Model Analysis of Tropospheric Aerosol Variability and Sources over the North Atlantic during NAAMES 2015-2016

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Introduction

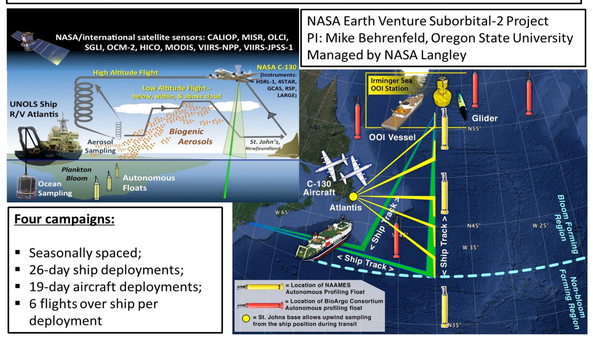
➢ The North Atlantic Aerosols and Marine Ecosystems Study (**NAAMES**; http://naames.larc.nasa.gov) is a five-year NASA Earth-Venture Suborbital-2 Mission to characterize the plankton ecosystems and their influences on remote marine aerosols, boundary layer clouds, and their implications for climate in the North Atlantic, with the 1st field deployment in November 2015 and the 2nd in May 2016.

➢ While marine-sourced aerosols have been shown to make important contributions to surface aerosol loading, cloud condensation nuclei and ice nuclei concentrations over remote marine and coastal regions, it is still a challenge to differentiate the marine biogenic aerosol signal from the strong influence of continental pollution outflow.

➢ We present an initial analysis to examine the spatiotemporal variability and quantify the sources of tropospheric aerosols over the North Atlantic during two field deployments using the GEOS-Chem chemical transport model and MERRA-2 reanalysis. We also used the NASA GMAO's GEOS-5 aerosol forecasts to support the NAAMES field mission.

NAAMES Objectives and Concept of Operations

1. Define environmental and ecological controls on plankton communities
2. Define linkages between ocean ecosystem properties and biogenic aerosols



NASA Earth Venture Suborbital-2 Project
PI: Mike Behrenfeld, Oregon State University
Managed by NASA Langley

Four campaigns:

- Seasonally spaced;
- 26-day ship deployments;
- 19-day aircraft deployments;
- 6 flights over ship per deployment

Model and Data

➢ GEOS-Chem: a global 3-D chemistry and transport model (v11-01f)
  - ✓ driven by the GEOS-FP assimilated meteorology (at 2°×2.5° horizontal resolution) from the NASA Global Modeling Assimilation Office (GMAO).
  - ✓ includes sulfate-nitrate-ammonium aerosol thermodynamics coupled to ozone-NOx-hydrocarbon-aerosol chemistry, mineral dust, sea salt [Jaegle et al., ACP 2011], elemental and organic carbon [Pye et al., ACP 2010] aerosols, especially a recently implemented parameterization for the marine primary organic aerosol emission [Gantt et al., GMD 2015].

➢ GEOS-Chem aerosol optical depth (AOD) calculated from the mass concentration, extinction efficiency, and particle mass density [Martin et al., JGR 2003].

➢ MODIS aerosol optical depths (AOD) data:
  - ✓ Level 3 daily aerosol product (1°×1° resolution)
  - ✓ Collection 6 (https://ladsweb.nascom.nasa.gov/data/)

➢ NASA GMAO MERRA-2 reanalysis
  - ✓ https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

➢ NASA GMAO GEOS-5 aerosol forecast products
  - ✓ http://gmao.gsfc.nasa.gov/forecasts

➢ NAAMES aircraft data
  - ✓ http://naames.larc.nasa.gov/

GEOS-Chem Aerosol and CO

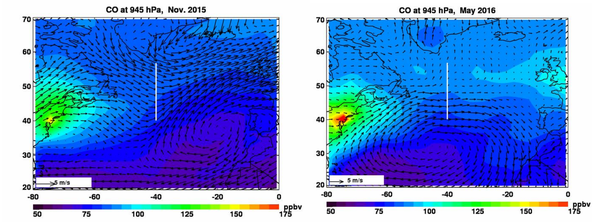


Fig. Monthly mean CO concentrations (ppbv) and winds near surface over the North Atlantic for Nov. 2015 (left) and May 2016 (right), as simulated by GEOS-Chem / GEOS-FP.

Along 40°W (nominal ship track 40-57°N), the ship has ample opportunities to sample marine air despite the influences of the North American continental outflow.

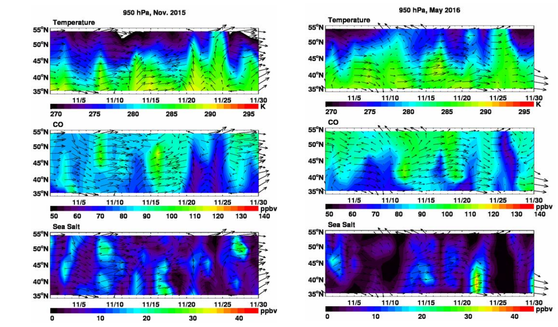


Fig. Hovmöller diagram of model surface temperature, CO and sea salt concentrations along 40°W over the North Atlantic (Left: Nov. 2015; Right: May 2016)

Major transport pathways for N.A. pollution over the North Atlantic: boundary-layer outflow, frontal lifting, and convective outflow. Enhanced sea salt aerosols often associated with strong wind & warm air from south.

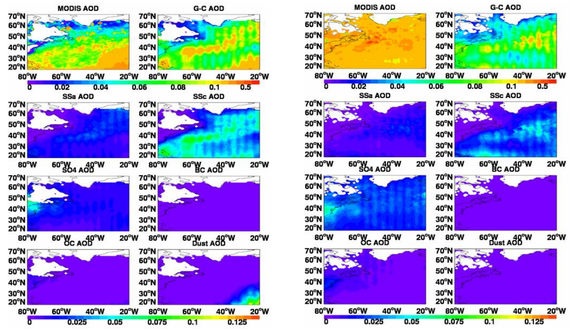


Fig. Evaluation of monthly mean GEOS-Chem / GEOS-FP AODs with MODIS (on Aqua) satellite retrievals for Nov. 2015 (left) and May 2016 (right). Model output are sampled at 1:30pm local time along the satellite orbit track.

In the NAAMES study region, sea salt and sulfate are major contributors to the total AOD.

Model reproduces the general spatial distribution of MODIS AODs in the NAAMES study region, but underestimates AODs in May 2016.

MERRA-2 Aerosol and CO

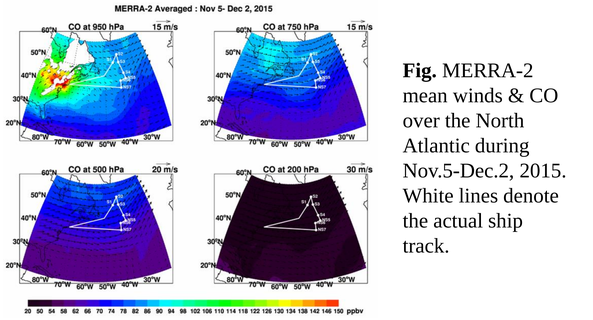


Fig. MERRA-2 mean winds & CO over the North Atlantic during Nov.5-Dec.2, 2015. White lines denote the actual ship track.

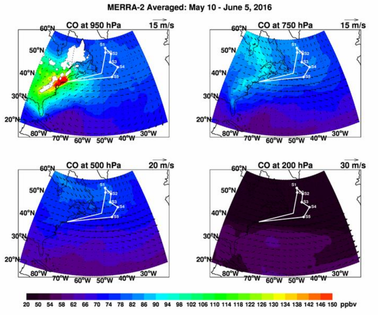


Fig. MERRA-2 mean winds & CO over the North Atlantic during May 10-June 5, 2016.

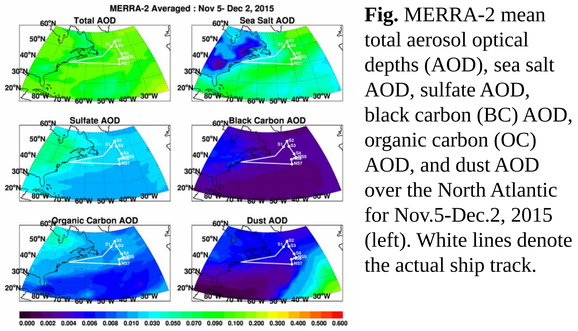
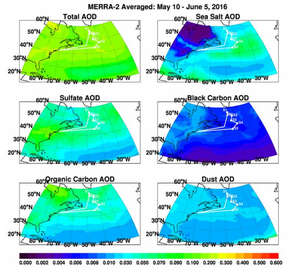


Fig. MERRA-2 mean total aerosol optical depths (AOD), sea salt AOD, sulfate AOD, black carbon (BC) AOD, organic carbon (OC) AOD, and dust AOD over the North Atlantic for Nov.5-Dec.2, 2015 (left). White lines denote the actual ship track.

Fig. (right) Same as above, but for May 10-June 5, 2016. Smaller sea salt AOD reflects lighter winds; Larger sulfate AOD results from more oxidation of SO_2.



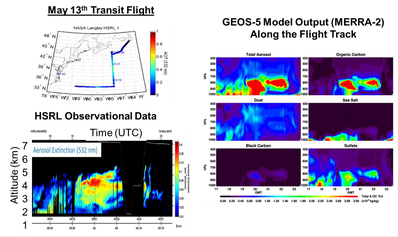


Fig. MERRA-2 captures the aerosol plume observed by HSRL during the transit flight on May 13, 2016.

GEOS-5 Aerosol Forecasting for NAAMES

We used the GEOS-5 aerosol forecast products to support the Nov. 2015 & May 2016 deployments of the NAAMES mission. The forecasts are provided by the Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center through the online data portal in the NASA Center for Climate Simulation (http://gmao.gsfc.nasa.gov/forecasts/).

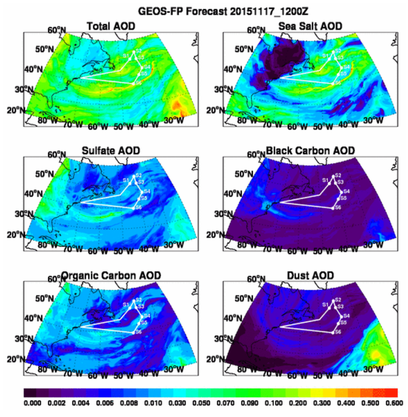


Fig. Aerosol optical depths over the North Atlantic at 12GMT, Nov. 17, 2015, as forecasted by the GEOS-5 FP model. White lines indicate the ship track along with ship stations.

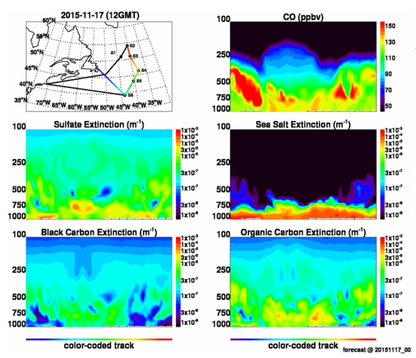


Fig. Curtain plots of CO and aerosol extinction coefficients at 12GMT, Nov. 17, 2015, as forecasted by GEOS-5 FP, along a nominal flight track (color line on the map).

Future Work to Help Answer NAAMES Science Questions

Can we discern ocean biology impacts on aerosols / clouds, or is the signal overwhelmed by North American pollution?

If we see an increase in organic aerosols in the atmosphere, is it due to local biogenic production? Is it due to transport of continental aerosols?

How "typical" is November 2015 and May 2016 in terms of atmospheric loadings and pollution transport?

How can we use NAAMES observations of the ocean, aerosols, and clouds to assess / improve their representation in models?

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