O_3 production & NAQFC performance in the Mid-Atlantic region in recent years

Pius Lee[1], Daniel Tong[1,2,3], Youhua Tang[1,2], Xinrong Ren[1,3], Christopher Loughner[1] , Barry Baker[1,4], Patrick Campbell[1,3], and Ariel Stein[1]

[1]Air Resources Lab., NOAA Center for Weather and Climate Prediction, College Park, MD
[2]GMU/Institute of Sustainable Earth,
Cooperative Institute for Satellite Earth System Studies (CISESS), Fairfax, VA
[3]UMD/Department of Atmospheric and Oceanic Science, CISESS, College Park, MD
[4]UMBC/Joint Center for Earth Systems Technology , CISESS, Baltimore, MD

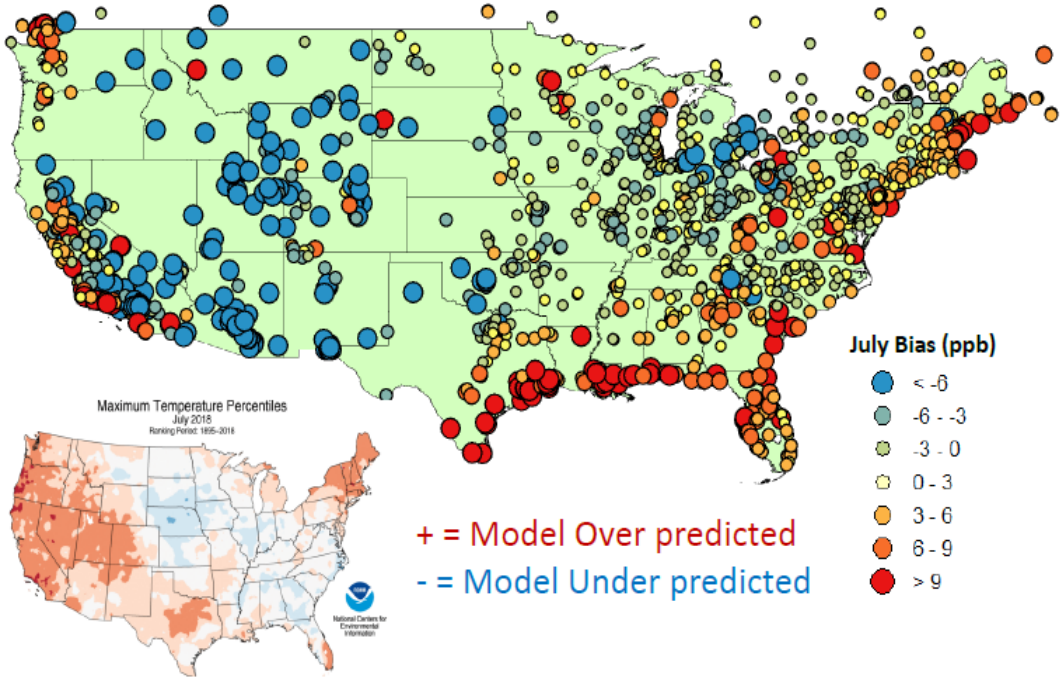
Talk Outline

A. Mid-Atlantic region poses various challenges for NAQFC:
   a) Model changes;
   b) Emission flux and chemical composition changes;
   c) Source-receptor relationship;
   d) Comparable impact by regional and local influences;
   e) Intermittent source;
   f) Complex terrain and land-sea interfaces

B. Campaign measurements valuable:
   i. Supersites: Collocated measurements of met and pollutant concentration
   ii. Land-sea-breeze focused campaign;
   iii. Long Range Transport focused campaign;
   iv. Characteristics of local emissions by specifically designed flights

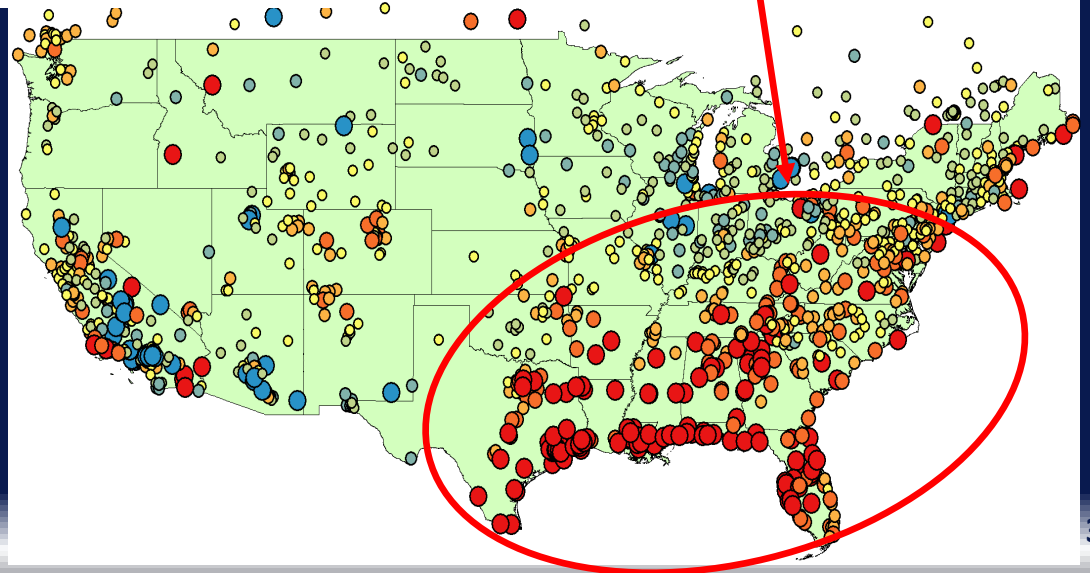
C. Science questions specific for the Mid-Atlantic Region:
   1. Emission trend
   2. Source apportionment

Monthly BIAS – 8hr Ozone
July: 2018



Summer time NAQFC O_3 forecast Performance:
2019 an extraordinary wet summer posed challenge esp. in South and Southeast
=> Meteorology decisive factor

Monthly BIAS – 8hr Ozone
July: 2019



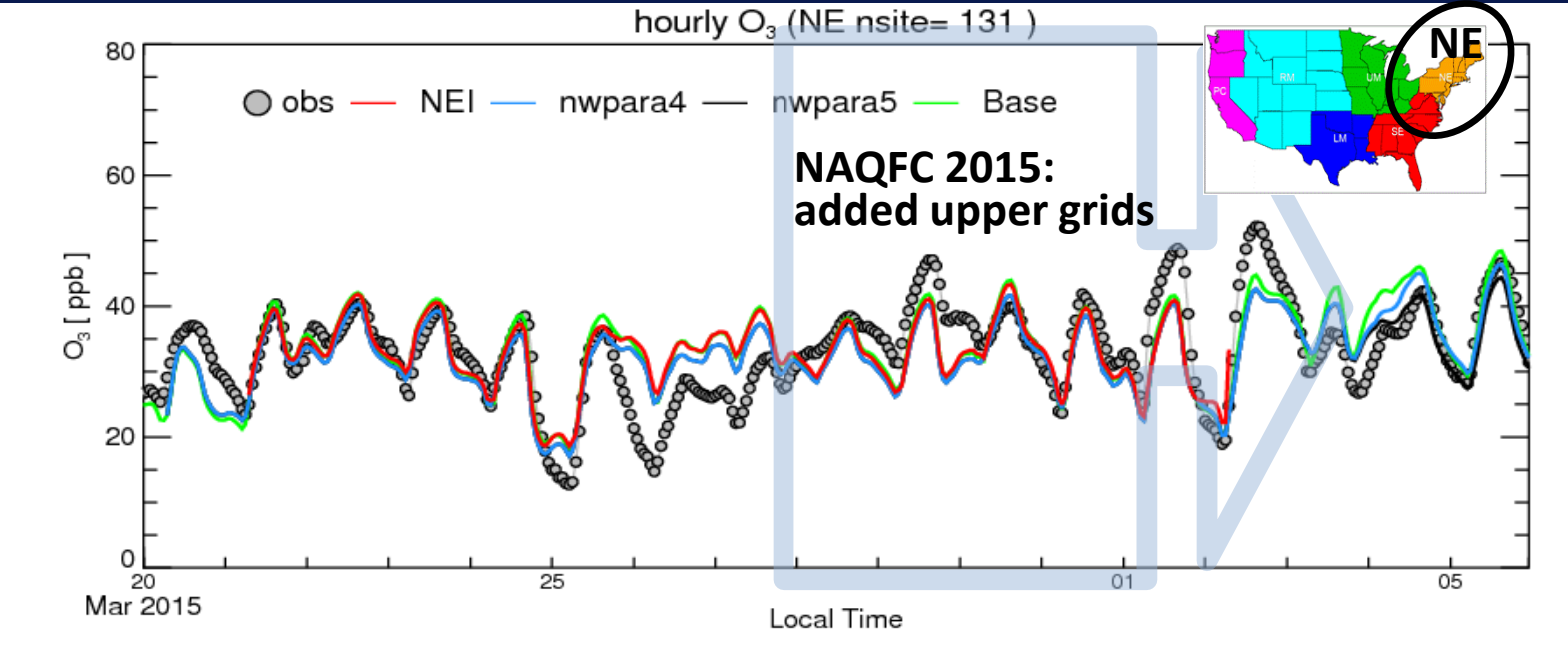
Courtesy: James Boyle and Joel Dreessen, MDE

NAQFC model and input changes 2015-2019

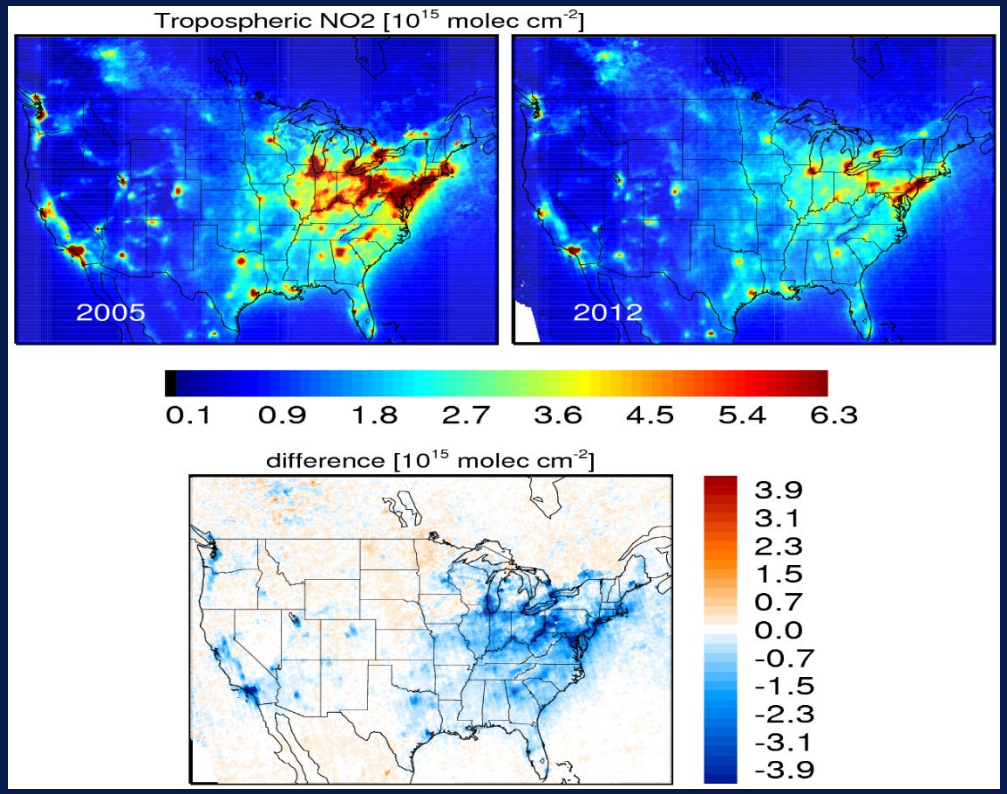
Emission changes:

NEI2005v1	NEI2011v1	NEI2014v2	Source Description
alm	c1c2rail	c1c2rail	Class I and I marine sources, railroad
	c3marine	c3marine	Class III marine sources (ocean going ships)
othmb	Canada EI	MEXICI EI	Mexican and Canadian mobile sources
mb	MOBILE6	MOVES	onroad
N/A	pt_oilgas	pt_oilgas	Oil and gas point sources

Model changes:

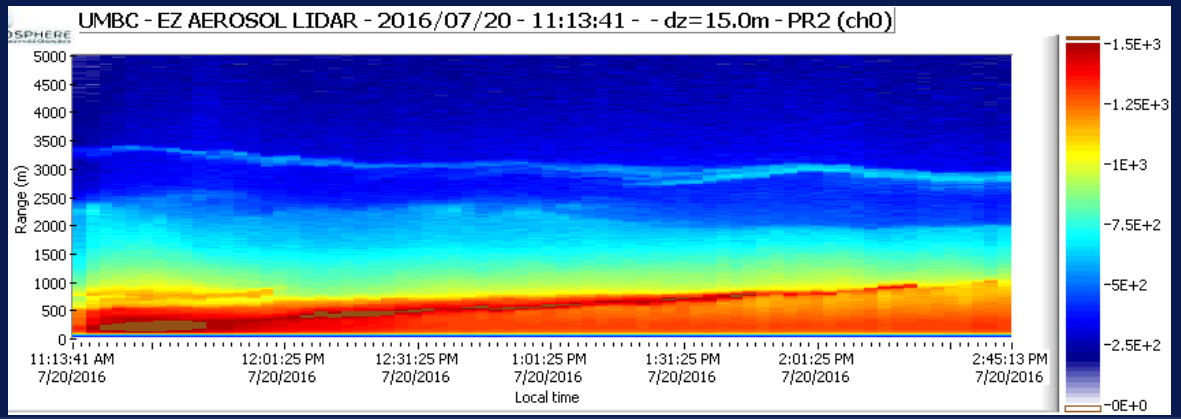


Chemical regime changes: emission as well as LRT



Mid-Atlantic saw > 75%
NOx reduction since 2005

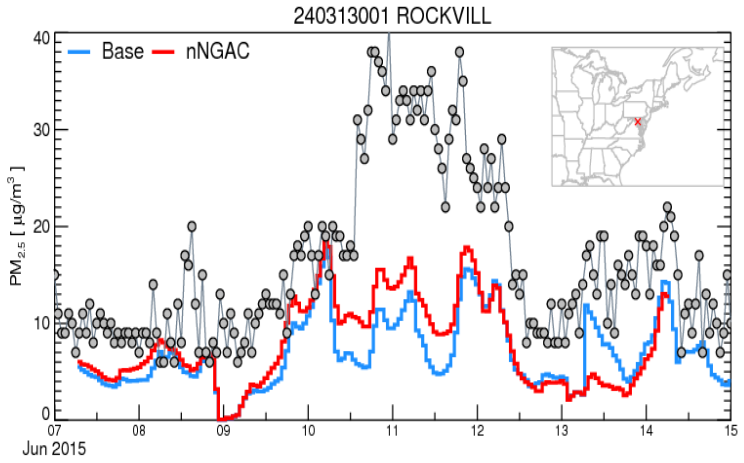
Occasional smoke intrusion
Courtesy: R. Delgado, UMBC

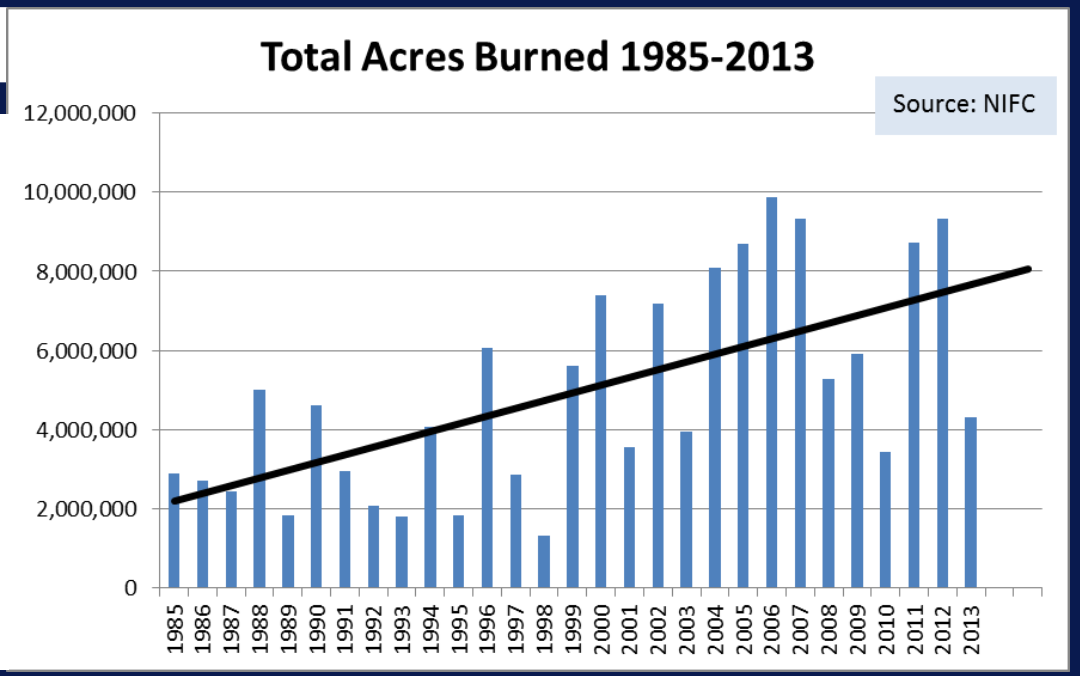


Intermittent sources seemed frequent and prominent

Courtesy: P. Lahm, USFS

Smoke from Canada impact MD





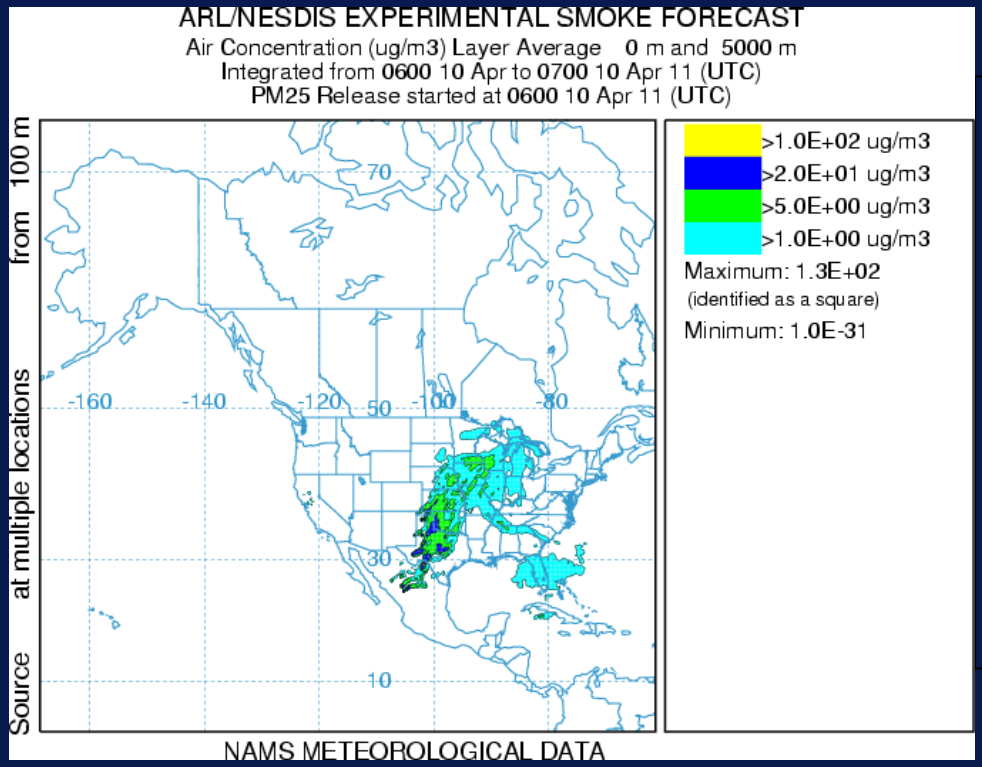
NO_x from wildfire follows the hydroxyl radical recycling to generate O_3, CO reinforces production of hydro-peroxyl radical pathway for O_3 production

$$CO + OH\cdot + O_2 \rightarrow CO_2 + HO_2\cdot$$
$$HO_2\cdot + NO \rightarrow NO_2 + OH\cdot$$
$$NO_2 + h\nu \rightarrow NO + O$$
$$O + O_2 + M \rightarrow O_3 + M$$

Net: $CO + 2O_2 + h\nu \rightarrow CO_2 + O_3$

Smoke Forecast System

- **Experimental testing phase began March 28, 2006**
- **Run daily at NCEP as part of the Air Quality Forecast Guidance to produce a 24-hr analysis and a 48-hr forecast**

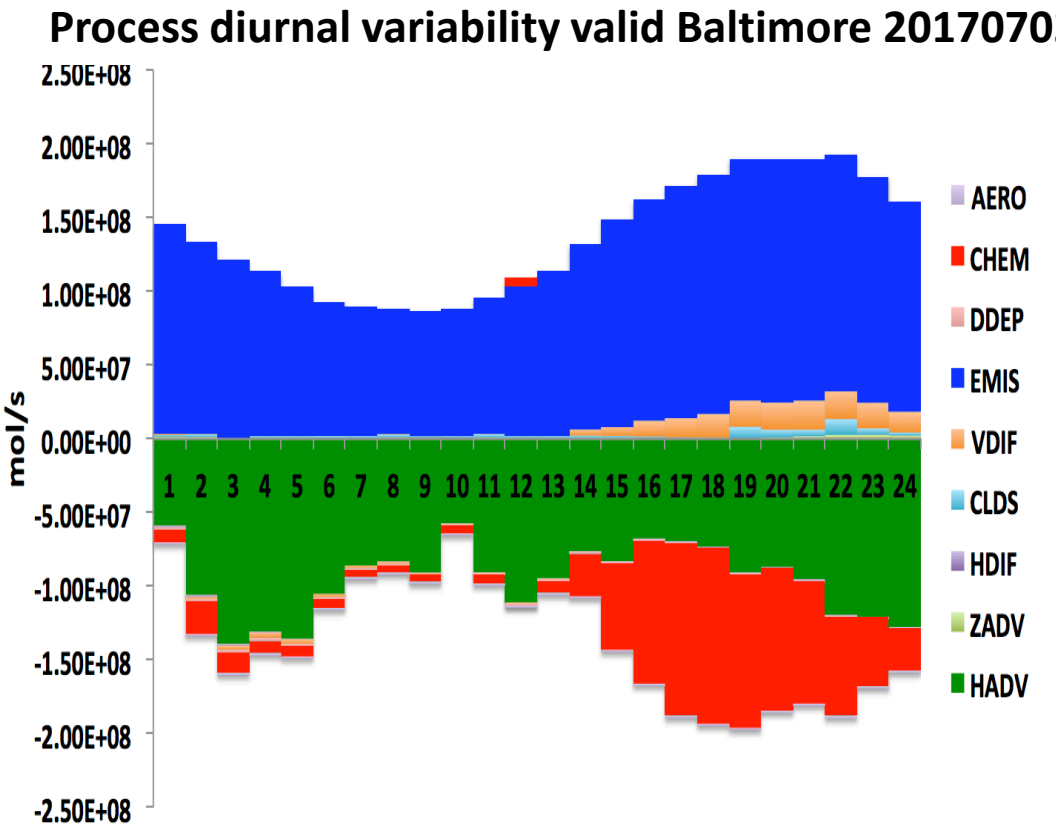


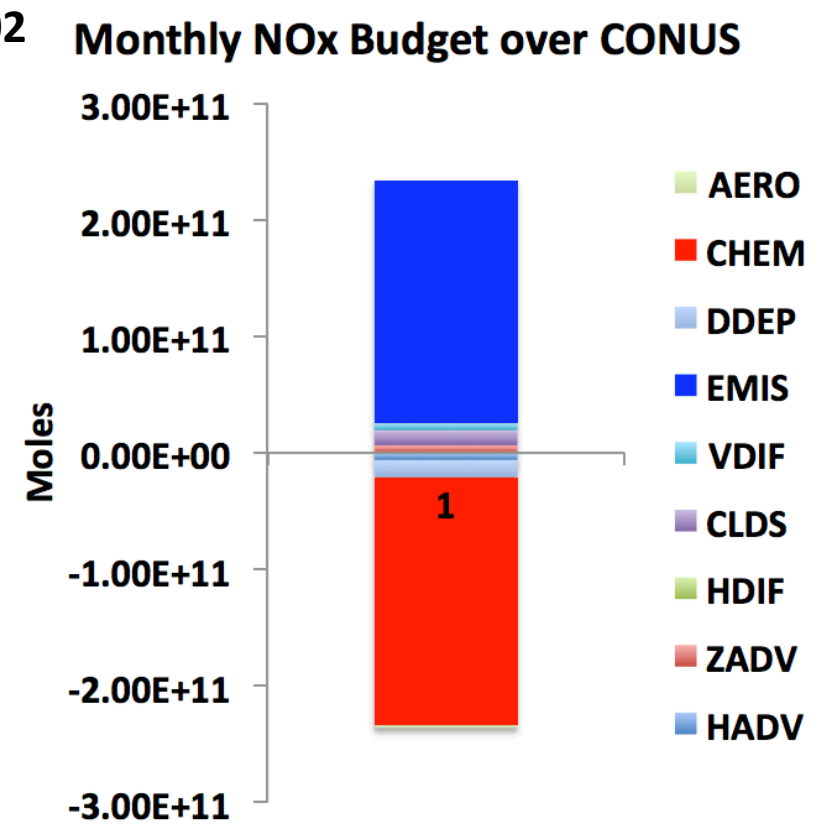
Daily Procedure

- Satellite detection of fire location and heat released
- Calculation of emissions
- HYSPLIT run
- Statistics calculation
- Web distribution

Rolph et al., 2007

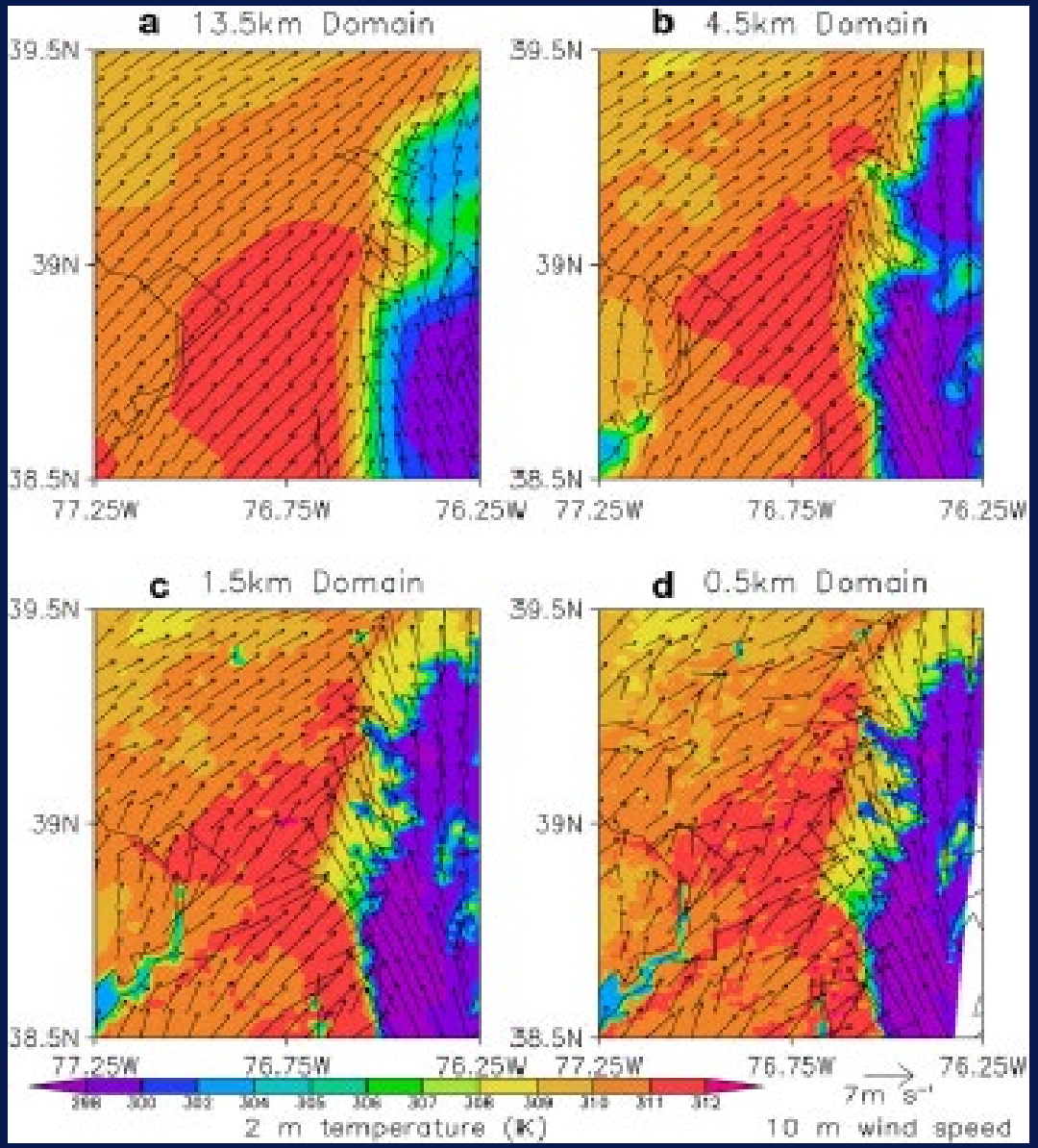
Process Budgeting for NO_x over Baltimore on July 2 2017 and monthly over CONUS





Chemistry (CHEM), Emission (EMIS) and Transport (Horizontal Advection - HADV) are the dominant processes to determine NOx budget locally and nationally.

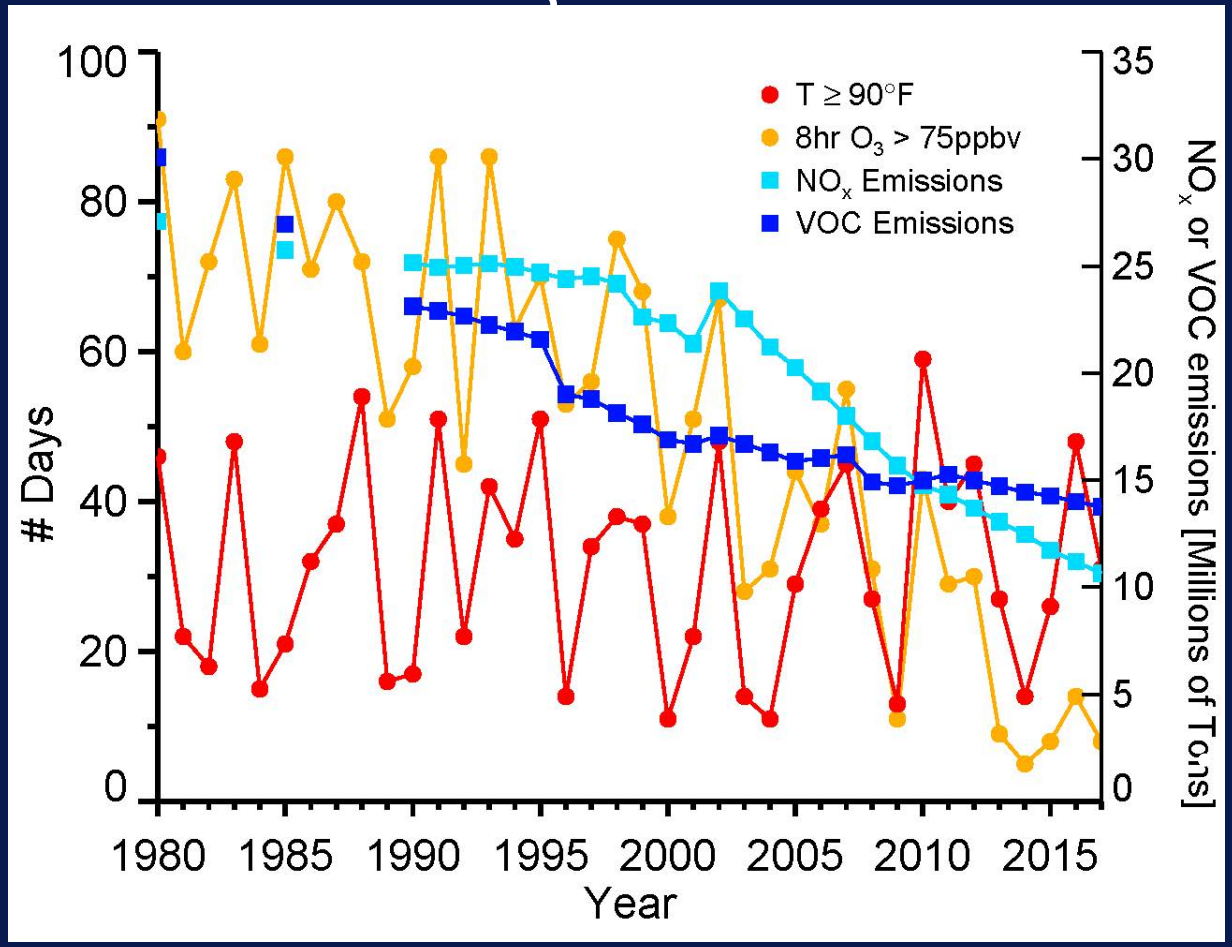
Finer grid spacing captures land-sea breeze



Loughner et al. 2011 *AE,* on: "Possible improvement in AQ modeling fidelity in capturing land-sea breeze processes by increasing model grid resolution:

(1) Better resolves cumulus convection;
(2) Better resolves aqueous phase reaction in cloud droplets;
(3) Better resolves near shore air mass convergence hence better capturing the transport of air pollutants.

Trends in O_3 exceedances vs. temperature



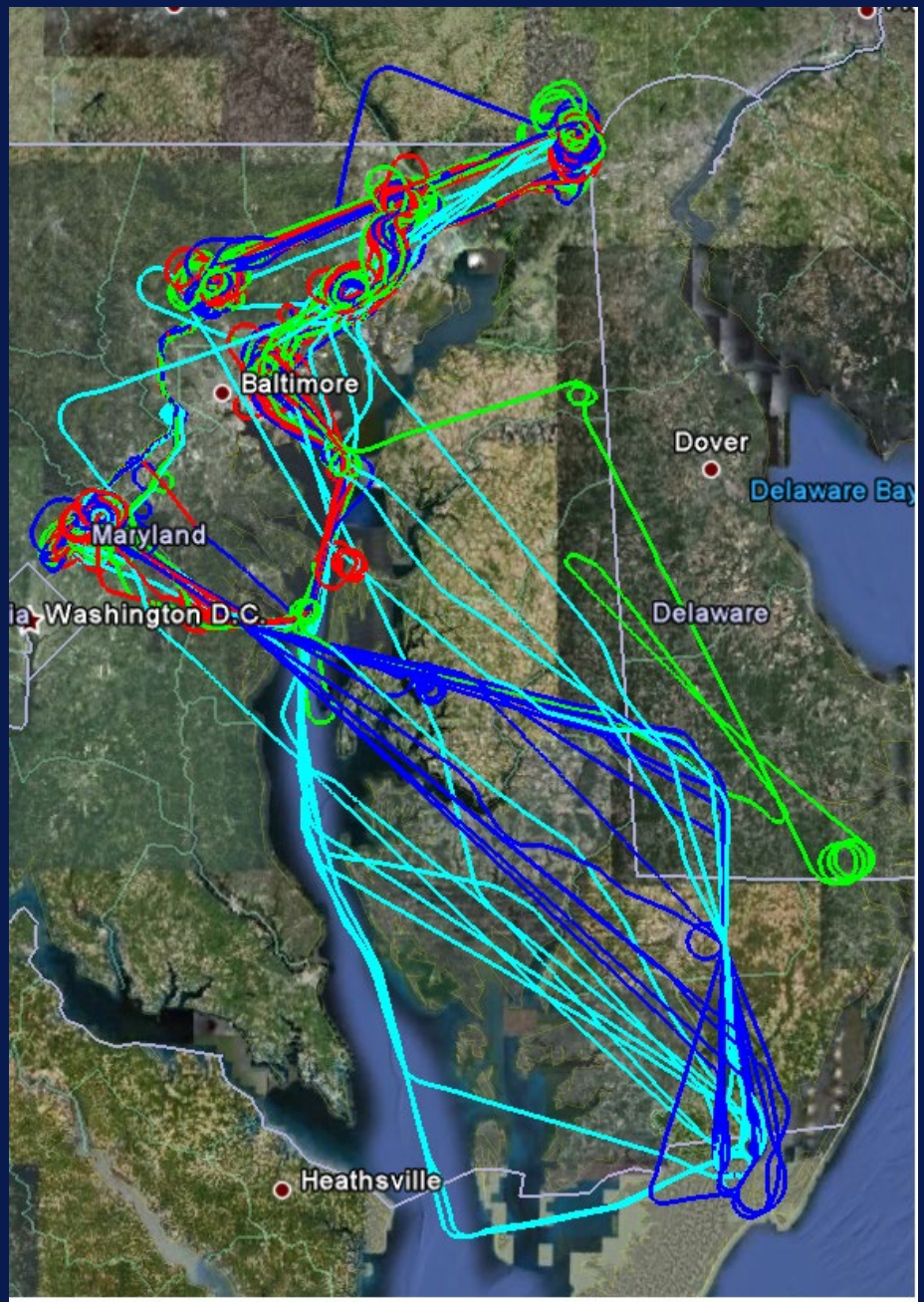
Decreasing trend in maximum 8 hour average ozone exceeding 75 ppbv correlates with decreasing trend in NO_x and VOC anthropogenic emissions reductions.

1980s: About double as many bad air days (8hr O3 > 75ppbv) than hot days ($T \geq 90^oF$).

2009: First time there were more hot days than bad air days in MD.

- All monitor data collected in MD from April through October.
- Daily max temperature from BWI.

Loughner et al. 2019, The benefits of lower ozone due to air pollution emissions reductions (2002-2011) in the Eastern US during extreme heat, JAWMA, 70, 193-205.

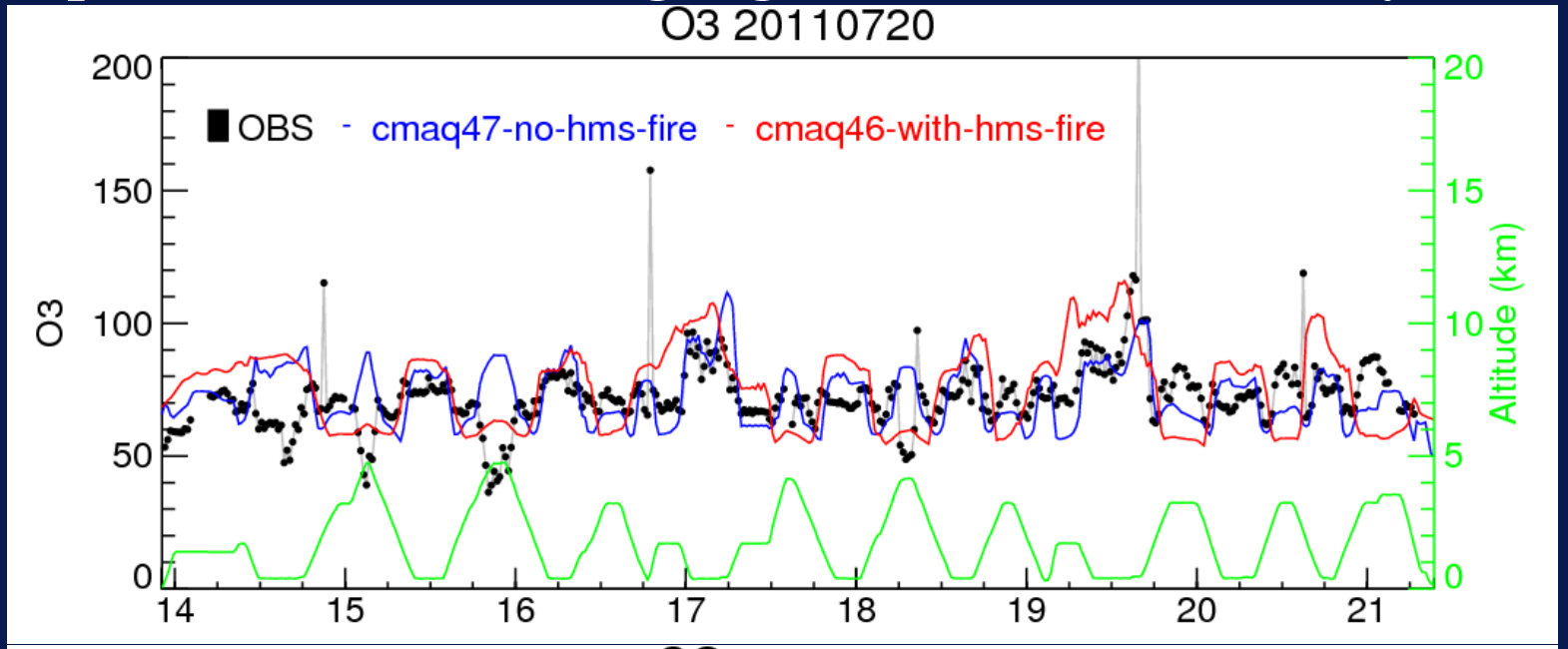


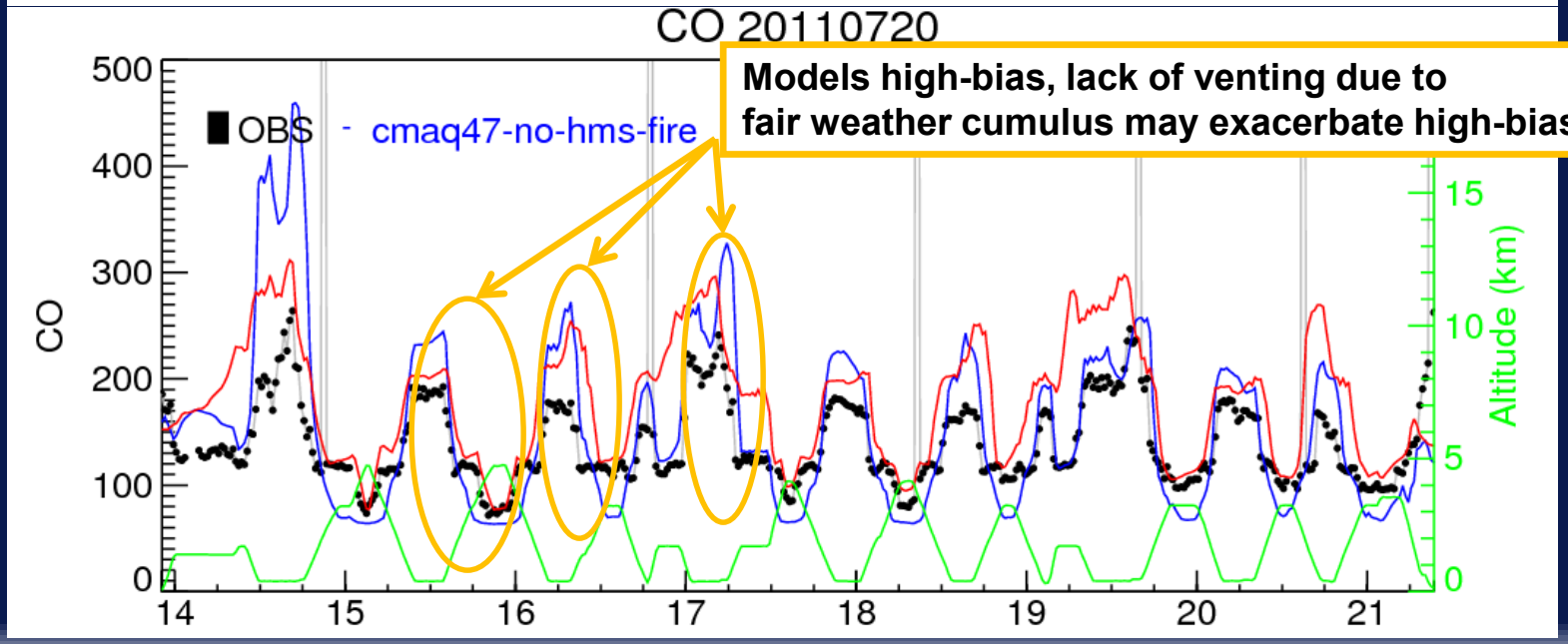
Campaign: Valuable data

NASA P-3B Flight Paths

July 1-29, 2011

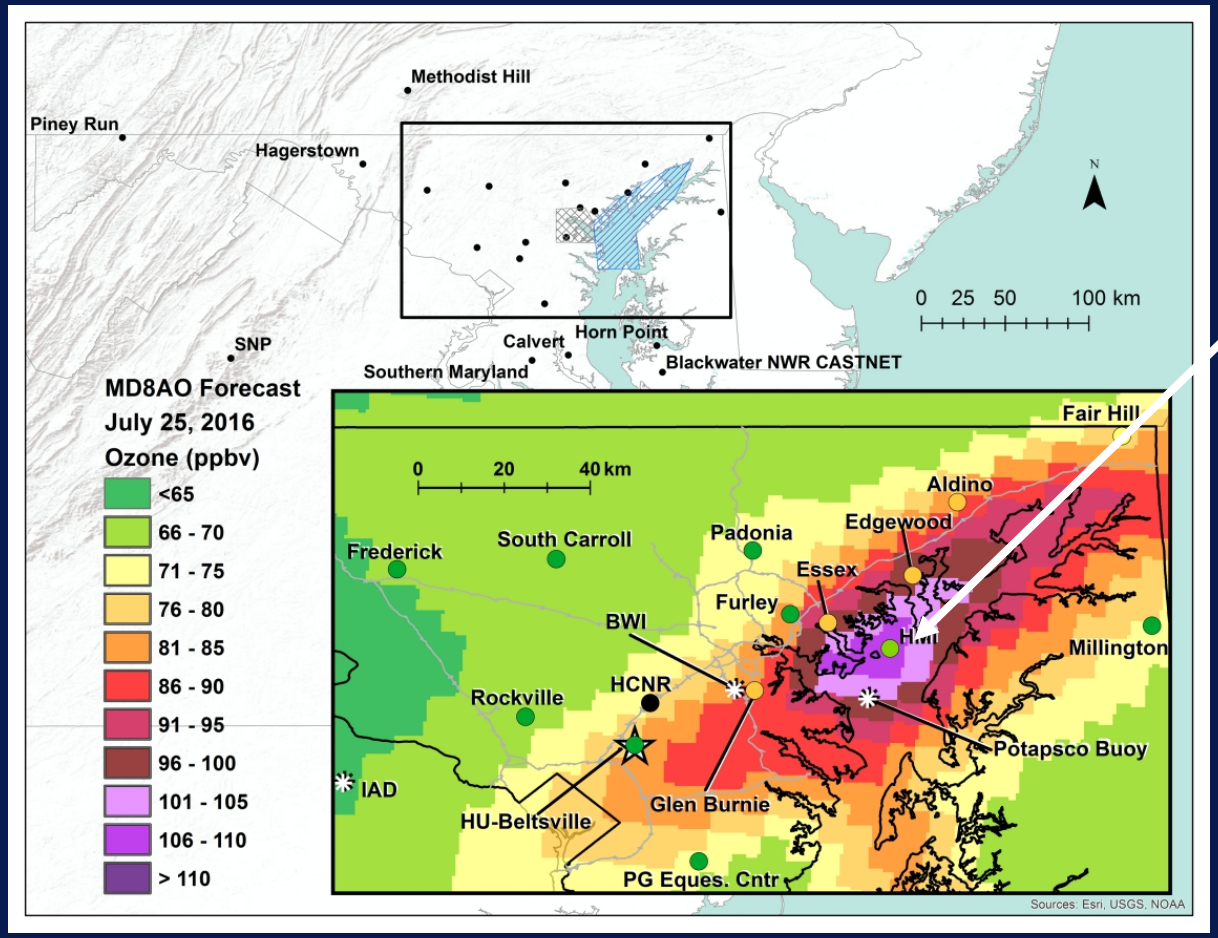
Comparison of Wind along flight track of P3B on July 20 2011





Models high-bias, lack of venting due to fair weather cumulus may exacerbate high-bias

Hart-Miller Island focused study: July 25 2016 Surface level Ozone measurement (shading was NAQFC)



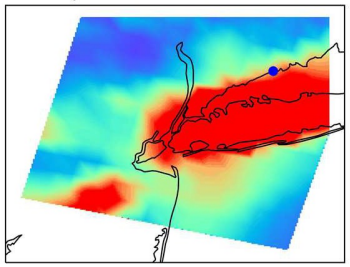
Hart-Miller Island showed severe over-prediction by NAQFC i.e., relative error as much as 40%, Marine boundary is a challenge.

Courtesy: J. Dreessen MDE

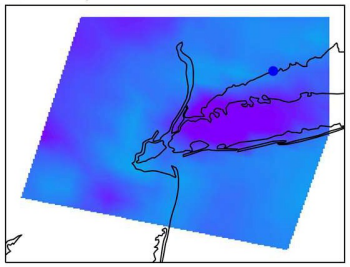
OWLETS-2: Verifying NAQFC forecast for Aug 28th 2018

NOAA NAQFC surface forecast

NO_2



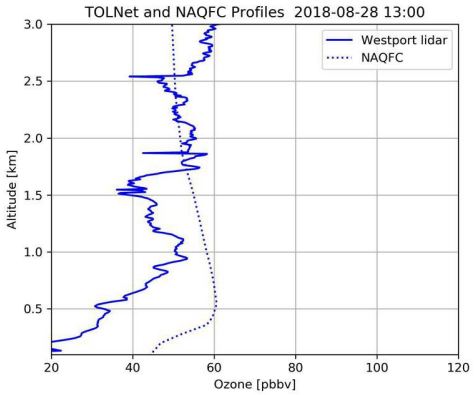
O_3

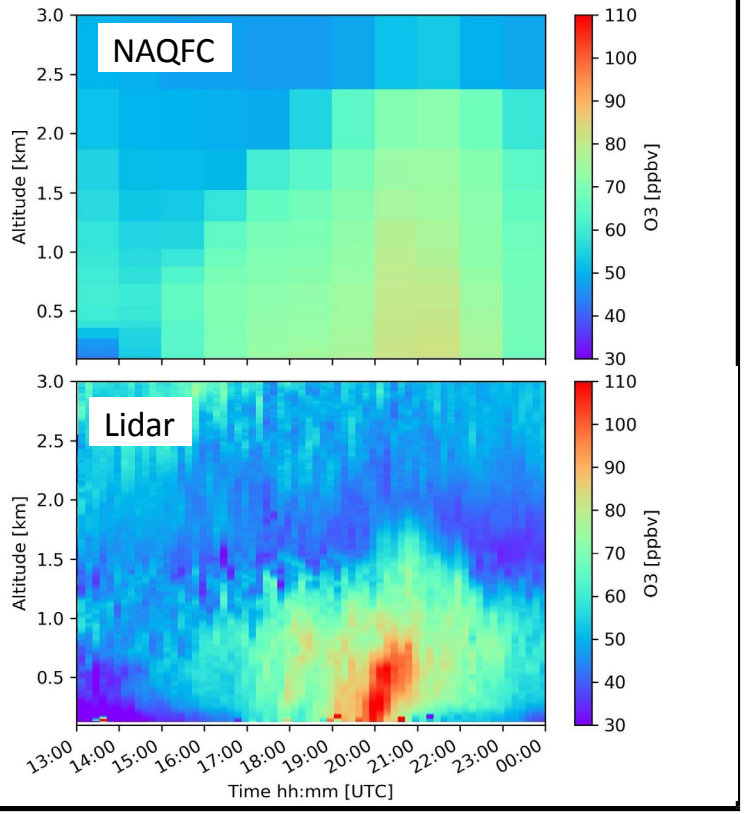


O_3 Vertical Profiles Westport, CT

PRELIMINARY

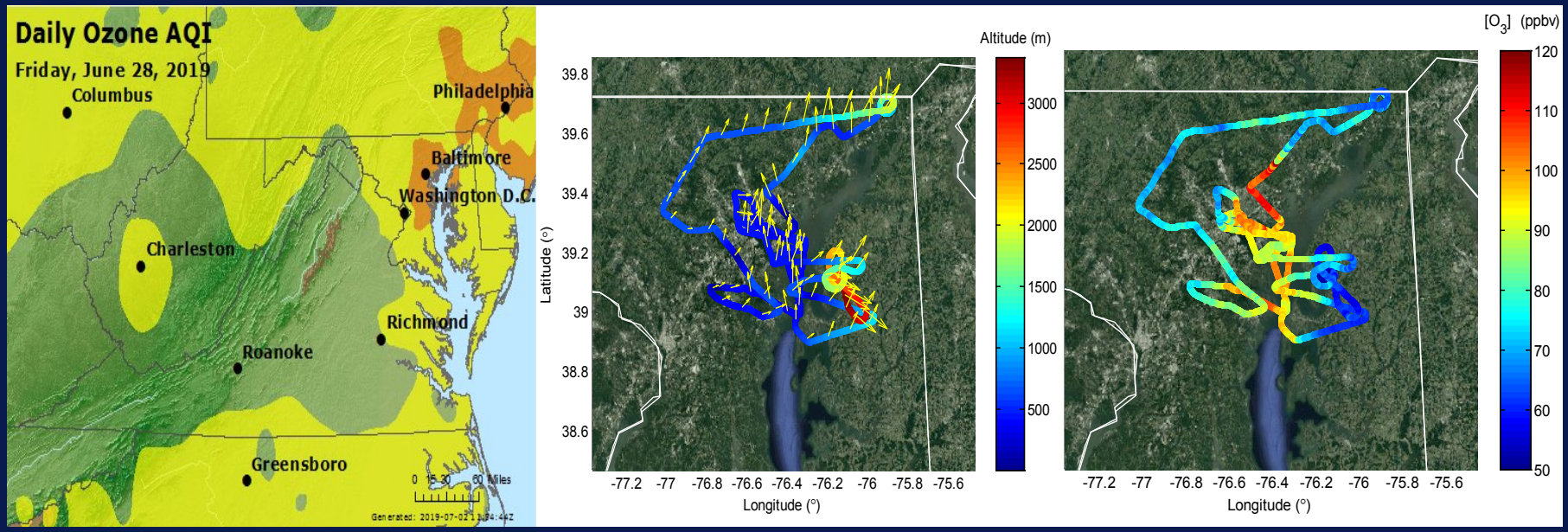
TOLNet (solid), NAQFC (dashed)





Courtesy: T. Berkoff

UMD flights over Baltimore on June 28, 2019

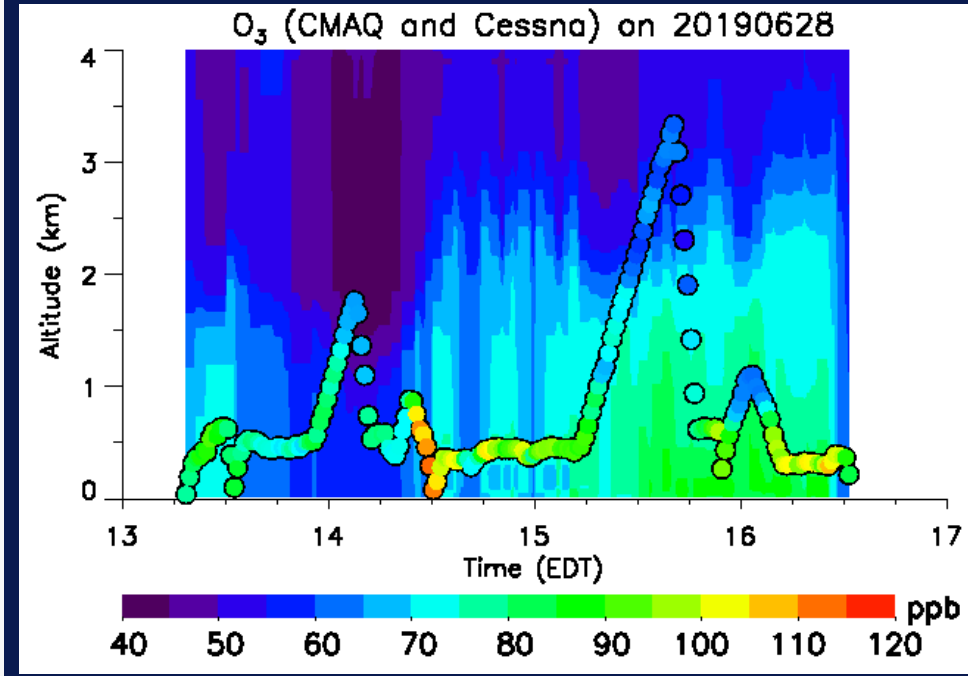


- In general, SW wind over the land
- SSE bay breeze near surface observed

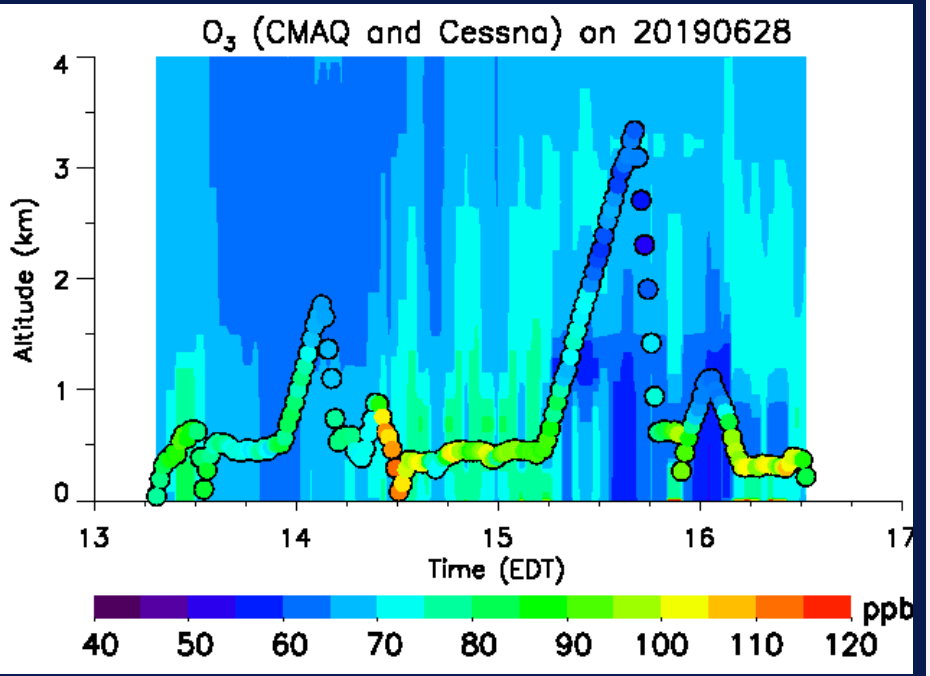
- High $[O_3]$ over the Bay and east of Baltimore
- Max. $[O_3]$ ~120 ppb over NE of Baltimore

O_3 Evaluation of NAQFC and UMD-PP along UMD flight transact on June 28 2019

NAQFC



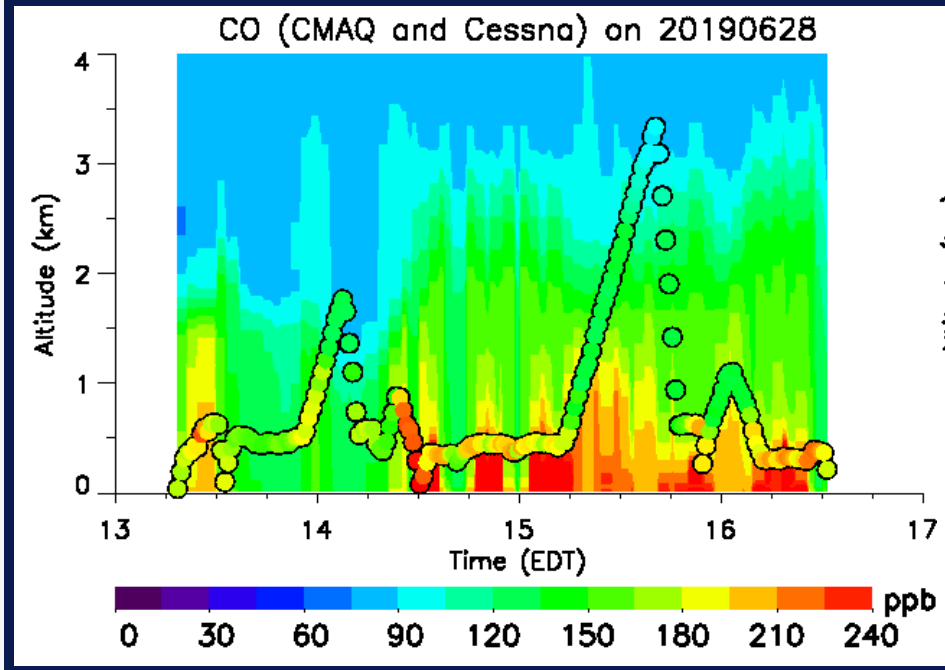
UMD-PP



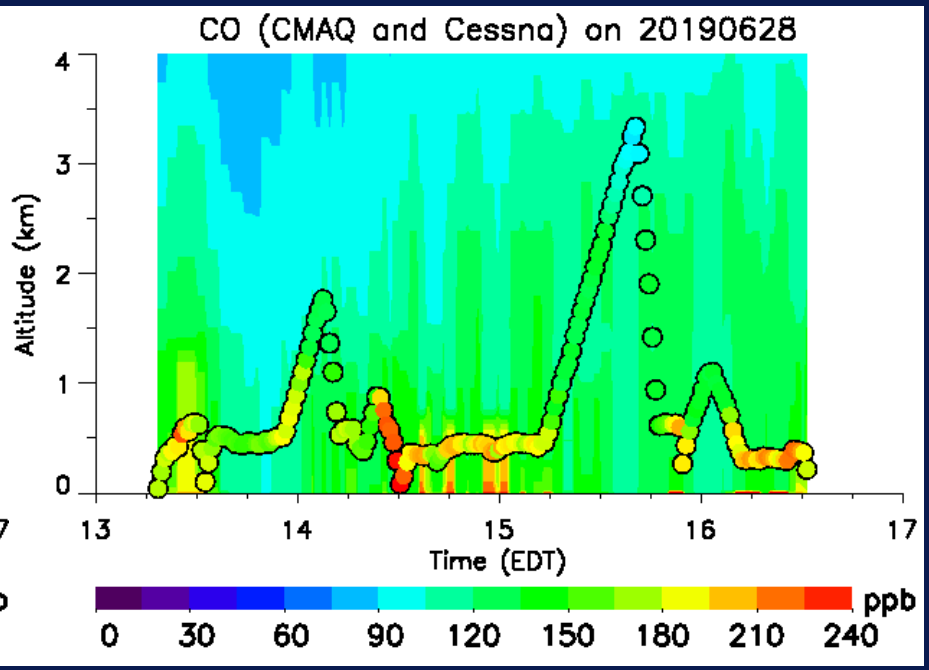
Courtesy: H. He, UMD

CO Evaluation of NAQFC and UMD-PP along UMD flight transact on June 28 2019

NAQFC

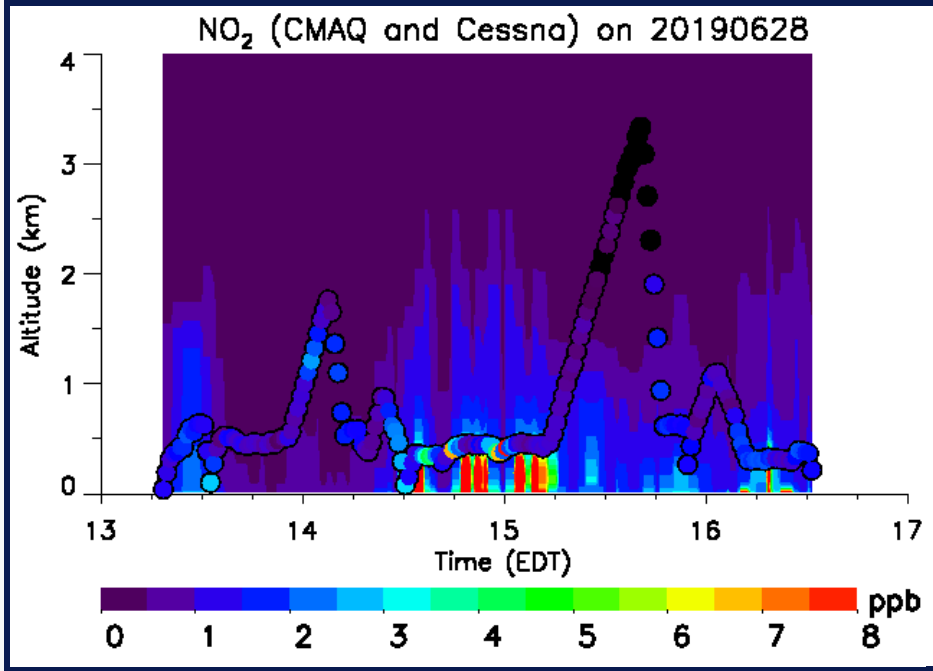


UMD-PP

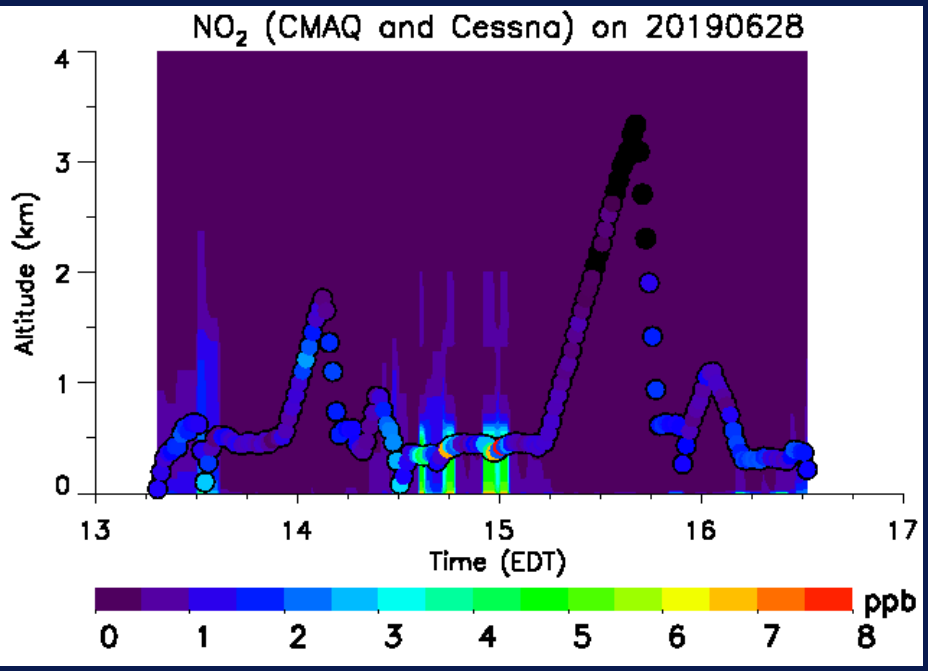


NO_2 Evaluation of NAQFC and UMD-PP along UMD flight transact on June 28 2019

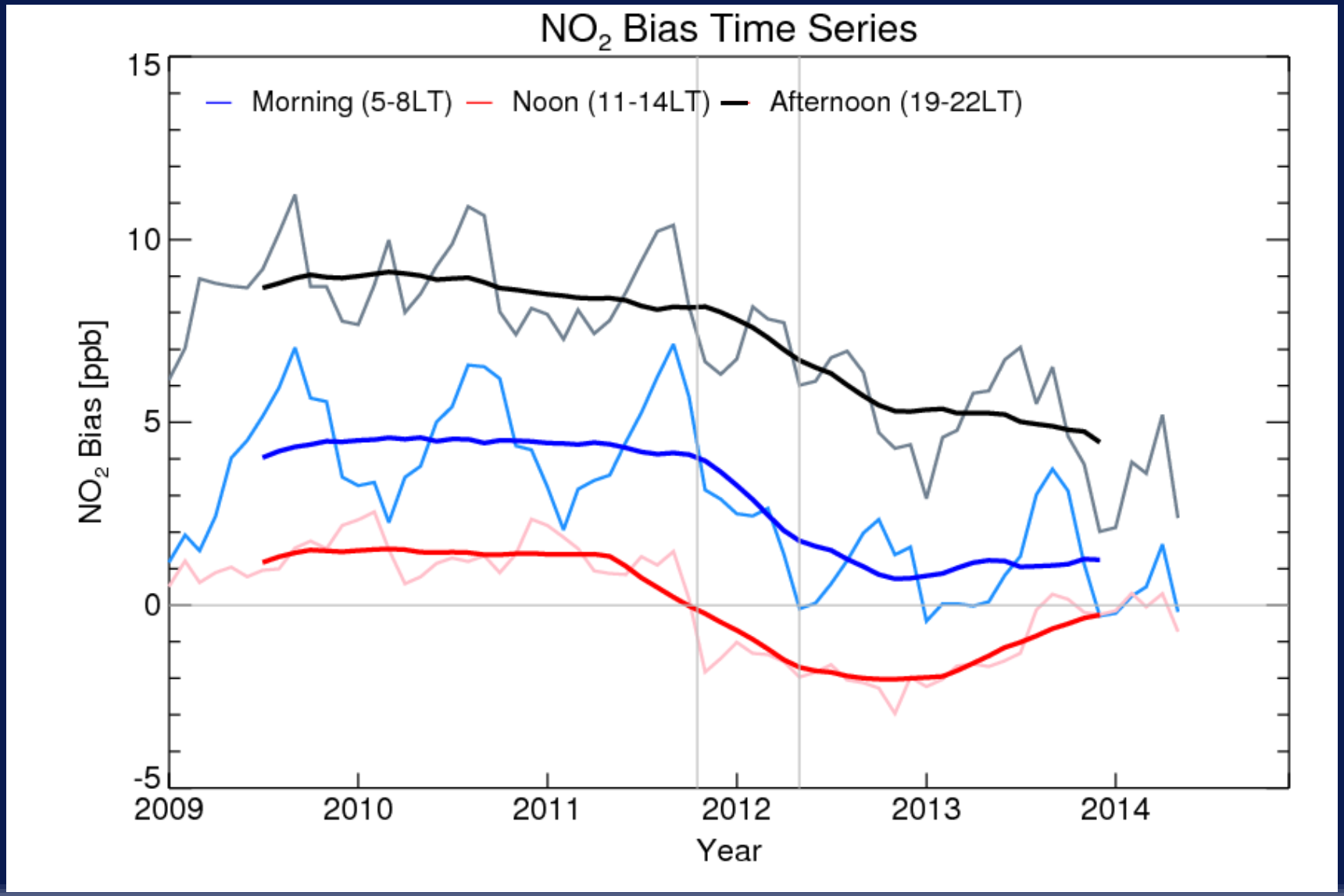
NAQFC



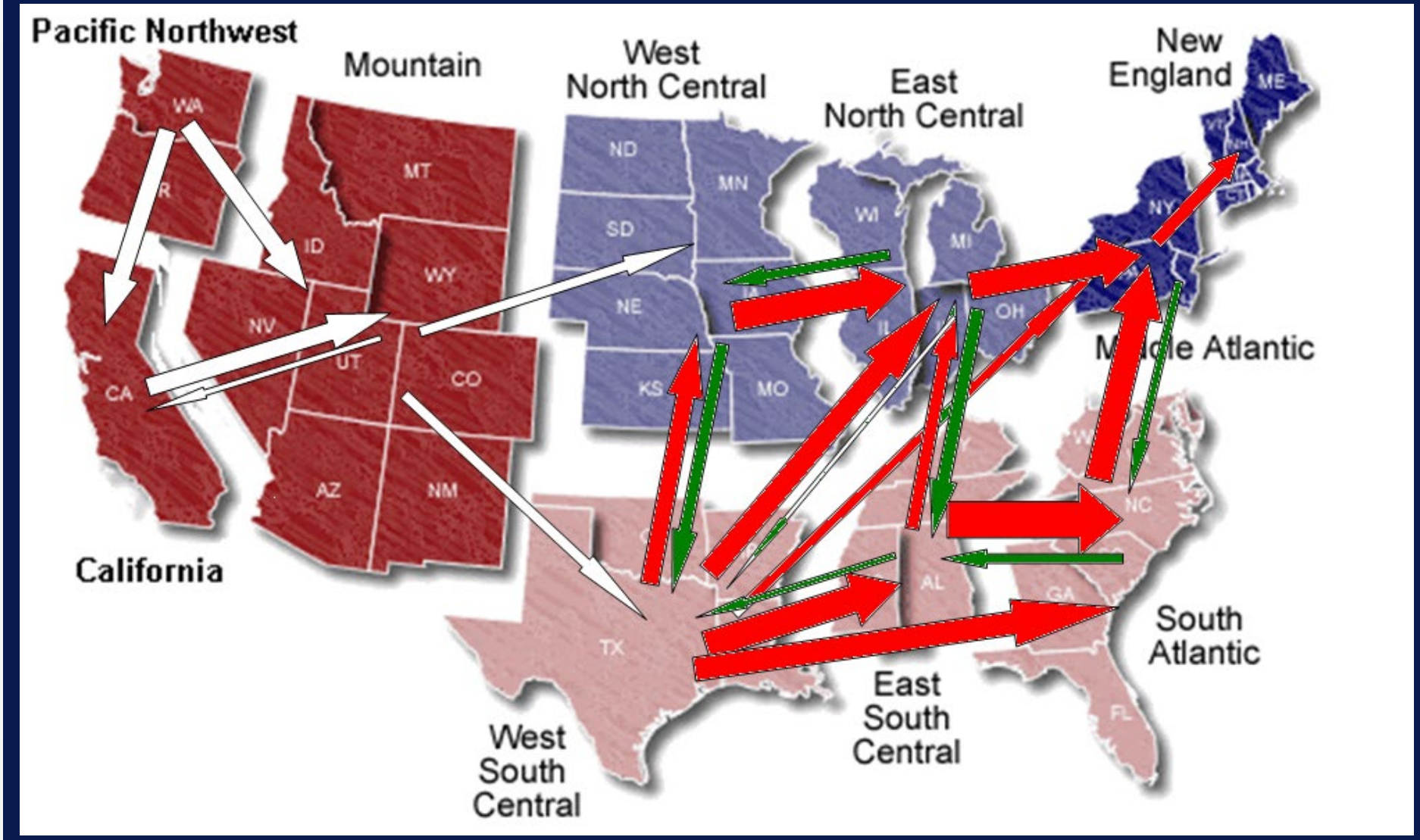
UMD-PP



Departure of diurnal variation of NO_2 (NAQFC-AQS)



Regional Transport of Surface O_3



(Source: Tong et al., Env. Int'l, 2009)

Summary

A. Mid-Atlantic region poses a few challenges for NAQFC:
   a) Complex meteorology (e.g., wet year) and strong land-sea influences;
   b) Rapidly evolving emission change: fuel composition and consumption;
   c) Influence of regional and transboundary transport;
   d) Intermittent sources;
   e) Complex terrain and land-sea interfaces

B. Campaign measurements valuable:
   i. Supersites: Collocated measurements of met and pollutant concentration;
   ii. Land-sea-breeze e.g., OWLETS,… etc;
   iii. Long Range Transport: coordinated campaigns e.g., DISCOVER-AQ,... etc;
   iv. Characterization of local emissions: e.g., UMD flights and HYSPLIT tagging

C. Science questions specific for the Mid-Atlantic Region:
   1. Emission trend;
   2. Source attribution