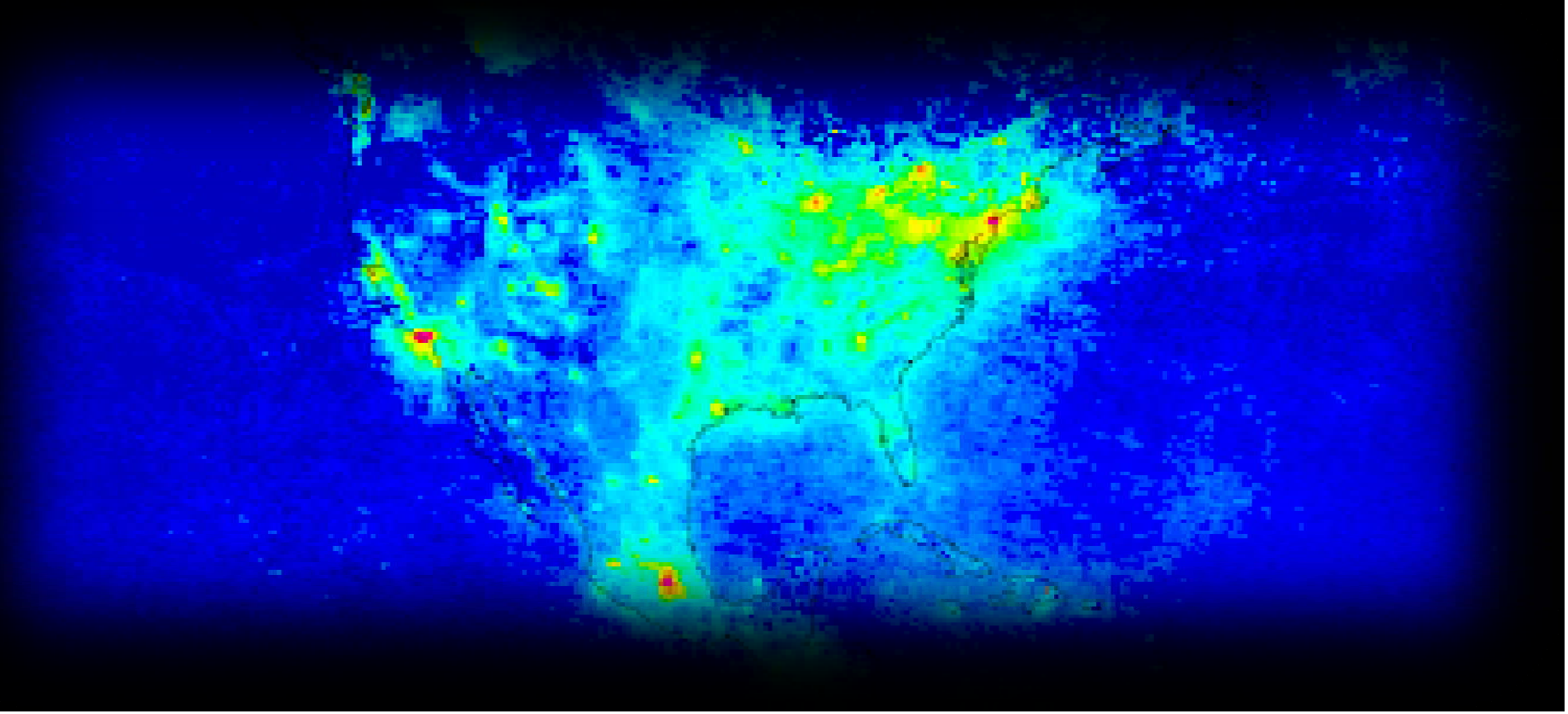
Spatial & Temporal Variability of NO_2 and other trace gases over US coastal waters

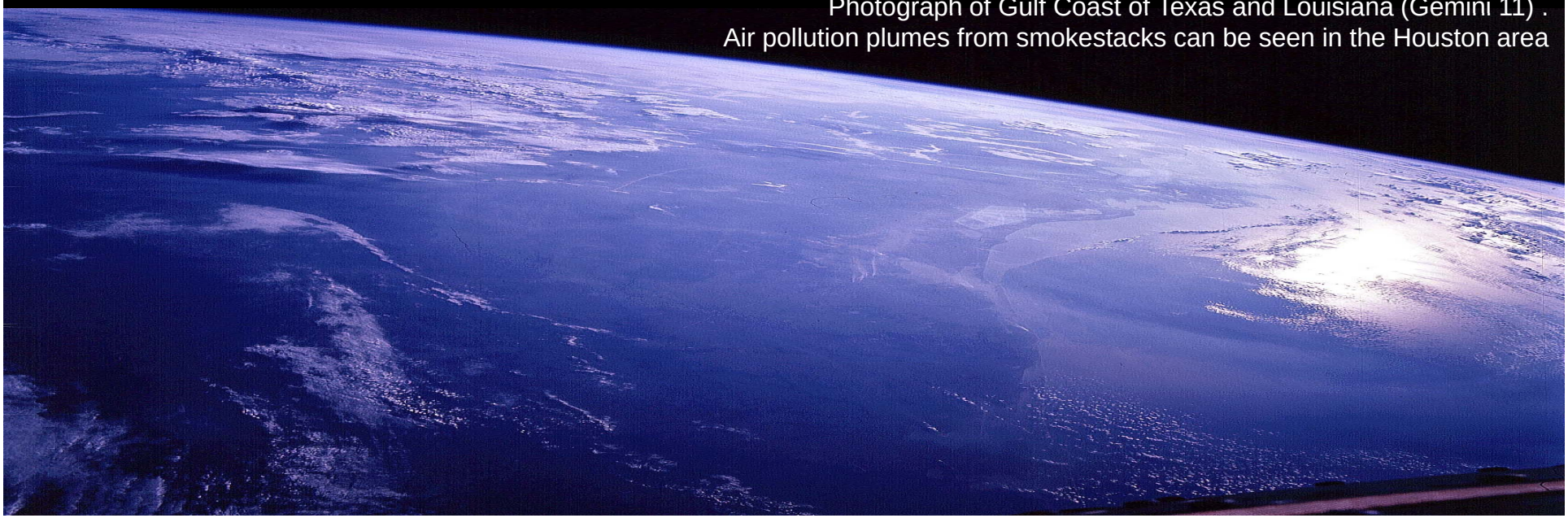
Distribution, Air quality, Nitrogen-deposition and Ocean color

Maria Tzortziou, Jay Herman, Alex Cede, Nader Abuhassan



❖ ***As the consequences of increasing air pollution, anthropogenic activities and climate variability are becoming more immediate and profound, understanding processes, feedbacks, interactions between the atmosphere and ocean components of the Earth System becomes increasingly important.***

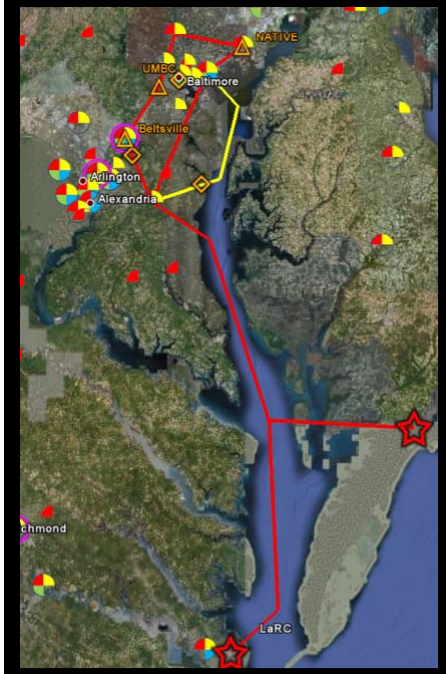
Need for detailed, integrated observations in the atmosphere-ocean system

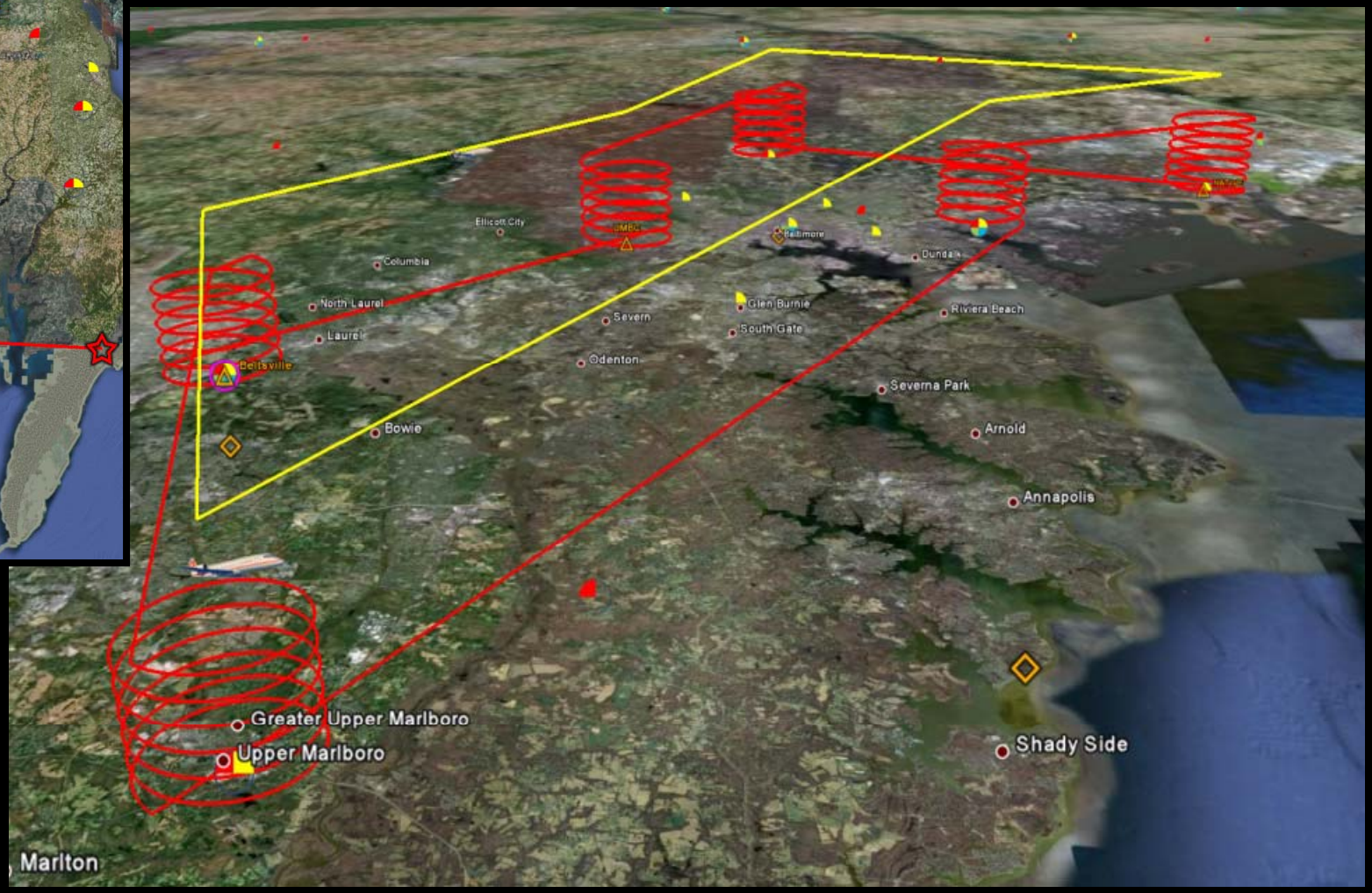


Photograph of Gulf Coast of Texas and Louisiana (Gemini 11) .
Air pollution plumes from smokestacks can be seen in the Houston area

❖***Opportunity for interdisciplinary science …***

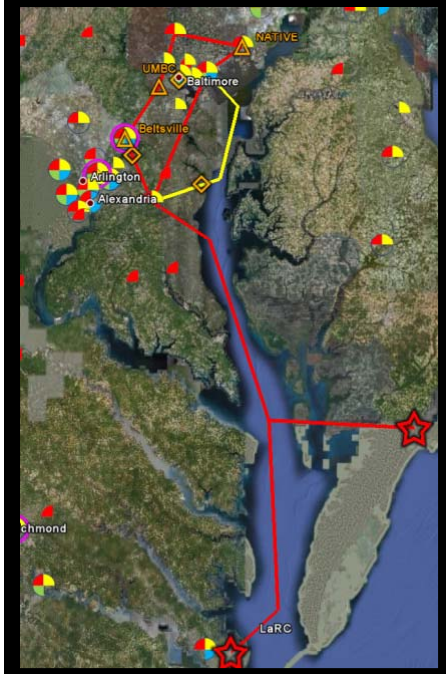
DISCOVER-AQ airborne observations over the Chesapeake Bay and the Gulf Coast

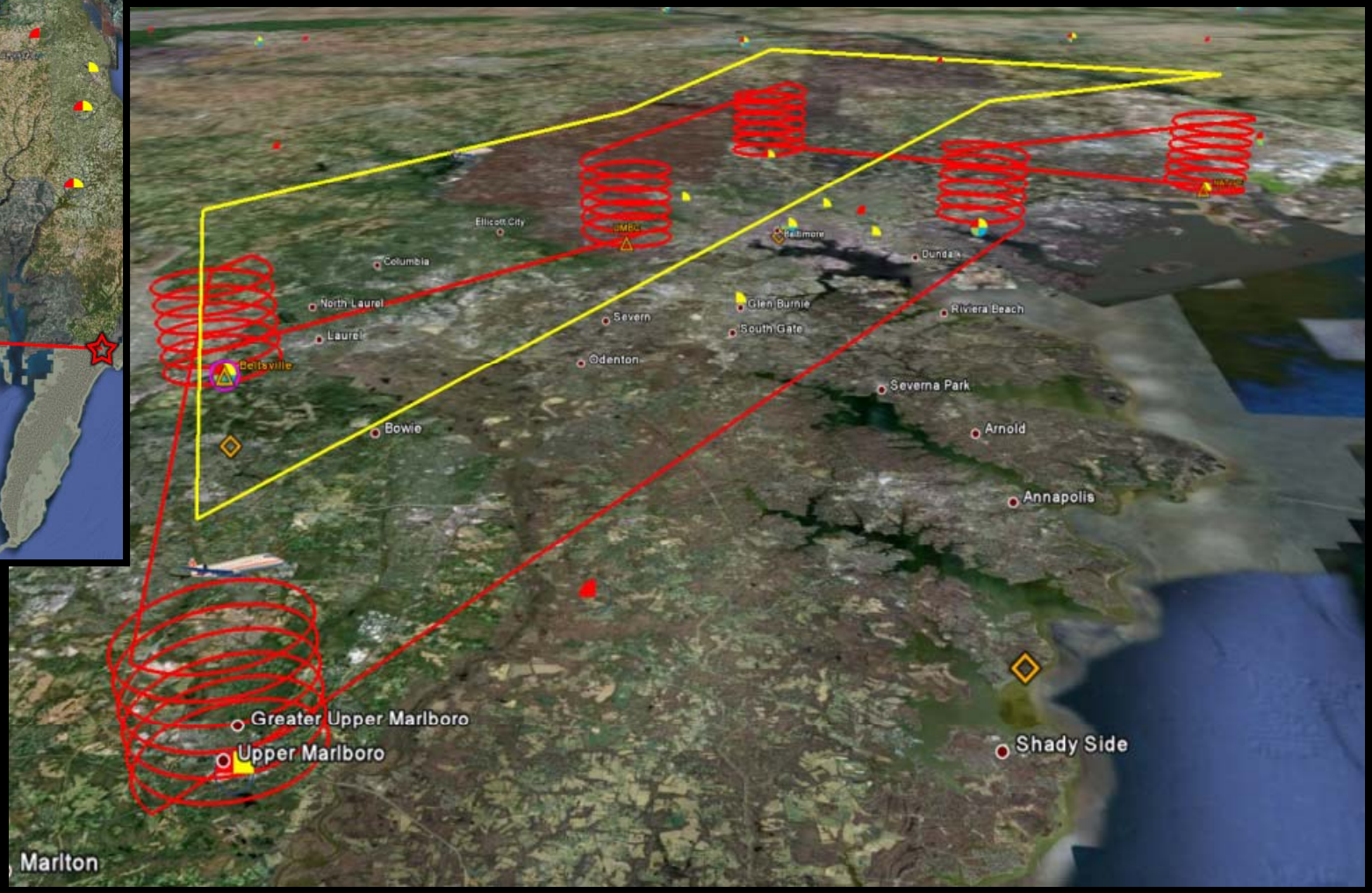




❖*Opportunity for interdisciplinary science …*

Challenge in coastal areas and adjacent ocean: *ground-stations that monitor changes in tropospheric air quality (aerosols, NO_2 , O_3, other trace gases) come to an abrupt end at the coastlines.*





To address this issue …

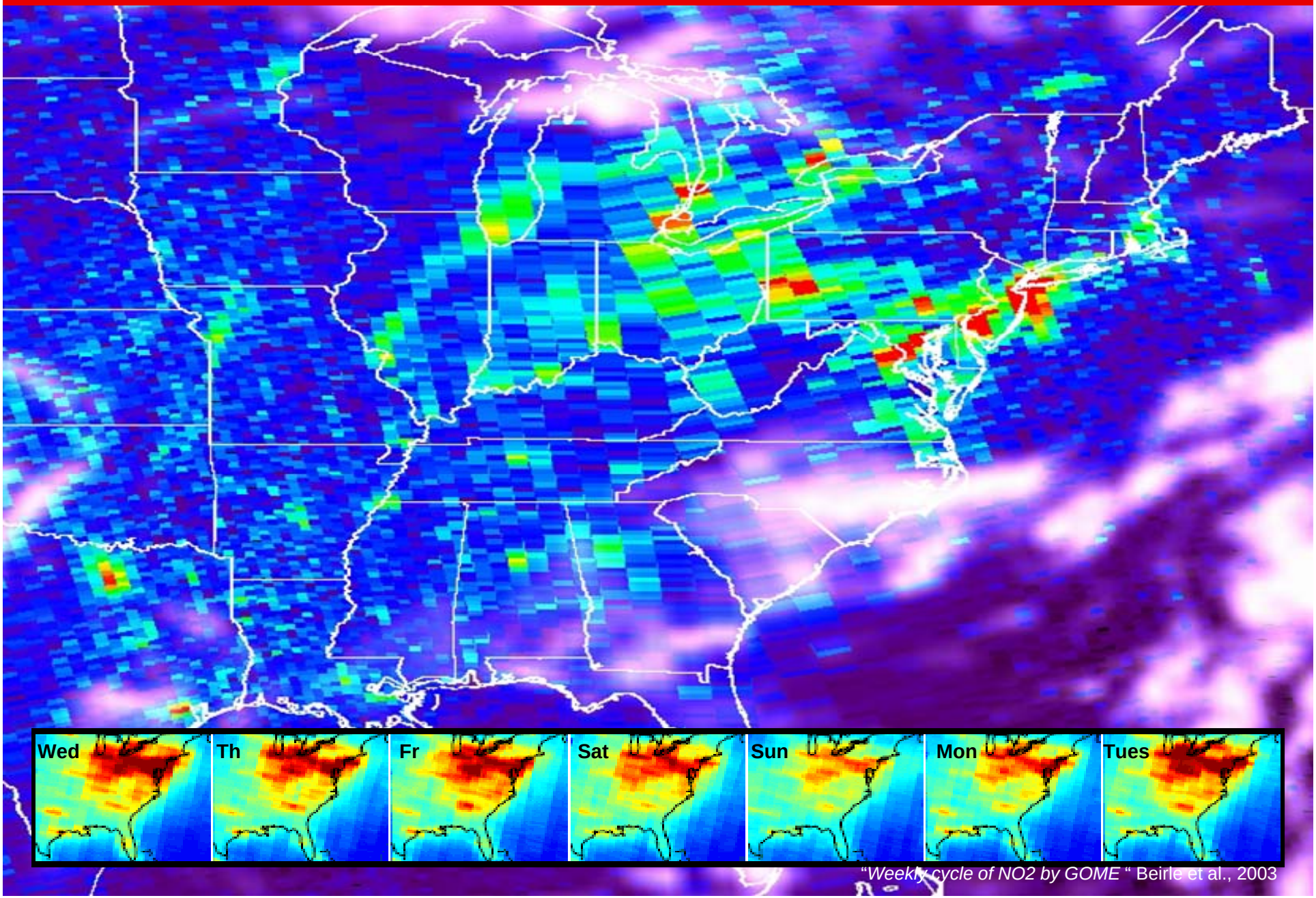
→We will extend measurements of the spatial and temporal patterns in traces gases and aerosols **over estuarine and coastal waters in the Chesapeake Bay/Mid Atlantic Bight region**

→ Measurements performed using the **Pandora spectrometers (NO_2, O_3, SO_2, HCHO, aerosols etc)**

→Combine in-situ observations with **Aura-OMI observations, aircraft measurements, and regional photochemical modeling (CMAQ and WRF-Chem)**

Projects:
-NASA-NIP Award (PI: Tzortziou,
Collaborators: Pickering, Herman, Mannino, Jordan, Dickerson)
- GEO CAPE activities (PIs: Tzortziou, Herman)

Evaluation of Satellite Products & Model Output in Coastal Regions



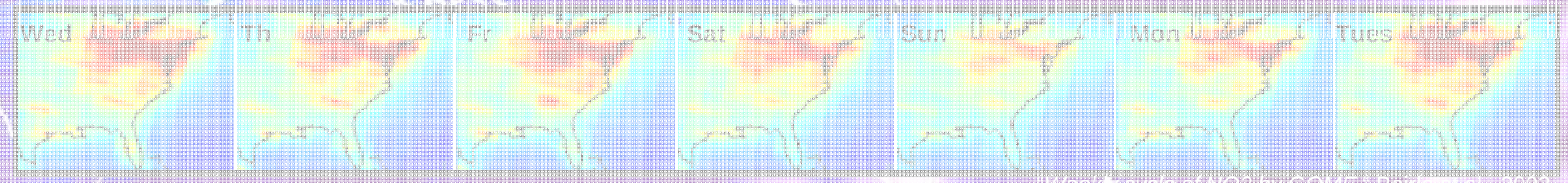
"Weekly cycle of NO2 by GOME " Beirle et al., 2003

Apply Pandora measurements (NO2, O3, SO2,HCHO etc) over coastal waters to:

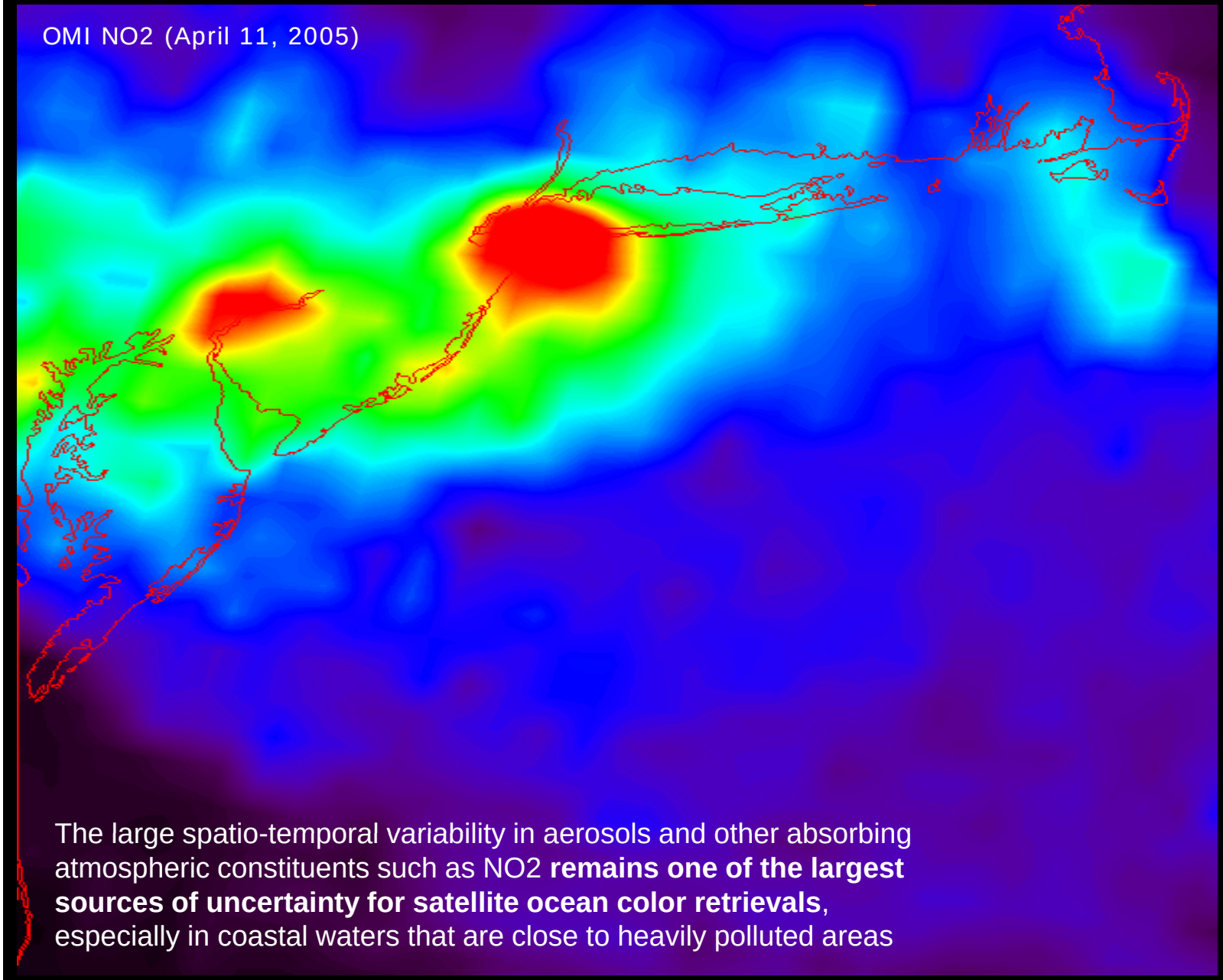
i) compare with collocated NASA-Aura OMI satellite NO_2 retrievals in coastal areas, examine NO_2 variability at scales smaller than OMI's 12 x 24 km pixel (nadir view), and evaluate assumptions in satellite tropospheric NO_2 retrievals (e.g. NO_2 profile shape).

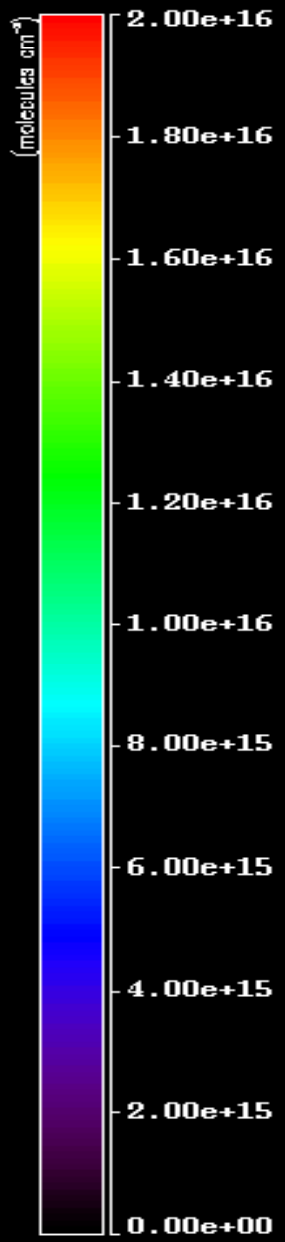
ii) evaluate air-quality model performance and emission inventories for improving model predictions of tropospheric NO_2 amounts, distribution and transport over the studied estuarine/coastal region.

The CMAQ and WRF-Chem models will be used, enhanced with a new lightning NOx emission scheme and aircraft NOx emissions.



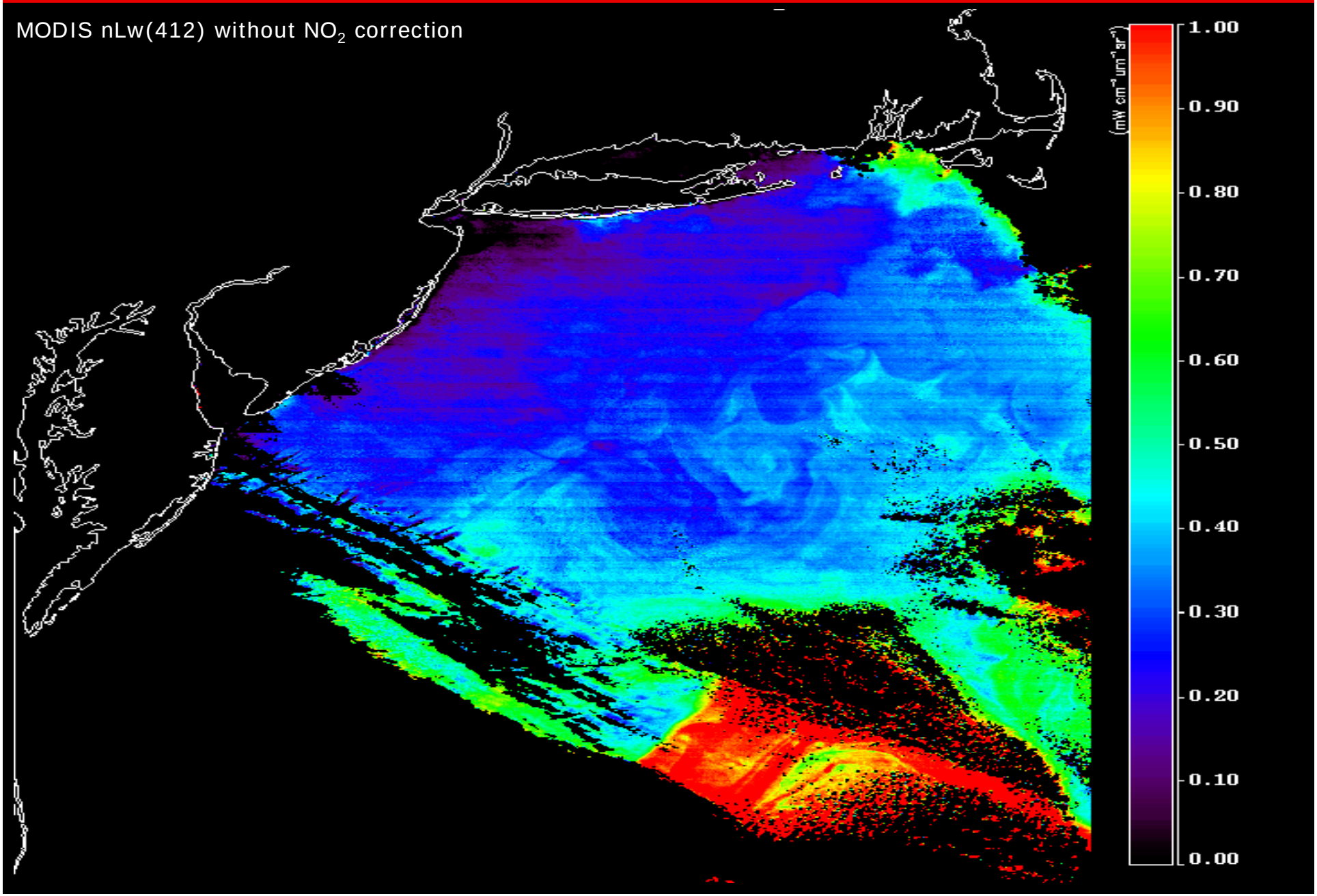
Weekly cycle of NO2 by GOME. Beirle et al. 2003





The large spatio-temporal variability in aerosols and other absorbing atmospheric constituents such as NO2 **remains one of the largest sources of uncertainty for satellite ocean color retrievals**, especially in coastal waters that are close to heavily polluted areas

MODIS nLw(412) without NO_2 correction



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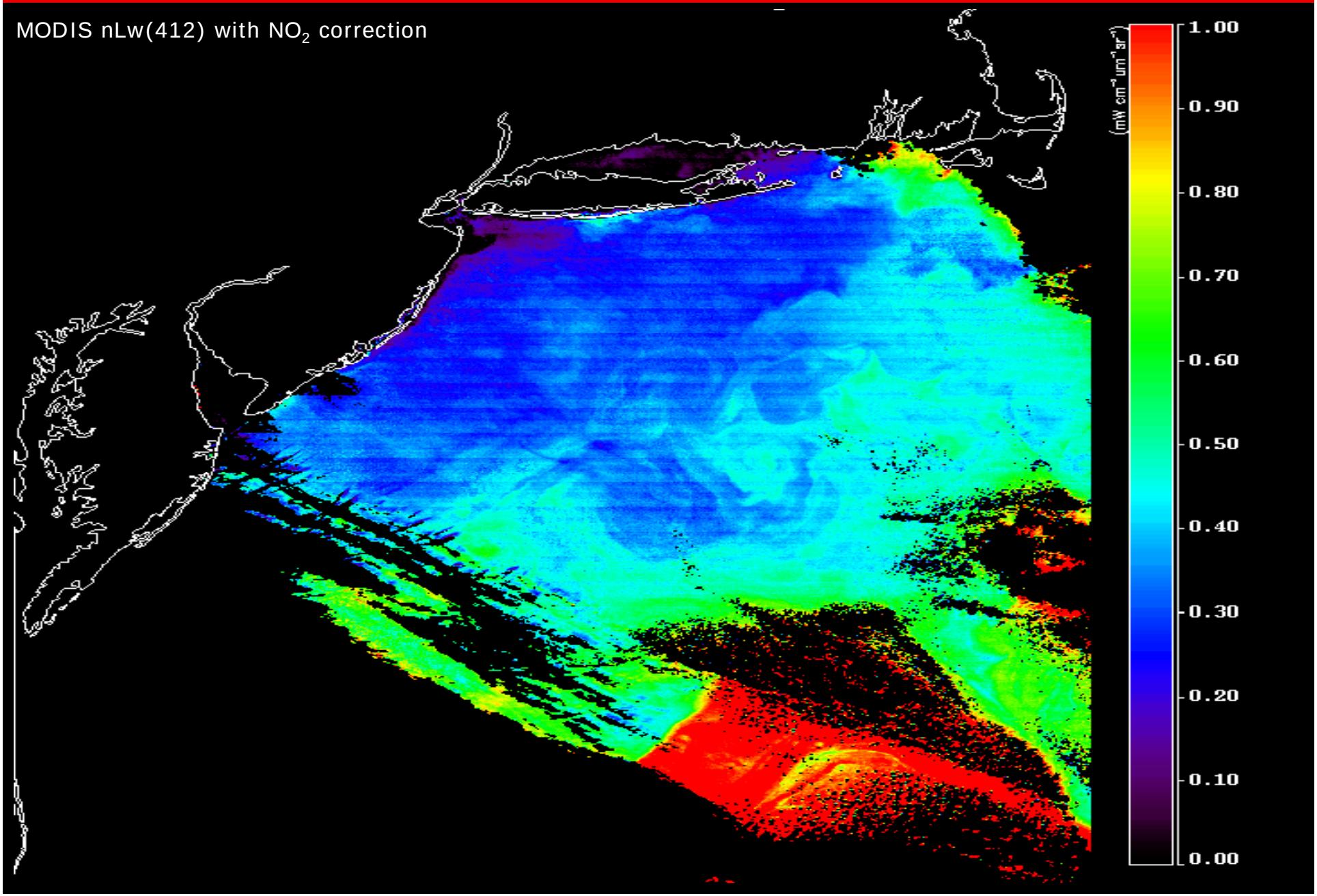
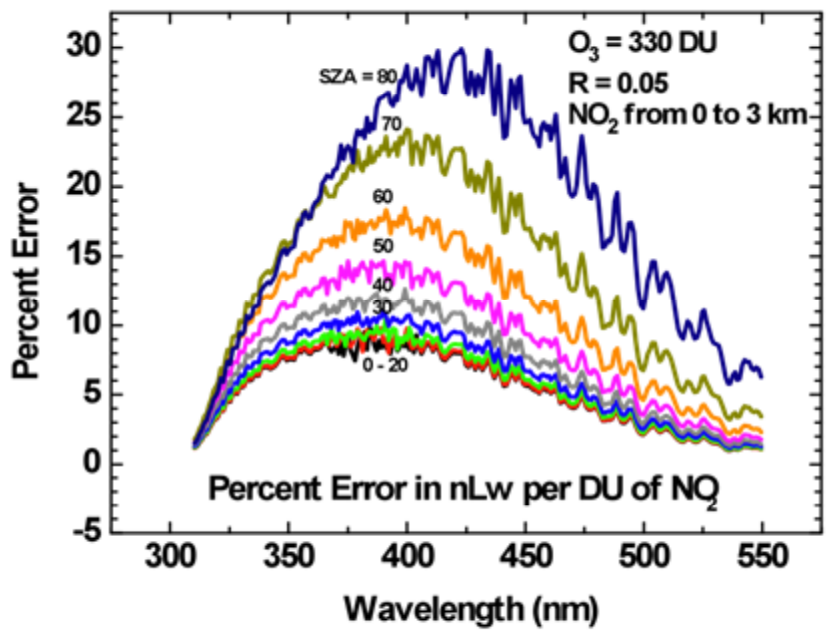


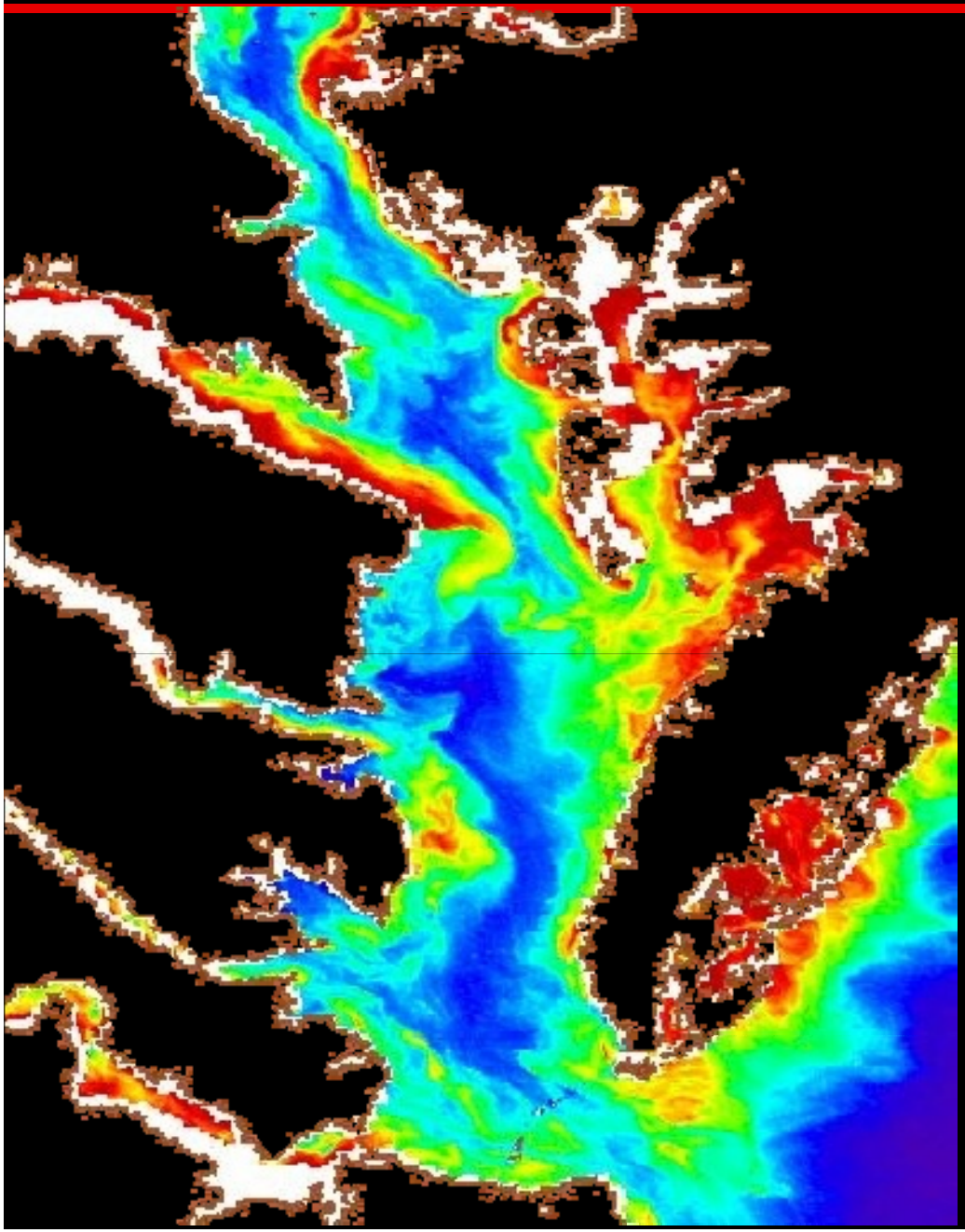
→ **5-7% error in nLw(410),** at low solar zenith angle (< 40º) and low look, for 0.5 DU change in NO_2 (typical variability of NO_2 close to Eastern US coastal areas).

→ **Error increases (reaching 15-20%)** for larger solar zenith and look angles, and as NO_2 is transported to higher altitudes.

→ This error is **spectrally dependant (from 350 to 500 nm with a maximum near 400 nm),** so it does not cancel out when using band-ratios for ocean color retrievals.



Coastal Ocean Biogeochemical Processes



- Study exchanges of materials (carbon and nutrients) across land-ocean interface
- Resolve near-shore geophysical features
- Understand time and space scales of biological, biogeochemical and optical variability

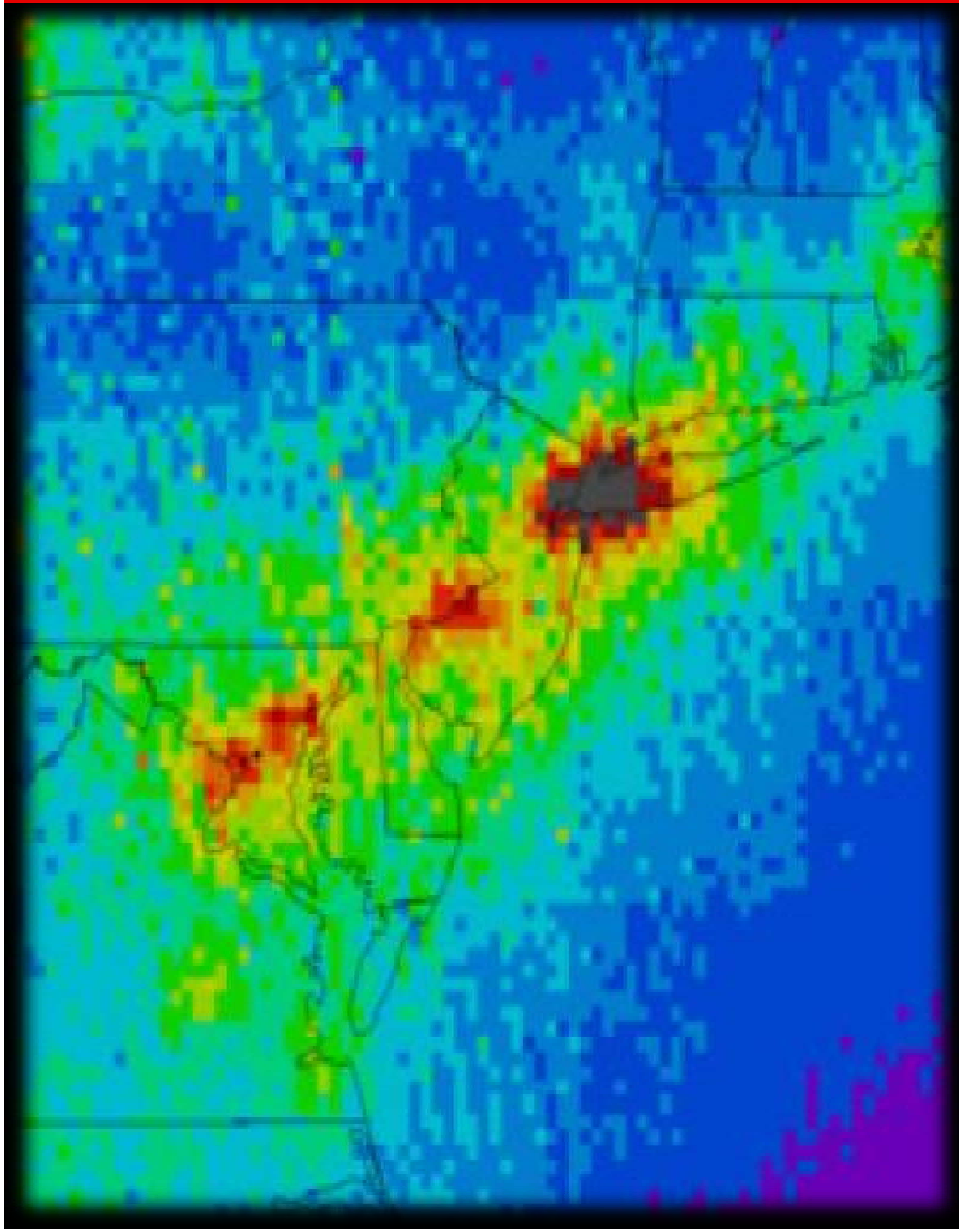
GEO CAPE Ocean STM:
Threshold Spatial Res: 375x375 m
Threshold Temporal Res: < 3hours

We need to understand atmospheric variability and accurately account for it in ocean color retrievals.

Otherwise it will lead to a false estimate of time-dependent underwater processes.

MODIS-Aqua:
water-leaving radiance at 645 nm and 250-meter resolution ($mWcm^{-2}mm^{-1}sr^{-1}$.) *(Reprinted from Franz et al. 2006)*.

Nitrogen Deposition in estuarine and coastal waters

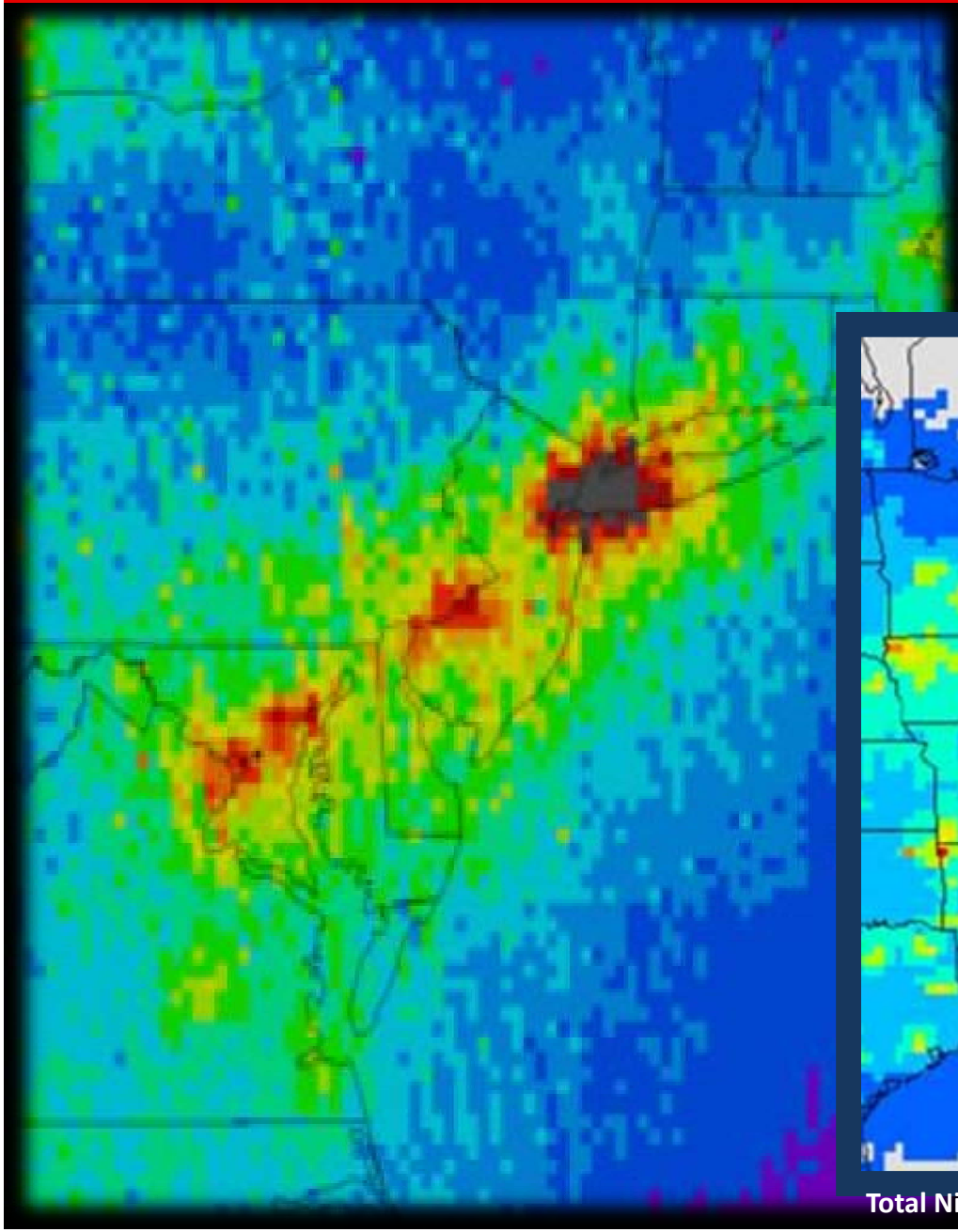


The environmental impacts of NO_2 are not confined to the atmosphere

NO_2 can act as an **acidifying and eutrophying agent in terrestrial and aquatic ecosystems** through dry/wet deposition of its oxidation products

In the Chesapeake Bay, **at least one third, and probably significantly more, of total nitrogen inputs comes from air deposition** *[STAC Publ. 09-001, 2009].*

Nitrogen Deposition in estuarine and coastal waters



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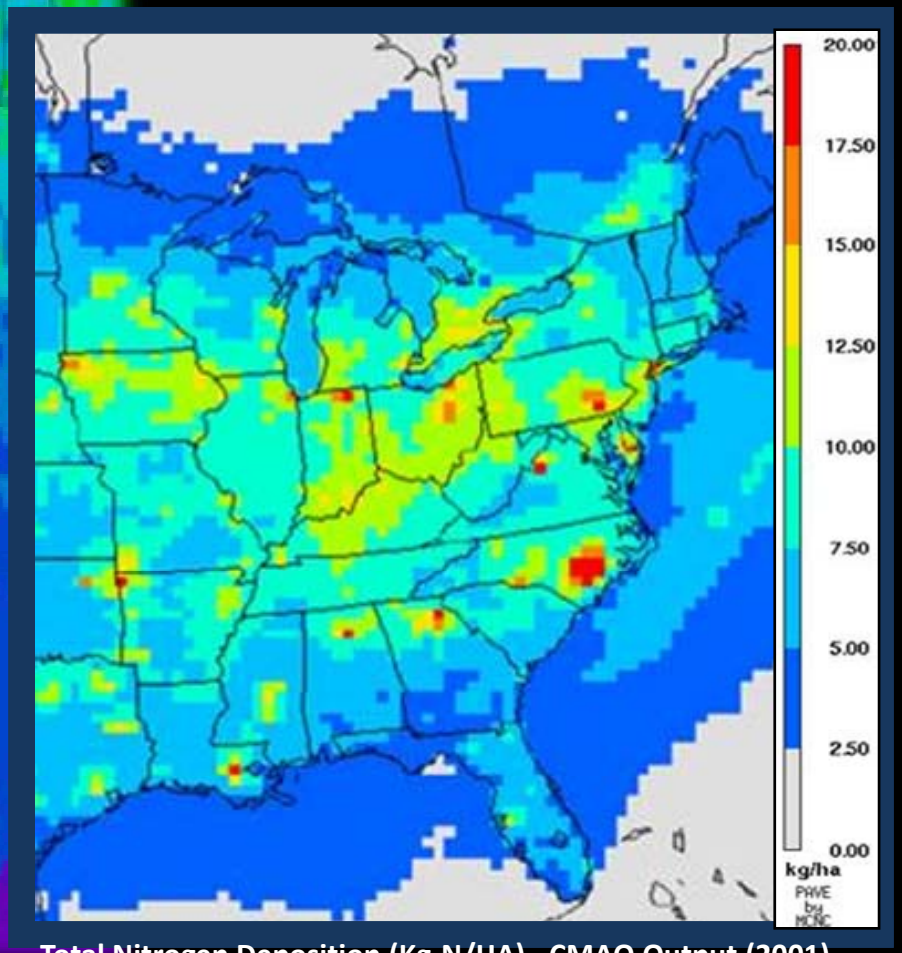
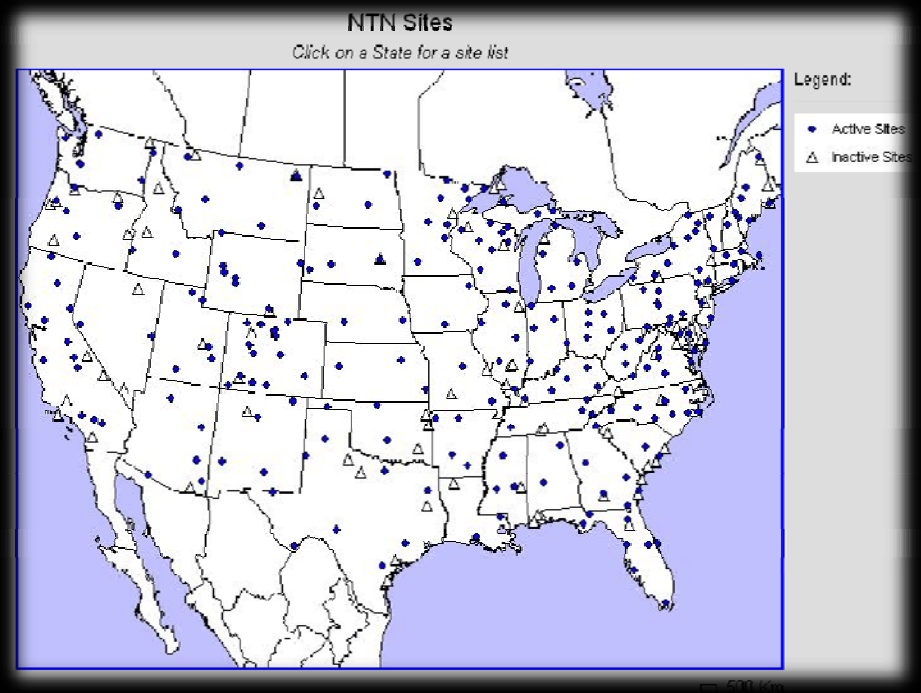


Total Nitrogen Deposition (Kg-N/HA)– CMAQ Output (2001)

Many ground-based programs monitoring atmospheric deposition on various watersheds in the US.

NADP/NTN (National Atm. Deposition Program /National Trends Network): wet deposition data



Concentrations of inorganic chemicals in precipitation (e.g. acidity (measured as pH), sulfate, nitrate, ammonium, chloride, and base cations).

CASTNet (Clean Air Status and Trends Network): ambient air pollution , estimates of dry deposition D=CVd

Ambient measurements of gaseous SO_2, HNO_3, and O_3, particulates (sulfate, SO_4^{2-}, nitrate, NO^{3-}, ammonium, NH^{4+}, other relevant ions), and meteorological parameters

Despite the importance of dry NOx deposition in urban areas, atmospheric NOx is among the most important parameters *currently missing* from CASTNet. This significantly inhibits accurate model estimates of oxidized-N dry deposition [e.g. Dennis, 2007].

Dry Deposition of Reactive N is Important
Important Fraction of Dry Deposition Not Being Measured

Numbers for Chesapeake Bay Watershed and Bay

	Specie	Kg-N ($x10^6$)
Dry Ox-N	NO	4.22
	NO_2	14.53
	PAN's	5.42
	Other	5.71
	HNO_3	55.12
	aNO_3^-	1.63
Dry Ox-N	Total	86.62
Wet Ox-N	Total	57.25
Dry Red-N	NH_3	34.75
	aNH_4^+	7.52
Dry Red-N	Total	42.27
Wet Red-N	Total	45.79

Not Being Measured (34%)

Dry Ox-N > Wet Ox-N

Not Being Measured (82%)

Dry Red-N < Wet Red-N

9

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

From Robin L. Dennis (Atmospheric Sciences Modeling Division, ARL/NOAA)
NADP 2007 Scientific Symposium Boulder, CO September 10-14, 2007

Nitrogen Deposition in estuarine and coastal waters

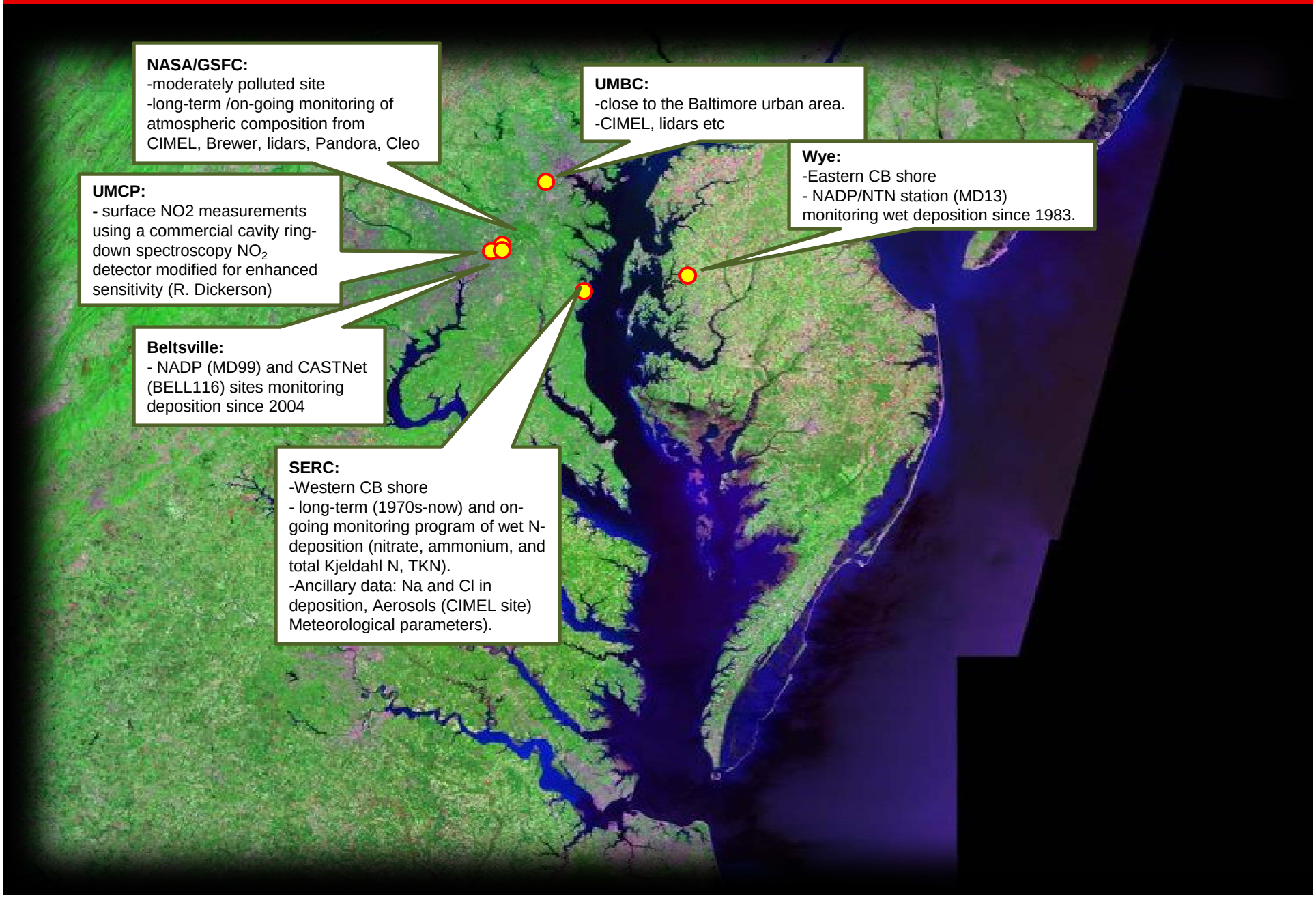
Our measurements of NO_2 over coastal areas, and at atmospheric deposition monitoring sites in the Chesapeake Bay watershed can be applied to:

→ complement current measurements at these sites with detailed (currently missing) NO_2 information

→ combined with satellite information and aircraft observations, can be applied to constrain photochemical models and evaluate model performance and emission inventories (including new schemes for lightning and aircraft NOx emissions) for improving model predictions of tropospheric NO_2 amounts, distribution and transport over coastal regions

→ compare model estimates of atmospheric dry/wet N-deposition with in-situ measurements and apply results to better understand observed spatial and temporal patterns of nitrogen deposition in the studied coastal region.

Variability of NO_2 and other trace gases over US coastal waters



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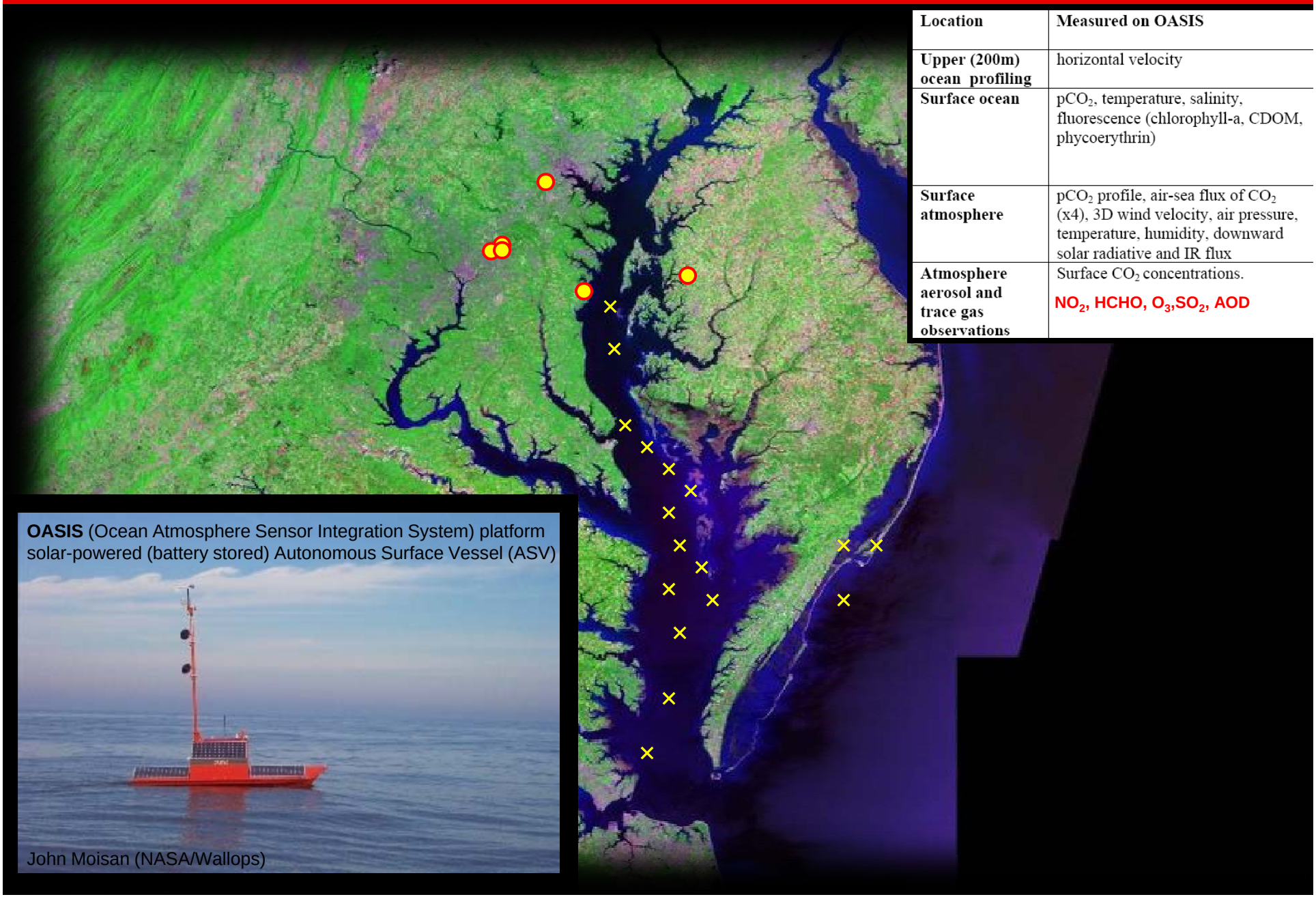

Location	Measured on OASIS
Upper (200m) ocean profiling	horizontal velocity
Surface ocean	pCO_2, temperature, salinity, fluorescence (chlorophyll-a, CDOM, phycoerythrin)
Surface atmosphere	pCO_2 profile, air-sea flux of CO_2 (x4), 3D wind velocity, air pressure, temperature, humidity, downward solar radiative and IR flux
Atmosphere aerosol and trace gas observations	Surface CO_2 concentrations. **NO_2, HCHO, O_3,SO_2, AOD**

OASIS (Ocean Atmosphere Sensor Integration System) platform solar-powered (battery stored) Autonomous Surface Vessel (ASV)

John Moisan (NASA/Wallops)

Variability of NO_2 and other trace gases over US coastal waters

OASIS Platform Data - CODAAC

HYDROSPHERIC AND BIOSPHERIC SCIENCES LABORATORY, NASA GSFC/WALLOPS FLIGHT FACILITY

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OASIS Platform Data

OASIS platform test data is now streaming in.

This includes data from sensors embedded on the platform and a view from the onboard camera.

+ OASIS platform data

The OASIS Platform

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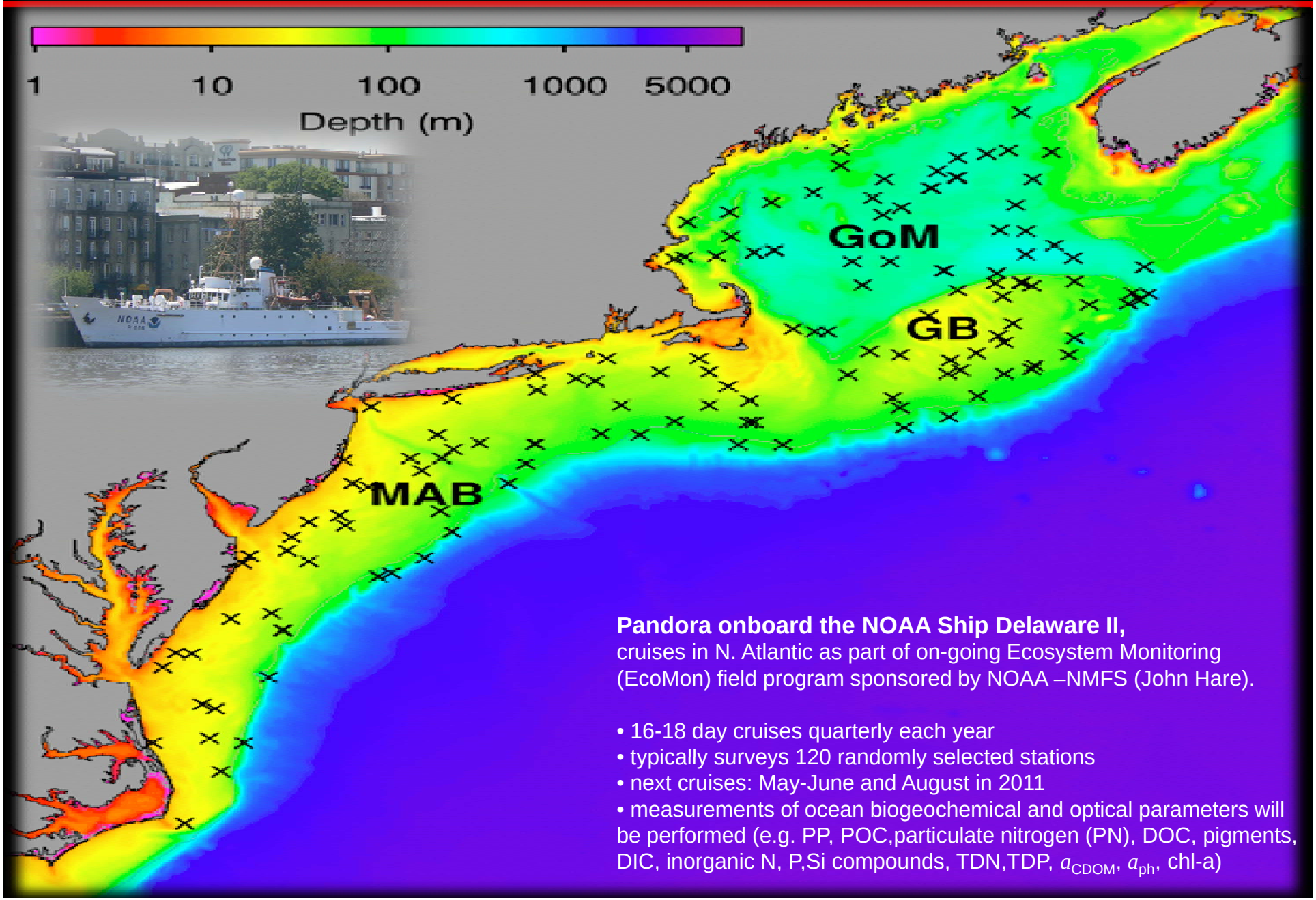

Pandora onboard the NOAA Ship Delaware II,
cruises in N. Atlantic as part of on-going Ecosystem Monitoring (EcoMon) field program sponsored by NOAA –NMFS (John Hare).

- 16-18 day cruises quarterly each year
- typically surveys 120 randomly selected stations
- next cruises: May-June and August in 2011
- measurements of ocean biogeochemical and optical parameters will be performed (e.g. PP, POC,particulate nitrogen (PN), DOC, pigments, DIC, inorganic N, P,Si compounds, TDN,TDP, a_{CDOM}, a_{ph}, chl-a)

Variability of NO_2 and other trace gases over US coastal waters

DISCOVER-AQ Science Team Meeting
5-7 October, Hampton, VA