Requirements to Hydrological Models

only climate model outputs but no observations as inputs

- Well connectivity with climate models

- Free-running capability without tuning for long period

- Integration capability of various hydrological processes

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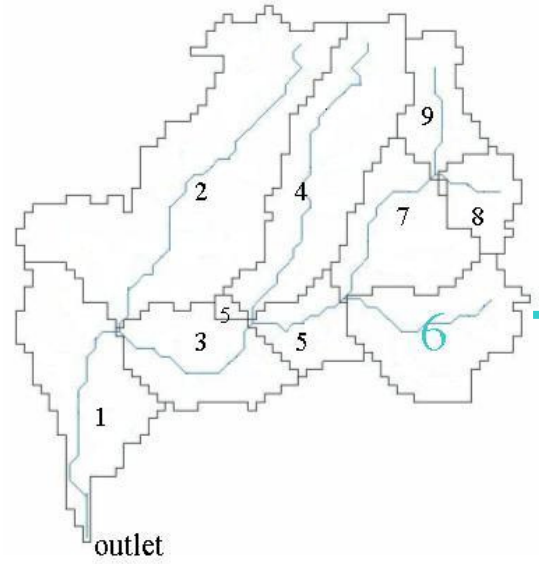
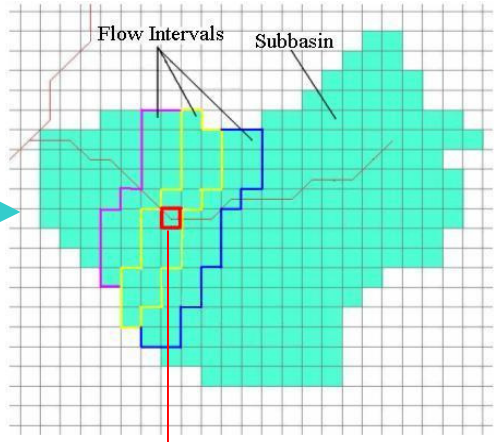
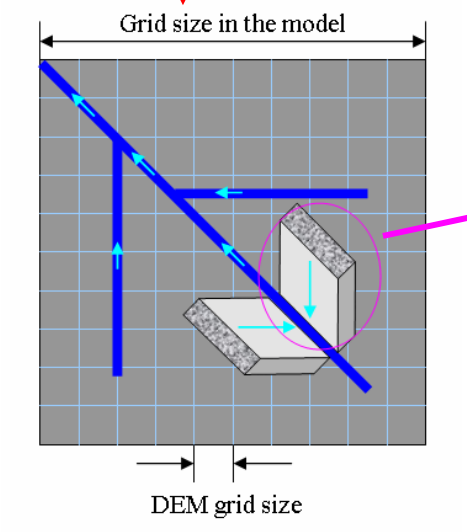
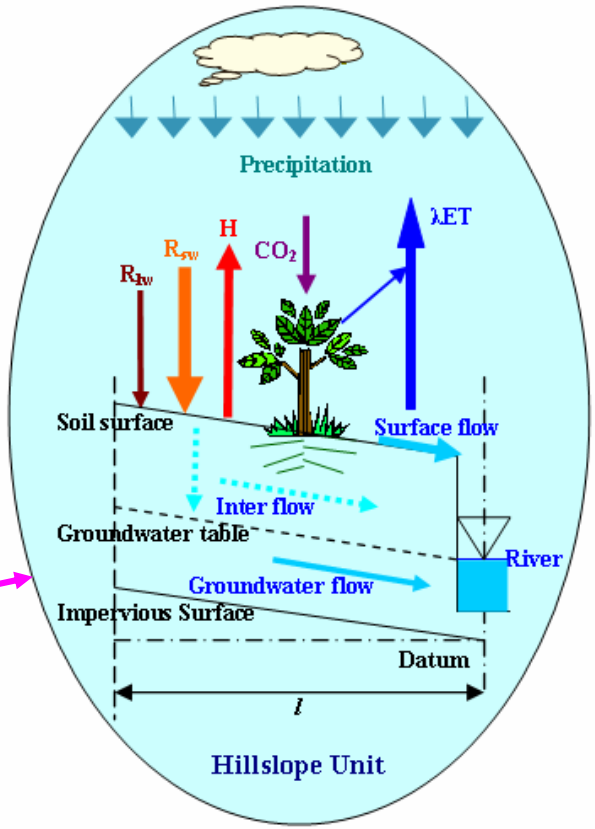
Wang, Koike et al. 2009

WEB-DHM
(Water and Energy Budget-based Distributed Hydrological Model)



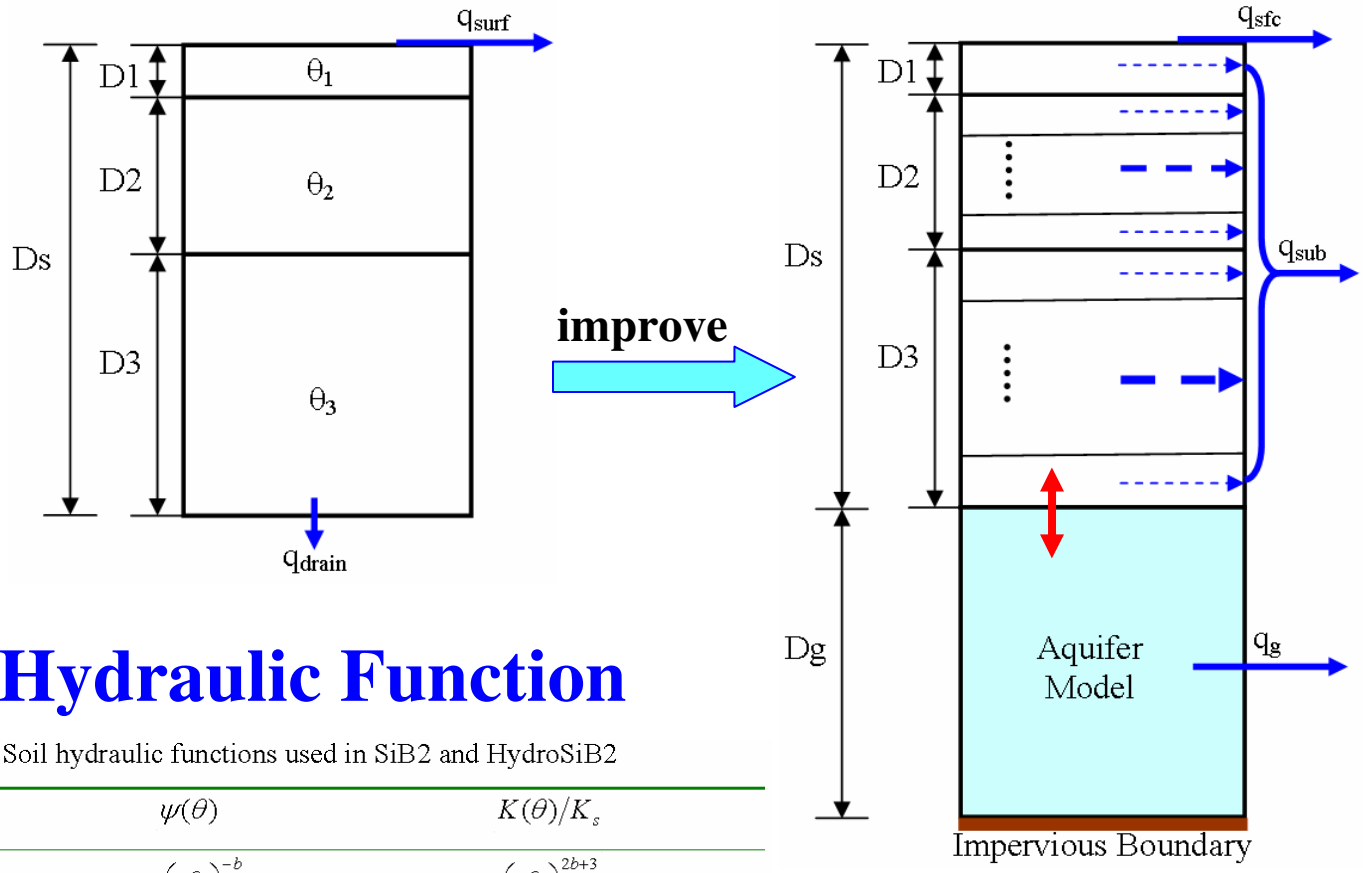






Improvements over 1-D LSM

(a) SiB2 (b) WEB-DHM



Soil Hydraulic Function

Table 1. Soil hydraulic functions used in SiB2 and HydroSiB2

Source	$\psi(\theta)$	$K(\theta)/K_s$	
Campbell (1974)	$\psi_s\left(\frac{\theta}{\theta_s}\right)^{-b}$	$\left(\frac{\theta}{\theta_s}\right)^{2b+3}$	**SiB2**
van Genuchten (1980)	$\frac{1}{\alpha}\left[(S)^{-1/m}-1\right]^{\frac{1}{n}}$	$S^{1/2}\left[1-\left(1-S^{-1/m}\right)^{m}\right]^{2}$	**WEB-DHM**

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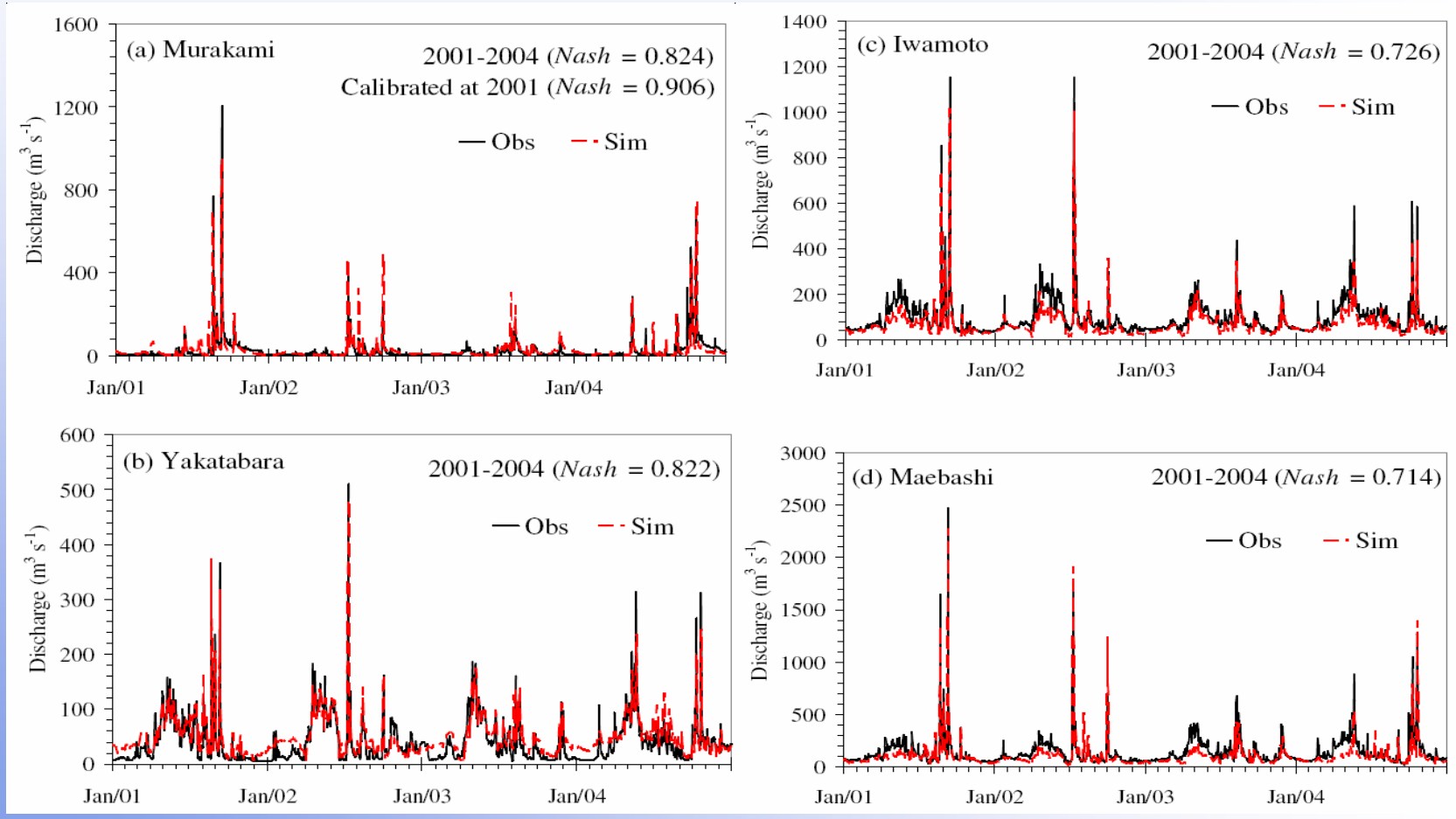
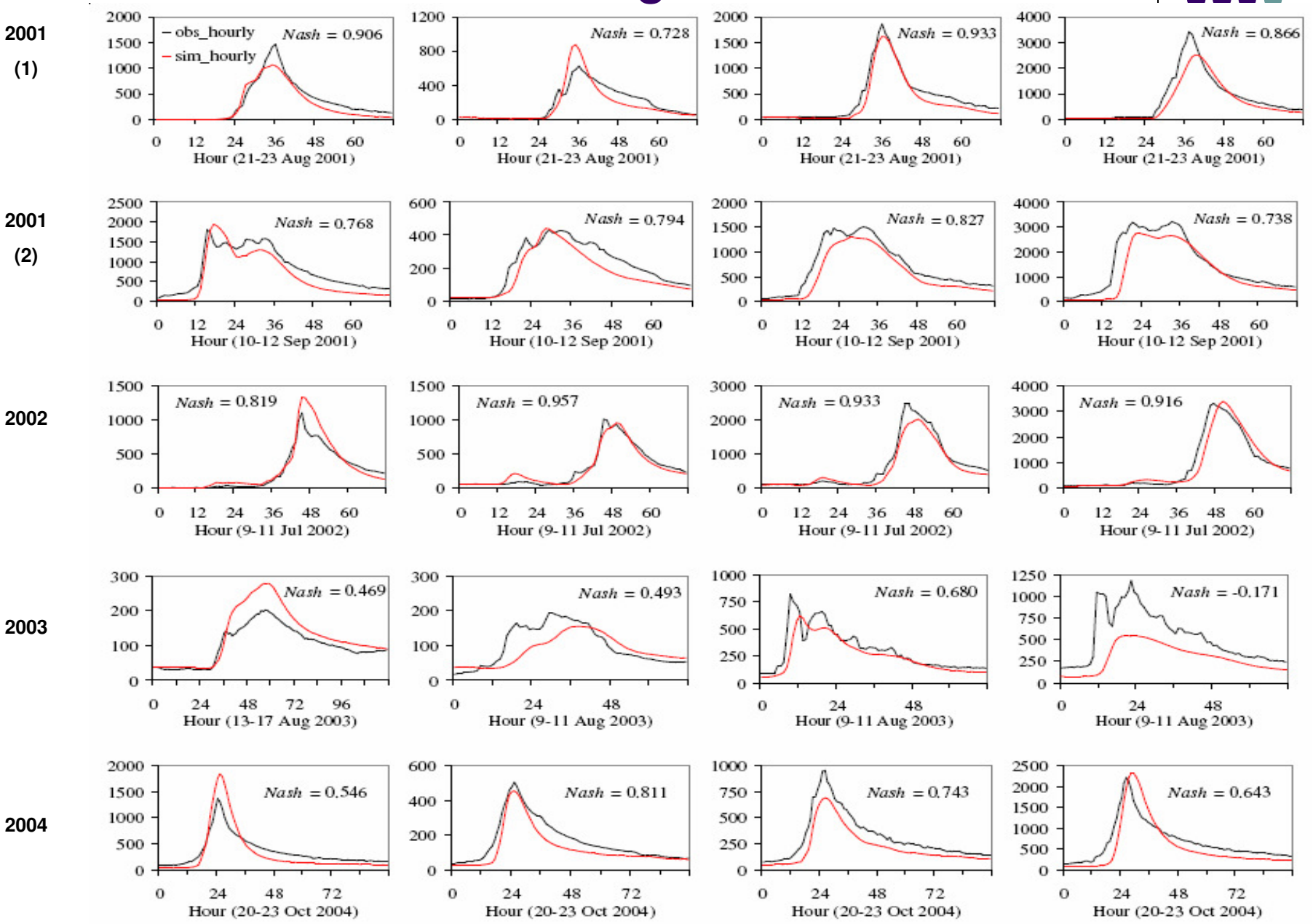
Calibration and validation with discharges at main stream gauges

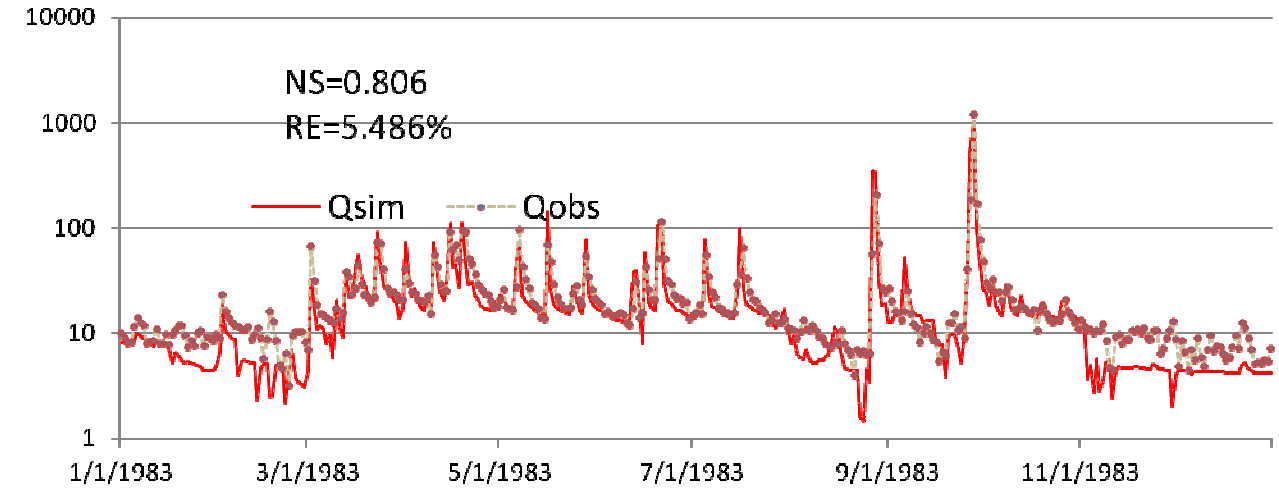


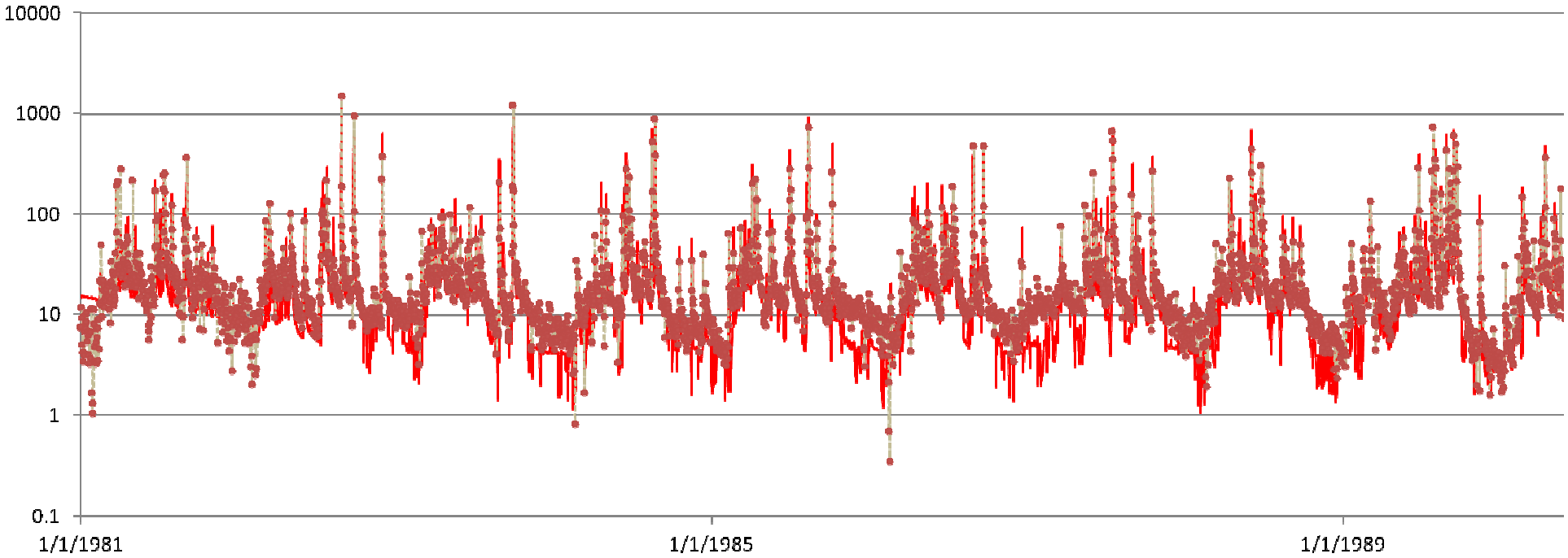
Annual Largest Flood Peaks



(a) Murakami **(b) Yakatabara** **(c) Iwamoto** **(d) Maebashi**

Yoshino River　1981－2000





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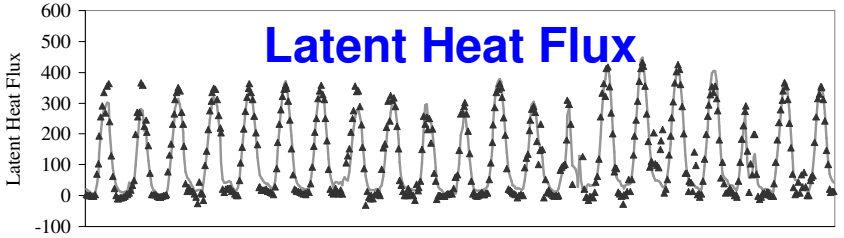
Model Evaluations with SGP97&SGP99 Observations

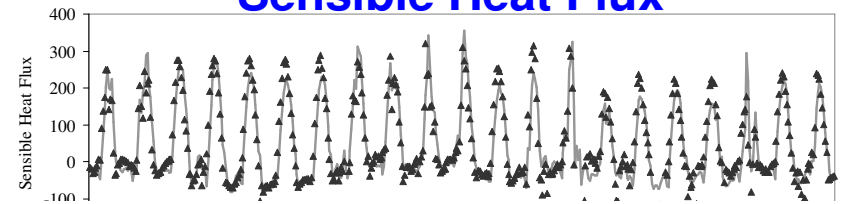
NOAA flux site

Net Radiation

Latent Heat Flux

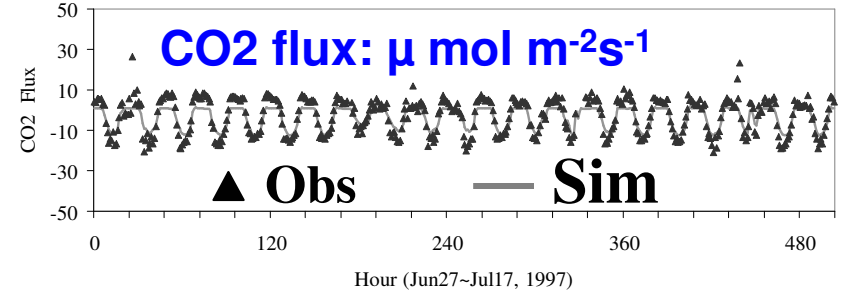


Sensible Heat Flux

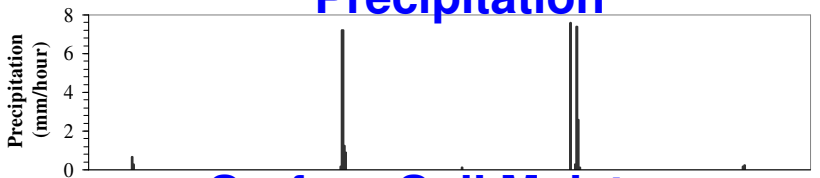


Ground Heat Flux

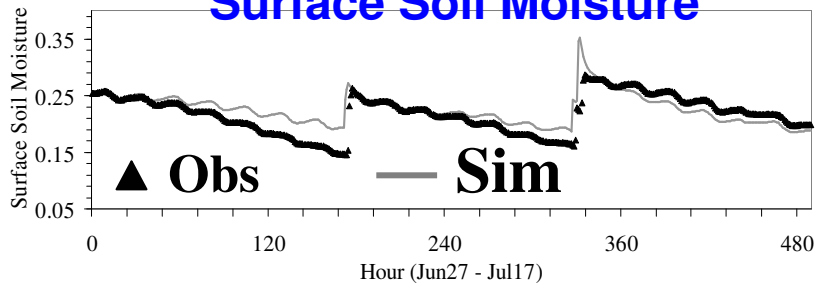
CO2 flux: μ mol m^{-2}s^{-1}



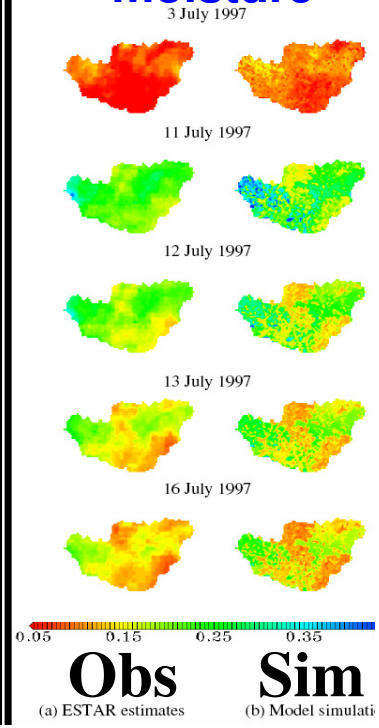
Precipitation



Surface Soil Moisture

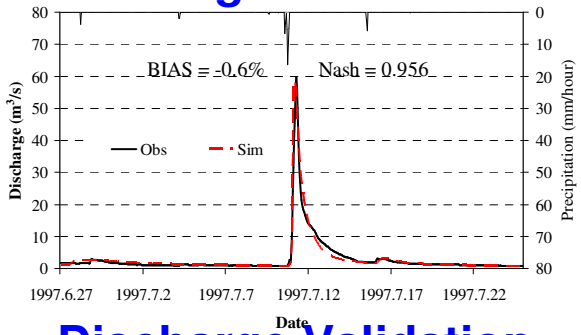


Surface soil moisture

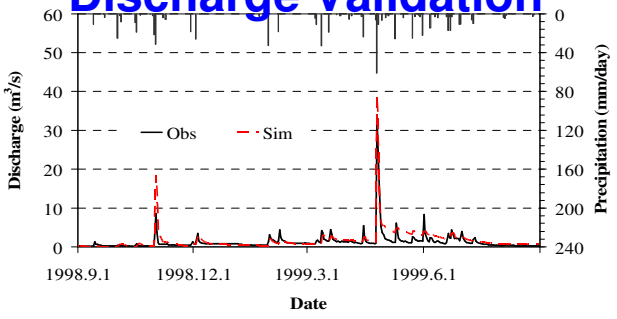


Basin-scale

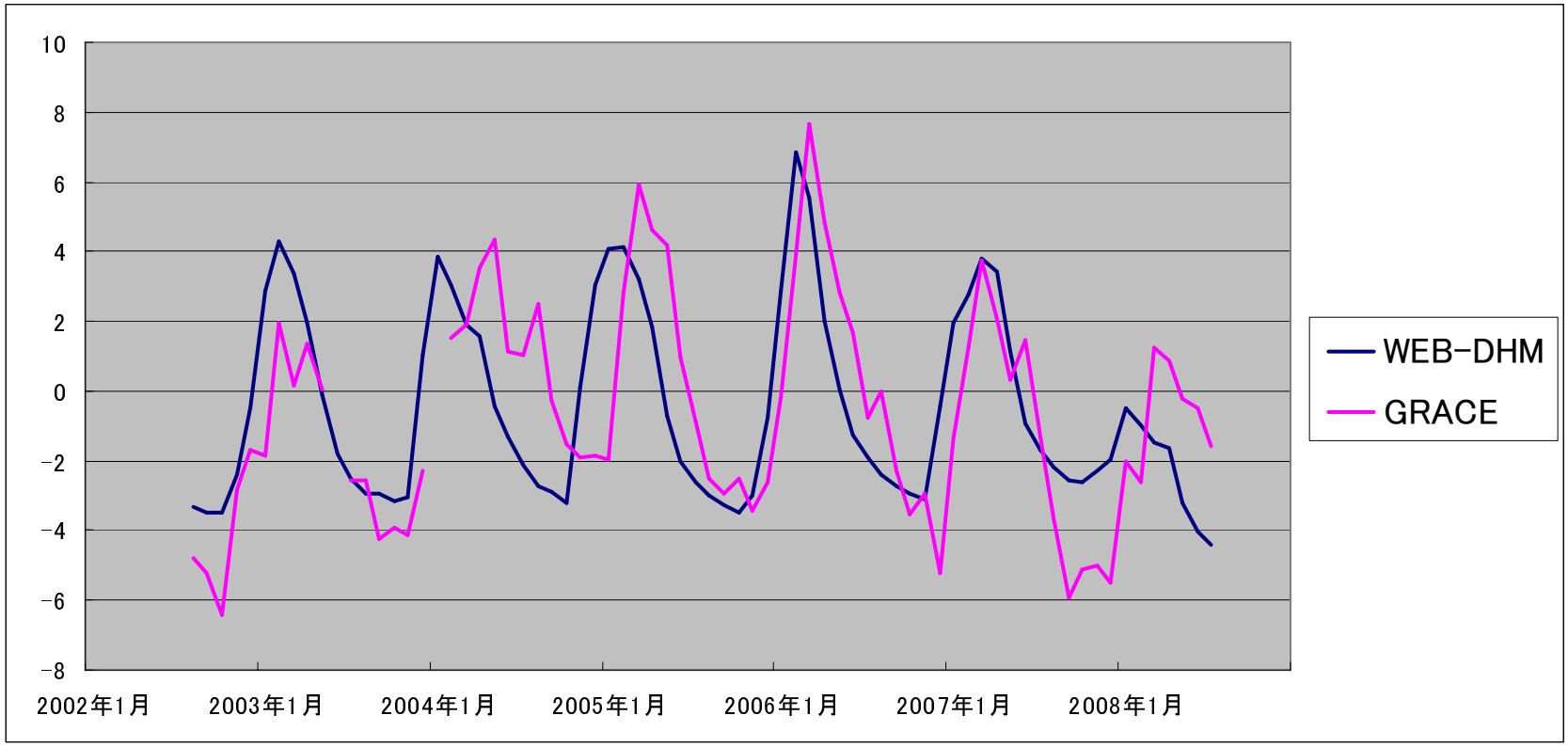
Discharge Calibration



Discharge Validation



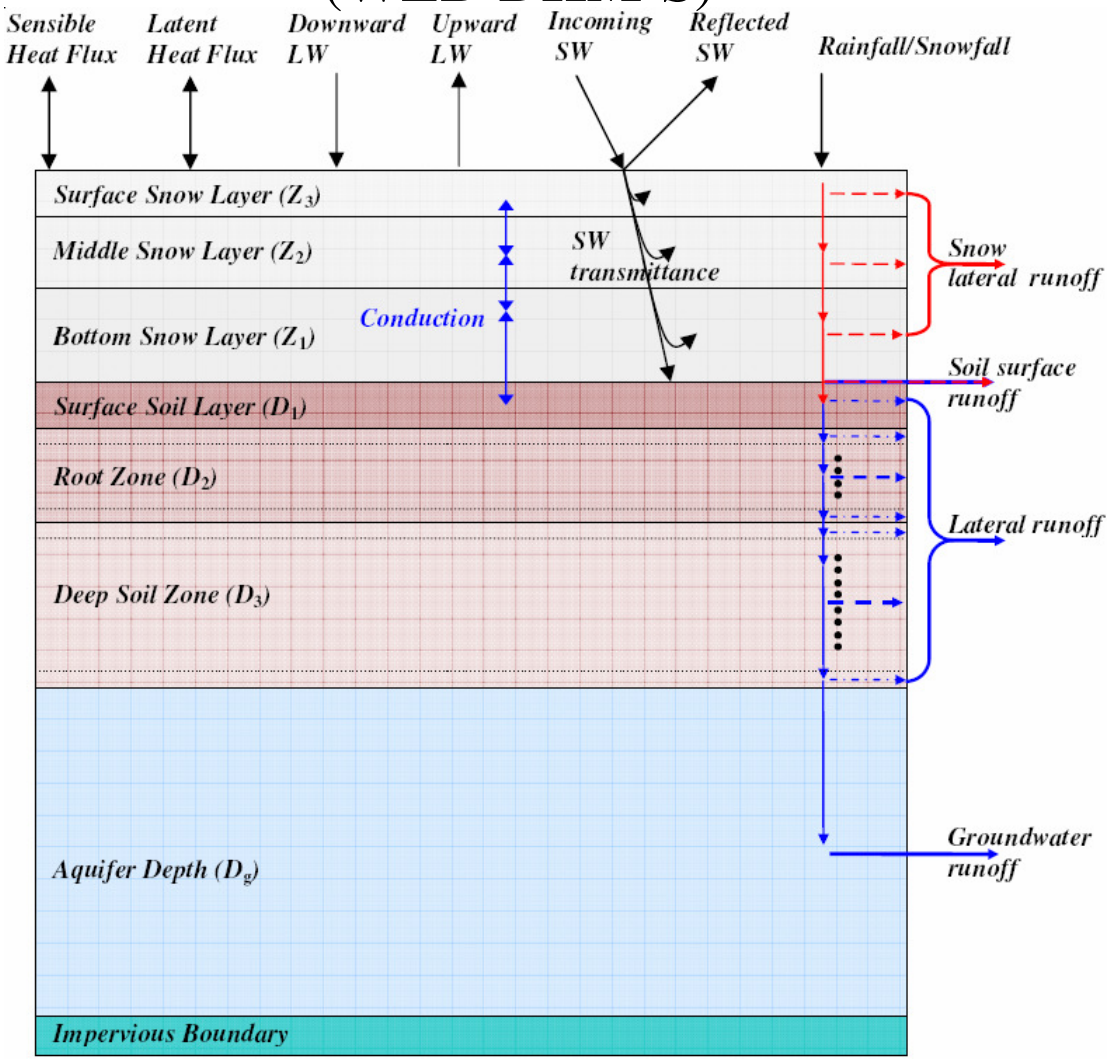
Model Simulation – Multi-Satellites Product (Ground Water in Semi-Arid Region)



Improving the snow physics of WEB-DHM

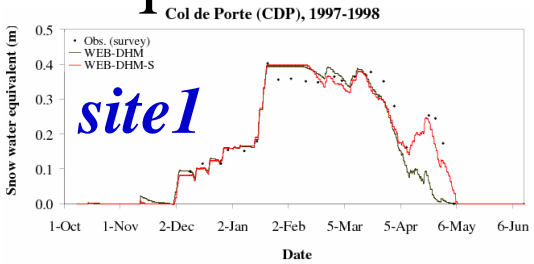
A three-layer snow model is added

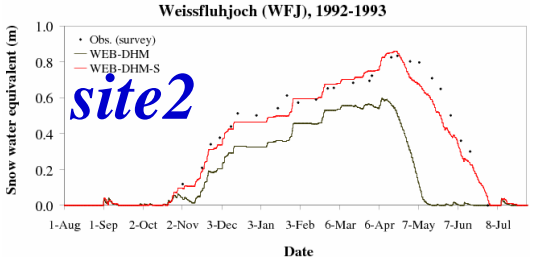
(WEB-DHM-S)



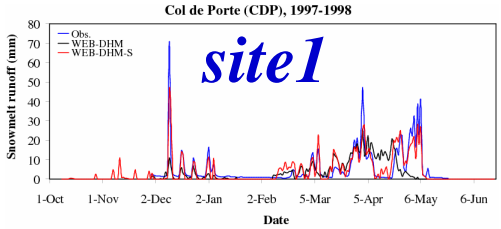
Shrestha, Wang, Koike et al., 2010

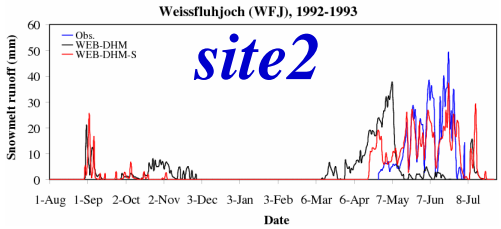
Snow Water Equivalent





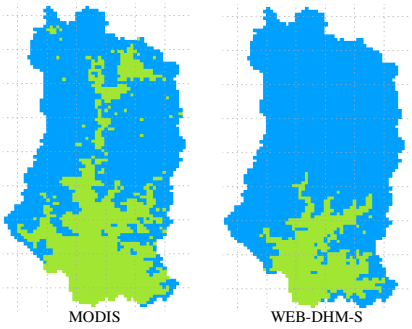
Snowmelt Runoff



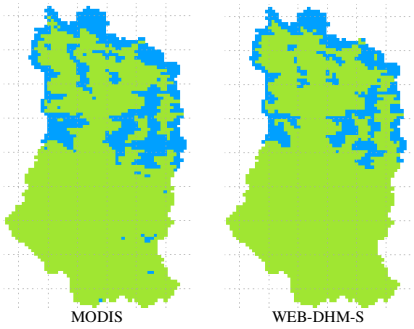


Comparison with MODIS snow cover product

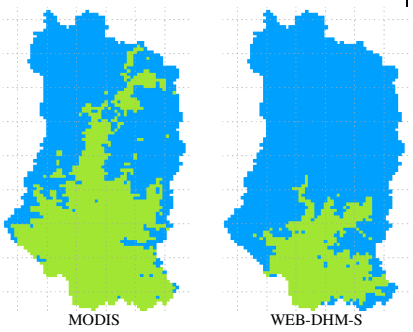
January 1, 2003



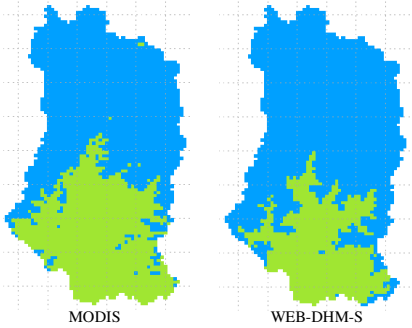
January 17, 2003



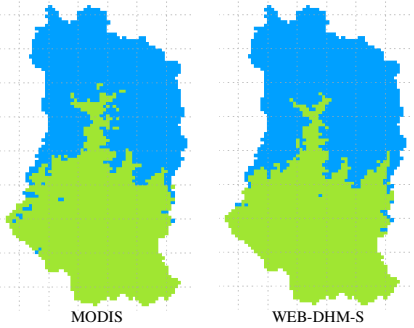
February 2, 2003



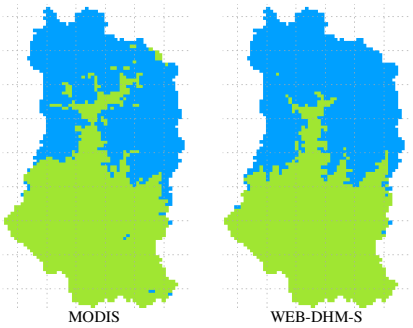
February 18, 2003



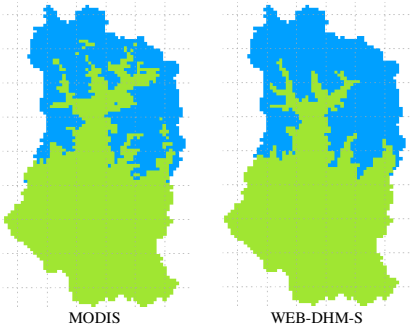
March 6, 2003



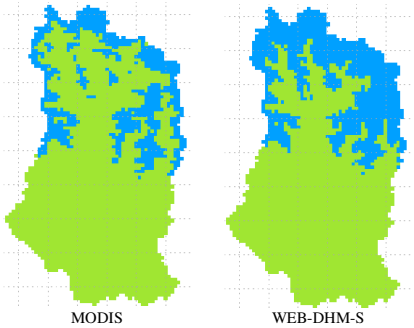
March 22, 2003



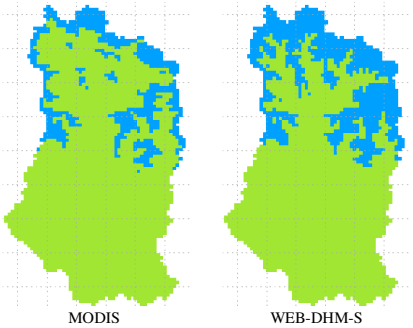
April 15, 2003



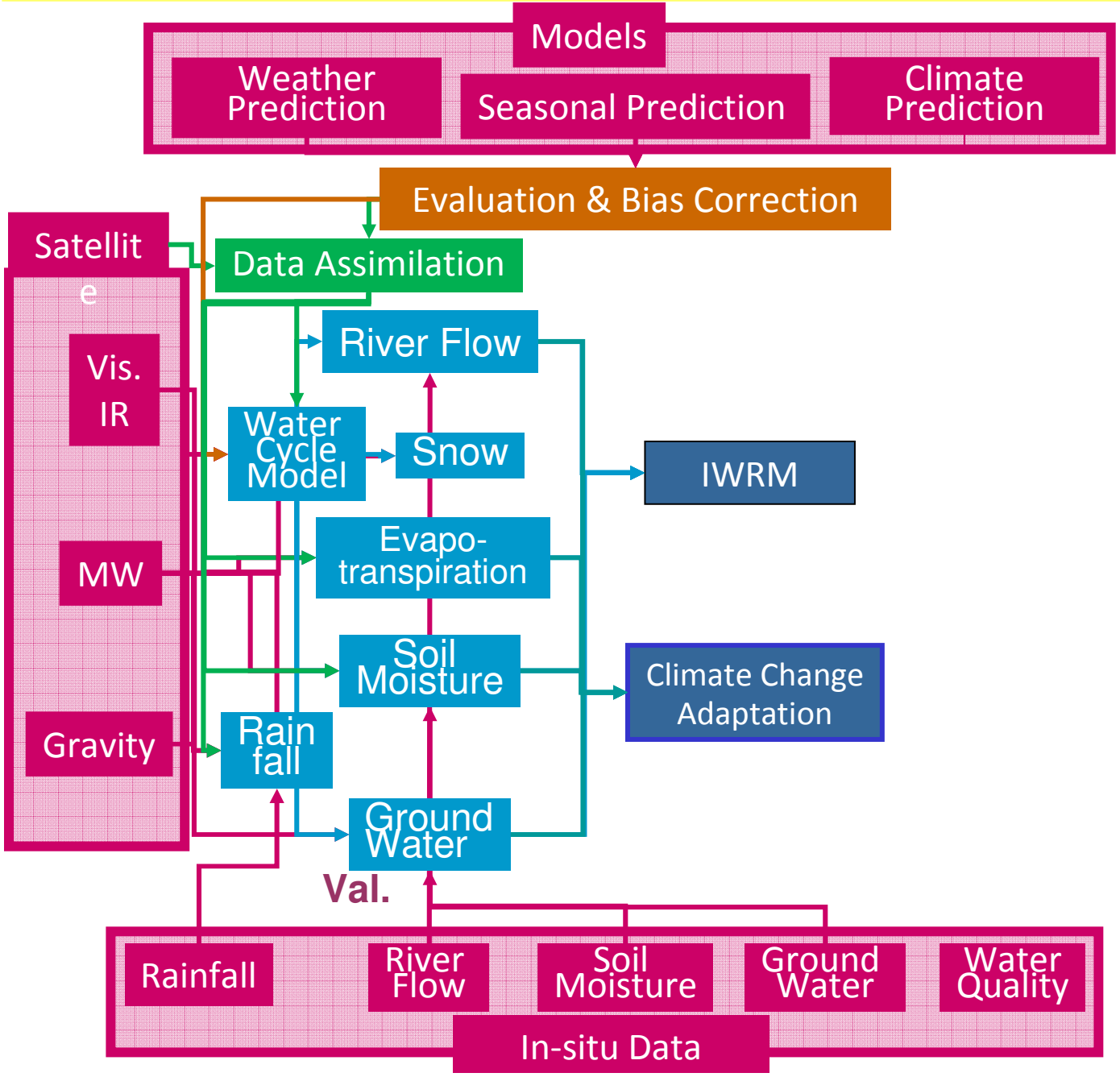
May 9, 2003



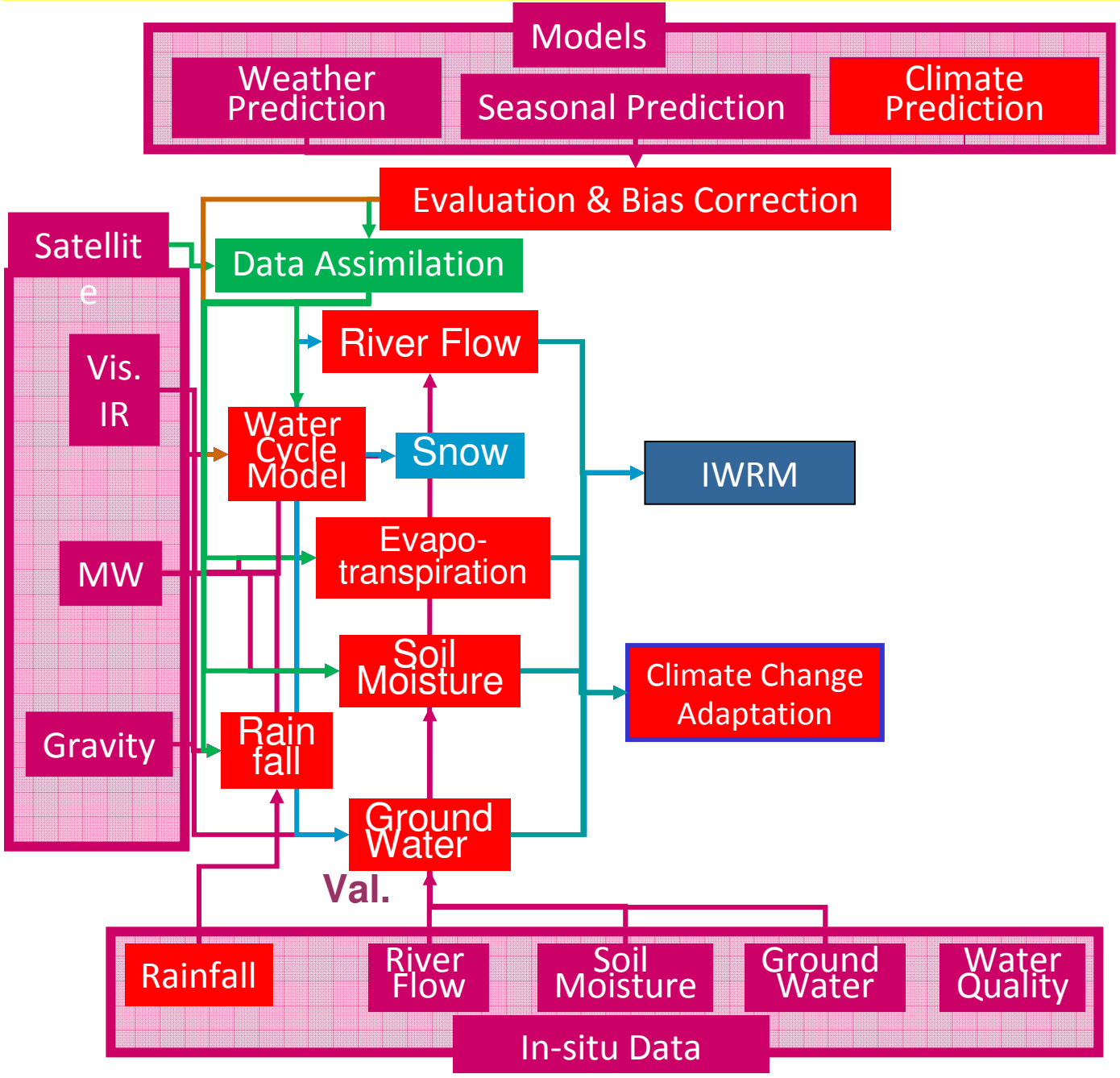
May 25, 2003



Water Cycle Integrator

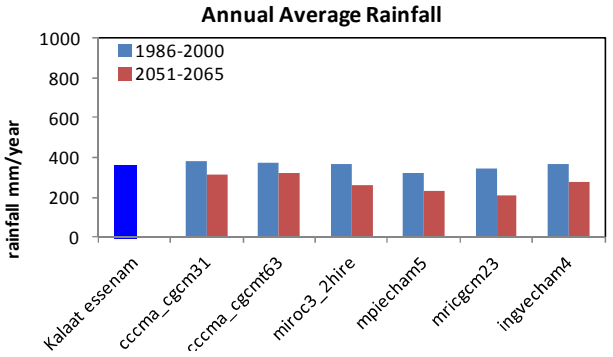


Water Cycle Integrator

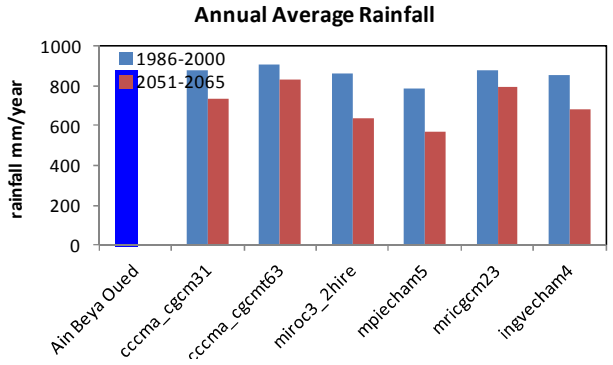


Mejerda River

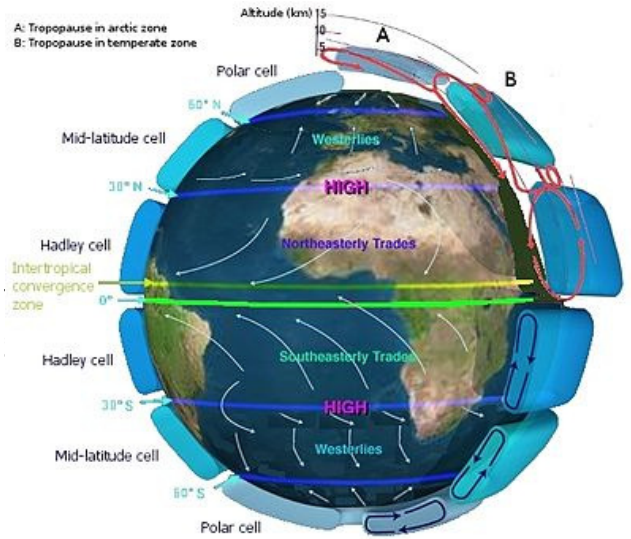
It is virtually certain that drought will become more severe.

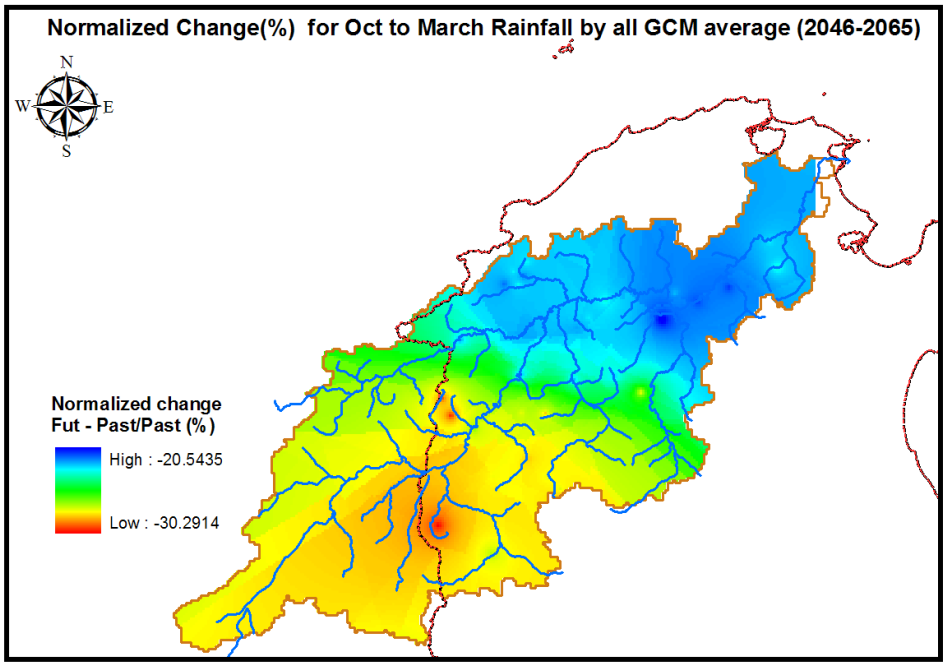


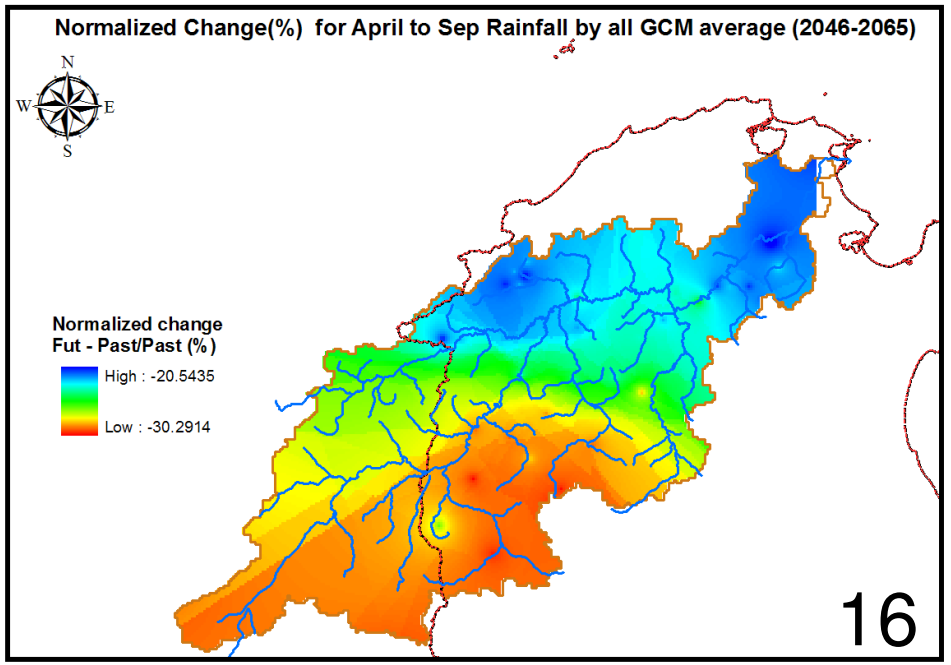
KALAAT ESSENAM



AIN BEYA OUED







Changes of Drought in Angat Dam Basin

GCM Model	Drought Discharge (m^3/s) *(average 355th rank)*		# of days/year that **baseflow < past drought discharge** *(average of 355th rank)*		Upper Limit of Drought Discharge(m^3/s) *(10th percentile of 355th rank)*		# of days/year that **baseflow < past drought discharge** *(10th percentile of 355th rank)*		Longest # of days for each year below average drought discharge	
	Past	Future	Past	Future	Past	Future	Past	future	Past	Future
MIROC	0.144	0.151	27	34	0.123	0.107	2	13	100	135
IPSL	1.85	6.46	22	0	1.6	5.939	2	0	59	0
INGV	0.17	0.194	30	11	0.138	0.156	3	0	104	76
GFDL_1	0.156	0.173	39	28	0.123	0.131	1	0	134	88
GFDL_0	0.174	0.175	44	64	0.122	0.116	3	13	167	255
CSIRO	0.15	0.154	37	34	0.13	0.11	5	15	193	191

red = drier in future; more frequent below drought discharge
blue = wetter in future; less frequently below drought discharge

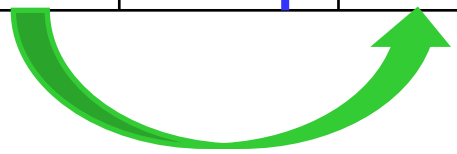
Changes of Drought at San Isidro gauge, Pampanga River Basin

GCM	**Drought Discharge (m^3/s)** *(average 355th rank)*		**# of days/year** that **baseflow < past drought discharge** *(average of 355th rank*		**Upper Limit of Drought Discharge(m^3/s)** *(10th percentile of 355th rank)*		**# of days/year** that **baseflow < past drought discharge** *(10th percentile of 355th rank)*		**Longest # of days for each year below average drought discharge**	
	Past	Future	Past	Future	Past	Future	Past	future	Past	Future
MIROC	3.84	2.529	22	34	0.899	0.58	3	9	93	106
IPSL	11.78	12.547	19	19	3.791	4.209	2	1	54	87
INGV	5.05	3.96	18	22	1.528	1.451	3	5	54	57
GFDL_1	4.78	2.93	30	43	0.749	0.665	2	2.95	96	111
GFDL_0	3.64	2.43	29	34	0.746	0.695	5	6	100	124
CSIRO	12.66	9.948	21	35	2.763	1.905	2	7	57	79

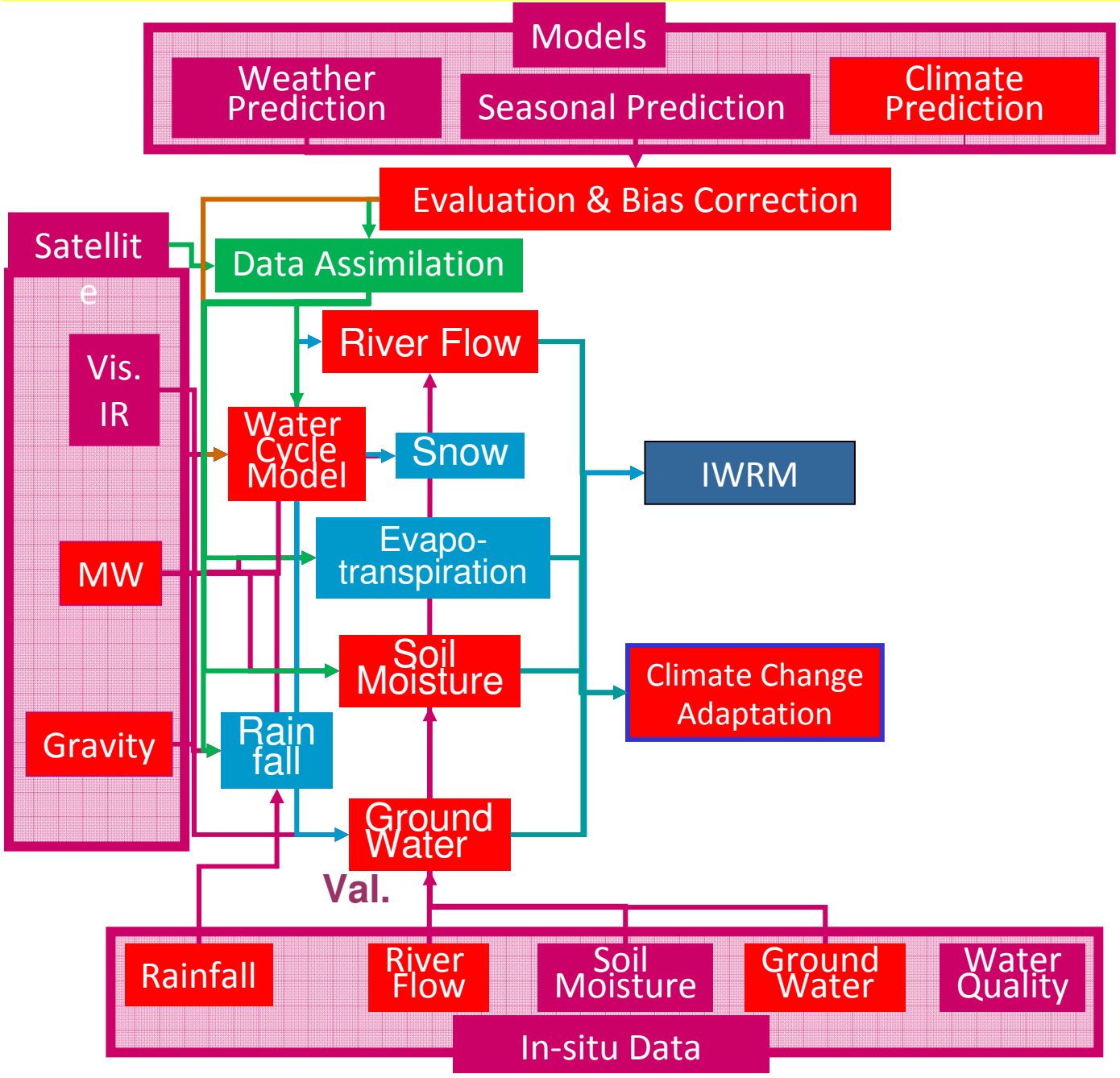
red = drier in future; more frequent below drought discharge
blue = wetter in future; less frequently below drought discharge

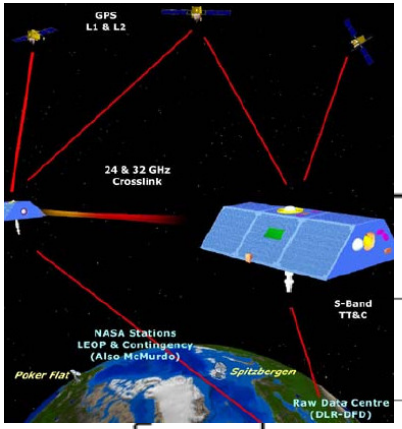
Past versus future Annual Average Discharge for each GCM for Angat dam inflow.

GCM	Annual Average Discharge (m^3/s)			
	Past		Future	
	Average	Stdev	Average	Stdev
MIROC	28.3	80.3	27.8	114.6
IPSL	35.3	94.4	63.7	159.7
INGV	32.8	85.0	35.4	105.4
GFDL_1	32.6	85.4	31.3	109.79
GFDL_0	35.0	90.3	34.2	101.66
CSIRO	28.5	67.1	30.3	152.80

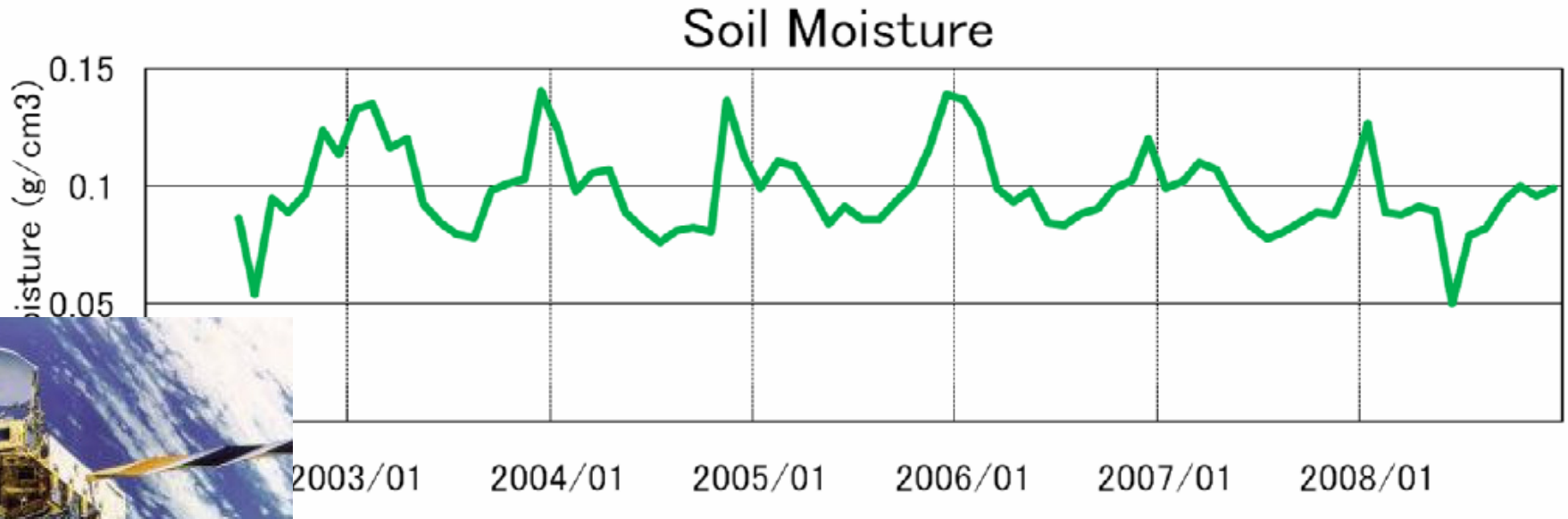


Water Cycle Integrator

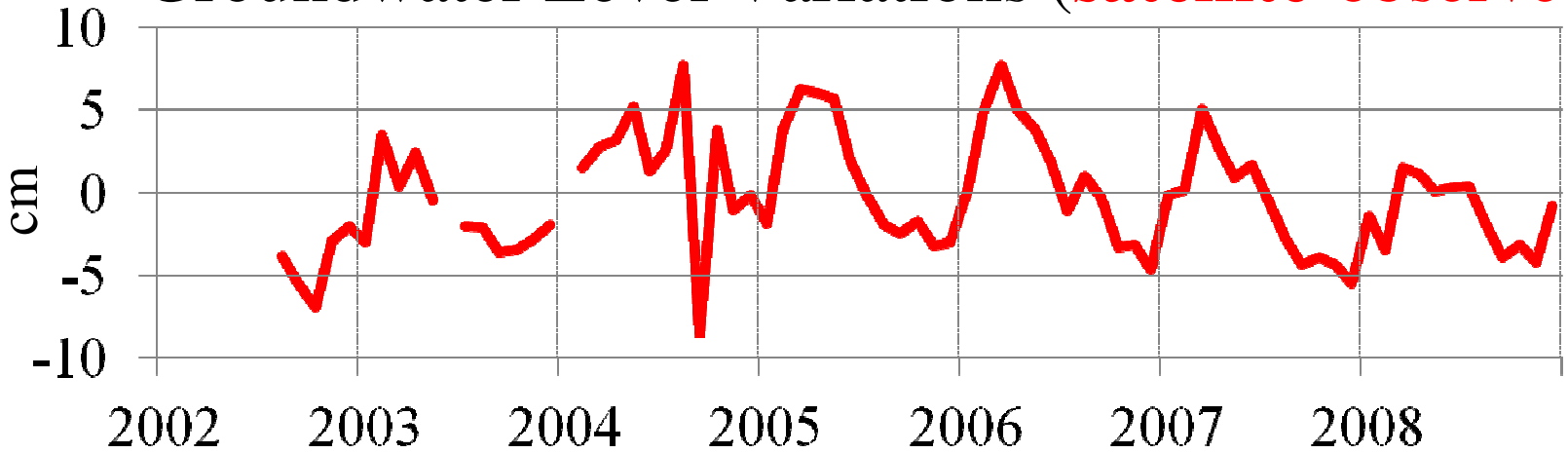


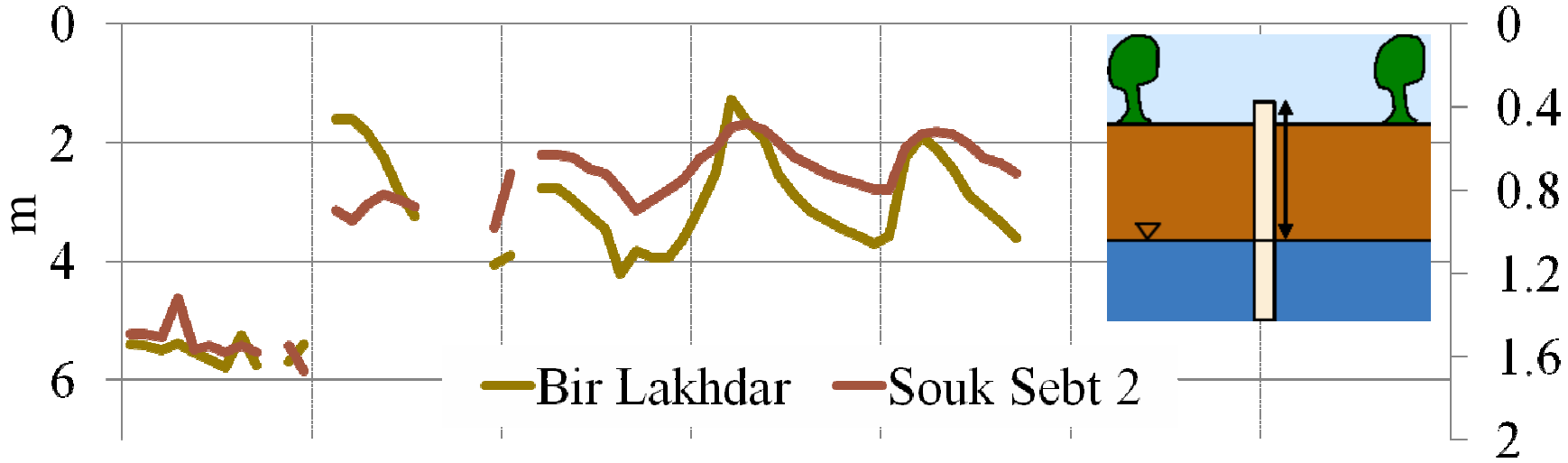

GPS
L1 & L2
24 & 32 GHz
Crosslink
S-Band
TT&C
NASA Stations
LEOP & Contingency
(Also McMurdo)
Poker Flat
Spitzbergen
Raw Data Centre
(DLR-DFD)

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
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01

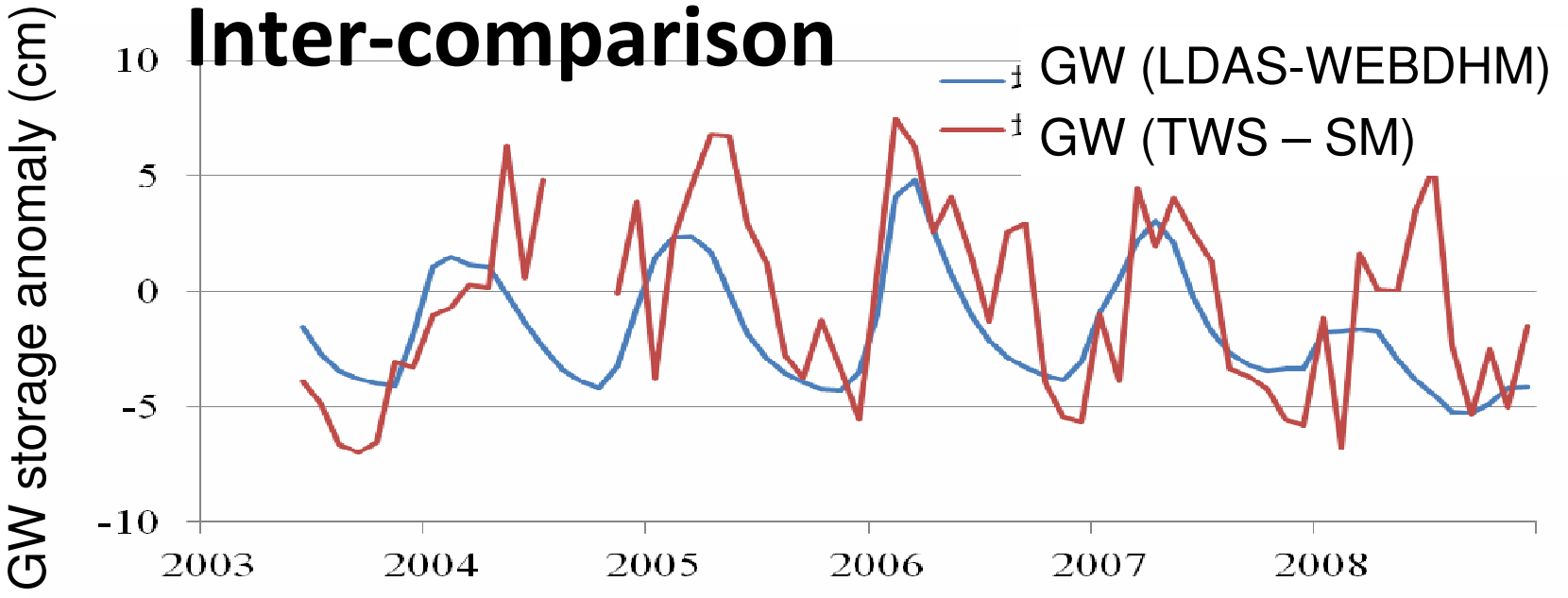
Groundwater Level Variations (**satellite**-observed)



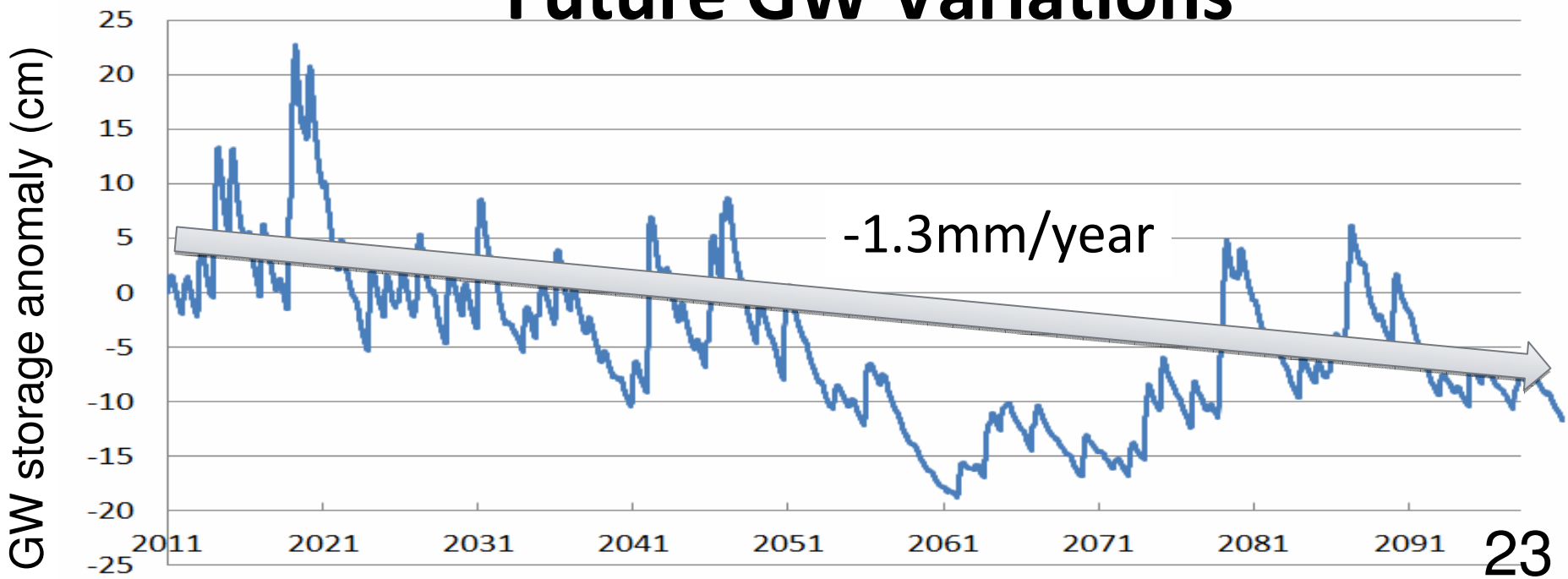


Groundwater Level Variations (**ground**-observed)

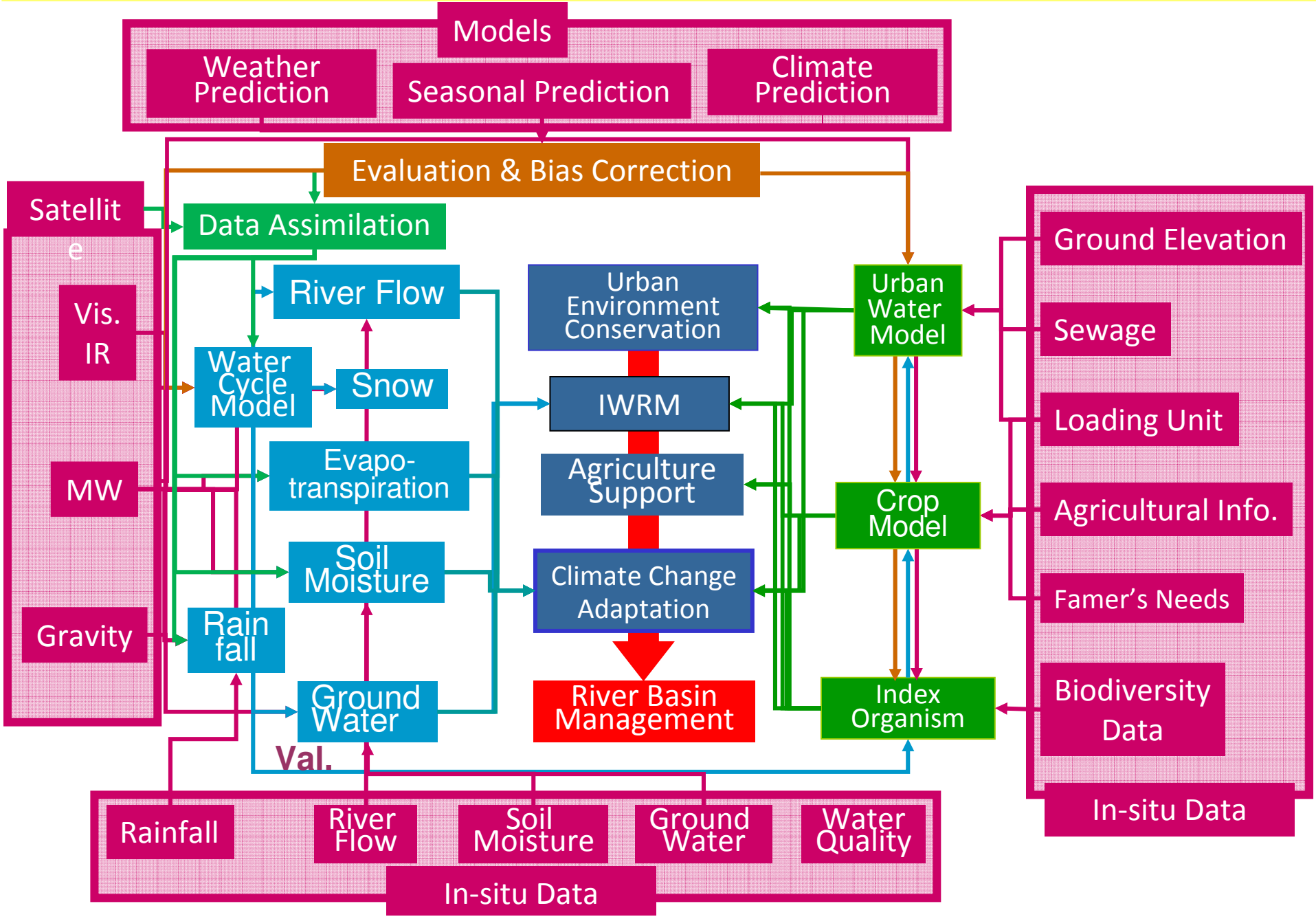
Inter-comparison



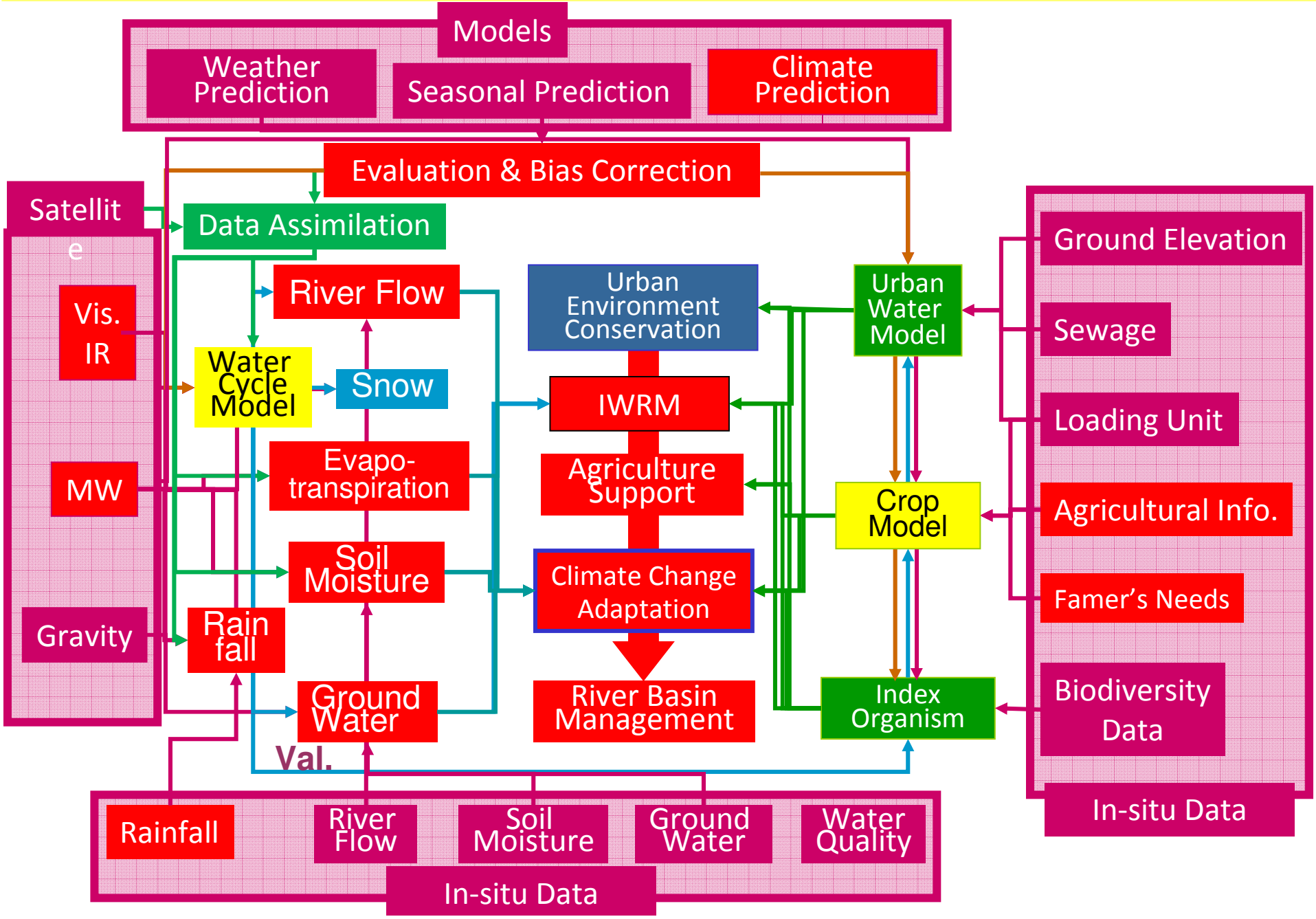
Future GW Variations



Water Cycle Integrator



Water Cycle Integrator



Cambodia CROP & WATER Watch

CROP DATA
- -- soil moisture
- -- irrigation
- -- discharge
- -- plant date
- -- yield simulation

RAIN MAP
- -- raw data
- -- corrected data

METEO. DATA
- -- latest data
- -- past data
- -- stats data
- -- station

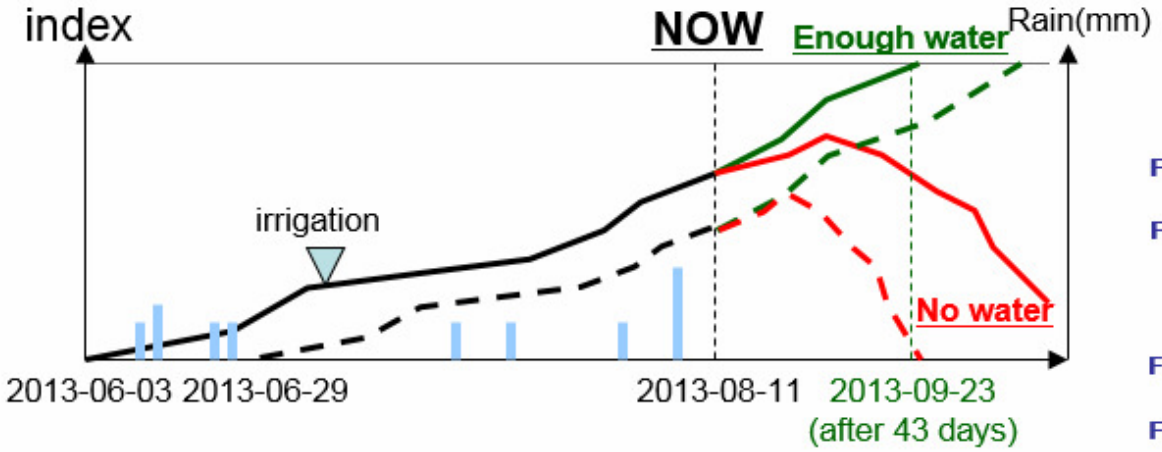
SATELLITE
- -- soil moisture map
  - -- 10km scale
  - -- 10-100m scale
- -- flooding area

Farmer 001: Pech Bora

Province Battambang

Village Phnom San Pau kaet

	Field# 1	Field# 2
LAT / LON		
type	Xx-045-kmr	YY-072-kmr
planting	2012 / Sep / 12	2012 / Sep / 12
Irrigation1	2012 / Sep / 12	2012 / Sep / 12
Irrigation2	2012 / Sep / 12	2012 / Sep / 12
Fertilixzation1	2012 / Sep / 12	2012 / Sep / 12
Fertilixzation2	2012 / Sep / 12	2012 / Sep / 12



Production

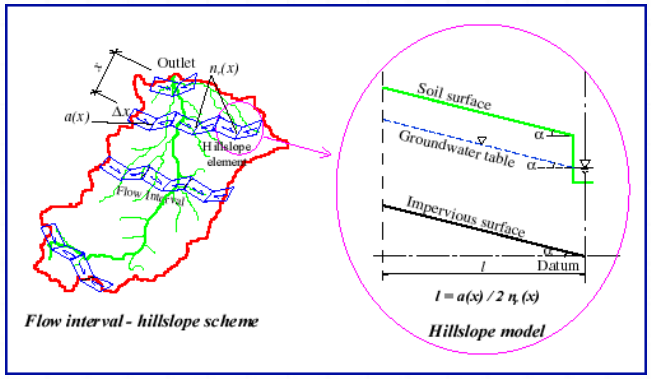
Enough water

Field 1	2.1 ton/ha
Field 2	2.0 ton/ha

No water

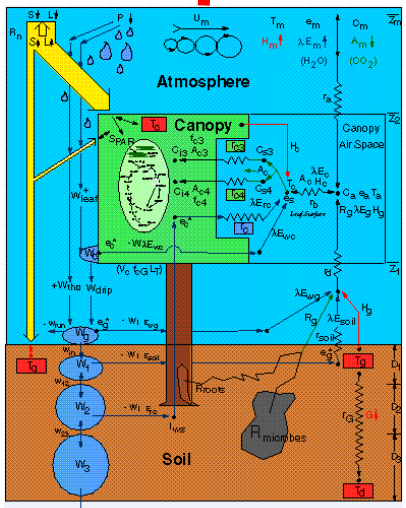
Field 1	0.6 ton/ha
Field 2	0.0 ton/ha

A eco-hydrological model: WEB-DHM + DVM



GBHM(river model)

Coupling



Hydro-SiB

⇒ WEB-DHM + DVM can simultaneously reproduce river discharge and vegetation growth.

+

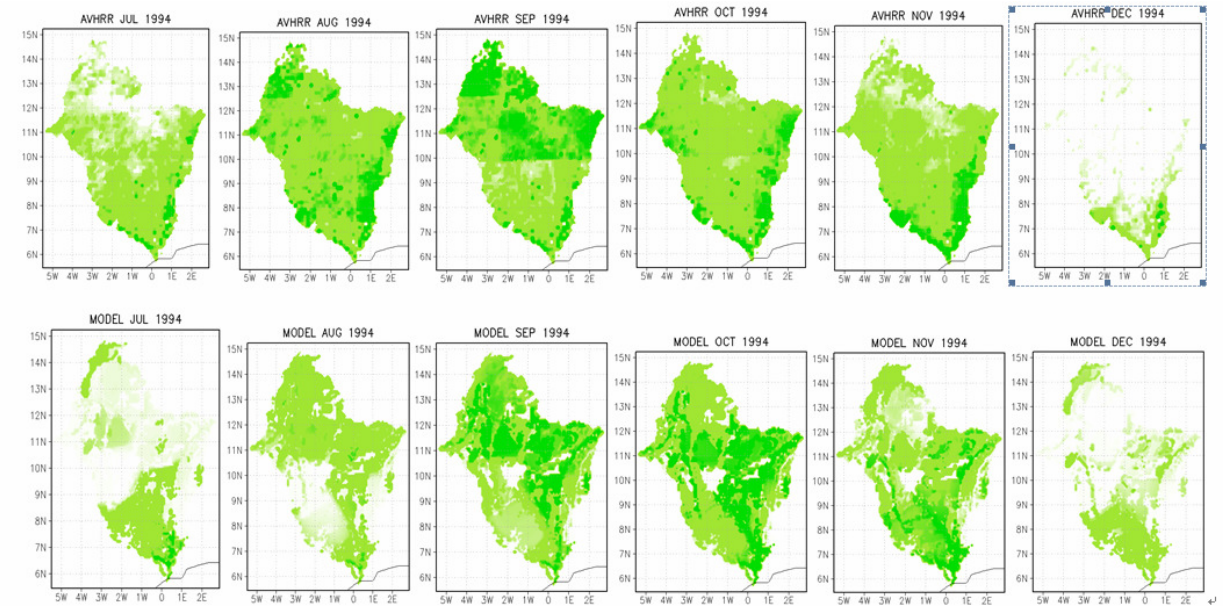
Dynamic Vegetation Model

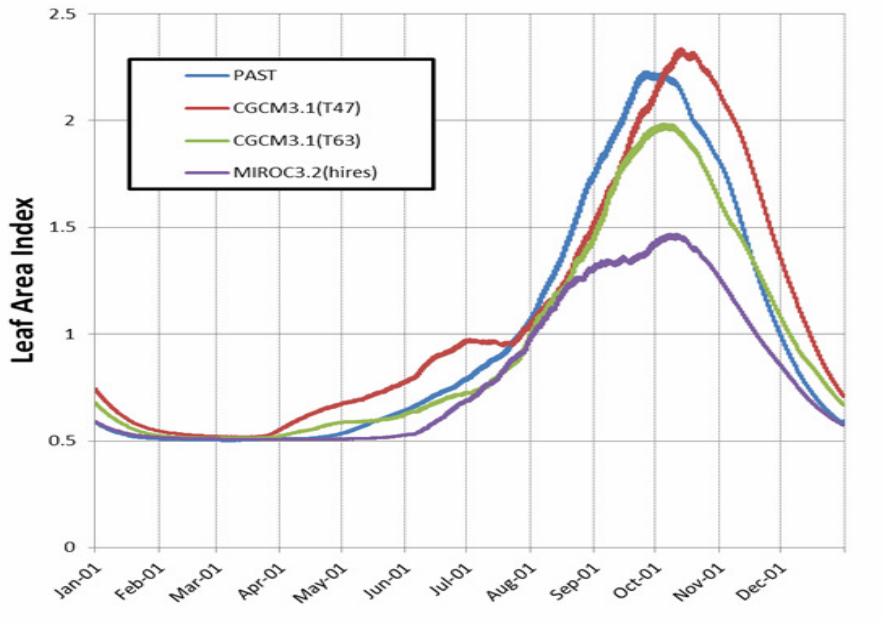
- Carbon Allocation Model
- Carbon-Pool Update Model
- Carbon-LAI Conversion Model

AVHRR LAI

Volta River

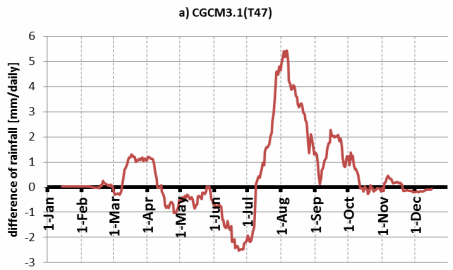
Simulated LAI



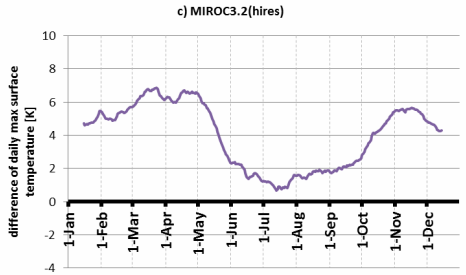


Climate Change
Impact Assessment
of Biomass Production
in the Volta River Basin

Precipitation



Air Temperature



Water Cycle Integrator