The Importance of ENSO Information in Water Resources Management:
Experience from the Pacific Islands and Bangladesh

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OBJECTIVES

(ENSO-based climate information products for Water Resources management (WRM))

- Overview of ENSO and Climate Variability
- **ENSO Impacts on WRM:** USAPI and Bangladesh
- **ENSO-based Forecasts for WRM:** USAPI and Bangladesh
EL NIÑO-Southern Oscillation (ENSO)

General Overview

ENSO refers to the effects of a band of sea surface temperatures which are anomalously warm or cold for long periods of time that develops off the western coast of South America and causes climatic changes across the tropics and subtropics.

The "Southern Oscillation" refers to variations in the temperature of the surface of the tropical eastern Pacific Ocean, with warming known as El Niño and cooling known as La Niña, and in air surface pressure in the tropical western Pacific.
El Niño/La Niña—Southern Oscillation (ENSO)  
(Develops in JAS, strengthens through OND, and weakens in JFM)

- **El Nino**—major warming of the equatorial waters in the Pacific Ocean
  - The anomaly of the SST in the tropical Pacific increases (+0.5 to +1.5 deg. C in NINO 3.4 area) from its long-term average;
  - A high pressure region is formed in the western Pacific and low-pressure region is formed in the eastern Pacific—this produces a negative ENSO index (SOI negative).

- **La Nina**—major cooling of the equatorial waters in the Pacific Ocean
  - The anomaly of the SST in the tropical Pacific decreases (-0.5 to -1.5 deg. C in NINO 3.4 area) from its long-term average;
  - A high pressure region is formed in the eastern Pacific and low-pressure region is formed in the western Pacific—this produces a positive ENSO index (SOI positive).
La Niña and El Niño

La Niña
(strengthened trade winds)

(Warm SST)
low pressure system

El Niño
(weakened trade winds)

(Cold SST)
high pressure system

Normal

Warm

Cool
The numbers of El Niño/ La Niña years have considerably increased in the recent years. Scientists argue that this is the result of climate variability and change (instability) and this trend is likely to continue in future as we are in a stage of changing climate; So, more frequent extreme events are likely in the future—
El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.

For more information on El Niño and La Niña, go to: http://iri.columbia.edu/ENSO


http://www.climate.gov/news-features/department/8443/all
El Niño and Sea Level

From March 2014 to May, sea level in Yap has dropped from +7.2 inches to +2.7 inches and about 9 inches drop in Malakal!
El Niño and Tropical Cyclones

El Niño shifts TC genesis Eastward over the North and South Western Pacific

- Less TC activity
  - Australia
  - Philippines
- More TC activity
  - Tropical Pacific
  - Hawaii
  - American Samoa

From the Royal Netherlands Meteorological Institute
http://www.knmi.nl/research/global_climate/enso/effects/
Water Crisis: Global Perspectives

• We are in the midst of a global freshwater crisis; we can live as much as 30 days without food but only seven days without water;

• Global water consumption is doubling every 20 years, and the demand to outstrip supply by 2040;

• By 2030, nearly half of the world's population will inhabit areas with severe water stress;

• The rush to control water resources is gathering momentum around the planet;

• Now the question is, if water is the kind of precious commodity that oil became in the 20th century, can delivery of clean water be possible to all in an age of climate change? OR money to be made in a time of water scarcity?
Conflict risk associated with ENSO

Drought is widely believed to relate to conflict!

a) Time series of NINO 3 and Annual Conflict Risk (ACR) for the teleconnected group

b) Linear and non-parametric fit of ACR against NINO 3

c) Number of conflict onsets in teleconnected countries during
   - El Niño, solid bars
   - La Niña, hatched bars

Global hotspots of water problems/conflicts

- Ogallala Aquifer: Cut off
- Mexico City: Sinking
- Spain: Water diversion
- Chad: Shrunk by 95%
- River Nile: Water sharing
- Israel/Jordan: River Jordan
- Iraq: 90% of wetlands loss
- Turkey: Water-rich
- Aral Sea: Toxic desert
- China: Flood (south), drought (north)
- Indus River: Pakistan and India
- Ganges: Bangladesh and India
- Brahmaputra/Meghna: Bangladesh/India/China/Bangladesh
El Niño Impacts: Past and Present!
Summary

• **El Nino—Major warming** of the equatorial waters in the Pacific Ocean
  • SST in the tropical Pacific increases (+0.5 to +1.5 deg. C in NINO 3.4 area) from its long-term average; **Weakened trade winds**

• **La Nina—Major cooling** of the equatorial waters in the Pacific Ocean
  • SST in the tropical Pacific decreases (-0.5 to -1.5 deg. C in NINO 3.4 area) from its long-term average; **Strengthened trade winds**

• As compared to 1950-1980, the numbers of El Niño/ La Niña years have considerably increased in 1981-2015. Scientists argue that this, at least in part, is the result of climate change (instability);

• **Huge global impact**
  • Physical Consequences: Impacts are visible in sea level, rainfall, and TC activities.

  • Social Consequences: Drought is widely believed to relate to conflicts—
    • Civil conflicts in the tropics doubles during EN year relative to a LN year
    • 21% of conflicts are contributed by EN/LN alone (Nature 476, 25 Aug 2011)
EL NIÑO and La Ninã

Impacts: USAPI and Bangladesh
(Two ENSO-sensitive ‘hotspots’ of climate hazards)
Study Area: Pacific Islands

USAPI stations: Open circle
non-USAPI stations: Black circle
Pacific Islands are the most vulnerable to climate variability and change—

Economic plans are dependent on climate-sensitive sectors—

Water resources is stressed—

ENSO has significant impact on the overall development—
• Water is Gold: USAPI Region
Impacts of ENSO: USAPI Region

1997-1998 El Niño

- Low rainfall/low sea level
- Water rationing in Majuro
- Palau experienced 9-month drought

2007-2008 La Niña

- Heavy rainfall/high sea level
- Damage of roads and infrastructures
- Impacts on agriculture/aquaculture through inundations; decline in soil quality
- Changes in surface/groundwater quality
‘Hot Spots’ of Climate Hazards: Bangladesh

Climate variability/change
– Water scarcity: A looming crisis?

Water availability in the Ganges, Brahmaputra Meghna region – ‘Comparison between current situation and the year 2050’

2030: -3% in winter, +11% in monsoon,
2050: -37% and +28%

India

Bangladesh

2000

Water availability

Demand >> availability
Demand > availability
Demand = availability
Availability > demand
Basin-wide rainfall-runoff is the primary cause of flooding;
Approximately 20 percent of the country is flooded annually;
In a major flood, non-crop damages are higher than crop damage;
Water resources are already stressed;
Economic plans are dependent on climate-sensitive sectors.
EL NIÑO and La Ninã

ENSO-based **Seasonal** Forecasts for Water Resources Management: USAPI and Bangladesh

*ENSO-based seasonal forecasts are successful in the USAPI region—Bangladesh can also benefit from it!!!*
PEAC’S Coordinated Research and Operational Activities

**Demand:** In 1990, the Government in the USAPI region expressed their need for customized climate services—tailored understandable technical information products for climate sensitive sectors.

I. The spatial resolution of large-scale climate models are too course to apply to these islands directly;

II. At PEAC, the output of the large-scale model data (i.e., ENSO) are used to develop statistical model for sea level and rainfall forecasts on seasonal time-scales.
SST Composites for low and high sea level years—Predictability

Guam

Probabilistic forecasts for sea level variability is possible well ahead of time....
Sea level variability is correlated to SSTs in the Pacific on seasonal time scales….
a) JFM_SST (30.5%)
b) AMJ_SST (26.2%)
c) JAS_SST (29.0%)
d) OND_SST (31.5%)
With a lead time of one or two seasons, the forecasts for all the seasons are skillful.
• CCA analysis can be generalized to a higher dimensional technique in which more than one predictor variable is used. By adding zonal winds we observe an increase in skill in our longer range forecasts.
Consolidated Seasonal Rainfall Forecasts

- In the Pacific Islands “Water is Gold”
- PEAC provides probabilistic outlook of seasonal rainfall forecasts from output of six dynamical model and two statistical models (including PEAC CCA)
  - Visual interpretation of current and forecast conditions
- Forecasts are used to plan water resources, anticipate tourism, plan crops, prepare for a drought situation etc.
As part of hazard management activities, PEAC has effectively developed a 5-stage operational model to provide ENSO-based climate forecasts and advance warnings to the USAPI region...

- **Stage 1: Forecast preparation**
  - predicts the occurrence and magnitude of an event (e.g., drought, flooding) in advance;

- **Stage 2: Interpretation and message formulation**
  - identifies the probable impacts of an event upon vulnerable communities;

- **Stage 3: Warning preparation and dissemination**
  - communicates and distributes the warning messages to disaster management agencies and vulnerable communities;

- **Stage 4: Response and feedback**
  - generates actions by concerned agencies and threatened communities for protection against hazards in response to warning;

- **Stage 5: Review and analysis**
  - continuously monitors the performance of various components of the FWRS for possible improvement.
Climate Forecasting, Warning and Response System (CFWRS)

1. **Stage 1** Forecast preparation
   - Forecast A
   - Forecast B
   - Consensus

2. **Stage 2** Interpretation
   - Warning messages

3. **Stage 3** Chain of dissemination
   - The Media
   - Research centers
   - Government agencies

4. **Stage 4** Response
   - Local Authorities, USAPI
   - Feedback

5. **Stage 5** Review and Analysis
   - Choices and responses
     - Farmers
     - Vulnerable Groups
   - Monitoring of all ‘feedback links’
Monthly Teleconference

- PEAC forecasts (i.e., sea-level, rainfall, tropical cyclone etc.) are placed for discussion within a PEAC-sponsored teleconference;
- The WSO from each of the island communities is invited to attend this conference;
- Representatives from the forecasting centers are also invited -- past, present, and future climatic conditions are brought up;
- A consensus forecast is achieved;
- Seasonal forecasts for rainfall, TC, are expressed as probabilities of occurrence – SL in deterministic format.

http://www.prh.noaa.gov/peac/update.php
Summary

This ENSO-based seasonal climate outlook has significantly enhanced the local governance capacity to address water related disasters.

- The output of the large-scale model data (i.e., ENSO) can be used to develop statistical forecasting scheme on seasonal time-scales;

- 5-stage research and operational model--(i) forecasting, (ii) interpretation and message formulation, (iii) warning preparation and dissemination, (iv) responses and feedback, and (v) review and analysis--is an efficient way to generate consensus seasonal climate outlook for hazard management;

- Interactive dialogue with “users” is essential and should be continuous (“eyeball-to-eyeball” communication important);
Bangladesh floods are connected to ENSO—El Niño to lower and La Niña to higher than normal flooding.

>>>1988 and 1998 are two ‘rapid ENSO transition year’
Table 1: ENSO Index and seasonal rainfall deviations in the greater Ganges-Brahmaputra-Meghna basins in Bangladesh

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<th>Jun</th>
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### ENSO and Seasonal Flooding

![Chart showing flood affected area (%) and deviation from normal for El Nino (Strong), El Nino (Moderate), La Nina (Strong), and La Nina (Moderate).]
The rainfall and stream-flows in Bangladesh is connected to variation in SST in the Pacific.
Composites for wet and dry—Predictability

Probabilistic flood forecasts is possible well ahead of time....
Flooding is correlated to SSTs in the Pacific on months-to-seasonal time scales....
Conclusions

- Climate variability in the USAPI region and Bangladesh are sensitive to ENSO;
- ENSO-based seasonal forecasts are successful for WRM in the USAPI region---Bangladesh can also benefit from it;
- As an adaptation strategy, ENSO-based climate information products are helpful for longer time-scale water resources management.