AEROMMA Marine Science Objectives: Chemistry/climate coupling in the marine boundary layer

Andrew Rollins, Patrick Veres
Jan Kazil, Gordon Novak, Siyuan Wang

AGES meeting, September 27, 2022

andrew.rollins@noaa.gov, patrick.veres@noaa.gov

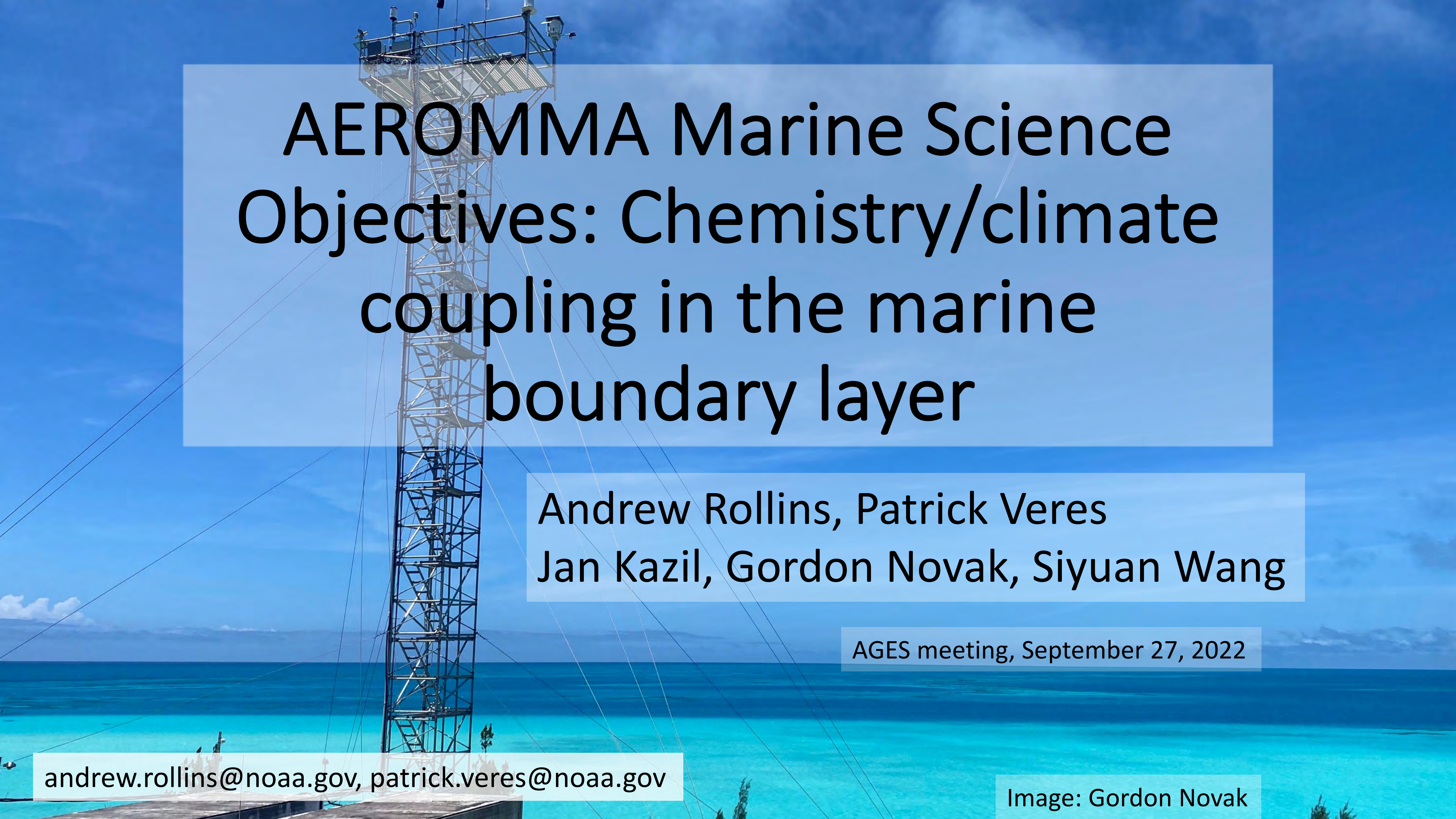
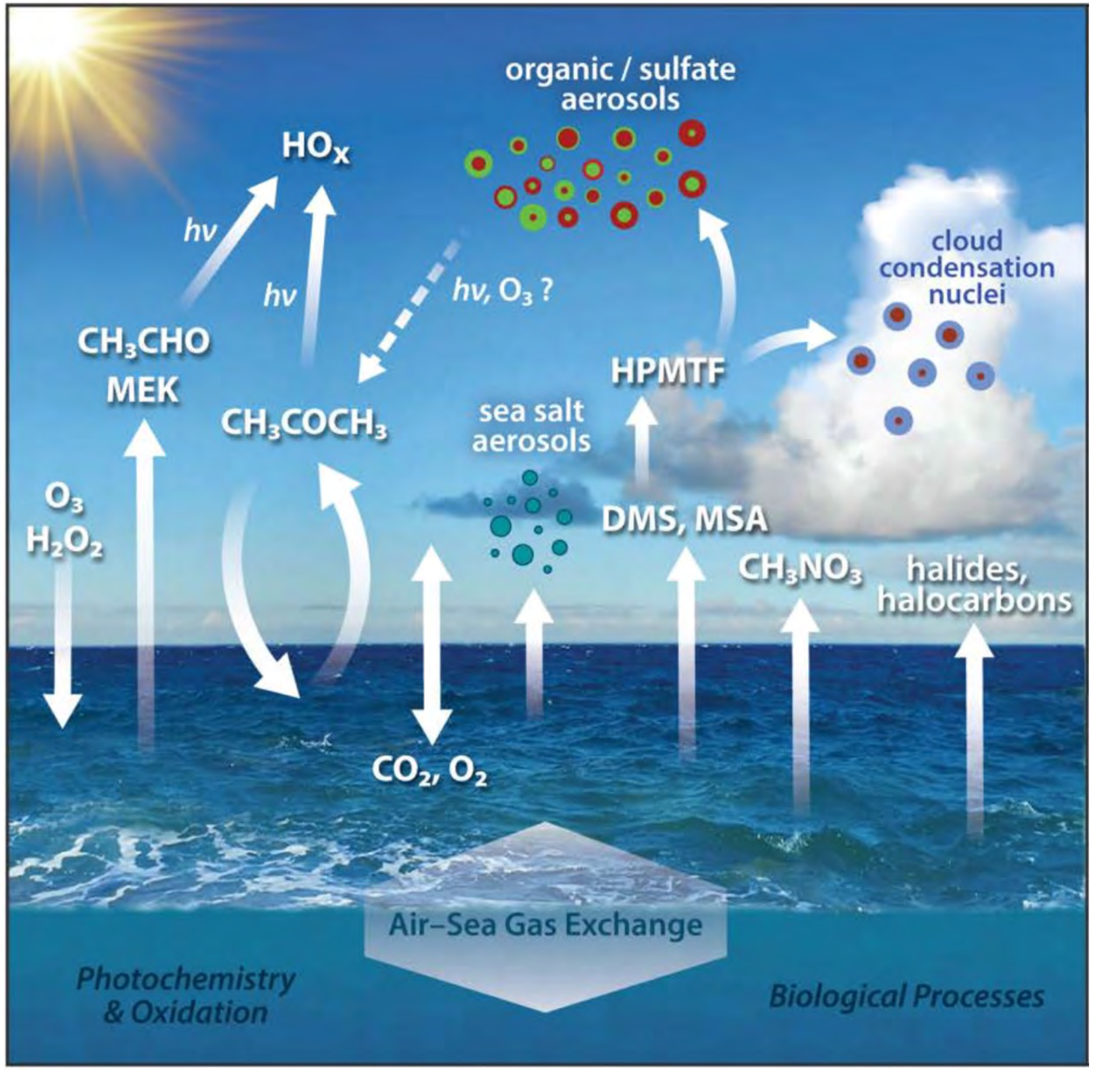


Image: Gordon Novak

AEROMMA Marine Science Themes

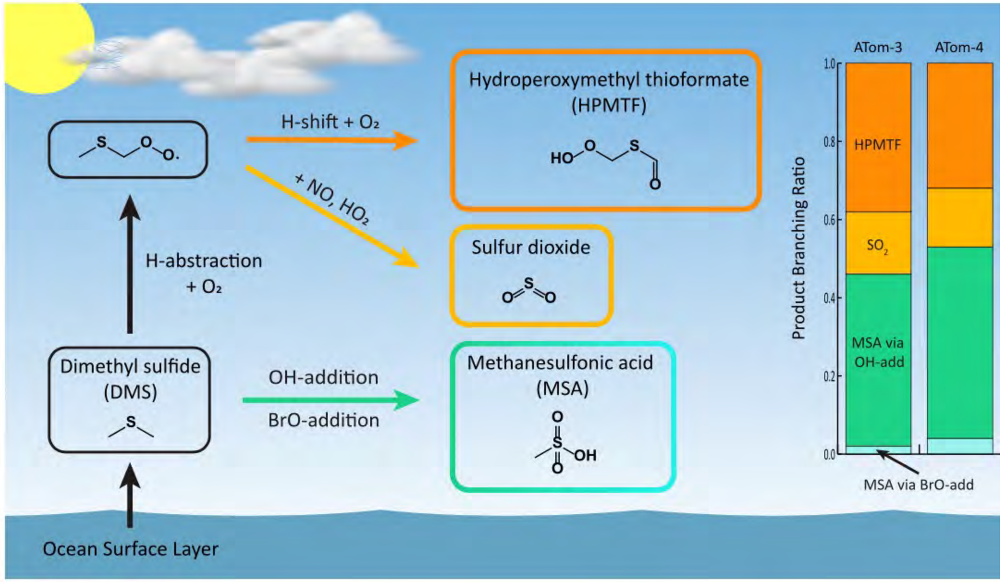


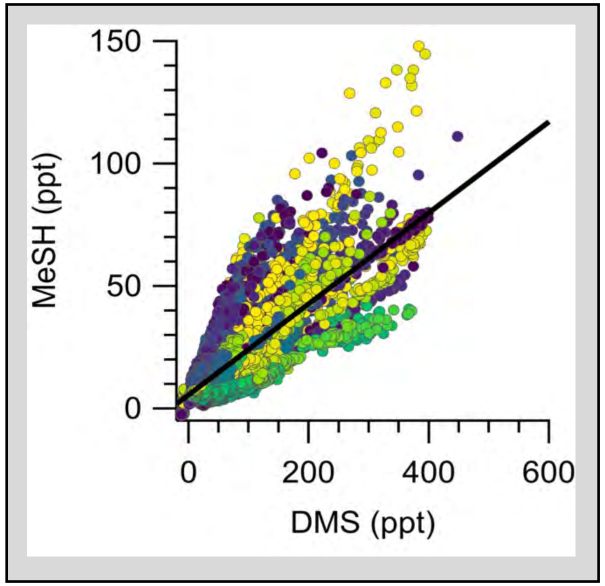
Thompson et al., 2022

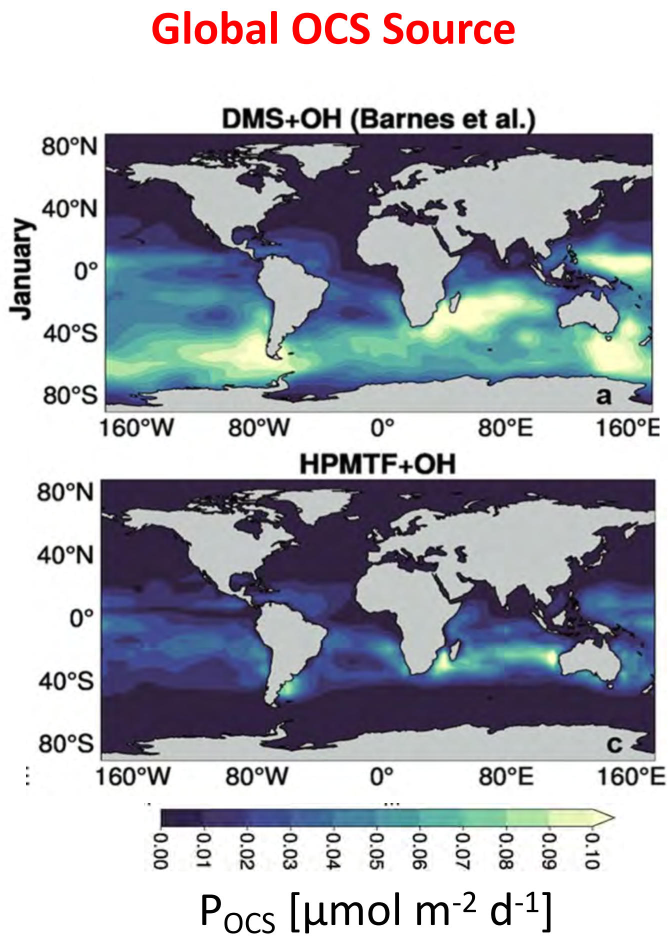
- **Sulfur emissions and chemistry**: Do we understand the source budget and fate of sulfur in the MBL?
- **Reactive Nitrogen**: Is the ocean a NOx source?
- **Air/Sea Exchange**: What are the fluxes of key gas phase species into and out of the oceans?
- **Aerosol Nucleation and Growth**: What chemical and microphysical conditions are conducive to this process? Are non-sulfur species important?
- **Coupling of Chemistry and Cloud Processes**: What are the key rates for cloud uptake of trace species affecting MBL chemistry? How does gas-phase chemistry via aerosol formation affect cloud properties?

Theme 1: Sulfur Emissions and Chemistry

Oceanic sulfur emissions and oxidation control CCN over vast regions of Earth's surface and may be the primary source of stratospheric sulfate aerosol via OCS.







Sulfur science targets
- Methanethiol / Dimethyl Sulfide emissions ratios
- Other sulfur containing organic emissions $DMSO_2$, CH_5NO_2S
- Evaluation of lab-derived sulfur chemical mechanisms
- Evidence for OCS sources
- Importance of various radicals (BrO, NO) on fate of emitted reactive S

Veres et al., 2020
Novak et al., 2021, 2022
Jernigan et al., 2022

Theme 2: Reactive N in the MBL

Differences between observed and expected NOx in remote regions represents major uncertainty in OH concentration & methane lifetime, O_3 tendency.

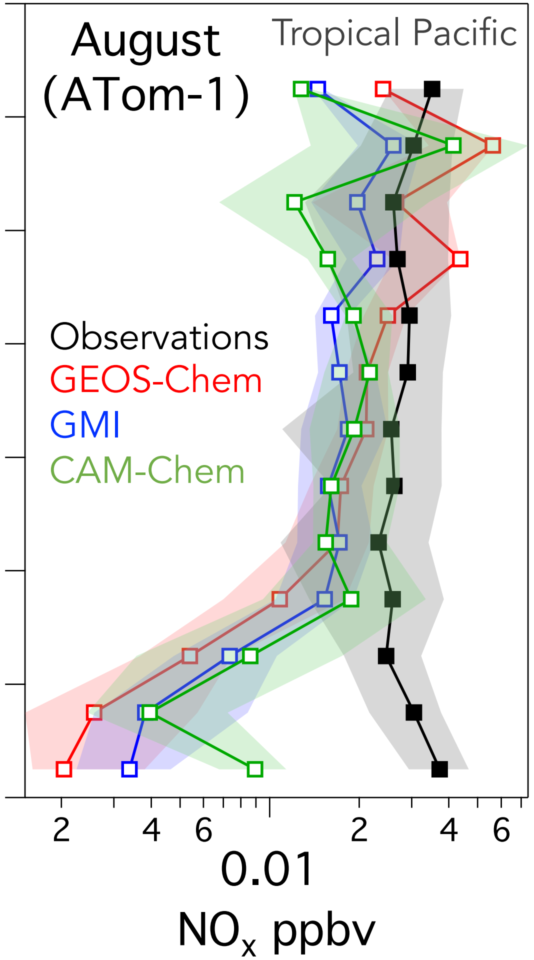
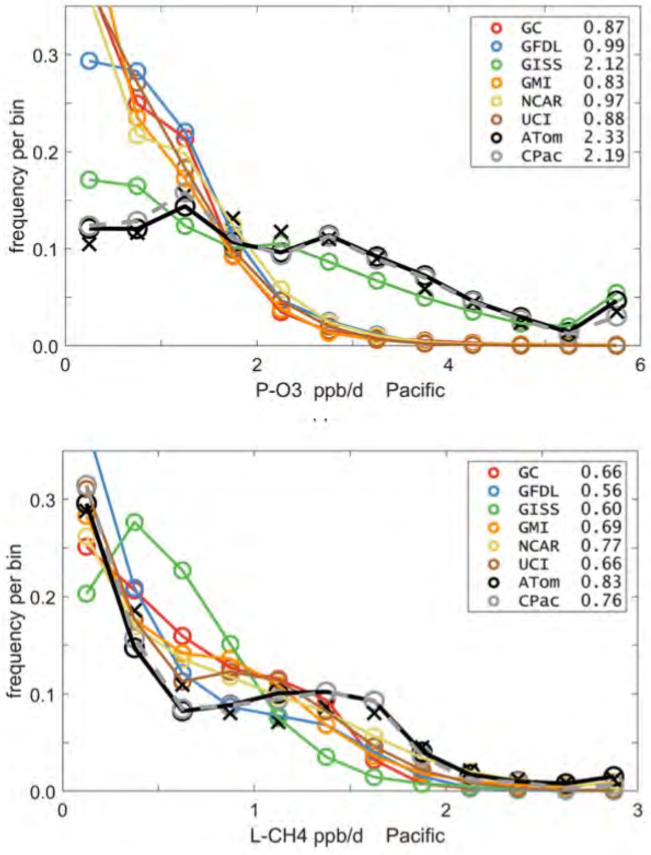


Figure: Chelsea Thompson



Guo et al., 2021

Potential sources

- Direct oceanic emissions
- Photolytic "re-noxification" of nitrate aerosols
- Downward transport of NOx or PAN in the FT

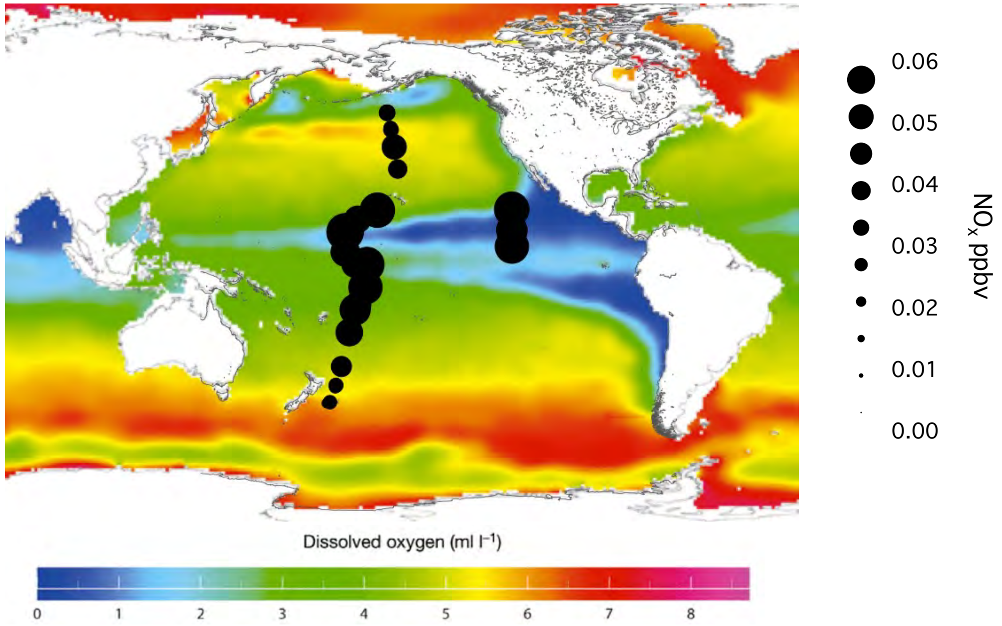
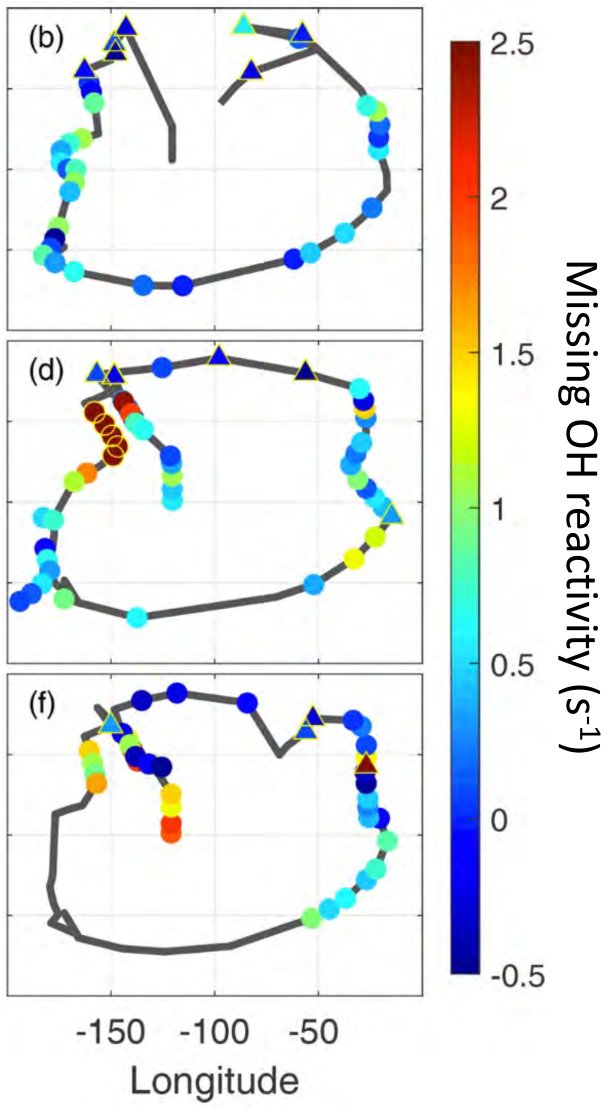


Figure: Chelsea Thompson

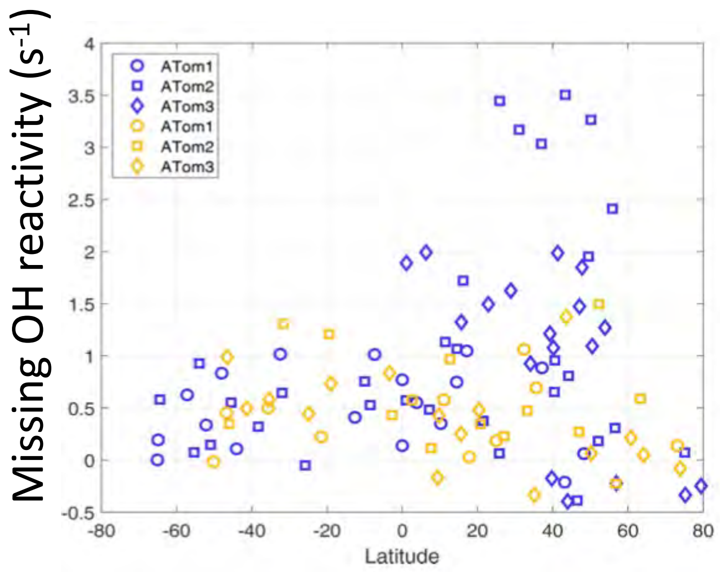
Theme 3: Air/Sea Exchange

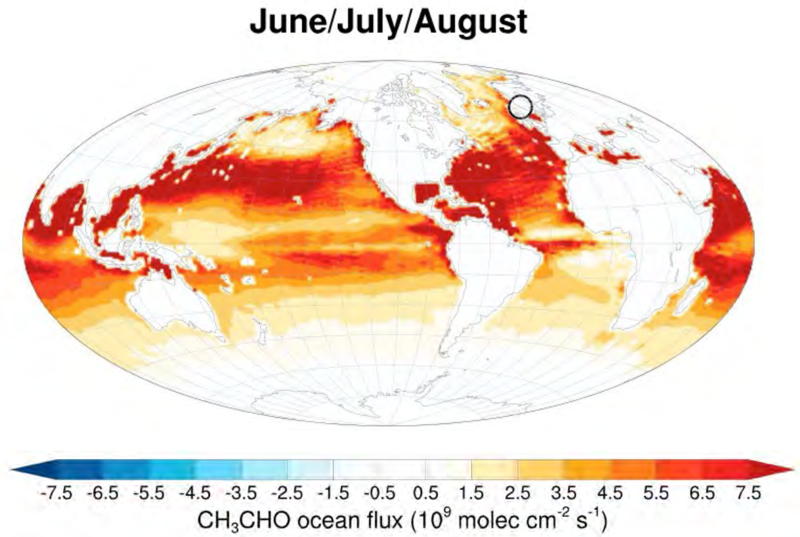
Fast observations of key trace gases in the MBL are rare / nonexistent for many species.
Indirect evidence suggests important sources of reactive N, S and C are unaccounted for.



AEROMMA will provide Observations of the Emissions / deposition of:

- Ozone
- NO
- Sulfur Species
- Acetaldehyde, Acetone
- Isoprene





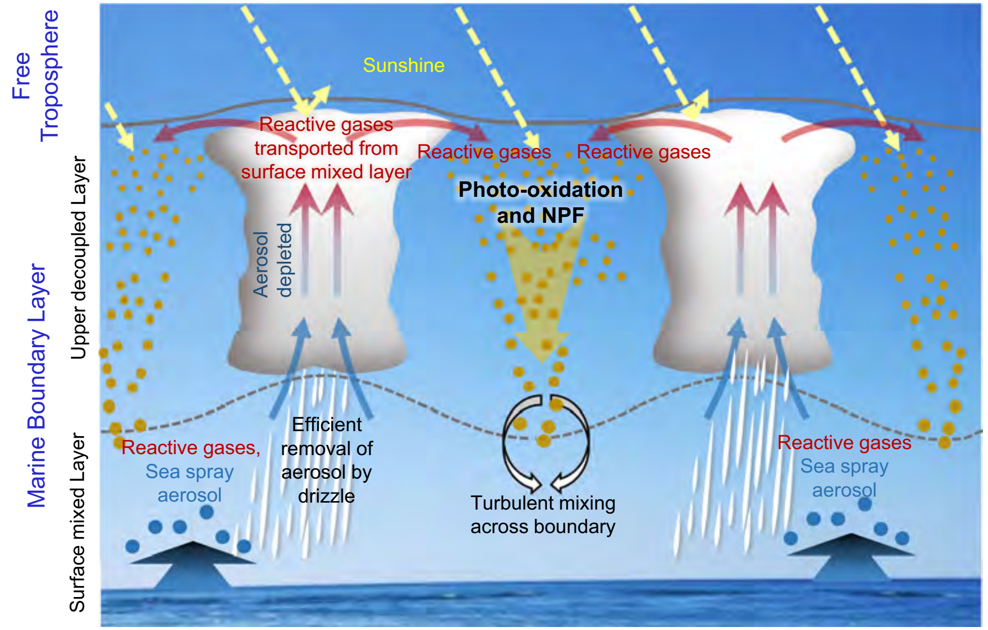
Wang et al., 2019; Thames et al., 2020

Theme 4: Aerosol Nucleation and Growth to CCN

What are the sources of CCN in the remote MBL?

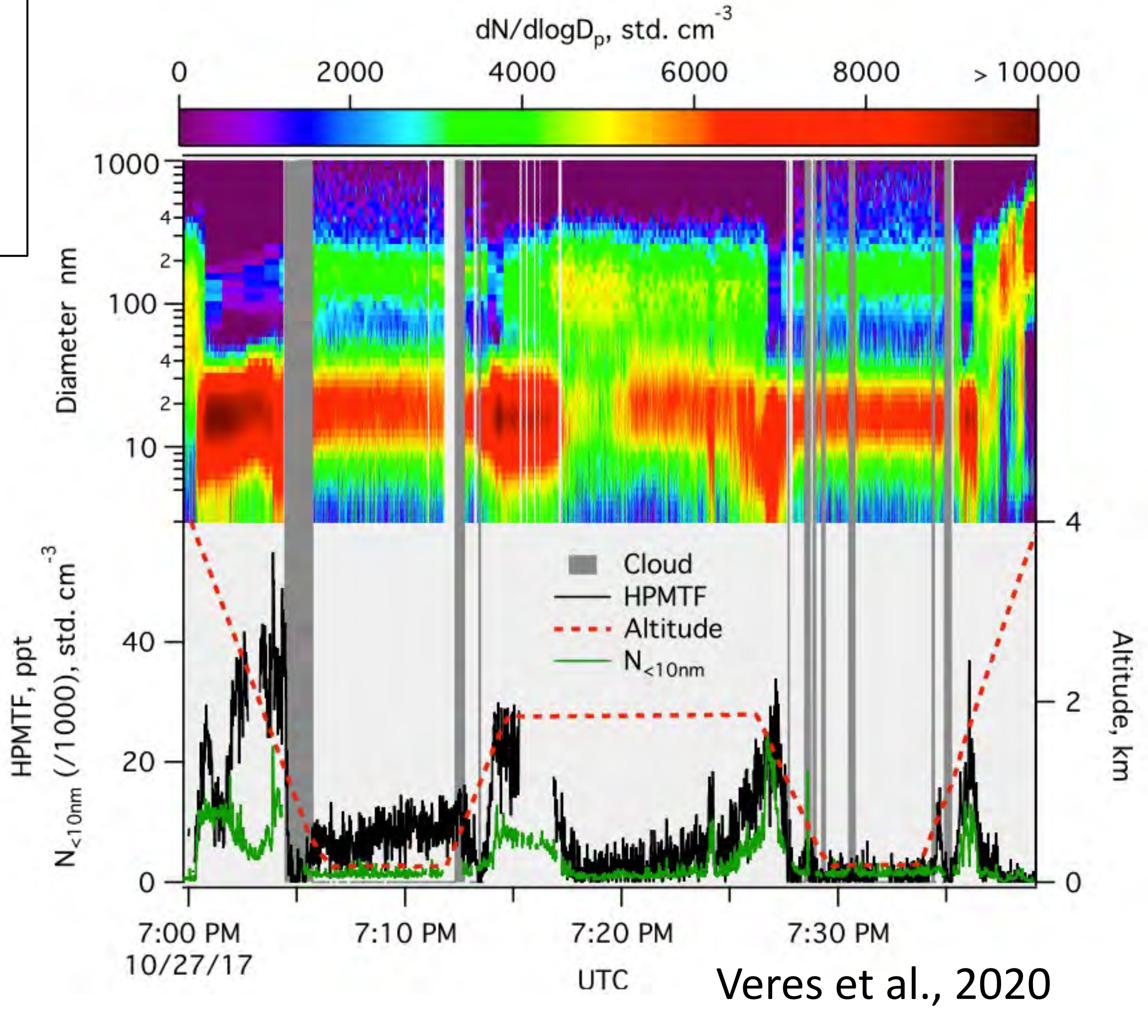
- Atom observations show that clean air parcels above MBL cloud layers can promote new particle formation.
- Targeted sampling and extended dwell in and around regions with NPF might allow for mechanistic understanding of the roles of various sulfur or organic compounds.

New particle formation can occur in a decoupled marine boundary layer



Zheng et al., 2021 *Nature Communications*

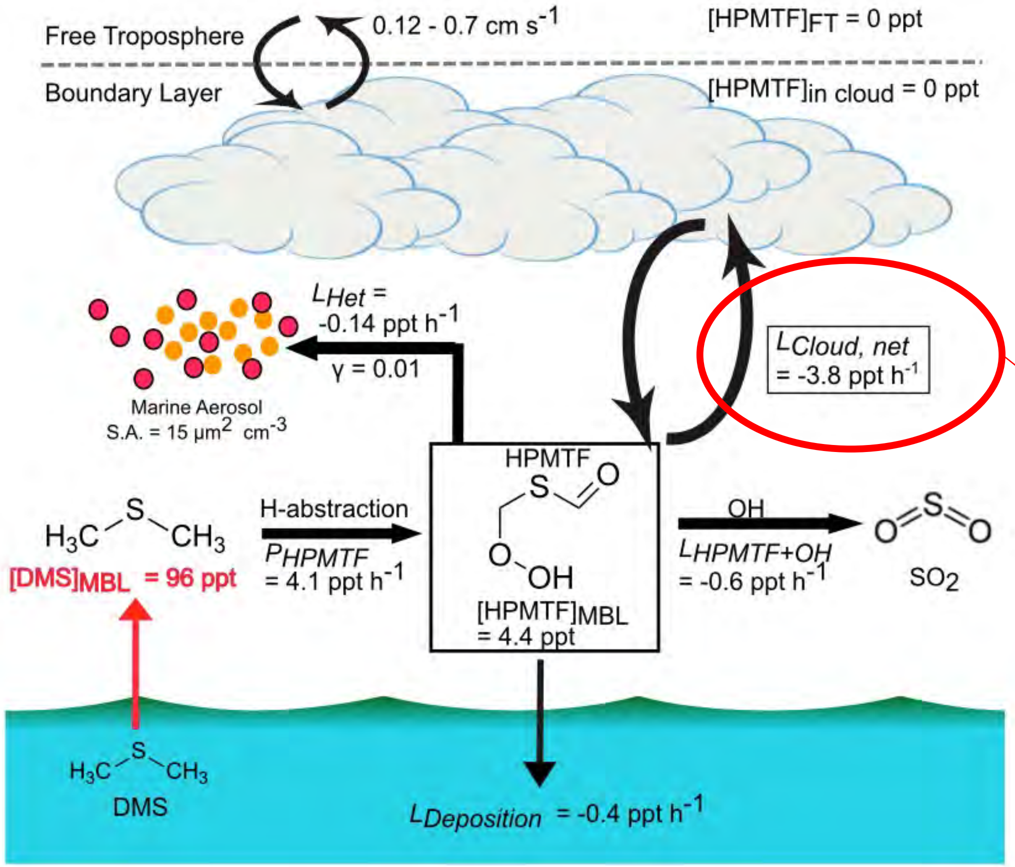
New particle formation from DMS oxidation observed during the NASA ATom mission



Veres et al., 2020

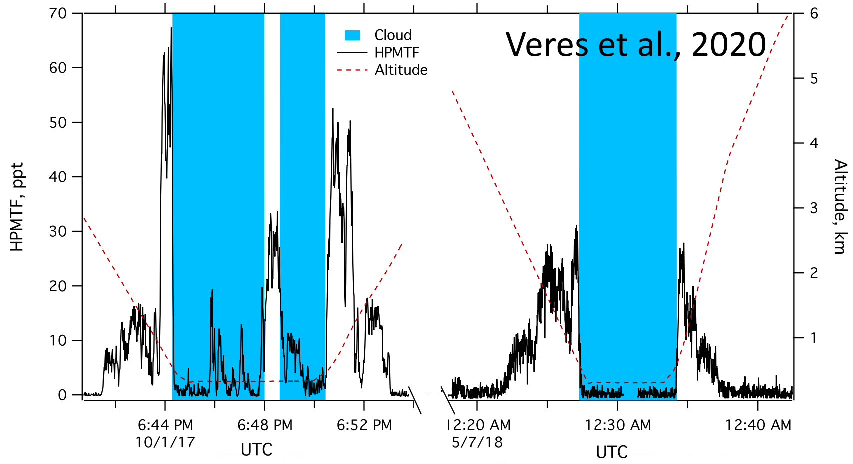
Theme 5: Coupling of Clouds and Chemistry

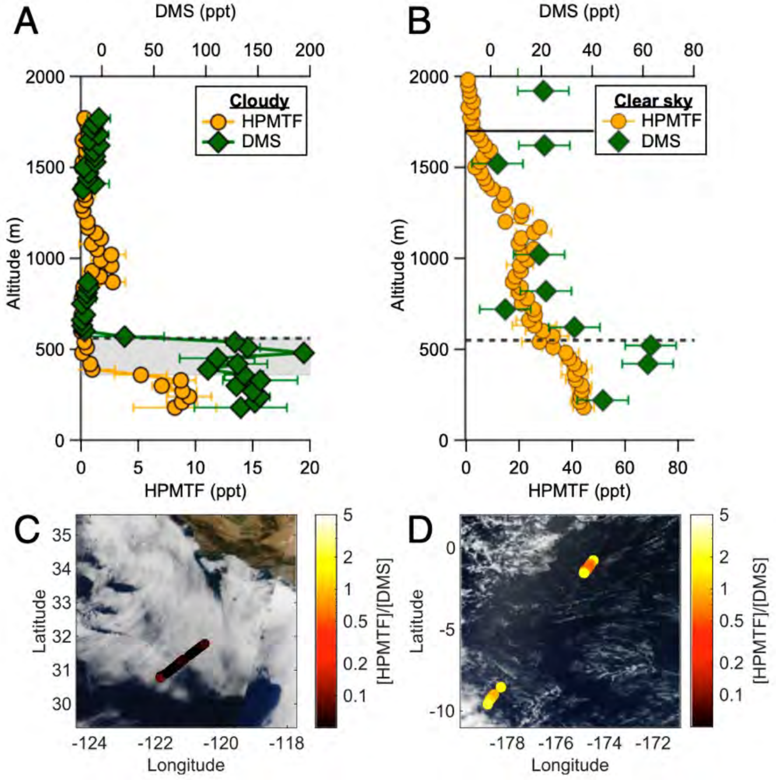
Clouds have major impact on abundance of key species in the MBL. Detailed chemical sampling in the vicinity of clouds is sparce and insufficient to understand impacts of various cloud types on chemistry.



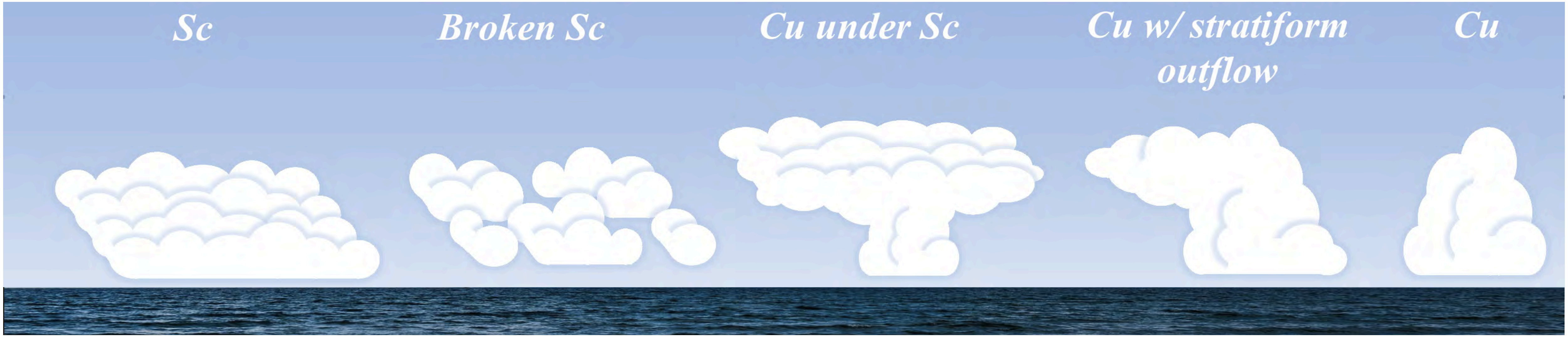
How much does this rate vary for variable cloud systems?

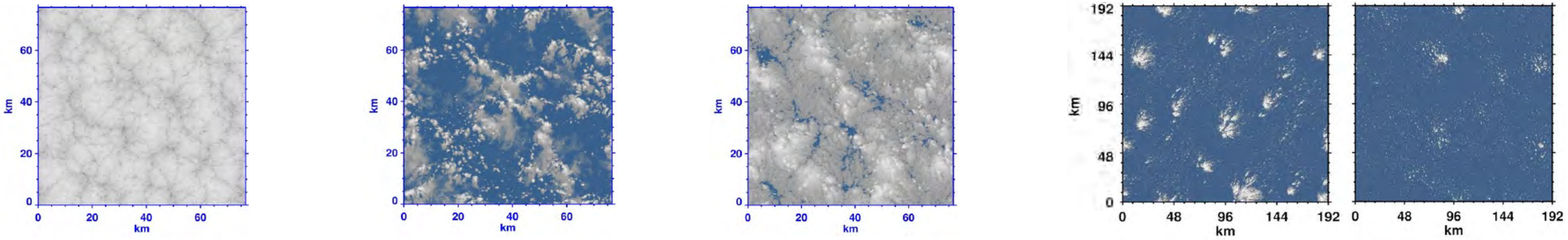
(Sample size n=1)





Novak et al., 2021





Large eddy simulations represent clouds and turbulent mixing at high resolution. Goals:

- Spatial variability of chemical species, fluxes, and conversion rates, depending on cloud type
- HPMTF processing pathways for:
  - different cloud types
  - degree of boundary layer decoupling
- Simulations for AEROMMA flights
- Emulate/evaluate what a global model would simulate in a grid box corresponding to the large eddy simulation domain

Large eddy simulations: Kazil et al., JAMES, 2021 Narenpitak et al., JAMES 2022

Cloud type illustration: Cesana et al., Earth Syst. Sci. Data, 2019

Sampling Strategy 1: Low latitude marine fluxes

Target flux sampling opportunities in tropical and mid-latitude Pacific where important fluxes of key species are inferred to occur

Location determined by several variables:

- Cloud fields
- DMS climatology
- NO_x abundance
- Wind speed
- Dissolved O_2

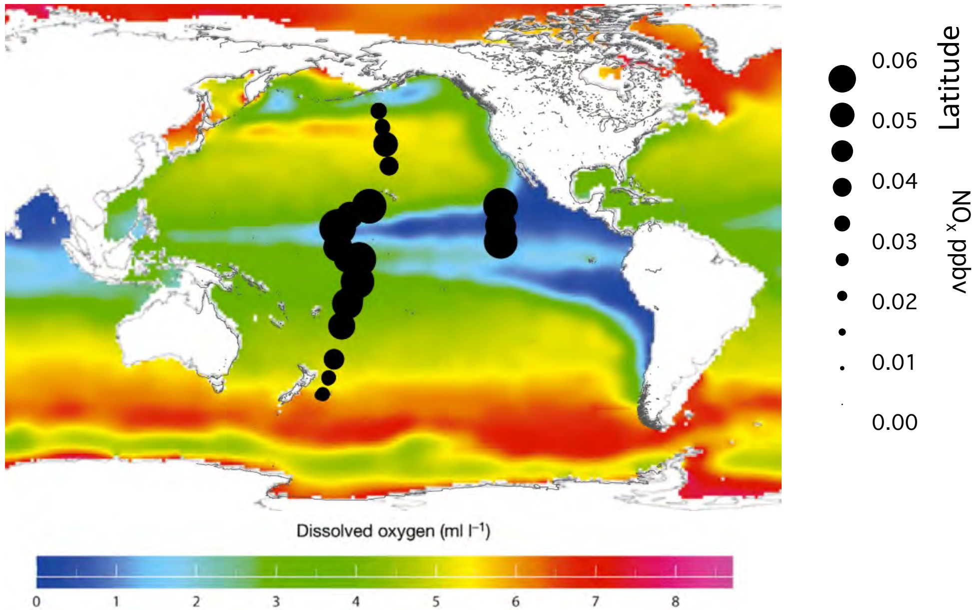
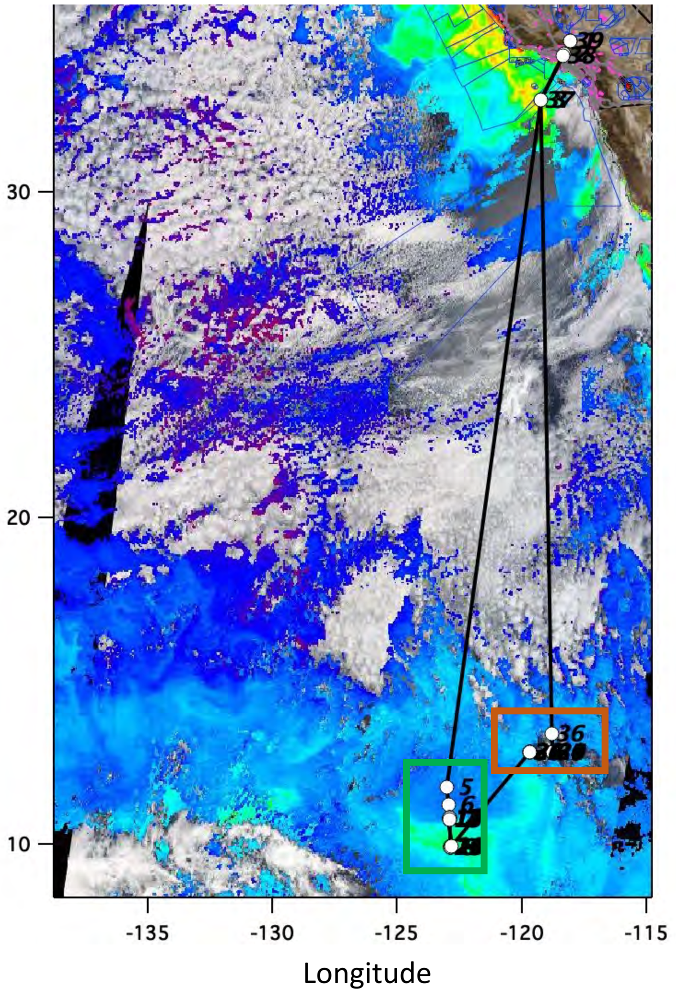
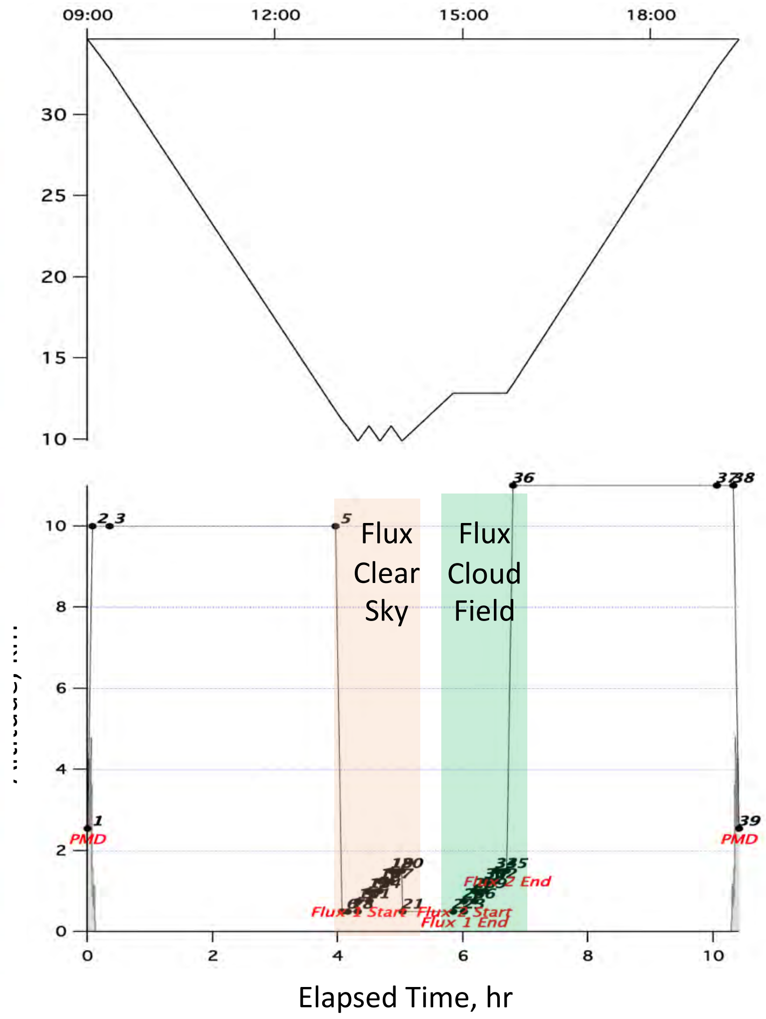


Figure: Chelsea Thompson



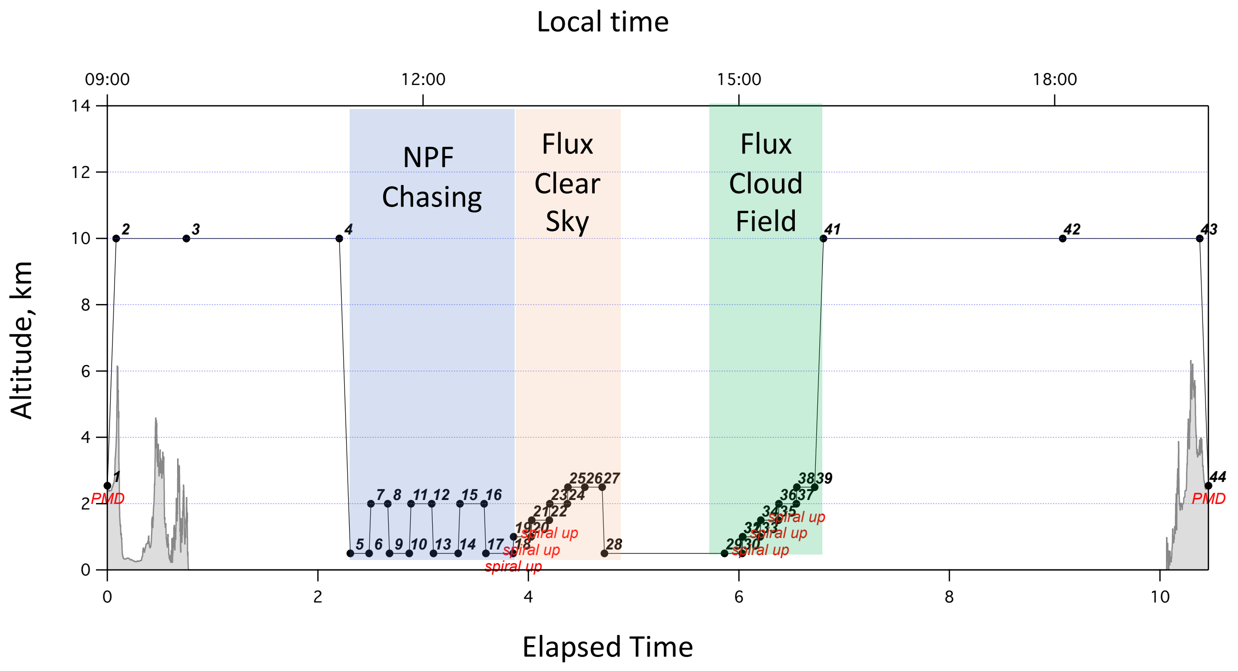


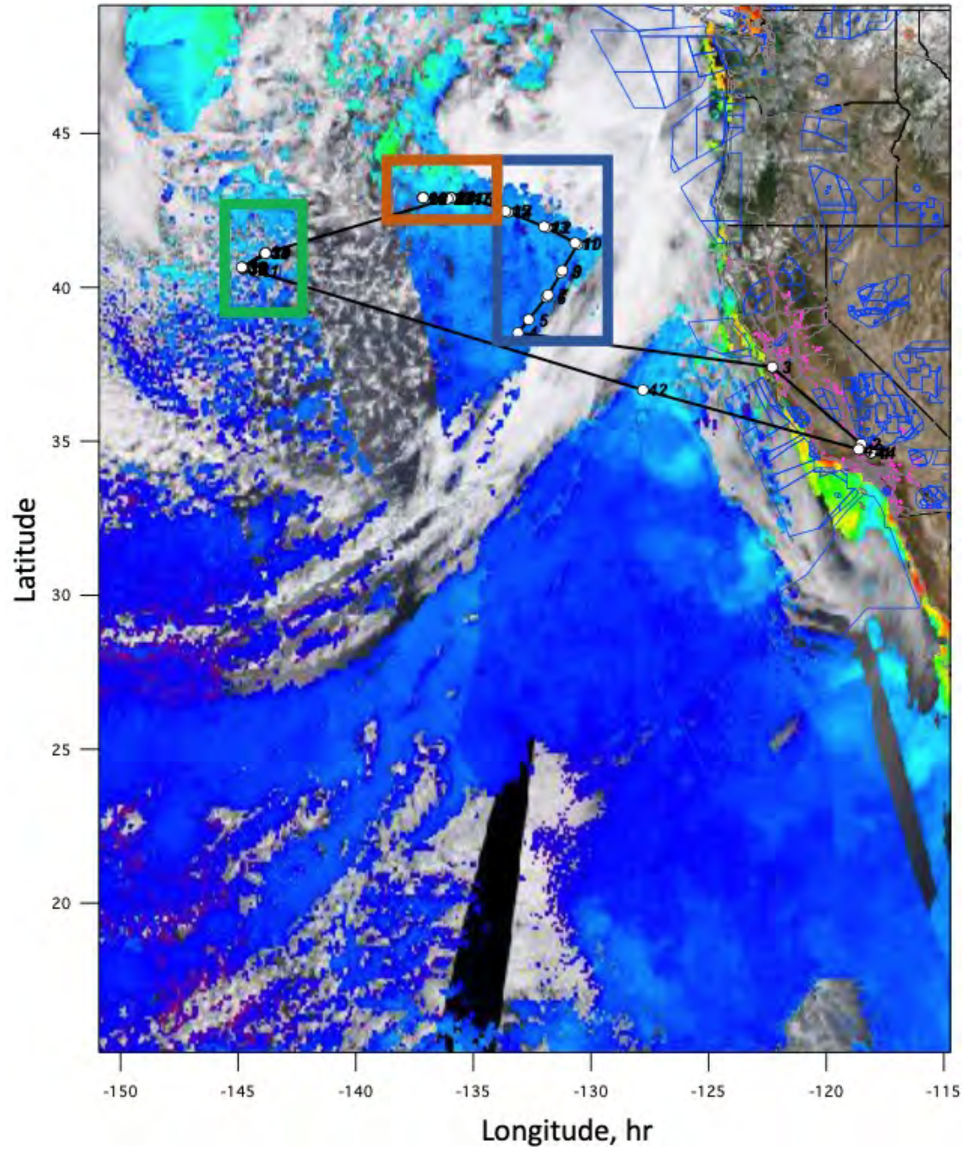
Sampling Strategy 2: Chasing New Particle Formation from DMS

1. Targeted sampling and extended dwell in and around regions with higher likelihood of NPF

2a. NPF Identified – Sample within region to observe evolution of NPF events

2b. No NPF identified - Divert to secondary goals of flux sampling in variable cloud and cloud free fields (as in example)





AEROMMA Marine: Expected Outcomes and Analysis Strategies

AEROMMA Targets

Direct observations of processes
- Ocean NO emission flux
- O_3 deposition velocity
- DMS / MeSH Flux ratio
- Organic carbon emissions

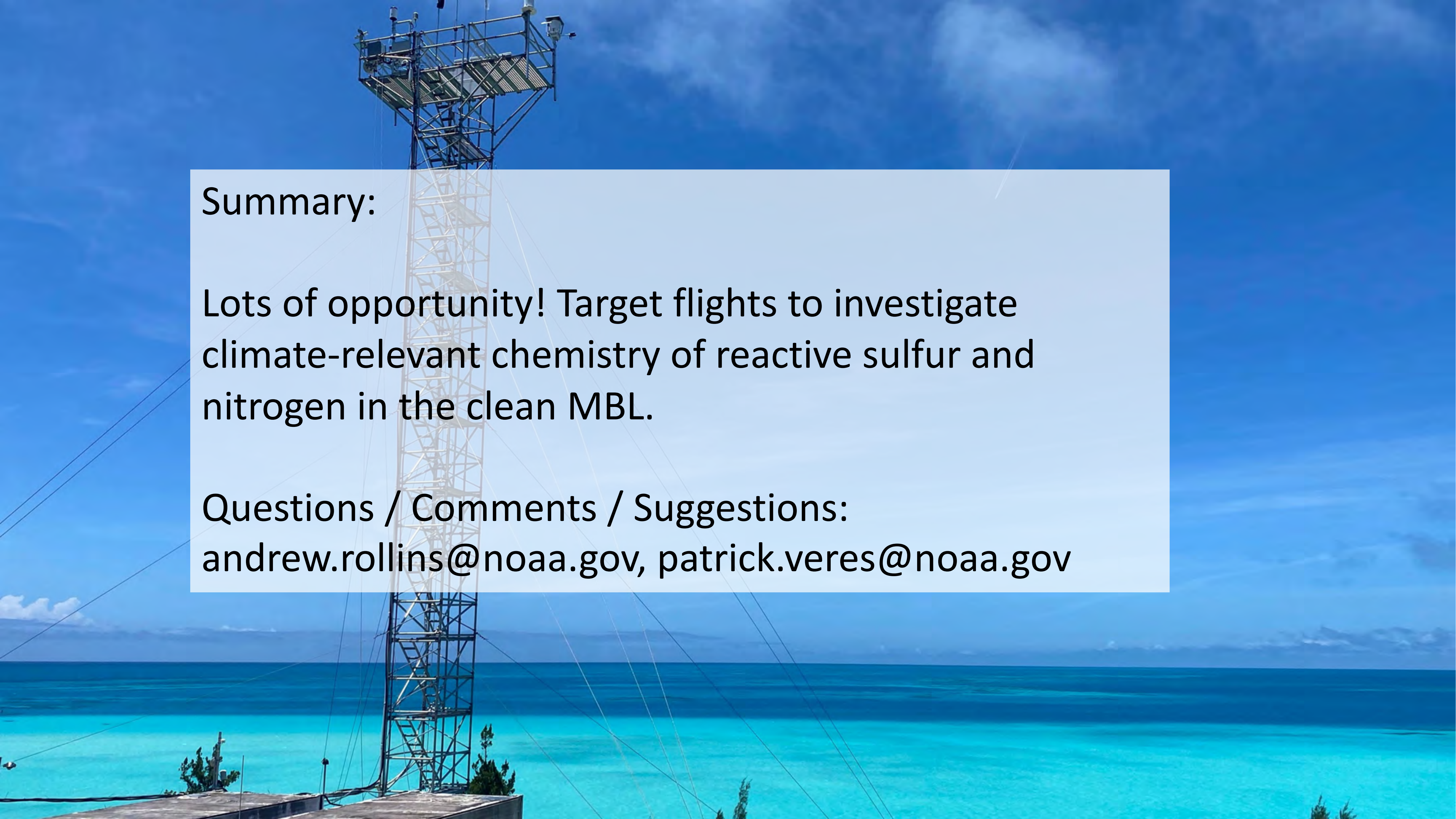
Budget closure using box models
- Marine gas-phase sulfur: DMS, MeSH, SO_2, HPMTF, OCS
- NO_y in the MBL

Large Eddy Simulation
- Is expected spatial distribution of reactive species and aerosols in and around clouds consistent with observations?

Climate Relevance

- How do marine sourced species control tendencies of key climate trace gases, e.g. CH_4, O_3?
- What are the roles of marine sourced species for aerosol NPF and growth?
- Is there a direct oceanic source of OCS relevant for stratospheric aerosol?

	RF1	RF2	RF3	RF4
Sampling Strategy	NPF/Cloud sampling	Tropical Flux Module	NPF/Cloud sampling	Tropical Flux Module
Locate/Observe NPF event	x			
NO and O3 Flux		x		x
DMS / MeSH Flux	x	x	x	x
Cloud loss rates	x		x	



Summary:

Lots of opportunity! Target flights to investigate climate-relevant chemistry of reactive sulfur and nitrogen in the clean MBL.

Questions / Comments / Suggestions:
andrew.rollins@noaa.gov, patrick.veres@noaa.gov