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MILITARY HYDROLOGY:
Total hydrologic awareness for advanced decision making

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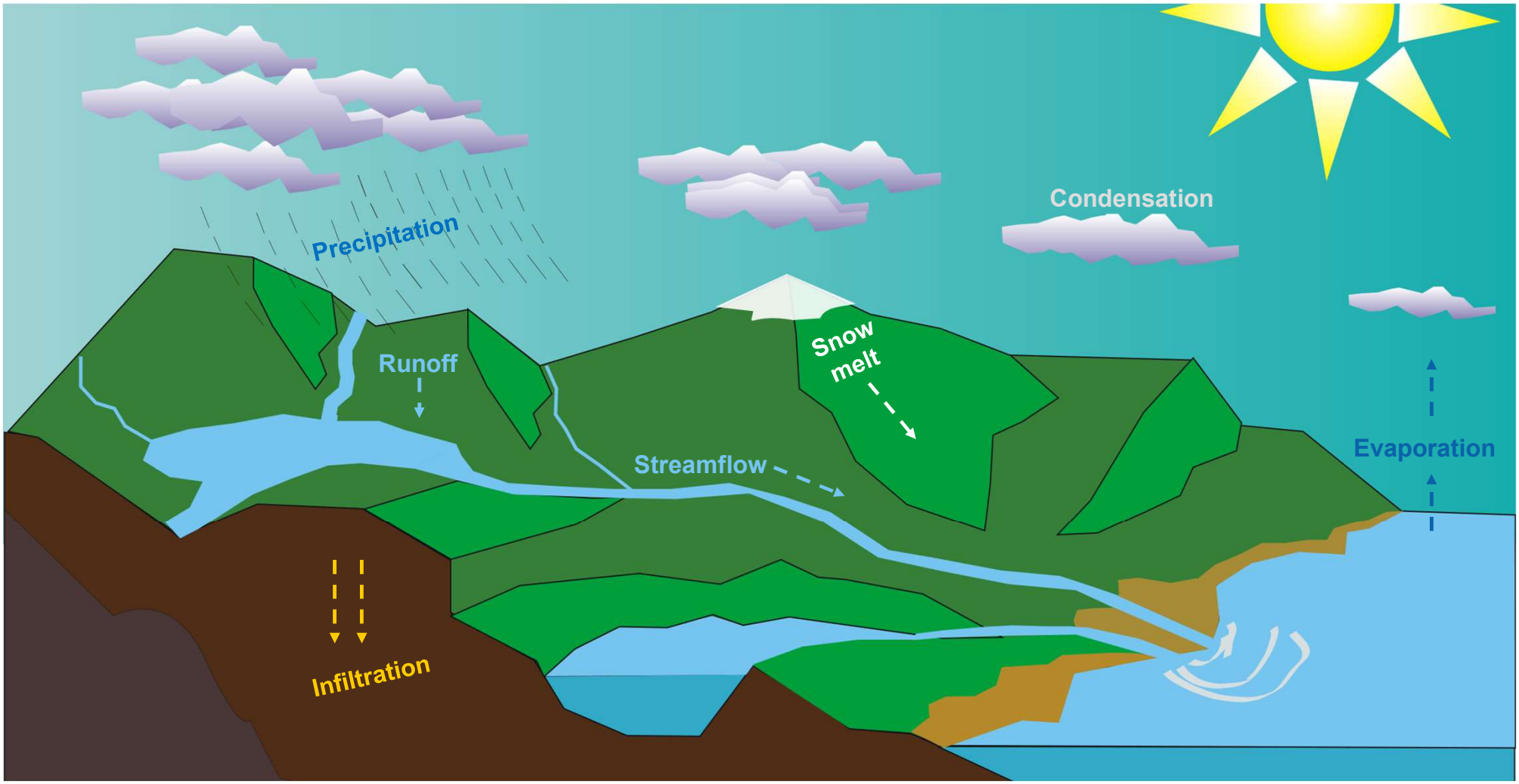
THE WATER CYCLE



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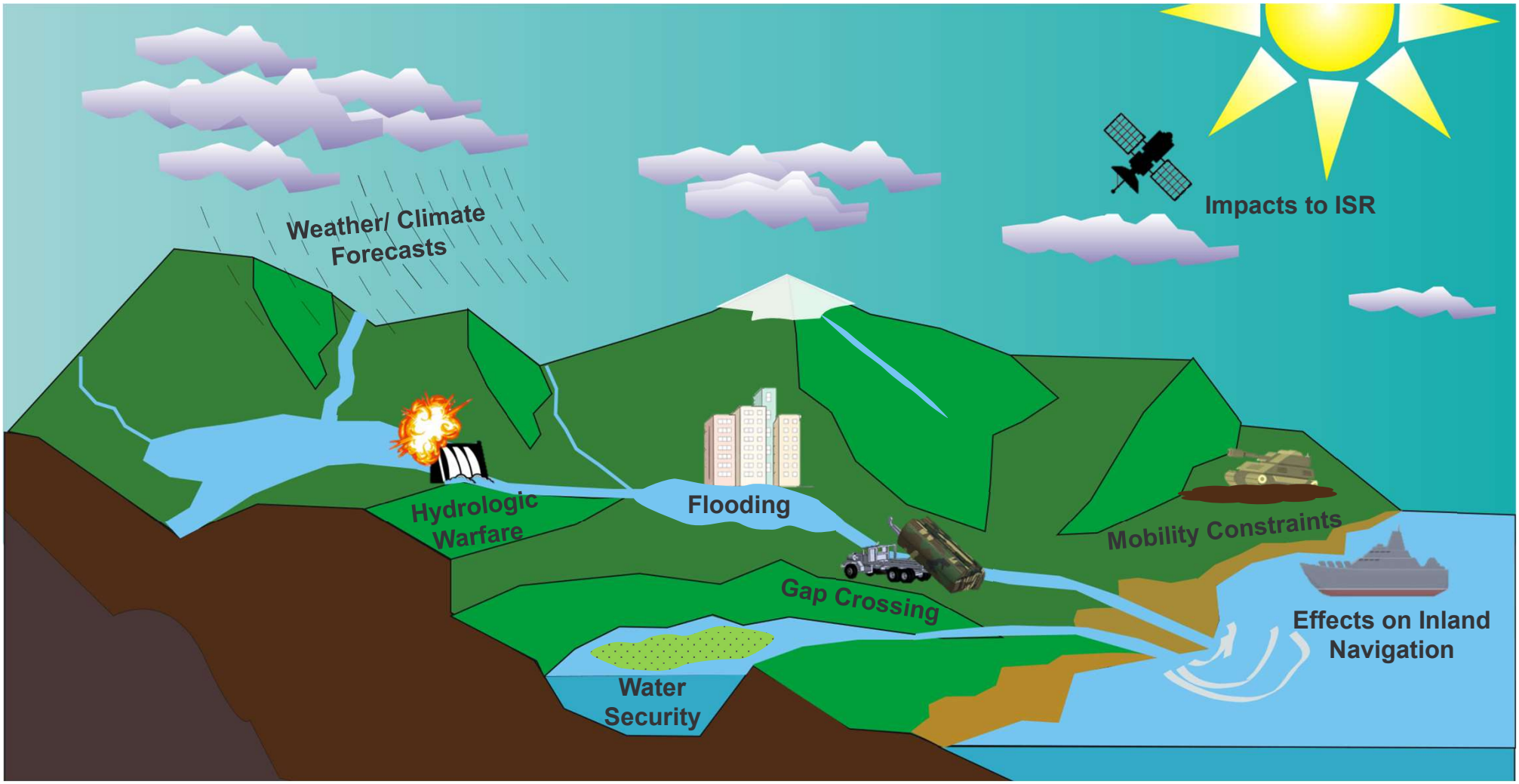
THE MILITARY HYDROLOGY LENS



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ASPECTS OF MILITARY HYDROLOGY

What: Characterization of surface and subsurface water features that may affect the planning and conduct of military operations

- **Meteorology** - Hydrology Interactions
  - Direct feed to understanding streamflow, state of the ground and water supply
- **Streamflow**
  - Flood forecasting, predicting stream width, depth, velocity, discharge and area flooded, breaching of dams and associated flood wave
- **State of the Ground** - Soil Moisture
  - Trafficability, cross-country mobility, impacts to runoff
- **Water Supply**
  - Finding and developing water sources, locating groundwater

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DEFINING HYDRAULIC WARFARE

- **Hydraulic warfare:** the use of water from reservoirs, rivers, canals, and other water features to impede the operations of an opposing force. This may involve breaching dams and rerouting watercourses.

Categories:

- Use of hydraulic installations (structures) in the interior zone of the enemy to damage the enemy war effort
- The tactical use and manipulation of hydraulic installations (structures) and water bodies on the battlefield
- Methods of overcoming hydraulic obstacles used by the enemy

Military Hydrology Bulletin, 1957

Historically used to:

- Create devastating floods
- Isolate troops
- Cut off supply lines
- Hinder river crossings
- Disrupt military timetables

Example from Dymer Dam to slow down the Russian advance towards Kyiv
International Rivers, 2022

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HISTORY OF HYDRAULIC WARFARE

- Logistics and barriers to transportation have been a concern of militaries since the time of the ancient Greeks
- The tactical use and manipulation of waterbodies and hydraulic structures on the battlefield have and continue to be a concern

The US National Archives, 1995

Soldiers installing pontoon bridges on the Sava River during Bosnian War.

The New York Times, 2007

South Korea has continually feared that North Korea will weaponize dams. This image is from the Peace Dam built to contain a large release from an upstream North Korean reservoir (Imnam Dam).

Hammond and Roseman, 1996

King Xerxes I of Persia moved his giant army into Greece using floating pontoon bridges

Dam busters destroyed German dams in WWII.

BBC, 2013

KHAKHOVKA DAM BREACH IN UKRAINE

- Modeling of the Khakhovka dam breach was conducted prior to the explosion and collapse of the structures
- Given the record high water levels reached in the reservoir in May 2023, the model results underestimated the flooding and damages that occurred downstream
- Modeling potential dam failures can be very useful, but does not always depict the worst-case scenario
  - Normal dam operations would likely not have allowed the reservoir to reach that water level
- Modeling allows for the prediction of flooded areas, determination of damages & impacted populations
  - Hydraulic structures are easily identifiable, and some models can be ran using limited data

Swedish model showing a worst-case scenario of a breach of the Kakhovka Dam in Ukraine; Henrik Ölander-Hjalmarsson of Dämningsverket

Dämningsverket/YouTube, 2022

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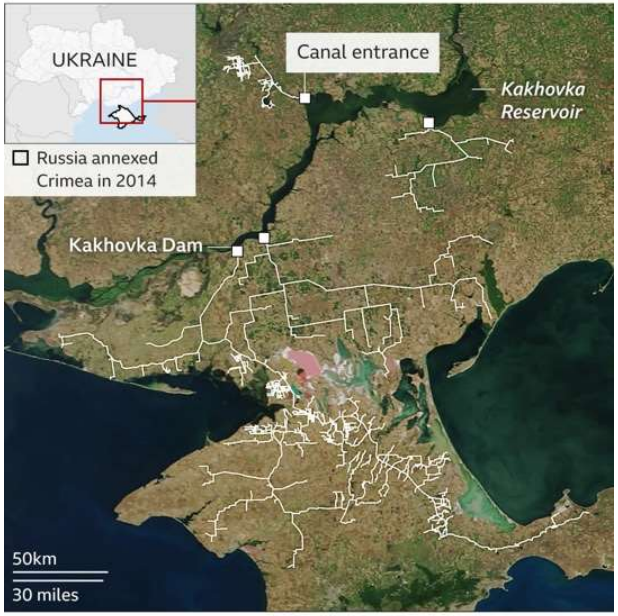
KHAKHOVKA DAM BREACH IN UKRAINE

- Dnieper River nearly returned to its natural channel prior to dam construction in 1956
- Loss of water had major impacts on canals, for both agricultural irrigation and cooling for nuclear power generation

Canal networks fed by Kakhovka Reservoir



Source: Open Street Map, Nasa Modis BBC

Reservoir supplied Zaporizhzhya Nuclear Power Plant, causing operators to rely on stable water level in cooling pond

The Associated Press, 2023

Kakhovka Reservoir almost completely dry

Source: Copernicus Sentinel-2 BBC

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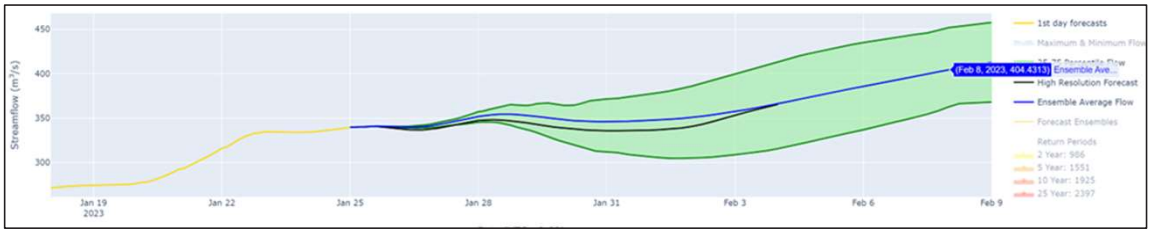
FLOOD ANALYSIS

- Understanding where the flood waters would reach in a severe flood or following a major precipitation event
- Forecasted flood models can provide flood maps based on the estimated return period using ensembled meteorological forecasts driven by runoff and precipitation
- Forensic analysis of flood events
  - Measure the duration of flood inundation
  - Identify cause of failure, impacts to structures and downstream areas
  - Identify if the event could have been forecasted/predicted with the right models or tools available

GEOGloWS, 2023



Hurricane Nana, Belize (2020)

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RAIN & WEATHER IMPACTS ON MOBILITY

- **Mud Season in Ukraine**
  - "…a phenomenon that takes place twice a year, first in spring — when the winter freeze subsides and the country's terrain and unpaved roads become virtually unpassable as they turn to mud."

SPRING 1942

CNBC, 2022

SPRING 2022

CNBC, 2022

Mud season was first faced in Ukraine during Napoleon Bonaparte's invasion of Russia in 1812

CNBC, 2023

The withstanding frozen subsoil prevents moisture from spring rains and melting snow on the surface from percolating downward and draining properly

Newsweek, 2023

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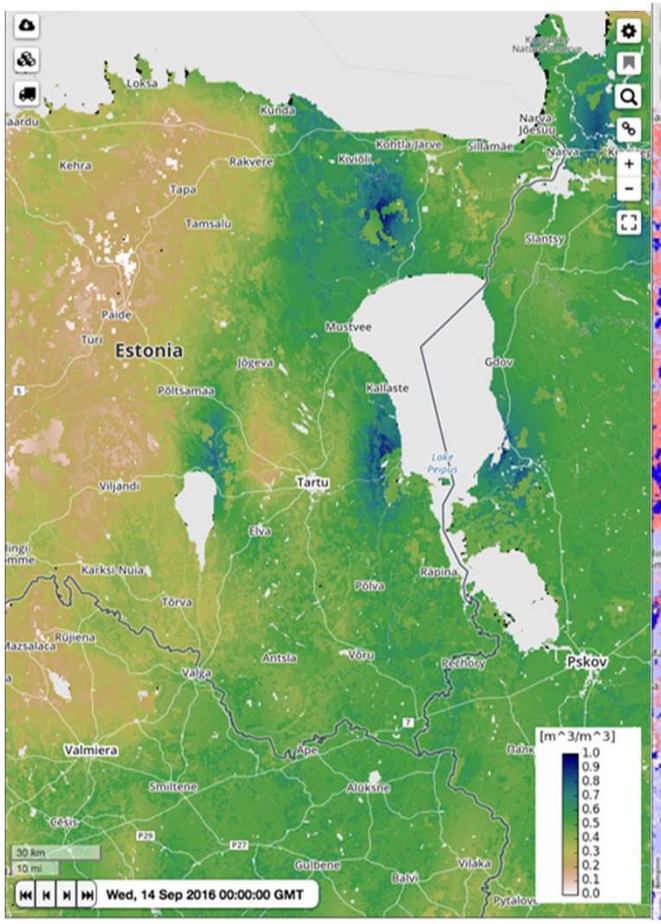
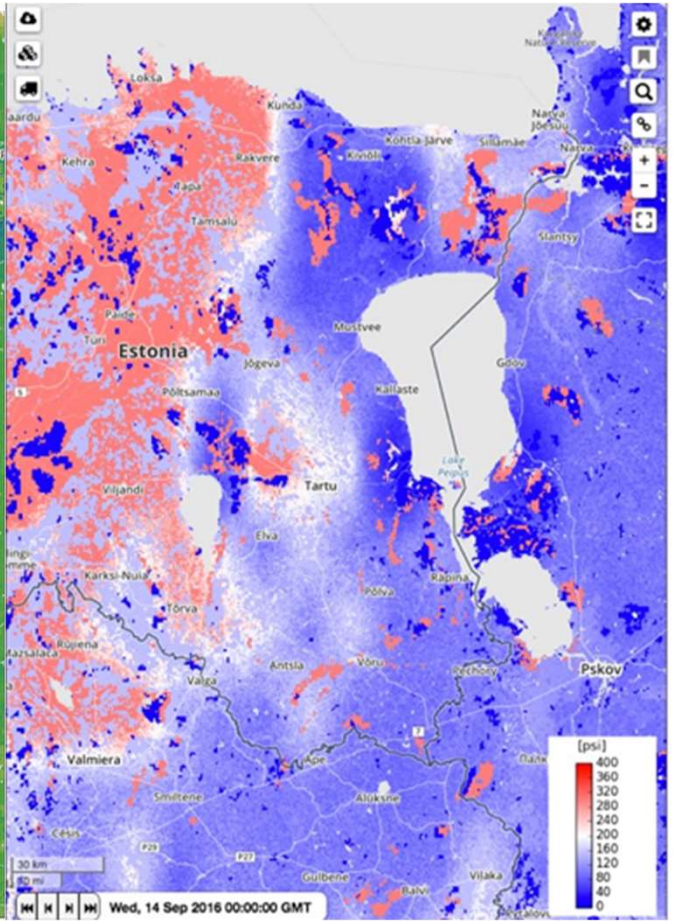
SOIL MOISTURE & SOIL STRENGTH PREDICTIONS

GeoWATCH

- Real-time, global soil moisture downscaling
- Physics-based model that redistributes weather-scale soil moisture based on high resolution terrain, soil type, land cover data
- Computes global 30m soil moisture
- Multi-year archive of global weather-scale land surface model data for seasonal climatological analyses
- Computes soil strength (RCI) from soil moisture and soil texture
  - Effects of soil temperature not included
- On-going research to include probability of frozen soil data layer



30m Soil Moisture



Soil Strength

Eylander et al., 2023

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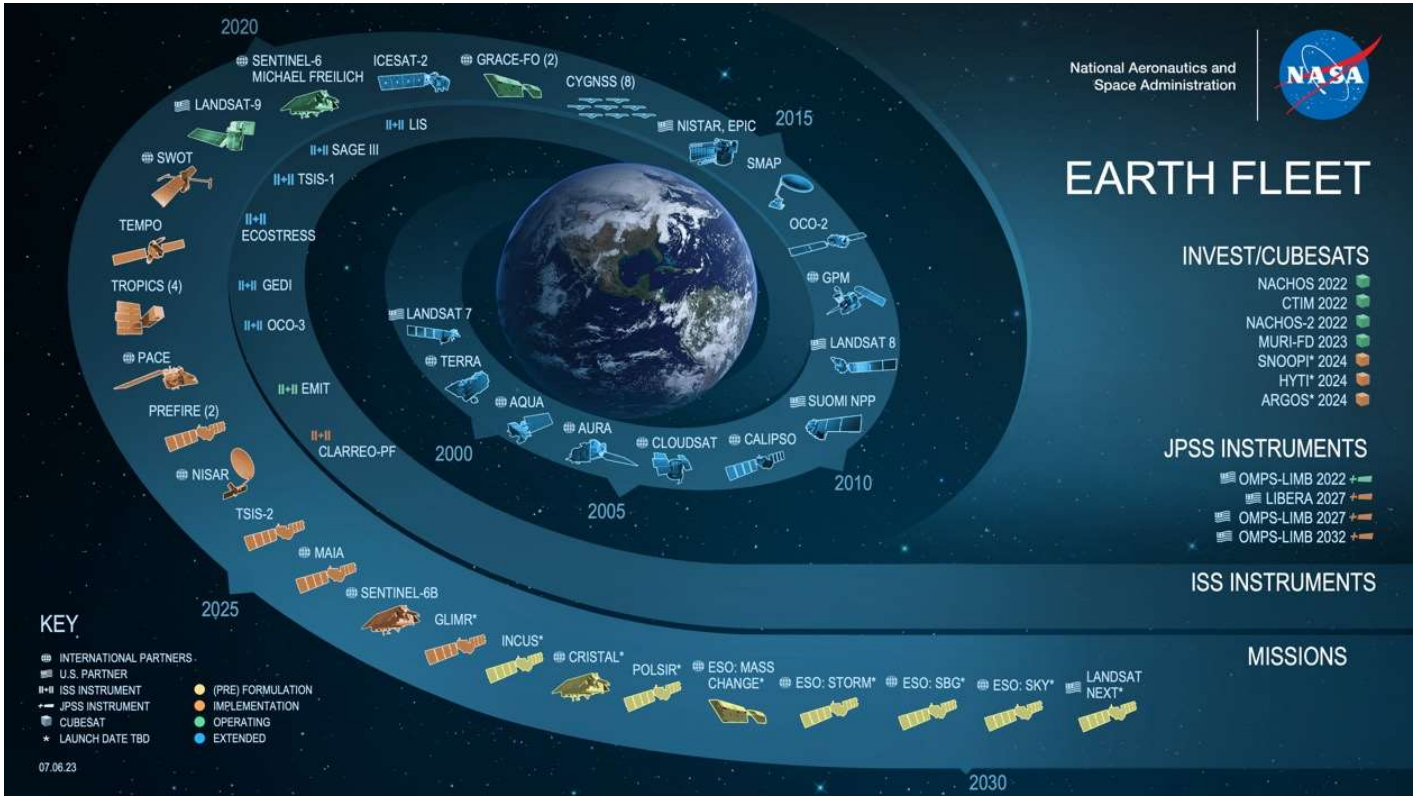
DATA AS AN ENABLER

The Reality:
- Transparent battlespace
- Rapid technology advancements

The Opportunity:
- More data than ever before
- Ability to augment in situ collections and experiments
- Insight to denied/ hard to reach areas
- Increase in model validation studies
- Incorporation of Machine Learning techniques
- Reduce soldiers' exposure for on ground reconnaissance

The Responsibility:
- Adequately communicate risk associated with these environmental hazards
- Understand model limitations and uncertainty



Changing the perspective: becoming proactive over reactive

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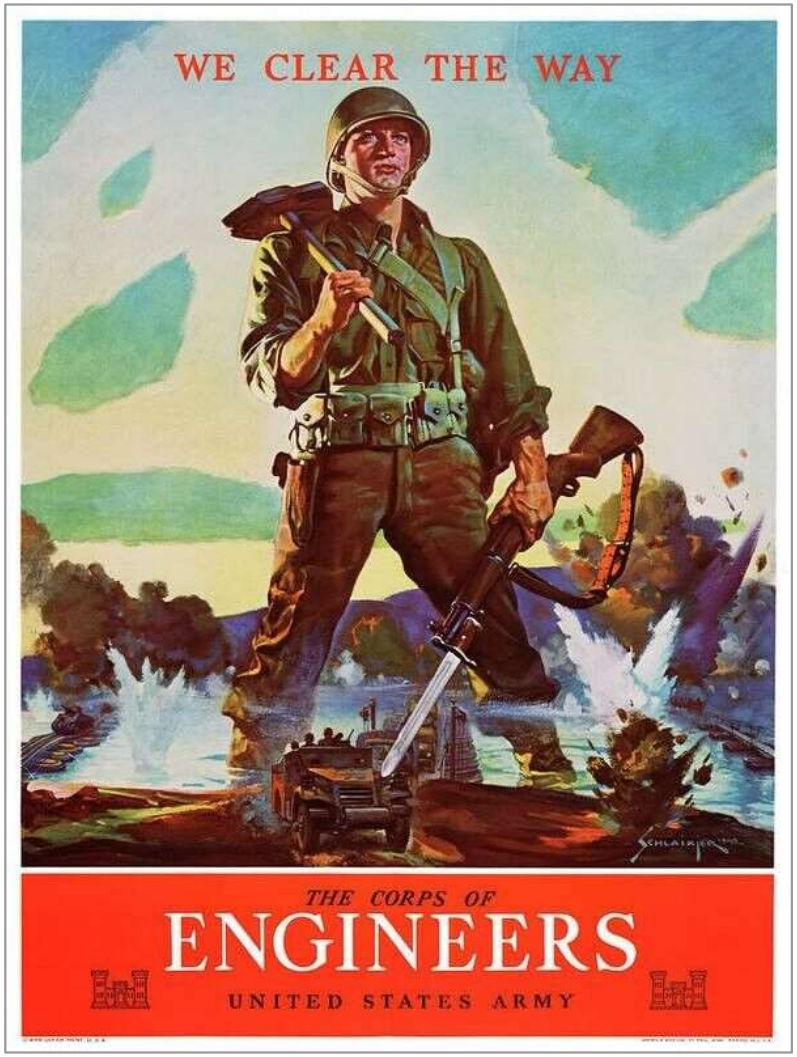
QUESTIONS

RECAP:

- Hydrology can impact missions in a multitude of ways
- Need for understanding risks imposed by these environmental factors
  - Likelihood of events
  - Severity of event
  - Seasonal variation
- Utilization of predictive modeling to enable decision support tools
- Understanding the needs of operating in an age of big data while also recognizing the disconnected nature of combat
- Proper data dissemination to capture mission planning requirements and uncertainty/ variation in data generation and analysis



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