Remote Sensing in hydrology & meteorlogy

Remote Sensing in hydrology & meteorlogy

- 74% of the Earth's surface is water
- 97% of the Earth's volume of water is in the saline oceans
- 2.2% in the permanent icecap
- Only 0.02% is in freshwater streams, river, lakes, reservoirs
- Remaining water is in:
    - underground aquifers (0.6%),
    - the atmosphere in the form of water vapor (0.001%)

Jensen, 2000

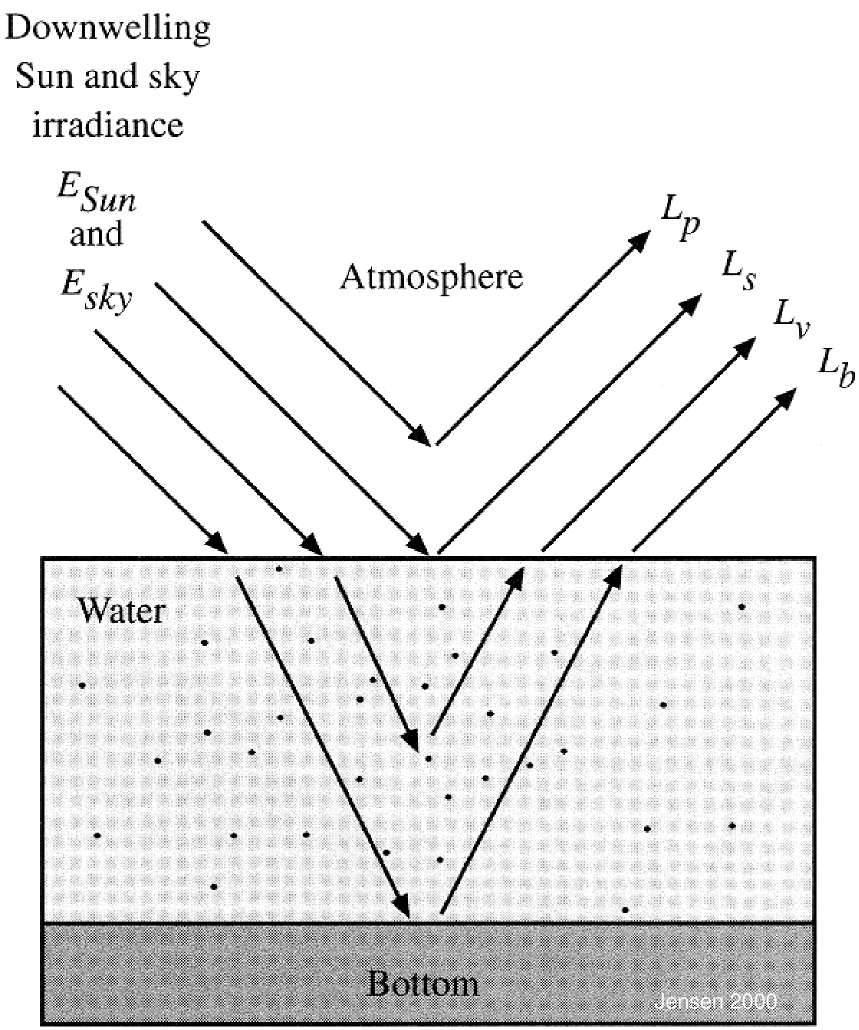
Remote Sensing in hydrology & meteorlogy

Application of remote sensing methods to hydrology and water resources:

- water-surface area (streams, rivers, ponds, lakes, reservoirs, and seas),
- water constituents (organic and inorganic),
- water depth (bathymetry), water-surface temperature, snow-surface area,
- snow-water equivalent, ice-surface area,
- ice-water equivalent, cloud cover,
- precipitation, and water vapor.

Snow Water Equivalent (SWE) is a measurement of the amount of water contained in snow pack.

Remote Sensing in hydrology & meteorlogy



$$L_t = L_p + L_s + L_v + L_b$$

$\mathbf{L_p}$ – atmospheric path radiance,

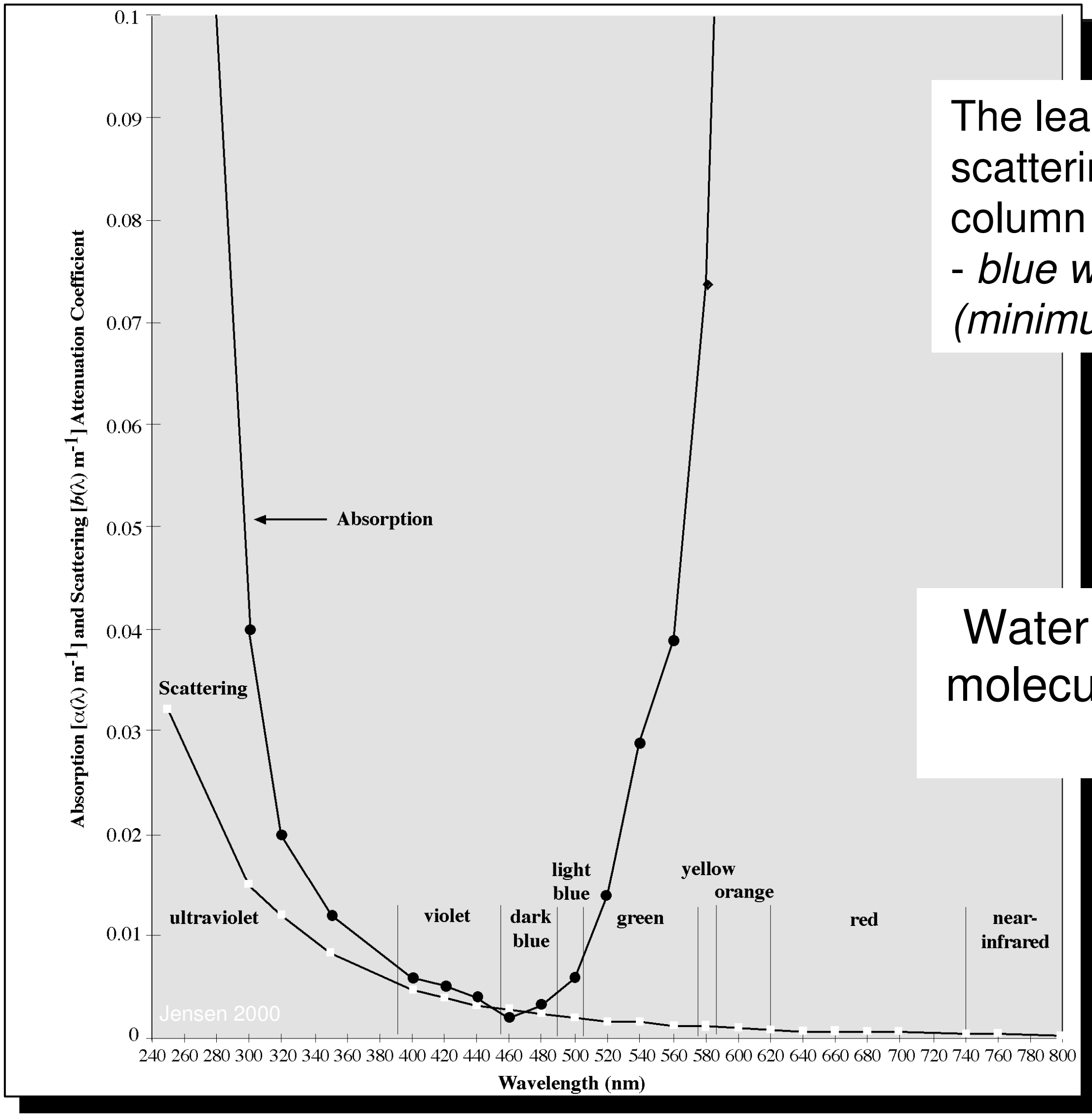
$\mathbf{L_s}$ – free-surface layer reflectance,

$\mathbf{L_v}$ – subsurface volumetric reflectance,

$\mathbf{L_b}$ – bottom reflectance.

Remote Sensing in hydrology & meteorlogy

Absorption and scattering in pure water



The least amount of absorption and scattering of incident light in the water column (therefore the best transmission) - *blue wavelength region 400-500 nm (minimum at 460-480 nm)*

Water appears blue because of molecular scattering of violet and blue light

Remote Sensing in hydrology & meteorlogy

Monitoring the Surface Extent of Water Bodies

Black and white infrared photograph of water bodies in Florida

Black and white infrared photograph with sunglint

The most useful spectral range to distinguish the land from water surface is between 740 - 2500 nm wavelength.

Jensen 2007

Remote Sensing in hydrology & meteorlogy

Water quality - sediments

$$L_v = \left[w_{c(\lambda)}, SM_{c(\lambda)}, Chl_{c(\lambda)}, DOM_{c(\lambda)} \right].$$

L_v – subsurface volumetric radiance (does not reach a bottom)

w – clear water,

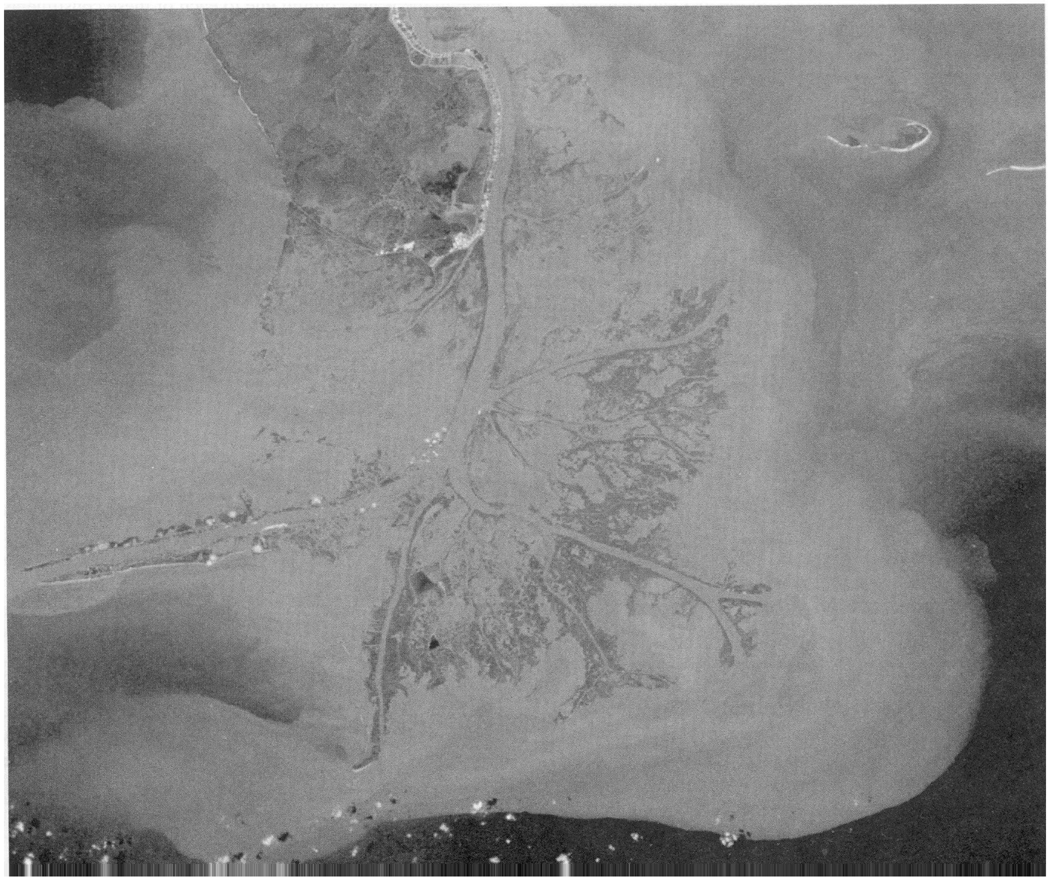
SM – inorganic minerals suspension ,

Chl – chlorophyll ,

DOM – dissolved organic material.

Remote Sensing in hydrology & meteorlogy

Water quality - sediments



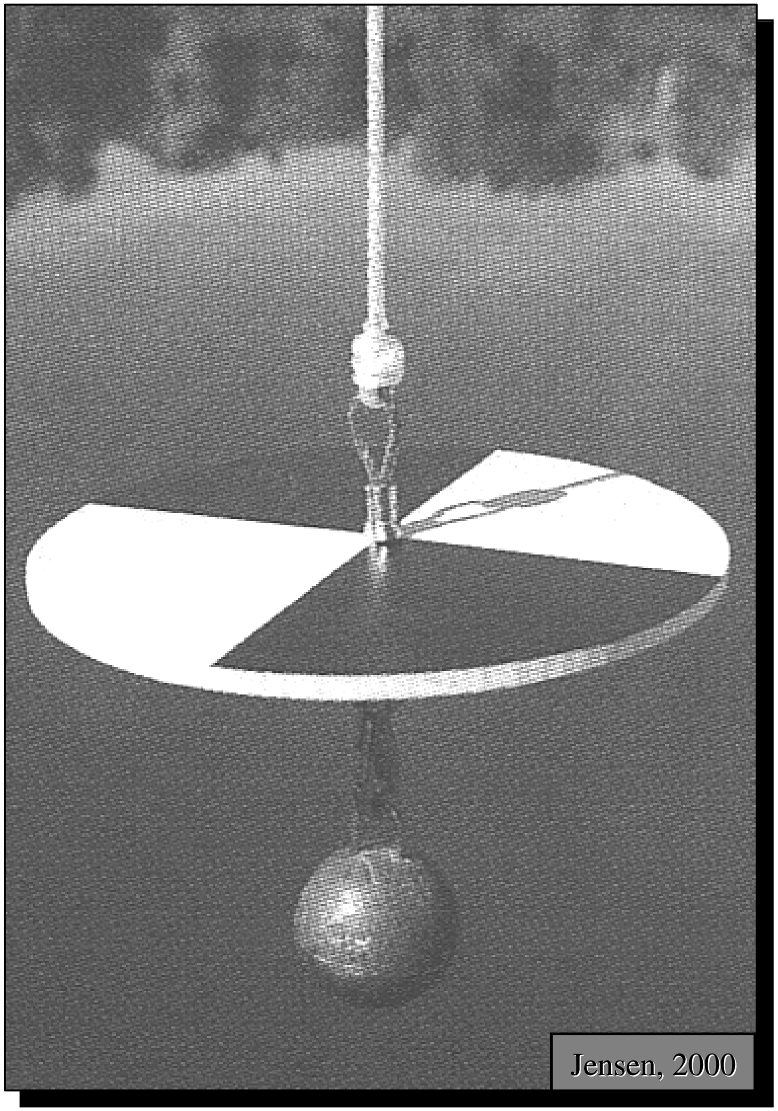
Space Shuttle Photograph of the Suspended Sediment Plume at the Mouth of the Mississippi River near New Orleans, Louisiana

The suspended sediments in natural waters consist mainly of primarily of silicon, aluminum and iron oxides in the form of the clay (3-4 mm), silt (5-40 mm) fine (41-130 mm) and coarse sand (131-1250 mm) particles. Their source is the erosion on agricultural fields, weathering of rocks, volcanic eruptions etc..

Jensen 2007

Remote Sensing in hydrology & meteorlogy

Water quality - sediments

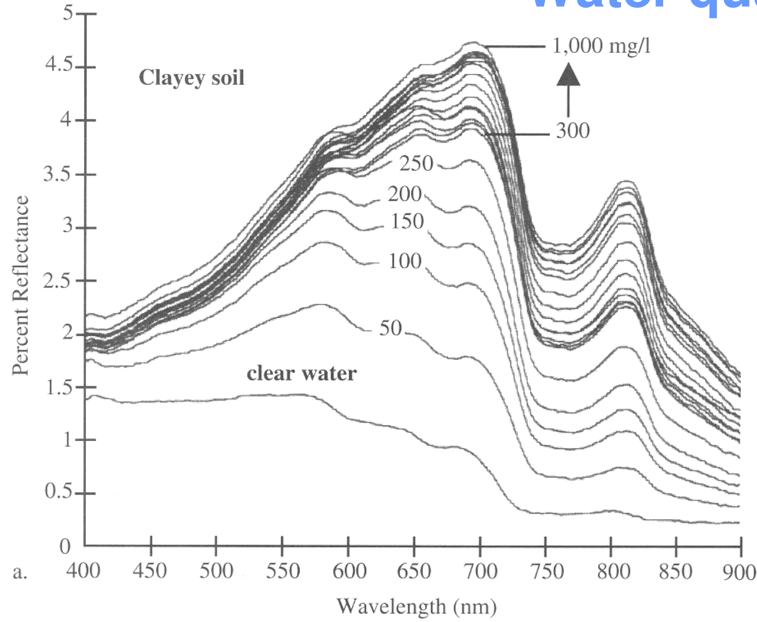


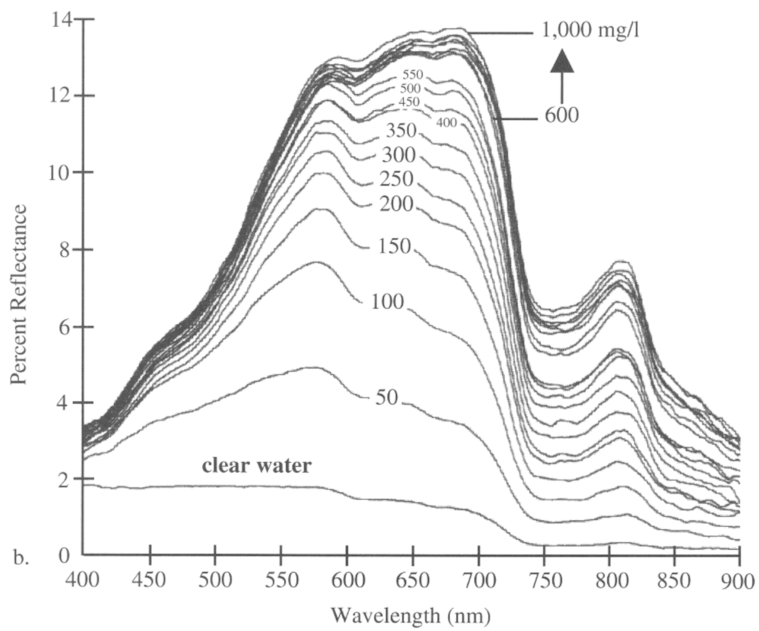
Secchi Disk

Nephelometer

Remote Sensing in hydrology & meteorlogy

Water quality - sediments





The reflection from the water with a suspension of two soils with different concentrations

Reflection maximum moves towards longer wavelengths with increasing thickness of the suspension.

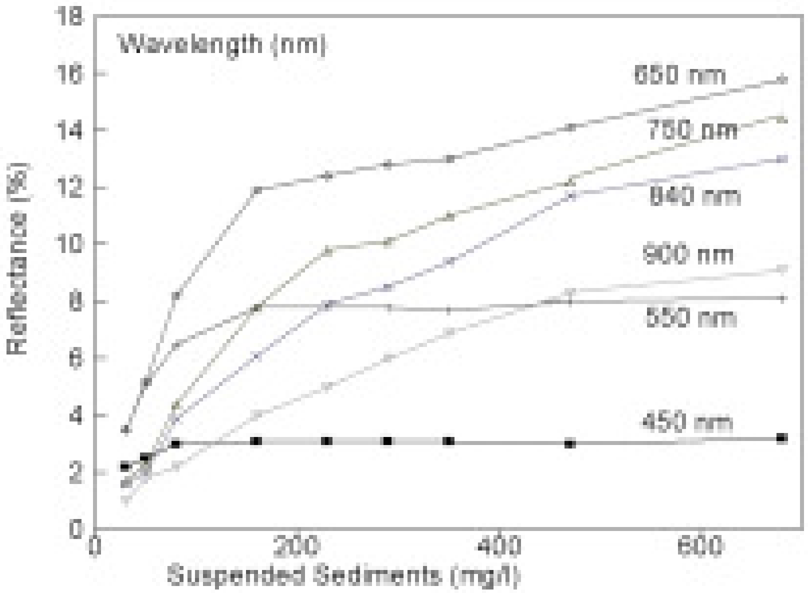
The strongest correlation (R> 0.90) exists between the concentration of the suspension and the reflection of waves of 714-880 nm

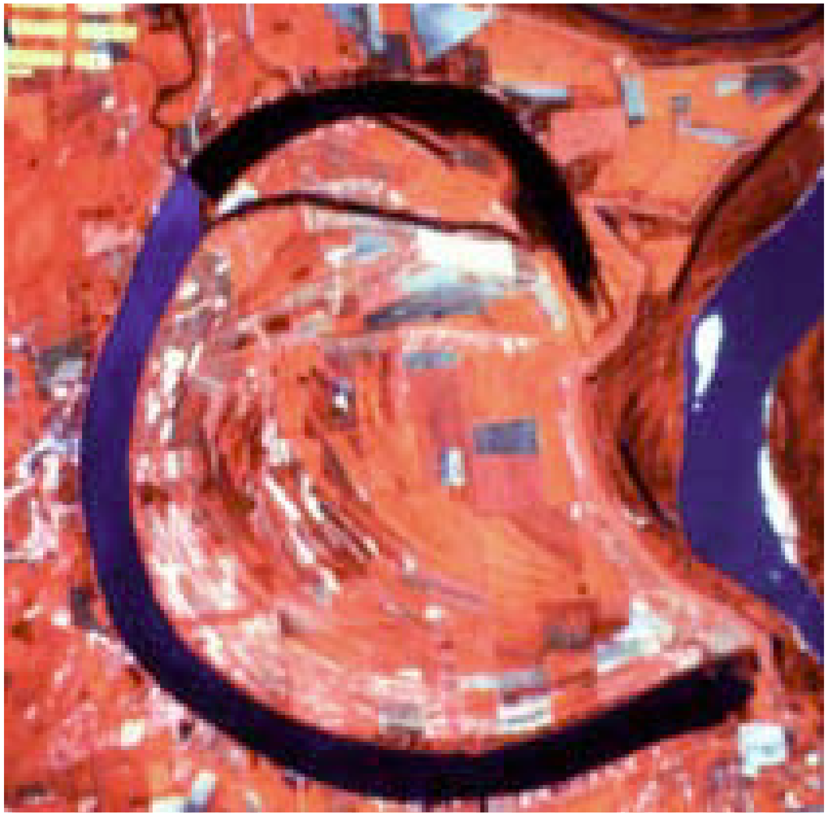
Wavelength range 580-690 nm provides information on the type of suspensionn while range 714-880 nm on quantitative information about the suspension.

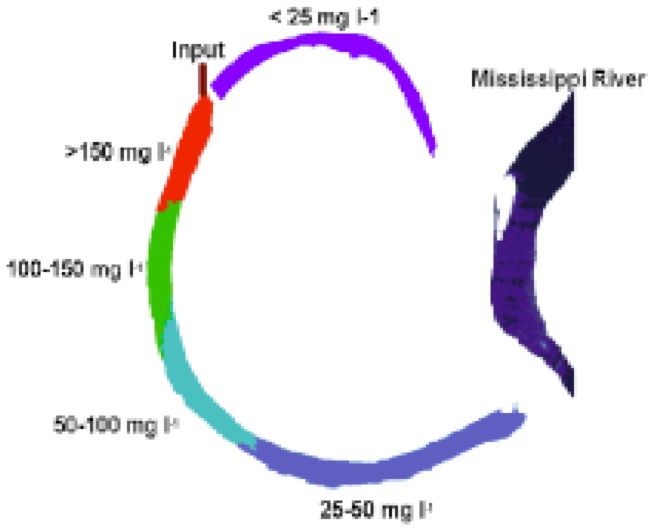
Lodhi et al., 1997; Jensen, 2000

Remote Sensing in hydrology & meteorlogy

Water quality - sediments







Landsat Thematic Mapper (TM) image
Chicot Lake, Arkansas

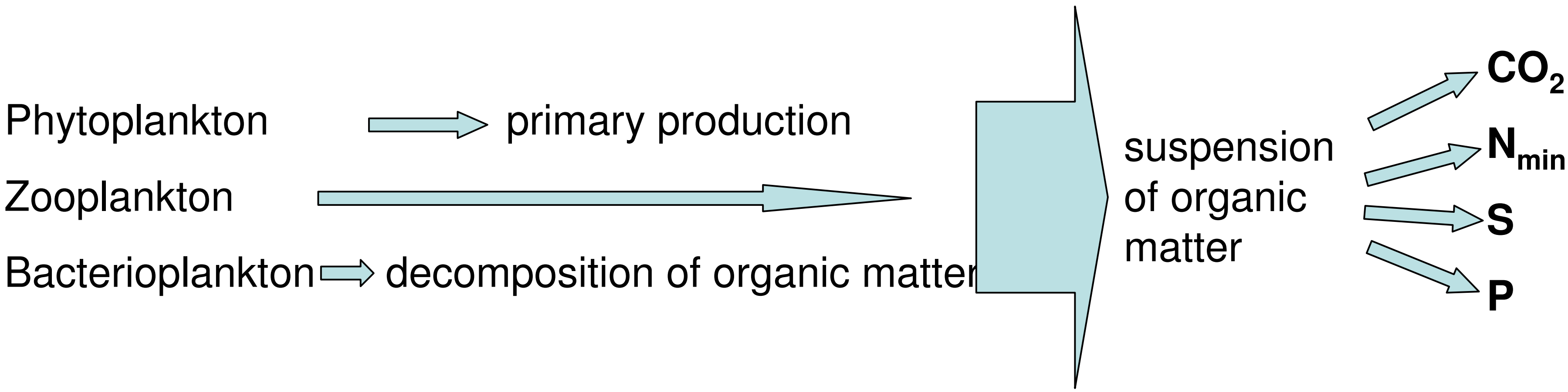
Ritchie and Cooper

Remote Sensing in hydrology & meteorlogy

Water quality – organic constituents

Optical depth *(optical thickness)* - the medium parameter, describing the change in intensity of light as it passes through the medium, such as gases, clouds, phytoplankton in the water and other suspensions. The depth of light penetration into the ocean depends on optical thickness of water.

Photic zone of the ocean is defined as the depth which is reached by 1% of the radiation used in photosynthesis (PAR photosynthetic available radiation - 300-700 nm.

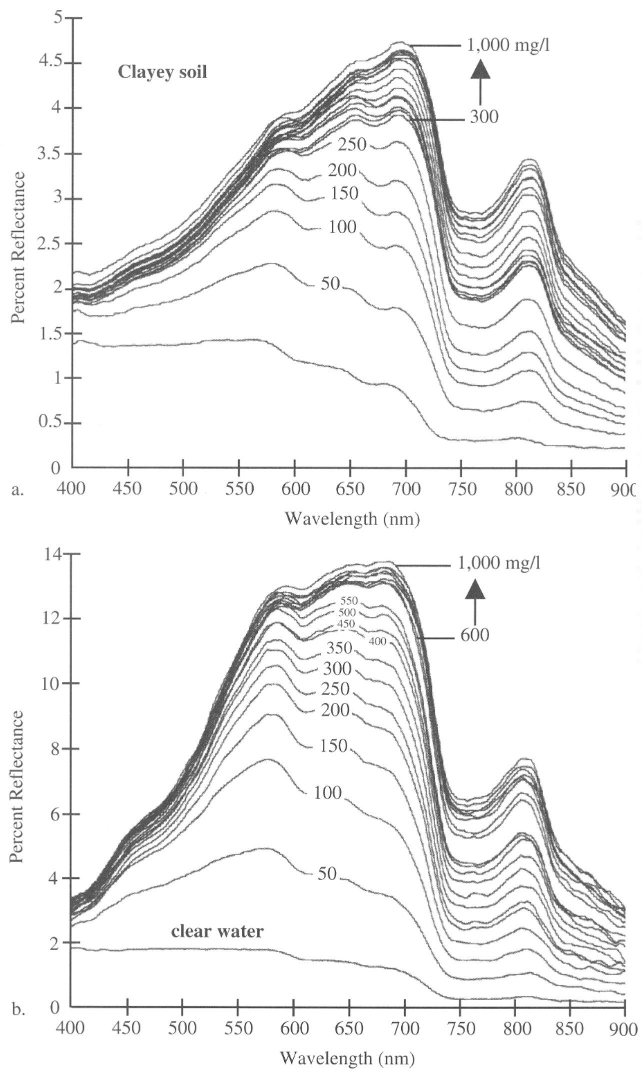


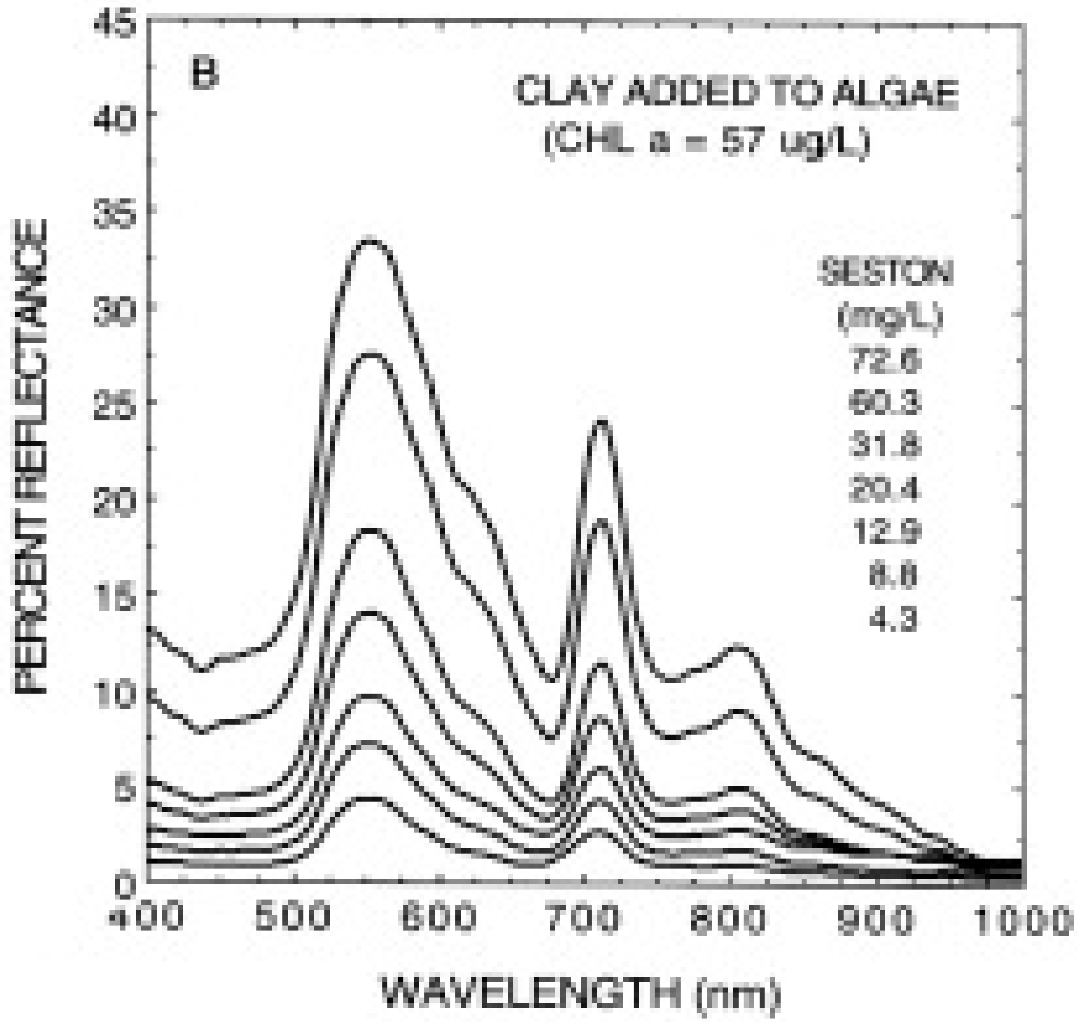
Colour suspended organic matter

- humic compounds (often yellow color)
- tannins (different colors - Canadian Hemlock *Tsuga canadensis*)

Remote Sensing in hydrology & meteorlogy

Water quality – mineral & organic constituents

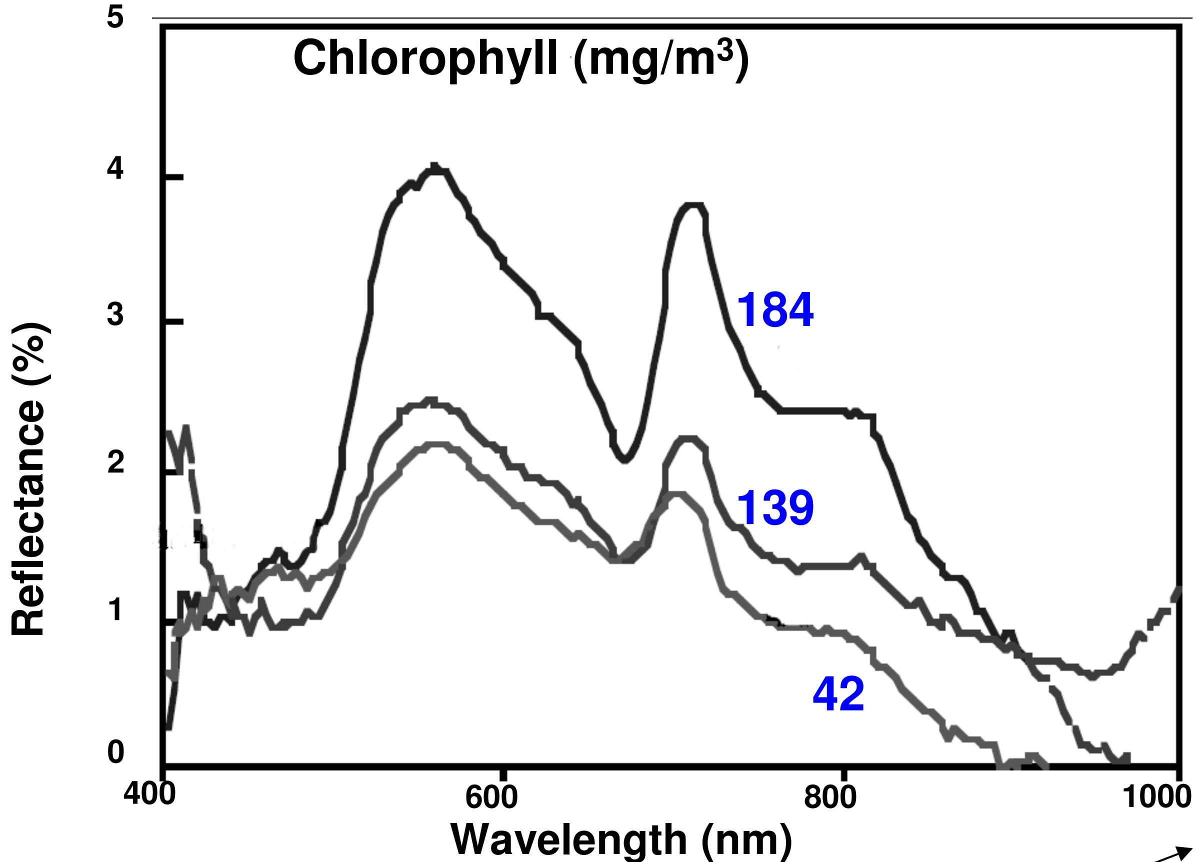




Remote Sensing in hydrology & meteorlogy

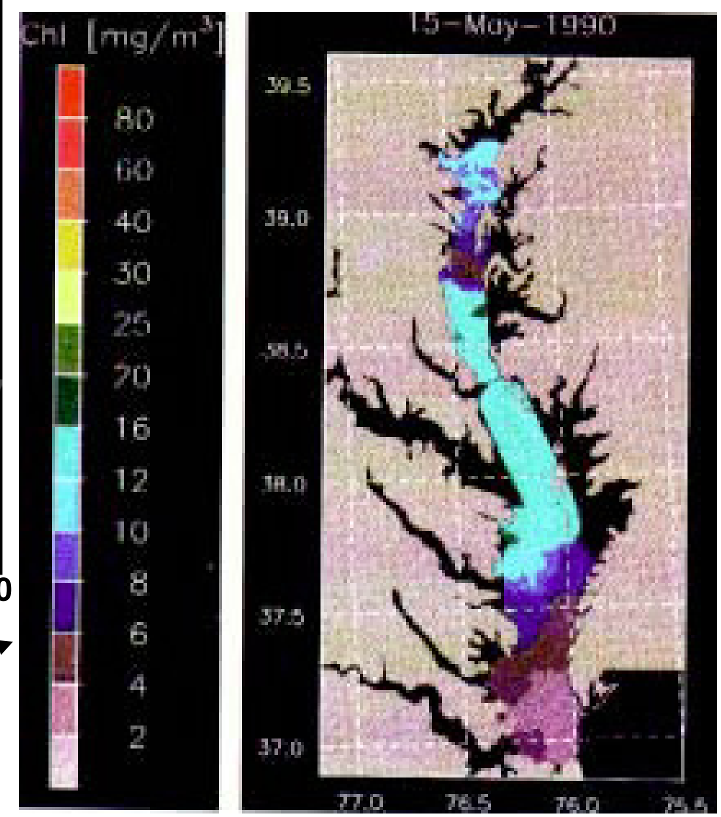
Water quality - sediments

The relationship between reflectance and chlorophyll from *in situ* measurements made under control conditions.



Eutrophication - an increase in the fertility of the waters.

Ritchie and Cooper



The map of total chlorophyll content in the Chesapeake Bay

$$Log_{10}\,[Chlorophyll] = a + b\,(-Log_{10}G)$$

a and ***b*** are empirical constants derived from *in situ* measurements, ***G*** is $[(R2)^2/(R1*R3)]$. R1, R2 and R3 is radiance at 460 nm, 490 nm, and 520 nm respectively.

Remote Sensing in hydrology & meteorlogy

Water quality - Chlorophyll in the oceans

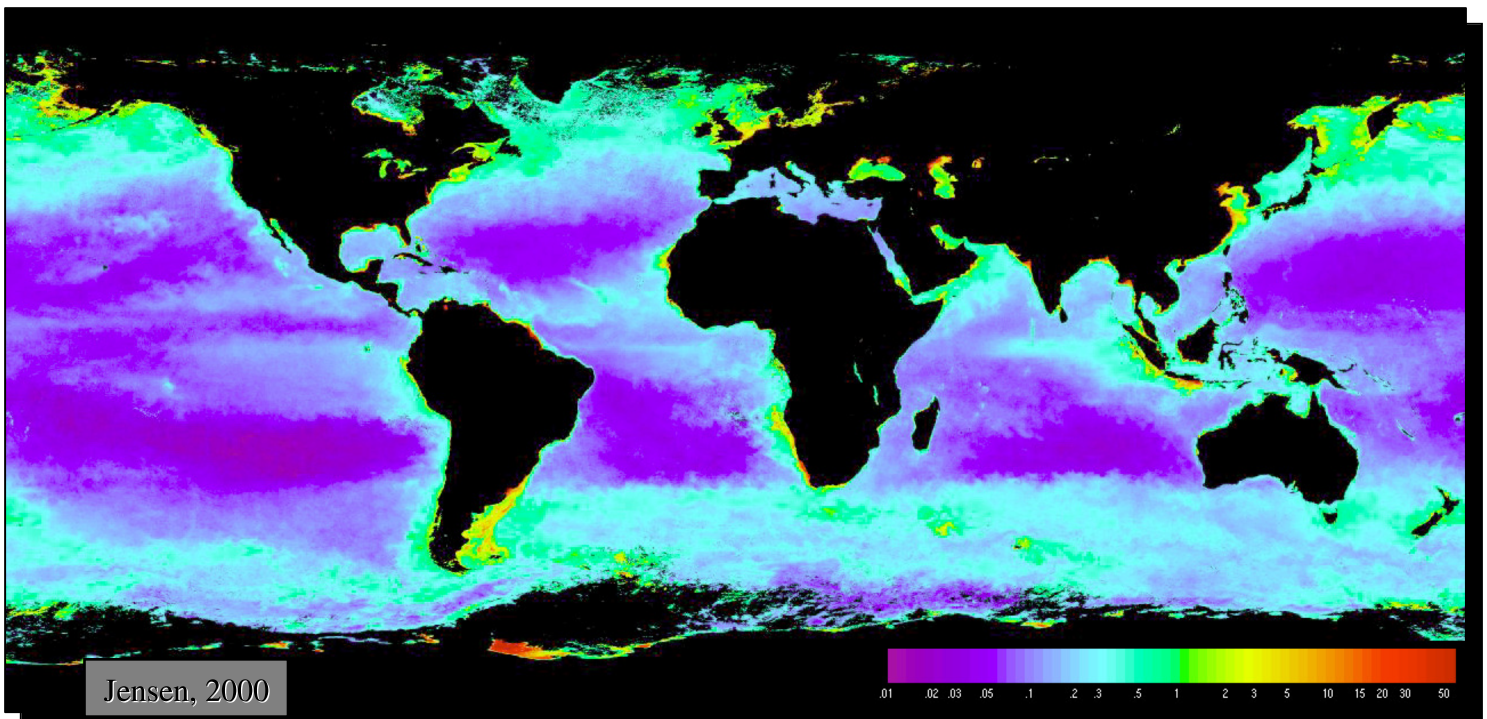
The relationship between the reflectance of selected wavelengths and concentration of chlorophyll in the water:

$$Chl = \mathrm{x}\,[L(\lambda_1)/L(\lambda_2)]^{\mathrm{y}}$$

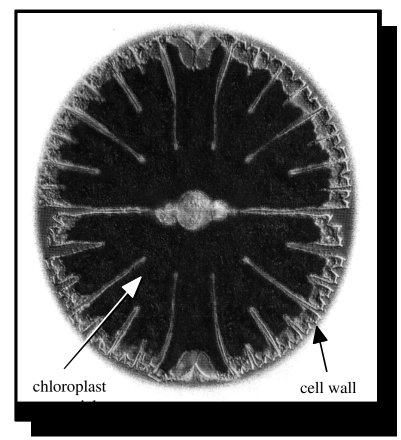
where: $L(\lambda_1)$ *i* $L(\lambda_2)$ **-** the reflected radiation in a particular wavelength ,

x i y - empirically determined constant.

The algorithms for the processing of SeaWiFS data using waves of 443/355 nm and 490/555 nm .



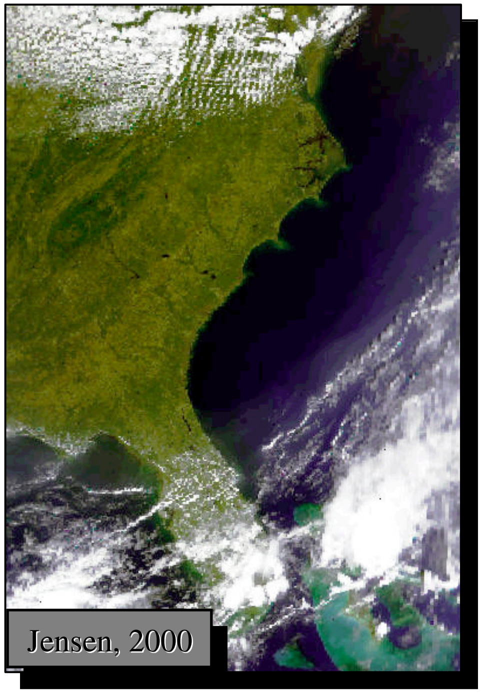
Chlorophyllo concentration (g/m3) on the basis of a satellite image SeaWiFS a registered in 1997 .



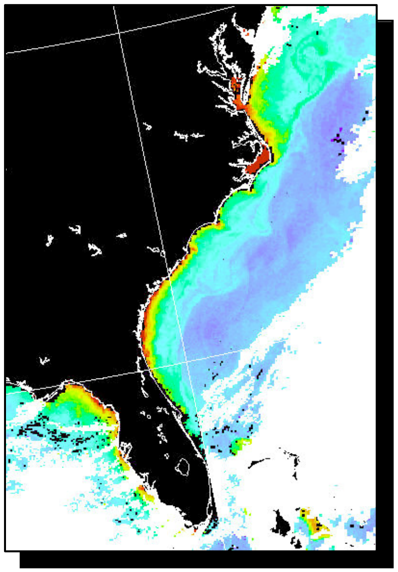
Picture of a single algae cell taken in the blue range.

Remote Sensing in hydrology & meteorlogy

Water quality - Chlorophyll in the oceans



True-color SeaWiFS image of the Eastern U.S. on September 30, 1997



Chlorophyll *a* distribution on September 30, 1997 derived from SeaWiFS data

SeaWiFS sensor onboard OrbView-2 satellite
Coast Watch Ocean Color Program
1997

Orbit: sunsynchronous, descending, 90 minutes, height 702 km.

Swath width: depending on the transmission method - LAC (in real time) 2 801 km and GAC 1 502 km.

Spatial resolution: in LAC mode 1.1 km and 4.5 km in GAC mode.

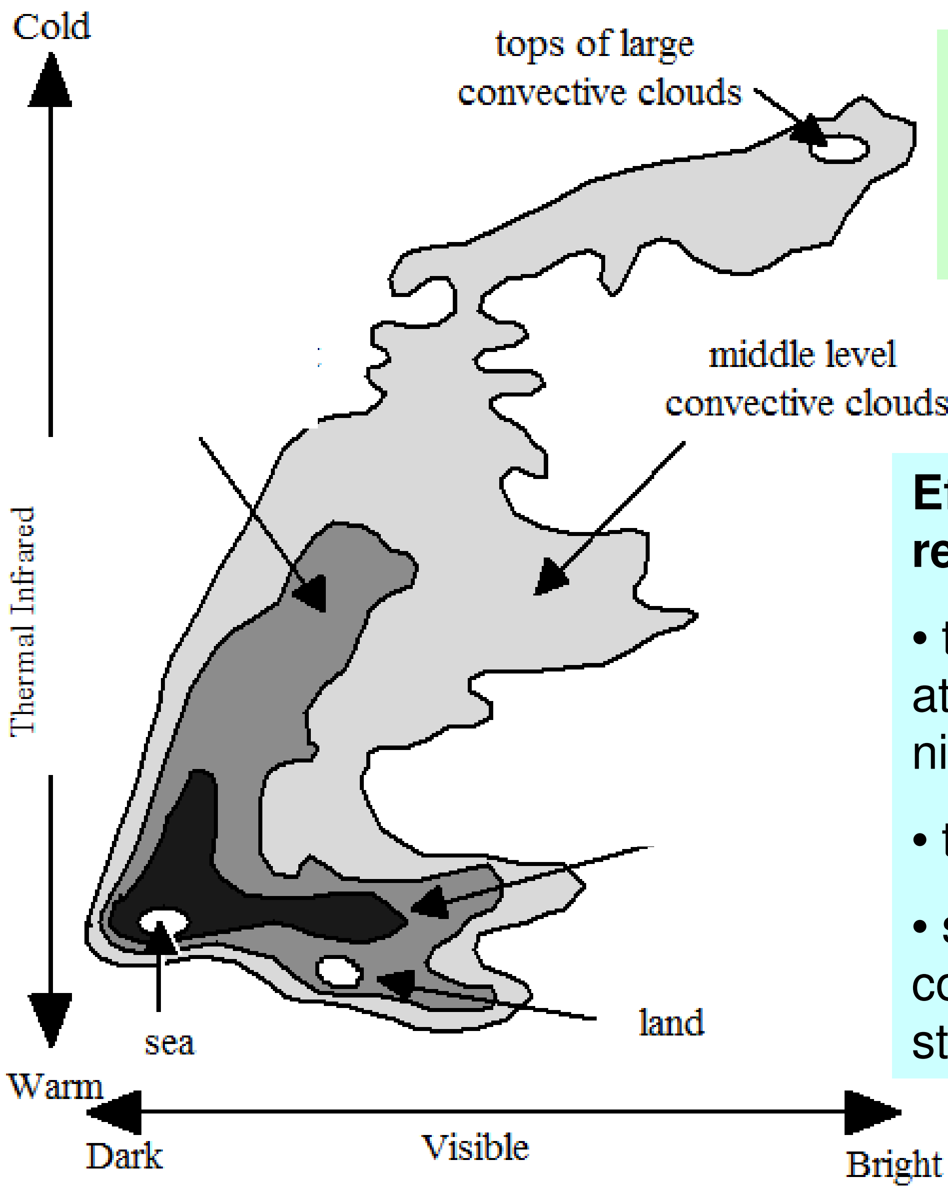
Exceeding the equator: noon +20 minutes.

Revisit: one day.

1	402-422 (violet)	organic suspension
1	423-443 (blue)	chlorophyll absorption
2	480-500 (blue-green)	pigment absorption
3	500-520 (blue-green)	chlorophyll absorption
4	545-565 (green)	pigments
5	660-680 (red)	korekcja atmosferyczna
6	745-785 (near infrared)	atmospheric correction, aerosols
7	845-895 (near infrared)	atmospheric correction, aerosols

Remote Sensing in hydrology & meteorlogy

Clouds



Determination of the type of clouds from multispectral data from the visible and thermal infrared spectrum.

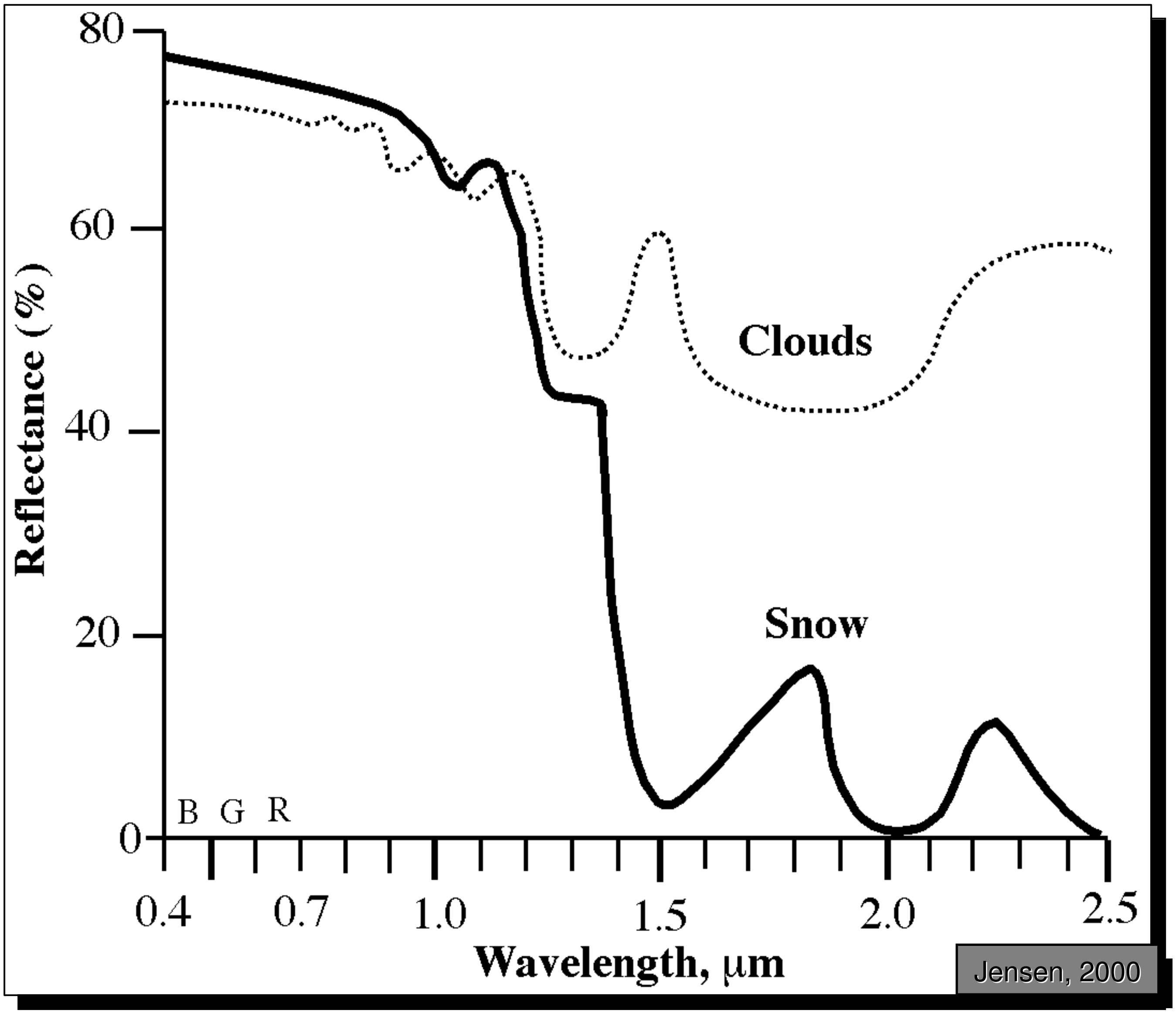
Effective modeling of global climate requires information about:

- the amount and type of aerosols in the atmosphere, both natural and anthropogenic origin.
- the size, type and height of clouds.
- spatial variation of the Earth's surface coverage (including information on the structure of the vegetation).

Jensen, 2000

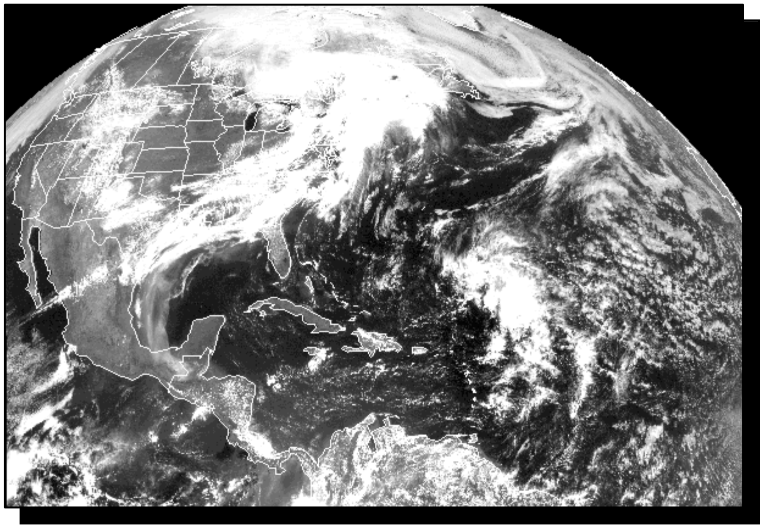
Remote Sensing in hydrology & meteorlogy

Clouds & Snow

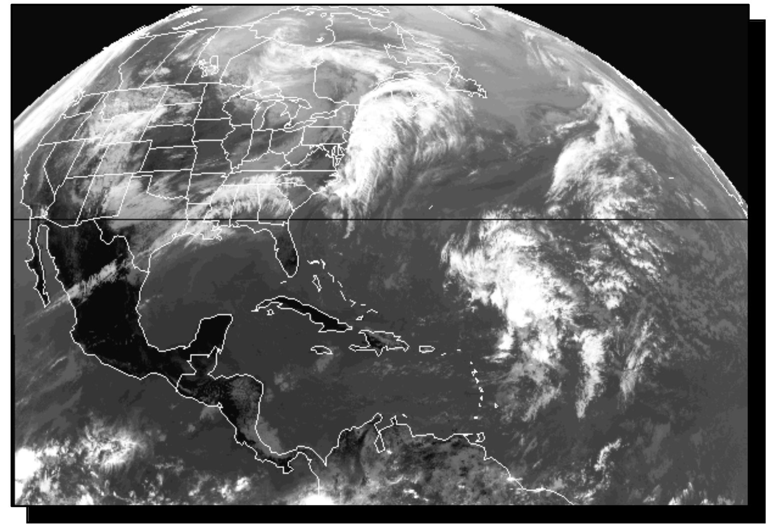


Remote Sensing in hydrology & meteorlogy

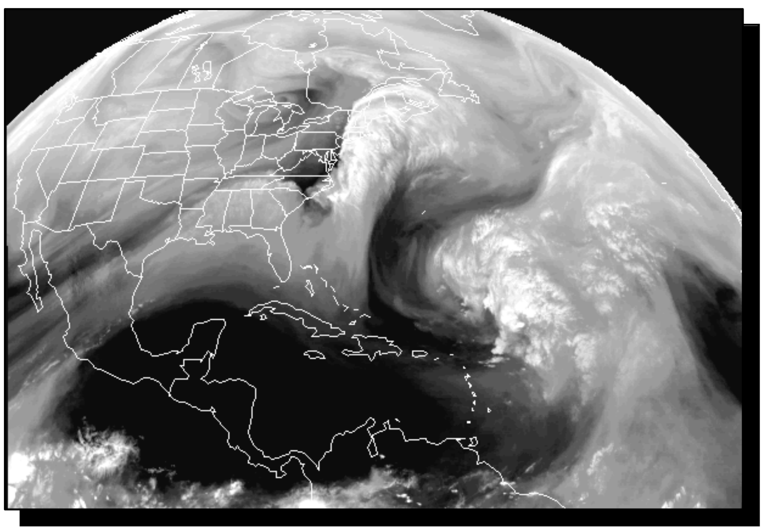
Clouds & Snow



GOES-East Visible



GOES-East Thermal Infrared



GOES-East Water Vapor

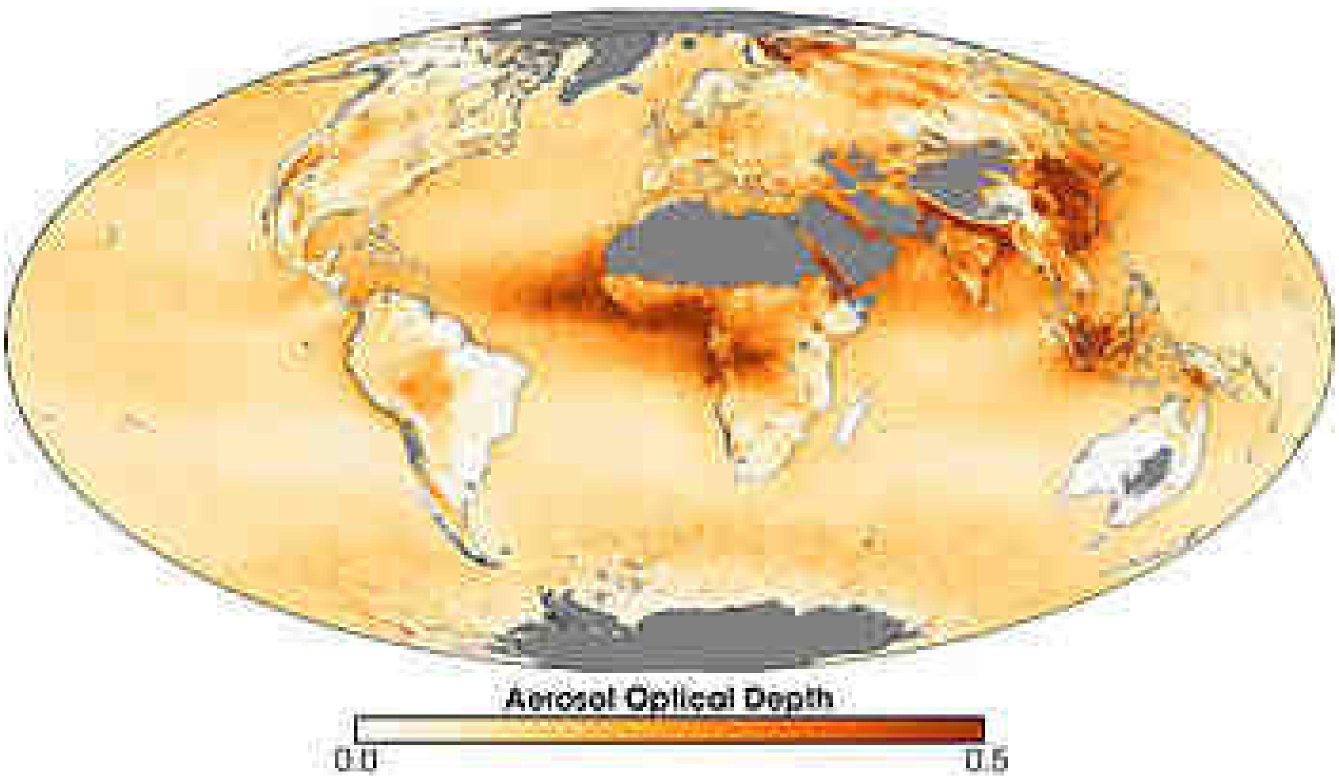
Images from three geostationary satellite channels GOES-East April 17, 1998

Remote sensing methods for determining the amount of precipitation are indirect and rely on the measurement of cloud reflectance, cloud-top temperature and/or the presence of frozen precipitation.

Jensen, 2000

Remote Sensing in hydrology & meteorlogy

Aerosols



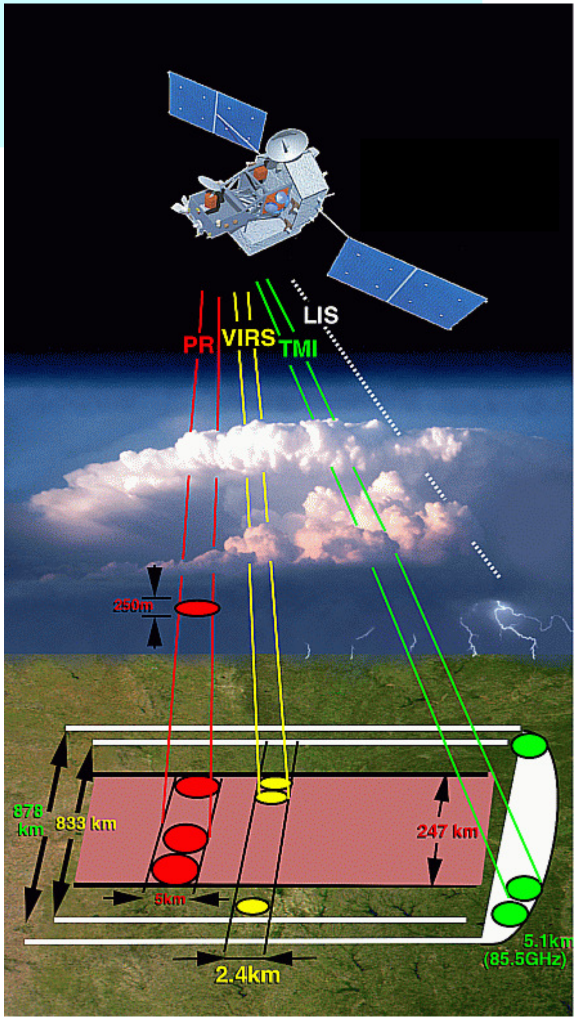
The aerosol optical thickness determined from satellite measurements (MODIS sensor).

Remote Sensing in hydrology & meteorlogy

Precipitation

Remote sensing methods for forecasting rainfall:

- Estimation of the thickness of the clouds on the basis of the reflectance in the VIS-NIR range.
- Temperature of the cloud tops.



TRMM *Tropical Rainfall Measuring Mission*

TRMM Satellite

Orbit: height 350 km
inclination 35

5 sensors:
- Precipitation Radar (PR),
- TRMM Microwave Imager (TMI),
- Visible Infrared Scanner (VIRS),
- Lightning Imaging Sensor (LIS),
- Clouds and Earth's Radiant Energy System (CERES).

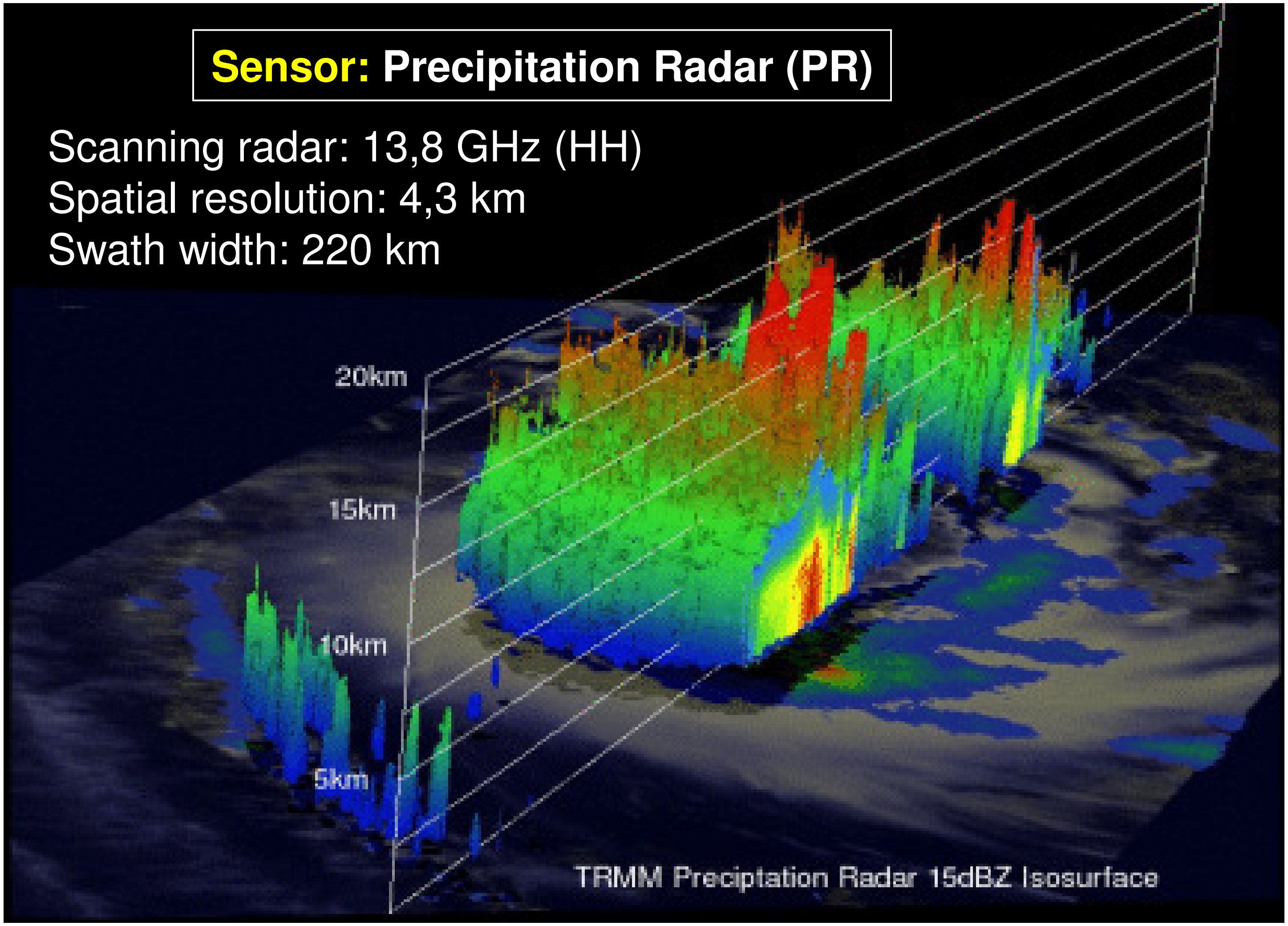
Remote Sensing in hydrology & meteorlogy

Precipitation

TRMM Tropical Rainfall Measuring Mission

PR measures the three-dimensional rainfall distribution over both land and oceans.

PR provides information about the rainfall actually reaching the surface, which is used to determine the latent heat of the atmosphere



Remote Sensing in hydrology & meteorlogy

Precipitation

TRMM *Tropical Rainfall Measuring Mission*

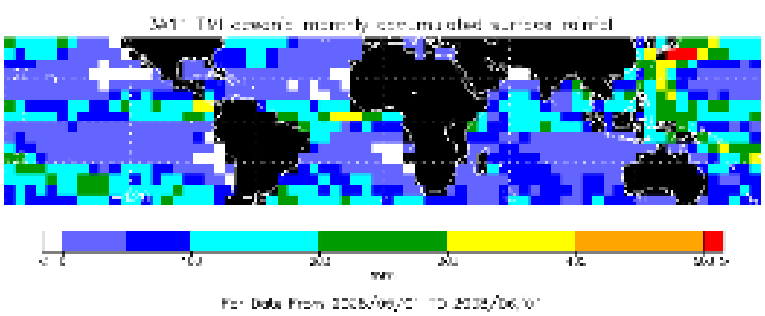
Sensor: **Microwave Imager (TMI)** ***passive radar***

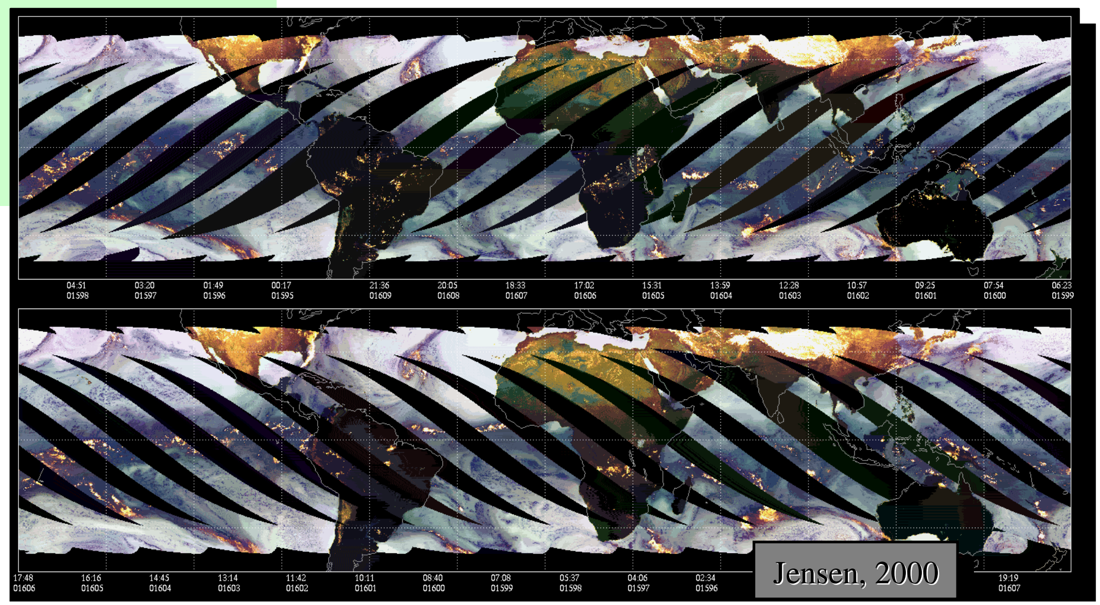
Estimation of precipitation over the oceans - the verification of climate models

Since 2001
Time reoslution: encirclement - 92,5 minutes,
16 laps a day.
Horizontal resolution: 5,1 km at 85,5 GHz.
Vertical resolution:
0.5 km from the surface to 4 km,
1.0 km from 4 to 6 km,
2.0 km from 6 to 10 km,
4.0 km from 10 to 18 km.
Swath width : 878 km.

Frequency:

10,7 GHz – 45 km
19,4 GHz
21,3 GHz
37,0 GHz
85,5 GHz
} 5 km





Remote Sensing in hydrology & meteorlogy

Precipitation

TRMM *Tropical Rainfall Measuring Mission*

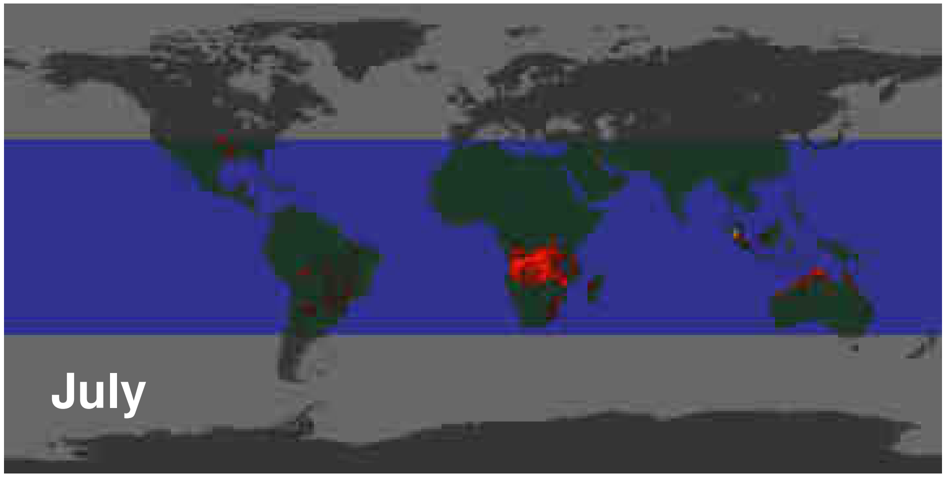
Sensor: Visible Infrared Scanner (VIRS)

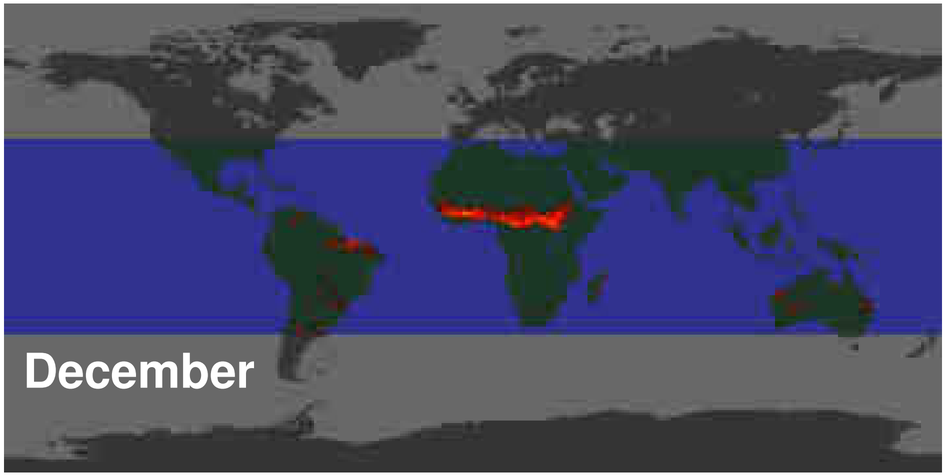
Estimating the amount of cloud cover and temperature cloud tops

Channels: 1 - VIS 630 nm,
2 - NIR 1 600 nm,
3 - NIR 3 750 nm,
4 - NIR 10 800 nm,
5 - IR 12 000 nm.

Spatial resolution: 2,4 km.

Swath width : 833 km.





VIRS is also capable of spotting active fires as well as evidence of burn scars. The two images compare the location of fires in July and December, 2000.

Remote Sensing in hydrology & meteorlogy

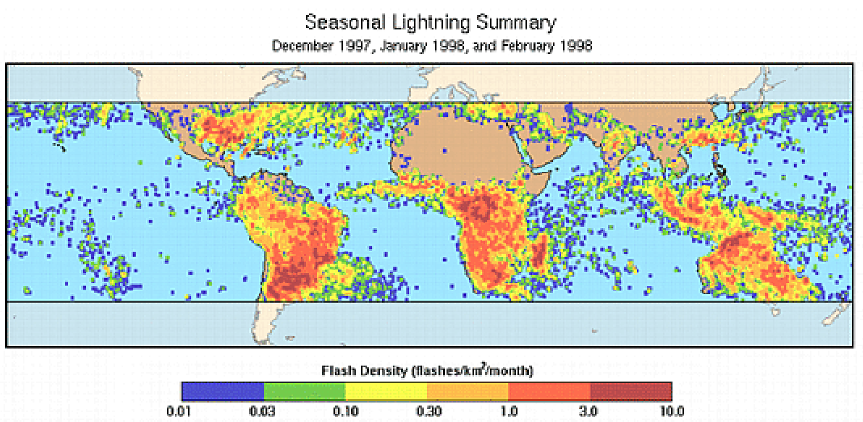
Precipitation

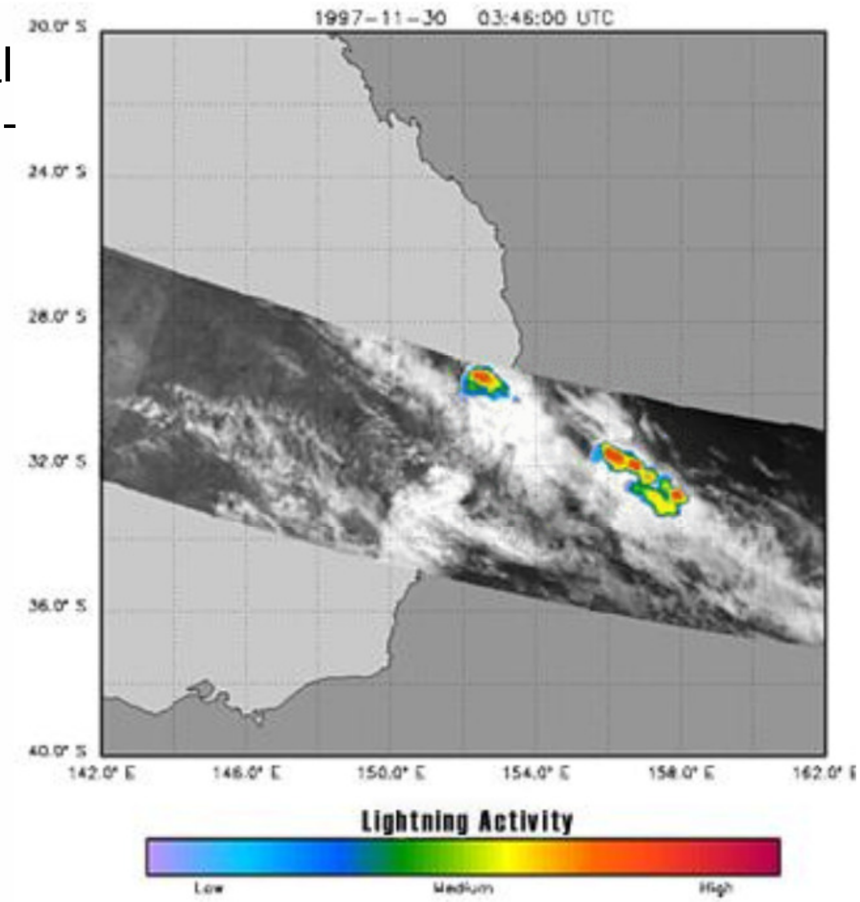
TRMM *Tropical Rainfall Measuring Mission*

Sensor: Lightning Imaging Sensor (LIS)

Detection of the distribution and variability of total lightning (cloud-to-cloud, intracloud, and cloud-to-ground lightning).

Channel: VIS 777 nm,
Spatial resolution: 5 km.
Swath width : 590 km.
Time of observation: 90s





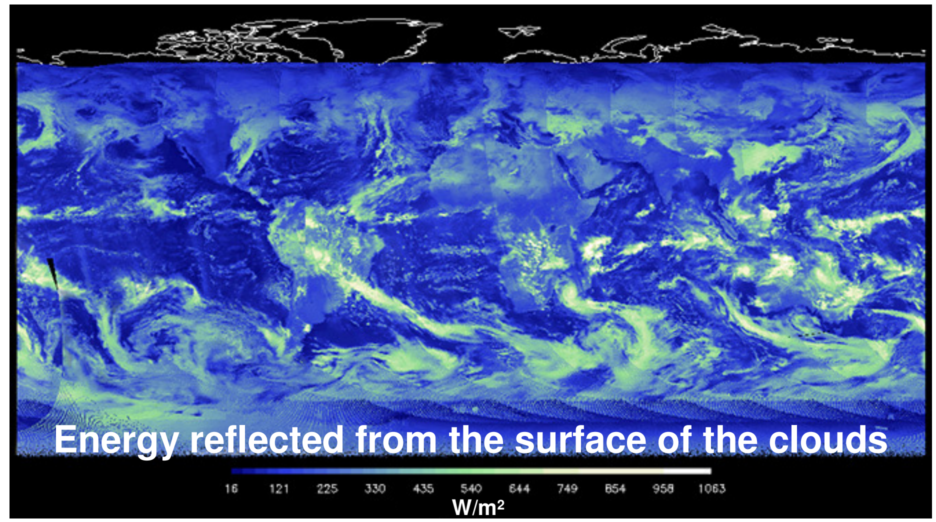
Remote Sensing in hydrology & meteorlogy

Precipitation

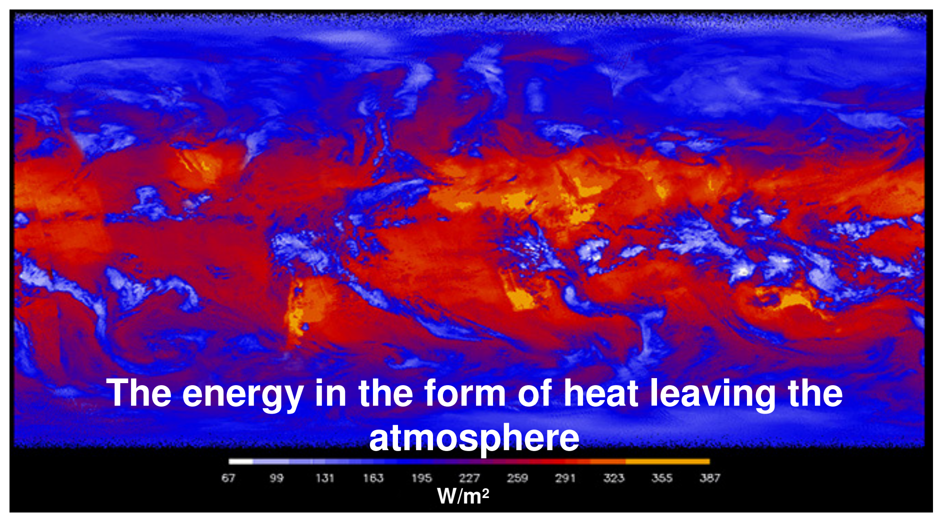
TRMM *Tropical Rainfall Measuring Mission*

Sensor: Clouds and Earth's Radiant Energy System (CERES).

Measurement of the emitted and reflected radiation from the Earth's surface and from atmosphere with the clouds and aerosols.

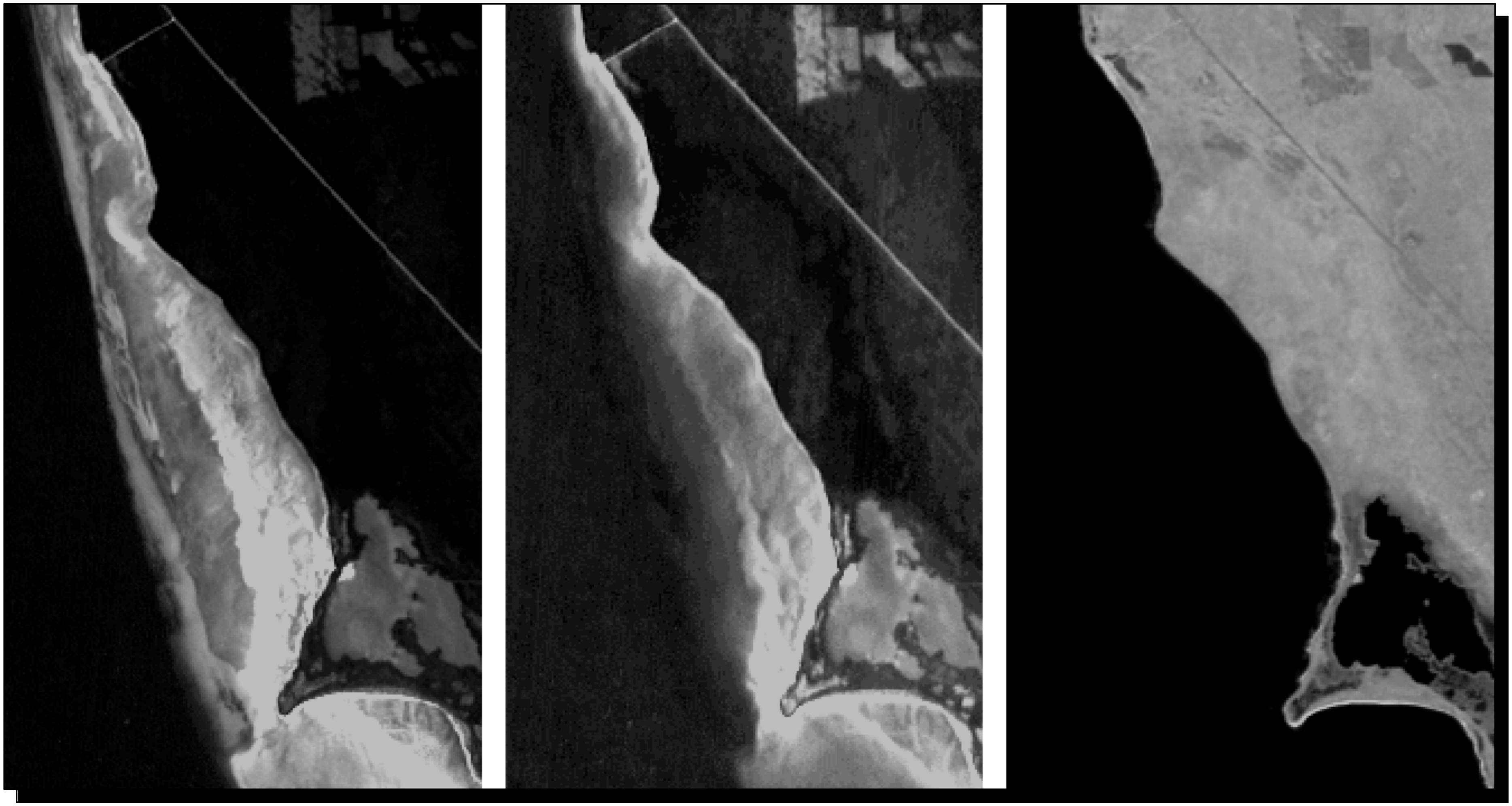


Channels: Total 300 – 100 000 nm,
VIS 300 – 500 nm,
IR 800 – 12 000 nm.



Remote Sensing in hydrology & meteorlogy

Bathymetry



SPOT Band 1 (0.5 - 0.59 mm) green

SPOT Band 2 (0.61 - 0.68 mm) red

SPOT Band 3 (0.79 - 0.89 mm) NIR

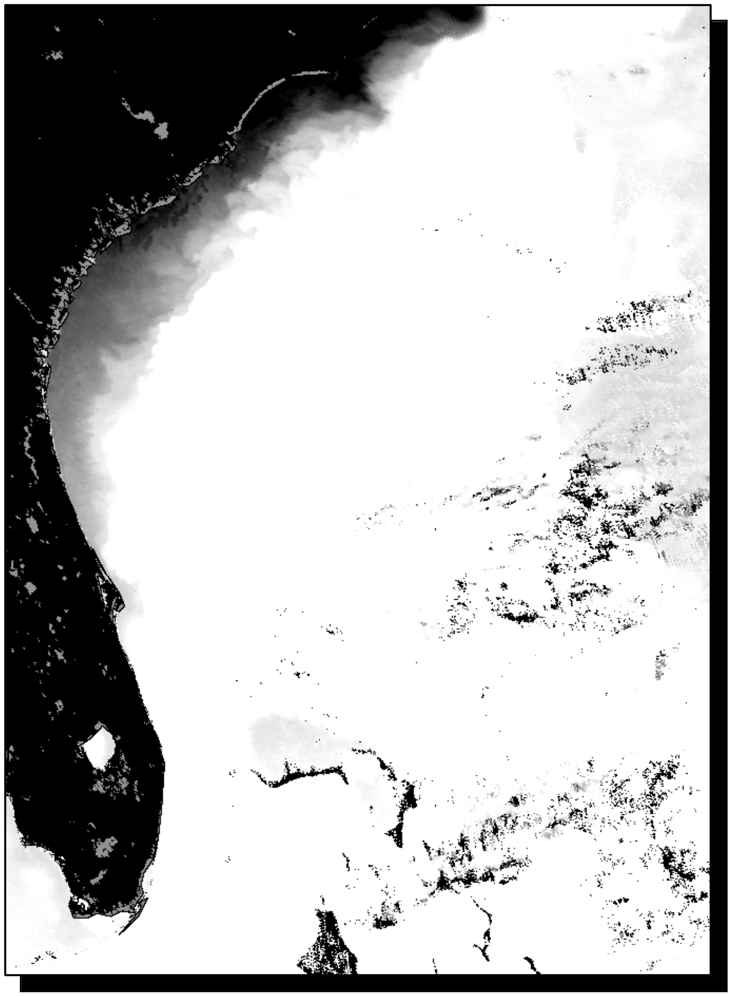
The most useful wavelengths for bathymetric surveys: 480 nm

Jensen 2007

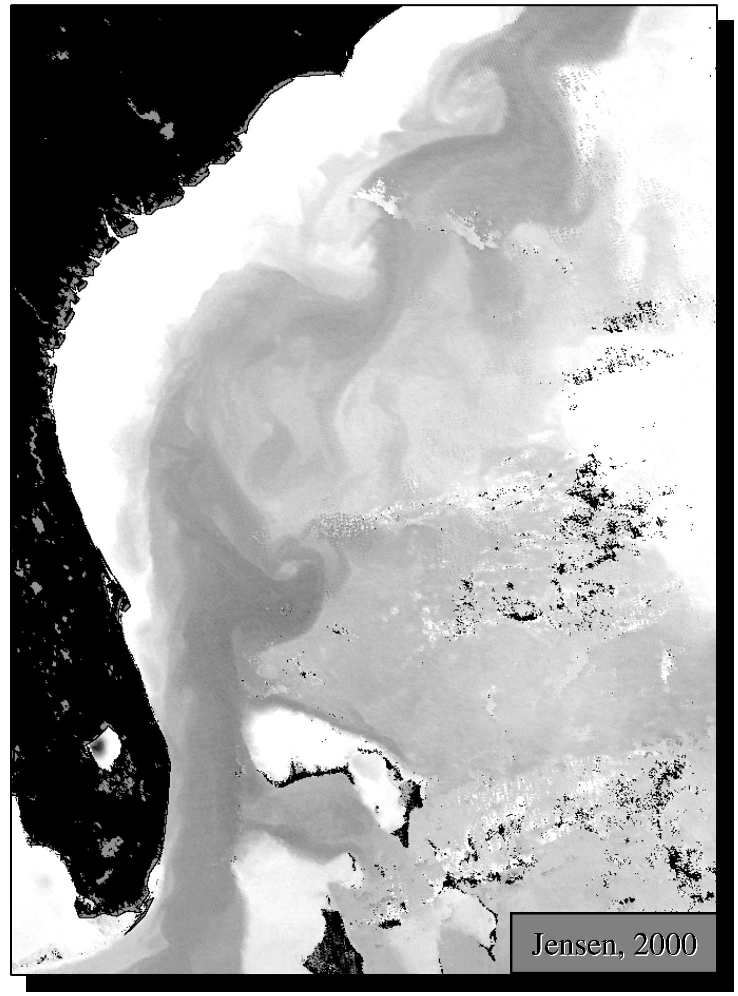
Remote Sensing in hydrology & meteorlogy

Surface water temperature

Sea-surface Temperature (SST) Maps Derived from A Three-day Composite of NOAA AVHRR Infrared Data Centered on March 4, 1999



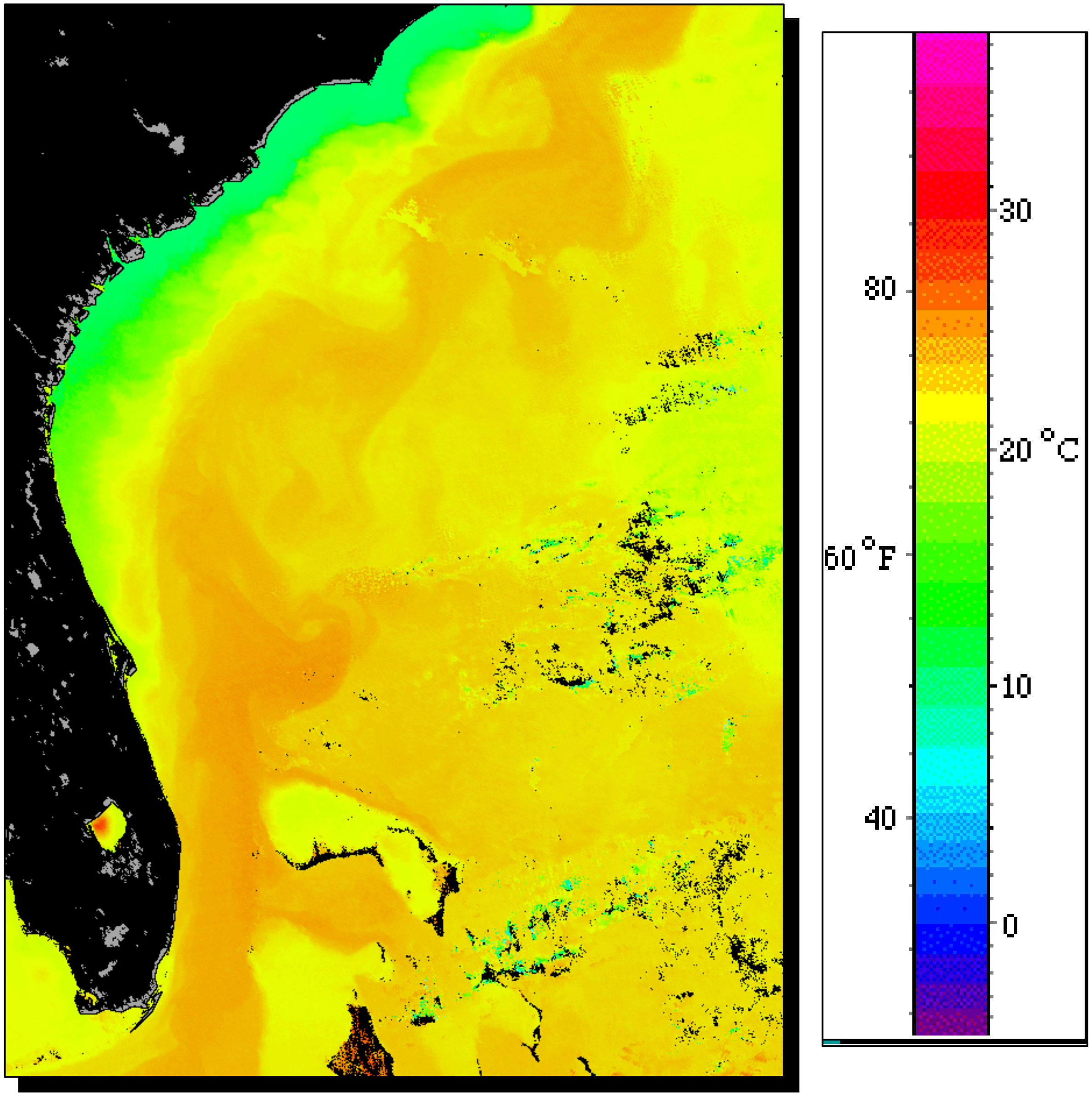
Adjusted to highlight nearshore temperature differences



Adjusted to highlight Gulf Stream temperature differences

Remote Sensing in hydrology & meteorlogy

Surface water temperature



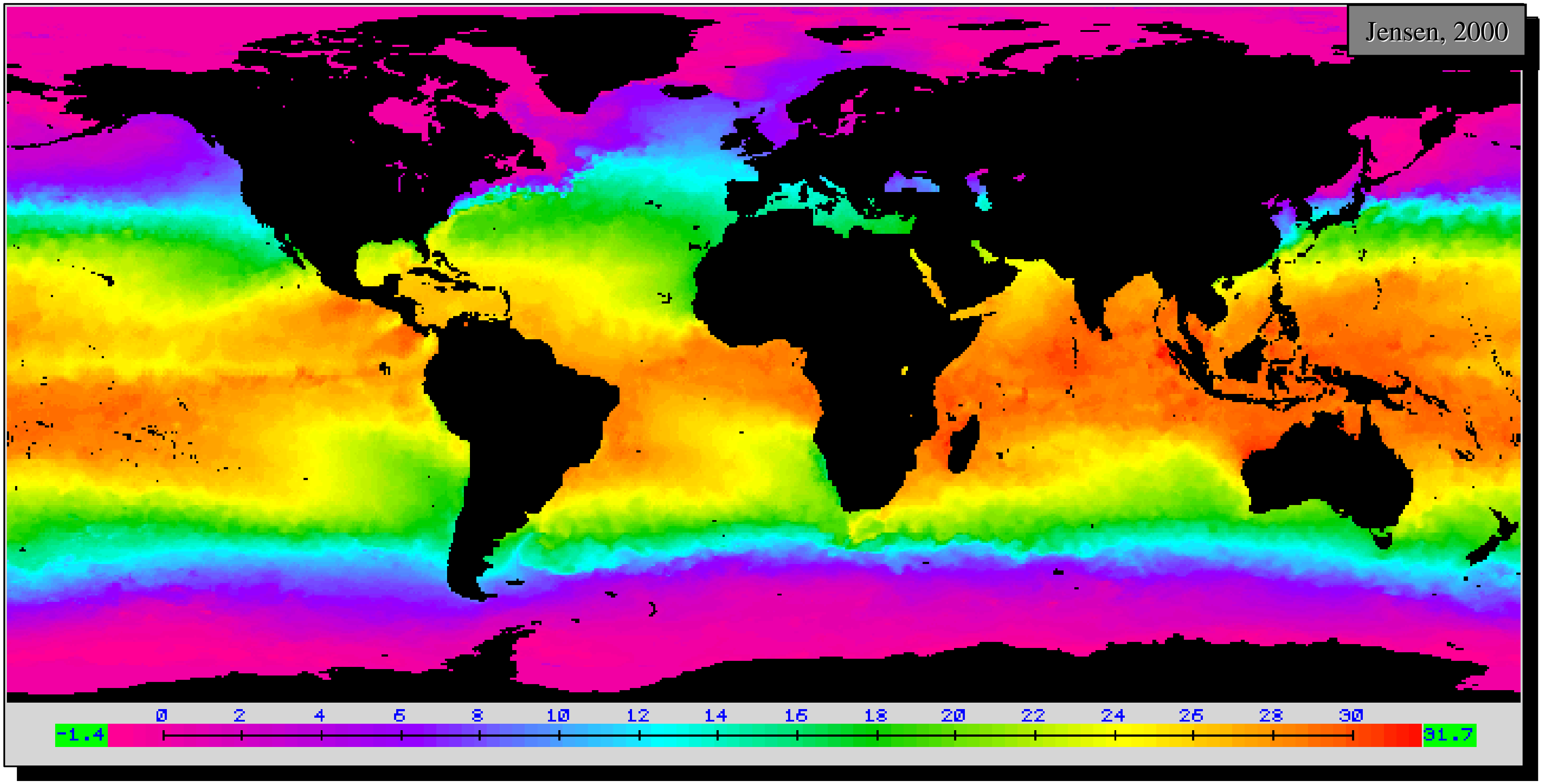
Composite Sea-surface Temperature (SST) Map of the Southeastern Bight Derived from AVHRR Data

Jensen, 2000

Remote Sensing in hydrology & meteorlogy

Surface water temperature

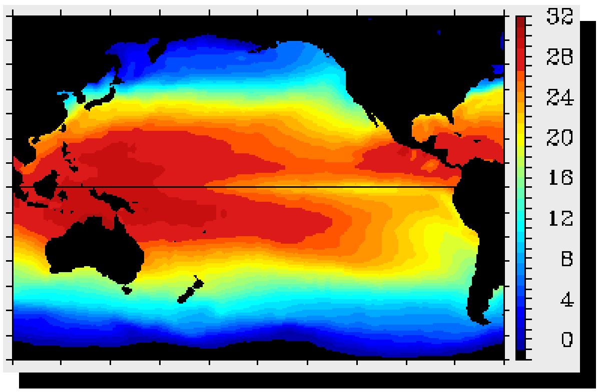
Worldwide Sea-surface Temperature (SST) Map Derived From NOAA-14 AVHRR Data



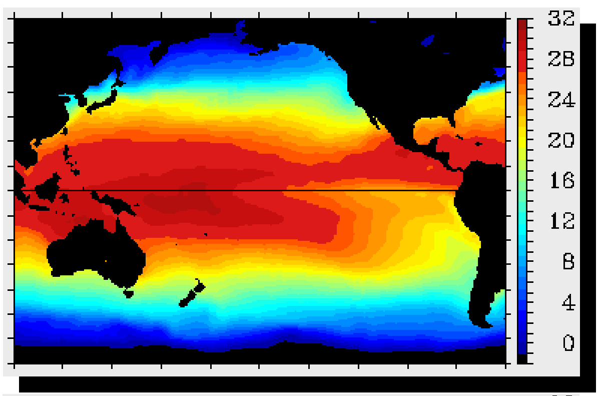
Three-day composite of thermal infrared data centered on March 4, 1999. Each pixel was allocated the highest surface temperature that occurred during the three days.

Remote Sensing in hydrology & meteorlogy

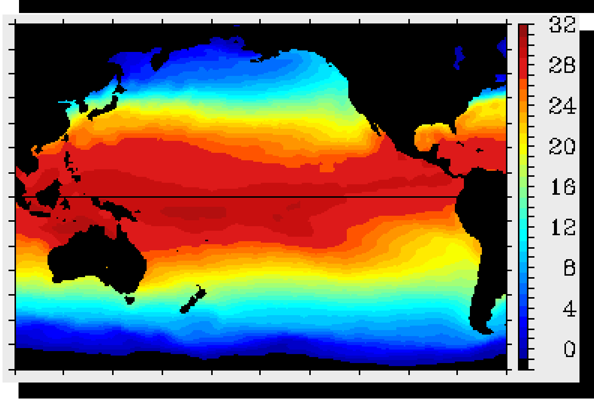
Surface water temperature



La Nina,
December
1988



December
1990



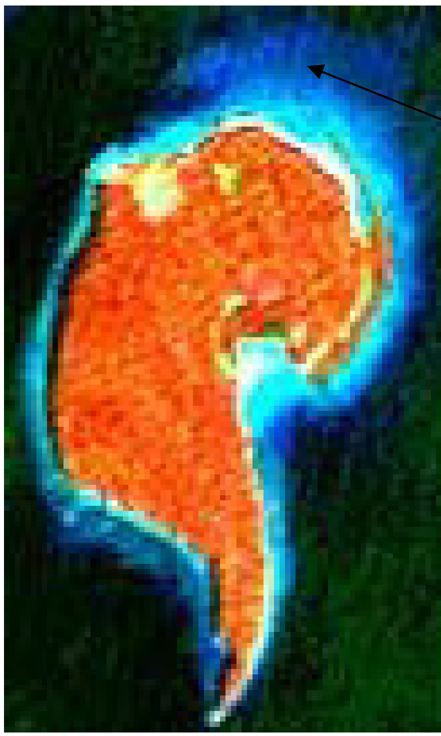
El Nino,
December
1997

Jensen, 2000

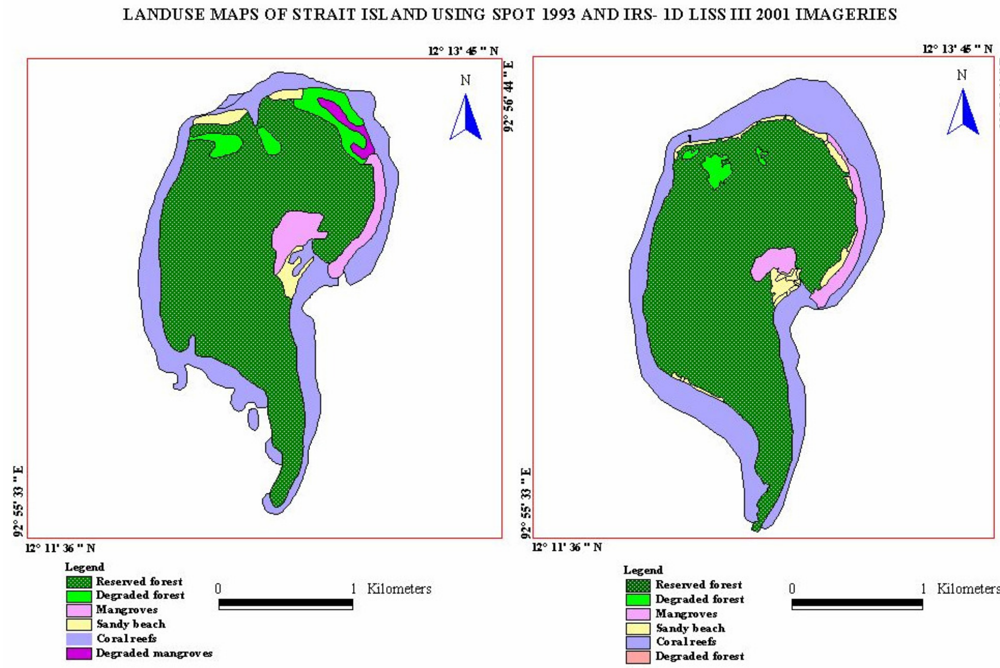
Reynolds Monthly Sea-surface Temperature (˚C) Maps Derived from *In situ* Buoy and Remotely Sensed Data

Remote Sensing in hydrology & meteorlogy

Coral reef monitoring



Coral Reef



Changes in Coral Reef Area in Andaman Islands

S. No.	Island	Area in ha. (1993)	Area in ha. (2003)	Change in area (ha.)	% Change
1.	Havelock	2062.30	1846.00	-216.30	(-) 10
2.	Neil	270.47	459.01	+188.54	(+) 70
3.	North Passage	384.73	435.84	+51.11	(+) 13
4.	Interview	1818.63	2764.51	+945.88	(+) 52
5.	East	197.36	177.46	-19.9	(-) 10
6.	Strait	90.80	127.28	+36.48	(+) 40
7.	Ross & Smith	272.76	459.81	+187.07	(+) 68
8.	Long	232.45	179.43	-53.02	(-) 23