Promoting the Value of Water Cycle Remote Sensing Missions and Climate Studies to Non-Traditional Consumers

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DEFINITIONS AND TERMINOLOGY

Consumers: Beneficiaries
Stakeholders, Clients, Customers

Research/ Academic Community

Peers, Students
Research Labs
Research Firms
Highly skilled

Specialized Sectors/ Professional Community

Healthcare
Engineering-Civil
Insurance
Social
Legislature…
Moderately skilled

Public Community

Basically any individual or group of stakeholders.
Very diverse
Least skilled

Number of Consumers

OVERVIEW

1. Societal (Application) Value for Non-traditional Consumers.

2. Key findings of Recent Application-driven Research

3. Packaging the Research as a Product for Consumers: Lessons Learned and Way Forward

Water Cycle Remote Sensing: Tactical Scale of Decision Making (*Transboundary Flood Management*)

Climate Studies: Strategic Scale of Decision Making (*Design and Operations of Large Dams*)

WATER CYCLE REMOTE SENSING

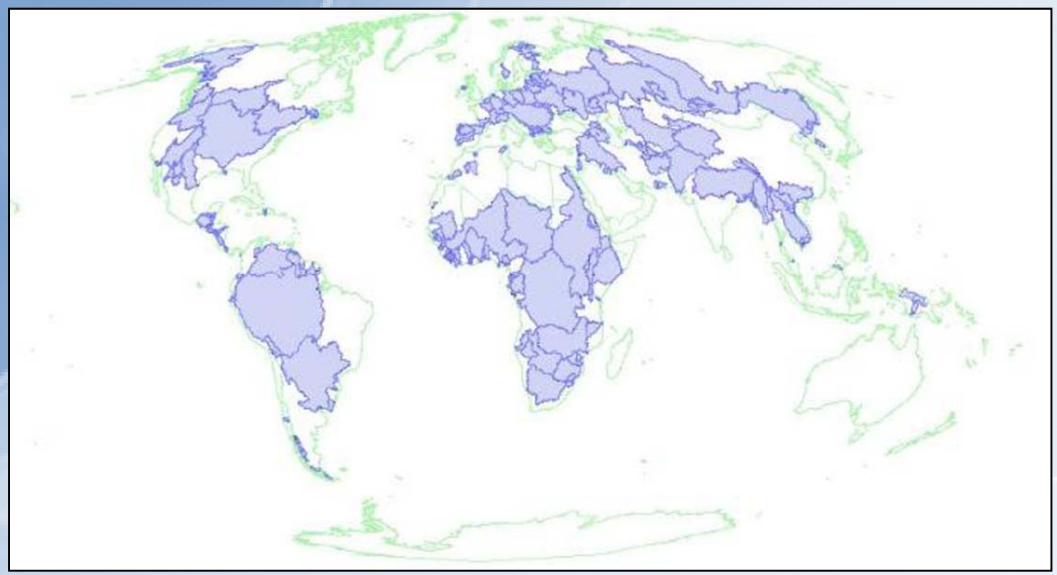
CONSUMER: PUBLIC COMMUNITY (TRANSBOUNDARY FLOOD MANAGEMENT)

TIMESCALE OF DECISION MAKING
DAYS TO WEEKS

TRANSBOUNDARY FLOOD MANAGEMENT

"Transboundary Flooding most catastrophic" (*Bakker, 2010*)

International River Basins (IRBs)

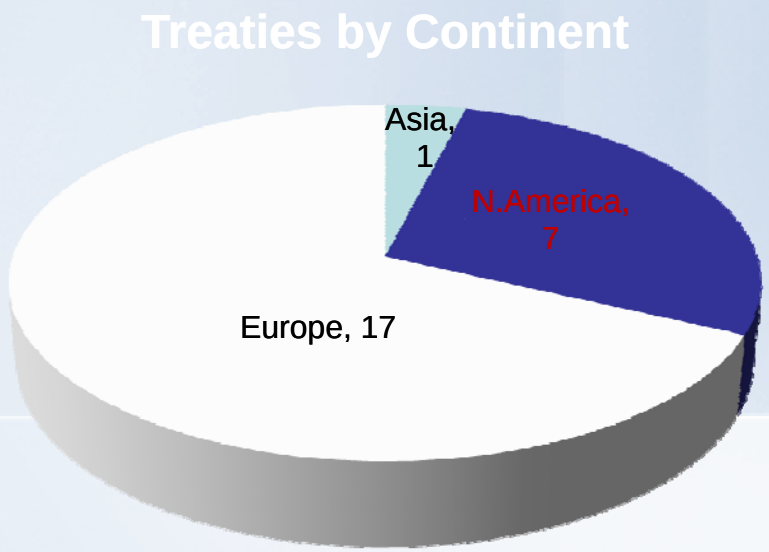


Source: Transboundary Freshwater Dispute Database, Oregon State (Credits: Aaron Wolf)

THE GLOBAL PICTURE

Percentage Area	Number of Countries
91-99%	39
81-90%	11
71-80%	14
61-70%	11
51-60%	17
41-50%	10
31-40%	10
21-30%	13
11-20%	9
1-10%	11

- 145 countries are associated in IRBs
- Accounts for 40% of total land surface.
- > 50% of total surface flow



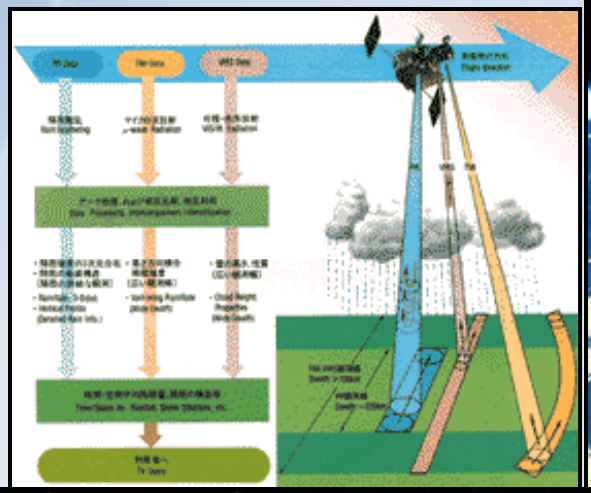
Distribution of treaties on transboundary flood management

(Balthrop and Hossain, *Water Policy*, 2009)

WATER CYCLE REMOTE SENSING MISSIONS:CAN THEY BE THE ANSWER?

Expected launch 2014
3 hourly global rainfall products at 10X10 km scale

TRMM



SWOT

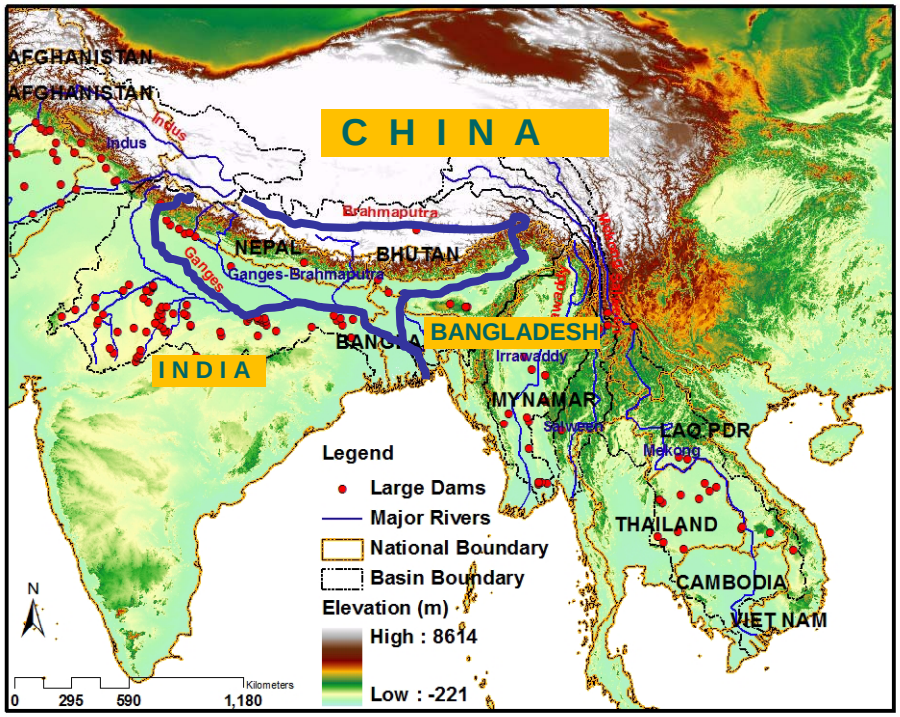
Expected launch– 2020

Q for major rivers every 7-14 days

SMAP

GANGES-BRAHMAPUTRA-MEGHNA BASINS

- 600 million inhabitants
- Downstream 200 million inhabitants
- Bangladesh comprises only 7% of total basin area.
- Lack of upstream rainfall/discharge *in real-time* limits range to <3day
- Complex dendritic rivers



Forecasting range using GPM/SWOT > 3 days can potentially improve:

1) Disaster preparedness
2) Short-term agricultural planning.
3) Prevent loss of life/health epidemics

21 day forecast is IDEAL according to Asian Disaster Preparedness Center

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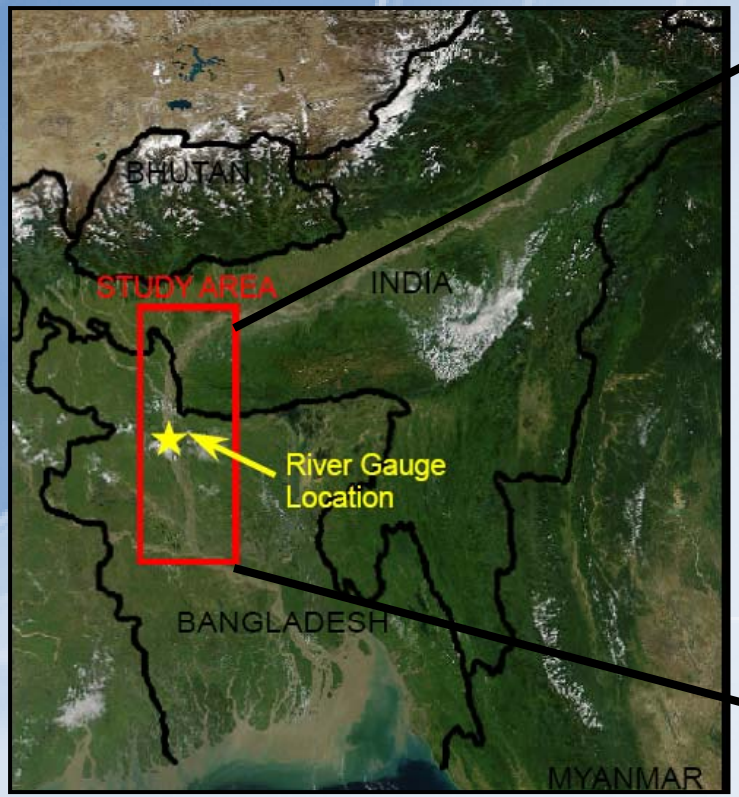
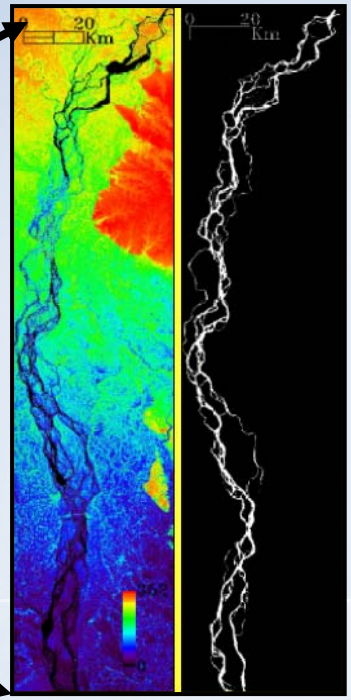
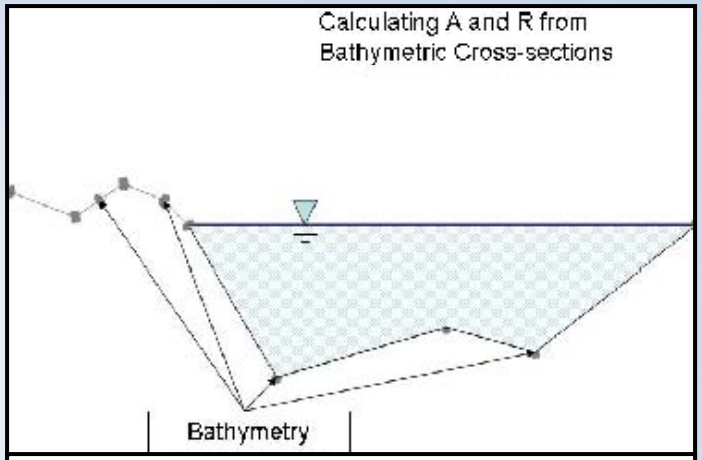
SPACE-BORNE DISCHARGE ESTIMATION OF COMPLEX RIVERS: WILL IT BE REALISTIC?

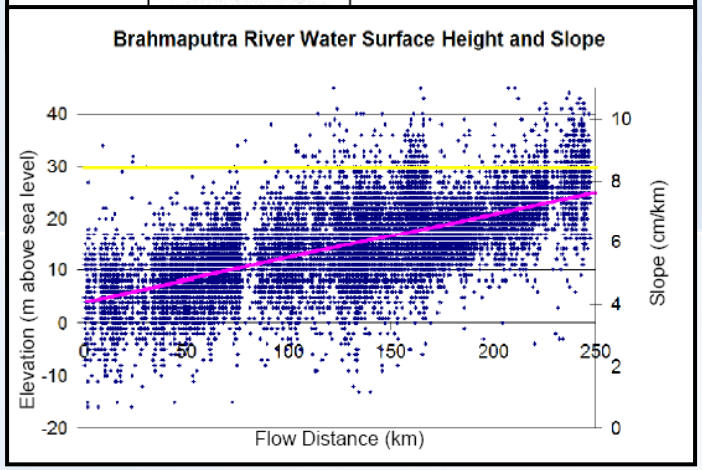


SRTM Overpass – Feb 20, 2000

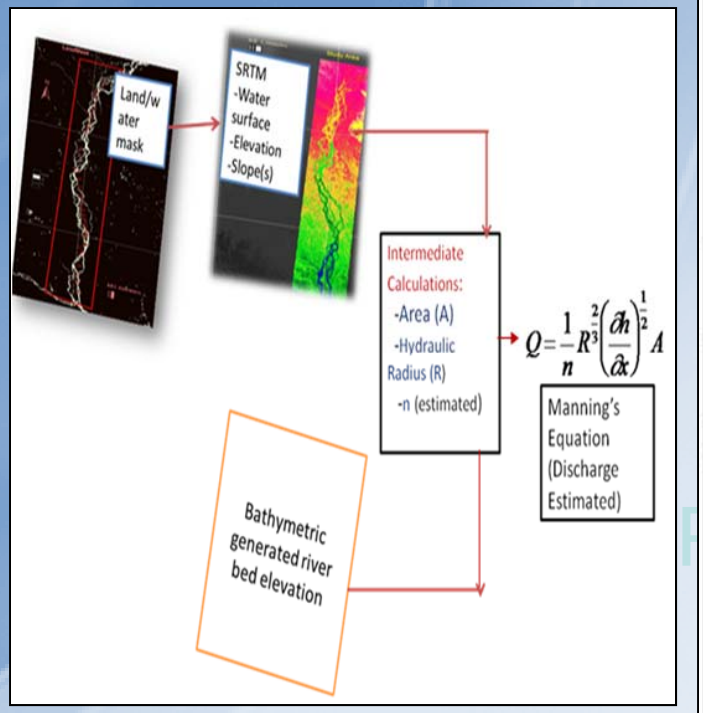


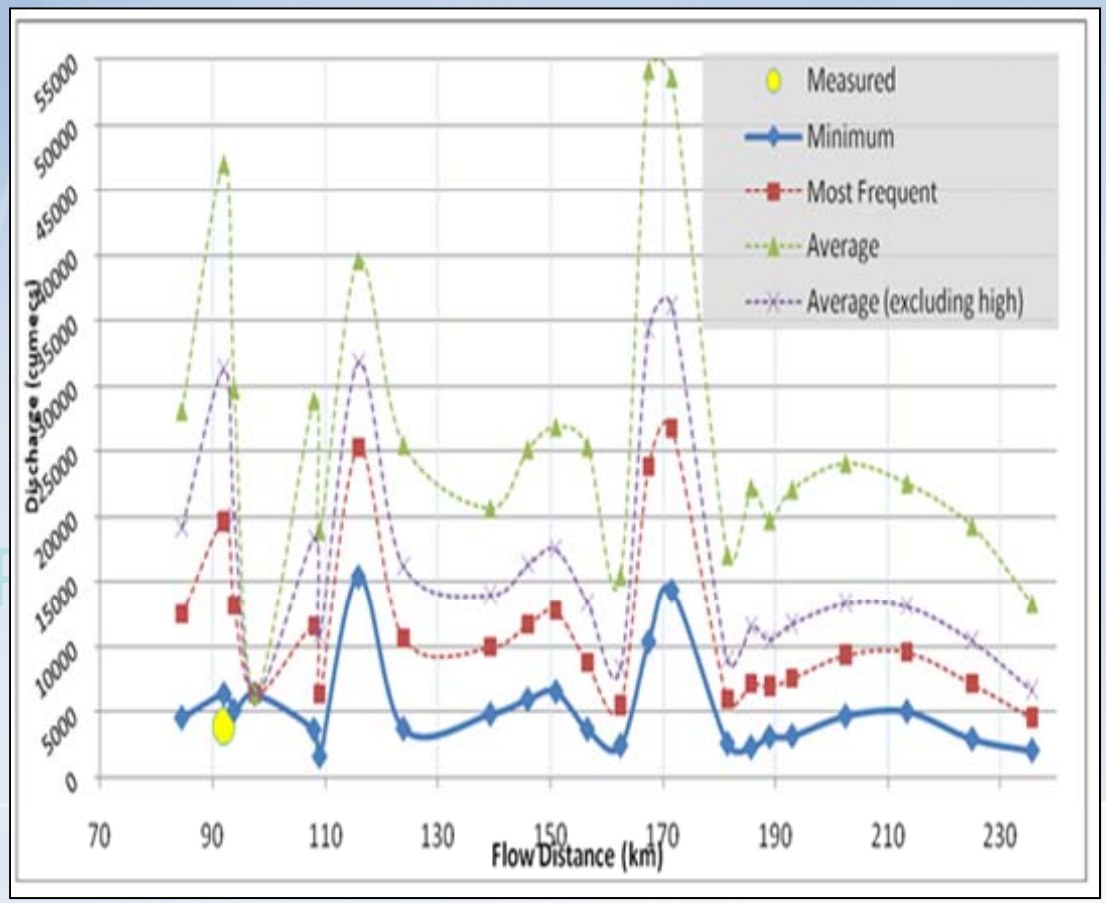
$$V = \frac{k}{n} R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$





SRTM-BASED DISCHARGE ESTIMATION

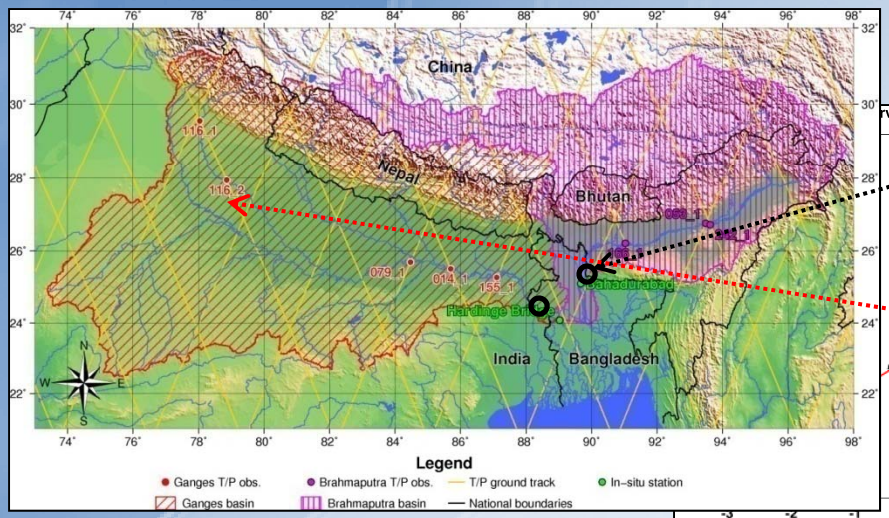




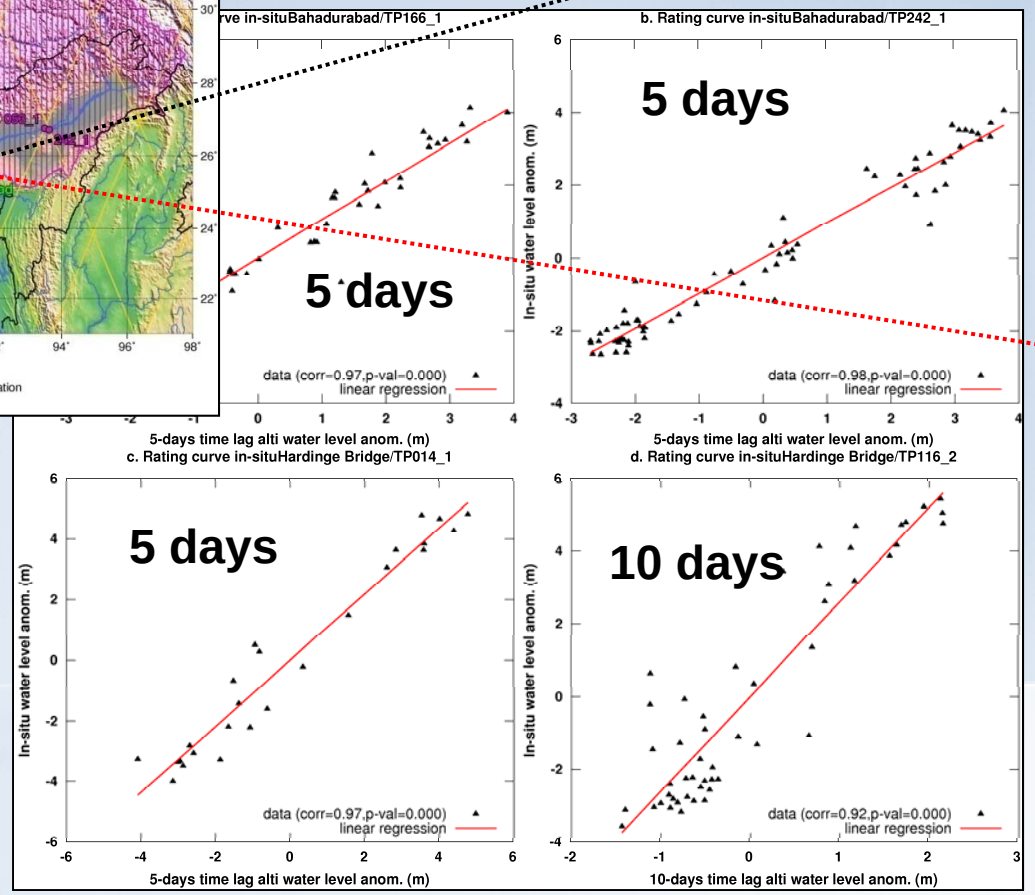
Woldemichael, A.T. A.Degu, W. Yigzaw, A.H. Siddique-E-Akbor, IEEE JSTARS (2010).

Hossain et al. 2009 – SWOT Mission Science Document – *"Reservoir, Transboundary Issues and Human Impacts"*

FORECASTING VALUE OF SATELLITE ALTIMETRY



Downstream (in-situ)



UPSTREAM

Topex/Poseidon (T/P) cross tracks on main rivers transboundary to Bangladesh

Source: Biancamaria et al. (2011), *GRL*

Altimeter Rating curves at forward lags

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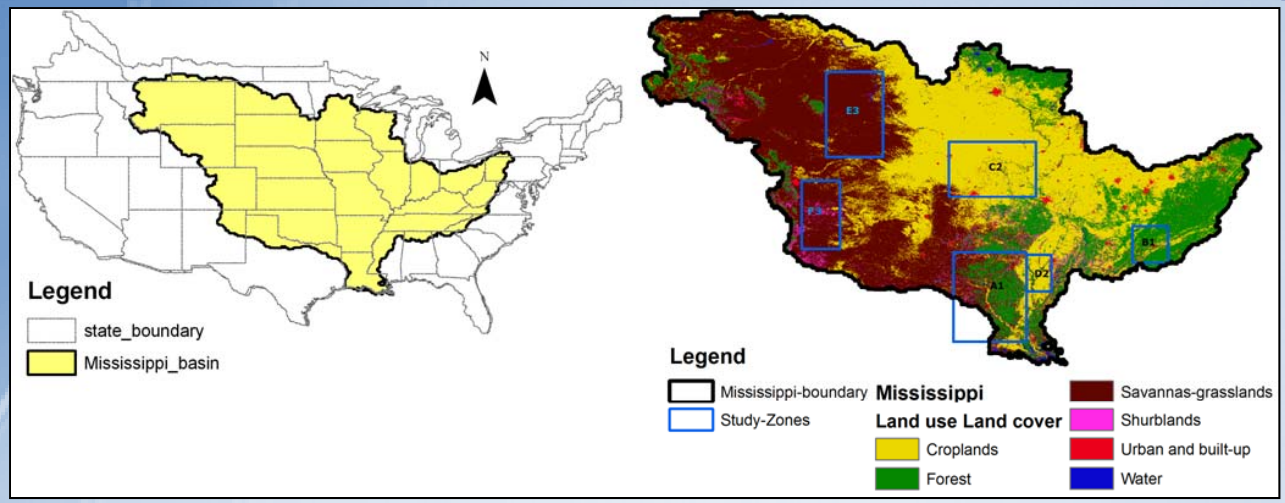
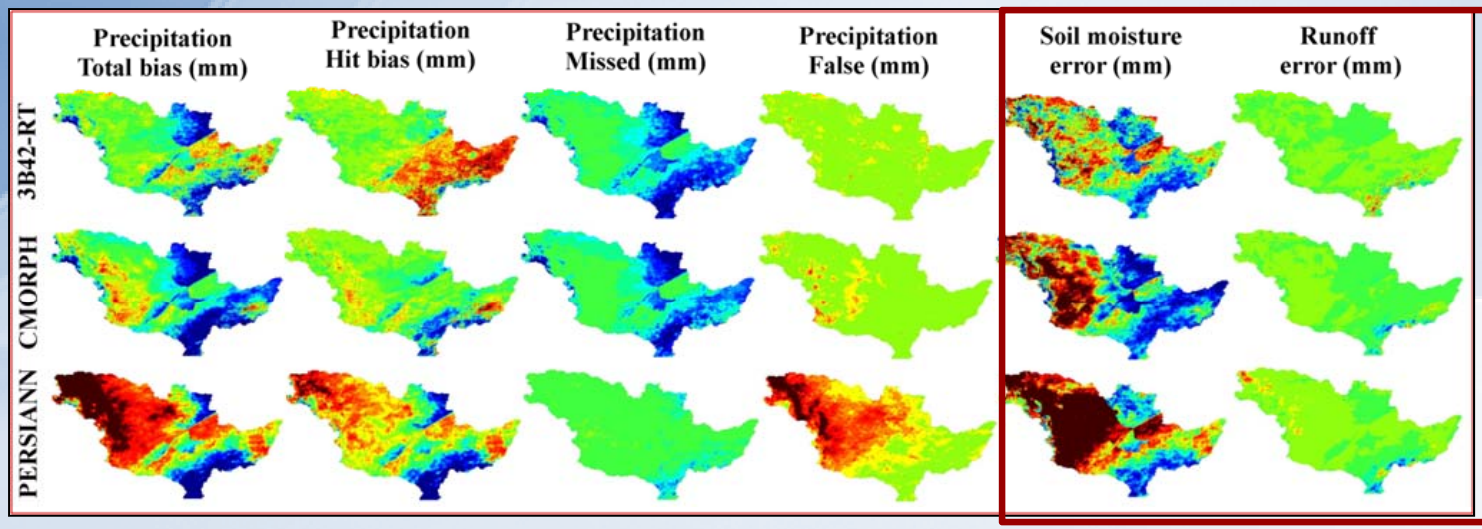
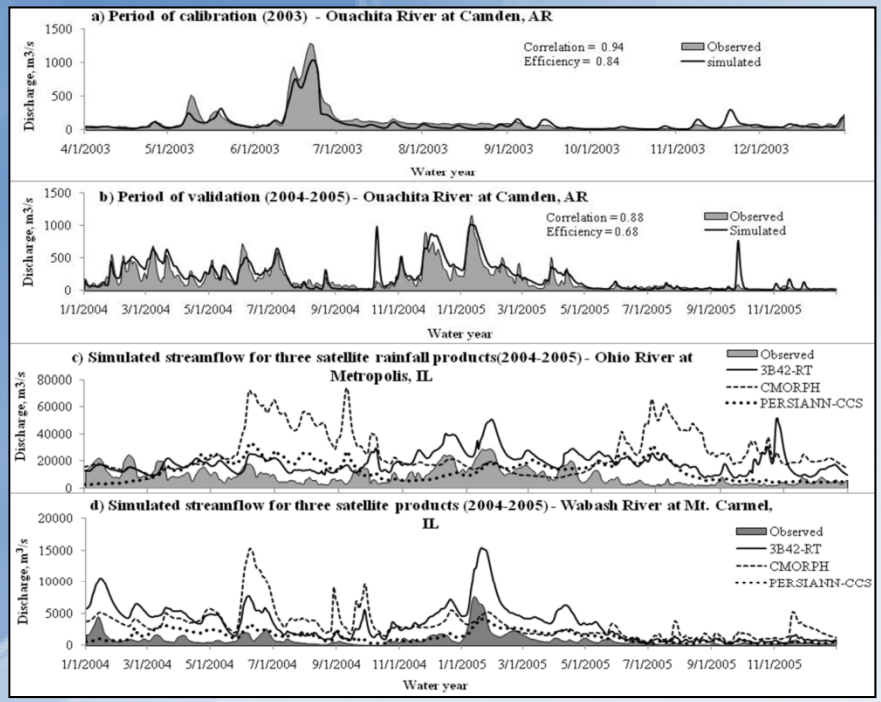
ON SATELLITE PRECIPITATION - GPM (UNCERAINTY/LAND COVER/TERRAIN)

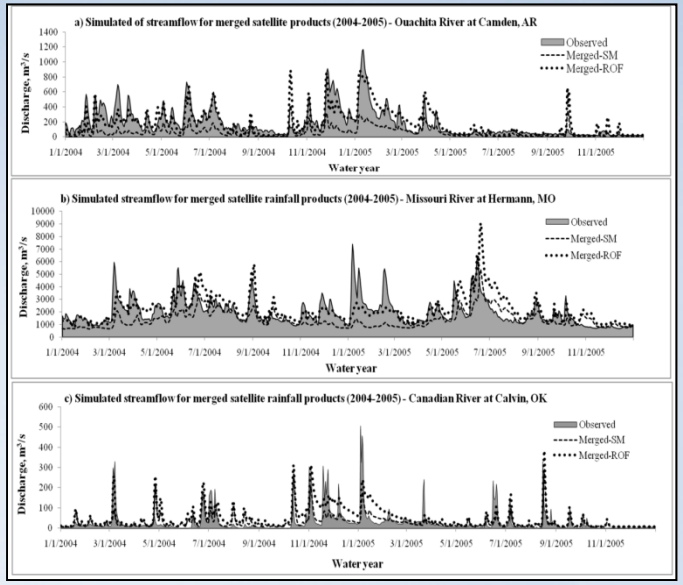




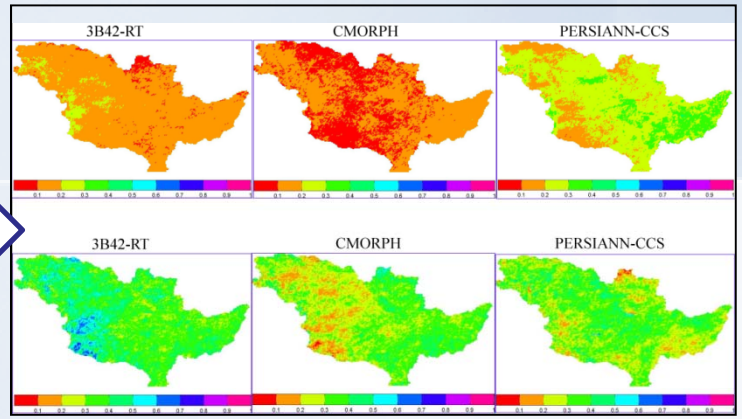
A Priori uncertainty in hydrologic simulation as a function of pixelized geophysical features

LEVERAGING *A PRIORI* UNCERTAINTY FOR IMPROVING STREAMFLOW PREDICTION





Pixel by pixel weight factors for merging to a single product



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Gebregiorgis, A.S., F. Hossain.(2011). *J. of Hydrometeorology* , (doi:10.1175/JHM-D-10-05023.1),

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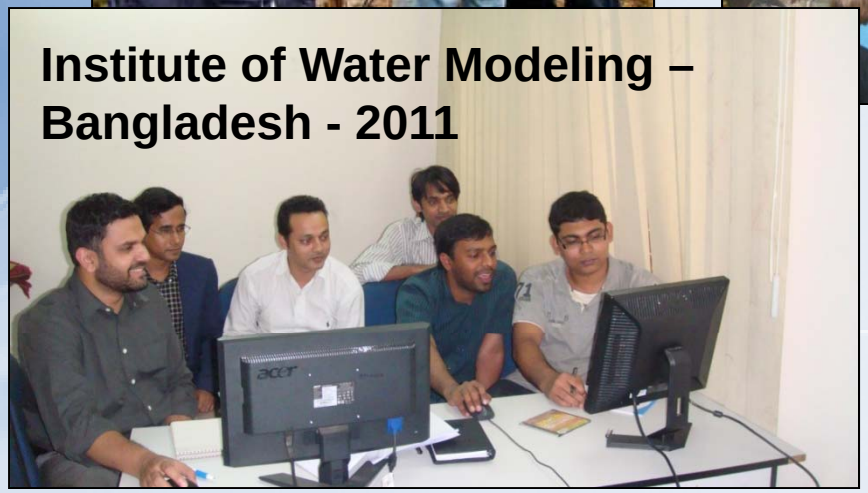
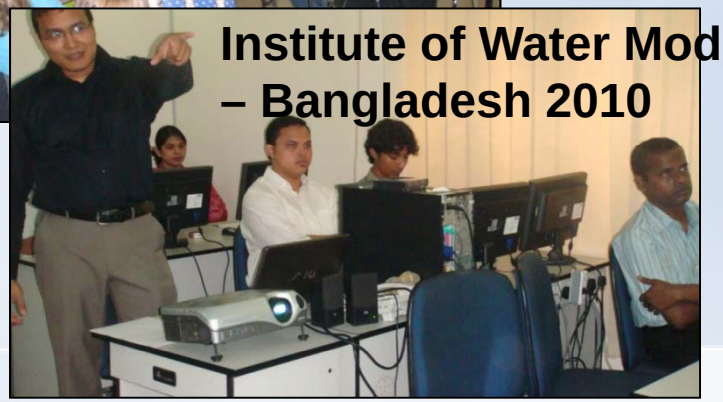
PROMOTION: HANDS ON CAPACITY BUILDING ACTIVITIES





Capacity building workshops each year (Volunteer Effort)
Not a lecture –active learning and place-based learning

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THE CONSUMER 'FEEDBACK' ON SATELLITE DISCHARGE ESTIMATION

1. **"***The remotely sensed discharge using SRTM data has very high errors even during dry season. Why bother? "*
2. *"The method of SRTM based discharge estimation still requires bathymetry which means you still need to go to the field. So it's not as useful and can not replace in-situ measurements."*
3. *"We have pressure transducers now that can measure water level every minute and relay the information real-time. Why bother to use a SWOT mission that will only cross a river section a few times a week?"*
4. *"The scatter in elevation data across a river cross section is too much. What should be the 'standard' elevation of the water level at a given river cross section? "*
5. *"Effective use of Landsat data to classify a flooding river of land and water areas will depend on the unlikely chance of the region being cloud-free during the Monsoon season."*

CONSUMER 'FEEDBACK' ON SATELLITE PRECIPITATION DATA

- *"We find it difficult to locate the URL of the satellite data portals through regular web search without having advanced knowledge of sensors/missions and technical terms."*

- *Satellite Data Portals need to be optimized in search engines (Google) [GIOVANNI does not show up in the first 20 hits]"*

- *"More documentation in the metadata and in the user support portals/websites/documentation on uncertainty is required."*

- *"More documentation in the metadata and in user support on the data latency of products is required for operational applications."*

- *"Guidance on deriving probabilistic analysis/estimation (say for discharge – 50th and 90th percentile) would be beneficial."*

CLIMATE STUDIES

CONSUMER: ENGINEERING COMMUNITY (LARGE DAMS- DESIGN AND OPERATION)

TIMESCALE OF DECISION MAKING
YEARS TO DECADES

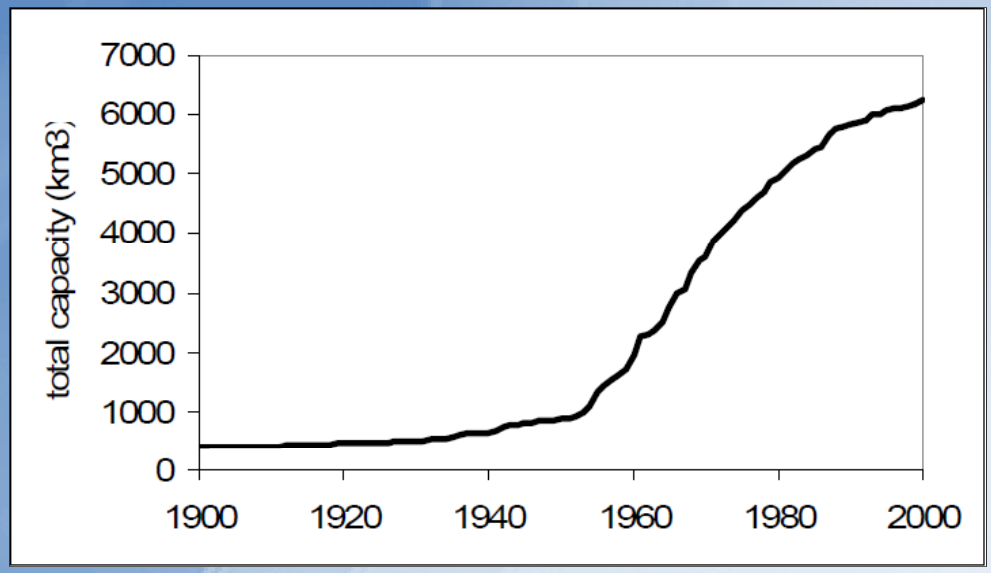
DESIGN AND OPERATION OF LARGE DAMS

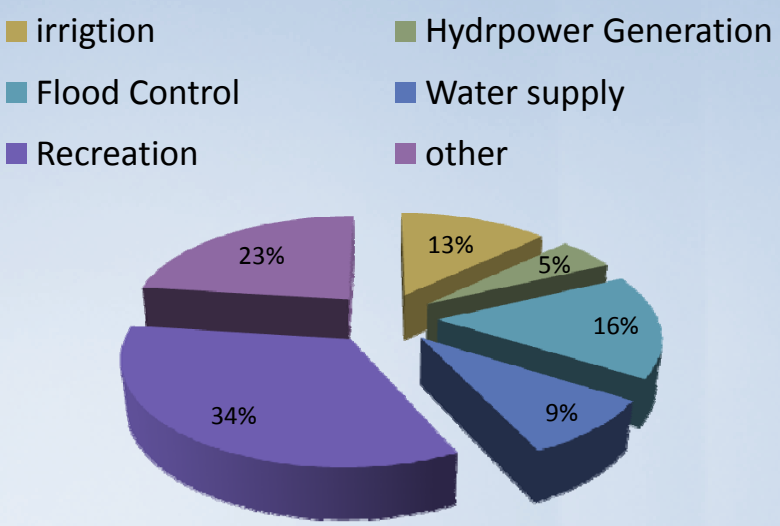
- Folsom Dam on American River – Reduction of design flood recurrence interval for dam from 500 years (in 1955) to 70 years (in 1986).

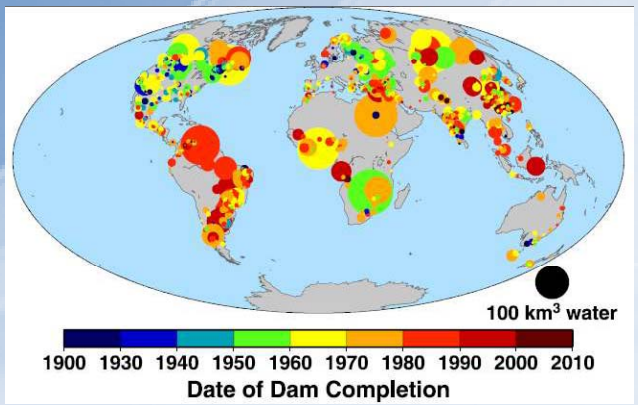
Folsom Dam and Folsom Lake

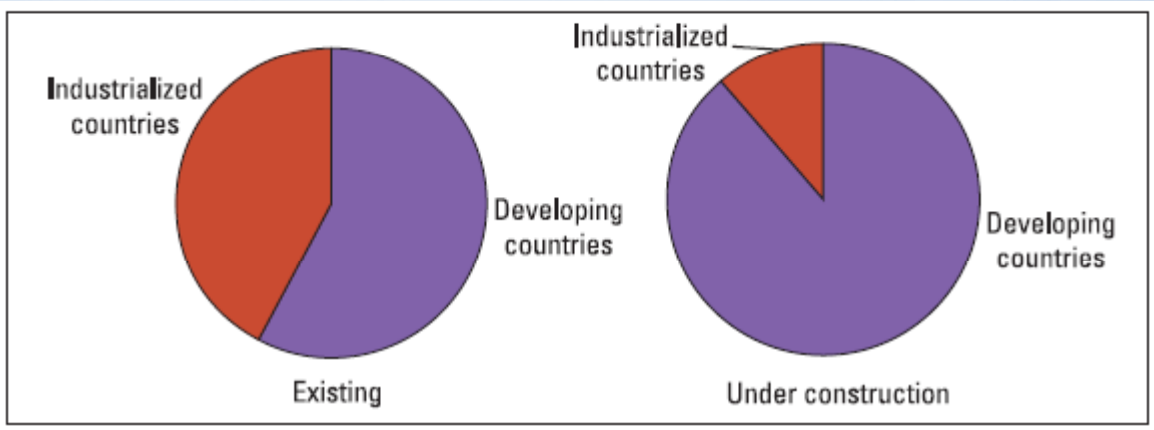
- Downstream Sacramento -most flood prone due to reduction in flood recurrence interval
- US Army Corps of Engineers current (billion+ dollar) project is to raise dam height by 7 feet to handle 250 year floods.
- *NRC report – Pineapple Express (Atmospheric Rivers), Rain on snow, Data*
- *Did the impoundment and land-use/land cover change play a role on extreme precipitation patterns in the region?*

ARTIFICIAL RESERVOIRS IN THE WORLD



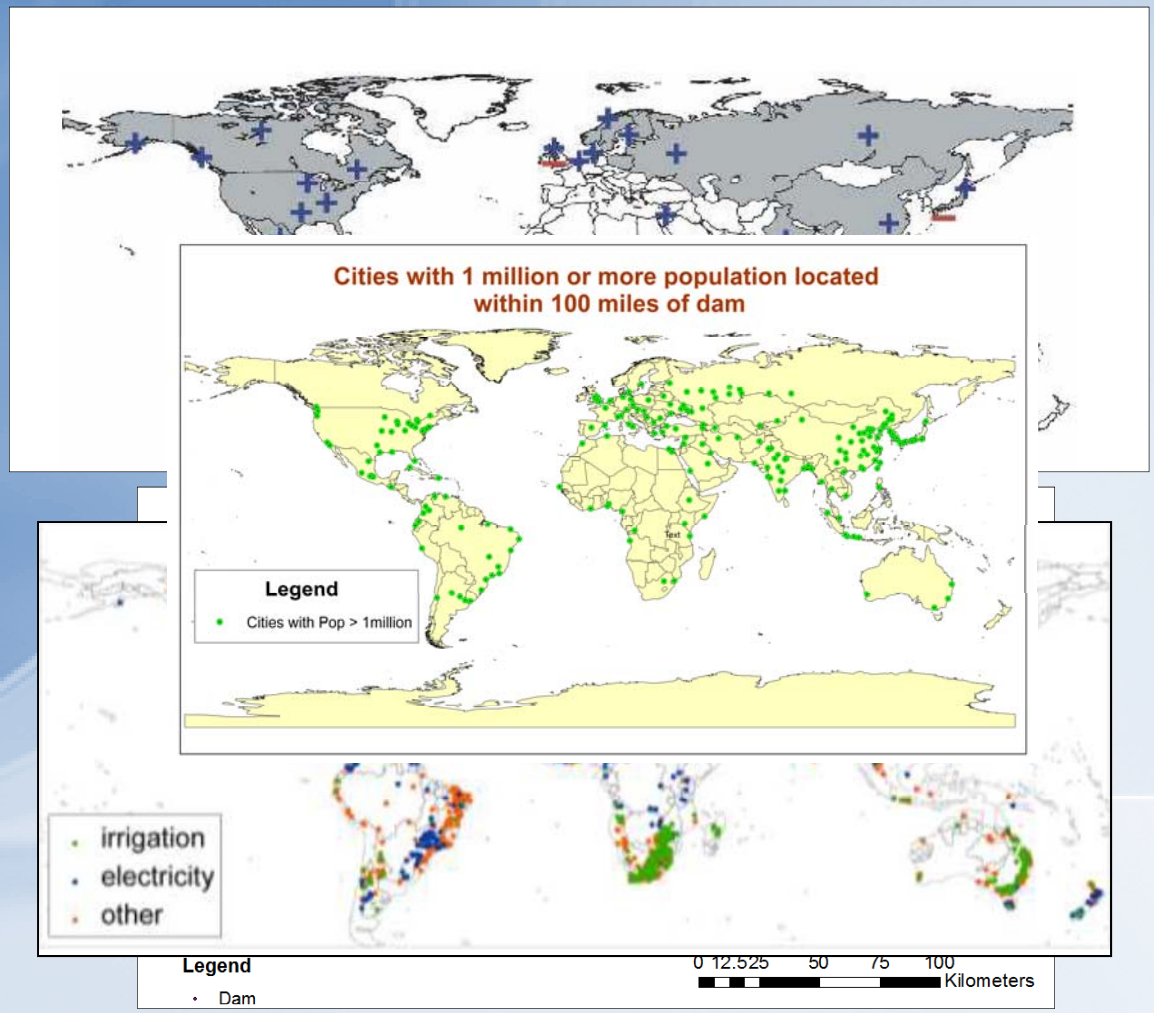






Source: ICOLD, GWSP, Biemans et al. 2011

BROADER CONTEXT: ANY CORRELATION?



Regions where disproportionate changes in extreme precipitation compared to the change in the annual and/ or seasonal precipitation have been documented (*after Groisman et al., 2005*).

40% of world's irrigation, **7%** of energy, **20%** of food production from dams; Irrigation increase: 40Mha (1900) to 215 Mha (2005 A.D)

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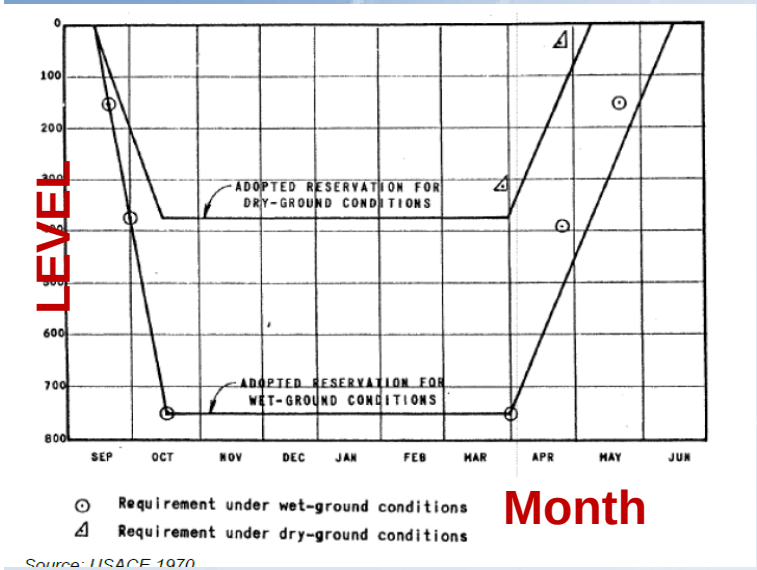
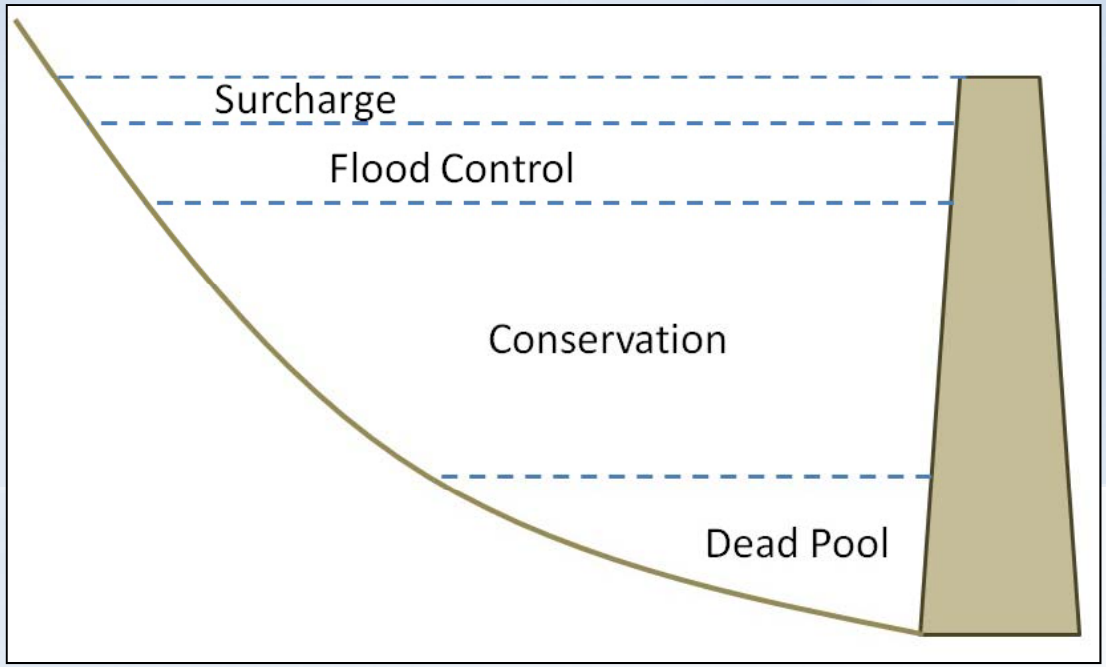
WHY SHOULD ENGINEERS CARE ABOUT CLIMATE STUDIES?

- Historically design and operations are 'one-way' – possible climate feedbacks and systematic alterations to flood frequency (*for whatever reasons*) ignored.
- Assumes stationarity of recurrence interval of extreme events

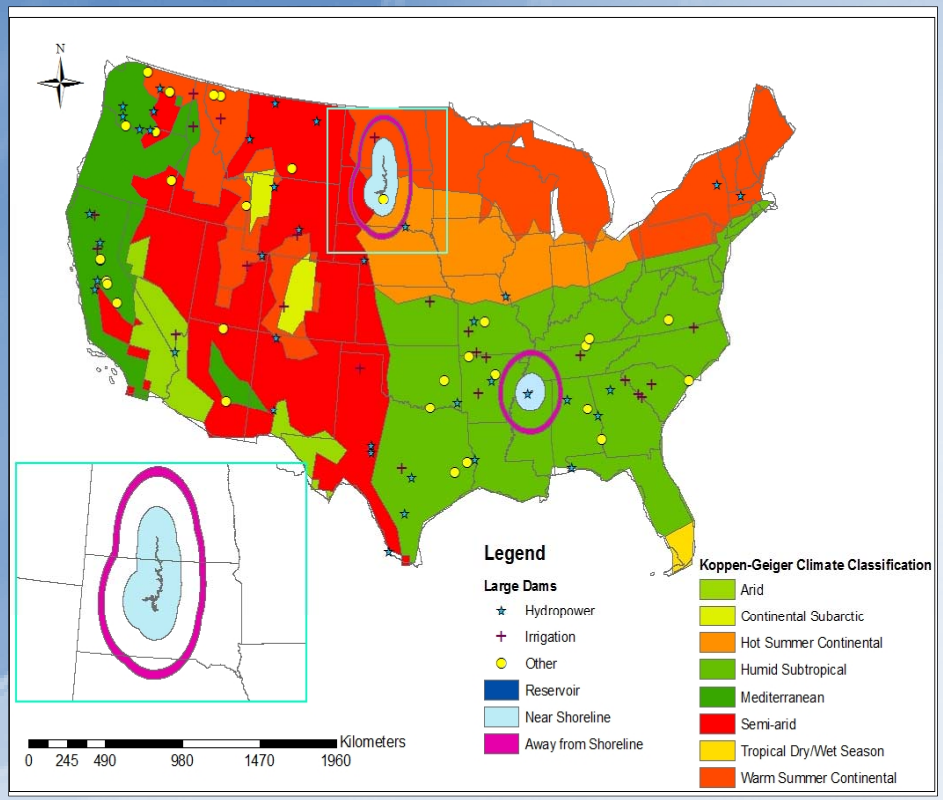


Source: USACE 1970



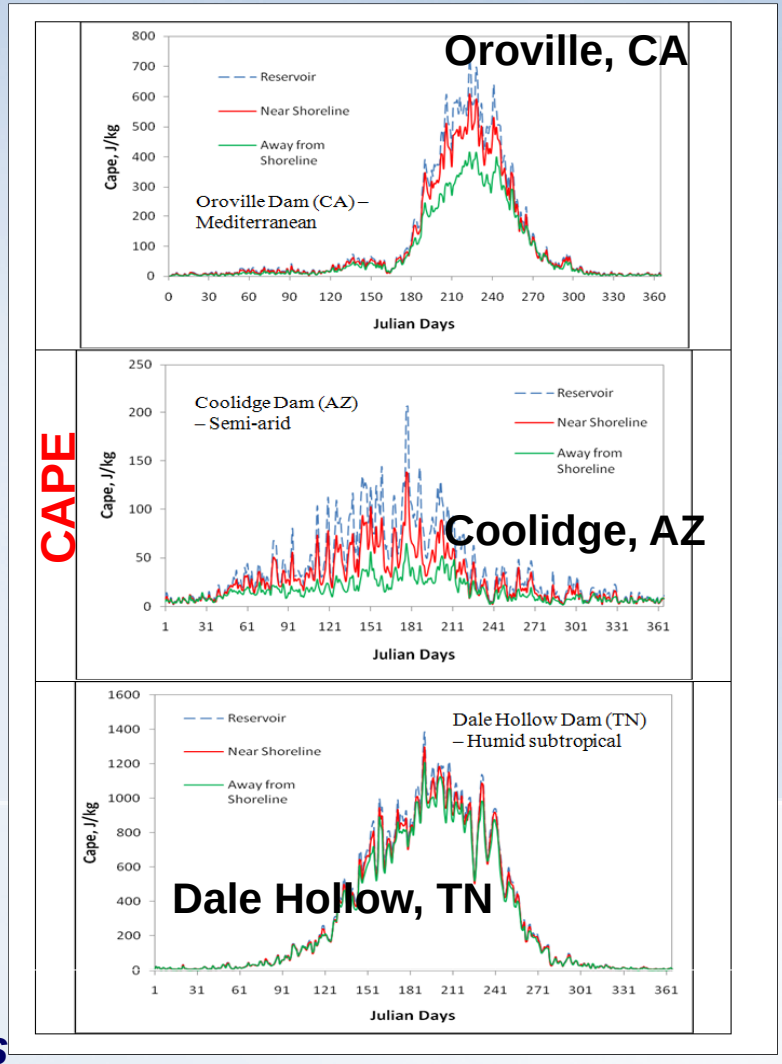
Typical 'rigid' rule book for dams (Oroville Dam – Source: USACE, 1970)

ANALYSIS OF DAMS IN US – USING ATMOSPHERIC REANALYSIS



Ninety-two large dams overlaid on Koppen Climate map

CAPE : 30 year mean from NARR; 2-3 times larger near reservoir shorelines in growing season Mediterranean and semi-arid climates



Julian Day

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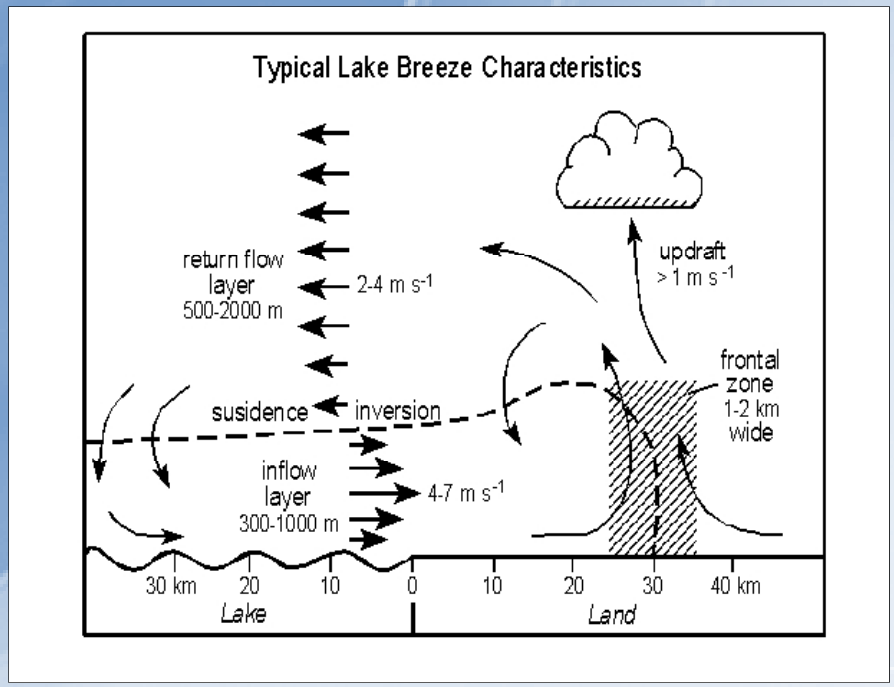
PHYSICAL MECHANISM HYPOTHESIS: FROM NATURE

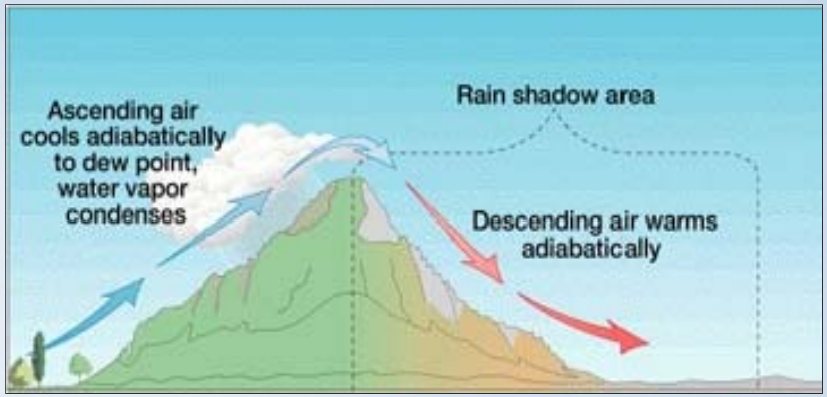
Moisture Supply



Lake Breeze Effect

Source: Fang Zhang -UGA

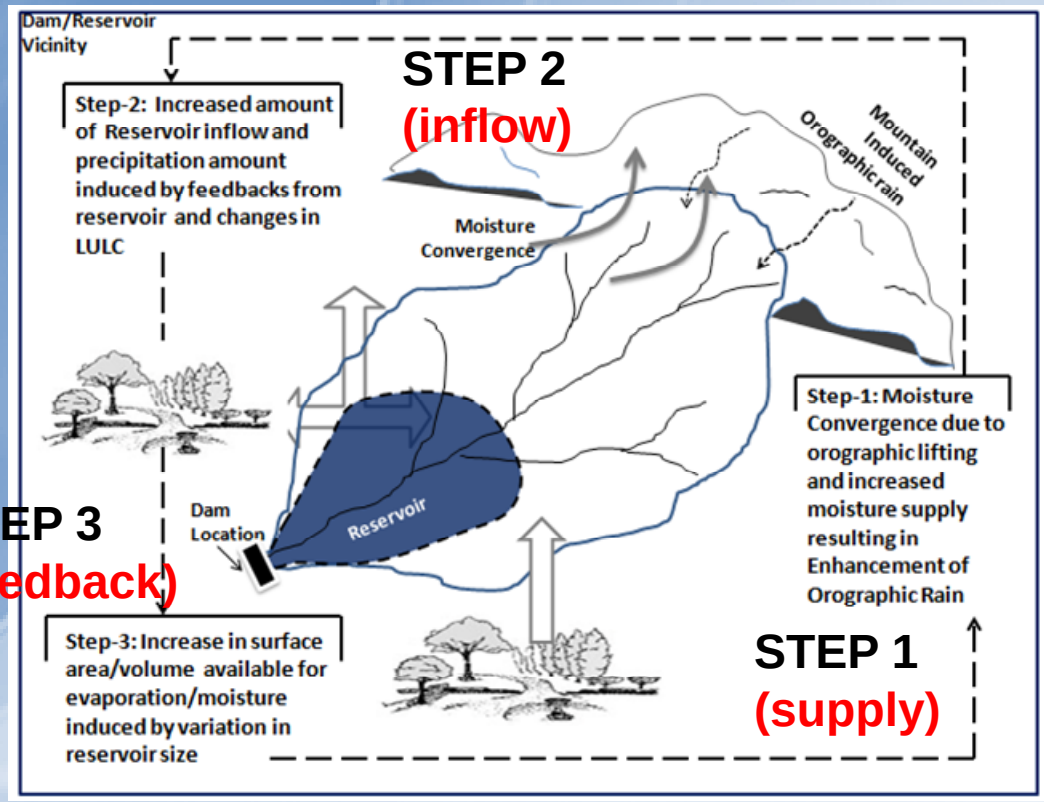
Lifting



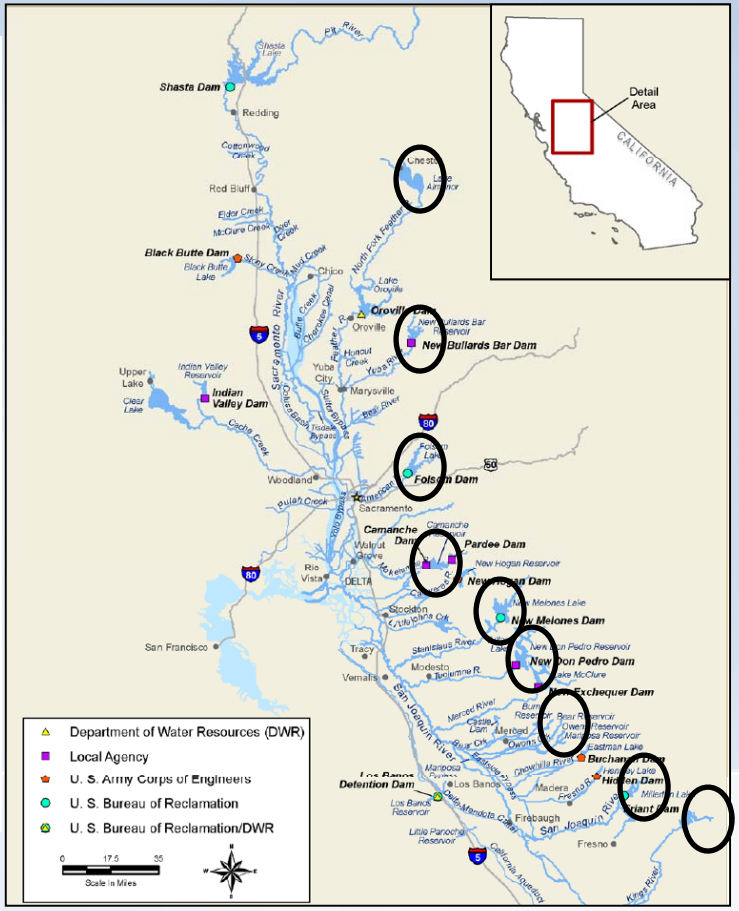
Feedback Mechanism between Lake/Wetlands and Rainfall

[Niger Inner Delta - +ve feedback Taylor (2010) – *Geophysical Research Letters*]

DAM-OROGRAPHIC RAIN POSITIVE (DORP) FEEDBACK HYPOTHESIS



DORP – 3 STEP PROCESS



California Central Valley Flood Management Program -2012

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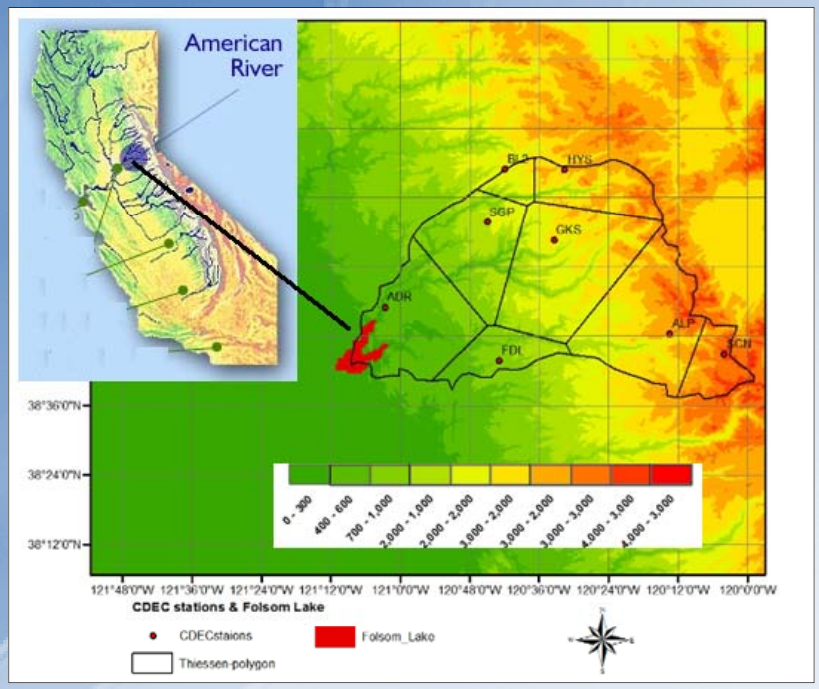
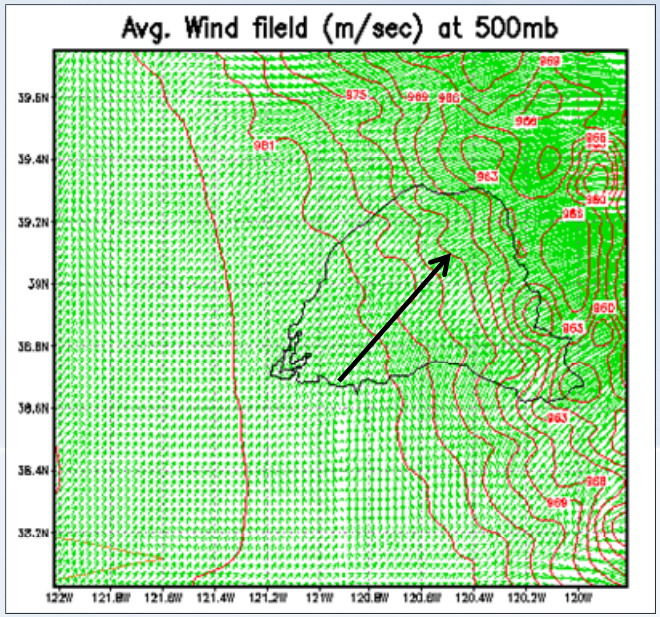
NUMERICAL MODELING OF STORM EVENTS





Regional Atmospheric Modeling System - RAMS 6.2
Dec 96 – Jan 97 major storm event
Rigorously validated against in-situ rainfall measurements

Prevalent wind direction at 500mb (Ideal for testing DORP Hypothesis)

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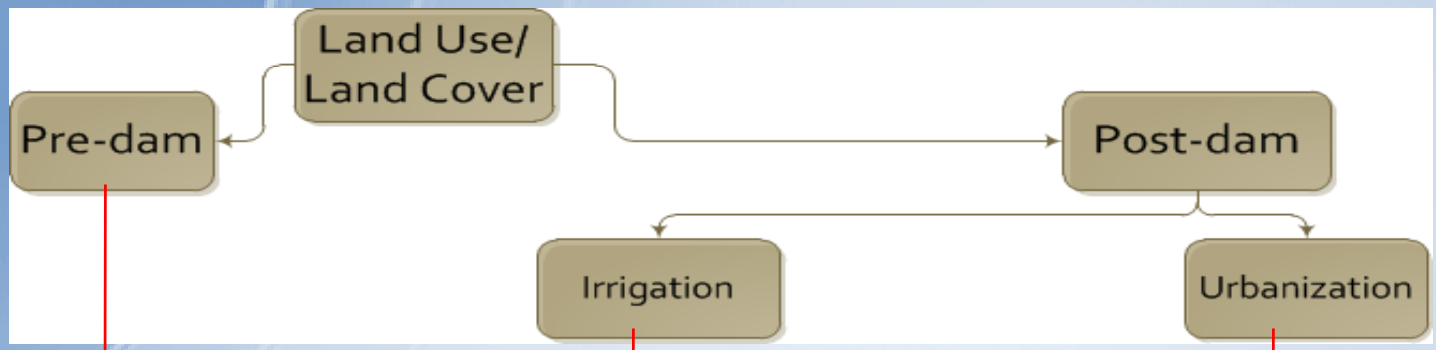
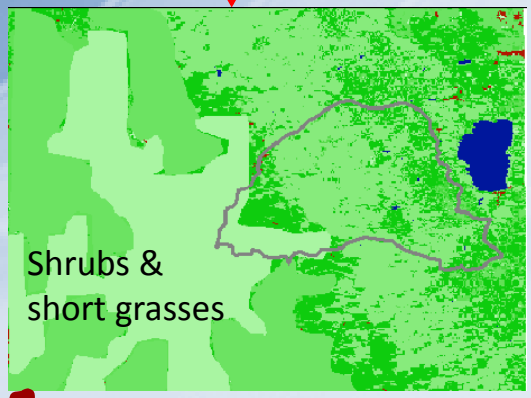
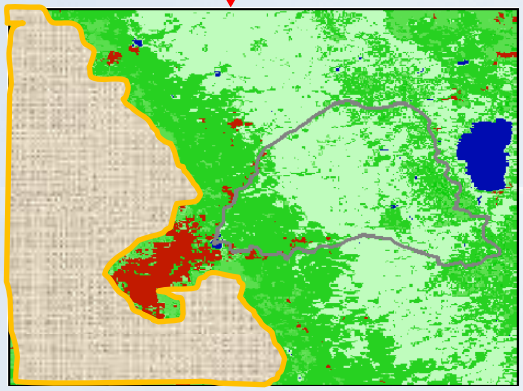
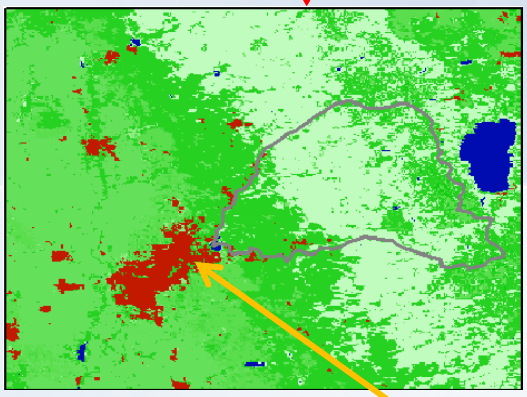
ANTHROPOGENIC LAND USE/LAND COVER CHANGES









Pre-dam (1950's LULC) – from HYDE

Post-dam (2003's LULC) – from MODIS

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DAM DESIGN PARAMETER: PROBABLE MAXIMUM PRECIPITATION

According to the World Meteorological Organization (WMO, 1986), PMP is defined as ‘***the greatest depth of precipitation for a given duration meteorologically possible at a particular location and at a particular time of year’.***

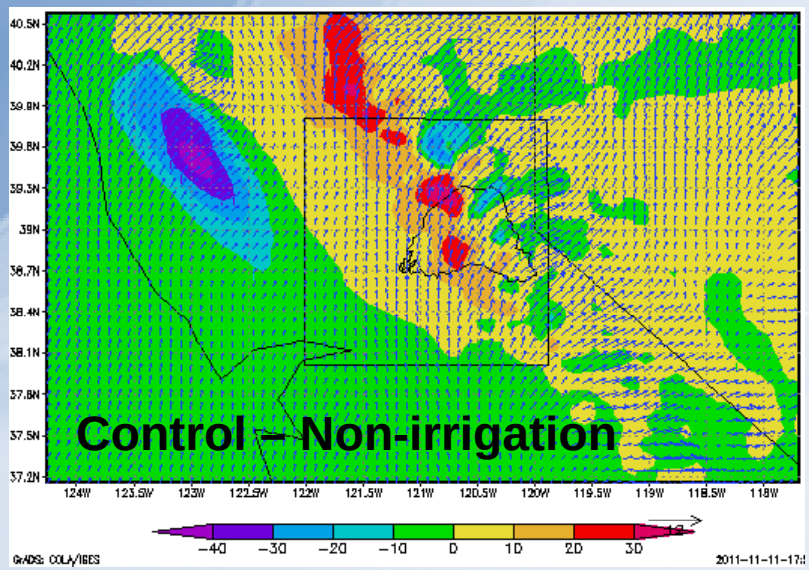
$$PMP = P \times \frac{w_p\,(maximum)}{w_p\,(storm)}$$

Currently determined from pre-dam records

W = precipitable water in the atmosphere, Wmax = maximum precipitable water estimated from the maximum daily dew point temperature records.

PMP SCENARIOS

Run Type (LULC change scenarios)	Maximum 72-hr basin-averaged precipitation (mm)	Difference from control (mm)	Percent increase/decrease from control
Control	353.93	-	-
Reservoir-double	357.84	-3.91	1.105% increase
Non-irrigation	343.51	10.42	2.94% decrease
Pre-dam	346.20	7.73	2.18%decrease



Surface area of reservoir plays a marginal role in intensifying design precipitation. Irrigation is the most dominant player with perhaps Sacramento expansion playing a secondary role.

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Woldemichael et al. 2012, Impact of Land use/land cover change on PMP, *Wat Res. Research*.

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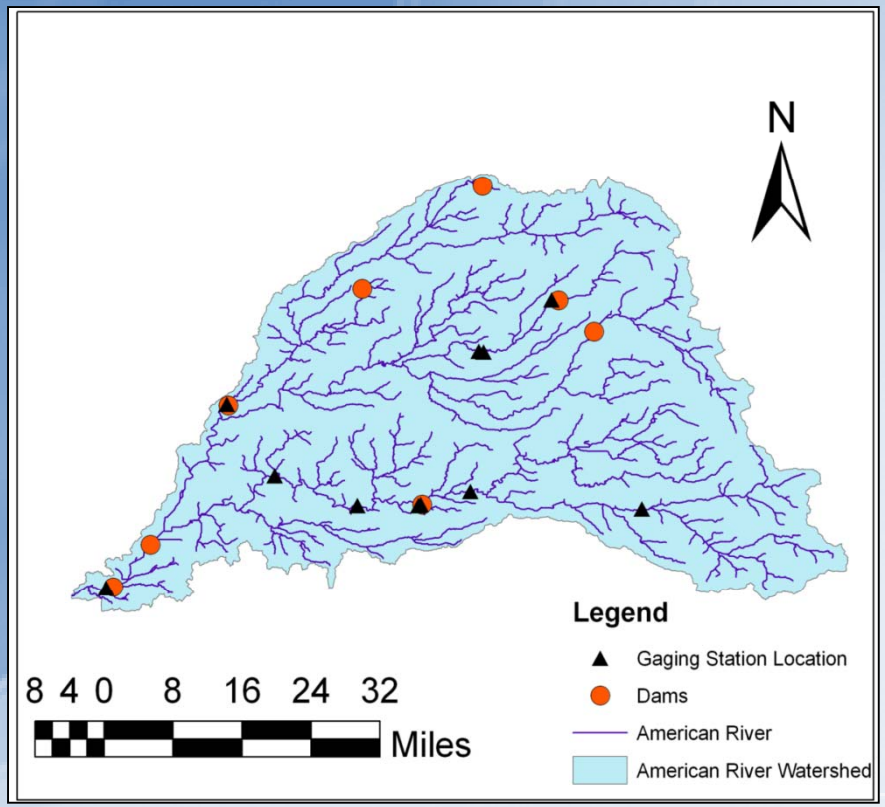
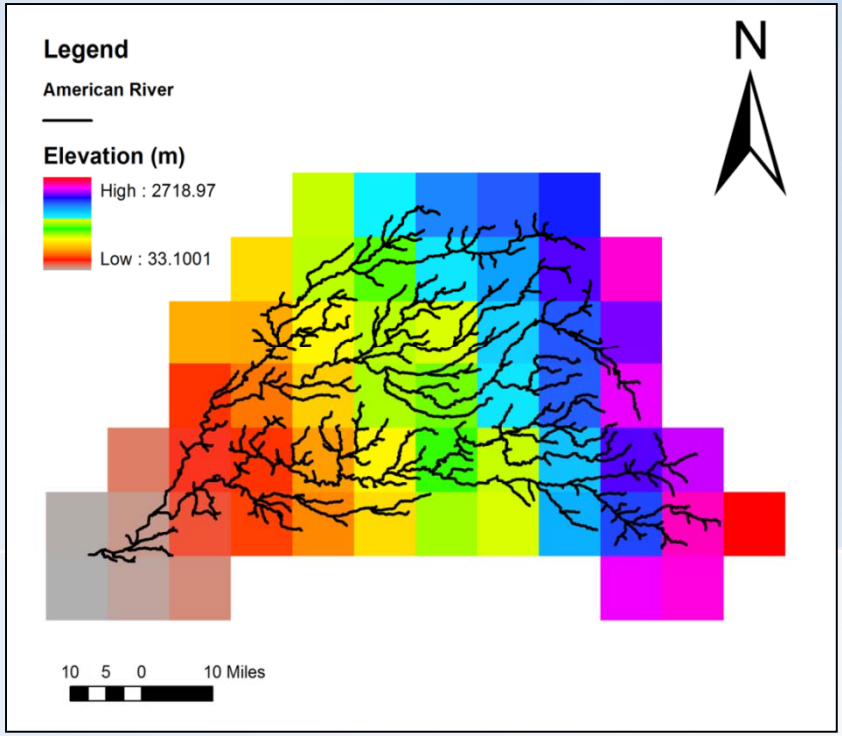
PROBABLE MAXIMUM FLOOD (PMF) SIMULATION



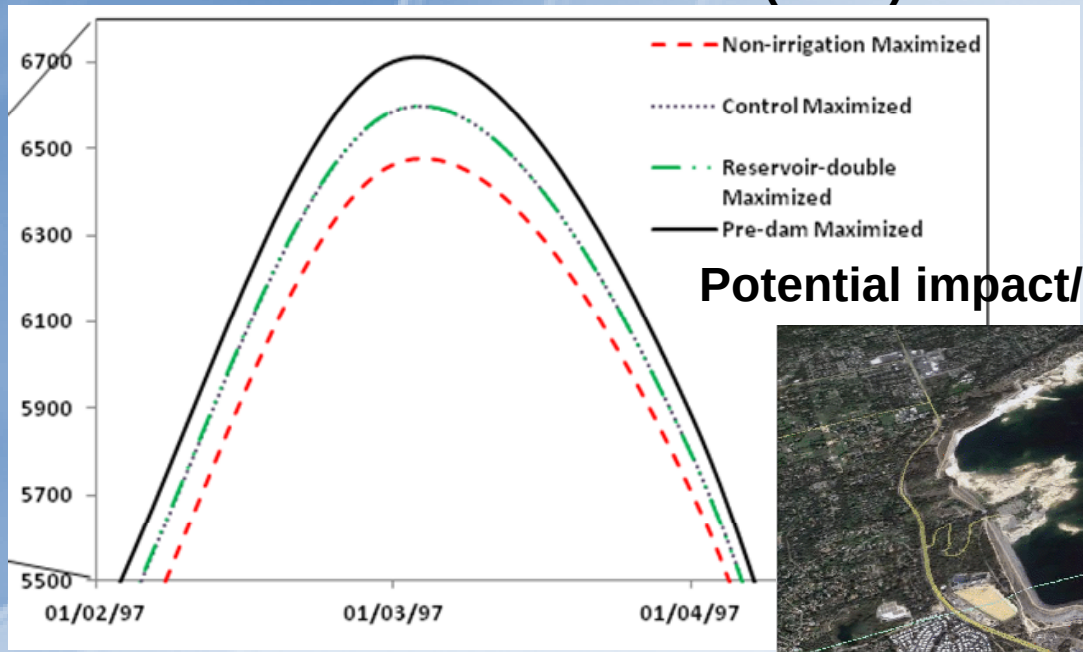
Variable Infiltration Capacity -3L Hydrologic Model



Yigzaw et al.(2012) Impact of Artificial Reservoir Size and Land Use/Land Cover Patterns on Estimation of Probable Maximum Flood: The Case of Folsom Dam on American River, *ASCE J. Hydrologic Engineering.*

PROBABLE MAXIMUM FLOOD (PMF) SIMULATION

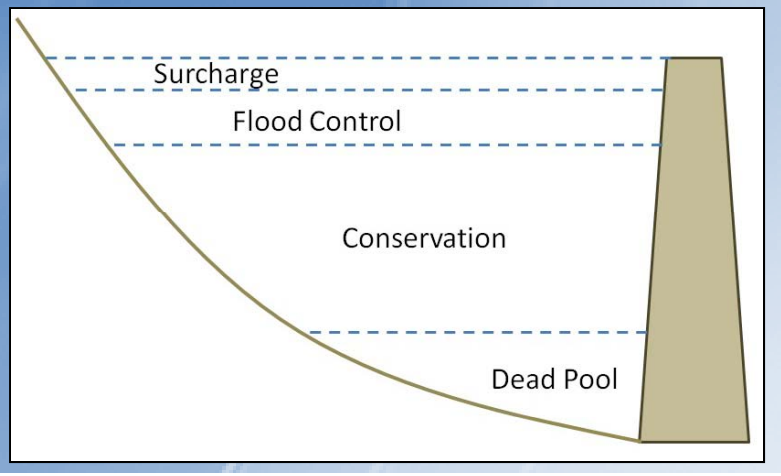
PMF inflow to reservoir (m3/s)

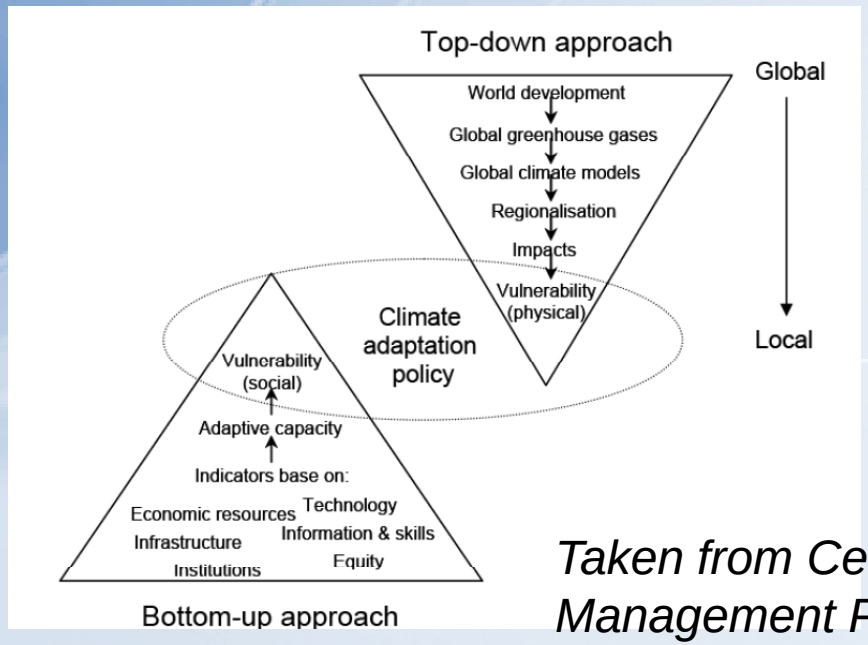


Potential impact/risk on downstream infrastructure

Levee capacity is about 4000 m3/s

CURRENT STATE OF 'INERTIA' IN CIVIL ENGINEERING COMMUNITY





Taken from Central Valley Flood Management Planning Program Report (2012)

SOME OF THE FEEDBACK:

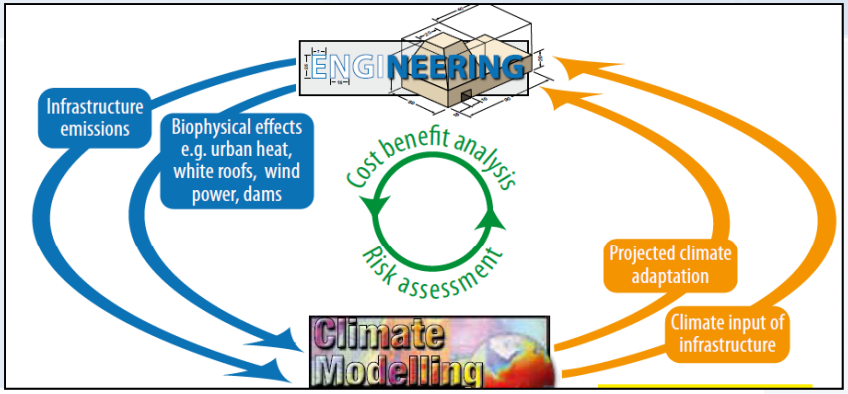
1. "Freeboard' and factors of safety adequate for any future contingency.
2. Sedimentation/loss of storage is minimal in most regions.
3. It's just a structure, how can it impact local climate extremes by itself?
4. GCM-based Climate-change Projection driven top-down adaptation/analysis should take care of mesoclimate impacts by *default.*
5. This is tree-hugger hysteria not appropriate for countries that need to develop rapidly

SUMMARY OF KEY ISSUES

- Inertia in accepting new ideas/approaches or technology - driven by skepticism, lack of (mutual) understanding of other's practice and lack of hands-on education on 'pros' and 'cons'.
- Institutional success of satellite based flood forecasting will depend on: a) better ownership of technology transfer b) more education on the limits of use c) understanding the cultural/social background of public users.
- Institutional success of climate studies for design and operation of dams will depend on: a) co-design of experiments with engineering community feedback b) more education/outreach c) tweaking of B.S curriculum (engineering) – General Education requirement

ASCE J. Hydrologic Engg – Forum Article, 2012

***Taken from "Global Change'* by IGBP, March 2012 Issue (Hossain and Pongtraz)**



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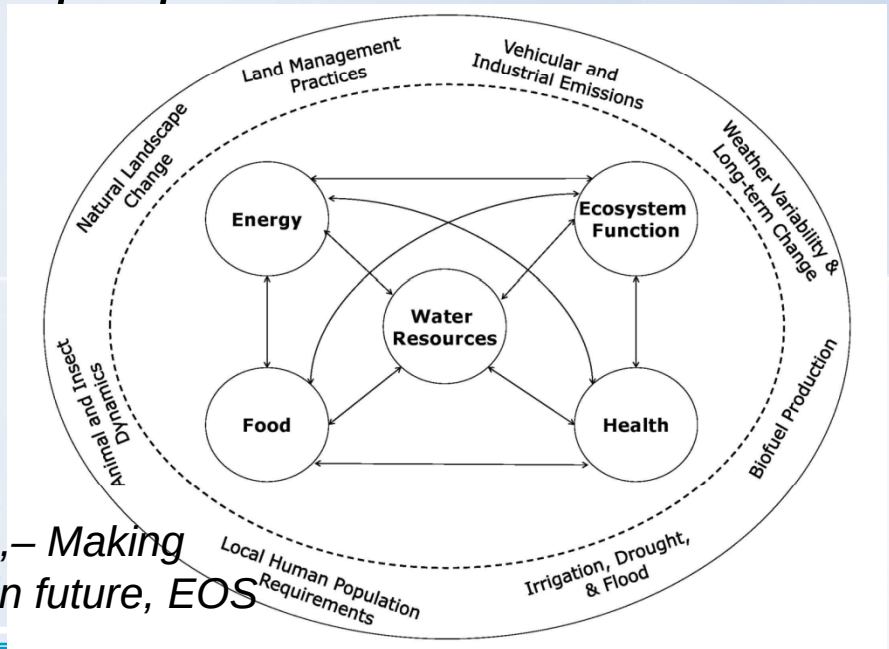
A WAY FORWARD

- More Hands-on Education Effort involving (active learning) of consumers (stakeholders)
- Co-design of Research Experiments with input from consumers.
- Working with Philanthropic Institutions: Broaden the value of water cycle satellites (beyond water – health, food, poverty) to increase appeal to non traditional consumers.
- *Is it possible to make massive amounts of satellite water data freely accessible on a daily basis to people around the world (much like Google Earth –intuitive design)?*
- Search Engine Optimization – Simple Issue involving social science (but can reach out to millions of web users)



Hossain et al., 2011,– Making sense of our water in future, EOS

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Tell me and I forget.

Teach me and I remember.

Involve me and I learn.

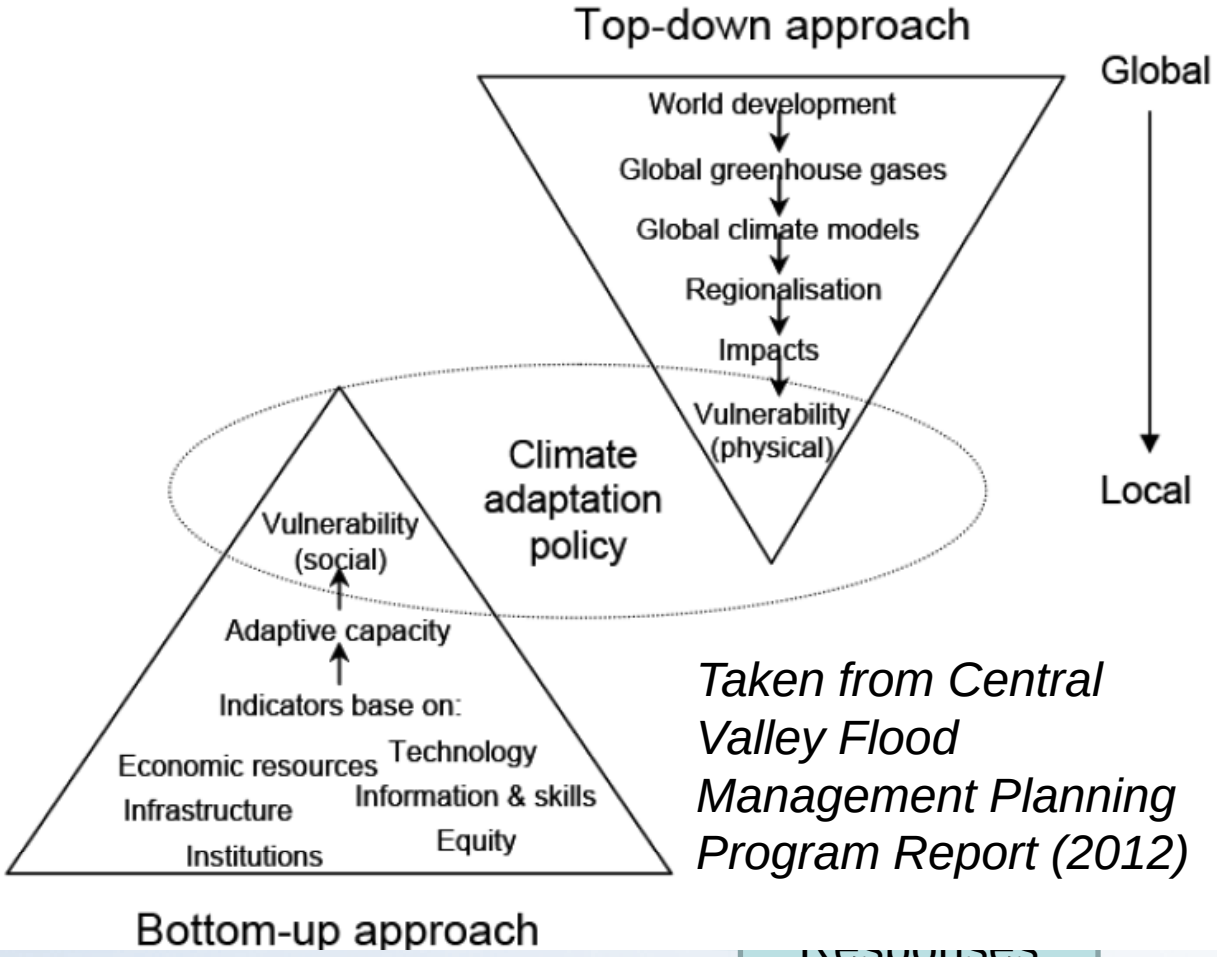
Benjamin Franklin

SOME OF THE REBUTTALS

1. *SWOT elevations will be well over an order of magnitude more accurate than SRTM. With adequate QA/QC and data assimilation/model calibration, estimation uncertainty can be minimized.*
2. *SWOT is not a gauge replacement mission. SWOT provides knowledge where there are no gauges. For rigid bed and single channel rivers, bathymetry is a 'one-time' requirement. For loose boundary and braided rivers annual bathymetry sampling is adequate. Hence, in-situ bathymetry is needed occasionally depending on the nature of the river system.*
3. *Pressure transducers are very expensive and have their own sources of errors and sampling challenges. (Theft or washout is a big problem!)*
4. *For rigid bed single channel rivers, the land/water mask is not a critical issue. For braided rivers with large flood plains, alternative schemes and data sources are available (RADARSAT; Bayesian modeling of land/water areas, data assimilation etc.)*

Top-down – more familiar **Bottom-up – more recent**

1a. Out



Taken from Central Valley Flood Management Planning Program Report (2012)

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O'Brien et al , 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy* 7 (1): 73–88