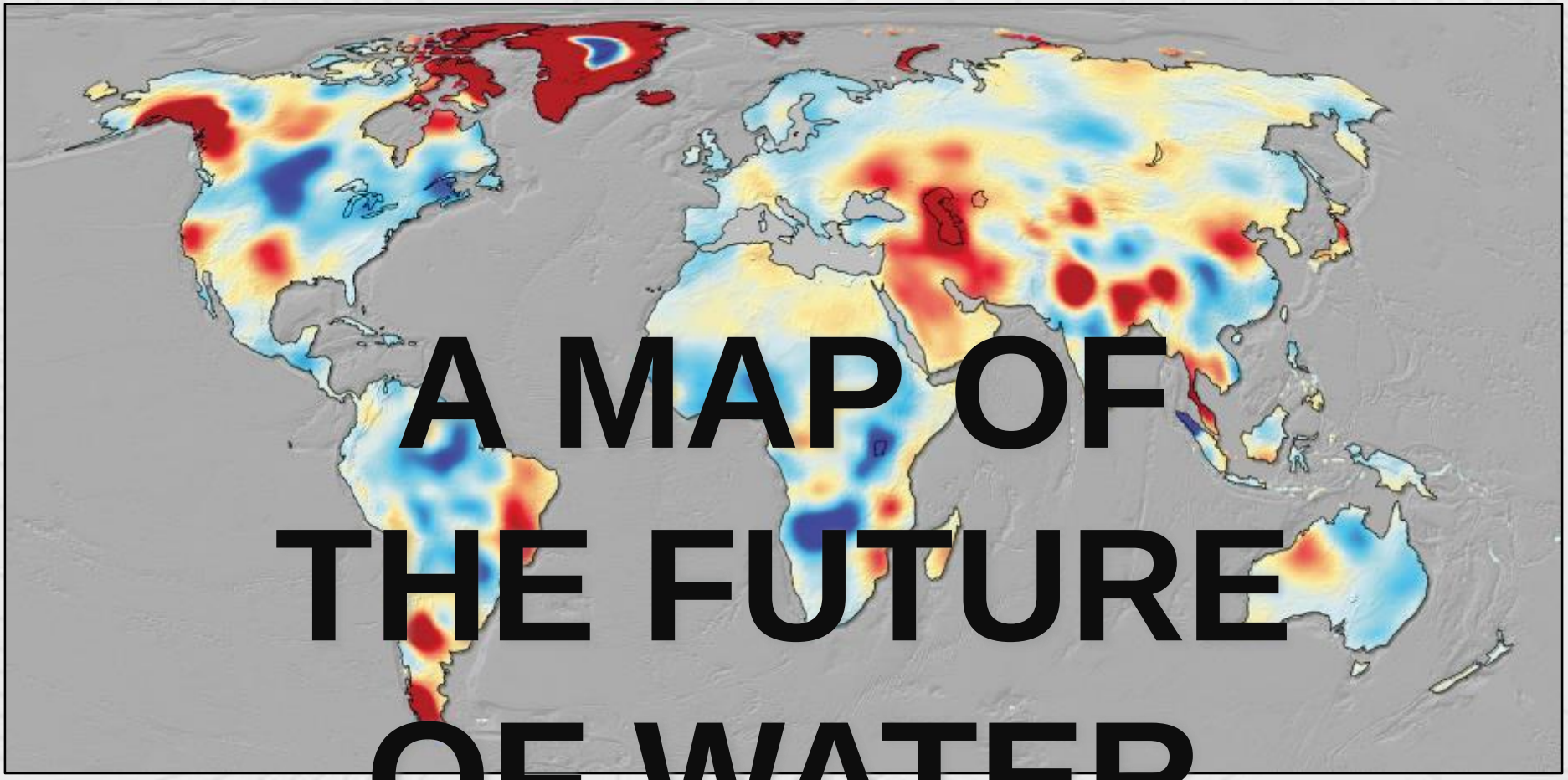
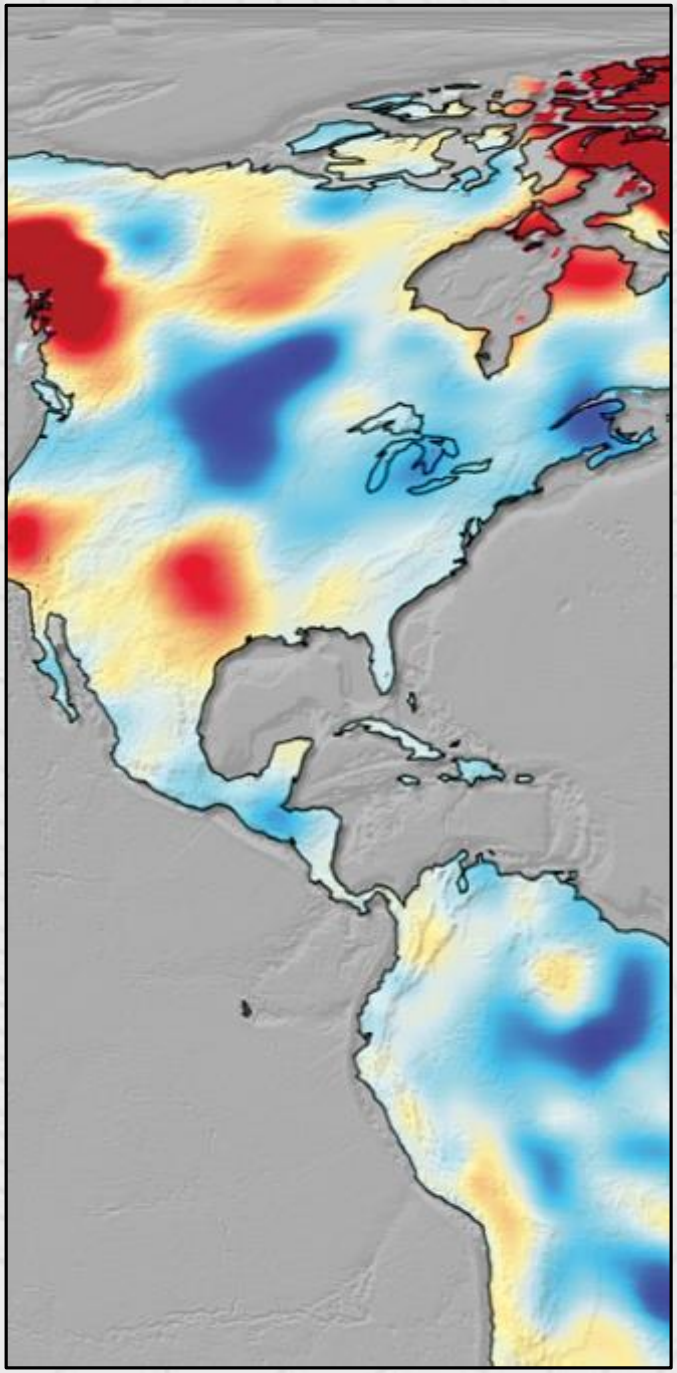


A MAP OF THE FUTURE OF WATER

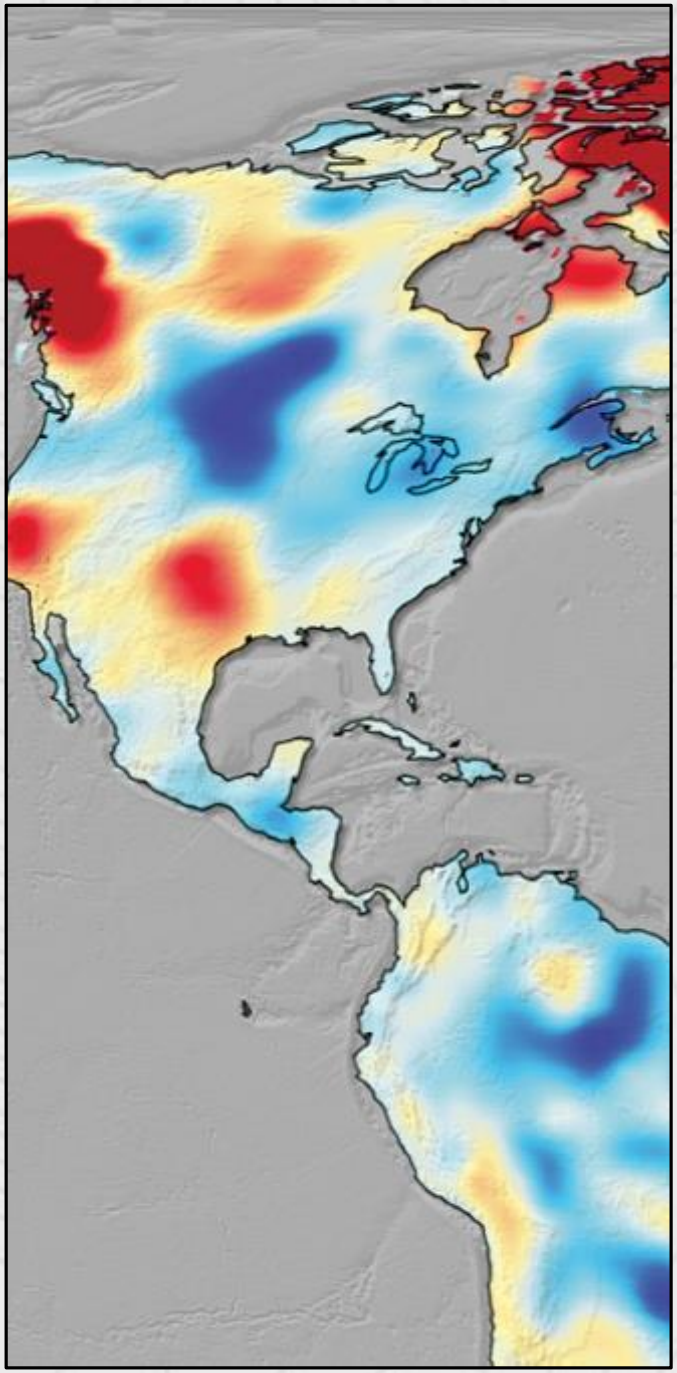
JAY FAMIGLIETTI
Global Institute for Water Security
University of Saskatchewan

PNWER Annual Summit, July 23, 2019, Saskatoon, SK



Overview

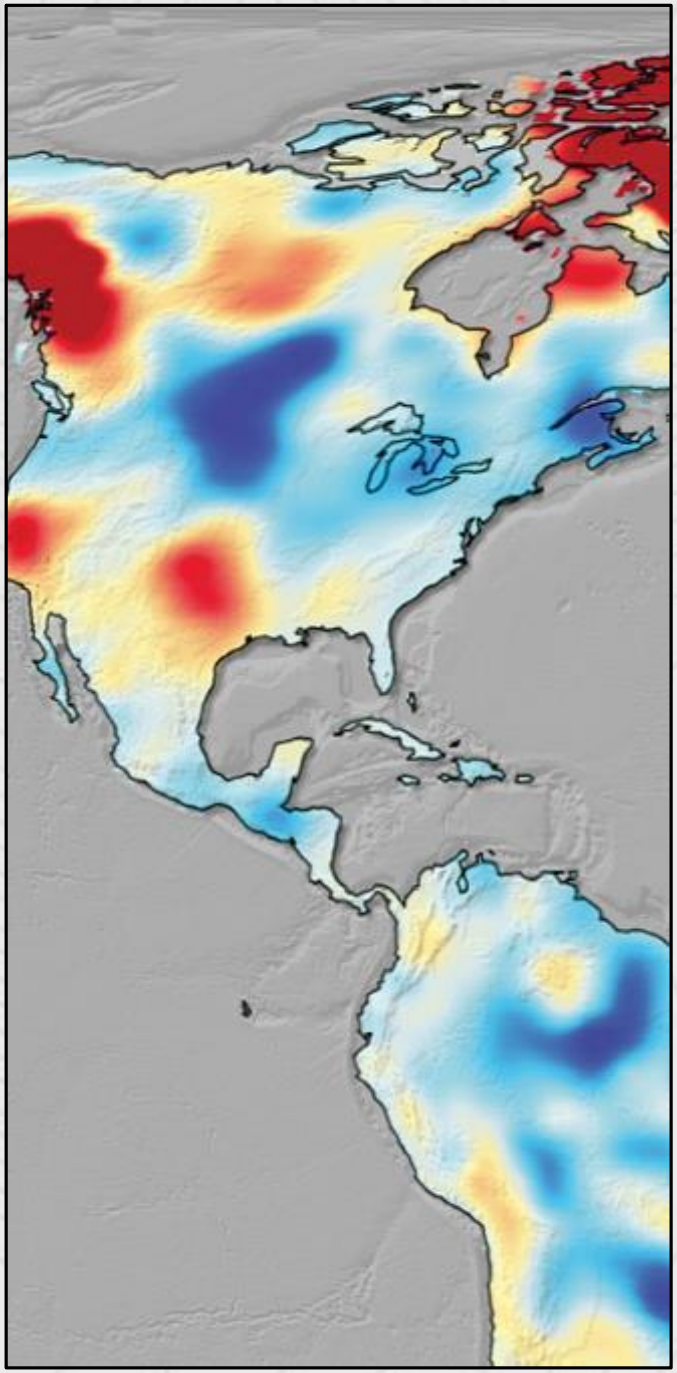
- Defining water security
- What are satellites telling us about water security?
- What are some implications and emerging policy needs for water, food and human security?
- What are we going to do about it?



Overview

- Defining water security
- What are satellites telling us about water security?
- What are some implications and emerging policy needs for water, food and human security?
- What are we going to do about it?

Photo by Jennifer Adler



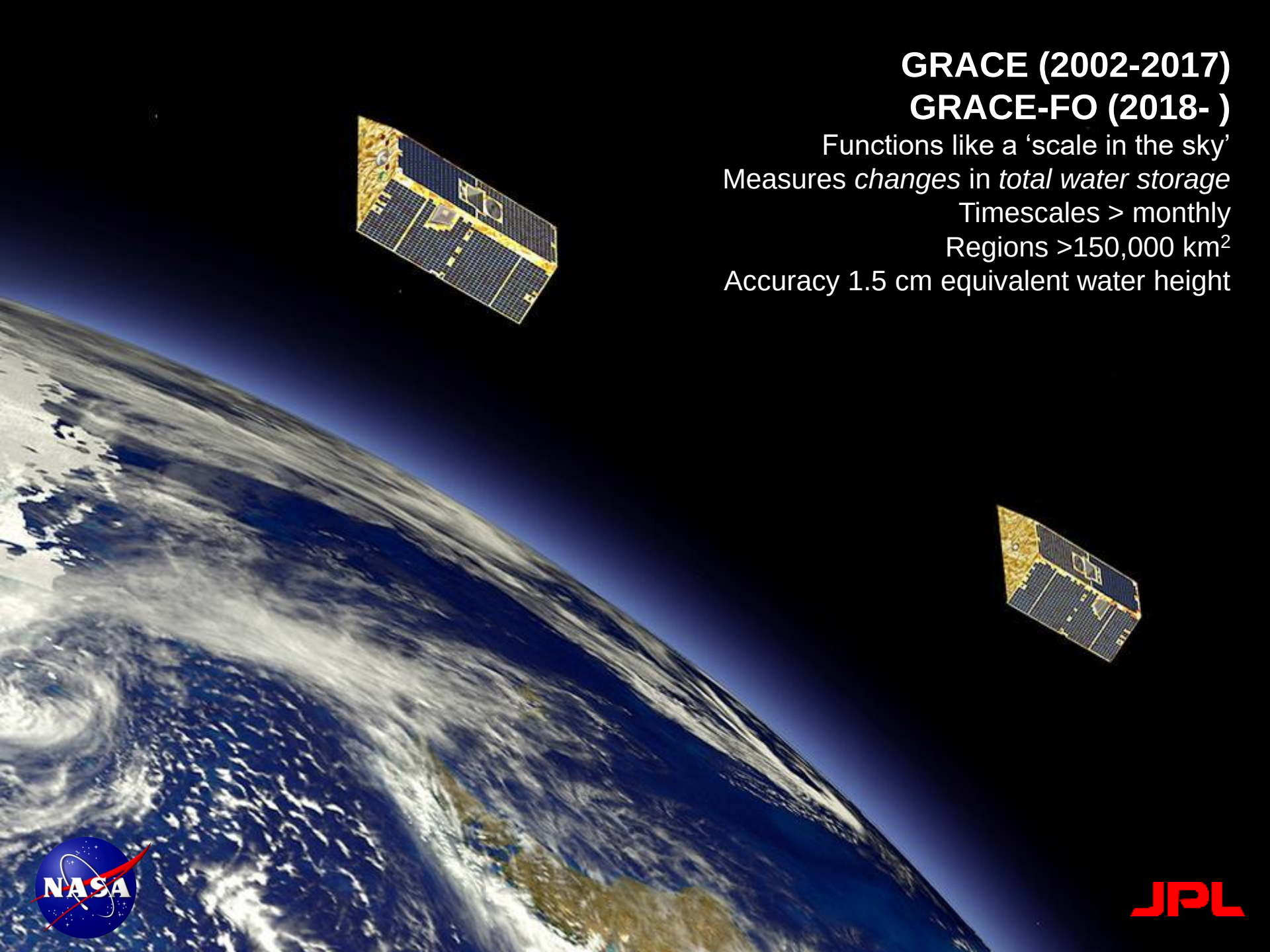
Overview

Defining water security

What are satellites telling us about water security?

What are some implications and emerging policy needs for water, food and human security?

What are we going to do about it?



GRACE (2002-2017)
GRACE-FO (2018-)

Functions like a ‘scale in the sky’

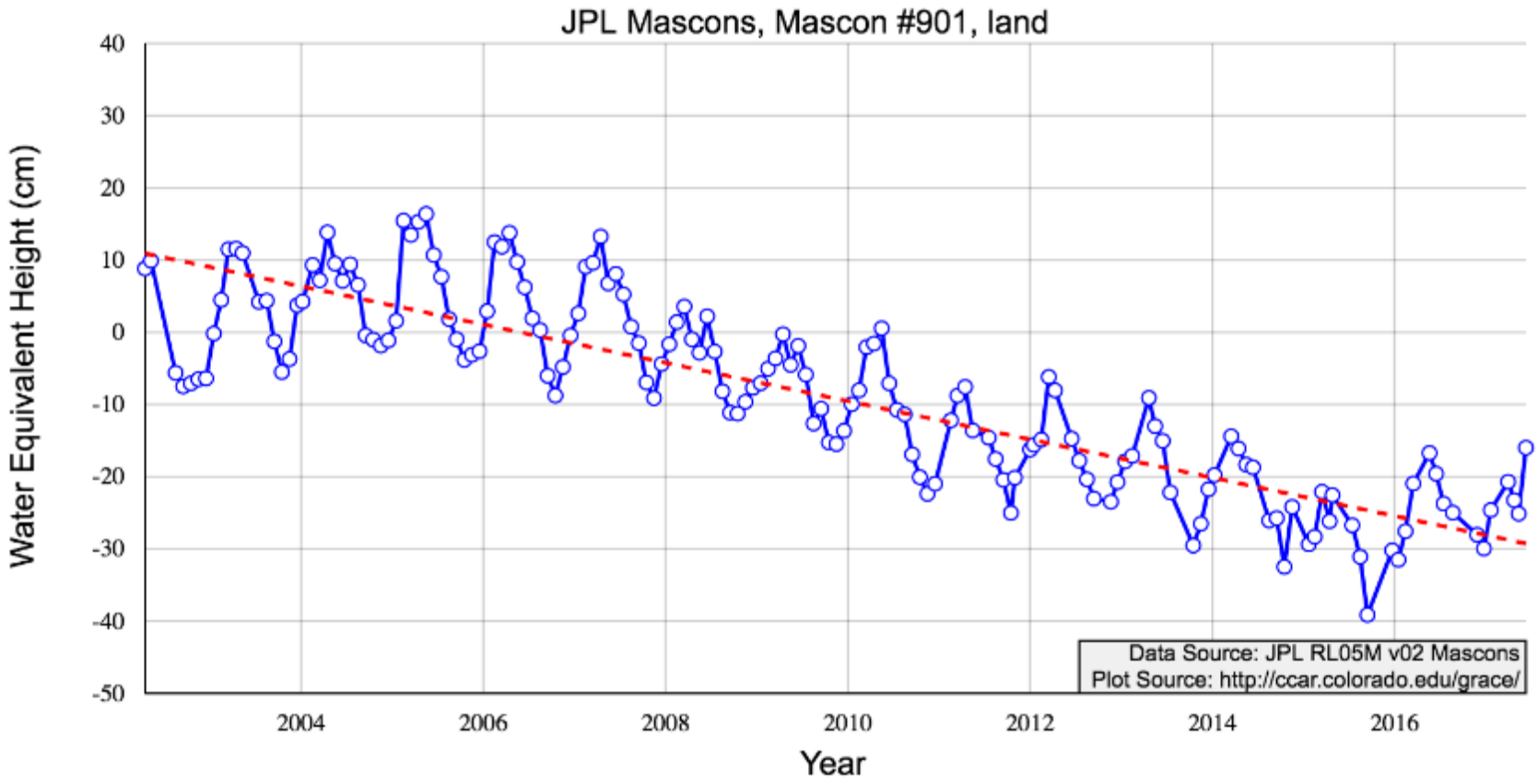
Measures *changes* in *total water storage*

Timescales > monthly

Regions >150,000 km^2

Accuracy 1.5 cm equivalent water height

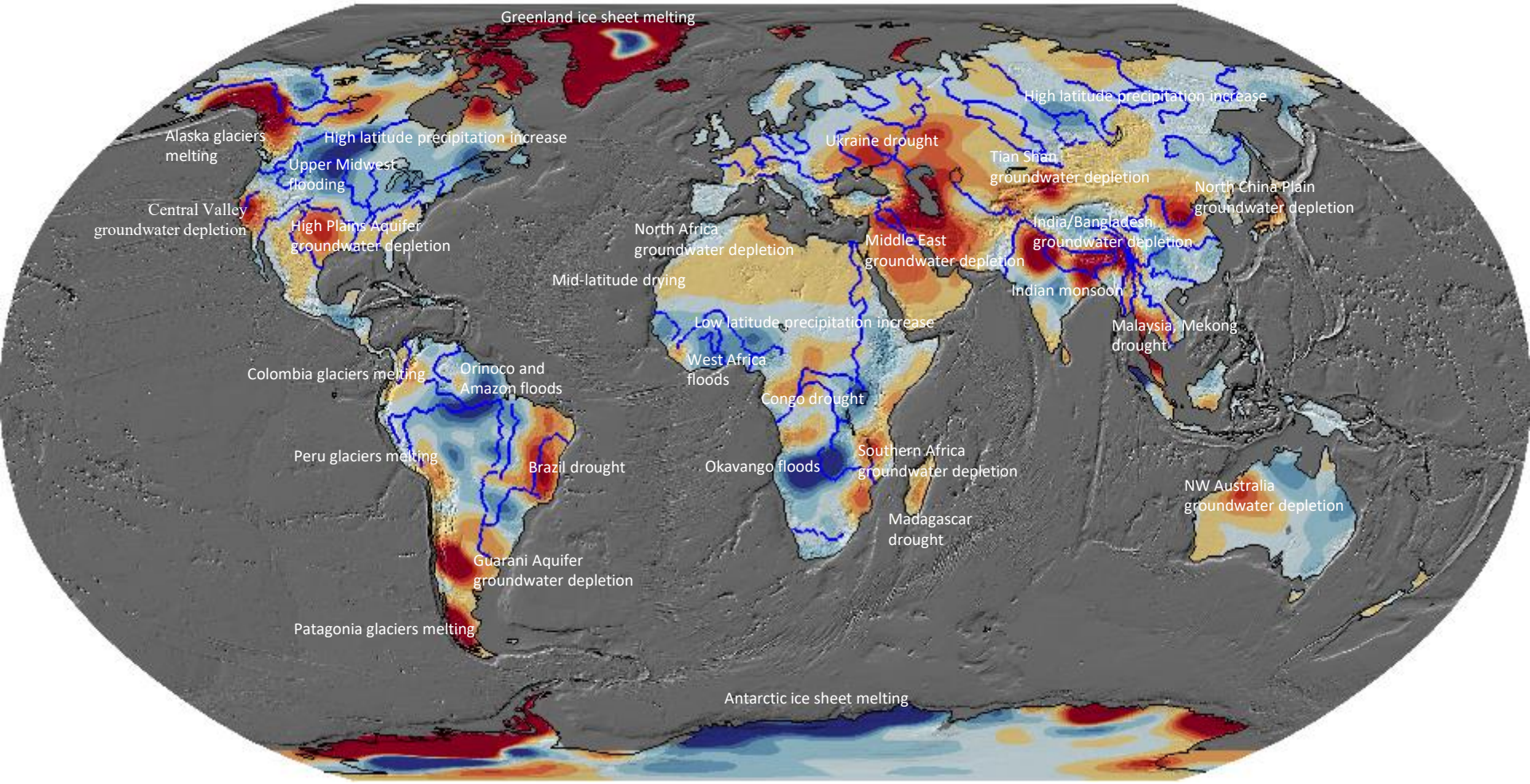
Western Iran GRACE Time Series for Changes in Total Water Storage (2002-2017)



Updated from Voss et al., 2013

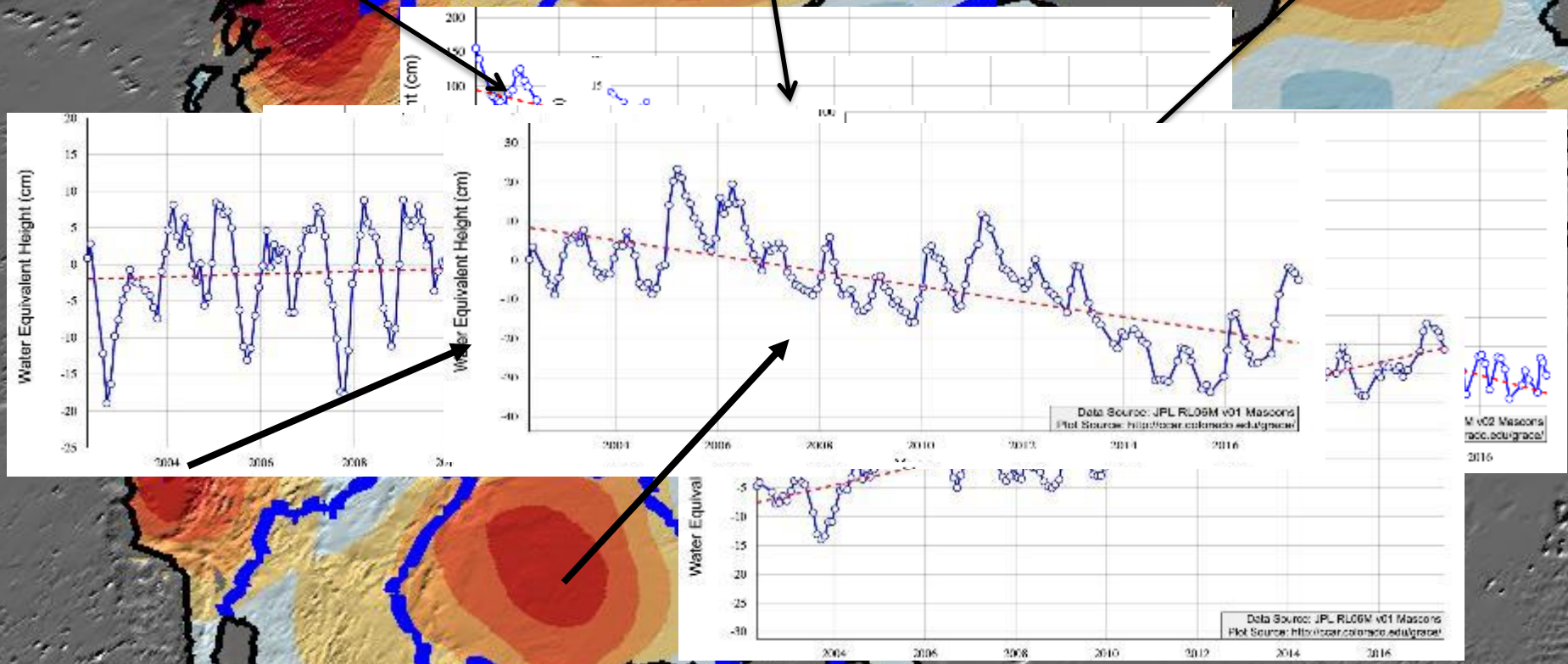
Changing freshwater availability from GRACE (2002-2016)

Rodell, Famiglietti et al., 2018, Nature, Emerging Trends in Global Freshwater Availability



Changing freshwater availability in North America from GRACE (2002-2016)

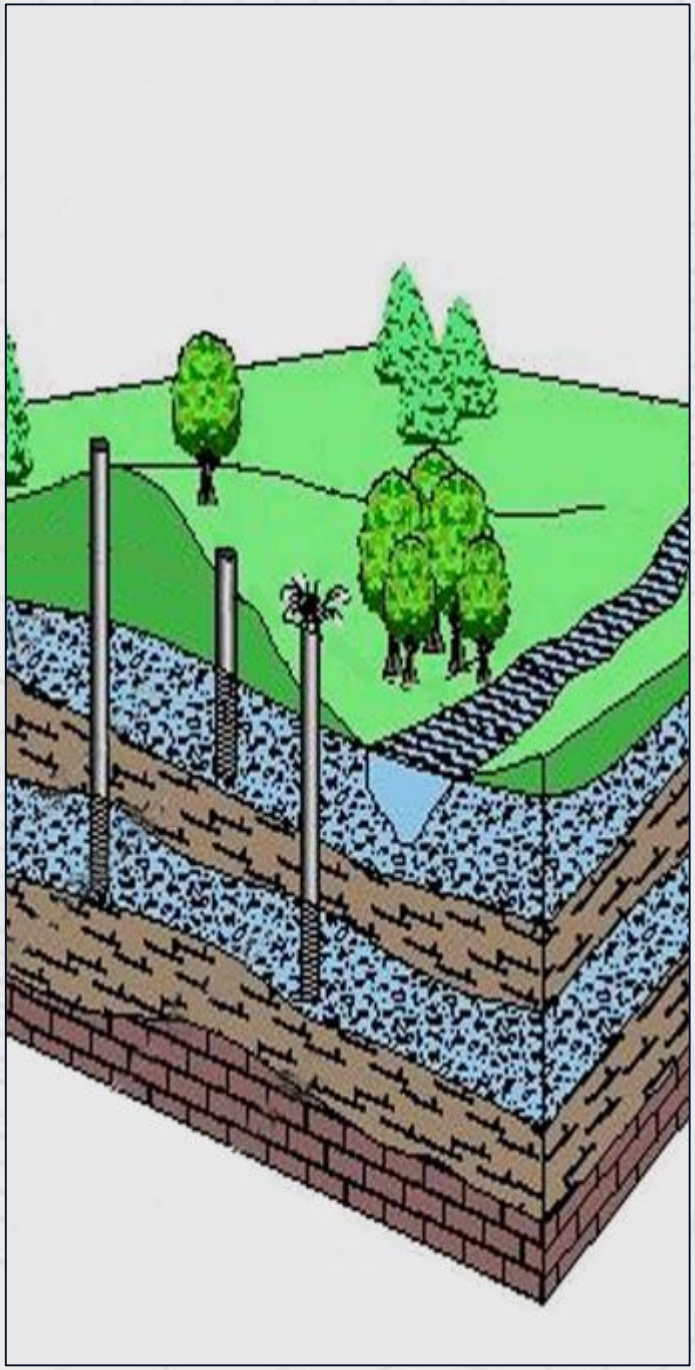
Rodell, Famiglietti et al., 2018, Nature, Emerging Trends in Global Freshwater Availability



multi-n

DJF

Reager et al., A decade of sea level rise slowed by climate-driven hydrology, Science, 2016



Groundwater

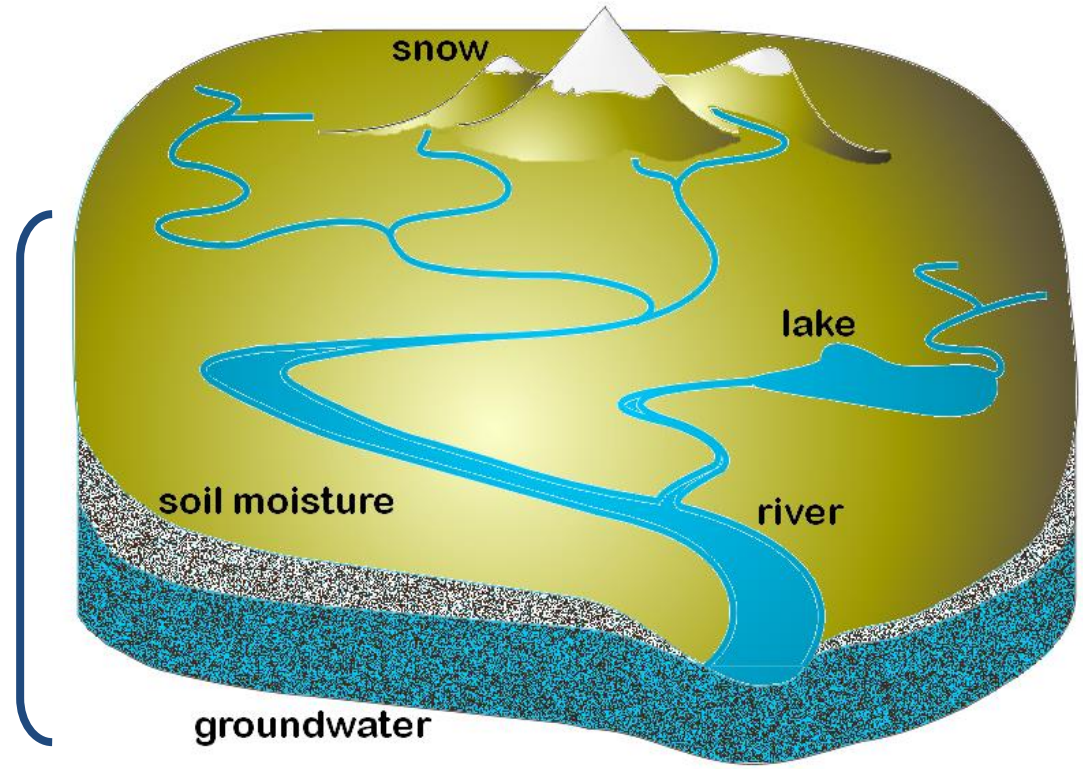
- The water stored under the ground in aquifers
- Primary water source for over 2 billion people
- Provides nearly half of the water for irrigation
- In many cases is non-renewable

How do we estimate groundwater storage changes with GRACE?

Rodell and Famiglietti, 2002, J. Hydrology

$$\Delta S_{LAND} = \Delta S_{SNOW} + \Delta S_{SW} + \Delta S_{SM} + \Delta S_{GW}$$

$$\Delta S_{GW} = \Delta S_{LAND} - \Delta S_{SNOW} - \Delta S_{SW} - \Delta S_{SM}$$



ΔS_{LAND}

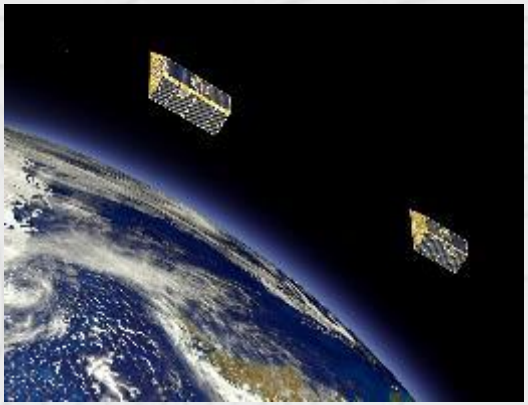
Remove this ($\Delta S_{SNOW} + \Delta S_{SW} + \Delta S_{SM}$) from ΔS_{LAND}

To isolate this (ΔS_{GW})

Future prospects for estimating groundwater storage changes from space

$$\Delta S_{Groundwater} = \Delta S_{Total} - \Delta S_{Snow} - \Delta S_{Surface\ Water} - \Delta S_{Soil\ Moisture}$$

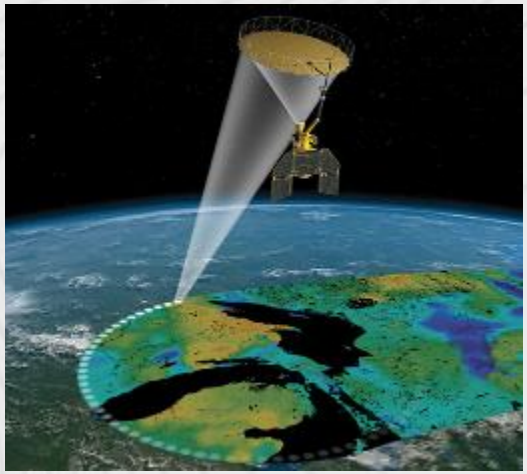
GRACE-FO (2018)



ASO (2013)

SWOT (2022)

SMAP (2015)



Chan[illegible]ge in Calif[illegible]-2017


The New York Times

Science Times TUESDAY, MAY 31, 2011

Groundwater Depletion is Detected From Space

By FELICITY BARRINGER

Irvine, Calif.

Scientists have been using small variations in the Earth's gravity to identify trouble spots around the globe where people are making unsustainable demands on groundwater, one of the planet's main sources of fresh water.

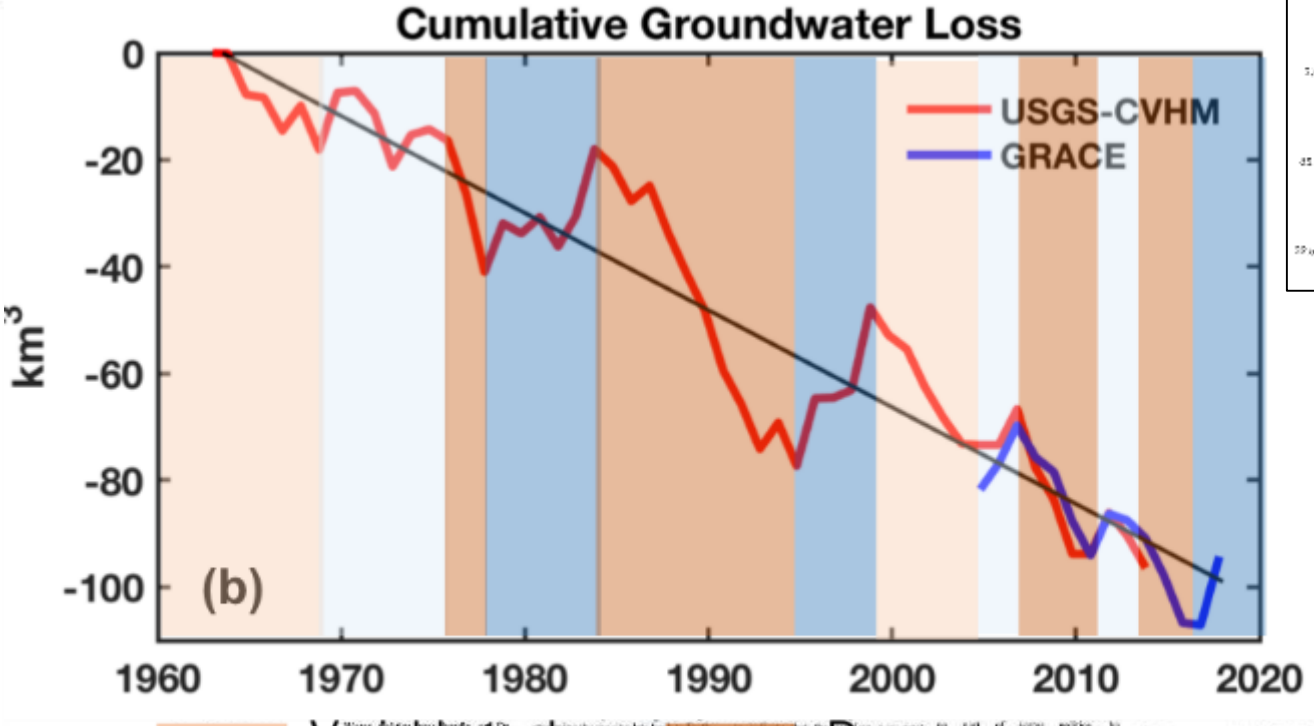
They found problems in places as

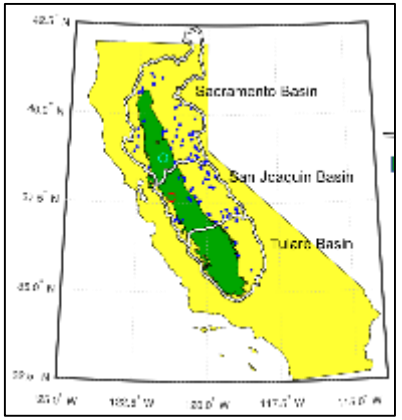
Sensing Groundwater

Hydrologists have used a pair of gravity-sensing satellites, known as Grace, to measure changes in the amount of groundwater in the Sacramento and San Joaquin River basins of California.

CHANGES IN GROUNDWATER STORAGE

<6 cubic miles per month





"I walked into his office and he pulled out a piece of paper saying, I'm trying to figure out how distribution of water makes the Earth wobble," said Dr. Famiglietti. "This was 1992. I was blown away. I instantly fell in love with the guy. I said, 'This is unbelievable, this is amazing, it opens up this whole area.'"

Back then the Grace experiment was still waiting in a queue of NASA projects. But he and Matt Rodell, a Ph.D. candidate under his supervision, threw themselves into investigating whether Grace would work, a so-called "proof of concept" exercise that turned out to show that Grace data was reliable and could support groundwater studies.

For decades, groundwater measurements in the United States had been made from points on the Earth's surface — by taking real-time soundings at 1,385 of the United States Geological Survey's observation wells and daily readings at 5,008 others. Those readings are supplemented by measuring water levels in hundreds of thousands of other wells, trenches and excavations.

The two satellites, each the size of a small car, travel in polar orbits about 137 miles apart. Each bombards the other with microwaves calibrating the distance between them down to intervals of less than the width of a human hair. If the mass below the path of the leading satellite increases — because, say, the

to part of water politics, he acknowledged that this might be hard to avoid, given that his role is to make sure the best data about groundwater is available, harvesting and disseminating all of the information he can about the Earth's water supply as aquifers dry up and shortages loom.

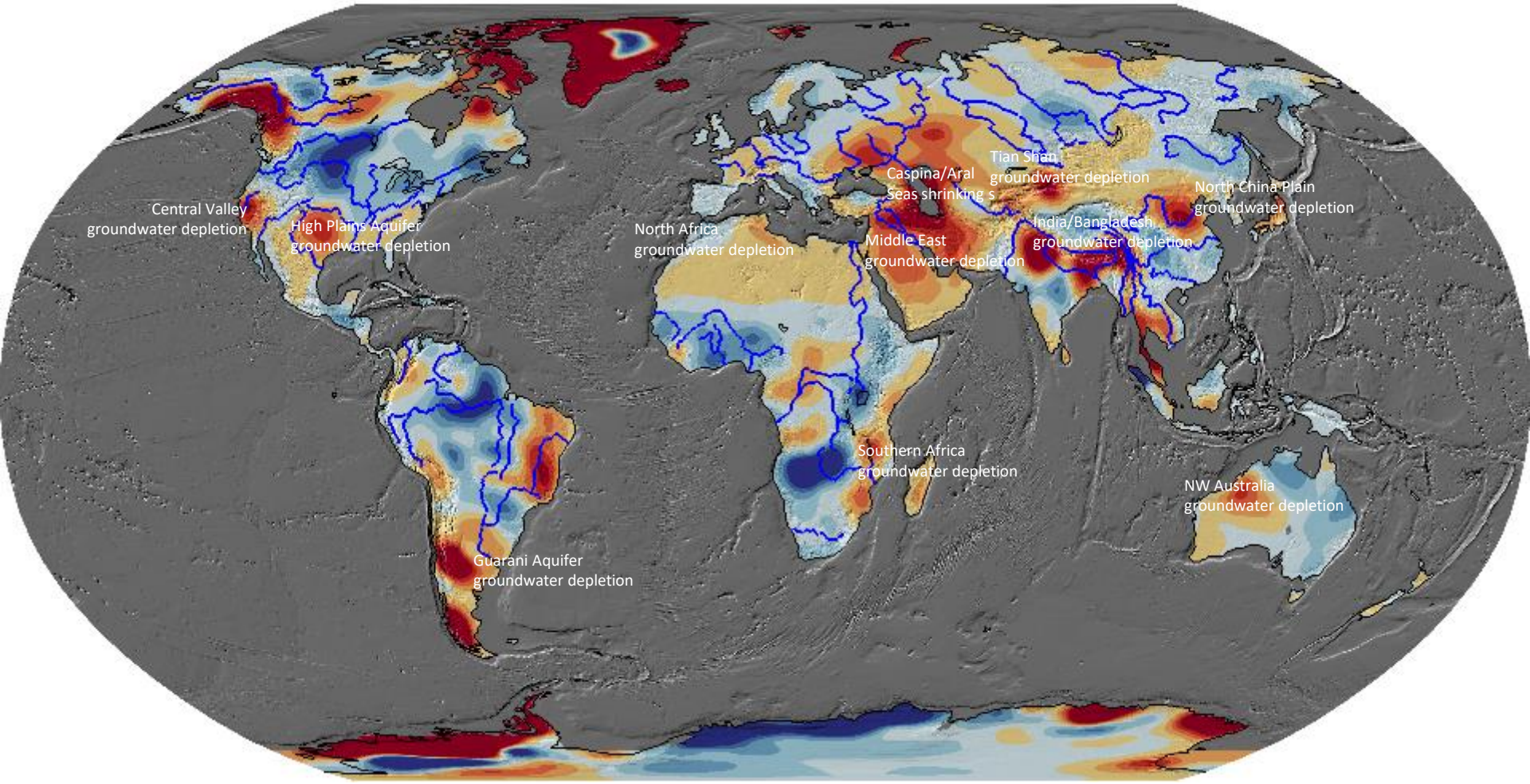
"Look, water has been a resource that has been plentiful," he said. "But now we've got climate change, we've got population growth, we've got widespread groundwater contamination, we've got satellites showing us we are depleting some of this stuff.

"I think we've taken it for granted, and we are probably not able to do that any more."

A version of this article appears in print on May 31, 2011, on Page D1 of the New York edition with the headline: Groundwater Depletion Is Detected From Space

Changing freshwater availability from GRACE (2002-2016)

Rodell, Famiglietti et al., 2018, Nature, Emerging Trends in Global Freshwater Availability



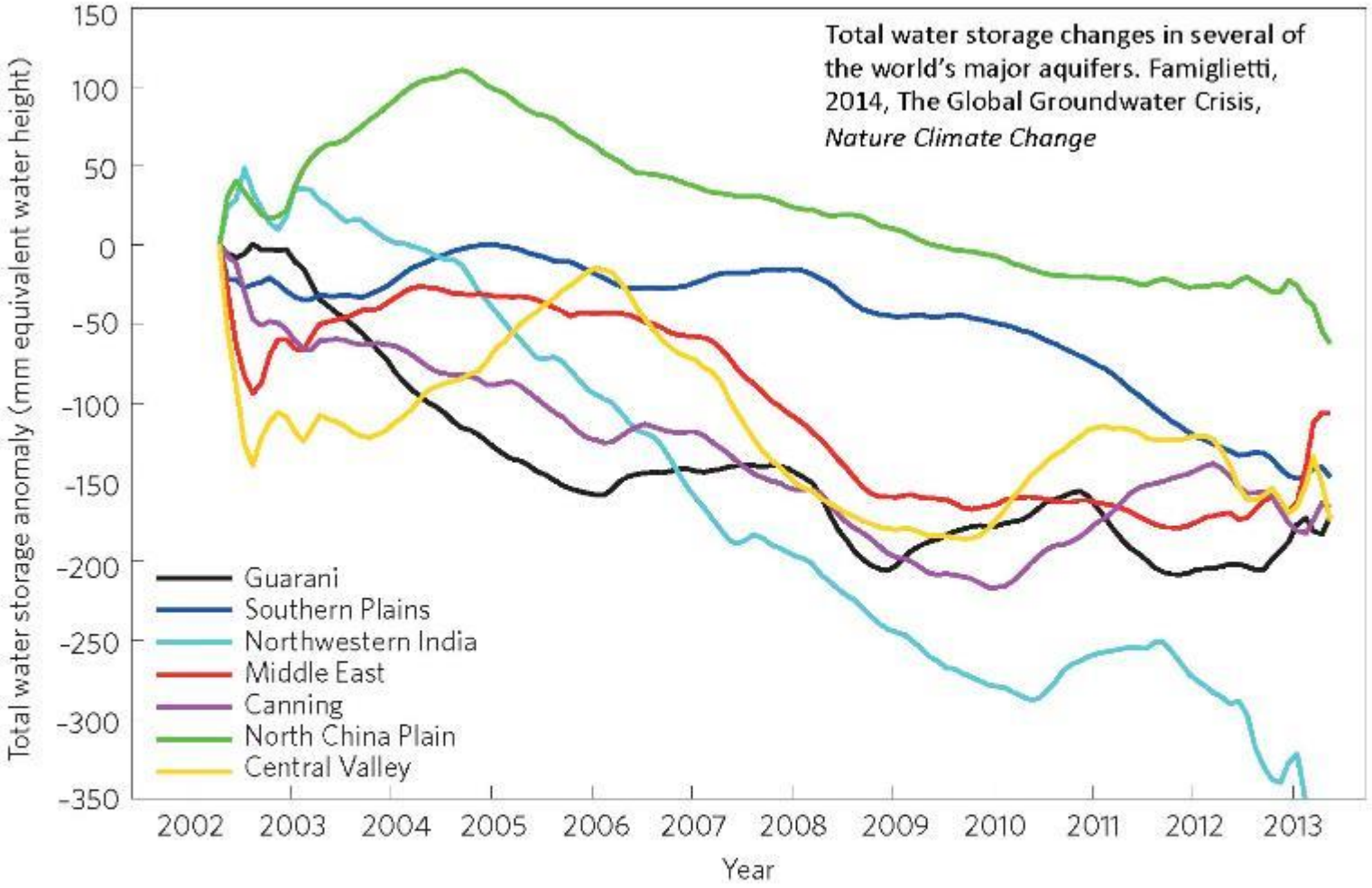
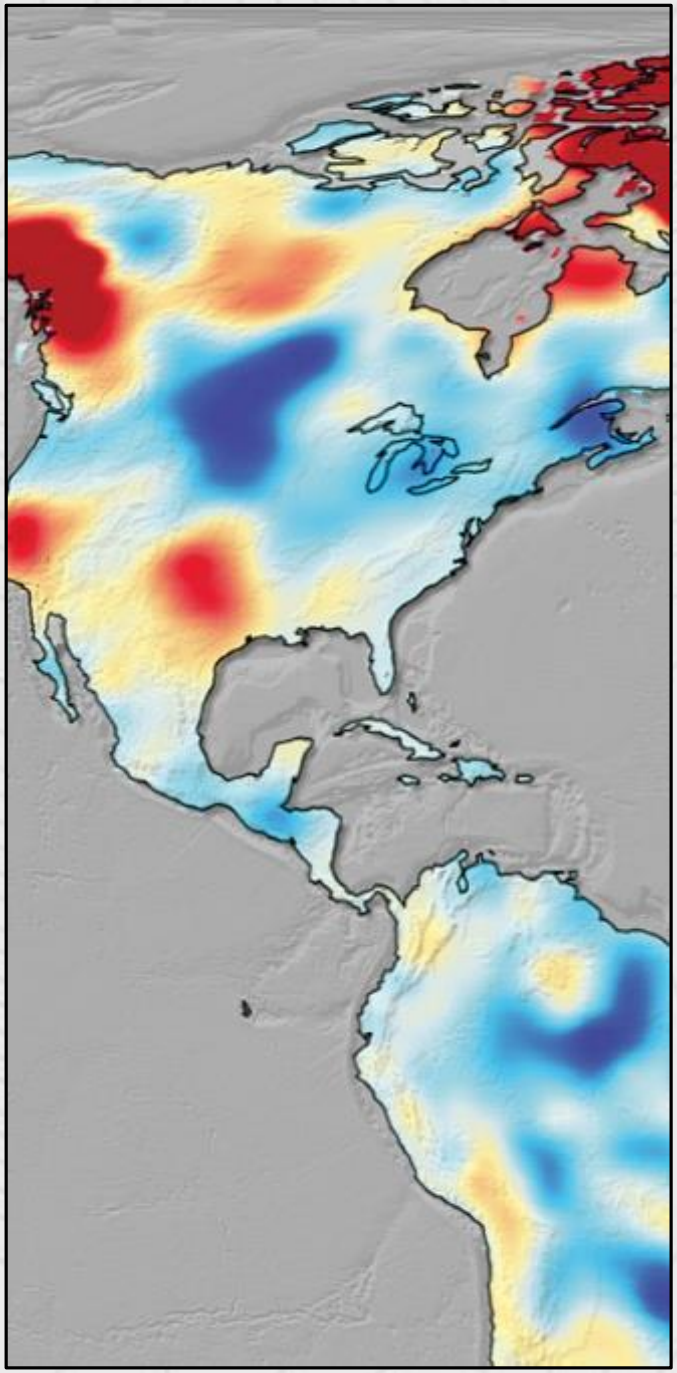


Figure 2 from *The global groundwater crisis, J. S. Famiglietti , Nature Climate Change 4, 945–948 (2014) doi:10.1038/nclimate2425 Published online 29 October 2014.* Water storage declines (mm equivalent water height) in several of the world's major aquifers in Earth's arid and semi-arid mid-latitudes, derived from the NASA GRACE satellite mission. The monthly storage changes are shown as anomalies for the period April 2002–May 2013, with 24-month smoothing. Image: J. S. Famiglietti and J. T. Reager, NASA Jet Propulsion Laboratory, California Institute of Technology; and University of California, Irvine, USA.



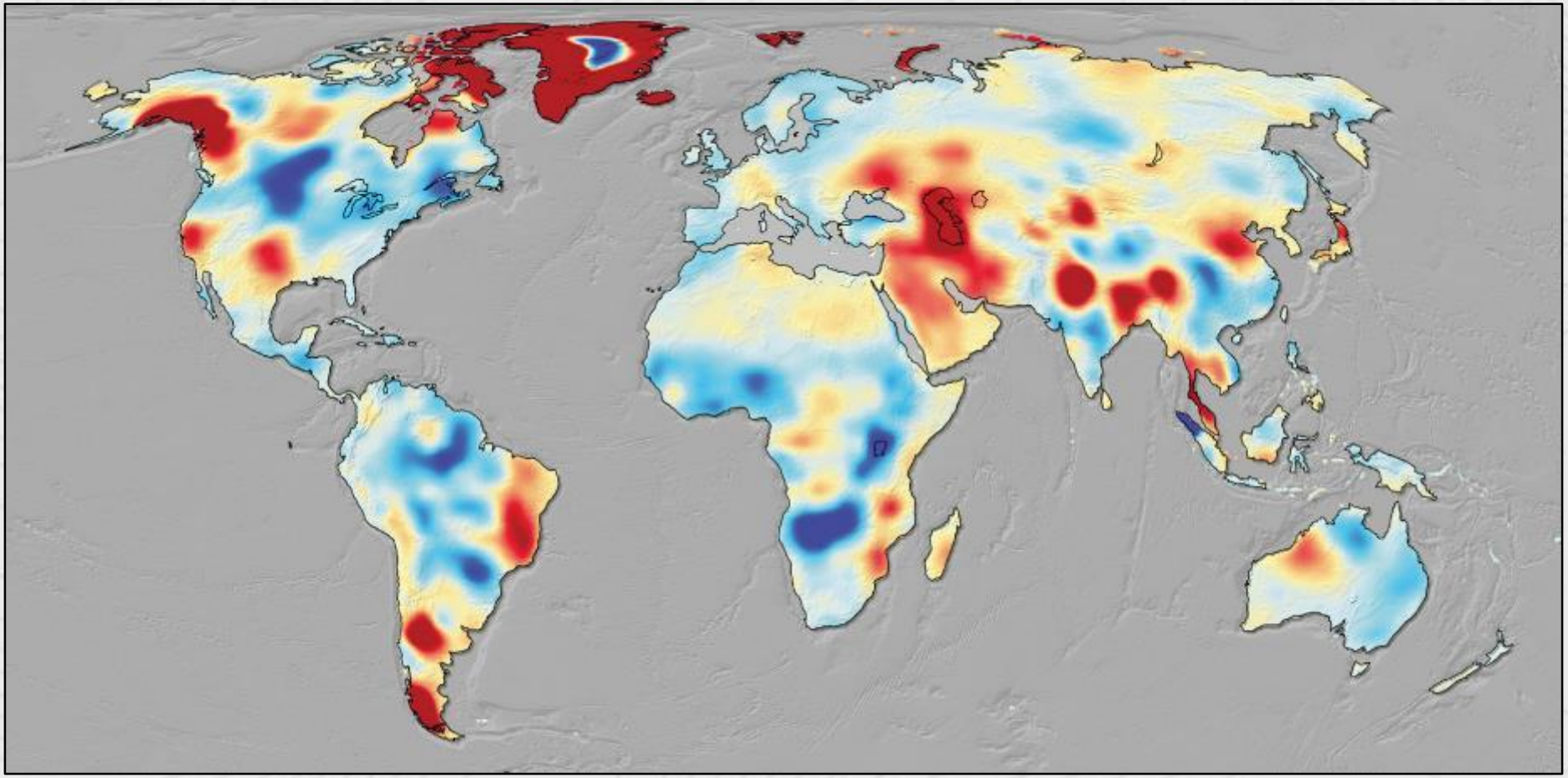
Overview

Defining water security

What are satellites telling us about water security?

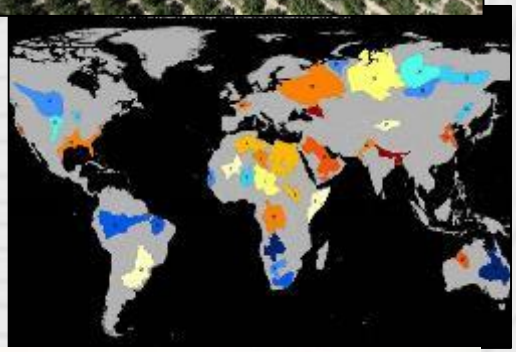
What are some implications and emerging policy needs for water, food and human security?

What are we going to do about it?



The human fingerprint on the freshwater landscape - through climate change, ice melt, changing extremes, and water management - is a dominant force that is dramatically changing patterns of water availability.

This change – and with it, major threats to water and food security -- is happening far more rapidly than most people realize.



Implications for food producing regions

- Most are in a state of chronic water scarcity
- There are many ‘solutions’ for metropolitan regions but fewer for agriculture
- Will we need to move water to the major food producing regions?
- Food-related water problems are national and international problems

Implications for socioeconomics, policy

- Society is not prepared for the water, food and energy future that confronts us
- Distinct classes of water ‘haves and have nots’ are emerging
- Violent conflict and water/climate refugees will increase
- Revisions to water law and new transboundary policies required

nature climate change

29 October 2014

opinion & comment

COMMENTARY:

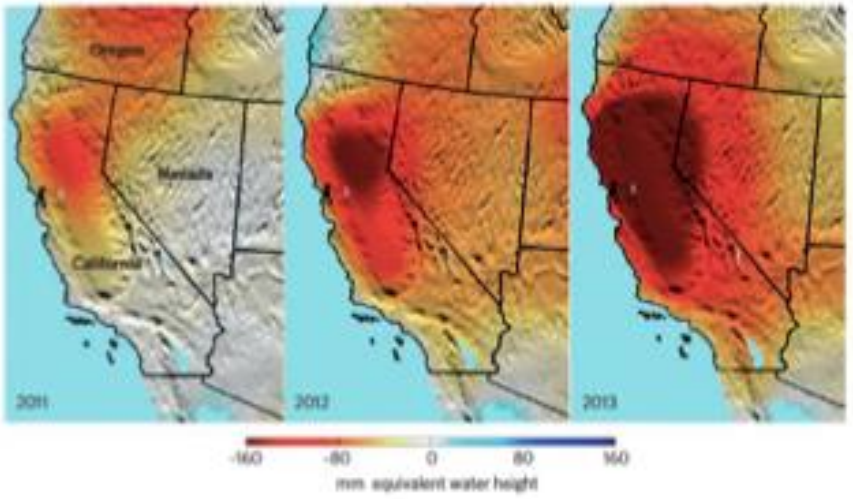
The global groundwater crisis

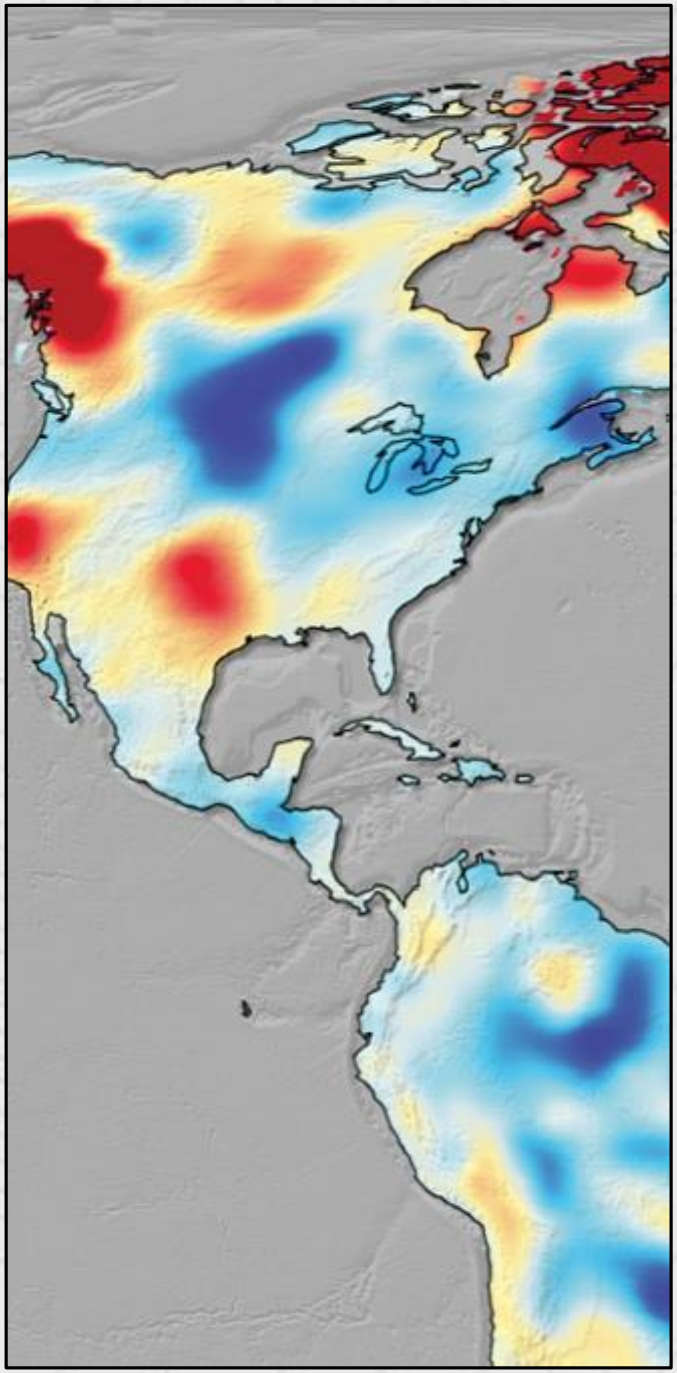
J. S. Famiglietti

Groundwater depletion the world over poses a far greater threat to global water security than is currently acknowledged.

Groundwater — the water stored beneath Earth's surface in soil and porous rock aquifers — accounts for as much as 33% of total water withdrawals worldwide[1]. Over two billion people rely on groundwater as their primary water source[2], while half or more of the irrigation water used to grow the world's food is supplied from underground sources[3].

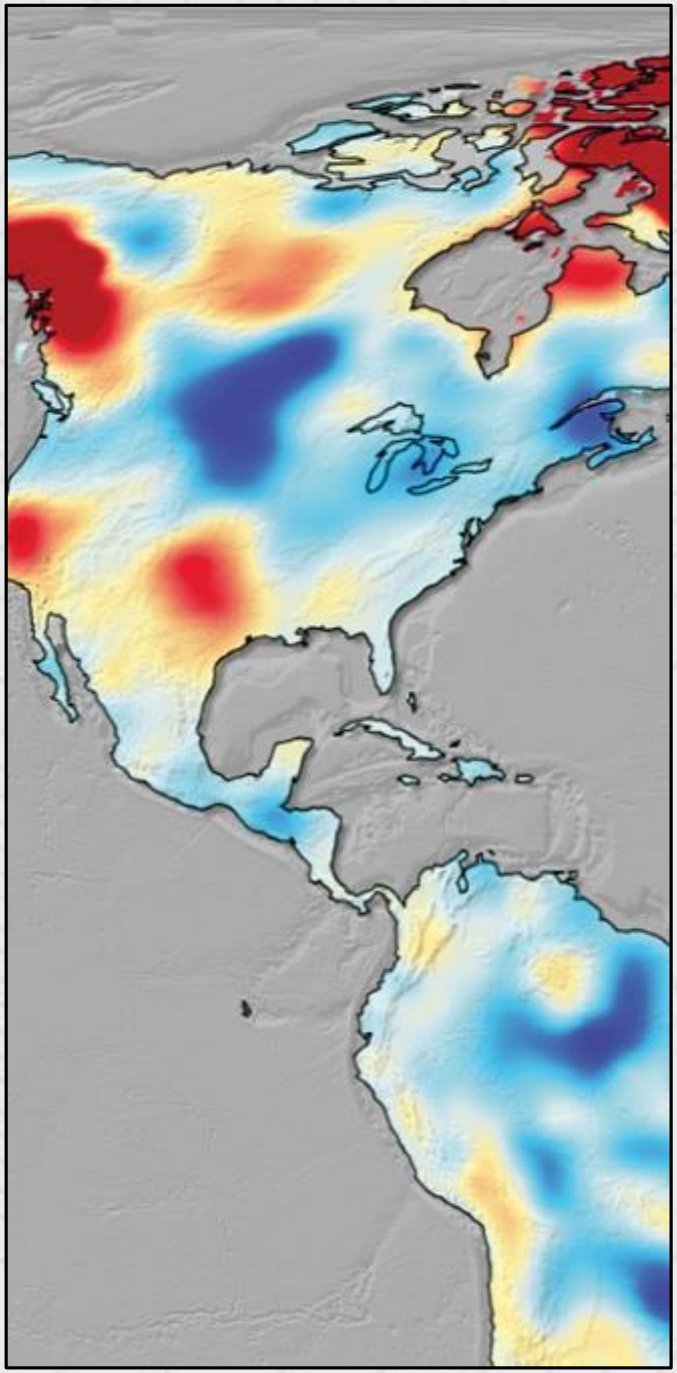
Groundwater also acts as the key strategic reserve in times of drought[4], in particular during prolonged events such as those in progress across the western United States (Fig. 1), northeastern Brazil and Australia. Like money in the bank, groundwater sustains societies through the lean times of little incoming rain and snow. Hence, without a sustainable groundwater reserve, global water security is at far greater risk than is currently recognized.





Overview

- Defining water security
- What are satellites telling us about water security?
- What are some implications and emerging policy needs for water, food and human security?
- What are we going to do about it?



Some perspective

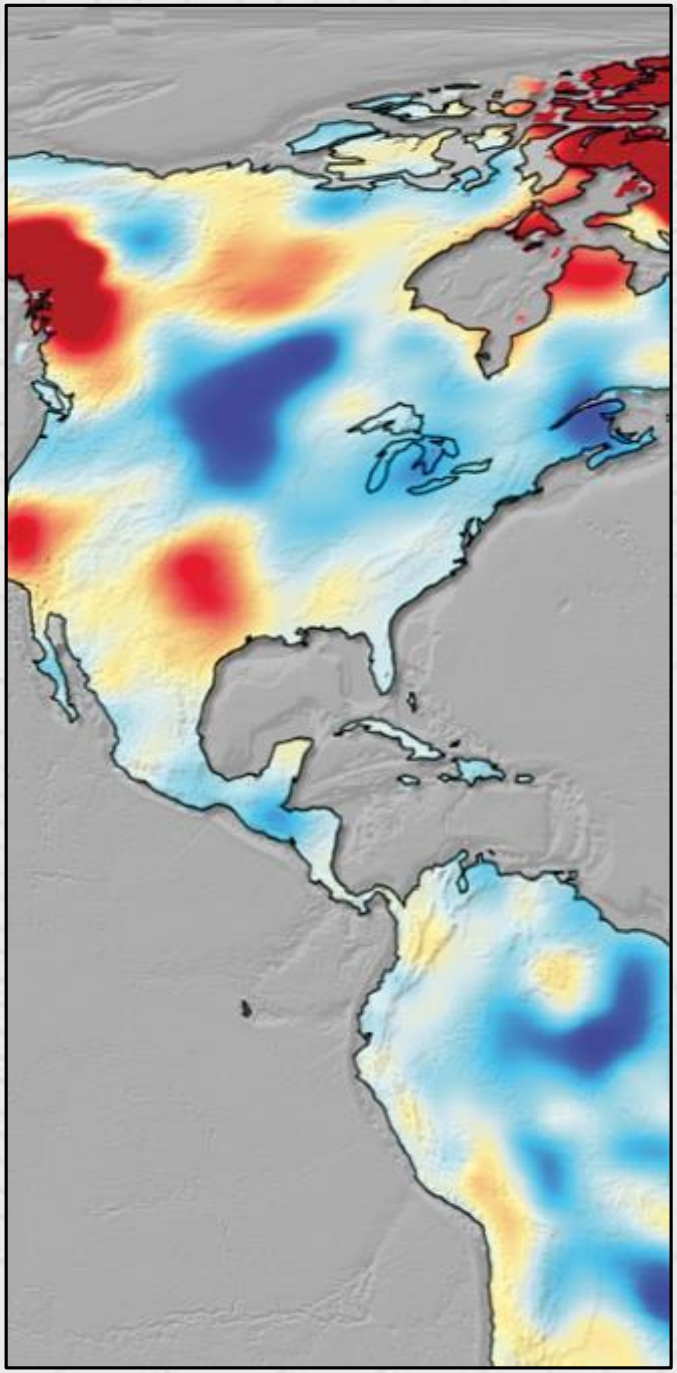
There is an urgent need for regional and global science, engineering and water policy innovations

Academics need to engage with policy makers, planners, stakeholder and the public to discuss adaptation strategies and science and policy needs

- Engage deeply and co-develop key questions
- Do the highest quality work
- Communicate to stakeholders, resource managers, elected officials and the public

We need to integrate across disciplines and institutions

https://trend.pewtrusts.org/

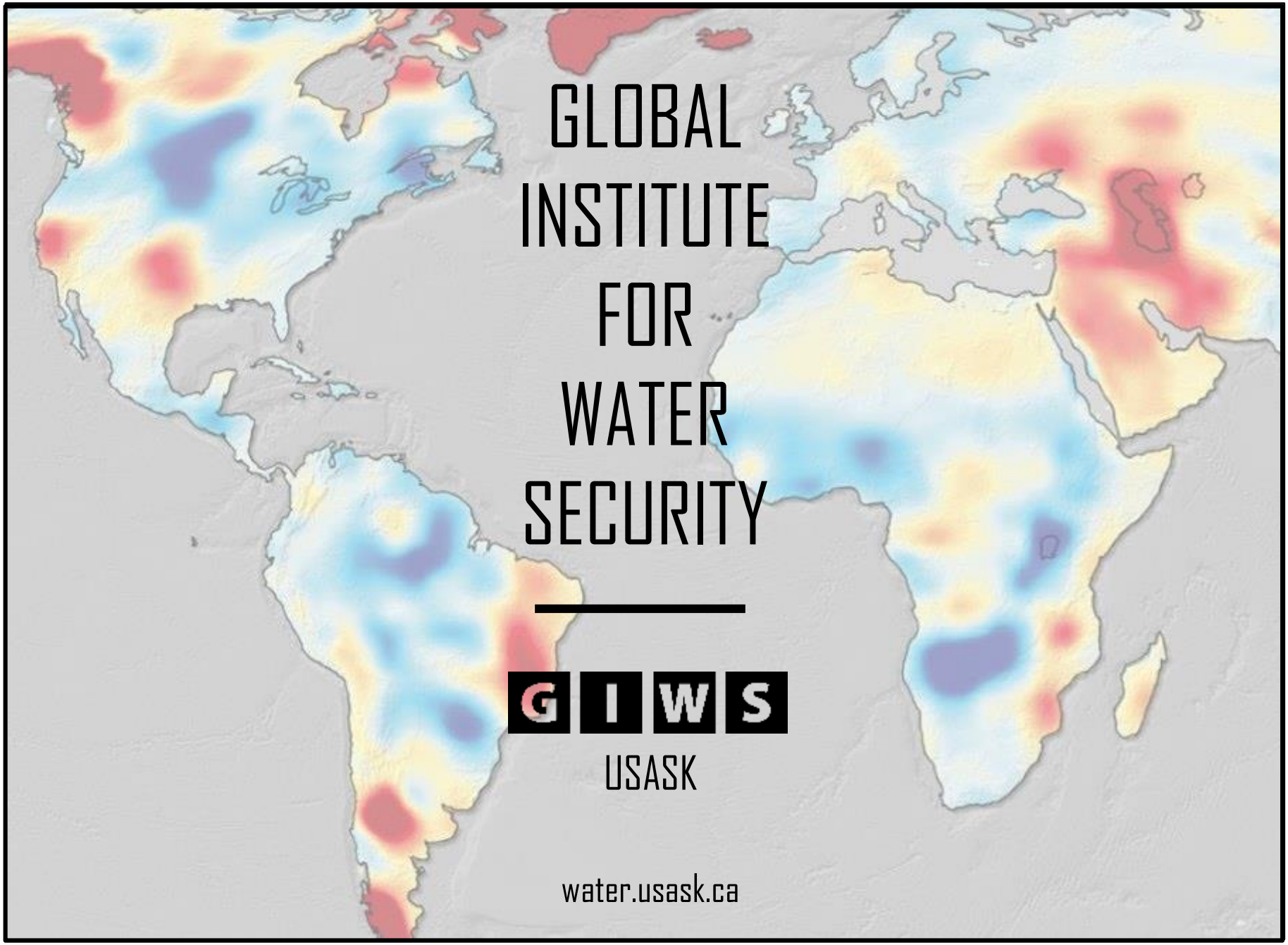


More Information

Trend, Future of Water issue
https://trend.pewtrusts.org

Personal website
https://jayfamiglietti.com

Twitter
@jayfamiglietti



GLOBAL INSTITUTE FOR WATER SECURITY

GIWS

USASK

water.usask.ca

UNIVERSITY OF SASKATCHEWAN
Global Institute for
Water Security
USASK.CA/WATER

UNIVERSITY OF SASKATCHEWAN
Global Institute for
Water Security
USASK.CA/WATER

UNIVERSITY OF SASKATCHEWAN
Global Institute for
Water Security
USASK.CA/WATER

GLOBAL INSTITUTE FOR WATER SECURITY

GIWS

USASK