

Lightning and Climate

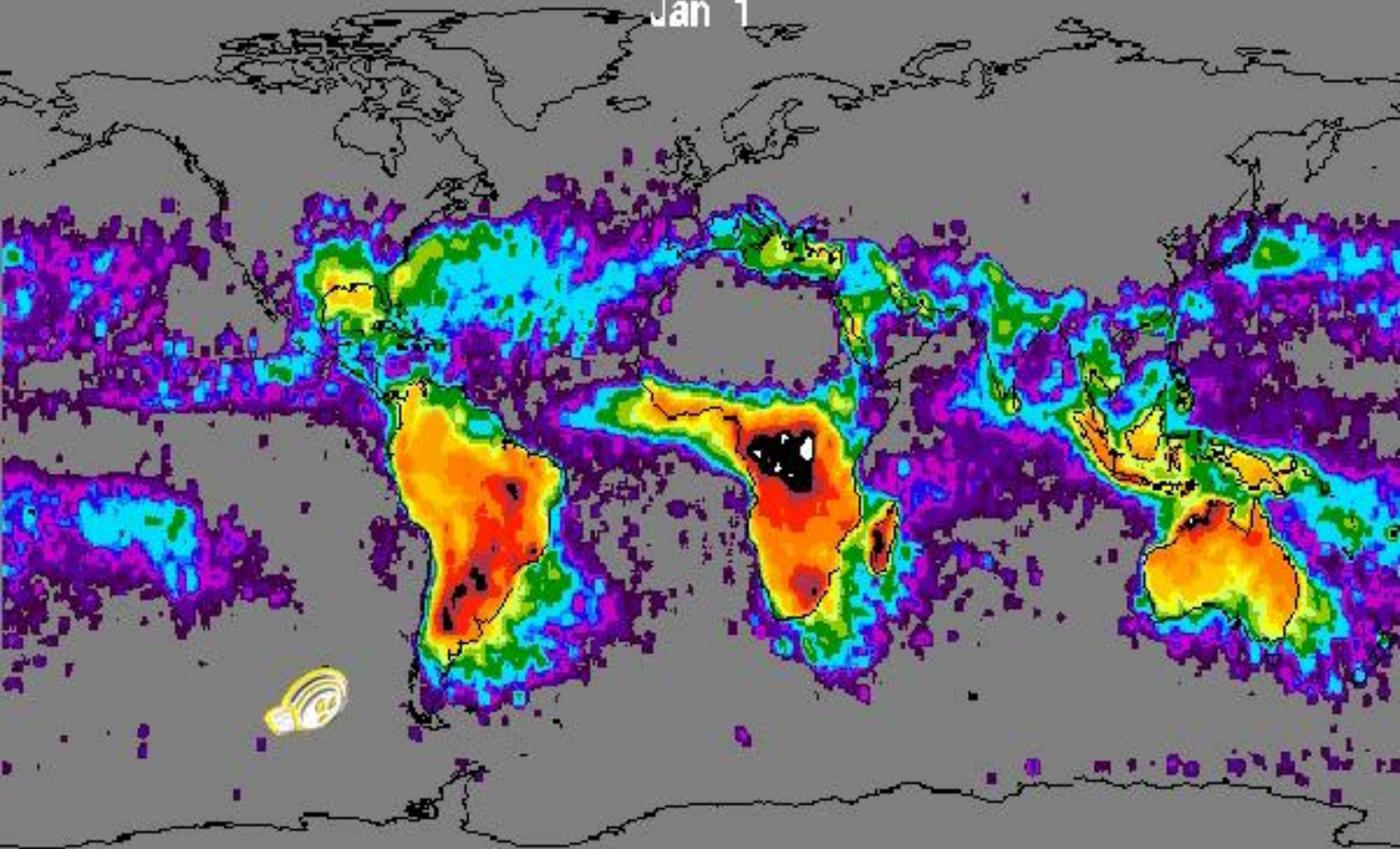
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Satellite tracking of lightning

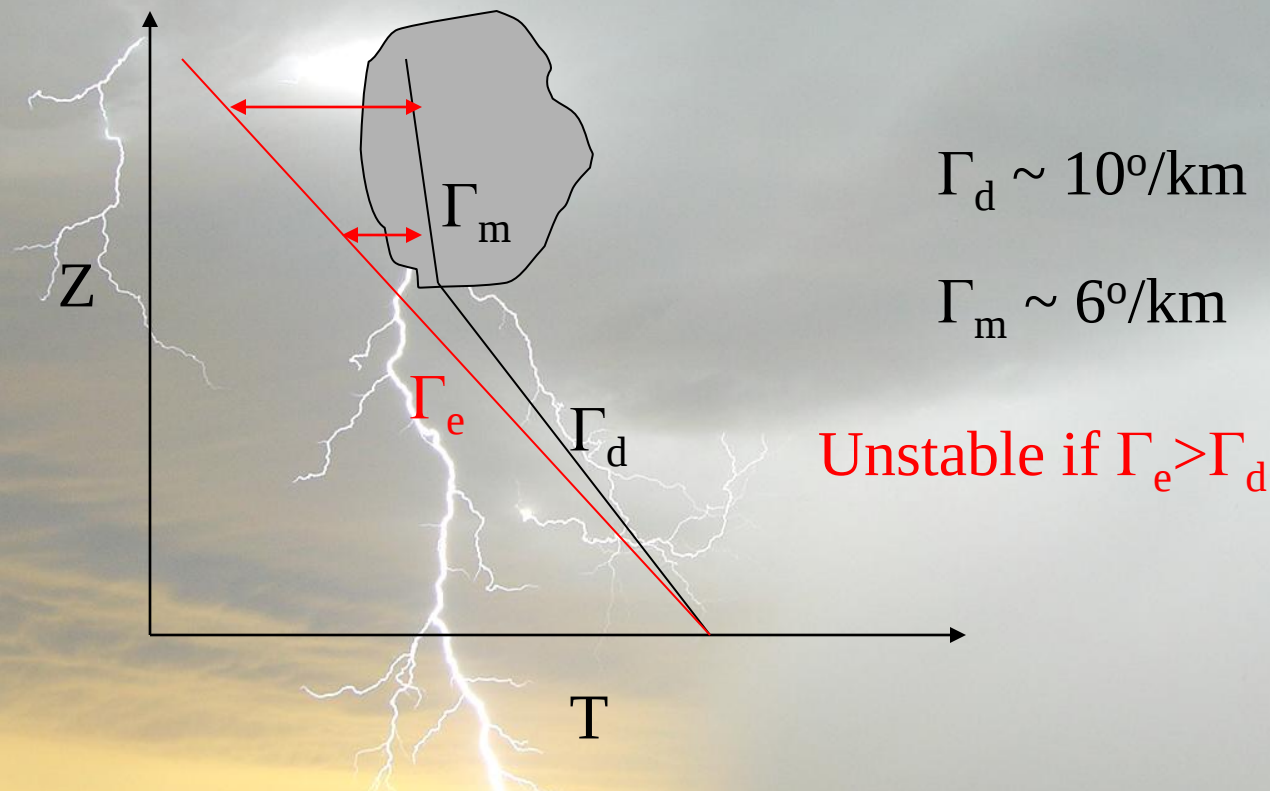
Jan 1



Optical Sensors

Thunderstorms and lightning need an unstable atmosphere to develop

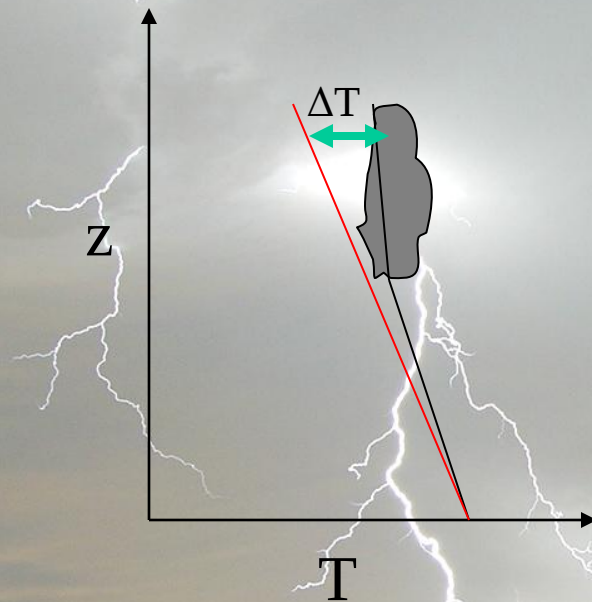
Under adiabatic ascent, air cools at the Adiabatic Lapse Rate



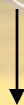
Lightning influenced by both changes in T_s , but also lapse rate aloft

Atmospheric Instability is not enough for lightning

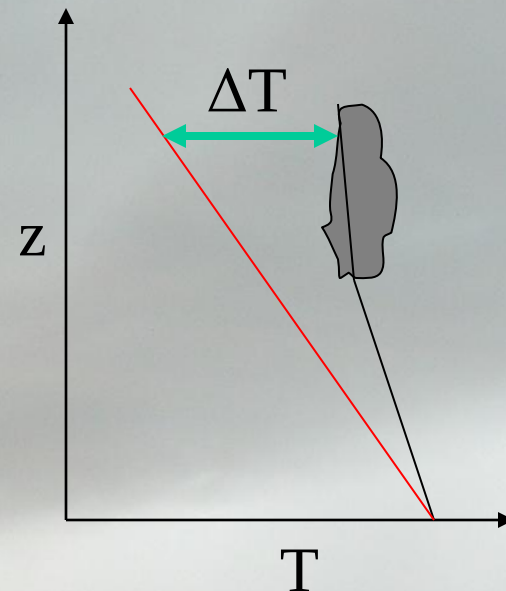
We need updrafts of at least 10 m/sec for significant electrification



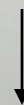
Oceans (weak updrafts)



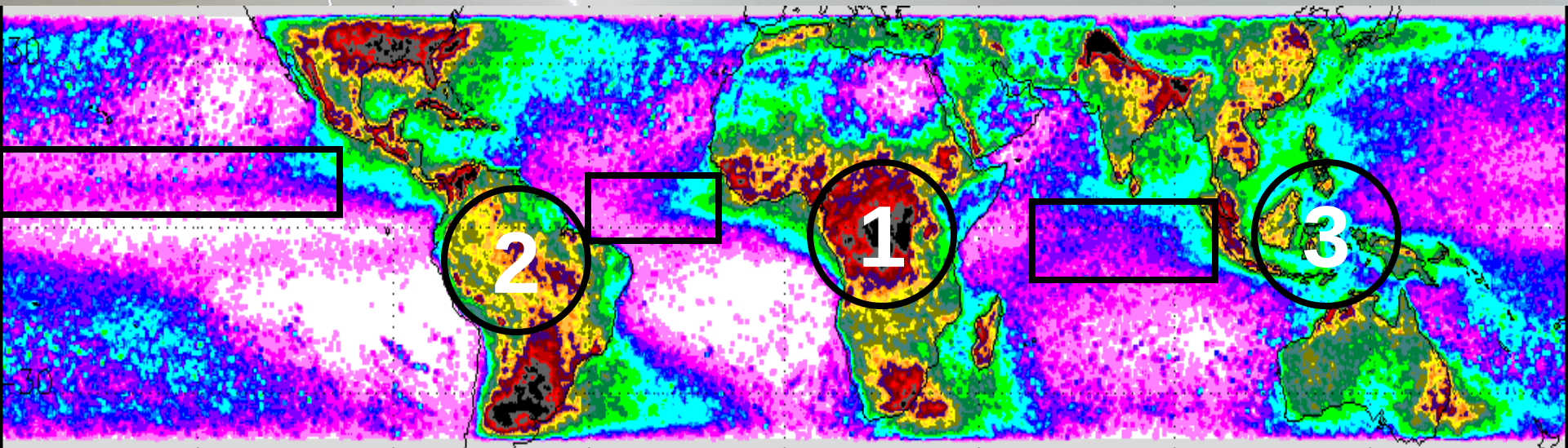
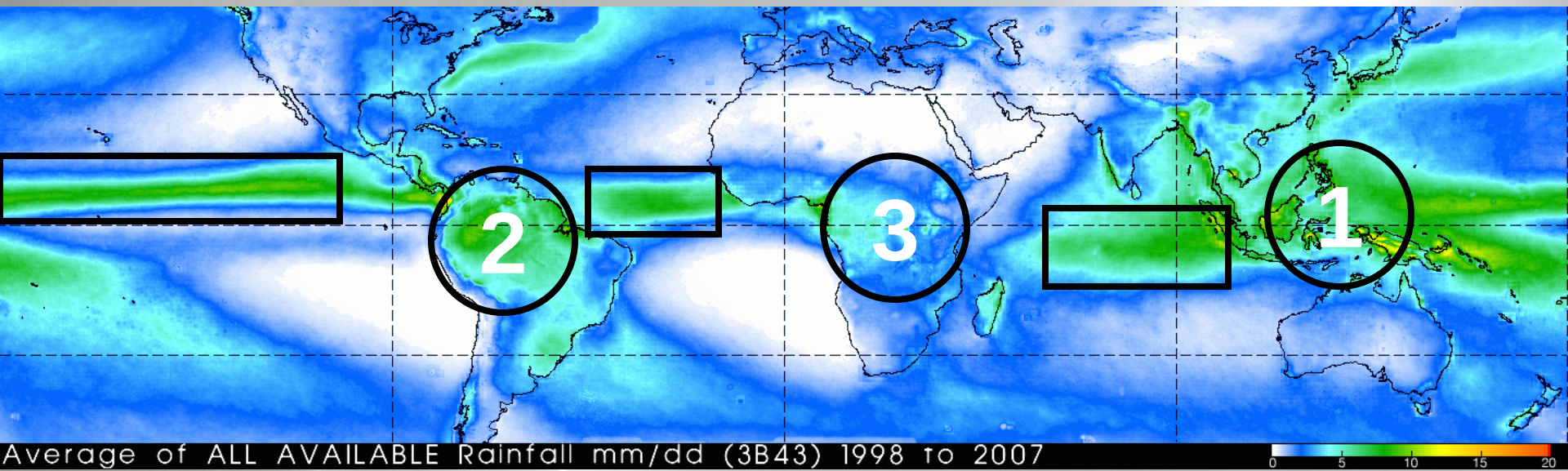
Rain with Little Lightning



Continents (strong updrafts)



Rain with Lots of Lightning



Rainfall and Lightning

Lightning prefers drier climates

Williams and Satori (2004)
Price (2008)

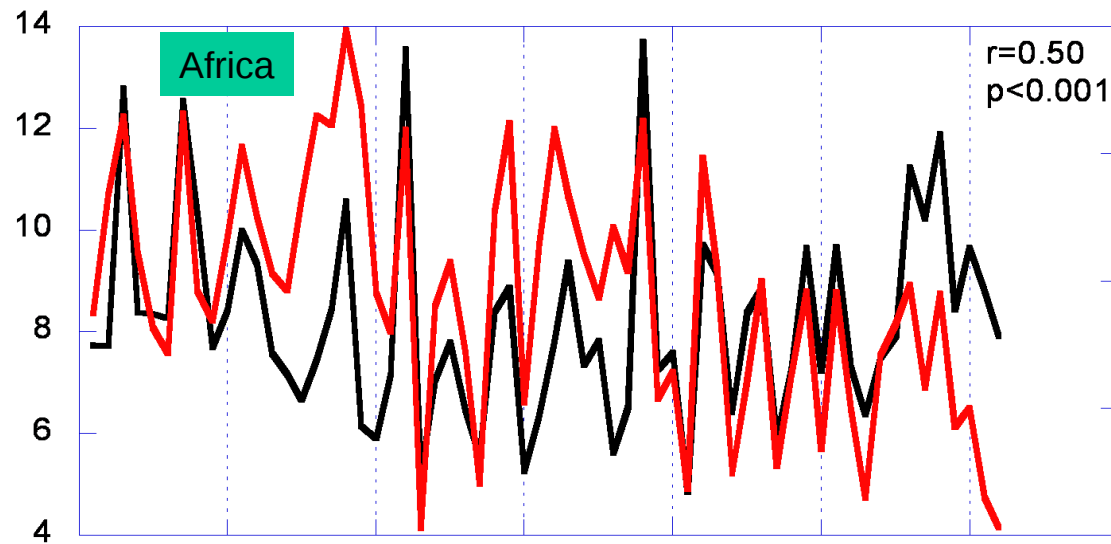
Surface Temperature and Lightning

Studies showing statistically significant **positive** correlations between **surface temperature** and lightning activity

- *Williams (1992)*
- *Price (1993)*
- *Williams (1994)*
- *Reeve and Toumi (1999)*
- *Markson and Price (1999)*
- *Price and Asfur (2006)*
- *Markson (2007)*

Magnetic Field Intensity

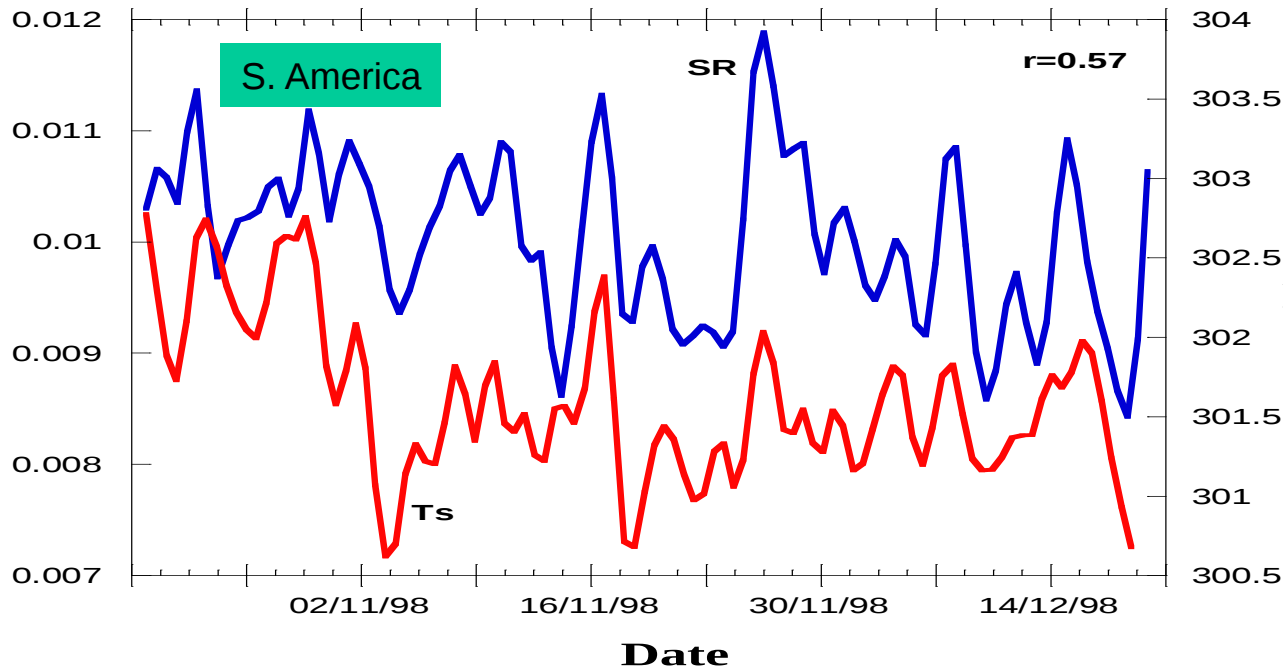
(pT^2/Hz)



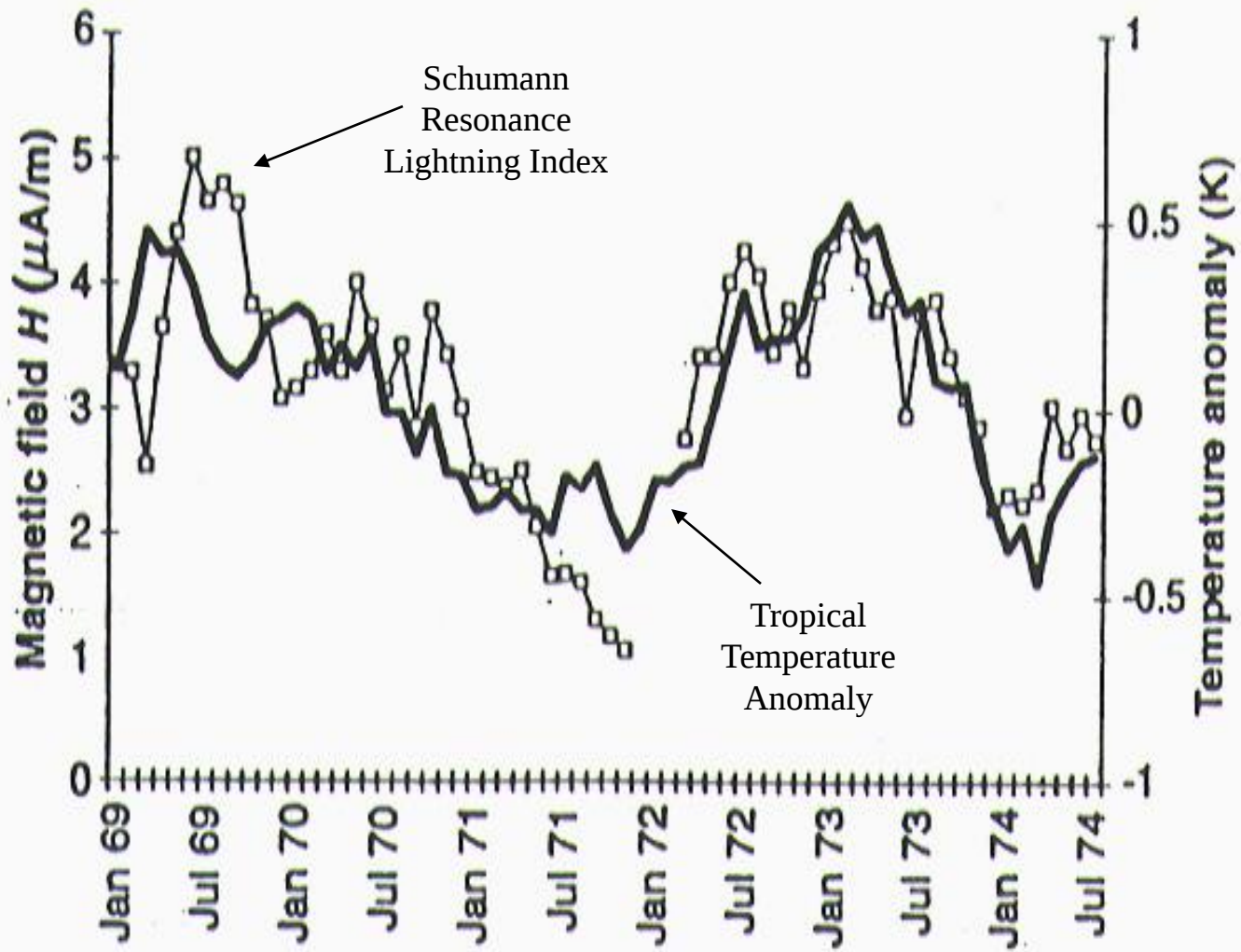
Temperature (K)

Magnetic Field Intensity

(au)



Temperature (K)

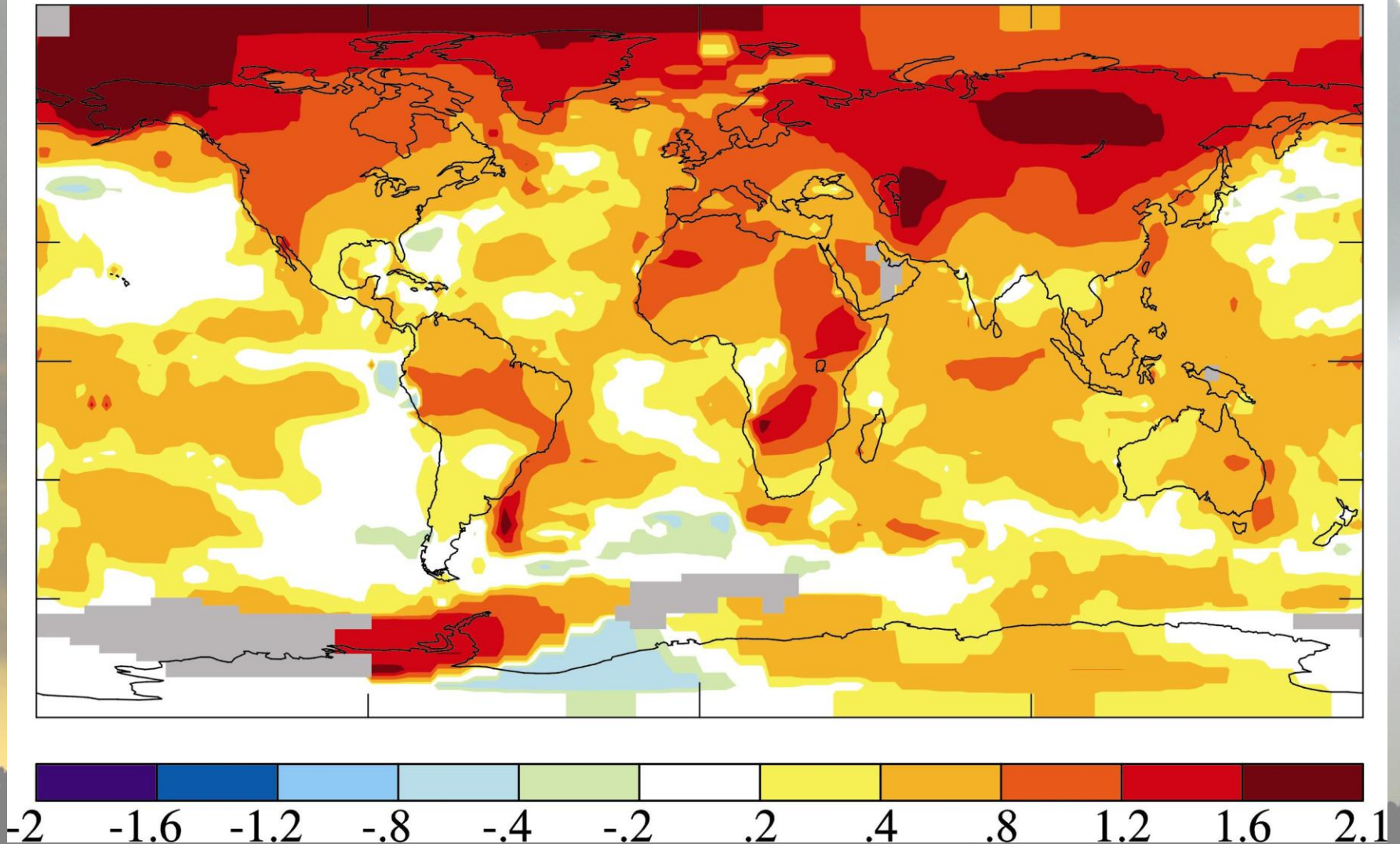


What about global warming?

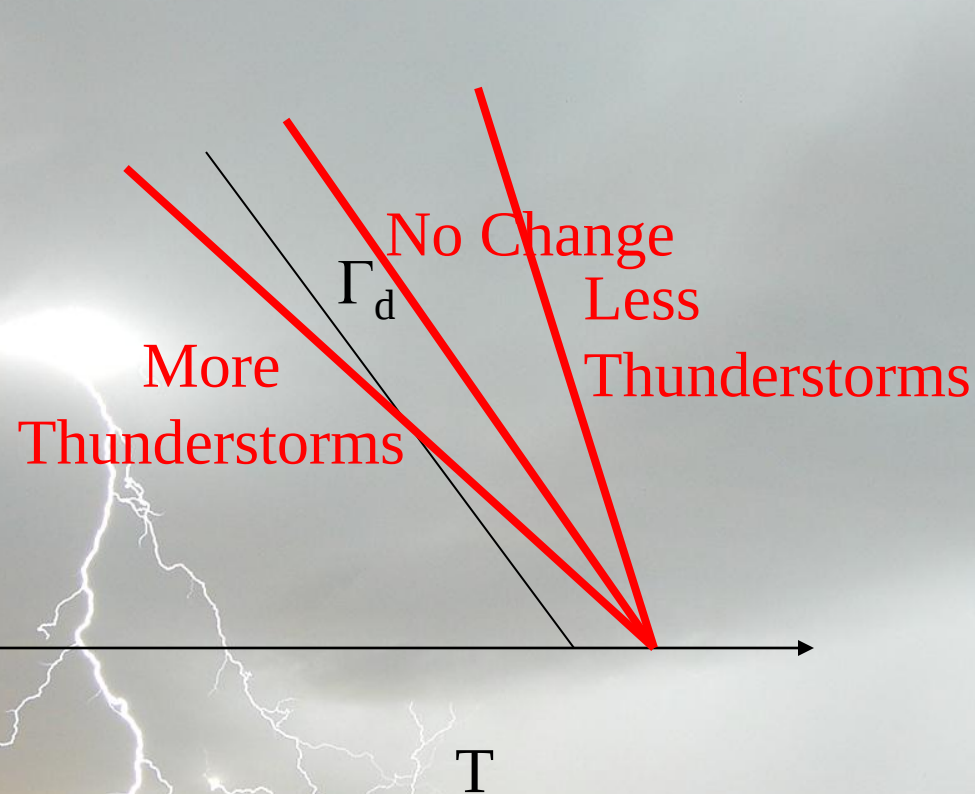
2001-2005 Mean Surface Temperature Anomaly ($^{\circ}\text{C}$)

Base Period = 1951-1980

Global Mean = 0.53

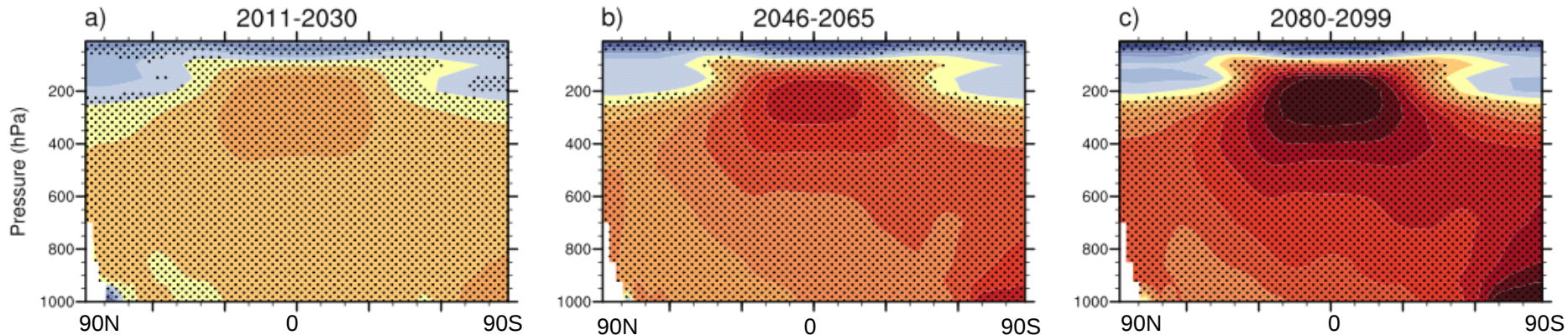


What about changes in Lapse Rate?

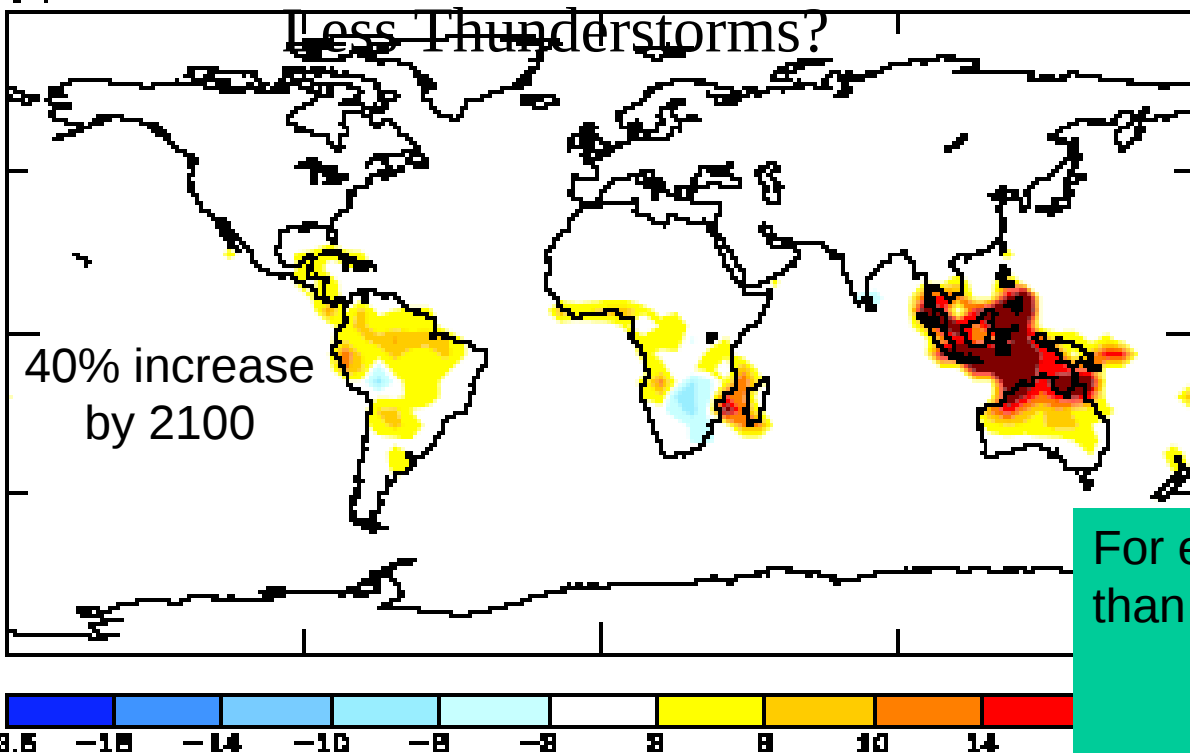


What is predicted for the future?

Maximum Warming Predicted in Tropical Upper Troposphere



(d) JANUARY LIGHTNING

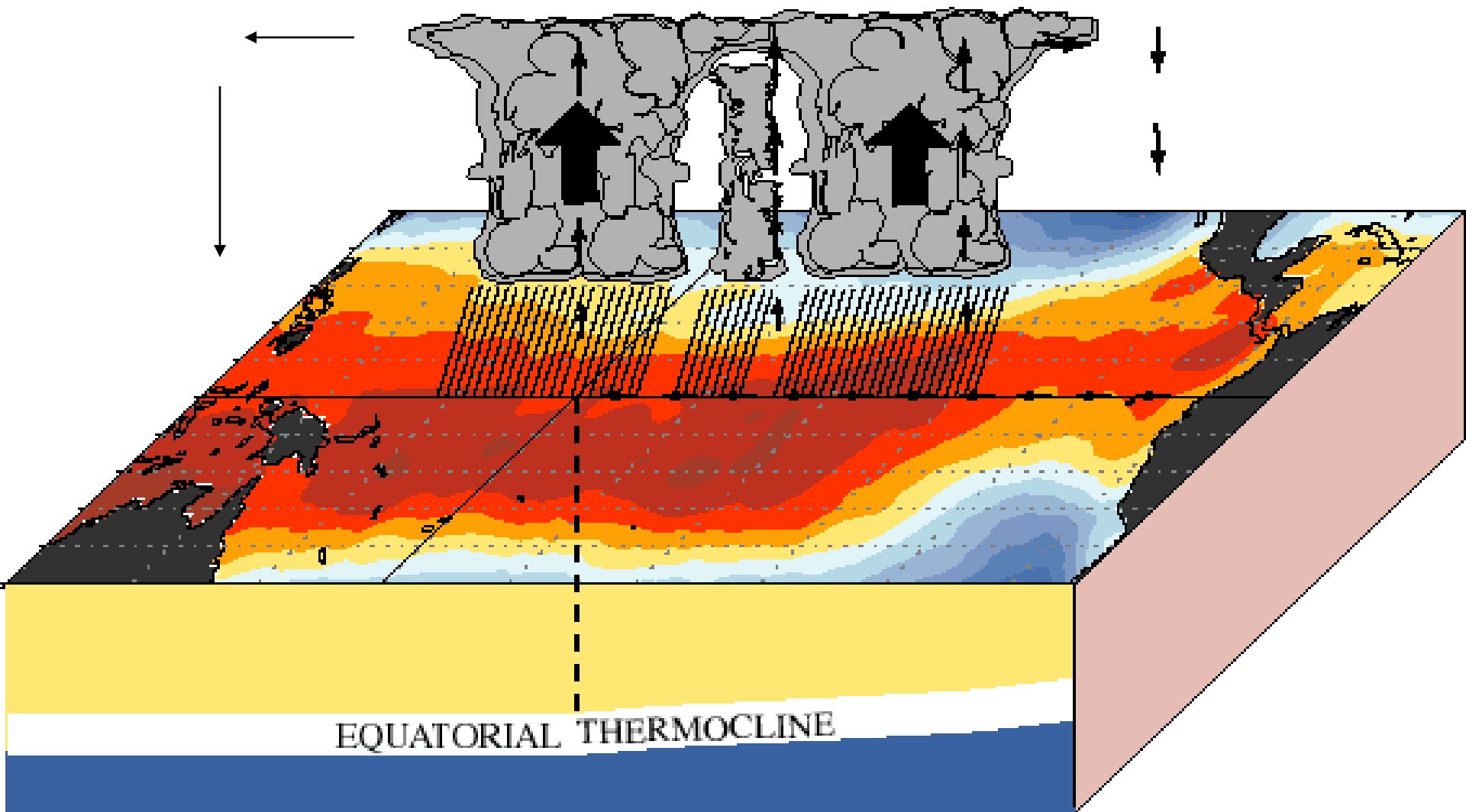


Anomalies are relative to the average of the period 1980 to 1999.
(IPCC, 2007)

Paradox?

For every 1K global warming, more than 10% increase in global lightning
Price and Rind (1994)
Grenfell et al. (ACP, 2003),
Shindell et al. (ACP, 2006)

December - February El Niño Conditions

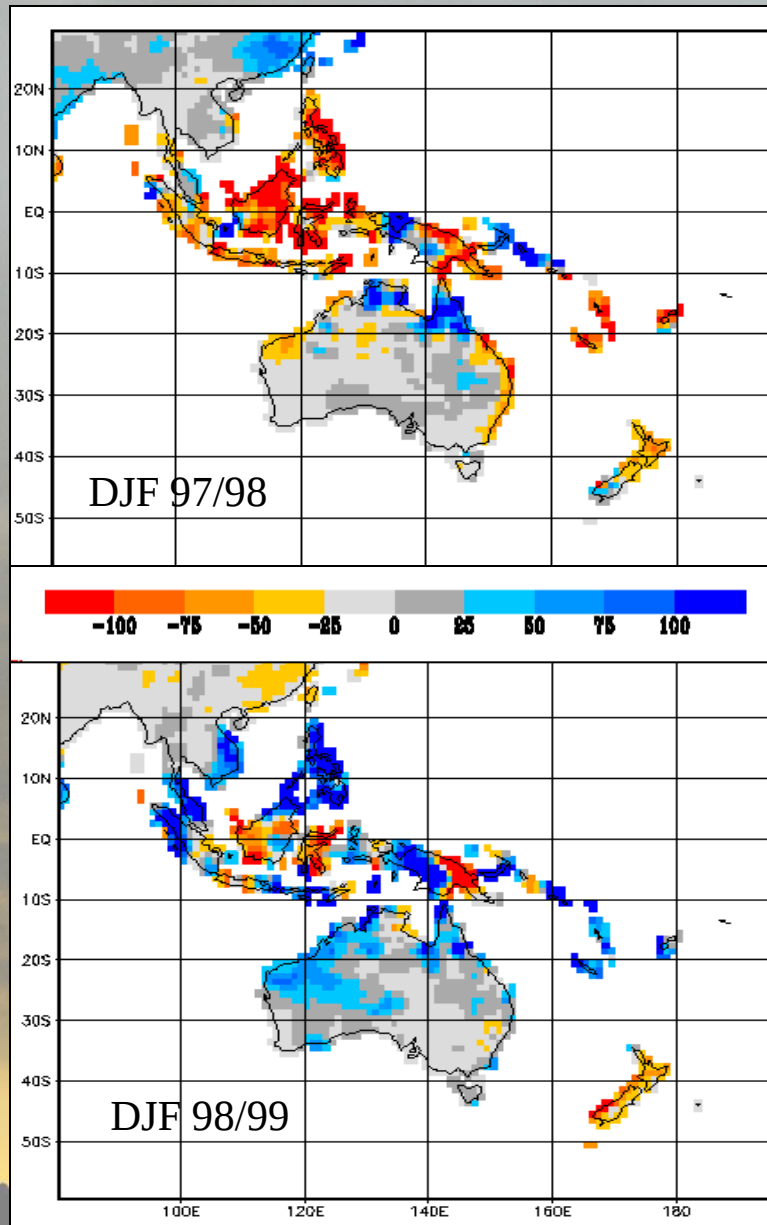


The El Niño-Southern Oscillation (ENSO)

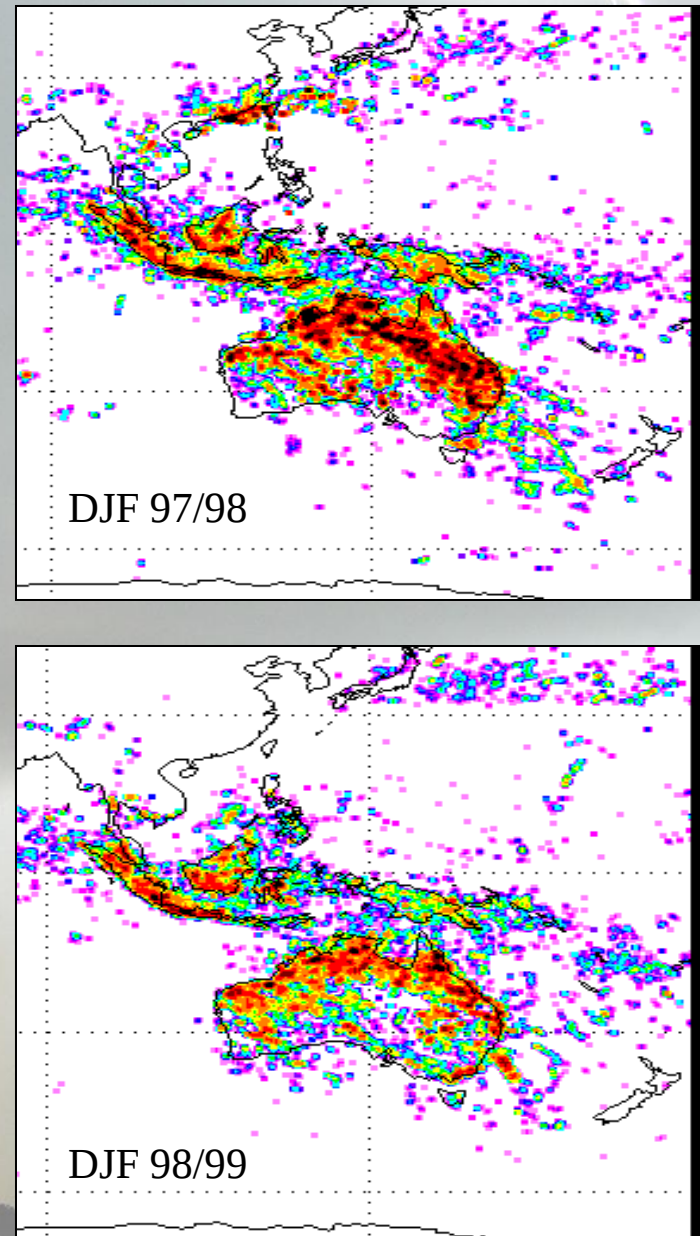
Precipitation Anomaly

OTD Lightning

El Nino

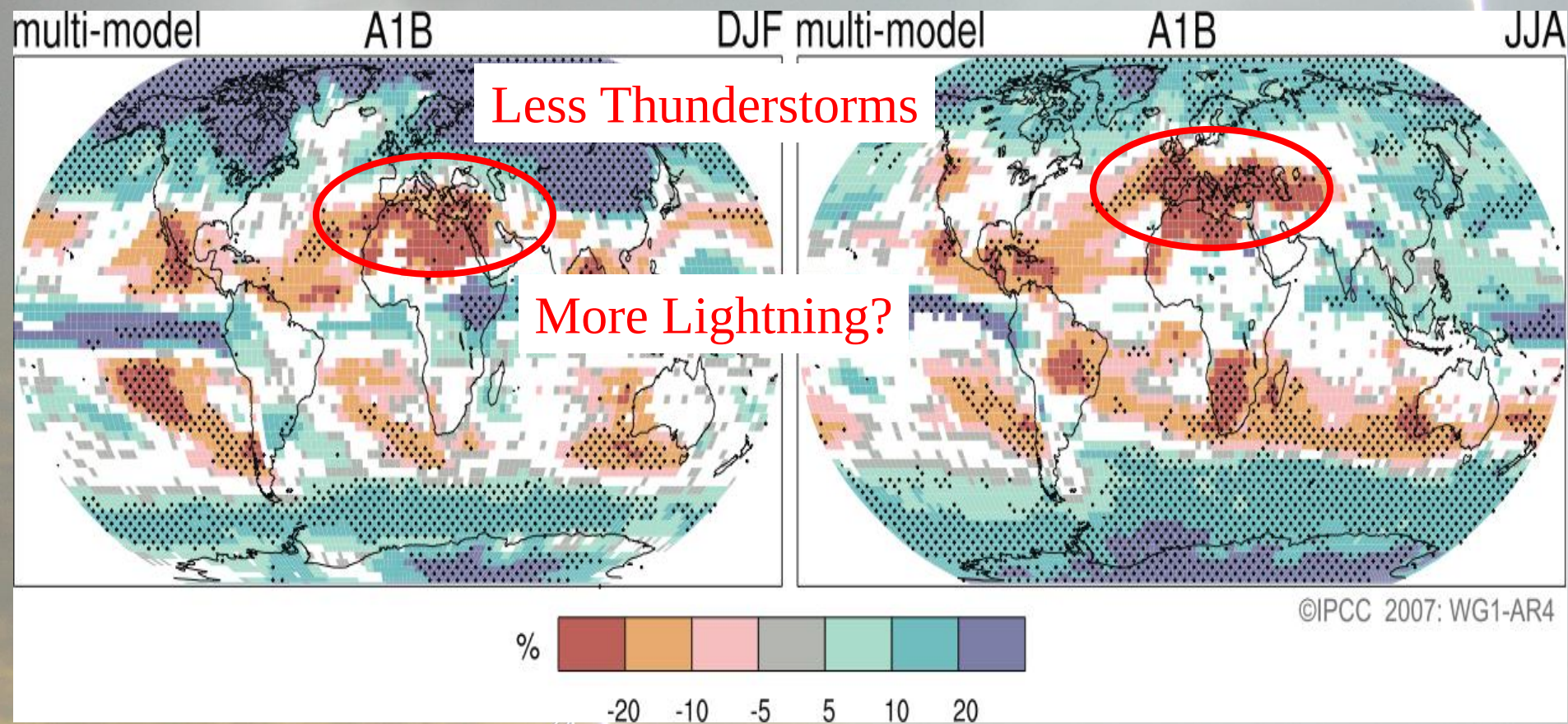


La Nina



+57%

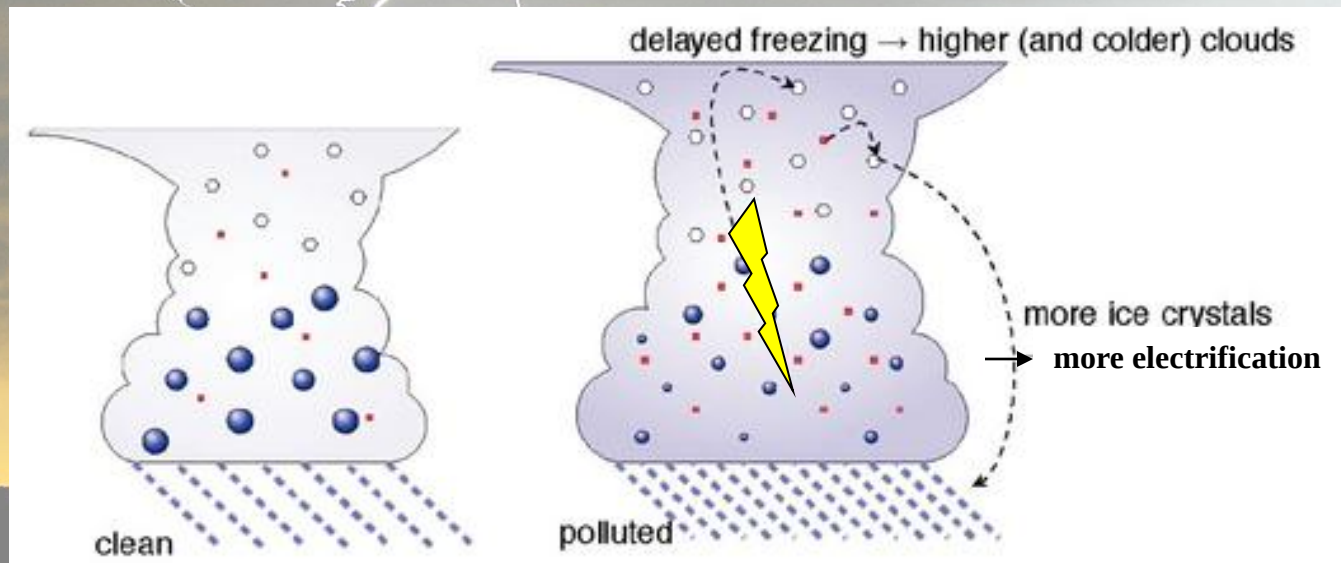
What is predicted for rainfall in the future?



Changes in Precipitation (%) by 2099

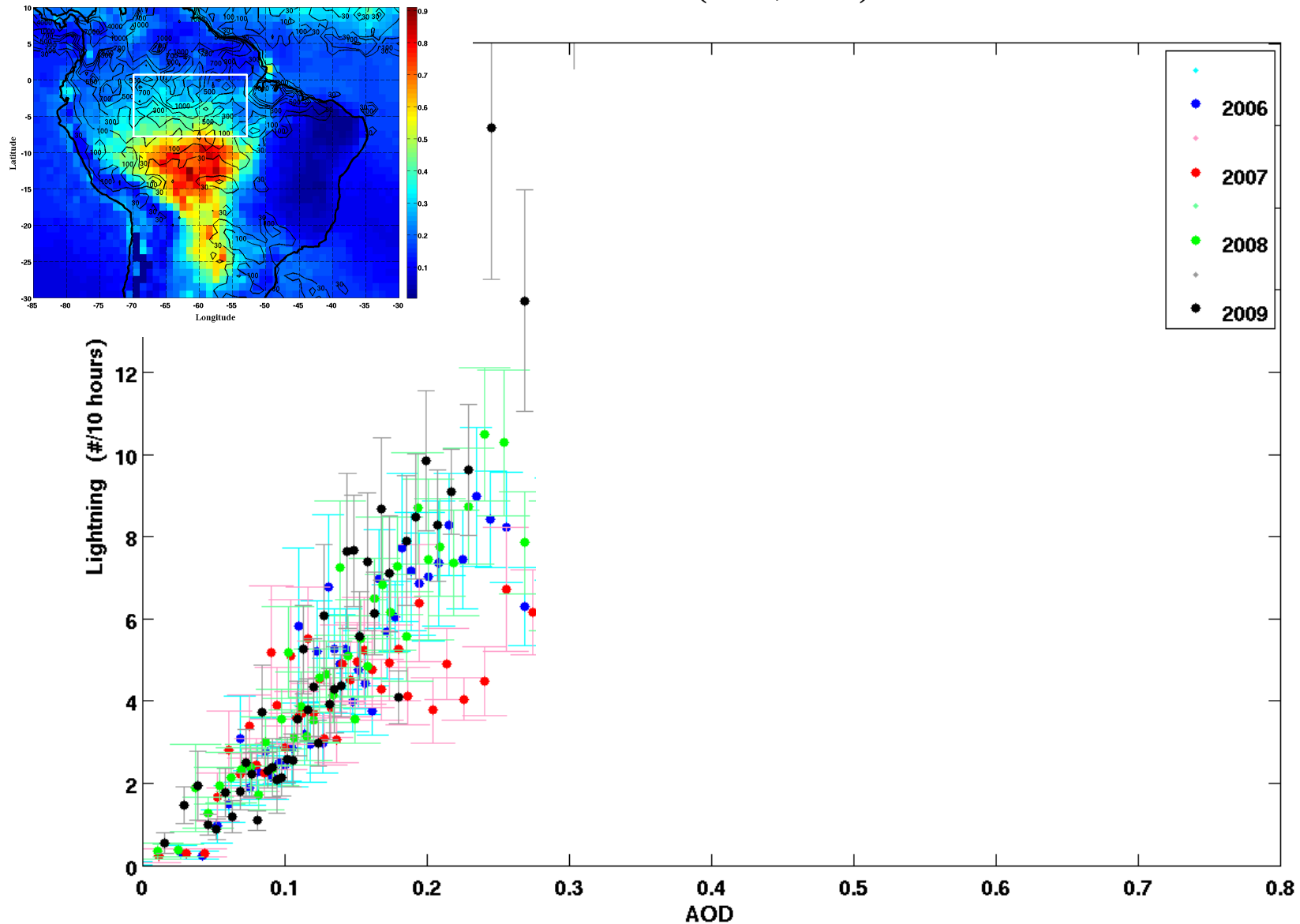
What about aerosols?

- ✓ 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)

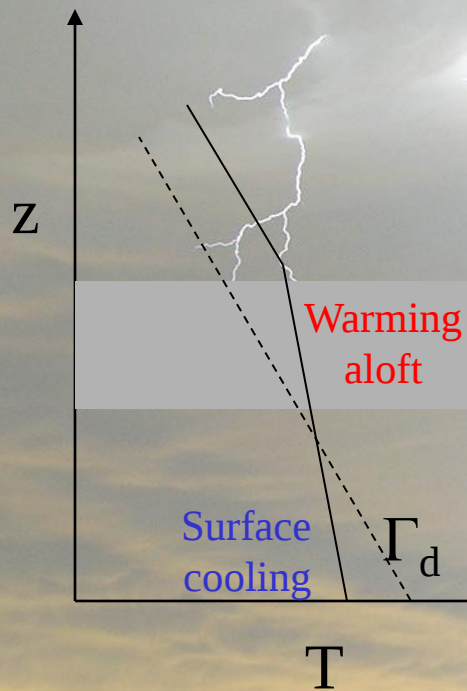


How does increasing aerosol loading impact lightning?

Altaratz et al (2010, GRL)



Too many aerosols stabilize the atmosphere

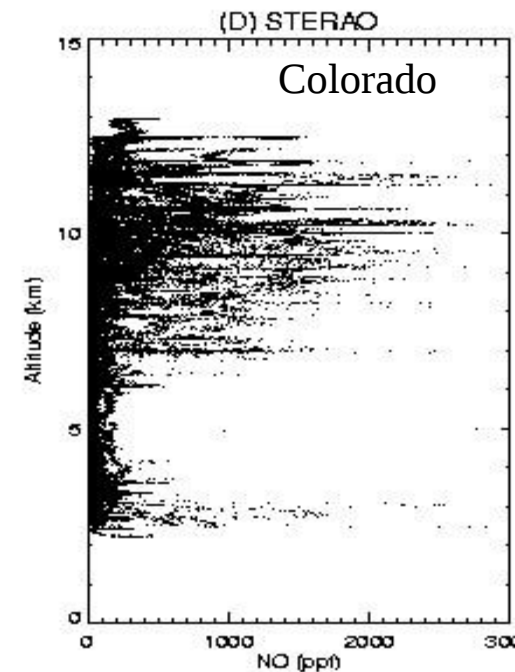
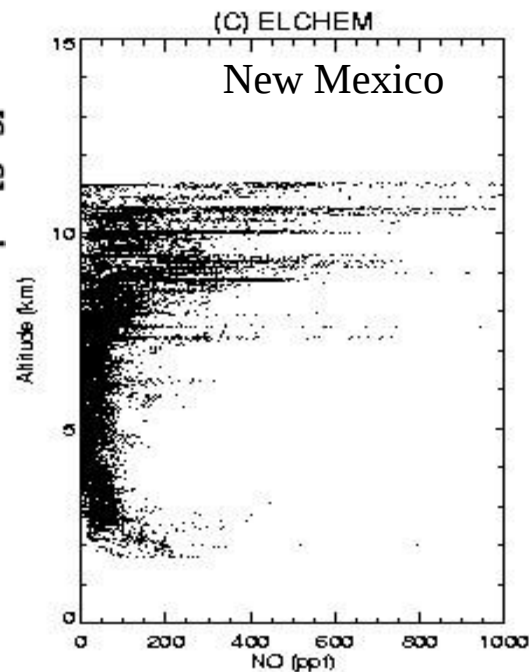
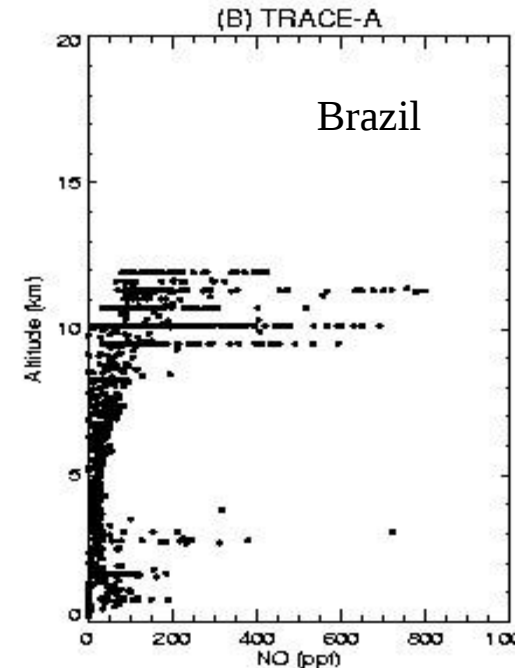
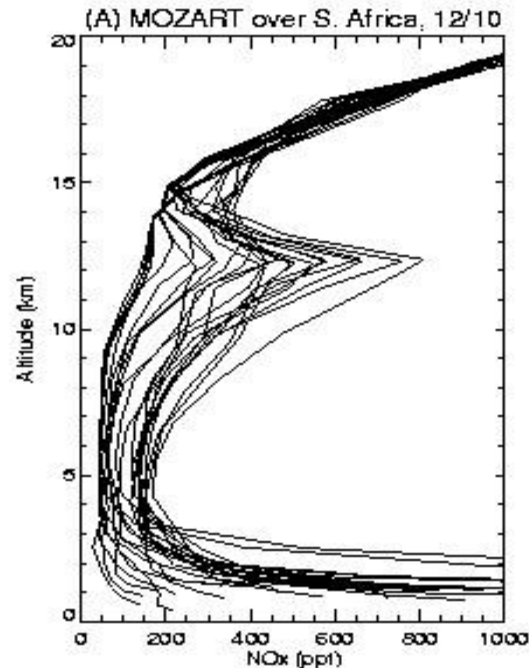
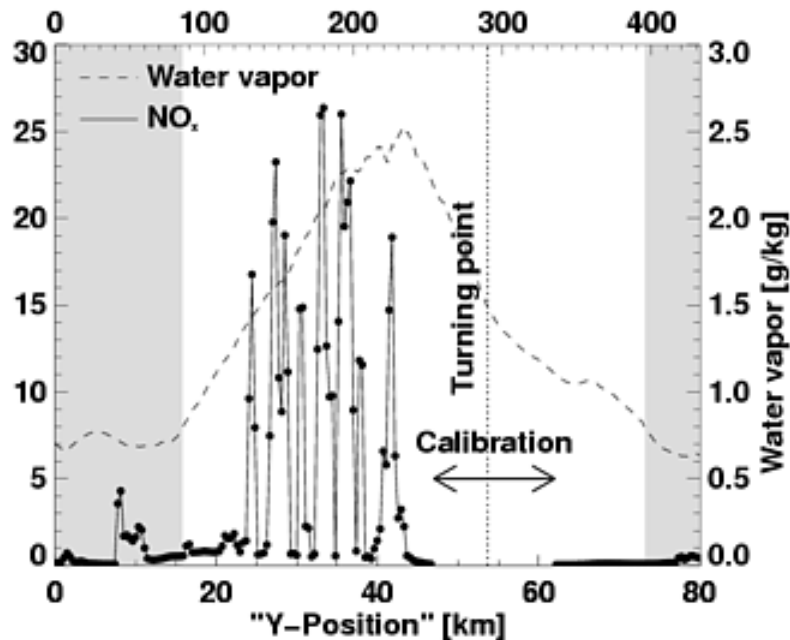


Is Lightning Important for Climate Change?

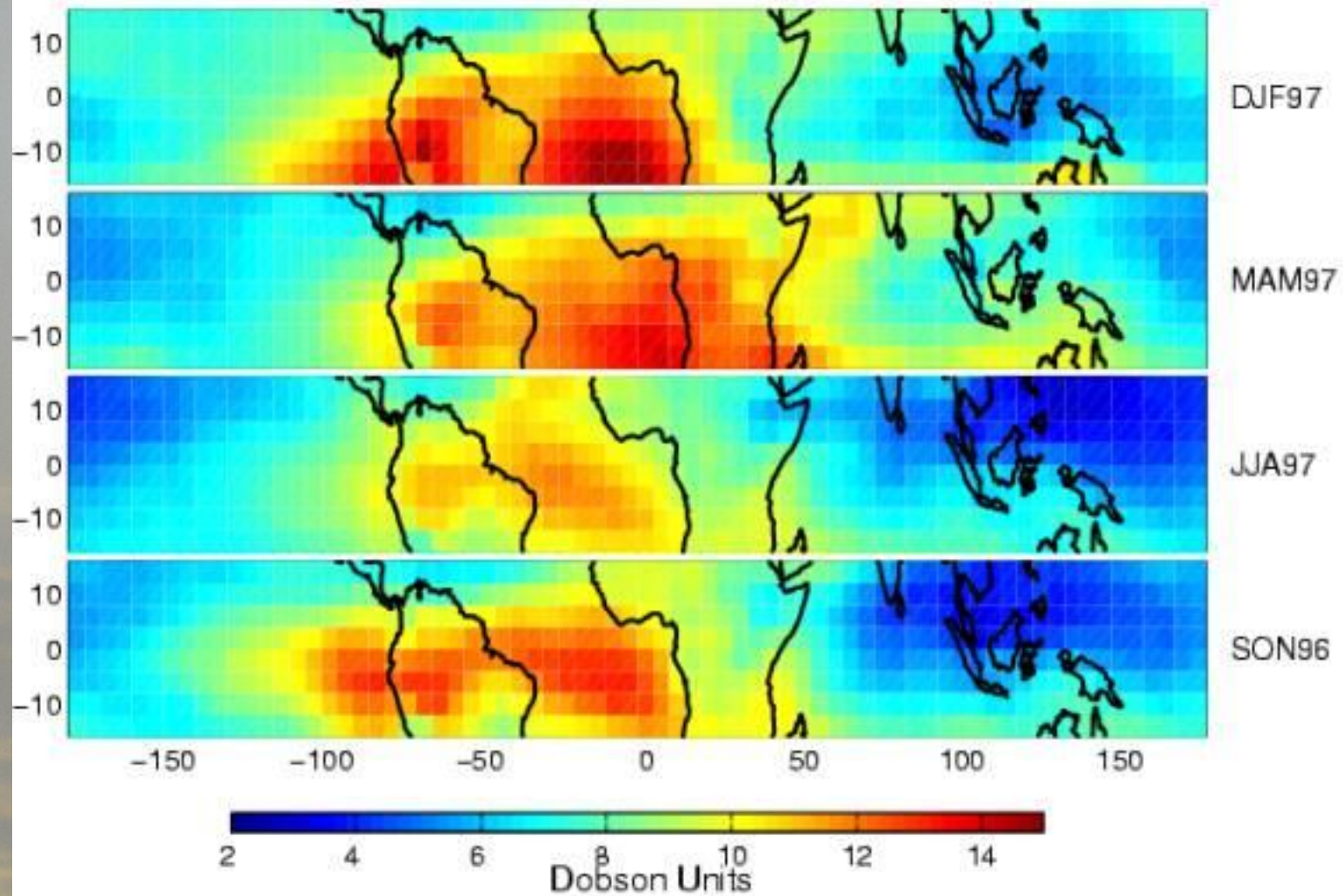
Tropospheric Chemistry

NO_x

flight time [s]



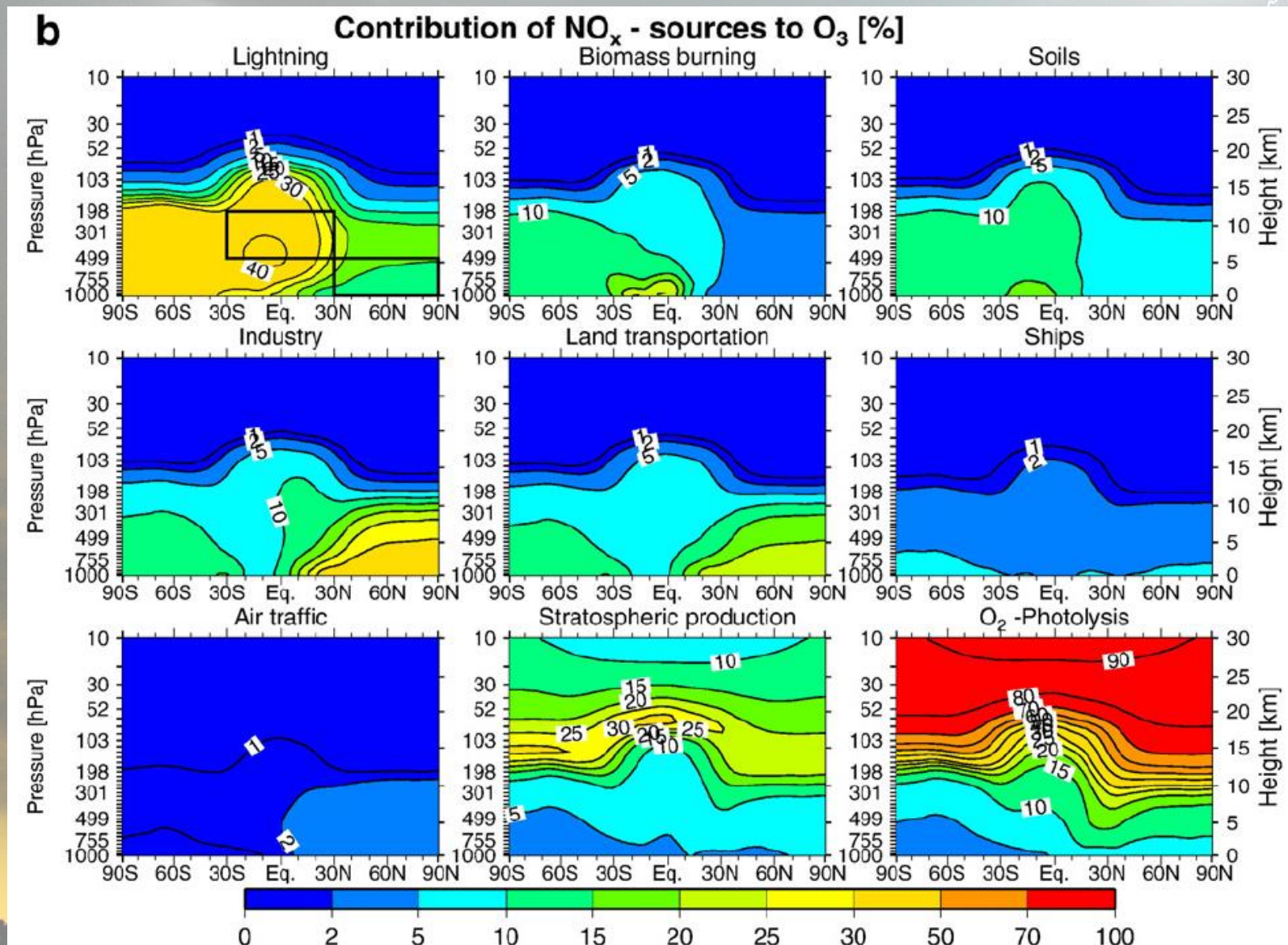
Ozone enhancement from lightning



Martin et al. (2001)

Huntrieser et al., (ACP, 2007)
Schumann and Huntrieser, (ACP, 2007)

Impact of various sources on **ozone** simulated with the climate-chemistry model E39/C for the period 1990-1999

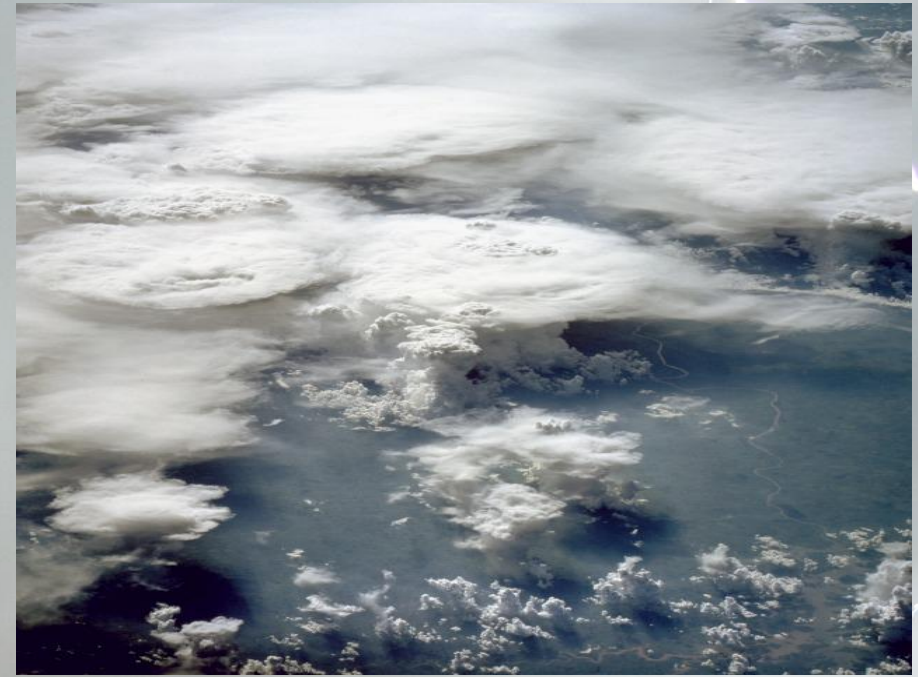
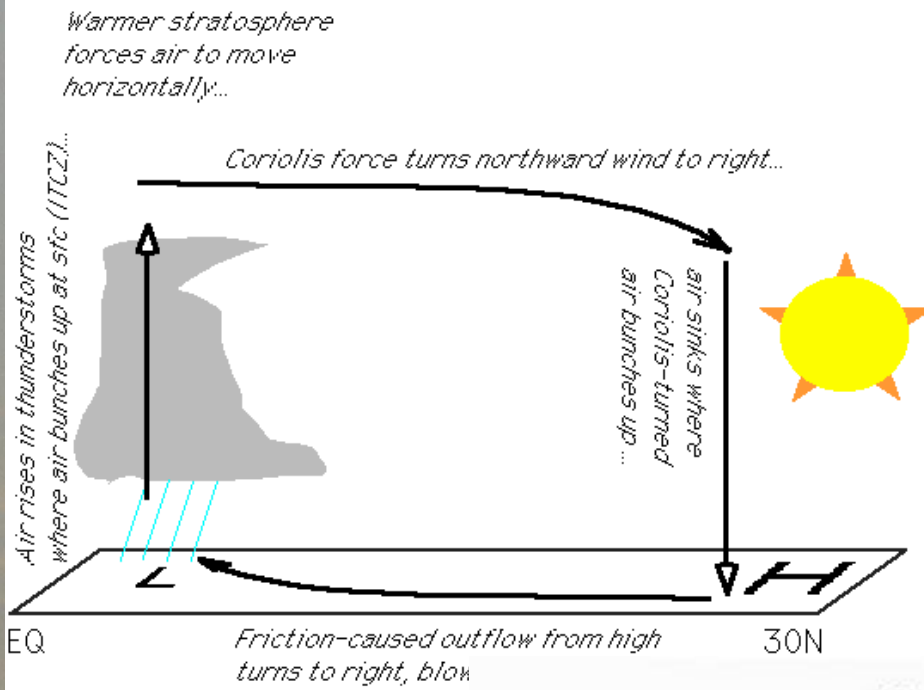


Lightning most important in tropical and SH regions.

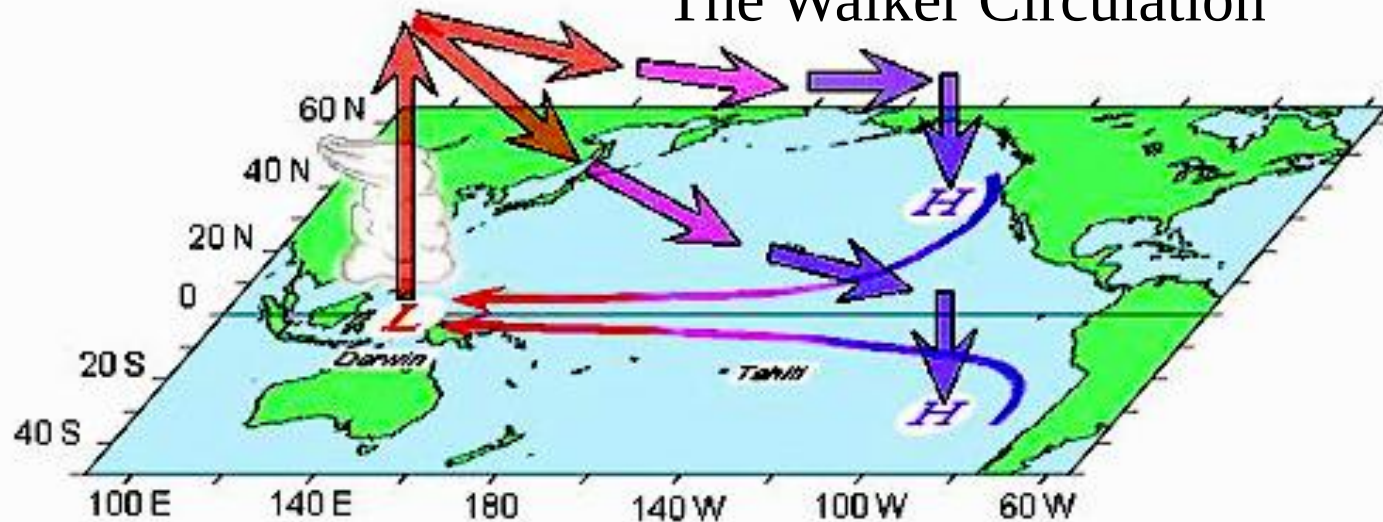
(Grewe, 2007)

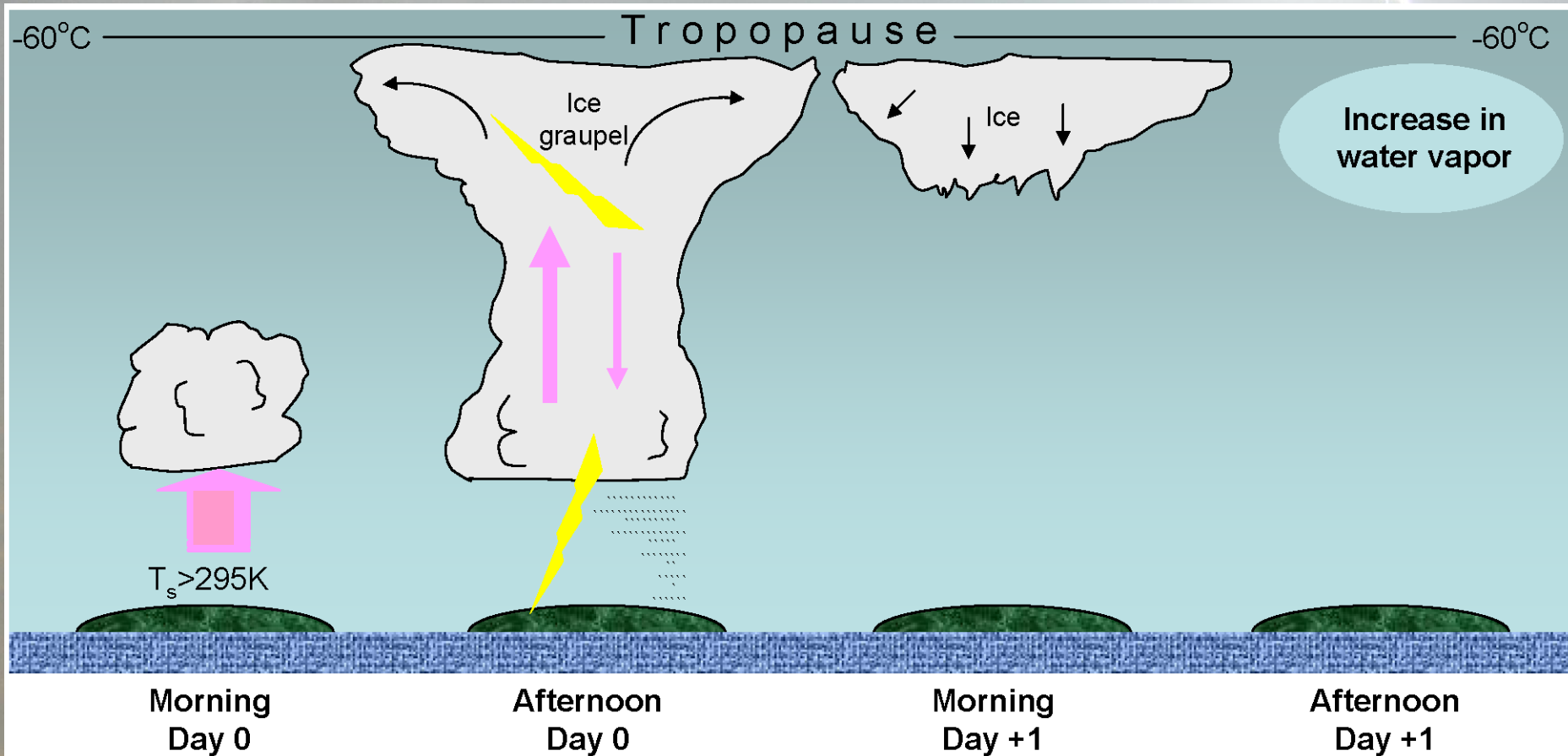
Lightning as a tool to study the Climate

The Hadley Circulation



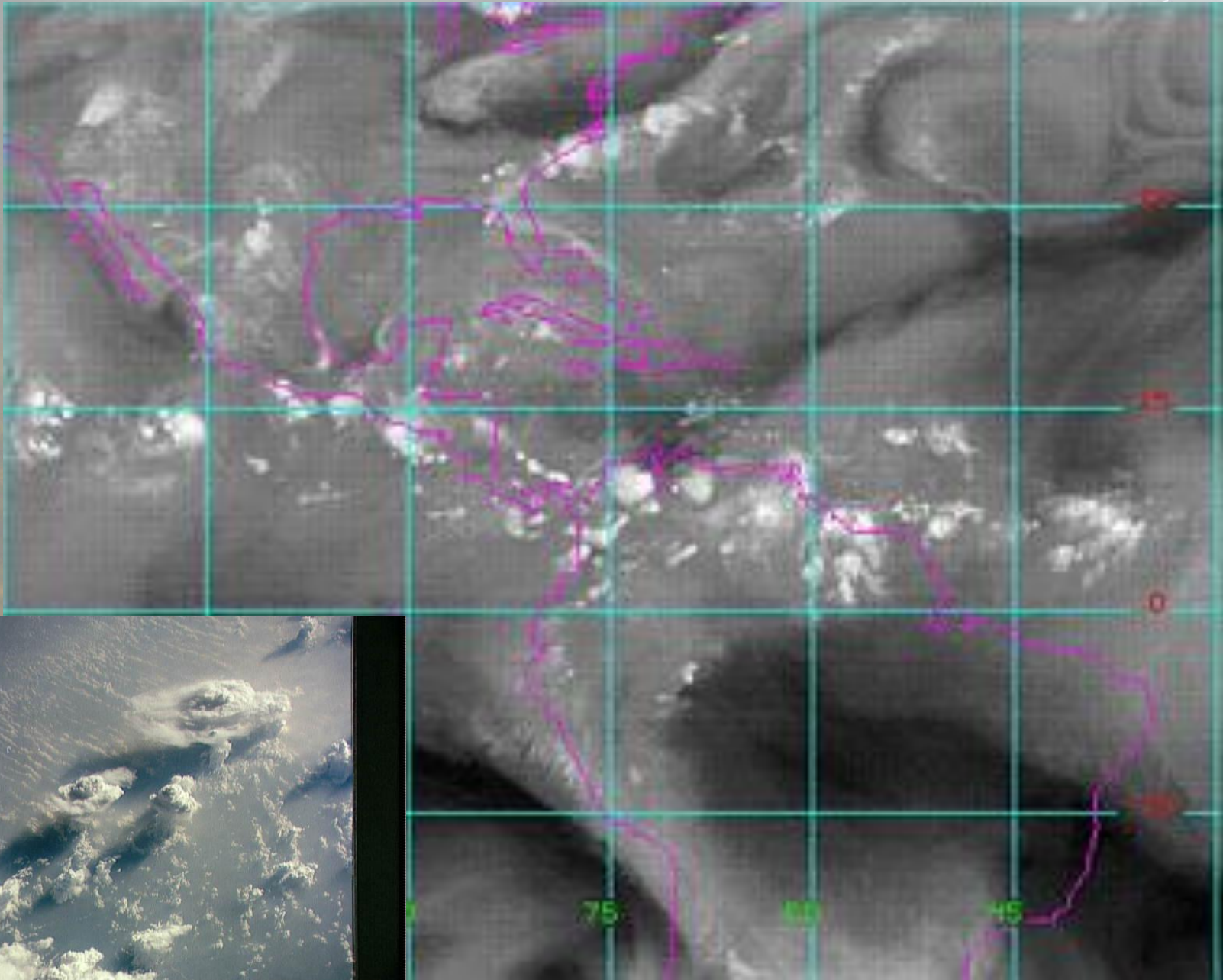
The Walker Circulation





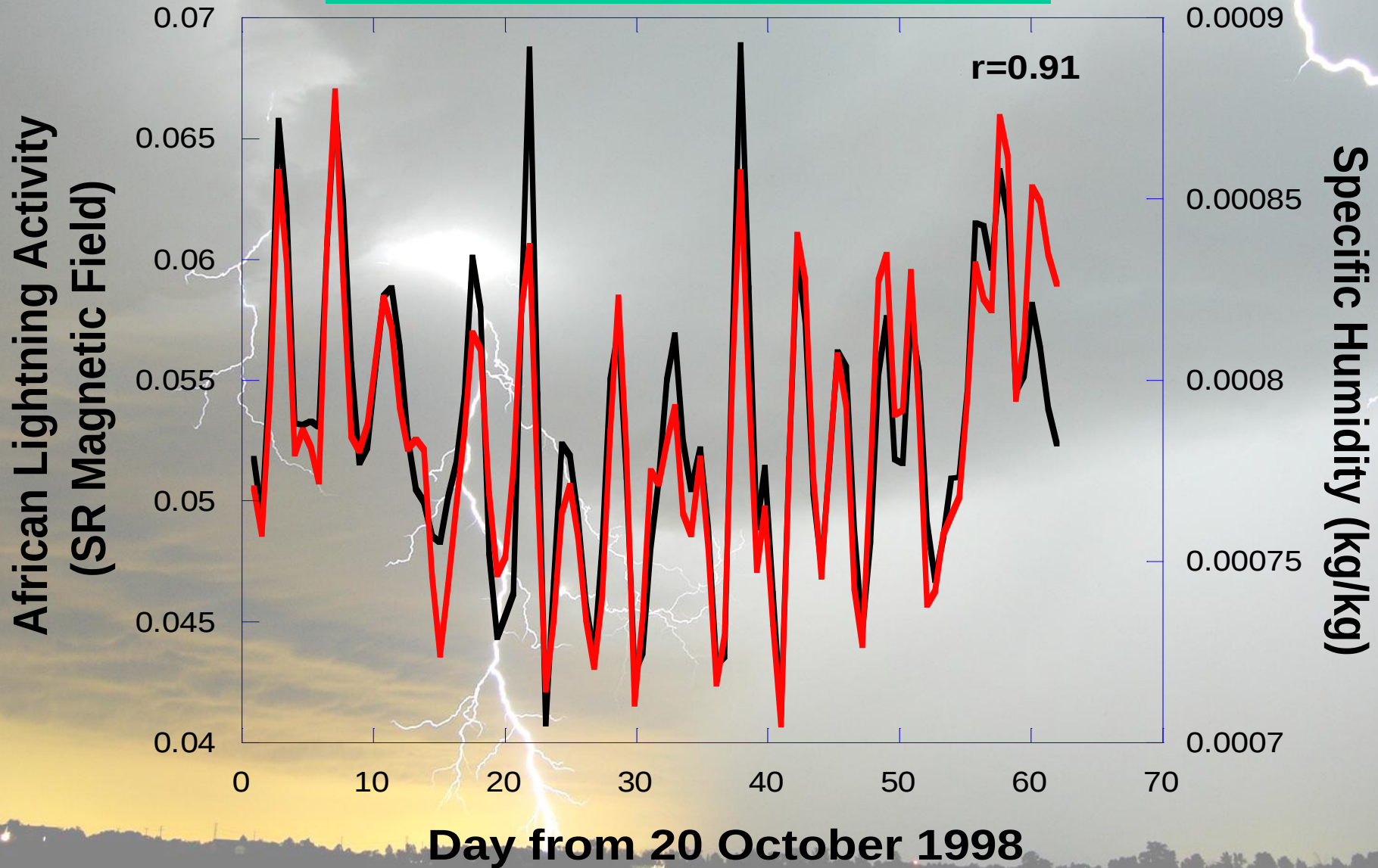
Lightning – UTWV (Price and Asfur, BAMS 2006)
Lightning – Clouds (Sato and Fukunishi, GRL 2005)
Lightning – Ice Crystal size (Sherwood et al., GRL 2006)
Lightning – Ice Water Path (Petersen et al., GRL 2005)

Upper Tropospheric Water Vapour

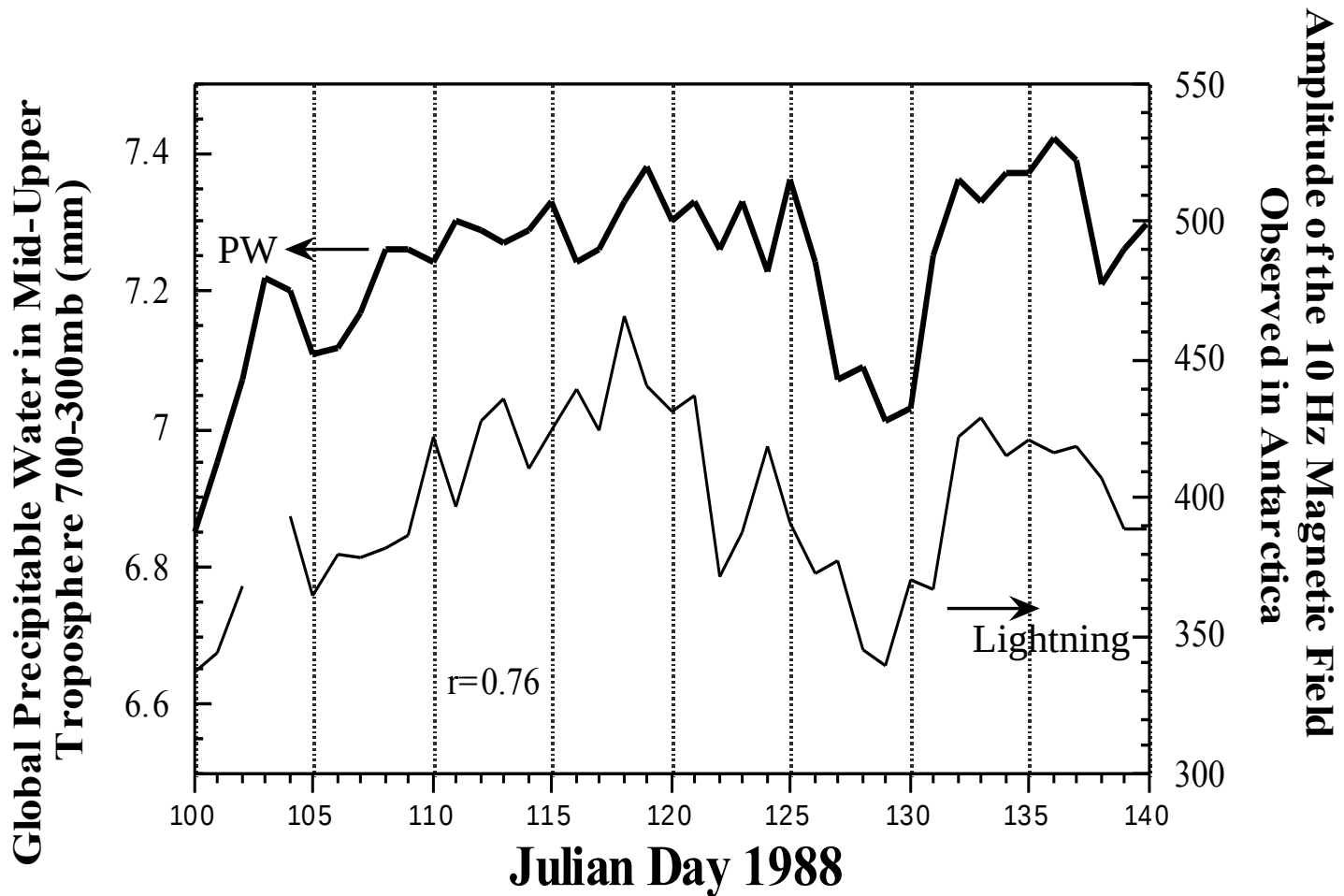


Lightning Activity vs. Specific Humidity (300mb) +24hours

26% SR change $\Rightarrow$ 0.1 g/kg change



Global Precipitable Water in the Mid-upper Troposphere Together with Global ELF (lightning) activity



Summary and Conclusions

