May 2019 SCOAPE (Satellite Coastal Oceanic and Atmospheric Pollution Experiment) Cruise: Gulf of Mexico Air Quality (AQ) near Oil & Natural Gas (ONG) Operations

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Thanks to: Ryan Stauffer, Debra Kollonige, N. Abuhassan, R. Swap, A. Kotsakis

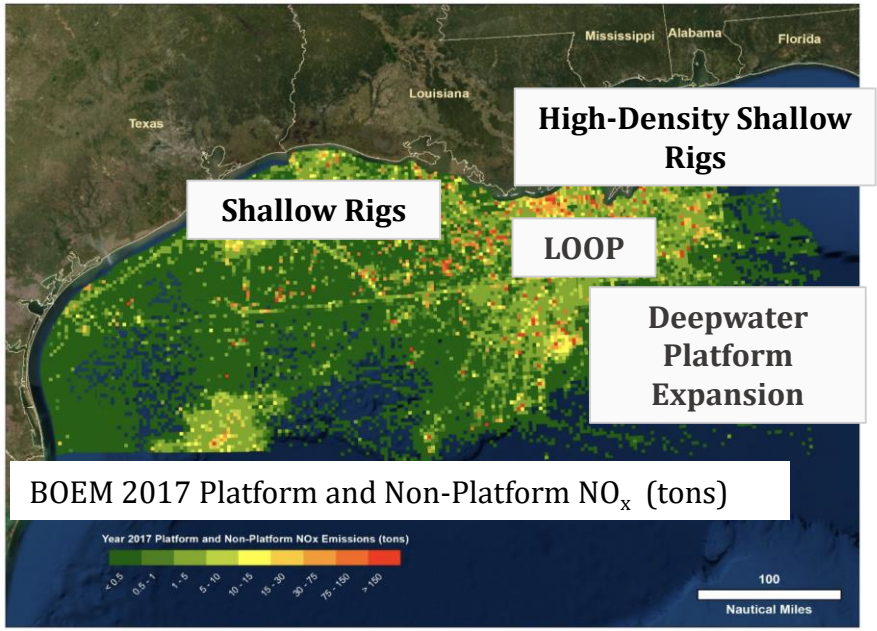
MARAMA WORKSHOP, 10 DEC 2020

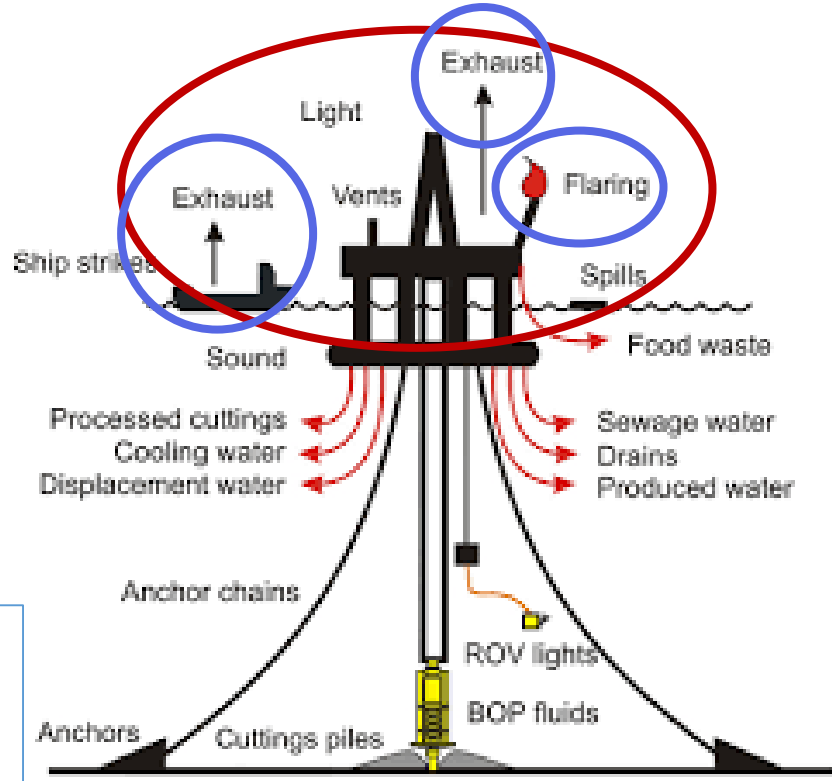
OUTLINE

- **Background: NASA-BOEM Project & SCOAPE Cruise**
- **Motivating Scientific Questions & SCOAPE Design**
- **Overview of Results: May 2019**
  - **Two meteorological & chemical regimes**, 10-14 May vs 14-17 May
    - Forecast CO & Satellite NO_2 View
    - Ozone and VOC pollution
  - **Satellite, Pandora, in-situ NO_2**
- **Summary: Answers to Questions**

Background: BOEM & Gulf of Mexico (GOM) AQ

NO_x + VOC mix + uv ➔ O_3





- BOEM = Bureau of Ocean Energy Mgt of Dept of Interior "regulates" off-shore AQ by collecting extensive fuel usage info in return for offshore operation leases. BOEM publishes triennial Emissions Reports (2017, **center**)
- BOEM's concern: Can GOM NO_x trigger ozone alert onshore?

BOEM has no GOM AQ measurements to verify emissions!

Deepwater Platform - Numerous Oil & Natural Gas "ONG" NO_x Sources

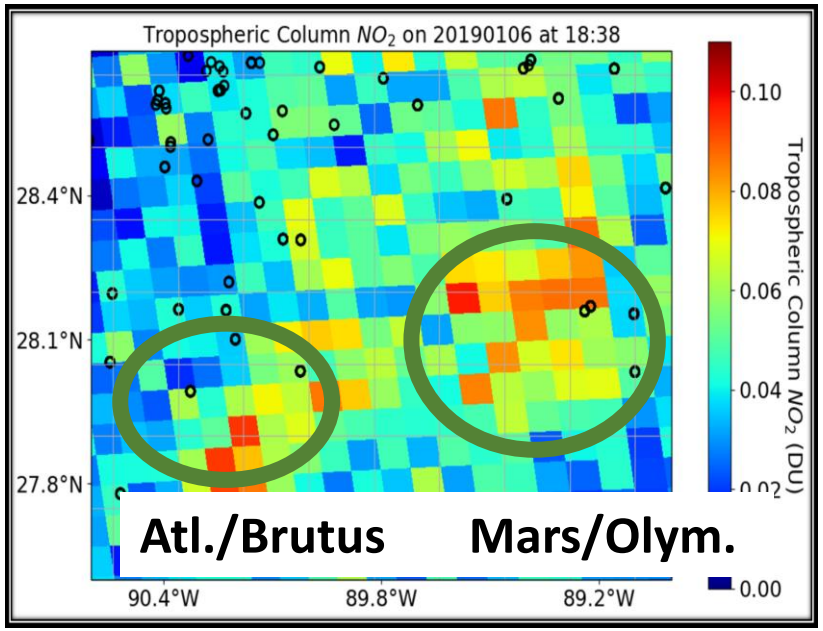
WHY: NASA/GSFC-BOEM Inter-Agency Agreement (2017-2020) for Assessing Feasibility of using Satellite Data for Offshore AQ Applications.

WHO: NASA-GSFC: B. Duncan (PI), A. Thompson (Co-I) & Chief Scientist

HOW: (1) NASA provides OMI & TROPOMI NO_2 satellite maps (**below**); **(2) NASA** conducts **cruise** for 2019 baseline AQ (O_3, NO_2, VOC, CO, CH_4) & OMI & TROPOMI NO_2 evaluation by newest Pandora spectrometers. 2 Pandoras, NO_2-sondes on Louisiana (LA) coast.

WHEN: 10-18 May 2019 experiment based at **LUMCON*, Cocodrie, LA (29.26°, -90.66°)**

TROPOMI Tropo. NO_2 Column



Cruise Design Factors: (1) Location of Platforms was main criterion. (2) Timing – Season of expected onshore flow. Review climatology for winds, clouds (uv/vis remote sensors). **Select May** – less cloudy than June, or stagnant or hurricane August! (3) Ship logistics: Instrument van and Remote Sensing instruments on bow of ship to avoid exhaust contamination

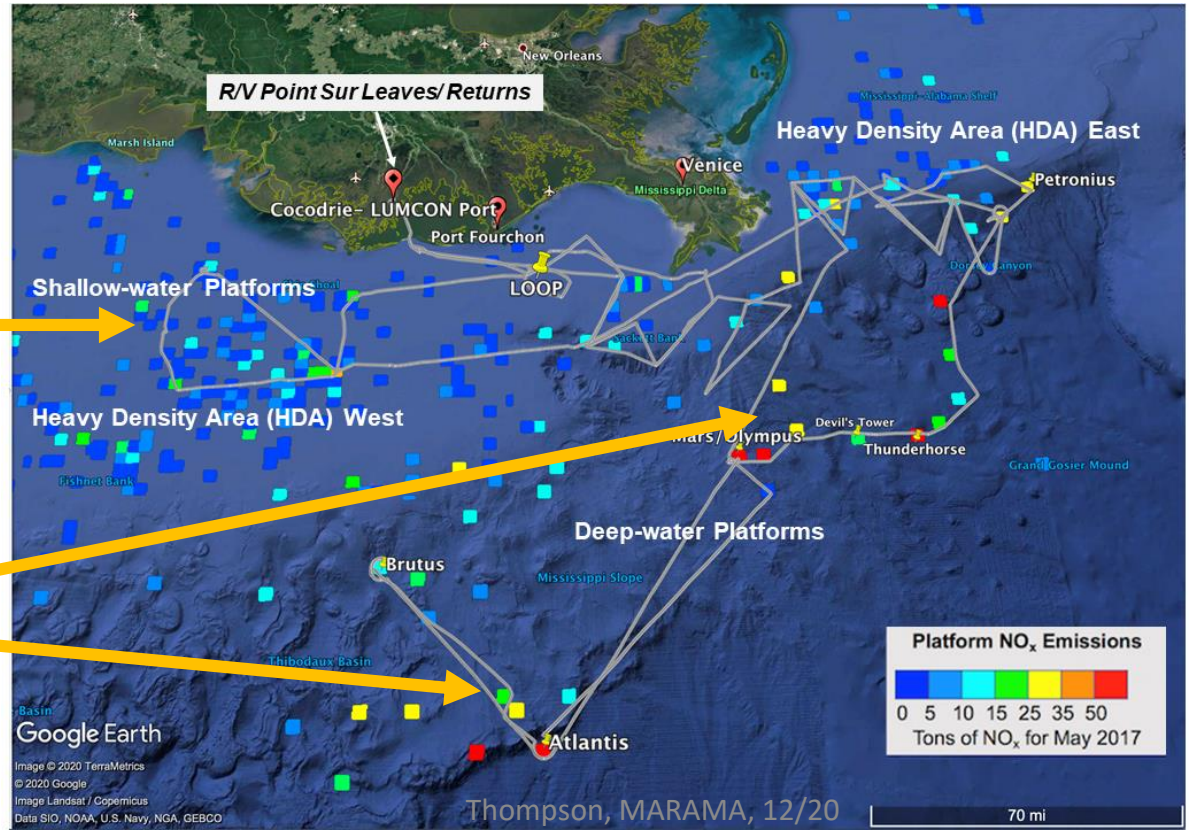
* LUMCON = Louisiana Universities Marine Consortium, Port

Scientific Questions and Cruise Design (in *EM* Article)

- How do pollutant levels over the open GoM compare to coastal Louisiana?
- Can **satellites** & ship instruments detect emissions from offshore ONG operations? How does near-shore (smaller, older op'ns) and deepwater pollution compare?
- Are satellite NO_2 columns accurate? How do remotely sensed NO_2 data compare to in-situ?

Numerous small emitters close to shore. **NAT. GAS - blue**

Big platforms – Largest emitters, Yellow-red. **OIL - red-yellow**



Satellite and Shipboard Views of Air Quality along the Louisiana Coast

by Anne M. Thompson, Debra E. Kollonige, Ryan M. Stauffer, Nader Abuhassan, Alexander E. Kotsakis, Robert J. Swap, and Holli (Ensz) Wecht

Environ. Manager [EM], Oct-2020. awma.org

SCOAPE Instruments on USM's *R/V Point Sur*

Red = In this talk

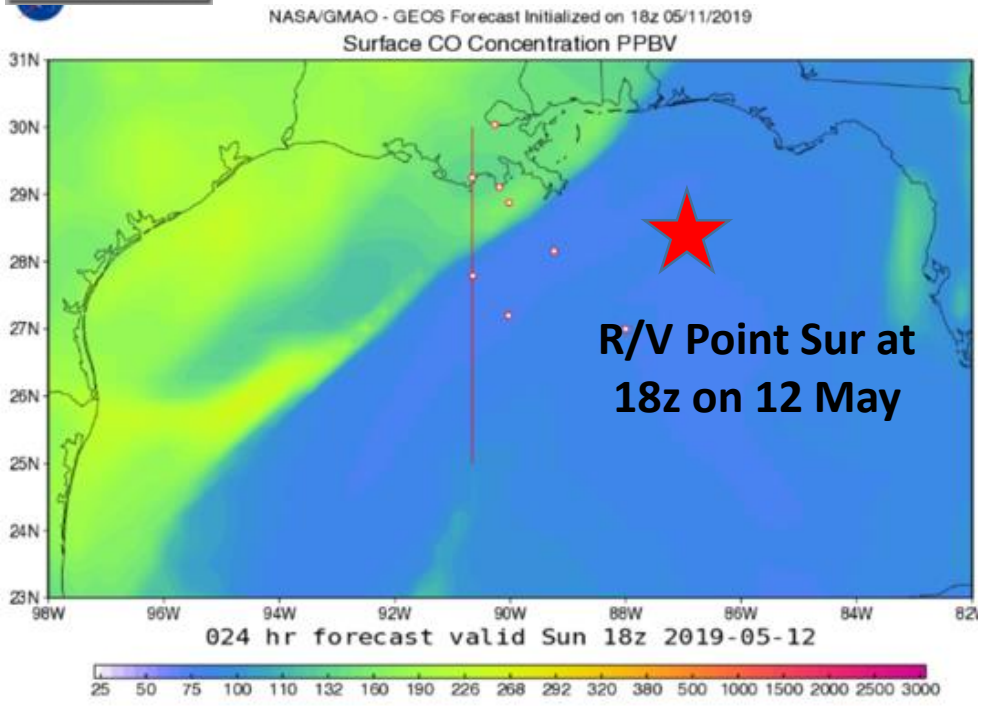
Species	Instrument	Collaborator
NO_2 (and gas calibrator)	*In-situ* (*Point Sur* and LUMCON)	NASA GSFC (Thompson and Sullivan)
Column NO_2 and O_3 ★	**Pandora (3 total: One on *Point Sur* and two at LUMCON)**	NASA GSFC (Swap)
NO_2	Sondes (coastal mobile measurements)	KNMI (den Hoed)
O_3	*In-situ*	NASA GSFC
	Ozonesondes	NASA GSFC
Temperature, RH, winds, etc.	Met system	*Point Sur*
Aerosol (AOD) & O_3 columns	MicroTops Sunphotometer	NASA GSFC
VOCs (plus CH_4 and CO)	*In-situ* flasks	UCI (Blake)
CH_4, CO_2, H_2O	Picarro	NASA GSFC (Kawa/Hanisco)
PBL height	Remote sensing ceilometer (*Point Sur* and LUMCON)	UMBC (Delgado) and Univ. of Houston (Flynn)
Aethalometer (black carbon)	*In-situ*	Conny (NIST)

R/V Point Sur

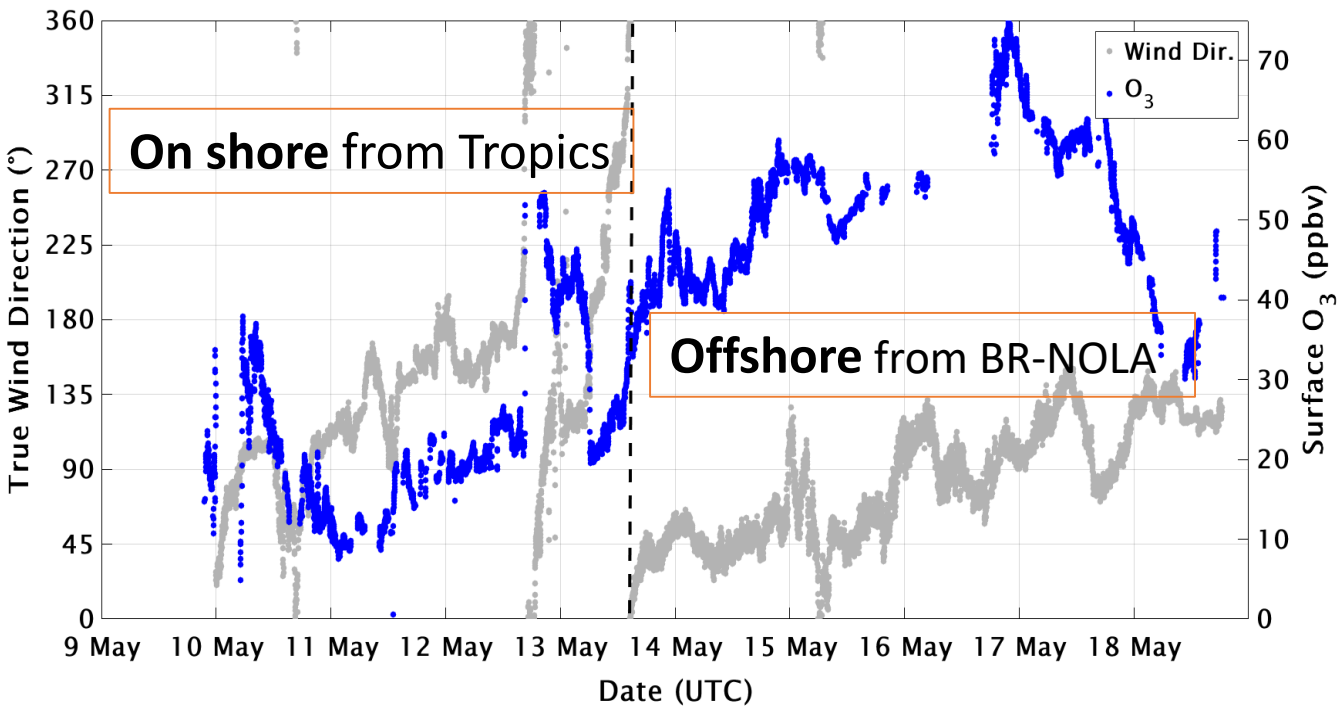
136-ft. Built 1980, owned by U. So Miss, LUMCON-operated

★ Total column (TC) NO_2 on ship from Pandora 66 remote sensor = ground-truth for satellite

Question 1: Land vs GOM.
Two Regimes: CO Forecast & Ozone Shift



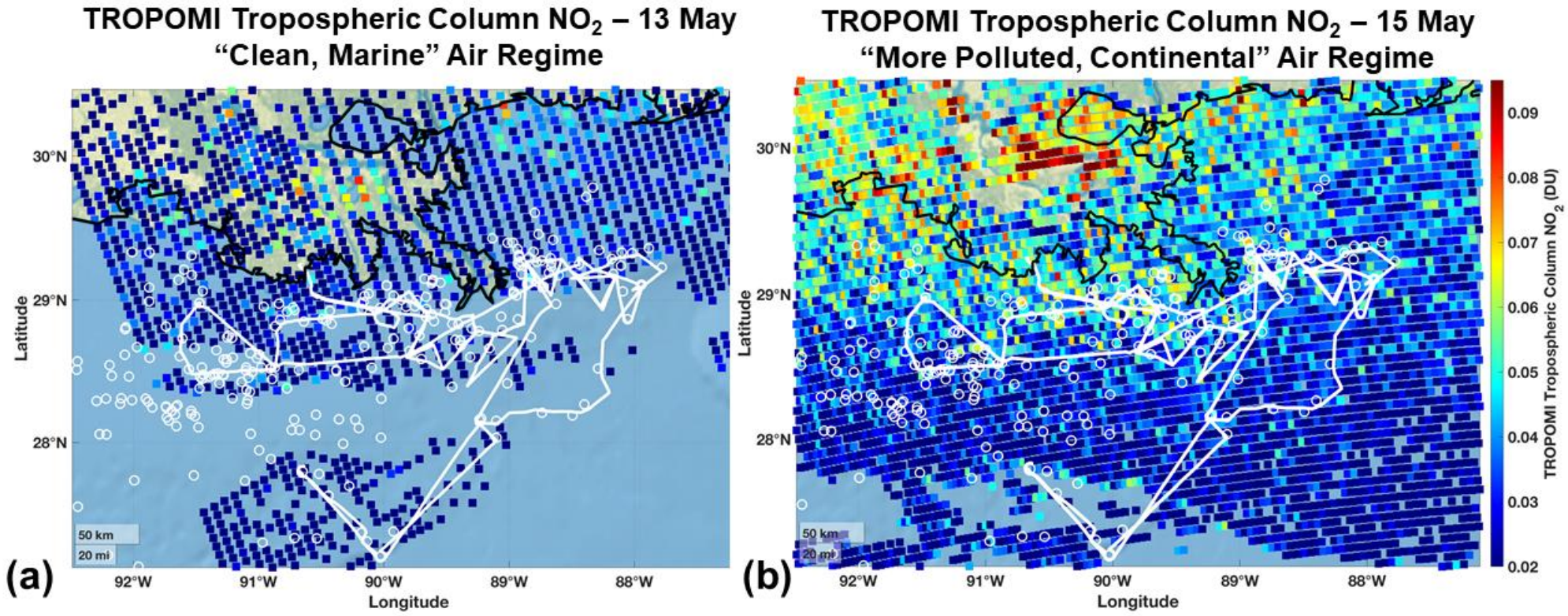
Surface CO f24h NASA GEOS-FP forecast valid 18z (13 CDT) on 12 May 2019.
https://fluid.nccs.nasa.gov/missions/mission_SCOAPE/



"True" (corrected for ship movement) wind direction (gray) & surface O_3 (blue) from R/V Point Sur during SCOAPE

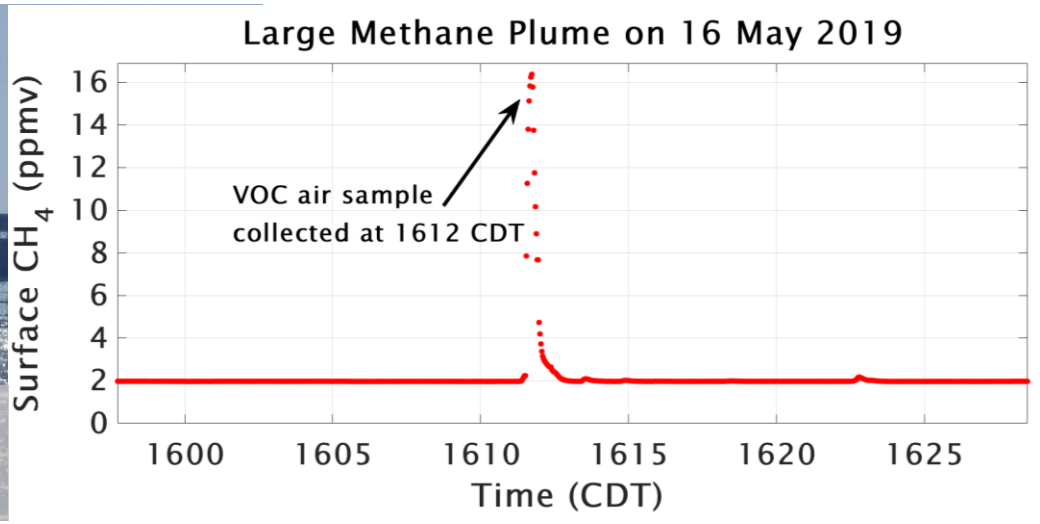
Question 1: Land vs GOM Contrast from TROPOMI

- Satellite maps (13 & 15 May) show clean, marine vs polluted continental air contrast
- Note early part of cruise (**left**) cloudier (missing data) than after 14 May (**right**)



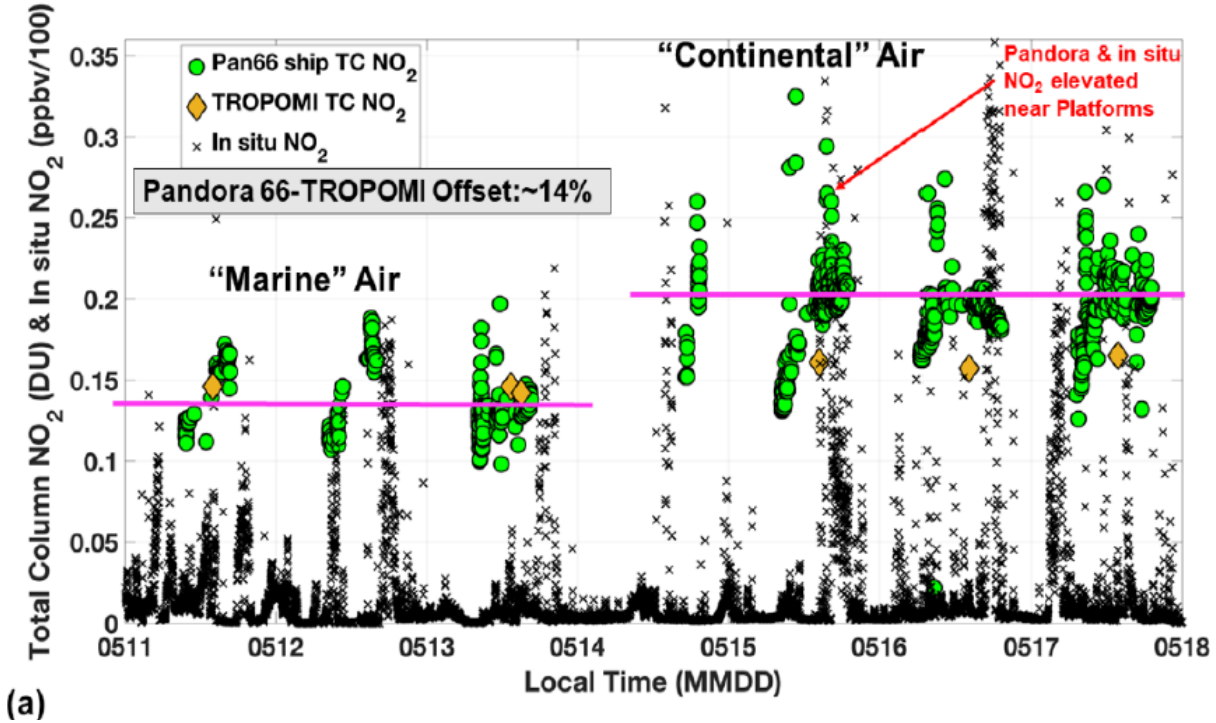
Question 2: Near-Shore ONG Signals vs Deepwater. Leaky Shallow Water Platform with VOC Canister from Plume

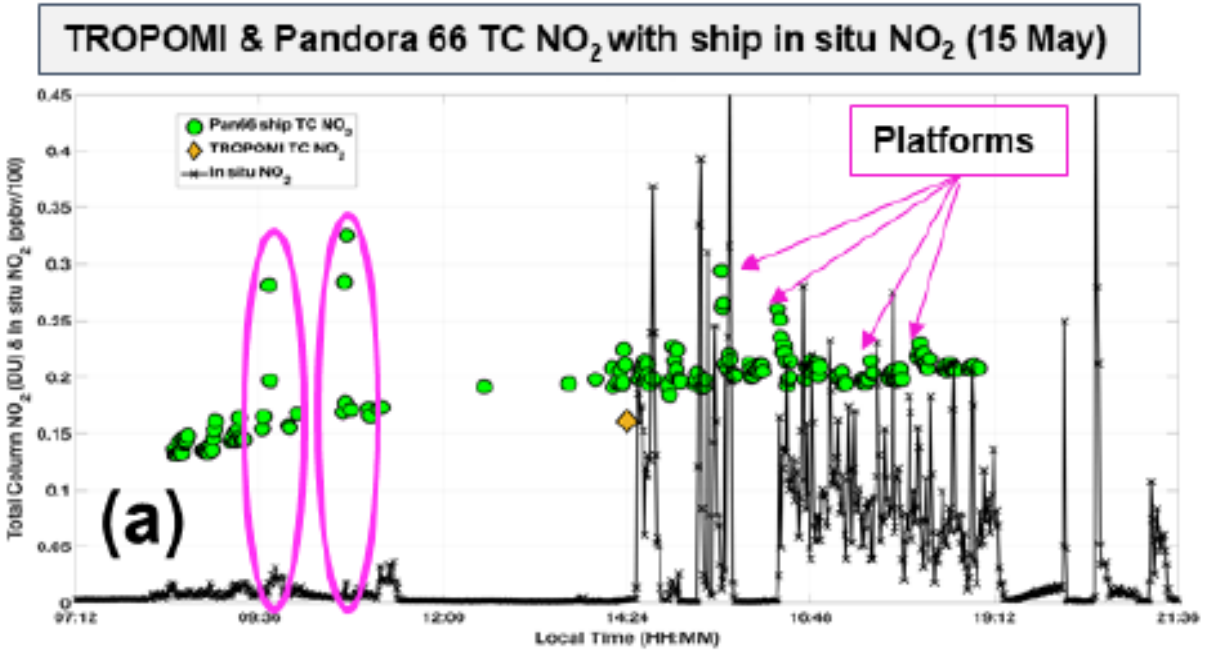
Shallow-water platform (28.9795°, -91.4760°) in photo appears to be the origin of this plume



VOC can species	Cruise Median	16 May Plume Can	Notes
CH_4 (ppmv)	1.96	**5.71**	Deep water platforms flare this off
CO_2 (ppmv)	415	418	No combustion, likely just leaky pipes
Ethane (ppbv)	2.1	**145**	C_2H_6; second largest component of fossil gas after CH_4
Propane (ppbv)	0.7	**90.1**	C_3H_8; byproduct of fossil gas processing
n-Butane (ppbv)	0.3	**29.9**	C_4H_{10}; i-Butane had similar concentrations
Benzene (ppbv)	0.04	**1.88**	C_6H_6; Known carcinogen

Question 3: Satellite & Pandora Column NO_2 Agree Well over Cruise (Left). Attribution of Pan/Ship Spikes to Platforms Needs More Analysis (Right)





*Figures 24 & 25a from **BOEM Report 47** (Sept. 2020)*

Summary: Answers to Scientific Questions

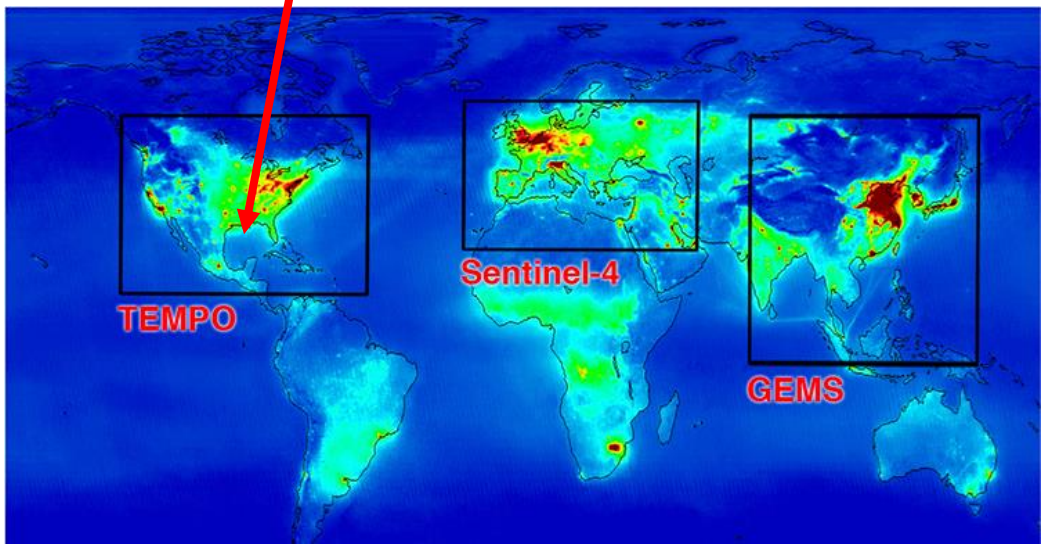
- What do pollutant levels measured by satellite over GoM look like and how do they compare to coastal Louisiana? ***GoM is much less polluted! (now)***
- Is there more ONG pollution in near shallow-water platforms than over deep-water? ***Yes for VOC, CH_4 but probably not for NO_x***
- Pandora shows TROPOMI TC NO_2 is accurate. ***Satellite detection of individual operations is limited.*** *Geostationary TEMPO (2023) will do better!*

- ***What Next?*** *Talking to BOEM about*

TRACER-AQ (9/2021) aircraft (GCAS)

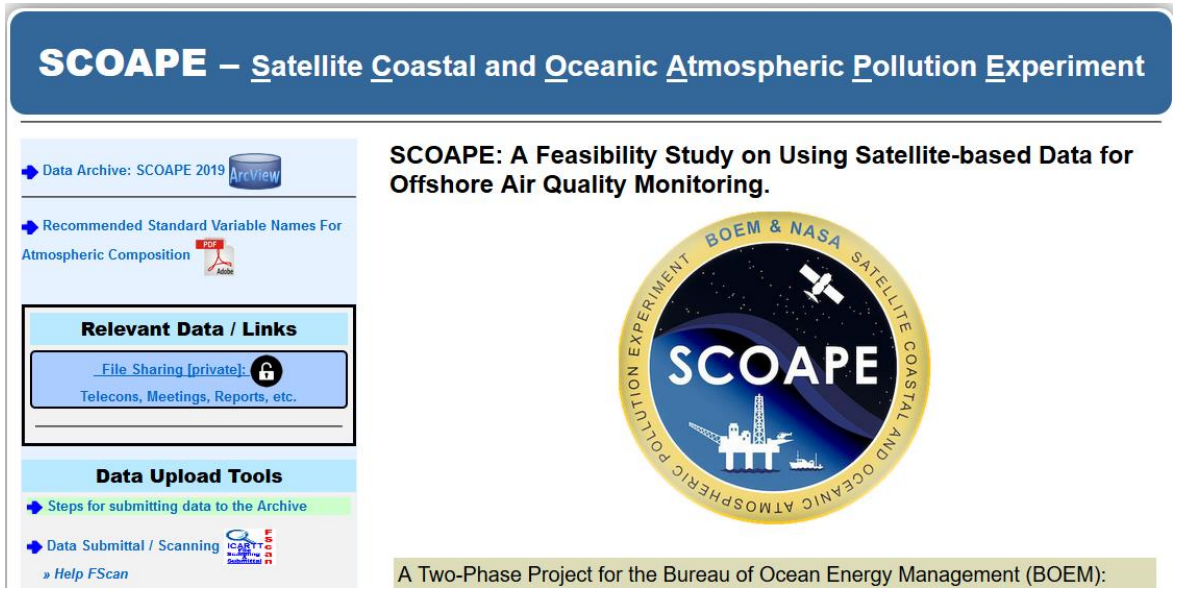
NO_2 sampling over GOM ONG area.

Compare to SCOAPE Pan NO_2



Thank You for Attention! Where are SCOAPE Data?

- **NASA LaRC-hosted Project Page: https://www-air.larc.nasa.gov/missions/scoape/index.html**
- **BOEM 2017 Emissions Report (Released October 2019): https://espis.boem.gov/final%20reports/BOEM_2019-072.pdf**



Current list for the RV-POINT-SUR Data:

Publications:

EM Article: Thompson et al., *EM,* http://pubs.awma.org/flip/EM-Oct-2020/thompson.pdf

NASA Report to BOEM:

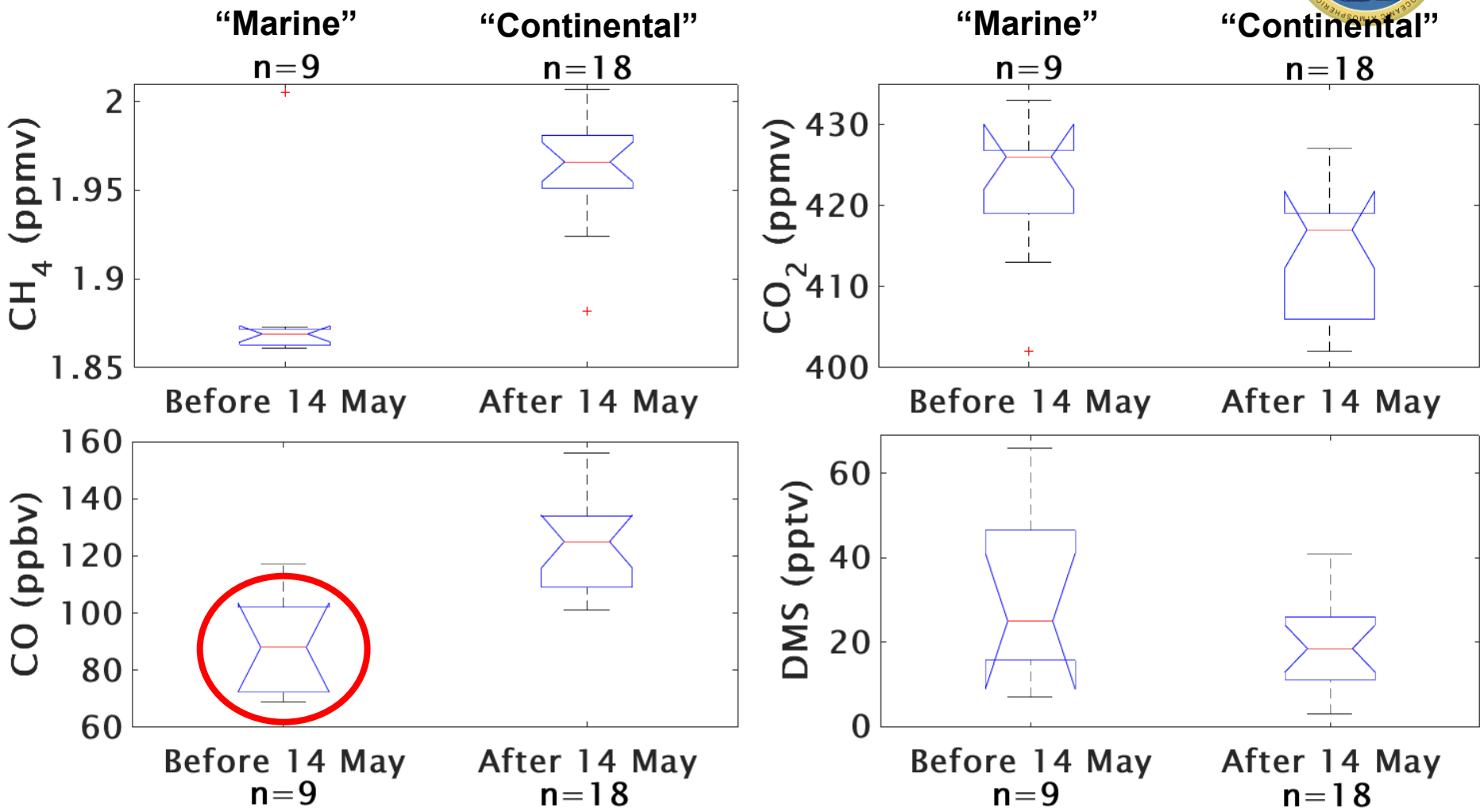
https://ntrs.nasa.gov/api/citations/20205008618/downloads/TM%202020500861 8%20Tech%20Report%20-%20(A.%20Thompson)%20-%20BOEM%202020-047%20Evaluation%20of%20NASA's%20Capabilities%20for%20AQ.pdf

Acknowledgments

- Additional Instruments: J. Sullivan, S.R. Kawa, T. Hanisco (NASA/GSFC), J. Conny (NIST), R. Delgado (UMBC), J. Flynn (Univ. Houston), D. Blake, B. Barletta (UCI)
- R/V *Point Sur* crew, Captain N. Allen
- *This study was funded in part by the U.S. Department of Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC through Inter-agency Agreement Number M17PG00026 with NASA*
- *This work was also supported by NASA's Applied Sciences Program (HAQAST)*
- Data credits: Copernicus Sentinel data processed by ESA & KNMI (2018), Sentinel-5P TROPOMI, Accessed from GES DISC in February 2019 for Jan. 2019 imagery: https://doi.org/10.5270/S5P-s4ljg54 .

Two Regimes: *Point Sur* VOC Canister Samples

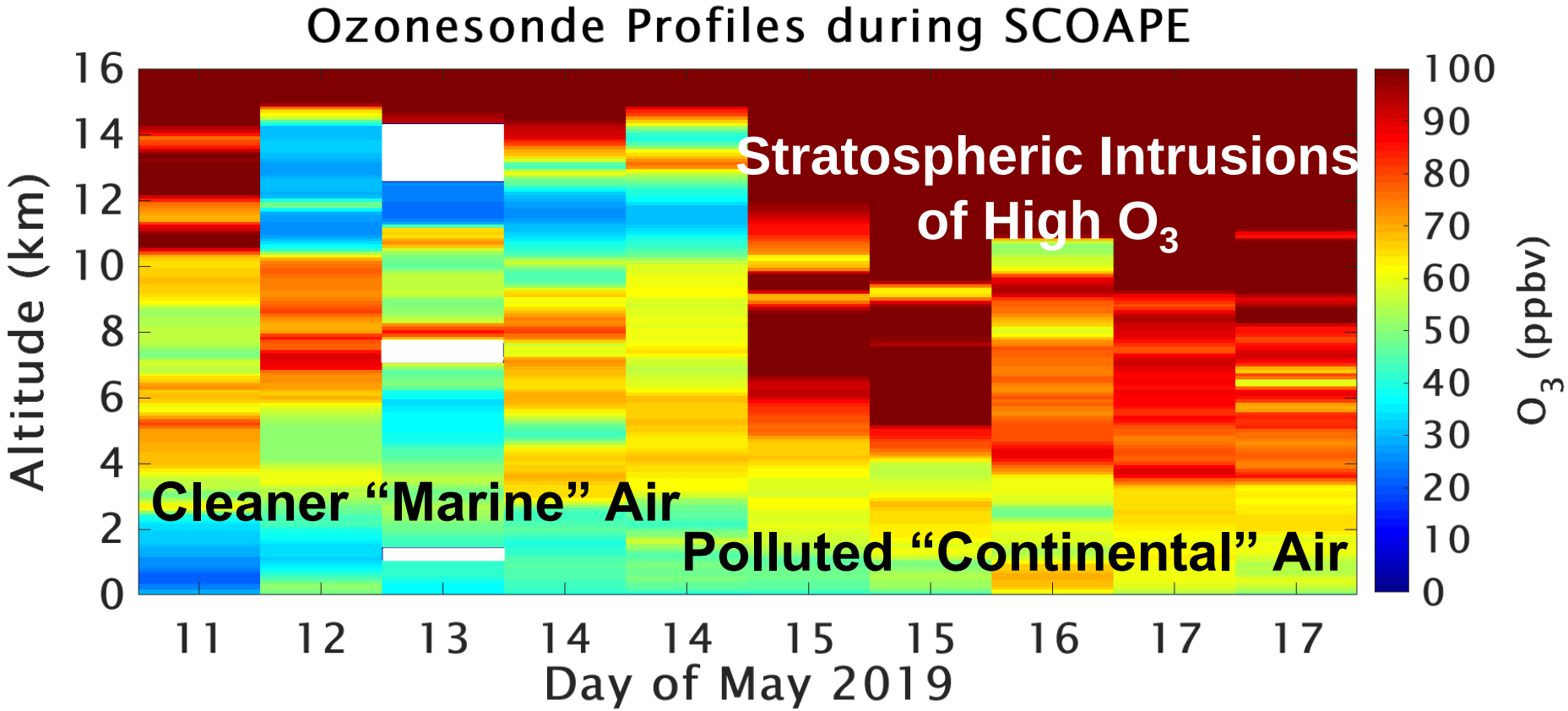
- R/V *Point Sur* VOC canister samples (UCI D. Blake lab) support the two regimes hypothesis
- Dimethyl sulfide (DMS; produced by marine algae, contributor to sulfate aerosols) decreases under continental influence
- Plots exclude one can (next slides…)



*Box plots showing median (**red line**), interquartile ranges (IQR; **blue box**), and 2x the median+IQR (whiskers) of four trace gases. Points beyond the whiskers are shown as red stars.*

Two Regimes: Ozonesonde Profiles

- Ozone profiles from R/V *Point Sur* indicate that marine/continental changes extend to the upper troposphere (UT)
- "Marine" air has very low UT O_3, indicating subtropical/tropical air masses
- Later in cruise, more surface O_3 pollution and stratospheric intrusions of high O_3



Ozonesonde O_3 mixing ratio profile "curtain." O_3 mixing ratios from the surface to 16 km in 100m-averaged bins are shown.