International School on Applications with the Newest Multi-spectral Environmental Satellites

held in Brienza from 18 to 24 Sep 2011

CIMSS

imaa istituto di metodologie per l'analisi ambientale

SSEC

Dottorato di Ricerca in Metodi e Tecnologie per il Monitoraggio Ambientale

Università degli Studi della Basilicata 1982

DIFA Dipartimento di Ingegneria e Fisica dell'Ambiente

Paul Menzel, Valerio Tramutoli, & Filomena Romana

Su 1 – 4 pm	Lecture 1	Instruments and Orbits
Mo 9 – 12 am	Lecture 2	Radiative Transfer in the Earth Atmosphere
	Homework 1 (due Thursday)	
Mo 2 – 5 pm	Lab 1	Planck Function and Intro to Hydra
Tu 9 – 12 am	Review	Lecture 1 & 2, Lab 1
	Lecture 3	Spectral signatures from Earth
Tu 2 – 5 pm	Lab 2	Interrogating Multispectral Data
We 9 – 12 am	Review	Lecture 3, Lab 2
	Lecture 4	Sounding with broad band and hyperspectral IR
	Quiz 1	
We 2 – 5 pm	Lab 3	Investigations with Imagers and Sounders
Th 9 – 12 am	Review	Quiz 1, Lecture 4, Lab 3
	Homework 2 (due Saturday)	
	Lecture 5	Microwave and time continuous (geostationary) measurements
Th 2 – 5 pm	Lab 4	Investigations of clouds and moisture with MODIS, AIRS and AMSU
	Lab	Assign and start Student Projects
Fr 9 – 12 am	Review	Homework 1, Lecture 5, Lab 4
	Lab	Student Projects
Fr 2 – 5 pm	Lab	Student Projects
Sa 9 – 12 am	Lab	Student Presentations using MODIS, IASI, AIRS, SEVIRI
	Review	Homework 2
	Lecture 6	Summary
	Quiz 2	

Remote Sensing Schools have been held in

Bologna, Italy (Sep 01)
Rome, Italy (Jun 02)
Maratea, Italy (May 03)
Bertinoro, Italy (Jul 04)
Andanes, Norway (Feb 06)
Cape Town, South Africa (Apr 06)
Krakow, Poland (May 06)
Ostuni, Italy (Jun 06)
Benevento, Italy (Jun 07)
Sao Paulo, Brazil (Nov 07)
Monteponi, Sardinia (Sep 08)
Istanbul, Turkey (Oct 08)
Perth, Western Australia (Feb 09)
Sasso di Castalda, Italy (Jul 09)
New Dehli, India (Feb 11)

Objective of School

An in depth explanation of methods and techniques used to extract information from environmental satellite data, with emphasis on the latest measuring technologies. The course will consist of lectures, laboratory sessions, group lab projects, homework and tests. The results from each of the group projects will be presented to the class by the participating students. English is the official language of the School. All provided material will be in English.

Lectures and Labs

Lectures and laboratory exercises emphasize investigation of high spatial resolution visible and infrared data (from MODIS and SEVIRI), high spectral resolution infrared data (from AIRS and IASI), and microwave sounding data (AMSU). Text for the classroom and a visualization tool for the labs are provided free; "Applications with Meteorological Satellites" is used as a resource text from ftp://ftp.ssec.wisc.edu/pub/menzel/ and HYDRA is used to interrogate and view multispectral data in the labs from http://www.ssec.wisc.edu/hydra/. Homework assignments and classroom tests are administered to verify that good progress is being was made in learning and mastering the materials presented. Classroom size is usually between twenty and thirty students.

Lectures

Applications with Meteorological Satellites is used as a resource text
It is available for free at *ftp://ftp.ssec.wisc.edu/pub/menzel/*

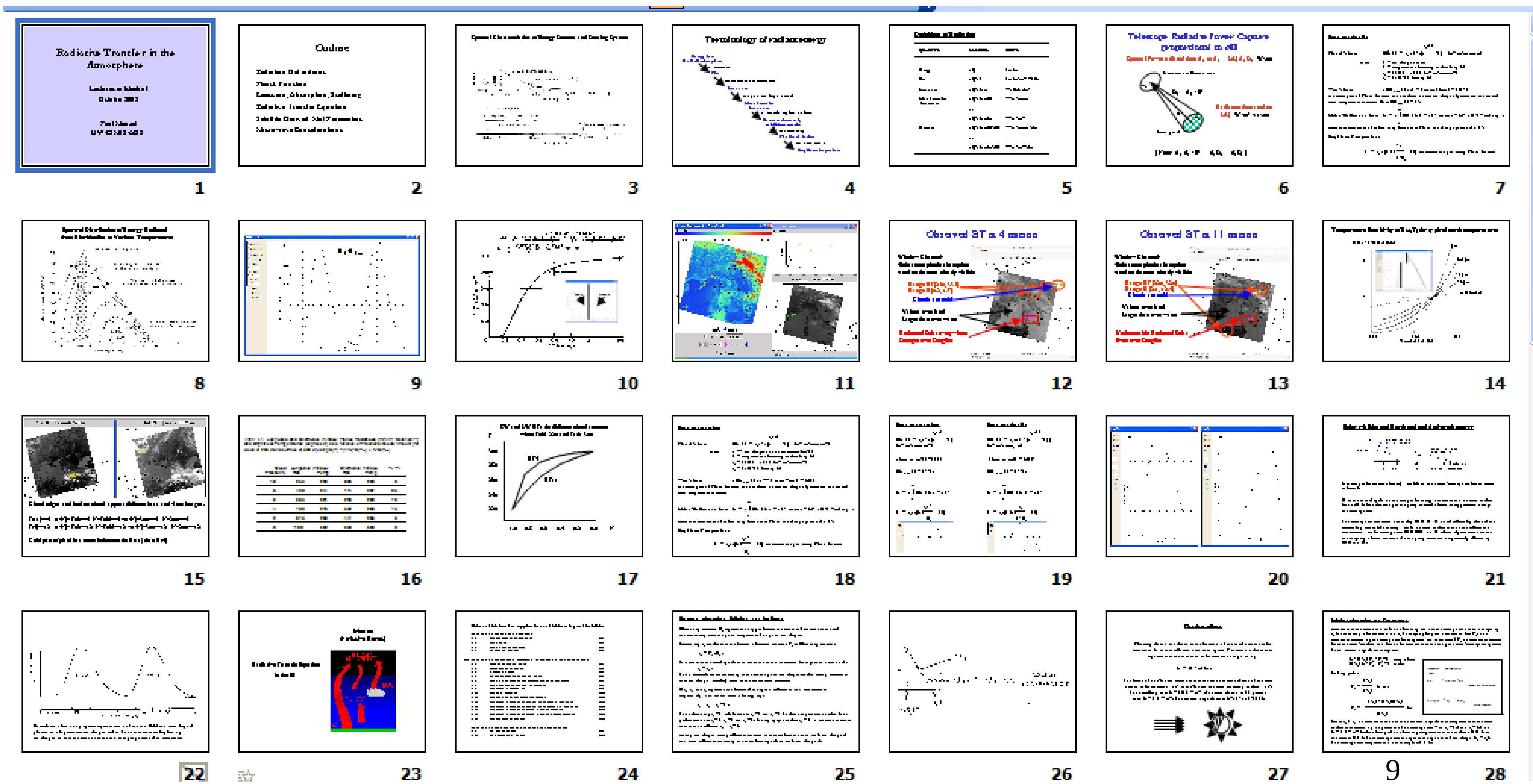
CHAPTER 1 - EVOLUTION OF SATELLITE METEOROLOGY
CHAPTER 2 - NATURE OF RADIATION *
CHAPTER 3 - ABSORPTION, EMISSION, REFLECTION, AND SCATTERING *
CHAPTER 4 - THE RADIATION BUDGET
CHAPTER 5 - THE RADIATIVE TRANSFER EQUATION (RTE) *
CHAPTER 6 - DETECTING CLOUDS *
CHAPTER 7 - SURFACE TEMPERATURE *
CHAPTER 8 - TECHNIQUES FOR DETERMINING ATMOSPHERIC PARAMETERS *
CHAPTER 9 - TECHNIQUES FOR DETERMINING ATMOSPHERIC MOTIONS
CHAPTER 10 - AN APPLICATION OF GEOSTATIONARY SATELLITE SOUNDING DATA
CHAPTER 11 - SATELLITE ORBITS
CHAPTER 12 - RADIOMETER DESIGN CONSIDERATIONS *
CHAPTER 13 - ESTABLISHING CLIMATE RECORDS FROM MULTISPECTRAL MODIS MEASUREMENTS
CHAPTER 14 - THE NEXT GENERATION OF SATELLITE SYSTEMS
CHAPTER 15 – INVESTIGATING LAND, OCEAN, AND ATMOSPHERE WITH MULTISPECTRAL MEASUREMENTS *

* indicates chapters covered

References, problems sets, and quizzes are included in the Appendices

Agenda includes material from Chapters 2, 3, 5, and 12

Lectures are given with powerpoint presentations



Material includes equations

Planck's Law $B(\lambda,T) = c_1 / \lambda^5 / [e^{c_2/\lambda T} - 1]$ (mW/m^2/ster/cm)

where λ = wavelengths in cm

T = temperature of emitting surface (deg K)

c_1 = 1.191044 x 10-5 (mW/m^2/ster/cm^{-4})

c_2 = 1.438769 (cm deg K)

Wien's Law $dB(\lambda_{max},T) / d\lambda = 0$ where $\lambda(\max) = .2897/T$

indicates peak of Planck function curve shifts to shorter wavelengths (greater wavenumbers) with temperature increase. Note $B(\lambda_{max},T) \sim T^5$.

Stefan-Boltzmann Law $E = \pi \int_o^\infty B(\lambda,T)\, d\lambda = \sigma T^4$, where σ = 5.67 x 10-8 W/m2/deg4.

states that irradiance of a black body (area under Planck curve) is proportional to T^4 .

Brightness Temperature

$$T = c_2 / [\lambda \ln(\frac{c_1}{\lambda^5 B_\lambda} + 1)]$$ is determined by inverting Planck function

And some derivations,

$$I_\lambda = \varepsilon_\lambda^{sfc} B_\lambda(T(p_s))\, \tau_\lambda(p_s) + \sum_p \varepsilon_\lambda(\Delta p)\, B_\lambda(T(p))\, \tau_\lambda(p)$$

The emissivity of an infinitesimal layer of the atmosphere at pressure p is equal to the absorptance (one minus the transmittance of the layer). Consequently,

$$\varepsilon_\lambda(\Delta p)\, \tau_\lambda(p) = [1 - \tau_\lambda(\Delta p)]\, \tau_\lambda(p)$$

Since transmittance is an exponential function of depth of absorbing constituent,

$$\tau_\lambda(\Delta p)\, \tau_\lambda(p) = \exp\left[- \int_p^{p+\Delta p} k_\lambda\, q\, g^{-1}\, dp\right] * \exp\left[- \int_o^p k_\lambda\, q\, g^{-1}\, dp\right] = \tau_\lambda(p + \Delta p)$$

Therefore

$$\varepsilon_\lambda(\Delta p)\, \tau_\lambda(p) = \tau_\lambda(p) - \tau_\lambda(p + \Delta p) = - \Delta\tau_\lambda(p) .$$

So we can write

$$I_\lambda = \varepsilon_\lambda^{sfc} B_\lambda(T(p_s))\, \tau_\lambda(p_s) - \sum_p B_\lambda(T(p))\, \Delta\tau_\lambda(p) .$$

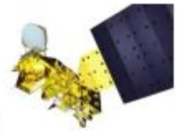
which when written in integral form reads

$$I_\lambda = \varepsilon_\lambda^{sfc} B_\lambda(T(p_s))\, \tau_\lambda(p_s) - \int_o^{p_s} B_\lambda(T(p))\, [\, d\tau_\lambda(p) / dp\,]\, dp .$$

Labs

HYperspectral viewer for Development of Research Applications - HYDRA

MSG,
GOES



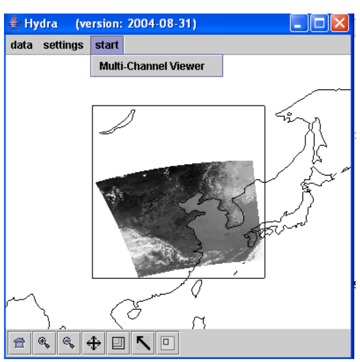
MODIS,
AIRS, IASI,
AMSU,
CALIPSO

Freely available software
For researchers and educators
Computer platform independent
Extendable to more sensors and applications
Based in VisAD
(Visualization for Algorithm Development)
Uses Jython (Java implementation of Python)
runs on most machines
512MB main memory & 32MB graphics card suggested
on-going development effort

Rink et al, BAMS 2007

Developed at CIMSS by
Tom Rink
Tom Whittaker
Kevin Baggett

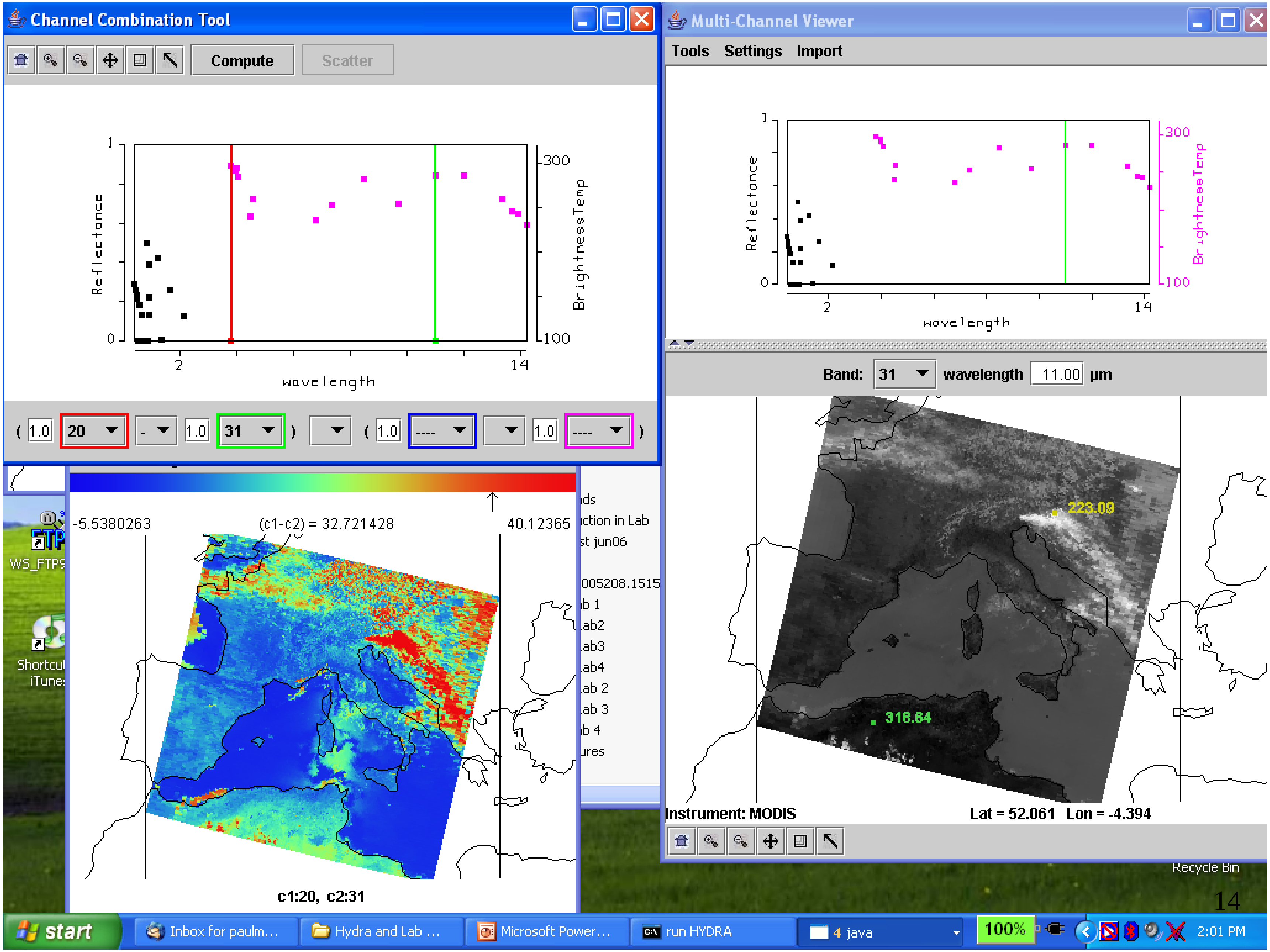
With guidance from
Paolo Antonelli
Liam Gumley
Paul Menzel
Allen Huang



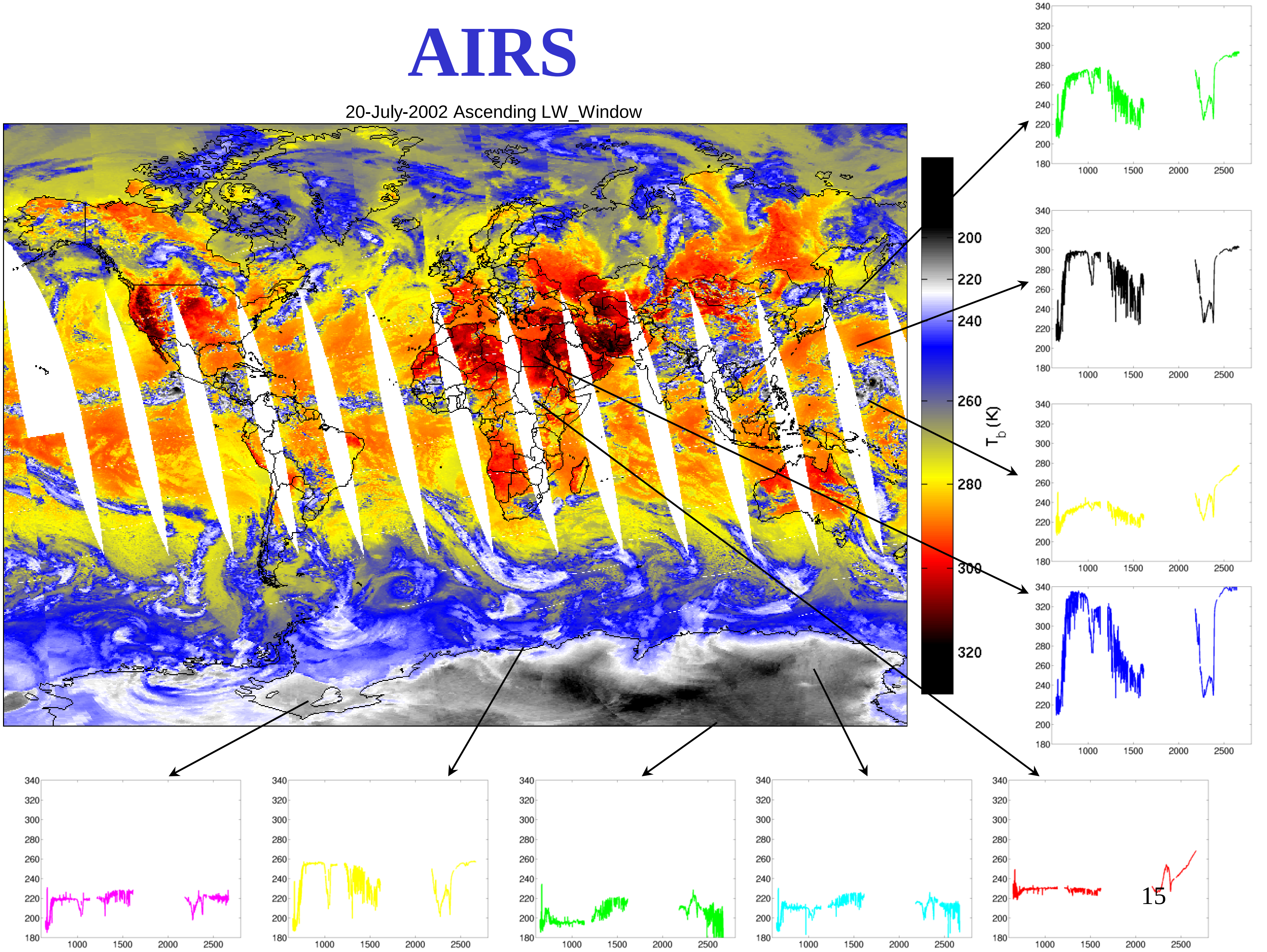
CIMSS

http://www.ssec.wisc.edu/hydra/

Viewing remote sensing data with HYDRA

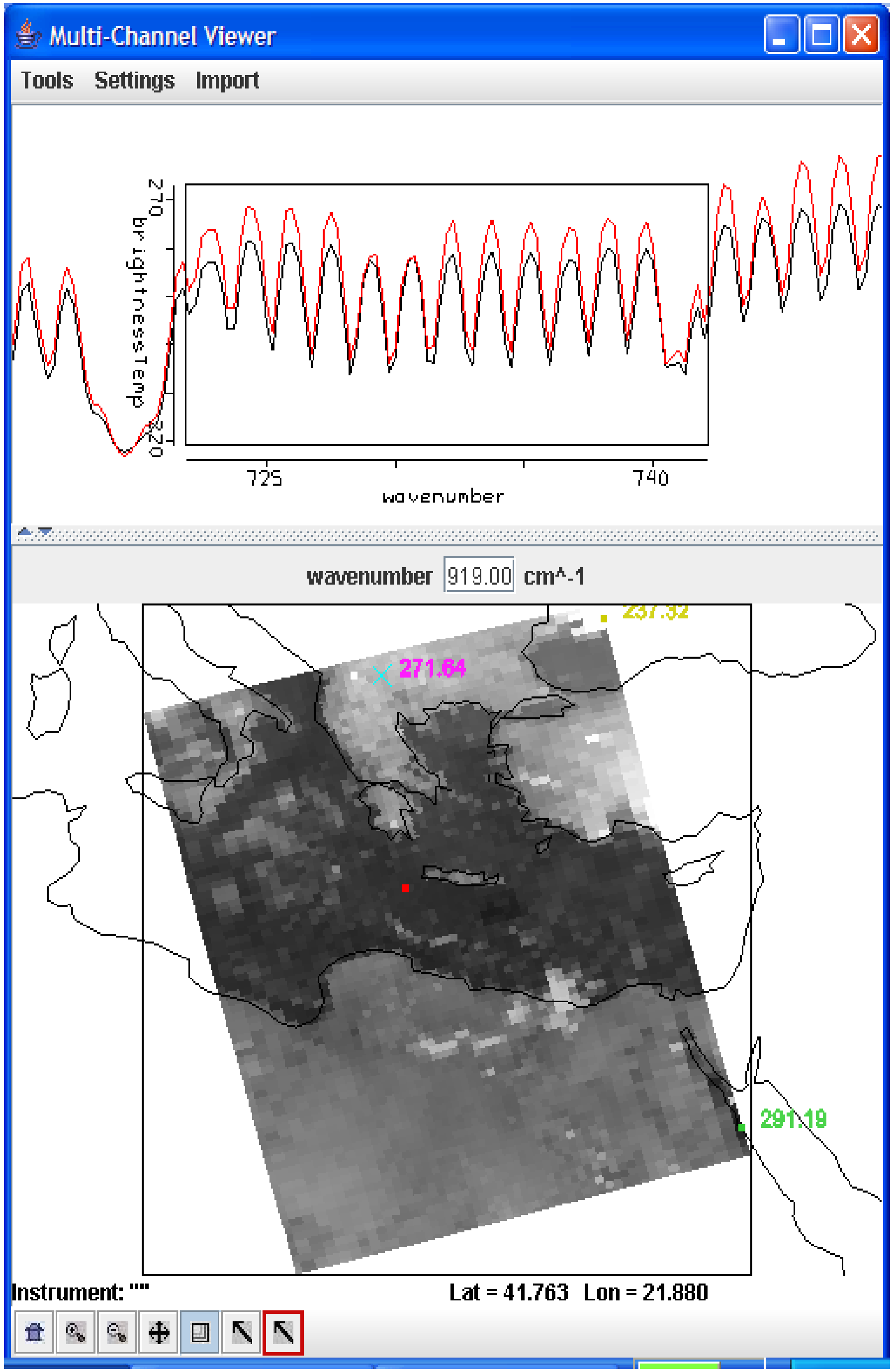


AIRS

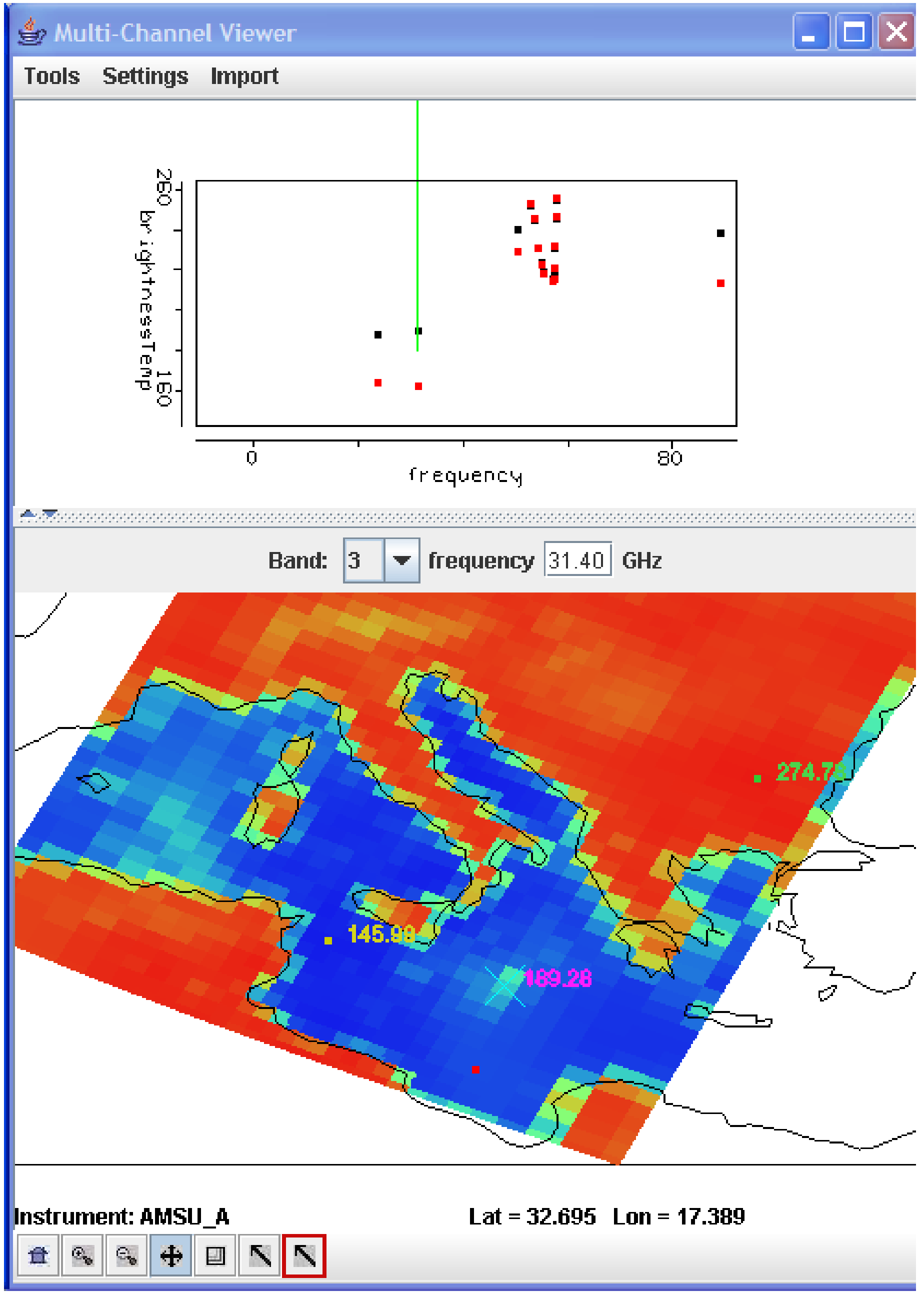


20-July-2002 Ascending LW_Window
T_b (K)
200
220
240
260
280
300
320
340
180
1000
1500
2000
2500

IASI


Multi-Channel Viewer
Tools Settings Import
brightnessTemp
270
220
725
740
wavenumber
wavenumber 919.00 cm^-1
271.64
291.19
Instrument: ""
Lat = 41.763 Lon = 21.880

AMSU



Multi-Channel Viewer
Tools
Settings
Import
260
brightnessTemp
160
0
80
frequency
Band:
3
frequency
31.40
GHz
274.7
145.98
189.28
Instrument: AMSU_A
Lat = 32.695 Lon = 17.389

Access to visualization tools and data

For hydra
http://www.ssec.wisc.edu/hydra/

For MODIS data and quick browse images
http://rapidfire.sci.gsfc.nasa.gov/realtime

For MODIS data orders
http://ladsweb.nascom.nasa.gov/

For AIRS data orders
http://daac.gsfc.nasa.gov/

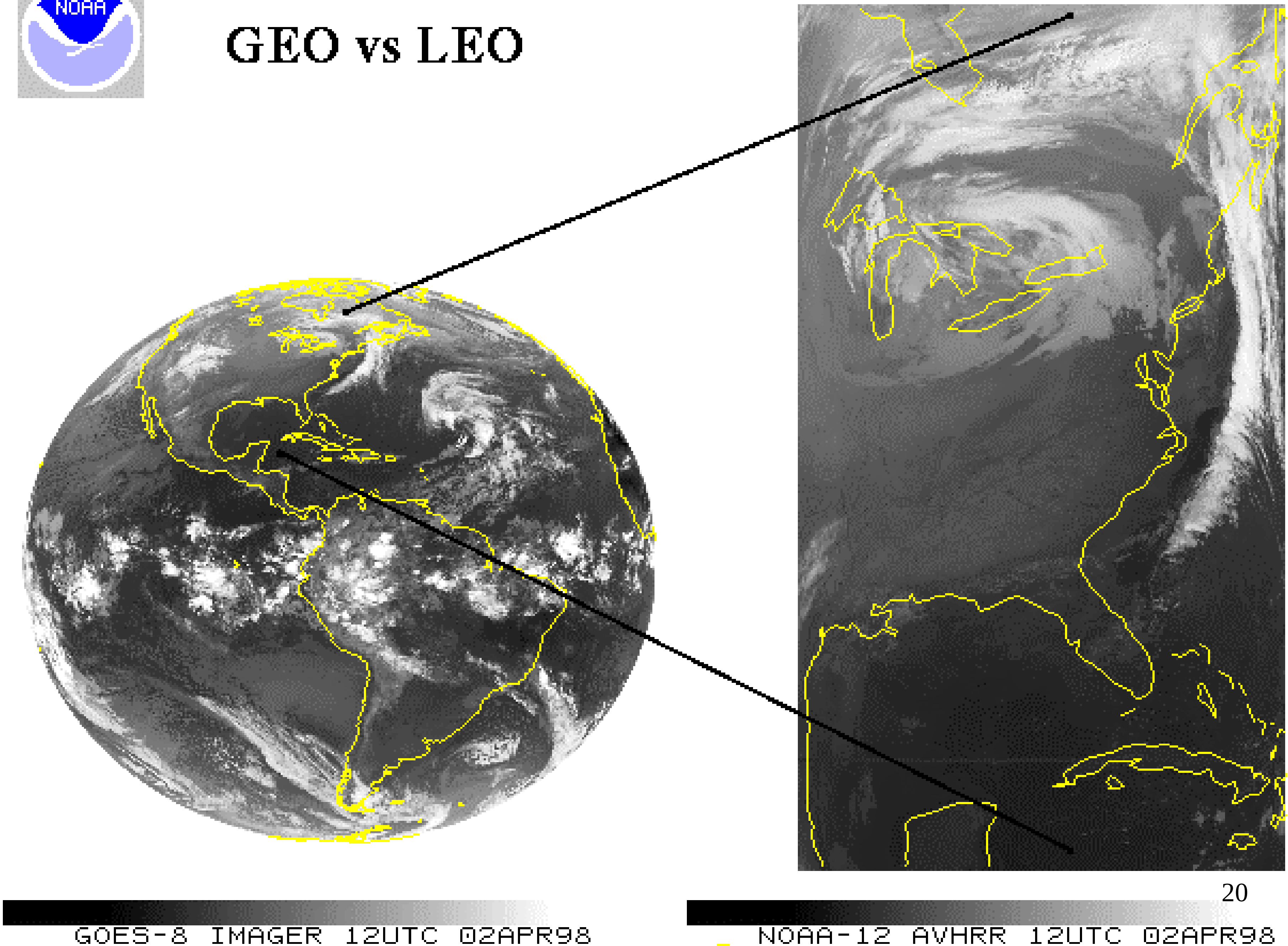
Orbits and Instruments

Lectures in Brienza

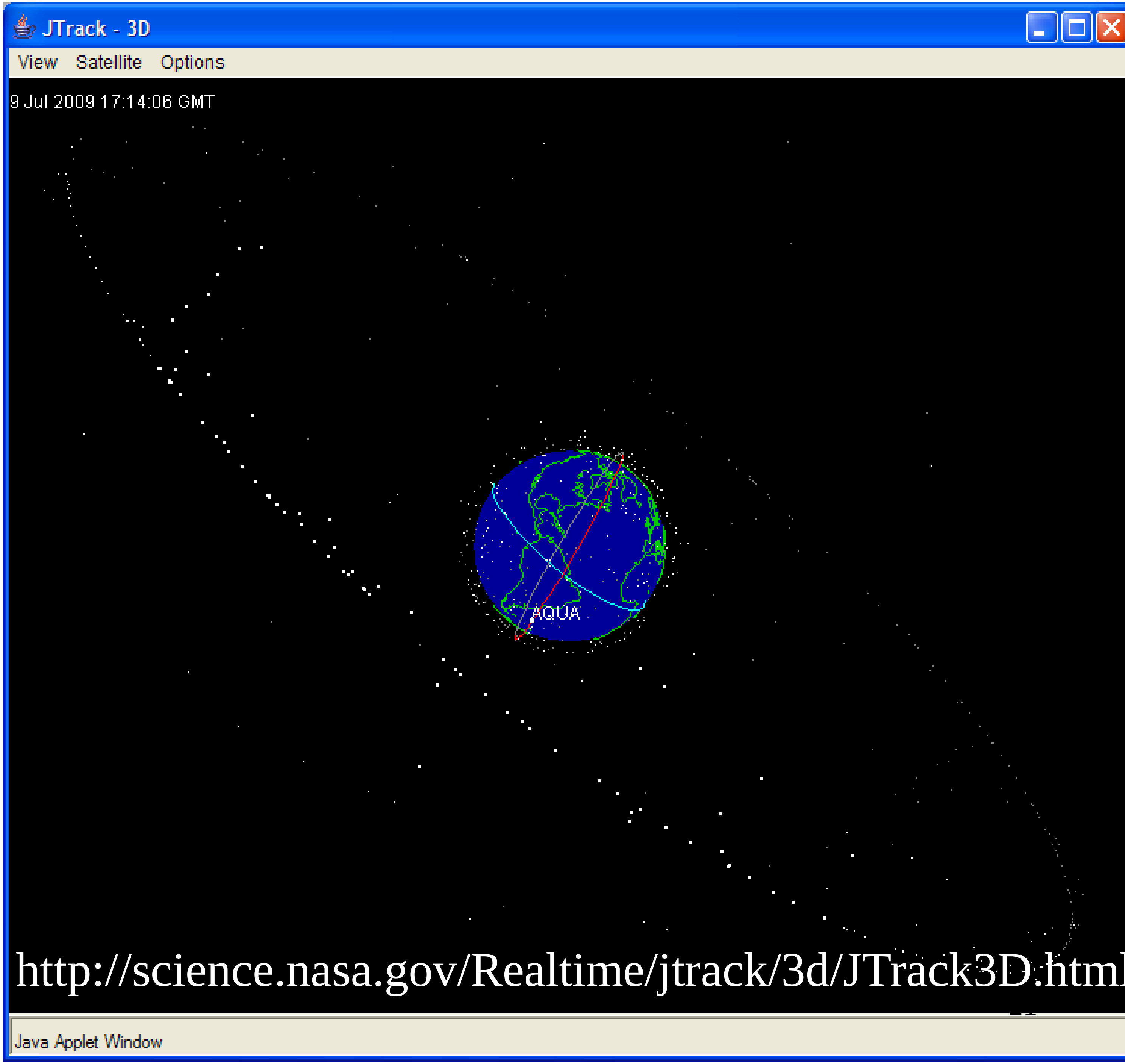
18 Sep 2011

Paul Menzel
UW/CIMSS/AOS

GEO vs LEO

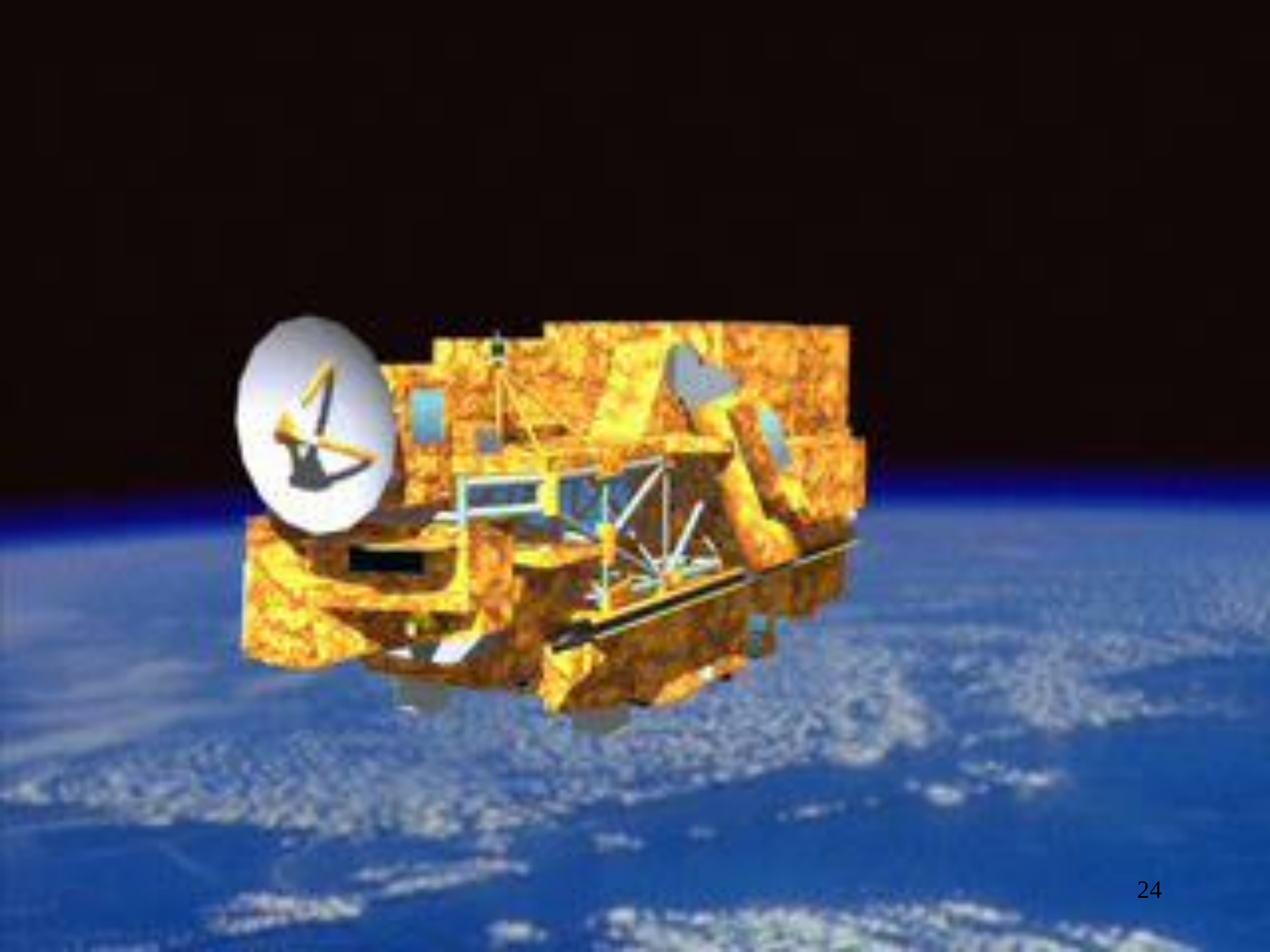


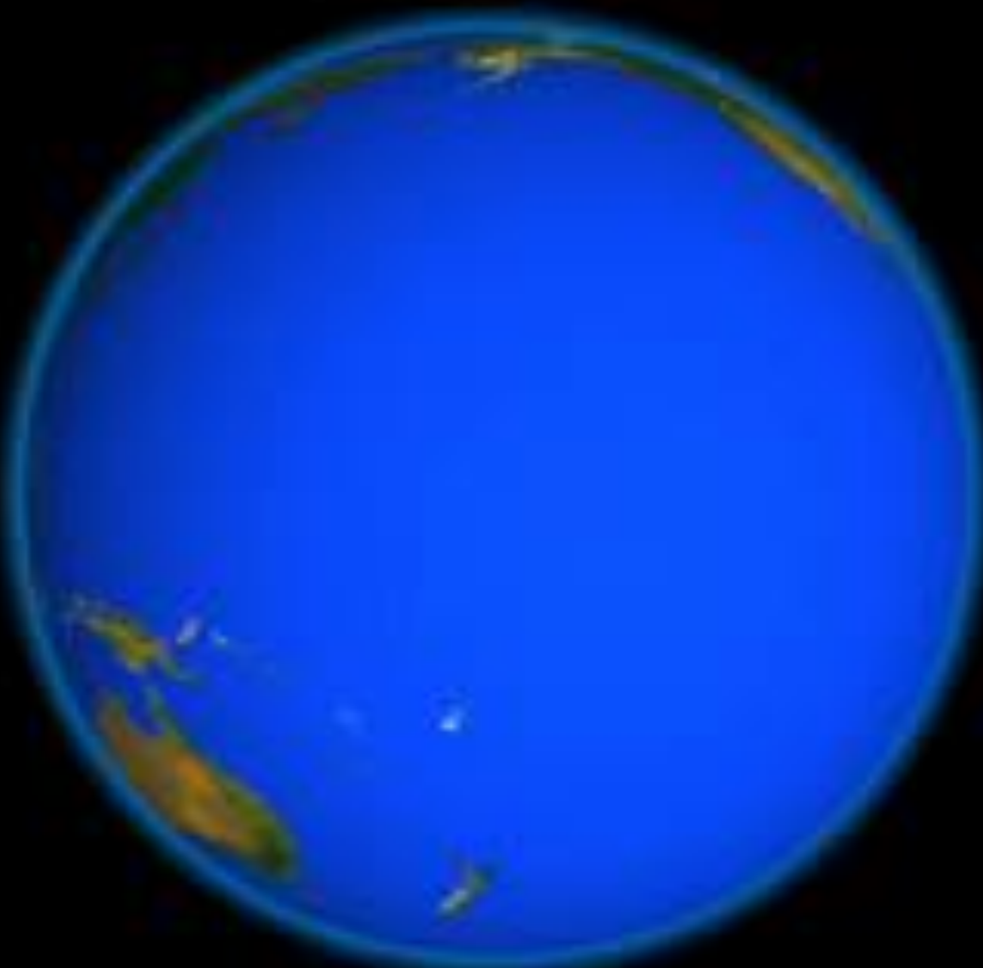
All Sats on NASA J-track



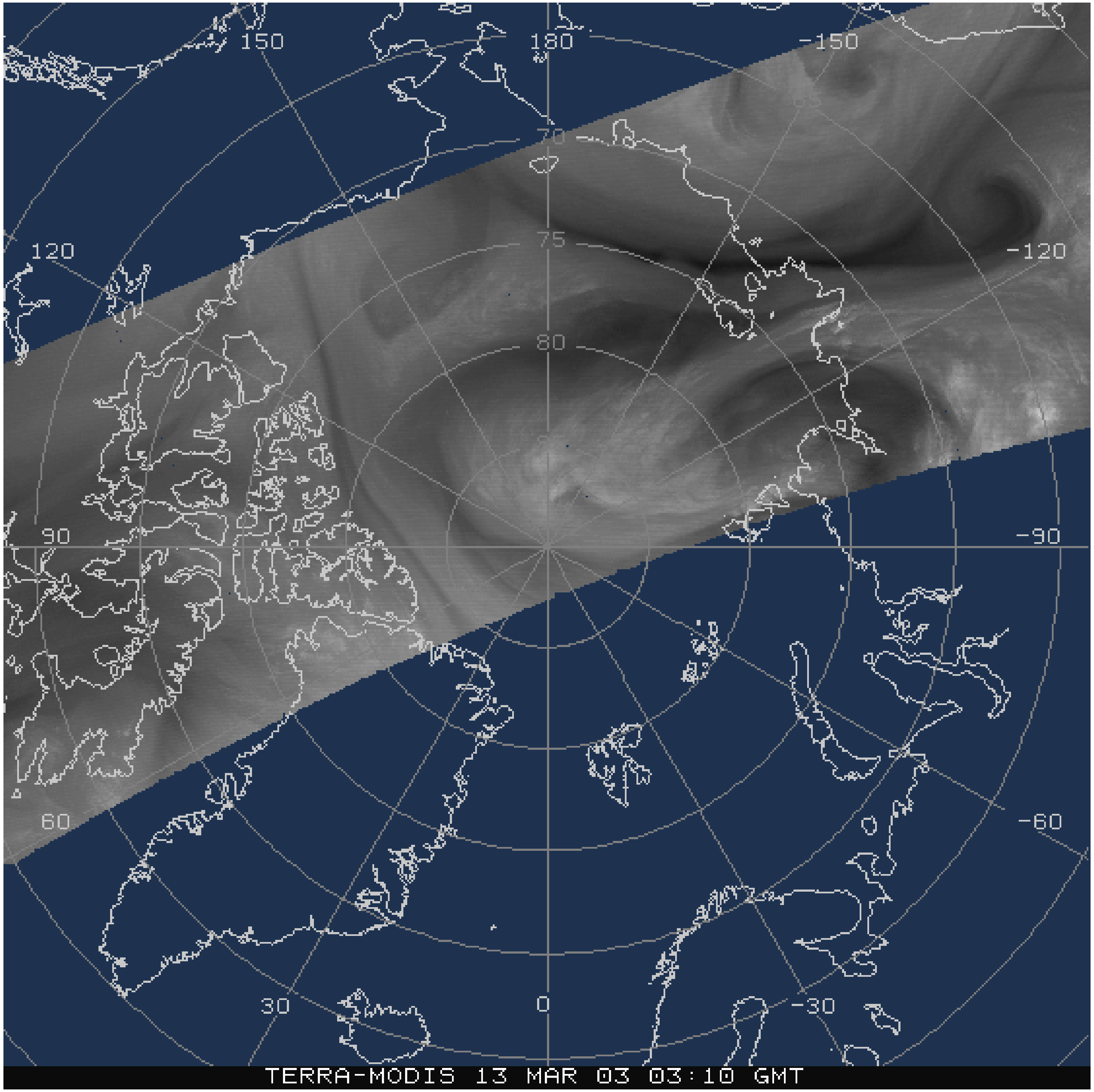
http://science.nasa.gov/Realtime/jtrack/3d/JTrack3D.html


METEOR 3M
(Russian Federation)
FY-1
(China)
High-resolution
Land use
Missions
850 KM
GOES-E
(USA)
75W
Oceanographic
Missions
GOES-W
(USA)
135W
GEOSTATIONARY ORBIT
R&D orbit
SUBSATELLITE
POINT
35 800 Km
MTSAT
(Japan)
140E
Polar orbit
Atmospheric
Chemistry
Missions
MSG
(EUMETSAT)
0 Longitude
FY-2
(China)
105E
Hydrological
Missions
METEOSAT
(EUMETSAT)
63 E
GOMS
(Russian Federation)
76E
Metop
(EUMETSAT)
NPOESS
(USA)

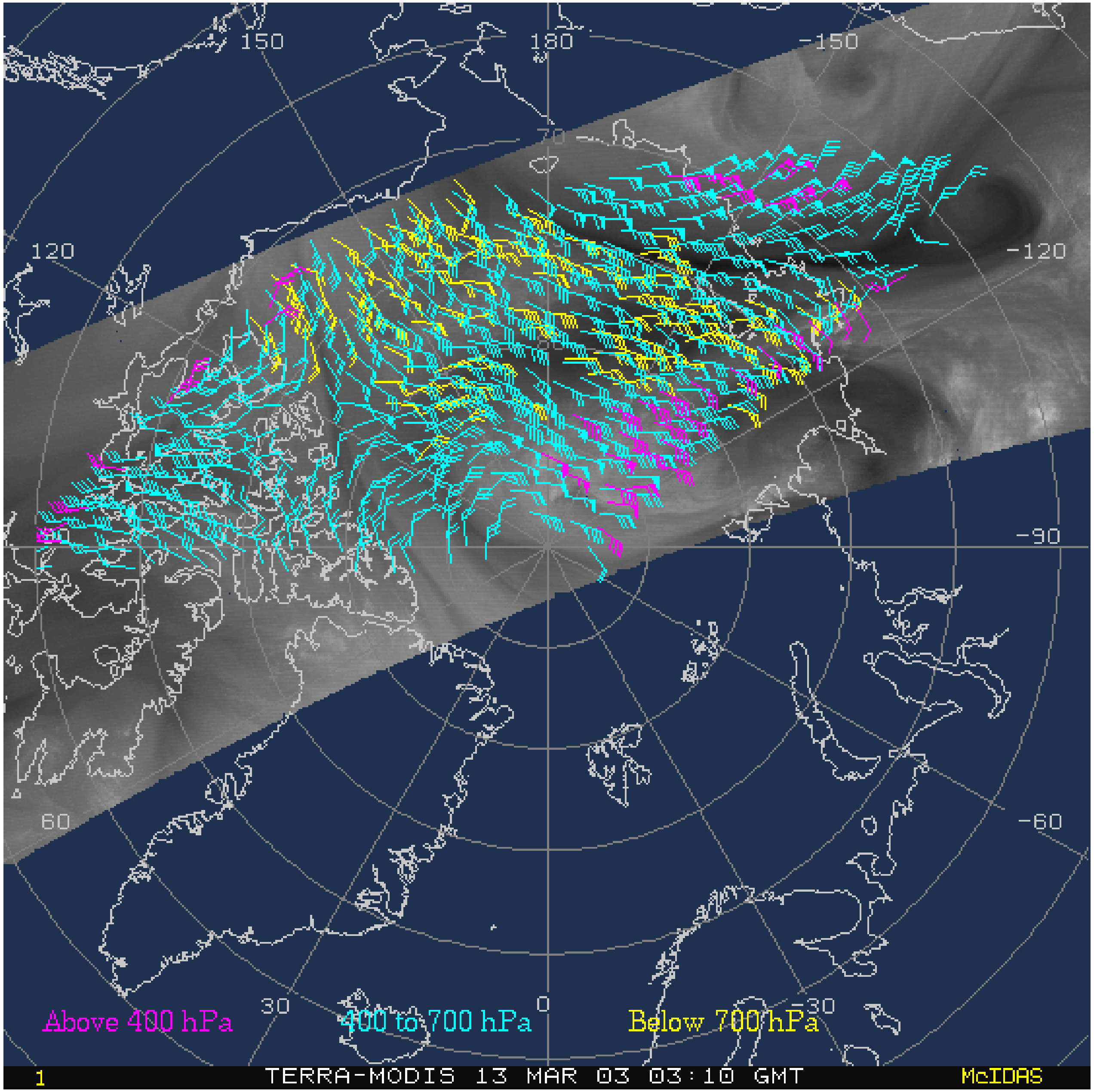




Leo coverage of poles every 100 minutes

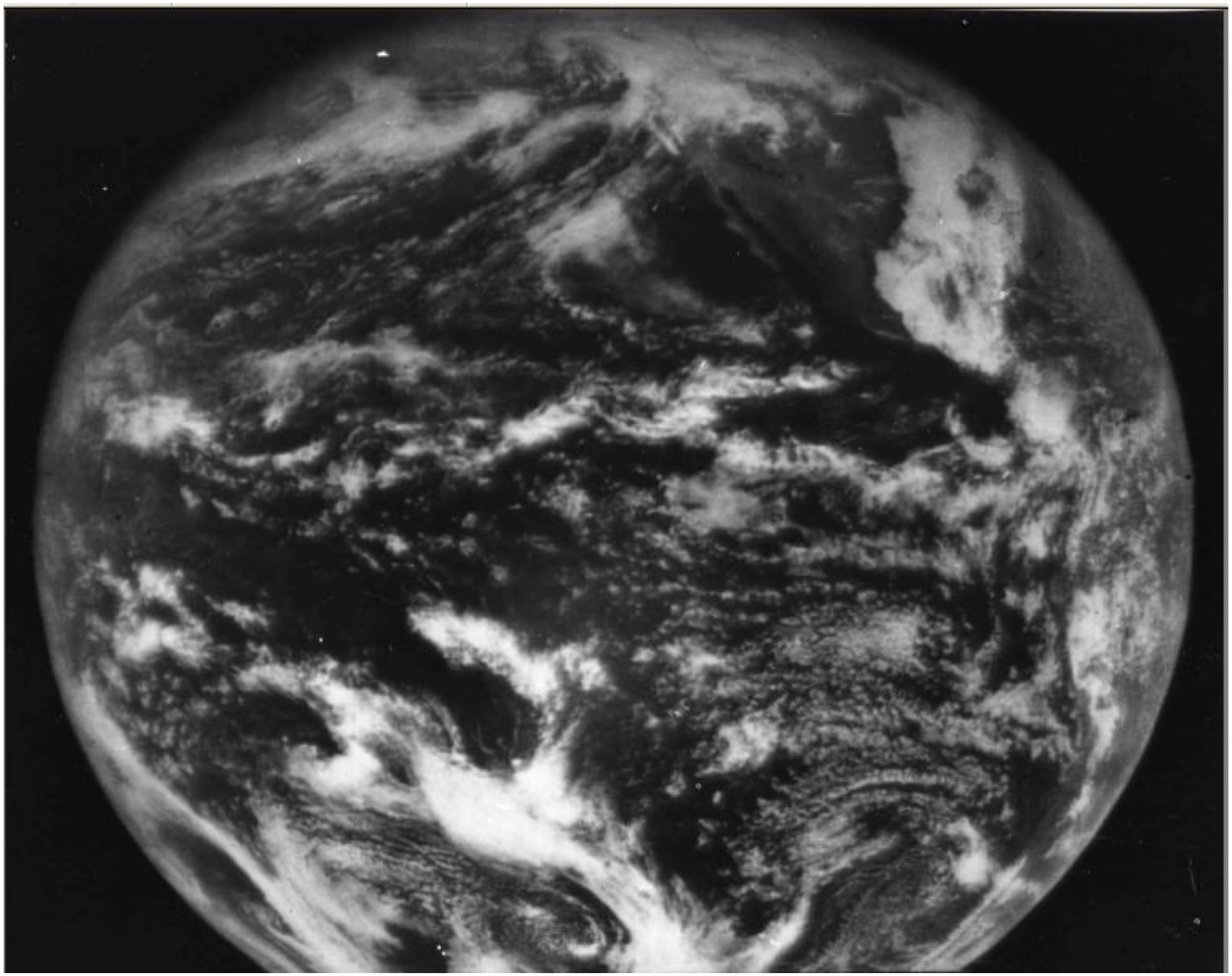


Tracking Polar Atmospheric Motion from Leo Obs

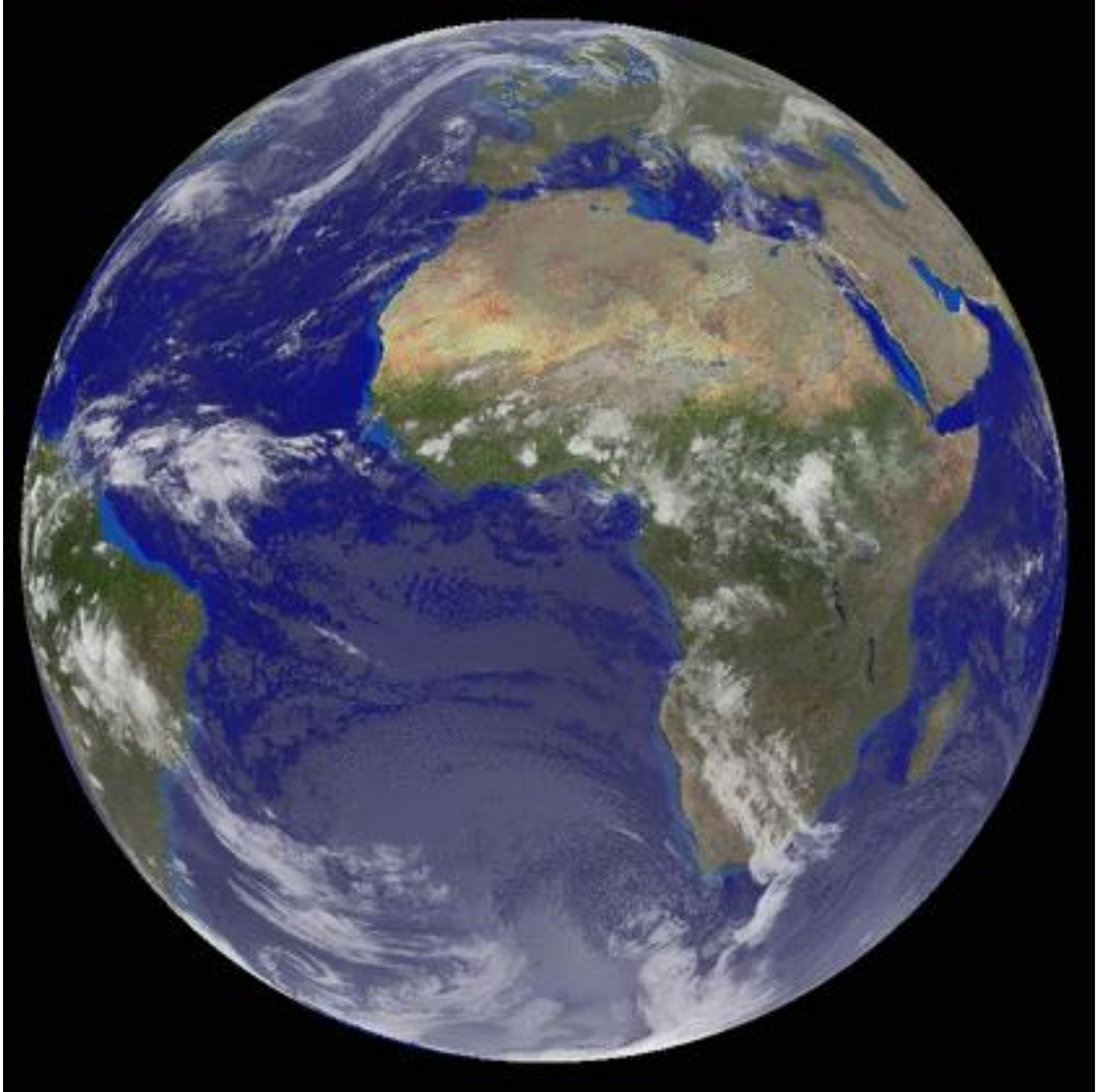


Getting to Geostationary Orbit

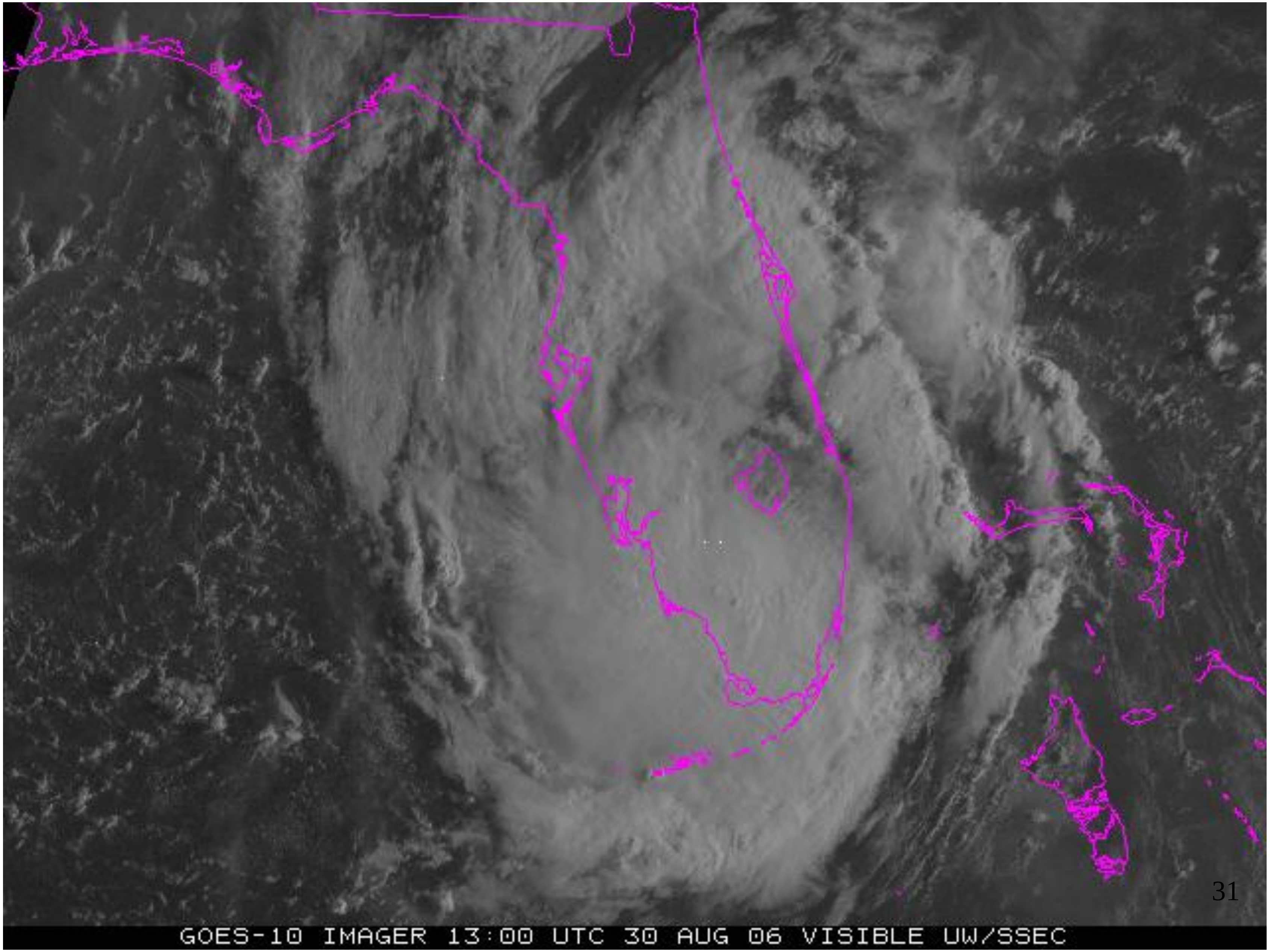
Observations from geostationary orbit

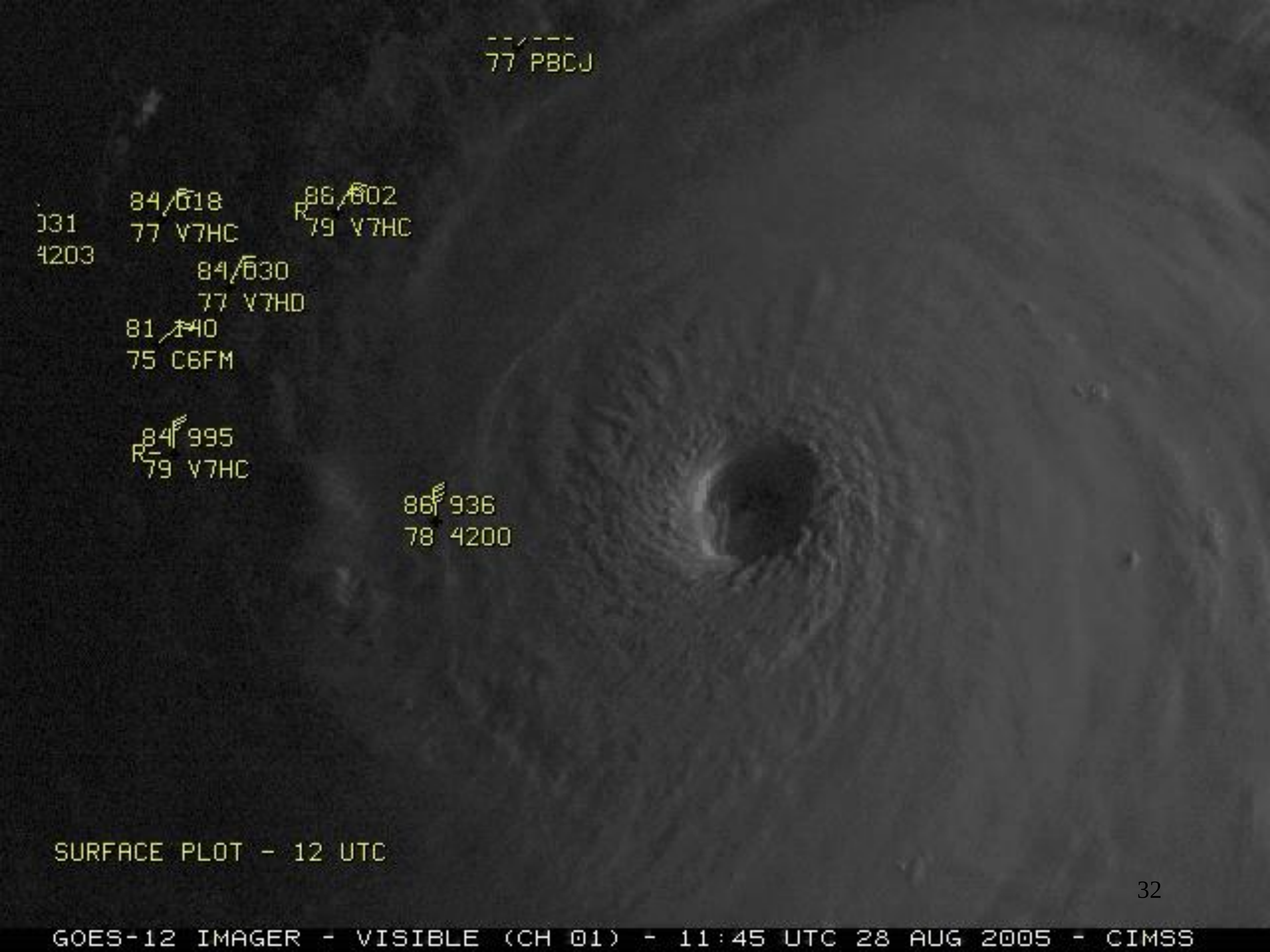


“the weather moves - not the satellite”
Verner Suomi

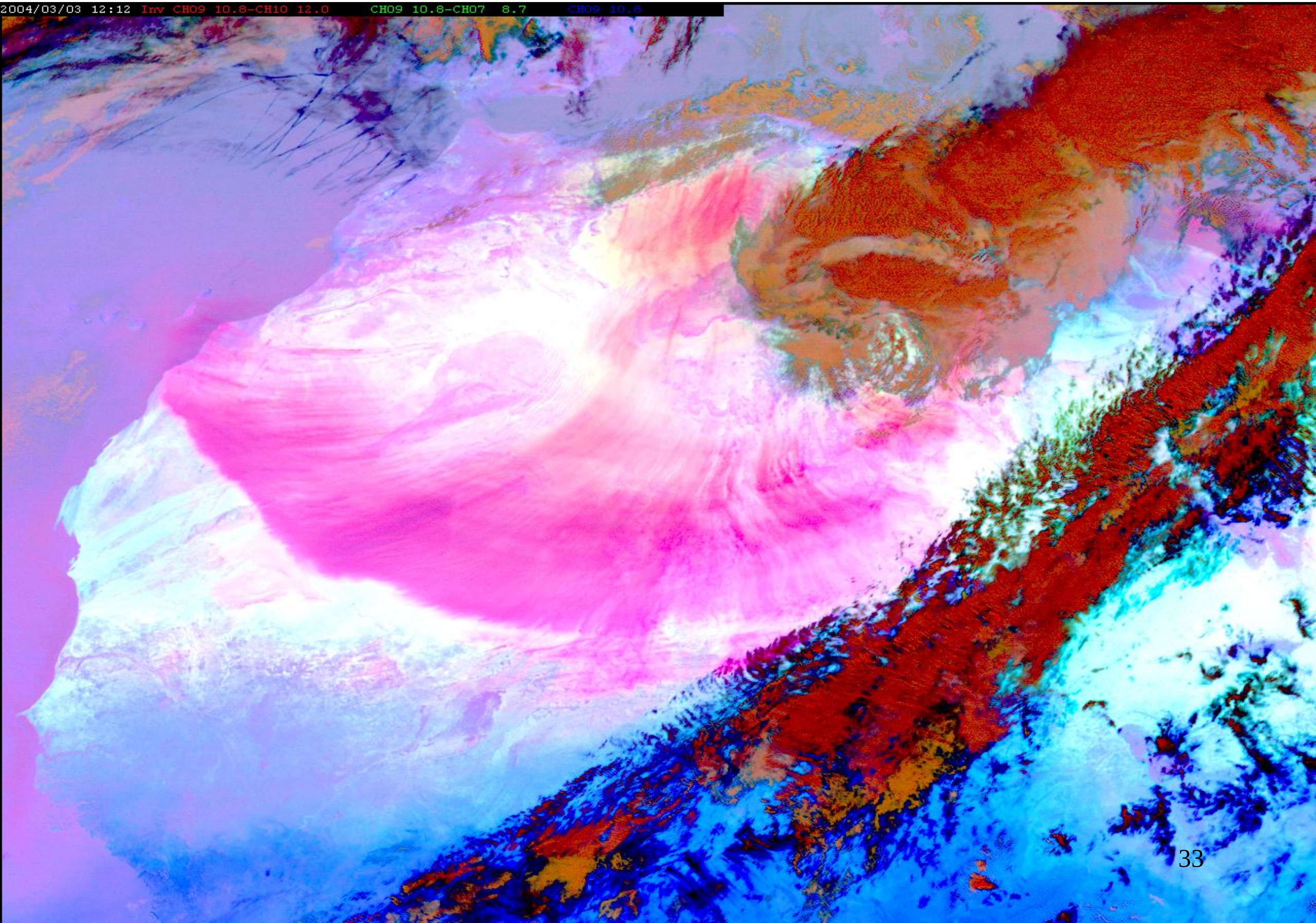


One minute imaging over Florida

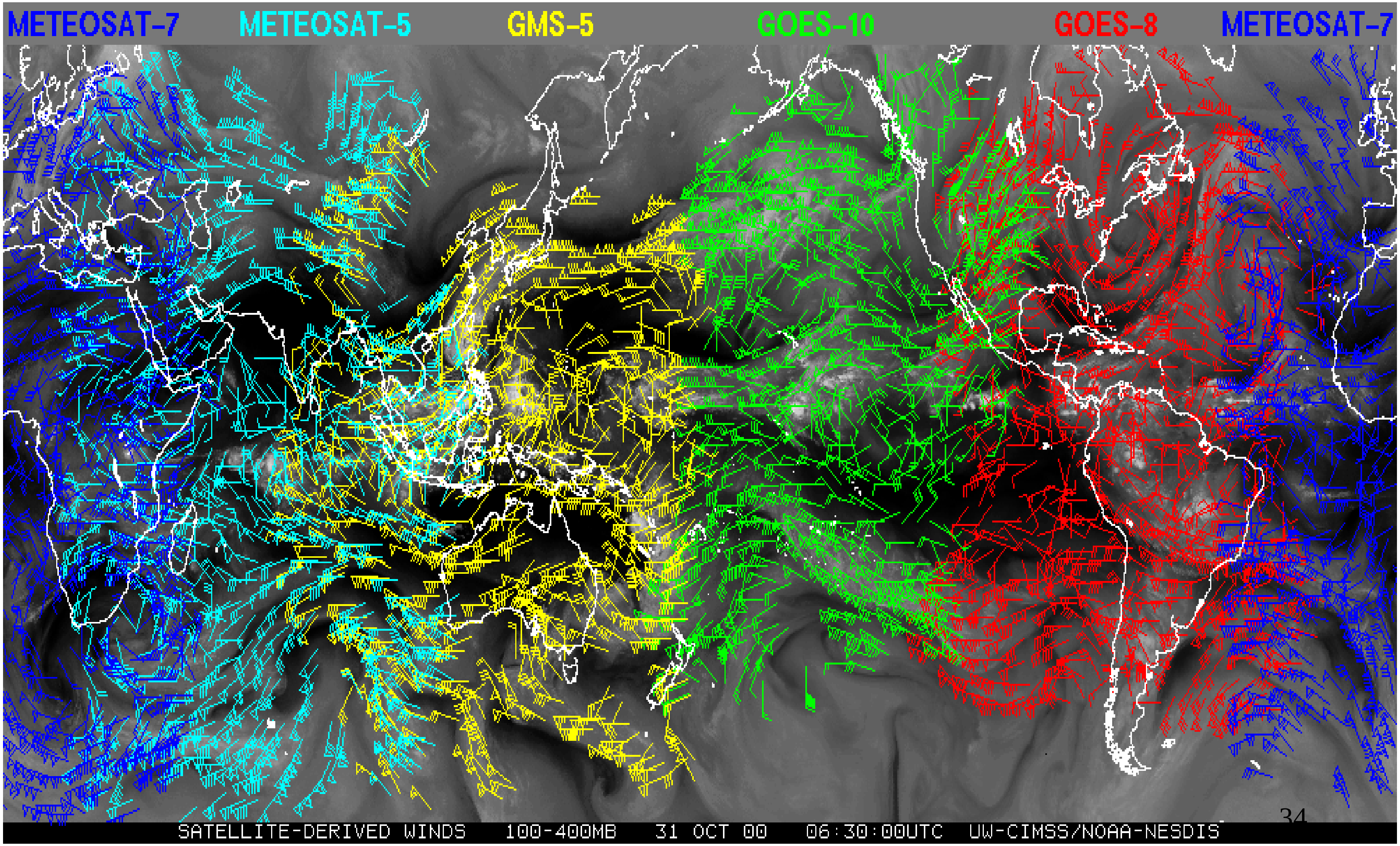



--/---
77 PBCJ
84/018
77 V7HC
86/002
79 V7HC
84/030
77 V7HD
75 C6FM
84 995
79 V7HC
86 936
78 4200
SURFACE PLOT - 12 UTC
GOES-12 IMAGER - VISIBLE (CH 01) - 11:45 UTC 28 AUG 2005 - CIMSS

SEVIRI sees dust storm over Africa



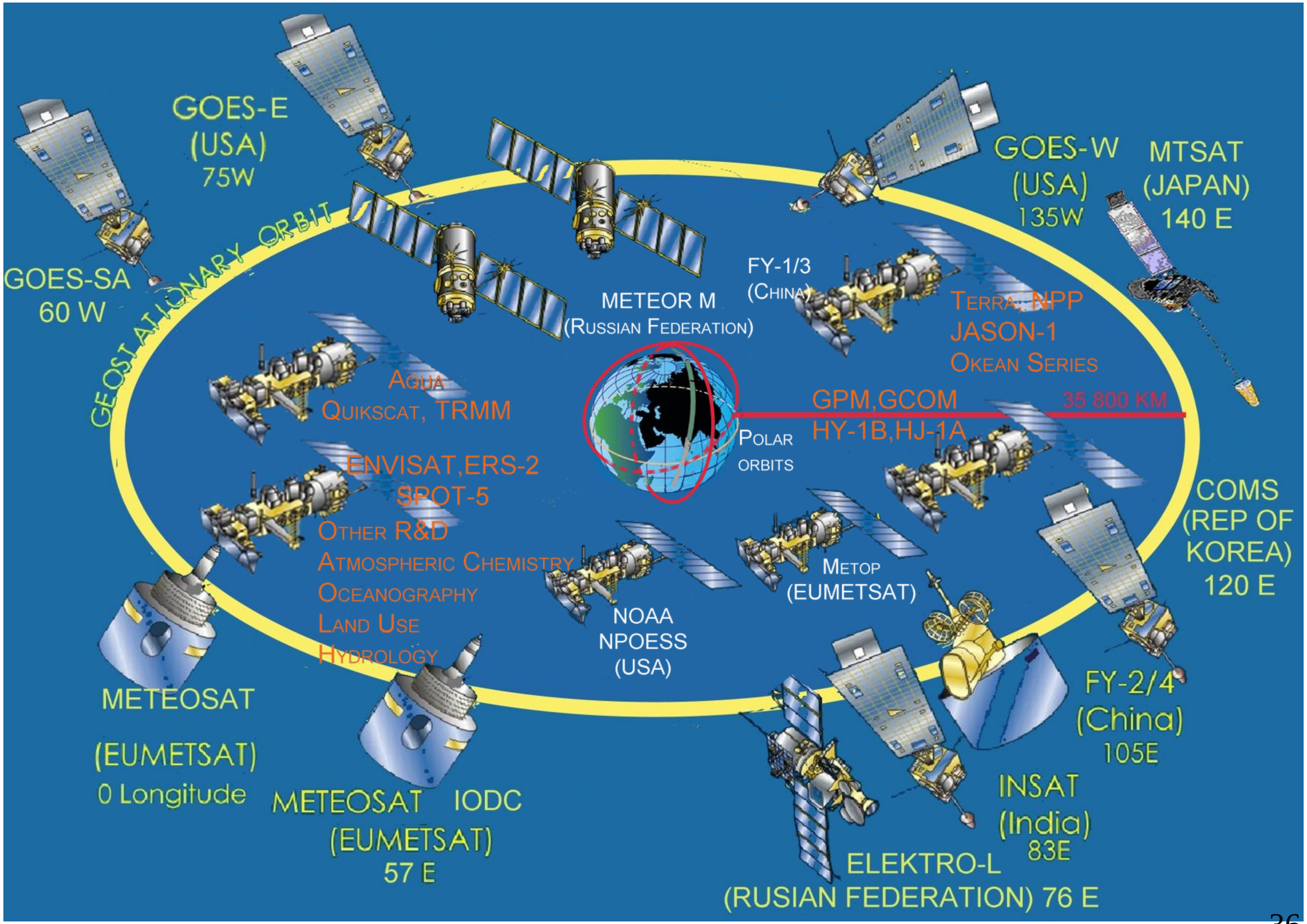
Five geos are providing global coverage for winds in tropics and mid-lats



Comparison of geostationary (geo) and low earth orbiting (leo) satellite capabilities

Geo	Leo
observes process itself (motion and targets of opportunity)	observes effects of process
repeat coverage in minutes ($\Delta t \leq 30$ minutes)	repeat coverage twice daily ($\Delta t = 12$ hours)
full earth disk only	global coverage
best viewing of tropics	best viewing of poles
same viewing angle	varying viewing angle
differing solar illumination	same solar illumination
visible, IR imager (1, 4 km resolution)	visible, IR imager (1, 1 km resolution)
one visible band	multispectral in visible (veggie index)
IR only sounder (8 km resolution)	IR and microwave sounder (1, 17, 50 km resolution)
filter radiometer	filter radiometer, interferometer, and grating spectrometer
diffraction more than leo	diffraction less than geo

Space-Based component of the Global Observing System (GOS)



Leo Observations

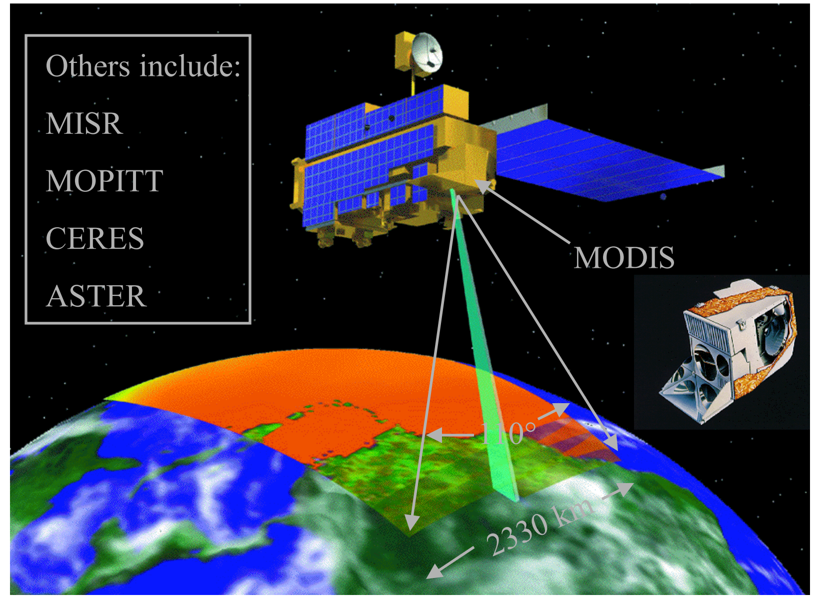
Terra was launched in 1999
and the EOS Era began

MODIS, CERES, MOPITT,
ASTER, and MISR
reach polar orbit

Aqua and ENVISAT
followed in 2002

MODIS and MERIS
to be followed by VIIRS
AIRS and IASI
to be followed by CrIS
AMSU leading to ATMS

Launch of EOS-Terra (EOS-AM) Satellite - A New Era Begins



MODIS instrument Specifications:

Bands 1-2 (0.66,0.86 μm): 250 m

Bands 3-7 (0.47, 0.55, 1.24, 1.64, 2.13 μm): 500 m

Bands 8-36: 1 km

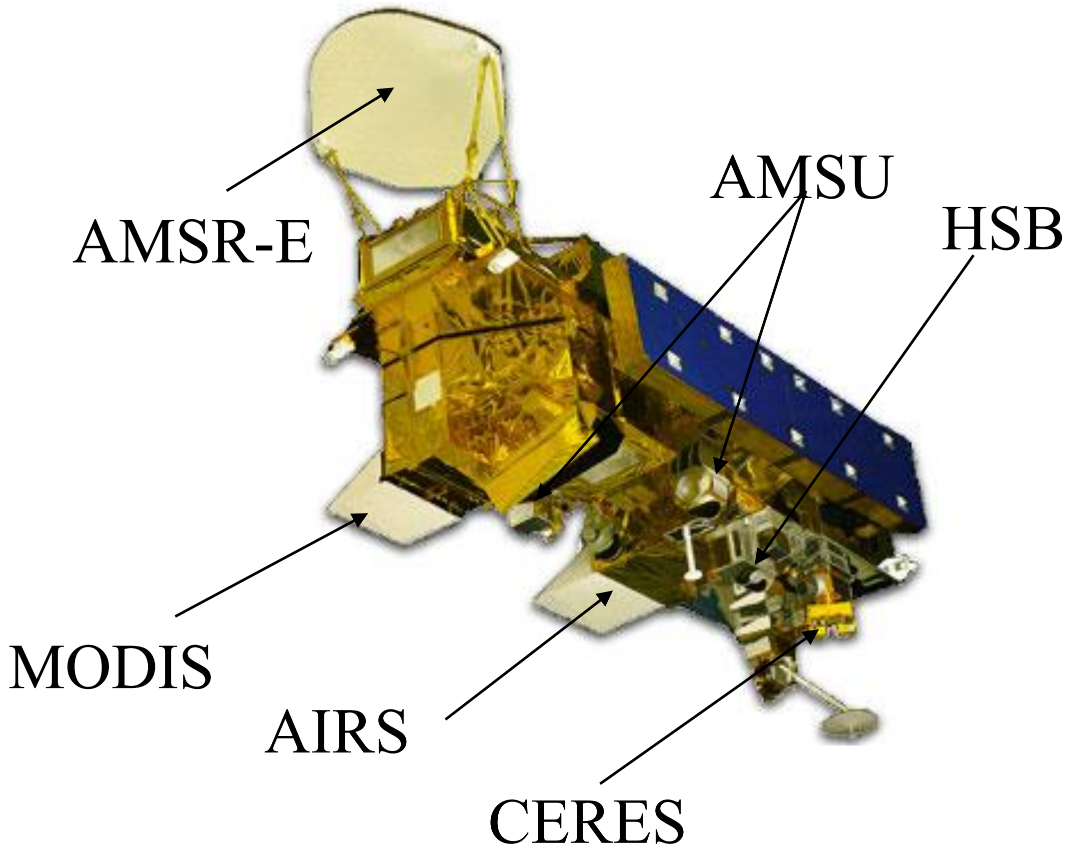
Launch date: December 18, 1999, 1:57 PT

Earth viewdoor open date: February 24, 2001

Allen Chu/NASA GSFC

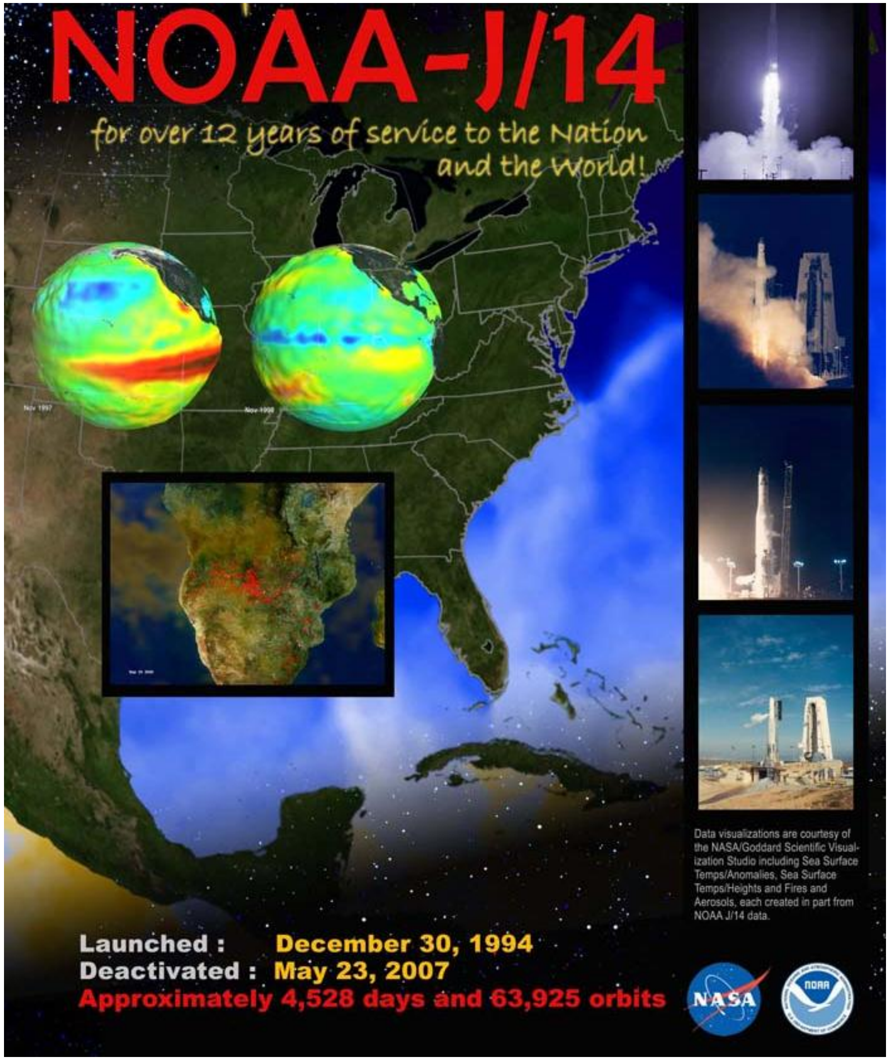
Followed by the launch of EOS-Aqua (EOS-PM) Satellite

"Thermometer in the Sky"



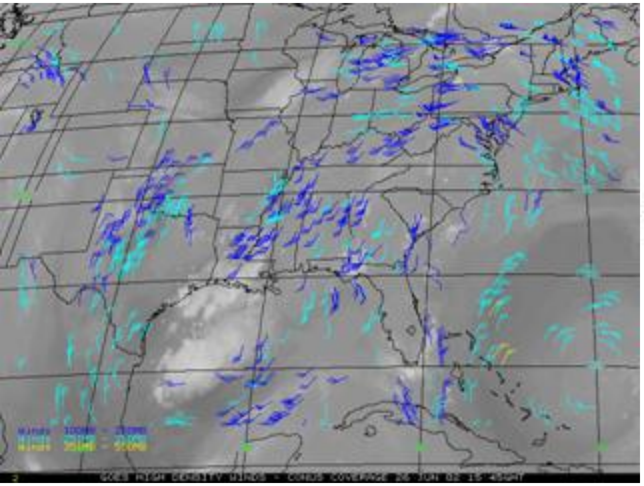
Launch date: May 4, 2002, 2:55 PDT
Earth view door open date: June 25, 2002

Joint Polar System

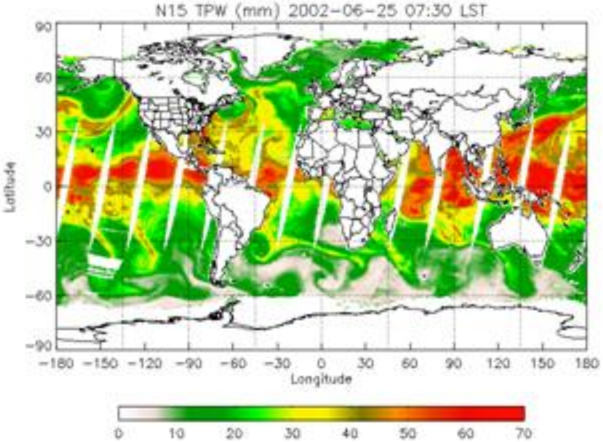


Atmospheric Products: Examples

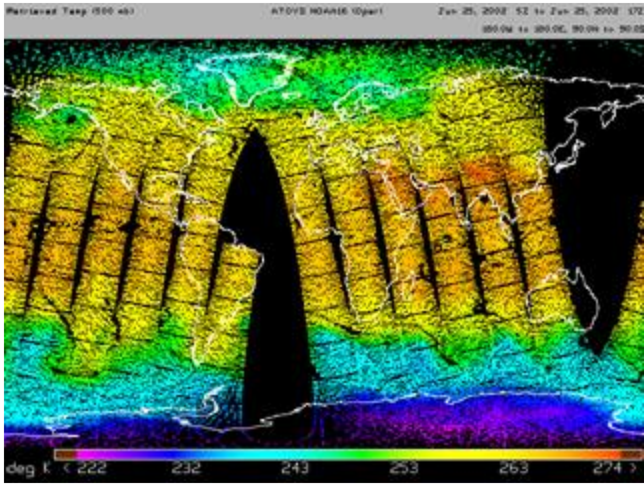
Winds



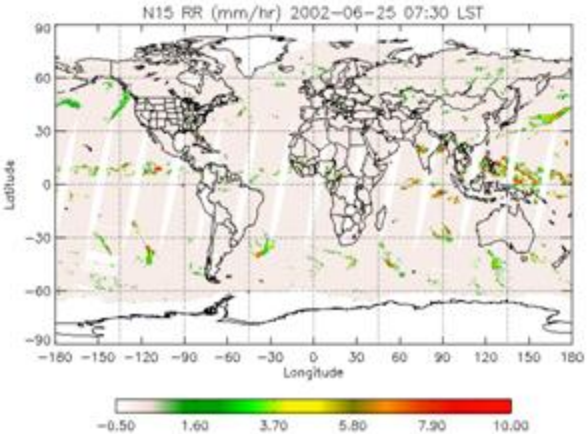
Total Water Vapor



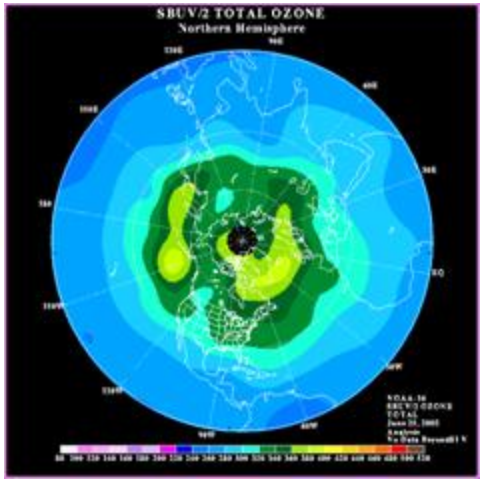
Temperature 500 mb



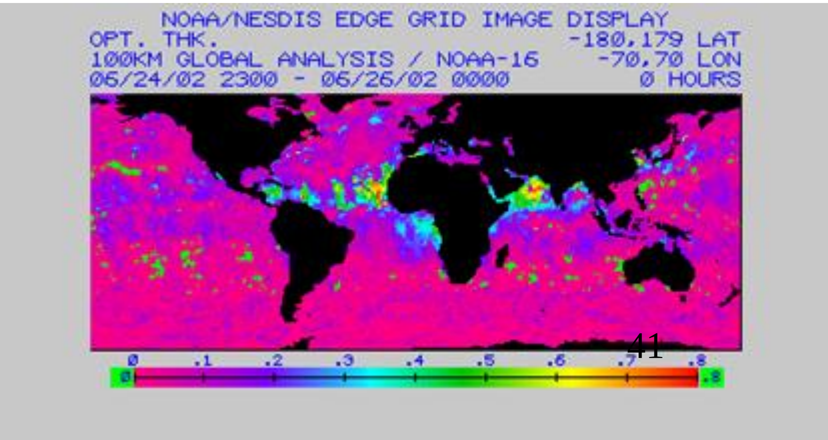
Rain Rate



Ozone

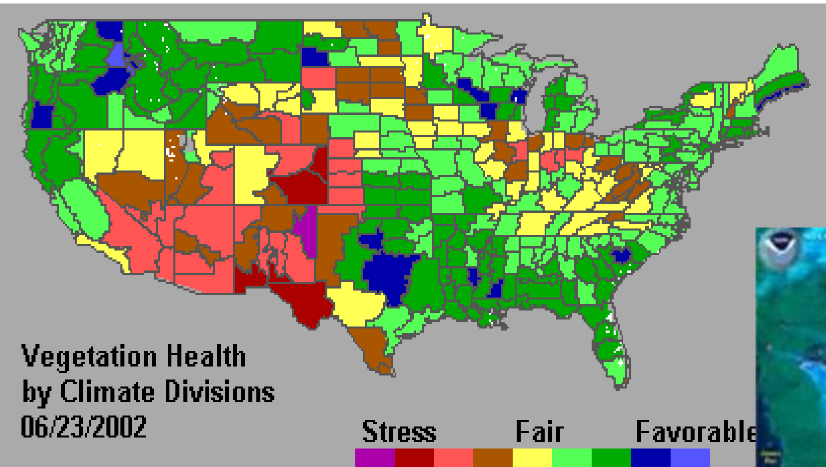


Aerosol Optical Thickness

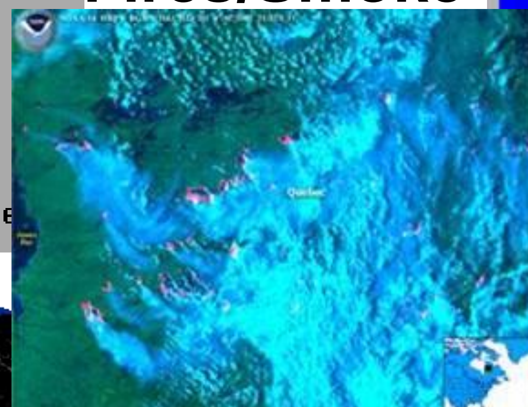


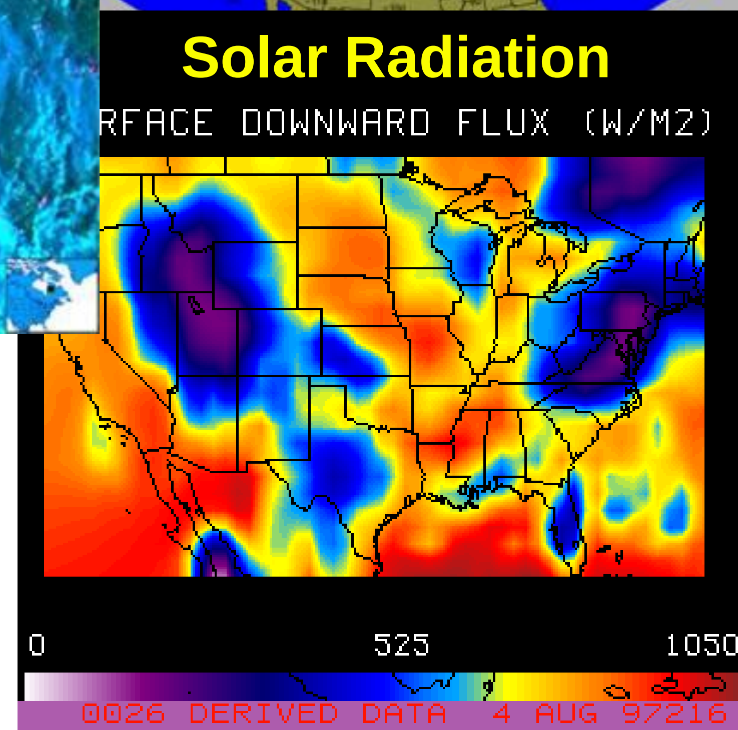
Land Surface Products: Examples

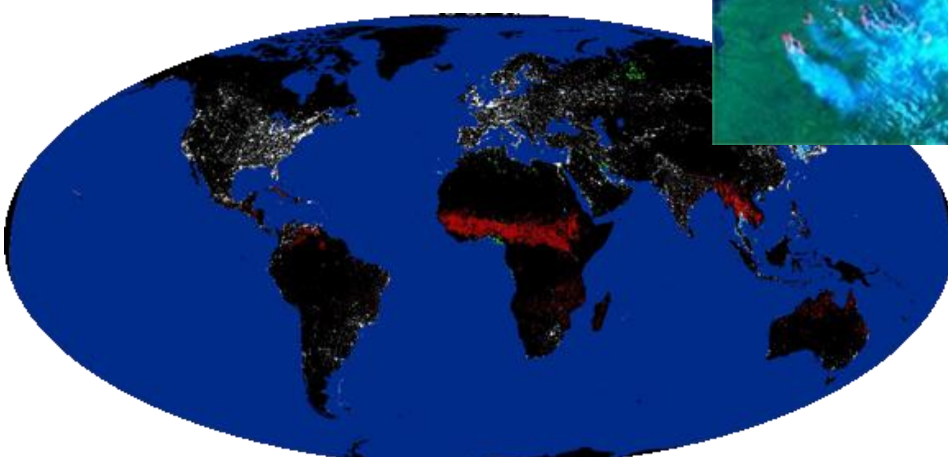
Vegetation Health



Quebec Fires/Smoke



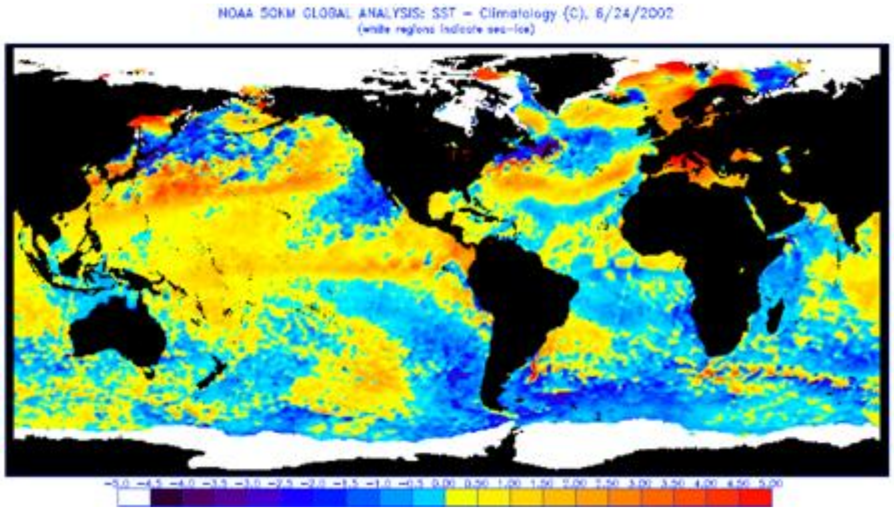




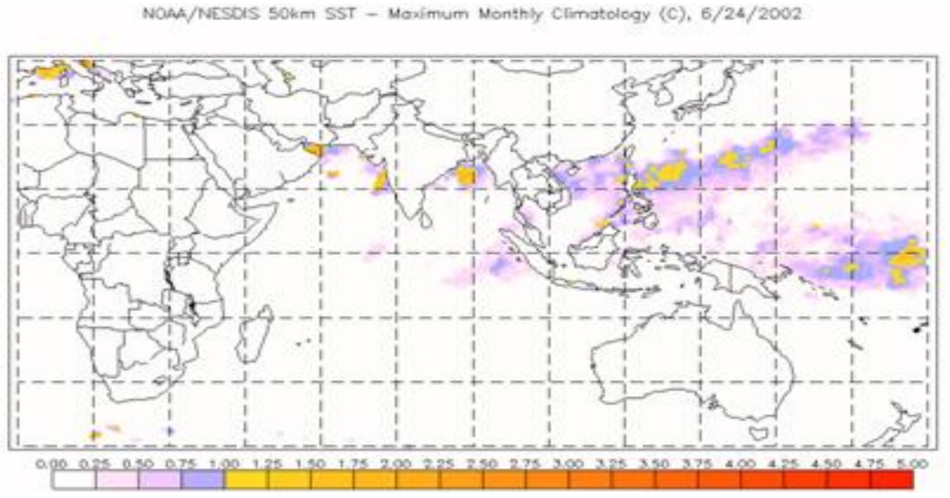
Global Lights/Fires

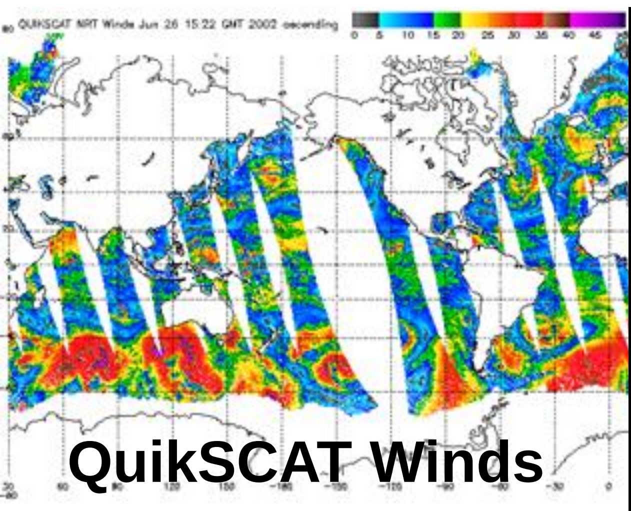
Ocean Products: Examples

SST Anomalies

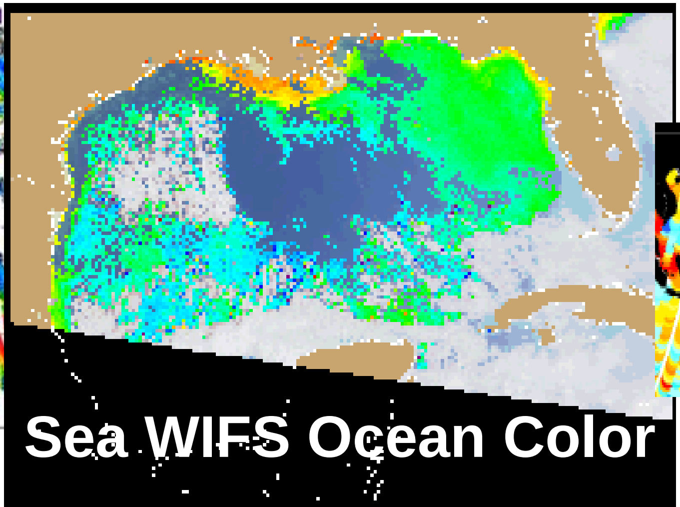


Hot Spots: Potential Coral Bleaching



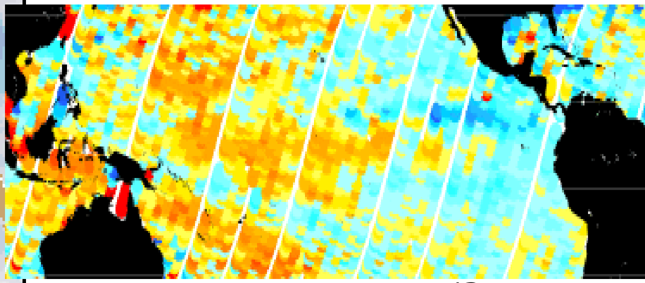


QuikSCAT Winds



Sea WIFS Ocean Color

TOPEX Sea Level



Remote Sensing Advantages

* provides a regional view

* enables one to observe & measure the causes & effects of climate & environmental changes (both natural & human-induced)

* provides repetitive geo-referenced looks at the same area

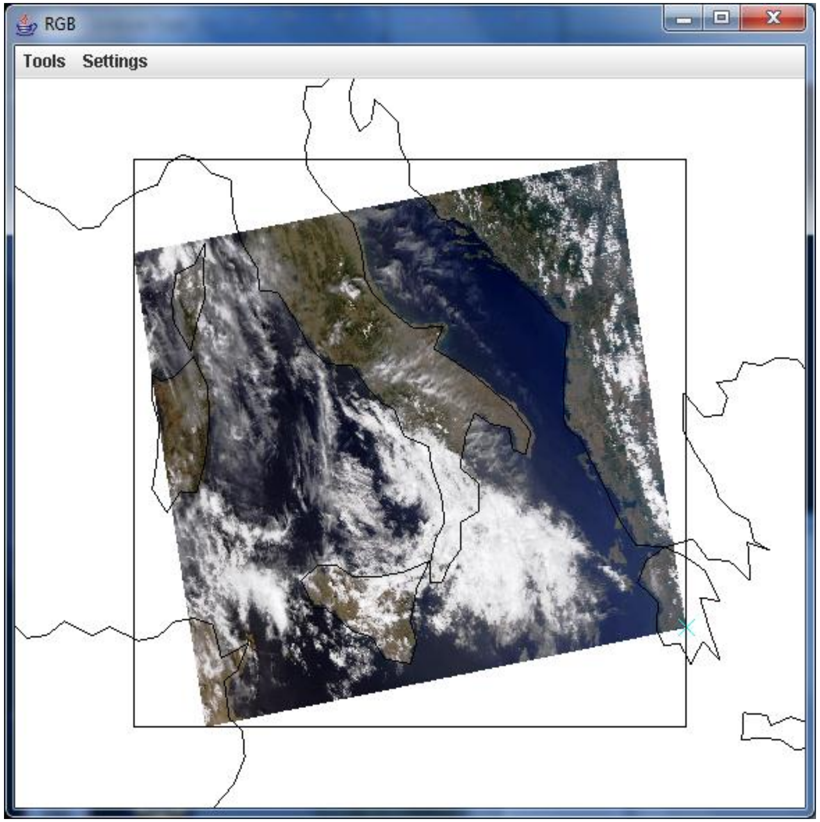
* covers a broader portion of the spectrum than the human eye

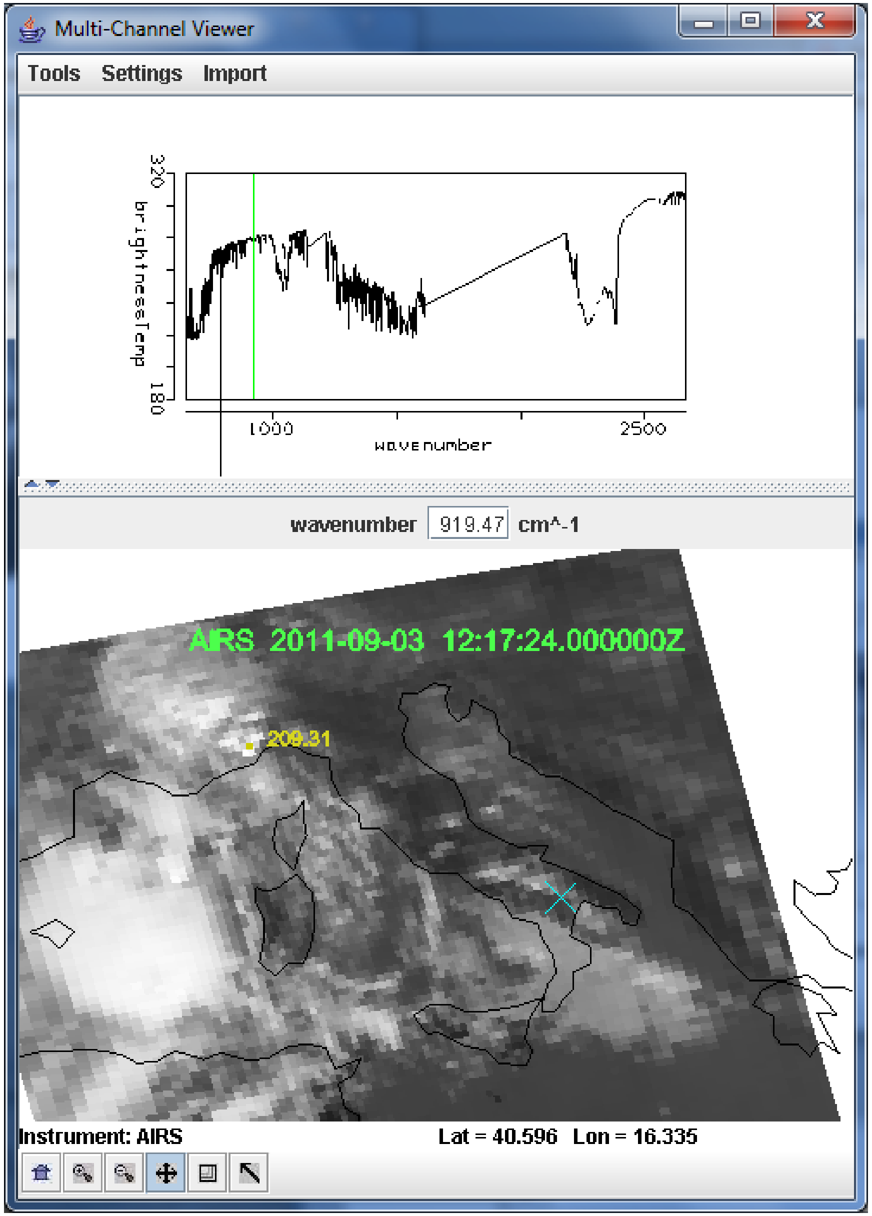
* can focus in on a very specific bandwidth in an image

* can also look at a number of bandwidths simultaneously

* operates in all seasons, at night, and in bad weather

Welcome to a Short Course in Remote Sensing





Brienza Short Course in Remote Sensing 18 – 24 Sep 2011

Dottorato di Ricerca in
Metodi e Tecnologie per il Monitoraggio Ambientale

SSEC

Dipartimento di Ingegneria
e Fisica dell'Ambiente

istituto di
metodologie per
l'analisi ambientale

CIMSS