National Aeronautics and Space Administration

NASA

EXPLORE EARTH

Merging Analytic Collaborative Frameworks with New Observing Strategies Toward a Digital Twin: *Earth* – Episodic Pulse Event Impacts on Ocean Carbon Cycle as an Example

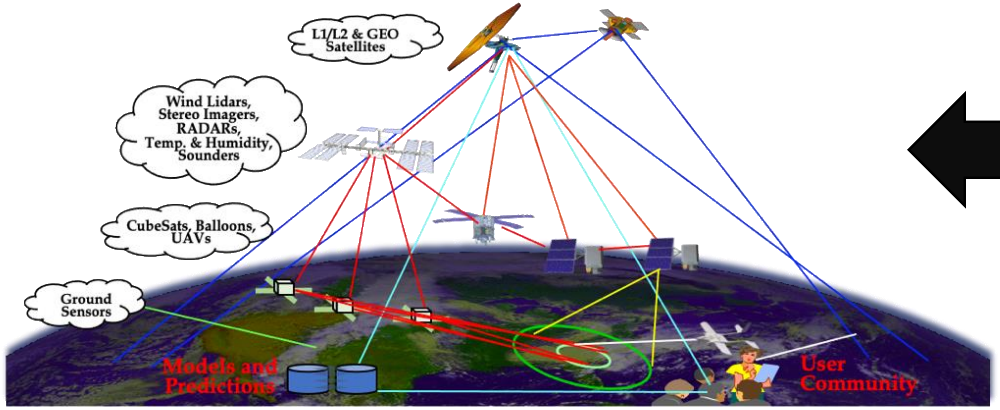
Laura Rogers[1], Joshua Carden[1], Blake Clark[2,3], Stephanie Schollaert Uz[2], Thomas Huang[4], Vardis Tsontos[4], Sreeja Nag[5,7], Vinay Ravindra[5,7], Joel Scott[6,8]

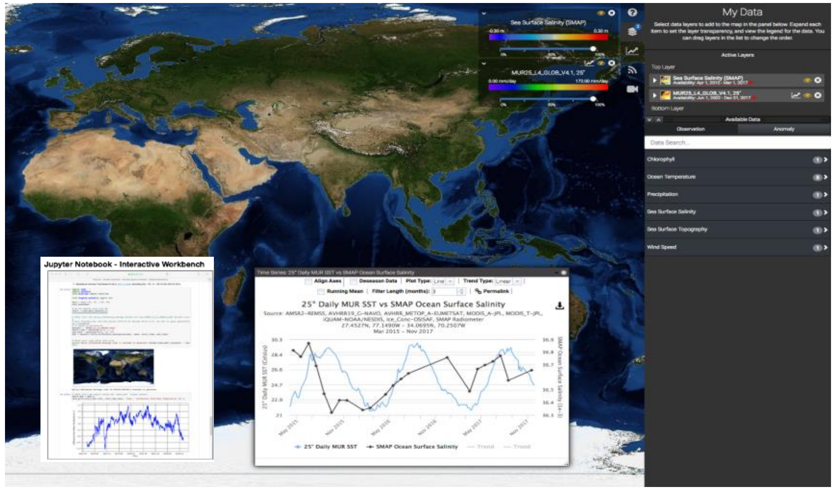
[1]NASA Langley Research Center, Hampton, VA, USA; [2]NASA Goddard Space Flight Center, Greenbelt, MD, USA; [3]University Space Research Association; [4]Jet Propulsion Laboratory, Pasadena, CA, USA; [5]NASA Ames Research Center, Moffet Field, CA, USA; [6]NASA Headquarters, Washington D.C., USA; [7]Bay Environmental Research Institute, Moffet Field, CA, USA; Agile Decision Sciences, Beltsville, MD, USA

Science to Technology and Back

Science Need

- Rare events exert a major influence: about 65% of change in biomass is caused by the 10% highest values. **The results suggest that frequencies of rare events might be as important for biological production as seasonal averages**
- Large river systems and marine receiving waters remain poorly characterized, particularly in the tropics, which contribute to a disproportionately large fraction of the transformation of terrestrial organic matter to carbon dioxide, and the Arctic, where positive feedback mechanisms are likely to amplify global climate change. **There are large gaps in current coverage of environmental observations along the aquatic continuum.**





Science Impact

A more comprehensive understanding of the impact of episodic events to help close the carbon budget through the use of dynamic architectures

NOS and ACF for Science Data Intelligence

Optimize measurement acquisition using many diverse observing capabilities, collaborating across multiple dimensions and creating a unified architecture

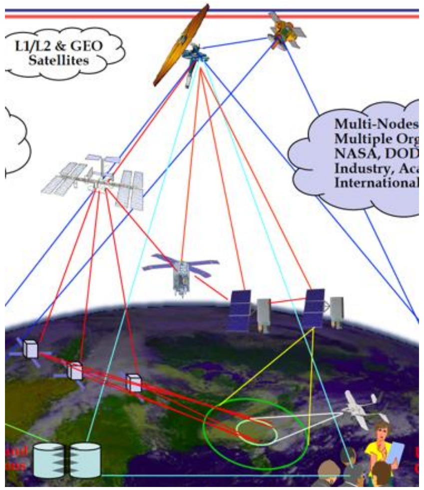
Assimilate Observations

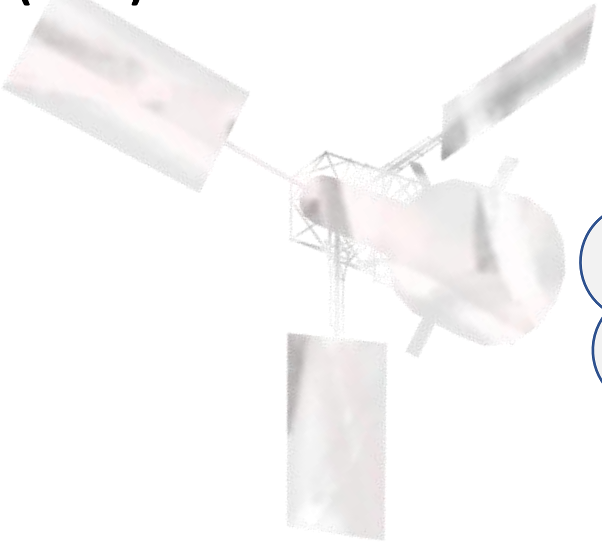
Enhance and enable focused Science investigations by facilitating access, integration and understanding of disparate datasets using pioneering visualization and analytics tools as well as relevant computing environments

New Observing Strategies (NOS)

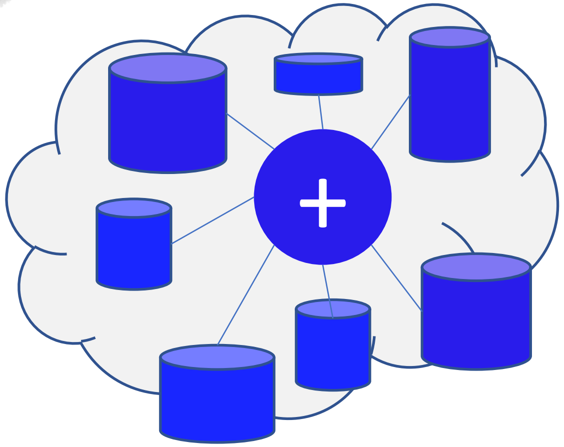
Acquire coordinated observations

Track dynamic and spatially distributed phenomena





Analytic Collaborative Frameworks (ACF)



Assimilate many various data into models and analytic workflows.

What additional observations are needed?

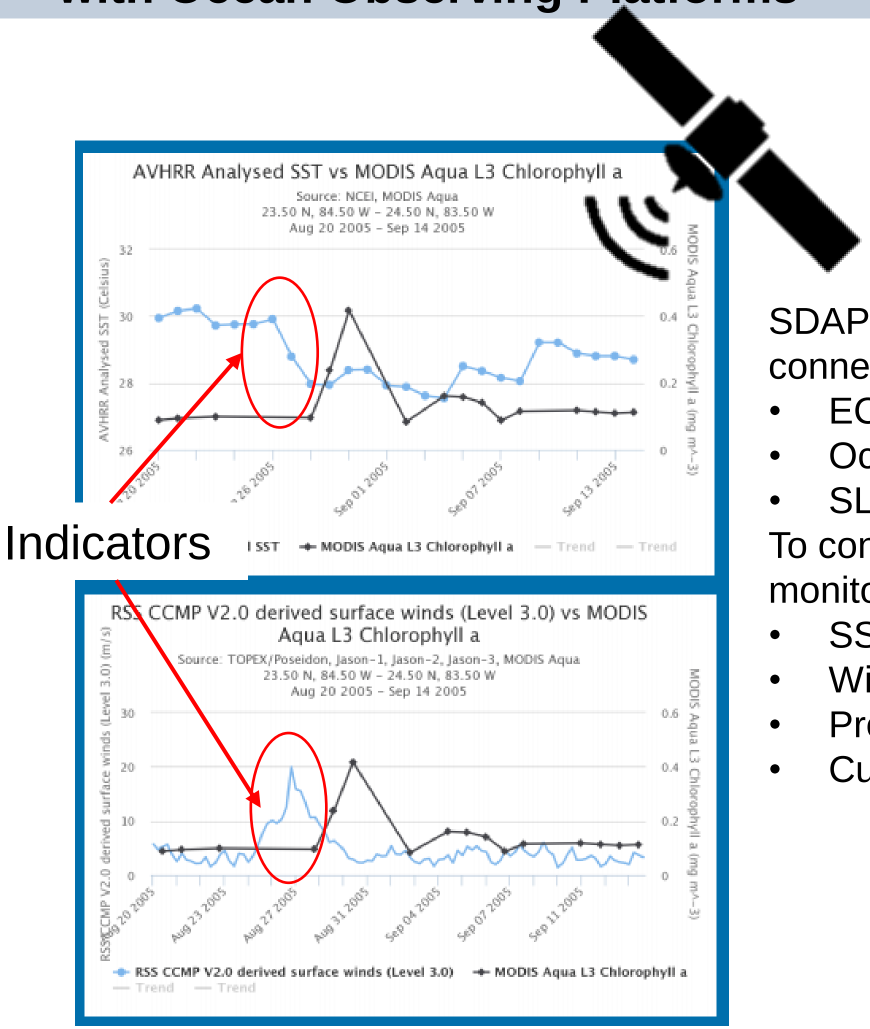
Example: OceanWorks, ACF for Ocean Science https://oceanworks.jpl.nasa.gov

Observation Requests

NOS+ACF acquires and integrates complementary and coincident data to build a more complete and in-depth picture of science phenomena

Ocean Carbon Cycle NOS Demonstration Study

Development of science requirements and NOS observing concepts to capture episodic events with Ocean Observing Platforms



The SST drop is correlated to both wind and precipitation data. The Chl-A data is lagged by about 3 days to the other observations like SST, wind and precipitation. (Liu, 2009)

SDAP instance connects with:
- ECCO and
- OceanXtremes
- SLC portal

To continuously monitor indicators
- SST
- Wind
- Precipitation
- Currents

Triggers D-SHIELD simulation for region and trades
- Spatial Extent
- Depth
- Sensor (hyperspectral vs imagery)
- Spatial/Temporal Resolution

To determine greatest science return

Platforms to consider:
- NASA/NOAA missions
- Commercial cubesats
- Autonomous underwater glider (AUVs)
- Shipboard in-situ measurements/Saildrones

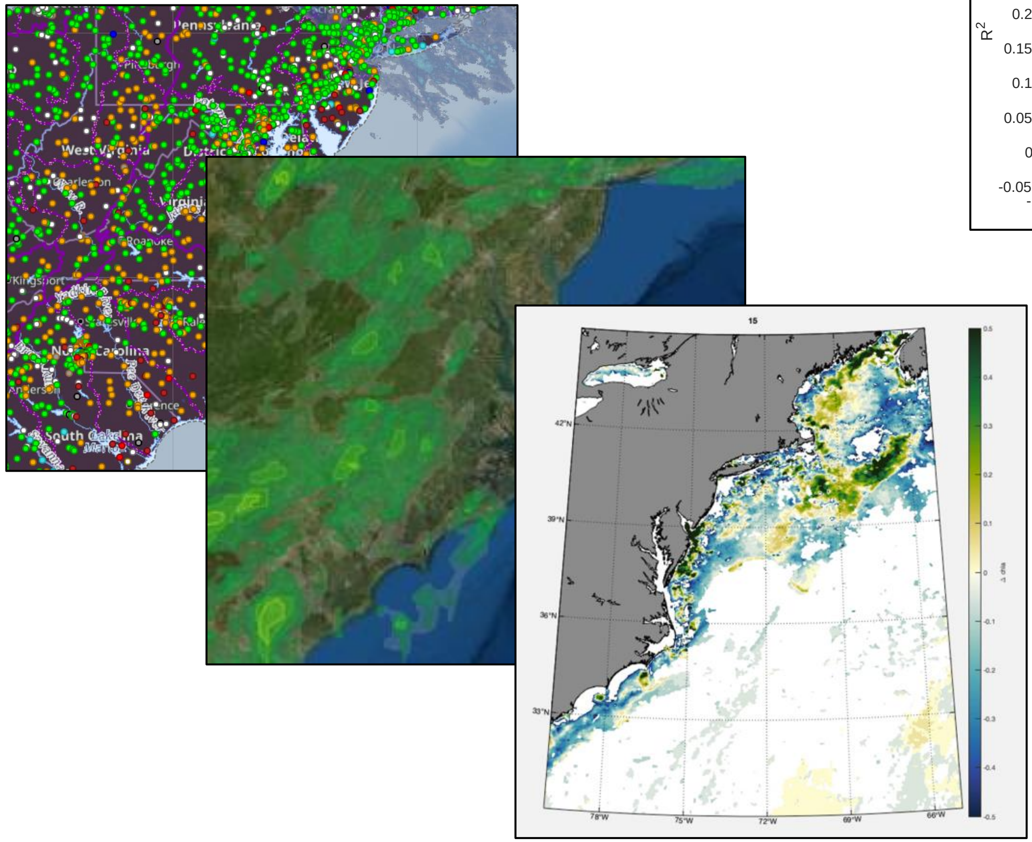
Goals

- Acquire relevant observational data and develop a workflow for implementation
- Identify predictive triggers to plan and schedule future observations
- Develop a messenger packet schema for information exchange across observing systems
- Identify gaps in current observations and opportunities for improvement using other observational and modeling capability
- Define “what-if” scenario opportunities

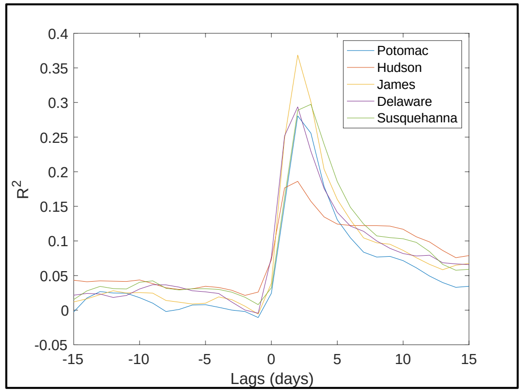
Scenario: Hurricane Michael (2018)

Baseline Observations

- Precip.: GPM/IMERG
- Stream Flow: USGS River Gauges
- Level 3 Ocean Color: MODIS/AQUA

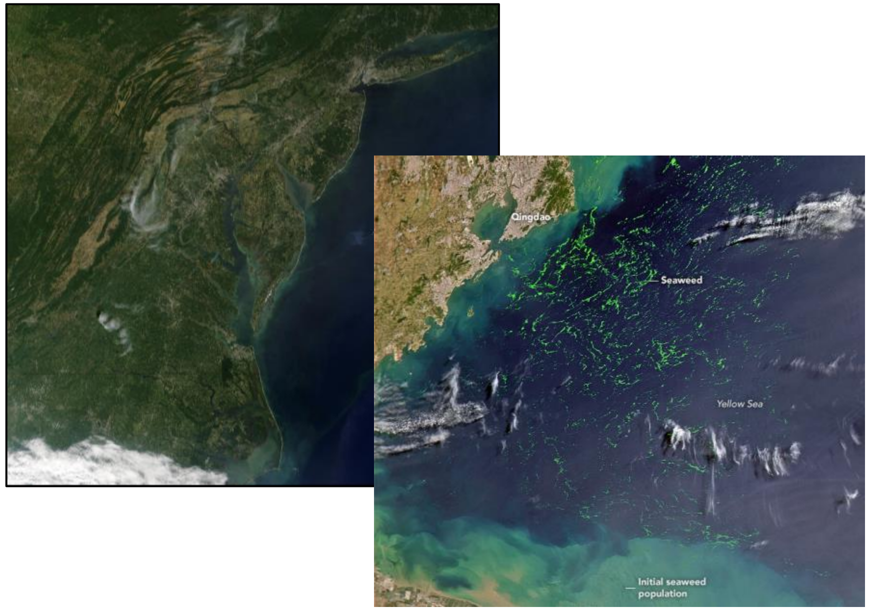


TRIGGER



Triggered/Sustained Observations

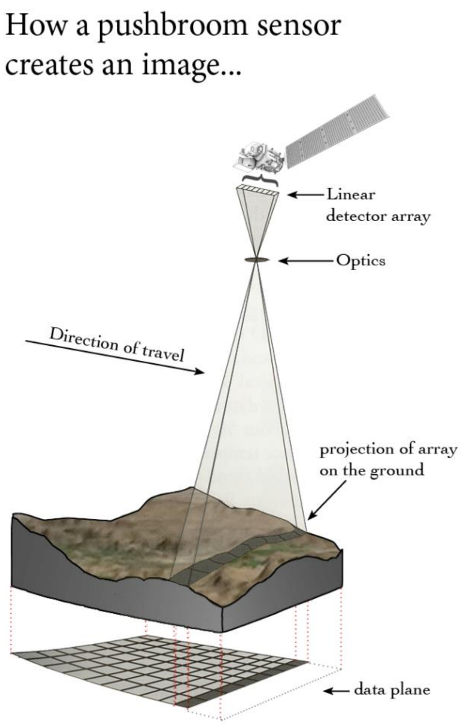
- Precip.: GPM/IMERG
- Stream Flow: USGS River Gauges
- Level 3 Ocean Color: MODIS/AQUA
- Landsat 9 (task)
- Seahawk 1 (task)
- Seahawk 2 (simulated)



SeaHawk observed algal slicks off Qingdao, China, June 2021, NASA Earth Observatory

Landsat 8/9

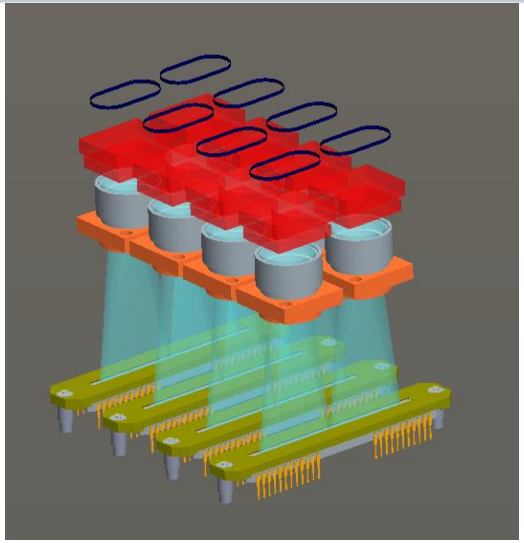
- Landsat 9 largely replicates its predecessor Landsat 8. Our analysis period is from July 2018, Landsat is allotted orbit-state corresponding its state in July 2019.
- OLI, TIRS instruments considered.
  - Pushbroom sensors with 185 km (15 deg) swath.
  - A simple optical model is used to evaluate the data-metrics such as SNR and NEDT.
    - Purpose is to give a *relative* sense of data-quality which can be used by the planner to prioritize higher-quality of observations.
- Considerations during the coverage-calculations.
  - Pushbroom sensors have very narrow AT-FOV. We define a scene-FOV to replace it. And later 'correct' it.
- Tasking:
  - **Tasking is to switch ON** when passing over region-of-interest, at the time-of-interest.



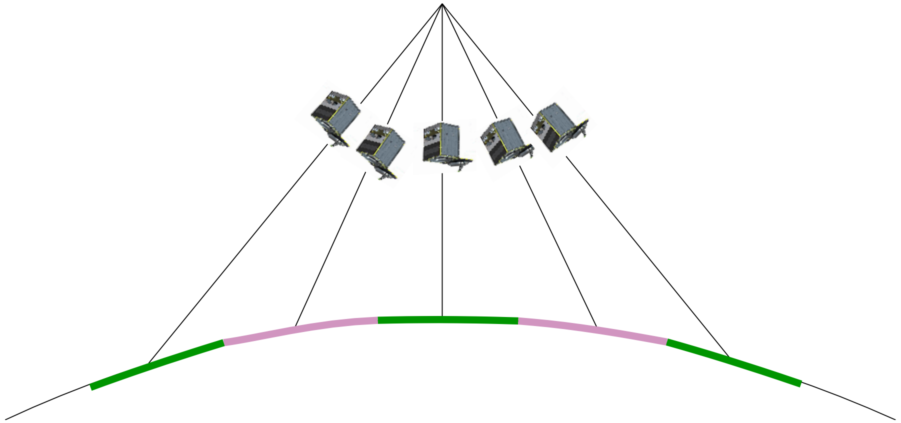
https://landsat.gsfc.nasa.gov/landsat-9/instruments

SeaHawk/HawkEye

- Two SeaHawk satellites are considered.
- SeaHawk1 was launched Dec 2018. Since our analysis period is from July 2018, SeaHawk1 is allotted orbit-state corresponding its state in July 2019.
- **SeaHawk2 is hypothetical** and is placed to form a Walker constellation in the same plane with SeaHawk1, i.e. 180 deg TA offset (provides more revisit). (Similar to the Sentinel-1A,1B orbits.)
- HawkEye instrument
  - Pushbroom, 22.6 deg FOV, 8 spectral-bands
  - Parameters of the model are based on the presentations available in the UNCW website.
    - Quantity such as SNR is to be used to get the relative sense of image quality.
- Tasking:
  - Maneuvering of the satellite to discrete-set of roll-angles is considered (5 in total).
    - 0 deg, +/- 22.6 deg, +/-45.2 deg
    - Chosen so that the there are no gaps between adjacent swaths
    - A finer set (with overlapping swaths) could be framed but at a computational-expense

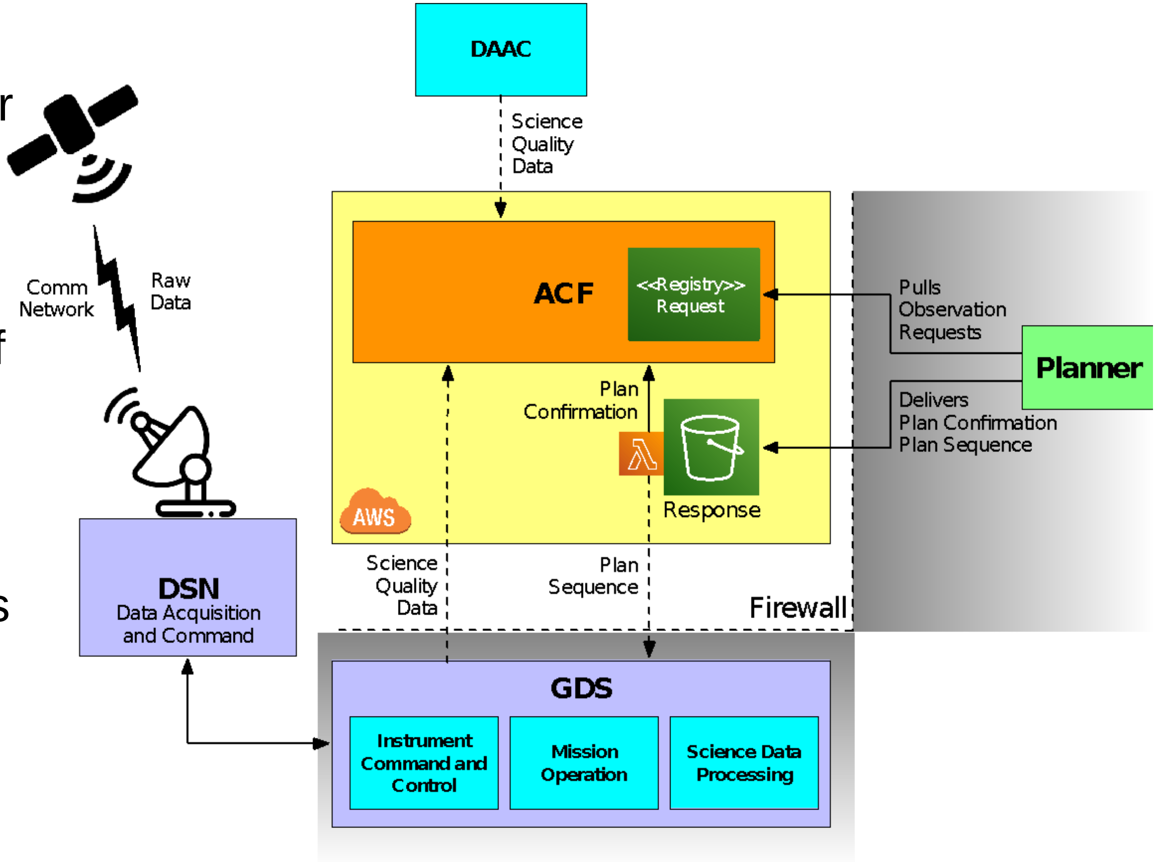


https://uncw.edu/socon/seahawk.html

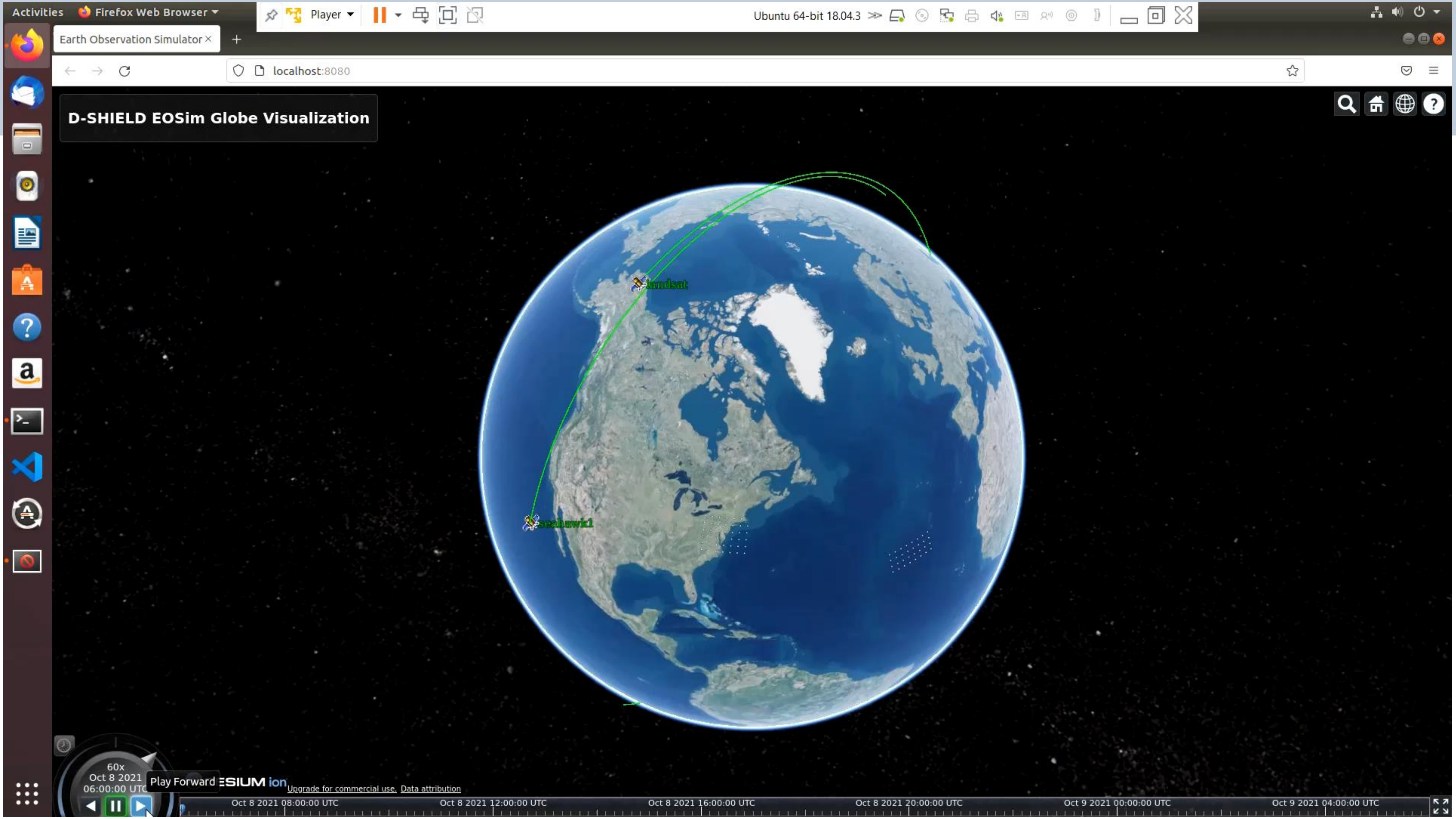


Messenger Schema

- Planner features:
  - The ‘planner’ simply selects the pointing-option over the plan-duration which results in maximum coverage.
  - The planner disregards night-time observations by looking at the computed SNR. (A simple example of how planner could consider data-metrics in its decision process.)
- The reported plan includes the area-observed in the form of discrete locations which represent sample-points of the area.

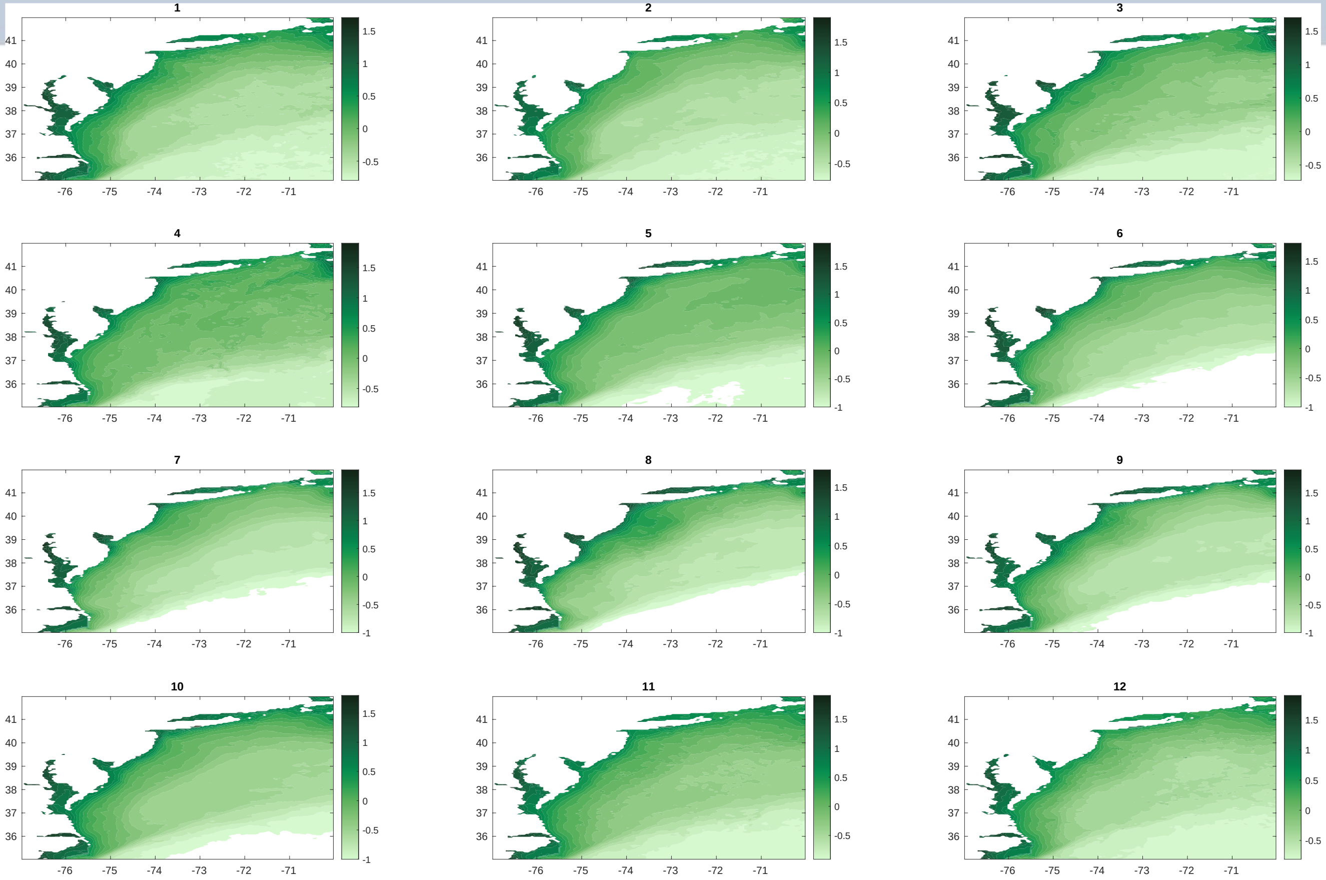


Architecture diagram from *“2021-10-24 Ocean Carbon Cycle NOS Message Schema"*

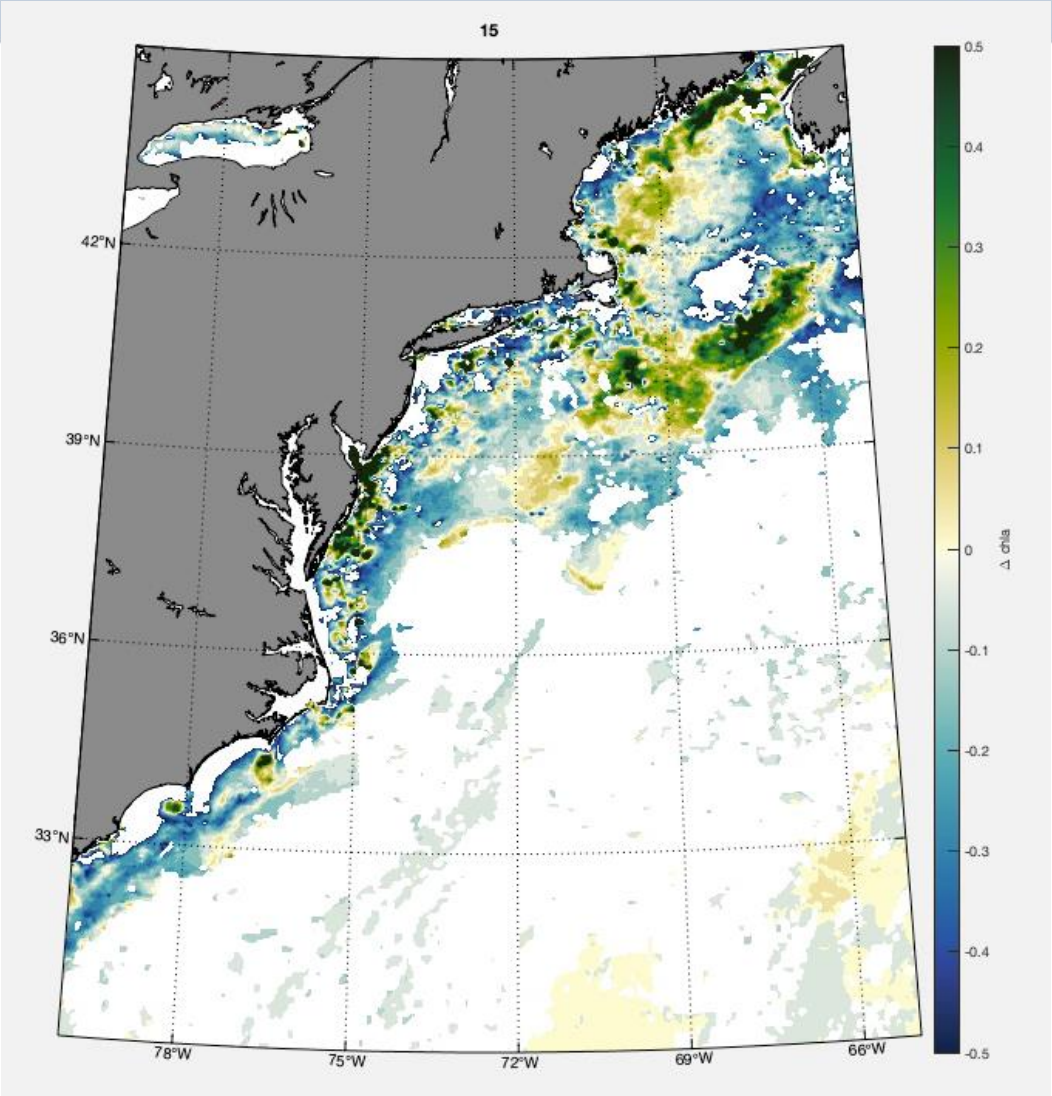


Activities
Firefox Web Browser
Player
Ubuntu 64-bit 18.04.3
Earth Observation Simulator
localhost:8080
D-SHIELD EOSim Globe Visualization
landsat
seahawk1
60x
Oct 8 2021
06:00:00 UTC
Play Forward
Upgrade for commercial use.
Data attribution
Oct 8 2021 08:00:00 UTC
Oct 8 2021 12:00:00 UTC
Oct 8 2021 16:00:00 UTC
Oct 8 2021 20:00:00 UTC
Oct 9 2021 00:00:00 UTC
Oct 9 2021 04:00:00 UTC

Baseline: MODIS-Aqua Level 3 Ocean Color Products



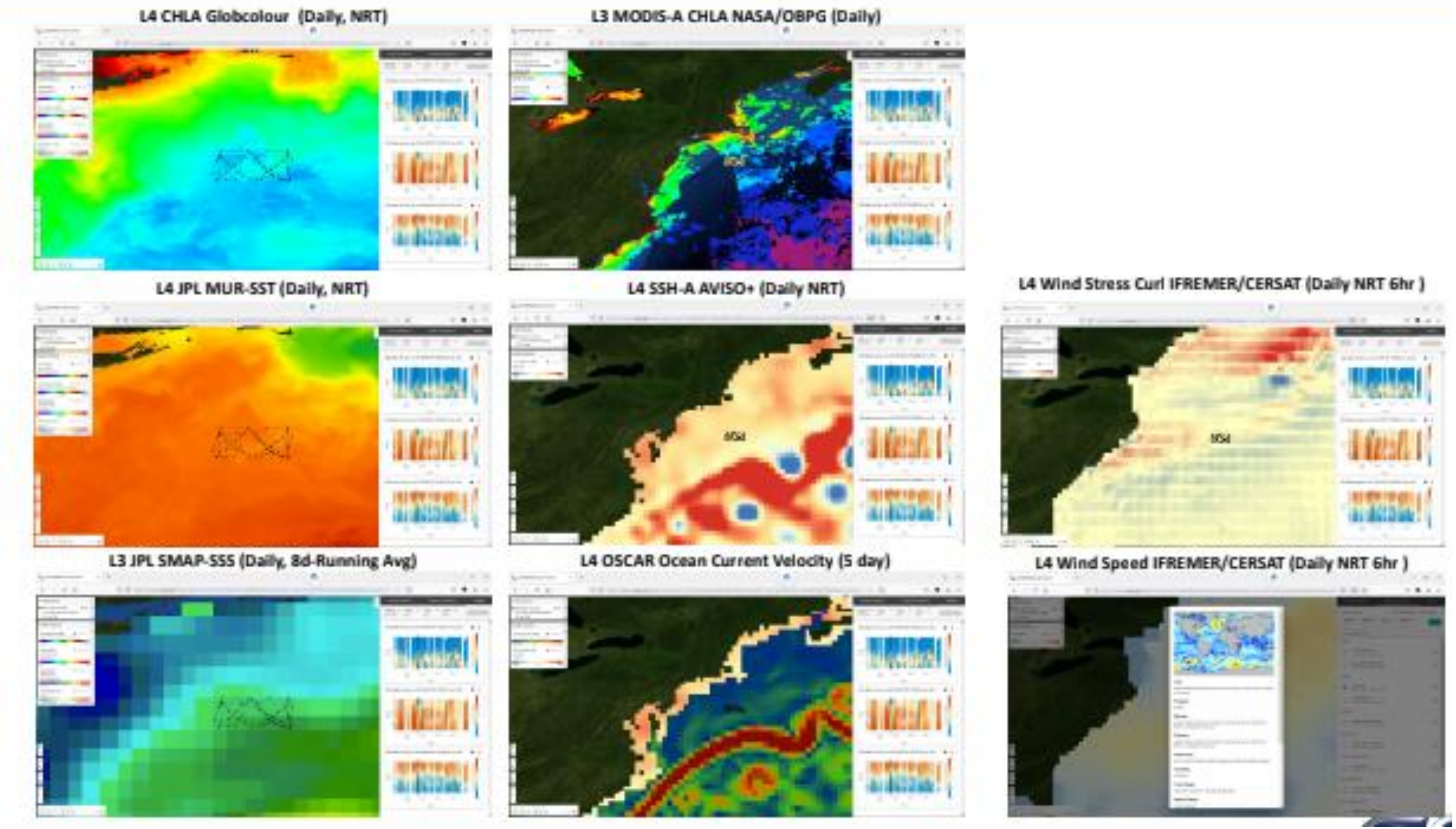
Climatological Values for Rrs and Chl a



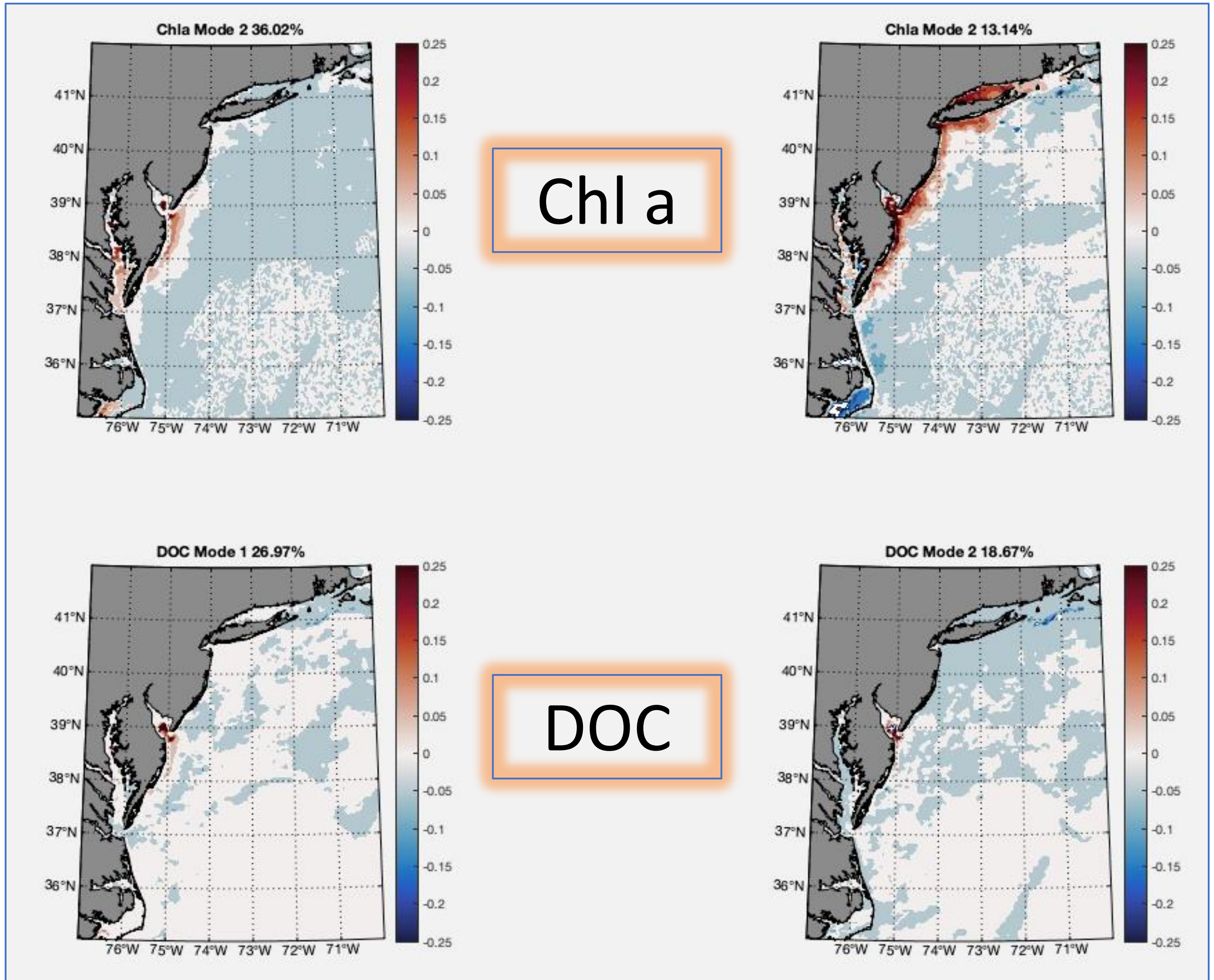
Also have climatological values for Rrs and derived products to have 1st order organic carbon cycle information

15-day Δ chl *a* for 2018

Integration with COVERAGE Data Viewer



First Steps Toward Identifying Regions of High Variance for Dynamic Tasking



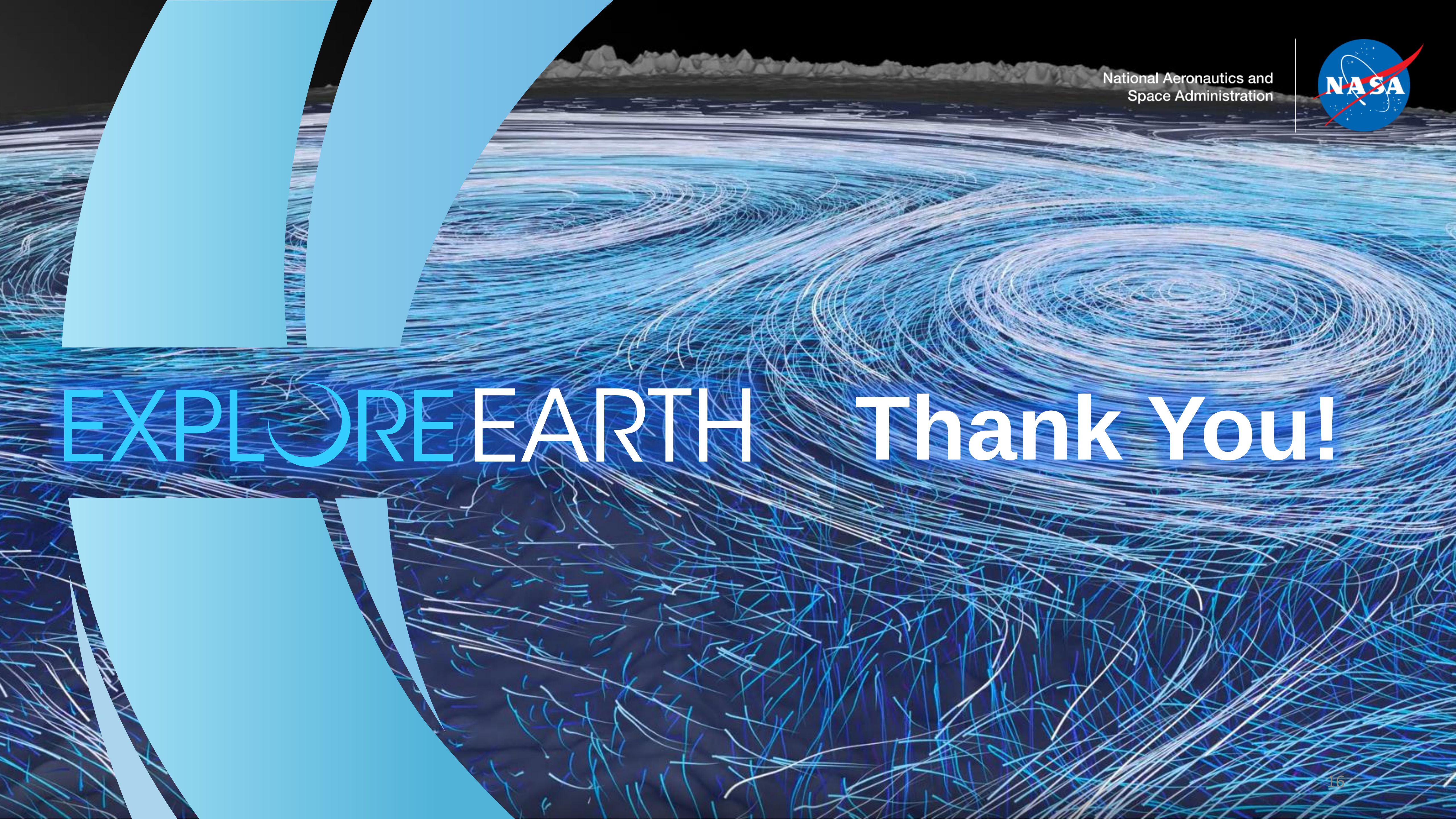
- Can use previous weeks observations to set up locations for future focused observations
- Need to incorporate real time ancillary information
- Use model predictions to refine and prioritize tasking

What can be done now?

Detect Transient Aquatic Events	Identify, Collect, and Aggregate Event-Relevant Data
• Via regionally-defined triggers for onset, lag, and dissipation • Ingest and process trigger datasets automatically	• Identify capable satellites • Identify overpass and data collection opportunities • Ingest and aggregate satellite data for scientific use

What's Next for NOS Oceans

Globally Connecting Land-Ocean Carbon	Closing the gap: High-spatial and High-temporal
• Integrate ML/AI techniques to define regional event triggers • Integrate additional data levels • An event-driven what-if scenario capability	• Scheduled, targeted and directed event observations • Dynamic deployment of suborbital assets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Thank You!