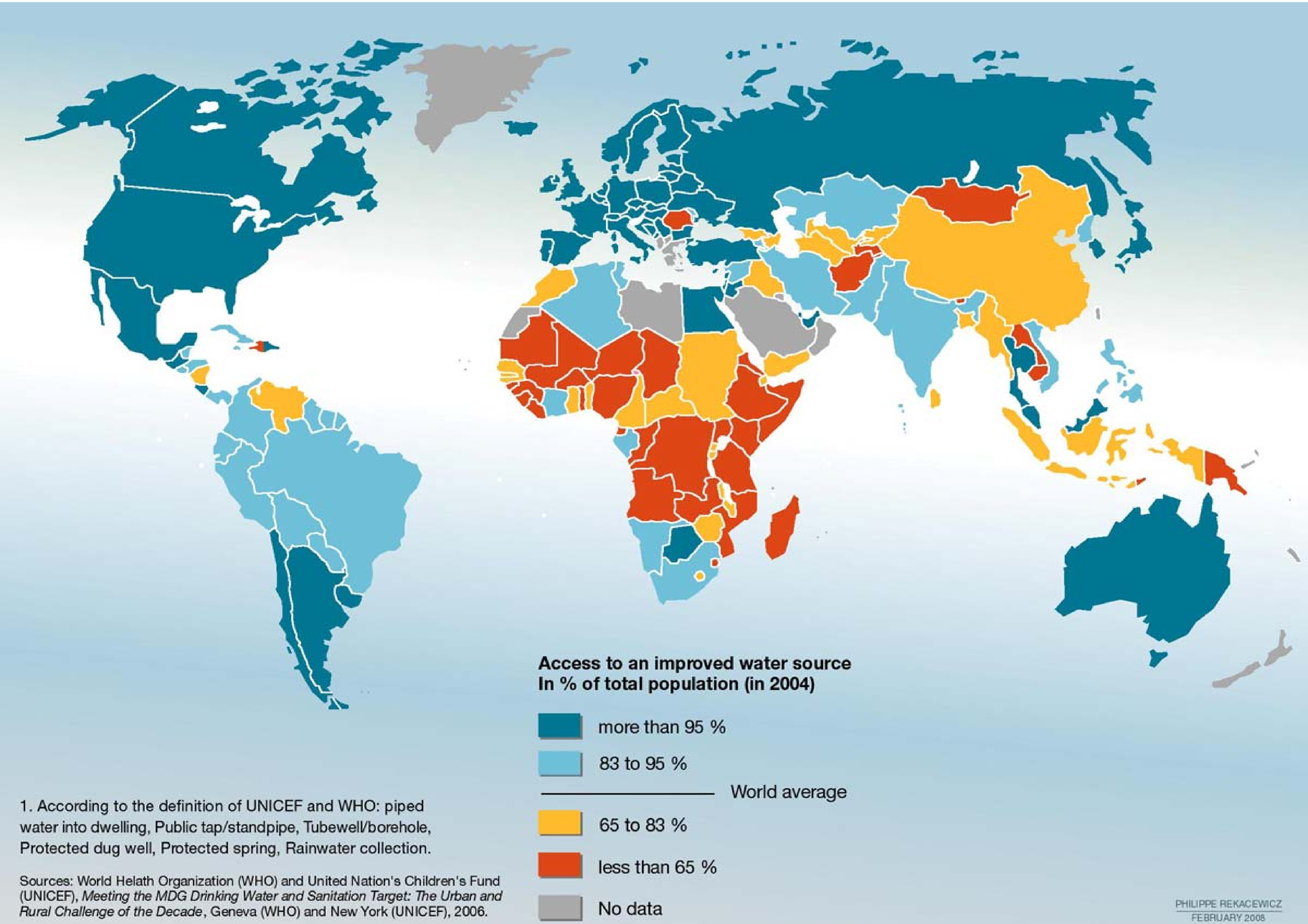
Remote Sensing of Water Quality and Sedimentation

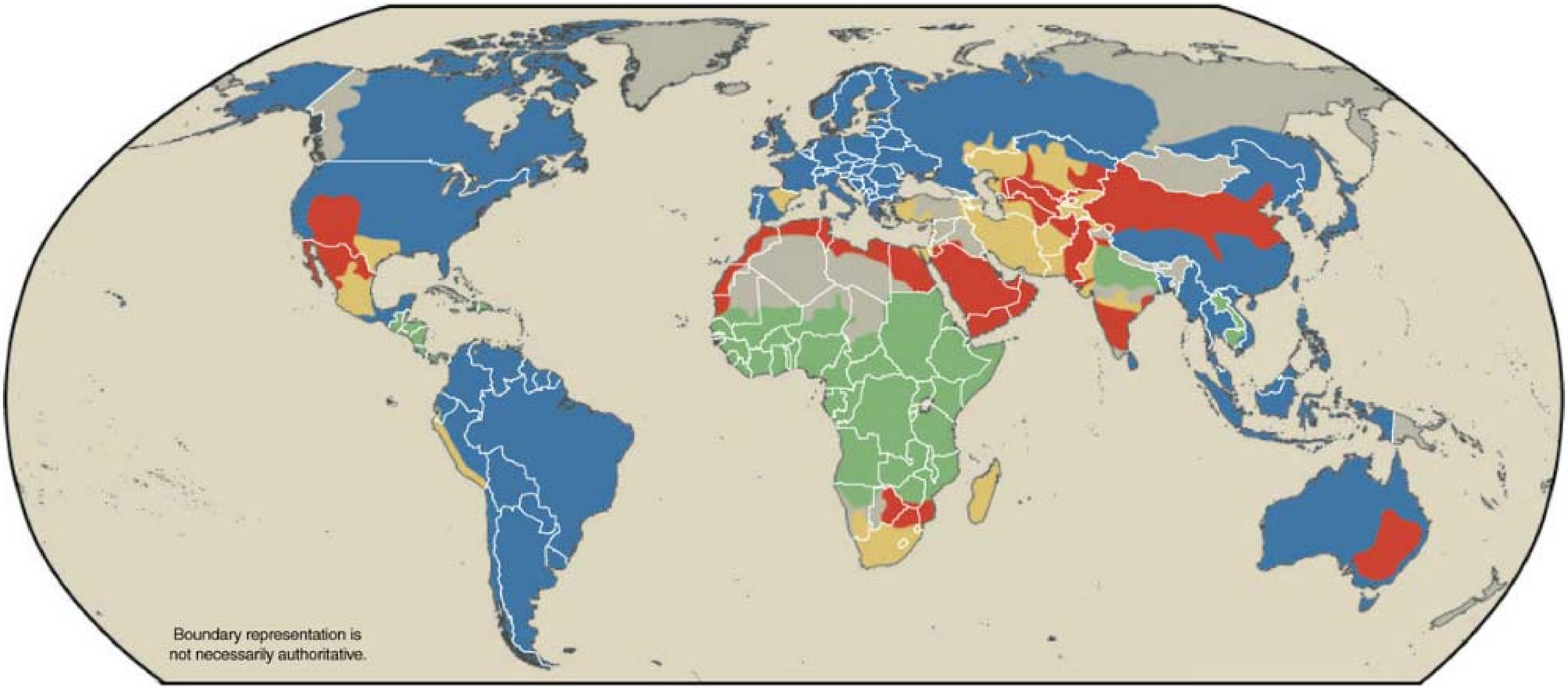
Dr. Tarendra Lakhankar



1. According to the definition of UNICEF and WHO: piped water into dwelling, Public tap/standpipe, Tubewell/borehole, Protected dug well, Protected spring, Rainwater collection.

Sources: World Helath Organization (WHO) and United Nation's Children's Fund (UNICEF), *Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade*, Geneva (WHO) and New York (UNICEF), 2006.

Projected Global Water Scarcity, 2025



Physical water scarcity: More than 75% of river flows are allocated to agriculture, industries, or domestic purposes. This definition of scarcity — relating water availability to water demand — implies that dry areas are not necessarily water-scarce.

Approaching physical water scarcity: More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.

Economic water scarcity: Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Little or no water scarcity: Abundant water resources relative to use. Less than 25% of water from rivers is withdrawn for human purposes.

Not estimated

Source: International Water Management Institute.





and it takes more than
450 years
for one bottle to break down

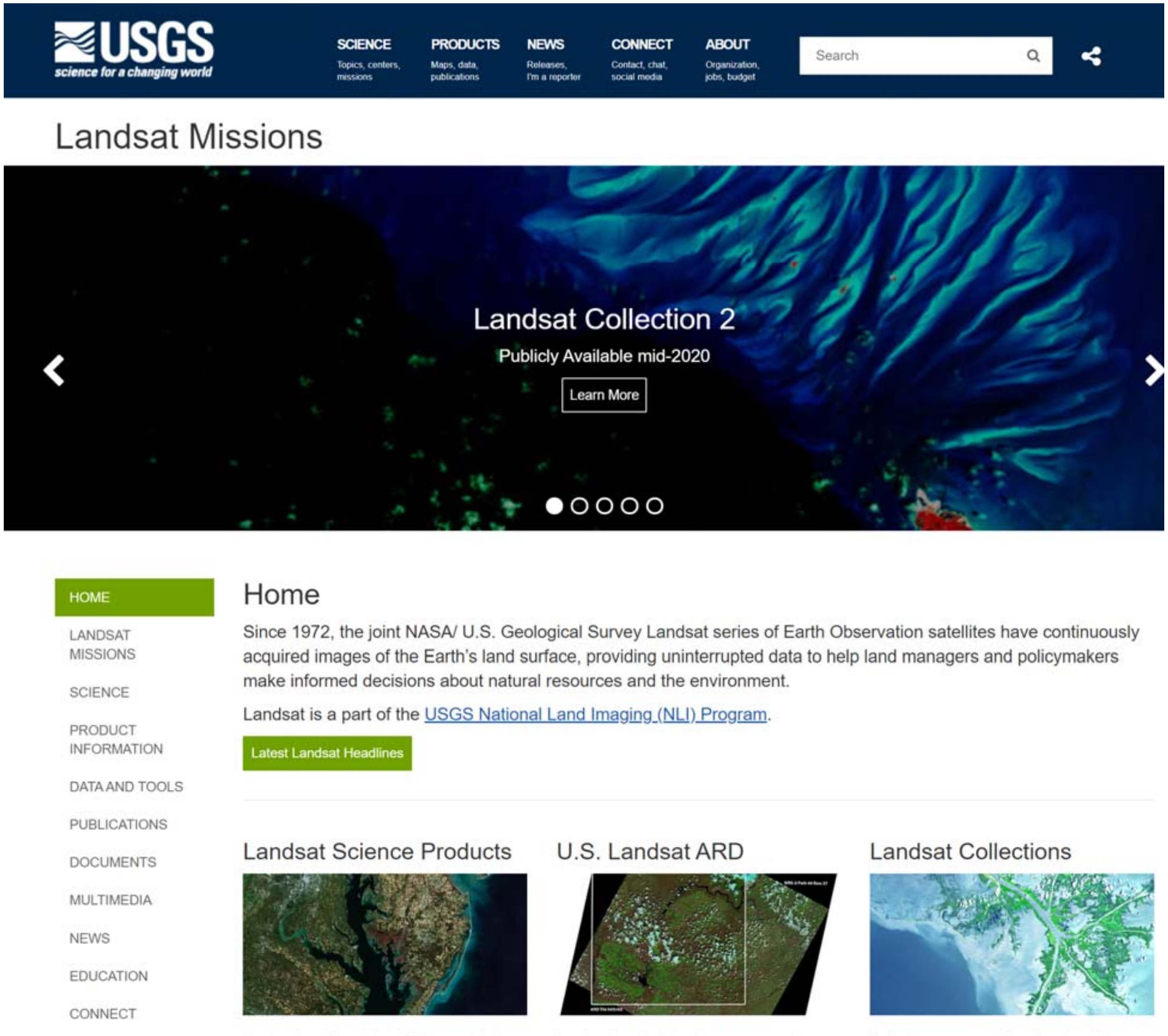
Water Quality

- **Water quality** is the physical, chemical and biological characteristics of water
- Vast majority of surface water on the planet is neither potable (fit for drinking) nor toxic
- Approximately 25% of the world's population has no access to potable water
- No simple property can tell whether water is polluted or not

Sources of Water Pollution

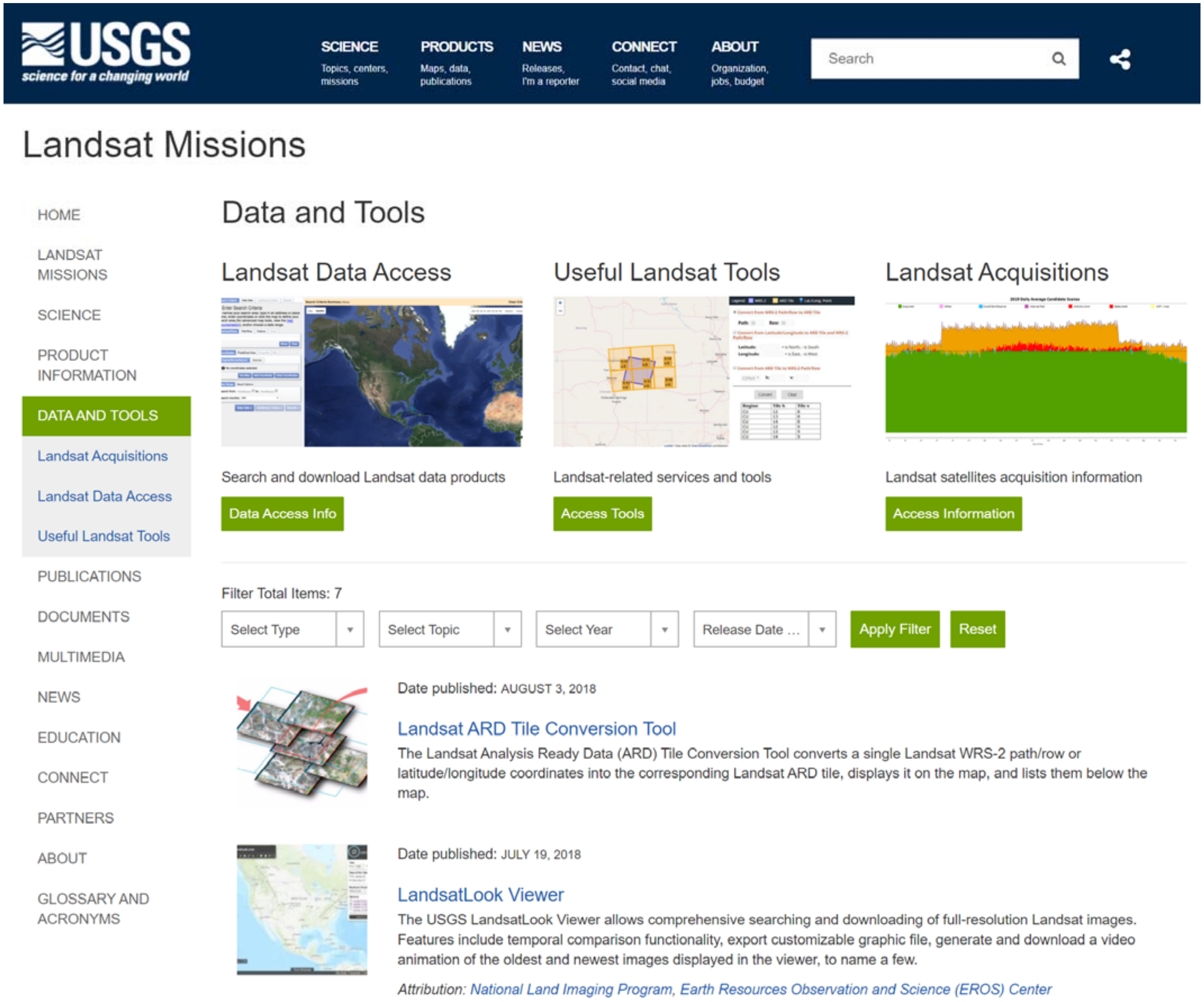
- Discharge
  - Industrial discharge of chemical wastes and byproducts
  - Discharge of poorly-treated or untreated sewage
  - Discharge of contaminated and/or heated water used for industrial processes
- Surface runoff
  - runoff from agricultural areas, urban storm water runoff and discharge of untreated sewage (especially in developing countries).
  - Surface runoff containing pesticides or fertilizers
  - Surface runoff containing spilled petroleum products
  - Surface runoff from construction sites, farms, or paved and other impervious surfaces
- Slash and burn farming practice, which is often an element within shifting cultivation agricultural systems
- Acid rain caused by industrial discharge of sulfur dioxide (by burning high-sulfur fossil fuels)
- Eutrophication by runoff containing detergents or fertilizers
- Underground storage tank leakage, leading to soil contamination, and hence aquifer contamination
- Inappropriate disposal of various solid wastes and, on a localized scale, littering
- Oil spills

Landsat Mission



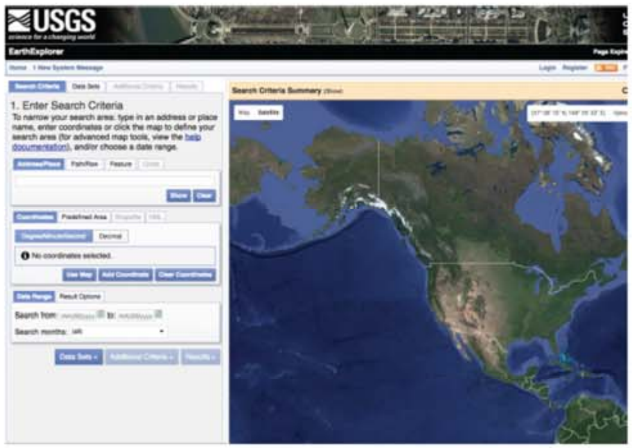
https://www.usgs.gov/land-resources/nli/landsat

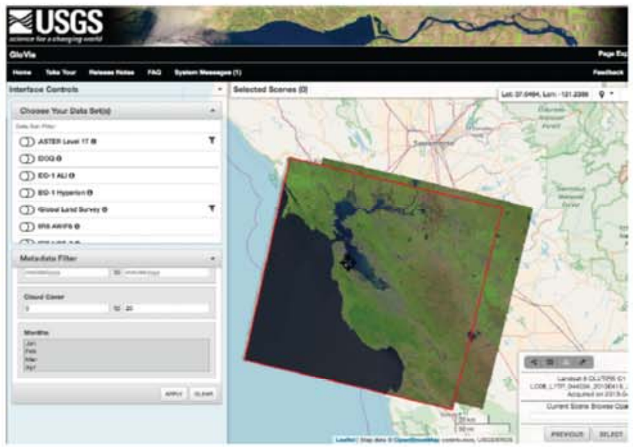
Landsat Mission



https://www.usgs.gov/land-resources/nli/landsat/data-tools

Get Landsat Images and Band Reflectance Data





Earth Explorer: http://earthexplorer.usgs.gov/

GloVis http://glovis.usgs.gov/

Landsat Look Viewer: http://landsatlook.usgs.gov/

- High spatial resolution, data at 16 days intervals, 25 years of archived data
- 95% accuracy in mapping wetlands compared to manual mapping
- Bands 4, 5, 7 best for detecting water
- (TM) Thematic Mapper - 30m spatial resolution
- Incident infrared wavelengths shows water body better than visible Bands.
- Strong absorption of light by water, giving a low spectral response
- Problems
  - Clouds or cloud shadows
  - Dense vegetation makes it difficult to define soil/water boundaries
  - Can only classify vegetation based on density

SPOT (satellite) Mission

- SPOT 1 launched February 22, 1986 with 10 panchromatic and 20 meter multispectral picture resolution capability. Withdrawn December 31, 1990.
- SPOT 2 launched January 22, 1990 and deorbited in July 2009.
- SPOT 3 launched September 26, 1993. Stopped functioning November 14, 1997.
- SPOT 4 launched March 24, 1998. Stopped functioning July, 2013.
- SPOT 5 launched May 4, 2002 with 2.5 m, 5 m and 10 m capability. Stopped functioning March 31, 2015.
- SPOT 6 launched September 9, 2012.
- SPOT 7 launched on June 30, 2014.

SPOT 6 and SPOT 7:

Spatial resolution:

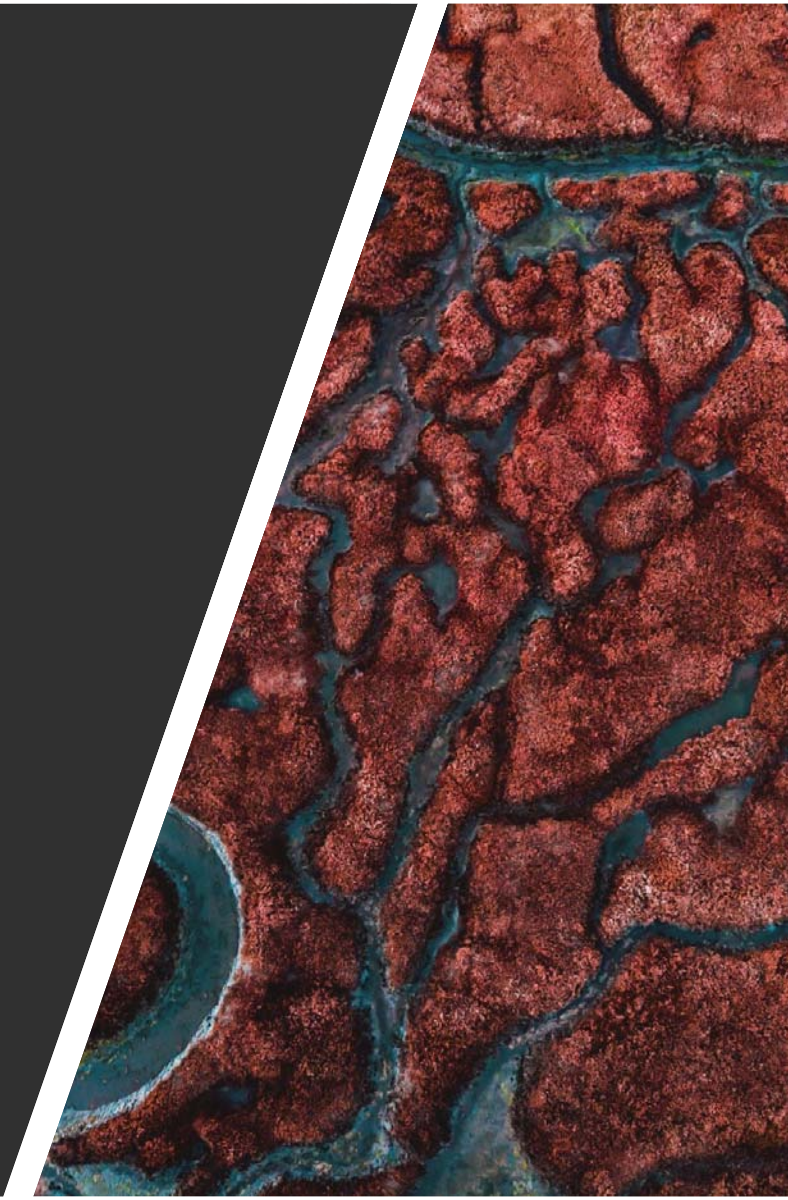
- Panchromatic: 1.5 m
- Colour merge: 1.5 m
- Multi-spectral: 6 m

Spectral bands:

- Panchromatic (450 – 745 nm)
- Blue (450 – 525 nm)
- Green (530 – 590 nm)
- Red (625 – 695 nm)
- Near-infrared (760 – 890 nm)

SPOT (satellite)

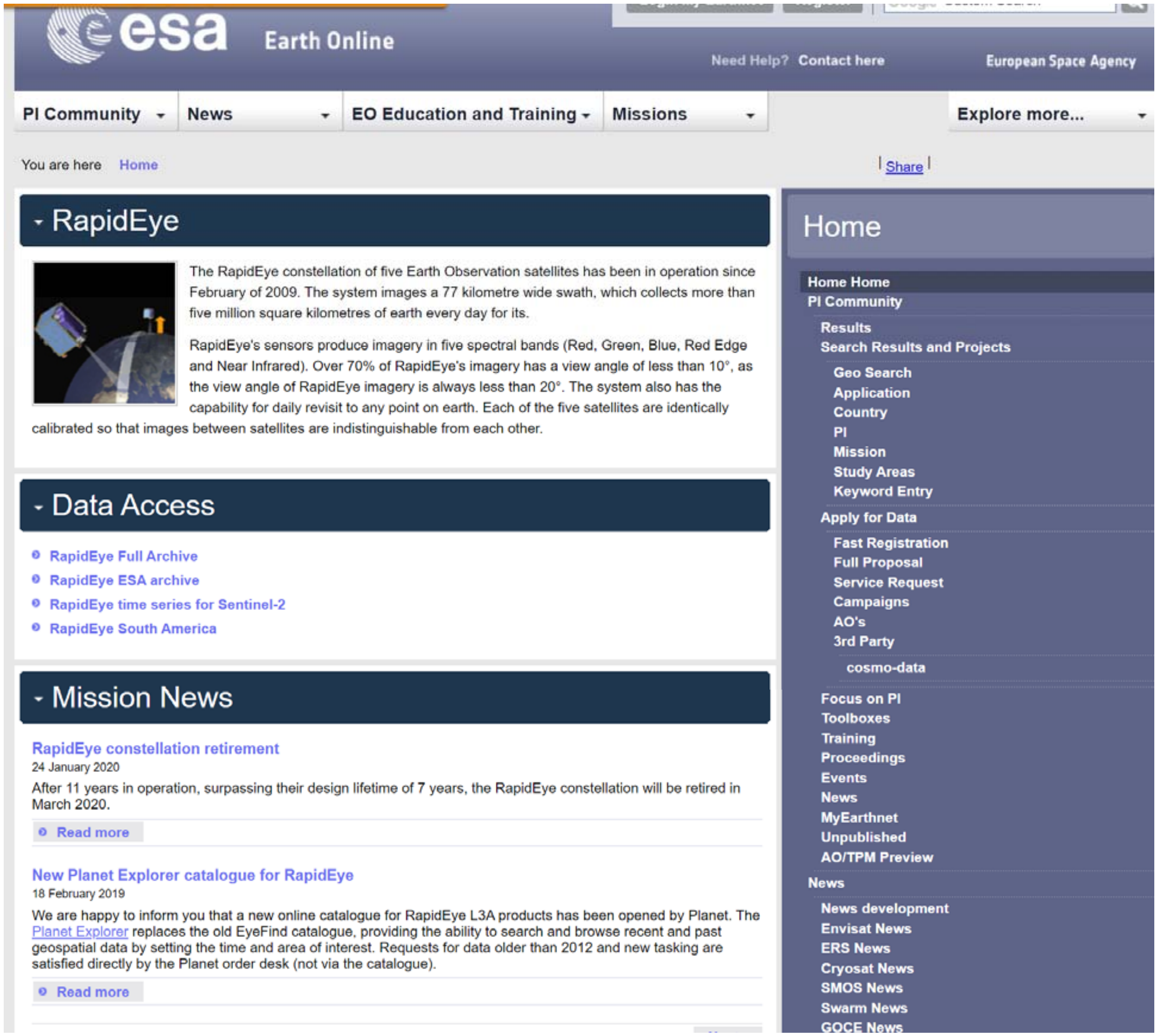
- Low reflectance of water in infrared Bands
- Searches a smaller area than Landsat images
- Records reflected radiation in green, red and near-infrared spectrum
- Detect changes in aquatic vegetation
- Used to measure algal growth and respiration rates



ASTER

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December 1999.

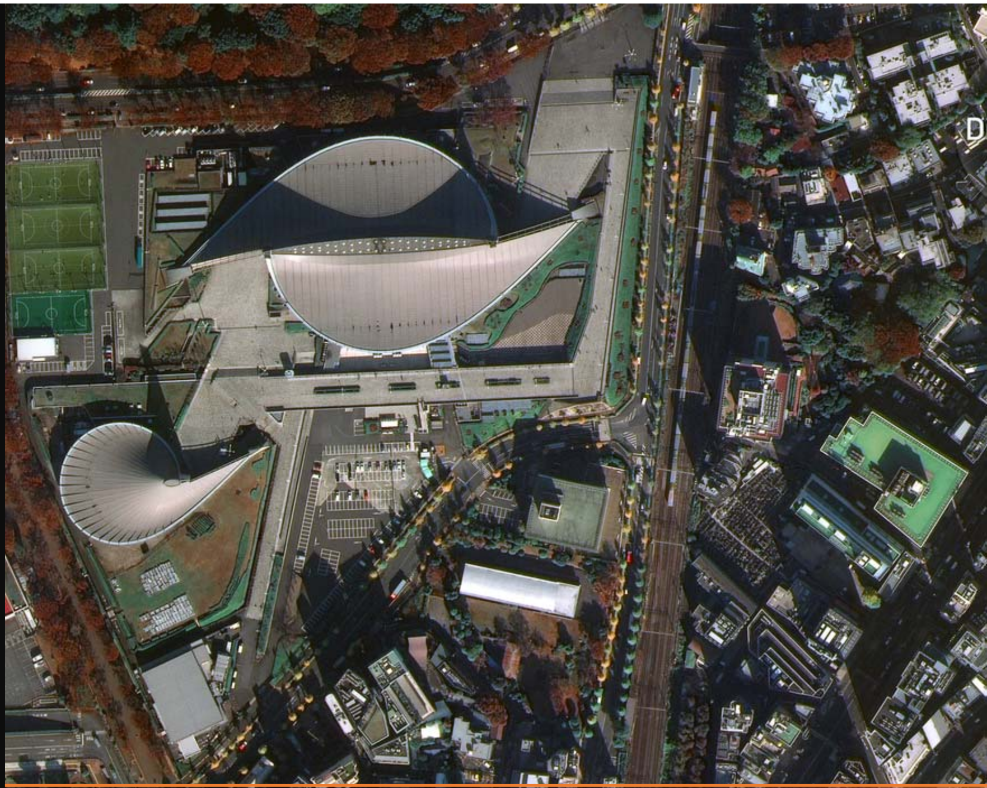
Spatial Resolution of 15 m

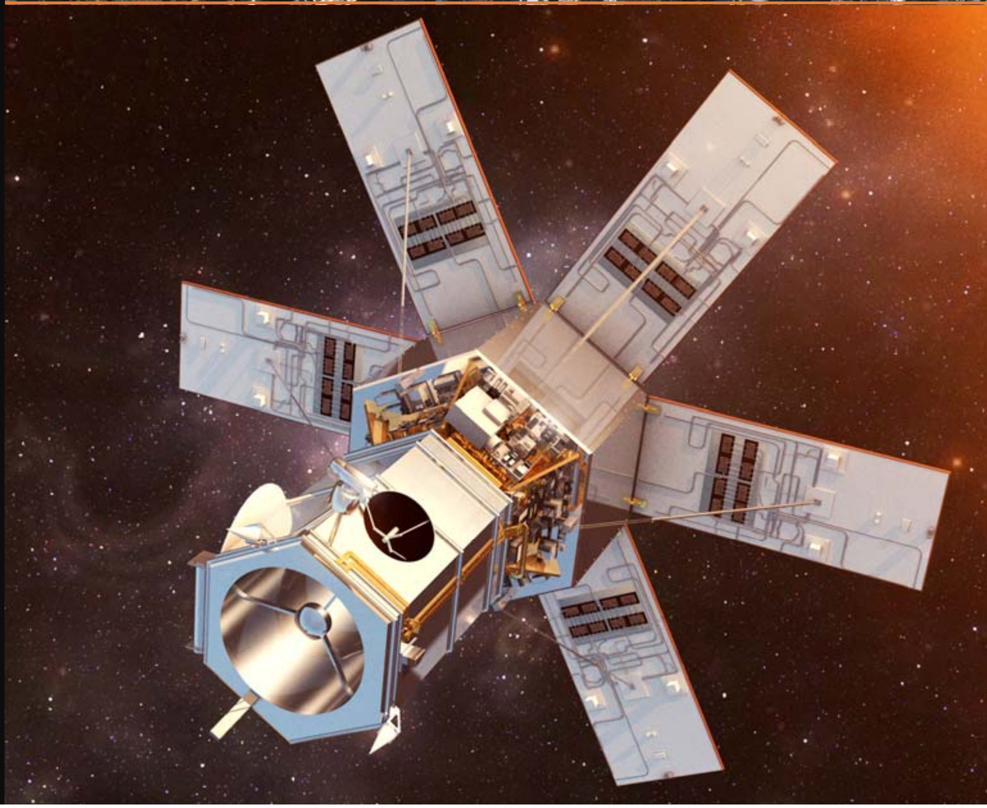

esa Earth Online
Need Help? Contact here
European Space Agency
PI Community
News
EO Education and Training
Missions
Explore more...
You are here Home
Share
RapidEye
The RapidEye constellation of five Earth Observation satellites has been in operation since February of 2009. The system images a 77 kilometre wide swath, which collects more than five million square kilometres of earth every day for its.
RapidEye's sensors produce imagery in five spectral bands (Red, Green, Blue, Red Edge and Near Infrared). Over 70% of RapidEye's imagery has a view angle of less than 10°, as the view angle of RapidEye imagery is always less than 20°. The system also has the capability for daily revisit to any point on earth. Each of the five satellites are identically calibrated so that images between satellites are indistinguishable from each other.
Data Access
RapidEye Full Archive
RapidEye ESA archive
RapidEye time series for Sentinel-2
RapidEye South America
Mission News
RapidEye constellation retirement
24 January 2020
After 11 years in operation, surpassing their design lifetime of 7 years, the RapidEye constellation will be retired in March 2020.
Read more
New Planet Explorer catalogue for RapidEye
18 February 2019
We are happy to inform you that a new online catalogue for RapidEye L3A products has been opened by Planet. The Planet Explorer replaces the old EyeFind catalogue, providing the ability to search and browse recent and past geospatial data by setting the time and area of interest. Requests for data older than 2012 and new tasking are satisfied directly by the Planet order desk (not via the catalogue).
Read more
Home
Home Home
PI Community
Results
Search Results and Projects
Geo Search
Application
Country
PI
Mission
Study Areas
Keyword Entry
Apply for Data
Fast Registration
Full Proposal
Service Request
Campaigns
AO's
3rd Party
cosmo-data
Focus on PI
Toolboxes
Training
Proceedings
Events
News
MyEarthnet
Unpublished
AO/TPM Preview
News
News development
Envisat News
ERS News
Cryosat News
SMOS News
Swarm News
GOCE News

RapidEye

Commercial high-resolution satellite data

- IKONOS-2 (2000-2015)
- OrbView-3
- GeoEye-1
- GeoEye-2 (WorldView-4)





Water Quality Indicators Observable from Satellites

- Turbidity / Sediments
- Sea Surface Temperature (SST)
- Chlorophyll-a (phytoplankton)
- Colored Dissolved Organic Matter (CDOM)
- Salinity
- Oil Spills in Water (Ocean)

Turbidity

Turbidity: measure of the degree to which water looses its transparency due to the presence of suspended particulates

Ideal Level: 1 NTU

High Level: 5 NTU and above

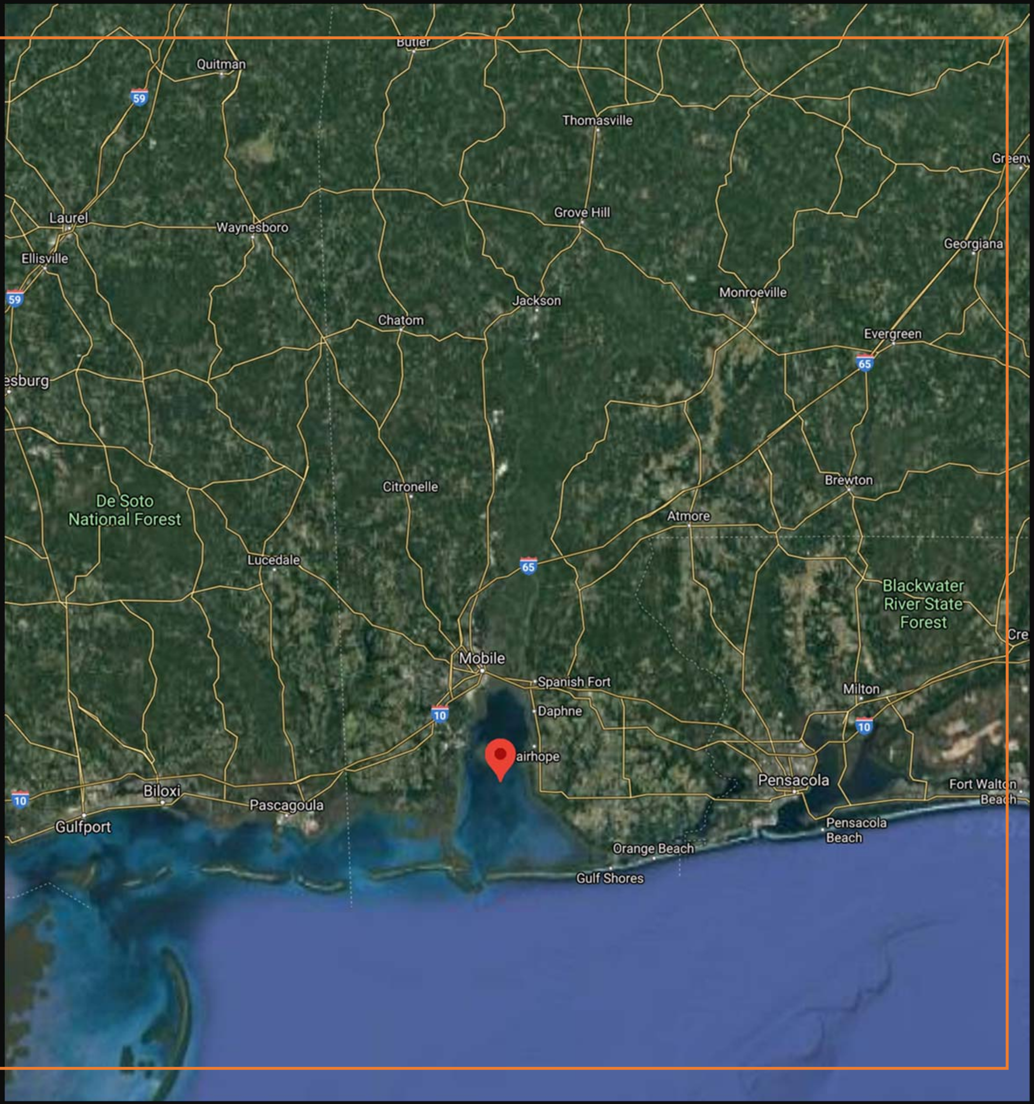
Nephelometric Turbidity Units

Results of high turbidity: high turbidity increases the absorption of sunlight thus making the water warmer. Warmer water has lower levels of dissolved oxygen causing fish and larvae to die.

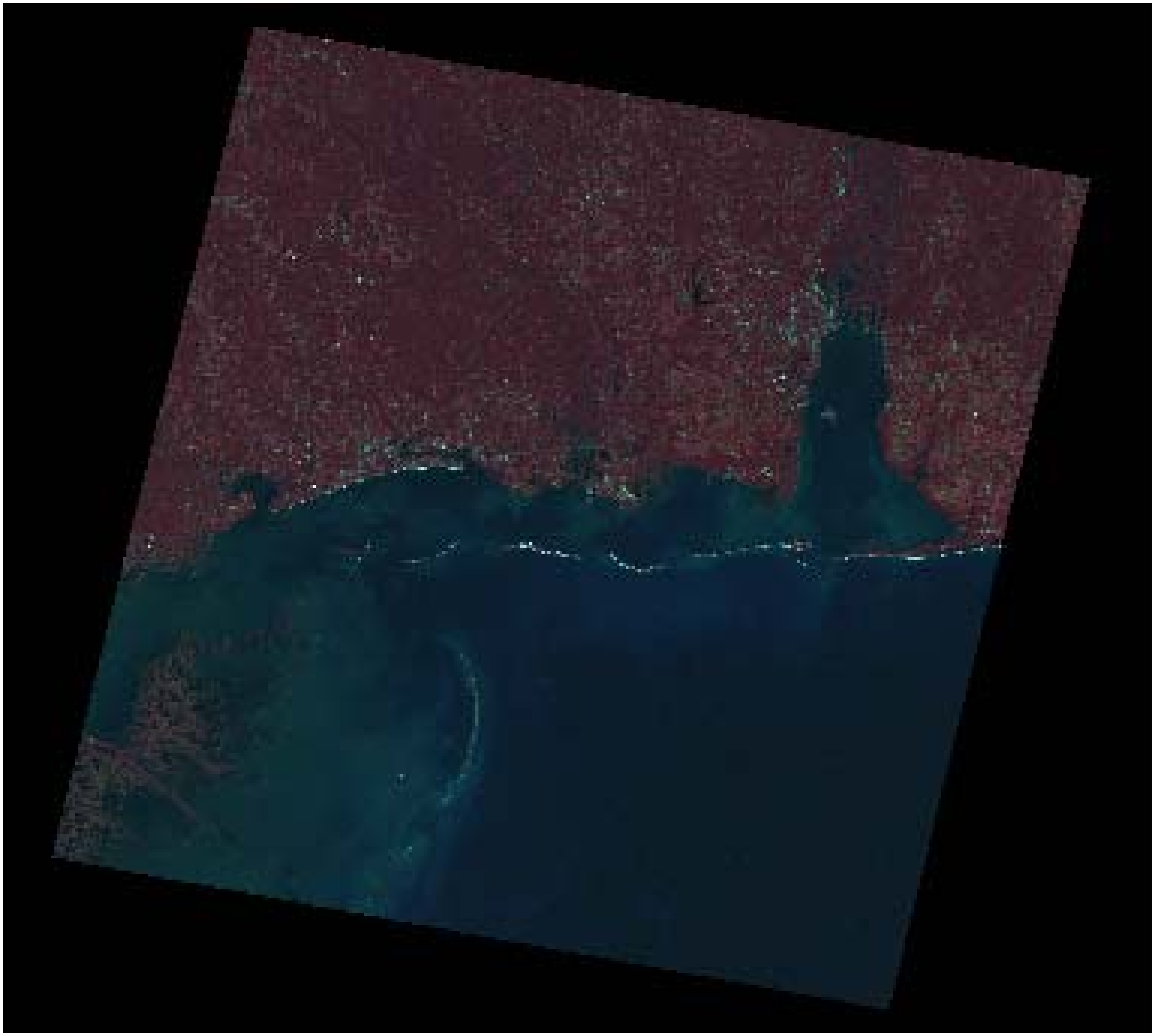
Causes of increased turbidity: increased levels of phytoplankton, sediment from erosion, re-suspended sediments from the bottom (stirred by bottom dwellers), waste discharge, algae growth, and urban runoff

This MODIS satellite image shows sediment plumes moving into the Gulf of Mexico from the main branch of the Mississippi River and through the bayous in its Delta region (visibleearth.nasa.gov)

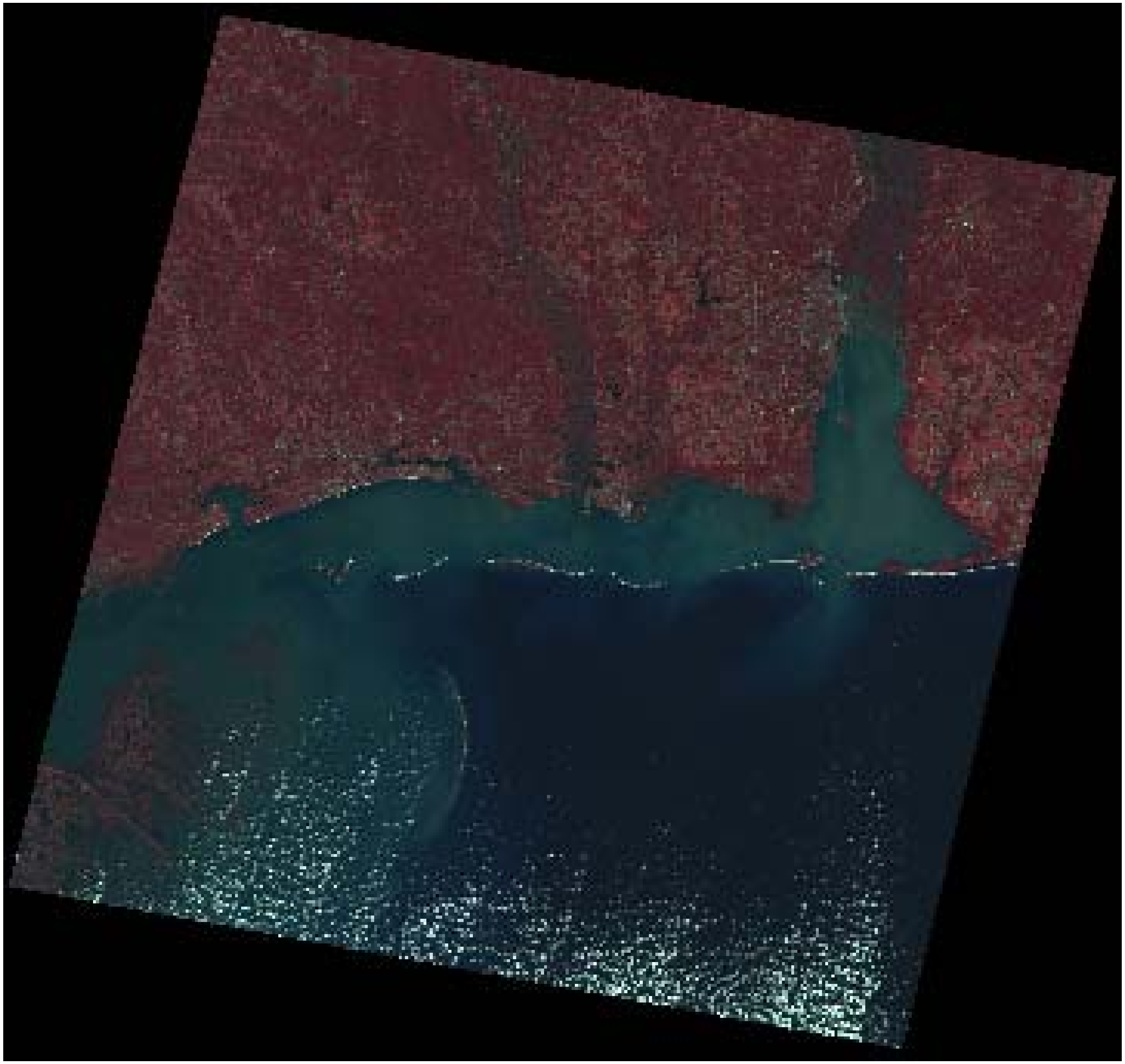
Example of measuring water parameters in Mobile Bay, Alabama



Landsat 11/27/1999 (Mobile bay)



Landsat 10/15/2001 (Mobile bay)



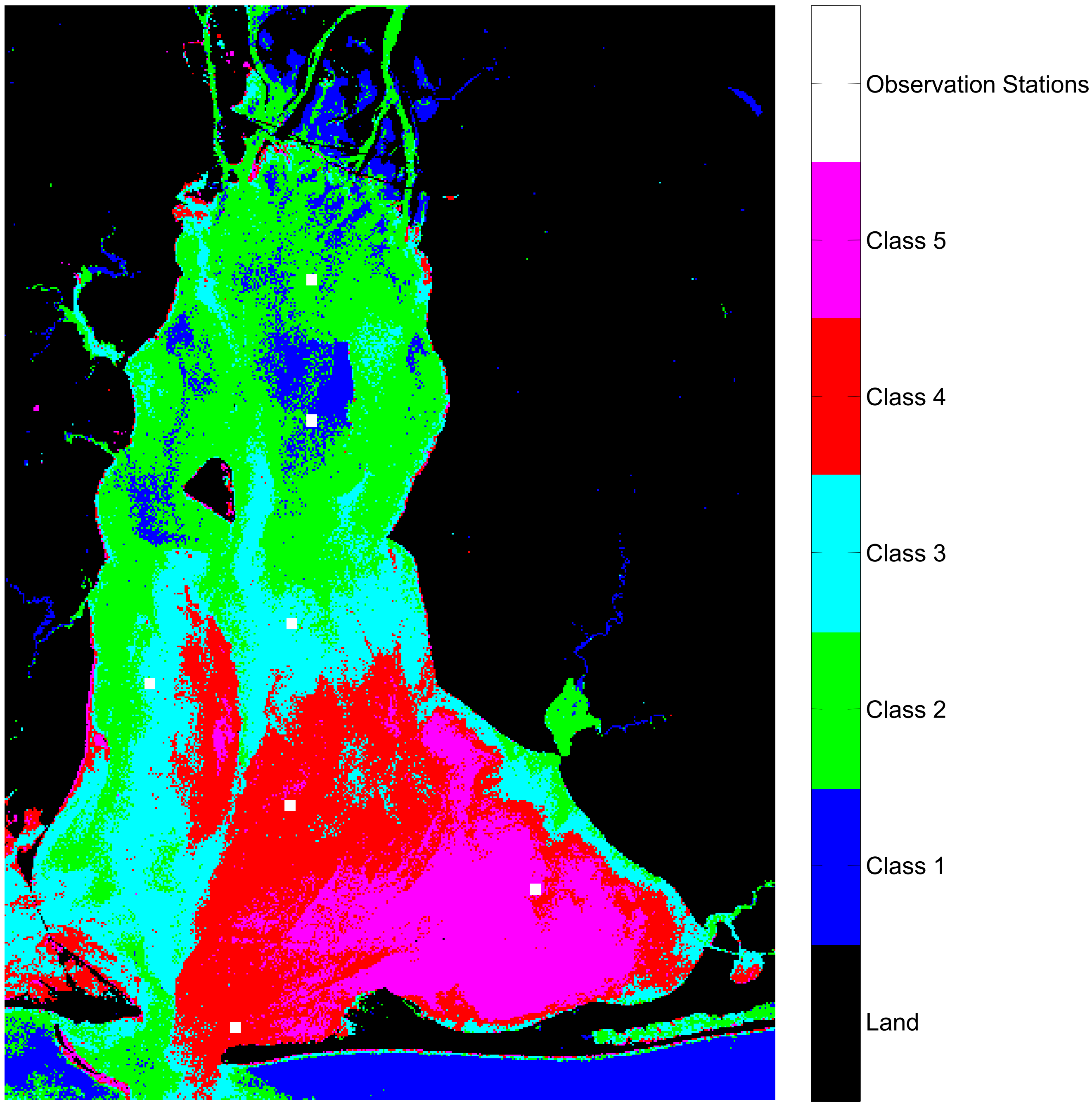
Landsat 2/17/2001 (Mobile bay)

Landsat 11/27/1999 (Mobile bay)

Landsat 10/15/2001 (Mobile Bay)

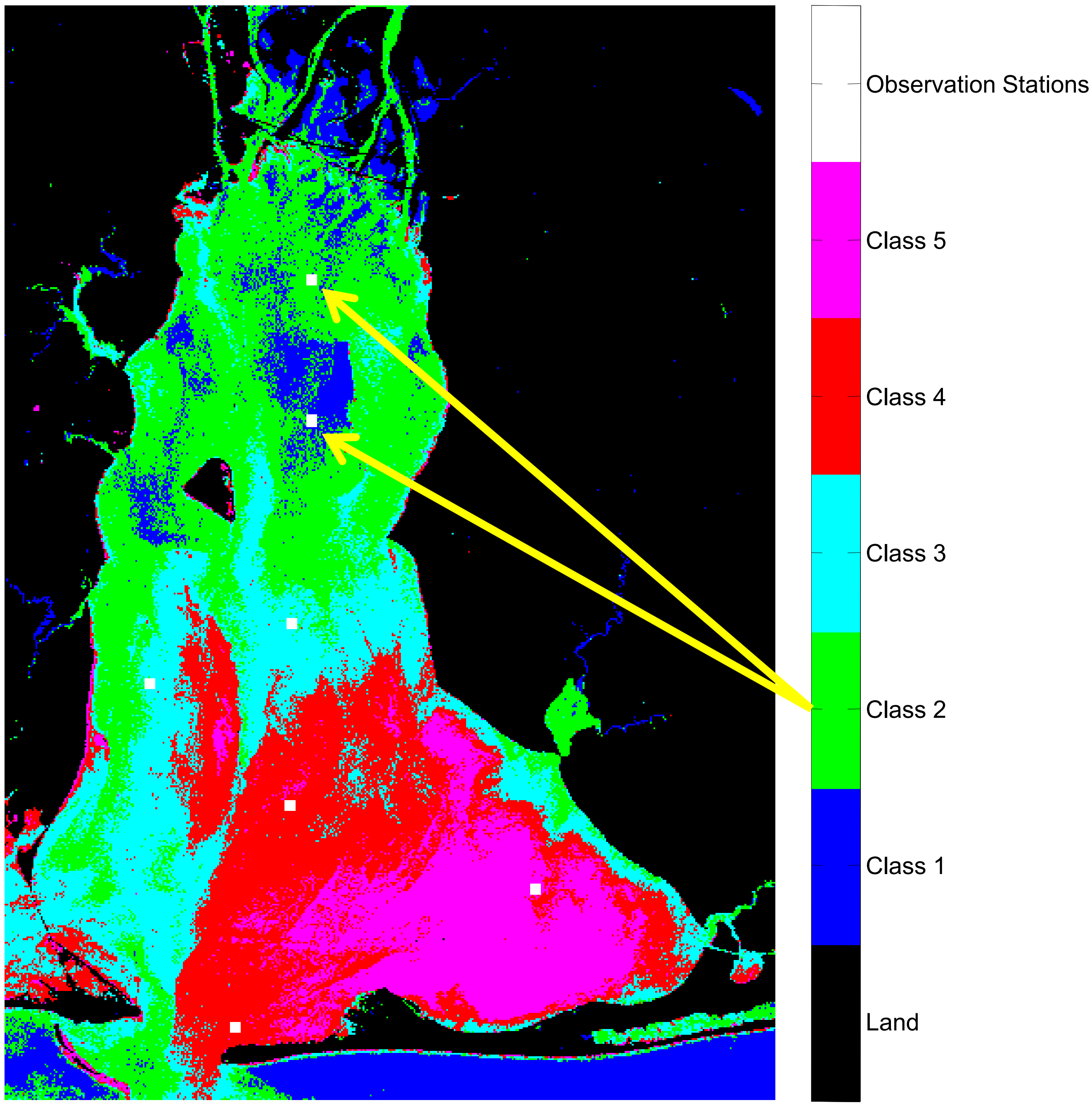
Landsat 2/17/2001 (Mobile Bay)

Landsat 9/26/1991 (Mobile Bay)

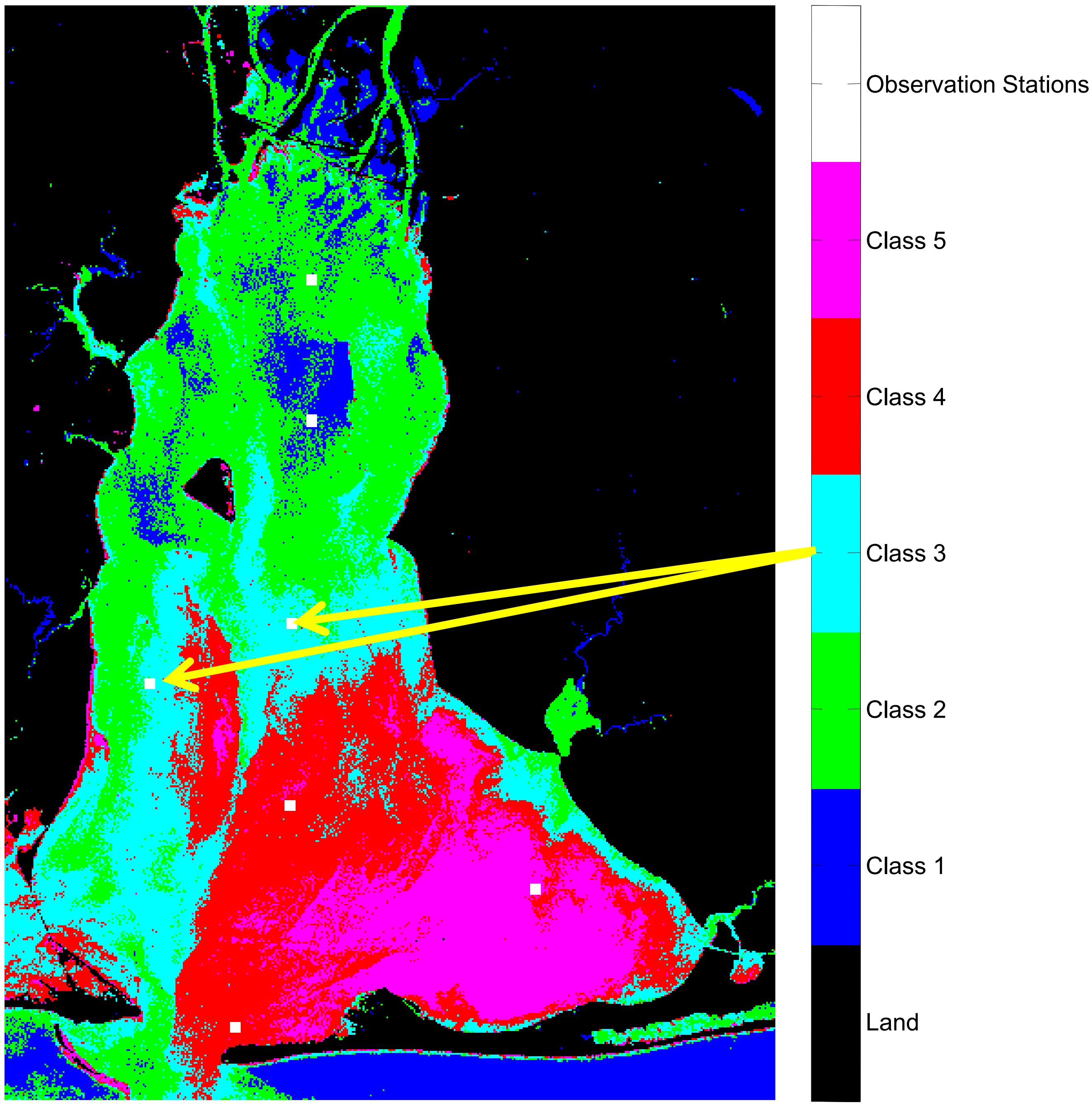


(Hard) Classification Result

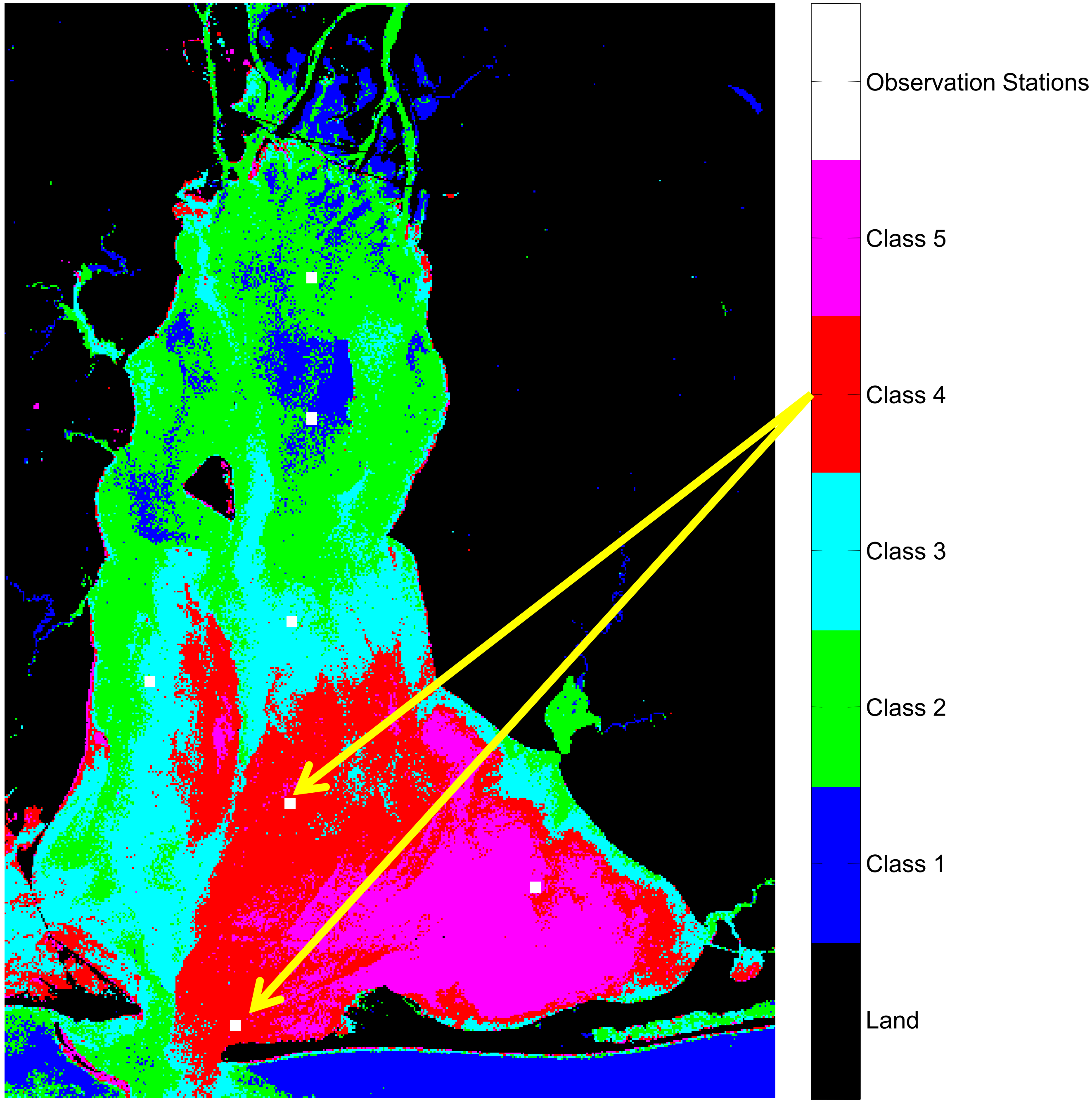
Turbidity
Stations1=5.1
Stations2=4.7



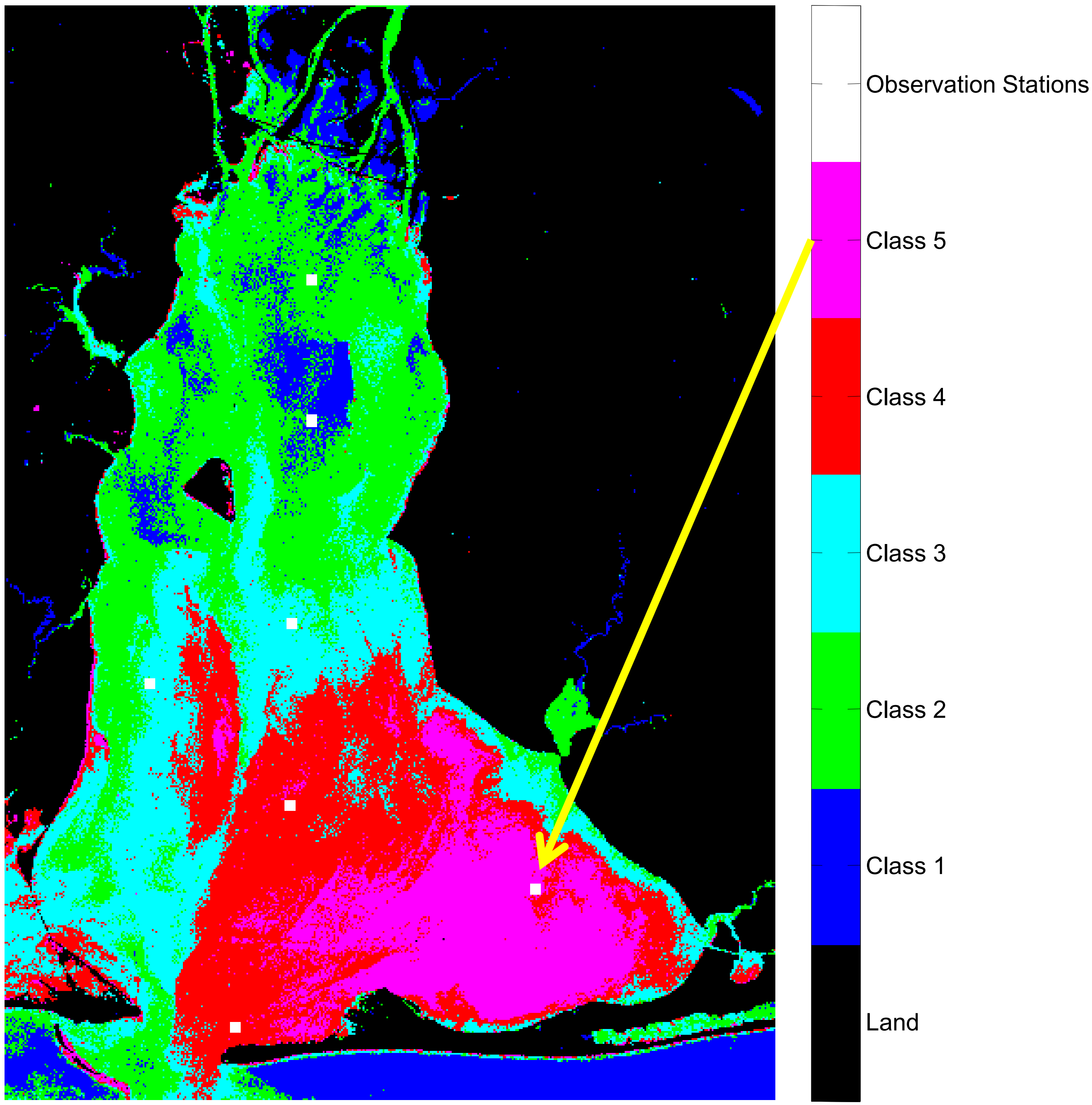
Turbidity
Stations3=20
Stations4=25



Turbidity
Stations5=9.8
Stations6= 10.3



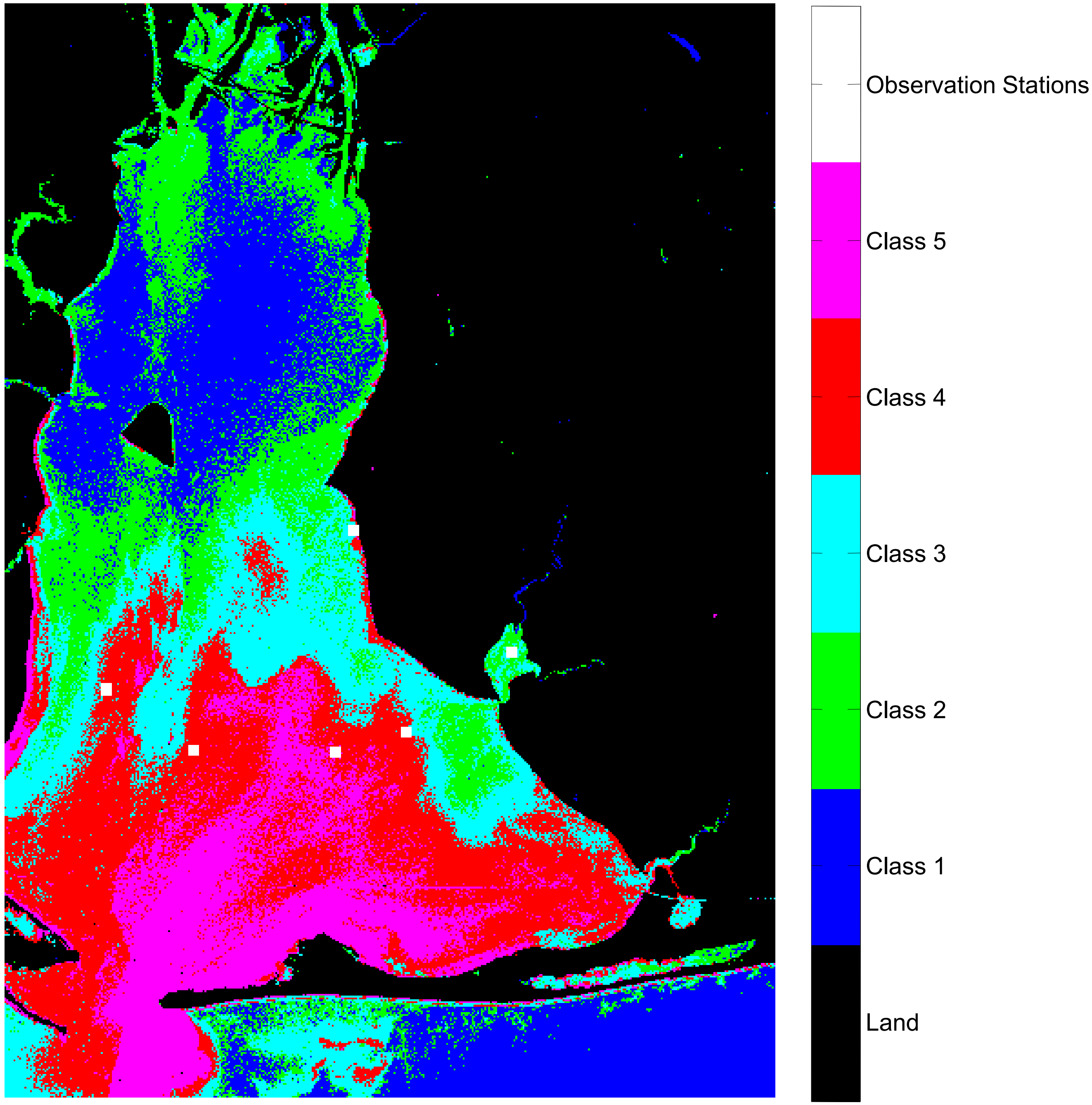
Turbidity
Stations7=27



Satellite Image 09/26/1991
Ground Truth(Turbidity) 09/27/1991

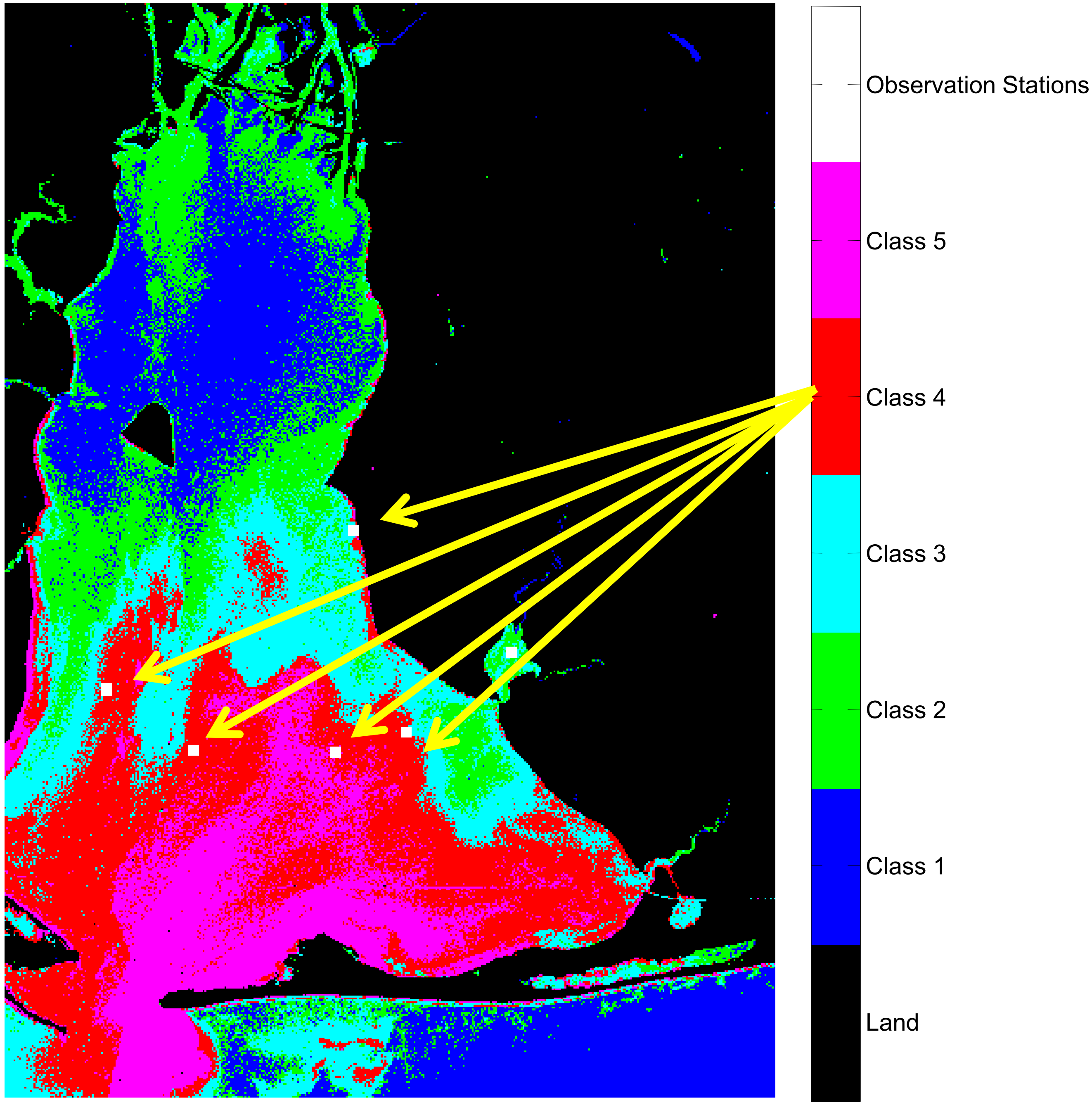
Stations	1	2	3	4	5	6	7
Class	2	2	3	3	4	4	5
Turbidity	5.1	4.7	20	25	9.8	10.3	27

Landsat 11/27/1999 (Mobile Bay)

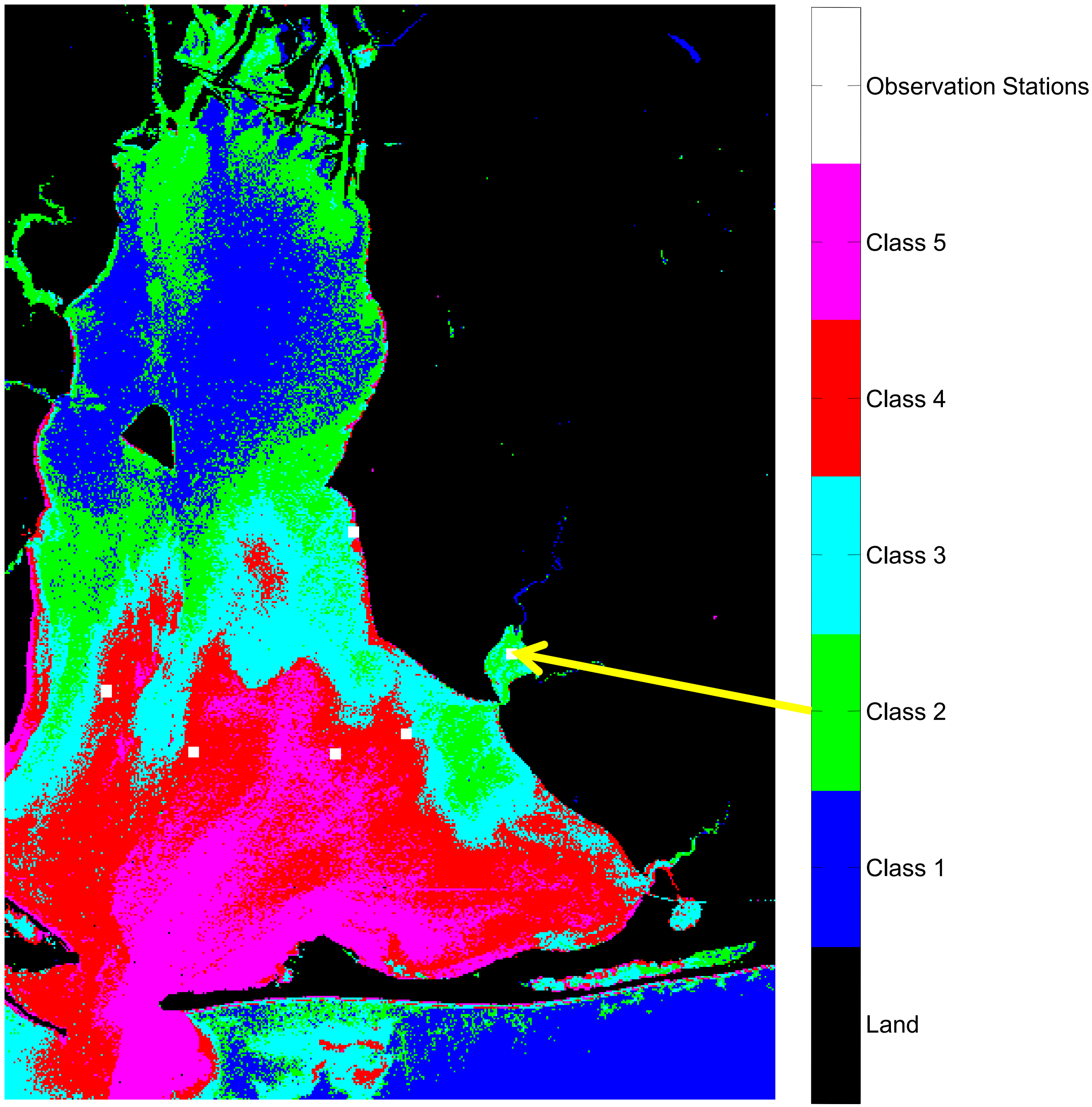


(Hard) Classification Result

Turbidity
Stations1=5.1
Stations2=5.5
Stations3=3.3
Stations4=4.4
Stations5=4.0
TSS
Stations1=24
Stations2=22
Stations3=17
Stations4=19
Stations5=16
CHL-A
Stations1=5.5
Stations2=7.0
Stations3=6.8
Stations4=4.4
Stations5=7.9

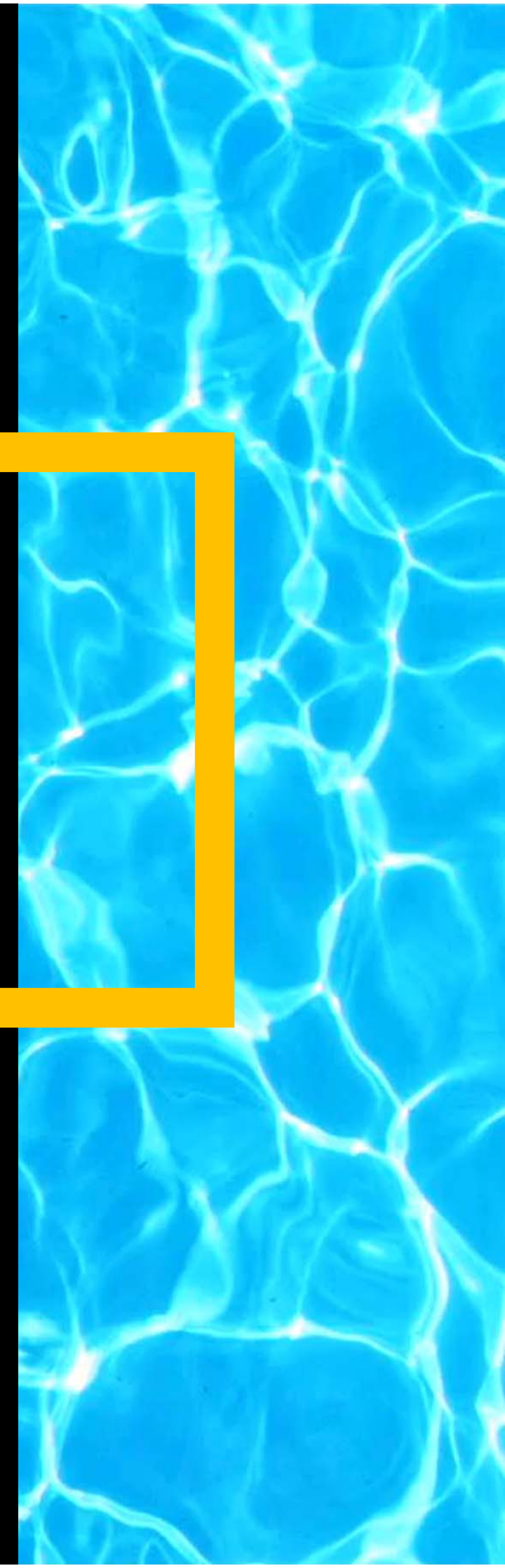


Turbidity
Stations6=7.9
TSS
Stations6=43
CHL-A
Stations6=37



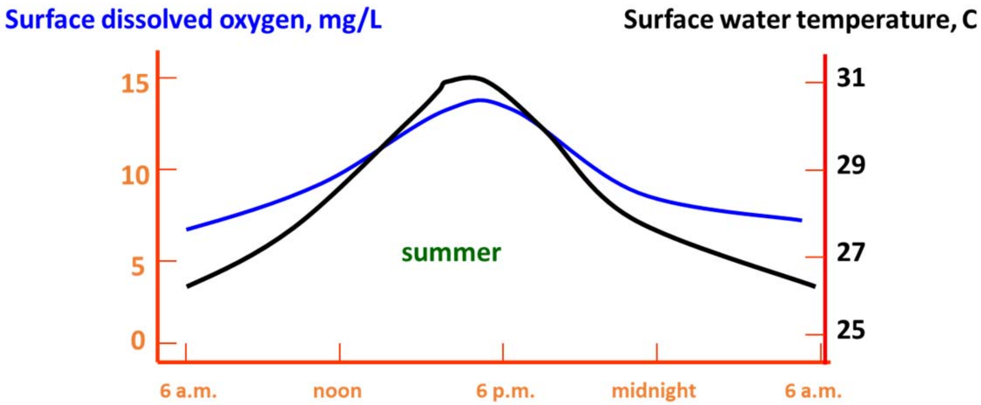
Satellite Image 11/27/1999
Ground Truth 11/27/1999

Stations	1	2	3	4	5	6
Class	4	4	4	4	4	2
Turbidity	3.3	4.4	5.5	5.1	4	7.9
TSS	17	19	22	24	16	43
Chl-A	6.8	4.4	7.0	5.5	7.9	37



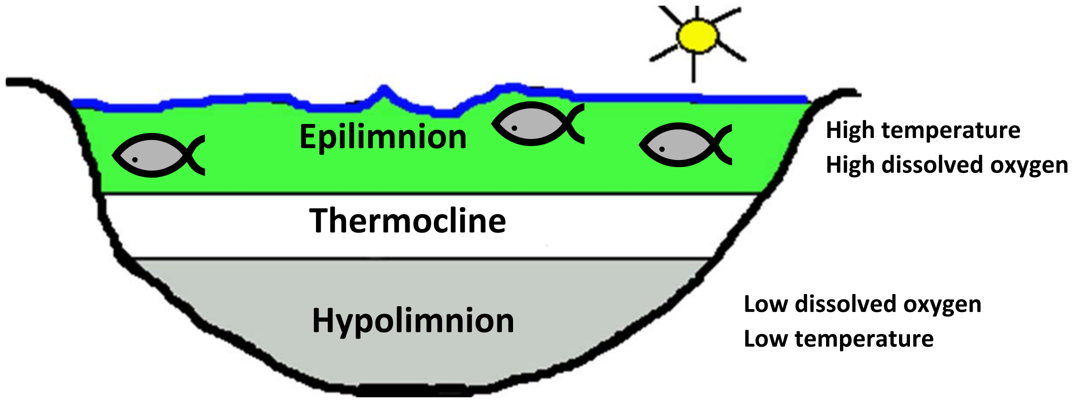
Temperature

- Temperature: measure of average kinetic energy
- Causes of change in temperature: source of water, time of year, suspended sediment, depth of water, and shade from shoreline vegetation
- Determine types of organisms that can live in water
- Affects how much oxygen water can hold
  - Warm water holds less oxygen
- Thermal Pollution (increased water temperature)
  - decreasing oxygen supply
  - killing fish juveniles which are vulnerable to small increases in temperature
  - affecting ecosystem composition.



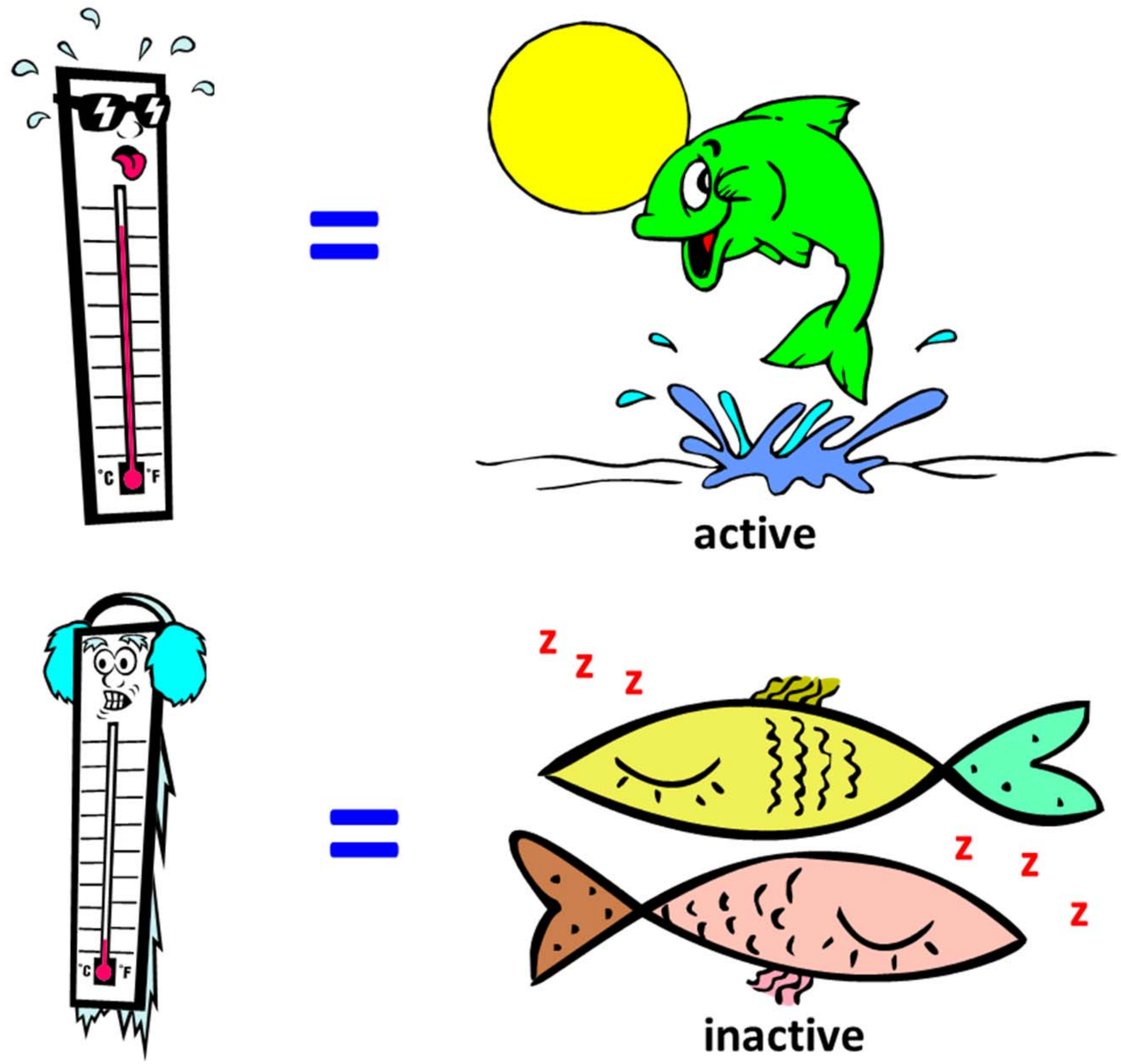
Dissolved oxygen and water temperature

Dissolved oxygen and water temperature



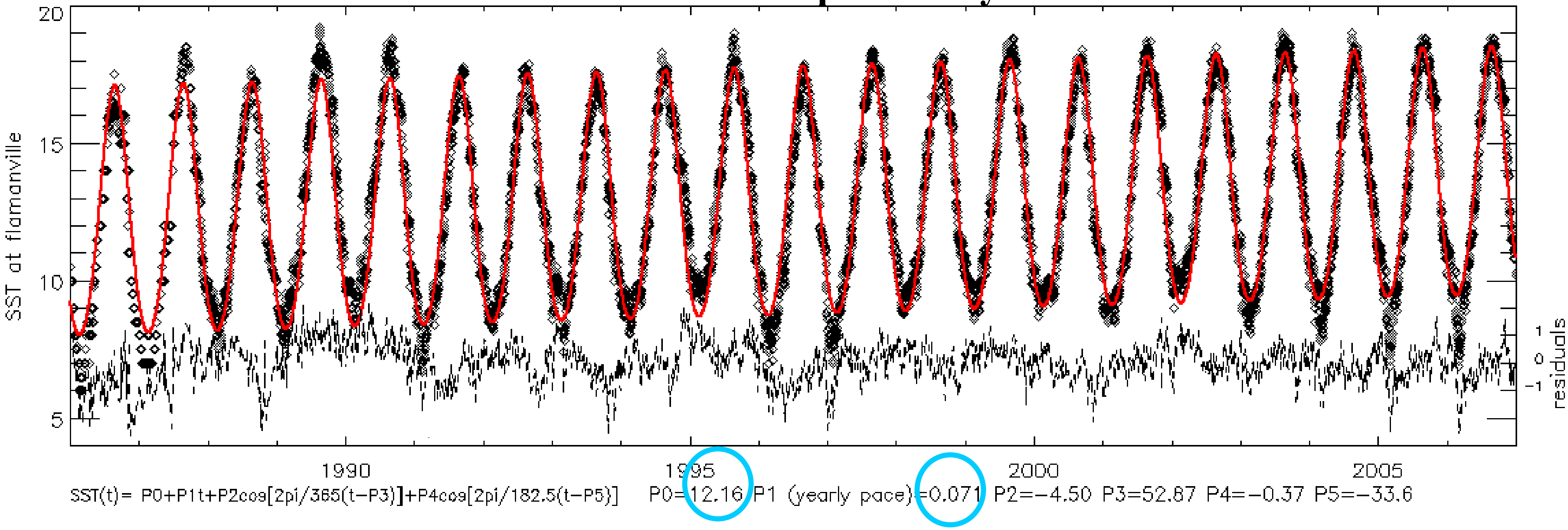
Stratification can cause dissolved oxygen and temperature to vary at different depths in the same system.

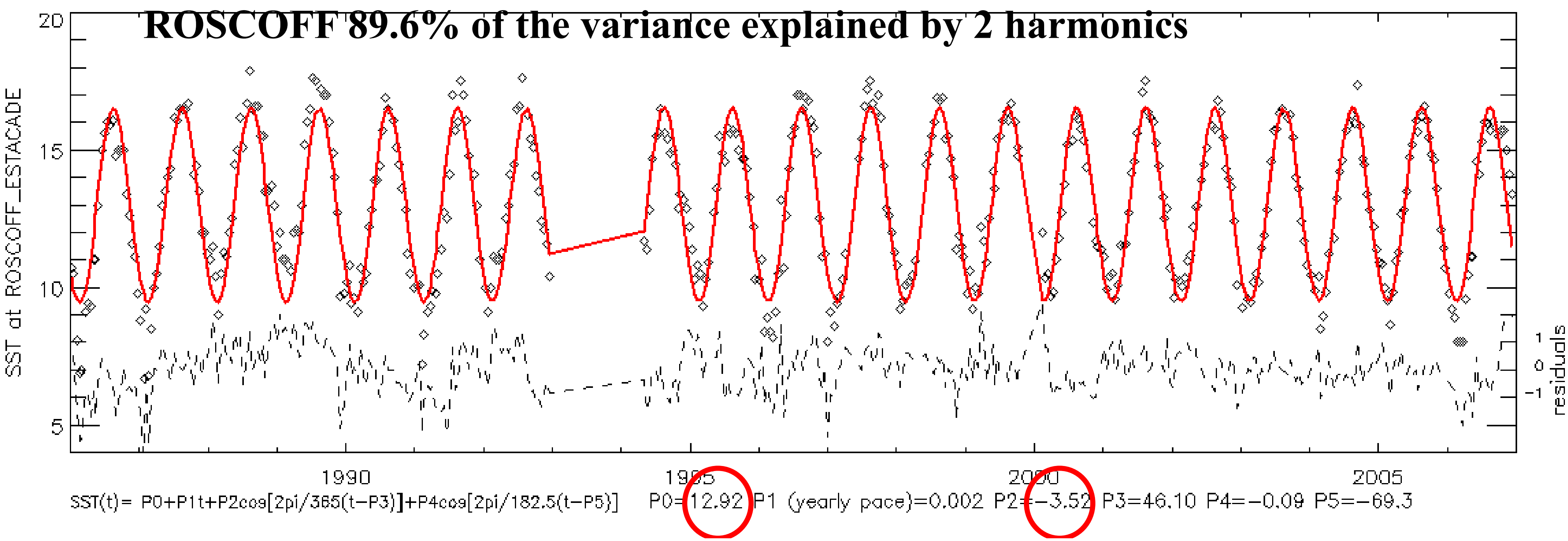
Water Temperature



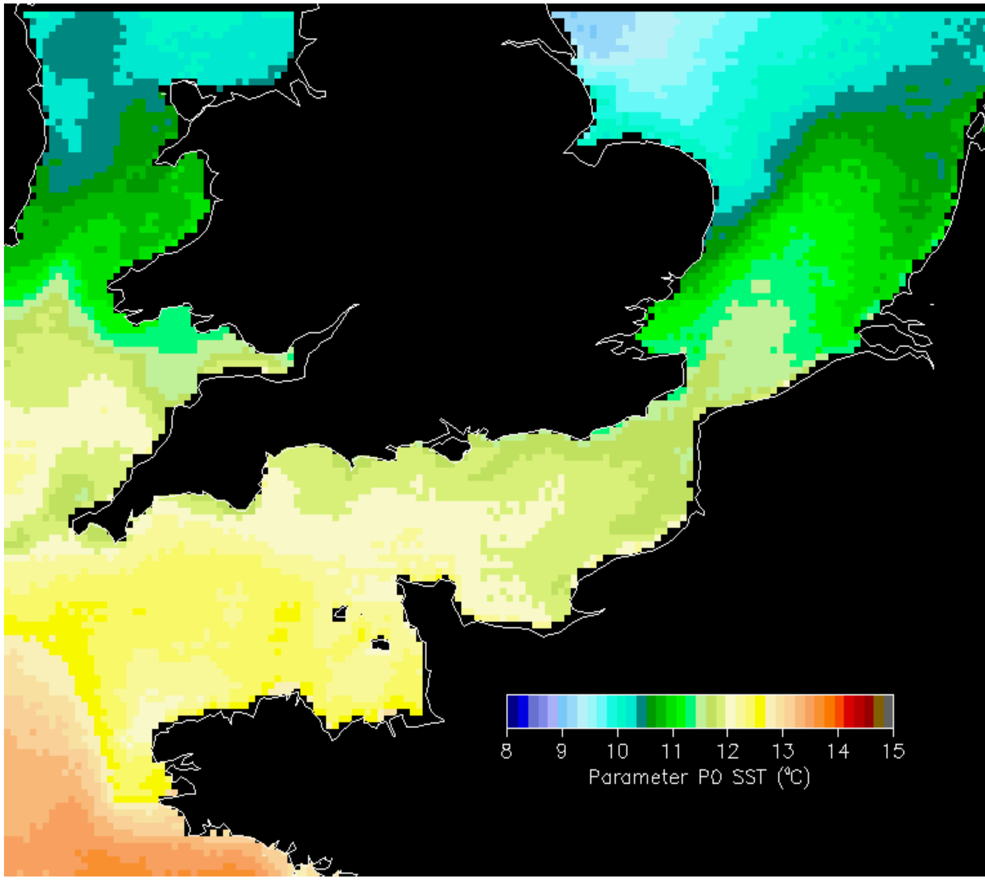
The temporal model for the average SST(x,t).

FLAMANVILLE 95.2% of variance explained by 2 harmonics

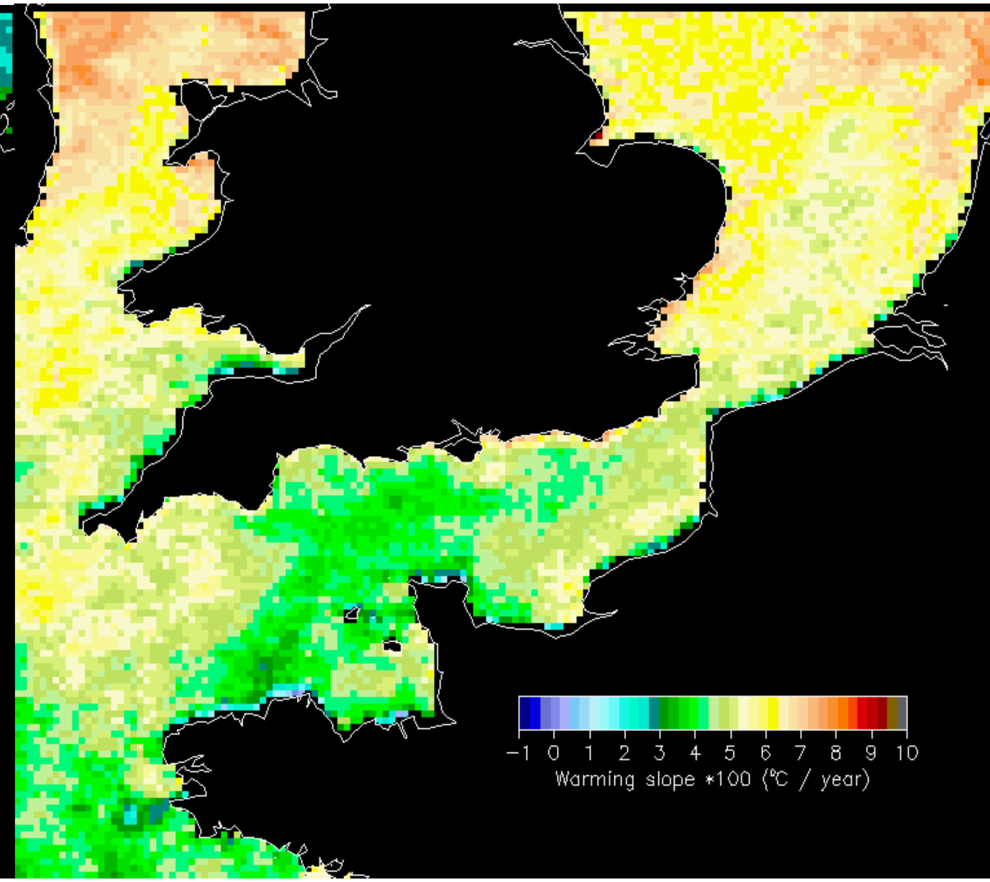




Parameters P0 and P1 calculated from AVHRR data (1986-2006)



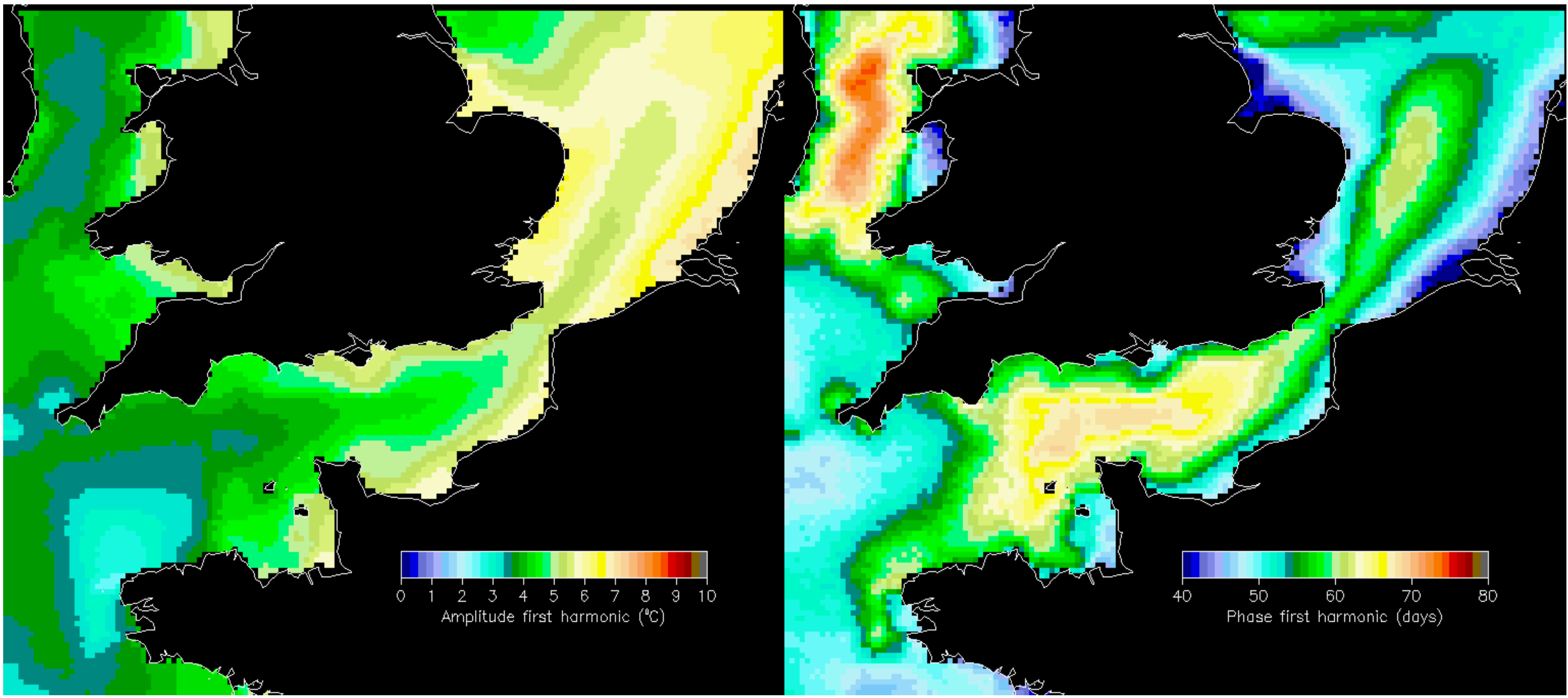
P0, average SST 1986



P1, warming slope

SST(t)= P0+P1*t - P2*cos[2pi/365(t-P3)]-P4*cos[2pi/182.5(t-P5)]

Parameters P2 and P3



P2, half amplitude of the first harmonic

P3, phase of the first harmonic

$$SST(t)= P0+P1*t- P2*\cos[2pi/365(t-P3)]-P4*\cos[2pi/182.5(t-P5)]$$

Salinity

Salinity

- Freshwater has a low ionic concentration (i.e. streams, rivers, ponds and lakes).
- Saltwater has a high ionic concentration (ocean waters).
- Brackishwater has an ionic concentration between freshwater and saltwater (mangroves).

Salinity

- Dissolved salt content in water
- Influences organisms that can live in that area
- Oceans are about 35 ppt or so

Water salinity			
Fresh water	**Brackish water**	**Saline water**	**Brine**
< 0.05 %	**0.05 - 3 %**	**3 - 5 %**	**> 5 %**
< 500 ppm	**500 - 30 000 ppm**	**30 000 - 50 000 ppm**	**> 50 000 ppm**

RS of Soil Salinity: AEM

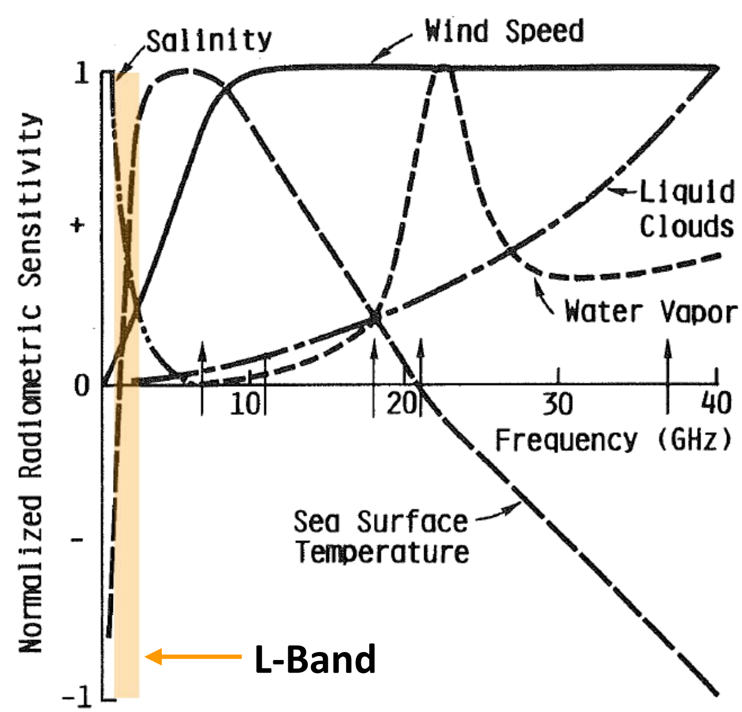
Airborne Electromagnetics

- Maps apparent conductivity of deep soil layers (few m to ~100 m).
- Only airborne systems that can map salinity hazard below the root zone
- Calibration issues for environmental applications
- Limited capability of sensing conductivity at the top few meters
- Unable to resolve thin individual layers

Microwave Emission of High-Saline Soils

L-Band Microwave Emission from Liquid Water

- Frequency-dependent sensitivity to salinity



Ulaby et al. (1986)

Microwave Emission of High-Saline Soils

L-Band Microwave Emission from Liquid Water

1. Pure water (Stogryn, 1971)

$$\varepsilon_w = \varepsilon'_w - j \cdot \varepsilon''_w$$

$$\varepsilon'_w = \varepsilon_{w\infty} + \frac{\varepsilon_{w0} - \varepsilon_{w\infty}}{1 + (2\pi f \tau_w)^2}$$

$$\varepsilon''_w = \frac{2\pi f \tau_w (\varepsilon_{w0} - \varepsilon_{w\infty})}{1 + (2\pi f \tau_w)^2} + \frac{\sigma_i}{2\pi \varepsilon_0 f}$$

where

ε_w = complex dielectric constant of water

ε'_w = real part of ε_w

ε''_w = imaginary part of ε_w

ε_{w0} = static dielectric constant of water

$\varepsilon_{w\infty}$ = high-frequency limit of ε_w

τ_w = relaxation time of water, *s*

f = frequency

σ_i = ionic conductivity of water

ε_0 = permittivity of free space, *F/m.*

Microwave Emission of High-Saline Soils

L-Band Microwave Emission from Liquid Water

2. Saline water (Stogryn, 1971)

$$\varepsilon_w = \varepsilon'_w - j \cdot \varepsilon''_w$$

$$\varepsilon'_w = \varepsilon_{w\infty} + \frac{\varepsilon_{w0} - \varepsilon_{w\infty}}{1 + (2\pi f \tau_w)^2}$$

$$\varepsilon''_w = \frac{2\pi f \tau_w (\varepsilon_{w0} - \varepsilon_{w\infty})}{1 + (2\pi f \tau_w)^2} + \frac{\sigma_i}{2\pi \varepsilon_0 f}$$

where

ε_w = complex dielectric constant of water

ε'_w= real part of ε_w

ε''_w = imaginary part of ε_w

ε_{w0} = static dielectric constant of water

$\varepsilon_{w\infty}$ = high-frequency limit of ε_w

τ_w = relaxation time of water, *s*

f = frequency

σ_i = ionic conductivity of water

ε_0 = permittivity of free space, *F/m.*

Summary

- For accurate and quantitative WQ monitoring analysis of spatially and temporally co-located, in situ measurements and satellite observations is required
- Feasibility of WQ monitoring in coastal and inland water bodies depends on spatial, temporal, and spectral resolutions of remote sensing observations
- Difficult to separate WQ parameters when sediments, dissolved matter, and Chl-a all are present
- It is not possible to characterize algal types or toxins only from remote sensing observations
- Remote sensing reflectance has to be corrected to account for contributions from atmospheric constituents such as aerosols
- Optical remote sensing observations cannot view the surface in the presence of clouds

Extra Slide

Terra and Aqua Satellites and Sensors

Terra

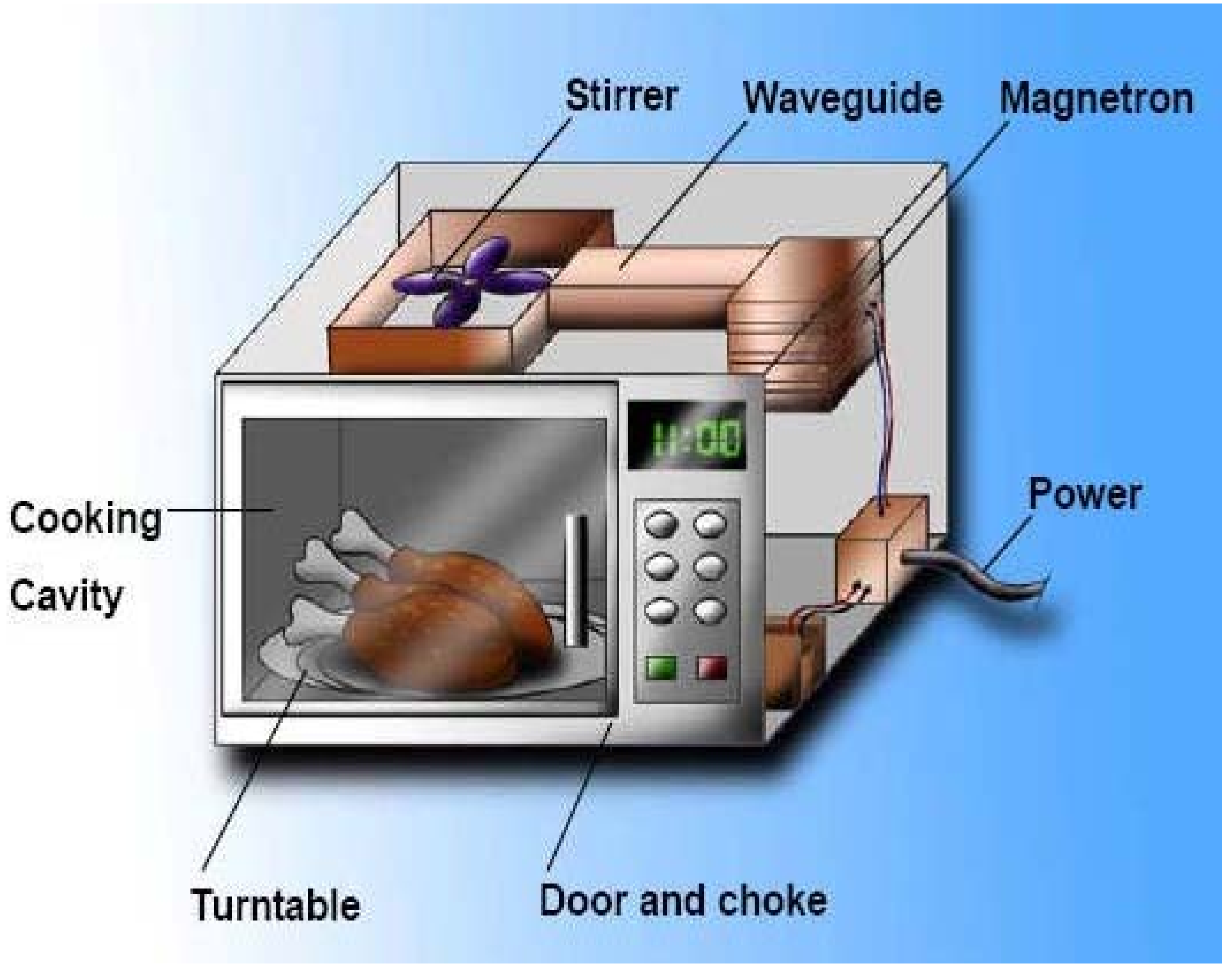
http://terra.nasa.gov

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – Present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT

Aqua

http://aqua.nasa.gov/

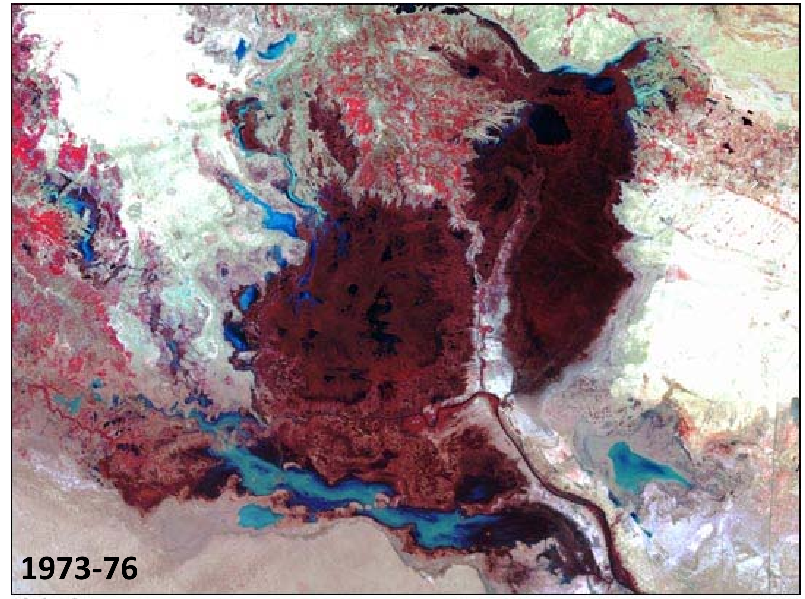
- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E



- Microwaves are electromagnetic waves, exactly the same as visible light except that microwaves have much longer wavelengths than the light our eyes detect.
- Microwaves cook food by heating the liquid water it contains. Each water molecule has a slight positive electric charge on one side and a slight negative charge on the other.
- As microwaves pass by, they exert forces on those charges, first one way, then the other, several billion times per second.
- The result of all this agitation is more violent random motion of all the water molecules in the food — in other words, the water gets heated.

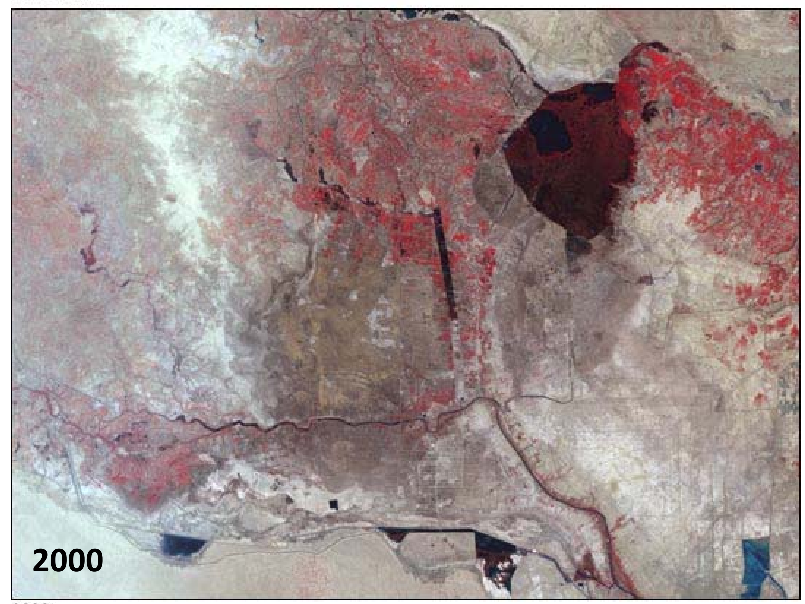
Monitoring Ecosystem Changes

- Gradual changes require long-term, repeat satellite coverage
- Landsat data are used to:
    - Precisely assess the area affected
    - Separate human from natural causes
    - Bridge the gap between field observations and global monitoring



1973 -1976

Loss of wetlands in Mesopotamia (dark red areas) since 1973 from Landsat. Courtesy Hassan Partow, UNEP

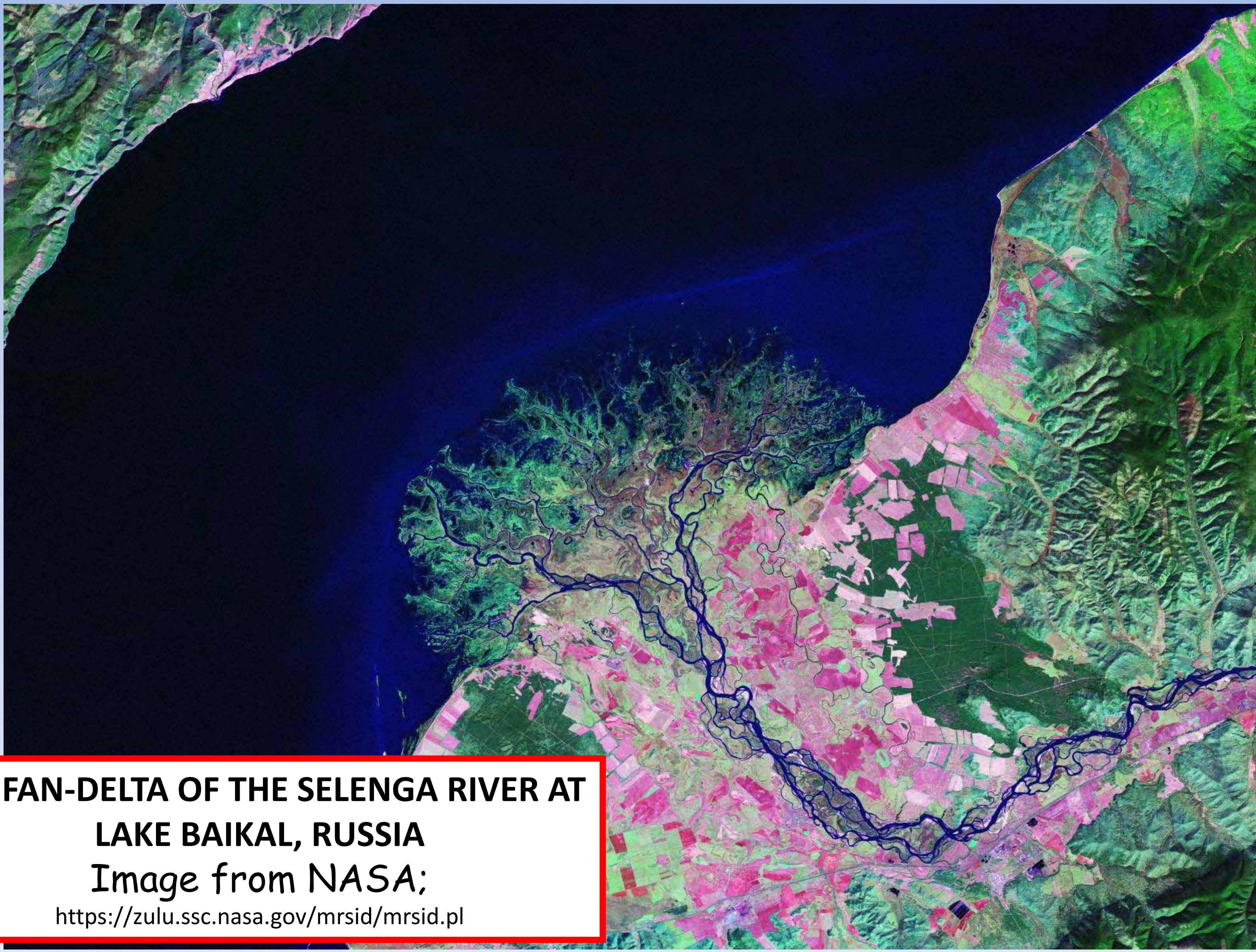


2000

Monitoring Ecosystem Changes

Terrigenous (or Lithogenous Sediments):

- derived from weathering of rocks at or above sea level (e.g., continents, islands)
- two distinct chemical compositions
  - ferromagnesian, or iron-magnesium bearing minerals
  - non-ferromagnesian minerals – e.g., quartz, feldspar, micas
- largest deposits on continental margins (less than 40% reach abyssal plains)
- transported as dissolved and suspended loads in rivers, waves, longshore currents



THE FAN-DELTA OF THE SELENGA RIVER AT LAKE BAIKAL, RUSSIA

Image from NASA;

https://zulu.ssc.nasa.gov/mrsid/mrsid.pl

pH

- Potential of Hydrogen – measures hydrogen concentration in water
- 7.0 is neutral on scale of 0 – 14
- Can affect how chemicals dissolve in water

Representative pH values	
Substance	**pH**
Hydrochloric Acid, 10M	-1.0
Lead-acid battery	0.5
Gastric acid	1.5 – 2.0
Lemon juice	2.4
Cola	2.5
Vinegar	2.9
Orange or apple juice	3.5
Tomato Juice	4.0
Beer	4.5
Acid Rain	<5.0
Coffee	5.0
Tea or healthy skin	5.5
Urine	6.0
Milk	6.5
Pure Water	7.0
Healthy human saliva	6.5 – 7.4
Blood	7.34 – 7.45
Seawater	7.7 – 8.3
Hand soap	9.0 – 10.0
Household ammonia	11.5
Bleach	12.5
Household lye	13.5