Threatened River Delta Systems:

Connections between continental land mass and ocean

Kyle McDonald, on behalf of Charles J. Vörösmarty, Zach Tessler and *many colleagues*

the City College of New York
CUNY The City University of New York
Environmental CrossRoads Initiative
CUNY ADVANCED SCIENCE RESEARCH CENTER

NASA LCLUC Spring Science Team Meeting
Rockville, MD 2-4 April 2013

NASA Land-Use / Land Cover Program

Global-scale assessment of threatened river delta systems: Evaluation of connections between the continental land mass and ocean through integrated remote sensing and process modeling

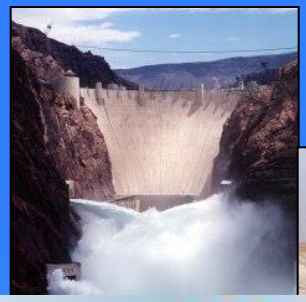
PIs, Senior Personnel and Staff

City College of New York (CUNY): Charles J. Vörösmarty (PI), Kyle McDonald, Balazs Fekete, Irina Gladkova, Michael Grossberg, Hansong Tang, Florian Lengyel

Baruch College (CUNY): Deborah Balk

University of Colorado (Boulder): James Syvitski, Albert Kettner, Sagy Cohen

Sanitation & access to clean water



"Engineered" water

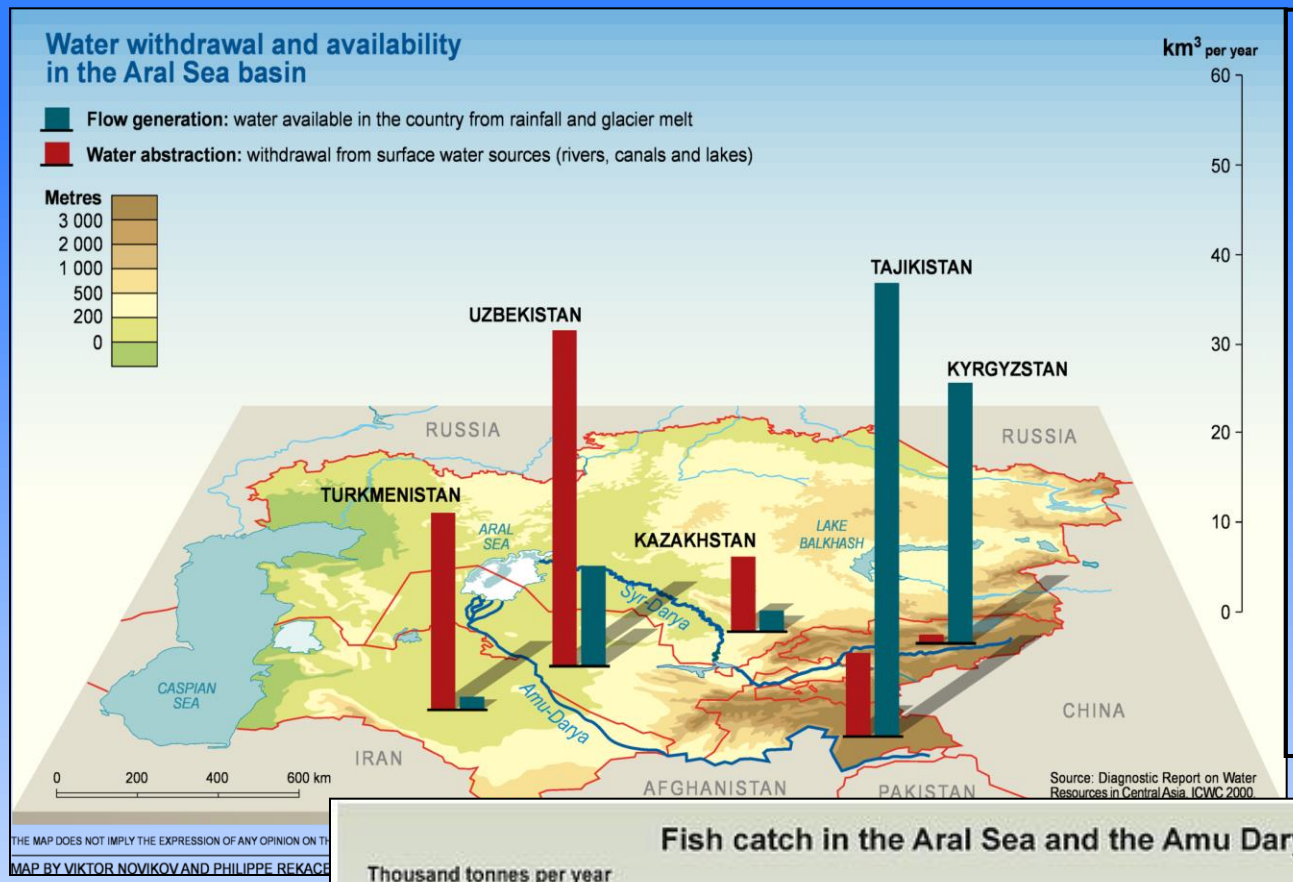
"Water…a profoundly local resource"
M. Muller (21 Sept.09)

for
ent

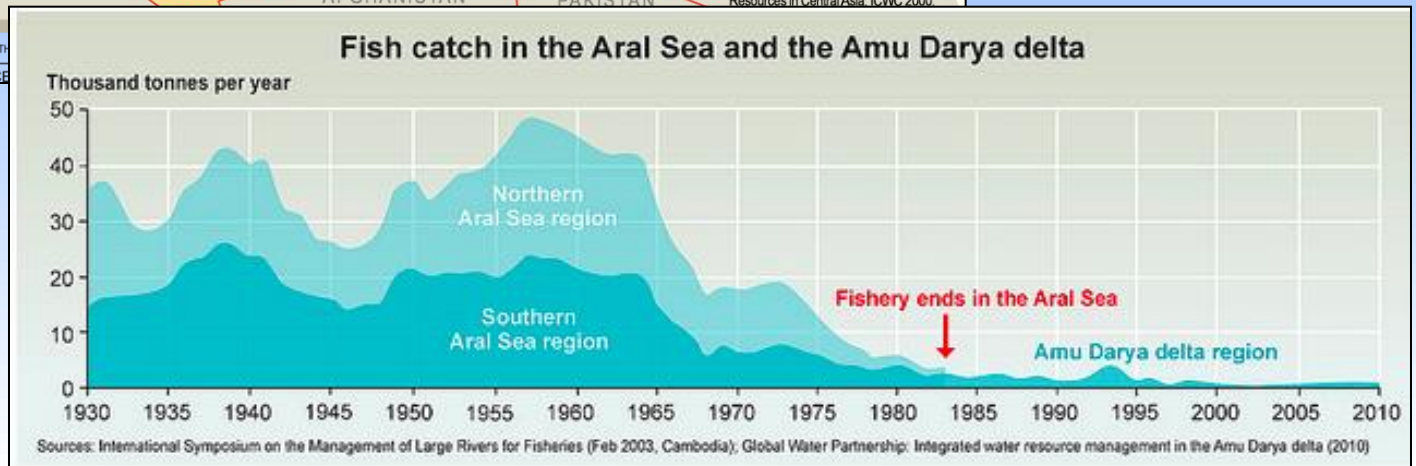
Climate change and its extremes

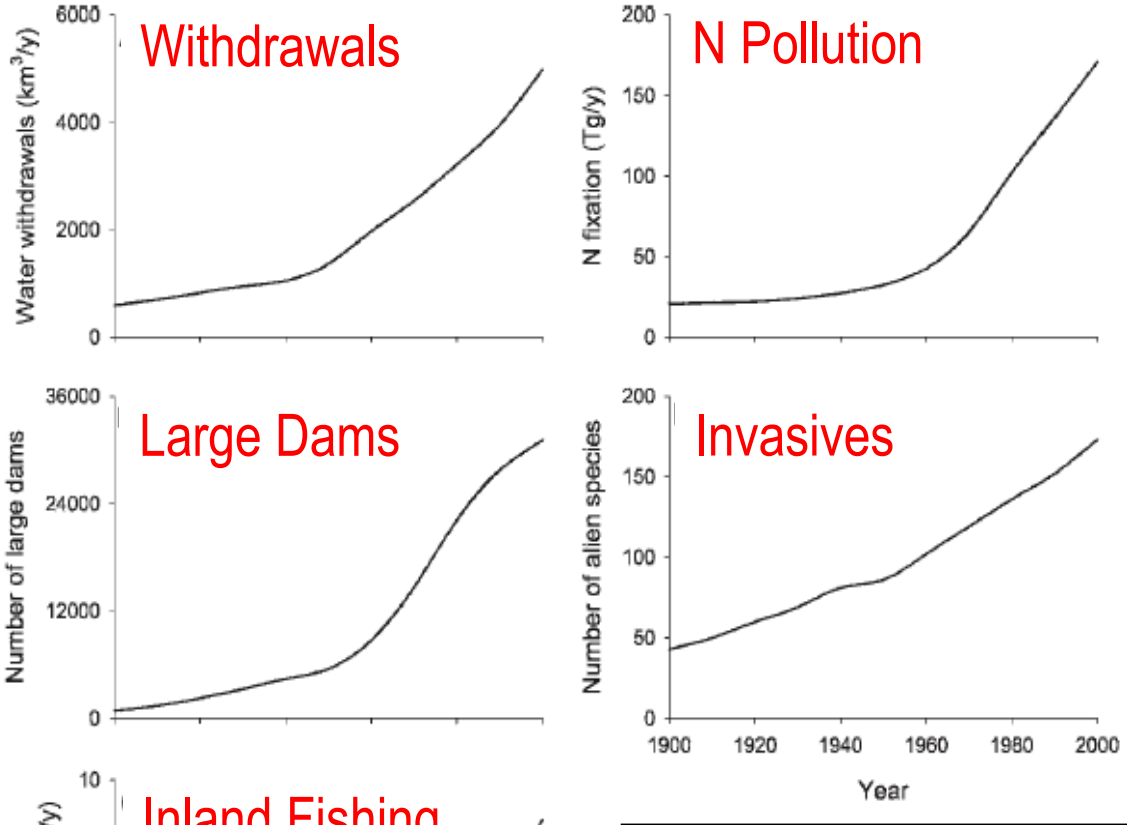
Ecosystem services

Local-Scale Problems "Scale-Up" to Basins and Regions
e.g., The Aral Sea Basin and Its Deltas



The quintessential story of how water, geopolitics, food security and ecosystem destruction conflict and collide within a regional basin context





Human Uses and Pressures on H_2O Global & Growing

From: Strayer and Dudgeon (2010), J-NABS

Nature: September 30 issue

Together, These Trends Paint a Picture of A Global Water System under Threat

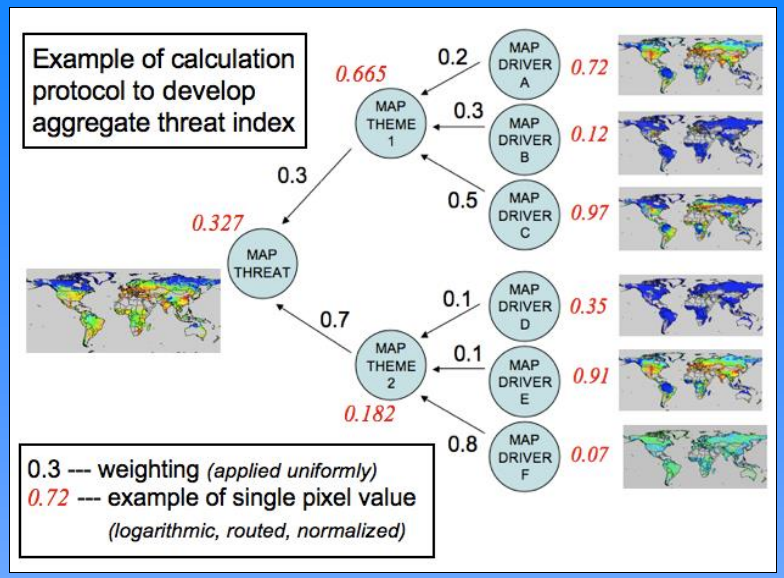
- *23 geospatial stressors*
- *4 categories w/ known impact*
  - --Watershed Management
  - --Water Resource Use
  - ---Pollutants
  - --Biotic factors
- *Analysis now on par w/ global climate change*

Visit: *www.riverthreat.net*

GWSP Global Water System Project

DIVERSITAS

Earth System Science Partnership



Calculation Strategy

- Conjoin classes of threat through consensus-based weightings (0-1)

$$T^k = \sum_{j=1}^{5} \sum_{i=1}^{N_j} W_j^k \omega_{j,i}^k D_i^k$$

- 4 ***Themes***
- 23 within-*Theme* ***Drivers***
- Threat routed through networks, normalized

THREAT TO FRESH WATER

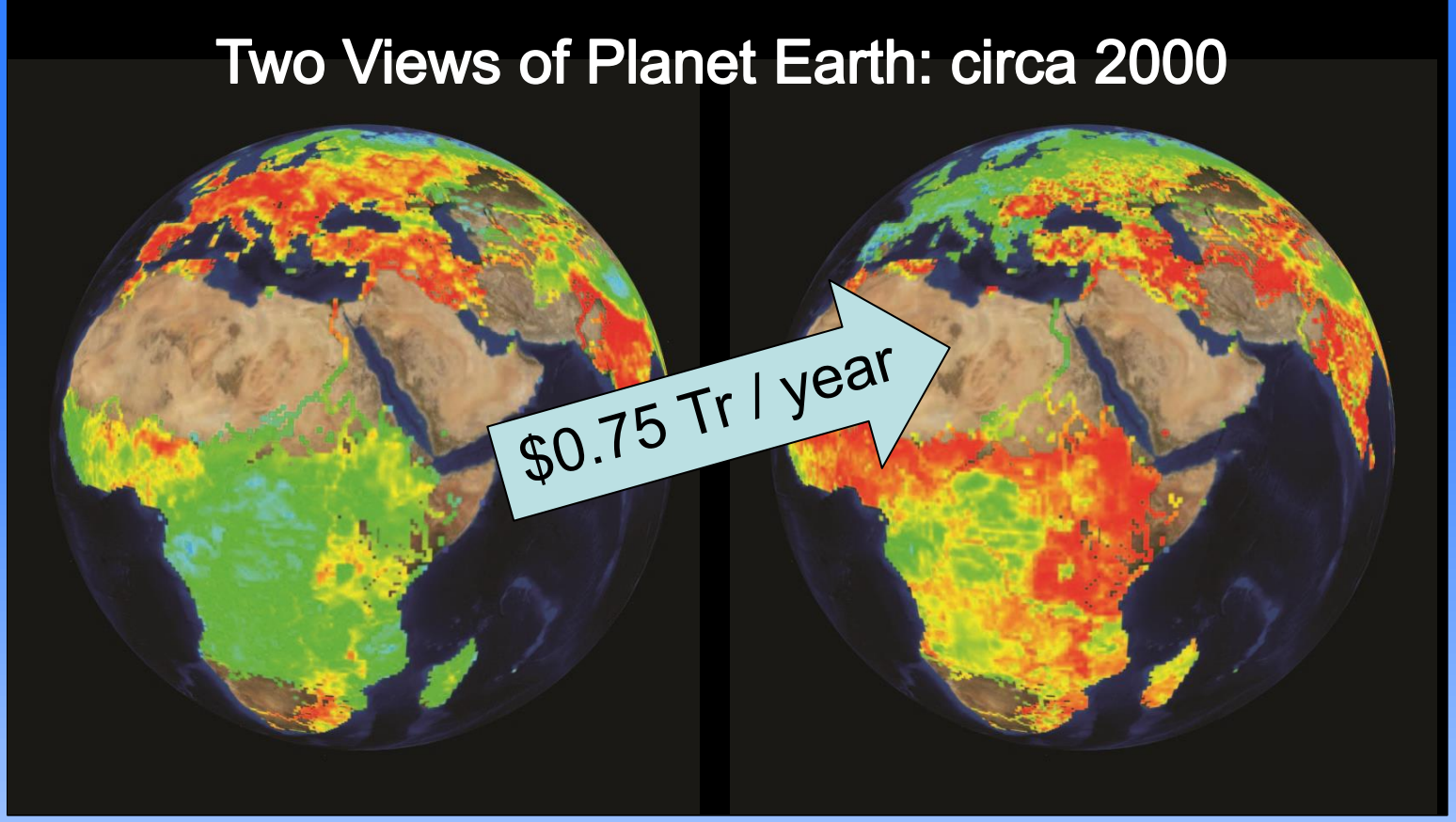
- Relative scoring
- Expert weightings
- Distinct perspectives for *Human Water Security* (*HWS*) and *Biodiversity (BD) Threat* (e.g. dams ⇧ for HWS but ⇩ for BD)
- Beneficiary investments in water-related infrastructure and services recognized for HWS*
  - -Flow stabilization
  - -Access to river corridors
  - -Clean drinking water

**Likely to be in the Trillions of USD*

GWSP Global Water System Project

DIVERSITAS

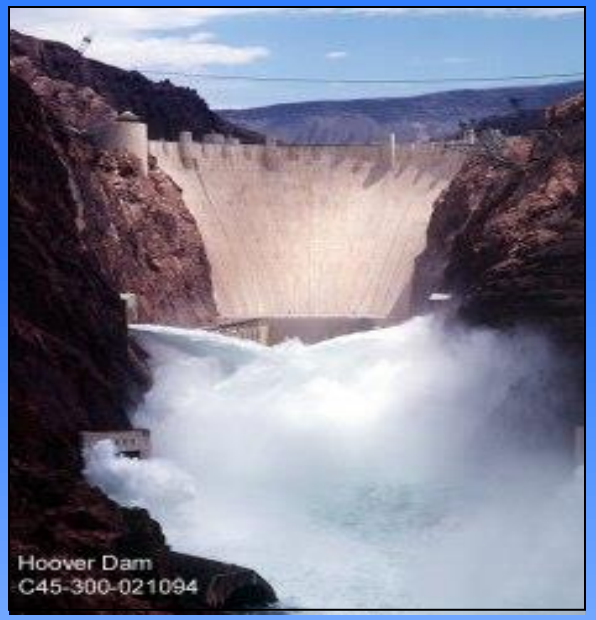
Two Views of Planet Earth: circa 2000



"Impair-then-Repair"

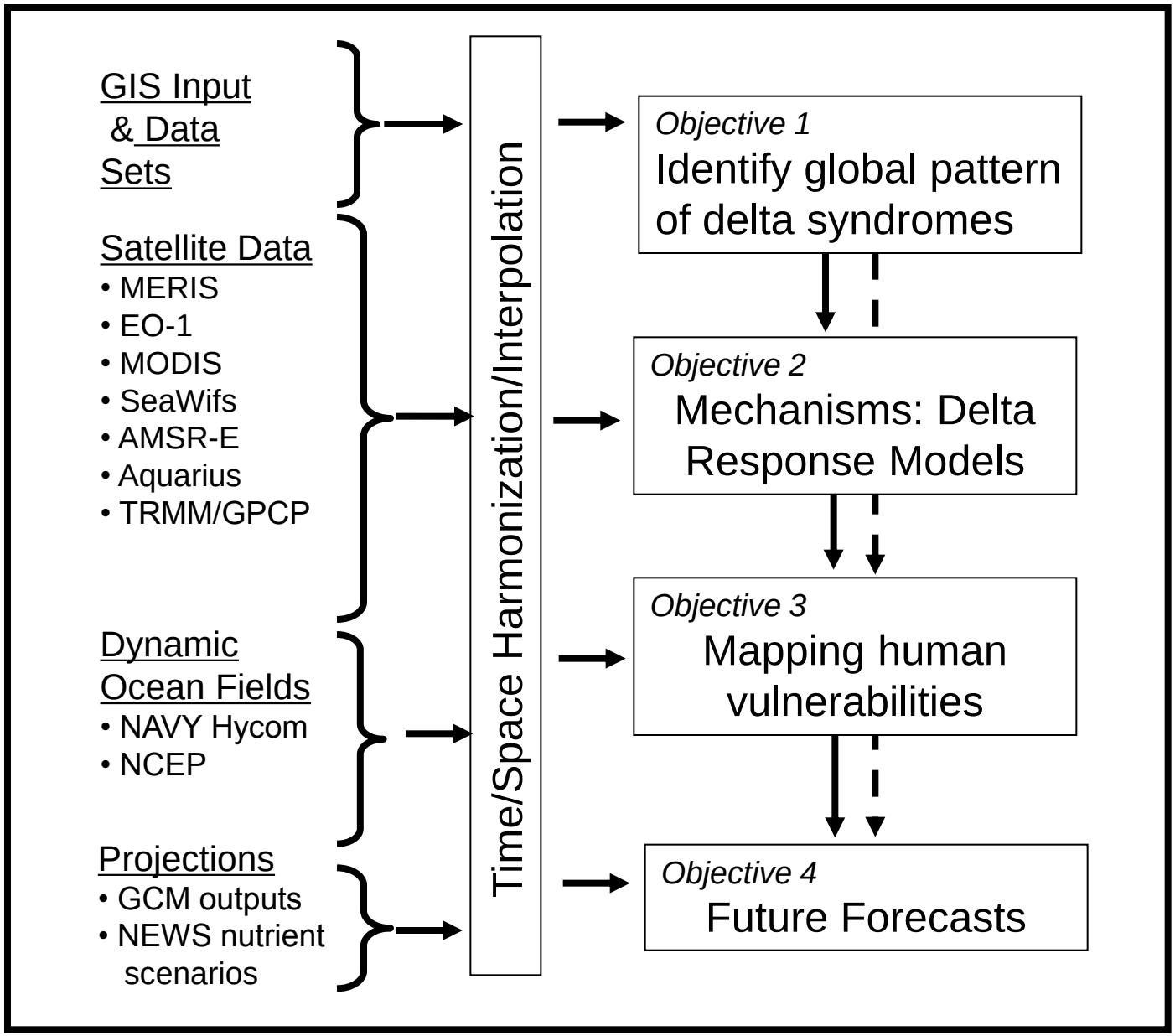
More People, More Development, More Water Stress Means More Water Engineering

- Widespread hydrological alterations arising from
  - *Irrigation*
  - *Dams and Reservoirs*
  - *Interbasin Transfer/Flow Diversion*
- Benefits & concerns: Among these are resource asymmetries in int'l basins
- These are costly "supply-side" or "hard path" solutions to water scarcity



Science Goal

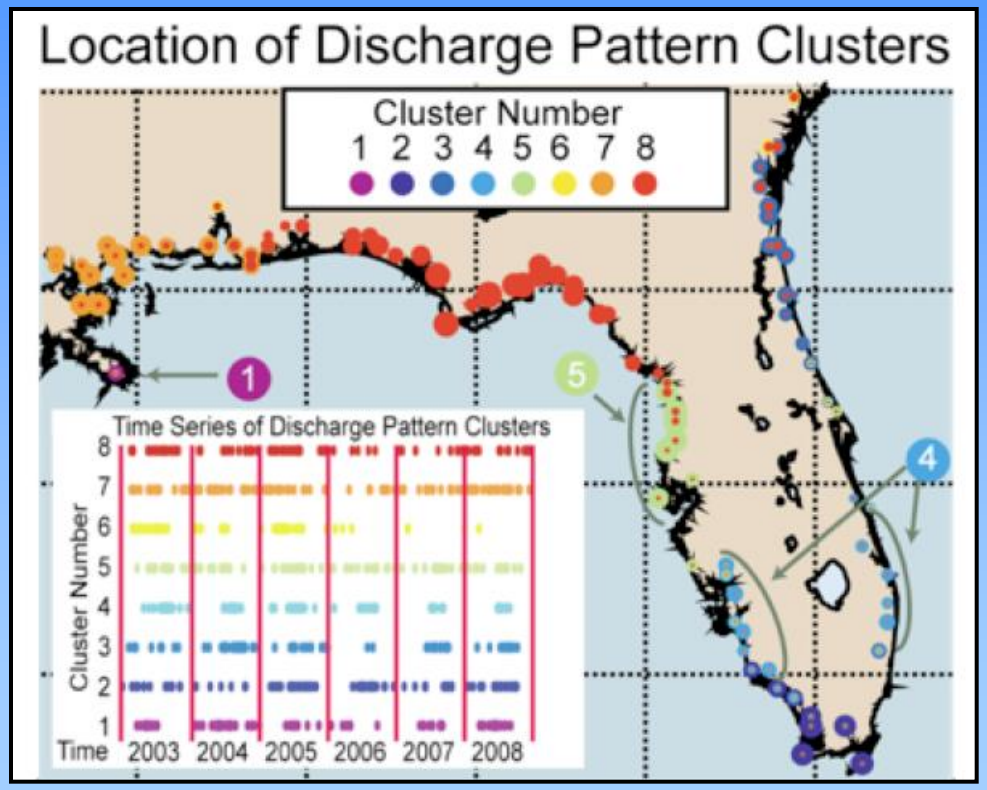
- To analyze how the strength and variability of land-to-ocean links, as defined by riverine sediment fluxes, local anthropogenic activities, and ocean processes, produce impacts on coastal delta systems, today and into the future


GIS Input & Data Sets
Satellite Data
• MERIS
• EO-1
• MODIS
• SeaWifs
• AMSR-E
• Aquarius
• TRMM/GPCP
Dynamic Ocean Fields
• NAVY Hycom
• NCEP
Projections
• GCM outputs
• NEWS nutrient scenarios
Time/Space Harmonization/Interpolation
Objective 1
Identify global pattern of delta syndromes
Objective 2
Mechanisms: Delta Response Models
Objective 3
Mapping human vulnerabilities
Objective 4
Future Forecasts

Objective 1

Identify global pattern of delta syndromes

--a global, synoptic fingerprinting system to detect space & time variations and hotspots in land-delta-ocean links



Remote Sensing Datasets

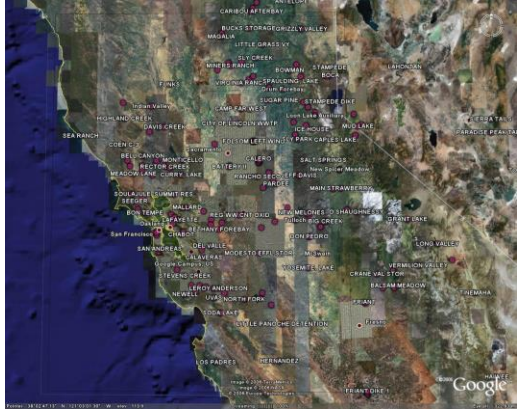
Table 2. Satellite products and ocean physical variables. A collection of similar scope (not shown) is available for land mass flux studies

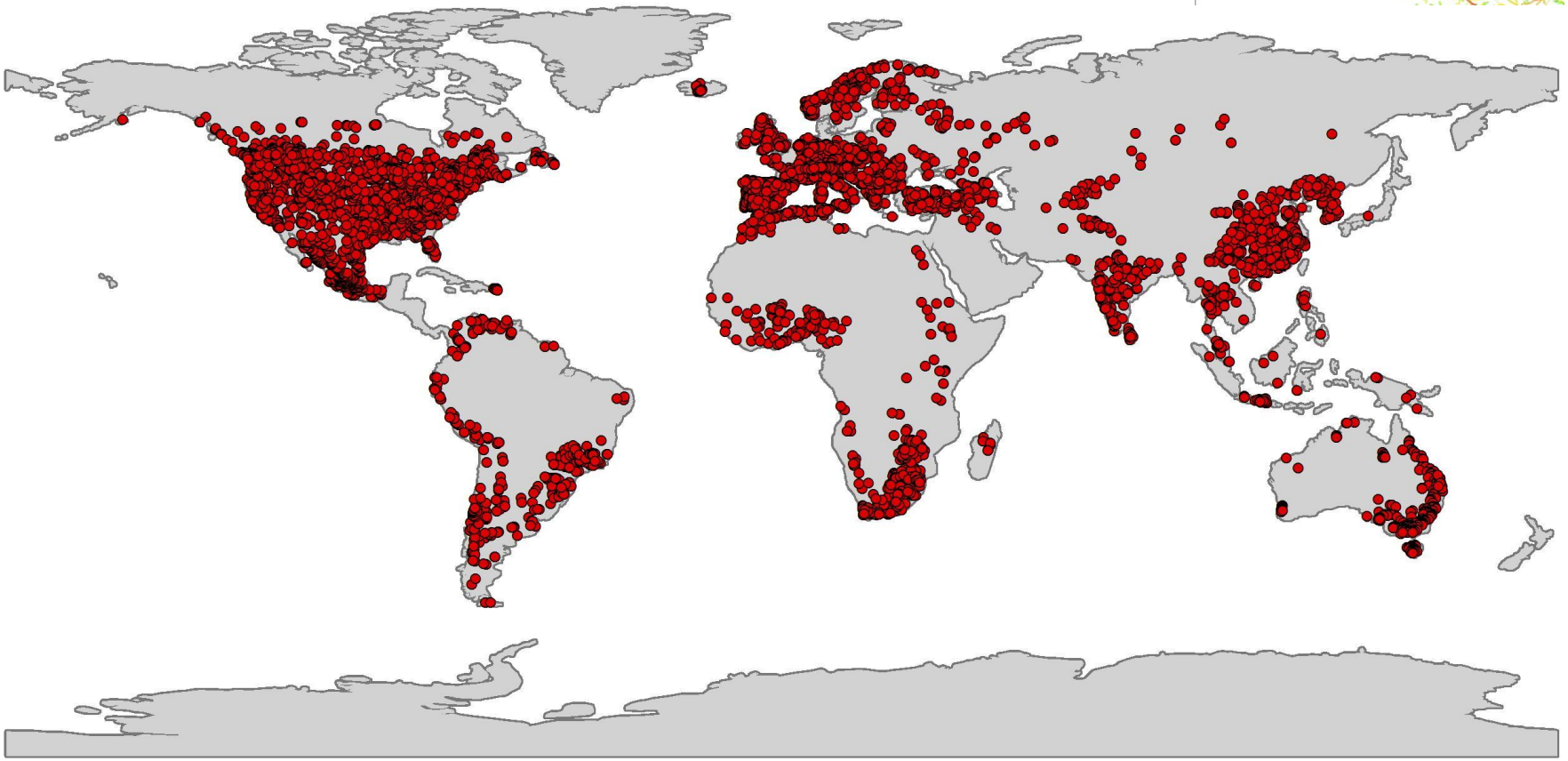
Product	Temporal Resolution	Spatial Resolution	Global	Source
T,S,currents with depth	6 hr	0.25°	Y	NAVY HYCOM
T.S.currents with depth	6 hr	~5km minimum	N	ROMS - this study
surface wind vector and met data	6 hr	0.25°	Y	NCEP
Surface wind vector	Daily	12 km/25 km	N/Y	QuikSCAT and/or blended wind products
Ocean gravity wave field data	6 hr	0.50°	Y	NOAA Wavewatch III
Sea surface temperature	Daily	9 km	Y	GHRSST - MWOI satellite blend from RSS
Satellite sea surface salinity	Daily/ monthly	9 - 150 km	N; limited by latitude	This proposal w/ AMSR-E, MODIS, Aquarius and SMOS
Ocean color suite: Chla, Kd, cdm, flh, PAR, bbp	Daily	9 km	Y	MODIS, OCTS, SeaWiFS, MERIS and this proposal
Bathymetry	n/a	0.016°	Y	NGDC-DEM

…but many others

Global Reservoir and Dam (GRanD) Database

Currently ~ 6600 dam locations referenced to SWBD polygons and HydroSHEDS river network

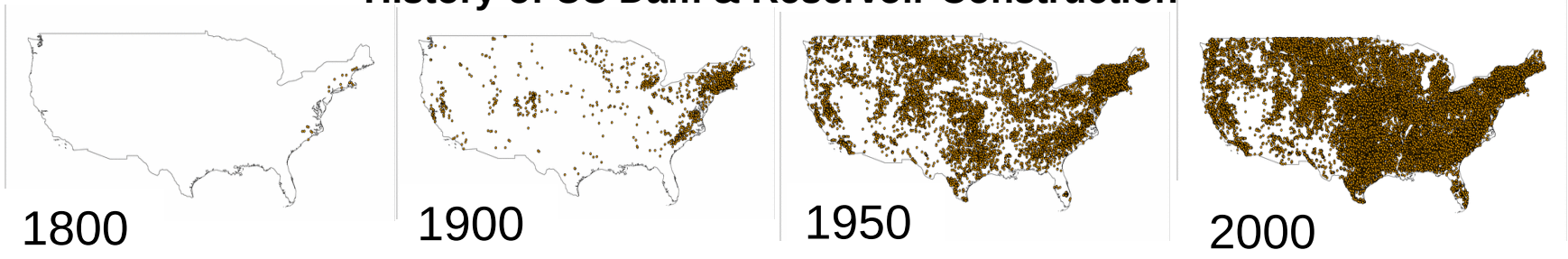


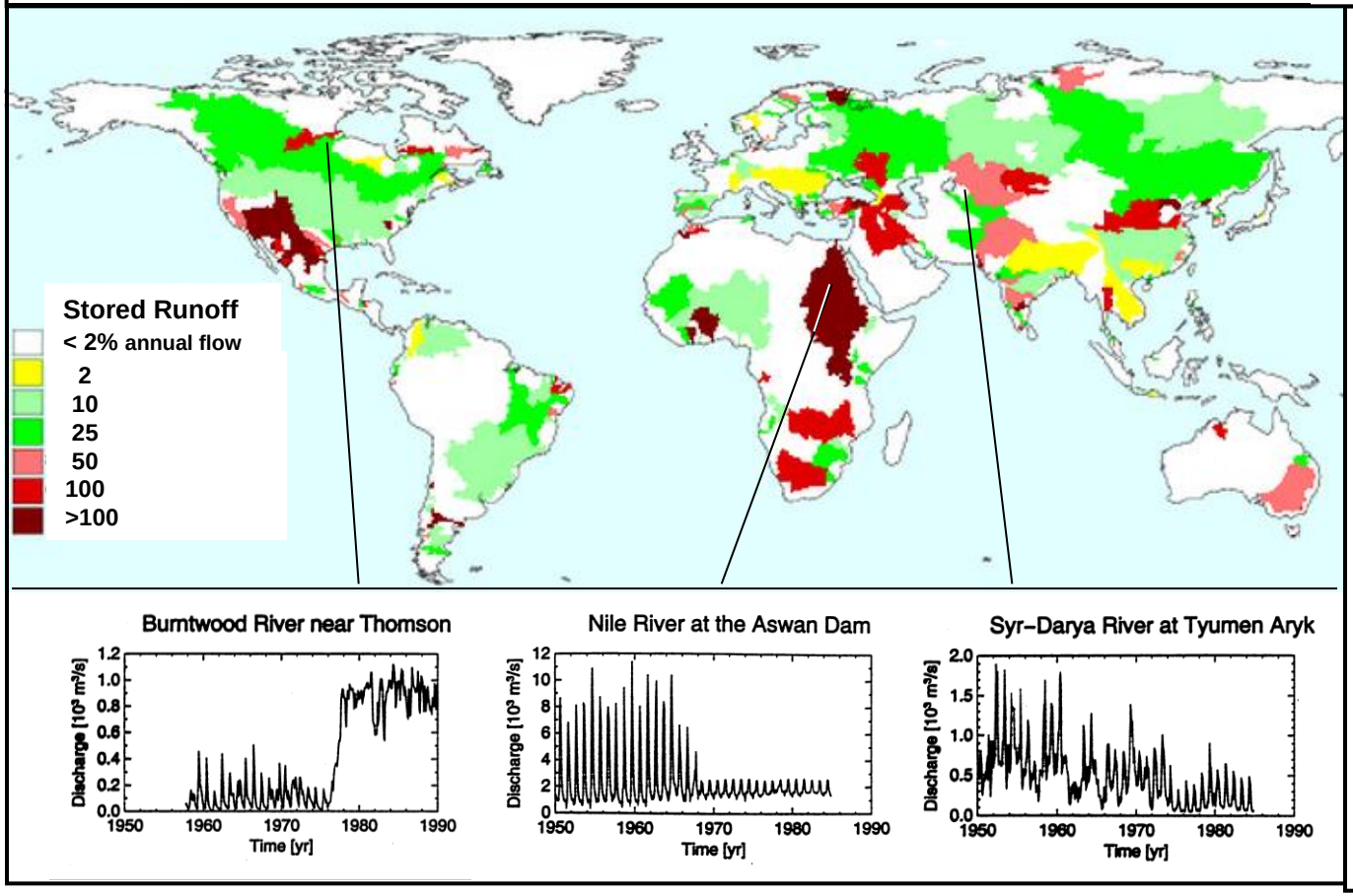


~ 2600 reservoirs ≥ 100 Mio. m^3

Total storage capacity ~ 6000 km^3 (>80% of world total)

History of US Dam & Reservoir Construction

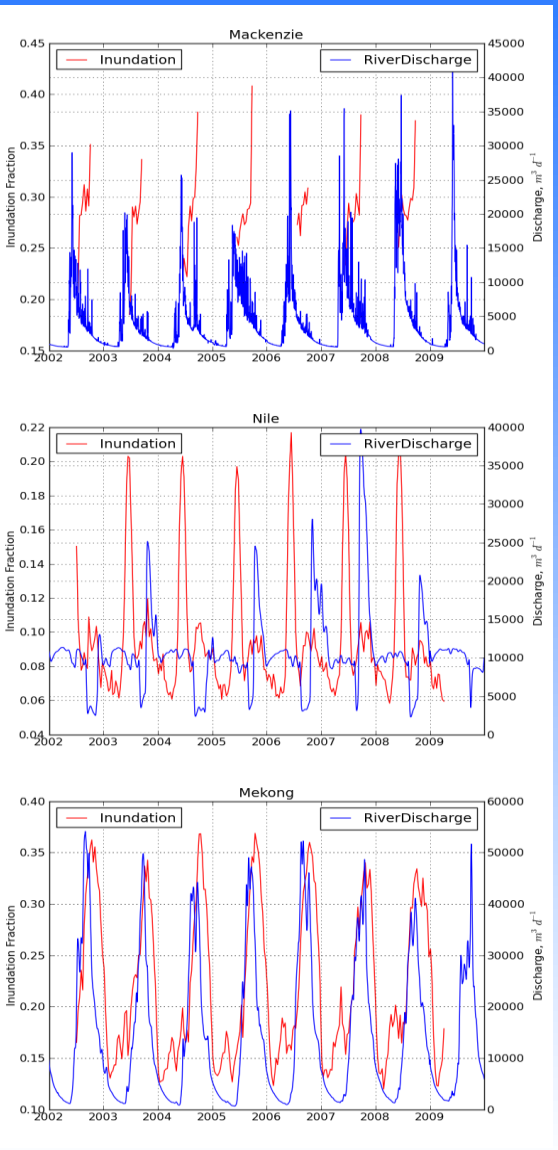


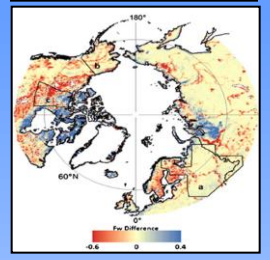


- 700% increase in water held by river systems
- Several years of residence time change in many basins
- Tripling of river runoff travel times globally (from 20 up to 60 days)
- Substantial impact on aquatic biodiversity
- Interception of 30% of continental TSS flux

Framing Committee/GWSP 2004, Eos AGU Transactions

Discharge & Satellite-Detected (AMSR-E) Inundation Time Series Provide "Fingerprints" of Delta Vulnerabilities





MACKENZIE

High lat., low development & population

--*River discharge leads….inundation follows ….then freezing*

NILE

Arid zone, high agriculture & population

--*Completely engineered flows out of phase with flooding…inundation timed to cropping*

MEKONG

Low urbanization (3%), high cropland density

--*River flows lead to inundation…water use "as available" to satisfy irrigation demand, but w/ low flow use*

Objective 2

Assess Response of Deltas to Contemporary Environmental Stressors

--process models of riverine sediment and its fate in coastal deltas, on a set of river delta case studies

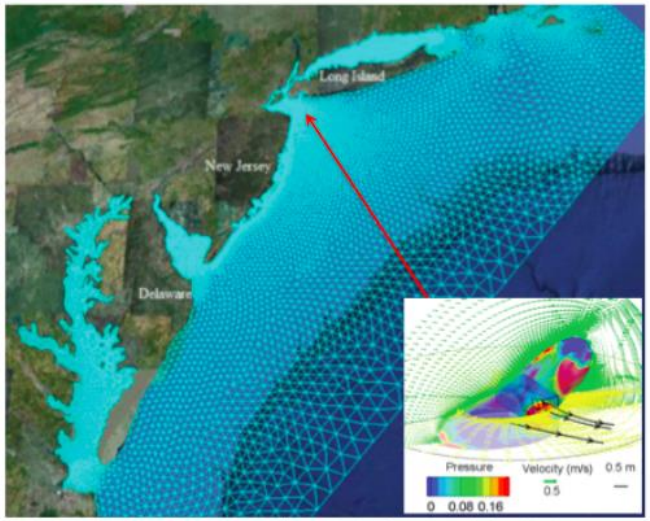
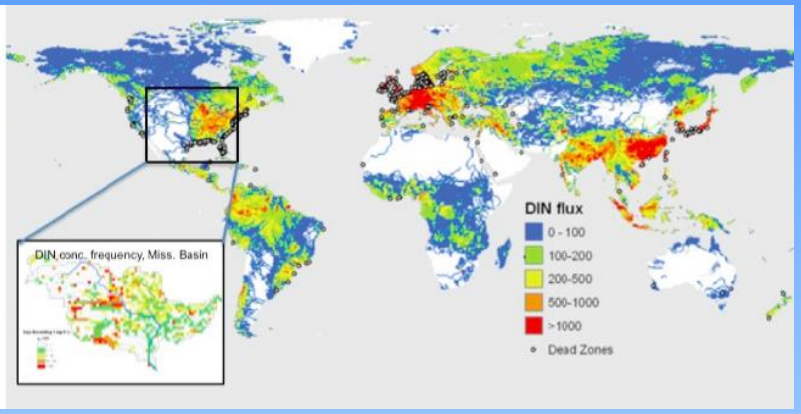
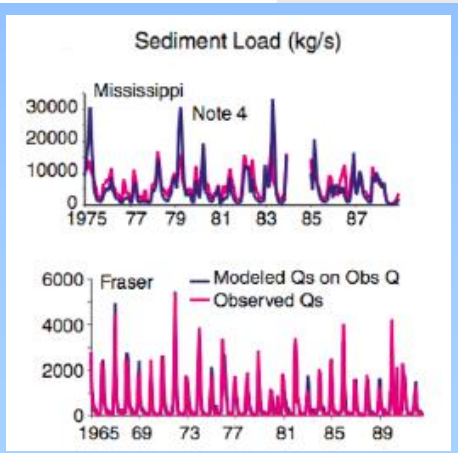


Figure 4 Example of FVCOM/CFD hybrid approach for high-resolution hydrodynamics. Background unstructured mesh: FVCOM. Inset: 3-D output fields (pressure and velocity) on the seabed.

Figure 1. FrAMES prediction of global DIN flux in continental rivers (kg km^{-2} y^{-1})[35,41] relative to dead zones[23]. Regions with high flux and hypoxia coincide in many parts of the world (e.g. N.A., Europe), but not all (e.g. India, China). We will use statistical and modeling techniques to extend this type of analysis to sediment fluxes to understand extent and timing of coastal delta responses to watershed characteristics.

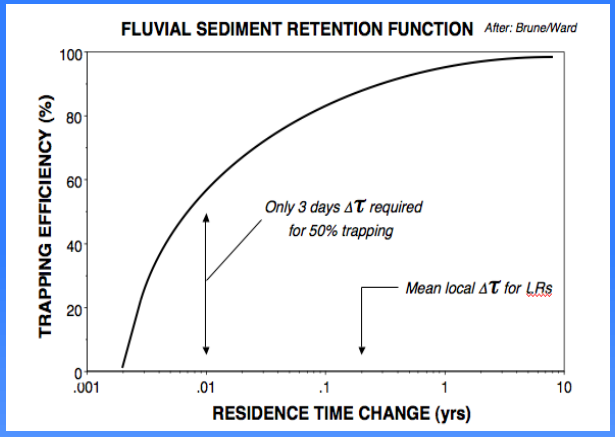


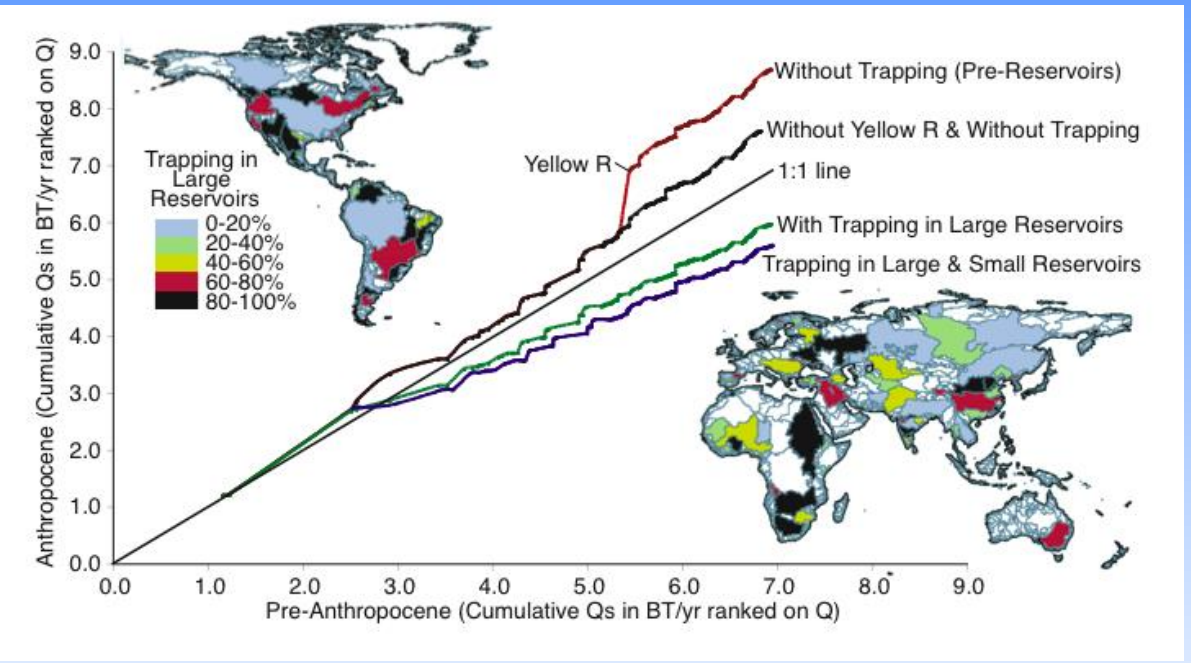


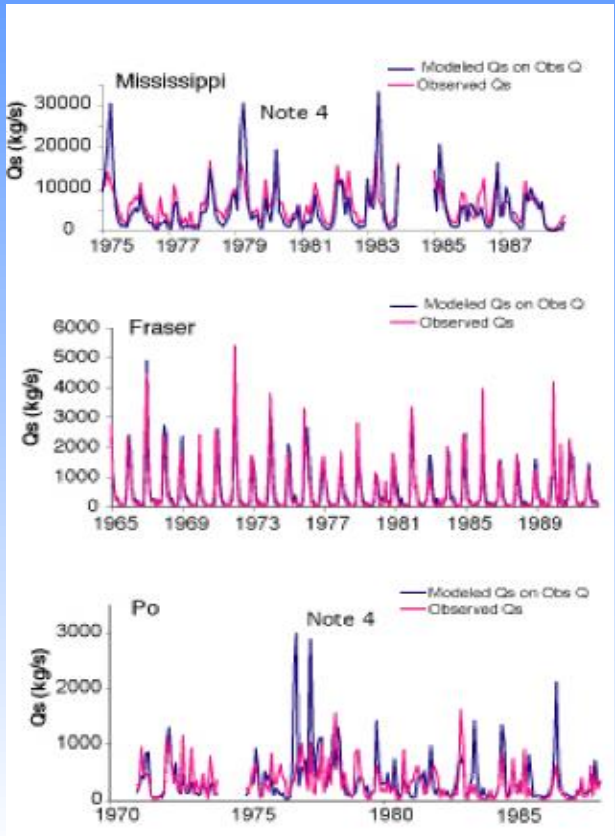
Byproduct of Impoundment:

Sediment Interception/Retention

- Confirms major impact from humans
- Erosion ⇑; impoundment ⇓
- **25-30% sediment fails to reach coasts**



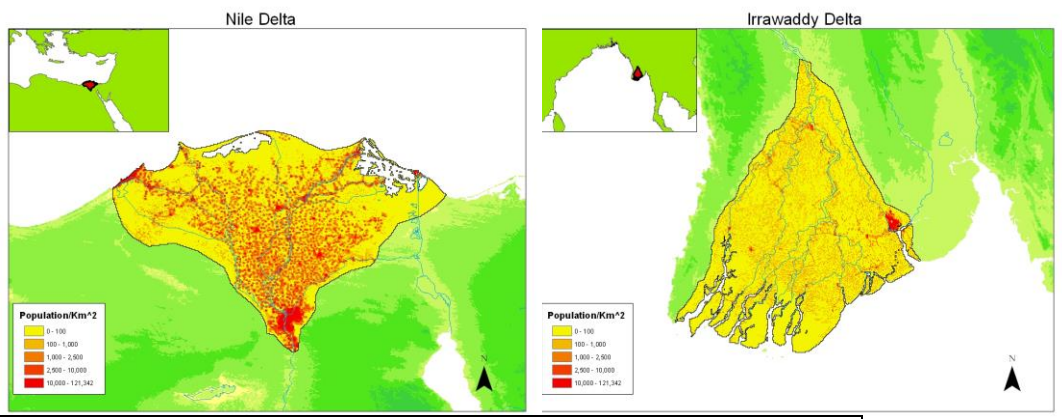




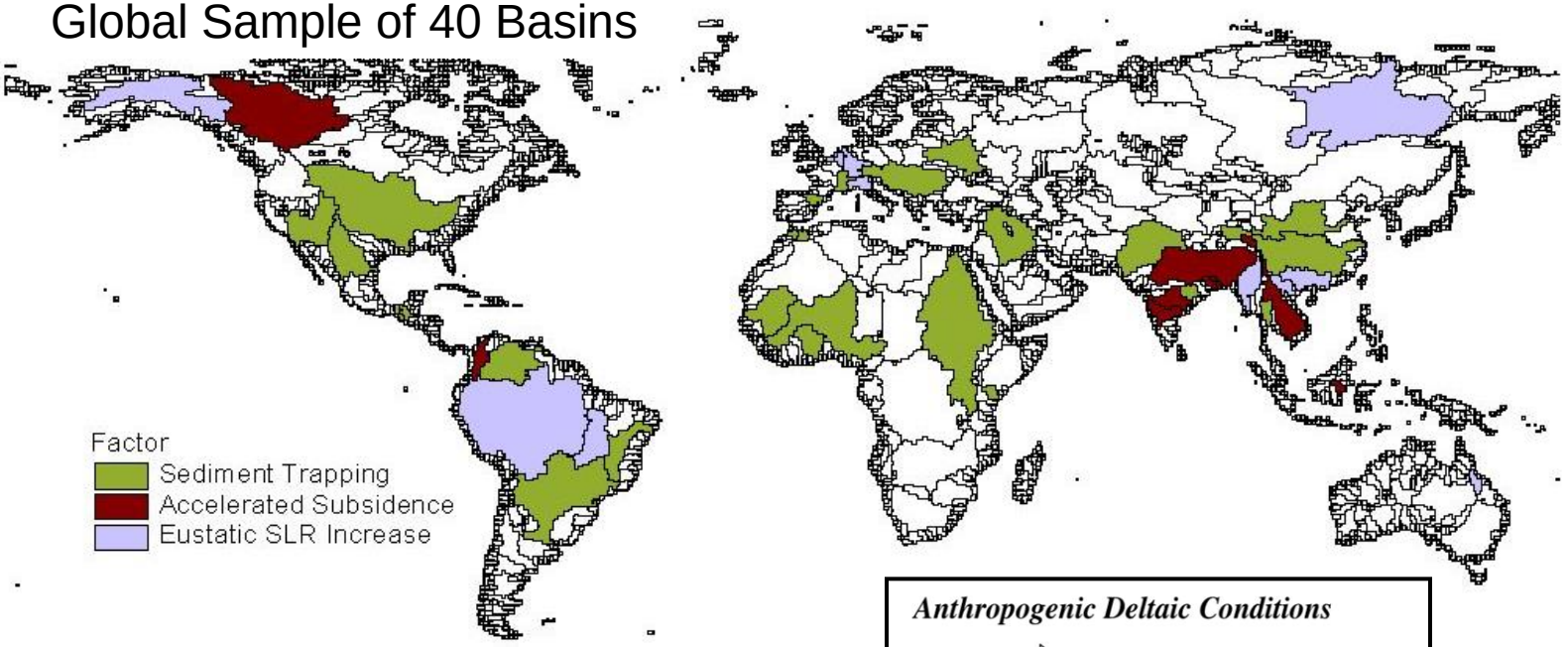
Syvitski et al., 2005, Science; Vörösmarty et al. 2003, Global & Planetary Change

Deltas Under Threat

Major Sources of Chronic RSLR:
Eustatic Sea Level Rise Only
Part of the Story



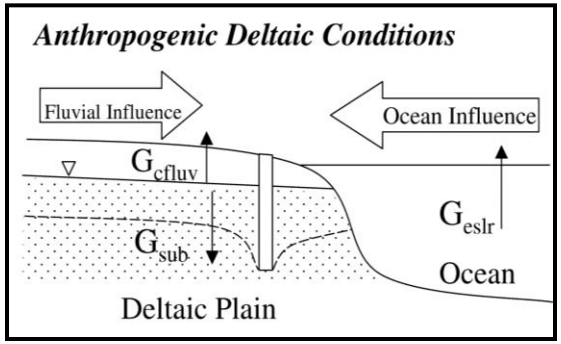
Global Sample of 40 Basins



Sources of Change:

-- 5 Eustatic Sea Level Rise
-- 8 Groundwater/petroleum extraction
-- 27 Upstream sediment trapping & diversion

Ericson et al., 2006, *Global and Planetary Change*



Yellow River Delta

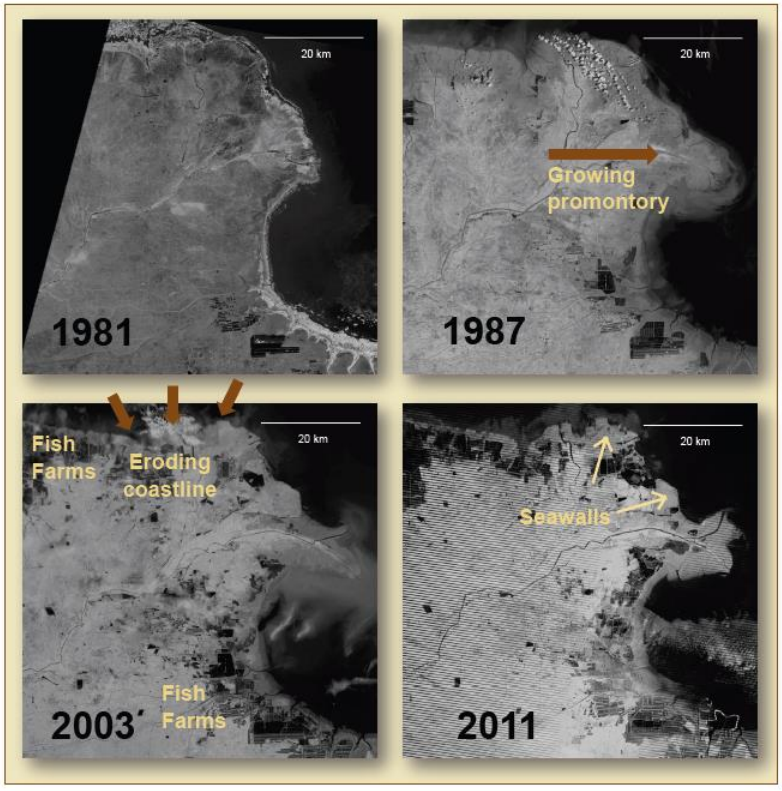
Population of more than 4,000,000 people

Exploding aquaculture industry

Oil extraction of 75,000 tons per day

Large agricultural operations

A heavily engineered river that dries up before it reaches the sea and carries much less sediment



The city of Dongying (Inset 1) is experiencing subsidence likely related to water usage.

Fig. 5. The city of Dongying hosts a population of almost two million people. Photo courtesy of Paul & Bernice Noll.

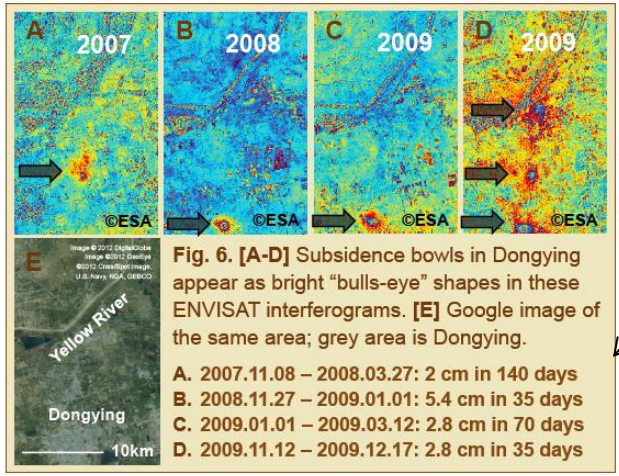


Fig. 6. [A-D] Subsidence bowls in Dongying appear as bright "bulls-eye" shapes in these ENVISAT interferograms. **[E]** Google image of the same area; grey area is Dongying.

A. 2007.11.08 – 2008.03.27: 2 cm in 140 days
B. 2008.11.27 – 2009.01.01: 5.4 cm in 35 days
C. 2009.01.01 – 2009.03.12: 2.8 cm in 70 days
D. 2009.11.12 – 2009.12.17: 2.8 cm in 35 days

Rates 100x SLR!!

New Opportunities for Satellite-based, Quasi-real time Monitoring of Progressive Risk (*here, Interferometric SAR*)

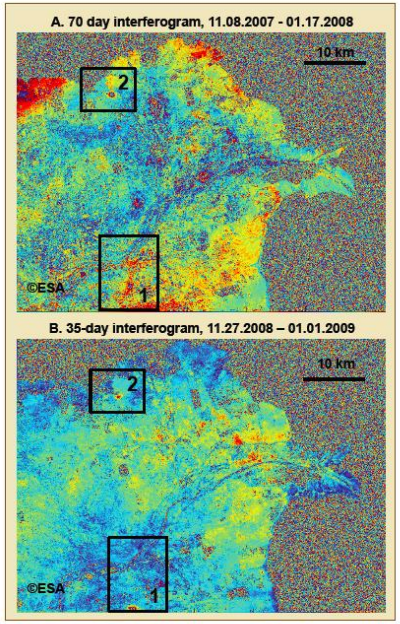


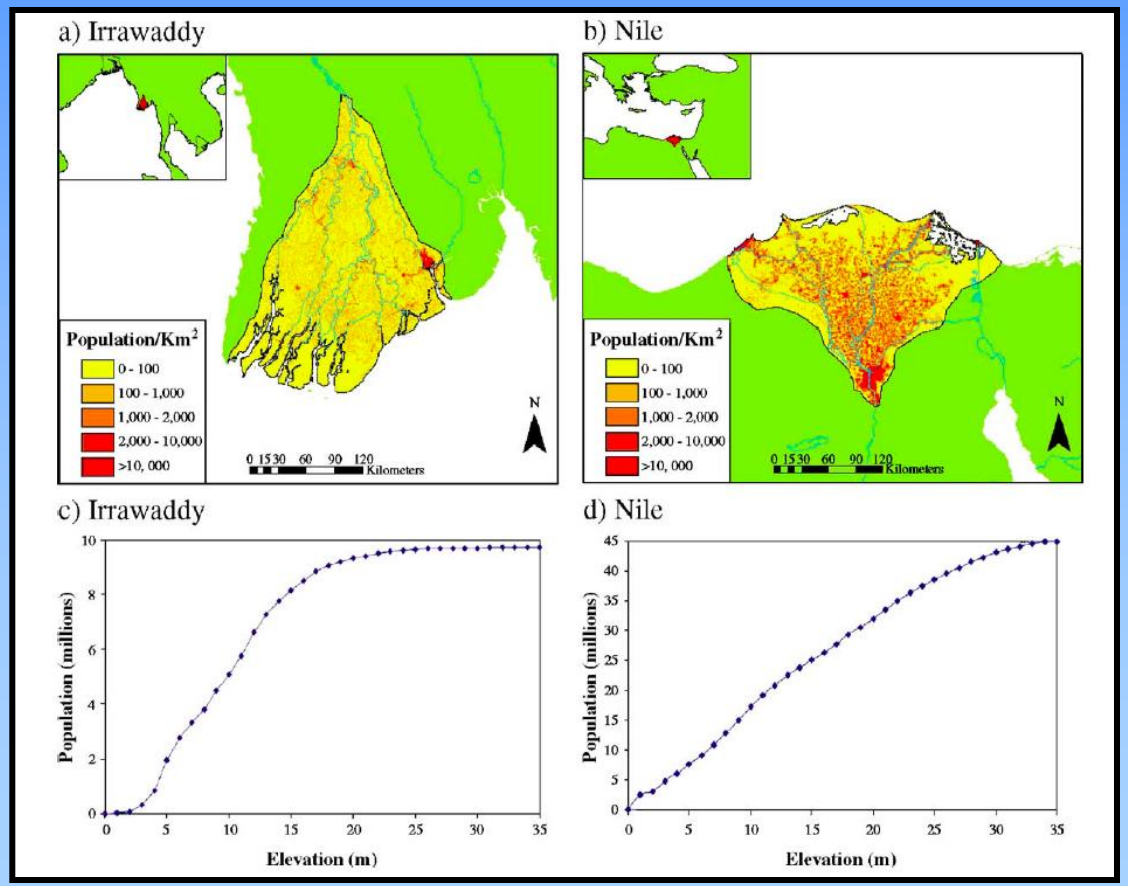
Fig. 4. Example whole-delta ENVISAT interferograms

Courtesy: Higgins, Overeem, Syvistki (CSDMS, UCBoulder)

Objective 3

Map Exposure and Vulnerability of Contemporary Populations

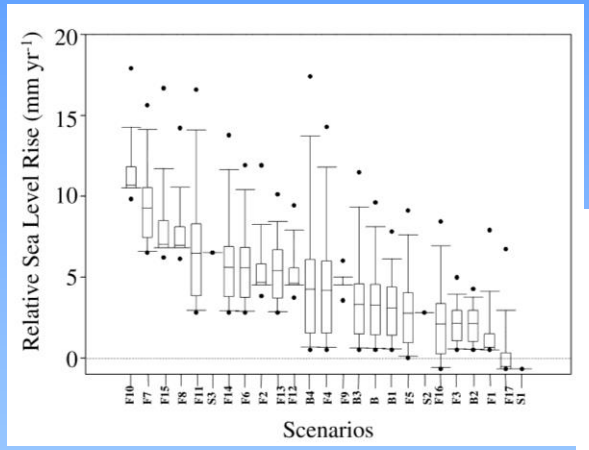
--geospatial demographic studies of populations and infrastructure (built & agricultural) at risk

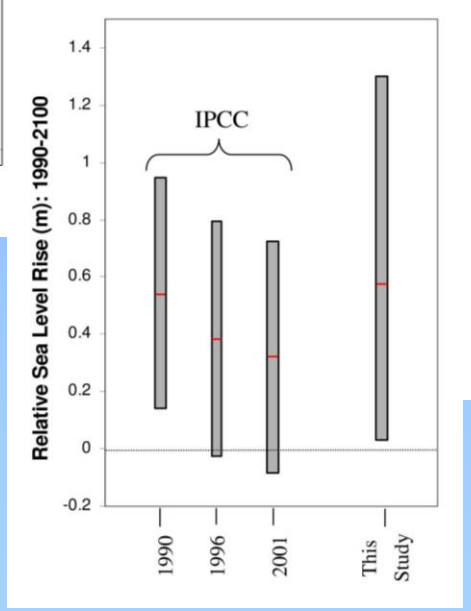


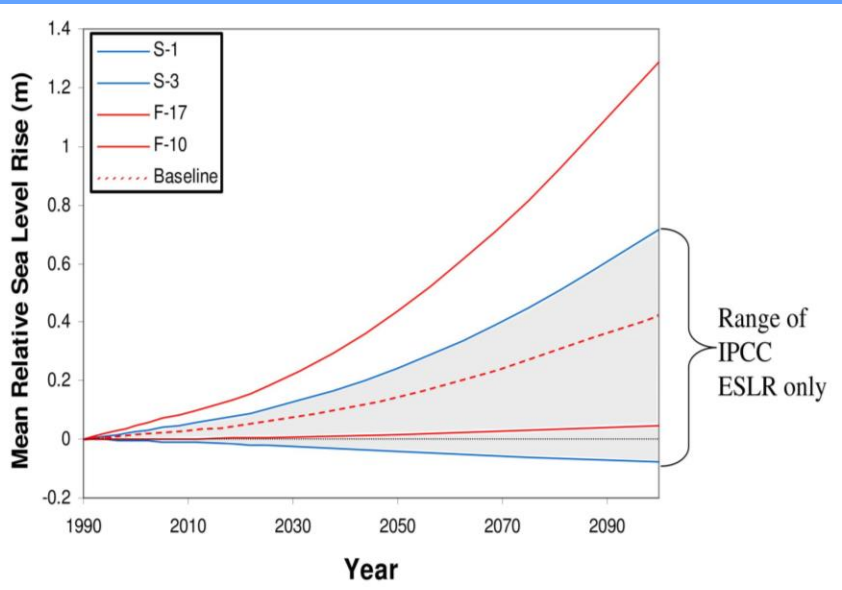
Objective 4

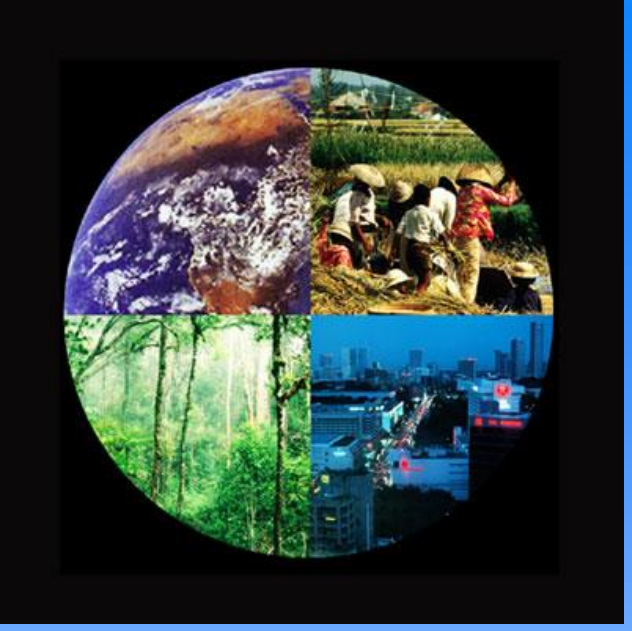
Future Forecasts of Land-to-Ocean Links, Coastal Delta Impacts, Societal Risk

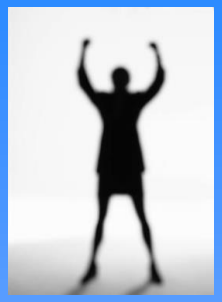
--scenarios and assessment of the changing nature of vulnerable delta systems of the world.











CENTRAL TENET OF THE GWSP

Humans are changing the global water system in a globally-significant way

without…..adequate knowledge of the system and thus its response to change

Earth System Science Partnership

GWSP Global Water System Project

Some References

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