Enhancing Air Force Weather Capabilities: Collaboration with NASA on Subseasonal to Seasonal Prediction

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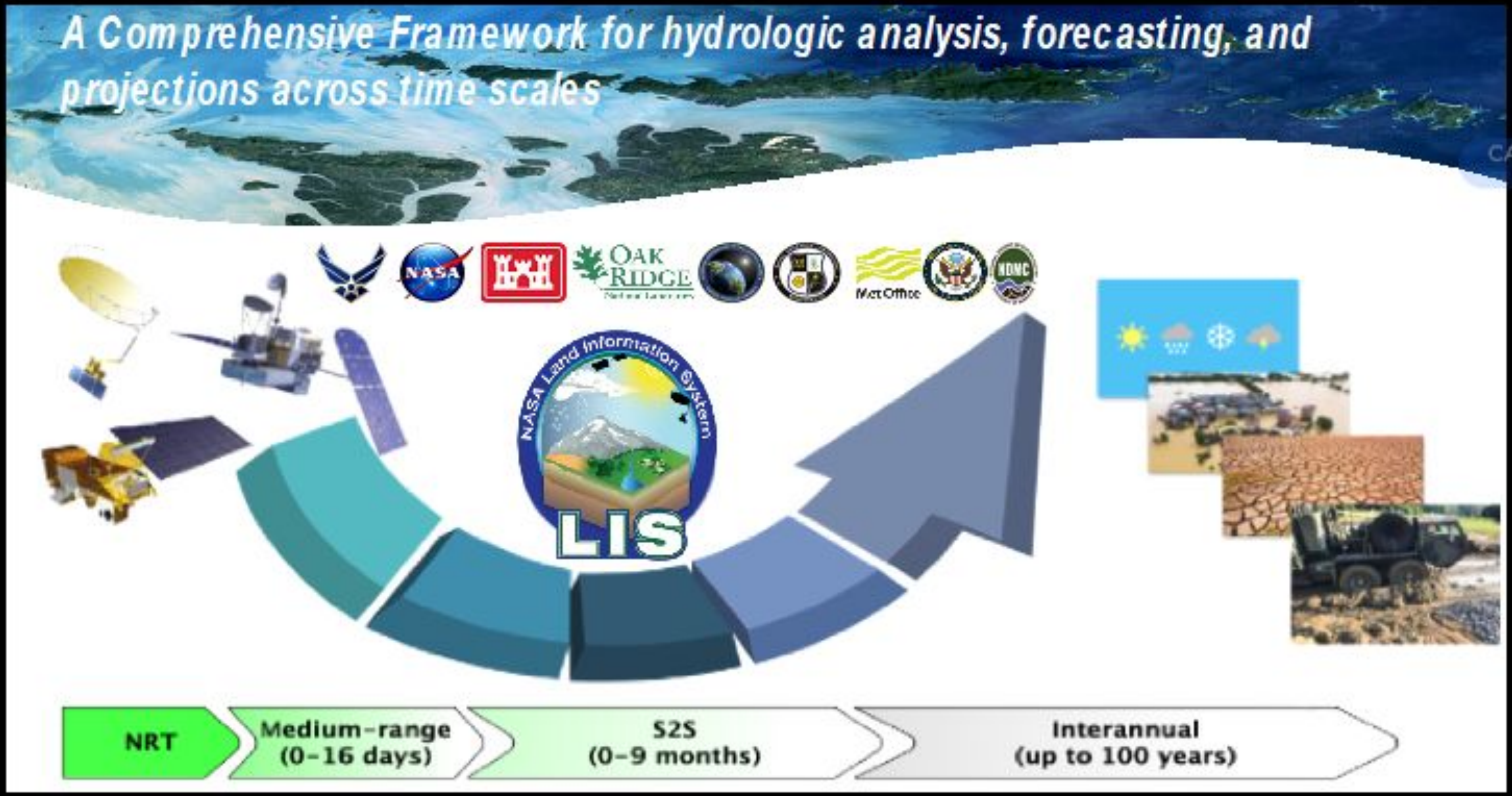
The Global Hydro-Intelligence (GHI) Subsystems: Spanning different timescales

A comprehensive framework for hydrological information across four operational sub-systems, each combining multiple models of physical processes and remote sensing data with visualization and decision support *across a spectrum of time scales and missions:*

- Near real-time (NRT; t_{-12}hours to t_0)
- Medium-range (MR; t_0 to t_{16} days)
- Subseasonal-to-seasonal (S2S; t_0 to t_9 months)
- Inter-annual / Climate projections (t_0 to t_{100} years)

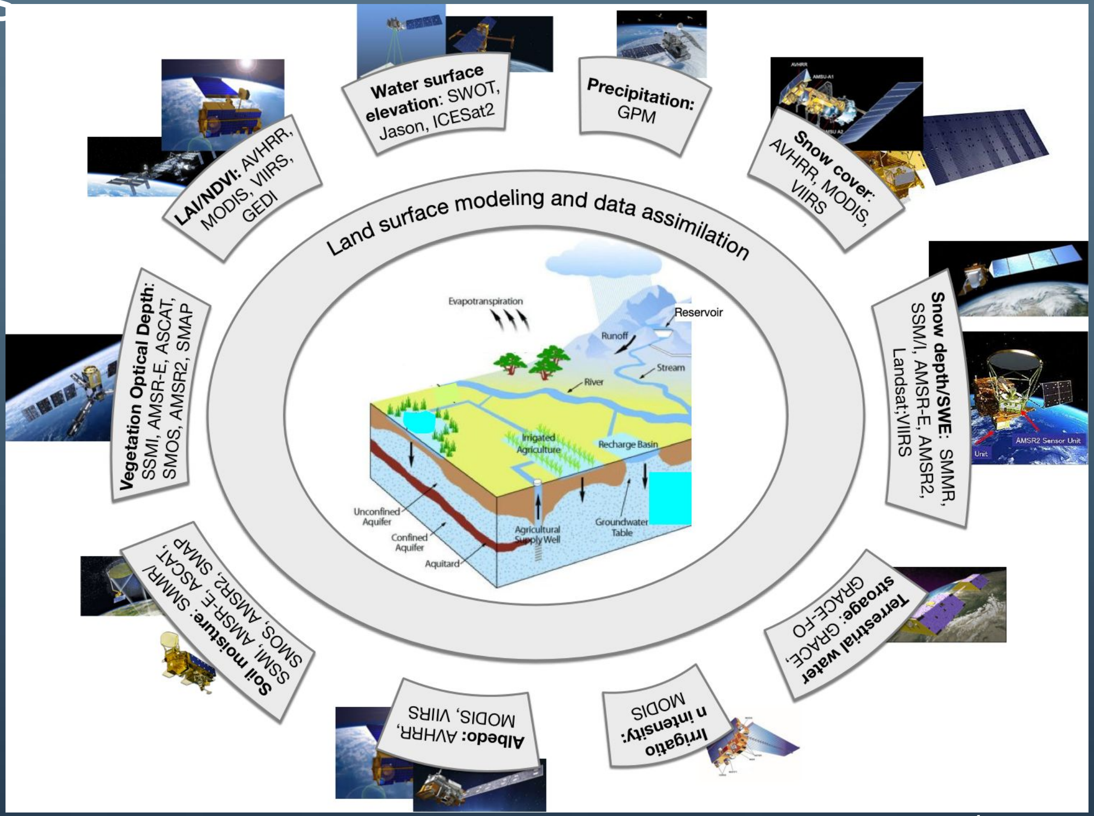


GHI S2S-Global Subsystem

- Building off the S2S efforts of the NASA Hydrological Forecasting and Analysis System (NHyFAS; *Arsenault et al., 2020; Shukla et al., 2020; Hazra et al., 2023*), this new globally based **GHI-S2S** system is geared towards supporting different U.S. government enterprises and their seasonal hydrological prediction needs.
- The **GHI-S2S** system also incorporates partners' inputs, such as from the U.S. Air Force, to help supply downstream users with a range of drought and flood potential metrics, including meteorological and agricultural drought prediction indicators, occurring across the globe.

Land Information System Framework (LISF)

- GHI-S2S uses ***LISF*** (*Kumar et al., 2006; Peters-Lidard et al., 2007*) as the primary software for:
  - generating the forecast and hindcast (“reforecast”) runs,
  - driving the land and hydrological models,
  - the data assimilation (DA) subsystem for the initial hydrological conditions,
  - preprocessor for all the parameter, DA and forecast initial condition files.
- LISF provides most end-to-end capabilities for running our forecasts for operational uses.



LISF Input Datasets

- **Forecast datasets**:

1) **Climate Forecast System, version 2** (**CFSv2**; *Saha et al., 2014*):

- 6-hourly files are used to generate the forcing ensemble members for the non-precipitation-based fields (e.g., T_{air}, Q_{air}, winds, downward radiation):
- The "time-series" based reforecast ("HPS" and "FL") and operational forecast files are used to take advantage of the 9-lead month forecasts.

2) **North American Multi-Model Ensemble (NMME;** *Kirtman et al., 2014*):

- 6 different climate models from different centers across North America:
  - CFSv2, GEOSv2, GFDL, GEM-NEMO, CCSMv4, CanCM4
- 9-lead months of multi-member precipitation forecasts from each model.

LISF Input Datasets

Retrospective forcing datasets:

- 30 years of forcing (1991-2020) blended with:
  - ***1991-2012***: NASA's **MERRA2** forcing (*Gelaro et al., 2017*) and **CHIRPS**, version 2 (*Funk et al., 2015*), precipitation data, which are bias-corrected to the LIS7.4 557 WW analysis dataset that includes the *NASA-USAF Precipitation Analysis (NAFPA) precipitation dataset* (*Kemp et al., 2022*).
  - ***From 1-Oct-2012 to near present time:*** Models are driven with the **USAF + NAFPA forcing data**.
  - This merged dataset is then used to bias-correct and spatially downscale (*BCSD*) the CFSv2 and NMME hindcast datasets (from 1991-2020) and then ongoing forecast runs (2022 and onward), based on *Wood et al., 2002; Arsenault et al., 2020.*

NASA / USAF Collaboration

- **Main goal in supporting the USAF's global land information system (LIS) – develop comprehensive framework for hydrological information across four operational sub-systems, combining models of physical processes and remotely sensed data and across a spectrum of time scales and missions.**
- **The Global Hydro-Intelligence (GHI) mission addresses these needs and timescales, from near-realtime (NRT) to climate forecast projections, out to 100 years in the future.**
- **GHI employs a suite of land surface and hydrology models, along with multi-variate data assimilations of different satellite-based products of snow and soil moisture, with additional products coming.**
- **Validation examples of the GHI NRT and S2S subsystems were presented. Current evaluations and future papers are in progress.**

GHI Goal

- Develop a comprehensive framework for hydrological information across four operational sub-systems, each combining multiple models of physical processes and remote sensing data with visualization and decision support *across a spectrum of time scales and missions*.

Sub-System	**Time Scale**	**IOC**
Near-real-time	t_{-12} to t_0 hours	Aug 2023
Medium-range	t_0 to 16 days	Nov 2023
Sub-seasonal-to-Seasonal	Hindcast ($t_{2021\text{-}1991}$) & t_0 to 9 months	Jan 2024
Inter-annual (Climate)	Historical ($t_{1950\text{-}2014}$) & Projections ($t_{2015\text{-}2100}$) years	Dec 2024

Air Force / NASA Collaboration Effect

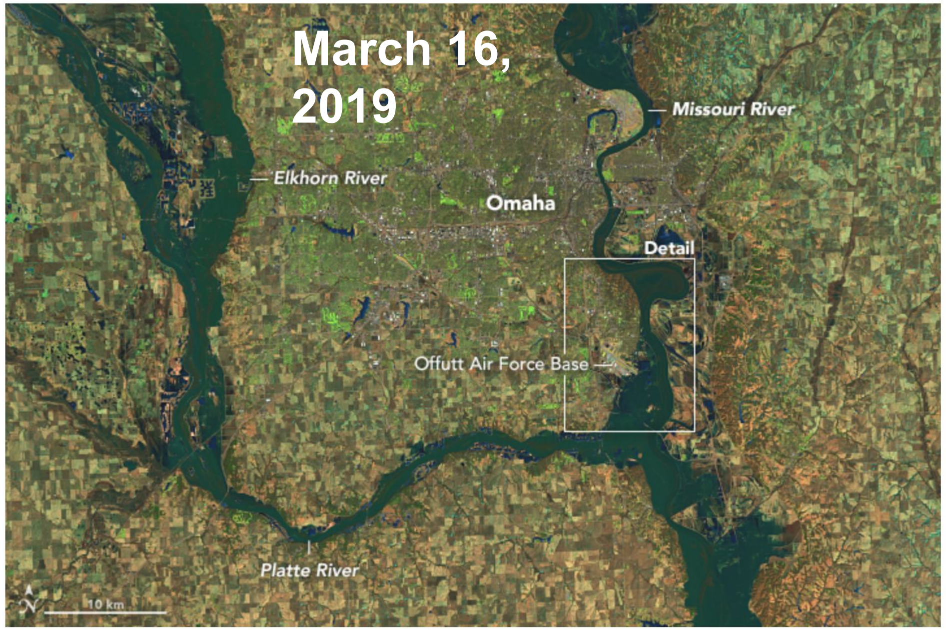
- Routine availability of GHI data at a *National Meteorological and Hydrological Services (NMHS) Center* (*i.e., HQ 557th WW*):
  - Encompasses all aspects of ***water security***[1];
  - Addresses the significant hydro-intelligence ***gaps*** identified by the defense and national security communities[2]; while
  - ***Transforming*** the way the USG conducts hydro-related business going forward

[1]e.g., WHAP Pillar 2 & GWS SOs 3,4

[2]See "Intelligence Community Assessment, ICA 2012-8, 2 February 2012"; and "Transboundary Water: Improving Methodologies and Developing Integrated Tools to Support Water Security, NASA/TM-2018-219026"

Offutt AFB 2019 Flood Case

Before the floods – image of the affected area before the floods, taken March 2018. Image; NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey.



After the floods – image of the affected area after the floods, taken 16 March 2019. Image; NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey.

Flooding of Eastern Nebraska began on March 14, 2019, due to heavy precipitation, snow melt and river ice jams and resulted in mass evacuations from the area.

From http://floodlist.com/america/usa/iowa-nebraska-floods-march-2019

Offutt AFB 2019 Flood Case

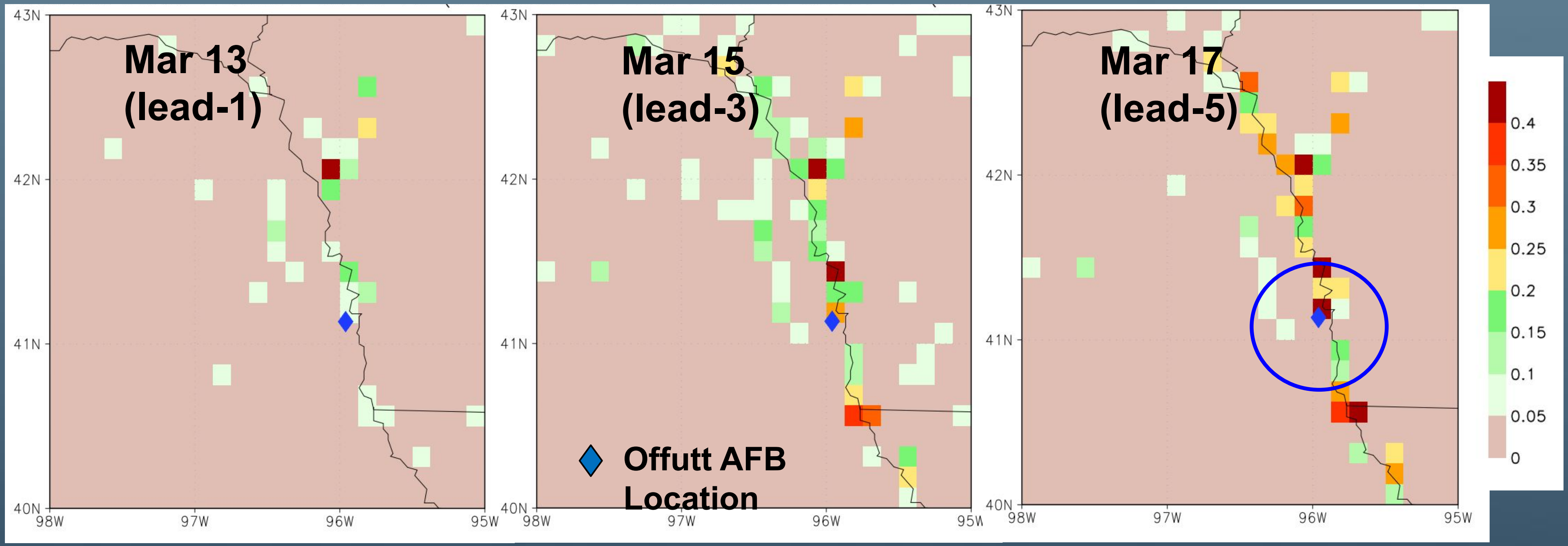
Flooding at Offutt AFB spanned from *March 15 to 20* due to the nearby Missouri River overflowing its banks.[1]

By Sunday morning of March 17th, "***one-third of the base was underwater***", which included 30 buildings and most of the main runway with flood waters reaching 8 feet.[2,3]

1- https://www.airforcetimes.com/news/your-air-force/2019/05/02/air-force-increases-estimate-to-repair-and-rebuild-offutt-to-420-million/
2- https://www.omaha.com/news/military/one-third-of-offutt-underwater-at-least-buildings-damaged-in/article_631f9b34-5271-50e8-b5eb-19f488daaf32.html
3 - https://www.military.com/daily-news/2019/03/18/dozens-buildings-underwater-offutt-air-force-base-after-massive-flood.html

Forecasted Flood Fraction Maps (from HyMAP)

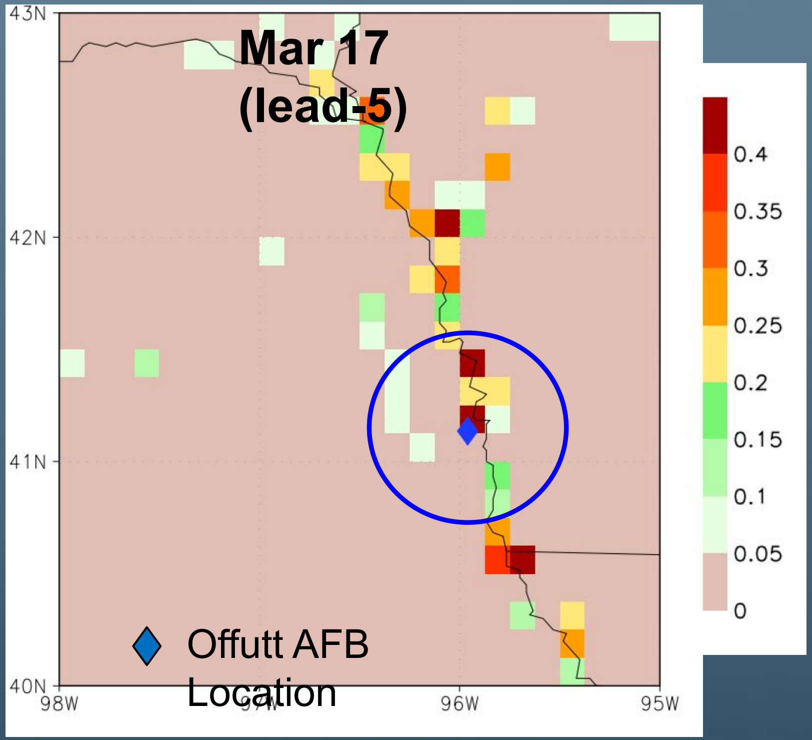
March-12 Initial Condition – Forecast Lead days: 1, 3 and 5



Flood area fraction predicted at different lead times. Peak flooding on March 17 (5th lead day) aligned with when max flooding was reported at Offutt AFB (*blue diamond*). Thus, flooding could have been predicted for this case at least 5-days in advance.

Forecasted Flood Fraction Maps (from HyMAP)

Floodwaters from the Missouri River overtook a large portion of the airfield at Offutt Air Force Base in Nebraska on March 17. At least nine aircraft were evacuated. (Air Force)



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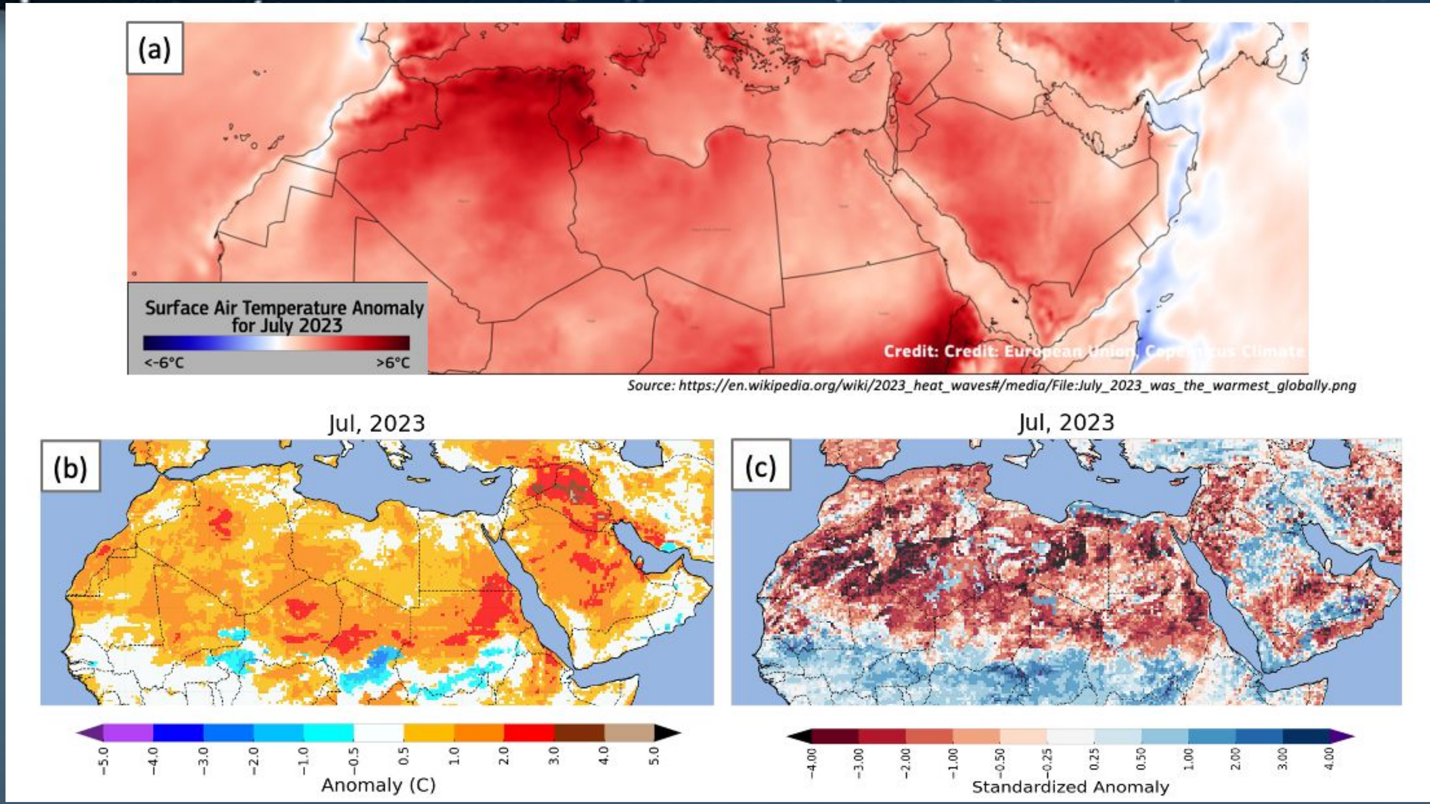
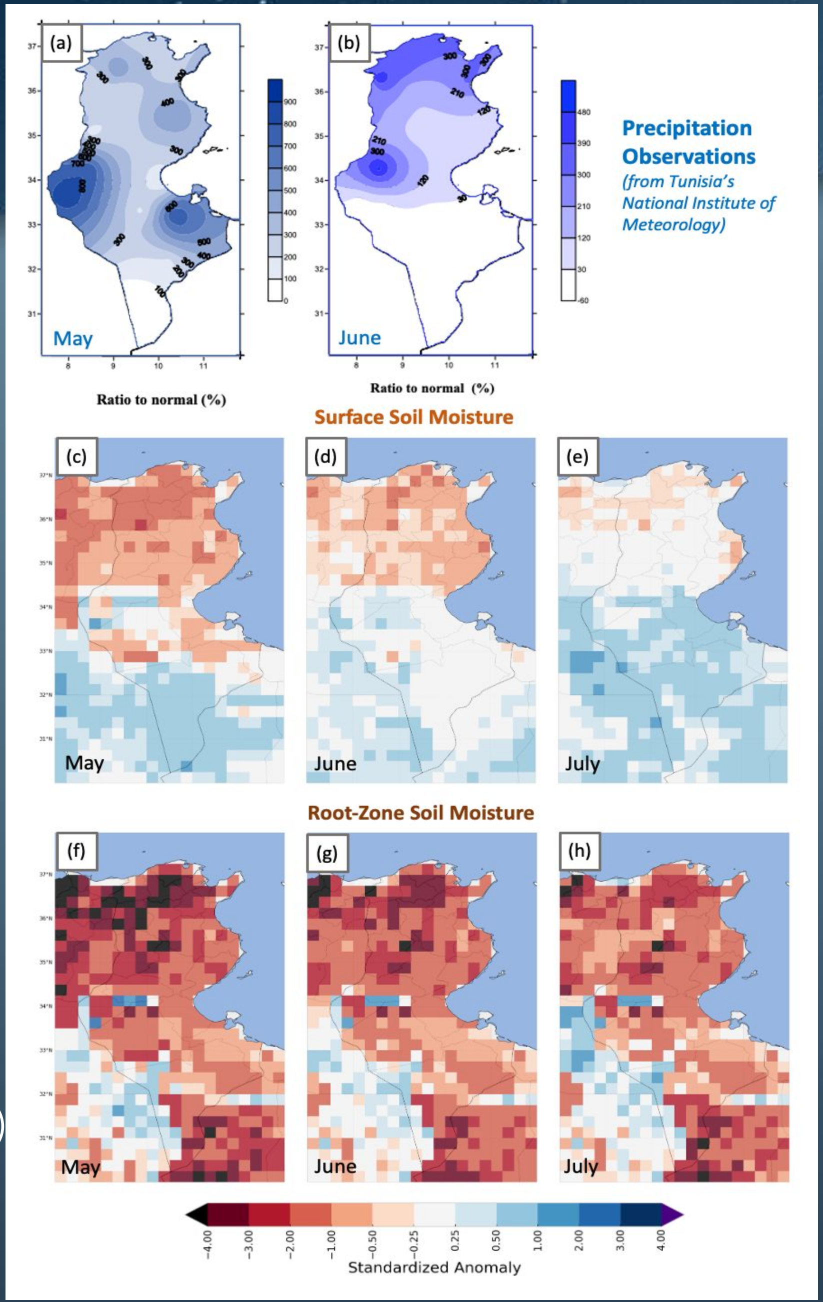
Drought Forecasts for Northern Africa

May-2023 forecast, lead = 2, July





Above: (a) July-2023 surface air temperature anomalies (°C), based on Sentinel satellite observations[1]. GHI-S2S's forecast of July-2023 (lead month=2, initialized from May-1) for b) CFSv2 air temperature anomalies (°C) and c) RZSM standardized anomalies for Northern Africa.

Anomalies calculated with averaged conditions or hindcast normal years, 1991-2020.

[1] Contains modified Copernicus Sentinel data, 2023, from the C3S Climate Bulletin, 9 Aug, 2023, https://en.wikipedia.org/wiki/2023_heat_waves#/media/File:July_2023_was_the_earmest_globally.png

Top Ref.: Tunisia's National Institute of Meteorology's May- and June-2023 reports: https://www.meteo.tn/en/actualites/climatological-report-month-may-2023-tunisia


Your Questions
Answered