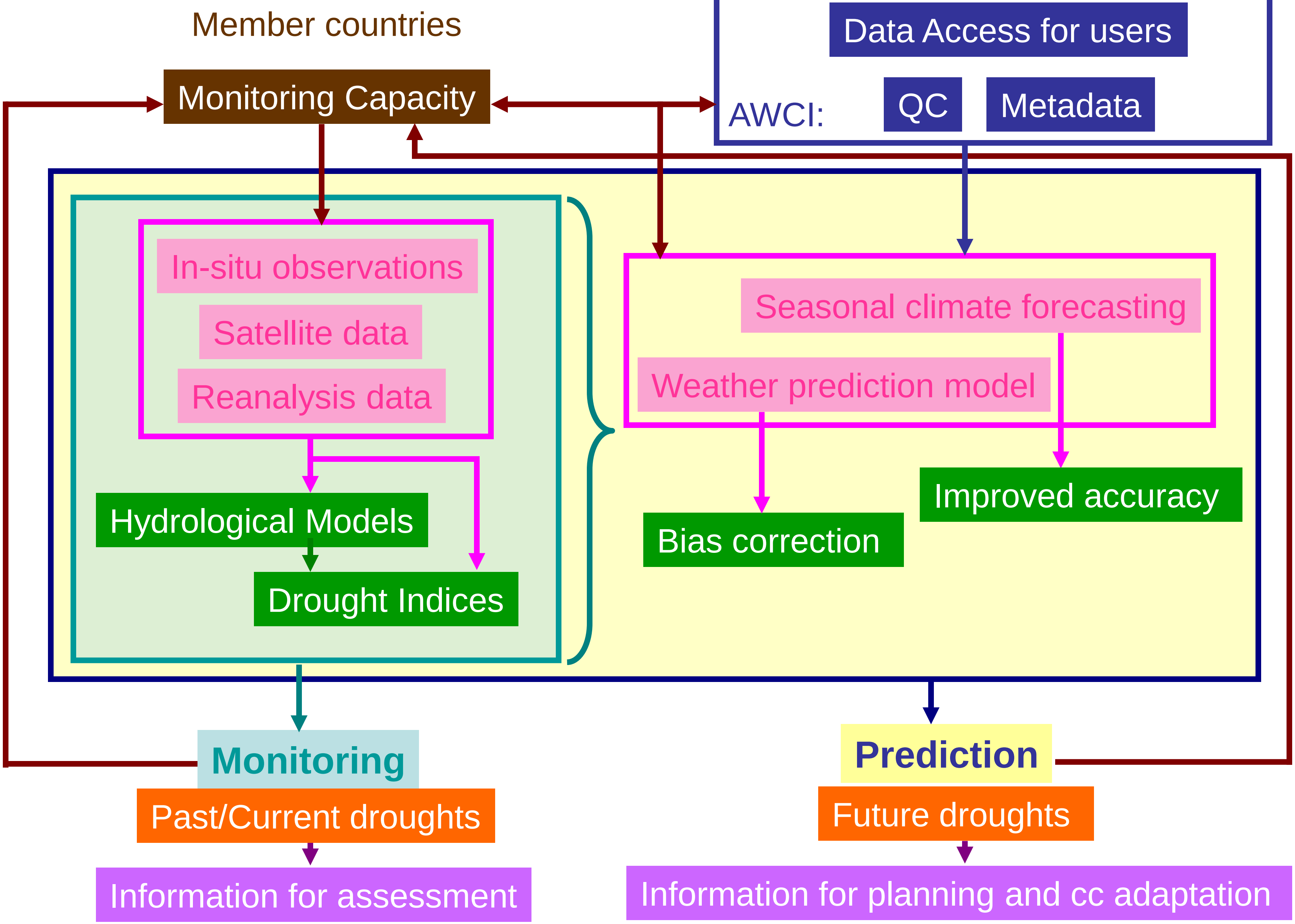
Drought Data Integration and Information Fusion in Asia

Case Basins:
Philippines, Malaysia, Thailand, Indonesia

Patricia Ann Jaranilla-Sanchez
University of Tokyo

The Second Asia/Oceania Meteorological Satellite User's Conference December 6-9, 2011, Tokyo

Drought Workbench:



Drought Monitoring Framework:

Member countries

Monitoring Capacity

AWCI:

- Storage/Archive of observed data
- Data Access for users
- QC
- Metadata

In-situ observations

(Long-term)
- •Rainfall
- •Temperature
- •Evapotranspiration
- • Discharge
- •Soil Moistures
- •Groundwater

Satellite data

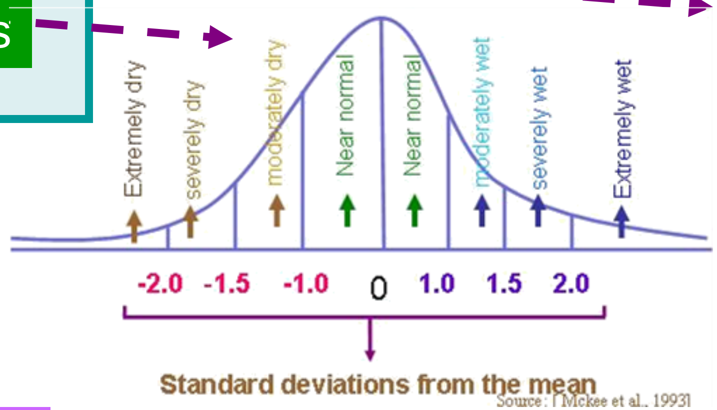
- •GRACE (total water)
- •TRMM (rainfall)
- •GsMap (combined satellite + obs)
- •APHRODITE
- •SSM/I (microwave brightness temperature)
- •MODIS (LAI/FPAR)
- •AVHRR (LAI/FPAR)
- •GMS= MTSAT (met. Parameters)
- •AMSR-E (brightness temp. converted to soil moisture)

Reanalysis data

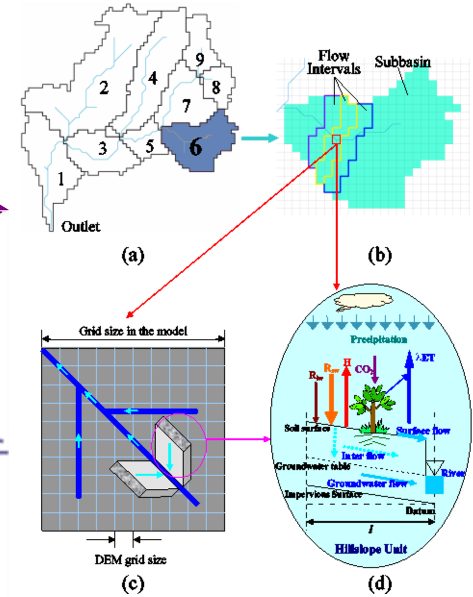
- •JRA25; JRA55
- •NCEP/NCAR

Hydrological Models

Drought Indices



SA



•WEB-DHM

Monitoring

Past/Current droughts

Information for assessment

CASE STUDY: *The Pampanga River Basin, Philippines*

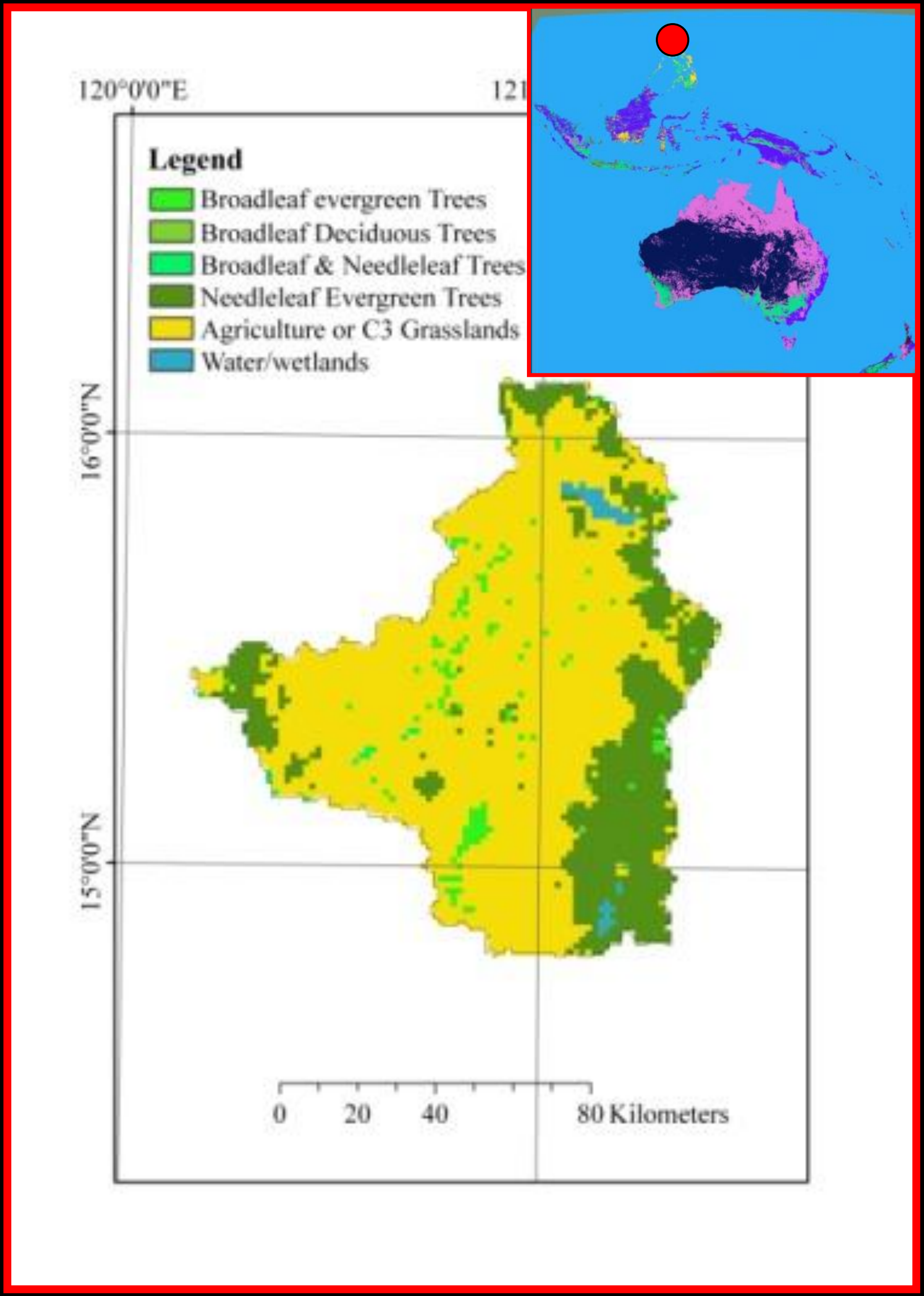
- Lies on the northern shore of Manila Bay
- Area: 10,033 sq. km draining to Manila Bay
- Major agricultural products: Rice, Corn, Sugarcane and tilapia
- a significant water resource for irrigation, hydropower, domestic water use and industrial use
- Metro Manila gets around 97% of its water supply from this basin
- Type II climate type
  - Wet season: May to Nov
  - Dry Season: Dec-April

SUMMARY OF MODEL INPUTS

Parameters	Parameter type
RAINFALL	Dynamic
LAI & FPAR	Dynamic
Meteorological parameters	dynamic
DEM	Static
SOIL	Static
LAND USE	Static

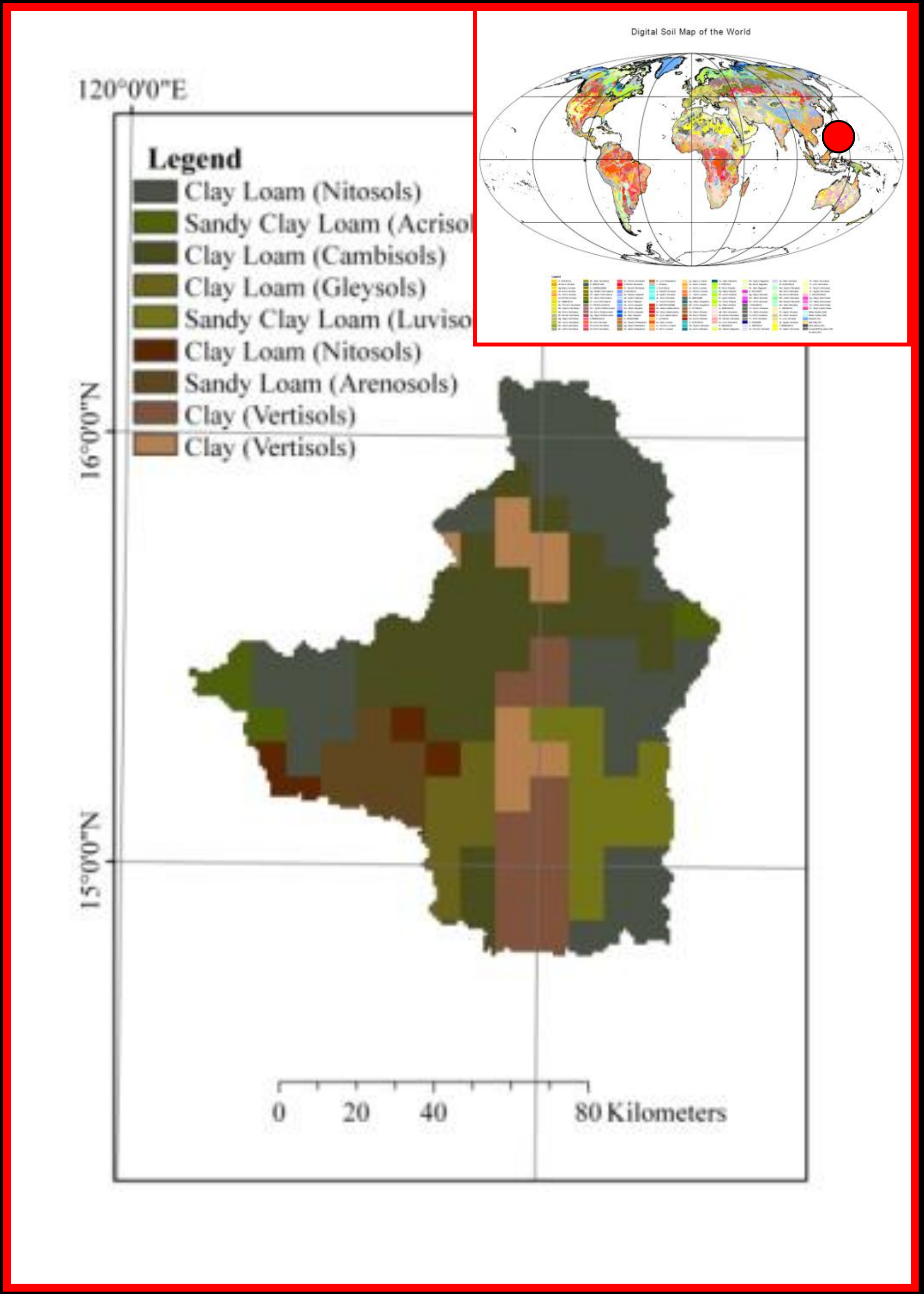
Land Use

- USGS Earth Resources Observation and Science map:
  - Eurasia Land Cover Characteristics Data Base Version 1.2
  - Based on 1-km AVHRR data from April 1992 through March 1993
  - Using SiB2 classification



Soil

- Obtained from the FAO's Digital Soil Map of the World
- ~ 1000m lat-long grid resolution

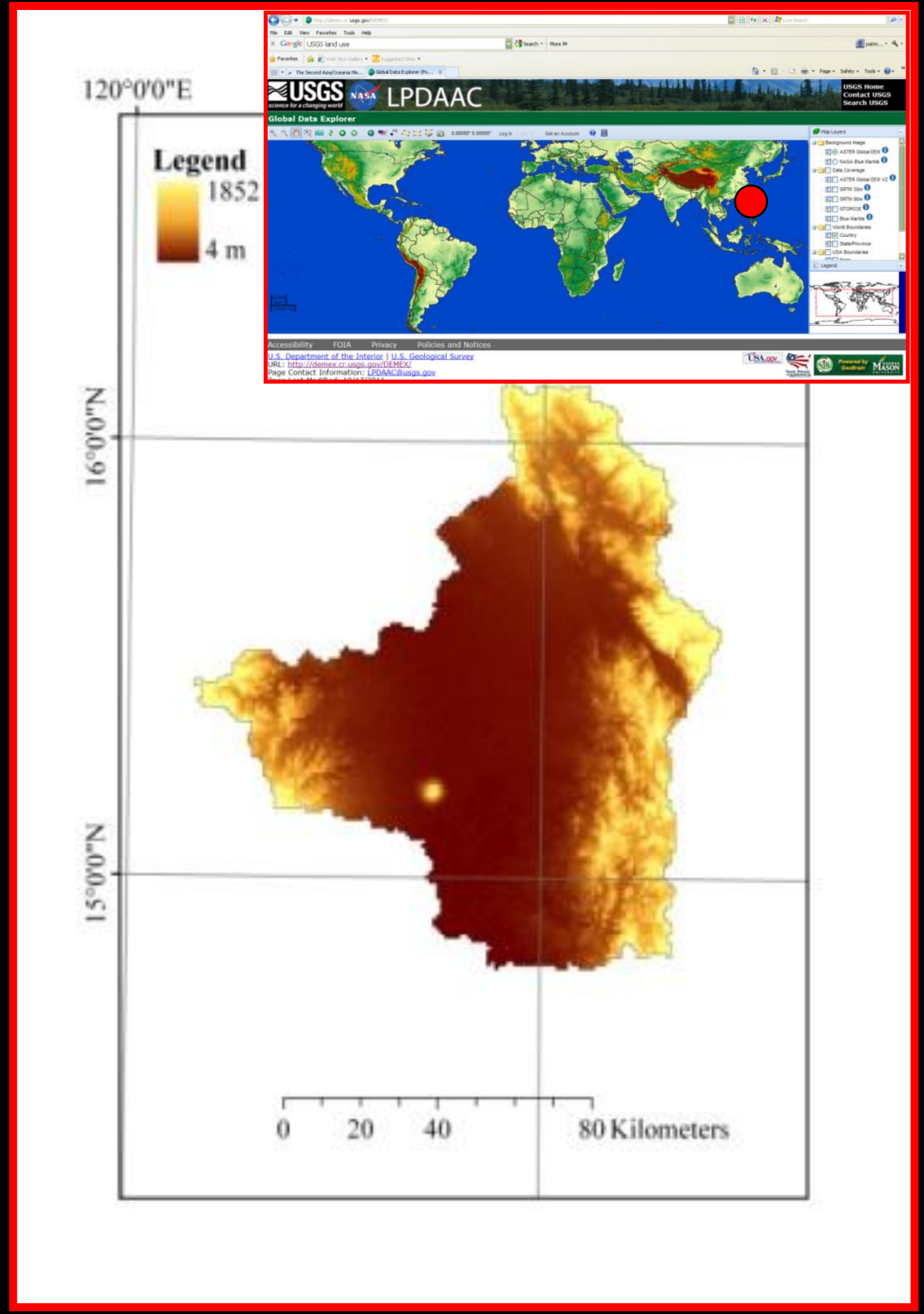


Digital Elevation Map

- GDEM V2 (Oct 2011)
- Product of NASA and METI
- Obtained from the USGS LPDAAC:

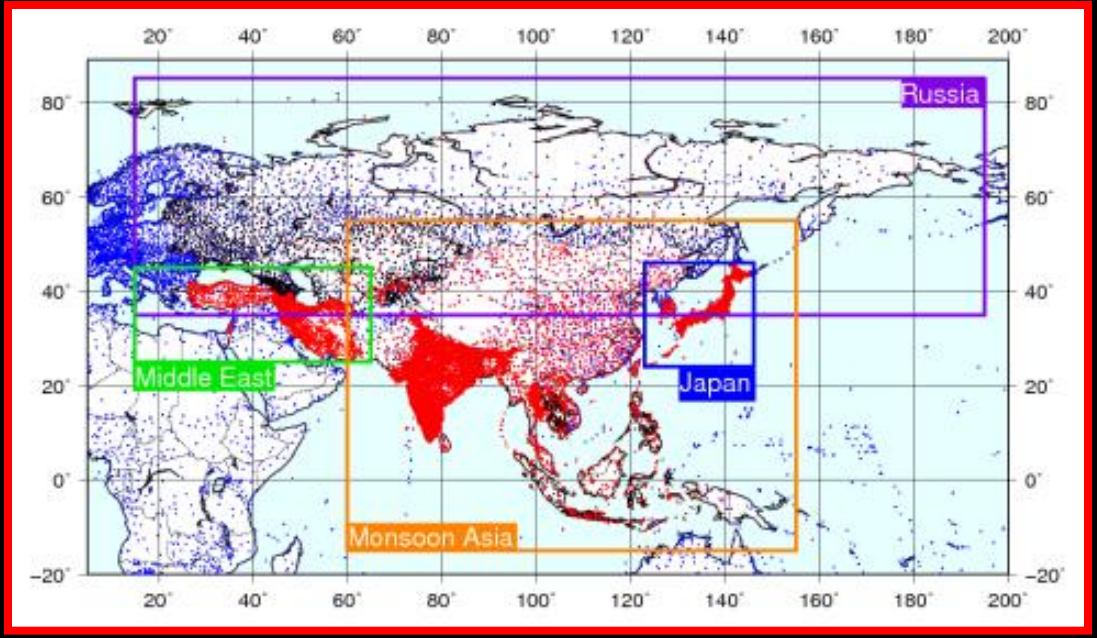
http://demex.cr.usgs.gov/DEMEX/

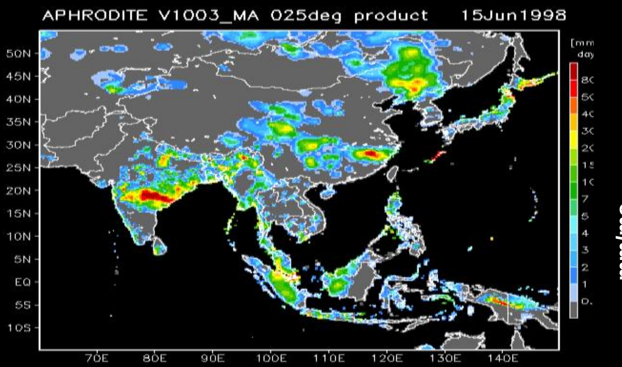
- from 30m lat-long grid resolution



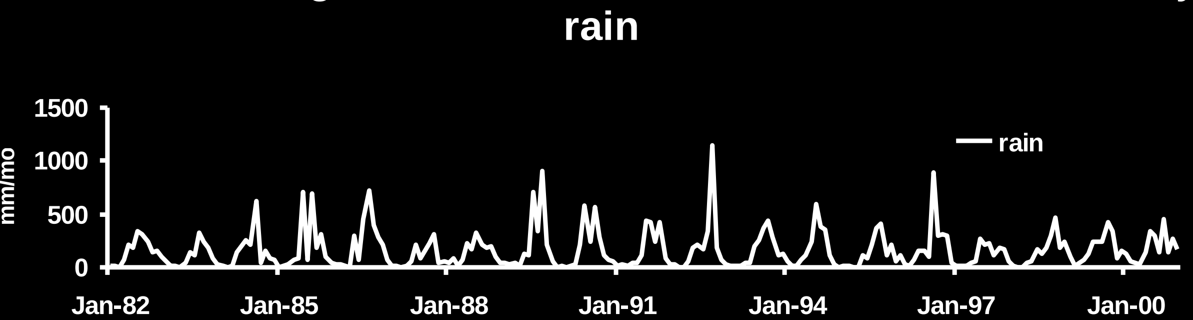
RAINFALL

- Sourced from the APHRODITE's Water Resources Rainfall Data over Monsoon Asia
- Lat-long Resolution 0.25º x 0.25º; daily data





Basin Average rainfall data: at the outlet in Manila Bay



APHRODITE: Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of the Water Resources. Website: http://www.chikyu.ac.jp/precip/index.html

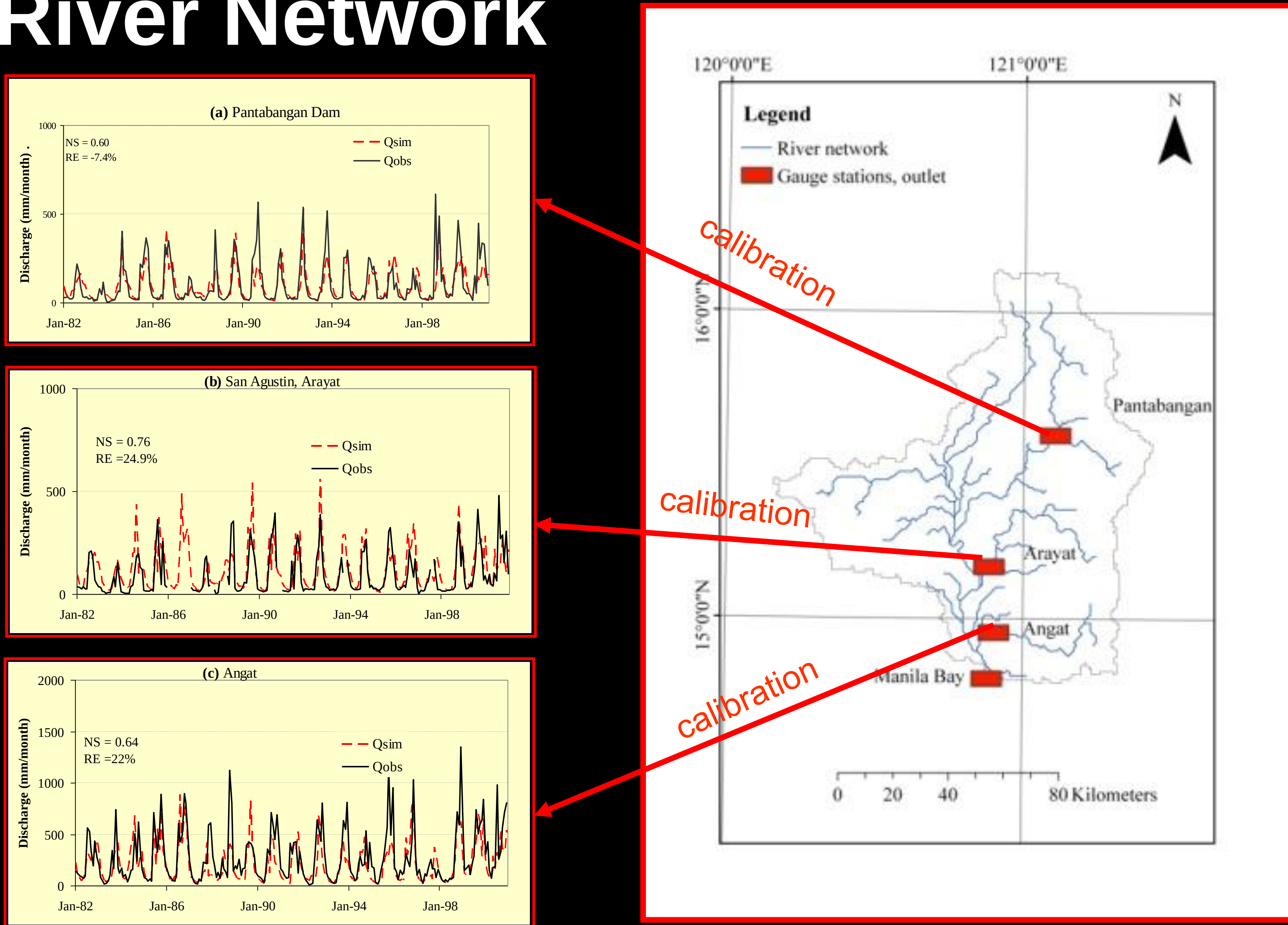
Dynamic Vegetation Parameters:

*Leaf Area Index (**LAI**) and Fraction of Photosynthetically Active Radiation absorbed by the green vegetation canopy (**FPAR**)*

- **LAI**: the one sided leaf area per unit ground area
- **FPAR**: the proportion of available radiation in the photosynthetically active wavelengths (400 to 700 nm) that a canopy absorbs
- **LAI** and **FPAR**: biophysical variables which describe canopy structure and are related to functional process rates of energy and mass exchange
- Obtained from AVHRR*
  - Spatial Resolution: 16km*16km
  - Temporal Frequency: Monthly
  - Spatial Extent: Global
  - Temporal Extent: July 1981 ~ May 2001

**Advance Very High Resolution Radiometer (AVHRR) from the NOAA/AVHRR Satellite*

River Network

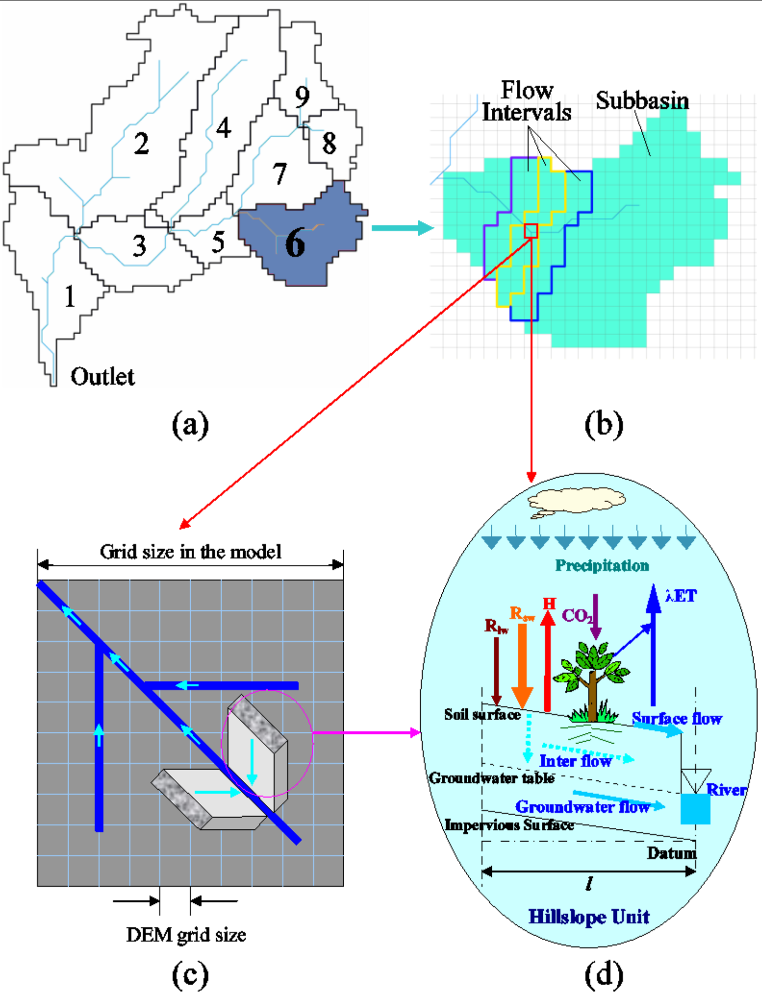


Other Surface Meteorological data: JRA-25 reanalysis

- Air temperature
- Relative humidity
- Air pressure
- Wind Speed
- Downward Solar and Longwave radiation
- Cloud fraction

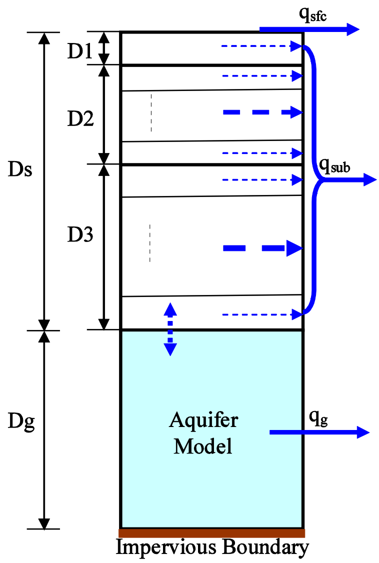
lat-lon grid resolution: 110 km; available every 6 hours

The Hydrological Model: WEB-DHM



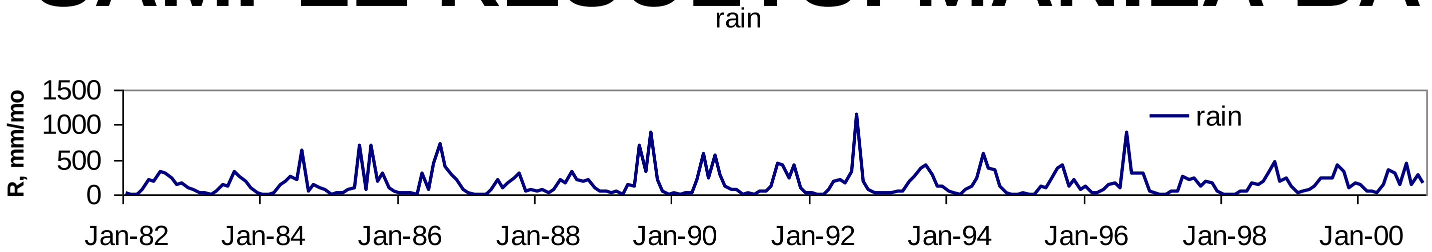
The Water and Energy Budget-based Distributed Hydrological Model

- Fully couples a simple biosphere scheme SiB2 with a hillslope hydrological model GBHM.
- Allows consistent descriptions of water, energy and CO_2 fluxes at the basin scale.

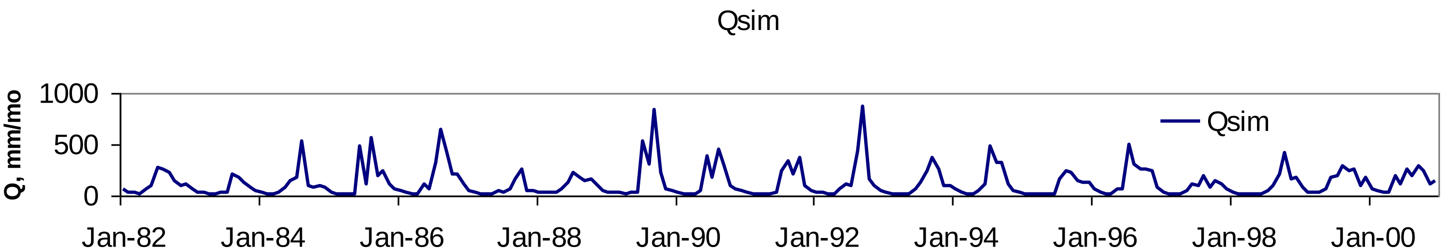


Benefits of WEB-DHM over other models: flexible, low computational requirements; comparable to commercially available models

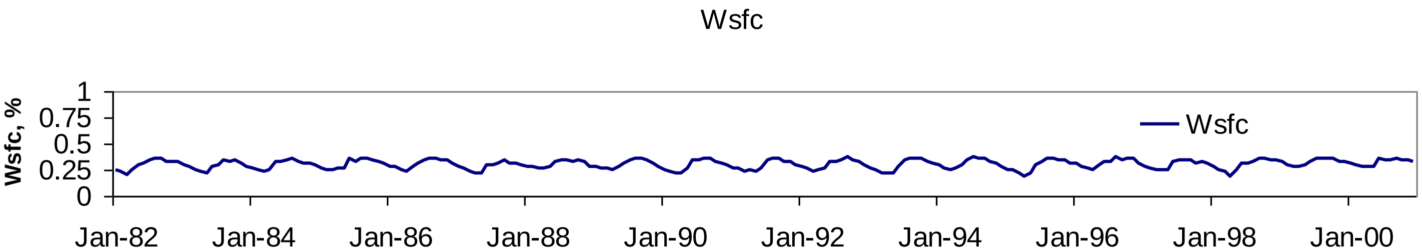
SAMPLE RESULTS: MANILA BAY OUTLET



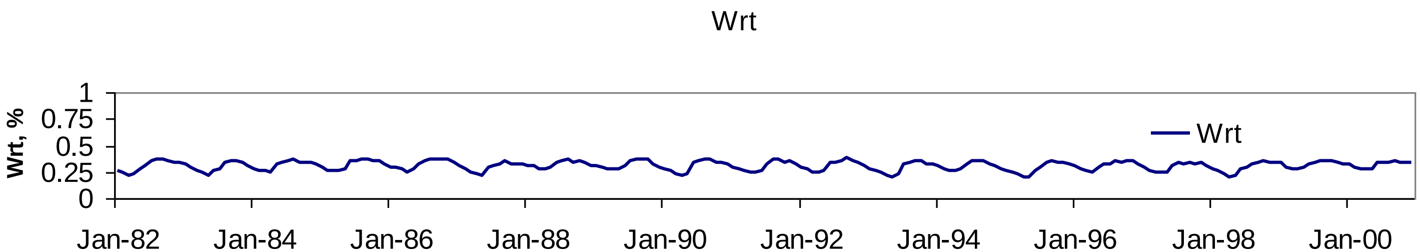
RAIN



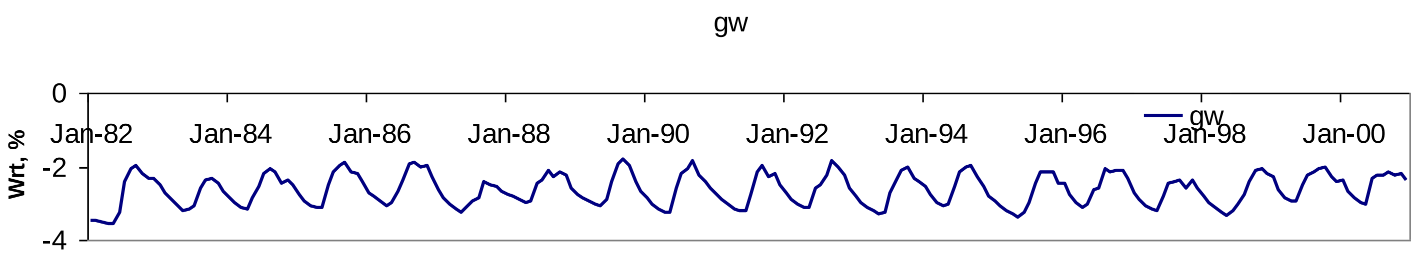
DISCHARGE



SURFACE SOIL MOISTURE



ROOT ZONE SOIL MOISTURE



GW LEVEL

Drought Quantification using the Standard Anomaly Index (SA)

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

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

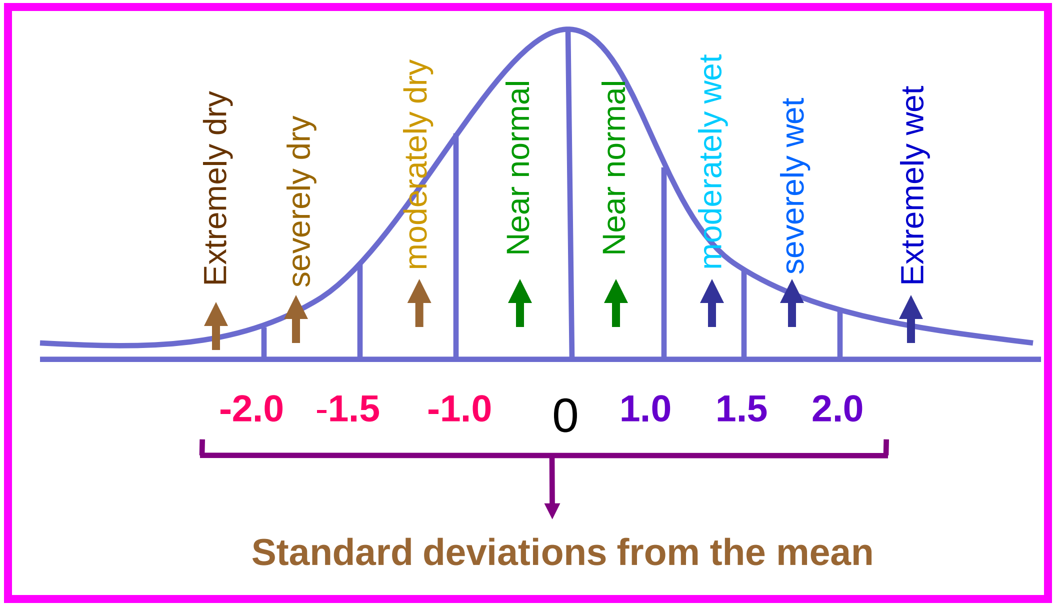
2) Normalize by calculating SA

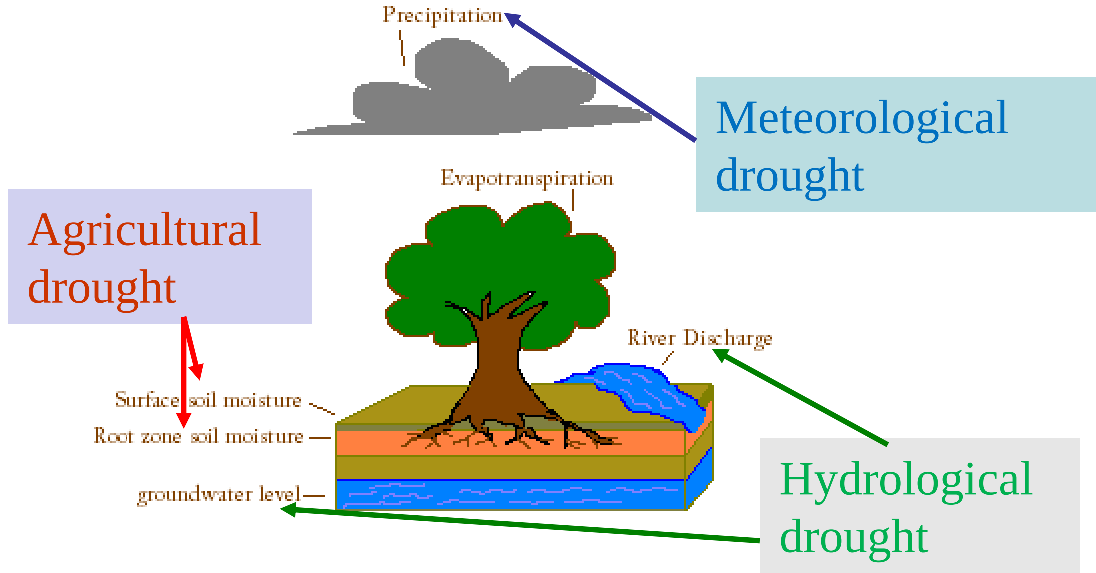
$$SA = Z = \frac{x_{transformed} - \bar{x}_{transformed}}{\sigma_{transformed}}$$

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

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

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

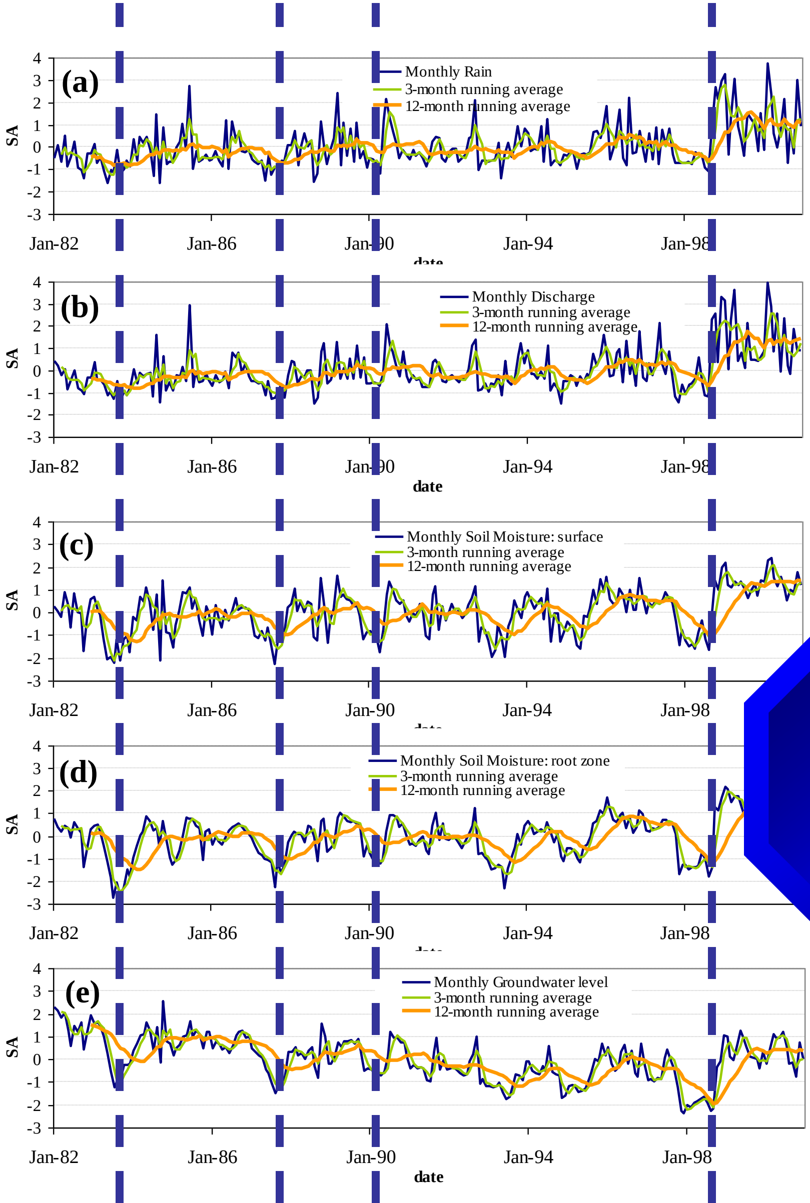


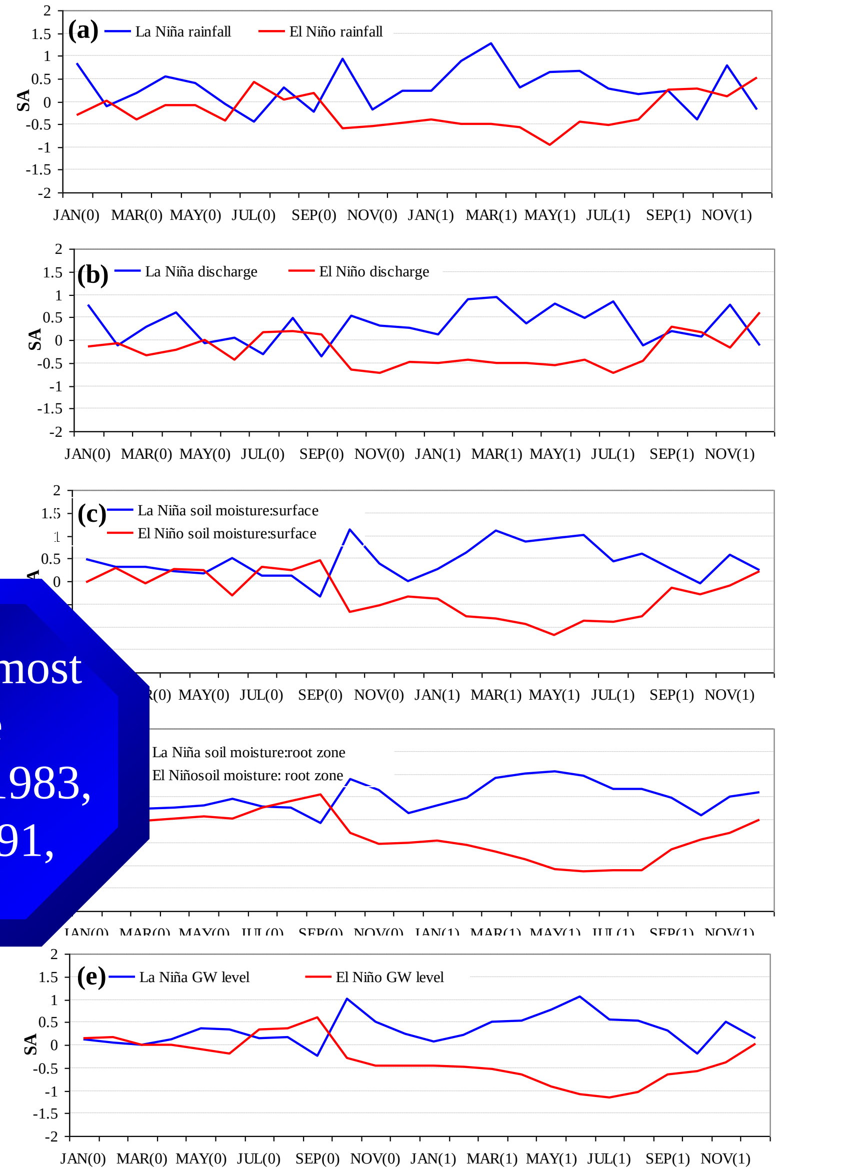


Jaranilla-Sanchez, P. A., et al. (2011)

Temporal SA: Philippines

Drought From literature and reports: 1982, 1983, 1987, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998





Reported most severe droughts: 1983, 1987, 1991, 1998

P-values for the student t-test comparing a. El Niño and b. La Niña two-year composites for rainfall, discharge, soil moisture at the surface, soil moisture at the root zone and groundwater using SA. (α=0.05).

a.El Niño vs. La Niña: using SA for year 1

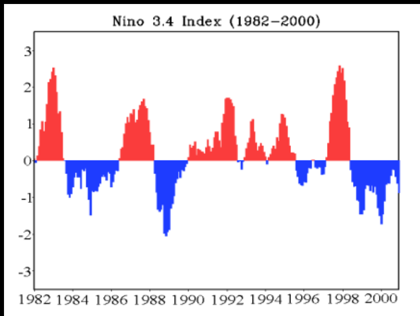
Drought Parameter	Jan (1)	Feb (1)	Mar (1)	Apr (1)	May (1)	Jun (1)	Jul (1)	Aug (1)	Sep (1)	Oct (1)	Nov (1)	Dec (1)
Rainfall	0.22	0.98	0.34	0.46	0.32	0.21	0.08	0.98	0.92	**<0.01**	**0.02**	0.16
Discharge	0.25	0.65	0.33	0.38	0.93	0.17	0.37	0.99	0.71	**<0.01**	**<0.01**	0.13
Soil Moisture (surface)	0.30	0.67	0.54	0.86	0.65	0.07	0.99	0.59	0.59	**<0.01**	**0.01**	0.41
Soil Moisture (root zone)	0.63	0.52	0.54	0.70	0.90	0.40	0.94	0.50	0.36	**0.01**	**0.01**	0.13
Groundwater level	0.89	0.67	0.64	0.84	0.84	0.61	0.61	0.15	0.09	0.15	0.21	0.42

b. El Niño vs. La Niña: using SA for year 2

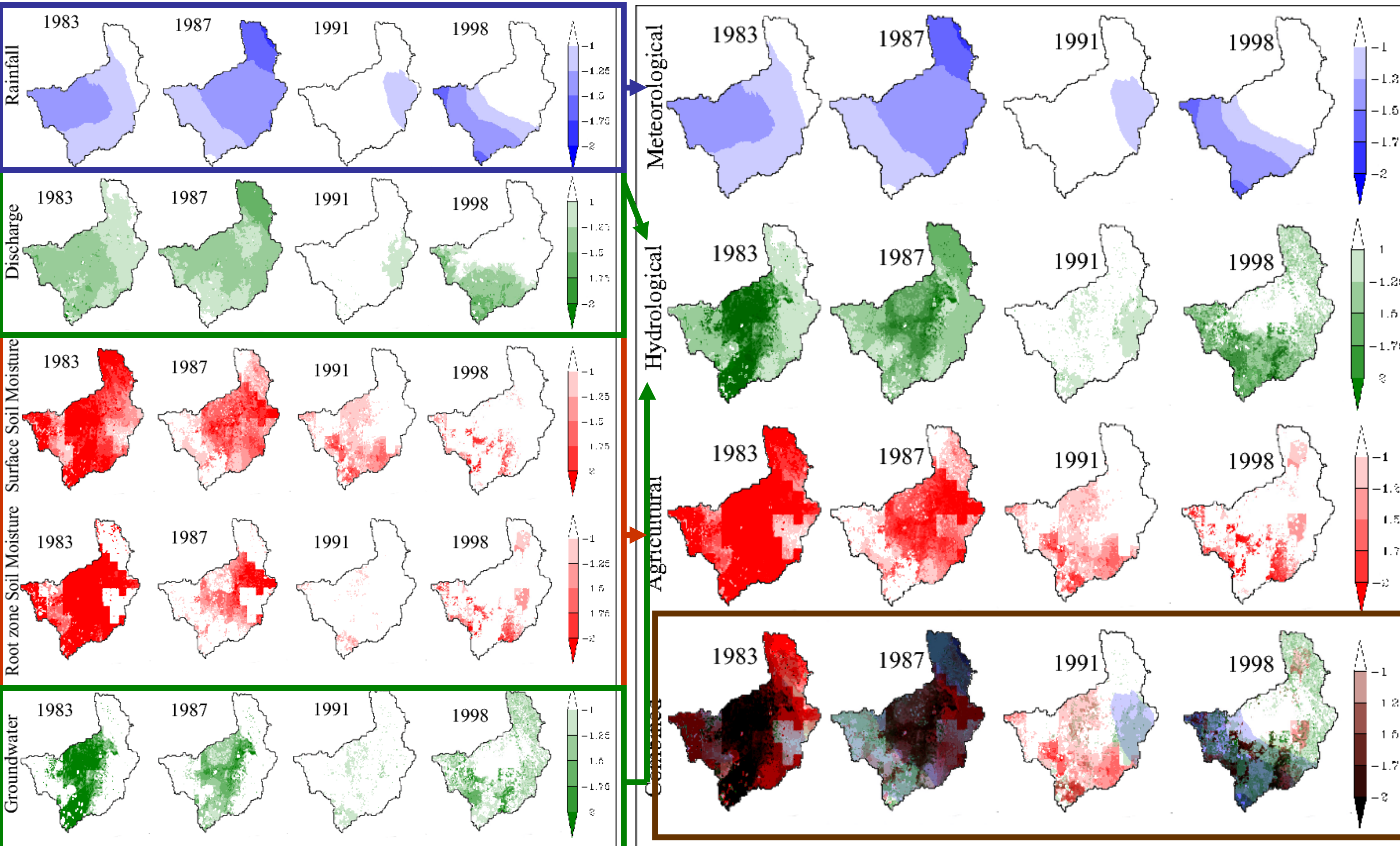
Drought Parameter	Jan (2)	Feb (2)	Mar (2)	Apr (2)	May (2)	Jun (2)	Jul (2)	Aug (2)	Sep (2)	Oct (2)	Nov (2)	Dec (2)
Rainfall	0.17	0.18	**0.04**	0.13	**0.01**	0.19	0.17	0.42	0.74	0.33	0.28	0.41
Discharge	0.07	0.19	0.07	**0.05**	**0.04**	0.35	**0.01**	0.39	0.92	0.95	0.05	0.40
Soil Moisture (surface)	0.10	**0.03**	**0.01**	**<0.01**	**<0.01**	**<0.01**	**0.01**	**0.03**	0.37	0.37	0.39	0.90
Soil Moisture (root zone)	0.11	0.06	**0.02**	**<0.01**	**<0.01**	**<0.01**	**0.01**	**0.01**	0.10	0.20	0.27	0.34
Groundwater level	0.40	0.30	0.14	0.07	**<0.01**	**<0.01**	**<0.01**	**0.01**	0.19	0.50	0.10	0.68

List of warm (El Niño) and cold (La Niña) ENSO events considered in the two-year composites for the years 1982-2000 *(Jaranilla-Sanchez et al., 2009, JSCE).*

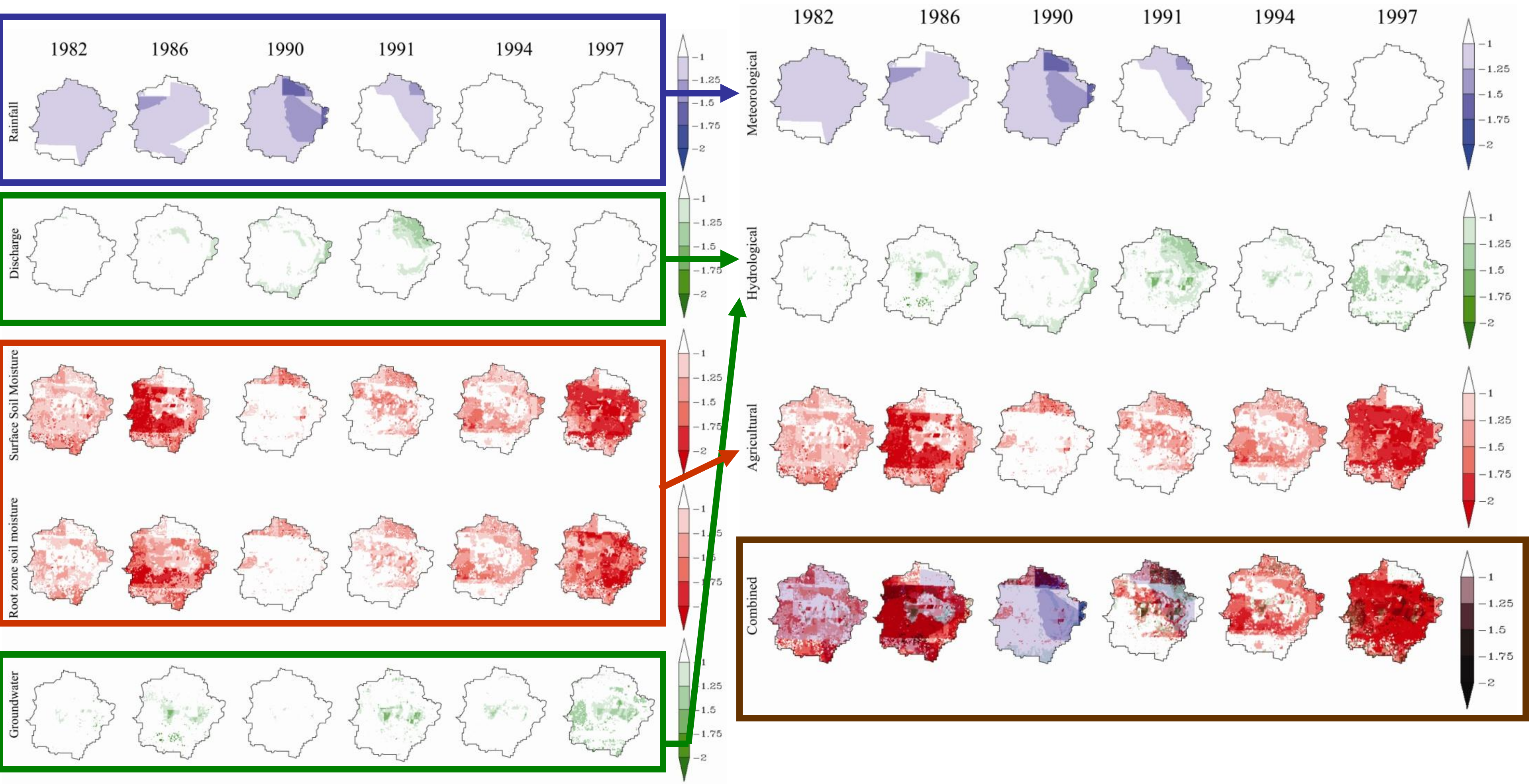
Warm ENSO events, or El Niño *(6 cases)*	1982/83, 1986/87, 1991/92, 1992/93, 1994/95, 1997/98
Cold ENSO events, or La Niña *(4 cases)*	1984/85, 1988/89, 1995/96, 1999/2000



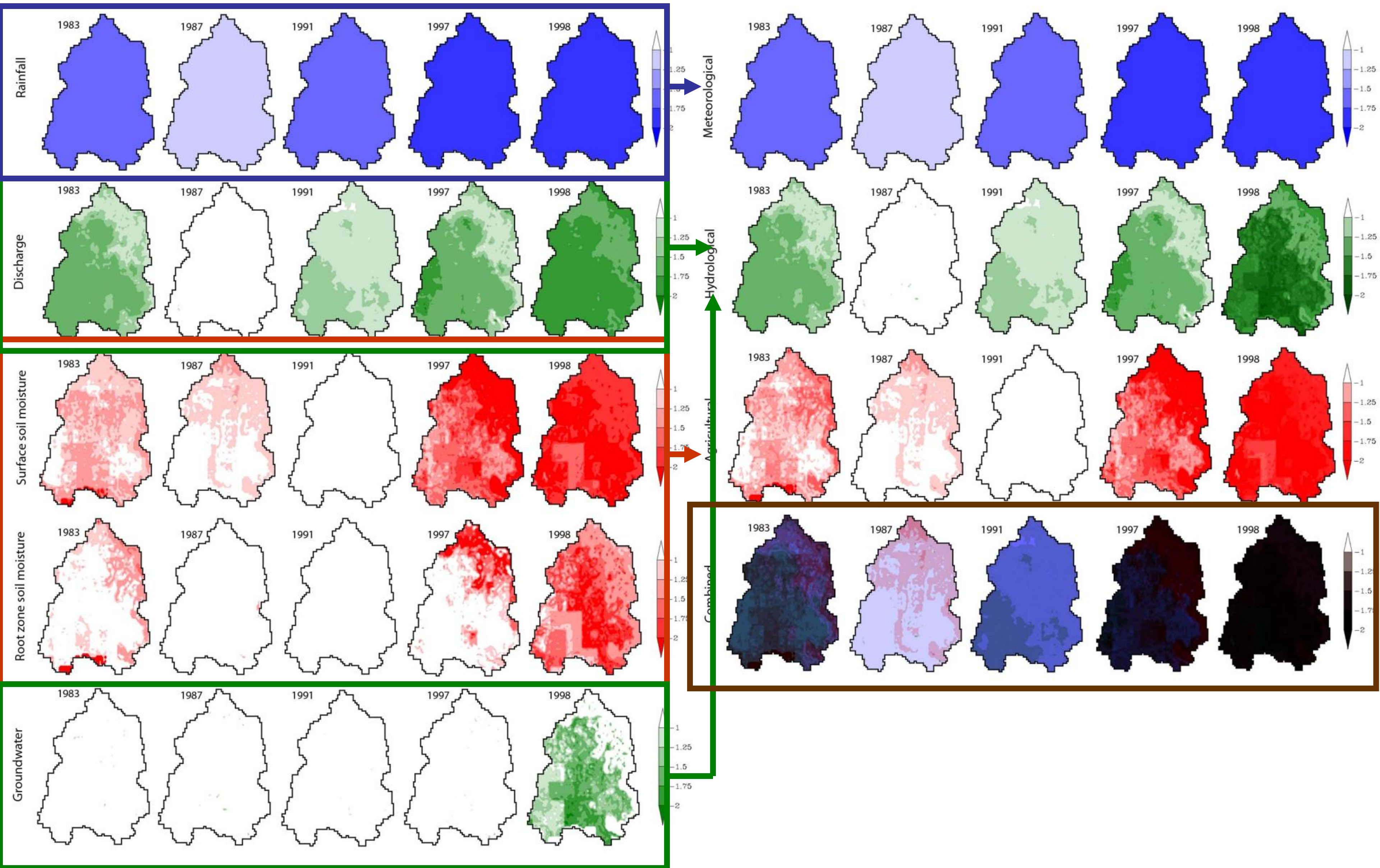
SPATIAL SA FOR THE PAMPANGA RIVER BASIN, PHILIPPINES



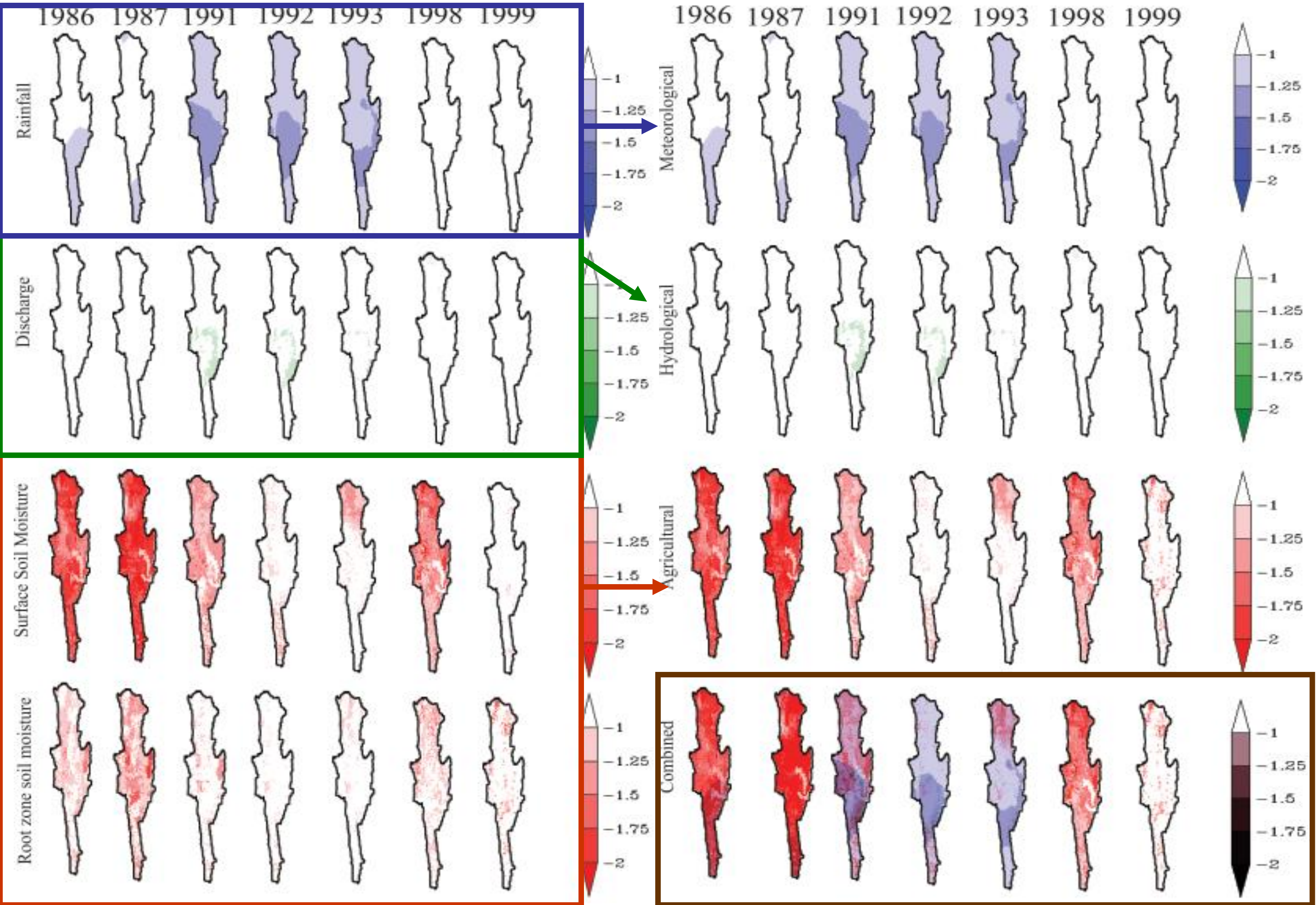
SPATIAL SA FOR THE UPPER CITARUM RIVER BASIN, INDONESIA



SPATIAL SA FOR LANGAT WATERSHED, MALAYSIA



SPATIAL SA FOR PING RIVER BASIN, THAILAND



TIME DELAY EFFECTS DURING ENSO YEARS ON THE HYDROLOGICAL PARAMETERS

Basin	First year	Second Year	Time delay
Pampangga	Oct-Nov	Feb-August	1 to 7 months
Langat	April-August	Dec	1 to 4 months
Ping	--	--	--
Upper Citarum	--	June-August	1 to 3 months

List of warm (El Niño) and cold (La Niña) ENSO events considered in the two-year composites for the years 1982-2000 (*Jaranilla-Sanchez et al., 2009, JSCE*).

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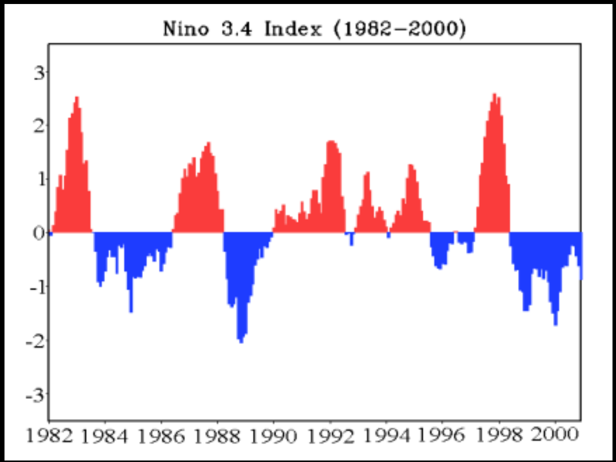
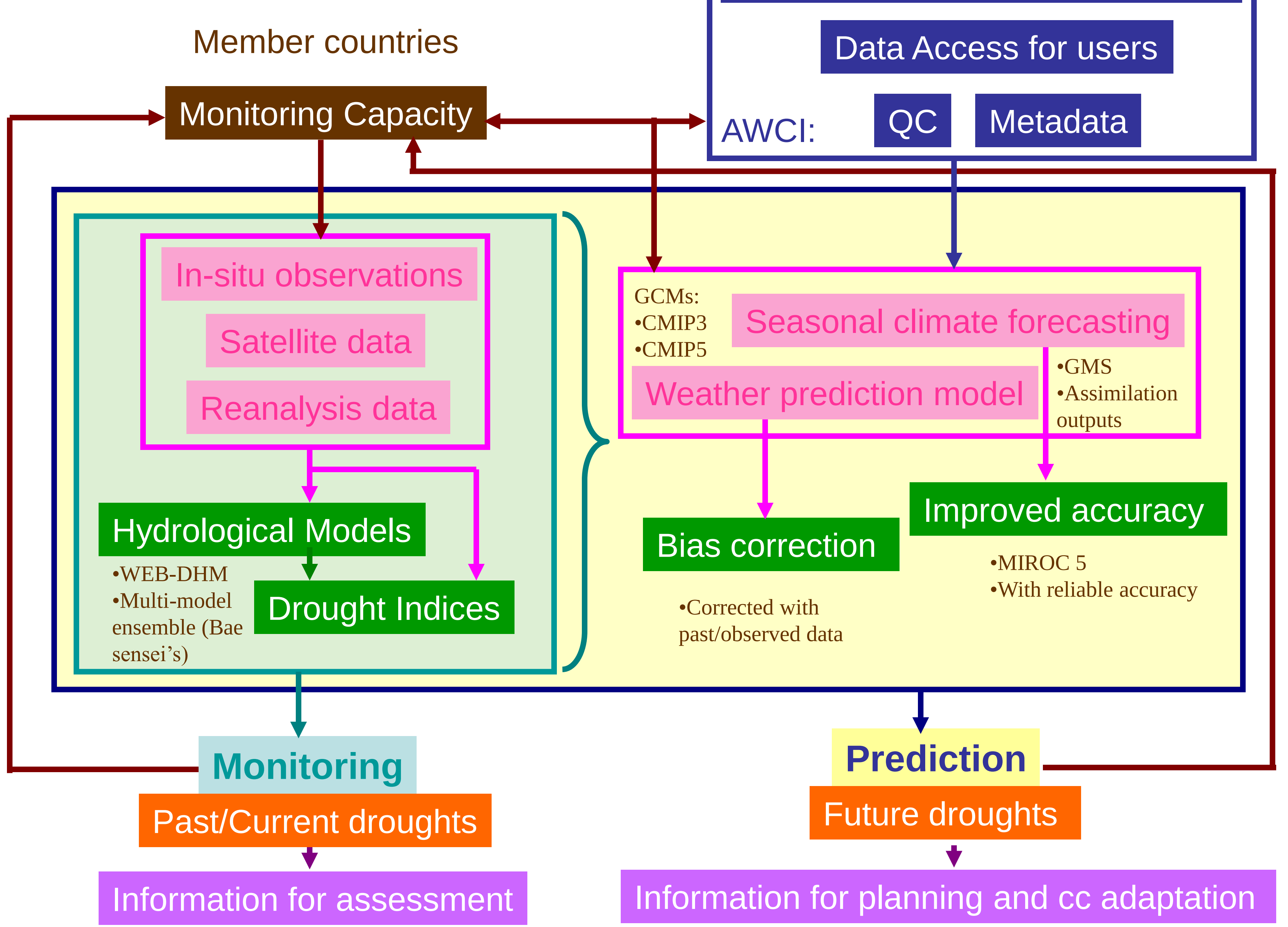


Drought Prediction Details:

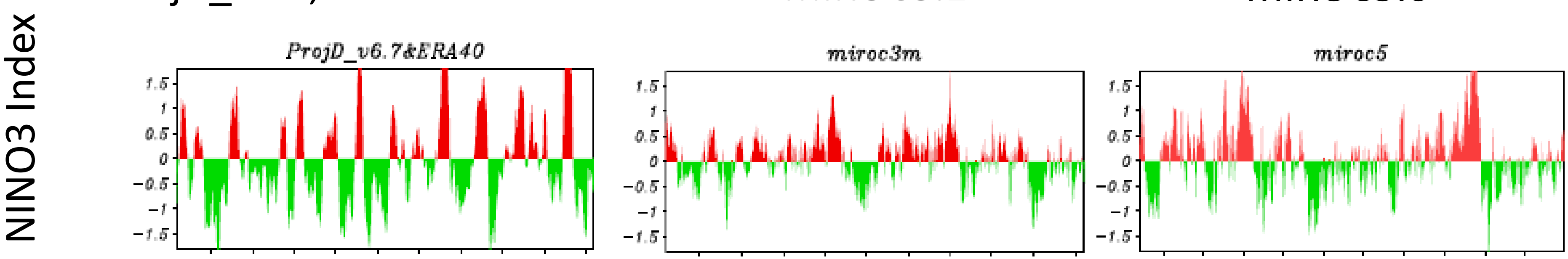


SEASONAL CLIMATE FORECASTING (SCF)

Dataset: MIROC (SPAM) by CCSR
MIROC by NIES-JAMSTEC

El Niño year (June 1983 – August 1983)
No Drought months on a mild El Niño year (March – May 1991)
El Niño year (September – November 1997)
La Niña year (December 1999- February 2000)

ProjD_v6.7, ERA40 | MIROC3.2 | MIROC5.0



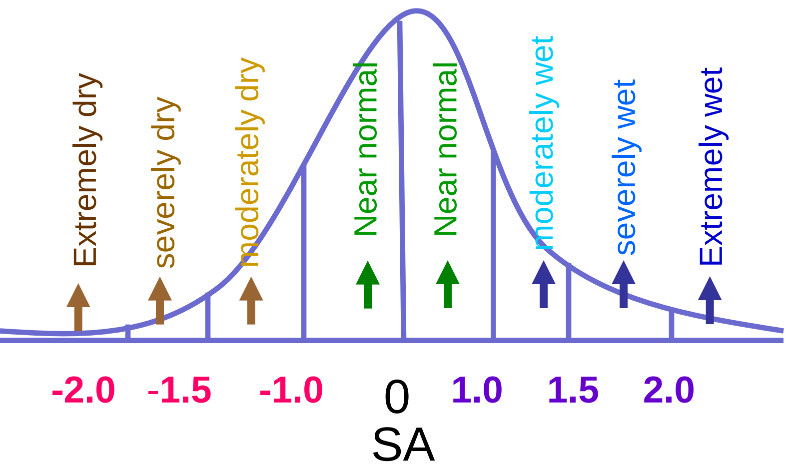
Figures were reproduced from Kimoto, et al. presentation 2010.

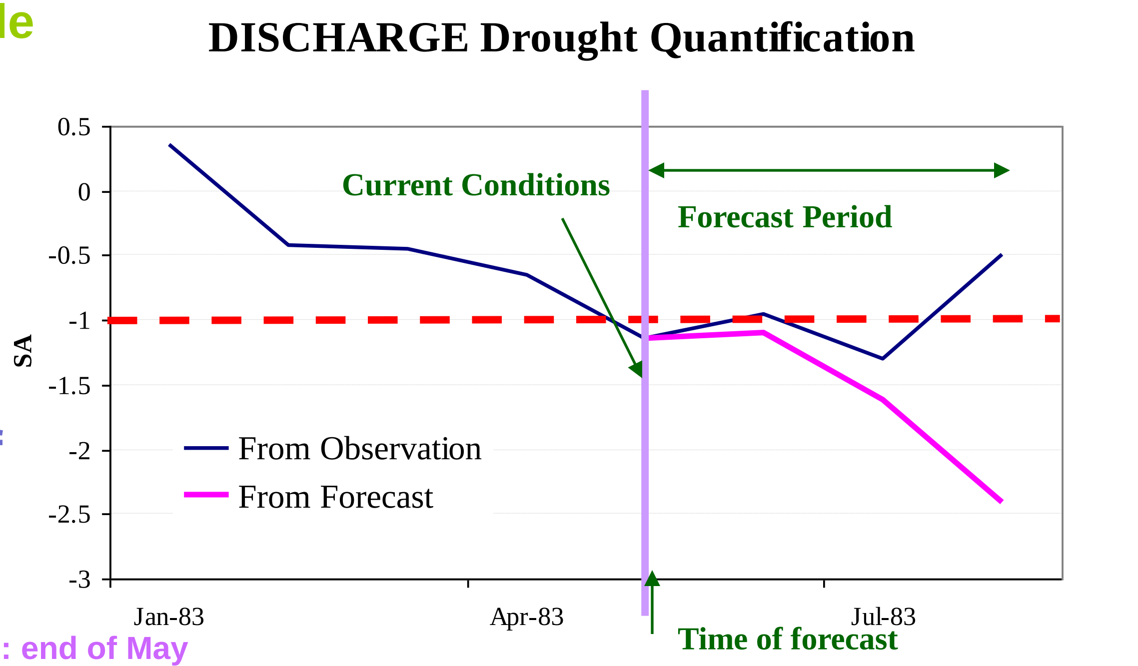
Drought Quantification: *hydrological drought* (Discharge)

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

Too extreme because high rainfall cannot be captured by the forecast in this grid scale





*purple line indicates beginning of forecast month: end of May

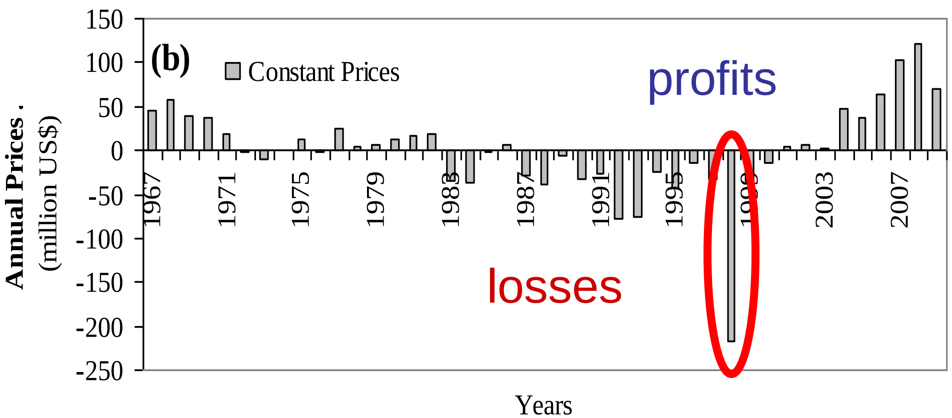
Discharge: Observed VS. SCF

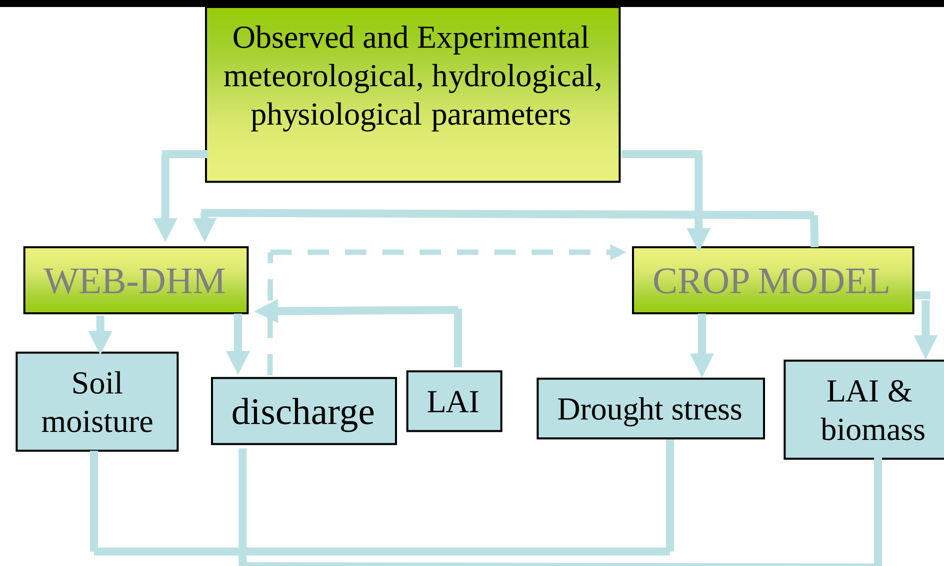
Months	**1st**		**2nd**		**3rd**	
Year	**Observed**	**SFC**	**Observed**	**SCF**	**Observed**	**SCF**
1983	↗ (red)	↗ (red)	↘ (red)	↘ (red)	↗ (green)	↘ (red)
1991	↘ (green)	↘ (green)	↗ (green)	↗ (green)	↘ (green)	↘ (green)
1997	↘ (green)	↘ (red)	↘ (green)	↘ (red)	↘ (red)	↘ (red)
1999-2000	↗ (green)	↘ (green)	↗ (green)	↗ (green)	↗ (blue)	↗ (blue)

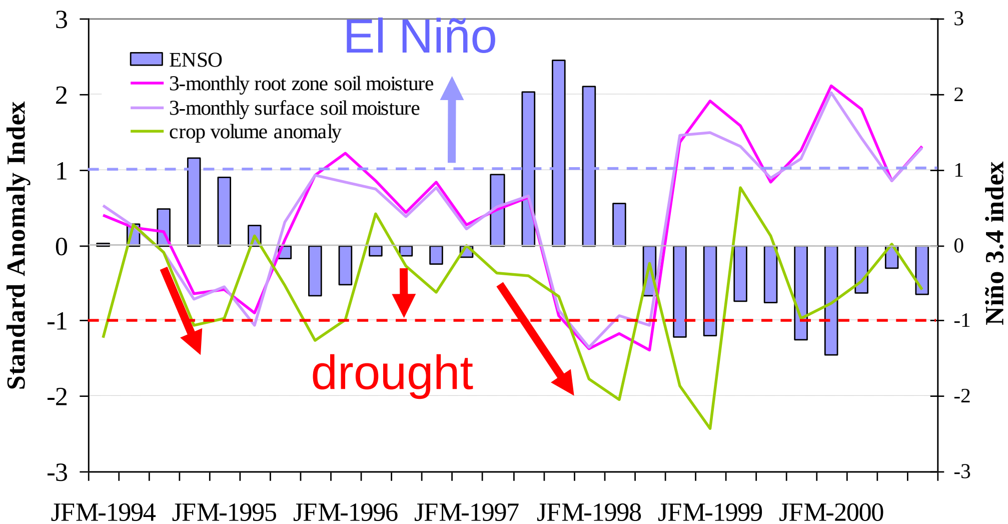
ARROW Legends: **red**= drought; **green**=normal; **blue**=wet

e.g. increase towards drought conditions ↗ (red)

Sample Application: Agricultural Production and Drought Monitoring







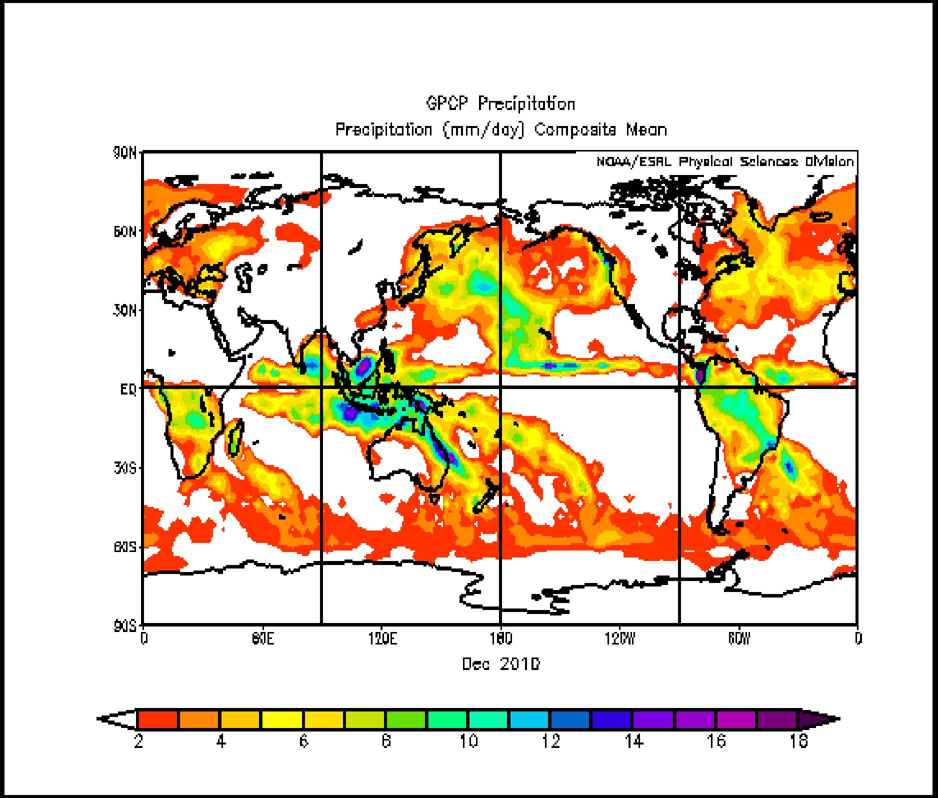
Sample output for rice production simulation:

year	Actual	simulated
1983	--	7012 kg/ha
1987	--	7247kg/ha
1991	--	6900kg/ha
1998	34164 metric tons (BAS, 2011)	6903kg/ha (34116 metric tons)

FUTURE???

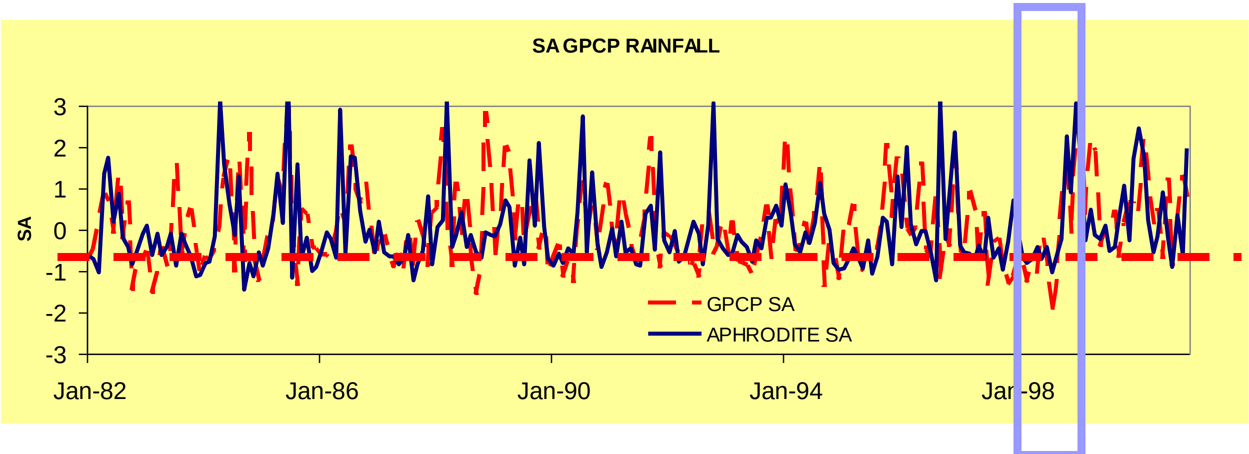
Determining drought tendencies from global datasets

- GPCP
- Global Precipitation Climatology Project monthly precipitation
- 1979-present
- combines observations and satellite precipitation data
- Lat-lon grid: 2.5° x2.5° global grids
- 88.75ºN - 88.75ºS, 1.25ºE - 358.75ºE

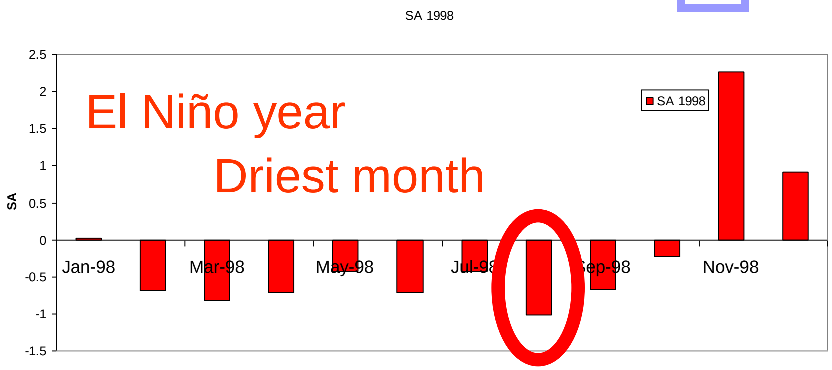


http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html

On using global datasets for drought Analysis
GPCP, Cloud Cover: dry years vs. wet years

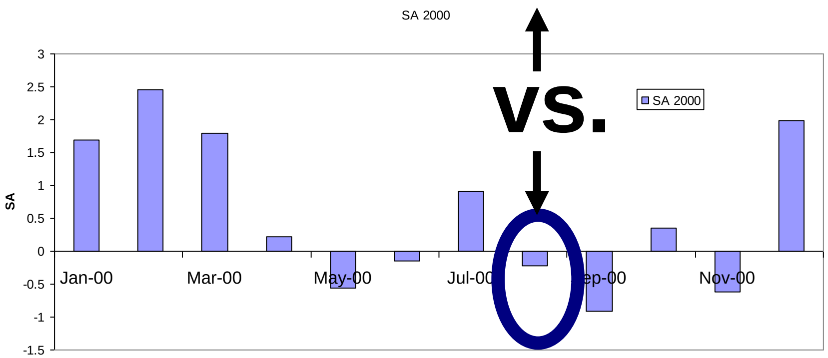


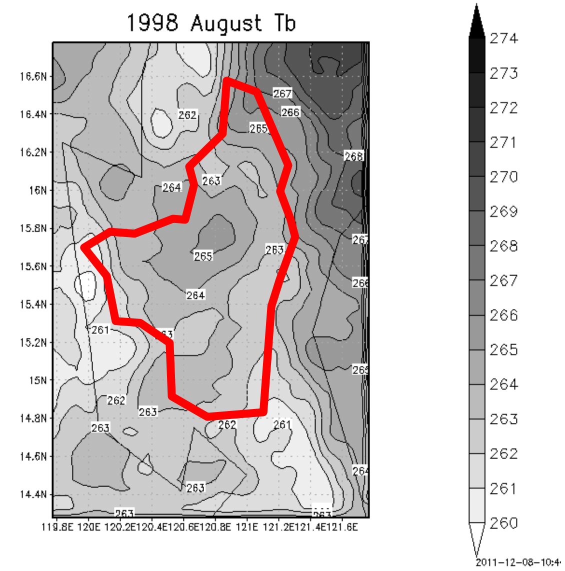
SA: 1998

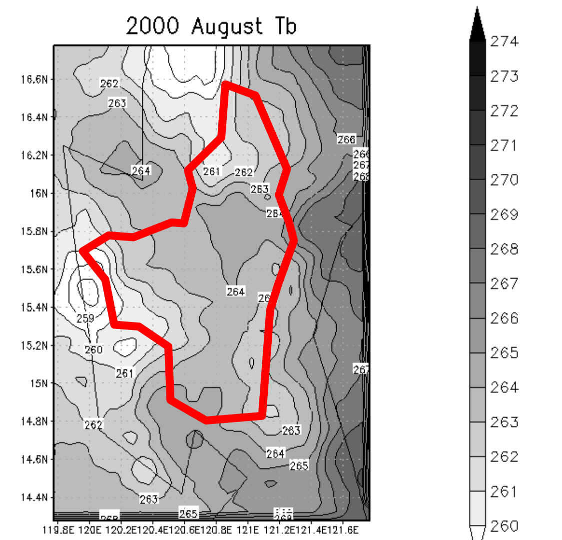


vs.

SA: 2000







GMS5 IR1 brightness temperature

Useful information we can get from this workbench: for Asia

Monitoring:
- When?
- Where?
- How severe?
- Timing?

Prediction:
- Increasing/decreasing trend? (frequency/severity)

What can we do?

Basin appropriate planning and adaptation

Biodiversity

Water resources

Energy

Economics

Society

others