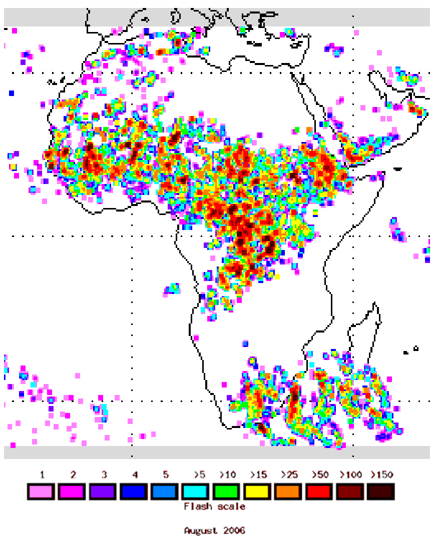
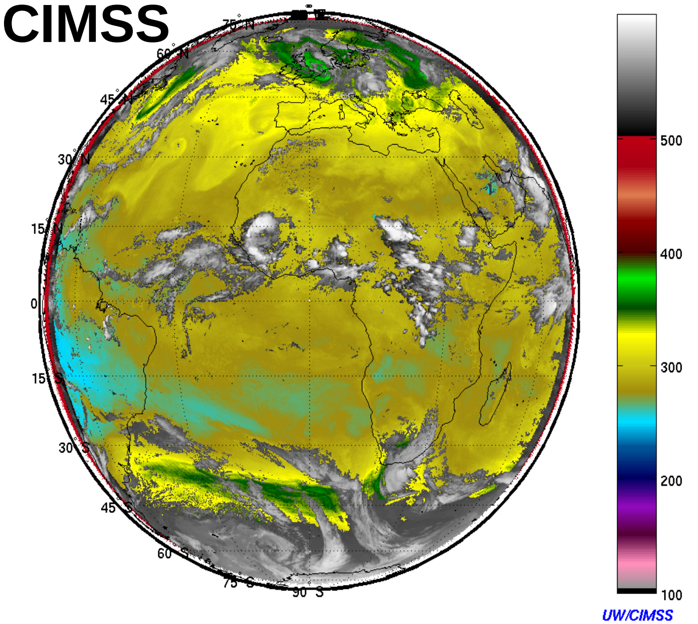
Impact of Lightning NOx on Assimilation of SEVIRI Total Column Ozone

Brad Pierce
NOAA/NESDIS/STAR at CIMSS

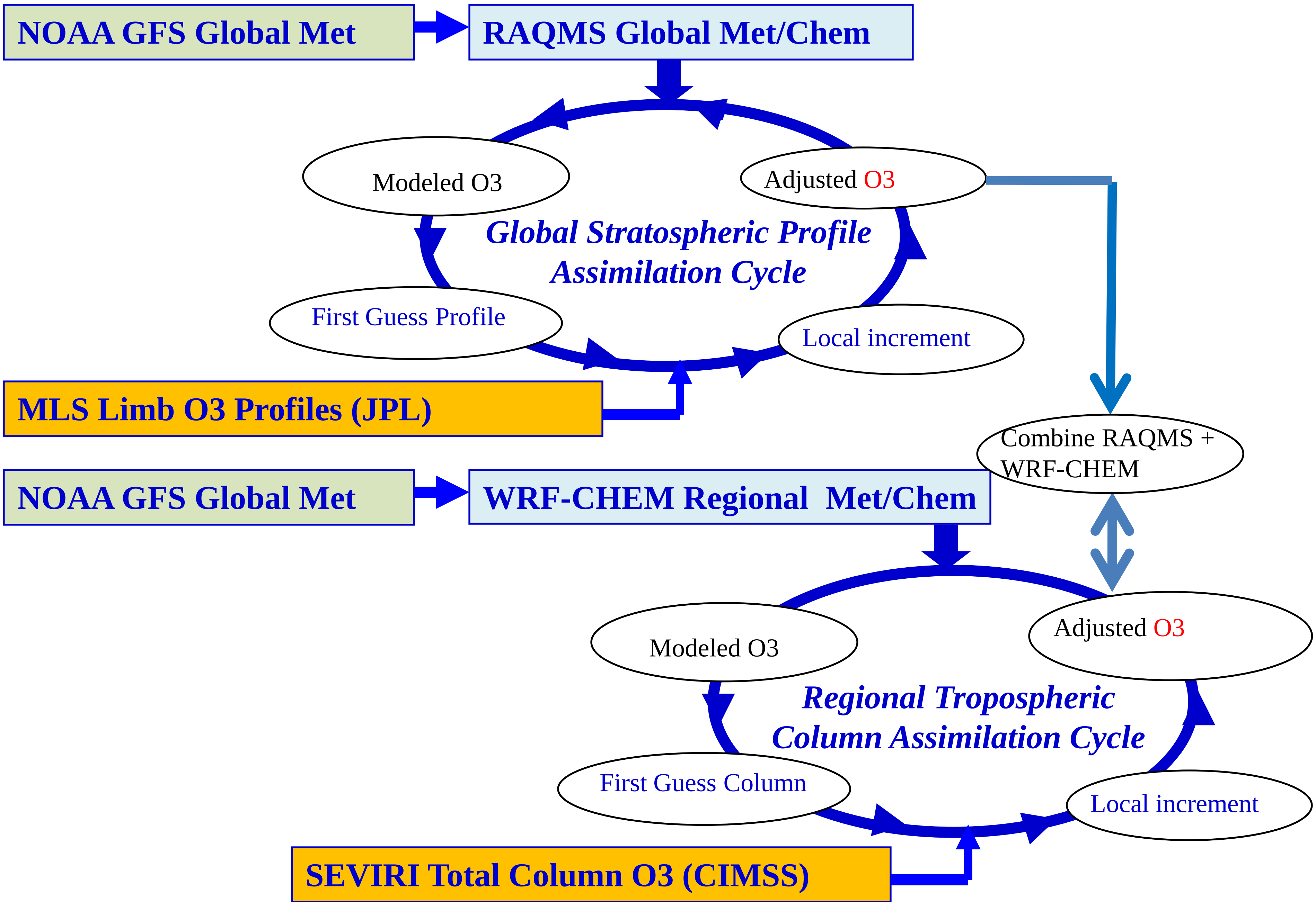


Lightning Imaging Sensor (LIS) August 2006 Flash Rate

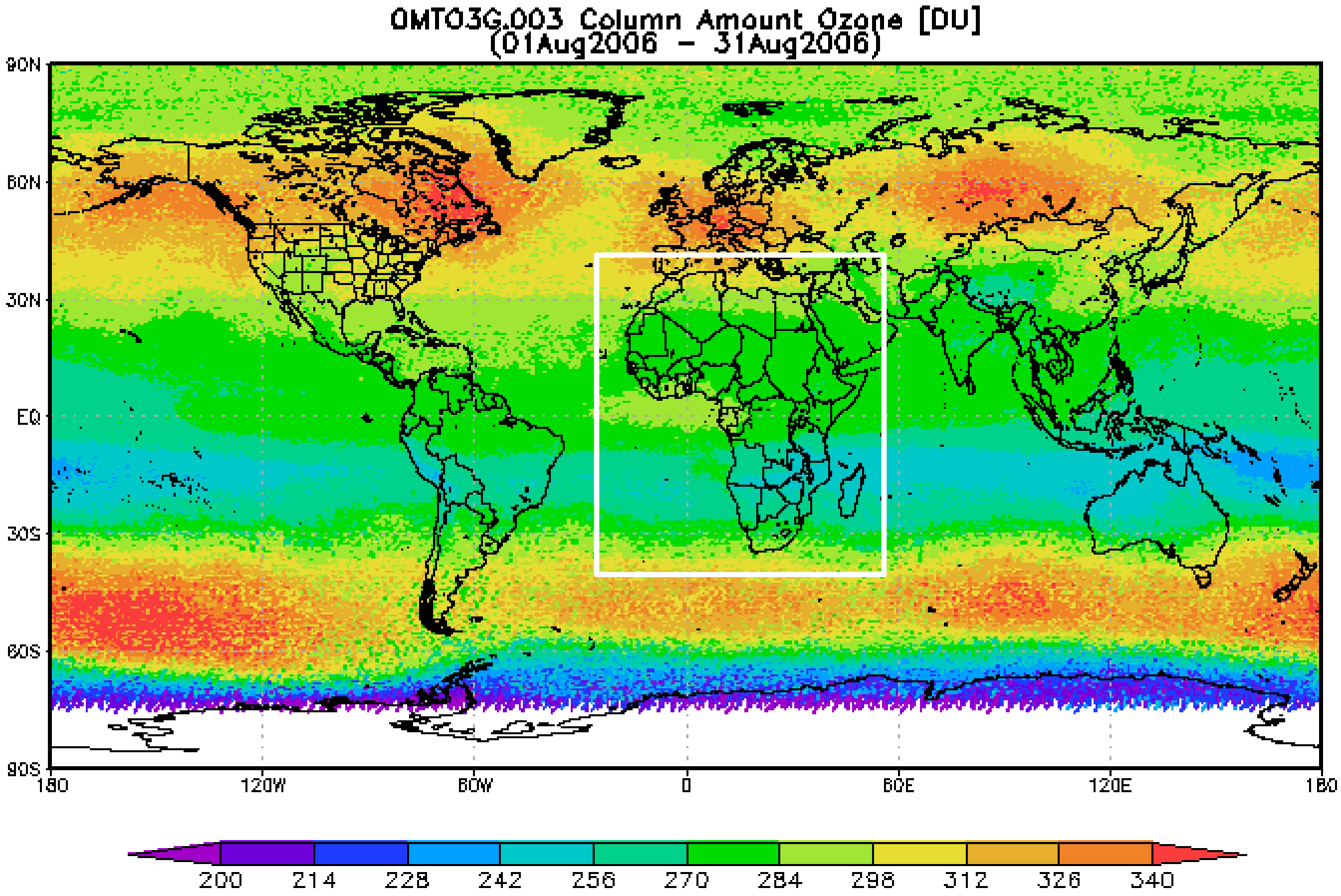


August 1st 2006 SEVIRI 18Z TCO retrieval

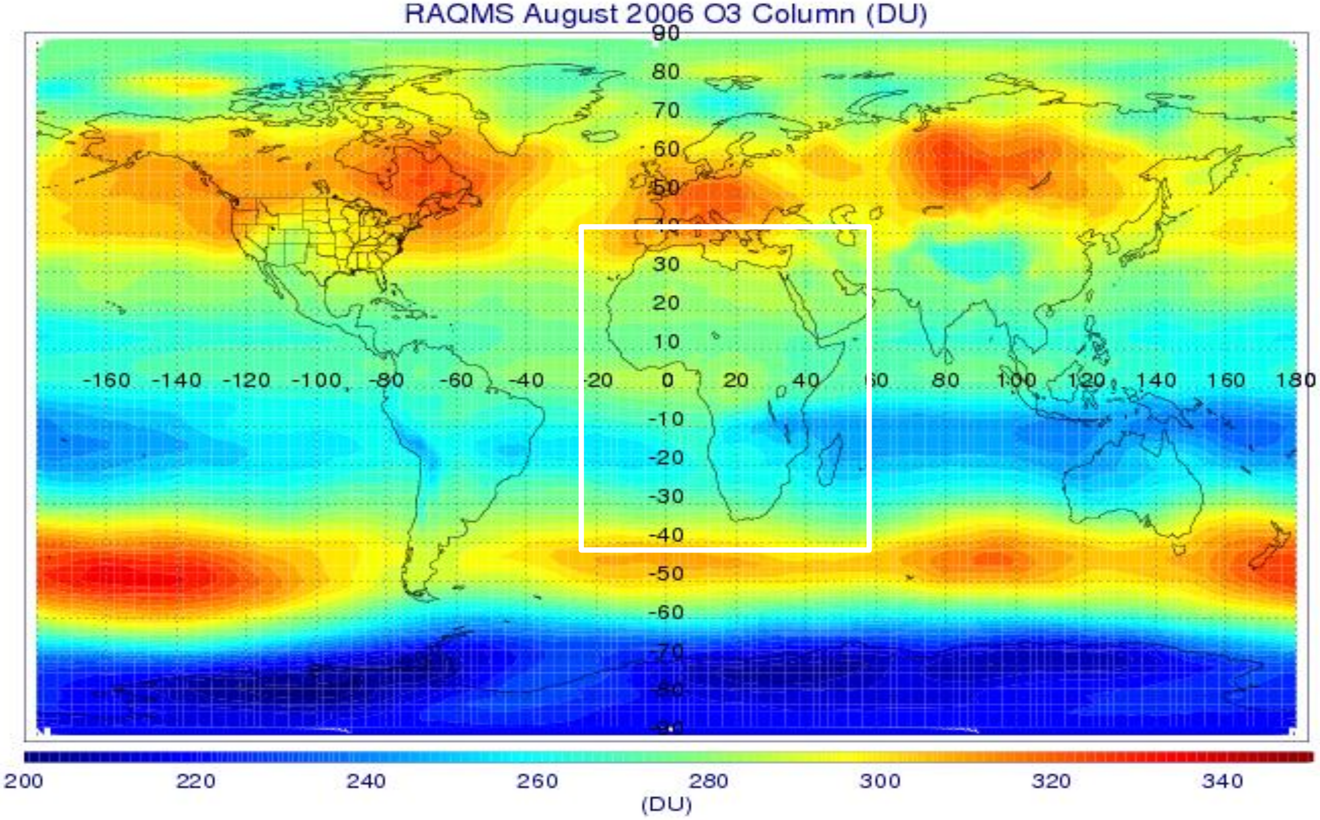
RAQMS MLS/WRF-CHEM SEVIRI O3 Assimilation Procedure



August 2006 Total Ozone Column (NASA Aura OMI Observations)



August 2006 Total Ozone Column (RAQMS MLS 12Z Analysis)

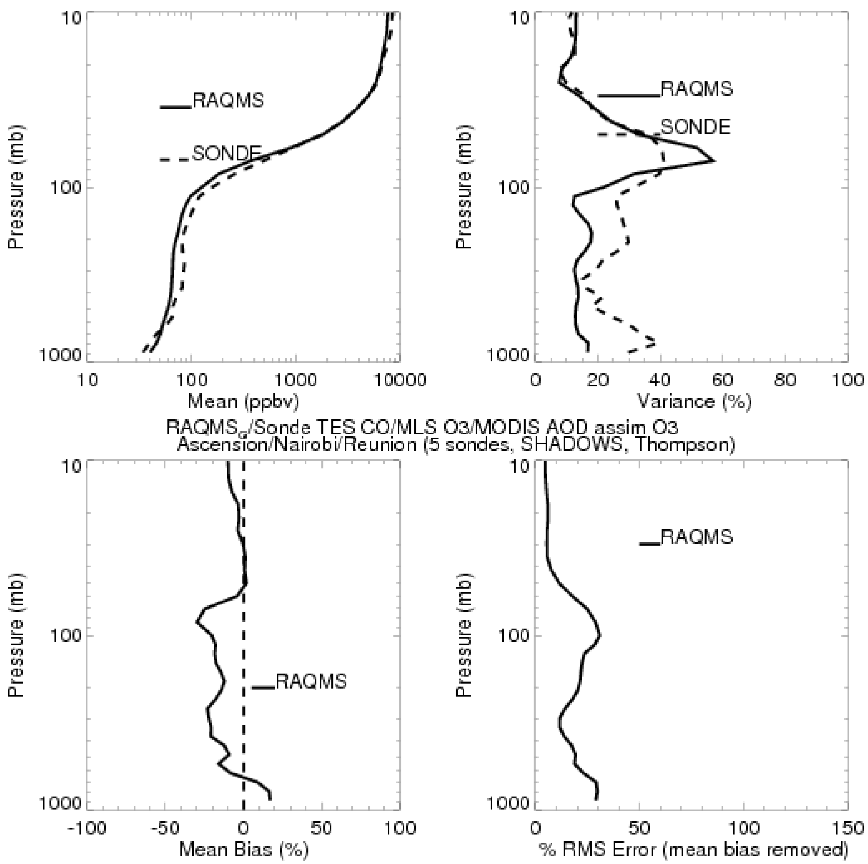


RAQMS MLS & WRF-CHEM SEVIRI Analysis

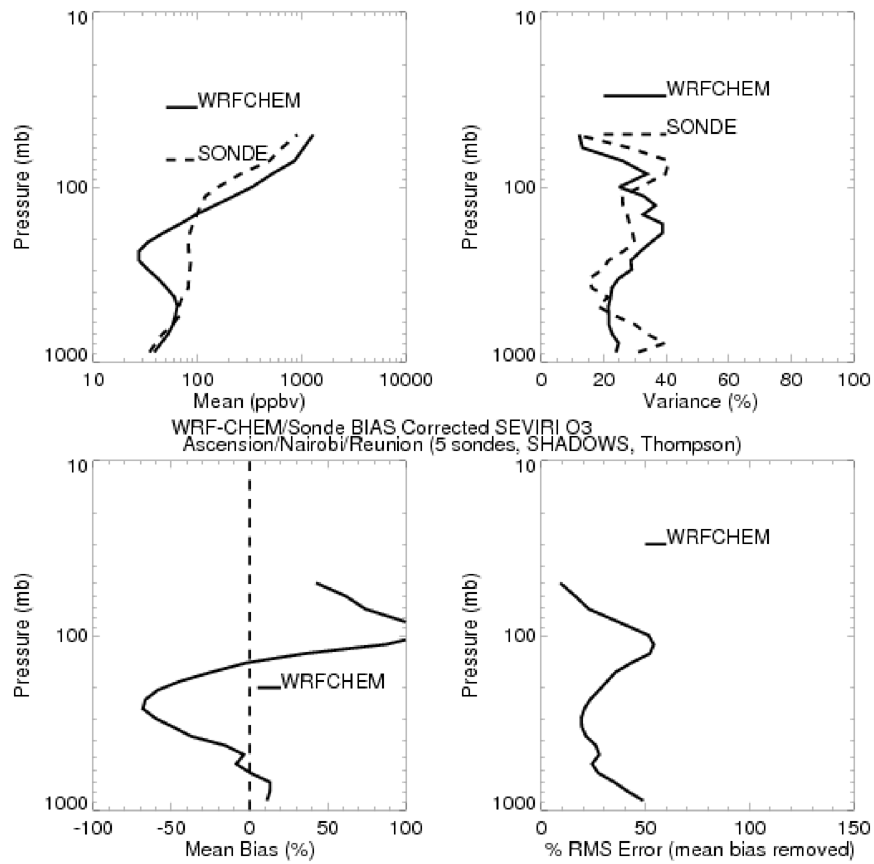
vs

SHADOWS ozonesonde data

RAQMS MLS Analysis

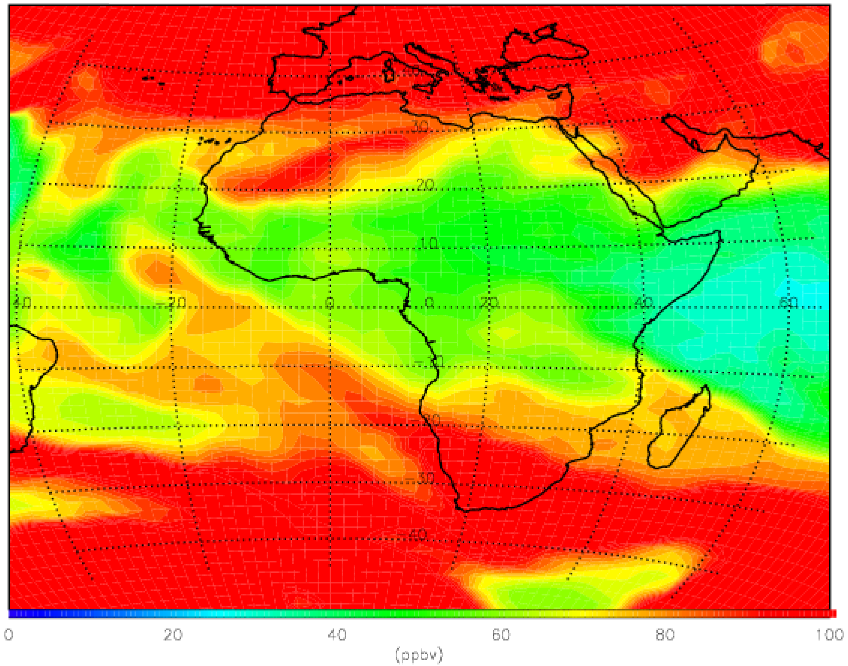


WRF-CHEM SEVIRI Analysis

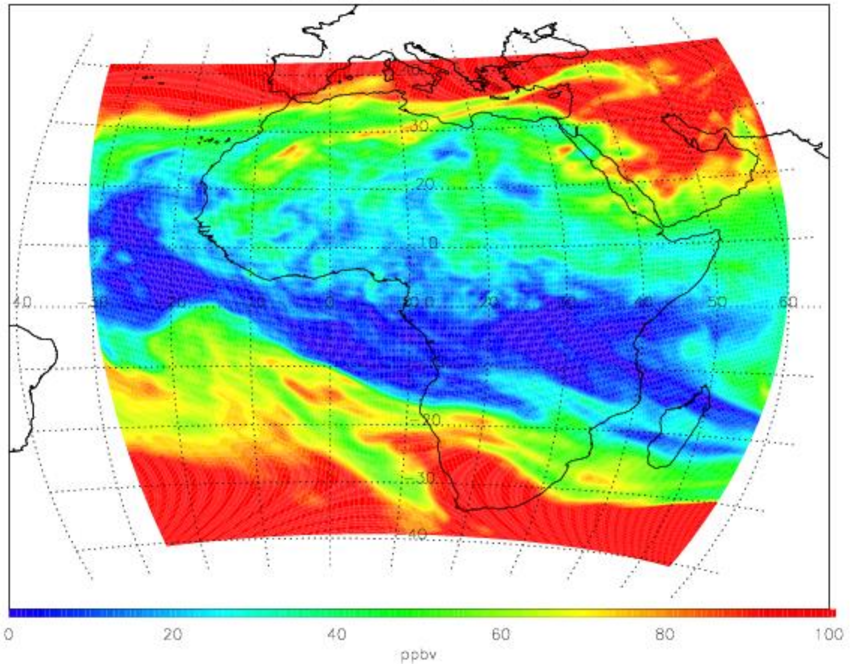


RAQMS and WRF-CHEM 200mb O3
18Z August 23, 2006

RAQMS 200mb O3
(2006-08-23, 18Z)



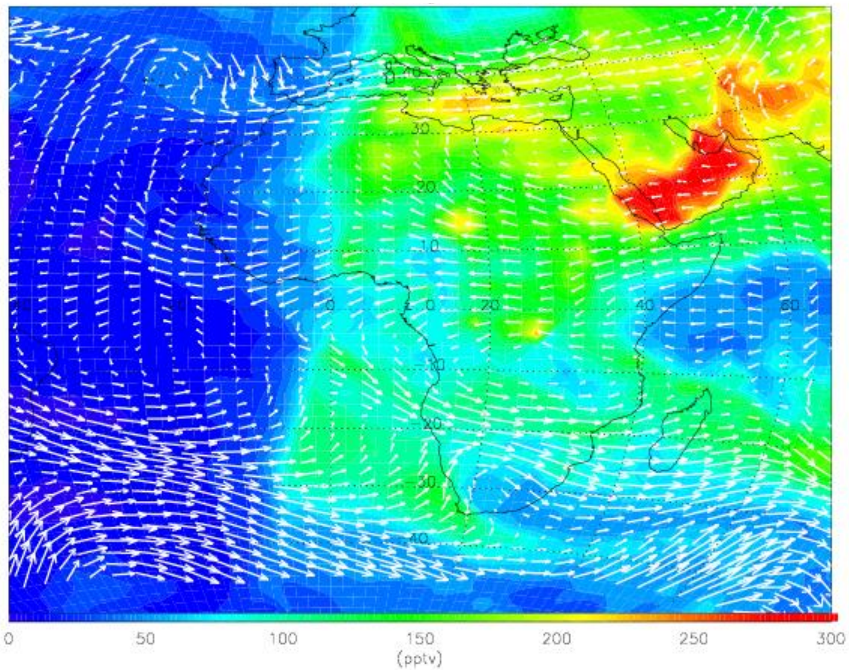
WRF-CHEM 200mb O3
(2006-08-23, 18Z)



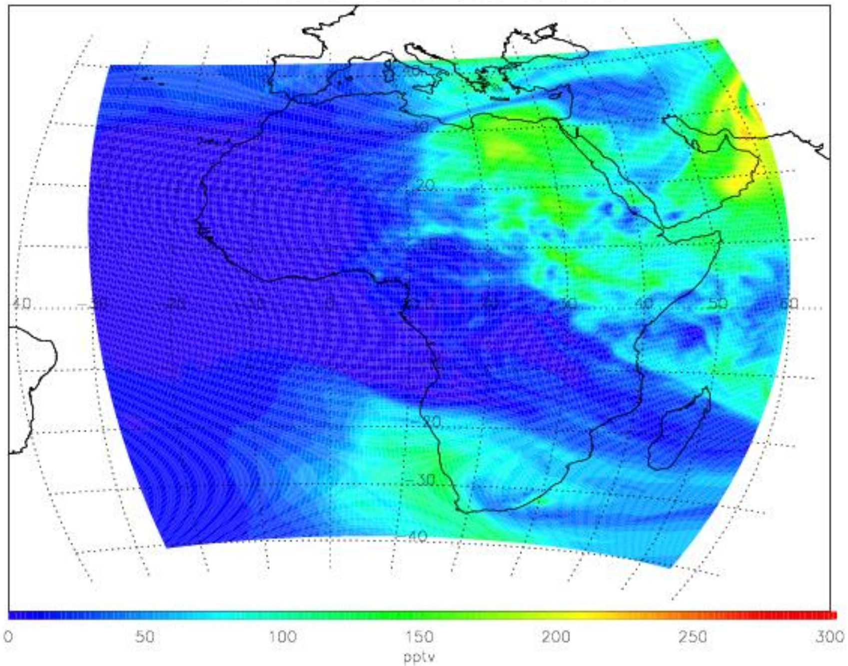
Lack of upper tropospheric ozone production down wind from Lightning NOx emissions leads to underestimates in WRF-CHEM upper tropospheric ozone over Equatorial and Southern Africa.

RAQMS and WRF-CHEM 200mb NO2
18Z August 23, 2006

RAQMS 200mb NO2
(2006-08-23, 18Z)

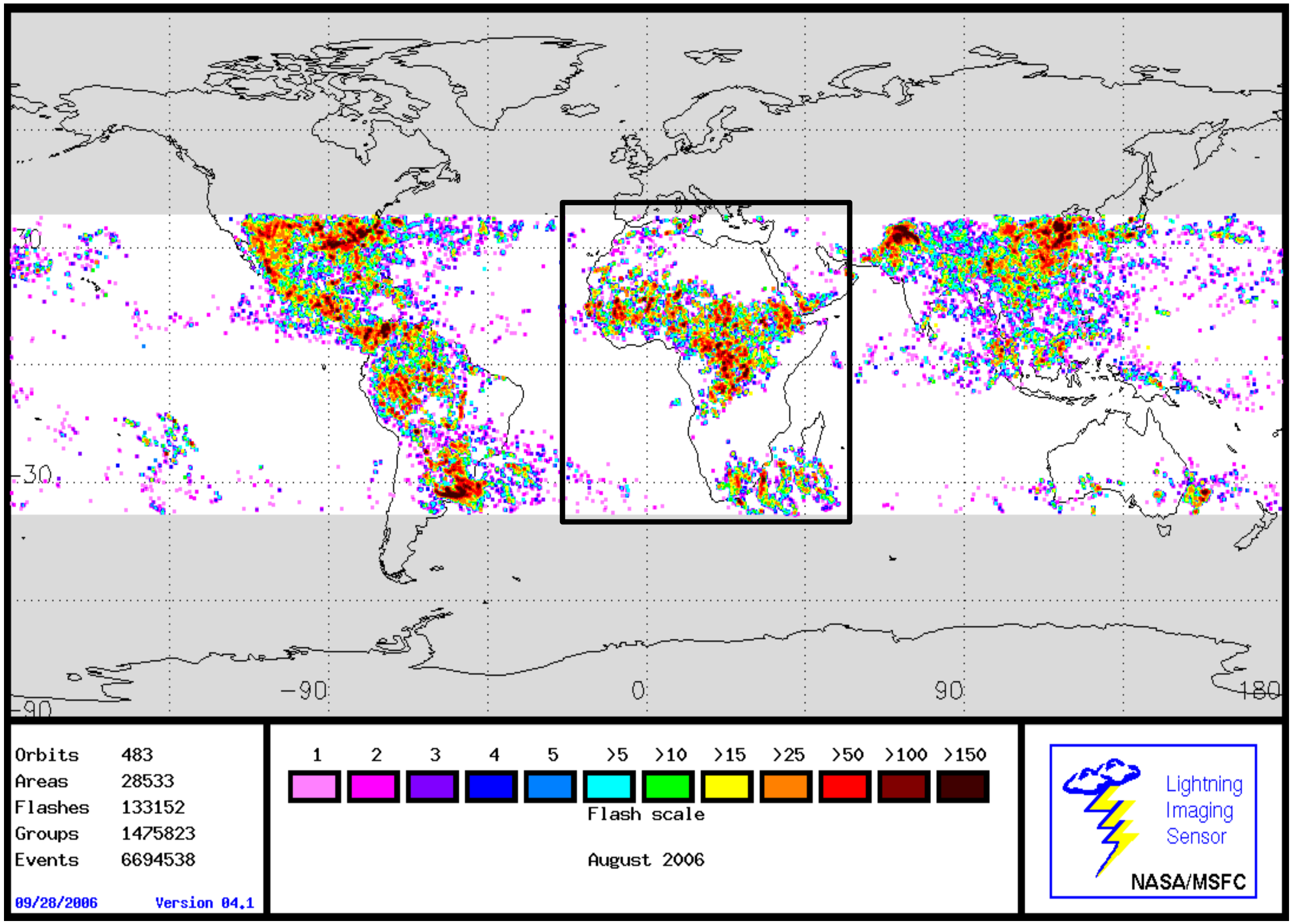


WRF-CHEM 200mb NO2
(2006-08-23, 18Z)

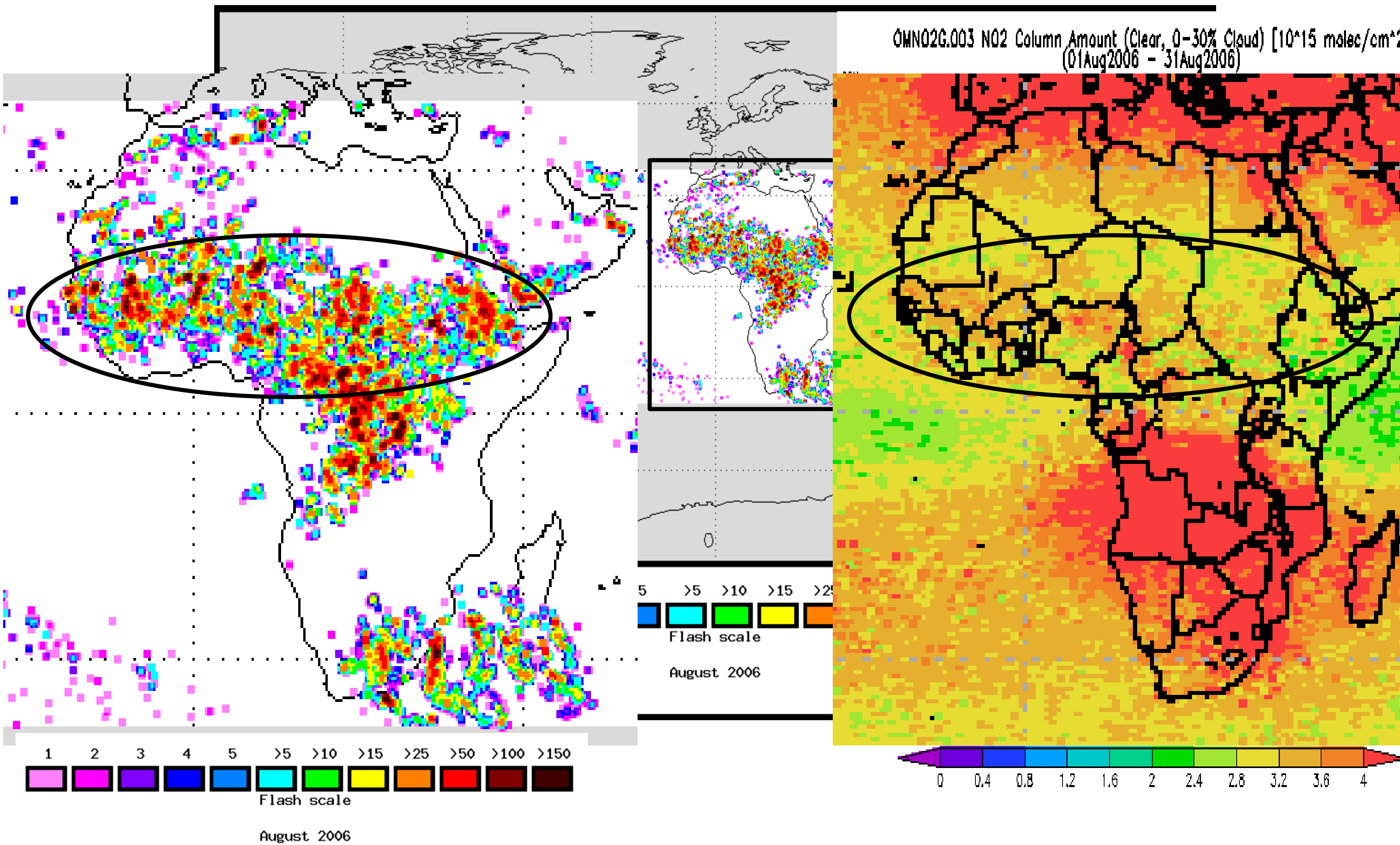


Down wind transport of Lightning induced NO2 significantly impacts South African upper troposphere (including Niarobi and Reunion ozonesondes)

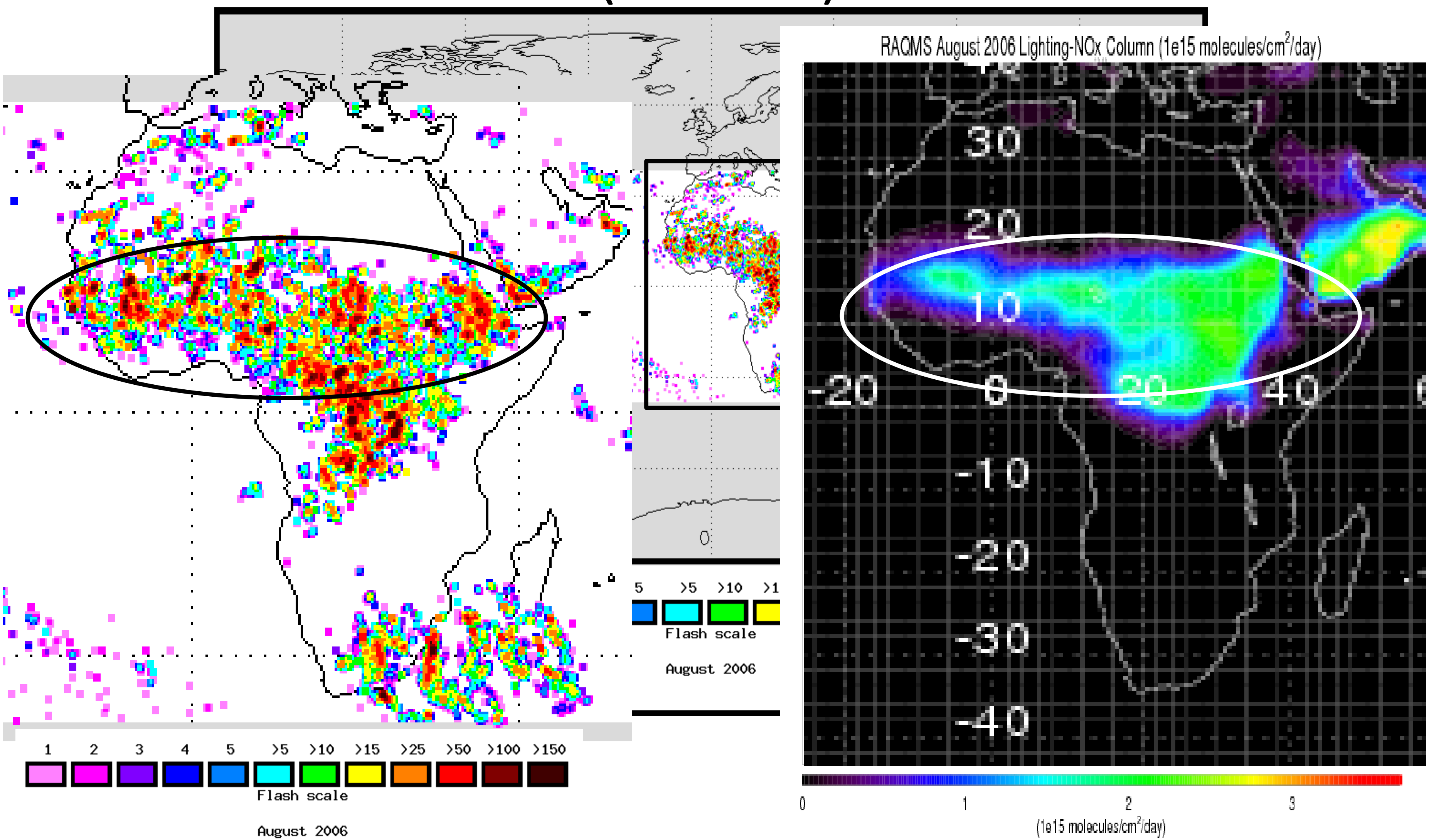
August 2006 Flash Rate
From NASA Lightning Imaging Sensor (LIS)



August 2006 NO2 Column
From NASA Ozone Monitoring Instrument (OMI)



August 2006 Lightning NOx Production From Realtime Air Quality Modeling System (RAQMS)



Column NO Lightning Source

(flash rate)*(cgnox*fcg+ccnox*(1.-fcg))

Where the fraction of cloud to ground (fcg) is dependent on the convective cloud depth (dz):

fcg = 1./(A*dz4+B*dz**3+C*dz**2+D*dz+E+1)**

With:

A= 0.021, B = -0.648, C = 7.493, D = -36.540, E = 63.090)

and:

cgnox = 6.7e26 molecules NO/cloud to ground flash
ccnox = 6.7e25 molecules NO/cloud to cloud flash

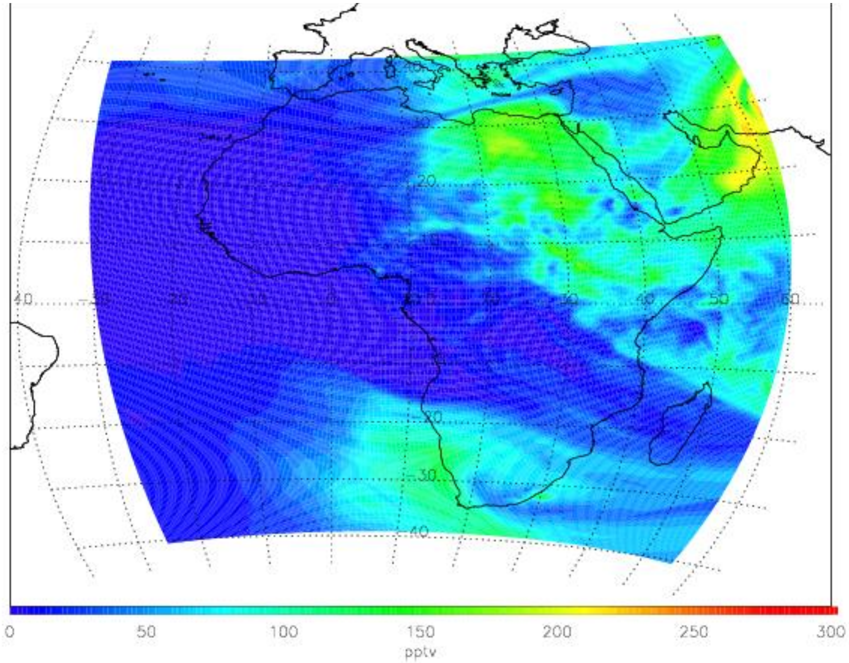
Lightning flash rate parameterization based on convective cloud height (Allen and Pickering, JGR 2002)

Land : flash rate = 3.44e-5*(convective cloud height)$^{4.9}$
Ocean: flash rate = 6.400e-4*(convective cloud height)$^{1.73}$

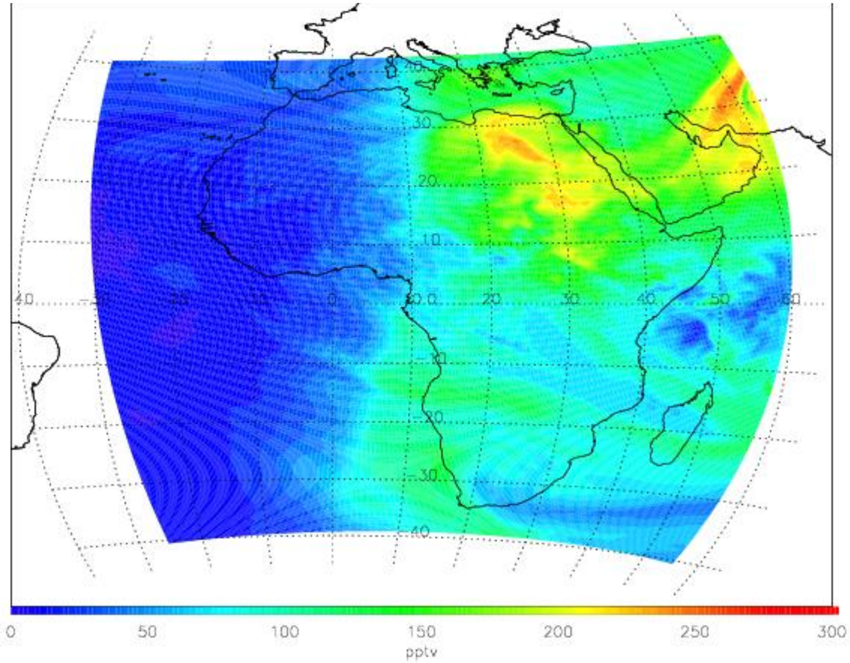
Scaled according to Pickering [pers.comm. 2005]

WRF-CHEM 200mb NO2 with and without Lightning NOX 18Z August 23, 2006

Without Lightning NOx

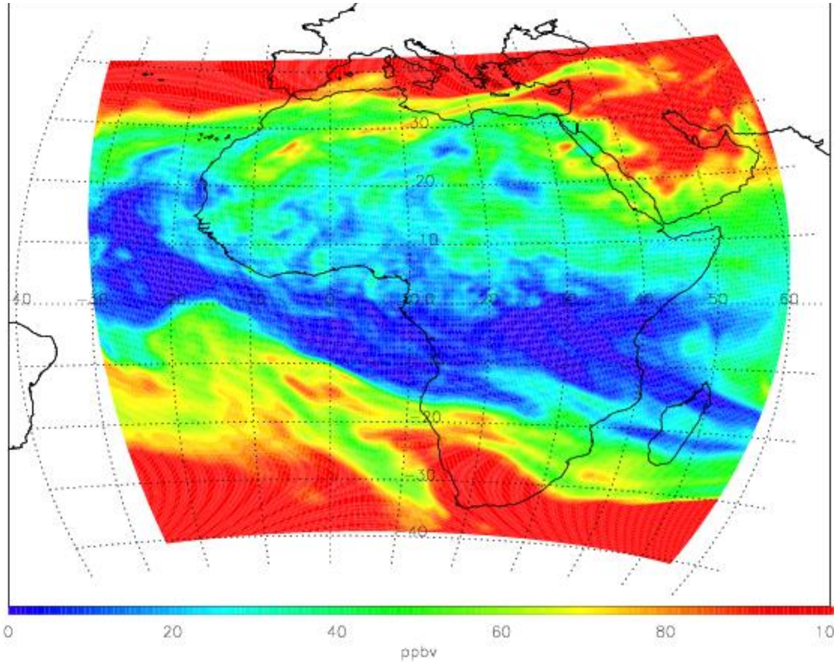


With Lightning NOx

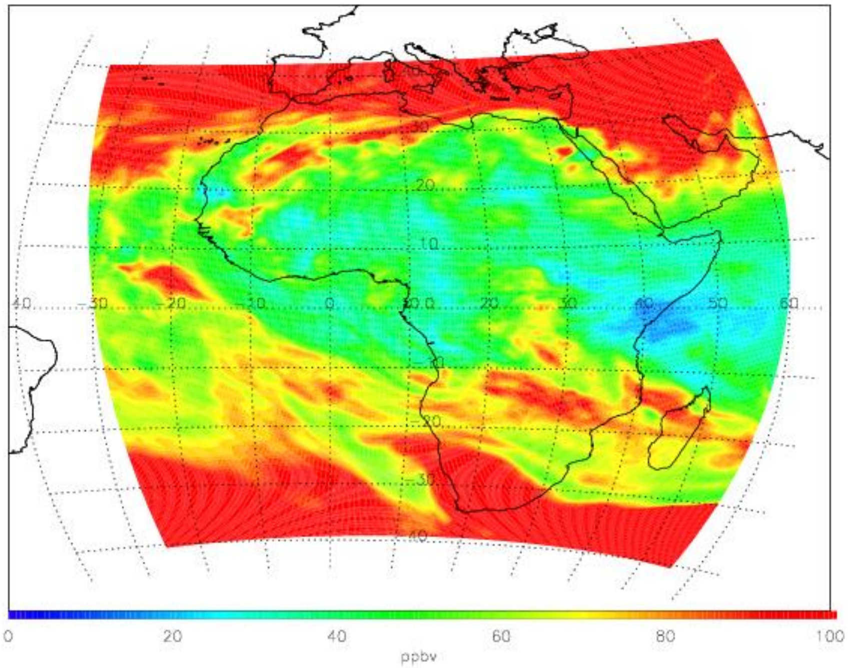


WRF-CHEM 200mb NO2
with and without Lightning NOX
18Z August 23, 2006

Without Lightning NOx



With Lightning NOx

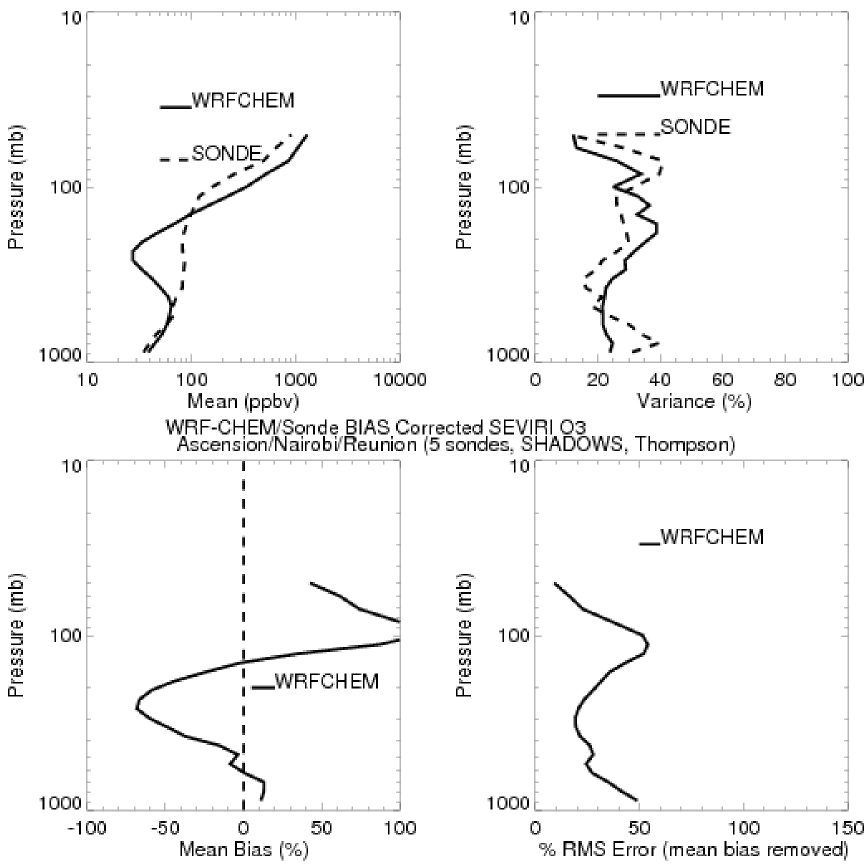


WRF-CHEM SEVIRI Analysis

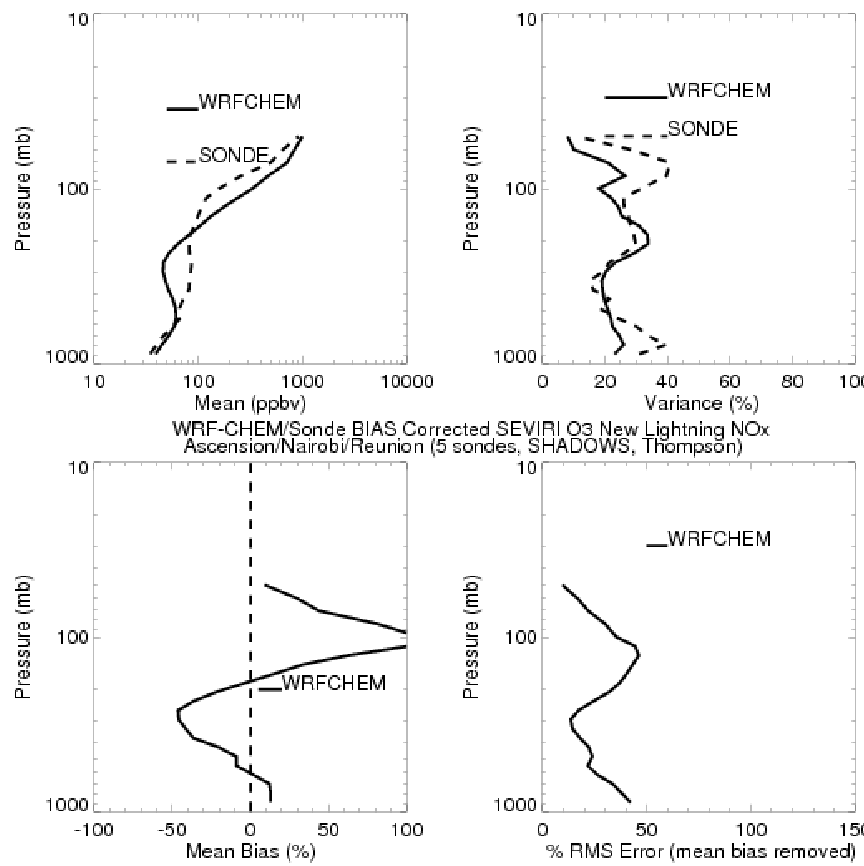
vs

SHADOWS ozonesonde data

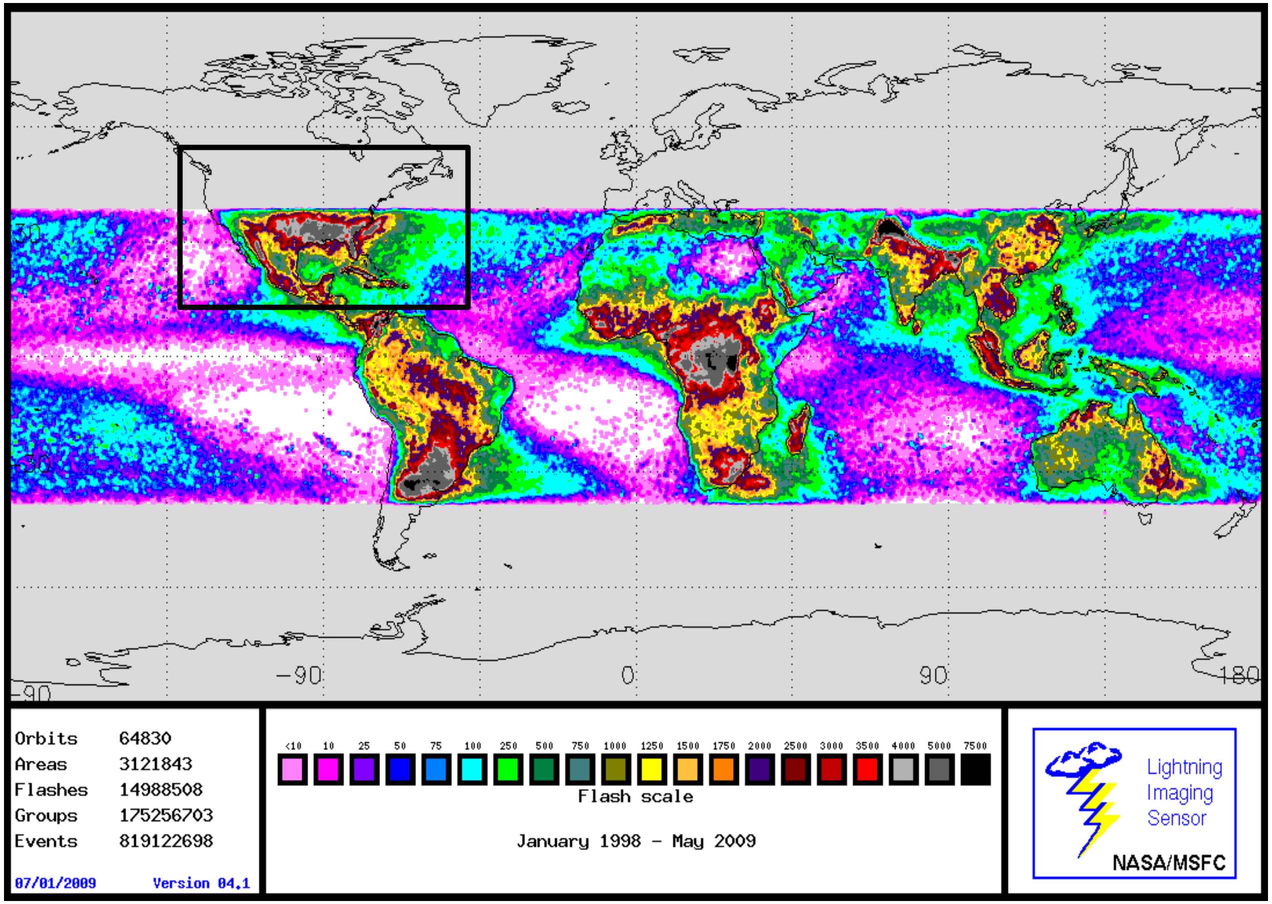
Without Lightning NOx



With Lightning NOx



Climatology of Annual Flash Rate From NASA Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS)



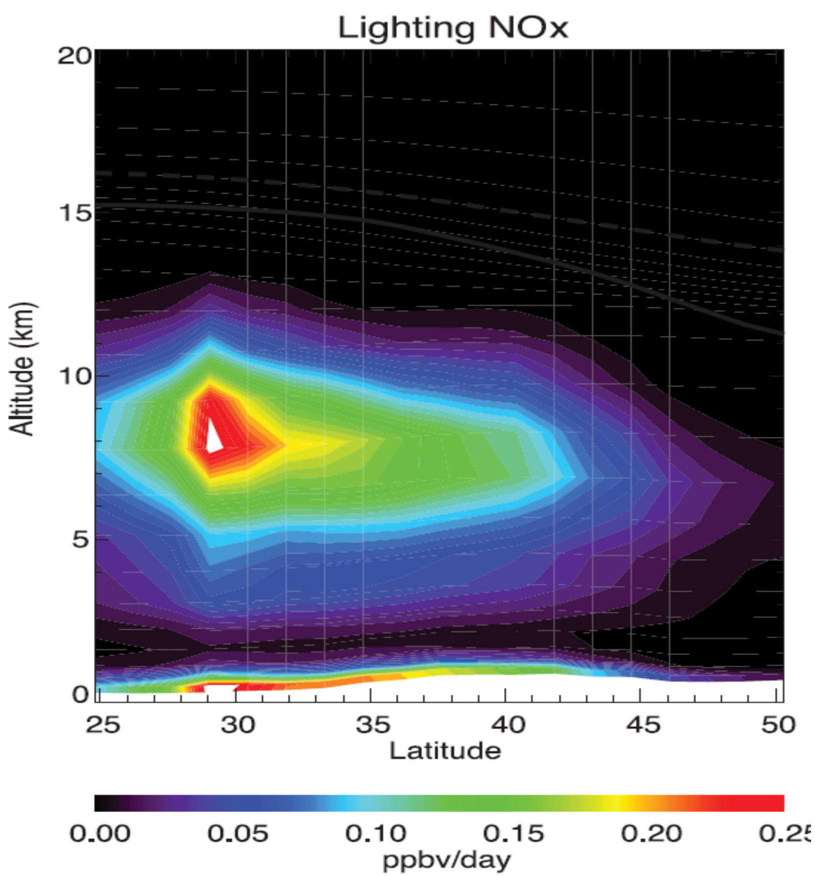
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D12S21, doi:10.1029/2006JD007722, 2007

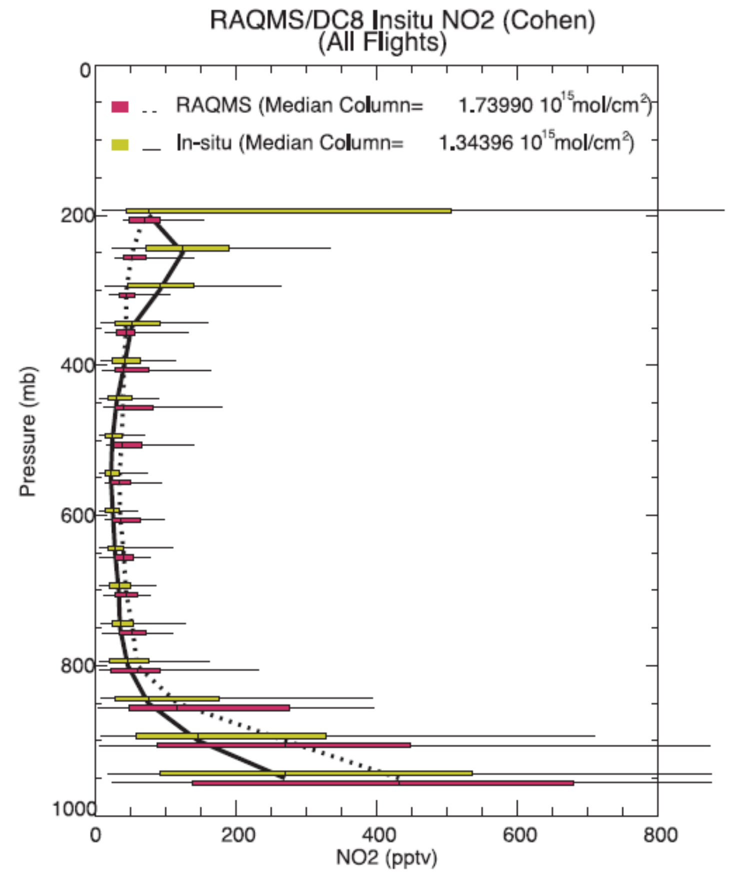
Chemical data assimilation estimates of continental U.S. ozone and nitrogen budgets during the Intercontinental Chemical Transport Experiment–North America

Robert B. Pierce,[1] Todd Schaack,[2] Jassim A. Al-Saadi,[1] T. Duncan Fairlie,[1] Chieko Kittaka,[1] Gretchen Lingenfelser,[1] Murali Natarajan,[1] Jennifer Olson,[1] Amber Soja,[1] Tom Zapotocny,[2] Allen Lenzen,[2] James Stobie,[3] Donald Johnson,[2] Melody A. Avery,[1] Glen W. Sachse,[1] Anne Thompson,[4] Ron Cohen,[5] Jack E. Dibb,[6] Jim Crawford,[1] Didier Rault,[1] Randall Martin,[7] Jim Szykman,[8,9] and Jack Fishman[1]

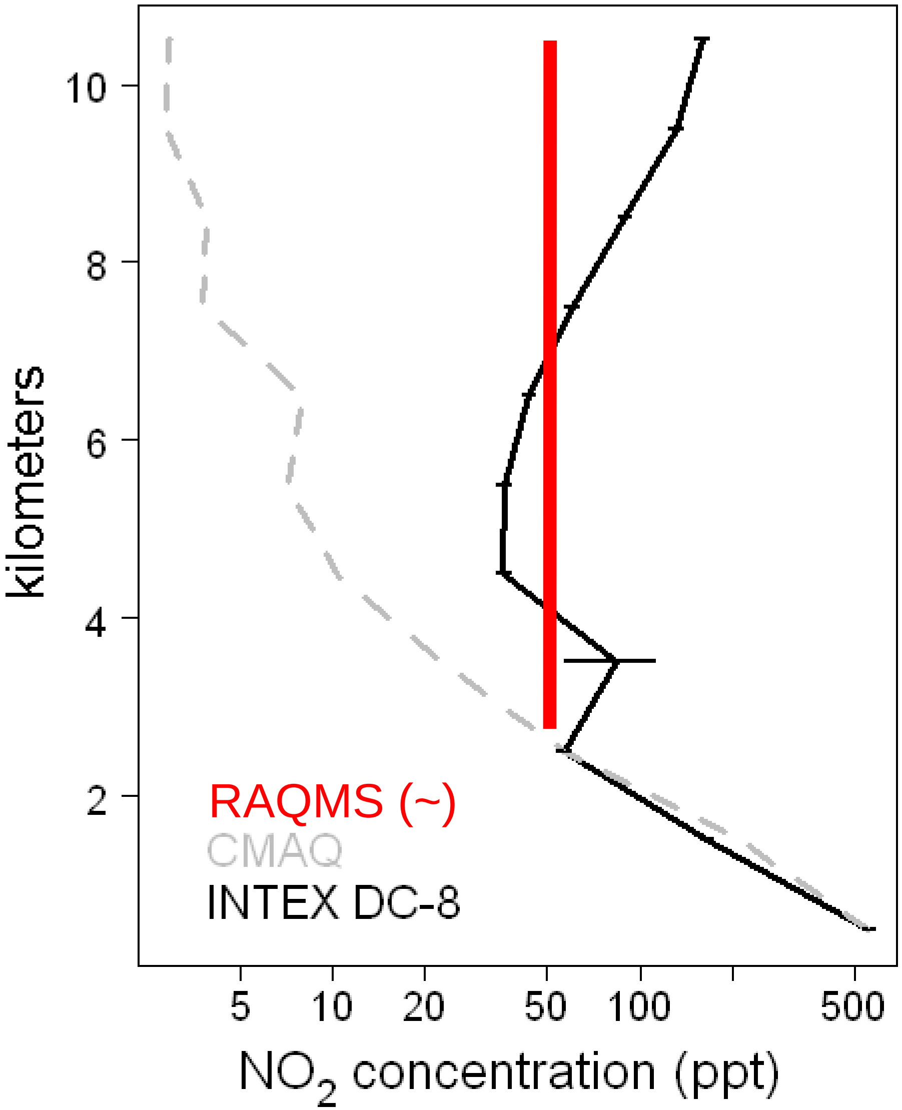
Total NOx emissions over the continental US during INTEX-A (1 July to 15 August 2004) was estimated at 0.94 Tg N, with lightning accounting for 0.16 Tg N.

Hudman et al. [2007] found best agreement with airborne NO2 measurements using total NOx emissions of 1.2 Tg N with 0.272 Tg N due to lightning.





Missing NO_2 Aloft



- CMAQ significantly underpredicts NO_2 relative to DC8 airborne measurements[1]
- Subsequent underestimate in O3 P-L will negatively impact future use of GOES-R total column ozone within Operational NAM-CMAQ AQ forecasting system

[1]**Pinder et al., 2008**

Slide adapted from Pickering et al., CMAS 2008

Synergy with proposed NASA Geostationary chemistry mission

GEO-CAPE

Geostationary Coastal Ocean and Air Pollution Events

Overview of the mission from the Decadal Survey

Geosynchronous Earth orbit with 3 instruments:

UV-visible-near IR wide area spectrometer covering 45°S to 50°N hourly (O_3, NO_2, CH_2O, SO_2, Aerosols)

- Steerable, high spatial resolution, event-imaging spectrometer
- IR correlation radiometer for CO mapping

Summary

-**Lightning NOx drives summertime continental ozone production in the upper troposphere**

-**Current regional chemical transport models significantly underestimate upper tropospheric NOx which contributes to underestimates in upper tropospheric O3**

-**The frequency of lightning is likely to be increased by climate change resulting in** enhanced UT ozone, which has a greenhouse warming potential 1/3 as large as CO2.

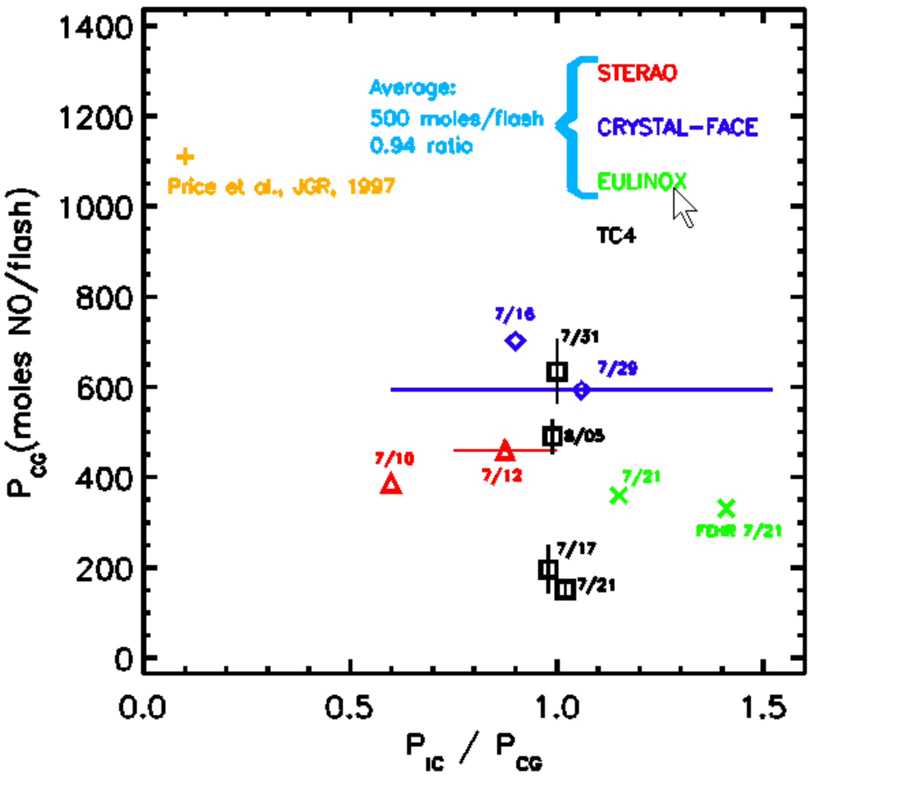
Possible GOES-R Risk Reduction Activity

Following Pickering et al [2008][1]:

(OMI based estimate of lightning-generated NO2 using model estimates of NO2 background and upwind lightning flash data from surface network)

Use GOME-2 and OMI NO2 retrievals combined with LIS flash rates and RAQMS/WRF-CHEM NO2 background to develop capabilities to use GLM+GEO-CAPE to estimate LNOx production

Summary of LNO$_x$ Production Estimates



[1]**Pickering et al., Lightning NOx production during the NASA TC4 experiment as observed by Aura/OMI,** 11th Conference on Atmospheric Chemistry, 89th American Meteorological Society Annual Meeting, August 2008