Satellite Monitoring of Water Quality in Lake Manzalah, Egypt

Real-Time Water Quality Monitoring Workshop
June 16 - 17 2009
St. John's, Canada

Motivation

- Lakes are vital component of Egypt's water resources
- Pressure of diverse, multiple uses creates potential for conflict and degradation
- Need for accurate, reliable lake water quality information

Lake Manzalah

- Physical Characteristics
  - Largest of Egypt's coastal lagoons
    - Total area ~1000 km^2
    - Free water surface ~500 km^2
  - ~1000 islands
  - Average depth ~1.3m
  - Several openings to Mediterranean Sea
  - Inflow of agricultural drainage water and wastewater
  - Population of 8 Million in area surrounding Lake Manzalah

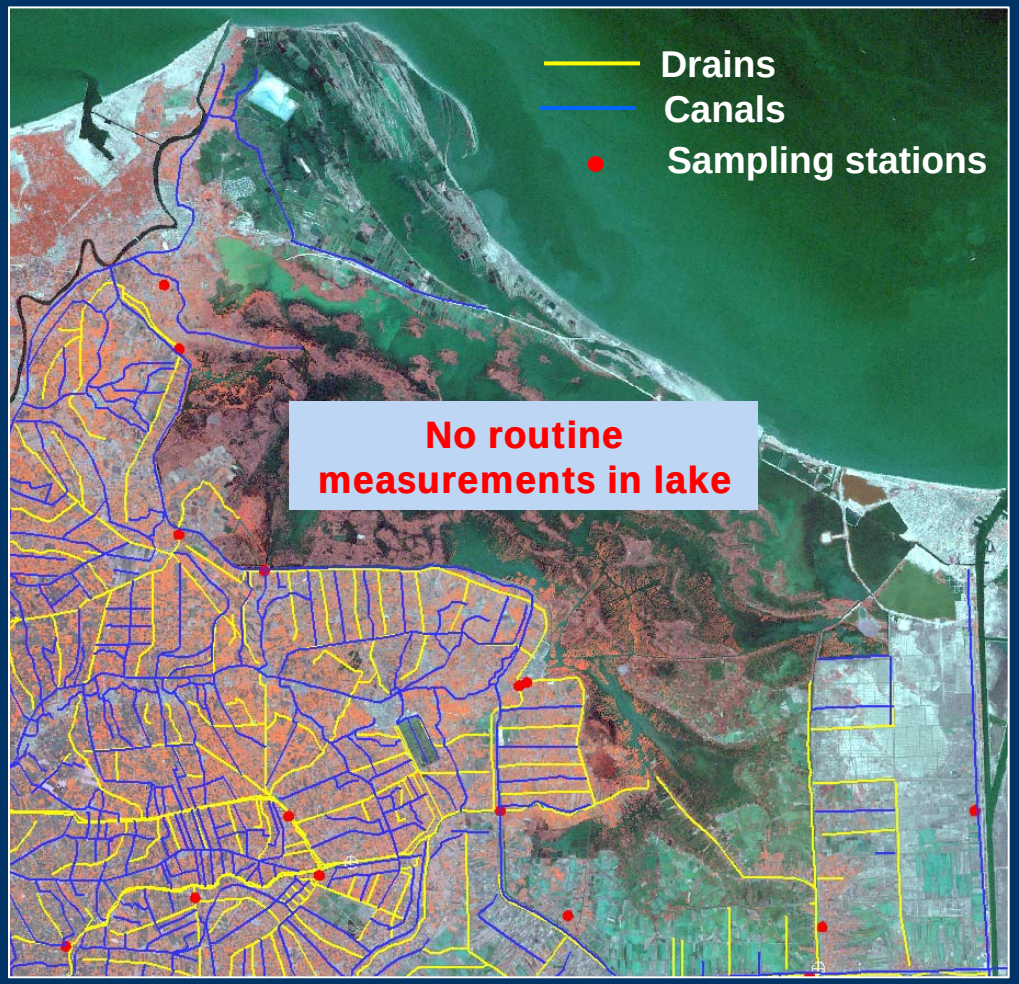
Lake Manzalah

- Pressures
  - Receptor for agriculture drainage, municipal sewage and industrial wastewater
  - Land reclamation
  - Invasive plant species

- Resources
  - Fisheries
  - Aquaculture
  - Wetland habitat

Monitoring and Information Needs

- Current monitoring program
  - Monthly in-situ measurements of water quality in drains and canals leading into Lake Manzalah
- Required information
  - Knowledge of spatial and temporal variability of water quality in lake
  - Information on surface cover status and change, incl. land reclamation and vegetation overgrowth

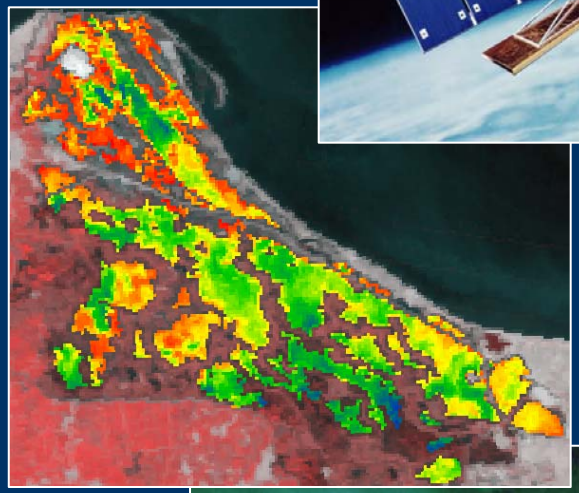


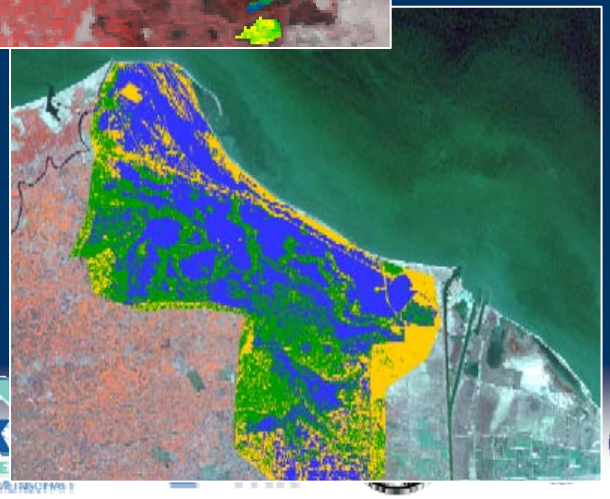
Project Objectives

- Demonstrate utility of EO for water quality monitoring and integrated water resources management (IWRM) in Egypt
- Show pathways for integration of EO into existing monitoring operations
- Build resident capacity to perform EO-based monitoring and exploit EO-based products for IWRM
- Explore opportunities for long-term funding (e.g. AfDB, CIDA, national) to sustain EO-based monitoring of all major water bodies in Egypt

Contribution of Earth Observation (EO)

- Systematic measurement of water quality over large areas
- Spatio-temporal variability of water quality
- Information on surface cover conditions and change
- Identification of critical areas (pristine/impaired) and trends
- Integration with in-situ data





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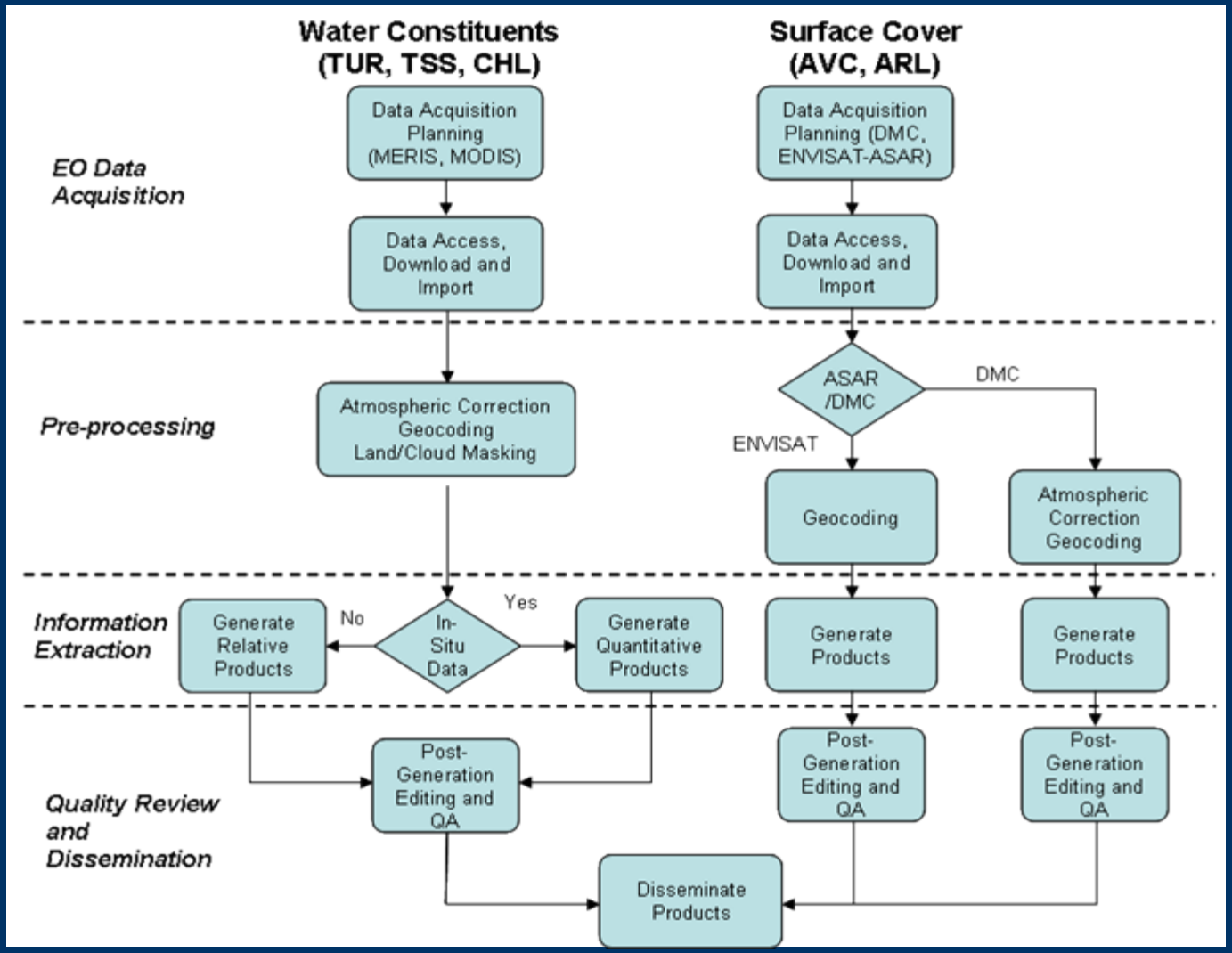
EO-Derived Products

Water Quality Product		Resolution	Frequency of Product Generation
Water Constituents	Turbidity (TUR)	300 m	Weekly
	Concentration of suspended sediments (TSS)	300 m	Weekly
	Concentration of chlorophyll-a (CHL)	300 m	Weekly
Surface Cover	Aquatic vegetation cover (AVC)	30 m	Quarterly
	Areas of reclaimed land (ARL)	30 m	Semi-annually

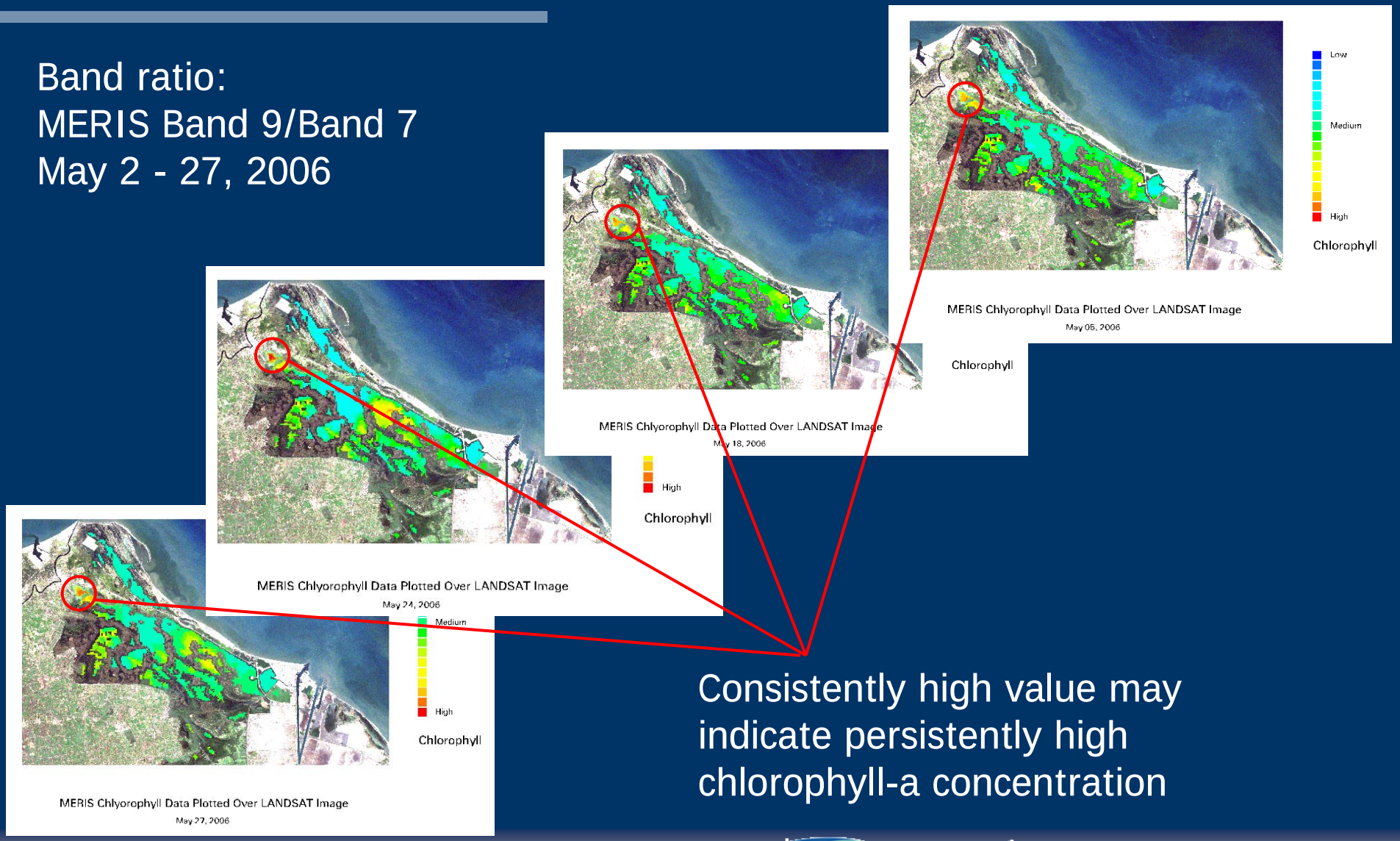
Processing Level	Water Constituents	Surface Cover
Basic	• Precision-geocoded image covering the area of interest • Annotated quicklooks (e.g. overlays of network of drains and canals, transportation network) • Designed to provide a quick overview of the entire lake and its surrounding environment	
Intermediate	• Precision-geocoded • Reflectance in selected spectral bands and band ratios colour-coded to highlight TUR, TSS and CHL • Annotated quicklooks can be generated • Designed to provide relative information about TUR, TSS and CHL variability	• N/A
Advanced	• Precision-geocoded • Quantitative TUR, TSS and CHL products • Annotated quicklooks • Generation relies on concurrently collected in-situ measurements and EO data	• Precision-geocoded • Baseline inventory of AVC • Baseline inventory of ARL • Change in AVC • Change in ARL

Process Flows



Relative Products - CHL

Band ratio:
MERIS Band 9/Band 7
May 2 - 27, 2006



Consistently high value may indicate persistently high chlorophyll-a concentration

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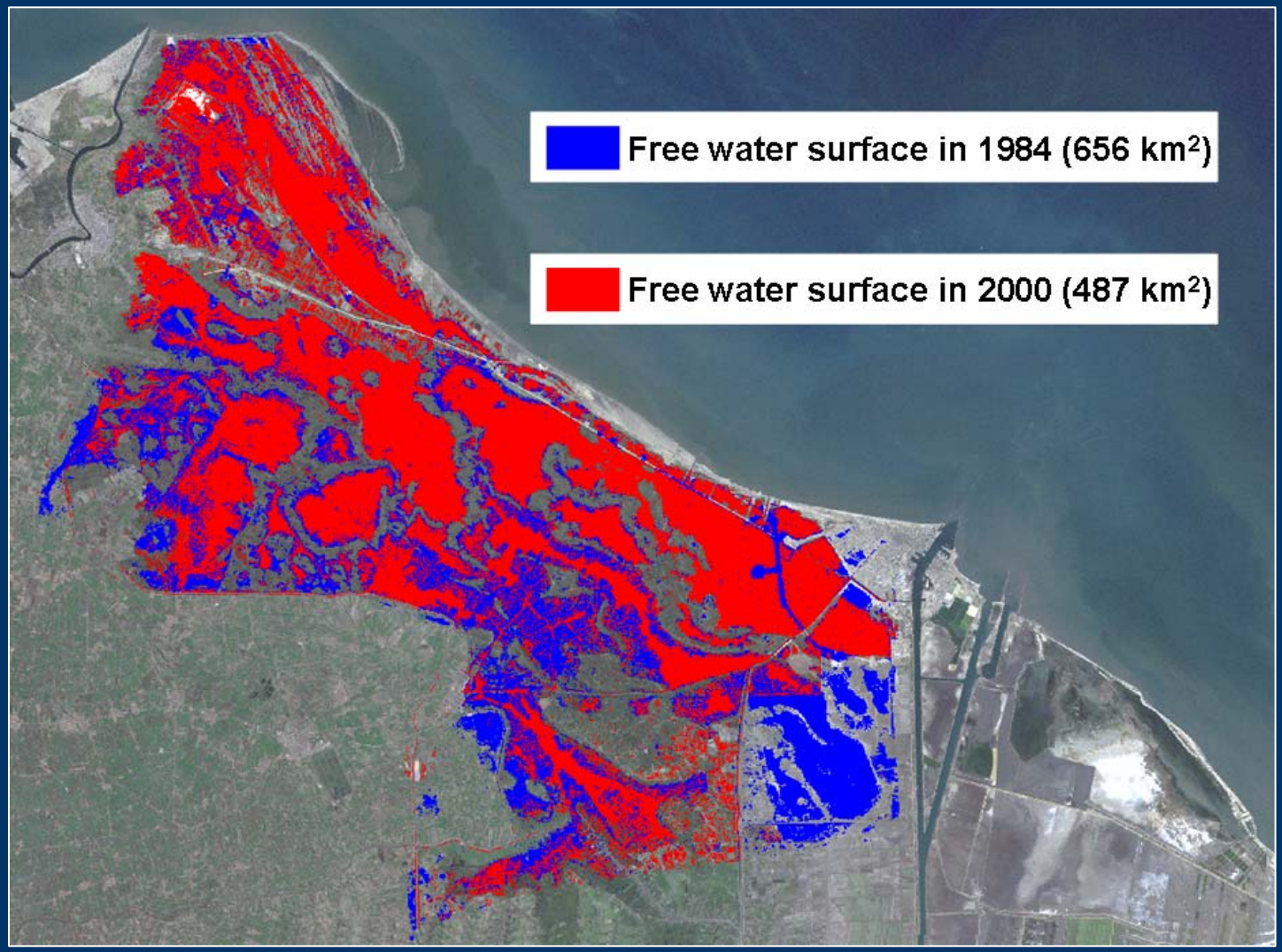
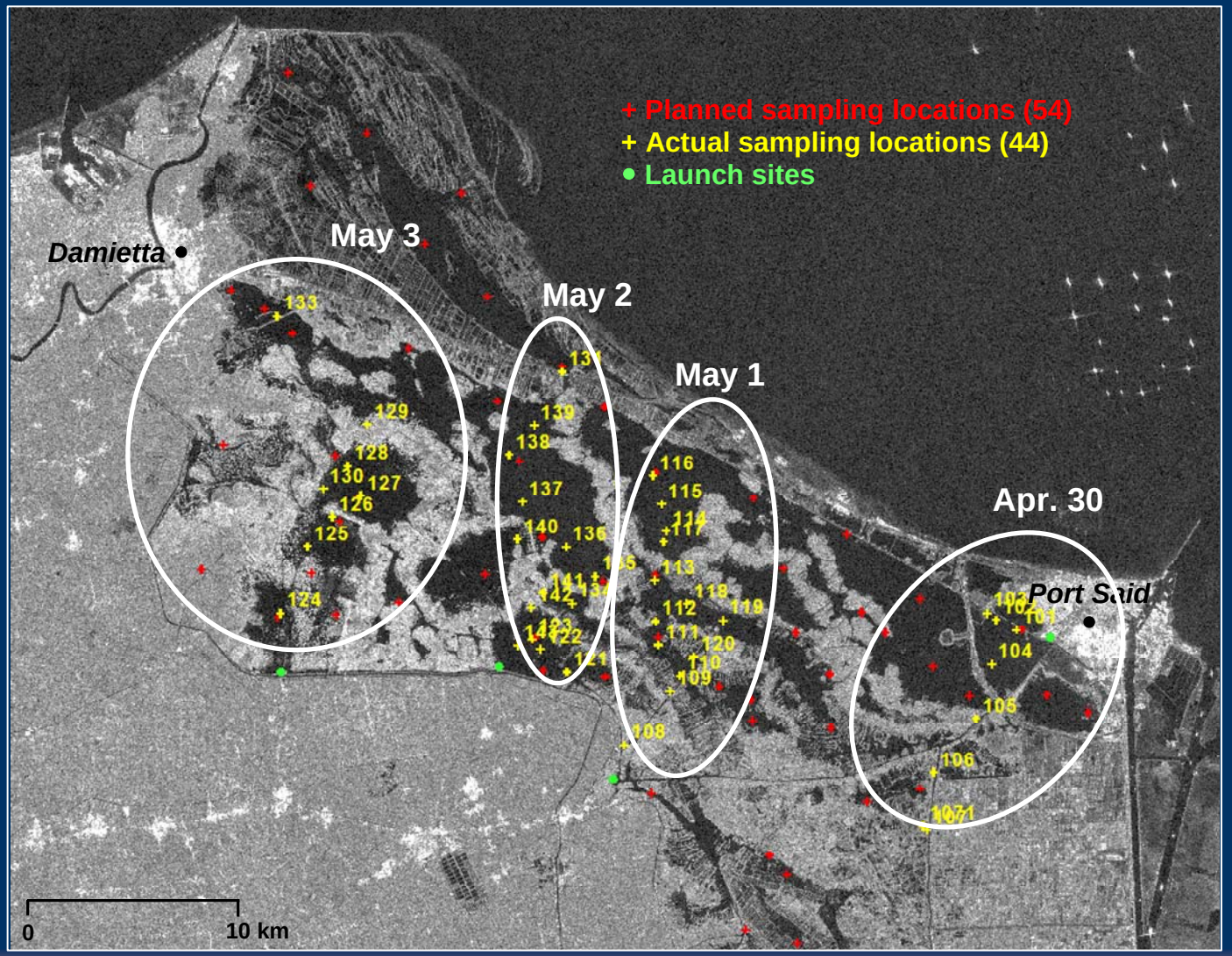
Change in Free Water Surface



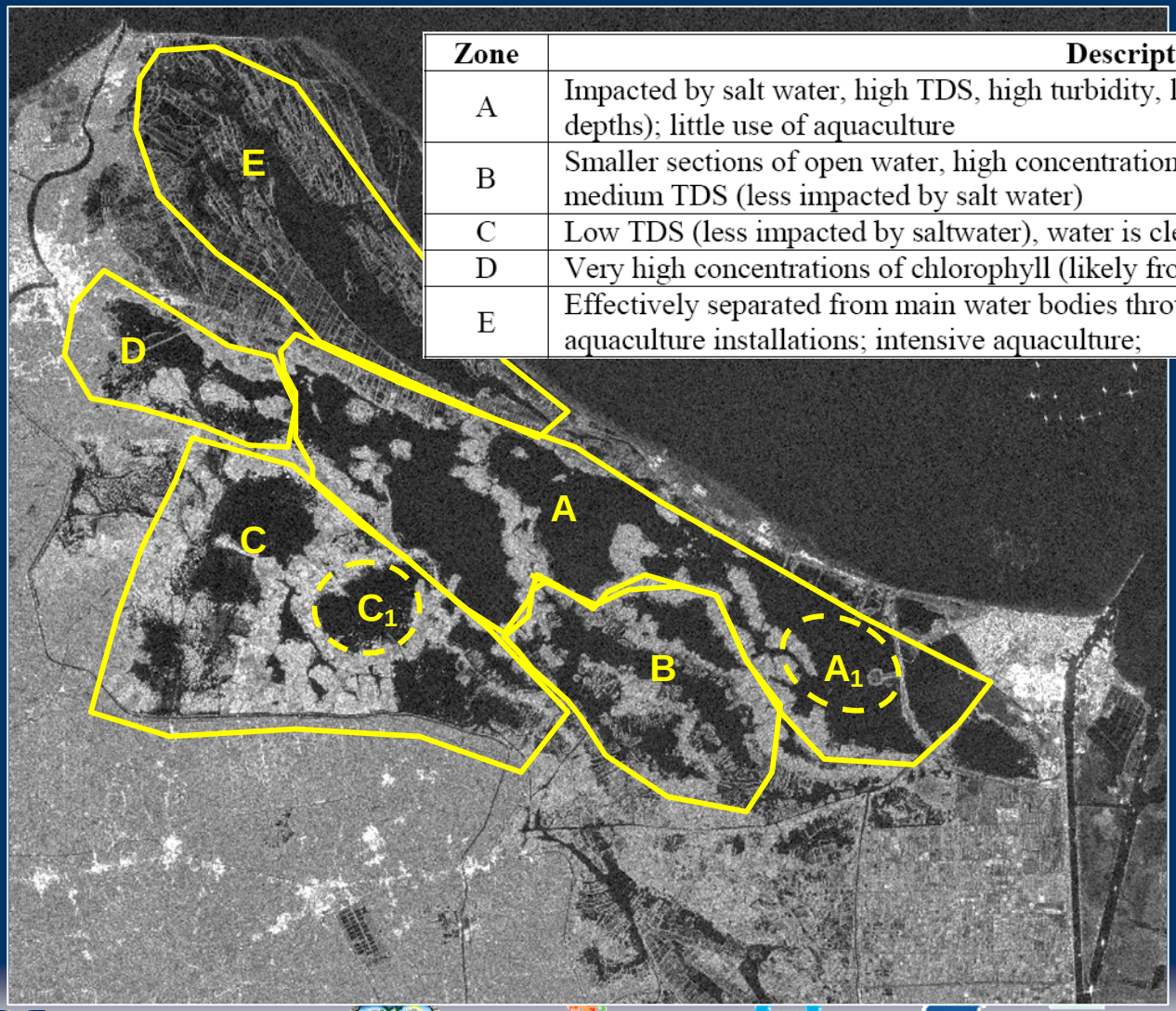
2007 Field Campaign



2007 Field Campaign

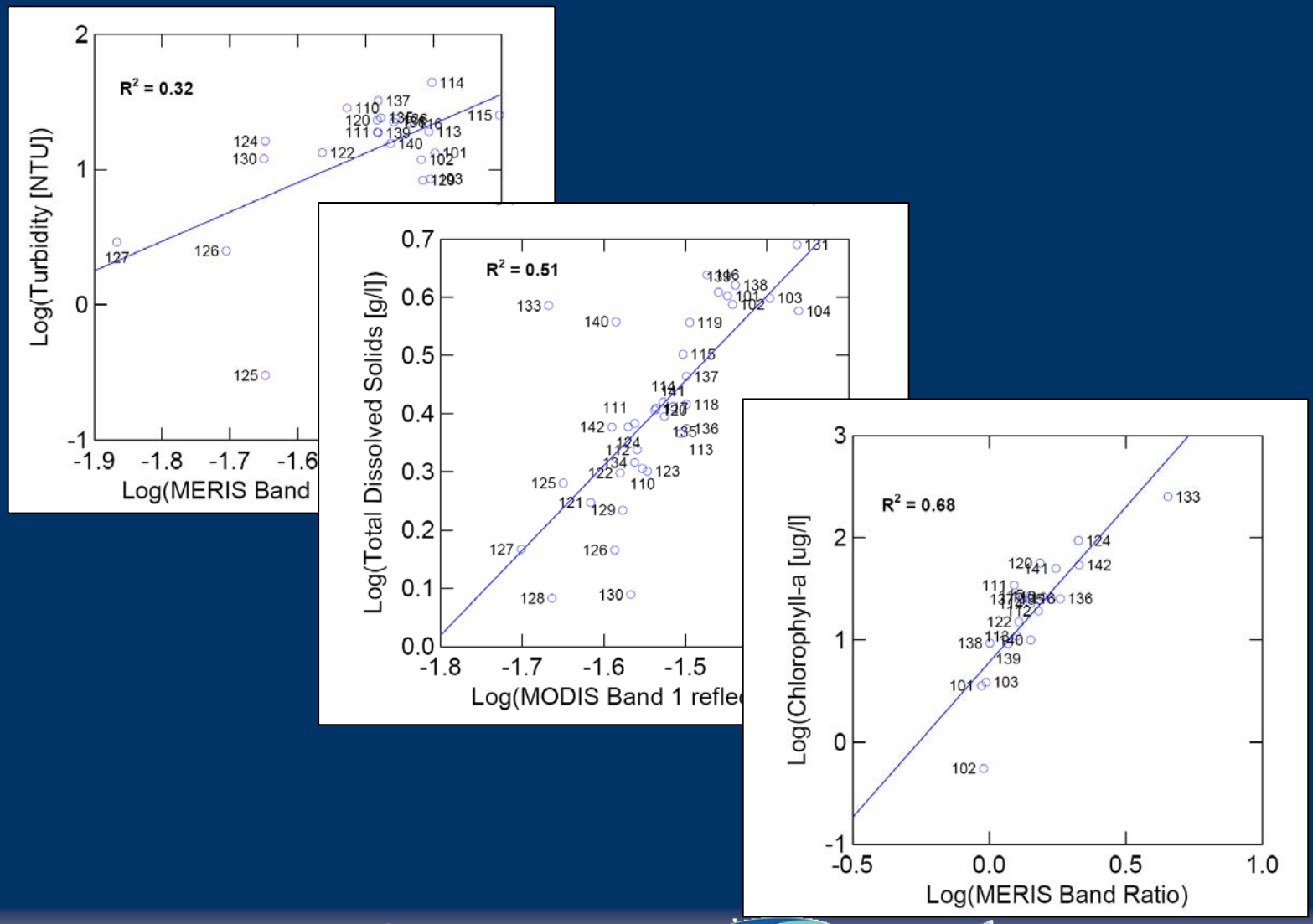
- Real-time water quality measurements (using hydrolabs)
  - Temperature
  - pH
  - TUR [NTU]
  - TDS [g/l]
  - CHL [mg/l]
  - Specific conductivity uS/m
  - Dissolved oxygen (concentration, saturation)
- Water depth [m]
- Bottom substrate
- Observations of land use and land cover
- Photographs and videos

Water Quality Zones



Zone	Description
A	Impacted by salt water, high TDS, high turbidity, low chlorophyll; open, deep water (max. depths); little use of aquaculture
B	Smaller sections of open water, high concentrations of chlorophyll, high turbidity, low-medium TDS (less impacted by salt water)
C	Low TDS (less impacted by saltwater), water is clear, floating/submerged vegetation, shallow
D	Very high concentrations of chlorophyll (likely from agricultural runoff)
E	Effectively separated from main water bodies through international road and permanent aquaculture installations; intensive aquaculture;

2007-2005 Results



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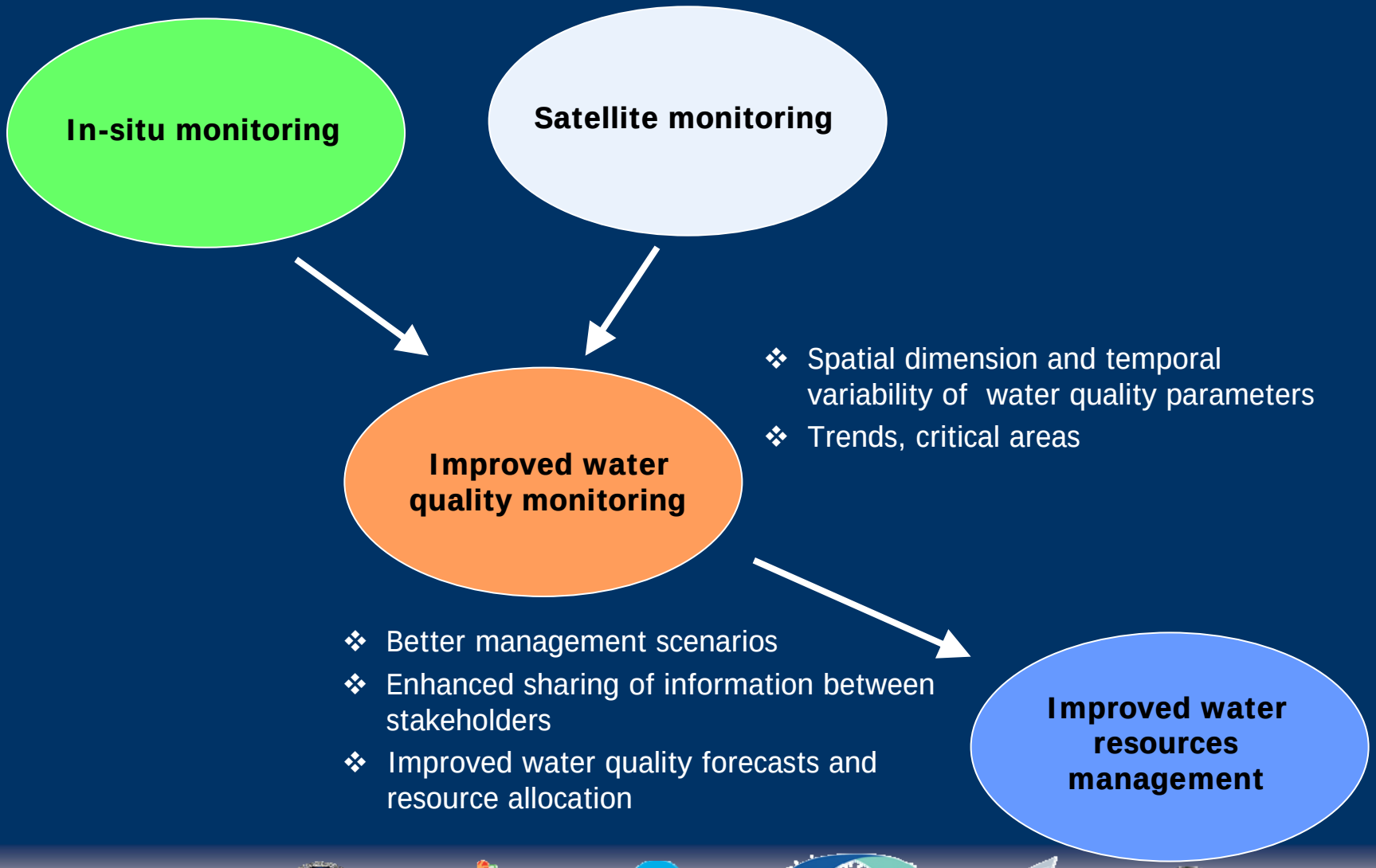
2007-2005 Results

- Statistically significant relationships between in-situ data and EO-derived products
  - Potential to capture spatio-temporal variability of water quality parameters
  - Value of data increases with length of time series
- Current in-situ and EO data not sufficient to build robust empirical relationship
  - Concurrent EO and in-situ data is required
- Integration of real-time water quality (RTWQ) and EO technologies
  - Calibration/validation of EO-derived water quality products
  - Information for water management

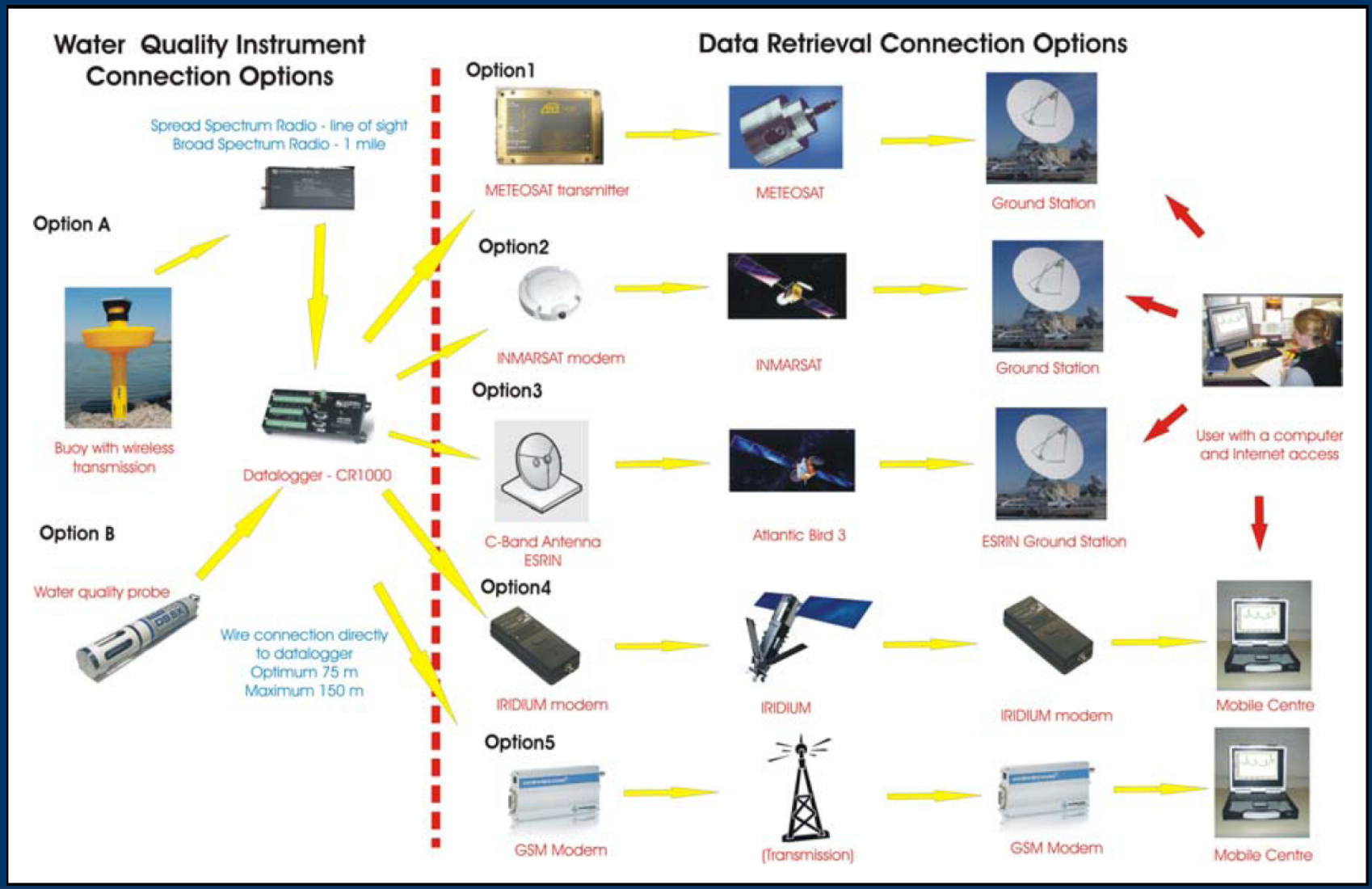
In-Situ and EO Data Integration



- Spatial dimension and temporal variability of water quality parameters
- Trends, critical areas

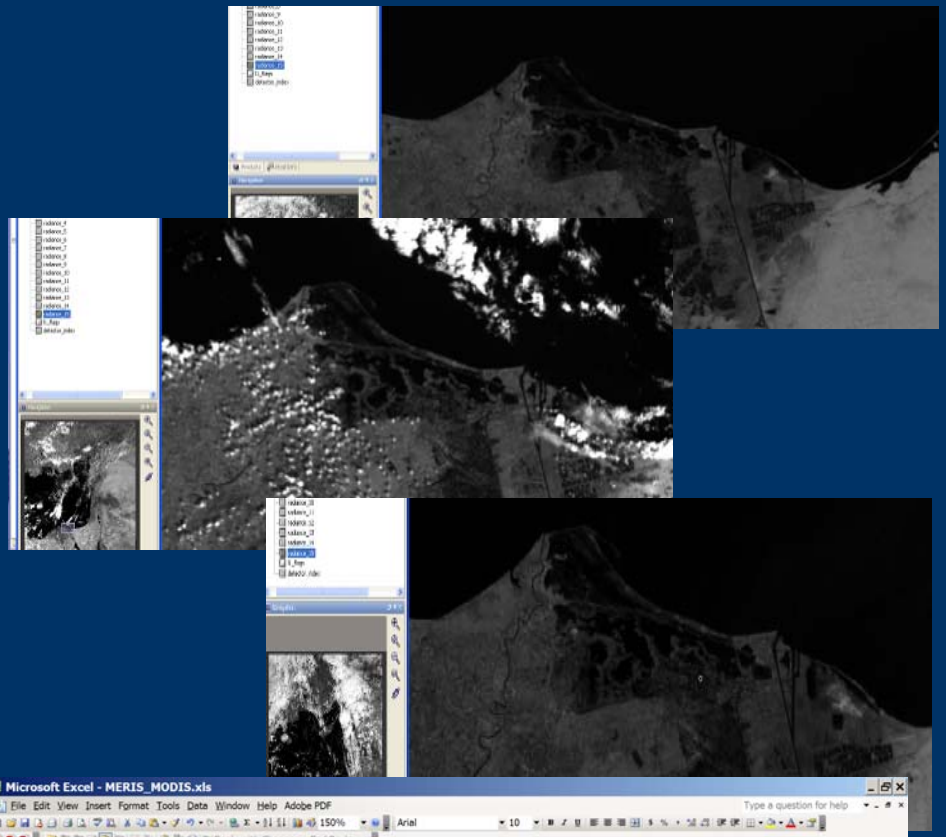
- Better management scenarios
- Enhanced sharing of information between stakeholders
- Improved water quality forecasts and resource allocation

In-Situ and EO Data Integration



EO Data

- Primary data source is MERIS
  - Access to FR data from background mission
  - Access of subsets via ftp site (26 scenes since Oct. 2008)
- Secondary data source is MODIS
  - Access via NASA LAADS (32 scenes since Oct. 2008)



Microsoft Excel - MERIS_MODIS.xls

Lake Manzalah Egypt Drainage Water Quality Project

IMAGERY

	MERIS Acquisitions		atmospheric conditions	DVD		MODIS Acquisitions		atmospheric conditions	DVD
1	2-Oct-08	8:18:53	good	3142	1	2-Oct-08	276	light cloud	3145
2	5-Oct-08	8:24:38	cloudy	3142	2	3-Oct-08	277	good	3145
3	6-Oct-08	7:53:22	cloudy	3142	3	4-Oct-08	278	good	3145
4	8-Oct-08	8:30:22	cloudy	3142	4	6-Oct-08	280	cloud	3145
5	9-Oct-08	8:00:44	cloudy	3142	5	7-Oct-08	281	cloud	3145
6	12-Oct-08	8:08:04	light cloud	3142	6	9-Oct-08	283	light cloud	3145
7	15-Oct-08	8:12:04	good	3142	7	12-Oct-08	286	cloud	3145
8	18-Oct-08	8:16:00	cloudy	3143	8	13-Oct-08	287	good	3145
9	21-Oct-08	8:21:44	very cloudy	3143	9	14-Oct-08	288	cloud	3145
10	24-Oct-08	8:27:29	very cloudy	3143	10	16-Oct-08	290	cloud	3145
11	25-Oct-08	7:57:50	very cloudy	3143	11	20-Oct-08	294	cloud	3145
12	27-Oct-08	8:34:43	heavy cloud		12	21-Oct-08	295	cloud	3145
13	31 Oct 08	8:07:29	good	3143	13	22 Oct 08	296	image ok but ROI is near the edge of frame	3145
14	3-Nov-08	8:13:09	cloudy	3143	14	23-Oct-08	297	light cloud	3145
15	6-Nov-08	8:18:50	good	3143	15	24-Oct-08	298	heavy cloud	
16	9-Nov-08	8:24:35	cloudy	3144	16	25-Oct-08	299	heavy cloud	3145
17	10-Nov-08	7:53:19	cloudy	3144	17	26-Oct-08	300	heavy cloud	3145
18	12-Nov-08	8:30:36	good	3144	18	2-Nov-08	307	light cloud	3145
19	16-Nov-08	8:04:38	good	3144	19	4-Nov-08	309	good	3145
20	22-Nov-08	8:17:43	very good	3144	20	6-Nov-08	311	good	3145
21	26-Nov-08	7:50:29	very good	3144	21	11-Nov-08	316	some cloud. ROI is near edge	3145

Sheet1 / Sheet2 / Sheet3

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In-Situ Equipment

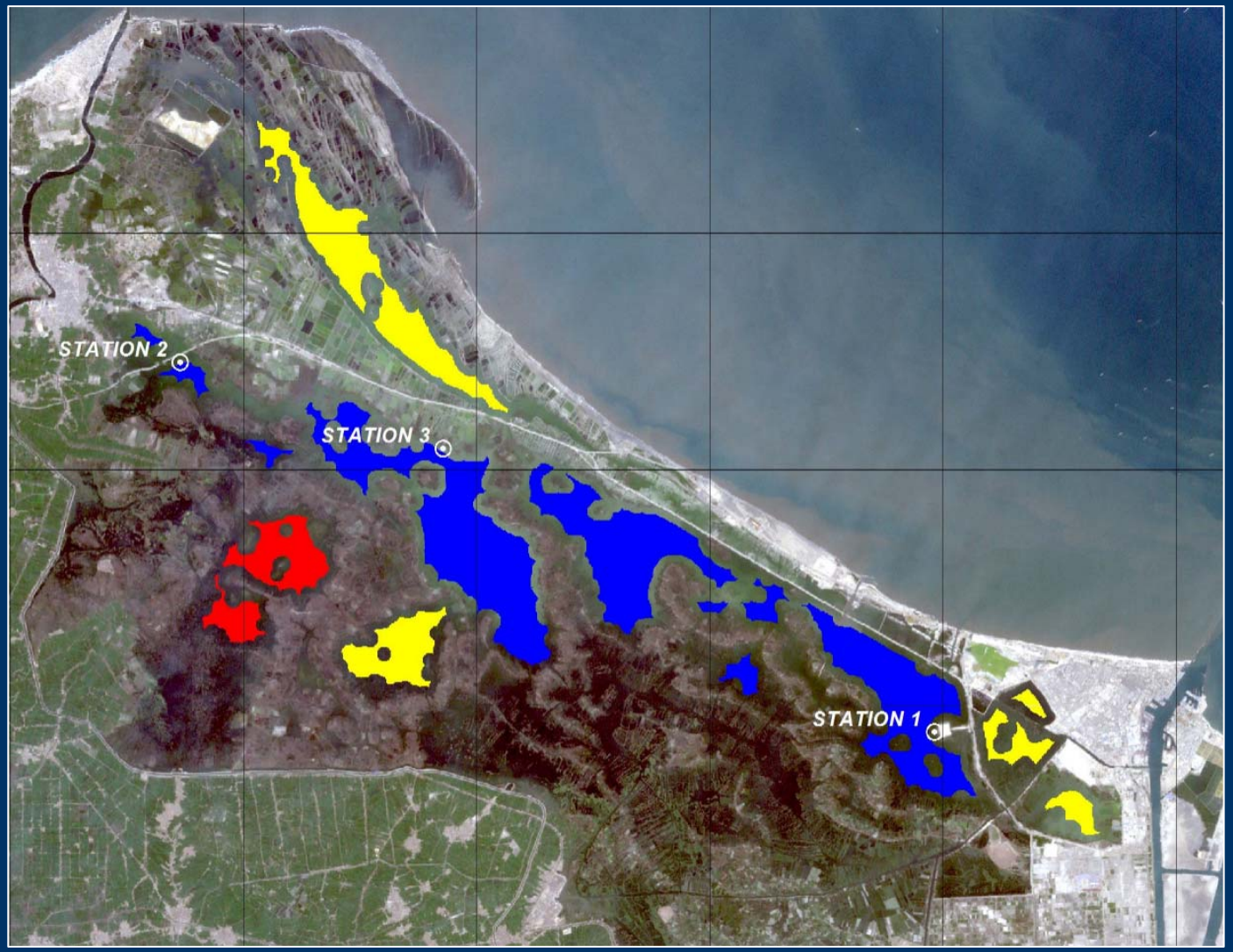
- Technical specifications for in-situ stations and data retrieval
  - Water quality probes
  - Data logger
  - Satellite communications
  - Ancillary equipment (pyranometer, camera)
  - Software, solar panels

- Assessment of technology options and procurement
  - Recommended system configuration
  - Purchase of equipment
  - System programming and testing

Deployment of In-Situ Equipment

- Sites must be representative of larger areas
  - Focus on large water bodies with little aquatic vegetation
- Access to site must be easy for installation and maintenance
  - Nearshore locations
- Equipment must be secure
  - Suitable housing/casing
  - Engage local residents
- Focus on what is essential to achieve objectives
  - Capture potential improvements in documentation
  - As simple as possible, as complicated as necessary

Potential Deployment Sites



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EO-Based Information Extraction

- Concurrent use of analytical and empirical approaches to build on past work and exploit synergies

- Analytical modelling
  - Input
    - Water inherent optical properties
    - RTWQ measurements
    - Satellite reflectances (uncorrected)
  - Model
    - Radiative transfer model
    - Neural network
  - Output
    - Atmospherically corrected satellite reflectances
    - Concentrations of chlorophyll-a, total suspended matter and dissolved organic matter

EO-Based Information Extraction

- Empirical modelling
  - Input
    - RTWQ measurements
    - Satellite reflectances (uncorrected/corrected)
    - Output from analytical models (corrected satellite reflectances and water quality output)
  - Model
    - Regression analysis (quantitative products)
    - Decision tree analysis (water quality categories)
  - Output: RTWQ parameters