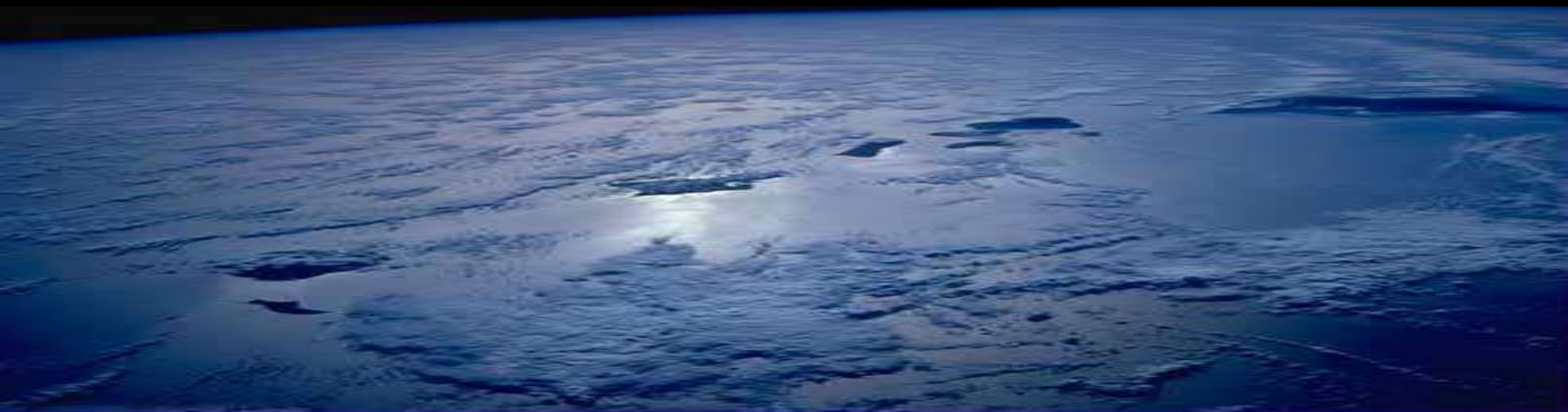
SeaWiFS, MODIS, & VIIRS

Ocean Color Processing Group

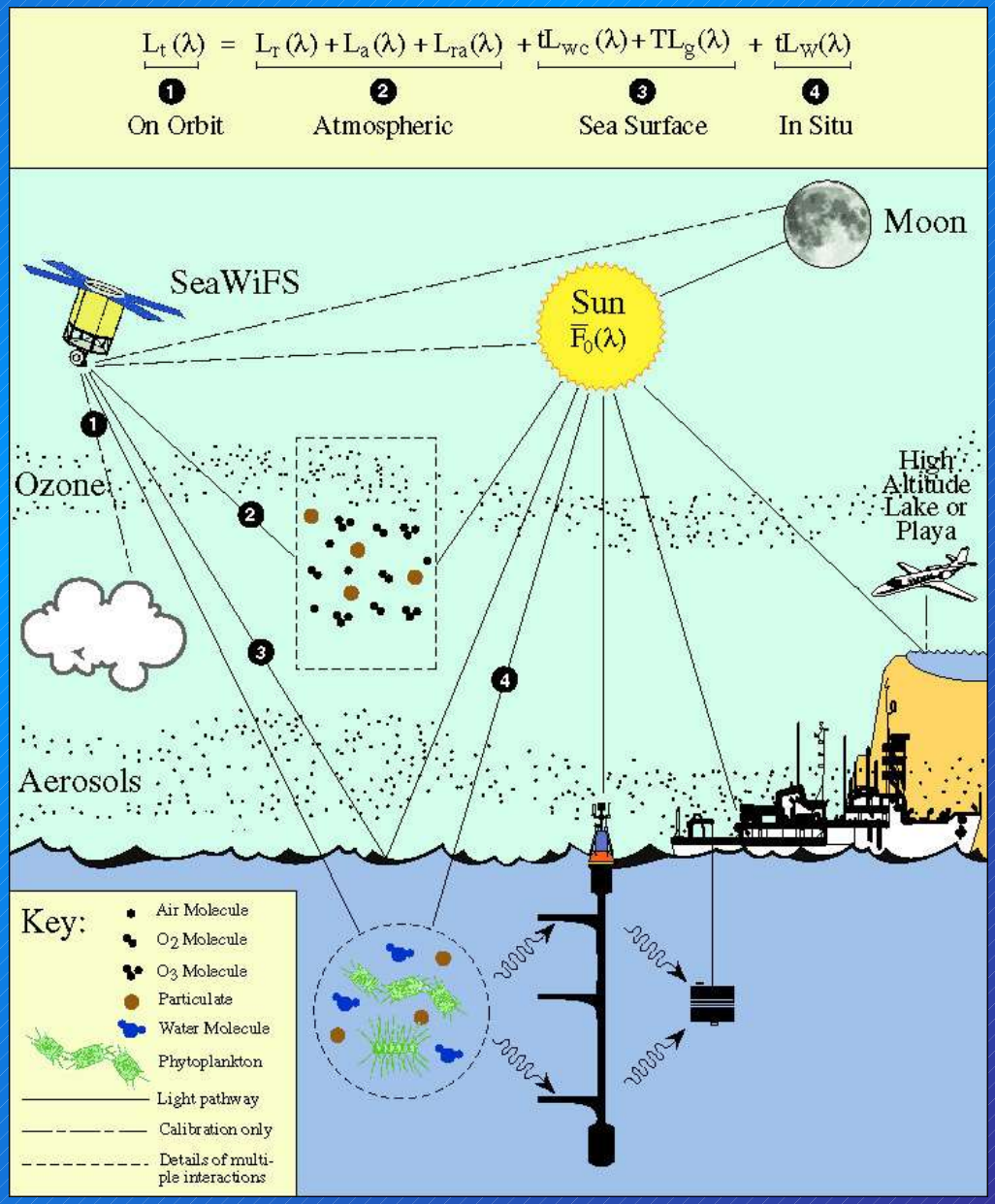
NASA Ocean Color Calibration & Validation Workshop
NIST
November 8-10, 2004



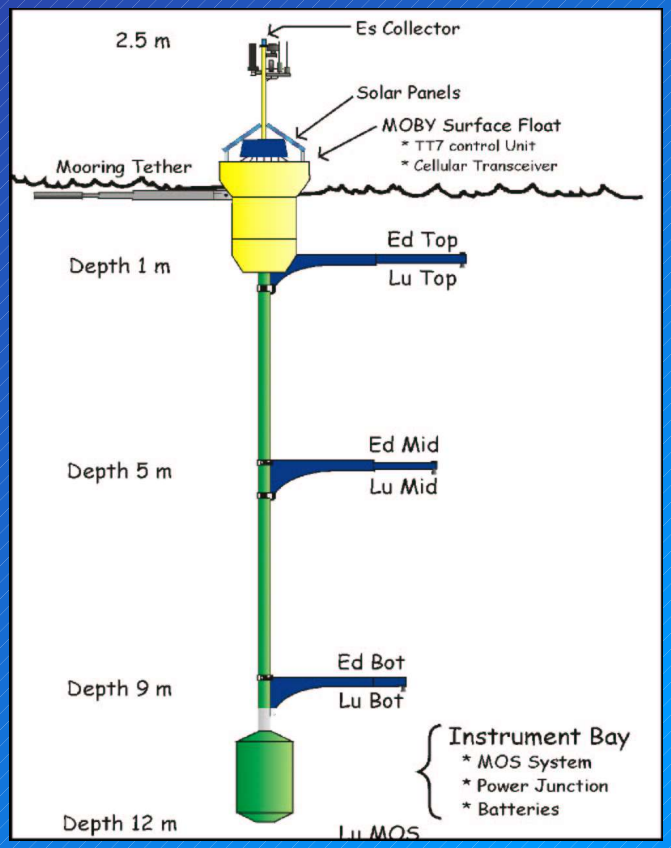
Calibration Validation Paradigm

Satellite Calibration Elements:

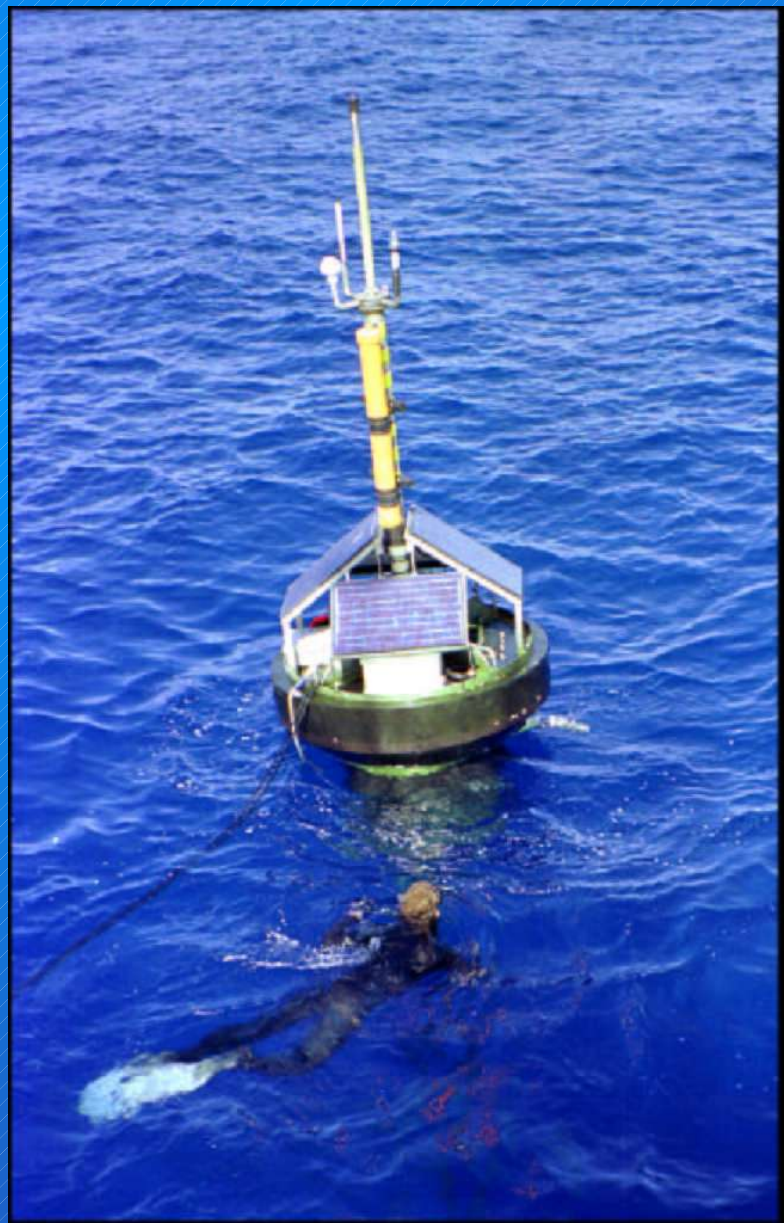
- **Laboratory** - before launch, sensor is calibrated in lab
- **On-orbit** - daily solar and monthly lunar observations are used to track changes in sensor response
- **Vicarious** - comparison of data retrievals to in-water, ship, and airborne sensors is used to adjust instrument gains



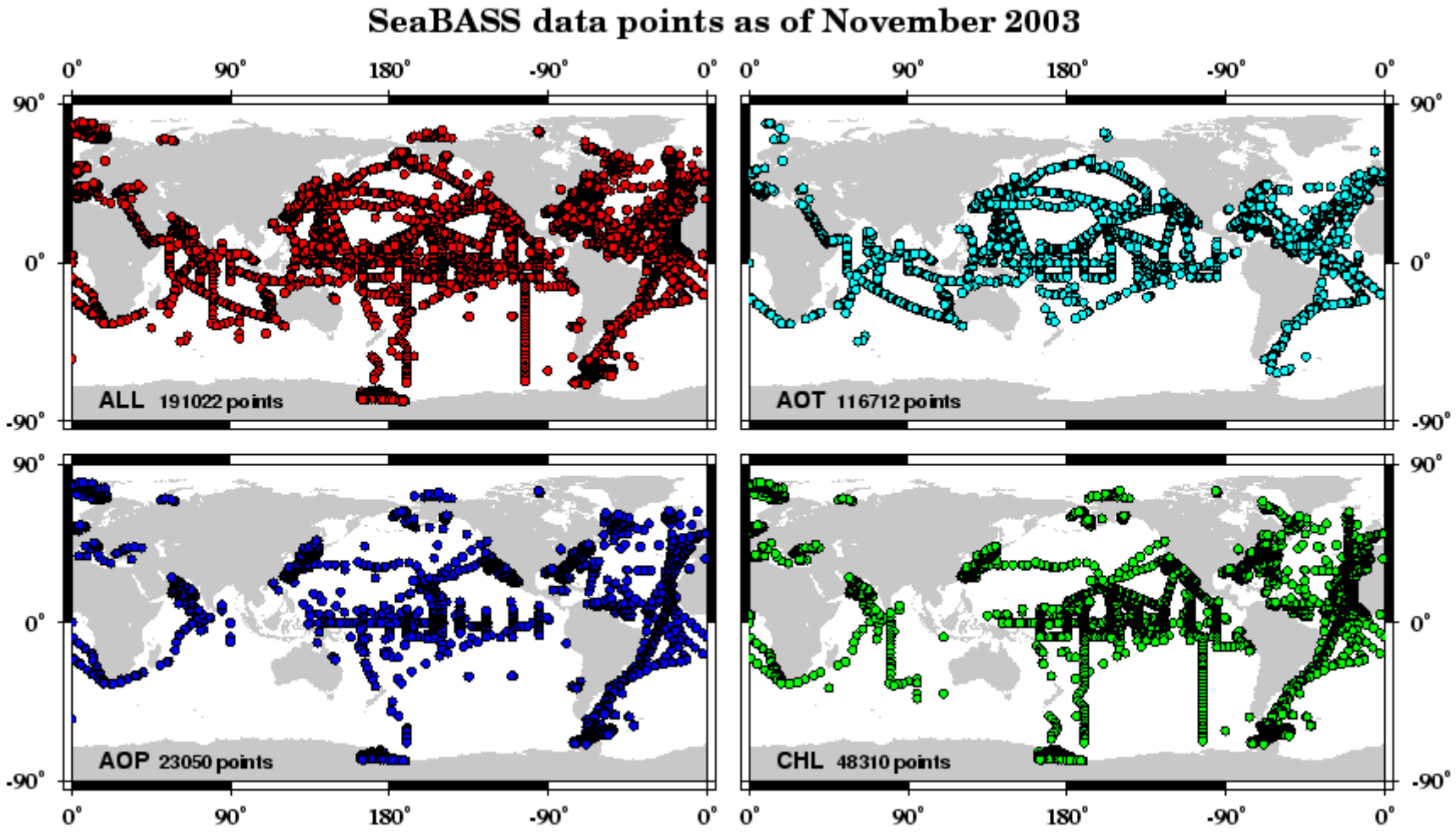
MOBY: Vicarious Calibration



MOBY used to adjust prelaunch calibration gains for visible bands using satellite-buoy comparisons.



SeaWiFS Bio-optical data Archive & Storage System (SeaBASS)



Data from over 1250 cruises

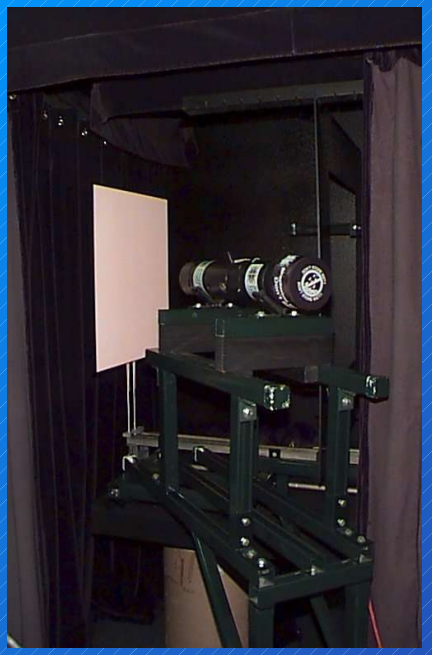
Apparent Optical Property (AOP); Chlorophyll-a (CHL); Aerosol Optical Thickness (AOT)

SeaWiFS & SIMBIOS Calibration Round Robins

(RR experiments in 1992, 1993, 1996, 1998, 1999, 2001, & 2002)

Goals

- Verify that all labs are on the same radiometric scale
- Document calibration protocols
- Encourage the use of standardized calibration protocols
- Identify where the protocols need to be improved

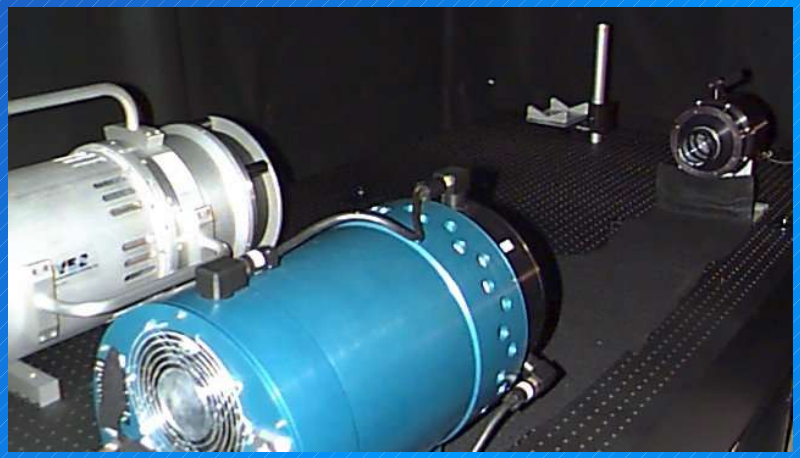


Radiance Calibrations (spheres & plaques)

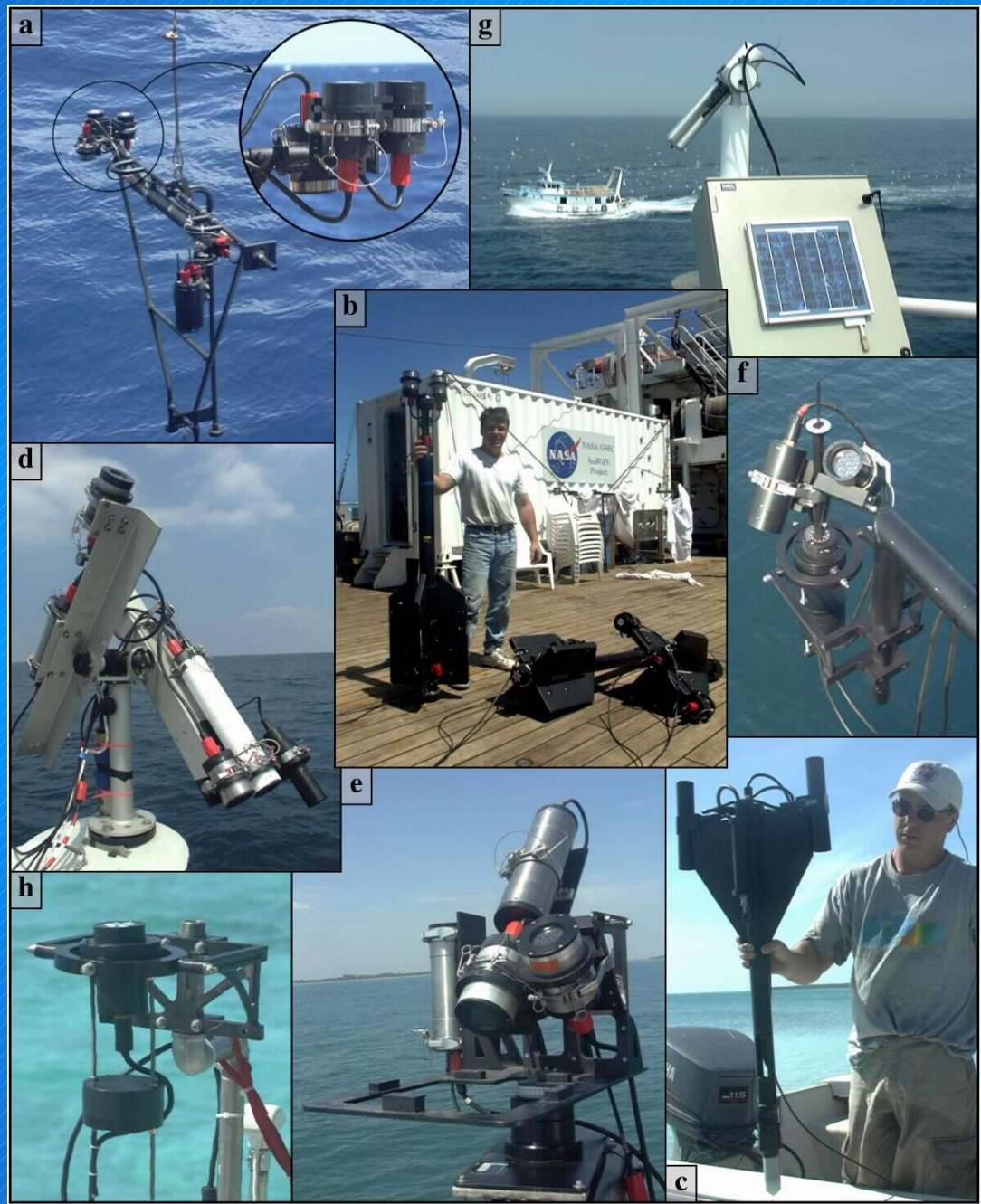
SeaWiFS Transfer Radiometer (SXR-1 & -2)

Field Measurement Technology Development

Various in-water & above water radiometers d



SeaWiFS Quality Monitor (SQM)
(NIST/NASA-developed portable field source for stability monitoring)



Ocean Color 865 nm Band: No Vicarious Calibration

- 865 nm measurements are used provide aerosol amounts in the atmospheric correction algorithm
  - SeaWiFS, MODIS, OCTS, VIIRS
- Comparisons for SeaWiFS suggest that band 8 calibration may be 5-10% too high
  - Southern Ocean band 8 gain study (~5-6%)
  - Comparisons with University of Arizona ground measurements (within 10%)
  - Comparisons with aerosol optical thickness data (AERONET & cruise data)
    - Scatter in results is large
    - SeaWiFS appears high

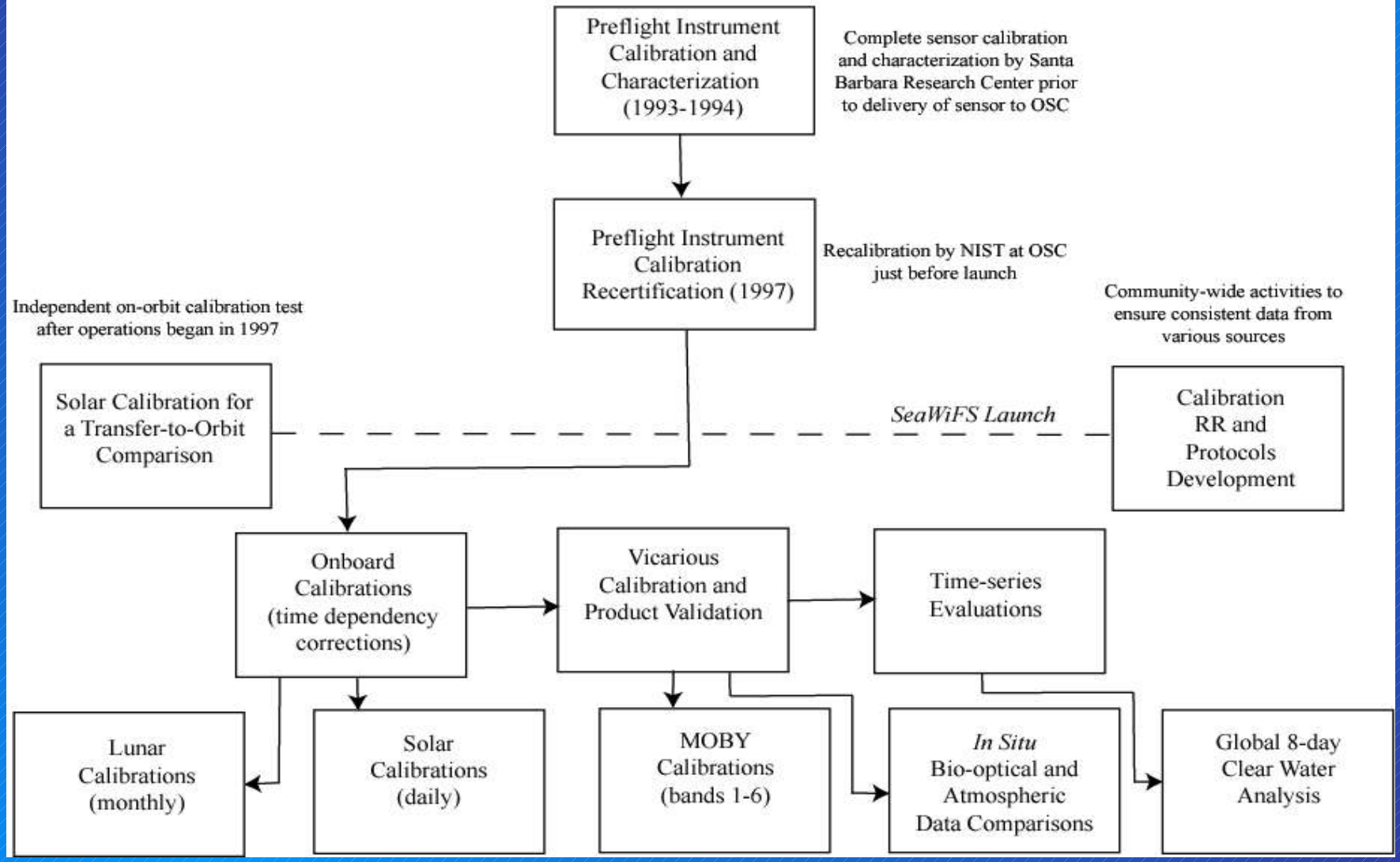
SeaWiFS

(September 1997-present)

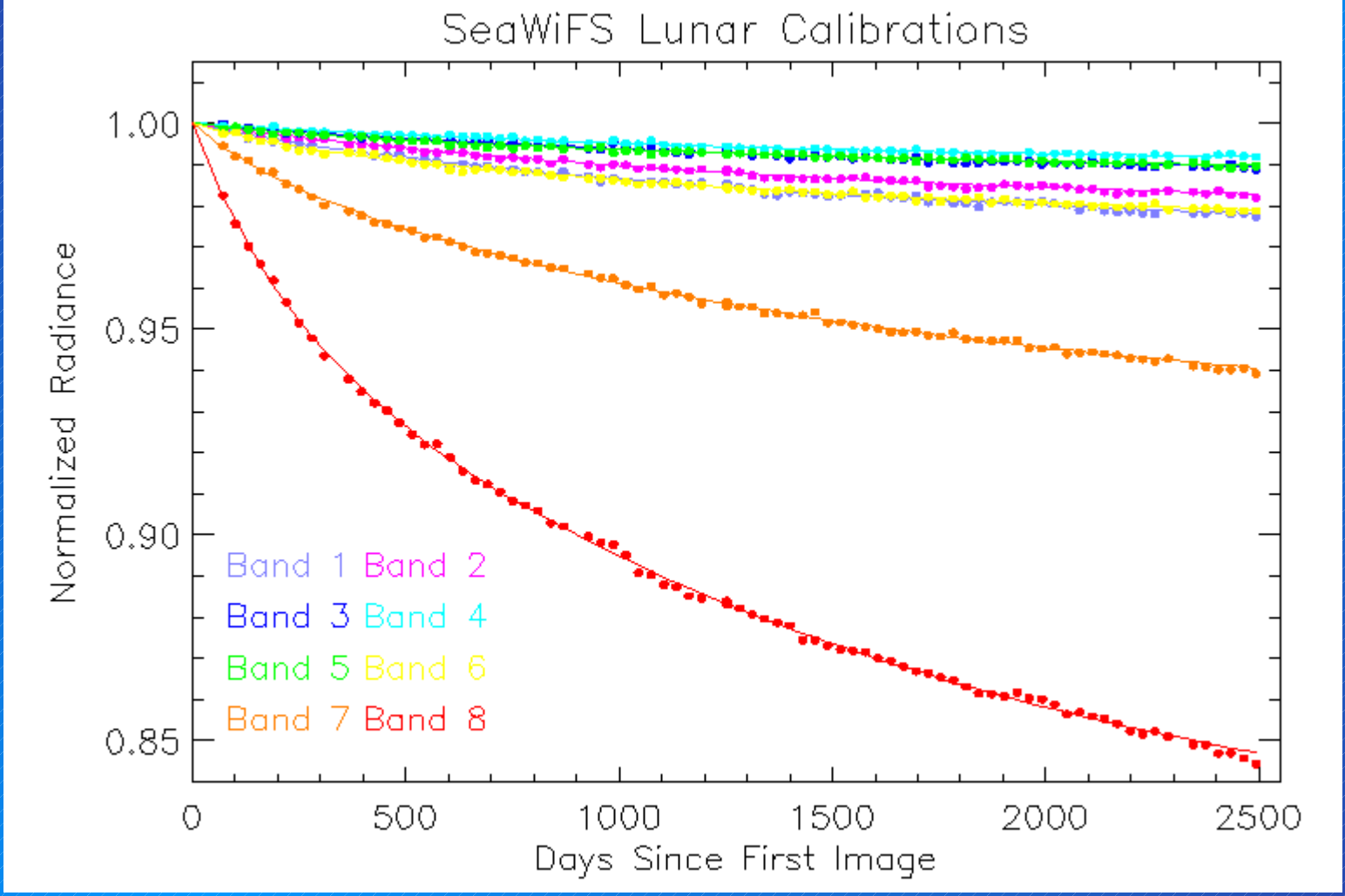
- **Sensor Attributes**
  - Rotating telescope
  - 412, 443, 490, 510, 555, 670, 765, 865 nm bands
  - 12 bit digitization truncated to 10 bits on spacecraft
  - 4 focal planes, 4 detectors/band, 4 gain settings, bilinear gain configuration
  - Polarization scrambler: sensitivity at 0.25% level
  - Solar diffuser (daily observations
  - Monthly lunar views at 7° phase angle via pitch

- **Mission Status**
  - All spacecraft subsystems healthy (power, telemetry, navigation, etc.)
  - Primary source of MODIS validation data
  - NASA data buy contract ends in December
    - 1-yr mission extensions in December 2002 & 2003
  - HQ willing to contribute to new data buy, but not be the lead

SeaWiFS Calibration Strategy



SeaWiFS Lunar Calibration Stability Tracking

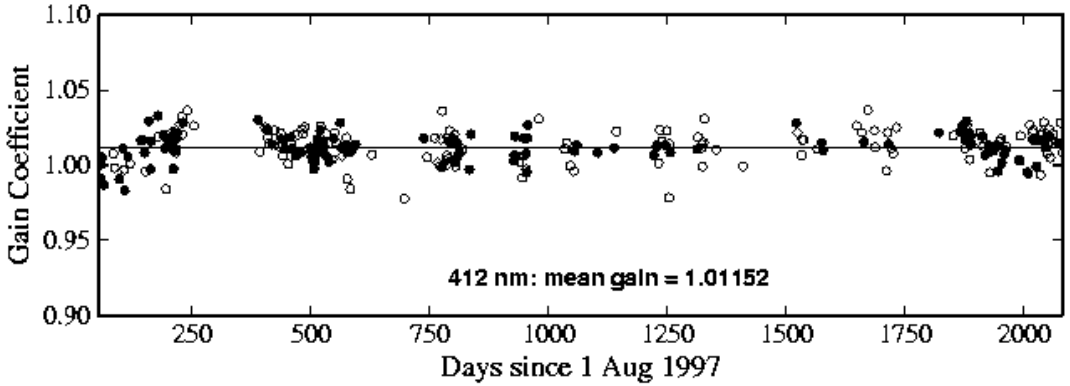


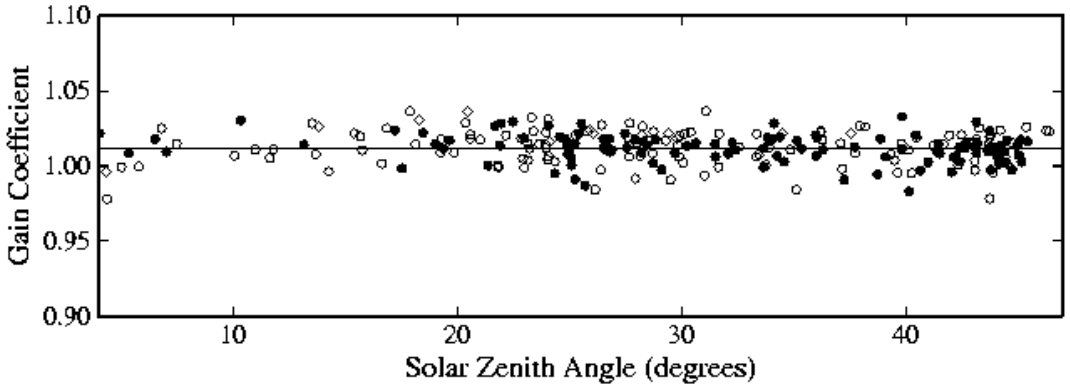
Lunar calibration: Monthly views of the moon at ~ 7° phase angle.
Gradual monotonic degradation primarily in NIR bands.

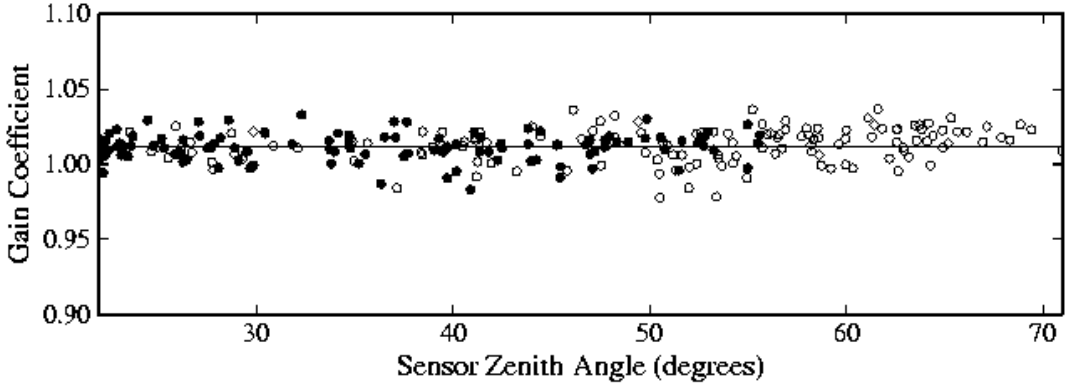
MOBY-based Vicarious Band 1 Gain Factors

- Overpasses used in operational gain determination

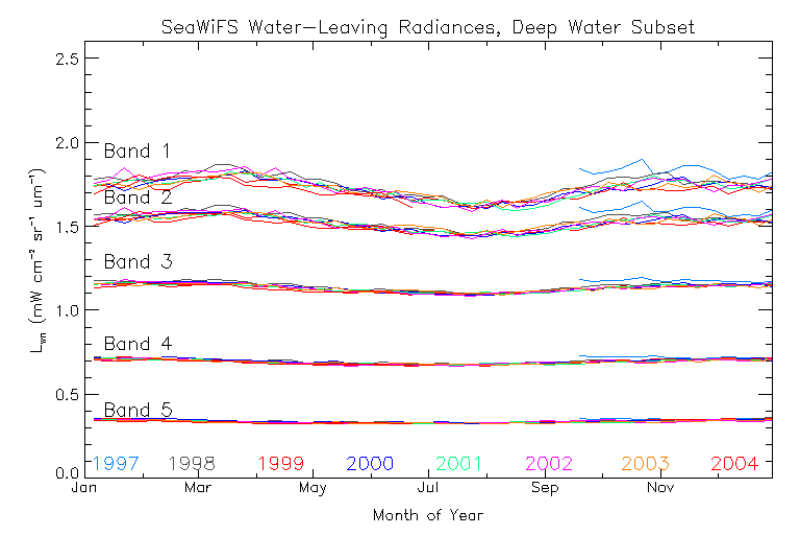
) Overpasses that failed gain analysis Q/C criteria



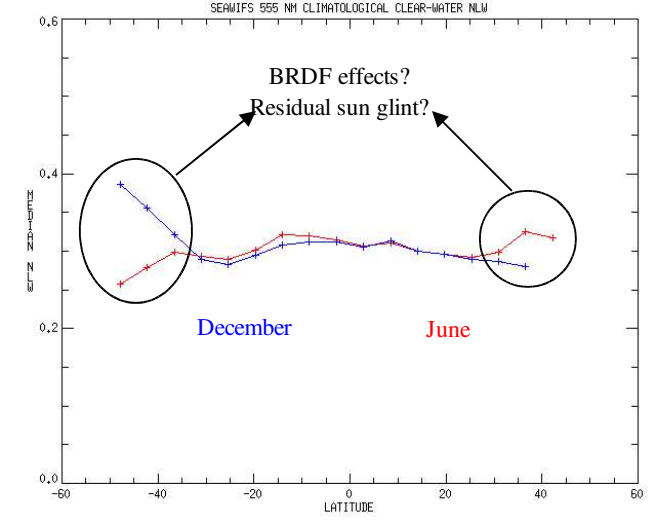




SeaWiFS Data Quality:
Global Consistency & In Situ Verification

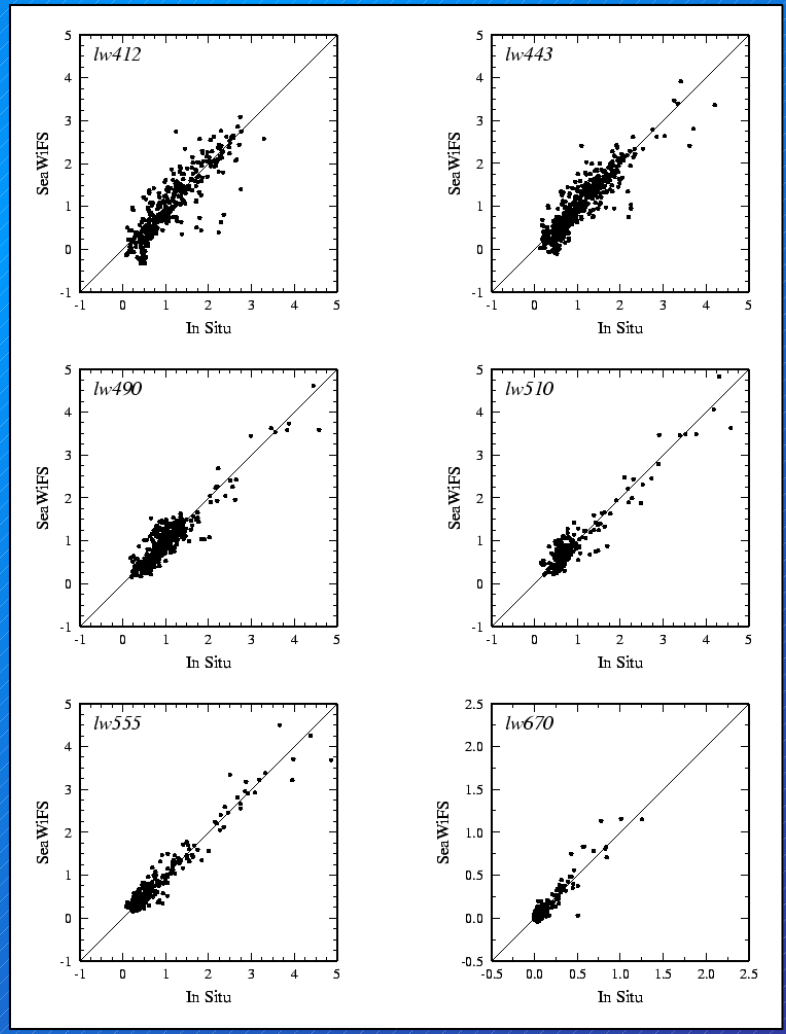


Temporal Consistency



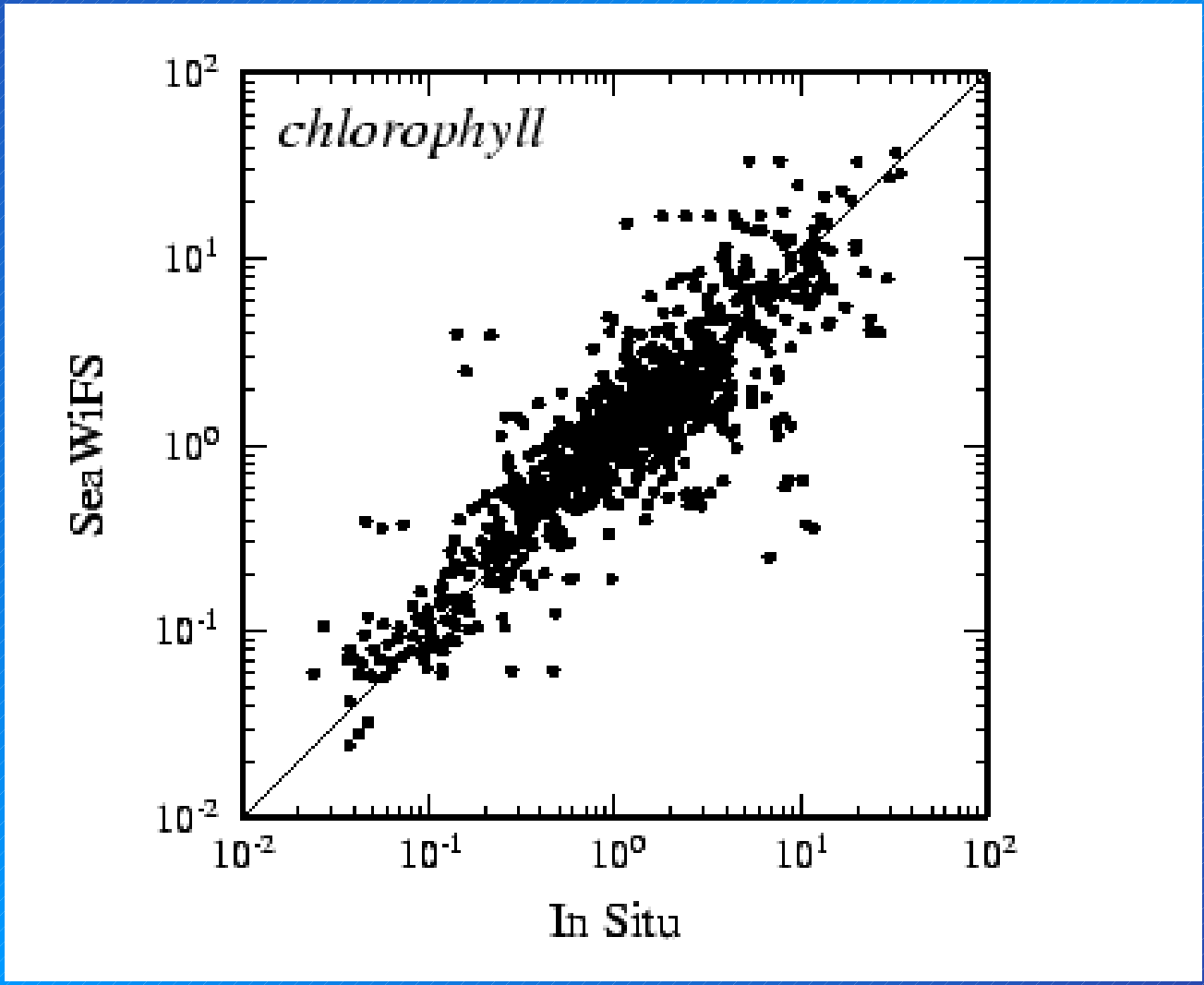
Spatial Consistency

Field Validation



* Lwn: Normalized Water-leaving Radiance

SeaWiFS Repro4: OC4 Chlorophyll



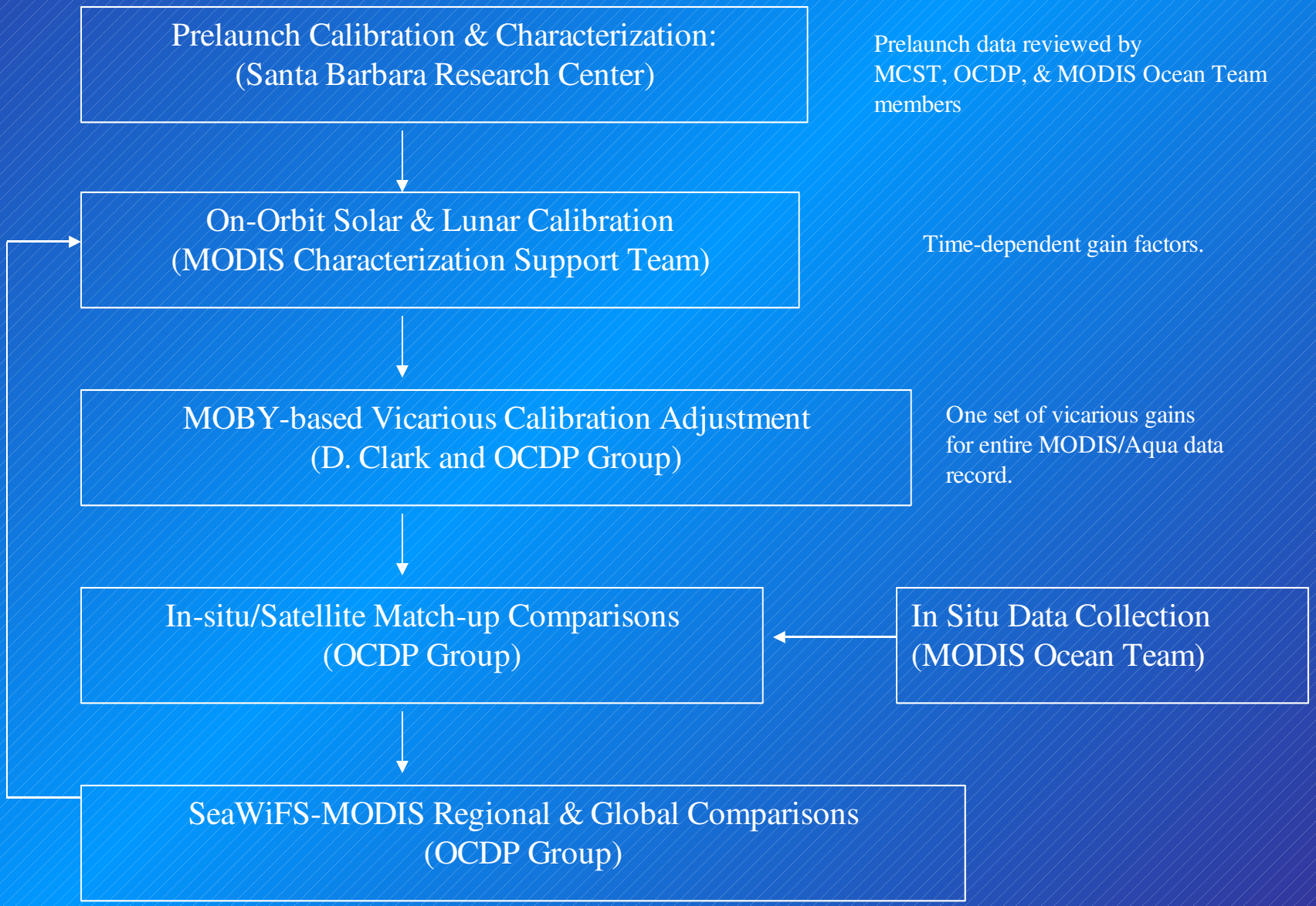
MODIS/Aqua
(July 2002-present)

- **Sensor Attributes for OC**
  - Rotating mirror
  - 413, 443, 488, 531, 551, 667, 678, 748, 870 nm bands
  - 12 bit digitization
  - 2 Vis-NIR focal planes, 10x40 detector arrays
  - No polarization scrambler: sensitivity at ~3% level
  - Spectral Radiometric Calibration Assembly (SRCA)
  - Solar diffuser (observations every orbit), Solar Diffuser Stability Monitor (SDSM)
  - Monthly lunar views at 55° phase angle via space view port

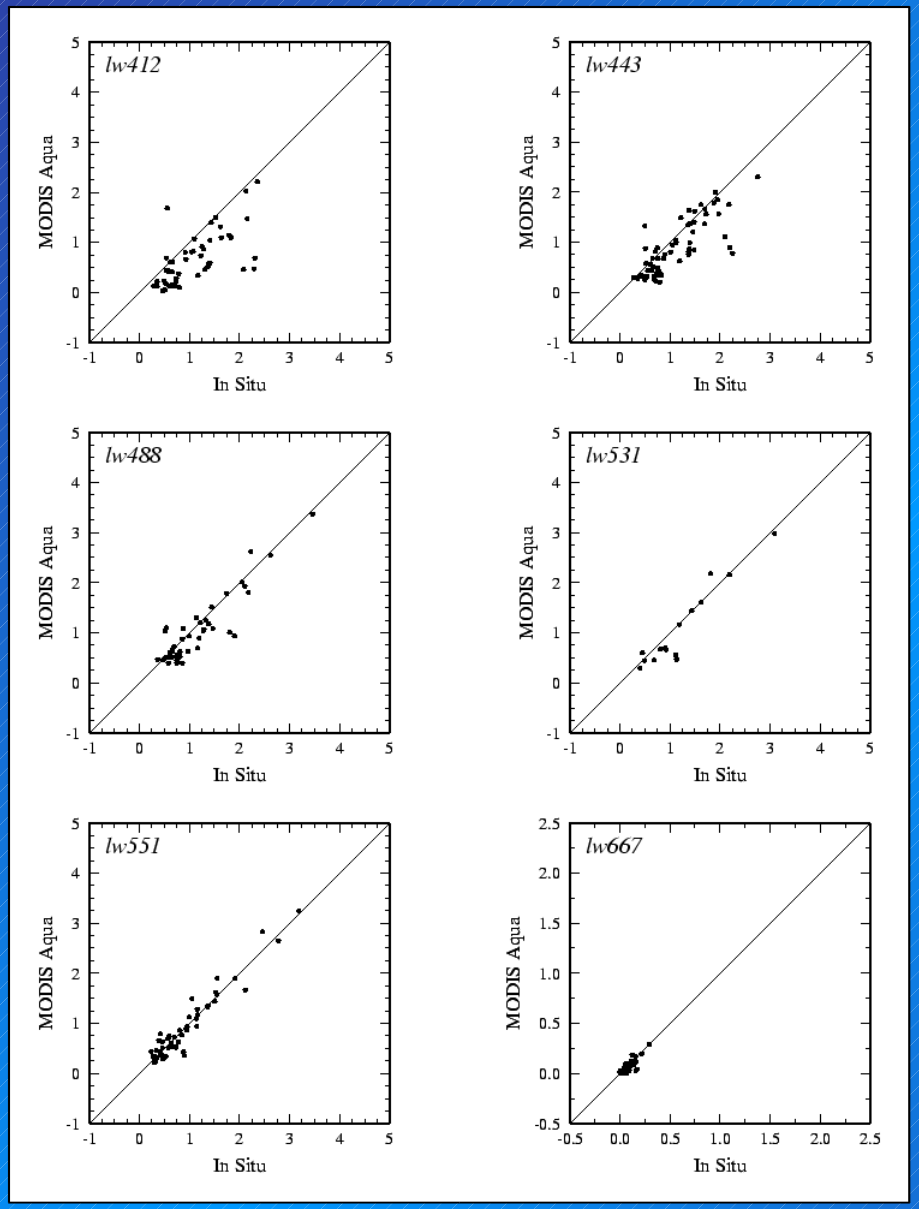
- **Aqua Mission Status**
  - All spacecraft subsystems healthy (power, telemetry, navigation, etc.)
  - Primary mirror properties changing over time; overall stability much improved over Terra
  - Prelaunch polarization and stray light characterizations sufficiently assessed for OC
  - Ocean Biology Processing Group working closely with MODIS Characterization Support Team on calibration issues

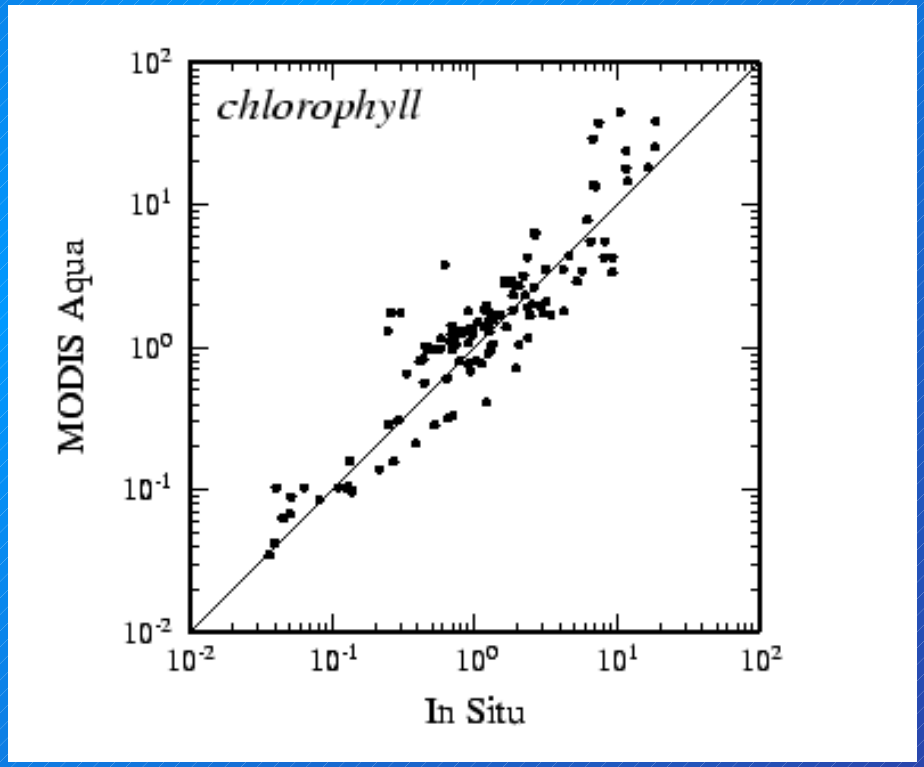
MODIS/Terra OC processing discontinued in Jan. 2004 because of sensor system instabilities. Present focus is on MODIS/Aqua.

MODIS OC Calibration

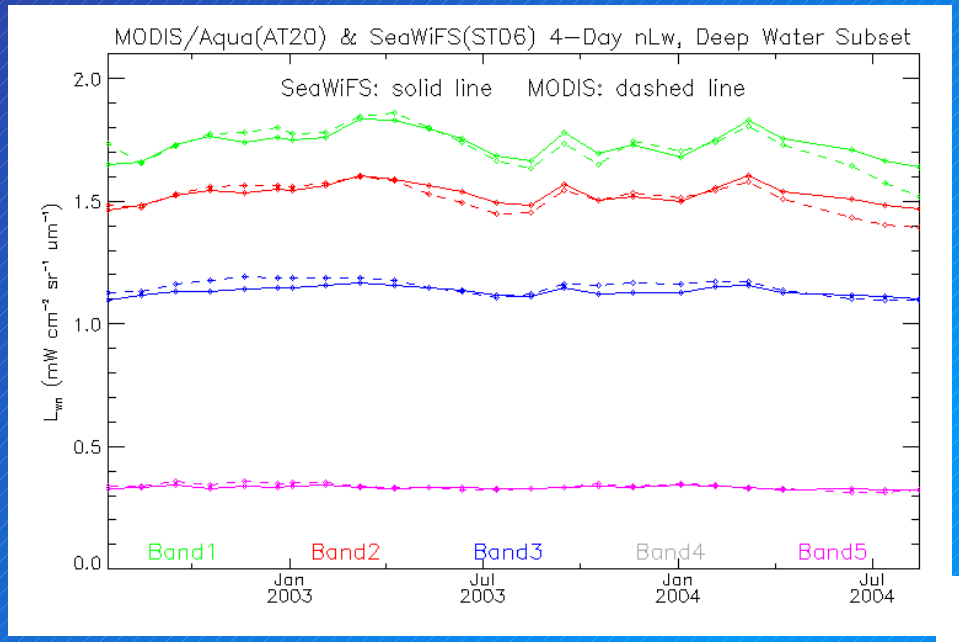


In Situ Match-up Results: Current Operational MODIS (Aqua) Processing





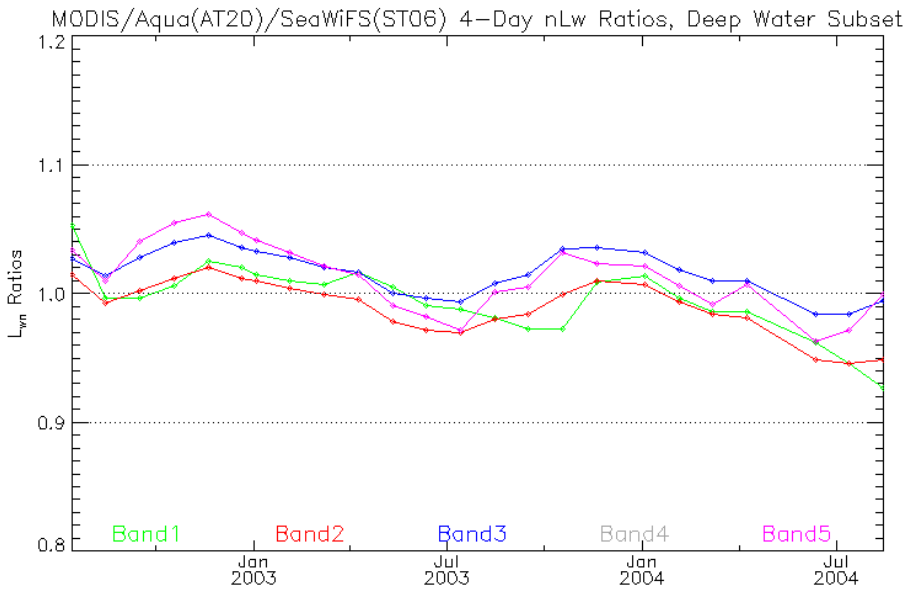
MODIS/Aqua-SeaWiFS Global Lwn's



Global averages very consistent.
Differences within ±5%.
Slight temporal trend evident, but much reduced with new solar diffuser corrections.

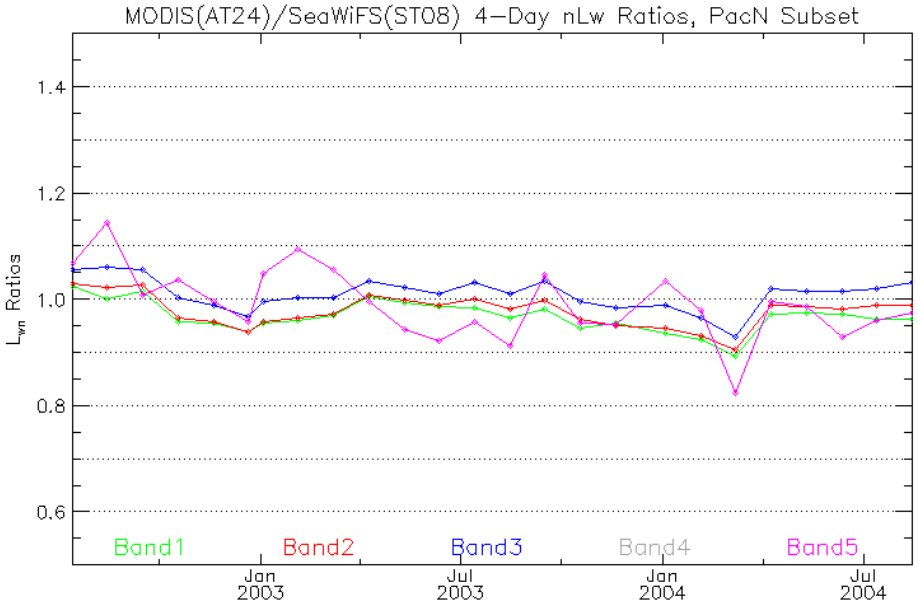
Lwn comparisons

Lwn ratios



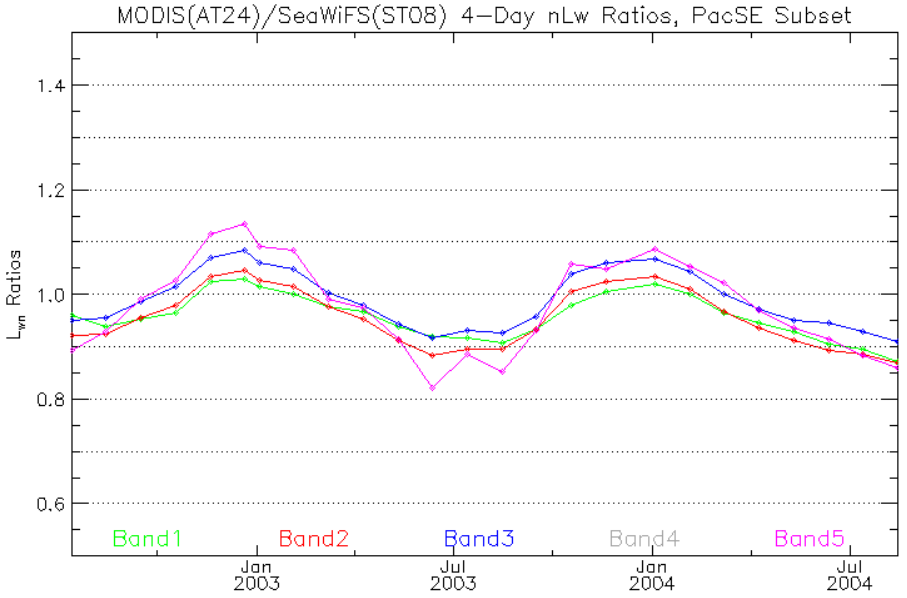
MODIS(Aqua)/SeaWiFS Lwn Ratios (N. Pacific):

Most recent comparison

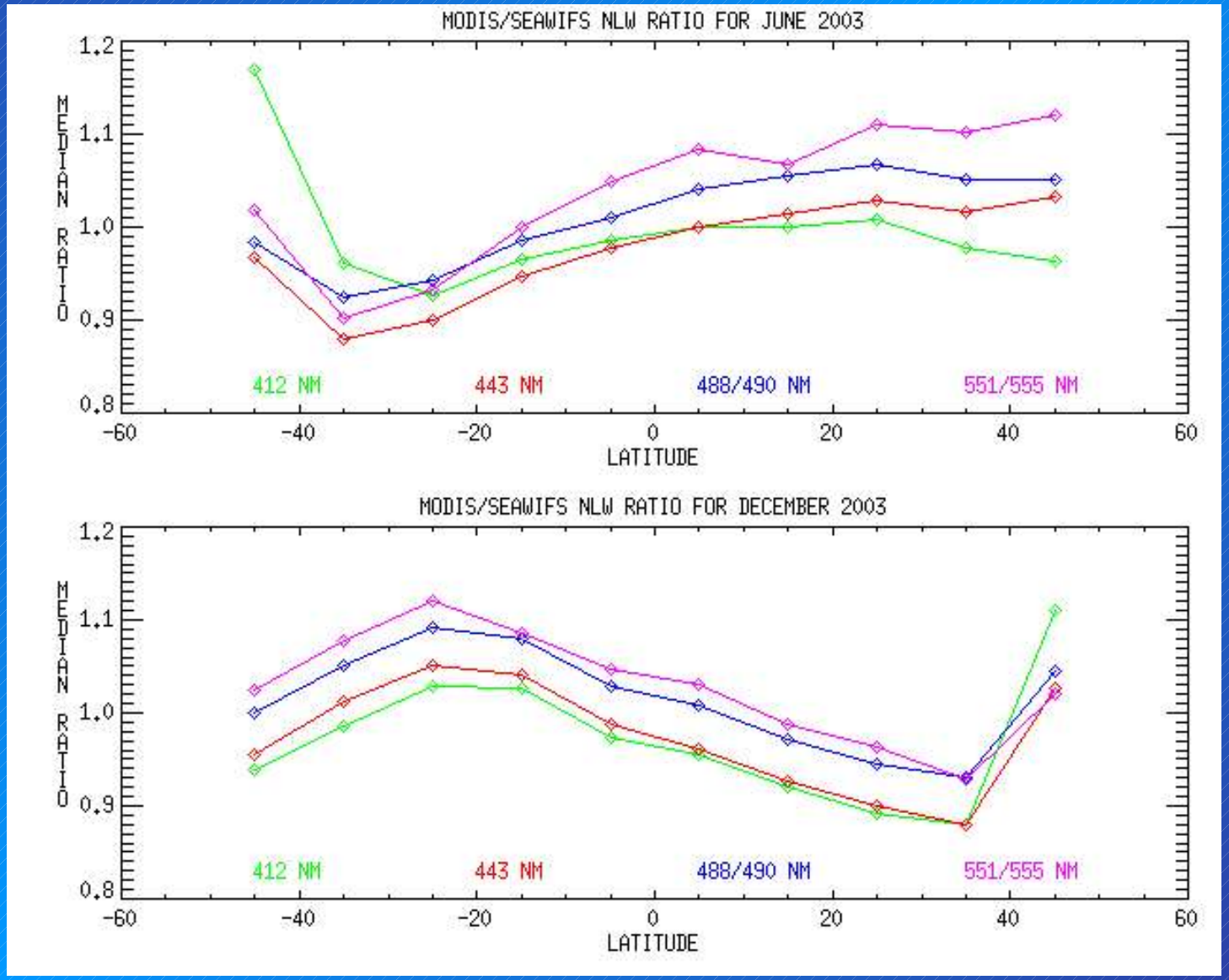


- "Best" polarization tables
- Refined m1's with yaw-angle correction
- Cloud dilation (stray light reduction)
- No f/Q correction

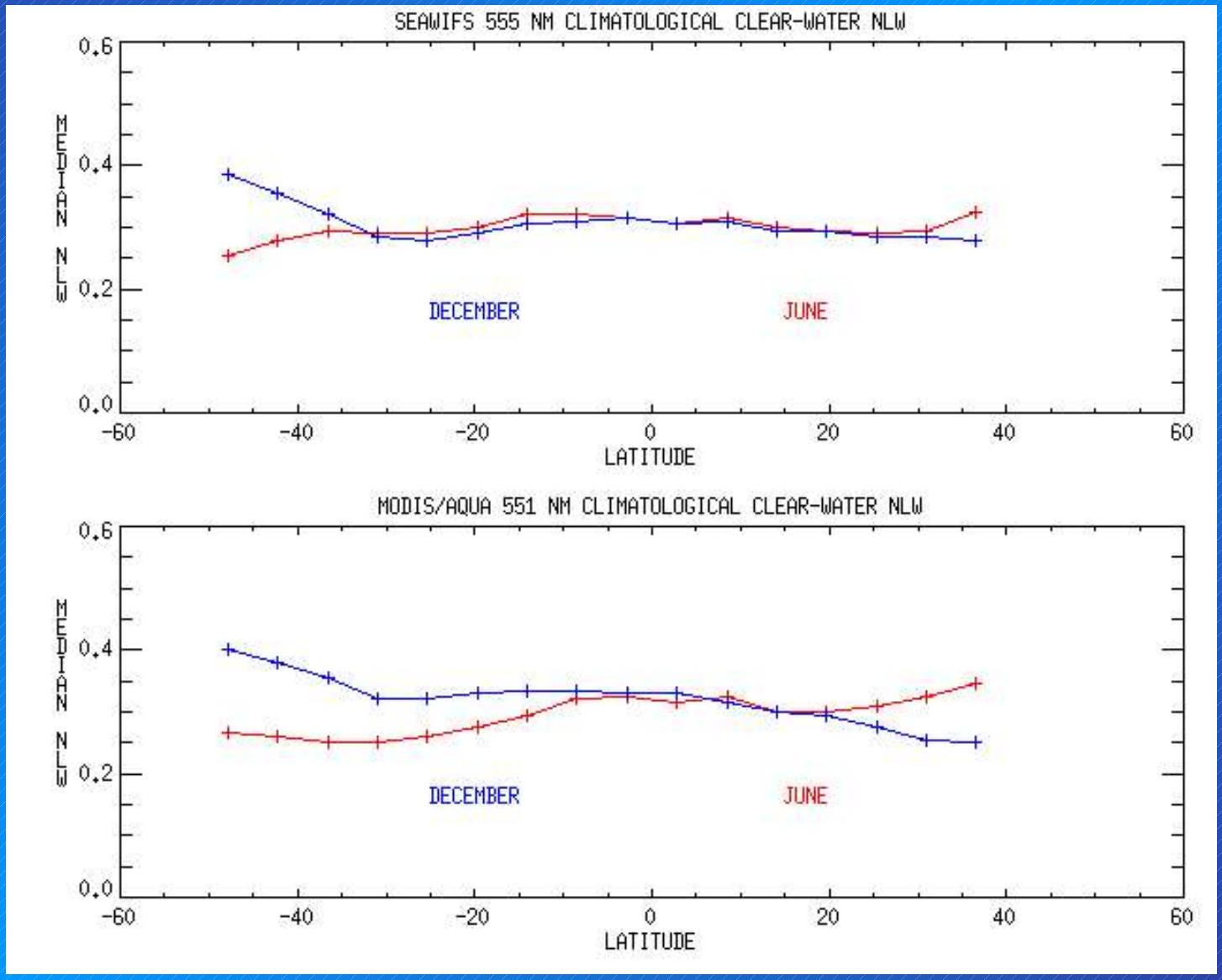
Southern Hemisphere still exhibits a distinct annual cycle in nLw ratios.



SeaWiFS/MODIS Seasonal Meridional Lwn Trends



SeaWiFS/MODIS Seasonal Meridional Lwn Trends

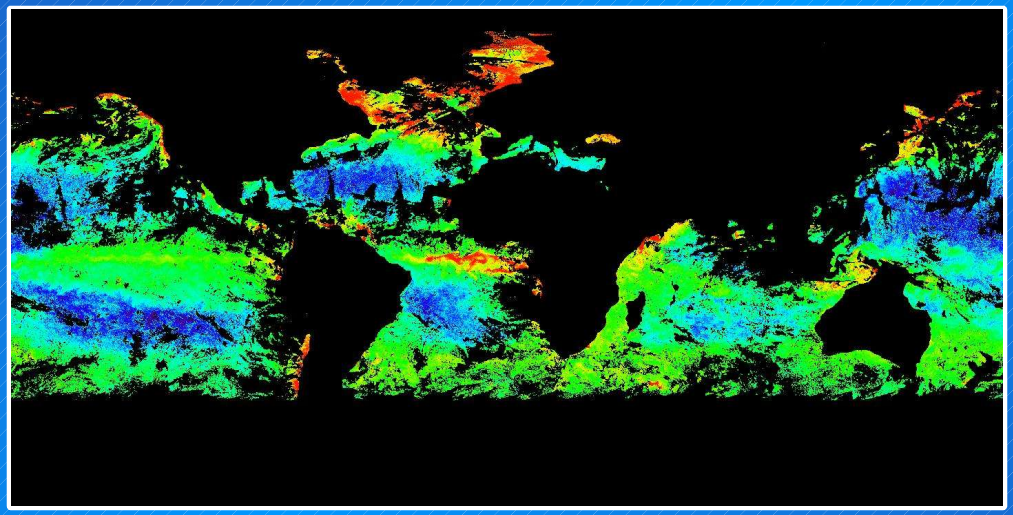


SeaWiFS & MODIS 4-Day Deep-Water Chlorophyll Images

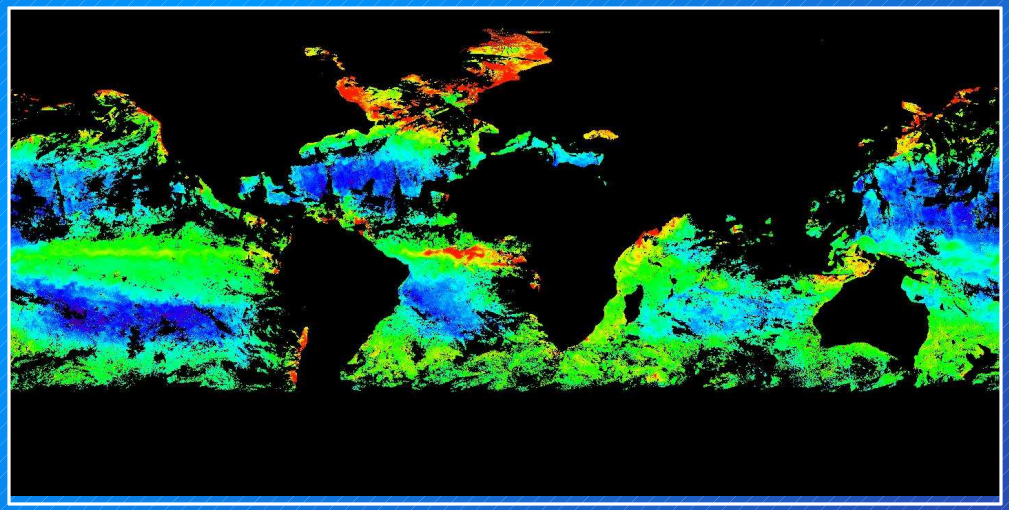
4 day composites, Summer 2002

0.01-1 mg/m^3

SeaWiFS



MODIS
(current operational processing)



The PhyLM Mission

NPP/VIIRS

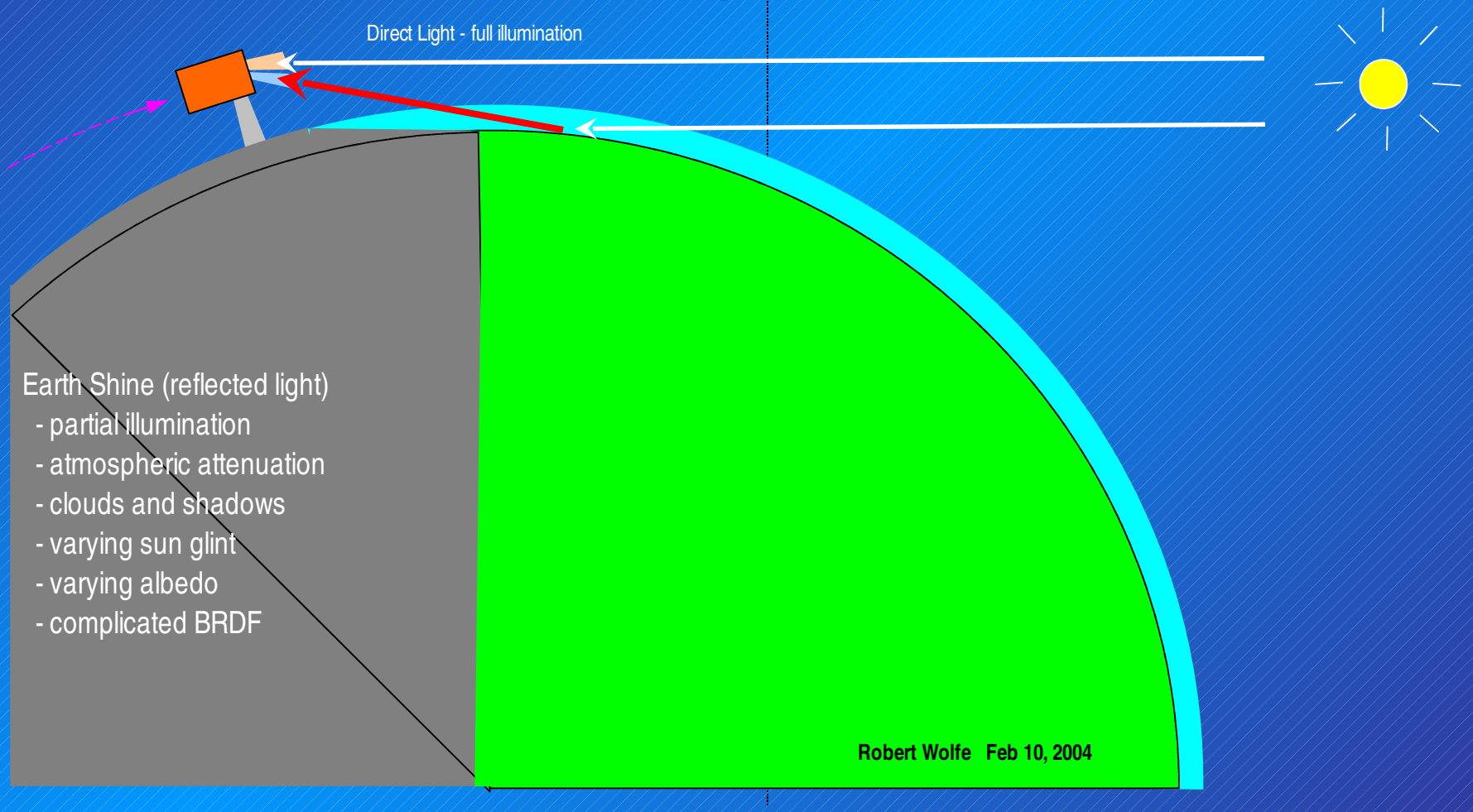
- **Sensor Design**
  - SeaWiFS-like rotating telescope
  - MODIS-like focal plane arrays
  - No polarization scrambler
  - Solar diffuser with stability monitor
  - 7 OC bands (412, 445, 488, 555, 672, 746, 865 nm)
- **Sensor Status**
  - Focal planes recently redesigned due to electronic crosstalk
  - Flight Unit weeks behind schedule
- **Mission Status**
  - 4 instruments: VIIRS, CrIS, ATMS, OMPS
  - Launch scheduled for late 2006
- **Ocean Color Concerns**
  - Solar diffuser Earth shine contamination
  - Limited lunar calibration
  - Incomplete prelaunch sensor calibration & characterization
  - Post-launch sensor diagnostic capability

VIIRS On-orbit Calibration Issues: Solar Diffuser

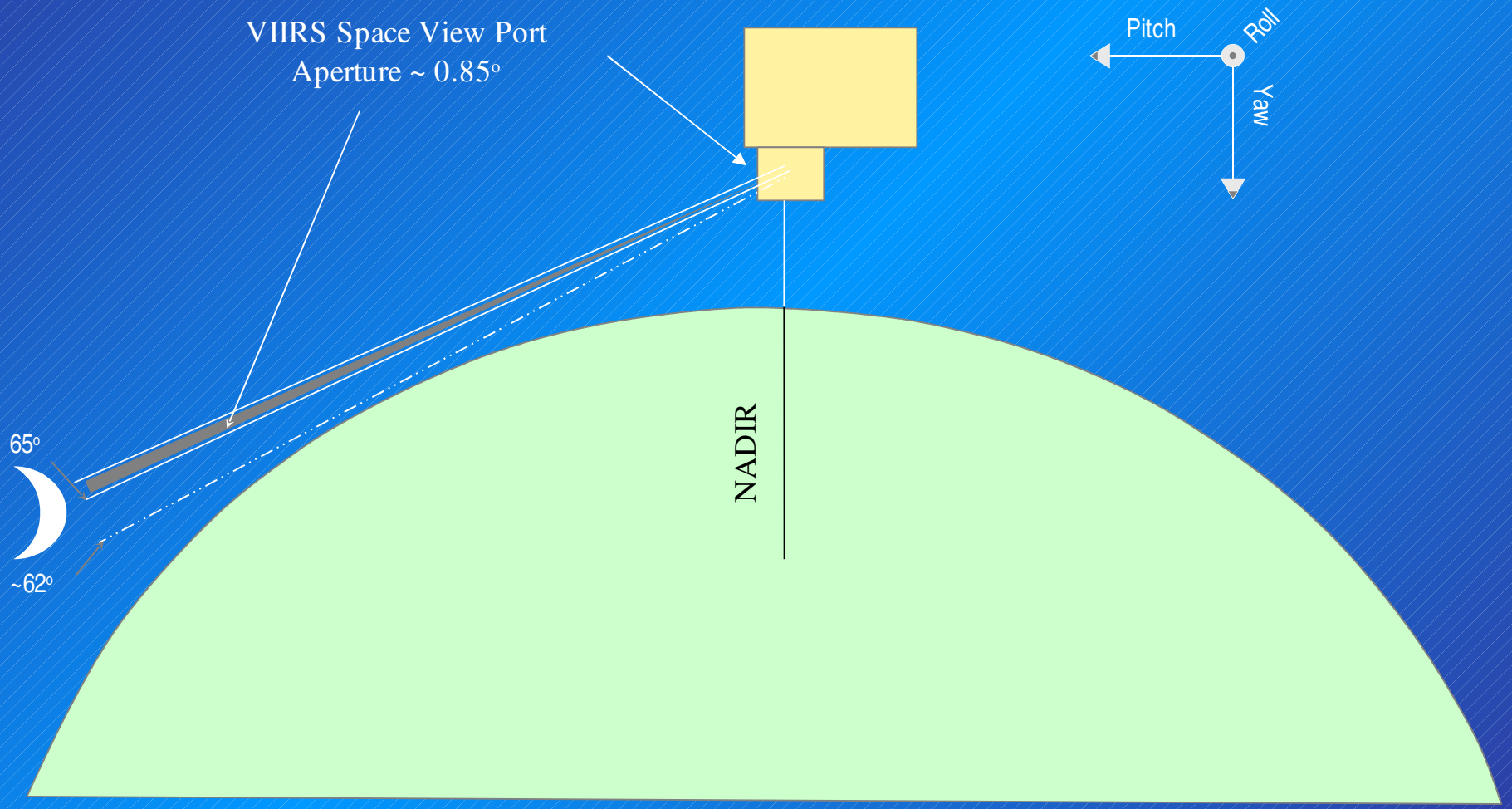
- The geometry of the SD, and the timing of the calibrations (close to the polar crossing), can result in sunlight reflecting off the Earth and onto the diffuser. The reflection occurs at high angles of incidence and in regions with high albedo (ice or open water).

- This effect has been confirmed for MODIS by both geometric modeling and actual data analysis (R. Wolfe).

- Extensive modeling for VIIRS (S. Mills) shows specular component is larger than for MODIS.



VIIRS On-orbit Calibration Issues: Lunar Calibration



Recommendation: Optimize lunar calibrations by rolling the spacecraft to collect data at constant 55° phase angle.

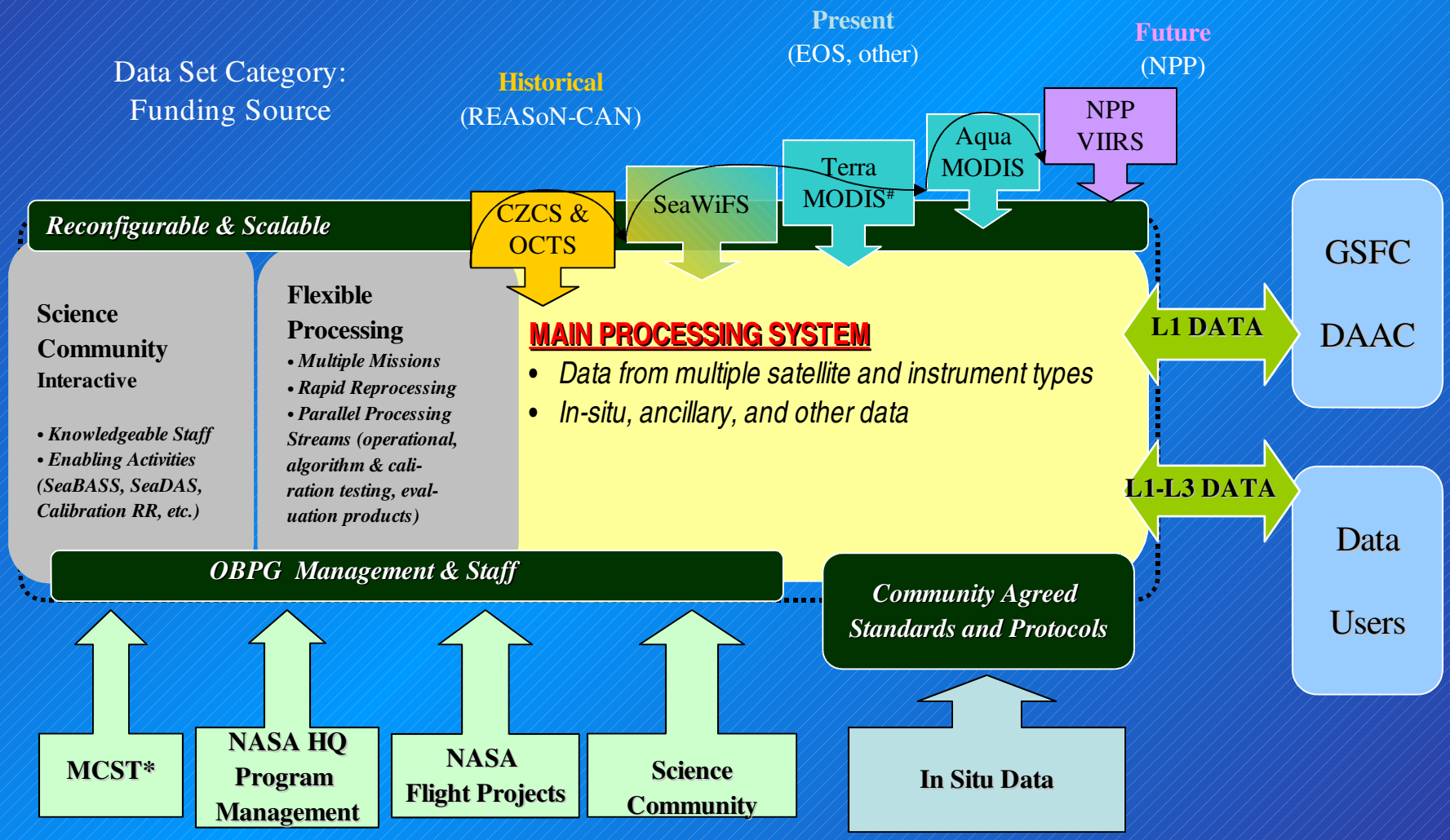
VIIRS OC Recommendations: August

- **Solar Diffuser: Primary on-orbit calibration source**
  - Complete solar diffuser & stability monitor system level characterization
  - Elimination of Earth shine
    - Additional of a shield
- **Robust system level sensor characterization**
  - Spectral out-of-band response
  - Polarization sensitivity
  - Temperature sensitivity
  - Electronic cross-talk
    - New focal plane design much better
  - Stray-light characterization
    - Includes point spread function
  - Sensor linearly (e.g., across gain shifts)
- **Lunar calibration**
  - Perform slight roll maneuvers for 55º phase angle observations
- **Sensor ray-trace model**
  - Need optical design and coating prescriptions

Update:
Optical prescriptions available
Earth shine issue being pursued at IPO
New focal planes not installed on EDU

BACK-UP SLIDES

Ocean Biology Processing System



* MODIS Characterization Support Team (NASA/GSFC)
\# Terra MODIS OC processing suspended in Jan. 2004

Ocean Color Data Processing, Cal/Val, & Algorithm Development Functions

Algorithm Development & Field Data Collection

- Algorithms
  - Atmospheric correction
  - Quality masks & flags
  - Bio-optical
  - Sea surface temperature
  - Data merger (time/space)
- Bio-optical & atmos. field data collection
- Science leadership/coord
- New product specification
  - Definition/Development
  - Resource/Performance Evaluation
  - Selection

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Sensor Calibration & Product Validation

- I/F with mission operations
  - Cal. strategies, schedules, and operations plans
- Round robins
  - Visible
  - Thermal IR
- Vicarious calibration
  - Data: MOBY, AERONET, ship
  - Data Analysis
- Protocol development for measurement and analysis
  - SST, OC, Atm. Corr.
- Instrument technology evaluation
- I/F with sensor/satellite mission calibration and characterization activities/groups (e.g., NCST)
- Q/C & archive in-situ data (product validation & algo. dev.)
- Product validation
  - Discipline Processing Group
  - Science Team

Data Processing

- I/F with IPO & NOAA
- I/F with NPP/CDMS
- Maintenance and infrastructure improvements within GSFC
- Climate data processing
  - Continuity data sets & data merger (historical/existing)
  - VIIRS
    - Simulated data develop.
    - End-to-end testing
- Data storage
  - RDRs, Level-1, EDRs
  - Ocean & ancillary data
- Algorithm testing & implementation (inc. new products)
- Quality control/assurance
  - Continuity data sets
  - VIIRS

Distribution & Outreach

- Real-time ground station support
- Data archive & distribution
- Community processing S/W (SeaDAS)
- Data Synthesis
- Science campaign support
  - Autonomous support
  - User services
  - Interface and data processing capability
  - RT data distribution
- Publication support
  - Science writer/editor
- Education outreach

Functions supported under NRAs
Discipline processing functions
Functions assumed by a NASA flight project, HQ, or another agency (NOAA)