Contribution of EO data and H SAF products for Hydrology

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& All the H SAF team

H SAF Project Manager

EUMETSAT H SAF

Outline

- why satellite products are important for hydrology
- Satellite products for hydrological applications
- some severi events

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Hydrological Services

Operational Service	Application
Operational Hydrological services	Flood and landslides forecasting
	Land management
	Water resources management
Agriculture	Drought monitoring
	Water resources management
Civil defence	Preparation for emergencies
	Emergency management
	Post-emergency phase

Precipitation

Soil moisture

Snow

Evapotranspiration

River discharge

Water body extent

Several hydrological Operational services are employed by National and international agencies and authorities in order to prevent hazards and natural disasters, as well to improve water management.
These services to cope their mandate need accurate and timely meteorological and hydrological parameters

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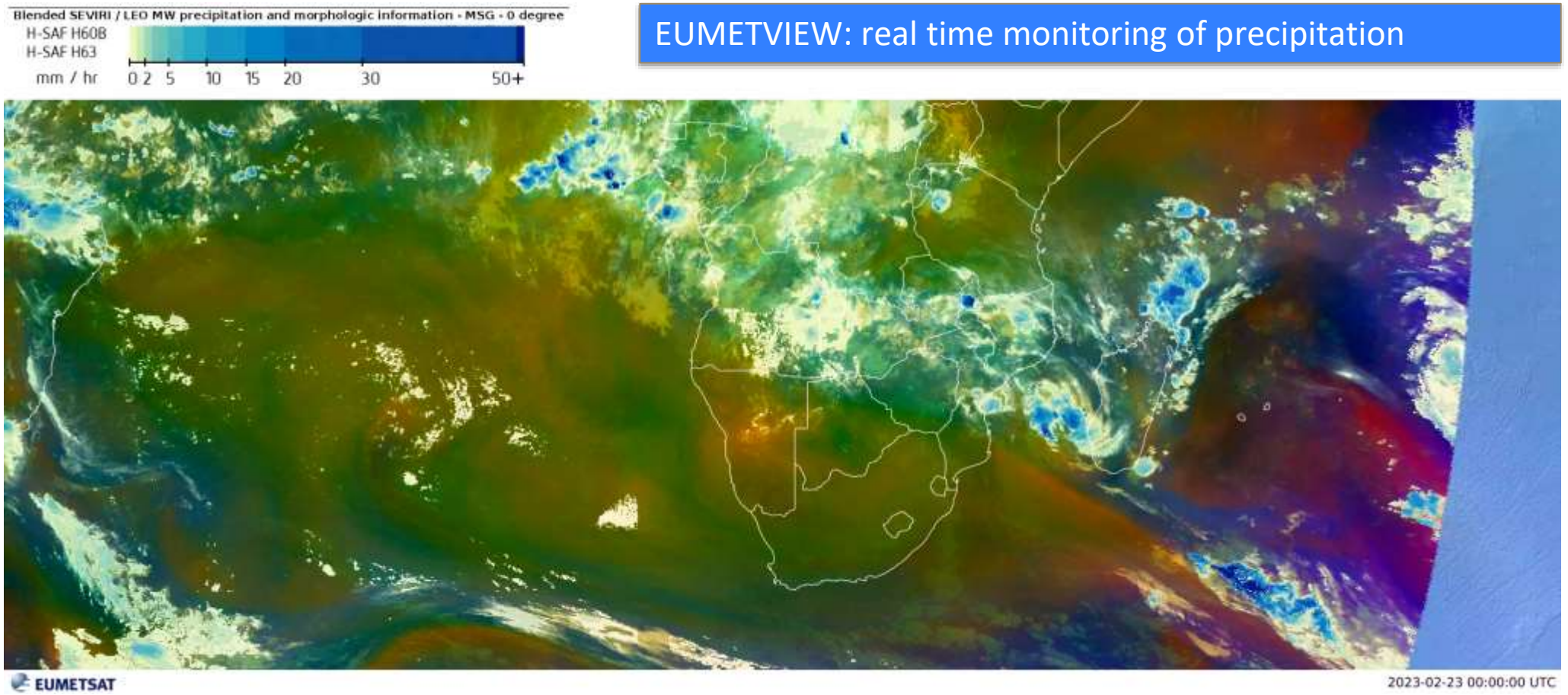
Why satellite products are SO IMPORTANT for Hydrology



EUMETVIEW: real time monitoring of precipitation

Satellite products continuously provide data independent from ground station with a wider view.

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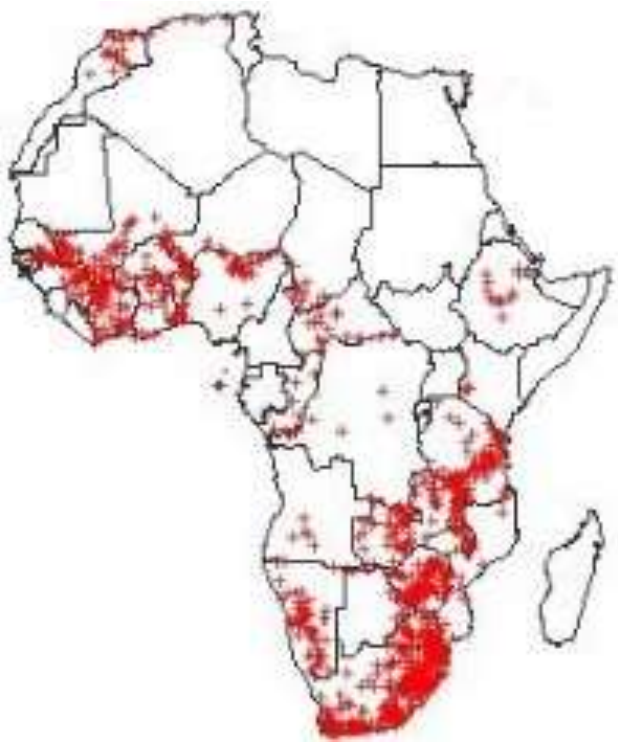
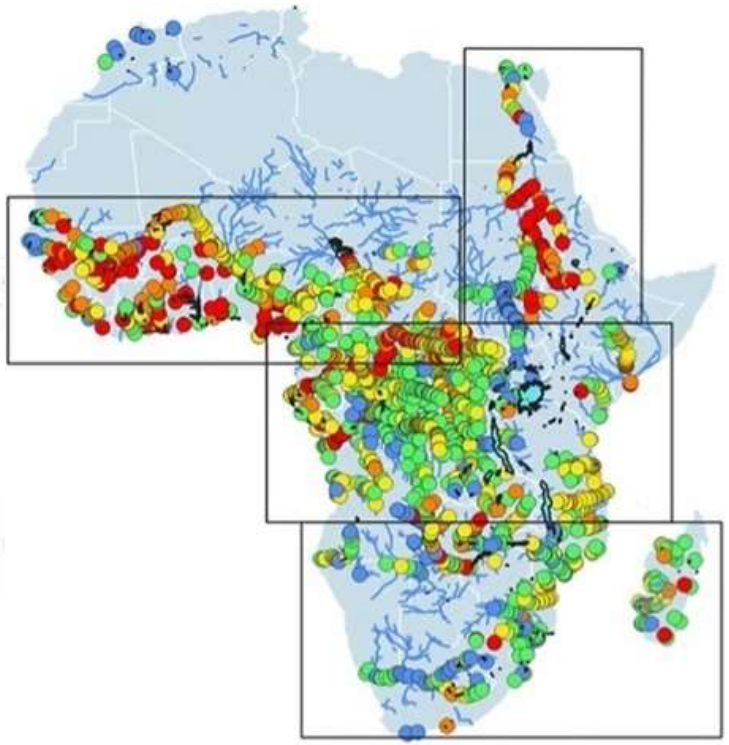
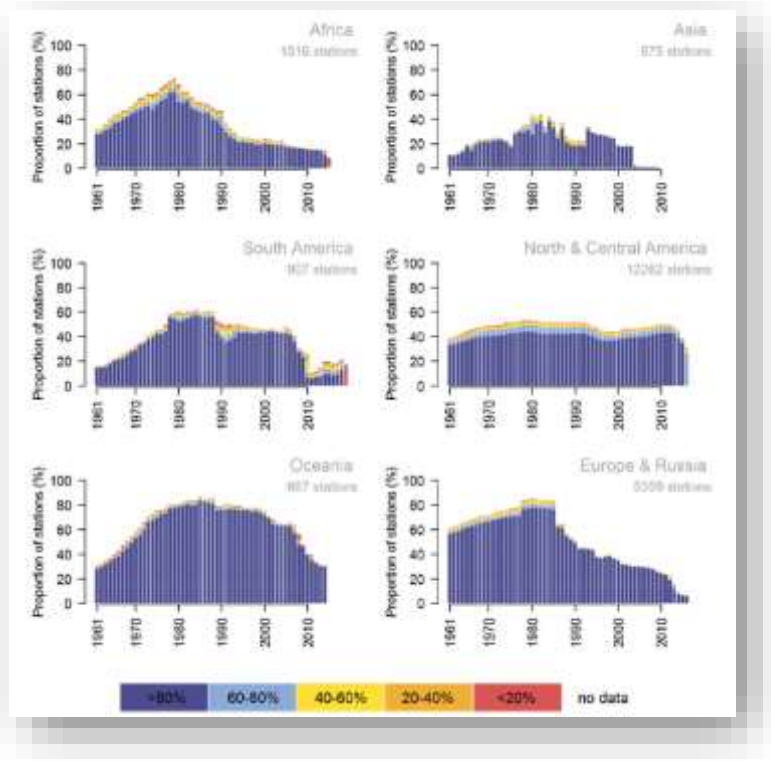
Why satellite products are SO IMPORTANT for Hydrology

RIVER DISCHARGE







Satellite products can largely increase our monitoring capability of the water cycle, particularly due to the recent strong decline of in situ observation networks.

Papa et al (2022 Surv Geophys) https://doi.org/10.1007/s10712-022-09700-9

Krabbenhoft et al (2022 Nat Sustain) https://doi.org/10.1038/s41893-022-00873-0

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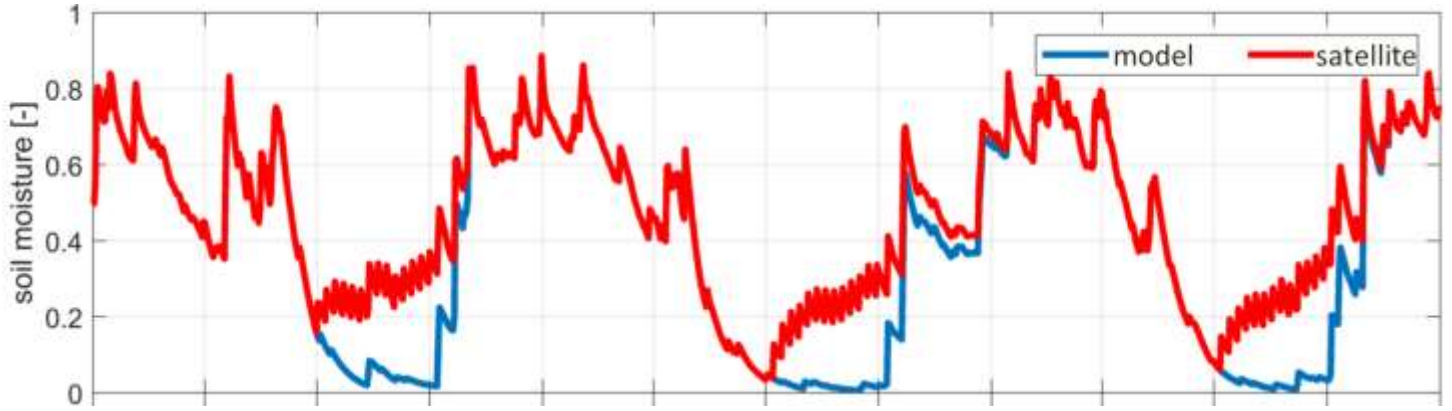
Why satellite products are SO IMPORTANT for Hydrology



Brocca et al (2018 JAG)
https://doi.org/10.1016/j.jag.2018.08.023

Satellite products can "see" processes that we are not able to model such as IRRIGATION

Earth observation missions from 2010 to 2030

In the last 50 years hundreds of satellites have been launched for earth observation purposes.

Relevant to hydrology, as the EUMETSAT satellites (MSG-MTG and Metop), SMOS and Sentinel-1, Sentinel 2. NASA Earth science missions, SMAP, GPM,

Different sources of satellite monitoring systems, diverse range of data-sets which allow us to estimate the parameters needed to answer to hydrological services.

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Satellite Application Facilities in Support to **Operational Hydrology and Water Management**

http://hsaf.meteoam.it/

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H SAF generates and archives satellite high-quality products to estimate:

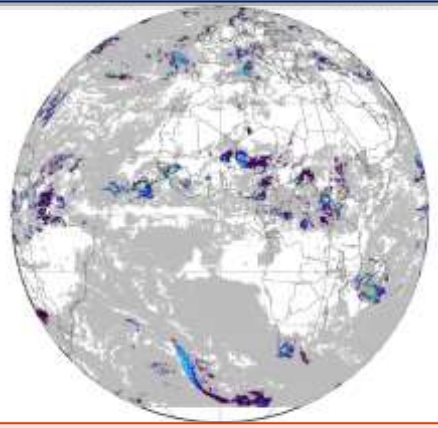
- ✓**precipitation** (rate and accumulated);
- ✓**soil moisture** (at surface and in the roots region);
- ✓**snow parameters** (as snow cover, melting conditions, water equivalent)

The consortium is composed by 11 countries:
Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey and ECMWF.

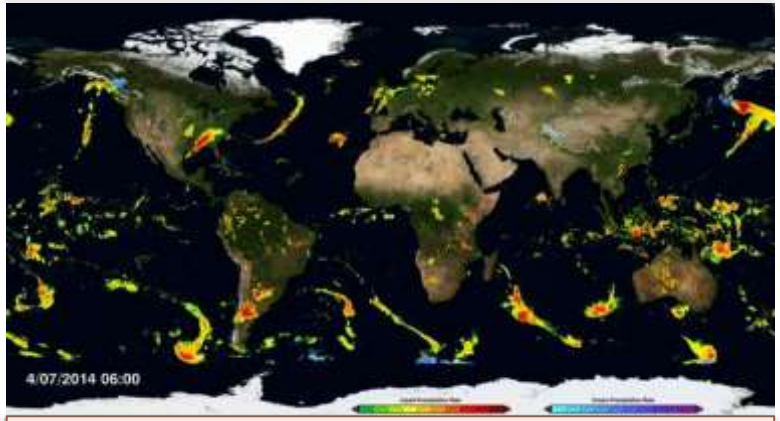
More than 50 researchers are involved in the project.

Remote Sensing of Precipitation

H SAF H60: 2020 to present
Rain Rate, 15-min, 0.05-degree



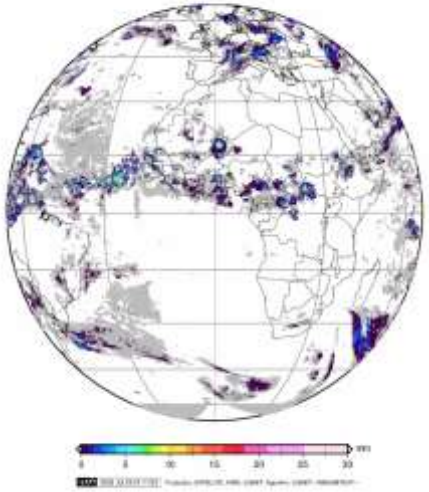
GPM IMERG: 2000 to present,
Rain Rate, 30-min, 0.1-degree



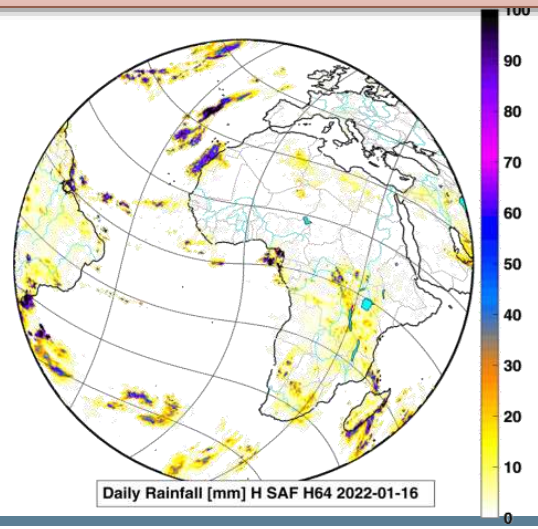
GSMaP: 2000 to present
Rain Rate, 1-h, 0.1-degree

...and many others:
TAMSAT
PERSIANN
CMORPH

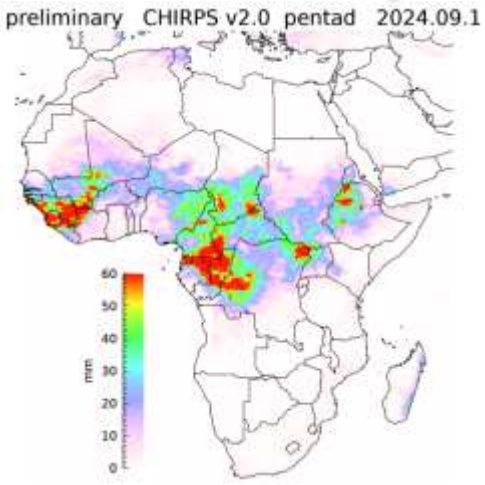
H SAF H61: 2020 to present
Accum. Prec. ,1-24 h, 0.05-degree



H SAF H64: 2020 to present,
Accum. Prec., 24-h, 0.25-degree

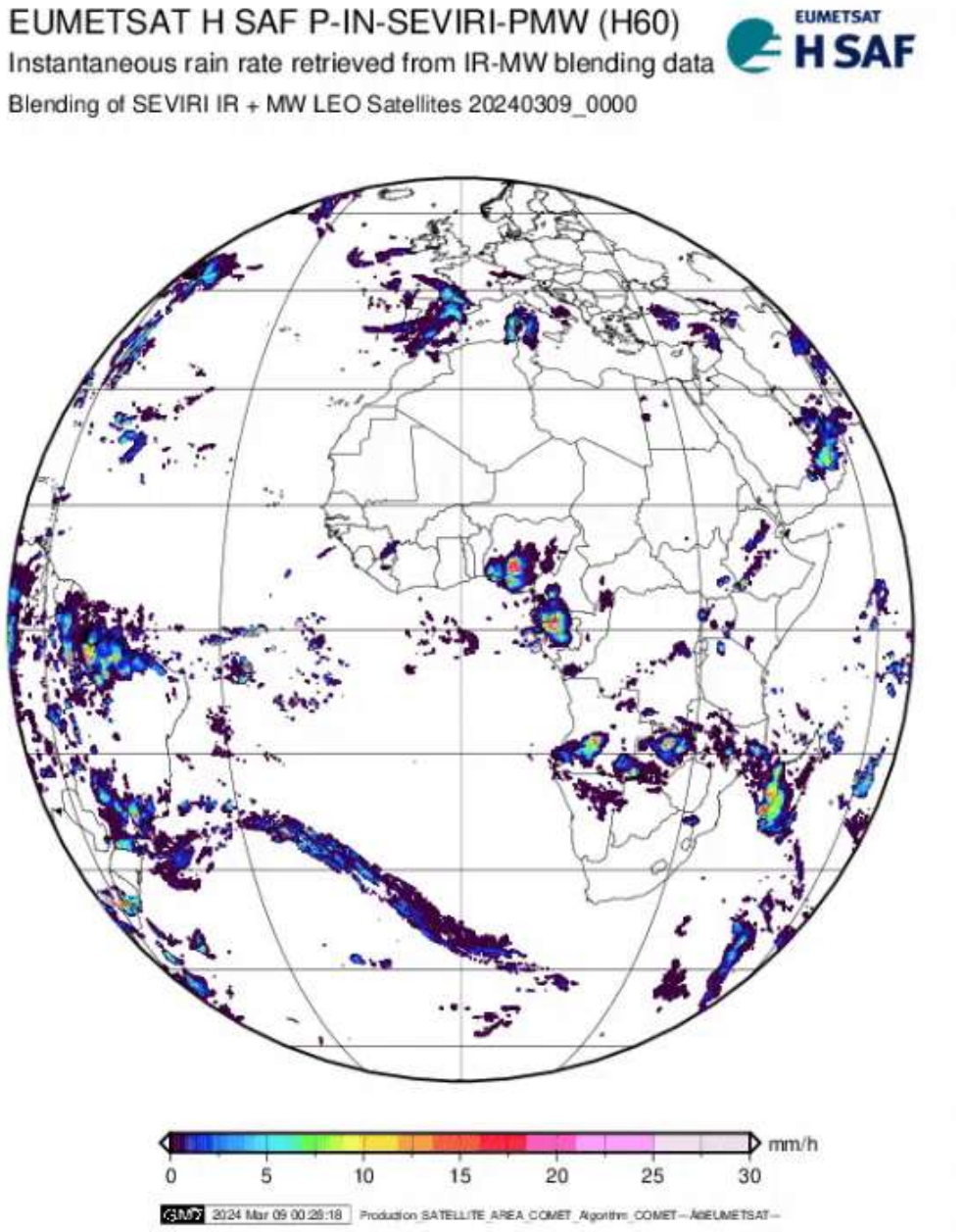


CHIRPS: 1981 to present,
Accum. Prec., 24-h, 0.05-d... ...



H SAF precipitation products (MW+IR): Rain Rate

- Parameter**: Rain Rate**
- Frequency**: 15 minutes**
- Spatial Sampling**: 3 Km**
- Latency**: 10 minutes**
- Available**: EUMETCAST**



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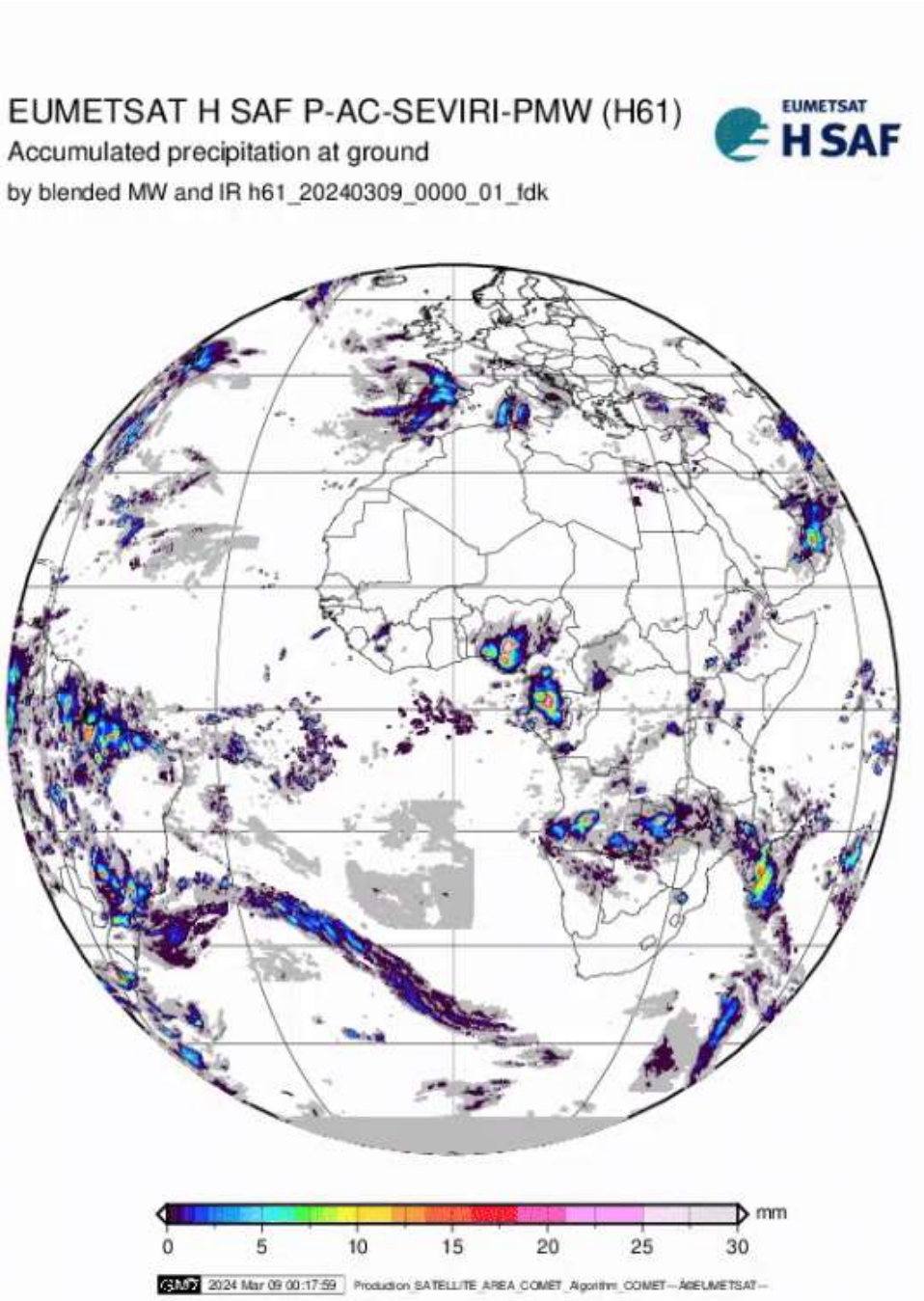
H SAF precipitation products (MW+IR): Accumulated Rain

- Parameter**: Accumulated Rain**
- Frequency**: 1 hour**
- Spatial Sampling**: 3 Km**
- Latency**: 20 minutes**
- Available**: EUMETCAST**



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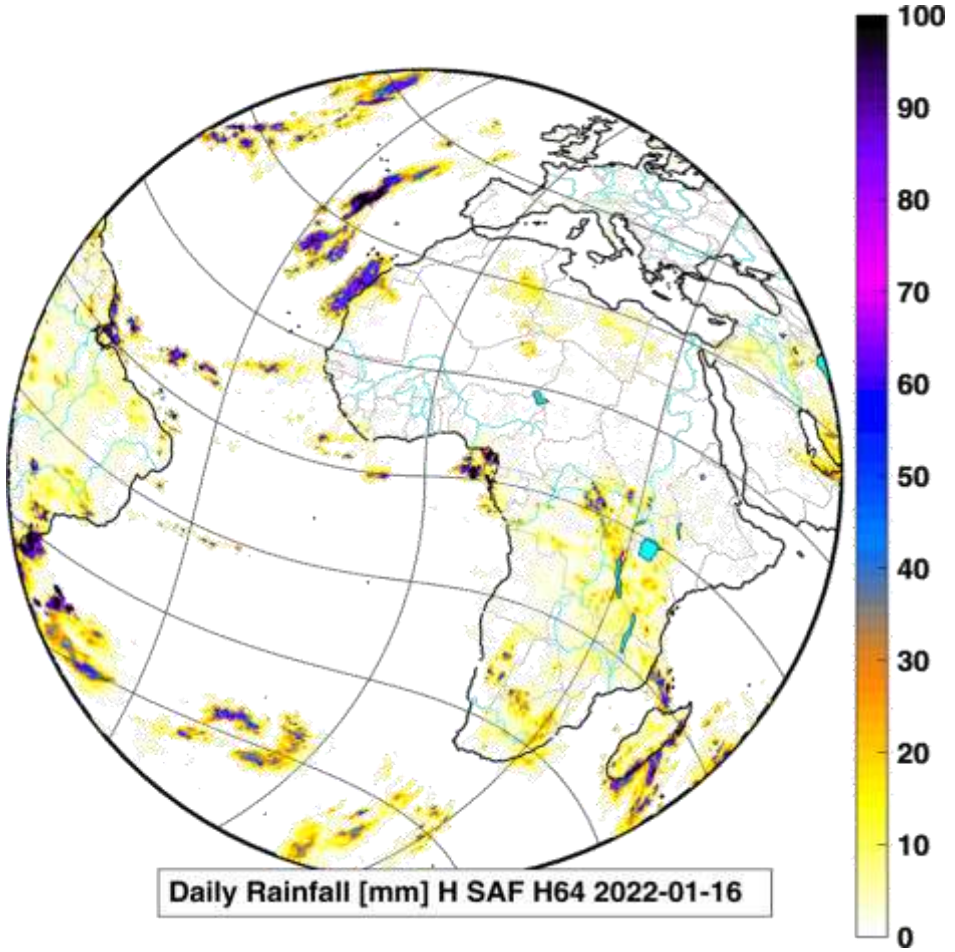
H SAF precipitation products (SM +MW): Daily Rain

- Parameter**: Daily Rain**
- Frequency**: 24 hours**
- Spatial Sampling**: 25 Km**
- Latency**: 15 hours**
- Available**: EUMETCAST**



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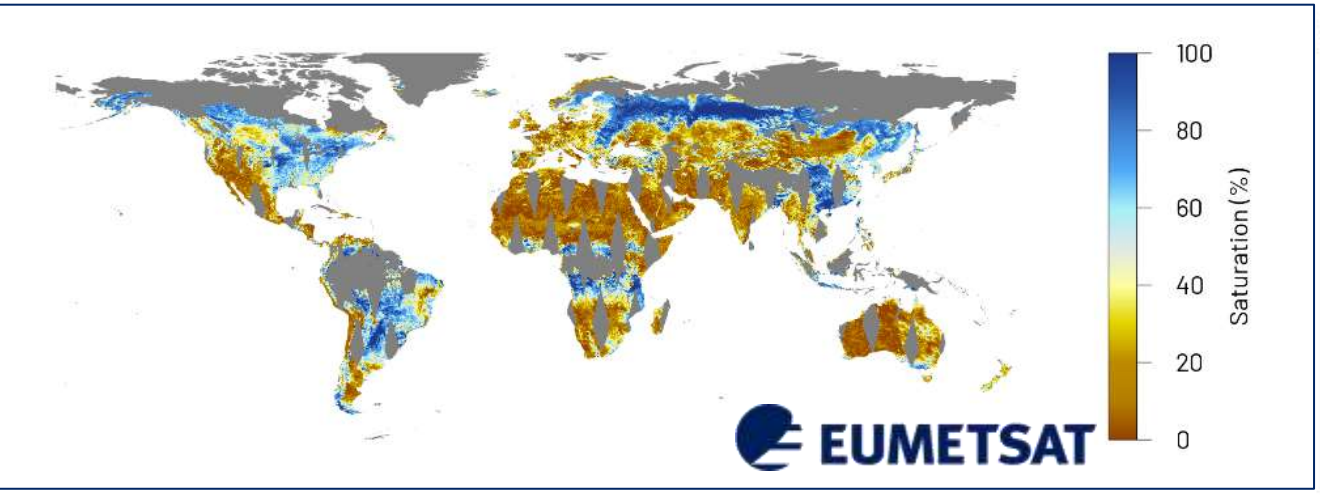
REMOTE SENSING OF SOIL MOISTURE

COPERNICUS C3S SOIL MOISTURE
1978 to present, 1/10-day, 0.25-degree

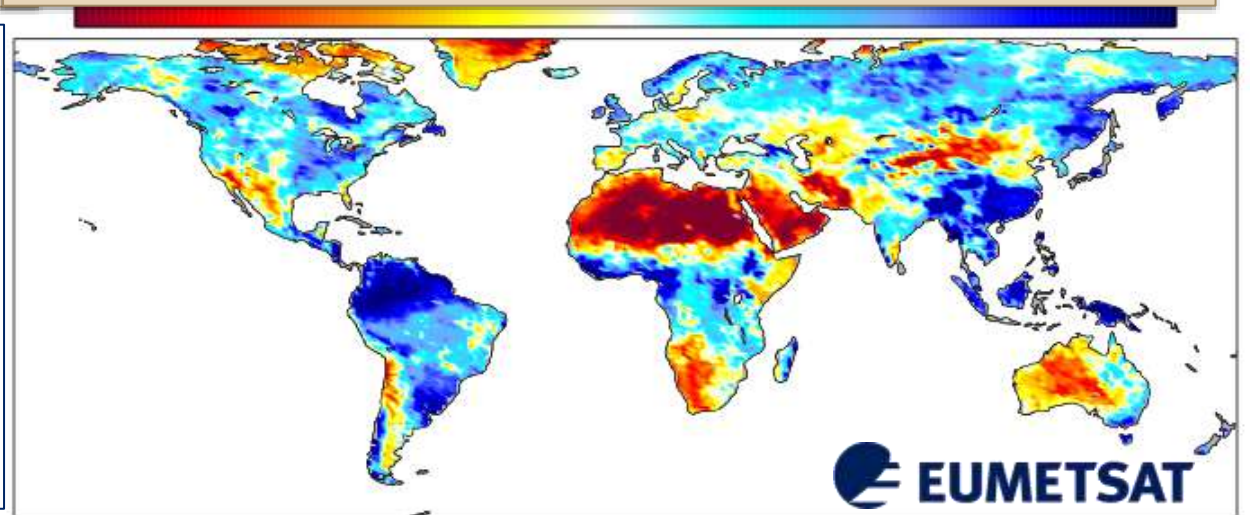
SOIL WATER INDEX: 2007 to present, 1/10-day, 0.1-degree

SURFACE SOIL MOISTURE: 2014 to present, 5-day, 1 km

H SAF SURFACE SOIL MOISTURE: 2007 to present, 1-day, 1-10-12,5 km



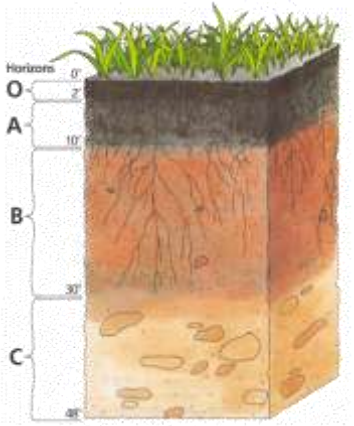
H SAF ROOT ZONE SOIL MOISTURE: 1992 to present, 1-day, 16 km

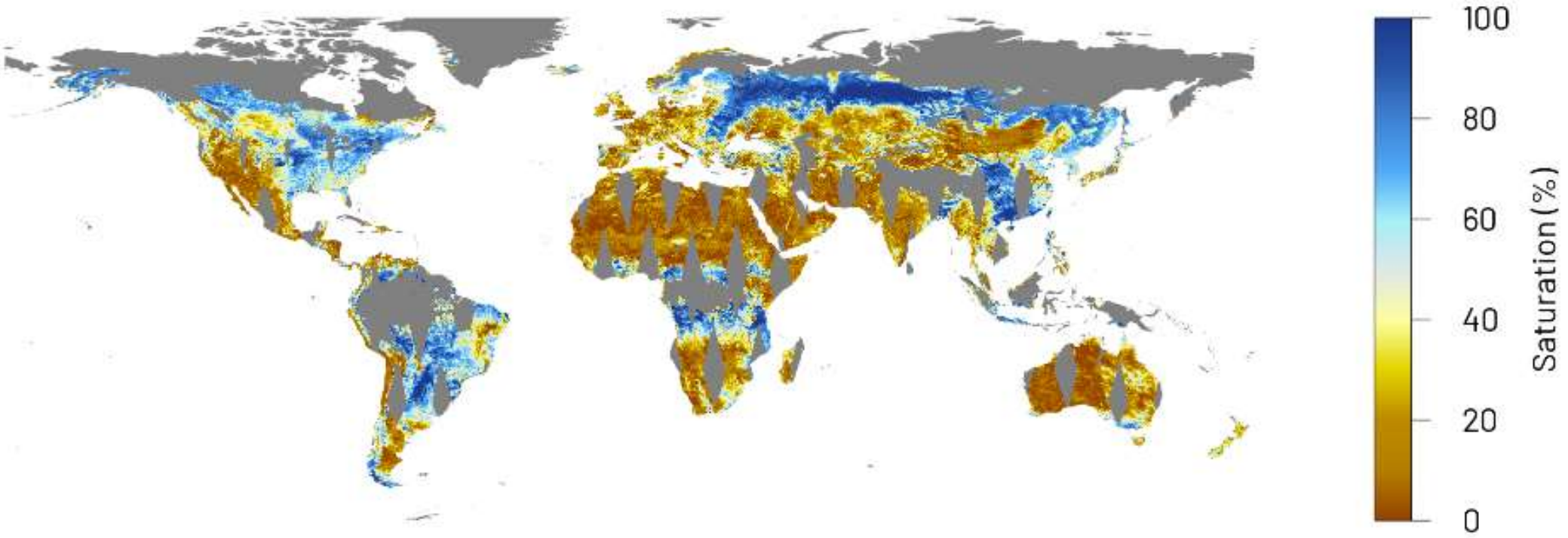


H SAF Soil Moisture products:

Surface Soil Moisture

- SSM is expressed in soil saturation (0-100%) representing the topmost soil layer (< 5 cm)
- **(Sub-)daily observations,**
- **Near Real Time Products (Latency 2 hours) :** Spatial sampling **25 Km → 12.5km → 6.25 km → 1 Km** (disaggregated**)**
- **Data Record: from 2007,** with spatial sampling **12.5 km.**





Wagner et al. 2013 (METZET)

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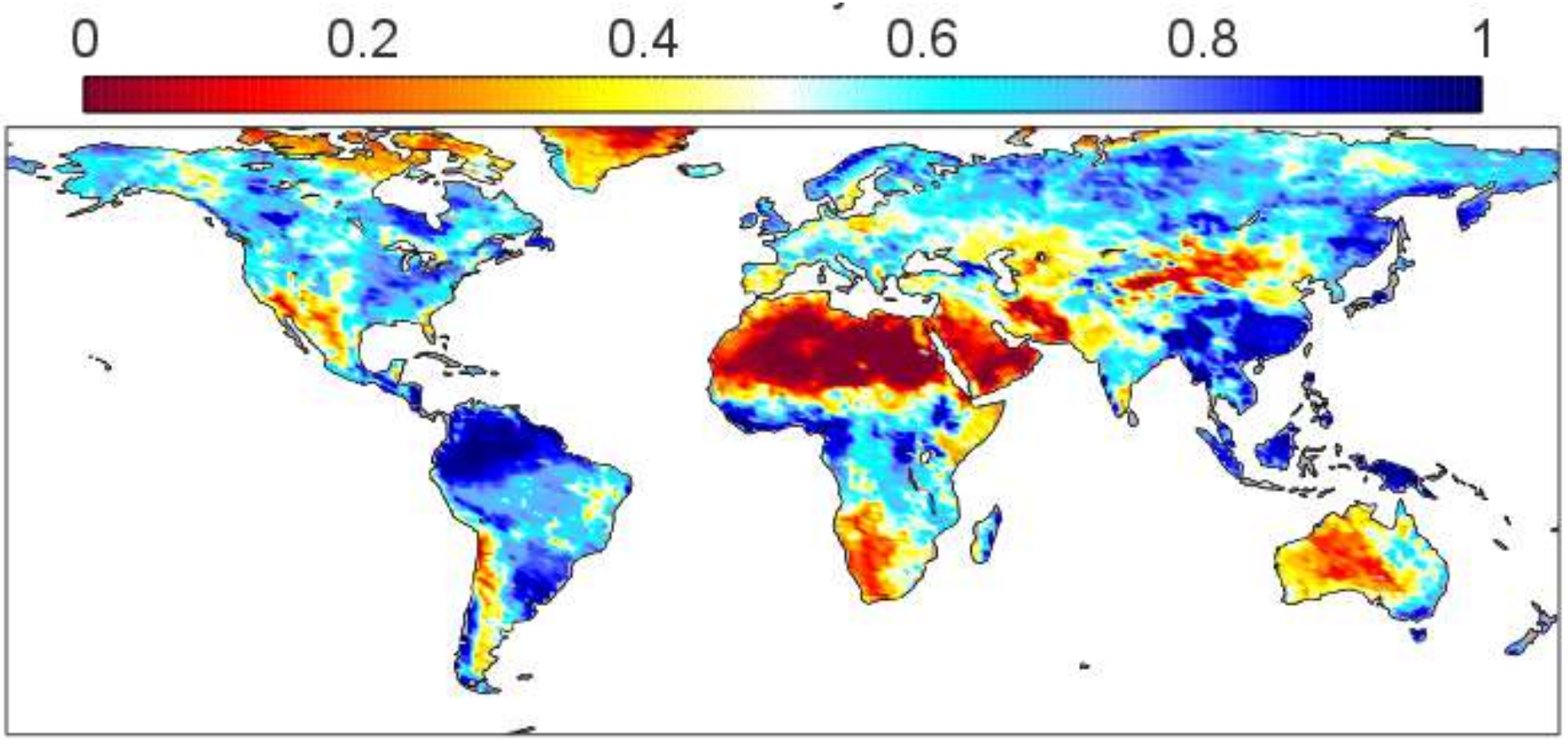
H SAF Soil Moisture products:

Root Zone Soil Moisture

- **RZSM is** expressed **as liquid soil wetness index at 4 layers;**
- **Daily observations (00 UTC);**
- **Near Real Time Products: 10 km spatial sampling**
- **Data Record: from 1992,** with spatial sampling **10 km.**

SM analysed over first 3 layers in H-TESSEL:
Layer 1: 0-7 cm
Layer 2: 7-28 cm
Layer 3: 28-100 cm
Layer 4 (not analysed): 100-289 cm



De Rosnay et al. 2013 (QJRMS)
Fairbairn et al. 2019 (JHM)

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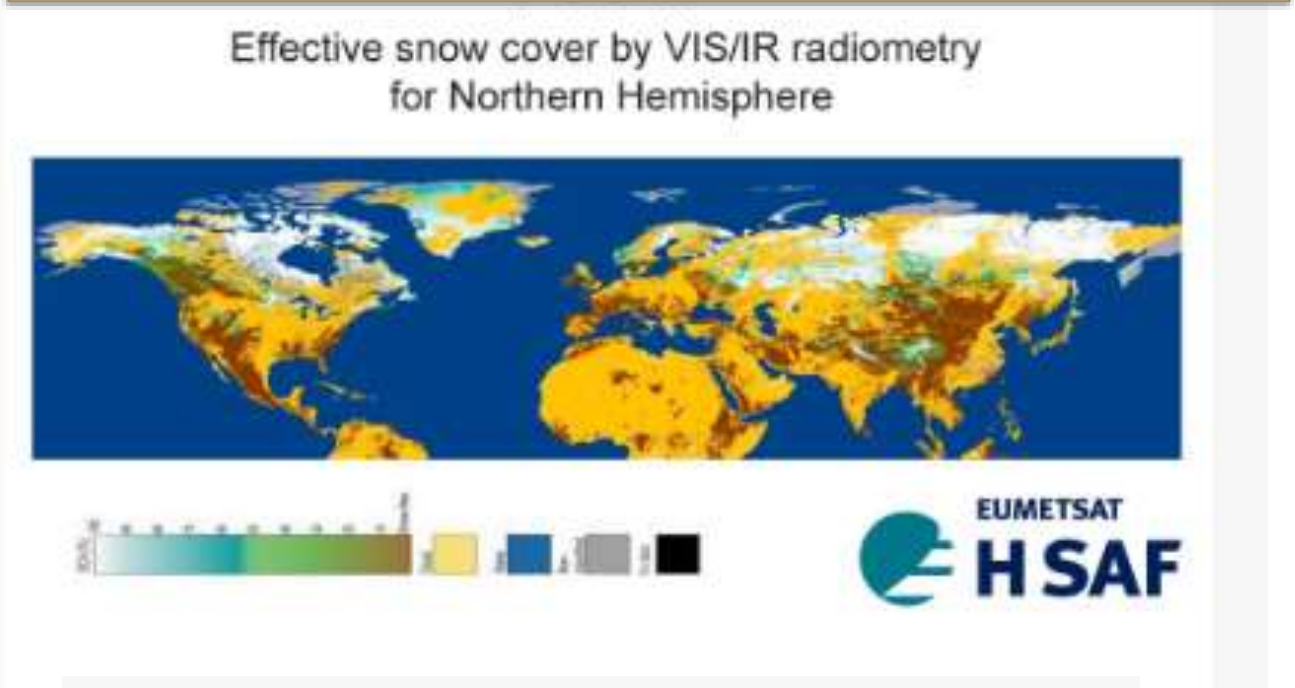
REMOTE SENSING OF SNOW

Snow Water Equivalent
2006 to present, Northern Hemisphere (35N-85N), 5km

H SAF Effective snow cover by VIS/IR radiometry
2022 to present, global covegare, 1-day, 2 km



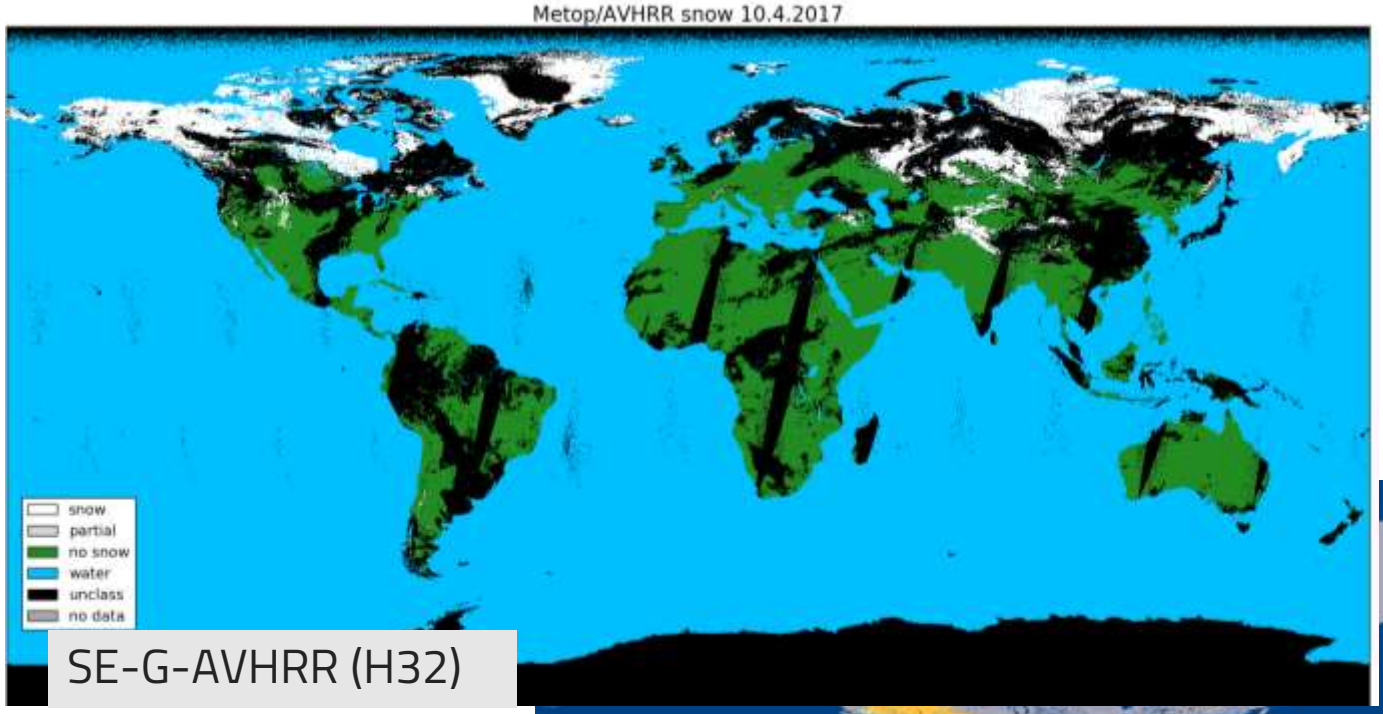
H SAF Snow products

Daily EPS Snow Cover: presence of snow over land.

- Sub-daily : Four products (integrals over 3, 6, 12 and 24 h) every three hours (rolling)
- Near Real Time Products (3 hours): spatial sampling 10 Km

Snow detection (snow mask) by VIS/IR radiometry:

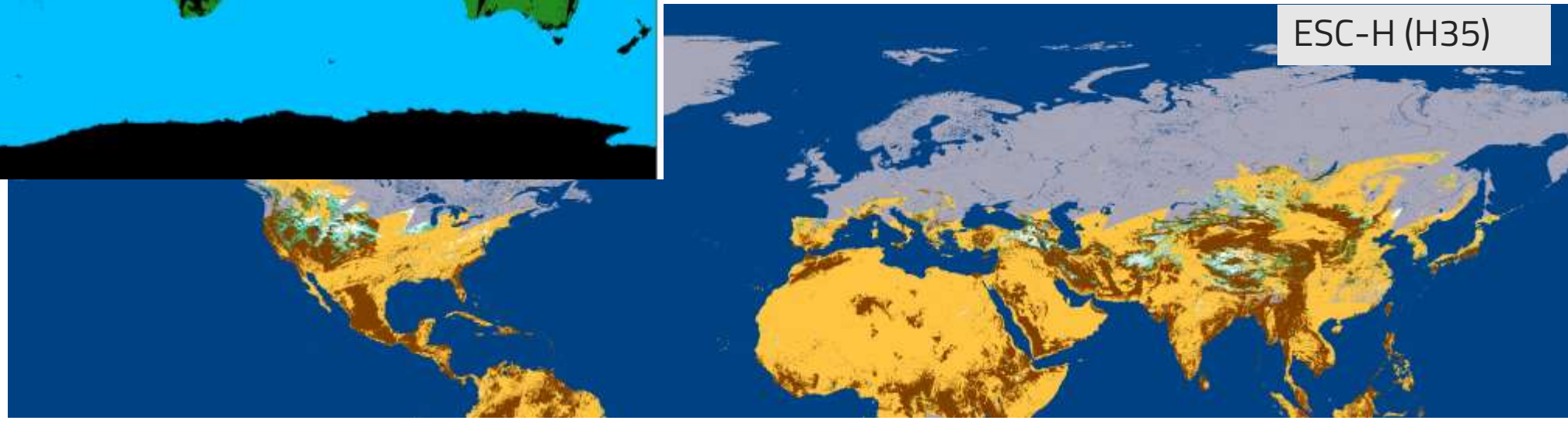
- Daily , Near Real Time Products (6 hours): SEVIRI Resolution



SE-G-AVHRR (H32)

Effective snow cover by VIS/IR radiometry

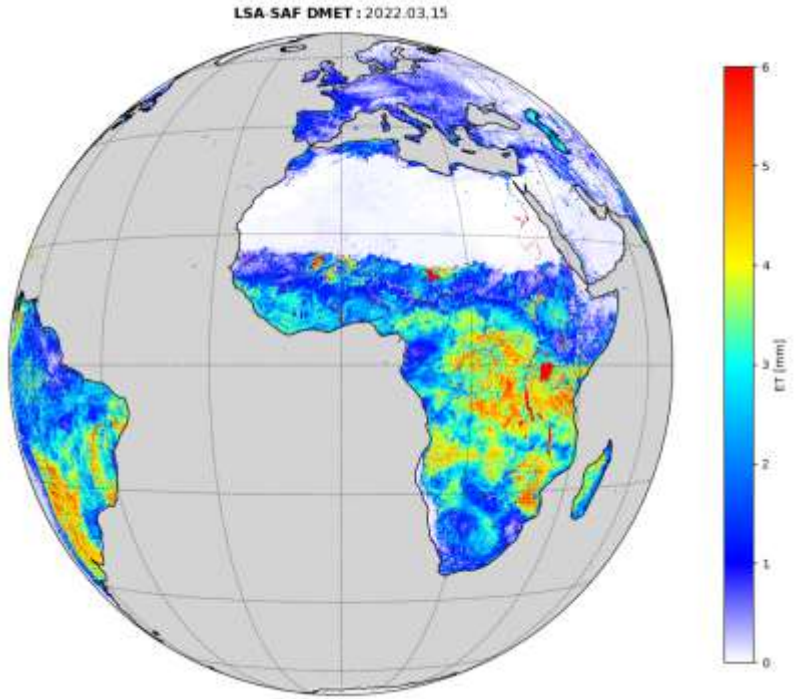
- Daily, Near Real Time Products (6 hours): spatial sampling 10 Km



ESC-H (H35)

Remote Sensing of Evapotranspiration

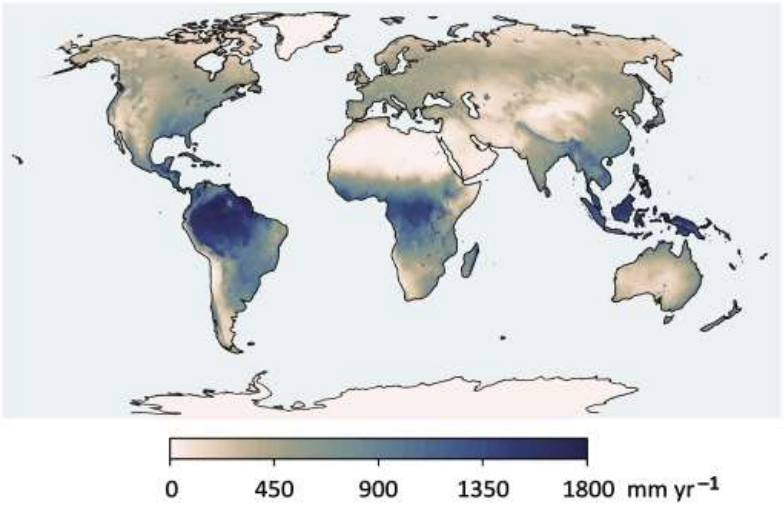
Land SAF: 2004 to present
Evaporation rate, 1-day, 3 km
(different versions)

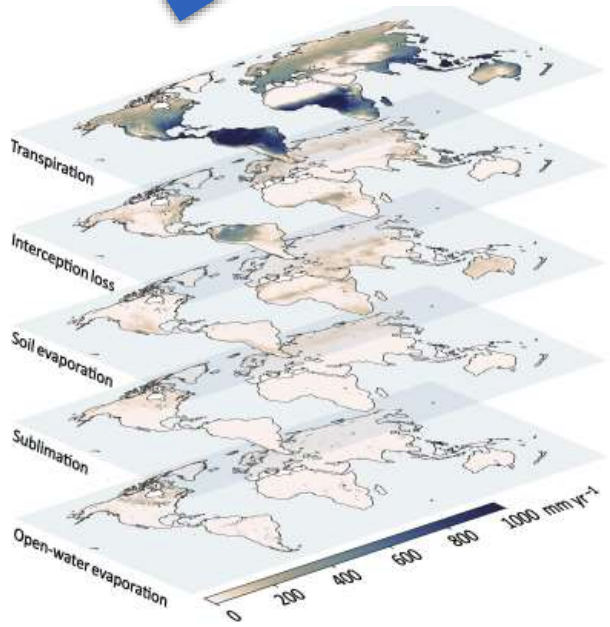


WaPOR: 2009 to present
Evaporation rate, 10-day, 300 m

...and many others:
USGS FEWS NET
ALEXI
EEFlux
PT-JPL
...

GLEAM4: 2003 to 2023
Evaporation rate, 1-day, 10 km



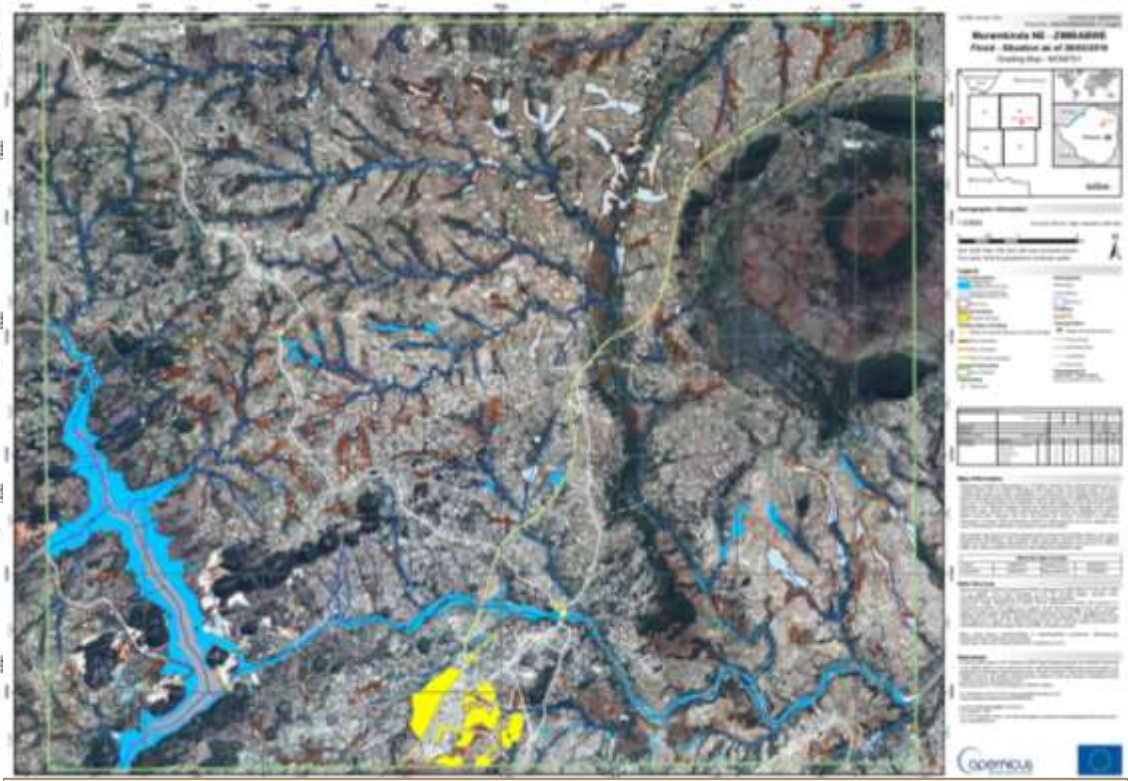


REMOTE SENSING FLOODS: COPERNICUS EMS– MAPPING

Post-disaster evaluation and preparedness analysis of flood in Togo 20/10/2020: delination map

Sentinel 1 and Sentinel

Post-disaster evaluation and preparedness analysis of flood in Zimbawe 26/03/2019: grading map



SPOT6 and Pleiades -1B

REMOTE SENSING LANDSLIDE: COPERNICUS EMS– MAPPING

Post-disaster evaluation and preparedness analysis of landslide risk in Ischia, Italy – Grounf motion analysis

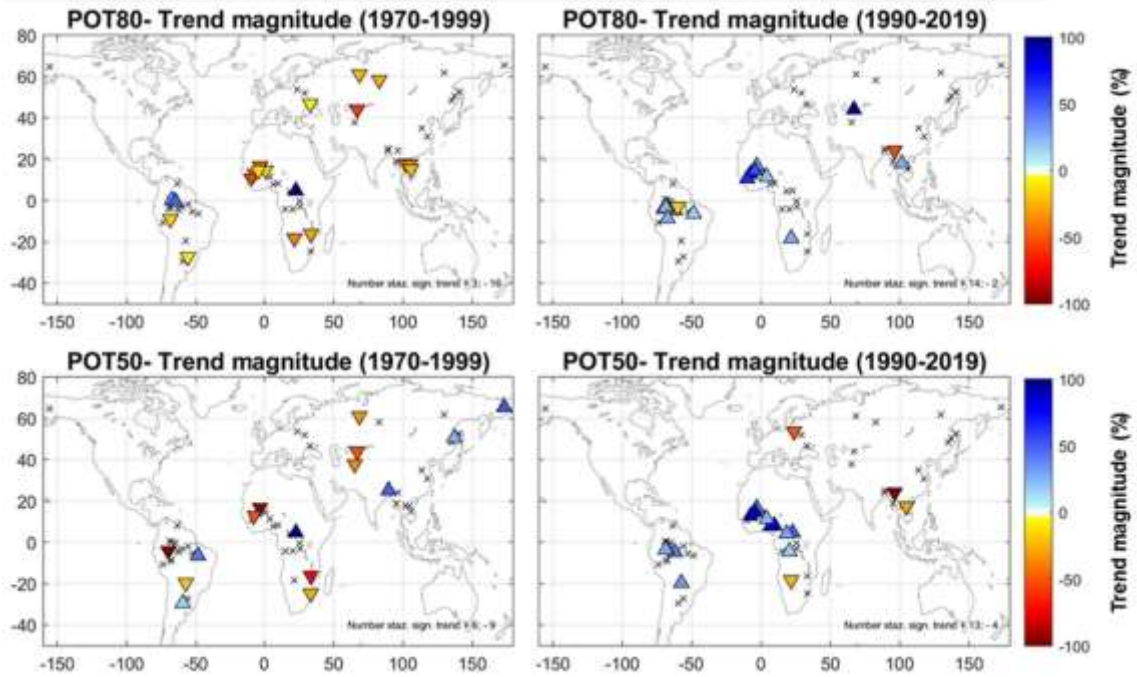
interferometric product based on Copernicus Sentinel - 1 data (2014 - 2022) GSD=20 m

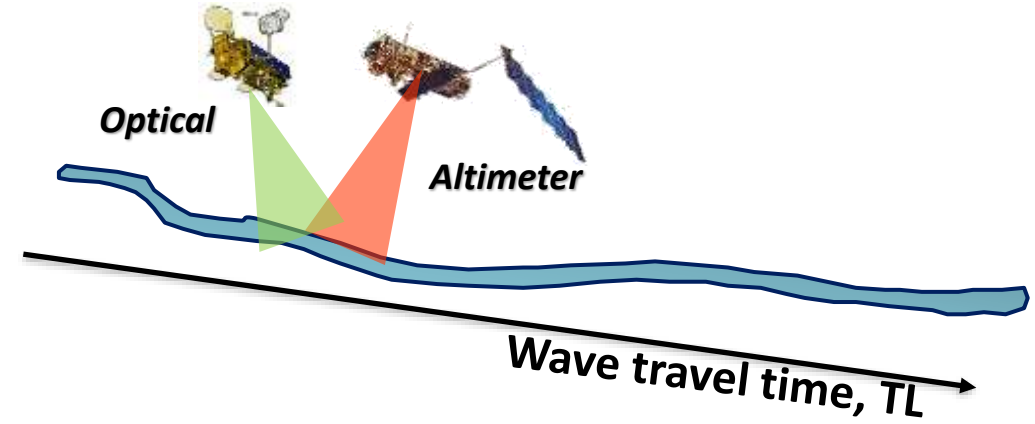
Post-disaster evaluation and preparedness analysis of landslide risk in Ischia, Italy – Delineation map

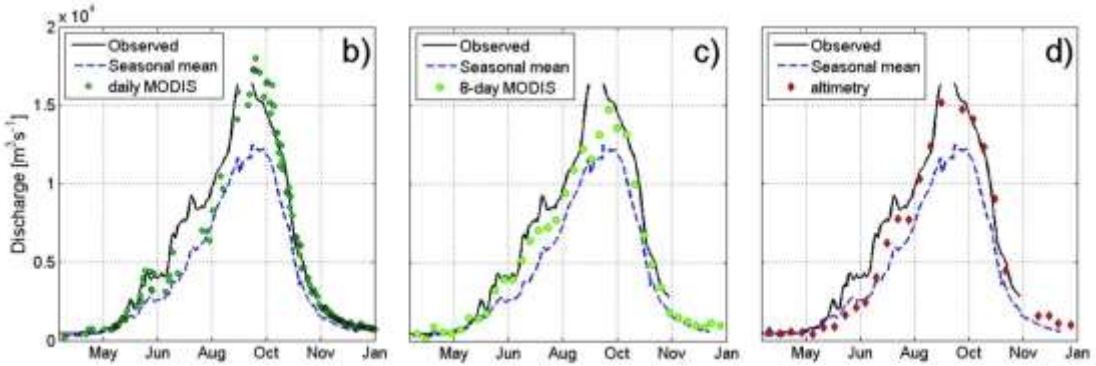
Pleiades data

REMOTE SENSING FOR RIVER DISCHARGE

Rating curves are used to extend the temporal series of river discharge in poorly gauged rivers and investigate long-term climate trend







Tarpanelli et al. 2017, Remote Sens Environ, doi:10.1016/j.rse.2017.04.015

Bellóni et al (2021 JoH) https://doi.org/10.1016/j.jhydrol.2021.126870

Tarpanelli and Domeneghetti 2021, Applied Sciences, doi:10.3390/app11083458

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REMOTE SENSING FOR WATER BODIES EXTENT:S2

San Giuliano Reservoir (Basilicata)

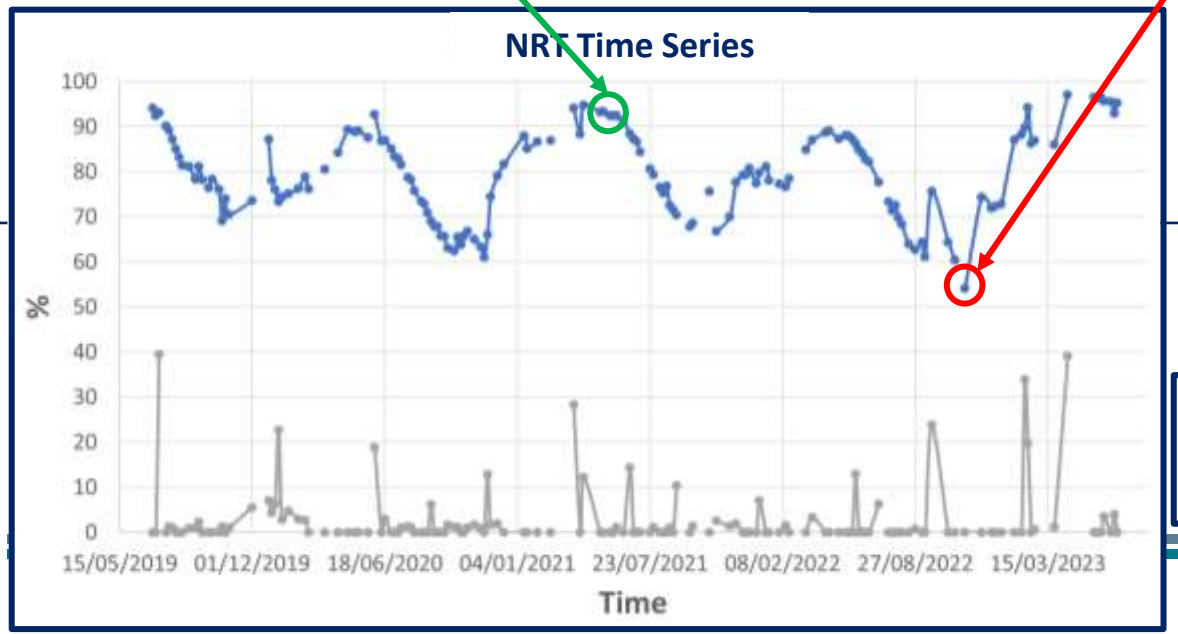
1. NRT WB Extent map

S2 Acquisition Day	13/06/2021
Daily WB % Extent	**91 %**

% Extent

S2 % Masked Pixels

*Masked pixels are pixels covered by clouds and clouds' shadows



1. NRT WB Extent map

S2 Acquisition Day	10/11/2022
Daily WB % Extent	**54 %**

2. NRT time series of WB % Extent

EUMETSAT H SAF

June 2020

Fanaco Lake

COSMO-SkyMed (SAR Image)
Spatial Resolution: 5 m

S2 (Optical Image)
Spatial Resolution: 10 m

Product processed by Cima Foundation under a license of the Italian Space Agency (ASI): OriginalCOSMO-SkyMed Product - ©ASI - 2020.

EUMETSAT H SAF

June 2021

Fanaco Lake

COSMO-SkyMed (SAR Image)
Spatial Resolution: 5 m

S2 (Optical Image)
Spatial Resolution: 10 m

EUMETSAT H SAF

June 2022

Fanaco Lake

COSMO-SkyMed (SAR Image)
Spatial Resolution: 5 m

S2 (Optical Image)
Spatial Resolution: 10 m

EUMETSAT H SAF

June 2023

Fanaco Lake

COSMO-SkyMed (SAR Image)
Spatial Resolution: 5 m

S2 (Optical Image)
Spatial Resolution: 10 m

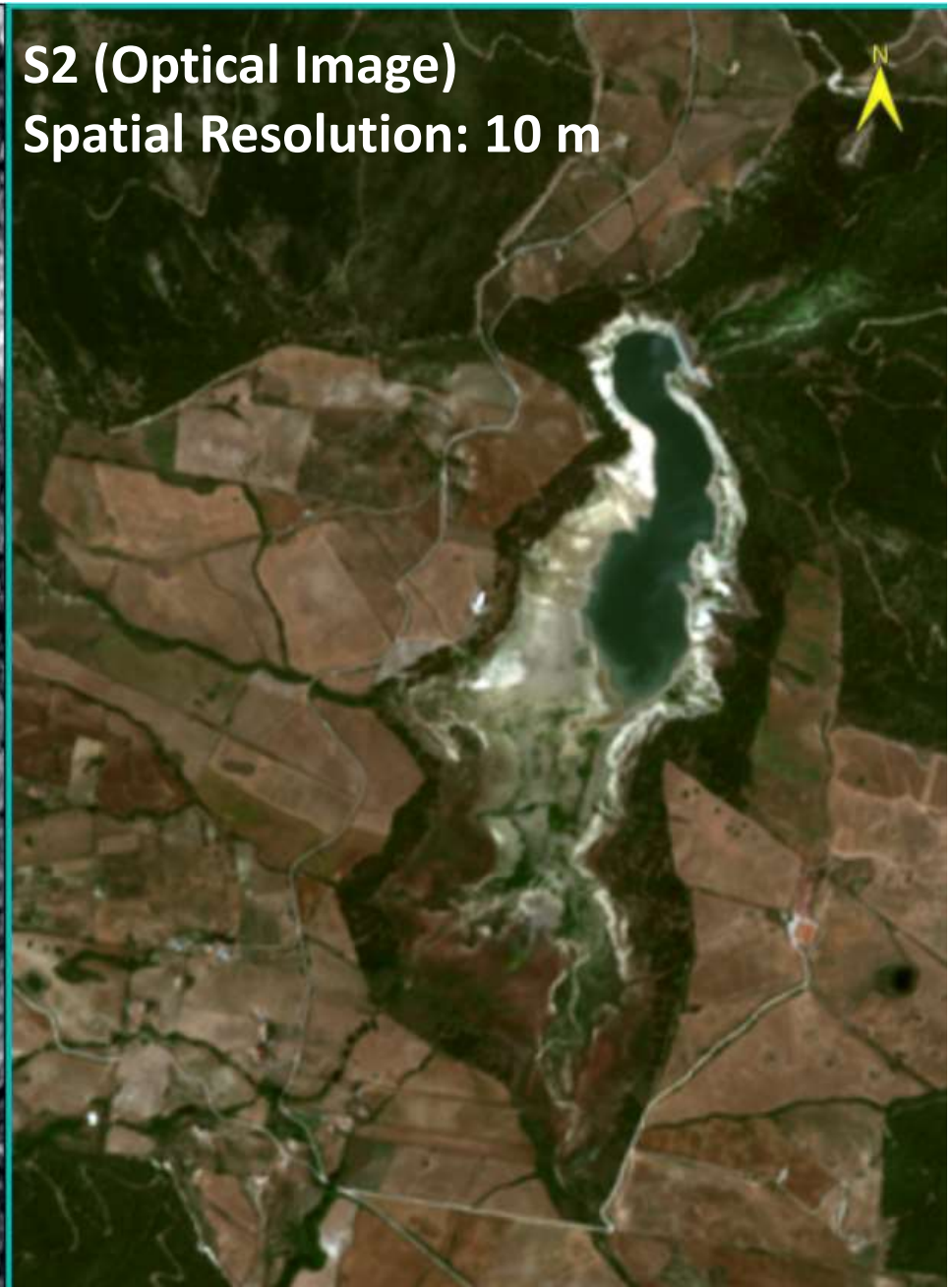
EUMETSAT H SAF

June 2024

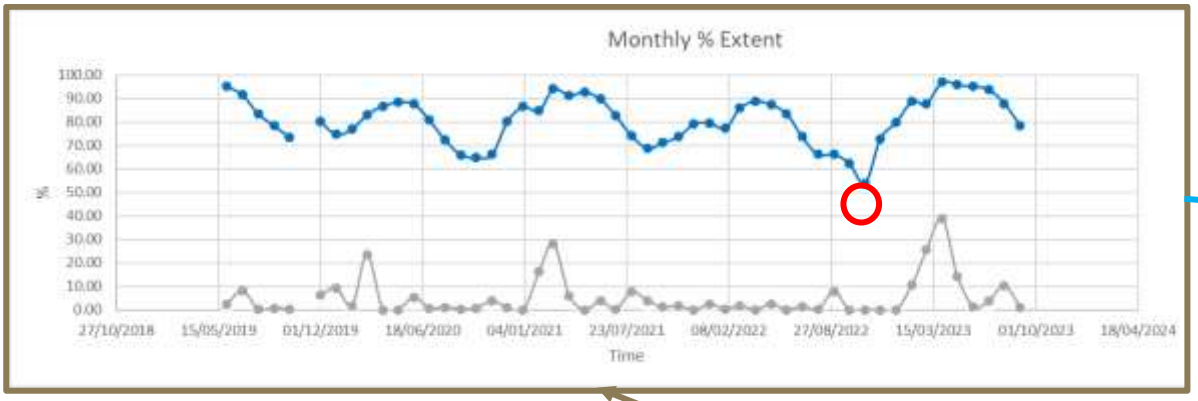
Fanaco Lake

COSMO-SkyMed (SAR Image)
Spatial Resolution: 5 m

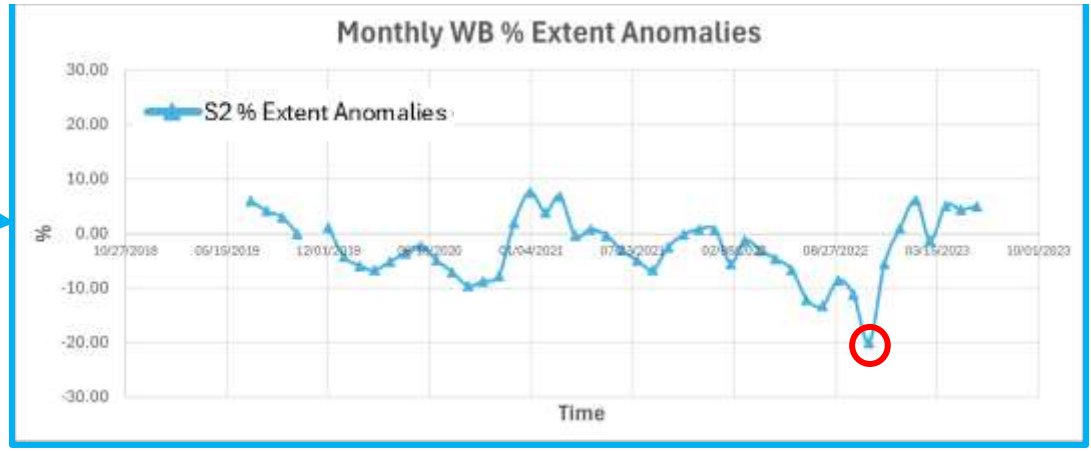
S2 (Optical Image)
Spatial Resolution: 10 m



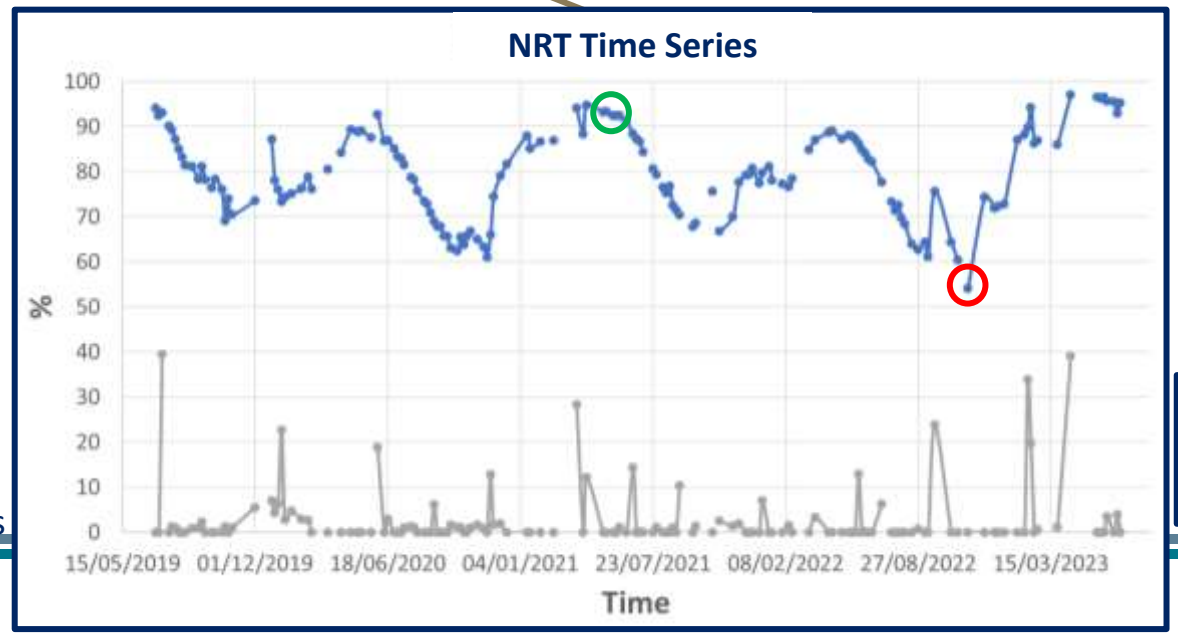
REMOTE SENSING FOR WATER BODIES EXTENT:S2



3. Monthly time series of WB % Extent



4. Monthly time series of WB % Extent Anomalies (long –term reference time period 2015-2023)



% Extent

S2 % Masked Pixels

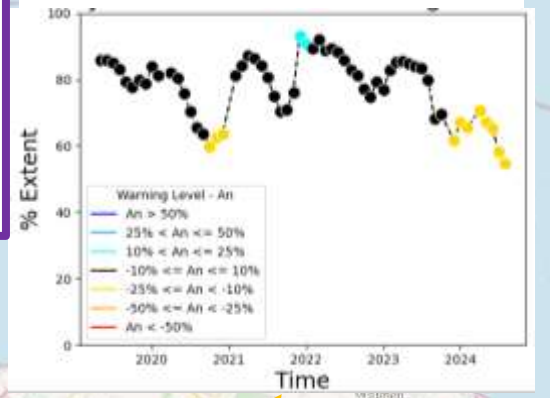
*Masked pixels are pixels covered by clouds and clouds' shadows

2. NRT time series of WB % Extent

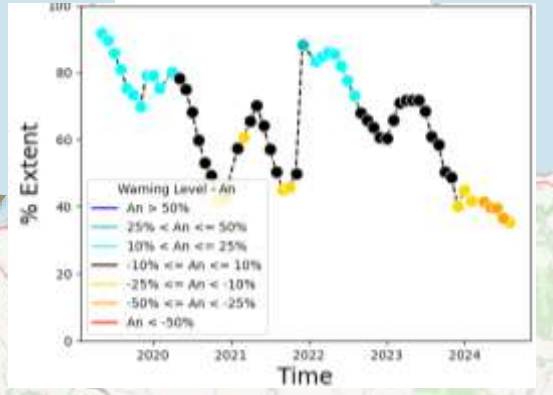
Monthly time series of WB % Extent for selected reservoirs located in Sicily + Anomaly Indicators for Warnings (January 2018 – August 2024)

Warning Level - An
- An > 50%
- 25% < An <= 50%
- 10% < An <= 25%
- -10% <= An <= 10%
- -25% <= An < -10%
- -50% <= An < -25%
- An < -50%

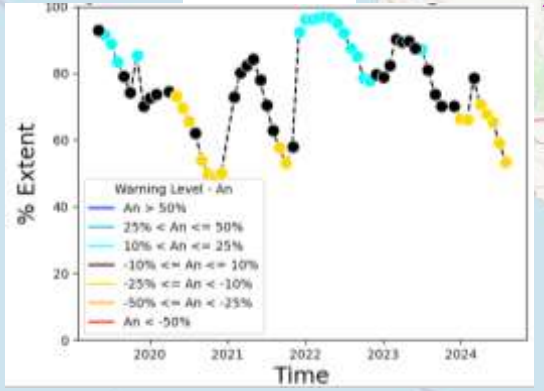
Piana degli Albanesi



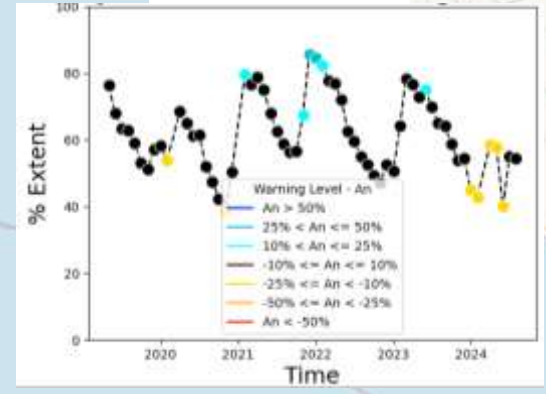
Rosamarina



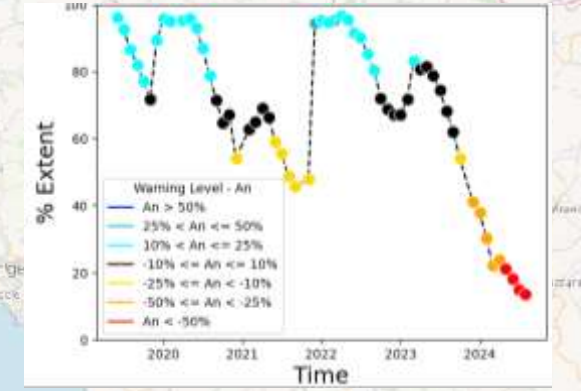
Poma



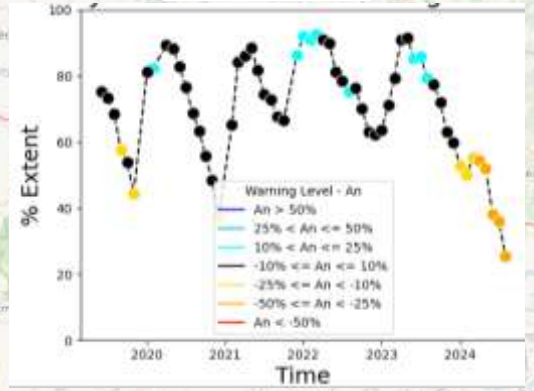
Scanzano



Fanaco



Ancipa



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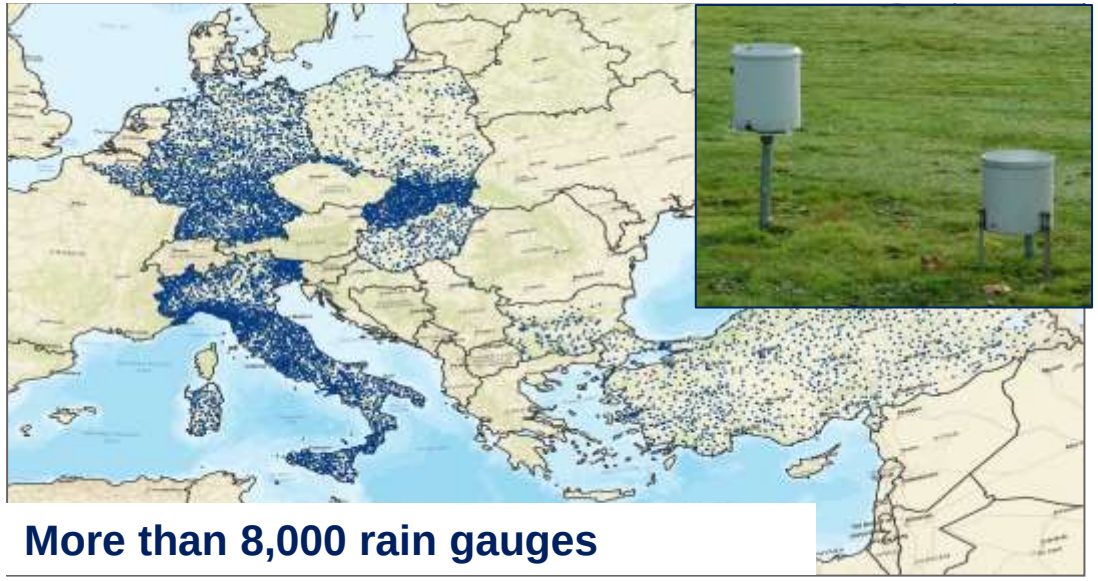
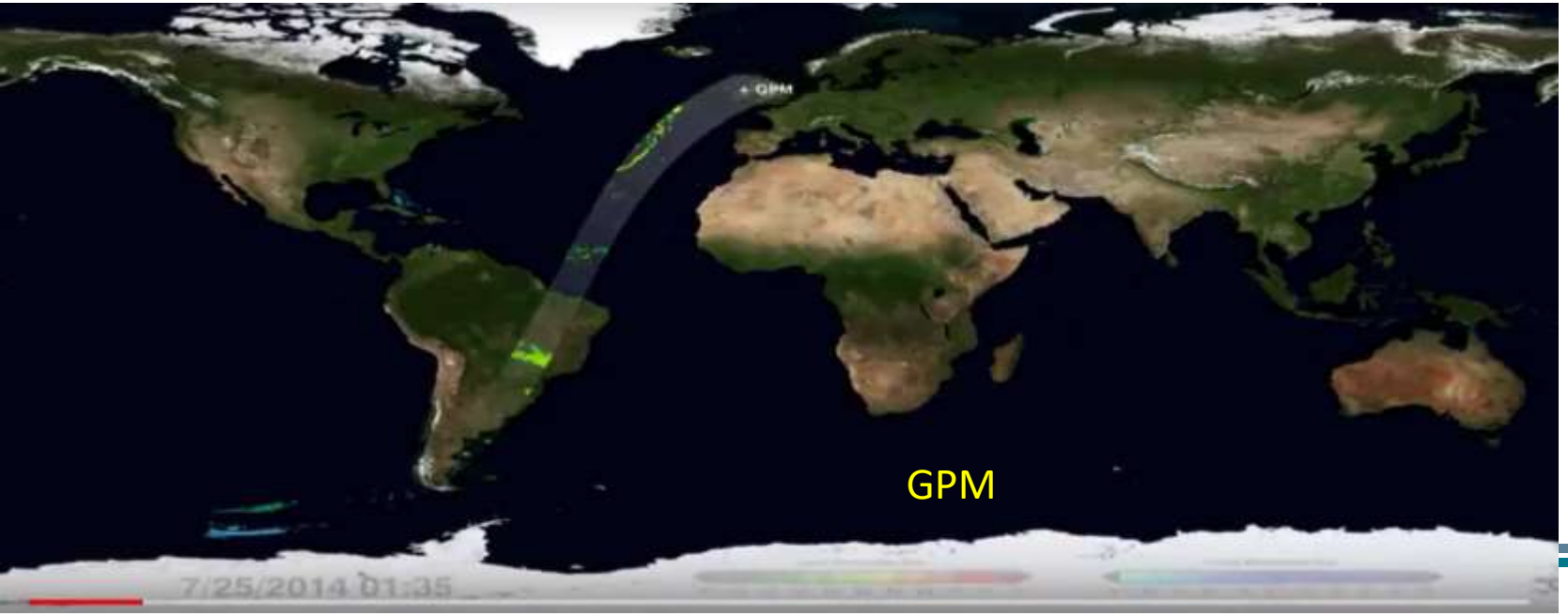
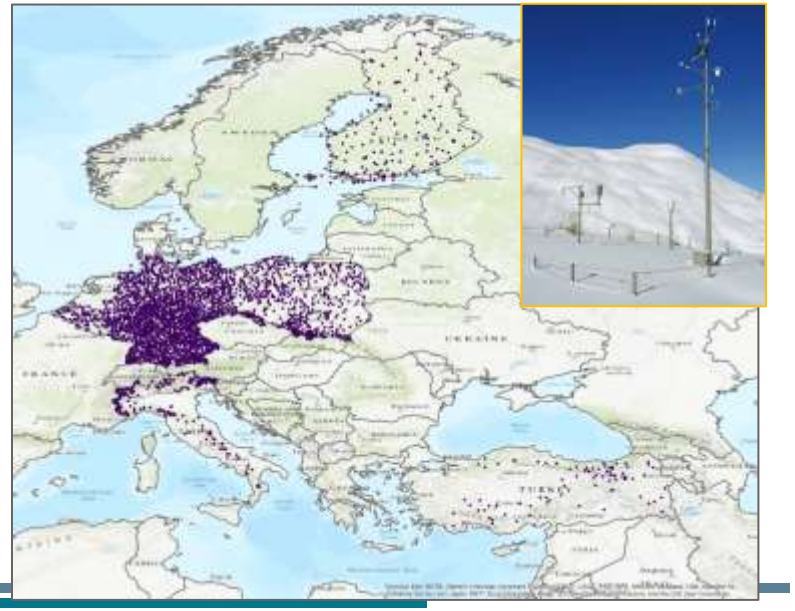
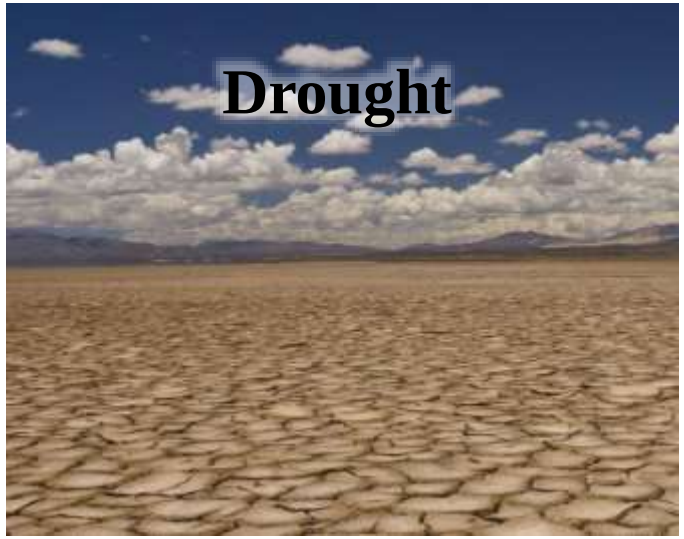




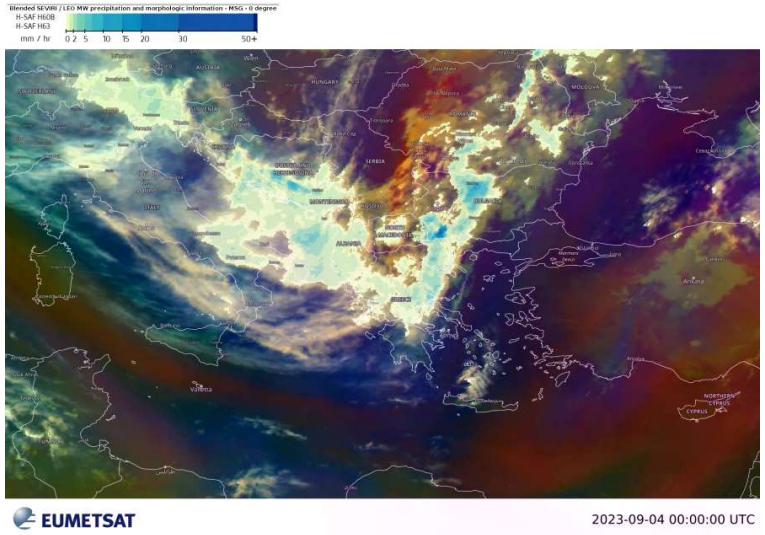


APPLICATIONS

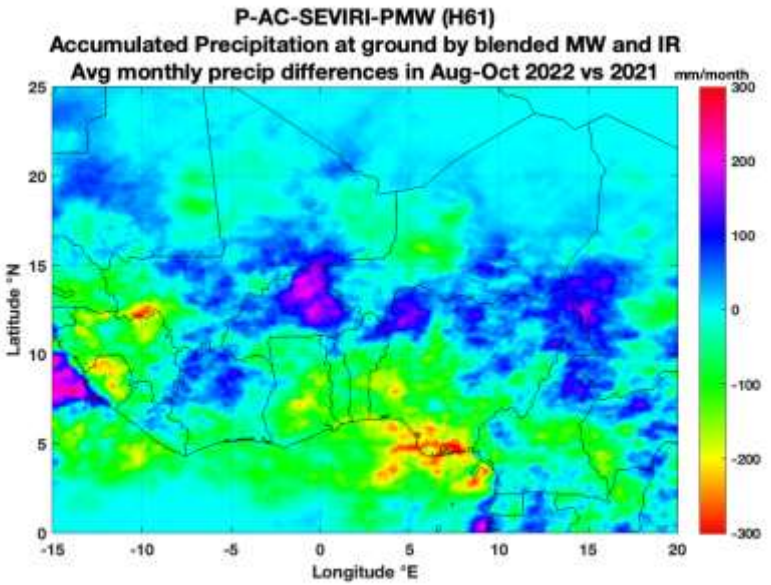
EXTREME EVENTS

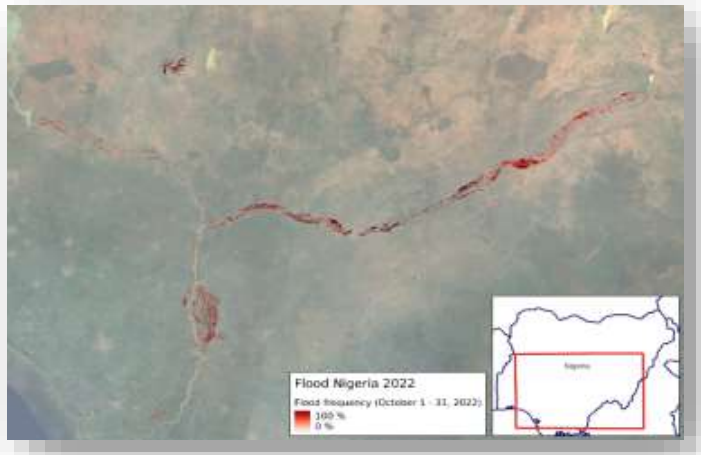


Flood in Grace and Lybia
September 2023

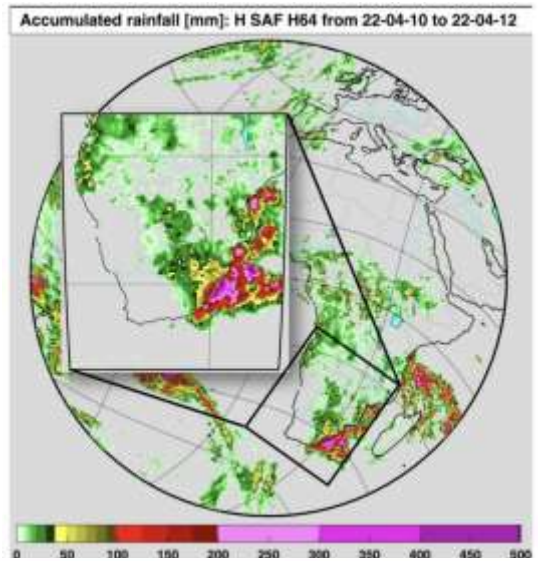


Flood in Nigeria
July 2022





Flood in South Africa
11-13 April 2022



Cite: https://www.france24.com/en/live-news/20220418-what-s-behind-southafrica-s-flood-disas

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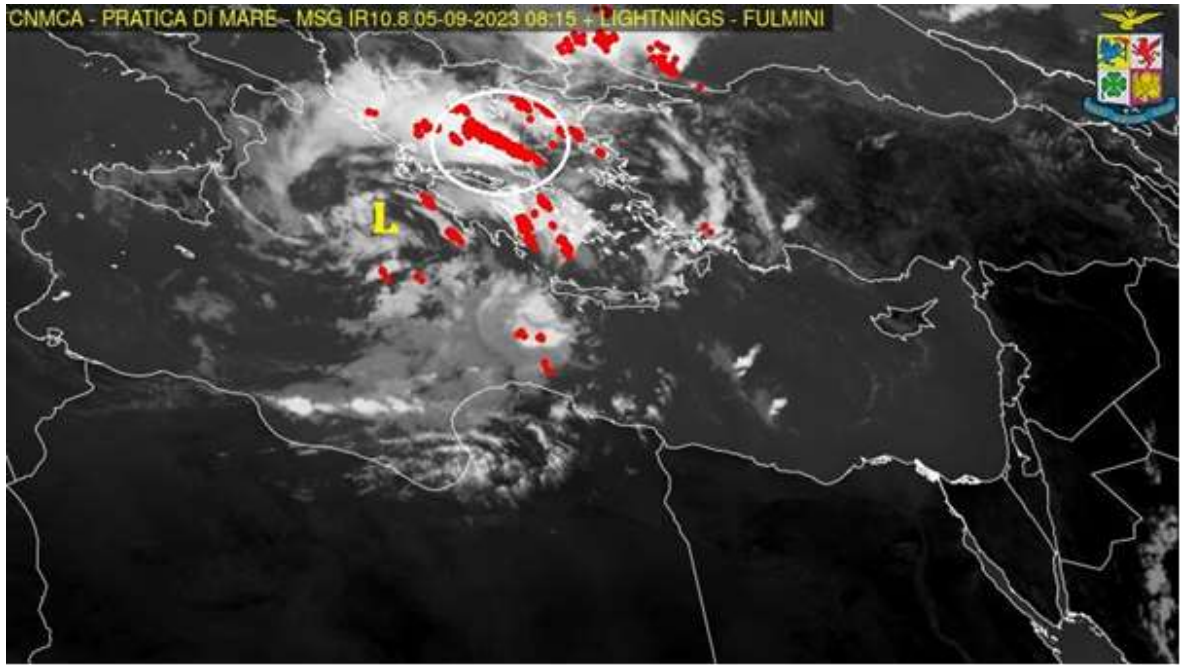
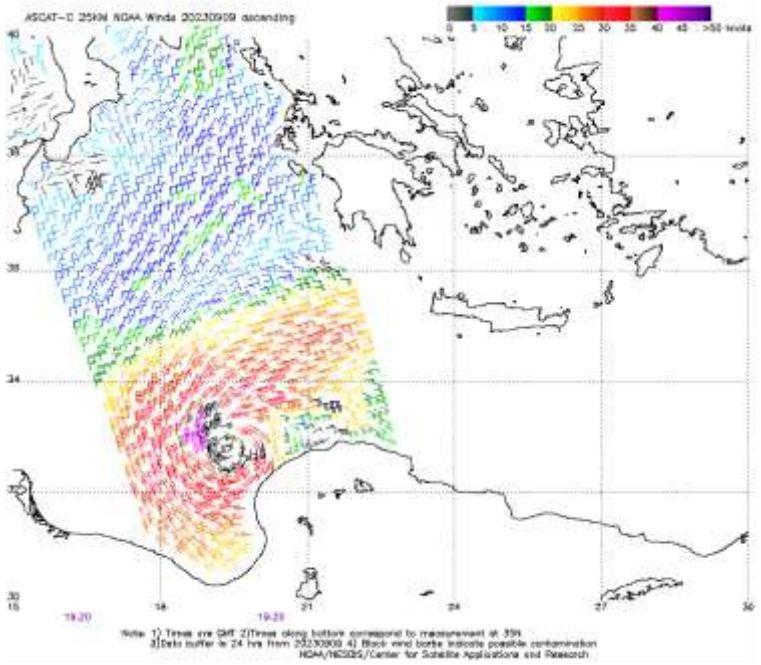
THE STORM DANIEL

FLOOD IN GRACE AND LYBIA - SEPTEMBER 2023

MSG satellite in the morning of the 5th September
Mediterranean Low (L), west of Peloponnesus; very thick clouds, lightnings with widespread thunderstorms (white circle)



ASCAT wind vectors



On 4th September 2023, a through, coming from eastern Europe and developing over Central Europe and the Middle East, begins to move south over the Balkan area. Widespread rain affects Greece, especially the eastern and central parts. On 5th, 6th and 7th September the through remains quasi-stationary and develops into a Mediterranean Cyclone over the Ionian

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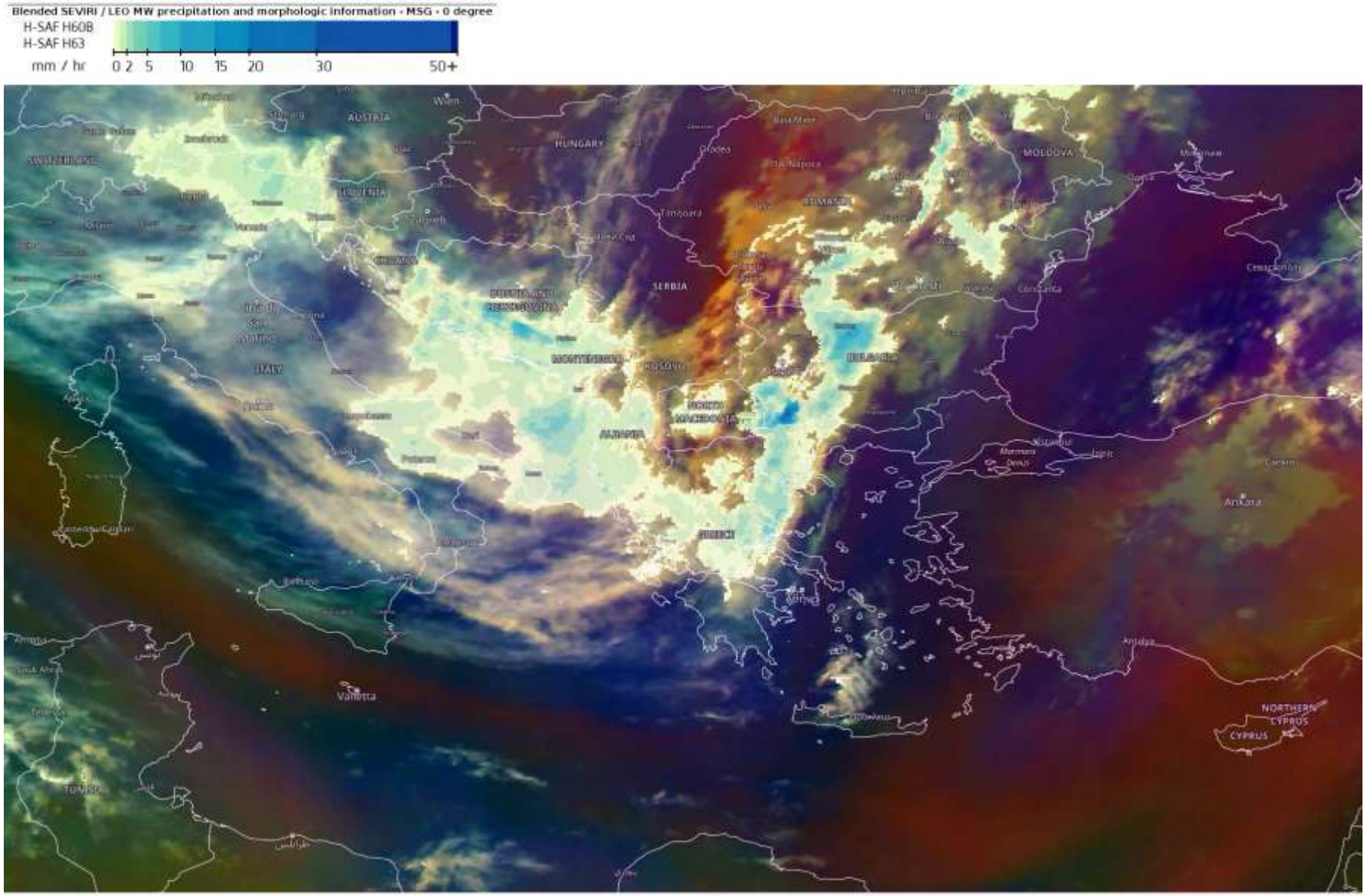
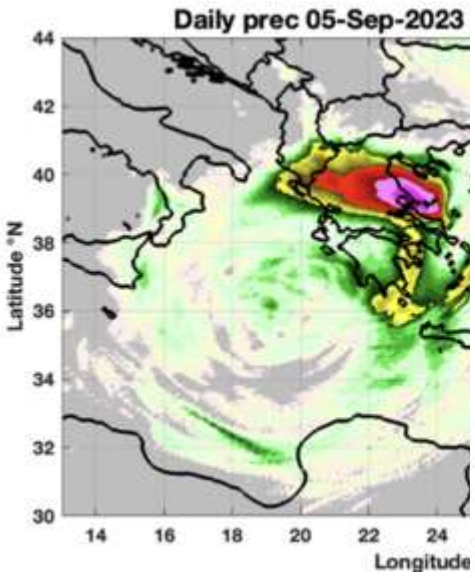
THE STORM DANIEL

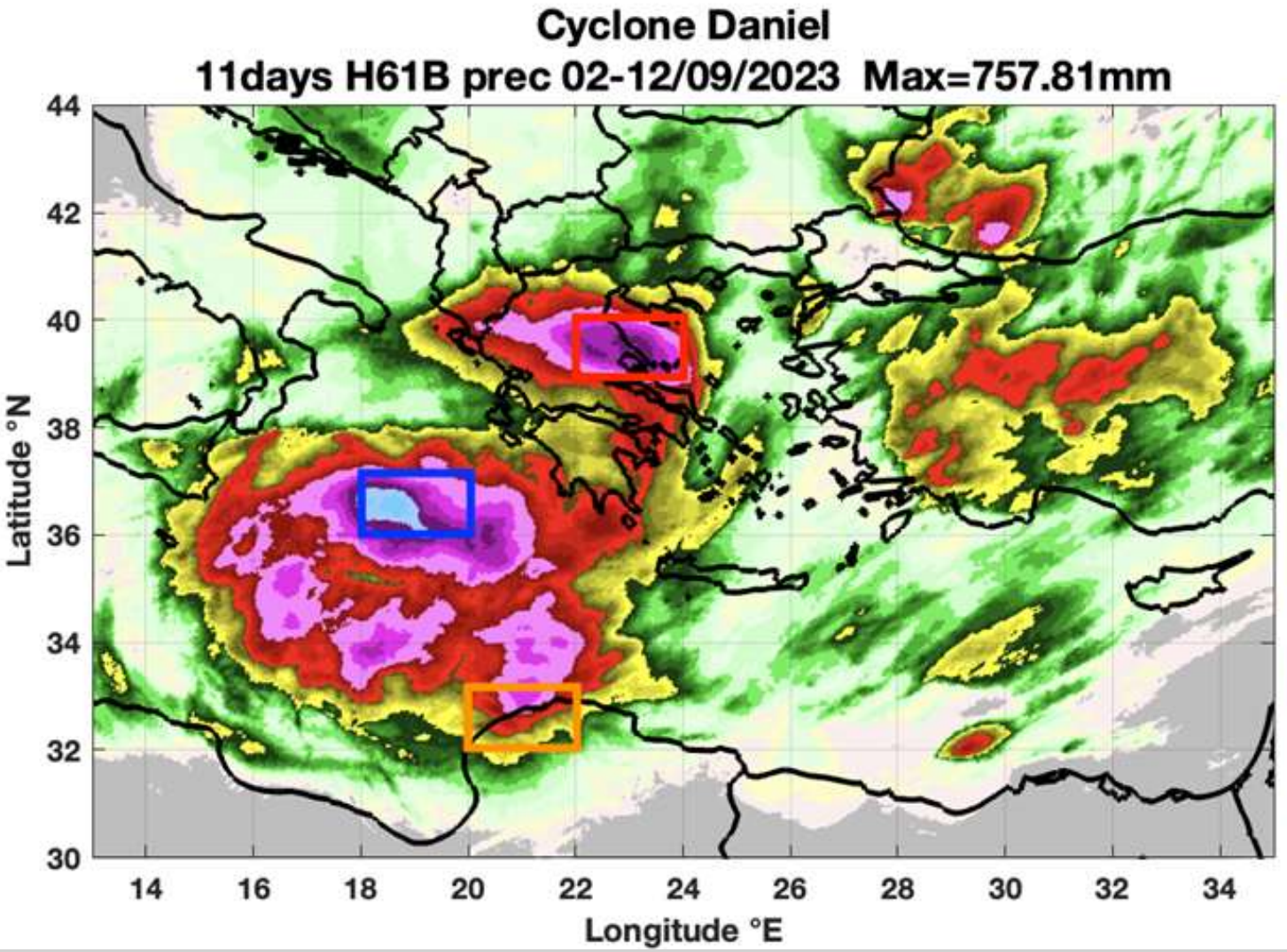
September 2023

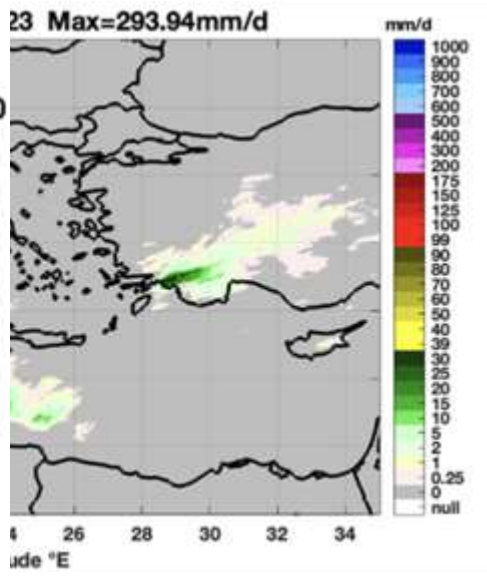


THE STORM DANIEL

September 2023







https://user.eumetsat.int/resources/case-studies/extreme-floods-in-libya-and-central-greece

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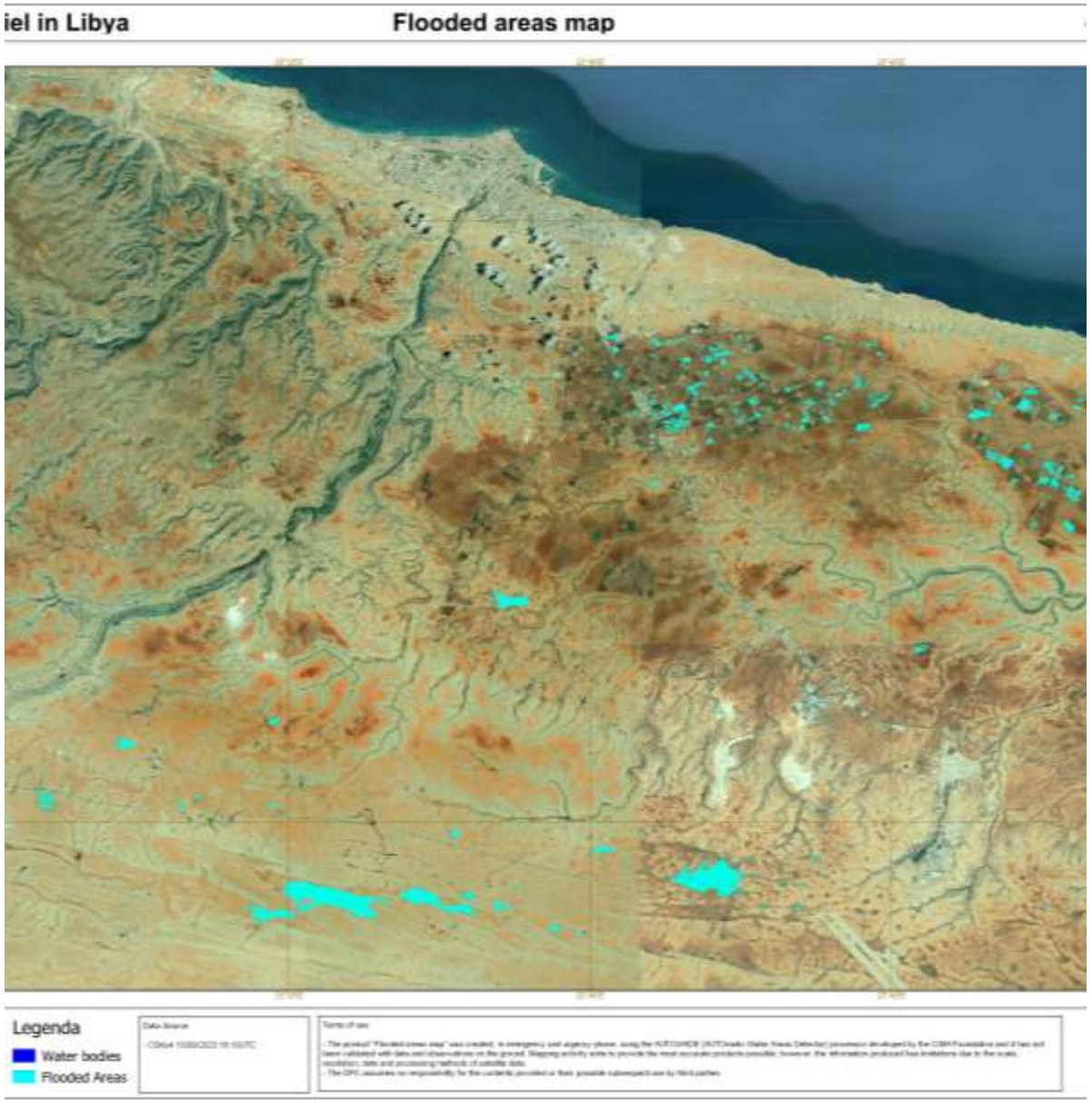
AXIOS Sections Local news Axios Pro About Axios Sign up Log In

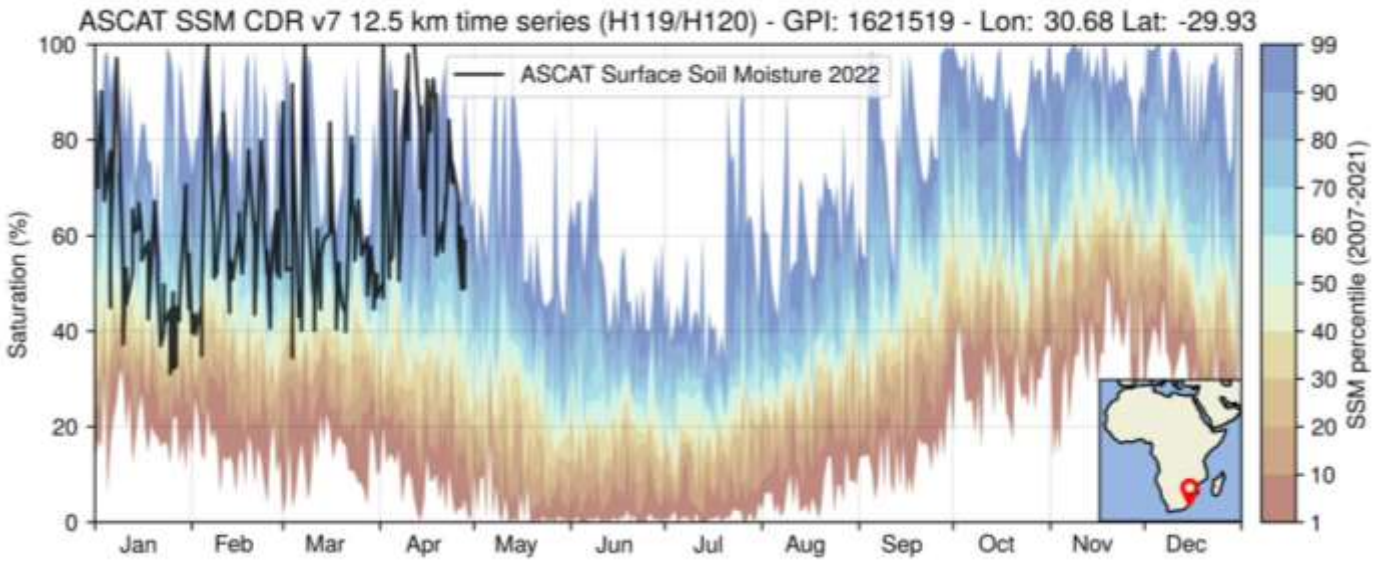
Satellite images taken before and after floodwaters in northeastern Libya burst through dams and wiped out buildings and entire neighborhoods show the sheer scale of the deadly destruction caused by Mediterranean Storm Daniel.

AXIOS Sections Local news Axios Pro About Axios Sign up Log In

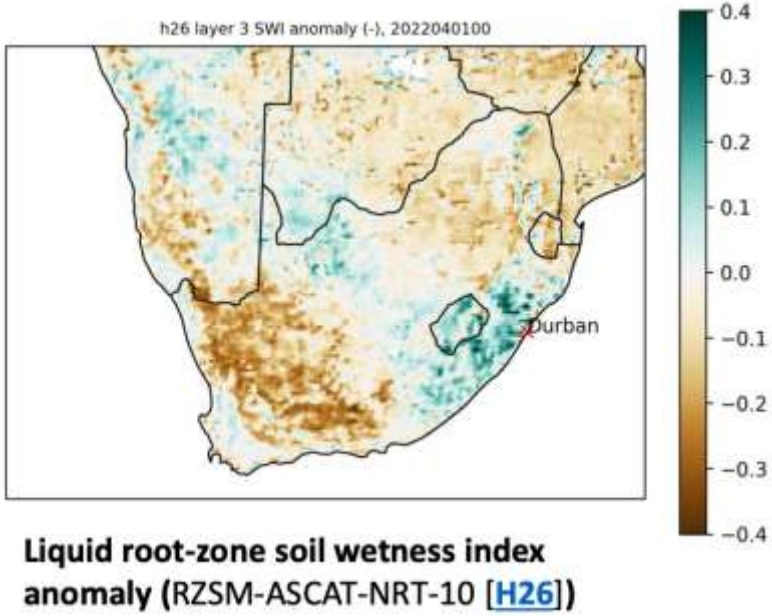
Satellite images taken before and after floodwaters in northeastern Libya burst through dams and wiped out buildings and entire neighborhoods show the sheer scale of the deadly



FLOOD IN SOUTH AFRICA APRIL 2022, ANTECEDENT CONDITION



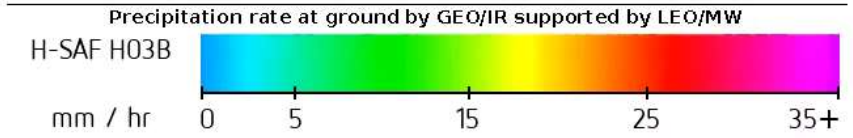
ASCAT SSM DR for an area close to Durban. Highly saturated soil surface conditions can be seen in the beginning of April 2022 compared to surface soil moisture percentiles derived from previous years 2007-2021.



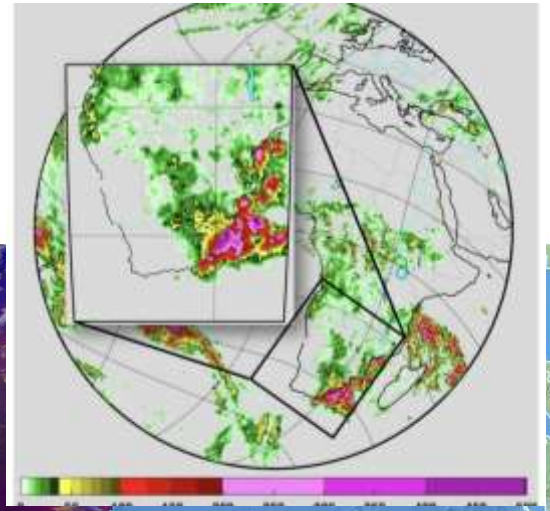
Liquid root-zone soil wetness index anomaly (RZSM-ASCAT-NRT-10 [H26])

Liquid root-zone soil wetness index 1st of April 2022 for layer 3, (28-100 cm depth). Saturated soil moisture conditions are present around Durban.

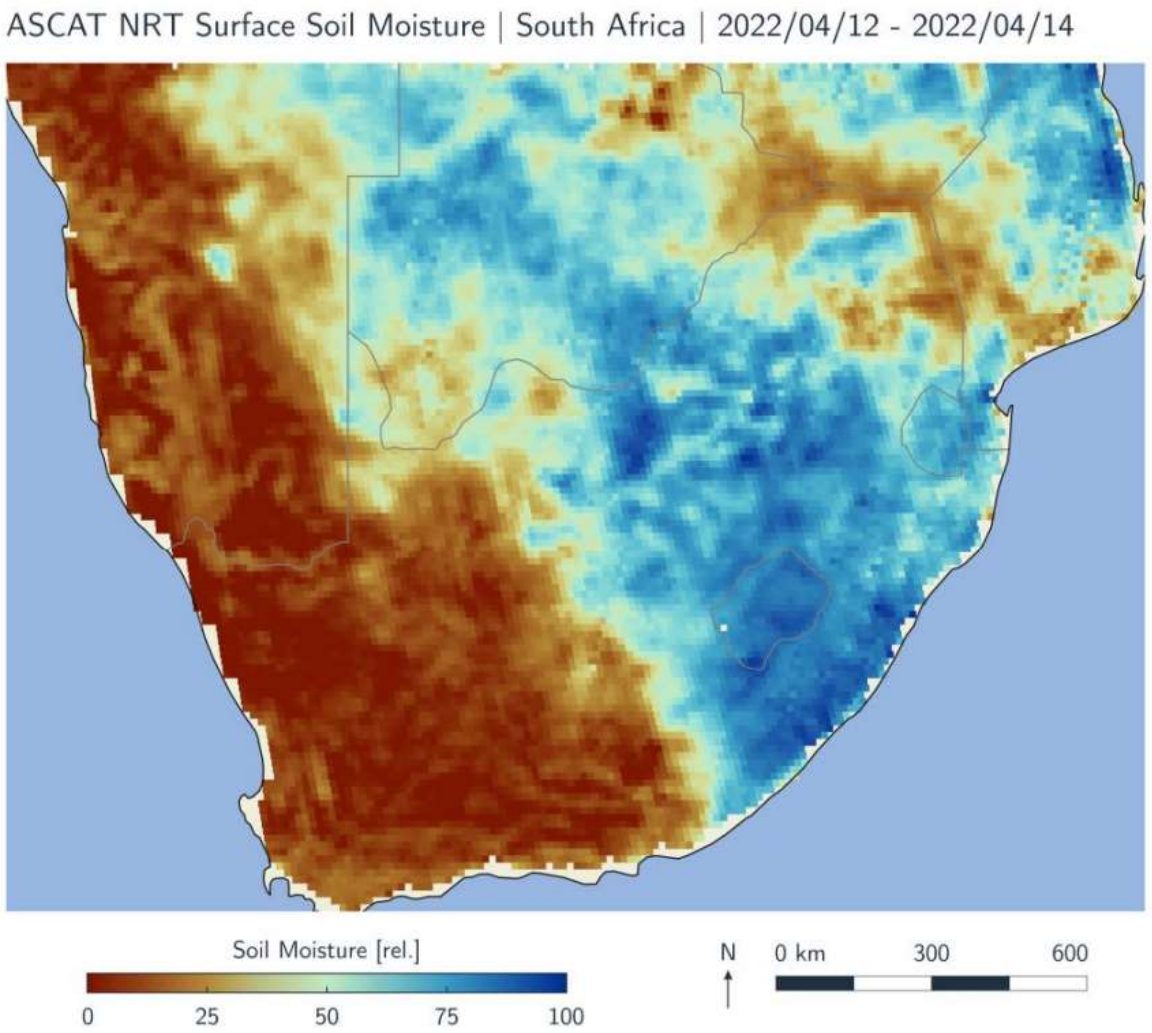
FLOOD IN SOUTH AFRICA APRIL 2022, PRECIPITATION



The city of Durban, in South Africa, is particularly vulnerable to heavy rainfall. An intense flooding has been registered in the period 11-13th April 2022.
P-AC-SM2RAIN [H64] product highlighted 300 mm of accumulated precipitation in 3 days, in the South Africa (11-13 April 2022).
P-IN-SEVIRI [H03] (Precipitation rate at ground by blended MW and IR) animation from EUMETview shows persistent, over nearly 3 days, precipitation in the South Africa (11-12 April 2022).



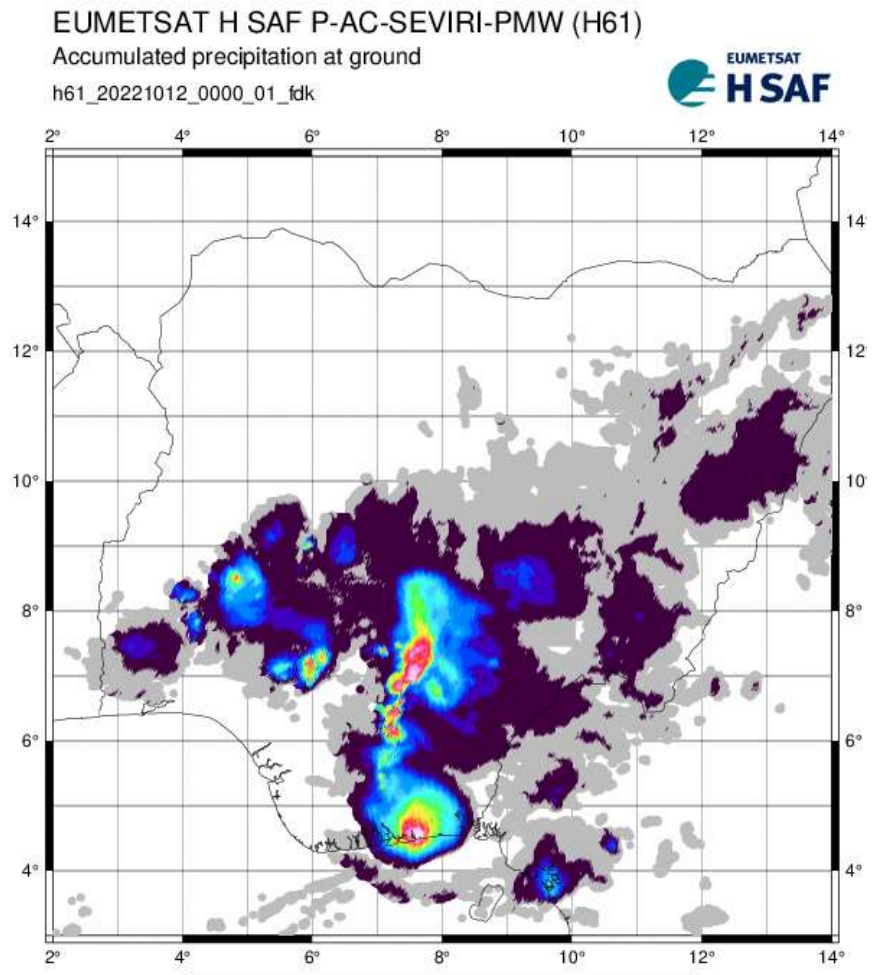
FLOOD IN SOUTH AFRICA APRIL 2022, ANTECEDENT CONDITION

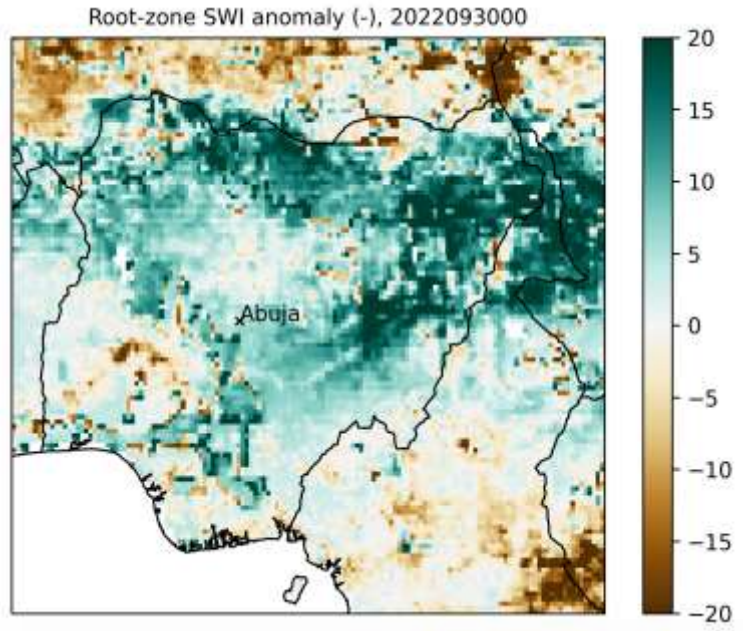


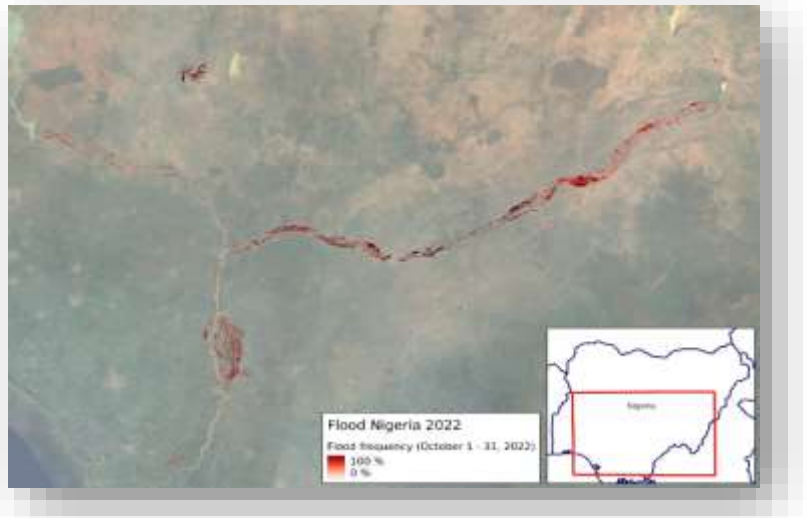
ASCAT SSM NRT products for the period 12-14 April 2022. Surface soil moisture saturation levels are very high in south-eastern South Africa due to heavy rainfall.

FLOODING IN NIGERIA: 1 Aug 2022 - 31 Oct 2022

Rainfall events occurred in the upstream section of River Niger during the month of October. These exceptional rainfall amounts along with the wetter conditions of the soil created the flood event that impaced 27 out 36 states causing more than 600 fatalities. Transport was affected for at least two weeks, and food and fuel supplies blocked.







Plot of the H SAF precipitation and root-zone soil wetness index anomaly (expressed as a percentage of saturation) for layer 3 (28-100cm depth) for 30 September 2022.

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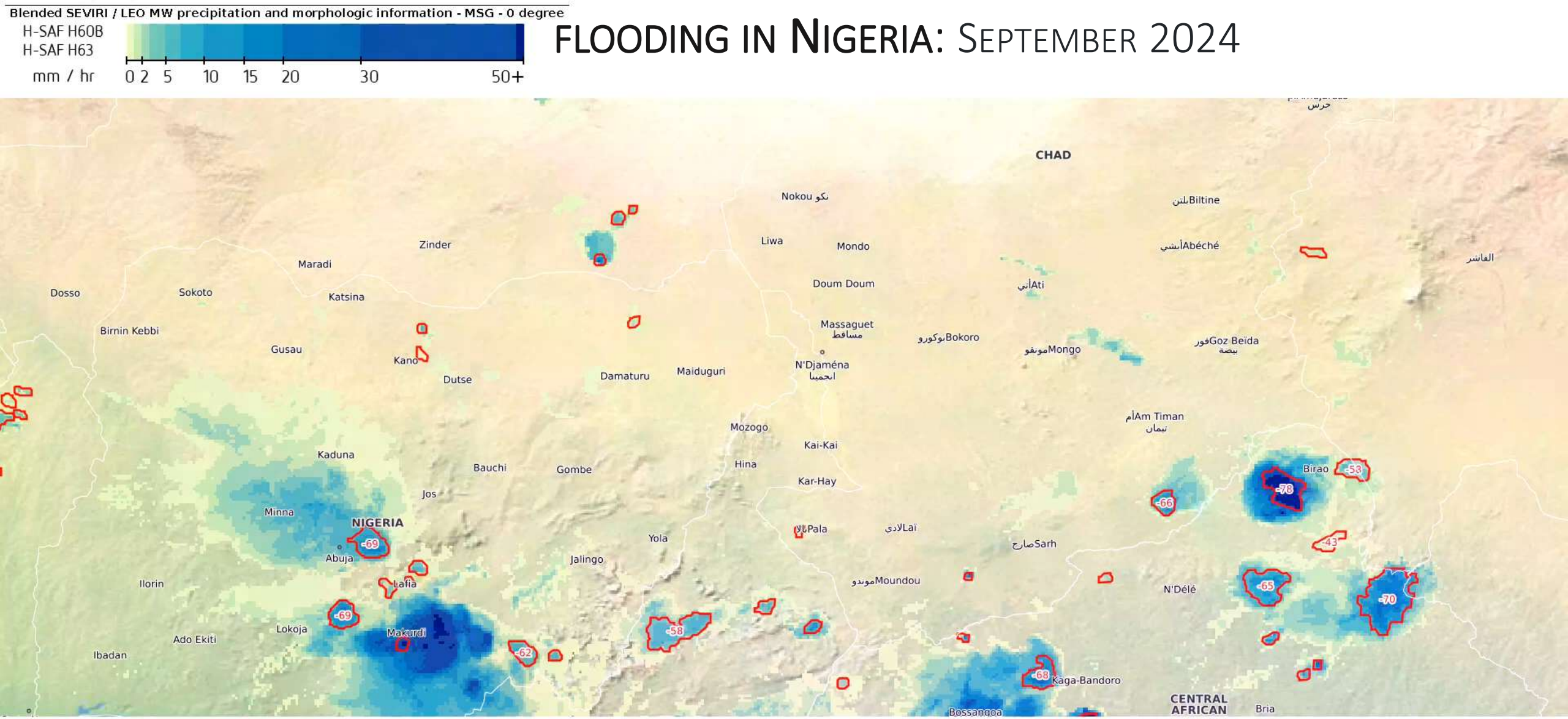
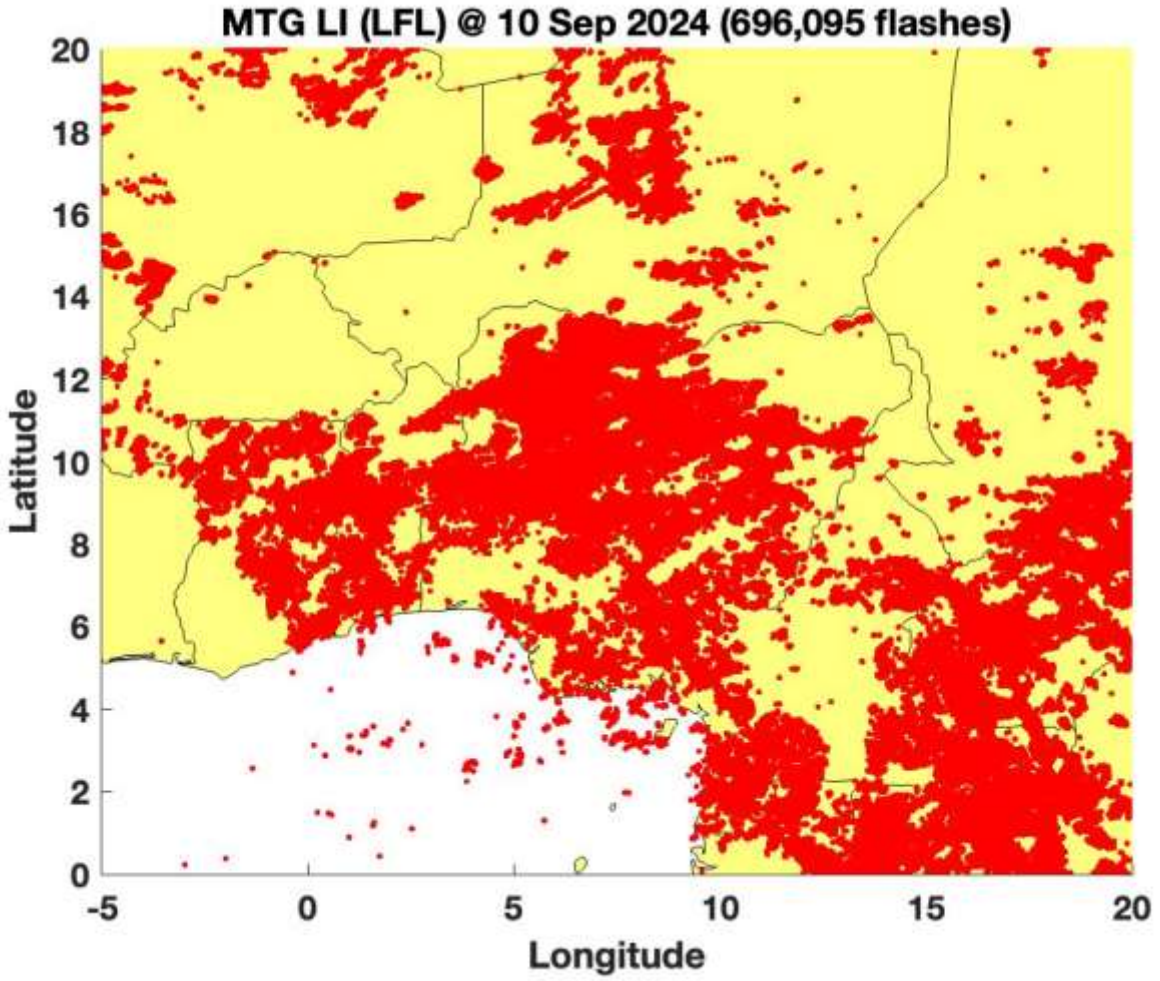
FLOODING IN NIGERIA: SEPTEMBER 2024



EUMETSAT

2024-09-06 00:30:00 UTC

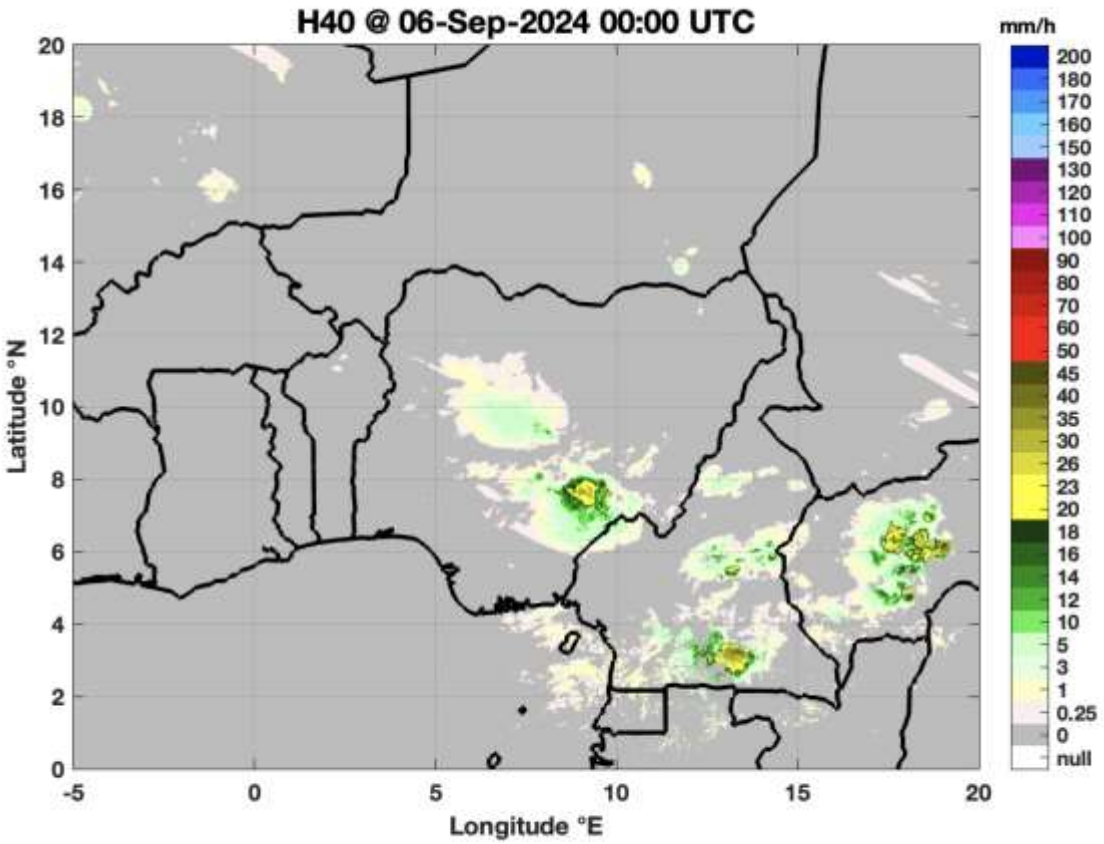
FLOODING IN NIGERIA: SEPTEMBER 2024



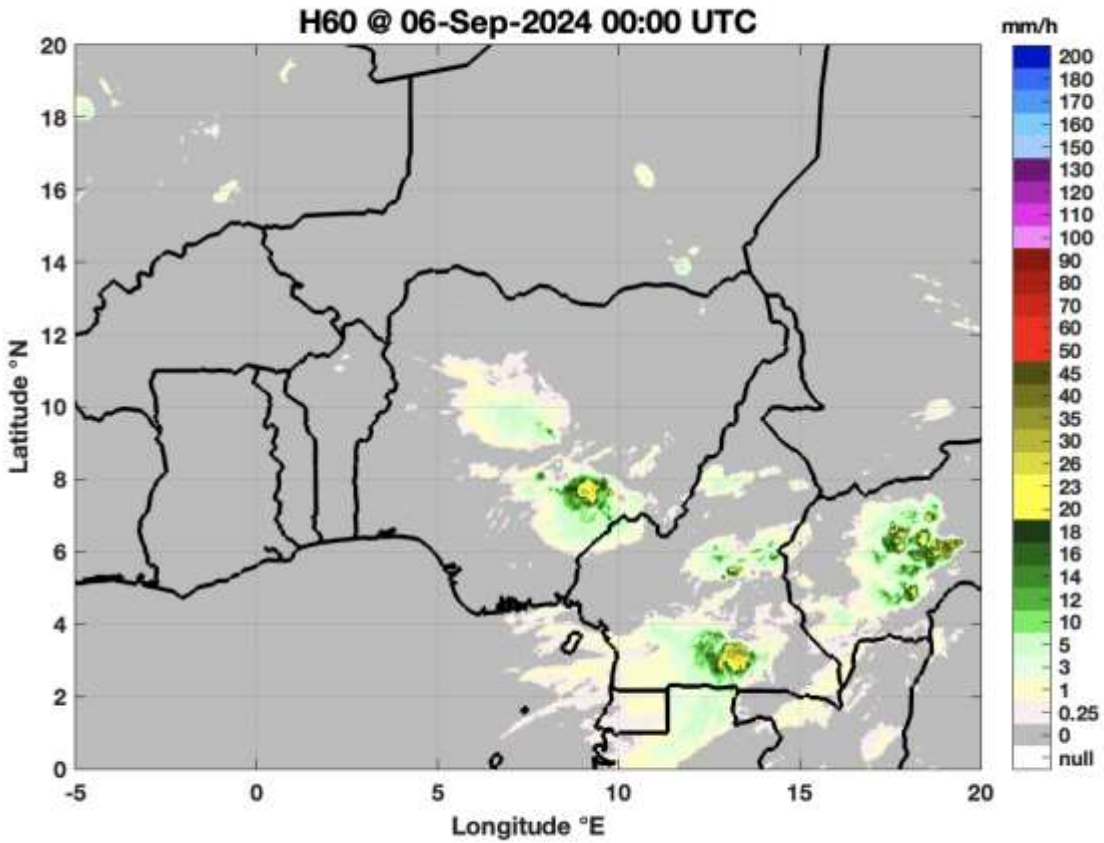
FLOODING IN NIGERIA: SEPTEMBER 2024

Rain Rate (MTG) vs Rain Rate (MSG)

Spat. Res:2km | Temp. Res: 10 min



Spat. Res:3km | Temp. Res: 15 min



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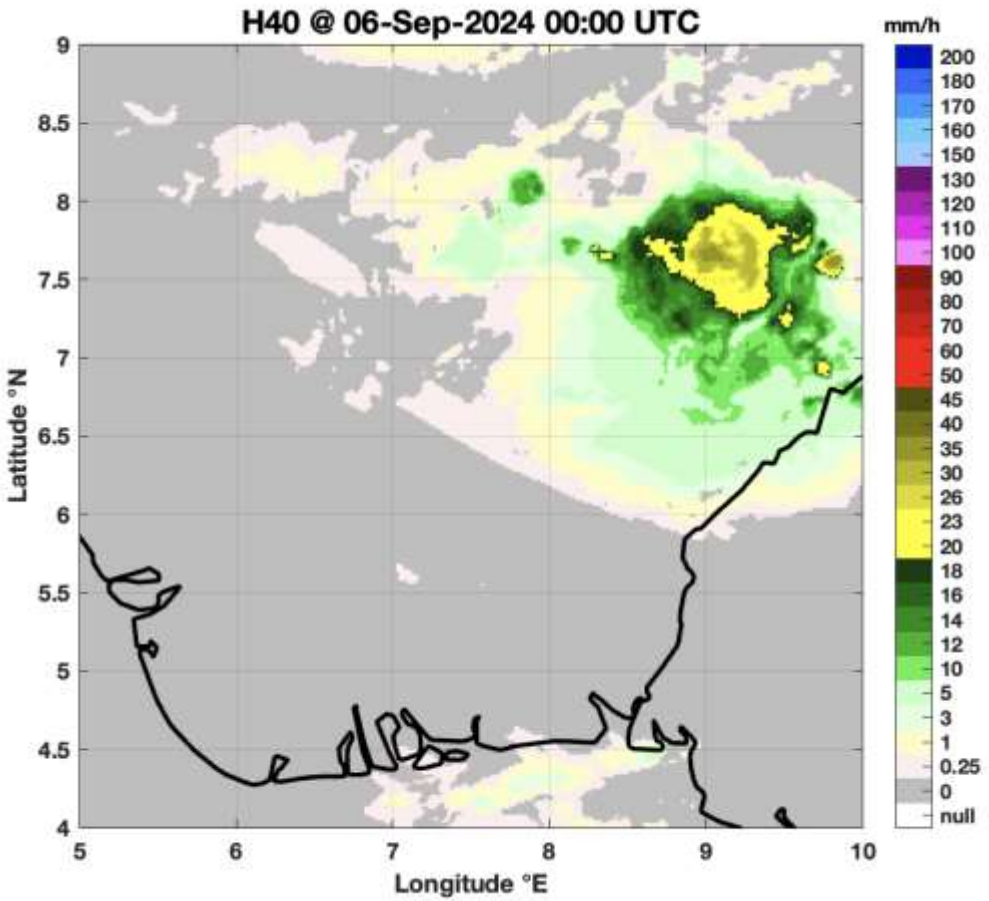
FLOODING IN NIGERIA: SEPTEMBER 2024

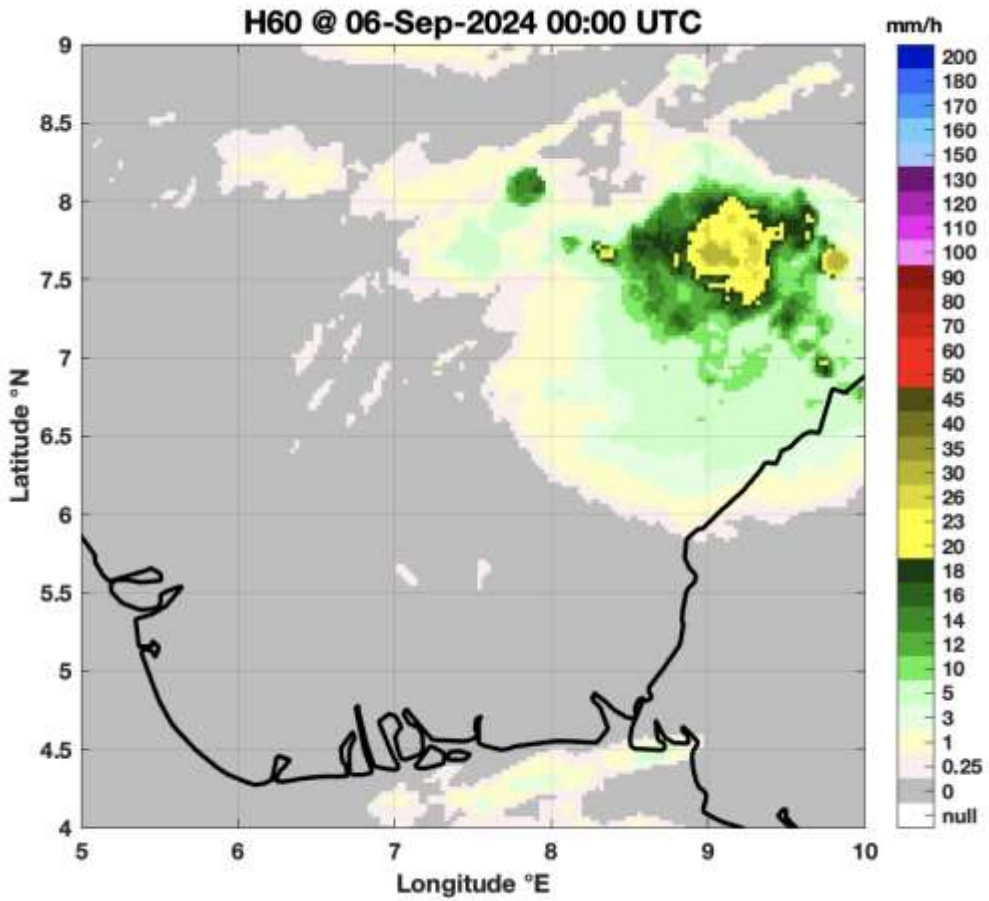
Rain Rate (MTG) vs Rain Rate (MSG)

Spat. Res:2km | Temp. Res: 10 min

Spat. Res:3km | Temp. Res: 15 min



Zoom



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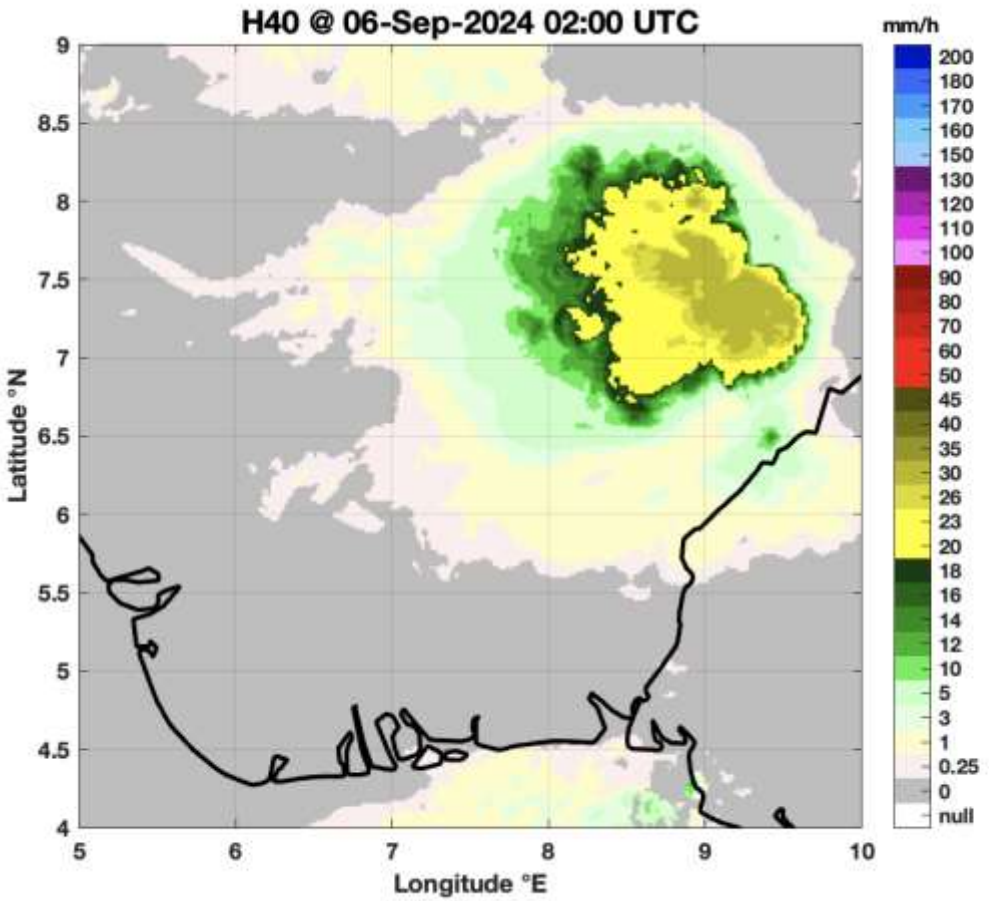
FLOODING IN NIGERIA: SEPTEMBER 2024

Rain Rate (MTG) vs Rain Rate (MSG)

Spat. Res:2km | Temp. Res: 10 min

Spat. Res:3km | Temp. Res: 15 min



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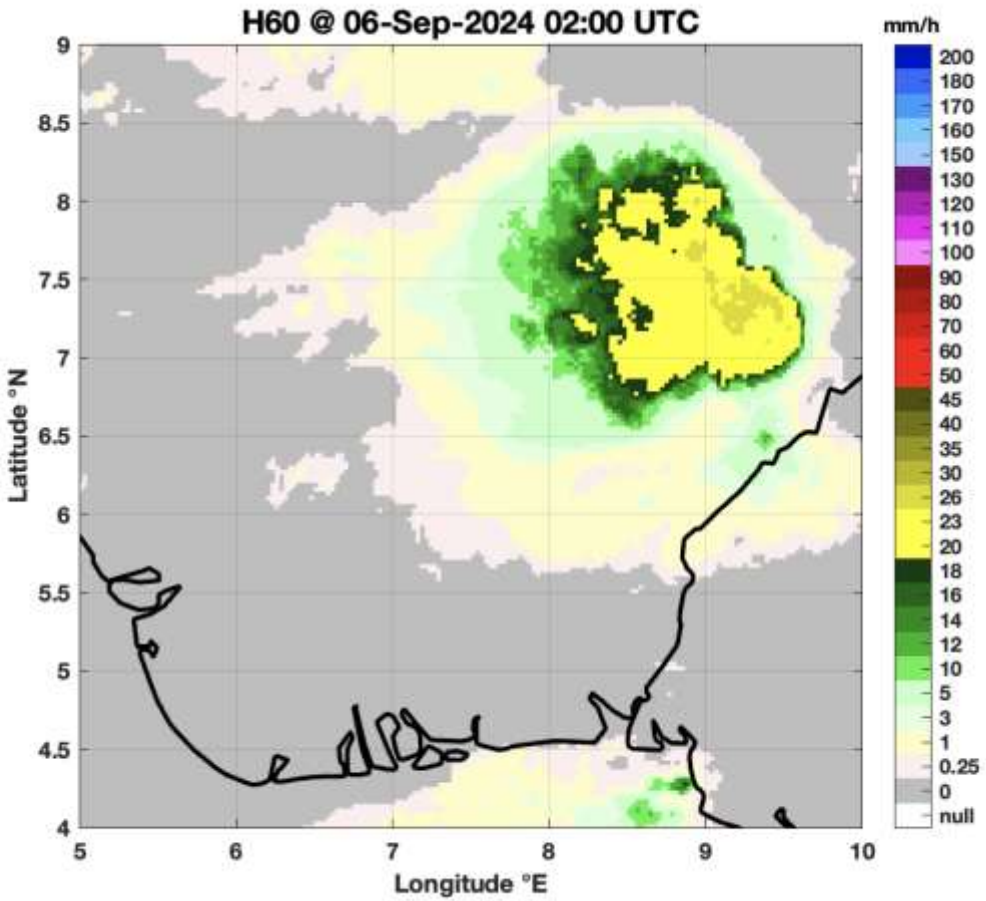

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FLOODING IN NIGERIA: SEPTEMBER 2024

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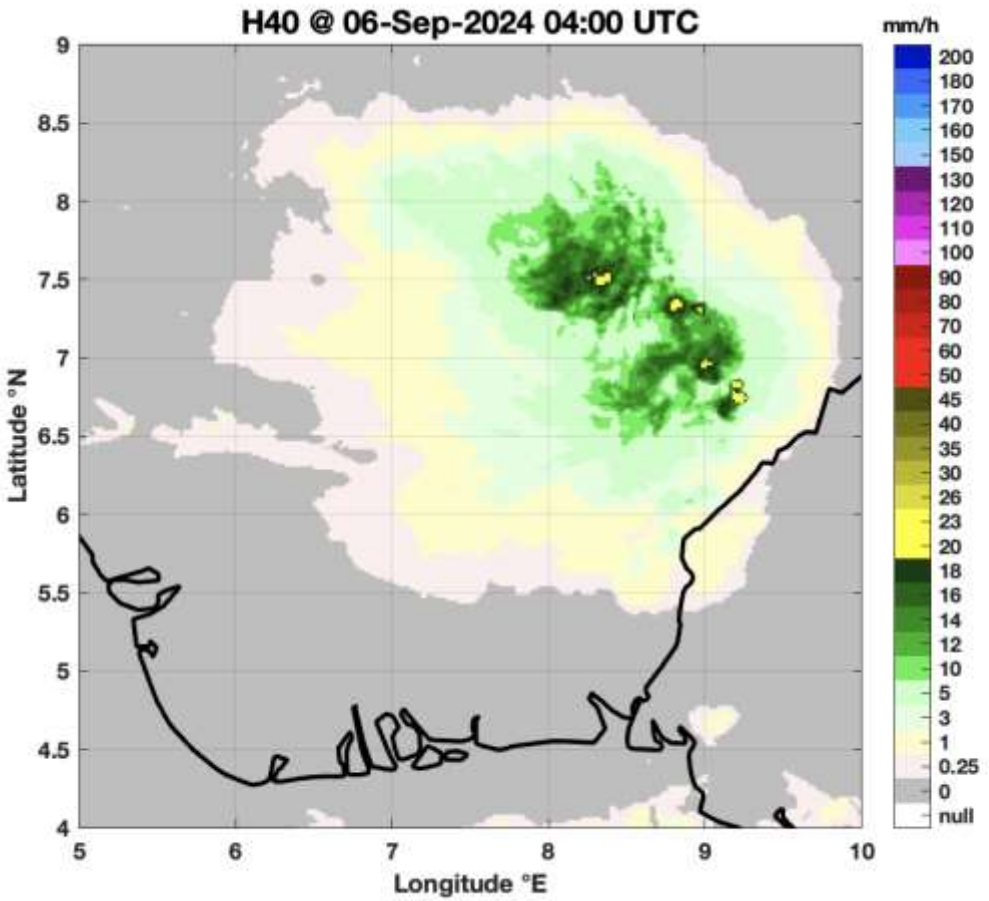
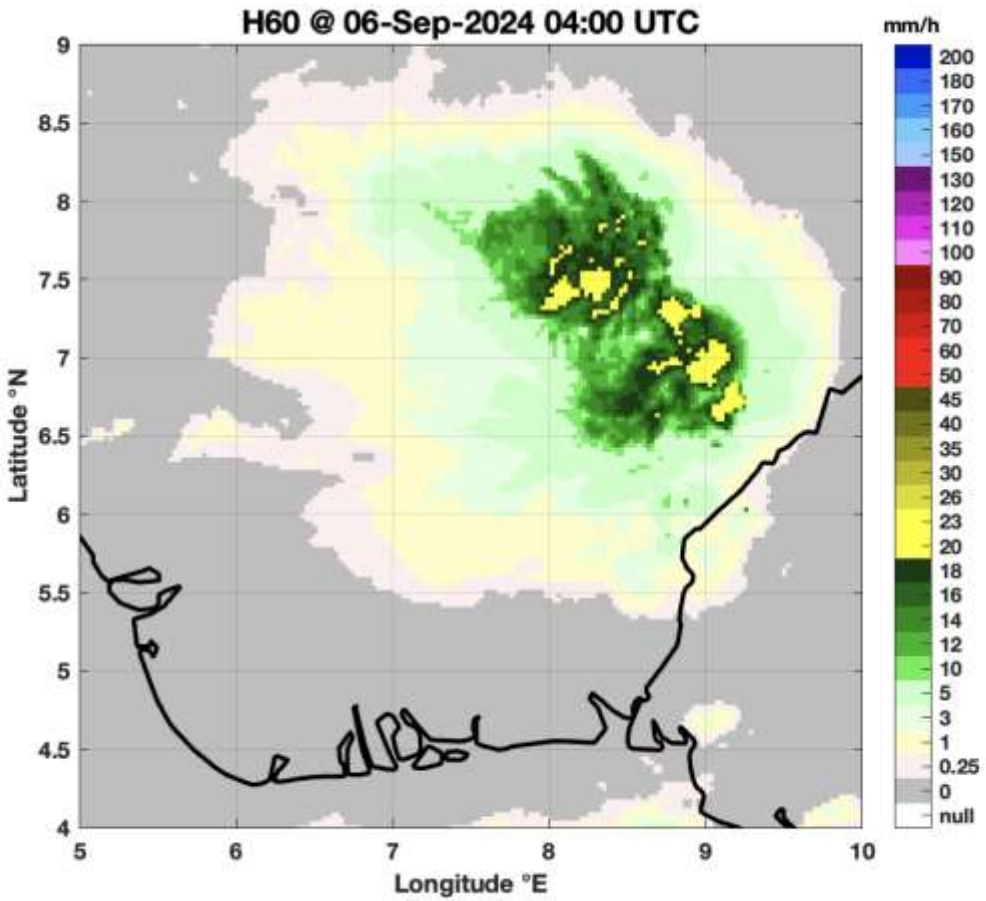
Spat. Res:2km | Temp. Res: 10 min

Spat. Res:3km | Temp. Res: 15 min



Zoom



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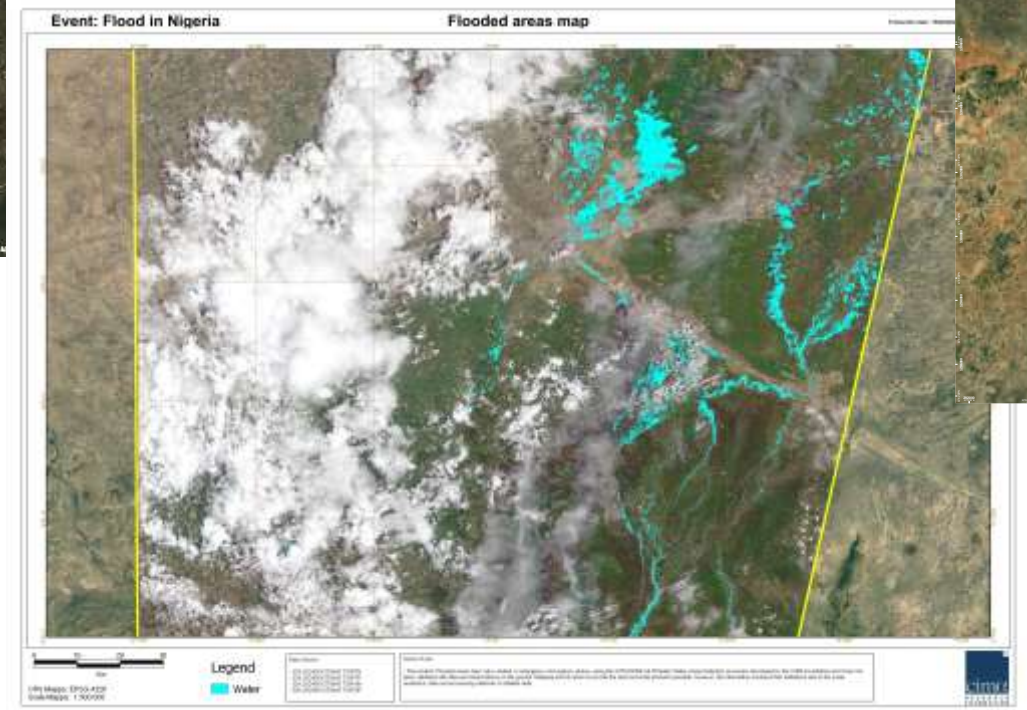
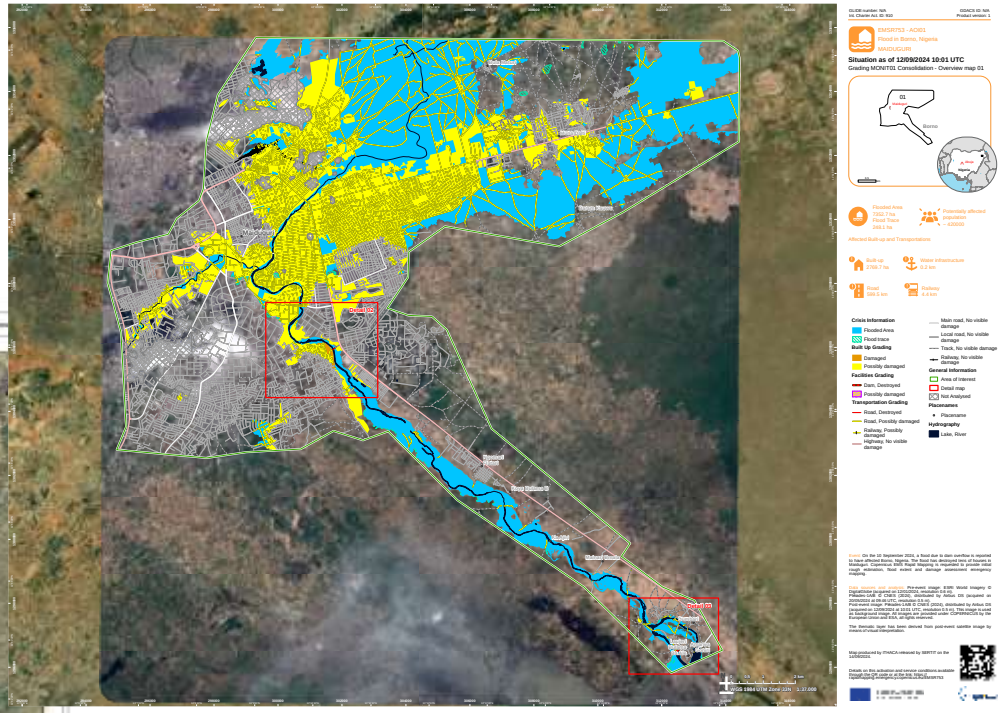
FLOODING IN NIGERIA: SEPTEMBER 2024

Flooding maps





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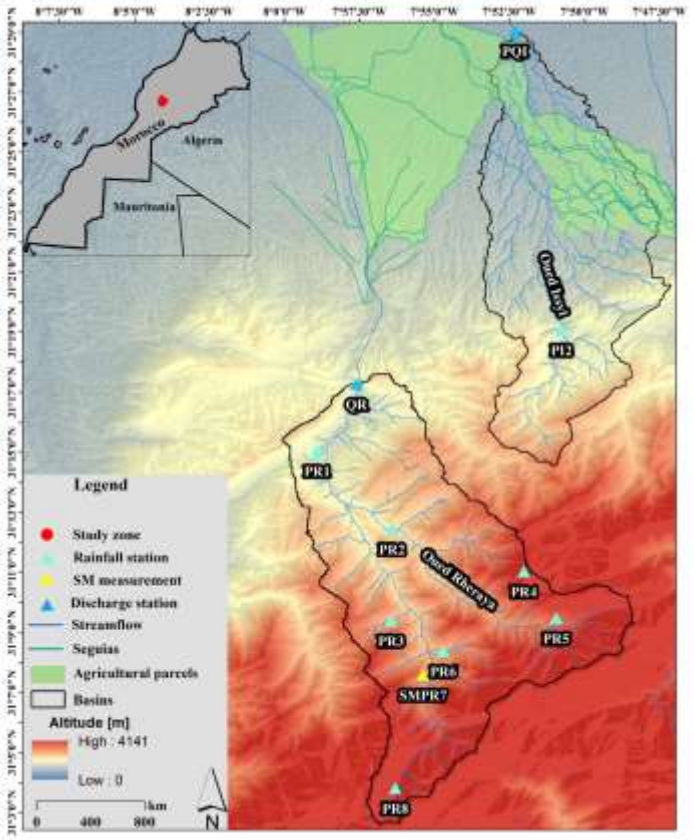
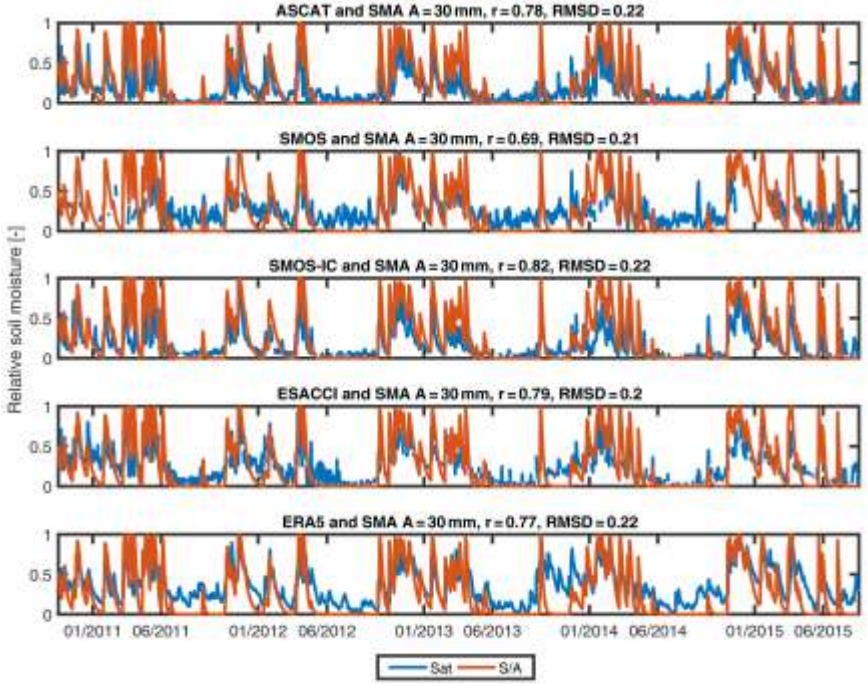
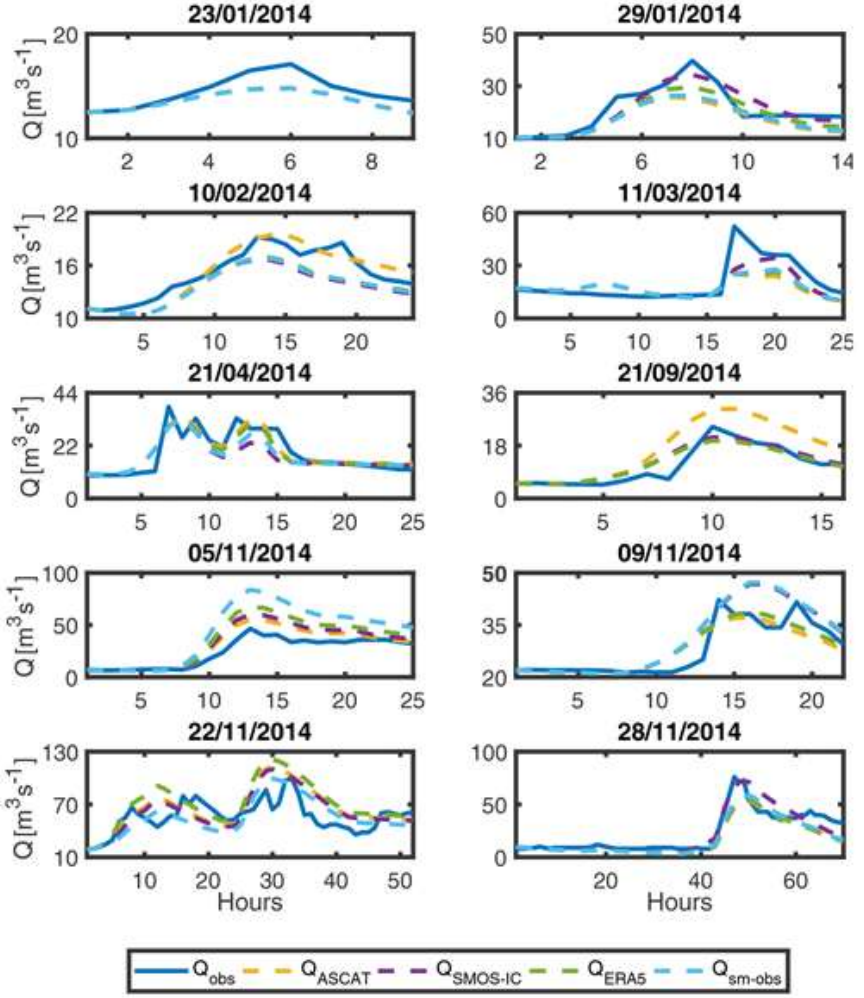
FLOOD FORECASTING IN MOROCCO



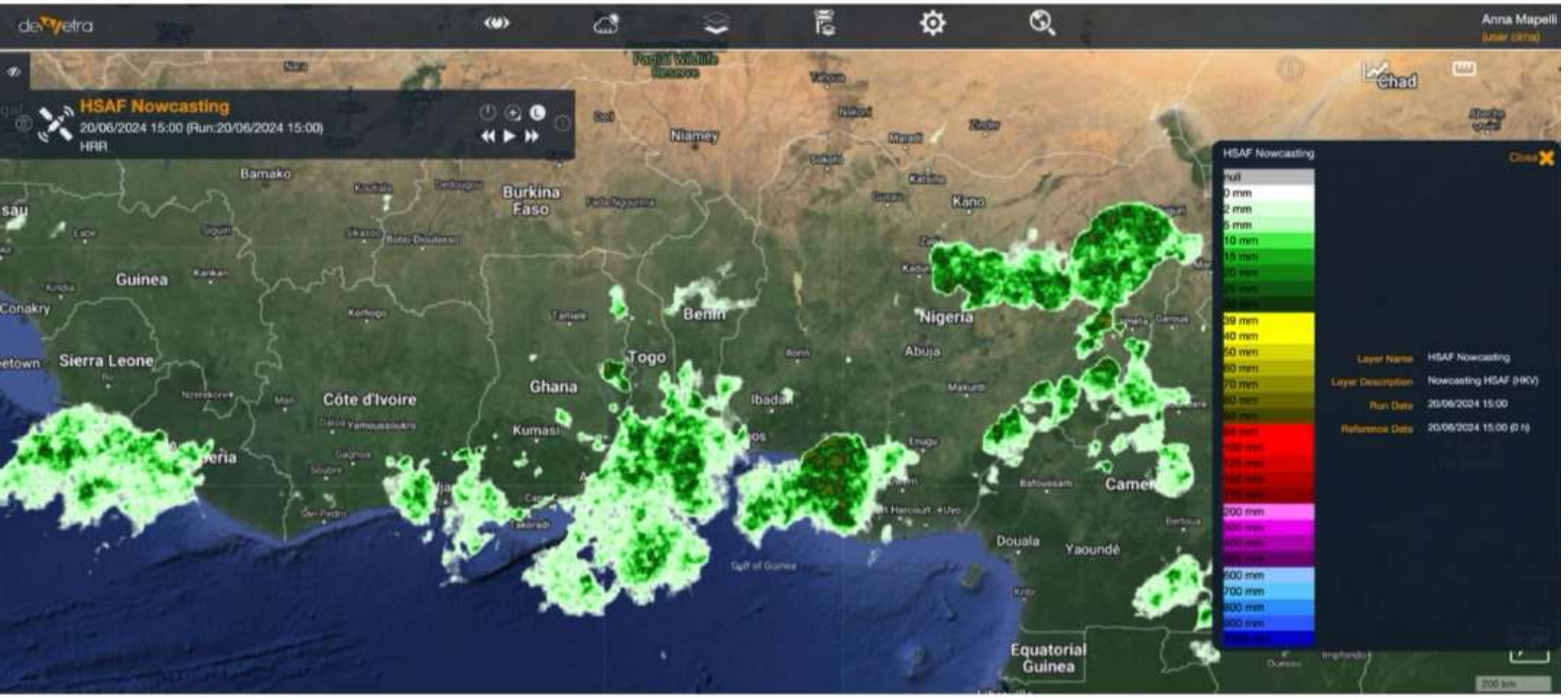




Satellite soil moisture are very useful to estimate the antecedent conditions before a rainfall event, thus providing essential information for flood prediction

El Khalki Mahdi et al. 2020 (NHESS)
Tramblay et al. 2012 (HESS)

RAINFALL EVENT NOWCASTING



Nowcasting product developed by HKV (https://www.hkv.nl/en/) in a WMO-project.
The nowcast is based on the P-IN-SEVIRI-PMW (60B) product.
The nowcasted rainfall is presented in mm/h for each 15min interval

Contacts
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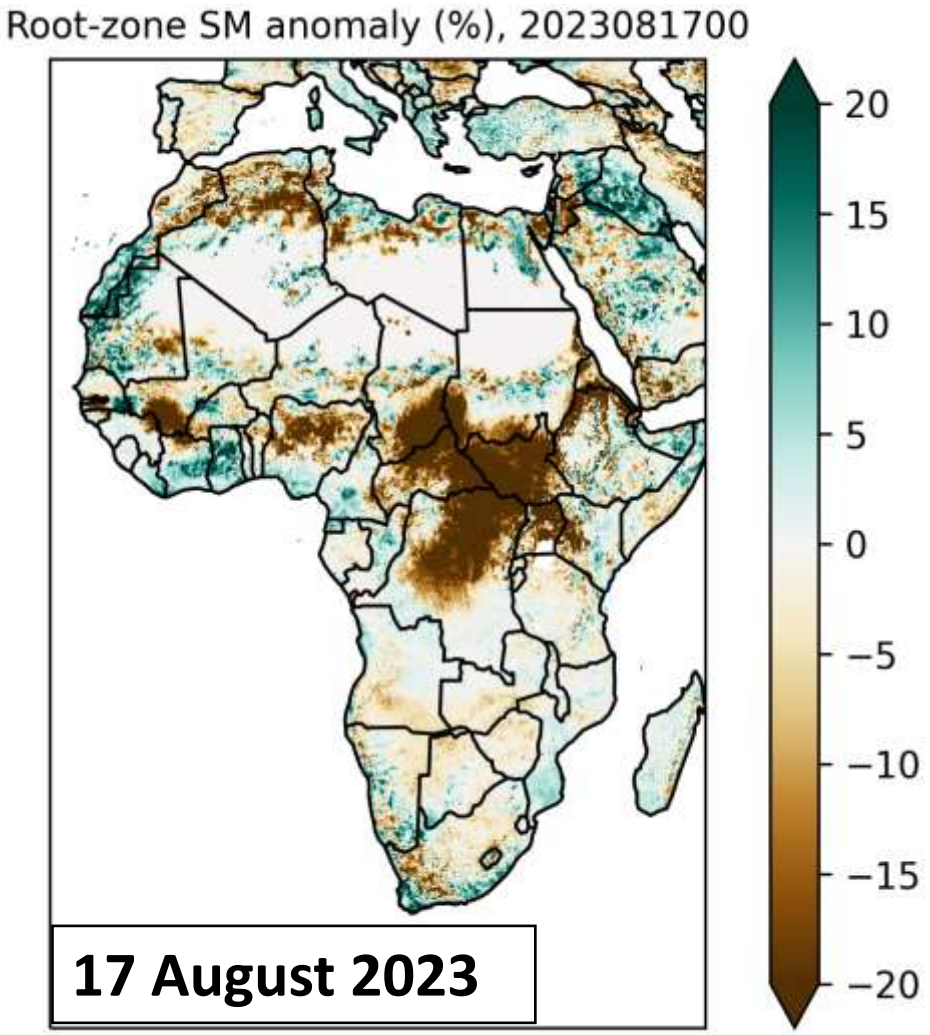
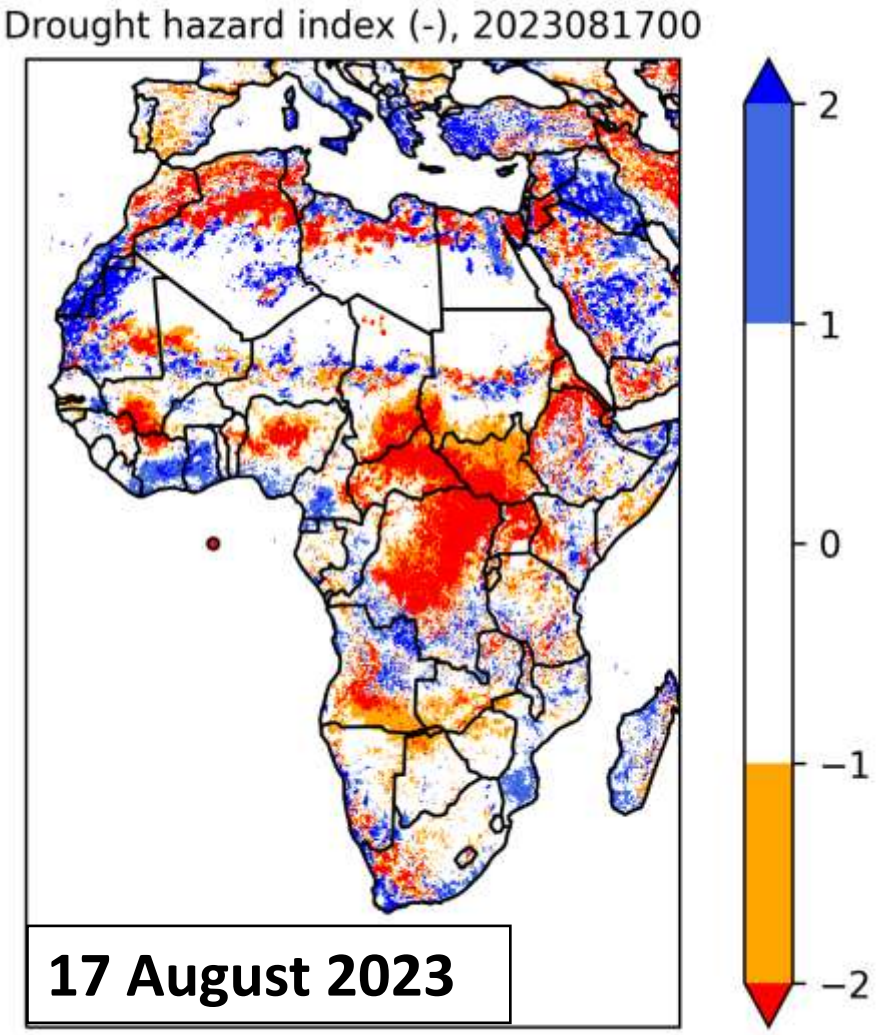
Nicole Jungermann: n.jungermann@hkv.nl

DROUGHT MONITORING IN AFRICA ROOT-ZONE SOIL MOISTURE





Comparison of near-real-time (NRT) product with data record can indicate droughts or flood

Drought conditions (<-1),
Severe drought (<-2)

Severe drought present over parts of central and eastern Africa

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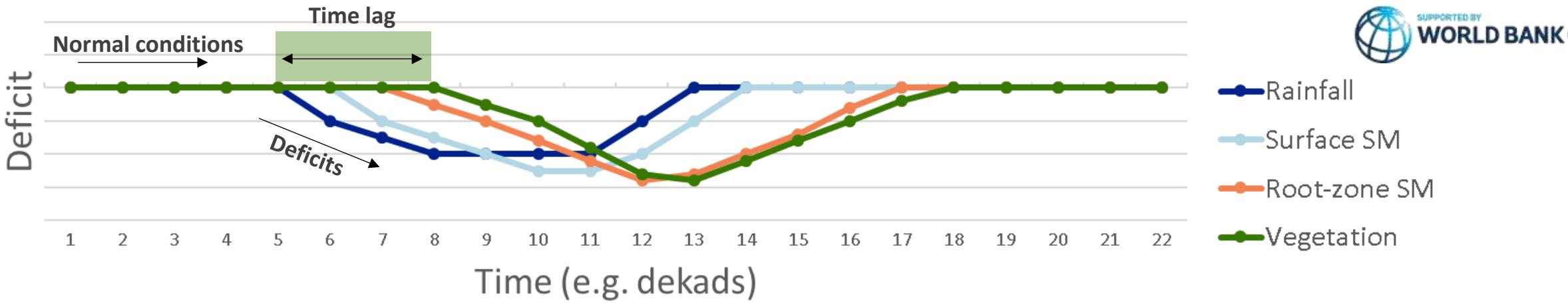
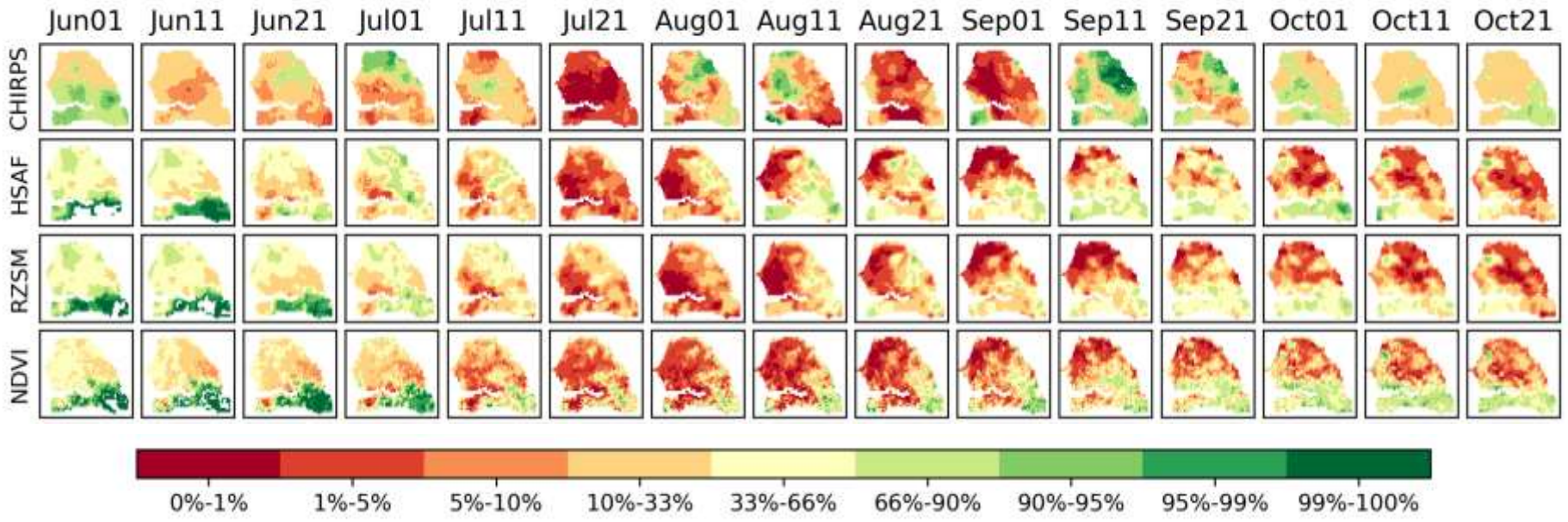
DROUGHT MONITORING IN SENEGAL

Disaster Risk Financing & Insurance Program

SUPPORTED BY WORLD BANK GROUP





Exploiting multiple variable we can monitor drought over time

2014 drought in Senegal

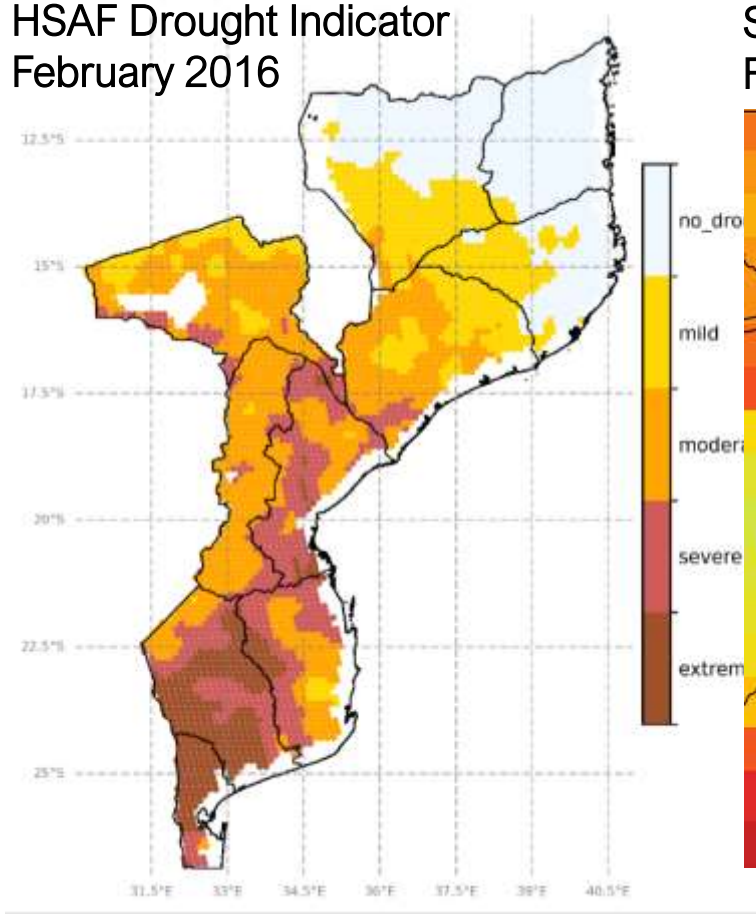
Vreugdenhil et al. 2022 (Frontiers in Water)

DROUGHT MONITORING IN MOZAMBIQUE

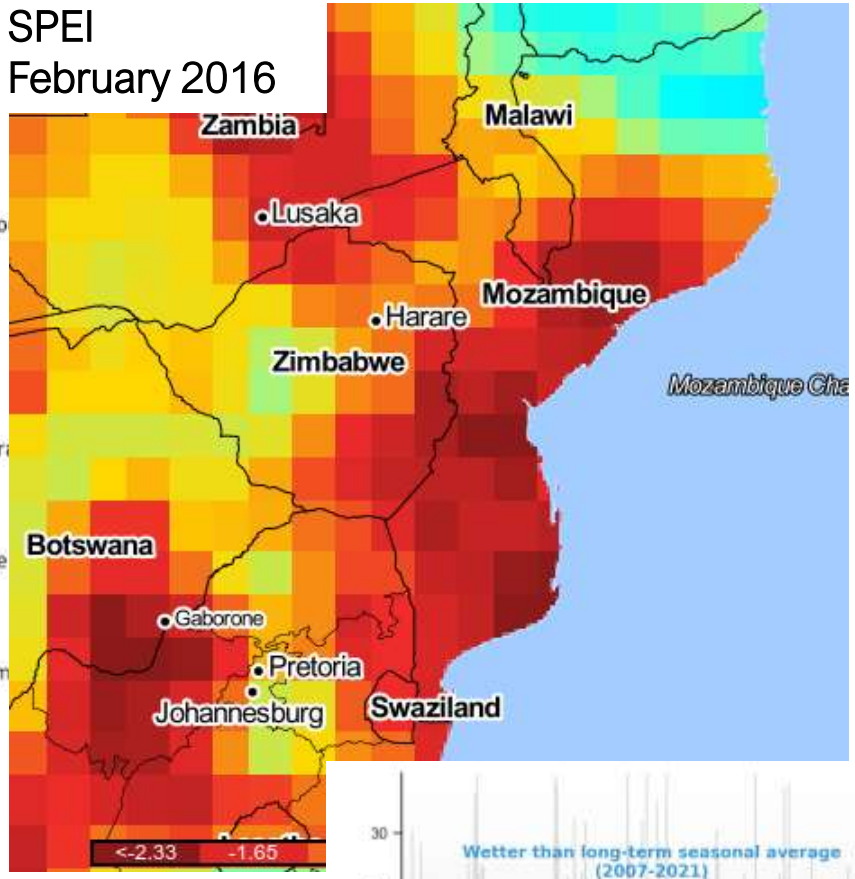
Disaster Risk Financing & Insurance Program

SUPPORTED BY WORLD BANK GROUP

HSAF Drought Indicator
February 2016

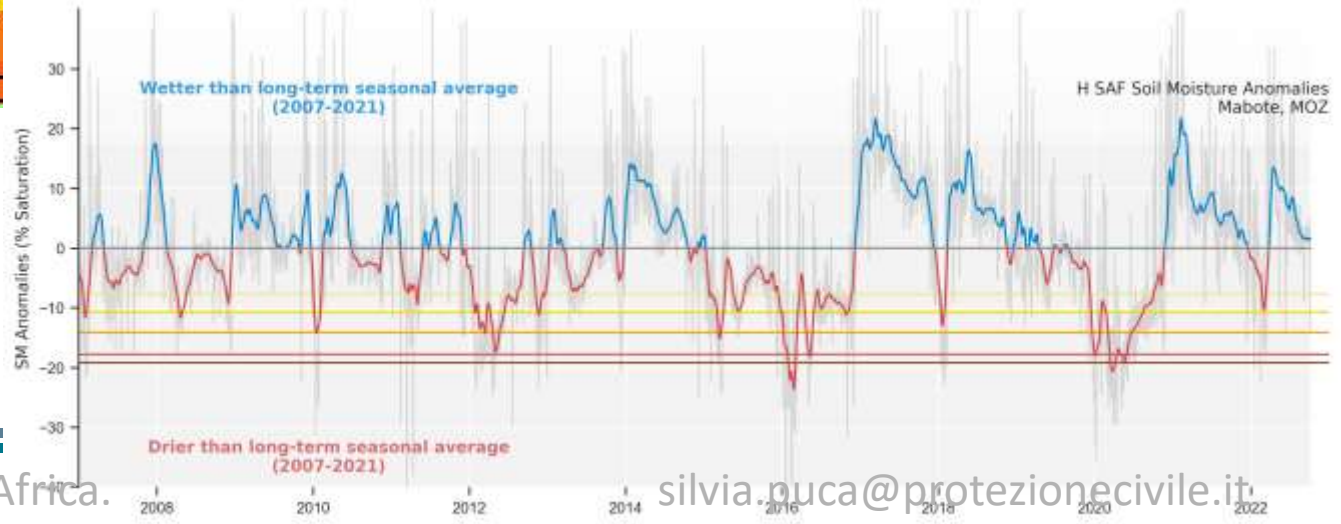


SPEI
February 2016



HSAF Soil moisture can provide reliable drought information at higher spatial resolution and NRT

Drought in 2015/2016 affecting 1.5m people mainly in south and central part



Vreugdenhil et al. 2022 (Frontiers in Water)

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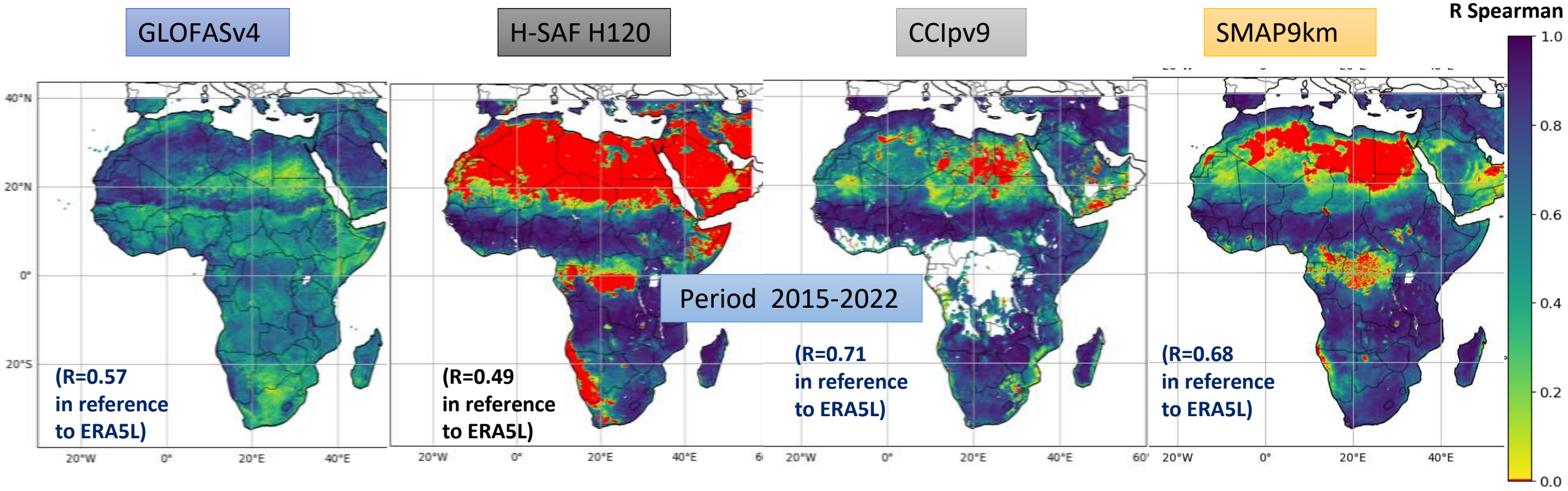
H SAF Soil Moisture for Drought Monitoring

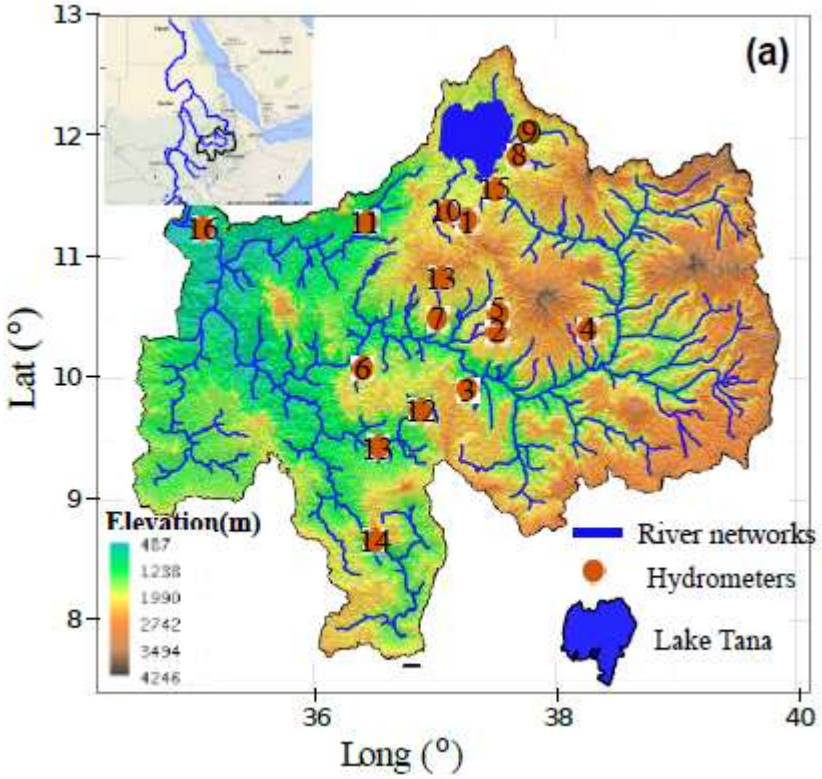
Distinct strengths / weaknesses exist between modelled (GLOFASv4) and RS SM products (H120, CCIp, SMAP)



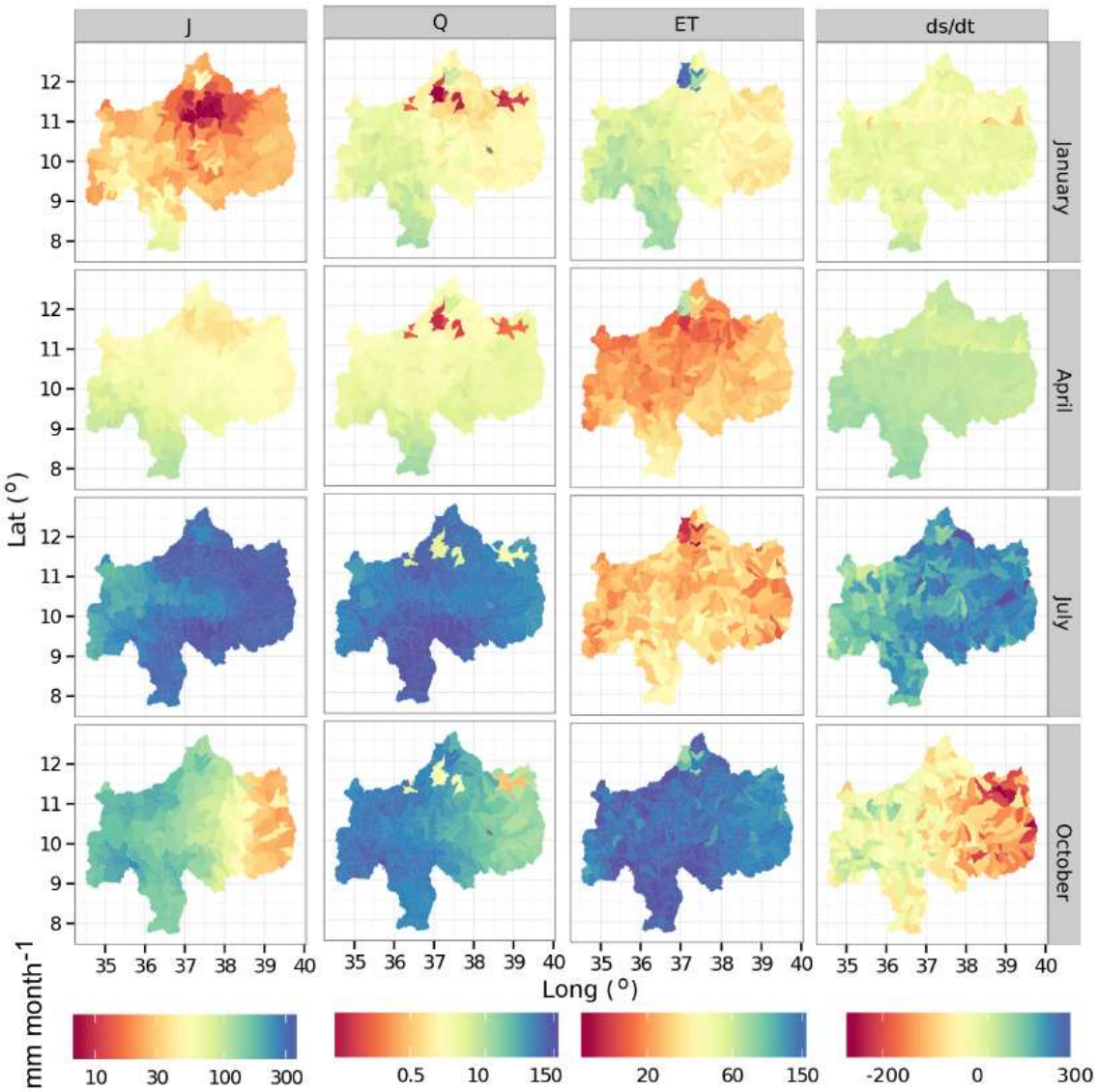
- The model-based GLOFAS (LISFLOOD model inside) excels at covering areas unable for RS but struggles in regions with singular hydrology
- Active ASCAT data surpasses all products in coverage over vegetation, continuity, frequency of visit but finds difficulties over arid areas
- Passive data sources (CCIp, SMAP9km) surpass the other data types of SM over arid areas but are the less capable over equatorial regions

Combining different types of data optimizes the applicability of these global SM products for drought monitoring

MODELLING THE WATER BUDGET: UPPER BLUE NILE



Satellite soil moisture (+precipitation and evaporation) products are useful to assess the long-term water balance essential for water resources management



Abera et al. 2017 (HESS)

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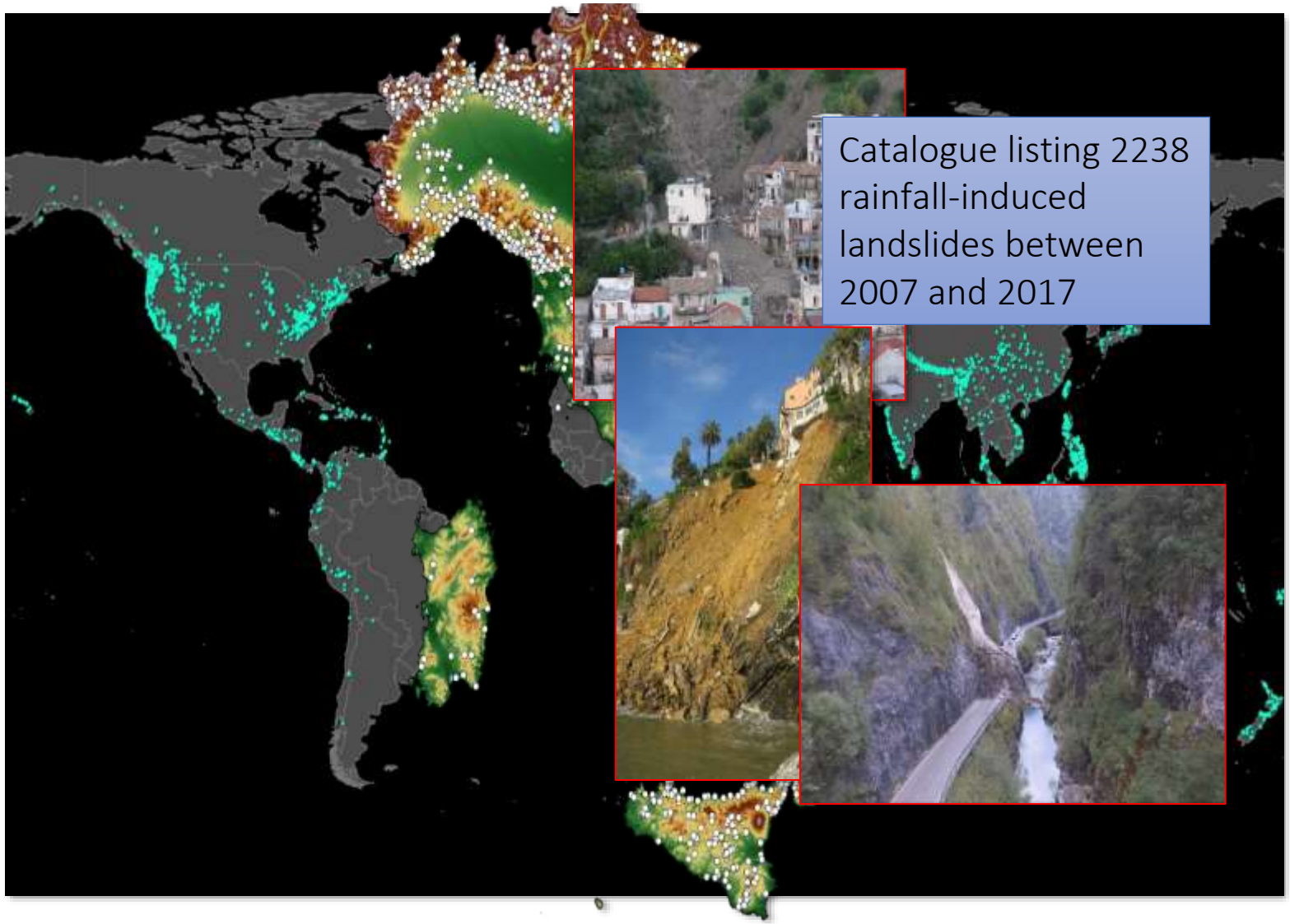
LANDSLIDE



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How to download data

https://h-saf.eumetsat.int

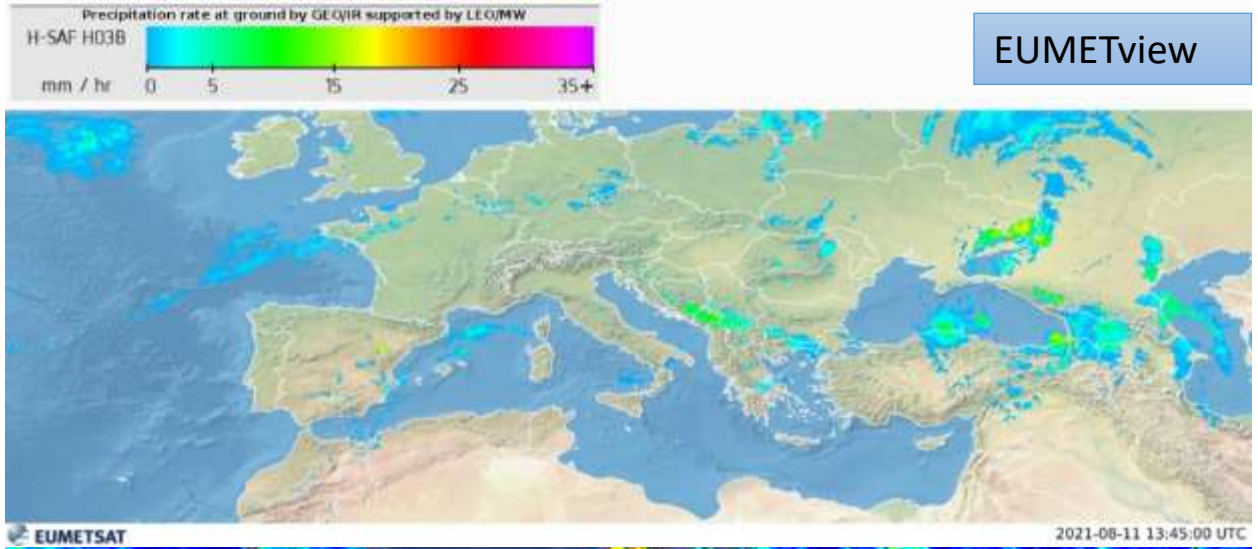
PUMA

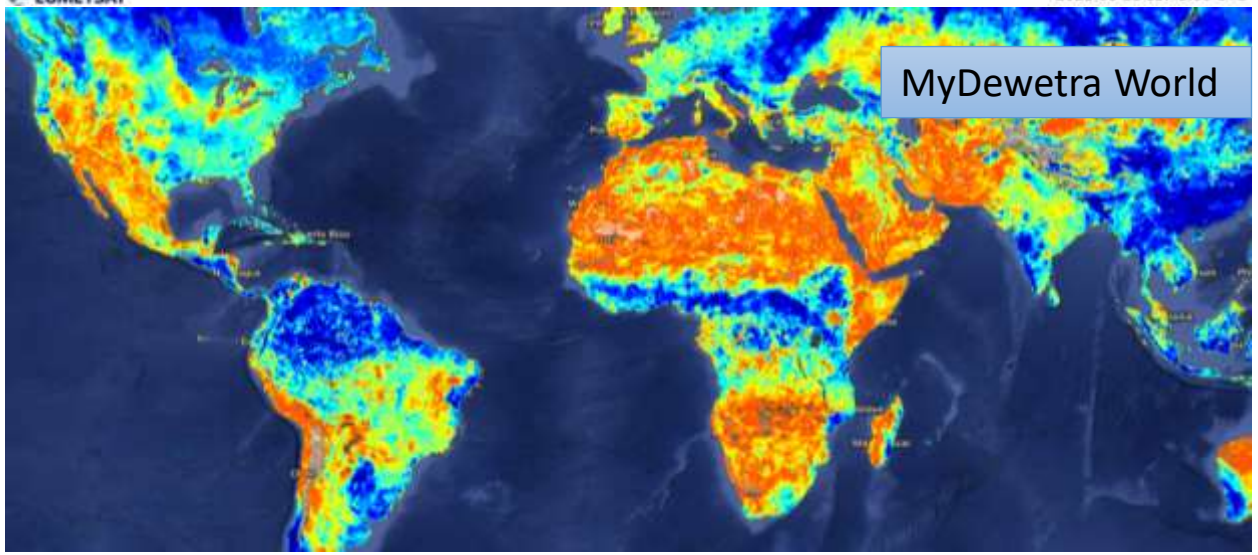
EUMETCAST

EUMETSAT DATA CUBE

EUMETview

MyDewetra World





What we have NOW using Satellites data

Precipitation
Soilmoisture
Snow
Floods monitoring

OPERATIONAL

Landslide
River Discharge
Water bodies extent

DEVELOP

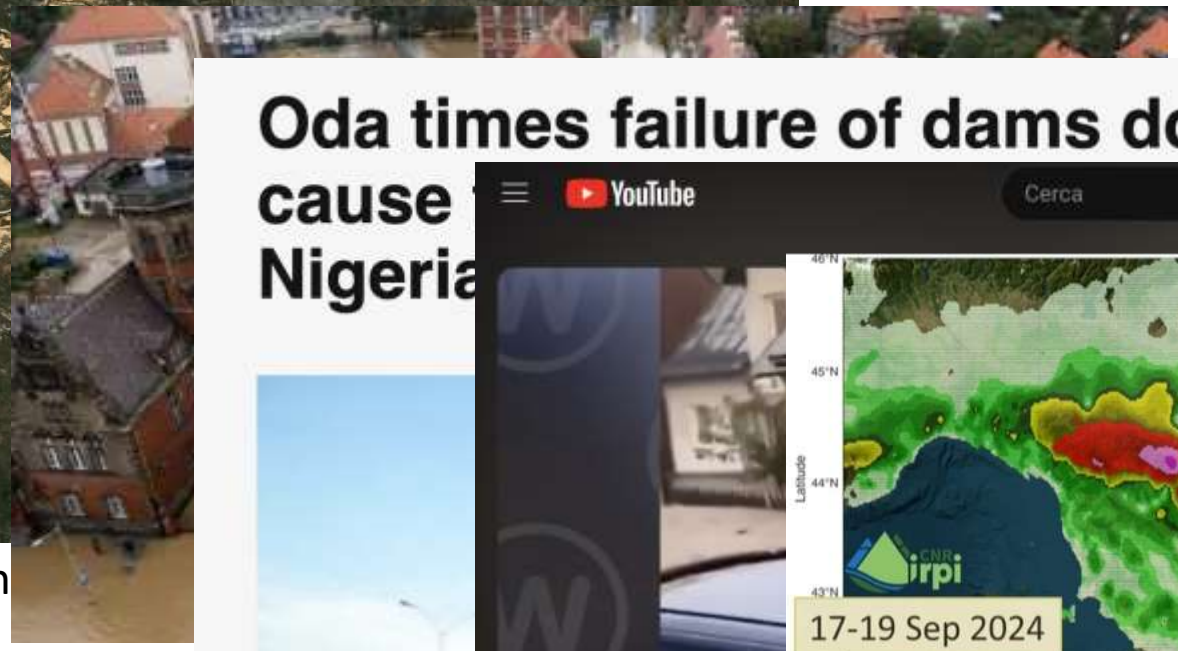
Which applications?

- Drought monitoring
- Extreme events monitoring and alert
- Water resources management
- Flood prediction and forecasting
- Agriculture

Brocca et al. 2024 (FSCI) https://doi.org/10.3389/fsci.2023.1190191

only In the last week

Different Countries
with the same problems!



flooding in th
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Laura Gozzi, Nick Tho
BBC News

Reporting from London, Bu

11 September 2024

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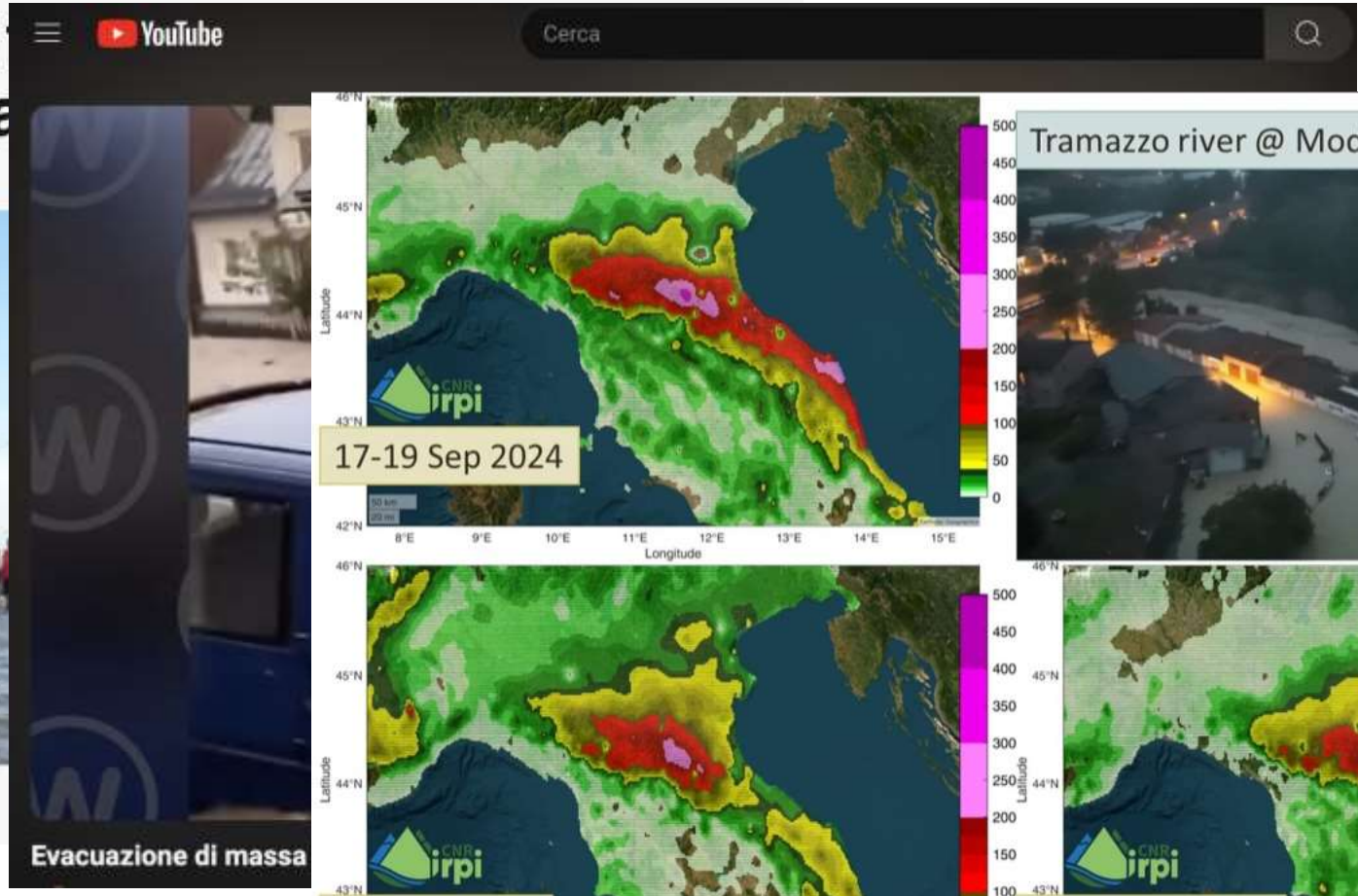
Nigeria



Thanks for your attention!

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