

Tech4DRR:
Toward an Earth System Digital Twin

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Human Factors
Changing Conditions

Earth System Digital Twins (ESDTs) Components

Earth Systems Digital Twins (ESDTs) are an emerging capability for understanding, forecasting, and conjecturing the complex interconnections among Earth systems, including anthropomorphic forcings and impacts to humanity.

=> What Now? What Next? What If?

What now?

Digital Replica . . .

An integrated picture of the past and current states of Earth systems.

What next?

Forecasting . . .

An integrated picture of how Earth systems will evolve in the future from the current state.

What if?

Impact Assessment . . .

An integrated picture of how Earth systems could evolve under different hypothetical what-if scenarios.



An ESDT includes:

- Continuous observations of interacting Earth systems and human systems
- From many disparate sources
- Driving inter-connected models
- At many physical and temporal scales
- With fast, powerful and integrated prediction, analysis and visualization capabilities
- Using Machine Learning, causality and uncertainty quantification
- Running at scale in order to improve our science understanding of those systems, their interactions and their applications

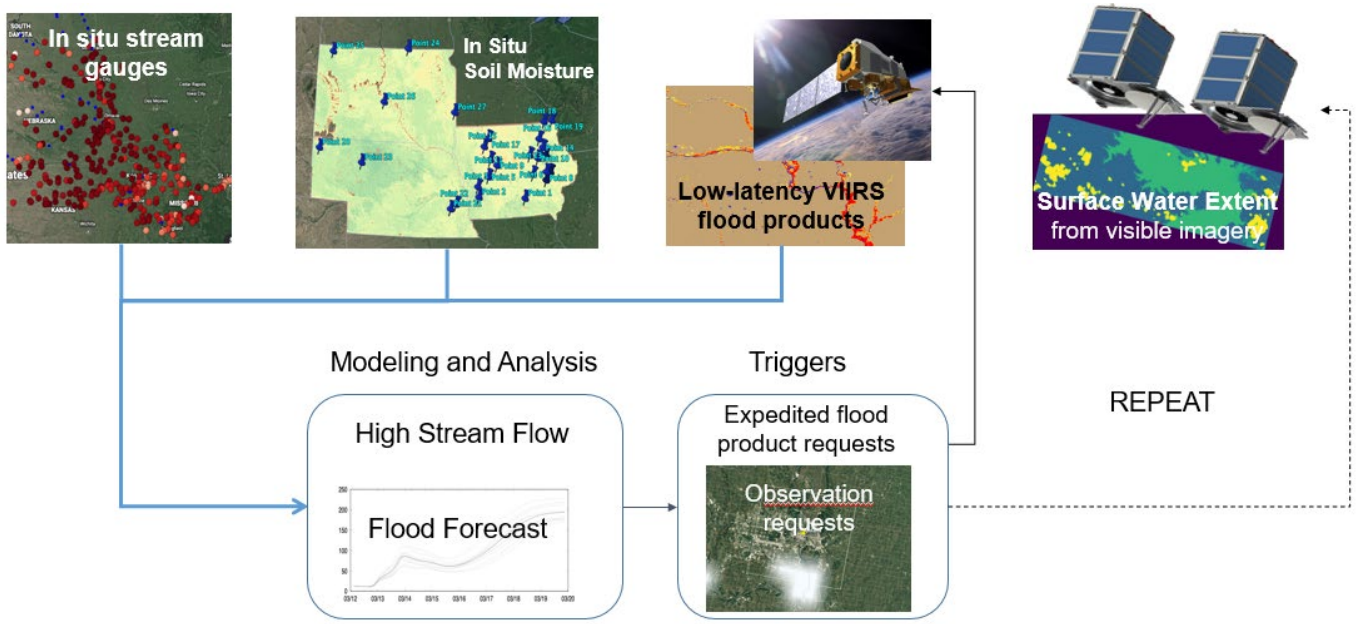
Flood Scenario – March 2019

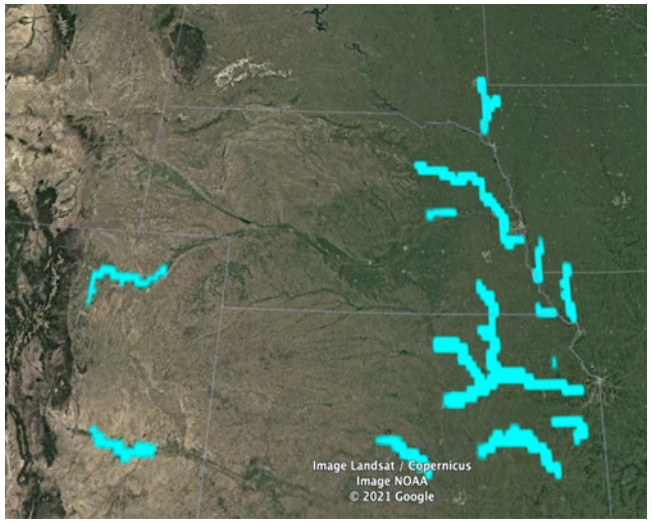




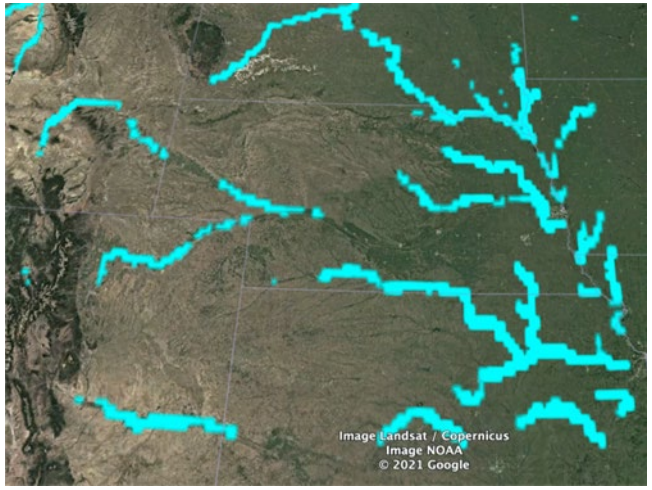


Credit: NASA Earth Observatory images by Joshua Stevens using Landsat data from USGS





Triggers ***without*** directed observations



Triggers ***with*** directed observations

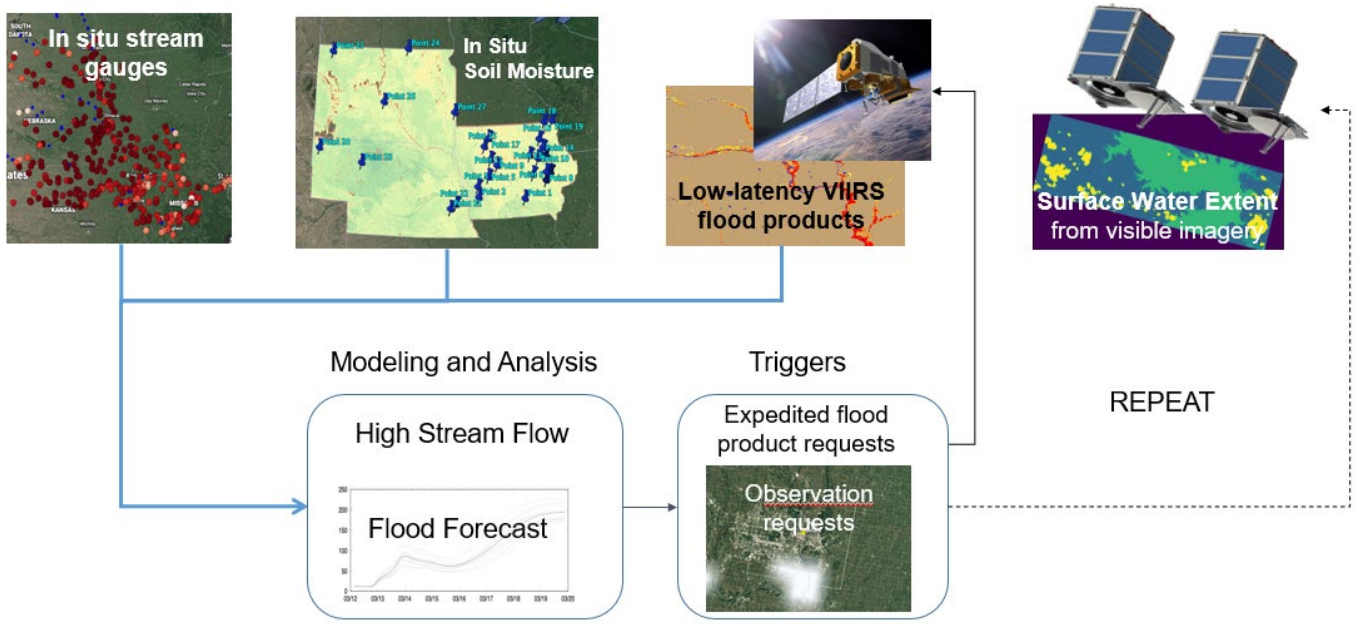
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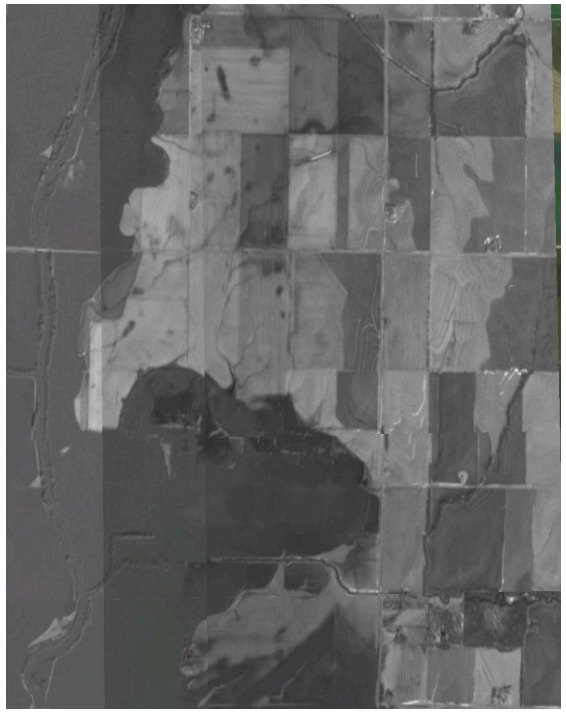




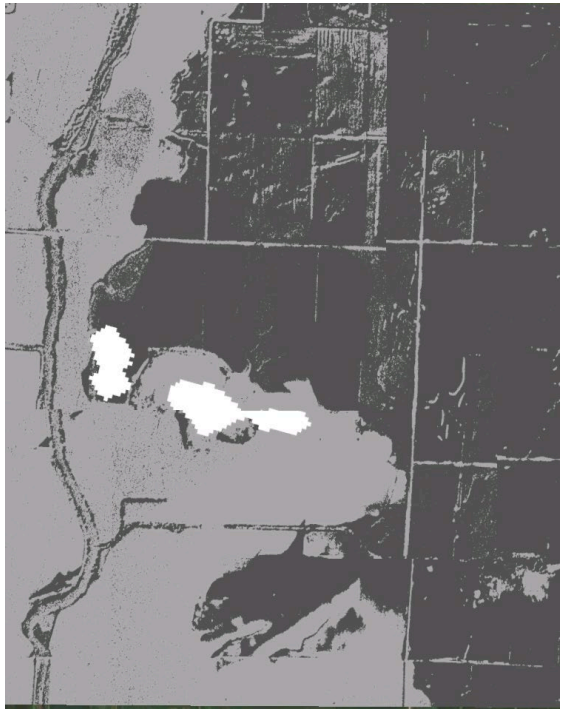


Credit: NASA Earth Observatory images by Joshua Stevens using Landsat data from USGS





High resolution images of flood peaks



VIIRS Surface water extent product

Provides better resolution of flood plains and more precise surface water extent.

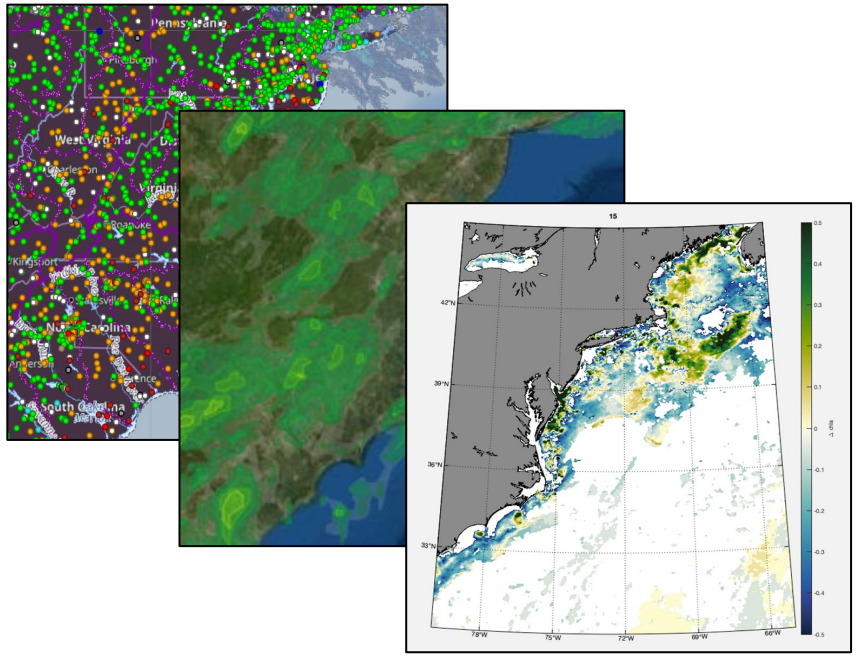
Forecast assimilating NOS-directed observations is ~30% better than same forecast without directed observations.

Algal Bloom Scenario

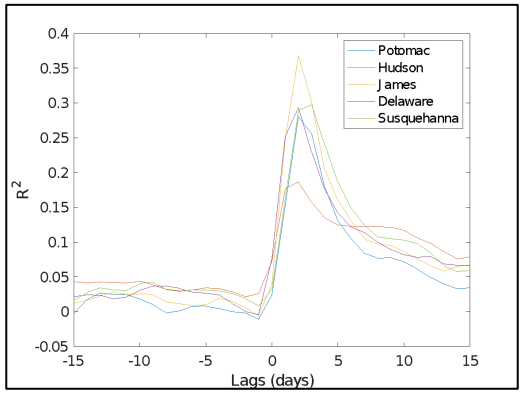
ESTO Earth Science Technology Office
AIST

Baseline Observations

- Precip.: GPM/IMERG
- Stream Flow: USGS River Gauges
- Level 3 Ocean Color: MODIS/AQUA
  (Confirm Chl-A Anomaly)



TRIGGER



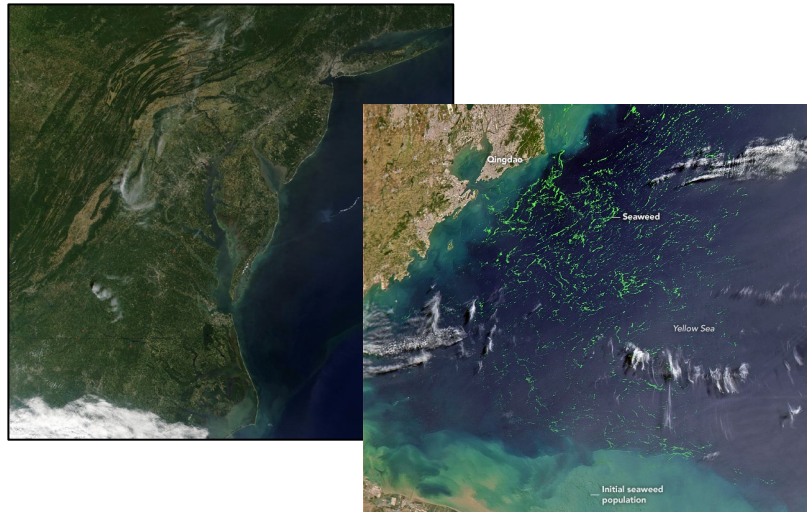
Detect increased river flow event

Ocean Carbon Digital Twin in Practice

- Can we identify sources/quantity of nutrients, reduce, and monitor Chl-a impact?
- Can the movement of nutrients in the coastal ocean be a proxy and can that proxy be a trigger for another observation?
- Can targeted observations at depth (glider) inform particulate make-up leading to new observation techniques?

Triggered/Sustained Observations

- Precip.: GPM/IMERG
- Stream Flow: USGS River Gauges
- Level 3 Ocean Color: MODIS/AQUA
- Landsat 9 (task)
- SeaHawk 1 (task)
- SeaHawk 2 (simulated)
- IOOS Glider Data



SeaHawk observed algal slicks off Qingdao, China, June 2021, NASA Earth Observatory

The Chasm

- Technology push vs demand pull
  - Art of the possible, user driven needs – how do we bring them together?
- Resolution – spatial and temporal
  - Is perfection the enemy of good enough or is it just not good enough?
- The human factor
  - A purple unicorn with 3 PhDs is required to understand the code, the data and the analytics – how can information be accessed and understood by a relatively normal human?


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