Earth Station Lab

AN EDUCATIONAL COMPUTER APPLICATION USING SATELLITE REMOTE SENSING DATA

BY STEVE MILLS

Introducing myself

- **EDUCATION**
  - 1988, California State Univ. Los Angeles, MS, Optical Physics
  - 1976, UCLA, BS, Physics; 1972, Santa Monica High School; 1969, Malibu Park Junior High.
- **EXPERIENCE (beyond Polymath Geo)**
  - ***L3Harris Space Systems****, Senior Scientist, Systems, May 2017 to Present*: Direct the design, integration and testing of space-based imaging systems under contracts with for NASA, NOAA and DOD.
  - ***Northrop Grumman Space Technology / TRW:*** VIIRS Radiometric Cal/Val & Algorithm Lead, Nov. 2011 to Sep. 2012; Optical Sensor Models & Analysis Section Head, Dec. 2010 to Oct. 2011; VIIRS Radiometric Modeling & Algorithm Lead, Feb. 2000 to Nov. 2010 **;** Senior Member of Technical Staff, May 1997 to Jan. 2000—Early development on JWST, phased array lasers and space laser com.
- **RECENT PUBLICATIONS (First Authorship)**
  - "VIIRS Day/Night Band—Destriping Imagery with Very Large Dynamic Range," *J. Imaging* **2016**.
  - "The Ground Track Oblique Cassini Projection used for producing VIIRS mapped imagery," *Proc. of SPIE* **2014**, 9218, 921809-1.
  - "VIIRS Day-Night Band (DNB) calibration methods for improved uniformity", *Proc. of SPIE* **2014**, 9218, 921809-1.
  - "VIIRS Day/Night Band (DNB) Stray Light Characterization and Correction." *Proc. of SPIE,* **2013,** 8866, 8866-63.

Introducing Polymath Geo

- Polymath Geo is a private, educational software start-up
  - A for-profit California corporation established in 2019
- Why for-profit?
  - There are many non-profits working to support geographic science education with the help of many generous supportersd
  - However, we see the need for some private investment to develop sustainable educational software, similar to the textbook industry
- Mission statement: We develop state-of-the-art, sustainable educational products that incorporate geographical information systems.
- "Polymath" defined: a person of wide-ranging knowledge or learning.
  - Geographic science covers a broad range of educational topics
    - Earth science: geography, meteorology, climatology, geology, biological sciences, oceanography
    - Social science: History, anthropology archeology, ethic and race studies

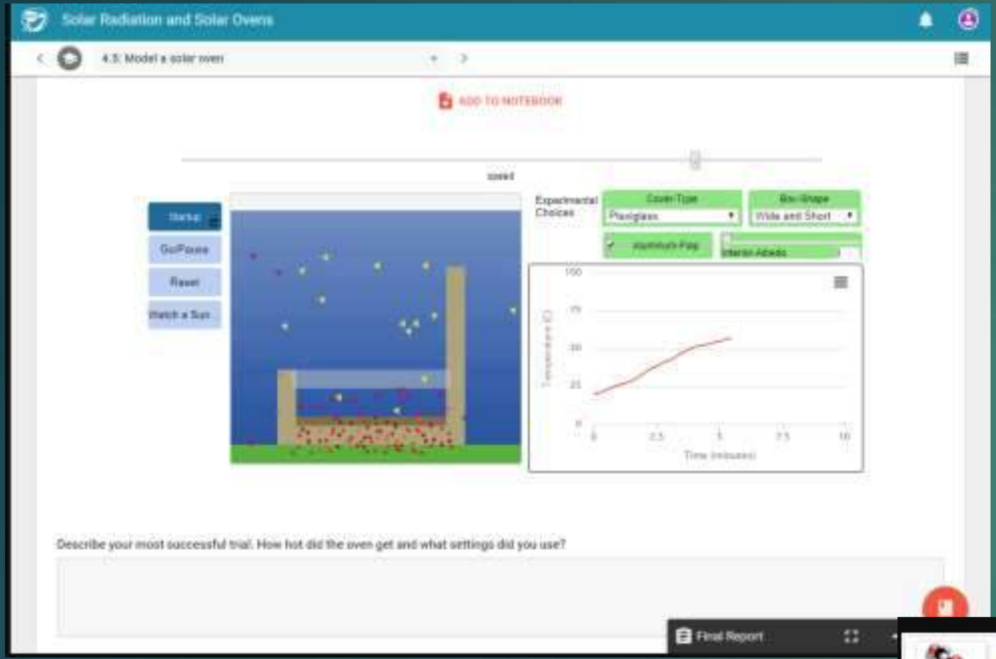
Virtual learning Environment (VLE) :WISE (Web-based inquiry science environment)

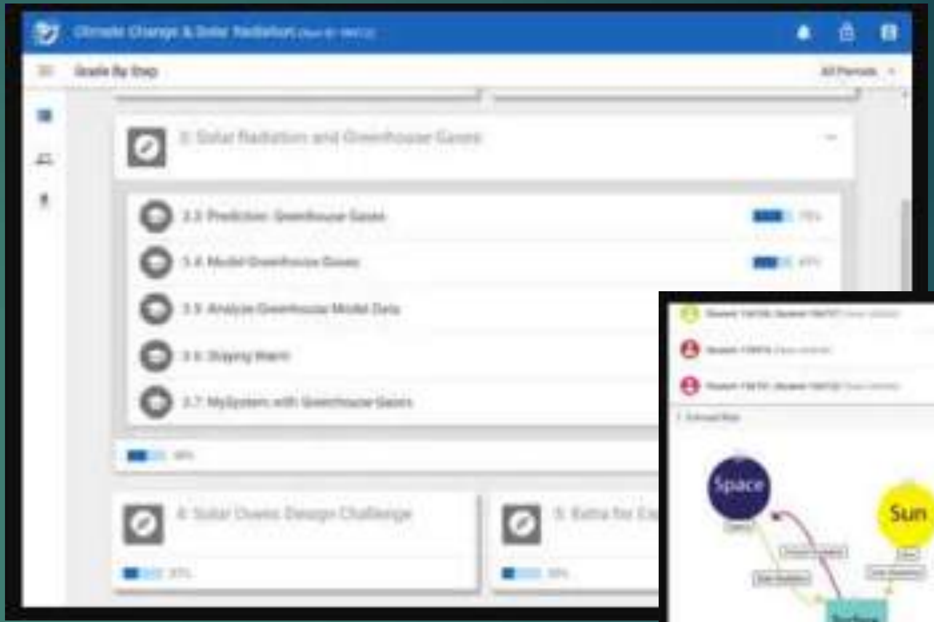
- A powerful online platform for designing, developing, and implementing science inquiry units
  - Since 1997, WISE has served a growing community
  - more than 20,000 teachers, researchers, and curriculum designers, over 200,000 K-12 students around the world.
- Inquiry-Based Learning
  - WISE engages students in the methods of real scientists and engineers.
  - takes a multidisciplinary approach so that students learn inquiry through activities that emphasize essential skills in reading, writing, and multimedia literacy.
  - Many of our units are also project-based and feature hands-on design challenges.
  - With WISE inquiry units, students not only learn skills that prepare them to be successful in STEM. They also learn skills necessary to be responsible, critical thinking citizens.
- Powerful Learning Technologies
  - WISE provides a simple user interface, cognitive hints, embedded assessments, and online discussions, as well as tools for drawing, annotation, concept mapping, diagramming, and graphing.
  - Students conduct investigations using interactive simulations and models. A notebook tool helps students collect ideas and organize evidence into research and design reports.
  - WISE units promote self-monitoring through collaborative reflection activities as well as automated, personalized guidance and adaptive instruction
- Standards-Aligned Curricula
  - growing collection of curriculum units
  - address key conceptual difficulties students encounter in science.
  - Units are carefully crafted to supplement teachers' core curricular scope and sequence and are iteratively refined through classroom-based research.
  - WISE units support the Next Generation Science Standards (NGSS), encourage 3-dimensional learning, and can be adapted to address local standards.

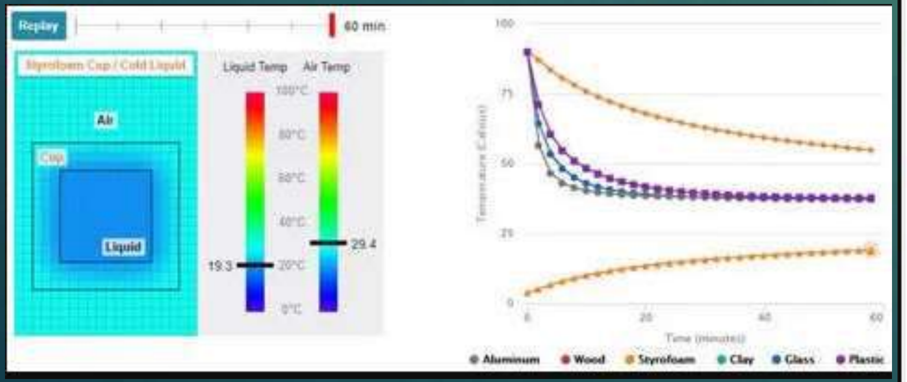
WISE Teacher, Student & Developer Tools

- WISE Students Collaborate to:
  - Pose relevant questions and make predictions
  - Experiment with computational models
  - Evaluate and distinguish discrepant information
  - Construct explanations through reflection and discussion
  - Design and build evidence-based solution
- Teacher Tools
  - Real-time progress monitor
  - Grade and give feedback + sample scoring rubrics
  - Automatically scored assessment items
- Teacher Tools (cont.)
  - Pause student screens
  - Share and collaborate with colleagues
- Authoring environment
  - supports customization
  - creation of new units
- Programmers & Developers
  - Developed at Univ. of Calif, Berkeley
  - open source so other instances allowed with changes for that instance
  - subsists on generous support from the National Science Foundation, which means it's available to anyone with an internet connection.
  - Driven by an active community of developers
  - https://wise.berkeley.edu

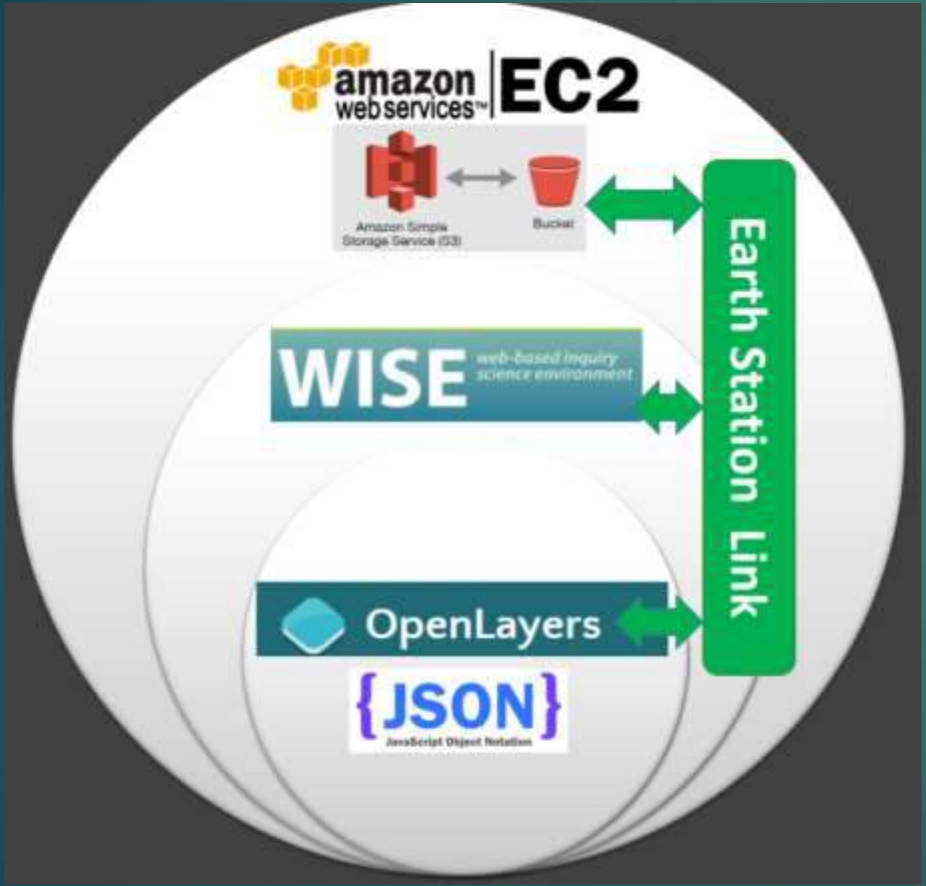
Screen shots from WISE

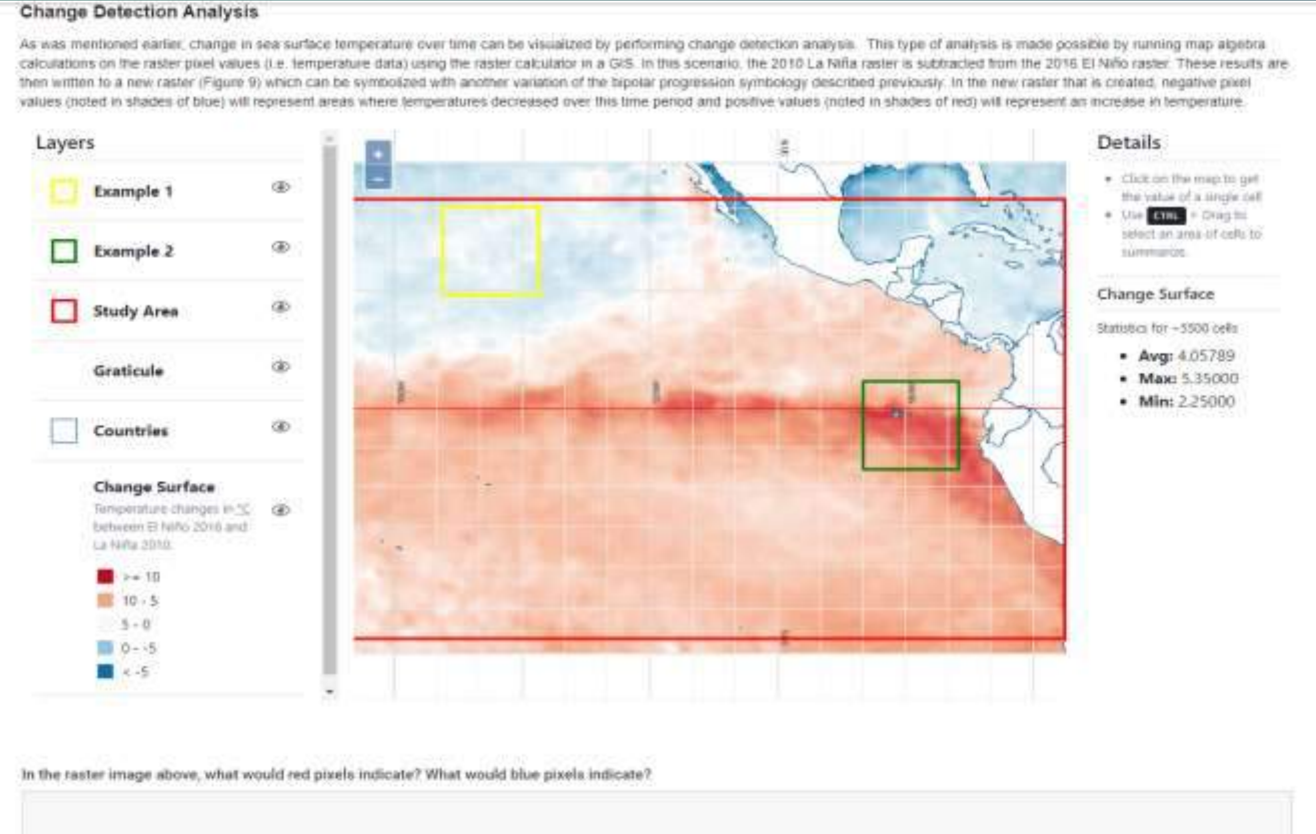






What is Earth Station Lab?





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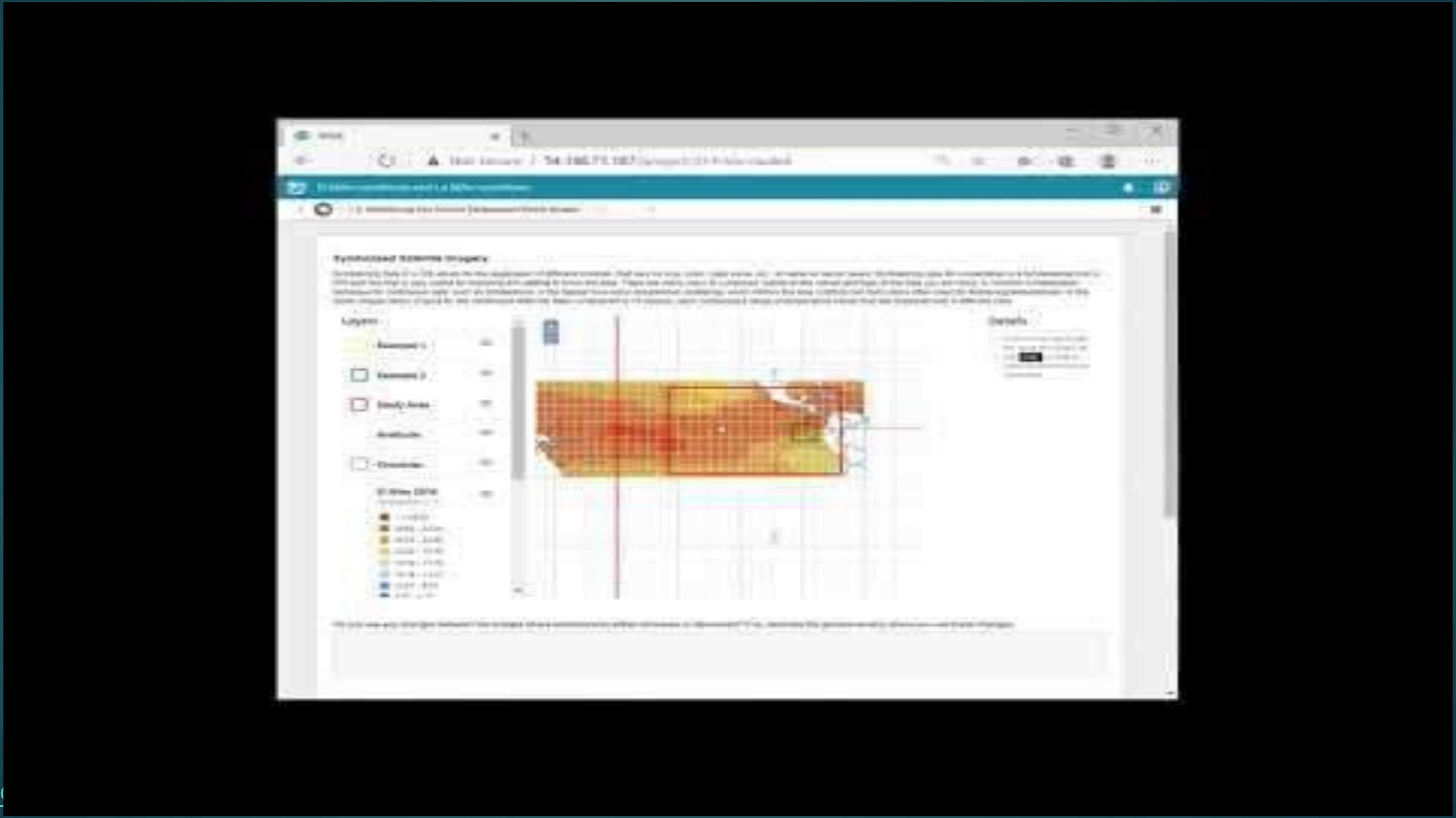
Earth Station Lab Video



https://y

Earth Station Lab (ESLab), first program developed for Polymath Geo

- **2019** - We contracted with the Center for Geospatial Science and Technology (CGST) at CSUN to develop a prototype
  - Uses WISE as the VLE
  - science lesson units incorporating the interactive use of satellite remote sensing data.
  - application is flexible enough to handle the great diversity of geographic data that is available but it is also simple enough for students to use in grades 9 to 13.
- **2020 -** CGST team further developed ESLab, producing a high school level lesson unit on El Niño-Southern Oscillation (ENSO).
  - Limited functionality,usability, and efficacy study with CSUN students
  - results of the study were presented at the 2021 American Meteorological Society (AMS) Conference
- **2021 –** Contract CGST to develop Earth Station Link (ESLink),
  - Simple to use data conduit application that connects with big satellite databases of NASA & NOAA,
  - converts this data into slippy maps compatible with OpenLayers.
  - designed to easily facilitate the transfer of data from government data portals to the lesson units in WISE. Further, it allows teachers to download local and timely customized data for their lesson unit

Earth Station Lab architecture

- The first layer is Amazon Web Services® (AWS)
  - Platform-as-a-Service (PaaS) product that allows for a cloud-based, pay-as-you go approach.
  - the system can be reconfigured as requirements grow. We have tested ESLab and determined that up to 50 instances of ESLab can be supported in the current configuration.
  - as the customer base grows, PG can reconfigure the instance to support thousands of users simultaneously to match the customer demand
  - it does not tax a school’s internet. This is also important because students often do not have devices with the capacity to support high bandwidth applications.
- The second layer is WISE, described on previous charts.
  - We have enhanced the authoring system in the ESLab instance to allow GIS-related functionality.

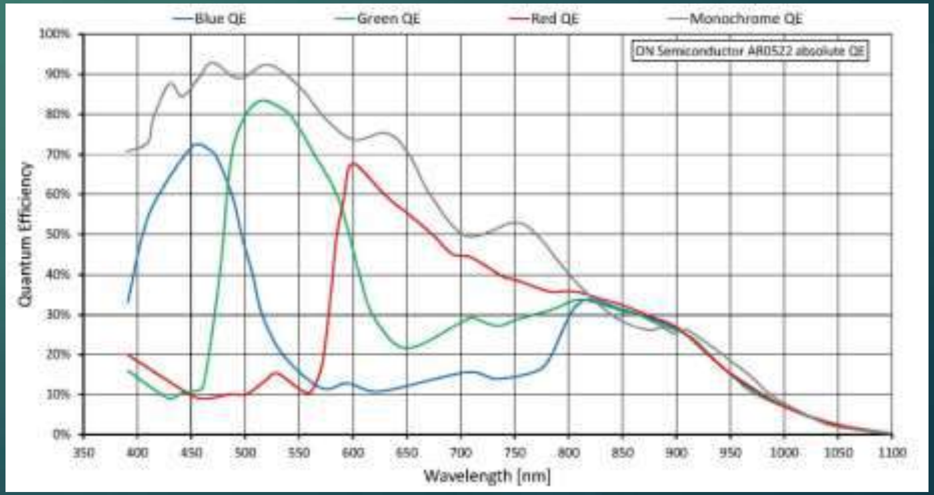
Earth Station Lab architecture

- The third layer OpenLayers,
  - an open-source JavaScript library for displaying map data in web browsers.
  - Interface for using rich web-based geographic applications in modern web maps
  - uses “slippy maps” that let the user zoom and pan around (Google Maps is another example).
  - Embedding OpenLayers within WISE gives ESLab the capability to incorporate interactive GIS within the lessons and makes ESLab unique.

ESLab Future Development: Ground Validation

PocketLab Weather

Near Infrared WebCam

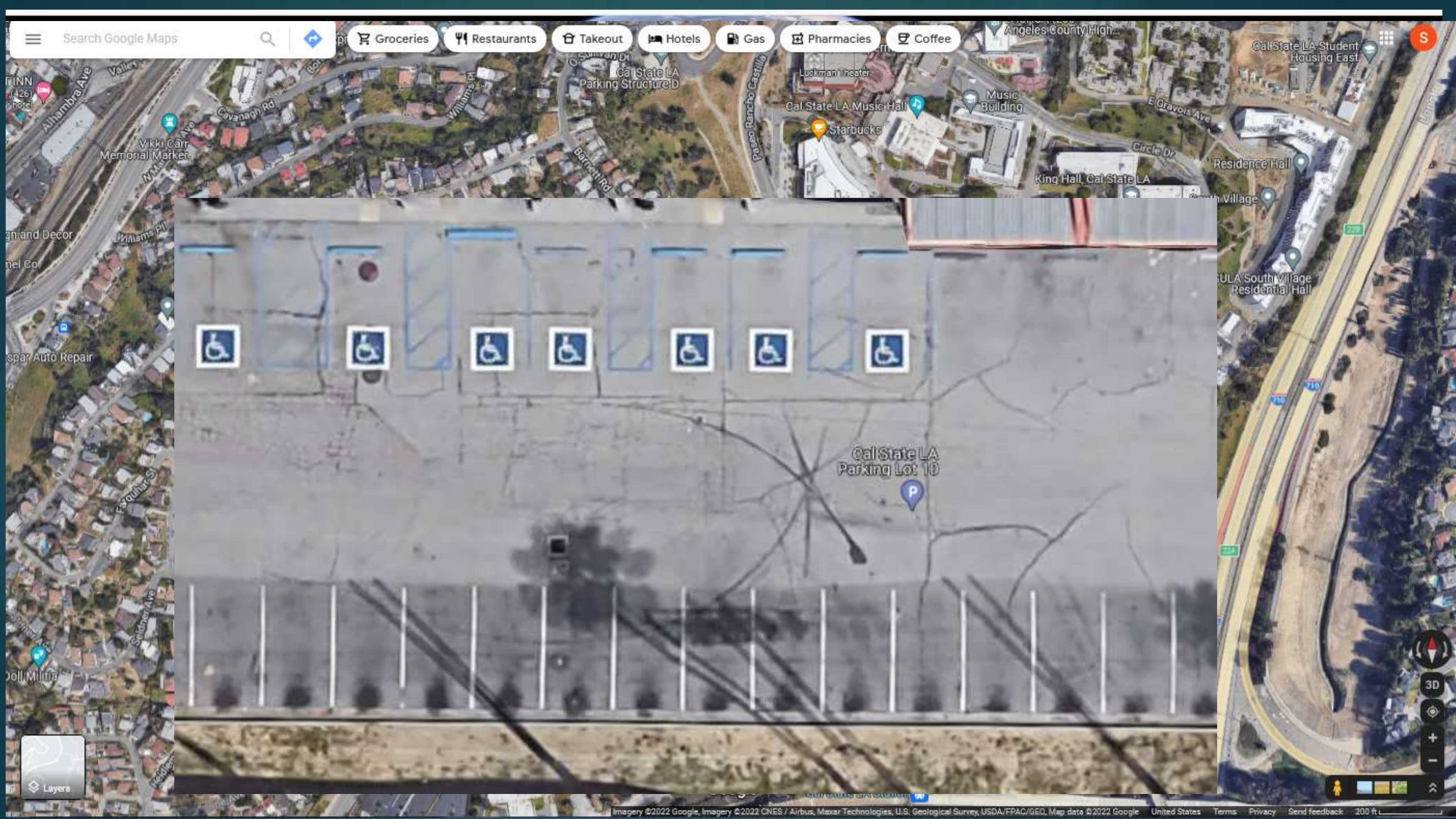


Earth Station Lab, acknowledgements

- California Stat Univ. Northridge, Center for Geospatial Science and Technology (CGST)
  - Vladimir Jimenez, MS Geographic Information Systems, Web Developer
  - Regan Mass, PhD, Associate Professor of Geography
  - Sanchayeeta Adhikari, PhD, Associate Professor of Geography
  - Danielle Bram & Ben Chou, Project Managers
- Educational Advisors
  - Dominique Evans-Bye, MA GIS, Science Educator, Clark Magnet High School , Glendale Unified
  - John Trunkwalter, MA, Geography, Retired aerospace project manager, part-time teacher

Earth observation is a “big data” problem

- Area of earth surface=510 million square km (5.1×10^8 km^2)
  - Landsat, at 30 m resolution, that is 5.7×10^{11} data elements or pixels.
- NOAA maintains the National Center for Environmental Information (NCEI) that includes 20 million gigabytes (2.0×10^{16} bytes)of Earth observation data
  - available through a host of internet portals.
  - This data includes measurements of the atmosphere, land surface and oceans
- NASA maintains 13 Distributed Active Archive Centers (DAAC) and provides links to over 60 internet data portals related to Earth science.
- Rapidly emerging field in computer science is “big data.”
  - concerned with extracting information from datasets that are too large or complex to be processed using traditional techniques.
  - Example of big-data company: Google



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NASA data level definitions

Data Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed. (In most cases, NASA's EOS Data and Operations System [EDOS] provides these data to the DAACs as production data sets for processing by the Science Data Processing Segment [SDPS] or by one of the SIPS to produce higher-level products.)
Level 1A	Level 1A (L1A) data are reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris) computed and appended but not applied to L0 data.
Level 1B	L1B data are L1A data that have been processed to sensor units (not all instruments have L1B source data).
Level 1C	L1C data are L1B data that include new variables to describe the spectra. These variables allow the user to identify which L1C channels have been copied directly from the L1B and which have been synthesized from L1B and why.
Level 2	Derived geophysical variables at the same resolution and location as L1 source data.
Level 2A	L2A data contains information derived from the geolocated sensor data, such as ground elevation, highest and lowest surface return elevations, energy quantile heights ("relative height" metrics), and other waveform-derived metrics describing the intercepted surface.
Level 2B	L2B data are L2A data that have been processed to sensor units (not all instruments will have a L2B equivalent).
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
Level 3A	L3A data are generally periodic summaries (weekly, ten-day, monthly) of L2 products.
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

Raw data

Raw, annotated

Calibrated

Corrected

Geolocated

Add elevation

Calib. & located

Calib. & regridded

Calib. & regridded

Environmental

- Every process from lowest to highest level involve algorithms on large numbers of data elements
- Therefore, each process offers an educational opportunity to teach massive data processing

Night time sea ice motion
East Central Greenland
Animation: 12/24 – 12/28 2012

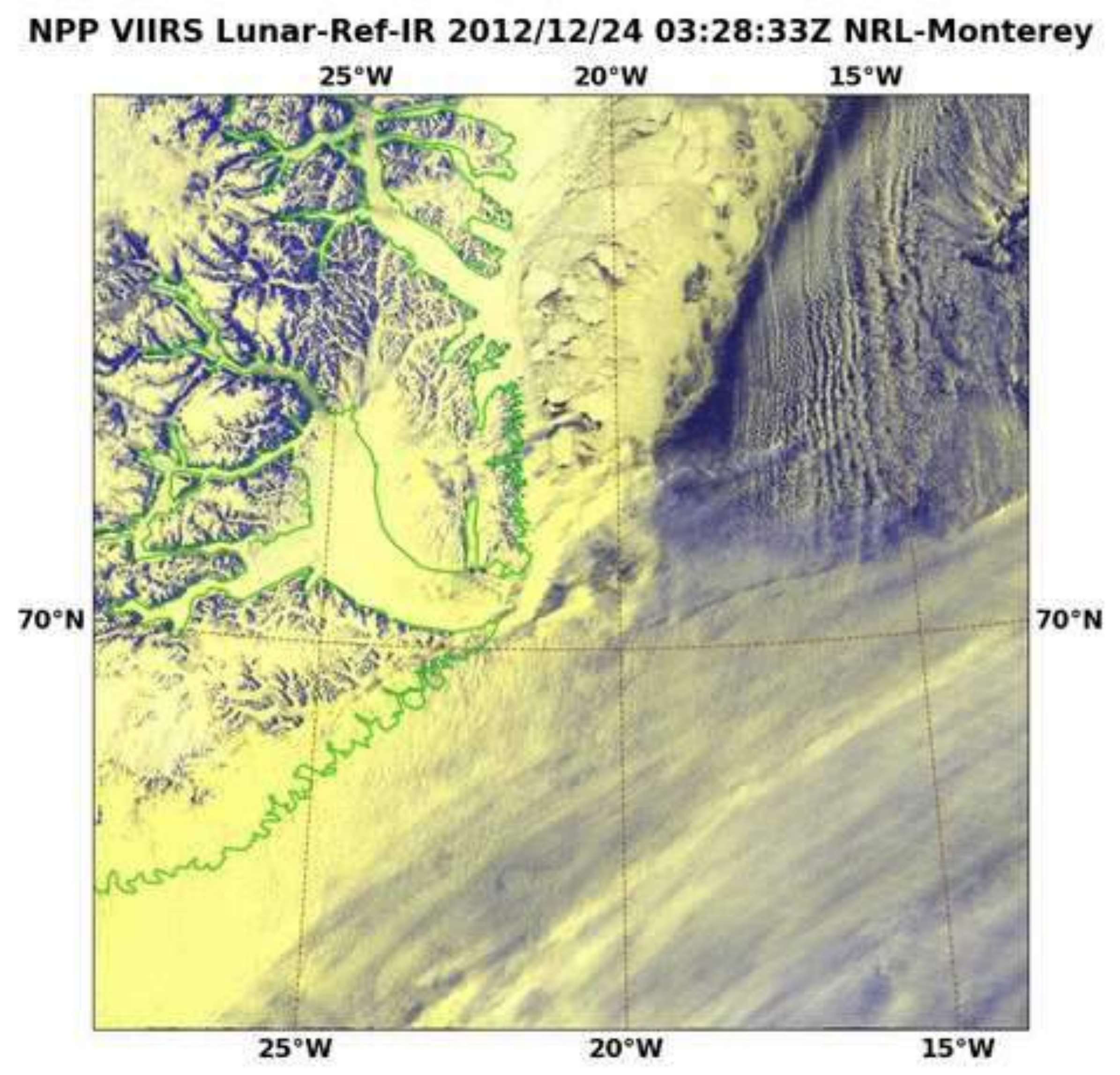
Multi-channel DNB Reflectances + IR

Sea ice motion using a single long wave IR channel is difficult for multiple reasons:

a) Discrimination between sea ice and thin clouds is harder due to their temperatures being very similar, DNB can see through thin polar clouds to the sea ice below more readily,
b) The color or b/w scale used to enhance the IR is very dynamic and needs to change from scene to scene, thus the ability to interpret and see sea ice is problematic unless tuned for a given scene which implies human interaction that is expensive to have available.
c) A standard DNB reflectance + IR product can be used for sea ice mapping while IR is problematic.

Acknowledgements:
Naval Research Laboratory, Marine Meteorology Division, Monterey, CA
Jeremy Solbrig, Steve Miller[2], Tom Lee, Arunas Kuciauskas, Mindy Surratt, Kim Richardson, Jeff Hawkins

[2]Cooperative Institute for Research of the Atmosphere (CIRA, Ft. Collins, CO)



Night time sea ice motion

East Central Greenland

Animation: 12/24 – 12/28 2012

Single channel IR

Sea ice motion using a single long wave IR channel is difficult for multiple reasons:

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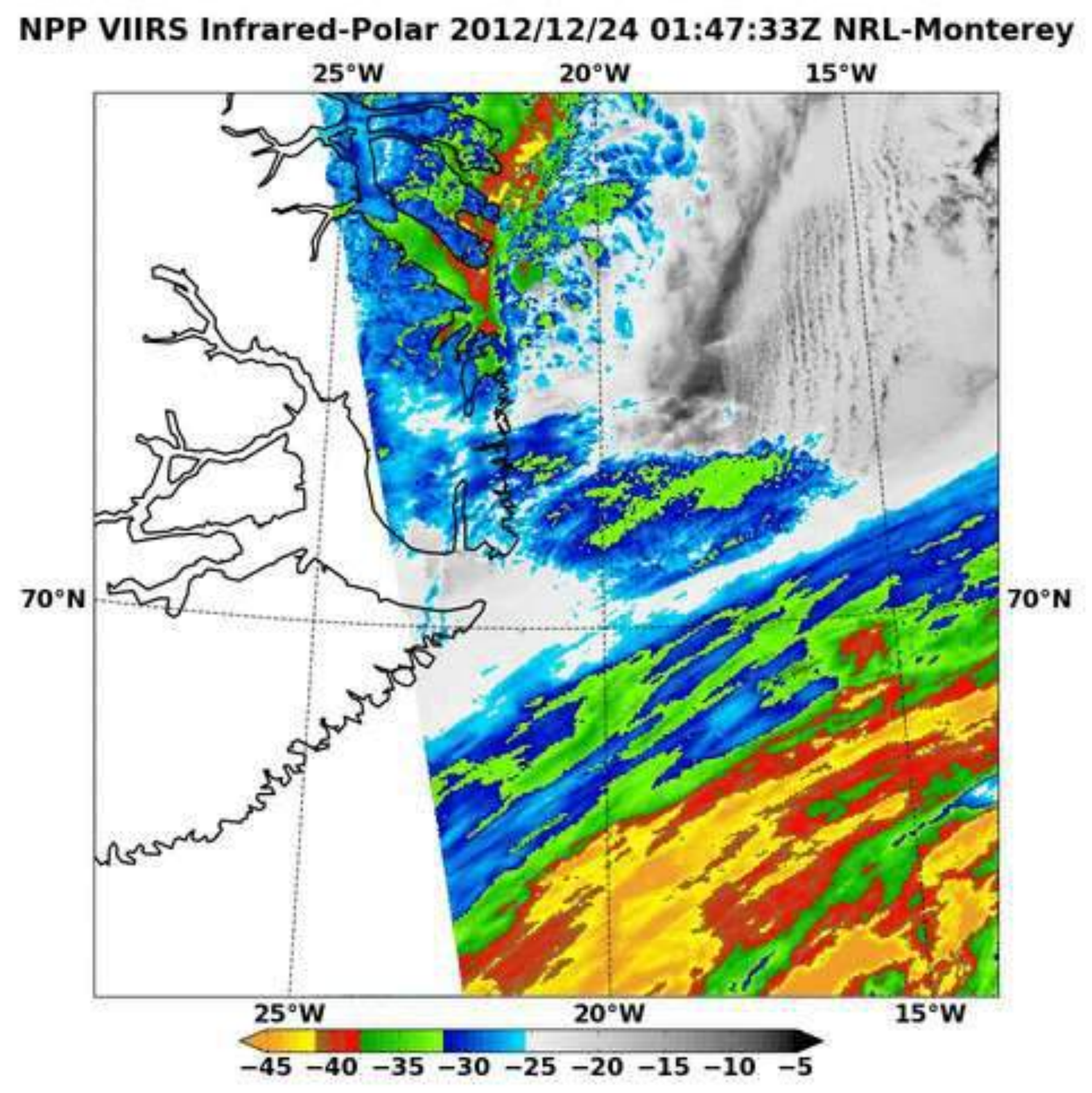
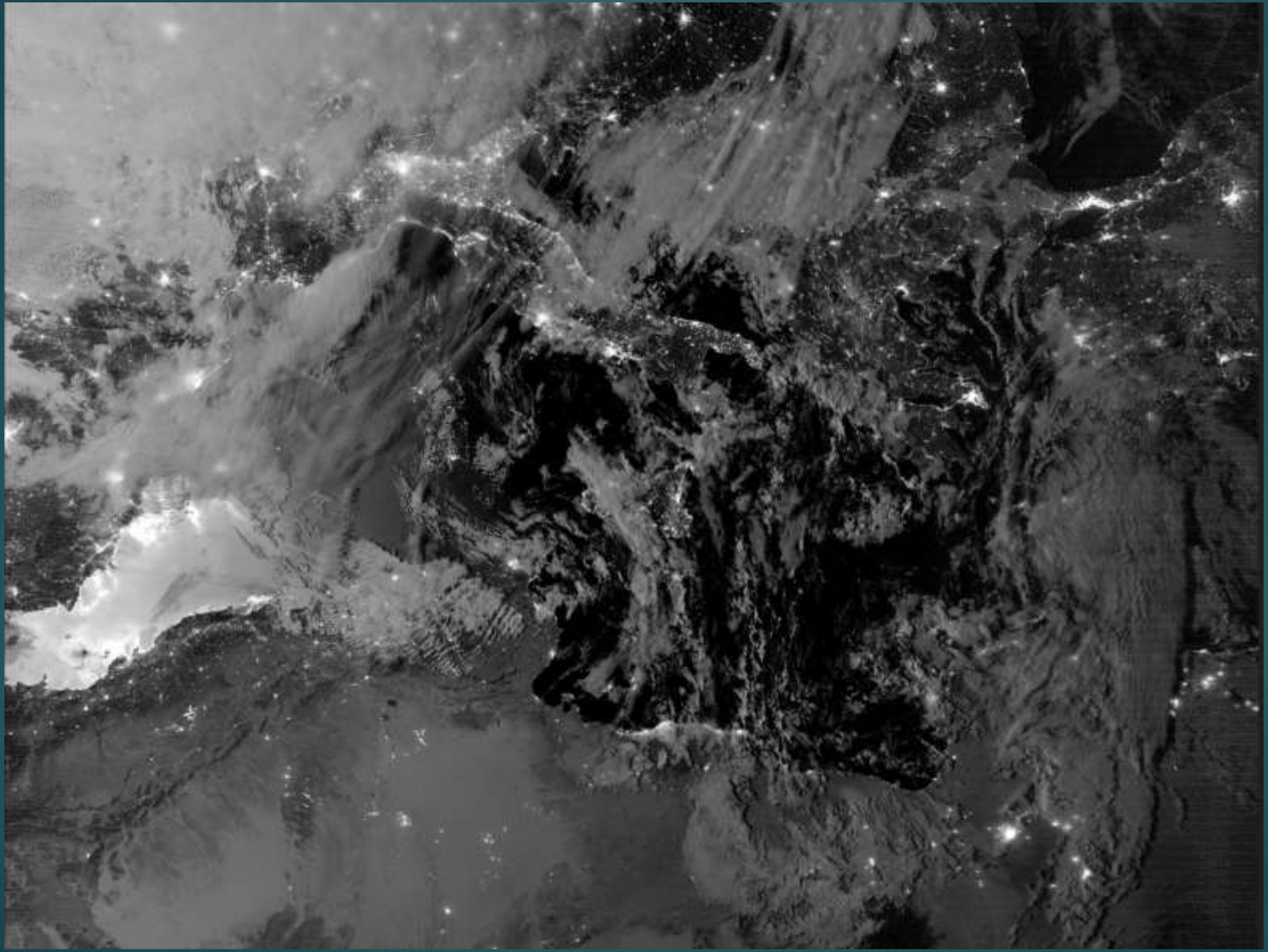


Mediterranean Sea by moonlight, VIIRS day/Night



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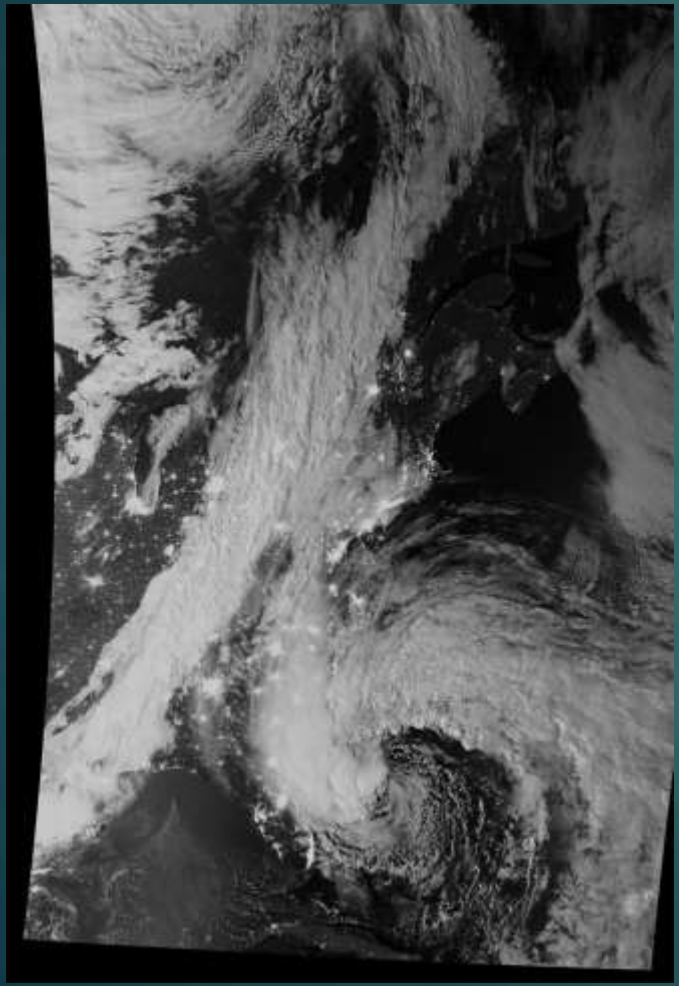
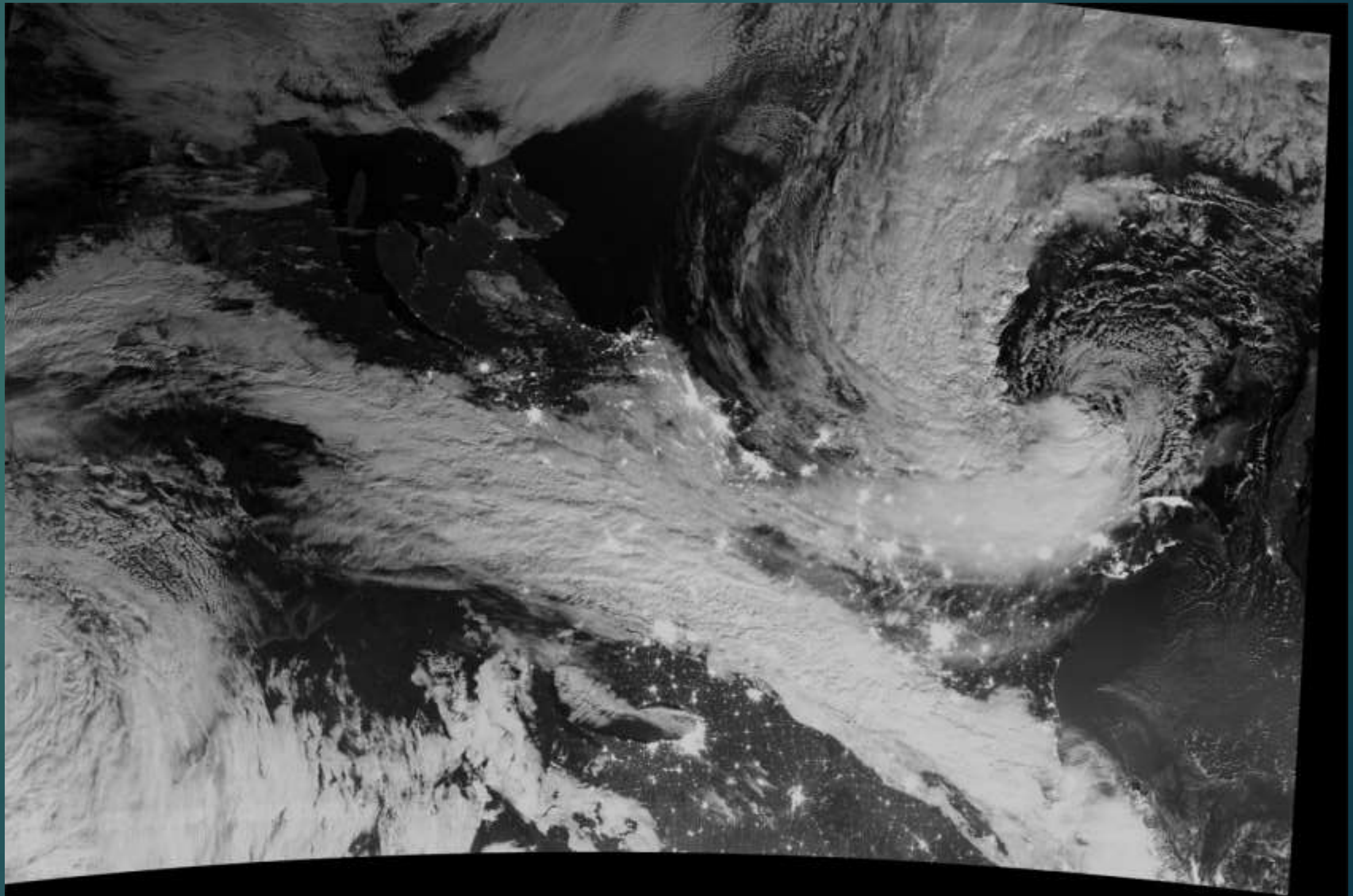
Hurricane Sandy, VIIRS Day/Night band

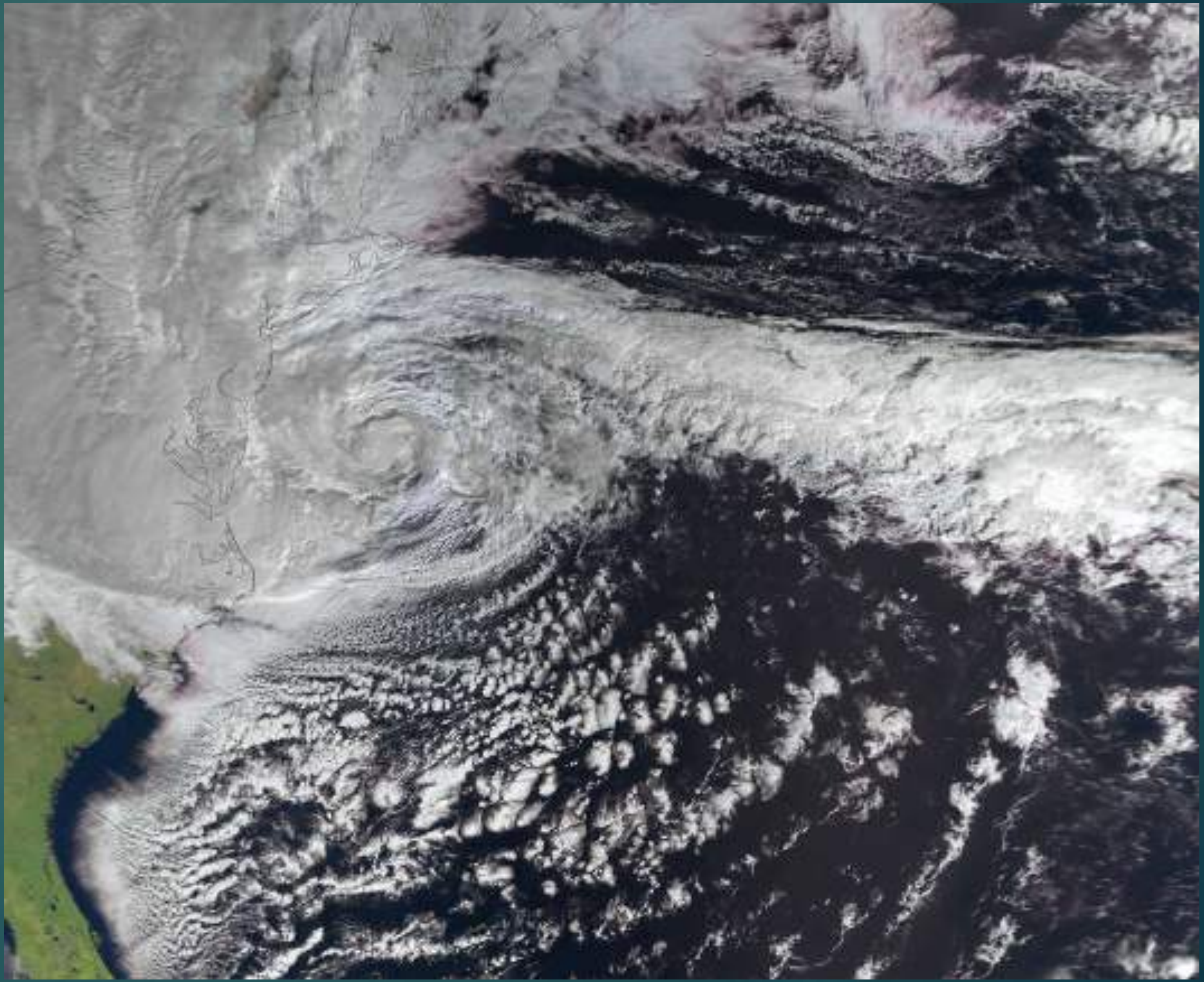
October 25, 2012



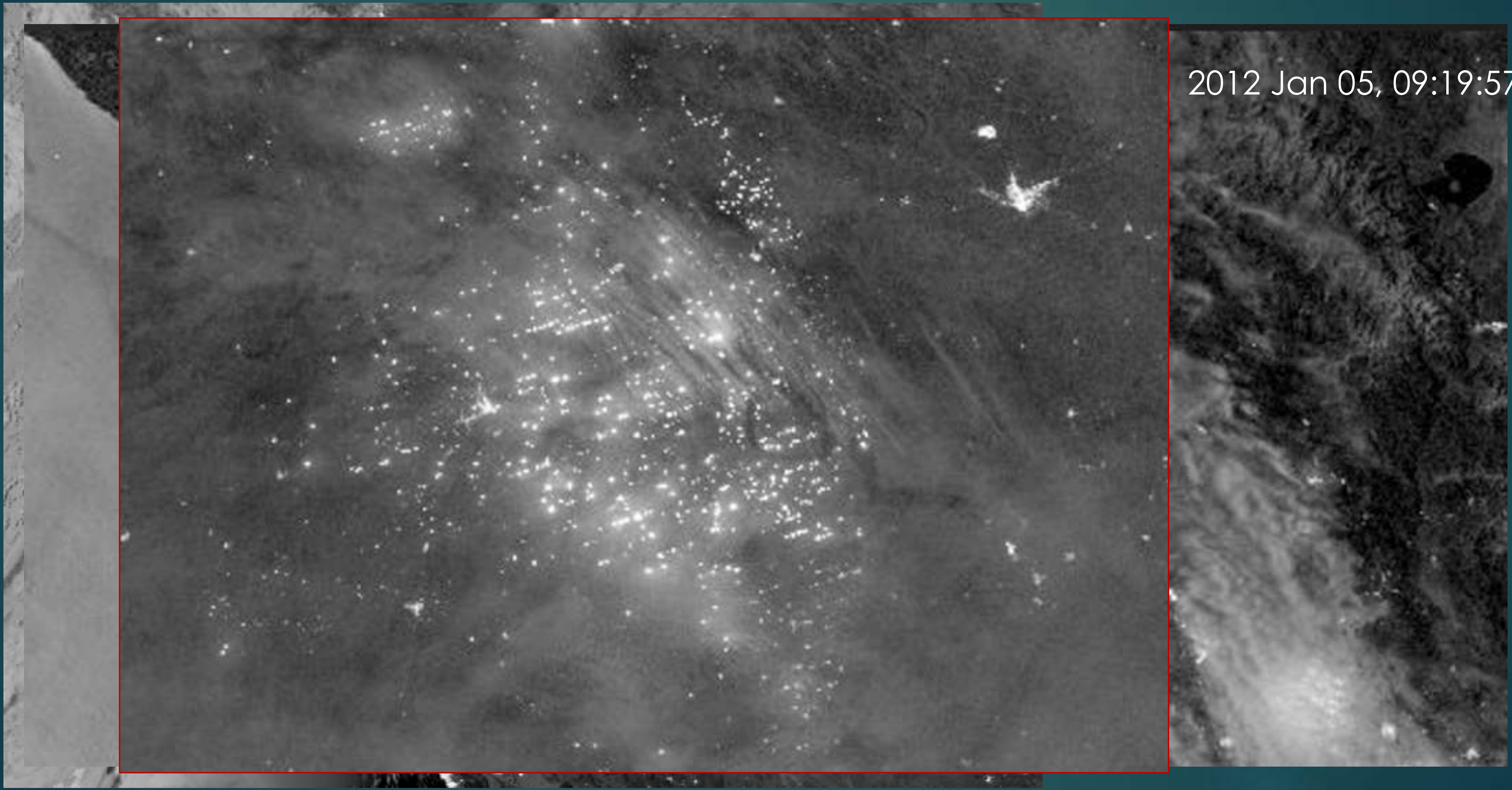


Hurricane Sandy, VIIRS imagery bands

October 26, 2012



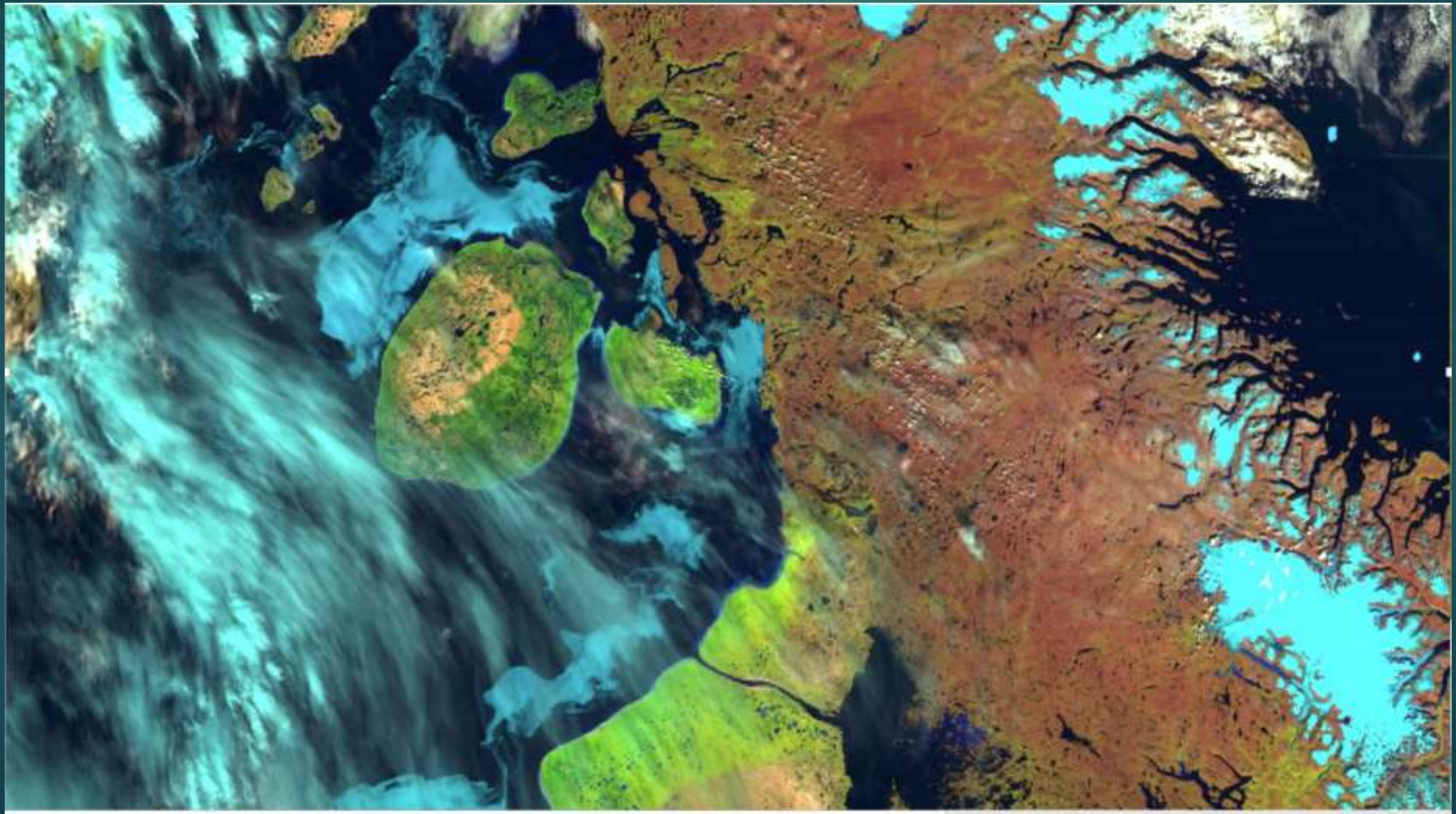
Western USA, DNB nighttime image



2012 Jan 05, 09:19:57 UTC

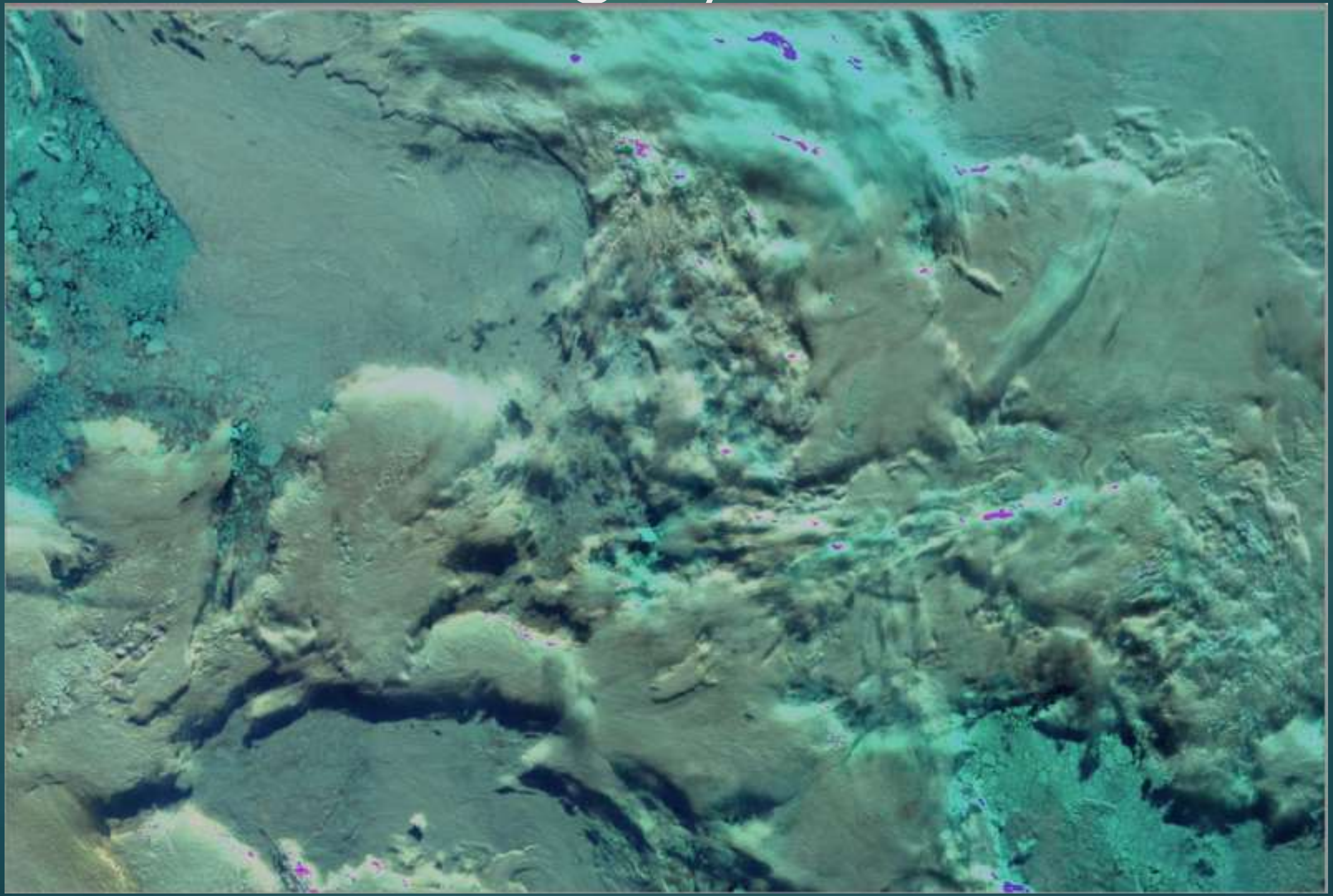
Baffin Is. & Prince Charles Is., Canada, Google Maps

Baffin Is. & Prince Charles Is., Canada, VIIRS Imagery Bands



Arctic Ocean, August 2013

VIIRS Imagery Bands



Amazon Basin, August 2013
VIIRS Imagery Bands