Polar and Geostationary Satellite System Synergy: Toward Optimum Utilization and Relationship to GEOSS

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GEOSS Societal Benefit Areas

- Improving weather information, forecasting and warning
- Reducing loss of life and property from natural and human induced disasters
- Improving water resource management through better understanding of the water cycle
- Understanding, assessing, predicting, mitigating and adapting to climate variability and change
- Improving the management and protection of terrestrial, coastal and marine ecosystems
- Understanding environmental factors affecting human health and well being
- Improving management of energy resources
- Supporting sustainable agriculture and combating desertification
- Understanding, monitoring and conserving biodiversity

Paradigm shifts

- **The system**: dynamic research component integrated with a powerful reliable operational component. Hypothesis: the capabilities of the operational system will be so great that both research and special mission satellites will be designed to fly in formation with the operational low earth orbiting satellites

- **Data, products and dissemination**: dynamic data and product stream. Opinion: sophisticated users (GEO) interested in availability of selected data and products, not everything

- **Merging research and operations**: a dynamic system and full exploitation. Belief: requires merging research and operations with the user becoming a part of the system. Ongoing training and education will be required to assure both proper data utilization and sophisticated and realistic user requirements over the broad range of GEOSS areas.

High Payoff, High Priority Synergy Areas

- **GPS radio occultation** for climate and high resolution sounding applications (with hyperspectral)
- **Hyperspectral infrared from geostationary** for multi-layer atmospheric motion vectors and high resolution vertical sounding applications (with GPS, system intercalibration)
- **Global precipitation constellation with active radar** that is fully integrated with the operational system for both exploitation over scales that range from nowcasting to climate (multiple systems!)
- **Hyperspectral visible to near infrared** sensors on both geostationary and polar orbiting satellites with very high resolution (250 meters or better) for detailed land and ocean studies (as a system and for system intercalibration)
- **Formation flying** with the operational constellation of small satellites with special sensors such as lidar for **aerosols and winds, cloud radar** (synergistic by its very nature)

List of satellite missions (by year and sponsoring agency)

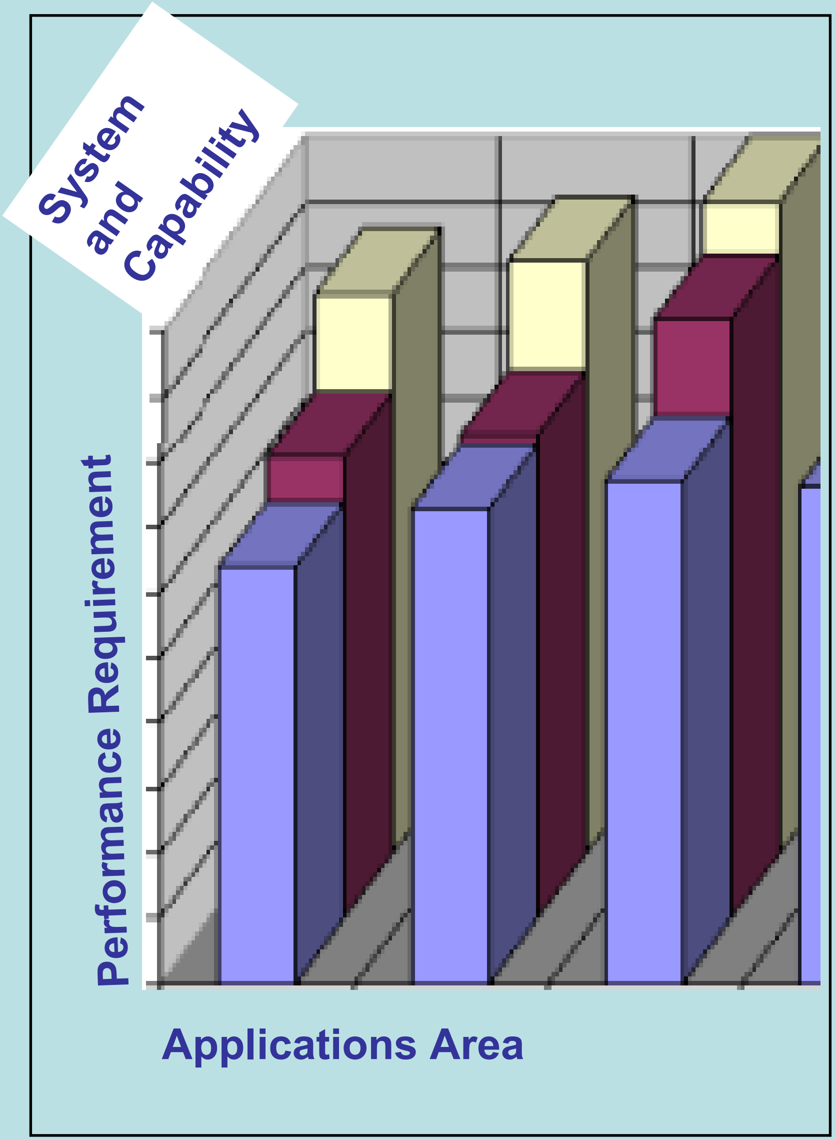
Launch Year	EO Satellite Mission (and sponsoring agency)
1967	Diademe 1&2 (CNES)
1975	STARLETTE (CNES)
1976	LAGEOS-1 (NASA)
1984	Landsat-5 (USGS)
	ERBS (NASA)
1990	SPOT-2 (CNES)
1991	METEOSAT-5 (EUMETSAT)
	NOAA-12 (NOAA)
	UARS (NASA)
1992	Topex-Poseidon (NASA / CNES)
	LAGEOS-2 (NASA / ASI)
1993	SCD-1 (INPE)
	STELLA (CNES)
1993	METEOSAT-6 (EUMETSAT)
1994	NOAA-14 (NOAA)
1995	GMS-5 (JAXA / JMA)
	ERS-2 (ESA)
	GOES-9 (NOAA)
	RADARSAT-1 (CSA)
1997	DMSP F-13 (NOAA)
	GOES-10 (NOAA)
	METEOSAT-7 (EUMETSAT)
1998	SPOT-4 (CNES)
	NOAA-15 (NOAA)
2003	ICESat (NASA)
	SORCE (NASA)
	INSAT-3A (ISRO)
	SCISAT-1 (CSA)
	UK-DMC (BNSC)
	RESOURCESAT-1 (ISRO)
	DMSP F-16 (NOAA)
	CBERS-2 (CAST / INPE)
2004	DEMETER (CNES)
	Aura (NASA)
	FY-2C (NRSCC)
	PARASOL (CNES)
	SICH-1M (NSAU / ROSKOSMOS)
2005	Meteor-M No1 (ROSHYDROMET / ROSKOSMOS)
	Vulkan-Kompas-2 (ROSKOSMOS)
	MTSAT-1R (JMA)
	NOAA-N (NOAA)
	GOES-N (NOAA)
	CARTOSAT-1 (ISRO)
	CRYOSAT (ESA)
	Monitor-E (ROSKOSMOS)
	CALIPSO (NASA / CNES)
	CloudSat (NASA)
	DMSP F-17 (NOAA)
	TopSat (BNSC)
	METEOSAT-9 (EUMETSAT)
	Resurs DK (ROSKOSMOS)
	ALOS (JAXA)
2007	Meteor-M No2 (ROSHYDROMET / ROSKOSMOS)
	OCEANSAT-2 (ISRO)
	RapidEye (DLR)
	SMOS (ESA)
	GOES-O (NOAA)
	HJ-1C (CAST)
	THEOS (GISTDA)
	OCO (NASA)
	SAOCOM 1A (CONAE)
	ADM-Aeolus (ESA)
	DMSP F-18 (NOAA)
	SAC-F (CONAE)
	Glory (NASA)
	SSR-1 (INPE)
2008	DSCOVR (NASA)
	ESA Future Missions (ESA)
	PICARD (CNES)
	GOSAT (JAXA)
	METEOSAT-10 (EUMETSAT)
	Pleiades 1 (CNES)
	SAC-D/Aquarius (CONAE / NASA)
	SAOCOM 1B (CONAE)
	GOES-P (NOAA)
	CBERS-3 (CAST / INPE)
	NOAA-N' (NOAA)
	FY-3C (NRSCC)
2009	GCOM-W (JAXA)
	Hyperspectral Mission (ASI)

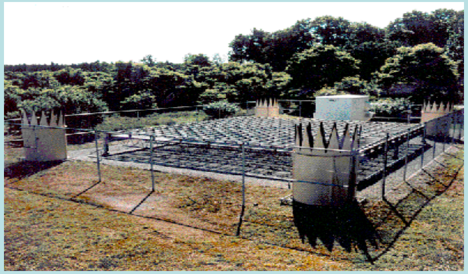
NOTICE THE GROWTH

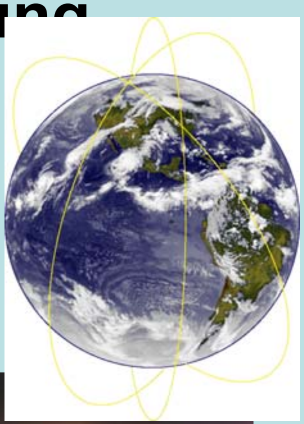
1998	SPOT-4 (CNES)
	NOAA-15 (NOAA)
	SCD-2 (INPE)
1999	INSAT-2E (ISRO)
	Landsat-7 (USGS)
	IRS-P4 (ISRO)
	QuikSCAT (NASA)
	DMSP F-15 (NOAA)
	Terra (NASA)
	ACRIMSAT (NASA)
	KOMPSAT-1 (KARI)
2000	GOES-11 (NOAA)
	CHAMP (DLR)
	NOAA-16 (NOAA)
	NMP EO-1 (NASA)
	SAC-C (CONAE)
2001	Odin (SNSB)
	GOES-12 (NOAA)
	BIRD (DLR)
	TES (ISRO)
	Jason (NASA / CNES)
	TIMED (NASA)
	METEOR-3M N1 (ROSHYDROMET / ROSKOSMOS)
2002	Envisat (ESA)
	GRACE (NASA)
	Aqua (NASA)
	SPOT-5 (CNES)
	NOAA-17 (NOAA)
	METEOSAT-8 (EUMETSAT)
	KALAPANA (ISRO)
	FedSat (CSIRO / CRCSS)
	Resurs DK (ROSKOSMOS)
	ALOS (JAXA)
	KOMPSAT-2 (KARI)
	TerraSAR-X (DLR)
	METEOR-3M N2 (ROSHYDROMET / ROSKOSMOS)
	METOP-1 (EUMETSAT)
	Baumanets (ROSKOSMOS)
	CARTOSAT-2 (ISRO)
	RADARSAT-2 (CSA)
	SICH-2 (NSAU)
2008	BelKA (ROSKOSMOS)
	BISSAT (ASI)
	FY-3A (NRSCC)
	IGPM (ASI)
	Kanopus-Vulkan (ROSKOSMOS)
	LAGEOS-3 (NASA / ASI)
	TerraSAR-L (BNSC)
	MTSAT-2 (JMA)
	GOCE (ESA)
	INSAT-3D (ISRO)
	RESOURCESAT-2 (ISRO)
	RISAT-1 (ISRO)
	NMP EO-3 GIFTS (NASA)
	CBERS-2B (CAST / INPE)
	NPP (NOAA)
	Elektro-L (ROSHYDROMET / ROSKOSMOS)
	HJ-1A (CAST)
	HJ-1B (CAST)
	HY-1B (CAST)
	Jason-2 (NASA / CNES)
	COSMO - SkyMed (ASI)
	FY-2D (NRSCC)
	FY-3B (NRSCC)
2009	GCOM-W (JAXA)
	Hyperspectral Mission (ASI)
	MEGHA-TROPIQUES (CNES / ISRO)
	Swarm (ESA)
	DMSP F-19 (NOAA)
	GPM Core (NASA)
	SAC-E/SABIA (CONAE)
	NPOESS-1 (NOAA)
	FY-2E (NRSCC)
	METOP-2 (EUMETSAT)
	Pleiades 2 (CNES)
2010	GCOM-C (JAXA)
	GPM Constellation (NASA)
	HYDROS (NASA)
	FY-3D (NRSCC)
2011	NPOESS-2 (NOAA)
	DMSP F-20 (NOAA)
	CBERS-4 (CAST / INPE)
	METEOSAT-11 (EUMETSAT)
2012	SAOCOM-2B (2) (CONAE)
	GOES-R (NOAA)
	SSR-2 (INPE)
	FY-3E (NRSCC)
2013	NPOESS-3 (NOAA)
	SAOCOM-2B (1) (CONAE)
2014	METOP-3 (EUMETSAT)
	FY-3F (NRSCC)
2015	NPOESS-4 (NOAA)
2016	FY-3G (NRSCC)
2018	NPOESS-5 (NOAA)
2019	NPOESS-6 (NOAA)

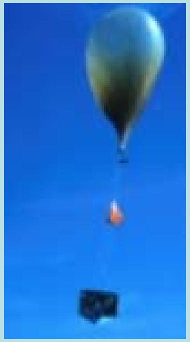
HOW DO WE FULLY EXPLOIT?

There are many components in the Global Observing System









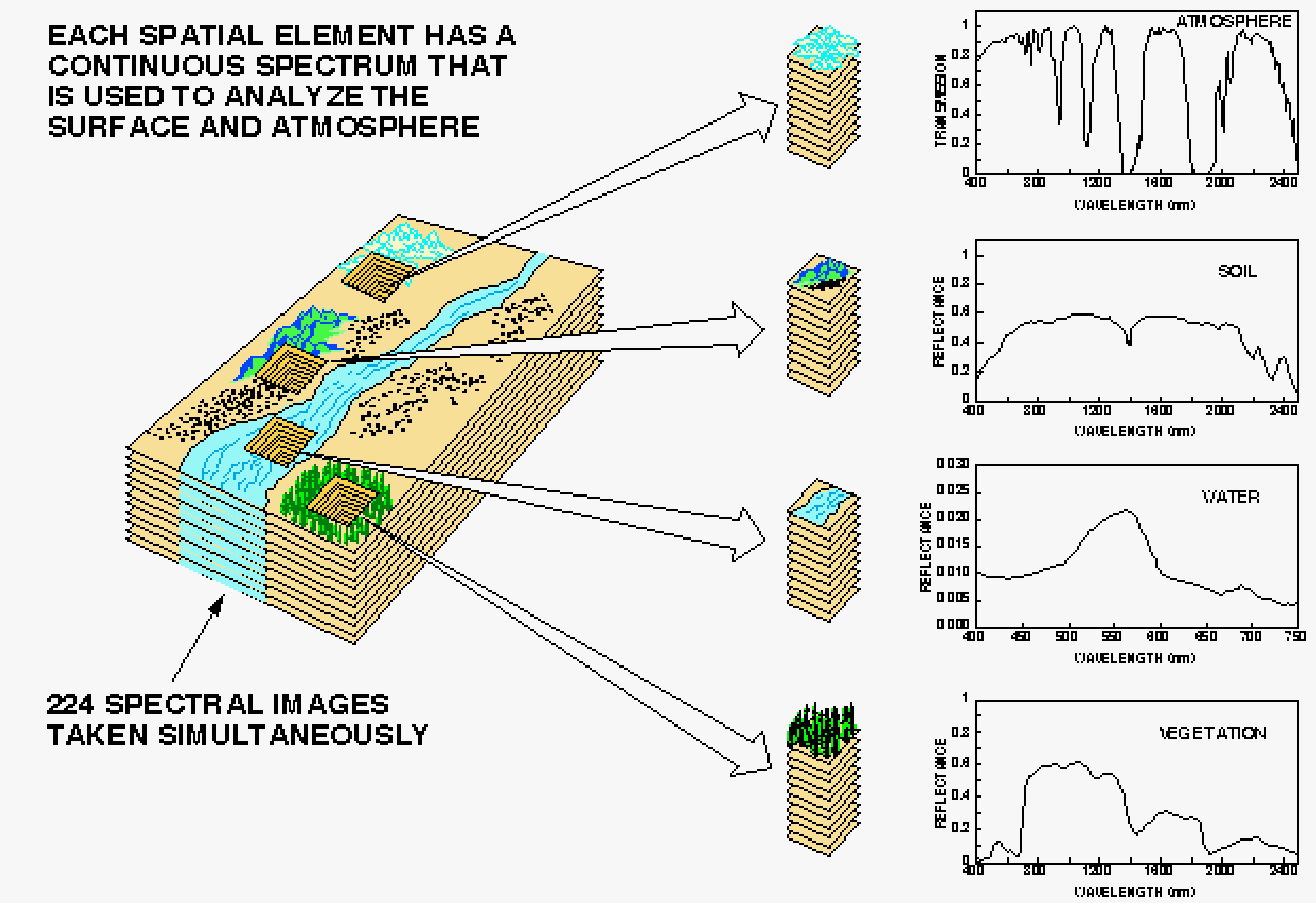
PRESENTATION ROADMAP

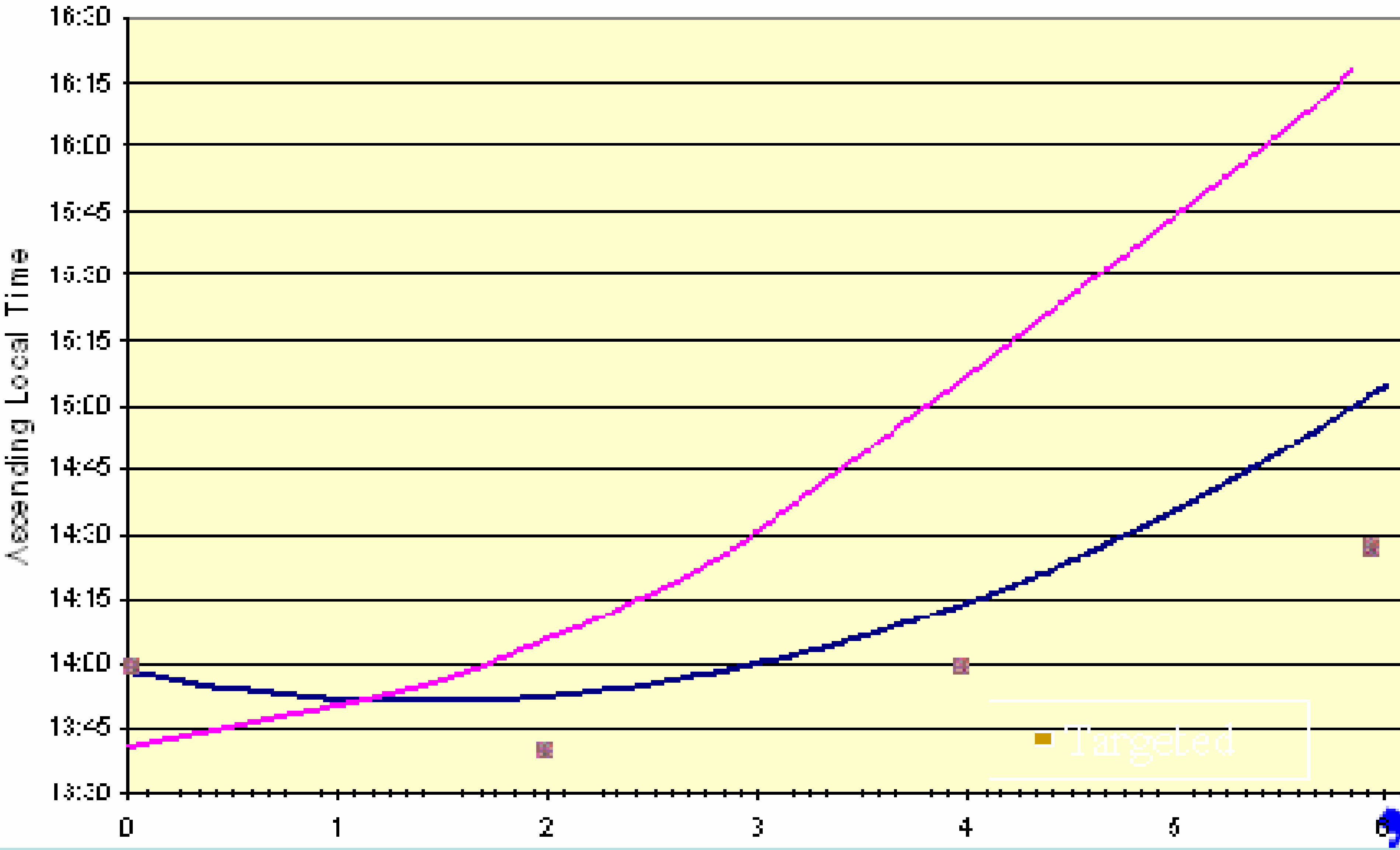
- A science of change
- Back to the future
- Four basic resolutions
- Operational and research systems during the next decade(s)
- Constellations and formations
- Examples of synergy
- Exploitation as a global community
- Moving forward: thoughts and challenges

A SCIENCE OF CHANGE

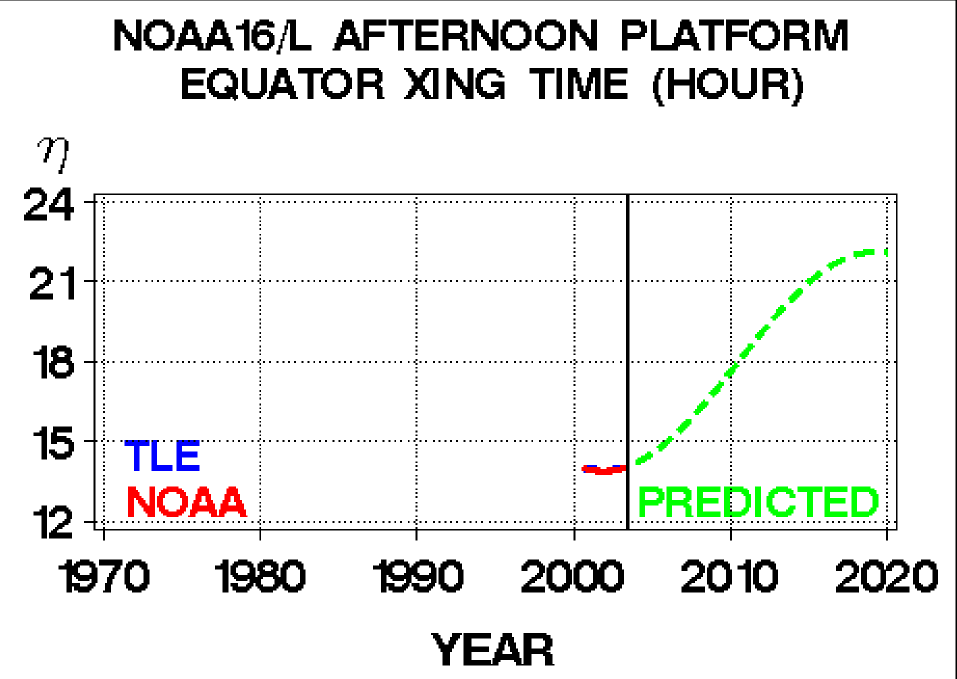
- High resolution digital age
- Precision orbits
- Research satellite data for operational purposes
- Distinction between polar, geostationary, research and operational sensors minimized
- Multi-platform multi-sensor products possible
- Change in the way we do business
  - Data handling
  - Science and product development
  - Training and utilization

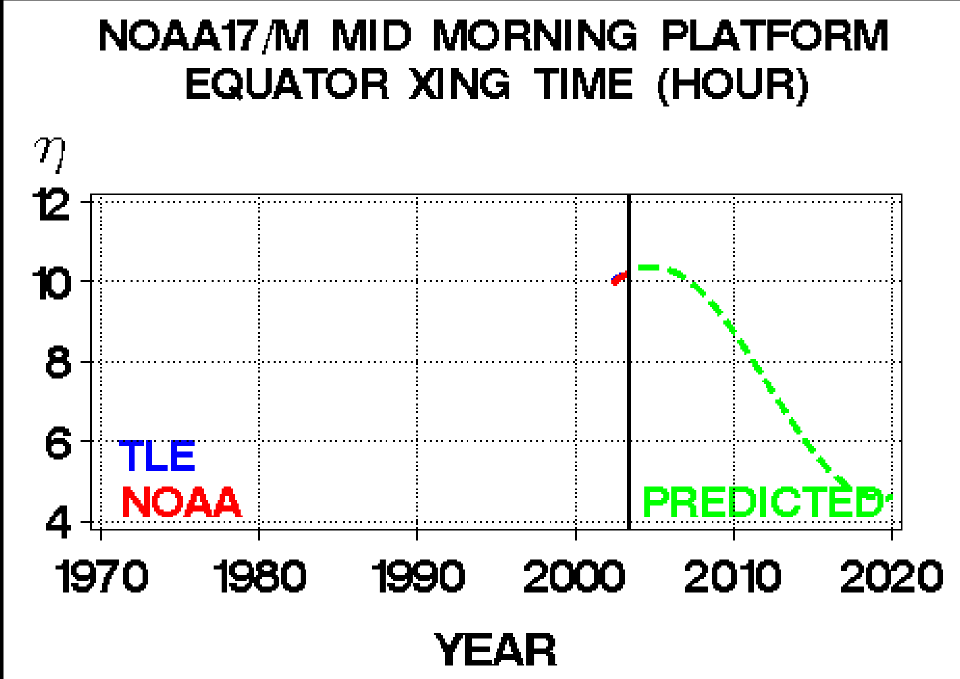
Today we're digital - Basic Premise





Drift in ascending node time over a six year period for NOAA-14, steep curve, versus drift for NOAA-16. Notice that for the first 5 ½ years of its life that NOAA-16 stays within ± 30 minutes of 1415.



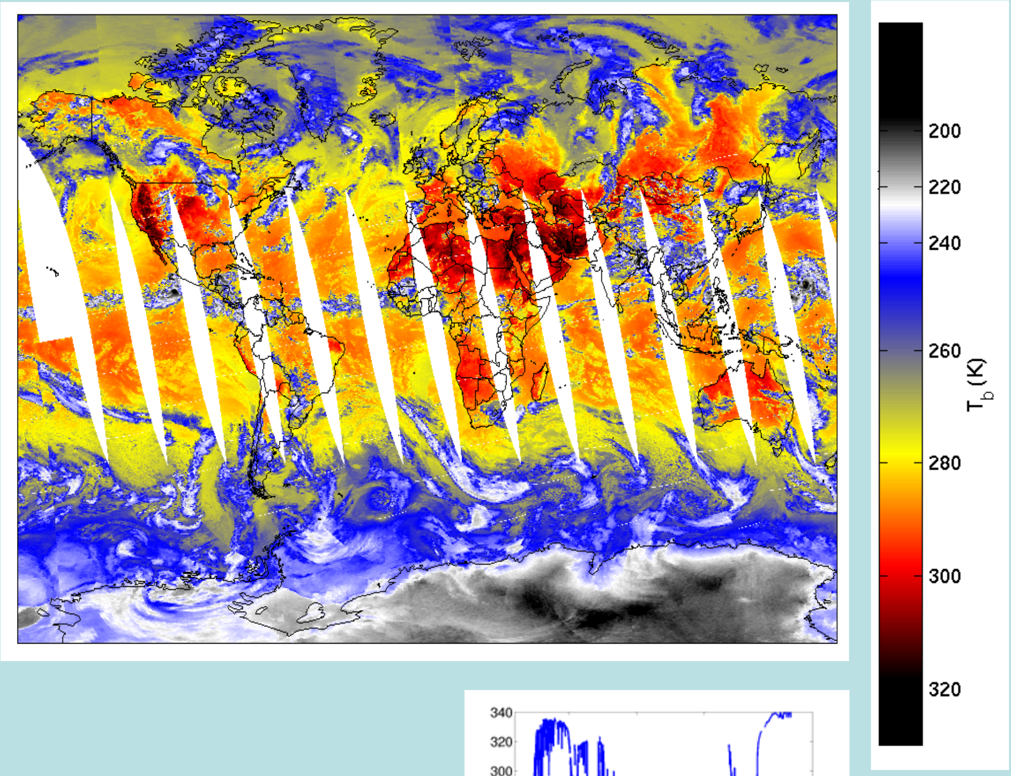


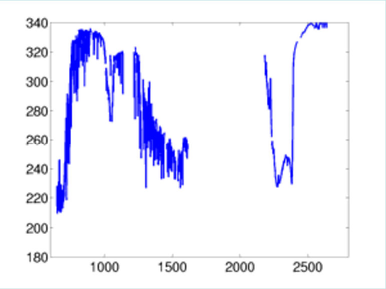
Courtesy of
Alexander Ignatov

By accounting for orbital drift NOAA satellites are launched into orbits that are stable across the satellite's projected lifetime. NPOESS will utilize on orbit fuel to maintain precise orbit and extend useful orbital life.

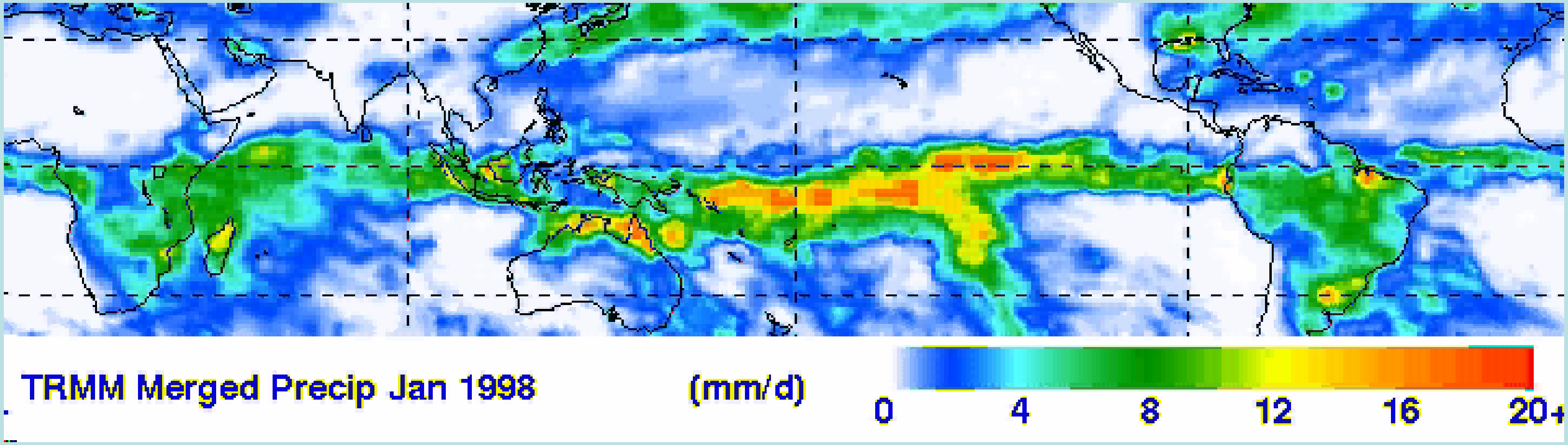
Research satellite operators providing data for operational utilization

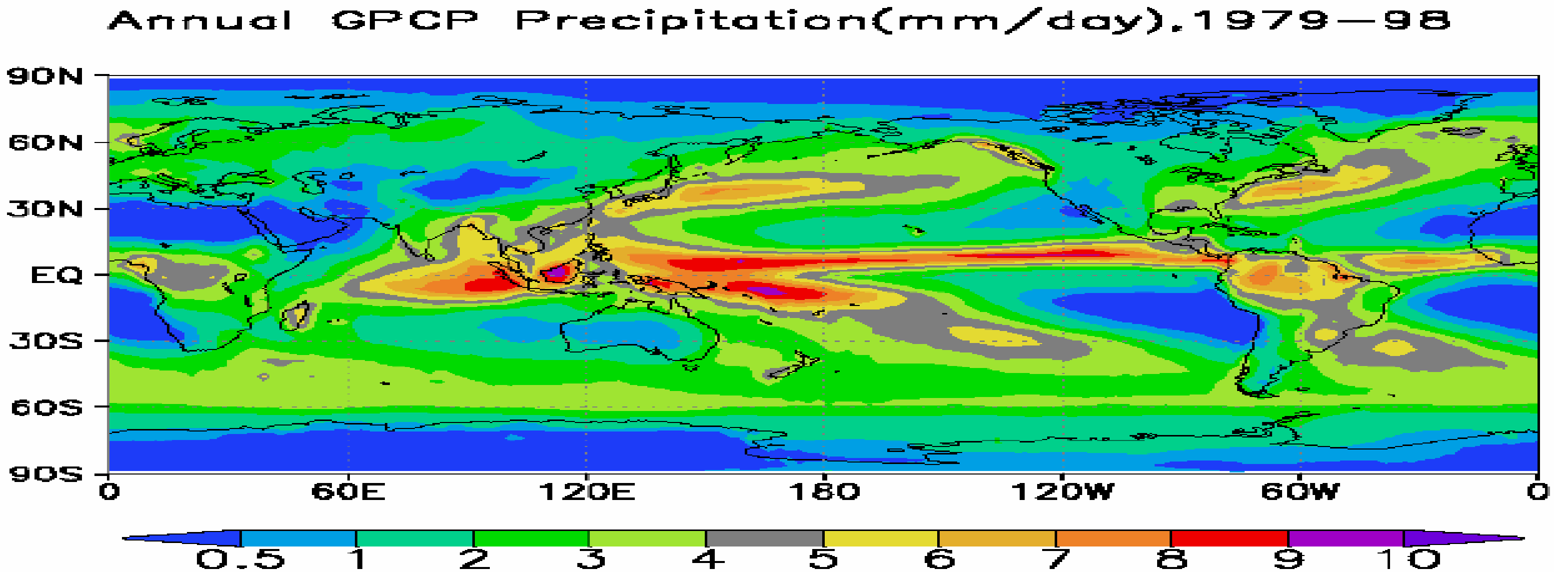
- **NASA providing MODIS Direct Readout from Terra and Aqua, Quikscat winds, and AIRS radiances for NWP centres from Aqua**
- **Altimetry data being provided by NASA/CNES and ESA (ERS ocean winds earlier)**
- **Plans also in place for NASDA and Roshydromet to provide data**





Multi-platform/Multi-sensor Products





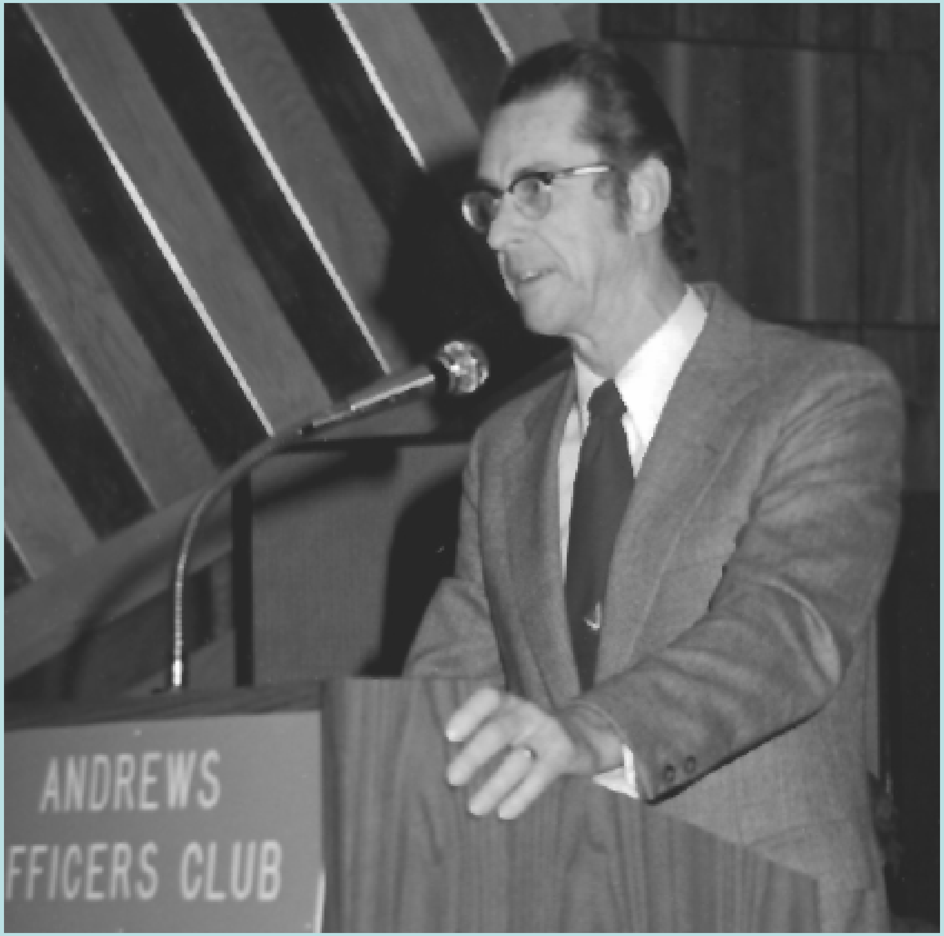
EVOLUTION TO TODAY'S OPERATIONAL SYSTEMS

What was significant?

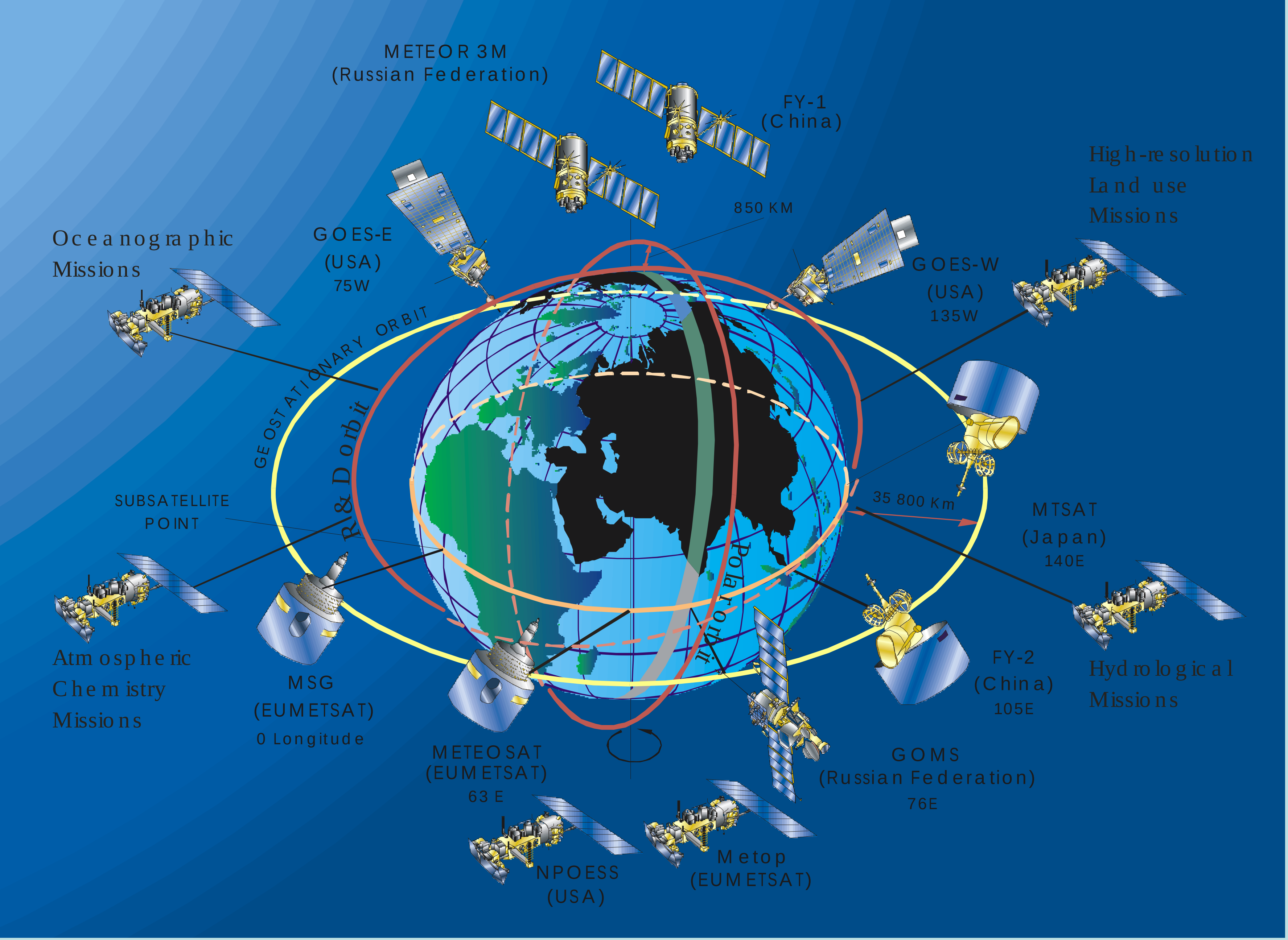
- Leadership
- Vision
- Understanding
- Utilization

In 1985 at the 25th anniversary of weather satellites, Dave was recognized for his leadership

Dave was cited for exceptional accomplishments … while directing the U.S. Civil Operational Environmental Satellite Program. During his tenure, the United States established its preeminent position in the monitoring of the global environment and never suffered a break in operational weather service.

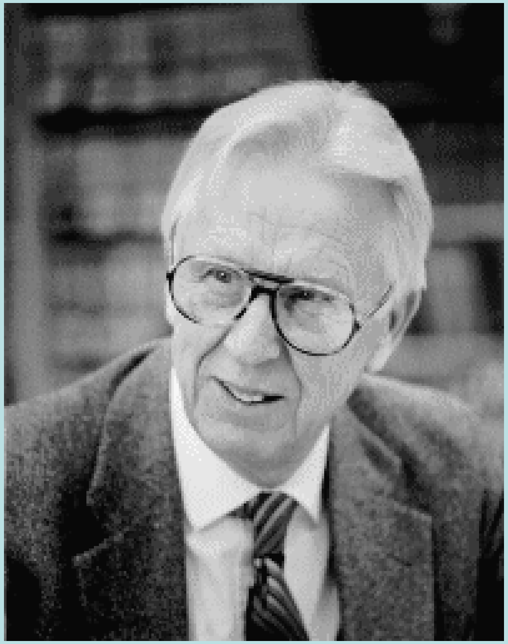


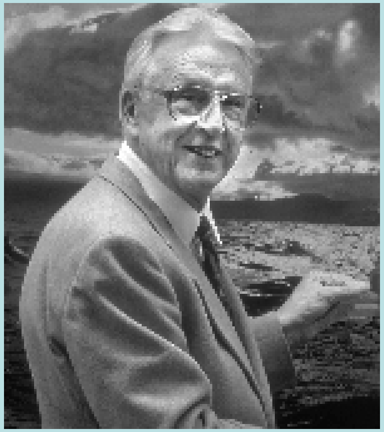
Leadership


METEOR 3M
(Russian Federation)
FY-1
(China)
High-resolution
Land use
Missions
850 KM
Oceanographic
Missions
GOES-E
(USA)
75W
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
NPOESS
(USA)
Metop
(EUMETSAT)

In 1985 at the 25th anniversary of weather satellites, Vern was recognized for his vision

Vern was cited for unparalleled scientific leadership and innovative engineering design and development in conceiving new sensors and applications from the first TIROS satellite through the GOES series.

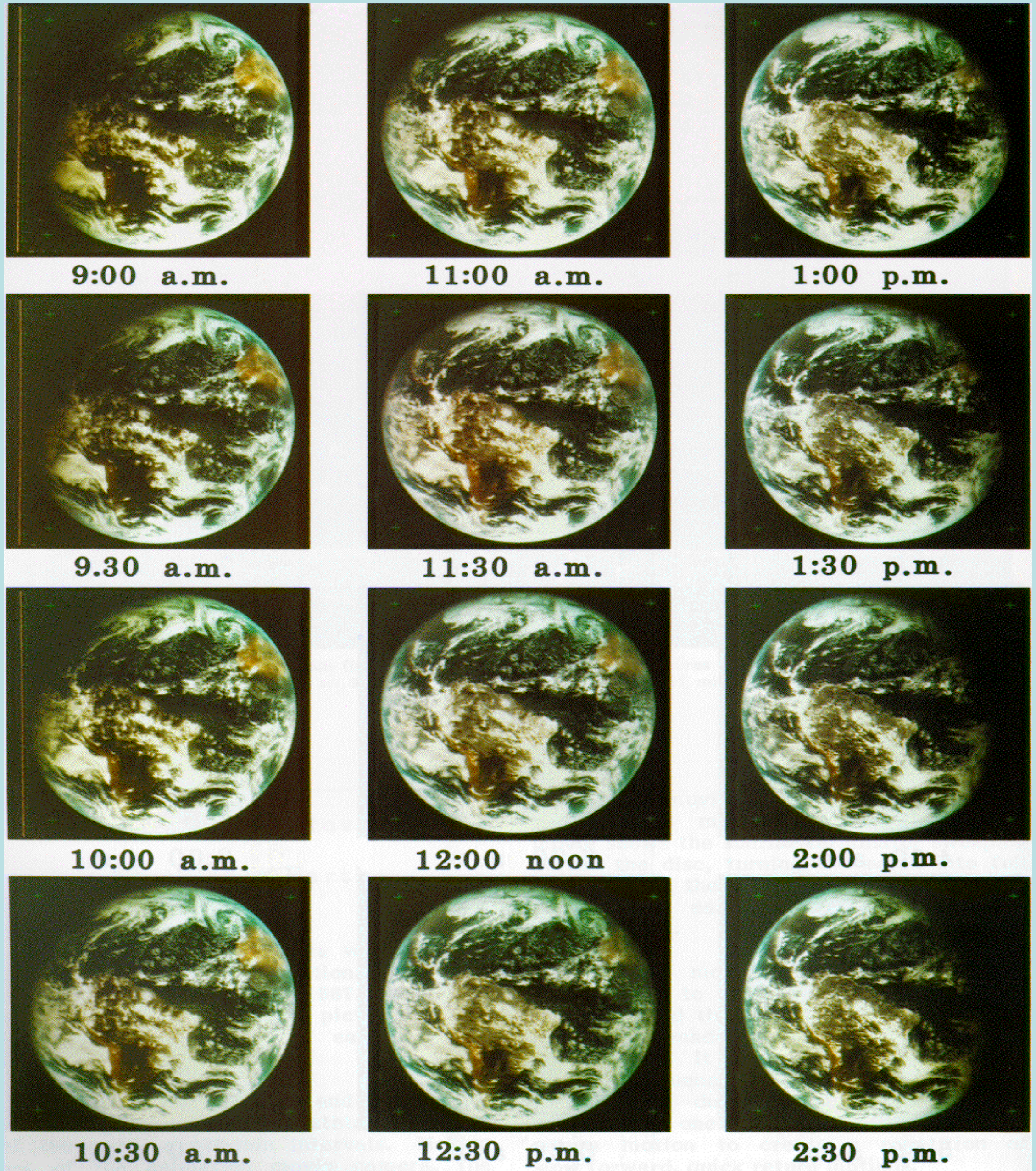




Vision

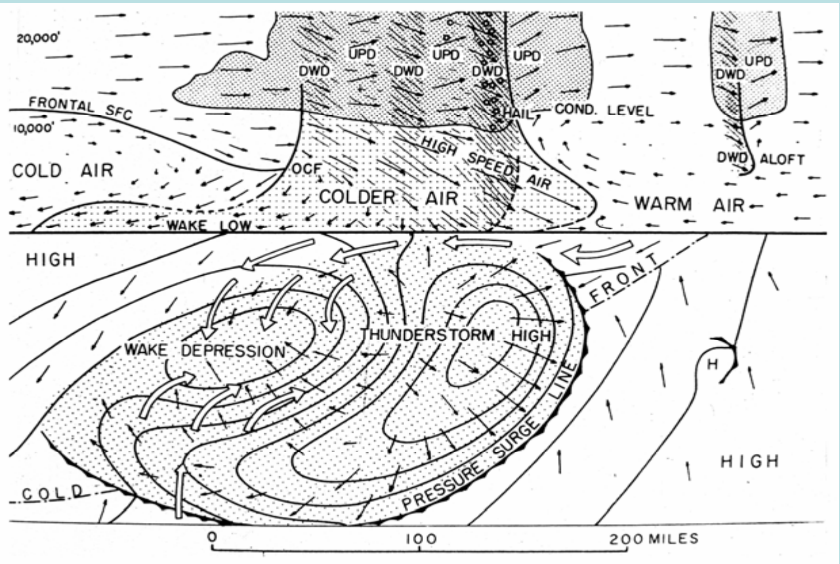
Suomi, Parent, and Fujita

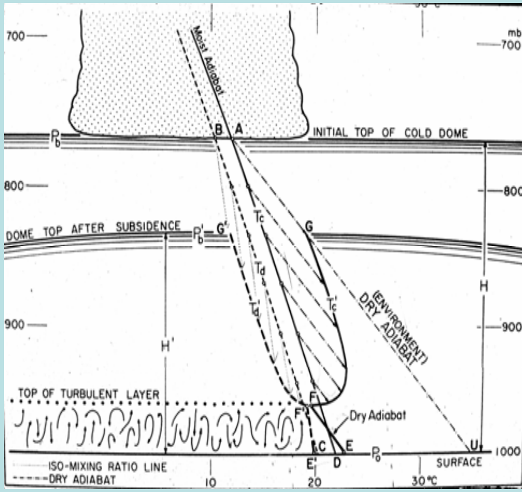
create first color movie of planet Earth with ATS-III pictures on 19 Nov 1967



In 1985 at the 25th anniversary of weather satellites, Ted was recognized for his understanding

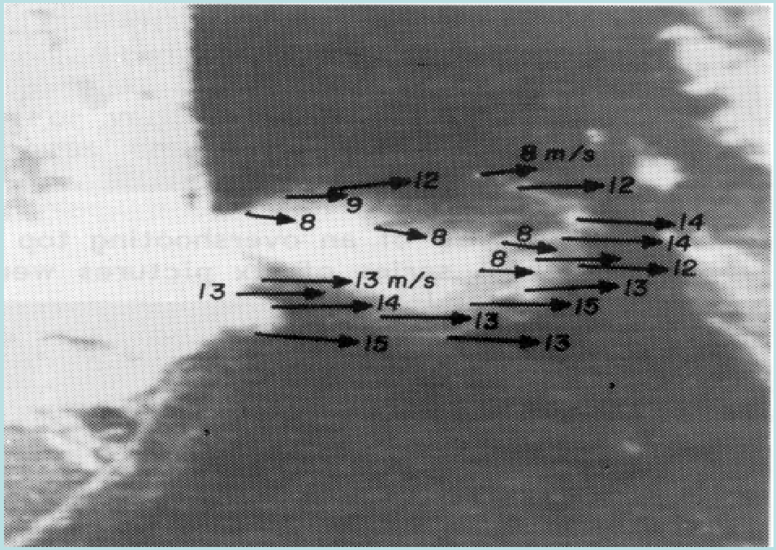
Ted was cited for ‘creative scientific leadership as an enthusiastic pioneer in the use of satellite imagery to analyze and predict mesoscale weather phenomena and to understand severe thunderstorms, tornadoes, and hurricanes.’

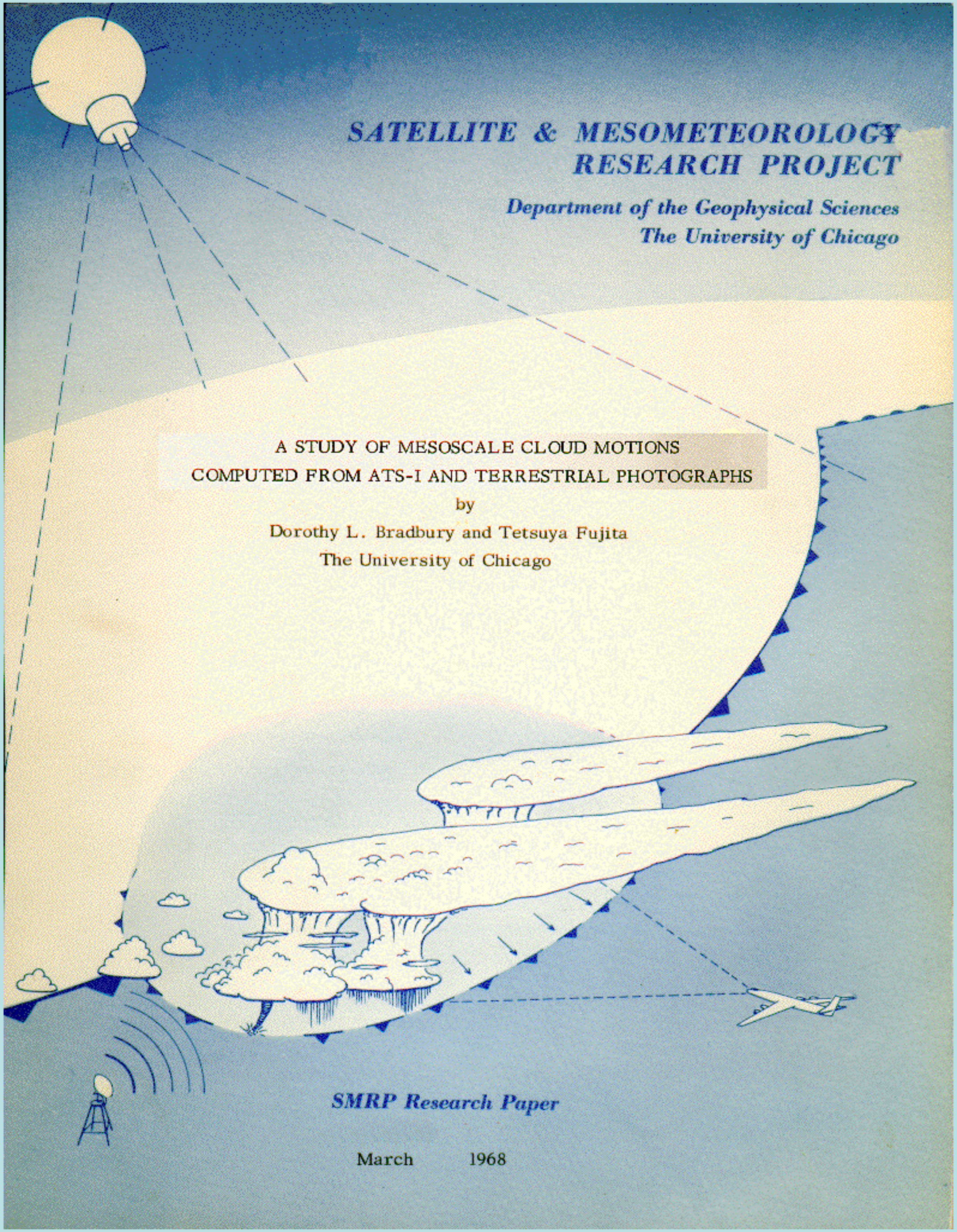




Understanding

The Mesometeorology Research Project added satellites and the SMRP papers from Ted and his U of Chicago colleagues became classics in atmospheric research



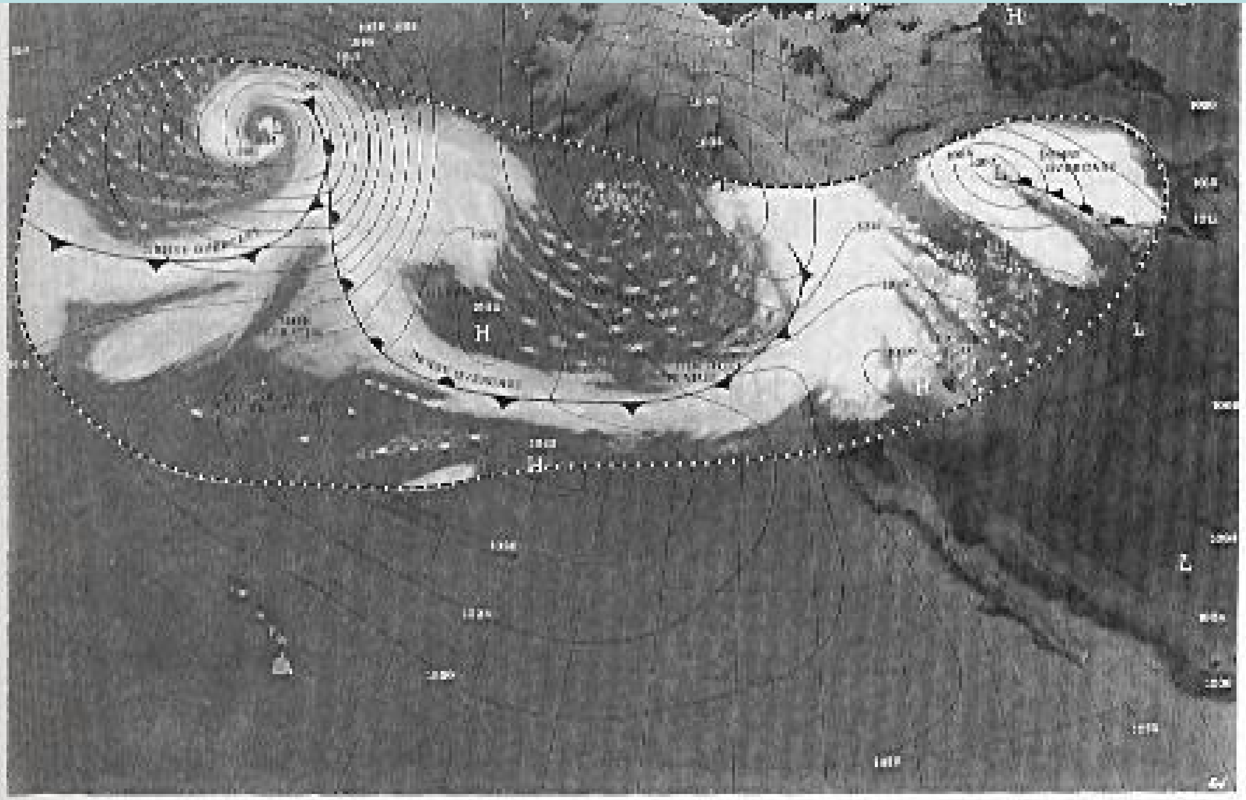


In 1985 at the 25th anniversary of weather satellites, Vince was recognized for utilization

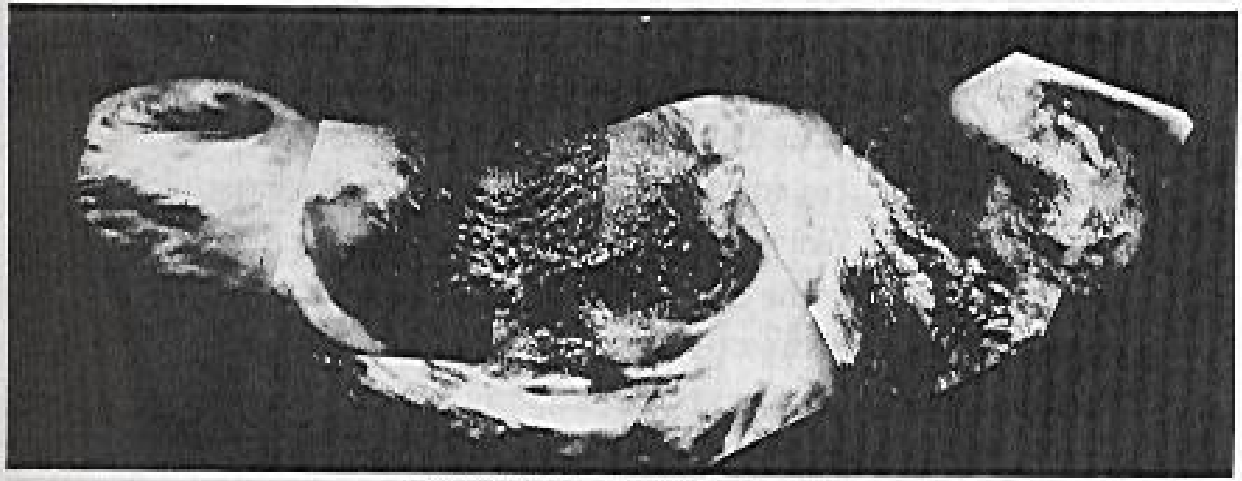
Vince was innovative, outstanding scientific leadership…that developed many of the techniques used in daily weather forecasting operations in the United States and throughout the world. He developed techniques to determine [a variety] of weather related phenomena from satellite images

Utilization

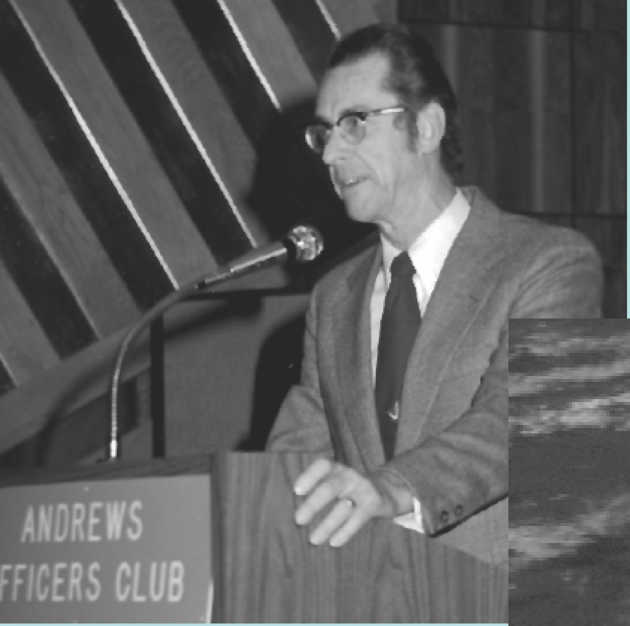
- **Weather map from May 20, 1960 (top) with artist rendering of clouds from the TIROS-1 photographic-mosaic taken that same day (bottom)**

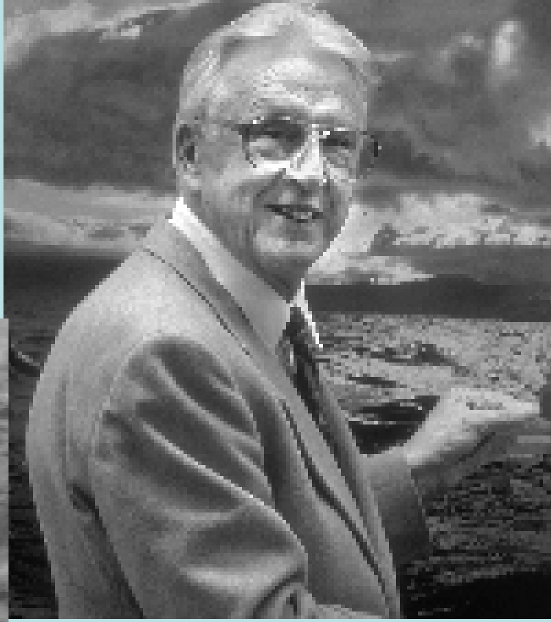


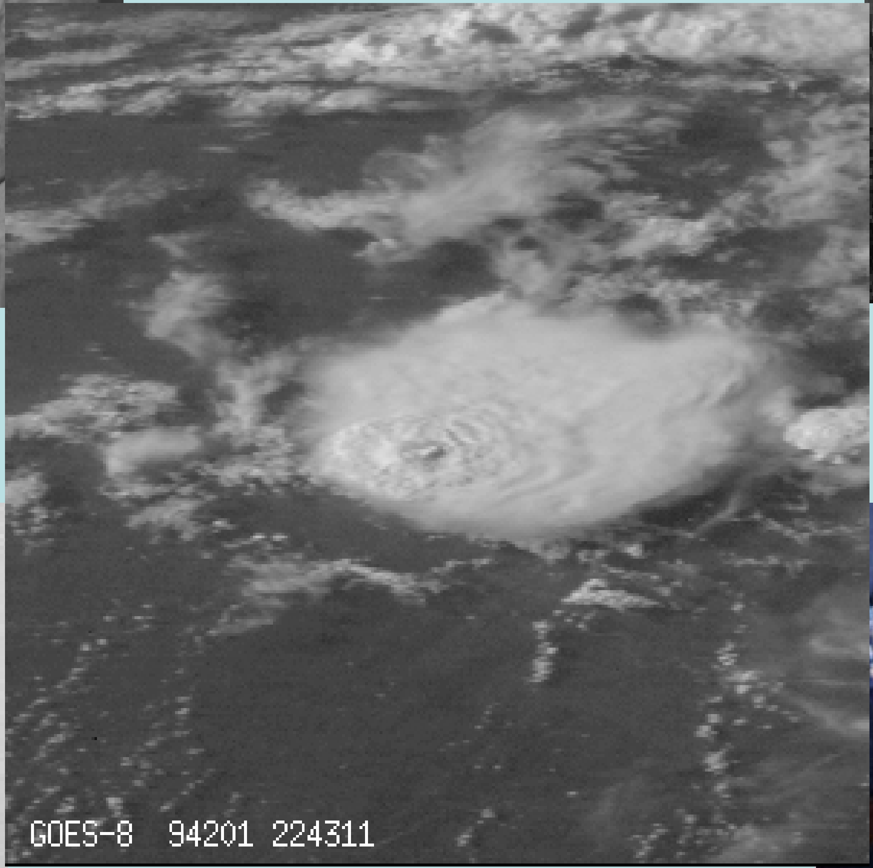
STORM FAMILY OVER THE NORTH PACIFIC OCEAN
TIROS CLOUD PICTURES SUPERIMPOSED ON CONVENTIONAL WEATHER MAP



ACTUAL TIROS PHOTOGRAPHS TAKEN ON MAY 20, 1960


ANDREWS
FFICERS CLUB



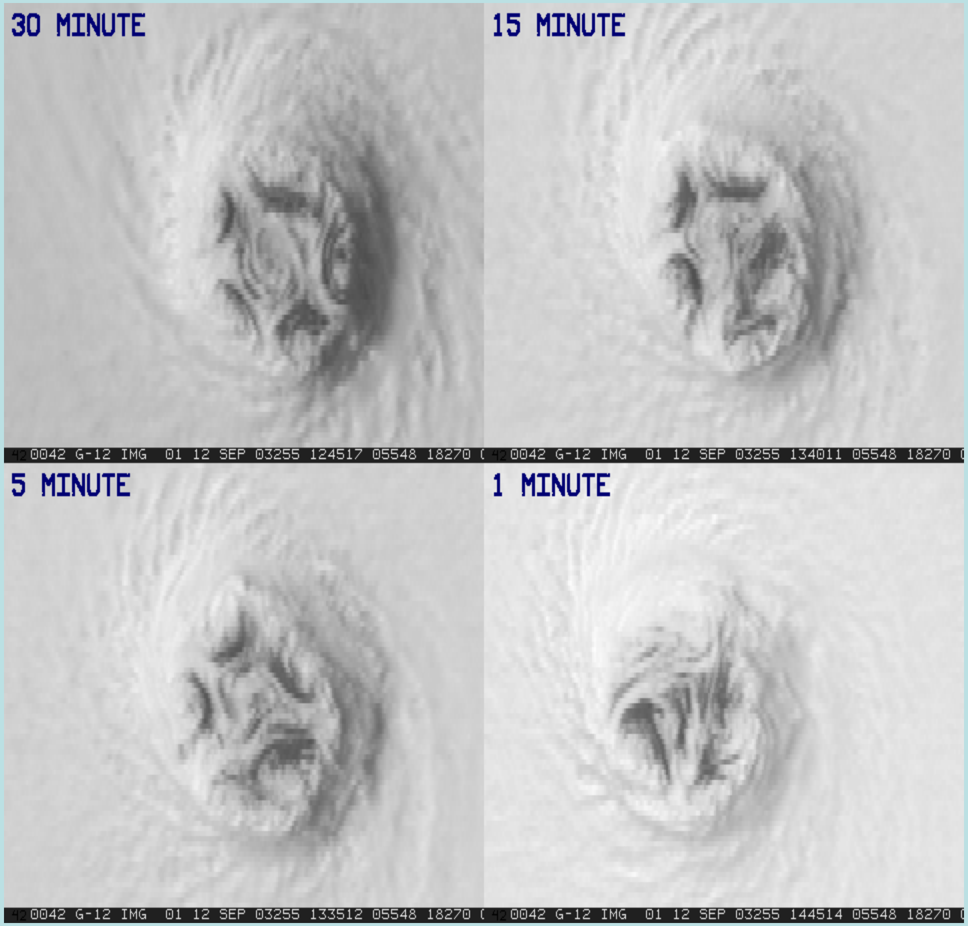

GOES-8 94201 224311

The spatial and temporal domains of the phenomena being observed drive the satellite systems' spectral needs as a function of space, time, and signal to noise.

Spectral Awareness In Terms of Space, Time, Signal to Noise and Scene Characteristics

With satellite remote sensing, there are four basic questions that need to be addressed

- They all deal with resolution:
  - temporal (how often)
  - spatial (what size)
  - spectral (what wavelengths and their width)
  - radiometric (signal-to-noise)



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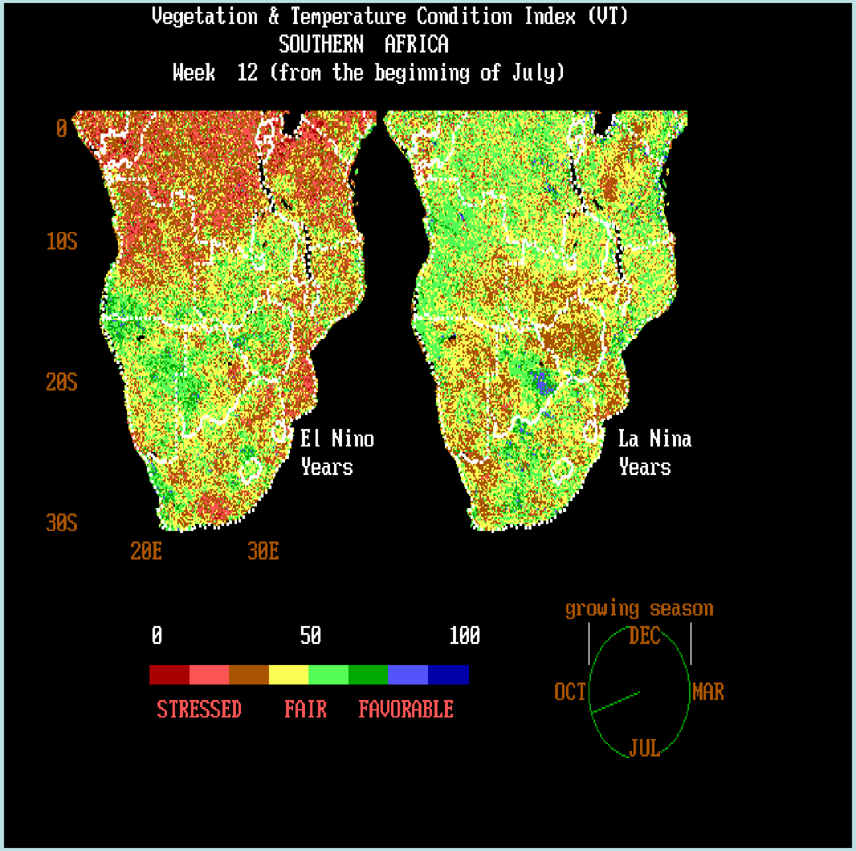

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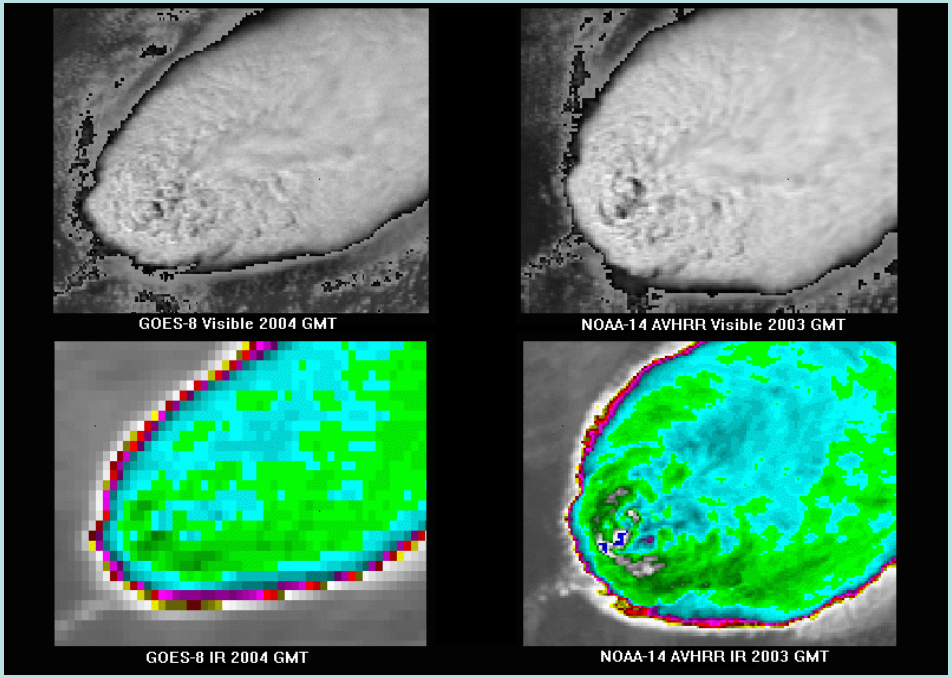
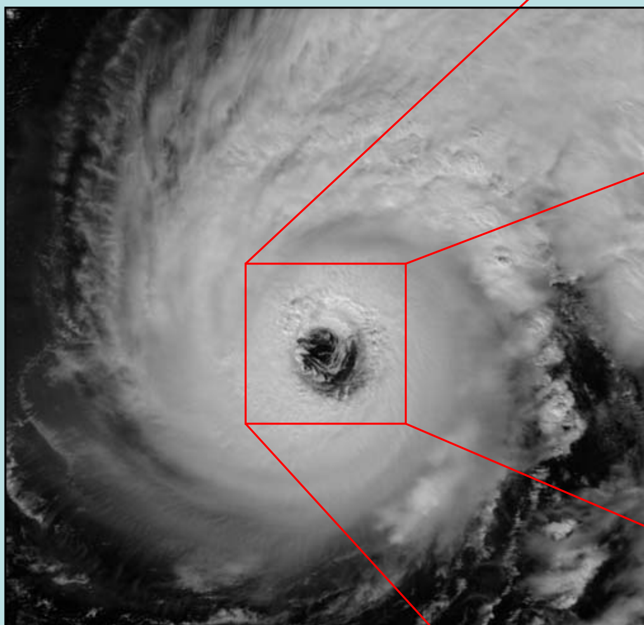
  - radiometric (signal-to-noise)
  - GOES and AVHRR 1 km Vis
  - GOES 4 km IR, AVHRR 1 km IR

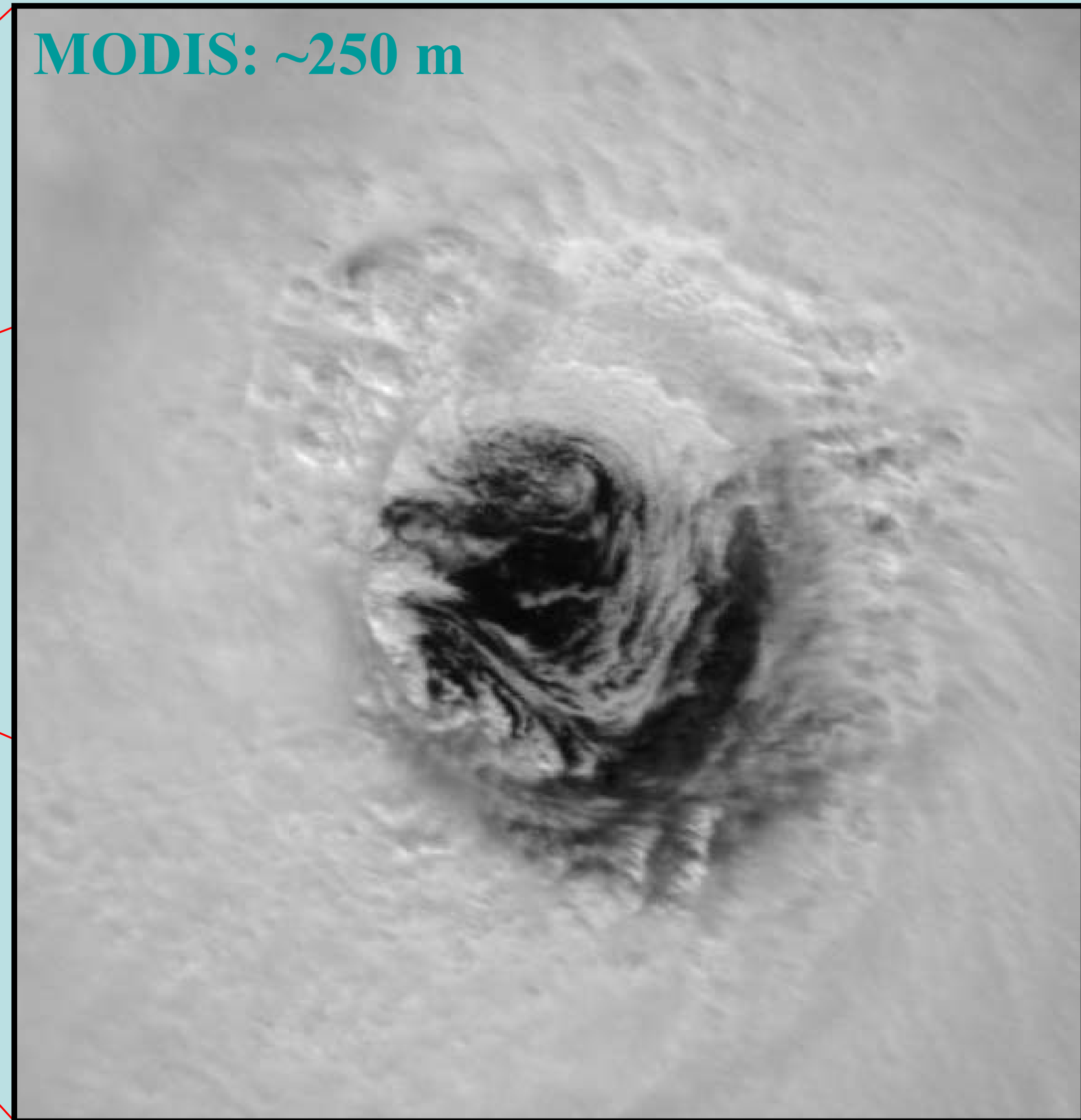


1 Km to 250 m

Hurricane Erin

09/09/01 ~1530 Z





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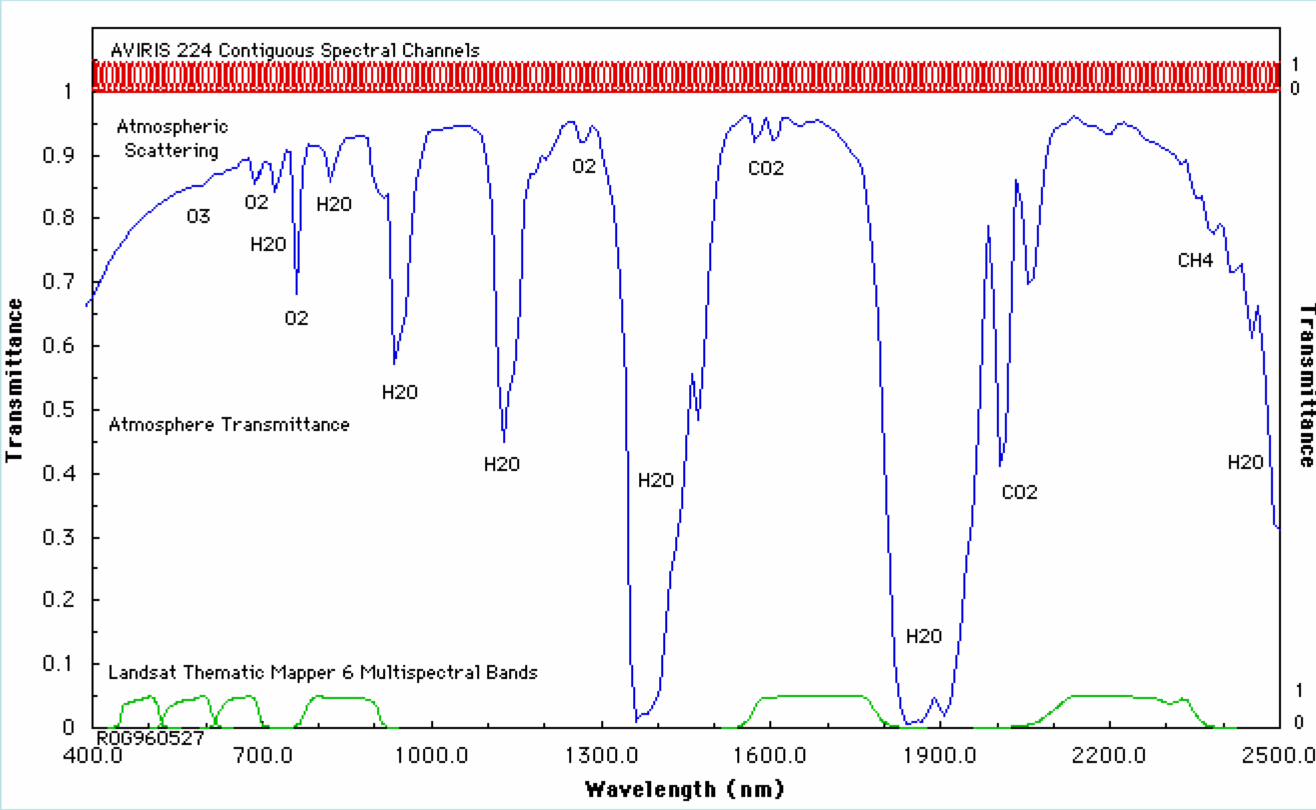

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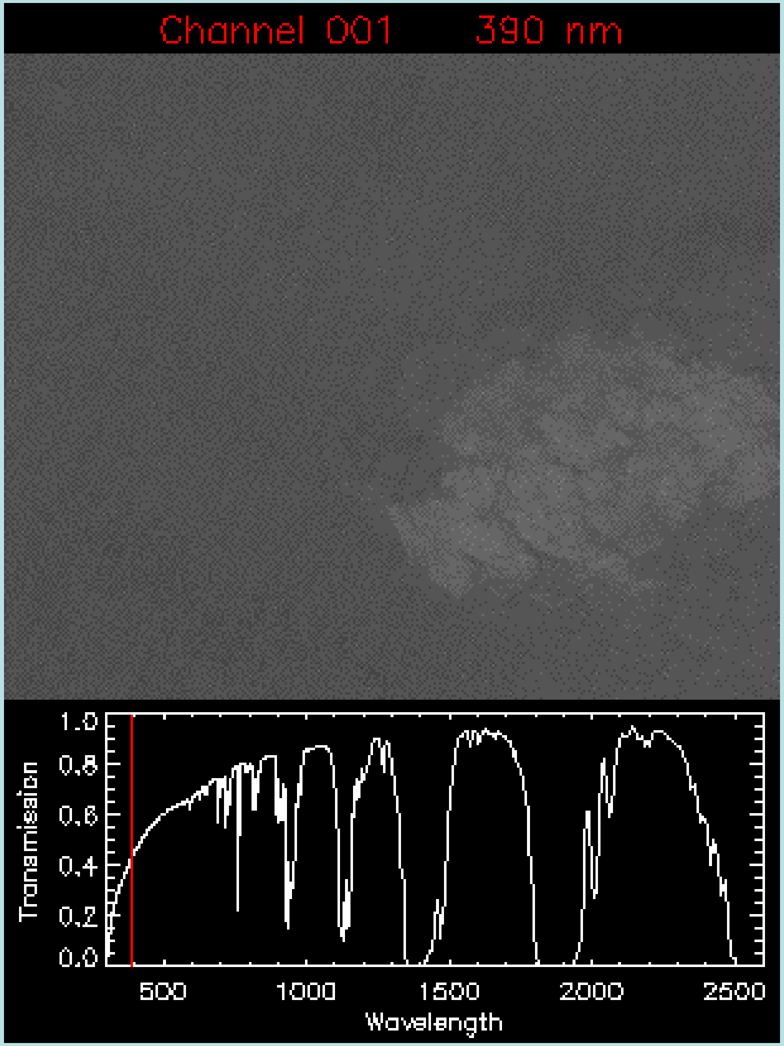
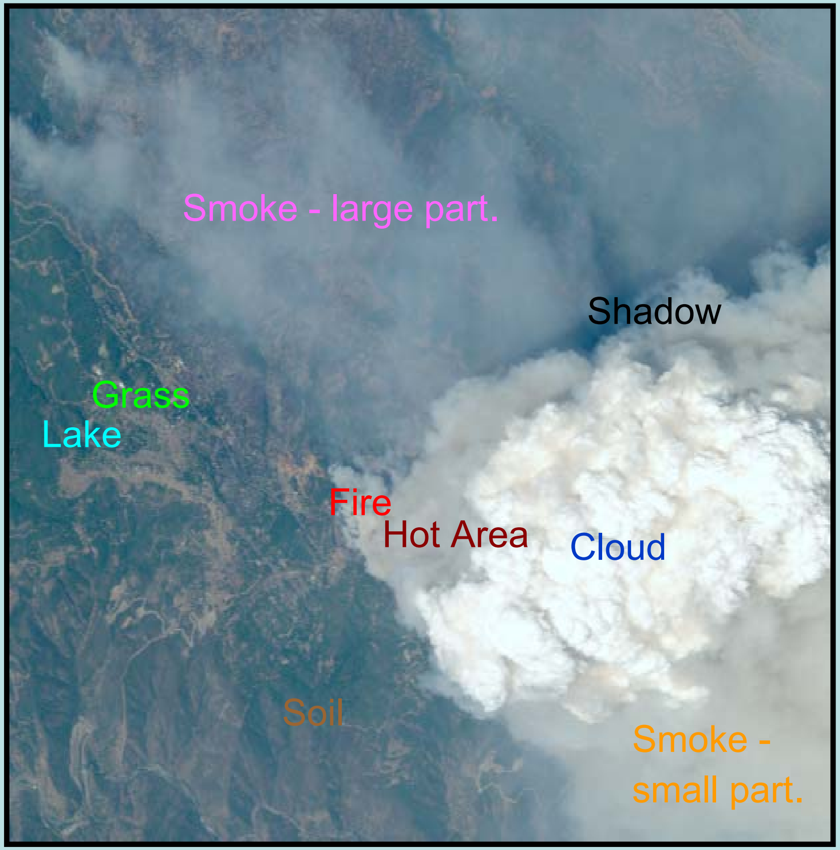
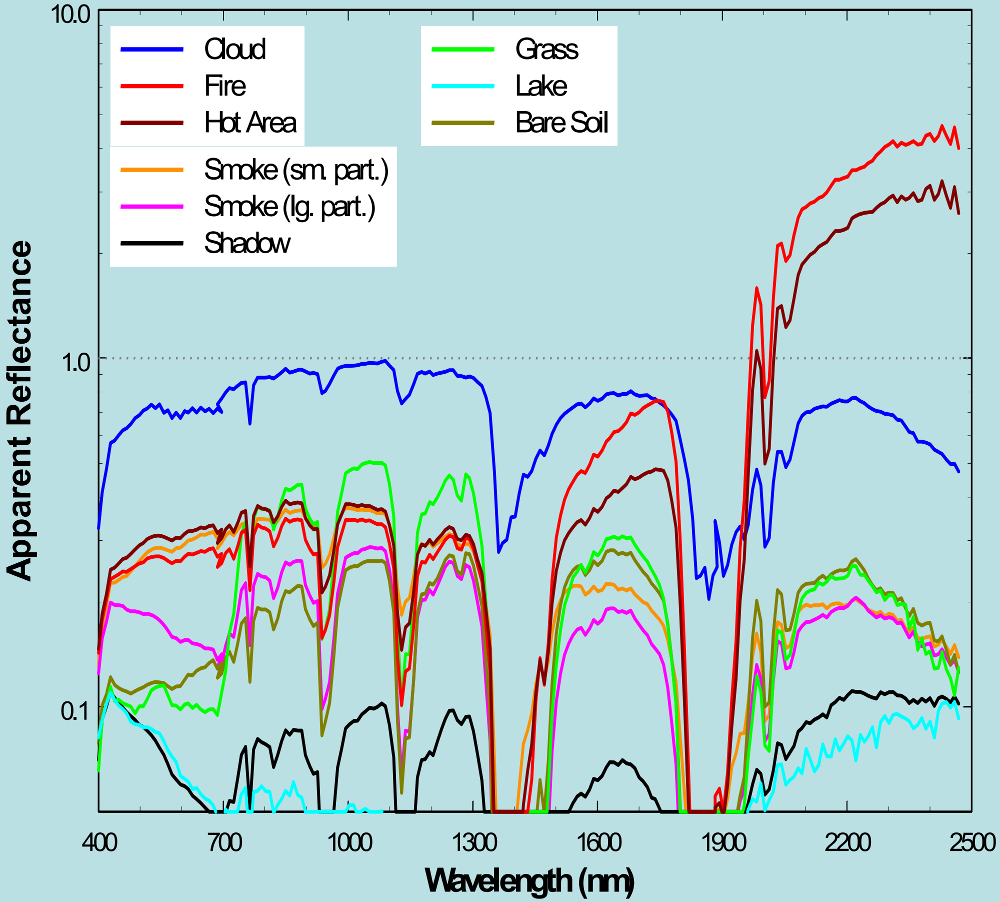


Example of AVIRIS Spectral Information from a Scene Depicting Cloud, Smoke and Active Burn Areas

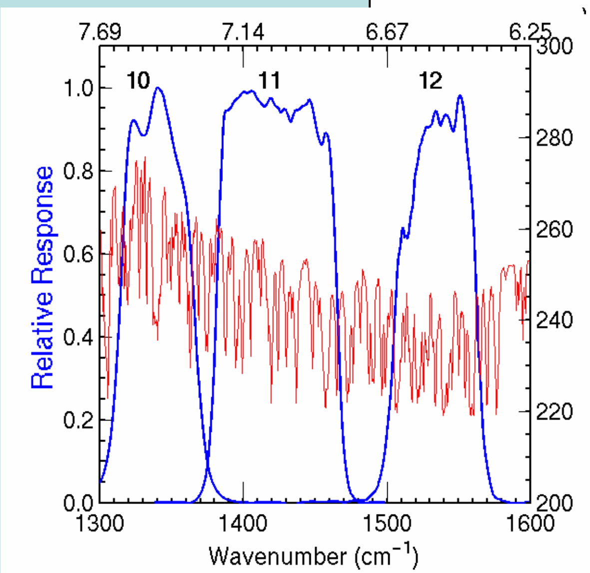
AVIRIS Image - Linden CA 20-Aug-1992
224 Spectral Bands: 0.4 - 2.5 μm
Pixel: 20m x 20m   Scene: 10km x 10km



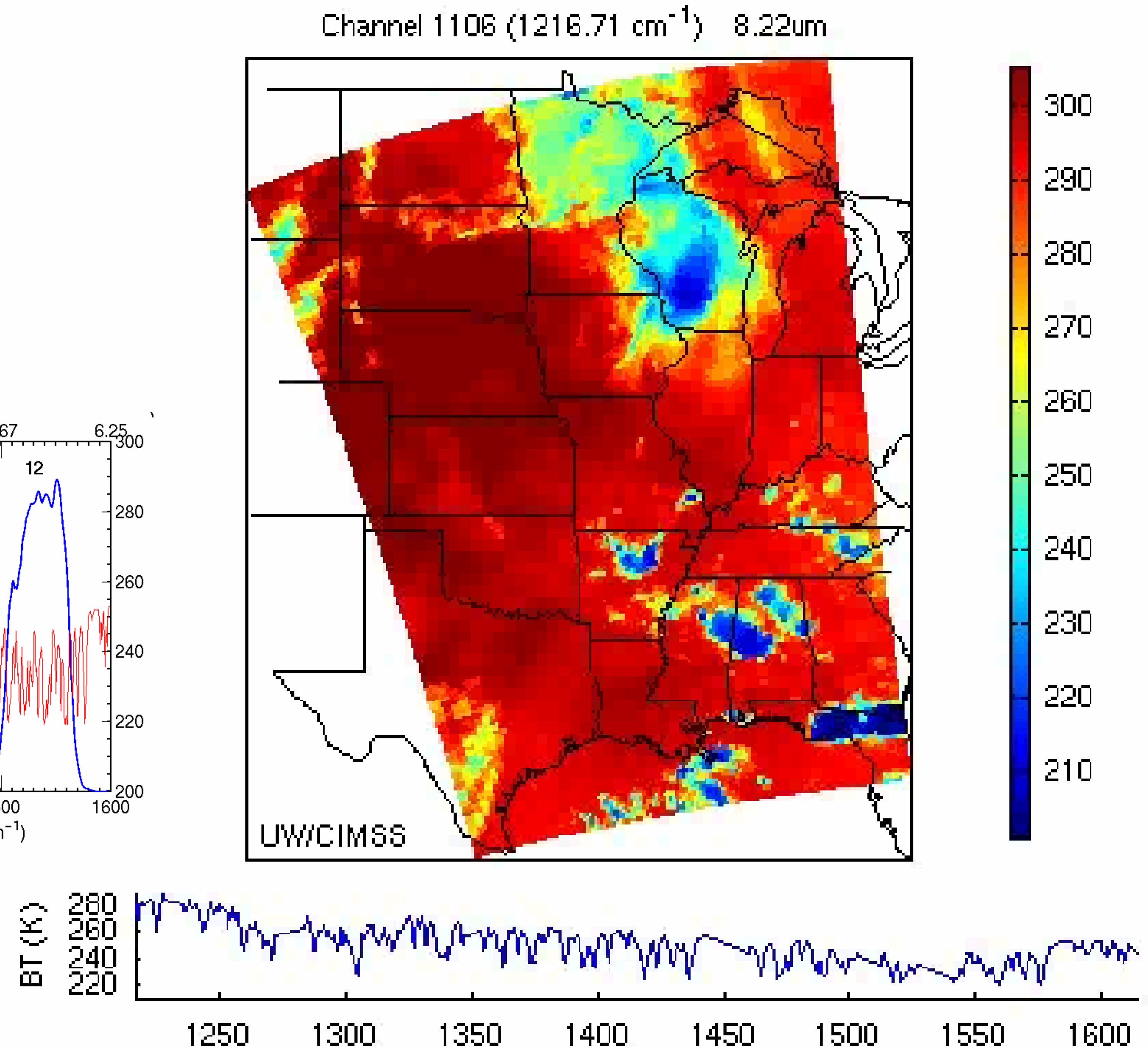
Spectral Signatures of Selected Pixels



High Spectral Resolution (AIRS) resolves H_2O spectral Features (right)

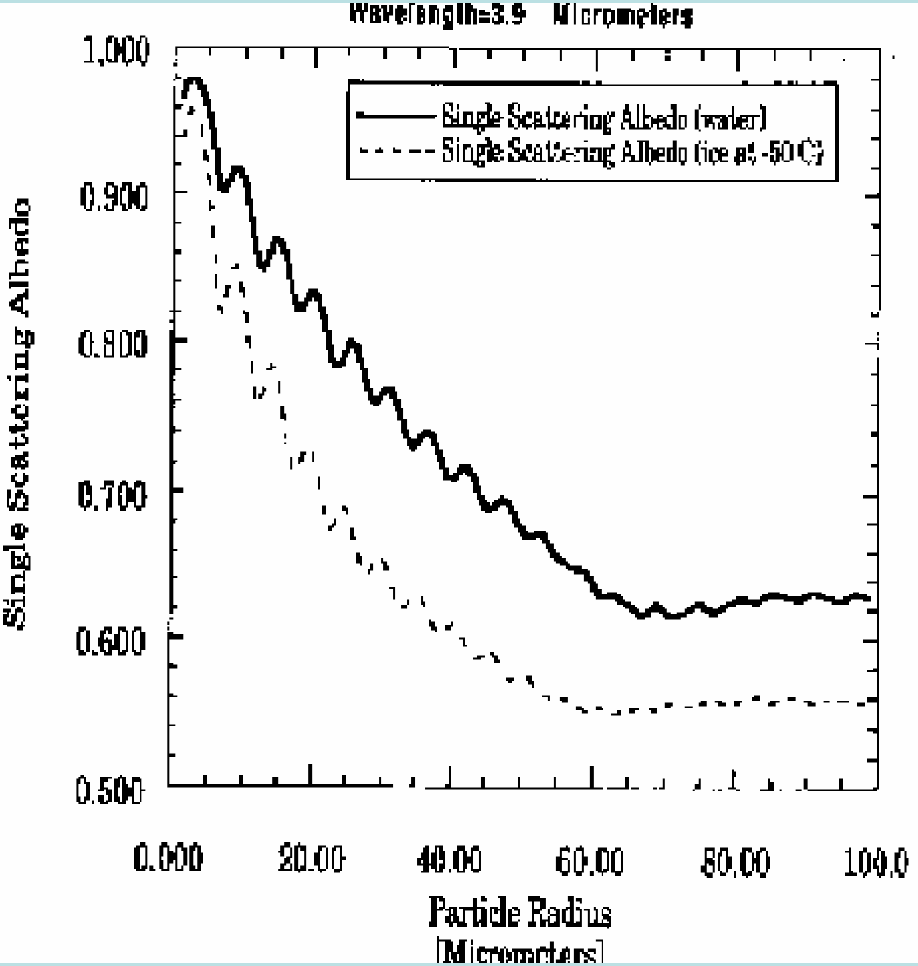


GOES-I/M era sounder H_20 Channels (above)

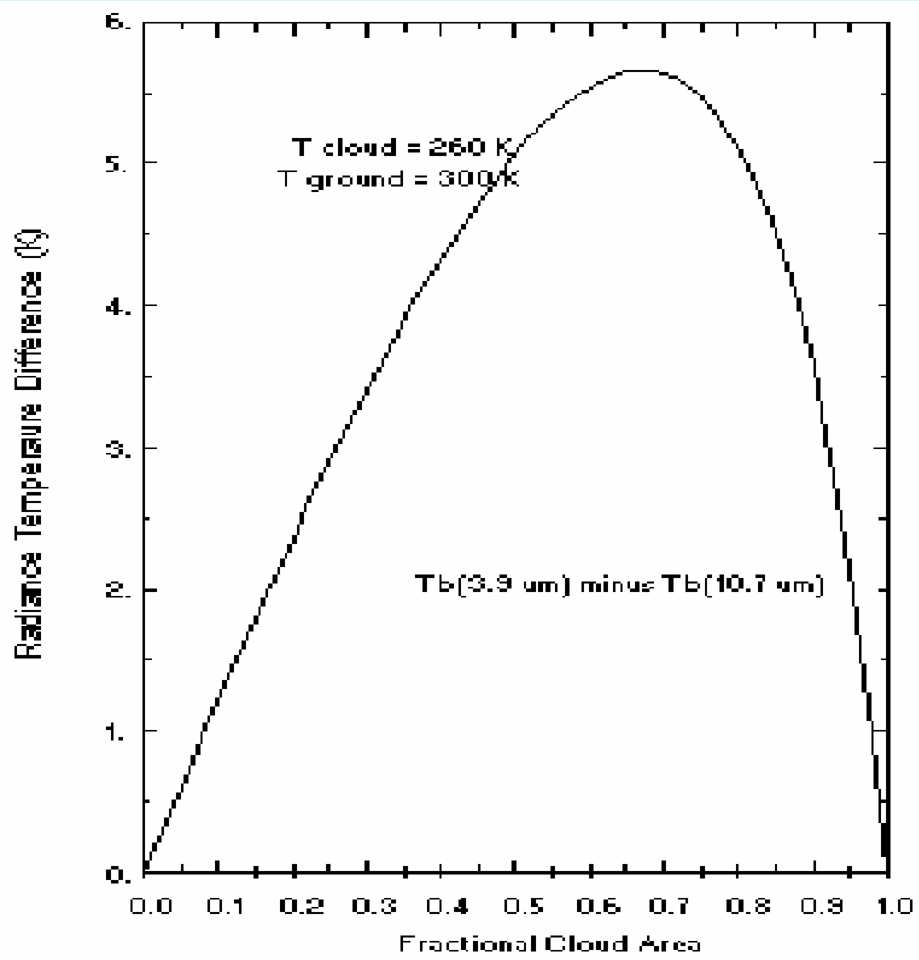


AIRS_Midwave_all_20Jul02_1920z.avi

Spectral Awareness

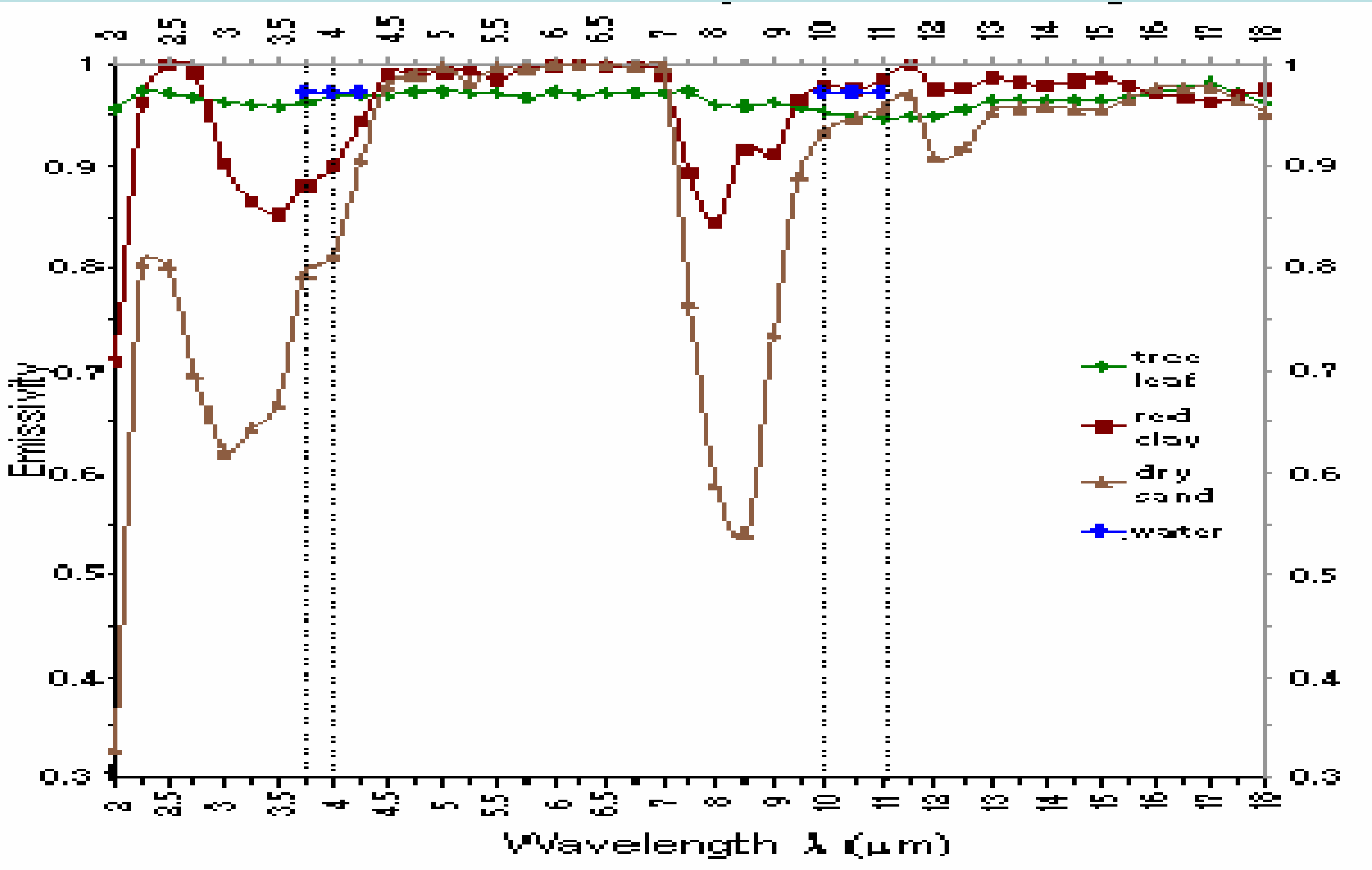


Scattering from water versus ice particles at 3.9 microns



Response of 3.9 vs. 10.7 microns to Temperature variability in a FOV

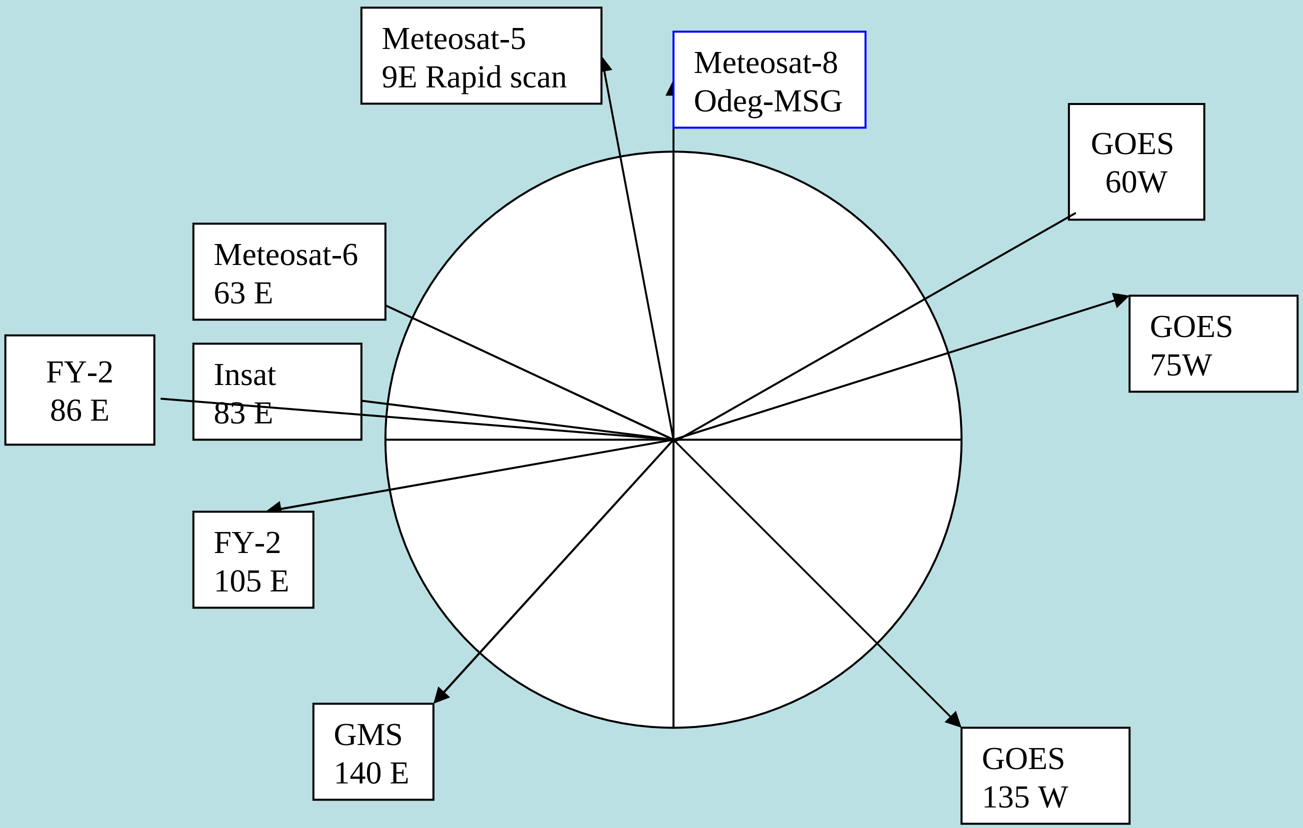
Spectral Awareness



During The Next Decade We Will Gain <u>Experience</u> With Satellite Data

- Multichannel, multispectral imagers
- Hyperspectral IR sounders and VIS to NIR imagers
- Active and passive microwave imagers
- Passive microwave sounders
- GPS constellation
- Active lidar
- Cloud and precipitation radars
- Lightning mappers
- …………..

Geostationary constellation and selected low earth orbiting satellites whose data are available today (7/2007)



NOAA-16 PM 17 AM

FY- 1D AM

METEOR-3M-N2 AM

Terra ConstellationAM

Aqua ConstellationPM

QuikSCAT AM

TRMM

ERS AM

Jason

COSMIC

Envisat AM

DMSP

SPOT AM

LANDSAT-7 AM

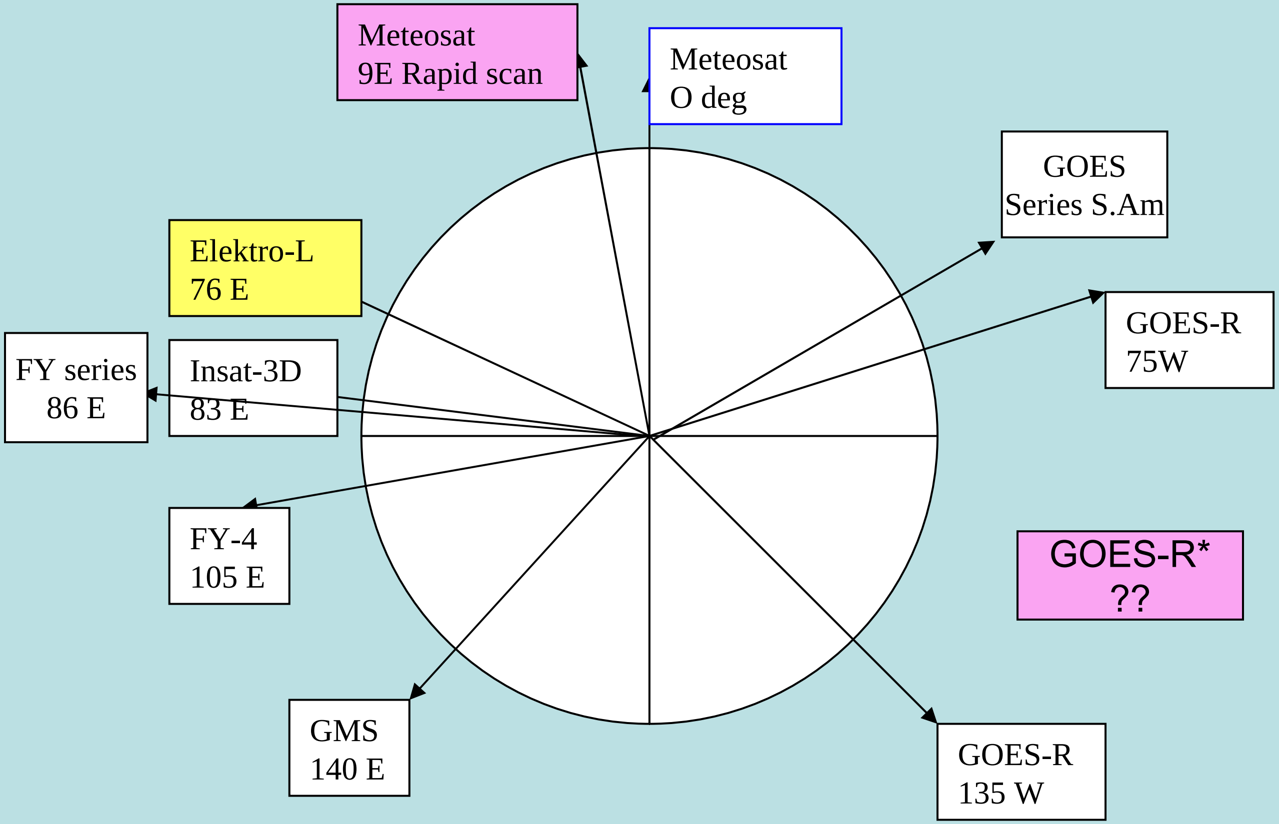
EO-1-AM

SAC-C

RESURS

IRS-P4

Geostationary constellation and selected low earth orbiting satellites whose data are anticipated in 2010-15



Roles of WMO and CGMS

METOP AM

NPOESS early AM & PM

FY- 3 AM/PM

METEOR-3M-N2 ?

NPP (PM)

ADM AM

GPM

GPS

DMSP

GOCE

SMOS AM

GCOM PM

CRYOSAT

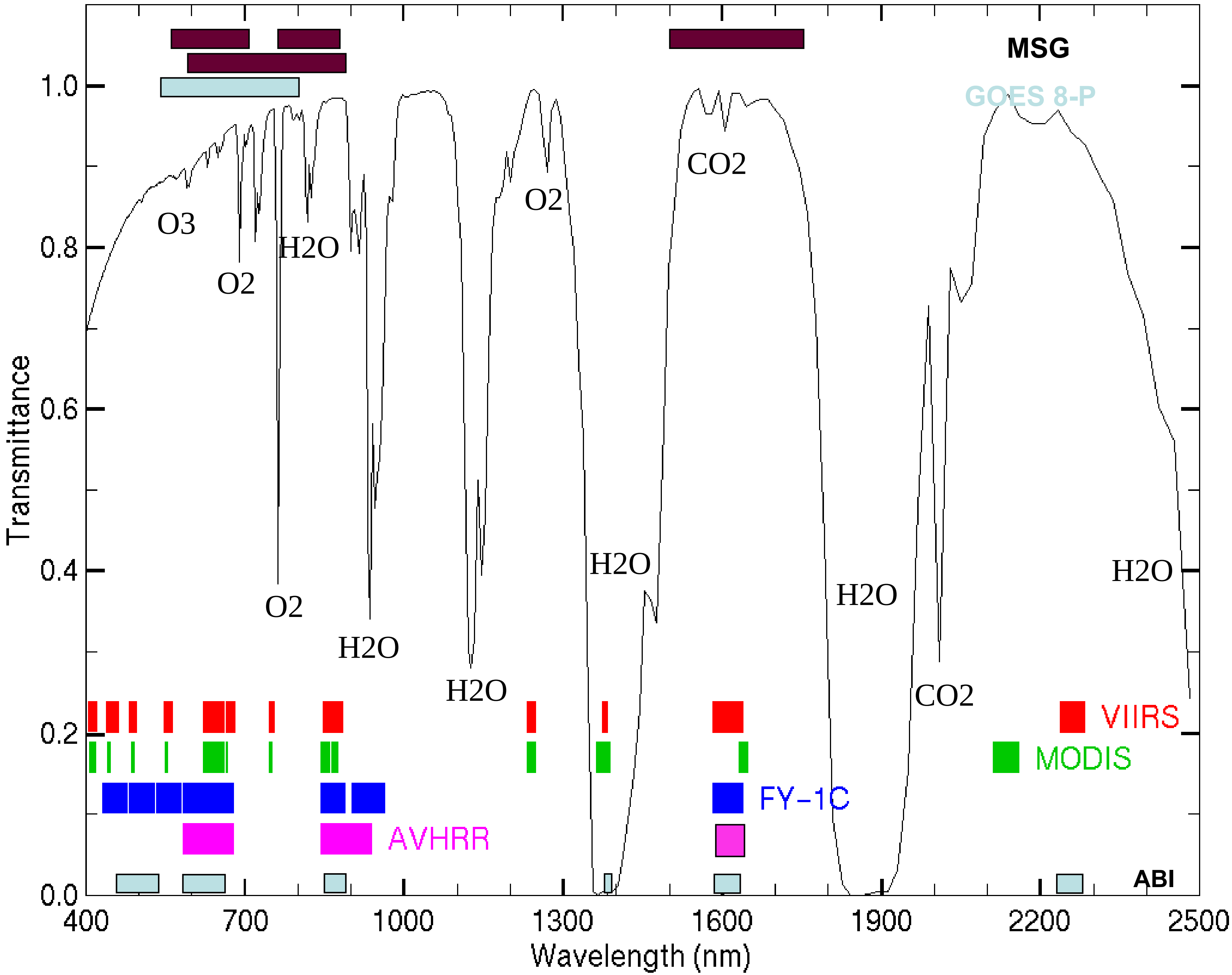
RESURS

IRS

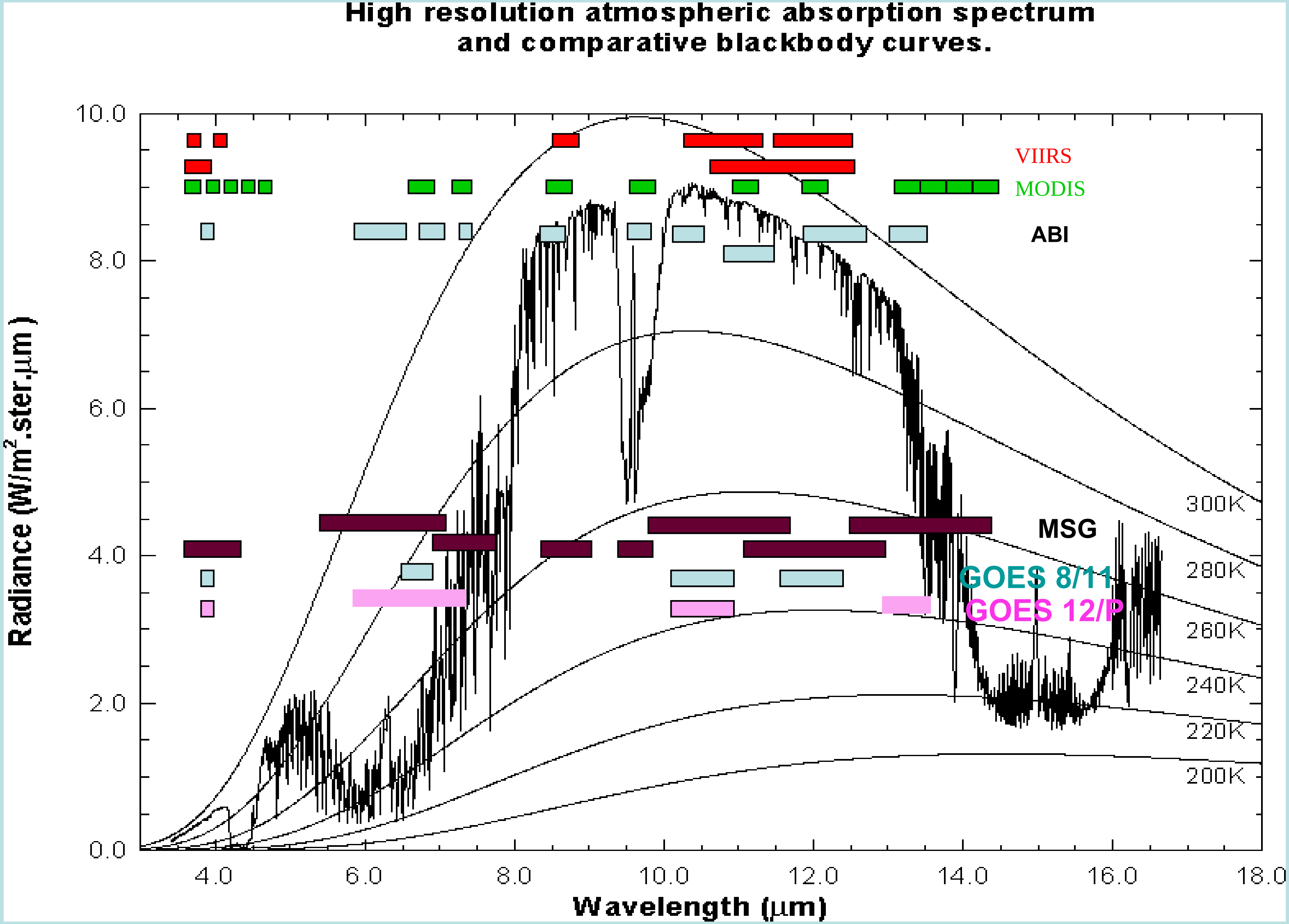
ALOS

GoSAT

VIIRS, MODIS, FY-1C, AVHRR, ABI, GOES, MSG



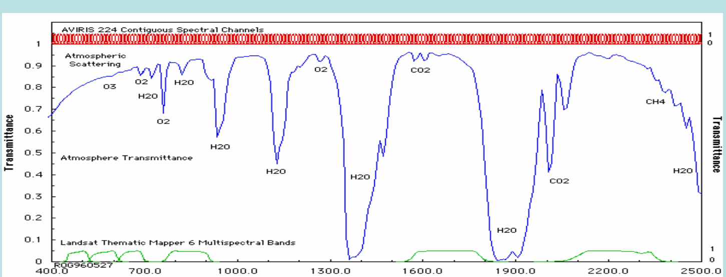
Earth emitted spectra overlaid on Planck function envelopes

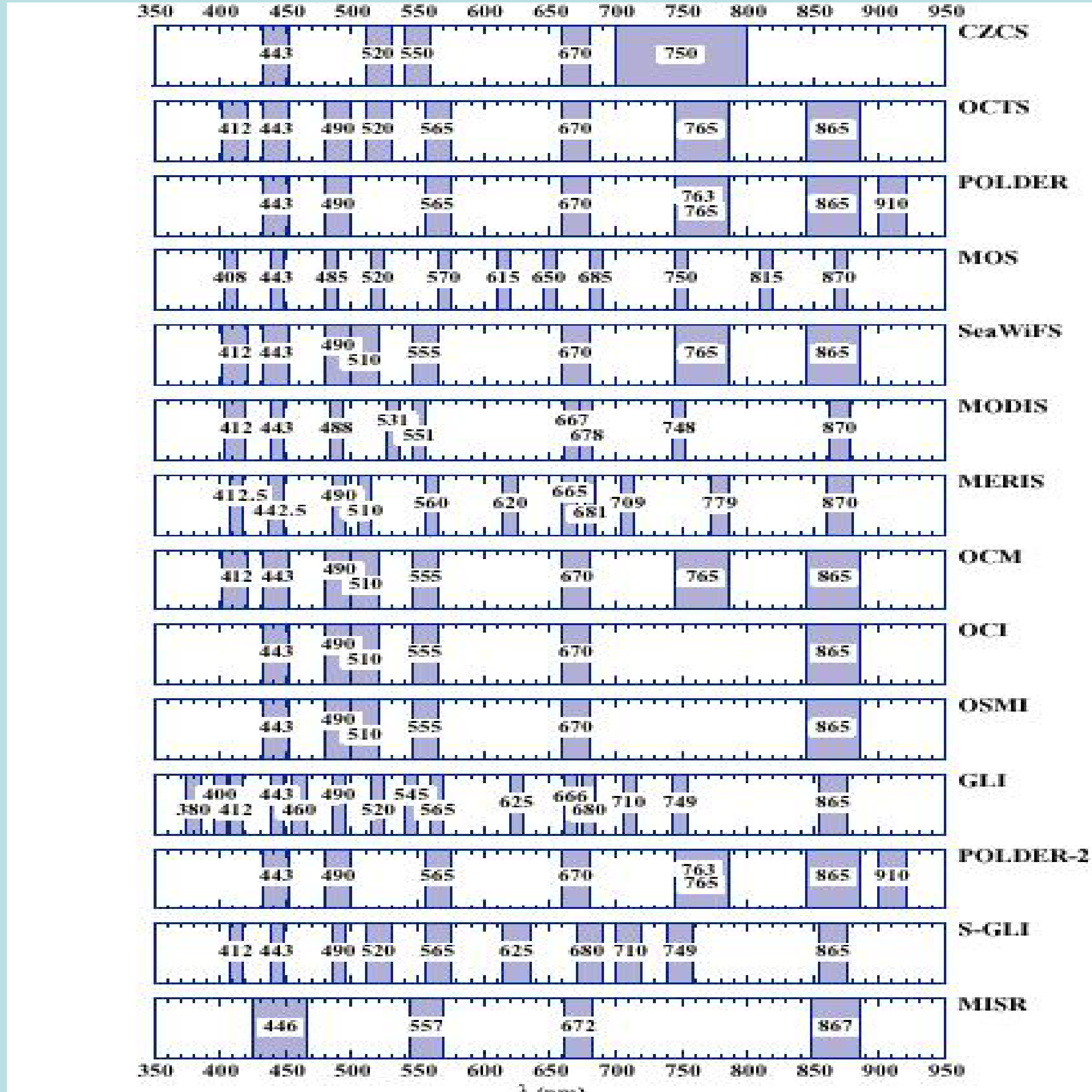


Channel Positions of Various Ocean-Color Sensors, 1978-2000* (380 – 950 nm)

For a multi spectral sensor

- Many spectral bands are identified for various applications
- Selection of band location and width are also important

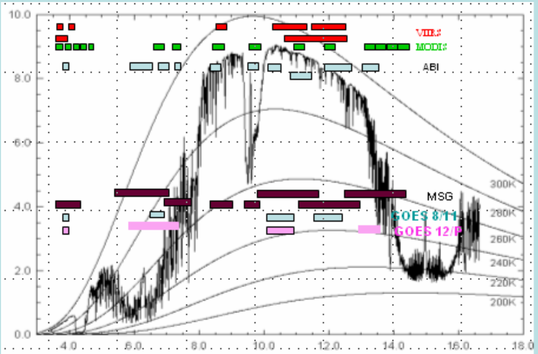




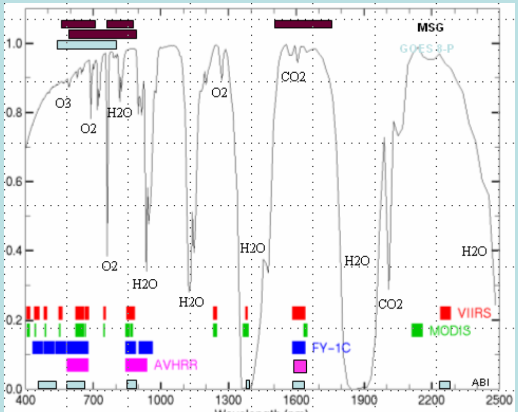
**** IOCCG Report #1***

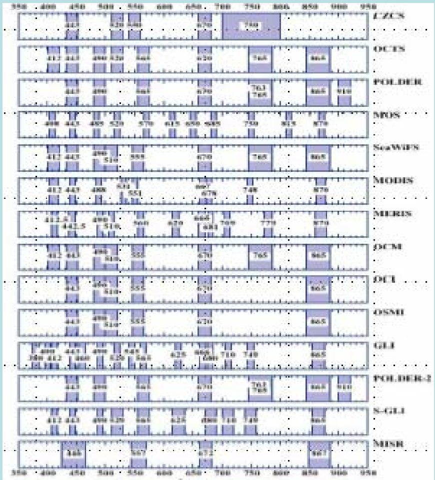
High Payoff: High Priority

- **Hyperspectral infrared from geostationary**



- **Hyperspectral visible to near infrared** sensors on both geostationary and polar orbiting satellites





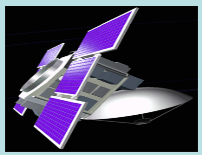
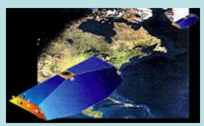
US Missions leading to future GOS

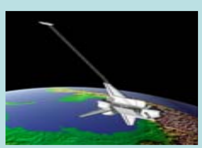
2005 | 2010 | 2020

Current Era

- POES
- GOES

- TRMM
- TOPEX
- EOS
- QUIKSCAT




Near Focus

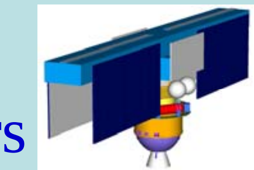
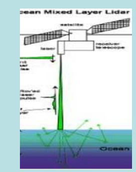
- NPP
- EO

- NPOESS
- GOES-R

- GPS

Advanced Concepts

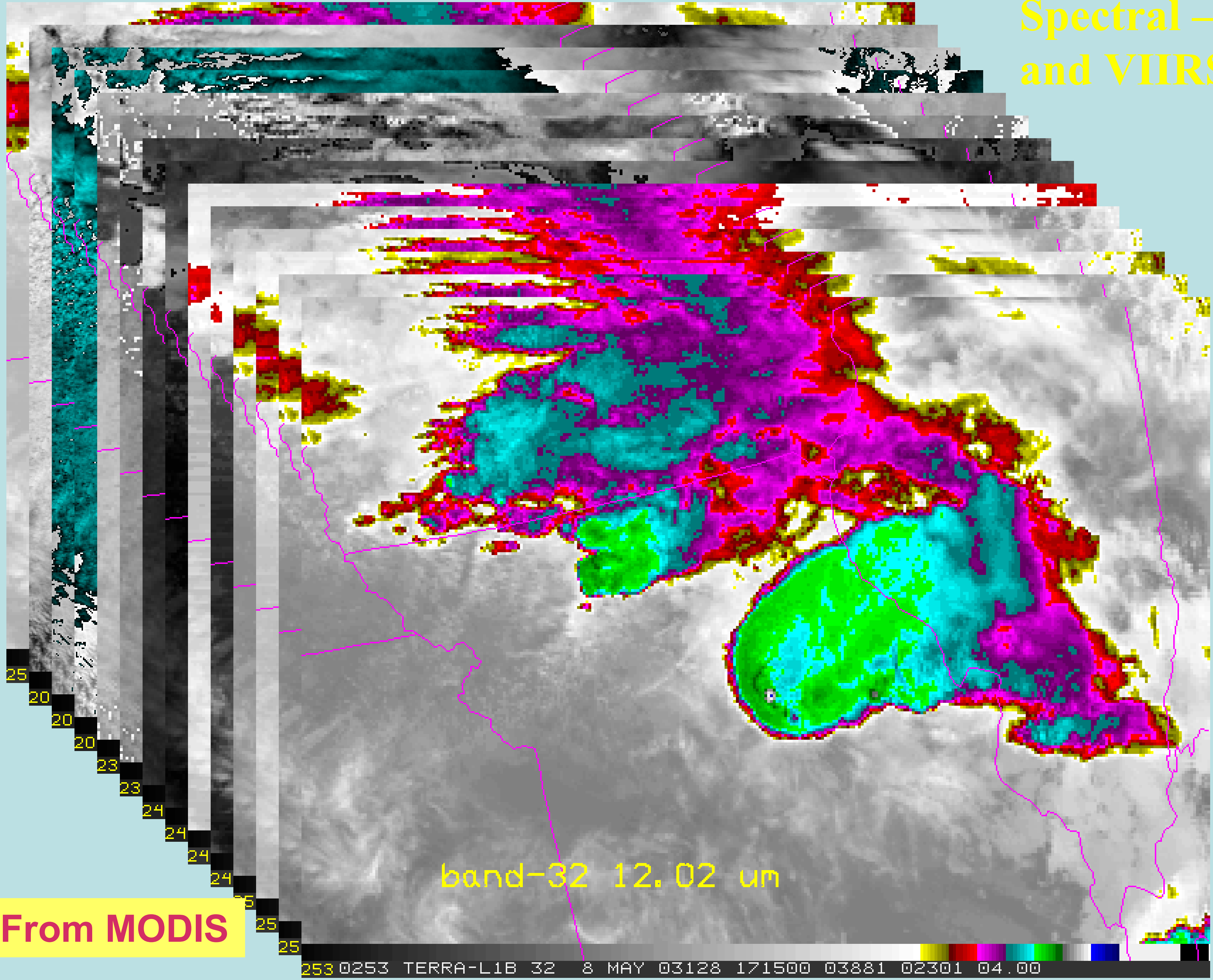
- Hyperspectral
- Imaging Lidars
- Geo Microwave
- CO_2 Lidar
- Synthetic Aperture Radiometry
- New Initiatives


NOAA lead Missions

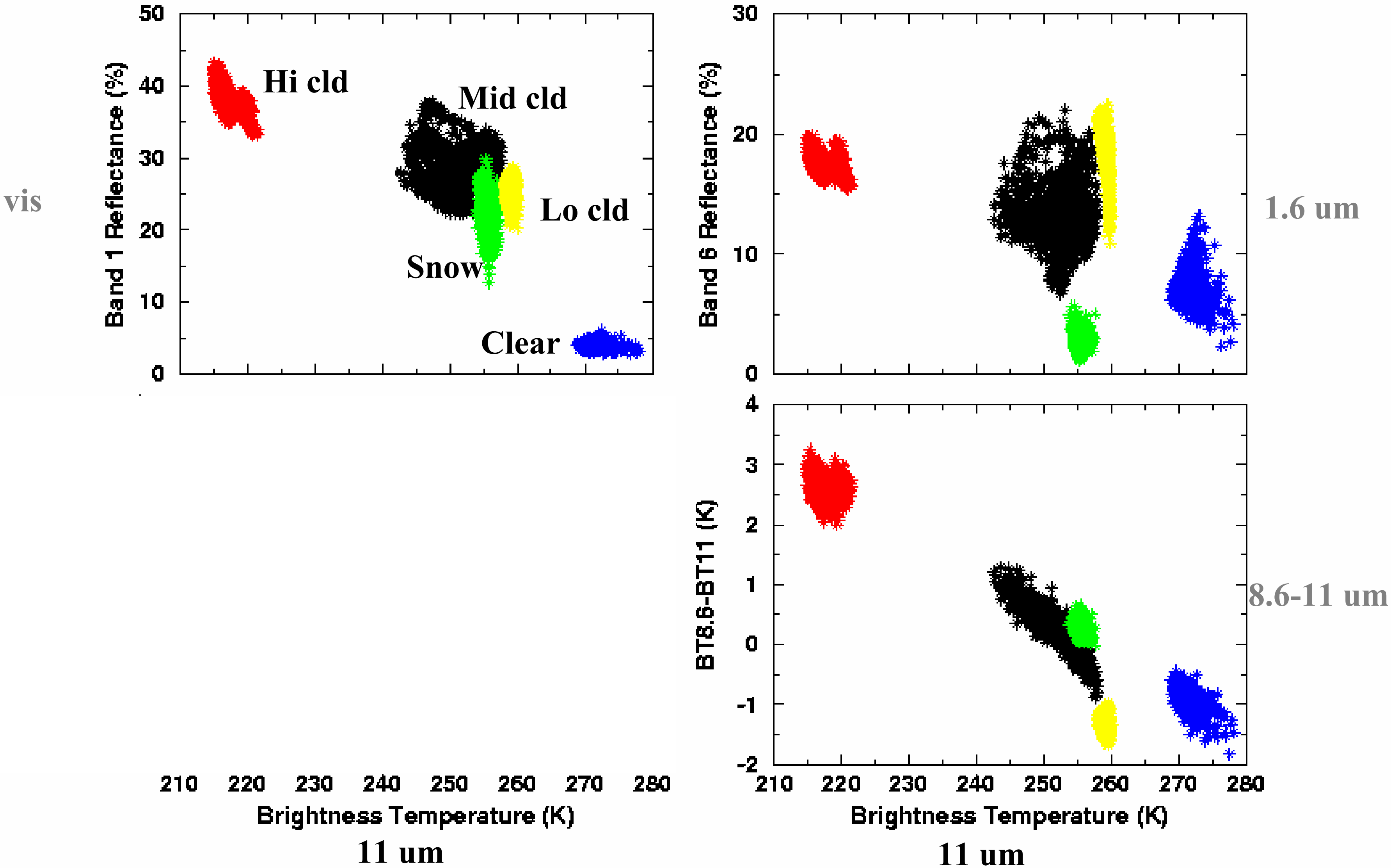
NASA leveraged Missions

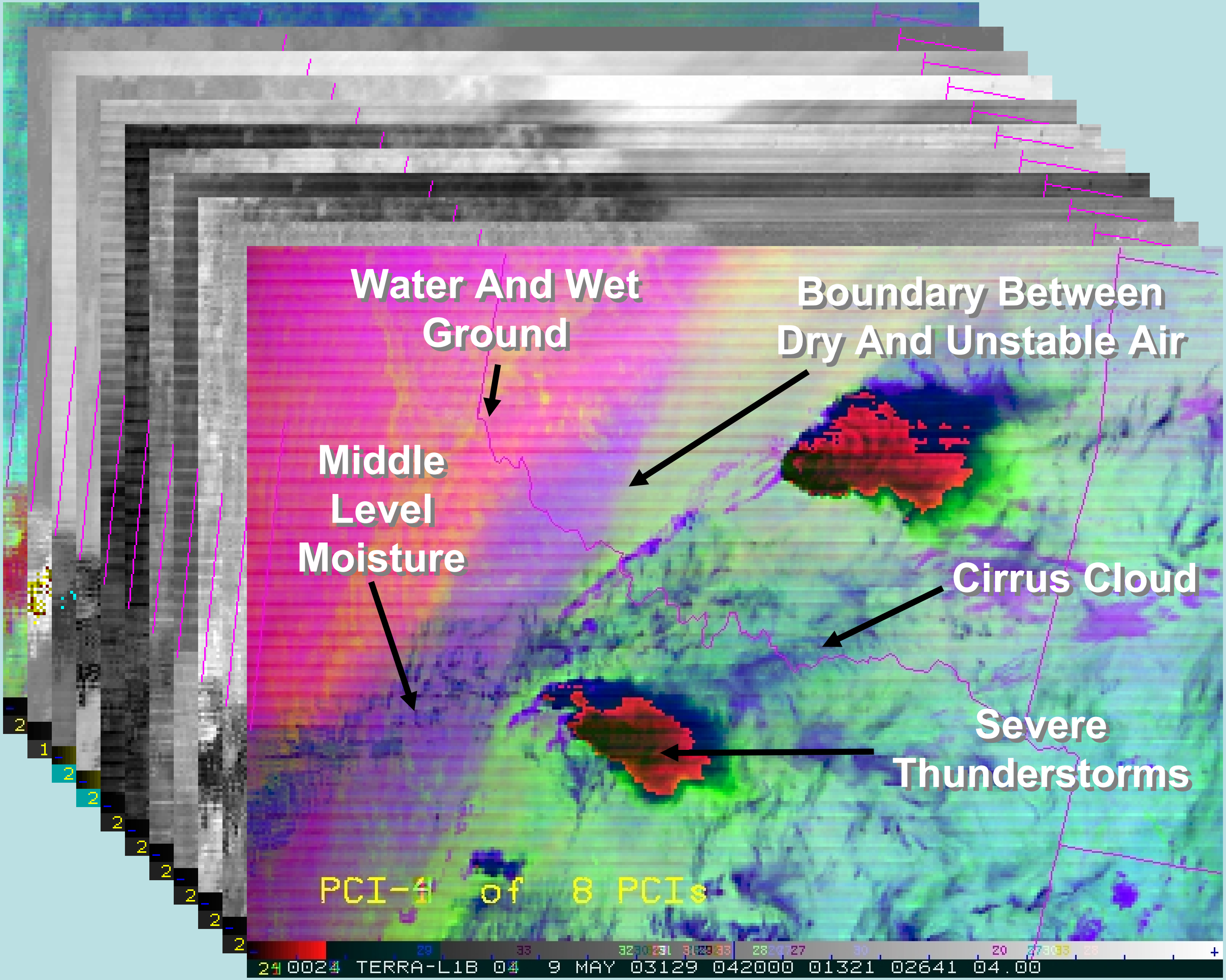
Spectral – ABI and VIIRS like



From MODIS

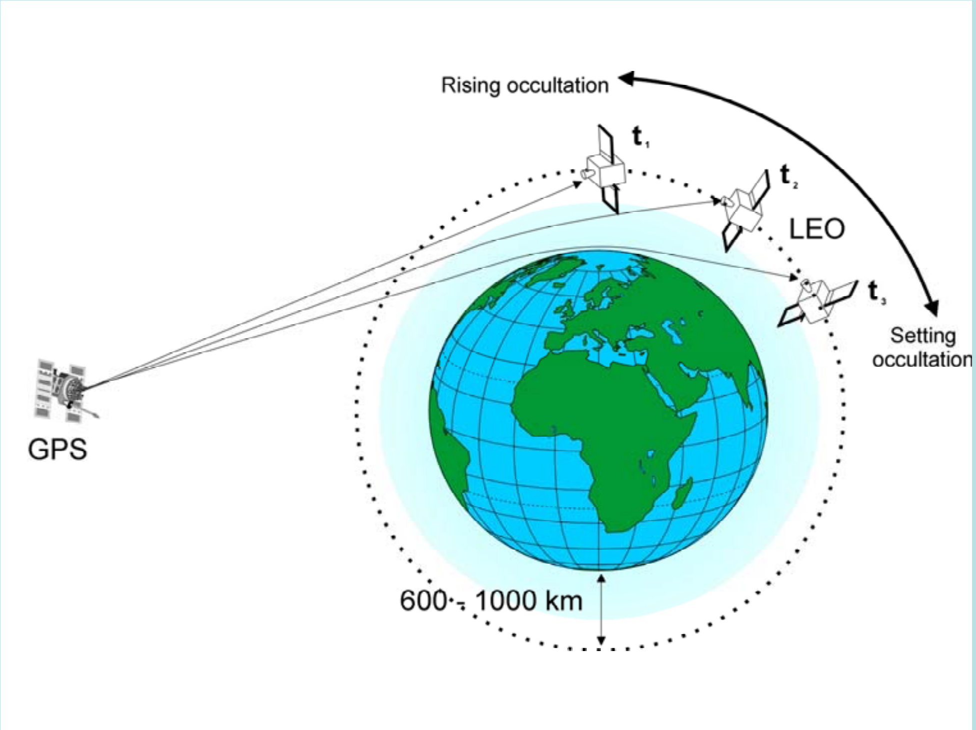
Clouds separate into classes when multispectral radiance information is viewed

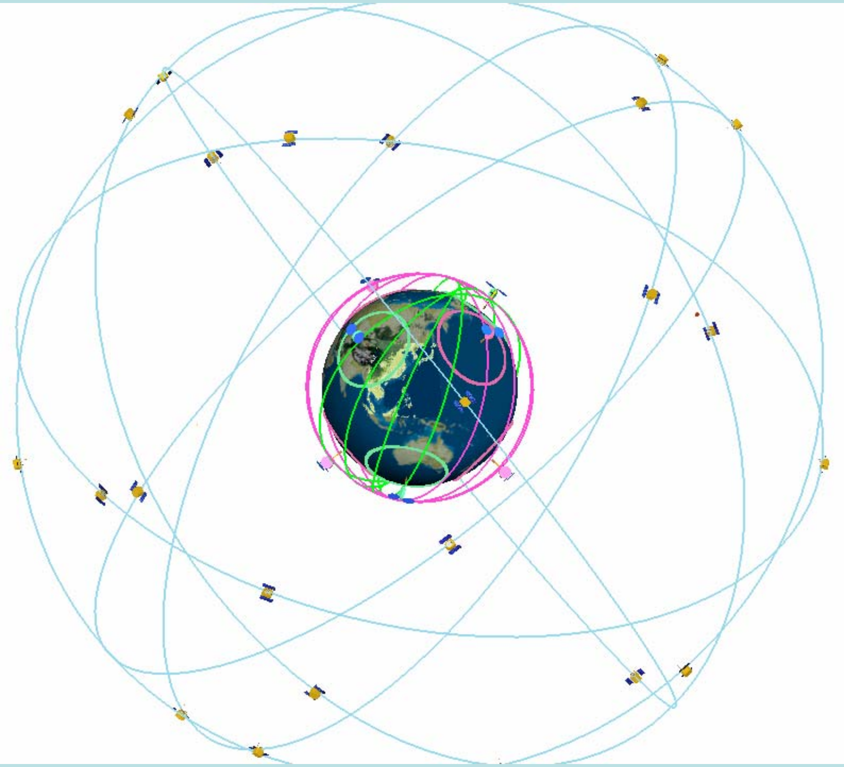




Nighttime MODIS simulation of GOES-R moist/dry front, clouds, wet ground and severe thunder-storms, based on principal component analysis imagery

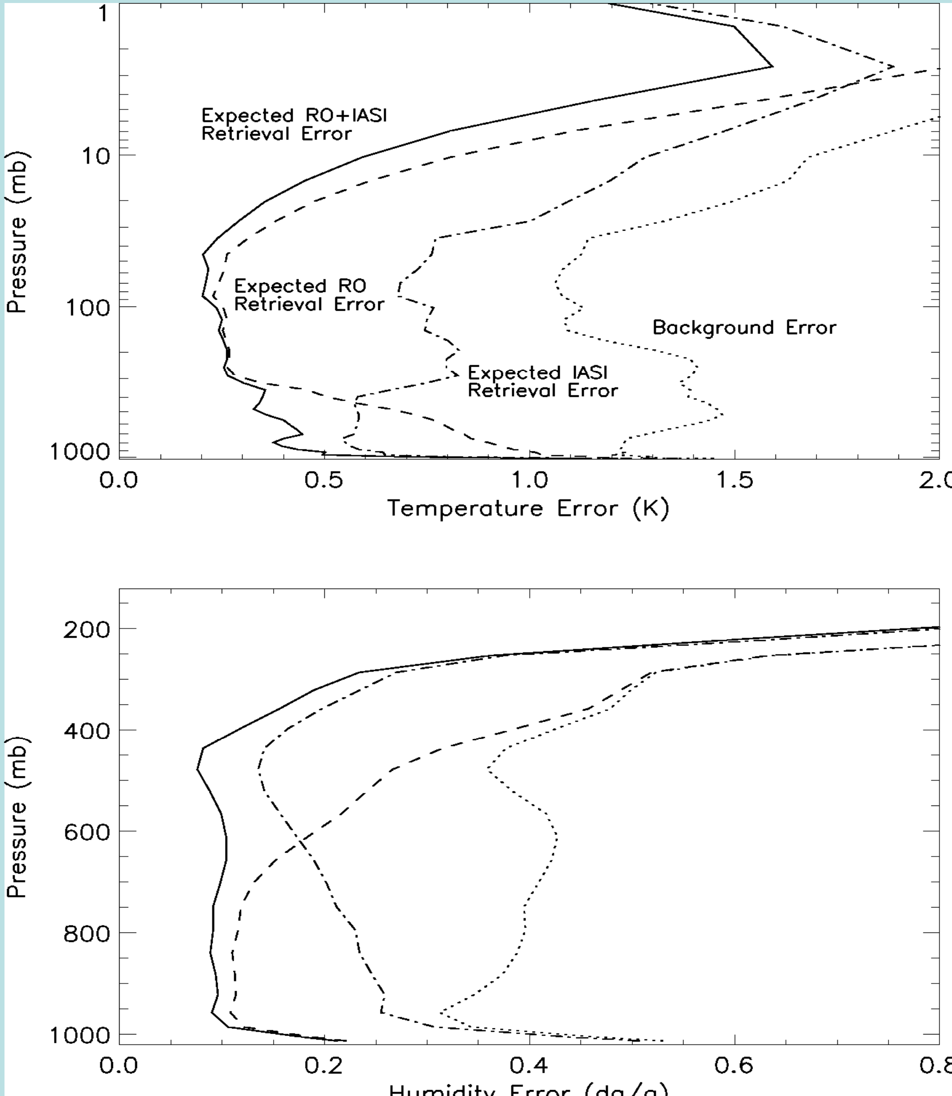
New products based on mathematical analysis of multi-channel images – every 5 minutes or less!





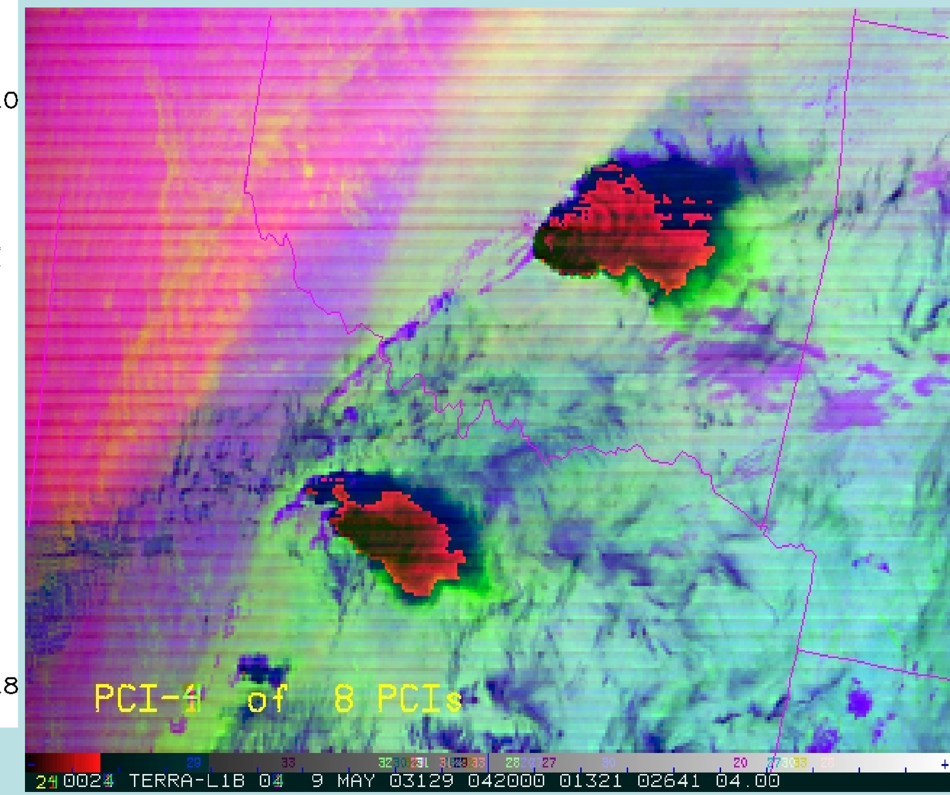
- **Space based (radio occultation)**
  - **Independent atmospheric sounder**
  - **High accuracy and vertical resolution (~300 m) demonstrated (GPS/MET, CHAMP, SAC-C)**
  - **Strong complement to GOES and POES sounders**
  - **COSMIC (2005) to provide 3000 soundings per day**
- **Ground based**
  - **Precipitable water**
  - **Slant-path water**

Inter-System
Polar and/or Geo with GPS RO



Collard and Healy, QJRMS, 129, p.2741, 2003

- **Can you imagine the impact of Radio Occultation when combined with the power of hyperspectral sounding for nowcasting severe weather ?**



High Payoff: High Priority

- **GPS radio occultation**

(with hyperspectral)

- **Hyperspectral infrared from geostationary**

Note: Polar is there with AIRS, CrIS and IASI

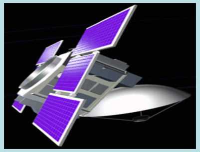
(with GPS)

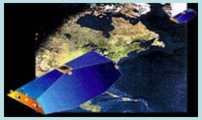
European Missions to future GOS

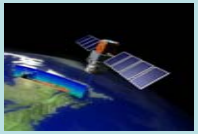
2005 | 2010 | 2020

Current Era | **Near Focus** | **Advanced Concepts**

- MSG





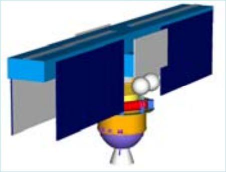


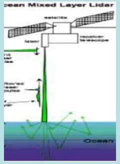
- ERS
- ENVISAT
- EOS
- QUIKSCAT

- Earth Watch & Explorer

- METOP
- MTG

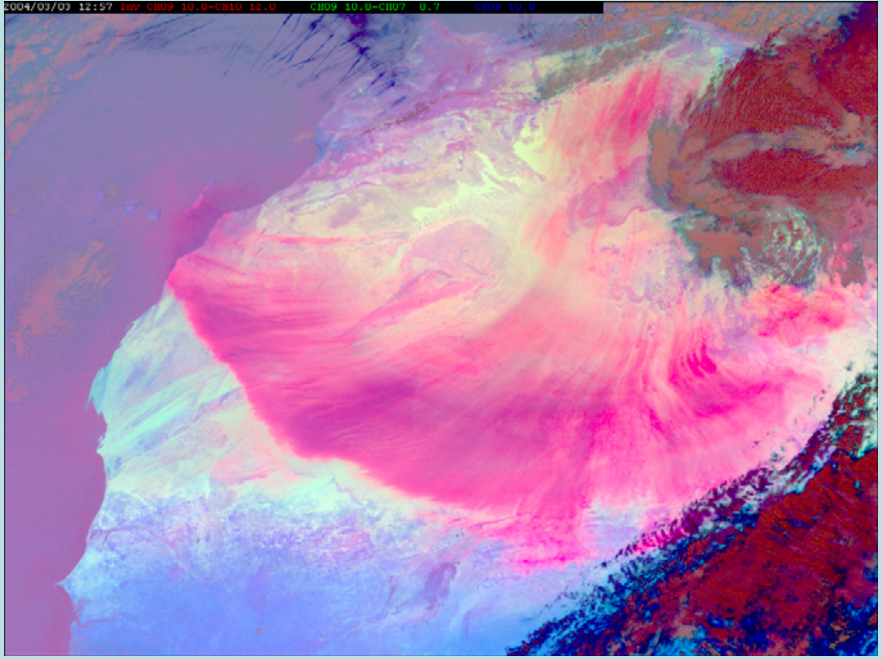
- Hyperspectral
- Wind Lidars
- Geo Soil Moist Sensors
- Cloud Lidar
- Broadband Radiation Imager
- Salinity
- New Initiatives

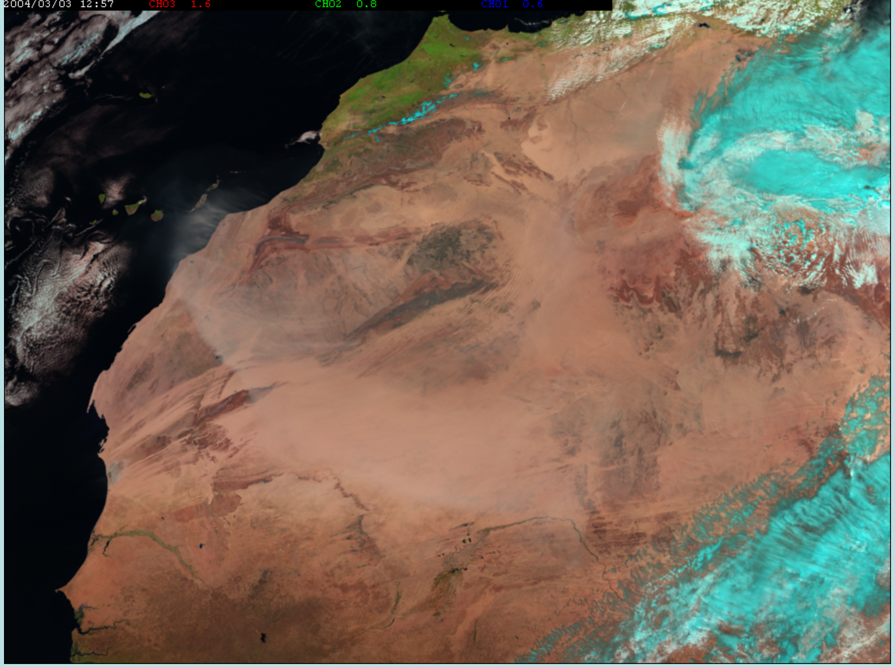


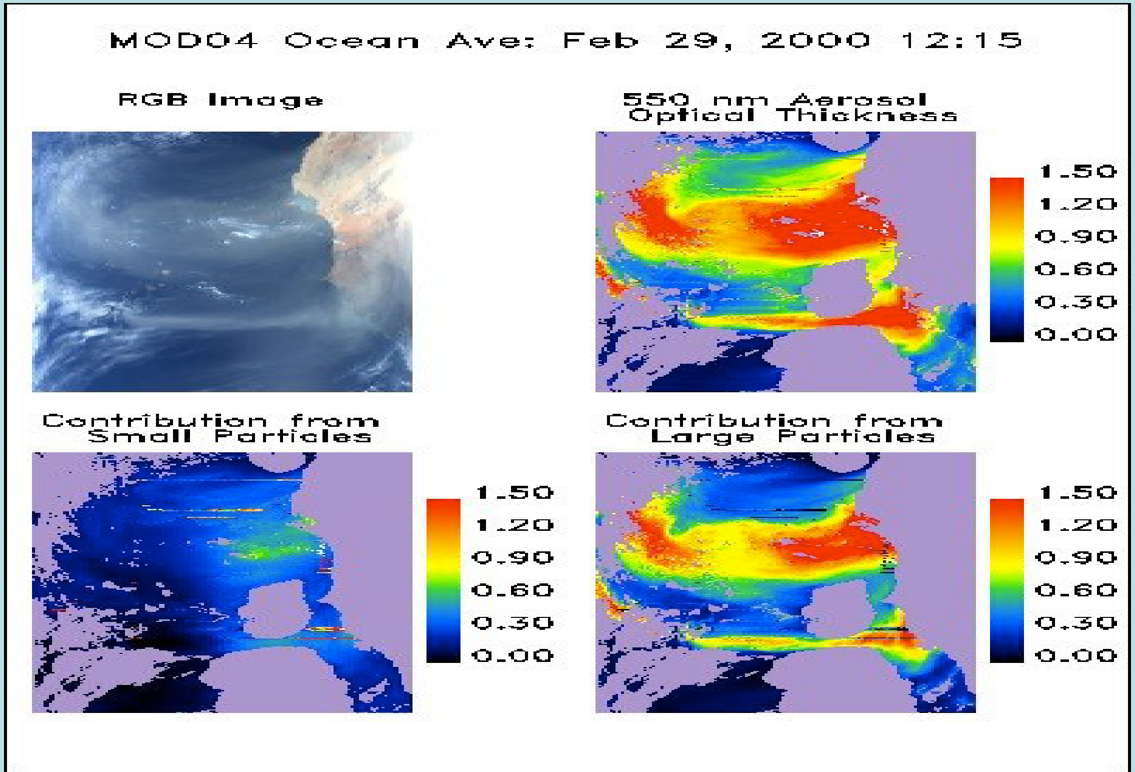


EUMETSAT lead Missions

ESA leveraged Missions

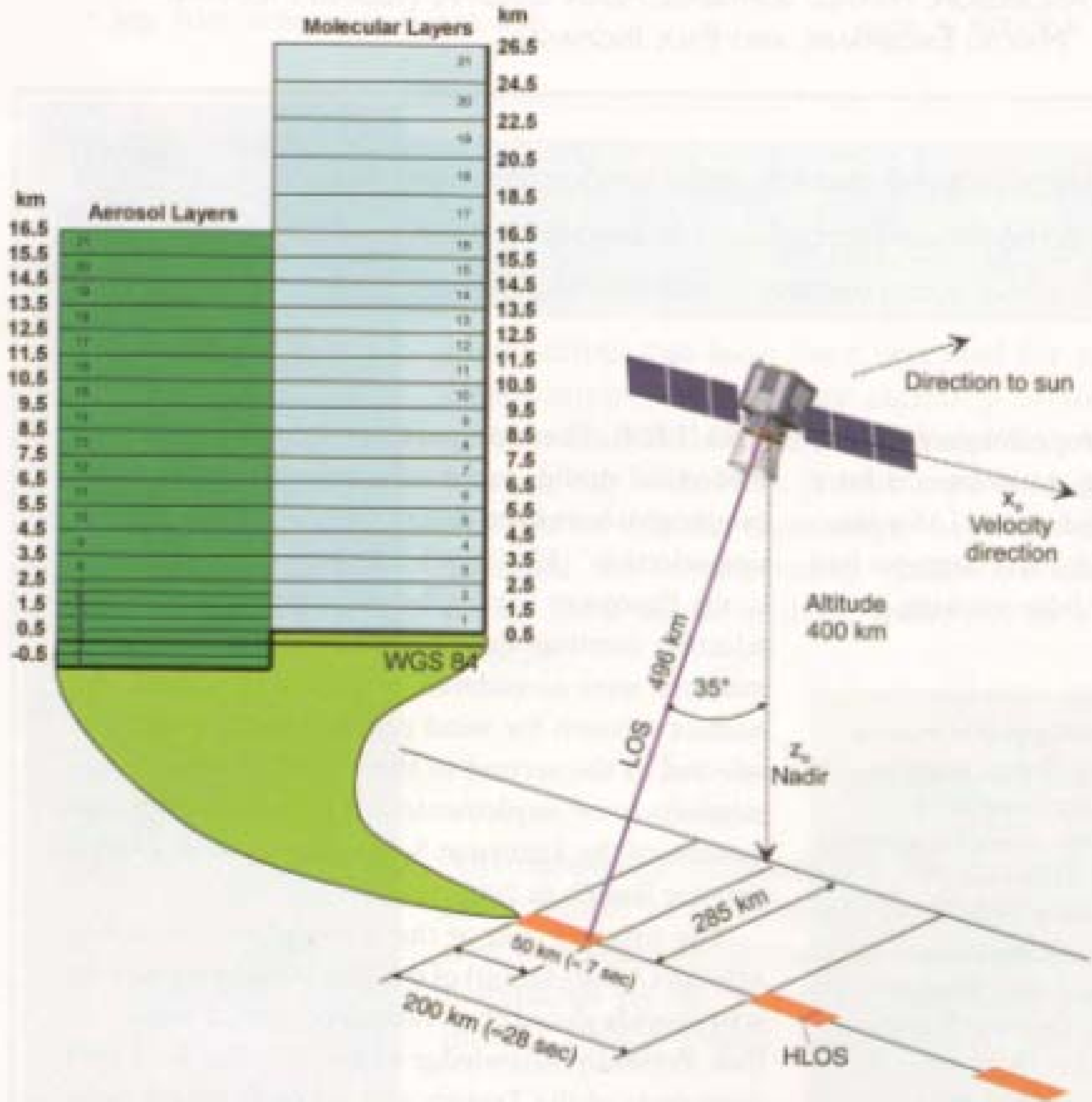

2004/03/03 12:57 Inv CH09 10.8-CH10 12.0 CH09 10.8-CH07 0.7 CH09 10.8


2004/03/03 12:57 CH03 1.6 CH02 0.8 CH01 0.6


MOD04 Ocean Ave: Feb 29, 2000 12:15
RGB Image
550 nm Aerosol Optical Thickness
1.50
1.20
0.90
0.60
0.30
0.00
Contribution from Small Particles
1.50
1.20
0.90
0.60
0.30
0.00
Contribution from Large Particles
1.50
1.20
0.90
0.60
0.30
0.00

Atmospheric Dynamics Mission (ADM)

Active Doppler wind lidar for determination of atmospheric winds (also aerosols). Flies in a dawn/dusk orbit

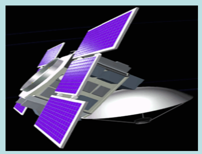


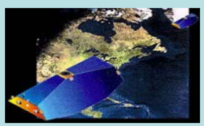
Japanese Missions to future GOS

2005 | 2010 | 2020

Current Era | **Near Focus** | **Advanced Concepts**

- GMS

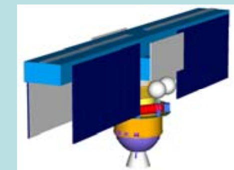




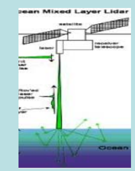
- **Terra (ASTER)**
- **TRMM**
- **Aqua (AMSR)**
- **Midori (ADEOS-II)**

GCOM
GoSAT
ALOS

- MTSAT



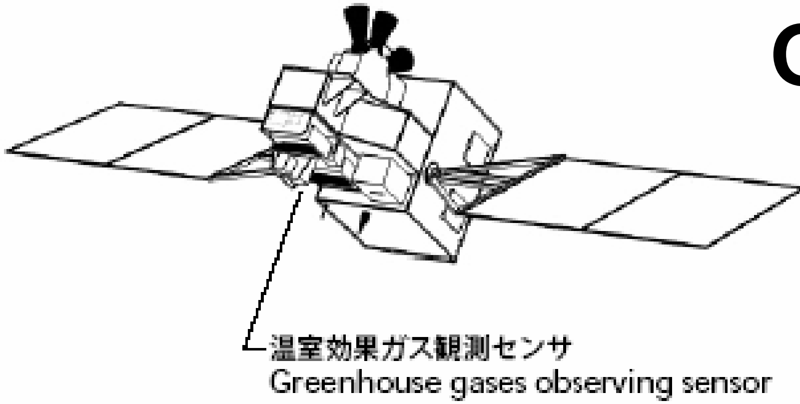
- Hyperspectral
- Adv. GLI
- Precipitation Mission
- New Initiatives



JMA lead Missions

JAXA leveraged Missions

GoSAT



質量：約1650kg(打上げ時)
Mass : Approx. 1650kg

電力：3.3kw(寿命末期)
Power : 3.3kw(EOL)

設計寿命：5年
Designed Life span: 5years

軌道：高度666km
Orbit : Altitude 666km

太陽同期準回帰軌道
Sun-Synchronous Sub-Recurrent orbit

傾斜角　約98度
Inclination Approx.98deg

宇宙航空研究開発機構
広報部
〒100-8260　東京都千代田区丸の内1-6-

Launch 2007

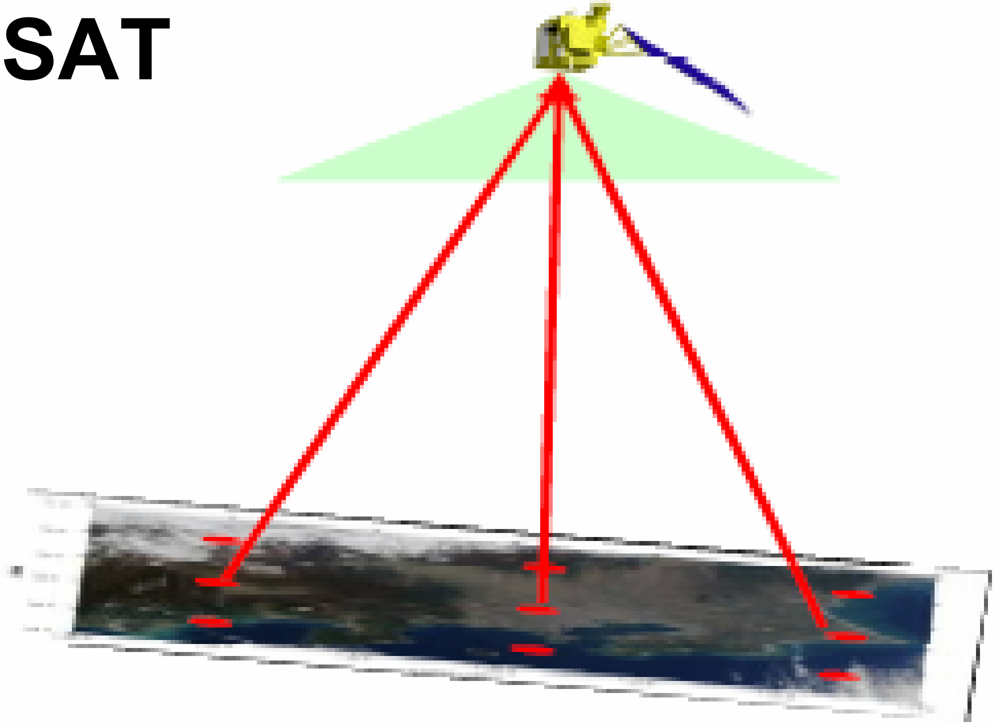
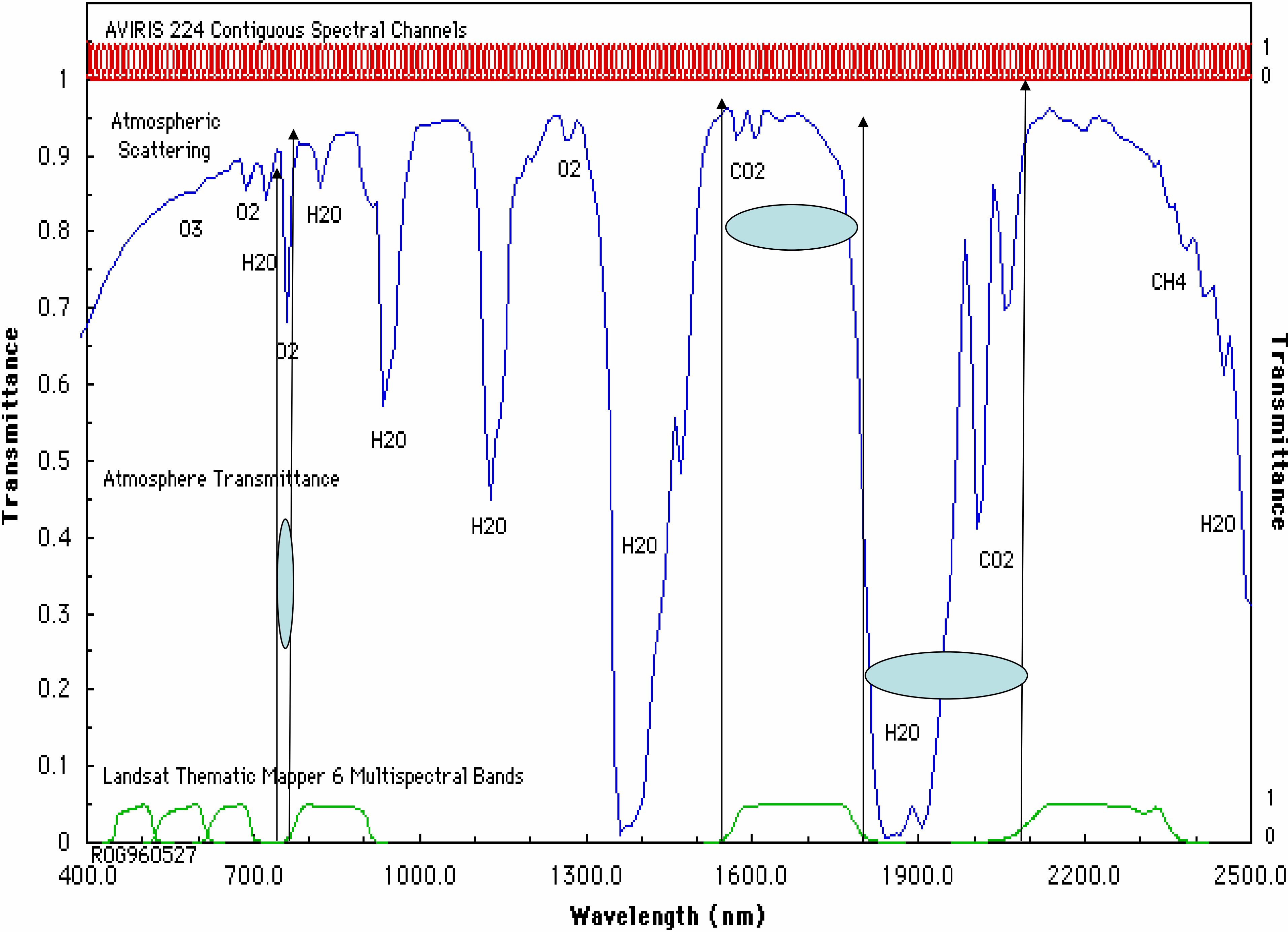
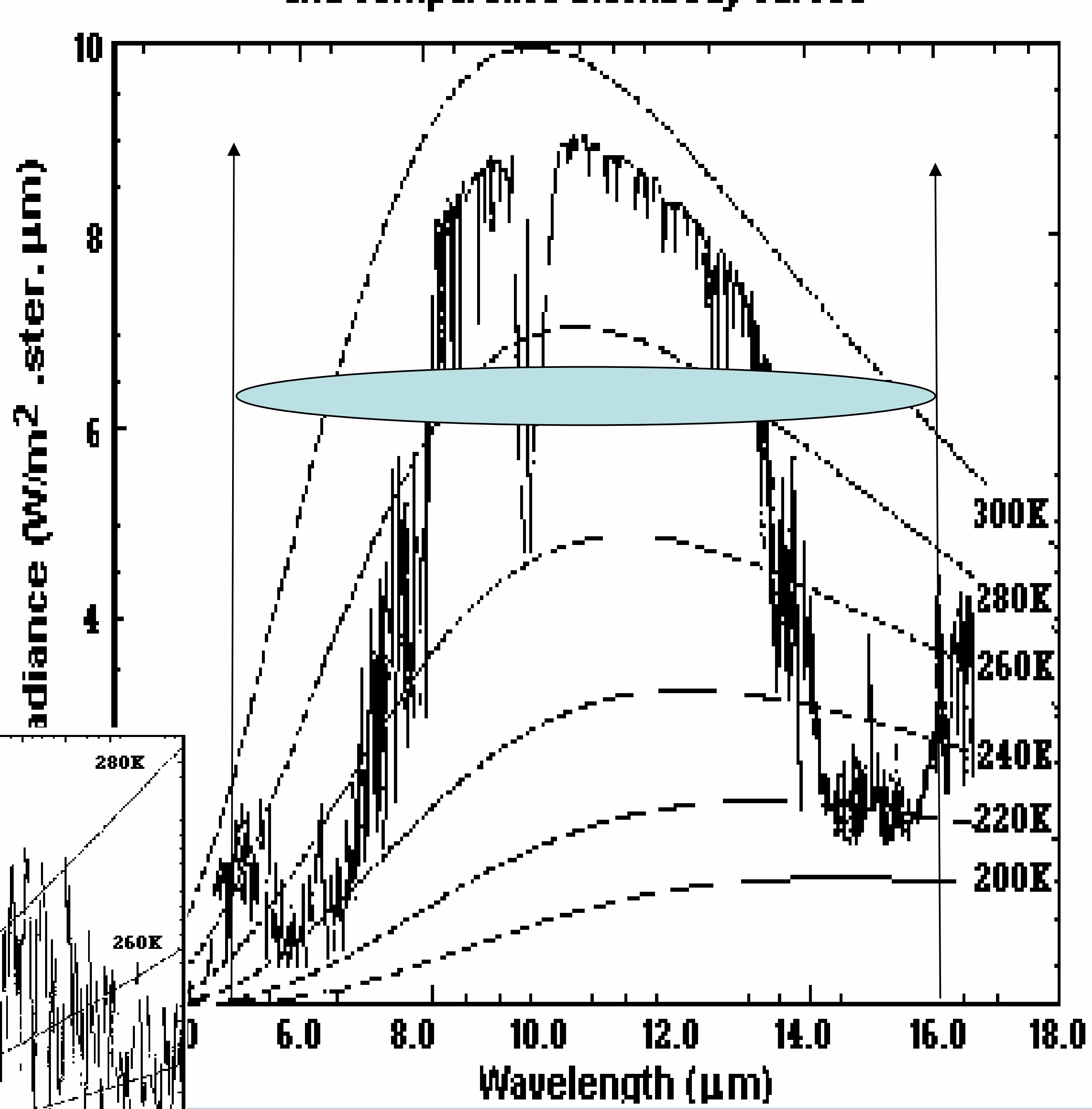


Table 1. The specification of the Greenhouse gases Sensor.

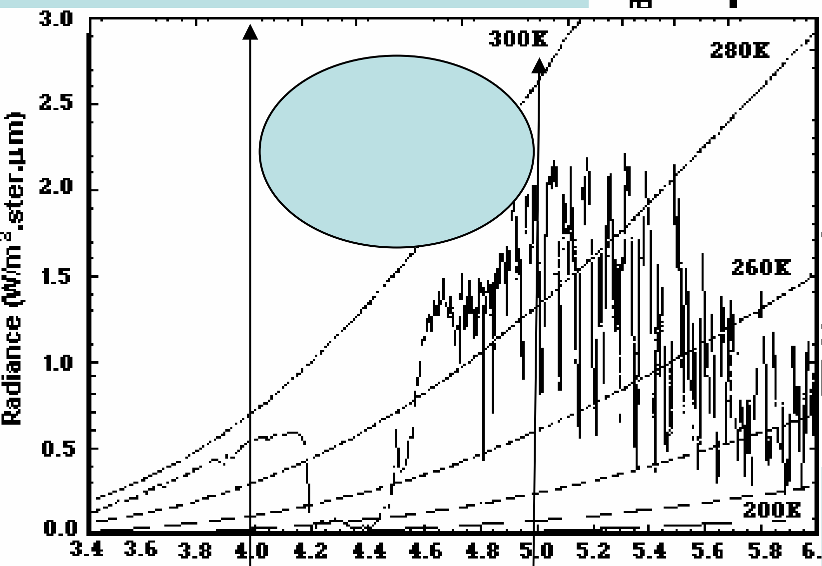
Ground Pointing Mechanism and Fore optics	Configuration	2-axes scanner (fully redundant)				
	Scanning	Cross Track (±35 deg□ Along Track (±20deg)				
	Field of view	IFOV 8 km□ 88 km (Interval) 790 km (scan width) (latitude of 30 deg)				
Fourier Transform Spectrometer	Speed	0.7□1 (Interferogram)/sec				
	Spectral band	1	2	3	4	5
	Coverage (cm^{-1})	12900-13200	5200-6400	4800-5200	2000-2500	660-2000
	resolution (cm^{-1})	0.5	0.2	0.2	0.1	0.1
	Detector	Si	InGaAs	InGaAs	InSb	PC-MCT
	Calibration	Solar Irradiance, Deep Space, Moon			Blackbody, Deep space	



AVIRIS 224 Contiguous Spectral Channels
Atmospheric Scattering
O3
O2
H2O
O2
H2O
H2O
H2O
O2
H2O
CO2
H2O
CO2
CH4
H2O
Atmosphere Transmittance
Landsat Thematic Mapper 6 Multispectral Bands
Transmittance
Wavelength (nm)
ROG960527
400.0
700.0
1000.0
1300.0
1600.0
1900.0
2200.0
2500.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



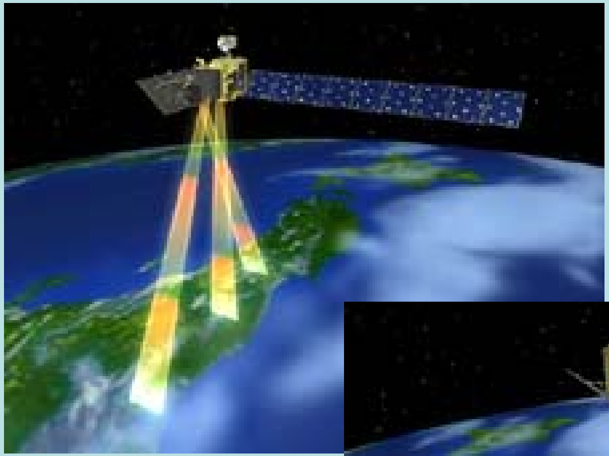
10
8
6
4
Radiance (W/m2 .ster. μm)
300K
280K
260K
240K
220K
200K
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Wavelength (μm)

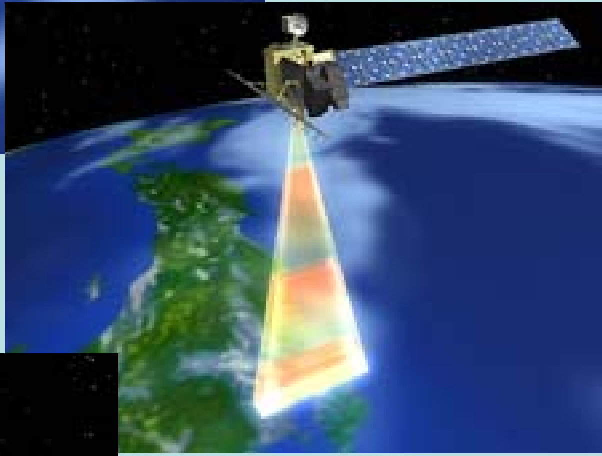


3.0
2.5
2.0
1.5
1.0
0.5
0.0
Radiance (W/m2.ster.μm)
300K
280K
260K
200K
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8

Land Observing Satellite (ALOS) will be used for precise land coverage observation. ALOS will be used not only for cartography, but also for environmental protection and disaster monitoring.

- **PRISM** **Panchromatic Remote-sensing Instrument for Stereo Mapping**
- **AVNIR-2** **Advanced Visible and Near Infrared Radiometer type-2**
- **PALSAR** Phased Array type L-band Synthetic Aperture Radar





Are we addressing the scope of the GOS in the context of GEOSS?

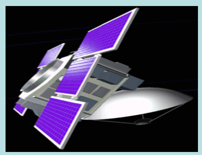
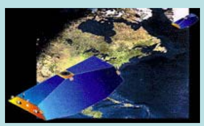
Russian Federation Missions to future GOS

2005 | 2010 | 2020

Current Era | **Near Focus** | **Advanced Concepts**

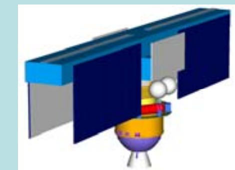
METEOR
OKEON

- RESURS

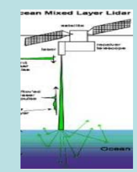





RESURS

ELECTRO-L



- Hyperspectral IR
- Synthetic Aperture Radar
- New Initiatives

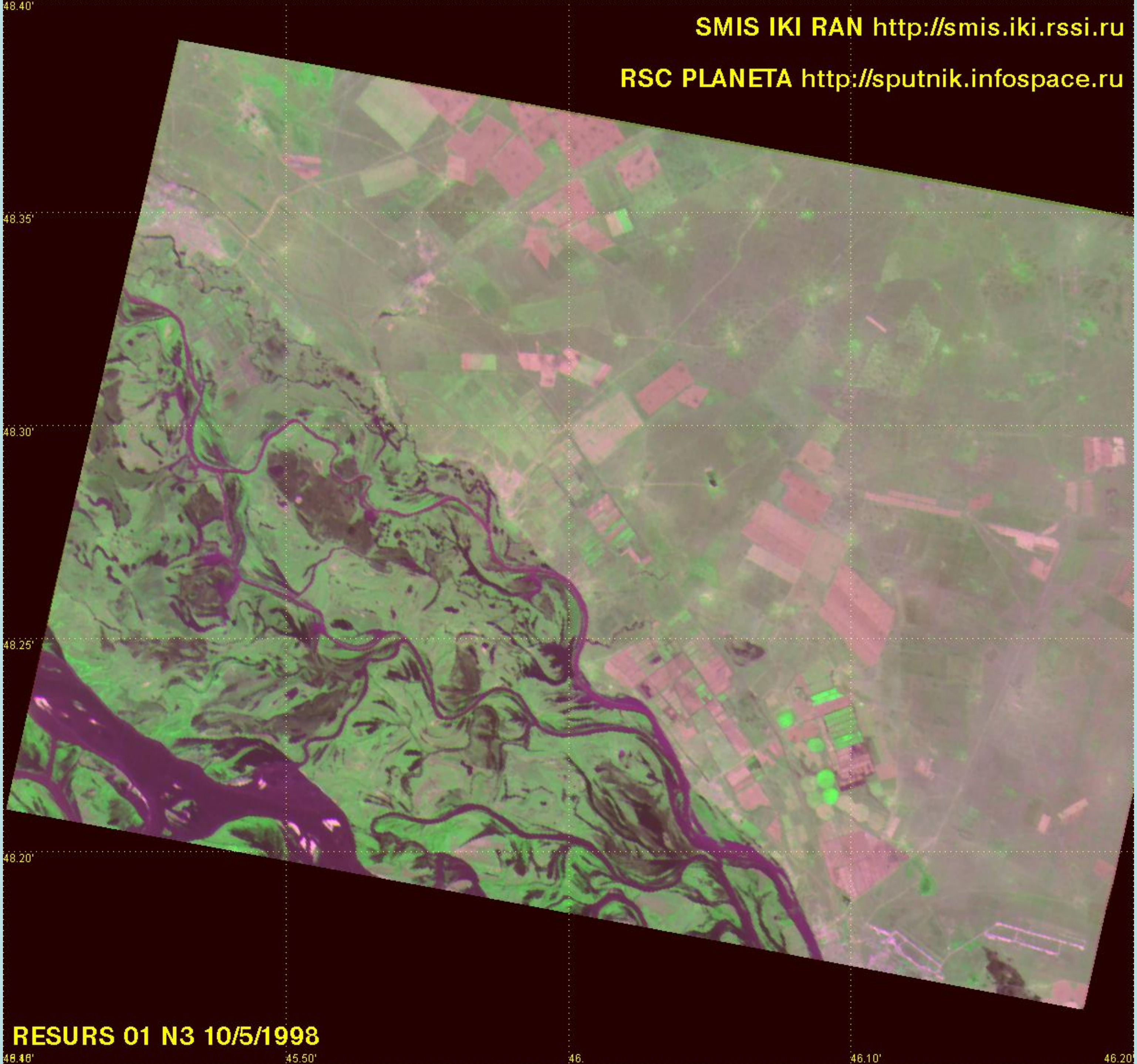


Operational Missions

Research Missions

Okean-01 Regular Onboard Equipment

Instrument	Main parameters
Side-looking radar RLS-BO	Resolution - 1.5-2.0 km Swath - 450 km Wavelength - 3.2 cm
UHF-radiometer (RM-08)	Resolution - 15 km Swath - 550 km Wavelength - 0.8 cm
Multichannel average-resolution scanning device (MSU-S)	Resolution - 370 km Swath - 1100 km Spectral bands - 0.6-0.7 um; 0.8-1.1 um
Multichannel low-resolution scanning device (MSU-M)	Resolution - 2 km Swath - 1900 km 2 channels Spectral bands - 0.5-0.6 um; 0.6-0.7 um; 0.7-0.8 um; 0.8-1.1 um
Kondor - system for collection and transmission of data from sea and ice stations	Transmission of data from stations, stations geopositioning
Radio channels 465.0 MHz 137.0 MHz	Downlinking to ground stations (main centers) Downlinking to network of autonomous stations



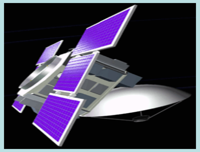
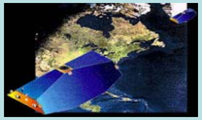
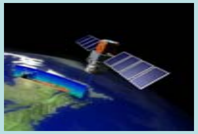
SMIS IKI RAN http://smis.iki.rssi.ru
RSC PLANETA http://sputnik.infospace.ru
RESURS 01 N3 10/5/1998
48.40'
48.35'
48.30'
48.25'
48.20'
45.50'
46.
46.10'
46.20'

India Missions to future GOS

2005	2010	2020

Current Era | **Near Focus** | **Advanced Concepts**

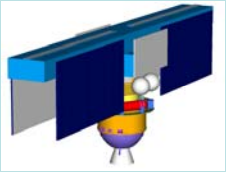
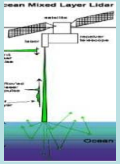
- INSAT
  - Kalpana
- IRS-P4
  - MSMR
  - OCM
- MegaTrop

Science, Technology
Applications focus
On Earth Resources

- **INSAT-3D**

IRS follow-on


IMD led Missions

ISRO led Missions

IRS-P4: OCM and MSMR

SATELLITE

- Altitude: 720 km
- Inclination: 98 deg
- Repetitive Cycle: 2 days

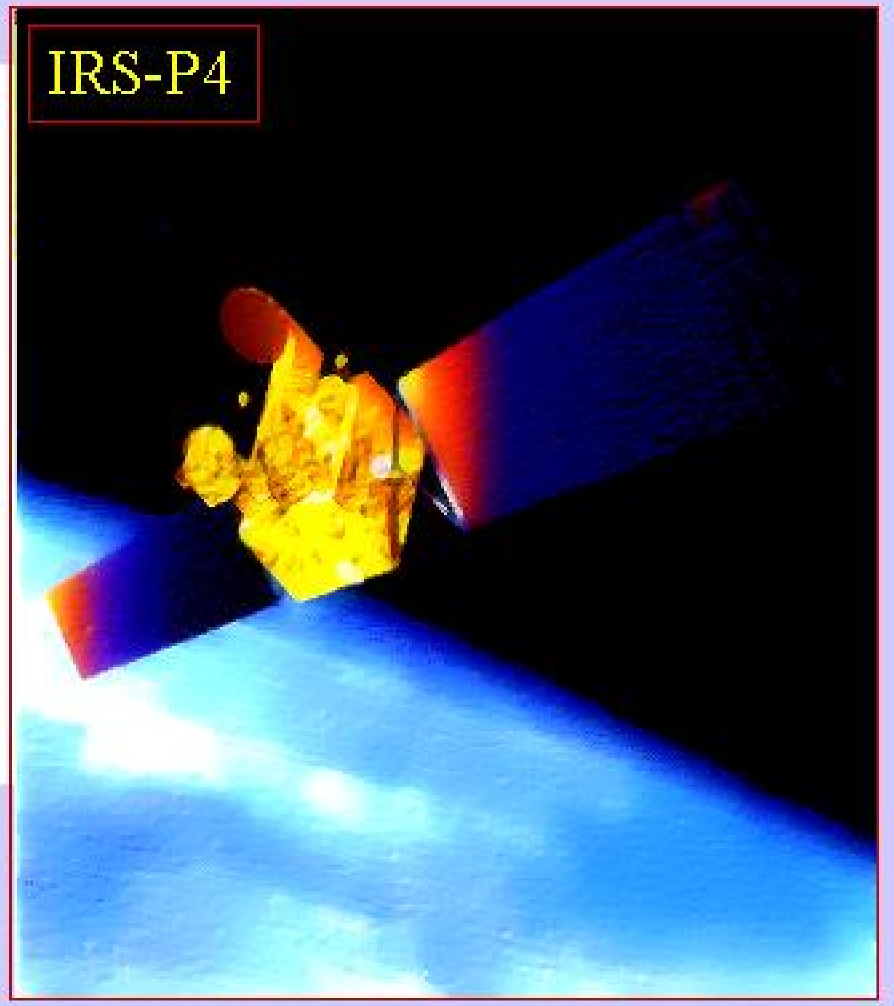
PAYLOADS

MSMR (Multi-frequency Scanning Microwave Radiometer)

- Frequency: 6.6, 10.65, 18 & 21 GHz
- Swath: 1360 km

OCM (Ocean Colour Monitor)

- Swath: 1420 km
- Field Of View: 360 m
- Spectral Bands: 8 (400-885 nm)



IRS-P4 Data Uses

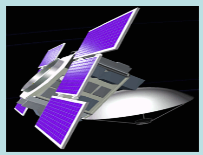
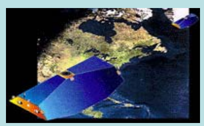
- Preharvest crop acreage and production estimation of major crops.
- Drought monitoring and assessment based on vegetation condition.
- Flood risk zone mapping and flood damage assessment.
- Hydro-geomorphological maps for locating underground water resources for drilling well.
- Irrigation command area status monitoring
- Snow-melt run-off estimates for planning water use in down stream projects
- Land use and land cover mapping
- Urban planning
- Forest survey
- Wetland mapping
- Environmental impact analysis
- Mineral Prospecting
- Coastal studies

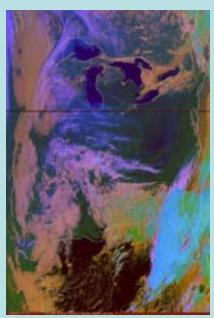
Chinese Missions to future GOS

2005 | 2010 | 2020

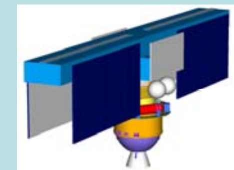
Current Era | **Near Focus** | **Advanced Concepts**

- FY1(leo)
- FY2 (geo)

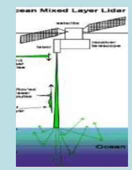






- FY3 (leo)
  (VIRR,MODI IRAS,MWAS MWRI,TOM/OP)
- FY4 (geo)
  (Imager,Sounder)



- Hyperspectral
- Conical MW
- New Initiatives

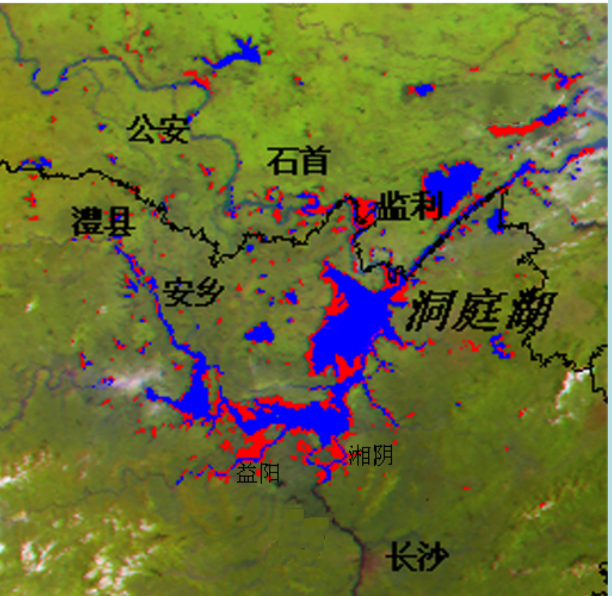



operational Missions

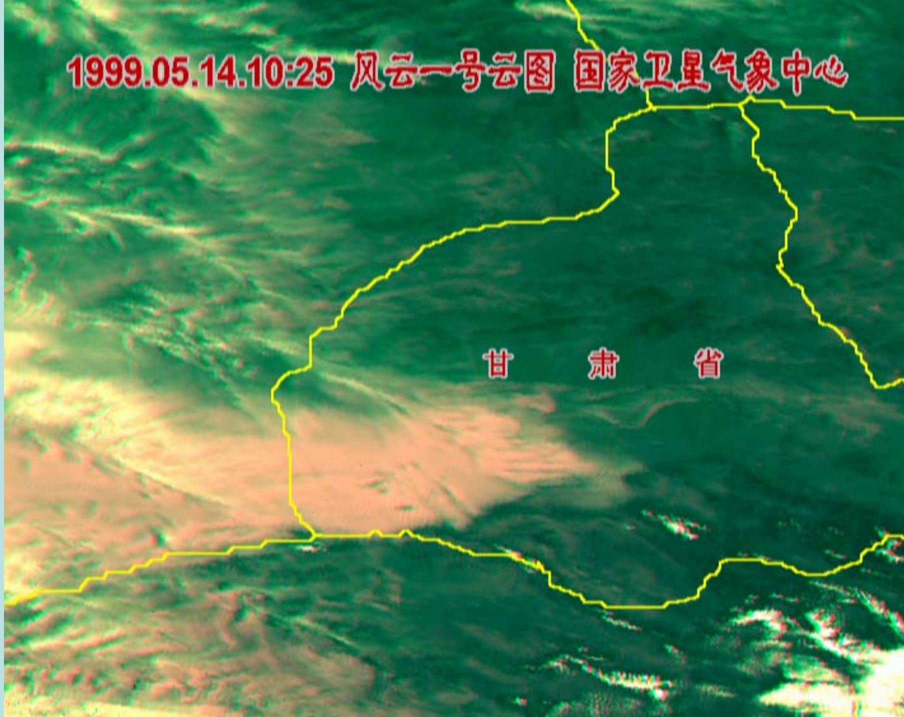
research Missions

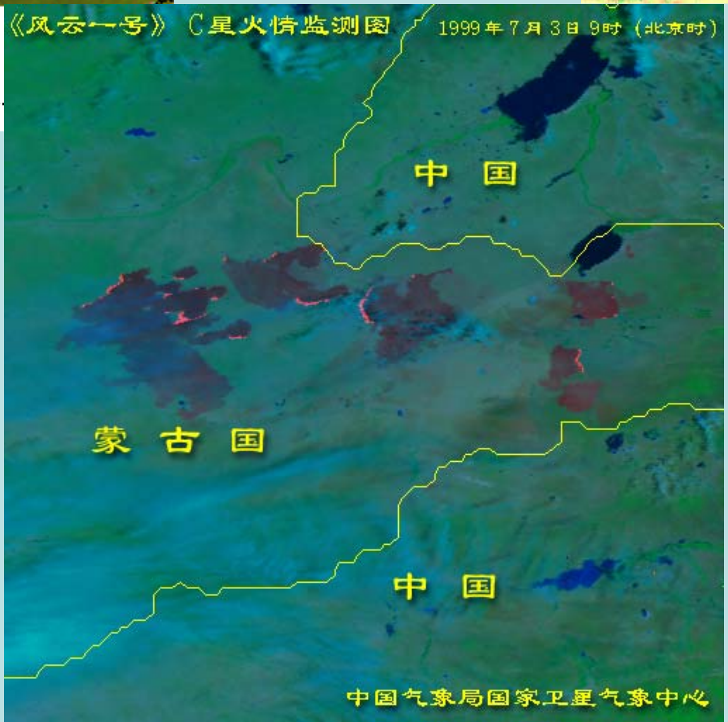
洞庭湖地区气象卫星水情监测图

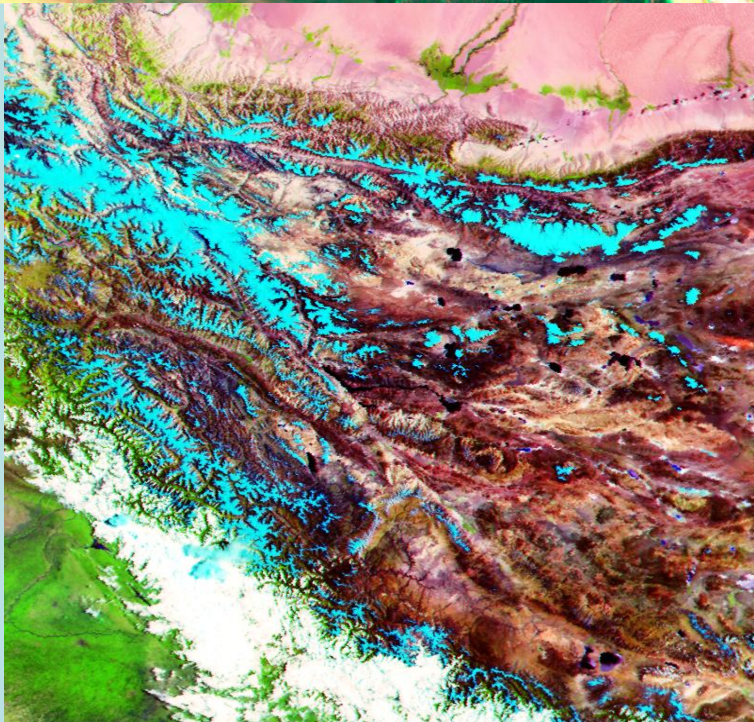
（1999年7月25日9时）



国家

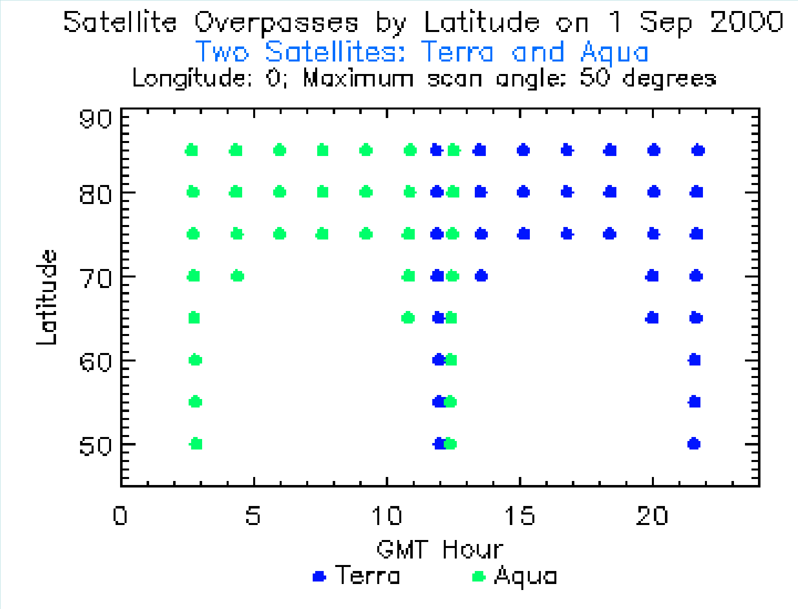


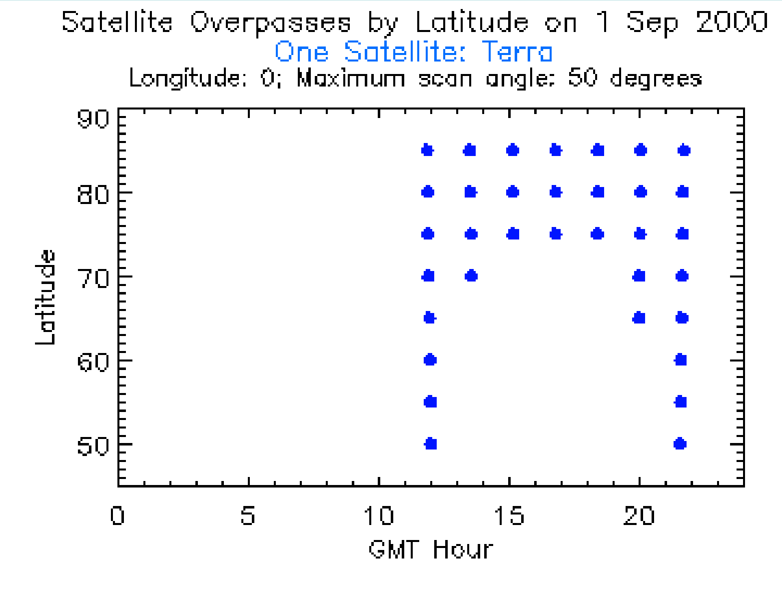


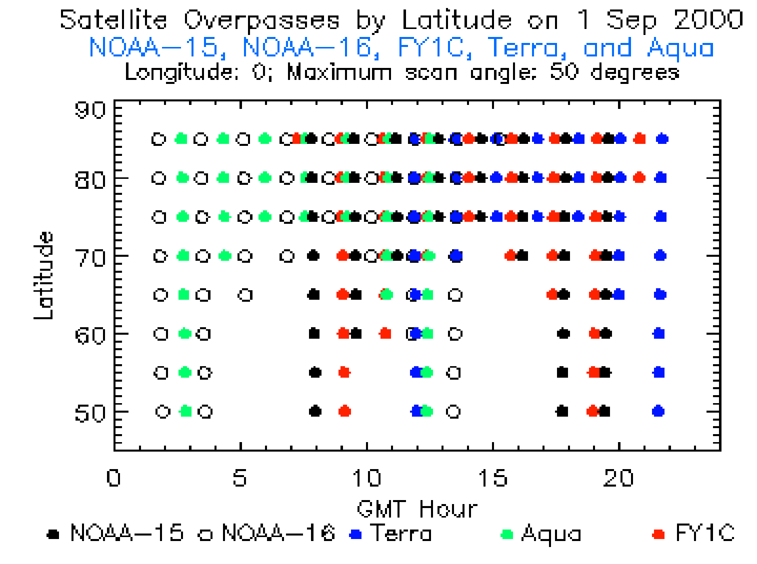


Orbital Issues

How often can wind vectors be obtained from a polar-orbiting satellites? The figure below shows the time of successive overpasses at a given latitude-longitude point on a single day with only the Terra satellite. The figure at the upper right shows the frequency of "looks" by two satellites: Terra and (the future) Aqua. The figure at the lower right shows the temporal sampling with five satellites.



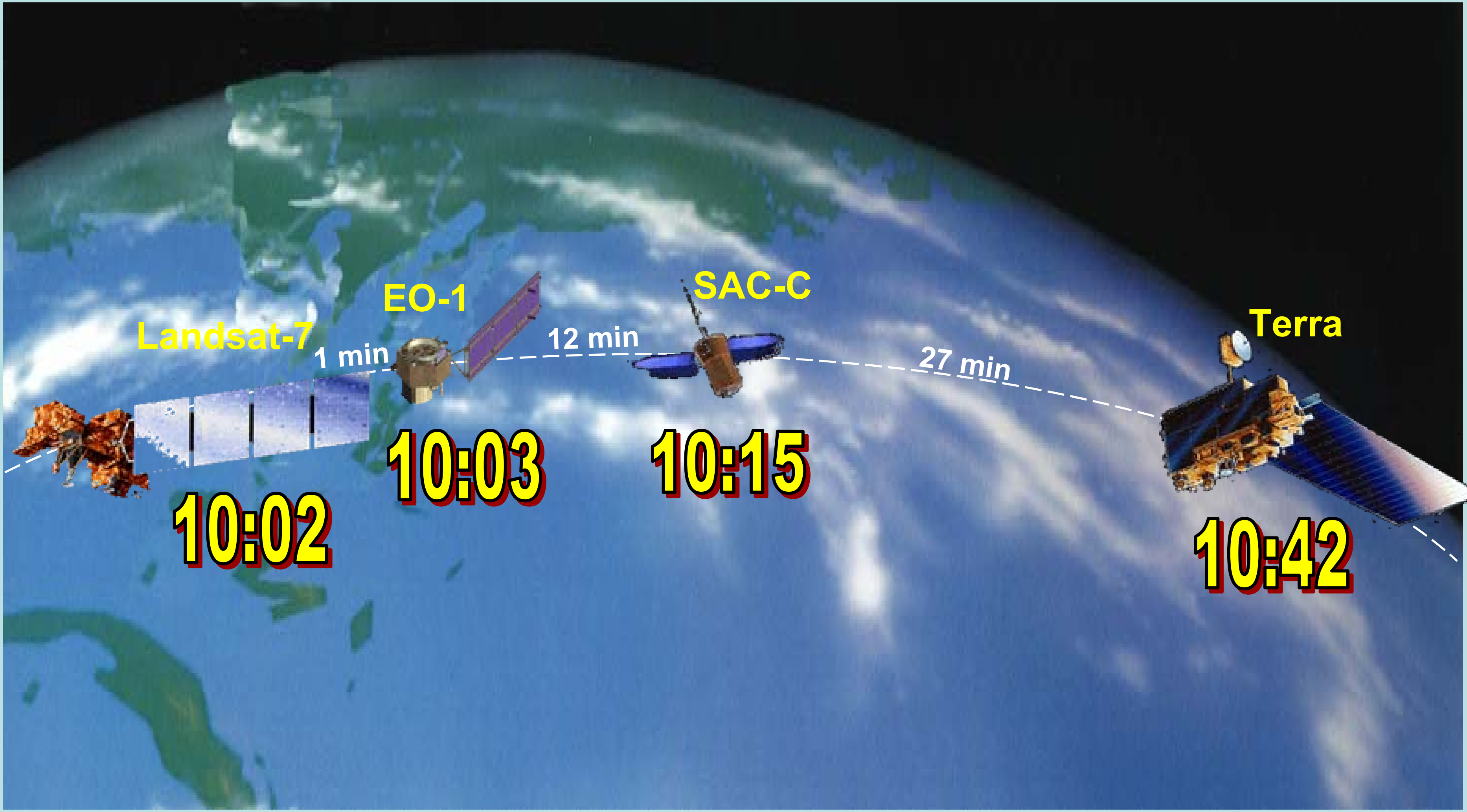




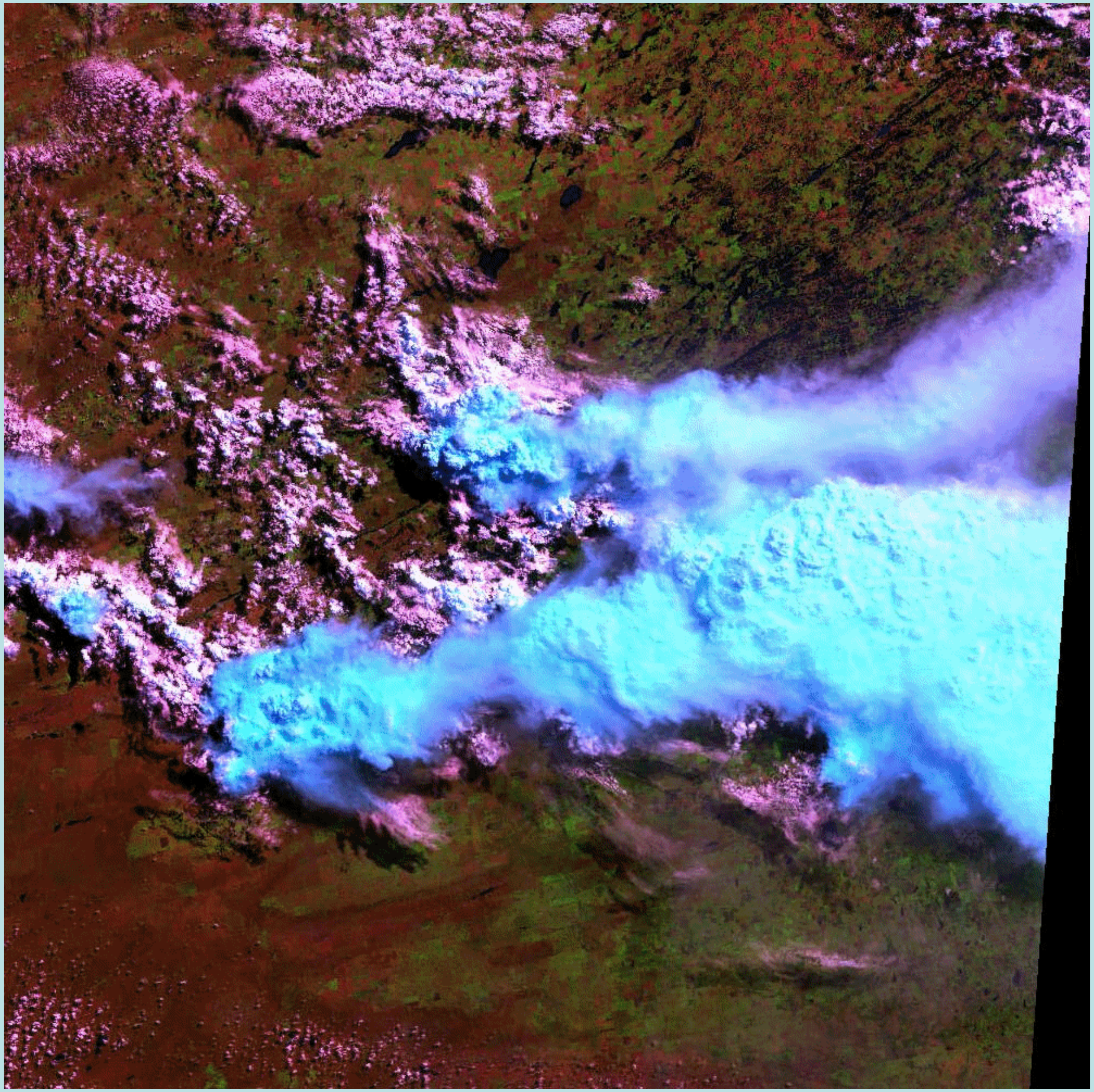
CONSTELLATIONS, FORMATIONS

- Precision orbits are allowing for polar formation flying
- Incredible polar orbiting potential
- Powerful and robust geostationary system

The Earth Observing System AM Constellation

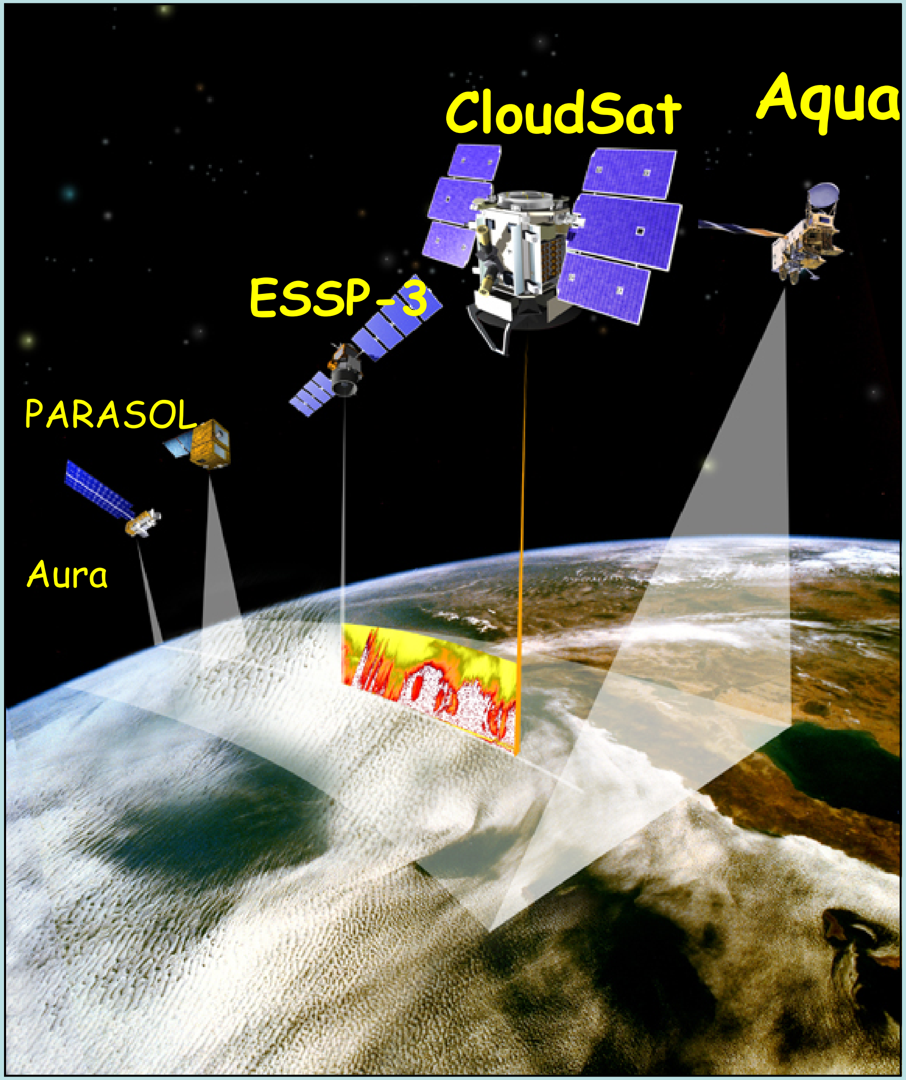


- “True color” movie made from multispectral images from the A.M. Constellation
- While this movie focuses on storm development, one can imagine how high spatial and spectral resolution imagery from Terra and EO-1, separated in time by 39 minutes could be used to investigate the development and evolution of ocean and coastal zone phenomena



Formation Flight

- Formation flight with EOS-Aqua.
- Is this the future?
    - Data applicable to all components of the GOS
    - In the context of GEOSS (Global Earth Observing System of Systems)



CloudSat Primary (left) and Secondary (right) Science Objectives

- Quantitatively evaluate the representation of clouds and cloud processes in global atmospheric circulation models, leading to improvements in both weather forecasting and climate prediction;
- Quantitatively evaluate the relationship between the vertical profiles of cloud liquid water and ice content and the radiative heating by clouds.

- **Improve and validate cloud information derived from other satellite systems, in particular those of EOS.**
- Improve our understanding of the indirect effect of aerosols on clouds by investigating (in cooperation with other satellite platforms) the effect of aerosols on cloud formation and cloud processes.

High Payoff: High Priority

- **Formation flying** with the operational constellation of small satellites with special sensors such as lidar for **aerosols and winds, cloud radar;** and lightning mappers (particularly at geostationary orbit)

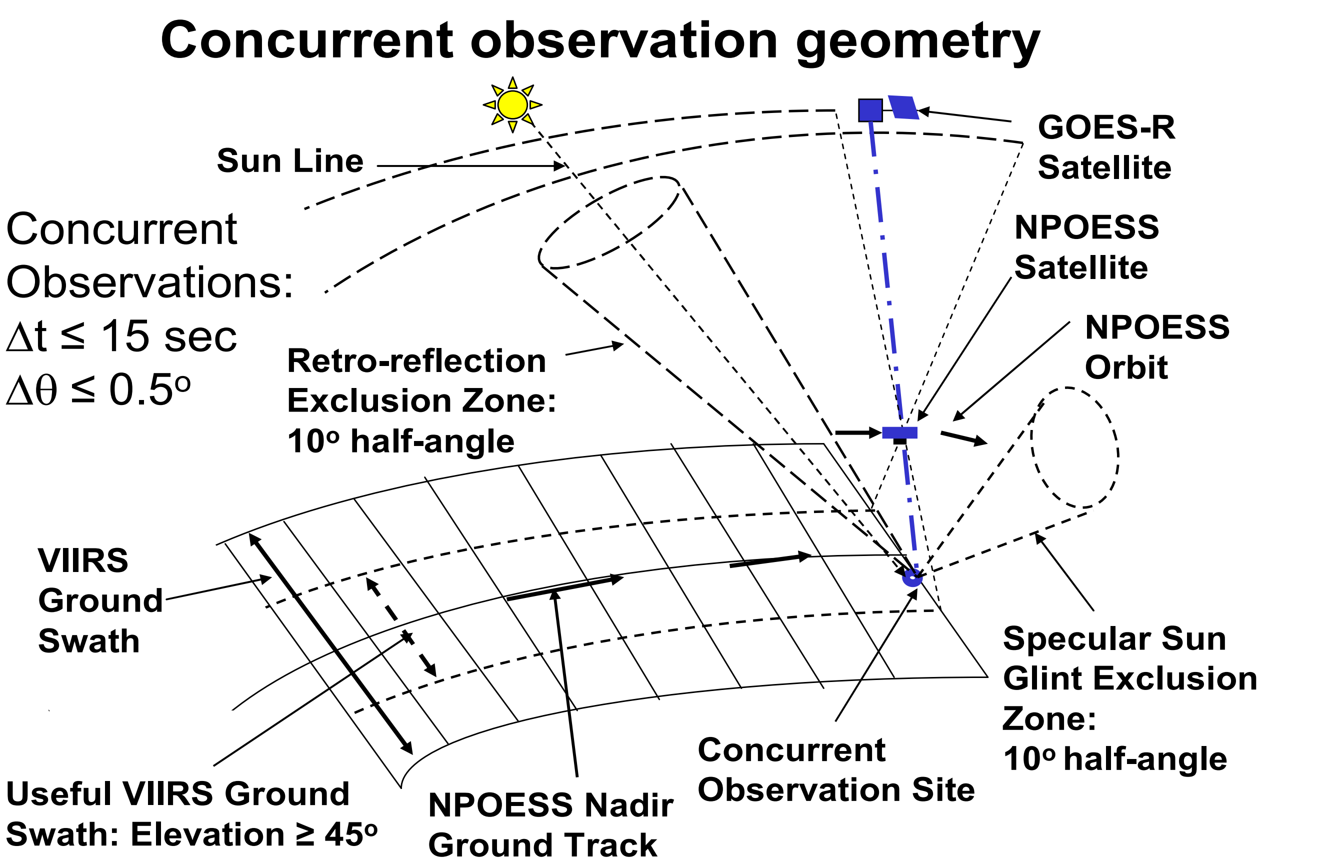
A few examples of synergy

- Climate
- NWP
- Nowcasting, severe weather
- Catastrophic response
- Hurricanes
- Ocean color

Intercalibration of Leo and Geo Sensors offers new opportunities

With hyperspectral measurements
With matched spectral bands

Leo VIS-NIR Reference for Calibration of Geo VIS-NIR Sensors



With matching spectral bands, VIIRS ↔ ABI calibration transfer should be possible with < 1% uncertainty

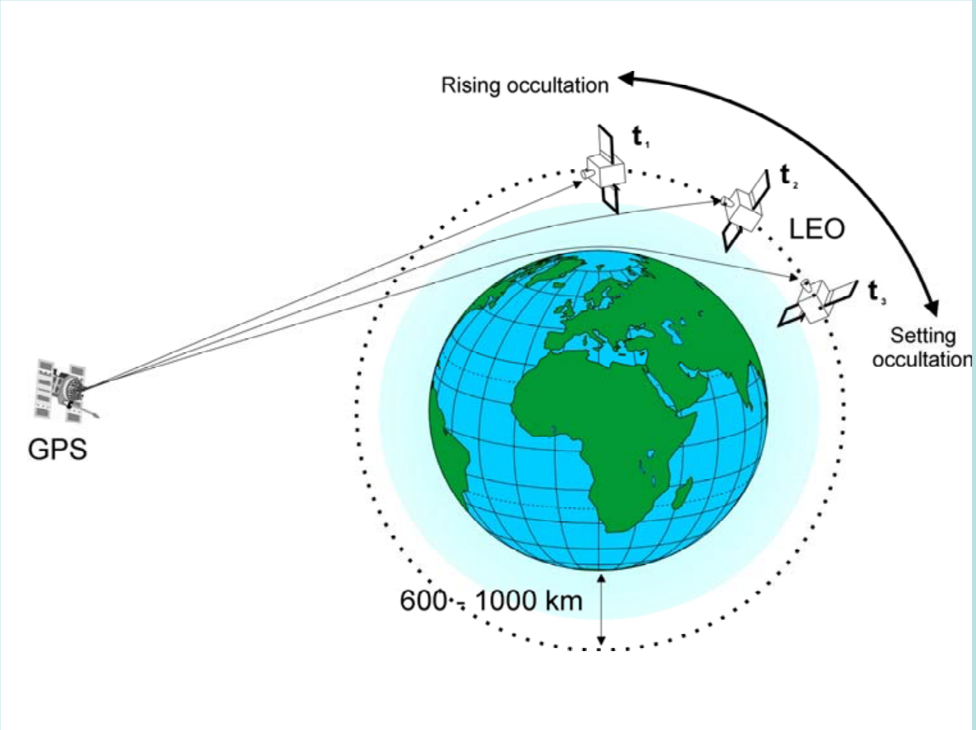
Simultaneous observations along common line of sight eliminate dominant errors; indirect transfer, ABI → VIIRS → ABI & VIIRS → ABI → VIIRS, may be more accurate than direct transfer

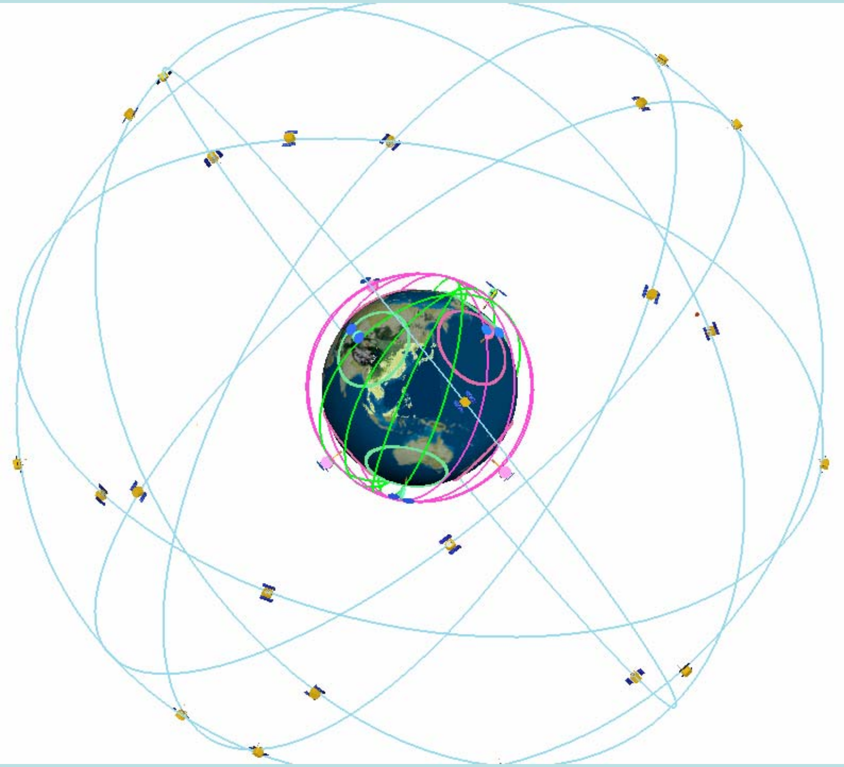
Slide Courtesy of Dr James Bremer from SWALES AEROSPACE

High Payoff: High Priority

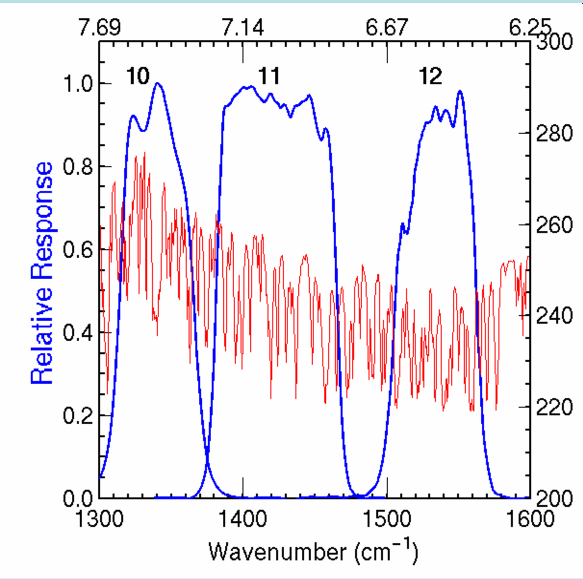
- **Hyperspectral infrared from geostationary**

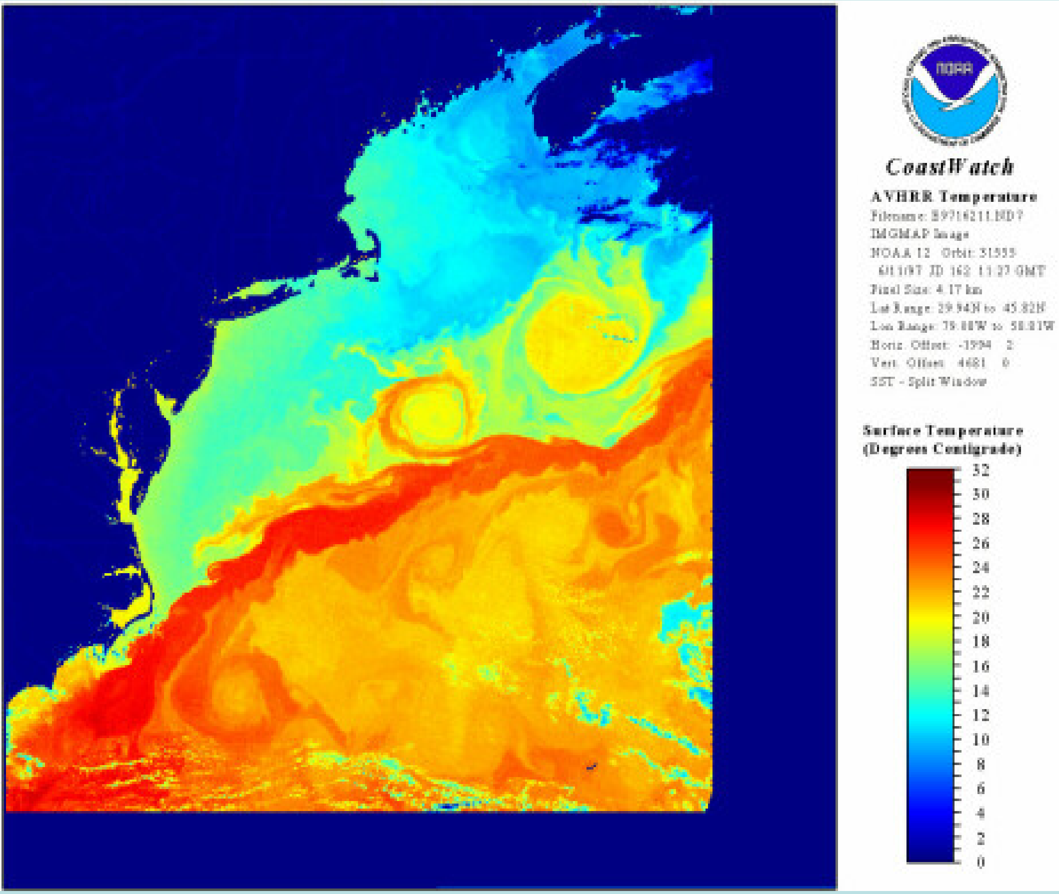
- **Hyperspectral visible to near infrared** sensors on both geostationary and polar orbiting satellites

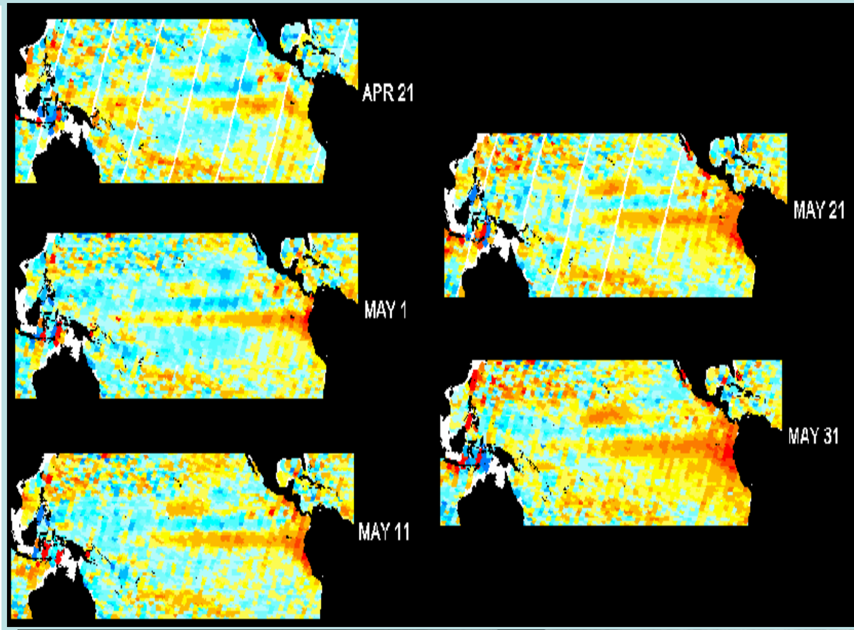


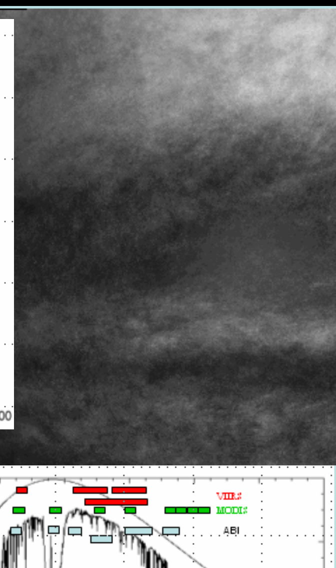


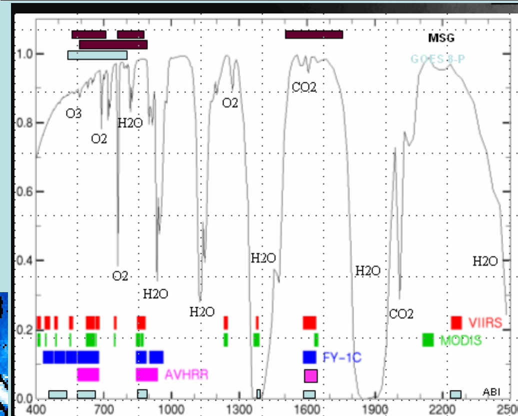
- Space based (radio occultation)
  - Independent atmospheric sounder
  - First order measurement
- Hyperspectral IR from geostationary orbit
  - Spectrally resolved radiances over same regions at same viewing angles over long time periods

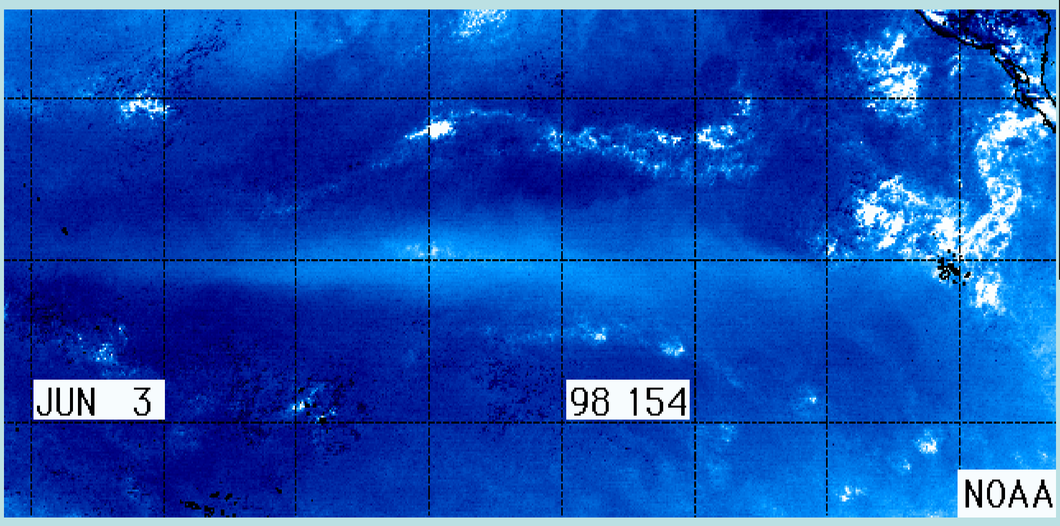


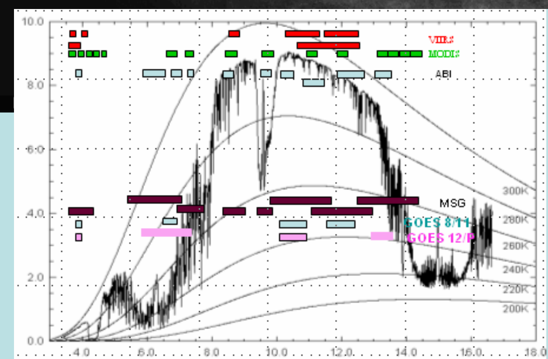

CoastWatch
AVHRR Temperature
IMGMAP Image
Pixel Size: 4.17 km
SST - Split Window
Surface Temperature
(Degrees Centigrade)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0


APR 21
MAY 1
MAY 11
MAY 21
MAY 31

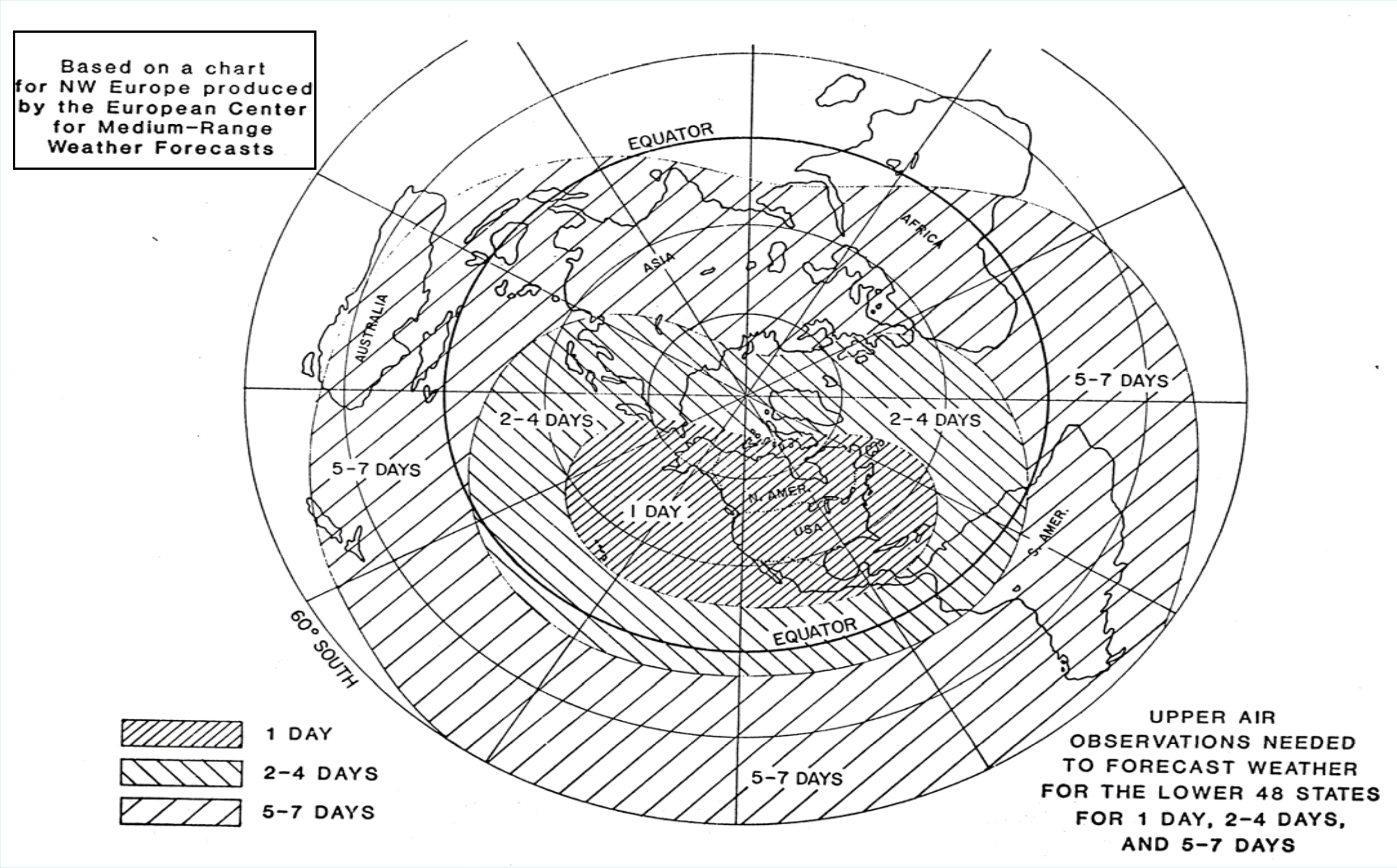

1 0001 GMS-5 01 31


MSG
GOES 8-P
O3
O2
H2O
CO2
VIIRS
MODIS
FY-1C
AVHRR
ABI
1.0
0.8
0.6
0.4
0.2
0.0
400
700
1000
1300
1600
1900
2200
2500


JUN 3
98 154
NOAA


VIIRS
MODIS
ABI
MSG
300K
280K
260K
240K
220K
200K
10.0
8.0
6.0
4.0
2.0
0.0

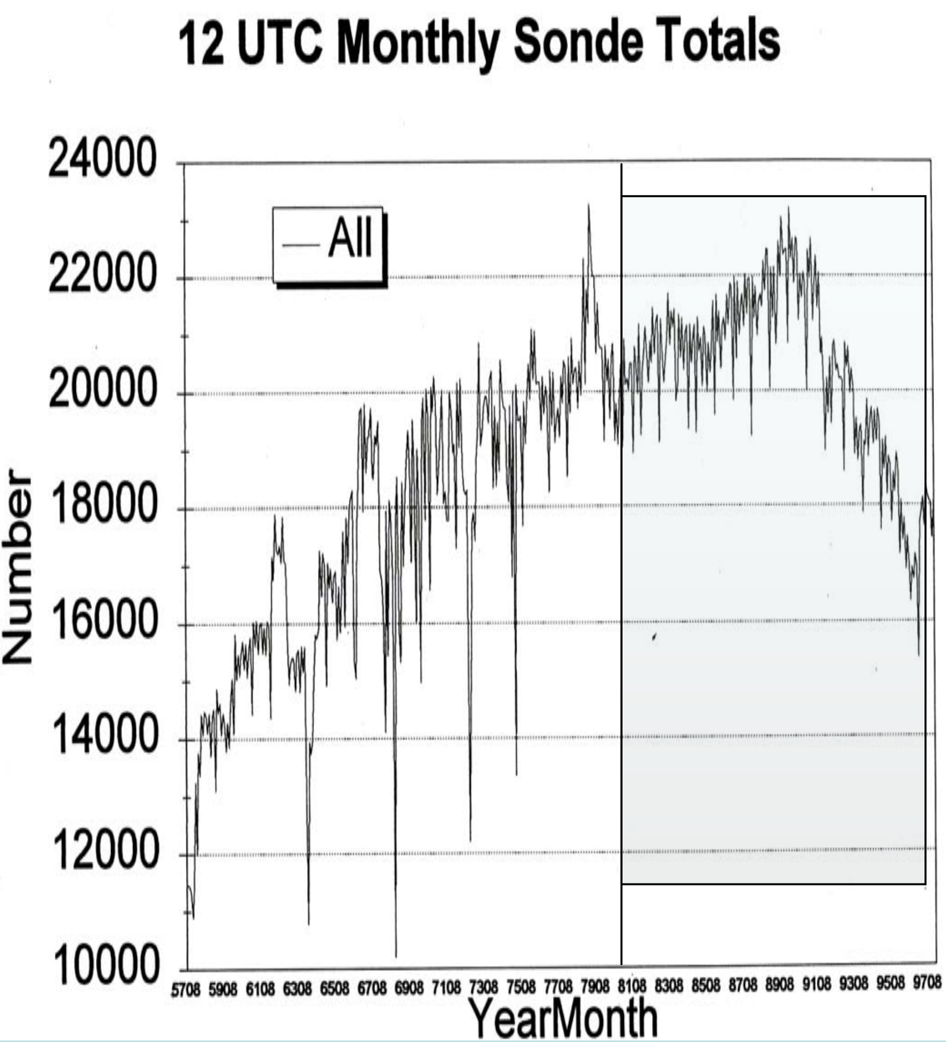
Upper Air Observations Needed To Forecast Weather For The Lower 48 States For 1, 2-4 & 6-7 Days

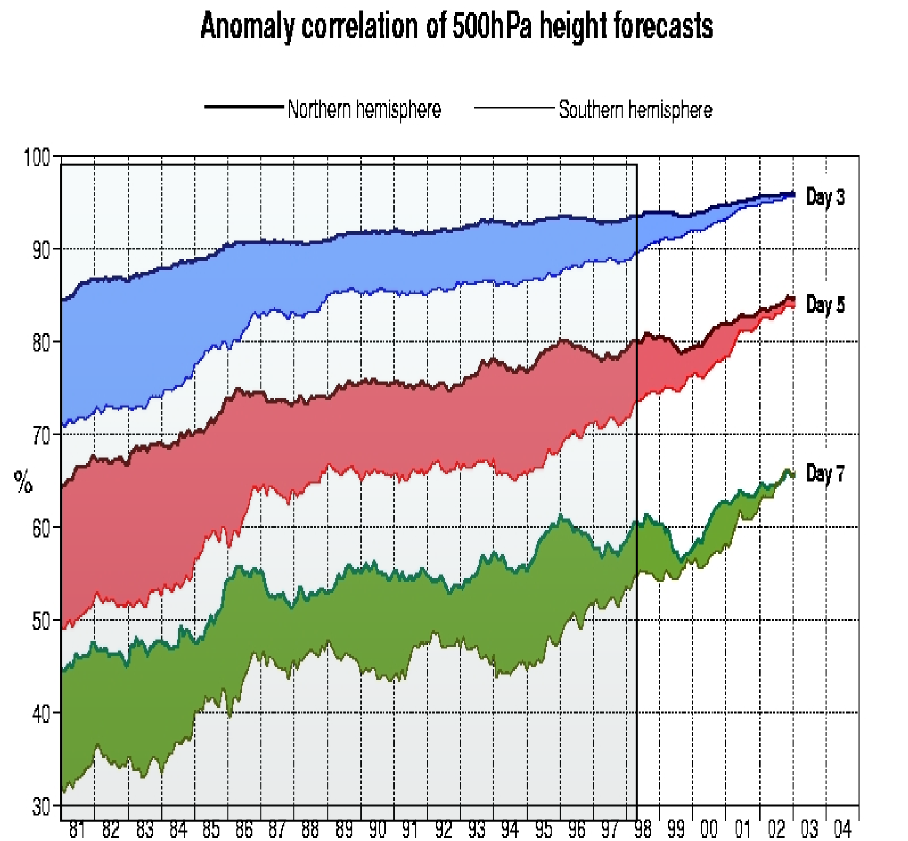


NWP systems are by their very nature need synergy

- Operational systems wealth of data
- Plus from the research side
  - Ocean surface winds
  - Hyperspectral IR
    - With cloud clearing from multi-channel imager
  - Passive Microwave
  - Global Rainfall
  - Polar atmospheric motion vectors

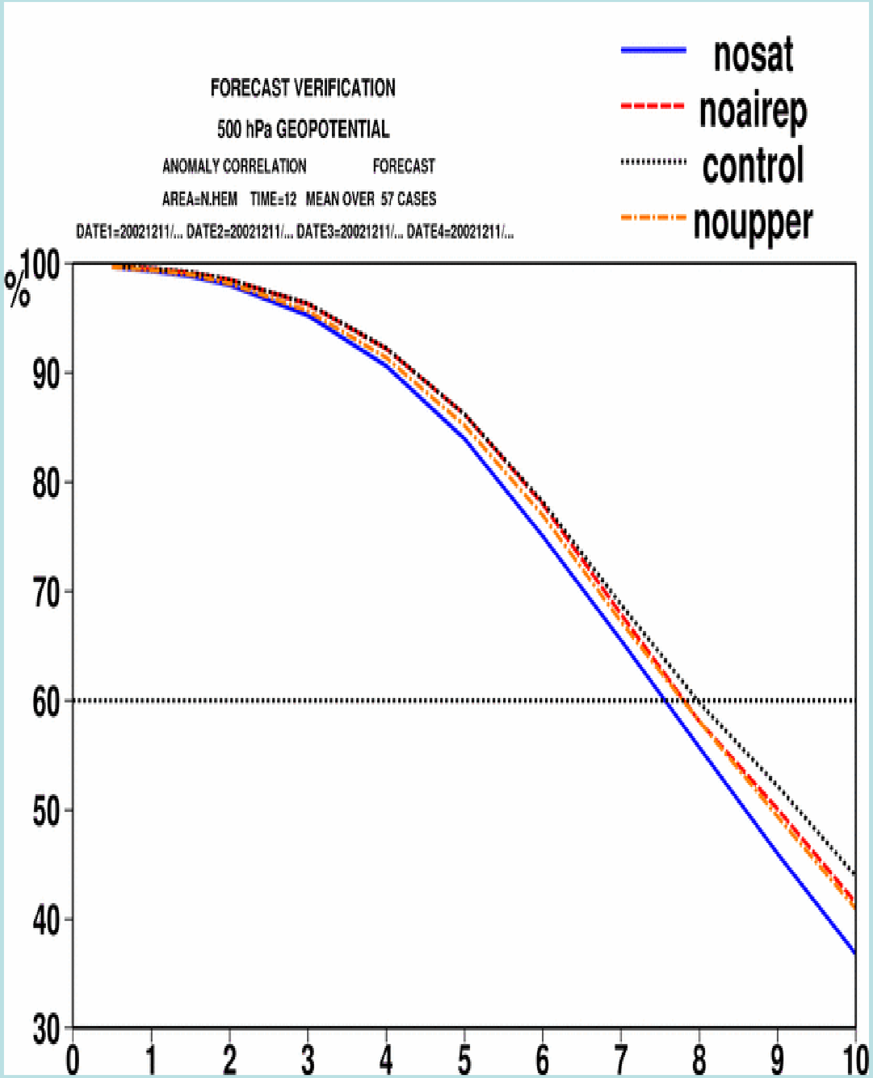
Evolution of forecast skill for northern and southern hemispheres in a time of decreasing rawinsondes





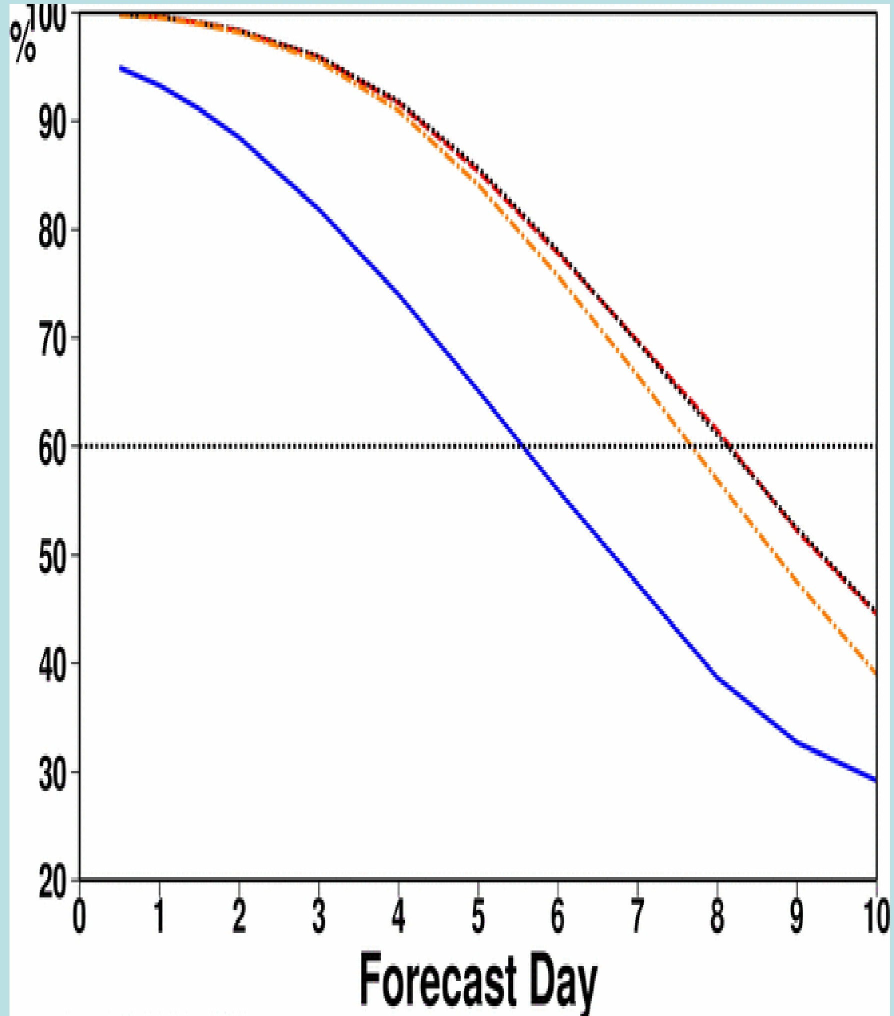
1957 81 97 81 97 04

Forecast skill for northern hemisphere



From ECMWF illustrating impact of removal of various observing systems data on forecast verification

and southern hemisphere

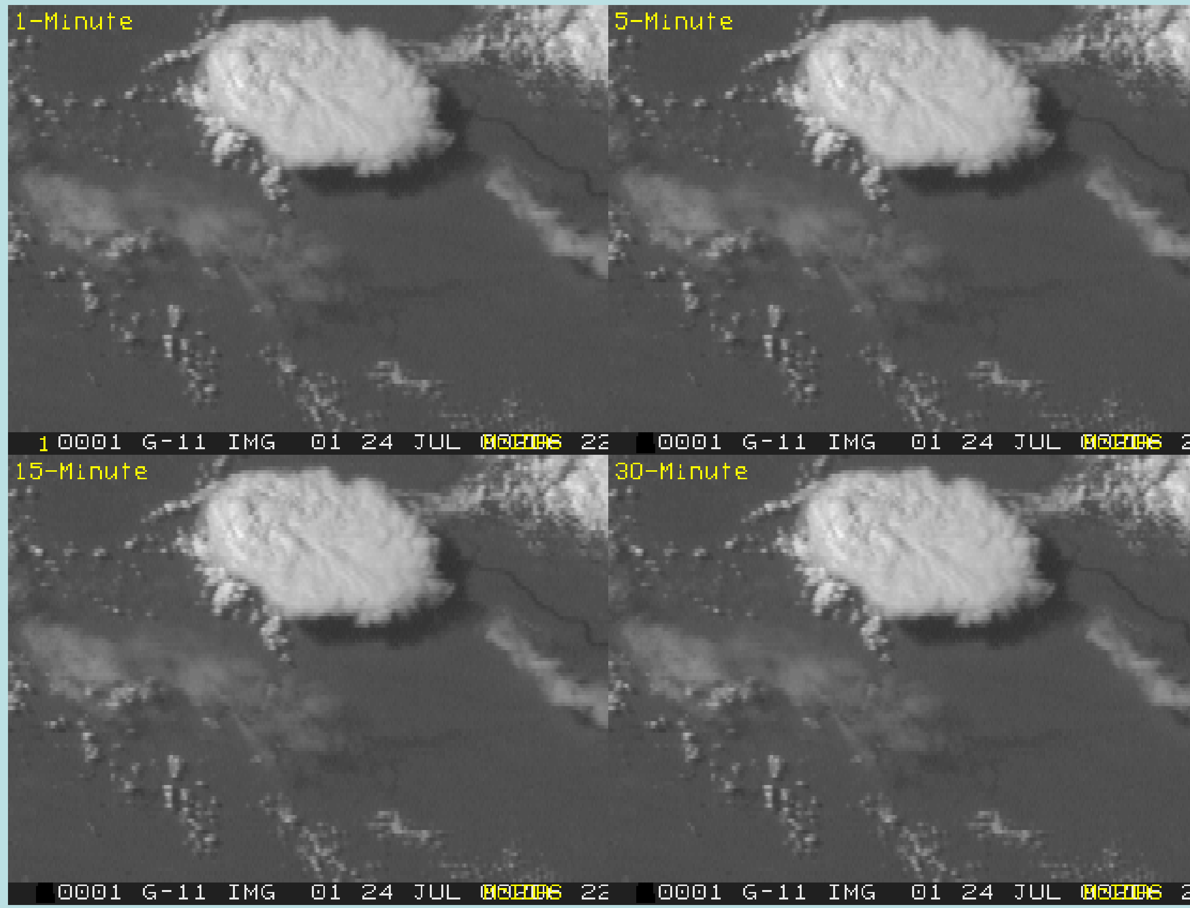


Temporal: a type of intra-satellite synergy

Comparison of animation sequences of severe thunderstorm over western Kansas. Movies at 30, 15, 5 and 1 minute intervals. While 5 minute interval imaging is routine for GOES-R, special imaging like this is possible at 1 minute intervals or less at 4(ABI) to 30 (HES-VNIR) times better spatial resolution than today.

GOES-R: Unique in spectra, space and time

The spatial and temporal domains of the phenomena drive the spectral needs as a function of space, time, and signal to noise. Nowcasting severe convection requires frequent imaging and sounding that can only be provided by geostationary satellites.

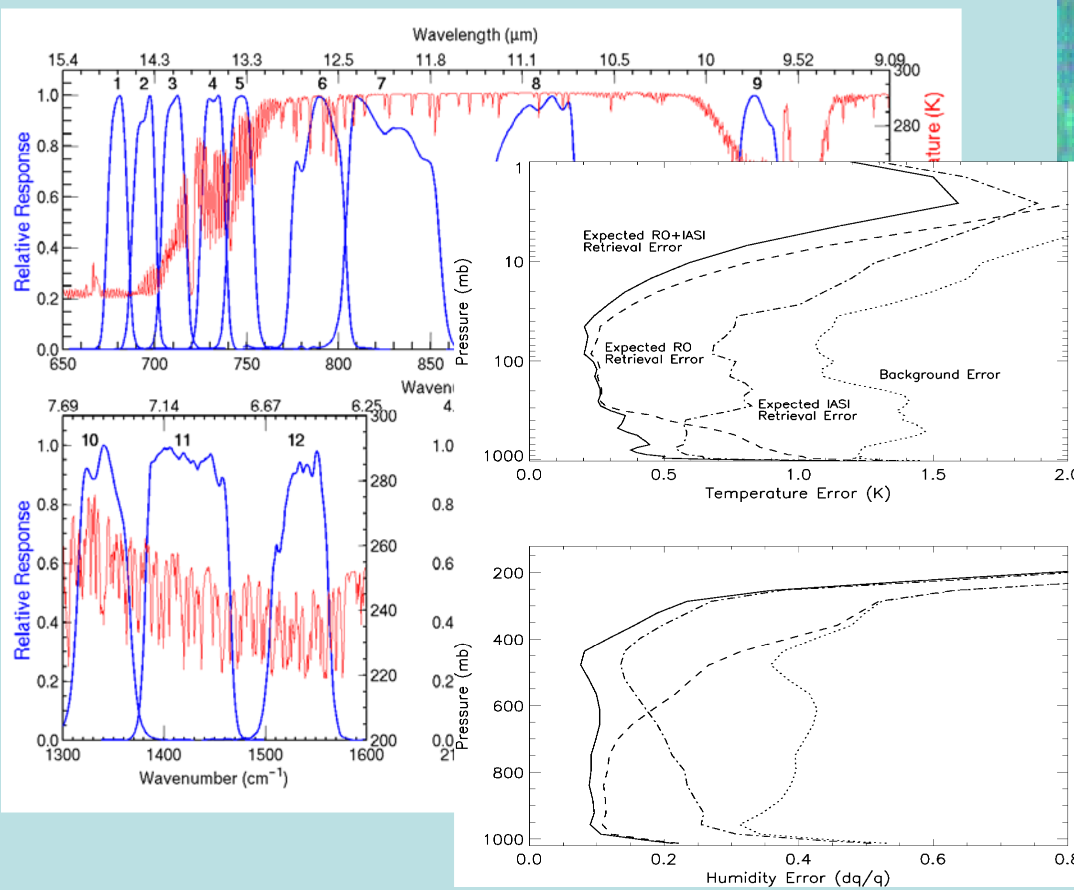


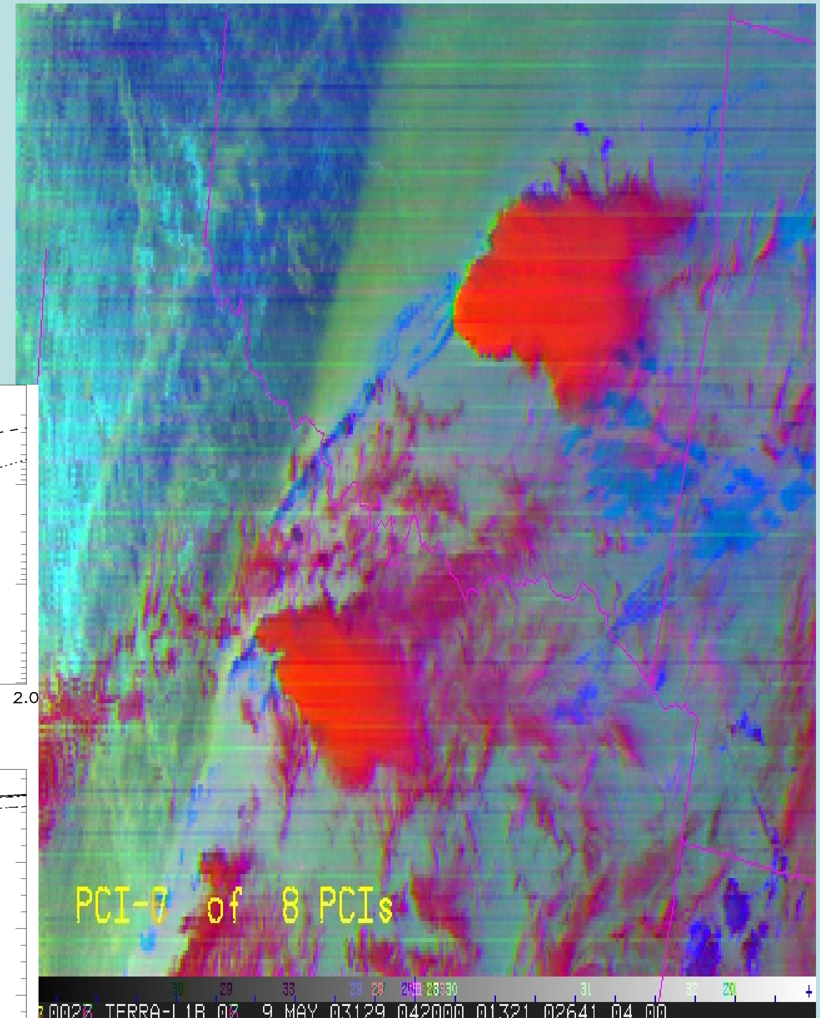
GOES-R era: this will be a multi-channel product

Adaptive Observing Leading To Adaptive Analysis

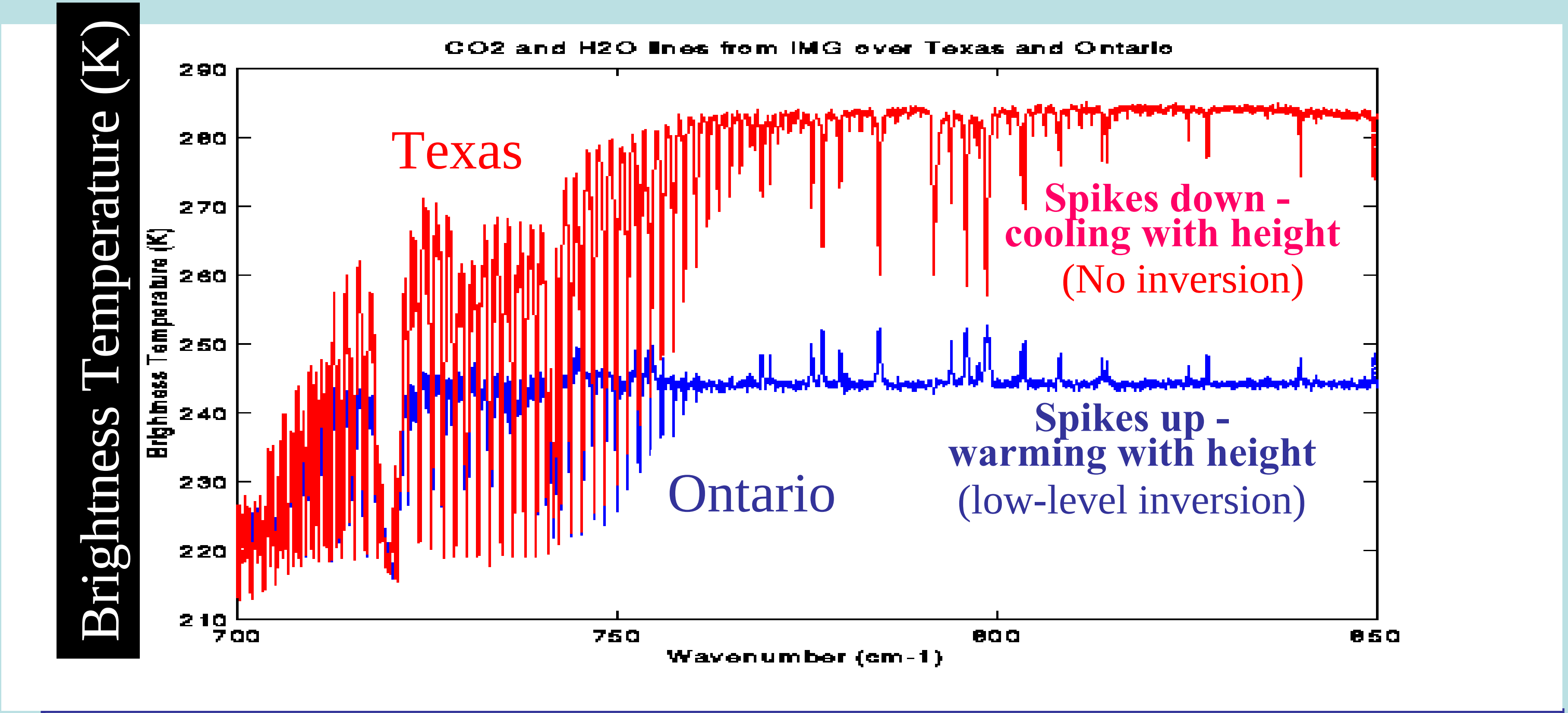
Intra-satellite

Observe Phenomena With Greater Information Content



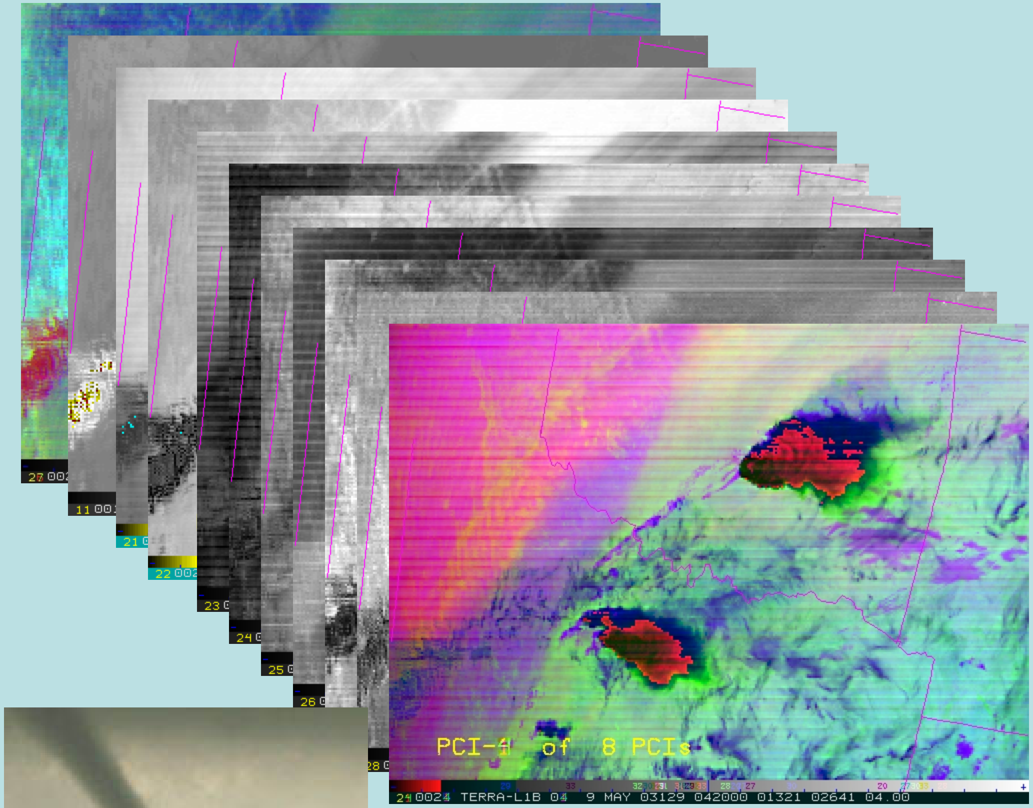


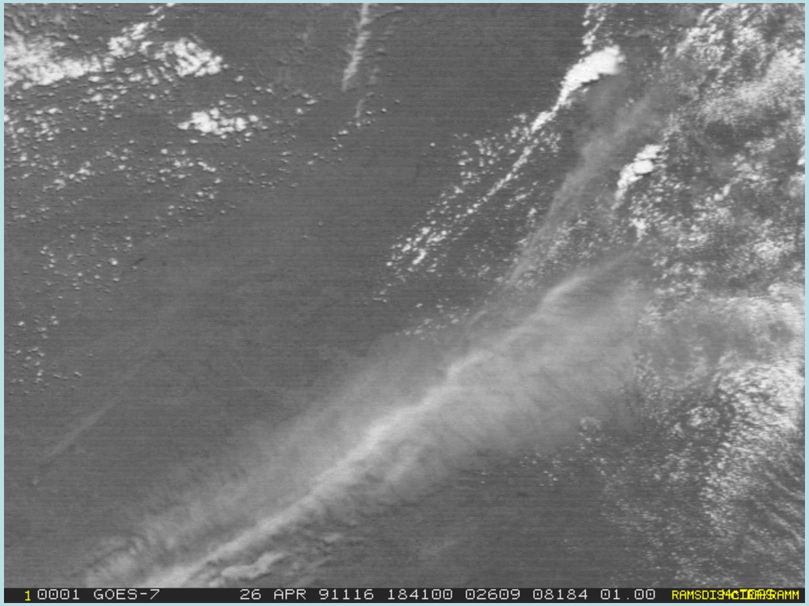
Detection of Temperature Inversions Possible with Interferometer



Detection of inversions is critical for severe weather forecasting. Combined with improved low-level moisture depiction, key ingredients for night-time severe storm development can be monitored. We will be able to monitor Boundary layer evolution and destabilization!!!

Temporal evolution: Single or multiple geostationary, or multiple polar, or geostationary & polar mix depending on location





The phenomena being analyzed helps define the spectral, spatial and temporal requirements of the satellite observing system. For satellite applications that employ animation that means that different applications and procedures depending on scale

Intra-System: GOES-E and GOES-W for stereo heights

(also inter-system stereo using high resolution polar imagery)

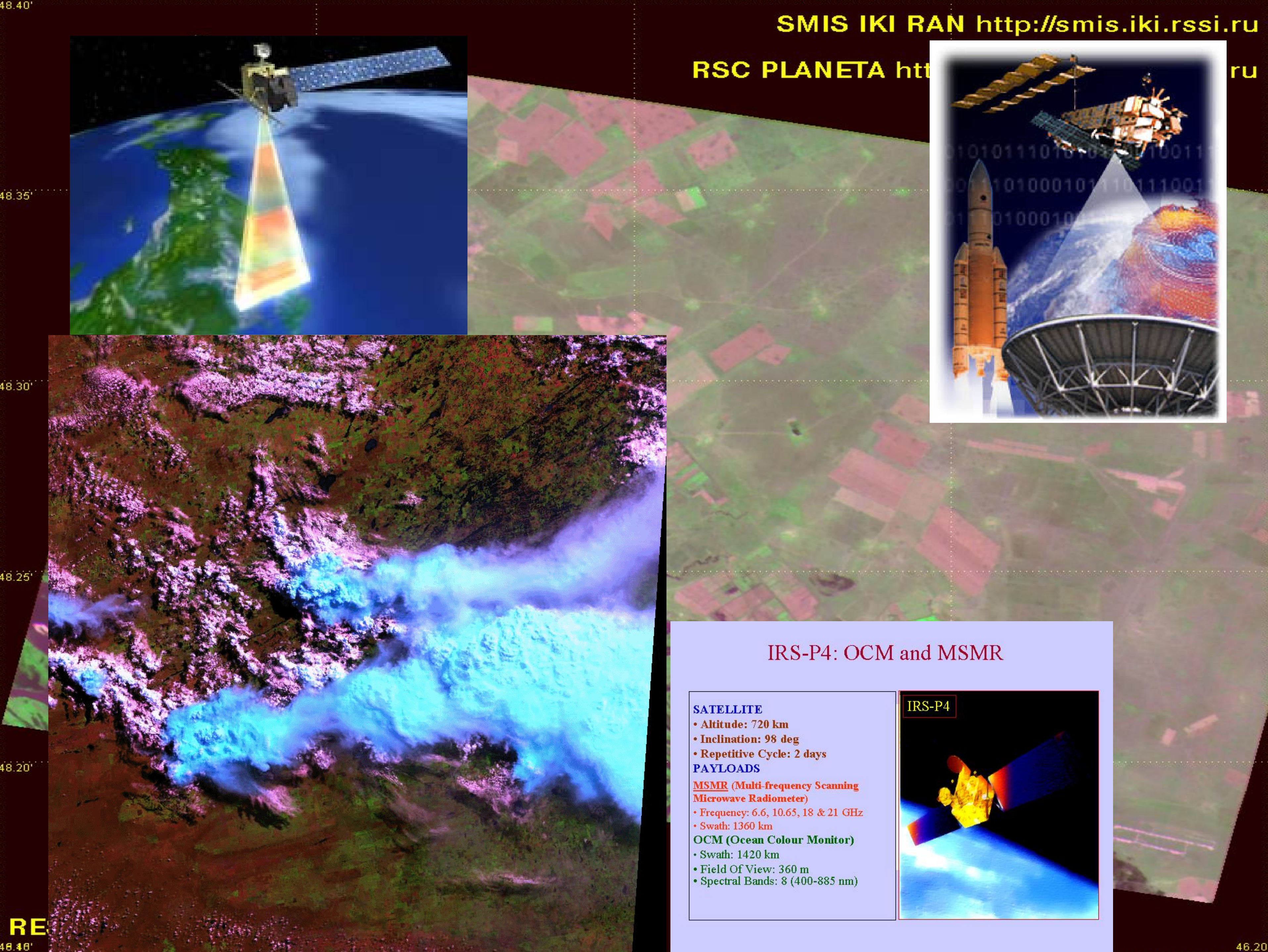
Intra-System: GOES-E and GOES-W for stereo heights & view of choice

(also inter-system stereo using high resolution polar imagery)

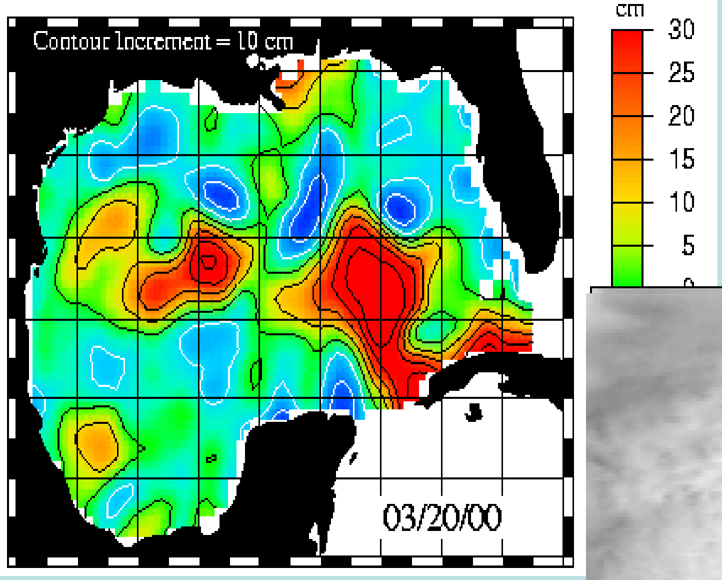
This damage was due to a tornado, it could have occurred over a similar or larger area due to explosions from various causes. Do you want to wait for conventional monitoring methods to begin damage assessment? With HES you can view immediately with exceptionally high spatial, spectral and temporal resolutions.

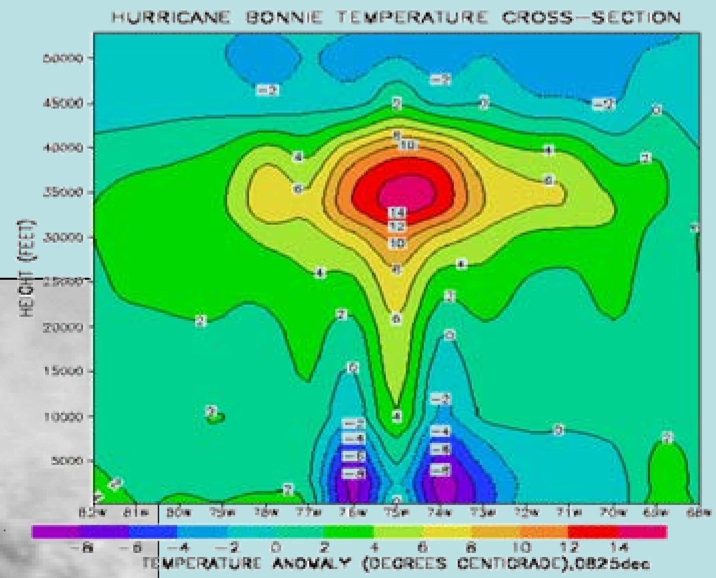

LaPlata tornado damage
path at 120 m resolution

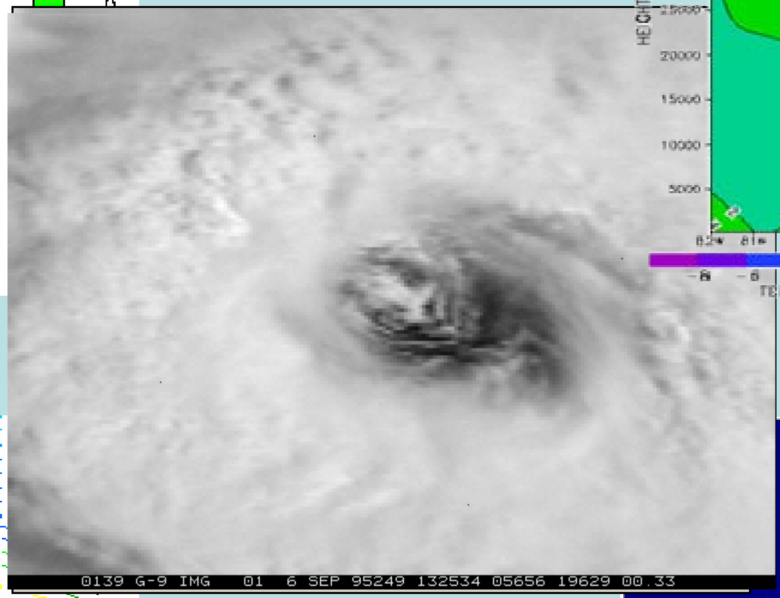

LaPlata tornado damage
path at 240 m resolution

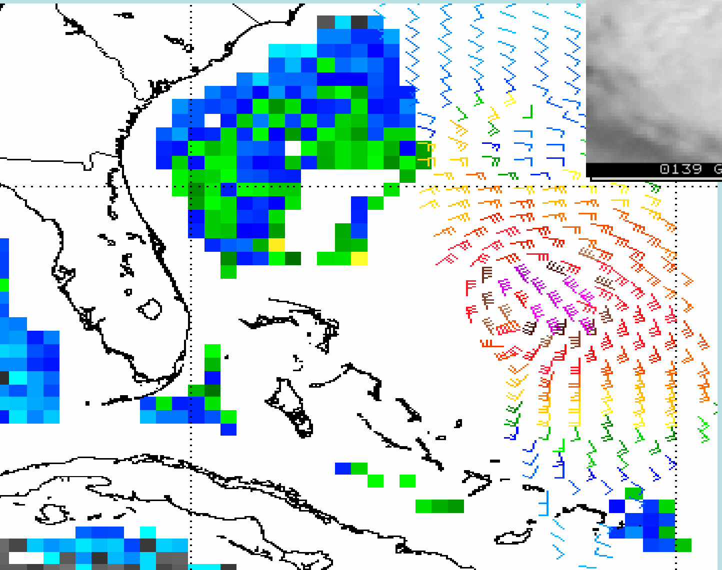

SMIS IKI RAN http://smis.iki.rssi.ru
RSC PLANETA htt
ru
48.40'
48.35'
48.30'
48.25'
48.20'
IRS-P4: OCM and MSMR
SATELLITE
• Altitude: 720 km
• Inclination: 98 deg
• Repetitive Cycle: 2 days
PAYLOADS
MSMR (Multi-frequency Scanning Microwave Radiometer)
• Frequency: 6.6, 10.65, 18 & 21 GHz
• Swath: 1360 km
OCM (Ocean Colour Monitor)
• Swath: 1420 km
• Field Of View: 360 m
• Spectral Bands: 8 (400-885 nm)
IRS-P4
RE
46.20

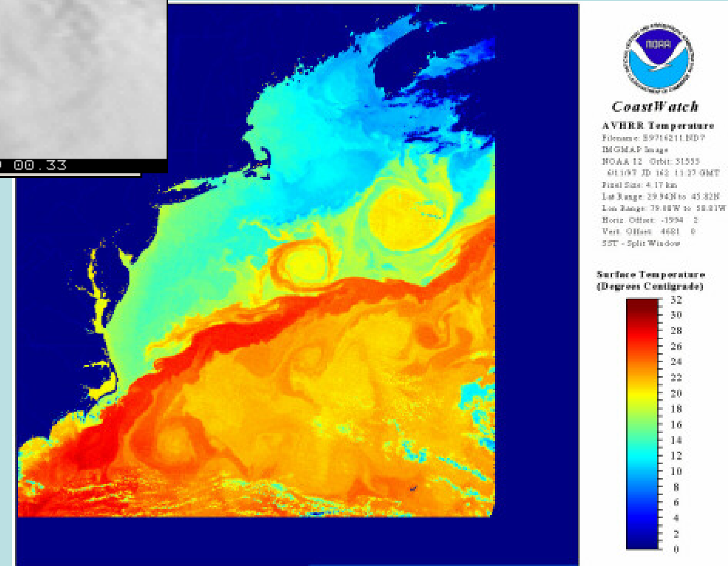
Winds, SST, Microwave anomaly and Altimetry
GOES Rapid Scan







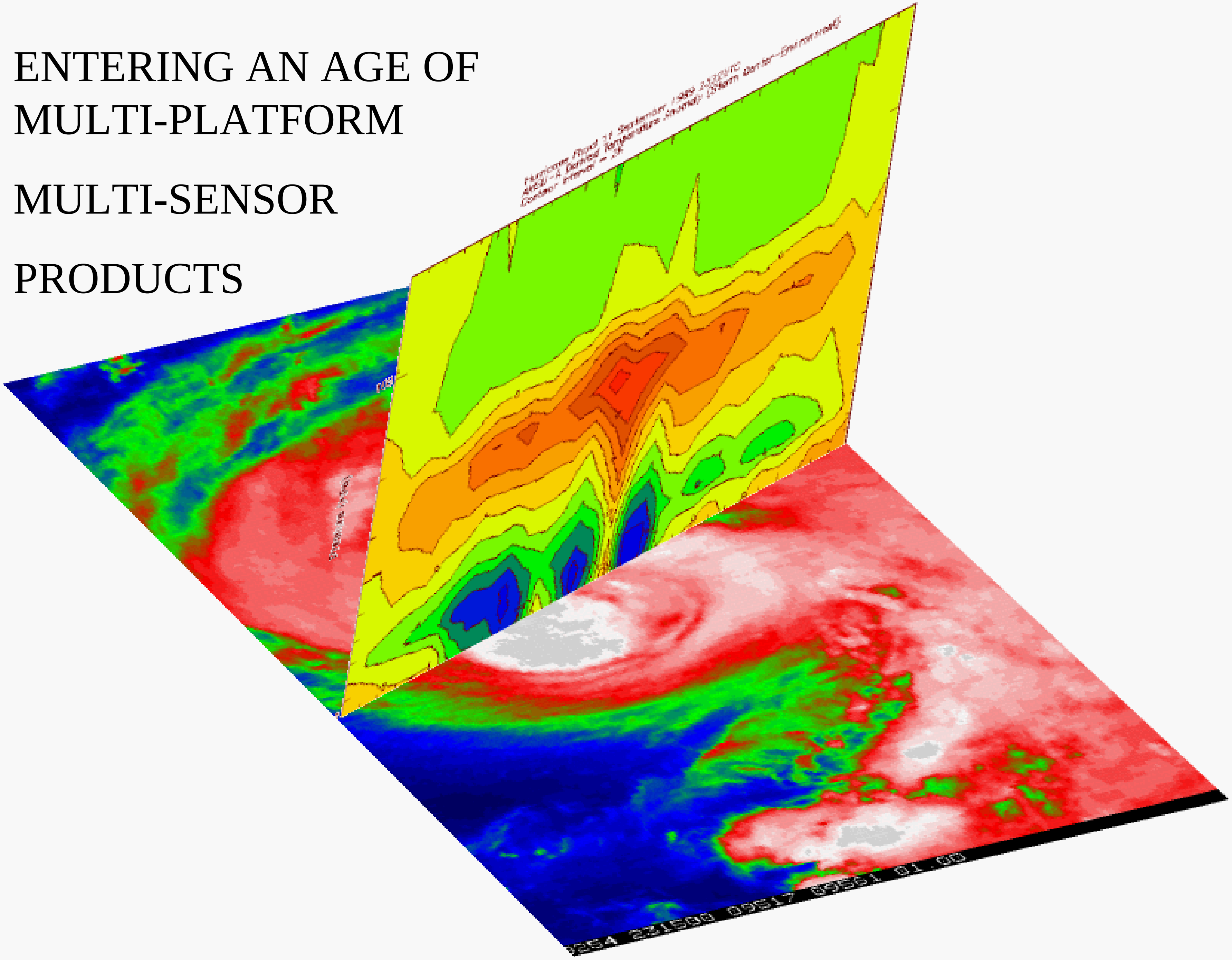


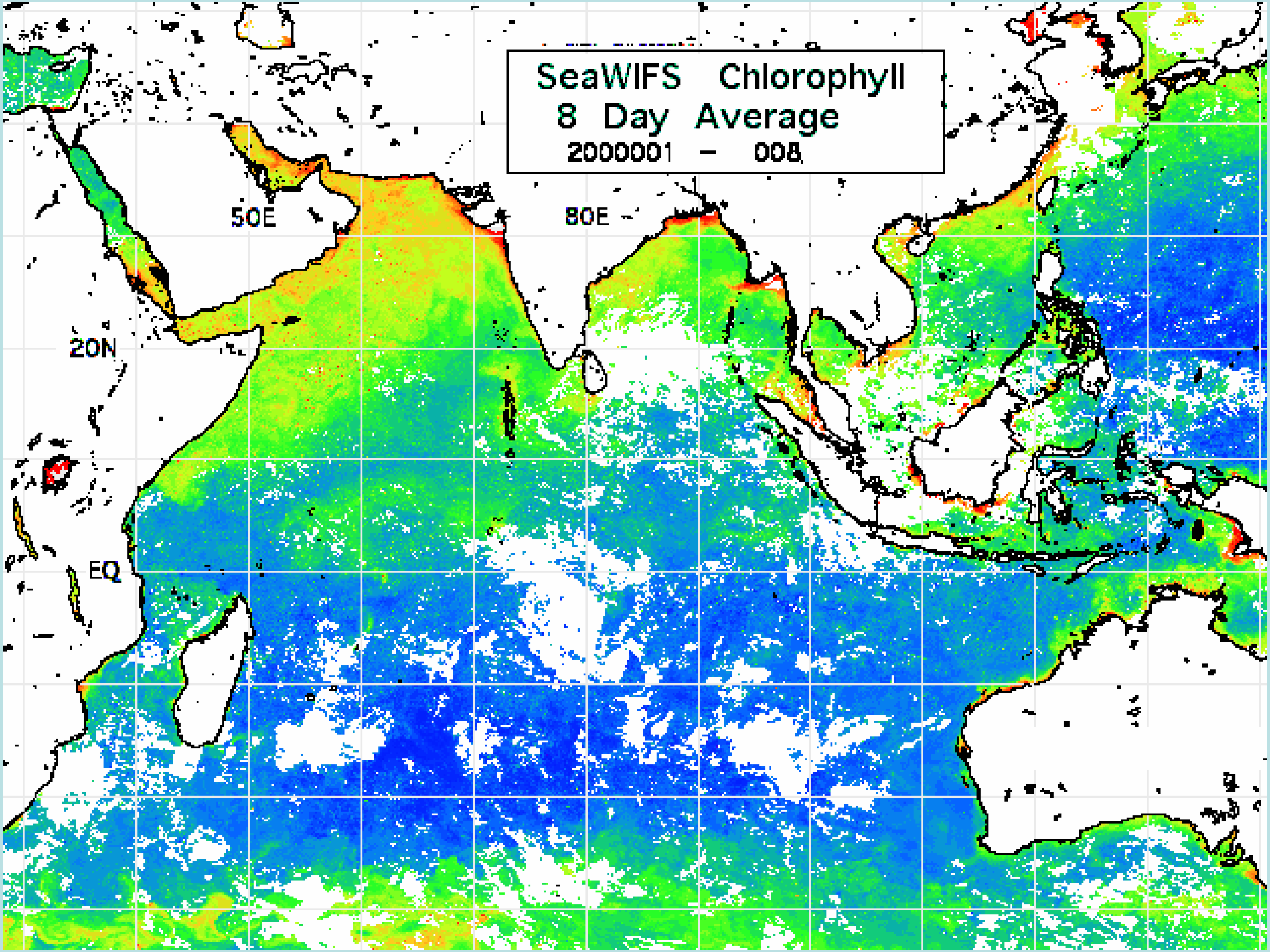


ENTERING AN AGE OF MULTI-PLATFORM

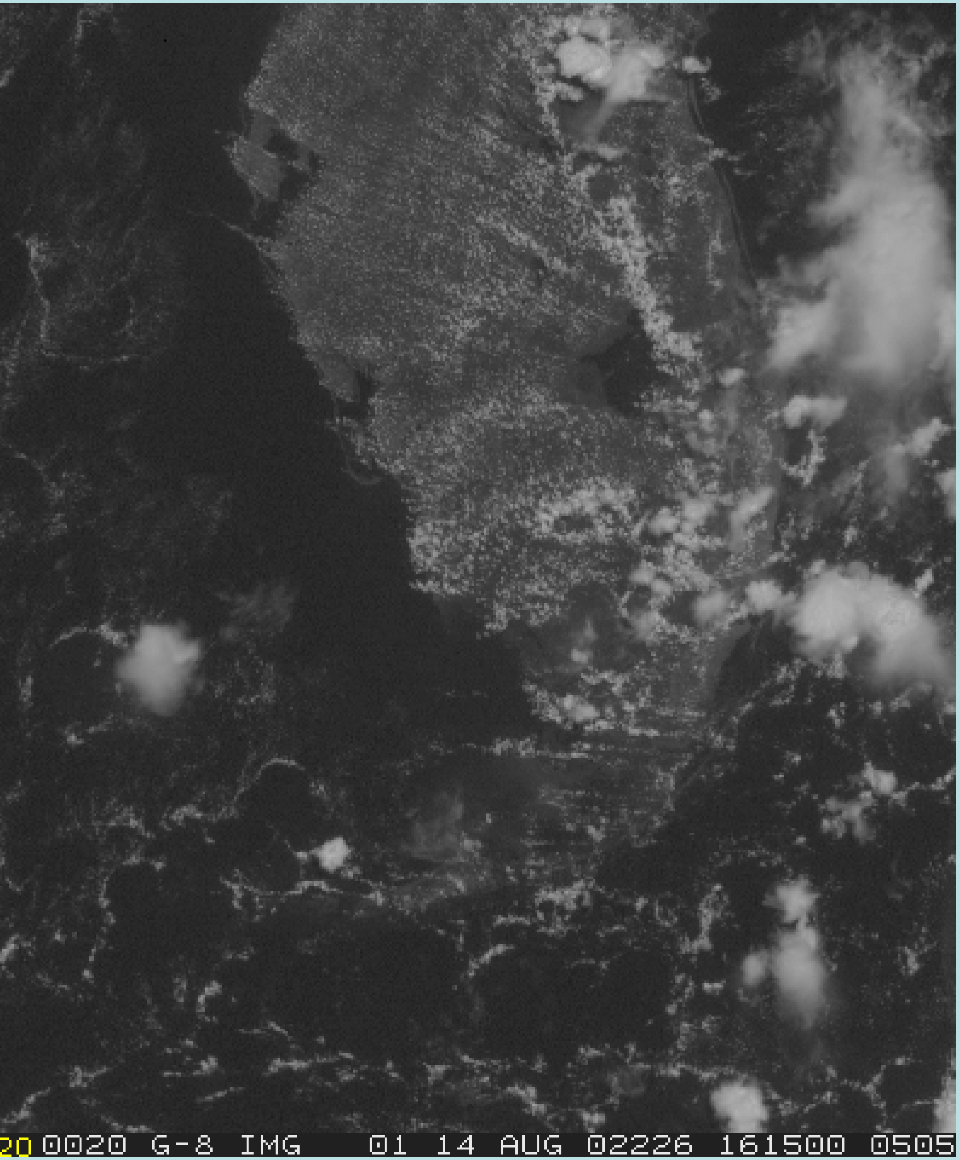
MULTI-SENSOR

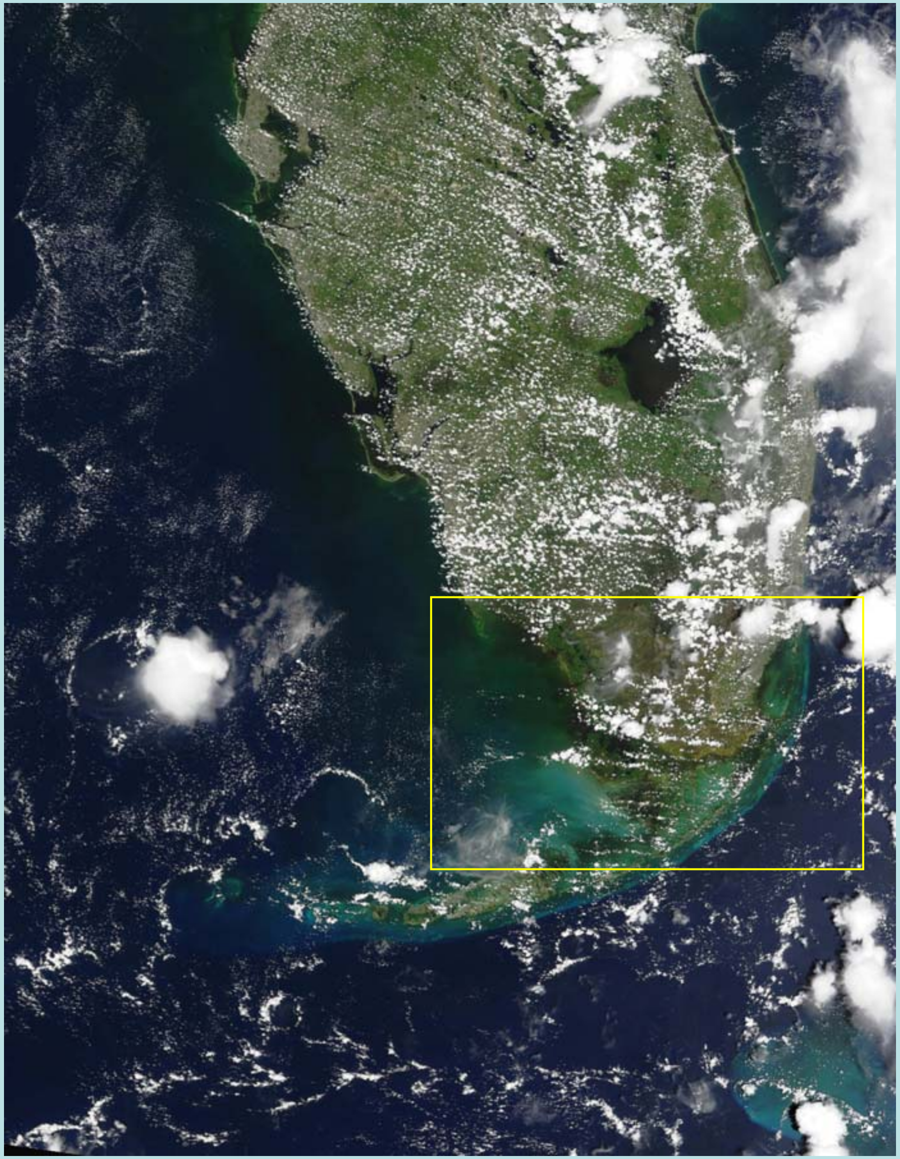
PRODUCTS




SeaWIFS Chlorophyll
8 Day Average
2000001 – 008
50E
80E
20N
EQ

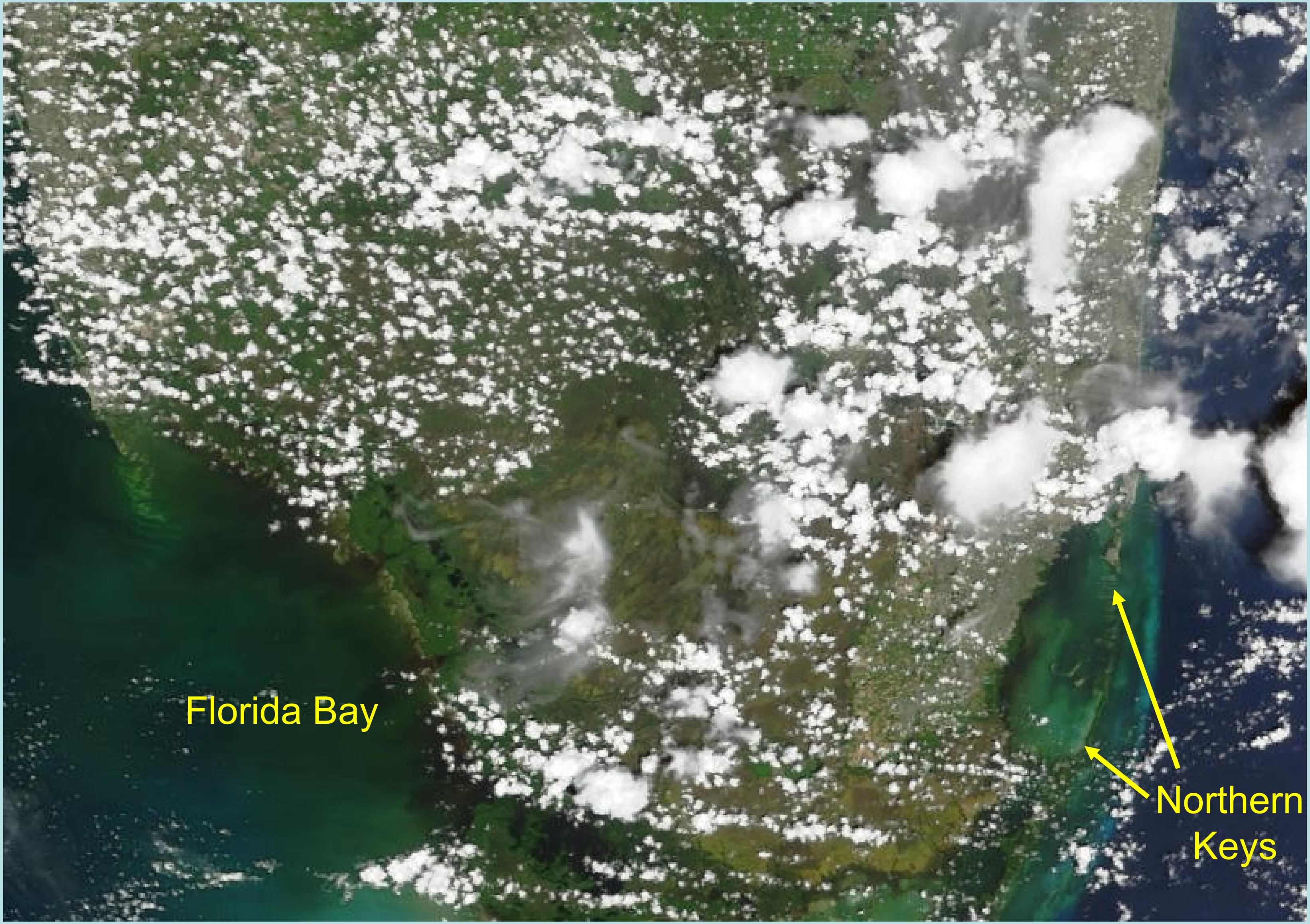
Example: Use ABI Data to Task HES VNIR



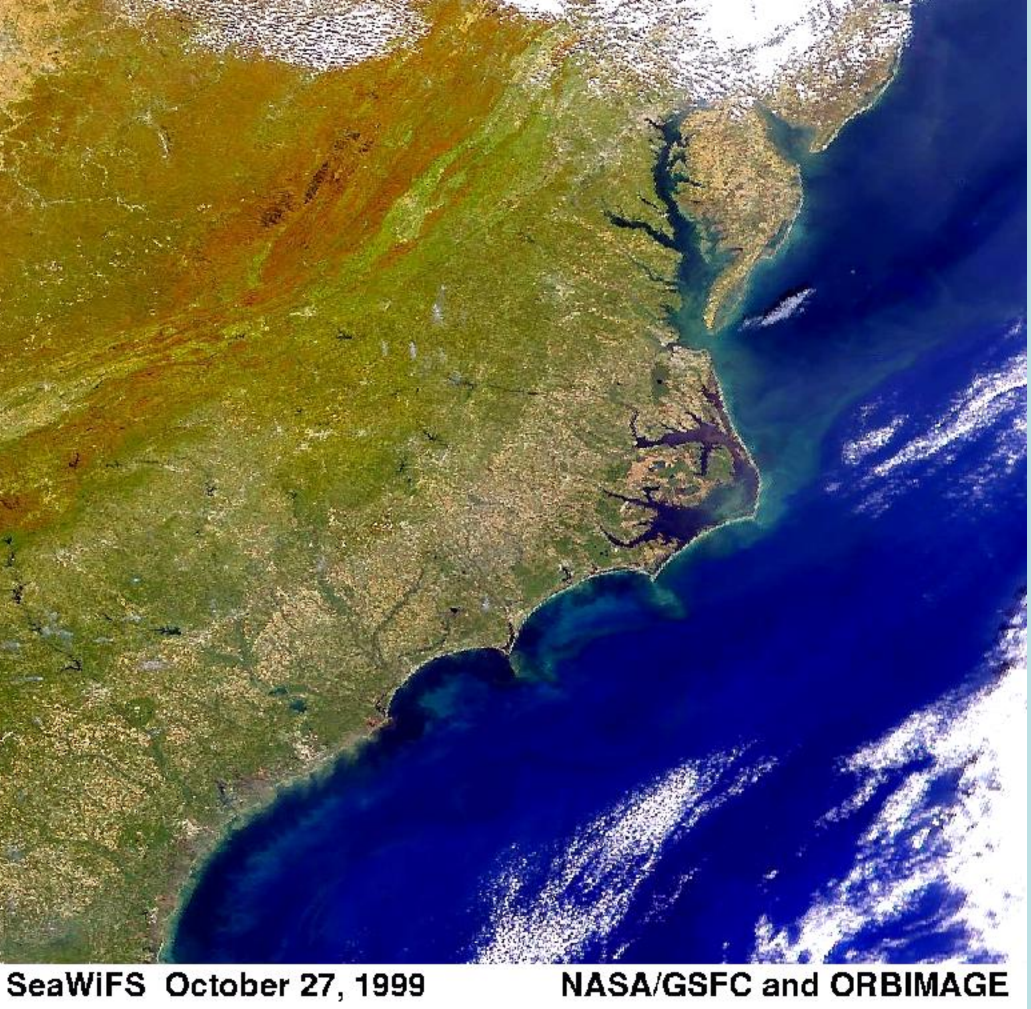


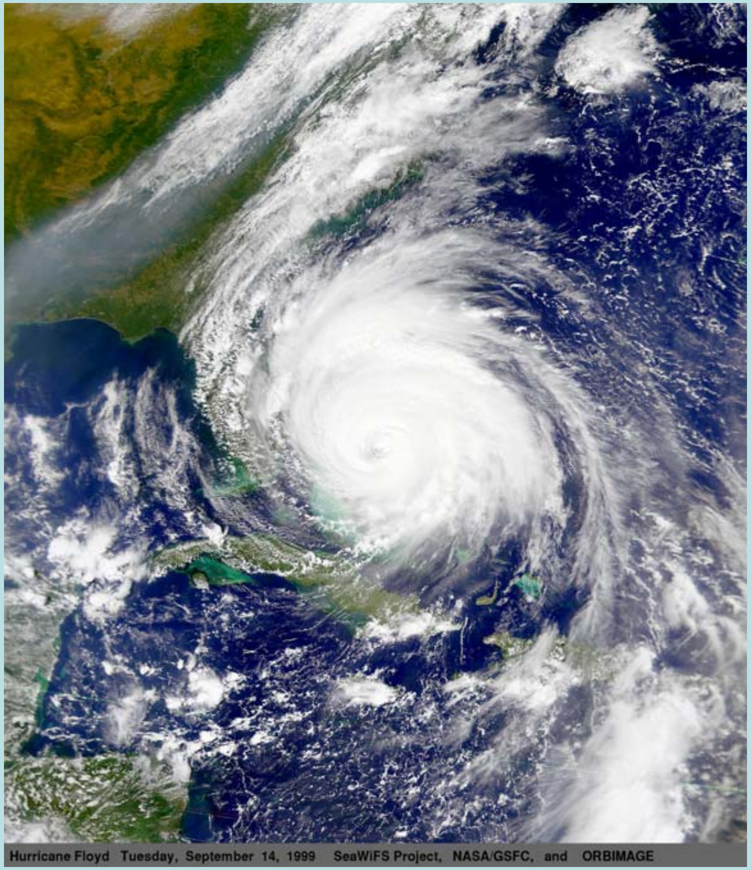
GOES-8 loop from 1615 to 2345: this loop illustrates the changes that occur in the cloud field after the MODIS pass and the need to dynamically task HES.

Despite increasing cloud cover, the Florida Bay and Northern Keys could be successfully imaged over several hours which will allow for observations of ocean color as well as changes due to tidal effects.

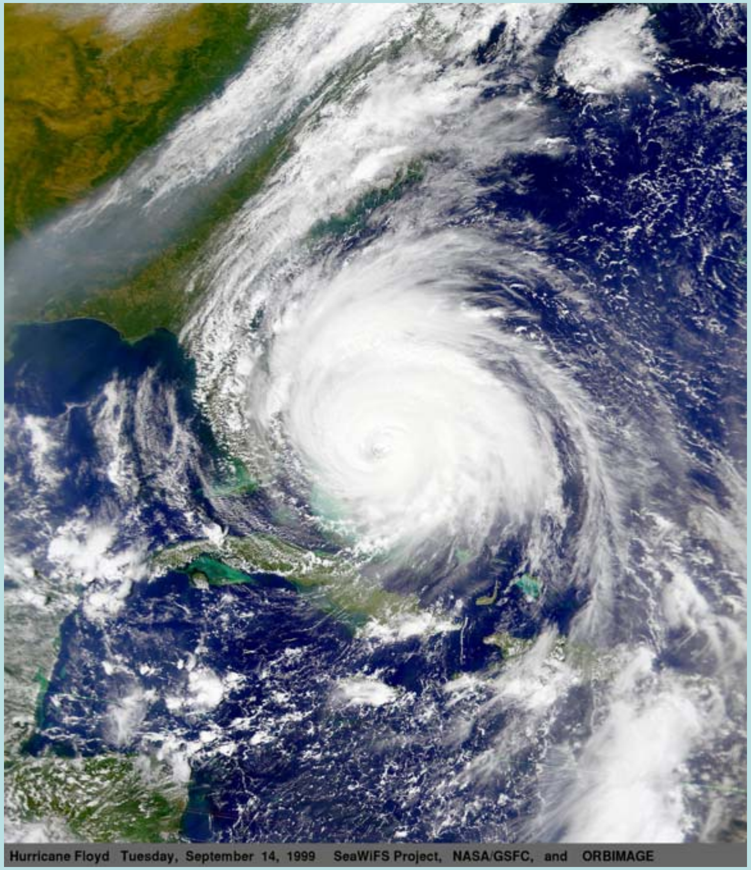


Then along came Floyd





It will be important to monitor such disasters hourly at very high resolution as will be available from HES'VNIR capability



Ocean color showing result of flooding interacting with pig farms. You want to be able to make daily cloud free images of this consequence of a natural disaster immediately and blend with SST, ocean currents and other information.

2015 Vision for GOS

for the Space based component

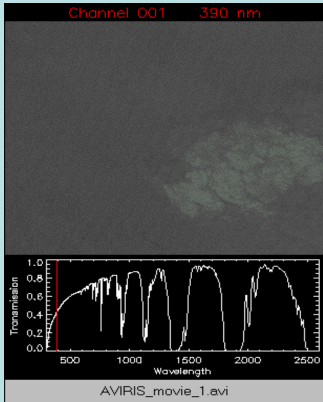
* 6 operational GEOs all with multispectral imager (IR/VIS); some with hyperspectral sounder (IR)
* 4 operational LEOs optimally spaced in time, all with multispectral imager (MW/IR/VIS/UV), all with sounder (MW), 3 with hyperspectral sounder (IR), all with radio occultation (RO), 2 with altimeter, 3 with conical scan MW or scatterometer
* Several R&D satellites, constellation small satellites for radio occultation (RO), LEO with wind lidar, LEO with active and passive microwave precipitation instruments, LEO and GEO with advanced hyperspectral capabilities, GEO lightning, possibly GEO microwave
* Improved intercalibration and operational continuity

What will be significant?

- Leadership
- Vision
- Understanding
- Utilization

Conclusion

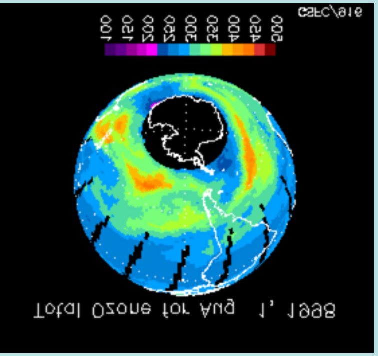
The advancement to improved microwave sensors, space-based lidar, radar, and hyper-spectral imaging and sounding is a *natural progression*, and will provide exciting new opportunities and challenges with truly adaptive observing systems



IN

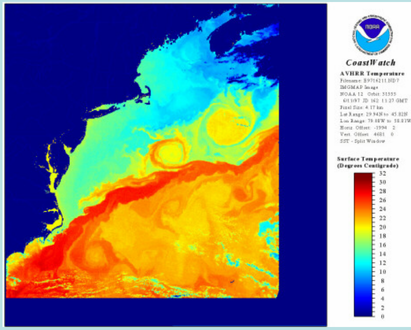
Meteorological Applications

THE



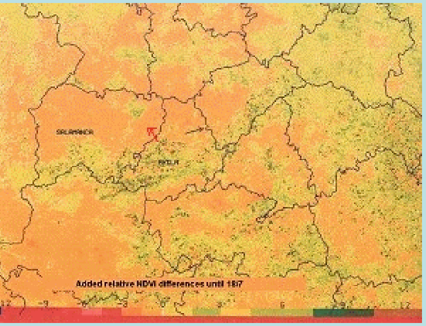
Climate Applications

CONTEXT



Ocean Applications

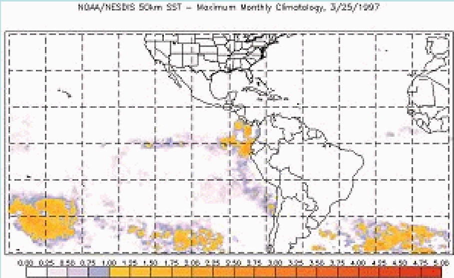
OF



Land Applications

GEOSS

Ecological Applications



New remote sensing capabilities are offering

higher spatial and temporal resolution

more spectral bands

higher spectral resolution

better science

Opportunities can be realized only with

new approaches

national and international partnerships

training for full utilization

early involvement in science teams

and associated field programs

Distinction shrinking between

POES and GOES sensors

research and operational sensors

operational use of research satellite data

international sensors (climate importance)

MOVING FORWARD: THOUGHTS AND CHALLENGES

Whose responsible?

- 5 new technology operational polar satellites
- 5-7 sophisticated operational geostationary satellites
- Array of research missions
- All applications areas will have the opportunity to exploit multiple satellite data sets from a variety of research and operational satellites, all at different spectral, spatial, radiometric and temporal resolutions

Full exploitation is only possible as a global community in partnership:

likely requiring fundamental changes to the way we do business and interact as a community

Paradigm shifts that must occur

- **The system**: dynamic research component integrated with a powerful reliable operational component. Hypothesis: the capabilities of the operational system will be so great that both research and special mission satellites will be designed to fly in formation with the operational low earth orbiting satellites

- **Data, products and dissemination**: dynamic data and product stream. Opinion: sophisticated users interested in availability of selected data and products, not everything

- **Merging research and operations**: a dynamic system and full exploitation. Belief: requires merging research and operations with the user becoming a part of the system. Ongoing training and education will be required to assure both proper data utilization and sophisticated and realistic user requirements.

High Payoff: High Priority

- **GPS radio occultation** for climate and high resolution sounding applications (with hyperspectral)
- **Hyperspectral infrared from geostationary** for multi-layer atmospheric motion vectors and high resolution vertical sounding applications (with GPS)
- **Global precipitation constellation with active radar** that is fully integrated with the operational system for both exploitation over scales that range from nowcasting to climate
- **Hyperspectral visible to near infrared** sensors on both geostationary and polar orbiting satellites with very high resolution (250 meters or better) for detailed land and ocean studies
- **Formation flying** with the operational constellation of small satellites with special sensors such as lidar for **aerosols and winds, cloud radar** and lightning mappers (particularly at geostationary orbit)

GEOSS Societal Benefit Areas

- Improving weather information, forecasting and warning
- Reducing loss of life and property from natural and human induced disasters
- Improving water resource management through better understanding of the water cycle
- Understanding, assessing, predicting, mitigating and adapting to climate variability and change
- Improving the management and protection of terrestrial, coastal and marine ecosystems
- Understanding environmental factors affecting human health and well being
- Improving management of energy resources
- Supporting sustainable agriculture and combating desertification
- Understanding, monitoring and conserving biodiversity

A closing observation

- GEOSS 10 Year Implementation Plan: “Understanding the Earth system – its weather, climate, oceans, land, geography, natural resources, and natural and human-induced hazards – is crucial to enhancing human health, safety and welfare, alleviating human suffering including poverty, protecting the global environment, and achieving sustainable development.”

- The space and ground-based components of the GOS are among the core contributors to GEOSS. Observing and accurately predicting the Earth’s environment is critical for the health, safety and prosperity of all nations.

- **Be vision driven**