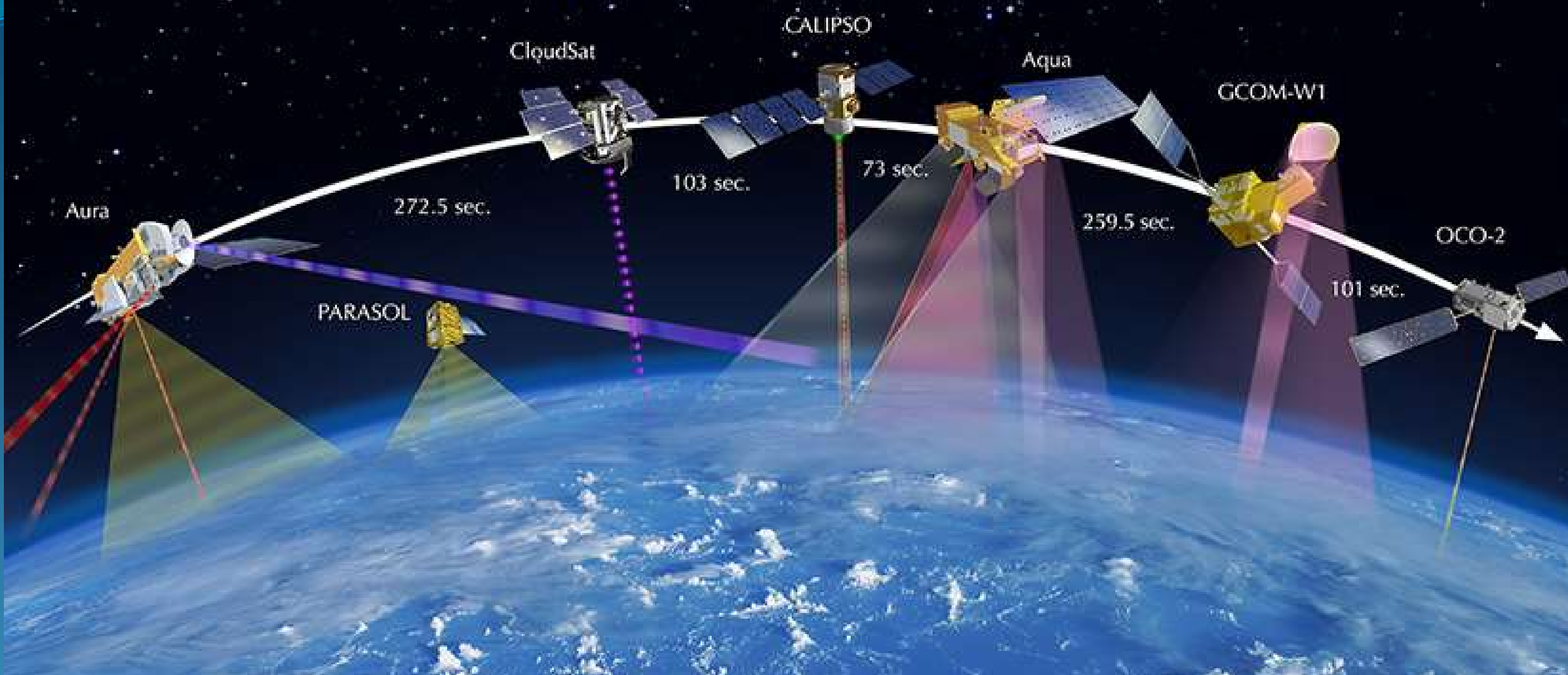
MET 611 – Satellite Data Applications



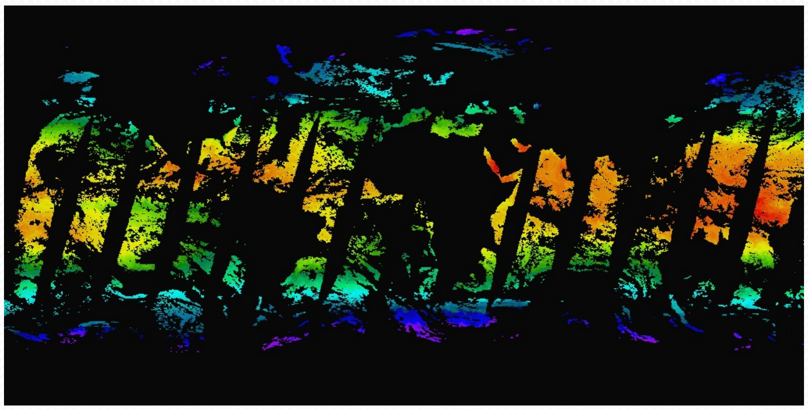
MODIS Ocean Products Introduction (SST, Ocean Color and Chlorophyll)

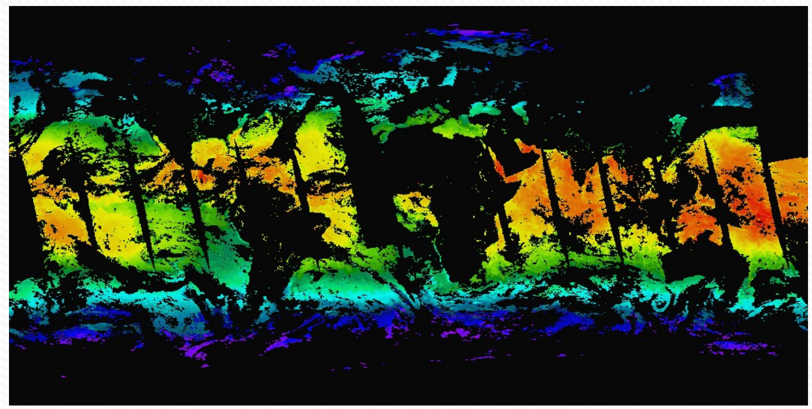
Jennifer D. S. Griswold

MODIS Instrument Considerations

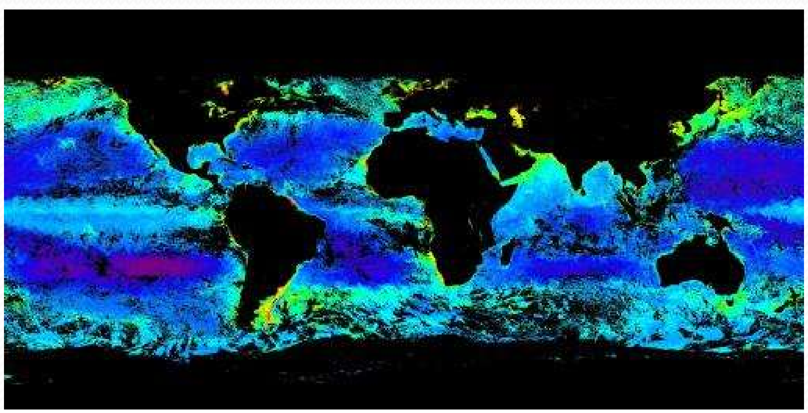
- MODIS Ocean Product algorithms are based on heritage instruments.

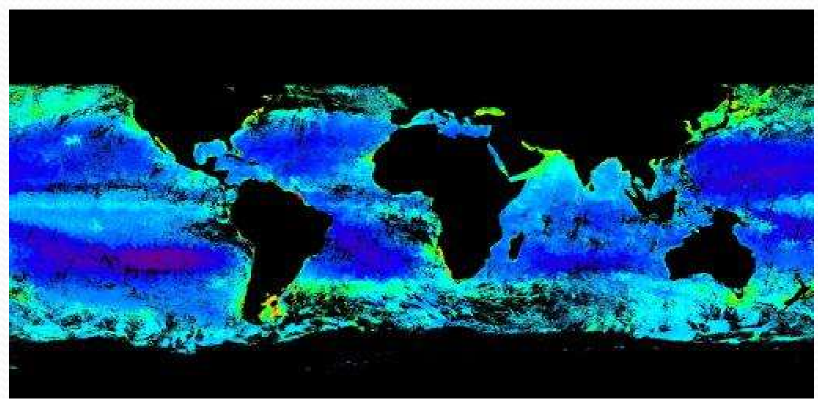
AVHRR Pathfinder SST Nov 1, 2000-306 Night (24 hours) ***MODIS*** Thermal SST





SeaWiFS Chl-Oc4v4 Nov 1, 2000 Weekly Composite ***MODIS*** Chl-MODIS

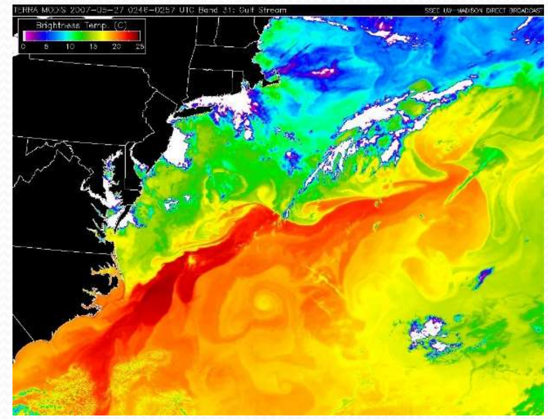




MODIS Comparison to AVHRR, SeaWiFS

- 12 bit digitization vs 10 bit → improved precision
- Lower noise detectors → subtle features better resolved
- Global 1 km data stream vs 4km → larger data sets but spatial features better resolved
- Additional spectral channels → improved and additional product algorithms, better quality determination
- Equatorial crossing time → significant impact on atmospheric correction
- **Shared calibration sources:**
  - **Optical** - MOBY buoy
  - **Infrared** - MAERI interferometer, buoys

Why does MODIS oceans have so many files and why is everything so BIG!

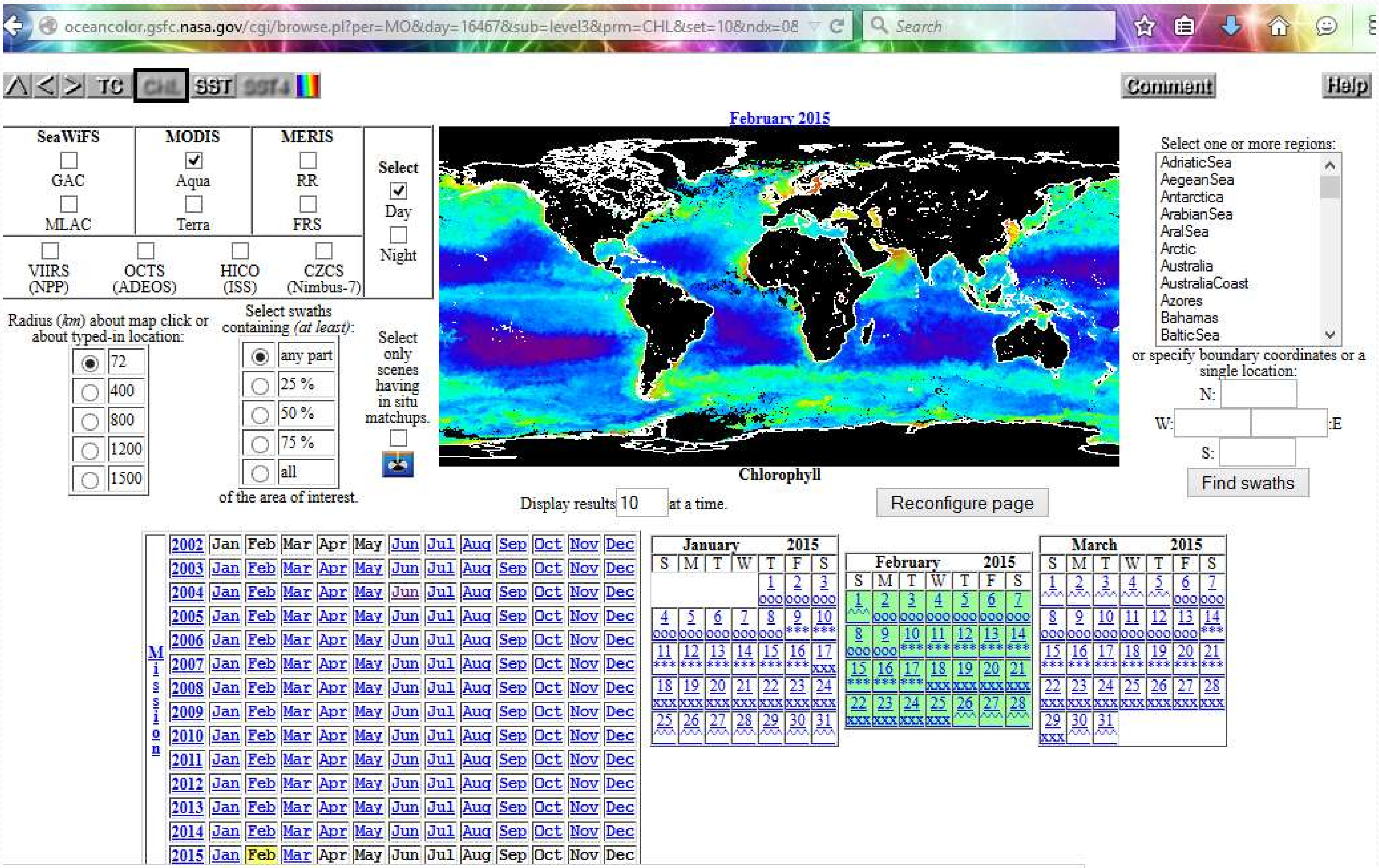


- 1 km global resolution every day
- Many more products
- Meeting the needs of a diverse user community (pleasing all the people all the time)
  - Pretty pictures/quick looks; Medium quality, low resolution
  - Tracking fronts and features; all pixels, high resolution
  - High quality climate data; High quality, medium resolution
  - Modelers; high quality, various projections not maps
  - Algorithm developers; underlying raw values

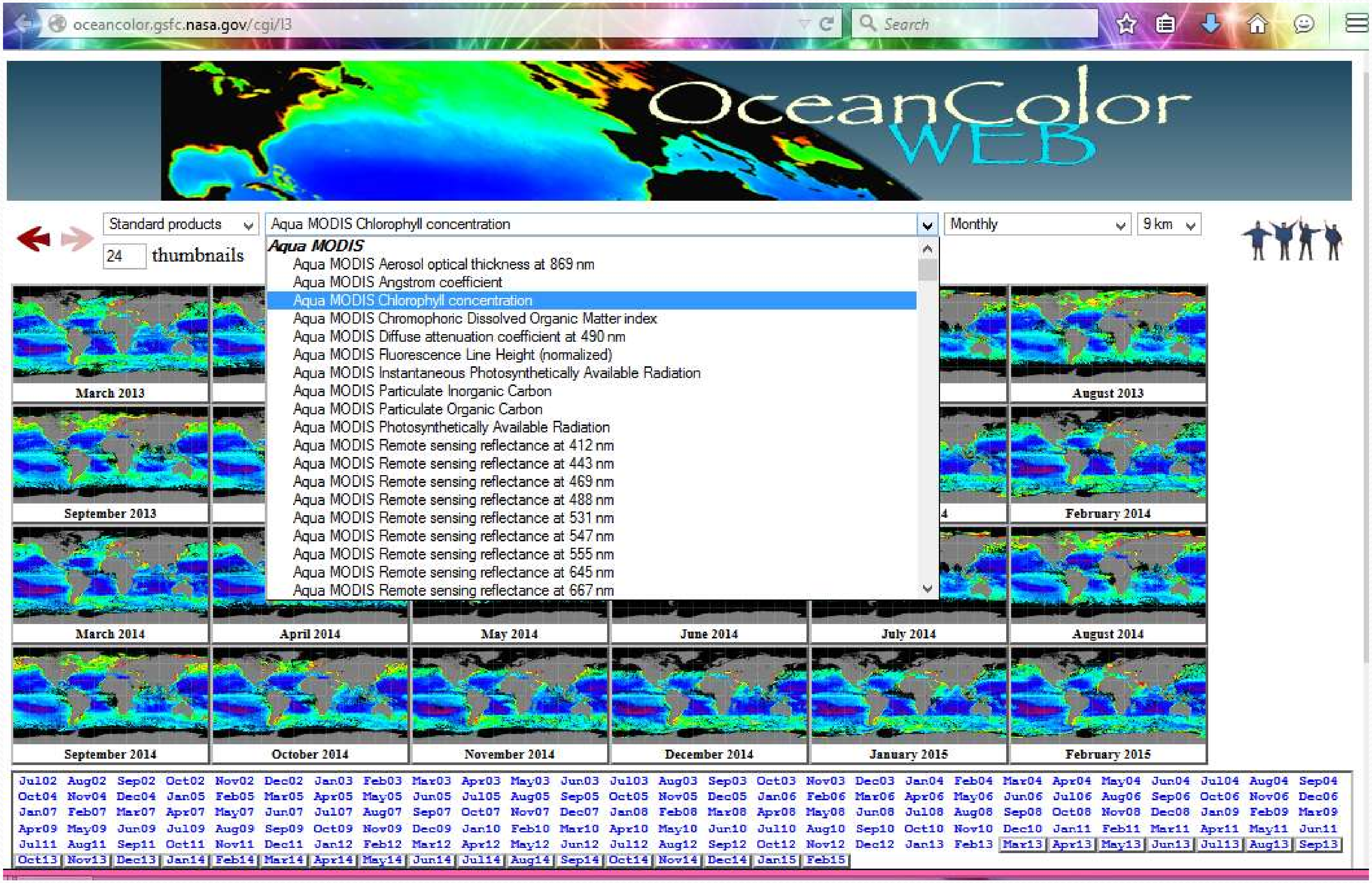
Where to get **data** and more **information**

https://oceancolor.gsfc.nasa.gov/

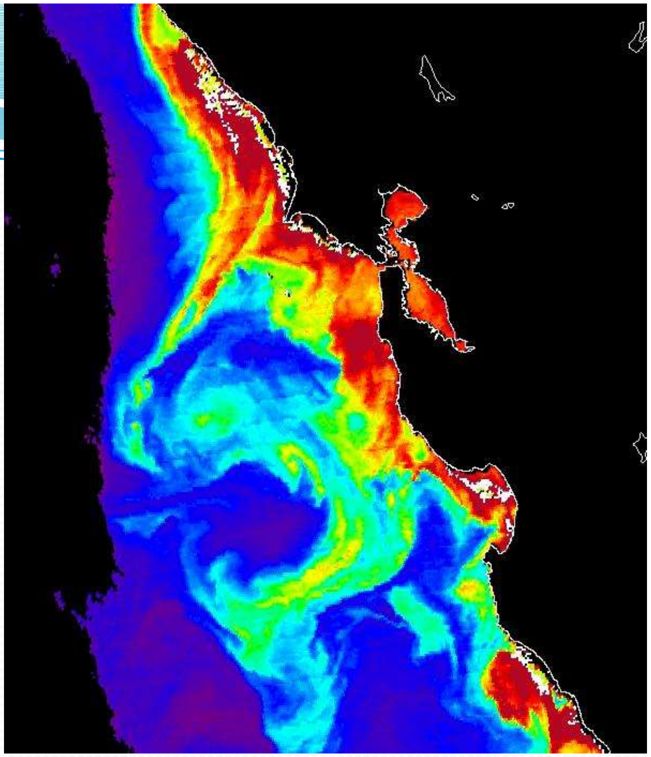
L1 and L2 Browser



L3 Browser


oceancolor.gsfc.nasa.gov/cgi/l3
Search
OceanColor WEB
Standard products
24 thumbnails
Aqua MODIS Chlorophyll concentration
Monthly
9 km
Aqua MODIS
Aqua MODIS Aerosol optical thickness at 869 nm
Aqua MODIS Angstrom coefficient
Aqua MODIS Chlorophyll concentration
Aqua MODIS Chromophoric Dissolved Organic Matter index
Aqua MODIS Diffuse attenuation coefficient at 490 nm
Aqua MODIS Fluorescence Line Height (normalized)
Aqua MODIS Instantaneous Photosynthetically Available Radiation
Aqua MODIS Particulate Inorganic Carbon
Aqua MODIS Particulate Organic Carbon
Aqua MODIS Photosynthetically Available Radiation
Aqua MODIS Remote sensing reflectance at 412 nm
Aqua MODIS Remote sensing reflectance at 443 nm
Aqua MODIS Remote sensing reflectance at 469 nm
Aqua MODIS Remote sensing reflectance at 488 nm
Aqua MODIS Remote sensing reflectance at 531 nm
Aqua MODIS Remote sensing reflectance at 547 nm
Aqua MODIS Remote sensing reflectance at 555 nm
Aqua MODIS Remote sensing reflectance at 645 nm
Aqua MODIS Remote sensing reflectance at 667 nm
March 2013
August 2013
September 2013
February 2014
March 2014
April 2014
May 2014
June 2014
July 2014
August 2014
September 2014
October 2014
November 2014
December 2014
January 2015
February 2015
Jul02 Aug02 Sep02 Oct02 Nov02 Dec02 Jan03 Feb03 Mar03 Apr03 May03 Jun03 Jul03 Aug03 Sep03 Oct03 Nov03 Dec03 Jan04 Feb04 Mar04 Apr04 May04 Jun04 Jul04 Aug04 Sep04
Oct04 Nov04 Dec04 Jan05 Feb05 Mar05 Apr05 May05 Jun05 Jul05 Aug05 Sep05 Oct05 Nov05 Dec05 Jan06 Feb06 Mar06 Apr06 May06 Jun06 Jul06 Aug06 Sep06 Oct06 Nov06 Dec06
Jan07 Feb07 Mar07 Apr07 May07 Jun07 Jul07 Aug07 Sep07 Oct07 Nov07 Dec07 Jan08 Feb08 Mar08 Apr08 May08 Jun08 Jul08 Aug08 Sep08 Oct08 Nov08 Dec08 Jan09 Feb09 Mar09
Apr09 May09 Jun09 Jul09 Aug09 Sep09 Oct09 Nov09 Dec09 Jan10 Feb10 Mar10 Apr10 May10 Jun10 Jul10 Aug10 Sep10 Oct10 Nov10 Dec10 Jan11 Feb11 Mar11 Apr11 May11 Jun11
Jul11 Aug11 Sep11 Oct11 Nov11 Dec11 Jan12 Feb12 Mar12 Apr12 May12 Jun12 Jul12 Aug12 Sep12 Oct12 Nov12 Dec12 Jan13 Feb13 Mar13 Apr13 May13 Jun13 Jul13 Aug13 Sep13
Oct13 Nov13 Dec13 Jan14 Feb14 Mar14 Apr14 May14 Jun14 Jul14 Aug14 Sep14 Oct14 Nov14 Dec14 Jan15 Feb15

MODIS Ocean Products



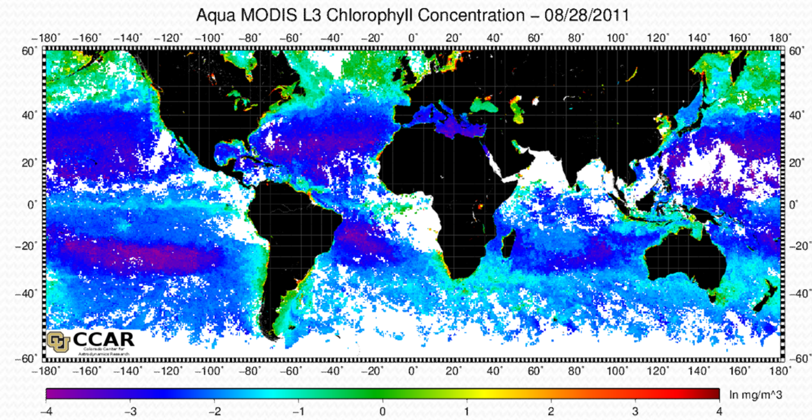
- **MODIS Instruments:**
  - Terra (1030 morning), MO*
  - Aqua (1330 afternoon) MY*
- **Resolution:**
  - **Spatial:**
    - Level 2 – 1 km swath , ~2030 km x 1354 km
    - Level 3 – 4 km, 36km, 1 deg [all products are global]
  - **Temporal Resolution:**
    - Level 2 - 5 minute granule;
    - Level 3 - daily, 8 day week, monthly, yearly
- **Other data sets:**

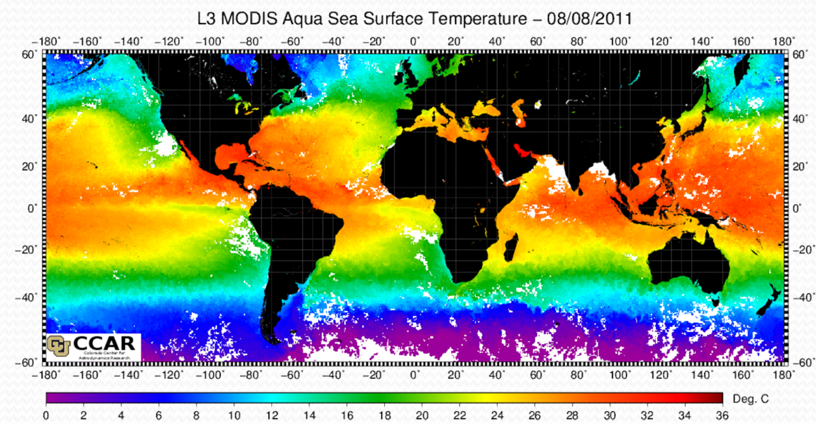
  - SST matchups database (kkilpatrick@rsmas.miami.edu)
  - ocean color diagnostic data sites

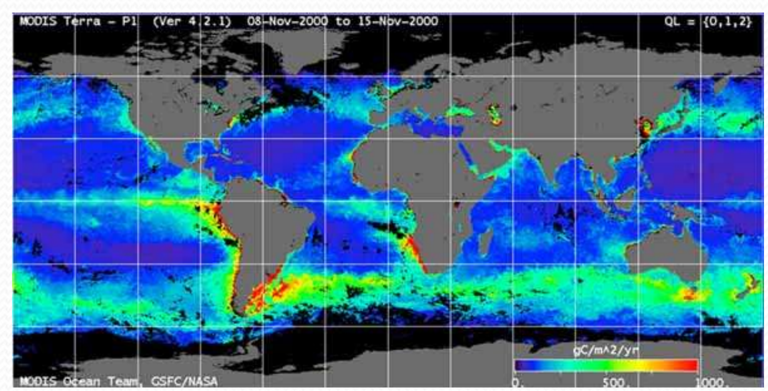
MODIS Ocean data products

- There are **86 ocean parameters available in over 100 categories of MODIS Ocean data types** archived by (and may be obtained from) the NASA Goddard Distributed Active Archive Center.

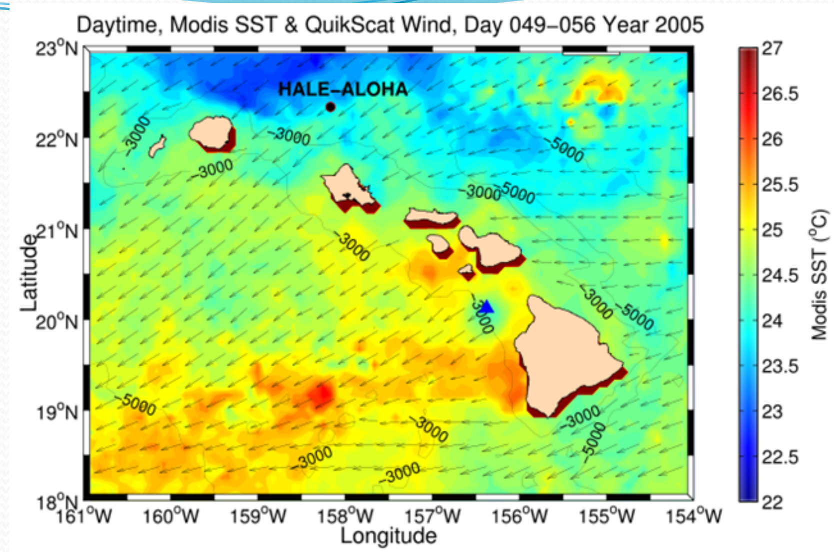
- **The three basic groupings of MODIS ocean data parameters are:**
  - ocean color
  - sea surface temperature
  - ocean primary production



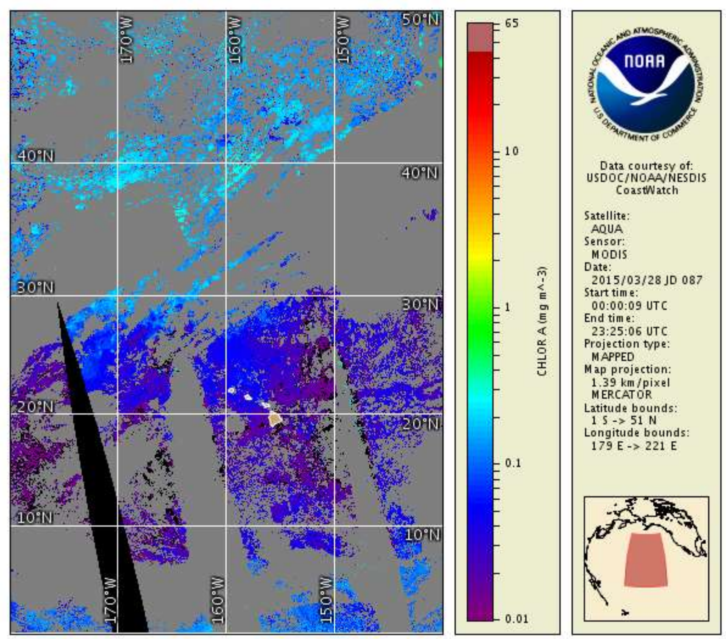




Parameters



- **36 Ocean Color** parameters
- **3 Sea Surface Temperature** parameters

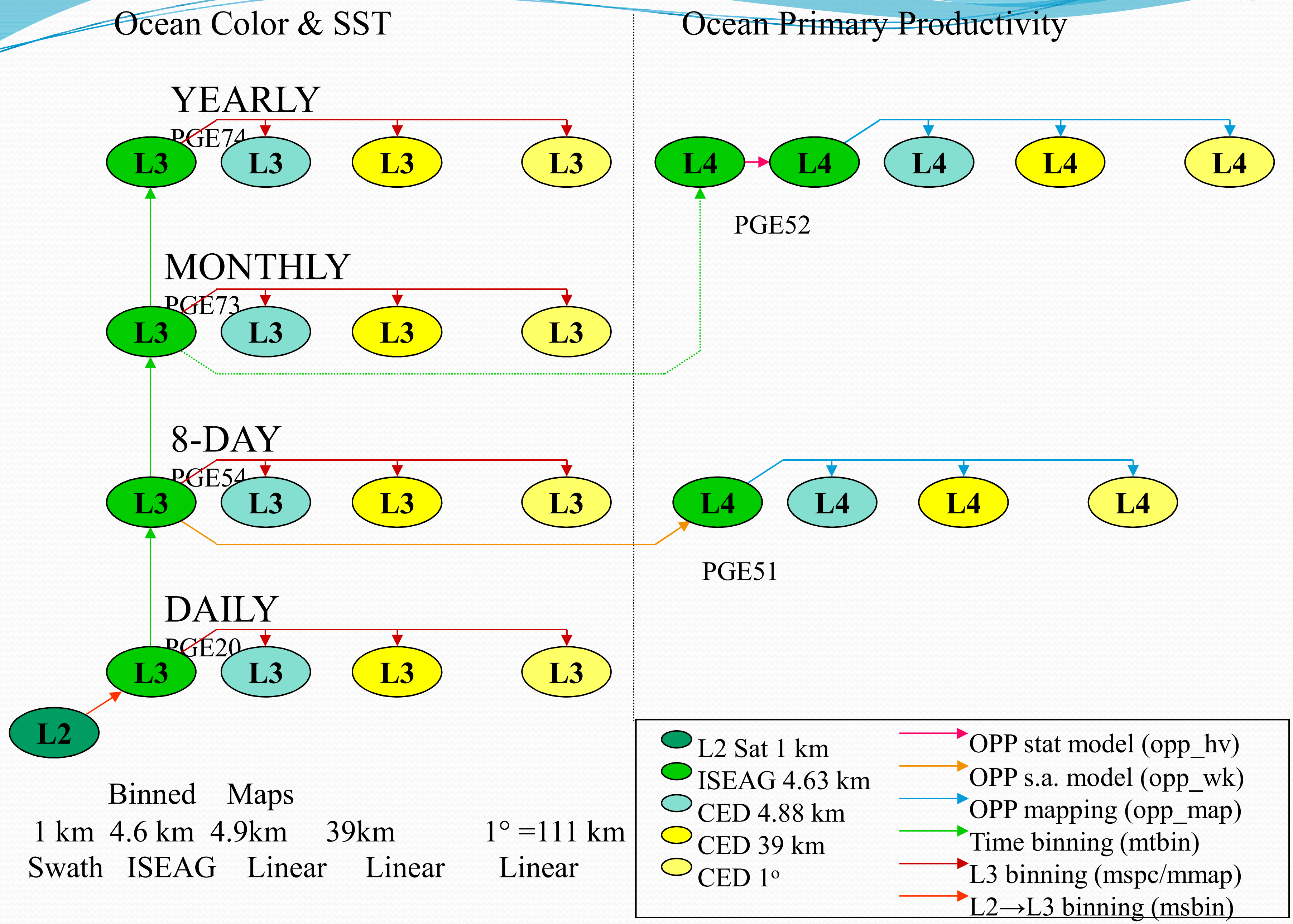


- **8 Primary Productivity** parameters
  - (including 2 Primary Production indices)
- **38 Quality Control** parameters

Processing Levels

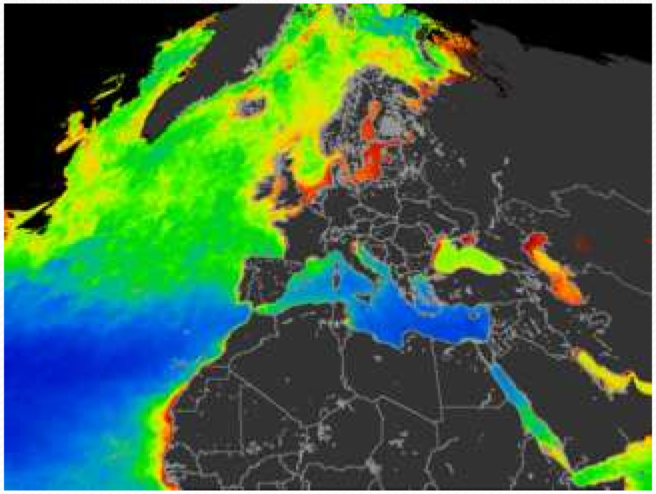
- **Level 1 - Unprocessed top of the atmosphere radiance/reflectance**
  - At 1-km spatial resolution
  - 5 minute granule time resolution; 288 granules/day
- **Level 2 swath data**
  - At 1-km spatial resolution
  - 5 minute granule time resolution; color 144/day, SST 288/day
- **Level 3 global binned or mapped data**
  - Spatial resolutions of 4.63km, 36km, or 1 degree
  - Time resolutions of one day, 8 days, a month or a year.
  - The Binned data use the integerized sinusoidal equal area *grid*
  - The Standard Mapped Images are in a cylindrical Equidistant Projection Centered at 0,0.

DATA BINNING PATHWAYS



Level 4 Productivity

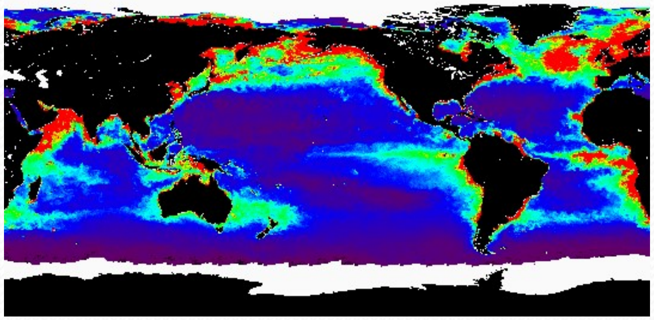
- Ocean primary production data is available only as binned or mapped Level 4 (i.e. L4) data.



- Ocean Productivity outputs are averaged weekly or yearly.

- Like the L3 data, the L4 data is organized spatially as either 4km ISEAG gridded bins or as maps using a Cylindrical Equidistant Projection.

- The mapped data products are available in a choice of 4km, 36km, or 1 degree spatial resolutions.



- More than one model is used for deriving these data products and some quality statistics are available.

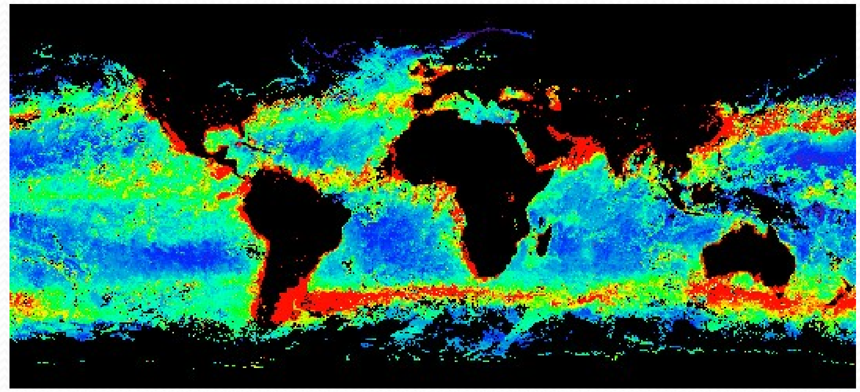
L2 filenames

2 night and 6 day ocean files for each 5 minutes

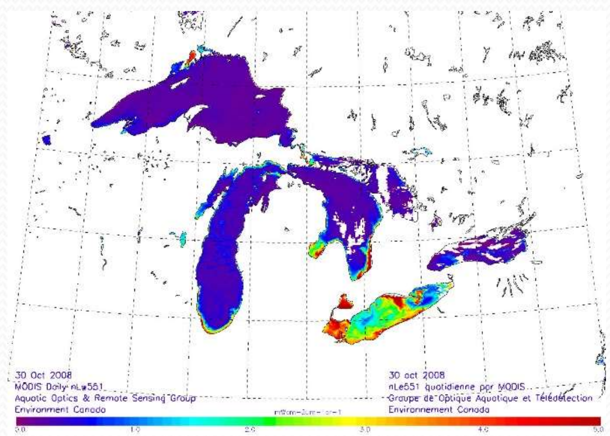
- M*DCL2 - water leaving radiance products
- M*DCL2A - derived products group 1
- M*DCL2B- derived products group 2
- M*DOCQC - ocean color QC parameters
- M*D28L2 -SST products
- M*D28QC- SST QC parameters
- File size ~80-100MB/file
  - * = “Y” for AQUA or “O” for Terra

Water leaving radiance products

- M*DOCL2 water leaving radiance (parameters 1-12)
  - 7 bands:
    - nLw412
    - nLw443
    - nLw488
    - nLw531
    - nLw551
    - nLw667
    - nLw678



  - Tau 865 Aerosol Optical thickness 865
  - Epsilon 765/865
  - Aerosol model 1
  - Aerosol model 2
  - Epsilon of clear water



nLw = water leaving radiance

The water-leaving radiance is defined as the upwelling radiance just above the sea-surface.

Derived products group 1

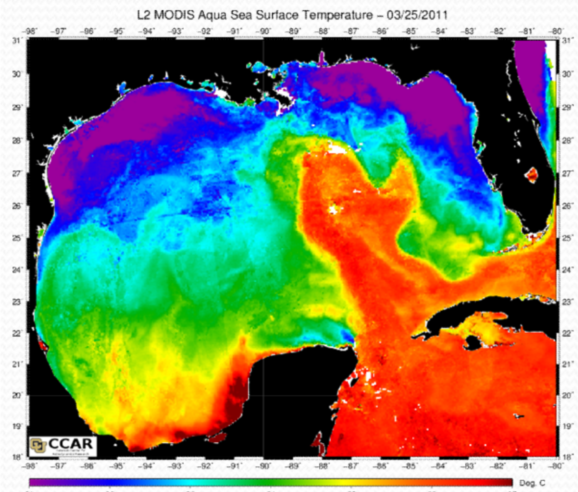
- **M*DOCL2A- 13 products (parameters 13-25)**
  - **CZCS_pigment Chlorophyll-a + pheopigment (fluorometric,empirical)**
  - **Chlor_MODIS Chlorophyll-a concentration (HPLC, empirical)**
  - **Pigment_c1_total Total pigment concentration (HPLC, empirical)**
  - **Chlor_flur_ht Chlorophyll fluorescence line height**
  - **Chlor_fl_base Chlorophyll fluorescence baseline**
  - **Chlor_fluor_effic Chlorophyll fluorescence efficiency**
  - **Susp-solids-conc Total suspended matter concentration in ocean**
  - **Cocco_pigment_conc Pigment concentration in coccolithophore blooms**
  - **Cocco_conc_detached Detached coccolithophore concentration**
  - **Calcite_conc Calcite concentration**
  - **K_490 Diffuse attenuation coefficient at 490 nm**
  - **Phycoeryth_conc Phycoerythrobilin concentration**
  - **Phycou_conc Phycourobilin concentration**

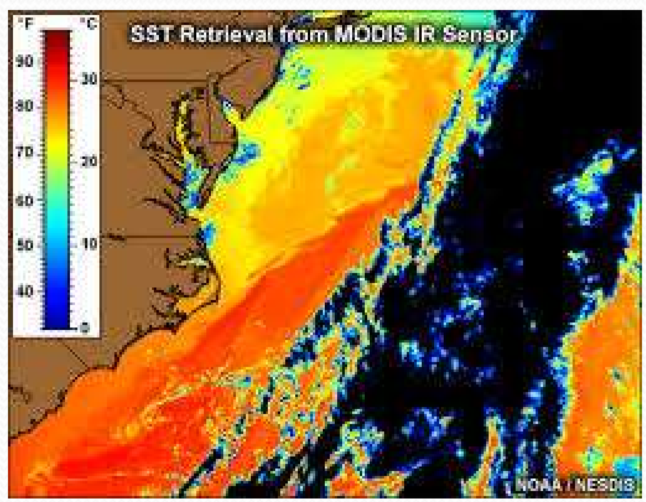
Derived products group 2

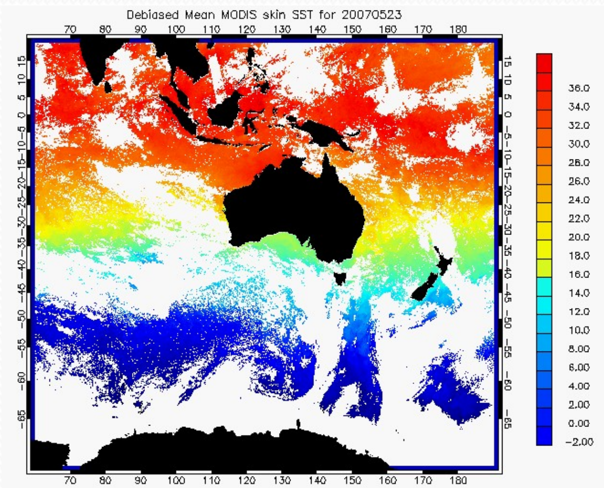
- M*DOCL2A -11 products (parameters 26-36)
  - **chlor_a2** **Chlorophyll-a concentration (SeaWiFS analog)**
  - **chlor_a3** **Chlorophyll-a concentration (semianalytic)**
  - **ipar** **Instantaneous photosynthetically available radiation**
  - **arp** **Instantaneous absorbed radiation by phytoplankton for fluorescence**
  - **absorp_coef_gelb** **Gelbstoff absorption coefficient at 400 nm**
  - **chlor_absorb** **Phytoplankton absorption coefficient at 675 nm**
  - **tot_absorb_412** **Total absorption coefficient at 412 nm**
  - **tot_absorp_443** **Total absorption coefficient at 443 nm**
  - **tot_absorb_488** **Total absorption coefficient at 488 nm**
  - **tot_absorb_531** **Total absorption coefficient at 531 nm**
  - **tot_absorb_551** **Total absorption coefficient at 551 nm**

SST L2 products

- M*28L2 - 3 products (parameters 36 to 40)
  - SST_D1 - Sea surface temperature (daytime), 11 um
  - SST_D2 - <u>Do not use</u> Sea surface temperature (daytime), 4 um
  - SST_N1 - Sea surface temperature (nighttime), 11um
  - SST_N2 -Sea surface temperature (nighttime), 4um







L2 Ocean color QC file

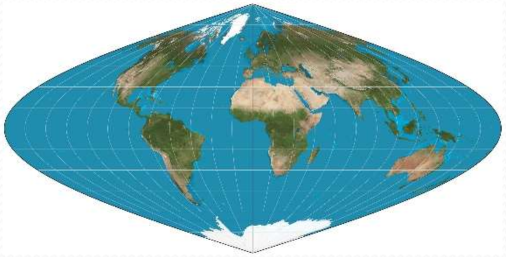
- M*DOCQC -
  - U_Wind m/s
  - V_Wind m/s
  - Pressure mBar
  - Humidity kg/m2
  - Ozone dobson
  - Latitude degree
  - Longitude degree
  - SolarZenith angle
  - SolarAzimuth angle
  - SatelliteZenith angle
  - SatelliteAzimuth angle
  - nLw670 W/m2/um/sr
  - Aerosol radiance 765 W/m2/um/sr
  - Rayleigh radiance 443 W/m2/um/sr
  - Glint radiance W/m2/um/sr
  - Whitecap radiance W/m2/um/sr

L2 SST QC file

- M*D28QC
  - D1,N1 Channel 20 brightness temperature degrees C
  - D2.N2 Channel 22 brightness temperature degrees C
  - D3,N3 Channel 23 brightness temperature degrees C
  - D4,N4 Channel 31 brightness temperature degrees C
  - D5,N5 Channel 32 brightness temperature degrees C
  - D6,N6 Channel 20 radiance W/m2/um/sr
  - D7,N7 Channel 22 radiance W/m2/um/sr
  - D8,N8 Channel 23 radiance W/m2/um/sr
  - D9,N9 Channel 31 radiance W/m2/um/sr
  - D10,N10 Channel 32 radiance W/m2/um/sr

L3 Binned global files

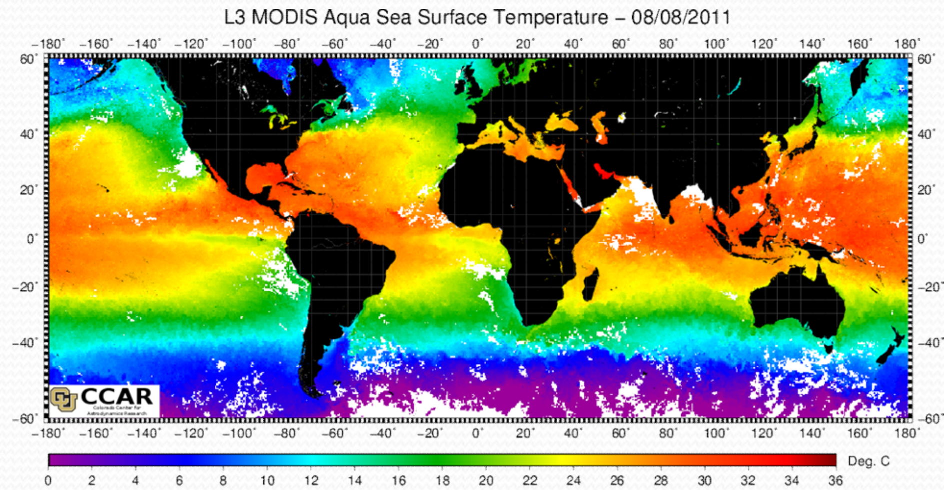
- Binned files M*DOC{D,W,M,Y}{prod#}.parameter M*D28{D,W,M,Y}{prod#}.parameter



- Only available at **4km** resolution
- **Intergerized Sinusoidal Equal Area Grid (ISEAG)**
- **Only bins with data values are present**
  - land bins and bins with no data are not in the files
  - Each file is self contained with sums, weights and quality levels, and all flags
  - Useful if you need to do statistics or your own averaging/compositing algorithms.
  - File size ~640MB

L3 Mapped Files

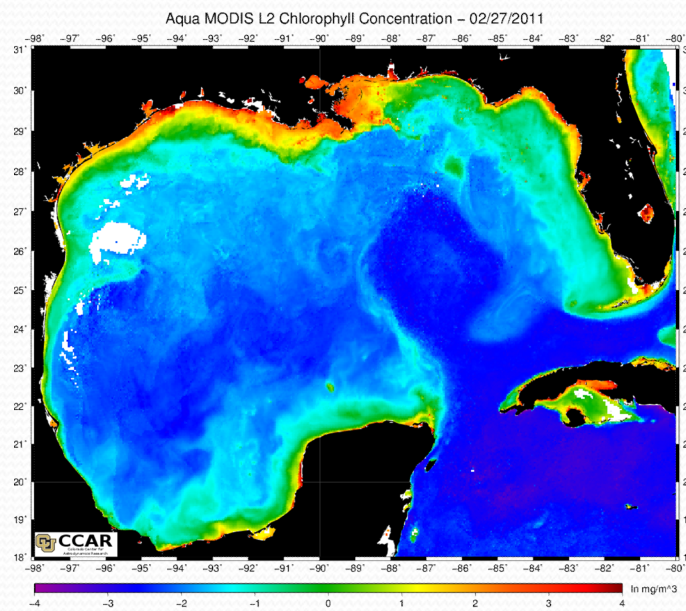
- Various time and space resolutions
- Cylindrical equidistant projection
- All bins present, including fill values (255) for land and missing data



- 8 map files for each product
  - Mean, Count,Stdev, Common flags,Quality flags,Flag byte 1, Flag byte 2, Flag byte 3
  - Files sizes : 4km =67MB, 36km=1MB,1deg= .2MB

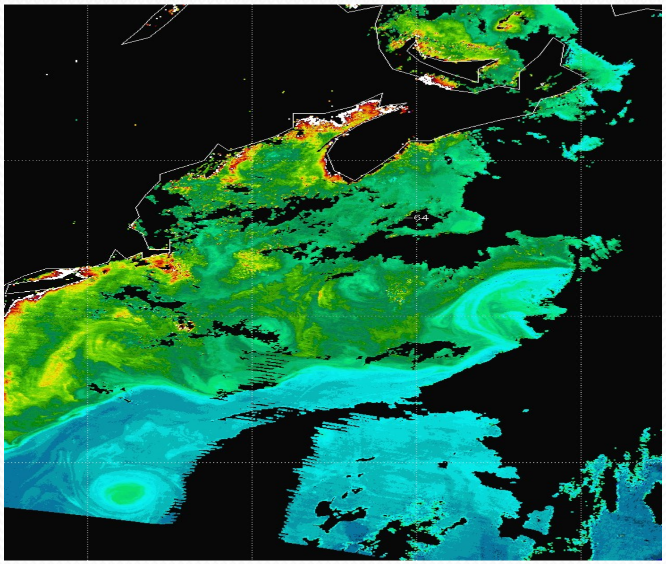
File Formats

- All Ocean products are in EOS HDF format
- Values are stored as counts
- Scaling information to convert from counts to real numbers is located in the file metadata for each parameter (SDS)
  - Scale_type
  - Slope
  - Intercept

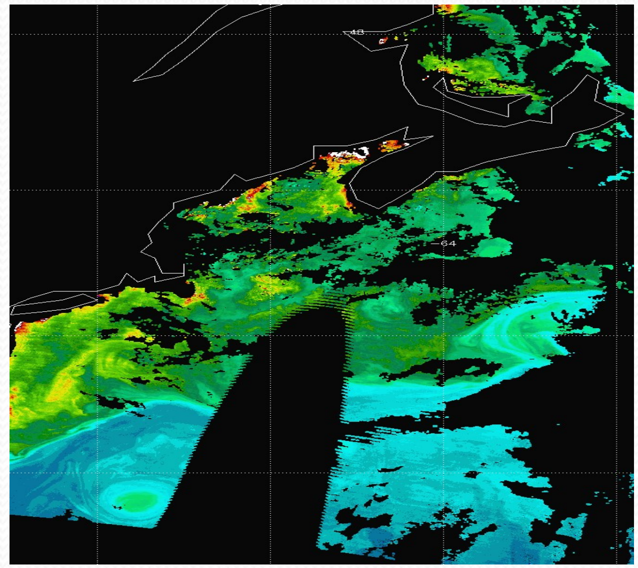


Pixel Quality Flags

QL=<=3



QL=0



Each product contains all values at all levels of quality you must filter the data for your application using the quality flag.

- Each pixel is associated with a quality level stored as a 2 bit value (0,1,2,3) in the "quality" SDS.
    - **The position of the quality level within the byte is given in the metadata attributes for each parameter ("Quality_Bits").**
    - Example: MODCL2A: Chlor_MODIS quality is in bit position 11-12, while Chlor_Fluor_ht is in position 19-20. (note: 1-based numbering convention)

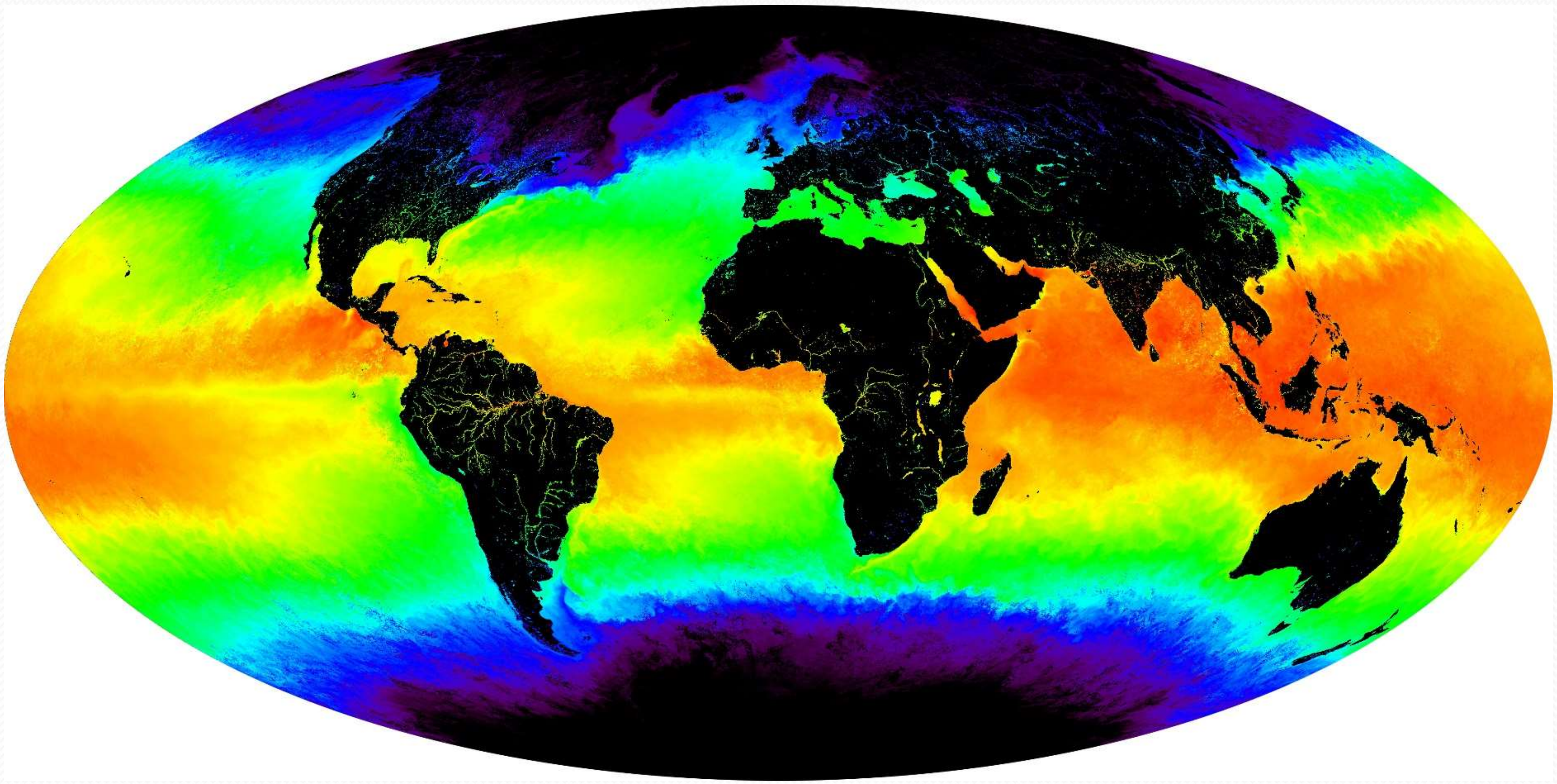
Quality level definitions

There are four quality levels

- 0=good
- 1=questionable/suspect
- 2= sun glint or possible cloud contaminated
- 3=bad, thick cloud or other failure

These levels are derived by evaluating various combinations of threshold tests common to all products and specific to individual products. Other sets of flags, known as common and product specific flags, are used to store the results of these threshold tests.

MODIS Ocean SST



SST: What wavelengths are used?

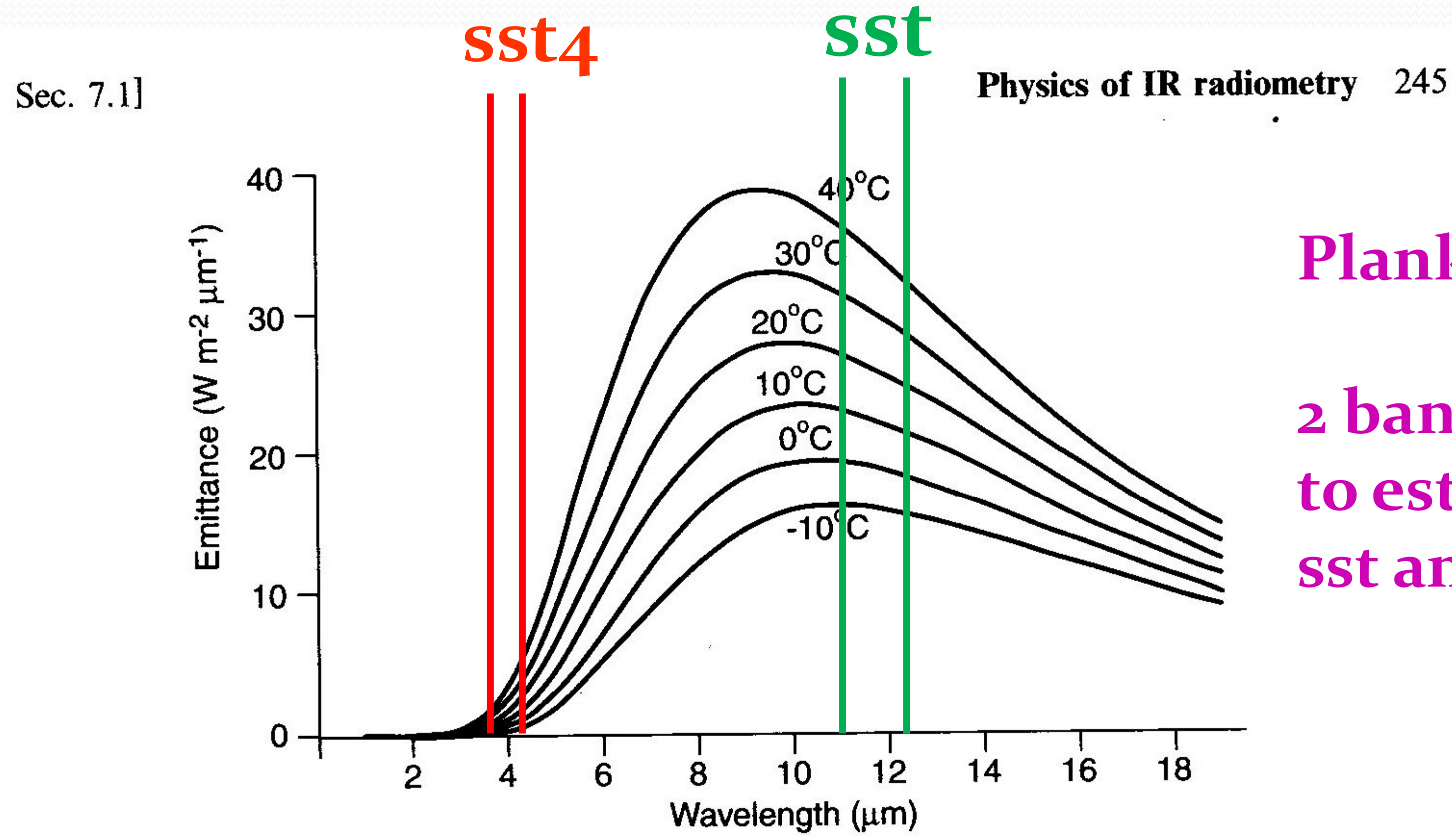


Figure 7.1. IR emission spectra of black bodies at temperatures between −10°C and 40°C.

Plank's Law

2 bands used to estimate sst and sst4

- **sst4** usable only at night (solar contributions)
- **sst** usable day and night (negligible solar contributions)

SST: What wavelengths are used?

Infrared observations of sea surface temperature

Table 7.1. *The properties of the AVHRR/3 bands and the MODIS bands used in SST algorithms*

AVHRR band	Wavelength (μm)	*NEΔT* (K)	MODIS band	Wavelength (μm)	*NEΔT* (K)
1	0.58–0.68				
2	0.725–1.0				
3A	1.58–1.64				
3B	3.55–3.93	0.1	20	3.660–3.840	0.05
			22	3.929–3.989	0.07
			23	4.020–4.080	0.07
4	10.3–11.3	0.1	31	10.78–11.28	0.05
5	11.5–12.5	0.1	32	11.77–12.27	0.05

sst4

sst

The *NEΔT* are determined at 300 K (MODIS specifications from http://modis.gsfc.nasa.gov; AVHRR specifications from NOAA KLM Users Guide at http://www2.ncdc.noaa.gov).

SST Determination from Space

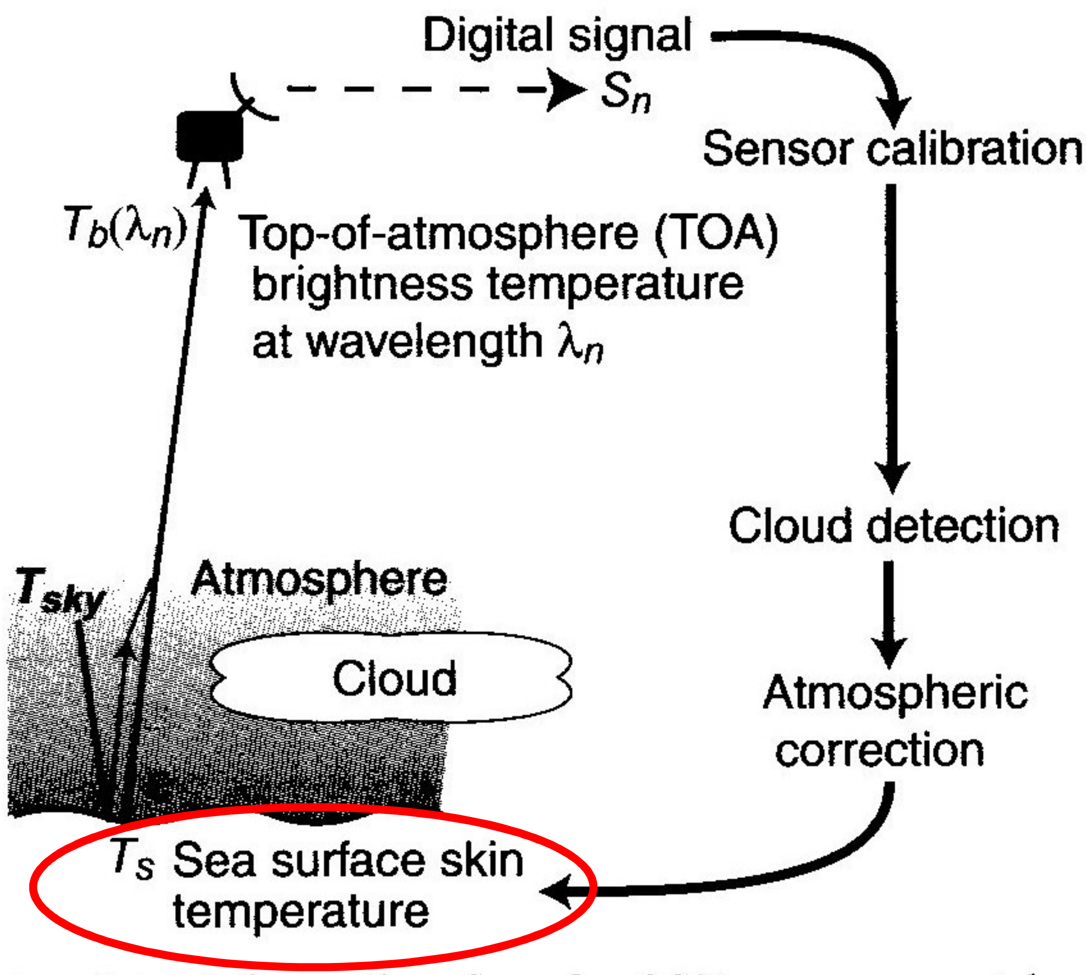


Figure 7.6. Schematic of the information flow for SST measurement by an IR radiometer.

[from Robinson, 2004]

SST Determination from Space

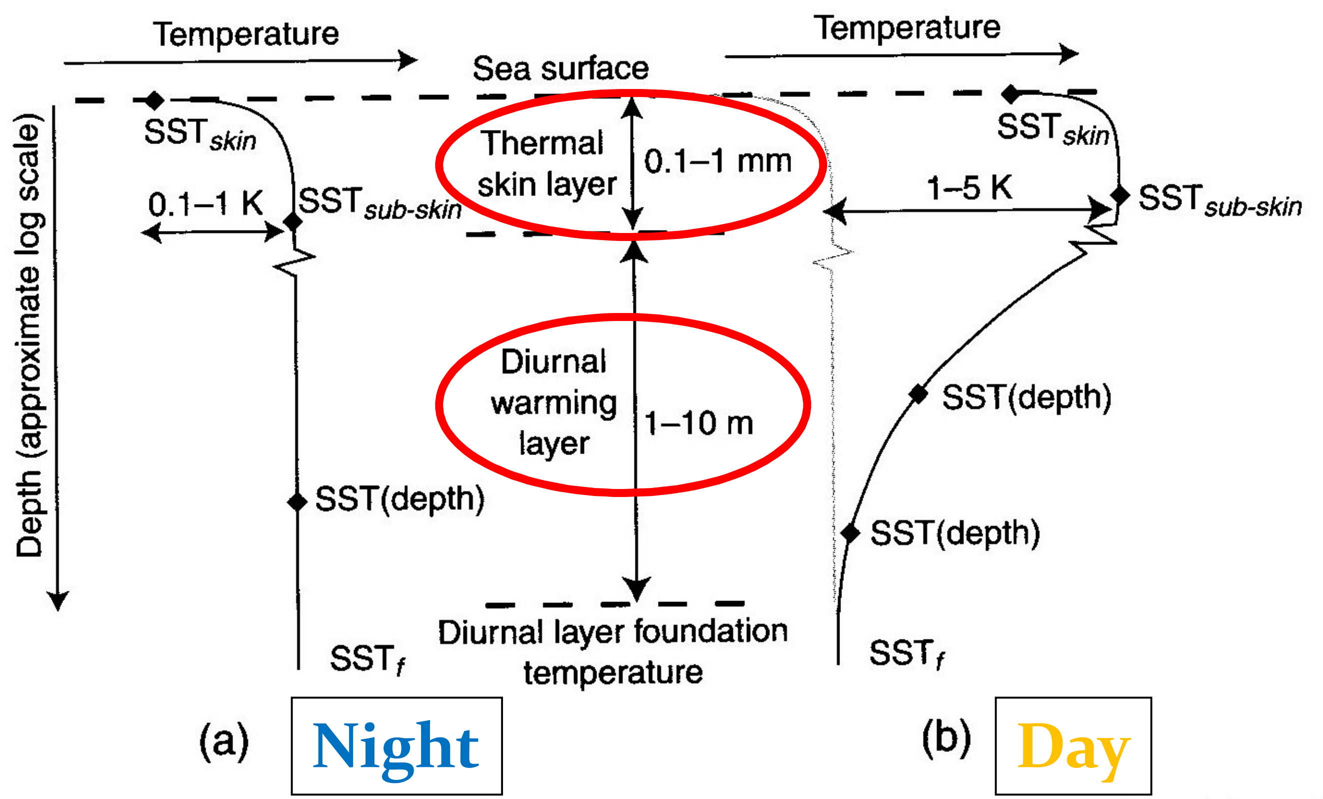


Figure 7.16. Schematic depicting the temperature structure near the sea surface (a) at night and (b) during the day in conditions suitable for diurnal warming. The figure shows where the *skin*, *sub-skin*, and *depth* measurements of SST are defined. SST_f represents the foundation temperature at the base of any diurnal thermocline that may be present.

[from Robinson, 2004]

SST Determination from Space

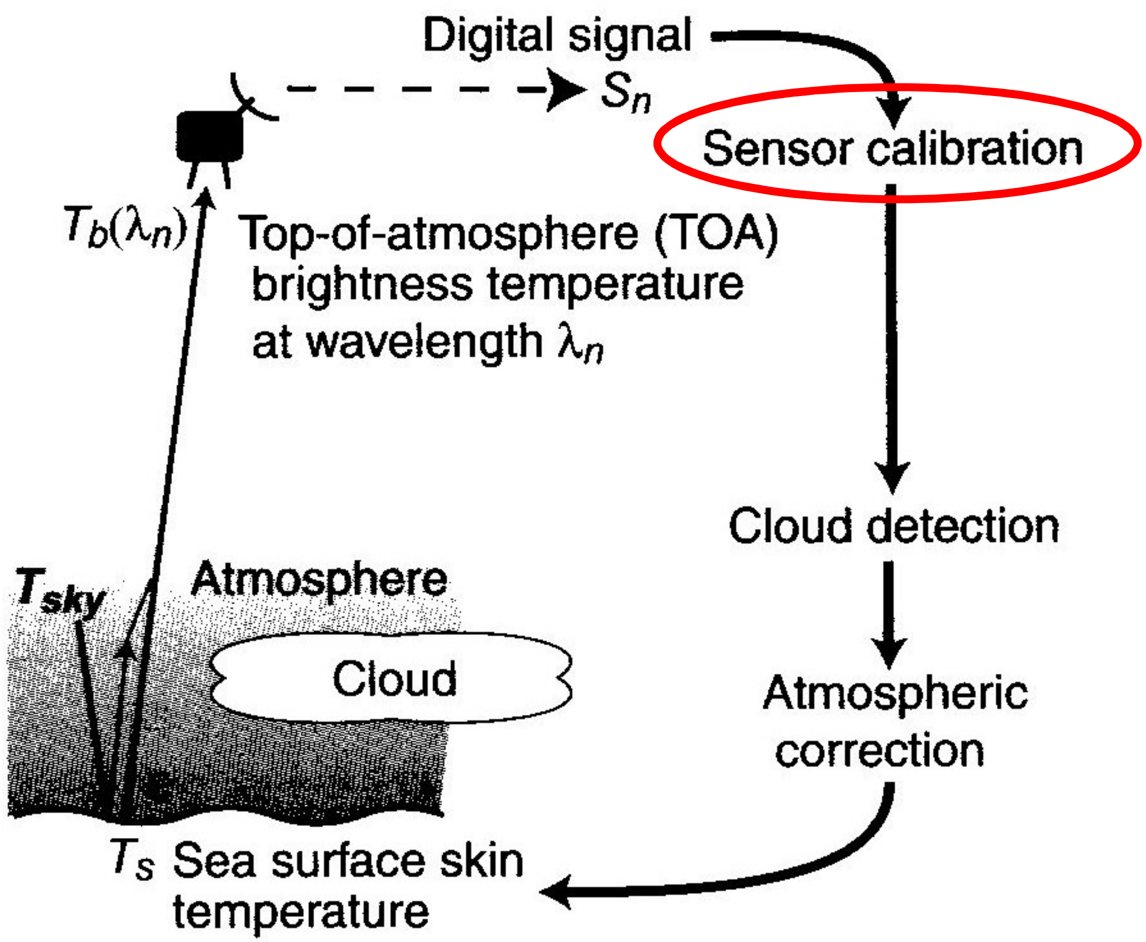


Figure 7.6. Schematic of the information flow for SST measurement by an IR radiometer.

[from Robinson, 2004]

Sensor Calibration

- Band-integrated radiance as a function of temperature (Planck's Law) at detector:

$$L(T_b) = \int C_1\, \phi(\lambda) \,/\, [\lambda^5 \pi \exp(C_2/\, \lambda T_b)-1]\, d\lambda$$

where:

T_b blackbody temperature

$\phi(\lambda)$ detector response function (determined pre-launch)

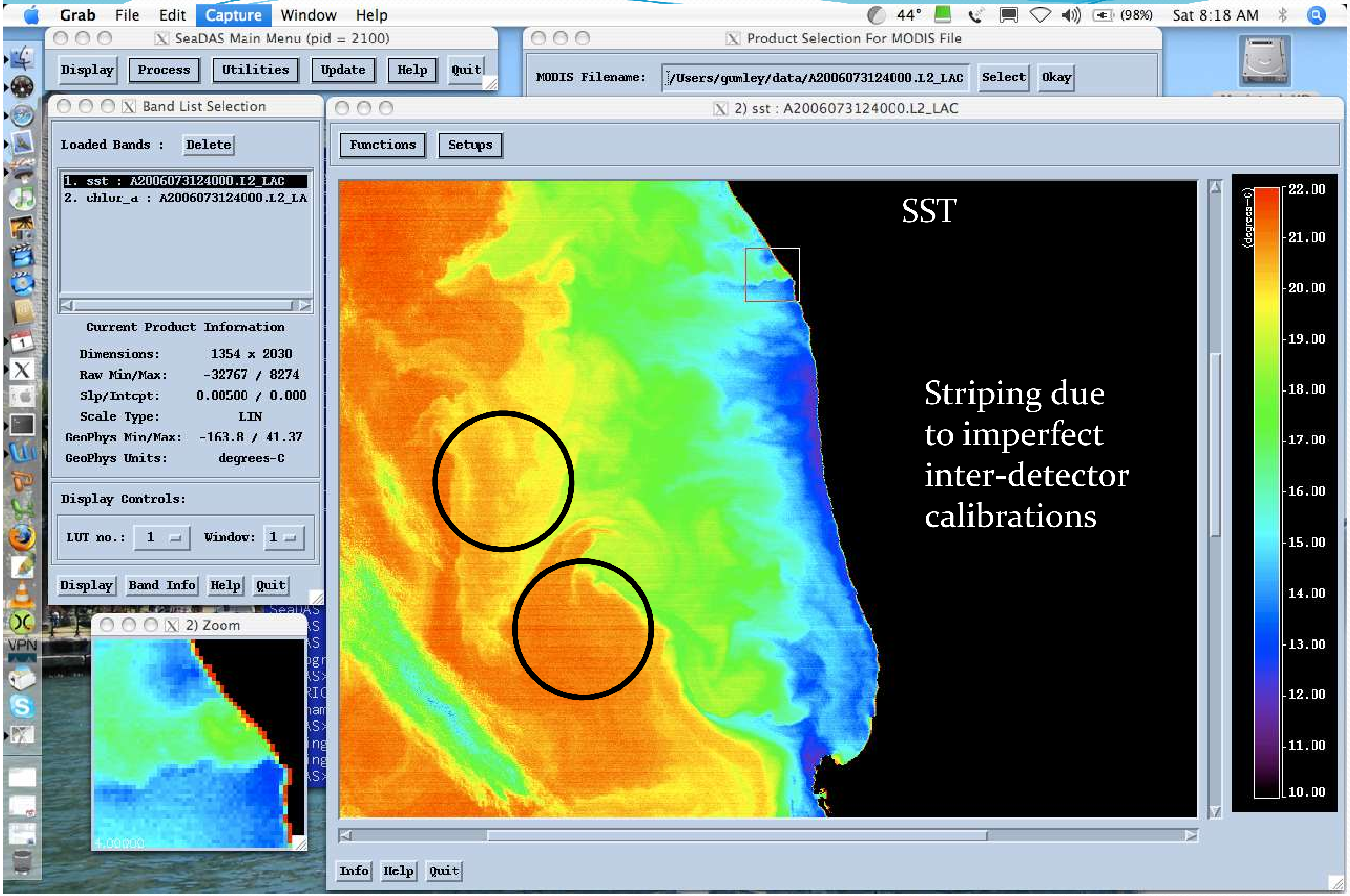
C_1, C_2 constants

- Calibration finds gain and offset to relate the digital output signal S to radiance at detector L:

$L = gain*S + offset$ or $T_b = A + B \ln(L)$

** Need 2 known points to find gain and offset for each detector

MODIS has 10 detectors scanned by 2 mirror-sides --> 20 calibrations



[from Gumley, 2006]

SST – Cloud Detection

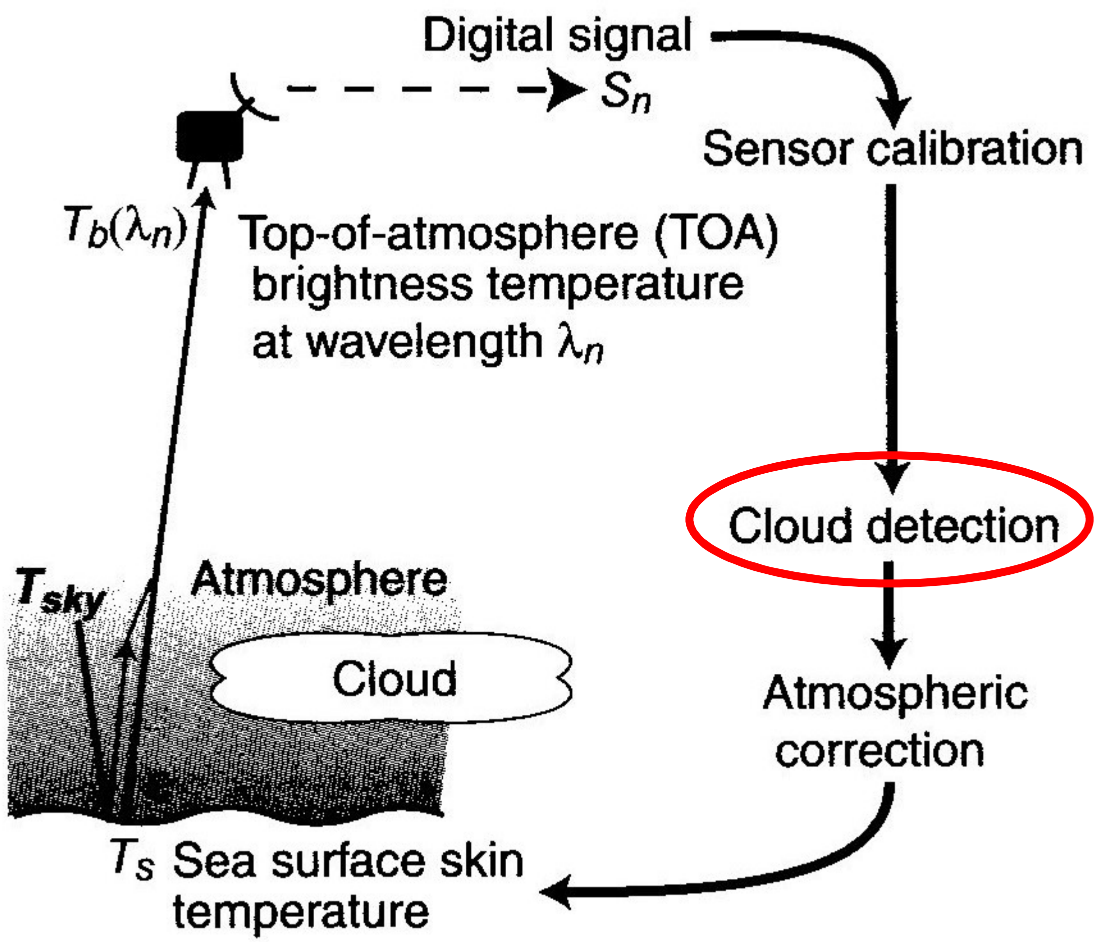


Figure 7.6. Schematic of the information flow for SST measurement by an IR radiometer.

[from Robinson, 2004]

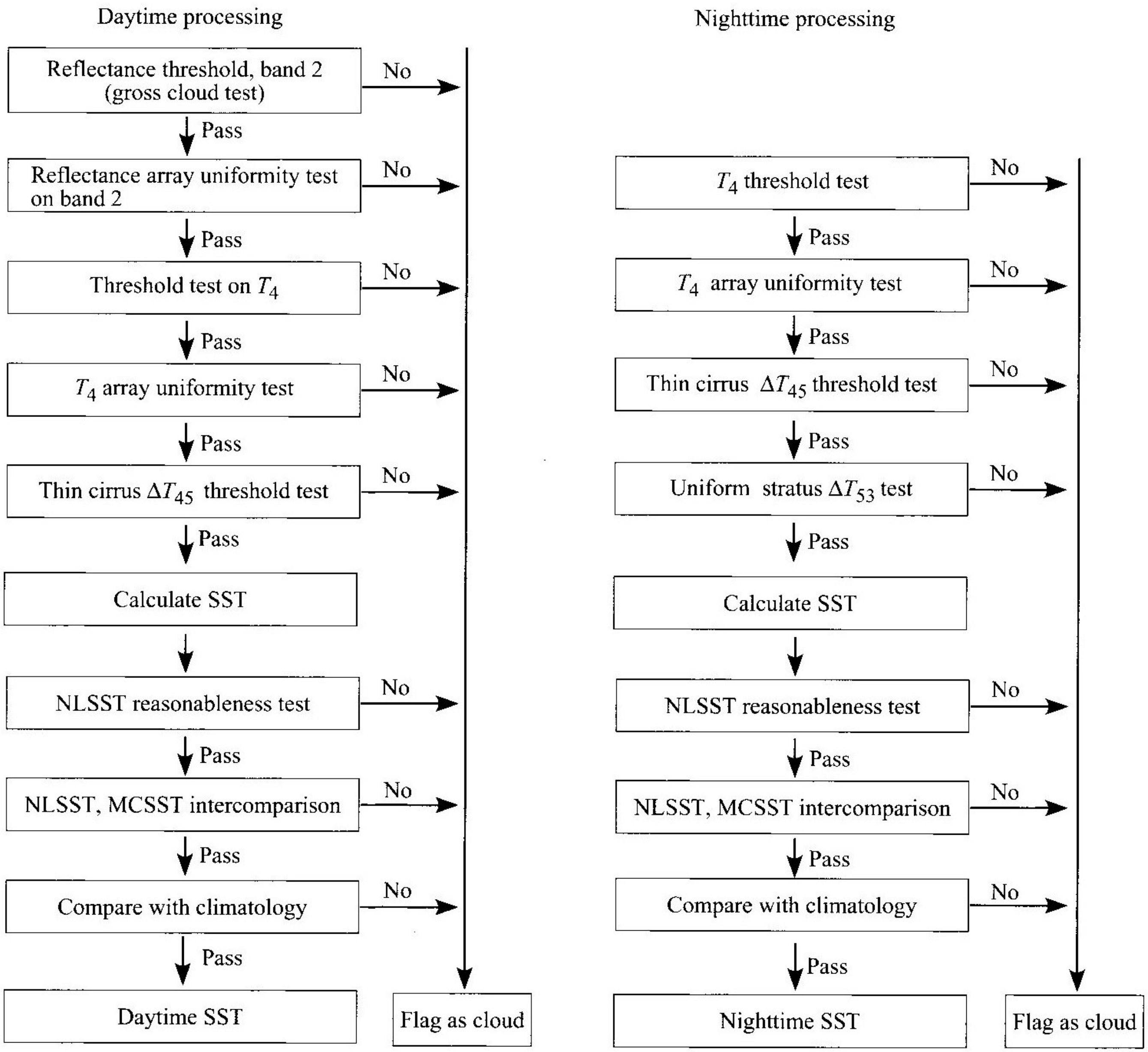


Figure 7.15. Summary of the AVHRR operational tests (Adapted from Figure 3 of May *et al.*, 1998).

[from Robinson, 2004]

SST - Atmospheric Correction

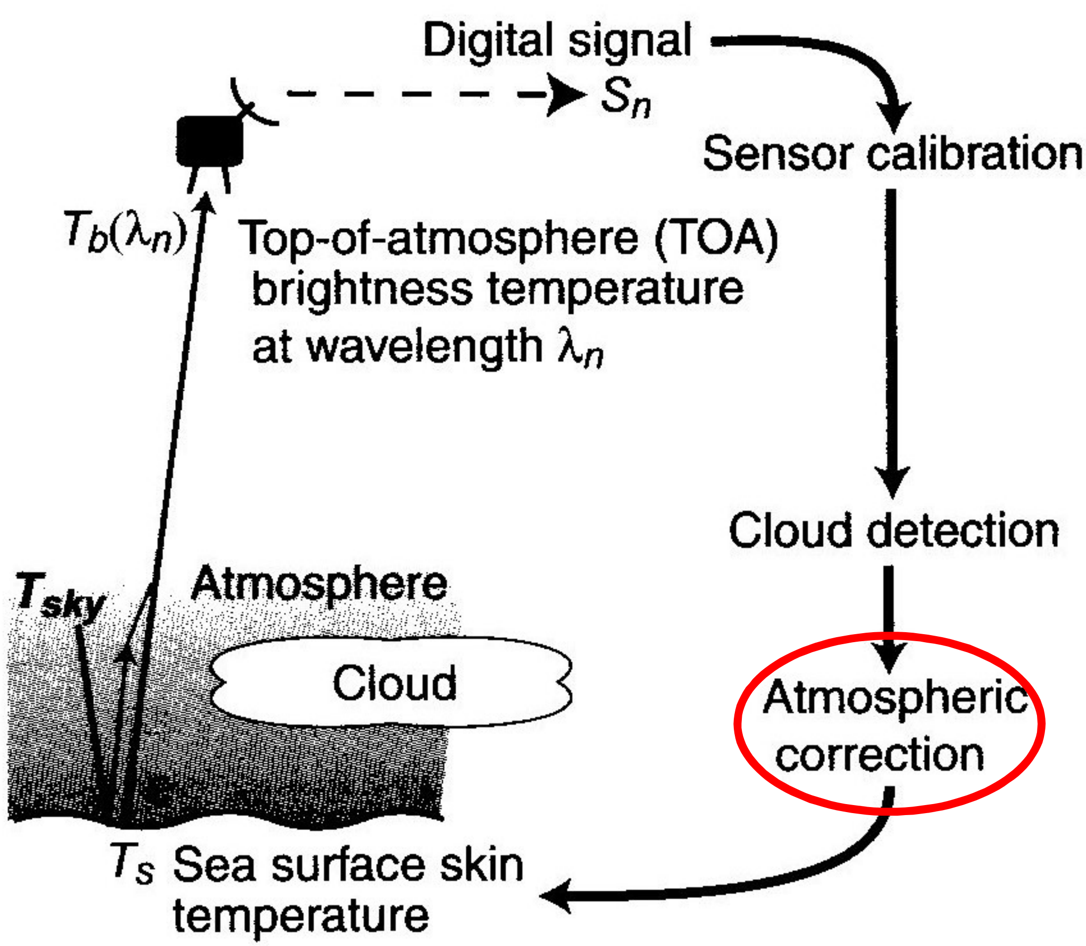


Figure 7.6. Schematic of the information flow for SST measurement by an IR radiometer.

[from Robinson, 2004]

MODIS Atmospheric Correction for Ocean Bands

- **Statement of the problem:**
  - Total radiance observed by the satellite is composed of 5-10% ocean signal and 90-95% atmosphere signal.
  - The atmospheric and ocean surface scattering effects must be accurately modelled and removed.
  - Desired parameter is normalized water leaving radiance (nLw) for MODIS bands 8, 9, 10, 11, 12, 13 (0.412, 0.443, 0.488, 0.531, 0.551, 0.667 microns)

MODIS Atmospheric Correction for Ocean Bands

- **Aerosol model selection:**
  - Assume zero (or negligible) water leaving radiance in the NIR bands (15 and 16; 0.750 and 0.865 microns); remainder is from aerosols.
  - This is extrapolated to visible wavelengths using aerosol models. For case 1 waters, NIR bands are used to select aerosol model.
  - Where this assumption is not valid, water-leaving radiance in NIR bands is estimated and removed prior to aerosol model selection.

Atmospheric Correction Algorithms

$$SST = a + b*T_4 + c*(T_4 - T_5) + d*(T_4 - T_5)*(\sec\theta - 1)$$

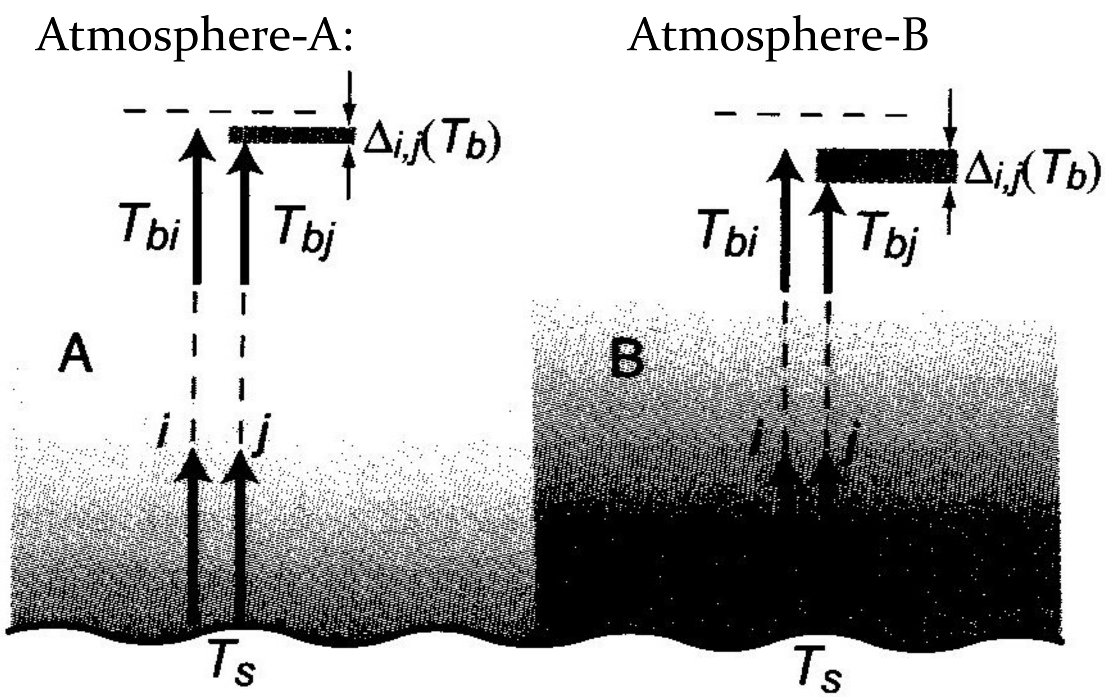


Figure 7.7. The basis of atmospheric correction algorithms: spectrally different absorption.

T_{bi} brightness temperature channel "i", e.g, T_4 (Band-31 in MODIS)
T_{bj} brightness temperature channel "j", e.g, T_5 (Band-32 in MODIS)

Is atmospheric correction always appropriate?

$$SST = a + b*T_4 + c*(T_4-T_5) + d*(T_4-T_5)*(\sec\theta-1)$$

Is anything lost by applying atmospheric corrections?

- Image noise may be enhanced
- Includes noise from 2 channels
- Thermal gradients are modified

If spatial structures, patterns, fronts, eddies, plumes are studied:

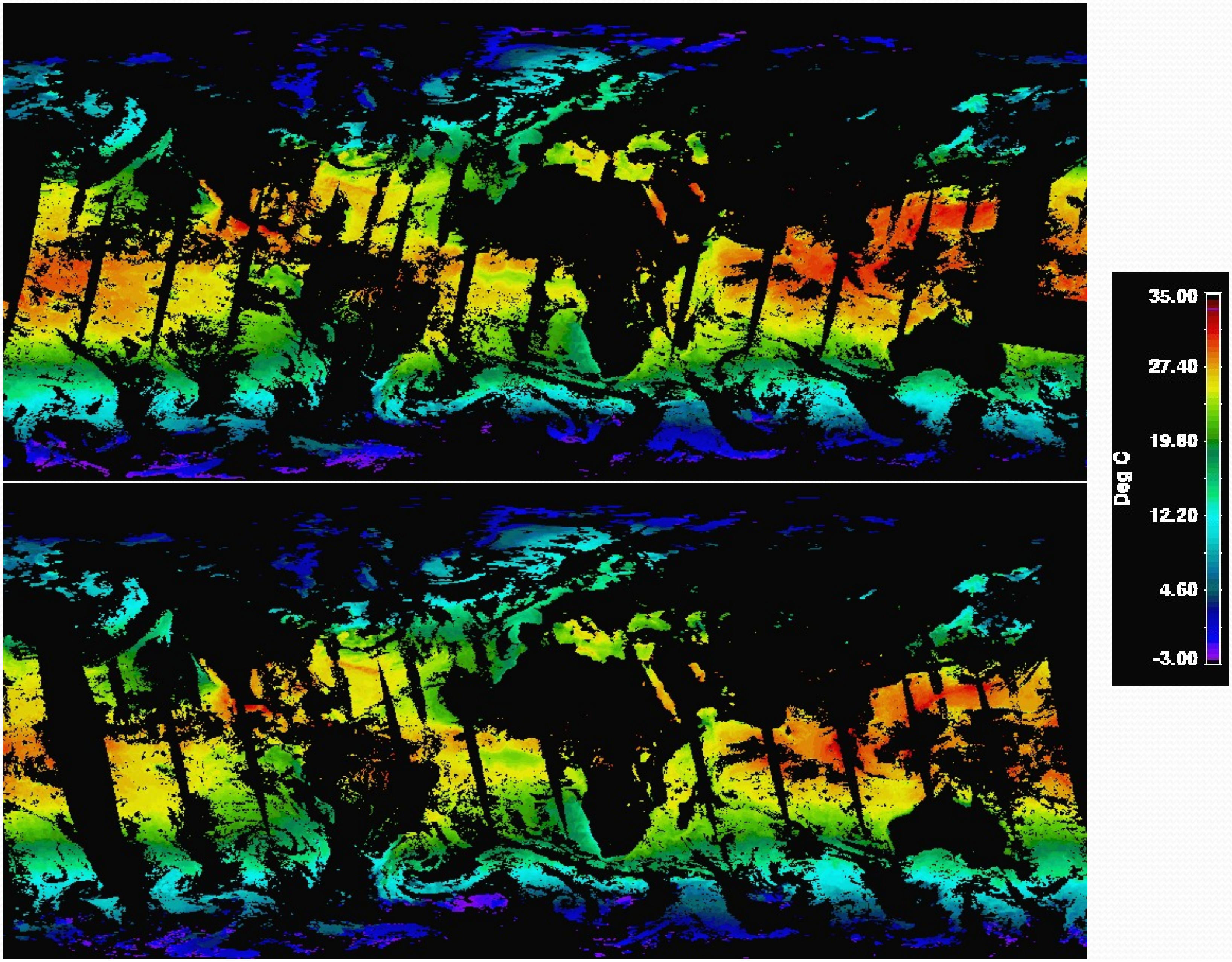
Use brightness temperatures T_i, not SST

MODIS Thermal SST - 25June02

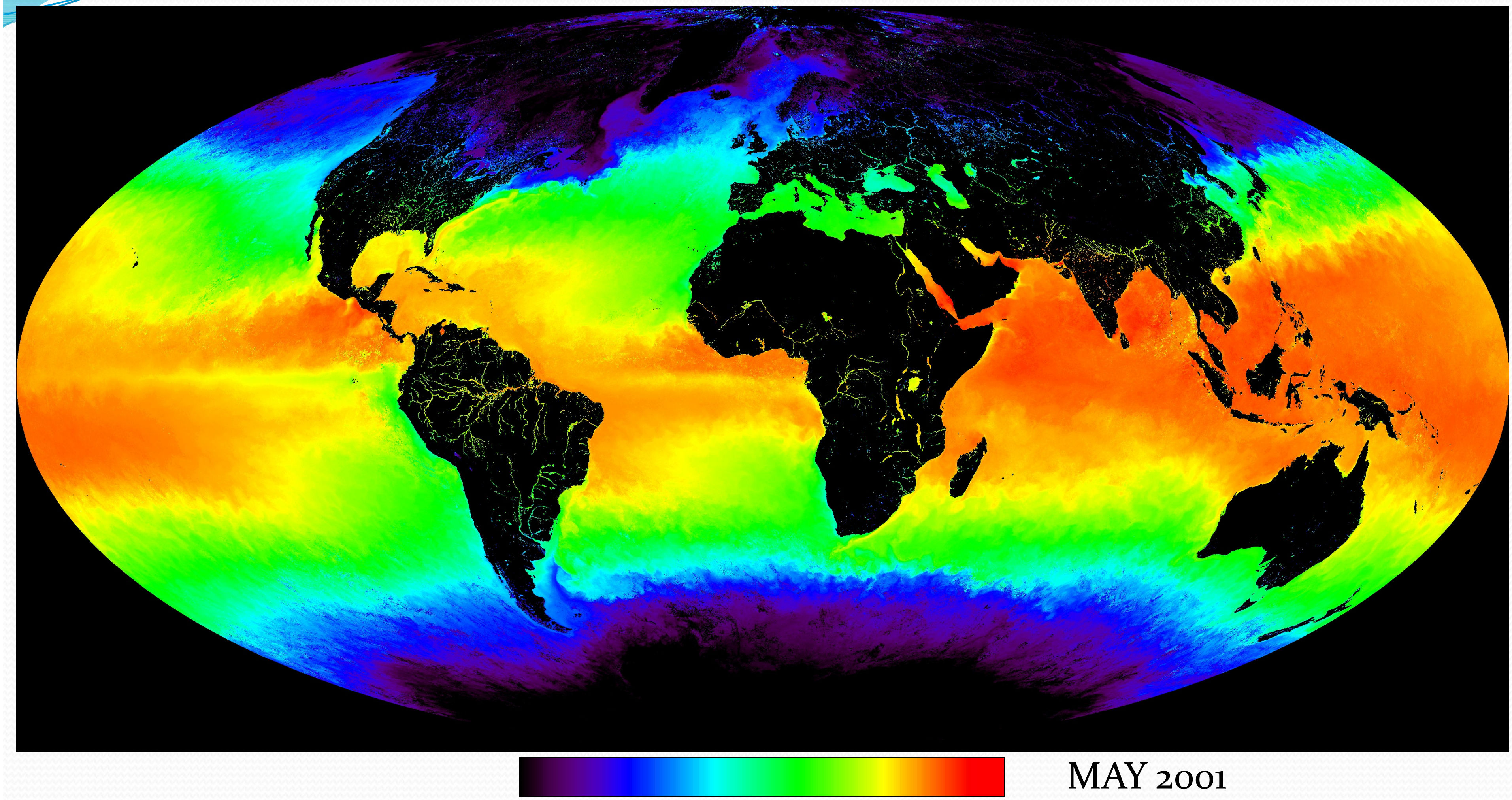
Terra

Separate image for each satellite

Aqua



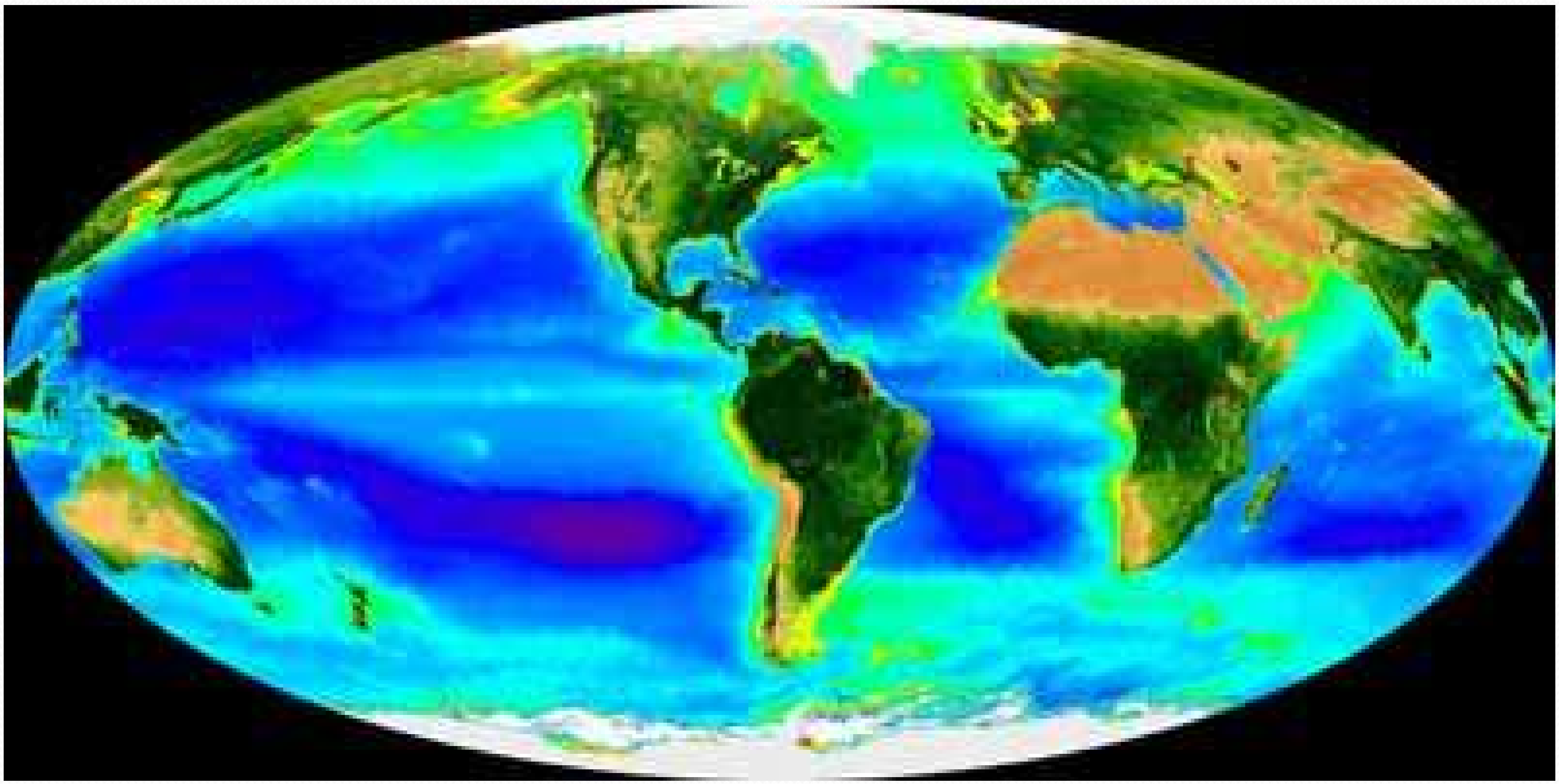
TERRA MODIS NIGHTTIME 4μm SST



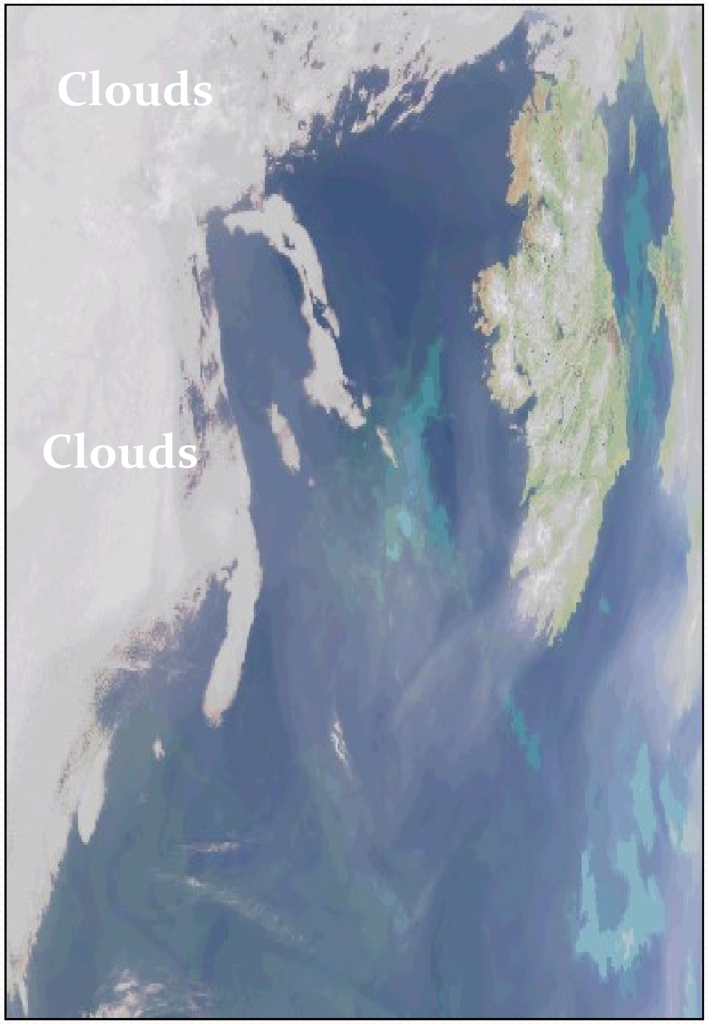
MAY 2001
V 3.3.1

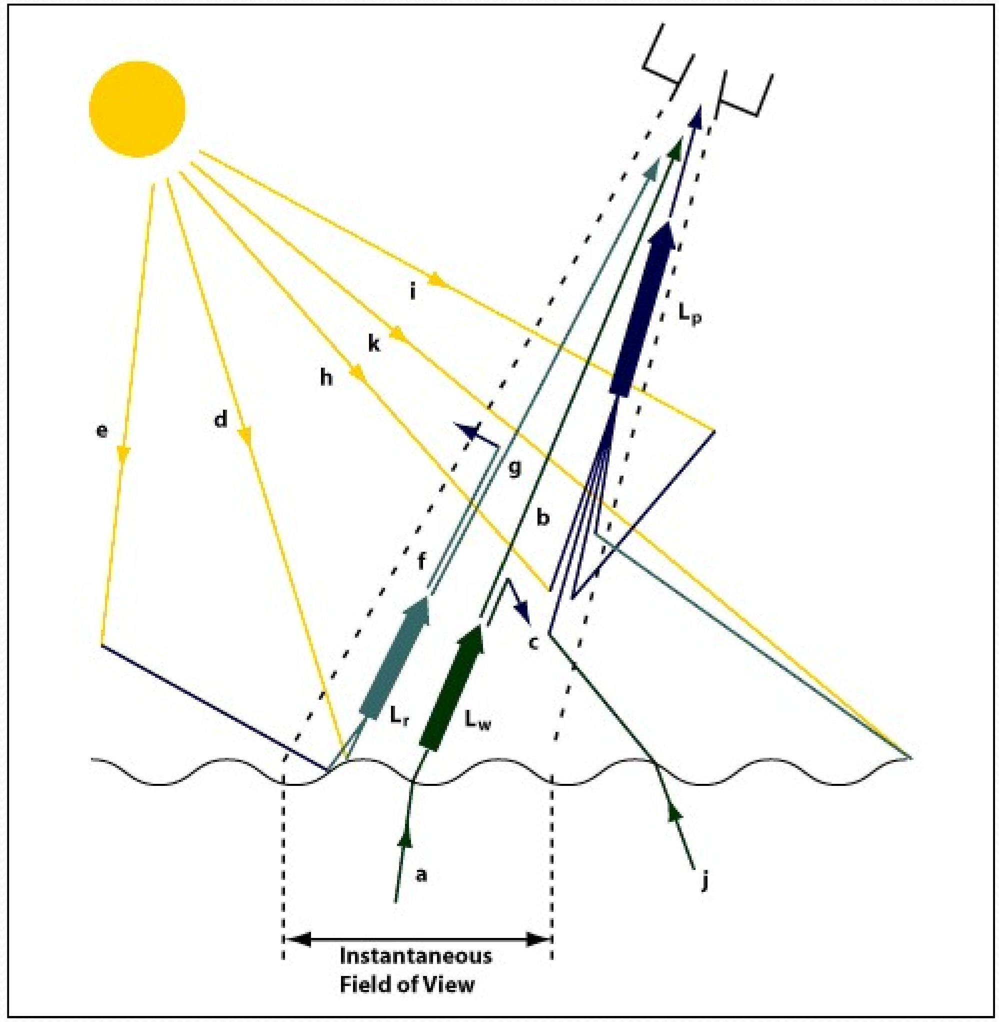
MODIS/OCEAN GROUP
GSFC, RSMAS

MODIS Ocean Color



Atmospheric correction for Ocean Color





- L_w is only 5-10% of signal reaching satellite: rest due to L_p
- L_p components: molecular (Rayleigh) & aerosols

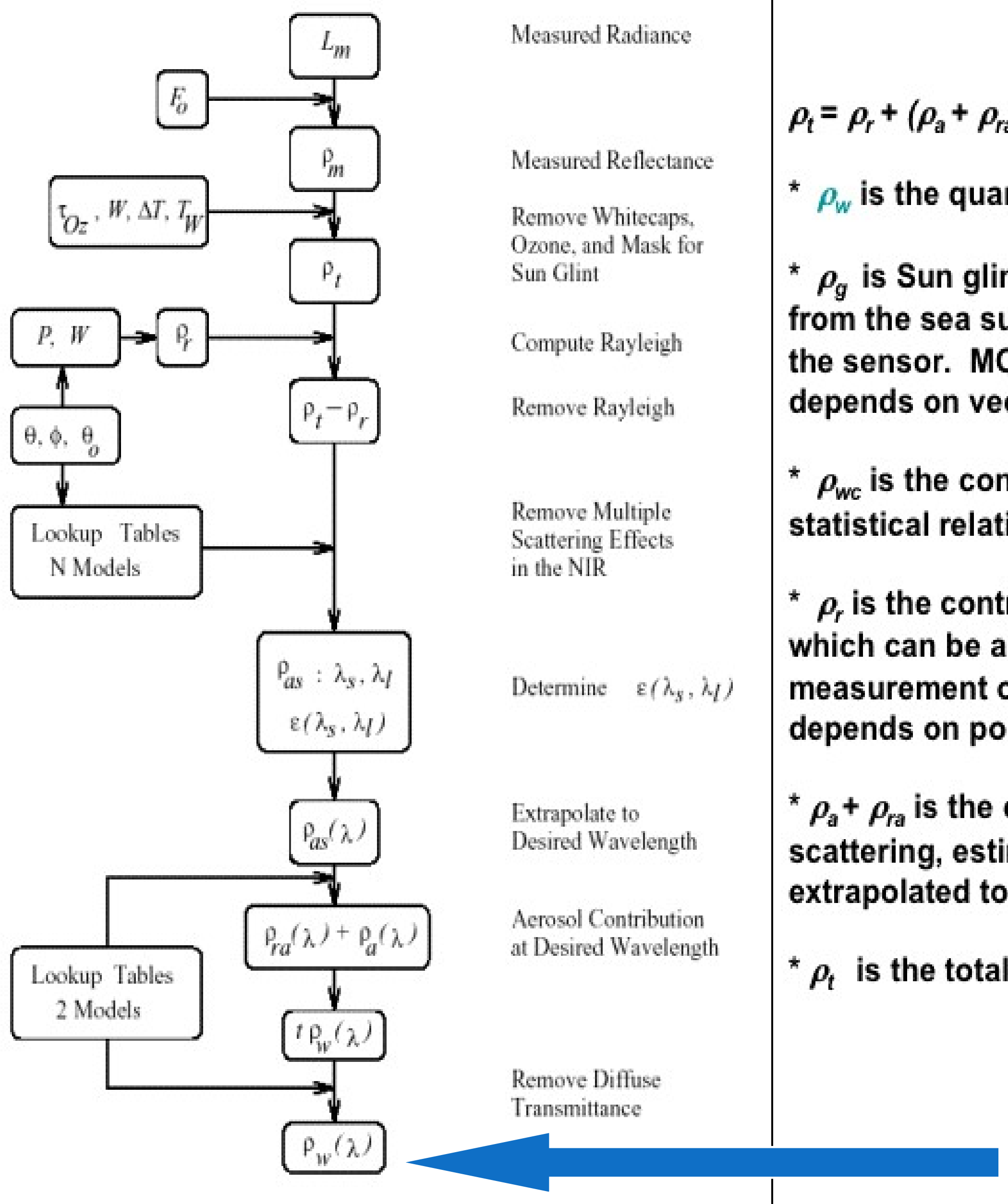


Figure 21. Annotated flow diagram of the algorithm.

$$\rho_t = \rho_r + (\rho_a + \rho_{ra}) + t\rho_{wc} + t\rho_g + t\,\rho_w$$

* ρ_w is the quantity we wish to retrieve at each wavelength.

* ρ_g is Sun glint, the direct + diffuse reflectance of the solar radiance from the sea surface. This effect for SeaWiFS is minimized by tilting the sensor. MODIS does not tilt and the sun glint must be removed, depends on vector winds and polarization.

* ρ_{wc} is the contribution due to "white"-capping, estimated from statistical relationship with wind speed.

* ρ_r is the contribution due to molecular (Rayleigh) scattering, which can be accurately modeled. MODIS requires accurate measurement of change in mirror reflectivity with angle of incidence, depends on polarization, winds, atmospheric pressure

* $\rho_a + \rho_{ra}$ is the contribution due to aerosol and Rayleigh-aerosol scattering, estimated in NIR from measured radiances and extrapolated to visible using aerosol models.

* ρ_t is the total reflectance measured at the satellite

MODIS Chlorophyll Algorithm

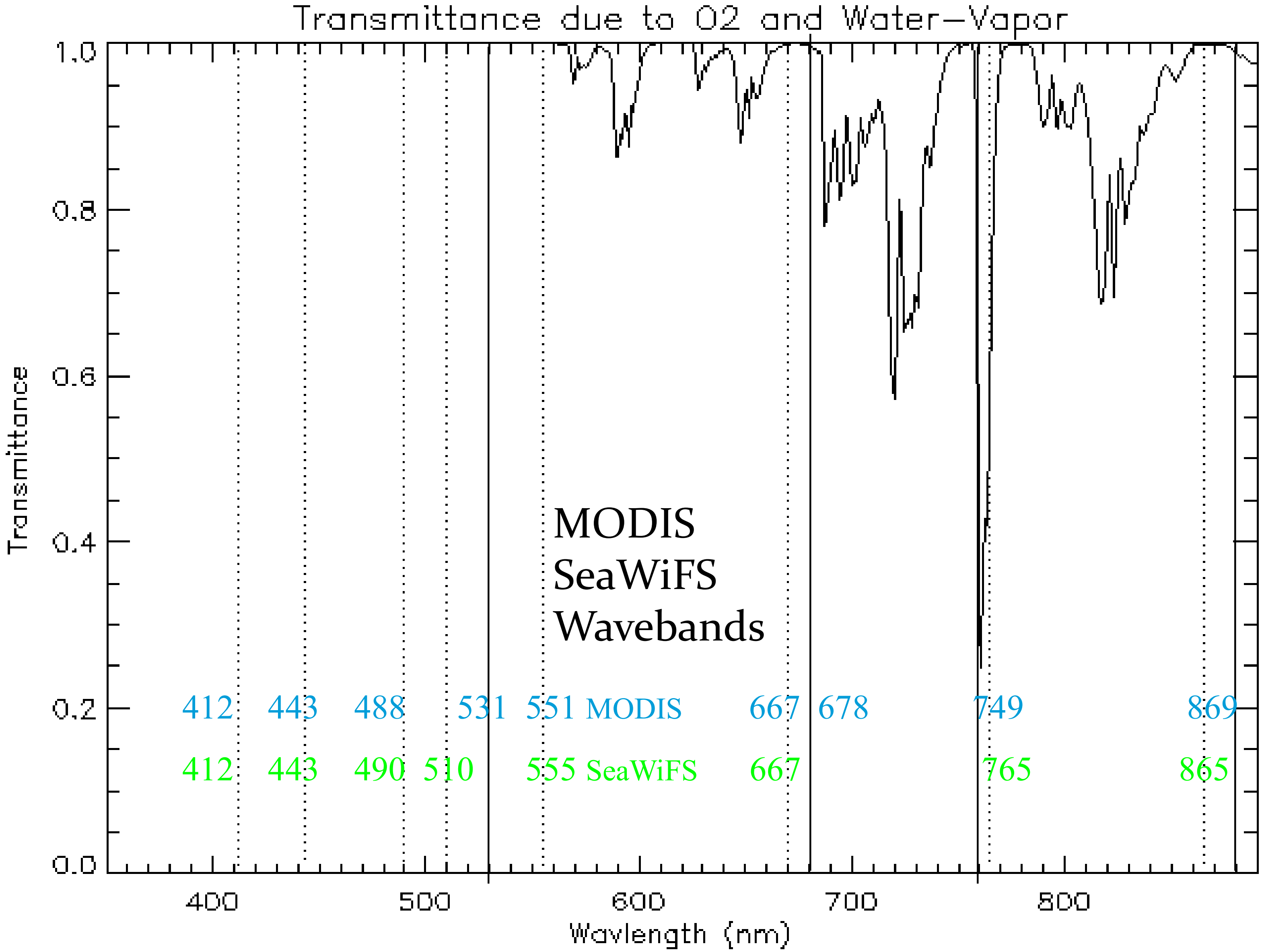
- Semi-analytical algorithm[1]

- **$Chl\_a = 10^{**}(0.283 - 2.753*R + 1.457*R^2 + 0.659*R^3 - 1.403*R^4)$**

- where:
  - $R = \log_{10}((R_{rs}443 > R_{rs}488) / R_{rs}551)$
  - R_{rs} = nLw / F_o (*remote sensing reflectance*)
  - F_o = extraterrestrial solar irradiance
  - nLw = water leaving radiance at 443, 488, 551

- *[1] Performance of the MODIS Semi-analytical Ocean Color Algorithm for Chlorophyll-a Carder, K.L.; Chen, F.R.; Cannizzaro, J.P.; Campbell, J.W.; Mitchell, B.G. Advances in Space Research. Vol. 33, no. 7, pp. 1152-1159. 2004*

Gaseous Absorption – Transparency Windows



MODIS - SeaWiFS Atmospheric Correction Differences

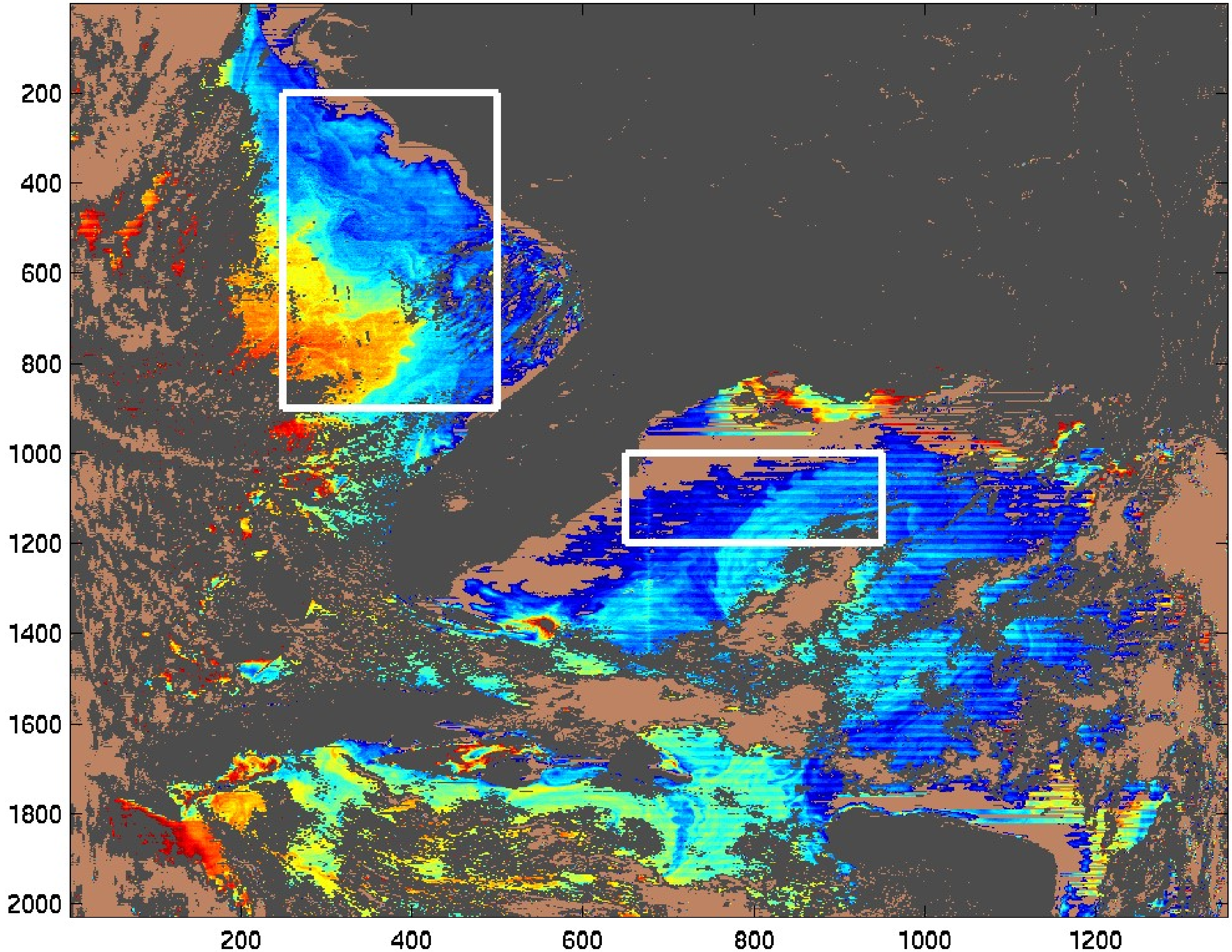
- **Glint** - Spectral diffuse glint term, modified Cox-Munk distribution with spectral weighting, must be removed for MODIS (non-tilting), SeaWiFS minimizes glint by tilting
- **Rayleigh** - Polarization varies with satellite and solar zenith angles, MODIS mirror angle of incidence (AOI) affects reflectivity, SeaWiFS has constant AOI mirror
- **Multiple (10) detectors per spectral band** - Affects Rayleigh, especially near nadir, SeaWiFS 1 detector/band
- **Equatorial crossing time** - SeaWiFS noon, MODIS Terra 1030, Aqua 1330. Effects sun glint, bi-directional reflectance

Atmospheric correction enhancements for MODIS

- Instruments effects - detector and mirror side banding
- Polarization
- Sun-glint
- Sun-satellite-observation point viewing geometry, overpass time and BRDF -bidirectional reflectance

Southeastern North America nLw 412nm

November 1, 2000

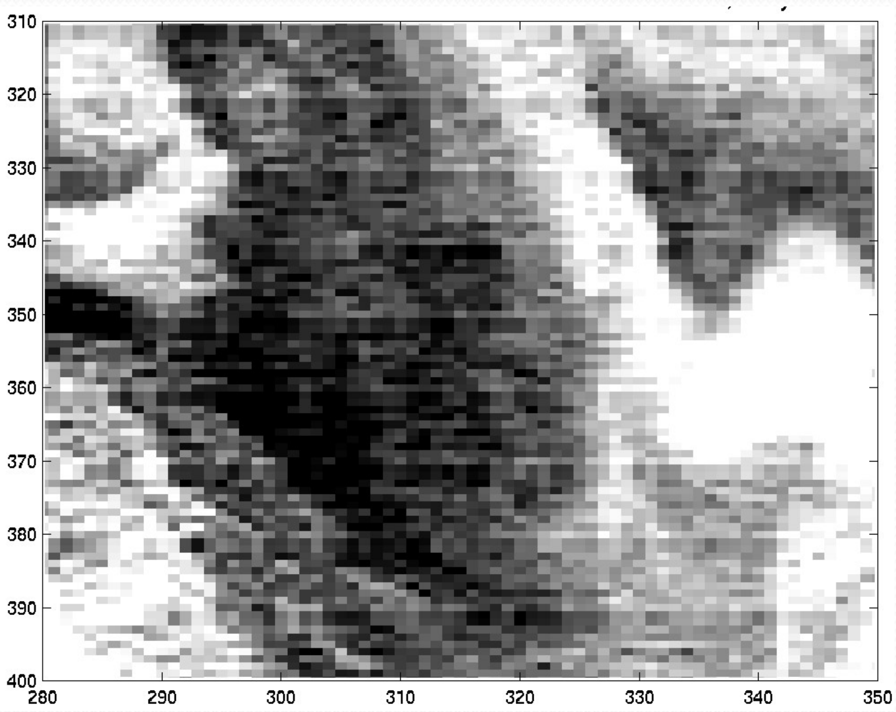


Examples of detector and mirror side banding before correction

Northeastern Gulf of Mexico nLw 412 nm

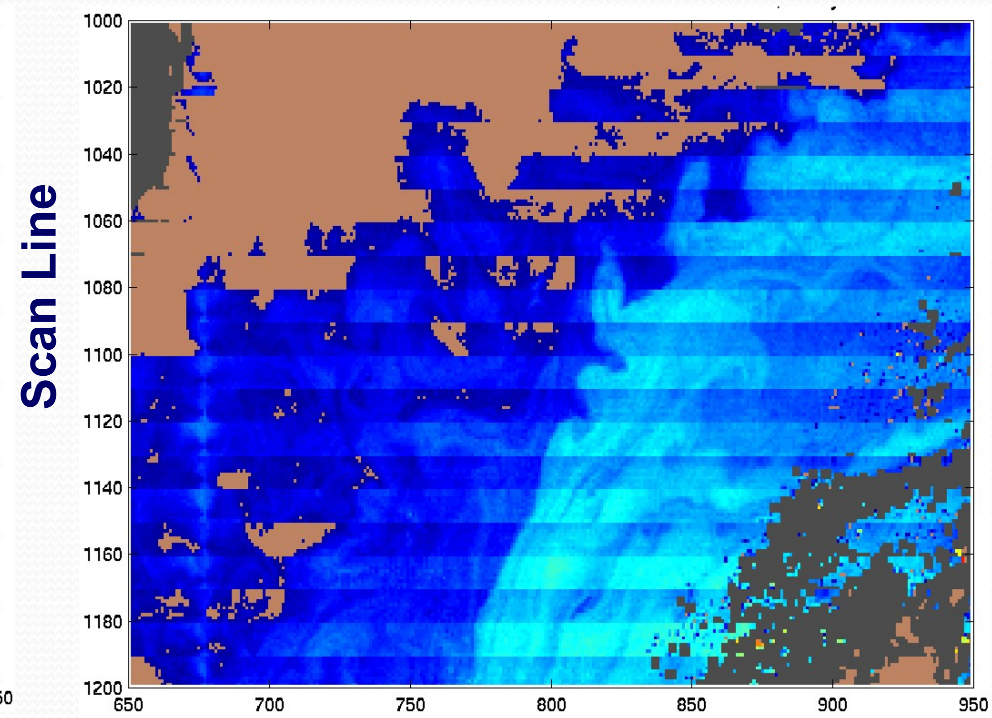
November 1, 2000

Detector Striping



Pixel Number

Mirror Side Banding



Pixel Number

Sun glint correction

- Sun glint influences large portions of the image. Several approaches to correcting the glint problem were investigated.

- Shape of sun glint determined from Cox-Munk distribution, **wind speed dependent**.
  - We assumed sun glint was direct, include only Rayleigh scattering
  - Added an aerosol component to the sun glint.
    - Result: improved Lw retrievals in regions of sun glint contamination with reasonable spectral behavior.
  - Include polarization.

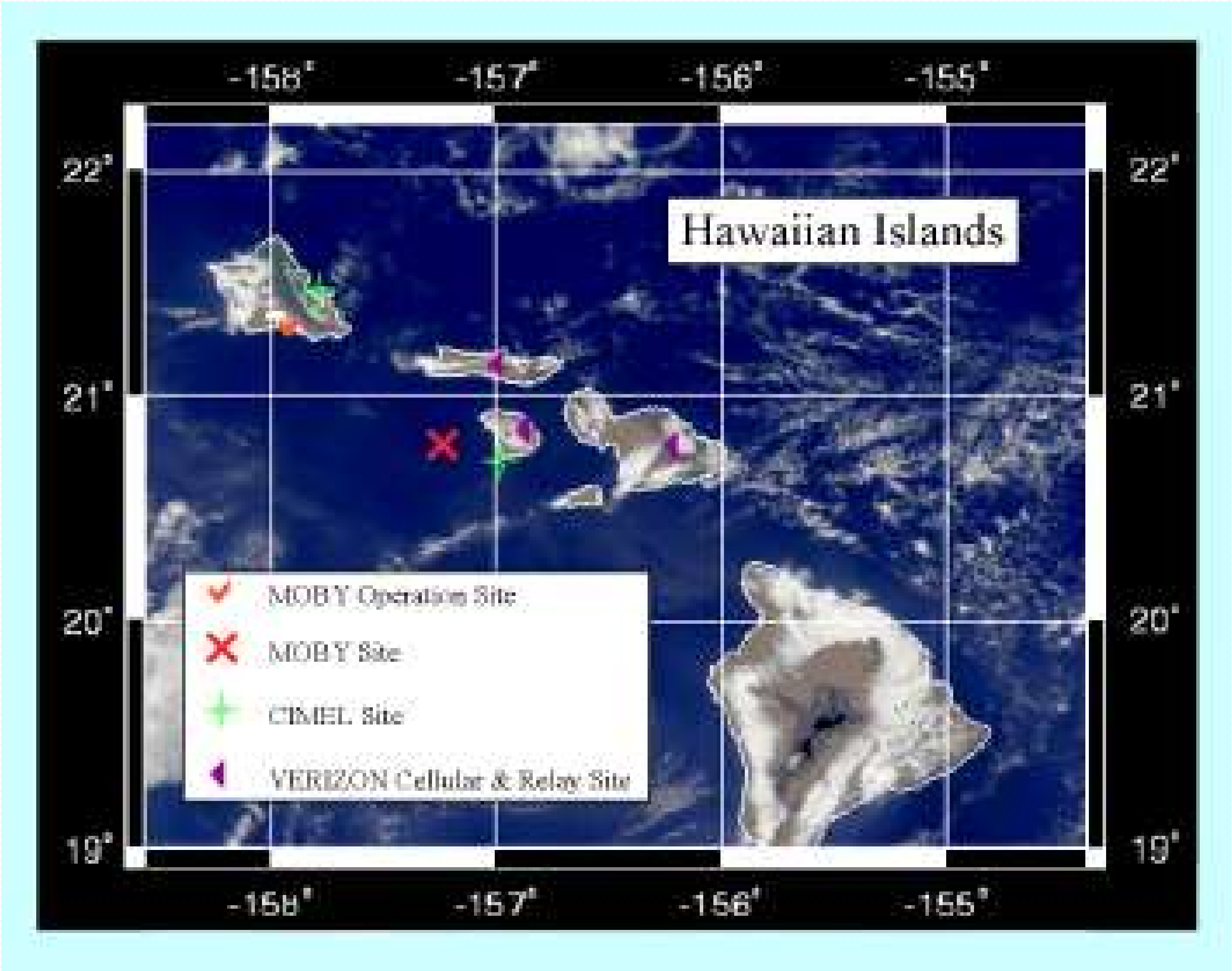
- **Sun glint correction** currently a workable approximation but is limited both by differences in shape between real sun glint spatial distribution and the shape provided by Cox-Munk and by the accuracy of the NCEP wind fields.

Calibration Approach

- Use at **surface nLw**, atmospheric and surface reflectance corrected
- **Validation site for in situ reference is MOBY @ Hawaii**, more extensive validation for other regions will require completion of reprocessing
- **Cross-scan:** Referenced to pixel 500, minimum of sun glint
- **Detector Balance:** Referenced to detector 5, low noise, center of detector array
- **Mirror side Balance:** reference to side 1
- **Remove time trends:** Compare modal peak for area surrounding MOBY to MOBY, high temporal density, not dependent on cloud free conditions
- **Calibration:** Adjust MOBY-MODIS single pixel match-ups to remove bias

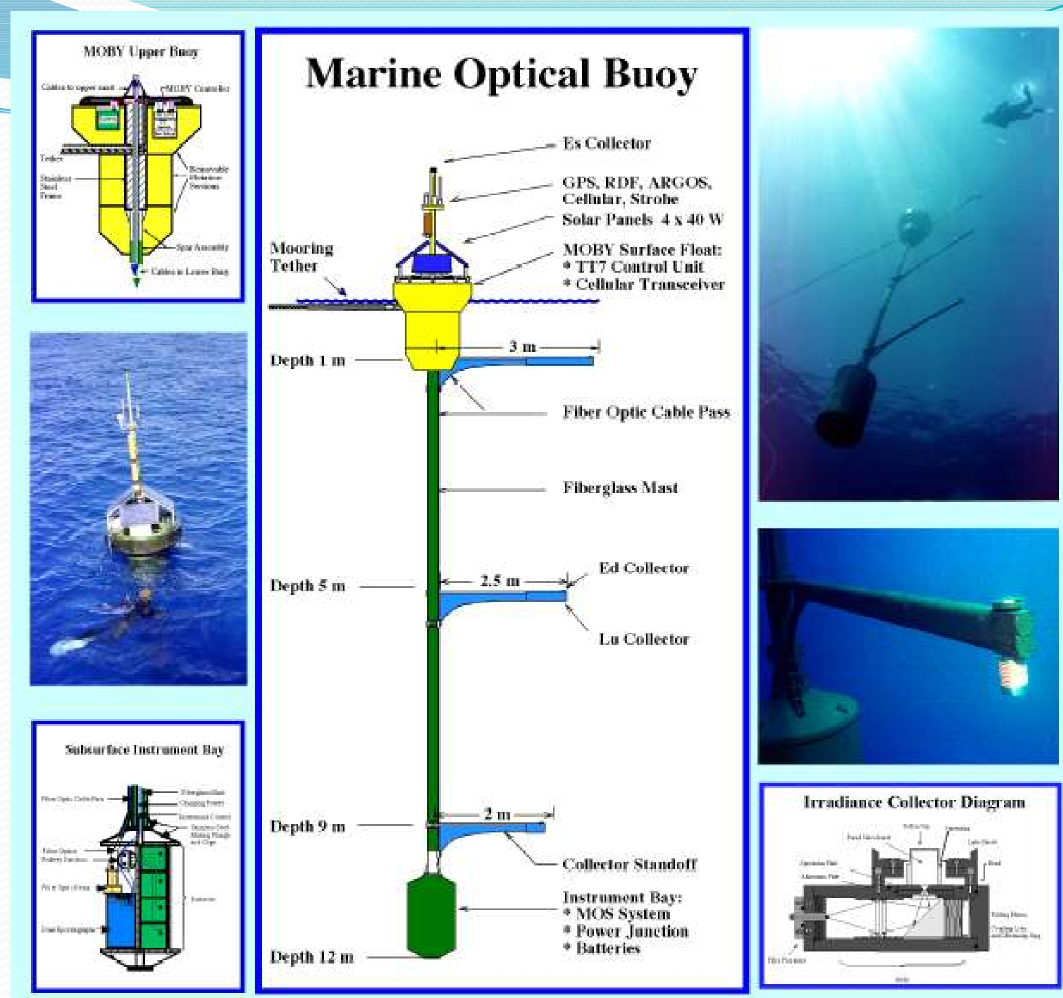
MOBY Calibration Site – Hawaii

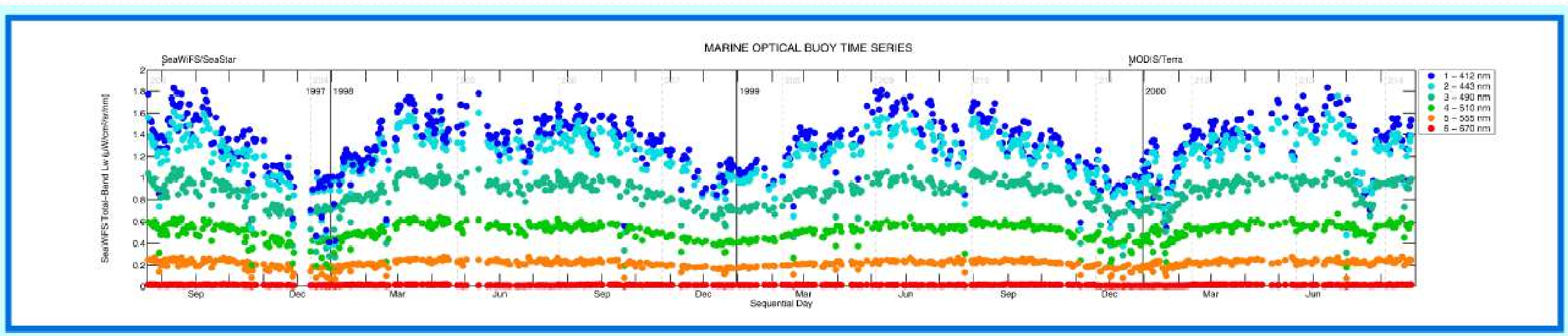
(Dennis Clark)



MOBY Instrument

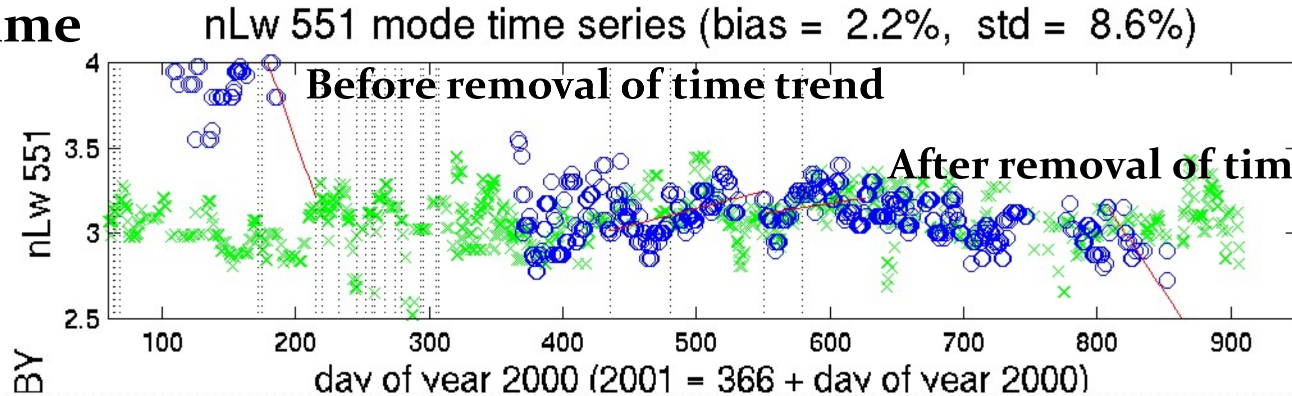
and spectral Time Series of MODIS ocean color bands





nLw Modal Terra MODIS-Moby Time Series

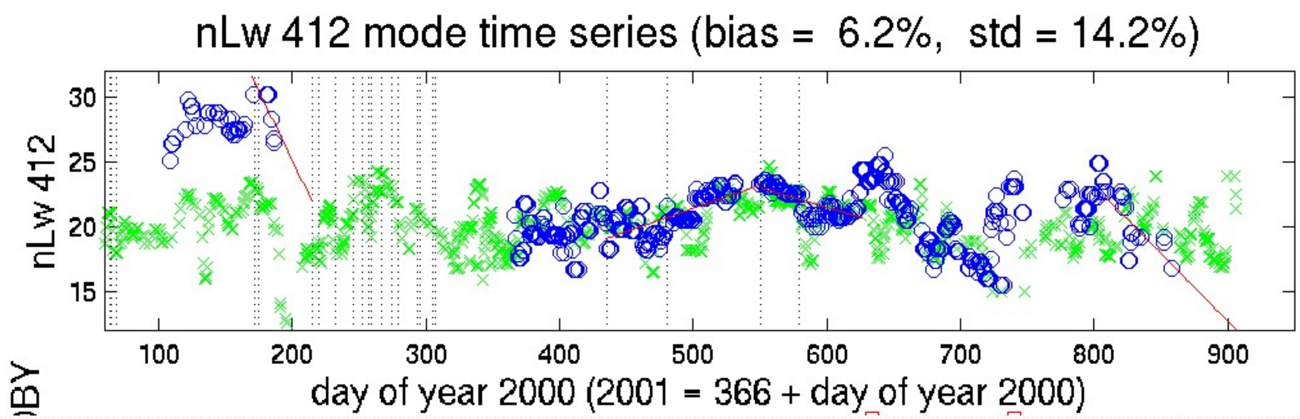
Modal time series of area around Hawaii used to remove time trends in MODIS calibration



Moby

Terra

Overall bias must be removed with MOBY matchups



New Forward
Col 4, V4 L1b

What’s the difference between MODIS Chlorophylls?

- **“Case 1” waters: Chlor_MODIS (Clark)**
  This is an empirical algorithm based on a statistical regression between chlorophyll and radiance ratios.

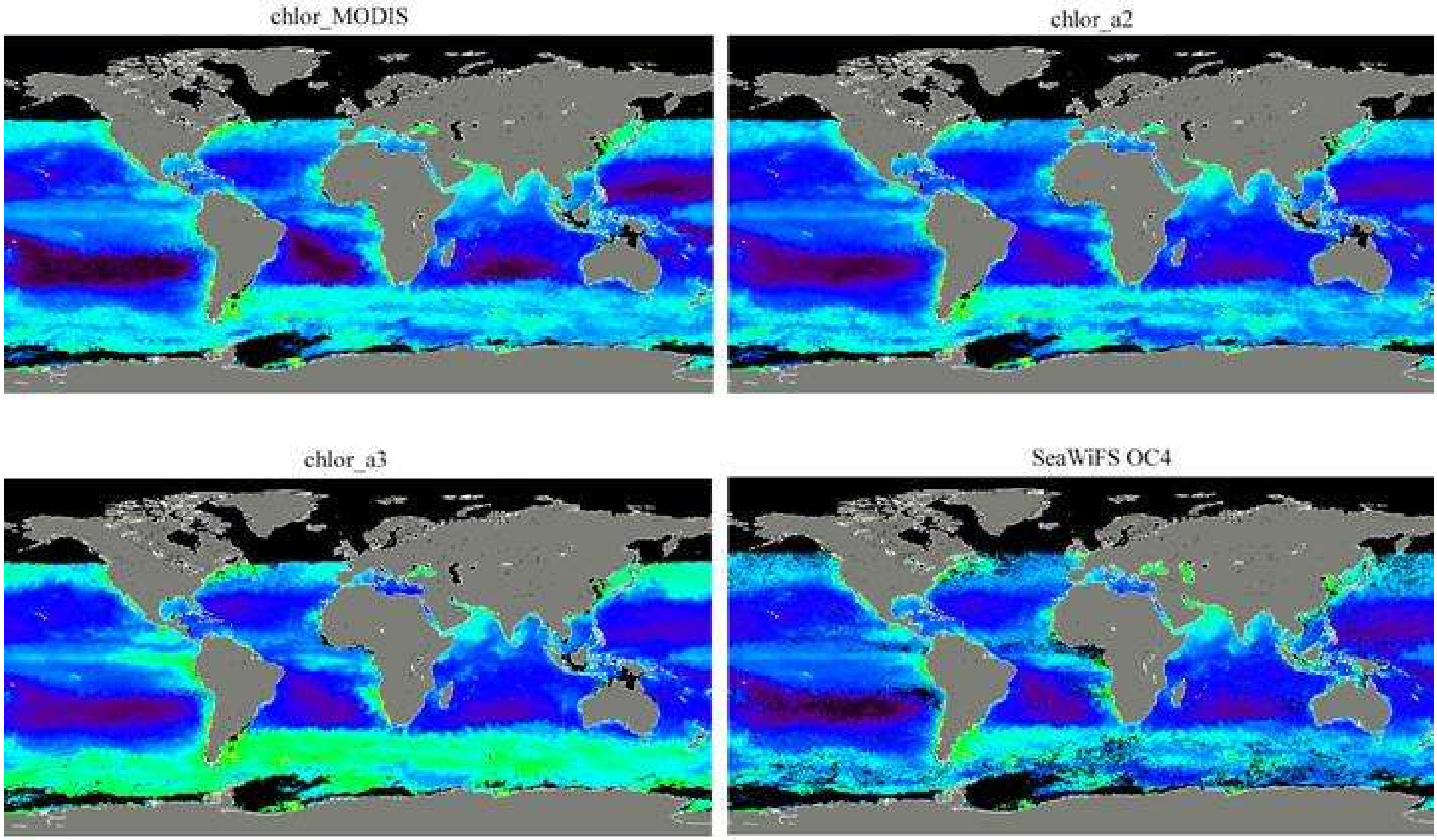
- **“Case 2” waters: Chlor_a_3 (Carder)**
  This is a semi-analytic (model-based) inversion algorithm. This approach is required in optically complex “case 2” (coastal) waters.

A 3rd algorithm was added to provide a more direct linkage to the SeaWiFS chlorophyll:

- **“SeaWiFS-analog” Chlor_a_2 (Campbell)**

- SeaWiFS algorithm OC4.v4 (O’Reilly)

Comparison of MODIS Chlorophyll Products with SeaWifs Chlorophyll

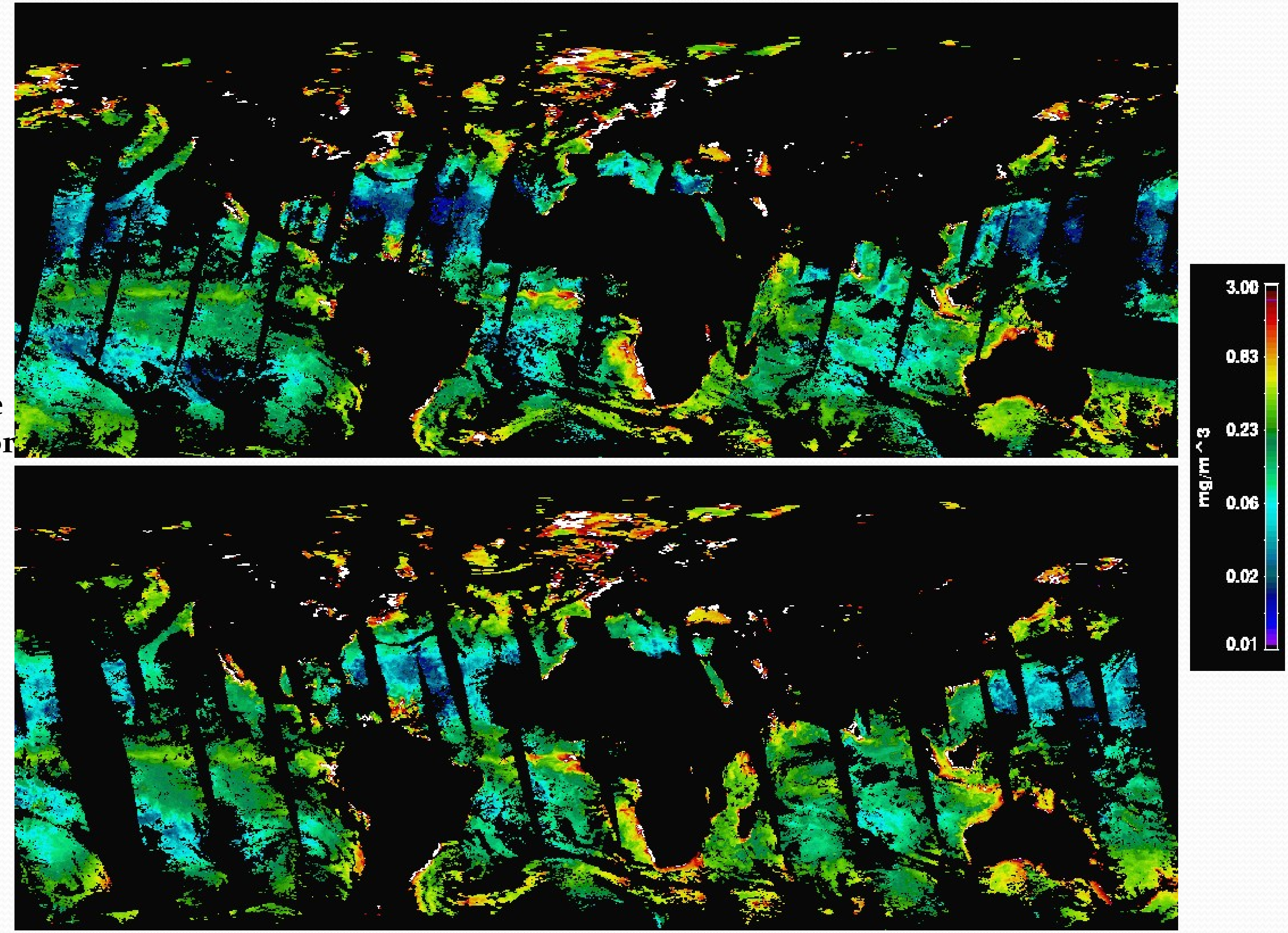


MODIS Chl-MODIS - 25June02

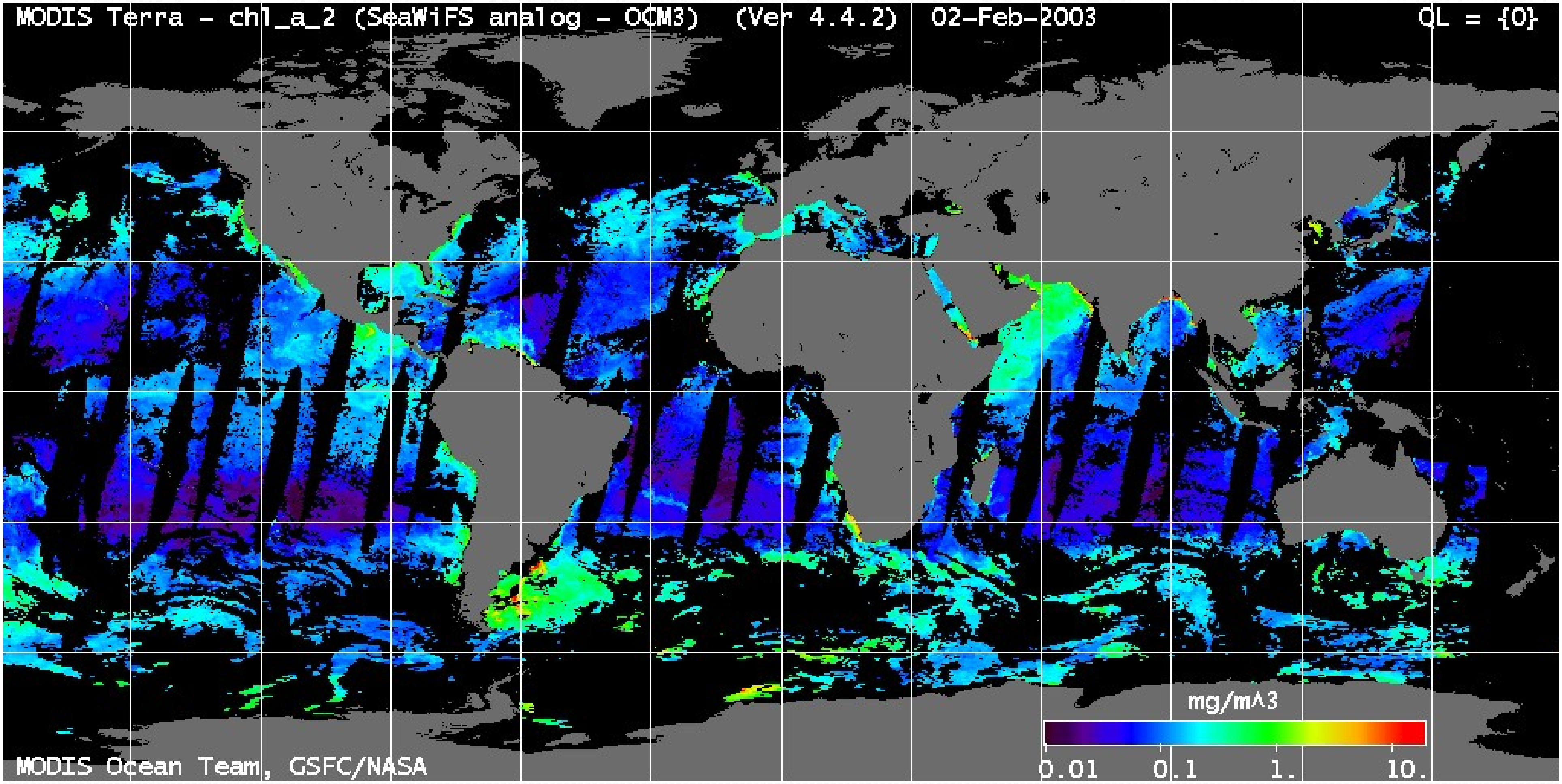
Terra

Separate image for each satellite

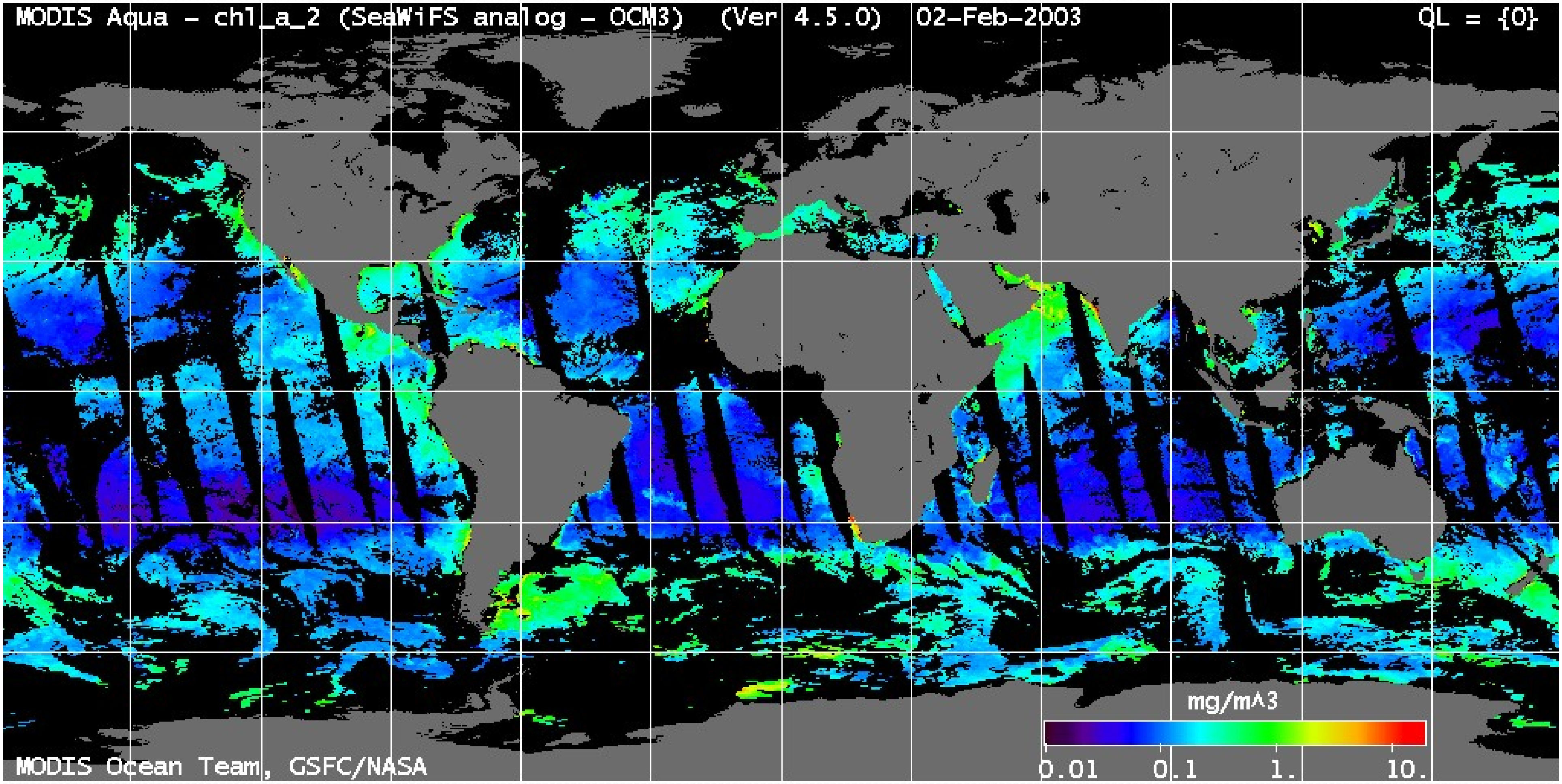
Aqua



Terra - Daytime Descending Orbits

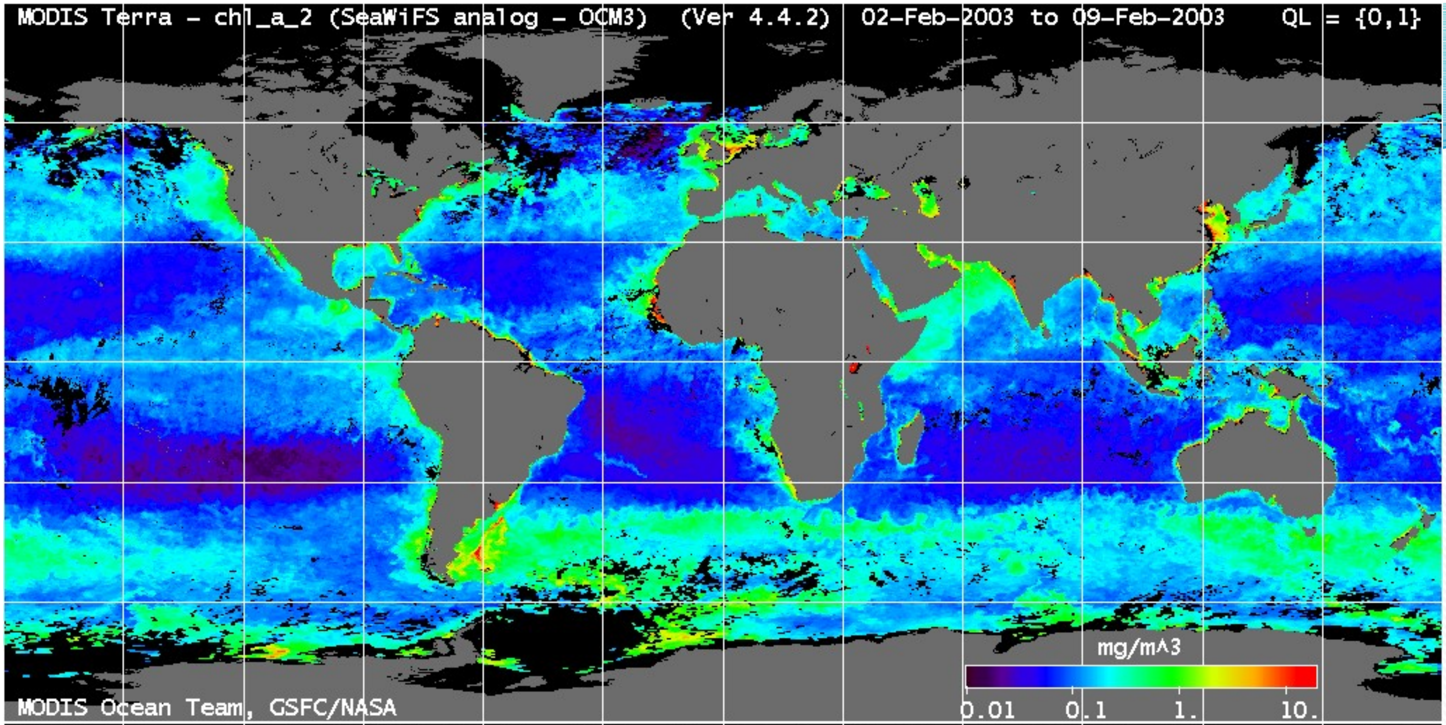


Aqua - Daytime Ascending Orbits



8 Day (Weekly) Composites

Terra



Aqua