FASTER

Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research

2nd FASTER SPECIALIZED TRAINING

on Climate change effects on water & land management in the Mediterranean

22-26 March 2021 (ONLINE)

AGENDA

Water Resources Evaluation and Management with the Aid of Remote Sensing

March 24th, 2021
Specialized training course, FASTER project, Tunisia

Hossein Hashemi
Department of Water Resources Engineering & Center for Advanced Middle Eastern Studies
Lund University, Sweden

What is the lecture about?

- In order to understand water resources and hydrological cycle issues, first, one needs to estimate the fluxes and storage using a variety of sources

- These sources include **ground-based** instruments such as rain gauges to measure rainfall, **satellite sensors** such as microwave radiometers and radars, and **model output** such as CPC (Climate Prediction Center).

- Use of these data helps us to quantify the various aspects of the hydrological cycle.

Topics

HYDROLOGICAL CYCLE

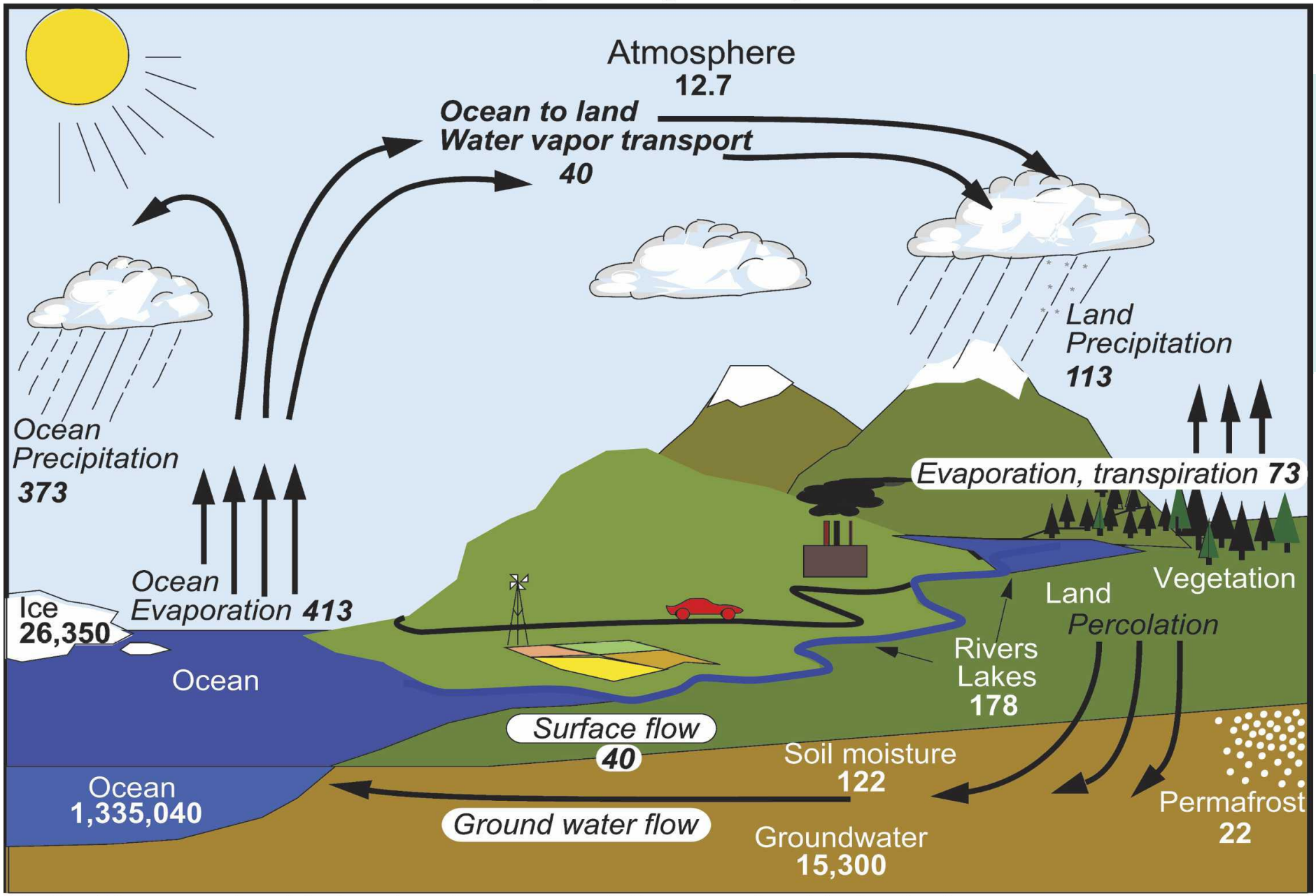
REMOTE SENSING BROAD PRINCIPLES

APPLICATIONS

In any hydrological study, we need to balance water – water cannot be created or destroyed

WATER BALANCE

Hydrological Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Trenberth et al, 2007 (NCAR)

Land surface water budget:

$$\overline{P} - \overline{E} = Q_s + Q_g + d\overline{S} / dt$$

where Q_s is river discharge, Q_g is groundwater discharge across basin boundary

and where $S = S_{sm} + S_{sn} + S_{lw} + S_g + S_{gi}$

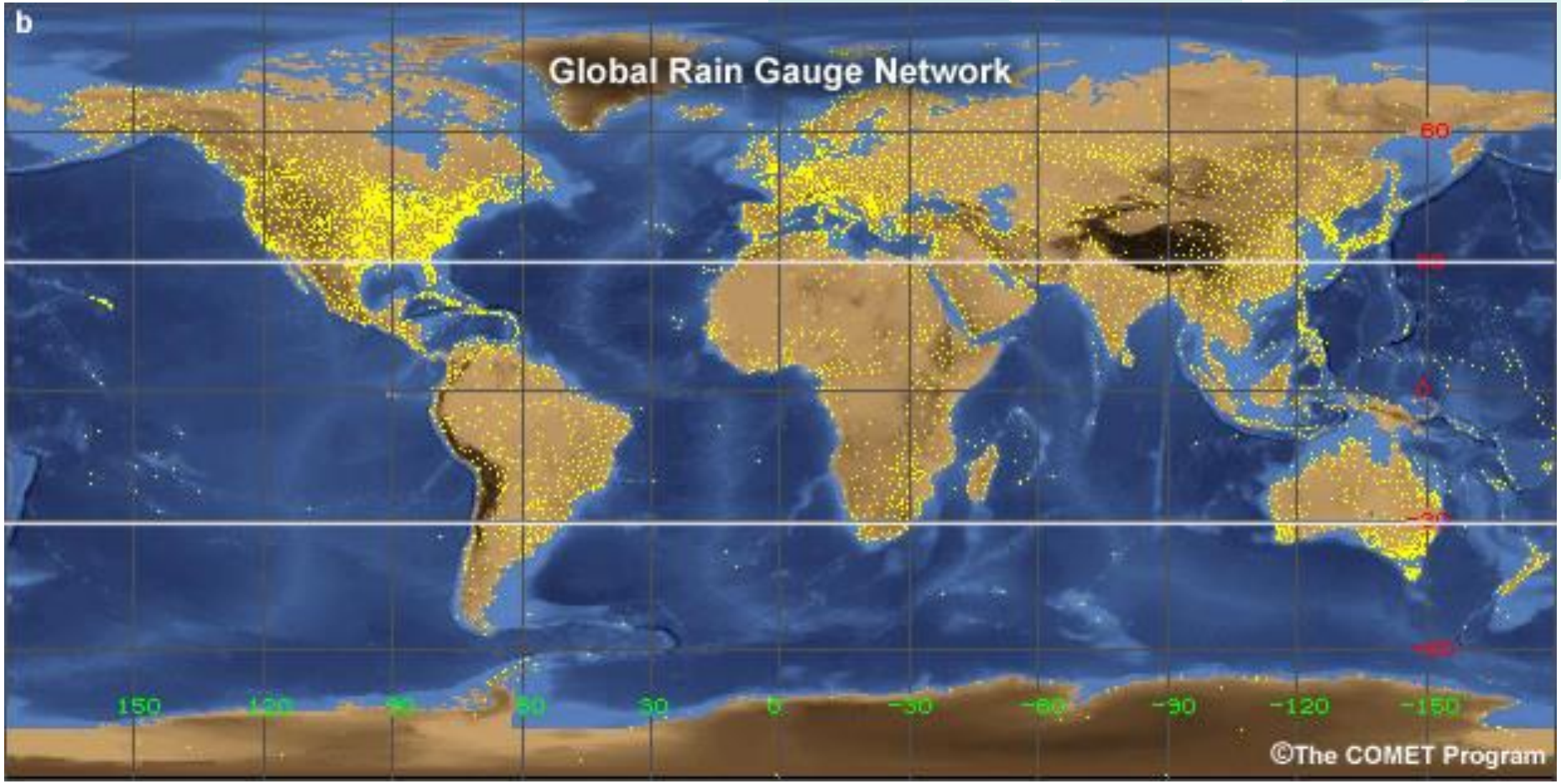
S_{sm} soil moisture
S_{sn} snow
S_{lw} lakes and wetlands
S_g ground water
S_{gi} glaciers and ice sheets

Variability and heterogeneity

Unfortunately, the land surface is extremely heterogeneous and has spatial heterogeneity (one portion is covered with trees and the other with crops) and temporal variability (more summer rainfall than in winter).

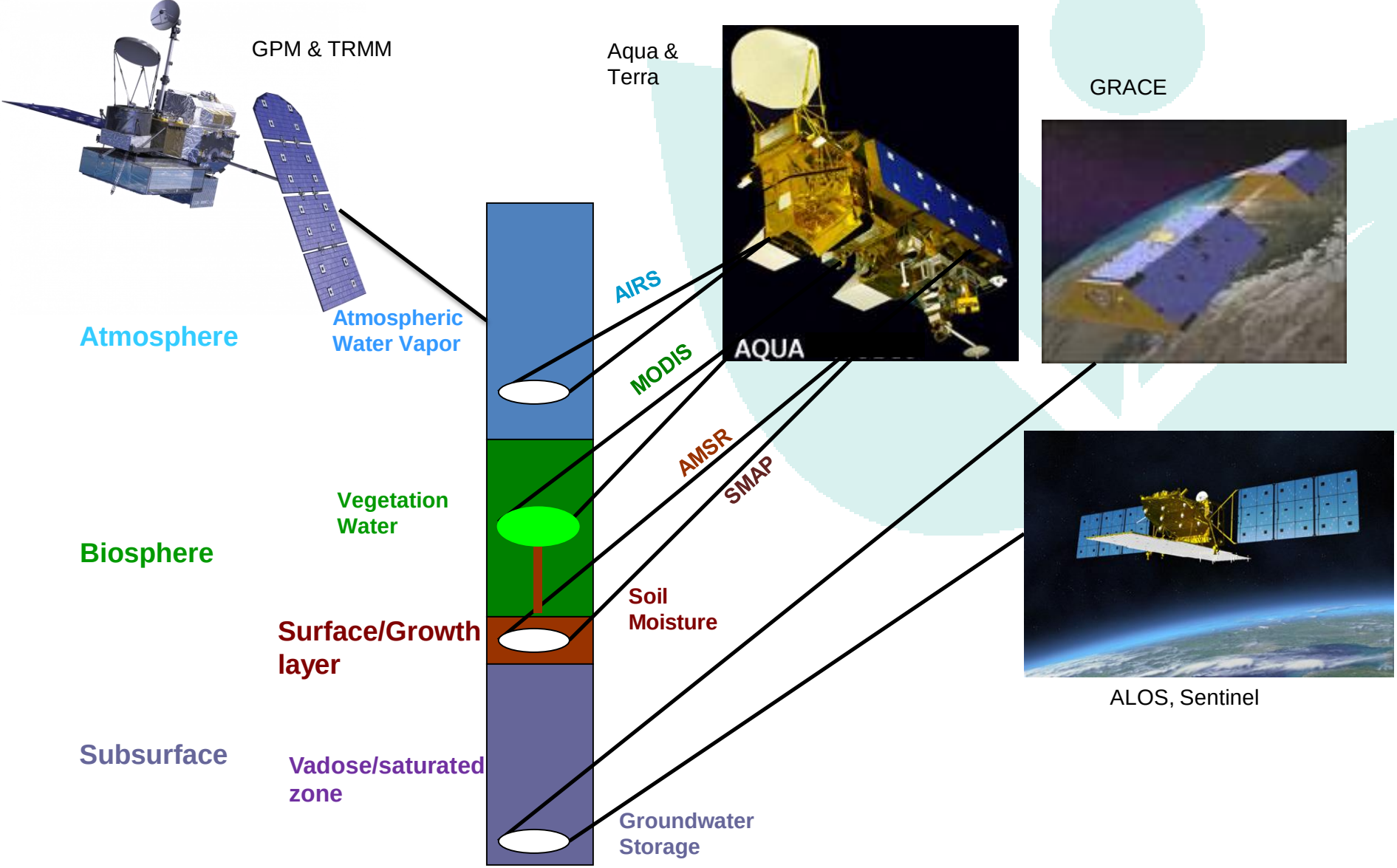
J Dandois 2003

Global Rain Gauge Distribution



Water Cycle

- **Atmosphere**: Precipitation, water vapor, and land surface fluxes
- **Land Surface:** Vegetation, soil moisture, snow/ice, surface storage (lakes), and river flow
- **Subsurface**: Groundwater system



Enable us to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment.

Observations from space

- Sun-synchronous polar orbits
  - Global coverage, fixed crossing, repeat sampling
  - Typical altitude 500-1500 km

- Low-inclination, non-Sun-synchronous orbits
  - Tropics, mid-latitudes, varying sampling
  - Typical altitude 200-2000 km

- Geostationary orbits
  - Regional views of full Earth disk, continuous coverage
  - Over Equator only, altitude 35000 km

Passive and active remote sensing

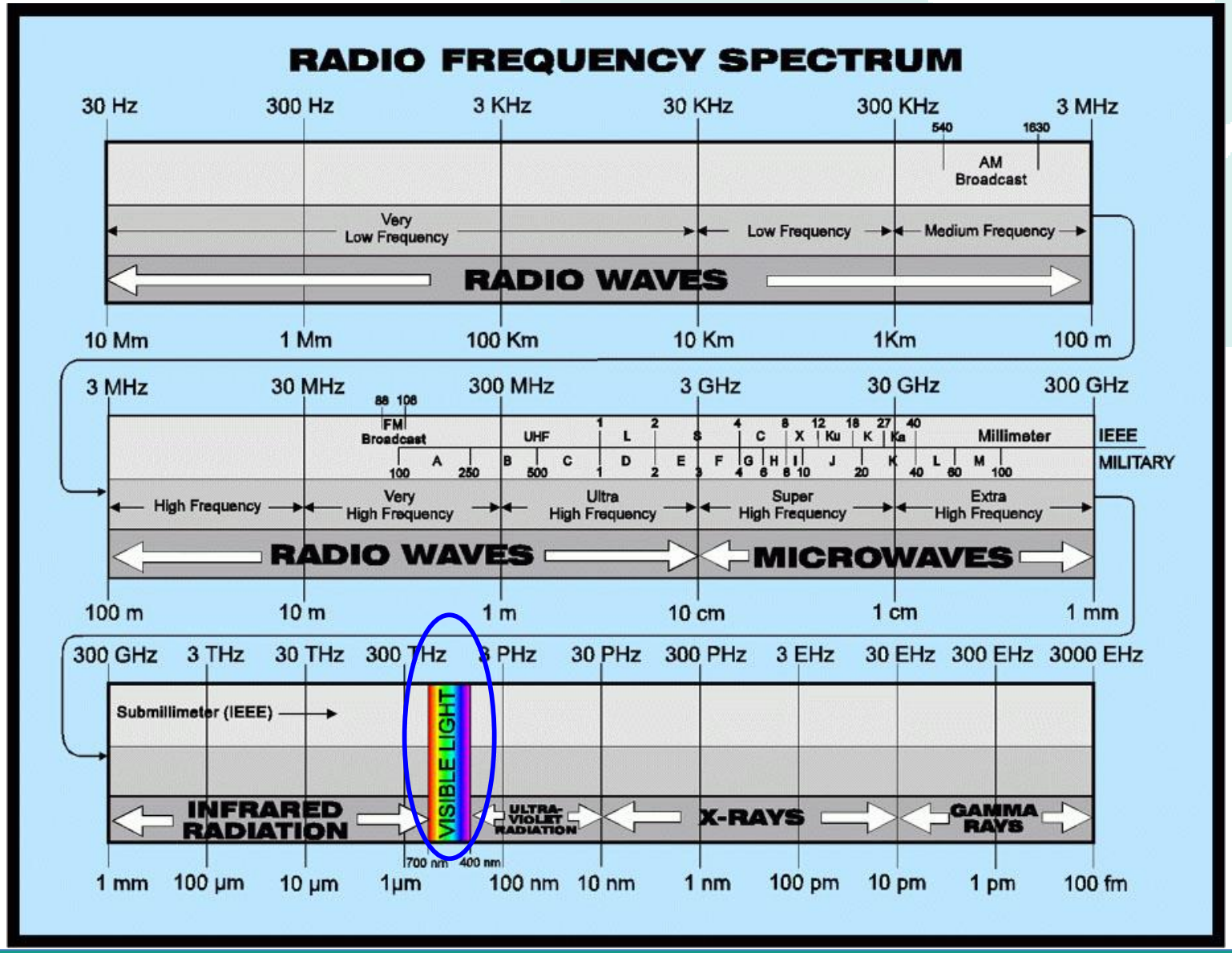
Passive: Source of energy is either the Sun or Earth/atmosphere

- Sun
  - Wavelengths from 0.4 to 5 μm
- Earth or its atmosphere
  - Wavelengths from 3 μm to 30 cm

Active: Source of energy is part of the system

- Radar
  - Wavelengths from mm to m
- Lidar
  - Typically around 1 μm

There are a lot of regions of the electromagnetic spectrum that are used in remote sensing



EXAMPLE

Precipitation

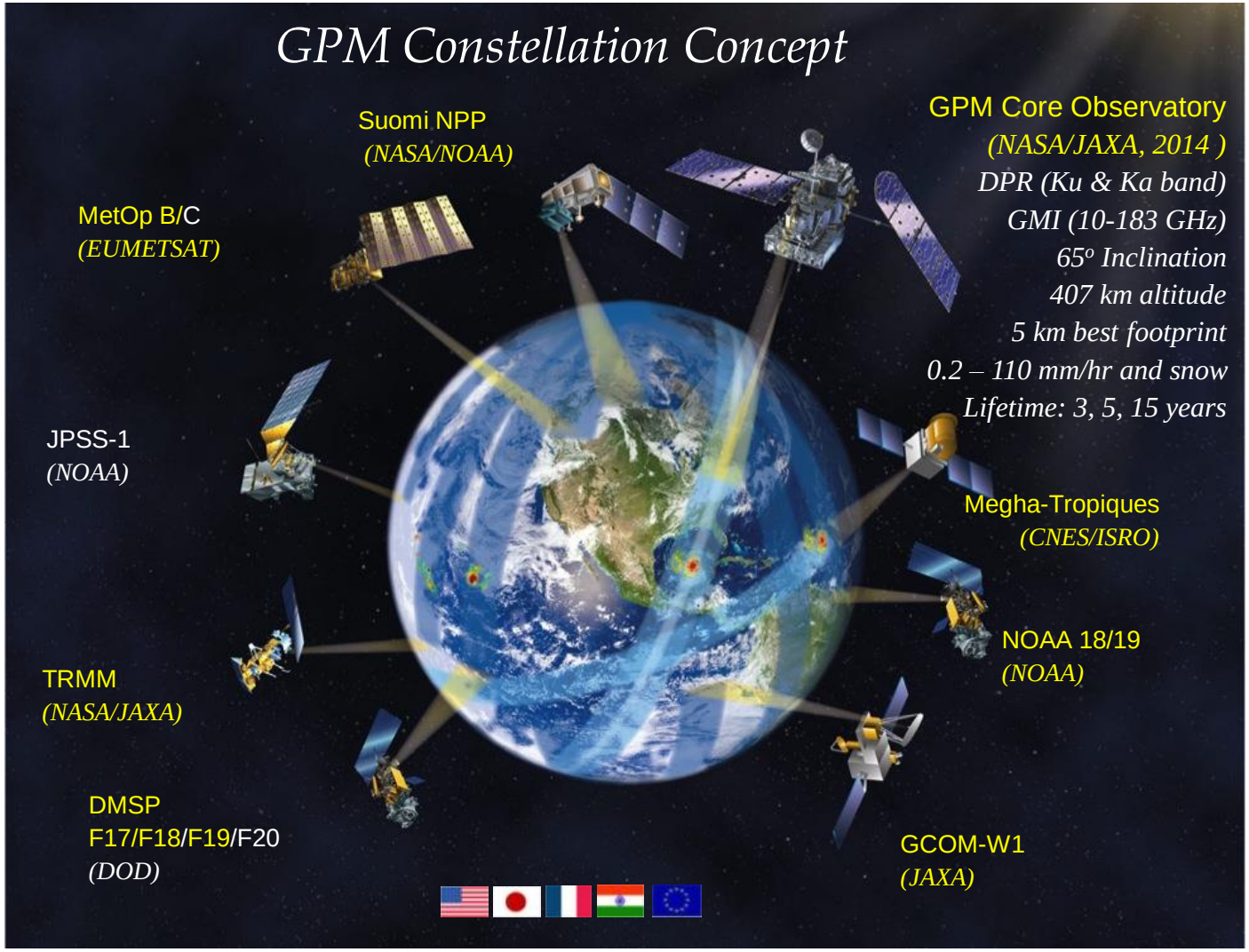
I. **Gauges**
II. **Satellite**
III. **Radar**

- Satellite Precipitation: *Tropical Rainfall Measuring Mission* (TRMM) & *Global Precipitation Measurement* (GPM) mission

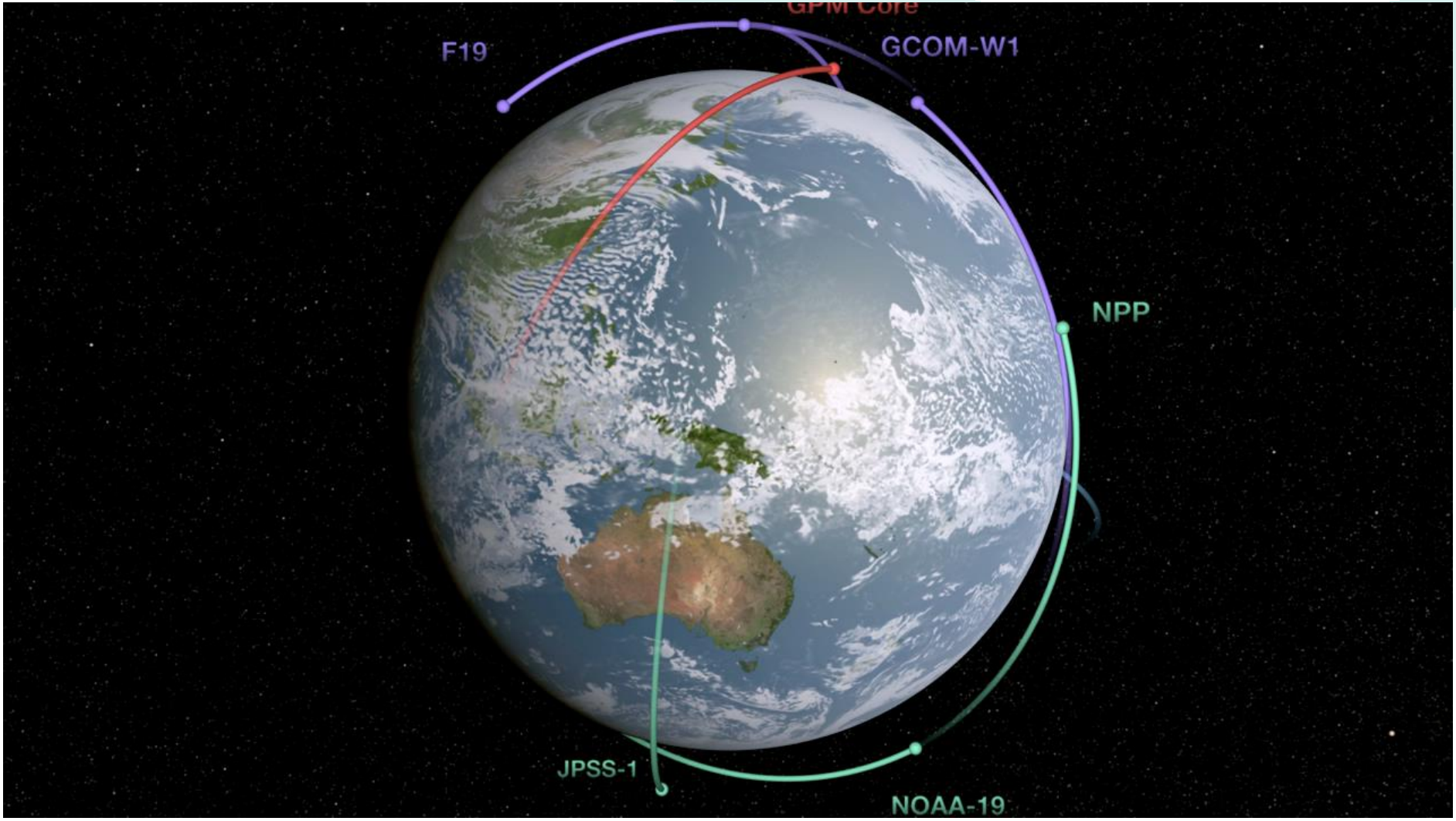
- Weather radar:

  C-band & X-band

Satellite Precipitation Measurements:
TRMM and GPM Missions



Next-Generation Unified Global Precipitation Products Using GPM Core Observatory as Reference


GPM Core
F19
GCOM-W1
NPP
JPSS-1
NOAA-19

TRMM satellite

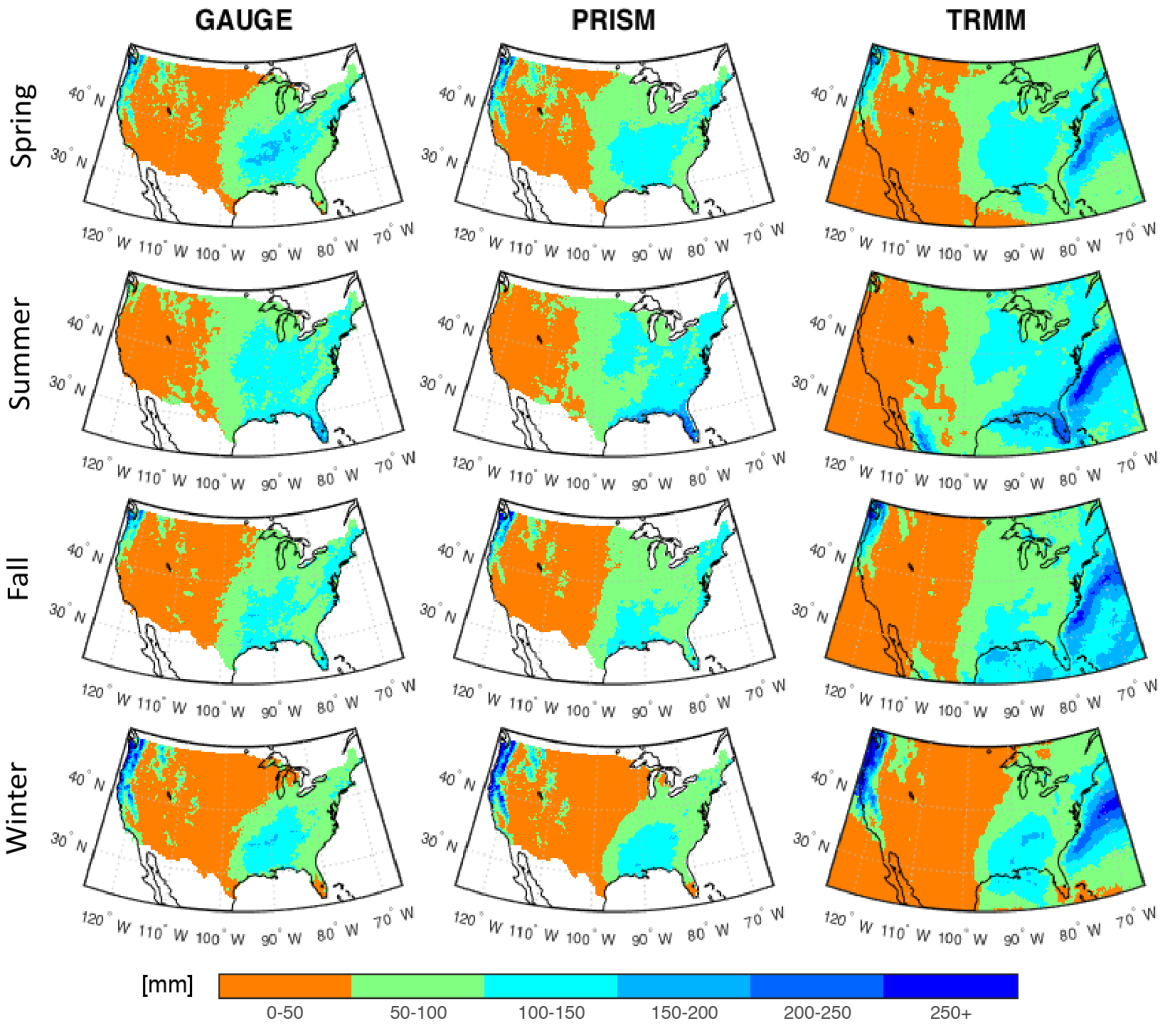
- Launch date: 1997
- Terminated: 2015
- Mission: precipitation measurements in the tropical and subtropical regions (-50°,+50°)
- Orbit altitude: 403 km
- Five instruments
- Spatial resolution: 0.25 degree
- Temporal resolution: hourly

GPM satellite

- Launch date: 2014
- Terminated: present
- Mission: precipitation
- measurements in the tropical
- and subtropical regions (-60°,+60°)
- Orbit altitude: 407 km
- Five instruments
- Spatial resolution: 0.1 degree
- Temporal resolution: half-hourly

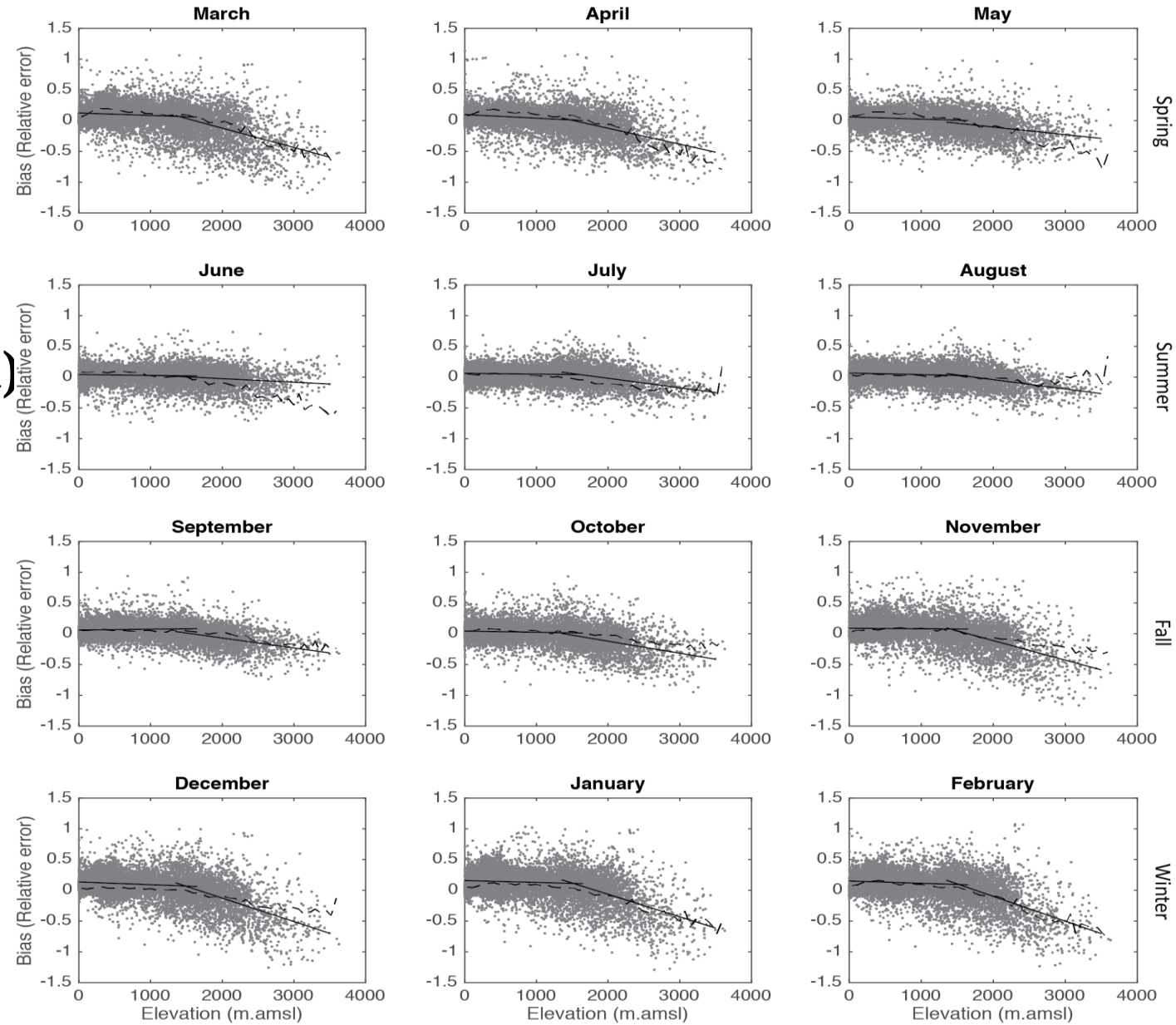
- Gridded gauge data set
- PRISM data set
- TRMM 3B43 data set

1998-2015



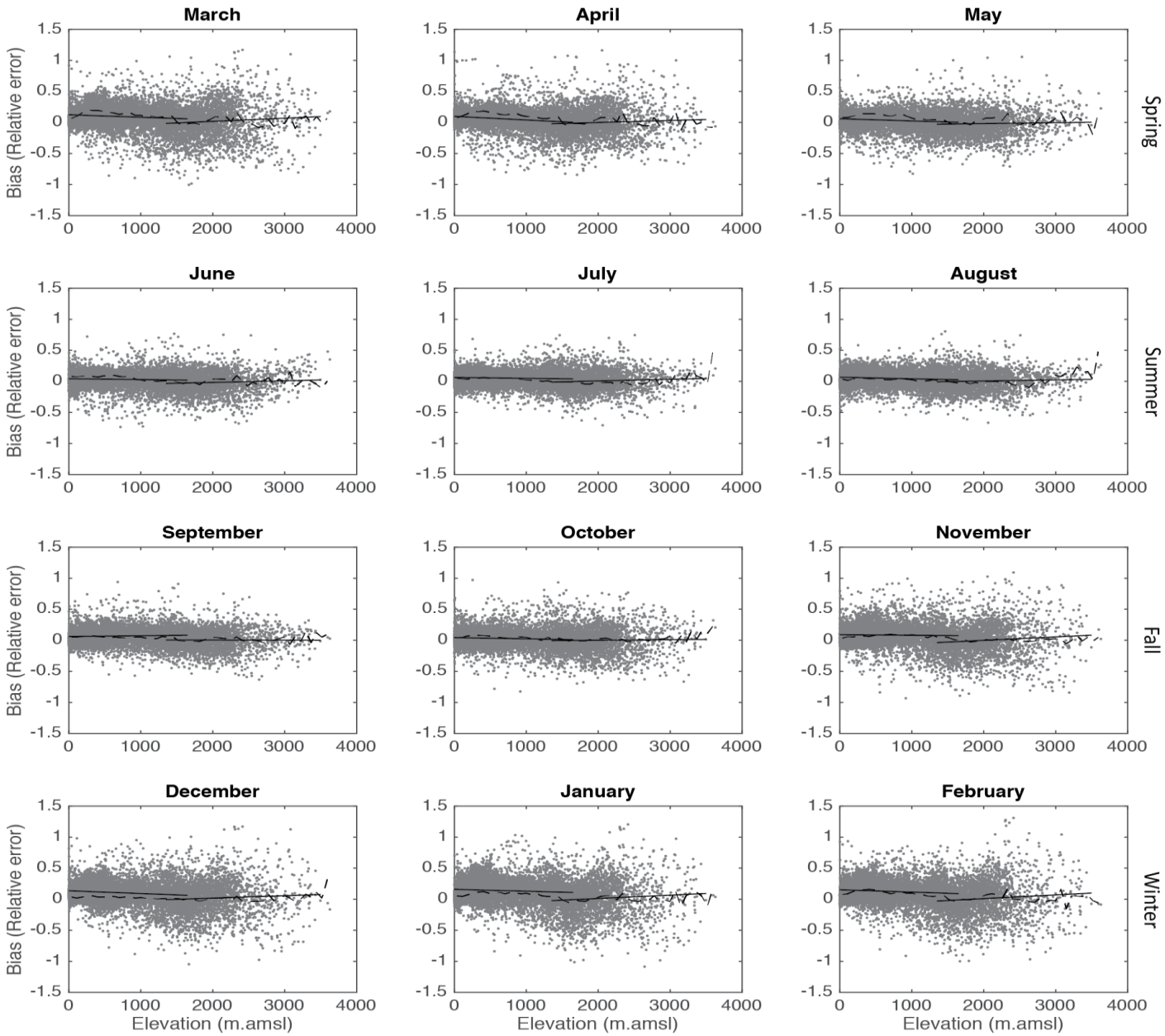
Hashemi et al., (2017)

Bias vs. elevation (before correction)



Hashemi et al., (2017)

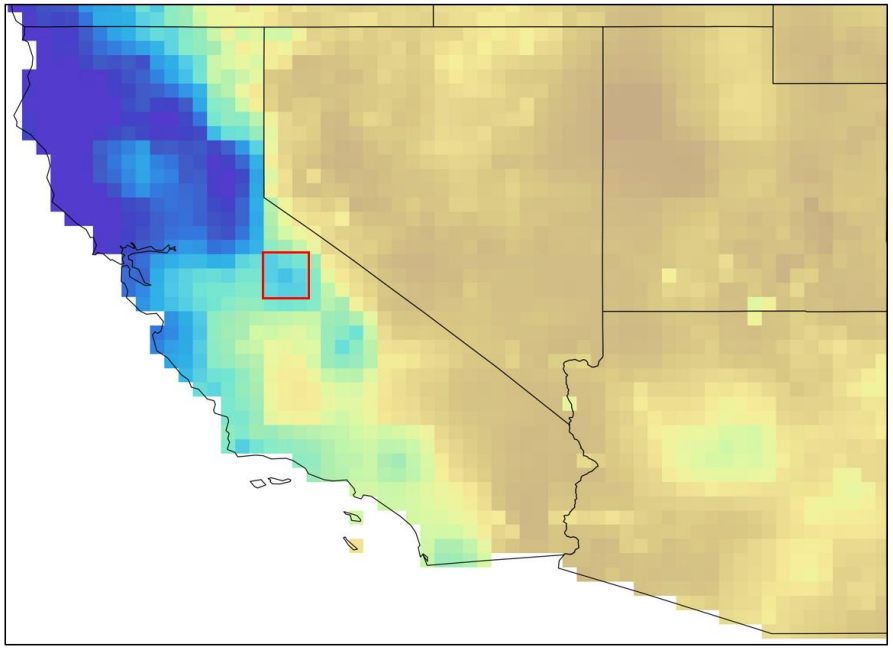
Bias vs. elevation (after correction)

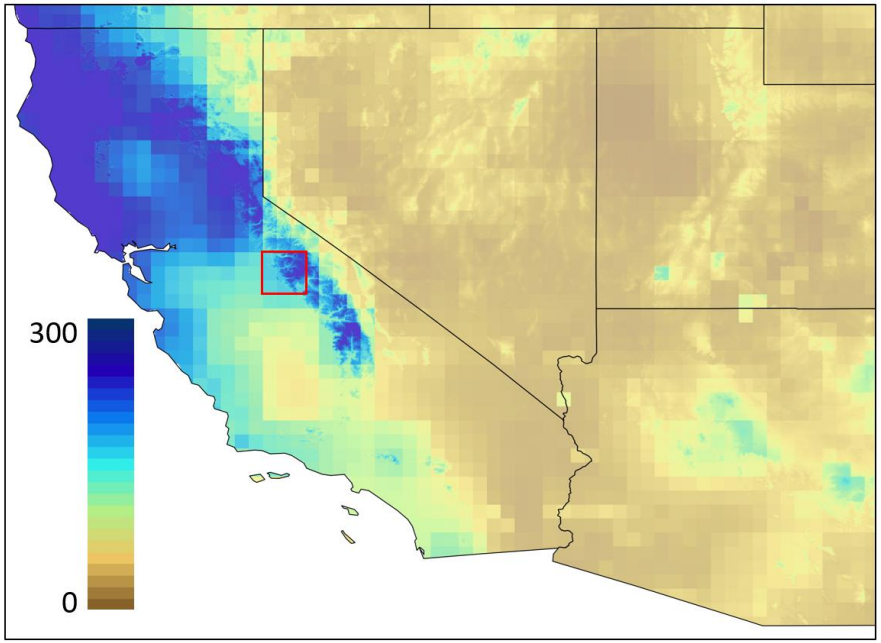


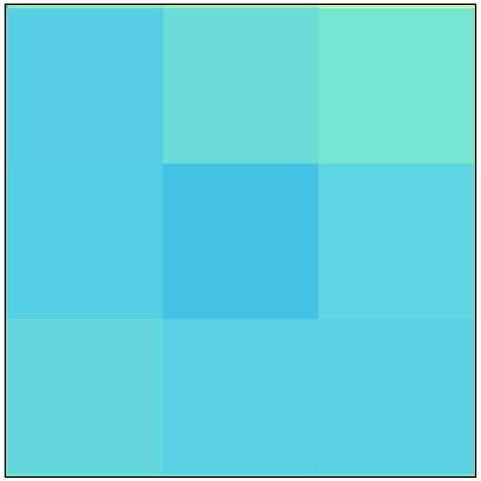
Hashemi et al., (2017)

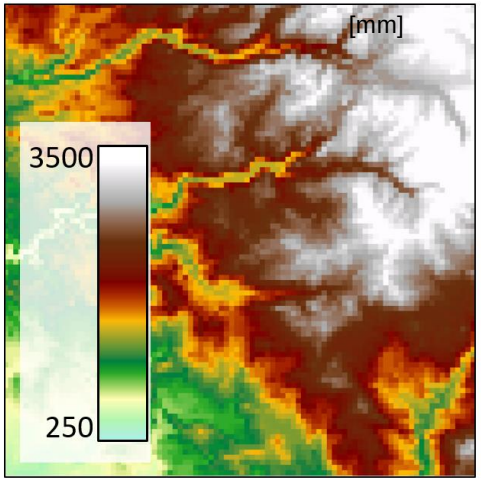
Original TRMM-3B43 (~25km)

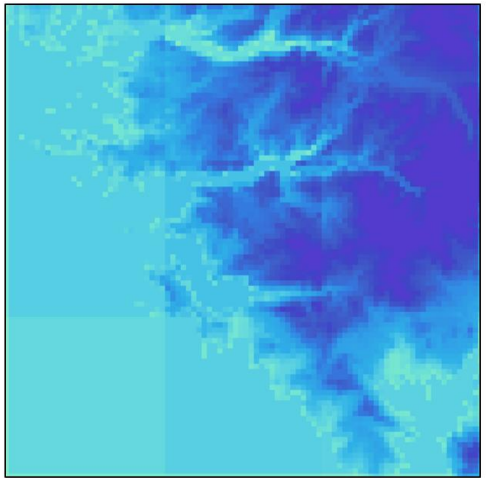
Corrected high-resolution TRMM 3B43 (~1km)







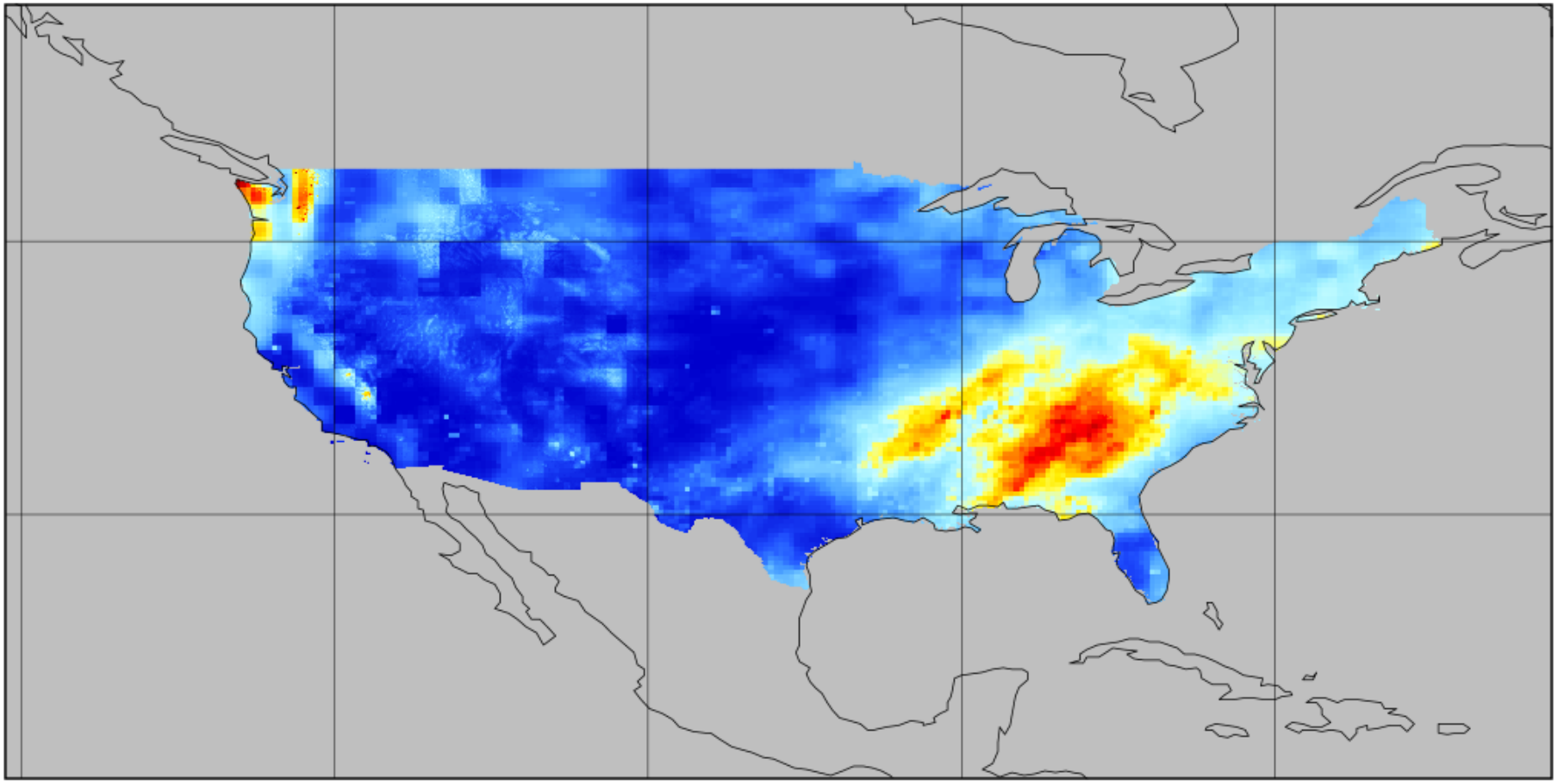




Hashemi et al., (2020)

January 1998

High Resolution Altitude Corrected (HRAC) Precipitation from TMPA and other sources

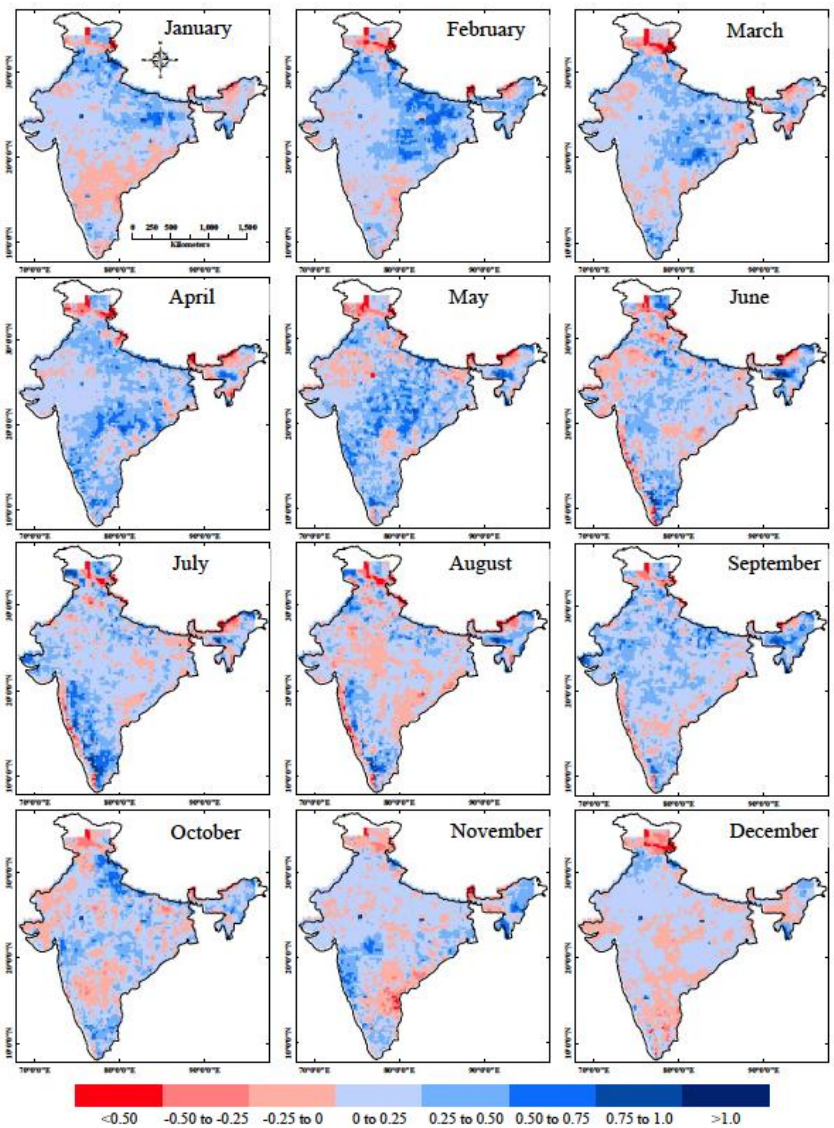


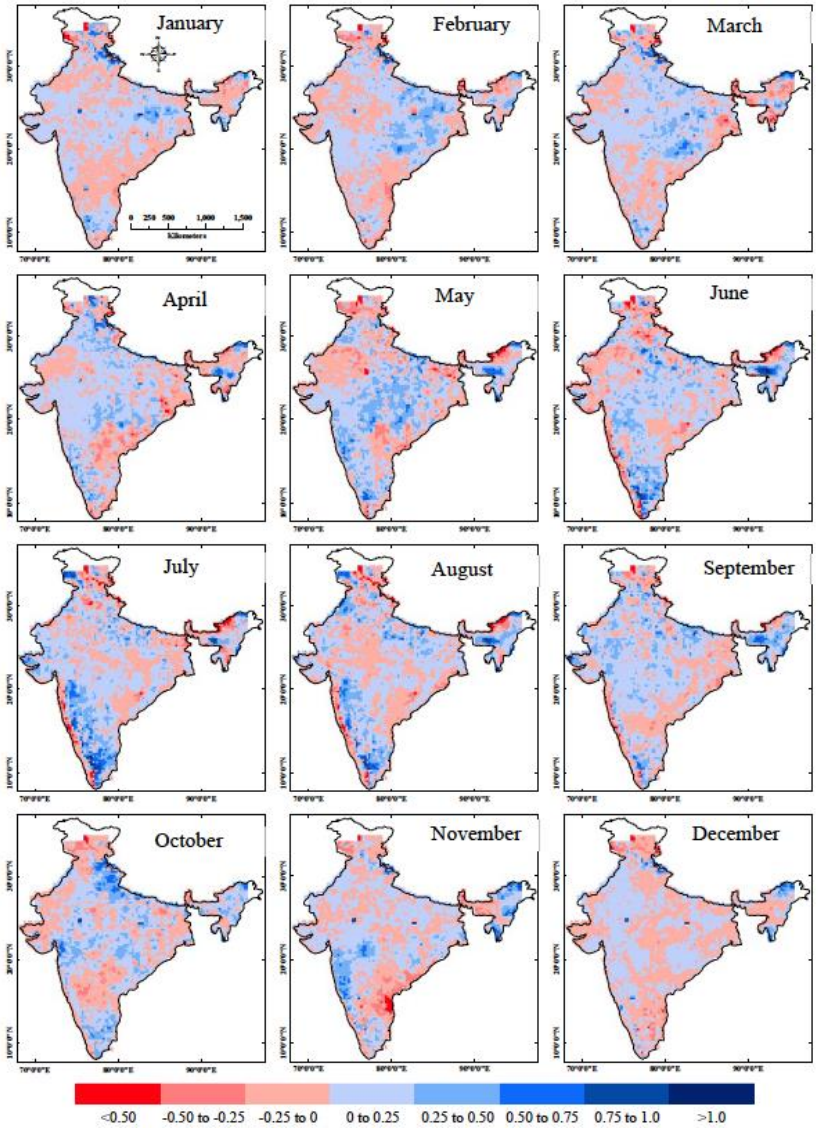
High Resolution Altitude Corrected (HRAC) Precipitation from TMPA and other sources (mm/hr)

Data Min = 0.0, Max = 0.8

India (TRMM)

Bias - Original TRMM

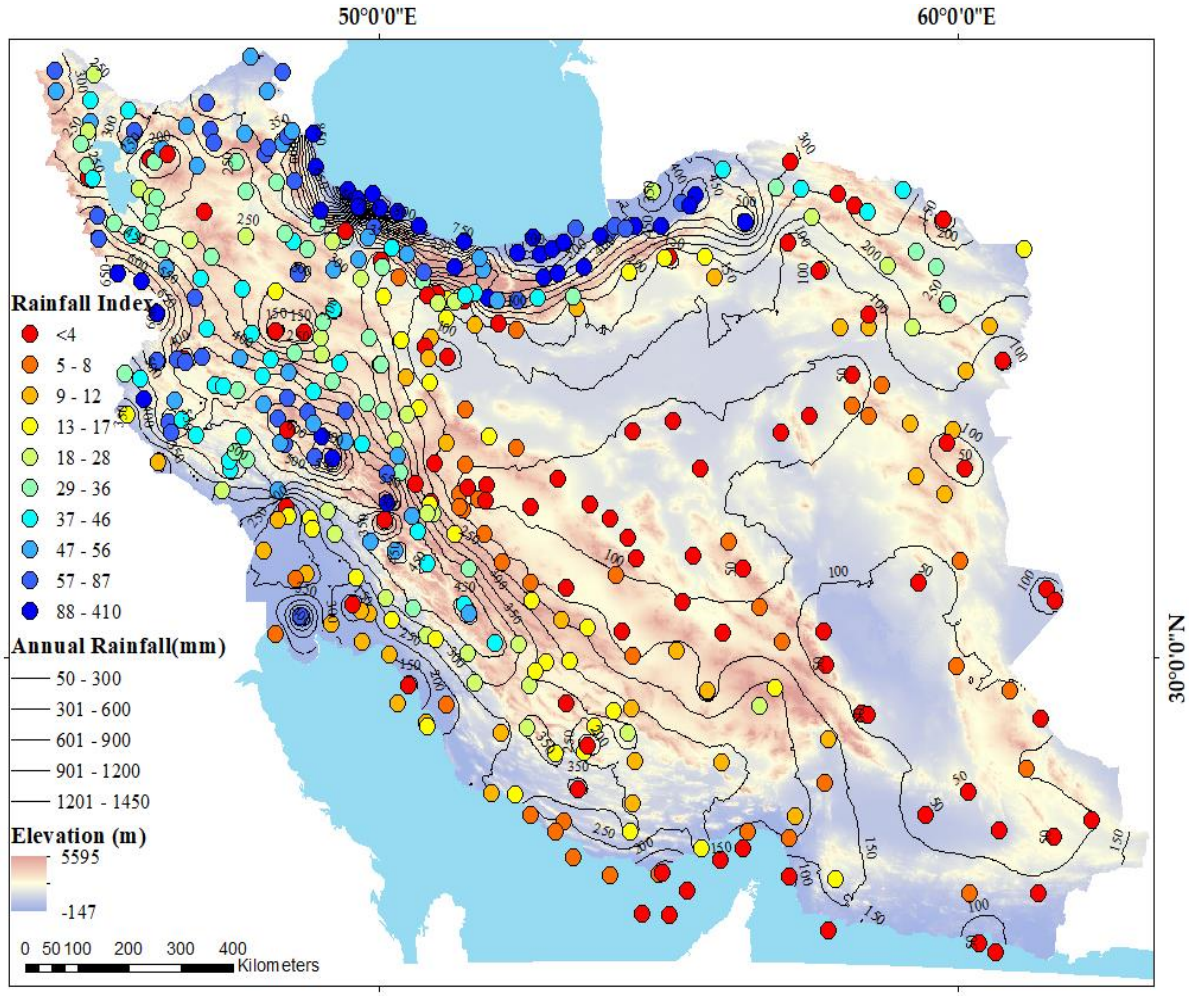


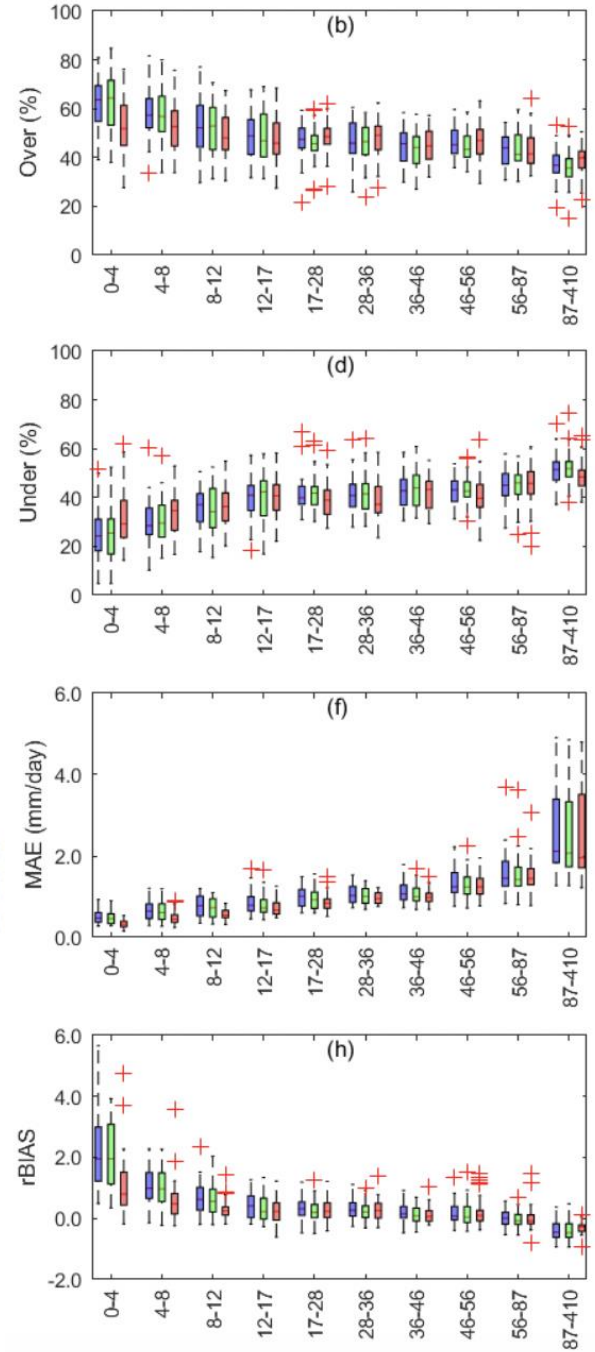


Bias - Corrected TRMM

Mondal et al., (2018)

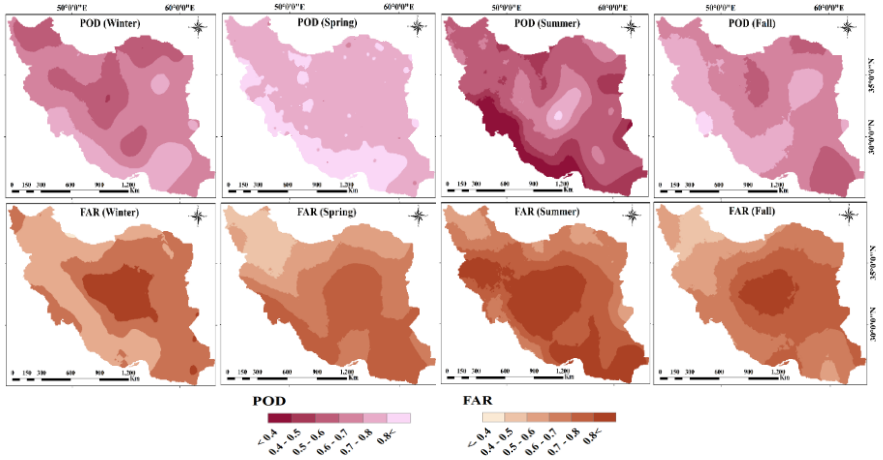
Iran (GPM IMERG)

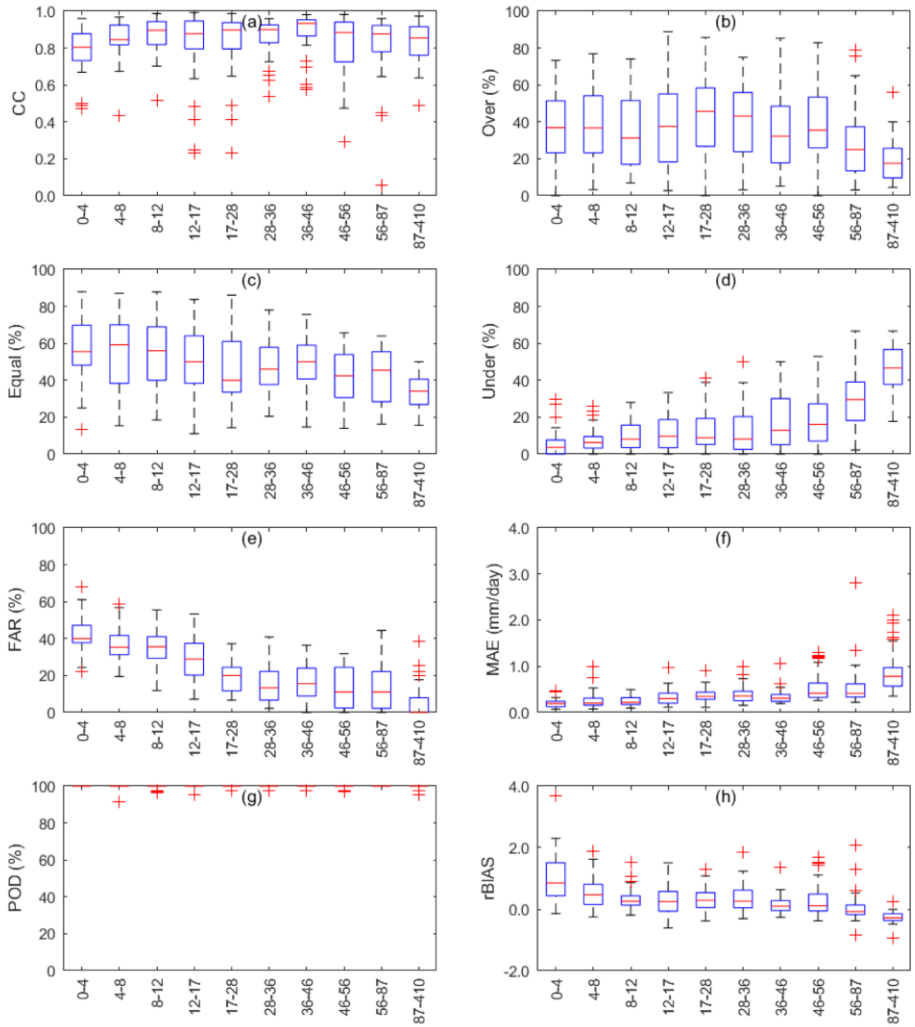




Maghsood et al., (2020)

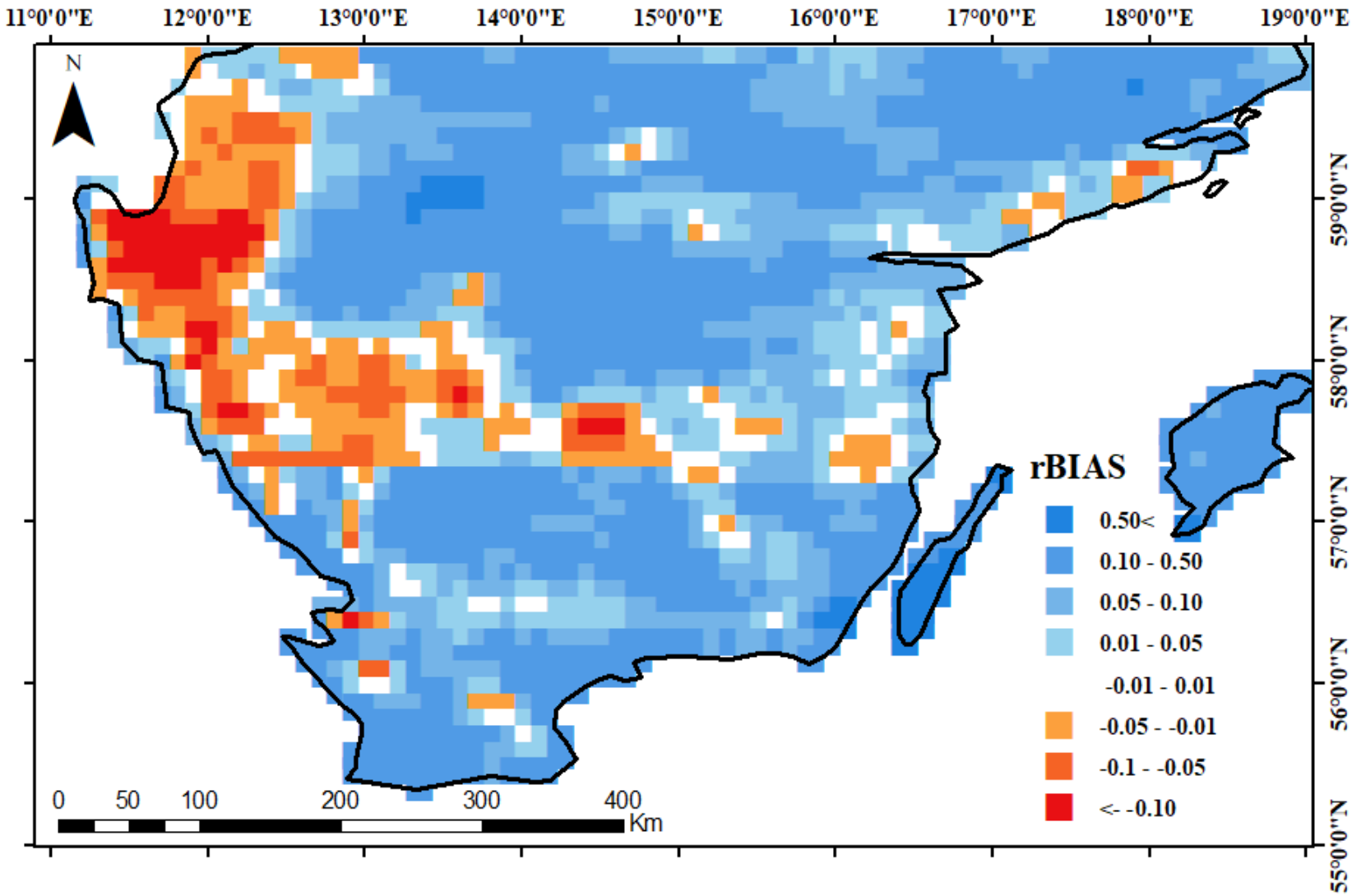
Iran (GPM IMERG)



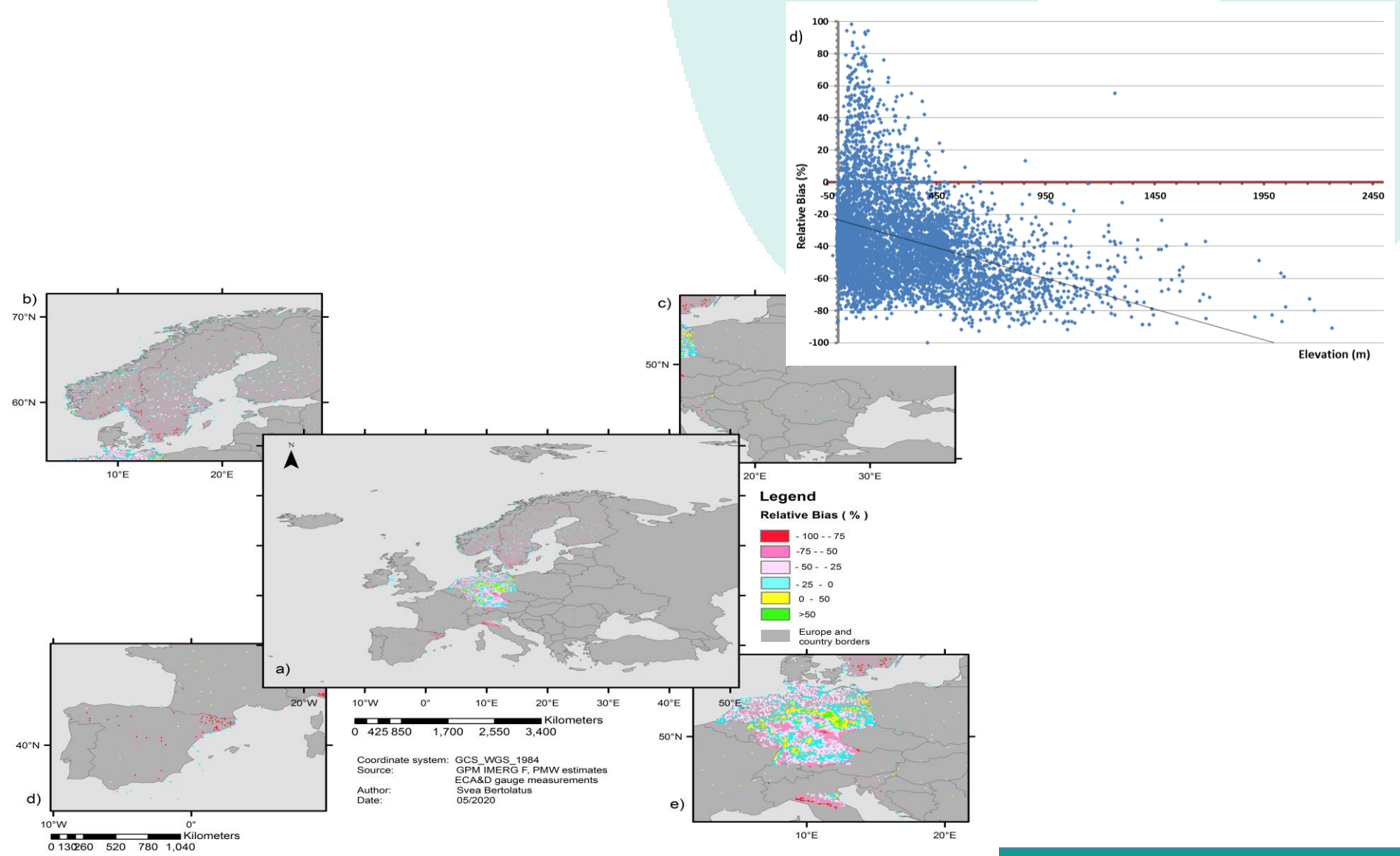


Maghsood et al., (2020)

C-band Radar (HIPRAD) vs. GPM IMERG



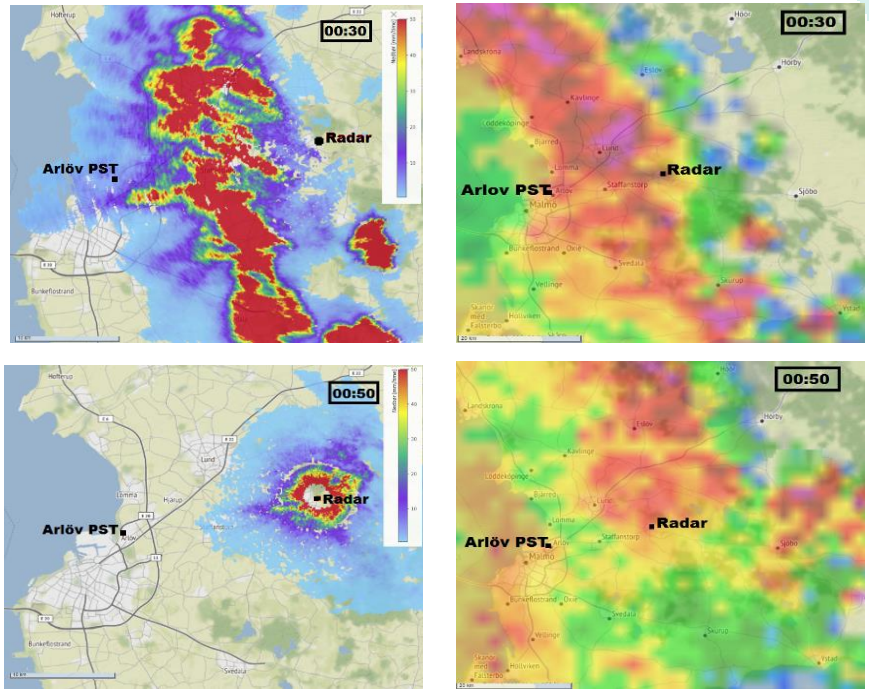
GPM performance over Europe

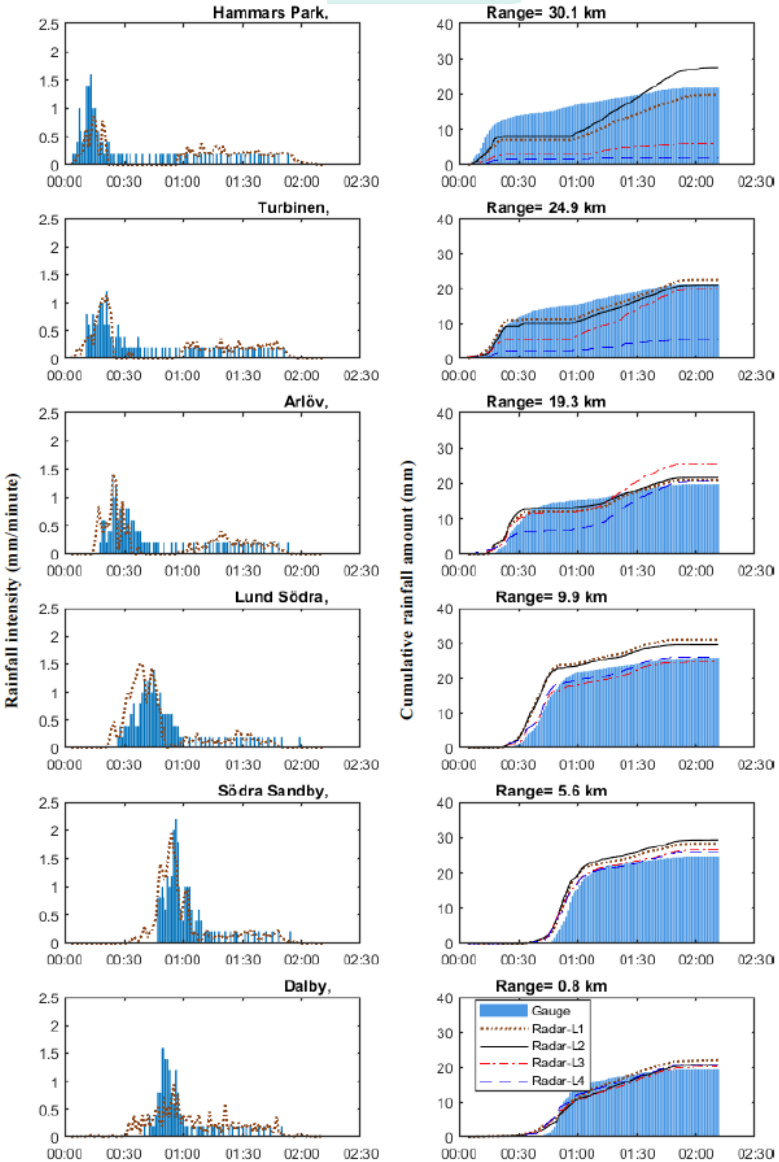


X-band Weather Radar

X-band WR

C-band WR

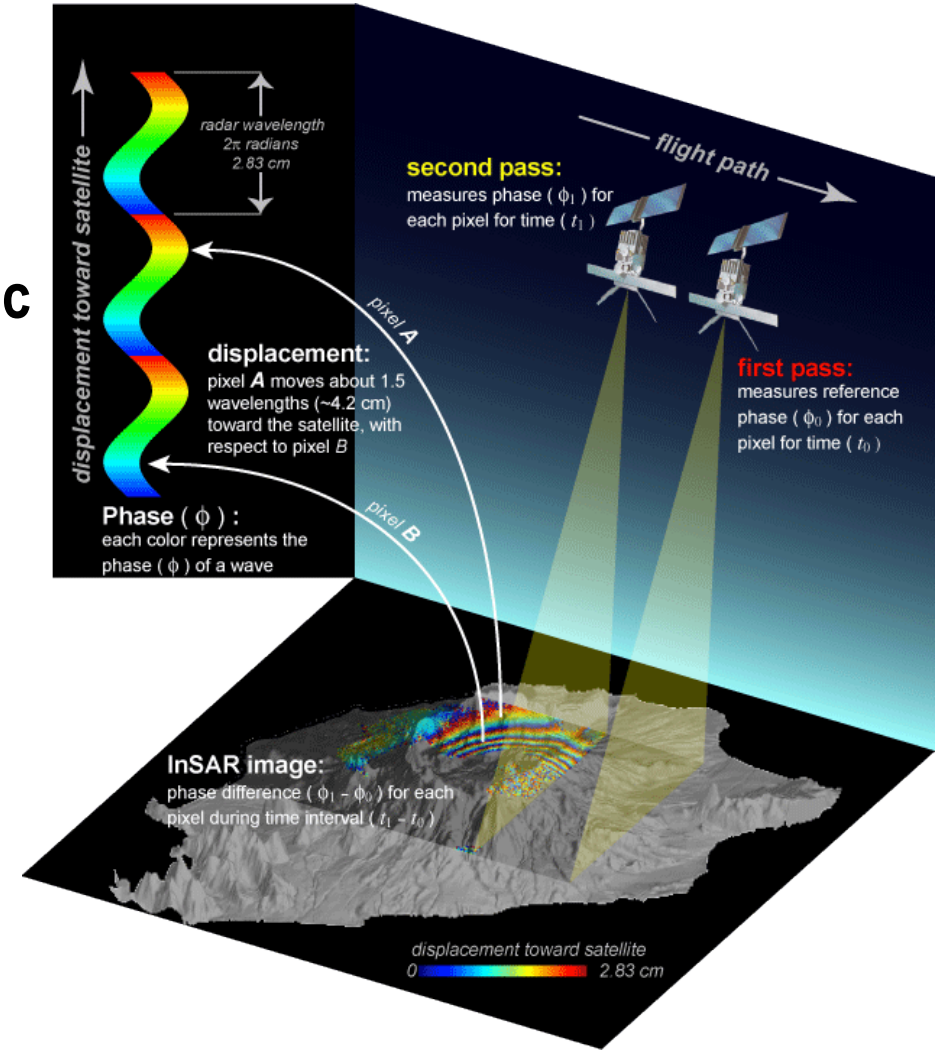




Hosseini et al., (2020)

Groundwater evaluation

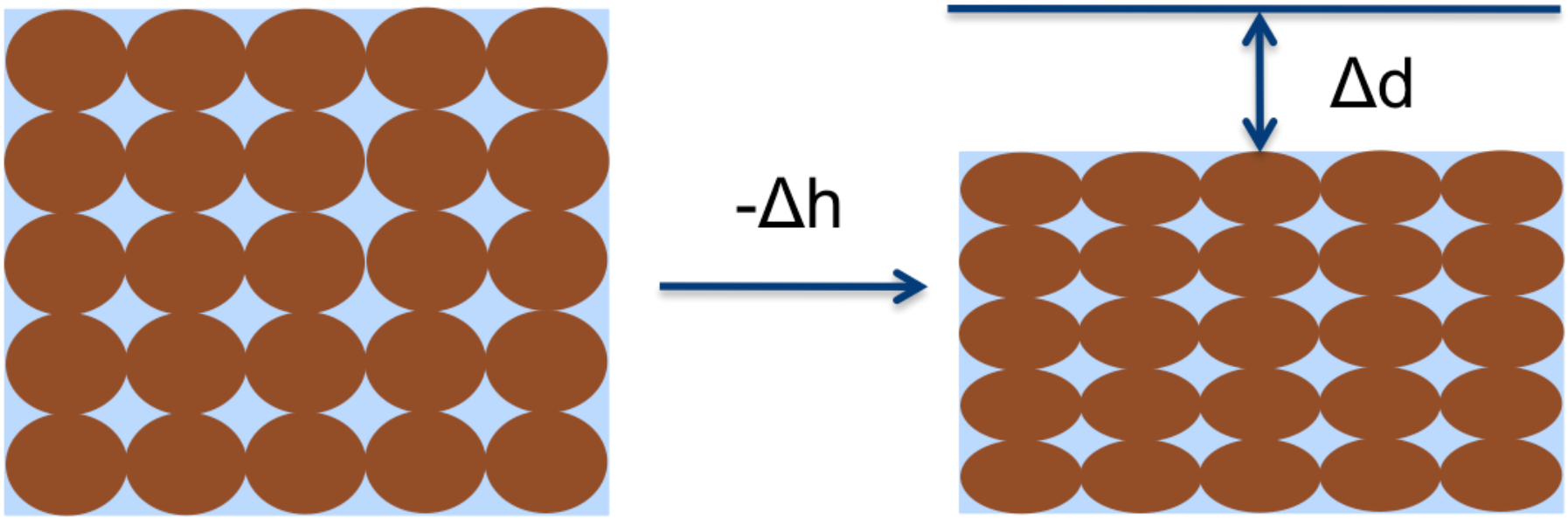
Ground deformation – Interferometric Synthetic Aperture Radar (InSAR)



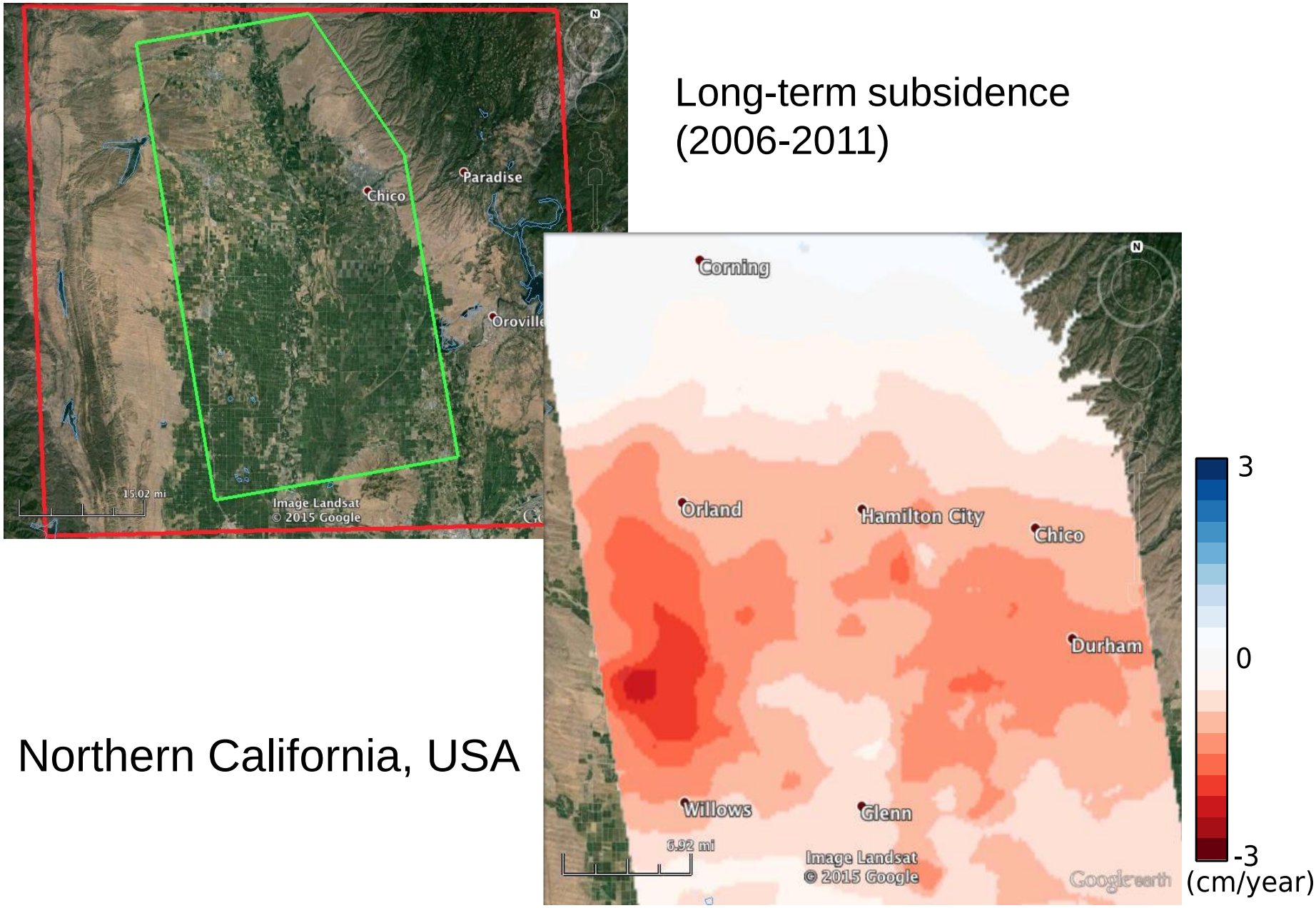
If we know the topographic height of pixel *A*, we can further measure any small ground deformation Δd along LOS direction occurring at pixel *A* between t_1 and t_2:

Measure groundwater levels in (semi-)confined aquifer

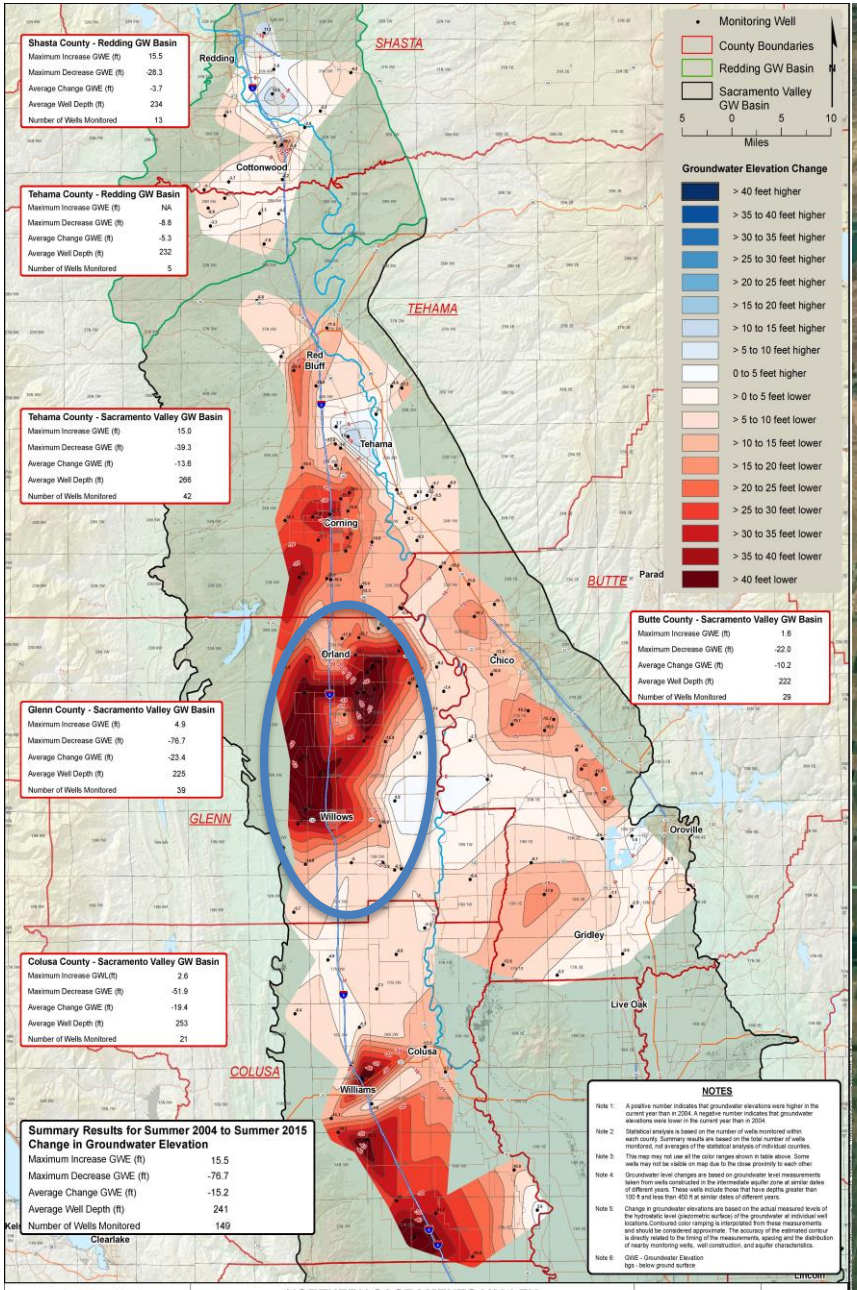
For a (semi-)confined aquifer system, head drop leads to effective stress increase and surface subsidence [Terzaghi, 1925].

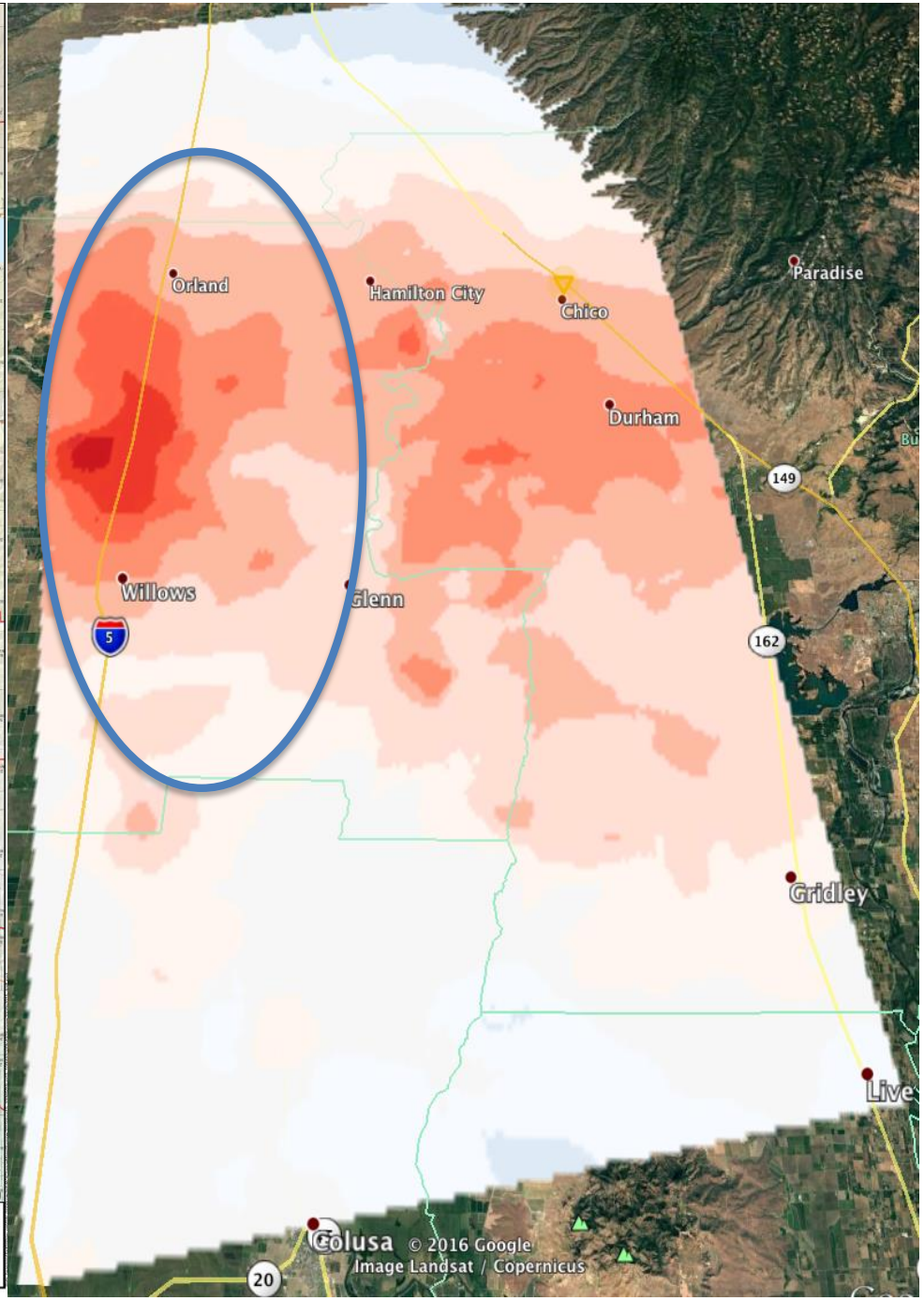


Long-term subsidence
(2006-2011)



Northern California, USA





STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE
2440 Main Street
Red Bluff, California 96080
(530) 529-7300

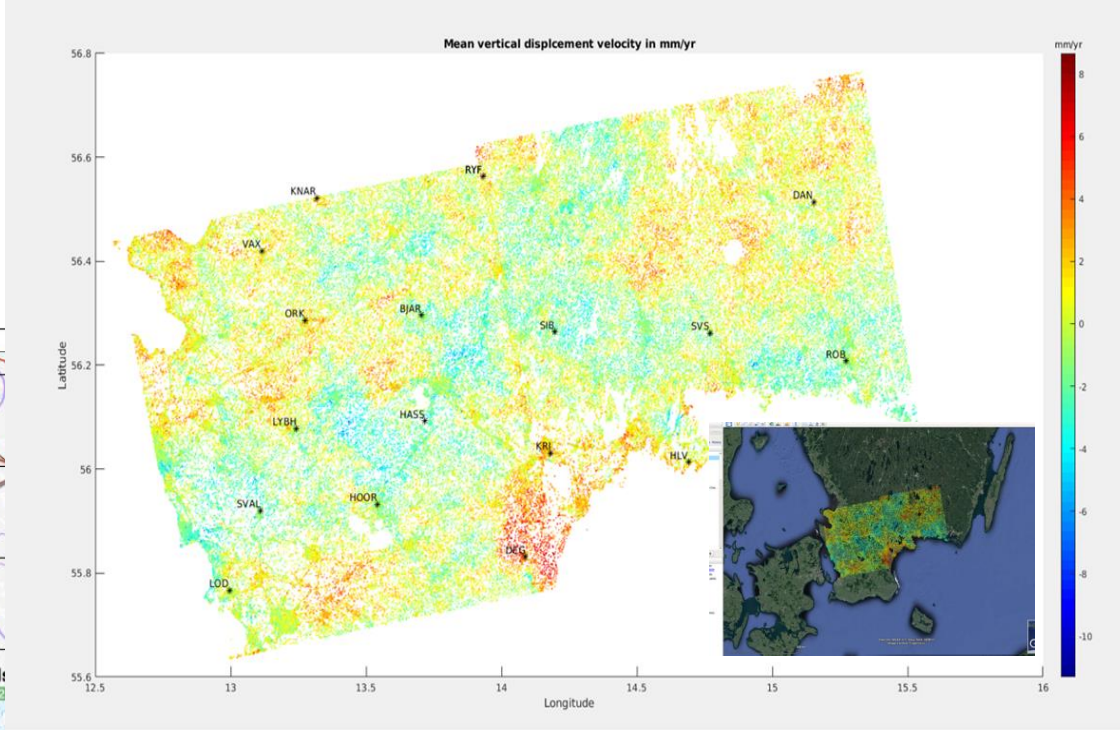
NORTHERN SACRAMENTO VALLEY
CHANGE IN GROUNDWATER ELEVATION MAP
SUMMER 2004 TO SUMMER 2015
100 to 450 ft WELL DEPTHS
(Well depths greater than 100 ft and less than 450 ft deep bgs)

PLATE 2C-B
Date: September 2015
BY: G. Gordon

http://www.water.ca.gov/groundwater/data and monitoring/northern region/GroundwaterLevel/gw level monitoring.cfm

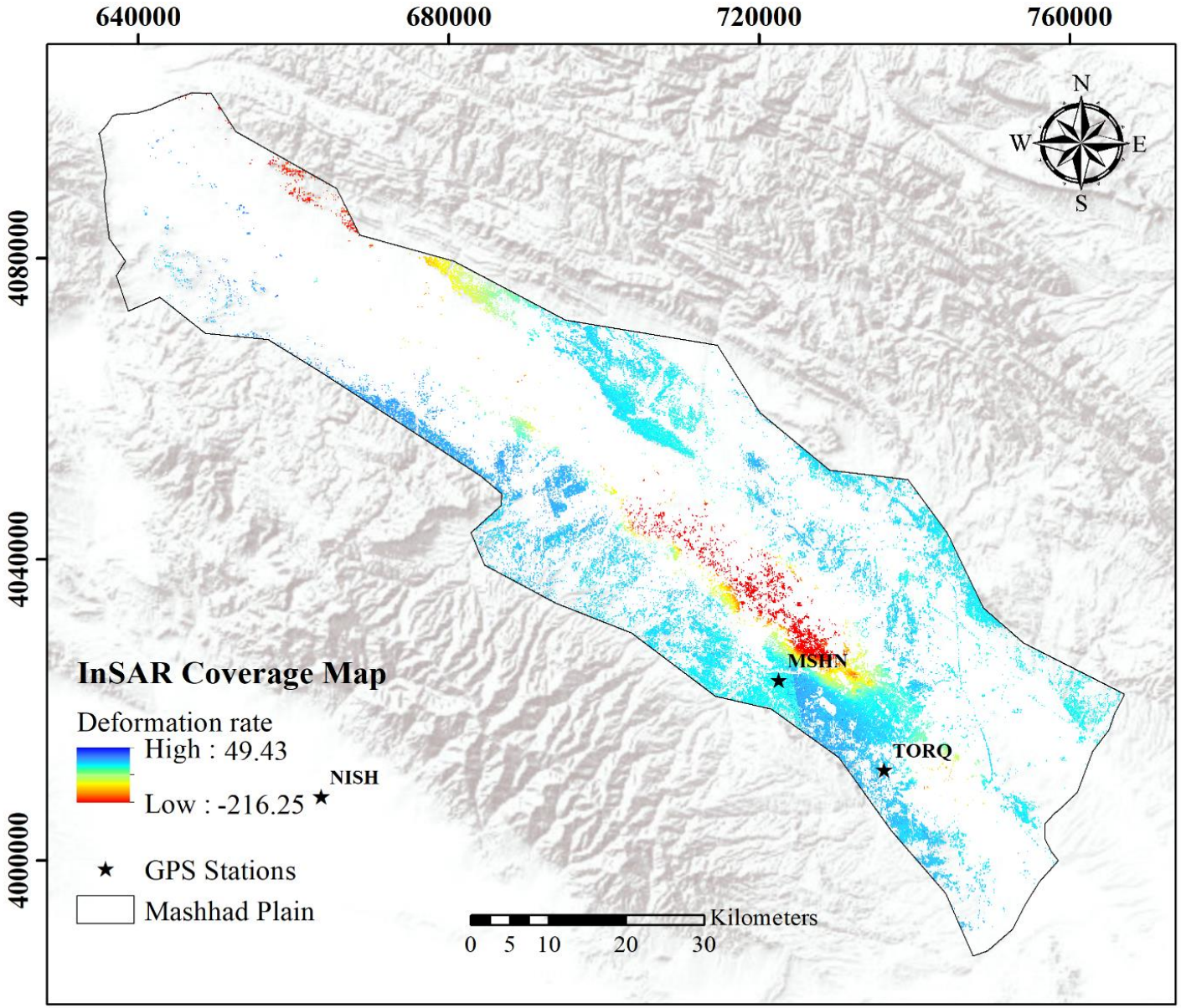
Southern Sweden

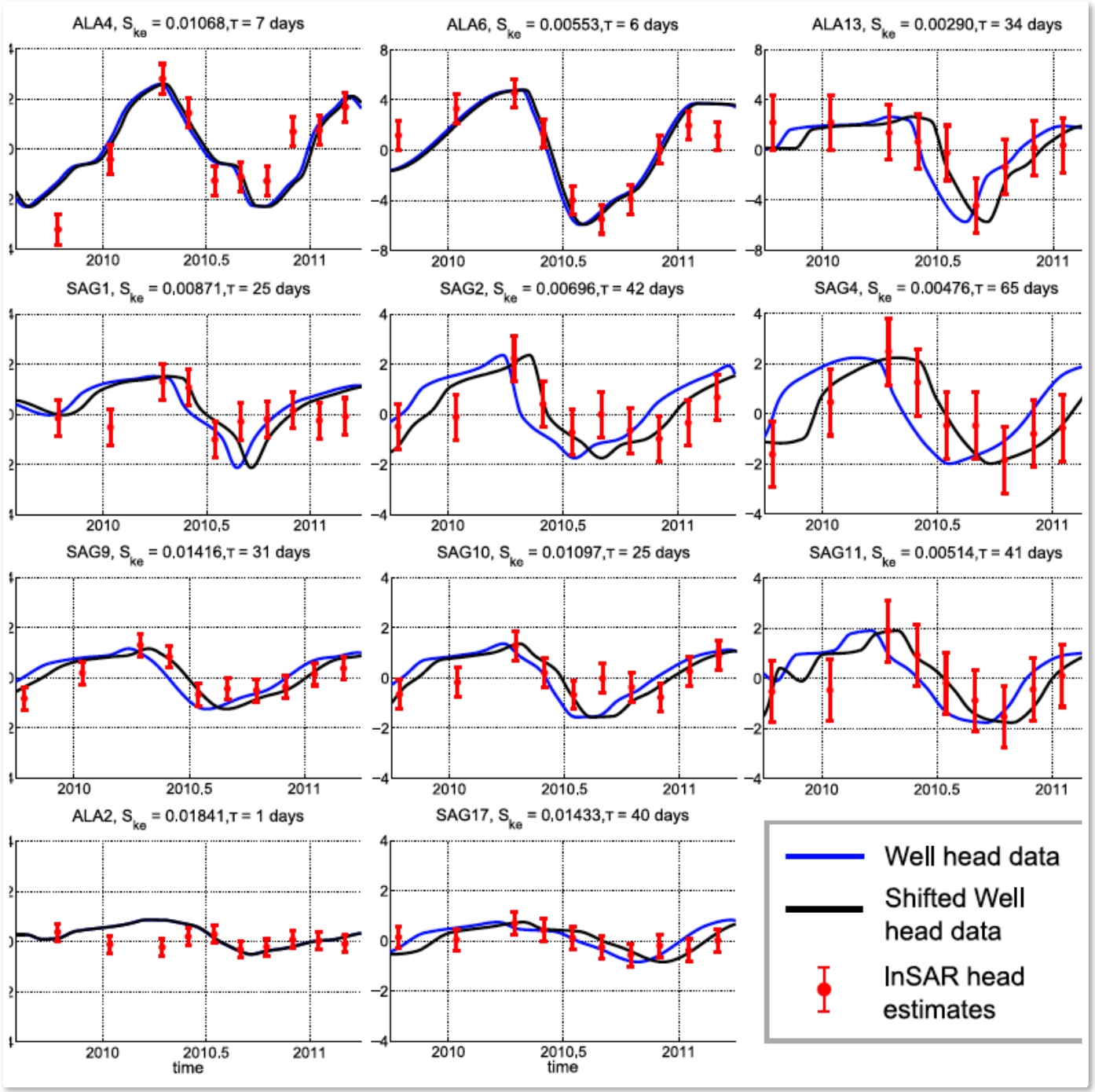
Groundwater aquifer



Deformation map

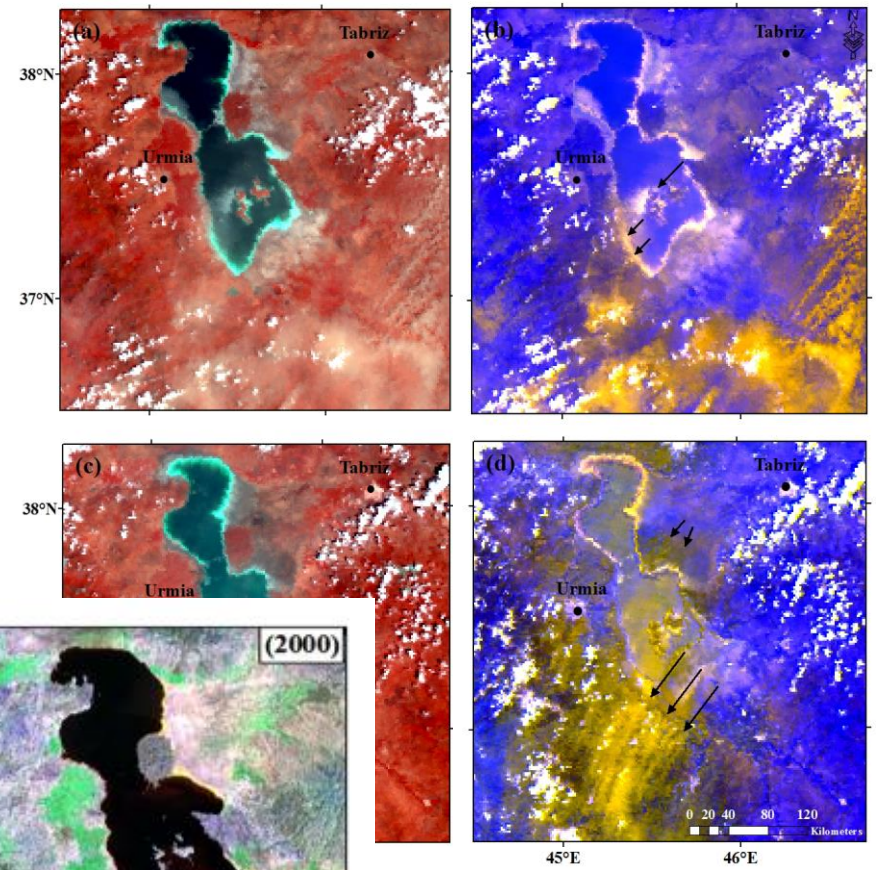
Deformation map measured by InSAR technique in north-eastern Iran

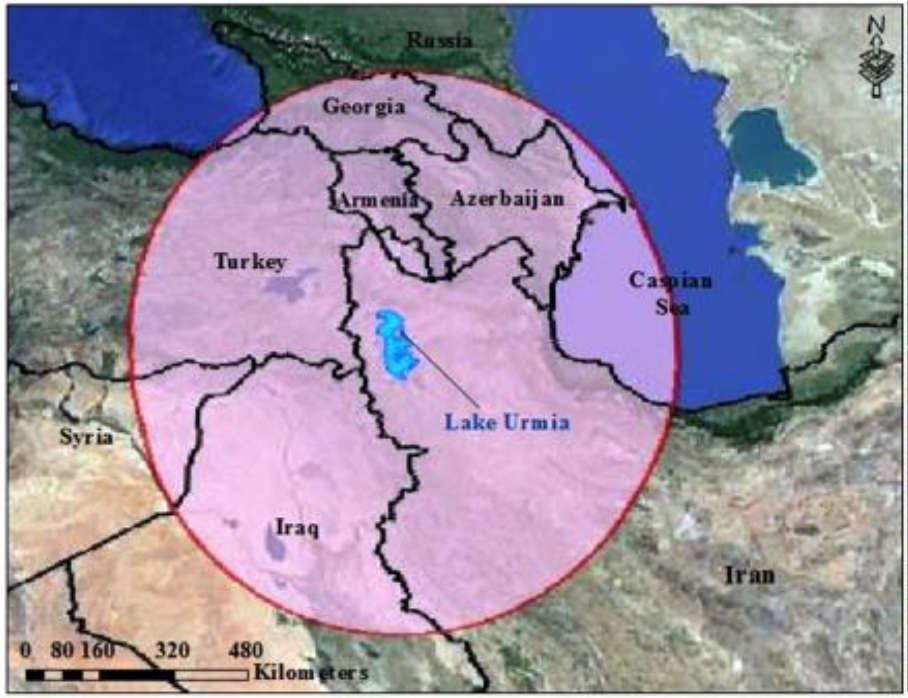


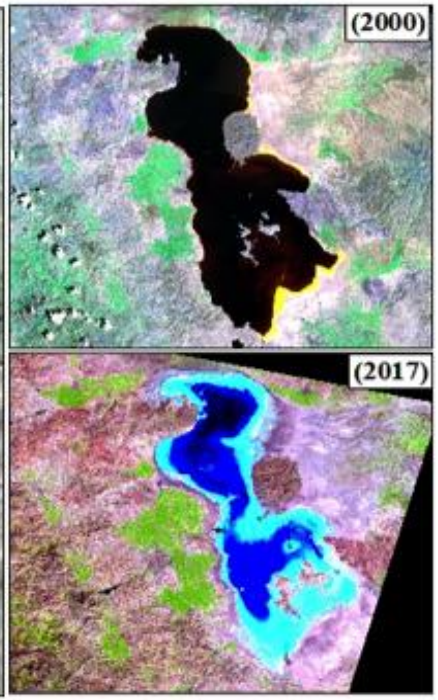


Chen et al, (2016)
Water Resources Research

Lake Urmia dust storm disaster (Iran)

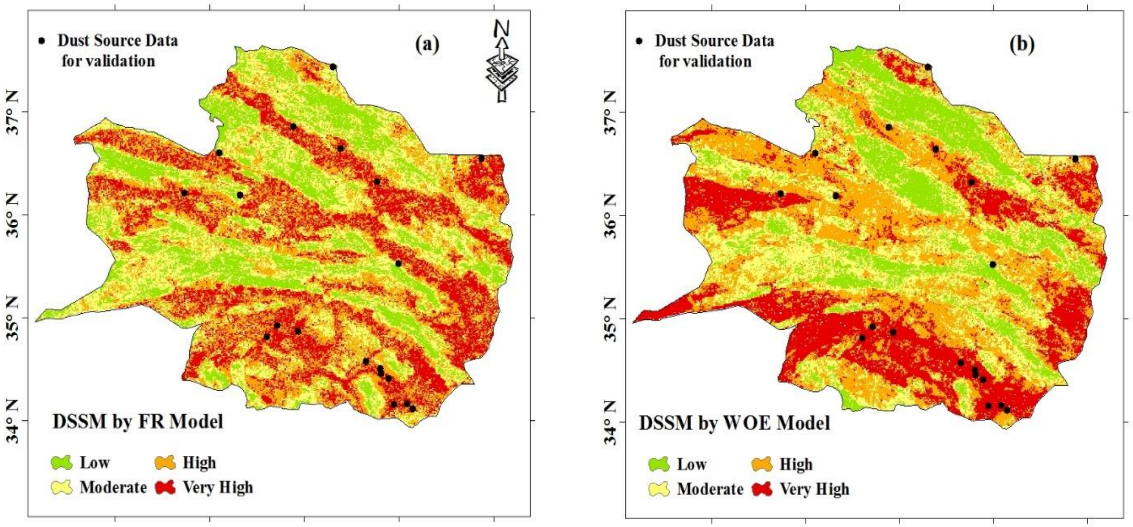


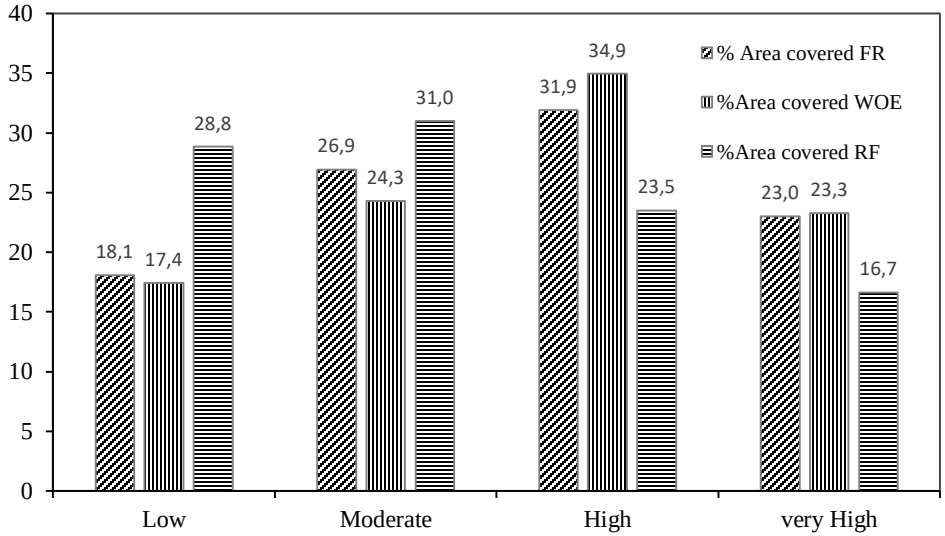


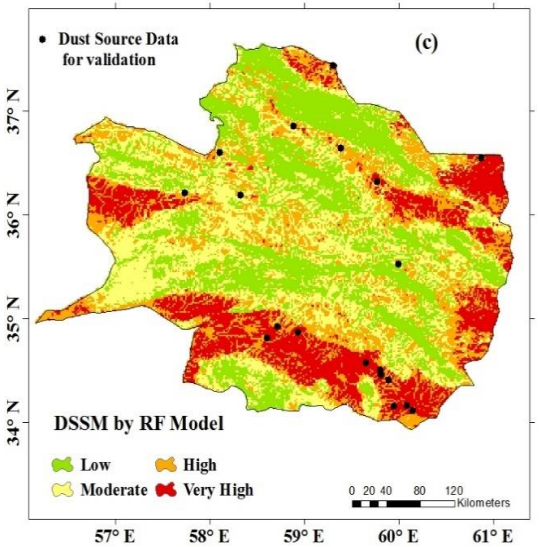


Boroughani et al., (2020)

Dust source susceptibility mapping





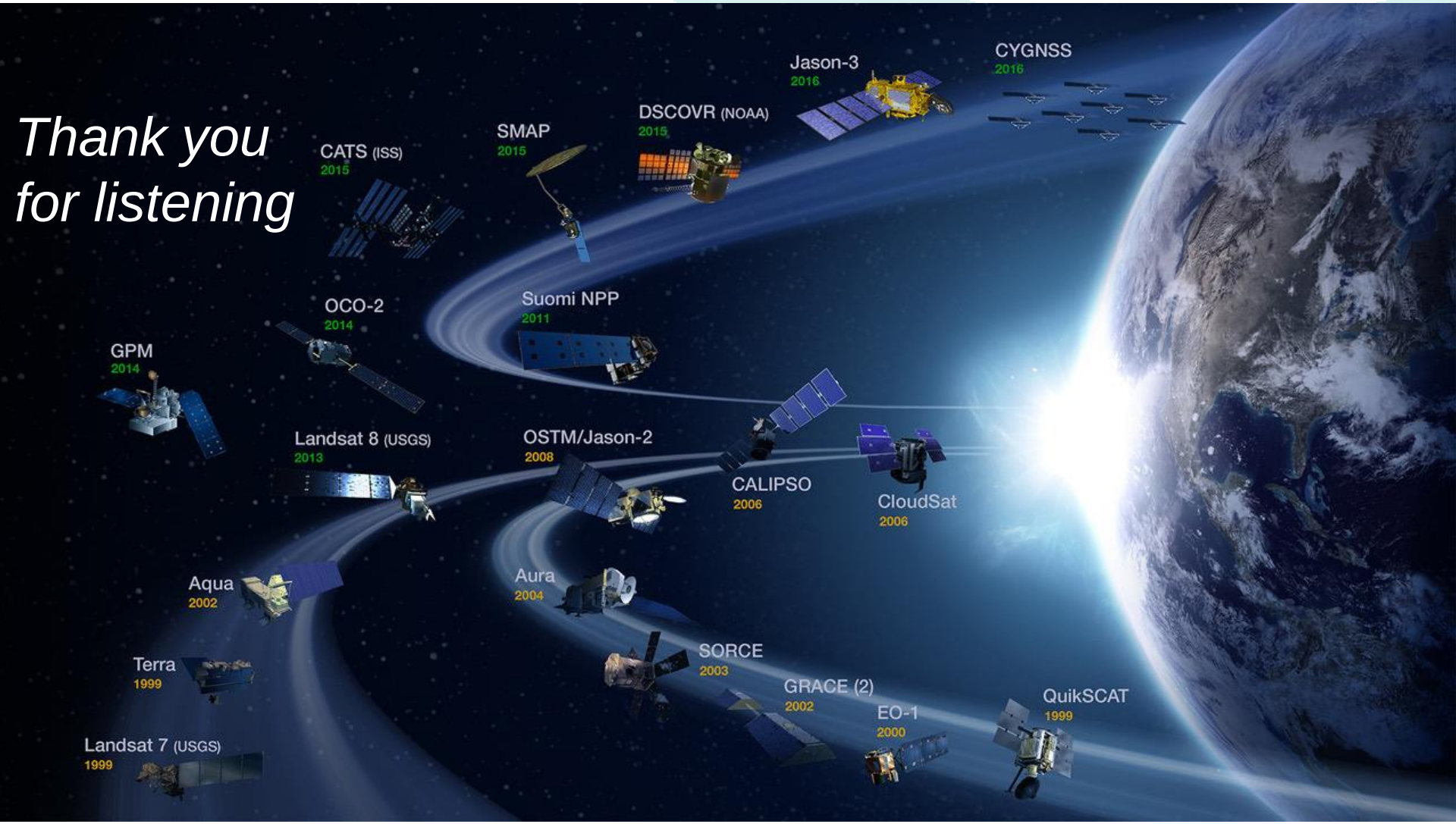


Boroughani et al., (2020)

Conclusion

- Remote sensing is the only option for obtaining routine, comprehensive hydro-environmental variables over most of the globe.
- No single data set has such fine-scale detail of hydro-environmental estimates at the global scale.
- Remote sensing assumes a central role in our science (and challenges us with new modeling and prediction paradigms), in the contemporary world.

Thank you for listening



Questions for discussion!

- Briefly describe your study basin, i.e., climate, available data, etc.
- Are you aware of any satellite-based projects in your study basin?
- Any ground-based weather radars in Tunisia?
- What type of in-situ rainfall measurement is common in Tunisia?
- Is there any report of subsidence in your region? What is causing subsidence?

That´s all for now!

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