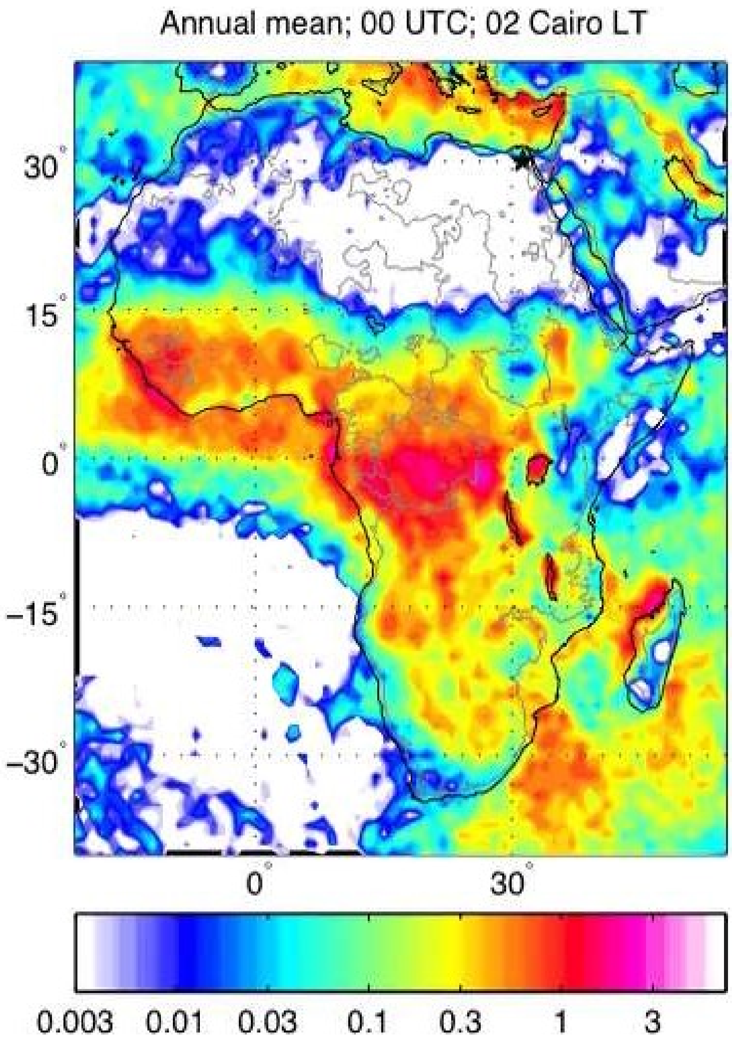

# Joint Global Climate Observing System / Commission for Climatology Task Team on Lightning Observations for Climate Applications

*AOPS TTLOCA Interim Report March 2018*

GCOS Secretariat, WMO
Robert Holzworth, Chair Lightning TT

WMO UNESCO IOC INTERNATIONAL COUNCIL FOR SCIENCE UN environment




Lightning Climatology with UT resolution

http://wwlln.net/climate/clim/ltghr_all_afr.mov

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# GCOS IP - New in the IP

# Lightning

## IP Action A29:

| | |
|---|---|
| Action | To define the requirement for lightning measurements, including data exchange, for climate monitoring and to encourage space agencies and operators of ground-based systems to provide global coverage and reprocessing of existing datasets |
| Benefit | Ability to monitor trends in severe storms |
| Who | GCOS AOPC and space agencies |
| Time frame | Requirements to be defined by 2017 |
| Performance indicator | Update to Annex A for lightning and commitments by space agencies to include lightning imagers on all geostationary platforms. Reprocessed satellite datasets of lightning produced. |
| Annual cost | US$ 10-30 million |

**-> AOPC 2017 charged GCOS secretariat to establish task team on lightning for climate applications**

# Lightning Task Team Members

**Valentin Aich** – GCOS/WMO/UN – Geneva, Switzerland

**Caterina Tassone** - GCOS/WMO/UN – Geneva, Switzerland

**Robert Holzworth,** University of Washington, Seattle USA

**Yuri Kuleshov,** RMIT University Melbourne, Australia

**Steven Goodman,** NOAA (retired, former GOES-R Chief Scientist), Huntsville, Alabama, USA

**Earle Williams,** MIT, Boston, Massachusetts, USA

**Colin Price,** Tel Aviv University, Tel Aviv, Israel

**Proposed Terms of Reference (derived from Action 29 of the IP):**

- Write and publish a peer reviewed paper to identify the potentials and challenges for lightning as climatological variable and propose a plan on how to establish operational monitoring of lightning for climate applications
- Review and update current lightning ECV requirements
- Define standards and requirements for data management and data exchange of lightning monitoring for climate applications
- Propose strategy for open data access for lightning climate applications given the dominance of the private sector in lightning monitoring
- Encourage space agencies and operators of ground-based systems to provide global coverage and reprocessing of existing datasets

# Lightning TT Schedule

- Constituted and First Telecon: Oct 26, 2017
- First Face-to-face meeting Feb 3-5, 2018 (action items assigned)
- Submit Announcement to EOS seeking community input (Feb 2018)
- (Interim report AOPC March 2018)
- Next Telecon: May 2018
- Draft White paper by August 2018
- Final report Sept/Oct 2018

**Remainder of Talk:  Discuss Lightning Data and Science**

**Data Sets:**

- **Thunder Day data – need WMO help**
- **Satellites (optical):  NASA/TRMM LIS, NOAA16/GLM, ISS, EUMETSAT, China**
- **Ground Based (RF): Public and Private**
  - **Note: only RF networks are actually global at this time**

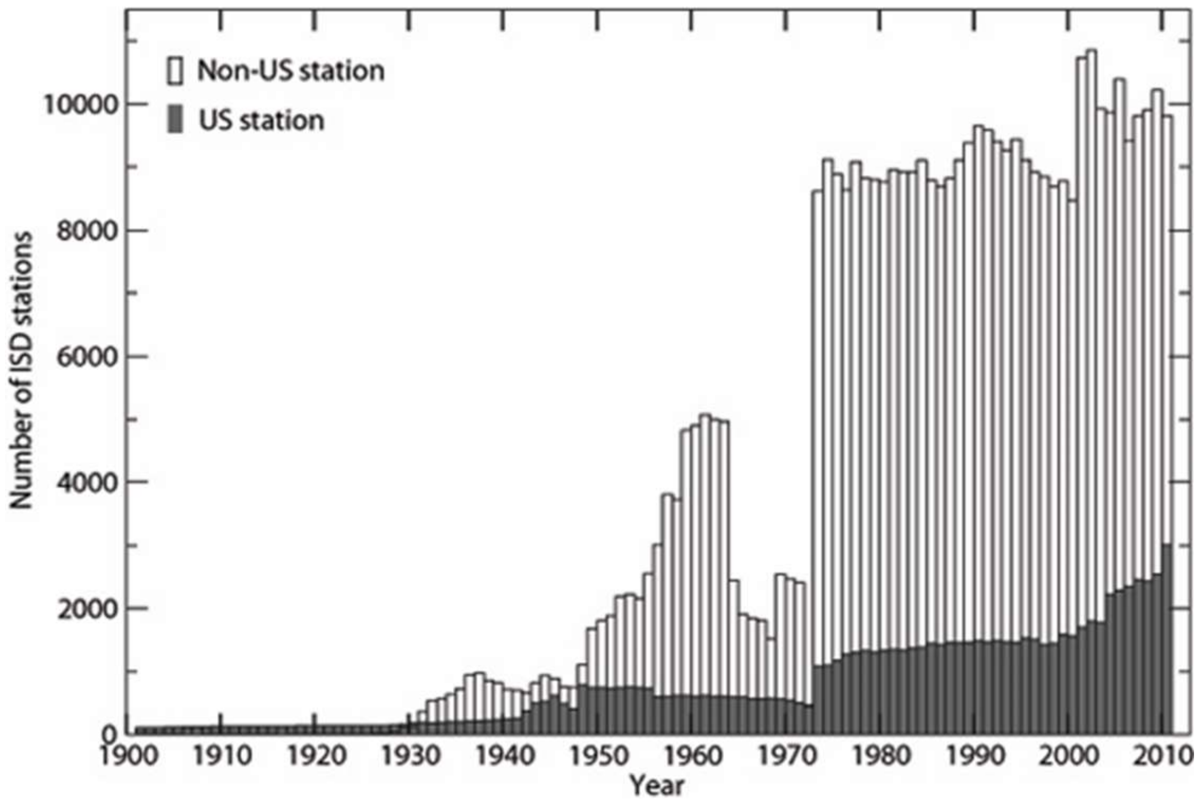
**Related Data:**

- **Global Aerosol data (e.g. EDGAR PM2.5)**
- **Sea Surface Salinity**
- **Global Wind**
- **Global Electric Circuit data**

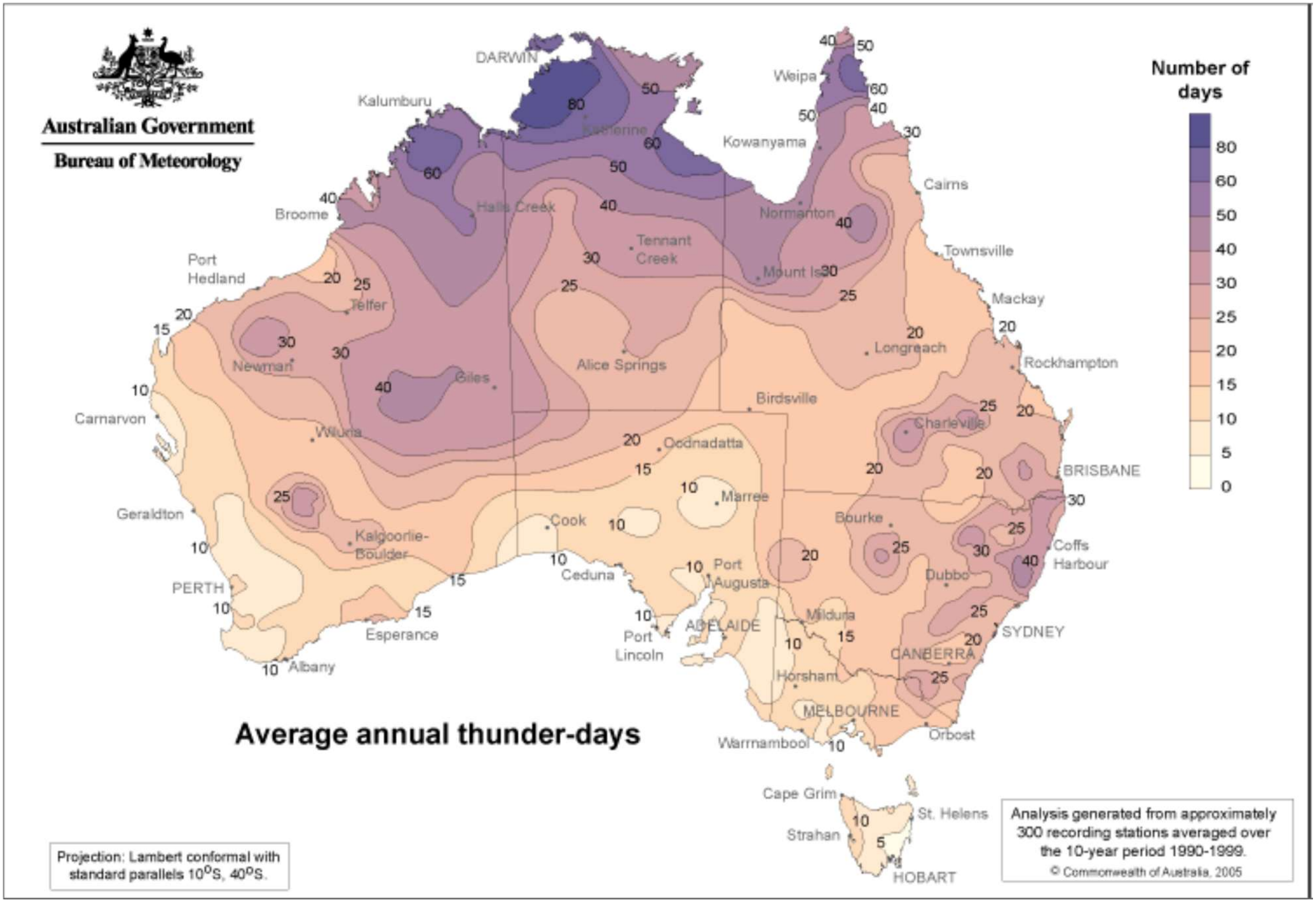
# Thunder Day data    (WMO can help, please):

Thunder Day Data means a day in which thunder was heard (typically within about 20-30 km max from observer)

**Evolution of reporting stations in the GSOD dataset (NOAA)**

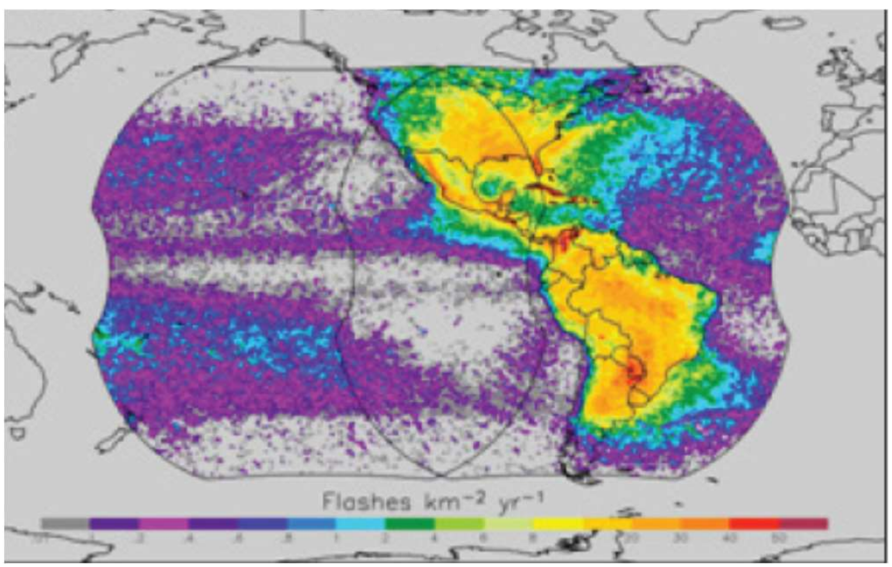



TT-LOCA is working to identify where other thunder-day data are located and to push for data to be organized and made available


Australian Government
Bureau of Meteorology
Average annual thunder-days
Number of days
80
60
50
40
30
25
20
15
10
5
0
DARWIN
Kalumburu
Katherine
Weipa
Kowanyama
Cairns
Broome
Halls Creek
Normanton
Tennant Creek
Townsville
Port Hedland
Mount Isa
Mackay
Telfer
Newman
Longreach
Rockhampton
Giles
Alice Springs
Carnarvon
Birdsville
Wiluna
Oodnadatta
Charleville
BRISBANE
Geraldton
Marree
Cook
Bourke
Coffs Harbour
Kalgoorlie-Boulder
Ceduna
Port Augusta
Dubbo
PERTH
Mildura
SYDNEY
Esperance
Port Lincoln
ADELAIDE
CANBERRA
Albany
Horsham
MELBOURNE
Orbost
Warrnambool
Cape Grim
St. Helens
Strahan
HOBART
Projection: Lambert conformal with standard parallels 10°S, 40°S.
Analysis generated from approximately 300 recording stations averaged over the 10-year period 1990-1999.
© Commonwealth of Australia, 2005

# Satellites

**NOAA/NASA OTD and TRMM/LIS - global coverage every few days (de-orbited)**
**Geostationary: NOAA16 GLM (Geostationary Lightning Mapper),**
**EUMATSAT – similar instrument planned in a few years**
**China: Geostationary sat launched**
**Low Earth Orbit (new): LIS spare on ISS now (57° inclination)**



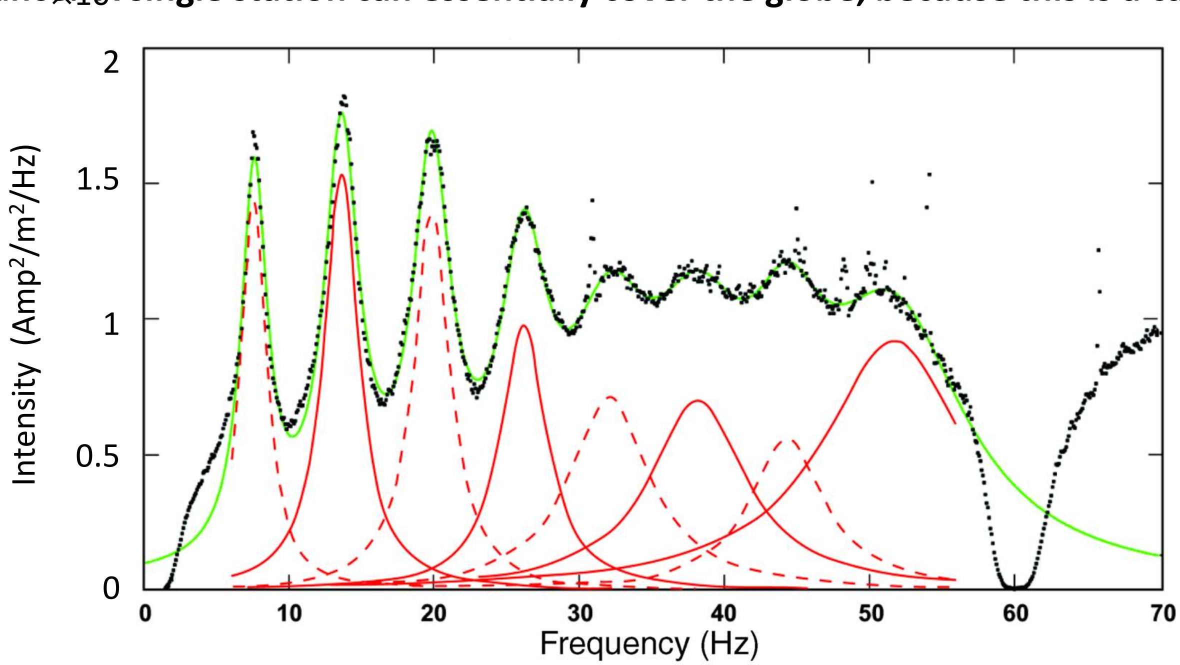

NOAA GLM Field of View
(with a climatology cut
from OTD/LIS)
(two Satellites view)

**No Satellite Lightning Locating system covers the globe, nor will it in the forseable future**

# Groundbased RF networks

## Three main frequency bands:  ELF, VLF and MF

**ELF:  Schumann Resonance:  A single station can essentially cover the globe, because this is a cavity resonance**



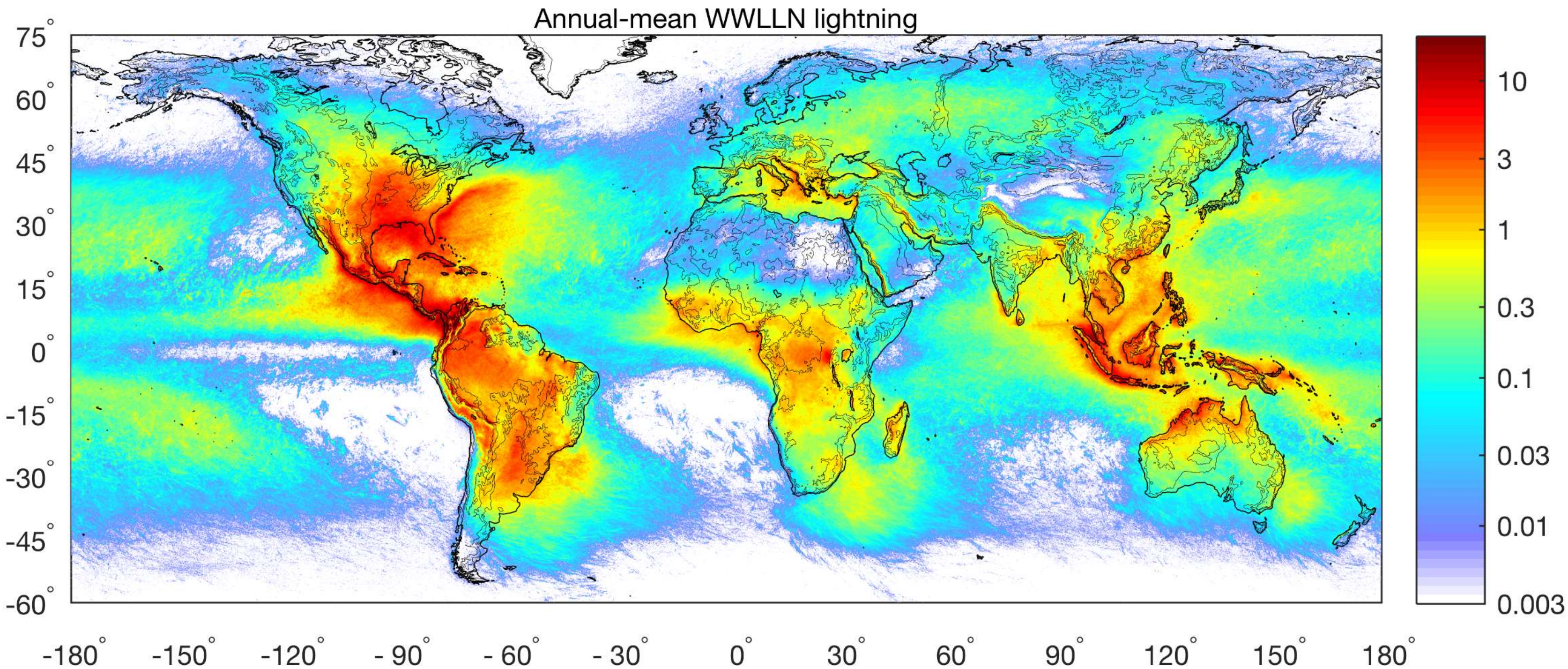

Lorentzian Fitting of  Schumann Spectrum: Inputs for Inversion

# Groundbased RF networks

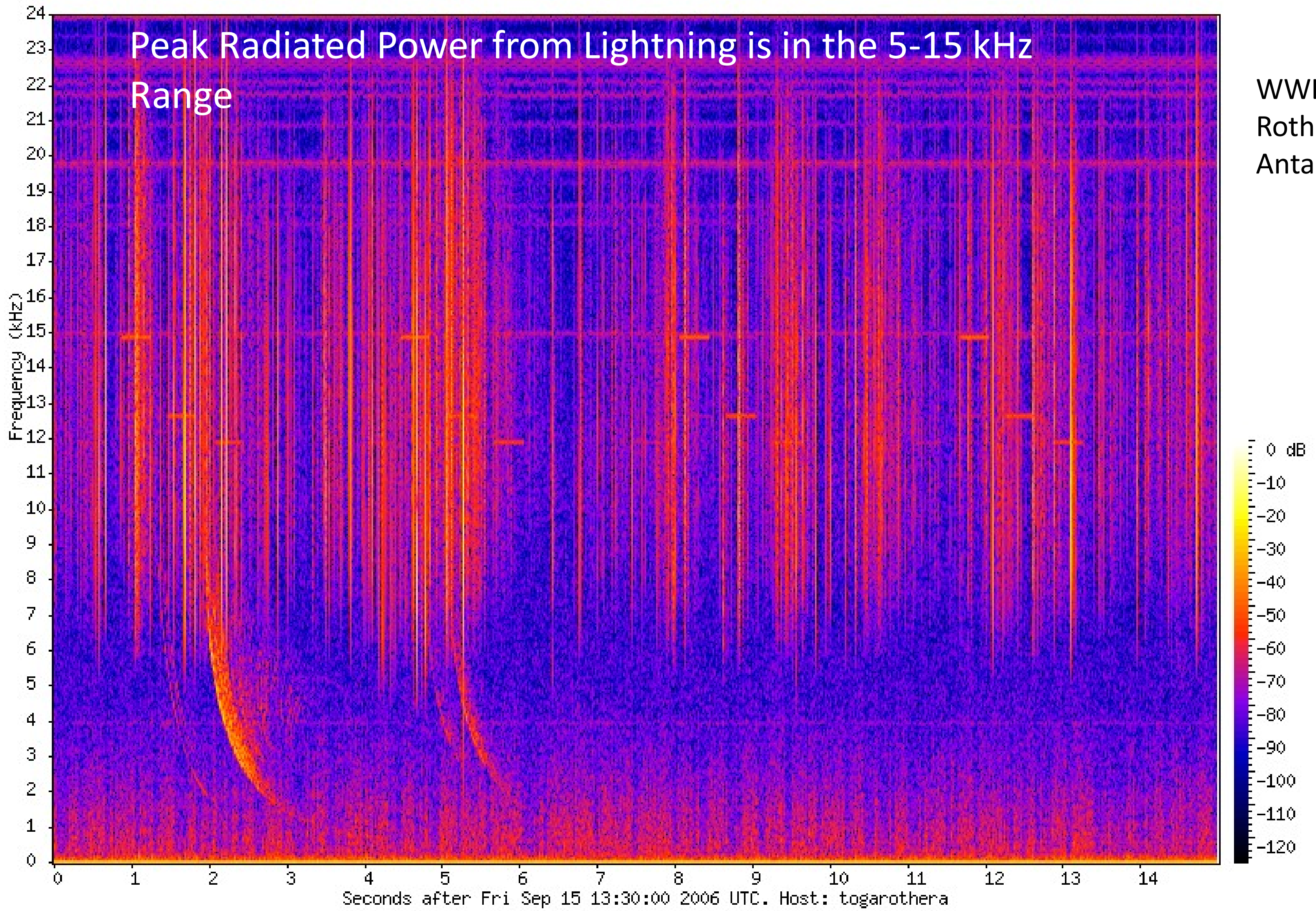
**Three main frequency bands: ELF, VLF and MF**

**VLF and MF: Regional and Global (Regional networks exist in China, Russia, Europe, USA, New Zealand, and other countries, each covering important areas)**

**Global VLF: WWLLN, ENGLN and GLD360 - data available in real time for whole globe (back to 2004)**



# Peak Radiated Power from Lightning is in the 5-15 kHz Range




WWLLN
Rothera station,
Antarctica

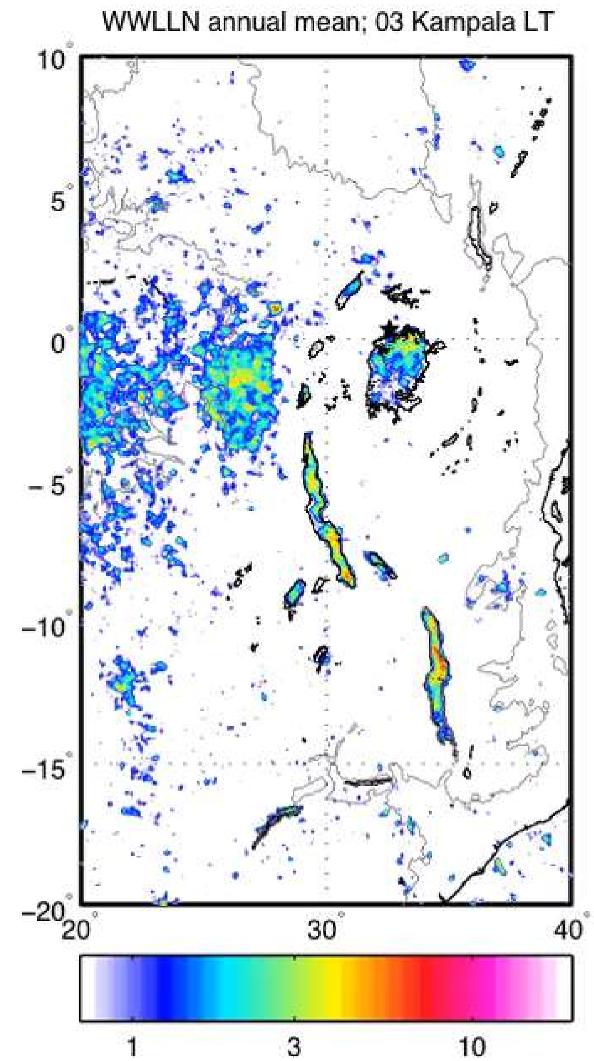
# Lightning Climatologies

Global Thunder Day data since 1930s

Regional Lightning Studies available for many countries since 1990s

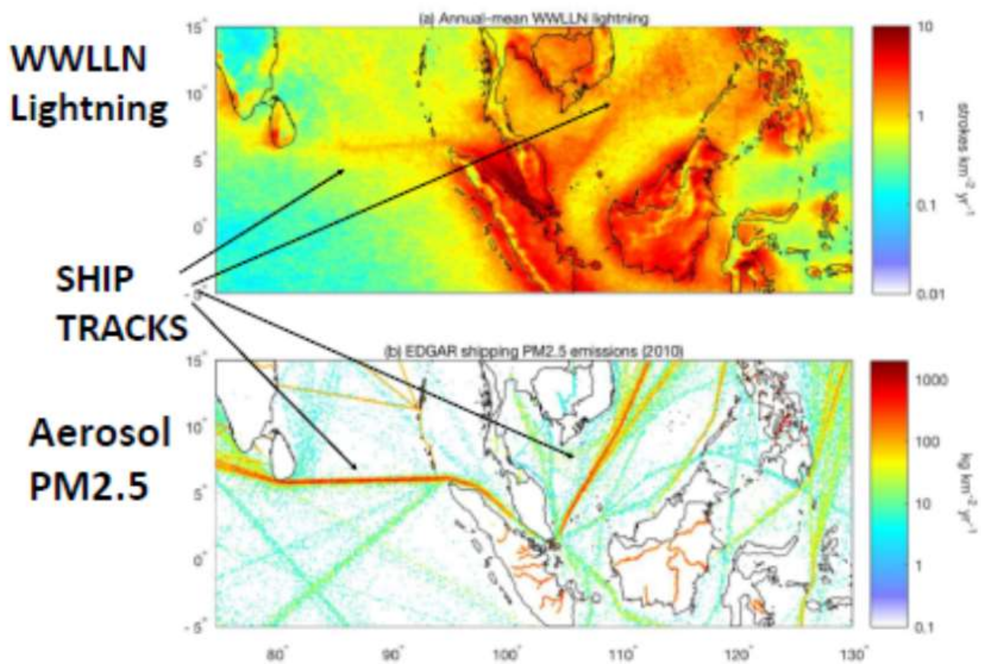
Global Lightning Climatology from NASA using OTD/LIS

Global Lightning Climatology now available at 10km, 1-hr resolution



# Other Relevant Data sets: ( for Lightning Studies)

**Global Aerosol data (e.g. EDGAR PM2.5)**
**Sea Surface Salinity**
**Global Wind**
**Global Electric Circuit data**




**Global Climatology data for 10+ years used to identify Human Aerosol pollution impact on severe weather**

# The Global Electric Circuit (first proposed by C.T.R. Wilson

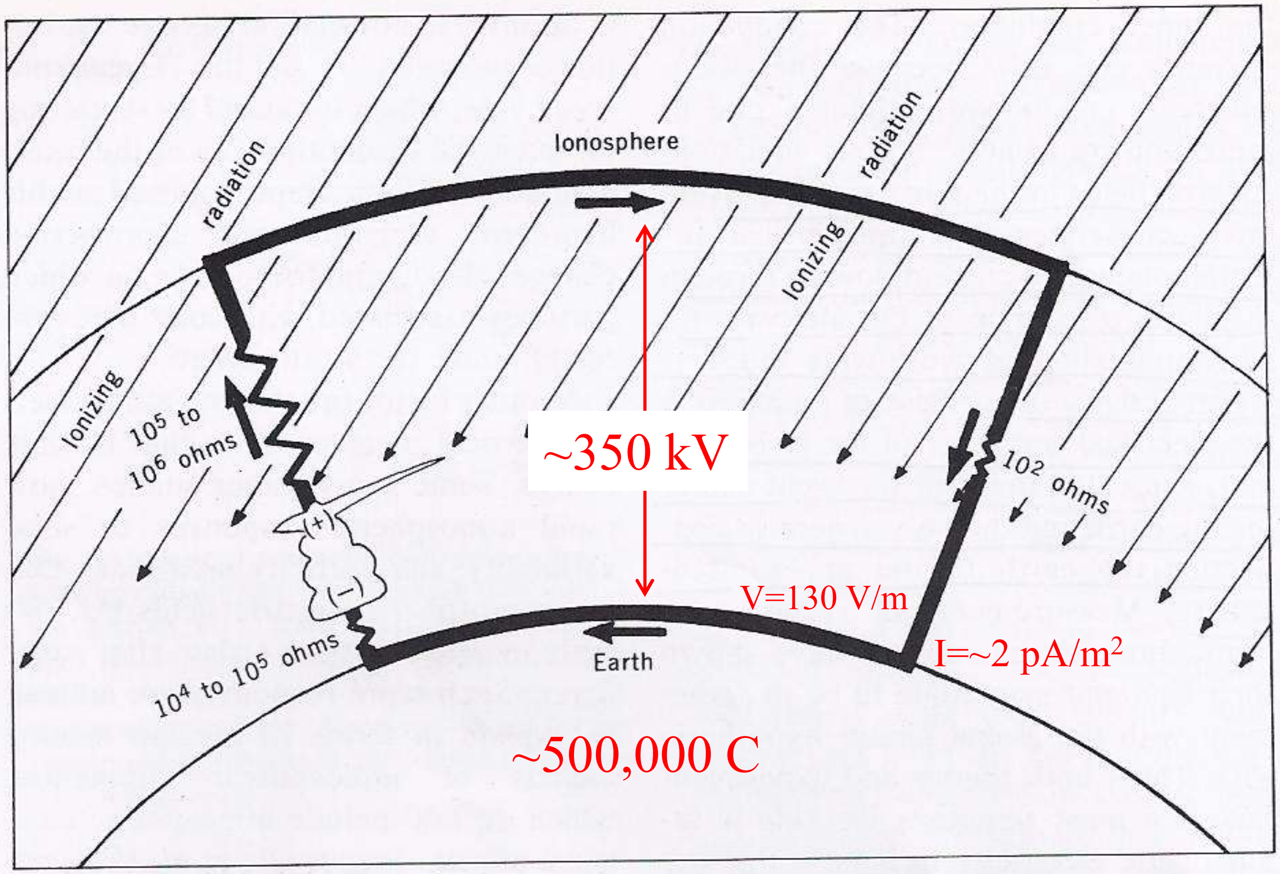
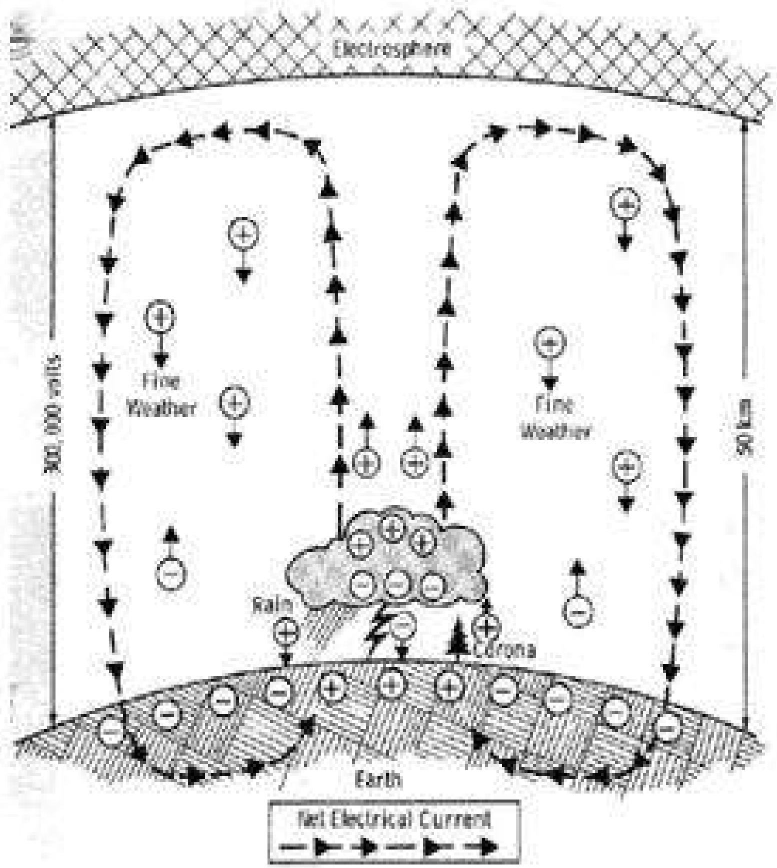
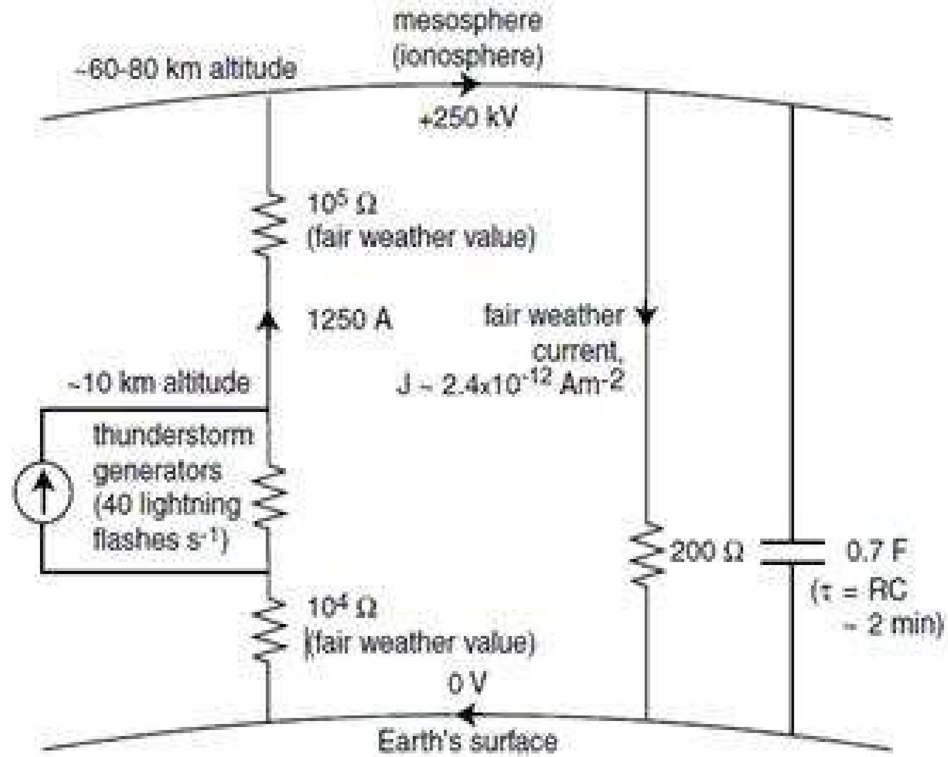



Fig. 3. Schematic of the global atmospheric electrical circuit illustrating relationships between resistive elements. The arrows indicate the accessibility of the controlling resistive element above the thunderstorm generator to the varying component of the ionizing radiation (*15*).

TEL AVIV UNIVERSITY אוניברסיטת תל-אביב




Current experiments are underway to collect the global Return Current from the collective effects of Thunderstorms

**TTLOCA:**

**Most Data sources for lightning have been identified**

**Next: Identify space and time resolution needed for Climate studies**

**Work with government and private sources to settle on a reasonable Climate data set for Lightning data**

**Identify the Meta-data needed for such data sets to be useful (detection efficiencies etc)**

**Request input from the community to help guide our recommendations**

**Write a white paper with our recommendations for Lightning data as an ECV**

# Thank You!

Contact me or Valentin for questions:

Robert Holzworth <bobholz@uw.edu>
Valentin Aich <vaich@wmo.int >

# Further Demonstrations of Lightning Climatology Studies:

Auxillary Sides:

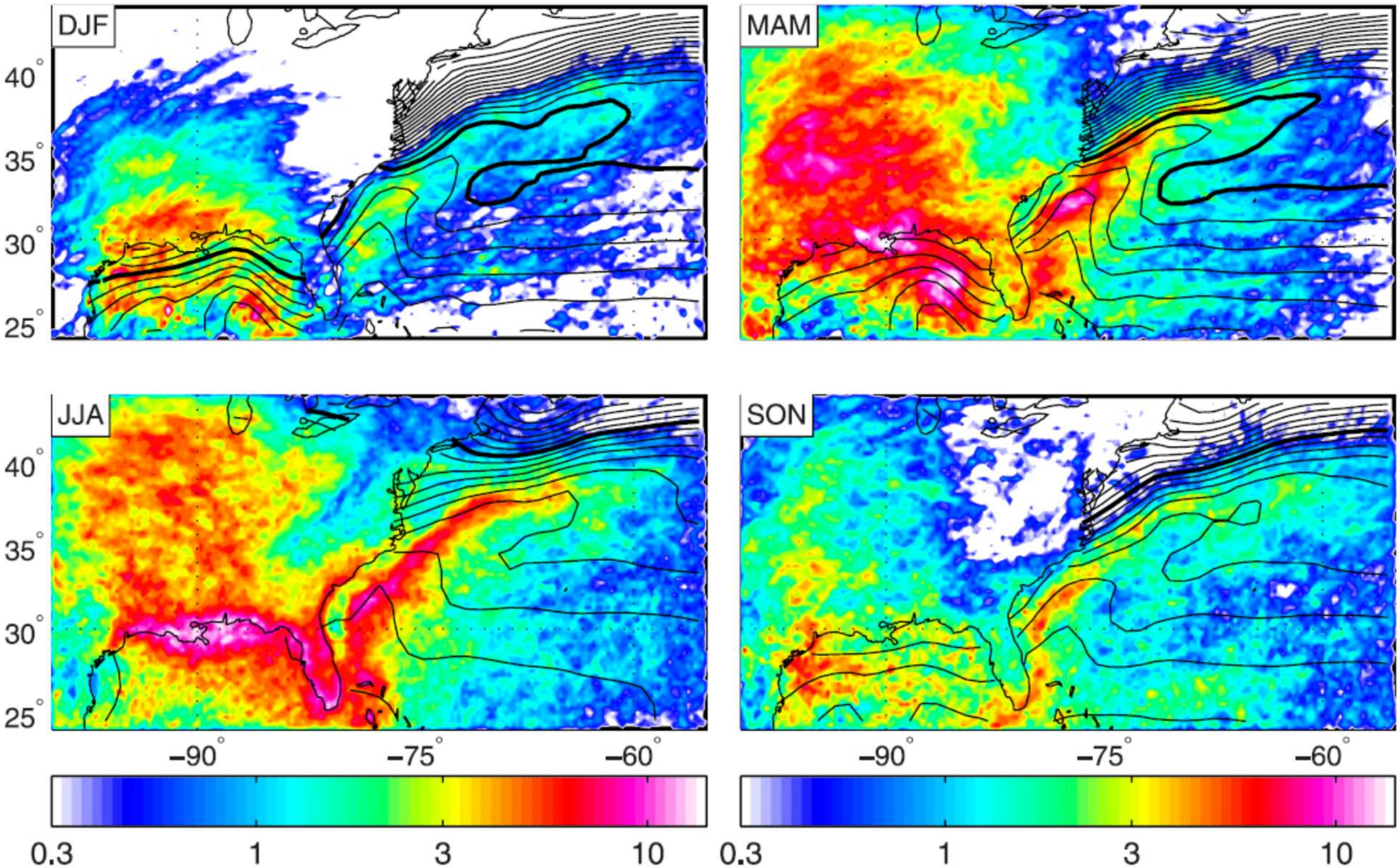
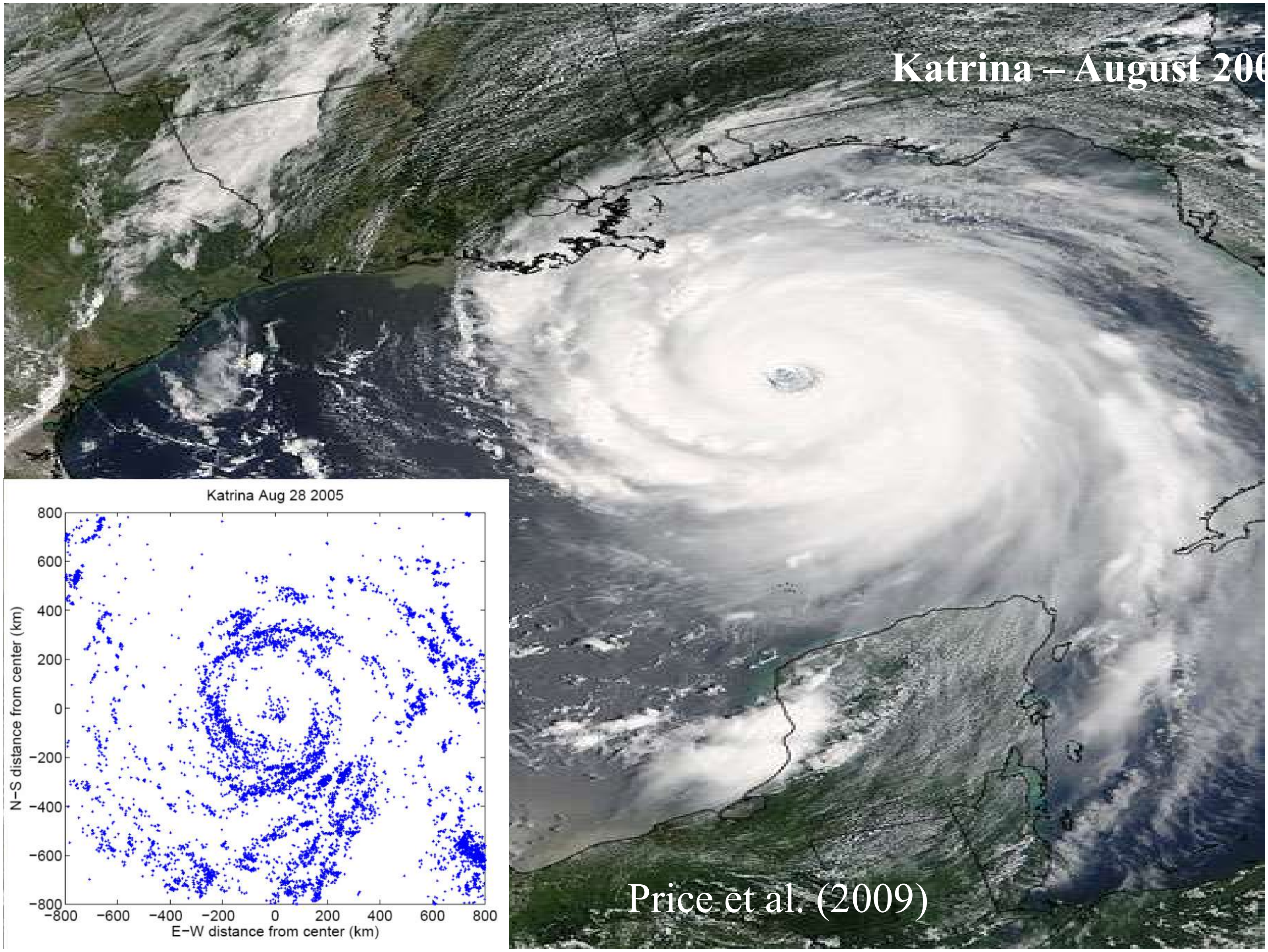
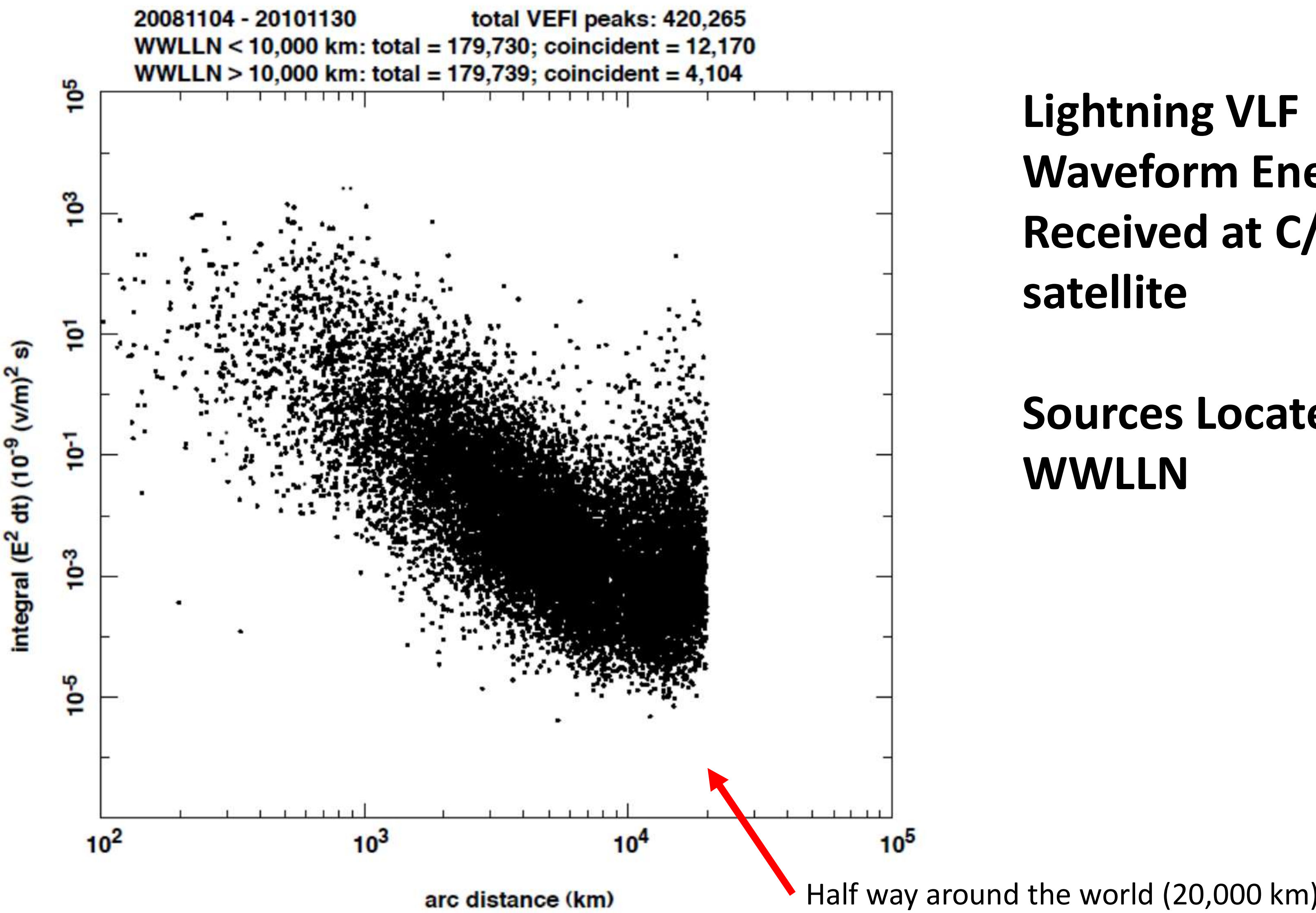



FIG. 4. As in Fig. 3, but for WWLLN lightning (strokes $km^{-2} yr^{-1}$).


Katrina – August 20
Katrina Aug 28 2005
N-S distance from center (km)
E-W distance from center (km)
800
600
400
200
0
−200
−400
−600
−800
−800 −600 −400 −200 0 200 400 600 800
Price et al. (2009)

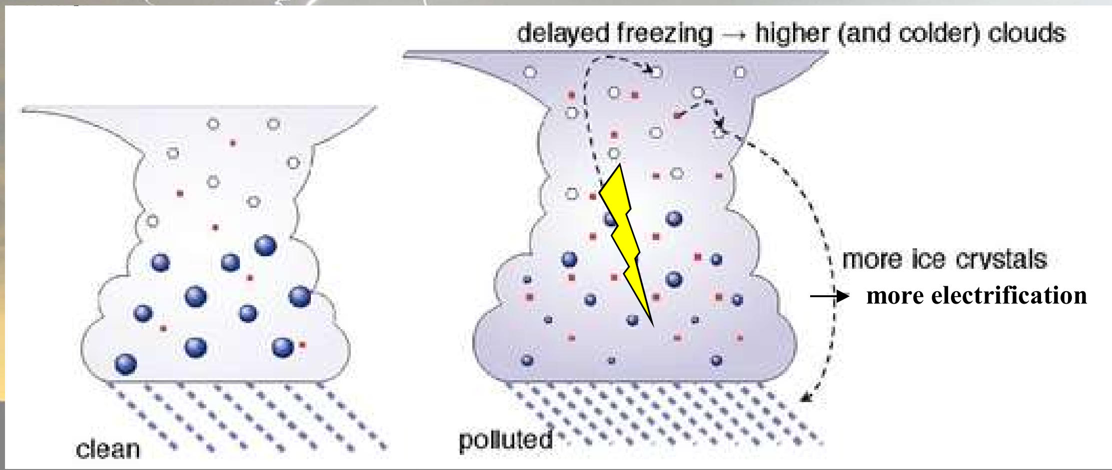



**Lightning VLF Waveform Energy Received at C/NOFS satellite**

**Sources Located by WWLLN**

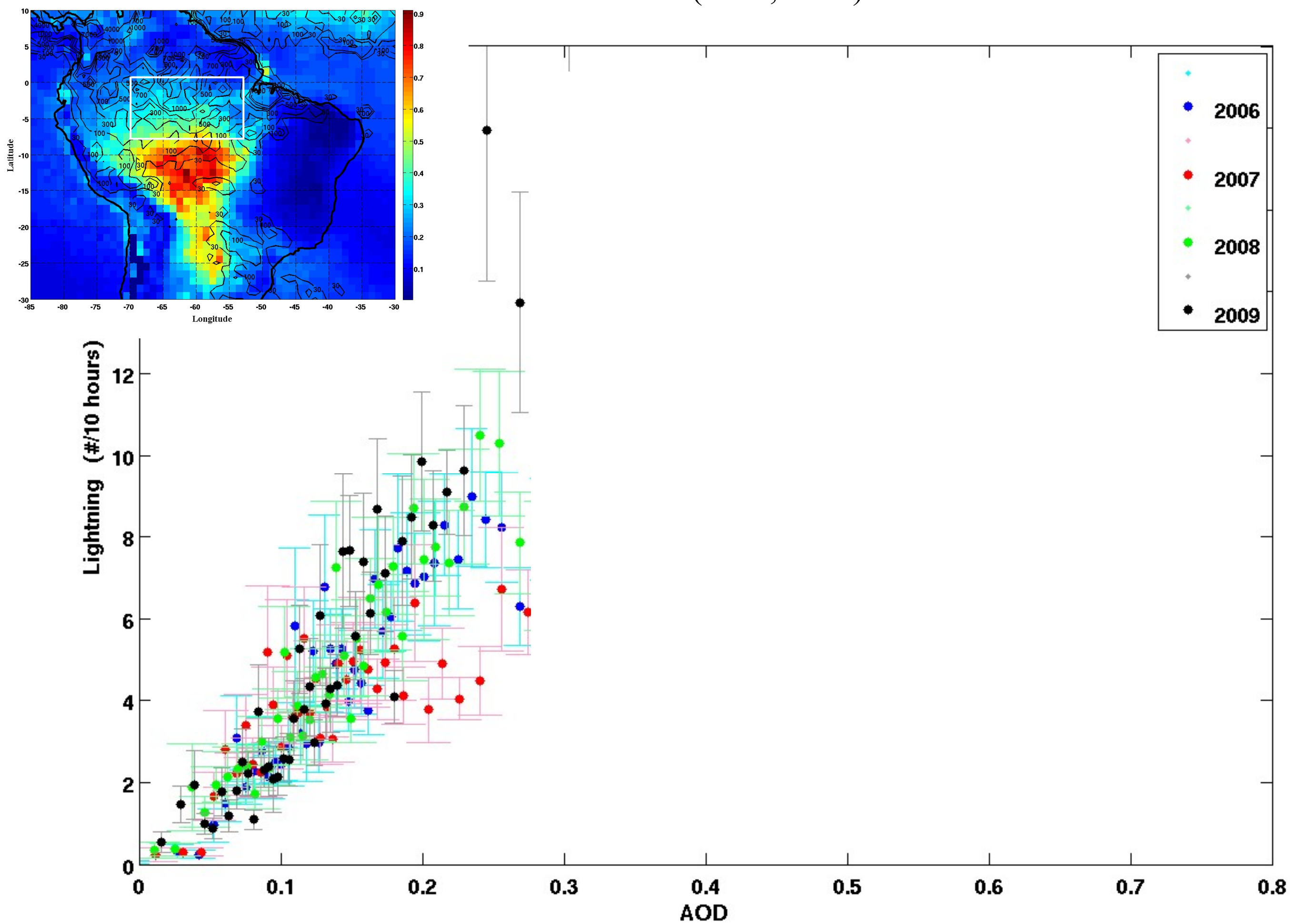
What about aerosols?
How will a more polluted atmosphere impact thunderstorms?

- ✓All cloud drops form on cloud condensation nuclei (CCN)
- ✓Ice crystals form on ice nuclei (IN)
- ✓Low levels of CCN support warm rain processes
- ✓High levels of CCN support cold rain processes (ice)
- ✓For cloud electrification we need supercooled drops, ice, and hail interacting in the mixed phase region of clouds (0 to -40C)

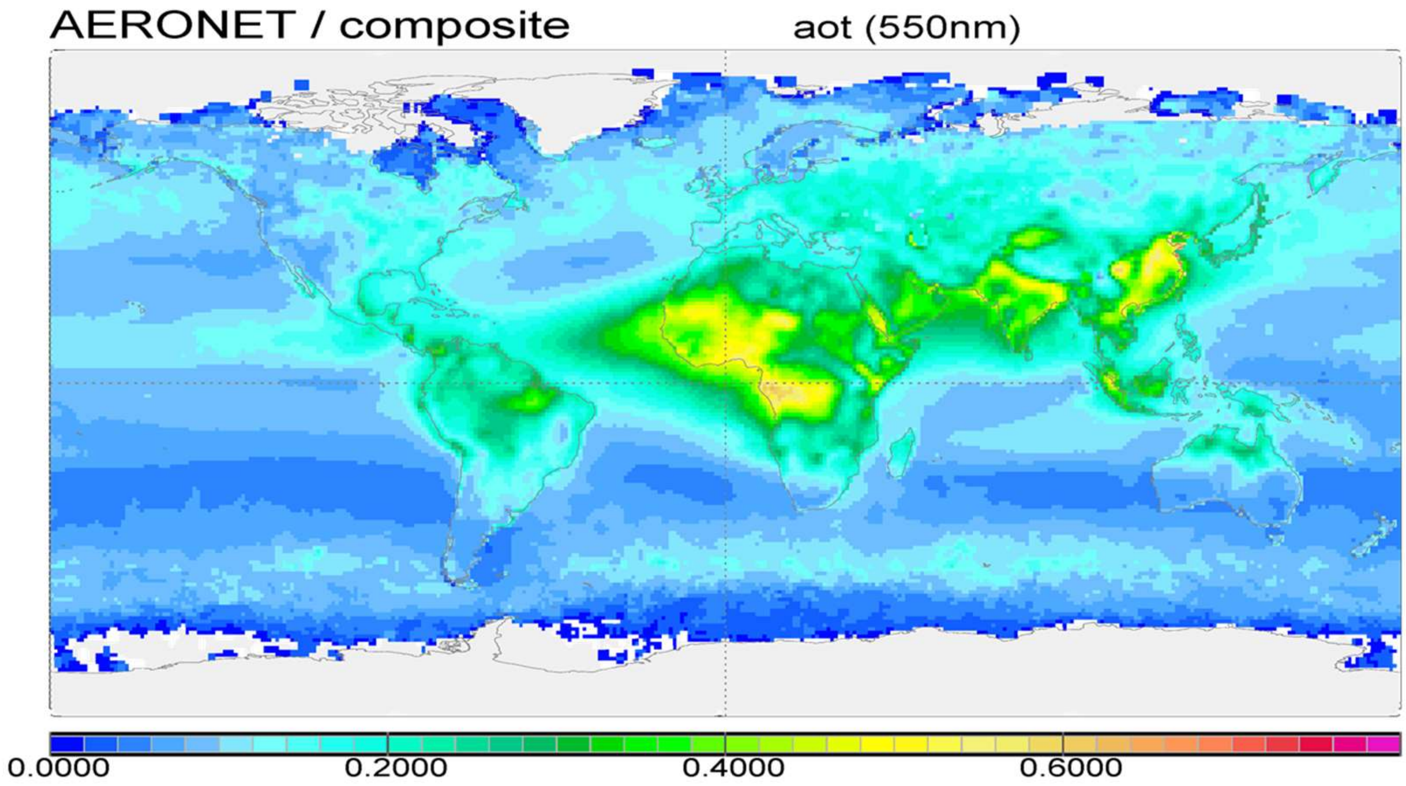


# How does increasing aerosol loading impact lightning?

Altaratz et al (2010, GRL)



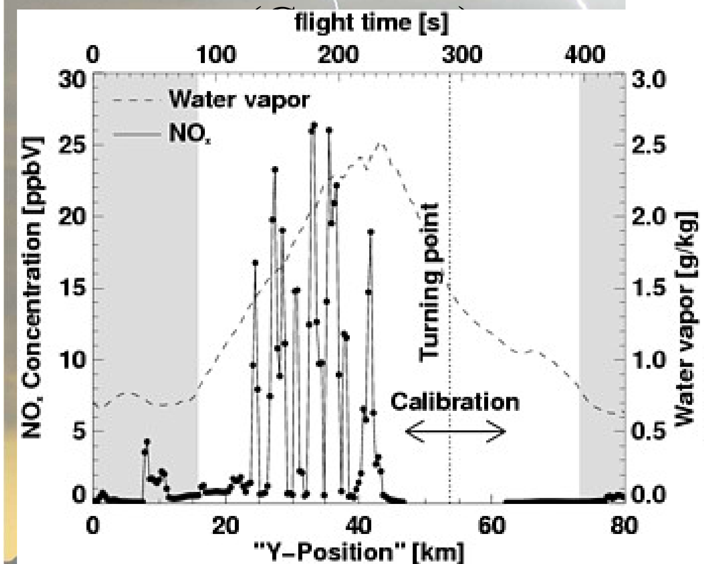
# Global Aerosol Observations
(Kinne, 2009)

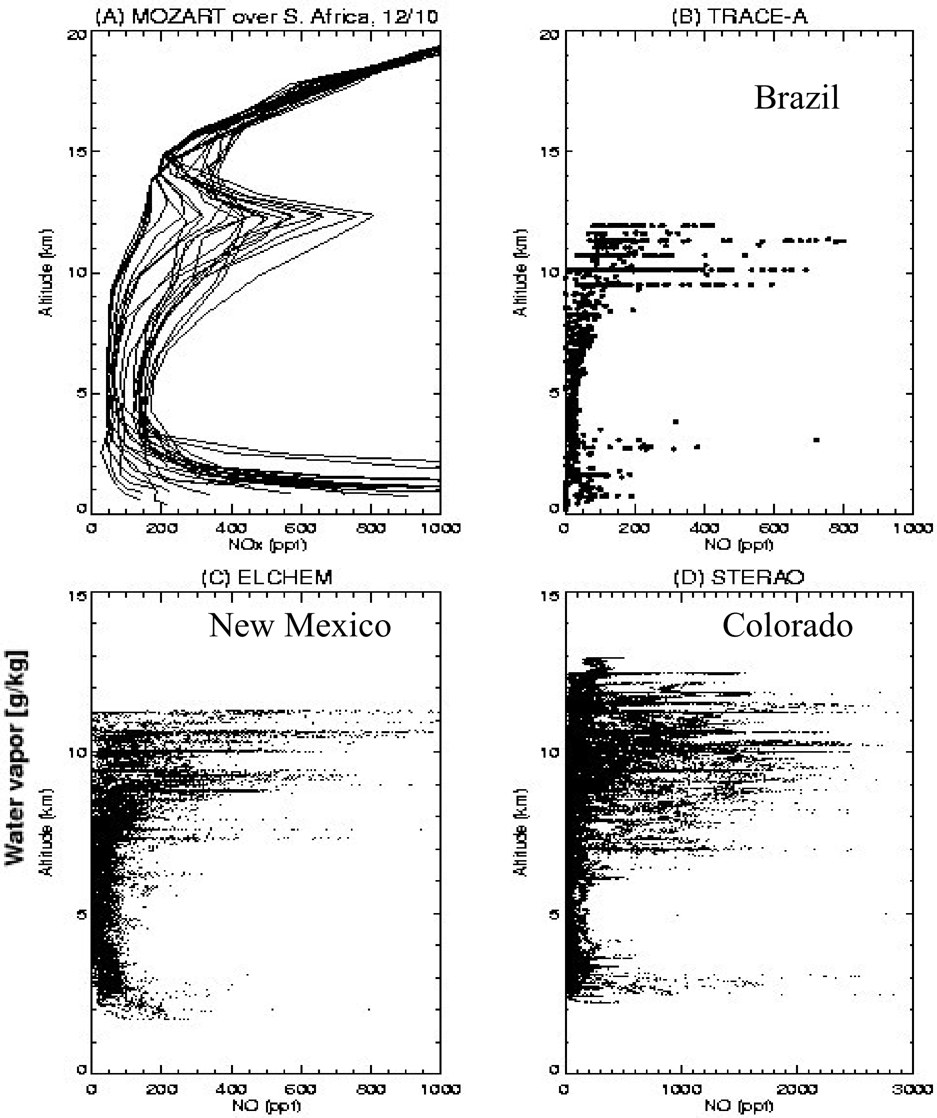


# Is Lightning Itself Important for Climate Change?

**Tropospheric Chemistry**

## $NO_x$



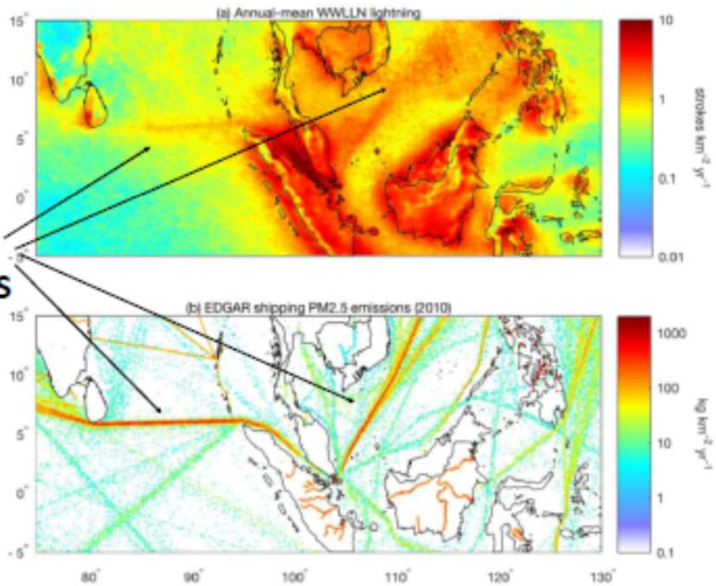



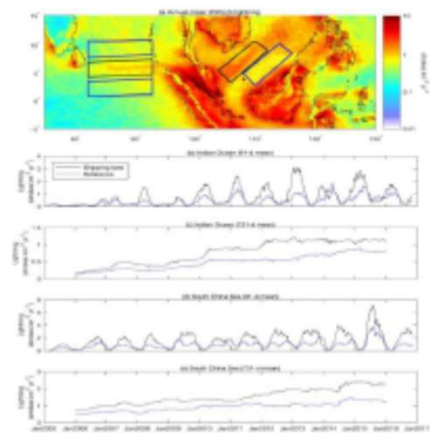
# The clearest evidence to date of aerosol pollution persistently affecting storm development and intensity.

**WWLLN Lightning**

**SHIP TRACKS**

**Aerosol PM2.5**

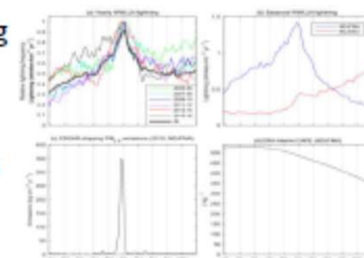


**Factor of Two Lightning increase over ship tracks** compared to adjacent regions

Lightning

Aerosols



Seasonal lightning

CAPE

Latest Result from UW Atmos. Sci, ESS, JISAO and NASA:

**Joel A. Thornton, Katrina S. Virts, Robert H. Holzworth, and Todd P. Mitchell, Lightning Enhancement Over Major Oceanic Shipping Lanes , Geophys. Res. Letters. (accepted 8/24/17) (in press) 2017**

## Conclusion: first evidence that ships affect storm intensity and lightning.

Notice how both Lightning peak, and Aerosol PM2.5 is centered on 6 degrees latitude. Notice that CAPE shows no such relationship (so not a natural weather phenomenon