# Aerosol Sources, Transport Pathways, and Scavenging During ACTIVATE: Model Products and Research Projects

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# Model Products

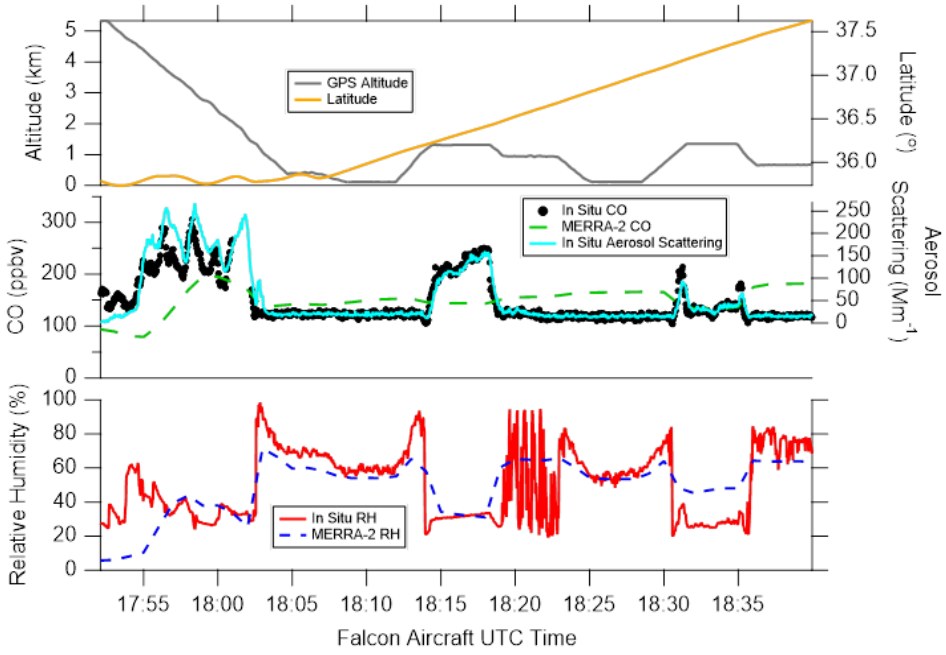
## 1) ACTIVATE MERRA-2 Data Sampled Along the Falcon (HU-25) Flight Tracks (https://www-air.larc.nasa.gov/cgi-bin/ArcView/activate.2019?MODEL=1)

- **Description**: MERRA-2 (Gelaro et al., J. Climate, 2017) is NASA's latest reanalysis produced with the GEOS-5 atmospheric data assimilation system. It assimilates AOD from ground and satellite-based remote sensors.

- **Product**: Selected MERRA-2 3-D fields of trace gases and aerosols and meteorological parameters are sampled for each 60-sec along the Falcon (HU-25) flight tracks during ACTIVATE. Data format: ICARTT file format standards V2.0.

| 3-D Fields |
|---|
| CO |
| Ozone |
| DMS |
| MSA |
| $SO_2$ |
| Sulfate |
| Sea salt (5 bins, 0.03-10μm) |
| Dust (5 bins, 0.1-10μm) |
| Hydrophilic BC |
| Hydrophobic BC |
| Hydrophilic OC |
| Hydrophobic OC |
| Factor used to convert μg $m^{-3}$ to μg std $m^{-3}$ |
| Relative humidity |
| Air temperature |
| Mass fraction of cloud ice water |
| Mass fraction of cloud liquid water |
| Specific humidity |

- **Applications**: Compare measurements with reanalysis; provide quantities not measured during ACTIVATE; perform statistical analysis of aircraft in-situ (vs. reanalysis) data.




- **Point of Contact**:
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# Model Products

## 2) FLEXPART Back Trajectory Product

**(https://www-air.larc.nasa.gov/cgi-bin/ArcView/activate.2019?TRAJECTORY=1)**

### ❑ Model Description:

- FLEXPART v9 and v10 ("FLEXible PARTicle dispersion model", https://www.flexpart.eu/).
- Driven by Global Forecast System Analysis (GFS-ANL 003, 1° by 1°, 26 levels, 3-hourly).
- Each trajectory (20,000 inert air parcels) is released every 10 mins along the flight track. Transport of the air parcels is simulated backward in time for 10 days.
- Model output contains a 4-D field of air mass residence time.
- Product data format: NetCDF.

### ❑ Data Download:

- Both model output (NetCDF files) and plots are available.
- Each output file corresponds to a release point along the flight track.
- URL: https://www-air.larc.nasa.gov/cgi-bin/ArcView/activate.2019?TRAJECTORY=1

### ❑ Applications:

- Residence time indicates air mass transport pathways.
- When coupled with emission (e.g., CO) inventories, residence time may be used to determine pollution sources and their relative contribution.
- Quantify precipitation along transport pathways.

### ❑ Point of Contact:

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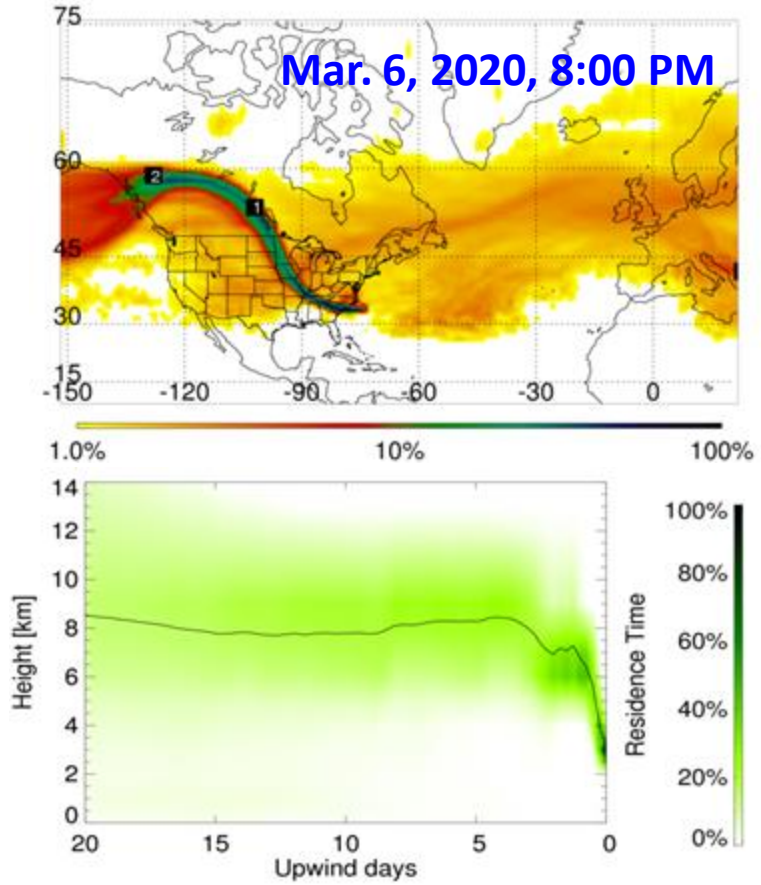



***Example Figure**: Horizontal and vertical views of simulated air mass residence time during transport. The labels on the map indicate the approximate locations of the center of the plume. Residence time is color coded by logarithmic grades representing its ratio to the location of maximal integrated residence time (100 %).*

# Research Projects

## 1) Tropospheric Aerosols Over the Western North Atlantic Ocean (WNAO) During the Winter and Summer Campaigns of ACTIVATE 2020: Sources, Transport, and Distribution

### ❑ Motivation:

- Aerosols act as cloud condensation nuclei or ice nuclei. Characterization of aerosol-cloud-meteorology interactions requires understanding of aerosol sources, composition, distribution, transport pathways, properties, and evolution.
- Continental outflow over the WNAO represent a mix of various aerosol sources, types, and are impacted by large-scale and synoptical weather systems, offering an excellent condition for testing current understanding of tropospheric aerosol processes (winter vs summer).

### ❑ Methodology:

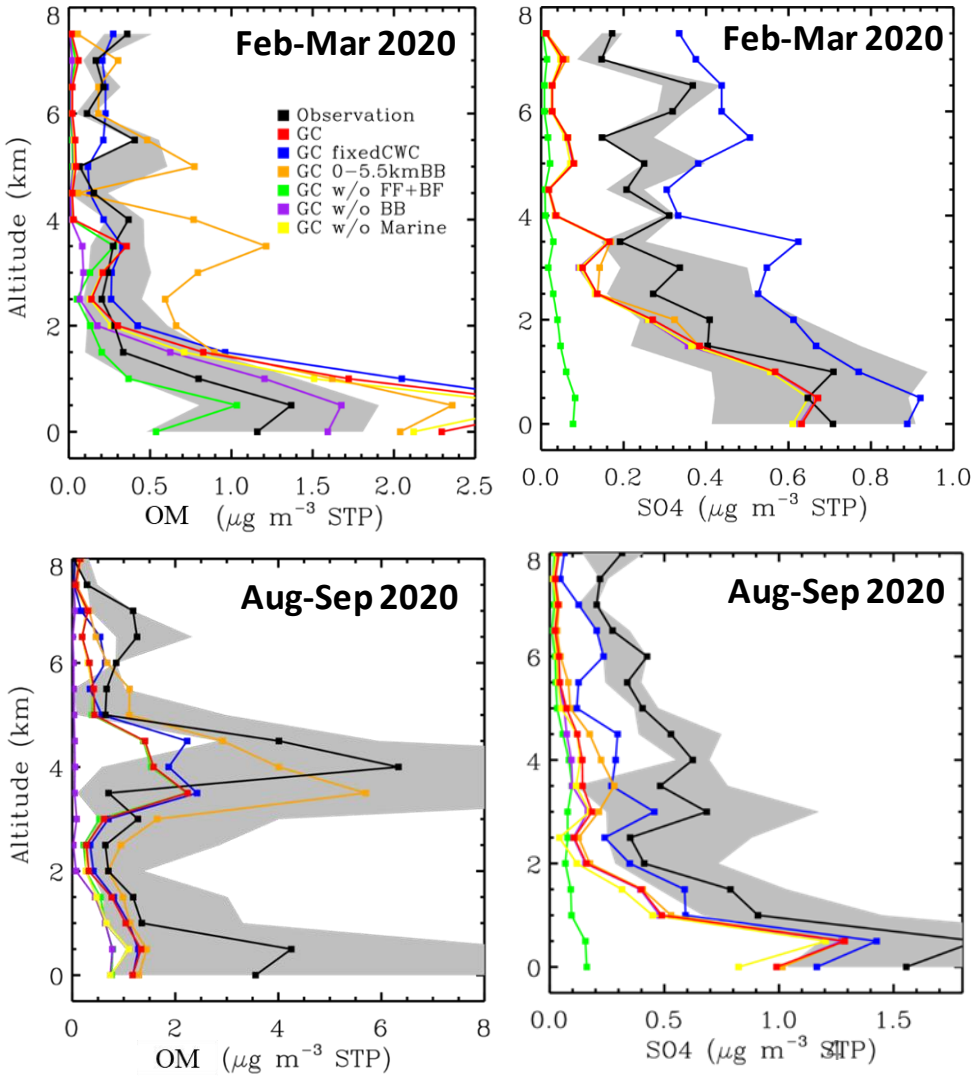
- GEOS-Chem / MERRA-2, model sensitivity experiments, two scavenging configurations wrt cloud water content, BB emission injection heights.
- ACTIVATE aircraft in situ (CO, AMS aerosol) and remote sensing (HSRL-2) measurements; CALIOP aerosol extinction profiles; AERONET AOD.

### ❑ Selected Results:

- Using MERRA-2 cloud water content in GEOS-Chem aerosol scavenging scheme improves model BL aerosol profiles & AOD in winter.
- Increasing BB emission injection heights from PBL to 0-5.5 km improves model simulations of aircraft in situ (AMS) and remote sensing (HSRL-2), surface remote sensing (AERONET), and satellite (CALIOP) aerosol observations during the western U.S. fire events (Aug.-Sept. 2020).
- Contribute to mission Objective 1A.

### ❑ Current status: Manuscript will be shared in ~1 month.

## Organic Matter & SO4 profiles: GC vs. Obs.



# 2) Tropospheric Aerosols Over the Western North Atlantic Ocean During the 4th and 6th phases of ACTIVATE (May-June 2021/2022): Sources, Transport, and Distribution

## ❑ Motivation:

- How different are aerosol sources, composition, distribution, and transport pathways over the WNAO during late spring - early summer compared to other seasons?
- What are the sources and vertical distribution of aerosols over the remote North Atlantic (Bermuda)?

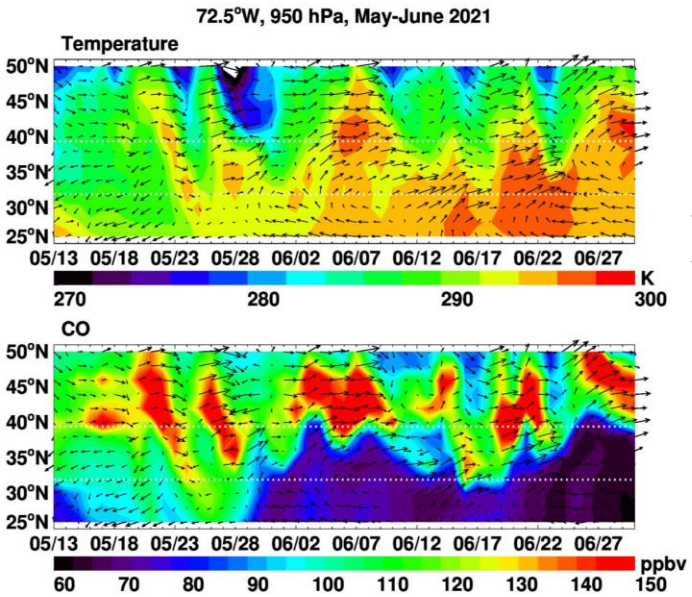
## ❑ Methodology:

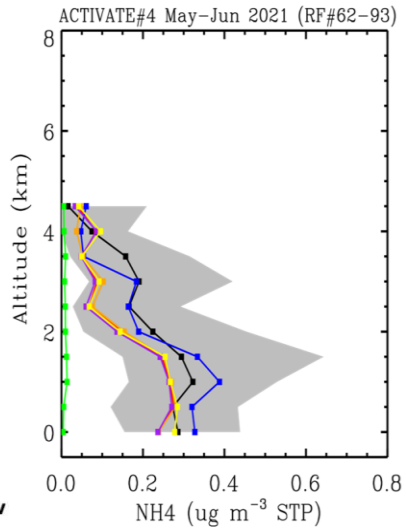
- GEOS-Chem / MERRA-2, model sensitivity experiments, two scavenging configurations wrt cloud water content, BB emission injection heights.
- ACTIVATE aircraft in situ (CO, AMS aerosol) & remote sensing (HSRL-2) measurements; CALIOP / CALIPSO aerosol extinction profiles; AERONET AODs.

## ❑ Selected preliminary results:

- BL outflow of N. American CO (pollution tracer) to the study region weakened significantly starting early June as the Bermuda High shifted westward.
- CO/aerosol vertical distribution is characterized by a distinct layer of enhancement at ~1-2 km.
- The model largely underestimates both HSRL-2 and CALIOP aerosol extinctions in the FT over the study domain. The impact of BB emissions on the FT aerosols needs further investigation.
- Contribute to mission Objective 1A.

## ❑ Current status: See poster by **H. Liu et al.** on a model analysis of ACTIVATE (May-June 2021)

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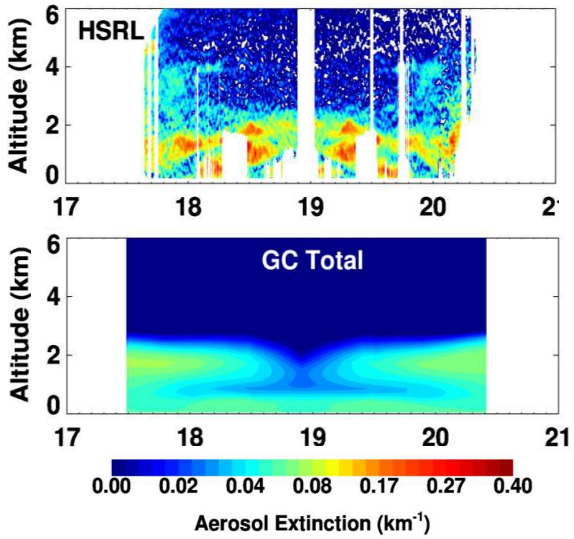


# 3) Size-dependent Below-Cloud Aerosol Scavenging and its Feedback on Clouds and Transport in the NASA GEOS Model During the Winter Campaign of ACTIVATE 2020

## ❑ Motivation:

- Current aerosol wet scavenging scheme in the NASA GEOS/GOCART model does not consider size-dependency of the scavenging process. We have implemented a size-dependent below-cloud scavenging scheme (Croft et al., ACP 2009) in the model.
- Continental outflow of aerosols is accompanied by seasonally prevalent large-scale clouds and precipitation over the WNAO in winter, providing an excellent opportunity to assess and constrain model parameterizations of aerosol below-cloud scavenging.

## ❑ Methodology:

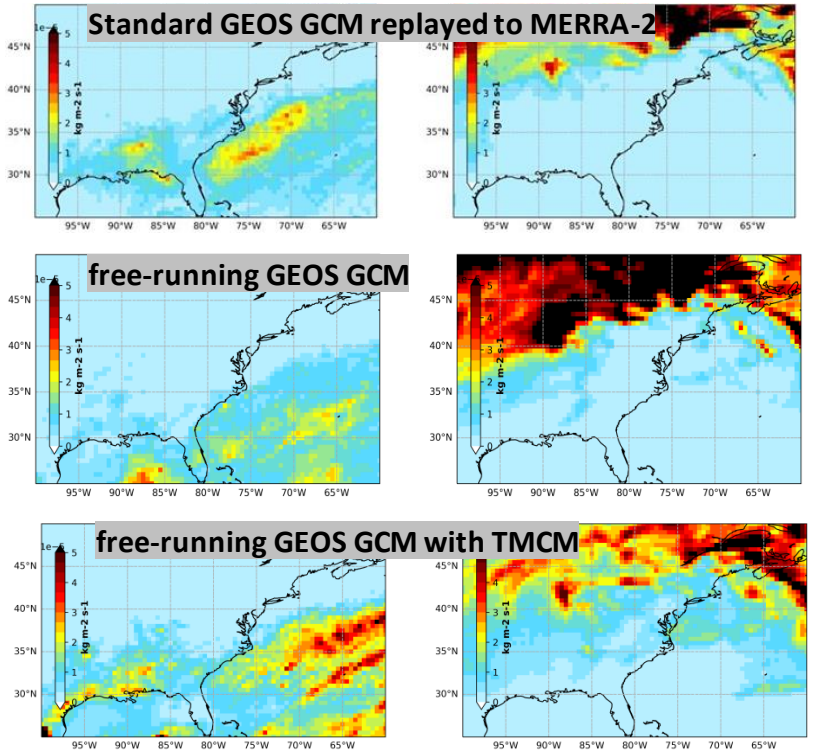
- Replay and free-running GCM experiments in c180 (~50km) resolution
- Radionuclide tracers: $^{222}Rn$ & $^{210}Pb$ to diagnose transport and scavenging
- Simulated aerosols (sulfate, nitrate, ammonium, BC, OC, dust, and sea salt) to compare with ACTIVATE measurements.

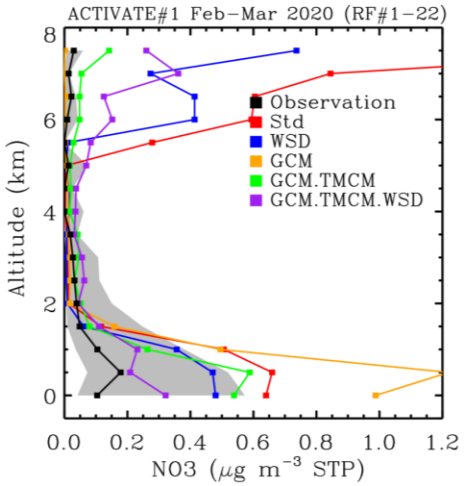
## ❑ Preliminary results and relevance:

- GEOS/GOCART results evaluated with Falcon aerosol measurements.
- The free-running GCM shows less efficient convective transport than the replay run and its simulated aerosol is more consistent with observations from ACTIVATE (Feb.-Mar. 2020).
- Two-moment cloud microphysics (TMCM) leads to more convective and non-convective precipitation (thus more scavenging) over the WNAO.
- Contribute to mission Objective 2B&D.

## ❑ Current status:

See poster by **B. Zhang et al.**; Manuscript in preparation.




↑ ***Simulated monthly mean convective & non-convective precipitation over the WNAO for Feb. 2020.***

← ***Comparisons between aircraft measured aerosols and model results for all flights during ACTIVATE#1. Observations and model results are averaged for every 500m vertically. Shading area indicate 25% and 75% percentiles of aircraft observations.***

# 4) Airmass precipitation history-based testing of model aerosol scavenging schemes

## ❑ Motivation:

- Aerosol removal due to wet scavenging in different cloud and precipitation regimes vary substantially.
- Large variances are often seen associated with the average profiles and suggest very different air masses. Individual aerosol sample could experience very different scavenging and transport history.

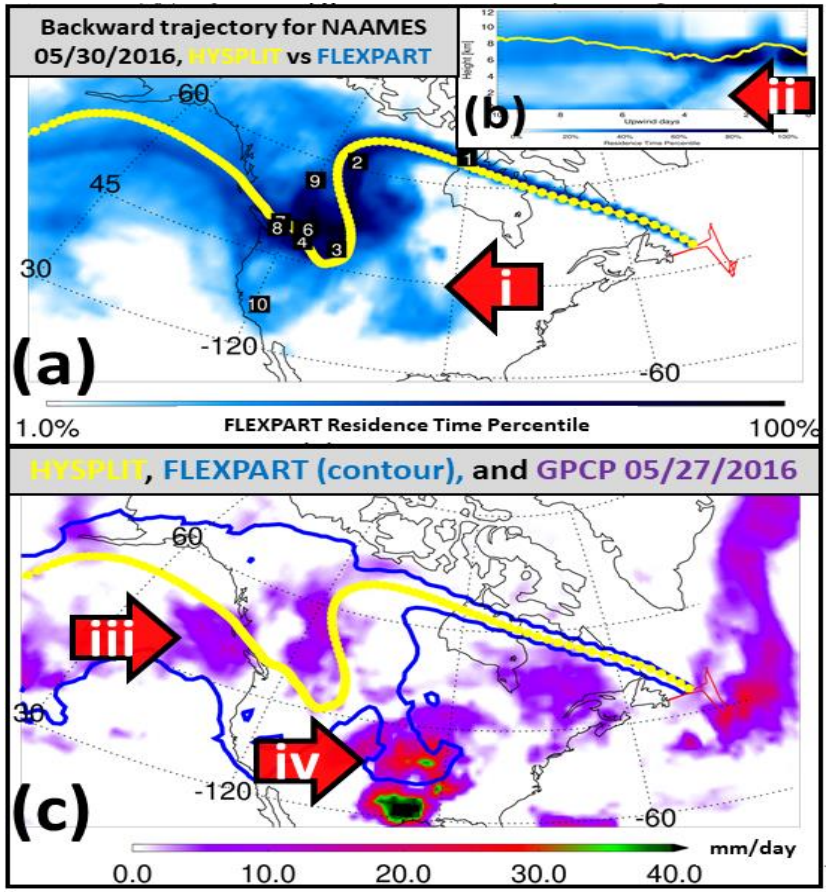
## ❑ Methodology:

- FLEXPART is used to quantify accumulated precipitation and other meteorological variables along transport pathways to better interpret aircraft aerosol measurements.
- Focus on aerosol scavenging in N. American outflow.

## ❑ Expected outcome and relevance:

- Better estimates of cloud/aerosol parameters for scavenging scheme (cloud water content, aerosol partitioning in clouds, etc.)
- Better understanding of existing biases associated with individual processes of aerosol scavenging.
- Contribute to mission Objective 2B&D.

## ❑ Current status: Modeling tool development




***Horizontally (a) and vertically (b) integrated FLEXPART residence time (blue) overlapped with the HYSPLIT single trajectory (yellow). (c) is the same with GPCP precipitation. Arrows indicate transport features shown in FLEXPART: (i) air mass mixing/convection, (ii) mass portion lifted from PBL, (iii) and (iv) precipitation influence missed by HYSPLIT but captured by FLEXPART.***