Global Best Practices in Flood:

Examples from Bihar & Bangladesh for Actionable & Measurable Flood Warning and Management for Pakistan

Stakeholder's Workshop: Flood Forecasting & Management

Organized by the Government of Pakistan and World Bank

Islamabad, 14 February 2013

Tufts University School of Engineering | Water Diplomacy | The Fletcher School

102 Years Ago…

"Hitherto the long range forecaster has been denied a seat in the banquet hall of science; …the general scientist has denounced him; the professional weather man has treated him with supercilious scorn" **(Ricard 1911).**

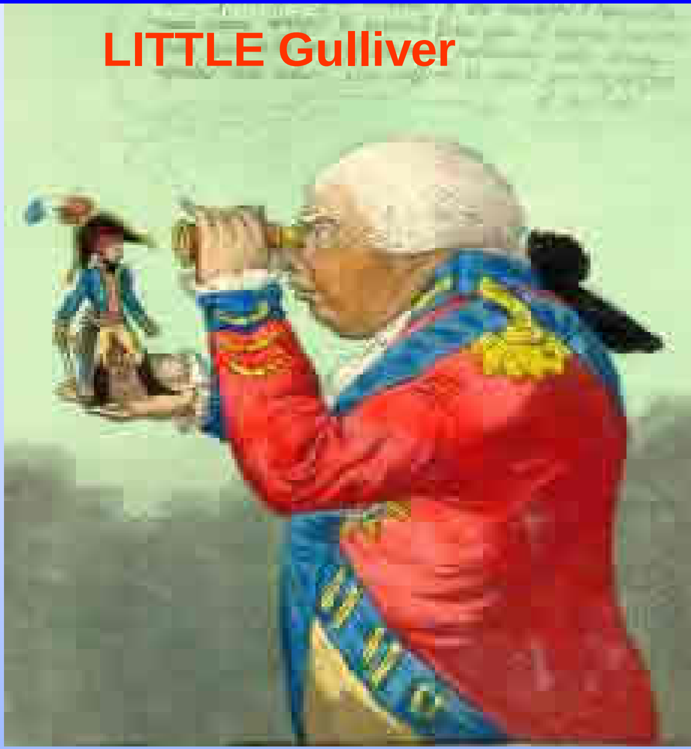
100 years later…

2010 Pakistan Flood: >20M people; >$40B Economic Impact
2011 Thailand Flood: >13M people; >$46B Economic Impact

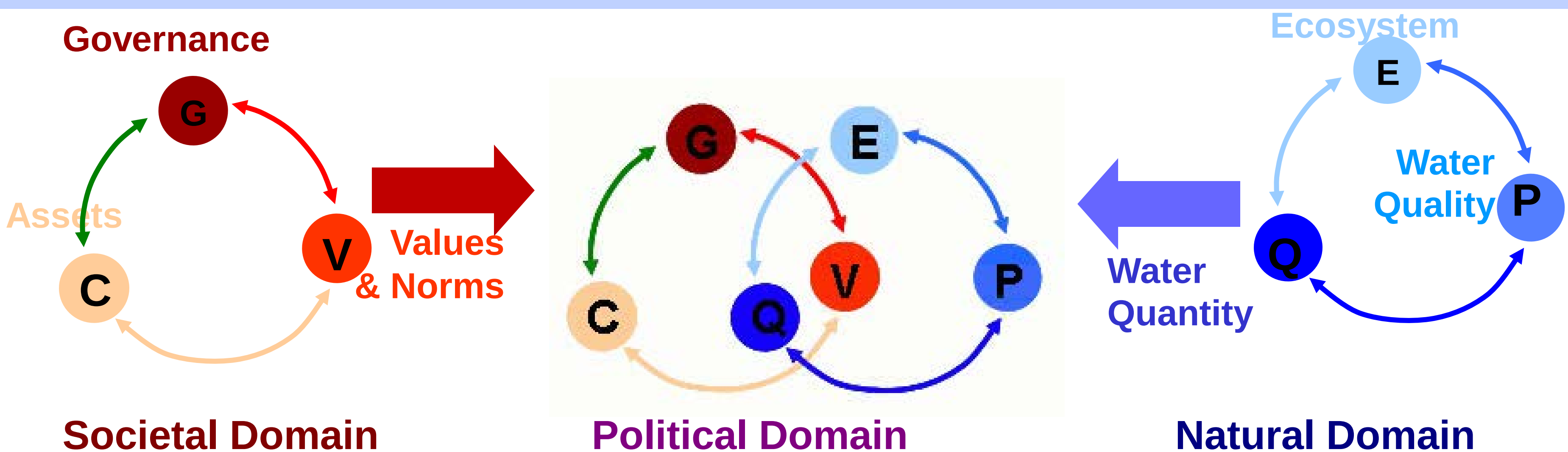
Floods in Asia: Lessons to be Learned

"…as Thailand begins its rehabilitation effort, it should not only include reconstruction of infrastructure but also restoration of the trust and confidence of the people. We need to continuously learn from mistakes and prepare for a better future." Irandoust and Biswas (2012)

Issues of SCALES; LEVELS; DOMAINS : Watershed; Problemshed; Policyshed



Issues of SCALES and DOMAINS : Watershed; Problemshed; Policyshed



Coupled Natural, Societal and Political Domain (NSPD)

Indus River System

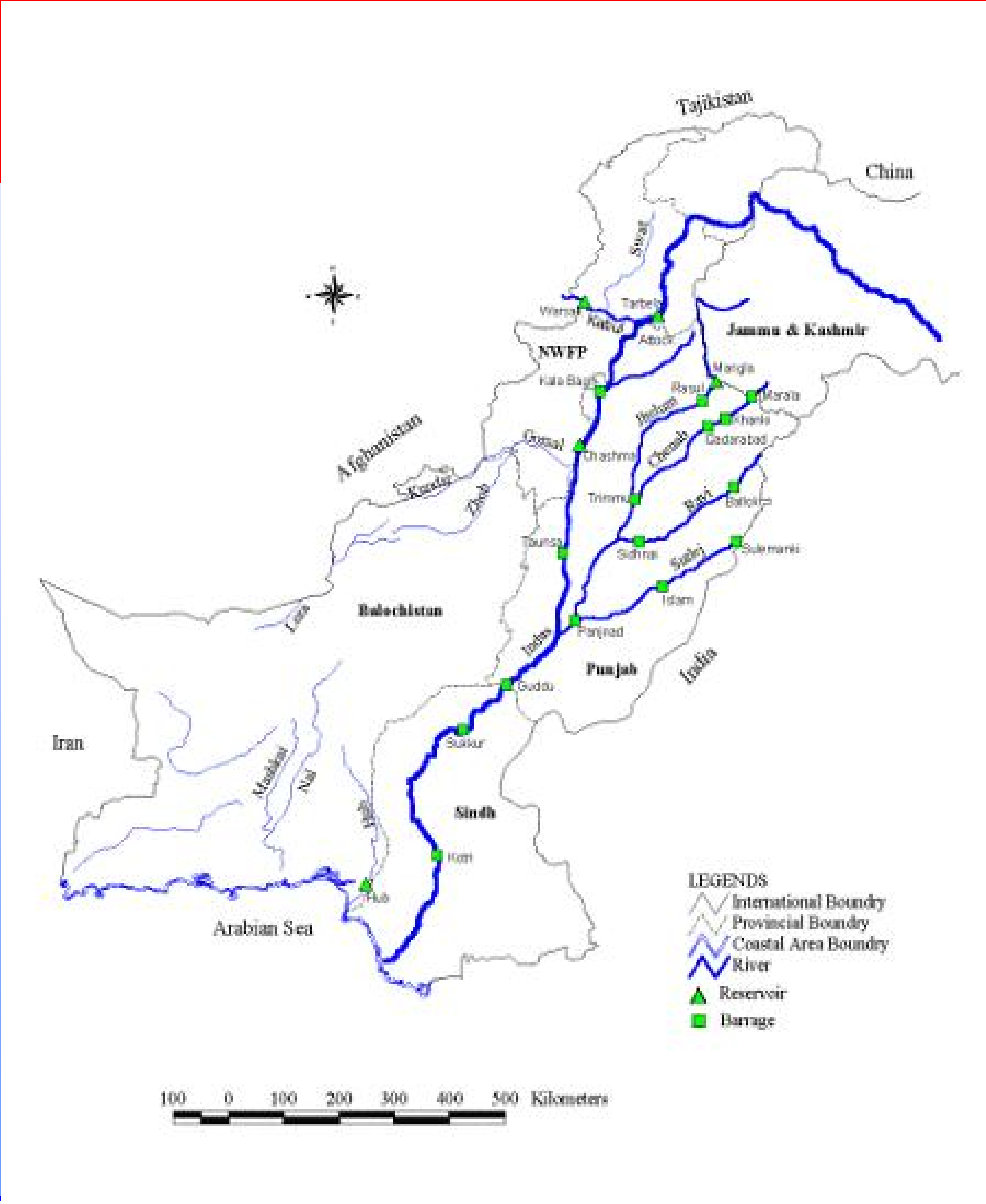
A Boundary Crossing Coupled Natural and Human System

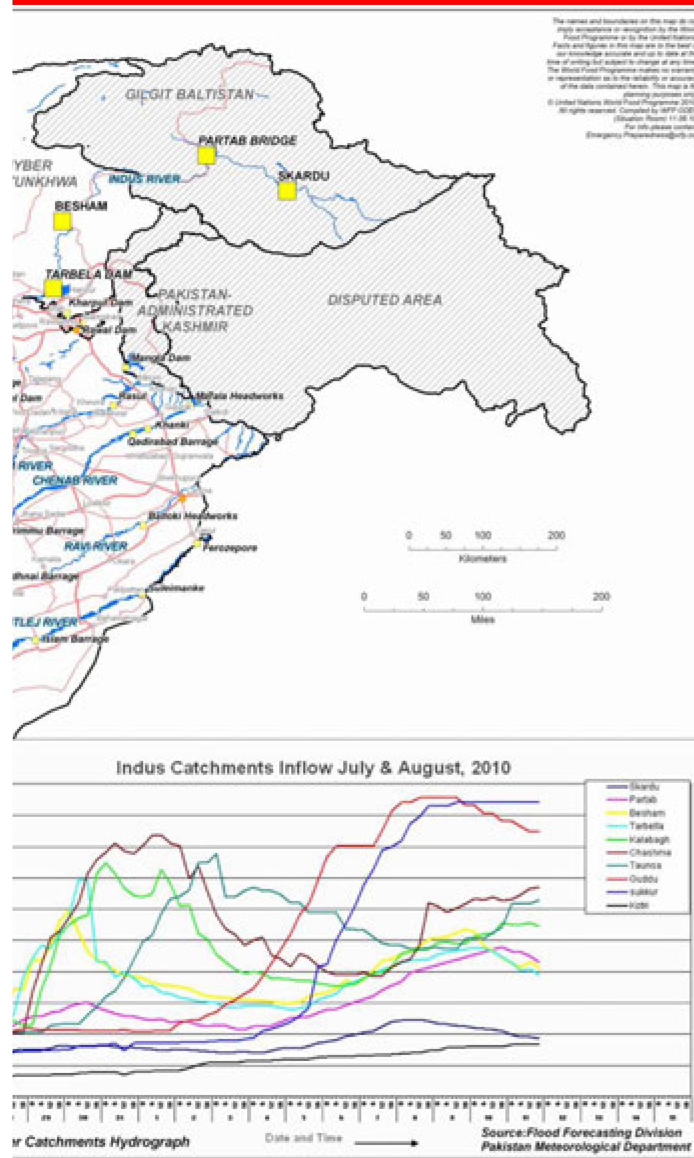
Domains
Scales
Levels

Watershed
Problem-shed
Policy-shed

stem

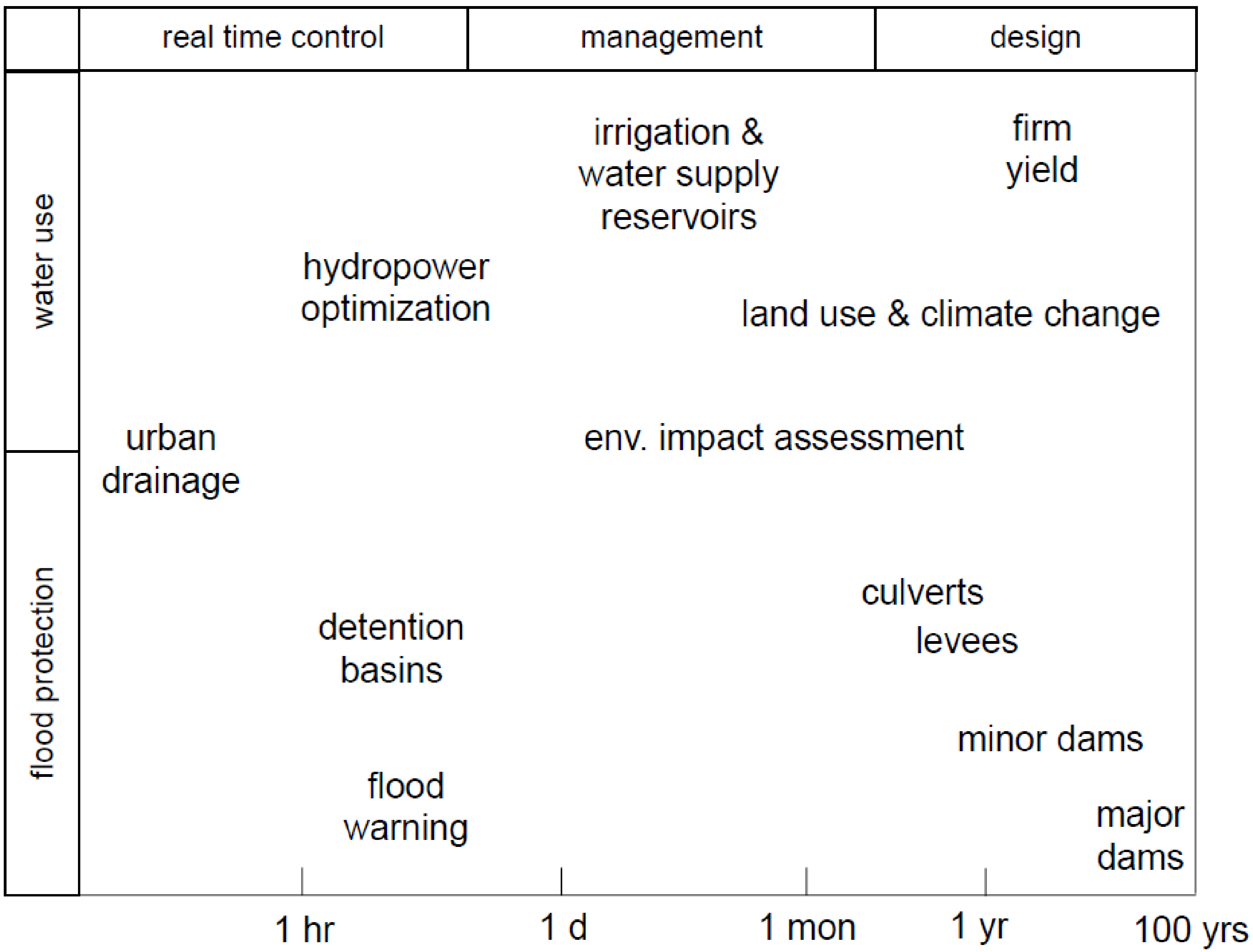
ural and Human System





Domains, Scales and Levels

Scale Challenges: Combination of cross-scale and cross-level Interactions



Flood Forecasting

Macro
Micro

Large
Small

Climate
Weather

Economic
Utility

Water
Quality

Governance &
Institutions

Ecological
Economics

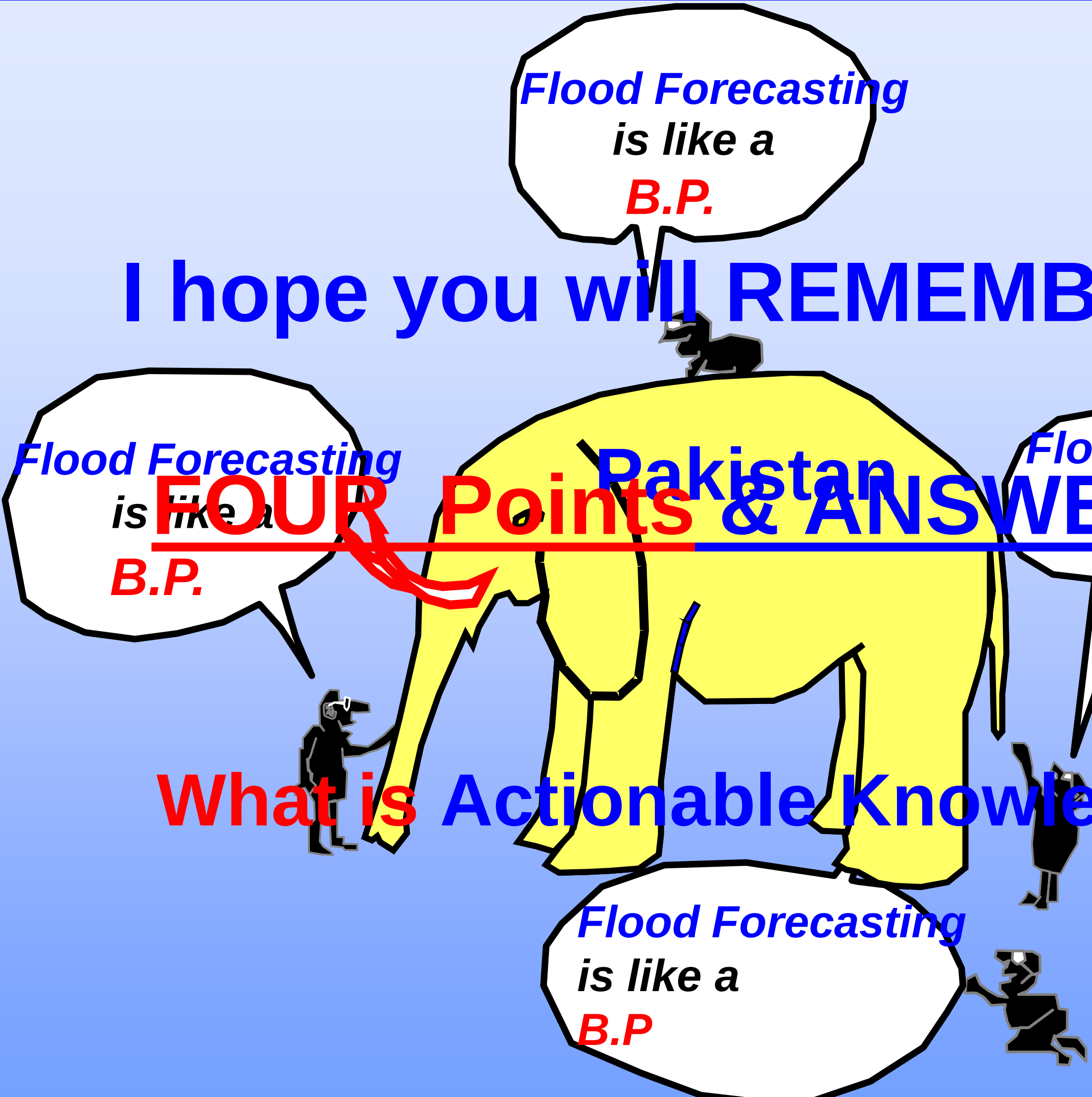
Culture &
Values

Water
Quantity

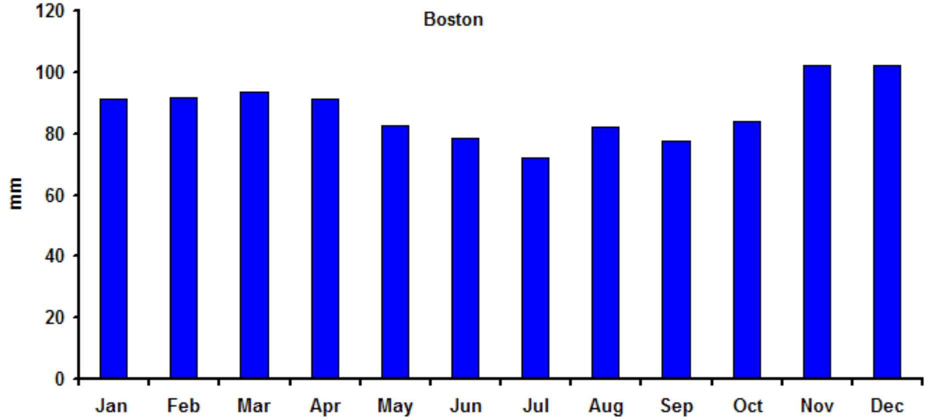
Water Management

I hope you will REMEMBER and RECALL

FOUR Points & ANSWER one question



What is Actionable Knowledge for Pakistan?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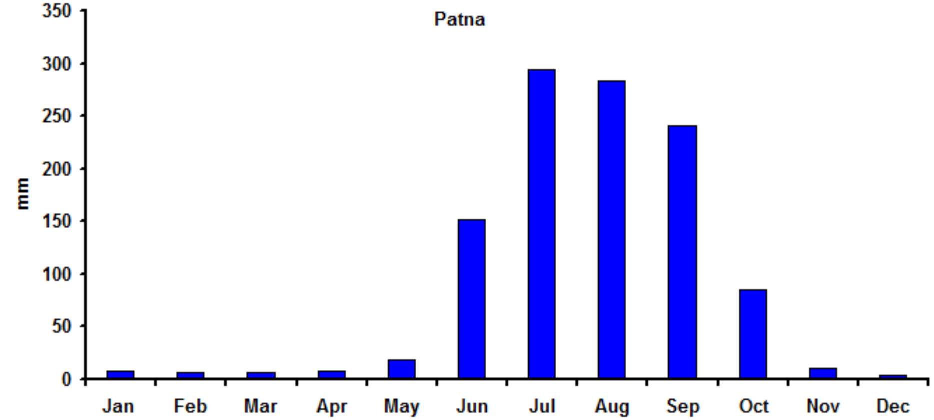
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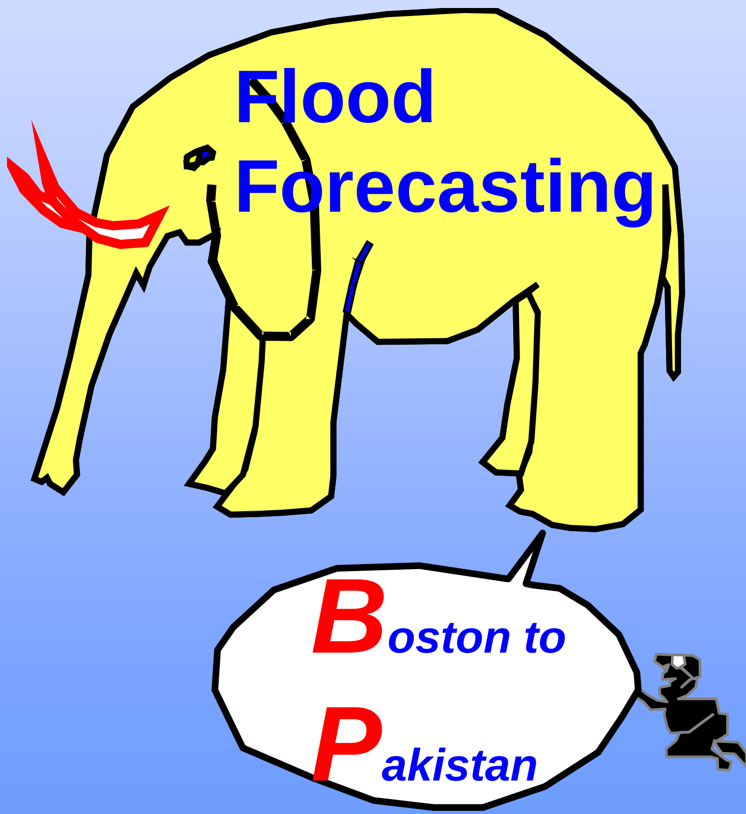
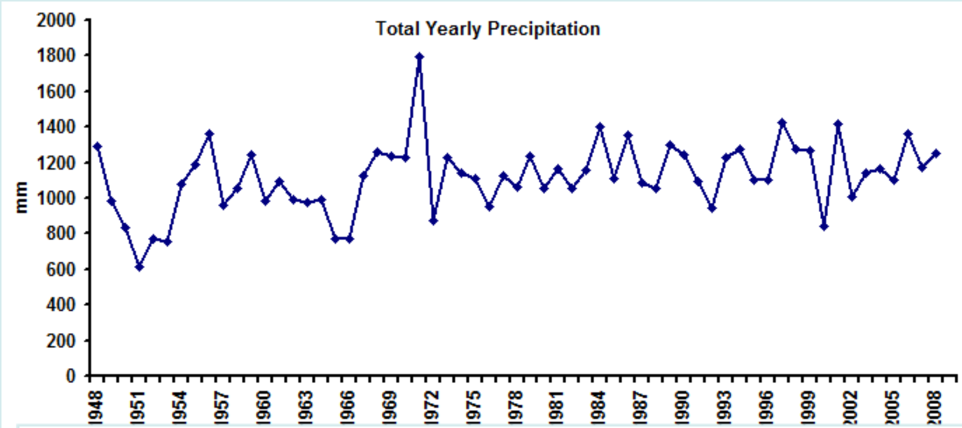

Flood Forecasting
Boston to
Pakistan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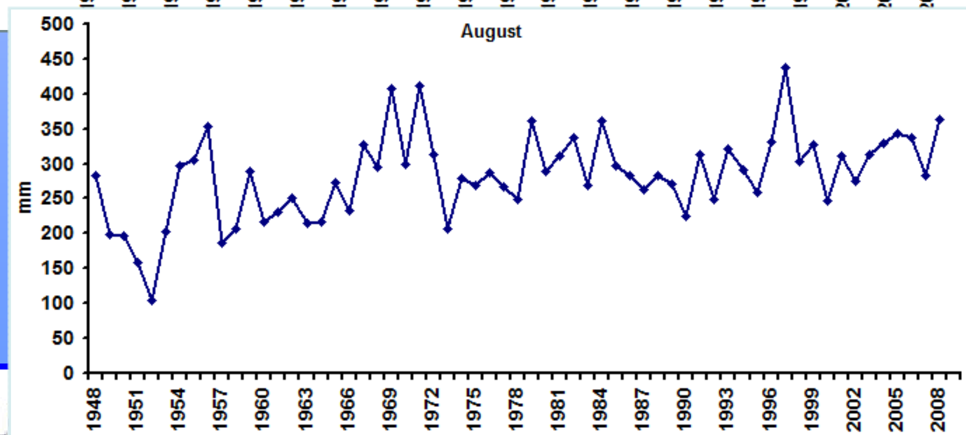
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2008

Flood Forecasting

Macro
Micro

Large
Small

Climate
Weather

Precipitation

Soil Moisture

Surface Runoff

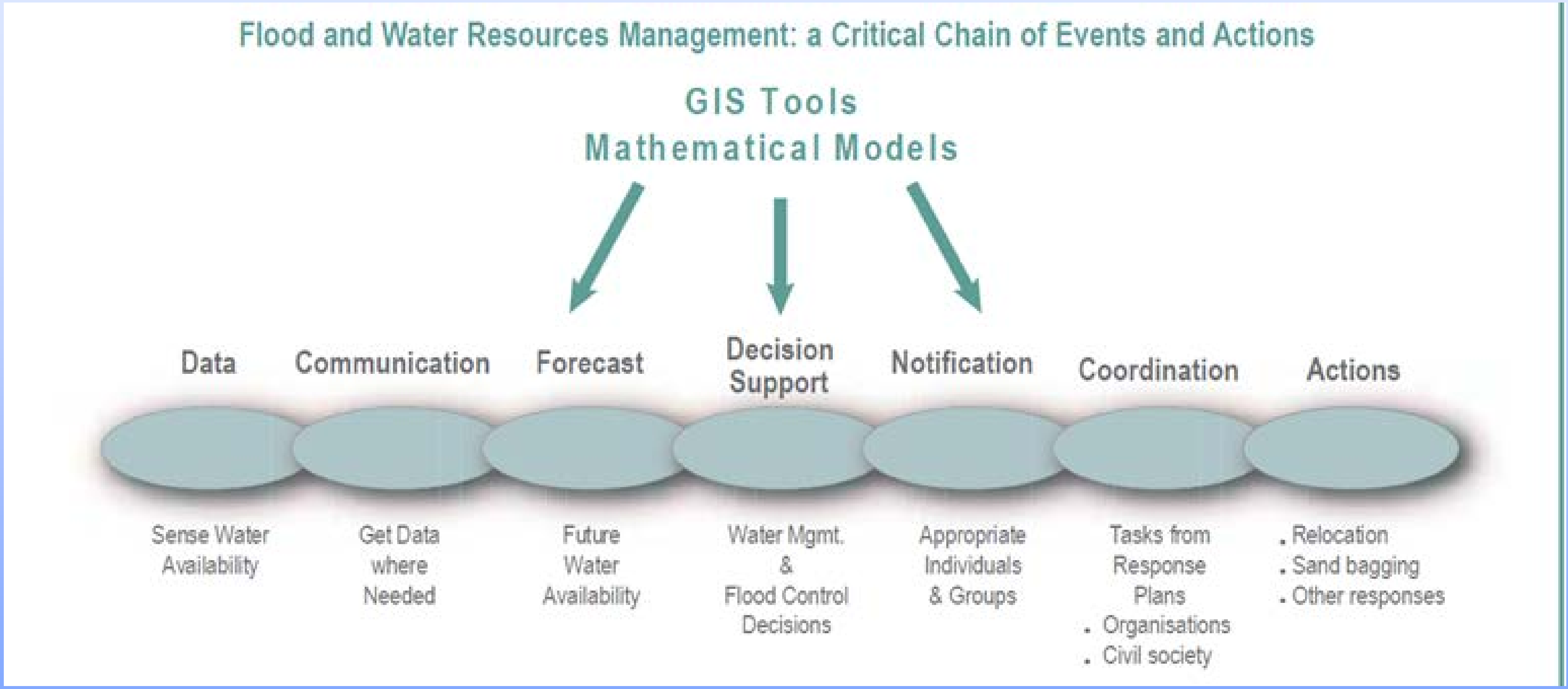
Vegetation

Topography

Evaporation

Water Management

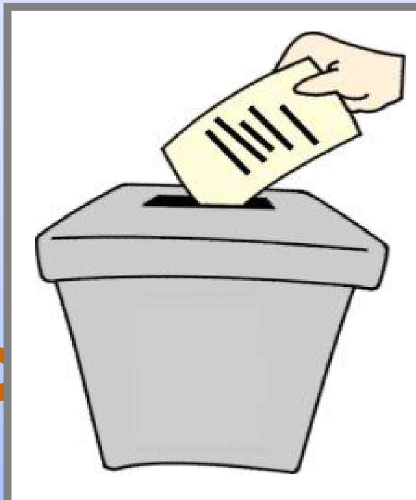
Connect THEORY and PRACTICE: Create Actionable Knowledge in WATER



Perception of water resources systems

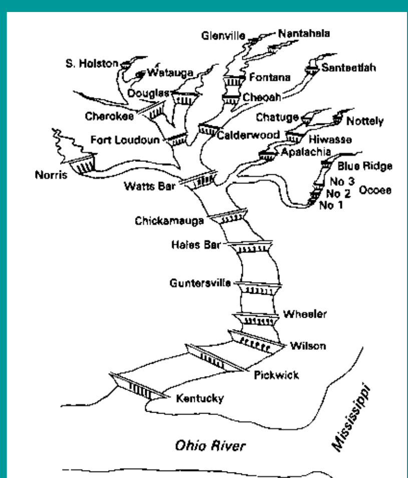
"People"

Politicians



Engineers

"Practitioners"



Justice

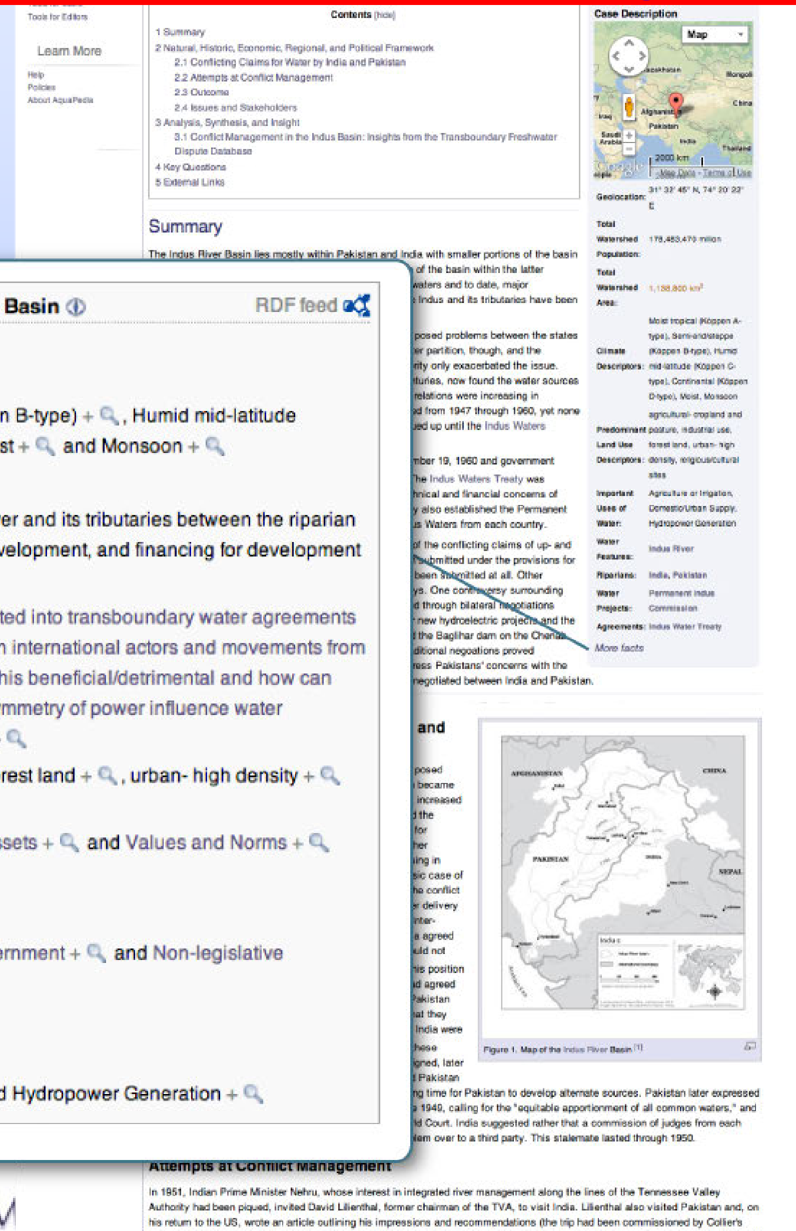
Scientists

Connect THEORY and PRACTICE: Create Actionable Knowledge in WATER

...lomacy Workshop (WDW) in 2011 and ...articipants master theory and practice of water network management tools and teach these tools to others.

Indus River System

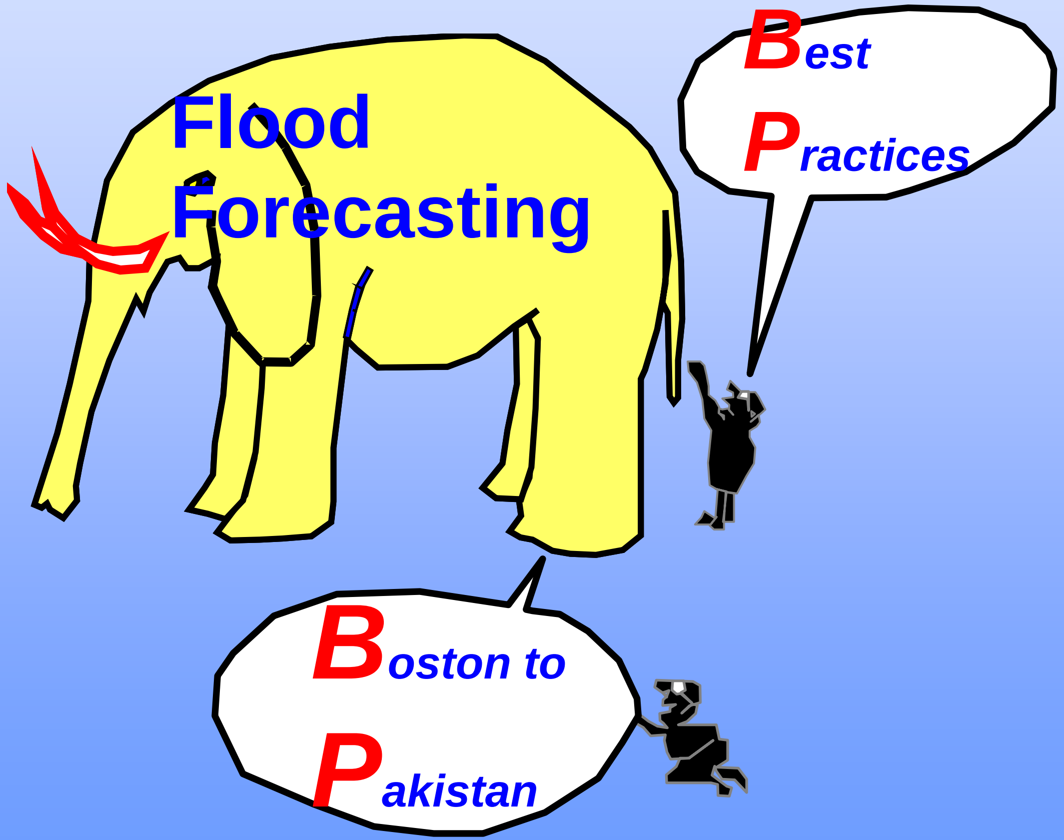
An Example from AquaPedia: What Can We Learn Together?

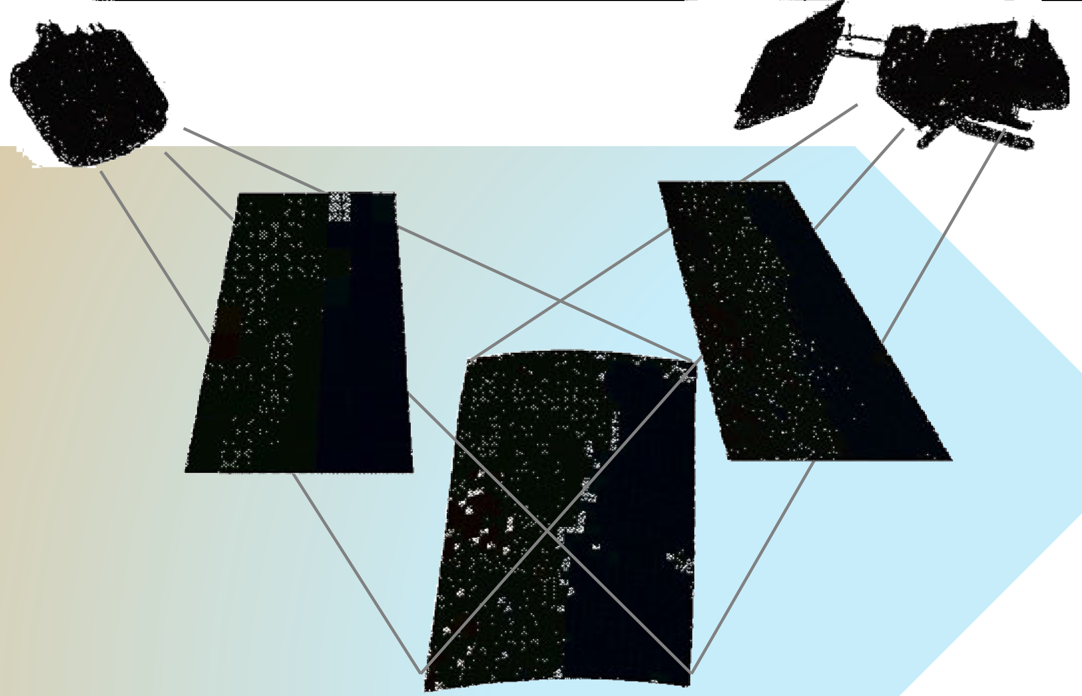


Facts about Conflict Management Strategies Among Riparians Within the Indus River Basin RDF feed

Agreement	Indus Water Treaty +
Area	1,138,800 km² (439,693.138 mi²) +
Climate	Moist tropical (Köppen A-type) + , Semi-arid/steppe (Köppen B-type) + , Humid mid-latitude (Köppen C-type) + , Continental (Köppen D-type) + , Moist + and Monsoon +
Geolocation	31° 32' 45" N, 74° 20' 22" E +
Issue	Negotiating an equitable allocation of the flow of the Indus River and its tributaries between the riparian states; developing a rational plan for integrated watershed development, and financing for development plans. +
Key Question	What mechanisms beyond simple allocation can be incorporated into transboundary water agreements to add value and facilitate resolution? + , To what extent can international actors and movements from civil society influence water management? How and when is this beneficial/detrimental and how can these effects be supported/mitigated? + and How does asymmetry of power influence water negotiations and how can the negative effects be mitigated? +
Land Use	agricultural- cropland and pasture + , industrial use + , forest land + , urban- high density + and religious/cultural sites +
NSPD	Water Quantity + , Water Quality + , Governance + , Assets + and Values and Norms +
Population	178,483,470 million +
Riparian	India + and Pakistan +
Stakeholder Type	Sovereign state/national/federal government + , Local Government + and Non-legislative governmental agency +
Water Feature	Indus River +
Water Project	Permanent Indus Commission +
Water Use	Agriculture or Irrigation + , Domestic/Urban Supply + and Hydropower Generation +

- Numerical Weather Prediction Model
- Rainfall-Runoff Model
- Flood Innundation Models





Before 1970s

2000s

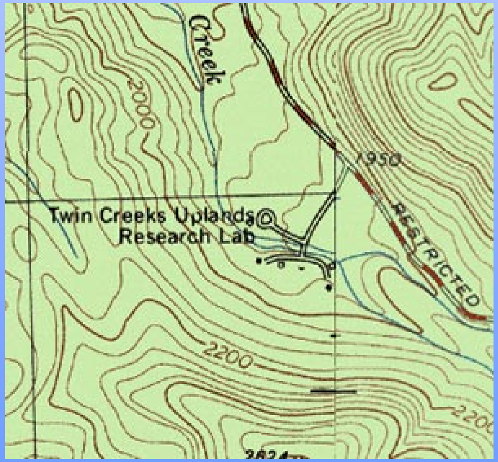
Transformative changes in measurement technologies.

Transformative developments for hydrometeorological science and understanding of hydrologic and climatic processes?

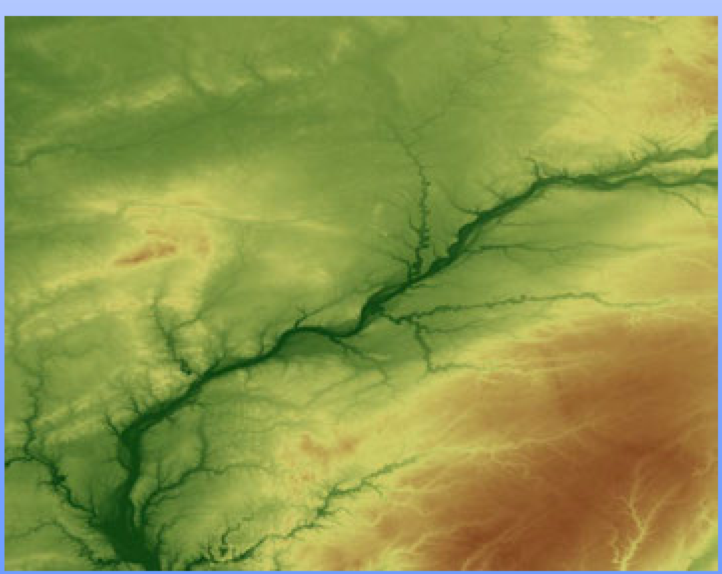
Digital Elevation

What They Made Possible.

- Enabled Spatial Hydrologic Modeling
- Linked Continental Hydrology and Oceans
- First Tool in Characterizing a Problem



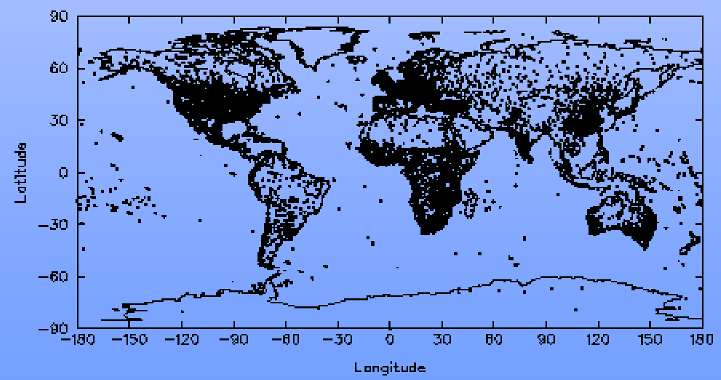
USGS Quad



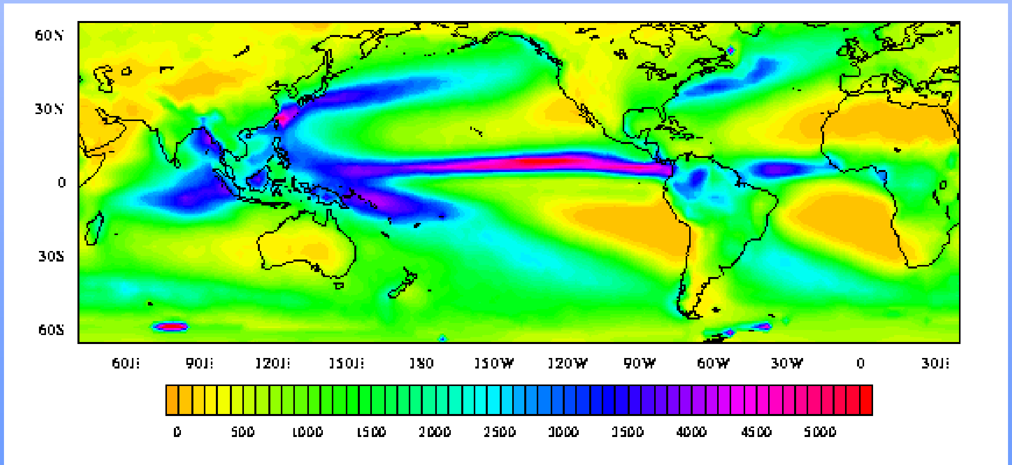
SRTM

Precipitation

- See Rainfall as Structured Fields That Move and Transform
- Catalyst in Understanding Macro-Scale Processes

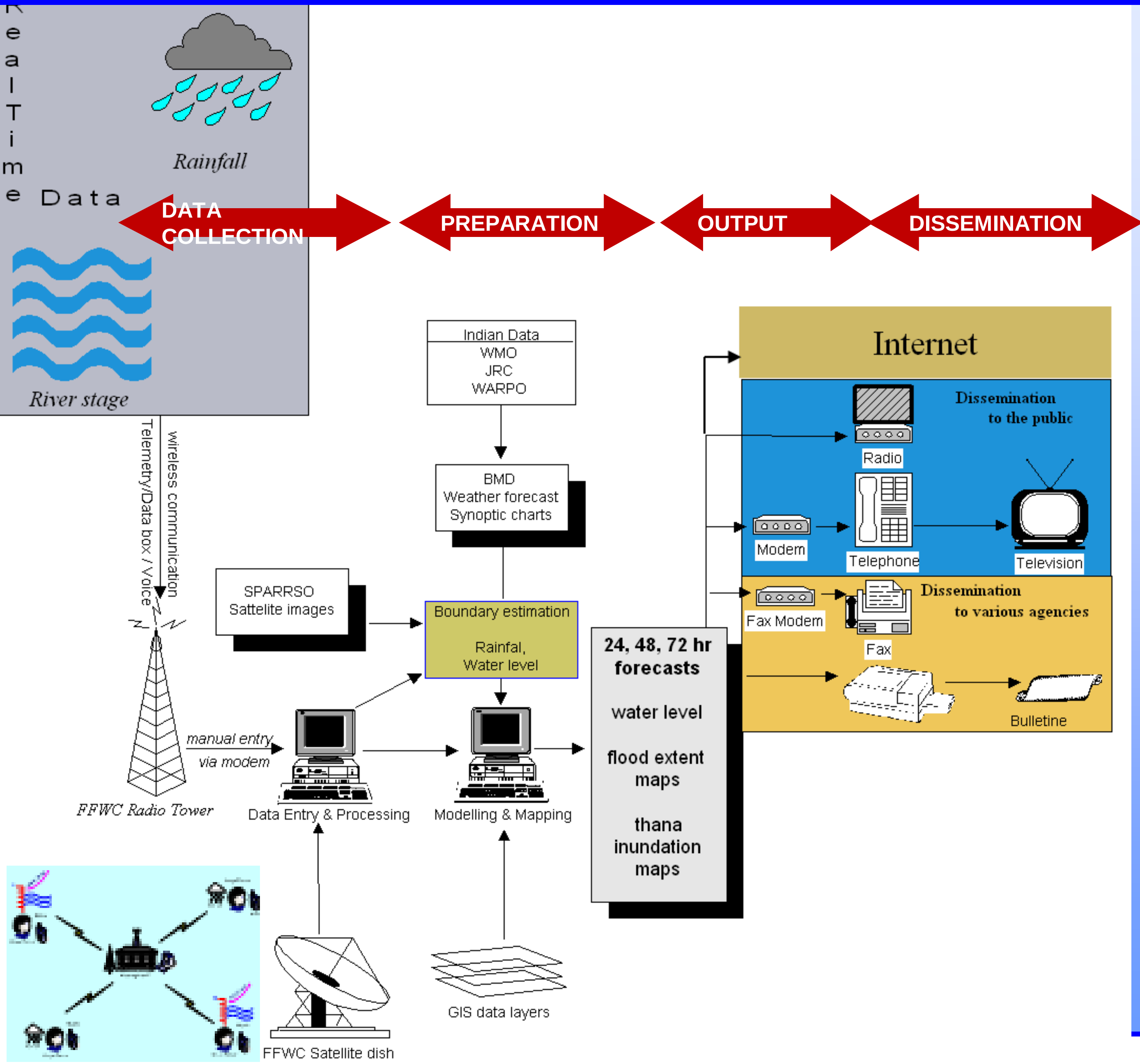


Precipitation Gauges



Regional to Global Linkages

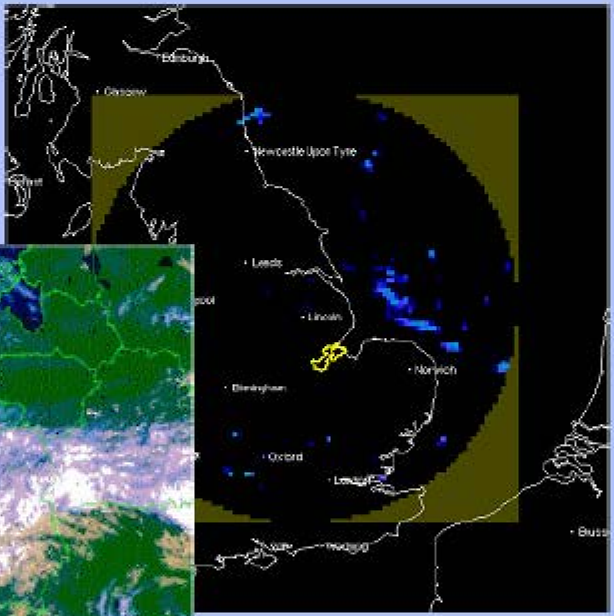
Flood Forecasting: What do we need?

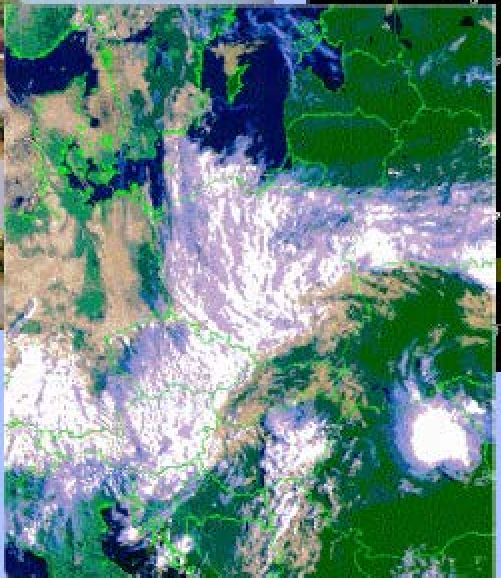


- Data Collection
- Preparation
- Output
- Dissemination

FLOODRELIEF

REaL-tImE Flood Decision Support System Integrating Hydrological, Meteorological and Radar Technologies





Application and
antitative assessment of
ew technologies for the
study catchments

P-8: Case study in
land

P-9: Case study in
K

1

WP-8: Case study - Poland

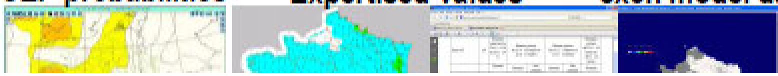
WP-9: Case study - UK

Various tools depending on anticipation

10 days | 5 days | 3 days | 1 days | 12 hours

CEP probabilities | Expertised values | 8x3h model data

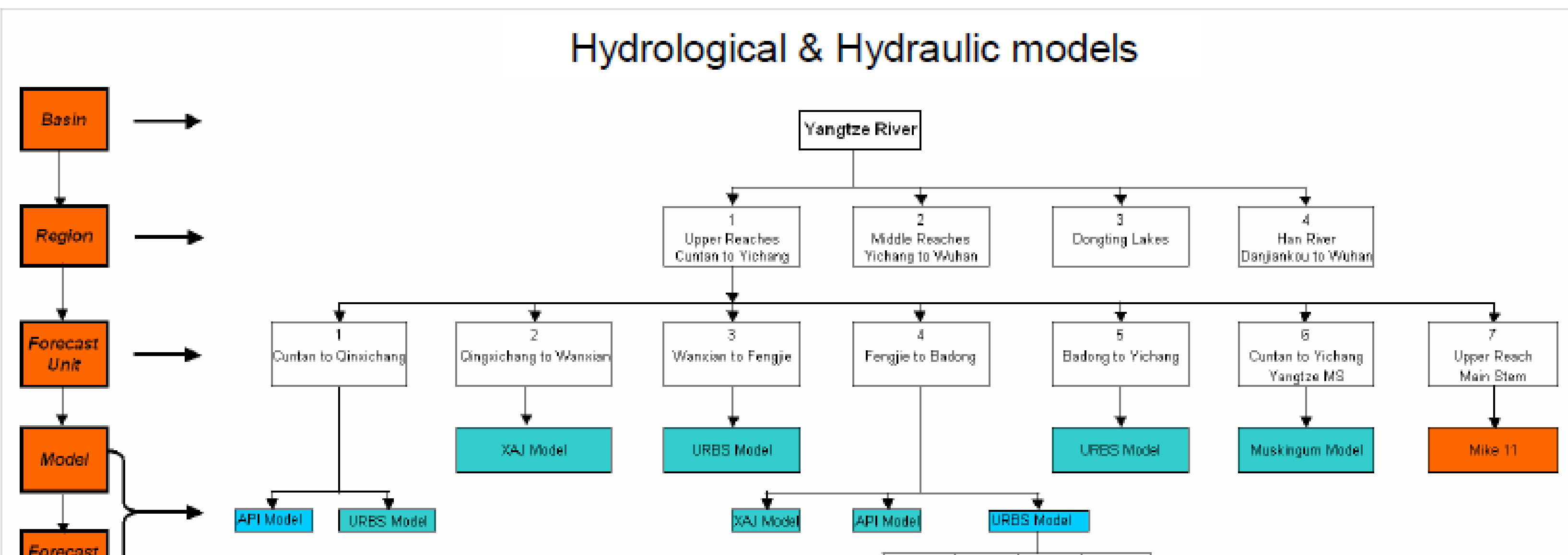
Rainfall



Short-term real-time Flood Forecasting System

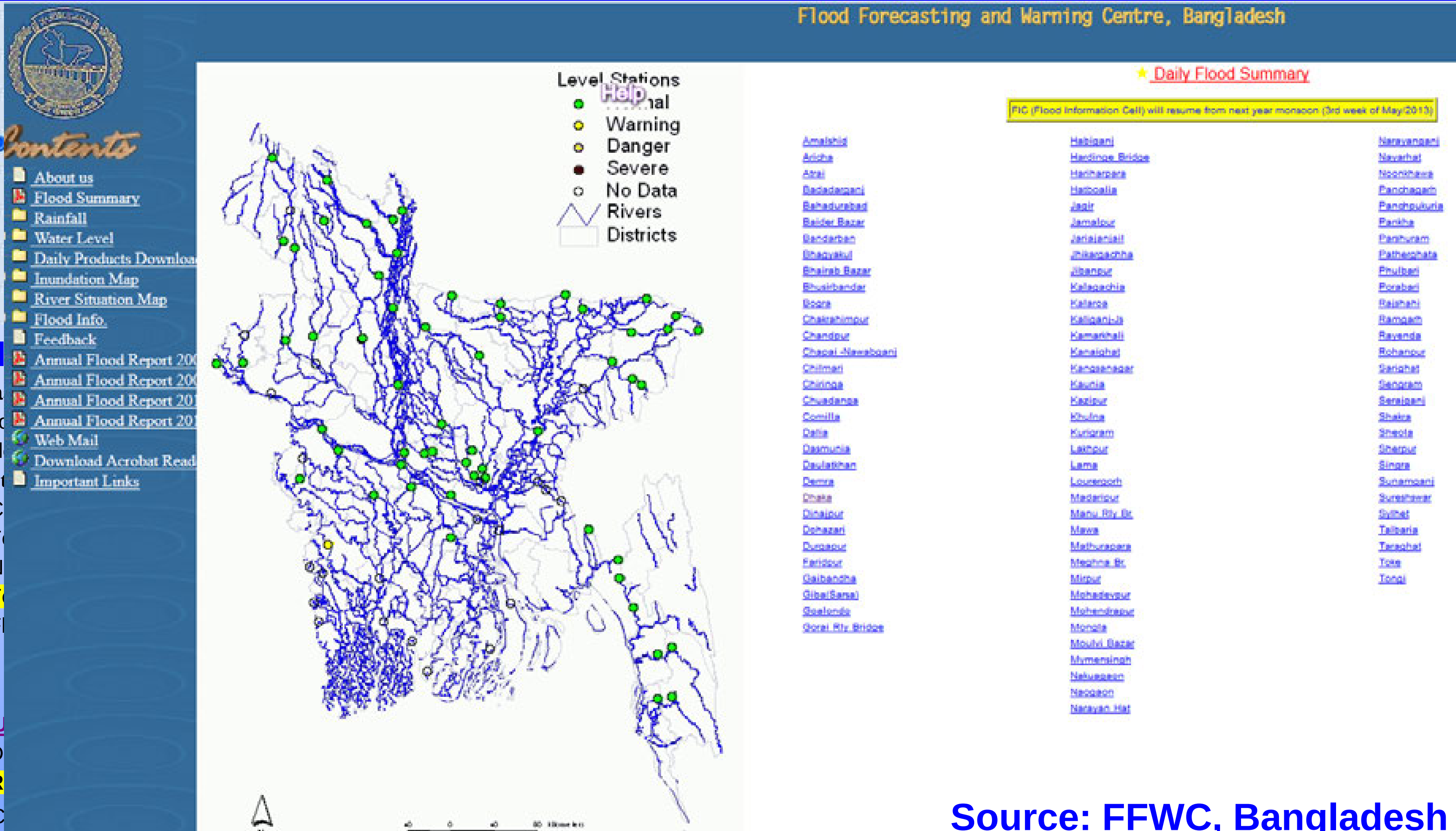
CWRC

Quantitative Precipitation Forecasting (QPF)



IER

Operational Flood Forecasting in Bangladesh



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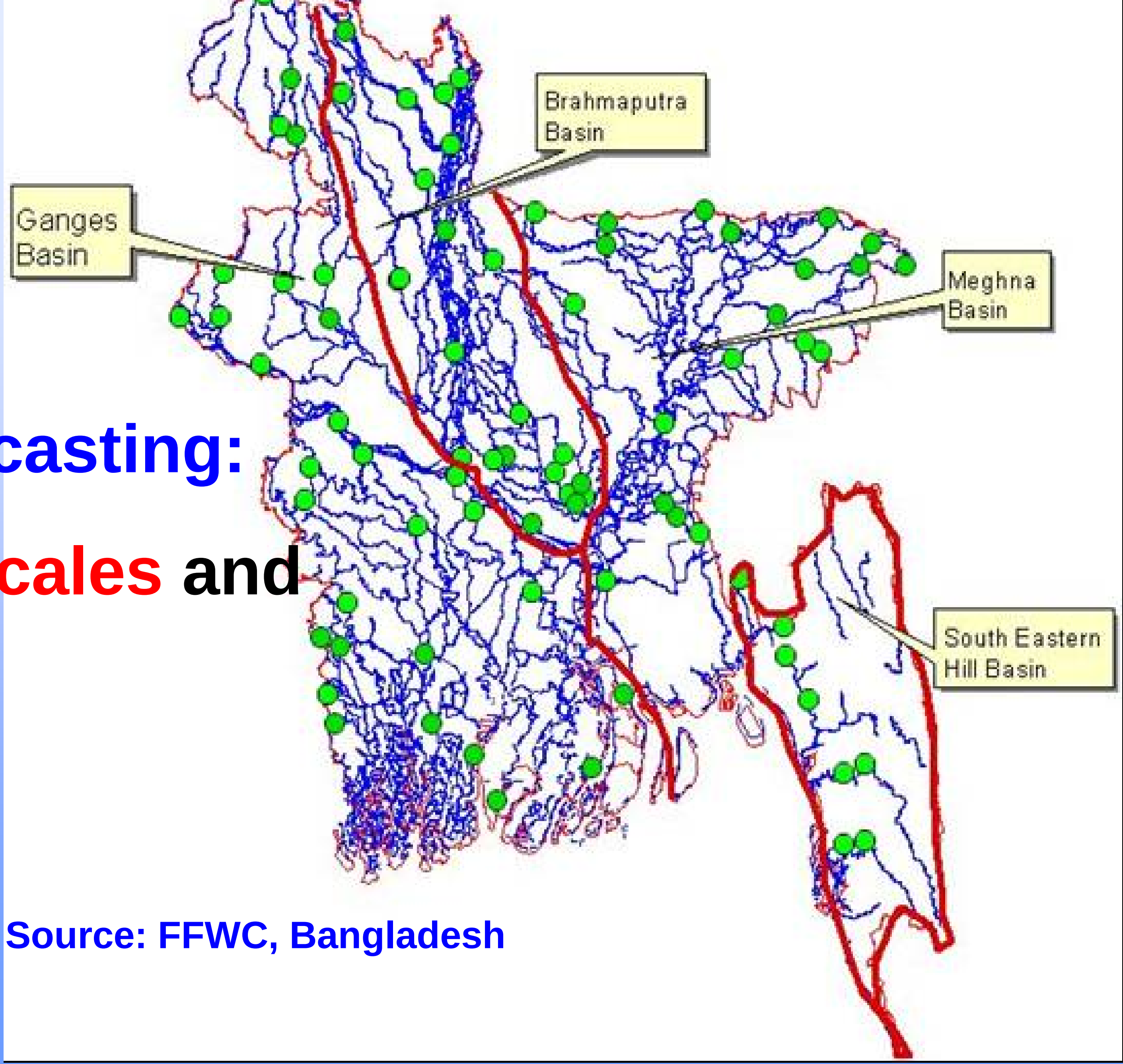
Source: FFWC, Bangladesh

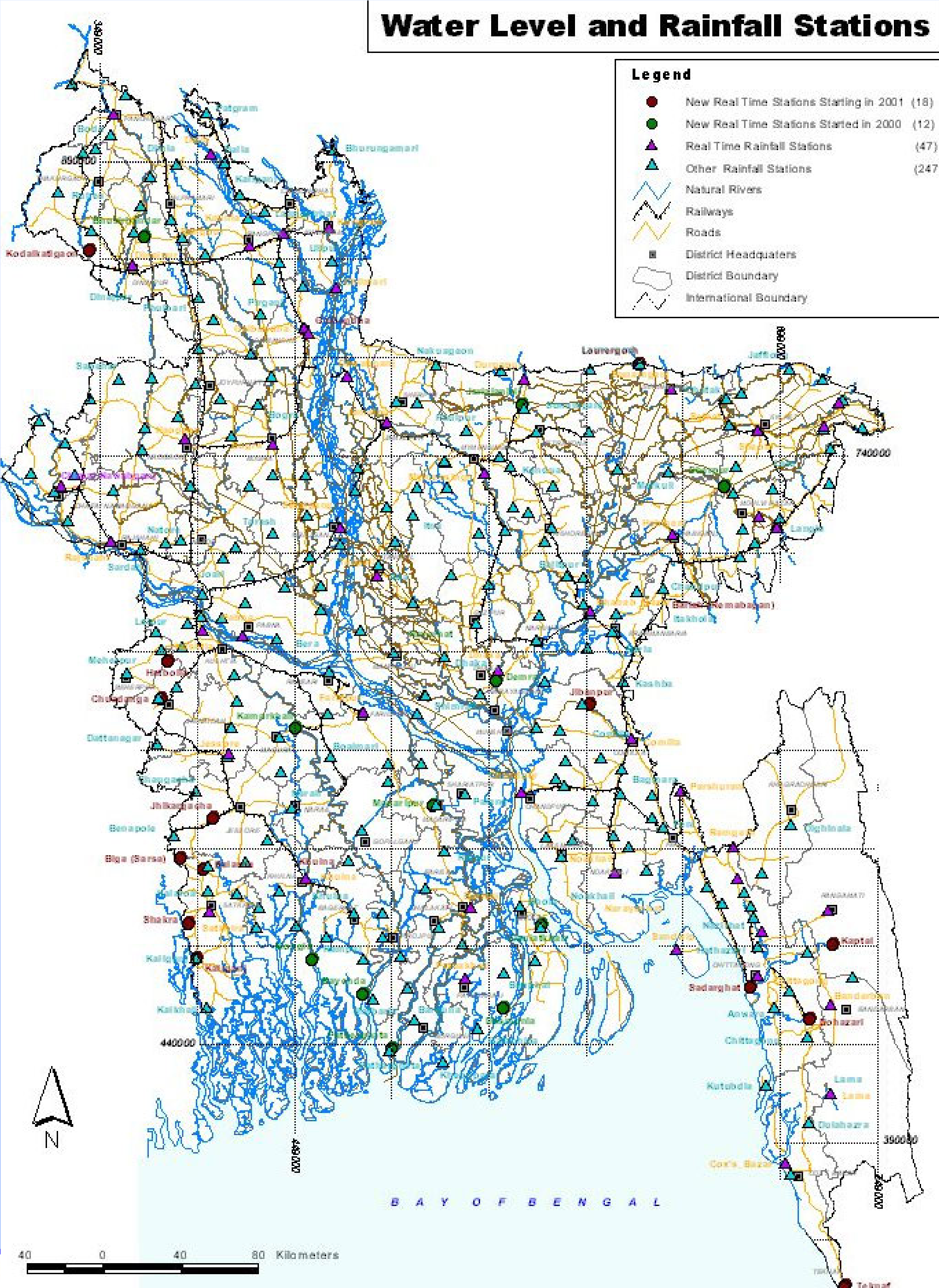
- Special flood situation report
- Thana inundation status map
- Flood forecast maps
- Monthly flood report
- Dry season bulletin (weekly)
- Annual Flood Report

Flood Forecasting:

Issues of Scales and Domains



Source: FFWC, Bangladesh



Real Time Data Collection:

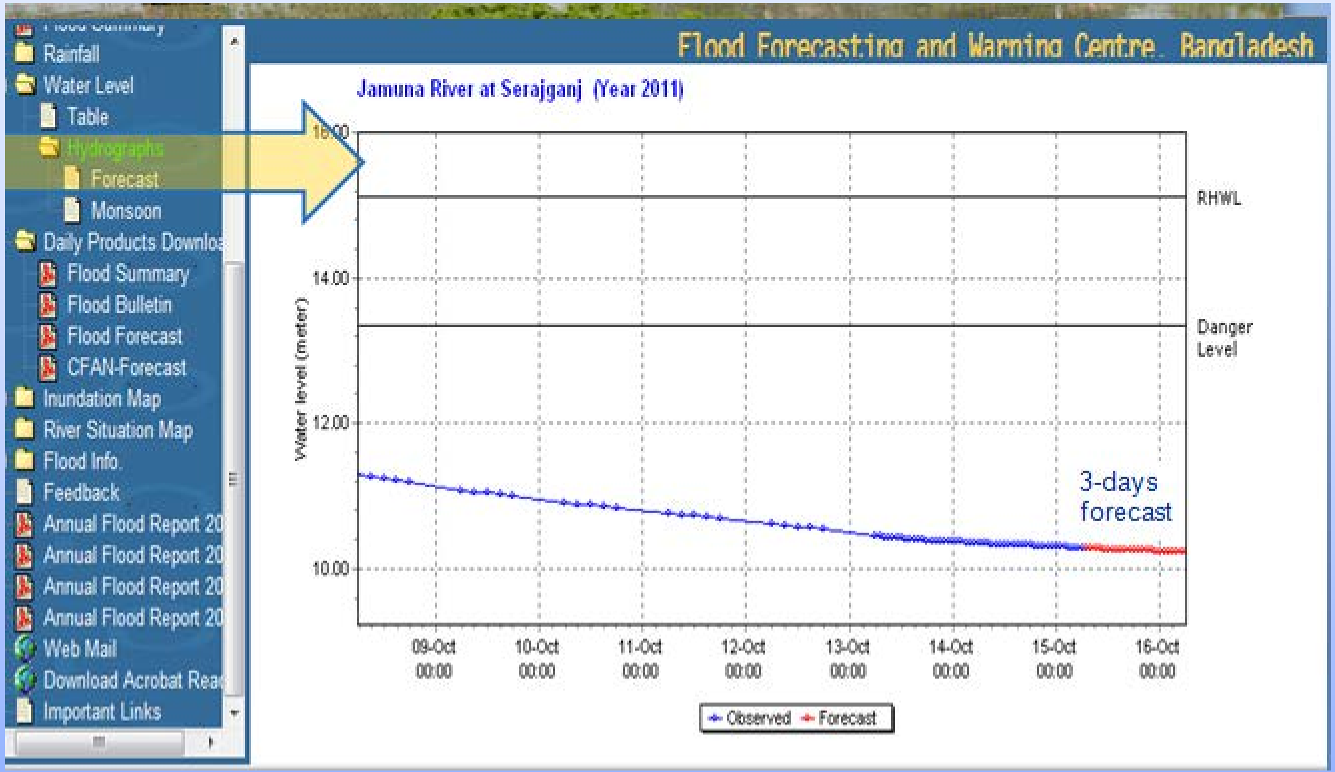
Rainfall : 55

Water Level : 73

Flood Forecasting:38 Stations

Source: FFWC, Bangladesh

Flood Forecasting in Bangladesh: 40 Years of Experience and Wisdom



Source: FFWC, Bangladesh

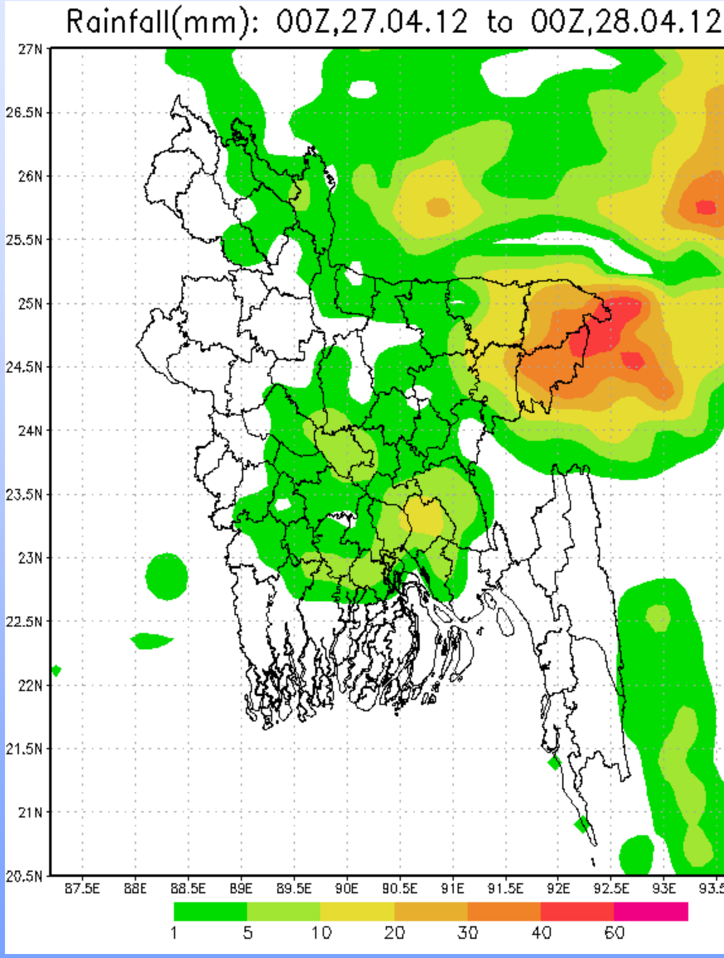
1972-90: 3-day Forecast by Gauge to Gauge Correlation

1990 up till now : 3-day Forecast: Deterministic Modeling (Operational)

Future: 1~10 day Forecast by Probabilistic Modeling (Experimental)

Special Outlook, FFWC, BWDB
25 April 2012

As per the Numerical Weather Prediction (NWP) of Bangladesh Meteorological Department (BMD), there is possibility of rainfall in the north east region of Bangladesh for next three days (from 26 to 28 April 2012). This may contribute to further rise of river water level in the Meghna Basin, in the north East region, specially in the Sylhet, Sunamgonj and Moulvibazar Districts.



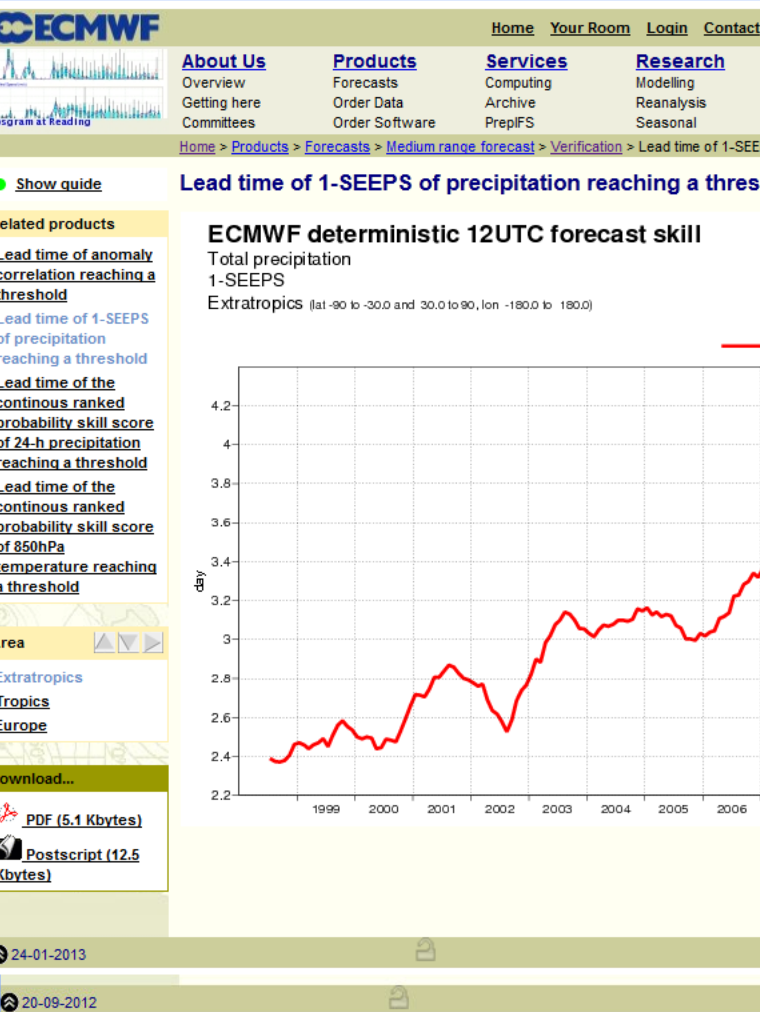
How was this Qualitative Forecast Done?

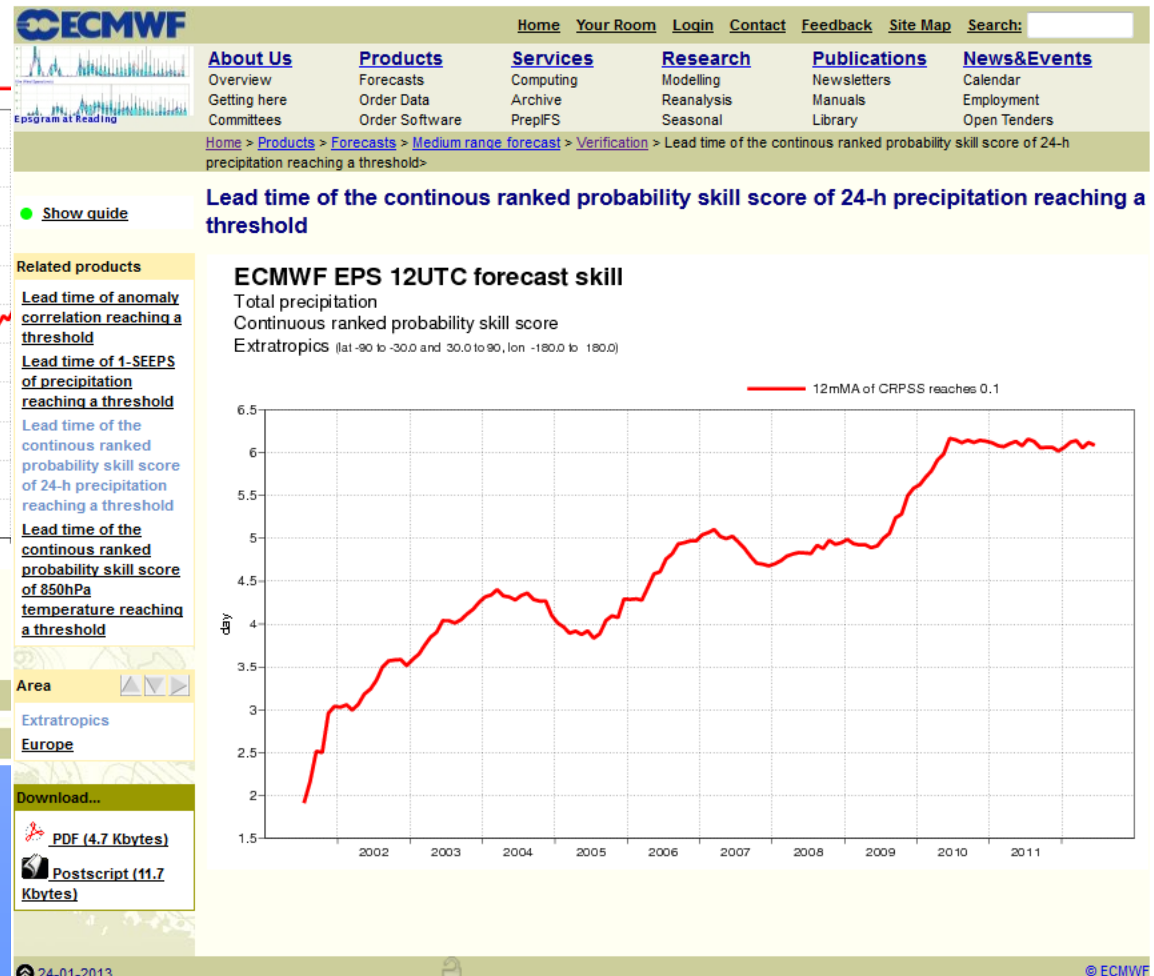
- **Bangladesh Meteorological Dept, 25 April 2012 Chart**
- **Indian Meteorological Department (IMD) forecast**
- **NOAA rainfall estimates from the web**
- **No Hydrological or Innundation model was used**
- **Dissemination to BWDB Field Offices**

For further detail visit http://www.bmd.gov.bd/nwp.php

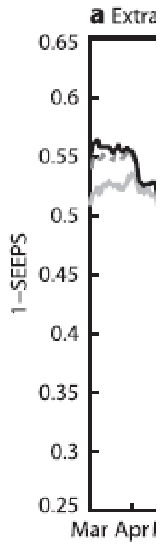
Source: FFWC, Bangladesh

ECMWF: Verification of Precipitation Forecast Skills





Intercomparison of Global Model Precipitation Forecast Skills



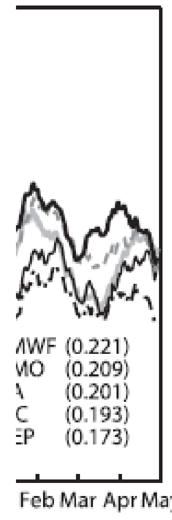


FIG. 3. Ti... and (b) tropics on forecast ... were available only from 1 ... –30 Apr 2011.

compared to those of m... from the contingency ta... scores, but are small c... ascribed to the varying quite pronounced. SEE... tropics. It is found that issue of observation r... suggest that just under ... the fact that gridbox va...

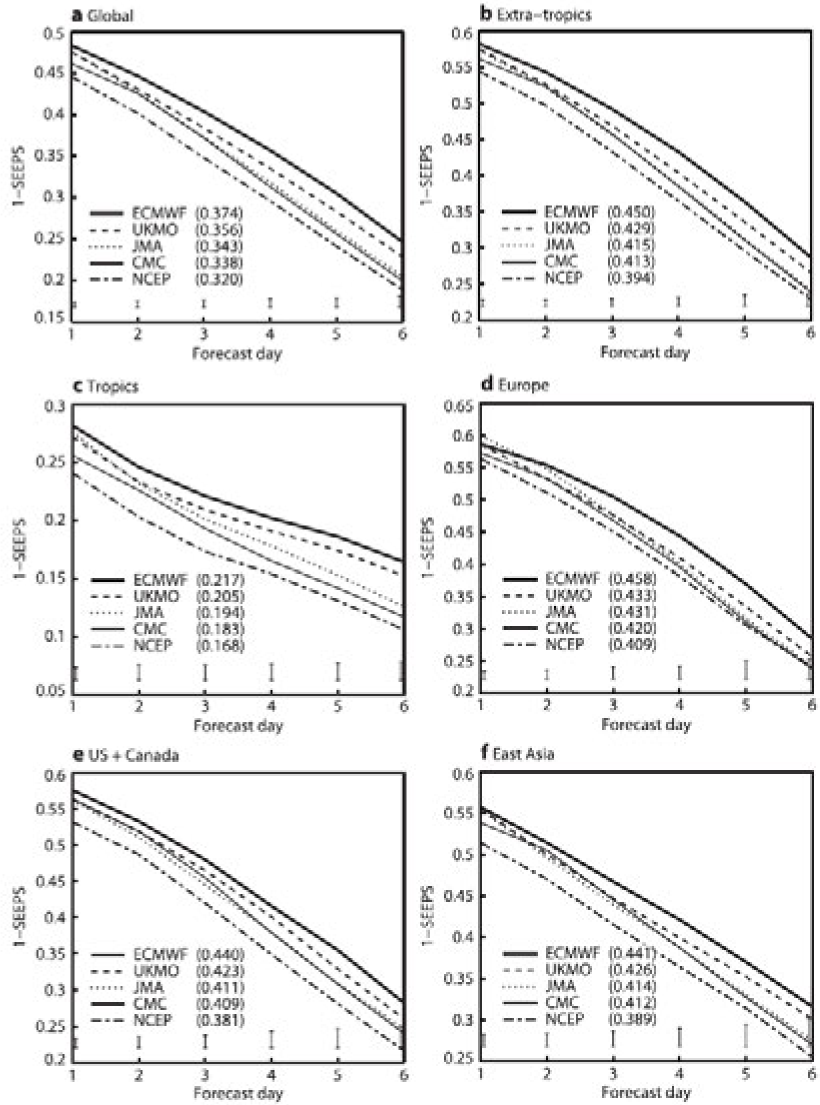


FIG. 4. Values of 1 − SEEPS for the CMC, JMA, NCEP, UKMO, and ECMWF models in different regions, averaged over the period 1 Jun 2010–30 Apr 2011, as a function of lead time. Mean values are given in parentheses. Error bars show width of 95% confidence intervals for model differences, derived from resampling of daily scores (see text for details).

Forecasting of Water Levels from Satellites: Example from Bangladesh

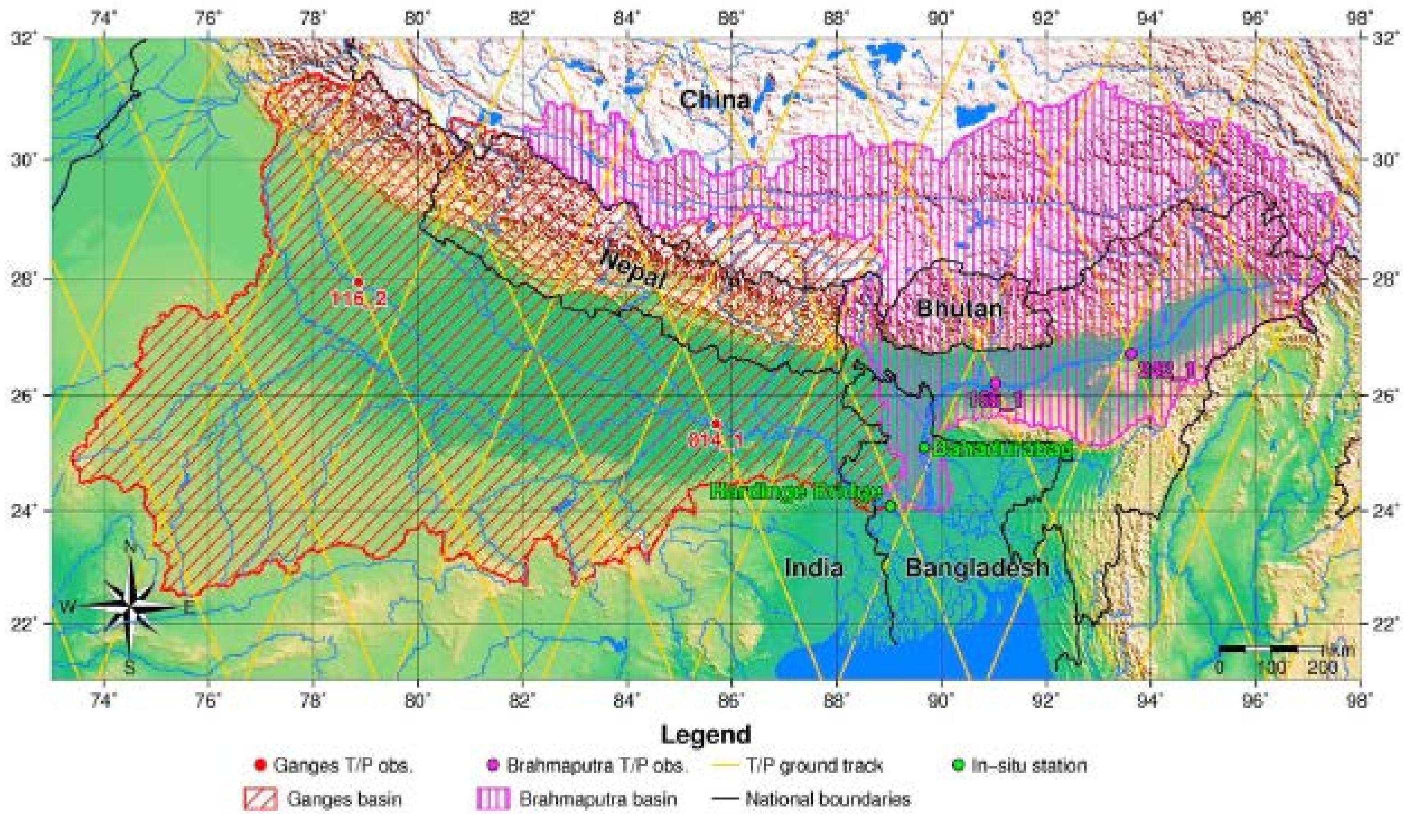


Figure 1. Map of the study domain. Ganges basin (red hatched area) and Brahmaputra basin (magenta hatched area) boundaries come from HYDRO1k. Locations of measurements from the satellite nadir altimeter Topex/Poseidon on the Ganges and the Brahmaputra rivers (available on HydroWeb) are represented, respectively, by red and purple dots (yellow lines correspond to the satellite ground tracks). Green dots correspond to the furthest upstream in-situ gauges in Bangladesh. The background topography used in this map is the ETOPO1 topography dataset. Lakes, rivers and political boundaries come from the CIA World Data Bank II.

Flood Innundation Map: 48-hour Forecast

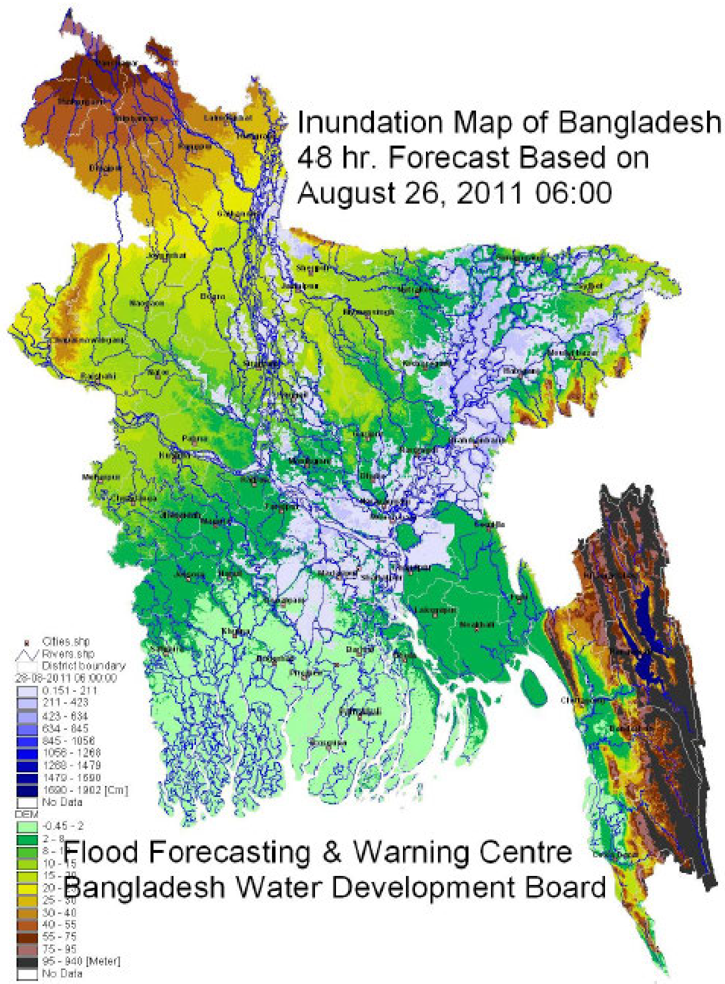
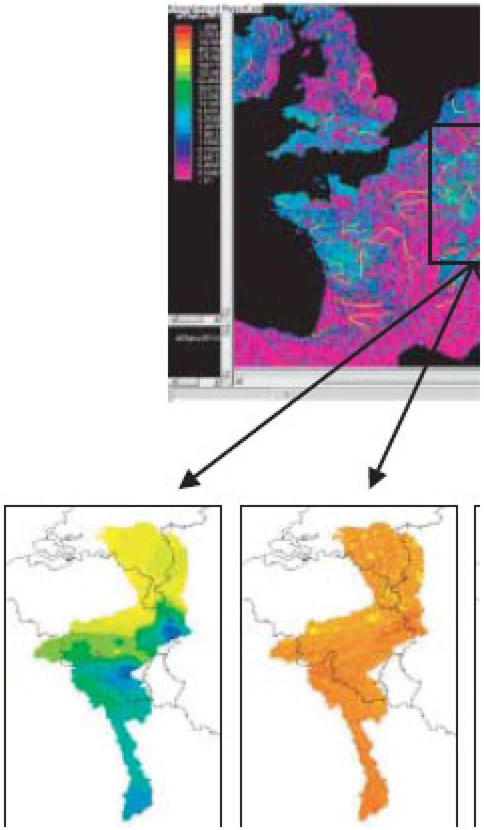


Figure 5. 2 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 26 August 2011)



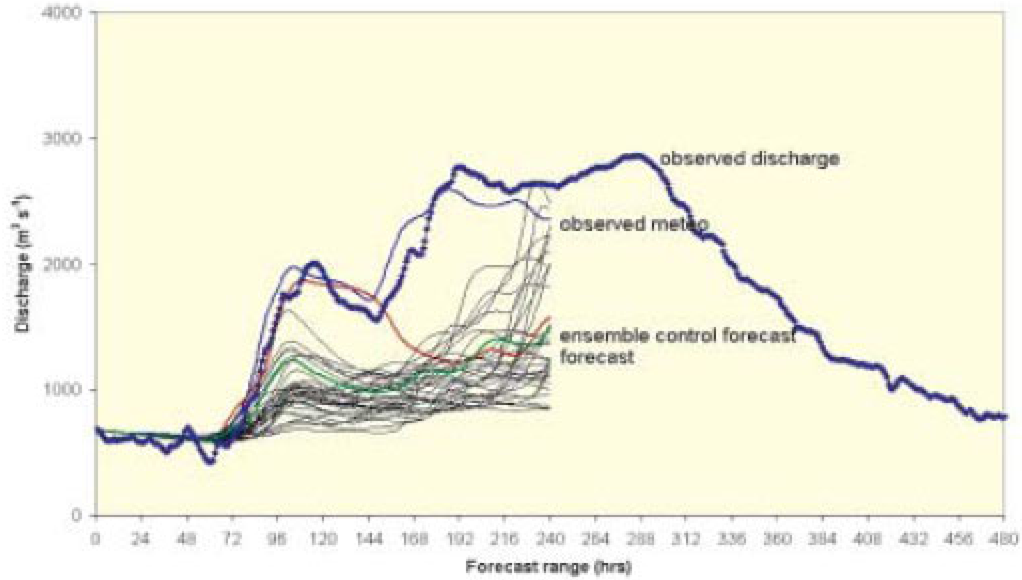


Figure 6 10-day discharge forecasts from the LISFLOOD-FF model for 0000 UTC on 19th January 1995 (hour 0) for the Borgharen gauging station on the River Meuse, The Netherlands. The observed discharge is shown as a thick blue line, the simulation driven by observed meteorologic data is shown as a thin blue line, the simulation driven by the ECMWF TL511L60 deterministic forecast is shown in red, the simulation driven by the ECMWF TL255L40 ensemble control forecast is shown in green and the simulations driven by the 50 ECMWF TL255L40 ensemble forecast members are shown in black.

Figur
and 1

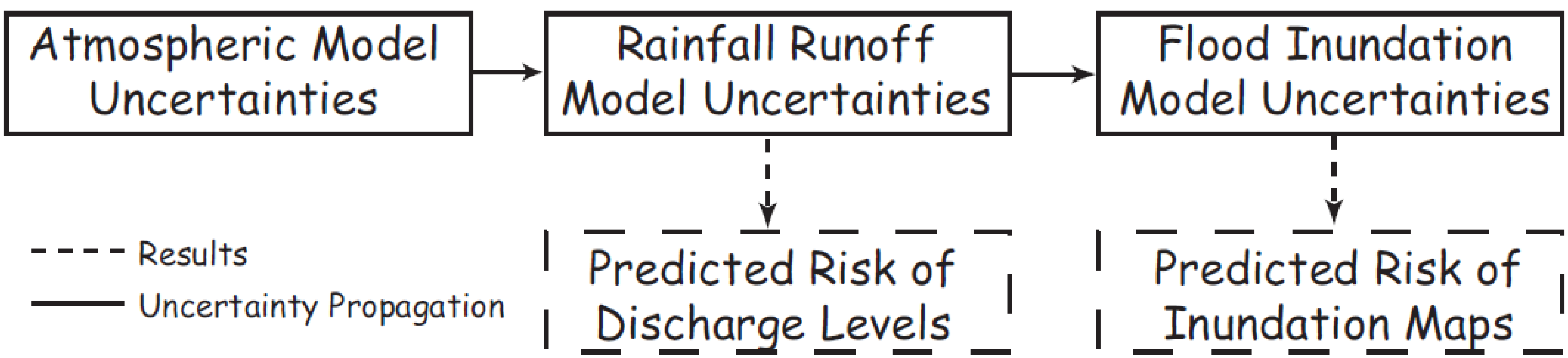
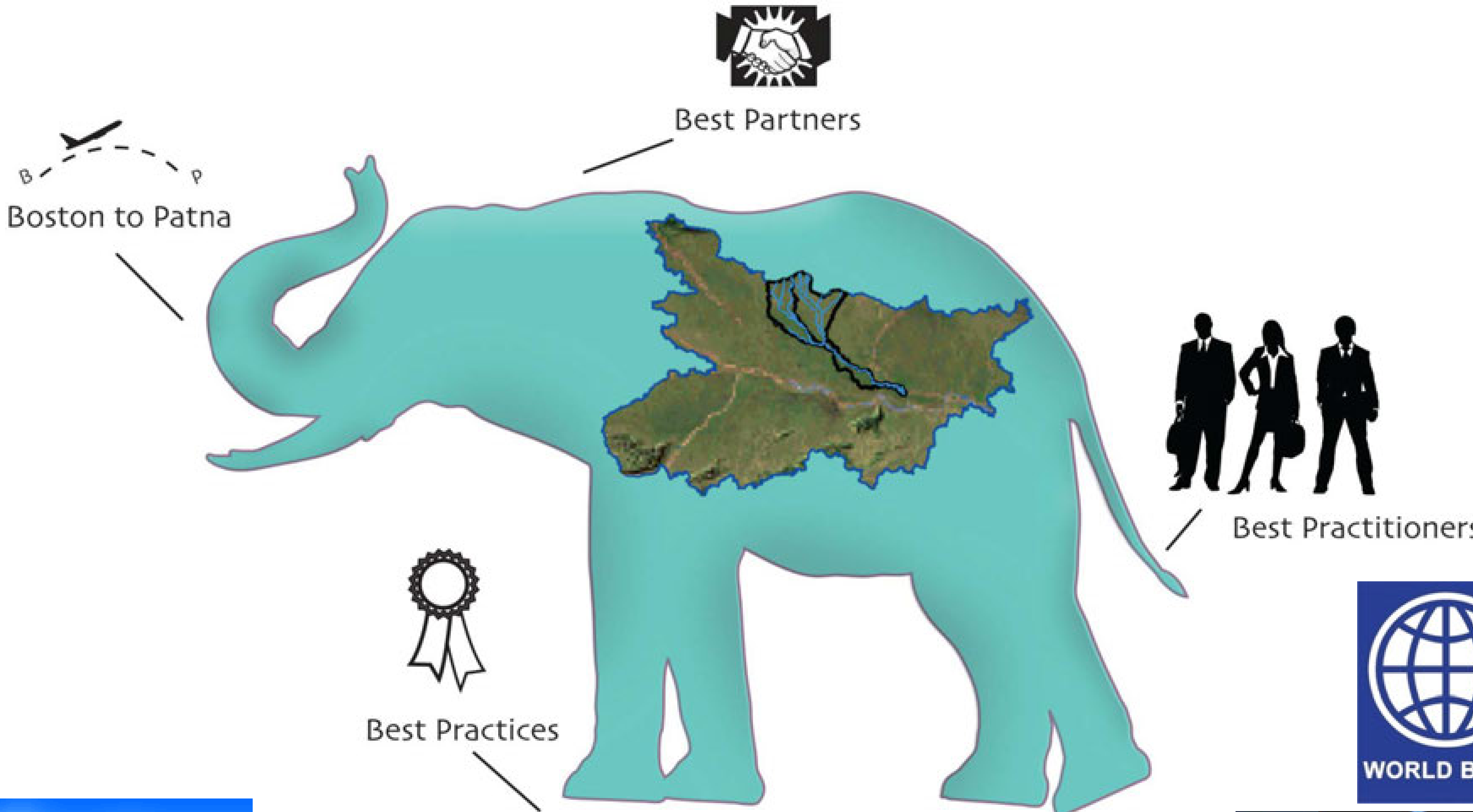


Fig. 1. *Sketch of the uncertainty cascade*

Four B.P.s for Actionable Water Knowledge in Bihar



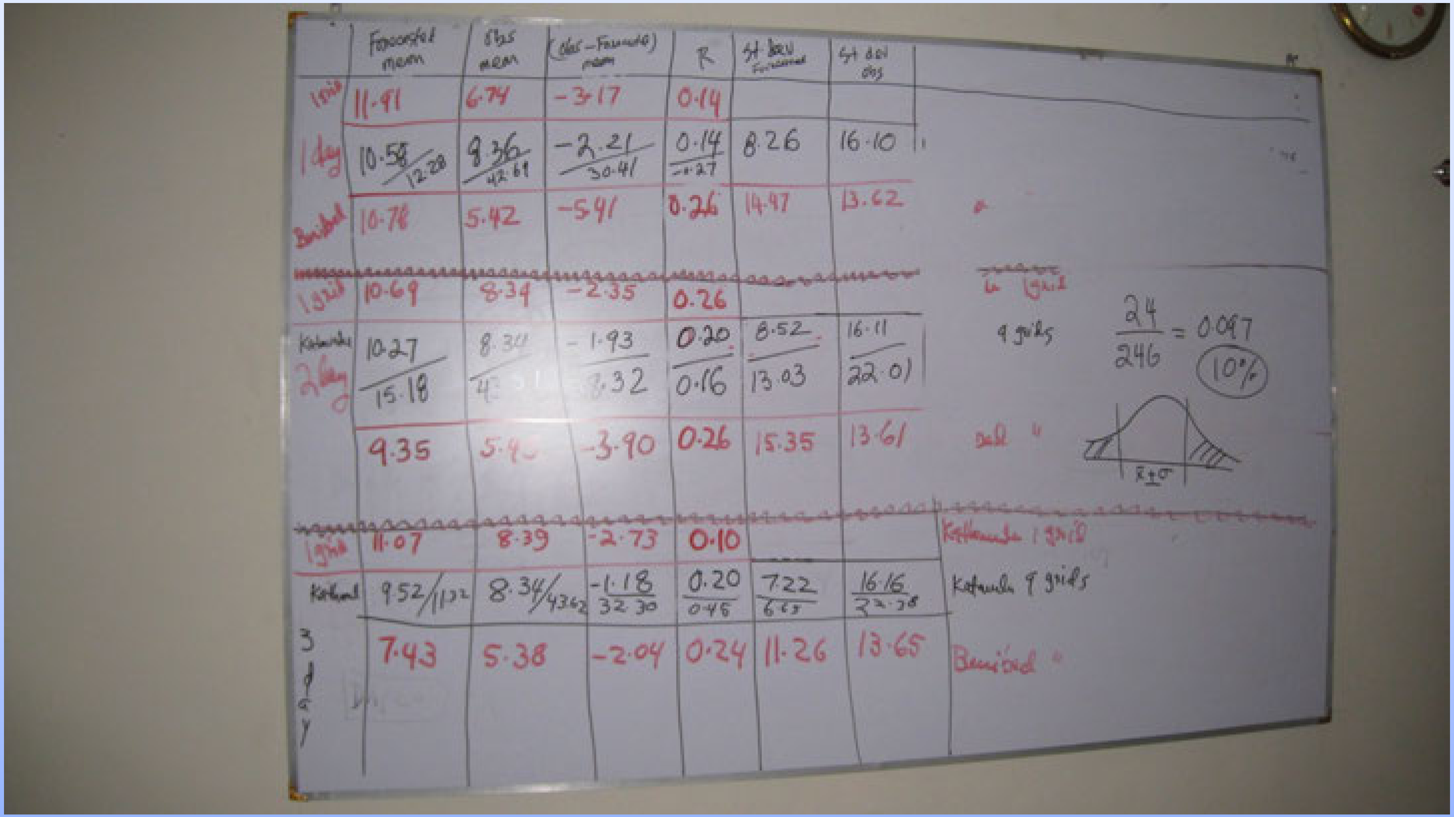
fmis Bihar

WORLD BANK

Tufts UNIVERSITY

Day 4: Review and HEC HMS for BA Basin

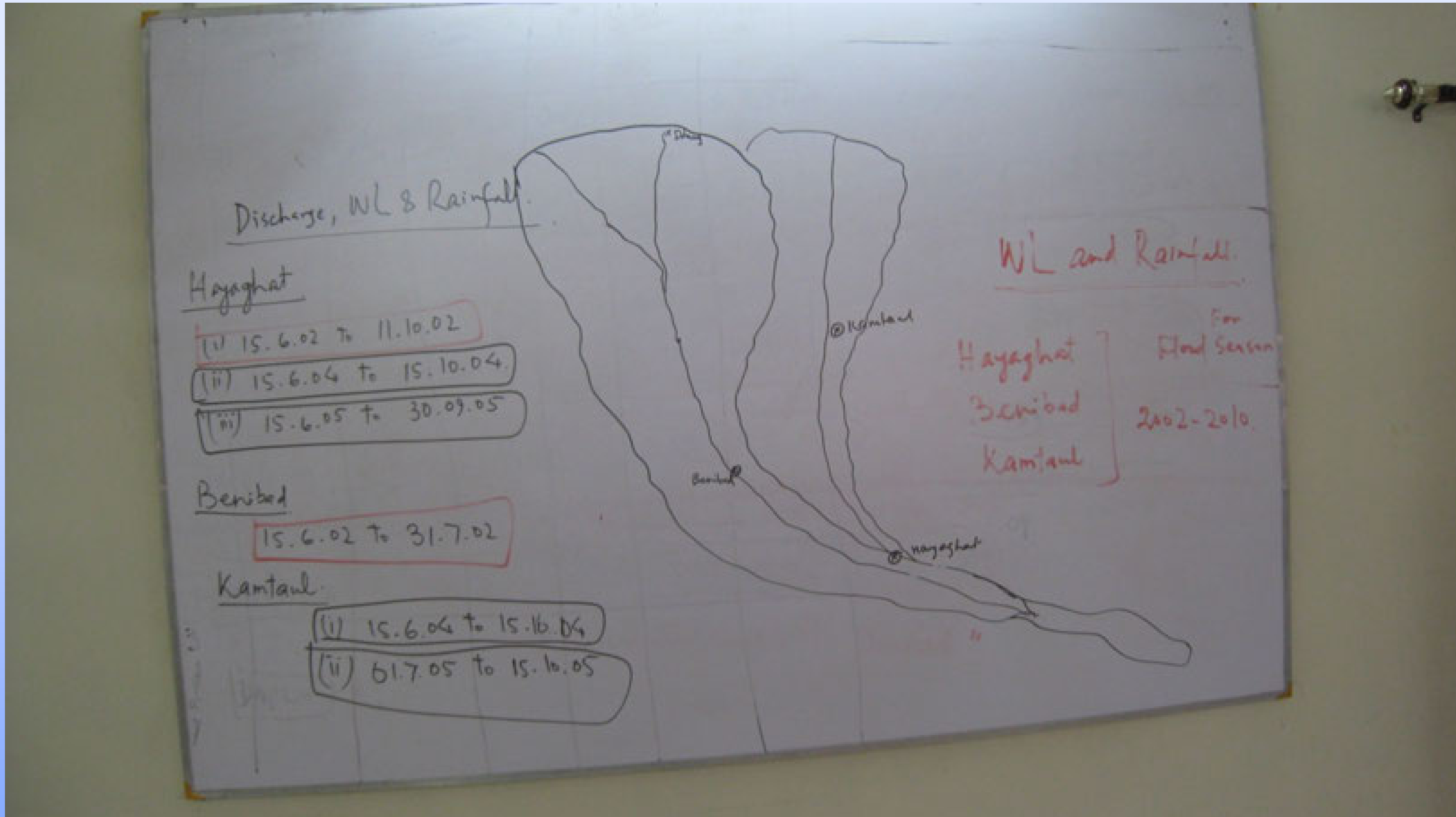
- Comparison of IMD Forecasted and Observed Rainall
- Available rainfall, water level and streamflow data
- ZERO order model for Forecasting Hyaghat Flow
- Review HEC-HMS implementaion
- Customize HEC-HMS for the BA Basin
- Calibration and Validation of HEC-HMS for the BA basin



2009 and 2010 flood seasons: Comparison of IMD forecasted rainfall And raingage observations from Benibad and Kathmundu suggests

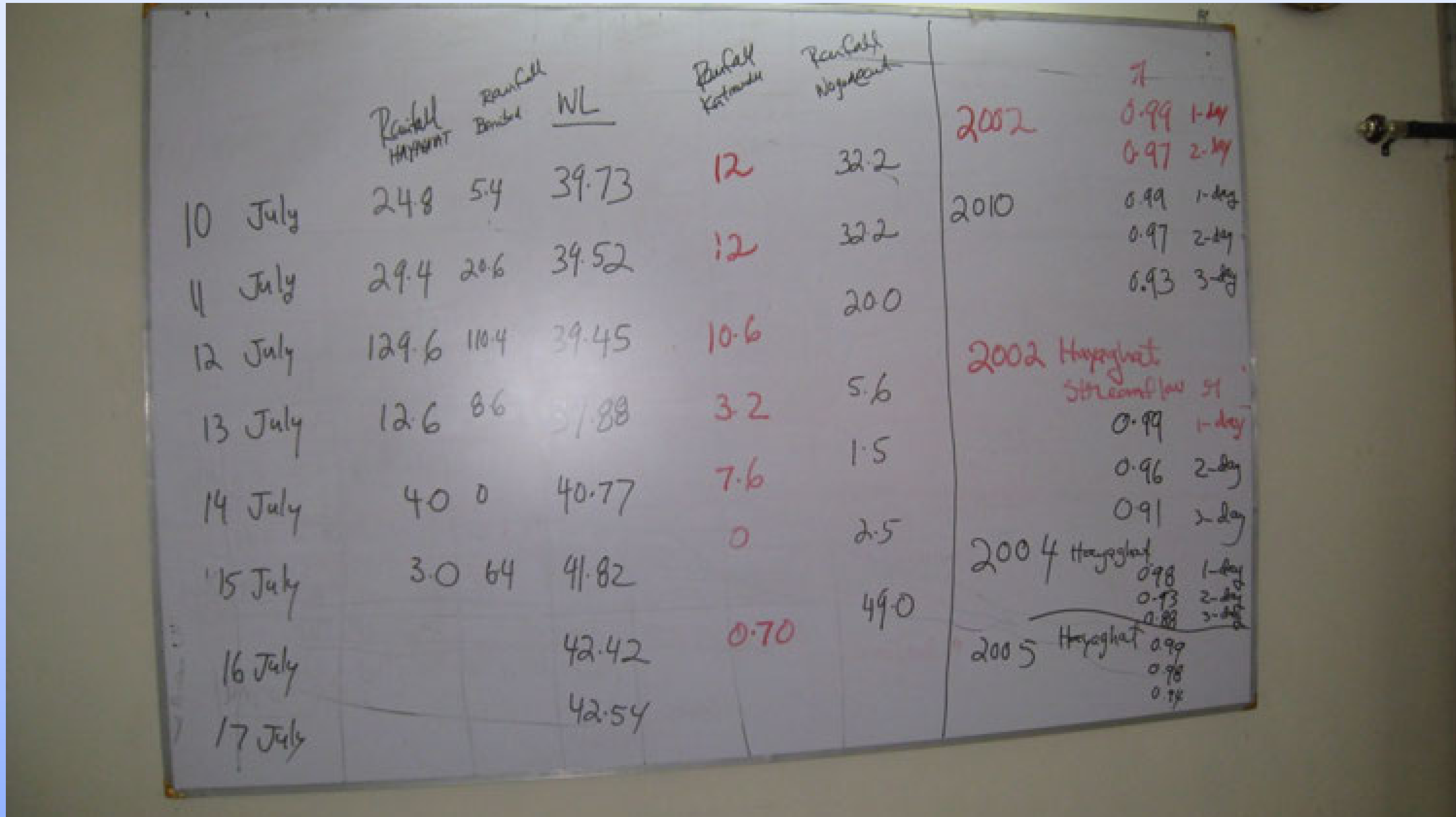
- **Very Low Correlation**
- **Forecasted rainfall is OVERESTIMATED**
- **When observed rainfall is greater than a threshold (mean + ONE standard deviation), forecasted rainfall is significantly UNDERESTIMATED.**

World Bank-Tufts Partnership in Bihar, India



Available rainfall, water level and stream flow data
Hourly Rainfall: Benibad, Kamtul, Hayaghat, Jhanjharpur: 2000-2005 selected storms

World Bank-Tufts Partnership in Bihar, India

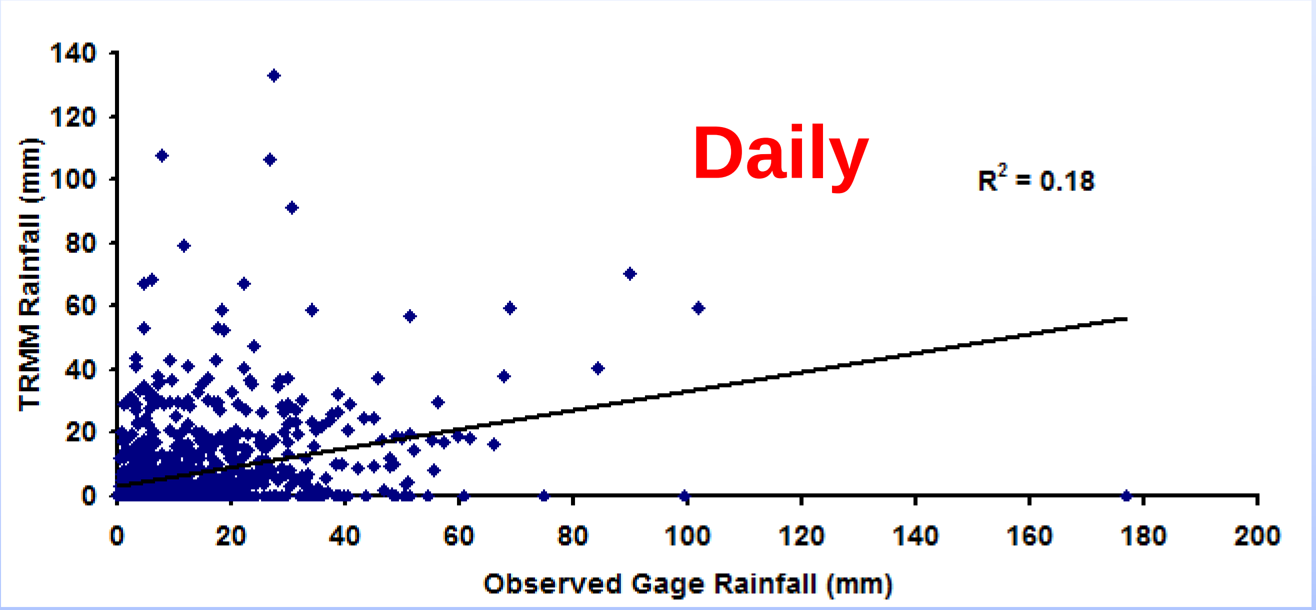


Hayaghat Water Level and Discharge Forecasting: ZERO Order Model

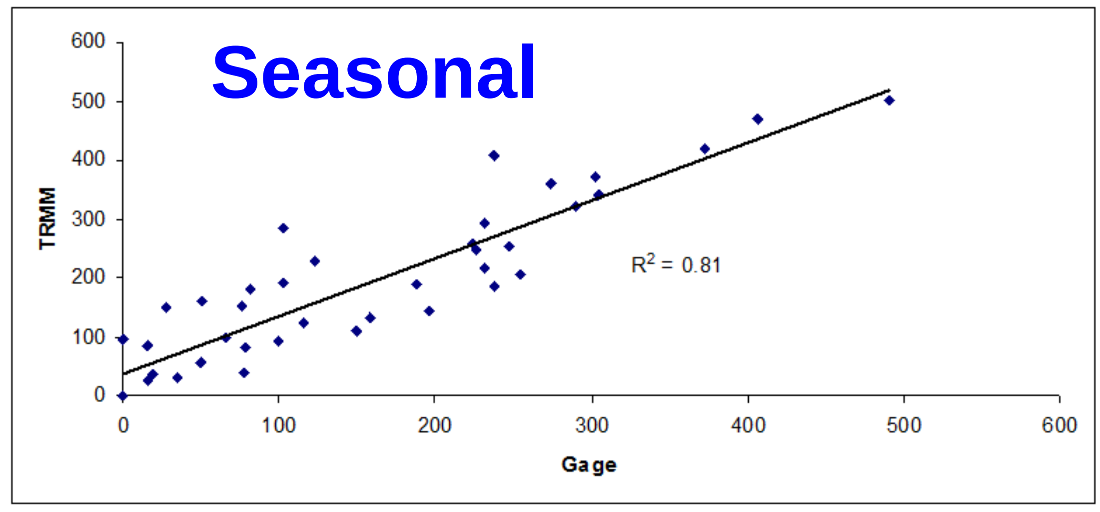
Flow/Water Level tomorrow = Flow/Water Level Today; This is 1-Day Forecast
Flow/Water Level Day after tomorrow = Flow/Water Level Today; 2-Day Forecast

- **Correlation between Forecasted and Observed Values are VERY HIGH**

World Bank-Tufts Partnership in Bihar, India

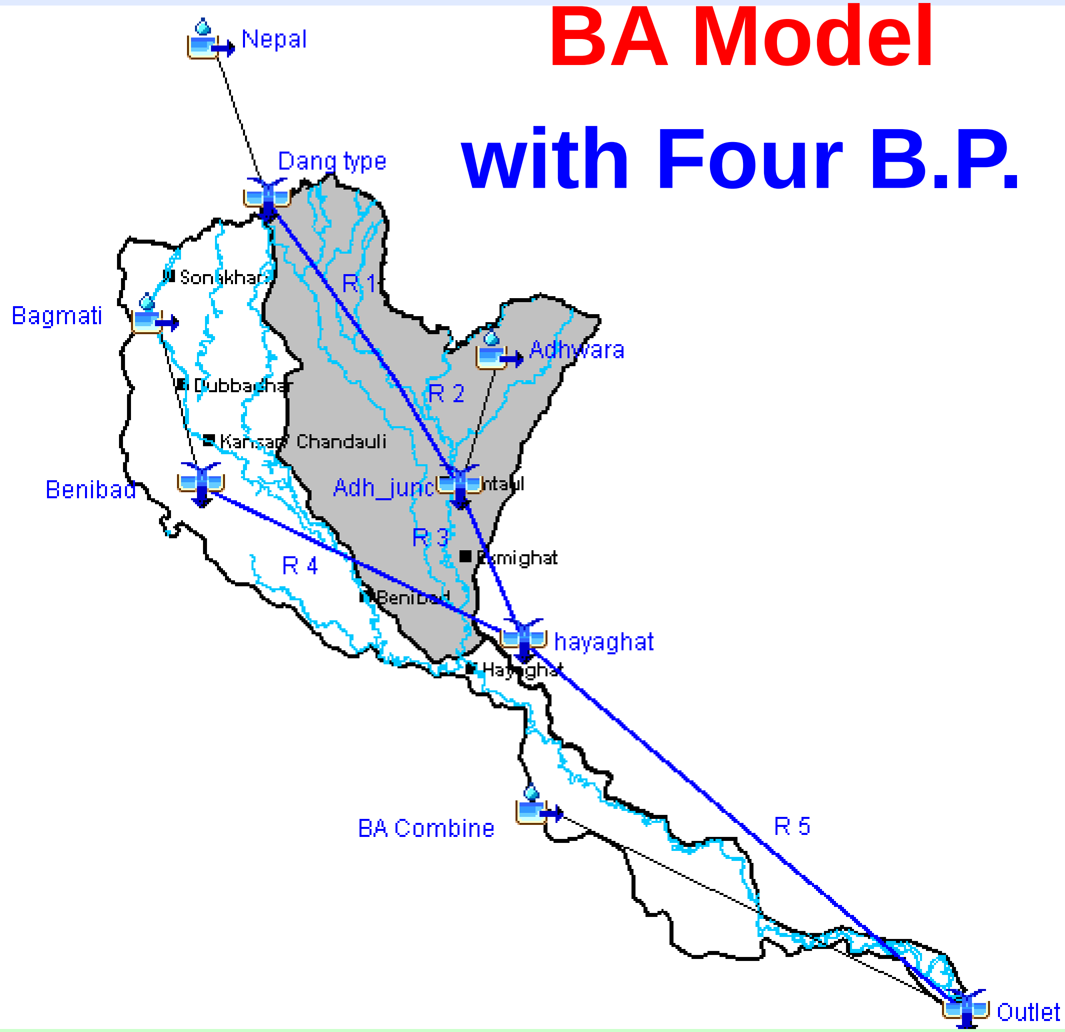


Rainfall from Satellite: TRMM



BA Model

with Four B.P.



One Year:

- How to set up the Model?
- What Data do we Need?
- What Forecasting Lead Time?

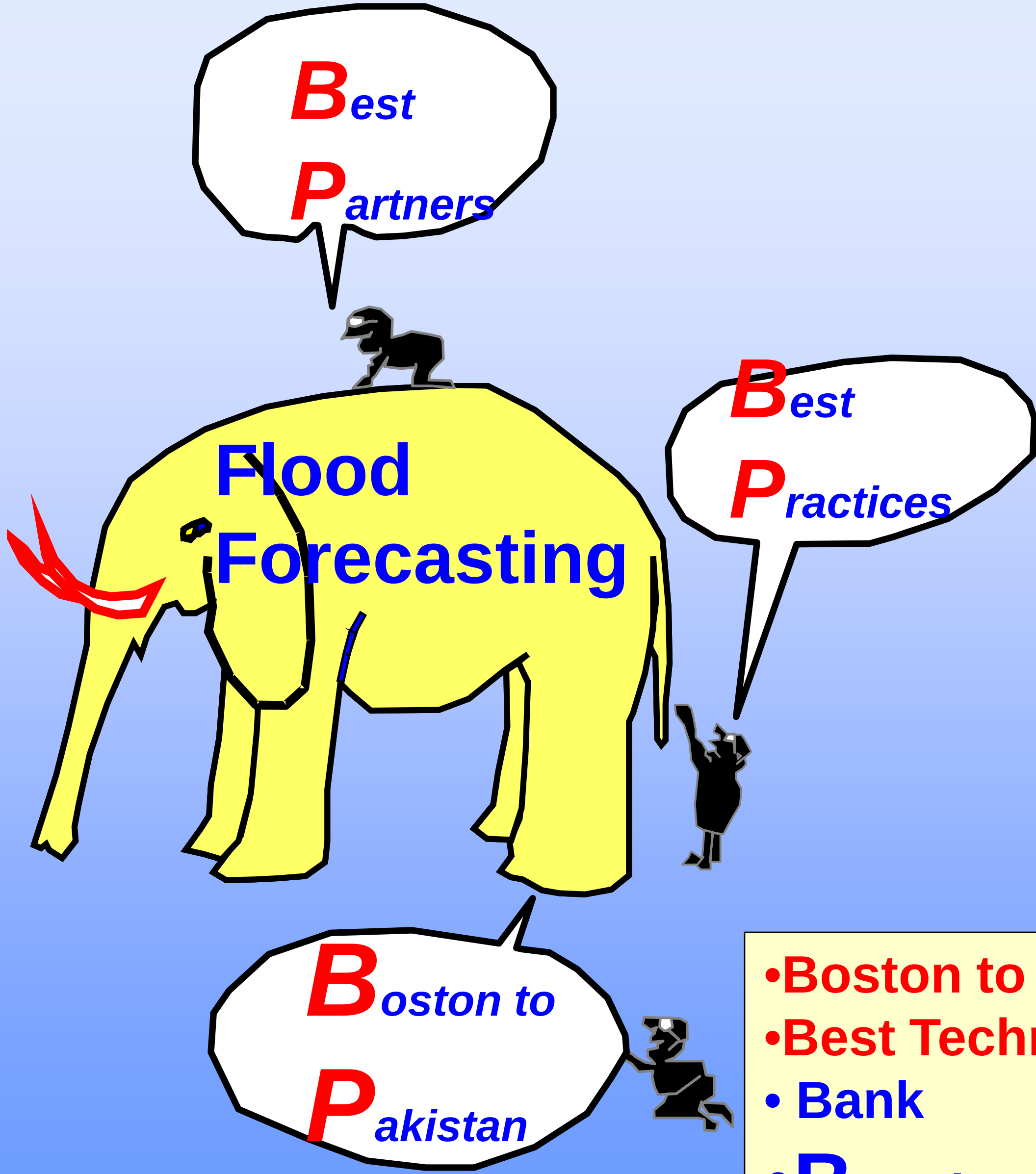
Three Years:

- An Operational Flood Forecasting Model
- Data Needs Identified?
- 72 Hours Lead Time

Five Years:

- An Operational and Validated Flood Forecasting Model
- Data integrated in modeling
- 3-6 Days Lead Time

Modeling is a Synthesis of Science and Art



- Boston to Patna
- Best Technology and Know How
- Bank
- **B**e Adaptive to **P**atna

Flood Forecasting & Water Management: Actionable Knowledge for Pakistan "How to prevent Hazard to become Disaster"

- **Improve RESILIENCE to water hazards in Pakistan**
  - **Non-Structural** (e.g. forecasting & warning systems)**/ Structural** (e.g. embankment, barrage, dams)
  - **Local/Provincial/National/International**
  - **Short/Medium/Long-term**

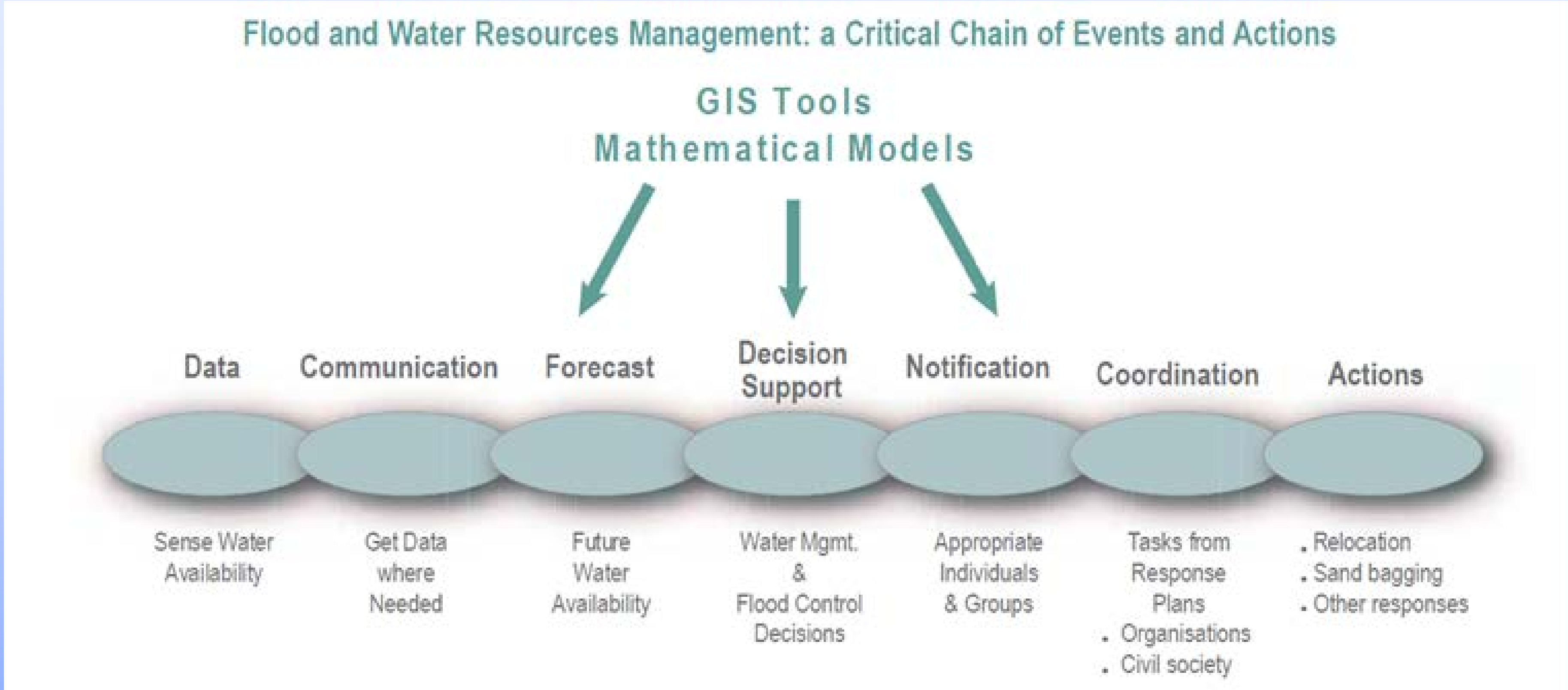
- **Improve water PRODUCTIVITY in Pakistan**
  - Improved basin planning and investment prioritization
  - Improved irrigated agriculture
  - Improved agricultural services

Primary Challenges for Pakistan: I^3

Problems and Conditions TO Solutions and Management

- **Information**
  - Models (Flood Forecasting; Water Management…Numerical Weather Prediction Models, Rainfall Runoff Models, Flood Innundation Models)
  - Data (Topographic Data; Rating Curves; Weather and Climate Data)
  - Lack of real-time LOCAL and BOUNDARY data
- **Institutions**
  - Build and Strengthen Institutions to address PROBLEMS and CONDITIONS
  - Integrate SHORT-term and LONG-term goals to CREATE ACTIONABLE KNOWLEDGE through strategic policy and MEASURABLE METRICS
- **Infrastructure**
  - Physical infrastructure
  - Build Capacity (Brilliant Practitioners from Pakistan who understand the "context" and current "know-how"

From Data and Models to Action and Implementation



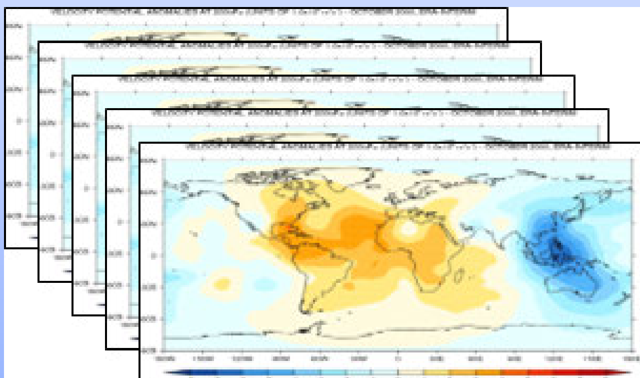
1. Introduction

An increasing number of disasters caused by natural hazards throughout Europe have been recorded in the past decades, affecting millions (Fig. 1; CRED, 2011; European Environment Agency, 2010) and causing an increase in economic losses (e.g., Barredo, 2009). The increase in losses up to now has mostly been associated with societal changes, rather than human-induced climatic changes (Barredo, 2009). Yet, it can be expected that extreme weather events, causing most of the natural disasters, will increase with changing climate (Easterling et al., 2000; Moras et al., 2011). Rising human and economic impacts of natural hazards have triggered the European Commission to develop legal frameworks such as the Water Framework Directive 2000/60/EC (2000) and the Floods Directive 2007/60/EC (2007), to increase prevention, preparedness, protection and response to such events and to promote research and acceptance of risk prevention measures within the society. An important part of a holistic approach to risk management of natural hazards is the set up of early warning systems. Early warning can be defined as 'the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response' (ISDR, 2004). Recent studies have illustrated that early warning systems can have significant benefits exceeding their development and maintenance cost (e.g., Rogers and Tsirkunov, 2011; Teisberg and Weiher, 2009).

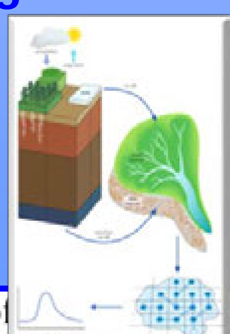
What is Global Flood Awareness System (GloFAS)?

GloFAS is a Joint collaboration between the EC Joint Research Centre and the European Centre for Medium-Range Weather Forecast

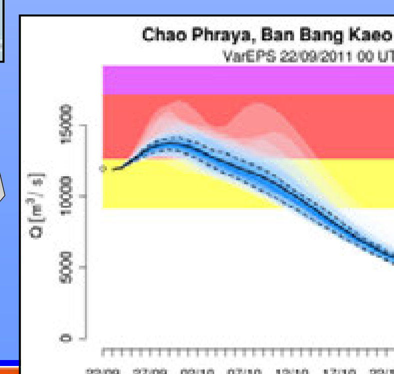
Global probabilistic weather forecast

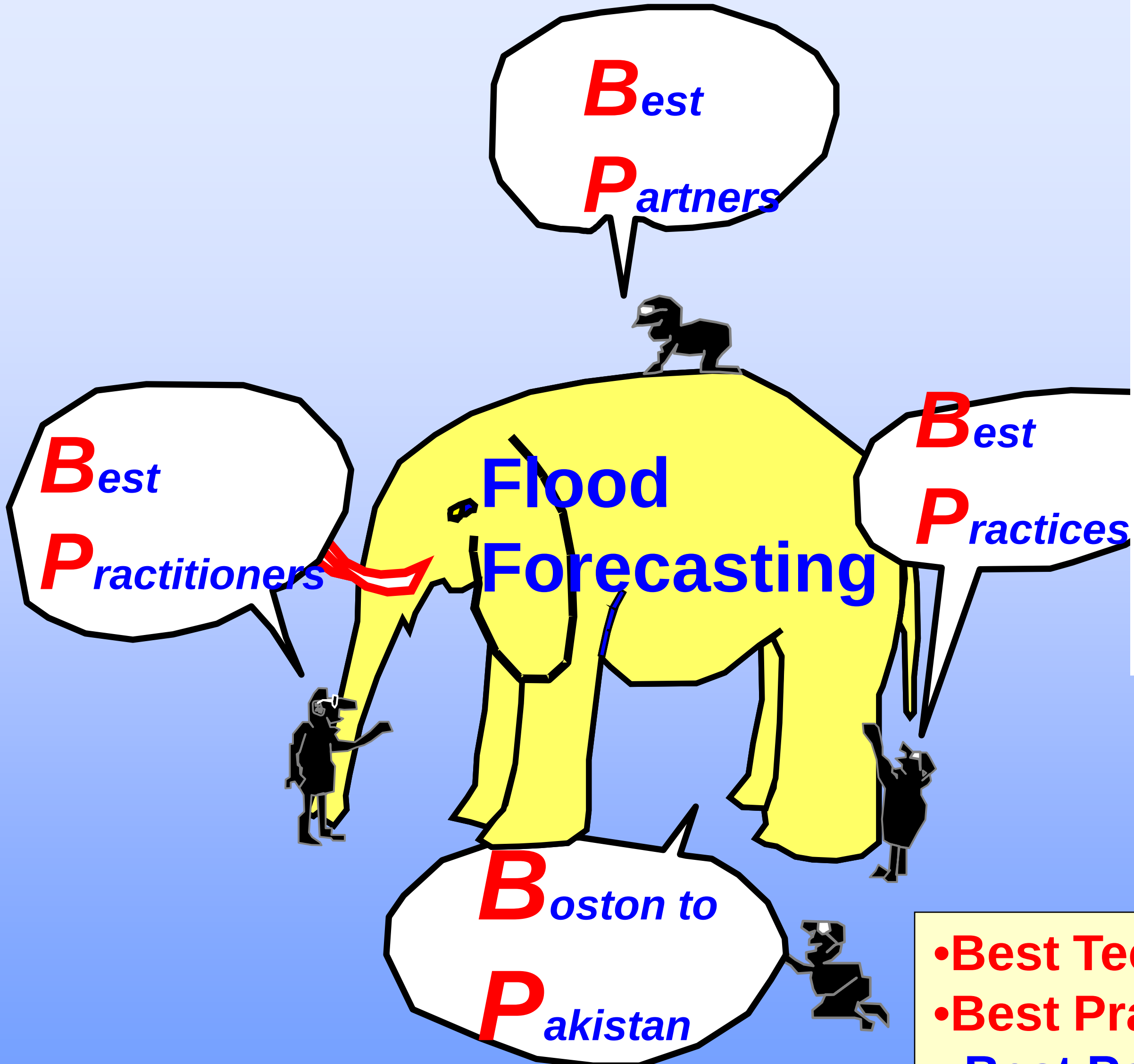


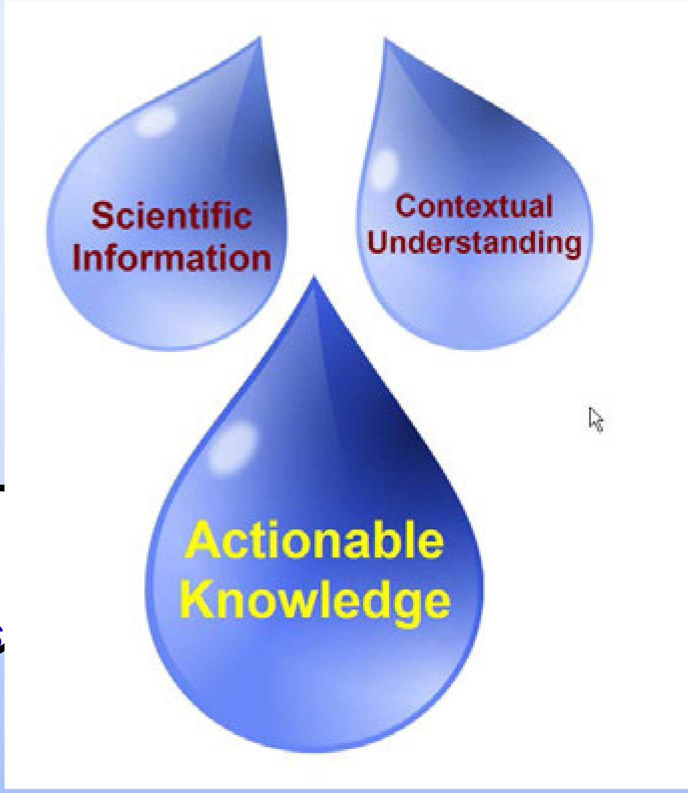
Hydrological model



Decision support information







- Best Technology
- Best Practices
- Best Partners
- **B**est **P**ractitioners for **P**akistan