Satellite-Based Assessment of Flooding Rainfall and Severe Convection Within the NASA Applied Sciences Disasters Program

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About the NASA Applied Sciences Disasters Program

Mission

Promote the innovative use of Earth observations (EO) to reduce disaster risk, improve response, hasten recovery, and foster resilience

Goals

- Harness NASA Capabilities for disaster management, risk reduction, and resilience
- Engage stakeholders in the use of EO throughout the disaster lifecycle
- Demonstrate the value and impact of EO to increase situational awareness and support actionable decision making

About the NASA Applied Sciences Disasters Program

- Proactive, holistic approach to the use of Earth-observing satellites and airborne assets
- Collaborative research and real-world applications
- Considerations for situational awareness and decision-making
- Enabling disaster risk reduction and resilience by:
  - Identifying pre-disaster vulnerabilities
  - Supporting operational responses to disasters
  - Providing context for mitigation and post-disaster recovery

Hail Storm Risk Assessment Using Space-Borne Remote Sensing Observations and Reanalyses

Kristopher Bedka, NASA Langley Research Center (LaRC), kristopher.m.bedka@nasa.gov

Example Impacts of Hailstorms in Southern Africa

Hail is the costliest severe weather hazard for the insurance industry, generating $10's of billions in losses across the world due to damage to homes, businesses, agriculture, and infrastructure

For example, according to Willis Re, 7 of the top 10 insured natural catastrophe events over South Africa since the 1970s have been associated with hail. ~45% of the total value of insured motor and property claims from natural perils over that period were caused by hail damage.

Hail catastrophe models (CatModels) estimate risk to an insurer's portfolio. CatModels are developed with climatologies defining hailstorm frequency/severity

Hail climatologies are difficult to derive over developing nations without hail reporting or climate-quality weather radar observations

Hailstorms and the damage they produce generate unique patterns in satellite imagery that has been collected for 25+ years, offering a new opportunity to identify hail-prone regions

Hail Storm Risk Assessment Using Space-Borne Remote Sensing Observations and Reanalyses

Kristopher Bedka, NASA Langley Research Center (LaRC), kristopher.m.bedka@nasa.gov

Example Impacts of Hailstorms in Southern Africa

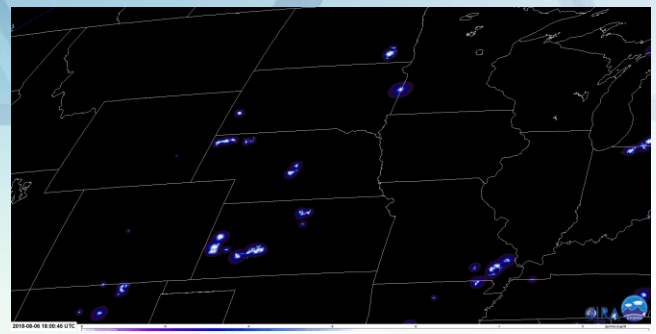
This project is using satellite observations, reanalyses, and models to:

1) Perform climatological hailstorm analysis to enable CatModel development and hailstorm resilience across the globe
2) Improve severe storm understanding and warning in regions without adequate weather radar coverage
3) Analyze hailstorm damage signatures in high spatial resolution optical imager and synthetic aperature radar (SAR) data to assess opportunities for post-disaster mapping and response

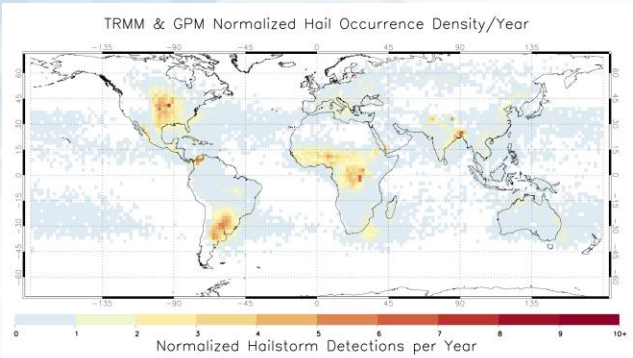
Hail Storm Risk Assessment Using Space-Borne Remote Sensing Observations and Reanalyses

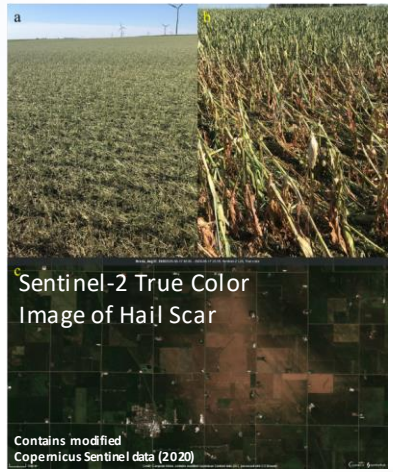
https://www.nasa.gov/feature/langley/nasa-takes-an-insured-look-at-hailstorm-risk

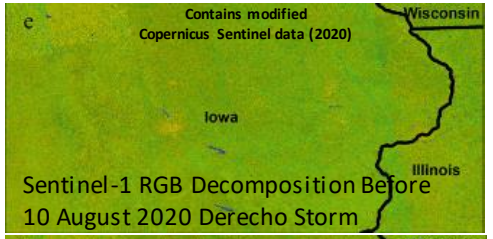
Geostationary Lightning Flash Rates and Flash Characteristics Consistent With Hailstorms

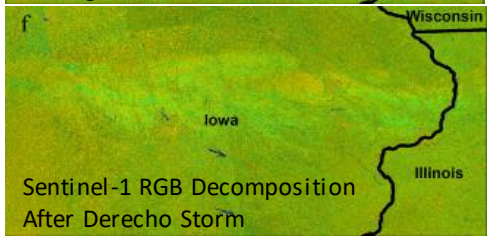


Up to 30-Year Duration Global Passive Microwave Hailstorm Databases



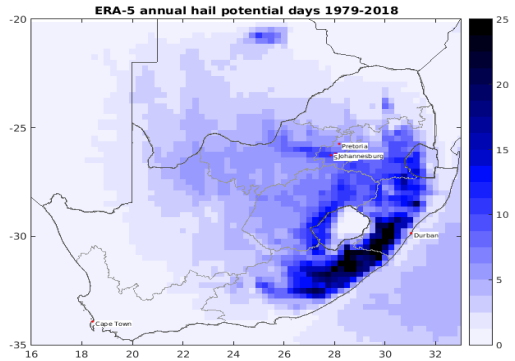


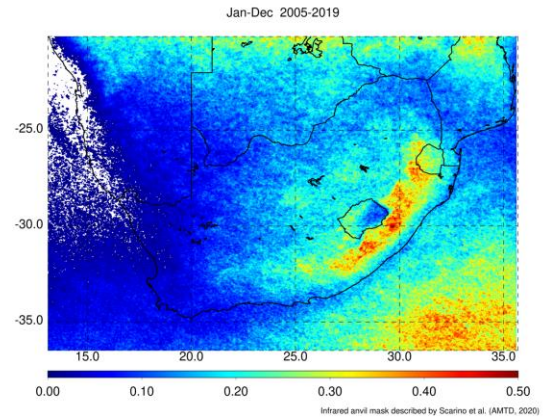




Develop the Highest Possible Resolution and Longest Duration Satellite and Reanalysis-Based Hail and Severe Storm Climatologies, Tested and Validated With Spotter Reports, Doppler Radar Hail Detection, and Insured Losses

Hailstorm Environment Climatologies From Reanalyses



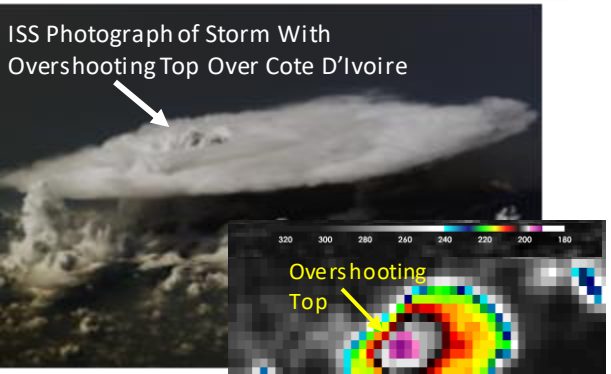


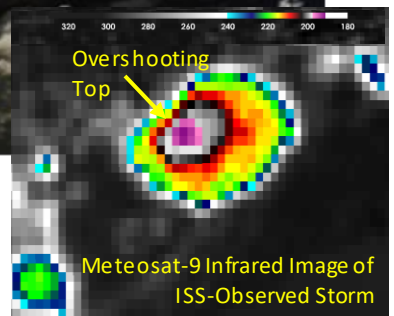
Demonstrate Use of High Resolution Optical Imager and SAR Data To Identify Hail Damage Swaths For Post-Event Response and Insurance Claim Analysis

Use Climatologies To Develop Reinsurance Hail Catastrophe Models, Improve Understanding of Hailstorm Distributions at High Spatio-Temporal Resolution, and Address Important Decadal Survey Science Questions

Provide Near-Real Time Geostationary Products To Aid Severe and Aviation Weather Forecasting

Visualize and Provide Data to The International Community With GIS-Based Tools





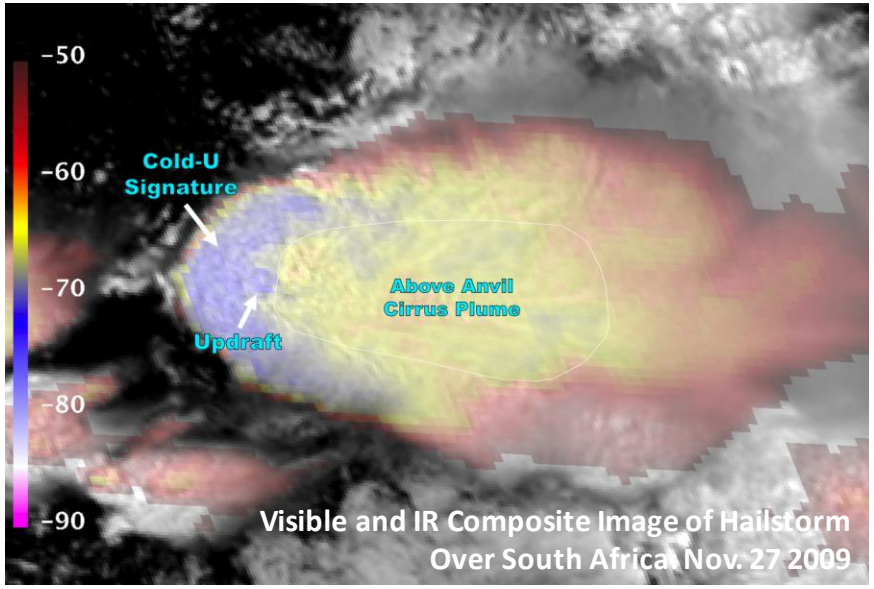
Up to 25 Year Duration, ~3-5 km and 10-30 min Resolution Regional GOES and Meteosat Visible and Infrared Detections of Hailstorm Clouds

Project Partners

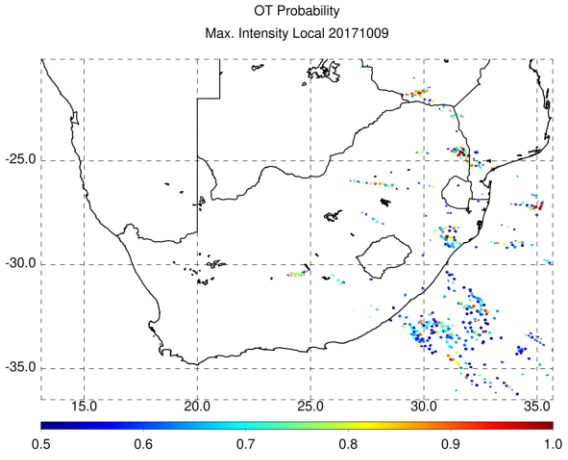
NASA LaRC and MSFC, Willis Towers Watson,
Karlsruhe Institute of Technology, University of Buenos Aires,
Brazil National Institute for Space Research CPTEC,
National Meteorological Service of Argentina, South African Weather Service,
Central Michigan University, University of Oklahoma

Meteosat Infrared Overshooting Cloud Top Detection Climatology Over Southern Africa

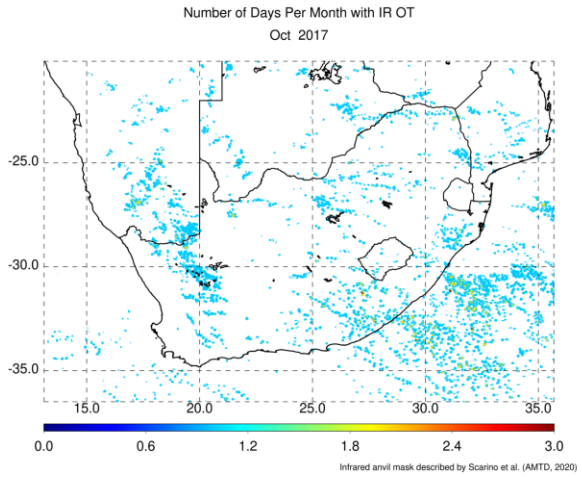
- **A 15-year NASA database of MSG SEVIRI infrared convection detection and characterization products were generated from 2005-2019 over Southern Africa**
  - 3 km pixels at 15 minute resolution
  - Data acquired and processed via McIDAS and the UW-Madison SSEC
  - Using methods of Khlopenkov et al. and Cooney et al. (JGR, 2021)
- **15-minute products are aggregated into daily files at hourly timesteps. The most extreme values at each 3 km pixel are recorded within an hour.**
  - Corrected for parallax and accumulated in local hour bins
  - Data then aggregated to monthly and multi-annual scales



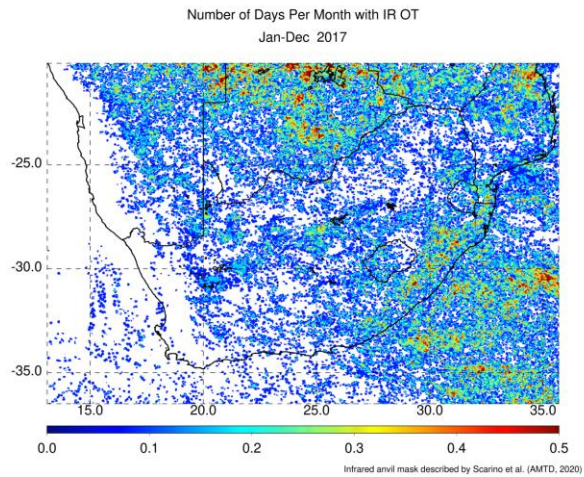
9 October 2017 Daily Overshooting Top (OT) Detections



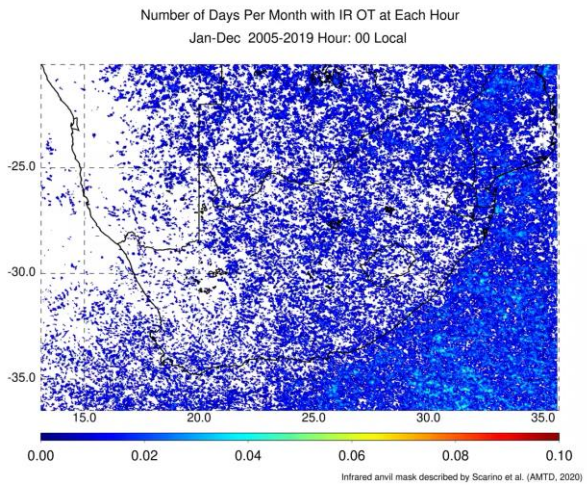
October 2017 Monthly OT Detection Counts



2017 Annual



2005-2019



March 2021 Willis Re South Africa Hail CatModel Release

A Hail Catastrophe Model (CatModel) over South Africa, developed using the following data and process is being now being used in insurance industry operations at Willis Re

1) Spatio-temporal clustering of Meteosat overshooting cloud top detections,
2) NASA TRMM and GPM microwave hail detection climatologies,
3) Storm environment data from ERA-5 reanalysis
4) Sophisticated statistical and stochastic modeling

https://www.willistowerswatson.com/en-GB/Insights/2021/03/a-new-view-of-south-african-hail-risk-for-the-re-insurance-industry

Willis Towers Watson

Article

A new view of South African hail risk for the (re)insurance industry

Share

By Alex Saunders, Rachel Gillespie and Geoffrey Saville | March 9, 2021

A new Willis Re hail natural catastrophe model for South Africa is indicative of how science is improving our understanding of the causes and insurance impacts of major hailstorms.

https://www.willistowerswatson.com/en-US/News/2021/03/willis-re-launches-new-south-african-hail-risk-model

Willis Towers Watson

Press Release

Willis Re launches new South African hail risk model

Share

March 9, 2021

LONDON, March 9, 2021 – Willis Re has launched a new Hail Catastrophe Risk Model which quantifies the risk from damaging hail events across South Africa. Developed in collaboration with Willis Research Network partners at NASA's Langley Research Centre and the Karlsruhe Institute of Technology (KIT) in Germany, the model delivers a robust view of hail risk for the (re)insurance market.

Media Contact

Sam Horril
Public Relations Coordinator
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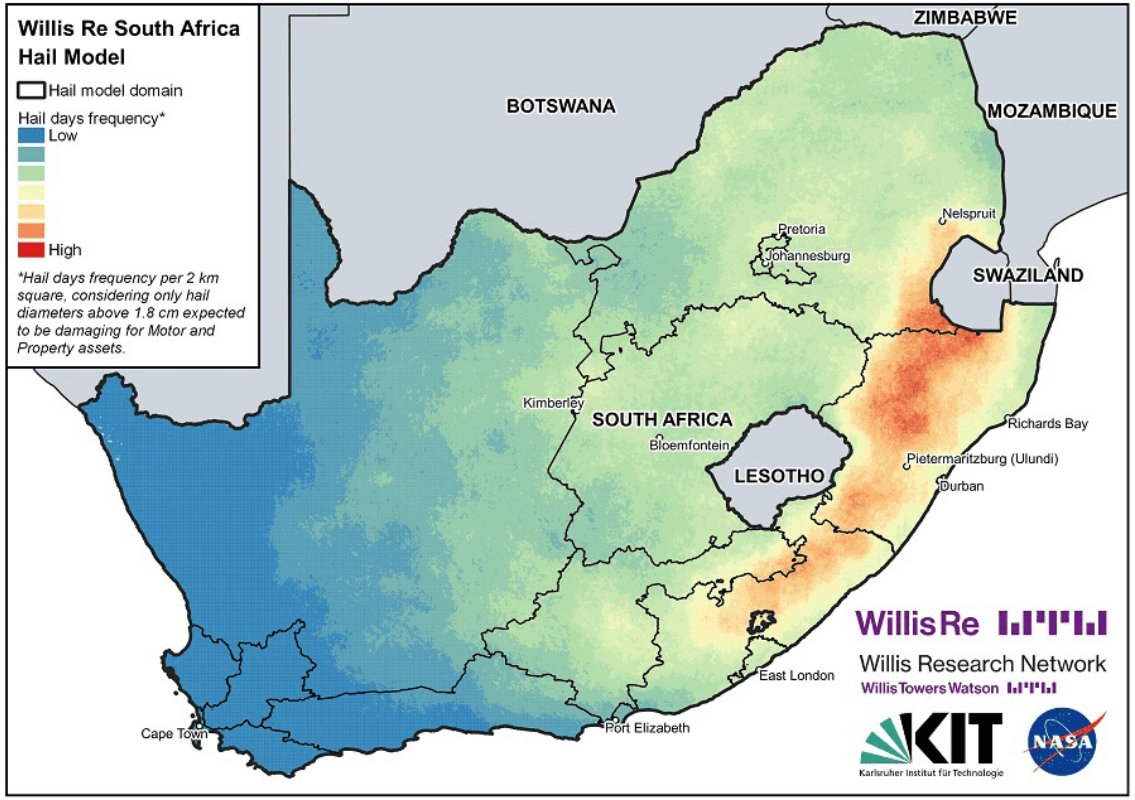
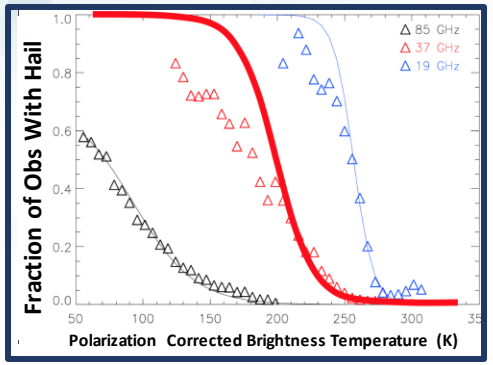
Cover Magazine interview with Willis Re describing South Africa Hail CatModel: https://cover.co.za/modeling-hail-risk-with-willis-re/?utm_source=linkedin&utm_medium=social&utm_campaign=Willis-Re_&utm_content=willis+re_dea30f3e-b764-4db1-ad03-b3ee0b4162a7_&utm_term=

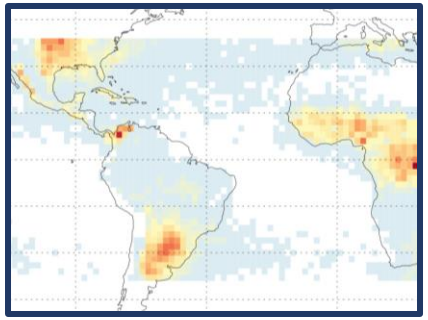


Global Hail Climatologies From Passive Microwave Imagers

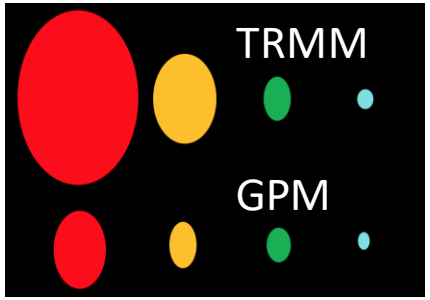
Train a hail detection algorithm on a TRMM feature database paired with surface hail reports over the US. Create a P_{hail} function based on both 37 & 19 GHz Polarization Corrected Brightness Temperature (PCTs)



After normalizing for orbit and sampling frequency, and filtering out likely surface ice artifacts, apply the retrieval the TRMM domain (38°S-38°N), to create a climatology

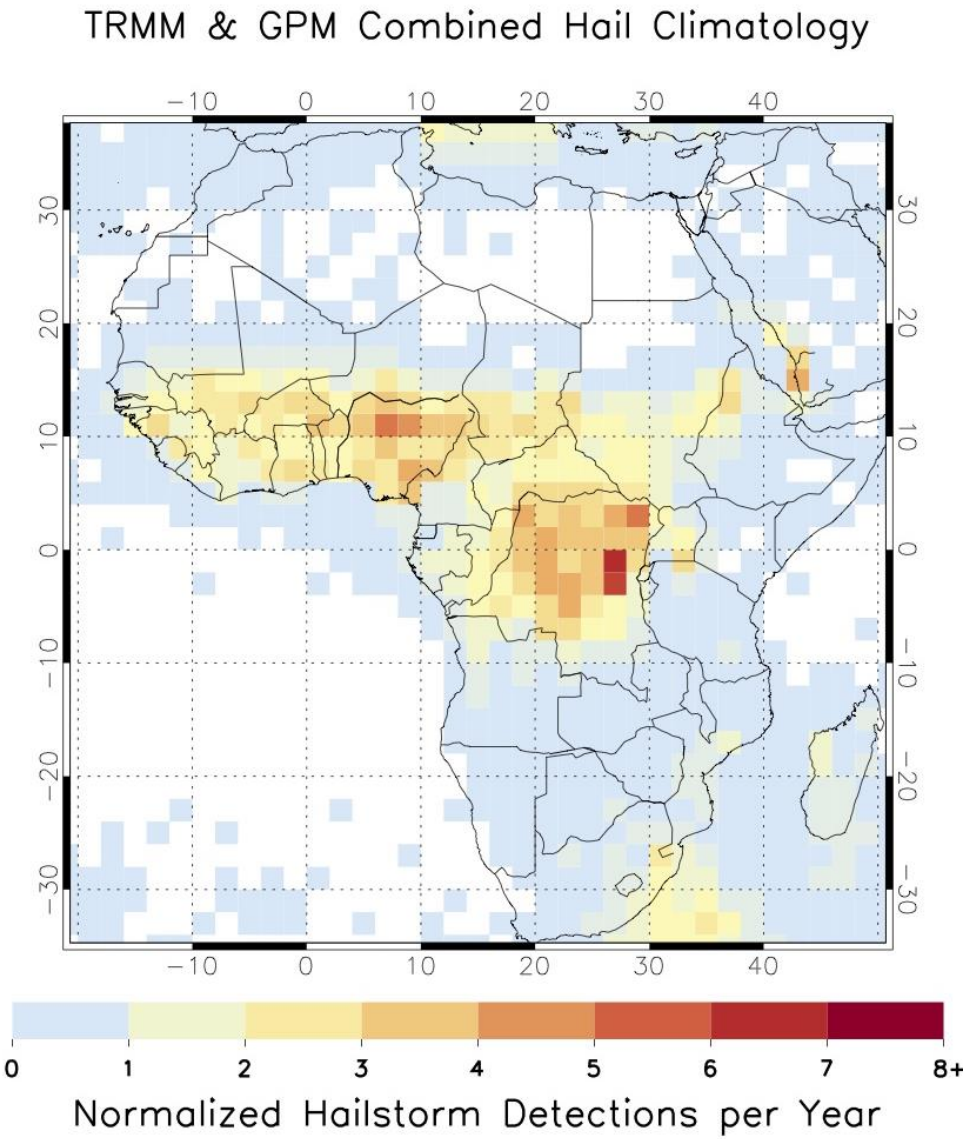


Using histogram-adjustment, scale the GPM (and other sensors) PCTs to the TRMM distribution, to account for differences in footprint size

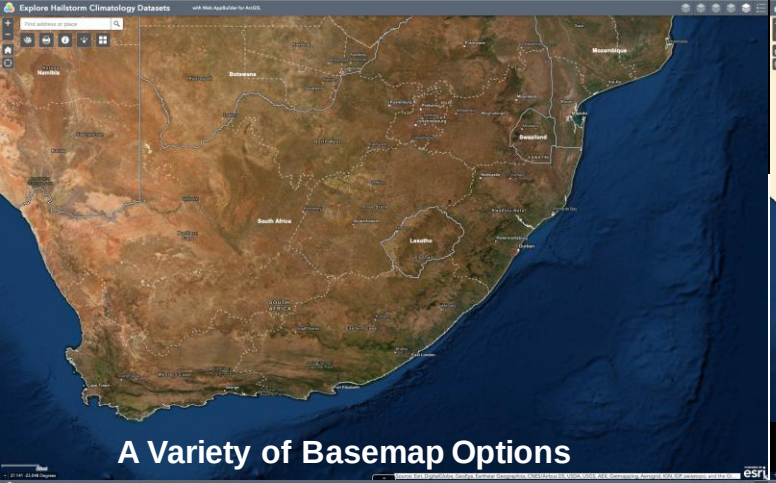


Bang and Cecil (JAMC, 2019, 2020)

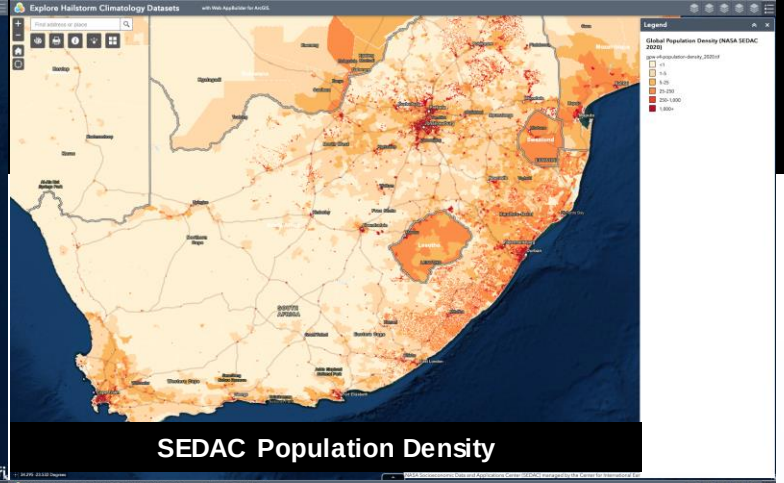
Apply the normalizations, adjustments, and filters to create climatologies



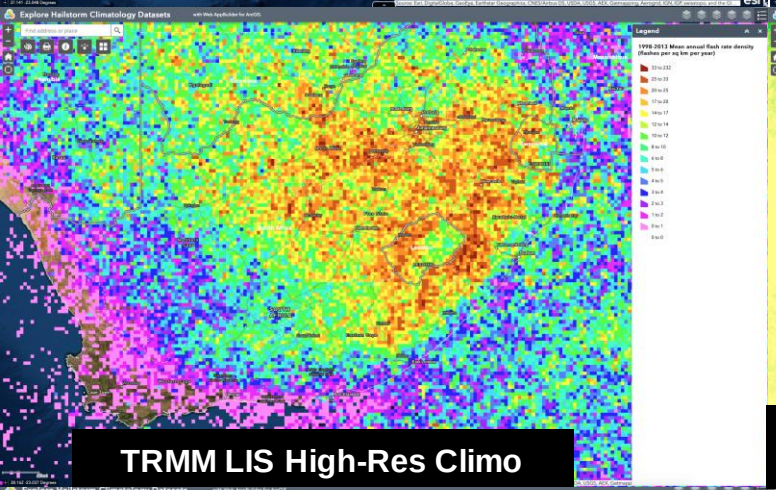
ArcGIS Interactive Satellite-Derived Hailstorm Data Visualization Portal



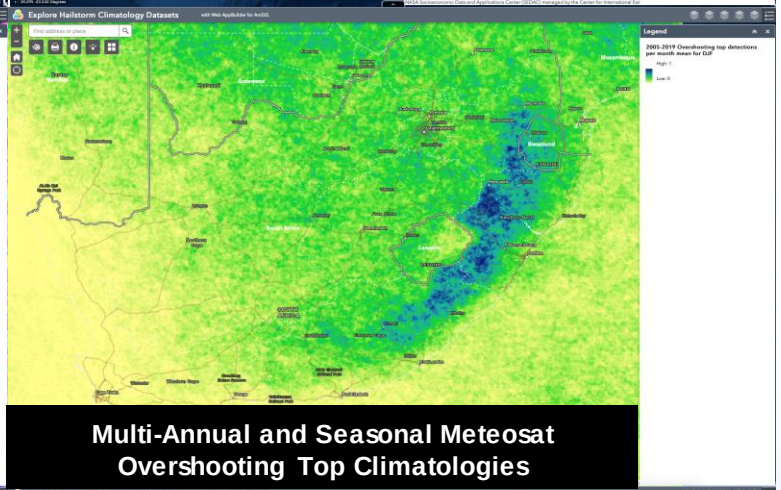
A Variety of Basemap Options



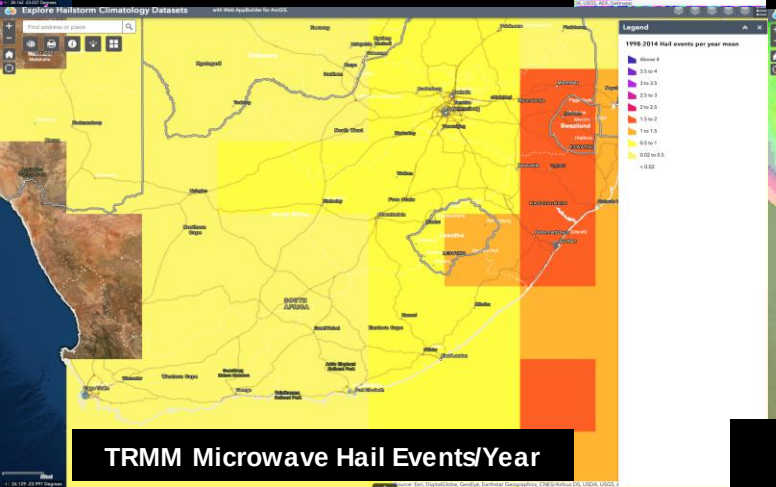
SEDAC Population Density



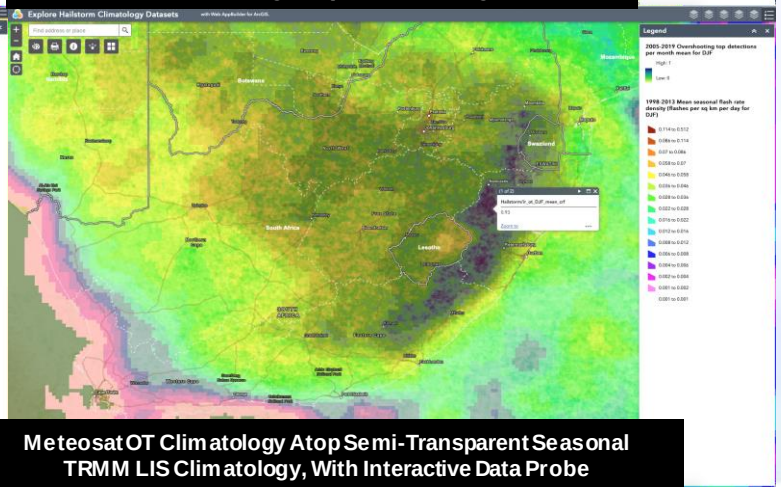
TRMM LIS High-Res Climo



Multi-Annual and Seasonal Meteosat Overshooting Top Climatologies



TRMM Microwave Hail Events/Year



Meteosat OT Climatology Atop Semi-Transparent Seasonal TRMM LIS Climatology, With Interactive Data Probe

- **An ArcGIS-based Hailstorm Data Visualization Portal was recently made available online for community feedback**
  - https://arcg.is/0C8eXC
- **GIS tool was developed by the Langley Atmospheric Science Data Center (ASDC), including:**
  - TRMM and GPM hailstorm detections
  - TRMM LIS lightning climatology
  - Meteosat overshooting top and anvil cloud climatologies

Key Features

- A variety of base maps
- Ability to overlay multiple satellite and socio-economic datasets
- Data probing
- Detailed city and landform labels

Rapid Flood Severity Classification and Alerting for the Spring 2020 Africa Floods: A Case Study

Margaret Glasscoe (University of Alabama in Huntsville), Bandana Kar (Oak Ridge National Laboratory), Kristy Tiampo (University of Colorado, Boulder), ZhiQiang Chen (University of Missouri, Kansas City), Marlon Pierce, Jun Wang (Indiana University), Douglas Bausch, Chris Chiesa, Greg Hampe (Pacific Disaster Center), Ronald Eguchi, Charlie Huyck, Guy Schumann (ImageCat, Inc)

MoM Objectives

1. Integrate two globally operational flood models - GloFAS (Global Flood Awareness System) and GFMS (Global Flood Monitoring System) to forecast flood severity. Outputs from HWRF (Hurricane Weather Research and Forecast System) and DFO (Dartmouth Flood Observatory) are also used to update severity in real-time.
2. Classify flood severity and send alerts based on severity level similar to USGS PAGER (used for severity alerting for earthquakes) using Pacific Disaster Center's (PDC) DisasterAWARE® platform.
3. Provide situational awareness information to impacted communities in near real-time for response and recovery efforts.
4. Validate and calibrate the model outputs using remote sensing (Synthetic Aperture Radar) derived flood outputs.

Purpose: Develop and deploy a Model of Models (MoM) approach integrating hydrodynamic models and remote sensing derived products for flood forecasting.

Setting Flooding in a Regional Context

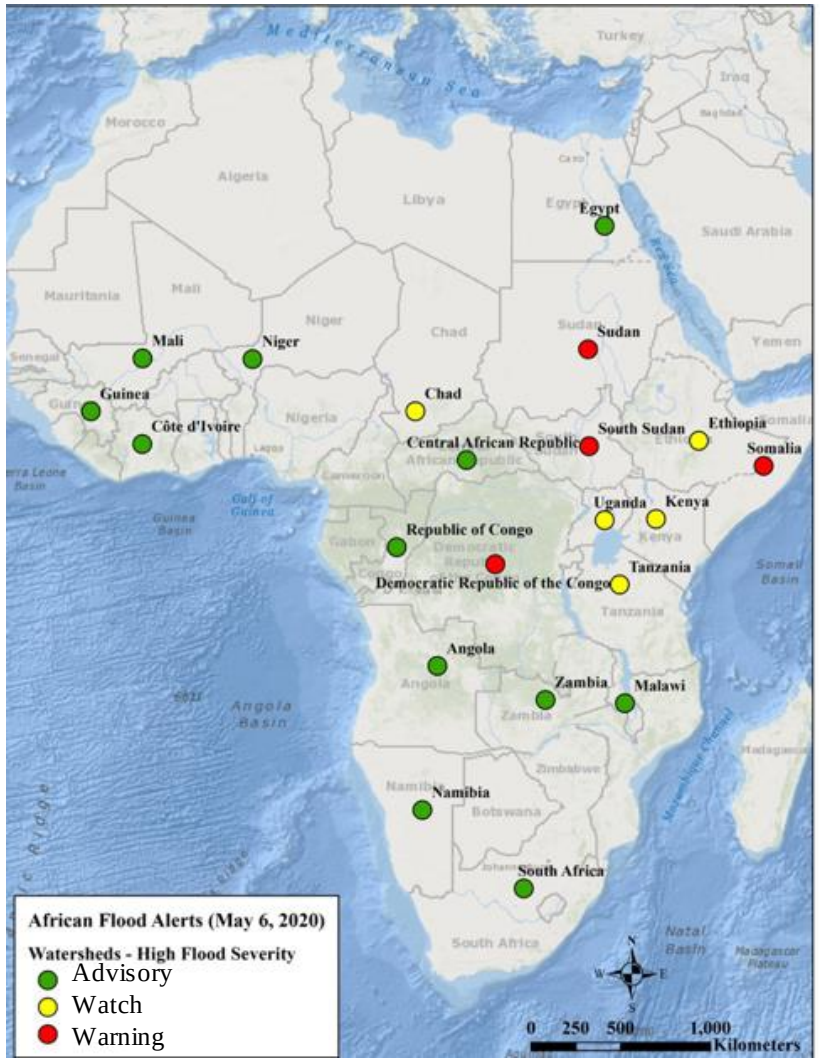
Model of Models: Watershed level flood severity

- The model of models is an ensembled model that forecasts flood severity at sub-watershed level.
- This allows identifying flood risk at a *regional* level.
- The flood severity information is used to obtain and process high-resolution Earth Observation data for determination of flood extent and assessment of societal and critical infrastructure impacts of flood.

Model of Models
Watershed/regional

→

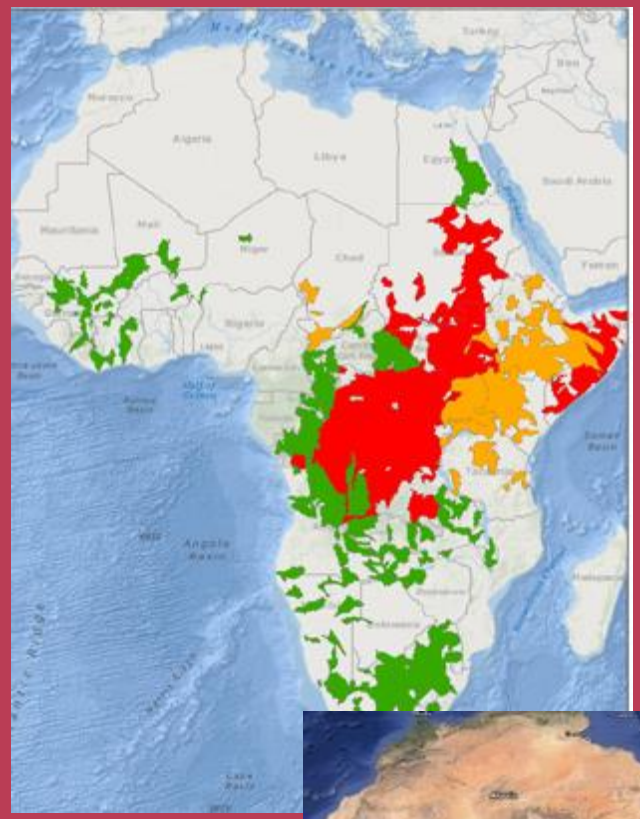
Remote Sensing/EO
Local/City

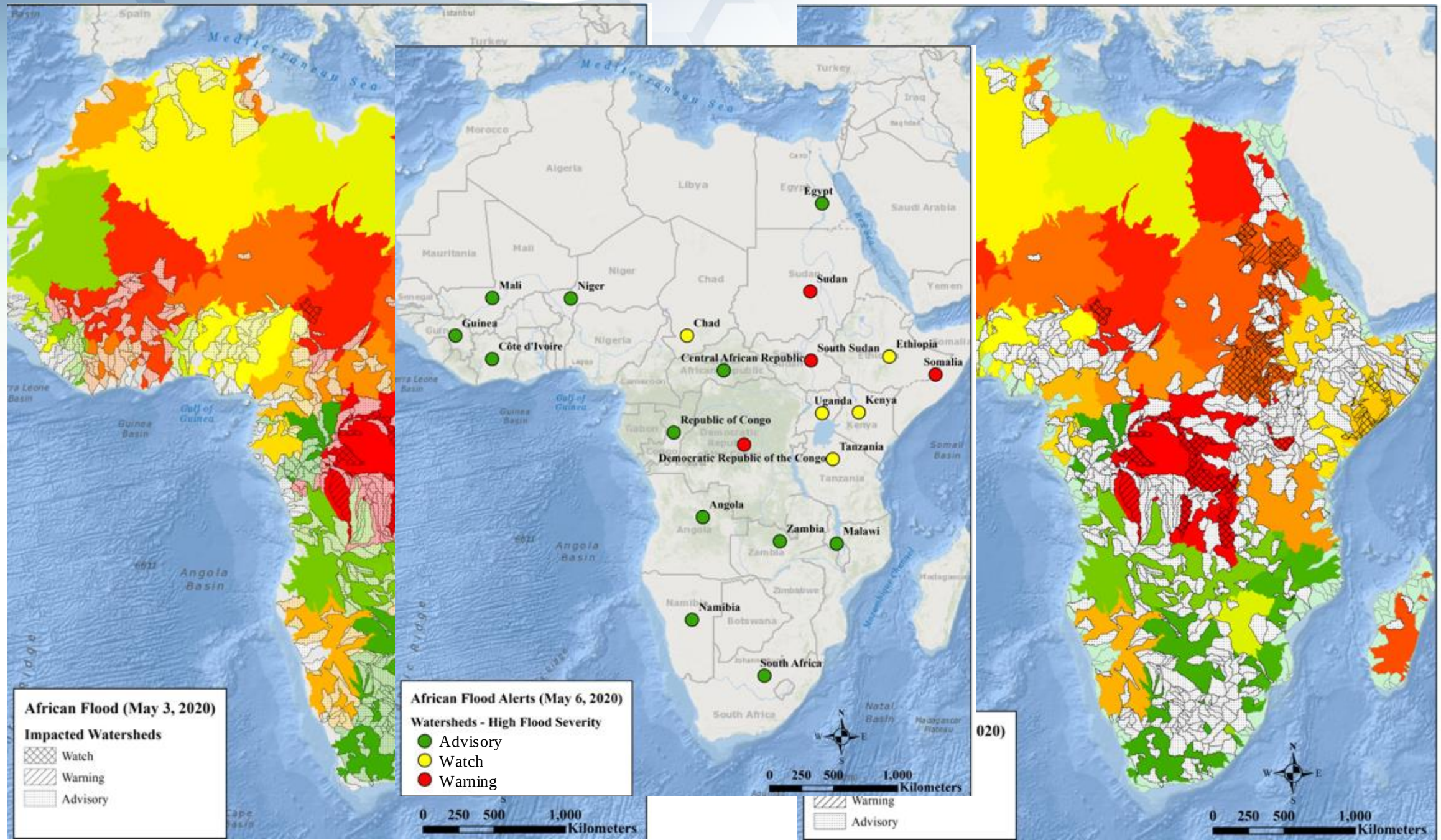


Flooding in Africa Based on MoM Flood Severity
(May 3-4, 2020)
(Red - Watch, Yellow – Warning and Green – Advisory)

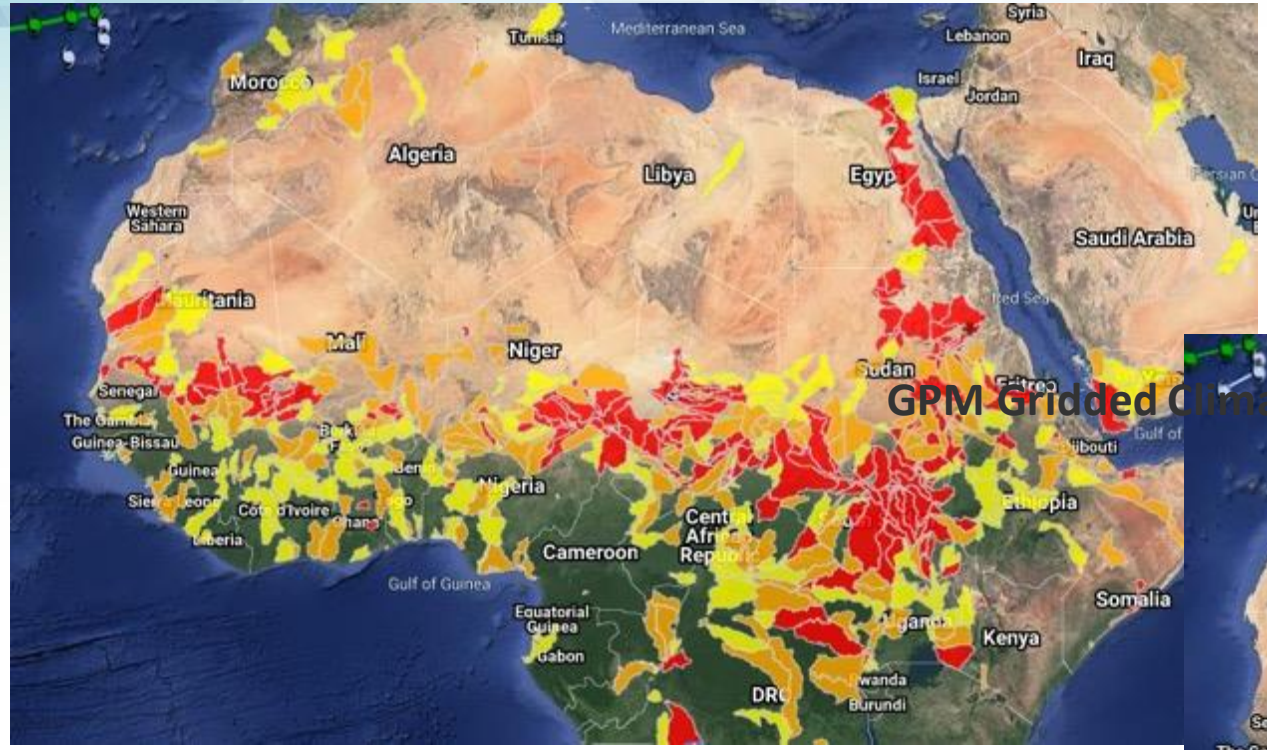
FLOODING IN EAST AND CENTRAL AFRICA SPRING 2020

- Central and east Africa, particularly the countries of Kenya, Somalia, Sudan, South Sudan, and the Democratic Republic of the Congo, experienced severe flooding in spring 2020 as greater and more widespread than normal rainfall occurred during their “long rains” season.
- Flooding in Africa led to exposure/risk to vulnerable populations and infrastructure
- These risks are often compounded by multiple associated events – heavy rainfall causing both flooding and landslides
- https://disasters.nasa.gov/africa-flooding-2020




African Flood (May 3, 2020)
Impacted Watersheds
Watch
Warning
Advisory
African Flood Alerts (May 6, 2020)
Watersheds - High Flood Severity
Advisory
Watch
Warning
Egypt
Sudan
Mali
Niger
Guinea
Chad
Côte d'Ivoire
South Sudan
Ethiopia
Central African Republic
Somalia
Uganda
Kenya
Republic of Congo
Tanzania
Democratic Republic of the Congo
Angola
Zambia
Malawi
Namibia
South Africa
0 250 500 1,000
Kilometers

Comparison of MoM Output and DisasterAWARE Manual Alert Locations (September 21st, 2020)



MoM Output

GPM Gridded Climatologies

DisasterAWARE Manual Alert Locations

Thank you!

Questions?

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