Best Practices on the Application of Climate Information for Water Resources Management

M.N. Ward[1], U. Lall[1,2], C. Brown[1], H.-H. Kwon[2]

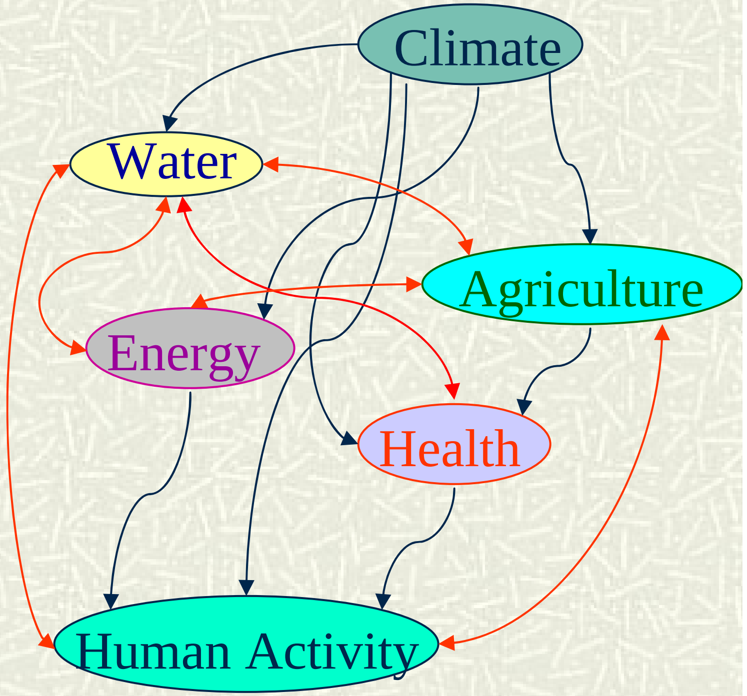
[1]International Research Institute for Climate and Society (IRI), The Earth Institute at Columbia University, New York, USA

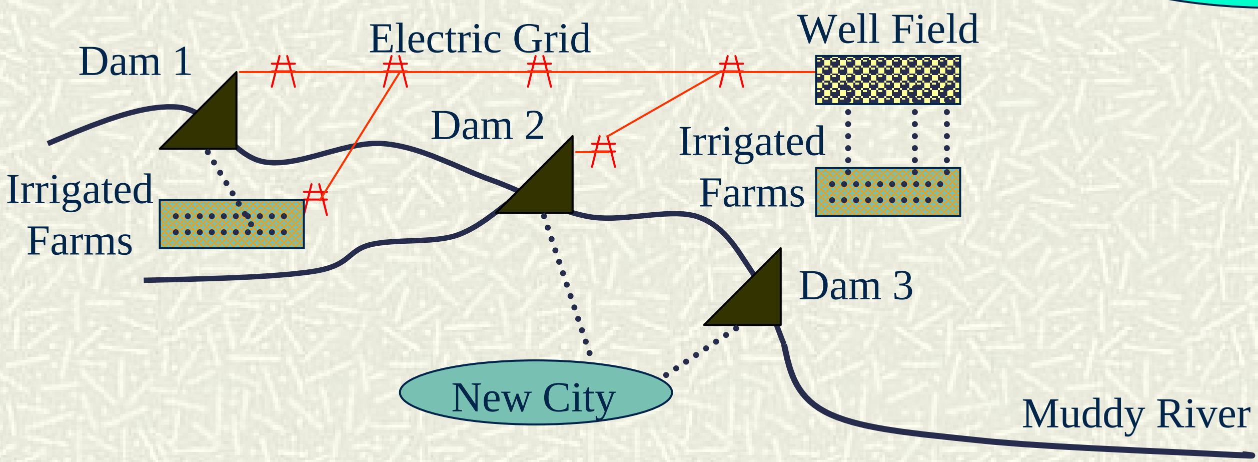
[2]Department of Earth and Environmental Engineering, Columbia University, New York, USA

Open seminar on the applications of climate information in various socio-economic sectors.
Tokyo, Tuesday 20th February 2007

Managing Water Resource Systems

- Balance Water Supply and Demand, avoid flood
- Historical rules for resource allocation
- How much, and when should these rules be modified based on new climate technologies
- How do we assess and communicate potential impacts of action & inaction ?
- Background risks for sustainable strategies and infrastructure development





Management options at different timescales of the available information

1. Monitoring and Short-term (several days) projections

2. Seasonal Prediction (next 3-6 months)

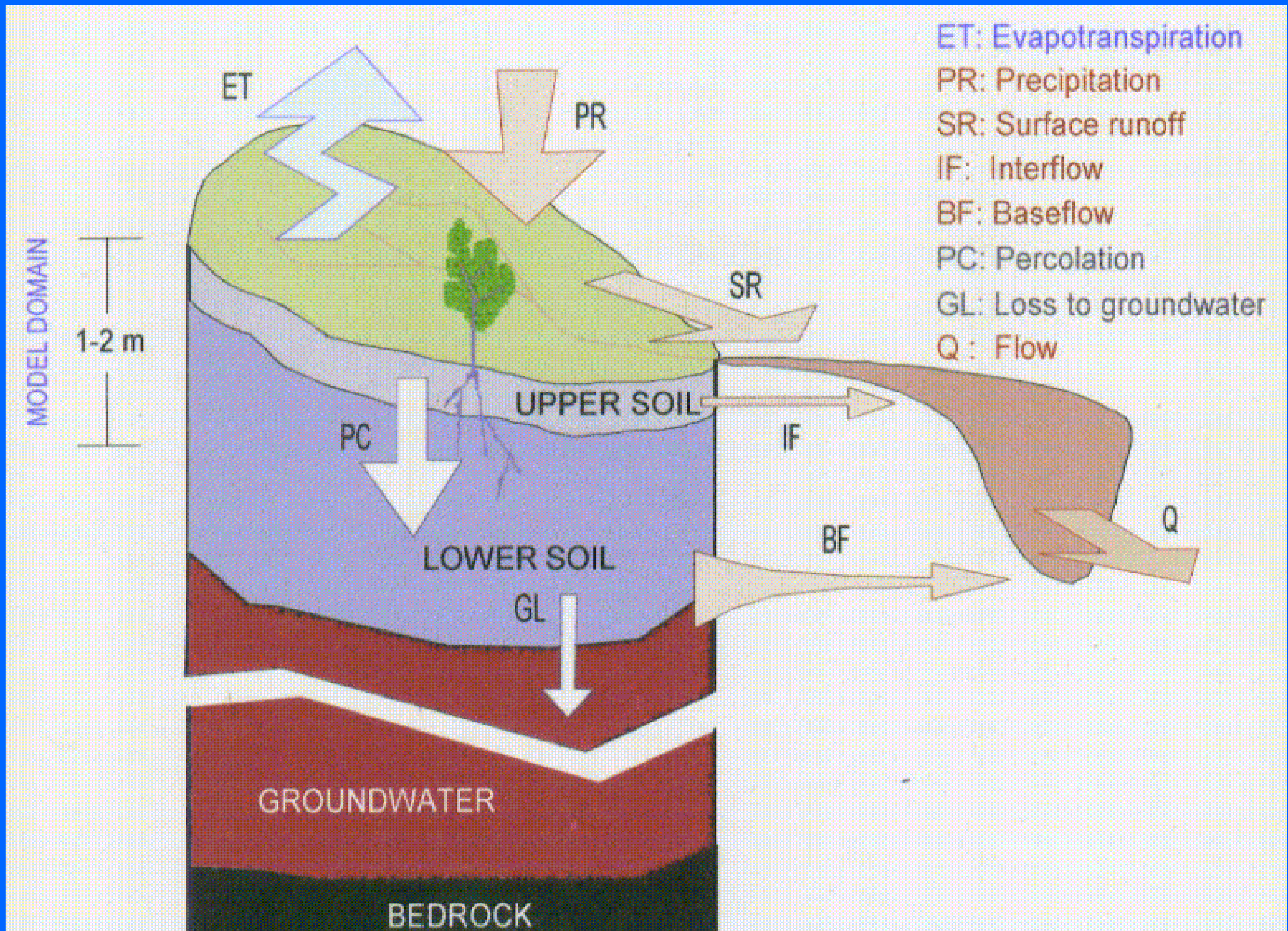
3. Merging knowledge on natural multidecadal (e.g. 10-30 years) and global change for water resources management

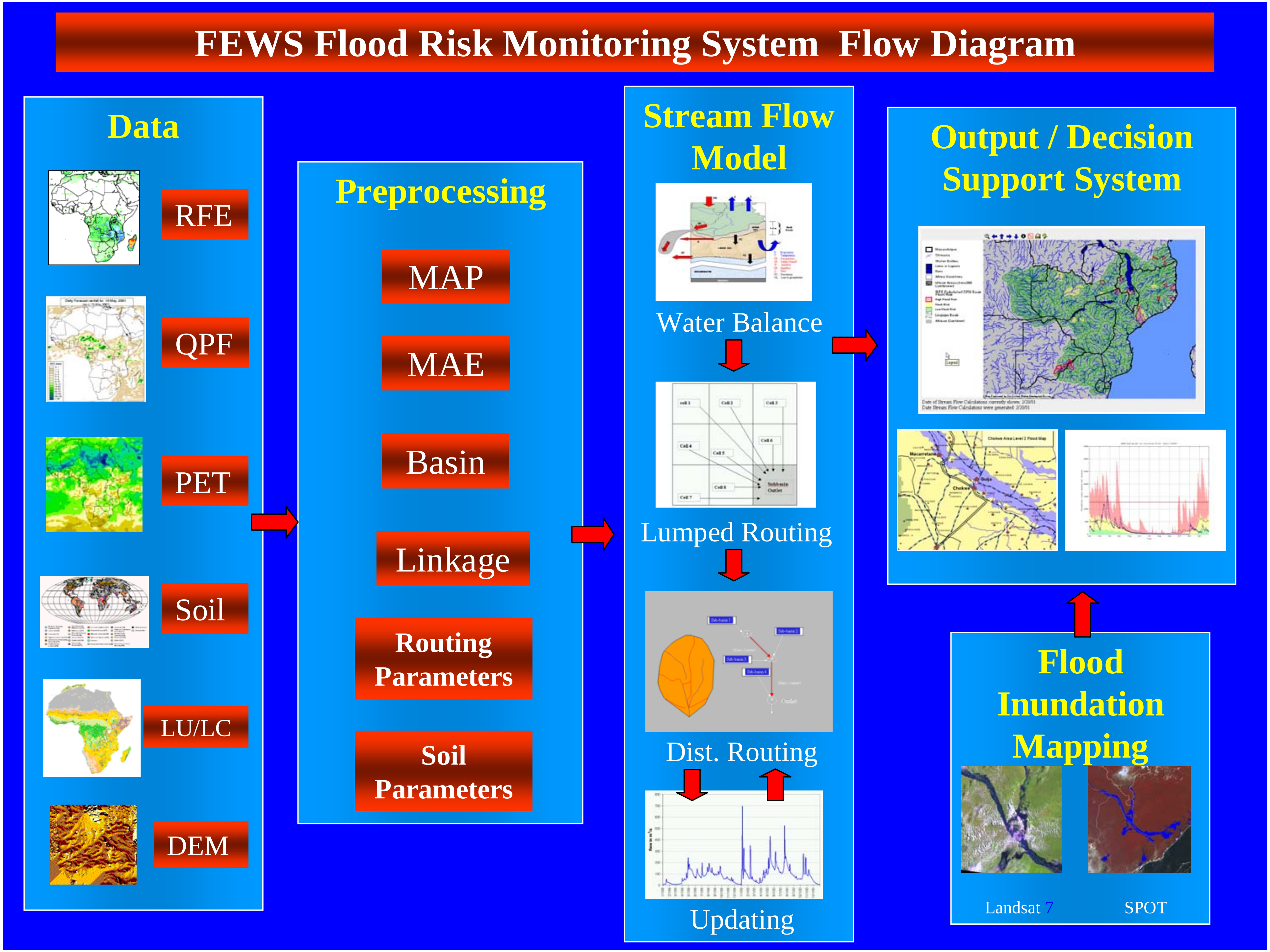
Section 1

Monitoring and Short-term projections

Flood prediction and management (including Mozambique case study)

Conception of FEWS Flood Model




FEWS Flood Risk Monitoring System Flow Diagram
Data
RFE
QPF
PET
Soil
LU/LC
DEM
Preprocessing
MAP
MAE
Basin
Linkage
Routing Parameters
Soil Parameters
Stream Flow Model
Water Balance
Lumped Routing
Dist. Routing
Updating
Output / Decision Support System
Flood Inundation Mapping
Landsat 7
SPOT

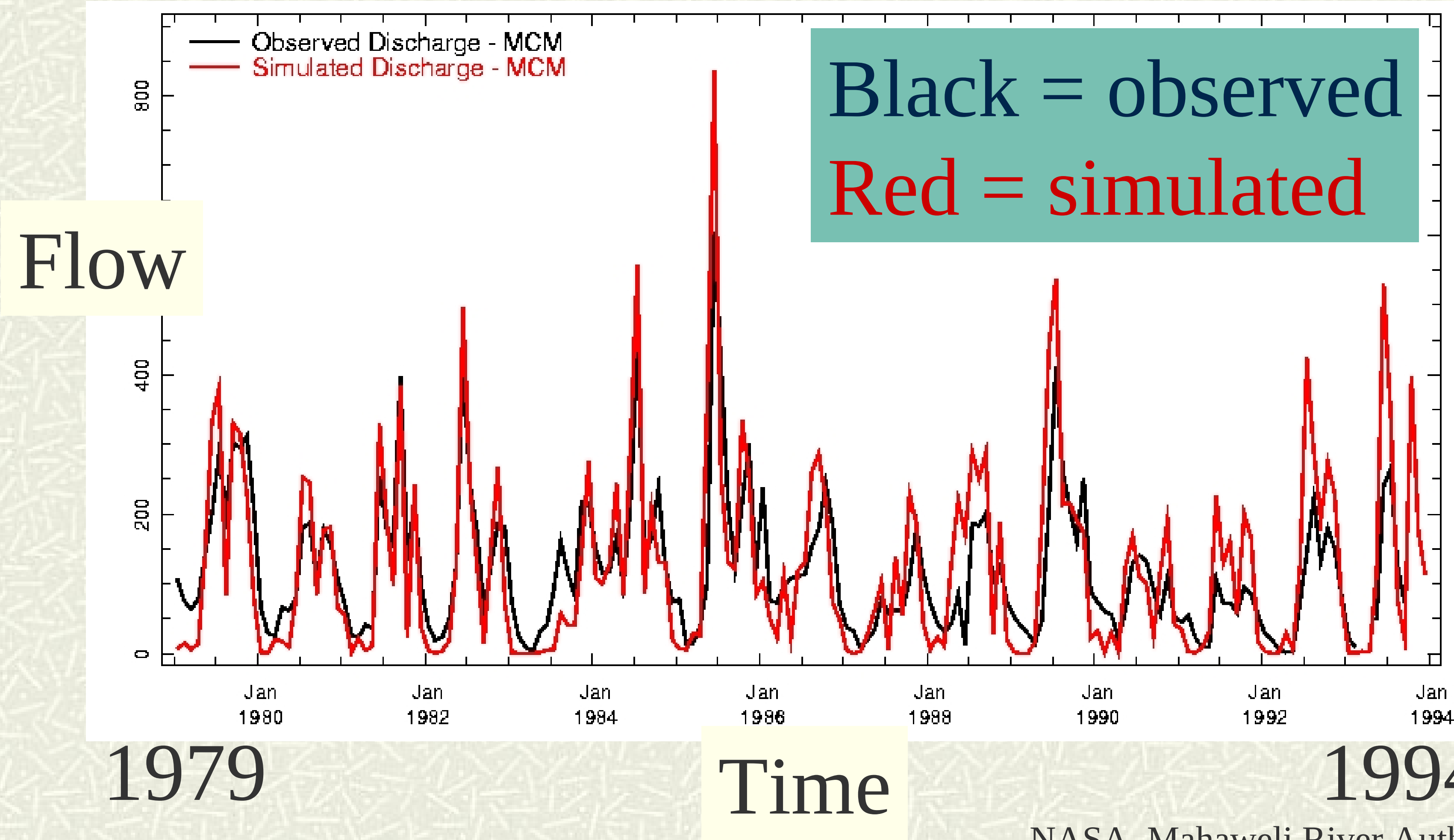
New opportunity: Reanalysis weather data

Case Study: surface hydrology in Sri Lanka

Potential for enhanced monitoring and prediction of weather-driven component of surface hydrology

ECMWF reanalysis weather data drives stream flow simulation for Mahaweli gauge location, Sri Lanka

(Reanalysis rainfall is bias corrected)



NASA, Mahaweli River Authority, IRI

Climate and Society No. 1

Eds, Hellmuth et al., 2007. Mozambique case study by Lucio et al.

Recent climate-related natural disasters in Mozambique

Year	Event	Areas affected	Number of people affected
2002–06	Drought	43 districts affected in South and Central provinces	800,000 affected
2001	Floods	Zambezi river	500,000 affected; 115 deaths
2000 ************	Floods	Limpopo, Maputo, Umbeluzi, Incomati, Buzi, and Save river basins, caused by record rainfall and 3 cyclones	More than 2 million people affected; 700 deaths
1999	Floods	Sofala and Inhambane provinces; highest rainfall level in 37 years; EN1 (major road) shut for 2 weeks	70,000 people affected; 100 deaths
1997	Floods	Buzi, Pungue and Zambezi rivers; no road traffic to Zimbabwe for 2 weeks	300,000 people affected; 78 deaths
1996	Floods	All southern rivers of the country	200,000 people affected
1994–95	Drought	South and Central parts	1.5 million people affected; cholera epidemic

(Lucio et al., 2007)

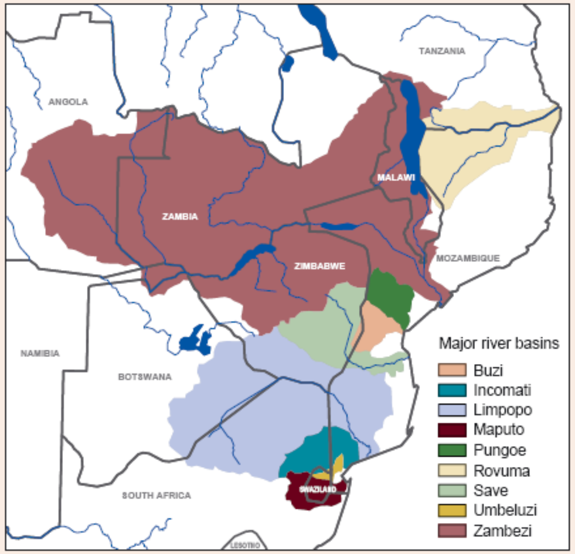


Figure 3. Mozambique, its neighboring countries, and major rivers basins.

Limpopo basin includes Zimbabwe, Botswana and S. Africa

Areas of the lower Limpopo basin were flooded for the first time in living memory; P-A. Pettersson/Still Pictures

Mozambique floods, Jan-Feb 2000

Aspects of good practice that were already in place

1. Seasonal forecast recognized increased risk of flooding through the rainy season due to presence of La Nina and other climate aspects (but no methods yet to quantify increased risks)

2. November – National disaster committee meets frequently and produces National Contingency Plan

Improvements in practice after 2000 Mozambique flood

1. Flood risk analysis for vulnerable areas (see section 3 of lecture)

2. Hydromet monitoring system enhanced

3. Linking monitoring/forecast information to trigger response

4. Consider news media, and communication

Section 2

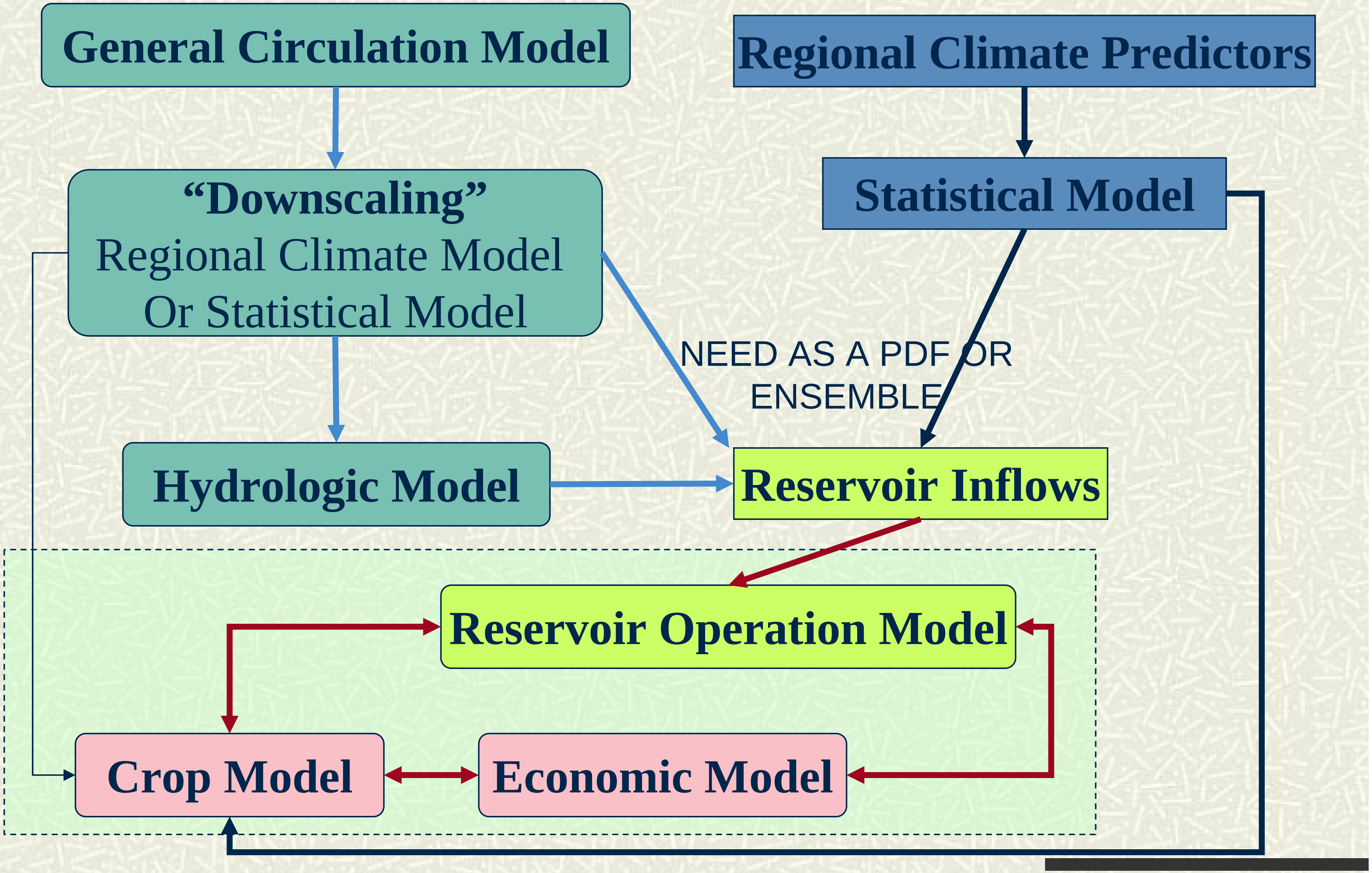
Bringing Seasonal Prediction Technology into Water Resources Management

Especially in tropical regions, capability exists now to forecast climate patterns 3-6 months into the future

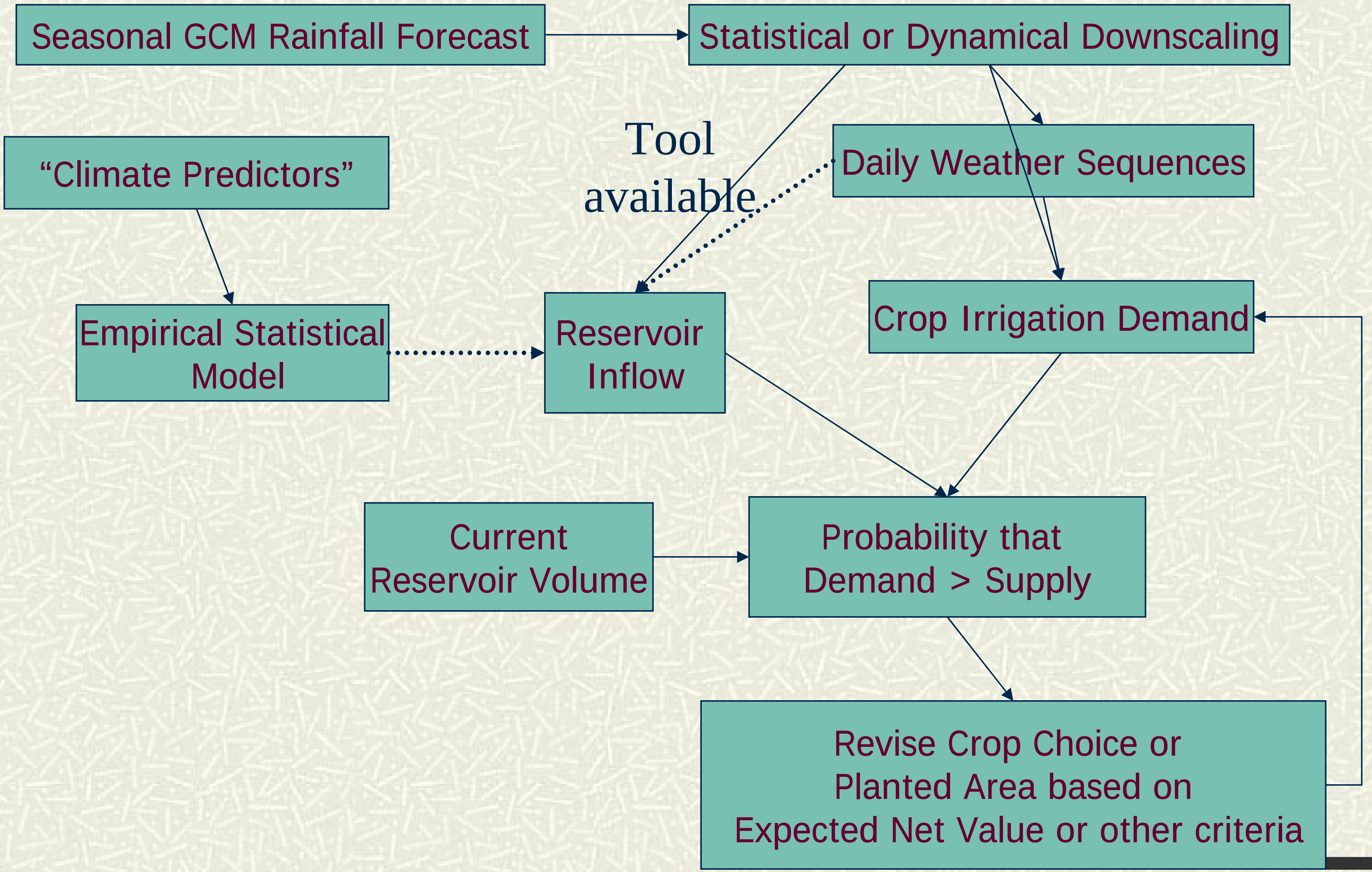
Forecasting Reservoir Inflow for Reservoir Operations

NEED AS A PDF OR ENSEMBLE

Forecasting Water Supply and Demand

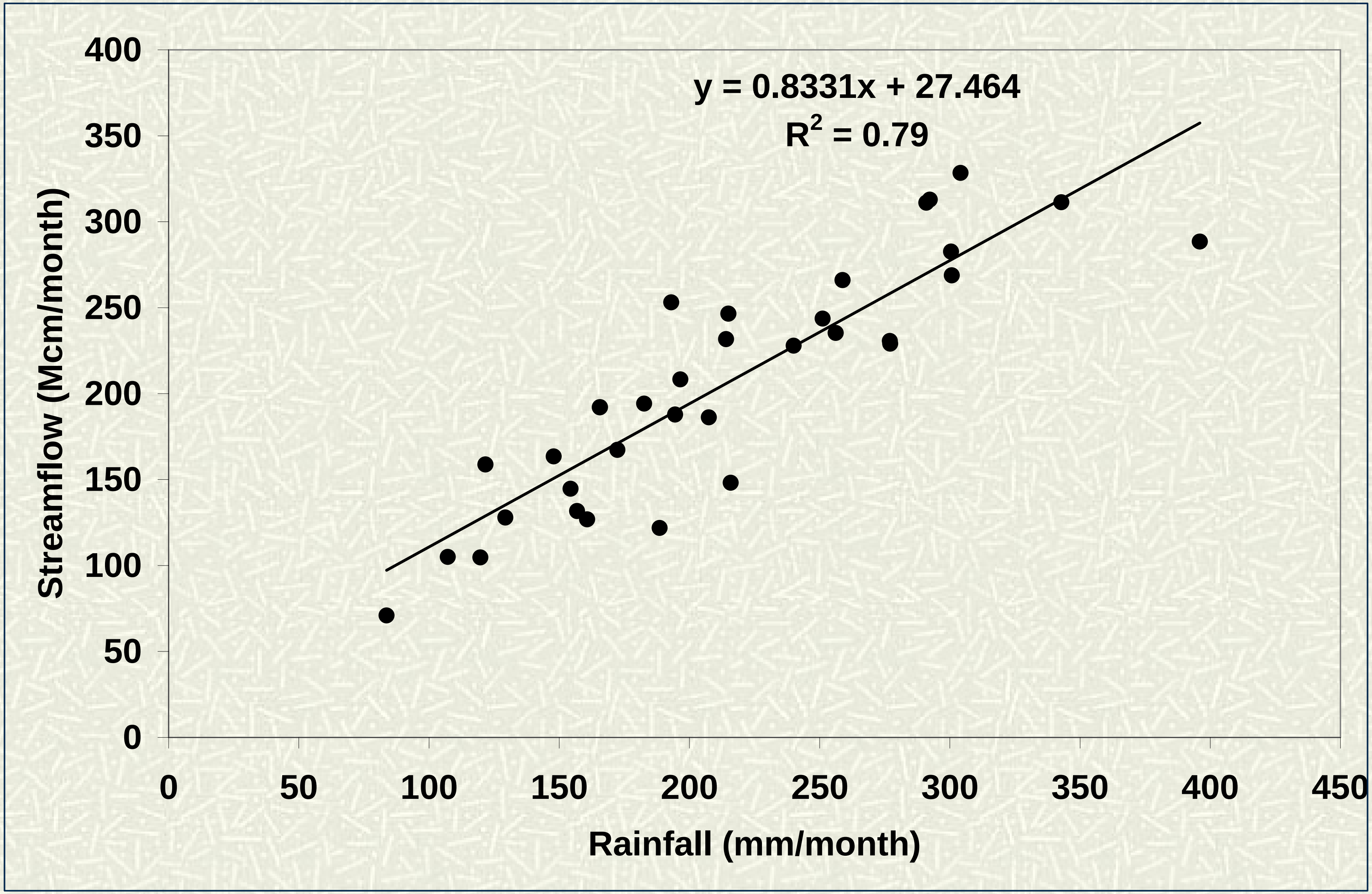


Possible Procedures

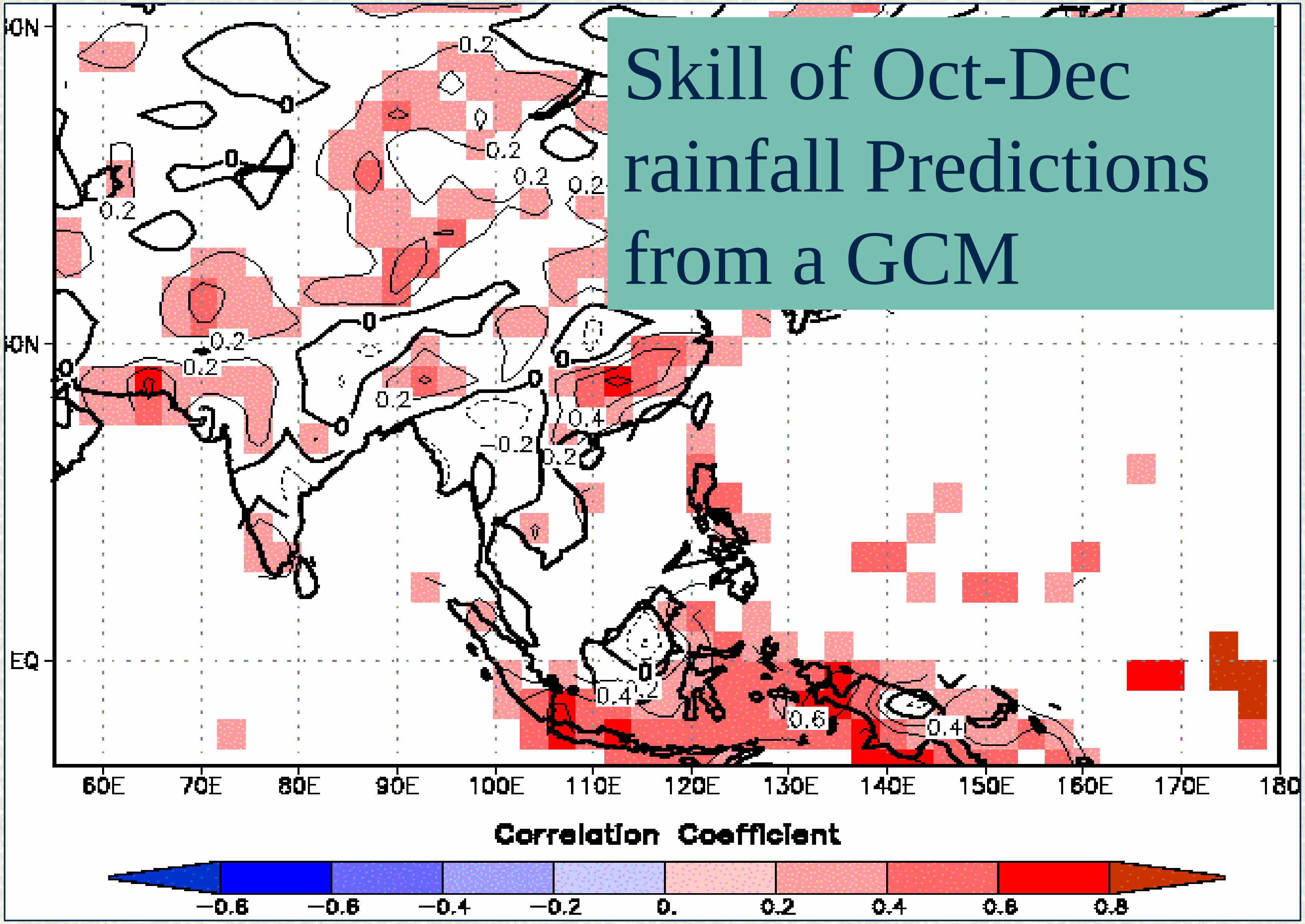


Exploring the management of Angat Dam, Philippines using seasonal inflow forecasts
(Most value in such low storage to inflow ratio settings)

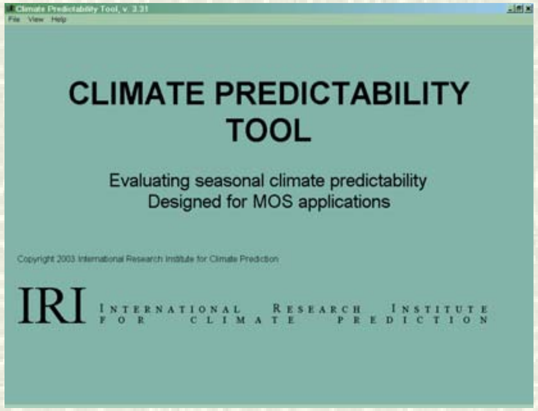
Rainfall-Runoff (Oct-Feb) Relation

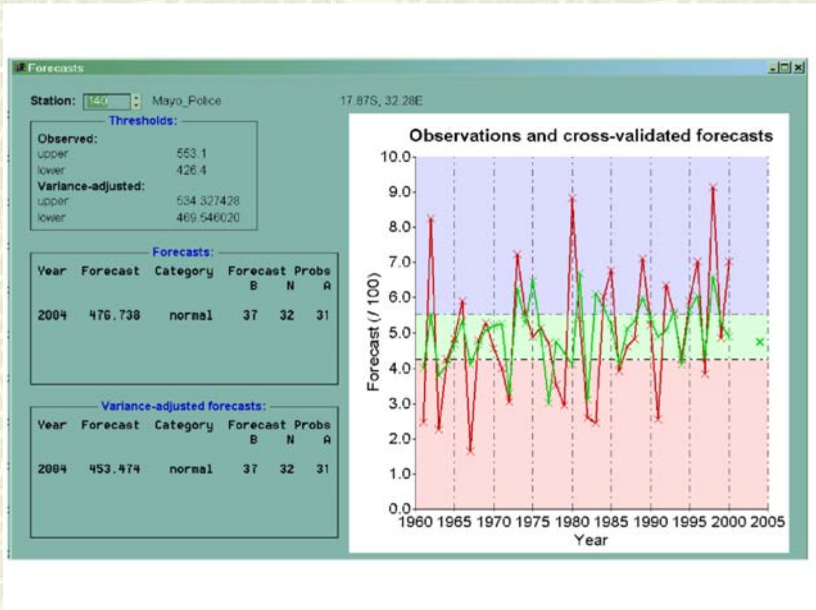


Reliable Seasonal Climate Forecasts are possible in many tropical locations



Software tool to translate GCM seasonal forecasts into a target variable

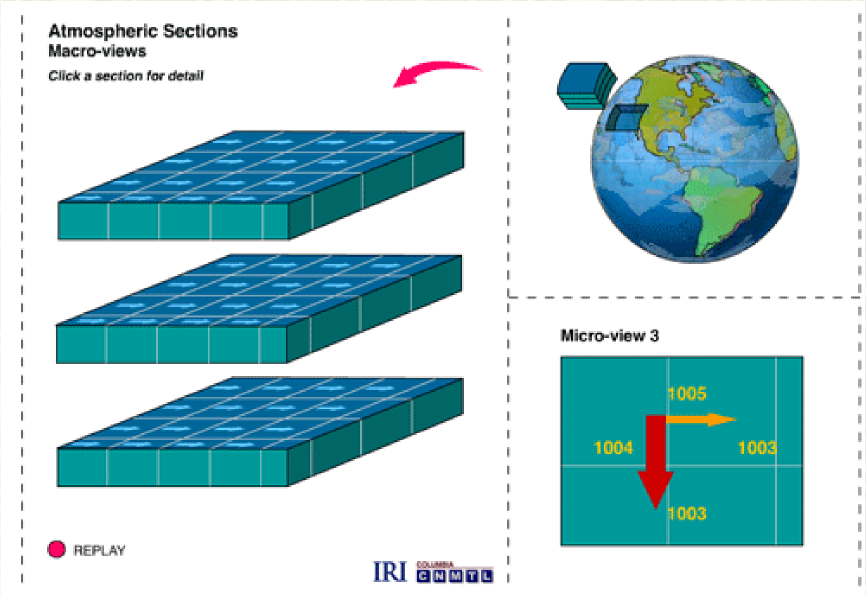




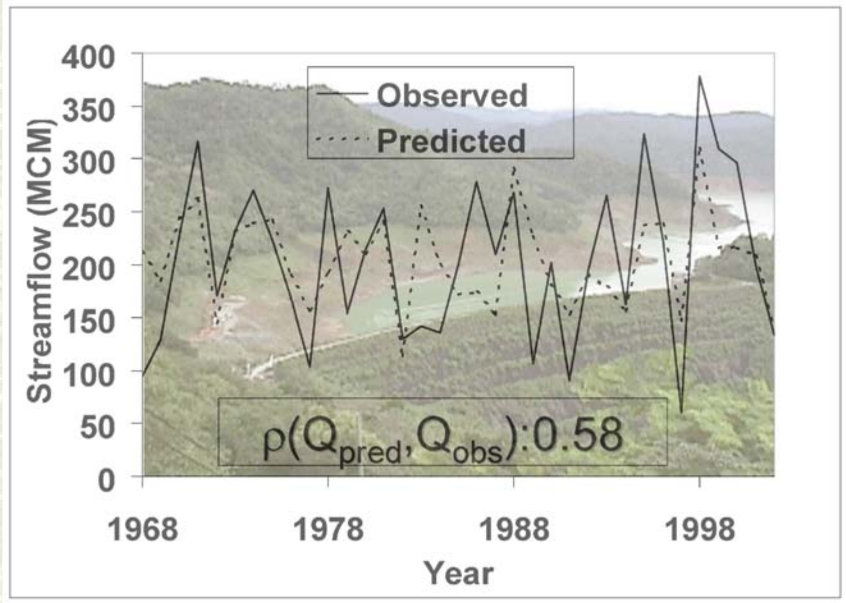
Freely available from IRI website

From General Circulation Model (GCM) to Reservoir Inflow Forecast

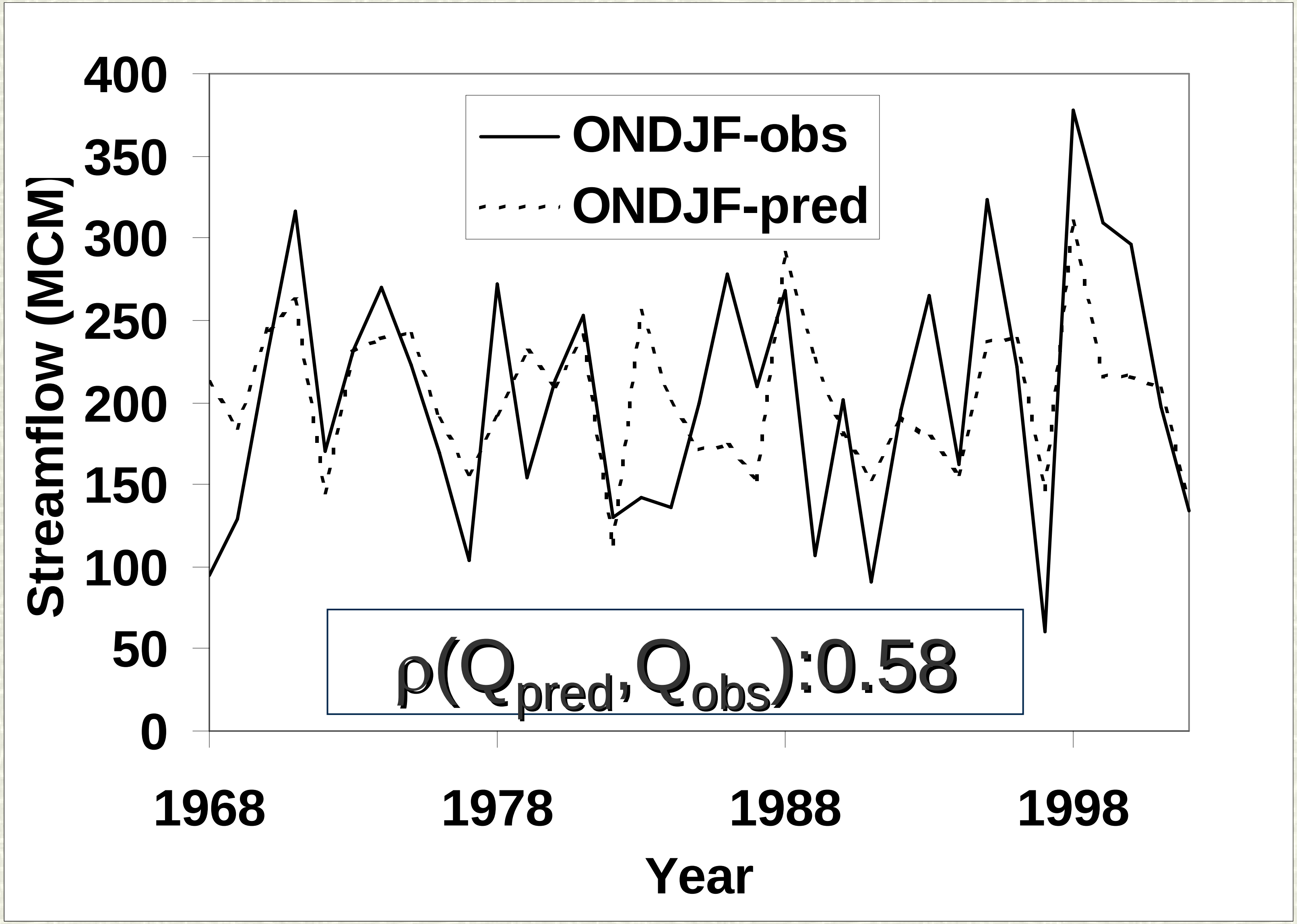
The GCM gives a large-scale climate forecast

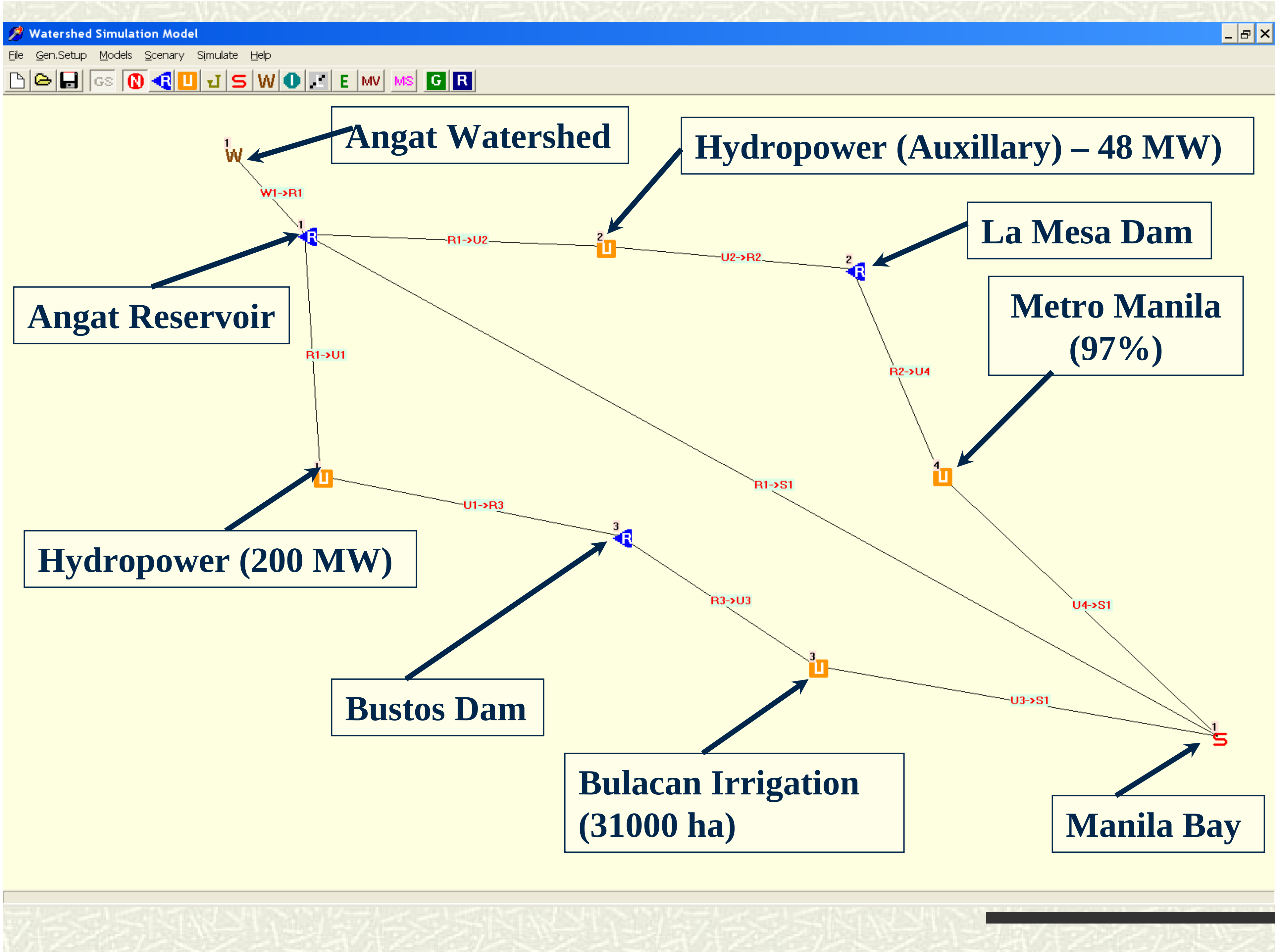


Then apply a statistical transformation to predict reservoir inflow

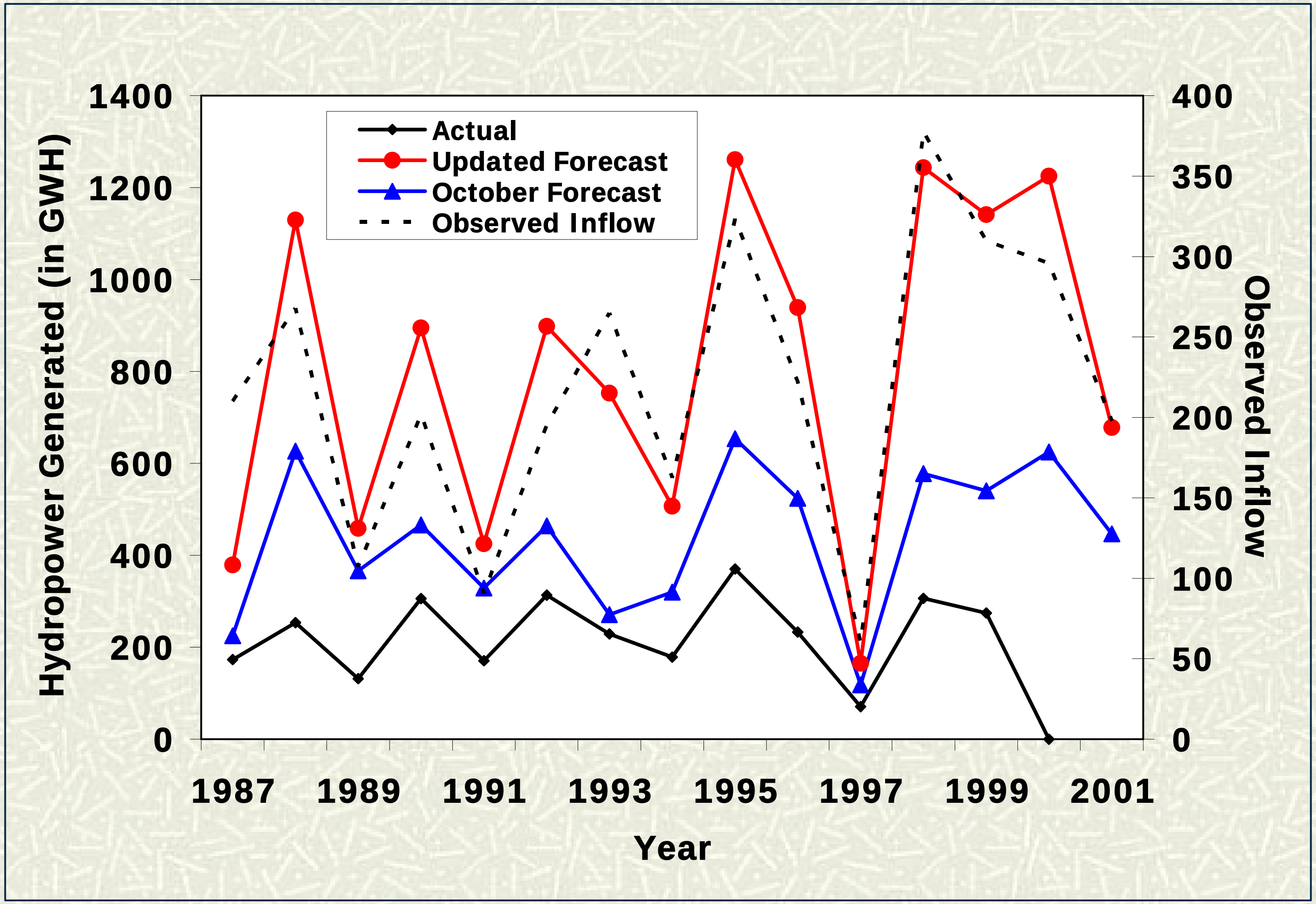


Translating large-scale forecast output from a GCM into Oct-Feb Reservoir inflow forecasts for reservoir management




Watershed Simulation Model
File Gen.Setup Models Scenary Simulate Help
Angat Watershed
Hydropower (Auxillary) – 48 MW)
La Mesa Dam
Angat Reservoir
Metro Manila (97%)
Hydropower (200 MW)
Bustos Dam
Bulacan Irrigation (31000 ha)
Manila Bay
W1->R1
R1->U2
U2->R2
R1->U1
R2->U4
R1->S1
U1->R3
R3->U3
U4->S1
U3->S1

Estimating Improved Hydropower Production using Seasonal Forecasts
Output from software illustrated in previous slide



Lall and Arumugam, 2006

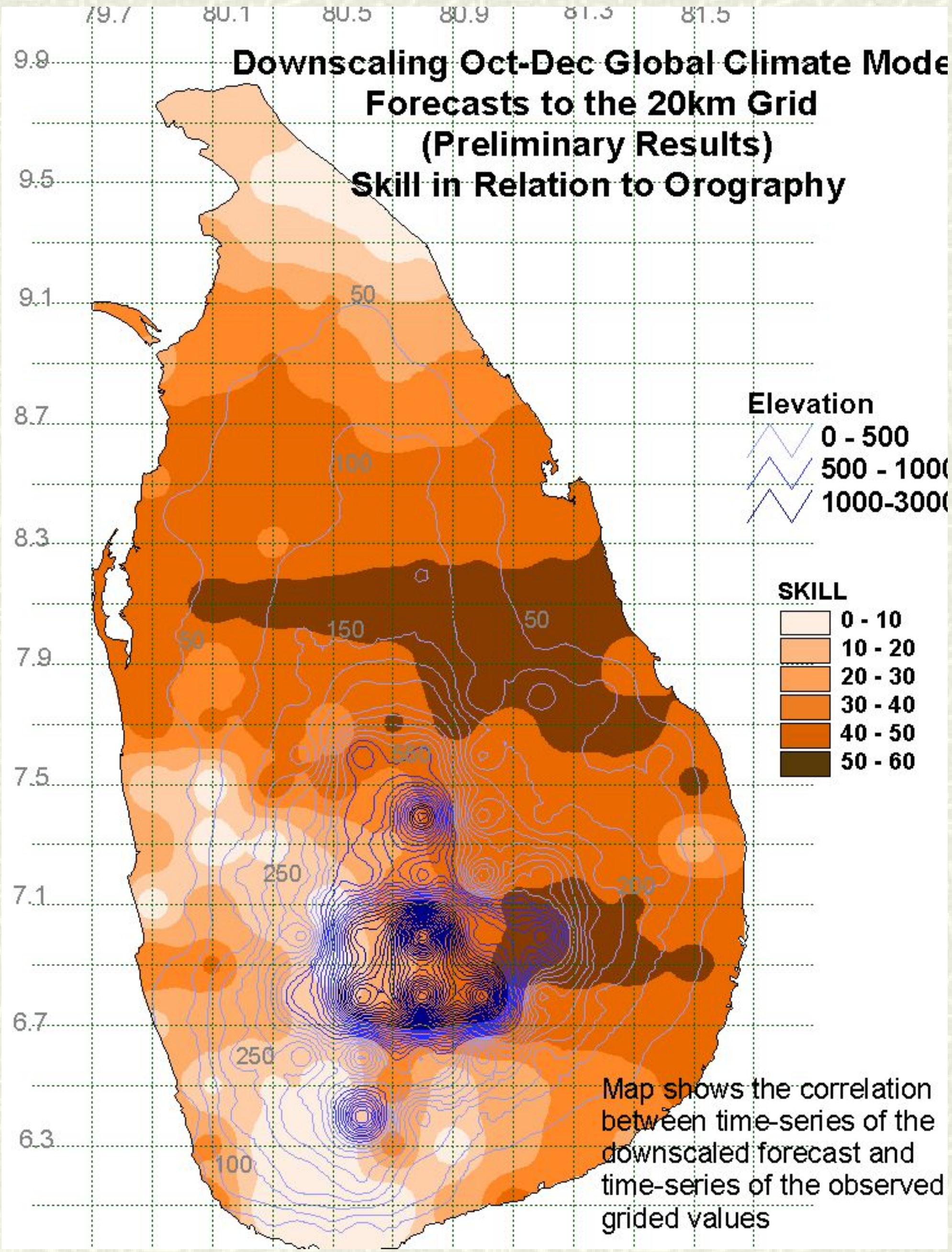
Two Caveats for Changing Practice Based on Seasonal Prediction

1) Technical: Care with downscaling the prediction signal

2) Societal: Participatory process and often need for policy change

Seasonal forecasts vary across Sri Lanka

High mountains can make downscaling information critical and complex

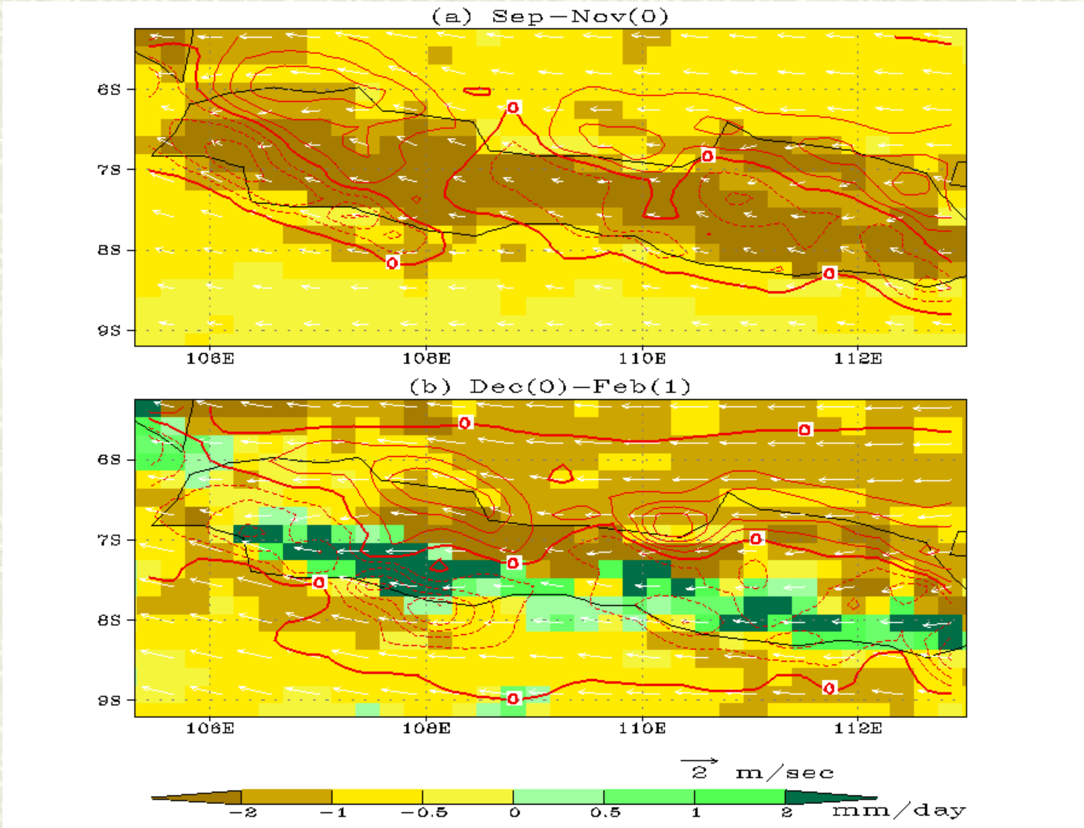


(Zubair et al.)

Modeling small scale seasonal rainfall anomalies across Java in El Nino Years

Sep-Nov

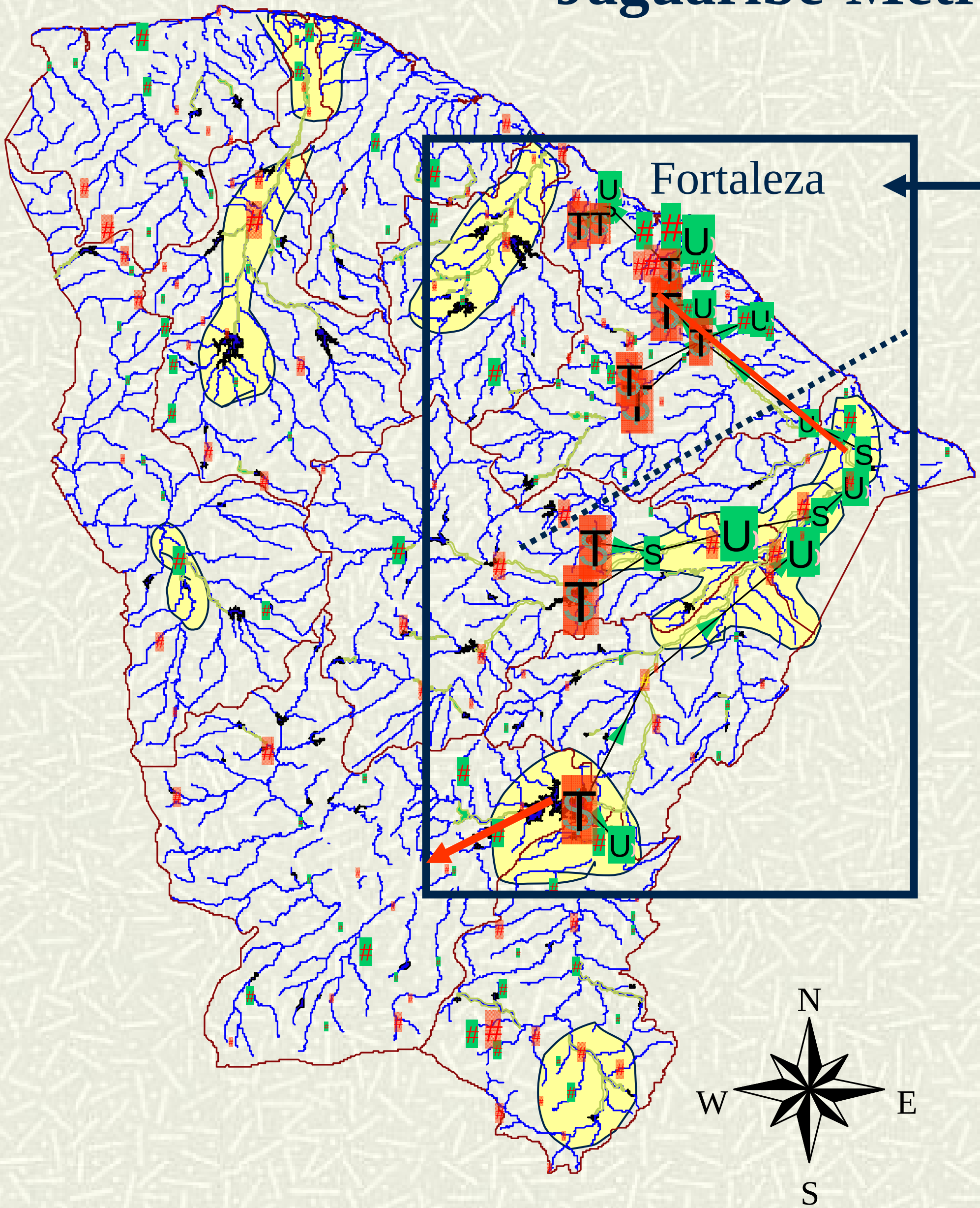
Dec-Feb



Brown = Below normal
Green = Above normal

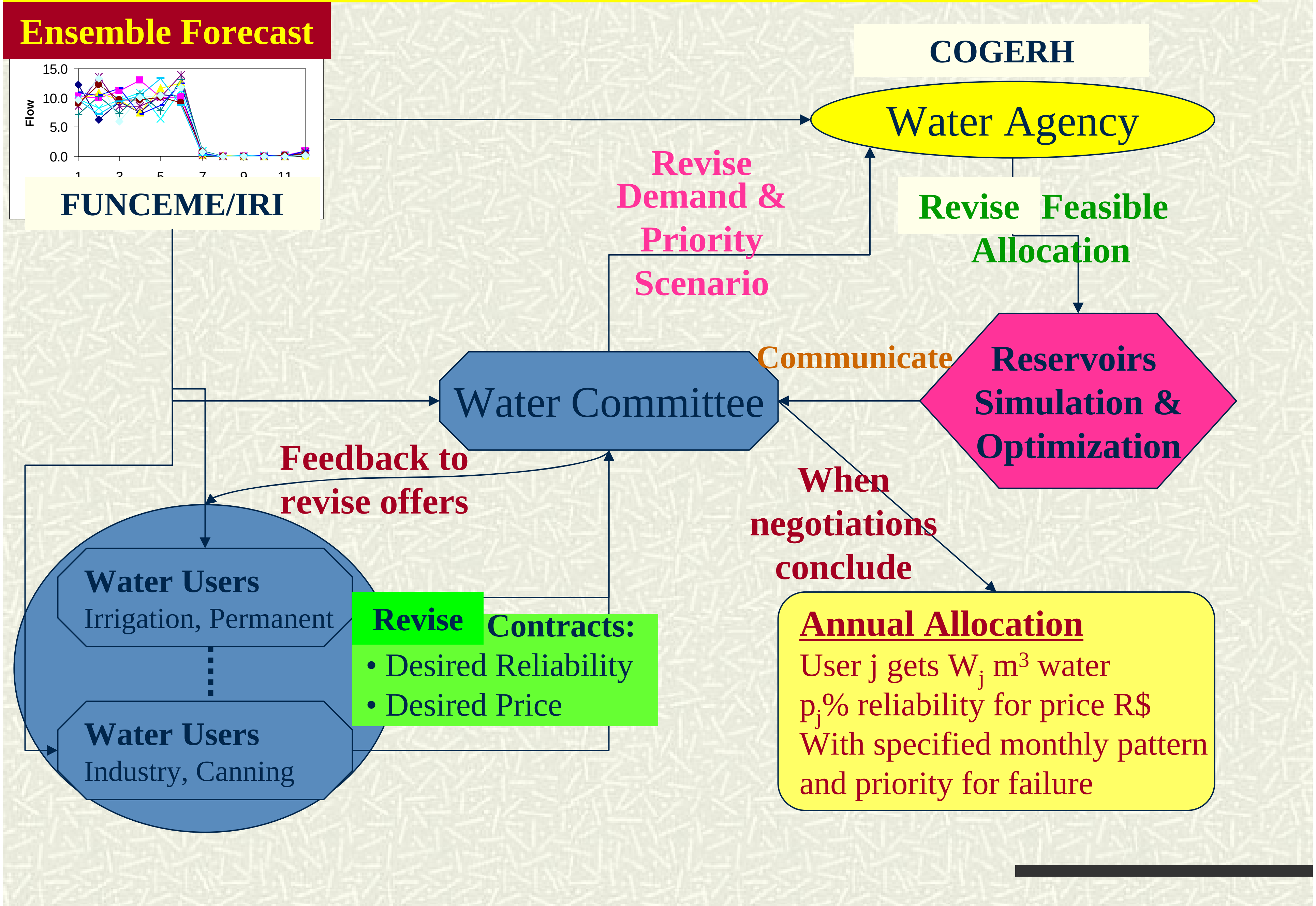
(Qian et al., 2007)

Jaguaribe-Metropolitano Hidrosystem



Adoption of new allocation strategies is complex process

Jan-Dec Water Macro-Allocation Plan --- Developed July-Oct



Water allocation matters to many people

Section 3
Background Hydroclimatic Risk Information

- For resource management strategies including infrastructure development

- For disaster risk management
  - cf Mozambique example

Analyses to inform strategies for infrastructure

Knowledge of climate variability is a key factor

Here estimates of storage volume needed by country

Table 2. Seasonal Storage Index (SSI). The seasonal storage index indicates the volume of storage needed to satisfy annual water demand based on the average seasonal rainfall cycle. The GDP's of countries lacking adequate storage in comparison to the SSI are notably low

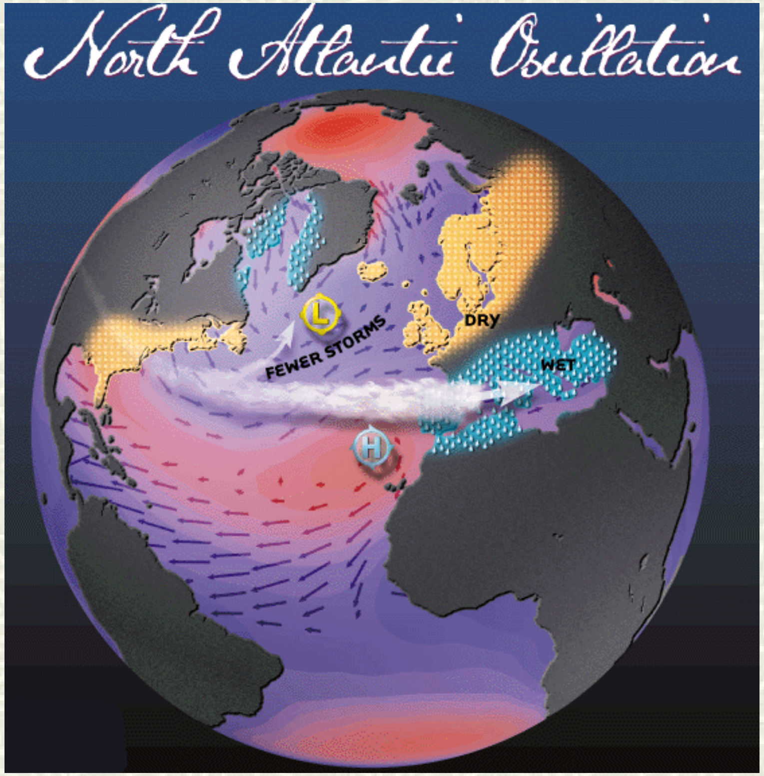
	Seasonal Storage Index (km^3)	SSI as % of Annual Volume	% Hard Water (of total)	Current Storage (% of SSI)	GDP ($, 2003)
India	356.60	21%	17%	76%	555
Bangladesh	62.28	41%	40%	33%	385
Ethiopia	40.99	10%	100%	8%	91
Nepal	29.86	47%	100%	0%	233
Vietnam	27.64	10%	100%	3%	471
North Korea	23.32	45%	100%	0%	494
Senegal	22.30	40%	100%	7%	641
Malawi	18.98	34%	100%	0%	158
Algeria	6.60	6%	100%	91%	2,049
Tanzania	5.50	1%	33%	76%	271
El Salvador	5.45	37%	100%	59%	2,302
Haiti	3.73	25%	79%	0%	300
Guinea	3.71	2%	100%	51%	424
Eritrea	2.75	11%	15%	3%	305
Burundi	2.64	19%	27%	0%	86
Albania	2.64	23%	100%	21%	1,915
Guinea-Bissau	2.48	11%	100%	0%	208
Sierra Leone	2.21	3%	100%	0%	197
The Gambia	2.14	56%	100%	0%	224
Rwanda	1.38	9%	3%	0%	185
Mauritania	1.34	2%	100%	66%	381
Swaziland	0.98	15%	100%	59%	1,653
Bhutan	0.40	1%	13%	0%	303

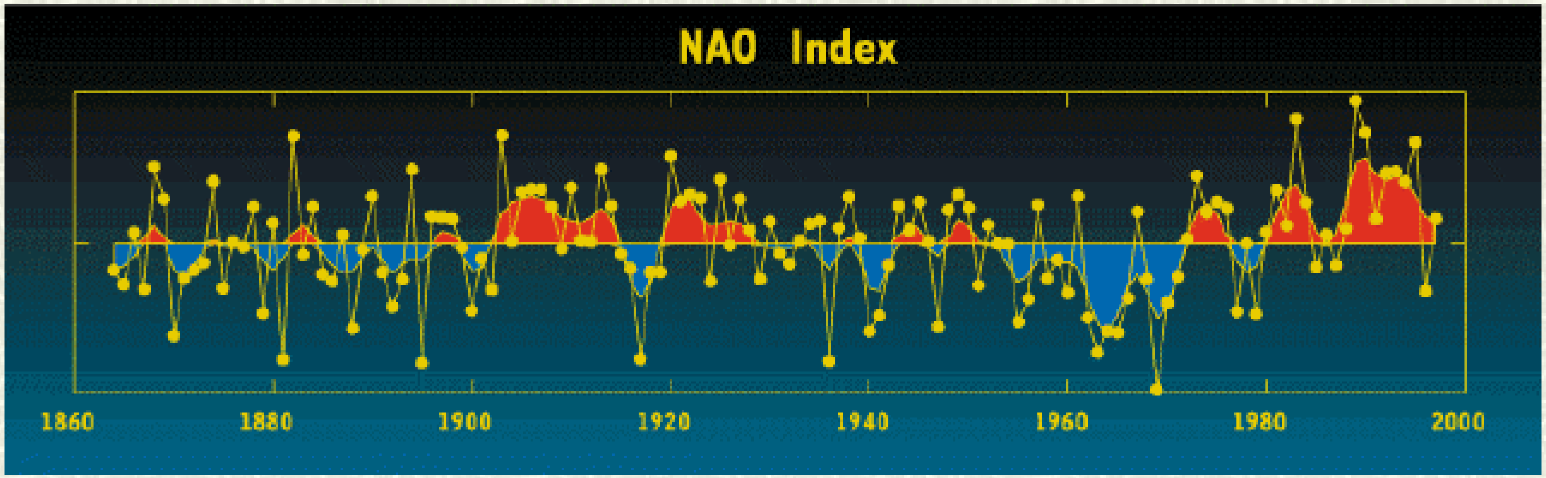
Brown and Lall, 2006

Multi-decadal variability is now recognized as a natural part of the climate system

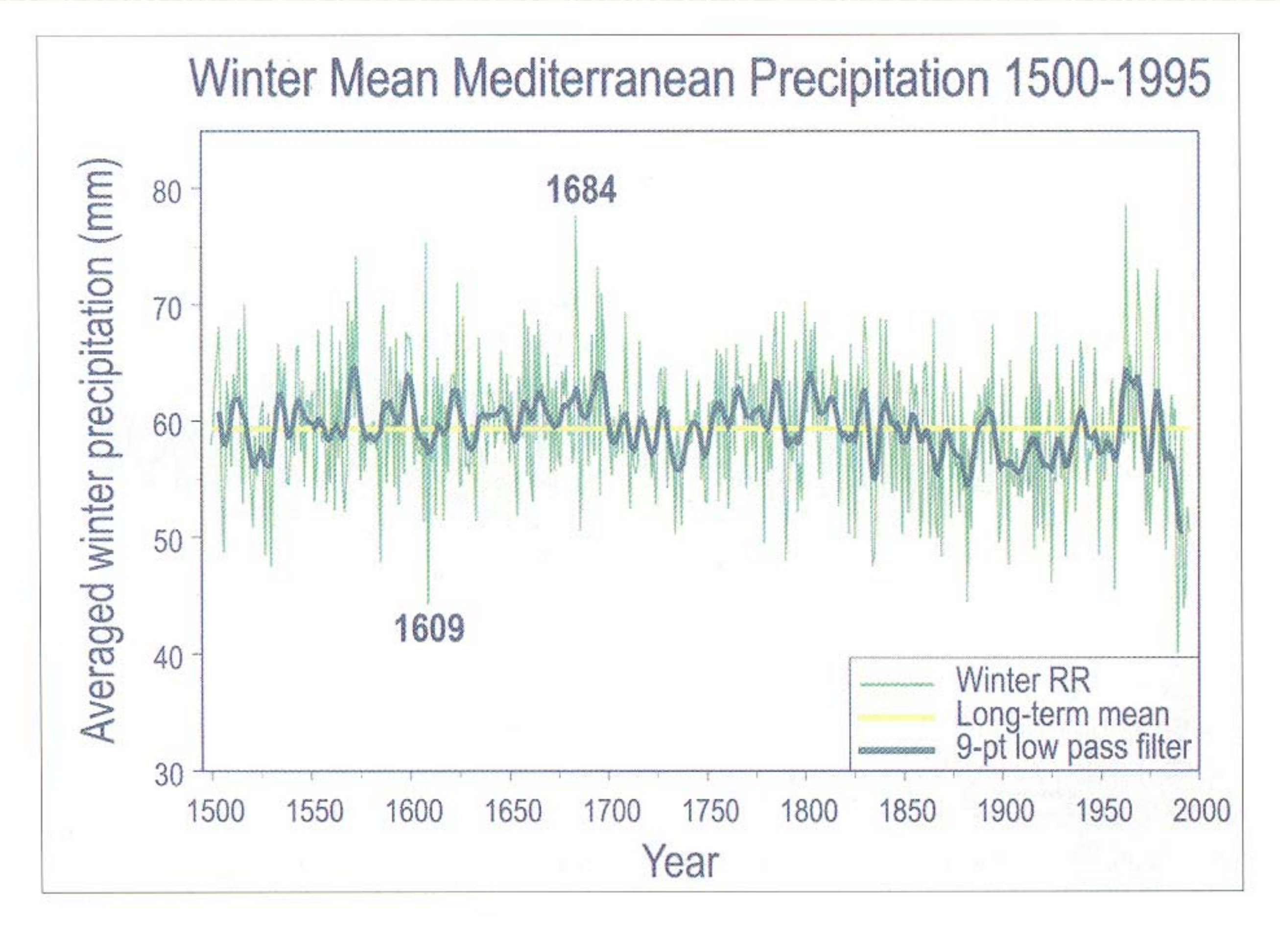
There is growing understanding of its sources and statistical properties

Motivates finding best ways to incorporate statistics for long-term planning



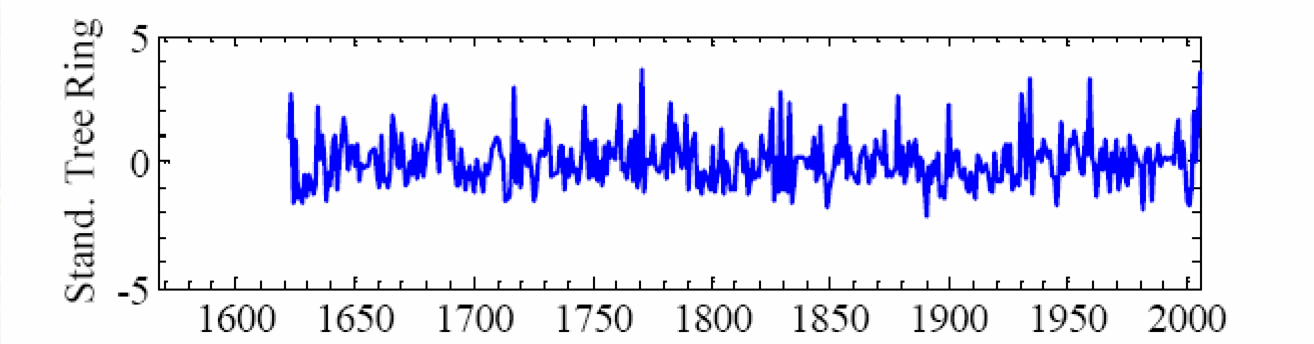


Expression in Regional Climate Fluctuations

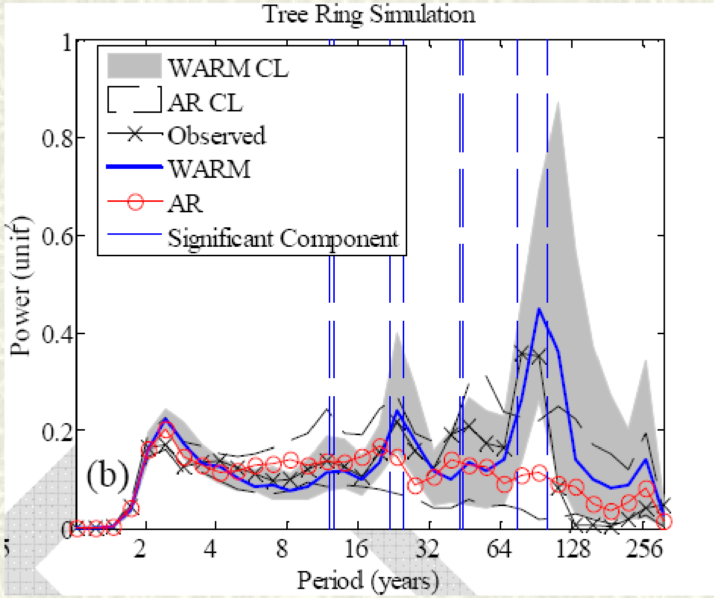


Luterbacher and Xoplaki, 2003

Developing information to support South Florida Water Management District



Models simulate low frequency statistical properties to guide management strategies



Power Spectrum

Kwon and Lall, 2006

Context of Global Change

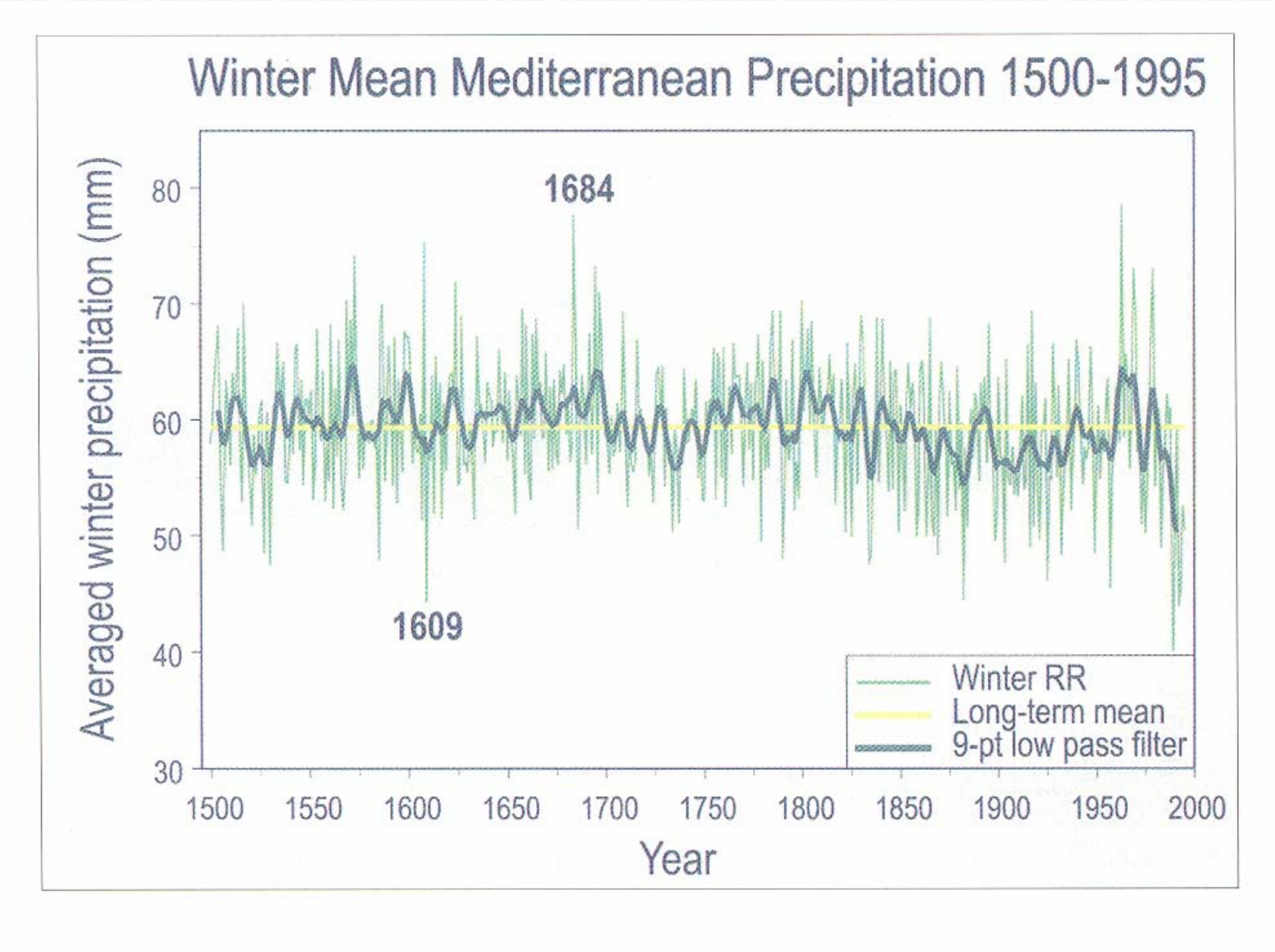
Climate/Environment and Socioeconomic

Linking Regional Water Supplies and Water Demands in a changing world

Availability of water for agriculture in the coming decades depends not only on changing climate, but also on population, economic development, and technology

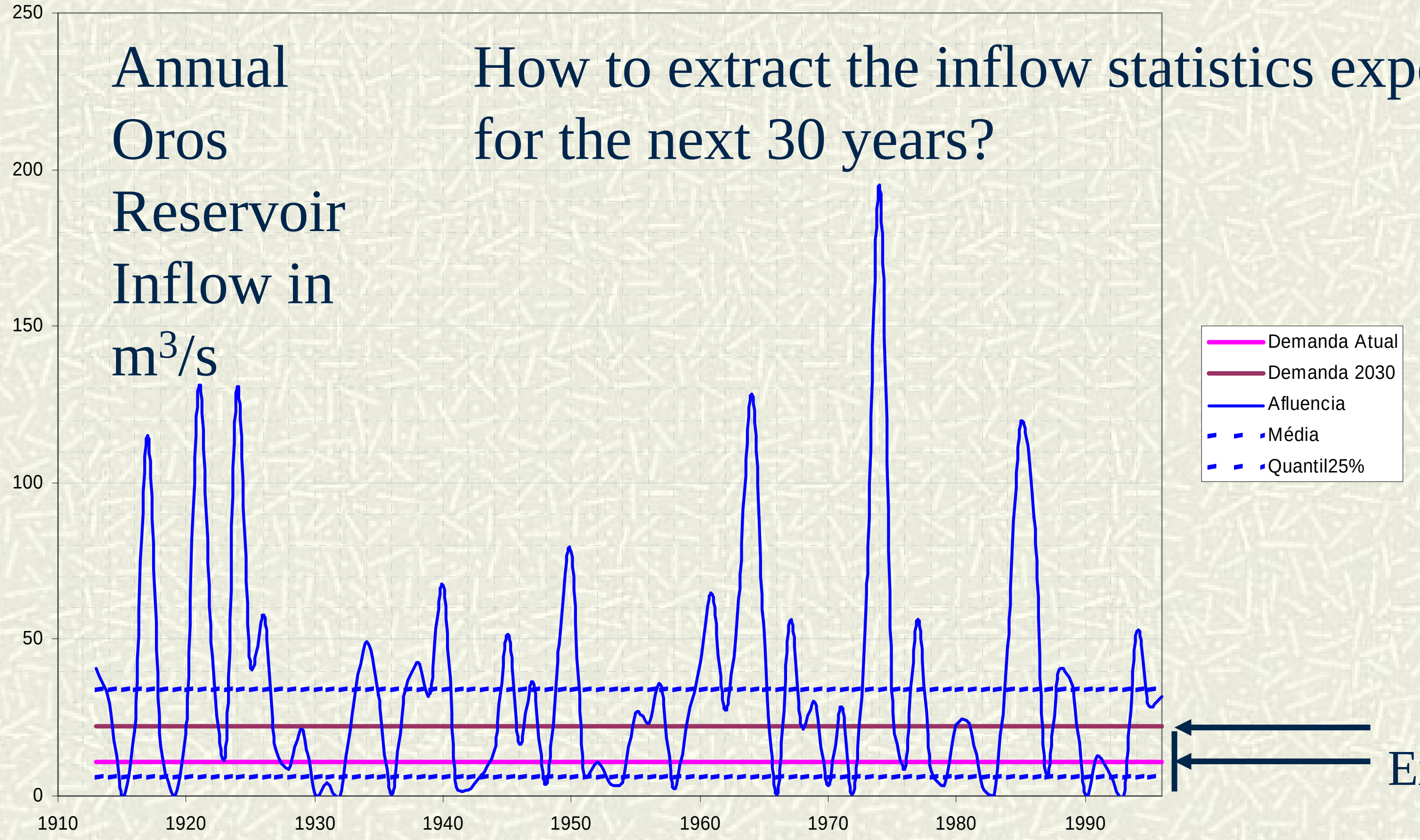
(C. Rosenzweig, NASA GISS & Columbia University)

Expression in Regional Climate Fluctuations



Luterbacher and Xoplaki, 2003

Water Resources Setting – Study in NE Brazil



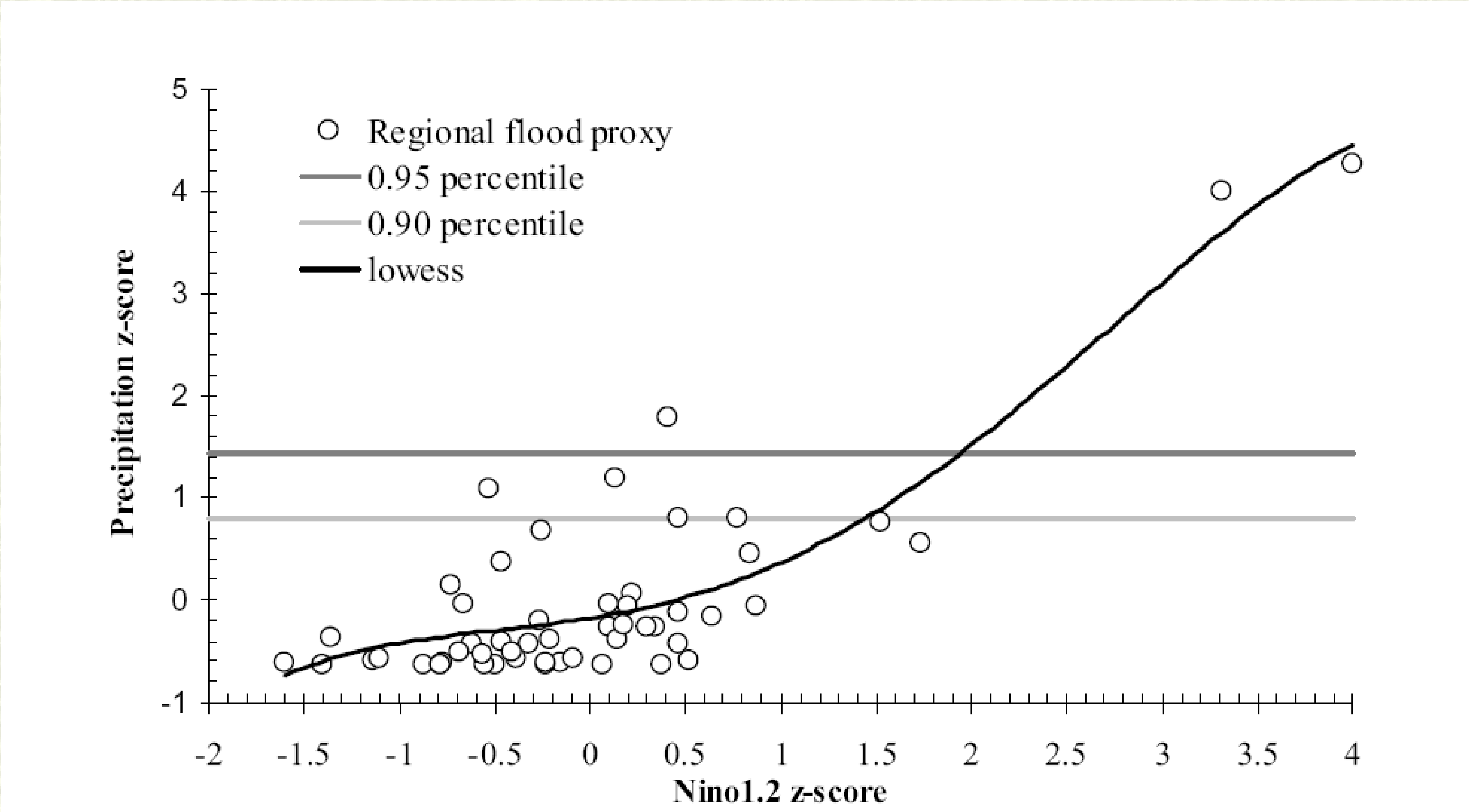
Projected & Existing Demand

Climate and Society No. 1

Insurance as a natural tool to better manage climate and hydroclimatic risk

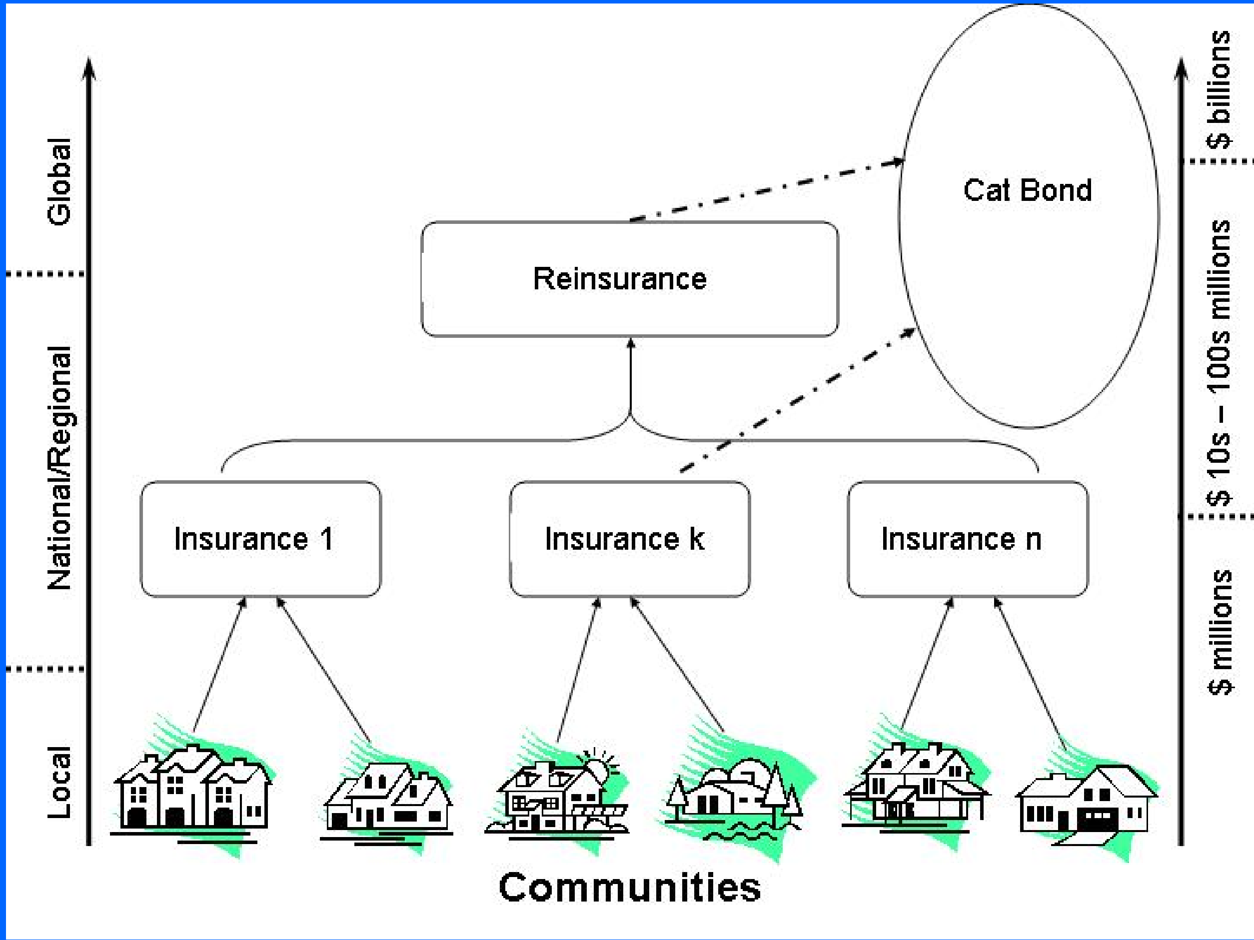
Weather / hydrology index insurance

Example for Peru, flood precipitation proxy (y-axis)
x-axis is Nino index, introducing predictability to the insurance problem



Khalil et al, 2007

Insurance could be a natural partner for innovative water resources management based on probabilistic climate information



Management options at different timescales of the available information

1. Monitoring and Short-term (several days) projections

2. Seasonal Prediction (next 3-6 months)

3. Merging knowledge on natural multidecadal (e.g. 10-30 years) and global change for water resources management