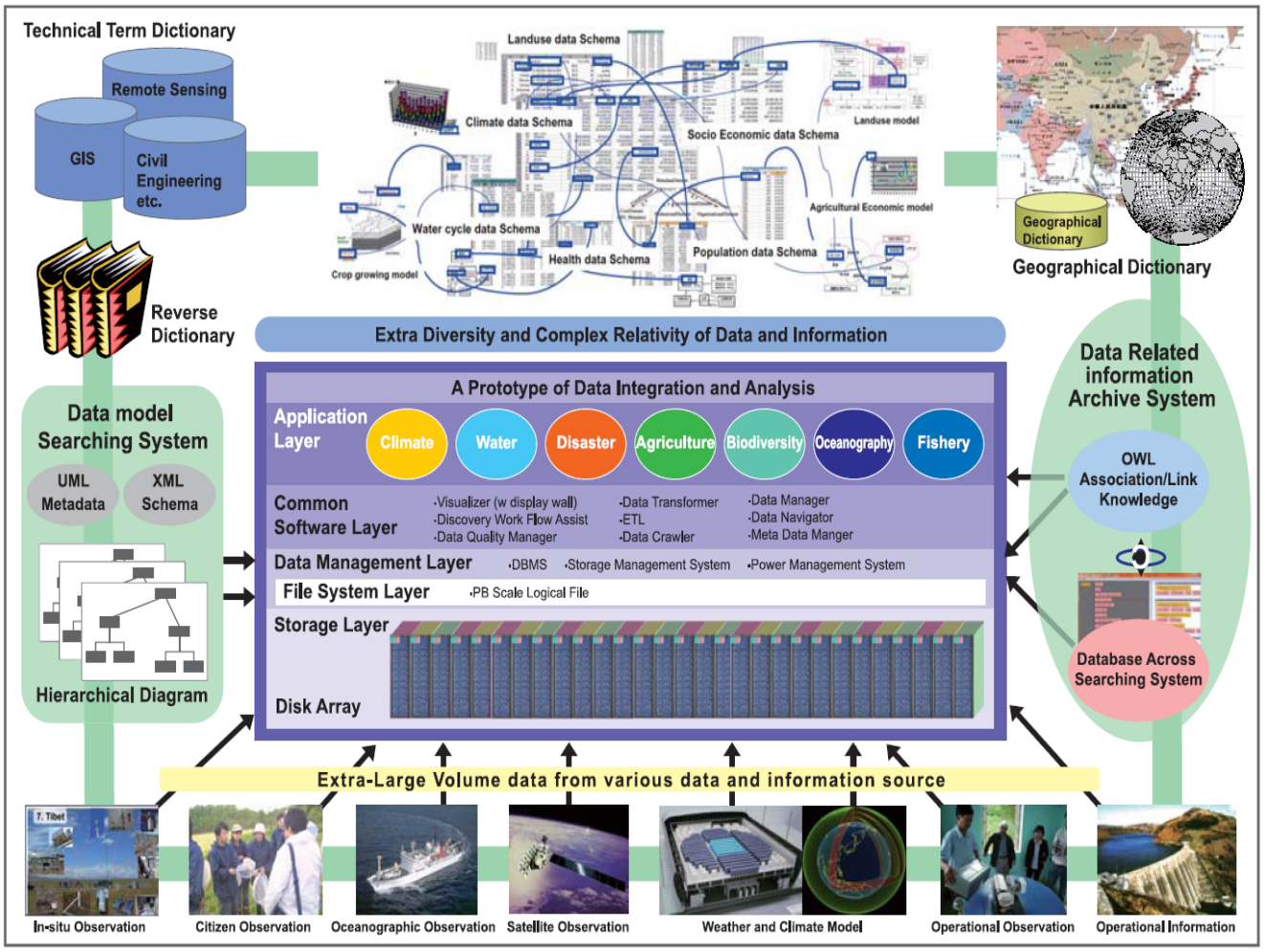
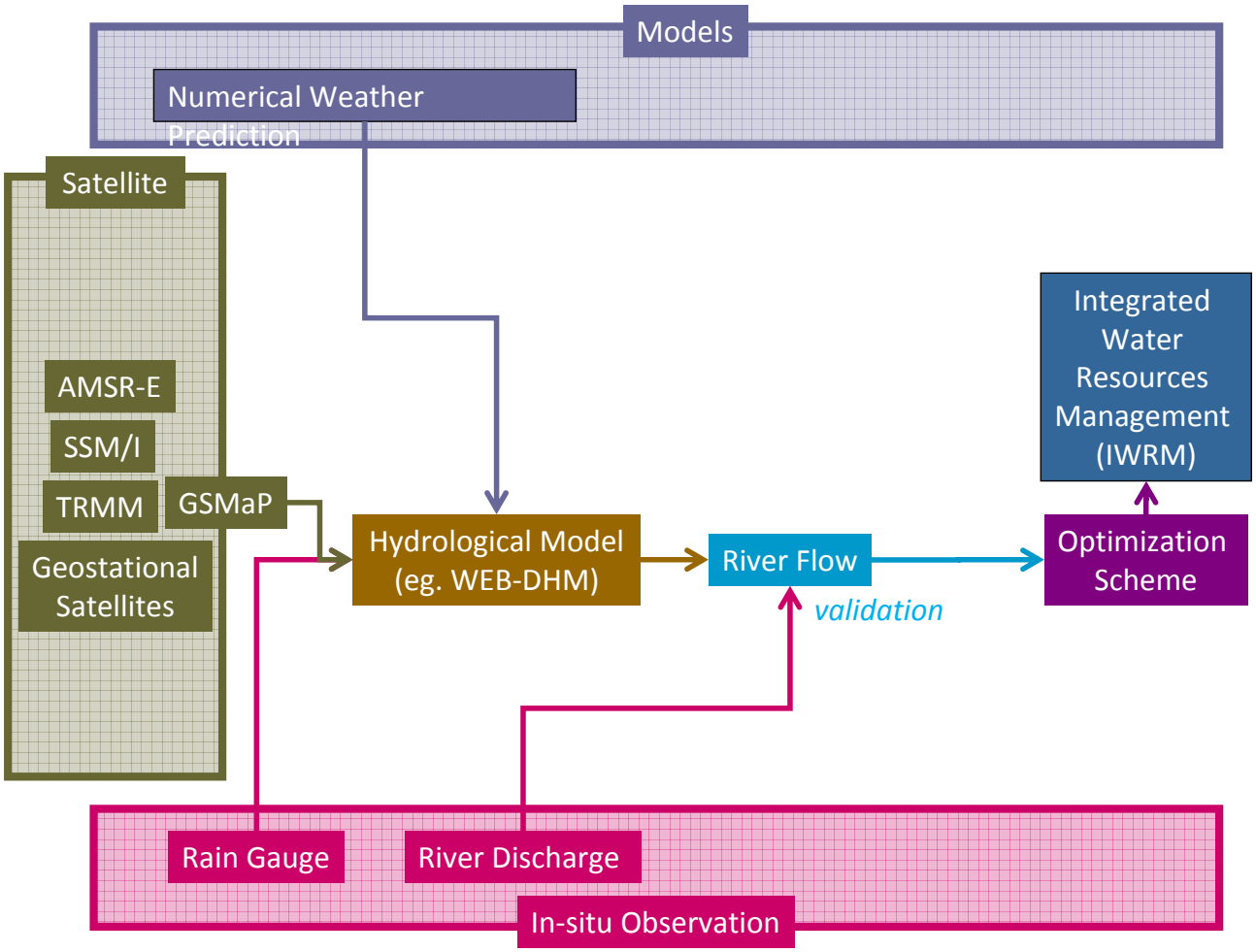


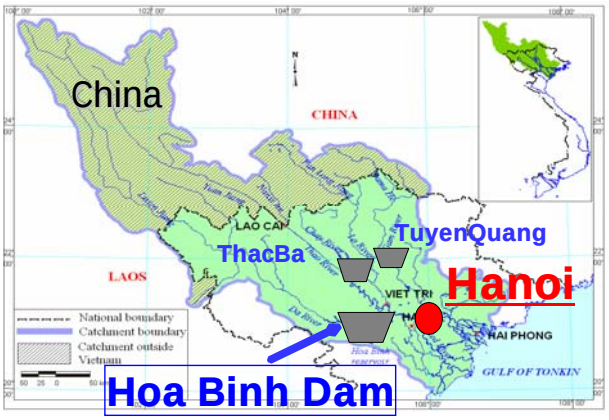
Models

Satellite

Data Integration

In-situ Observation





The Red River Basin: 160,000 km^2

Flood disaster in Hanoi

- Tropical cyclones
- Historical flood events with damages
- Death toll: around 100psn/year
  Economic loss: $1.2 billion (2006)

Increasing demand for hydropower generation

- Increasing by 15%in each year (due to economic growth & urbanization)
- Hydropower: 60% of total electricity
- Unstable water supply (70% of annual rainfall accumulates in Jul-Sep)

Objective function for the optimal operation of HoaBinh Dam

Objective Function

$$MinimizeF = w_1\left(\sum_{t=1}^{T}\frac{1}{T}\left(H_{ds\_sim} - H_{ds\_opt}\right)^2\right) + w_2\left(\sum_{t=1}^{T}\frac{1}{T}\left(R_{dam\_sim} - R_{\max}\right)^2\right)$$

near the ideal water level of Hanoi (8 m)

near the max WL of HoaBinh reservoir

H_{ds_sim} : Simulated WL at Hanoi

H_{ds_opt} : Ideal WL at Hanoi (8m : 70% of war

R_{dam_sim} : Simulated WL at HoaBinh Dam

$R_{\max}$: Max WL of HoaBinh Dam (117m)

Flood Control (FC) / Water Use (WU) can be changed:

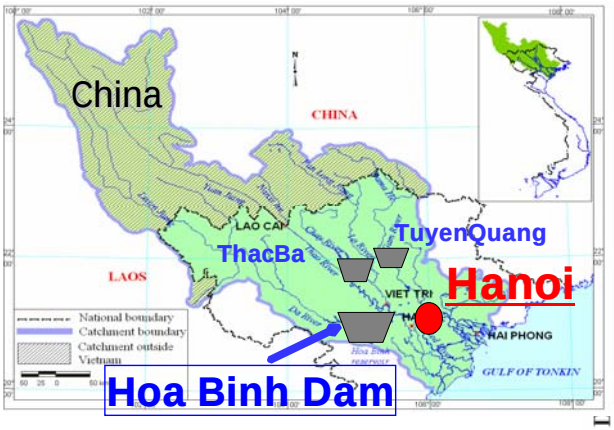
$w_1 : w_2 = FC : WU$

Optimized variable

Min hydropower/ecosystem water use Max value from observation

$$Q_{release} = a * Q_{inflow} \qquad (0.5 < a < 5.0)$$

※Dam release will be same as inflow if simulated reservoir WL is higher than max reservoir WL.



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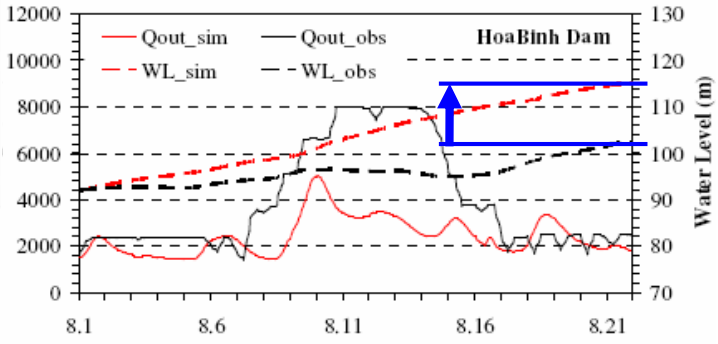

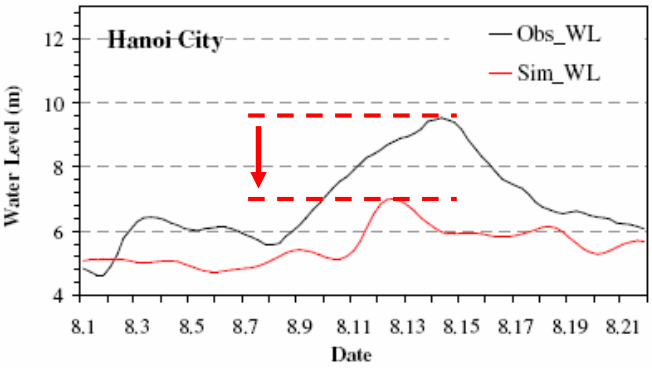

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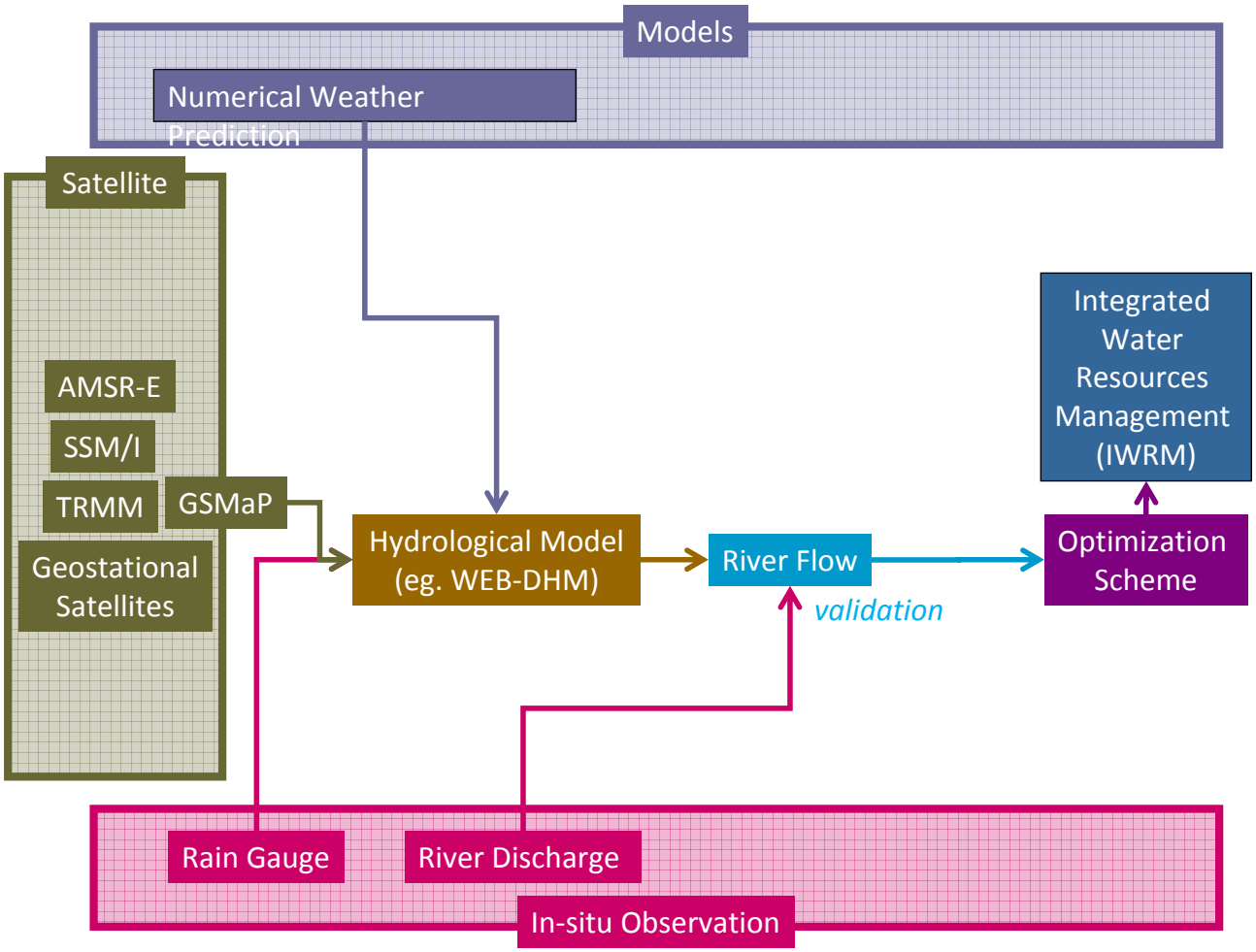
Models
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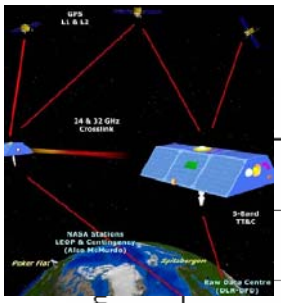
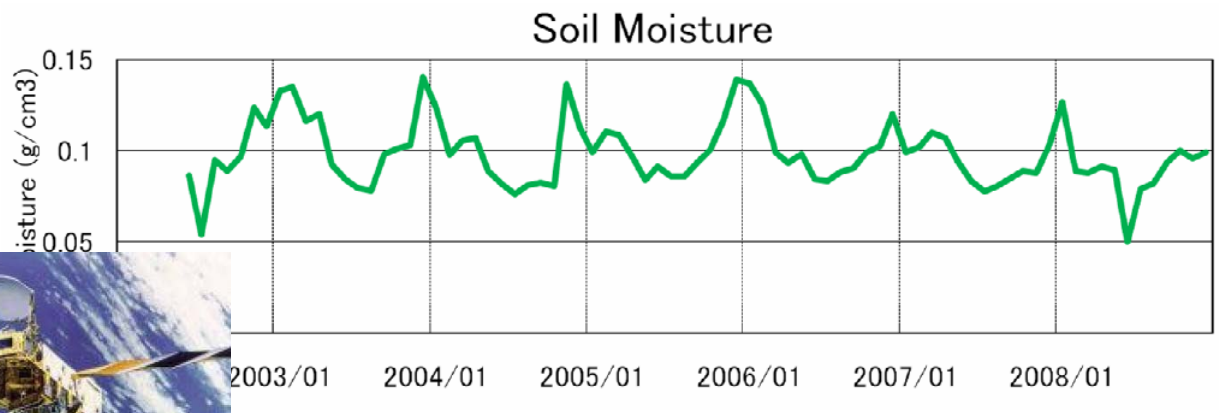
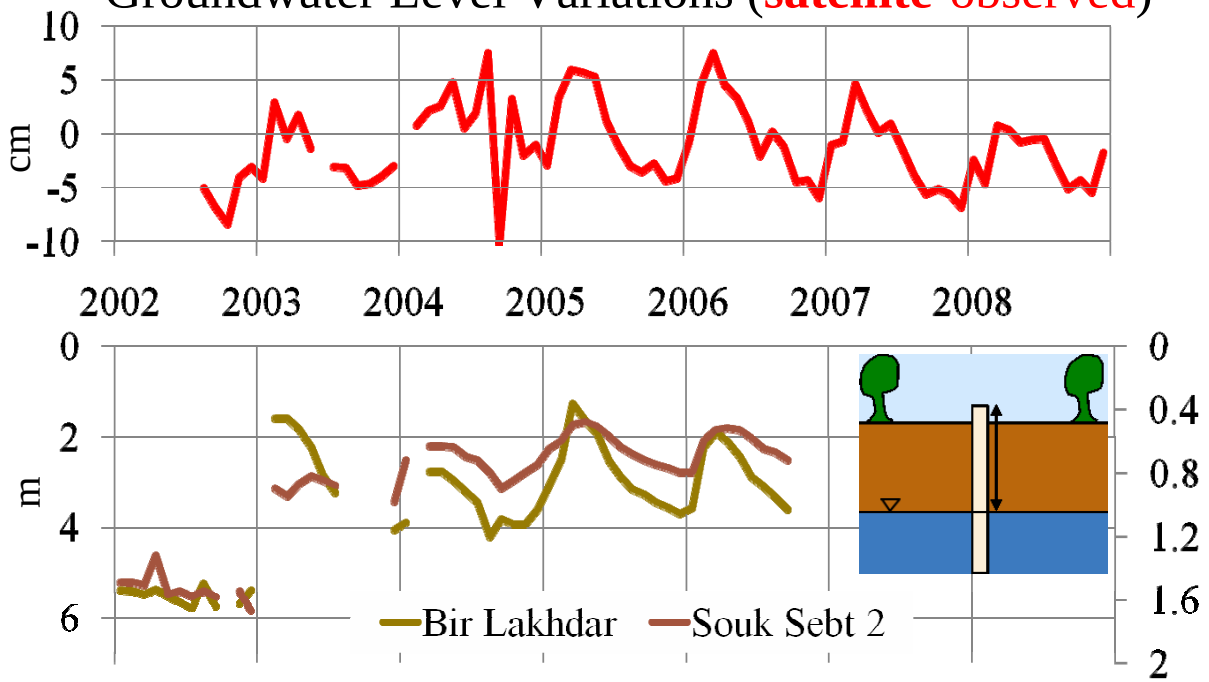


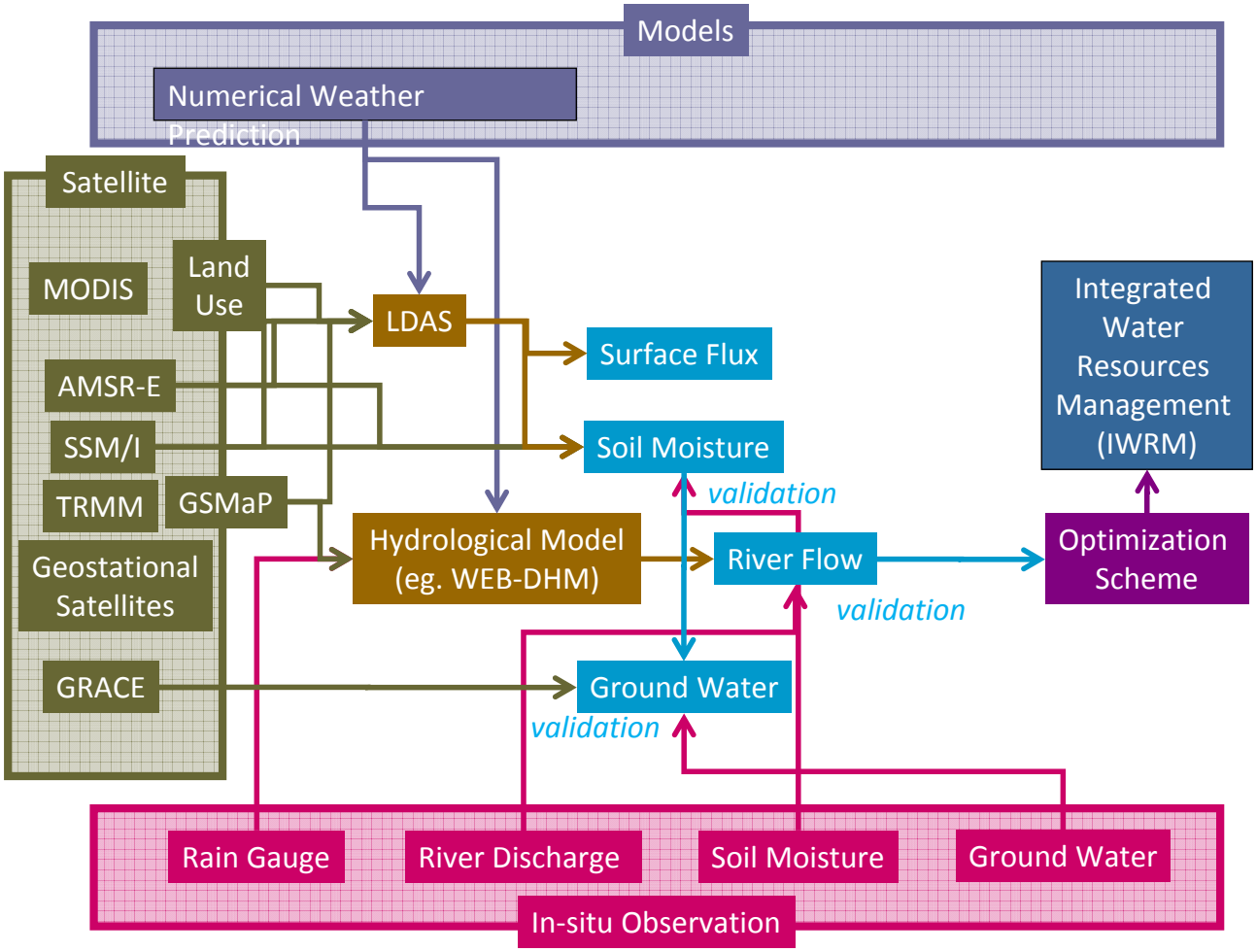
Terrestrial Water Storage Change
TWS (cm
−5
−10
2002/01
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01


Soil Moisture
0.15
0.1
0.05
(g/cm3)
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01

Groundwater Level Variations (**satellite**-observed)



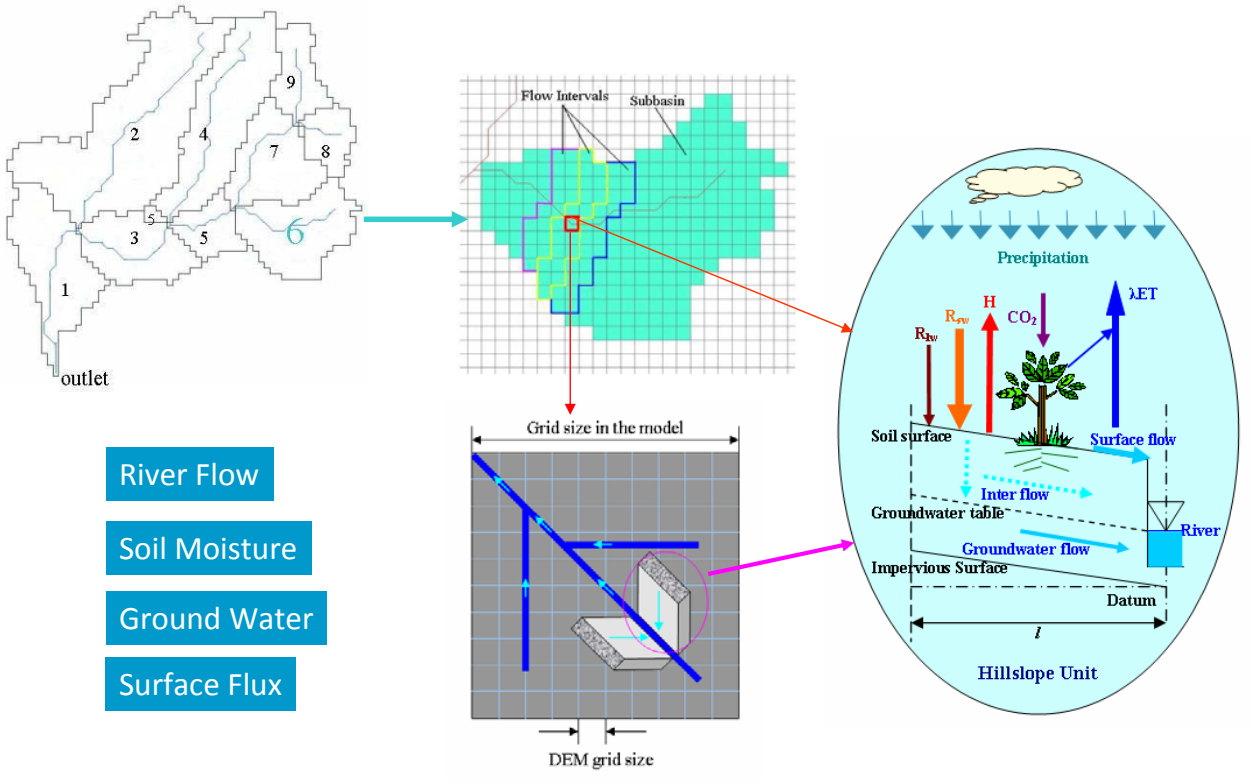
Groundwater Level Variations (**ground**-observed)



WEB-DHM

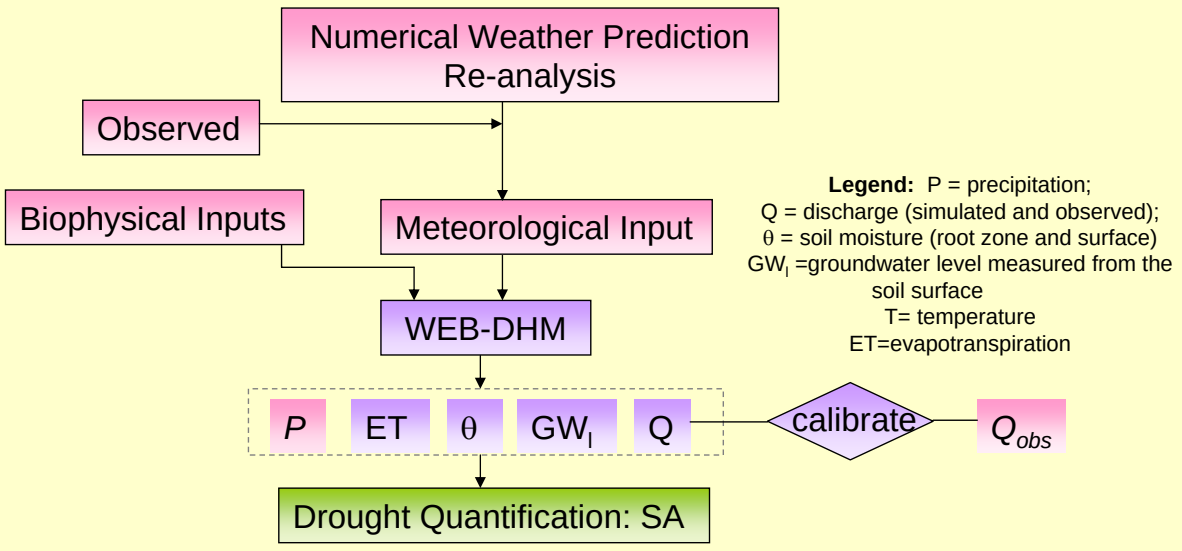
Wang et al. WRR, 2009

(Water and Energy Budget-based Distributed Hydrological Model)



Drought

Monitoring, Seasonal Prediction and Climate Change Impact Assessment



Drought Quantification: The Standard Anomaly Index

1) Transform the best-fit distribution pattern into a standardized distribution

$$x_{transformed} = \frac{x - \mu}{\sigma}$$

2) Normalize by calculating SA

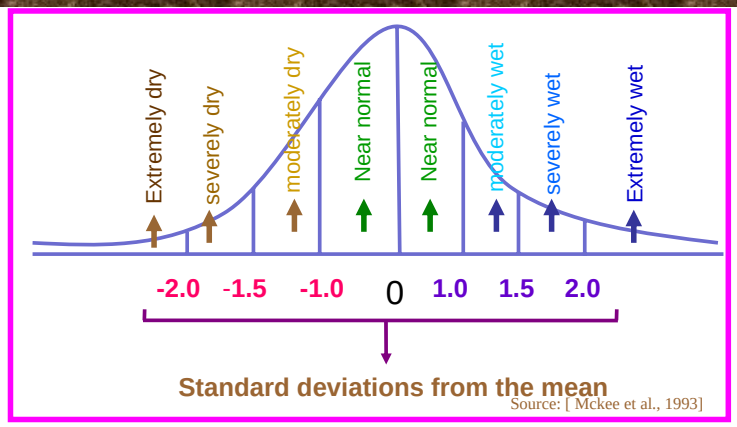
$$SA = Z = \frac{x_{transformed} - \bar{x}_{transformed}}{\sigma_{transformed}}$$

$$\sigma = \sqrt{\mathrm{var}(x)}$$

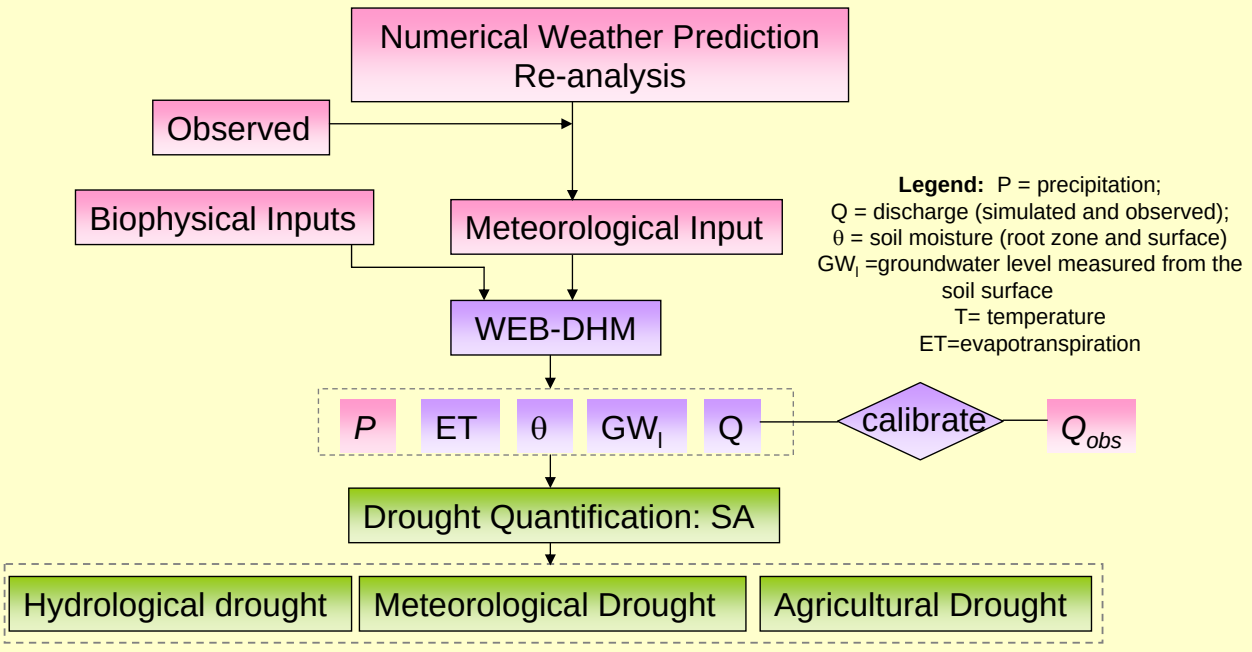
$$\mathrm{var}(x) = \int (x-\mu)^2 f(x)dx$$

$$\mu = \int x f(x)dx$$

Jaranilla-Sanchez, P. A., et al. (2011), Water Resour. Res., in press.



Drought
Monitoring, Seasonal Prediction and Climate Change Impact Assessment



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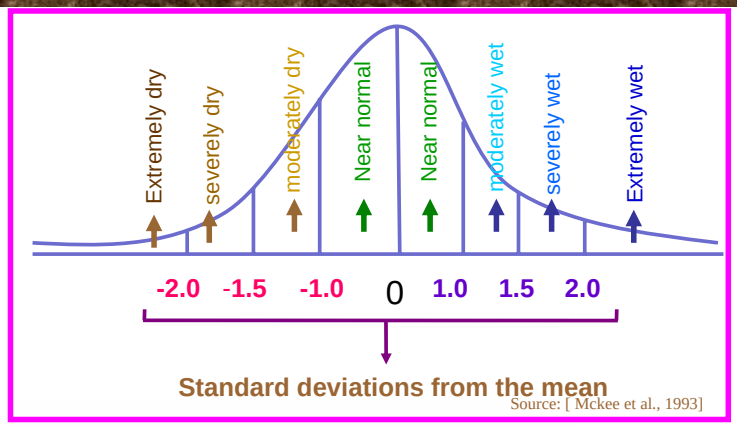
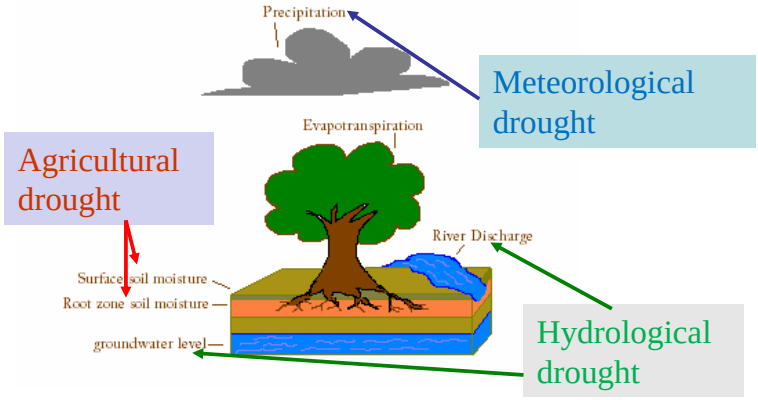
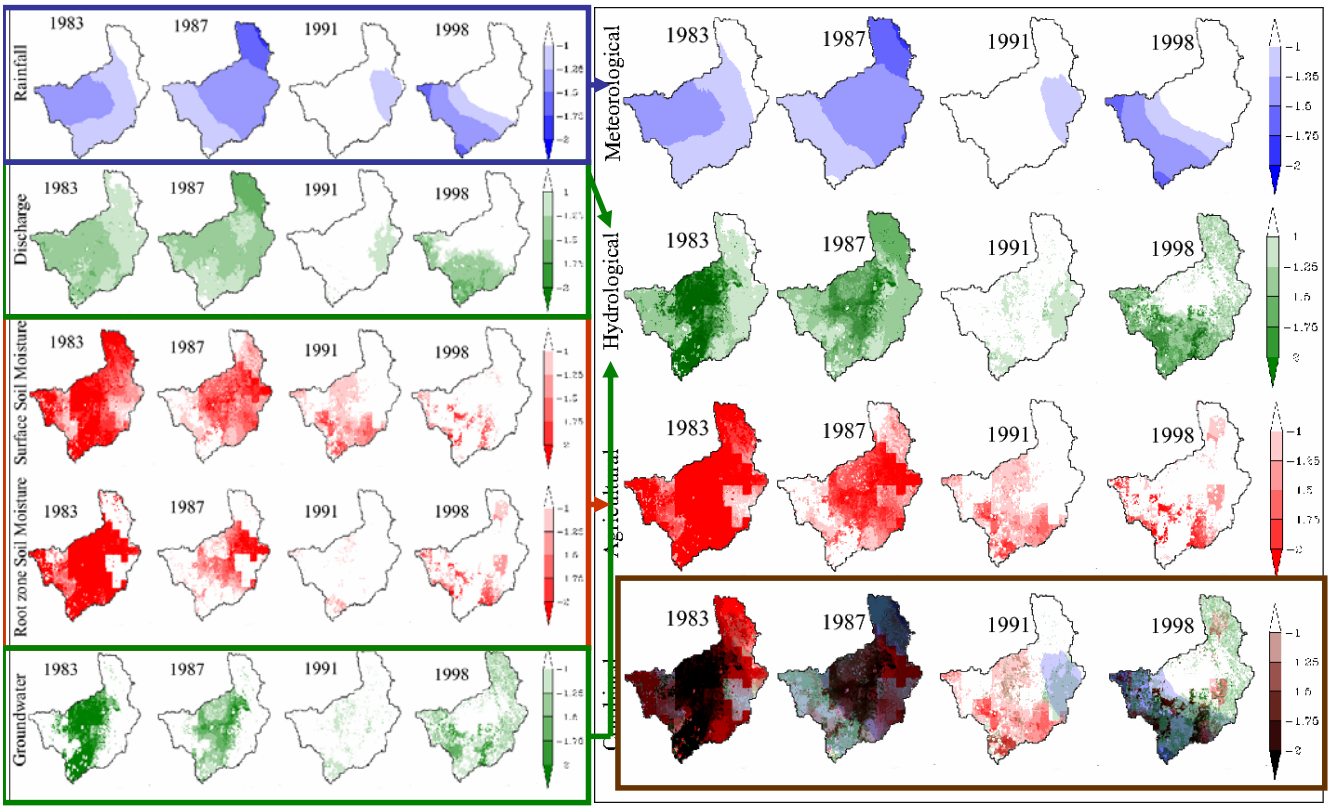




Spatial SA: Philippines



Drought

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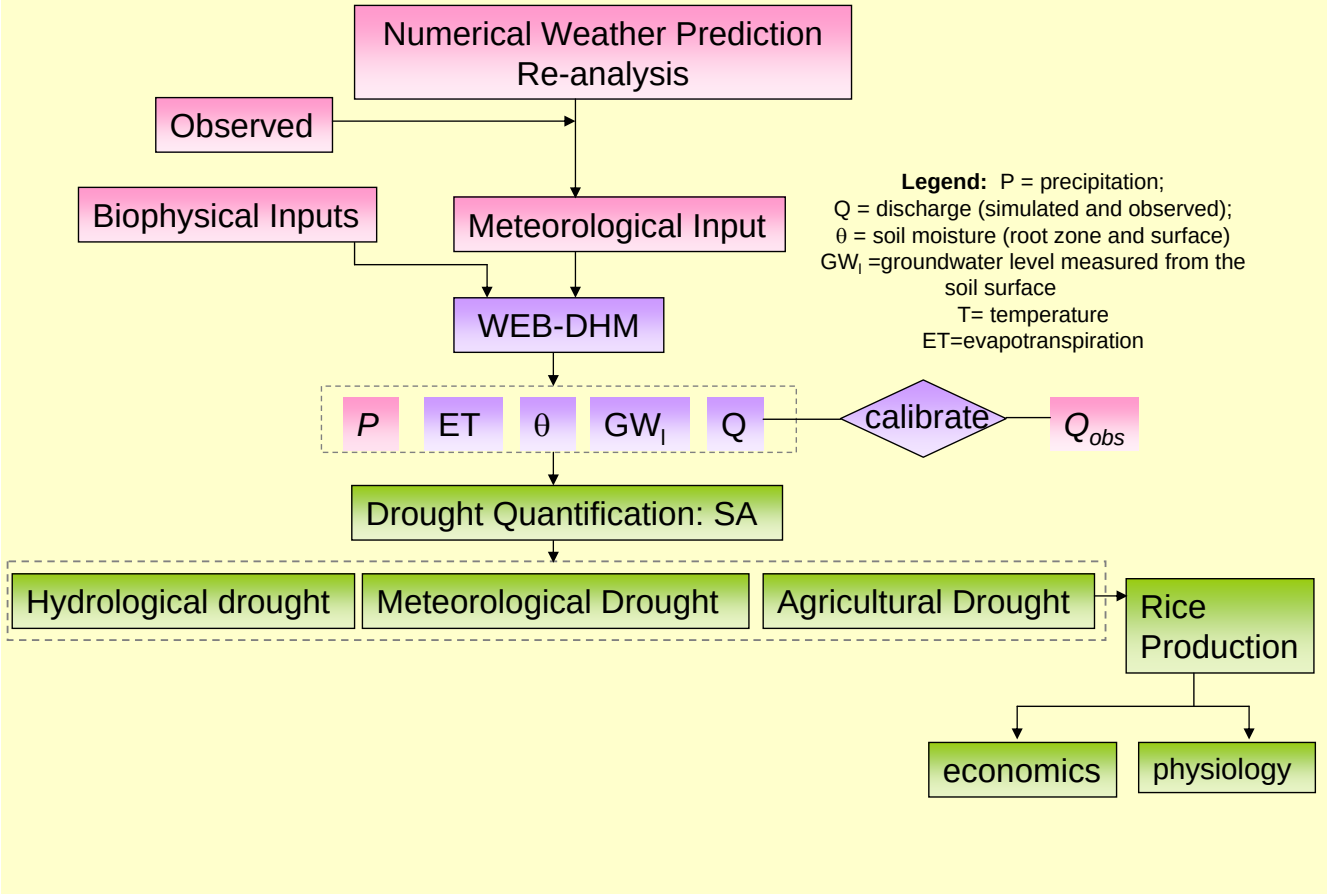
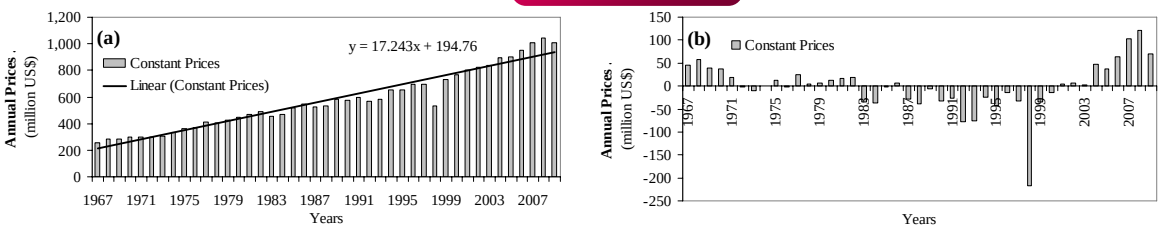
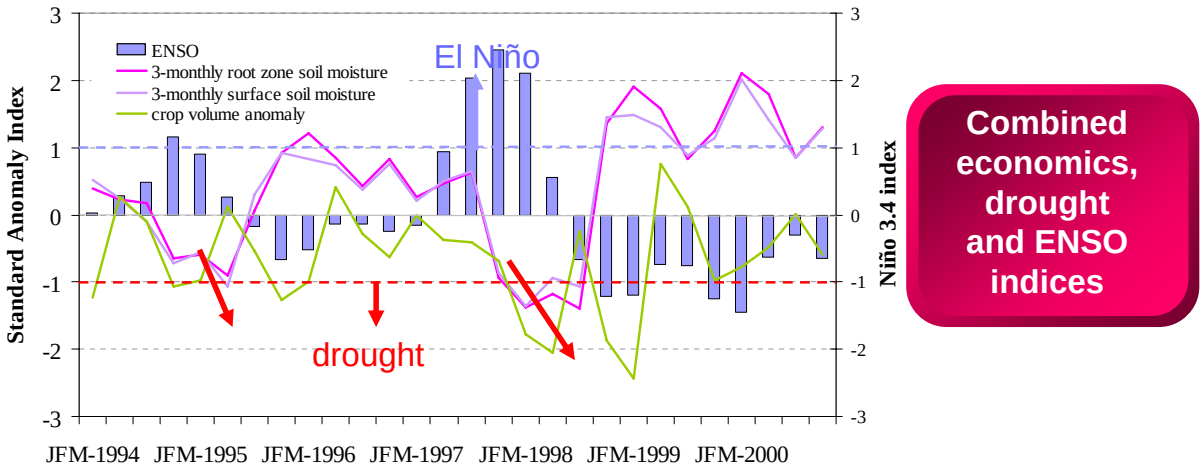


Impacts of Drought in Agriculture: Philippines

economics

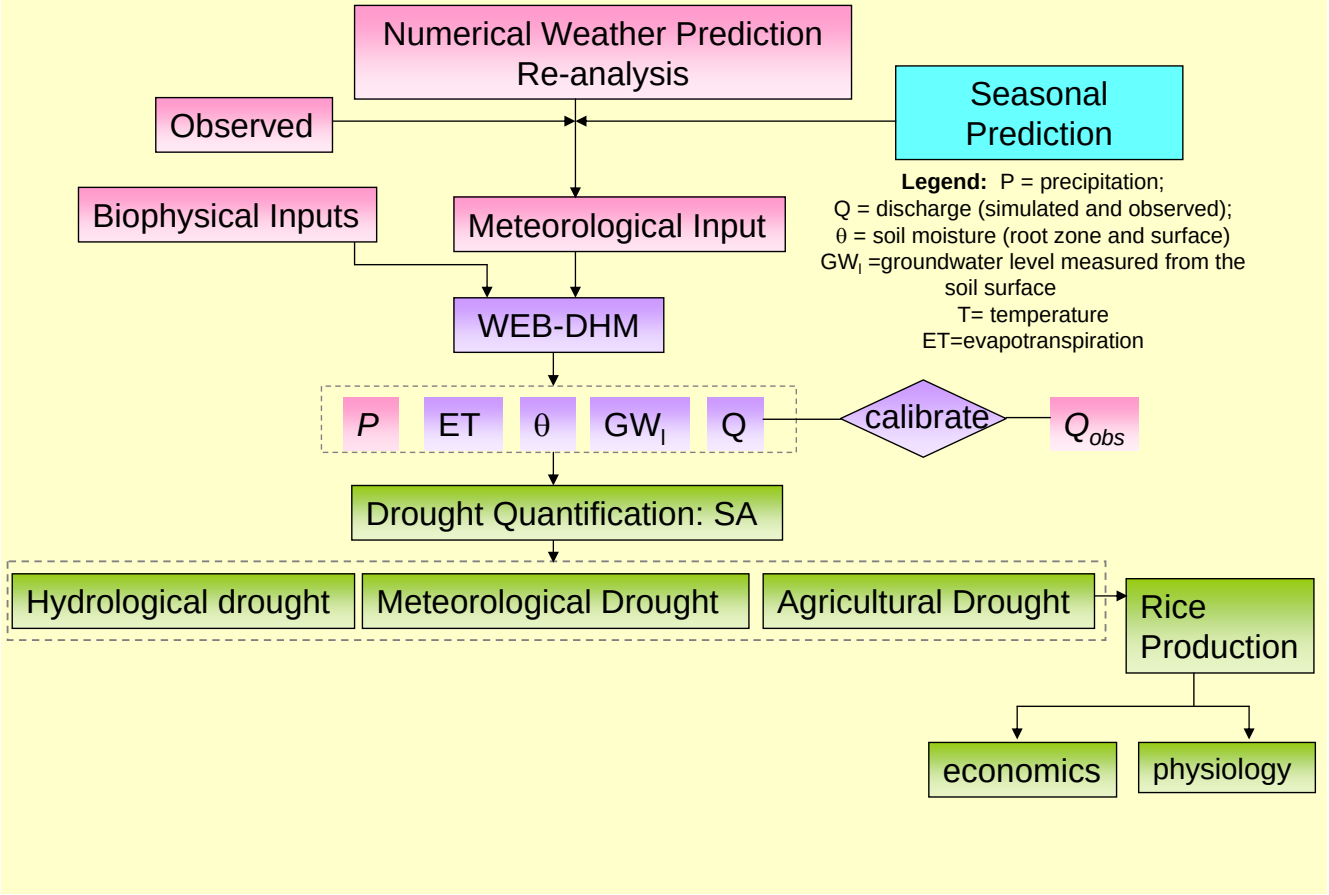




Combined economics, drought and ENSO indices

Drought

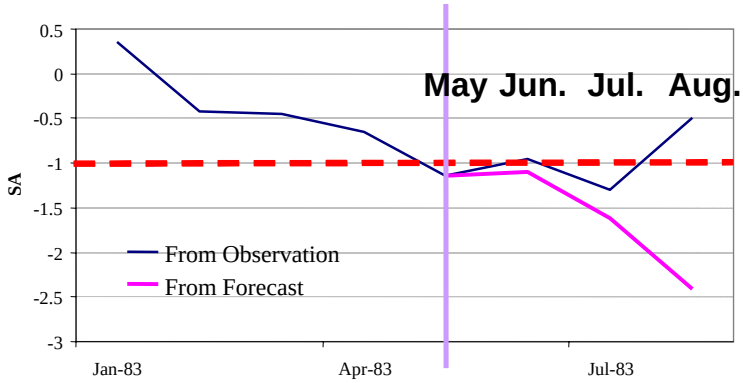
Monitoring, Seasonal Prediction and Climate Change Impact Assessment



Seasonal Drought Prediction

Month	SA FROM OBSERVED DISCHARGE	SA FROM FORECAST DISCHARGE
June	-0.954	-1.010455
July	-1.30505	-1.61425
August	-0.4937	-2.41276

Close enough, drought conditions can be forecasted

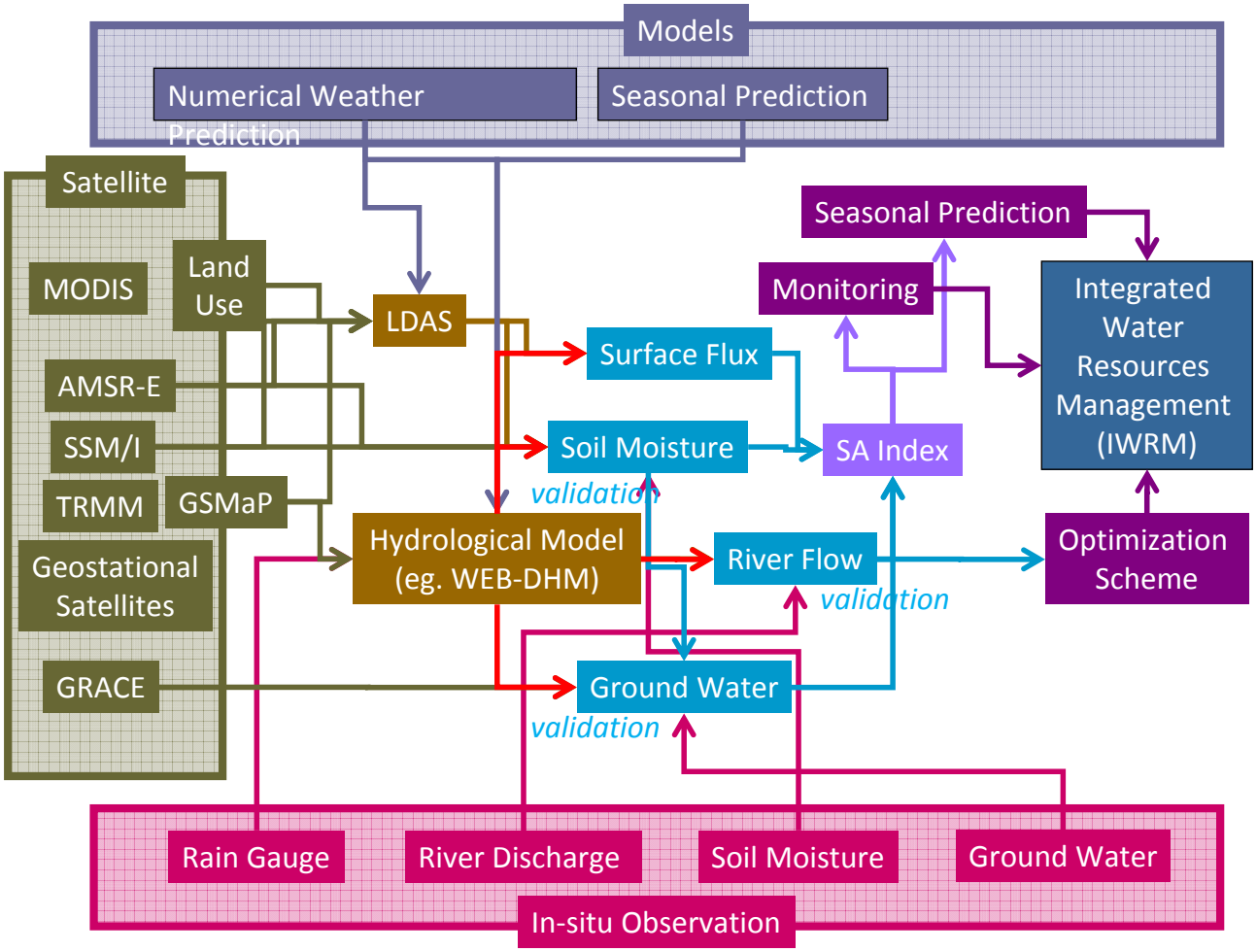


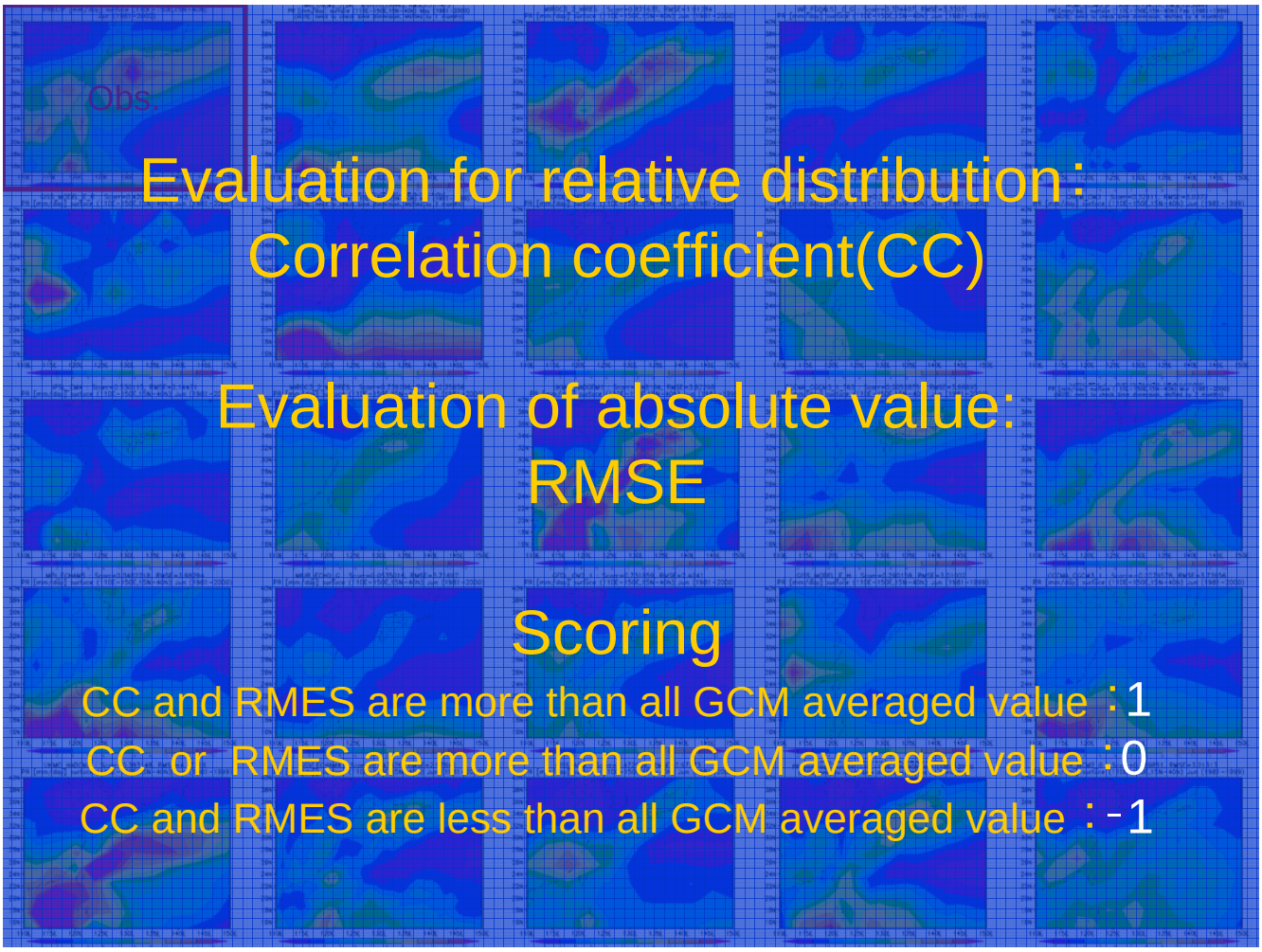
Seasonal Drought Prediction

Months	1st		2nd		3rd	
Year	Observed	SFC	Observed	SCF	Observed	SCF
1983	↗	↗	↘	↘	↗	↘
1991	↘	↘	↗	↗	↘	↘
1997	↘	↘	↘	↘	↘	↘
1999-2000	↗	↘	↗	↗	↗	↗

ARROW Legends: **red**= drought; **green**=normal; **blue**=wet

e.g. increase towards drought conditions ↗





Evaluation for relative distribution：
Correlation coefficient(CC)

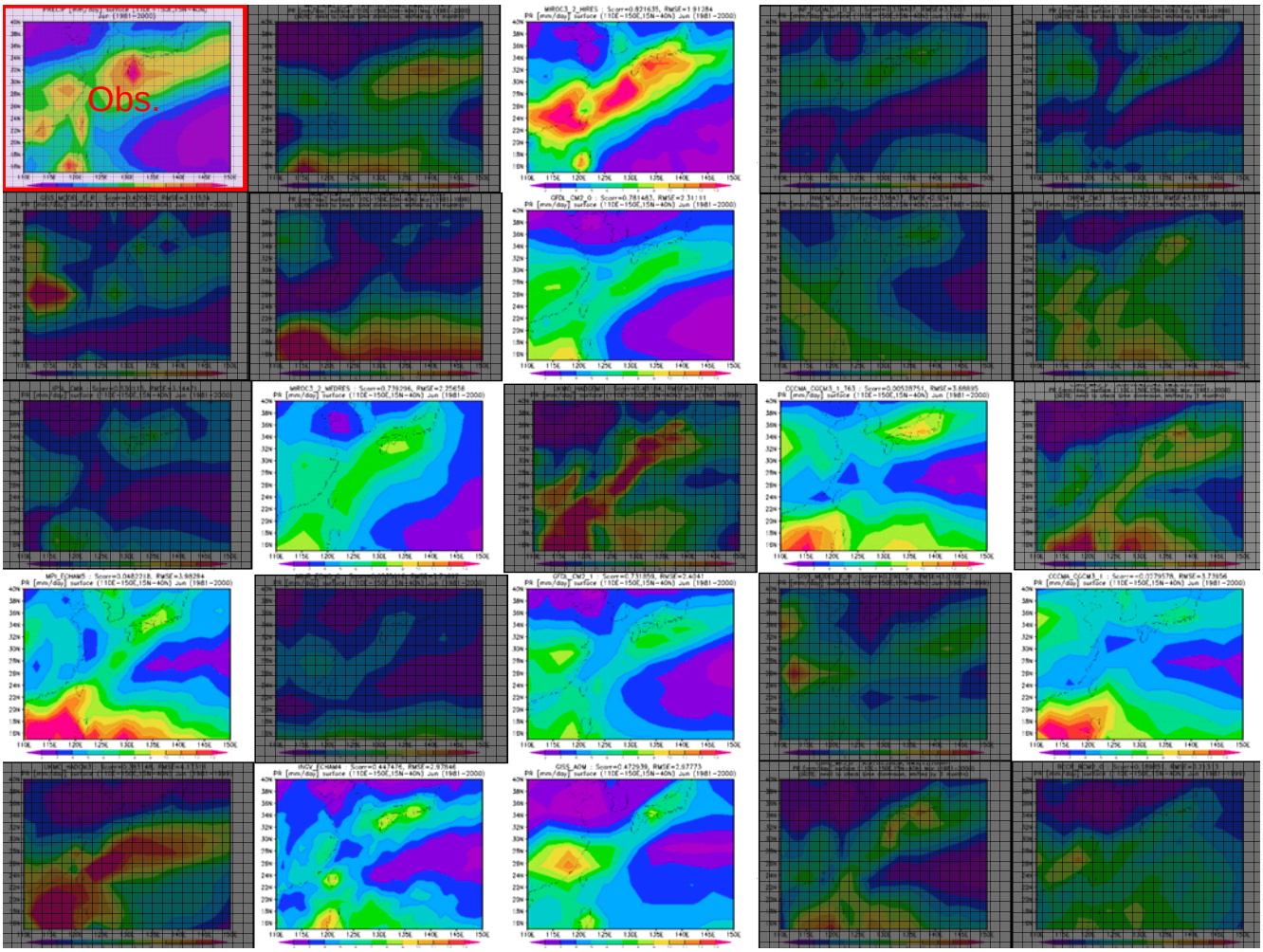
Evaluation of absolute value:
RMSE

Scoring

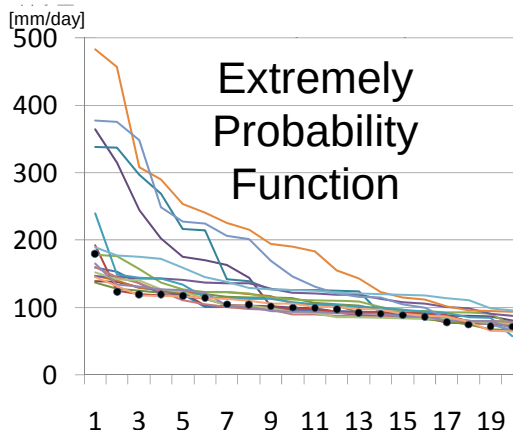
CC and RMES are more than all GCM averaged value ：1

CC or RMES are more than all GCM averaged value ：0

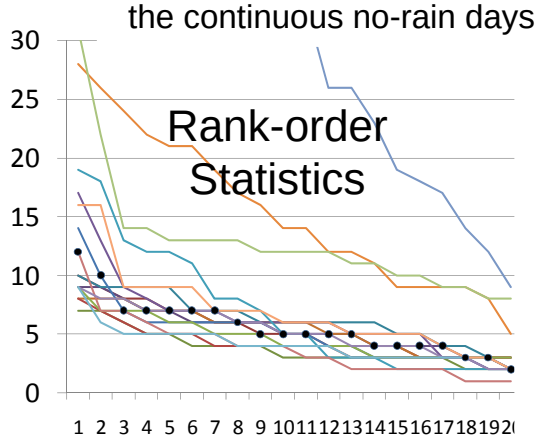
CC and RMES are less than all GCM averaged value ：-1



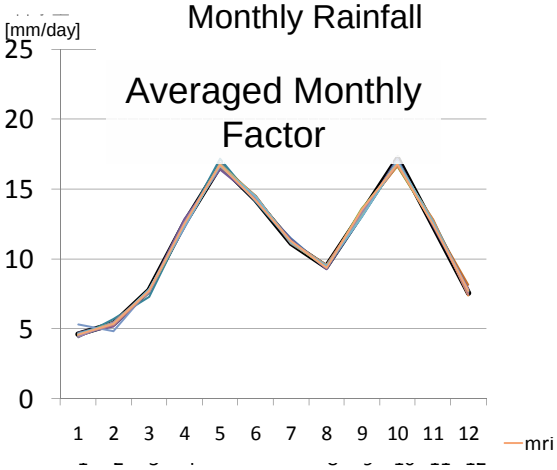
Annual Maximum Daily Rainfall



Maximum number of the continuous no-rain days



Monthly Rainfall

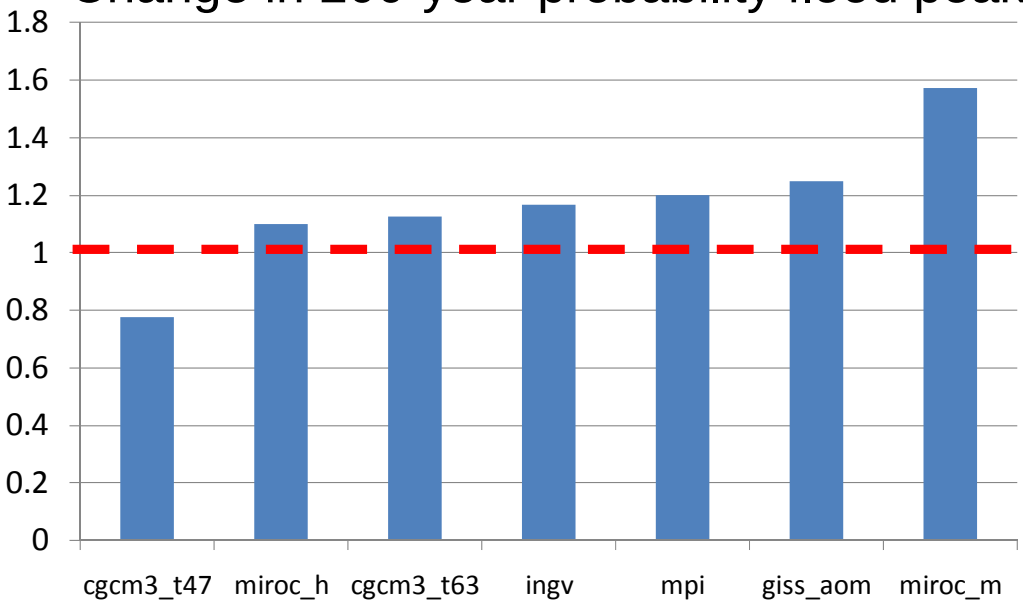


Main Problems with the GCM Outputs:

- •Large Diversity
- •Low Extreme Heavy Rainfall Rate
- •Small Number of No Rainfall Day but Long Drizzle
- •Low Seasonal Representation
- •Low Spatial Distribution
- →**Bias Correction, Downscaling, Multi-model Analysis Coupling with Hydrological Models**

Climate Change Impact Assessment

Change in 200-year probability flood peak



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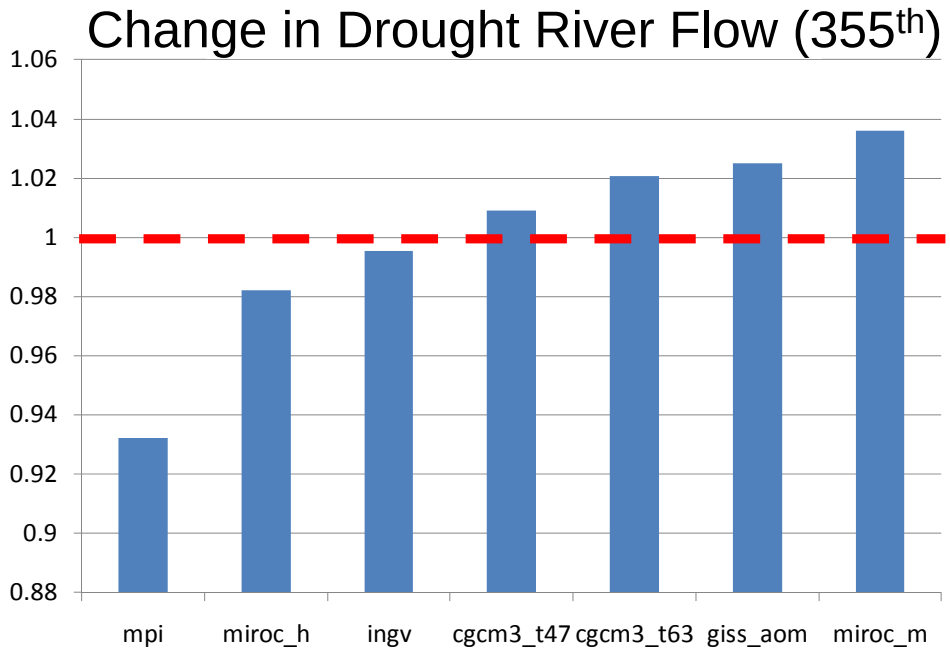
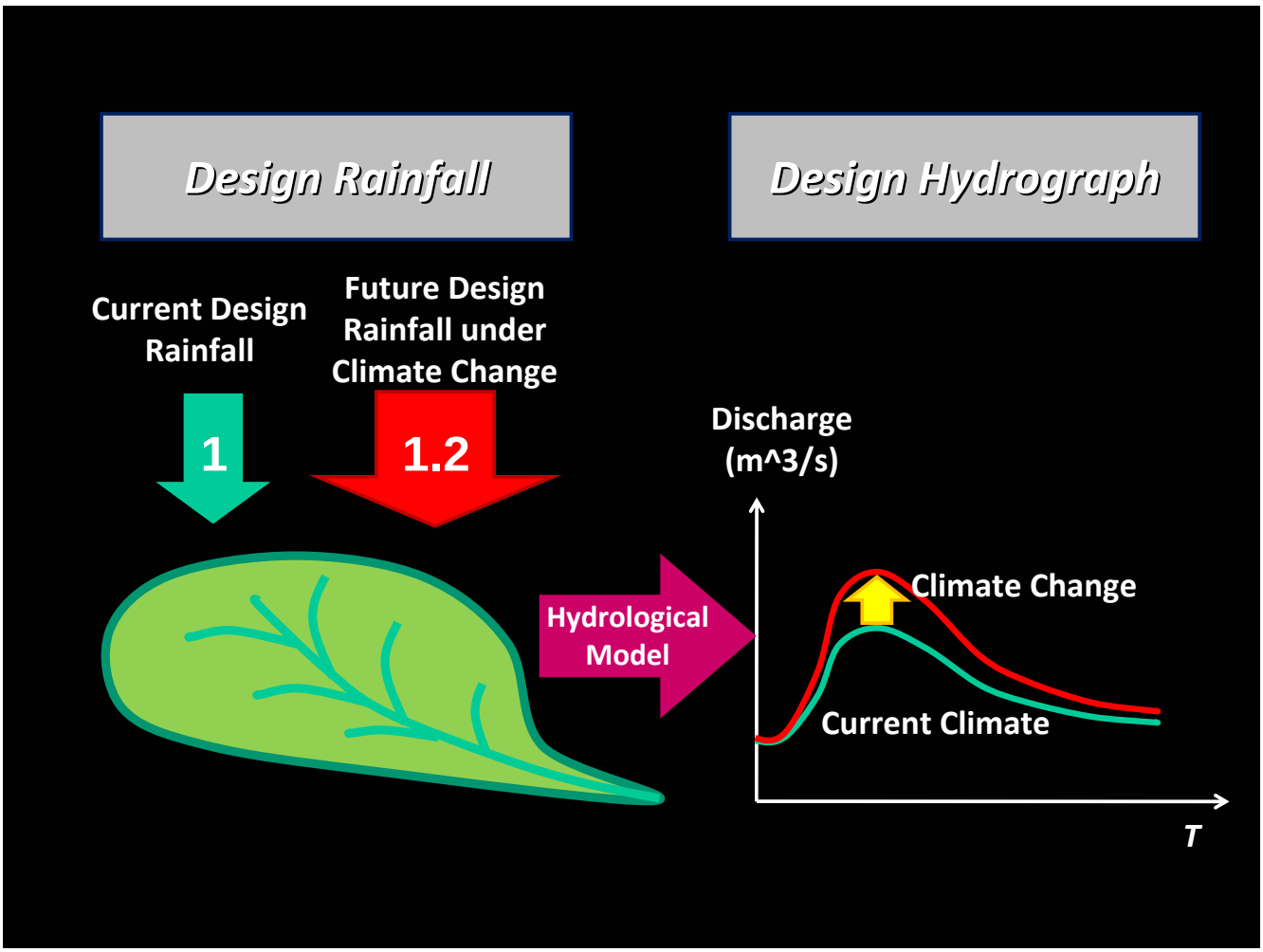
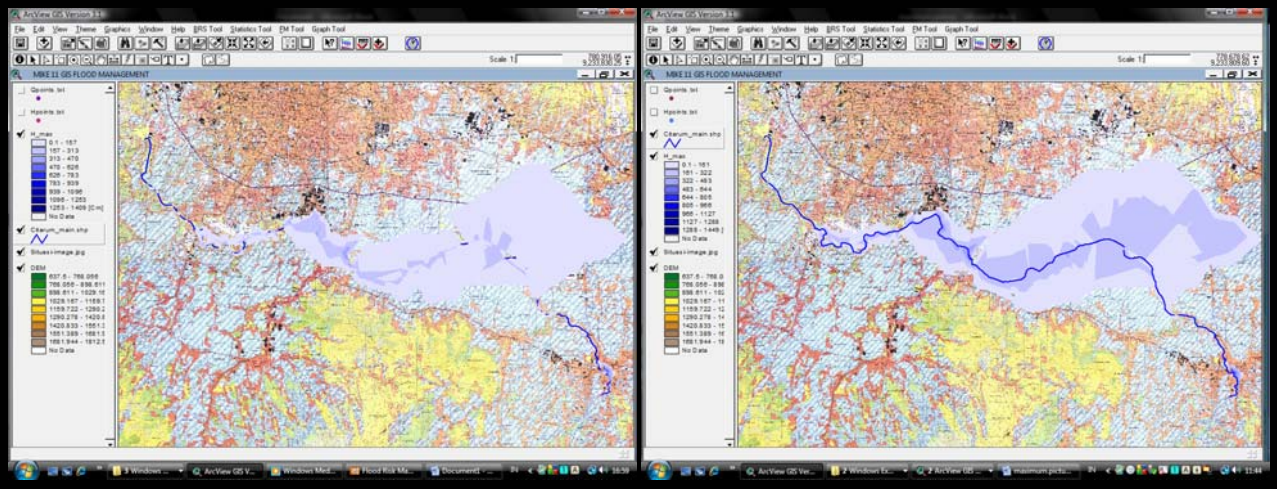




Climate Change Impacts on Flood Control Plan in Indonesia

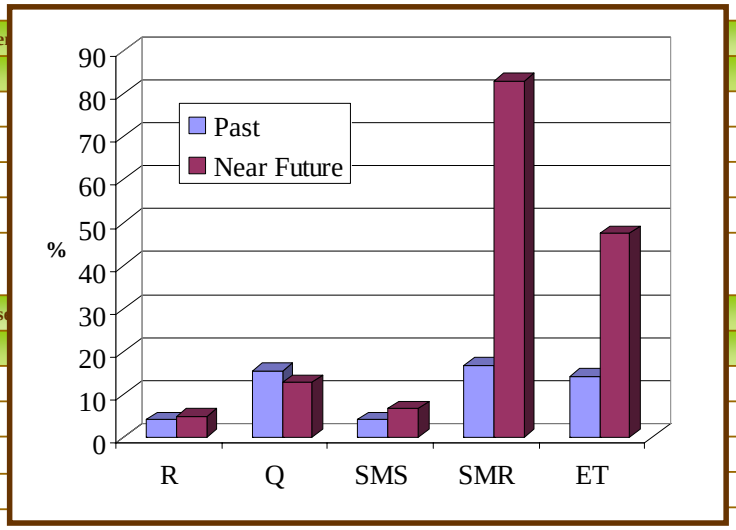


10year Probable flood
Current Climate

10year Probable flood
50 years later

SA Past and Near Future: Philippines

SA category	Past GCM ensemble		Near future GCM ensemble	
R	# of Months		# of Months	%
Mild	9		13	5.70
Moderate	0		2	0.88
Severe	0		0	0
TOTAL	9		15	6.58



SA category	Past GCM ensemble		Near future GCM ensemble	
SMS	# of Months		# of Months	%
Mild	20		37	16.22
Moderate	11		39	17.11
Severe	4		113	49.56
TOTAL	35		189	82.89

Legend:

R=rainfall

Q=discharge

SMS=surface soil moisture

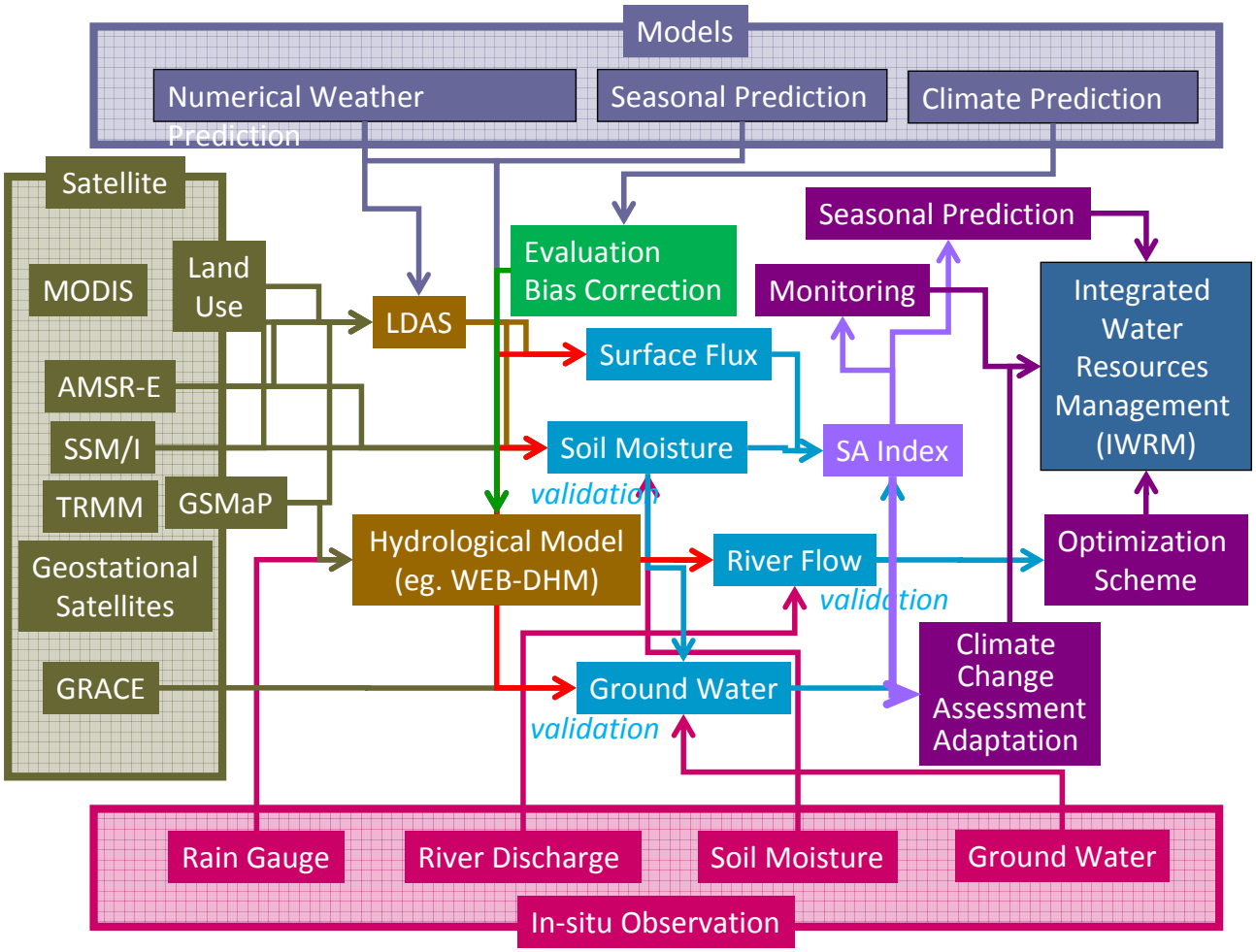
SMR=root zone soil moisture

ET=evapotranspiration

Large increase in severe drought conditions at the root zone in the near future

-translates to more severe agricultural drought

	Near future GCM ensemble	
	# of Months	%
	38	16.67
	38	16.67
	32	14.03
	108	47.37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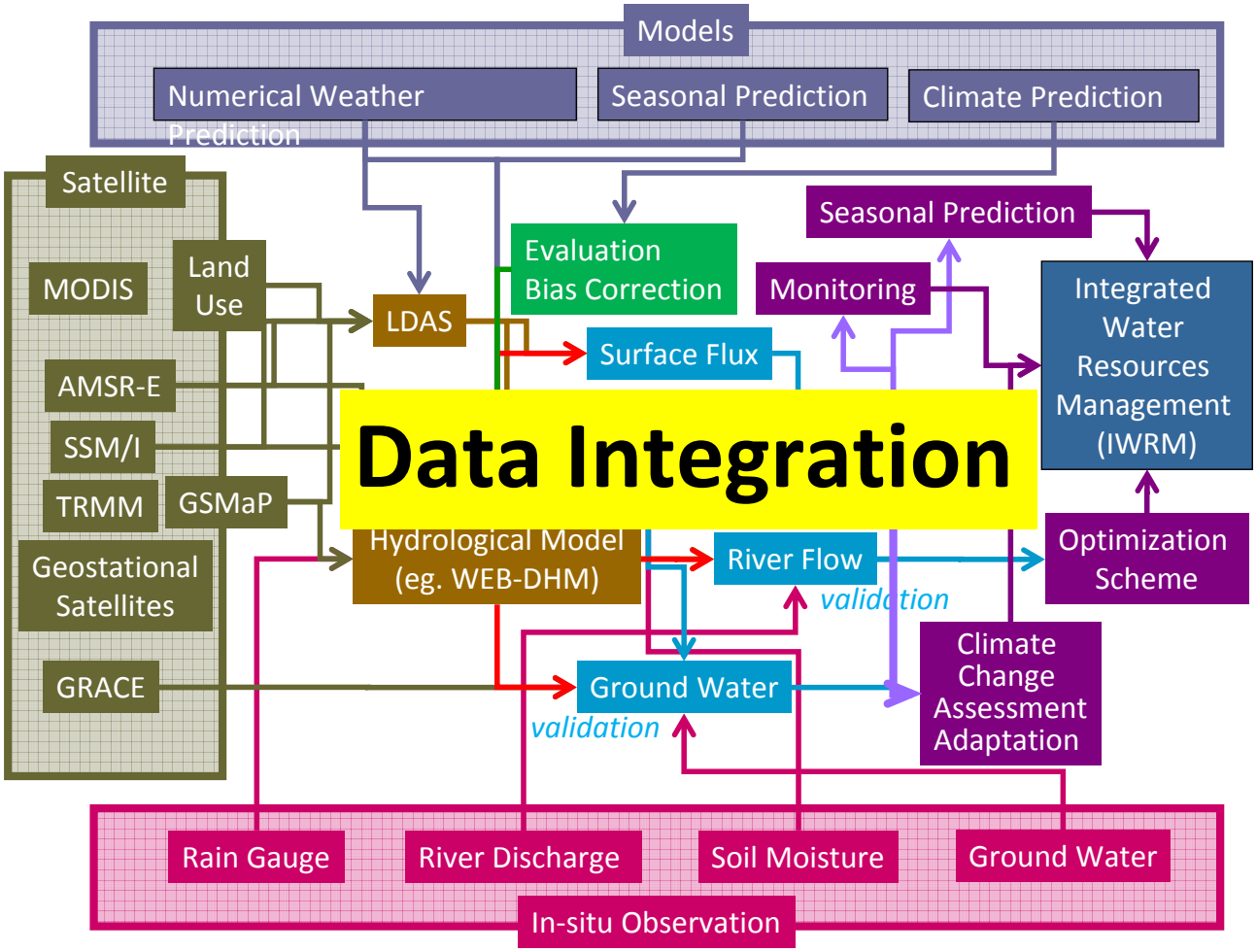
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