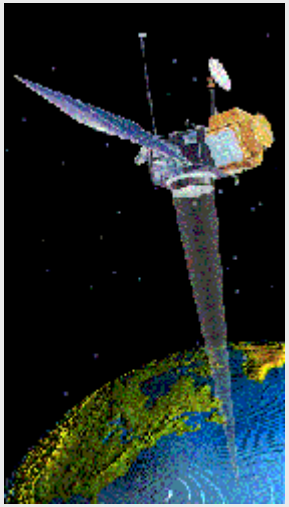
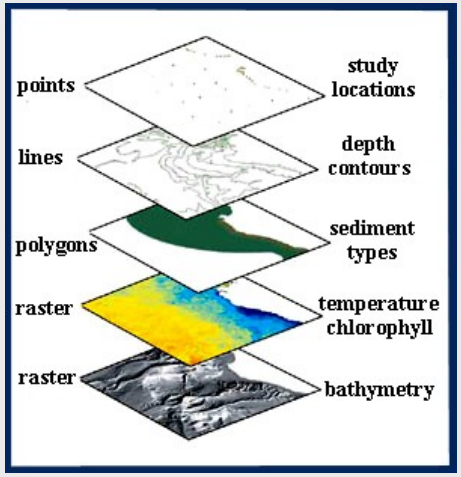
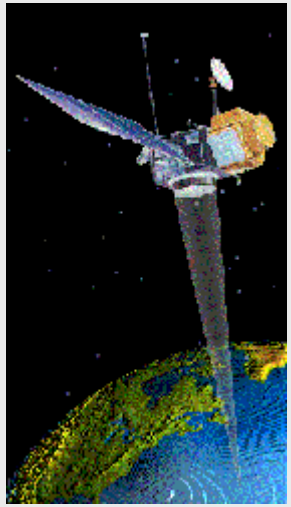
MARINE SATELLITE REMOTE SENSING



MARINE GEOGRAPHIC INFORMATION SYSTEMS



MARINE SATELLITE REMOTE SENSING



- Capabilities
- E/M Spectrum
- RS Process
- Sensors
- Satellites
- Sensor Types
- Orbits
- Data & Data Archives
- Final Image Products Issues

Unique Capabilities

Remote - global coverage possible

Non-intrusive and wide coverage - economical

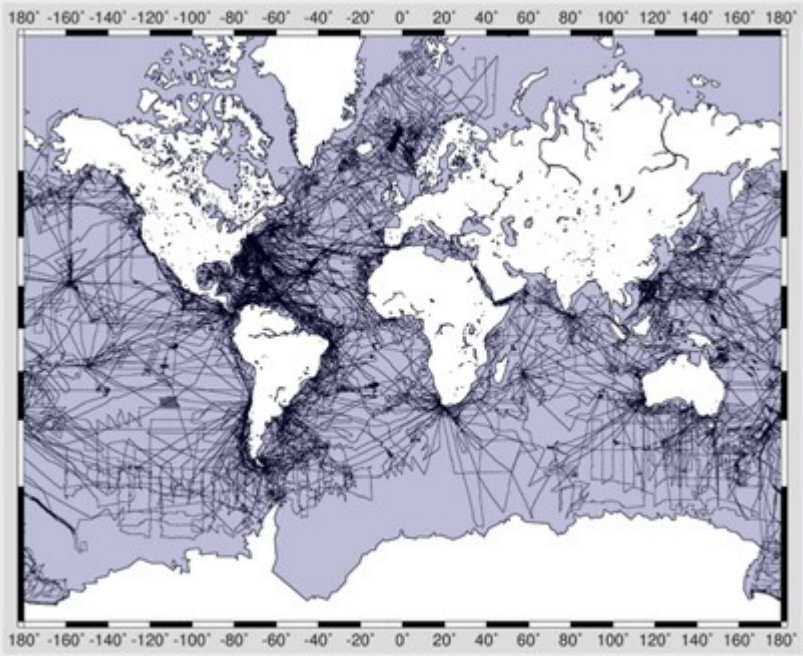
Multiple scales - ideal different applications

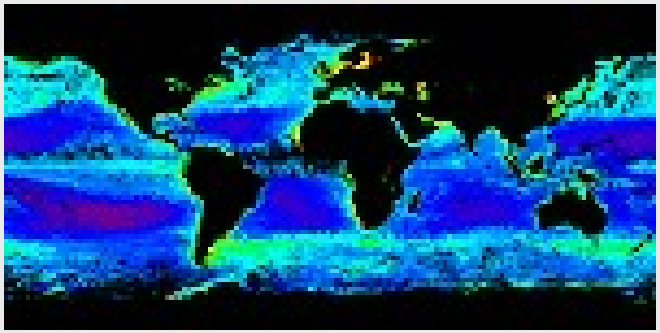
Wide spectral range - thermal, microwave

Hyperspectral - more applications

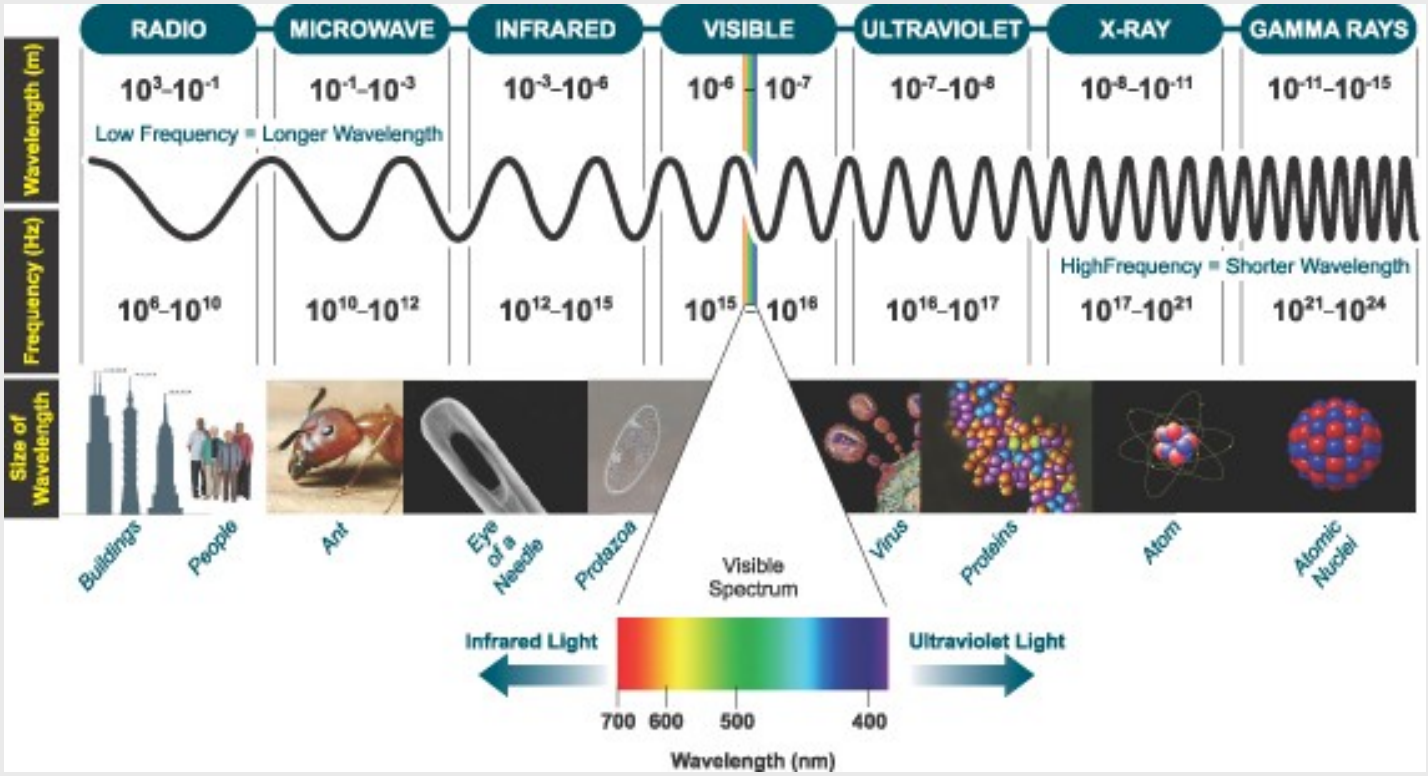
Repetitive coverage - ideal for environmental monitoring

Earth’s rotation and gravity on their best!



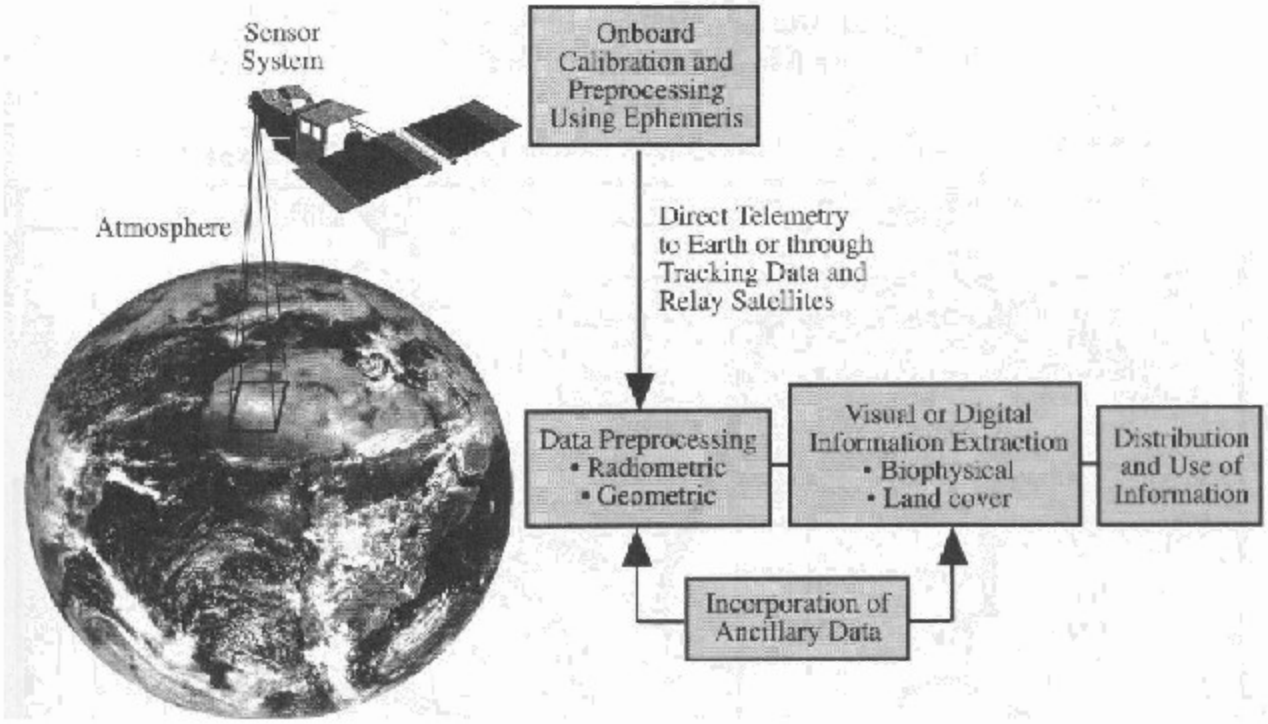


Radio waves, microwaves, x-rays, gamma rays, and the spectrum of visible colors are all really the same thing: electromagnetic energy. The differences are their wavelengths.
A photon of shorter-wavelength light packs and emits more energy than a photon of longer-wavelength light.

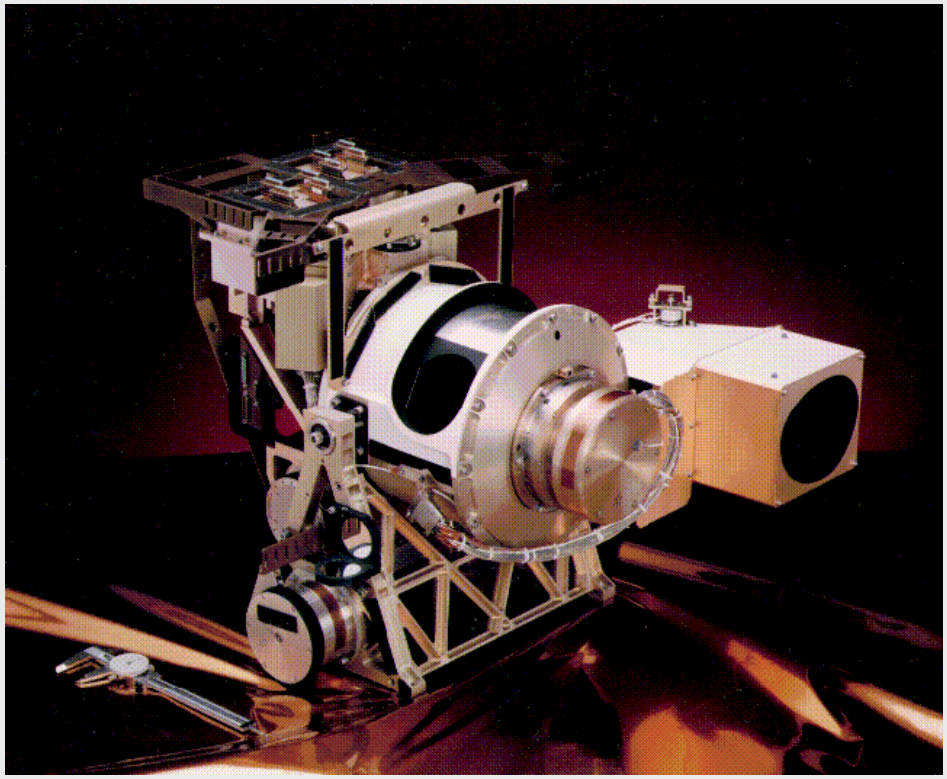


Light is part of the electromagnetic spectrum, fluctuations of magnetic and electric fields

Remote Sensing Processes



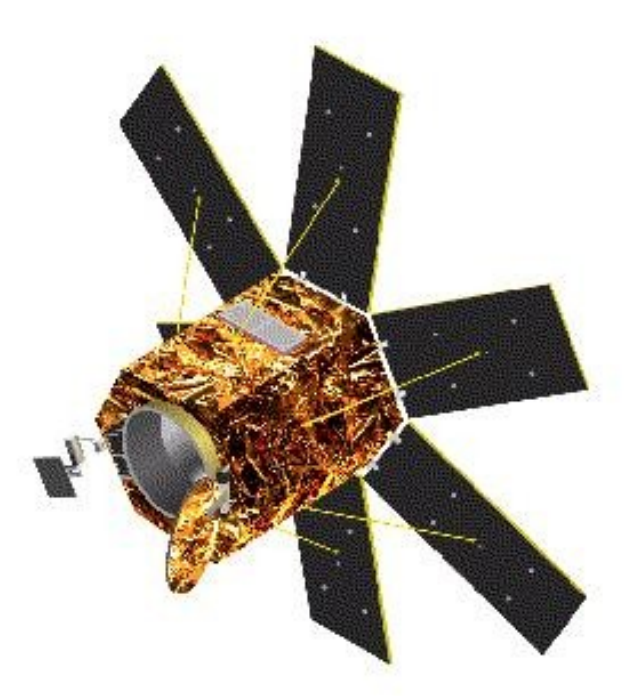
The SeaWiFS Sensor
Sea-viewing Wide Field-of-View Sensor



Most remote sensing instruments (sensors) are designed to measure photons based on the **photoelectric effect** (reason for Nobel to Einstein): When a beam of light hits a material, electrons are emitted and scattered as reflectance. These are measured by the sensor's detector. The magnitude of the electric current produced (number of photoelectrons per unit time) is directly proportional to the light intensity.

Different materials undergo photoelectric effect release of electrons over different wavelength intervals.

The OrbView - # satellite carrying SeaWiFS sensor

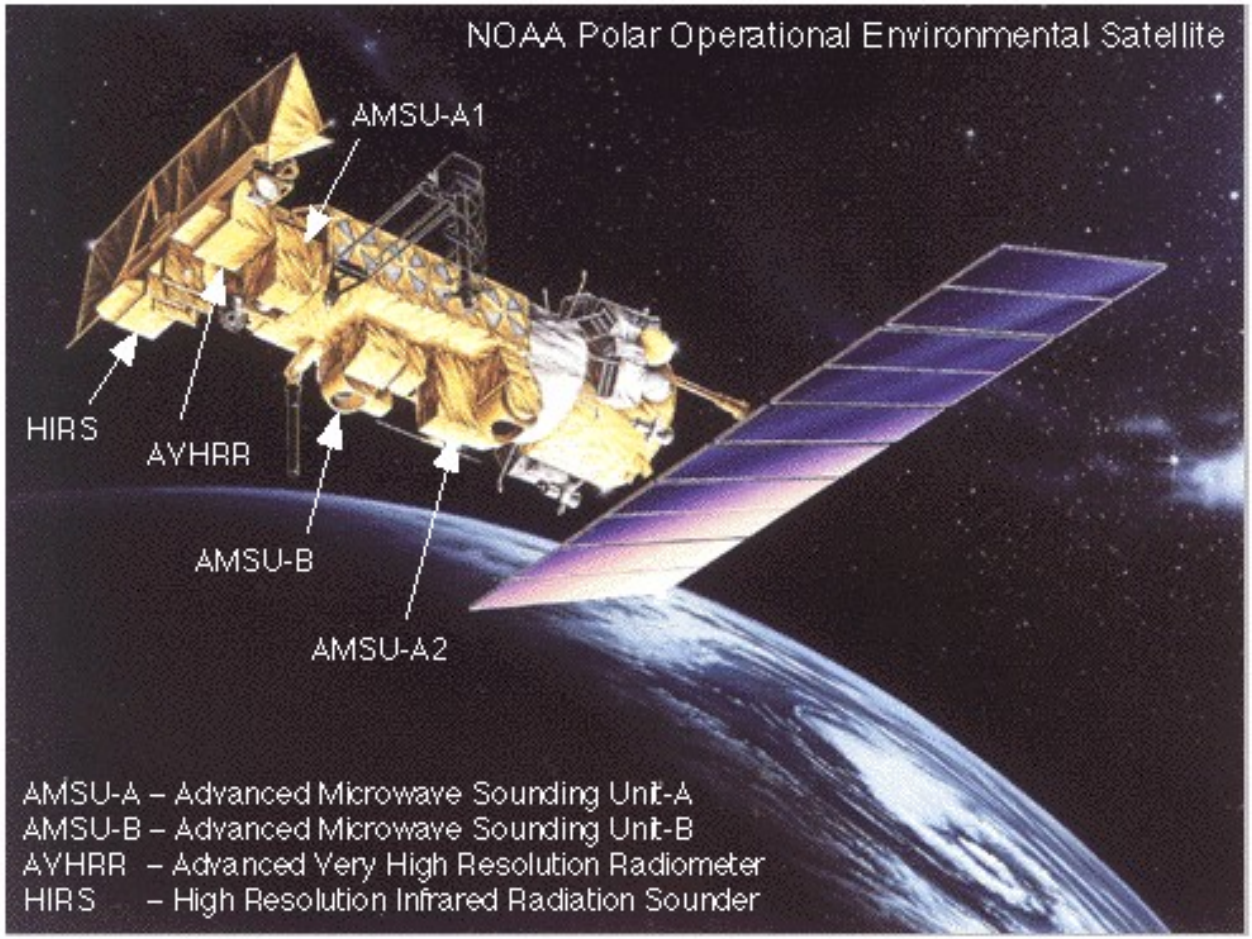


OrbView - 4

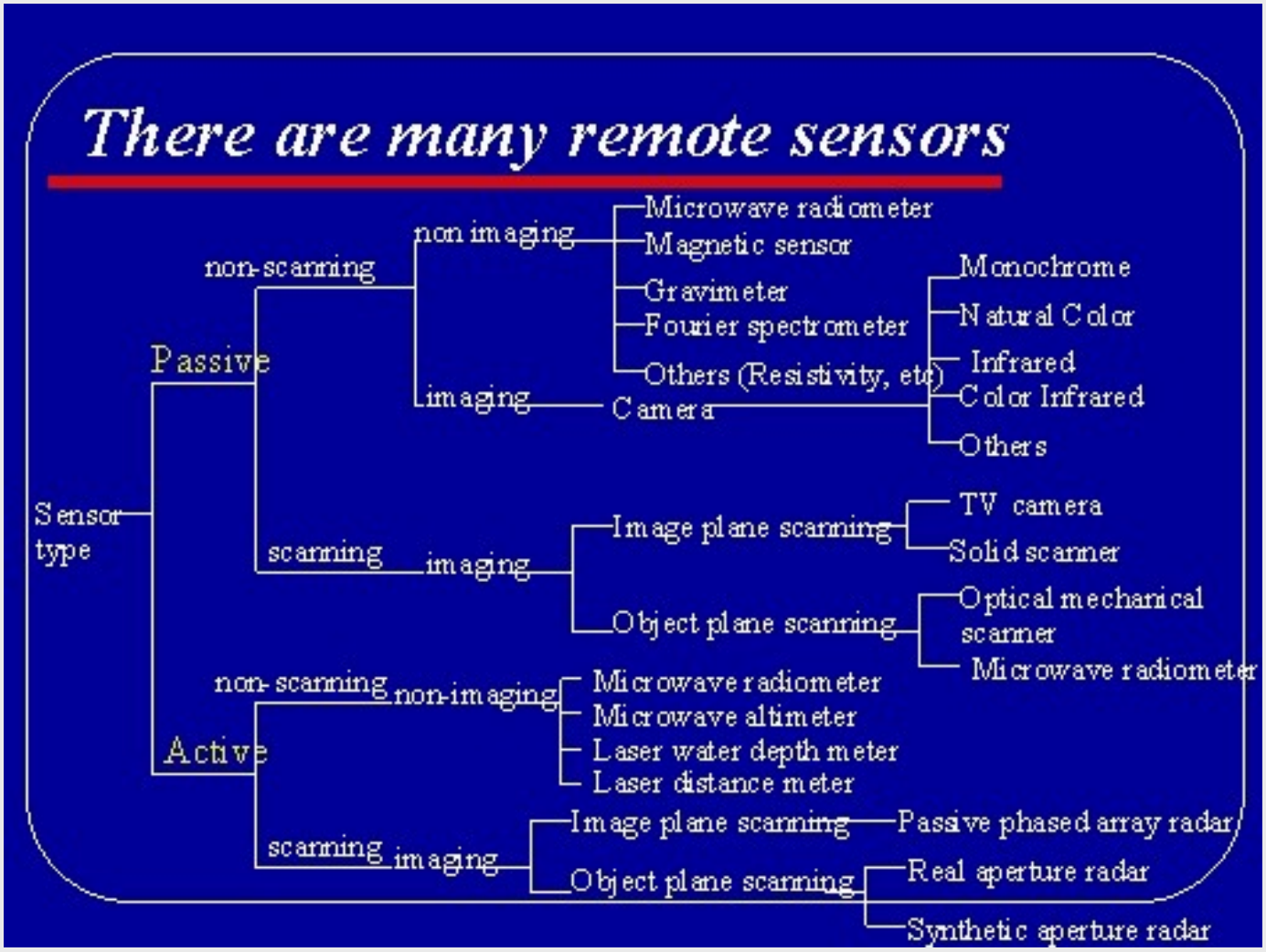
OrbView - 2

Solar panels for energy – electronics – calibration equipment – antennas – reflectors – emitters – receivers – sensors – detectors. Ground control stations.

A satellite may carry many sensors



Different ways satellite sensors measure the Earth



Sensors:

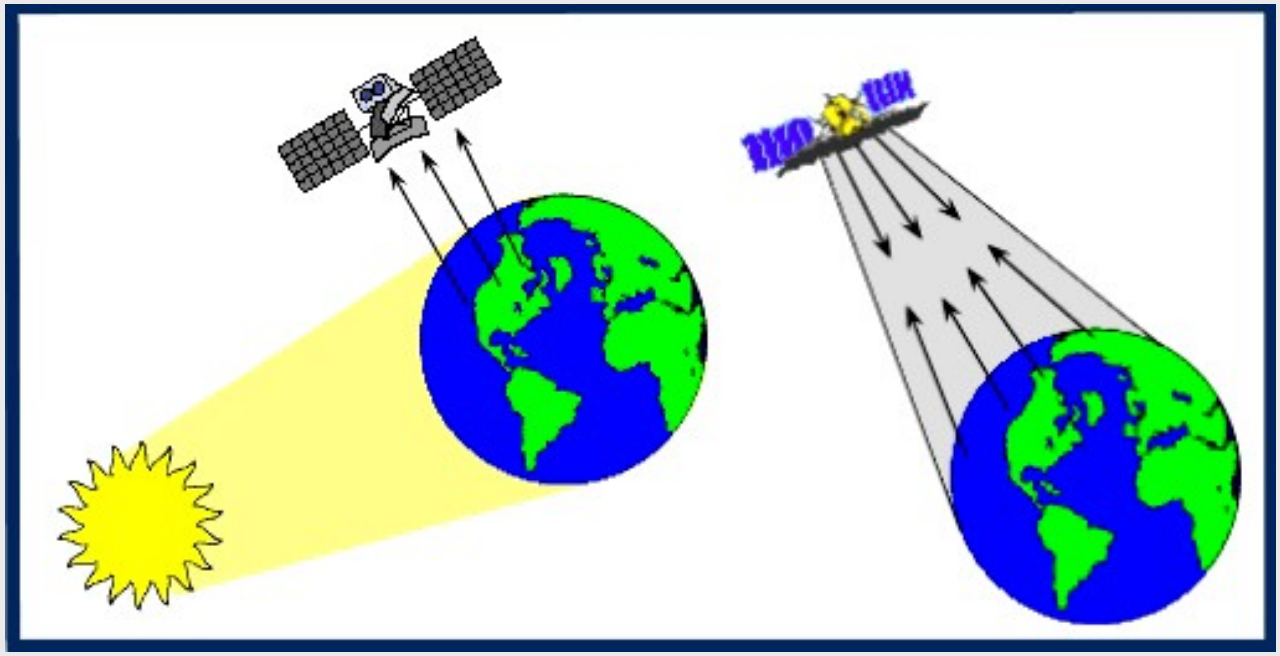
Non-imaging: measure radiation received from all points in the sensed target, integrate this, and reports the result as an electrical signal strength or some other quantitative attribute, such as radiance (astrometric and geodetic applications).

- **Imaging:** the electrons released are used to drive an image producing device (likeTV) guided by electronic detectors; since the radiation is related to specific points in the target, the end result is an image (environmental applications).

Radiometer is a general term for any instrument that quantitatively measures the EM radiation in some interval of the EM spectrum. If the sensor includes a component, such as a prism that can break radiation extending over a part of the spectrum into discrete wavelengths and separate them at different angles to detectors, it is called a **spectrometer**.

Spectroradiometer tends to imply that the dispersed radiation is in bands rather than discrete wavelengths. Most space sensors are spectroradiometers.

SATELLITE REMOTE SENSING

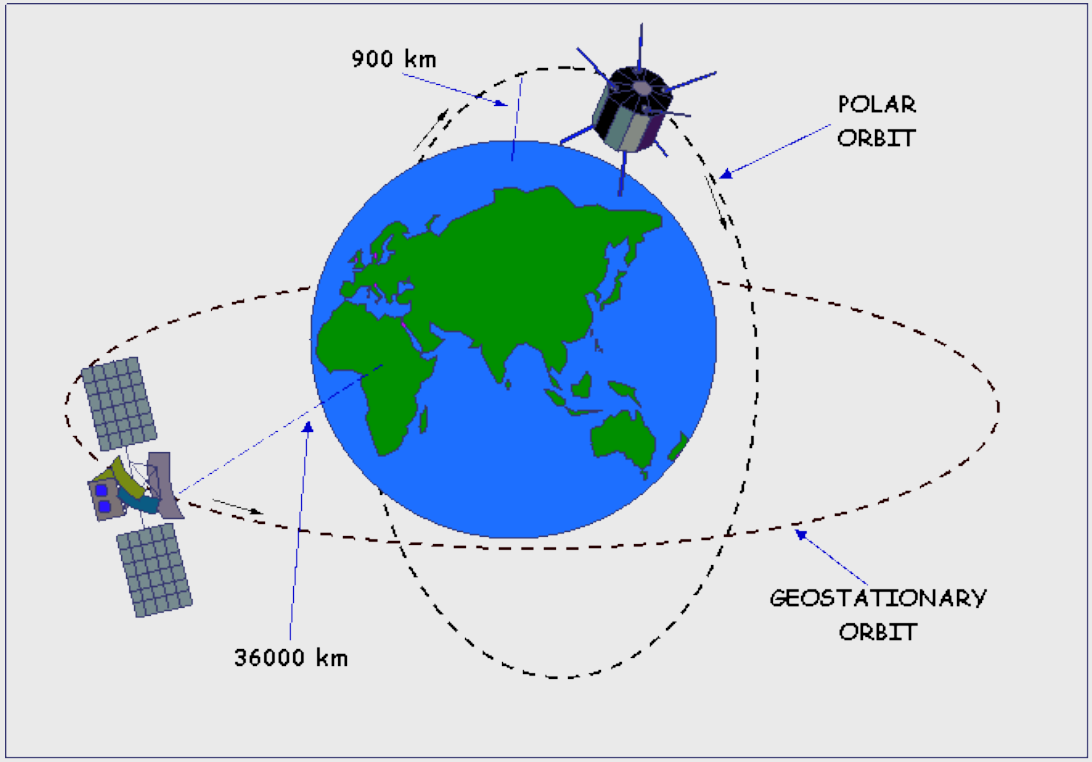


The passive and active Remote Sensing sensor systems.

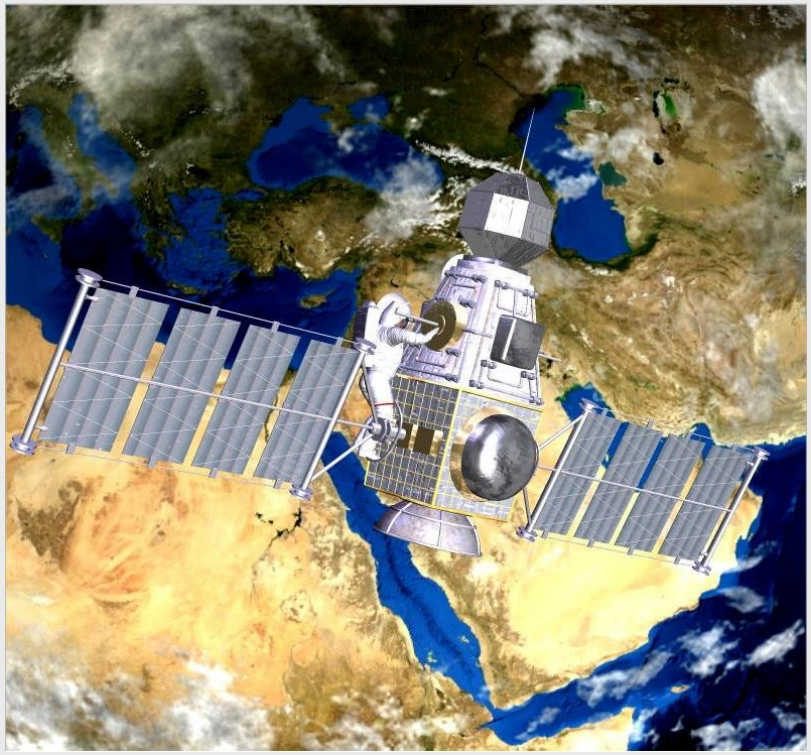
Sensors absorb either the sun's light reflectance to the earth (passive) or they transmit and absorb their own signal (active).

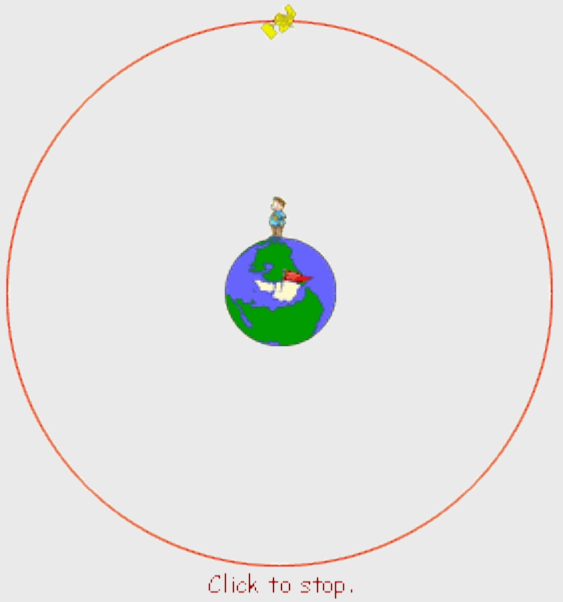
Different environmental parameters are measured by each sensor system.

The **geostationary** and **polar orbits** of environmental satellites. Sensors in geostationary orbit constantly monitor the same area of the Earth while sensors in polar orbit provide data for essentially all Earth's surface.



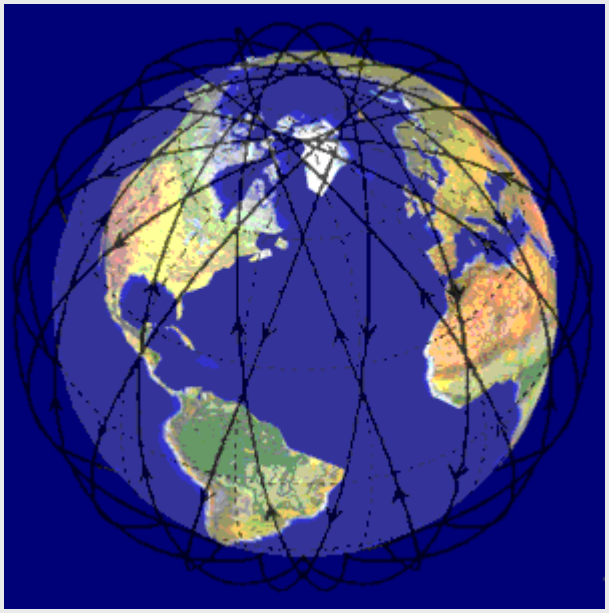
Geostationary satellite

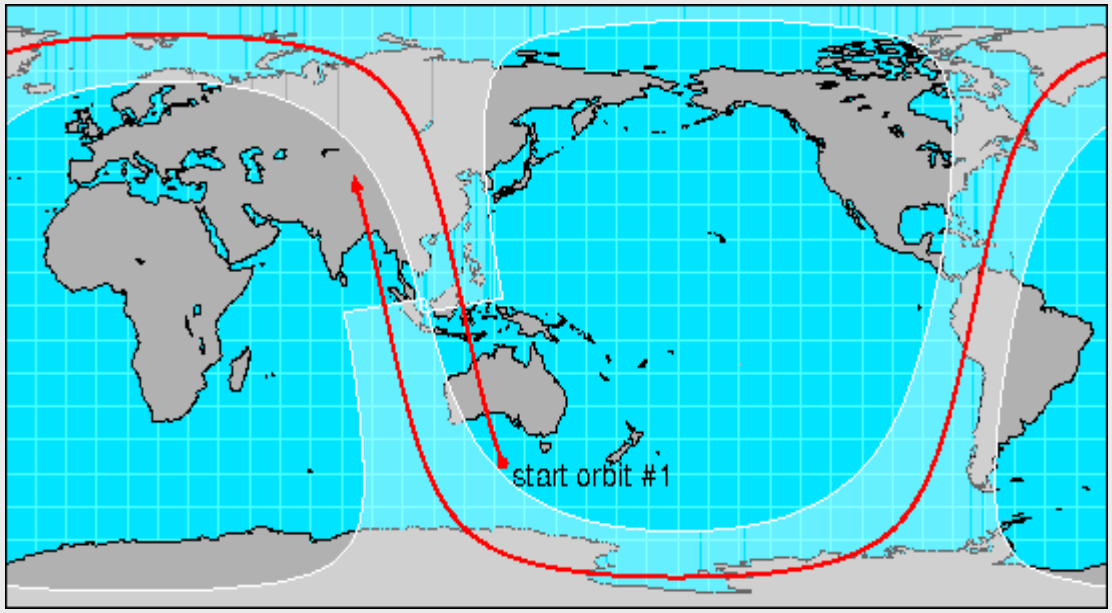




A geostationary orbit is a geosynchronous orbit directly above the Earth's equator. From the ground, a geostationary object appears motionless in the sky.

Polar orbits





Satellite has a fixed orbital plane perpendicular to the planet's rotation.
It will pass over a region with a different longitude on each of its orbits.

MARINE SATELLITE REMOTE SENSING

Main Measured Parameters

Current:

- ✓SST (Sea Surface Temperature distribution)
- ✓Chl-a (Sea Surface Chlorophyll-a concentration)
- ✓PAR (Photosynthetically Active Radiation)
- ✓ALT (Altimetry)
- ✓WIND (Wind Speed & Direction)

…and a variety of derived measurements (sea level anomalies, sea currents, suspended sediments, etc)

Near-Future:

- ➢SSS (Sea Surface Salinity)
  - Soil Moisture and Ocean Salinity (SMOS) by ESA: 2008
  - Aquarius by NASA & Space Agency of Argentina: 2009

MARINE SATELLITE REMOTE SENSING

Main Satellite Sensors

- ✓Advanced Very High Resolution Radiometer (AVHRR): SST
- ✓Sea-viewing Wide Field-of-view Sensor (SeaWiFS):Chl-a, PAR
- ✓Moderate-resolution Imaging Spectroradiometer (MODIS): SST, Chl-a
- ✓QuikSCAT (Quik Scatterometer): WD, WS
- ✓SeaWinds: WD, WS
- ✓T/P (TOPEX/Poseidon): SL
- ✓ERS1/2 (Earth Resources Satellite): SL
- ✓Jason1: SL
- ✓EnviSAT (Environmental Satellite): SL

MARINE SATELLITE REMOTE SENSING

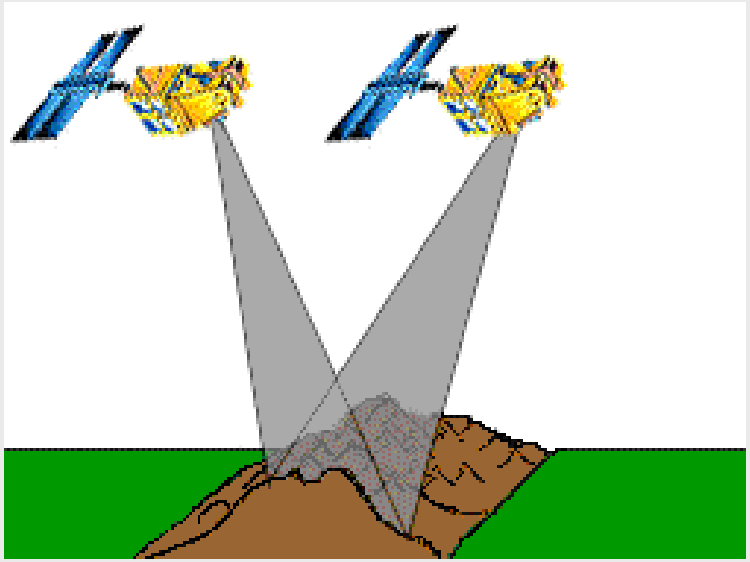
Measured Environmental Parameters
2 or 4 things to note

1. SPATIAL RESOLUTION (pixel size)
Is the spatial extent of our study area represented adequately by available satellite data?

MARINE SATELLITE REMOTE SENSING

Measured Environmental Parameters
2 or 4 things to note

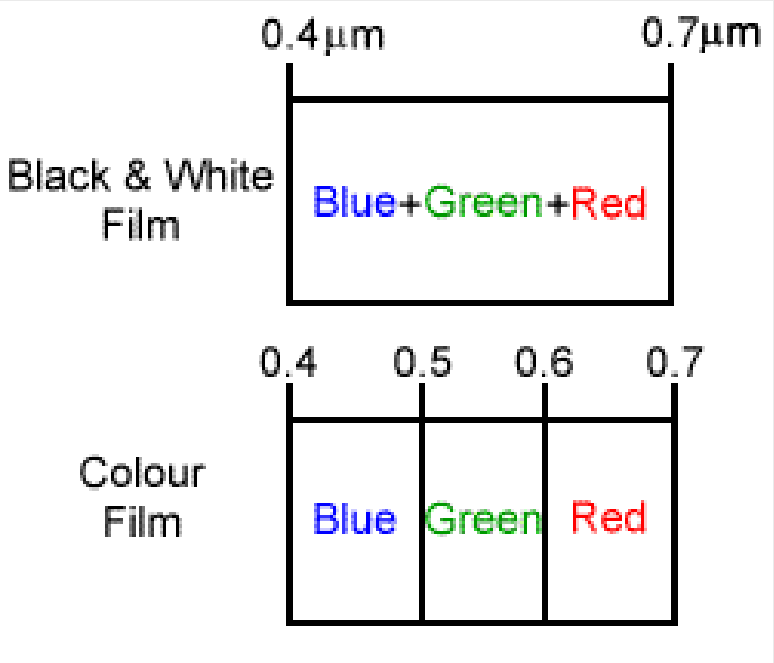
2. TEMPORAL RESOLUTION (daily, weekly, monthly, seasonal)
Is the time period of our study represented adequately in the available time series of satellite data?



MARINE SATELLITE REMOTE SENSING

Measured Environmental Parameters
2 or 4 things to note

3. SPECTRAL RESOLUTION (how many different spectral bands)
Are available spectral bands of our satellite data adequate to describe our parameter of interest? Mostly yes!

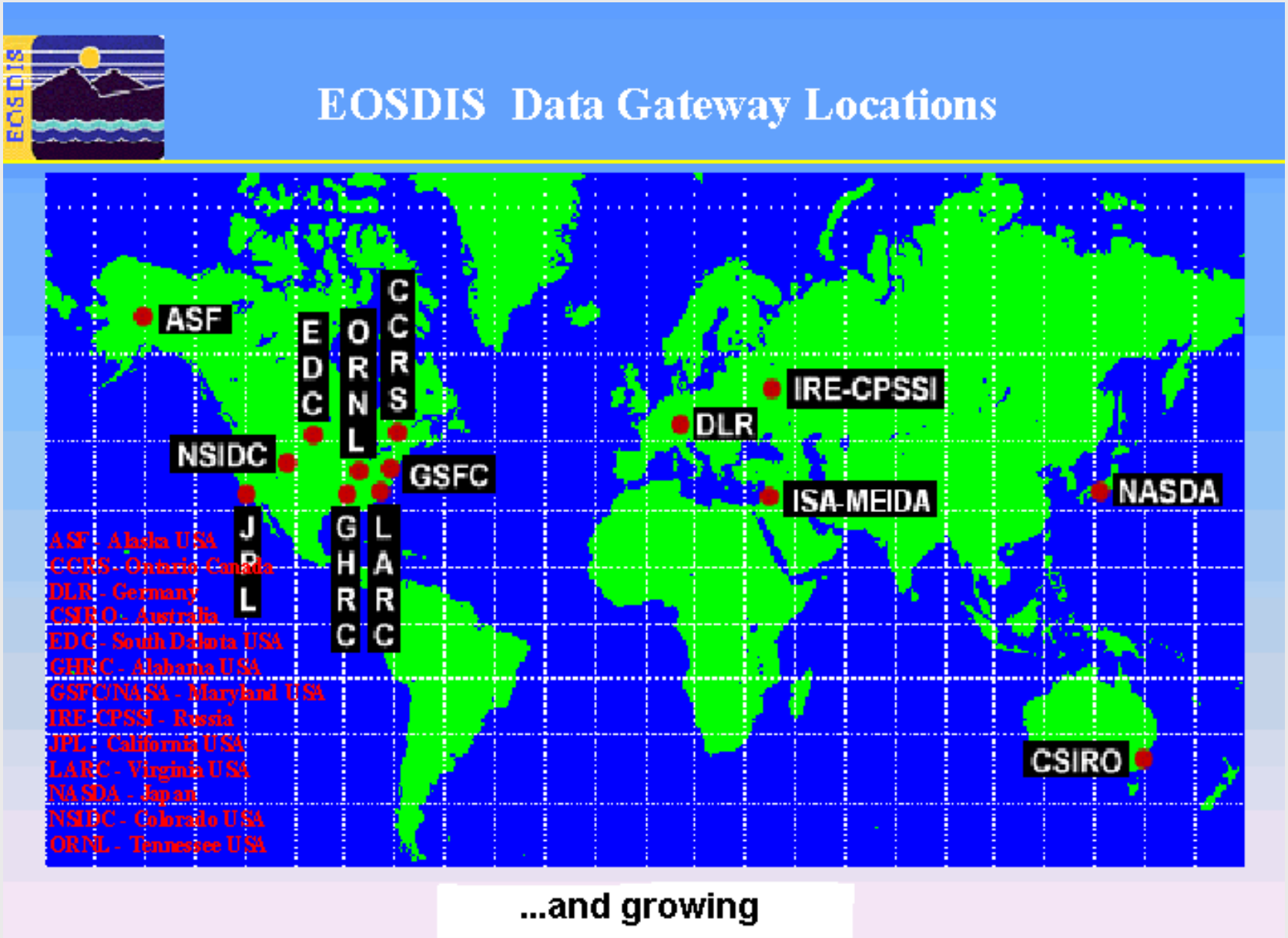


MARINE SATELLITE REMOTE SENSING

Measured Environmental Parameters
2 or 4 things to note

3. RADIOMETRIC RESOLUTION (intensity sensors detect)
Is the resulted satellite image adequate to describe our parameter of interest?

MAJOR ONLINE RS DATA ARCHIVES

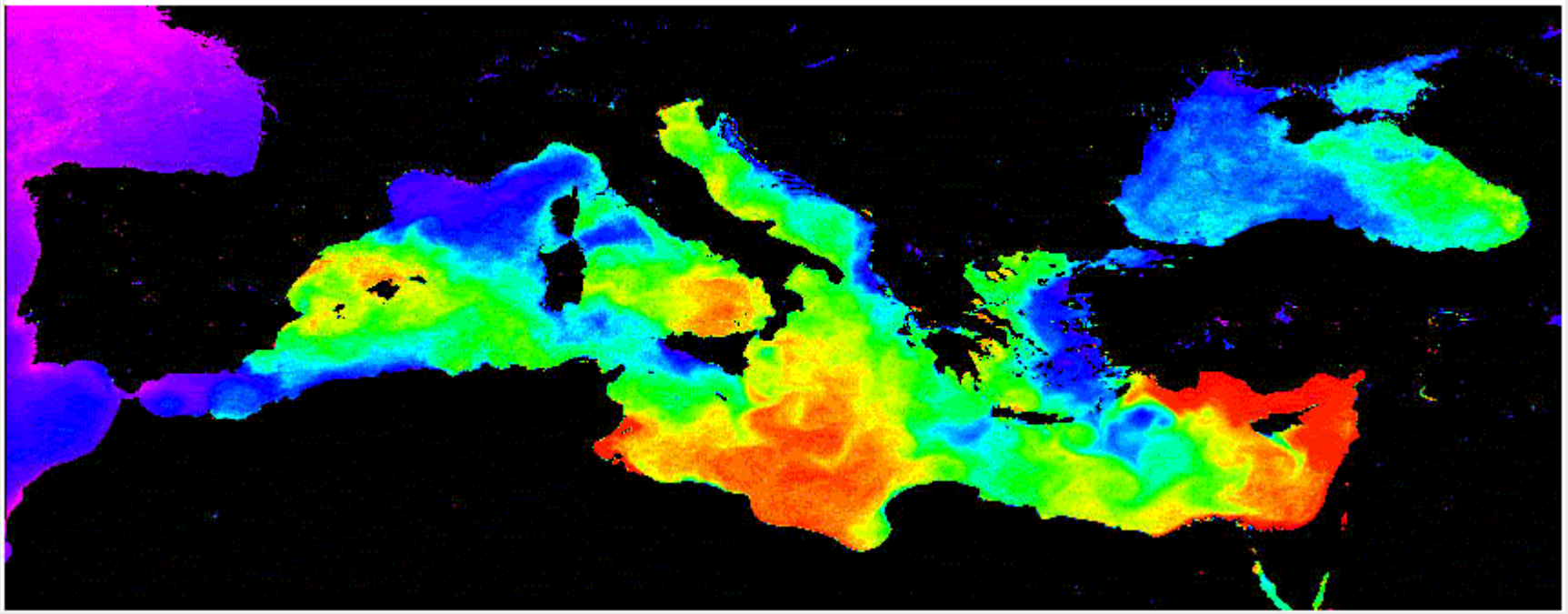


...and growing

MARINE SATELLITE REMOTE SENSING

Data Sources

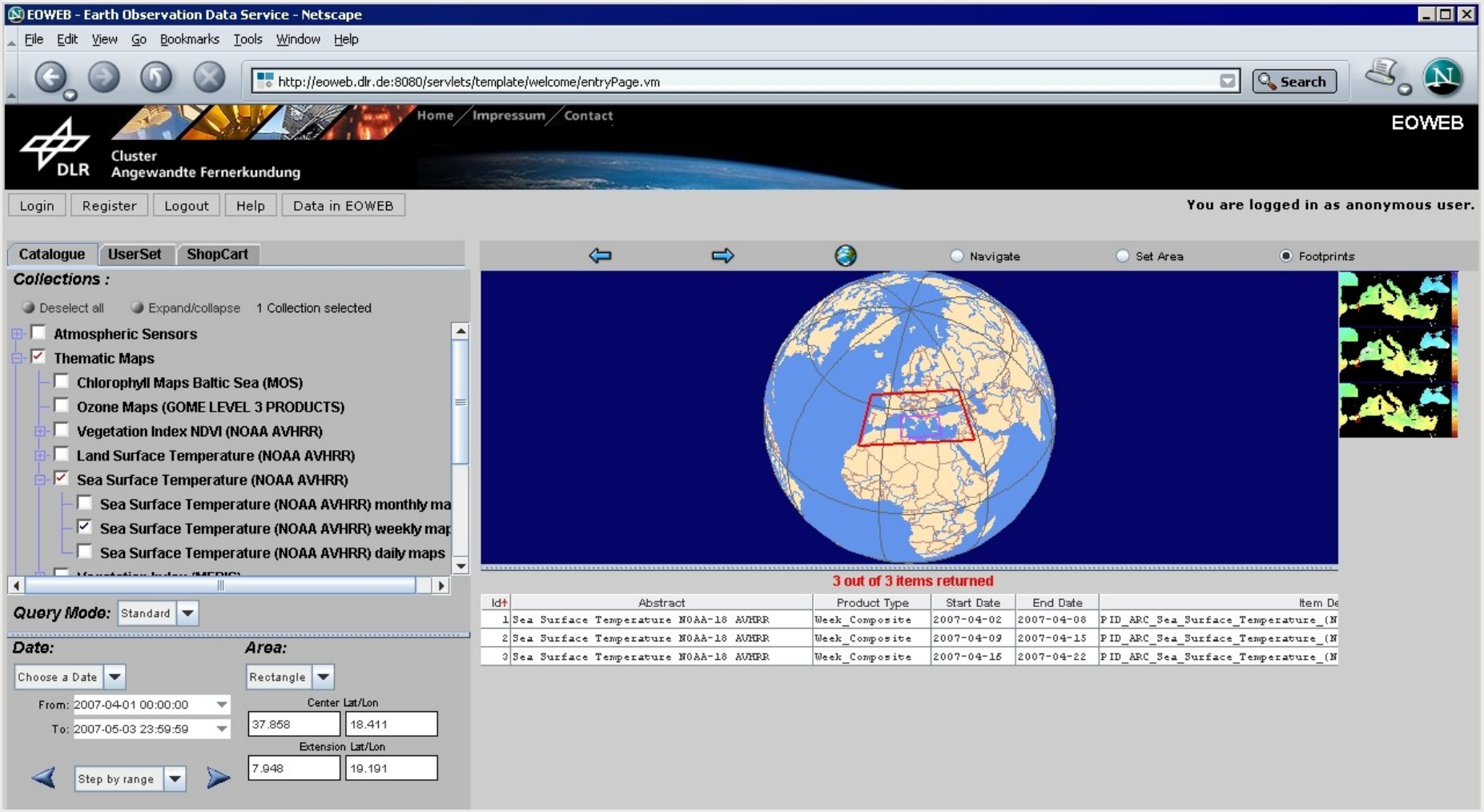
Sea Surface Temperature



DLR-EOWEB, Germany http://eoweb.dlr.de:8080/index.html

Spatial Resolution: 1.2km
Temporal Resolution: daily, weekly, monthly, 1993-onwards

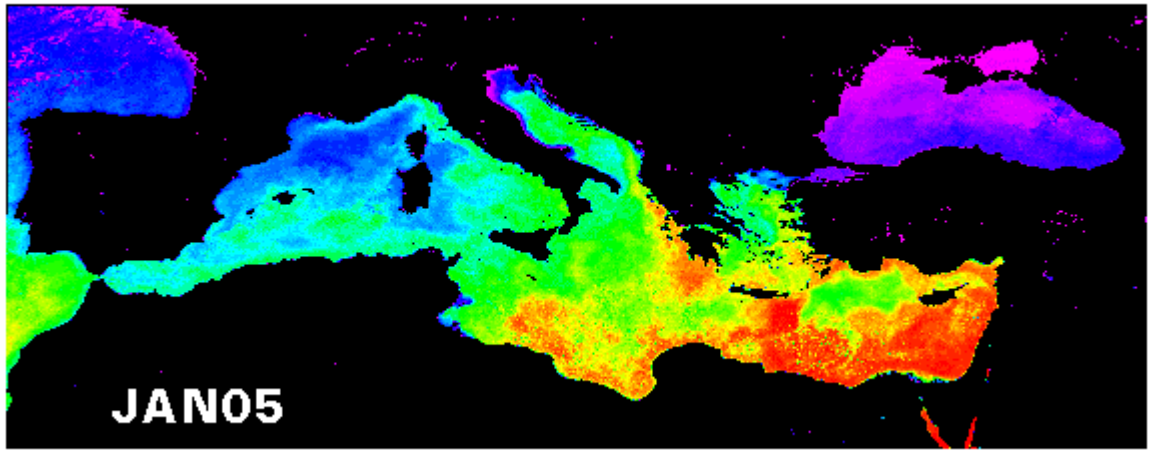
EOWEB – DLR - SST



DLR-EOWEB, Germany http://eoweb.dlr.de:8080/index.html

MARINE SATELLITE REMOTE SENSING

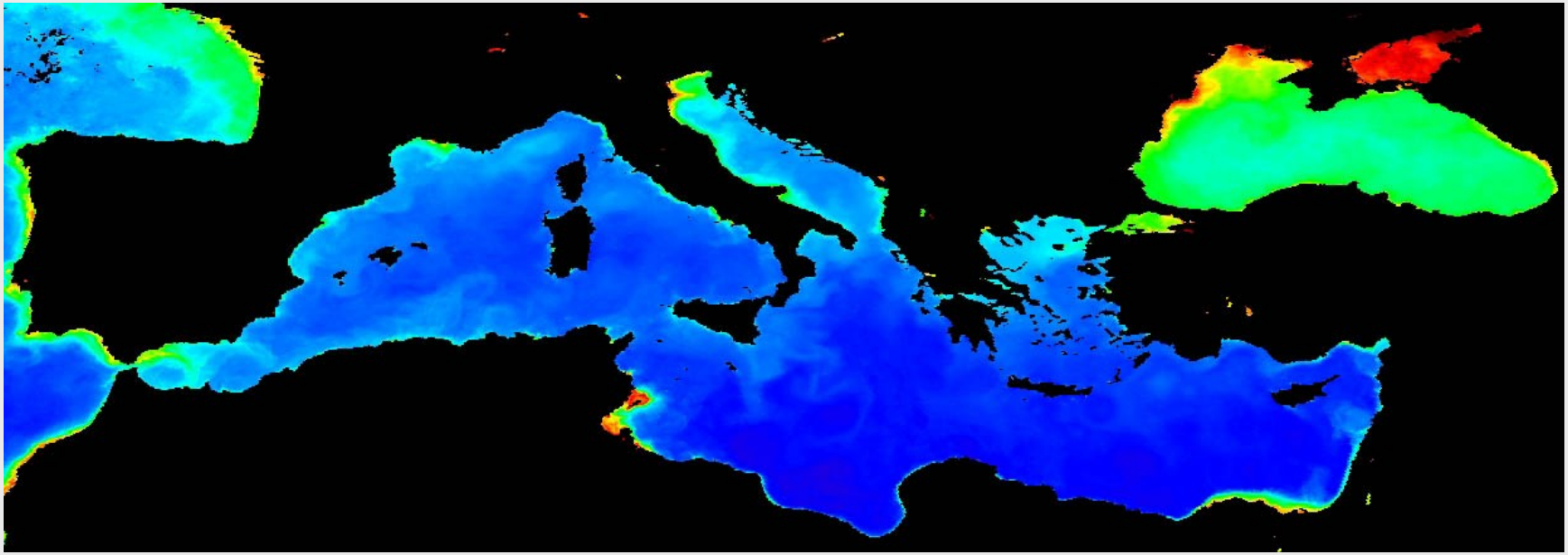
SST 2005



MARINE SATELLITE REMOTE SENSING

Data Sources

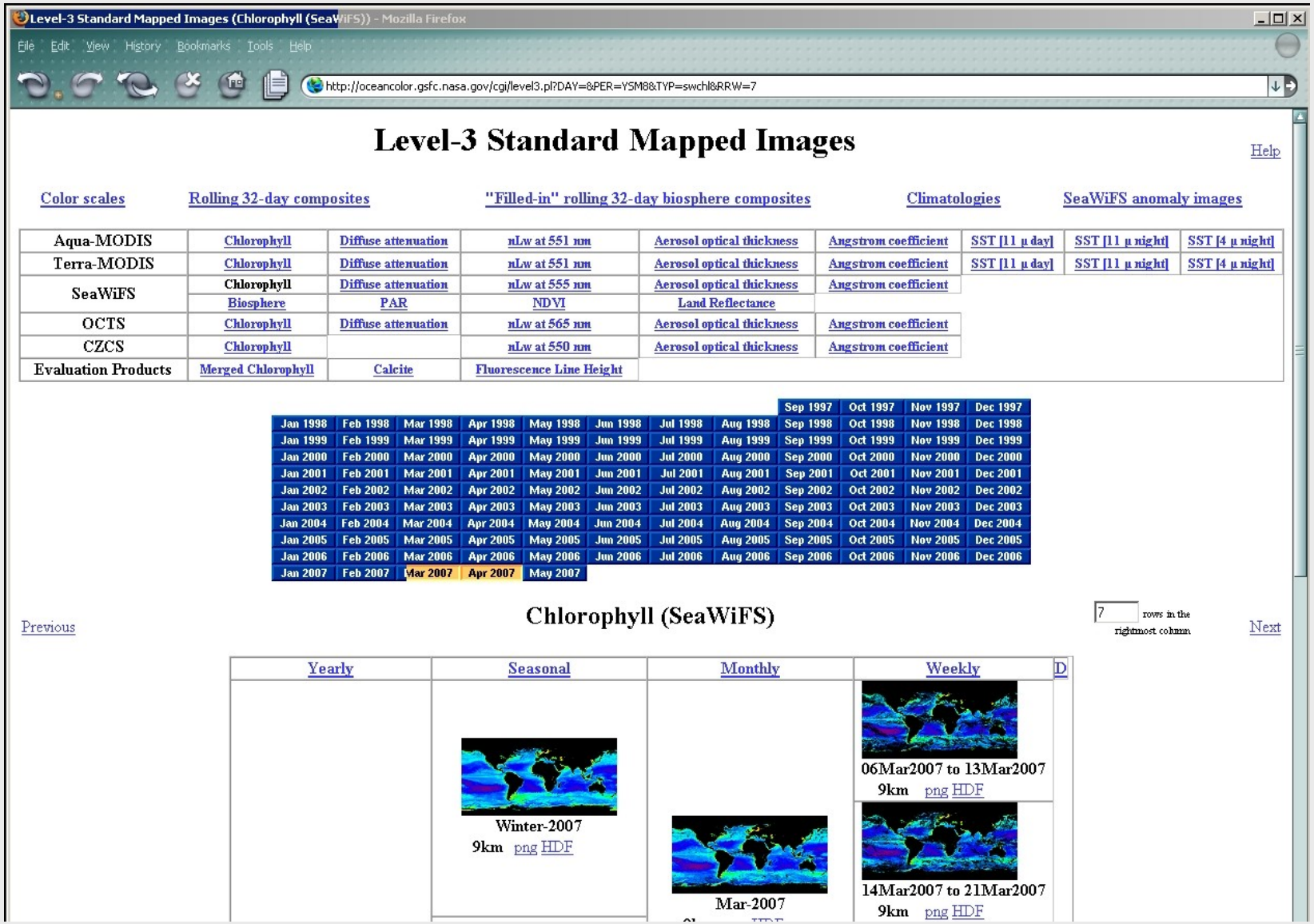
Sea Surface Chlorophyll-a



NASA-OceanColorWEB, USA http://oceancolor.gsfc.nasa.gov/

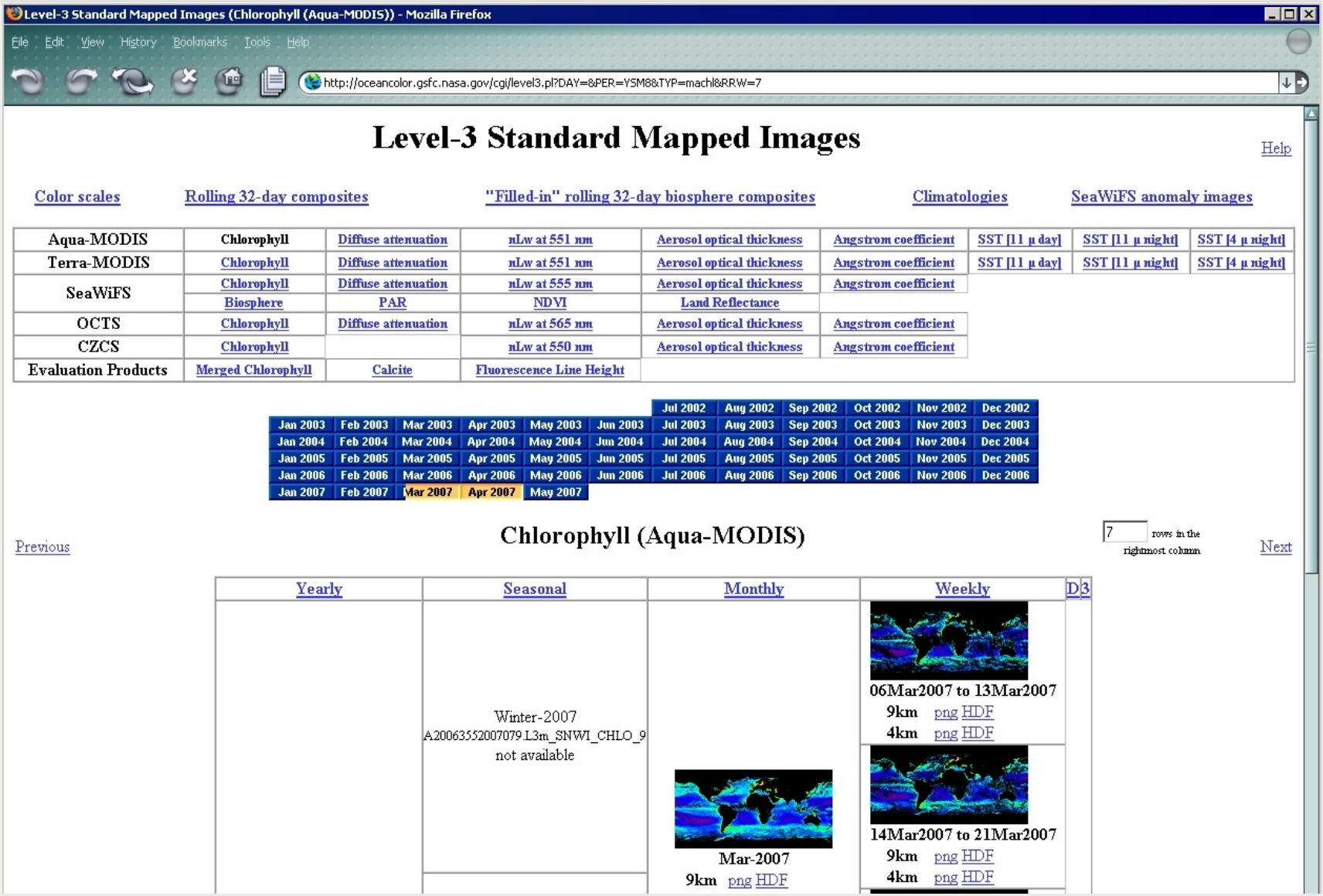
Spatial Resolution: 4km and 9km
Temporal Resolution: daily, weekly, monthly, 1998-onwards

OCEANCOLOR - SeaWIFS



NASA-OceanColorWEB, USA http://oceancolor.gsfc.nasa.gov/

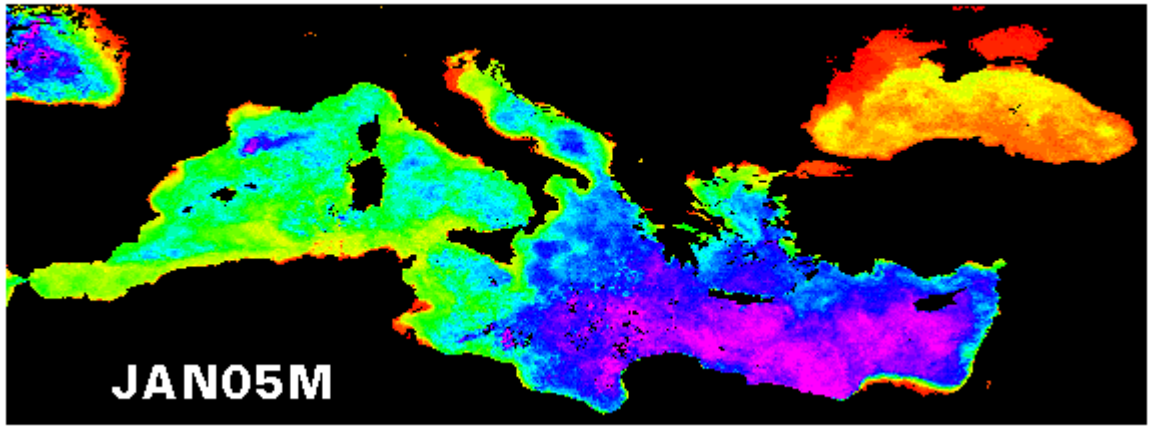
OCEANCOLOR – Aqua-MODIS



NASA-OceanColorWEB, USA http://oceancolor.gsfc.nasa.gov/

MARINE SATELLITE REMOTE SENSING

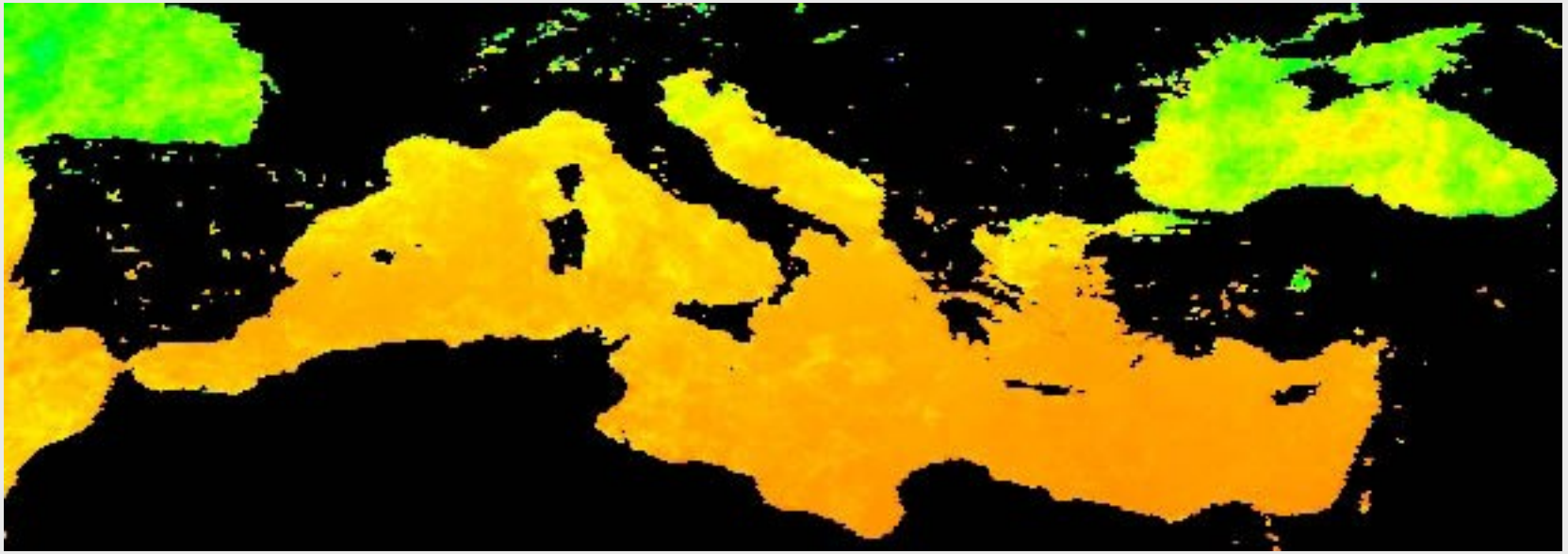
Chl-a 2005



MARINE SATELLITE REMOTE SENSING

Data Sources

Photosynthetically Active Radiation



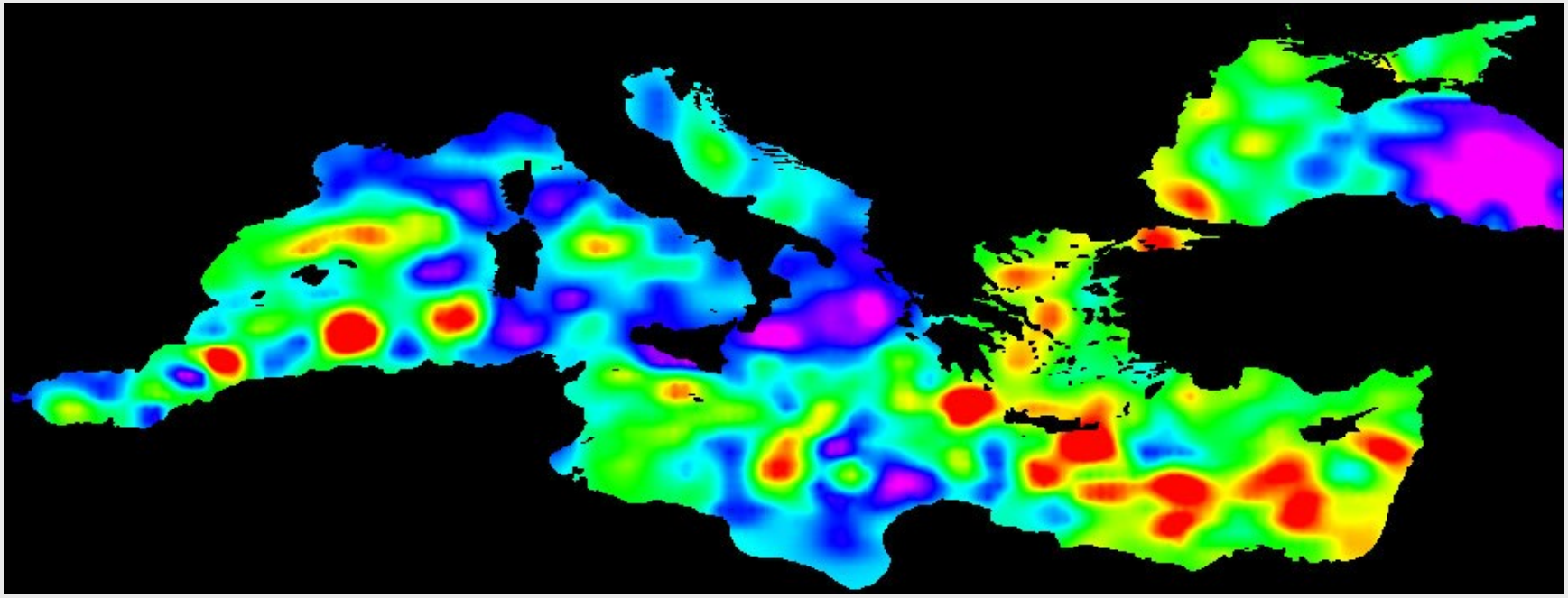
NASA-OceanColorWEB, USA http://oceancolor.gsfc.nasa.gov/

Spatial Resolution: 9km
Temporal Resolution: daily, weekly, monthly, 1998-onwards

MARINE SATELLITE REMOTE SENSING

Data Sources

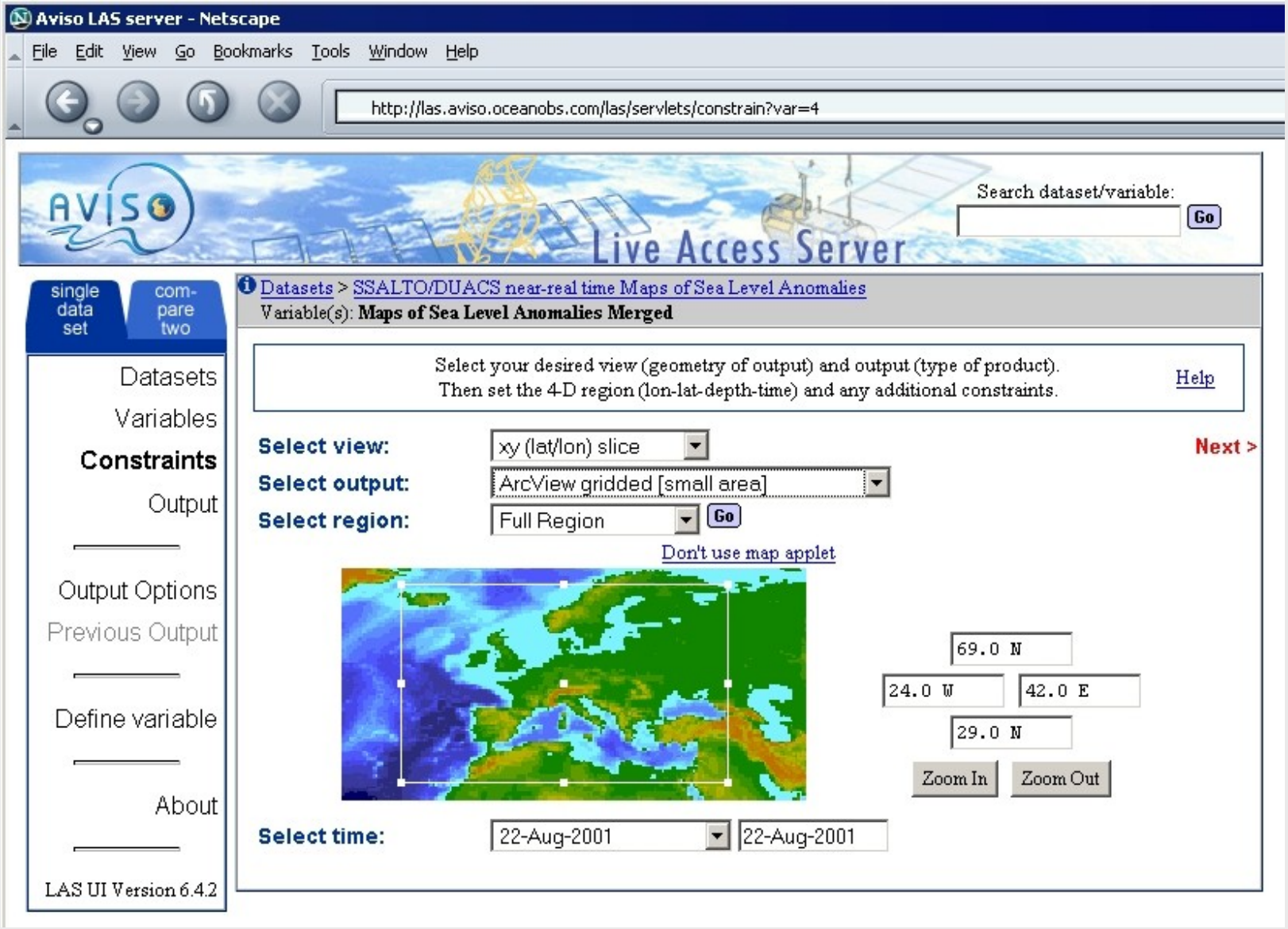
Sea Level Anomaly



CNES-CLS-Aviso, France http://www.aviso.oceanobs.com/

Spatial Resolution: ~15km
Temporal Resolution: weekly, 1993-onwards

AVISO – FR Sea Level Anomaly

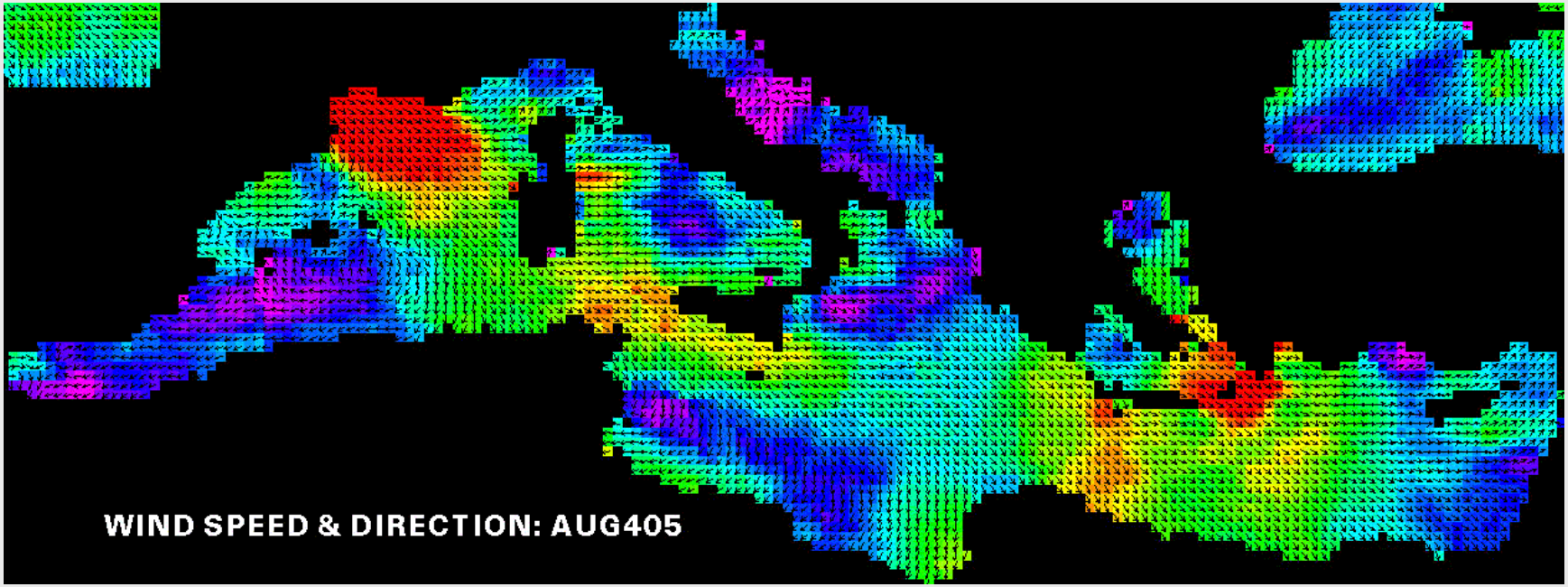


CNES-CLS-Aviso, France http://www.aviso.oceanobs.com/

MARINE SATELLITE REMOTE SENSING

Data Sources

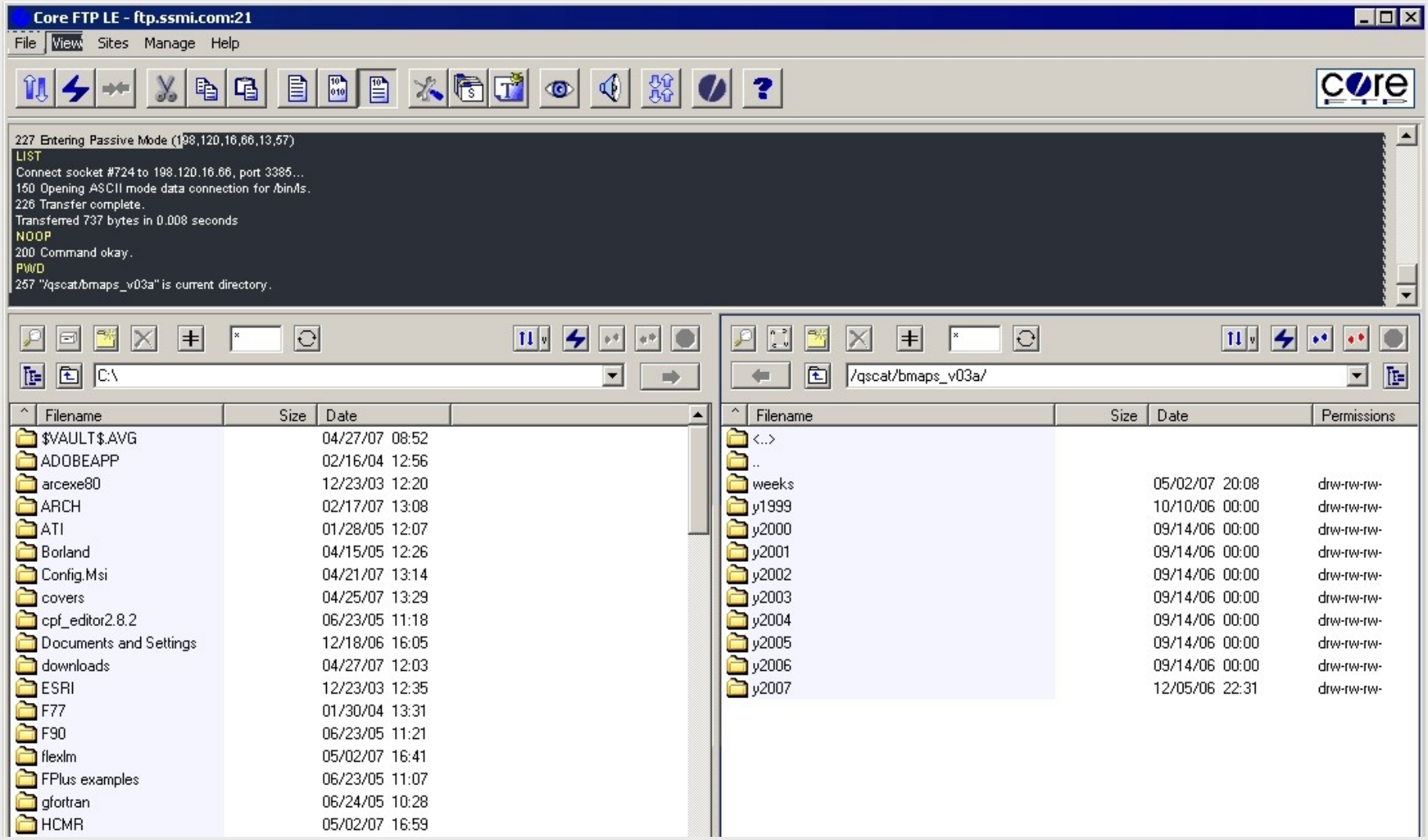
Wind Speed & Direction



RS Systems, USA http://www.ssmi.com/

Spatial Resolution: ~15km
Temporal Resolution: daily, weekly, monthly, 1999-onwards

RSDATA SYSTEMS - WIND SPEED & DIRECTION

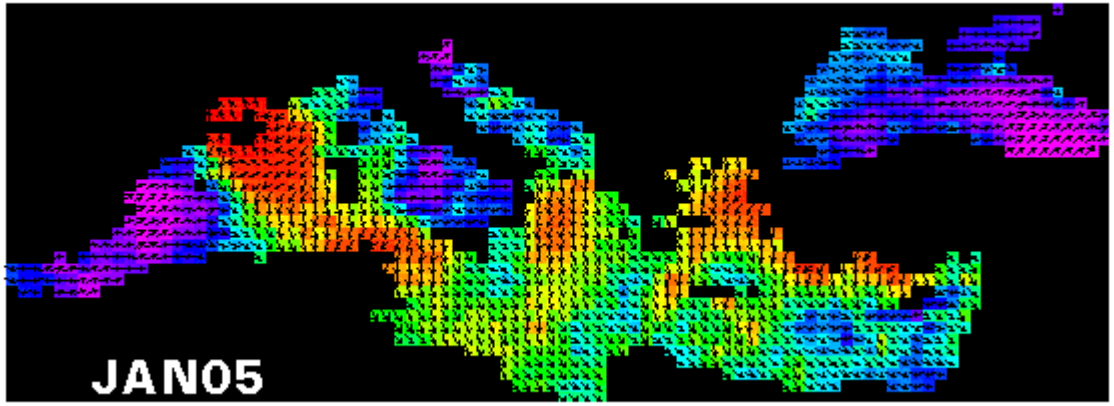


[RS Systems, USA](http://www.ssmi.com/)

http://www.ssmi.com/

MARINE SATELLITE REMOTE SENSING

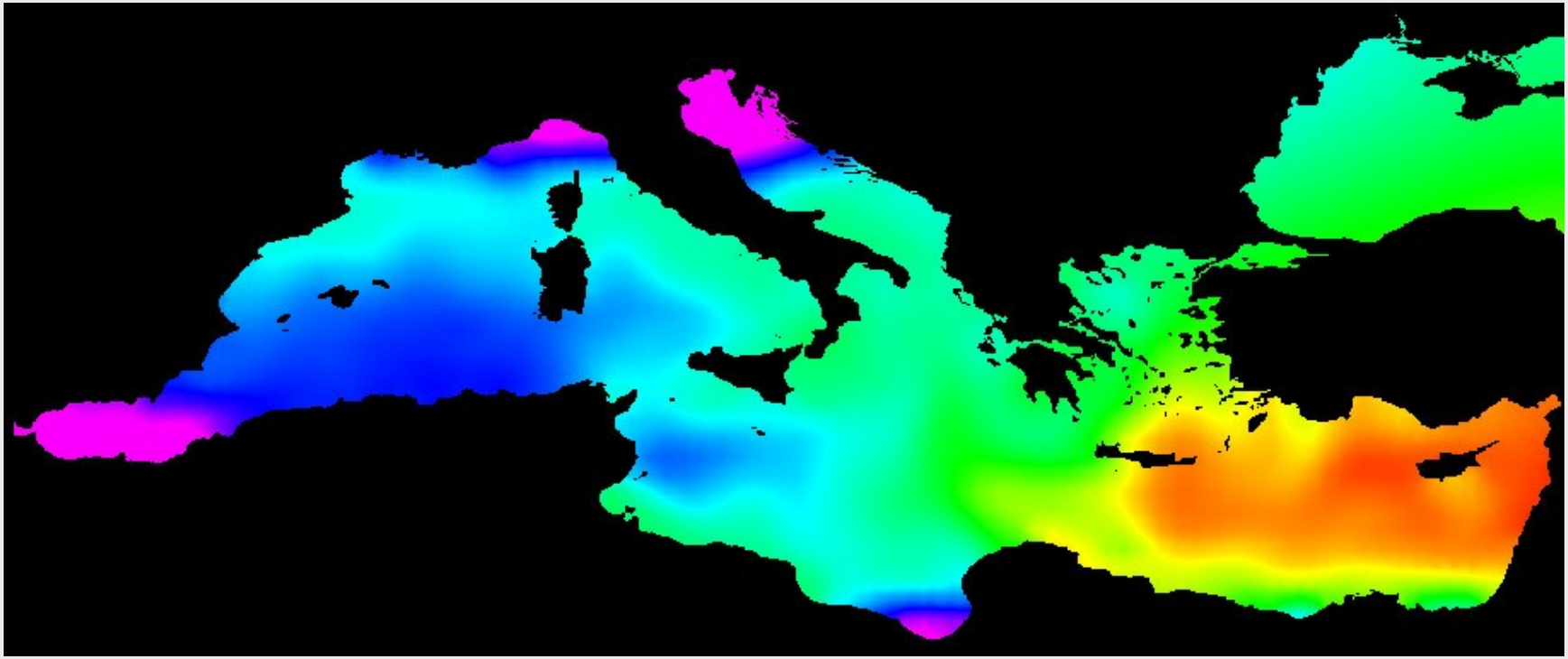
WIND SPEED & DIRECTION 2005



Modelled Data

Data Sources

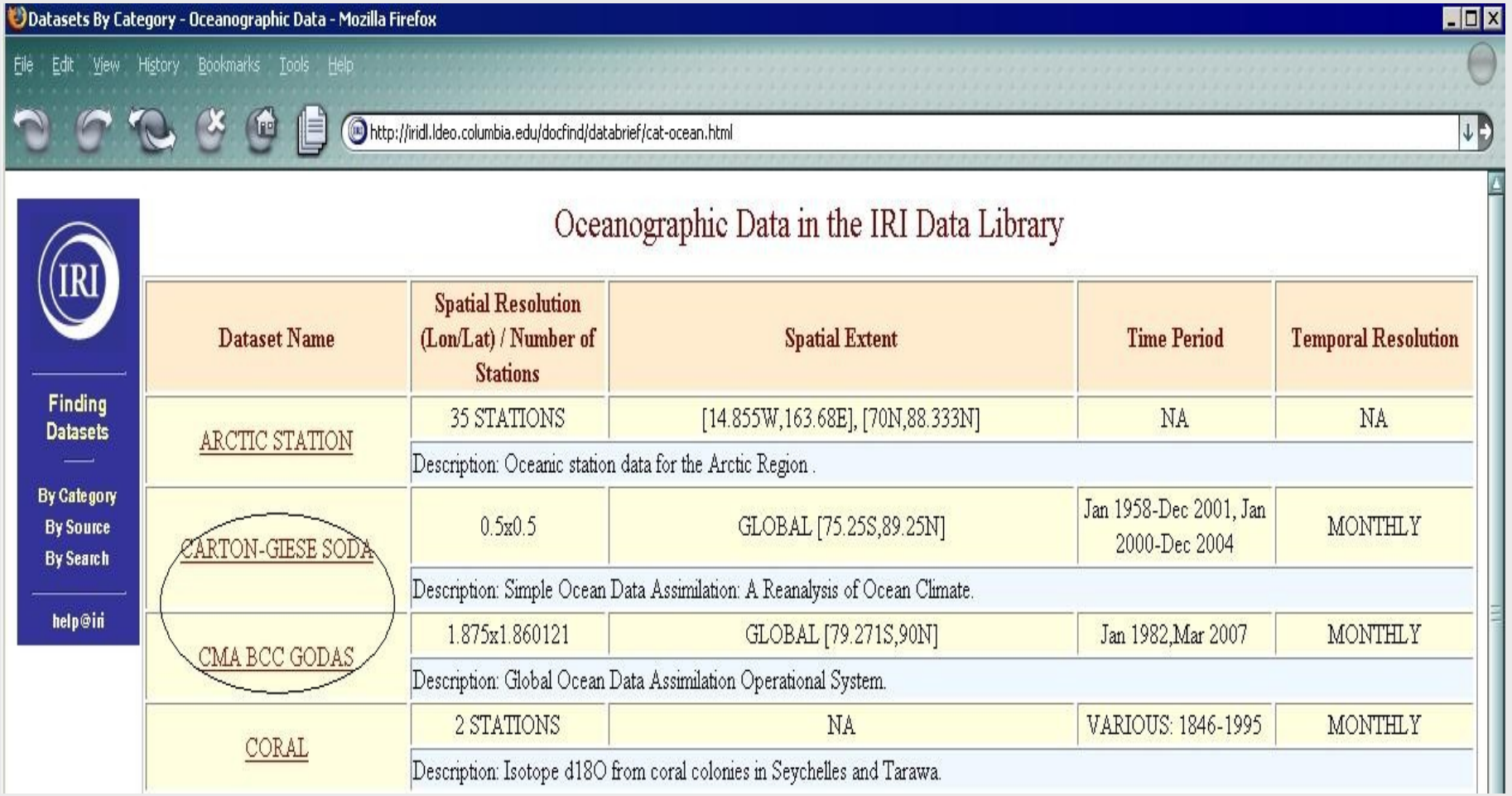
Sea Surface Salinity



IRI-LDEO-CDL, USA **http://ingrid.ldeo.columbia.edu/**

Spatial Resolution: **~40km**
Temporal Resolution: **daily, weekly, monthly, 1999-onwards**

UNIV. COLUMBIA - Salinity



Oceanographic Data in the IRI Data Library

Dataset Name	Spatial Resolution (Lon/Lat) / Number of Stations	Spatial Extent	Time Period	Temporal Resolution
ARCTIC STATION	35 STATIONS	[14.855W,163.68E], [70N,88.333N]	NA	NA
	Description: Oceanic station data for the Arctic Region .			
CARTON-GIESE SODA	0.5x0.5	GLOBAL [75.25S,89.25N]	Jan 1958-Dec 2001, Jan 2000-Dec 2004	MONTHLY
	Description: Simple Ocean Data Assimilation: A Reanalysis of Ocean Climate.			
CMA BCC GODAS	1.875x1.860121	GLOBAL [79.271S,90N]	Jan 1982,Mar 2007	MONTHLY
	Description: Global Ocean Data Assimilation Operational System.			
CORAL	2 STATIONS	NA	VARIOUS: 1846-1995	MONTHLY
	Description: Isotope d18O from coral colonies in Seychelles and Tarawa.			

IRI-LDEO-CDL, USA http://ingrid.ldeo.columbia.edu/

3D DATA SOURCE BASED ON RS DATA + SURVEYED DATA

Mercator Ocean, Operational Ocean Forecasting - Products and Services - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.mercator-ocean.fr/html/produits/description/welcome_en.html

MERCATOR

Products

Mercator Ocean
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Images bulletin
Interpreted bulletin
Live Access Server
Opendap Server
HTTP Server
Maps Server
Applications
Science
Collaborations
Publications
Glossary
Site map
Search
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Printable version

Products ▷

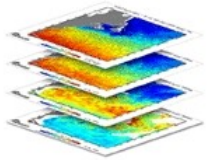
Access terms | Handbooks | Images bulletin | Interpreted bulletin | Live Access Server | Opendap Server | Maps Server

Mercator products

Current and forecast 3D ocean products : web images and digital products

Mercator web image buleltins are designed for a wide audience, while digital products target professional ocean users such as scientists, fishermen, military users, oil producers and racing yachtsmen.

Images bulletin



Find out about all the web products available:

- Visualize the weekly bulletin
- Tutorial
- The illustrated Mercator system
- A voyage of discovery

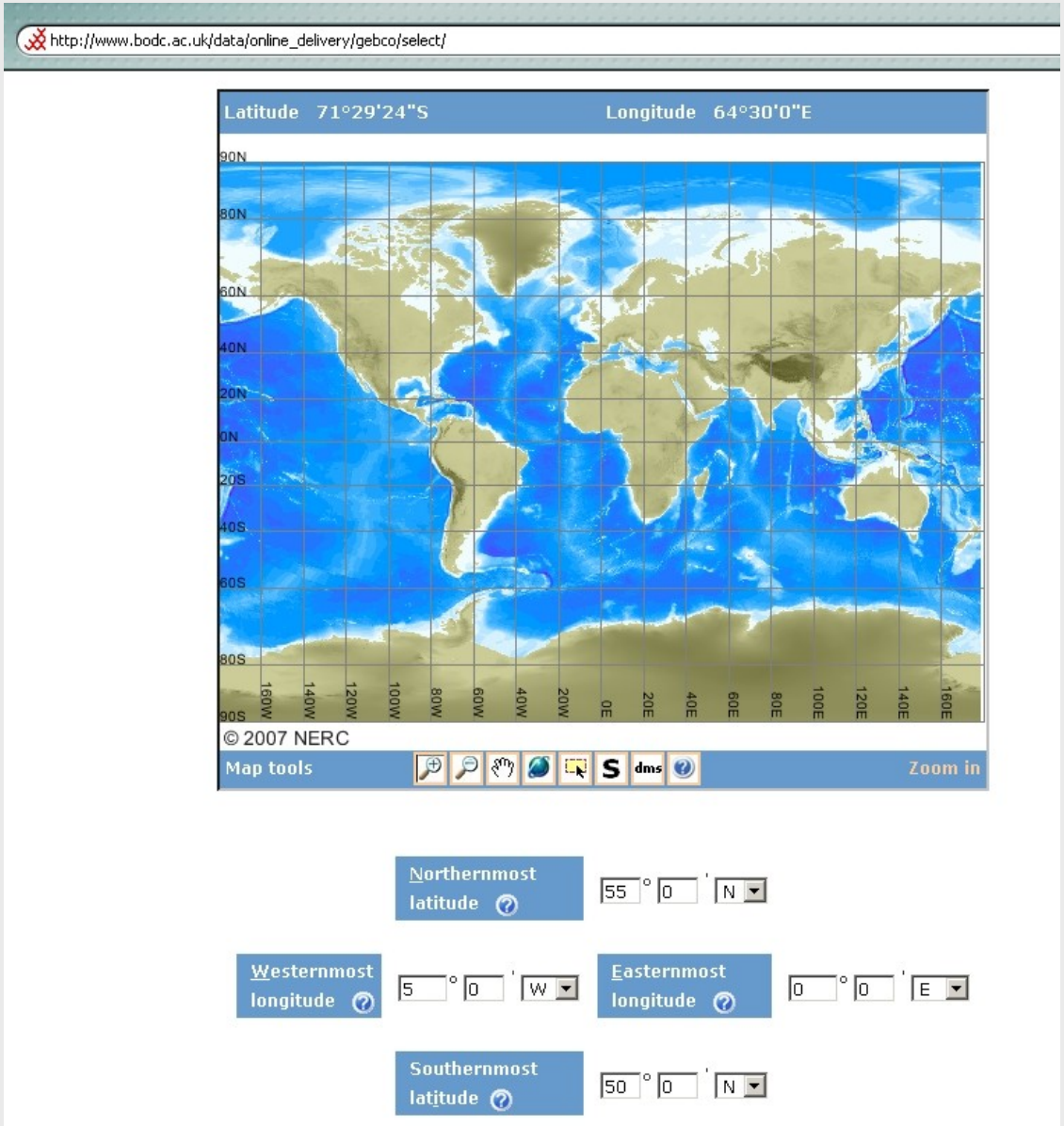
Digital products

Digital products are files for professional users and are available on a remote server. Please make an e-mail request to products@mercator-ocean.fr or download a request form.

- Digital products handbook
- Access Opendap Server (authorized access : see conditions)
- Live Access Server : Draw your own map and retrieve the data (authorized access : see conditions)

MERCATOR, FR http://www.mercator-ocean.fr/

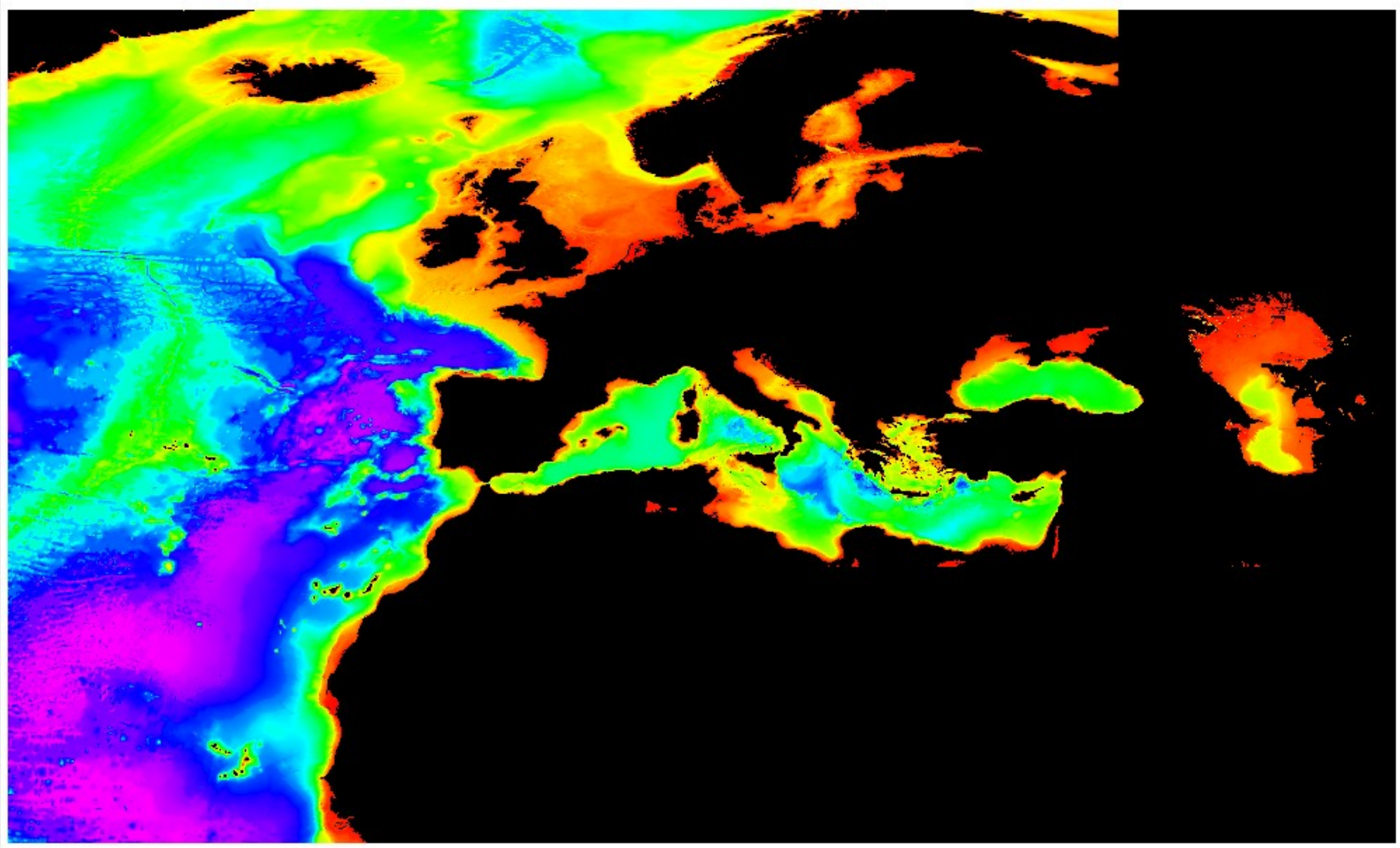
BATHYMETRY DATA SOURCE



GEBCO One Minute Grid, British Oceanographic Data Centre

http://www.bodc.ac.uk/

BATHYMETRY – EUROPEAN SEAS



FINAL IMAGE PRODUCTS (L3)

- ✓ L1 (raw data), L2 (corrected), L3 (image data)
- ✓ L3 ready-to-use
- ✓ Provided in different distribution formats
- ✓ Provided with image values 0-255
- ✓ …with image-to-real values tables or equations
- ✓ Classification

Classification Techniques

✓ Unsupervised

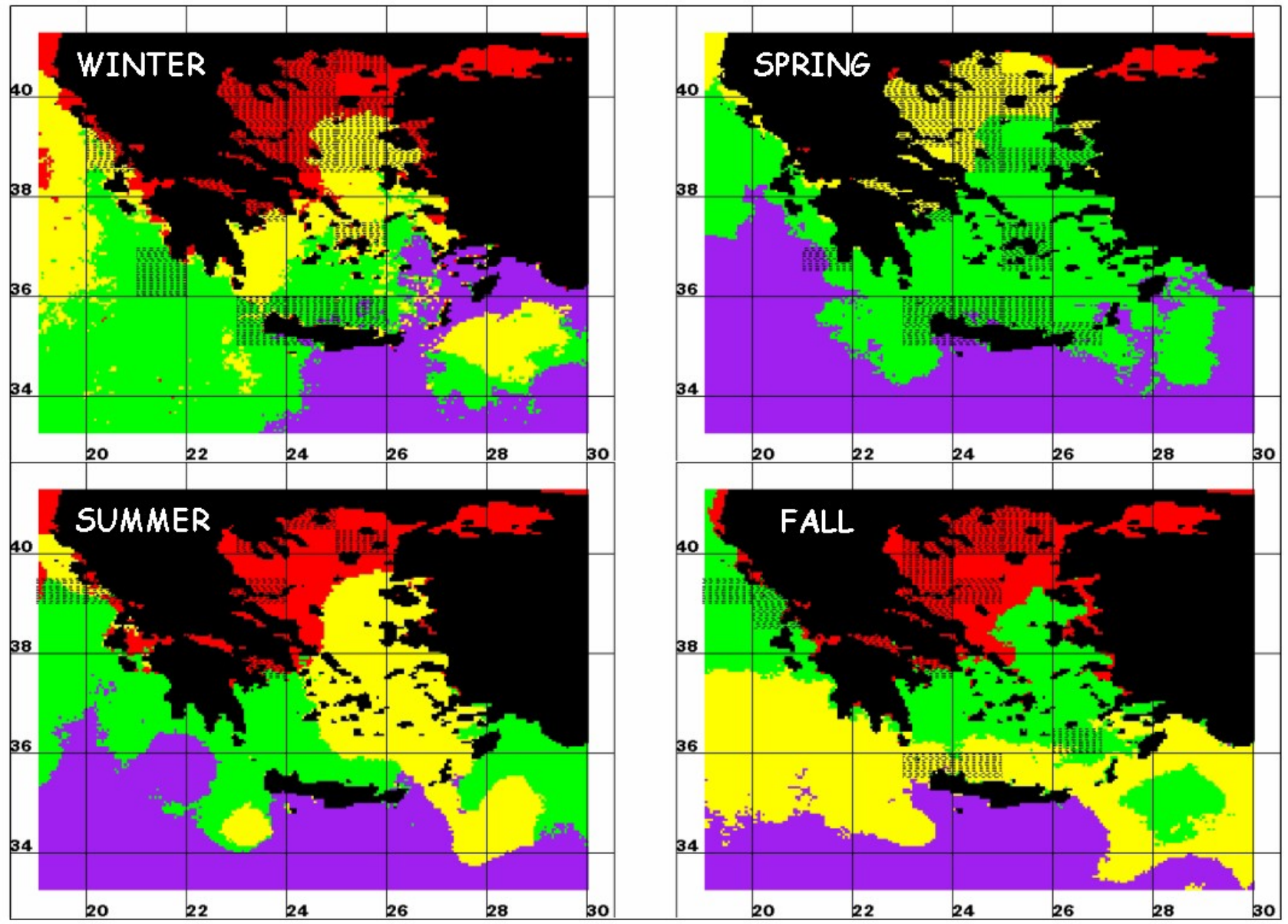
Clustering does not require the user to specify any information about the features contained in the images but just the cluster number

✓ Supervised

Spectral signatures are developed from specified locations in the image. Such locations are 'training sites' and are defined by the user.

Combined Classification

Combined Classification of SST ↓, Chl-a ↕, SAL ↓



RS L3 IMAGE DATA PROCESSING IN GIS

image processing basic routine

```
imagegrid may07.tif may07a

may07b = select(may07a, 'value > 0 & value < 255')

gridwarp may07b linkdd.txt may07

joinitem may07.vat sst.lut may07.vat value
```

georeference

4095.500	-0.500	42.855	28.052
2047.750	-0.500	16.500	28.052
-0.500	-0.500	-9.846	28.052
3455.500	4.928	34.574	28.104
3485.798	131.470	34.941	29.503
3163.239	129.842	30.815	29.504
3295.095	168.897	32.571	29.977
2256.027	199.196	19.125	30.277
22.832	200.087	-9.641	30.297

image-to-real_value conversion

```
1,0.13
2,0.25
3,0.38
4,0.50
5,0.63
6,0.75
7,0.88
8,1.00
.,.
.,.
.,.
249,31.13
250,31.25
251,31.38
252,31.50
253,31.63
254,31.75
```

DATA HOLDINGS BY HCMR

- ✓ Sea Surface Temperature
- ✓ All SeaWiFS Products (Chl-a, PAR, etc)
- ✓ Sea Surface Salinity
- ✓ Sea Level Anomaly
- ✓ Wind Speed & Direction
- ✓ Bathymetry
- ✓ Coastlines

Resolutions: European Seas, weekly, monthly

Marine GIS Intro and some examples

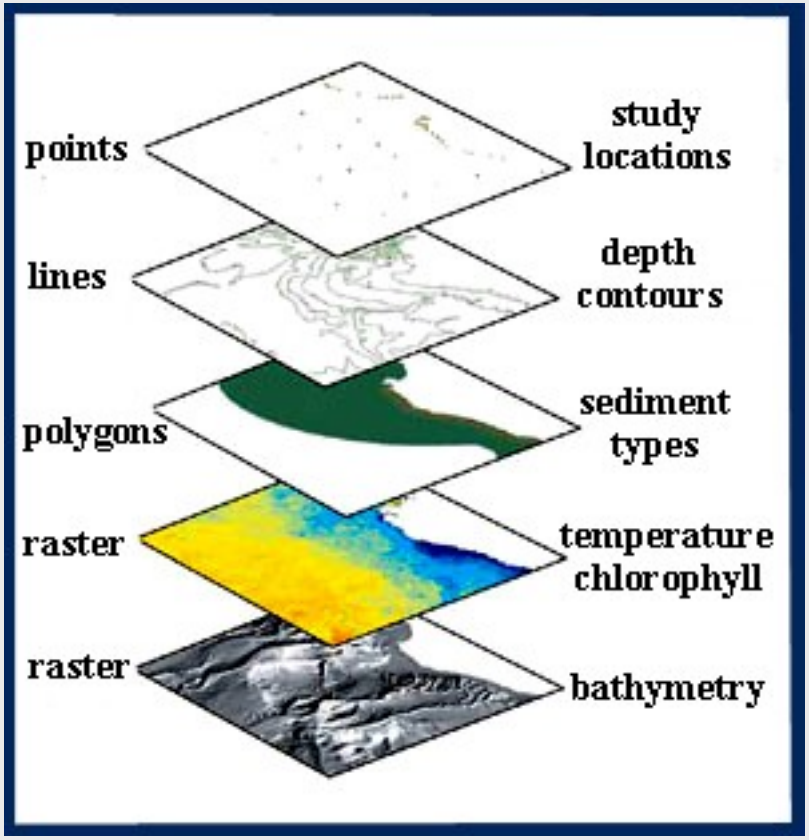
GIS

GI SCIENCE ←:::→ GI SYSTEMS

Geographic Information Science (GI Science), the scientific content to Geographic Information Systems (GI Systems), the technical content of GI Science, are both emerging and coherent science and technology fields with two important research streams:

- **research in basic GI Science (e.g. software integration, data scale and resolution, process models)**
- **research using GI Systems (e.g. data modeling and integration, decision support)**

GEOGRAPHICAL INFORMATION SYSTEMS

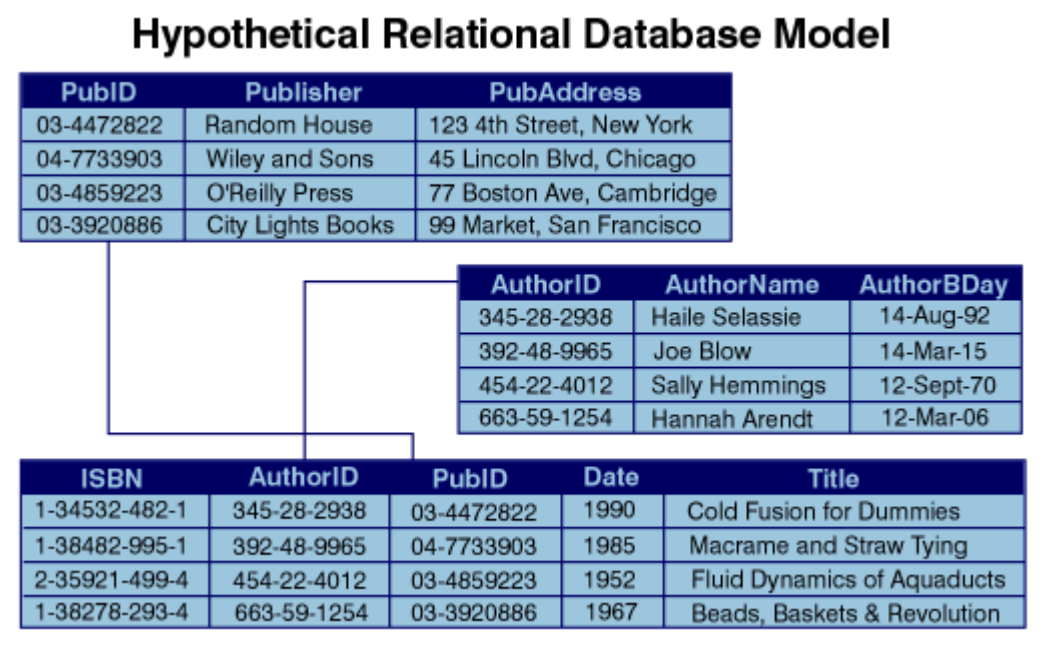


Examples of the variety of data types handled by Marine GIS.

Points, lines and polygons are vector data type while satellite imagery and model output are raster data type.

Under GIS relational databases, different data formats are uniformly stored and referenced through a common geo-reference system. Then, spatial integration and GIS analysis of different data types is applied.

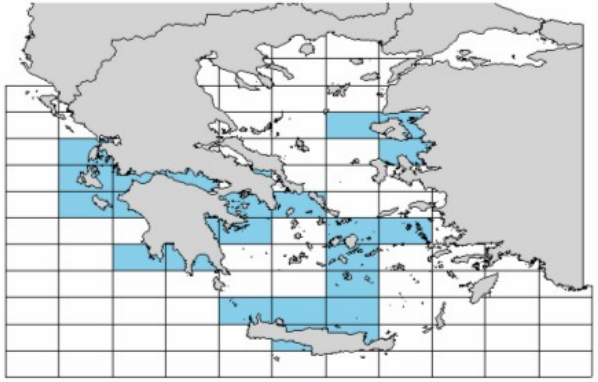
GIS RELATIONAL DATABASE
(attribute data)



Examples of a **vector GIS database** including fisheries attribute data represented spatially by **points**, **lines** and **polygons**.

POINT DATA (*e.g. Fish Acoustic Survey*)

LINE DATA (*e.g. Fish Longlines*)

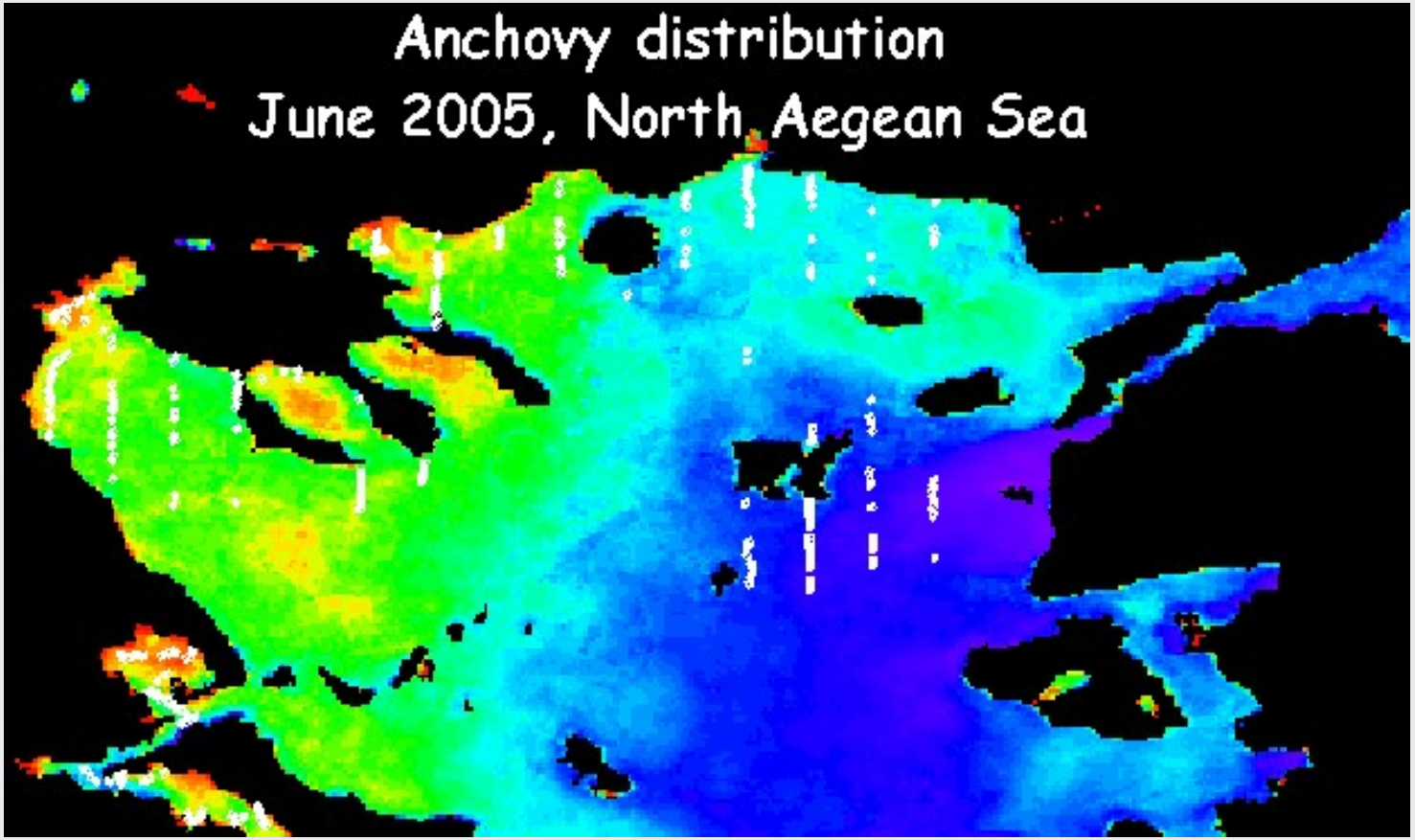


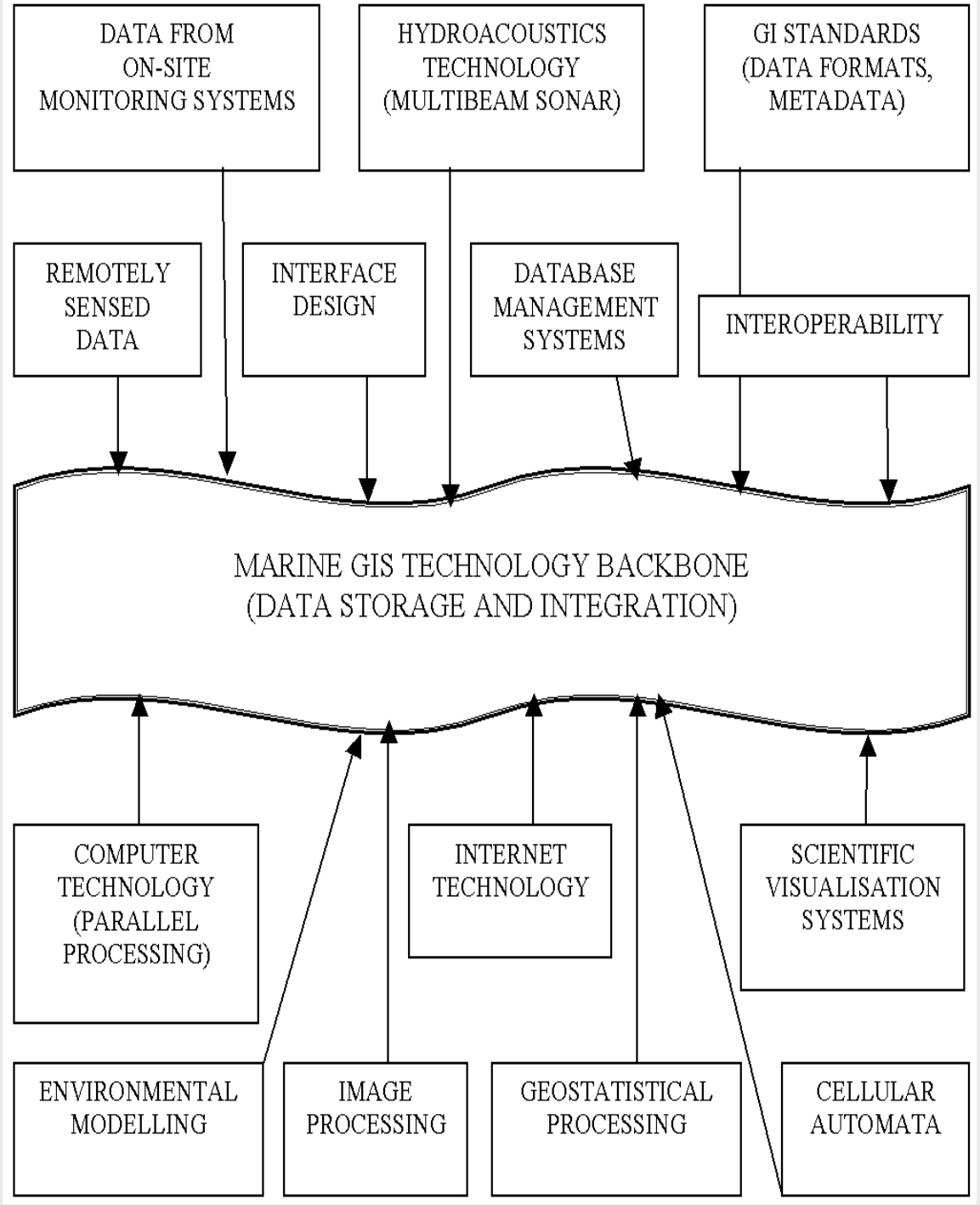
POLYGON DATA (*e.g. Fish Production*)

Each spatial feature (point, line, polygon) is linked through an identification number (id) to an associated attribute table that stores fisheries data:

Id = 102
Area = 1800sqm
Fish = 35kg
Date = 15Sep05

Overlay of **vector** and **raster** GIS datasets including anchovy attribute data (vector-points) and sea surface temperature (raster-colors).





GIS

are

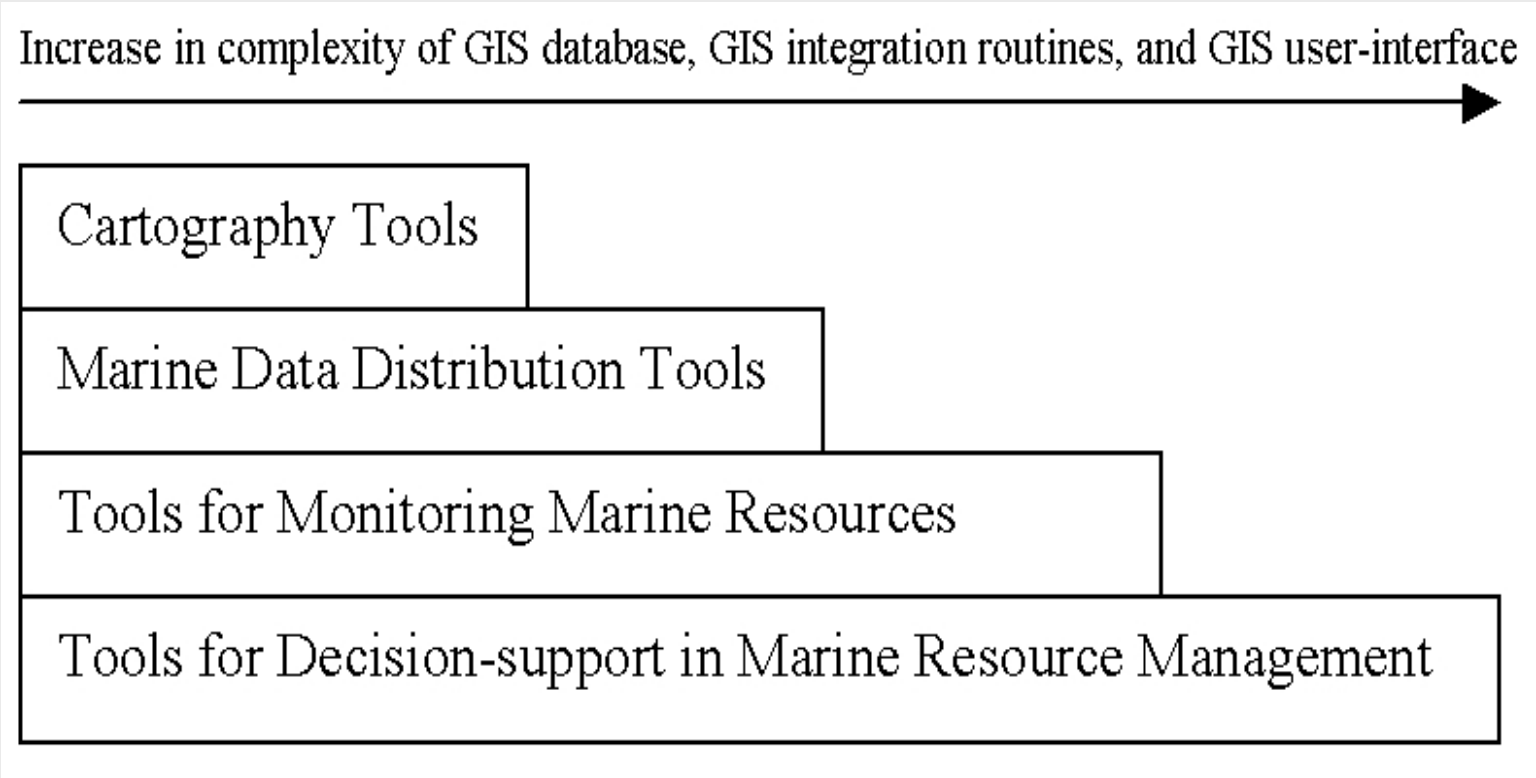
linked to

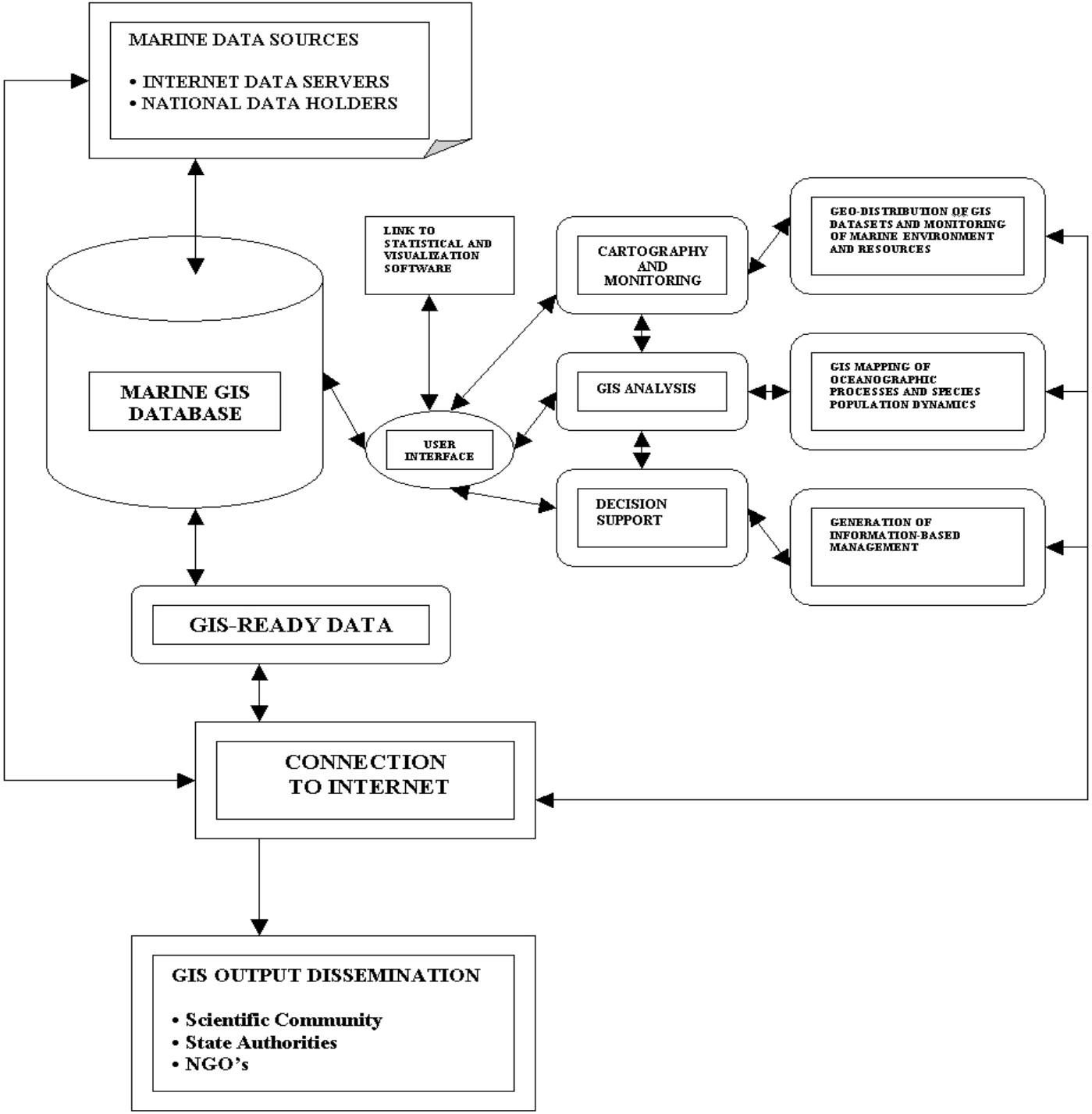
many

other

disciplines

The Essential Goal of Marine GIS





Conceptual Model of Marine GIS Development

First GIS Publications early '90s

Manley, T.O. and Tallet, J.A. (1990). Volumetric visualization: An effective use of GIS technology in the field of oceanography. *Oceanography* **3**, 23-29.

Meaden, G. (1994). The One That Got Away? GIS in Marine Fisheries. *Mapping Awareness* **8(7)**, 20-23.

Marine GIS Book 1
2000

Marine and Coastal Geographical Information Systems - Mozilla Firefox

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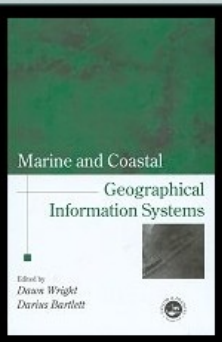
http://dusk2.geo.orst.edu/book/



Click to read back cover

Marine and Coastal Geographical Information Systems

Hardcover ISBN: 0-7484-0862-2
Paperback ISBN: 0-7484-0870-3

"This landmark text should be an integral part of any academic curriculum encompassing marine and coastal sciences and should be on the bookshelf of any geographic information or marine scientist."
-- InReview, *Geospatial Solutions*, September 2000 issue

Edited by Dawn Wright (Oregon State University, USA) and Darius Bartlett (University College Cork, IRELAND)

Foreword by Mike Goodchild

Marine GIS Book 2
2002

Geographic Information Systems in Oceanography and Fisheries - Mozilla Firefox

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http://arch.her.hcmr.gr/announce.html

(ISBN-10: 0415284635 -- ISBN-13: 978-0415284639 -- Dewey: 551.46/00285 21 -- LCCN: GC38.5 .V35 2002 GC38.5 .V35 2002)

Geographic Information Systems in Oceanography and Fisheries

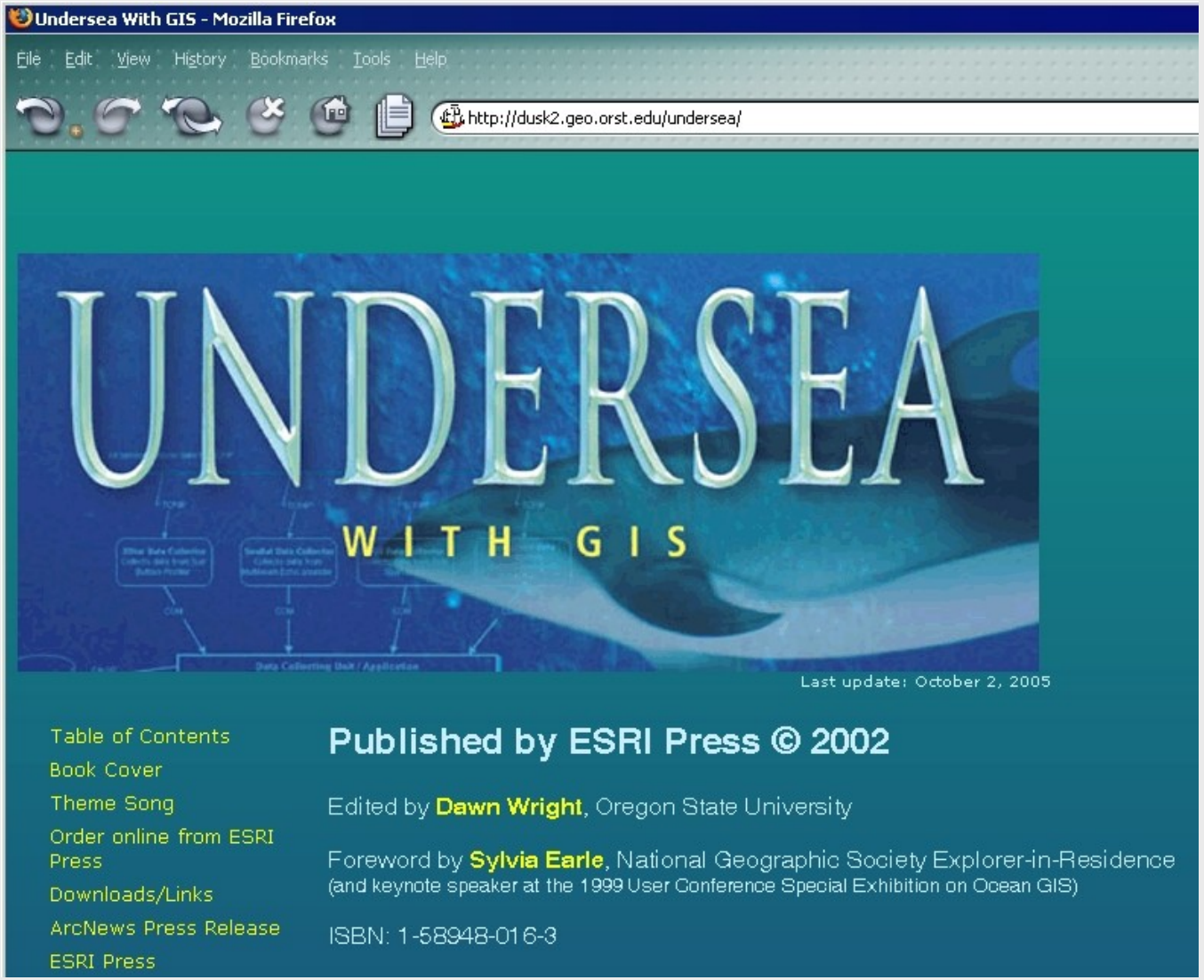
-- Published May 23, 2002 by Taylor & Francis --

Author: Vasilis D. Valavanis, Hellenic Center for Marine Research, Greece

Marine GIS applications share only about a fifth of GIS history. They created a new application theme in the field of Geographical Information Systems posing several challenges in the domain of Geographical Information Science. These new challenges originate from the fact that a computerized application is called upon to model the dynamics of marine environment and provide meaningful explanations about these dynamics. The opposing strength of marine GIS is that it fully develops the central point of GIS technology, that of geo-referenced data integration, to explain the dynamic relations between marine processes and species population characteristics.

Geographic Information Systems in Oceanography and Fisheries (ISBN-10: 0415284635 and ISBN-13: 978-0415284639), a publication by Taylor & Francis / Spon Press UK / Routledge USA under the GIS and Remote Sensing Arena, overviews existing marine GIS developments and presents new innovative approaches of using GIS in the examination of the dynamic relations that characterize the marine world including marine GIS macro routines for the development of Oceanography and Fisheries GIS applications.

Marine GIS Book 3
2002



Marine GIS Book 4
2004

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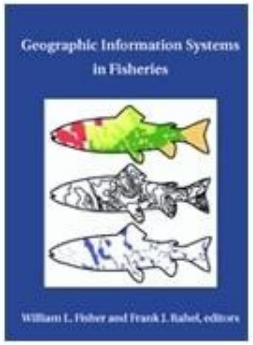
Geographic Information Systems in Fisheries



William L. Fisher and Frank J. Rahel, editors

276 pages, hardbound Published by American Fisheries Society Publication date: February 2004

Marine GIS Book 5
2005

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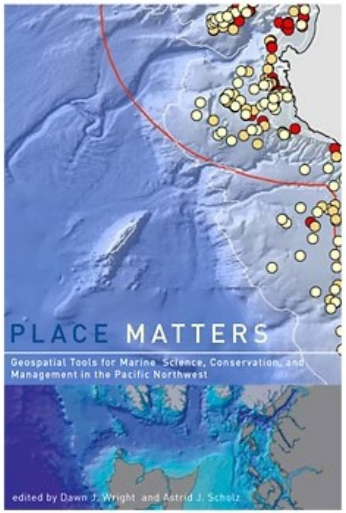
http://dusk2.geo.orst.edu/aaas/

[Main Ecotrust Book Site | Place Matters Listserv | OSU Press | Questions/Comments]



click cover art above to go to main Ecotrust site

Place Matters: Geospatial Tools for Marine Science, Conservation, and Management in the Pacific Northwest

forthcoming in Spring 2005, Oregon State University Press

Chapter	Title/Authors	Lead	Word Count
Foreword	Sylvia Earle		**1177**
Preface (pdf)	Dawn J. Wright, Astrid J. Scholz		**865**

Marine GIS Book 6
2007

Reference Book for Arc Marine: the ArcGIS Marine Data Model - Mozilla Firefox

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http://dusk2.geo.orst.edu/djl/arcgis/book.html

Arc Marine
Reference Book

ESRI
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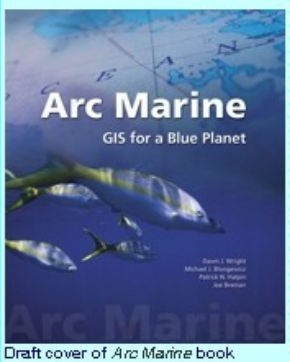


Draft cover of *Arc Marine* book
Click image to enlarge

Reference Book in Press (due out June 1, 2007)

Wright, D.J., Blongewicz, M.J., Halpin, P.N. and Breman, J., in press, 2007. *Arc Marine: GIS for a Blue Planet*, Redlands, CA: ESRI Press, ~275 pp. ISBN 978-1-58948-017-9

At a time when the health of our oceans is seen as crucial to our very existence, marine researchers have developed a data model that supports seafloor mapping, fisheries management, marine mammal tracking, monitoring of shoreline change, and water temperature analysis. Our ability to measure change in oceans and along coasts has increased as marine GIS has grown more complex. *Arc Marine: GIS for a Blue Planet* presents the initial results of a successful effort to create and define a data model for the marine community—that group of academic, government, military, and private oceanographers, resource managers, conservationists, geographers, nautical archaeologists and others who support better management of complex spatial analysis in marine applications. The data model not only provides structure to storing and analyzing marine data but helps users create maps and 3-dimensional scenes of the marine environment in ways invaluable to decision making. The standards and best practices that emerged from the case studies in *Arc Marine: GIS for a Blue Planet* help form a diverse set of resources to draw from as the marine community strives to understand, illuminate, chart, and explore the unknown depths. As a teaching tool, *Arc Marine: GIS for a Blue Planet* serves as a perfect starting point for the intermediate student or as a resource for the expert in marine GIS and its implementation.

Marine GIS Book 7
early 2009

Marine Geographic Information Systems
Theory and Applications

By
Valavanis V.D., Wright D., Georgakarakos S., Kitsiou D.

To be published by
Springer-Verlag

A University Textbook targeting close-to-BSc and MSc-PhD fellows
including theoretical background on GIScience
and applied GISystems exercises in accompanied CDROM & website

A joined effort of:

–Hellenic Center for Marine Research, Greece:
–Oregon State University, USA:
–University of Aegean, Greece:
Management Lab

Lab

-Marine GIS Lab (furniture just received!)
-Davey Jones' Locker Lab
-Fisheries Resources

-GIS and Remote Sensing

GIS Mapping of Ocean Processes

1. Marine Productivity Hotspots

Measurements: location, area, DSST, DChl-a

2. Mesoscale Thermal Fronts

Measurements: location, length, DSST, DChl-a

3. Ocean Gyres

Measurements: location, area, DSST, DChl-a

Marine Productivity Hotspots (MPH)

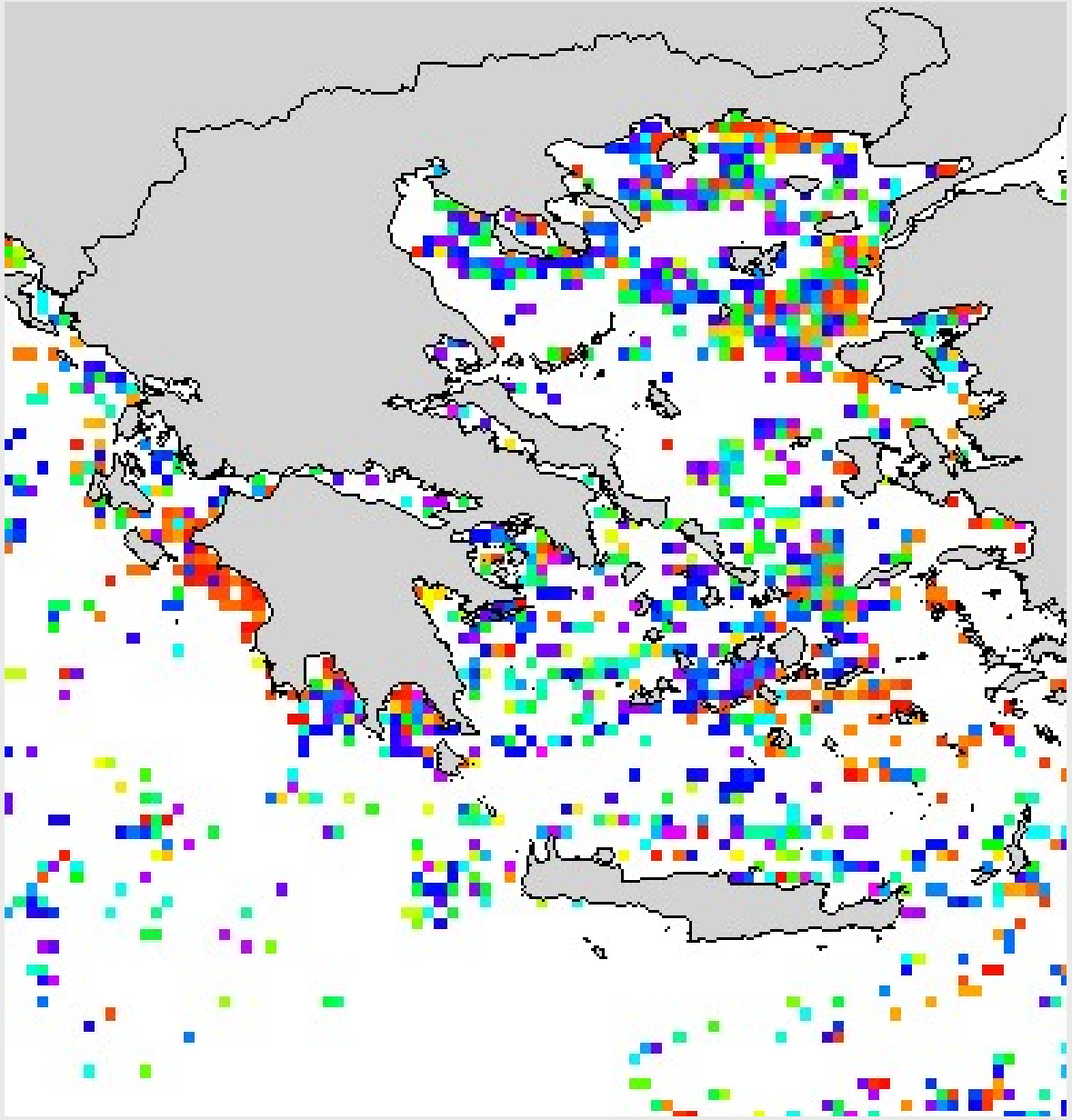
MPH: lowSST/highChl-a anomalies

How are they computed:

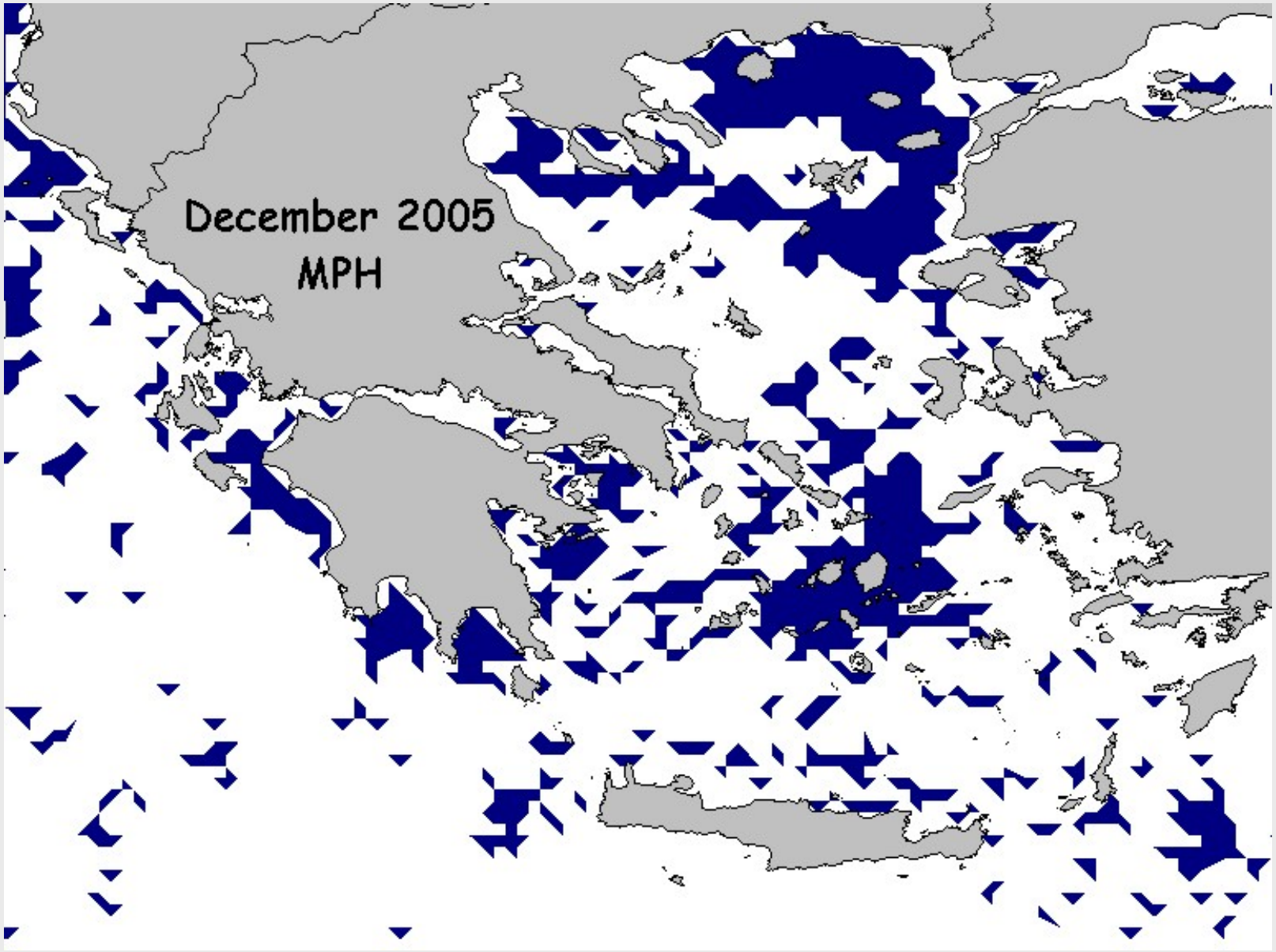
1. **Initial data: Monthly AVHRR SST and SeaWiFS Chl-a imagery**
2. **Production of climatology for SST and Chl-a**
3. **Production of monthly anomaly in SST and Chl-a**

MPH: Selection in anomaly maps of simultaneous below-average SST and above-average Chl-a patterns

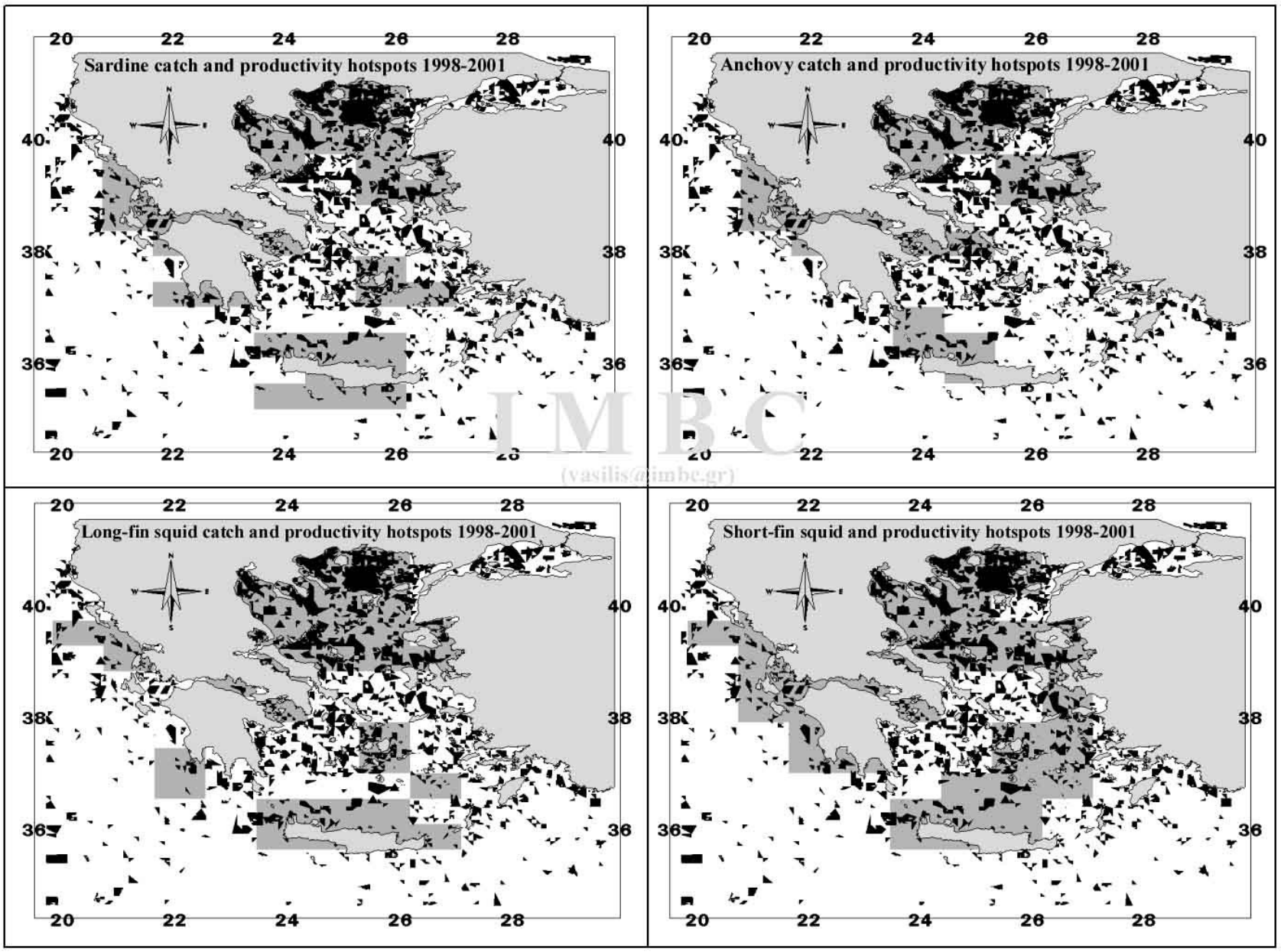
Marine Productivity Hotspots (grid)



Marine Productivity Hotspots (polygons)

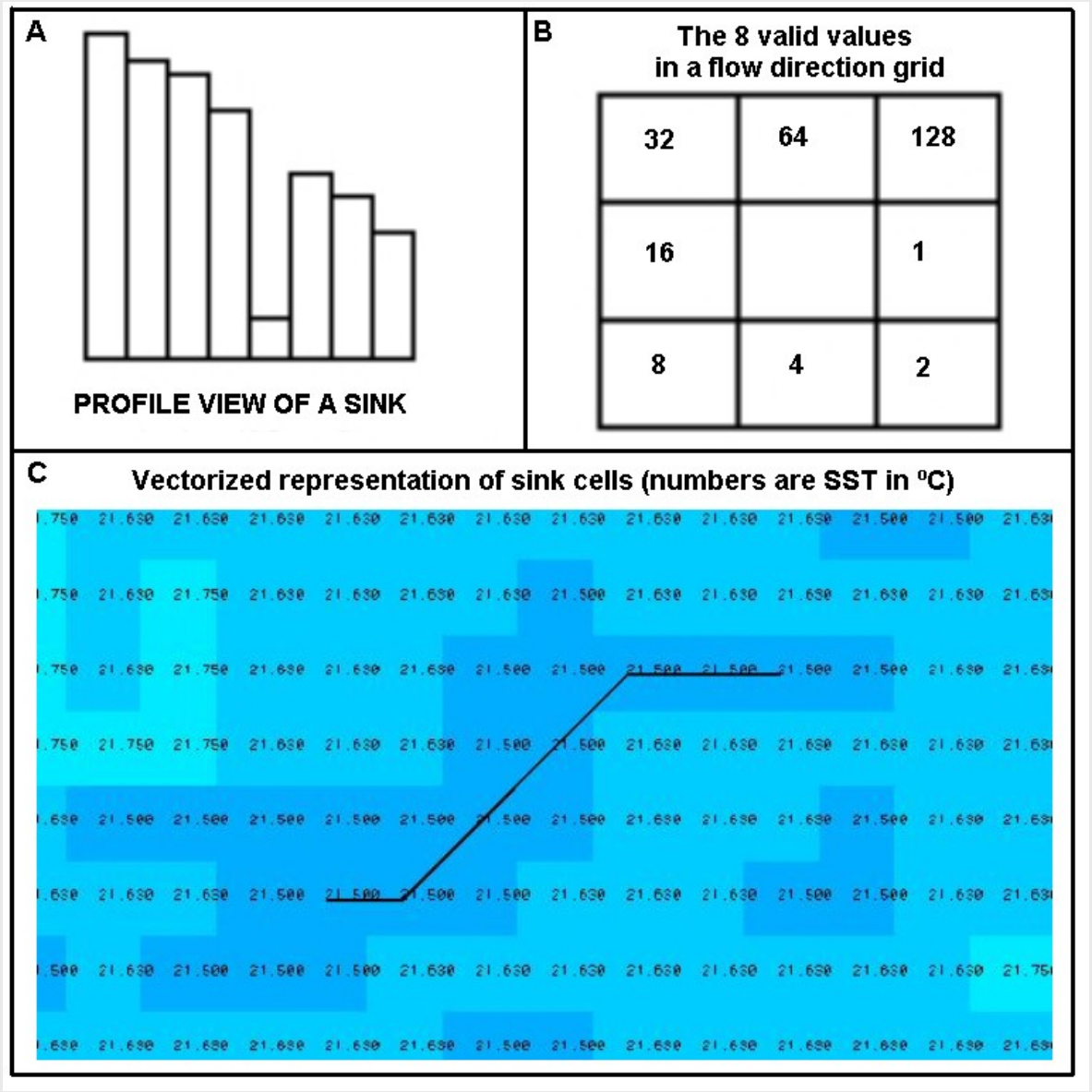


Marine Productivity Hotspots with Fisheries Production



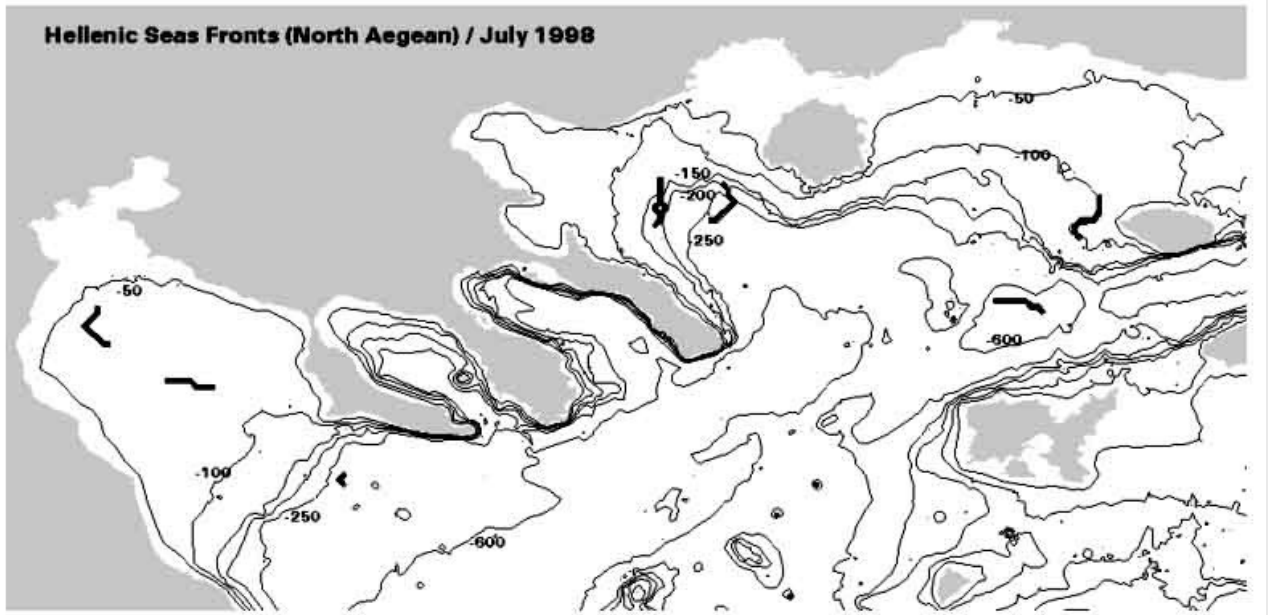
Marine Productivity Hotspots

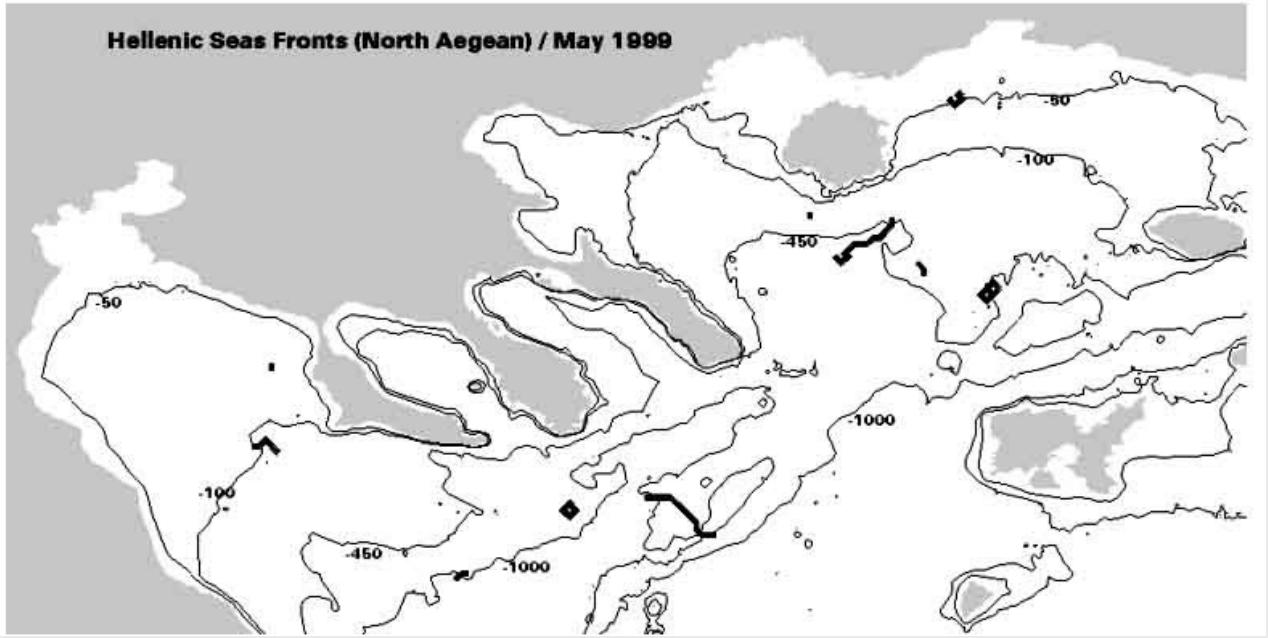
Mesoscale Thermal Fronts (MTF)



Spatially connected sinks with simultaneous DSST < 0 and DCHL > 0 patterns are mapped as mesoscale thermal fronts

Mesoscale Thermal Fronts (coastal, shelf-break, open-water)





Ocean Gyres
(cyclonic/anticyclonic eddies)

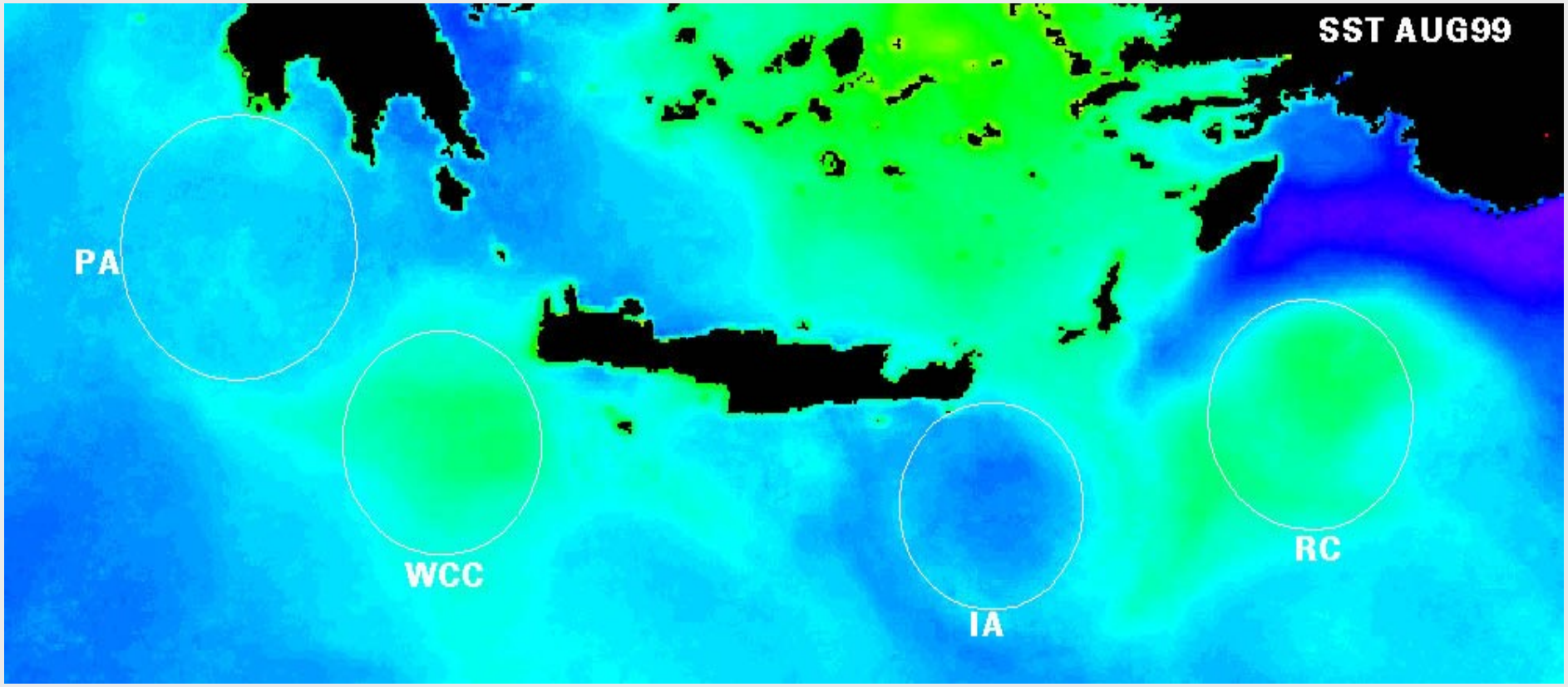
Major Gyre/Eddy formations in SE Mediterranean:

1. Pelops Anticyclone
2. West Cretan Cyclone
3. Ierapetra Anticyclone
4. Rhodes Cyclone

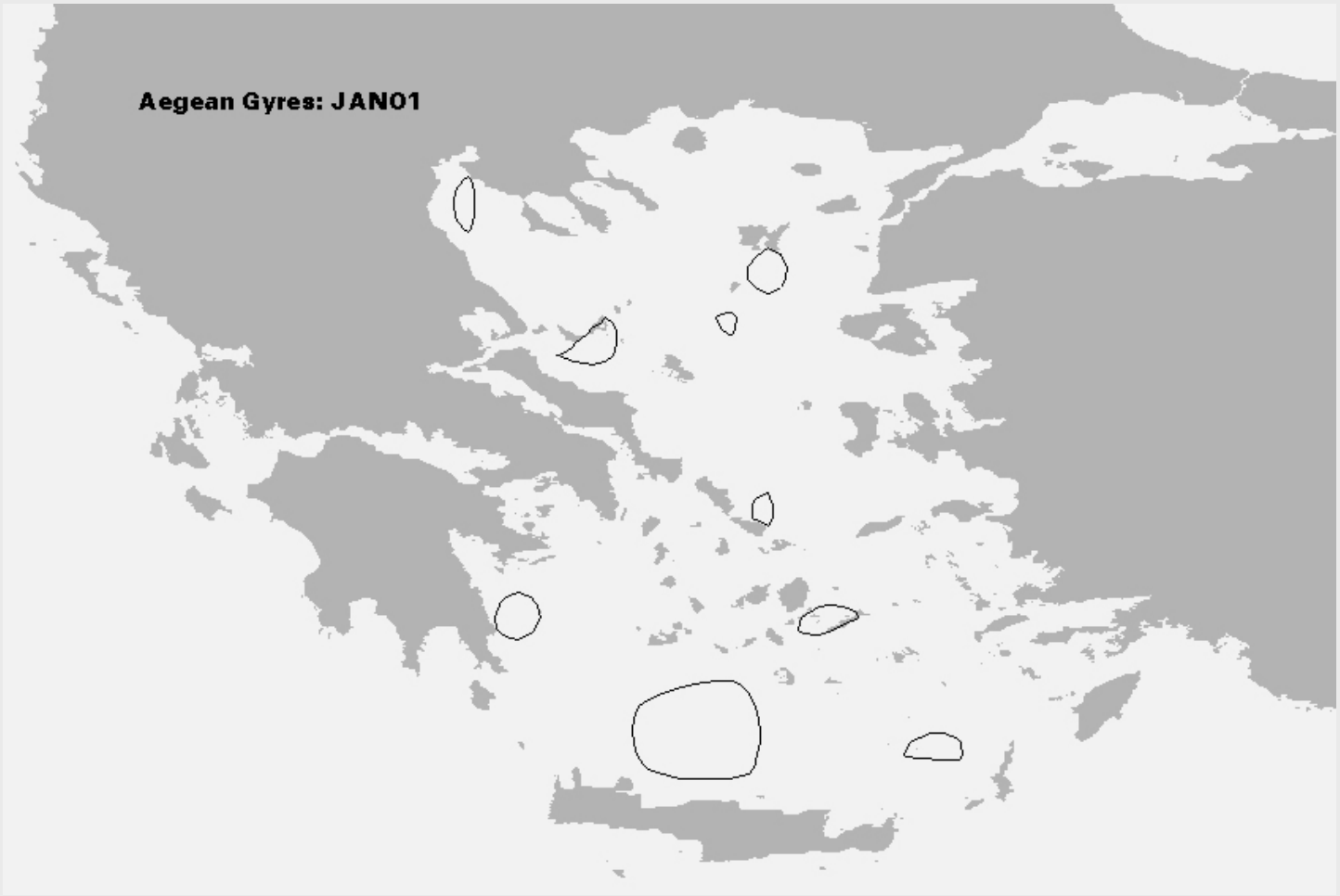
METHOD:
ON-SCREEN DIGITIZING FROM SST IMAGES
WHERE GYRE THERMAL SIGNALS ARE STRONG

Mapping Area for Ocean Gyres

PELOPS **A**NTICYCLONE:	**warm water trap - low productivity**
WEST **C**RETAN **C**YCLONE:	**cold water pump - high productivity**
IERAPETRA **A**NTICYCLONE:	**warm water trap - low productivity**
RHODES **C**YCLONE:	**cold water pump - high productivity**



Ocean Gyres
(cyclonic/anticyclonic eddies)



Small-scale Gyre/Eddy Formations in the Aegean Sea

METHOD:

HERE GYRE THERMAL SIGNALS ARE WEEK BUT DEPICTED WELL IN ALTIMETRY DATA.

METHOD IS BASED ON CONTOURING OF SLA IMAGES.

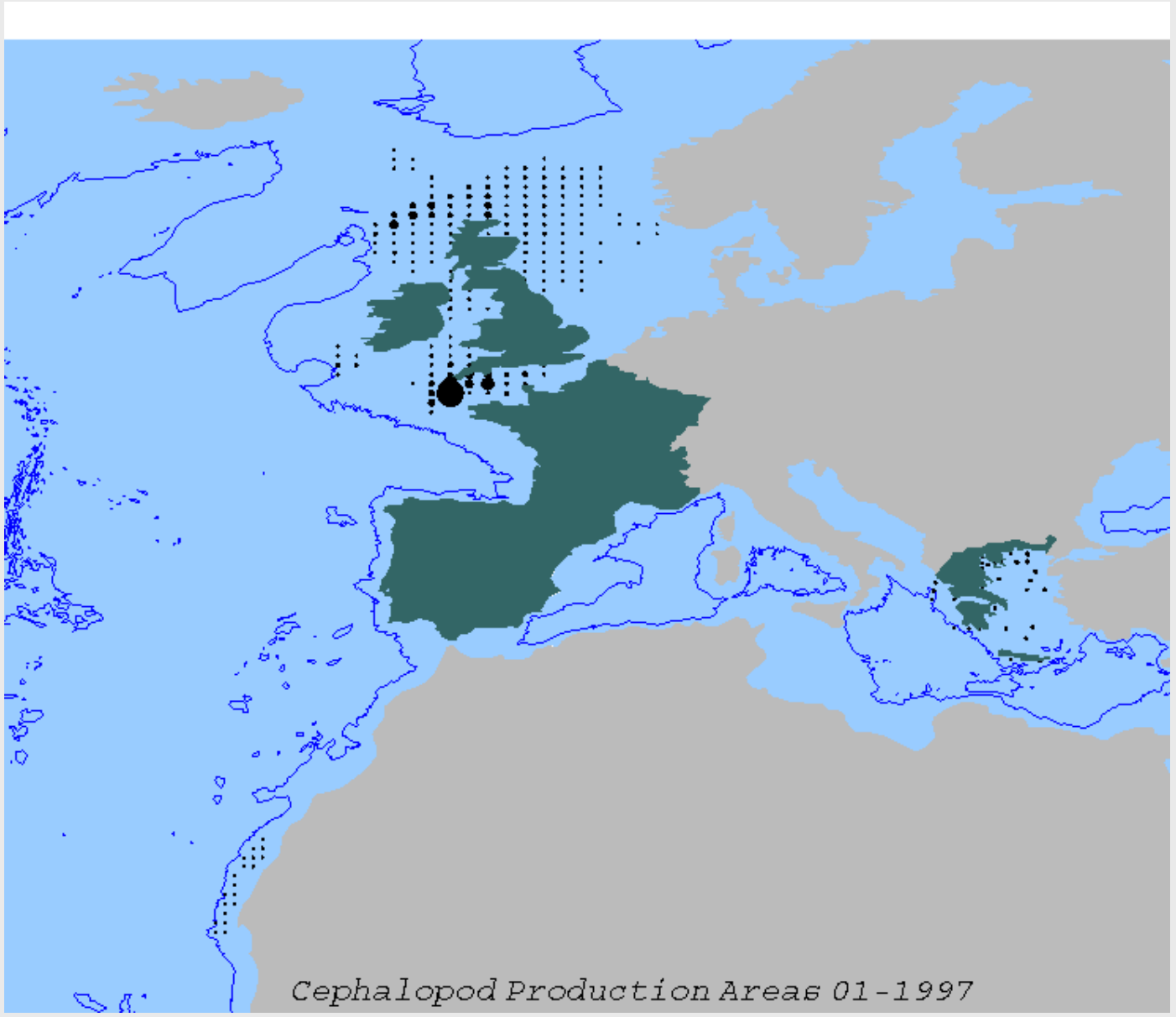
GIS Mapping in Fisheries

Fish Distributions

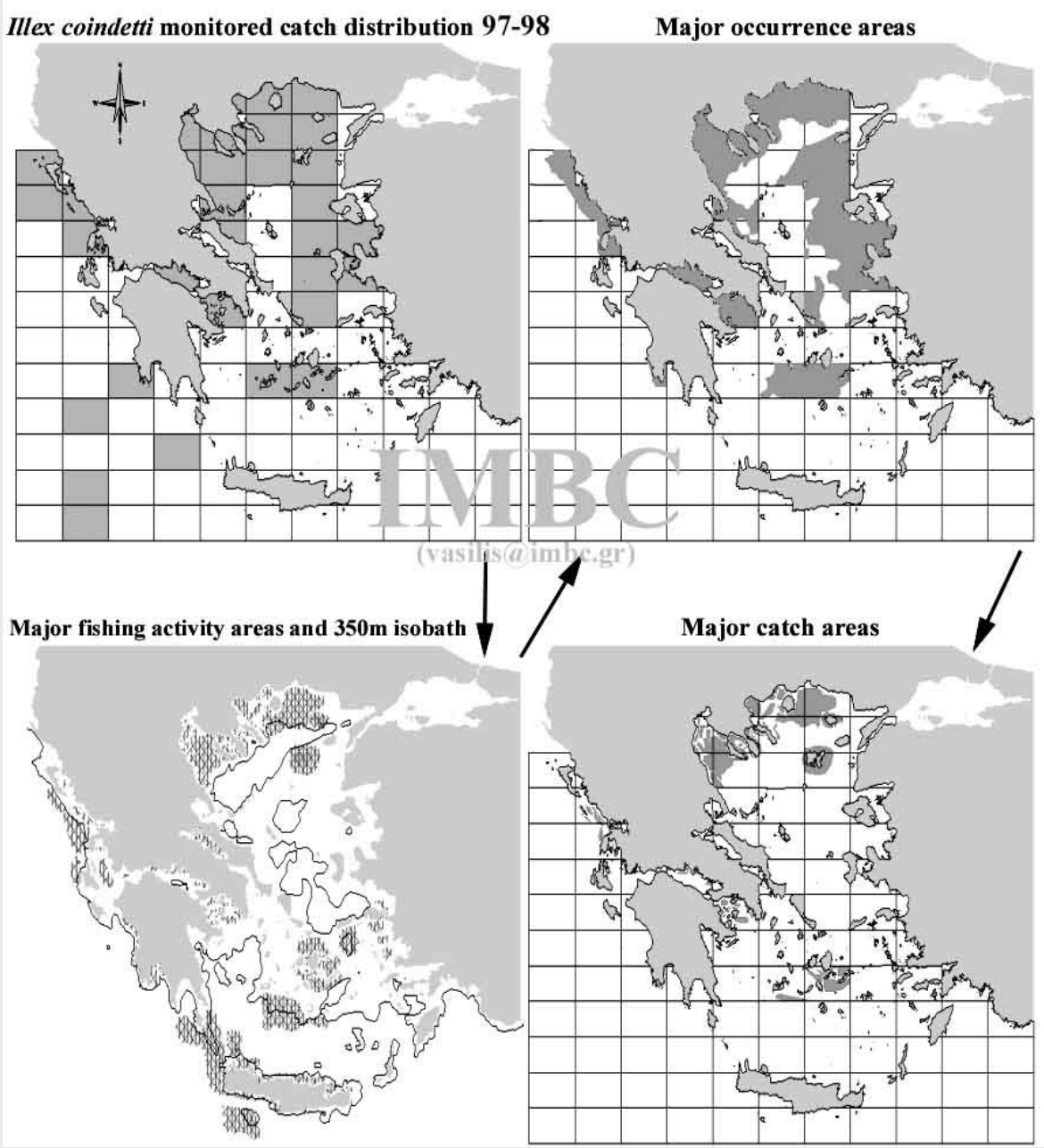
Species Life history data

Essential Fish Habitats

Animation of cephalopod production data

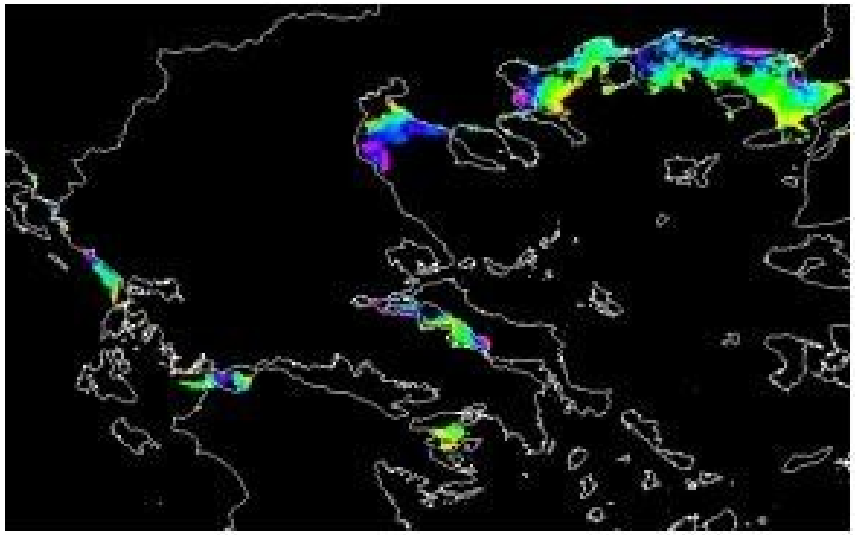


Mapping of Major Catch Areas based on abiotic life history parameters



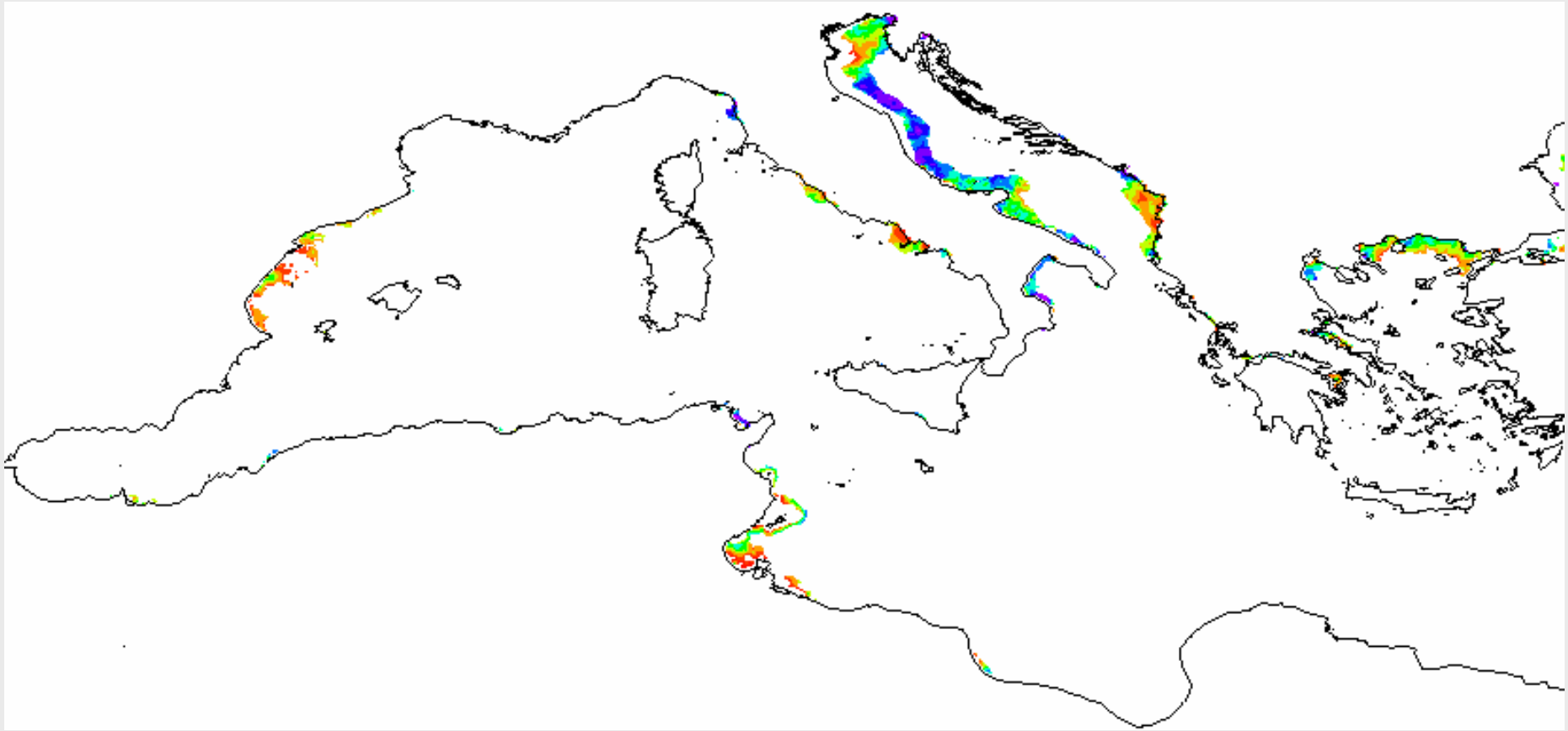
Mapping of Essential Fish Habitats (EFH) based on environmental parameters

INITIAL DATA:
Surveyed acoustic presence/absence data (July 2004)



RESULTING EFH MAP:
EFH Map based on habitat environmental descriptors

Mapping of Essential Fish Habitats (EFH) based on environmental parameters



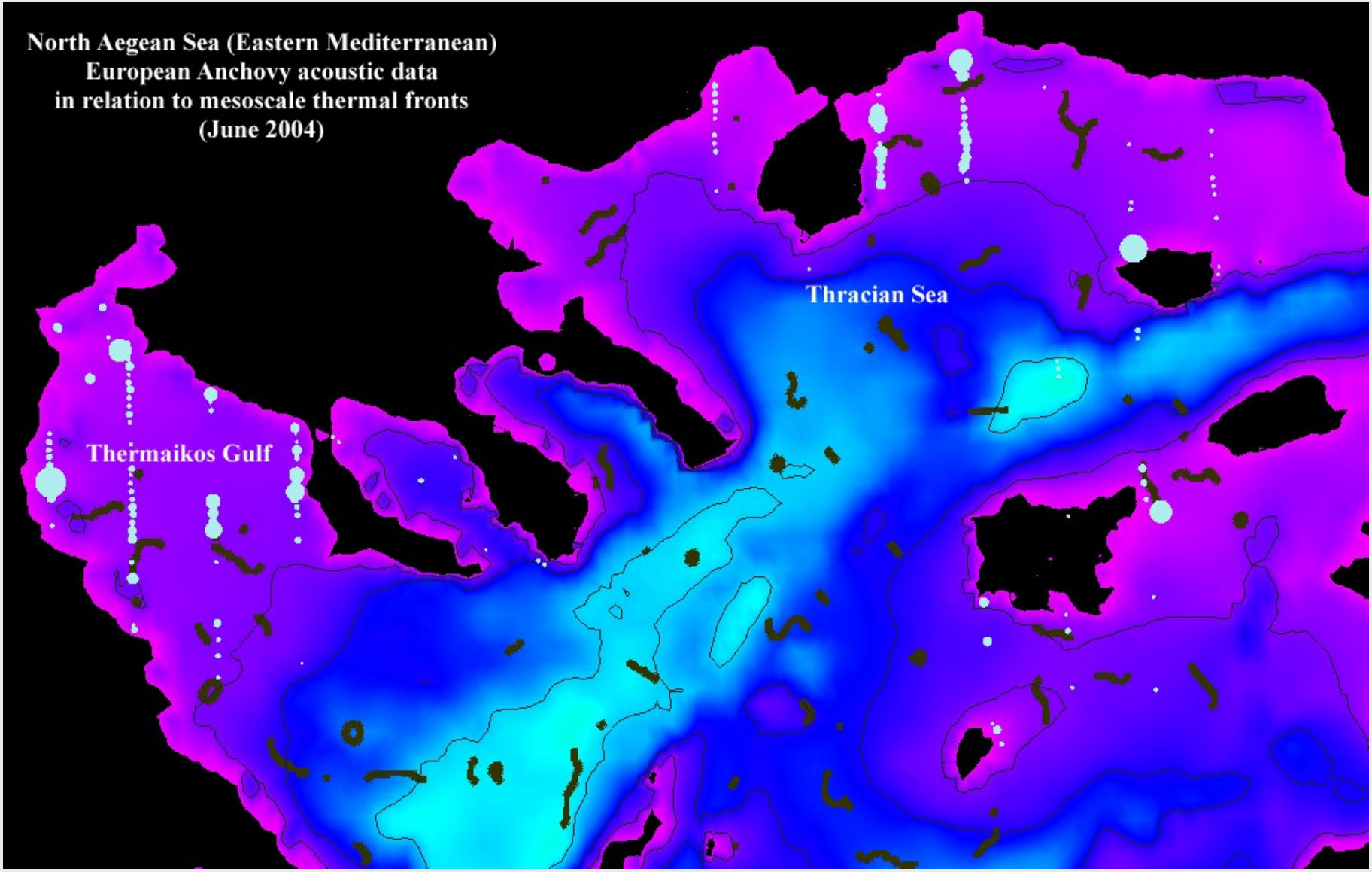
Environmental Approach to EFH Designation

Method overview: Surveyed data→satellite data→GAMs→env. ranges→GIS

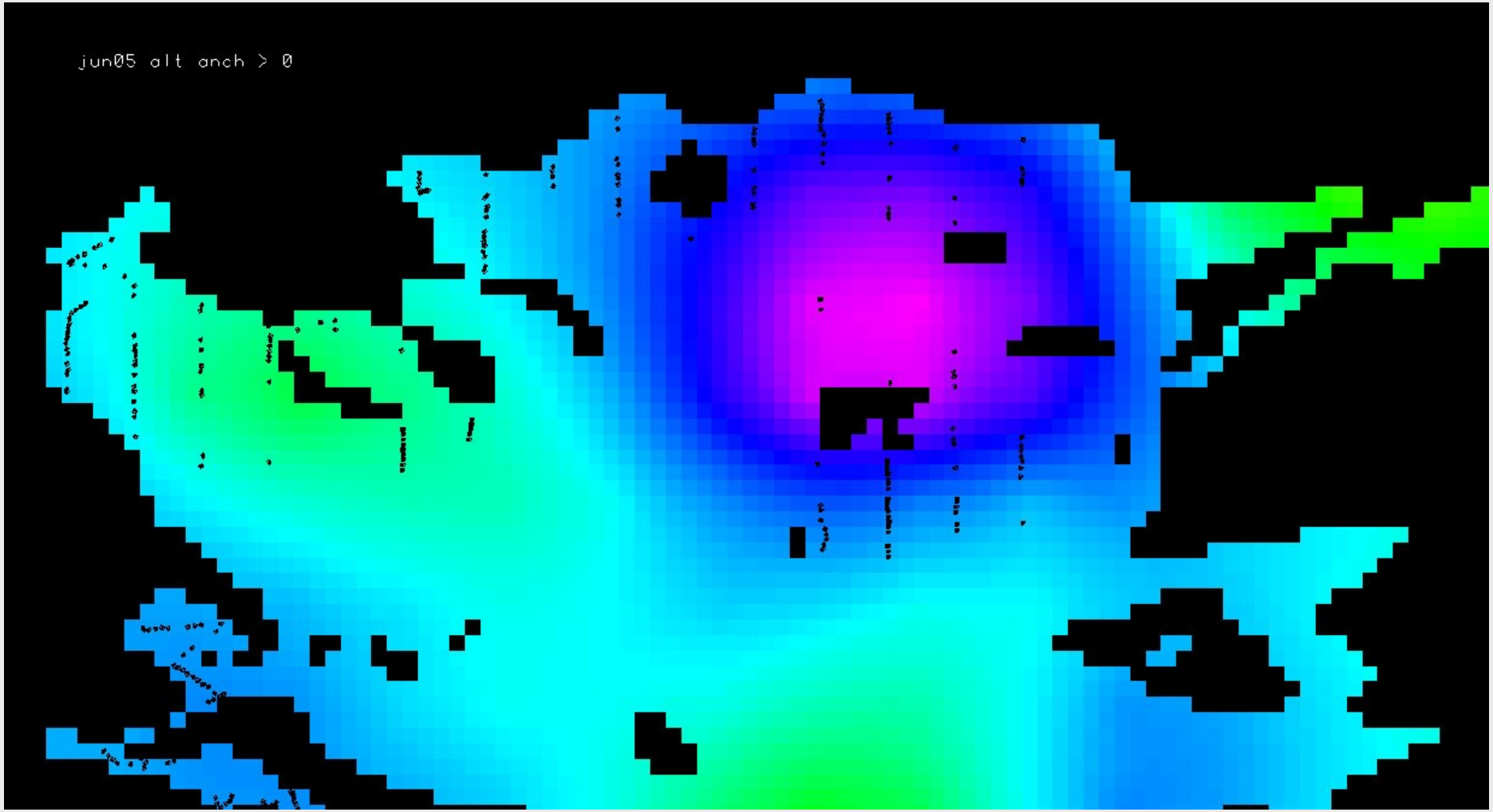
EFH mapping:

- ✓ **Presence/Absence surveyed data**
- ✓ **Extraction of environmental parameters from satellite data**
- ✓ **Development of GAMs**
- ✓ **GAMs extraction of minimum and maximum environmental ranges**
- ✓ **Application of ranges to satellite images through GIS**
- ✓ **GIS selection of areas that are simultaneously characterized by all input environmental ranges**

Relation of mesoscale fronts to the distribution of fish populations

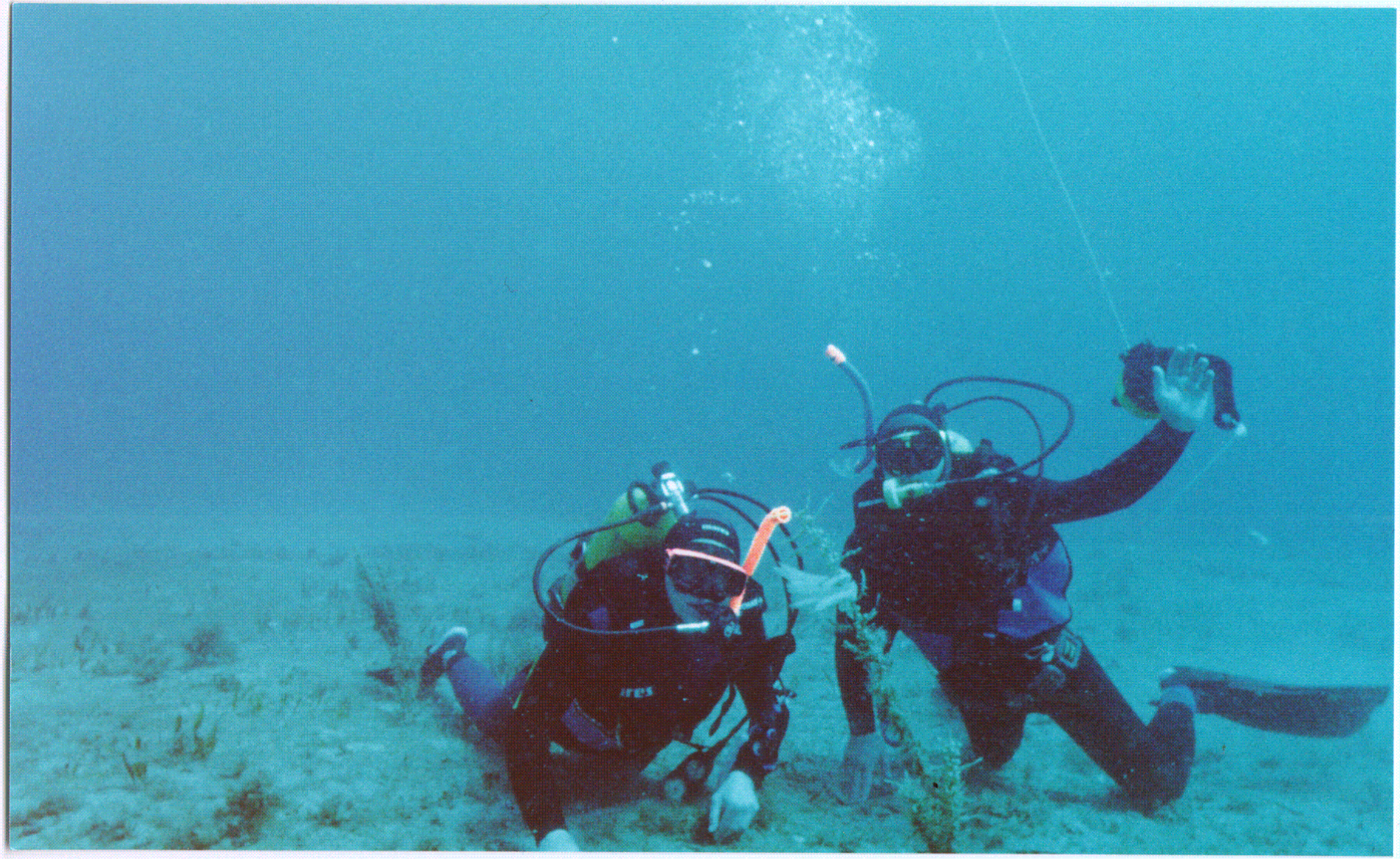


Relation of small-scale gyres to the distribution of fish populations



HCMR HOLDINGS OF GIS PRODUCTS

- ✓ Mesoscale Thermal Fronts
- ✓ Marine Productivity Hotspots
- ✓ Ocean Gyres/Eddies
- ✓ Essential Fish Habitats



Loligo vulgaris unhatched eggs attached on arrowhead (*Sagittaria* spp.)
Heraklion, Mononaftis Bay, Crete Island, Greece (February 2000)

ECOSUMMER-Crete is over! Many thanks for making it great!