Forecasting and Monitoring Intense Thunderstorms in the Hindu-Kush Himalayan Region: Preliminary Results from Spring 2018 Demonstration (P2-14)

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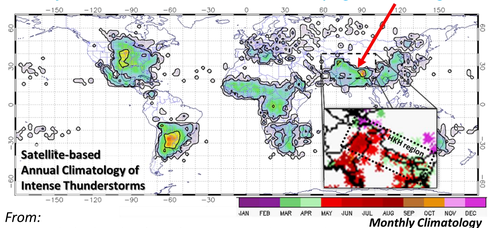
Introduction

- Some of the most intense thunderstorms on Earth plague the Hindu-Kush Himalayan (HKH) region of south-central Asia, esp. during the pre-monsoon months of March through May (see Figure below).
- All thunderstorm hazards are common, including large hail, tornadoes, damaging straight-line winds, deadly lightning, dust storms, and flash flooding.
- This NASA/SERVIR Applied Sciences Team project seeks to use modeling and remote-sending assets to build early warning capabilities and facilitate timely disaster response for high-impact weather events in the HKH region.

Some of the most intense thunderstorms on Earth plague the HKH region:



From:
Cecil and Blankenship (2012)

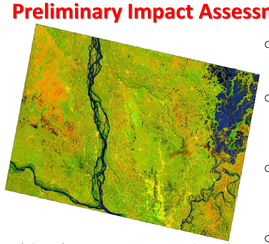
Premonsoon (April-May): Bangladesh to eastern Nepal
Monsoon (June-August): Nepal to northern Pakistan

Preliminary Storm Reports and Casualties

- Sourced from regional news/media outlets; Mar-May 2018
- Not necessarily an exhaustive list
  - 17 lightning events with fatalities
  - 16 damaging wind events and 7 damaging hail events
  - Over 200 fatalities estimated

Event	Location	Lightning	Wind	Hail
29-Mar-18	Bhutan			X
	NE India	X	X	
30-Mar-18	Bangladesh	X	X	X
	Nepal			X
	N India			X
	NE India	X	X	
11-Apr-18	NW India	X	X	
17-Apr-18	N. India	X	X	
21-Apr-18	NE India		X	
22-Apr-18	Bangladesh	X	X	
29-Apr-18	Bangladesh	X		
	N. India	X		
30-Apr-18	Bangladesh	X	X	
2-May-18	N. India	X	X	
6-May-18	Bangladesh	X		
	NE India	X	X	
7-May-18	NE India		X	
9-May-18	Bangladesh	X		
	NE India	X	X	
10-May-18	Bangladesh		X	X
	NE India		X	
11-May-18	Bangladesh	X	X	X
	NE India		X	X
13-May-18	N. India	X	X	
15-May-18	Bangladesh	X		

Preliminary Impact Assessment with Satellite Imagery



(above) 8 June 2018 Sentinel-1 False color SAR RGB image denotes areas of water [blue] in central Bangladesh.

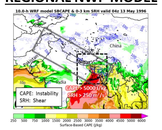
- Passive and active remote sensing was preliminarily evaluated to detect [hail] damage from intense thunderstorms in the HKH region.
- Due to small heterogeneous agricultural areas in the HKH region, it was difficult to identify damaged areas using analysis techniques that are successful in the U.S.
- We will thus re-direct focus to remote-sensing methods and identification techniques to map flooding and inundation areas from intense thunderstorms and annual monsoon rains.
- These techniques and methods will be transferred to end-users and stakeholders during the final year of the project.

Overarching Project Objectives

- Develop High-Impact Weather Assessment Toolkit (HIWAT) for the HKH region.
- Jointly develop HIWAT capabilities and training with the International Centre for Integrated Mountain Development (ICIMOD), the NASA/SERVIR hub based out of Kathmandu, Nepal.
- Demonstrate capability in end-user environment (i.e., "Tethys" web mapping interactive service).
- Transition HIWAT to ICIMOD for future execution and maintenance.

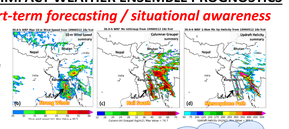
HIWAT Components

REGIONAL NWP MODEL



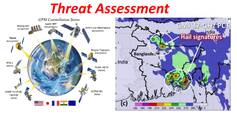
HIGH-IMPACT WEATHER ENSEMBLE PROGNOSTICS

Short-term forecasting / situational awareness



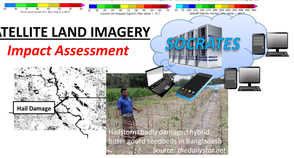
GPM SATELLITE OBSERVATIONS

Threat Assessment



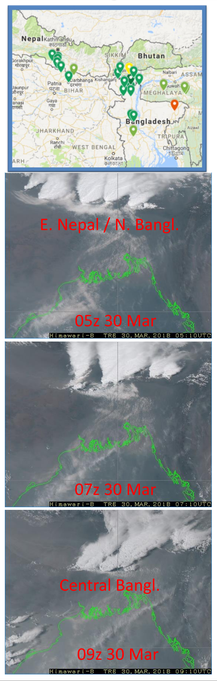
SATELLITE LAND IMAGERY

Impact Assessment

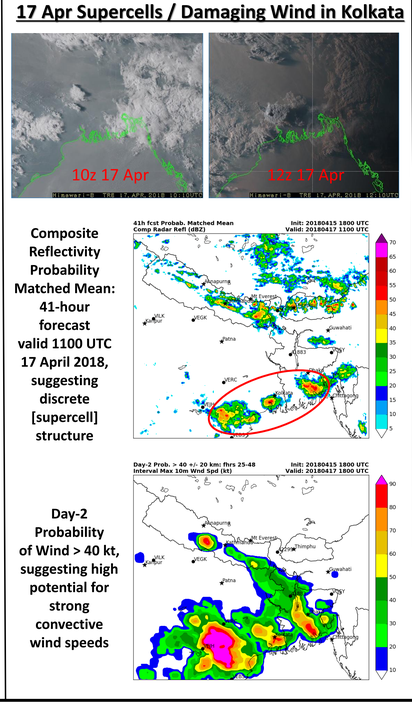


Sample Ensemble Forecast Plots for Select Events

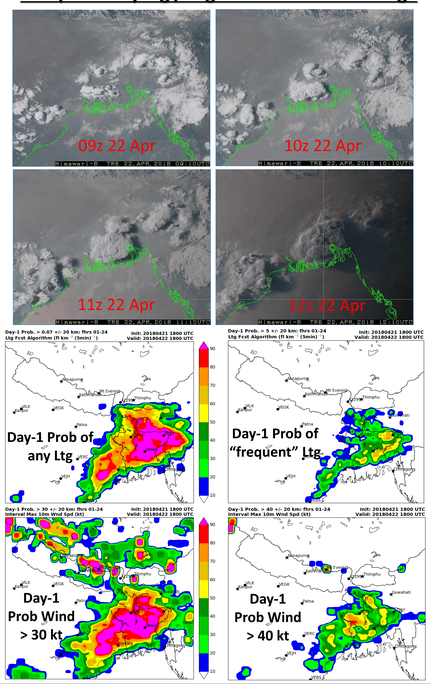
30 Mar Large Hail & Wind; E. Nepal / Bangladesh



17 Apr Supercells / Damaging Wind in Kolkata

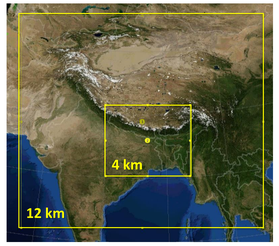


22 Apr Deadly Ltg / High Wind in central Bangl.



Methodology and Datasets

- Daily, real-time 12-member NWP ensemble; pre-monsoon months of March-May 2018
  - Convection-allowing ensemble system with sufficient spread in solution; 18z daily initializations
    - Weather Research and Forecasting (WRF) model within Unified Environmental Modeling System (UEMS)
    - 12-km outer grid/4-km nested grid; all analysis done on 4-km nest (see domain figure below)
    - 12 different initial/boundary conditions from NCEP/EMC's GFS and GEFS operational models
    - Physics variability using 3 planetary boundary layer and 4 microphysics schemes (see table below)
  - 48-hour forecasts with hourly output, displayed on internal project web page for real-time and archive
  - Cluster: SERVIR Operational Cluster Resource for Applications - Terabytes for Earth Science [SOCRATES]
    - Using "head" node and 12 virtual Linux nodes, each with 32 processors and 128 GB RAM
    - Each node runs a single ensemble member; post-processing / product generation on head node
- Proxy model fields to represent convective hazards (Kain et al. 2008, 2010)
  - Convective Intensity: Composite reflectivity
  - Lightning: Lightning Forecast Algorithm (LFA; McCaul et al. 2009)
  - Straight-Line Winds: Maximum output interval 10-m wind speed
  - Hail Threat: Maximum output interval total column graupel
  - Mesocyclone/tornado: Maximum output interval updraft helicity
  - Flooding rainfall: Accumulated precipitation thresholds (esp. 3-hourly)



12-km/4-km nested domain for convection-permitting ensemble.

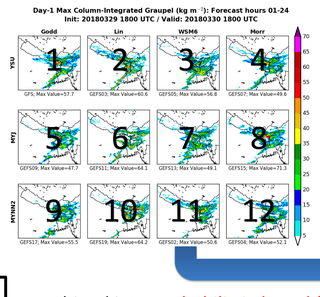
PBL ↓ MP →	Goddard 3-ice with graupel	Lin 6-class	WSM6 6-class	Morrison double moment
Yonsei State University (YSU)	HKH1: GFS	HKH2: GEFS 03	HKH3: GEFS 05	HKH4: GEFS 07
Mellor-Yamada Janjic (MYJ)	HKH5: GEFS 09	HKH6: GEFS 11	HKH7: GEFS 13	HKH8: GEFS 15
Mellor-Yamada Nakanishi and Niino (MYNN2)	HKH9: GEFS 17	HKH10: GEFS 19	HKH11: GEFS 02	HKH12: GEFS 04

12-member ensemble system with variations of initial/boundary conditions and WRF PBL (rows) and microphysics (columns) schemes.

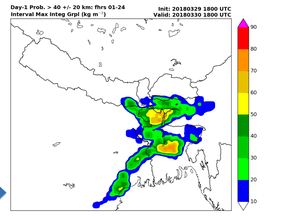
Output NWP Ensemble Products

- Summarize 12-member ensemble system into meaningful fields for intense thunderstorm forecast guidance (largely following Schwartz et al. 2015)
  - Postage stamp plots: Thumbnail view of all ensemble members each hour
  - Ensemble statistics: Mean, Minimum, Maximum, Spread/standard dev.
  - Paintball plots: Threshold applied to various fields and then color-coded by ensemble member with varying transparency
  - Probability products: Probability of exceeding thresholds (as in paintball plots)
  - Daily summaries: Summarizes first and second 24-h forecast periods for a quick look into Day-1 and Day-2 thunderstorm hazards and overall spatial coverage
- Probability products
  - Grid point probability: $Prob_{ij}\ (\%) = 100 \times \left(\frac{Hits}{n}\right)$; where n = # of ens. members
  - Neighborhood probability: Search for "hits" within neighborhood window, then compute probability using formulation above; apply Gaussian smoother
  - Probability Matched Mean (PMM): Replace ensemble mean values with those sampled from distribution of all ensemble members (Ebert 2001; Clark 2017)

Ensemble Forecast Concept Design



Day-1 Probability of Large Hail

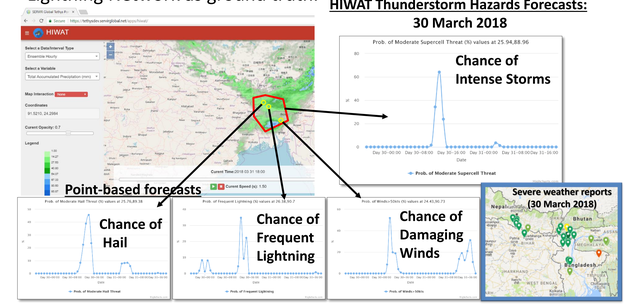


Combined into *probabilistic-based forecast* guidance (e.g., severe hail)

Ongoing and Future Efforts

- Continuing HIWAT ensemble simulations through 2018 wet monsoon
- Transitioning products into NASA/SERVIR Tethys Application
  - Interactive web mapping service capable of layering HIWAT probability maps over other geo-navigated datasets.
  - Data sampling and interactive time series plots generated on the fly for select points and/or user-outlined polygons (see sample images below).
- Conduct verification of individual ensemble member precipitation and PMM, against GPM/IMERG-Final precipitation rates
- Verification of LFA total lightning flash rates using Earth Networks Total Lightning Network as ground truth.

HIWAT Thunderstorm Hazards Forecasts:
30 March 2018



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