CEOS Disaster Risk Management Flood Pilot Status and Plans

Presented at the CEOS Disasters Working Group Meeting #7 in Rome, Italy

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Outline

- **Flood Pilot overview**
- **Status of data acquisition and exploitation**
  - **JAXA ALOS-2 / PALSAR-2 data use**
- **Pilot status report:**
  - **Objective A: Global component status**
  - **Objective B: Regional component status**
    - **Caribbean/Central America**
    - **Southern Africa**
    - **Southeast Asia**
  - **Objective C: Capacity Building**
- **Issues and Risk Management**

CEOS DRM Flood Pilot Overview

- **Goal:** demonstrate effective application of EO to the full cycle of flood management at all scales by:
  - **Objective A:** Integrating information from existing NRT global flood monitoring / modeling systems into a Global Flood Dashboard;
  - **Objective B:** Delivering EO-based flood mitigation, warning, and response products and services through regional end-to-end pilots in:
    - Caribbean/Central America (focus on Haiti)
    - Southern Africa (inc. Namibia, South Africa, Zambia, Zimbabwe, Mozambique, and Malawi);
    - Southeast Asia (focus on lower Mekong Basin and Java)
  - **Objective C:** Encouraging at least base-level in-country capacity to access EO and integrate it into their operational systems and flood management practices

Data Acquisition Status

- Detailed EO Requirements for each Pilot approved at 2013 Plenary; acquisition allocations approved at 2014 Plenary
- Individual requests from each Pilot coordinated by co-leads and detailed on consolidated request form
- Data distribution co-ordinated by co-leads (the lack of standardized data distribution makes it very labor-intensive)

Mission / Instrument	Repeat or Revisit	Swath Width	Spatial Resolution	Agency	Image Counts		
					Annual Quota	Since 9/2016 WGDisasters Meeting	Cumulative Total
Optical - Coarse Resolution (>100 m)							
Terra / MODIS	1 day	2230 km	250, 500, 1000 m	NASA			
Aqua / MODIS	1 day	2230 km	250, 500, 1000 m	NASA			
NPP / VIIRS	1 day	3000 km	375, 750 m	NASA			
Optical - Moderate Resolution (10 to 100 m)							
Sentinel-2A / MSI	10 days	290 km	10, 20, 60 m	ESA		0	0
EO-1 / ALI	204 days	185 km	10, 30 m	NASA	300	48	129
Landsat-8 / OLI	16 days	185 km	15, 30 m	USGS		39	117
Optical - High Resolution (<10 m)							
SPOT (archive only)	26 days	60 km	1.5 and 6 m	CNES		0	0
Pleiades	26 days	20 km	50 cm and 2 m	CNES	50	0	10-12*
L-Band SAR							
ALOS-2 / PALSAR-2	14 days	25 to 350 km	10 to 100 m	JAXA	100	32	47
C-Band SAR							
Sentinel-1A / SAR	12 days	80, 250, 400 km	9, 20, 50 m	ESA		12	64
Sentinel-1B / SAR	12 days	80, 250, 400 km	9, 20, 50 m	ESA		0	0
Radarsat-2 / SAR-C	1-6 days	50 to 500 km	8 to 100 m	CSA	500 (3 yr)	21	144
X-Band SAR							
Cosmo Sky-Med / SAR-2000	5 days	10 to 200 km	1 to 100 m	ASI	300	37	144

*includes a set of 4 stripes over Jakarta corresponding to 7-9 individual images

ALOS-2 PALSAR-2 Data Use (1/4)

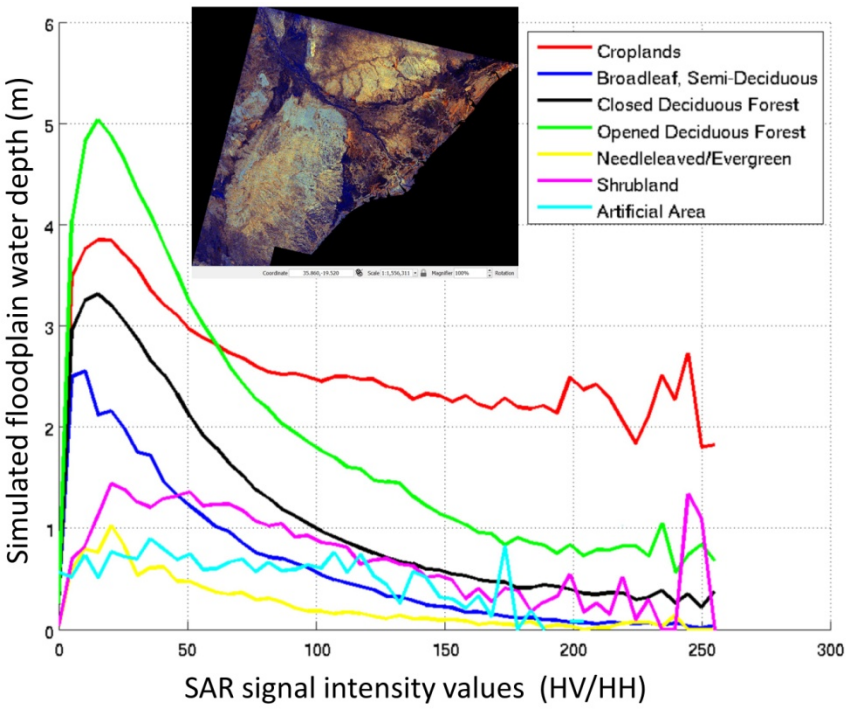
- 47 ALOS PALSAR-2 images (all from Charter activations) have been obtained for Flood Pilot use:
  - 6 images over Vietnam, 31 July / 4 August 2015;
  - 2 images over Myanmar, 11-16 August 2015;
  - 6 images over India (Chennai), 9 December 2015;
  - 6 images over Louisiana, 18 January 2016;
  - 4 images over Haiti, 5 September 2016.
  - 30 images over Panama and Costa Rica, 21 Nov-13 Dec 2016.
- Users:
  - NASA: Fritz Policelli (GSFC); Jordan Bell (MSFC); Sang-Ho Yun (JPL)
  - Universities: Bob Brakenridge (U. Colorado), Huan Wu (University of Maryland), Guy Schumann (UCLA), Zac Flamig (U. of Oklahoma)
  - Regional Centers: David Farrell (CIMH), Amaranth Giriraj (IWMI)

ALOS-2 PALSAR-2 Data Use (2/4)

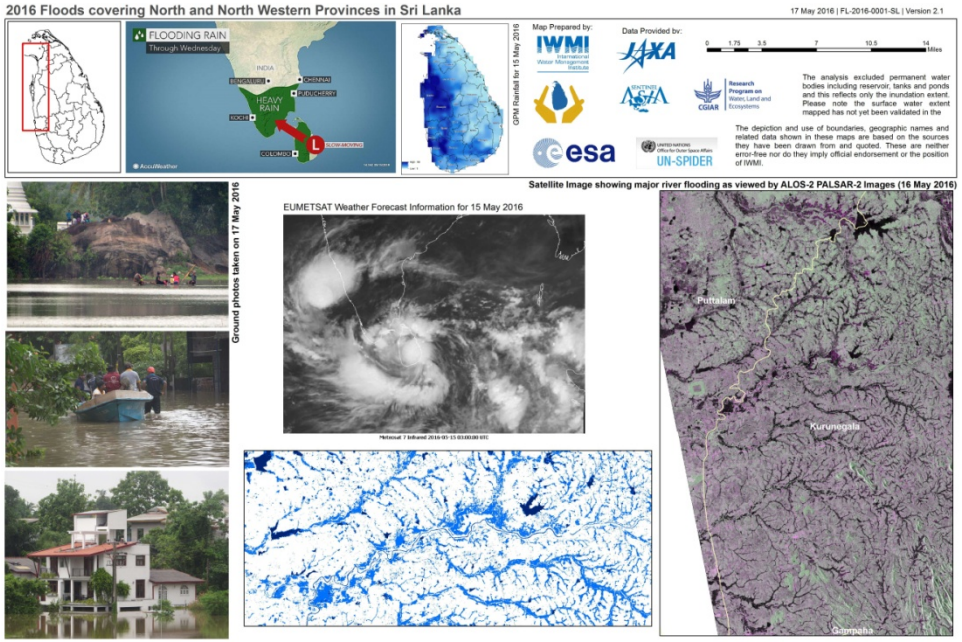
- Caveats:
  - Images from the first four Charter cases were obtained via an agreement with the Charter that was reached in early 2016, so these data were not suitable for real-time use.
  - Prior to this agreement, licensing issues prevented the Flood Pilot from obtaining PALSAR-2 data from Charter activations.
  - For several other (non-Charter) events of interest PALSAR-2 was not tasked at the right time.
  - The Dartmouth Flood Observatory attempted to use the Haiti images but they did not show any flooding.
  - There are other examples of PALSAR-2 use by Pilot members who had separate arrangements with JAXA (see next slide)

ALOS-2 PALSAR-2 Data Use (3/4)

Examples of PALSAR data from other sources used by Pilot members:



Comparison of SAR signal compared to land cover and (modeled) inundation depth over Malawi, 14 January 2015 (figure courtesy G. Schumann, UCLA)



International Water Management Institute Flood Maps in NW Sri Lanka, 17 May 2016

ALOS-2 PALSAR-2 Data Use (4/4)

(courtesy B. Brakenridge, U. of Colorado)

- Lesson learned: a better approach would have been to request access for retrospective cases in addition to the real-time cases, because
  - Normal (non-flood) scenes at the same scale are essential to provide a robust means of accurately discriminating flooded from non-flooded regions;
  - Scenes from previous floods are also critical for
    - Validation of past events;
    - Comparison of current events to past events (e.g., return period)
- The ESA Sentinel system is a great example of this: one can download the latest scene and also easily identify and download exact repeat scenes from previous months and years to compare.
- Even for providers who charge for images, such collections may be of interest to those with the resources to purchase larger collections (e.g., the Development Banks)

How Data Are Being Exploited

Geographic Area	Product	Value Added Partner
Global	Flood extent maps and flood forecasts	Dartmouth Flood Observatory, University of Maryland
Haiti	Flood extent maps, flood risk maps, landslide maps, flash flood guidance / threat maps, integrated risk assessment platform	SERTIT, CIMA, INGV, Altamira, CIMH, RASOR FP7, NOAA/HRC
Other Caribbean islands, Central America	Flood damage maps, change detection products, co-registered map overlays	CATHALAC, CIMH, NASA/GSFC, RCCP (Costa Rica)
Namibia	Flood extent maps, flood warning products, co-registered map overlays	Namibia Hydrology Dept, Namibian Water Authority, NASA
Zambezi basin	Flood extent maps, flood forecast models, flood hazard maps, flood depth forecasts	Lippmann Institute (HAZARD, WATCHFUL), Deltares, RSS
Mekong	Flood extent maps, flood risk maps, flash flood guidance / threat maps	Mekong River Commission, ADPC, NASA, NOAA, HRC, USGS, Univ. of South Carolina, Texas A&M , IMWI
Java (Bandung, Jakarta, Cilacap)	Flood risk maps, subsidence maps tied to flood risk, tsunami risk maps (Cilacap only), flood extent maps	SERTIT, Deltares, CIMA, Altamira, INGV, RASOR FP7,

Products used by: national end users, civil protection agencies, World Bank, Red Cross, World Food Program, River Commissions (Kavango, Zambezi, Mekong)

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Objective A: Global Component Status

- 2014 Milestone: initial pilot Global Flood Dashboard website with linkages to major global projects and systems and archive flood products
- 2015 Milestone: functional linkages between the Global Flood Dashboard and the three regional flood component areas; indication of regions of interest based on reports of flooding; showcase at WCDRR
  - 2015 Status: Functional requirements completed and presented at WCDRR and shared requirements with potential host agencies
  - 2016-17 Status: **75% complete—**Discussed hosting with B. Koetz of ESA...still under evaluation. Discussed possible hosting on CIMA servers with Roberto Rudari; supportive of demo but funding needed for ongoing operations. Submitted proposal to NASA grant call that would include hosting of the Global Flood Dashboard.

Objective A: Global Component Status

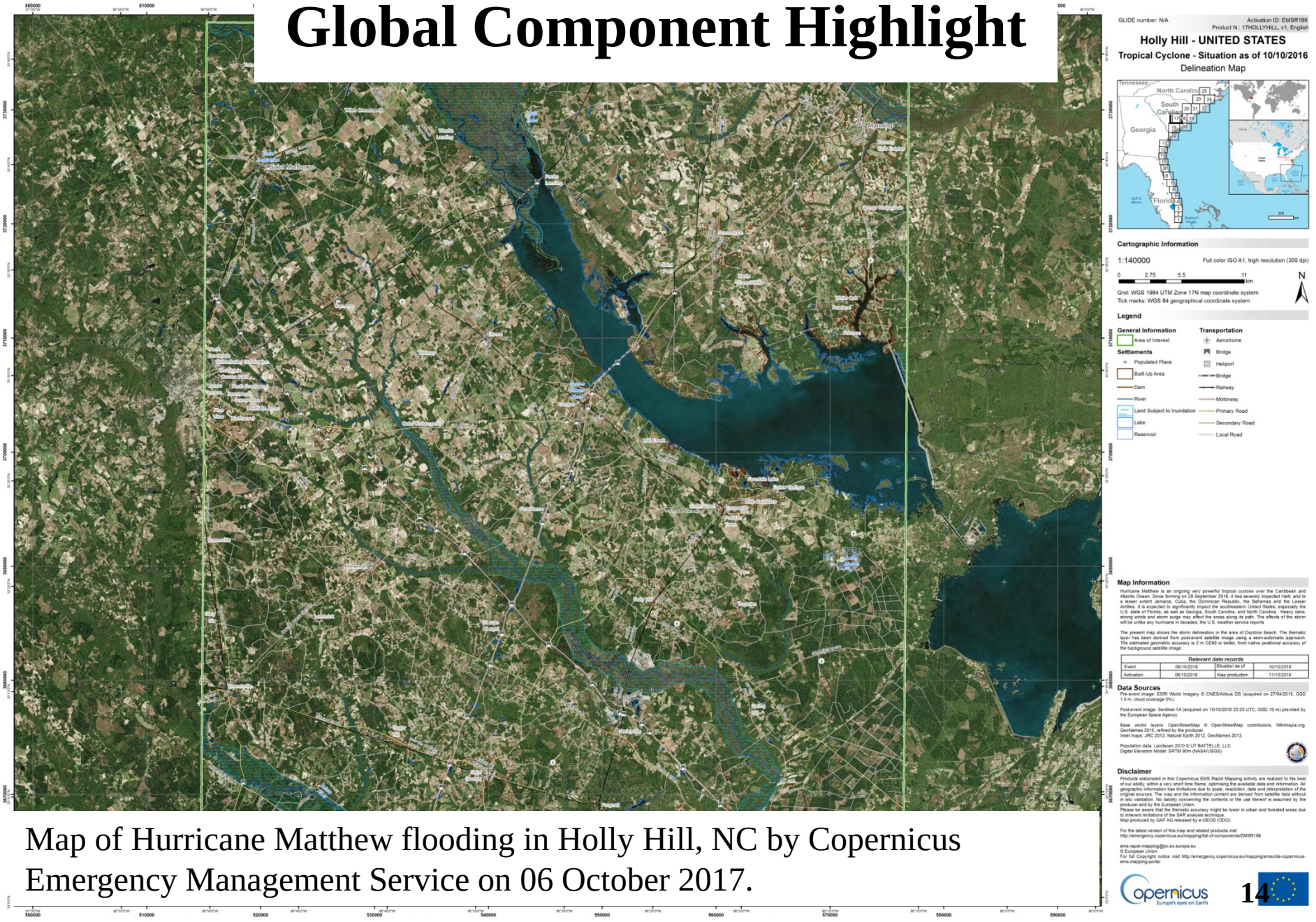
- 2016-17 Milestone: draft a plan for longer-term sustainability; provide functional linkages to additional user-selected polygons of interest beyond the three regional Pilot areas.
  - Status:
    - Submitted responses to long-term sustainability questions on 16 September 2016; in the process of revising based on feedback from Andrew
    - In concert with GeoDARMA, reach out to UN, World Bank, International Red Cross, and other potential partners to implement the global and regional Flood Pilot modeling and monitoring capabilities that are interconnected via an API on a more permanent basis

Global Component Highlight

- Mapping of the Hurricane Matthew flooding in North Carolina using Landsat 8 data and MODIS (Dartmouth Flood Observatory)

Aerial photographs show large sections of Lumberton, a town of about 22,000, flooded. The Lumber River rose two feet higher than its previous record level. Hundreds of residents fled.

Global Component Highlight



Map of Hurricane Matthew flooding in Holly Hill, NC by Copernicus Emergency Management Service on 06 October 2017.

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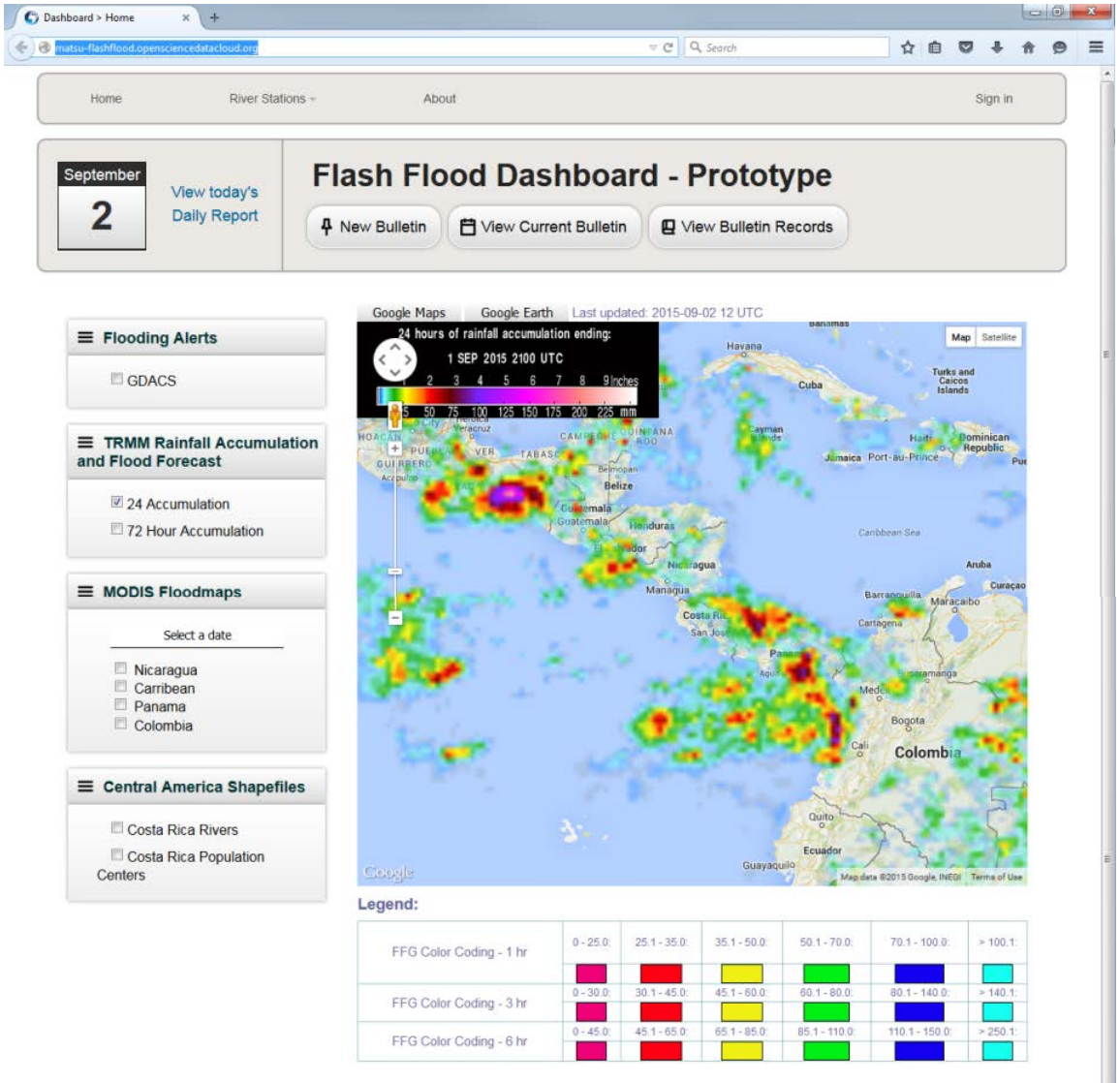
Objective B: Caribbean/Central American Component Status (1/8)

- 2014 Milestones:
  - Flood dashboard based on Namibia pilot adapted to Caribbean and Central American users
    - Status: Prototype Flood Dashboard completed: http://matsu-flashflood.opensciencedatacloud.org/
  - Flood monitoring (i.e., targeted EO data acquisitions)
    - Status: Targeted EO acquisitions in 2014 for Guatemala, Panama, Trinidad, Haiti, and Belize
  - Contributions of data to KAL Haiti data base
    - Status: Completed

Objective B: Caribbean/Central American Component Status (2/8)

http://matsu-flashflood.opensciencedatacloud.org/

(To be replaced with the Open GeoSocial API in 2017—see slide 18)



Objective B: Caribbean/Central American Component Status (3/8)

- 2015 Milestones:
  - Flood monitoring during 2015 season
    - Status:
      - Panama (June); EO-1 / MODIS / Landsat flood maps for CATHLAC
      - Dominica (August—TS Erika): COSMO-Sky-Med, Radarsat-2, and EO-1 data
      - Bahamas (October—H Joaquin); EO-1 images, GPM rainfall, GFMS flood predictions, flood maps from multiple sensors
  - RASOR risk management platform operational for flood risk and landslide risk analysis in Haiti
    - Status: Subsidence mapping completed and reported at March 2016 meeting; proposal submitted to extend and deepen this work through the Global Facility for Disaster Reduction and Recovery (GFDRR) in collaboration with the Haitian government.
  - 10-year flood archive based on Deltares Flood Monitoring Programme
    - Status: Deltares did not receive funding to continue collaboration with this Pilot region.

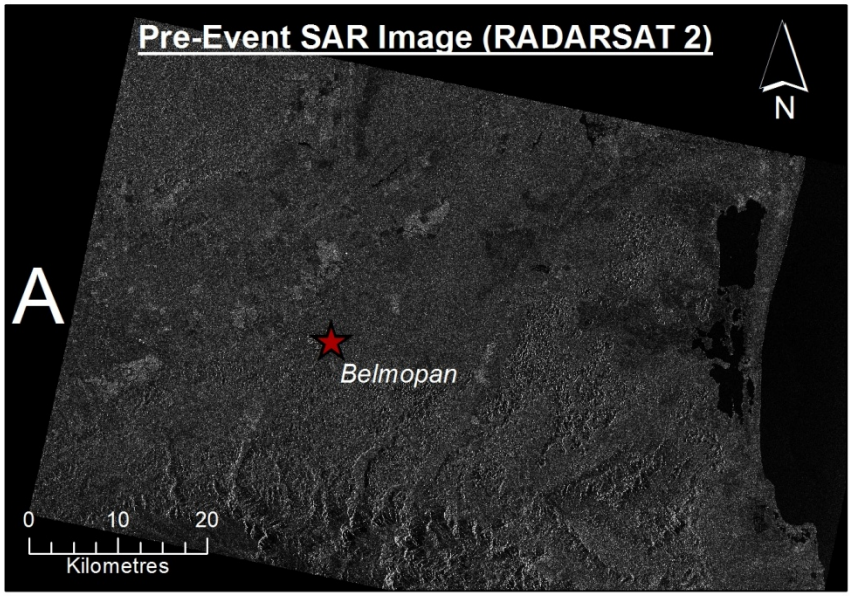
Objective B: Caribbean/Central American Component Status (4/8)

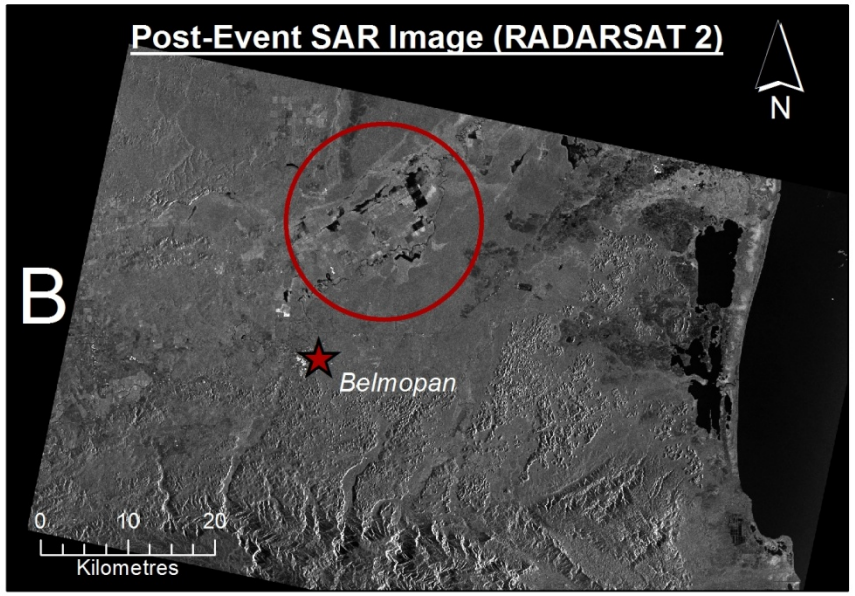
- 2016-17 Milestones:
  - Flood monitoring during 2016 season
    - Status: Provided optical imagery (EO-1 and MODIS) and GFMS for Mexico (TS Danielle—June), Belize (H Earl—August), and Hispaniola (H Matthew—October)—also RADARSAT-2, Sentinel-1A and ALOS-2 for Hispaniola. Requested Panama and Costa Rica (both November) Charter data in late November but response received in March.
  - Draft a plan for longer-term sustainability
    - Status: Intent is to transition much of this work into AmeriGEOSS, but details need to be worked out with GEO-DARMA; also waiting on results of NASA Flood Pilot call
- Overall Status: **75%** complete.

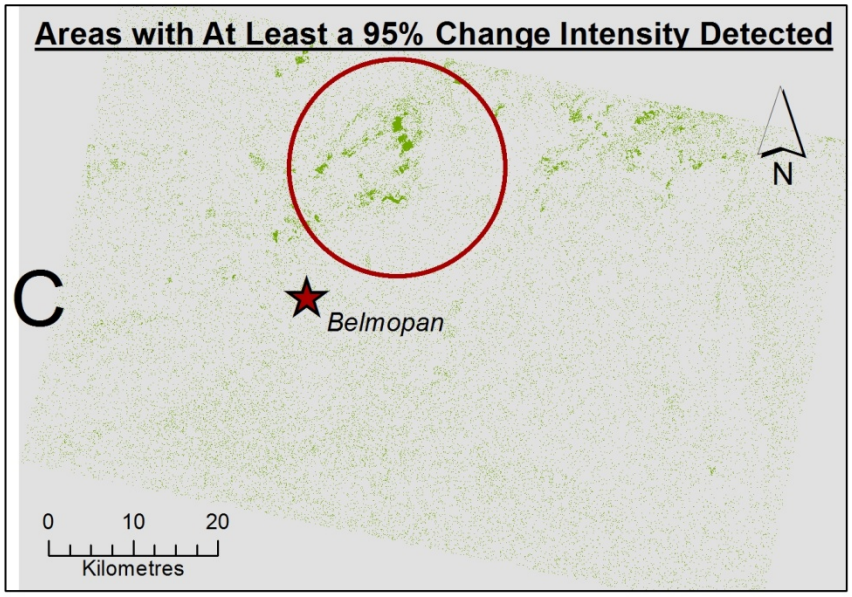
Objective B: Caribbean/Central American Component Status (5/8)

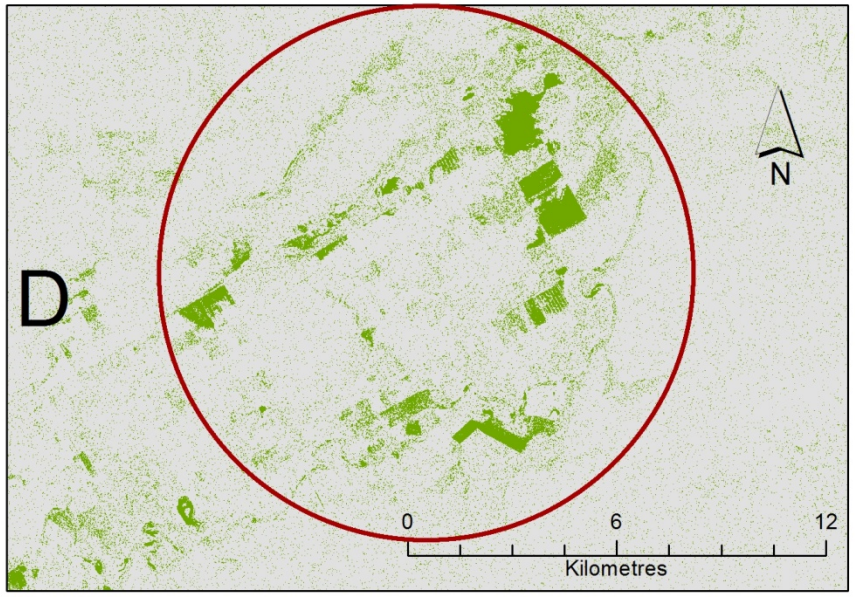
- Other Planned Activities / Accomplishments
  - Collection of background Radarsat-2 pre-event imagery at known look angles and modes for the entire region (CSA-Giguere)
    - Status: Completed; 8 complete sets of background images collected over all of Central America and the Caribbean
  - Damage assessment studies to analyze satellite-derived inputs as compared to ground-based manual techniques (CIMH-Farrell)
    - Status: Analysis in Saint Vincent and the Grenadines (using Radarsat and EO-1), and in Dominica (using Radarsat and COSMO-SkyMed) has been hampered by lack of pre-event imagery with same characteristics as post-event imagery; this work will be revisited if suitable matching pairs can be obtained. Currently looking at the effects of Hurricane Earl in Belize using pre- and post-event Radarsat-2 data (next slide); after additional refinement these routines will then be tested on other datasets as they become available. Upcoming training on SAR image processing for CIMH personnel may is expected to enhance future efforts.

Objective B: Caribbean/Central American Component Status (6/8)





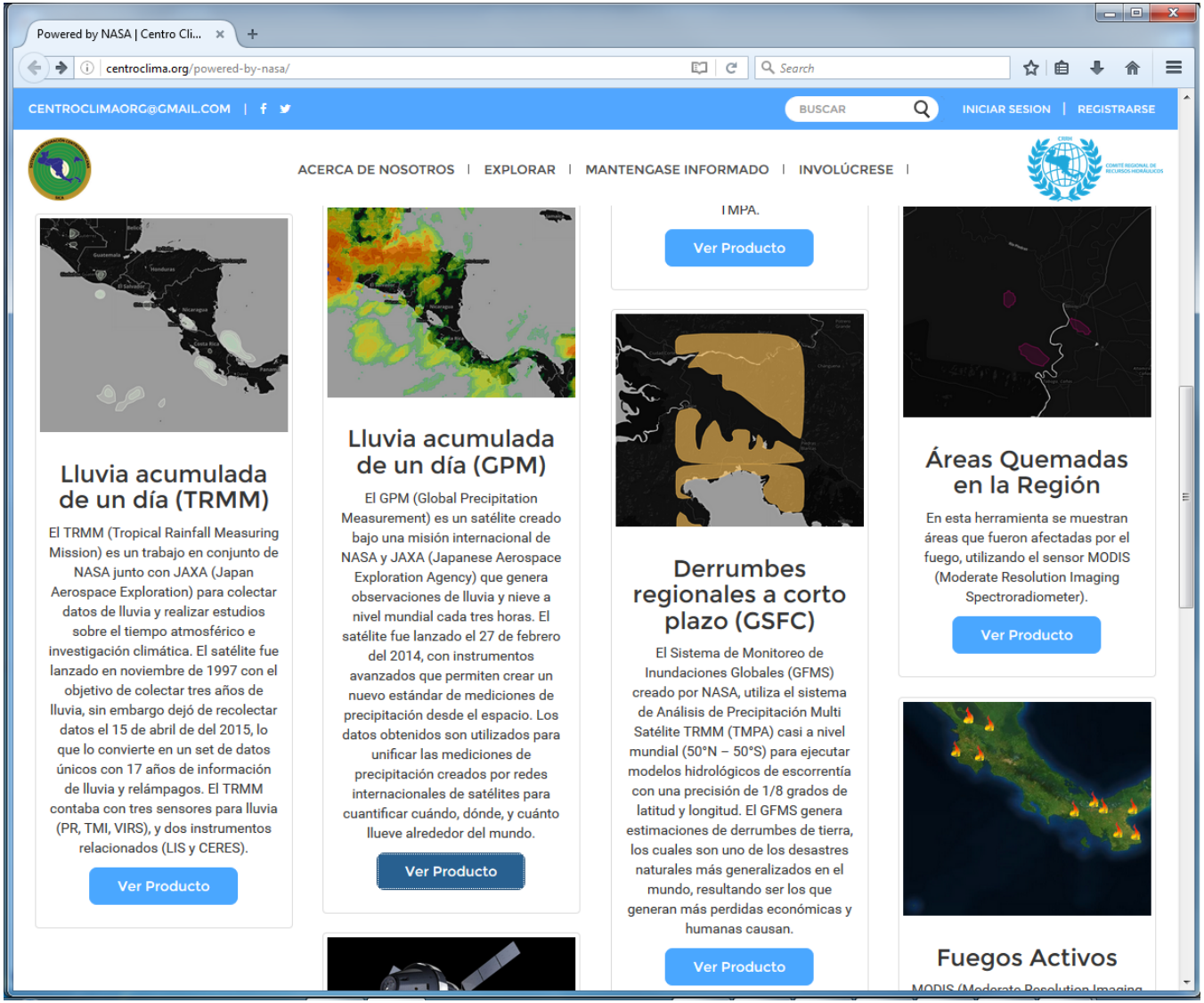




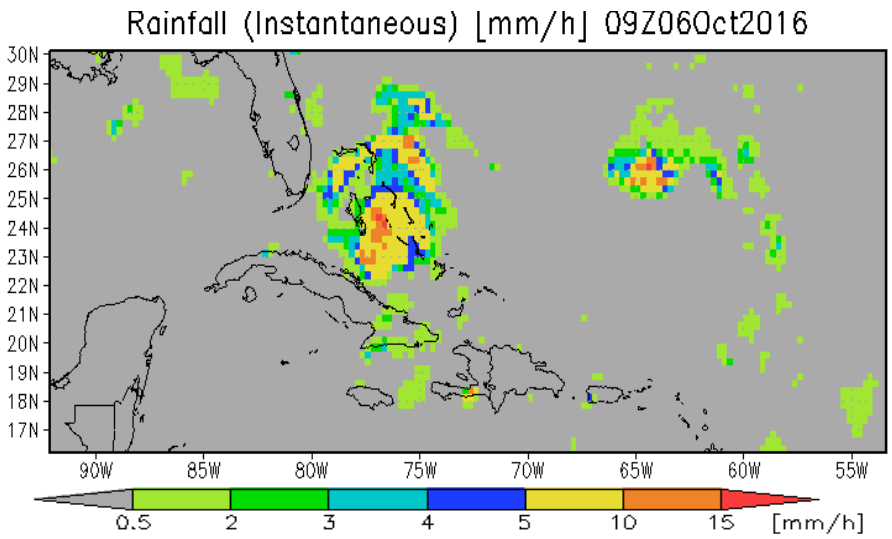
Objective B: Caribbean/Central American Component Status (7/8)

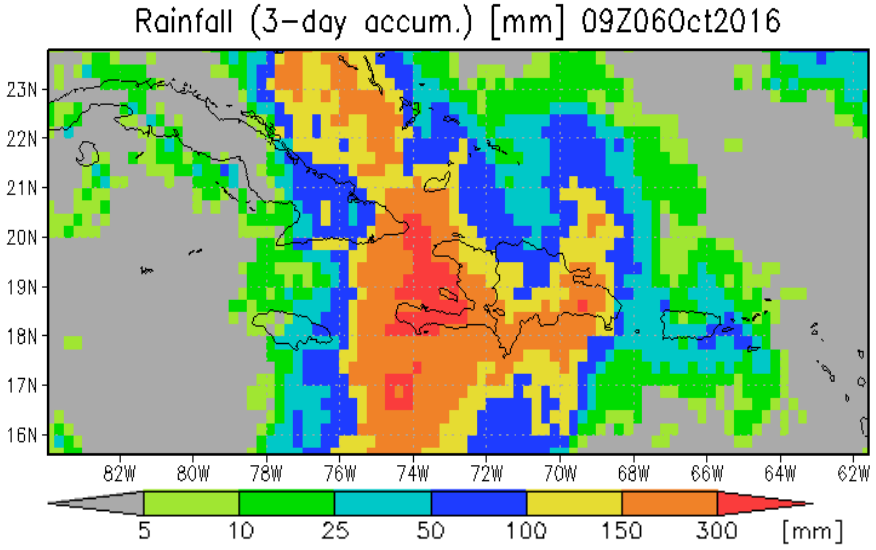
- Other Planned Activites / Accomplishments (cont.)
  - Open GeoSocial API for publishing / visualizing flood modeling and monitoring products installed at DAI in Costa Rica
    - Part of the disasters component of the Climatic Information Platform for Central America and the Dominican Republic under the Regional Climate Change Program (RCCP) funded by USAID; software installation supported by a grant from SICA/CEPREDENAC.
    - Training workshop conducted in early May 2016 in Costa Rica
    - System operational since May 2016: http://centroclima.org/powered-by-nasa/ (example on next slide)—replaces the current Caribbean / Central America Flood Dashboard

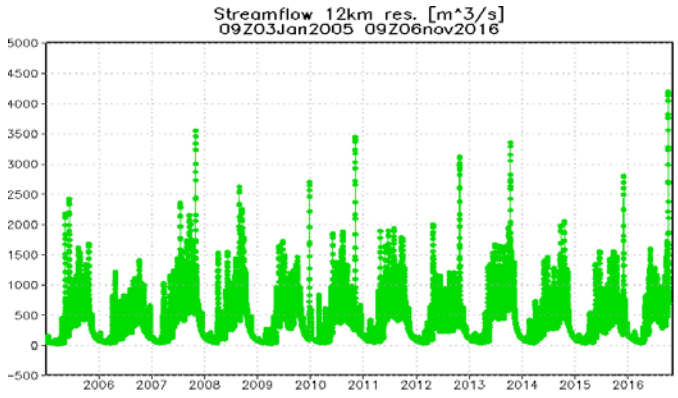
Objective B: Caribbean/Central American Component Status (8/8)



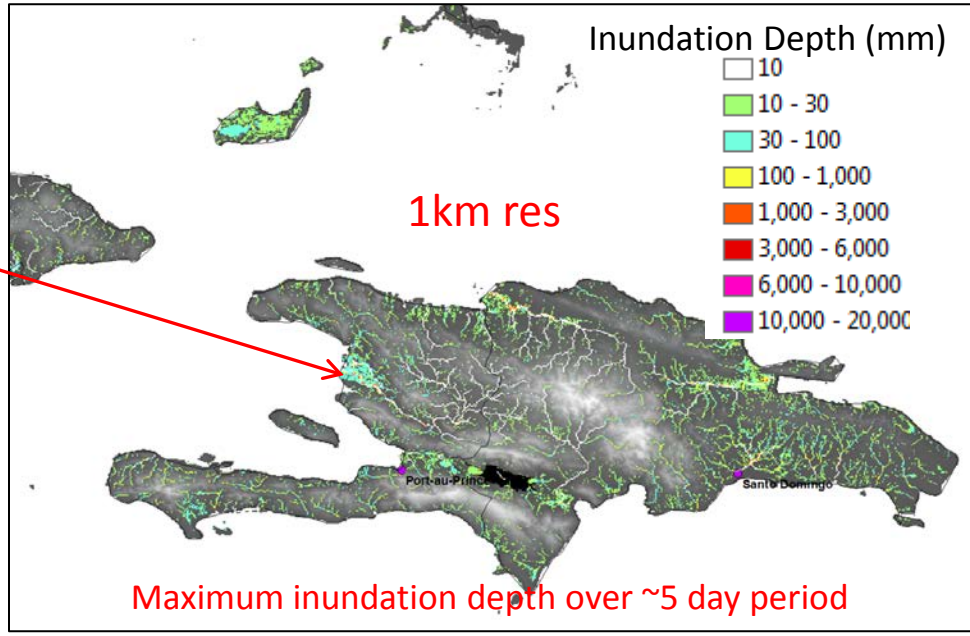
Caribbean / Central America Highlight







Largest peak discharge since 2005
@ La Artibonite River mouth



Maximum inundation depth over ~5 day period

Credit: Huan Wu/Bob Adler, UMD

Aggregated Inundation map from Oct 2 to Oct 6 09Z UTC

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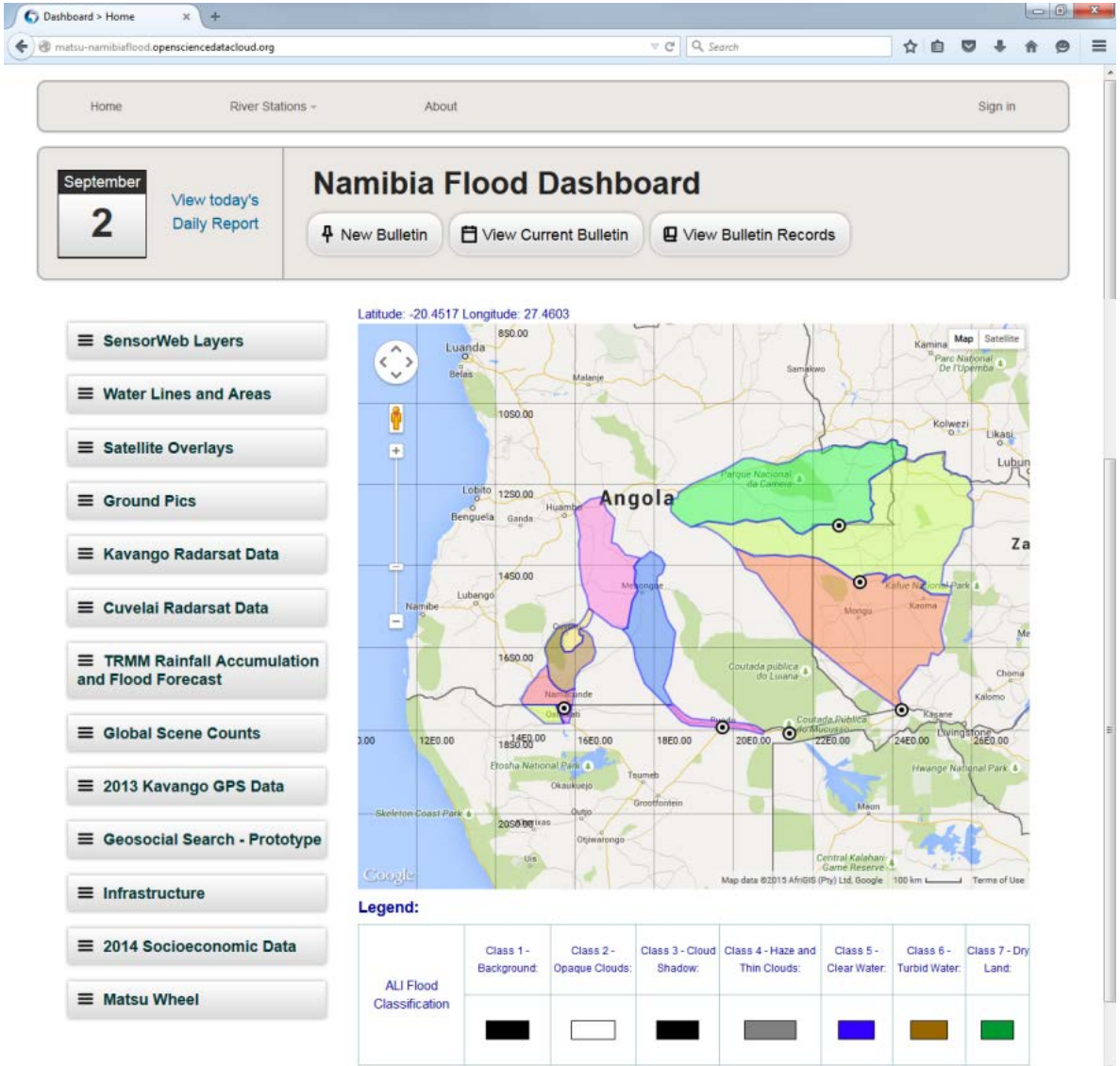
Objective B: S. Africa Component Status (1/6)

- 2014 Milestones:
  - Flood monitoring during early 2014
    - Status: Acquisitions from NASA and CSA under previous agreement within GEO task
  - Updates to flood dashboard
    - Status: Upgraded Flood Dashboard completed: http://matsu-namibiaflood.opensciencedatacloud.org/
- 2015 Milestones:
  - Flood monitoring during early 2015
    - Status: Radarsat-2 images provided for Namibia during flooding on 24 Feb; three Archive Radarsat-2 images of Malawi (early January—ordered in March) provided to LIST for Flood Hazard Mapping that were Disaster Charter acquisitions
  - 10-year flood archive over region based on Deltares Flood Monitoring Programme
    - Status: Deltares did not receive funding to continue collaboration with this Pilot region.

Objective B: S Africa Component Status (2/6)

http://matsu-namibiaflood.opensciencedatacloud.org/



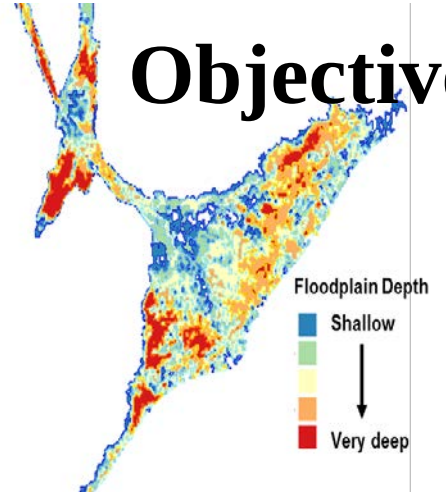
Objective B: S. Africa Component Status (3/6)

- 2016-17 Milestones:
  - Flood monitoring during 2016 season
    - Status: Charter data just requested for ongoing Madagascar floods
  - Draft a plan for longer-term sustainability
    - Status: Intent is to transition much of this work into AfriGEOSS but details need to be worked out.
- Status: **75%** complete.

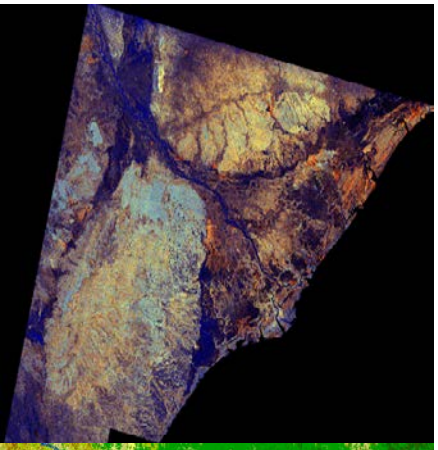
Objective B: S Africa Component Status (4/6)

- Other Planned Activities
  - Improvements to flood model by computing river width and deriving more realistic and complete stream networks derived from Landsat-8 (UCLA-Schumann; results in next slide)
    - Status: Validating the improved flood model outputs with MODIS and ALOS-2 flood maps (see next slide)
  - Using a flood modeling study of the Lower Zambezi to define areas for high-resolution LiDAR acquisitions over the floodplains to construct higher-resolution DEMs for flood modeling / forecasting (UCLA-Schumann)
    - Status: DEM has been completed; terms of access still being worked out with the World Bank
  - Implementation of regional CREST flood model in Namibia, Kenya, and South Africa (U of Oklahoma-Hong/Flaming)
    - Status: SERVIR grant secured to transition from CREST to EF5 flood model; work began November 2016 with RCMRD. These products are being provided through the Open GeoSocial API under RCRMD control (web interface is being implemented).

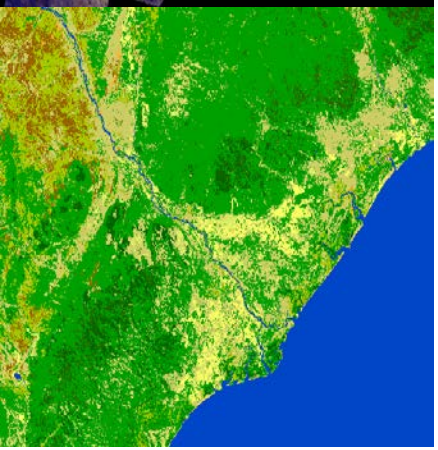
Objective B: S Africa Component Status (5/6)



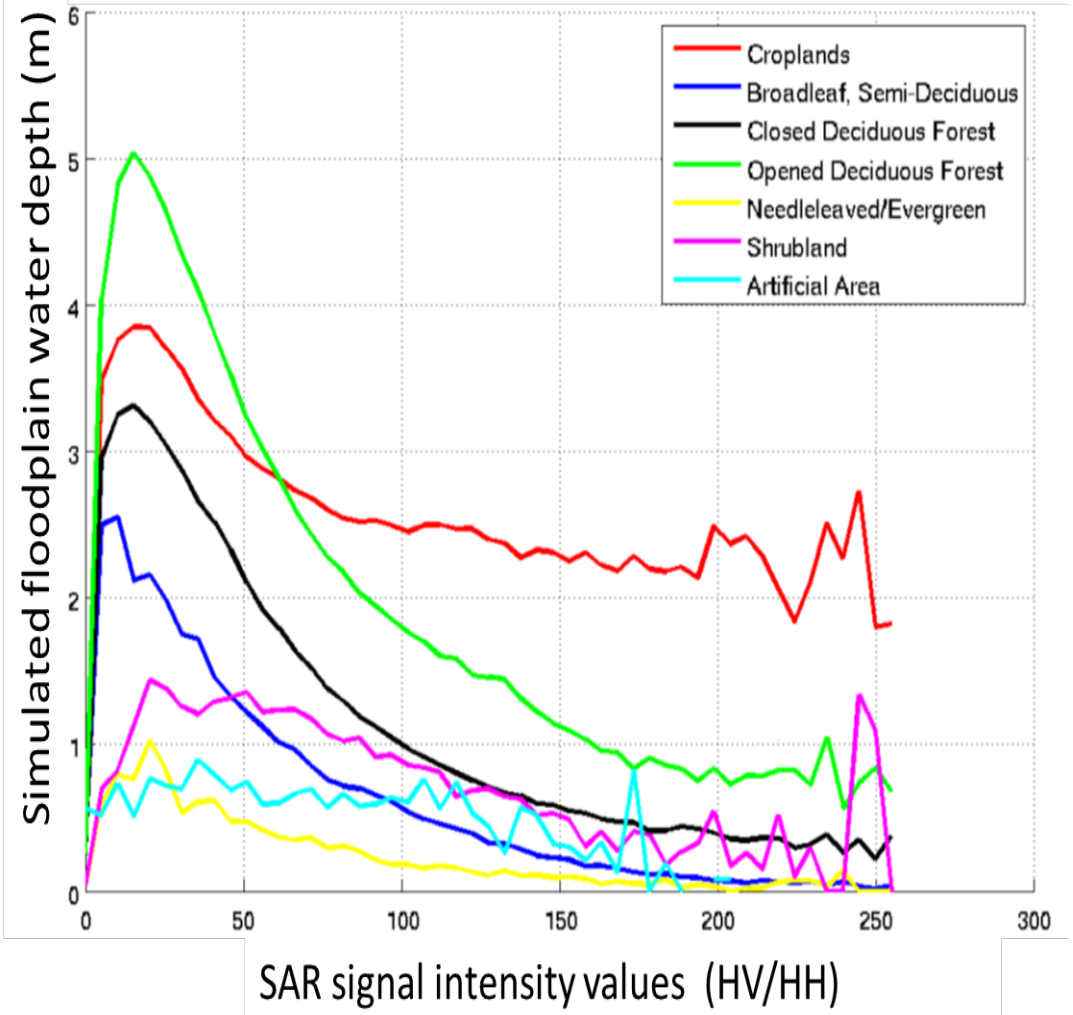
2-D flood model simulation based on Water Balance Model (WBM) long-term simulated hydrologic flows



ALOS-PALSAR L-band flood image of the 2015 event. RGB composite of multiple polarizations (HV, HH, HV/HH)



Detailed land cover classification (2009) based on ESA's GLOBCOVER: http://due.esrin.esa.int/page_globcover.php



Coupled WBM-LISFLOOD-FP flood model is capable of simulating floodplain depth magnitudes. Cross-validating those with ALOS L-band polarizations for different flooded vegetation can improve satellite-based flood mapping.

Contributors: G. Schumann, V. Dang, A. Kettner & B. Brakenridge

Objective B: S Africa Component Status (6/6)

- Other Planned Activities
  - Framework for evaluating flood model forecasts in the Zambezi basin using satellite-derived flood extent maps (LIST-Matgen)
    - Status: In progress; results can also be used to evaluate and modify model calibration parameters and thus improve accuracy
  - Invited talk at International Society of Remote Sensing of the Environment (ISRSE) in Tshwane, South Africa during 8-12 May (need sponsor to support travel for Namibia or Kenya collaborators to present on behalf of the Flood Pilot).

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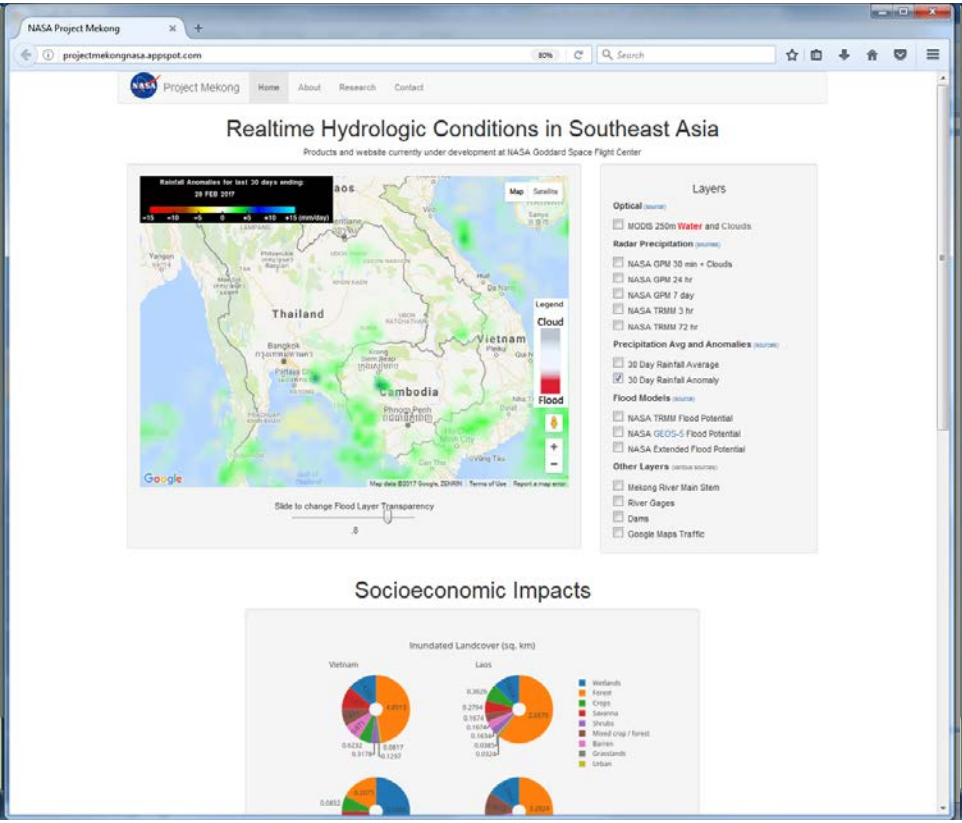
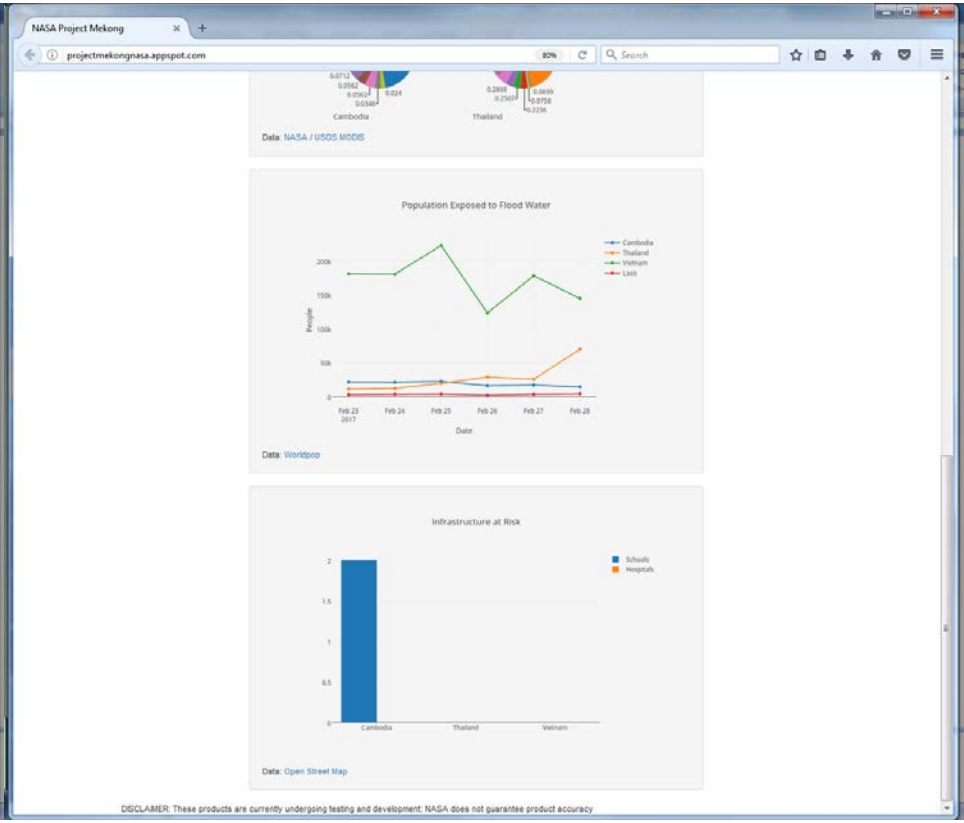
Objective B: SE Asia Component Status (1/10)

- 2014 Milestones:
  - User consultations on new pilot products
    - Status: Open GeoSocial API flood forecasting and event mapping software installed at ICIMOD in 2015.
    - Under SERVIR funding, a flood inundation system was installed at ADPC in January (http://projectmekongnasa.appspot.com/; see next three slides for examples)
  - Test TRMM/GPM-based Global Flood Modeling System (GFMS) 1km resolution flood modeling product over the Lower Mekong Basin (contingent on river gauge data being obtained)
    - Status: On hold—unable to obtain gauge data for this application. SERVIR project will not be a way forward due to usage restrictions.
  - Flood Dashboard development based on Namibia pilot example adapted to SE Asia users
    - Status: Completed http://matsu-seasia.opensciencedatacloud.org/

Objective B: SE Asia Component Status (2/10)

http://projectmekongnasa.appspot.com/





Objective B: SE Asia Component Status (3/10)

Figure 1

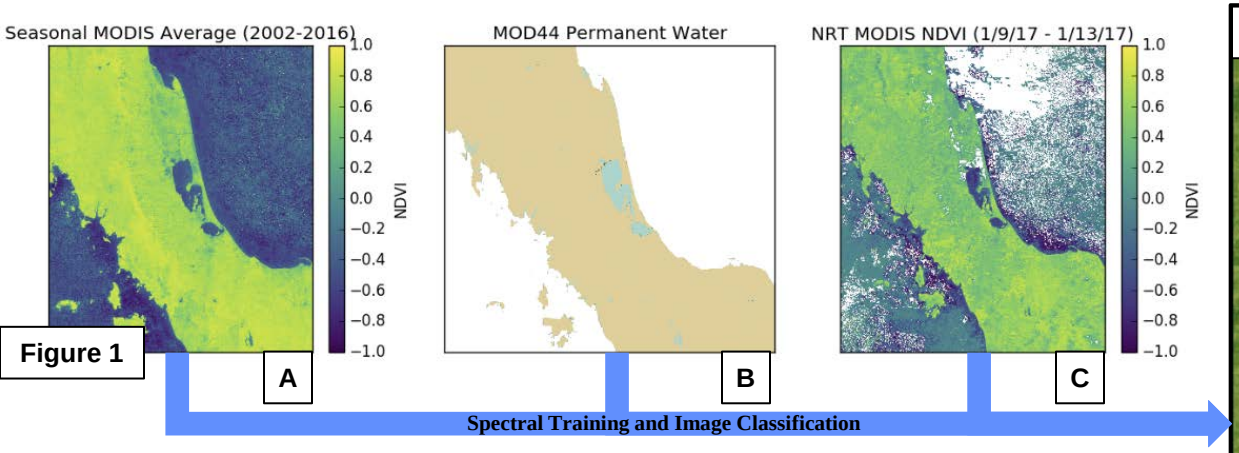
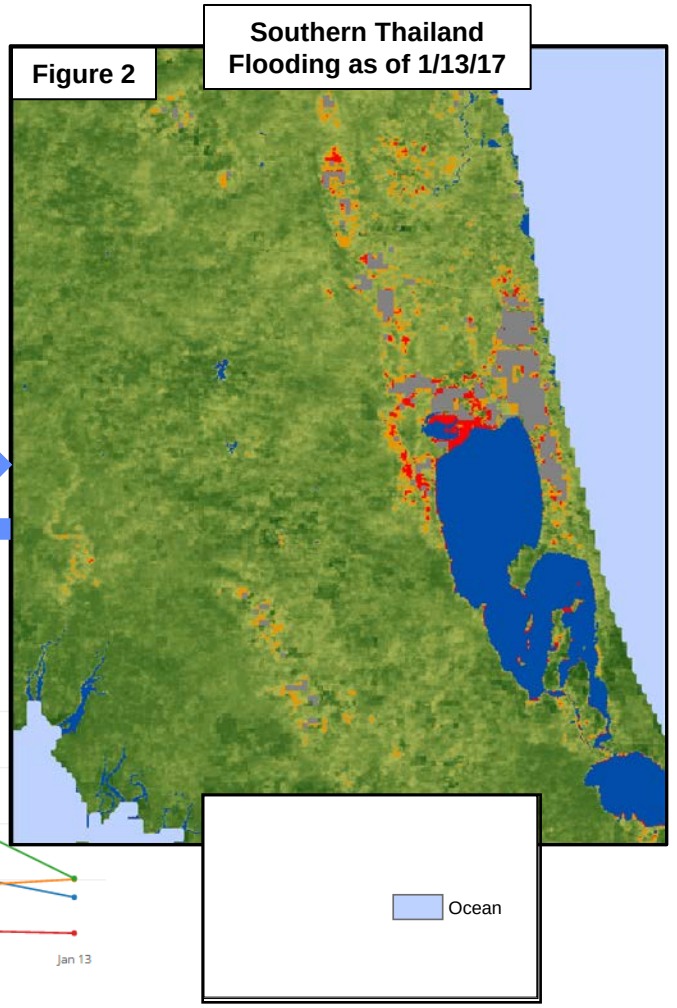
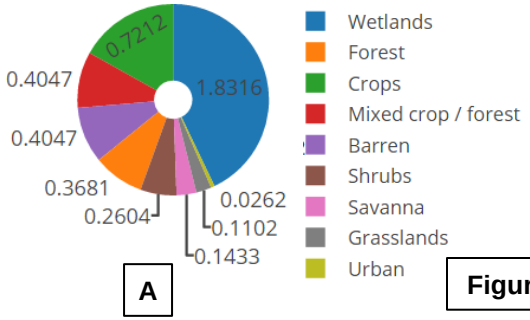


Figure 2



Impacted Landcover (sq km.) in Thailar
(as of 1/13)



Population Exposed to Flooding
(as of 1/13)

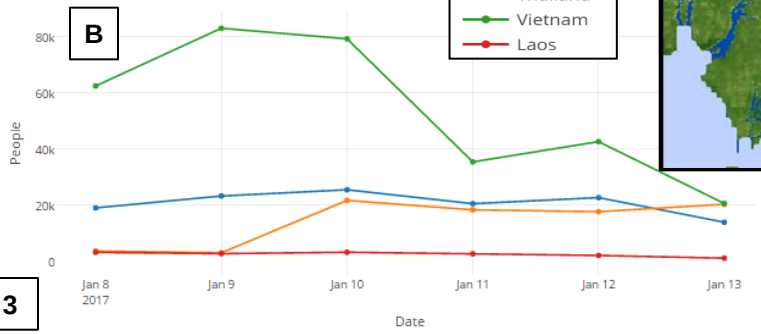


Figure 3

MODIS satellite observations and derived information products (e.g. flooded areas and socioeconomic impacts) are being used by regional NGO's like the Asian Disaster Preparedness center to identify floods and associated impacts to people and infrastructure in near real-time.

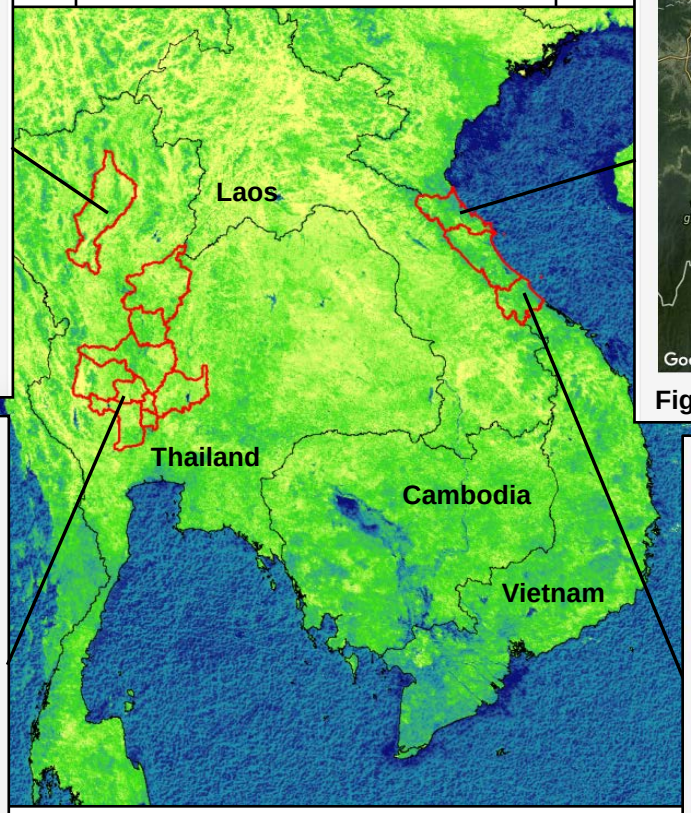
Credit: A. Ahamed, J. Bolten, NASA GSFC

Interactive Web Map: http://projectmekongnasa.appspot.com

Objective B: SE Asia Component Status (4/10)

Figure 2

Figure 1: MODIS-NDVI Composite (10/27/2016 – 11/06/2016)



Provinces Experiencing Flooding (Red Cross)

Real Time Surface Water (MODIS; 250m)

Figure 3

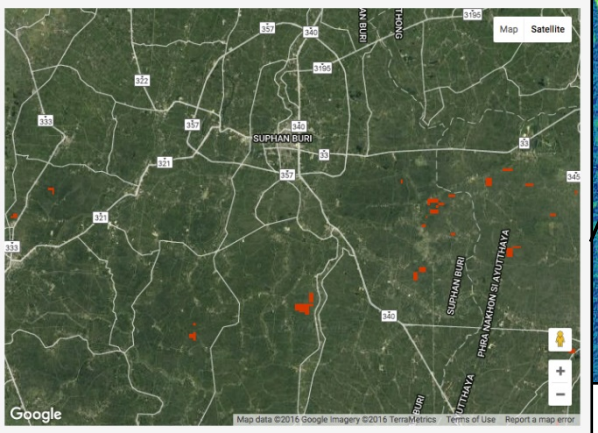


Figure 4

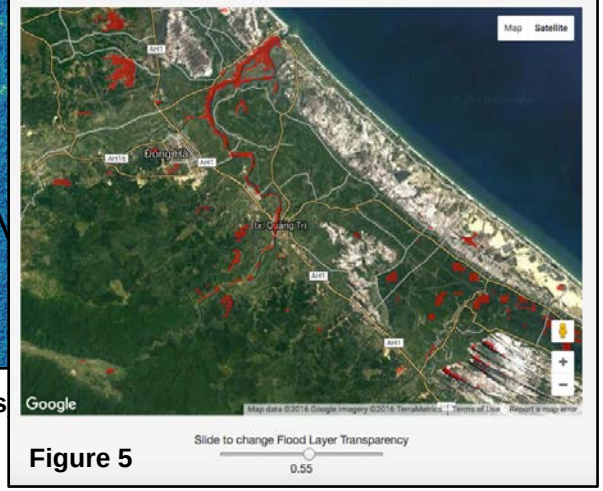


Figure 5

Near Real Time MODIS observations improve impact assessments for flood events reported by international agencies in the flood-prone Lower Mekong region of Southeast Asia.

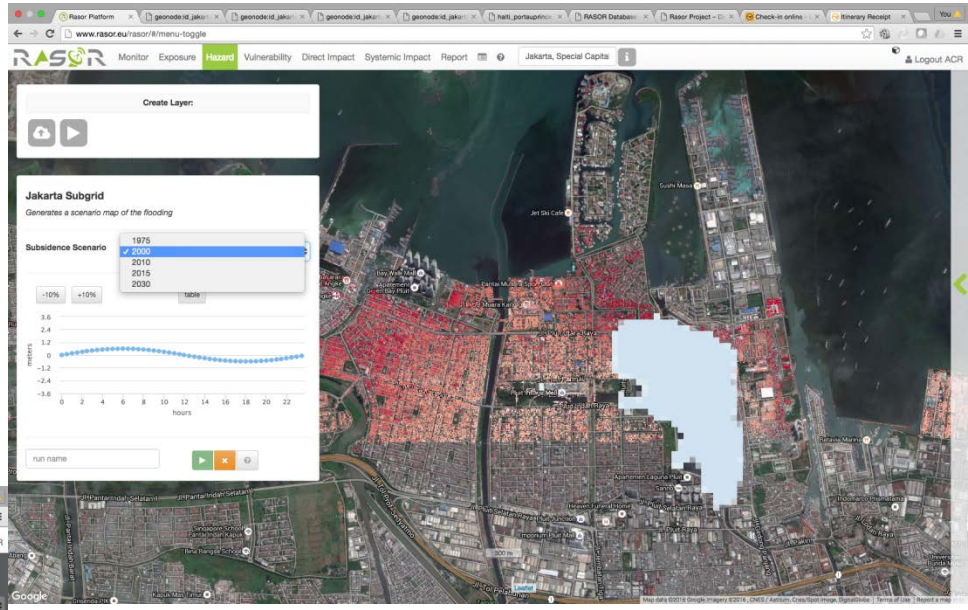
Credit: A. Ahamed, J. Bolten, NASA GSFC

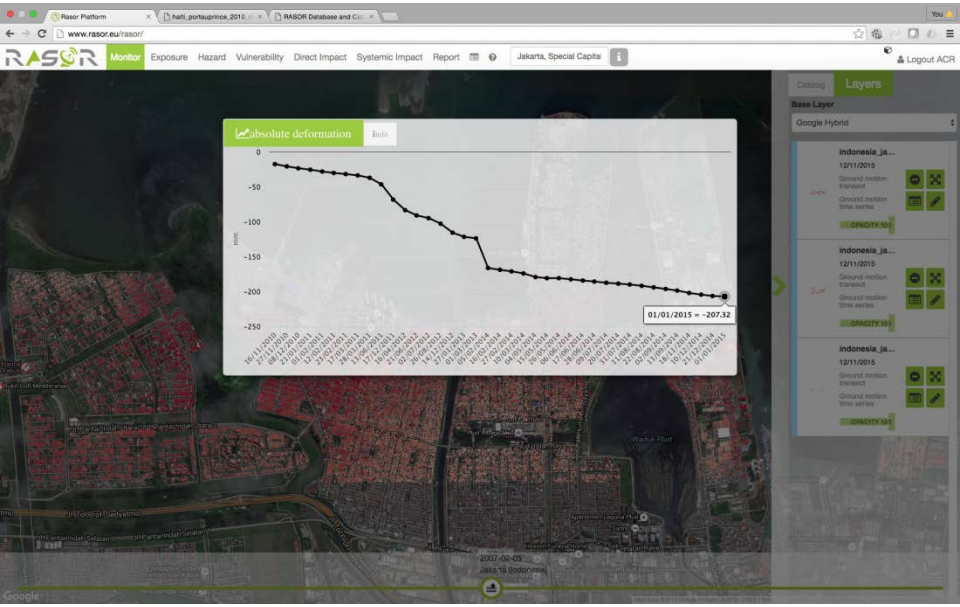
Objective B: SE Asia Component Status (5/10)

- 2015 Milestones:
  - Operational test bed for RASOR risk management system for test sites in Java
    - Status: Phase 2 proposal by RASOR team to fund extensions of 2007-11 / 2013-15 risk mapping work (see next slide) to additional high-risk areas in Indonesia is currently under review by the EC. RASOR also used Pleiades data to generate more accurate maps of urban landscape for damage potential assessment. Recently obtained World Bank funding to highlight how EO can be used in conjunction with flood models to improve loss estimates and DRR planning in Myanmar and SE Asia.
  - Integration of flood dashboard
    - Status: Current Dashboard may go away before the end of the Pilot due to end of NSF grant support
  - Initial services for Mekong River Commission
    - Status: See above

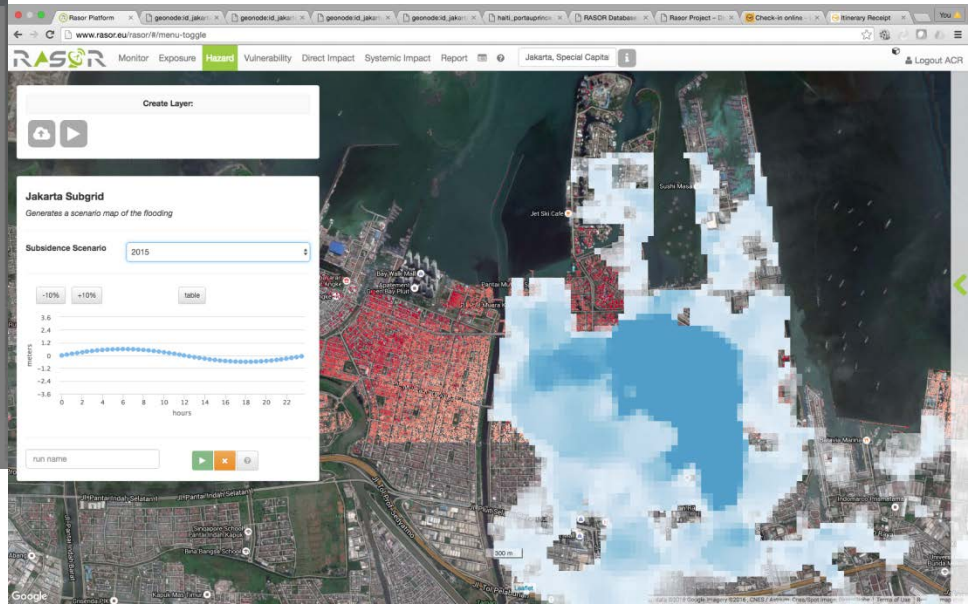
Objective B: SE Asia Component Status (6/10)

Coverage area of the same (hypothetical) flood in 2000 (top right) and 2015 (bottom right) showing the impacts of subsidence.



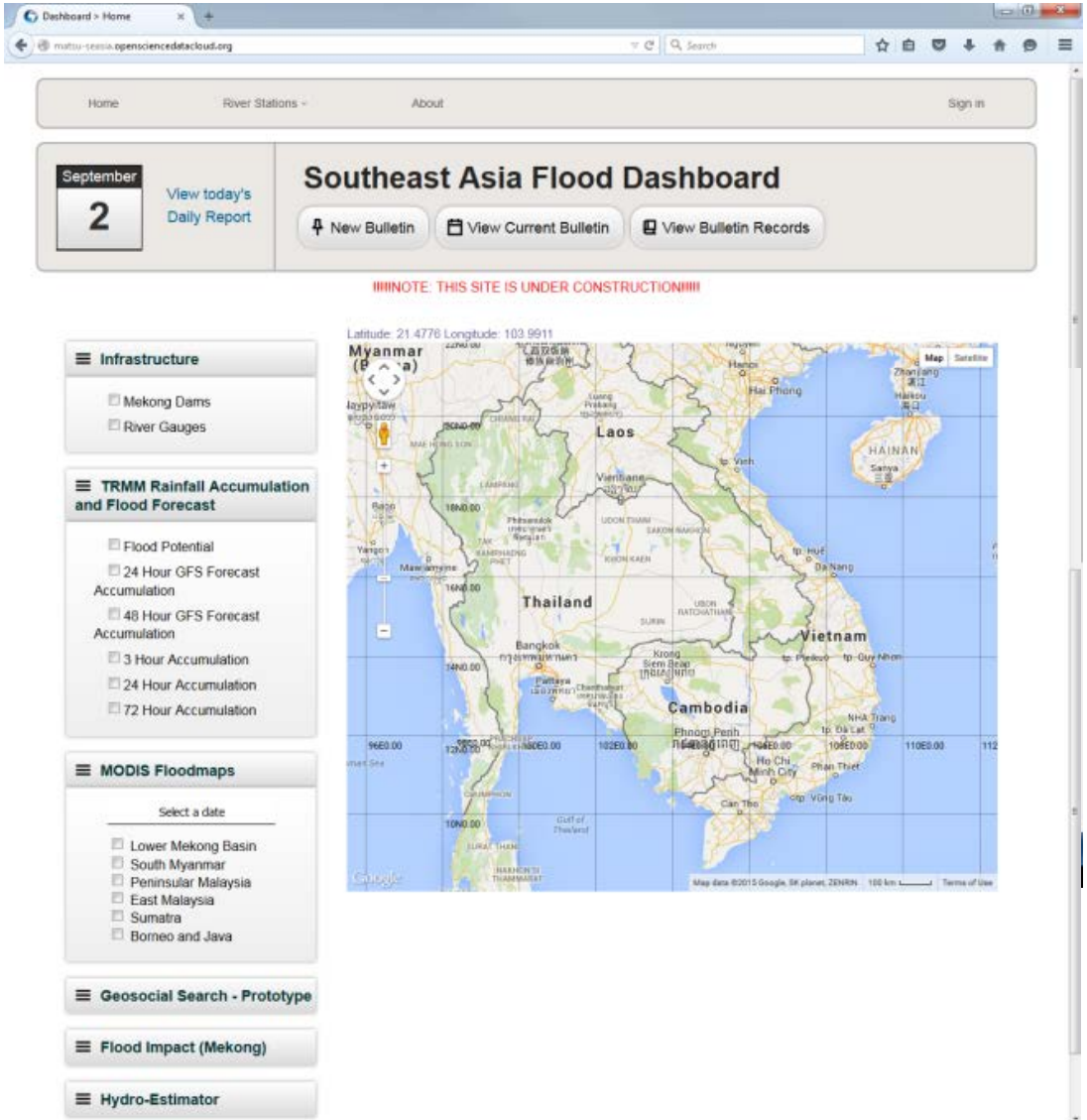


Point subsidence in Bandung, 2010-2015 from ALOS (2007-11) and CSK (2013-15).



Objective B: SE Asia Component Status (7/10)

http://matsu-seasia.opensciencedatacloud.org/

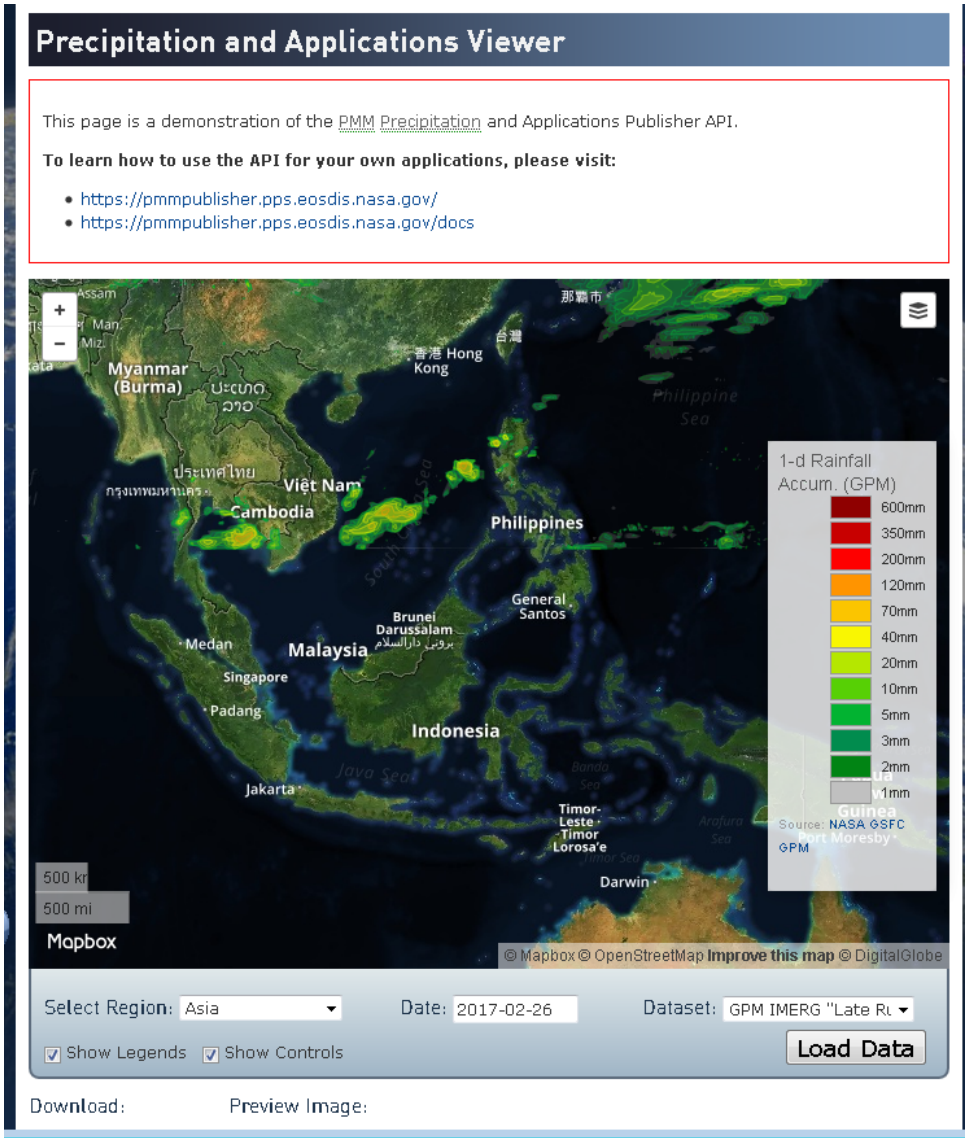


Objective B: SE Asia Component Status (8/10)

- 2015 Milestones (cont.):
  - 10-year flood archive over region based on Deltares Flood Monitoring Programme
    - Status: Deltares did not receive funding to continue collaboration with this Pilot region.
  - 1st new TRMM/GPM and other flood monitoring products
    - Status: iMERG rainfall and GFMS flood products being served under Open GeoSocial API at https://pmm.nasa.gov/precip-apps
- 2016-17 Milestones:
  - Flood monitoring during 2016 season
    - Status: Provided optical imagery for flooding in Sri Lanka (May) and Myanmar (June / November); Indonesia (September).
  - Draft a plan for longer-term sustainability
    - Status: Intent is to build this capacity into ADPC via the SERVIR Applied Science Grant but details need to be worked out
- Status: **80%** complete.

Objective B: SE Asia Component Status (9/10)

https://pmm.nasa.gov/precip-apps



Objective B: SE Asia Component Status (9/10)

- Other Planned Activites
  - Indonesia and Java risk assessments and subsidence calculations (Deltares-Villars)
    - Status: Deltares did not receive funding to continue collaboration with this Pilot region.
- Other Activities:
  - Interaction with the World Bank in December 2015 as part of the RO meeting revealed types of flood products that would be useful to their needs assessments and ongoing recovery support.
  - Provided demonstration of the Open GeoSocial API interface on the ojo-streamer client to World Bank GFRR personnel in April 2016 and to the Sri Lanka head disaster manager in July 2016.
  - Provided Open GeoSocial API interface demo and code to the Pacific Disaster Center in December 2016.

Outline

- Flood Pilot overview
- Status of data acquisition and exploitation
  - JAXA ALOS-2 / PALSAR-2 data use
- **Pilot status report:**
  - Objective A: Global component status
  - Objective B: Regional component status
    - Caribbean/Central America
    - Southern Africa
    - Southeast Asia
  - **Objective C: Capacity Building**
- **Issues and Risk Management**

Objective C: Capacity Building Status (1/2)

- Caribbean/Central American Component:
  - Implemented previously mentioned Open GeoSocial API Flood Monitoring software suite
    - Training workshop by NASA GSFC personnel (supported by SERVIR and USAID) in Costa Rica held in May 2016
    - Now creating products in real time and delivering to regional partners
  - Working through AmeriGEOSS to extend this capability to other portions of the Americas (Chile, Colombia, and Mexico)
    - 2-day disaster training course on disasters (including floods) for AmeriGEOSS participants conducted in Bogata in June 2016
    - Demonstrated the CentroClima Open GeoSocial API to MARN (Ministerio de Medio Ambiente y Recursos Naturales) in El Salvador in December 2016
- Southern Africa Component:
  - Worked with Namibia Department of Hydrology to monitor the status of small farming ponds using Radarsat-2 and EO-1 data (January 2017).

Objective C: Capacity Building Status (2/2)

- Southeast Asia Component:
  - SERVIR funding (J. Bolten) for new ADPC flood products, including ADPC-produced NDVI differences in the Mekong as a new product
  - Provided demonstration of the Open GeoSocial API interface on the ojo-streamer client to ADPC in April 2016 and to the Sri Lanka head disaster manager in July 2016.
  - Provided Open GeoSocial API interface demo and code to the Pacific Disaster Center in December 2016.

Outline

- Flood Pilot overview
- Status of data acquisition and exploitation
  - JAXA ALOS-2 / PALSAR-2 data use
- Pilot status report:
  - Objective A: Global component status
  - Objective B: Regional component status
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    - Southeast Asia
    - *Special Event: Mississippi River (US)*
  - Objective C: Capacity Building
- **Issues and Risk Management**

Issues and Risk Management Approach

- Feasibility and acceptance of Flood Pilot sustainability plan after December 2017 needs additional development and involvement of stakeholders and sponsors

Data Use: Recent (since September) Publications / Conference Presentations

Publications

Bolten, J., 2017: Remote sensing information systems for real-time and historic flood monitoring in Southeast Asia. *International Journal of Applied Earth Observation and Geoinformation*, in review.

Clark, III, R., Z. L. Flamig, H. Vergara, Y. Hong, J. J. Gourley, D. J. Mandl, S. Frye, M. Handy, and M. Patterson, 2016: Hydrological modeling and capacity building in the Republic of Namibia. *Bulletin of the American Meteorological Society*, in press. (Early online release 13 December 2016)

Schumman, G., 2017: Remote sensing of floods. *Oxford Research Encyclopedia of Natural Hazard Science*, in press.

Wu, H. and Adler, R., 2017: Evaluation of Quantitative Precipitation Estimations (QPE) and Hydrological Modeling at the Iowa Flood Studies Focal Basins. *Journal of Hydrometeorology*, in review.

Conference presentations (oral unless otherwise noted): None this period

Questions / Discussion