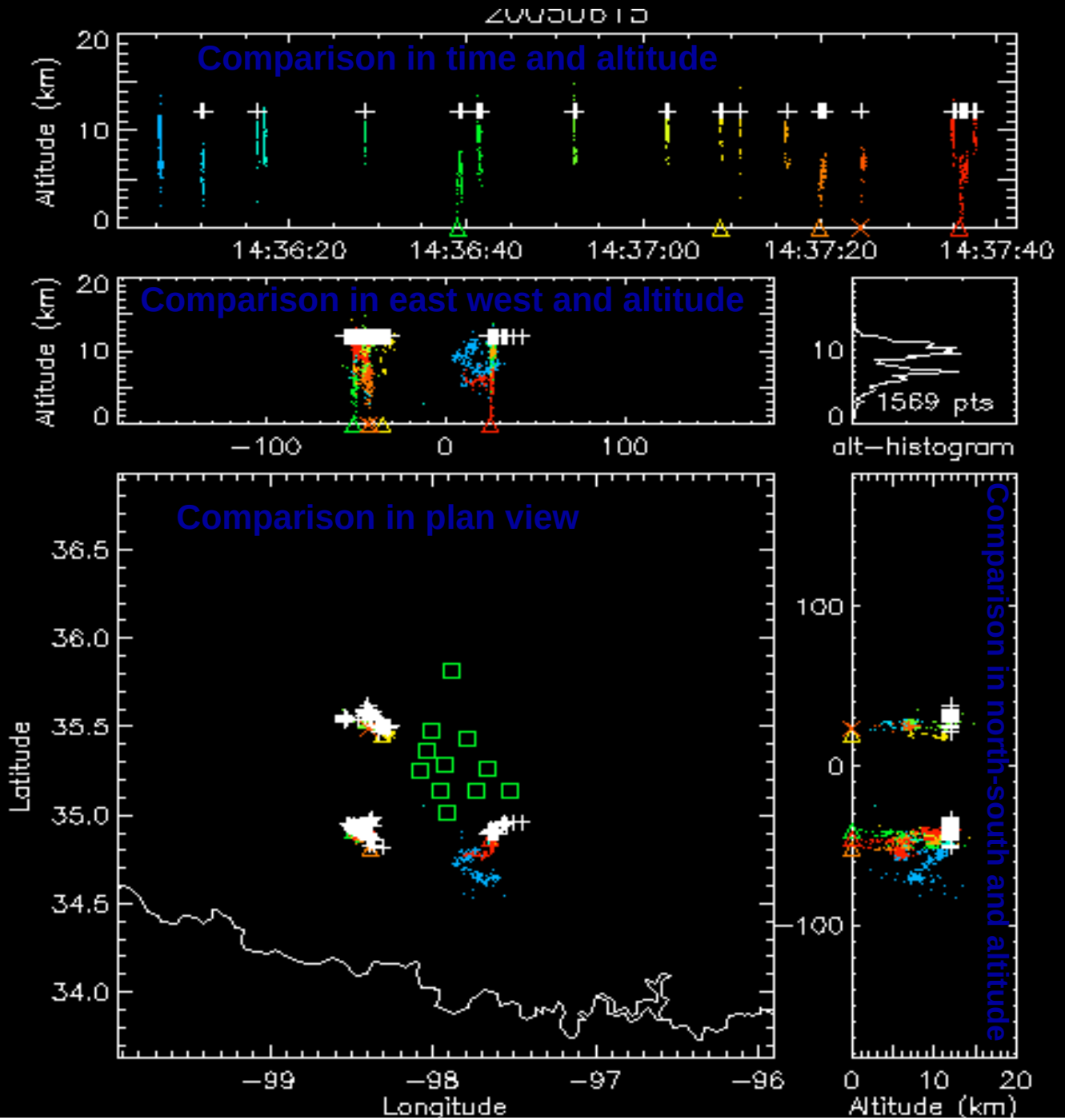
Multi-Sensor Observations of Lightning in Oklahoma
W. L. Boeck, at al.2006

1.White symbols:

LIS satellite

2.Coloured symbols:
Ground-based 3 dimensional, colour coded according to time

3. Green rectangles:
Location of ground based sensors



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Types of ground based systems

- **EA Technology** : Magnetic direction finding at 1 kHz, high detection efficiency for cloud to ground strikes [UK]
- **Met Office ATDNET**: Time of arrival at around 9.766kHz, (13.7kHz), measurement bandwidth 3kHz, detection efficiency depends on sensor spacing, but very wide area of coverage, [Long range]
- **Vaisala**: Broadband, 1 kHz to 350 kHz**,** uses both time of arrival and magnetic direction finding**,** high detection efficiency for cloud to ground + VHF 118 MHz for cloud to cloud [widely used]
- **LINET**: Uses magnetic direction finding and time of arrival observing at LF and VLF with sensors about 100km apart [Europe]
- WWLLN : Uses time of group arrival, frequency 3 to 30kHz [global long range]

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Specifications for ground based systems will be in terms of:

- Location accuracy, but usually will vary within a network given the condition of the sensors and their distribution
- Detection efficiency, strokes or flashes??
- What is minimum limit on size of discharge detectable, e.g. 20 kA
- More difficult to define for intra-cloud discharges
- Manufacturers recommend total lightning measurements, but not necessarily cheap
- False alarm rate

NOTE: Forecast model needed, since simple extrapolation in time and space does not cope well with the way thunderstorms develop.

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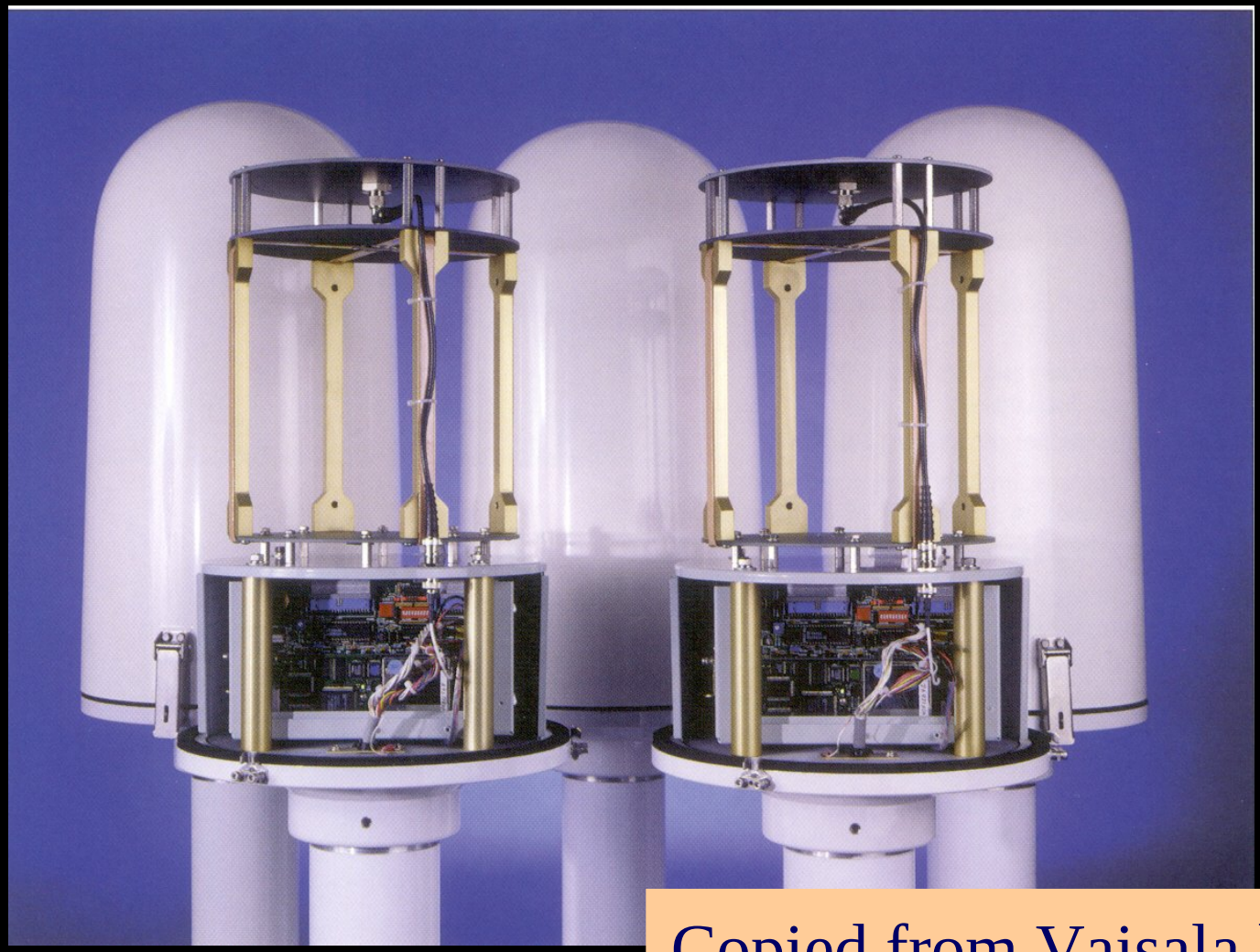
Impact broadband ground sensors for Vaisala system [about 90 for western Europe]



Copied from Vaisala literature

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ATD[NET] Sferics Lightning Location

10 to 12 sensors for Western Europe

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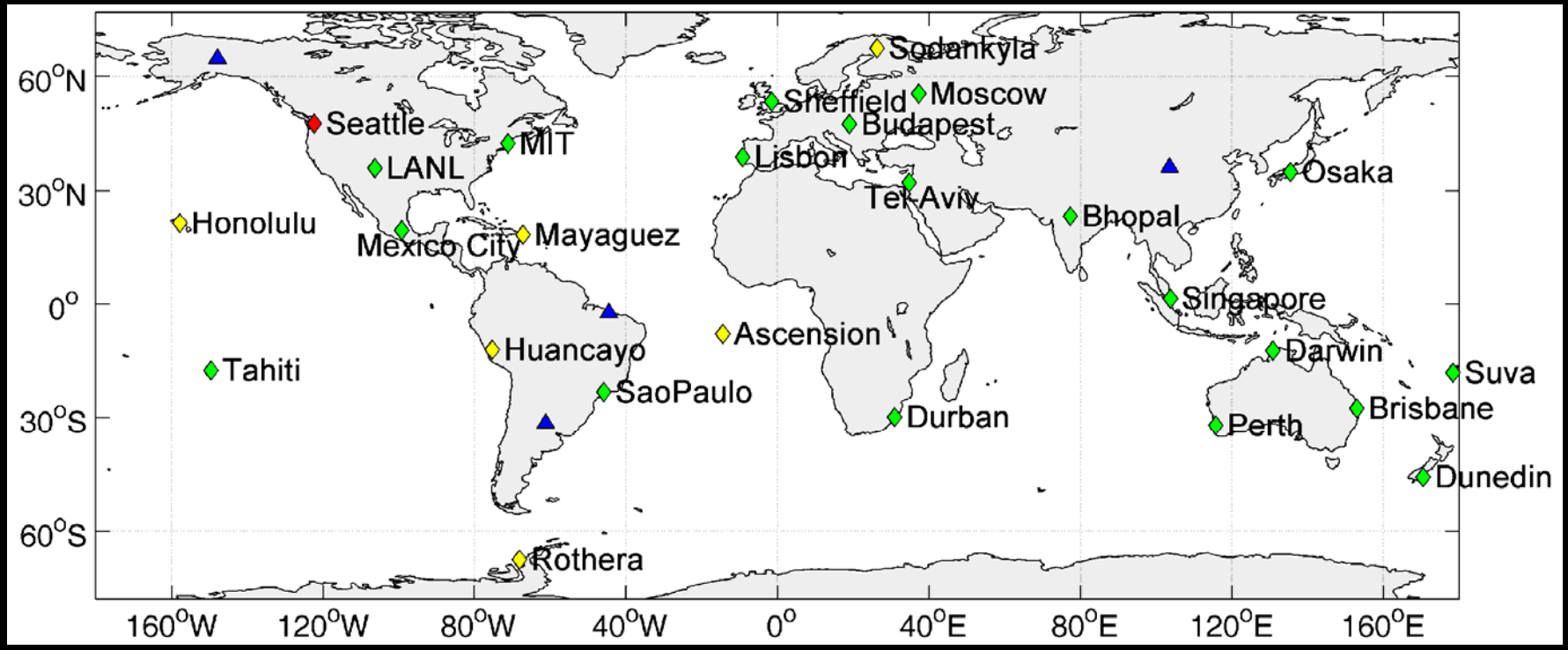
WWLLN sensor locations.

This network design currently gives best performance in Australasia
(from WWLLN website).



Observes radiation emitted between 3kHz and 30kHz

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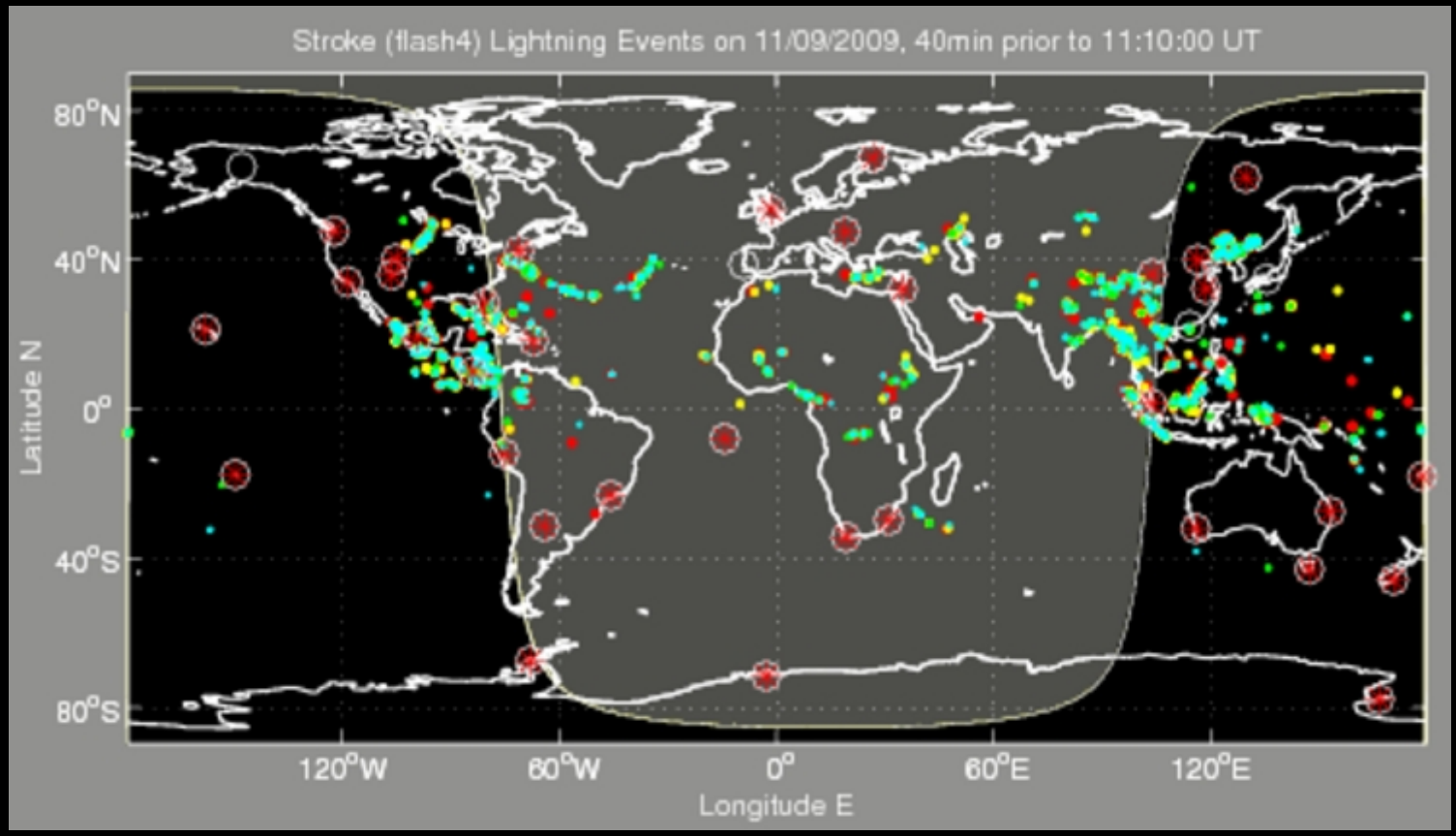
WWLLN 40 minute summary
Prior to 11:10 UTC, 11 Sep 09



http://webflash.ess.washington.edu/TOGA_network_global_maps.htm

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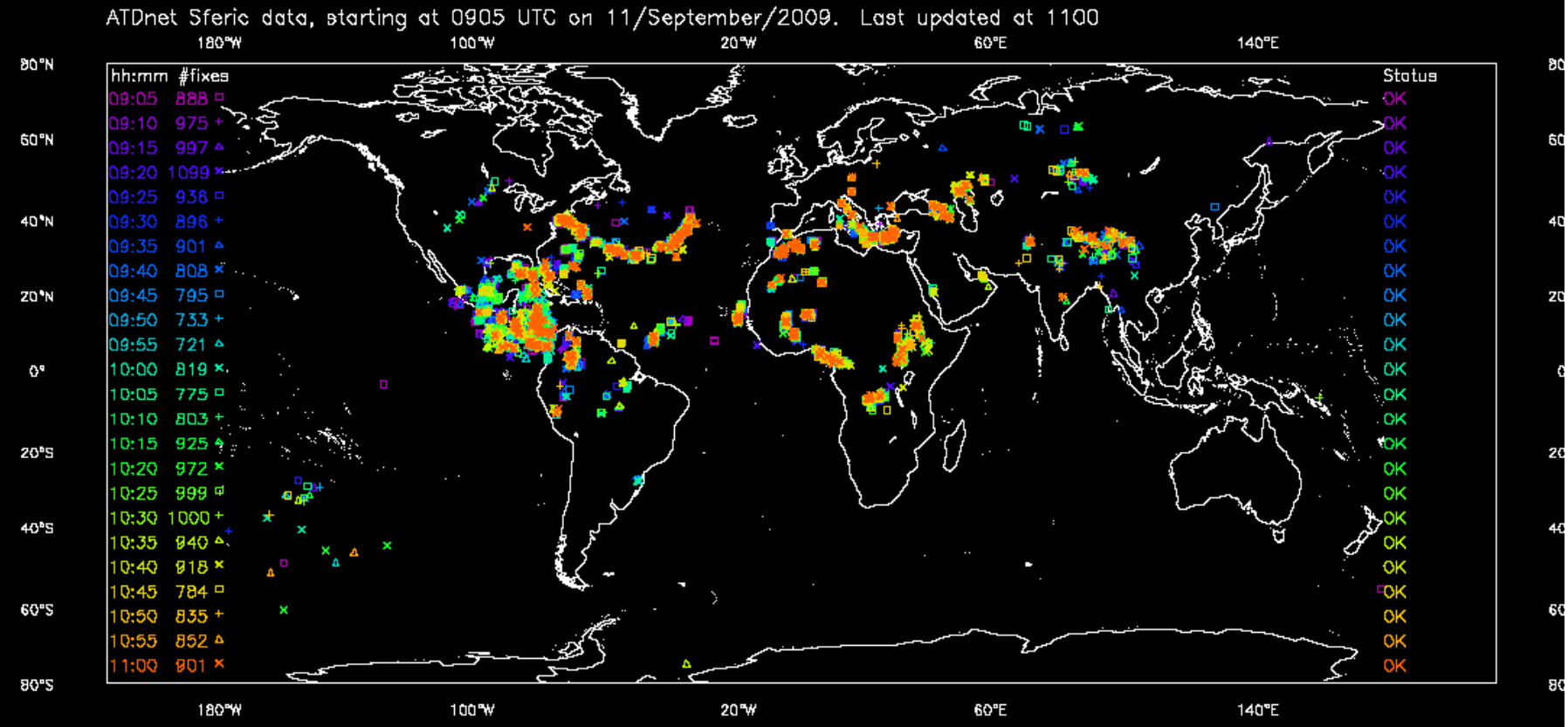
ATDnet 120 minute summary
Prior to 1100 UTC, 11 Sep 09



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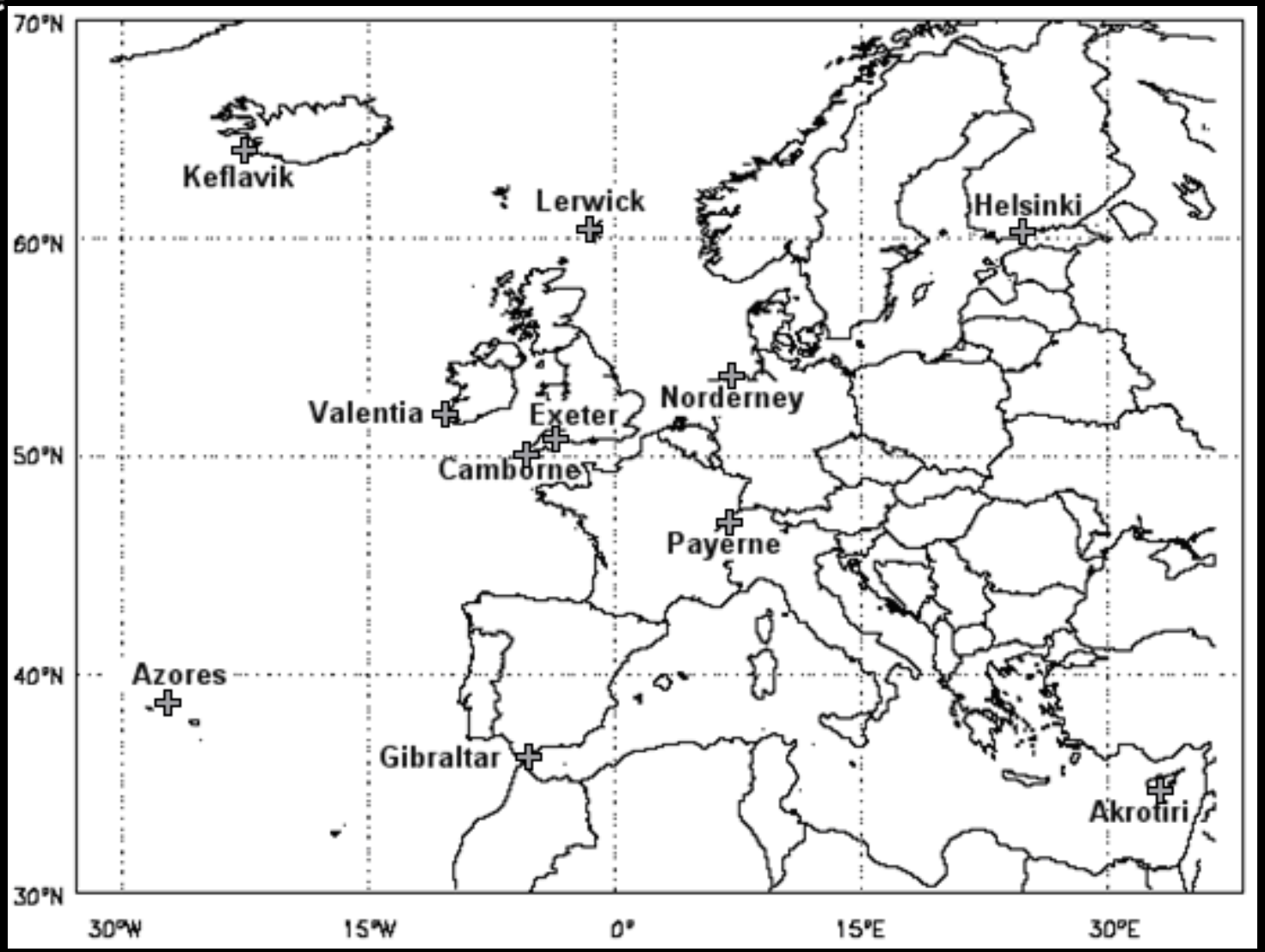
ATDnet NOS locations (September 2009)

Additionally, there is a NOS at La Réunion in the southern Indian Ocean and two soon to be installed at Walvis Bay, Namibia and in Northern Croatia



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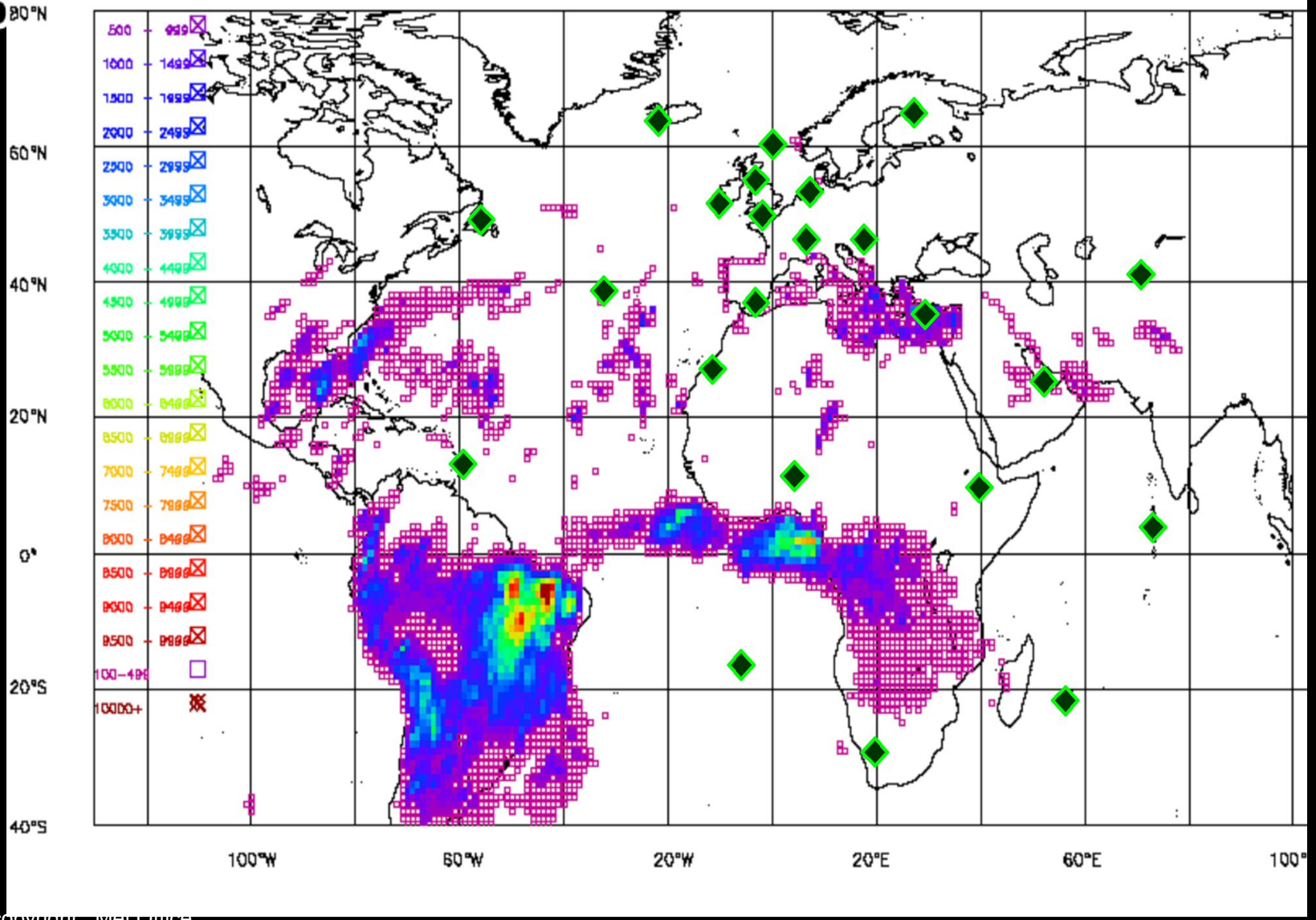
Possible ATDNet sensor locations in 2011

Possible ATDNET sensor locations in 2011, ◆

superimposed on ATDNET Climatology, number of flashes per 1° latitude and longitude box for January 2008



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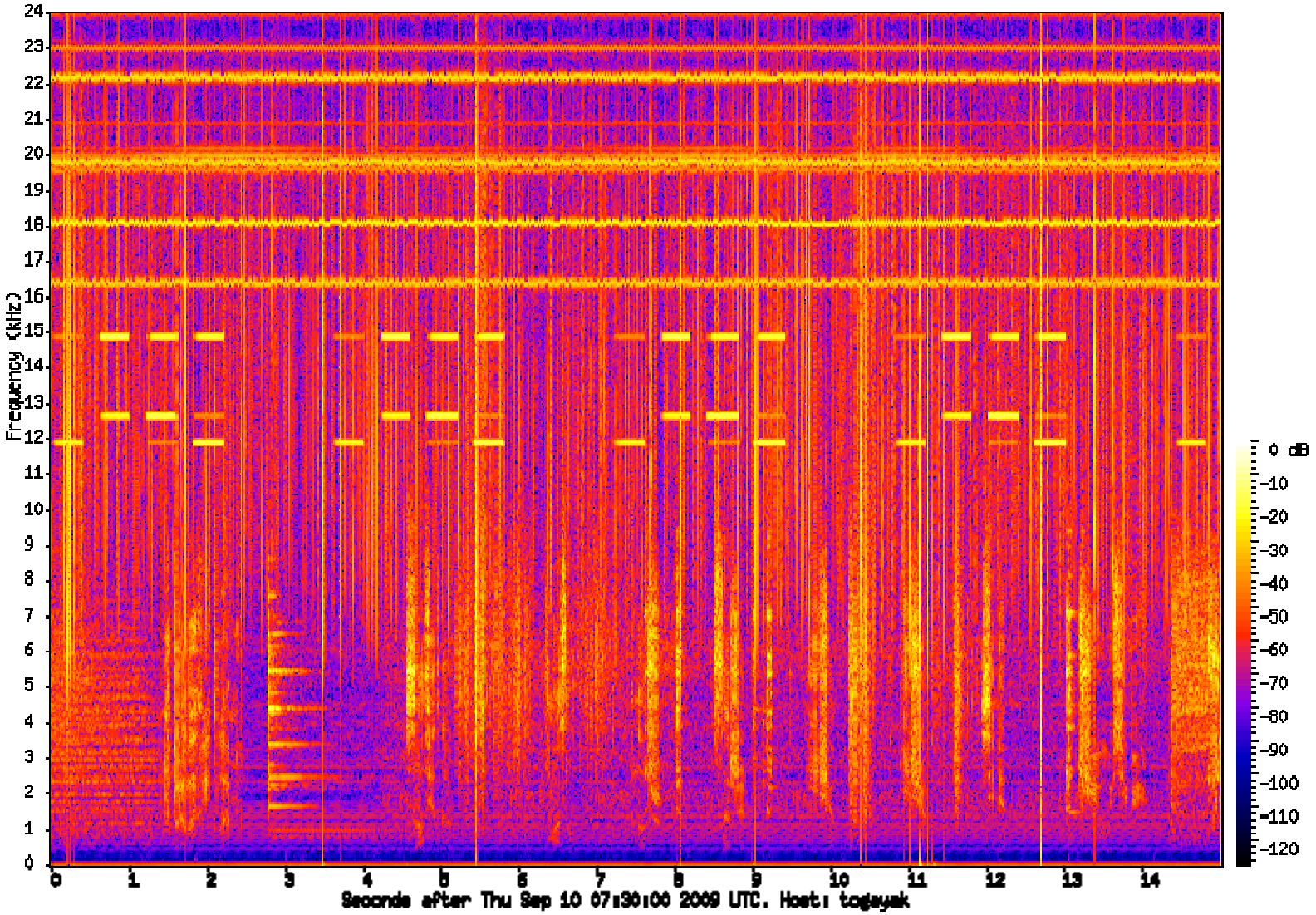
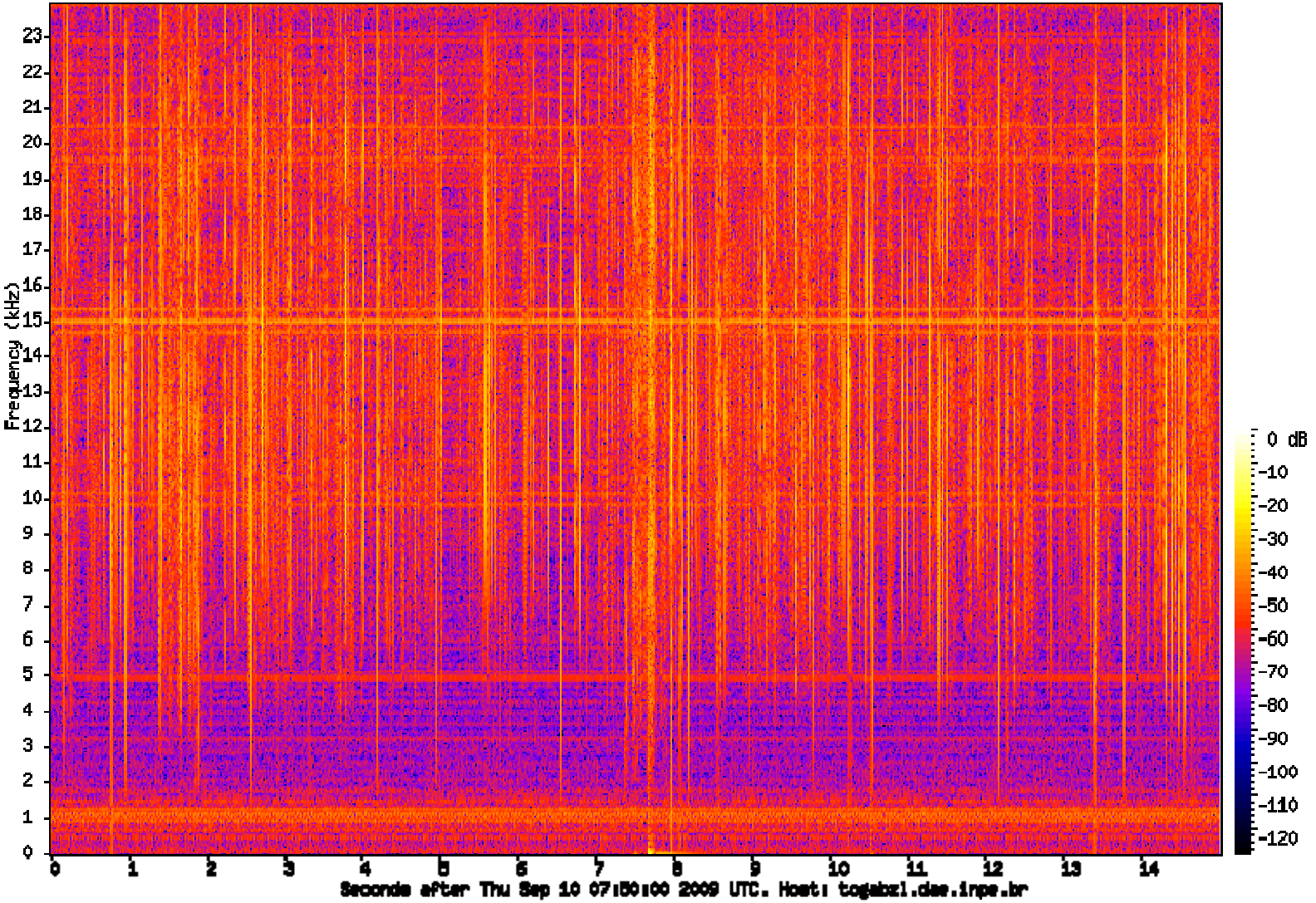
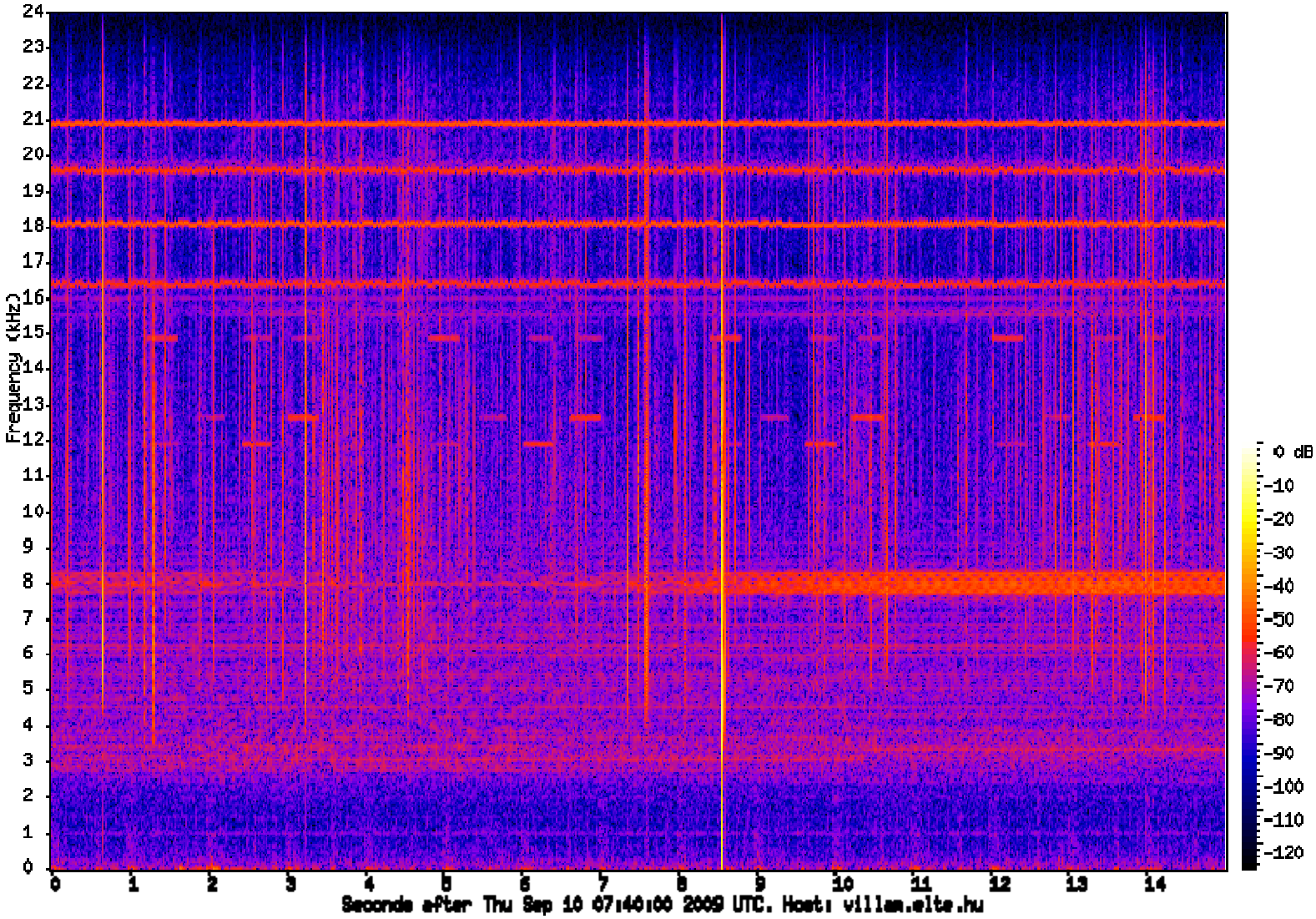
WWLLN: Yakutsk (From WWLLN website)



WWLLN: Sao Paulo (From WWLLN website)



WWLLN: Budapest (From WWLLN website)



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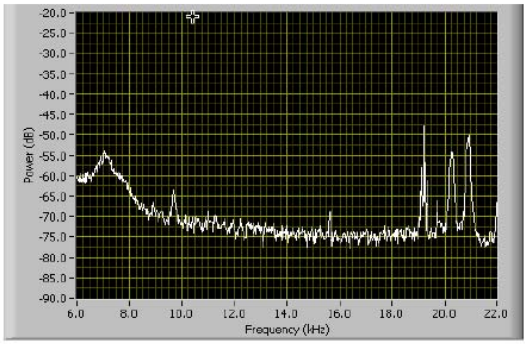
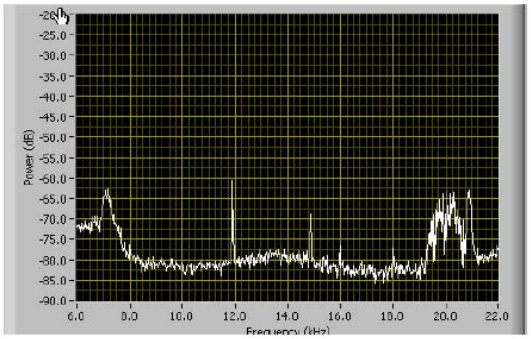
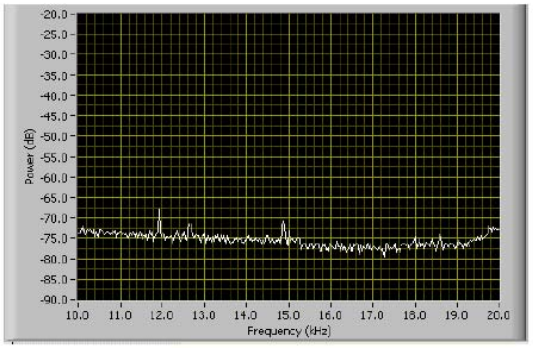
Spectral plots between 6 and 20 kHz at Gibraltar, Akrotiri, Exeter, Lerwick, Nordeney and Valentia ATD receiver locations



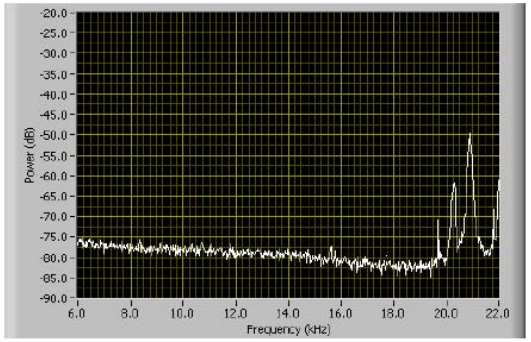
Spectral Plot from Gibraltar ATD receiver



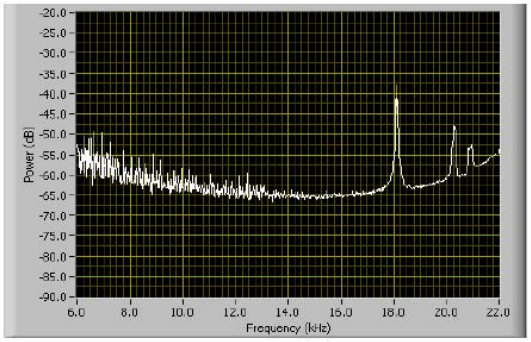
Spectral Plot from Akrotiri ATD receiver



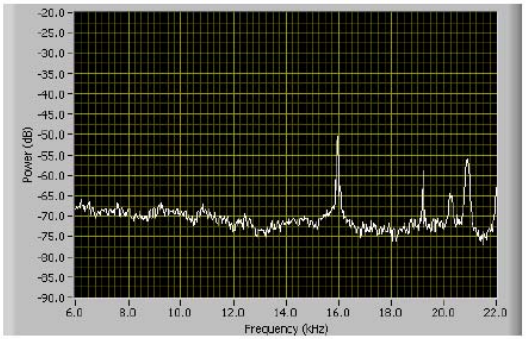
Spectral Plot from Exeter ATD receiver



Spectral Plot from Lerwick ATD receiver



Spectral Plot from Nordeney ATD receiver



Spectral Plot from Valentia ATD receiver

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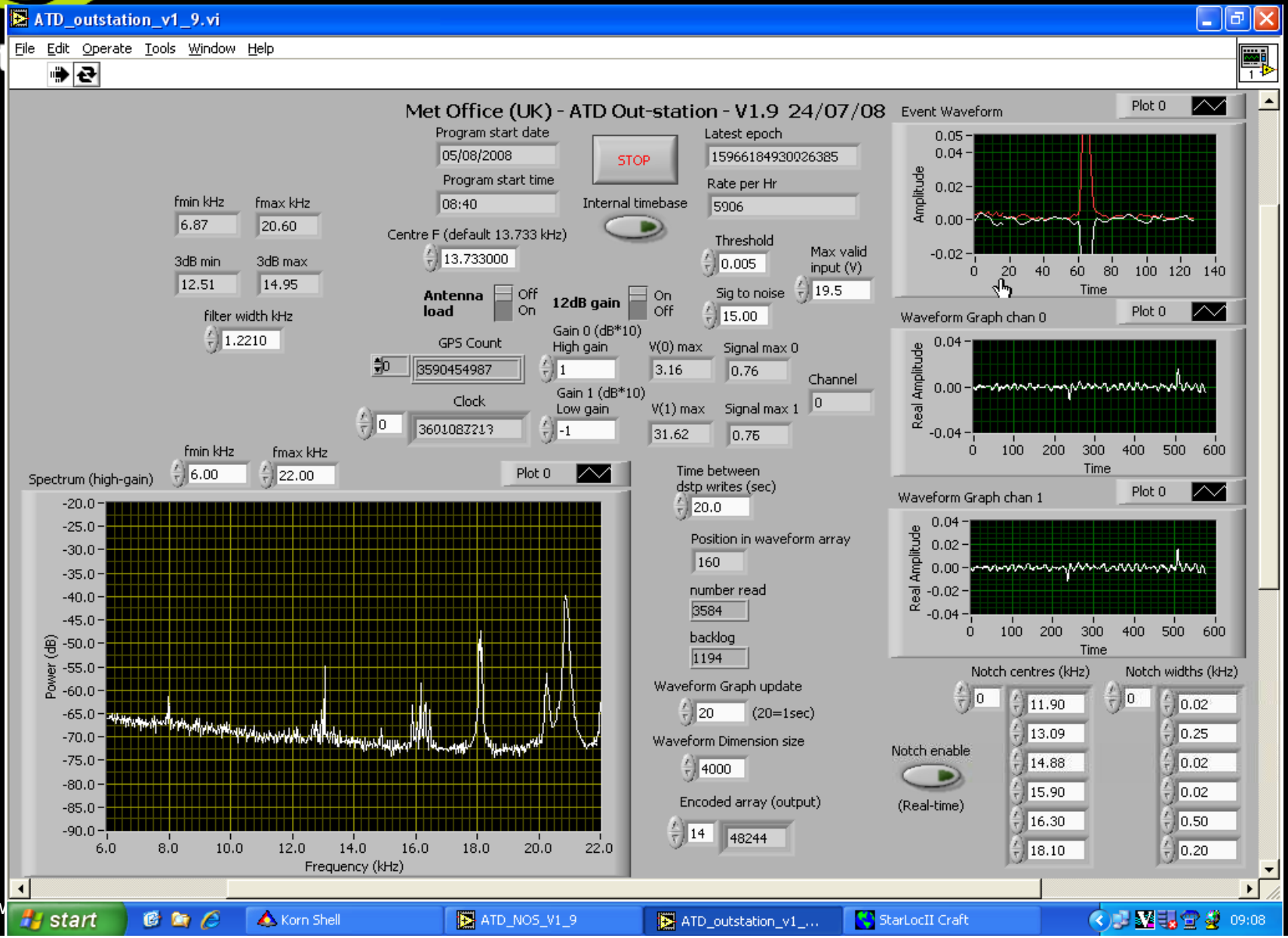
Signals received at Payerne outstation



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Global climatology

-but how do you check stability of performance?

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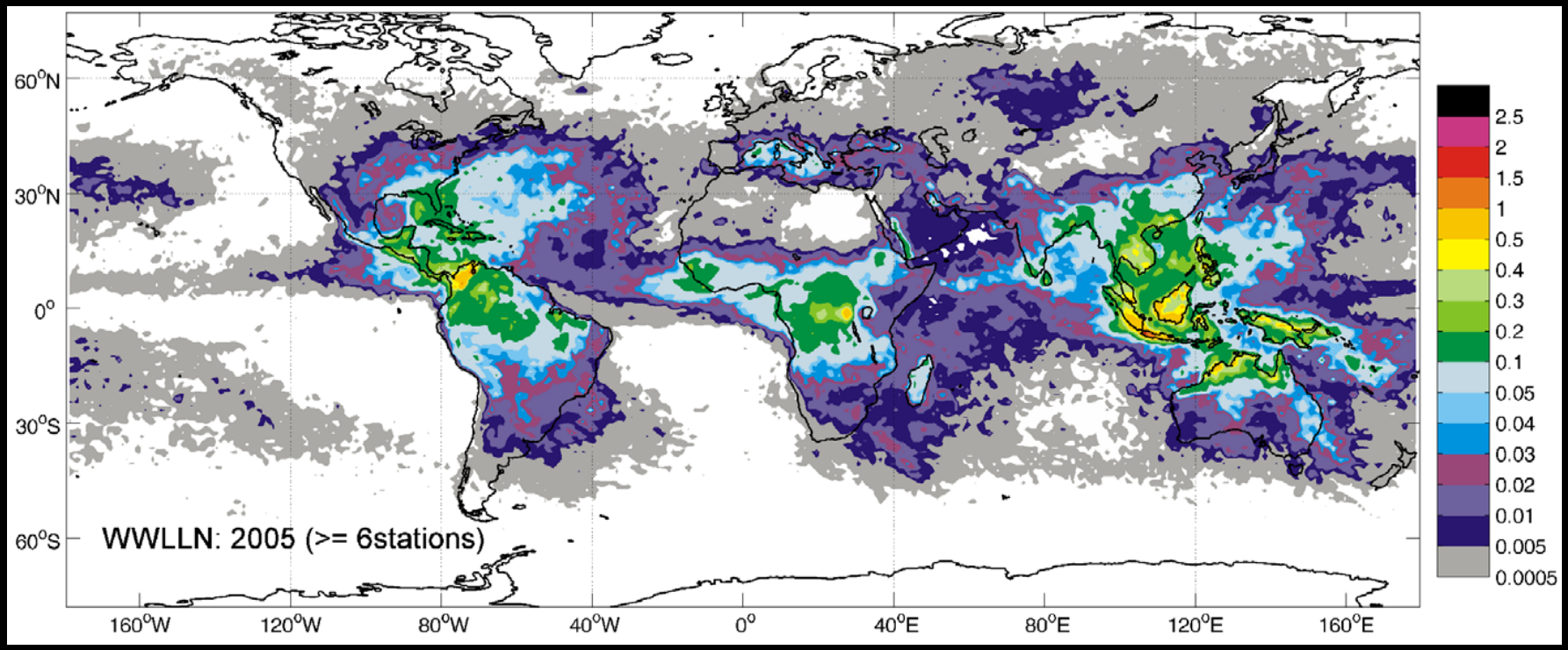
Annual climatology of WWLLN lightning locations for 2005, for >6 station locations



Mostly cloud to ground strokes

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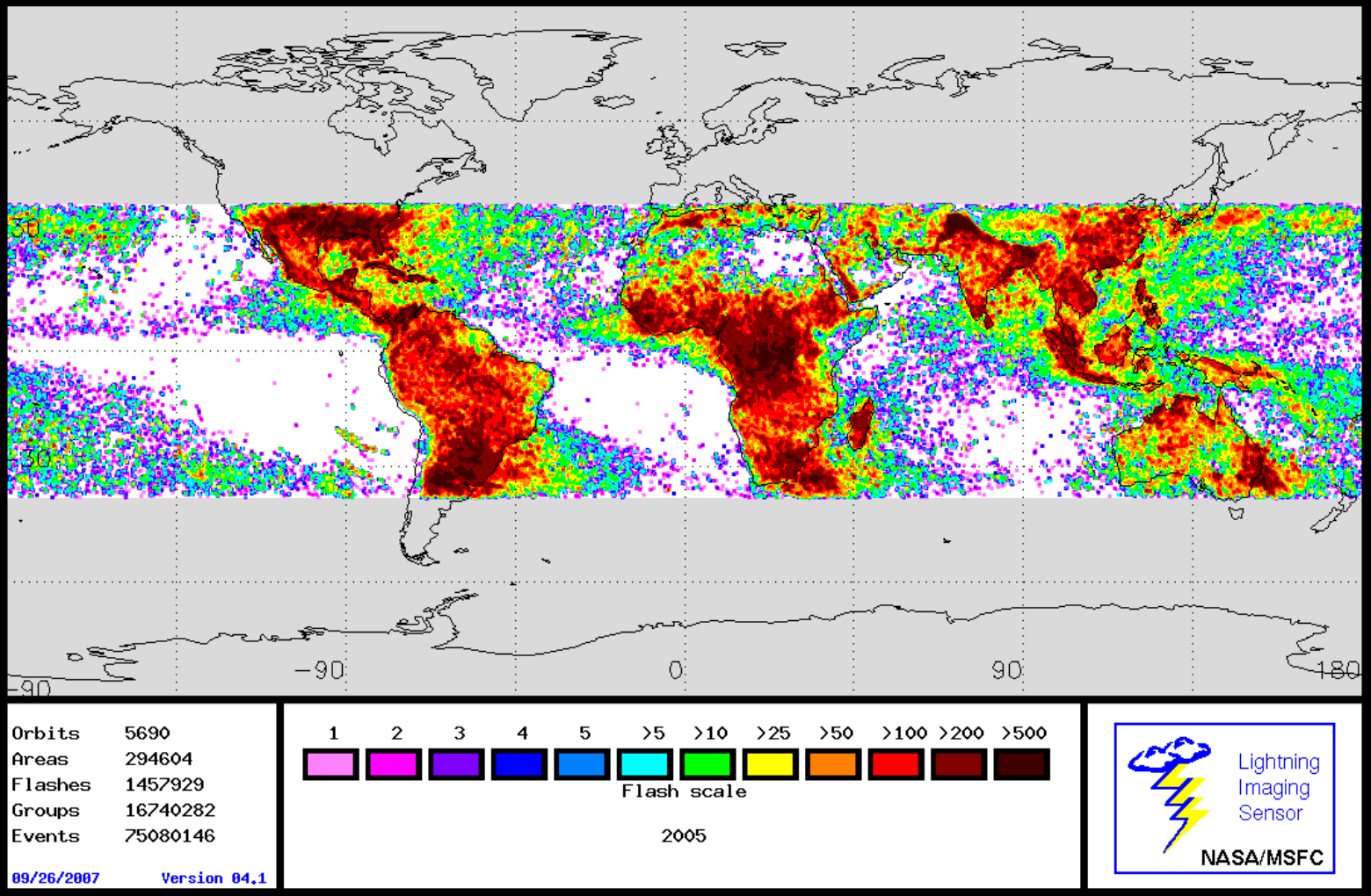
LIS climatology for 2005



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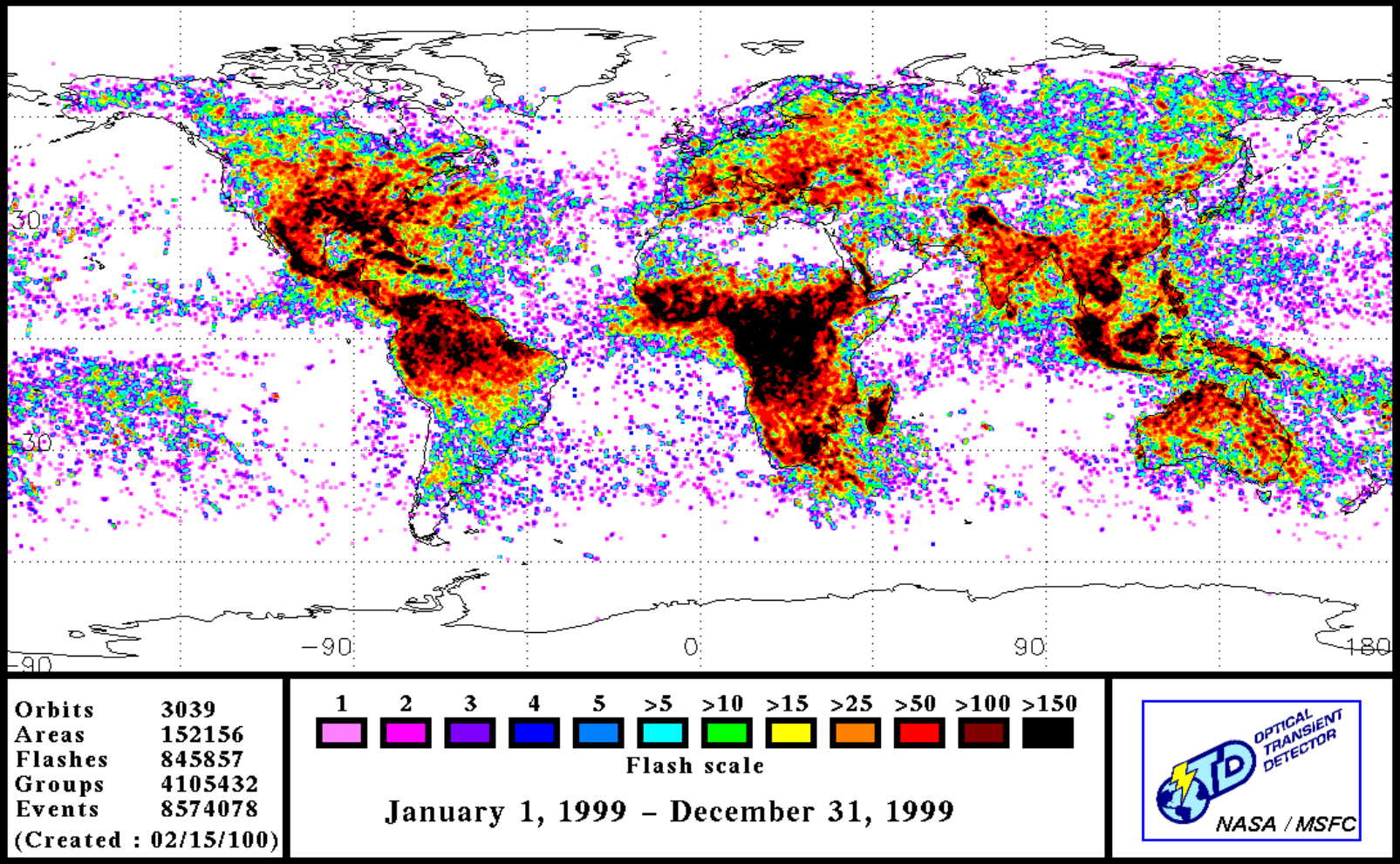
Optical Transient detector,1999
Larger area of coverage ,
but more spasmodic samples



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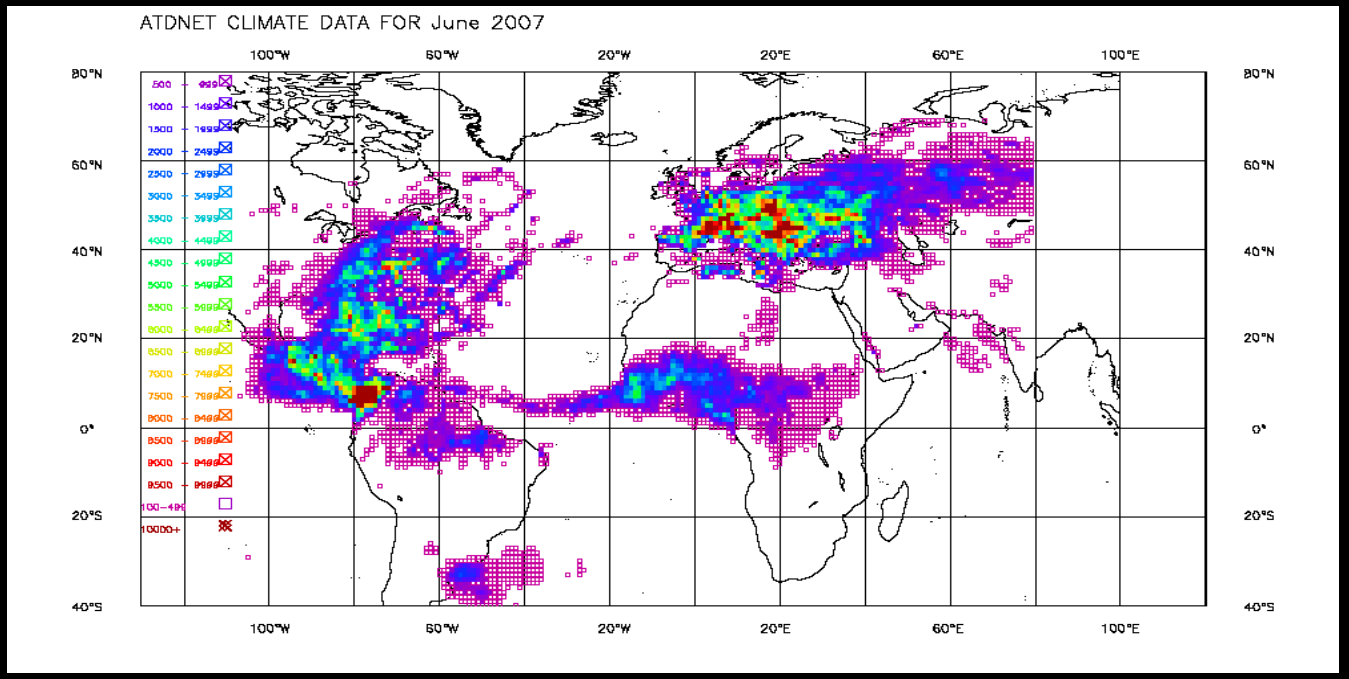
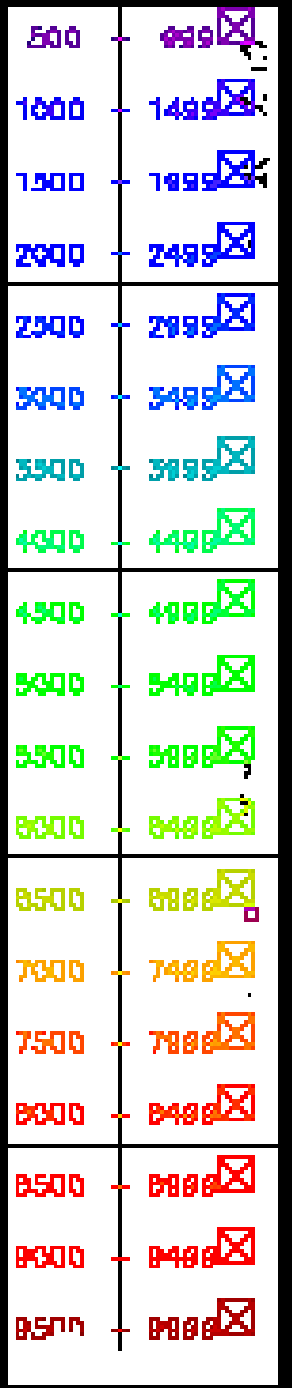
ATDNET climatology for June 2007





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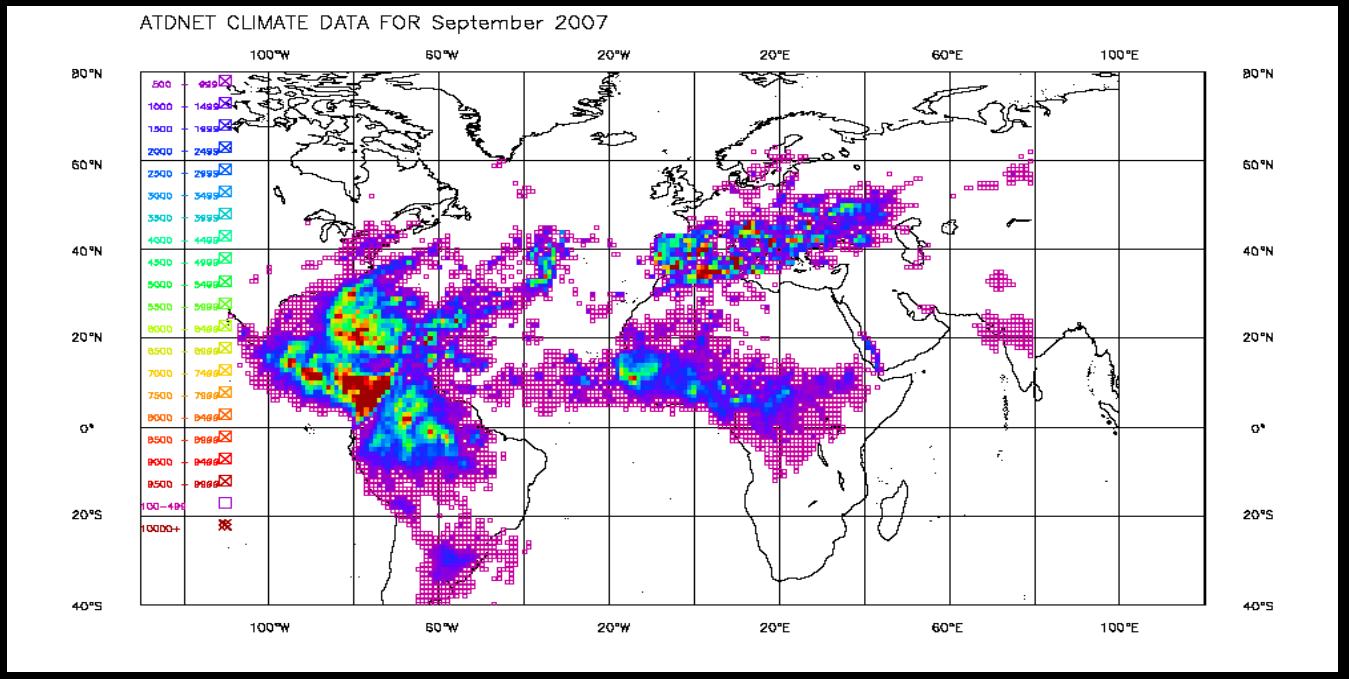
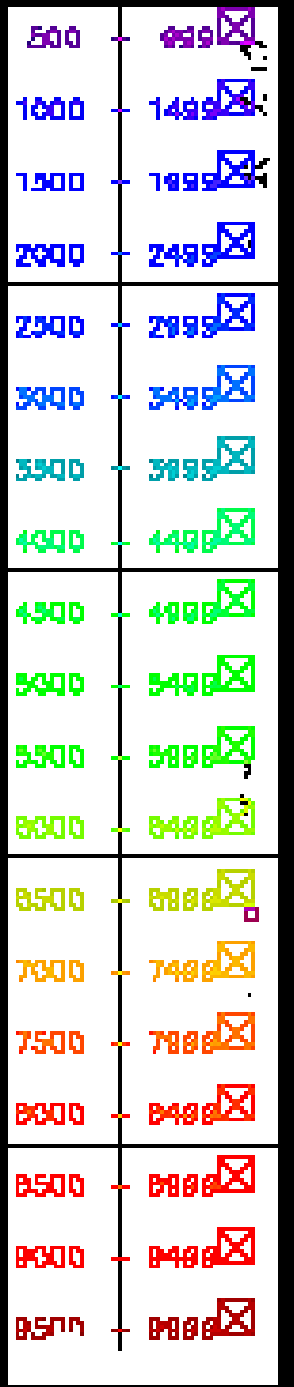
ATDNET climatology for September 2007





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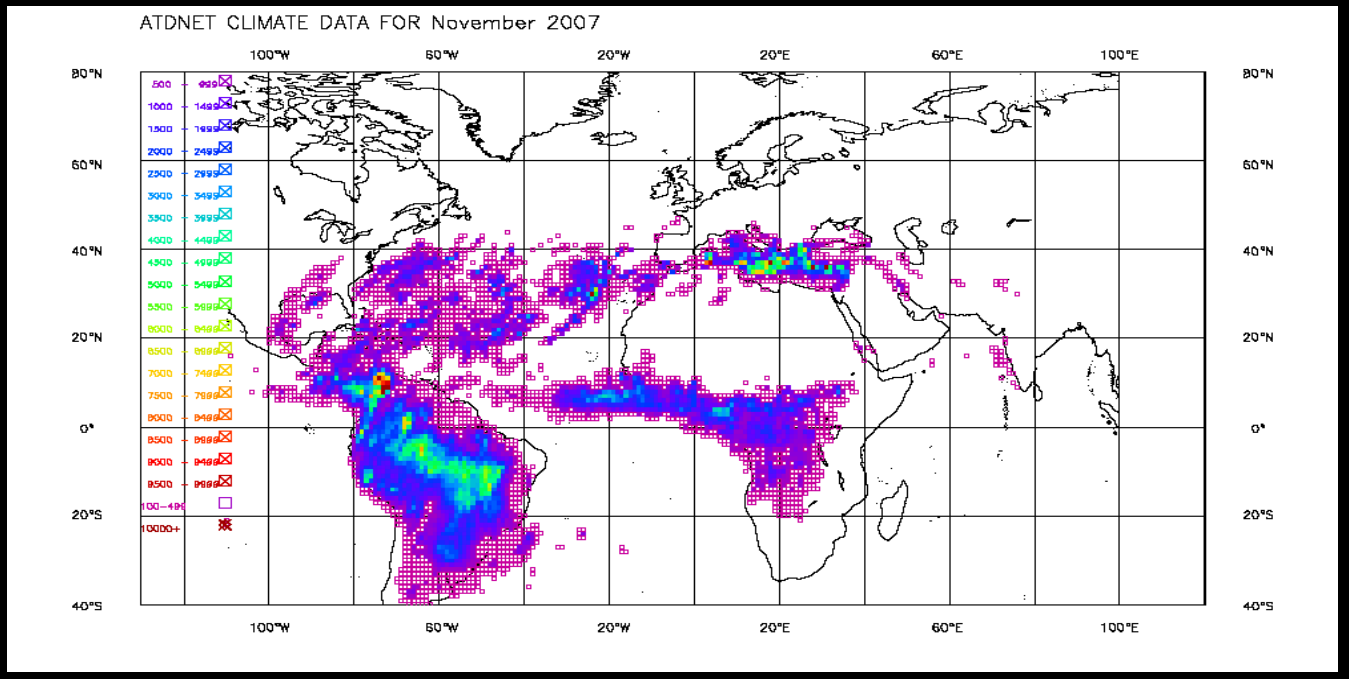
ATDNET climatology for November 2007



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UK Met Office ATD system

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UK Met Office ATD system

- Frequencies around 9 to 10 kHz used since 1939
- Originally as CRDF, but Arrival Time Difference since 1987
- At these frequencies the sky waves, reflected off the ionosphere, propagate for very large distances with relatively little attenuation and are preceded by a ground wave at shorter ranges.
- Thus, it is possible to receive the emissions from the cloud to ground strokes at thousands of kilometres from the stroke location.
- A distributed network of ground based sensors can locate the origin of the lightning stroke, using the time differences between the arrivals of the lightning emission at the individual sensor sites.

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UK Met Office ATD system

- Currently 11 sensors, but there are plans to install more
- Monitoring in 2004 showed increasing levels of interference around the original centre frequency 9.766kHz so this was moved to 13.733kHz in 2007, but with some loss of performance. Measurement bandwidth 3kHz.
- This is a completely passive service
- No international recognition exists so far for use of these frequencies for lightning detection despite being used since 1939, as none seemed to be necessary until now, hence WRC-12 AI1.16.
- ATD has always co-existed with radionavigation services at these frequencies, with notch filters being used where necessary.

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Arrival Time Difference fixing process

- Accurate time calibration - rubidium oscillators, checked by GPS
- Waveforms are Fourier analysed and sent to the central control station on request
- Waveforms from different outstations are correlated to estimate time differences
- Arrival Time Differences are then used to calculate lightning position by iterative method
- Distribution of data messages every five minutes
- Future Communications use VPN

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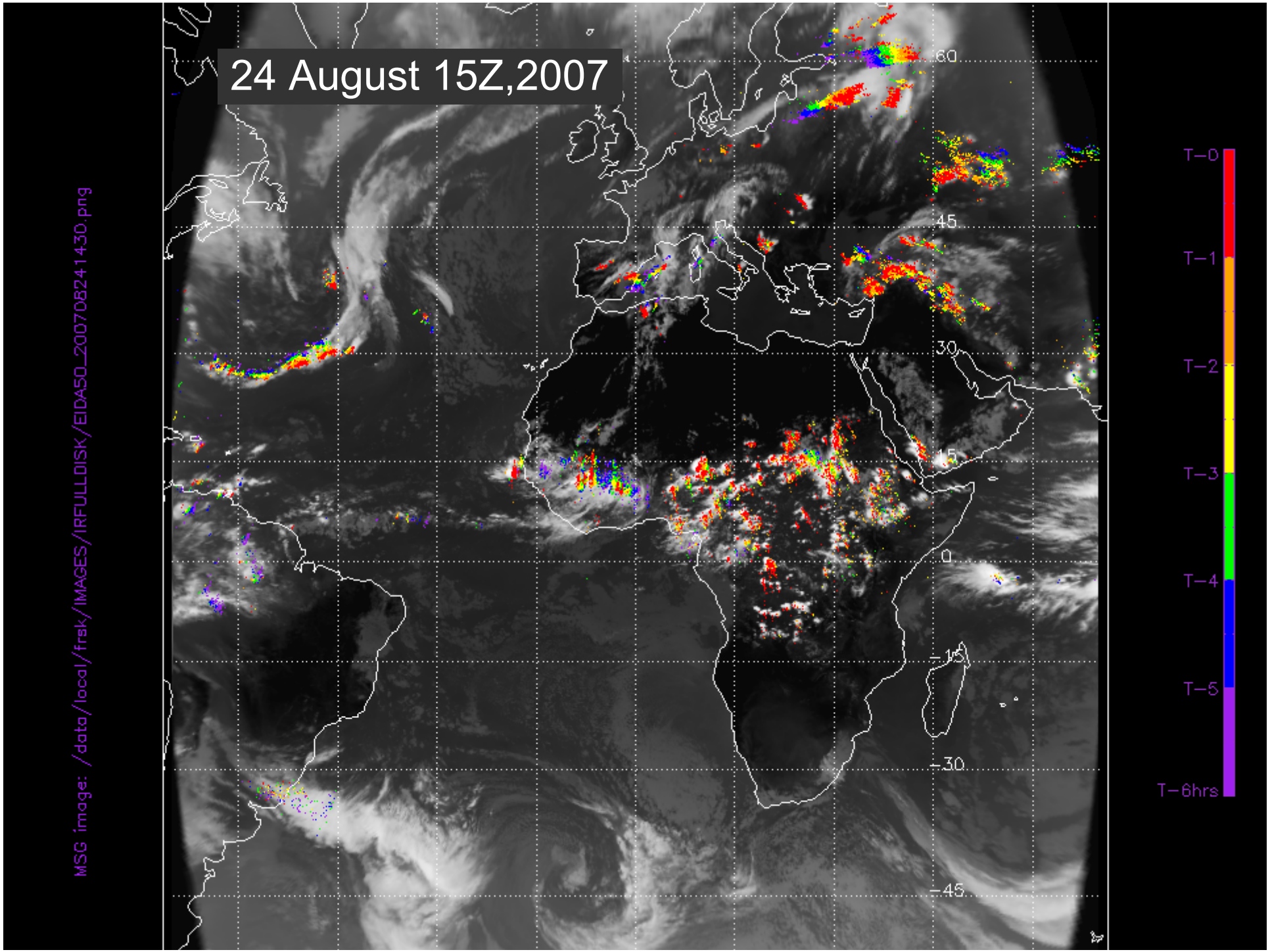
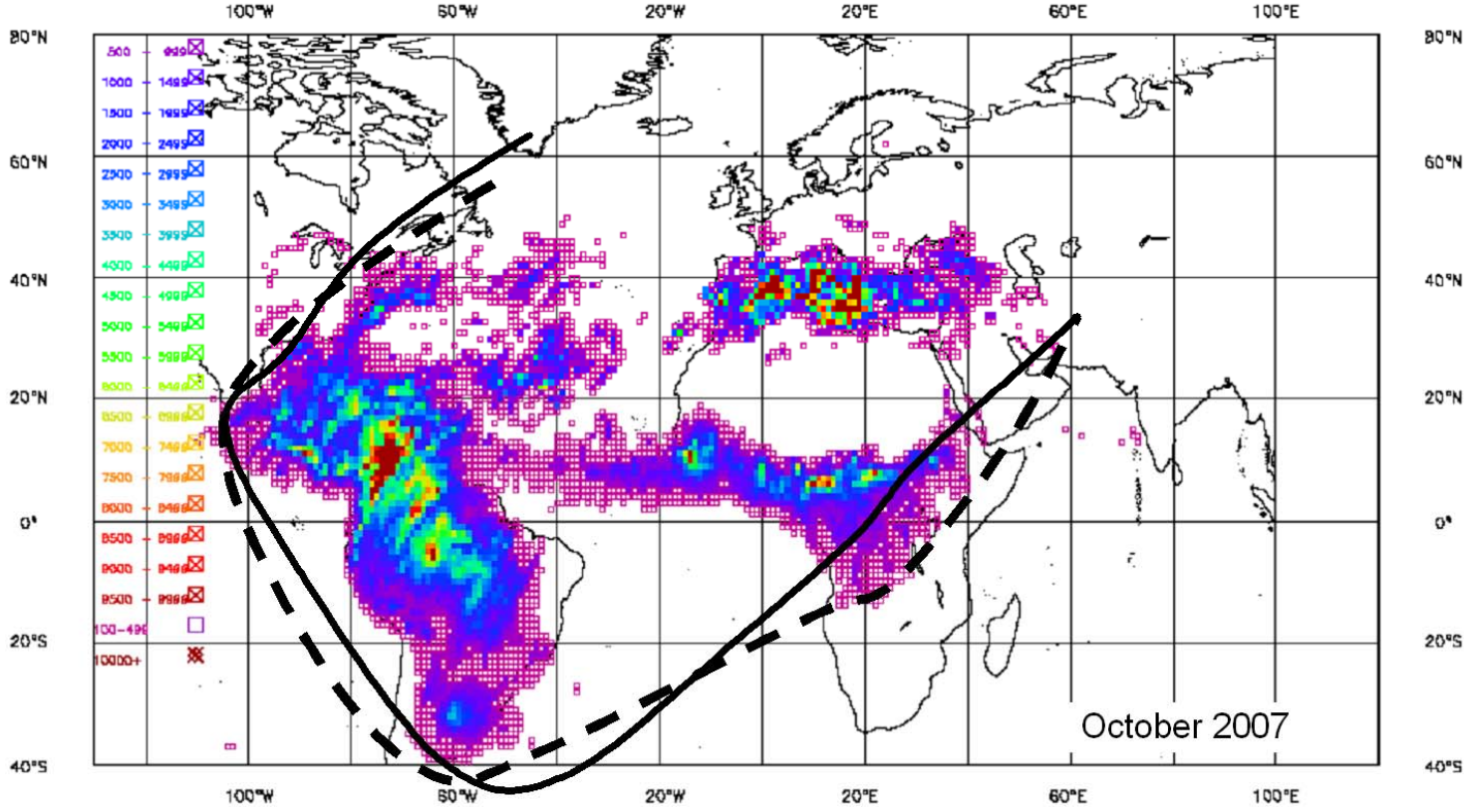

24 August 15Z,2007
MSG image: /data/local/frsk/IMAGES/IRFULLDISK/EIDA50_20070824143O.png
60
45
30
15
0
-15
-30
-45
T-0
T-1
T-2
T-3
T-4
T-5
T-6hrs

Current (Sep 2009) ATD system network coverage

Dashed line October, November, December 2007

Solid line, June, July, August 2007



Estimated area of useful detection for ATDNET compared to LIS satellite climatology superimposed on ATDNET lightning climatology for October 2007

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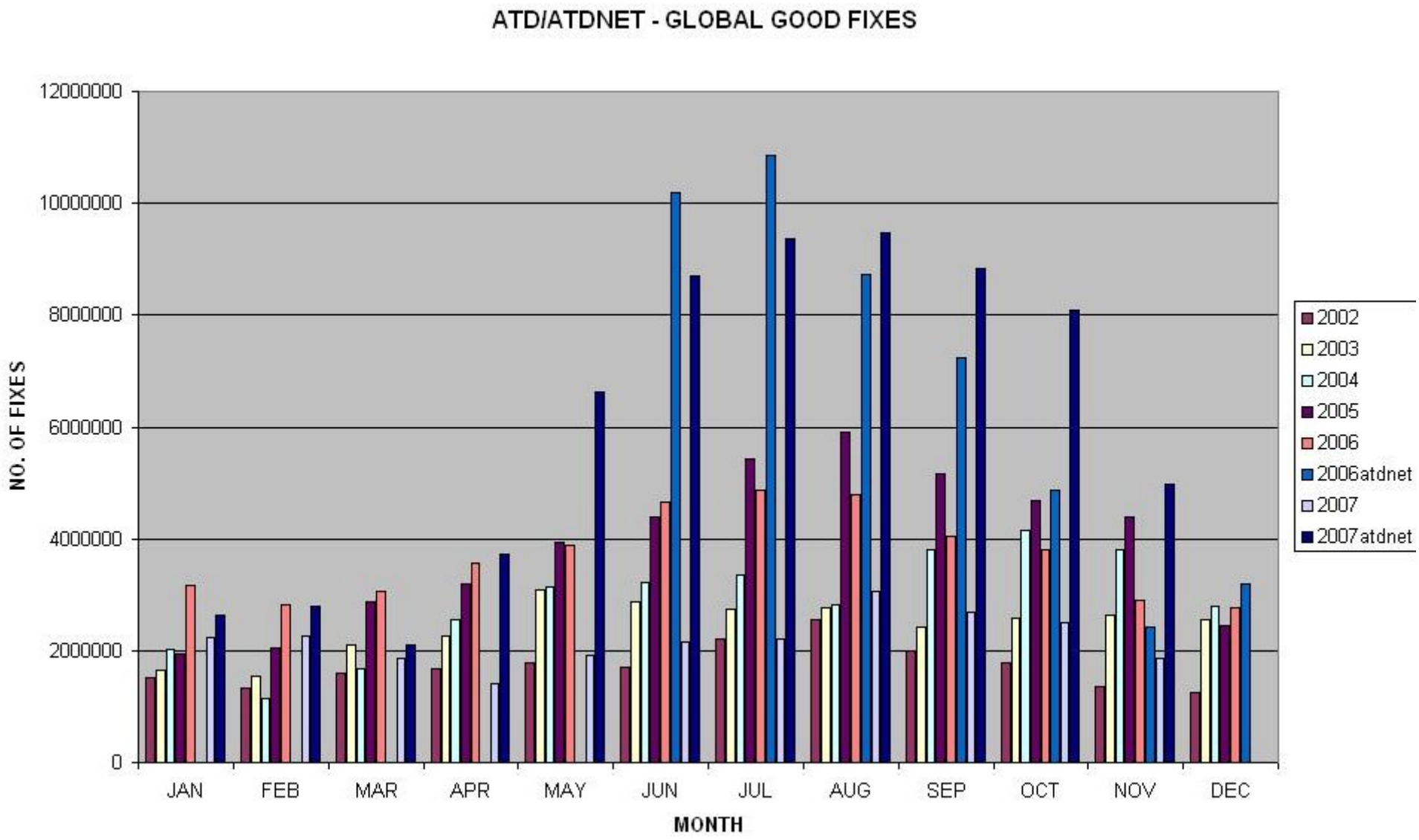

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Conclusions

- Satellite and ground based systems observe different activity in storms
- Identification of cloud to ground strikes is essential for safety operations and is best performed with ground based systems
- Relationship between thunderstorm activity and convection is complex ,as the significance of the ice phase in convection varies with each event
- The ratio of cloud to ground strokes to intracloud activity is probably different from sea to land.

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Questions and answers

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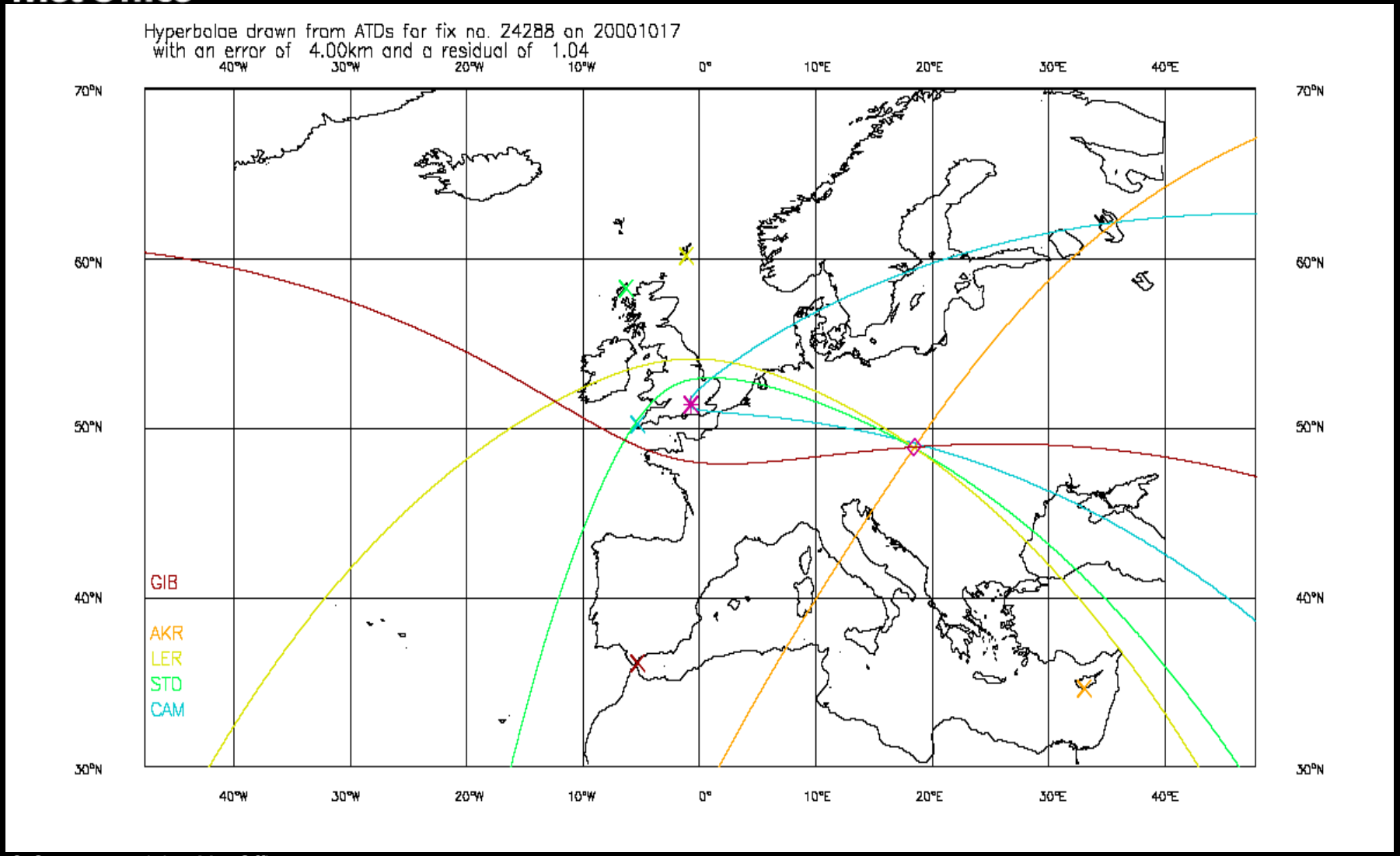
6 stations → 5 hyperbolae



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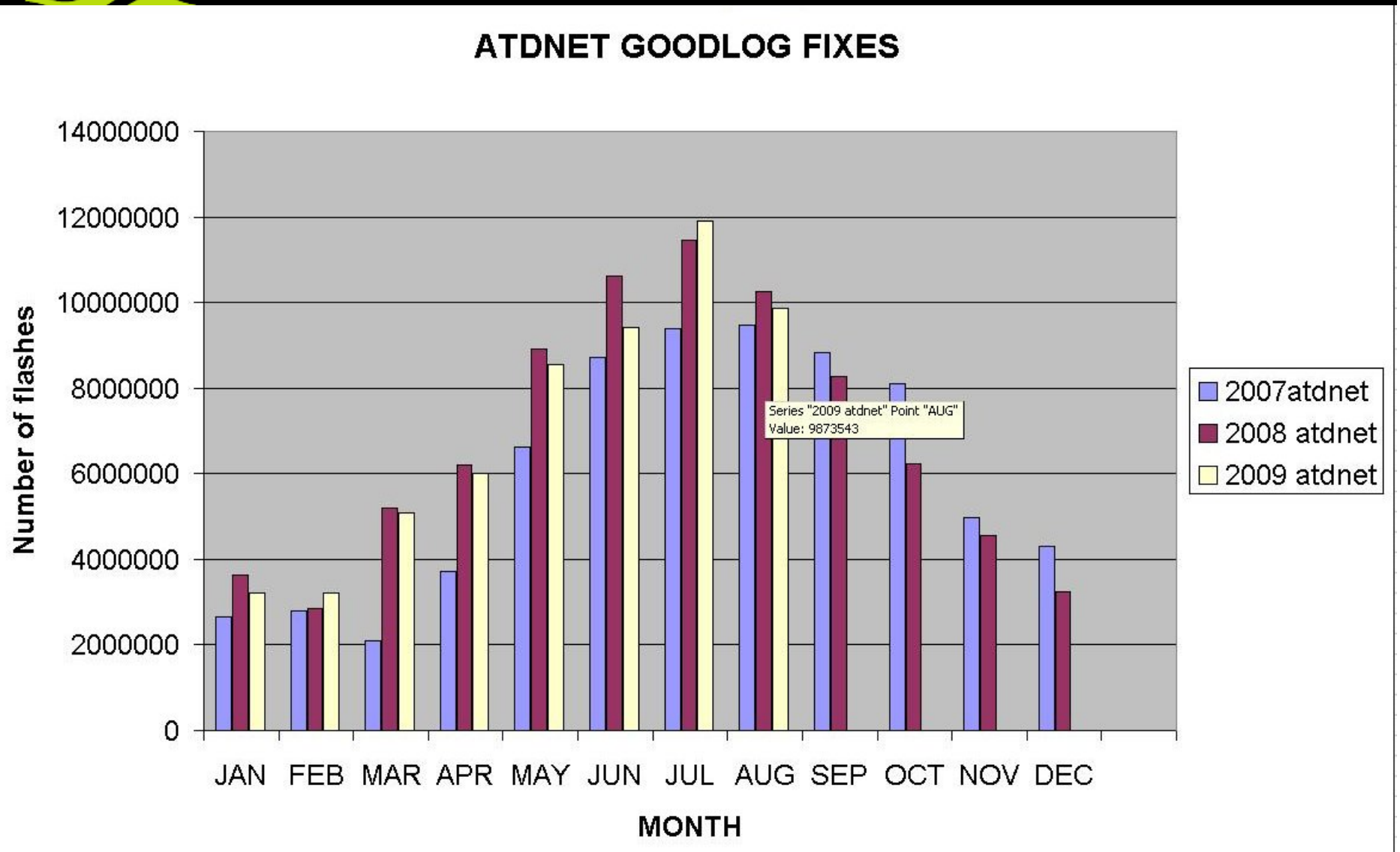

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