Present Status and Future Directions for Remote Sensing Contributions to Integrated Coastal Observing Systems

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Overview of Talk

- Importance of coastal regions
- Emerging coastal observing systems
- Role of remote sensing observations and needs
- Coastal Theme of the Integrated Global Observing Strategy
- Future Directions: Continuous Coastal Awareness Networks

Importance of Coastal Zones

- Coastal zones are the sites of some of the most important, productive and unique ecosystems on Earth and home to abundant/diverse flora & fauna.

- Prime locations of human habitation, commerce, resources (e.g., food) and recreation are found in the coastal zone worldwide.

- However, both the natural and human elements of coastal zones are vulnerable to disturbances associated with natural climate variability in conjunction with human impacts on local, regional and global levels.

- These disturbances impact the capacity of the coastal zone to support humans, goods and services.

- Thus, the ability to detect and predict changes in key coastal indicators in a timely manner is a crucial albeit largely unfulfilled need given the dynamic nature of coastal zones, requiring a broad suite of observations.

- However, significant progress is underway given the continued development of coastal observing systems, consisting of in situ & remote elements.

Global Coastal Observing Systems

Coastal module of the Global Ocean Observing System (GOOS)

- Marine services, natural hazards, and public safety
- Public health risk
- Ecosystem health
- Living marine resources

http://ioc.unesco.org/goos/coop.htm

Coastal module of the Global Terrestrial Observing System (GTOS)

- Human dimensions, land use/cover, and critical habitat alterations
- Sediment loss and delivery
- Water cycle/water quality
- Effects of sea level change, storms, and flooding

http://www.fao.org/gtos/C-GTOS.html

Remote sensing can contribute to improved understanding and management of many important coastal issues, e.g.,:

- Hydrological and biogeo-chemical cycles
  - ➢ Carbon flux
- Ecosystem health and productivity
  - ➢ Harmful algal blooms
- Coastal urbanization and development
  - ➢ Water quality
- Coastal hazards

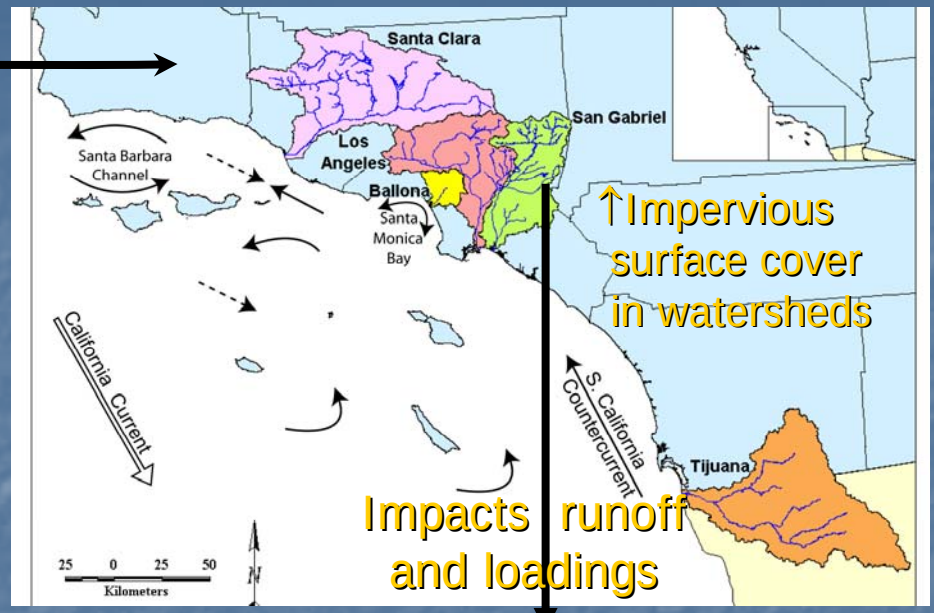
NASA MODIS True-Color Image, March 5 2001

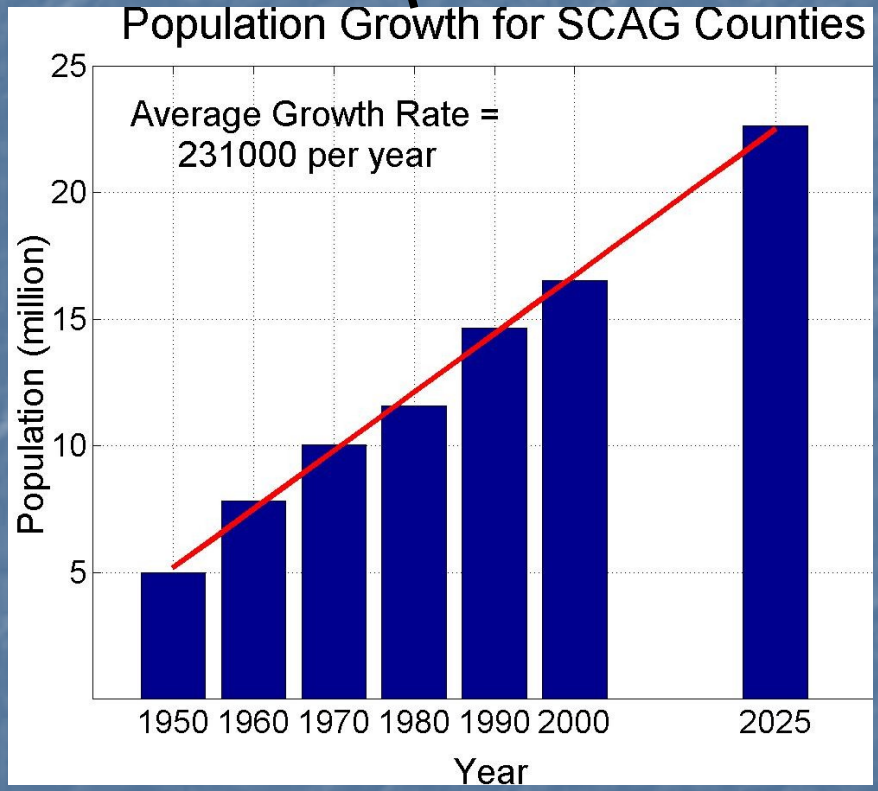
Mississippi River Sediment Plume

(Courtesy: http://visibleearth.nasa.gov/)

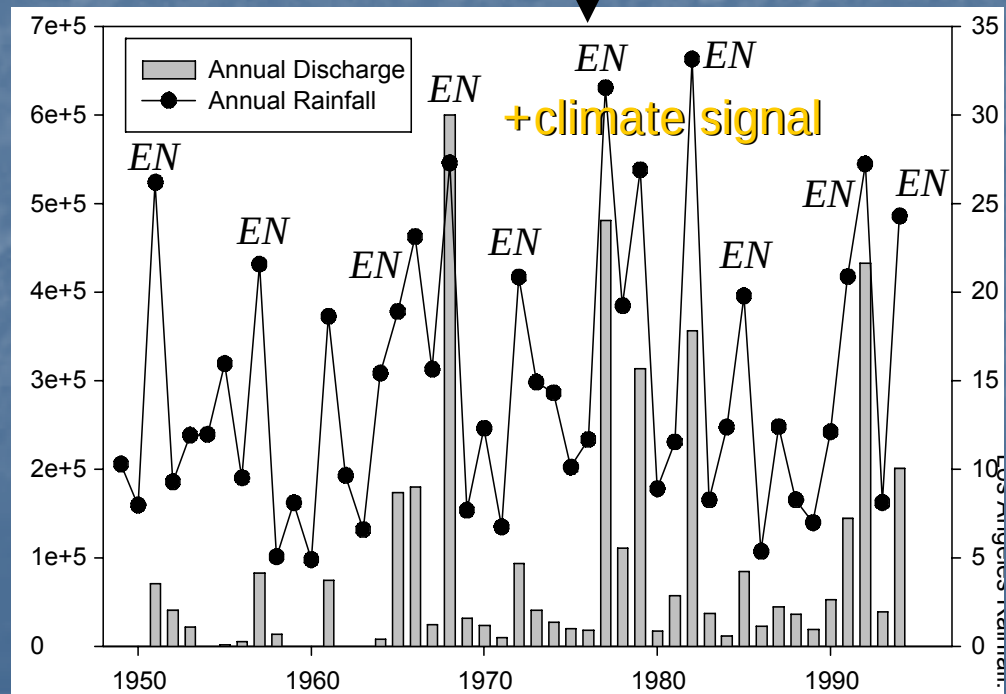
Climate Variability & Urbanization in S. California

Urbanization



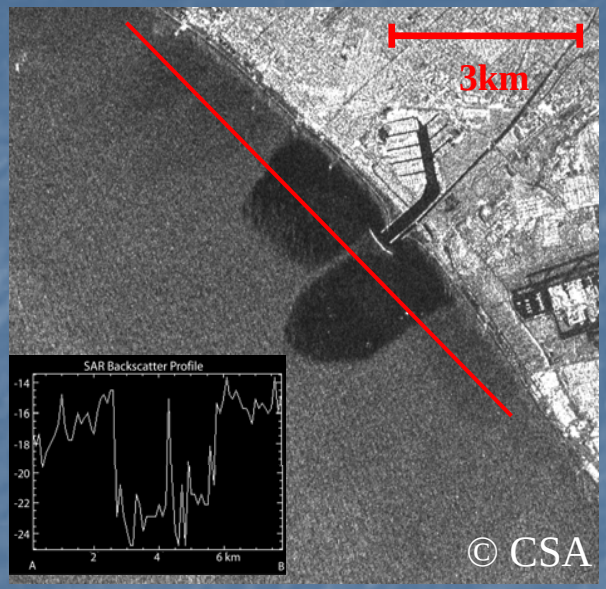


Population Growth

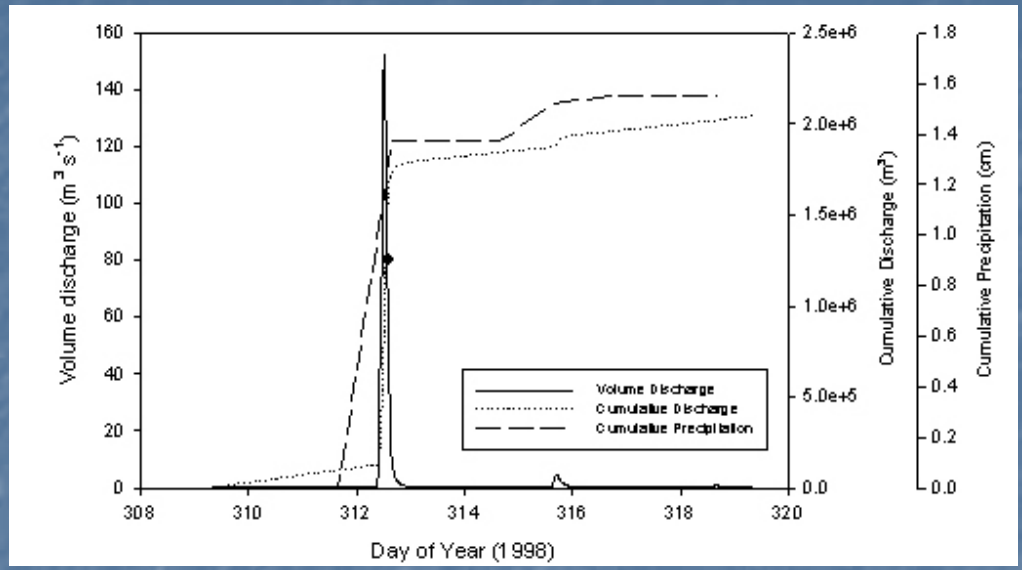


S. California Stormwater Runoff Plumes (*DiGiacomo et al., 2004*)

RADARSAT SAR, 8 Nov. 1998

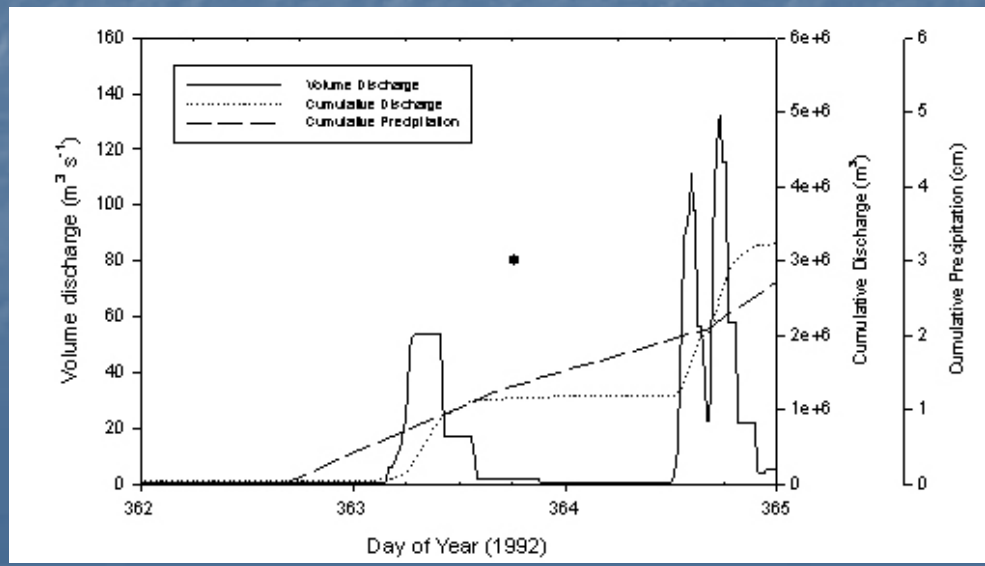


- SAR image at discharge peak

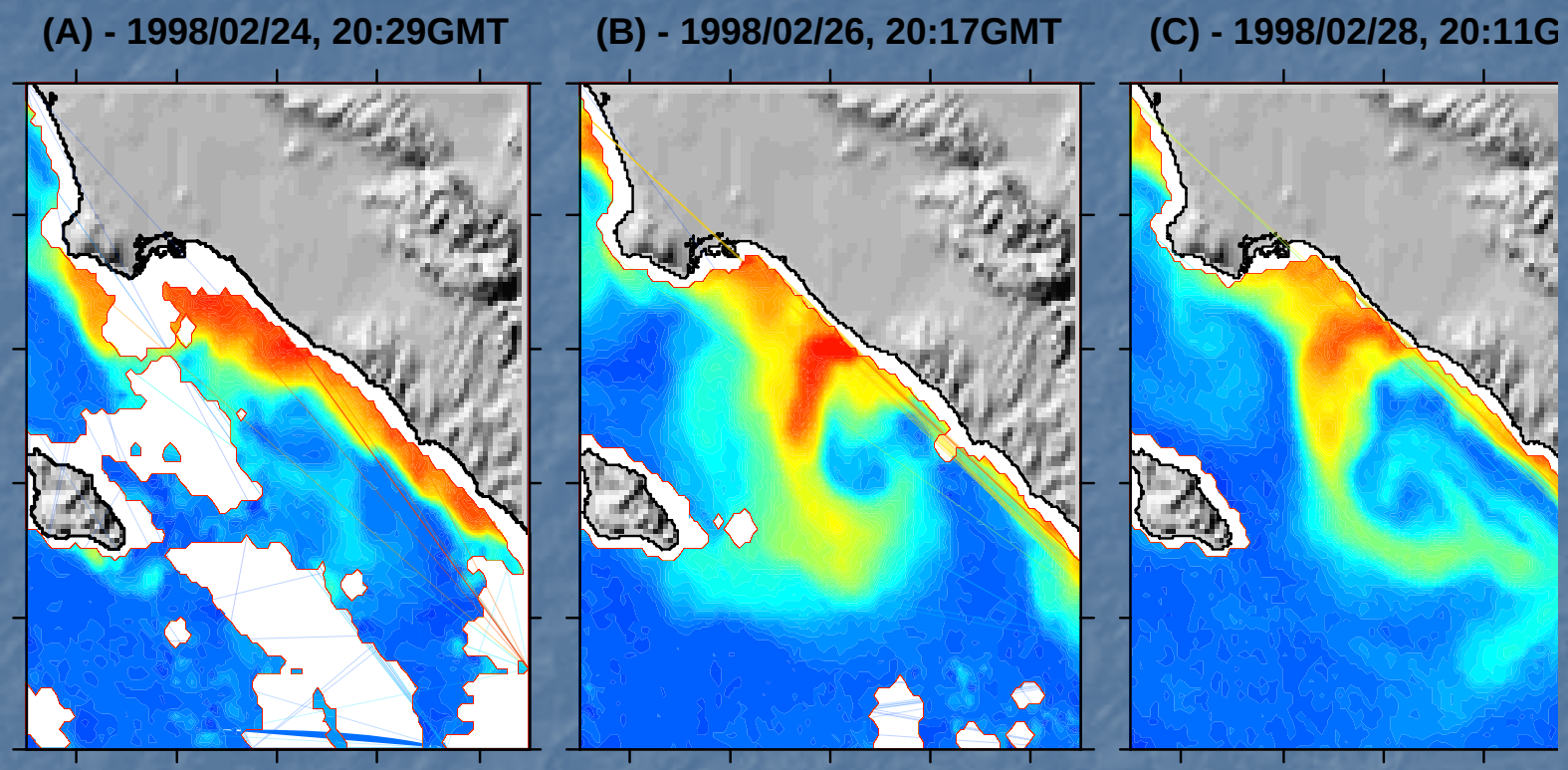


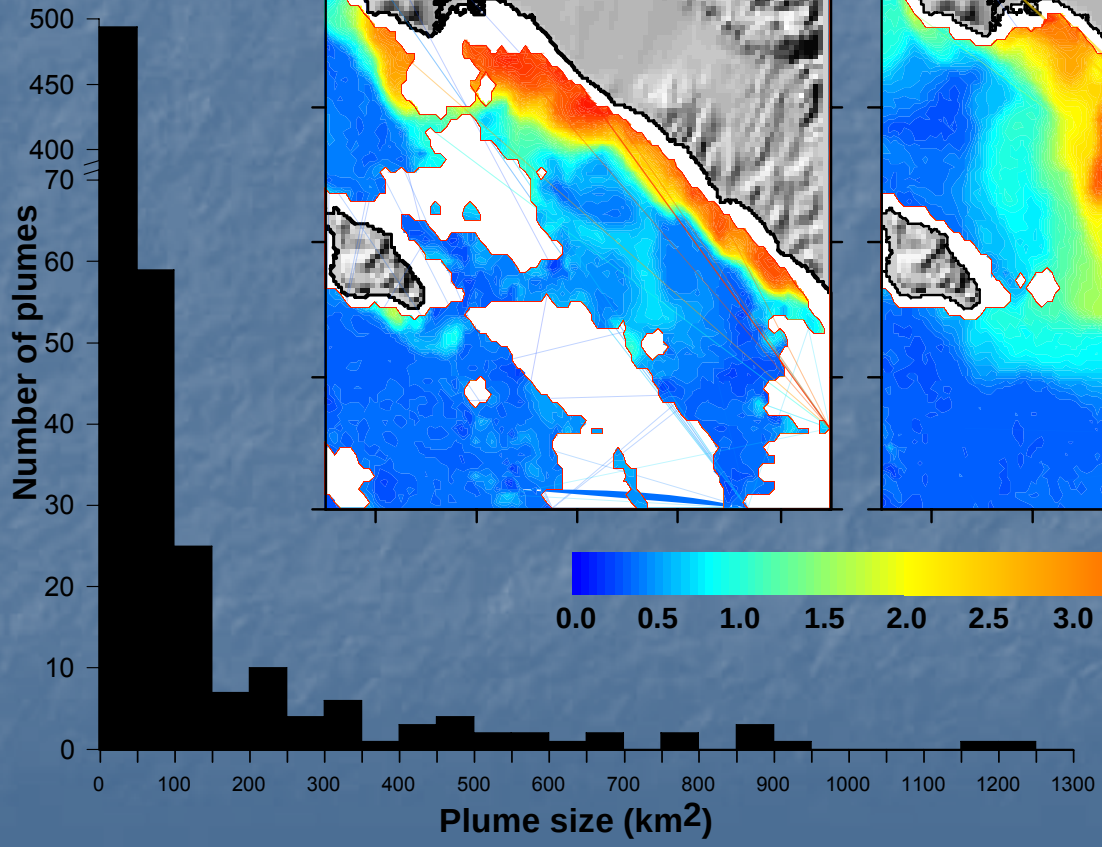
ERS-1 SAR, 28 Dec. 1992

- SAR image 11 hours after discharge peak



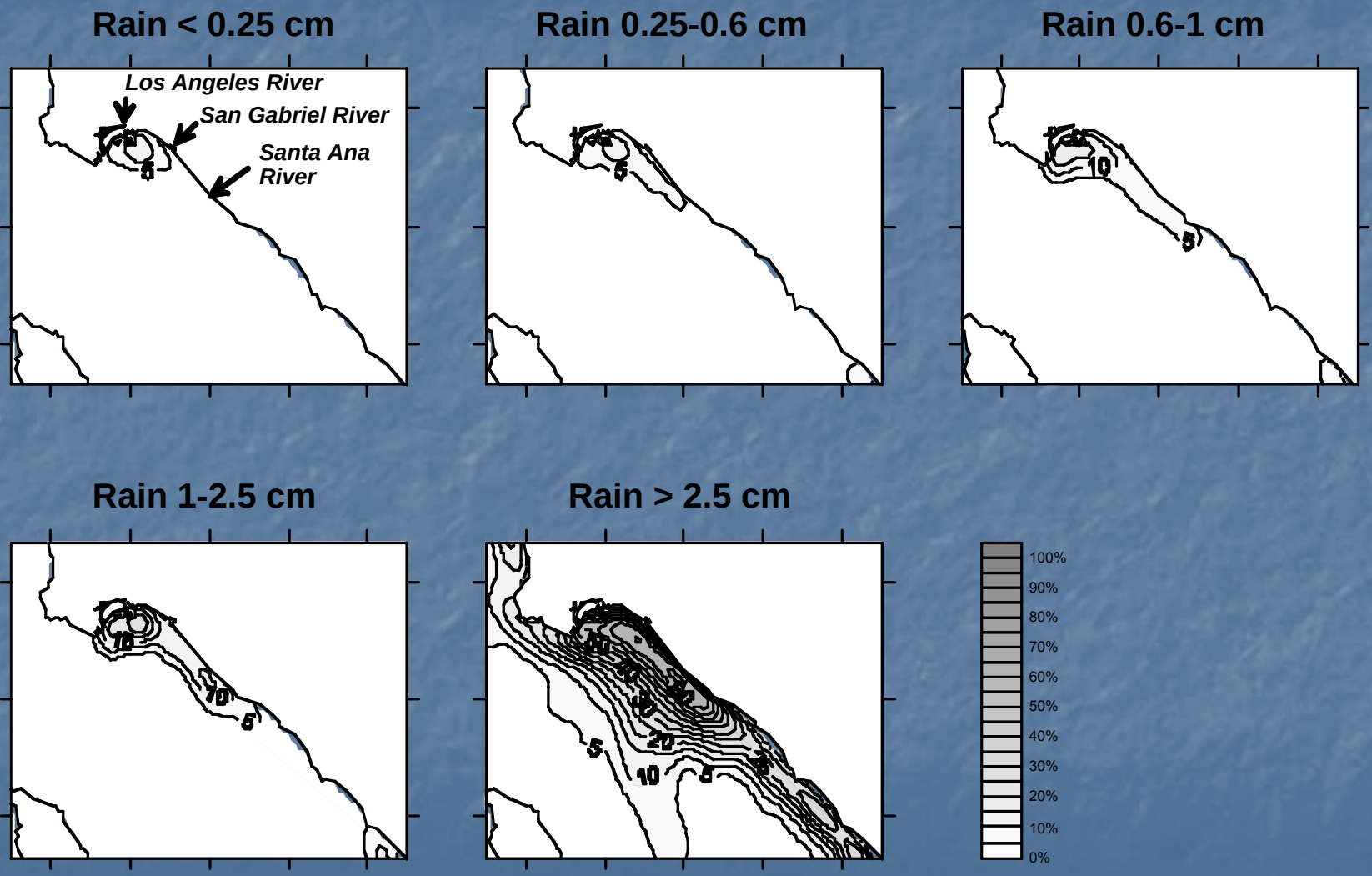
SeaWiFS ocean color imagery of stormwater runoff plumes off San Pedro Shelf, CA





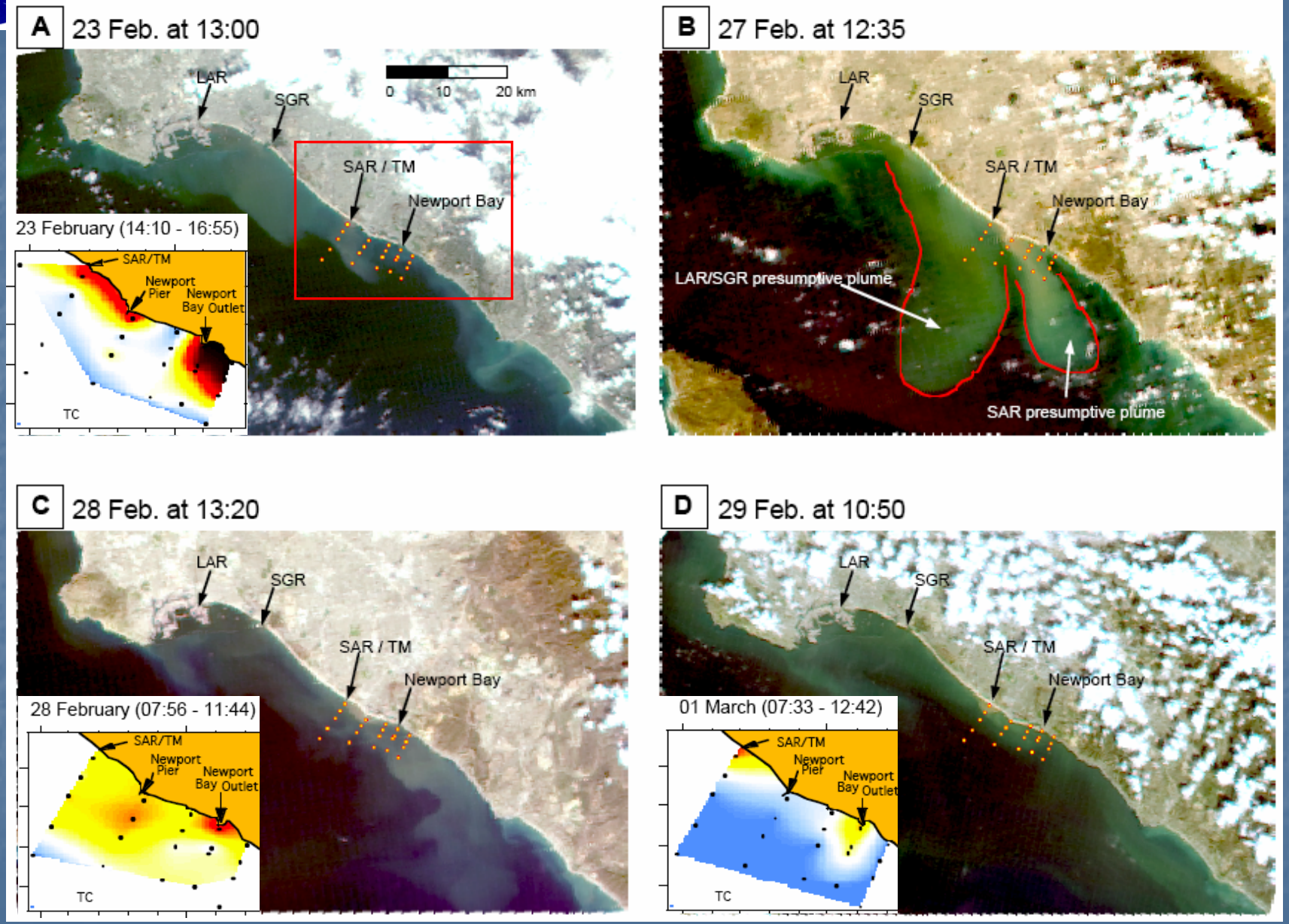
Nezlin and DiGiacomo, In Press, Continental Shelf Research

Stormwater plume distribution via satellite ocean color (1997-2004) relative to rain amount



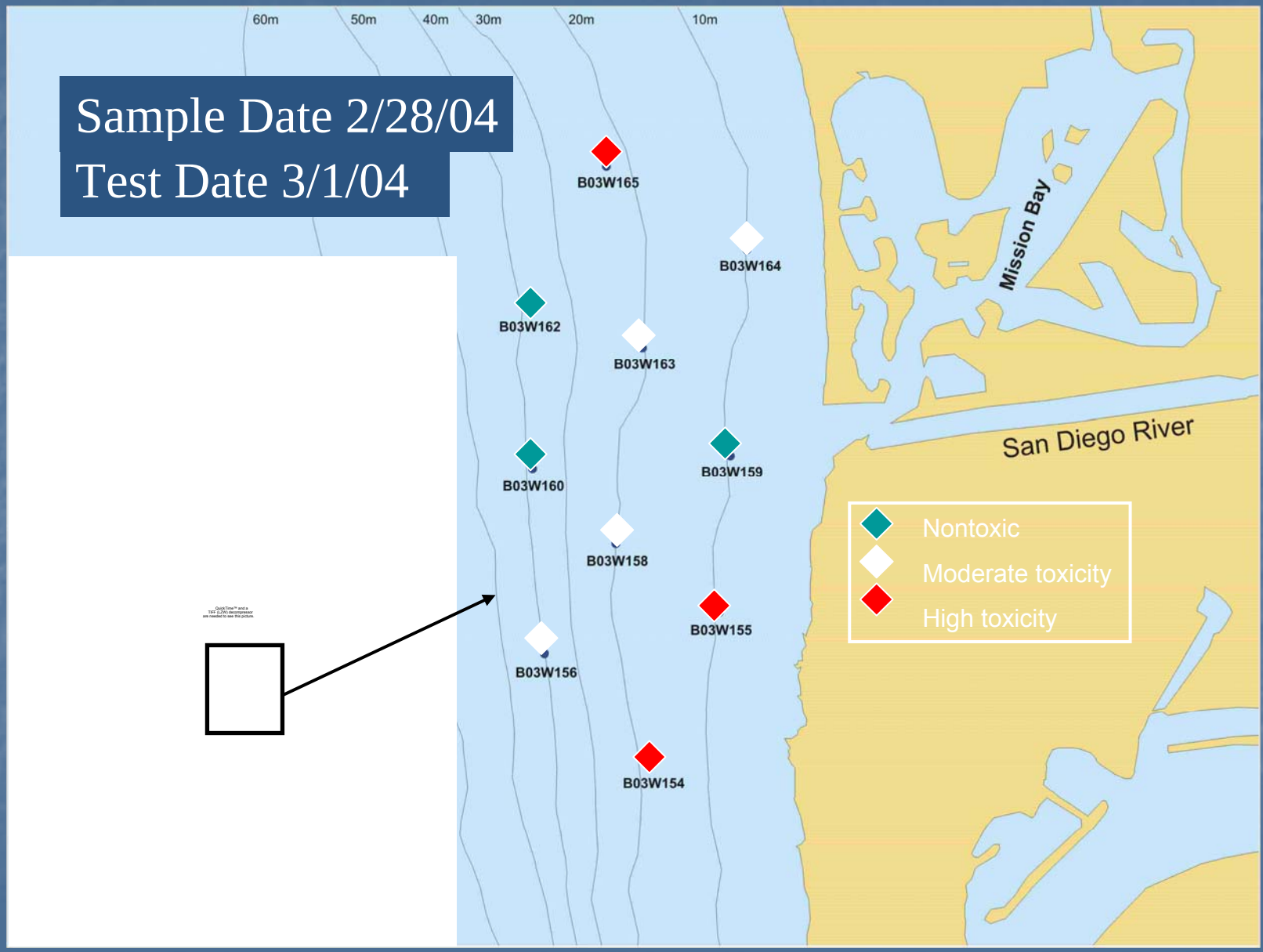
Nezlin, DiGiacomo, Stein, & Ackerman; Submitted: Remote Sensing of Environment

MODIS true color imagery of stormwater runoff plumes

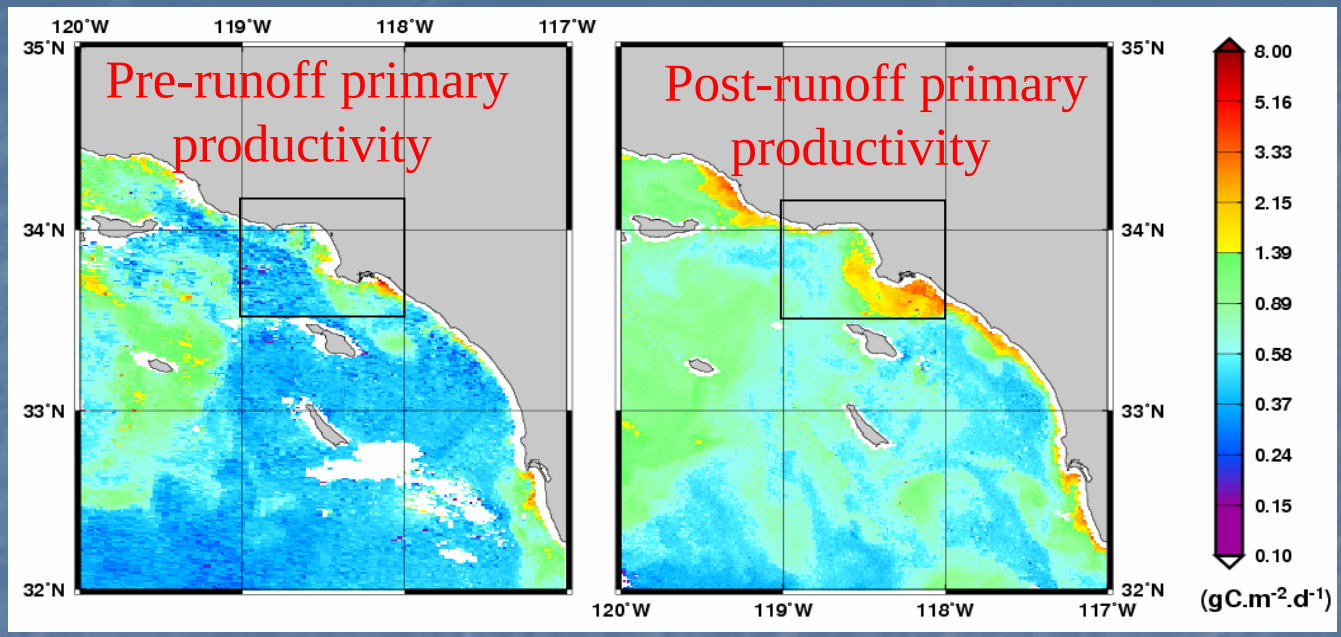


Ahn, Grant, Surbeck, DiGiacomo, Nezlin, Jiang, in press, Environmental Science and Technology

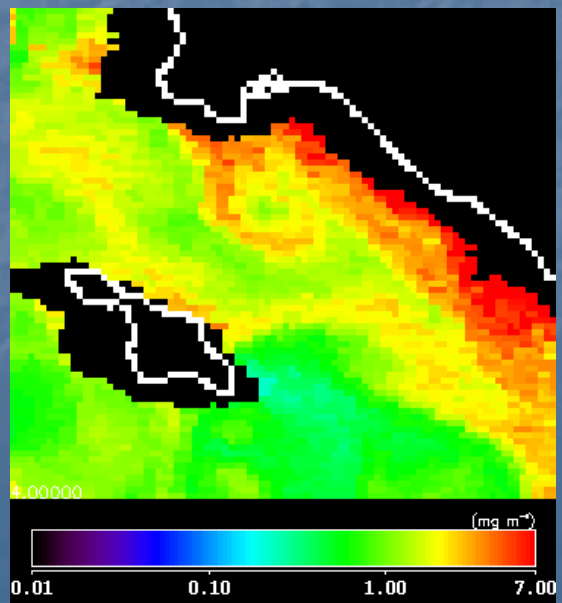
Runoff Plumes and toxicity off San Diego River, CA



Biogeochemical and Ecological Impacts of Stormwater Runoff off S. California



Primary-productivity composites (using 1 km SeaWiFS and AVHRR data); before and after a winter storm event. Mean primary productivity in the boxed region was **82% higher** in the right panel.

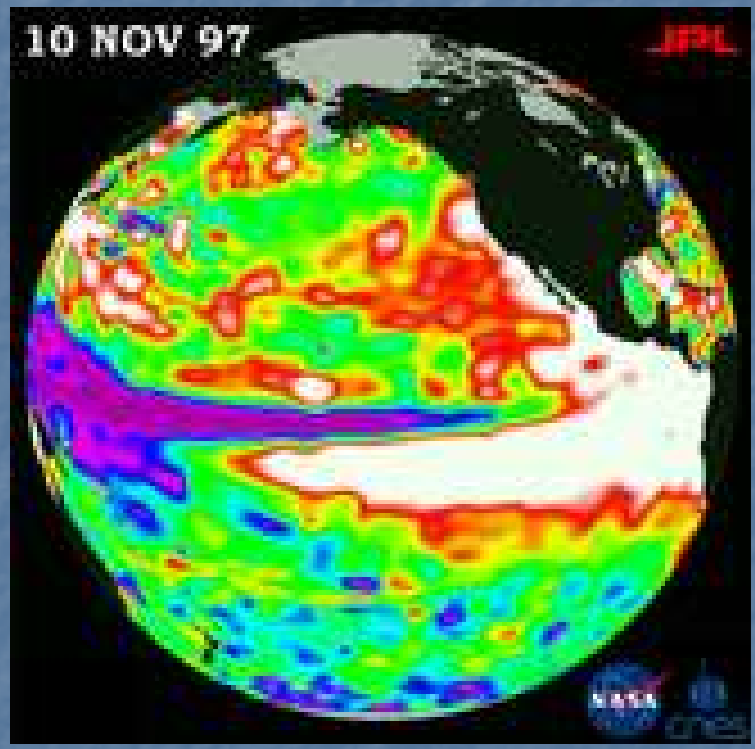


SeaWiFS chlorophyll-a image 6 days after winter storm event potentially revealing a ***Pseudo-nitzschia*** **bloom**. Also note cyclonic eddy transporting shelf waters offshore.

Benefits of Remote Sensing

- Synoptic coverage
- Potential global sampling
- Frequent Temporal Repeats
- Consistent measurements

NASA/CNES TOPEX-Poseidon



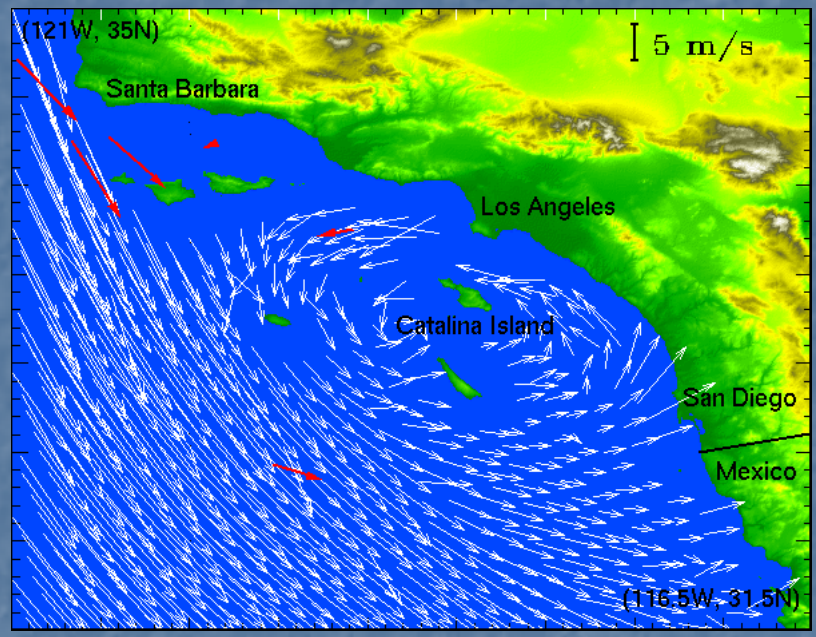
Sea level height anomaly during
1997-1998 El Nino

(Courtesy: http://visibleearth.nasa.gov/)

Drawbacks of Remote Sensing

- Spatial resolution (=>satellite)
- Temporal revisits often inadequate (esp. w/cloud cover, tidal aliasing)
- Limited parameters
- Accuracy
- Primarily limited to surface

NASA QuikSCAT Winds, March 13 2000



Surface Wind Circulation of Catalina Eddy

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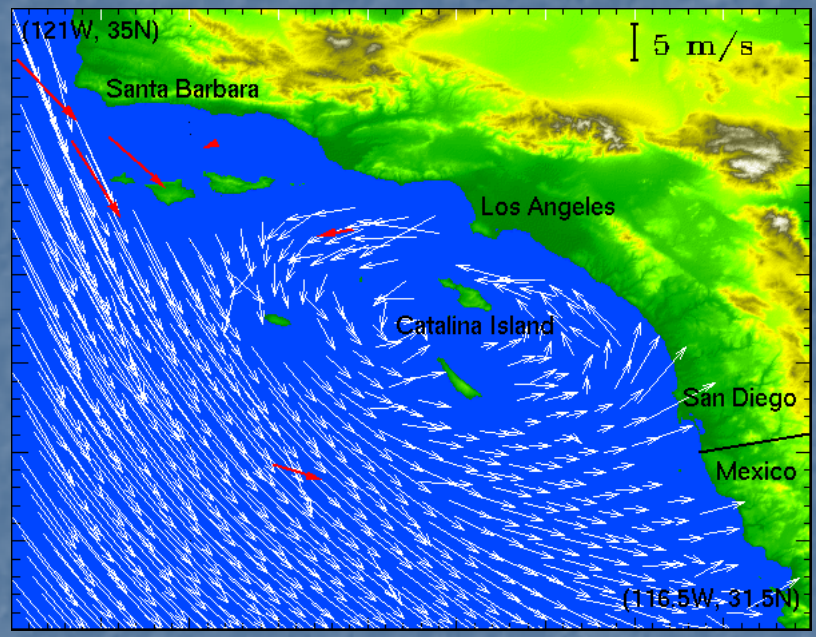

Surface Wind Circulation of Catalina Eddy

- DATA ≠ information - need to create derived information products in support of user needs.

Priorities for enhancing utility of remote sensing in coastal regions

- Ensuring availability and continuity of suitable (e.g, adequate spatial, temporal, and spectral resolution) observations for coastal research and applications

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- Integrating observations (e.g., terrestrial and aquatic; RS & in situ; natural and socio-economic) and developing tools and techniques (e.g., models, GIS) to generate and deliver information products for improved decision support and coastal management

Coastal Theme of the Integrated Global Observing Strategy

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Overview of IGOS:

- A strategic planning process, consisting of 14 members that represent data providers and users, whose goal is to improve Earth observing capacity for decision-making

- For more details, please visit: http://ioc.unesco.org/igospartners/

Coastal Theme of the Integrated Global Observing Strategy

Goal of Coastal Theme:

Develop a strategy for integrated global observations that will provide improved understanding of earth system variability and change in the coastal zone, with a particular emphasis on the **land-sea-air interface**.

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Objectives of Coastal Theme:

- ***Specify*** coastal user information needs and observation requirements
- ***Evaluate*** existing/planned capabilities and identify gaps & continuity needs
- ***Establish*** a framework to integrate observations across the land-sea-air interface in support of coastal research and improved coastal management
- ***Stimulate & facilitate*** coordination & collaboration among diverse groups/organizations

Coastal Theme Co-Chairs: Paul DiGiacomo (JPL) & Liana McManus (UM)

The following priority issues have been identified for the IGOS Coastal Theme:

Coastal Human Populations, including coastal hazards and coastal development and urbanization *(~ LOICZ Themes 1 & 3*)

Coastal Ecosystems, including the hydrological and biogeochemical cycles, and ecosystem health and productivity. *(~ LOICZ Themes 2 & 4*)

The following priority issues have been identified for the IGOS Coastal Theme:

Coastal Human Populations, including coastal hazards and coastal development and urbanization

Coastal Ecosystems, including the hydrological and biogeochemical cycles, and ecosystem health and productivity.

Targeted User Groups:

- Regional & global environmental assessments, agencies, accords & conventions
- Advisory & regulatory agencies
- National governments
- Research communities
- Commercial organizations

Expected Benefits of IGOS Coastal Theme

- **Identify** gaps in observations and reduce unnecessary duplication
- **Strengthen** the linkage between *in situ* and space-based observations, integrated with watershed-ocean models, for coastal research and management applications
- **Stimulate** building of long-term coastal data sets
- **Facilitate** the integration and implementation of the coastal components of GOOS and GTOS, particularly working with space agencies to ensure development and continuity of necessary observations
- **Establish** priorities for research & development projects to improve the operational elements of observing systems and other programmes
- **Support** user needs through improved products and services
- **Cross-cutting** links with other IGOS themes as well as the emerging GEO effort

Observing Requirements for IGOS Coastal Theme:

Geophysical:

ocean winds, waves, sea surface height, currents, salinity, temperature, discharge, precipitation, ice cover;

Biological and Biogeochemical:

pigments, nutrients, particulate and dissolved matter, aerosol properties, slicks and spills, fluorescence, optical properties, O_2 and pCO_2;

Mapping (Physical, Ecological, and Socio-Economic):

topography, bathymetry, shoreline position & use, high/low tide lines, habitat types and condition, land cover/use, reef maps, coastal population assessments/demographics.

Coastal Observing Challenges

Observation	Knowledge Challenges	Resolution Challenges	Continuity Challenges
Geophysical	▪ Blending SST data streams ▪ Measuring salinity remotely ▪ Improve SSH measurements ▪ Measure currents from space ▪ Assimilate HF radar data and derive user products ▪ Develop SAR algorithms & assess other measurements	▪ Extracting higher resolution info from satellite wind sensors ▪ Add additional Doppler weather radar & HF radar sites	▪ Maintain and expand stream & tide gauge networks ▪ Maintain microwave RS capabilities for ice ▪ facilitate HF radar transition: research to operational mode
Biological & Biogeo-chemical	▪ Hyperspectral ocean color ▪ Improve bio-optical algorithms ▪ Merged chlorophyll products ▪ Ocean color/ SAR data relationships with ecology ▪ Taxonomic discrimination ▪ Improve aerosol characterization	▪ Need ocean color observations from geostationary orbit ▪ more nutrient measurements ▪ Rapid & accurate pollutant assays	▪ Maintain global multi-spectral ocean color observations for context and climate data records

Coastal Observing Challenges

Observations	Knowledge Challenges	Resolution Challenges	Continuity Challenges
Mapping	▪ Need a common habitat classification system ▪ Spatially explicit socio-economic variables	▪ Require high spatial res. hyperspectral imagery for corals and vegetation ▪ Improve availability and use of high-res. color and lidar data for physical mapping ▪ Access to highest res. DEMs	▪Maintain DMSP-OLS for human population assessments ▪ Maintain high-res. multispectral optical imagers for habitat maps
CROSS CUTTING	▪ Satellite CAL/VAL ▪ Standardize & QA/QC in situ obs ▪ Adaptive sampling ▪ Power/telemetry/ biofouling issues	▪ require improved temporal & spatial resolution from satellite sensors ▪ Expand coverage of in situ measurements	▪ Need to facilitate transition from research to operational satellites ▪ Need to maintain and replace in situ assets

Recommended Space Agency Observing Priorities for Coastal Areas

- **PROVIDE**
  - high frequency, hyperspectral ocean color observations of coastal areas
  - synoptic observations of coastal currents and salinity
  - higher resolution/improved coverage for ocean vector winds & SSH
  - high spatial and spectral resolution capacity to assess coral reef community changes & terrestrial vegetation assessments
- **IMPROVE**
  - calibration/validation of measurements in coastal regions
  - data management infrastructure (near-real time delivery; climate data records)
- **SUPPORT** development of a Coastal Data Assimilation System (**CODAS**)
- **FACILITATE** international efforts to blend high-resolution multi-sensor data products
- **ENSURE** access to highest resolution DEM as soon as possible

COCOA: Coastal Ocean Carbon Observations & Applications

- **COCOA** is a geostationary hyperspectral coastal carbon mission concept to be proposed as a NASA Earth System Science Pathfinder (ESSP) mission.

- **COCOA** will quantify the carbon pools and pathways of the coastal ocean, a crucial need identified in the Ocean Carbon and Climate Change (OCCC) Implementation Strategy, 2004.

- By intensively focusing on North America, **COCOA** will target representative coastal processes that impact the *global* carbon cycle:

  - Eastern Boundary Current coastal upwelling systems
  - Western Boundary Current (Gulf Stream)
  - Major riverine inputs (Mississippi River)
  - Episodic features (**hurricanes, harmful algal blooms, plumes**)

- The COCOA PI is Prof. Janet Campbell of University of New Hampshire.

Integration Challenges	Integration Strategies
Communication: Biases in disciplines & applications	▪ **Interdisciplinary** training programs/workshops > Prioritizing interdisciplinary observation products
Data Access & Management ▪ What data is available? ▪ Data sharing across national boundaries ▪ Fully "dry" land & Fully "wet" ocean data/models; separation of remote and *in situ* data	▪ **Coordinated** cataloguing, archiving & distribution of current and historical coastal datasets & metadata; potentially leveraging the GTOS-TEMS database ▪ **Improve Data Management Infrastructure** to store, (re)process and disseminate expanding data streams, incl. (near) real-time & climate data records ▪ **Modeling & data assimilation => *CODAS***
Unique Challenges ▪ Mapping the coast ▪ Scale dependent attributes ▪ People at coastal interface	▪ **Tidal monitoring, hydrodynamic models + vertical datum transformation tool** ▪ **Long term time series and data continuity** ▪ **Data integration** > Land & sea; humans & ecosystem **=> *Coastal GIS***

Key Coastal Theme highlights and upcoming activities:

- *June 2003*: Approval of Coastal Theme Development at IGOS-P-10
- *November 2004*: Approval of Coastal Theme Report at IGOS-P-11bis
- *Summer 2005*: Publication of Coastal Theme Report by IOC
- *Fall 2005+*: Coastal Theme implementation, including development of prototype efforts and pilot projects
- *2006-7*: Coastal Theme workshops, product/capability development and capacity building

Coastal Theme Prototype Development Efforts w/Focus on *Data Assimilation*

Prototype Effort #1:

Coastal Development and Urbanization, Human Health and Ecosystem Health: Assessing global patterns of impacts from nutrient and pollutant/pathogen loadings.

Goals:

1. Assessment and projection of regional and global drivers, pressures, biogeophysical and socioeconomic impacts and responses;
2. Quantitative assessment, analysis and prediction of the impacts and interactions among these local and global pressures and responses in coastal biogeophysical and socioeconomic systems, supporting evaluation of alternative development scenarios for local and regional planning and coastal management at time scales of years to decades; and,
3. Short-term forecasting of ecological and health risks, at time and space scales suitable to support short-term operational management responses, e.g. beach closures, aquaculture management, ballast water exchange.

Anticipated Partners: CEOS, C-GOOS, C-GTOS, LOICZ, WHO, et al.

IGOS Coastal Theme contributions/intersection with GEO effort

IGOS COASTAL THEME	GEOSS
USER ISSUES	Societal Benefit Areas
Coastal hazards	Disasters; Climate
Coastal development & urbanization	Human Health; Agriculture; Energy; Climate; Water
Ecosystem health & productivity	Ecosystems; Biodiversity
Hydrological & biogeochemical cycles	Water; Weather; Climate

IGOS Theme leaders recently tasked by GEO leadership to assist with the development of the 2006 GEOSS Workplan, particularly identifying linkages.

Future directions in coastal observations……

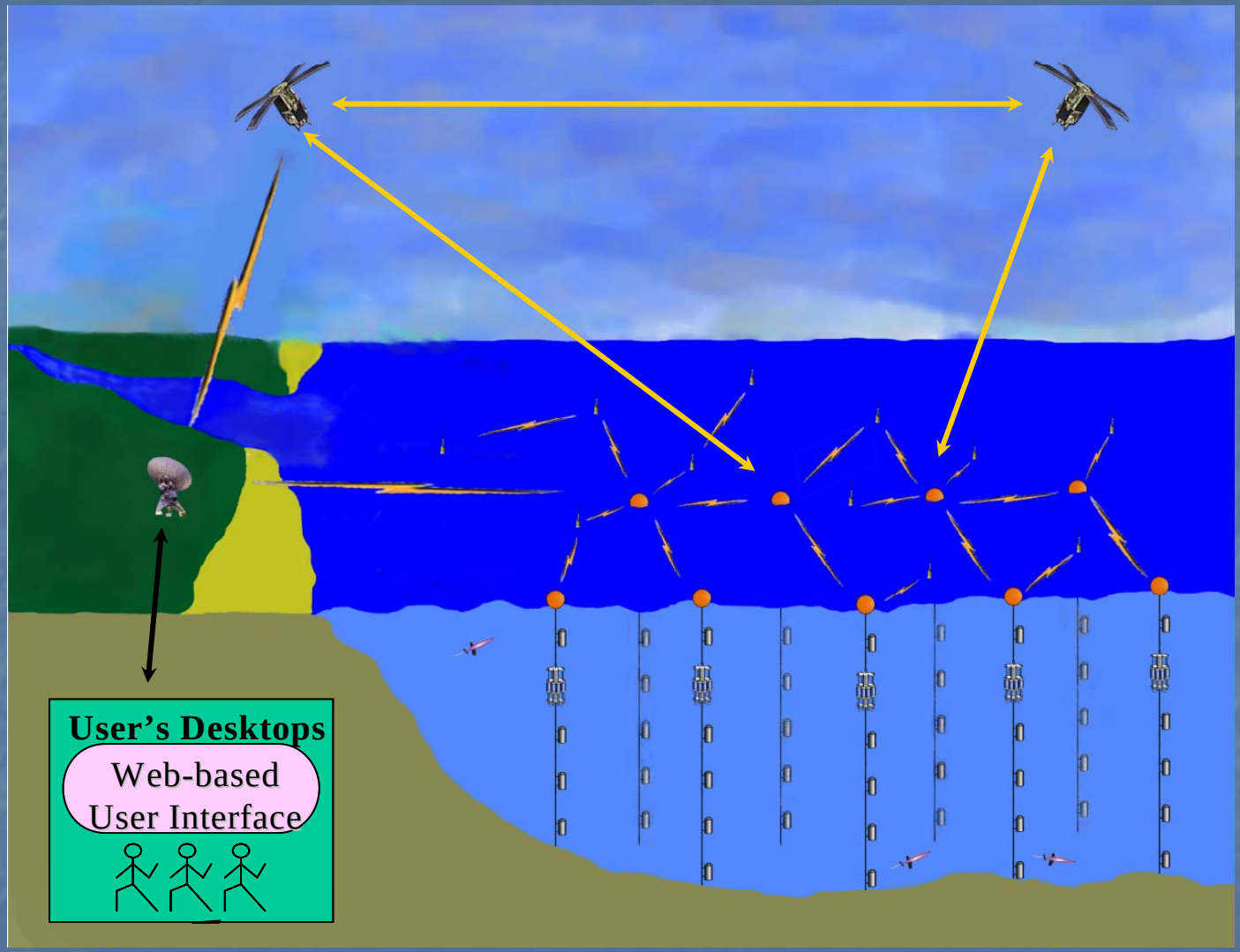
Toward "Continuous Awareness" of Coastal Regions

- In the context of the Global Earth Observing System of Systems (GEOSS), there is a need to develop the capability for "Continuous Awareness" of coastal regions towards real-time, integrated system-wide understanding of coastal processes, phenomena and human/ecosystem impacts.

- Toward this model, we need to pursue architecture and development of a *truly* integrated coastal observing system that might include:

  => Co-located active/passive instruments on single/multiple space-based platforms
  => A constellation of multiple space-based vantage points (e.g., GEO, MEO, LEO)
  => Multi-sensor/platform *in situ* observing networks of fixed and mobile assets (e.g., GOOS, NSF-ORION)
  => Sensorweb system approach integrating remote and *in situ* observing assets for event detection & response
  => Assimilation of observations for realistic nowcasting & forecasting

Continuous-Coastal Awareness Network



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More information:

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