Sounder observations and WRF-Chem Model simulations: Impact study on tropospheric ozone increases observed during the 2010 AEROSE Campaign

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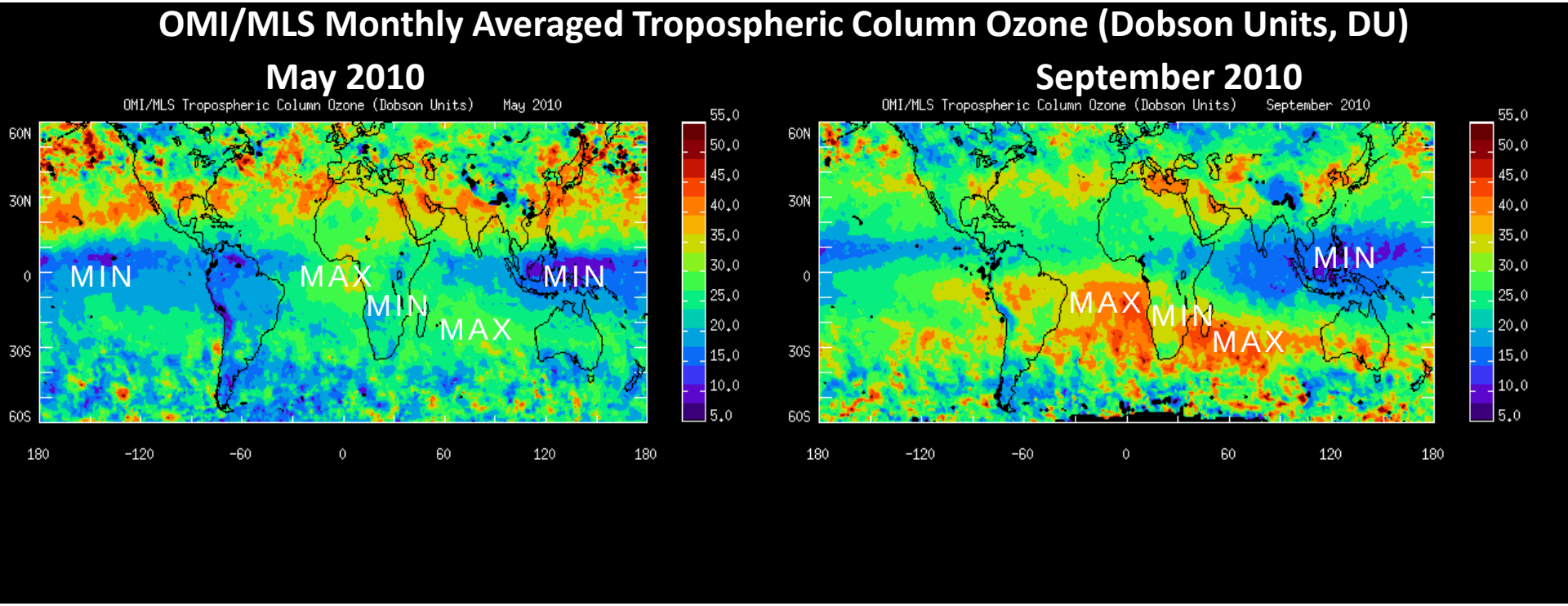
Outline

- Background
- Motivation
- Ozonesonde Measurements
- Sounder data: IASI
- Chemistry Version of the Weather Research and Forecasting (WRF-Chem) Model Specifications
- WRF-Chem Model Initial results
- Conclusions
- Future Work
- Acknowledgements

Background: Tropospheric ozone wave one

- Ozone maximum over the Tropical Atlantic Ocean and minimum over Tropical Pacific Ocean [Thompson et al., 2003].
- Ozone maximum over Equatorial Atlantic Ocean usually peaks annually in September



Ziemke et al., [2006]

Background: Previous Work

- Ozonesonde launches aboard the NOAA R/V Brown during ***Aerosols and Ocean Science Expeditions (AEROSE)*** Campaigns of 2006-2013 detected tropospheric ozone enhancement.

- 20 km WRF-Chem Model simulations [Smith et al., 2014; 2015, in prep] June 2006 case study suggest increases in ozone due to primarily westward transport ozone precursors (detected during 2006 AEROSE campaign, see Morris et al., 2006; Hawkins, 2007; Jenkins et al., 2008; Smith, 2012; 2014)

  - 30+ ppbv occur off of the coast of Equatorial Africa in the lower troposphere
  - 11-15 ppbv from LNO_x downwind of deep convection and is enhanced throughout the troposphere

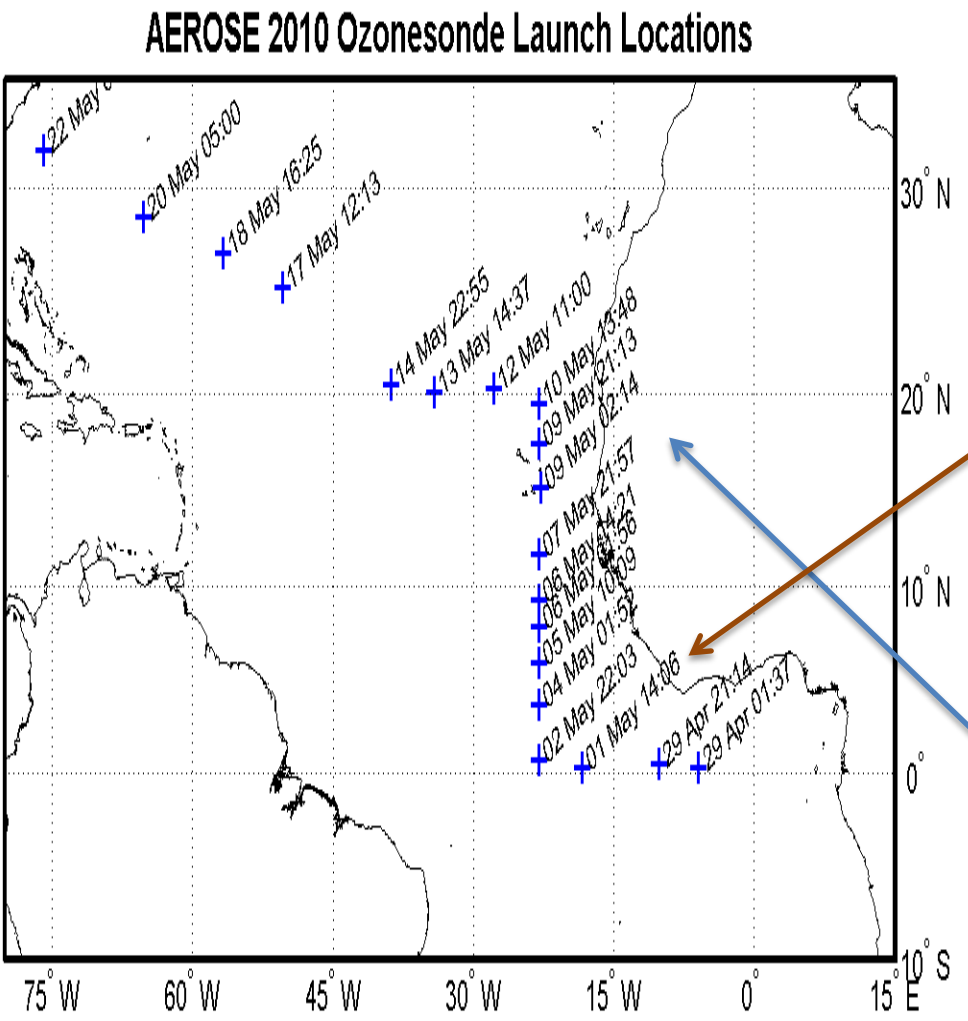
Motivation

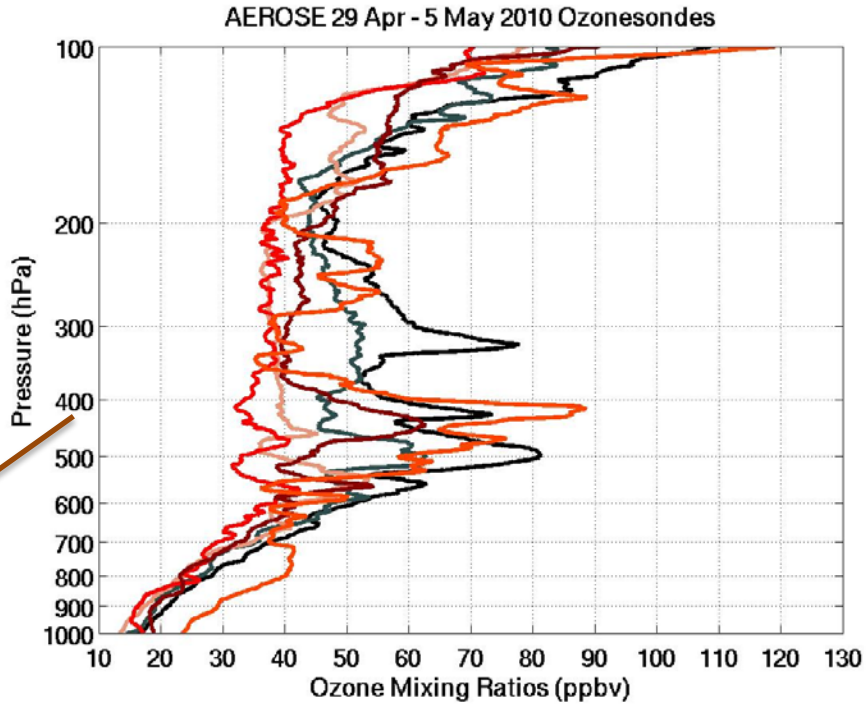
- A subsequent ***AEROSE*** campaign in 2010 detected enhanced tropospheric ozone during late April/early May

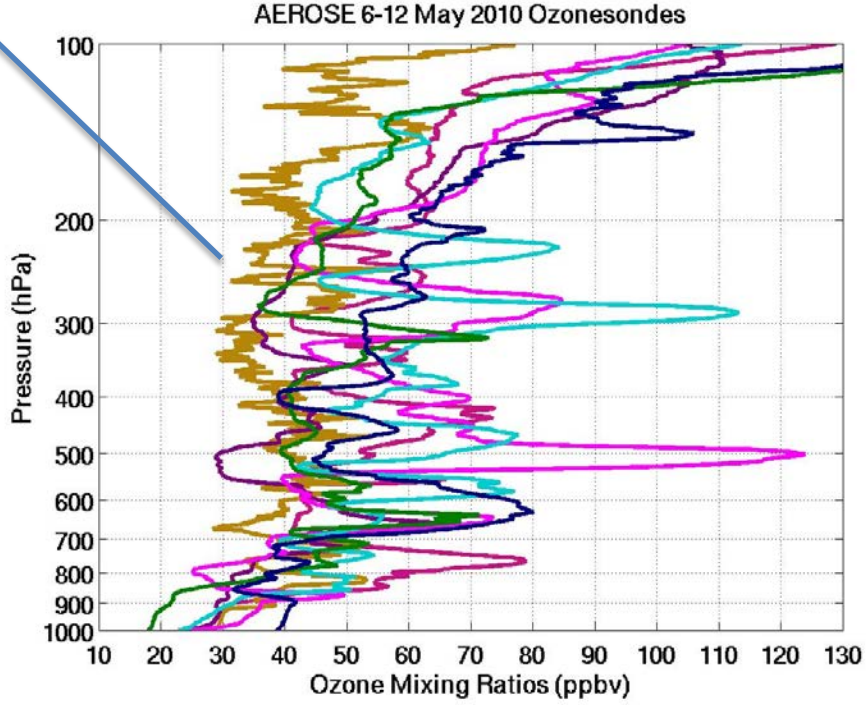
- Unlike the 2006 case, late April/May 2010 is a transitional period
  - Northern Hemisphere (NH) biomass burning and Equatorial/SH LNO_x
  - Nearly exclusive NH LNO_x and SH biomass burning

- High resolution regional WRF-Chem model to
  - examine biomass burning transport and to quantify carbon monoxide and ozone
  - compare it to IASI retrievals at similar pressure levels

- Advantages of ***NOAA-Unique Satellite Sounder Products (IASI and CrIS for Ozone, IASI for CO)***:
  - Retrieves trace gas ozone mixing ratios
  - Retrieves the ozone precursor CO mixing ratio
  - Retrieval times aligned with ozonesonde launches during ***AEROSE*** Campaigns
  - Data is free and open to the public
  - Contains AIRS heritage
  - Will be operational for years to come
  - **www.class.noaa.gov**



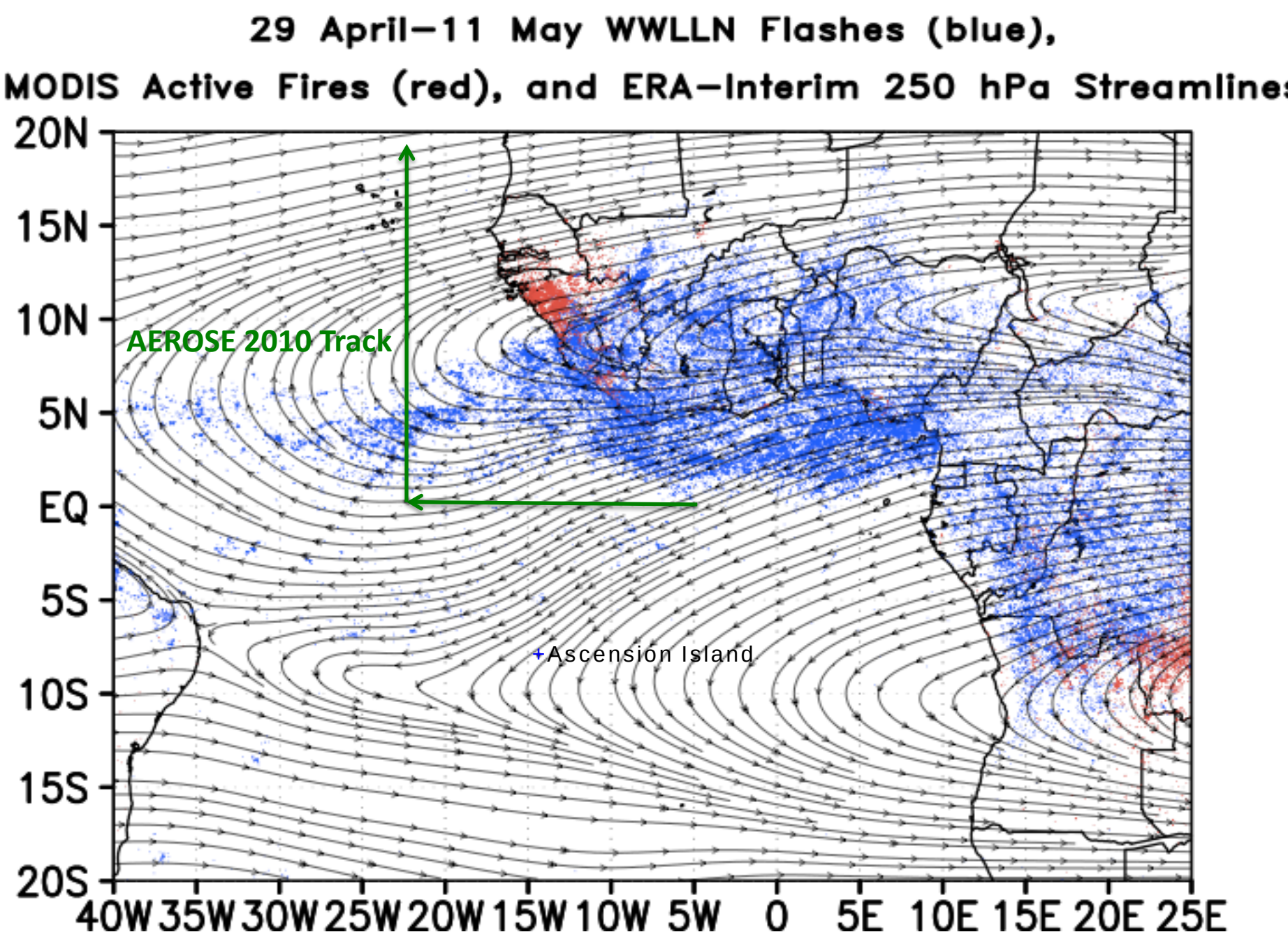


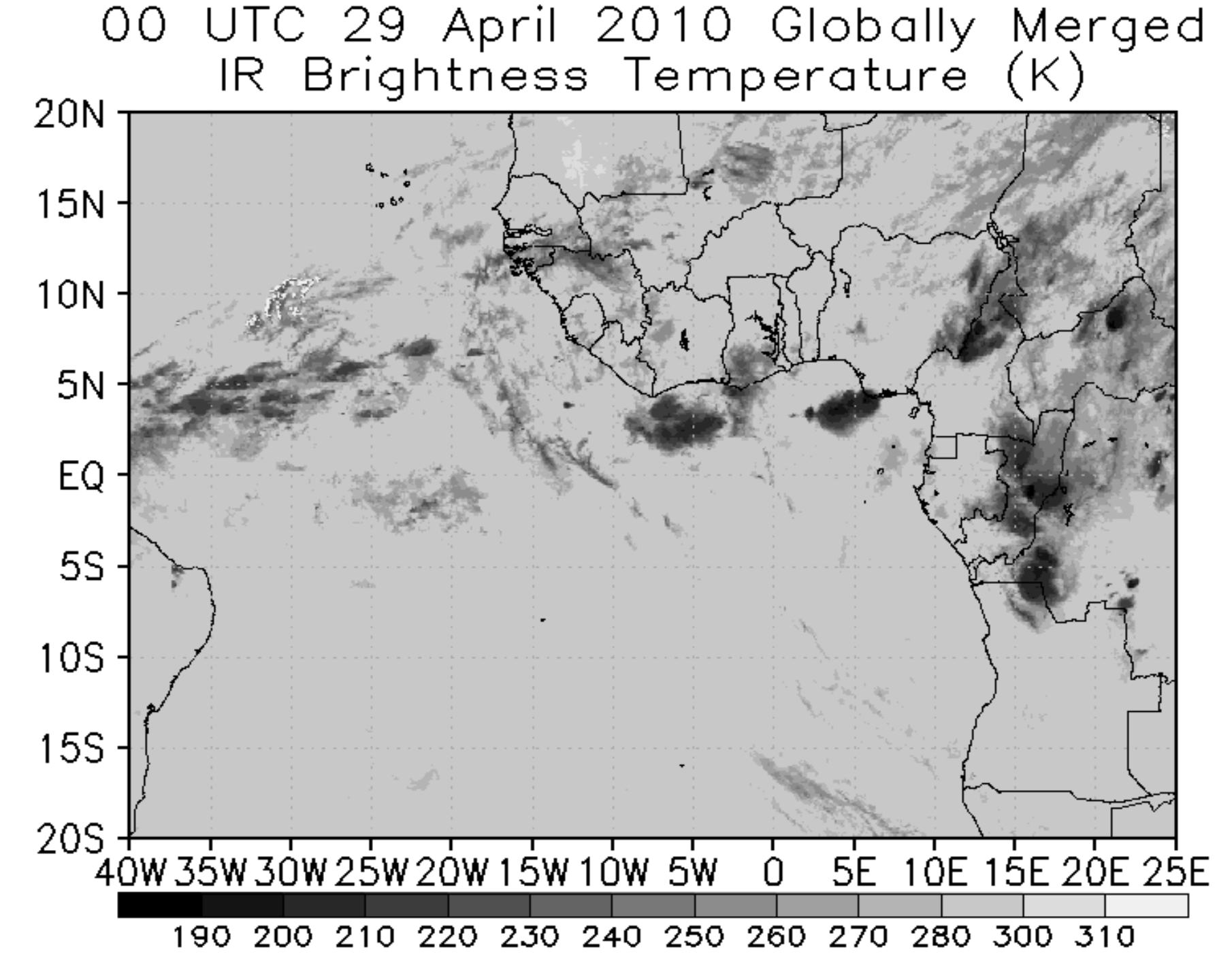


Ozone Increases

Middle Troposphere: 10-80 ppbv

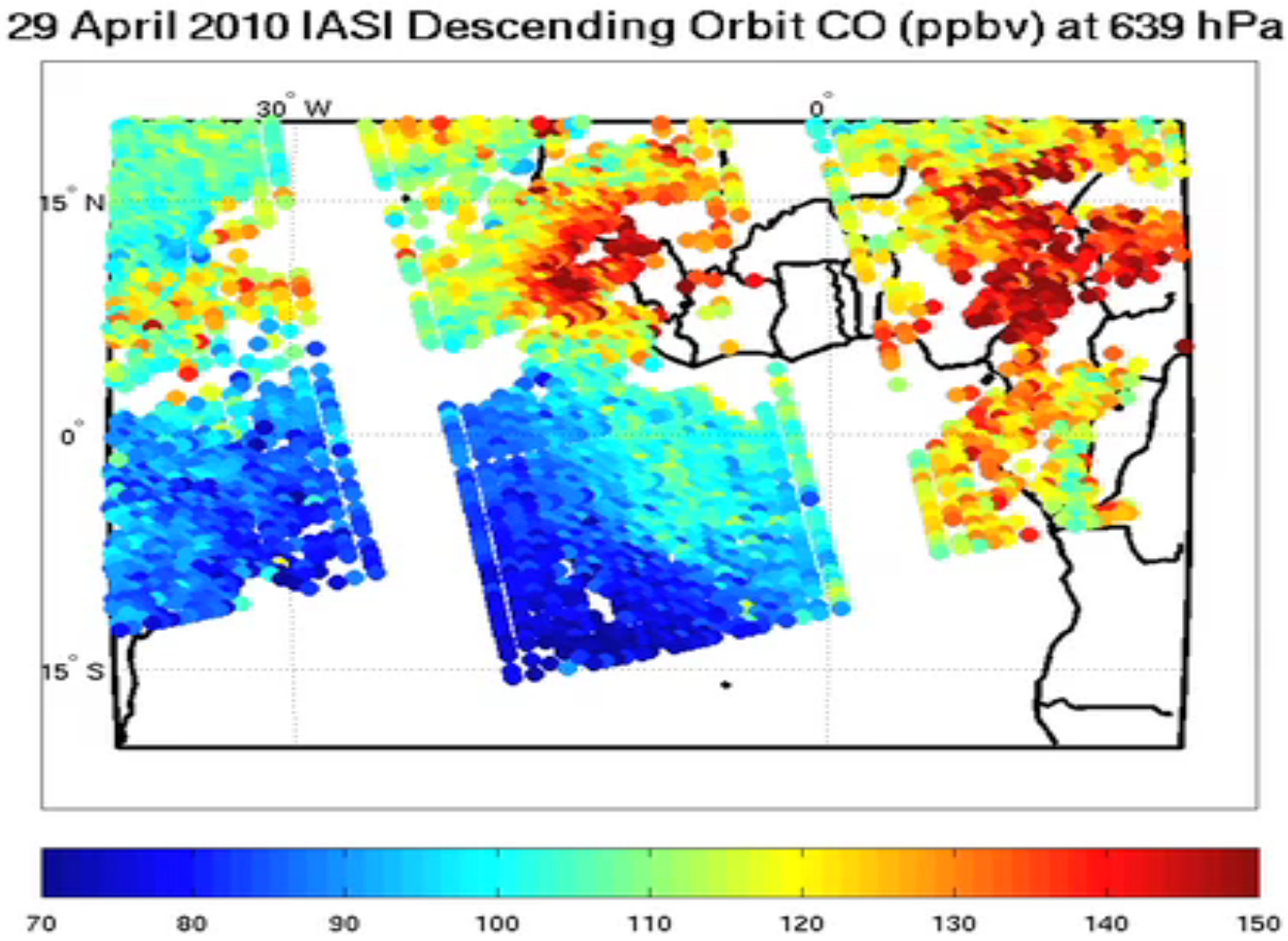
Upper Troposphere: 0-40 ppbv


29 April–11 May WWLLN Flashes (blue),
MODIS Active Fires (red), and ERA–Interim 250 hPa Streamlines
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W 35W 30W 25W 20W 15W 10W 5W 0 5E 10E 15E 20E 25E
AEROSE 2010 Track
Ascension Island

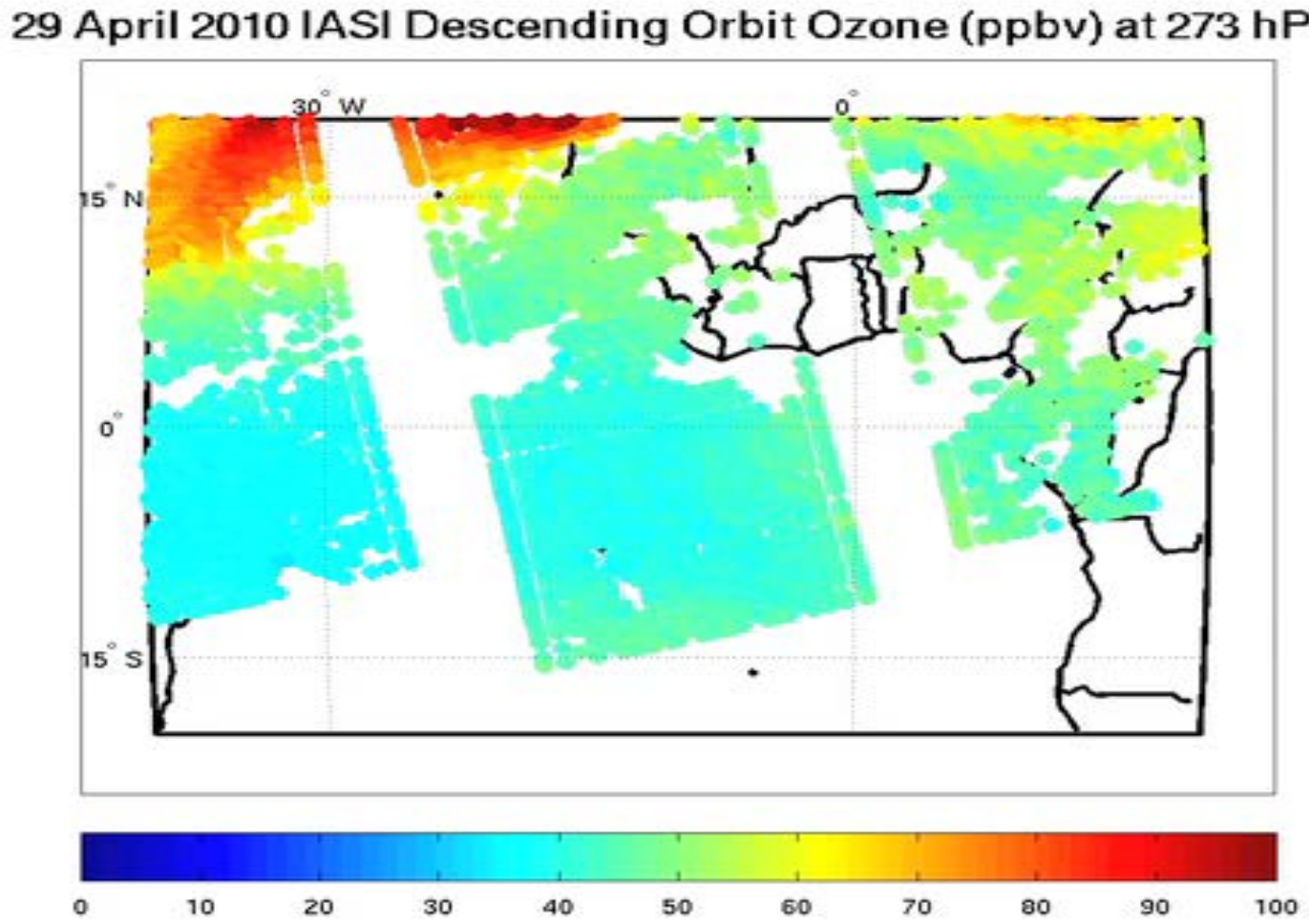

00 UTC 29 April 2010 Globally Merged
IR Brightness Temperature (K)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W 35W 30W 25W 20W 15W 10W 5W 0 5E 10E 15E 20E 25E
190 200 210 220 230 240 250 260 270 280 300 310

IASI 29 April -12 May 2010
Average 639 hPa Carbon Monoxide

Note:
2-per day orbital data

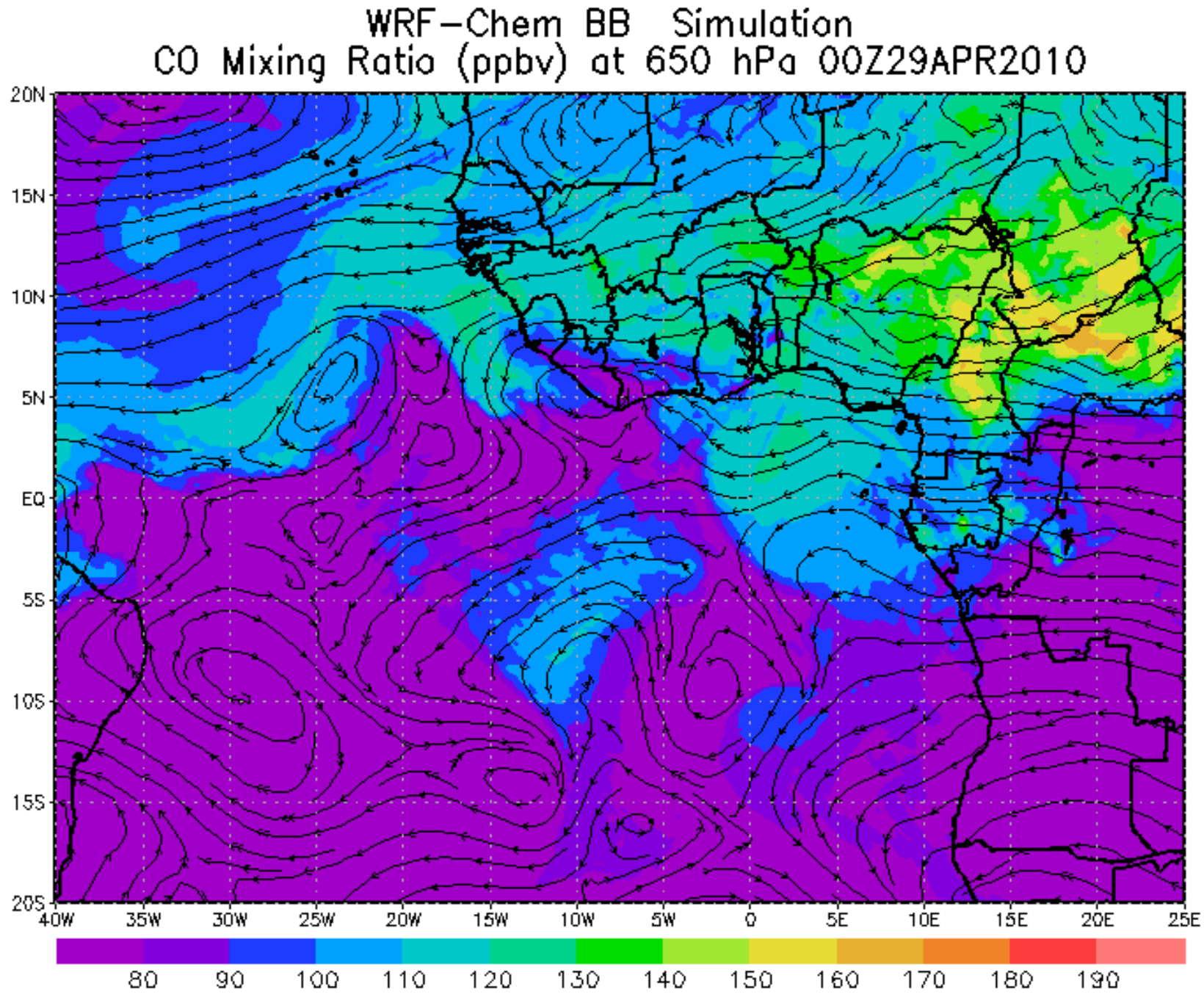


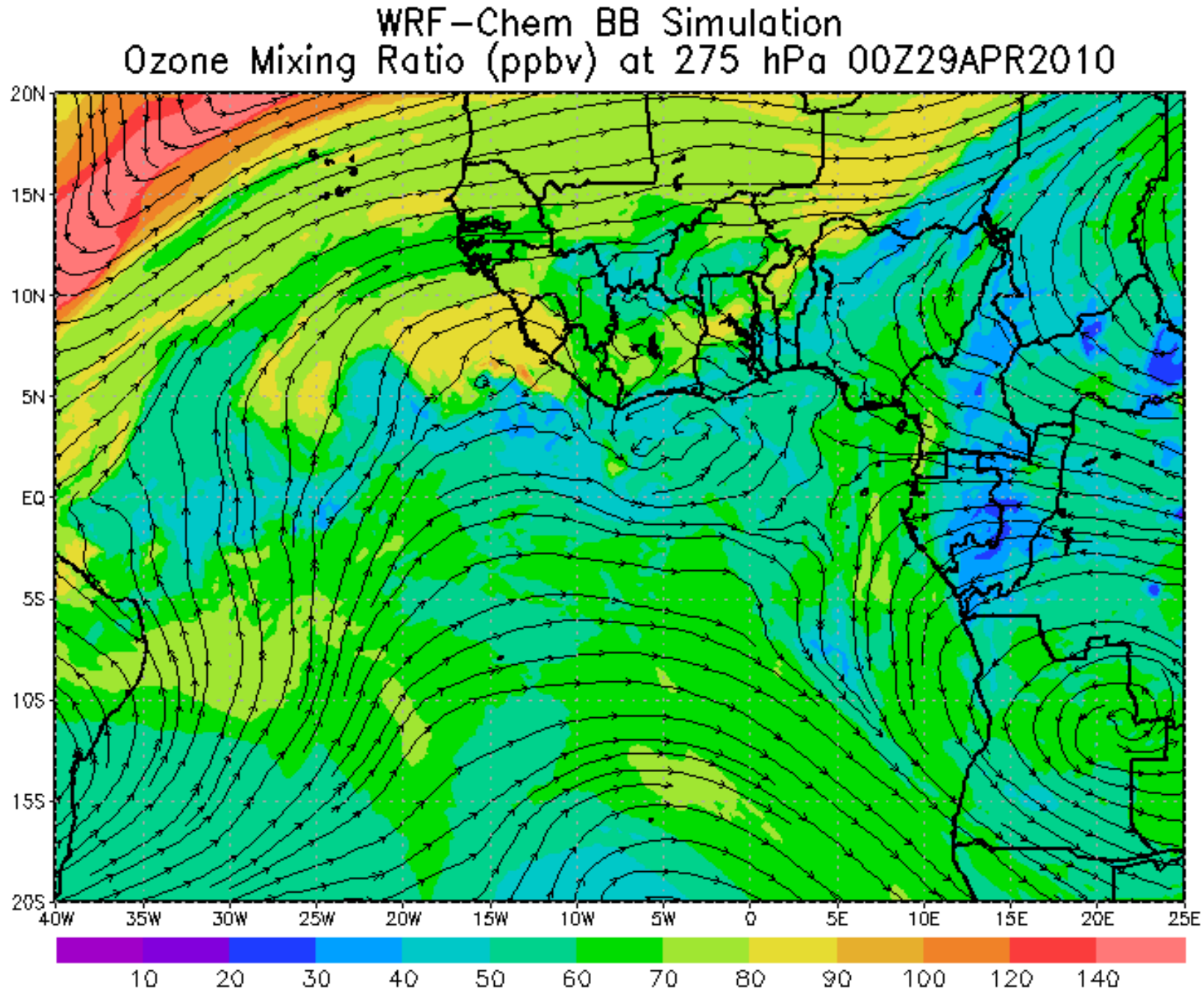
IASI 29 April -12 May 2010
Average 273 hPa Ozone

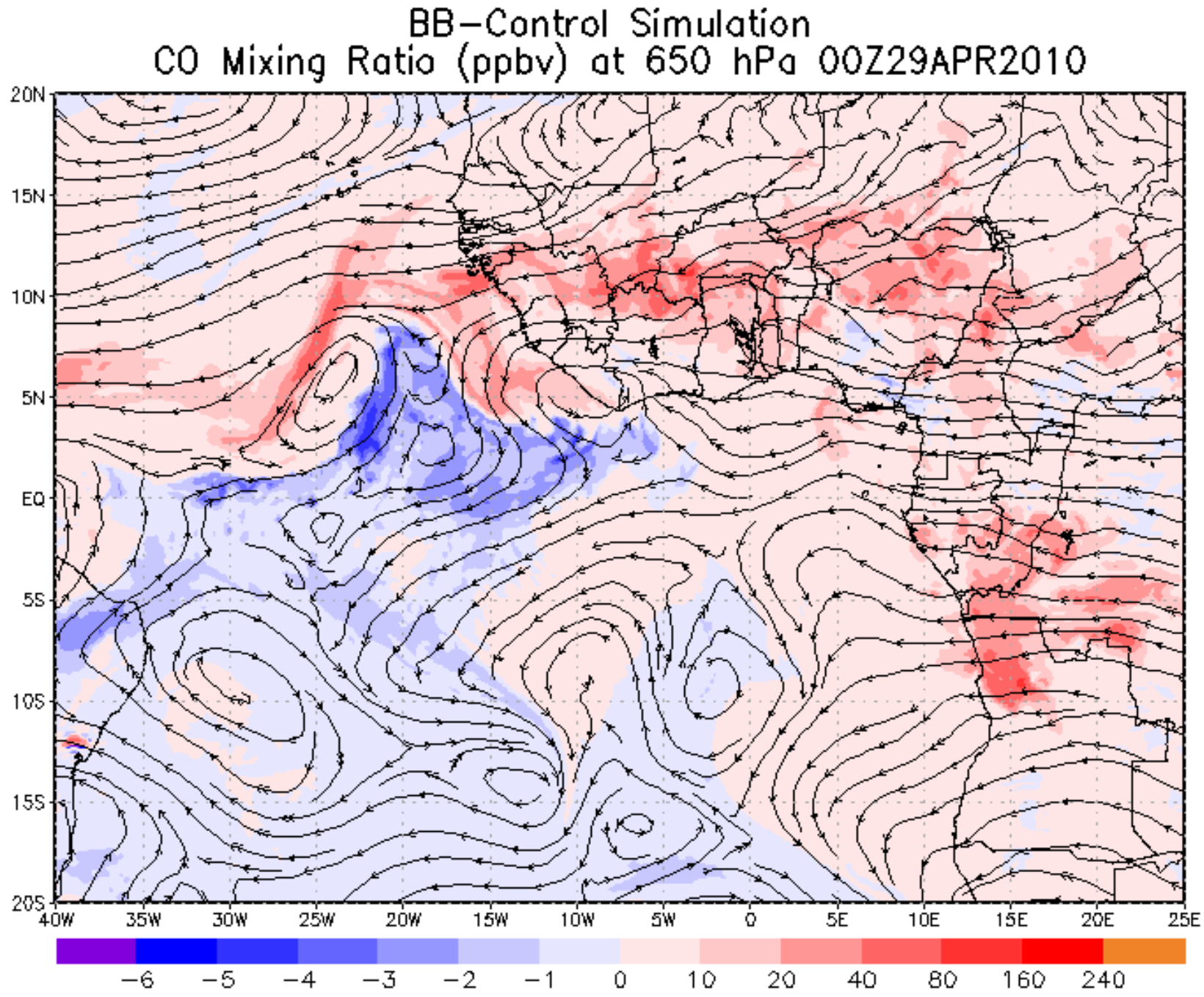


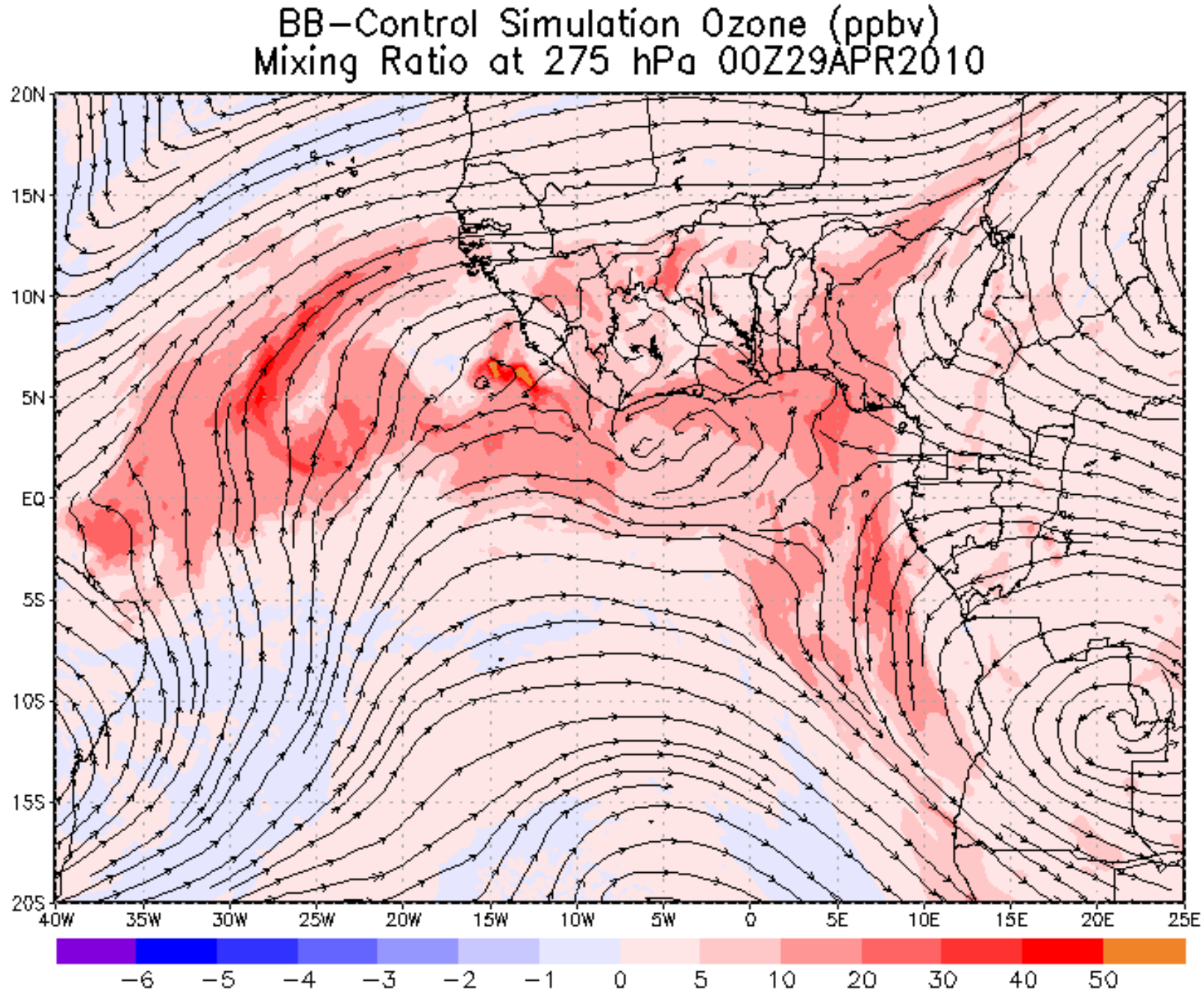
WRF-Chem MODEL PARAMETERS	SETTINGS
PERIOD	00 UTC 8 April to 00 UTC 12 May 2010
DOMAIN	40°E to 25°W and 20°N to 20°S
RESOLUTION	12 km
MODEL TOP	50 hPa
CHEMICAL MECHANISM	MOZART 4
CUMULUS SCHEME	New Grell
METEOROLOGICAL INITIAL AND LATERAL BOUNDARY CONDITIONS	1° x 1° GFS Final Analysis
CHEMICAL INITIAL AND LATERAL BOUNDARY CONDITIONS	MOZART 4

12 km WRF-Chem Simulations	ANTHROPOGENIC EMISSIONS *MOZART*	BIOGENIC EMISSIONS *MEGAN*	FIRE EMISSIONS *FINN* *(Fire Inventory of NCAR)*
CONTROL	Yes	Yes	*No*
BB	Yes	Yes	Yes


WRF−Chem BB Simulation
CO Mixing Ratio (ppbv) at 650 hPa 00Z29APR2010
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W
35W
30W
25W
20W
15W
10W
5W
0
5E
10E
15E
20E
25E
80
90
100
110
120
130
140
150
160
170
180
190


WRF–Chem BB Simulation
Ozone Mixing Ratio (ppbv) at 275 hPa 00Z29APR2010
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W
35W
30W
25W
20W
15W
10W
5W
0
5E
10E
15E
20E
25E
10
20
30
40
50
60
70
80
90
100
120
140


BB−Control Simulation
CO Mixing Ratio (ppbv) at 650 hPa 00Z29APR2010
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W
35W
30W
25W
20W
15W
10W
5W
0
5E
10E
15E
20E
25E
−6
−5
−4
−3
−2
−1
0
10
20
40
80
160
240


BB–Control Simulation Ozone (ppbv)
Mixing Ratio at 275 hPa 00Z29APR2010
20N
15N
10N
5N
EQ
5S
10S
15S
20S
40W
35W
30W
25W
20W
15W
10W
5W
0
5E
10E
15E
20E
25E
−6
−5
−4
−3
−2
−1
0
5
10
20
30
40
50

Analysis and Conclusions

- The WRF-Chem model levels examined are within the peak of the IASI averaging kernels
- IASI and WRF-Chem Model ozone are comparable quantitatively and spatially
  - 110-130 ppbv at 650 across the Sahel of Africa
  - Plumes emerge of the coast of Guinea and Gabon/Cameroon
  - Likely from convective transport
- IASI, AEROSE ozonesonde, and WRF-Chem Model ozone are comparable
  - 50-60 ppbv at 275 hPa across the Sahel early in period then a decrease to 30-40 ppbv
- Model suggests that the upper tropospheric (UT) ozone increases of 10-40 ppbv collect over the Gulf Guinea in early May as is shown in the OMI Tropospheric Column Ozone

Future Work

- Apply IASI Offline averaging kernels to WRF-Chem model output to compare observations to model
- Use IASI CO and ozone retrievals and WRF-Chem model output to understand ozone increases at 500 hPa
- Examine back-trajectories with Lagrangian Model
- Execute trace Gas EDR data assimilation experiment
- High-resolution simulation examining tropospheric ozone enhancement from lightning-induced nitrogen oxides during this 2010 period

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