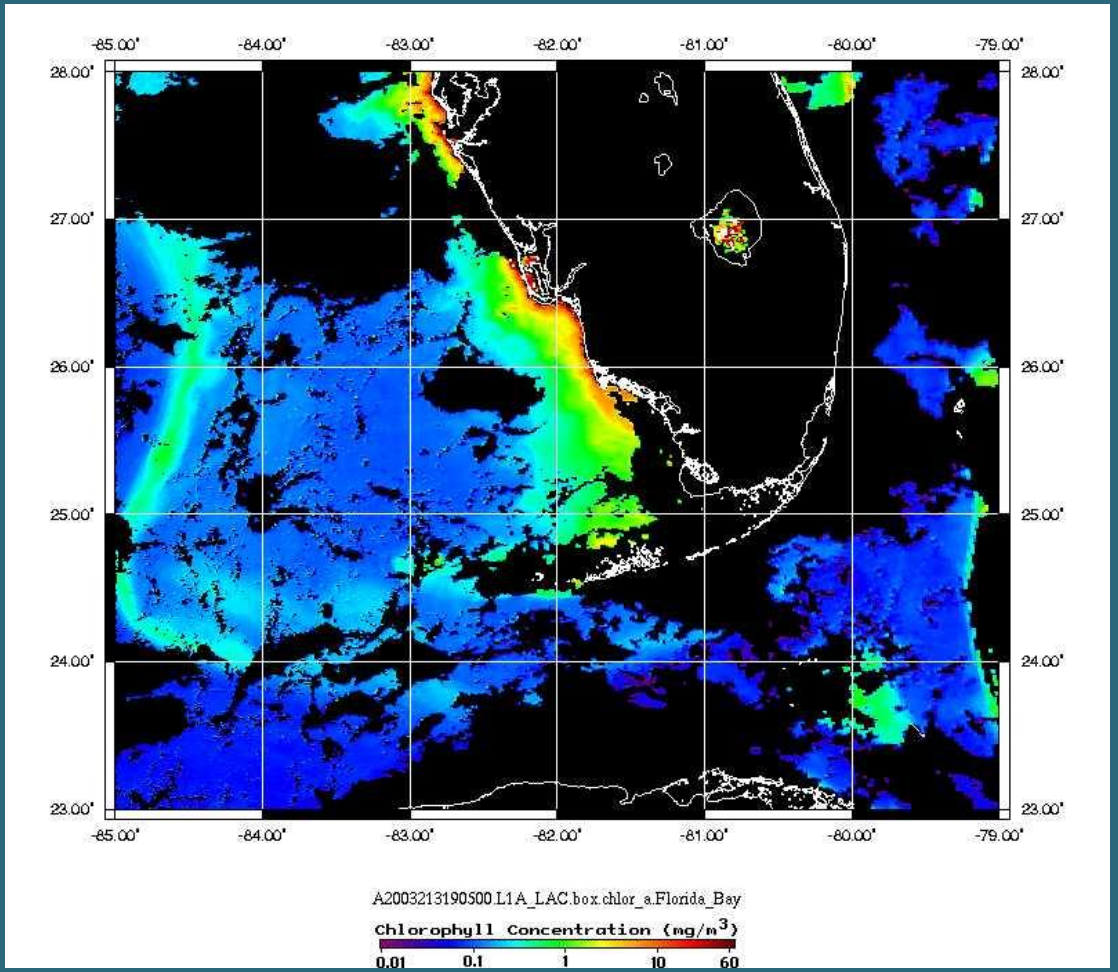
MODIS Ocean Products



MODIS/AIRS Workshop
Pretoria, South Africa
April 4-7, 2006

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University of Wisconsin-Madison

CIMSS

SSEC

MODIS Ocean Standard Products

Geophysical Parameter Name	Description
nLw_412	Normalized water-leaving radiance at 412 nm
nLw 443	Normalized water-leaving radiance at 443 nm
nLw_488	Normalized water-leaving radiance at 488 nm
nLw_531	Normalized water-leaving radiance at 531 nm
nLw_551	Normalized water-leaving radiance at 551 nm
nLw_667	Normalized water-leaving radiance at 667 nm
Tau_869	Aerosol optical thickness at 869 nm
Eps_78	Epsilon of aerosol correction at 748 and 869 nm
Chlor_a	OC3 Chlorophyll a concentration
K490	Diffuse attenuation coefficient at 490nm
Angstrom_531	Angstrom coefficient, 531-869 nm
SST	Sea Surface Temperature: 11 micron
SST4	Sea Surface Temperature: 4 micron (night only)

MODIS Atmospheric Correction for Ocean Bands

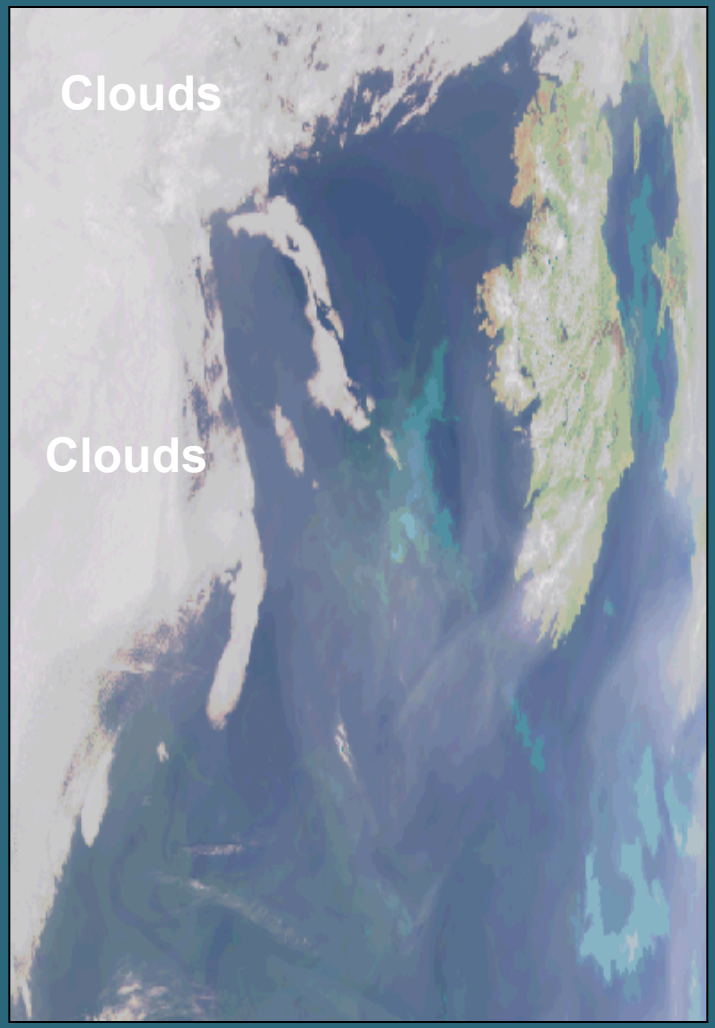
Statement of the problem:

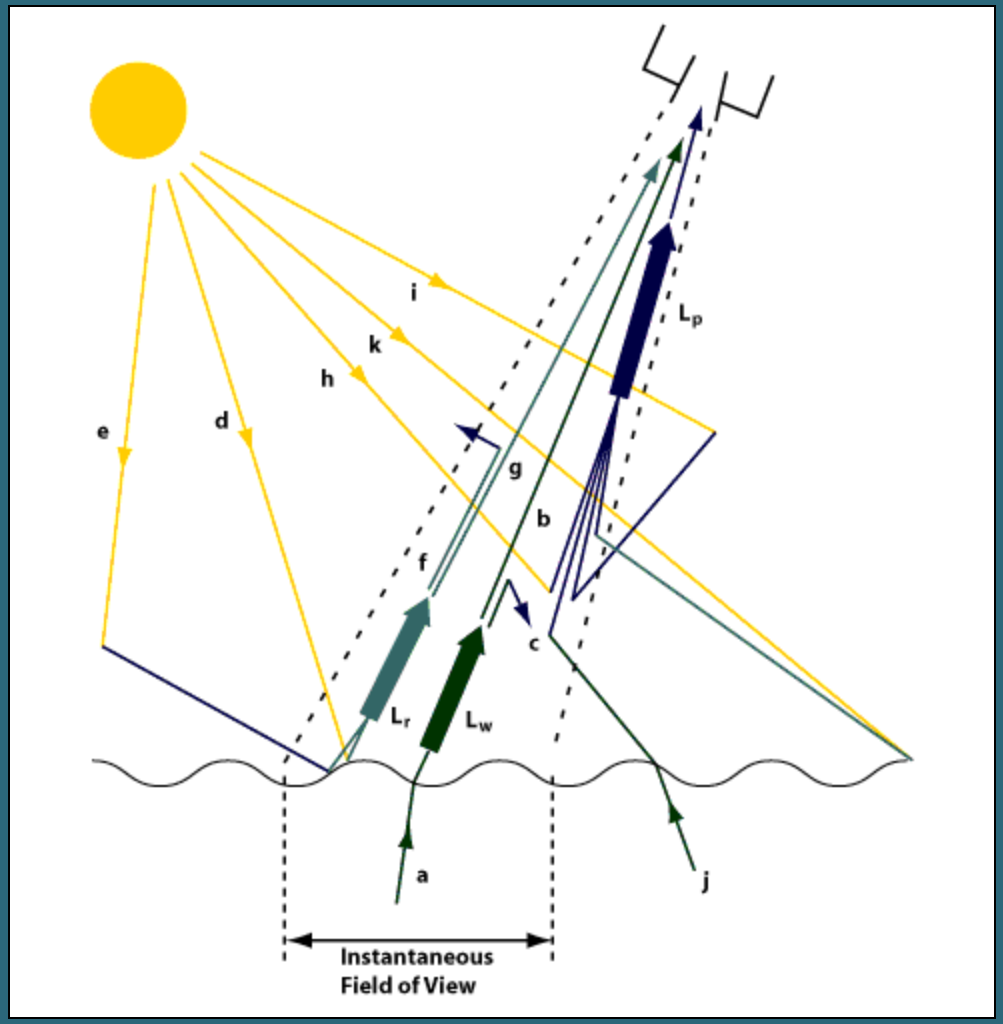
- Total radiance observed by the satellite is composed of 5-10% ocean signal and 90-95% atmosphere signal.
- The atmospheric and ocean surface scattering effects must be accurately modelled and removed.
- Desired parameter is normalized water leaving radiance (nLw) for MODIS bands 8, 9, 10, 11, 12, 13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

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 is critical for ocean color retrievals





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

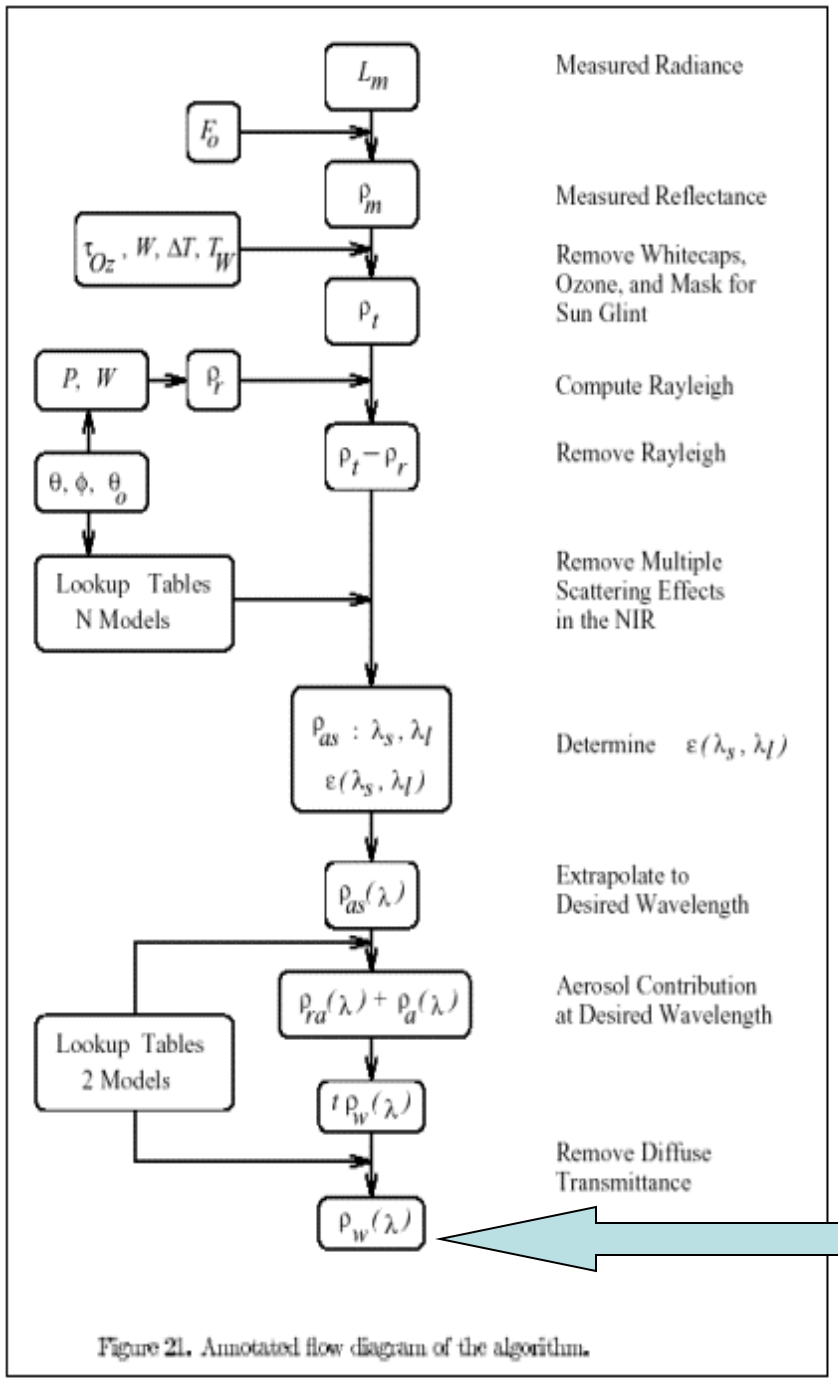


Figure 21. Annotated flow diagram of the algorithm.

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

* 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

Reflectance at water surface

MODIS Chlorophyll Algorithm (OC3)

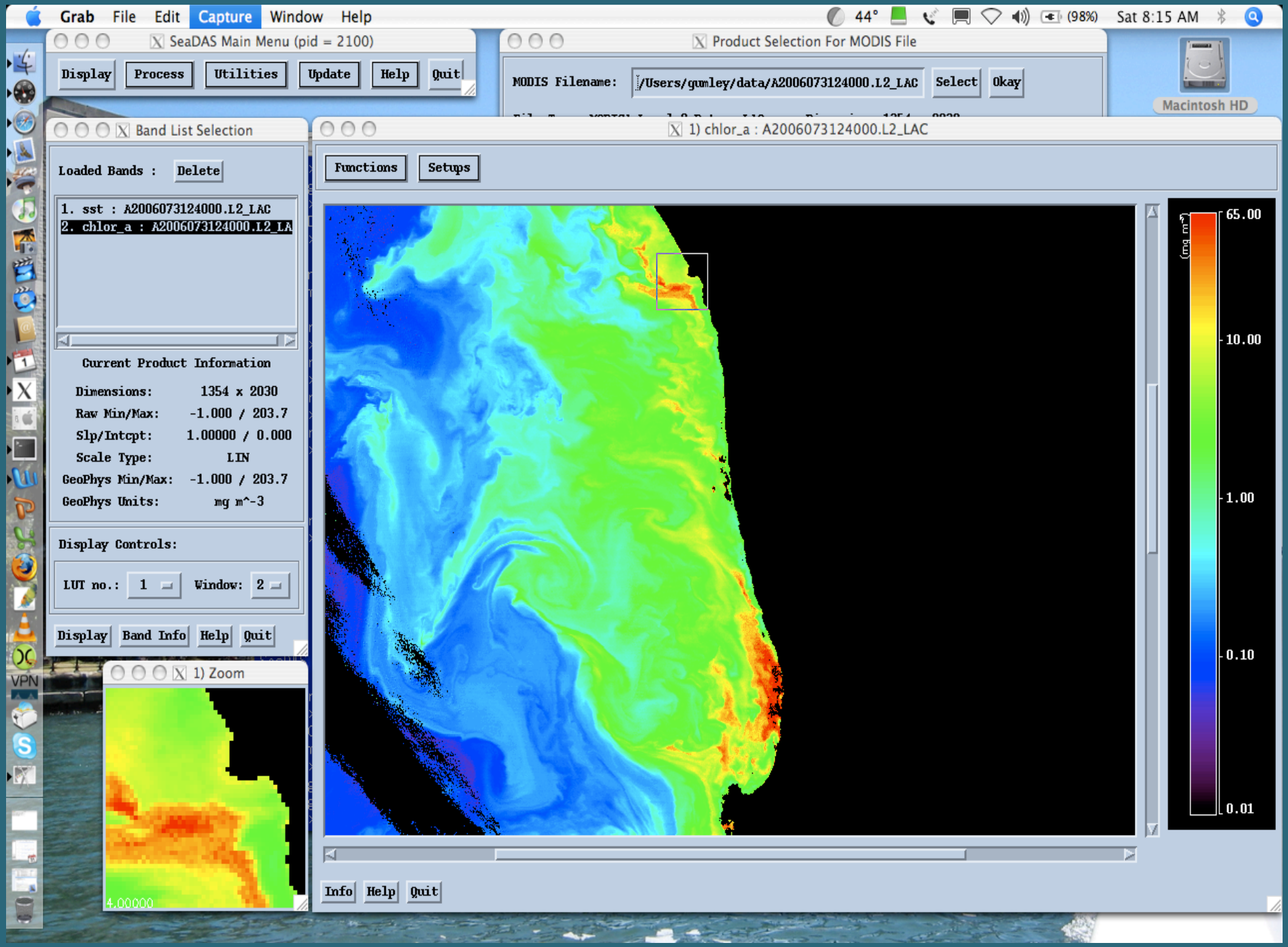
Semi-analytical algorithm[1]

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

where:

R = log10((Rrs443 > Rrs488) / Rrs551)
Rrs = nLw / F0; remote sensing reflectance
F0 = 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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44° (98%) Sat 8:15 AM
SeaDAS Main Menu (pid = 2100)
Display Process Utilities Update Help Quit
Product Selection For MODIS File
MODIS Filename: /Users/gumley/data/A2006073124000.L2_LAC Select Okay
Macintosh HD
Band List Selection
Loaded Bands : Delete
1. sst : A2006073124000.L2_LAC
2. chlor_a : A2006073124000.L2_LA
Current Product Information
Dimensions: 1354 x 2030
Raw Min/Max: -1.000 / 203.7
Slp/Intcpt: 1.00000 / 0.000
Scale Type: LIN
GeoPhys Min/Max: -1.000 / 203.7
GeoPhys Units: mg m^-3
Display Controls:
LUT no.: 1 Window: 2
Display Band Info Help Quit
1) chlor_a : A2006073124000.L2_LAC
Functions Setups
65.00
10.00
1.00
0.10
0.01
Info Help Quit
1) Zoom
4.00000

MODIS Shortwave Infrared Sea Surface Temperature (c5)

sst4 = a0 + a1 * BT39 + a2 * dBT + a3 * (1.0/mu - 1.0)

where:

dBT = BT39 - BT40

BT39 = brightness temperature at 3.959 um, in deg-C

BT40 = brightness temperature at 4.050 um, in deg-C

mu = cosine of sensor zenith angle

a0, a1, a2, and a3 are time dependent coefficients derived from match-ups between observed MODIS brightness temperature and field measurements of SST.

Note: sst4 is not valid during daytime because of solar reflection.

MODIS Longwave Infrared Sea Surface Temperature (c5)

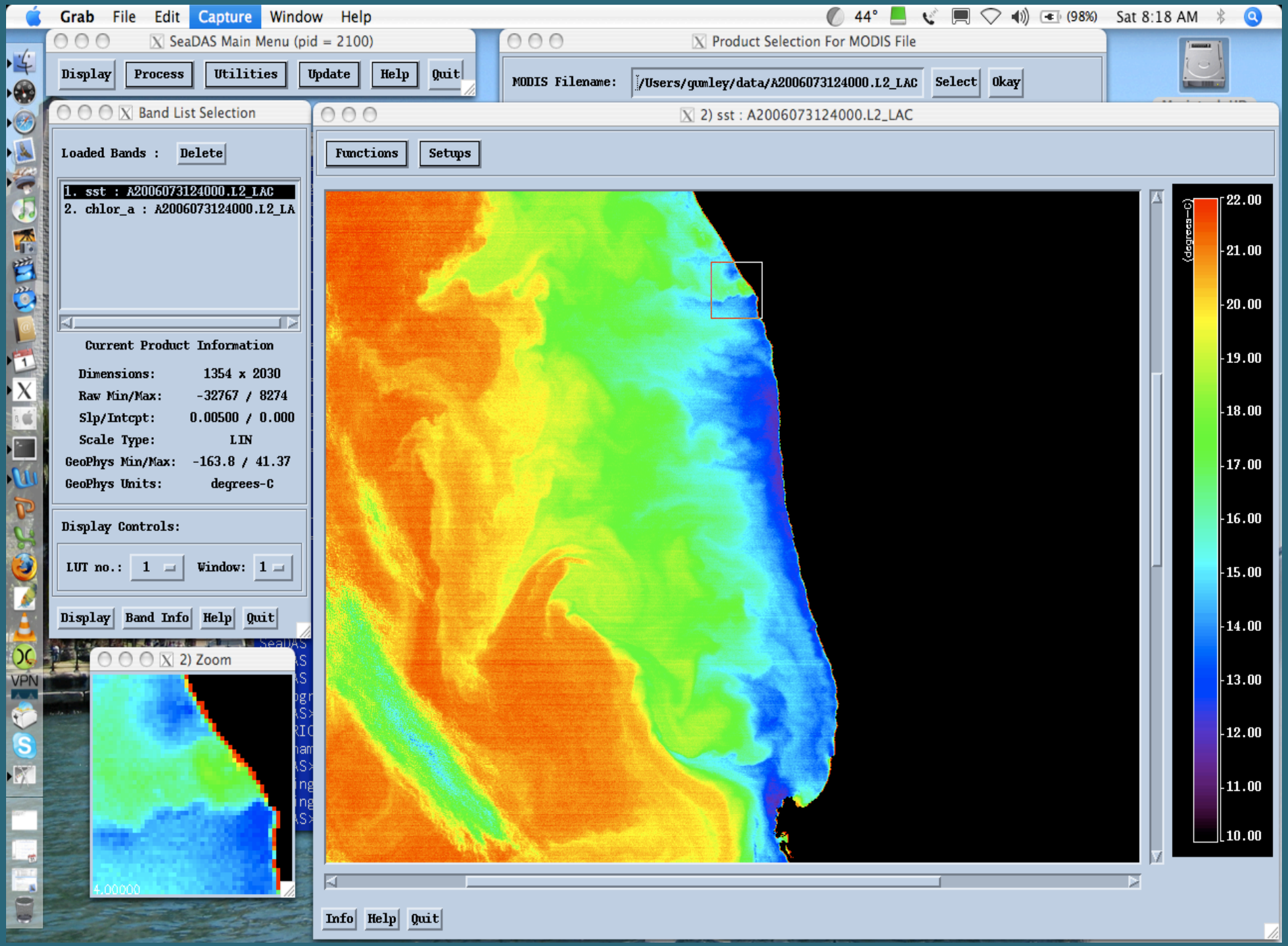
dBT <= 0.5
sst = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)

dBT >= 0.9
sst = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)

0.5 < dBt < 0.9
sstlo = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)
ssthi = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)
sst = sstlo + (dBT - 0.5)/(0.9 - 0.5)*(ssthi - sstlo)

where:

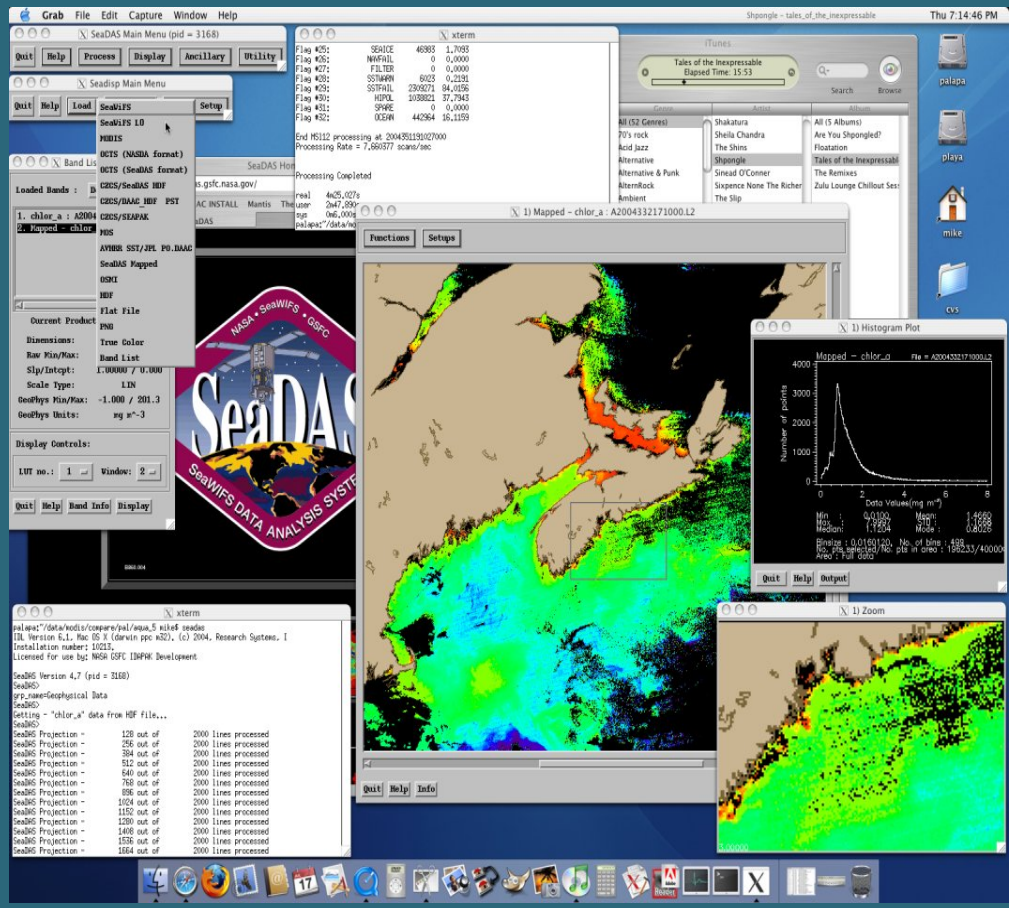
dBT = BT11 - BT12
BT11 = brightness temperature at 11 um, in deg-C
BT12 = brightness temperature at 12 um, in deg-C
bsst = Either sst4 (if valid) or sstref (from Reynolds OISST)
mu = cosine of sensor zenith angle
a00, a01, a02, a03, a10, a11, a12, a13 derived from match-ups


Grab File Edit Capture Window Help
44° (98%) Sat 8:18 AM
SeaDAS Main Menu (pid = 2100)
Display Process Utilities Update Help Quit
Product Selection For MODIS File
MODIS Filename: /Users/gumley/data/A2006073124000.L2_LAC Select Okay
Band List Selection
Loaded Bands : Delete
1. sst : A2006073124000.L2_LAC
2. chlor_a : A2006073124000.L2_LA
Current Product Information
Dimensions: 1354 x 2030
Raw Min/Max: -32767 / 8274
Slp/Intcpt: 0.00500 / 0.000
Scale Type: LIN
GeoPhys Min/Max: -163.8 / 41.37
GeoPhys Units: degrees-C
Display Controls:
LUT no.: 1 Window: 1
Display Band Info Help Quit
2) sst : A2006073124000.L2_LAC
Functions Setups
(degrees-C)
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
Info Help Quit
2) Zoom
4.00000

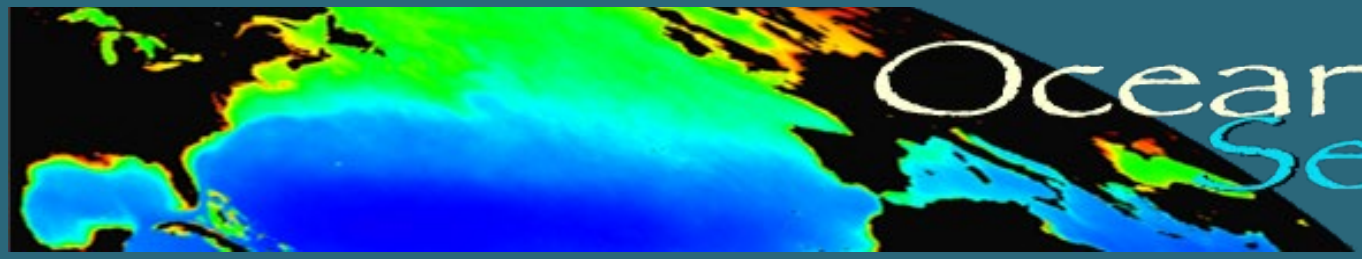
OceanColor SeaDAS

The official NASA MODIS ocean processing algorithms are implemented in the SeaWIFS Data Analysis System (SeaDAS).

SeaDAS is a comprehensive freely available software package for the processing, display, analysis, and quality control of ocean color and SST data.



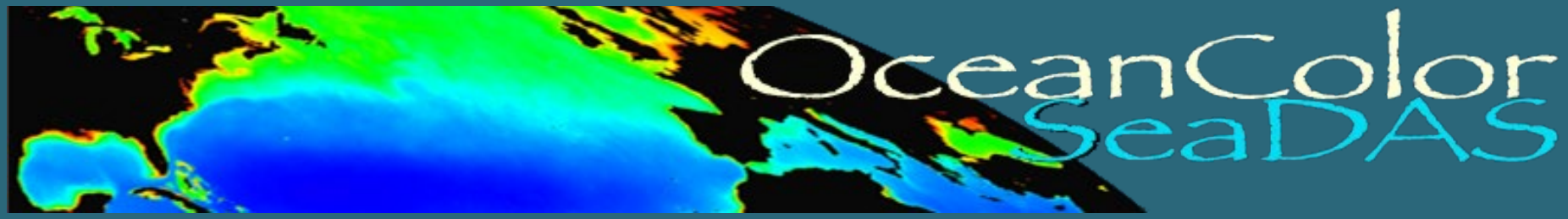
http://oceancolor.gsfc.nasa.gov/seadas/



SeaDAS MODIS Features:

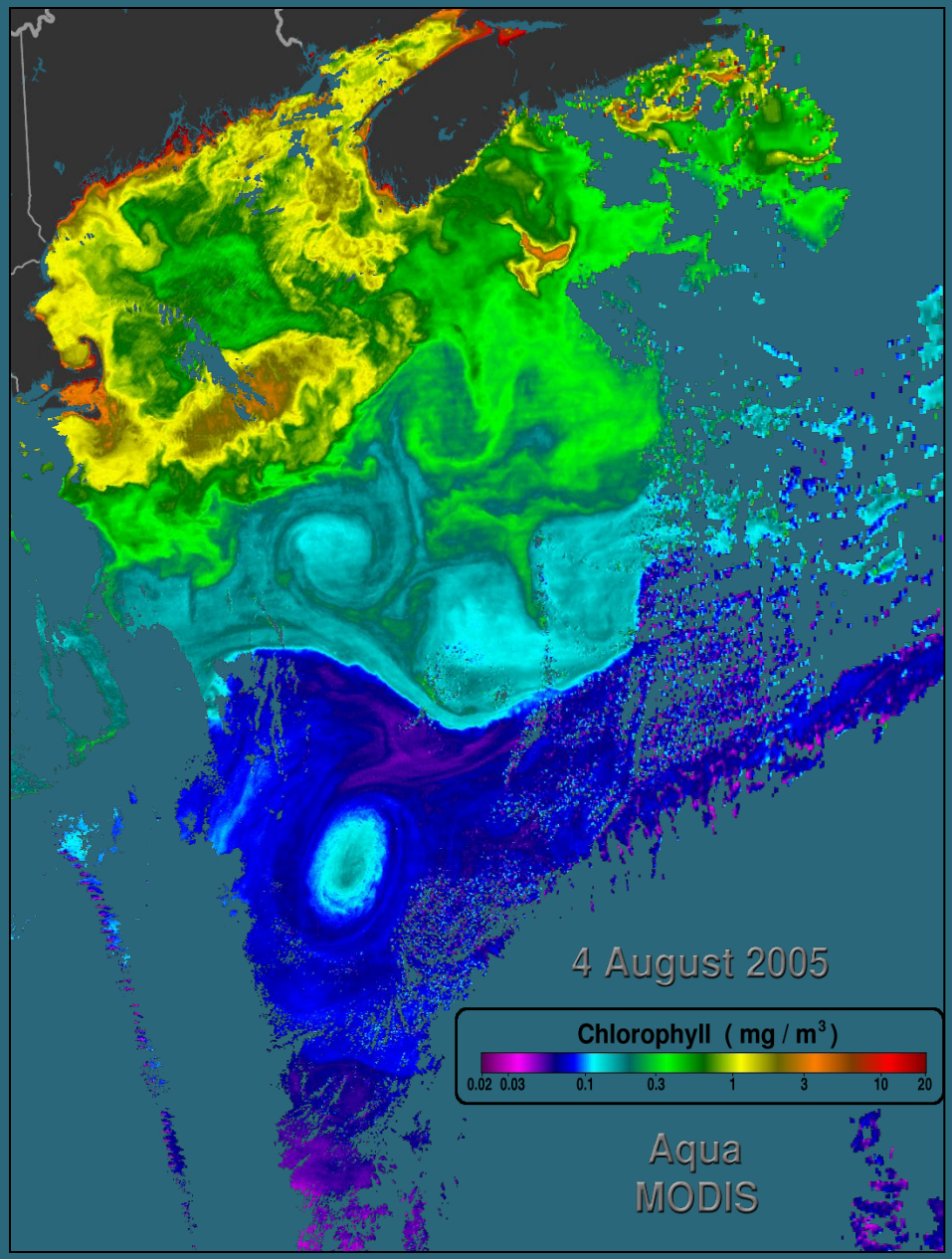
- L0 to L1A Direct Broadcast (DB) processing
- L1A and Geolocation processing (DB or DAAC)
- L1A to L1B processing
- L1B to L2 processing (ocean color and SST)
- L2 and L3 binning
- SMI (Standard Mapped Image) creation

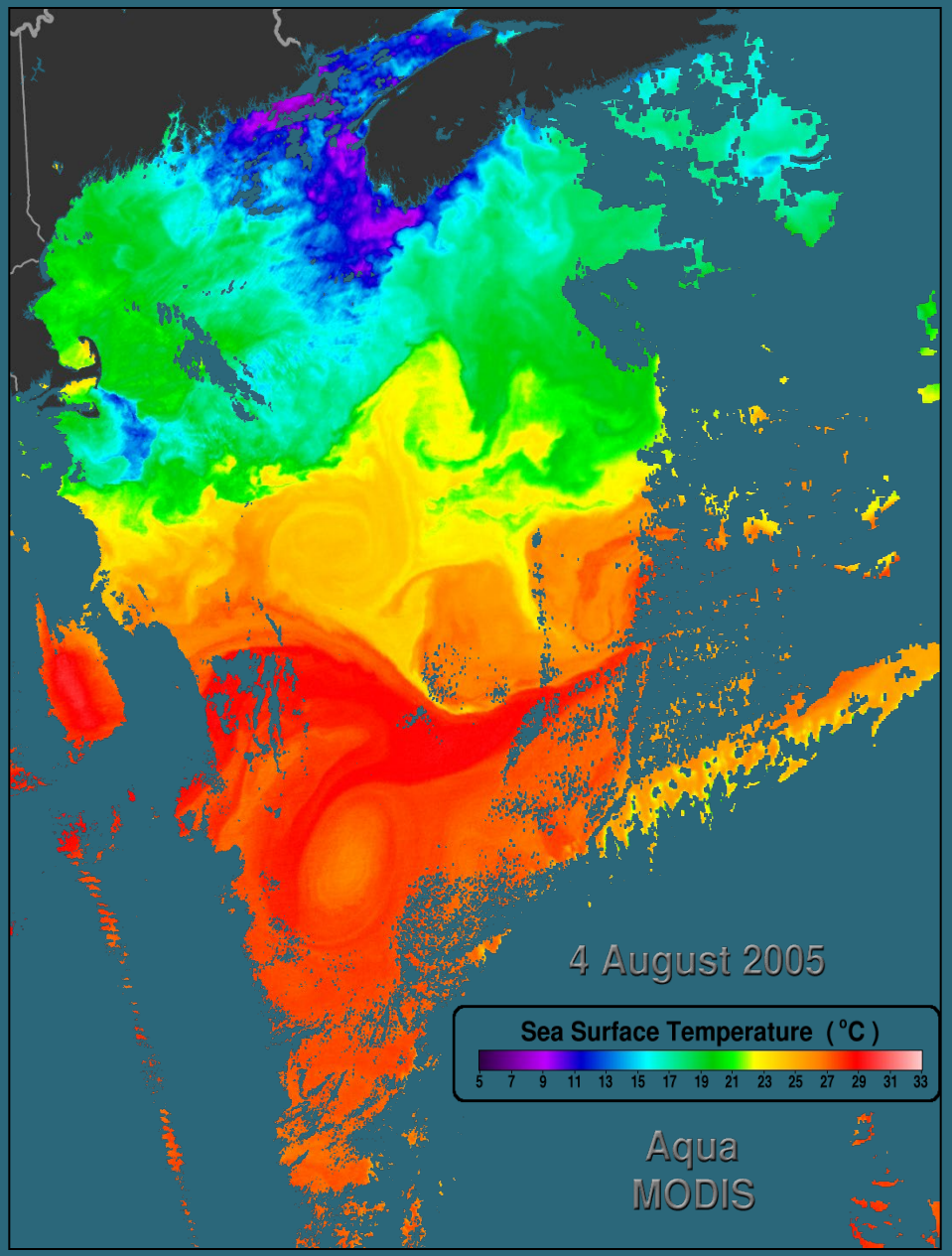
Platforms:	PC workstations (Intel Linux) G3, G4, or G5 Macintosh computers (OS X) SUN UltraSPARC workstations (Solaris) SGI O2 workstations (IRIX)
Memory:	256MB minimum, 512MB+ suggested
Disk:	SeaDAS software package (display only version): ~150MB SeaDAS software package (with processing capabilities): ~900MB Files required for runtime SeaDAS capability: ~400MB Optional DEM maps for processing over land and lakes : ~700MB Optional DEM maps for MODIS geolocation terrain correction: ~600MB 10GB of free space



SeaDAS General Features:

- User-controlled display scaling
- Multiple frame buffers for image display
- Interactive annotation generation
- Histogram and color bar
- Color manipulation, multiple concurrent color tables, density slicing
- Cursor location and data displaying
- Image data spreadsheet for raw and/or geophysical values
- Image looping/movie
- Scatter plot/contour plot/profile plot
- Data display across multiple bands
- Bathymetry generation
- Arithmetic band functions
- X-Y shifting
- User-defined band operations
- Postscript, PNG output image formats.
- ASCII, HDF SD, and binary flat file output data formats.


4 August 2005
Chlorophyll (mg / m3)
0.02 0.03 0.1 0.3 1 3 10 20
Aqua
MODIS


4 August 2005
Sea Surface Temperature (°C)
5 7 9 11 13 15 17 19 21 23 25 27 29 31 33
Aqua
MODIS