Operationalizing a Research Sensor: MODIS to VIIRS

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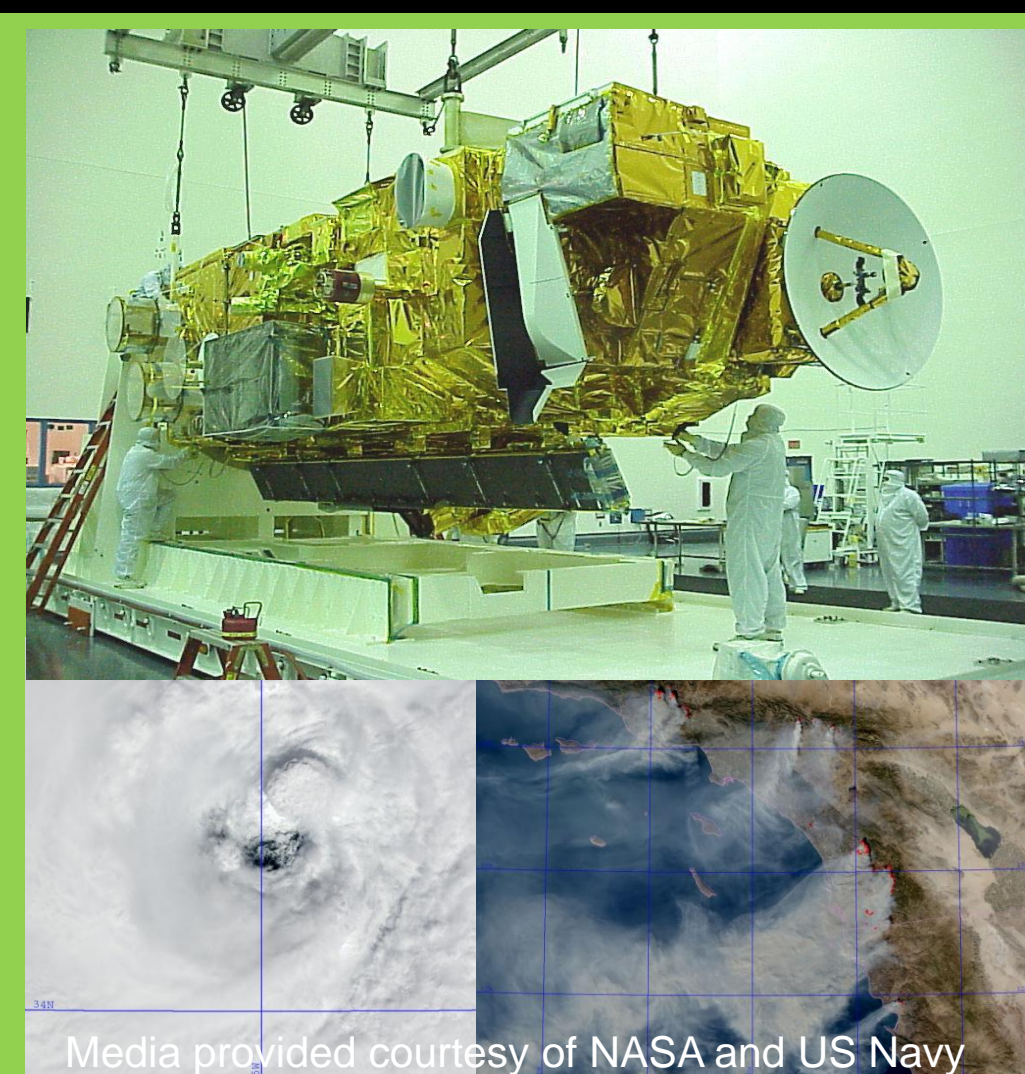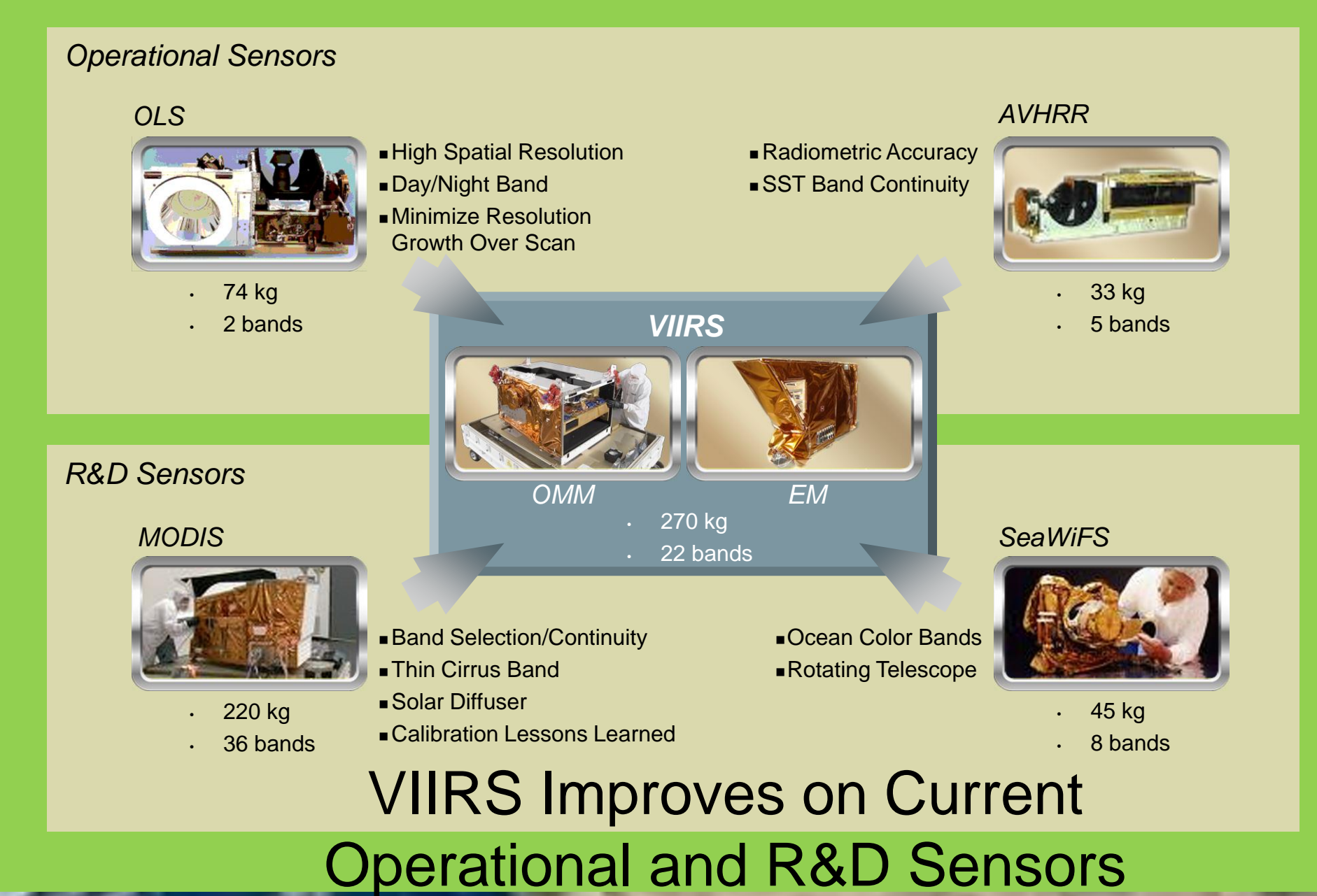
Operationalizing the Sensor

- MODerate resolution Imaging Spectroradiometer (MODIS) built by Raytheon for NASA's Earth Observing System (EOS)
- Research instrument with:
  - 36 spectral bands, ranging in wavelength from 0.4 µm to 14.4 µm
  - Spatial resolution: 2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km
  - Full aperture end-to-end onboard calibration for all spectral bands
- MODIS data has provided unprecedented insight into large-scale Earth system science questions related to cloud and aerosol characteristics, surface emissivity and processes occurring in the oceans, on land, and in the lower atmosphere
- MODIS has been operating on the EOS Terra satellite since 1999 and on the EOS Aqua satellite since 2002, providing excellent data for scientific research and operational use

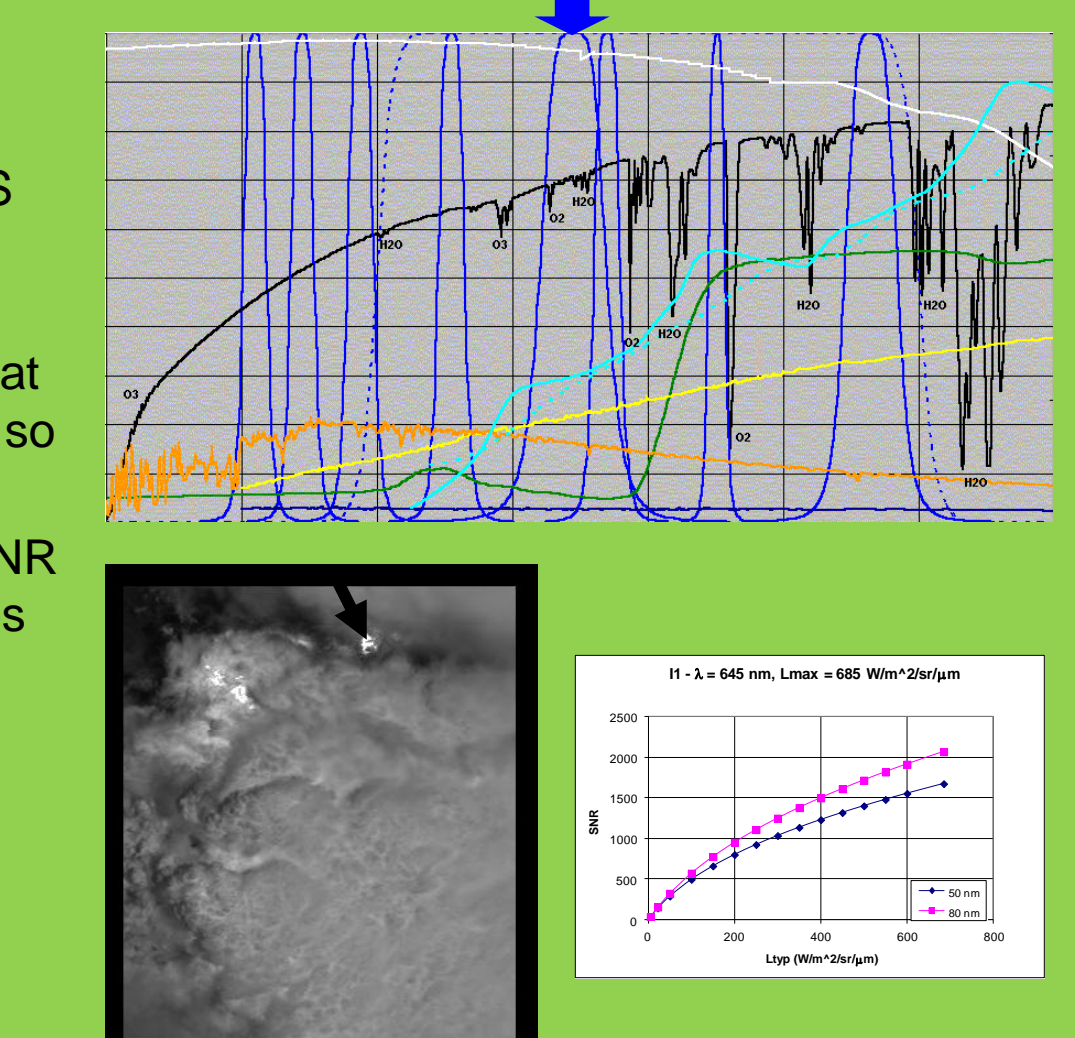Media provided courtesy of NASA and US Navy

Research Sensor - MODIS

Operational Sensors

OLS
- High Spatial Resolution
- Day/Night Band
- Minimize Resolution Growth Over Scan
- 74 kg
- 2 bands

AVHRR
- Radiometric Accuracy
- SST Band Continuity
- 33 kg
- 5 bands

VIIRS
OMM · EM · 270 kg · 22 bands

R&D Sensors

MODIS
- Band Selection/Continuity
- Thin Cirrus Band
- Solar Diffuser
- Calibration Lessons Learned
- 220 kg
- 36 bands

SeaWiFS
- Ocean Color Bands
- Rotating Telescope
- 45 kg
- 8 bands

VIIRS Improves on Current Operational and R&D Sensors

- Much improved spectral coverage and spectral resolution of VIIRS versus AVHRR enables new weather, climate, ocean color and agricultural data products
- Much better spatial resolution of VIIRS versus AVHRR in the VNIR bands enables much sharper imagery
- Fully calibrated solar reflectance bands provide unprecedented radiometric accuracy

Imagery
Sea Surface Temperature
Clouds
Aerosols
Ocean Color
Land Imaging

Environmental Issues — Assess impact of changing climate and anthropogenic effects for preserving ecological diversity
Weather Forecasting/Disaster Mitigation — Early warning of hurricanes and other hazardous weather conditions; Greater ability to identify and protect high risk communities
Warfighter Support — Better weather forecasting for combat mission planning/ops; Improved battlespace awareness via better imagery
Crucial Resources — Improved ability to protect drinking water sources; Early warning of conditions leading to food shortages
Public Health — Early warning of health hazards for effective disease control

Updating the Science

- Merged the best features of the MODIS and CLAVR algorithm heritage to arrive at an initial VCM algorithm
- Updated the VCM algorithm based on new capabilities of VIIRS, e.g.:
  - Detection of thin cirrus (VIIRS Band M9 was narrowed to minimize out-of-band response)
  - Detection of clouds over snow and ice (VIIRS Band I3 provides unprecedented global resolution in the shortwave infrared to highlight snow/ice absorption)
  - Discrimination of cloud phase both day and night (VIIRS dynamic range and SNR were optimized based on early Terra MODIS results)

Example: the VIIRS Cloud Mask (VCM)

- PDR solution was a nonlinear regression approach, deemed the only way to meet requirements over bright surfaces (snow, desert)
- After VIIRS down-select, Raytheon had the freedom to engage with albedo experts at Boston University (developers of the MODIS algorithm)
- Surface Albedo algorithm was converted to a hybrid solution:
  - Bright Pixel Sub-Algorithm (BPSA) employs nonlinear regression approach
  - Dark Pixel Sub-Algorithm (DPSA) employs MODIS approach
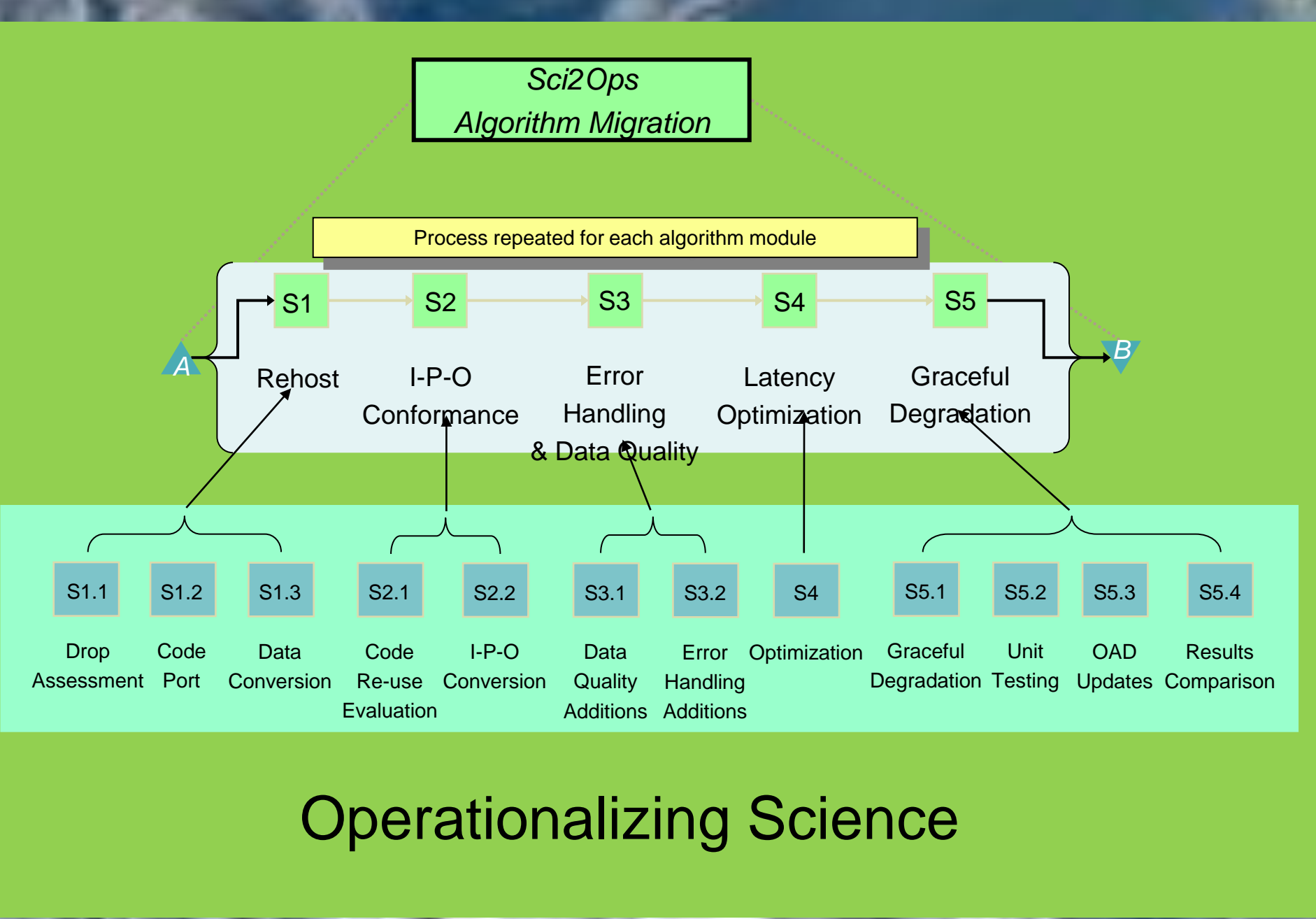 - Both outputs reported globally
- New gridded products and algorithms were added to support the DPSA
  - Surface Reflectance, Black and White Sky Albedos, etc.

Surface Albedo Algorithm Evolved from VIIRS PDR to CDR

- Key input for multiple EDRs
- Originally designed to be spectrally equivalent to MODIS band 1 (620-670nm)
- Once Terra MODIS data were available, it was determined that I1 would saturate over clouds, so Lmax was increased
- When Lmax was increased, SNR performance at lower radiances was compromised
- To recover SNR, band was widened to 80 nm
- To preserve chlorophyll response, band was shifted to 640 nm

VIIRS Band I1 – Evolution Over Time

Operationalizing the Algorithms

Sci2Ops
Algorithm Migration

Process repeated for each algorithm module

S1 Rehost | S2 I-P-O Conformance | S3 Error Handling & Data Quality | S4 Latency Optimization | S5 Graceful Degradation

S1.1 Drop Assessment | S1.2 Code Port | S1.3 Data Conversion | S2.1 Code Re-use Evaluation | S2.2 I-P-O Conversion | S3.1 Data Quality Additions | S3.2 Error Handling Additions | S4 Optimization | S5.1 Graceful Degradation | S5.2 Unit Testing | S5.3 OAD Updates | S5.4 Results Comparison

Operationalizing Science

Category	Requirements	Implementation
Robustness		Coding standards
	24 x 7 ops tempo	Interface standards for output, mnemonics, constraints
	Manage missing inputs	
	Assess data "goodness"	Common utilities
Performance		Ao = 0.9999
	Latency	Latency (detection to delivery) = 80 mins (J1)
	Availability	30 mins (J2)
	Fidelity	
Maintainability		Standardized implementation
	Life Cycle Cost	Coding best practices, standard libraries and languages
	Rapid Updates	

Implementing Operational Production Needs

VIIRS

Operational VIIRS Chain

Results

Lessons learned from MODIS helped enabled quick turnaround of VIIRS results
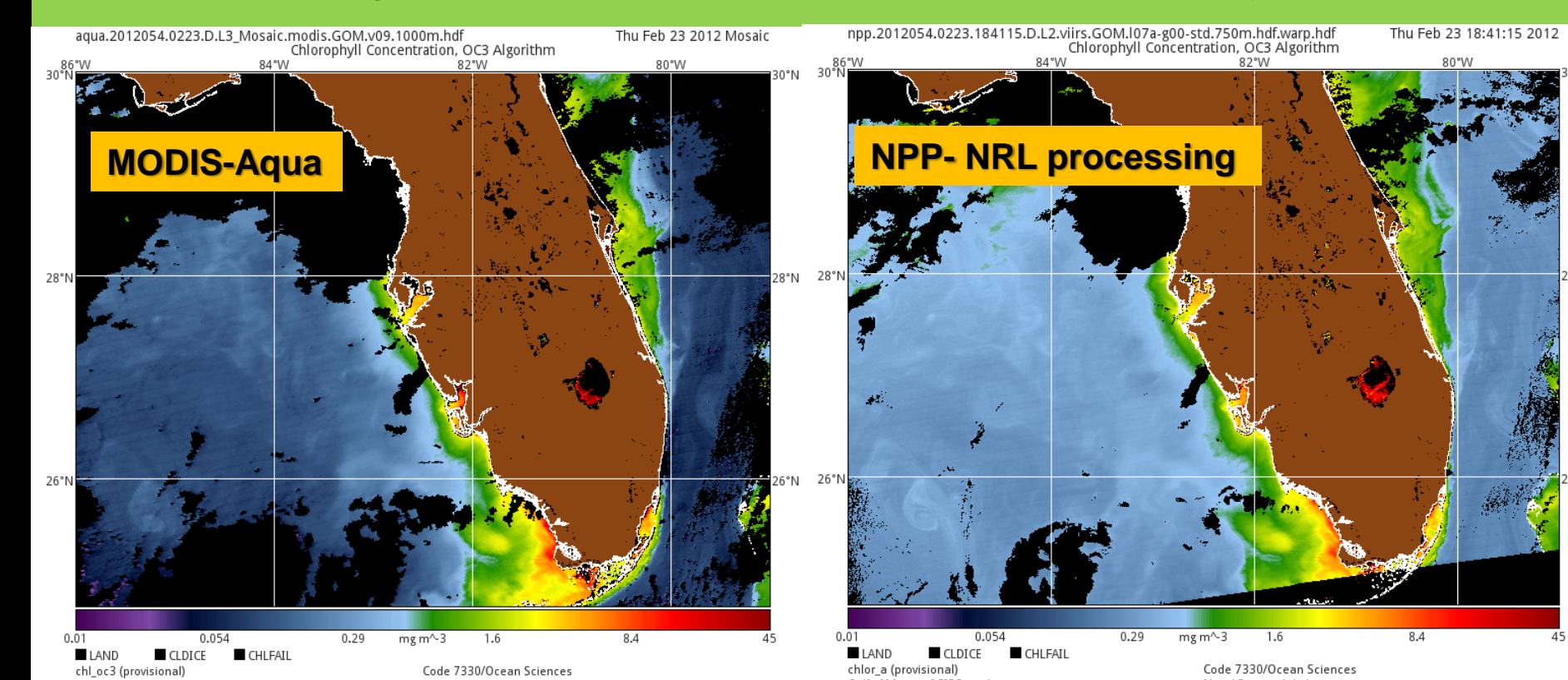
- After 6+ months of operation, all VIIRS bands continue to produce excellent images with expected high quality
- Sensitivity (SNR and NEdT) meets sensor requirements for all detectors and all bands, consistent with pre-launch values
- On-orbit calibration coefficients consistent with pre-launch values, except for M13 (4 µm) which is being updated
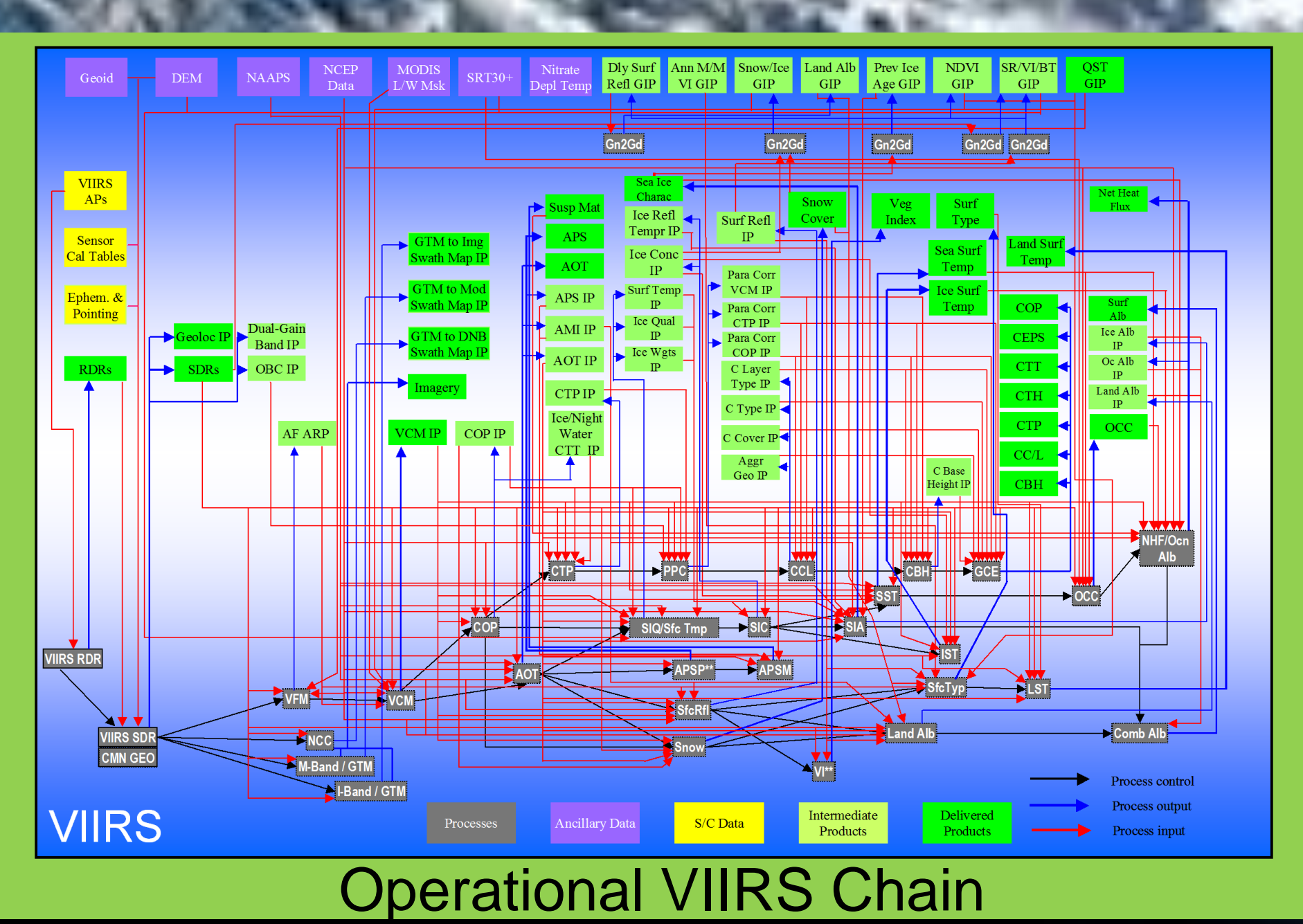- On-orbit anomalies are well understood and are being tracked

Amazon Delta
Media provided by NASA GSFC

VIIRS true color imagery compares very well with nearly simultaneous MODIS imagery

MODIS · VIIRS

California from MODIS at 2028Z and VIIRS at 2033Z
Media provided by Arunas Kuciauskas et al. at US Naval Research Lab Monterey

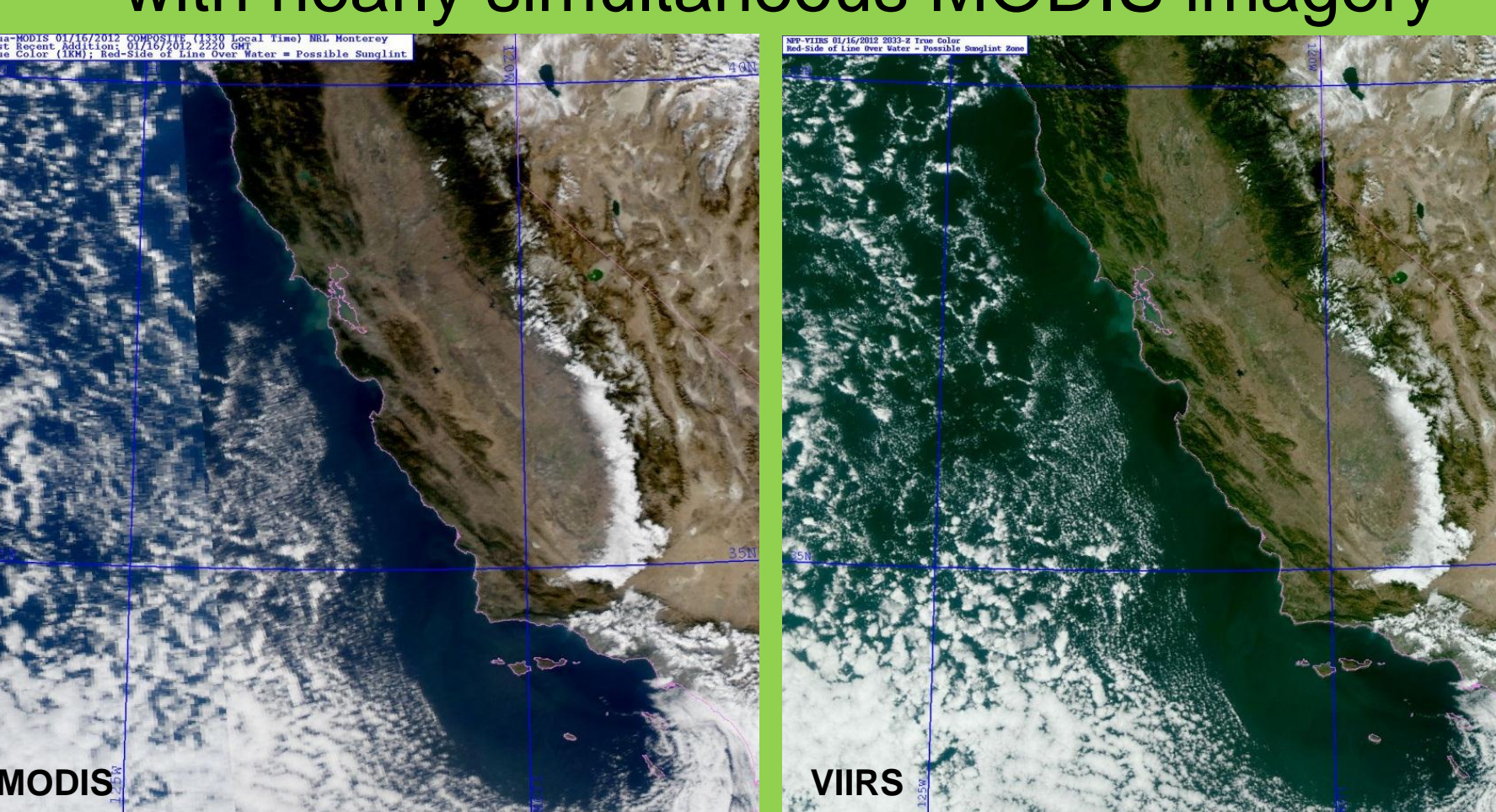### Work continues to validate VIIRS data products and complete operationalization

- VIIRS data is flowing through the ground system to major data centers including NESDIS, AFWA and CLASS and is being analyzed continuously
- Radiometry and geolocation look good
- Initial VIIRS data products for ocean features, retrieved nLW and chlorophyll have similar quality as MODIS
- Ongoing work is tuning cloud masks and other algorithms
- Suomi NPP program office reports that VIIRS sensor data will be publicly available soon

MODIS-Aqua · NPP - NRL processing

Media provided by US Naval Research Lab Stennis