
John Bolten (NASA GSFC)
Motivation

Flooding in the Mekong

- Floods are among the **most common and damaging** natural disasters
- Coastal and low-lying regions are particularly susceptible*
- Climate change effects are likely to increase flood risks

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Flooding in the Mekong

• Floods are among the most common and damaging natural disasters
• Coastal and low-lying regions are particularly susceptible*
• Climate change effects are likely to increase flood risks

It is critical to understand the impacts of flood events to improve disaster response and flood mitigation at local and regional levels

The Water Landscape

- How can we reduce our uncertainty propagation of hydroclimatic extremes?
- For example, will a meteorological drought lead to a hydrological or agricultural drought? — How? When? Where?
- How do phases in P-E relate to soil moisture, surface drainage, base flow, groundwater storage, river discharge, and vegetation productivity?

Image Credit: Chagnon, 1989
Closings the Terrestrial Water Budget Using Remote Sensing

\[ \Delta W / \Delta t = E + T - P - \text{div} \, Q \]

Atmospheric Water Balance

**Energy Balance**

\[
\text{Rn} + H + \text{LE} + G = 0
\]

\( \text{Rn: Radiation} \)
\( \text{Shortwave: GOES} \)
\( \text{Longwave: AIRS/AMSU} \)

\( H, G: \text{Surface Temperature} \)
\( \text{AIRS, AVHRR, MODIS} \)

\( \text{Clouds: GOES} \)
\( \text{Water Vapor (LE): AIRS/AMSU} \)

The land surface water and energy budgets are linked via evapotranspiration.

**Water Balance**

\[
\Delta Z \frac{\Delta \theta}{\Delta t} = P - E - T - R
\]

\( \theta = \text{Soil Moisture} \)
\( \text{Microwave Radiation: AMSR, SMOS, SMAP} \)

\( P = \text{Precipitation} \)
\( \text{Microwave Radiation: SSM/I, TRMM, GPM} \)

\( E = \text{Evaporation/Surface Humidity} \)
\( \text{Infrared & Microwave Radiation: AIRS/AMSU} \)

\( T = \text{Transpiration/NDVI} \)
\( \text{Visible & NIR: MODIS, AVHRR, GLI, VCL} \)
\( \text{Vegetation: NDVI, AVHRR, MODIS, Landsat} \)

\( R = \text{Runoff/River Level} \)
\( \text{Lasers & Radar: TOPEX, Radarsat, SWOT*} \)

Total Water/Groundwater: GRACE


NASA's Applied Remote Sensing Training Program

Presenter: John Bolten (GSFC)
Satellites, Sensors, and Timelines

**Atmosphere**
- Terra/Aqua (AIRS): water vapor profile, clouds, air temp profile, surface temperature, 12.5 km (2000 - present)

**Total Water**
- GRACE (2002-2017)
- GRACE-FO: 100 km (2018-present)

**Rainfall**
- TRMM: 25 km, 3-hr (1998-2015)
- GPM: 10 km, 30 min (2014 – present)

**Soil Moisture**
- Aqua (AMSR-E): c-band radar (2002-2015);
  (AMSR): 25 km (2002-2011)
- SMAP: L-band radar (2015); 36 km (2015-present)
- SMOS: 25 km (2009-present)

**Wetness**
- Nimbus-7 (SMMR): C-band 150 km (1978 – 1987)
- DMSP-F8-13 (SSM/I) and DMSP-F15-18 (SSMIS): wetness, rainfall, clouds 12-50 km (1987–present)

**Rainfall**
- NOAA-15 (AVHRR): NDVI, surface temperature 4 km (1980 - present)
- Terra/Aqua (MODIS): NDVI, surface temperature 1 km (2000 - present)

**Vegetation**
- Landsat: Vegetation, Land-Use Land Cover 30 m
Objective

Improved & Guided Decisions for Water Resources Management

Tools and Models

Remote Sensing/In-Situ Data Products

SERVIR Mekong partners and collaborators feedback and contributions
Hydrologic Decision Support System for the Lower Mekong River Basin

- The LMRB (drainage area of ~ 495,000 km²) SWAT Model setup closely follows MRC sub-basin configuration [Rossi et al., 2009]
- A digital elevation model (DEM) with 1 arc-sec grid resolution, ASTER was adopted
- Harmonized World Soil Database [FAO et al., 2012], version 1.2 was implemented
- MODIS, NDVI, Landsat TM, and ETM+ data products were used to obtain lower Mekong Basin LULC map

Discharge data obtained from the Mekong River Commission (MRC, www.mrcmekong.org)
Updated discharge data were interpolated from recent observed level data obtained from the Asian Preparedness Disaster Center (ADPC, www.adpc.net)

Rossi, et. al., 2009. Hydrologic evaluation of the lower Mekong River Basin with the soil and water assessment tool model. IAEJ 18, 1-13, http://114.255.9.31/iaej/EN/Y2009/V18/01-02/1
SWAT: Soil and Water Assessment Tool

https://swat.tamu.edu/

- SWAT is a conceptual watershed-scale hydrological model designed to address challenges related to water management, sediment, climate change, land use change, and agricultural chemical yield.
- The SWAT applications range from the field scale to the watershed scale to the continental scale.
- The SWAT model components are hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management.

LMB LULC Types That Can Affect Hydrology and SWAT Hydrologic Modeling Results

- **Agriculture LULC Types**
  - Rain fed vs. irrigated rice (single vs. double-cropped)
  - Other annual crops (e.g., row crops, sugar cane, cassava)
  - Shifting vs. permanent field crop cultivation

- **Forest LULC Types**
  - Mainly broadleaved with different levels of deciduousness
  - Gradient of nearly pristine to highly disturbed forests
  - Bamboo habitats
  - Industrial forest plantations (e.g., rubber)

- **Other LULC Classes**
  - water, barren, urban

Photos of Lower Mekong Basin LULC types were acquired from the Mekong River Commission

Workflow for Deriving LULC Maps

- Landsat data from circa 2011 Landsat dry season mosaic
- 2010 MODIS 32-day NDVIs from dry season used for forest mapping
- All 12 dates of 2010 MODIS 32-day NDVIs used to map agriculture

1997 to 2010 LULC Change Map of LMB - 9 LULC Classes Per Date

The underlaying image above is from Bing aerial/satellite imagery accessed through QGIS.
Project 2010 LULC Map vs MRC Recoded 1997 LULC Map
(e.g., Subset of SB7)

- The 2010 LULC map has multiple permanent agriculture types, while the 1997 LULC map only has one general permanent agriculture type
- The 2010 LULC map has a finer scaled minimum mapping unit vs. 1997 map (0.0625 km$^2$ vs. 0.5 km$^2$)
- The 2010 LULC map also shows more urban areas (bright red on maps above)

Images are from: Remote Sensing 2018, 10, 1910; doi: 10.3390/rs10121910
Summary: Key Points

• The project updated LULC maps for the Lower Mekong Basin that are being used in MRC SWAT models for SBs 1-8
  – 18 total LULC types were mapped for 2010 update of previous 1997 map
• Results of LULC accuracy assessments for SBs 4 and 7 both showed high overall agreements with reference data (80%+)
  – The 2010 LULC map included more permanent crop types than on the 1997 LULC map
  – Rice was mapped on the 2010 LULC map according to number of crops per year
  – MODIS NDVI data from dry season enabled mapping of basic deciduous and evergreen broadleaved forest types
  – Landsat multispectral data from dry season enabled mapping of scarce, finer, scaled LULC types (e.g., urban and open water areas)
• The project’s LULC maps are being used in LMB SWAT models to aid water and disaster management
• For additional information, see paper in Remote Sensing 2018, 10, 1910: doi:10.3390/rs10121910
## SWAT Calibration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Correction factor</td>
<td>\textit{r_Precipitation{SB#s}_pcp} -0.6 0.01</td>
</tr>
<tr>
<td><strong>High Flows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN2</td>
<td>Initial SCS runoff curve number to moisture condition II</td>
<td>\textit{r_CN2.mgt} -10 10</td>
</tr>
<tr>
<td>AWC</td>
<td>Available water capacity of the soil layer</td>
<td>\textit{r_SOL_AWC{_sol} -10 10</td>
</tr>
<tr>
<td>ESCO</td>
<td>Soil evaporation compensation factor</td>
<td>\textit{v_ESCO.bsn} 0.5 0.9</td>
</tr>
<tr>
<td><strong>Base Flows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW_DELAY</td>
<td>Groundwater delay time</td>
<td>\textit{a_GW_DELAY.gw} -30 60</td>
</tr>
<tr>
<td>REVAPMN</td>
<td>percolation to the deep aquifer to occur</td>
<td>\textit{a_REVAPMN.gw} -750 750</td>
</tr>
<tr>
<td>GWQMN</td>
<td>Threshold depth of water in the shallow aquifer</td>
<td>\textit{a_GWQMN.gw} -1000 1000</td>
</tr>
<tr>
<td>GW_REVAP</td>
<td>Groundwater &quot;revap&quot; coefficient</td>
<td>\textit{v_GW_REVAP.gw} 0.02 0.1</td>
</tr>
<tr>
<td>RCHRG_DP</td>
<td>Deep aquifer percolation fraction</td>
<td>\textit{a_RCHRG_DP.gw} -0.05 0.05</td>
</tr>
<tr>
<td>GWHT</td>
<td>Initial groundwater height</td>
<td>\textit{v_GWHT.gw} 0.0 1.0</td>
</tr>
</tbody>
</table>

SWAT model with Remote Sensing Climate Input Data

- Minimum and maximum air temperature processed using GLDAS Noah Land Surface Model L4 3 hourly 0.25 x 0.25 degree V2.0

SWAT Model Streamflow Calibration

- Sequential calibration from Upper Mekong inlet to Kratie, Cambodia

## Remote Sensing and Gauge Driven SWAT Models – Streamflow Comparison

<table>
<thead>
<tr>
<th>Sub Basin #</th>
<th>NSE (RS Driven Model)</th>
<th>NSE (In-Situ Driven Model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB#1 Chiang Sean</td>
<td>0.96</td>
<td>0.91</td>
</tr>
<tr>
<td>SB#2 Luang Prabang</td>
<td>0.94</td>
<td>0.70</td>
</tr>
<tr>
<td>SB#3 Vien Tiane</td>
<td>0.91</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub Basin #</th>
<th>Qerr % (RS Driven Model)</th>
<th>Qerr % (In-Situ Driven Model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB#1 Chiang Sean</td>
<td>0.81</td>
<td>0.53</td>
</tr>
<tr>
<td>SB#2 Luang Prabang</td>
<td>-0.29</td>
<td>2.02</td>
</tr>
<tr>
<td>SB#3 Vien Tiane</td>
<td>0.88</td>
<td>-3.31</td>
</tr>
</tbody>
</table>

Monthly mean observed and simulated discharge in m³/s at six sub-basin watersheds in calibration of the LMRB model (TRMM)

Remote Sensing (GPM) & LMRB SWAT Model

• The GPM-IMERG precipitation data used to drive the LMRB model for verification

• The SWAT model is able to explain between 71% and 96% of the variance observed in the monthly discharge from Chiang Sean, Thailand, to Kratie, Cambodia, when driven by GPM-IMERG


Lower Mekong River Basin Streamflow Variability Change

- Sensitivity analysis for the Lower Mekong River Basin Colwell index predictability ($P$)
- Observed predictability during 2001-2015 time period at SB4, SB5, and SB6 is 0.342, 0.325, and 0.317 respectively
- Predictability change (y-axis) reports the scaled predictability change, i.e., $(P_{sim} - P_{obs})/P_{obs} \times 100$


Mukdahan (Thailand)

Pakse (Laos)

Kratie (Cambodia)
High Flow Disturbance Analysis

NASAaccess – Downloading & Reformatting Tool for NASA Earth Observation Data Products

**GLDASpolyCentroid**
Generate air temperature input files as well as air temperature stations file from NASA GLDAS modeled remote sensing products.

**GPMpolyCentroid**
Generate rainfall input files as well as rain station file from NASA GPM remote sensing products.

**GLDASwat**
Generate SWAT air temperature input files as well as air temperature stations file from NASA GLDAS modeled remote sensing products.

**GPMswat**
Generate SWAT rainfall input files as well as rain stations file from NASA GPM remote sensing products.


http://tethys-servir.adpc.net/apps/nasaaccess2/
NASA Access has been officially released by NASA on its Github terminal https://github.com/nasa/NASAaccess
Examining Reservoir Scenarios

- **Baseline (December 2016)** – this is the same as Regan et al's, (n.d.) Baseline development scenario

- **Current (October 2018)** – the baseline scenario plus the now commissioned lower Sesan II and completed Nam Kong 2 reservoir in Laos

- **Under contract/construction** – includes the previous scenarios plus the dams that are at the stage of on-ground works. This includes Upper Kontum, Nam Kong 3, Xe Nam Noy 2 - Xe Katam 1

- **Contracted/licensed** – this includes the dams in the previous scenarios and dams listed as licensed by the MRC: Xe Katam; Xekong 4; Nam Kong 1 and Xe Kaman 4

- **Lower Sekong** – Under contract/construction plus lower Sekong

- **Lower Srepok 3** – Under contract/construction plus Lower Srepok 3

- **Cambodia Sesan and Srepok** – An alternative to the lower Sekong. Under construction plus Lower Srepok 3, lower Sesan 3 and lower Srepok 2
Near Real-Time Flood Damage Assessment
From Data to Decisions

Validation Summary

- **Overall accuracy**: 87%
- **Pixels analyzed**: > 7 million
- **Accuracy Range**: 79% - 98%
- **Conditions**: Flood, Non – Flood
- **Sensors**: (1) Envisat ASAR, (2) Radarsat – 2, (3) TerraSAR-X, (4) Disaster Monitoring Constellation (DMC)

Near Real-Time Flood Inundation Mapping


Operational Near Real-Time Flood Inundation maps based on relative anomalies in NDVI from MODIS 250-m data

Stakeholders: Mekong River Commission
Near Real-Time Flood Inundation Mapping

Operational Near Real-Time Flood Inundation maps based on relative anomalies in NDVI from MODIS 250-m data

Stakeholders: Mekong River Commission

<table>
<thead>
<tr>
<th>Reference Data</th>
<th>Date</th>
<th>Overall Accuracy</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISERV</td>
<td>1-Nov 2013 (n = 200)</td>
<td>88.50%</td>
<td>0.77</td>
</tr>
<tr>
<td>Landsat 7 ETM+</td>
<td>1-Nov 2013 (n = 300)</td>
<td>94.00%</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Damage Framework

Flood Depth Estimations

• Apply method from Cham et al. (2015)*

• Extract flood extent from detection tool

• Generate points around the perimeter – Sample elevation values from DEM

• Produce Triangulated irregular Network (TIN) to visualize water surface elevation


Damage Framework

Flood Depth Estimations

- Apply method from Cham et al. (2015)*
- Extract flood extent from detection tool
- Generate points around the perimeter – Sample elevation values from DEM
- Produce Triangulated irregular Network (TIN) to visualize water surface elevation


Damage Framework

Flood Depth Estimations

- Utilizes improved Multi-Error-Removed Improved-Terrain (MERIT) DEM\textsuperscript{6}
- ~20% increase in land area mapped with 2-meter or better vertical accuracy

Location & Objectives

2011 Southeast Asia Floods
- La Niña event – 143% increase in rainfall
- Onset of southwest monsoon

Objectives
- Use 2011 flood event as case study to demonstrate feasibility
- Integrate framework into Project Mekong near real-time platform

Land Cover / Land Use

**Updated Land Cover**
- Produced by MRC (2010)
- Landsat-5 derived at 30 m resolution
- 19 unique land cover classifications
- 9,357 survey points collected for validation

**Lower Mekong Basin Land Cover**

![Map of Lower Mekong Basin Land Cover](image)

**Figure 3.** (A) Land use/land cover (LULC) map produced by Mekong River Commission (MRC, 2010). (B) Inset showing study extent and LULC details considered in this analysis. (C) Close view of the Tonle Sap Lake region, Cambodia.
Population / Infrastructure

Socioeconomic Data
- NASA Socioeconomic Data and Applications Center (SEDAC)
  - Gridded population density (GPW)
  - Global gridded roads (gROADS)

Open Source Data
- Building location (centroids) and footprints:
  - OpenStreetMaps

Population Density

Damage Calculations

<table>
<thead>
<tr>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 1 2 2 3</td>
</tr>
<tr>
<td>1 3 2 1 2 5</td>
</tr>
<tr>
<td>0 5 4 1 1 2</td>
</tr>
<tr>
<td>0 1 0 2 2 3</td>
</tr>
<tr>
<td>1 2 5 5 3 4</td>
</tr>
<tr>
<td>1 2 3 4 5 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land Use Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Rice - 1 crop/yr</td>
</tr>
<tr>
<td>2 Mixed Annual Crops</td>
</tr>
<tr>
<td>3 Cleared before 2010</td>
</tr>
<tr>
<td>4 Orchard</td>
</tr>
<tr>
<td>5 Flooded Forest</td>
</tr>
<tr>
<td>6 Grassland/Sparse Vegetation</td>
</tr>
<tr>
<td>7 Deciduous Shrubland</td>
</tr>
<tr>
<td>8 Urban</td>
</tr>
<tr>
<td>9 Barren - Rock Outcrops</td>
</tr>
</tbody>
</table>

**Damage Model**

**“Standard Method”**

\[ S = \sum_{i=1}^{n} a_i n_i S_i \]

where

- \( a_i \) = damage factor category \( i \)
- \( n_i \) = number of units in category \( i \)
- \( S_i \) = maximum damage per unit in category \( i \)

**Maximum Damage Values (\( S_i \))**

<table>
<thead>
<tr>
<th>Land utility</th>
<th>USD/m²</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice, totally destroyed</td>
<td>0.078</td>
<td>Leenders et al. (2009)</td>
</tr>
<tr>
<td>Crop, totally destroyed</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>Other Plants, totally destroyed</td>
<td>0.147</td>
<td></td>
</tr>
<tr>
<td>Rice, partially destroyed</td>
<td>0.027</td>
<td></td>
</tr>
<tr>
<td>Crop, partially destroyed</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>Other Plants, partially destroyed</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td><strong>Fishery</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm, Ponds and paddy fields</td>
<td>0.639</td>
<td>Leenders et al. (2009)</td>
</tr>
<tr>
<td>Shrimp and shell fish</td>
<td>1.706</td>
<td></td>
</tr>
<tr>
<td>Freshwater fish</td>
<td>0.048</td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban area</td>
<td>29</td>
<td>Giang et al. (2009)</td>
</tr>
<tr>
<td>Rural area</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Provincial road</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>National road</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Railway</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>0.044</td>
<td></td>
</tr>
<tr>
<td>Other crops</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>


**Depth-Damage Curves**

**Damage Factor (\(a_i\)): General**

**Damage Factor (\(a_i\)): Rice-Specific**

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**Figure 5.** Damage factor curves for agriculture, forest, and infrastructure classes (upper) and rice varieties (lower) found in the Lower Mekong Basins (LMB). Curves digitized and adapted from Chen (2007) [49].

### Visualizing Impacts

<table>
<thead>
<tr>
<th>Land Utility</th>
<th>Area (km²)</th>
<th>Damages (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Rotated with Annual Crop</td>
<td>13,355.05</td>
<td>645,235,056</td>
</tr>
<tr>
<td>Annual Crop</td>
<td>1502.03</td>
<td>126,696,853</td>
</tr>
<tr>
<td>Shifting Cultivation</td>
<td>38.02</td>
<td>3,073,550</td>
</tr>
<tr>
<td>Orchard</td>
<td>332.35</td>
<td>6,572,509</td>
</tr>
<tr>
<td>Flooded Forest</td>
<td>3542.54</td>
<td>2,889,181,644</td>
</tr>
<tr>
<td>Grassland</td>
<td>1938.22</td>
<td>44,535,518</td>
</tr>
<tr>
<td>Shrub Land</td>
<td>1398.63</td>
<td>34,103,750</td>
</tr>
<tr>
<td>Urban</td>
<td>275.17</td>
<td>710,538,630</td>
</tr>
<tr>
<td>Bare Land</td>
<td>68.65</td>
<td>0</td>
</tr>
<tr>
<td>Industrial Plantation</td>
<td>1.42</td>
<td>24,608</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>8.43</td>
<td>2,905,977</td>
</tr>
<tr>
<td>Evergreen Forest</td>
<td>2.28</td>
<td>1,530,465</td>
</tr>
<tr>
<td>Forest Plantation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bamboo Forest</td>
<td>11.35</td>
<td>8,798,317</td>
</tr>
<tr>
<td>Coniferous Forest</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mangrove</td>
<td>1.71</td>
<td>842,254</td>
</tr>
<tr>
<td>Marsh/Swamp</td>
<td>482.85</td>
<td>12,703,670</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>8.32</td>
<td>211,169</td>
</tr>
<tr>
<td>Aquaculture Rotated with Rice</td>
<td>26.39</td>
<td>27,770</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22,993</strong></td>
<td><strong>4,486,981,740</strong></td>
</tr>
</tbody>
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<td>0</td>
</tr>
<tr>
<td>Industrial Plantation</td>
<td>1.42</td>
<td>24,608</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>8.43</td>
<td>2,905,977</td>
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<tr>
<td>Evergreen Forest</td>
<td>2.28</td>
<td>1,530,465</td>
</tr>
<tr>
<td>Forest Plantation</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Bamboo Forest</td>
<td>11.35</td>
<td>8,798,317</td>
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<tr>
<td>Coniferous Forest</td>
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<td>-</td>
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<tr>
<td>Mangrove</td>
<td>1.71</td>
<td>842,254</td>
</tr>
<tr>
<td>Marsh/Swamp</td>
<td>482.85</td>
<td>12,703,670</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>8.32</td>
<td>211,169</td>
</tr>
<tr>
<td>Aquaculture Rotated with Rice</td>
<td>26.39</td>
<td>27,770</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>22,993</td>
<td>4,486,981,740</td>
</tr>
</tbody>
</table>


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**Figure 6.** Results of damage assessment for land cover categories. Color gradient represents severity of damages in USD/m².
Limitation of Current System > Future Work

Updated Data
- Socioeconomic datasets
- Locally-specific valuations
- Improved geospatial information

Feedback
- What information is useful?
- How would it be used?

<table>
<thead>
<tr>
<th>Tangible</th>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Damage to infrastructure</td>
<td></td>
<td></td>
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<tr>
<td>• Global roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Energy infrastructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Schools &amp; hospitals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Building footprints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Impacts to populations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Loss of human life</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Biodiversity effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Loss to ecosystem services (e.g., riparian vegetation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Psychological suffering</td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>Intangible</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Agricultural production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Income loss from industry/tourism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Emergency evacuation costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Education disruption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Impacts to place and culture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Community Resilience</td>
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</tr>
</tbody>
</table>
Regional Workshop on Near Real-Time Flood Monitoring Service
Bangkok, Thailand (Jan 24-25, 2018)
Damage Assessment in Laos

Scientists Deploy Damage Assessment Tool in Laos Relief Efforts

The July 23 failure of the Xepian-Xe Nam Noy hydropower dam unleashed more than 130 billion gallons of water on rural villages in southern Laos, in Southeast Asia, devastating thousands of houses and businesses and displacing more than 6,000 people. As authorities scrambled to gather information in the wake of the disaster, scientists at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, activated a new tool to help them assess the damage and get help to people in need.
Flood Damage Assessment System Activated for July 25 Laos Dam Break

• By the numbers
  • >3,740 people impacted
  • 1,349 buildings
  • 373 km of affected roads
  • $54 million (USD) of potential damage to infrastructure and land cover

PI: John Bolten (NASA GSFC)
Project Scientists: Perry Oddo (NASA GSFC), Aakash Ahamed (Stanford U.)
Contributors: NASA SERVIR, NASA MSFC, SIG, ADPC
Flood Damage Assessment System Activated for July 25 Laos Dam Break

- Sentinel 1 and ALOS 2 data were used to derive flood inundation map for affected lands in Laos (leads: NASA SERVIR, NASA MSFC, SIG, U. of Houston, ADPC)

- Flood inundation depths estimated using Triangular Interpolated Network extracted from MERIT DEM elevations

- Socio-Economic data from OpenStreetMap and WorldPop used to estimate flood impact based on depth estimates

- Damage estimates calculated using estimated flood depths and Dutch ‘Standard Method’

PI: John Bolten (NASA GSFC)
Project Scientists: Perry Oddo (NASA GSFC), Aakash Ahamed (Stanford U.)
Contributors: NASA SERVIR, NASA MSFC, SIG, ADPC
Flood Damage Assessment System Activated for July 25 Laos Dam Break

Dam location

Flooded land

PI: John Bolten (NASA GSFC)
Project Scientists: Perry Oddo (NASA GSFC), Aakash Ahamed (Stanford U.)
Contributors: NASA SERVIR, NASA MSFC, SIG, ADPC
Value of NRT Earth Observations

Time Is Money, But How Much? The Monetary Value of Response Time for Thai Ambulance Emergency Services

Henrik Jaldell, PhD, Prachaksvich Lebnak, MD, Anurak Amornpetchsathaporn, MD
1Department of Economics, Karlstad University, Karlstad, Sweden; 2Emergency Medical Institute Thailand, Bangkok, Thailand

Abstract

Objective: To calculate the monetary value of the time factor per minute and per year for emergency services. Method: The monetary values for ambulance emergency services were calculated for two different time factors, response time, which is the time from when a call is received by the emergency medical service call-taking center until the response team arrives at the emergency scene, and operational time, which includes the time to the hospital. The study was performed in two steps. First, marginal effects of reduced fatalities and injuries for a 1-minute change in the time factors were calculated. Second, the marginal effects and the monetary values were put together to find a value per minute. Results: The values were found to be 5.5 million Thai baht/min for fatality and 326,000 baht/min for severe injury. The total monetary value for a 1-minute improvement for each dispatch, summarized over 1 year, was 1.6 billion Thai baht using response time. Conclusions: The calculated values could be used in a cost-benefit analysis of an investment reducing the response time. The results from similar studies could for example be compared to the cost of moving an ambulance station or investing in a new alarm system.

Keywords: cost-benefit, emergency medical service, medicine, response time.

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Value of NRT Earth Observations

The total monetary value for a 1-minute improvement for each dispatch, summarized over 1 year, was 1.6 billion Thai baht using response time.
Tethys App for Visualizing and Sharing Inputs/Outputs of the LMRB SWAT Model

http://tethys-servir.adpc.net/apps/swat2/

Tethys SWAT Tool
Data Sources

- **Elevation:** MERIT DEM (90 m)
- **Flood Extent:**
  - 2011 case study: ENVISAT-ASAR Wide Swath Mode (ESA)
  - NRT (future implementation): Will use flood detection output from Project Mekong (NASA LANCE MODIS-derived)
- **Land Cover:** Mekong River Commission
  - Landsat-based 30 m resolution, resampled to 90 m
- **Infrastructure**
  - Building footprints: OpenStreetMaps (accessed through Mapzen interface)
  - Roads: Global Roads Open Access Data Set (gROADS), v1 (NASA SEDAC)
- **Population:**
  - Gridded Population of the World (GPW), v4 (NASA SEDAC)
From 11th to 18th March 2019, water levels along the lower Mekong River from Thailand’s Chiang Saen to Lao PDR’s Luang Prabang were fluctuated above their long-term averages (LTAs) the same trend as last week, although no rainfall in these areas. The trend from 19th to 25th March 2019 will be gradually slightly increasing and still keep stays above their LTAs. For downstream reaches from Lao PDR’s Vientiane to Cambodia’s Kompong Cham, the trends will be the same as upstream part. The lower reaches from Cambodia’s Phnom Penh at Chaktomuk, Koh Khel, Neak Luong to Viet Nam’s Tan Chau on the Mekong River and Chau Doc on the Bassac River will be slightly increasing and stay above their LTAs due to the abnormal rainfall in March 2019 in the floodplain area.

Forecasted water level for 22 stations (updated every Monday)  more »
Observed water level compared to long term average for 13 stations (updated every Monday)  more »
Lower Mekong River Basin

John D. Bolten¹, I. Mohammed¹, and J. Spruce², P. Oddo¹, V. Lakshmi³, C. L. Hung³, R. Srinivasan⁴, C. Doyle¹, D. Nguyen⁵, Nelson⁶, S. McDonald⁶, C. MeeChaiya⁷, P. Towathiraporn⁷, S. Pulla⁸, A. (Weigel) Markert⁸

¹NASA Goddard Space Flight Center
²NASA Stennis Space Center
³University of South Carolina
⁴Texas A&M University
⁵Mekong River Commission
⁶Brigham Young University
⁷Asian Disaster Preparedness Center, Bangkok, Thailand
⁸NASA Marshall Spaceflight Center
References


References


