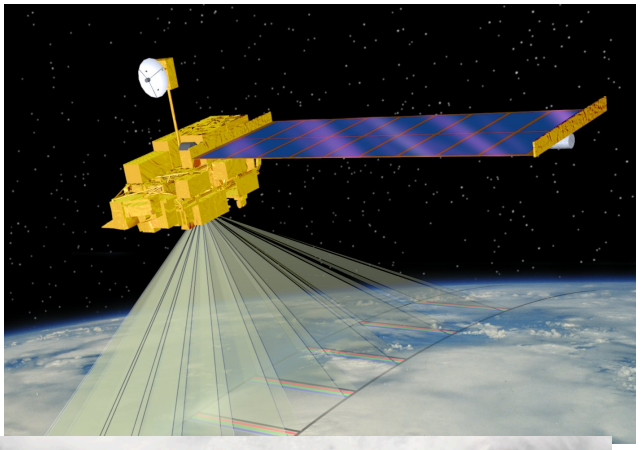
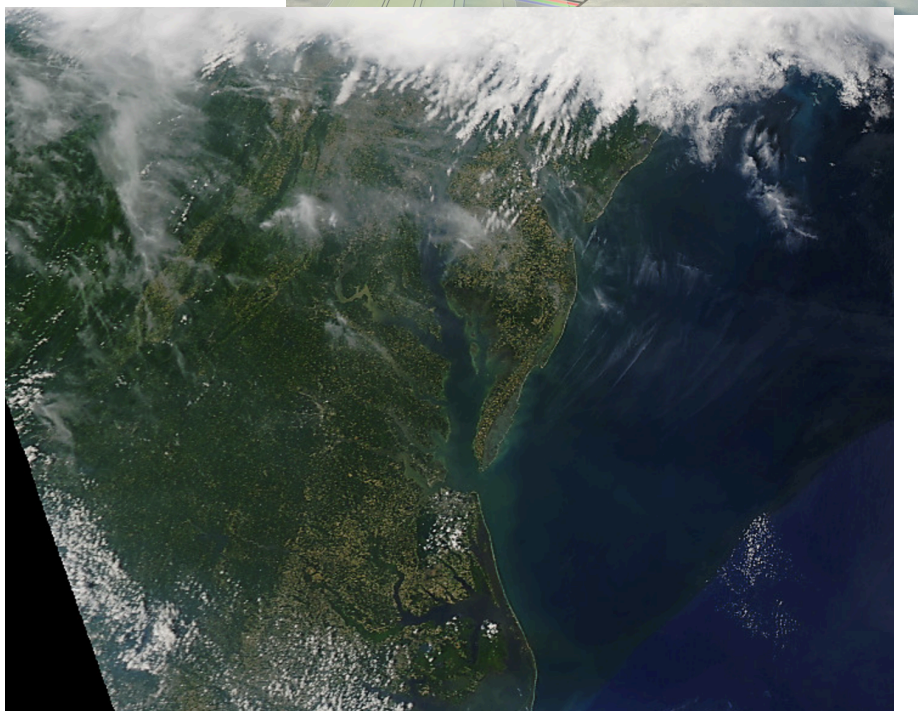
Introduction to the MODIS sensor and products





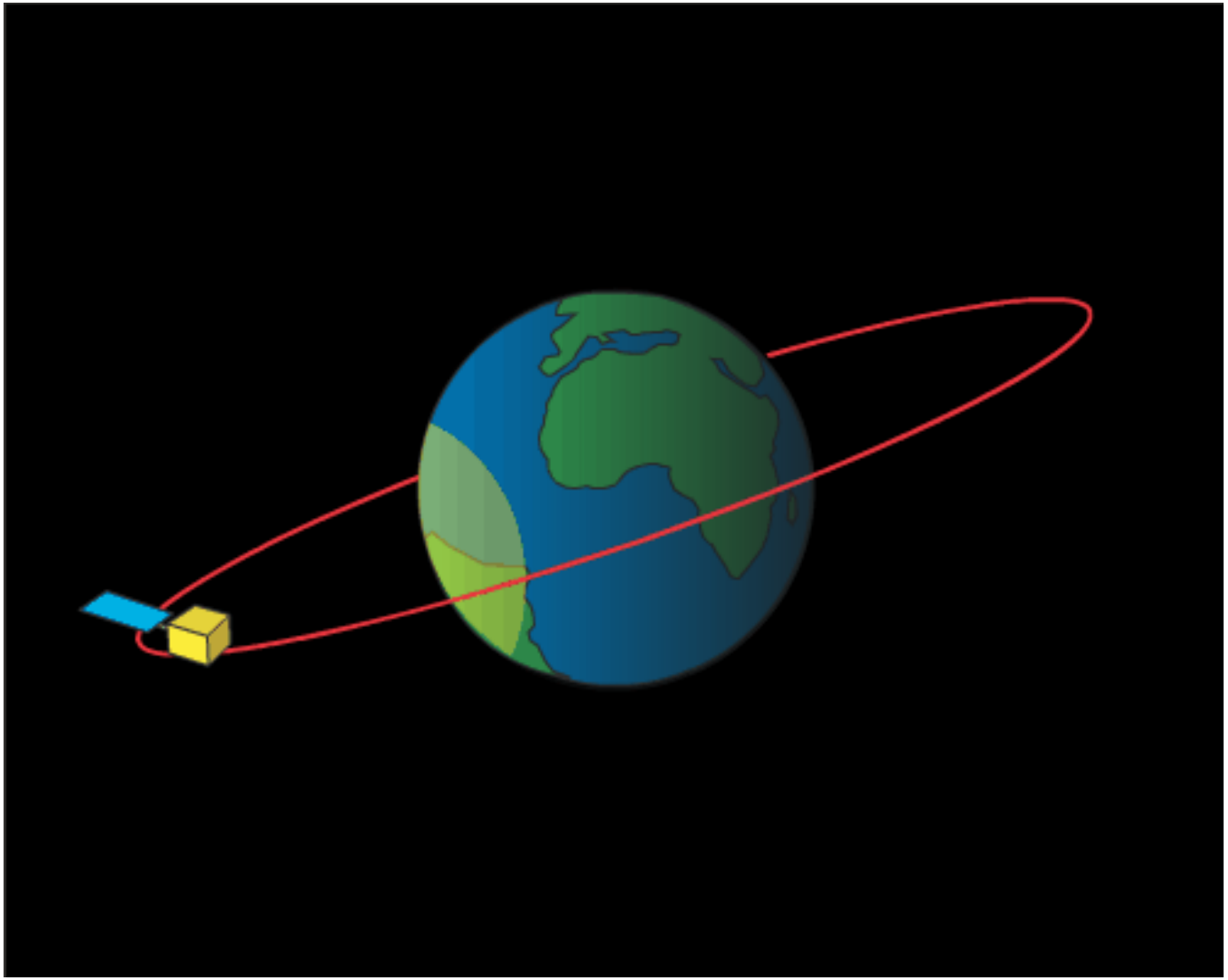
Direct Broadcast Applications Workshop

Hampton University
June 2017

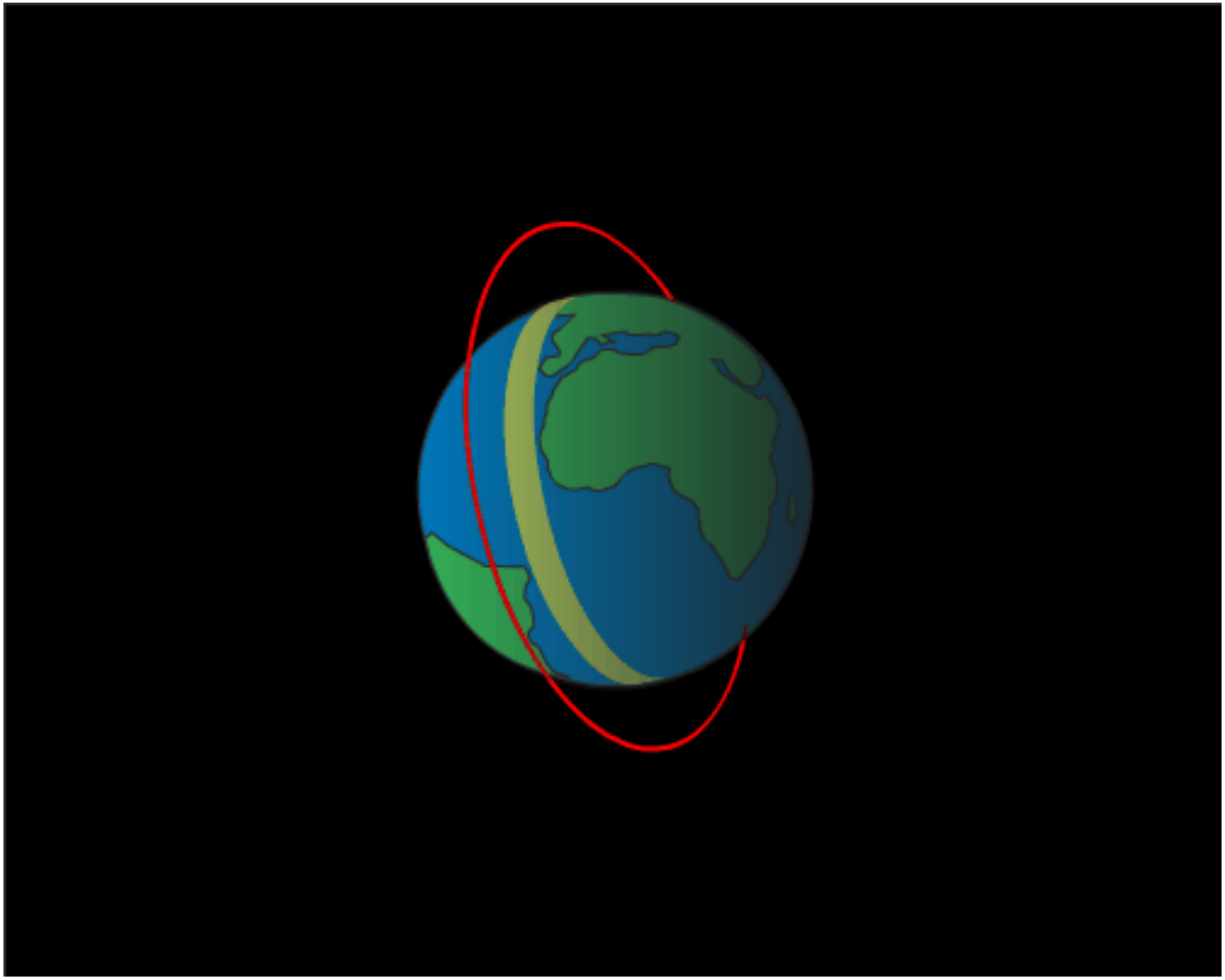
Kathleen Strabala (Liam Gumley)
Space Science and Engineering Center
University of Wisconsin-Madison

SSEC

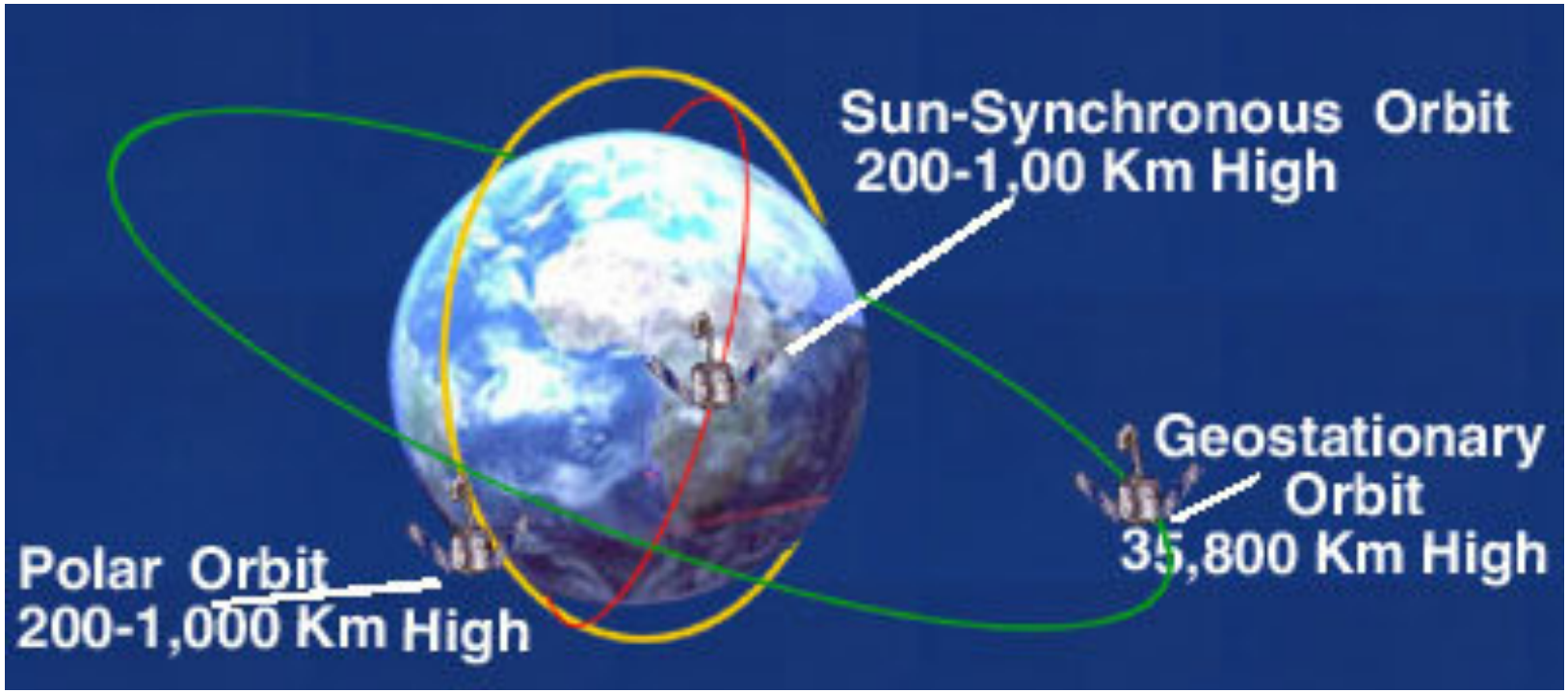
Geostationary Satellite Orbit



Polar Satellite Orbit - Low Earth Orbit (LEO)



Polar Versus Geostationary Orbit



A Sun-synchronous orbit is one where the satellite passes over any given point of the planet's surface at the same local solar time.

Terra

Launched: Dec. 18, 1999

10:30 am descending node

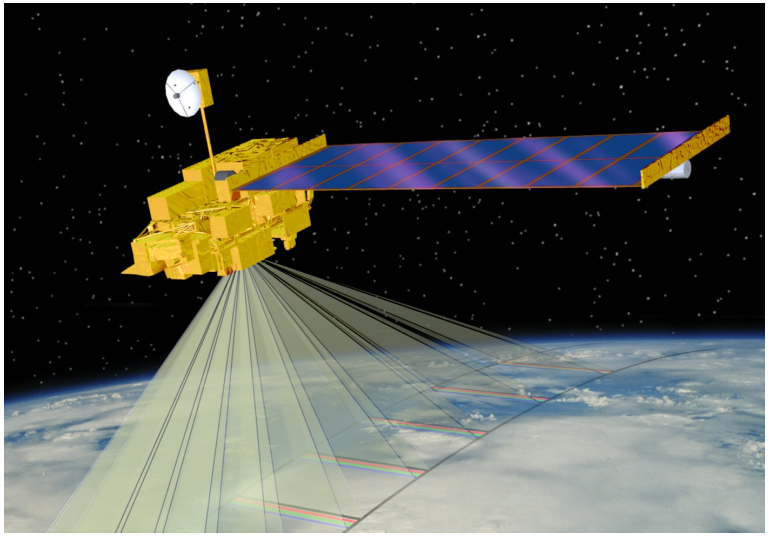
ASTER: Hi-res imager

CERES: Broadband scanner

MISR: Multi-view imager

MODIS: Multispectral imager

MOPITT: Limb sounder



Expected lifetime > 15 years

MODIS Overview

- MODIS is a scanning spectroradiometer that collects imagery in 36 spectral bands from the shortwave visible spectrum (0.41 microns) to the longwave infrared spectrum (14.2 microns).
- MODIS sensors are flying in sun-synchronous polar orbit on the NASA Terra and Aqua satellites.
- MODIS data are used for a wide variety of Atmosphere, Land, and Ocean applications.
- MODIS data are transmitted to the Earth in real-time and can be received and processed by anyone with the appropriate equipment and software.

Terra MODIS first light image, 24 Feb. 2000

Birdfoot Delta
Mississippi River
USA

Aqua

Launched: May 4, 2002

1:30 pm ascending node

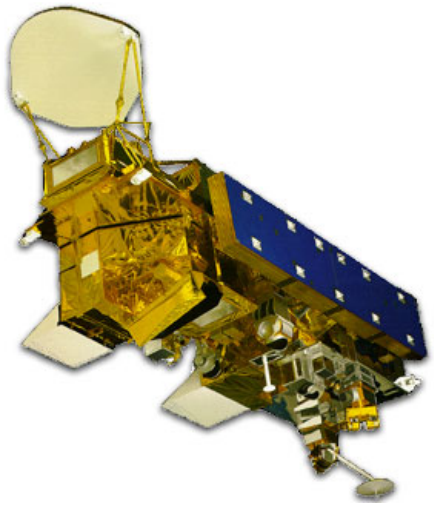
AIRS: Infrared sounder

AMSR-E: Microwave scanner

AMSU: Microwave scanner

CERES: Broadband scanner

MODIS: Multispectral imager



Expected lifetime > 15 years

Moderate Resolution Imaging Spectroradiometer (MODIS)

Heritage: AVHRR (land), SeaWIFS (ocean), HIRS (atmosphere)

Spectral coverage: 36 bands from 0.4 to 14.2 microns

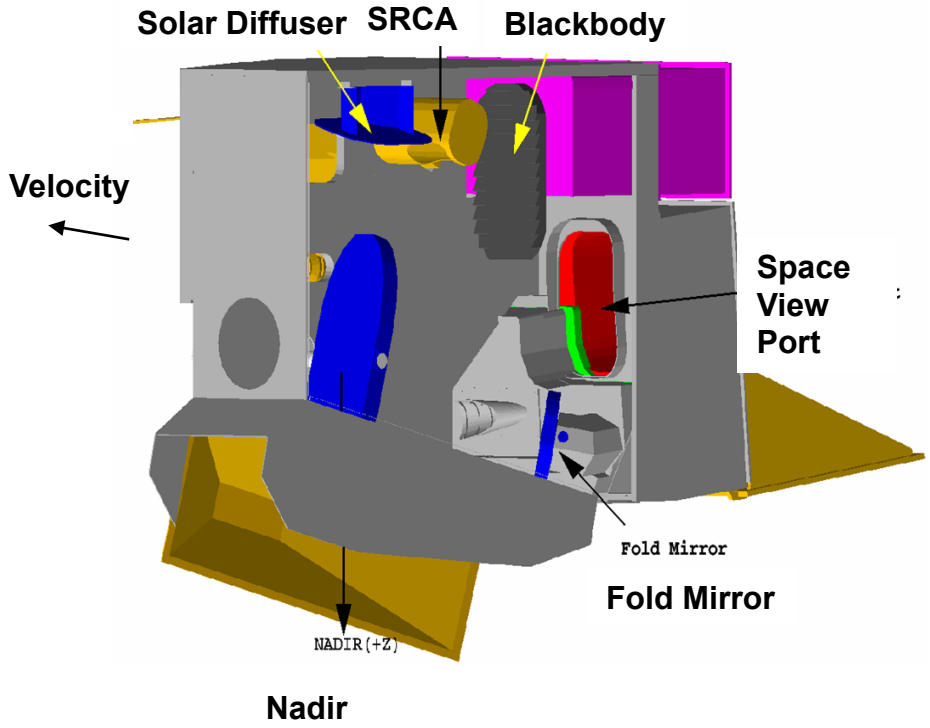
Spatial resolution: 2 bands @ 250 m; 5 @ 500 m; 29 @ 1000 m

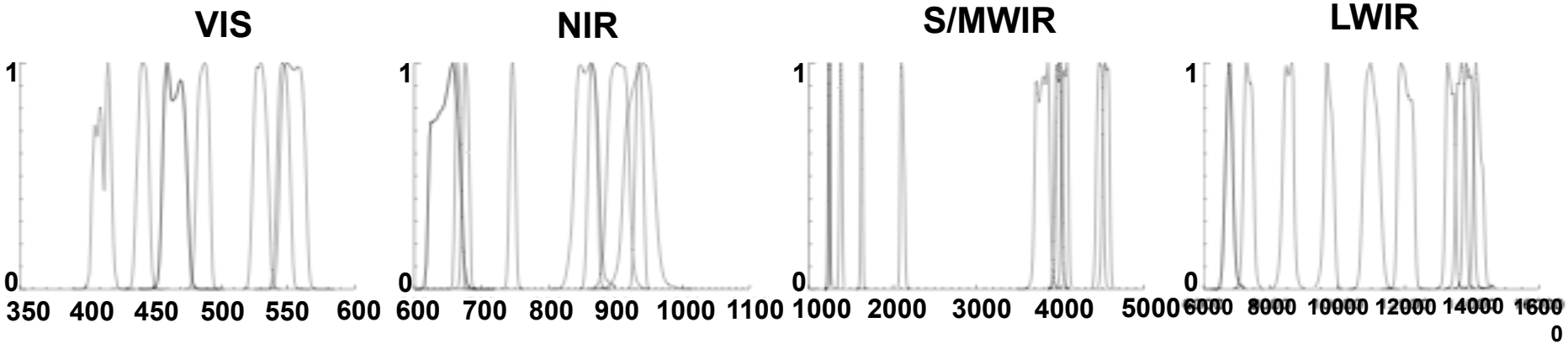
Major differences:

- Many spectral bands
- Multiple samples along track on each earth scan
- Higher spatial resolution
- On-orbit radiometric, spatial, and spectral calibration
- Improved radiometric accuracy and precision (12-bit)
- Improved geolocation accuracy
- Higher data rate requiring X-band direct broadcast

MODIS Instrument Overview

- 36 spectral bands (490 detectors) covering 0.4 to 14.5 μm
- 4 Focal Plane Arrays: Visible, Near Infrared, Shortwave Infrared, Longwave Infrared
- On-Board Calibrators: SD/SDSM, SRCA, and BB (plus space view)
- 12 bit (0-4095) dynamic range
- 2-sided Paddle Wheel Scan Mirror scans 2330 km swath in 1.47 sec
- Day data rate = 10.6 Mbps; night data rate = 3.3 Mbps





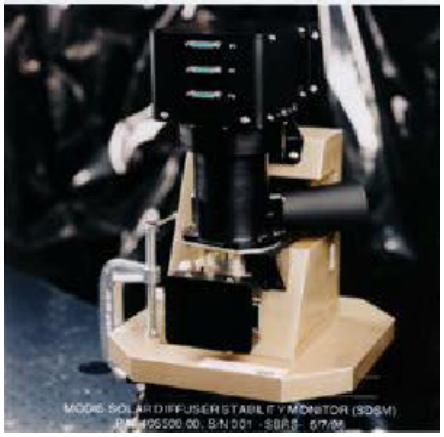
MODIS Calibration

- MODIS features multiple calibration sensors to allow precise spectral and radiometric calibration on-orbit.
- Solar Diffuser (SD) allows reflected solar bands to be calibrated on-orbit using the sun as a source.
- Solar Diffuser Stability Monitor (SDSM) monitors the reflectivity of the Solar Diffuser.
- Spectroradiometric Calibration Assembly monitors the spectral and spatial performance of reflected solar bands.
- Black Body with known emissivity and temperature provides warm calibration source for thermal infrared bands.
- Space View provides cold calibration source.

MODIS On-board Calibrators

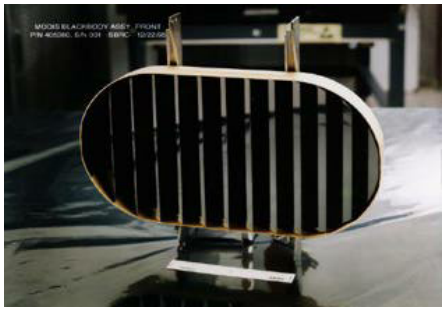
SD

SDSM

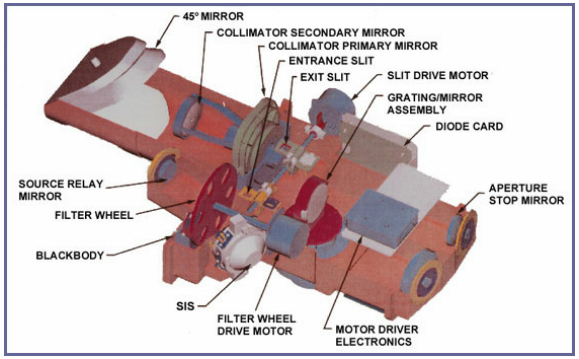


- **SD** – Solar Diffuser for RSB calibration, SD BRDF determined from pre-launch, referenced to a transfer standard calibrated at NIST
- **SDSM** – Solar Diffuser Stability Monitor for tracking SD degradation
- **BB** – Blackbody (12 thermistors reference to NIST standard) for TEB calibration. Emissivity determined from pre-launch calibration using a blackbody calibration source.
- **SRCA** – Spectroradiometric Calibration Assembly for spectral and spatial characterization

BB



SRCA



MODIS Challenges

Multiple detectors:

- Differences between detectors are noticeable
- Dead or out-of-family detectors must be handled
- Multiple samples along track introduce bowtie distortion

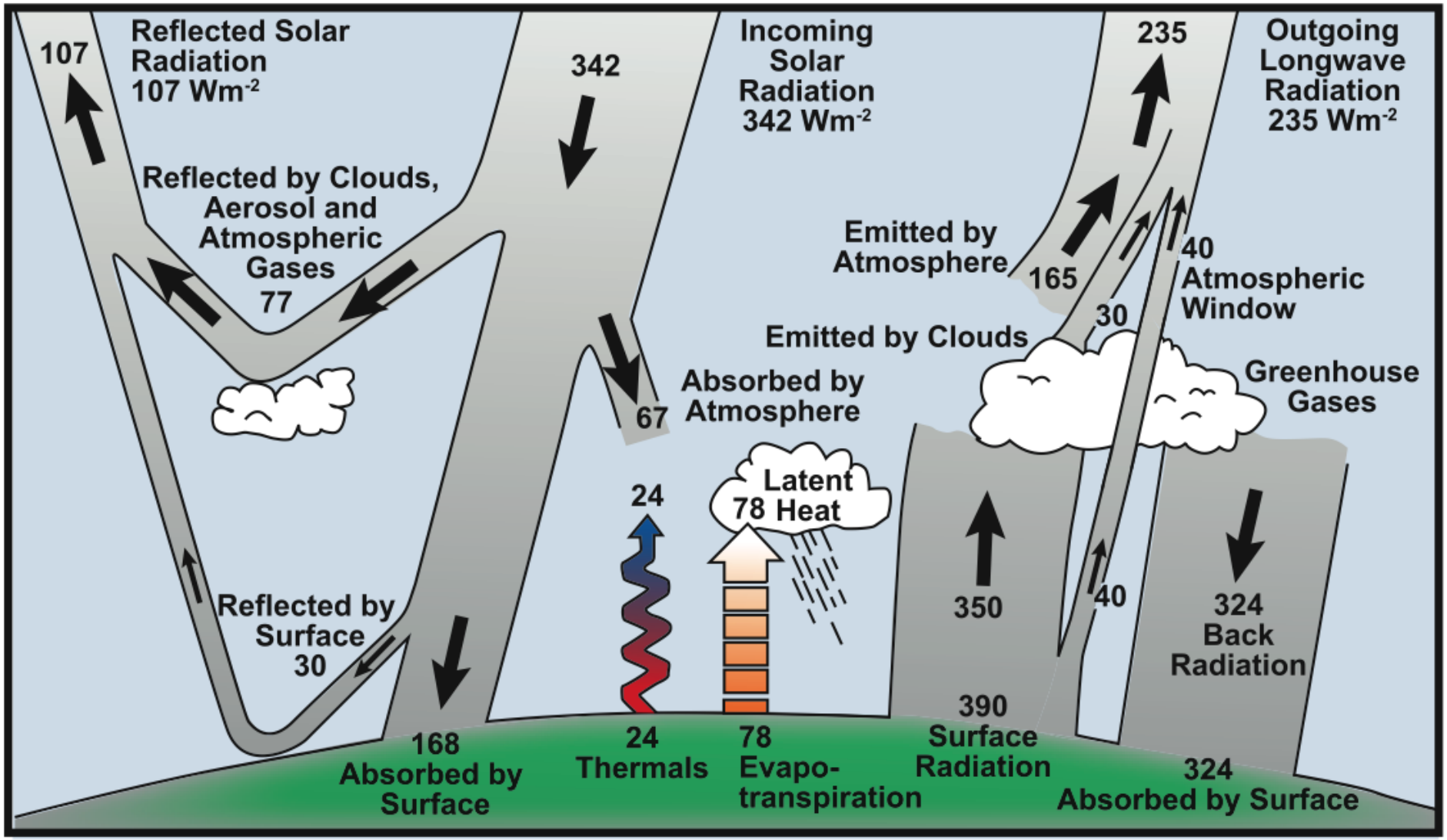
Spectral information:

- Many interdependent bands
- How to use the spectral information? (algorithm design challenge)

Data rate:

- Order of magnitude larger than heritage sensors

Global Energy Budget



From IPCC Report 2015

MODIS Reflected Solar Bands

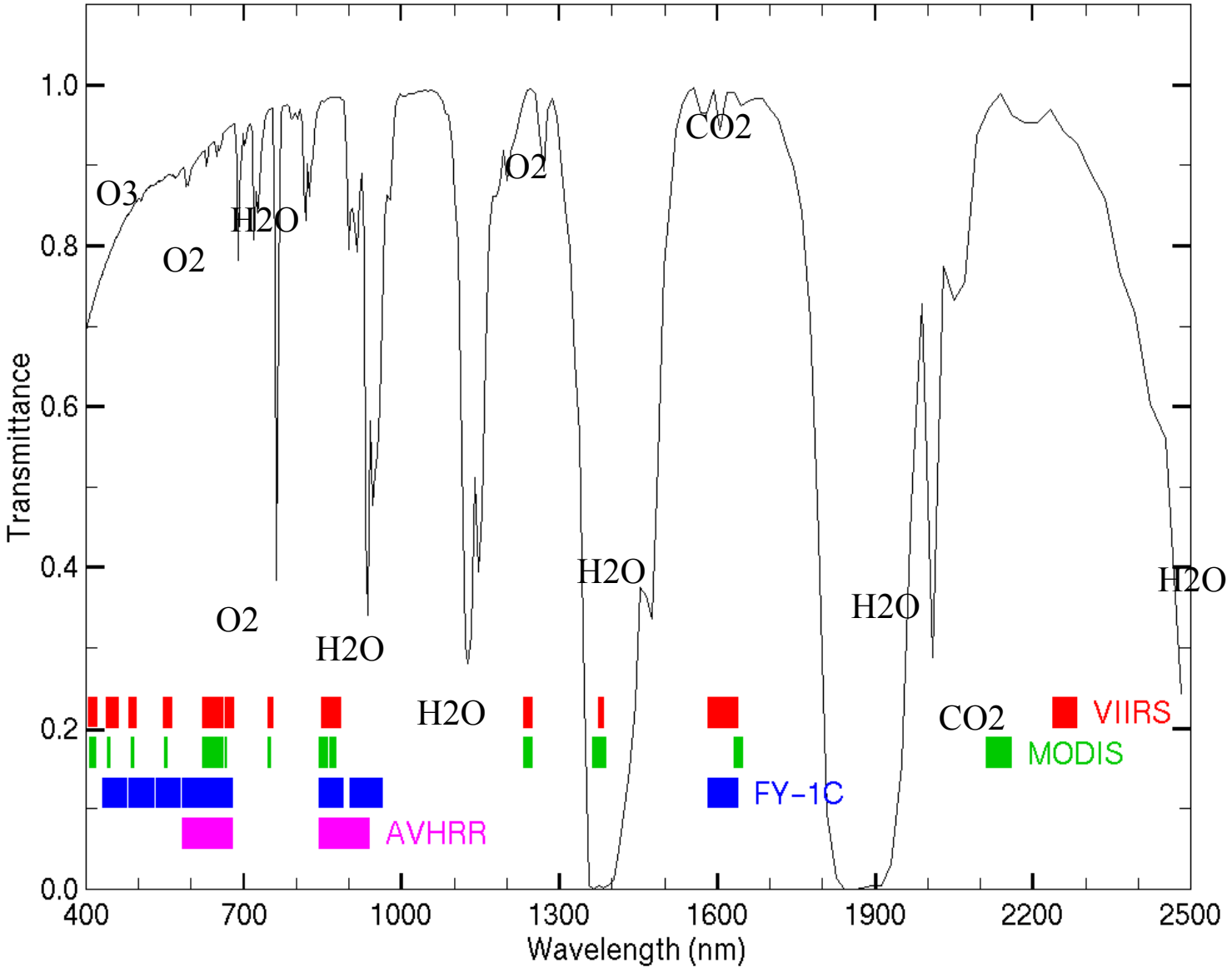
- MODIS bands 1-19 and 26 are known as reflected solar bands.
- These bands primarily sense photons reflected and scattered from the atmosphere and surface at wavelengths from 0.41 to 2.2 microns.
- The primary source of these photons is incoming solar radiation.
- Since the sun is the primary energy source for these bands, they normally operate only during the day.

MODIS Reflected Solar Bands

Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required SNR[3]	Spatial Resolution
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128	250 meters
	2	841 - 876	24.7	201	
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243	500 meters
	4	545 - 565	29.0	228	
	5	1230 - 1250	5.4	74	
	6	1628 - 1652	7.3	275	
	7	2105 - 2155	1.0	110	
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880	1000 meters
	9	438 - 448	41.9	838	
	10	483 - 493	32.1	802	
	11	526 - 536	27.9	754	
	12	546 - 556	21.0	750	
	13	662 - 672	9.5	910	
	14	673 - 683	8.7	1087	
	15	743 - 753	10.2	586	
	16	862 - 877	6.2	516	
Atmospheric Water Vapor	17	890 - 920	10.0	167	
	18	931 - 941	3.6	57	
	19	915 - 965	15.0	250	
Cirrus Clouds	26	1380			

Visible/Near-Infrared Transmittance Spectrum

MODIS bands are shown in green



MODIS Thermal Emissive Bands

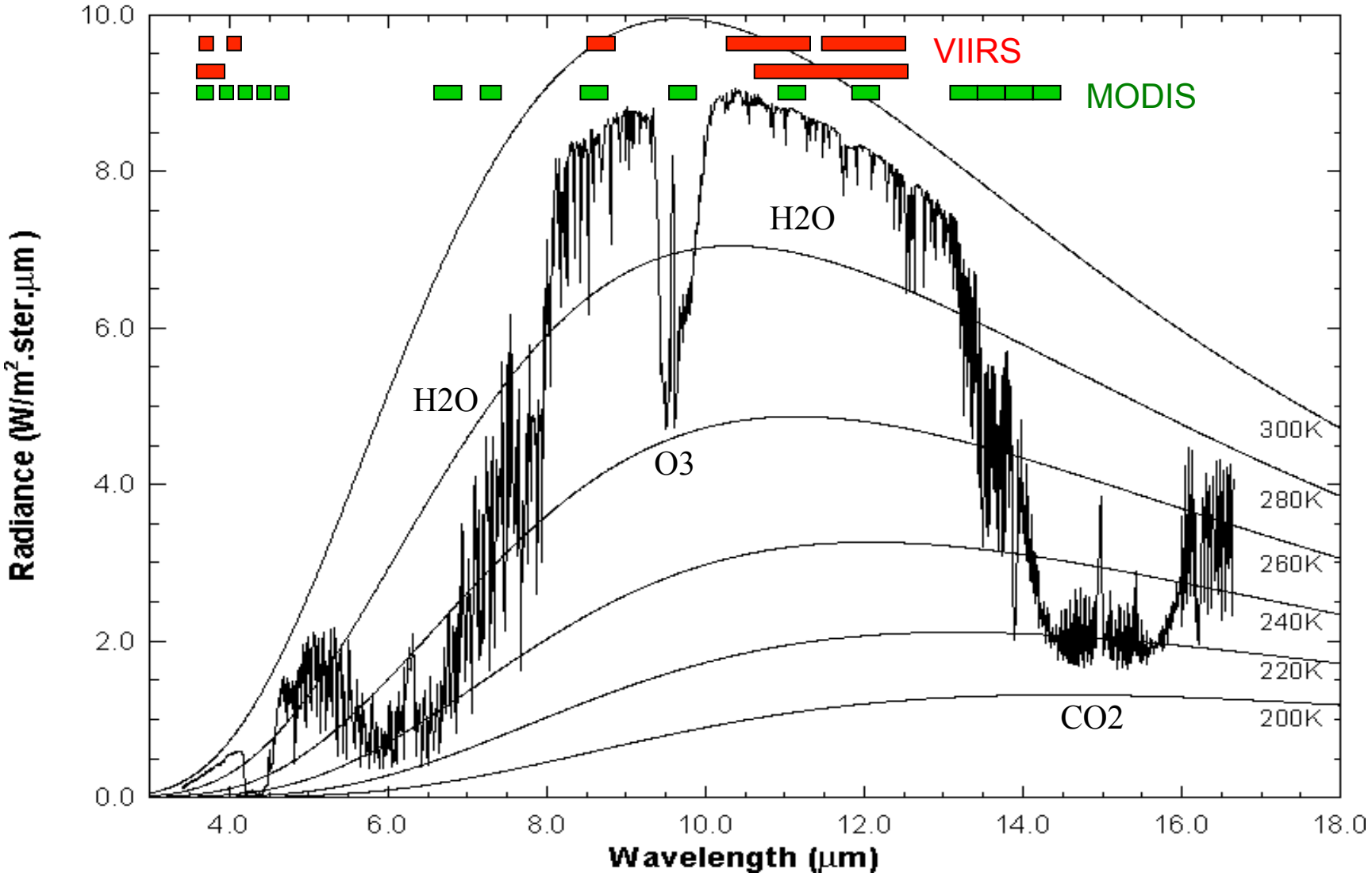
- MODIS bands 20-25 and 27-36 are known as thermal emissive bands.
- These bands primarily sense photons emitted from the atmosphere and surface at wavelengths from 3.7 to 14.2 microns.
- The primary source of these photons is emission by the atmosphere, clouds, land surface, and water surface.
- There is a small amount of reflected solar radiation at shorter wavelengths (< 5 microns)
- Since the Earth is the primary emitting source for these bands, they operate during day and night.

MODIS Thermal Emissive Bands

Primary Atmospheric Application	Band	Bandwidth[1]	$T_{typical}$ (K)	Radiance[2] at $T_{typical}$	$NE^{\Delta}T$ (K) Specification	$NE^{\Delta}T$ (K) Predicted
Surface Temperature	20	3.660-3.840	300	0.45	0.05	0.05
	22	3.929-3.989	300	0.67	0.07	0.05
	23	4.020-4.080	300	0.79	0.07	0.05
Temperature profile	24	4.433-4.498	250	0.17	0.25	0.15
	25	4.482-4.549	275	0.59	0.25	0.10
Moisture profile	27	6.535-6.895	240	1.16	0.25	0.05
	28	7.175-7.475	250	2.18	0.25	0.05
	29	8.400-8.700	300	9.58	0.05	0.05
Ozone	30	9.580-9.880	250	3.69	0.25	0.05
Surface Temperature	31	10.780-11.280	300	9.55	0.05	0.05
	32	11.770-12.270	300	8.94	0.05	0.05
Temperature profile	33	13.185-13.485	260	4.52	0.25	0.15
	34	13.485-13.785	250	3.76	0.25	0.20
	35	13.785-14.085	240	3.11	0.25	0.25
	36	14.085-14.385	220	2.08	0.35	0.35

Thermal Infrared Absorption Spectrum

MODIS bands are shown in green



MODIS Orbit and Scan Geometry

Sun synchronous polar orbit

Orbit period: 100 minutes

Terra: 10:30 am local descending at the equator

Aqua: 1:30 pm local ascending at the equator

Repeat cycle: 16 days (same as Landsat; precisely controlled)

Scan mirror: Double sided, 20.3 revolutions/minute

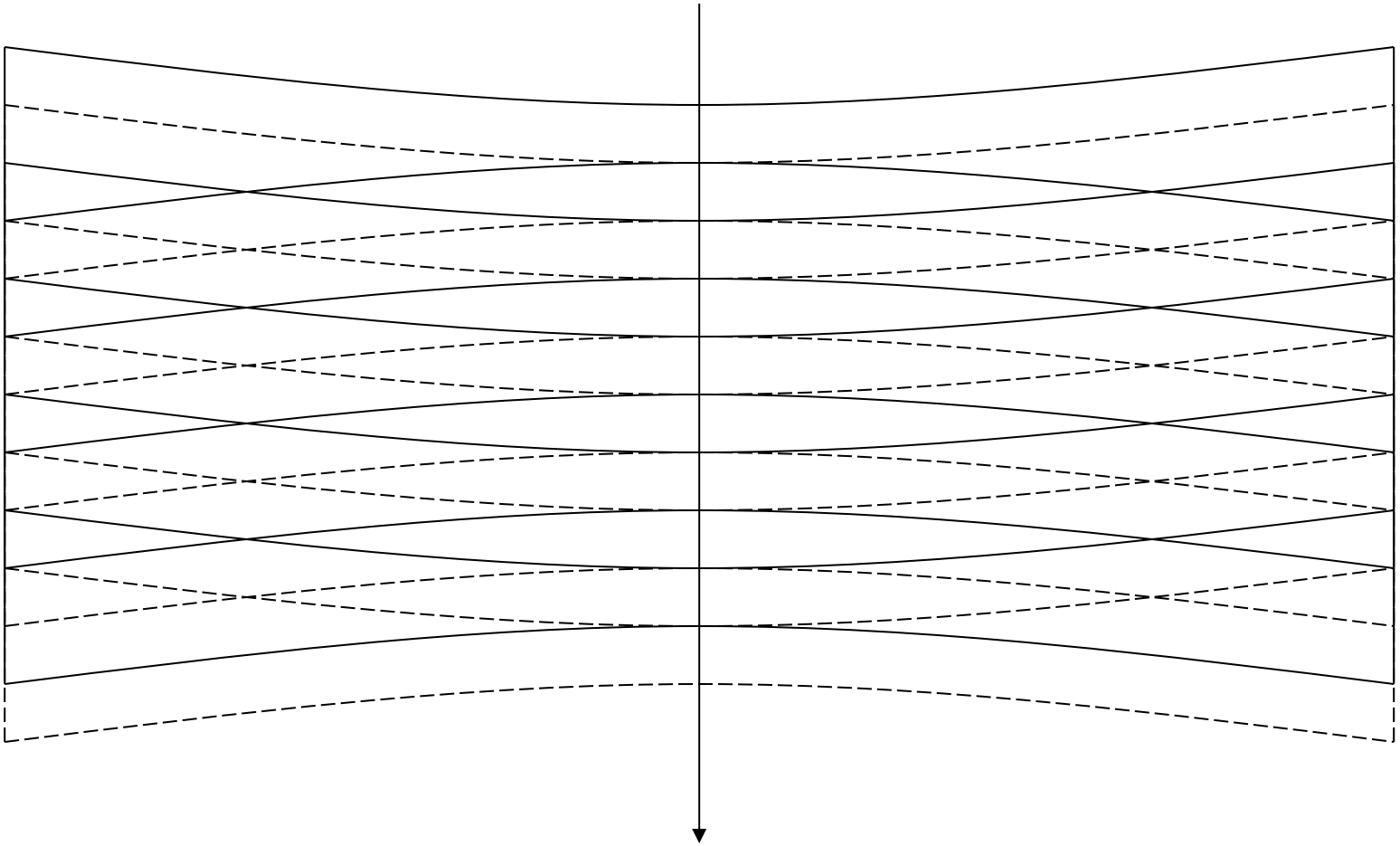
Scan rate: 1.477 scans/sec

Scan angle: +/- 55 degrees

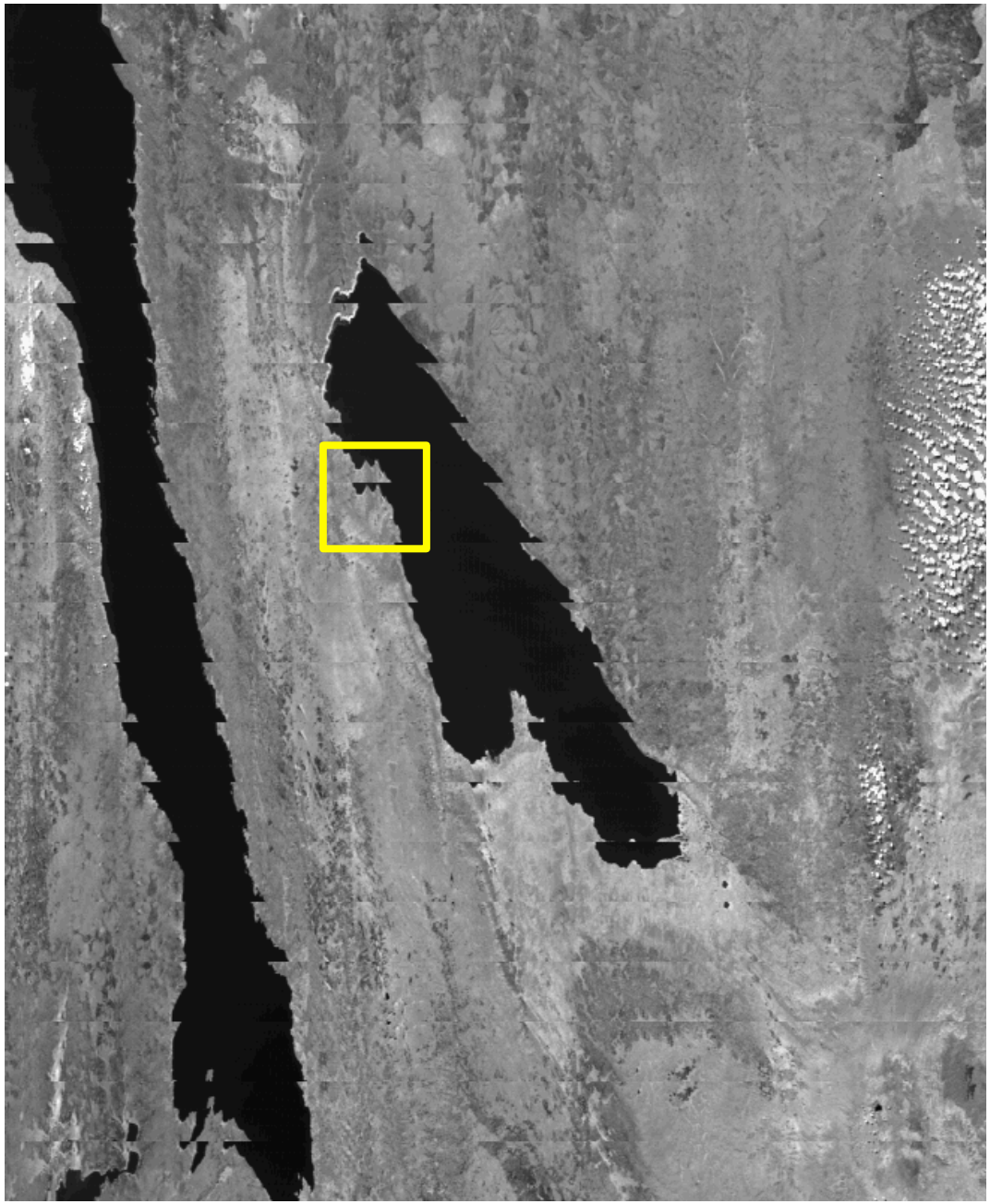
Swath width: 2330 km across track, 10 km along track

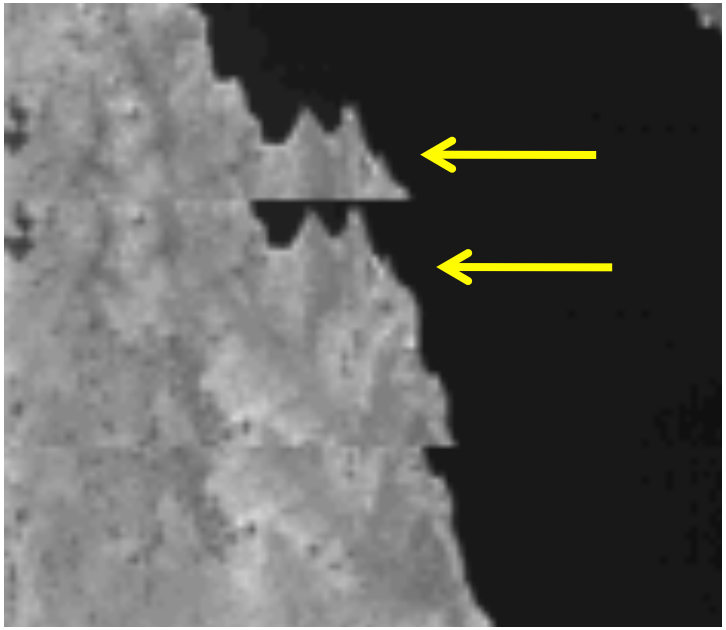
MODIS Bowtie

Consecutive “bowtie” shaped scans are contiguous at nadir, and overlap as scan angle increases…



MODIS bowtie artifacts at edge of swath





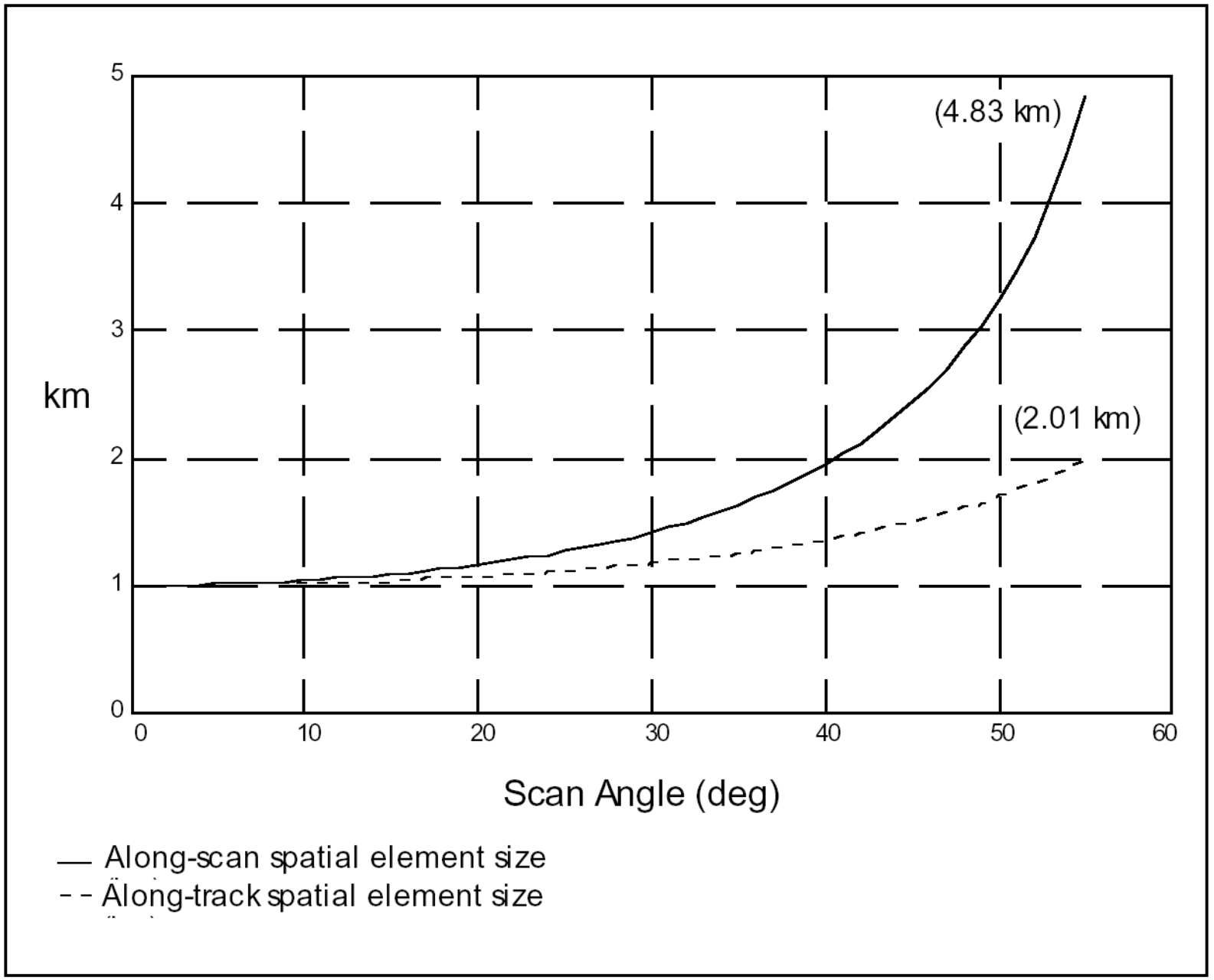
Band 2 (0.87 micron)

250 meter resolution

MODIS Bowtie Artifacts

1. Are not a ‘problem’: they are a consequence of the MODIS sensor design
2. Can be removed for visualization purposes by reprojecting the image onto a map
3. Do not affect science algorithms that run on a pixel-by-pixel basis or within one earth scan
4. Are also present on next generation of operational polar orbiting imagers (VIIRS on SNPP/JPSS-1)

Growth of MODIS 1 km pixel with scan angle

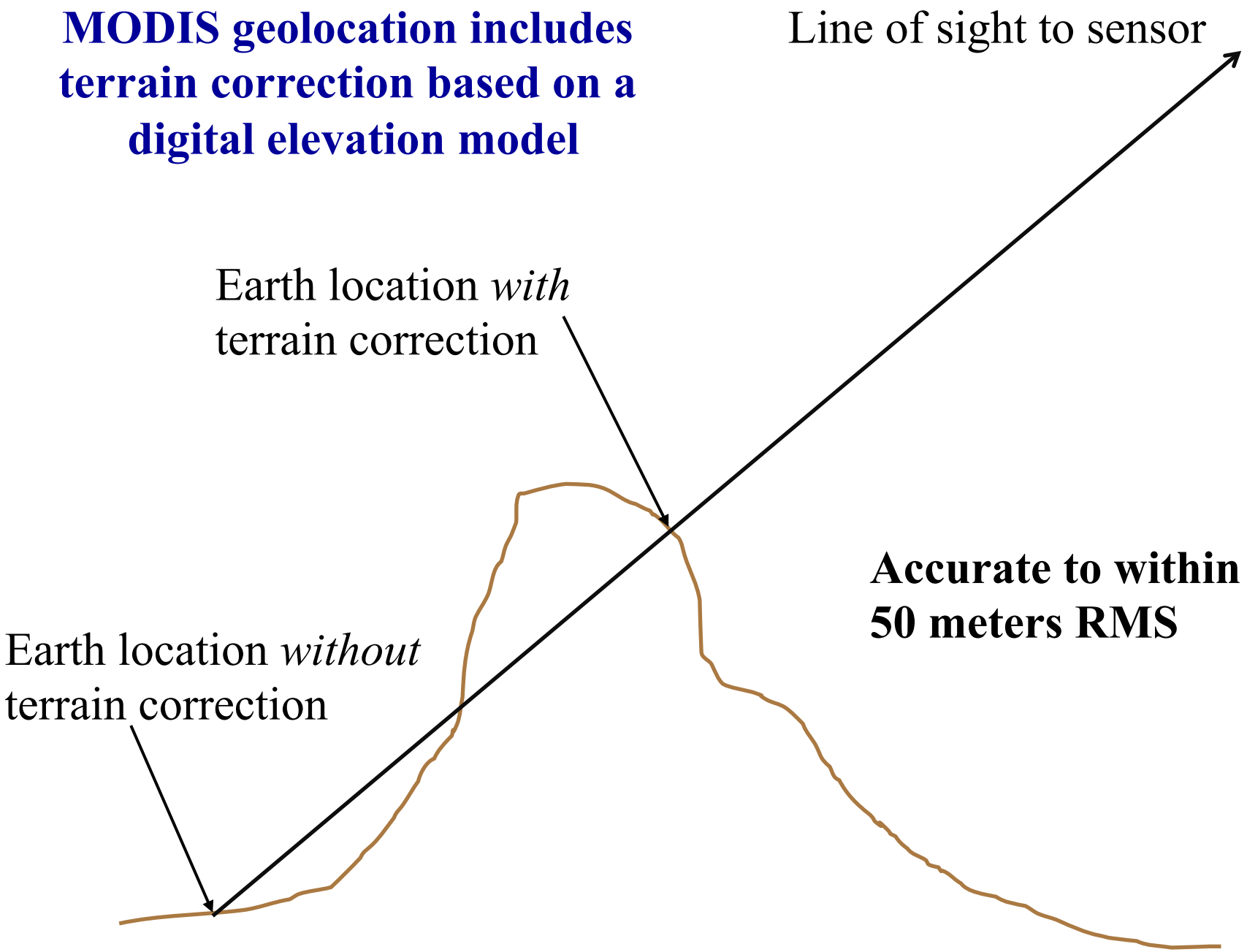


MODIS Geolocation

Earth locations computed for every 1000 meter pixel (WGS84):

- Geodetic latitude (degrees, -90S to +90N)
- Geodetic longitude (degrees, -180W to +180E)
- Sensor zenith and azimuth (degrees, pixel to sensor)
- Solar zenith and azimuth (degrees, pixel to sun)
- Terrain height above geoid (meters)
- Land/Sea mask
  - 0: Shallow Ocean
  - 1: Land
  - 2: Ocean Coastlines and Lake Shorelines
  - 3: Shallow Inland Water
  - 4: Ephemeral (intermittent) Water
  - 5: Deep Inland Water
  - 6: Moderate or Continental Ocean
  - 7: Deep Ocean

MODIS geolocation includes terrain correction based on a digital elevation model



MODIS Science Team

- MODIS Characterization Team
- MODIS Ocean Team
- MODIS Land Team
- MODIS Atmosphere Team

Now merging into discipline teams – cross platform

MODIS Ocean Products and Applications

(MODIS Ocean Team)

MODIS Ocean Color Products

Rrs_412	short	sr^-1	Remote sensing reflectance at 412 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_443	short	sr^-1	Remote sensing reflectance at 443 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_469	short	sr^-1	Remote sensing reflectance at 469 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_488	short	sr^-1	Remote sensing reflectance at 488 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_531	short	sr^-1	Remote sensing reflectance at 531 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_547	short	sr^-1	Remote sensing reflectance at 547 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_555	short	sr^-1	Remote sensing reflectance at 555 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_645	short	sr^-1	Remote sensing reflectance at 645 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_667	short	sr^-1	Remote sensing reflectance at 667 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_678	float	sr^-1	Remote sensing reflectance at 678 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
chlor_a	float	mg m^-3	Chlorophyll Concentration, OCI Algorithm	mass concentration chlorophyll concentration in sea water	6
chl_ocx	short	mg m^-3	Chlorophyll Concentration, OC3 Algorithm	mass concentration chlorophyll concentration in sea water	7

MODIS Ocean Color Derived Products

Kd_490	short	m^-1	Diffuse attenuation coefficient at 490 nm, KD2 algorithm	diffuse attenuation coefficient of downwelling radiative flux in sea water	N/A
pic	short	mol m^-3	Calcite Concentration, Balch and Gordon	mole concentration of particulate inorganic carbon in sea water	8
poc	short	mg m^-3	Particulate Organic Carbon, D. Stramski, 2007 (443/555 version)	mole concentration of particulate organic carbon in sea water	9
ipar	short	einstein m^-2 s^-1	Instantaneous Photosynthetically Available Radiation	downwelling photosynthetic photon radiance in sea water	N/A
nflh	short	W m^-2 um^-1 sr^-1	Normalized Fluorescence Line Height		10
par	int	einstein m^-2 day^-1	Photosynthetically Available Radiation, R. Frouin	surface downwelling photosynthetic photon flux in air	11

Sea Surface Temperature

MODIS Land/Surface Products and Applications

(MODIS Land Team)

MODIS Land Products

MOD 09 - Land Surface Reflectance
MOD 10 - Snow Cover
MOD 11 - Land Surface Temperature & Emissivity
MOD 12 - Land Cover/Land Cover Change
MOD 13 - Gridded Vegetation Indices (NDVI & EVI)
MOD 14 - Thermal Anomalies (Fires)
MOD 15 - Leaf Area Index & FPAR
MOD 16 - Evapotranspiration
MOD 17 - Net Photosynthesis and Primary Productivity
MOD 29 - Sea Ice Cover
MOD 43 - Nadir BRDF Adjusted Reflectance
MOD 44 - Vegetation Cover Conversion

MODIS Atmosphere Products and Applications

(MODIS Atmosphere Team)

MODIS Atmosphere Products

MOD04 Aerosol Product
MOD05 Total Precipitable Water – Daytime
MOD06 Cloud Product
MOD07 Atmospheric Profiles
MOD35 Cloud Mask

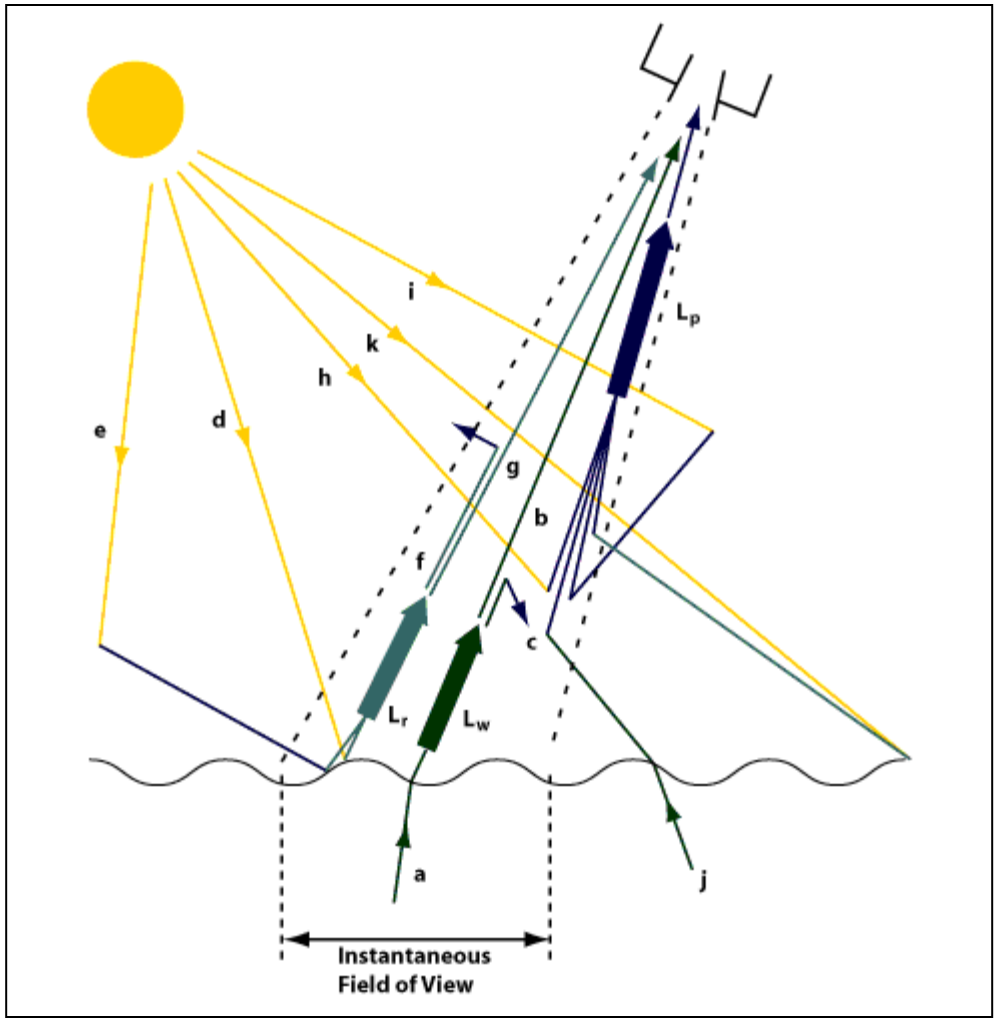
MODIS Atmosphere Gridded Product

End of Part 1

MODIS Ocean Color

- Ocean color products are derived from MODIS bands 8 to 16 (0.41 – 0.87 microns).
- These bands have high gain settings in order to sense the optical effects of chlorophyll and particulates within the water.
- At blue and green wavelengths (0.41 – 0.55 microns), the signal from the ocean surface is usually less than 10% of the signal reaching the sensor in space.
- The remaining 90% of the signal comes from other sources including scattering from the atmosphere and reflection from the ocean surface.
- Removal of the atmosphere signal is known as atmospheric corrrection.

Atmospheric correction is critical for ocean color



L_w – only 5% of signal reaching satellite: rest due to L_p

L_p components: molecular (Rayleigh) & aerosols

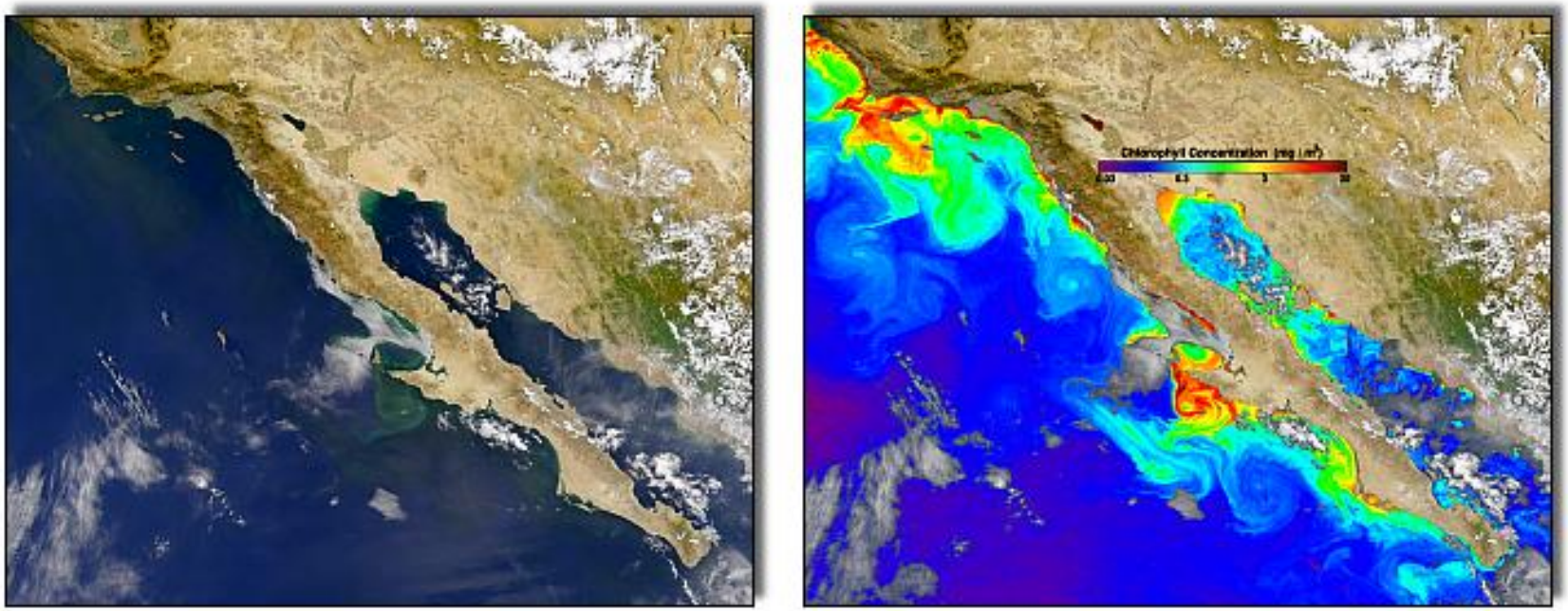
MODIS Ocean Color Products

Rrs_412	short	sr^-1	Remote sensing reflectance at 412 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_443	short	sr^-1	Remote sensing reflectance at 443 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_469	short	sr^-1	Remote sensing reflectance at 469 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_488	short	sr^-1	Remote sensing reflectance at 488 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_531	short	sr^-1	Remote sensing reflectance at 531 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_547	short	sr^-1	Remote sensing reflectance at 547 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_555	short	sr^-1	Remote sensing reflectance at 555 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_645	short	sr^-1	Remote sensing reflectance at 645 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_667	short	sr^-1	Remote sensing reflectance at 667 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
Rrs_678	float	sr^-1	Remote sensing reflectance at 678 nm	surface ratio of upwelling radiance emerging from sea water to downwelling radiative flux in air	N/A
chlor_a	float	mg m^-3	Chlorophyll Concentration, OCI Algorithm	mass concentration chlorophyll concentration in sea water	6
chl_ocx	short	mg m^-3	Chlorophyll Concentration, OC3 Algorithm	mass concentration chlorophyll concentration in sea water	7

MODIS Ocean Color Derived Products

Kd_490	short	m^-1	Diffuse attenuation coefficient at 490 nm, KD2 algorithm	diffuse attenuation coefficient of downwelling radiative flux in sea water	N/A
pic	short	mol m^-3	Calcite Concentration, Balch and Gordon	mole concentration of particulate inorganic carbon in sea water	8
poc	short	mg m^-3	Particulate Organic Carbon, D. Stramski, 2007 (443/555 version)	mole concentration of particulate organic carbon in sea water	9
ipar	short	einstein m^-2 s^-1	Instantaneous Photosynthetically Available Radiation	downwelling photosynthetic photon radiance in sea water	N/A
nflh	short	W m^-2 um^-1 sr^-1	Normalized Fluorescence Line Height		10
par	int	einstein m^-2 day^-1	Photosynthetically Available Radiation, R. Frouin	surface downwelling photosynthetic photon flux in air	11

Chlorophyll

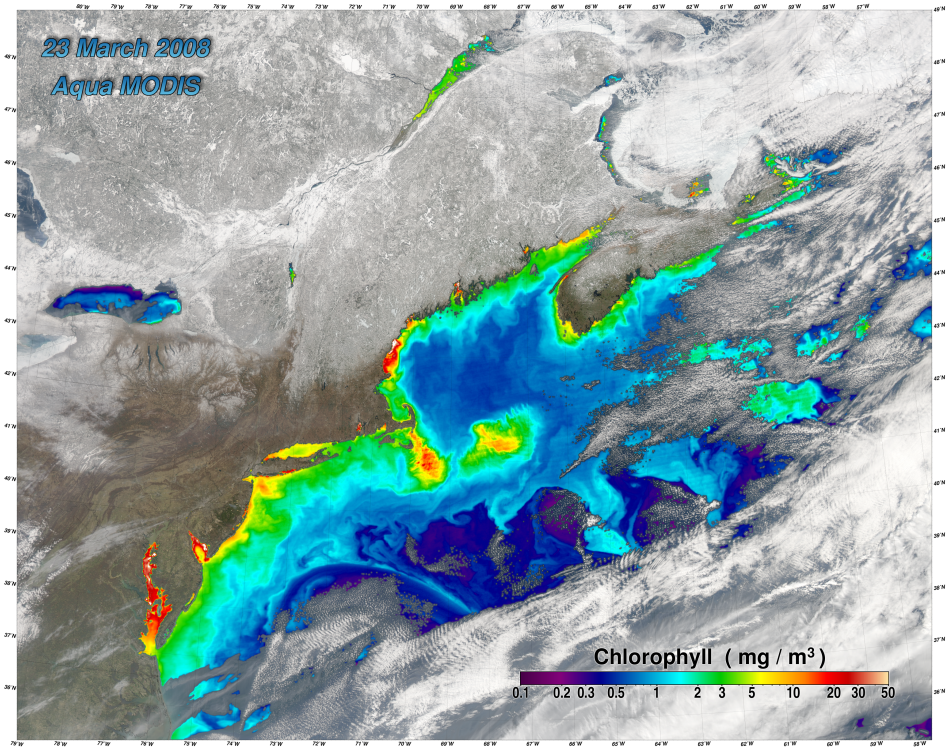


August 10, 2003

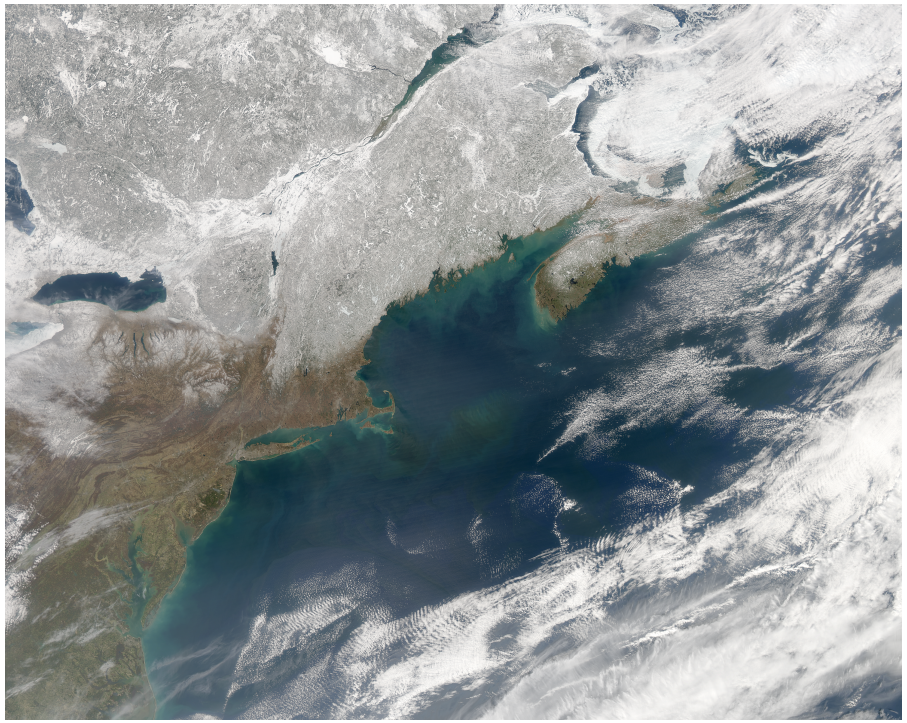
Strong absorption of the blue light by phytoplankton in chlorophyll-rich waters results in low water-leaving radiance in the blue bands.

Dominant band shifts from blue to green with increasing chlorophyll concentration.

March 23, 2008 MODIS Aqua
Northeast USA and Canada



Chlorophyll concentration

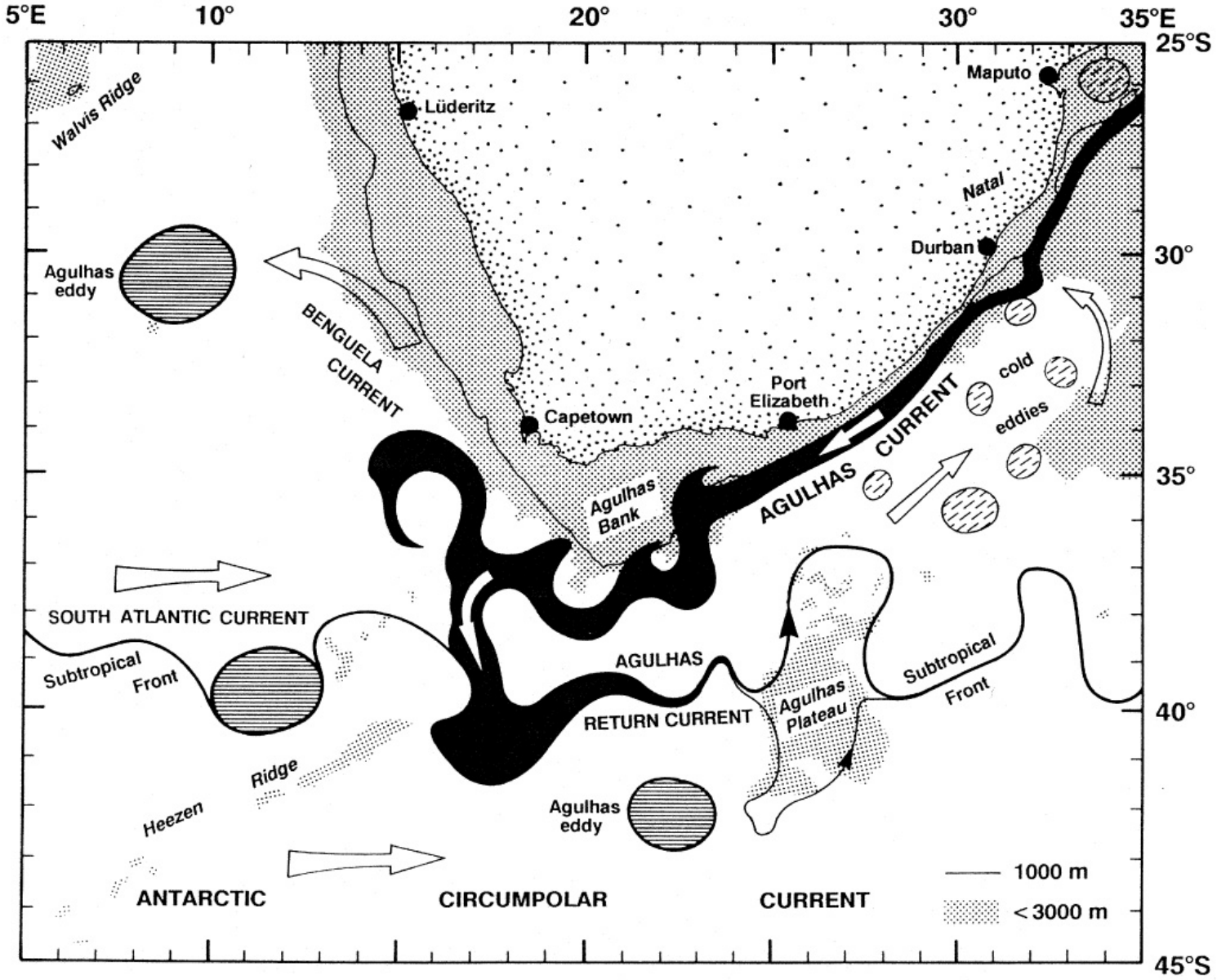


True color

MODIS Ocean Temperature

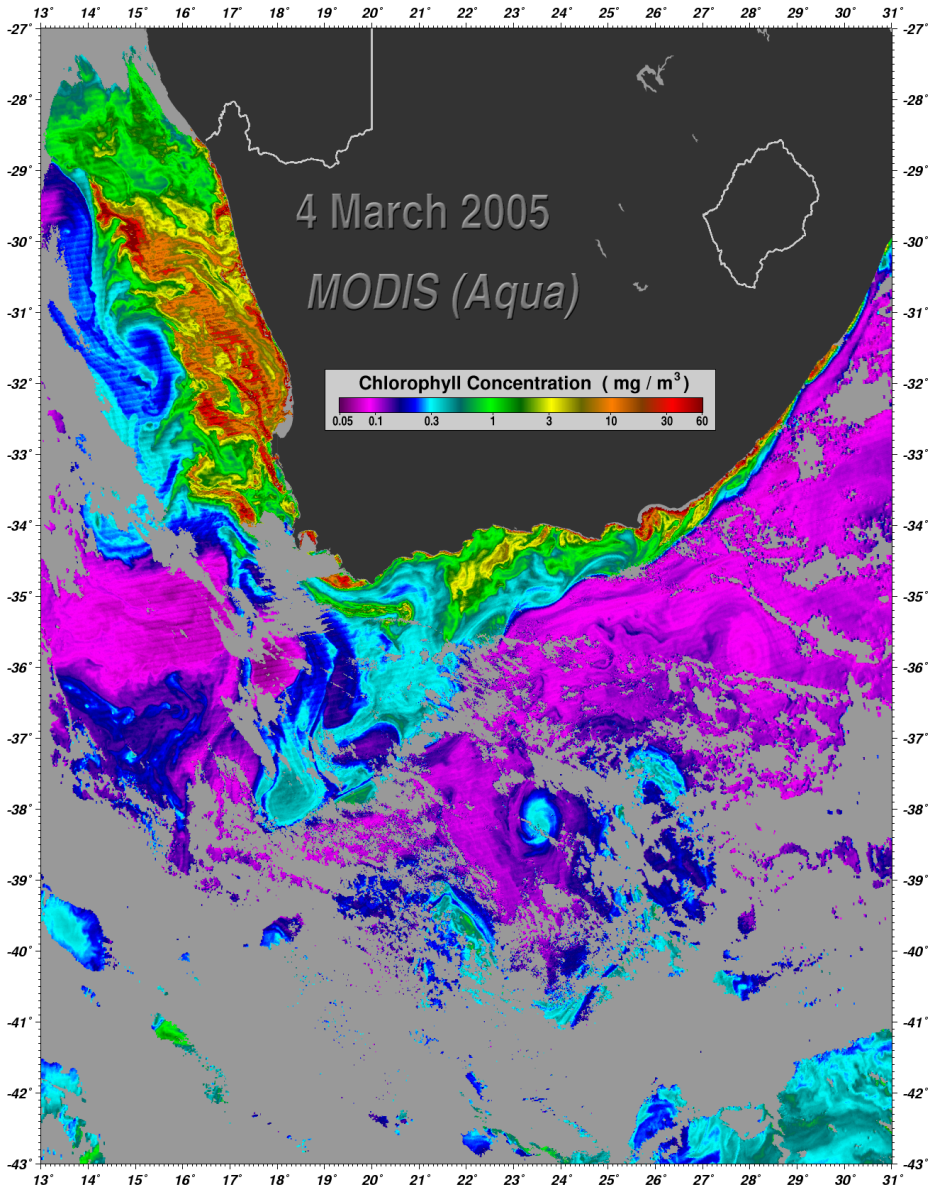
- Sea surface temperature products are derived from MODIS bands 20, 22, 29, 31, and 32 (thermal infrared).
- These bands sense the thermal emission from the ocean surface layer (in the absence of clouds).
- Bands 31 and 32 (11 and 12 microns) are used day and night since there is very little reflected solar radiation at these wavelengths.
- Bands 20 and 22 (3.7 and 3.9 microns) are only used at night because of solar reflection.
- Corrections for water vapor absorption are derived from band differences.

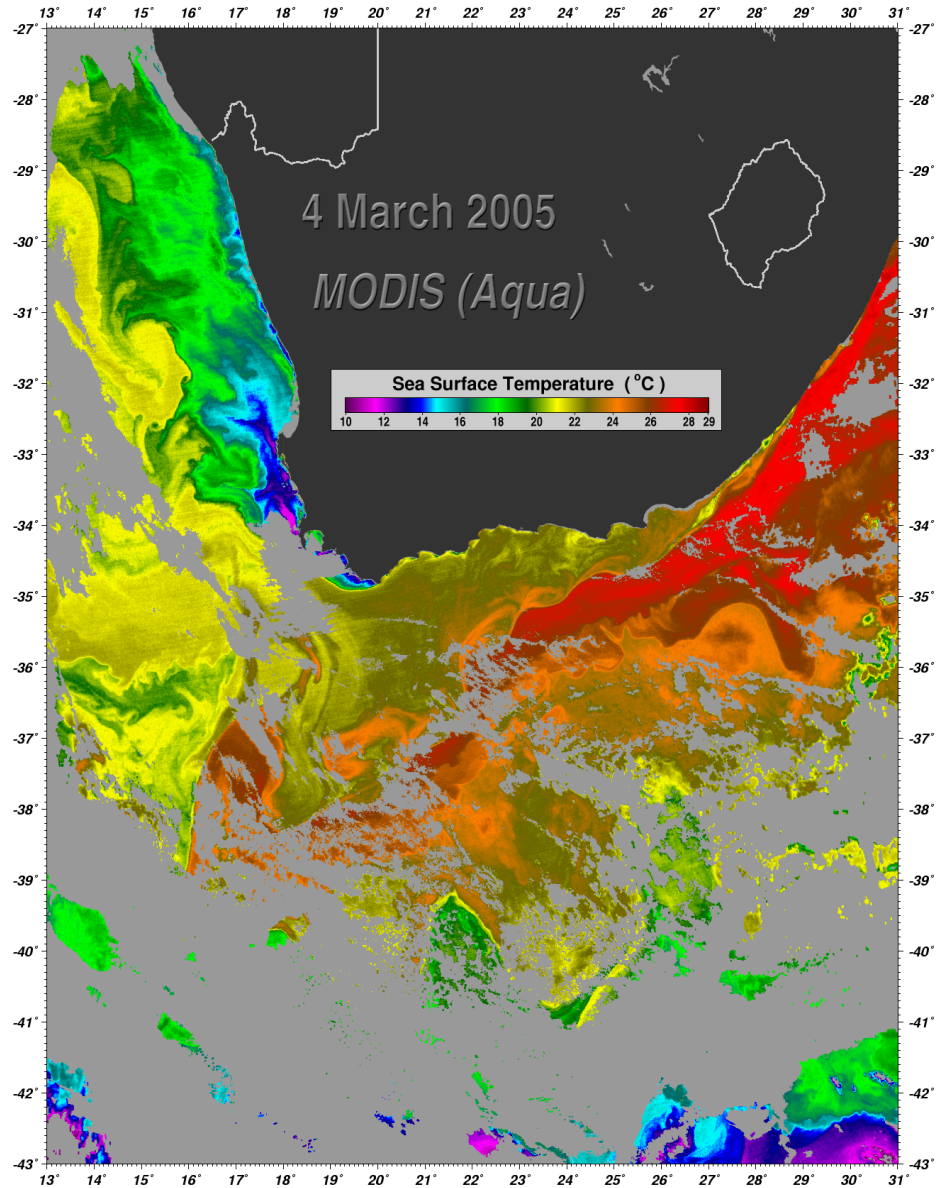
Ocean currents near Southern Africa



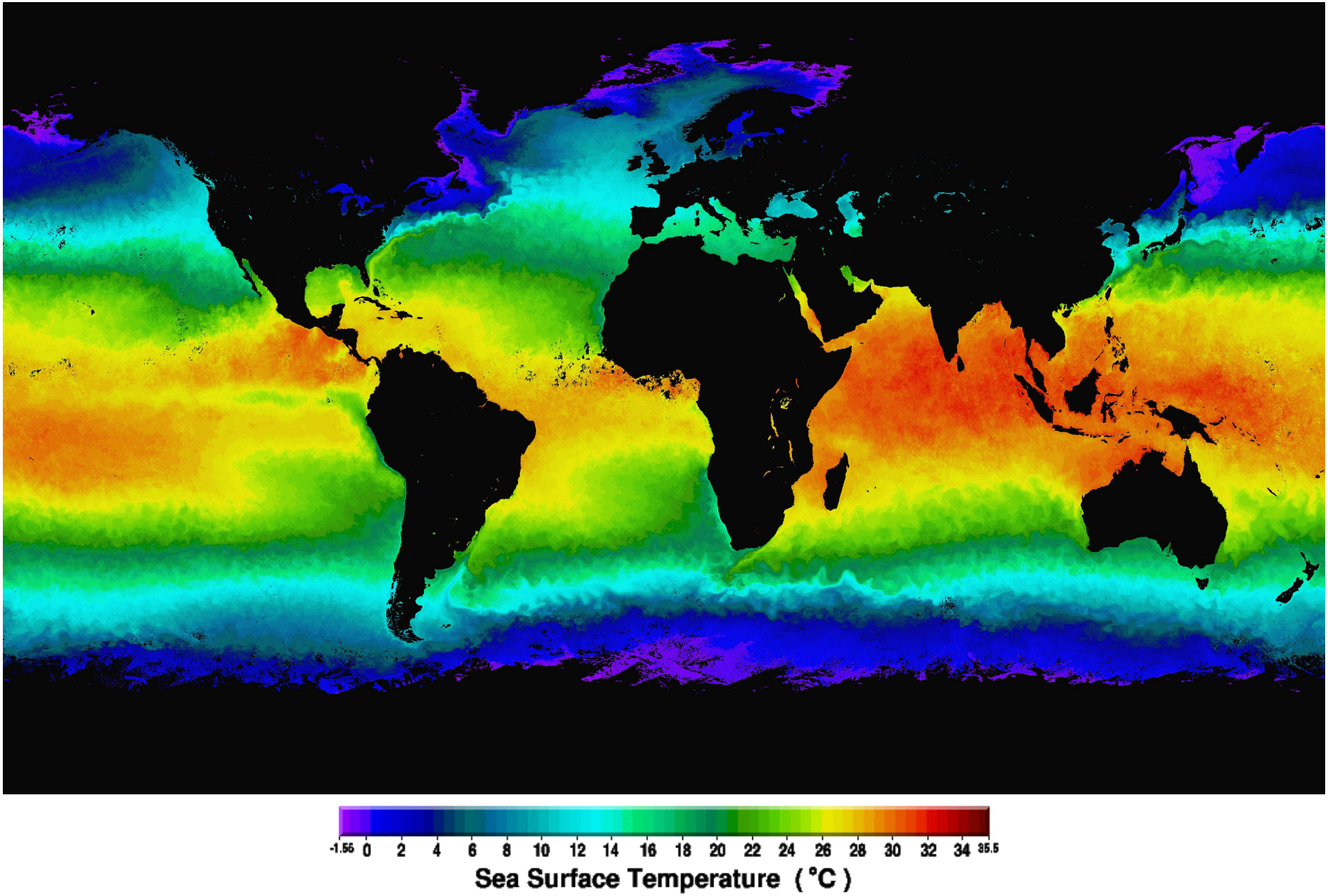
Peterson and Stramma, 1991

Agulhas & Benguela Currents

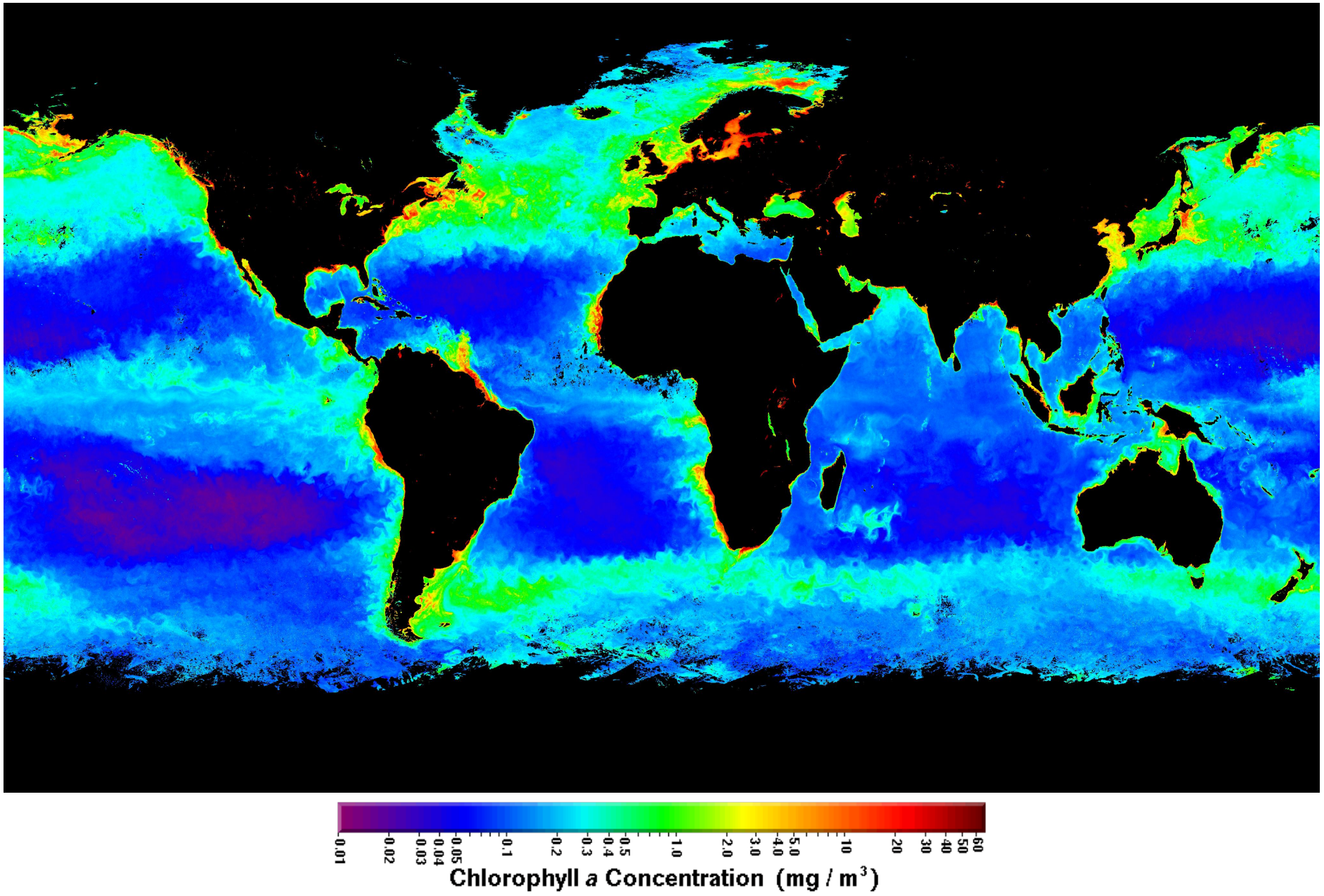




Aqua MODIS Sea Surface Temperature, April 2004



Aqua MODIS Chlorophyll Concentration, April 2004



MODIS Land/Surface Products and Applications

(MODIS Land Team)

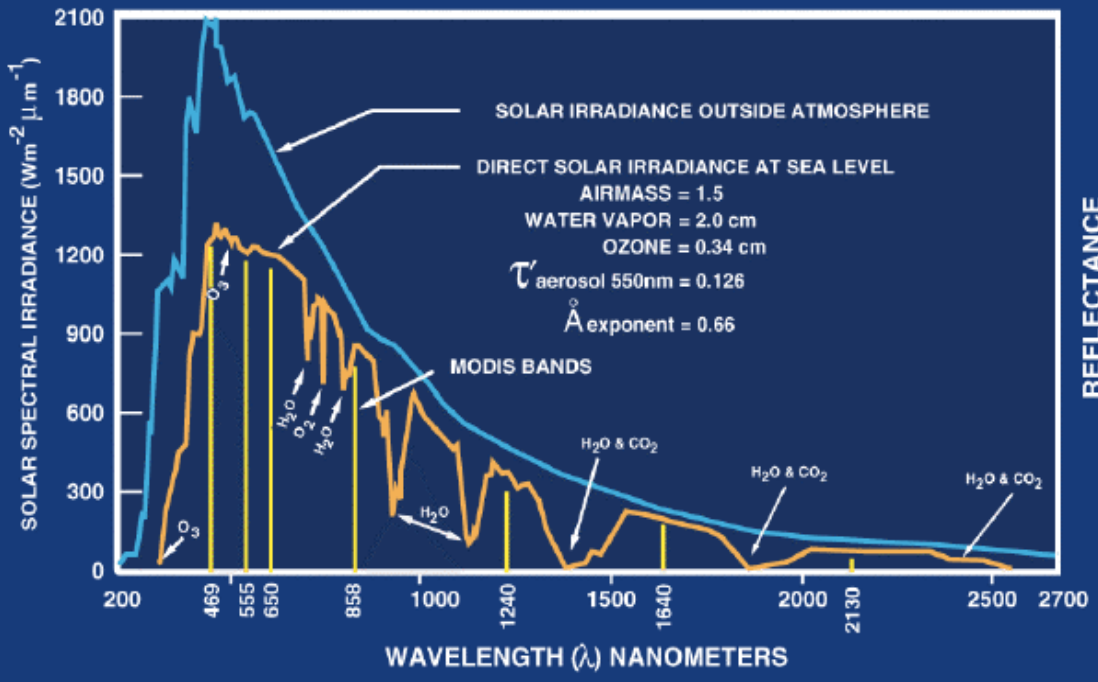
MODIS Land Products

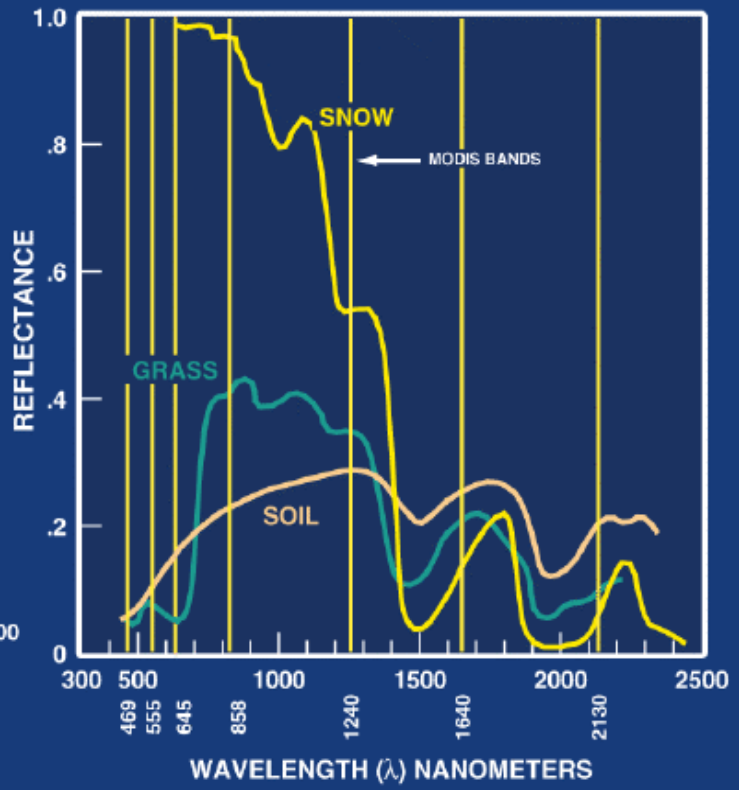
MOD 09 - Land Surface Reflectance
MOD 10 - Snow Cover
MOD 11 - Land Surface Temperature & Emissivity
MOD 12 - Land Cover/Land Cover Change
MOD 13 - Gridded Vegetation Indices (NDVI & EVI)
MOD 14 - Thermal Anomalies (Fires)
MOD 15 - Leaf Area Index & FPAR
MOD 16 - Evapotranspiration
MOD 17 - Net Photosynthesis and Primary Productivity
MOD 29 - Sea Ice Cover
MOD 43 - Nadir BRDF Adjusted Reflectance
MOD 44 - Vegetation Cover Conversion

MODIS Vegetation Products

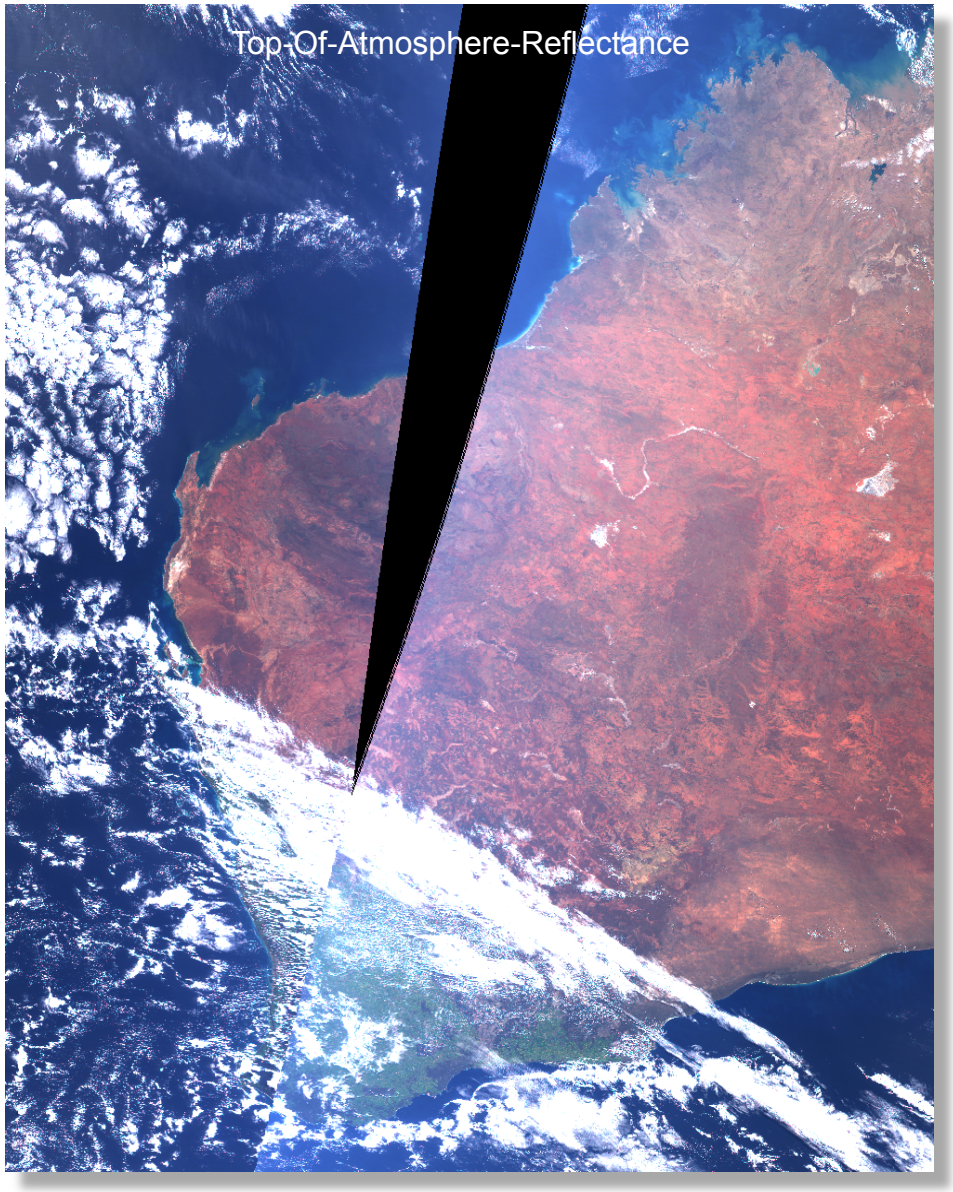
- Surface vegetation products are derived from MODIS bands 1 and 2 (0.67, 0.87 microns).
- These bands have the highest spatial resolution of any MODIS band (250 meters).
- At 0.67 microns, vegetation is an absorber of incoming photons. At 0.87 microns, vegetation is a reflector of incoming photons. The ratio of reflectance between these bands allows vegetation properties to be derived
- Removal of the atmosphere signal and of surface directional effects is important for long term changes to be resolved.

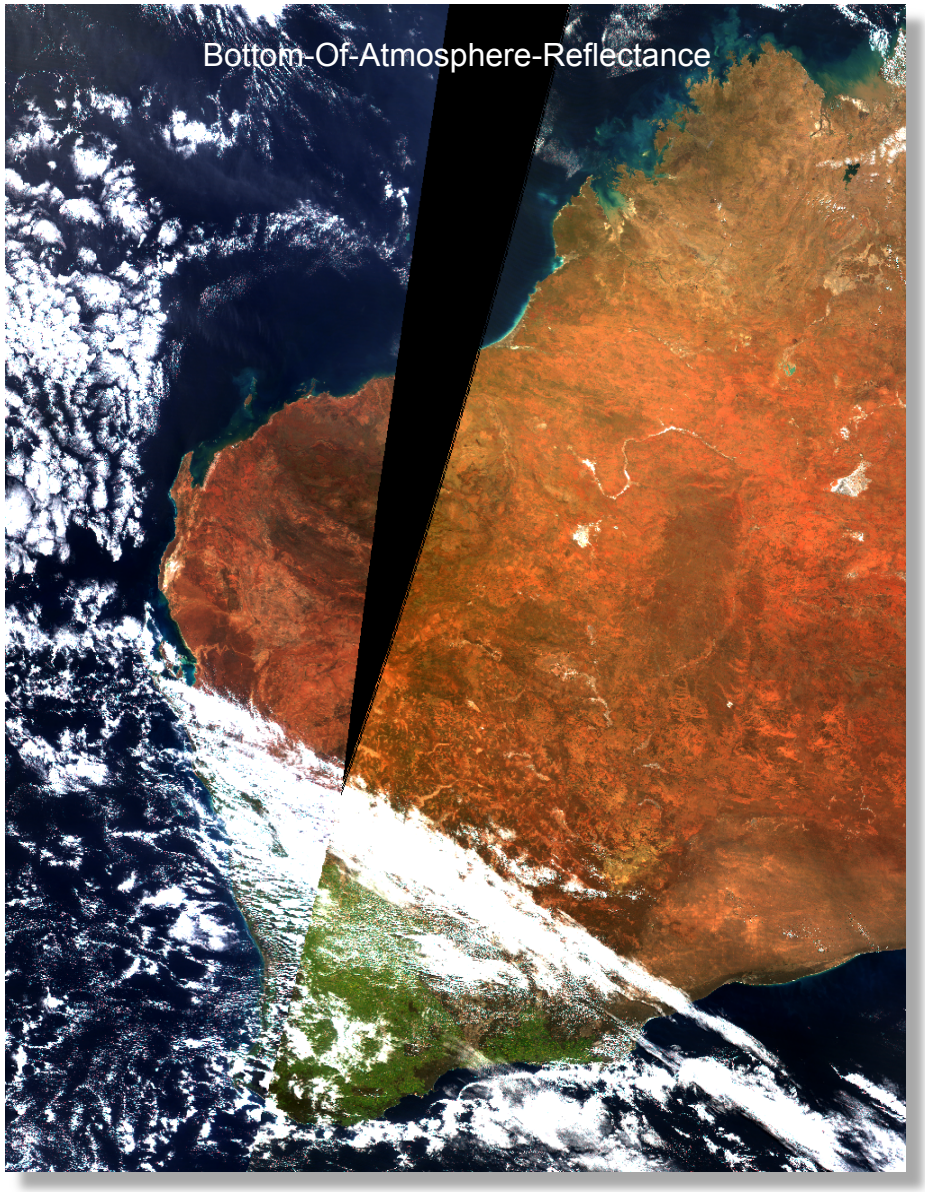
LAND-SOLAR RADIATION





Atmospheric scattering is removed to retrieve surface properties

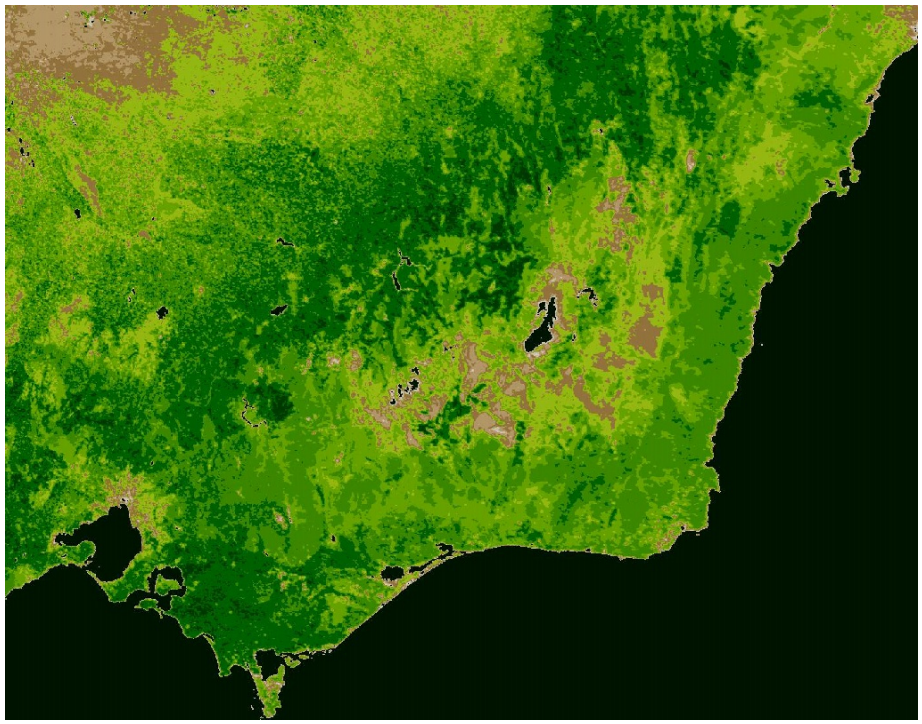




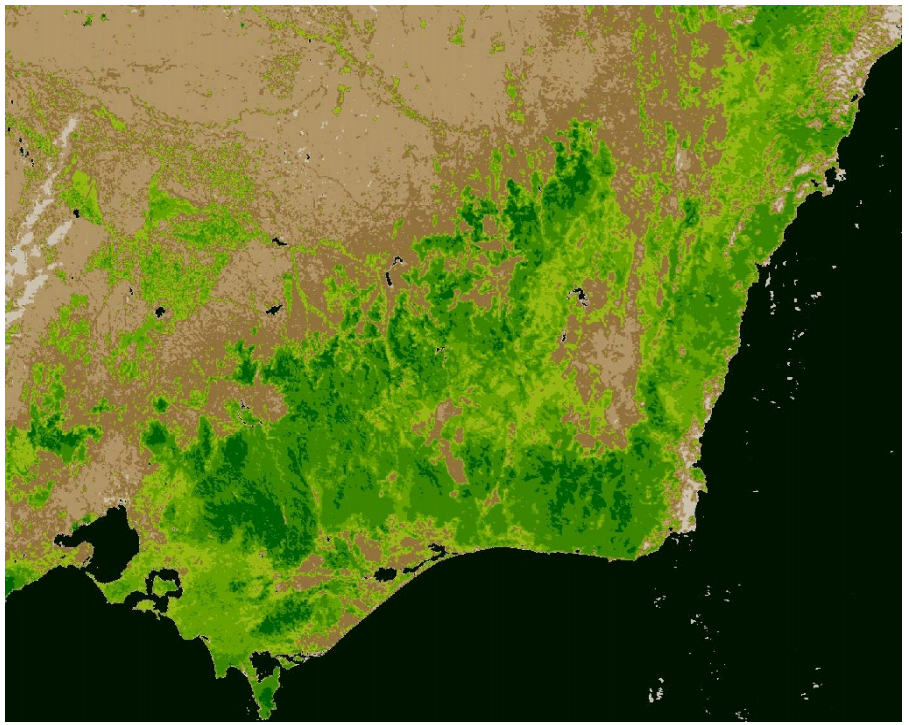
Terra MODIS 09/09/2003 01:27UTC 03:04UTC

Normalized Difference Vegetation Index

South East Australia



Nov 2003
Spring



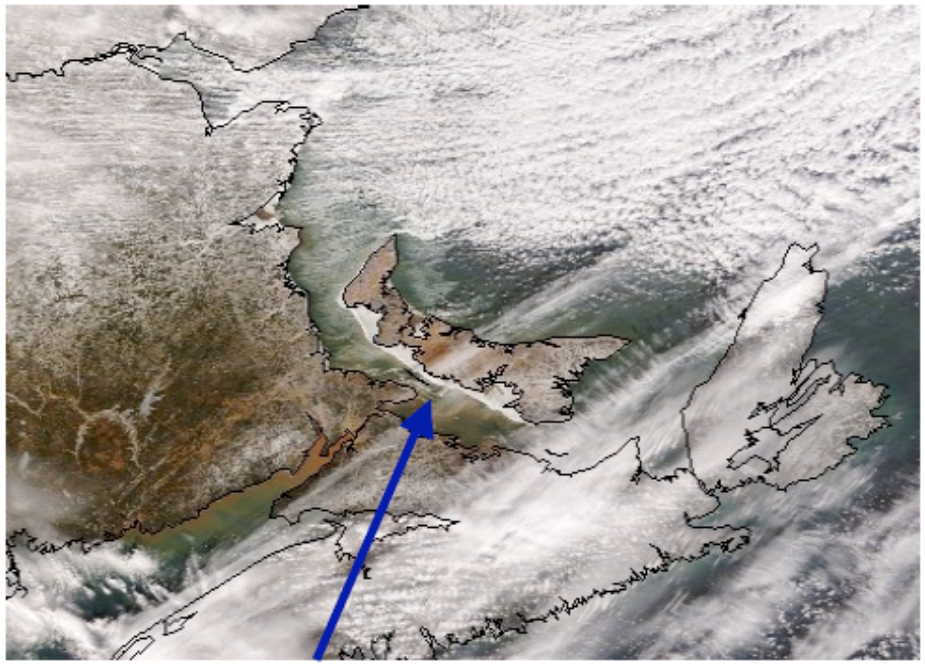
Apr 2004
Autumn

Canadian Ice Service integrates MODIS into operational data stream for ice monitoring

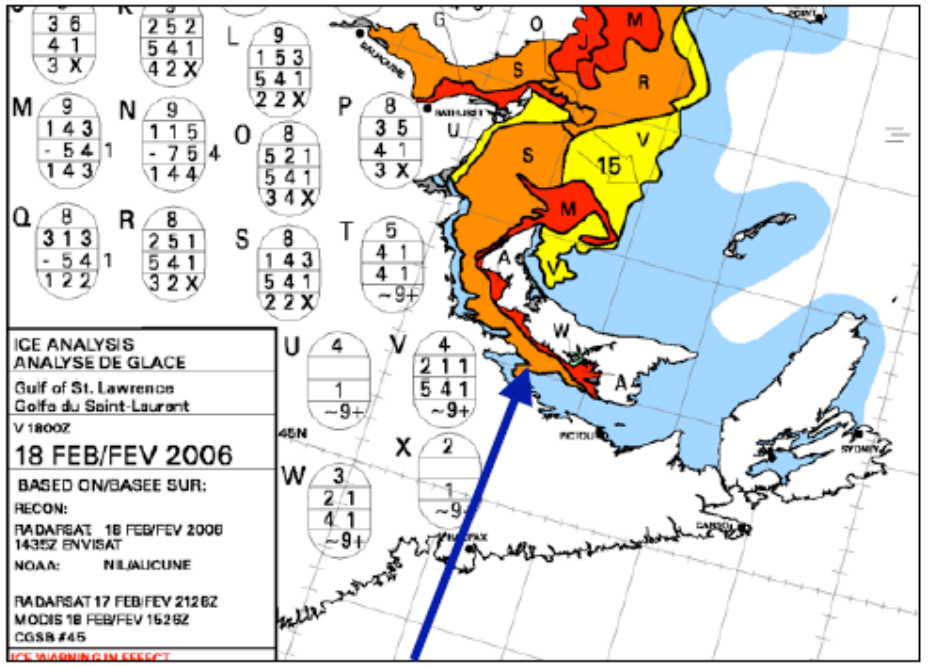
CIS data suite includes RadarSat and Envisat (SAR); AMSR, QuikScat and SSM/I (microwave); MODIS, OLS, NOAA and GOES (visible images).

- MODIS supplements SAR data in clear sky conditions.
- 250 meter resolution true color GeoTIFF images are obtained daily from SSEC for Great Lakes, Hudson Bay, Labrador coast, and Gulf of St. Lawrence.

MODIS helps to define ice boundary along southern Prince Edward Island



MODIS DB image 2006/02/18 15:26 UTC

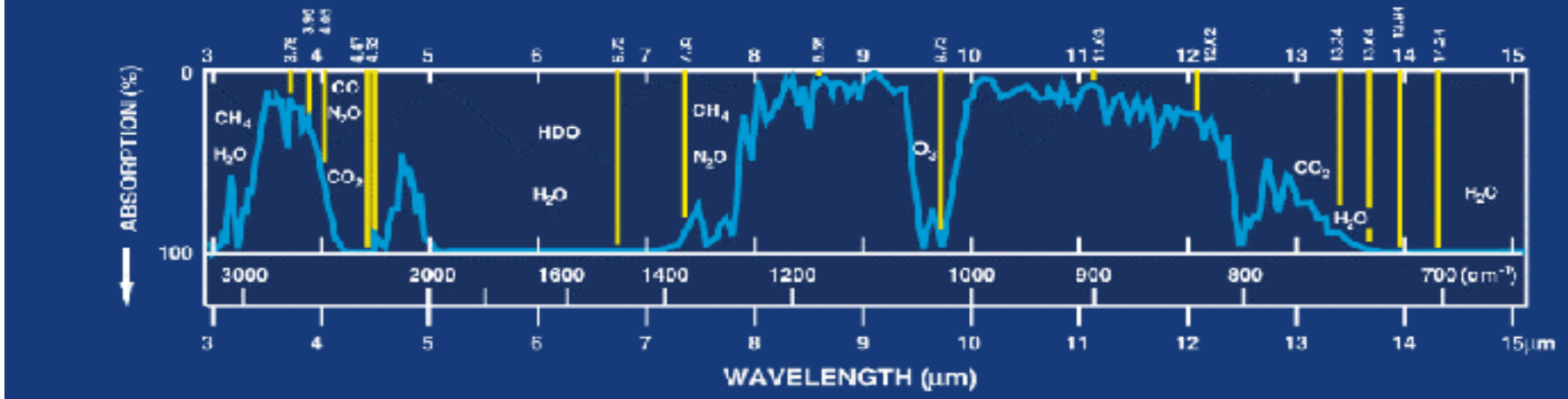


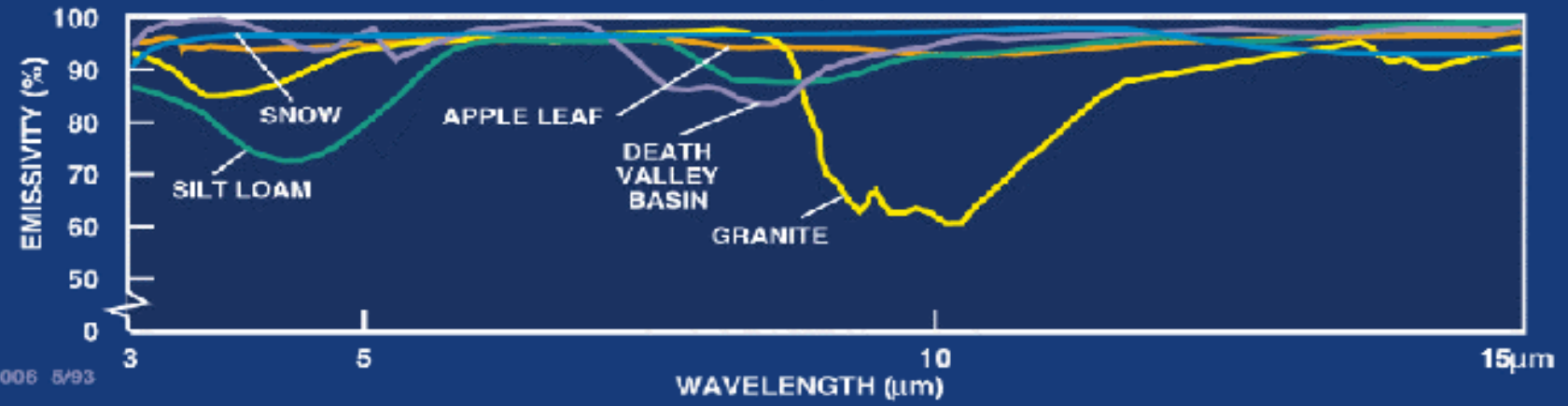
CIS Ice Analysis 2006/02/18

MODIS Land Surface Temperature

- MODIS bands 31 and 32 (11 and 12 microns) are used to detect land surface temperature.
- The signal sensed in orbit is dominated by (a) the surface temperature, and (b) the surface emissivity.
- Land surfaces have different emissivities depending on the surface type and conditions.
- The land surface emissivity must known or modeled correctly in order to accurately retrieve land surface temperature over all surface types (e.g., desert, forest, soil, grassland).

LAND - THERMAL RADIATION





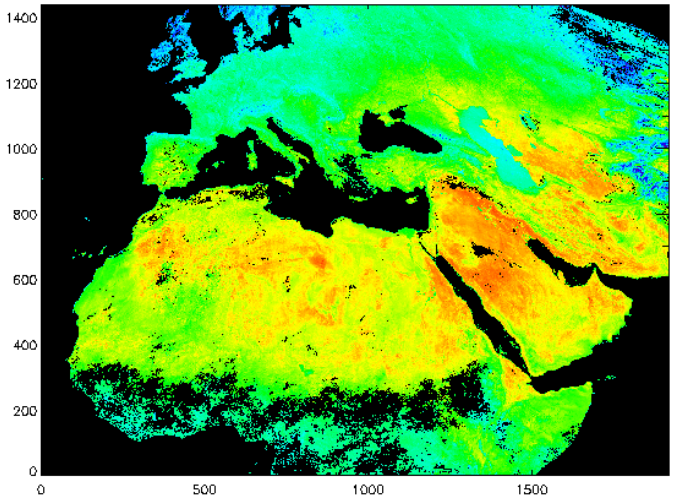
C351.006 5/93

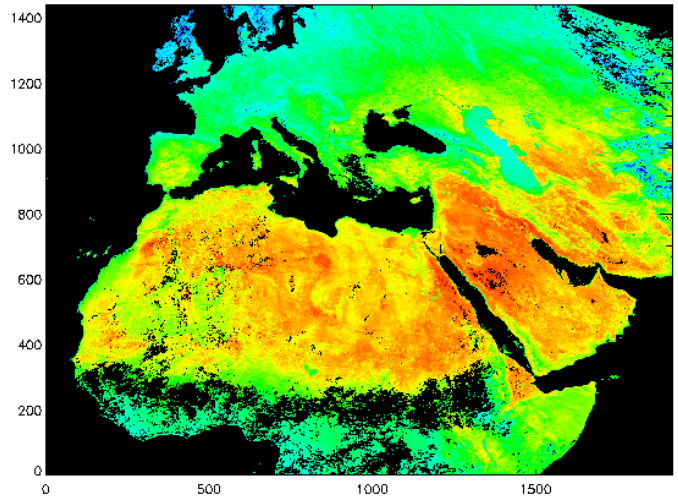
LSTs retrieved from Terra and Aqua MODIS data

on data days 176-177 and 185-190 (06/25-26 & 07/4-9)

to show spatial distribution of the diurnal variation

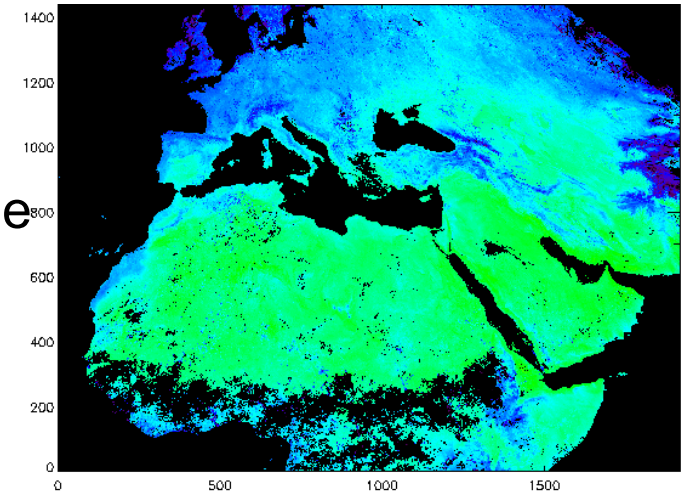
daytime Terra

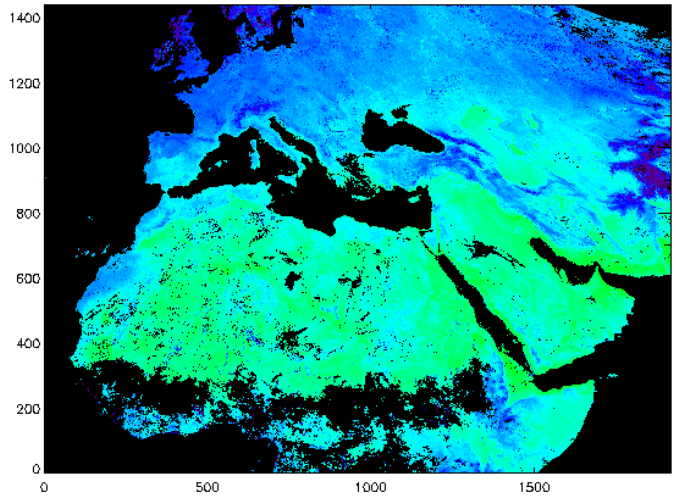




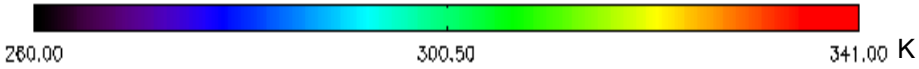
daytime Aqua

nighttime Terra





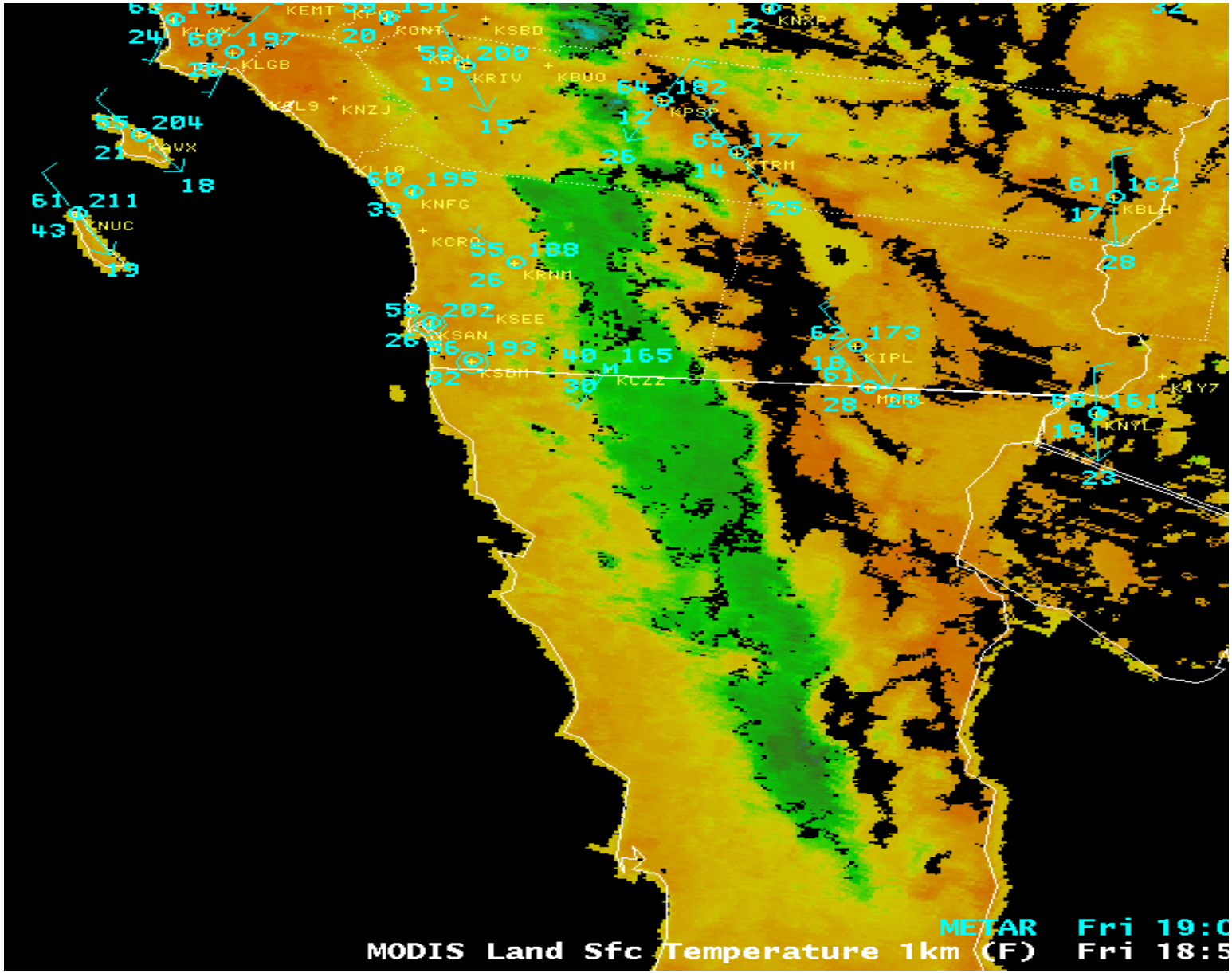
nighttime Aqua



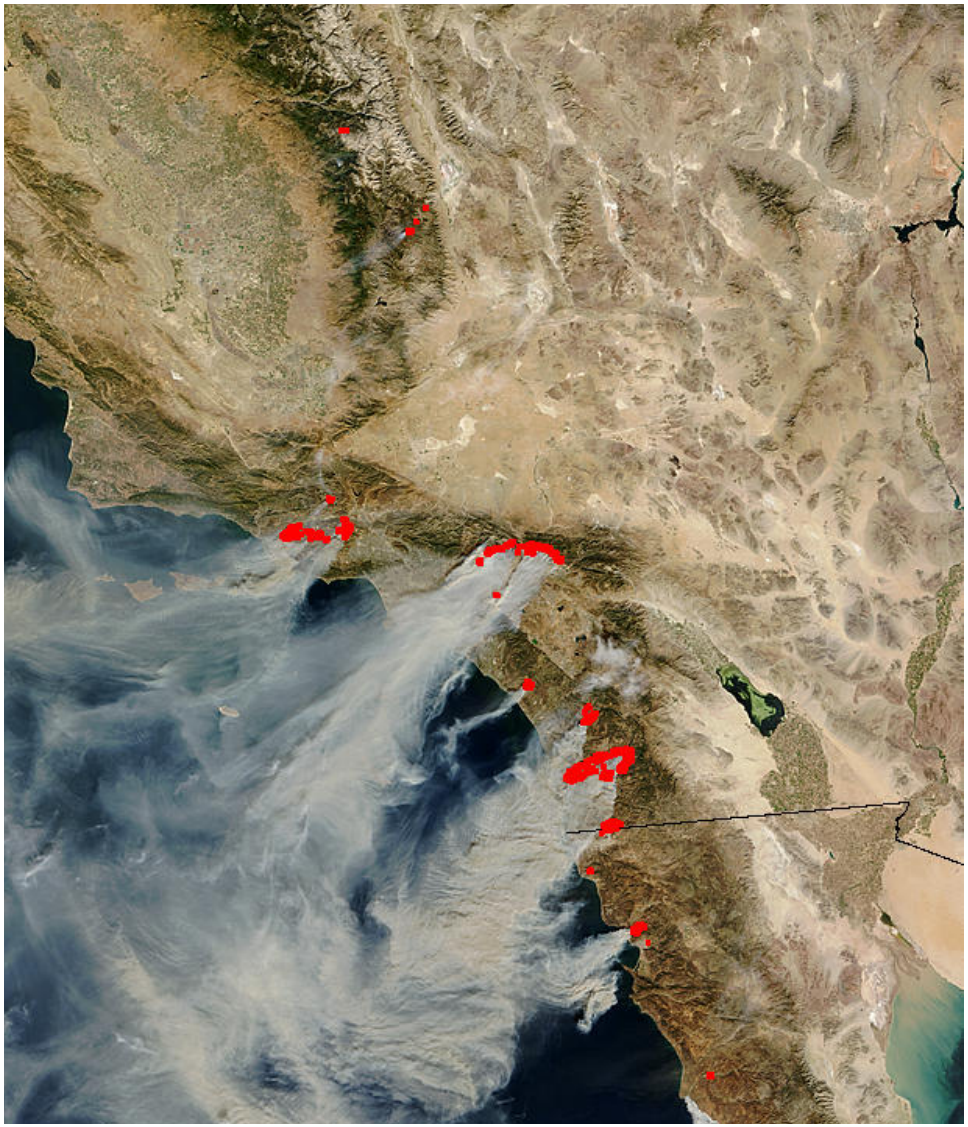
ICESS Institute for Computational Earth System Science University of California, Santa Barbara

MODIS True Color

MODIS Land Surface Temperature



MODIS Active Fire Detection



California – 10/26/03

- The algorithm considers the spectral signature (in middle and thermal infrared) of each pixel and compares it to the non-burning surrounding pixels
- The natural variability of the surrounding background is taken into account
- Fewer false detections than traditional threshold-based algorithms
- Sensitive enough to detect small fires

MODIS Global Fires

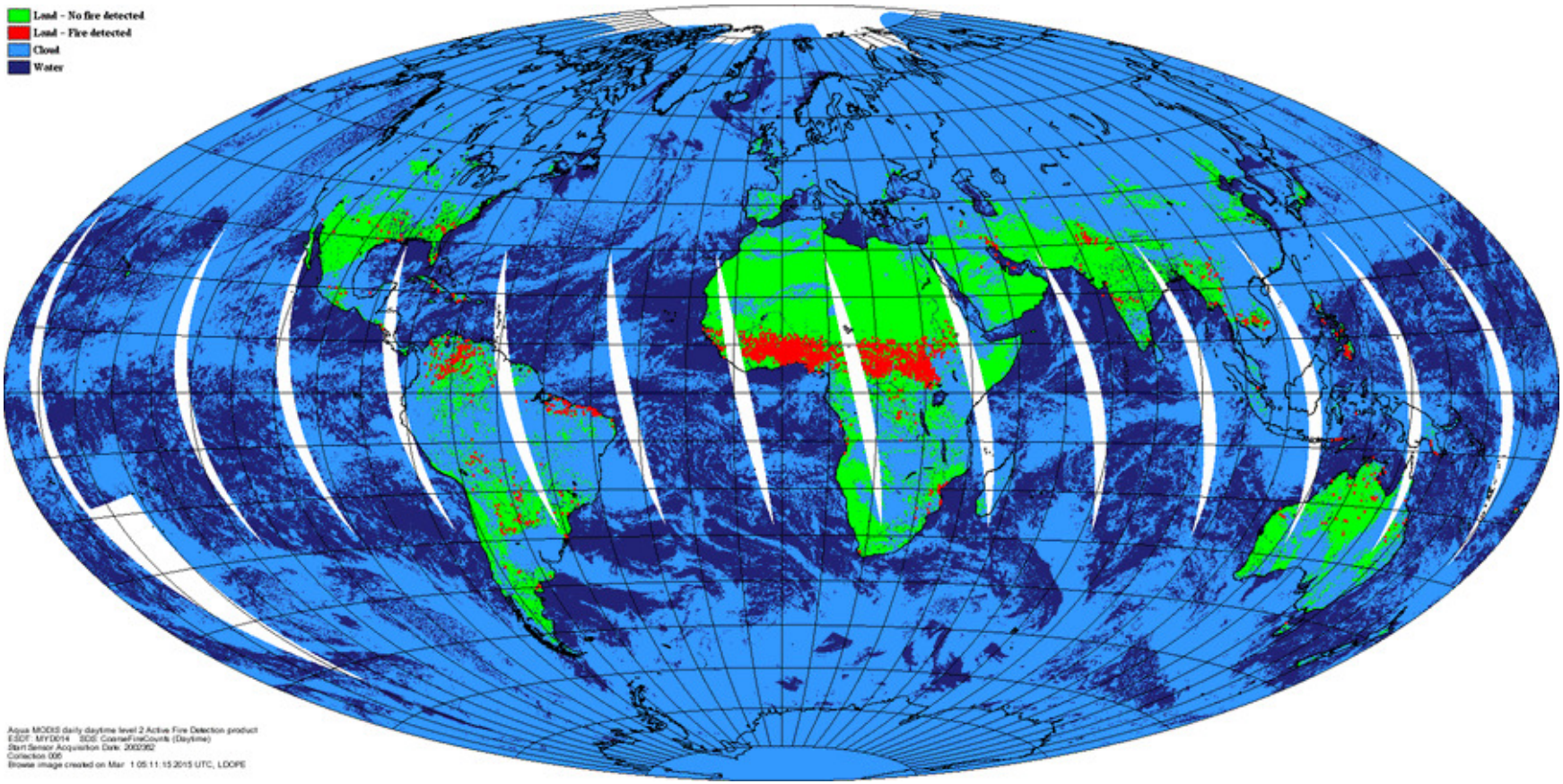


Figure 7: Example Collection-6 Aqua MODIS active fire global browse image for 28 December 2002 showing all daytime overpasses. Fire pixels are shown in red, cloud pixels are shown in light blue, and areas lacking data are shown in white. Browse image courtesy of the LDOPE.

MODIS Atmosphere Products and Applications

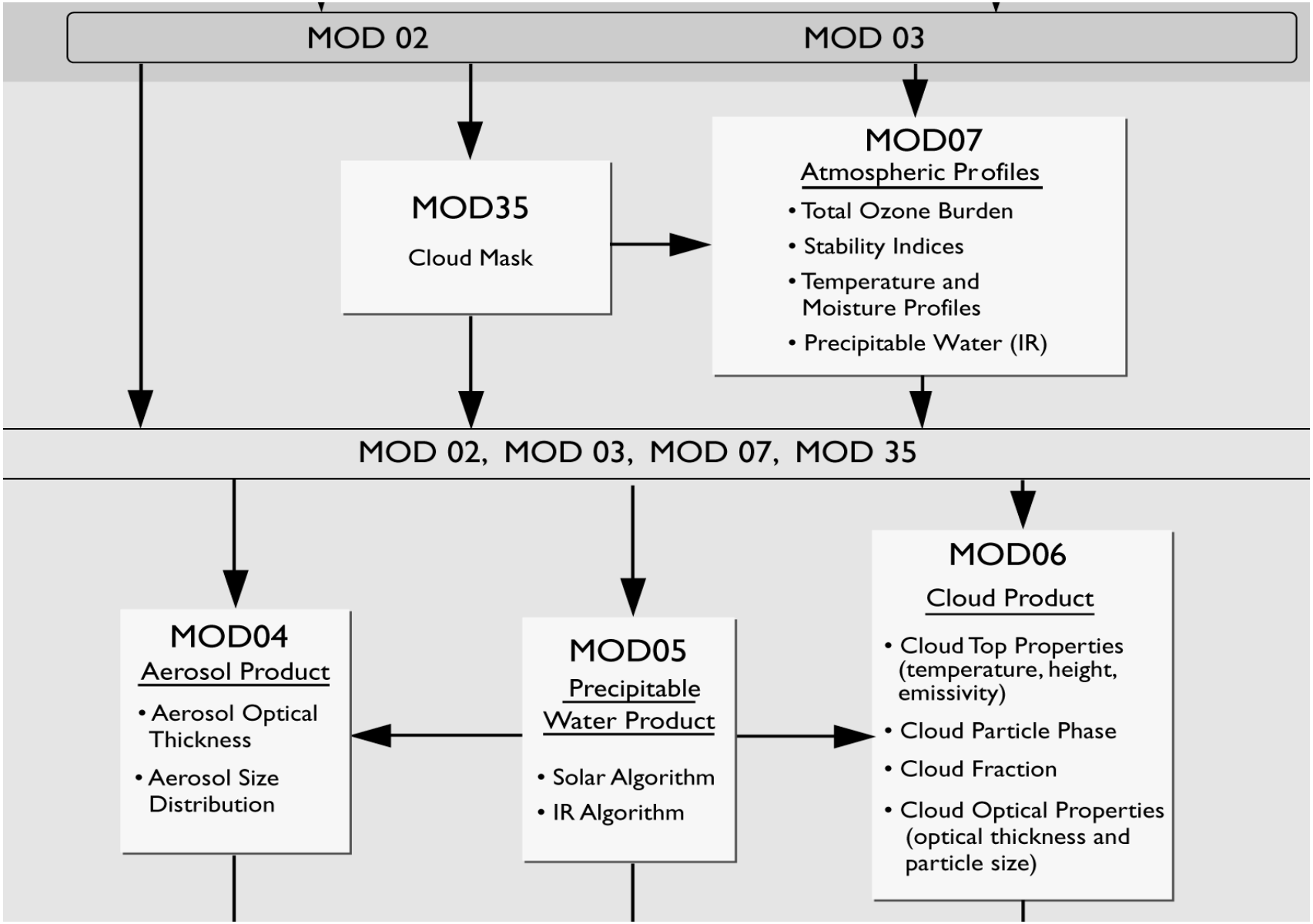
(MODIS Atmosphere Team)

MODIS Atmosphere Products

MOD04 Aerosol Product
MOD05 Total Precipitable Water – Daytime
MOD06 Cloud Product
MOD07 Atmospheric Profiles
MOD35 Cloud Mask

MODIS Atmosphere Gridded Product

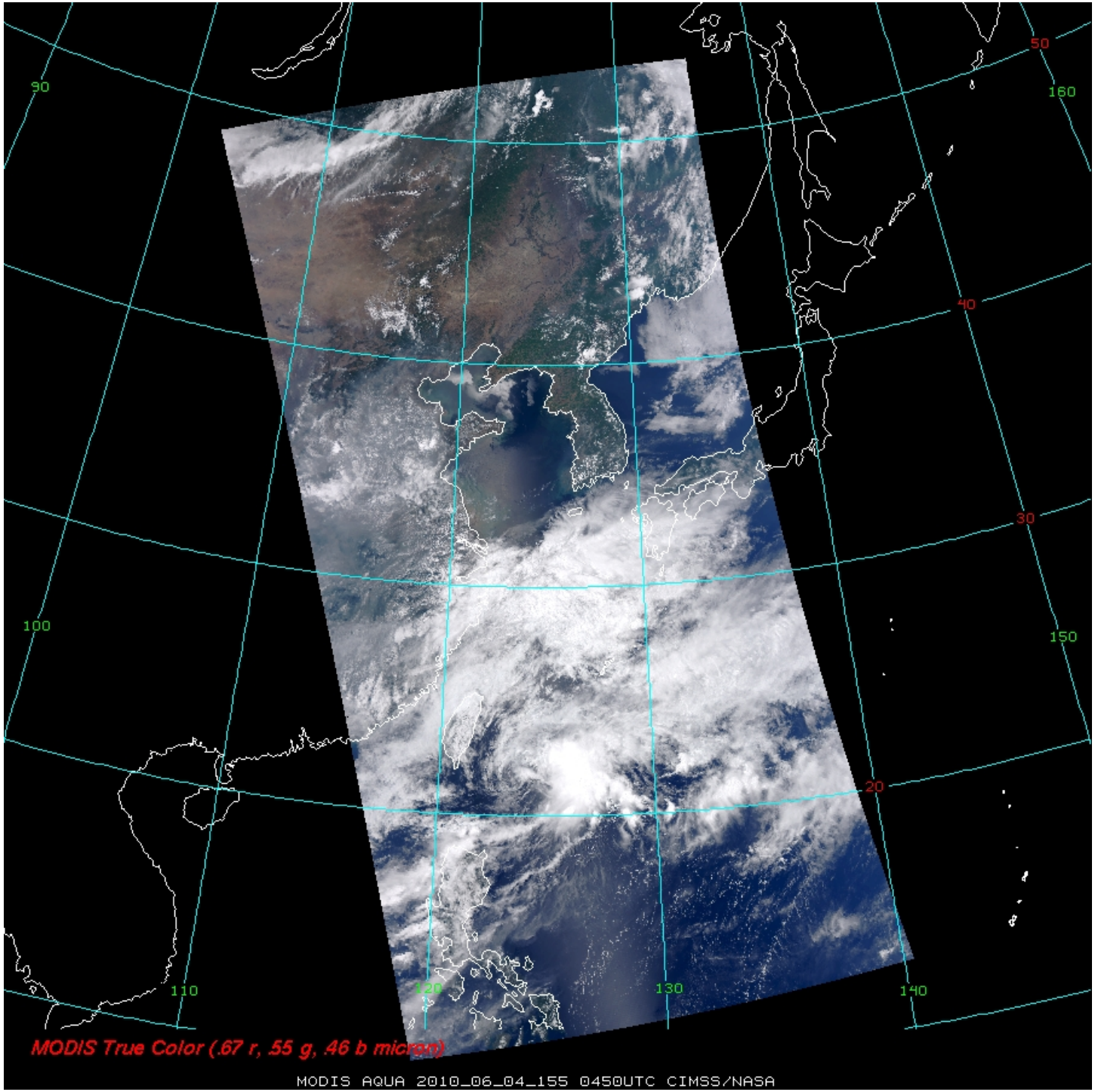
MODIS Atmosphere Product Flowchart

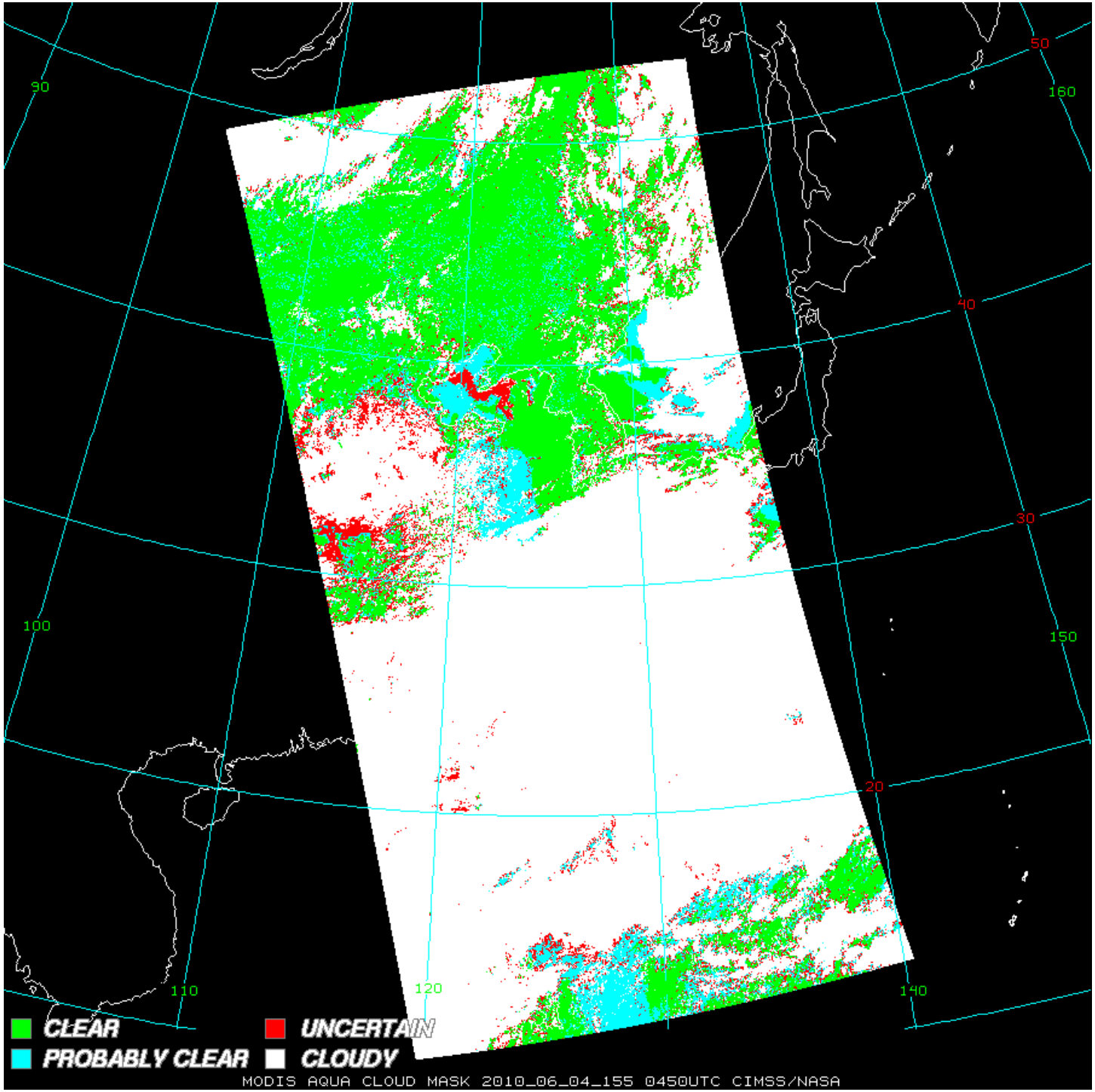


MODIS Cloud Mask

- **1 km** spatial resolution **day & night**, (250 m day)
  - **19 spectral bands (0.55-13.93 µm, incl. 1.38 µm)**
  - 11 individual spectral tests (function of 5 processing paths) combined for initial pixel confidence of clear
  - temporal consistency test over ocean, desert (nighttime); spatial variability test over ocean
- **48 bits per pixel** including individual test results and processing path
- **Result classes are**

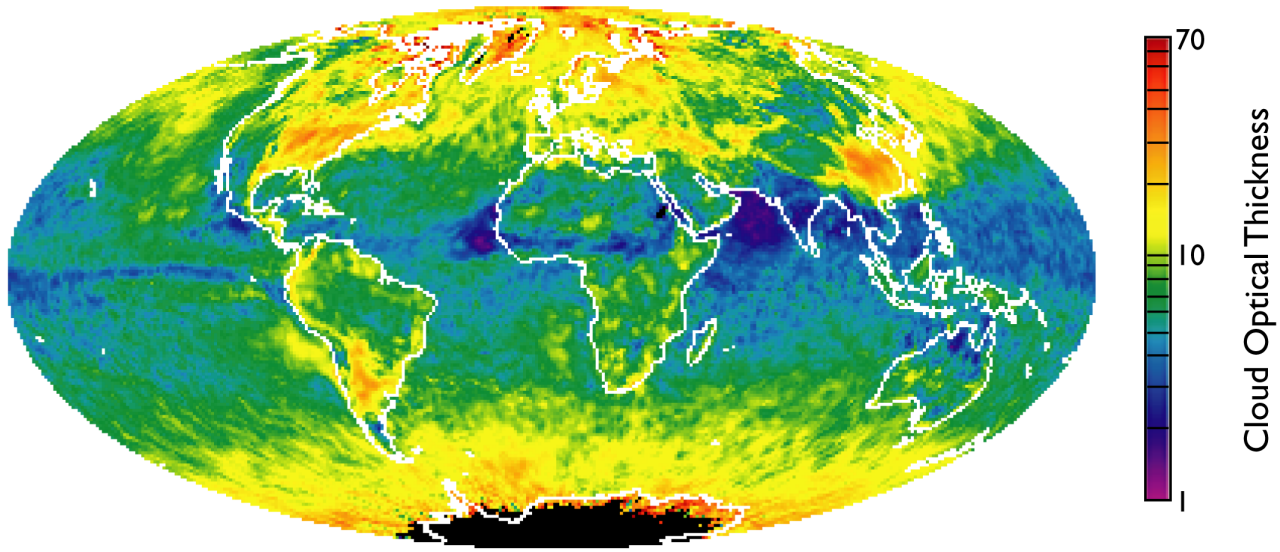
  Confident Clear, Probably Clear, Uncertain, Cloudy


90
50
160
40
30
100
150
20
110
120
130
140
MODIS True Color (.67 r, .55 g, .46 b micron)
MODIS AQUA 2010_06_04_155 0450UTC CIMSS/NASA

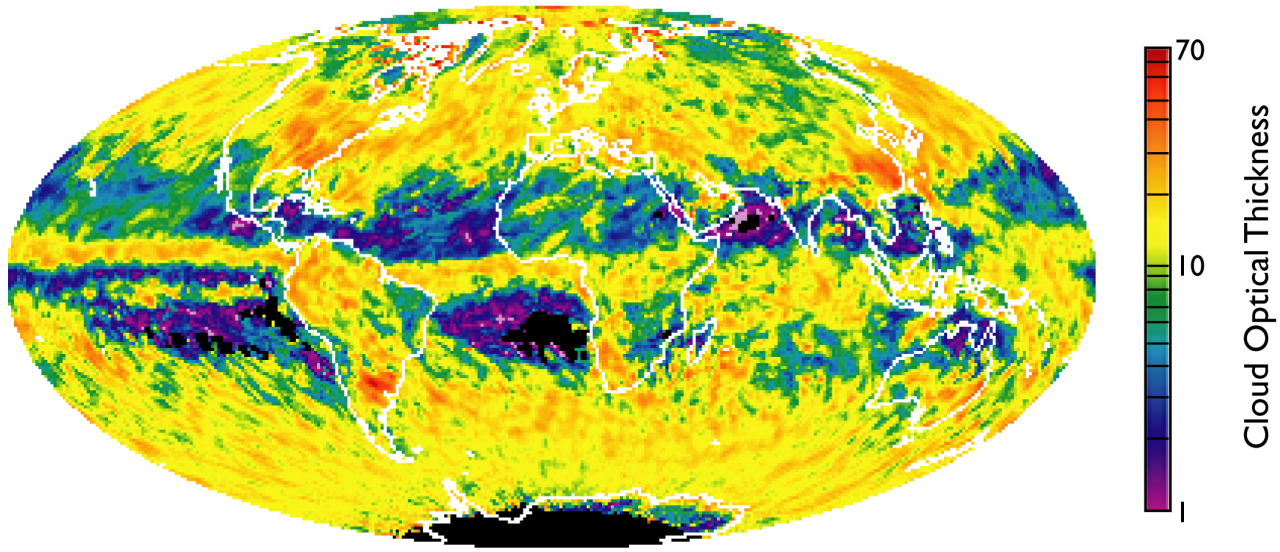

90
50
160
40
30
100
150
20
110
120
140
CLEAR
UNCERTAIN
PROBABLY CLEAR
CLOUDY
MODIS AQUA CLOUD MASK 2010_06_04_155 0450UTC CIMSS/NASA

Monthly Mean Cloud Optical Thickness

Cloud Optical Thickness (Water)

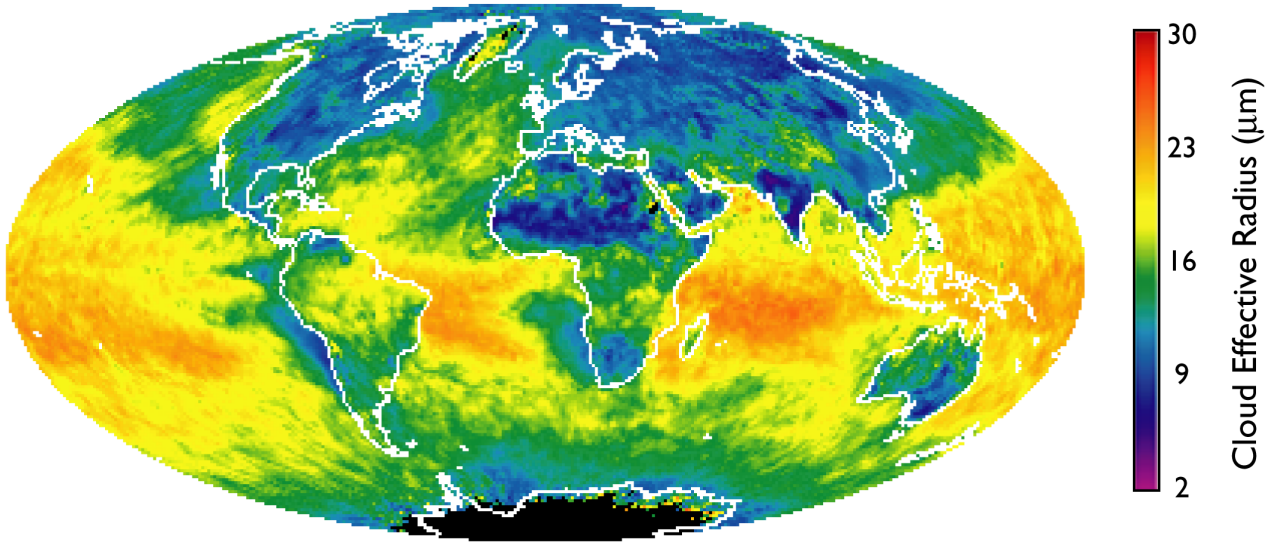


Cloud Optical Thickness (Ice)

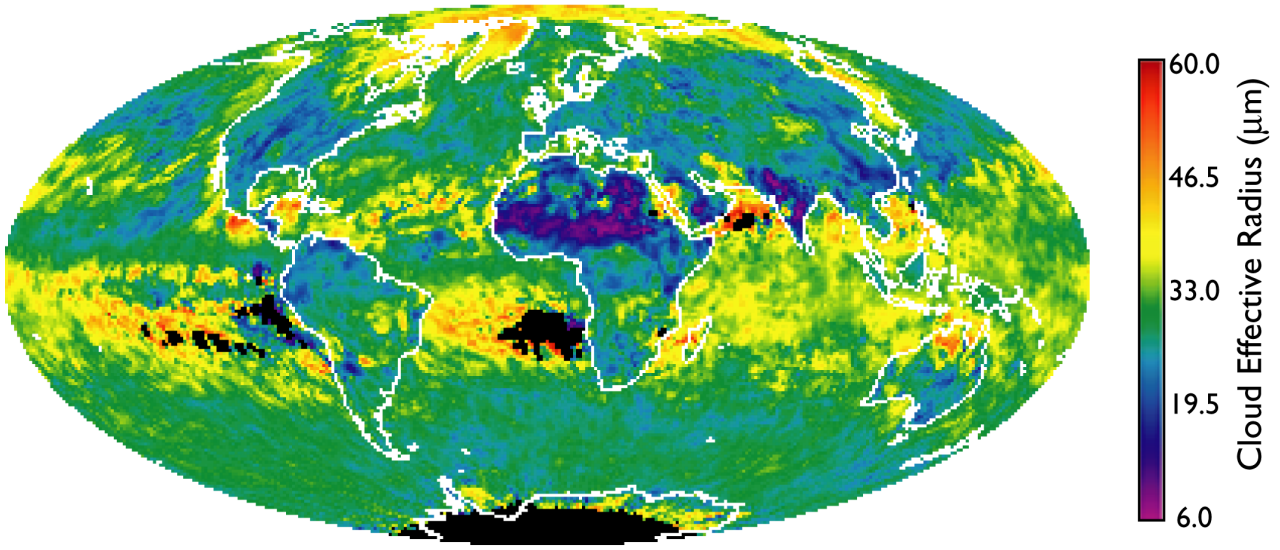


Monthly Mean Cloud Effective Radius

Cloud Effective Radius (Water)

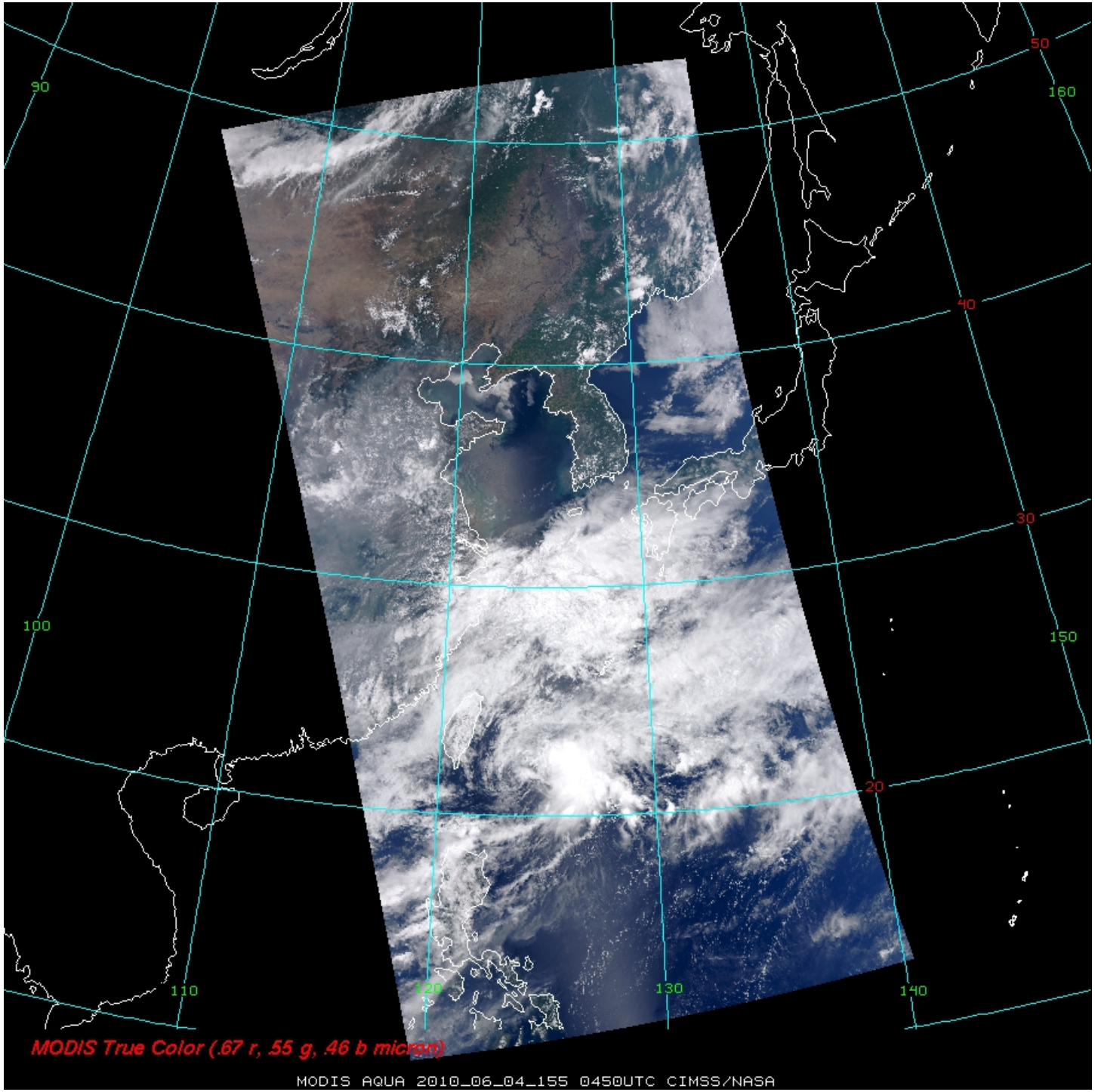


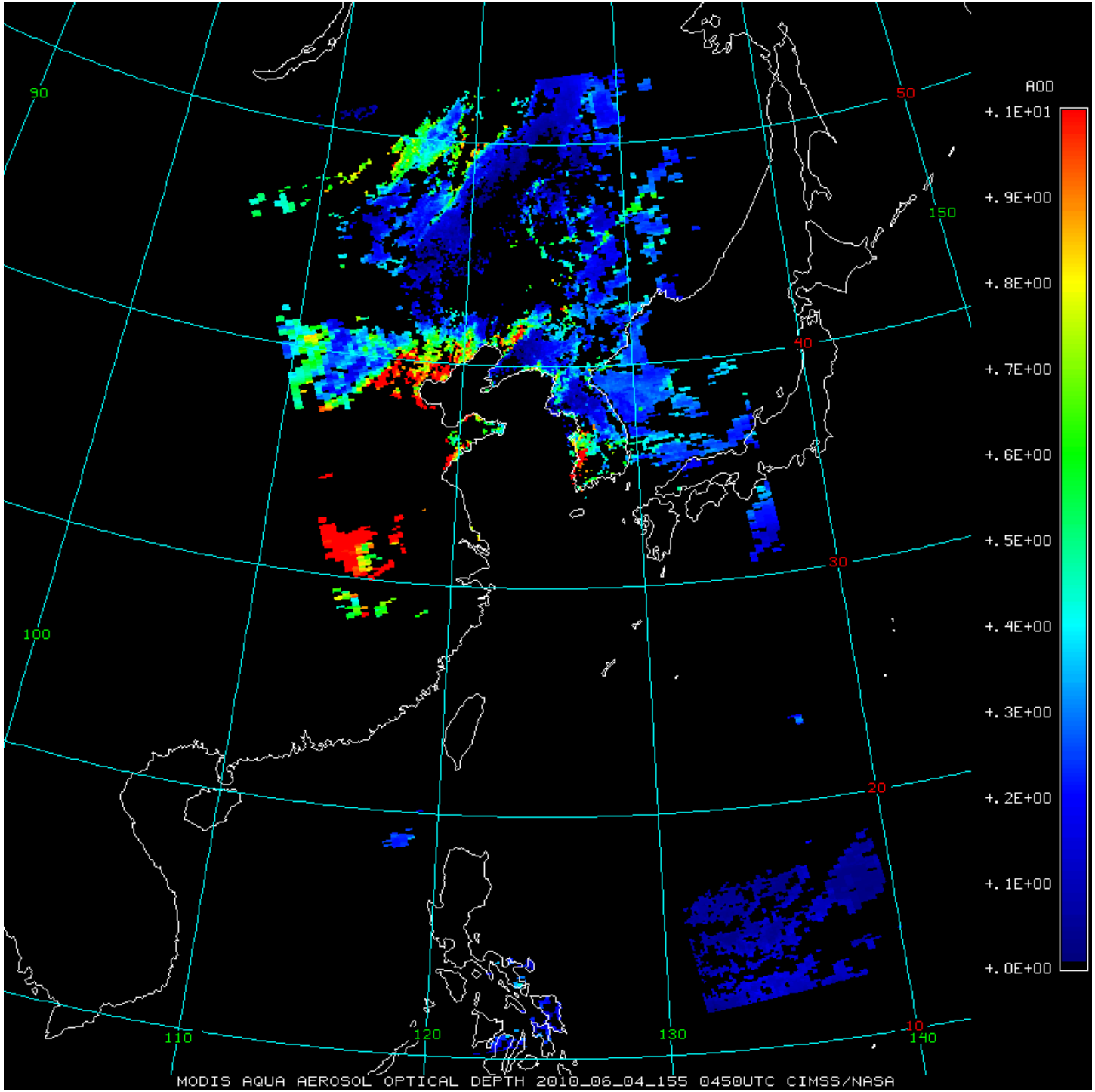
Cloud Effective Radius (Ice)



MODIS Aerosol Product

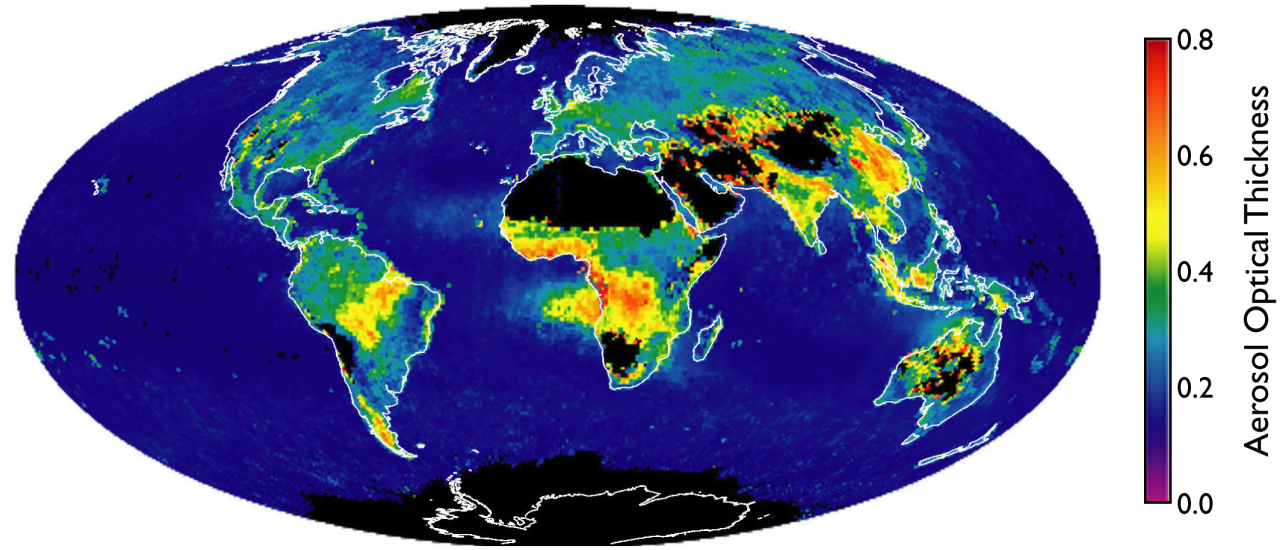
- Separate aerosol retrieval algorithms for land and water
- Algorithm matches observed reflectances to a lookup table of precomputed reflectances for a wide variety of aerosol conditions
- Over land, atmospheric and land surface reflectance are separated by estimating the surface contribution from the measured reflectance at 2.13 microns for dark targets
- Final land products include aerosol optical thickness at 0.47, 0.56, and 0.65 microns at 10-km spatial resolution, and the fine mode (radius 0.6 micron) fraction of the aerosol optical thickness at 0.56 microns
- Over ocean the surface contribution to the total reflectance is small and can be calculated
- Retrieved aerosol products are represented by the best fits between observed reflectance and the lookup table
- Ocean products include aerosol optical thickness at 0.47, 0.56, 0.65, 0.86, 1.24, 1.64, and 2.13 microns at 10-km spatial resolution, effective radius of the particle population, and fine mode fraction


90
50
160
40
30
100
150
20
110
120
130
140
MODIS True Color (.67 r, .55 g, .46 b micron)
MODIS AQUA 2010_06_04_155 0450UTC CIMSS/NASA

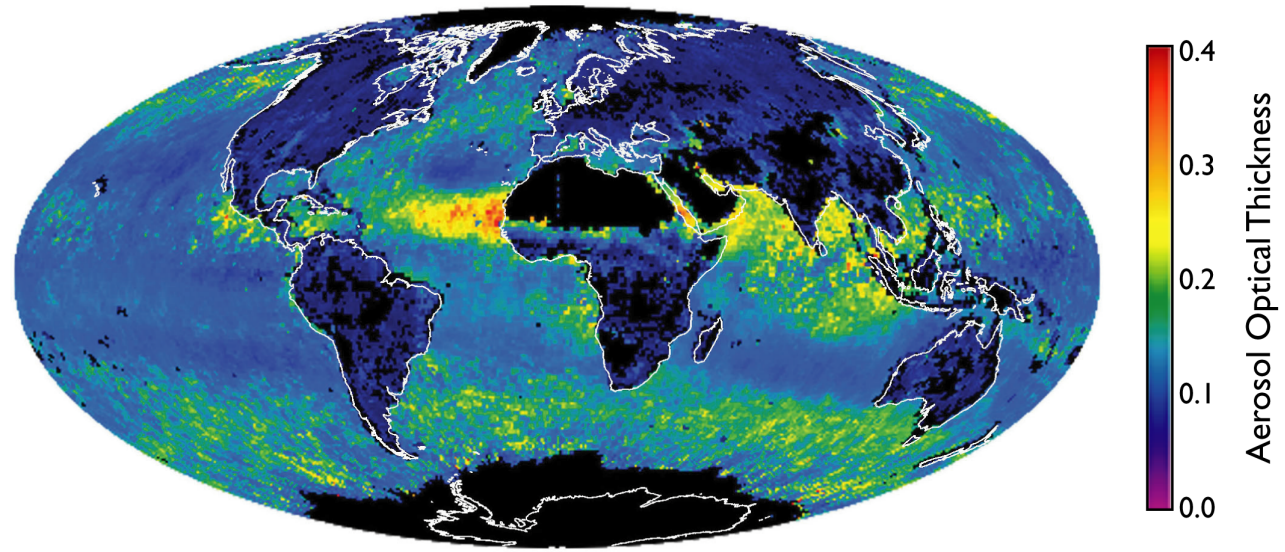

AOD
+.1E+01
+.9E+00
+.8E+00
+.7E+00
+.6E+00
+.5E+00
+.4E+00
+.3E+00
+.2E+00
+.1E+00
+.0E+00
90
50
150
40
100
30
20
110
120
130
10
140
MODIS AQUA AEROSOL OPTICAL DEPTH 2010_06_04_155 0450UTC CIMSS/NASA

Monthly Mean Aerosol Optical Thickness

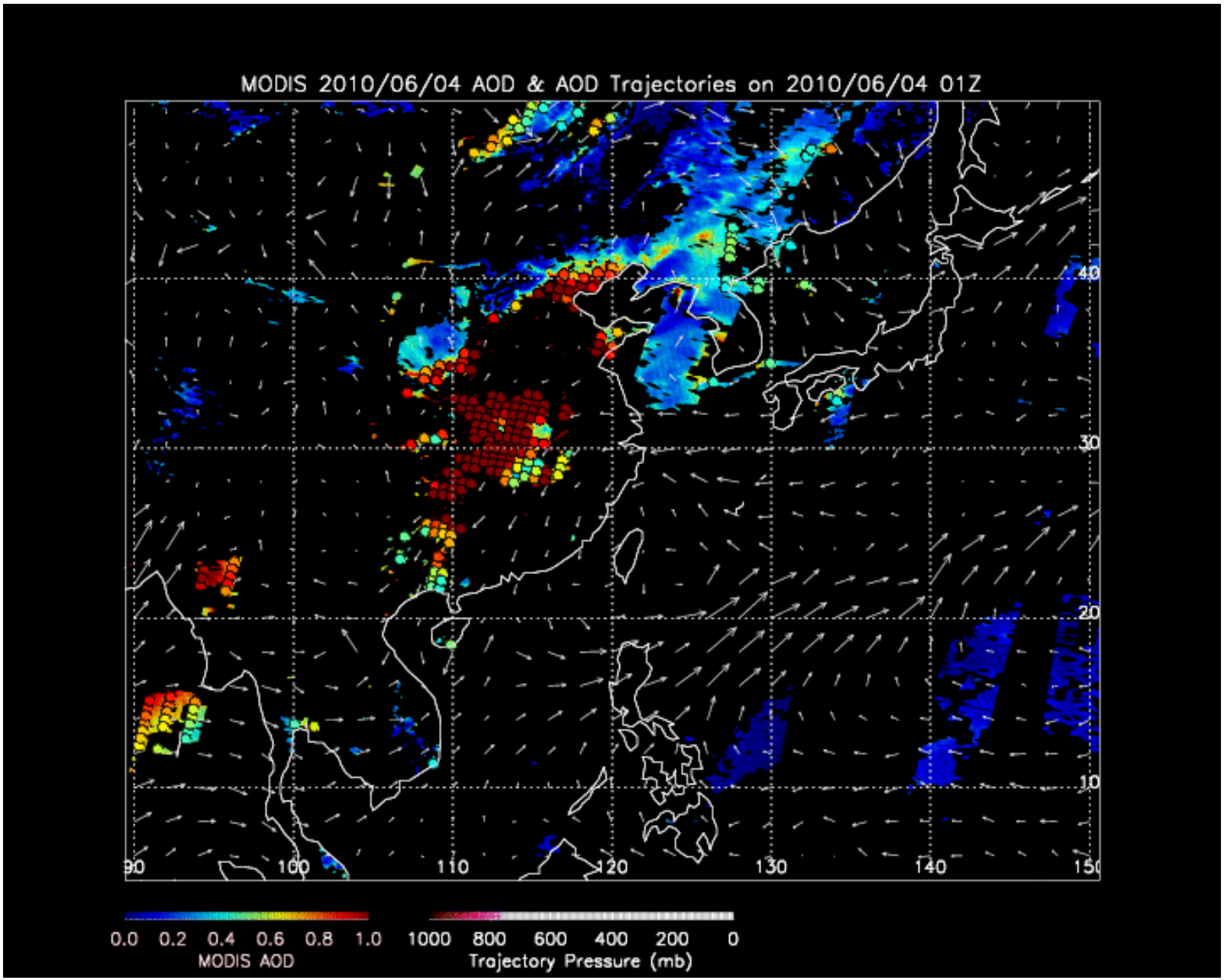
Aerosol Optical Thickness (Fine Mode)



Aerosol Optical Thickness (Coarse Mode)



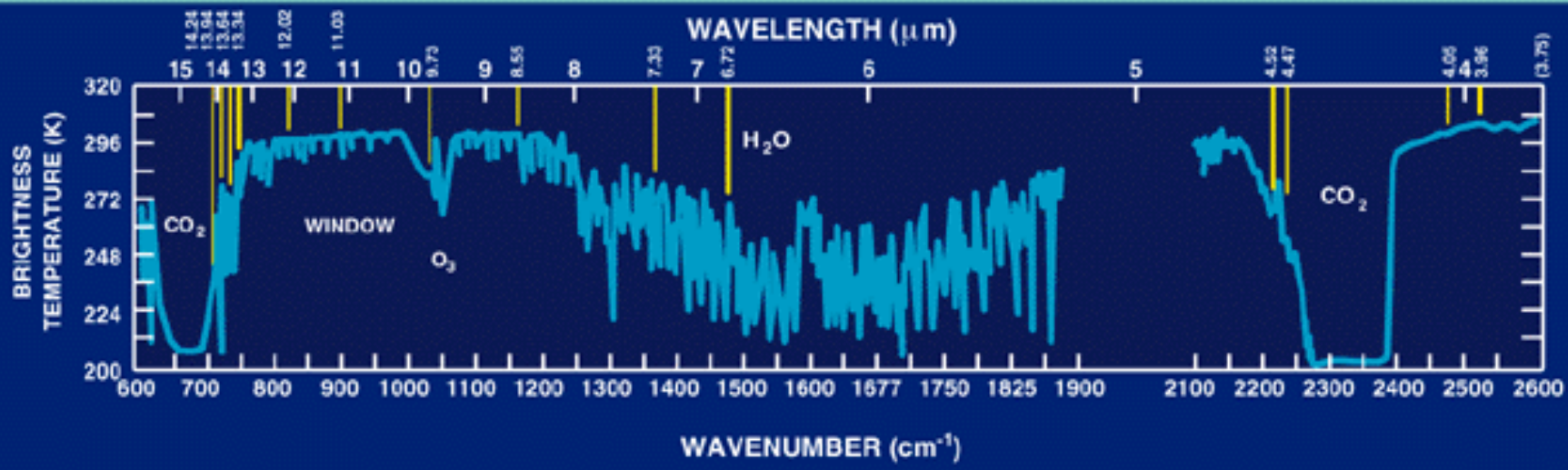
MODIS IDEA-I Product for 2010/06/04

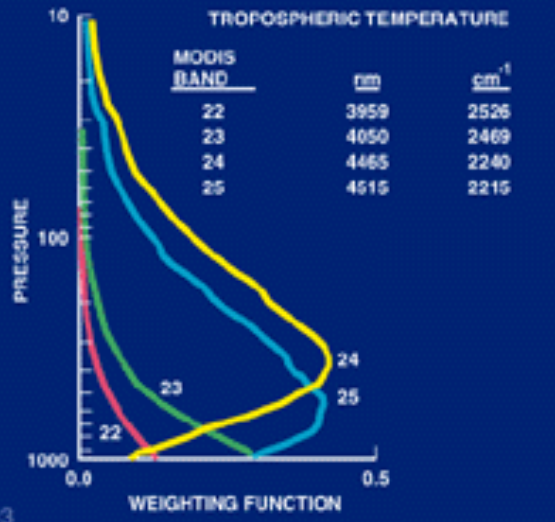


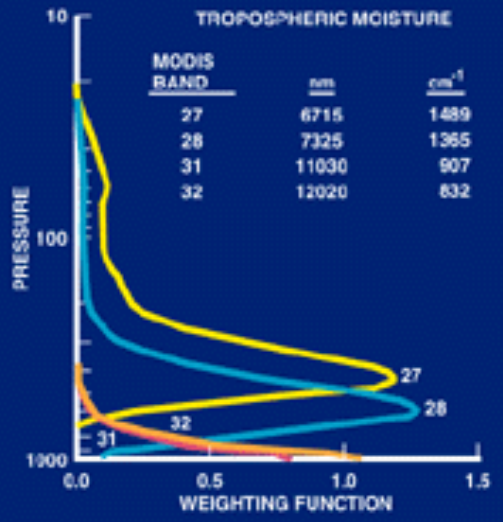
MODIS Atmosphere and Cloud Products (Thermal Emissive)

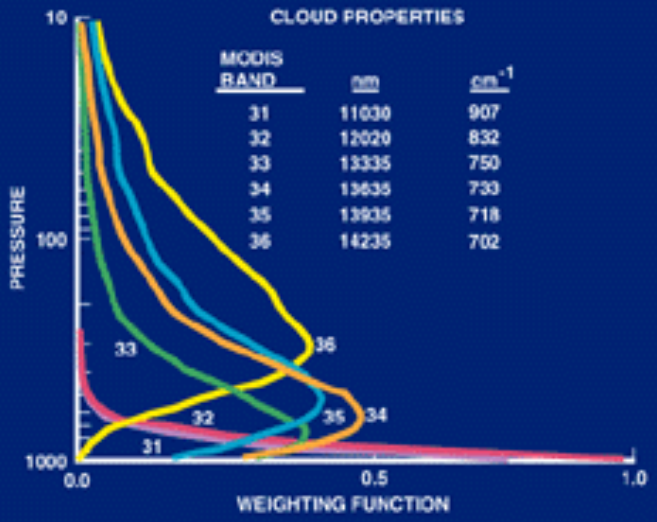
- MODIS bands 23-25 and 27-36 are used to sense the temperature and water vapor structure of the atmosphere in clear sky regions, and to infer cloud top pressure, temperature, and effective emissivity.
- In clear sky, the signal at the satellite is dominated by the surface for so-called “window” bands, by a mixture of surface and atmosphere emission and absorption for “partially opaque” bands, and by absorption and emission in the atmosphere for “opaque” bands.
- For clouds, the ratio of radiances between longwave infrared bands contains information about the cloud top pressure, temperature, and effective emissivity.

ATMOSPHERE - THERMAL RADIATION



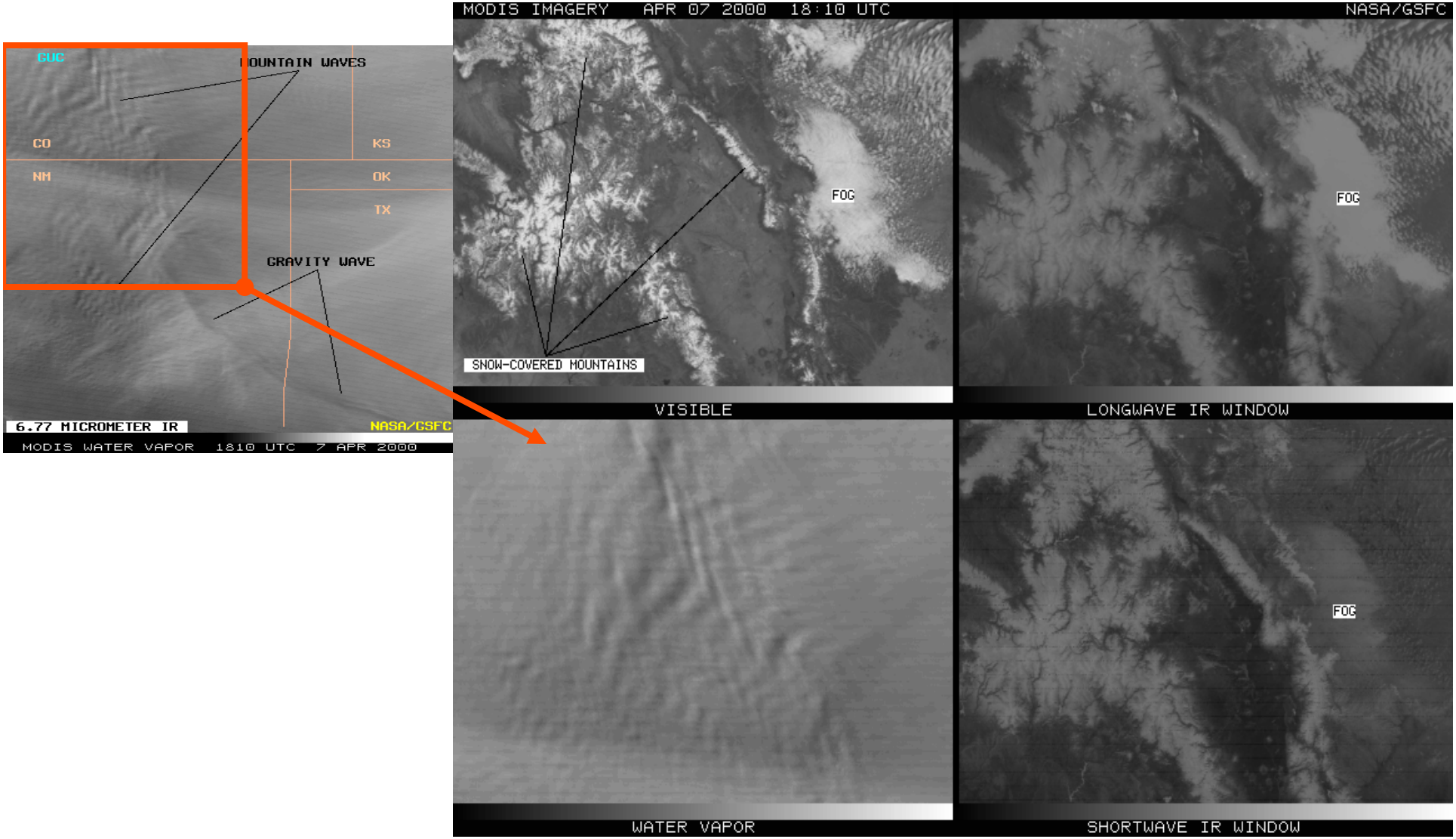






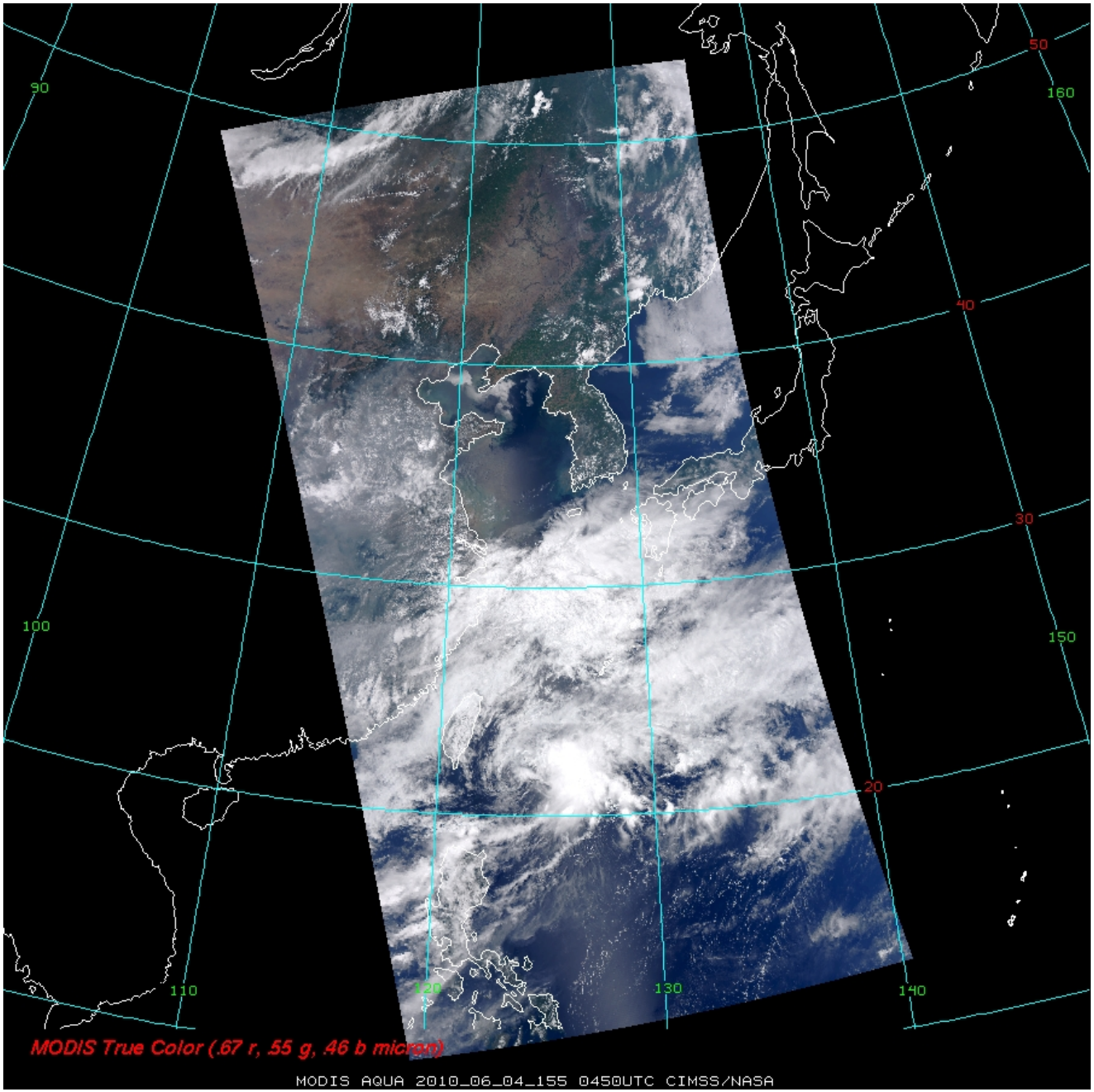
E351.002 5/93

Four Panel Zoom of Cloud-Free Orographic Waves revealed in Water Vapor Imagery



Aqua MODIS True Color Image: 2010/06/04

Note land, ocean, and sunglint surfaces, and mix of high clouds, low clouds, and fog.



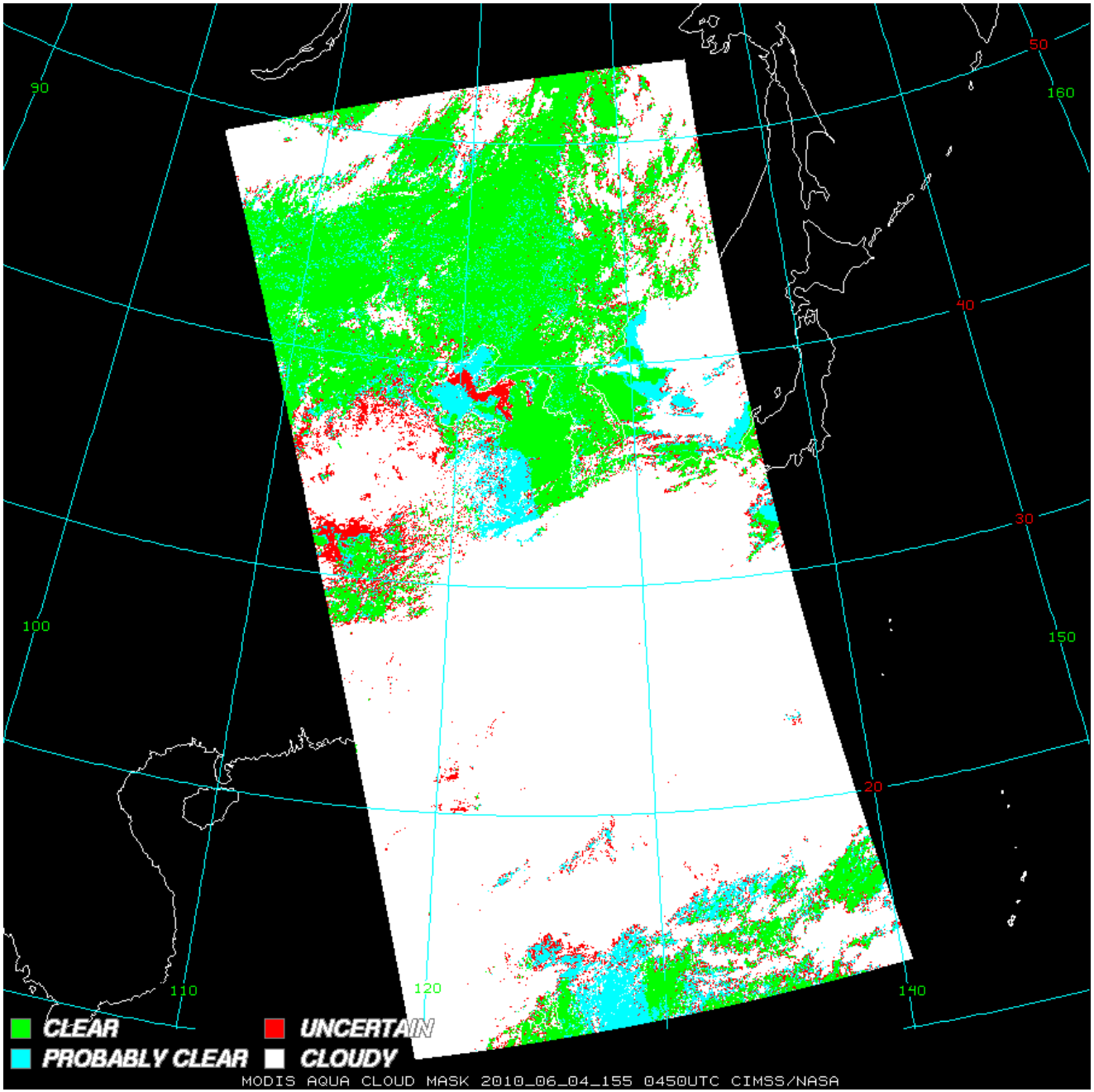
MODIS Cloud Mask Product (MOD35)

Clear and Cloudy Sky (everywhere)

Day/Night

1 km resolution

Fuzzy logic spectral tests



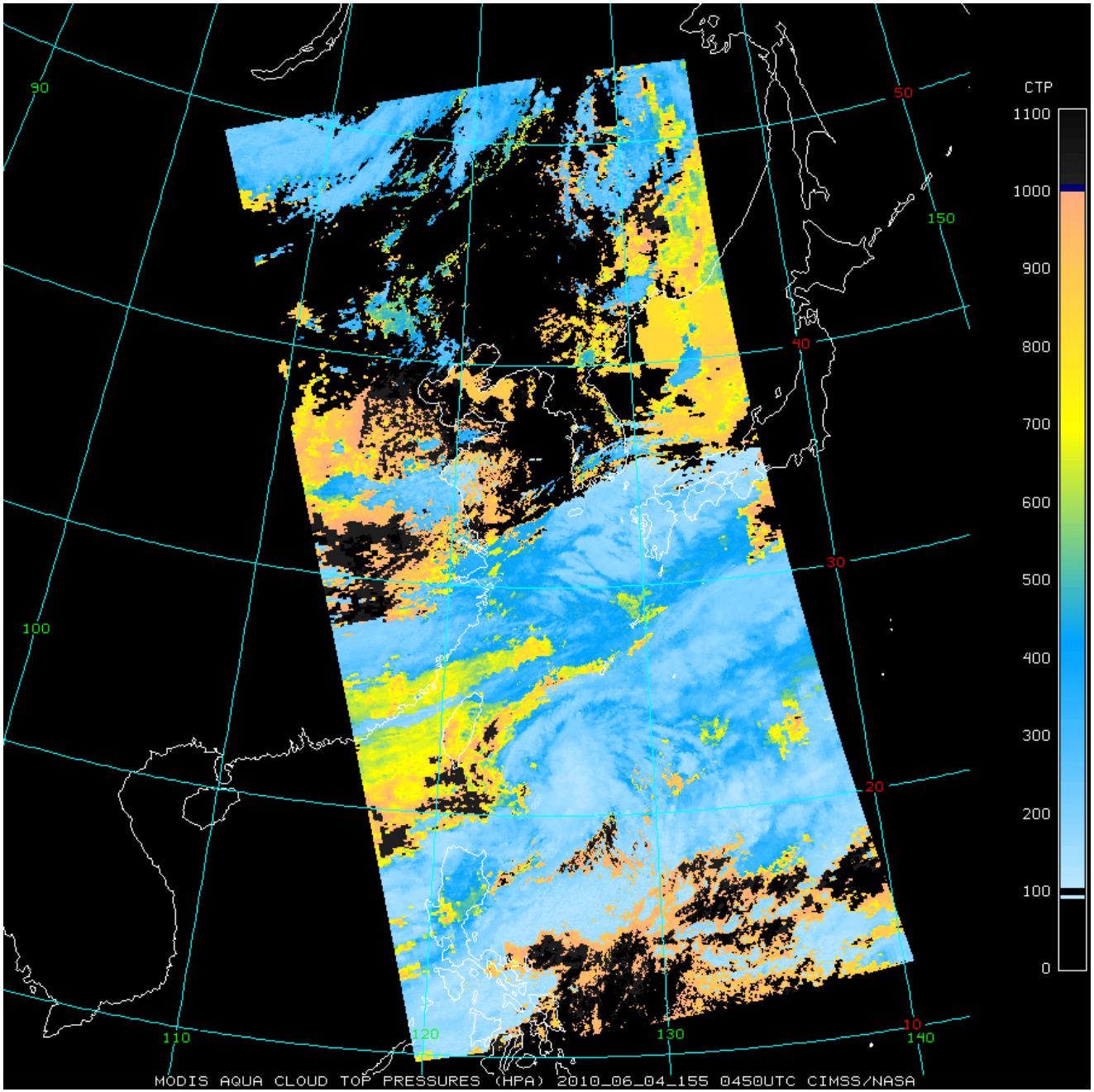
MODIS Cloud Top Pressure Product (MOD06)

Cloudy Sky Only

Day/Night

5 x 5 km resolution

CO_2 slicing algorithm



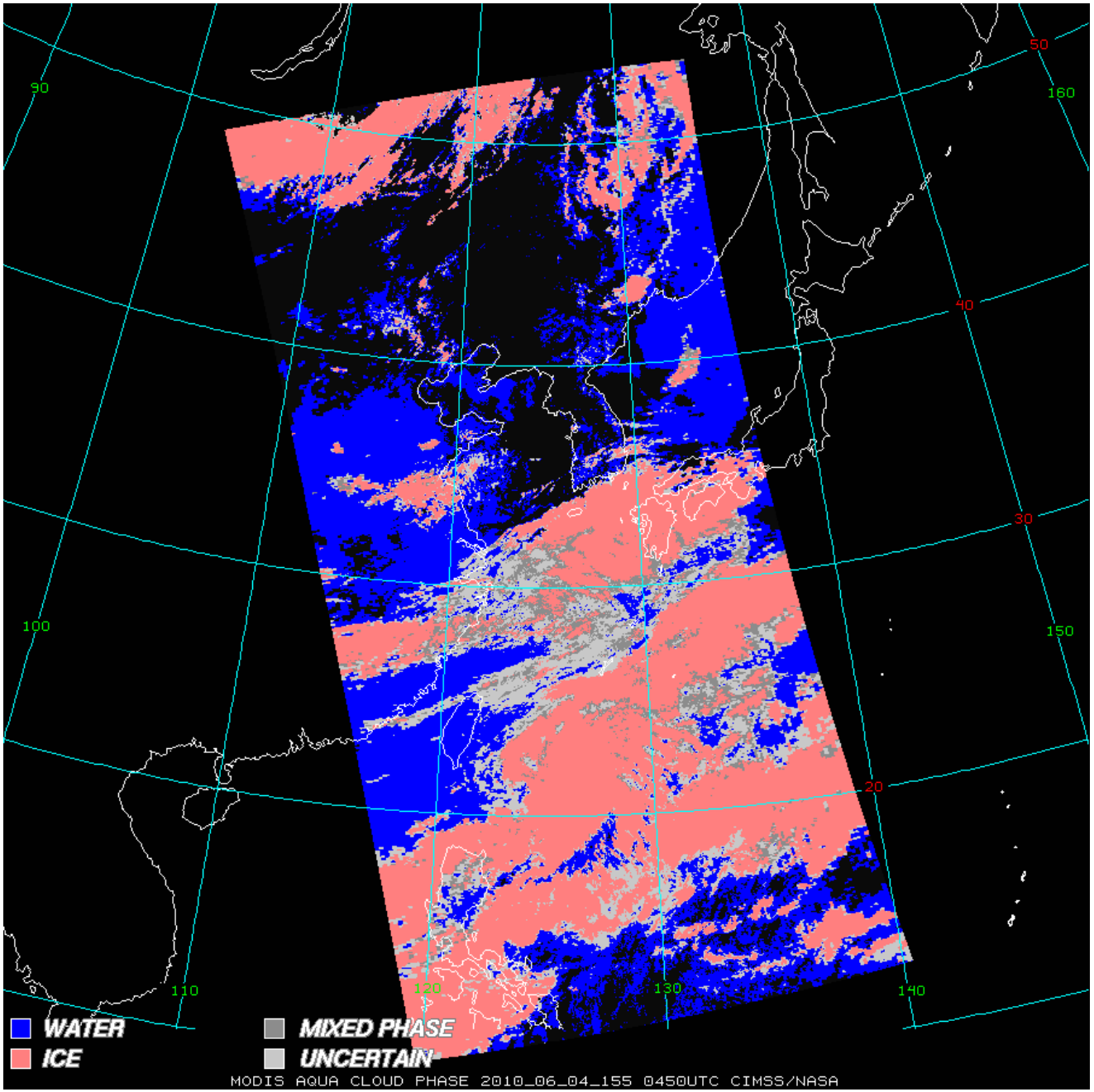
MODIS Cloud Phase Product (MOD06)

Cloudy Sky Only

Day/Night

5 x 5 km resolution

Threshold Algorithm



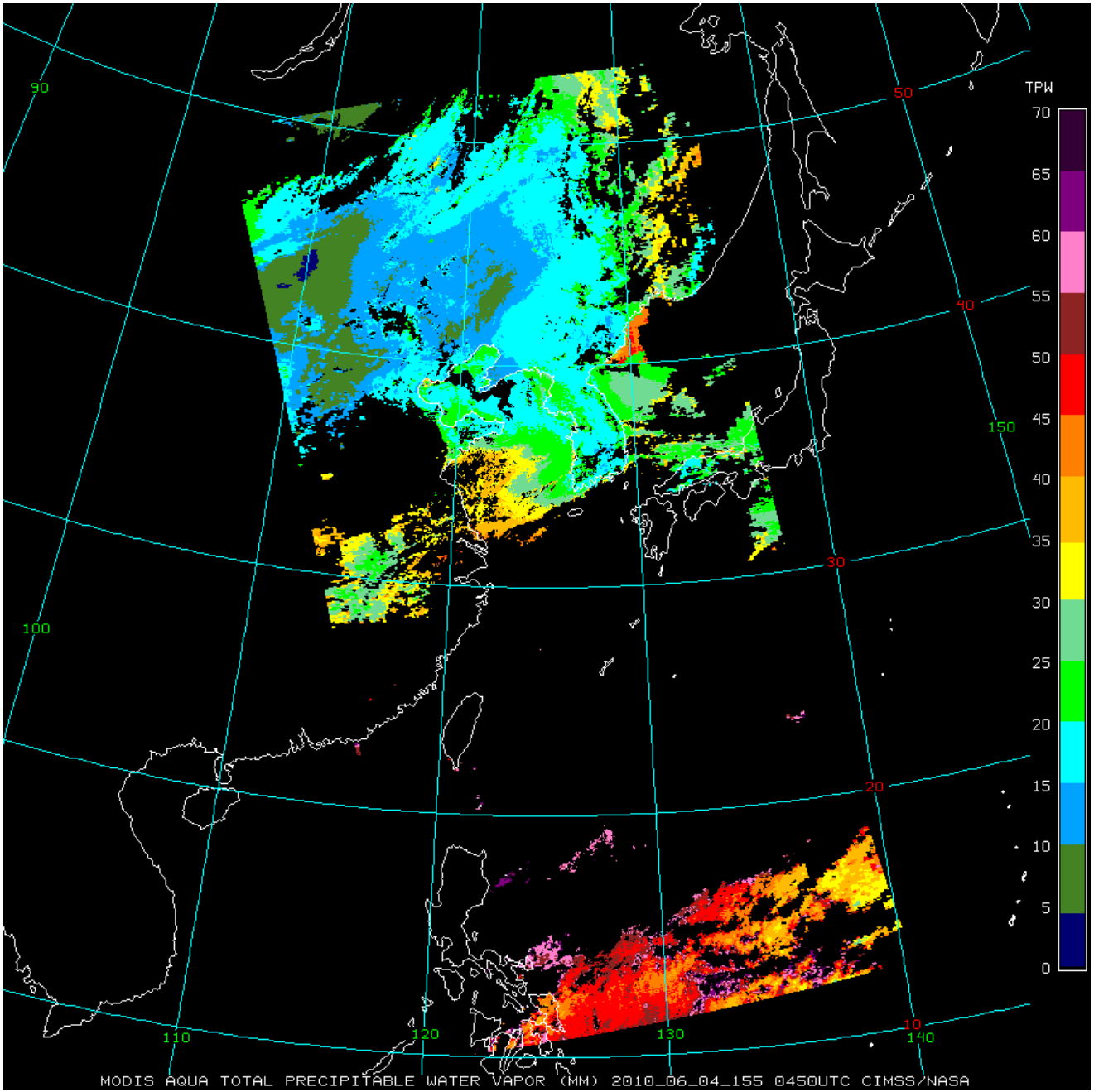
MODIS Water Vapor Product (MOD07)

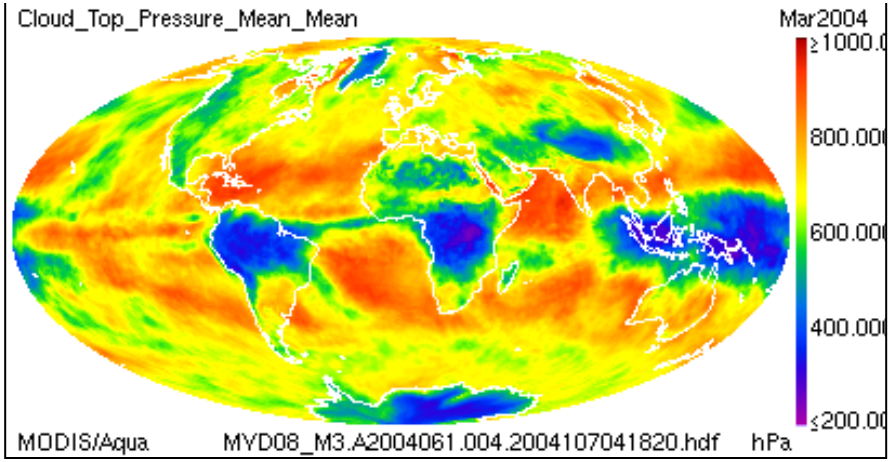
Clear Sky Only

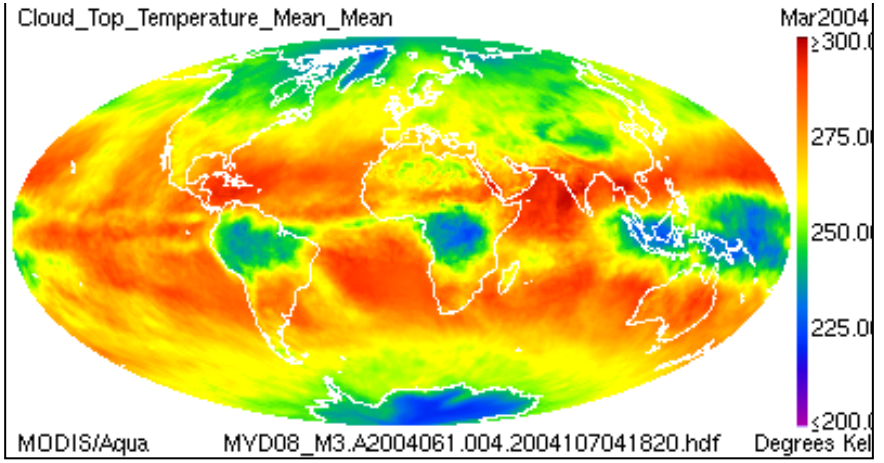
Day/Night

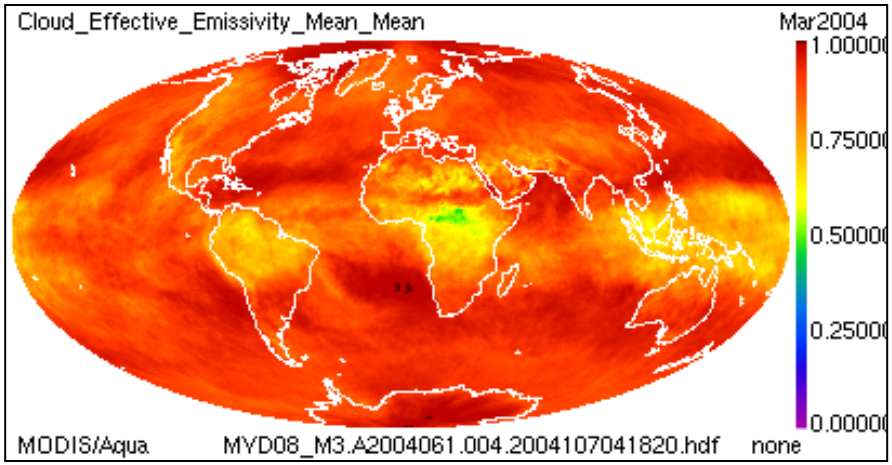
5 x 5 km resolution

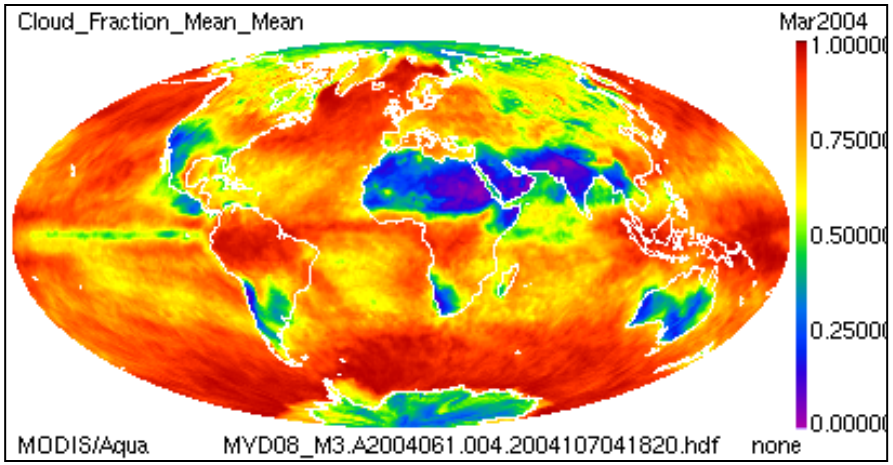
Statistical Algorithm

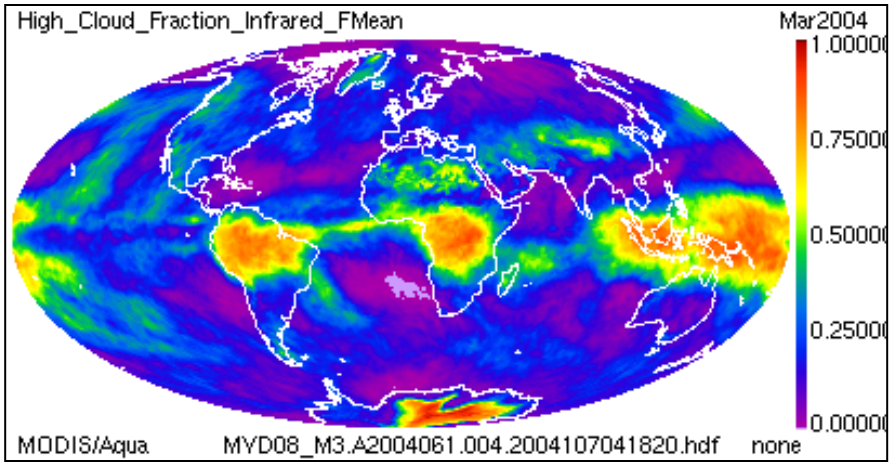












MODIS Cloud Top Properties Level 3 Products March 2004

End of Part One