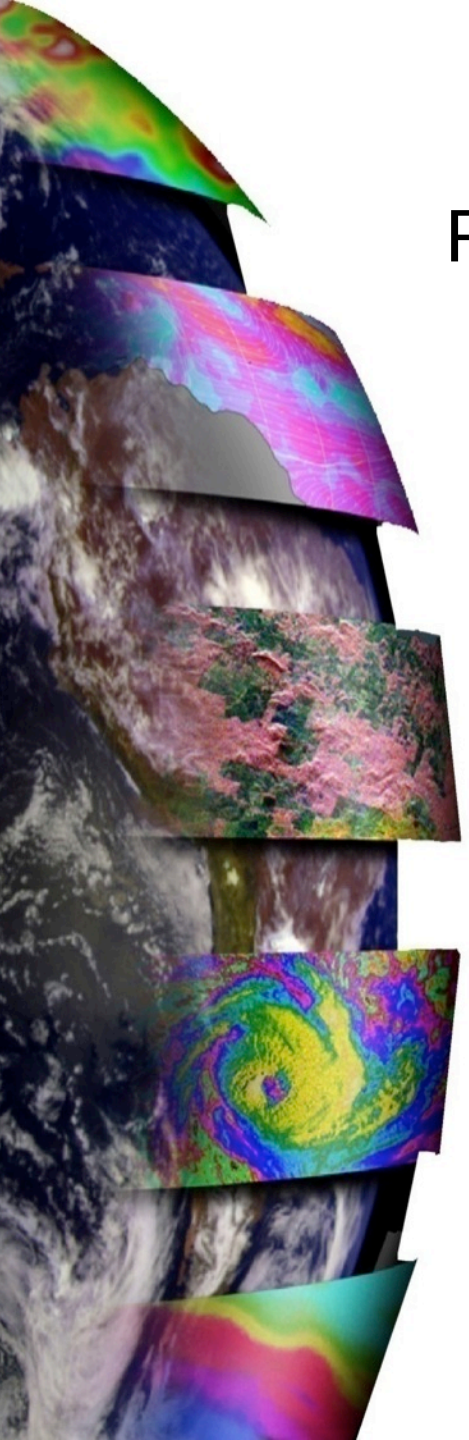
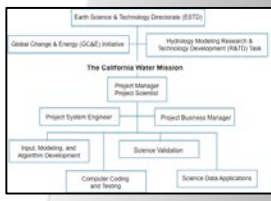


Remote Sensing and Earth Science

Science, Engineering & Technology



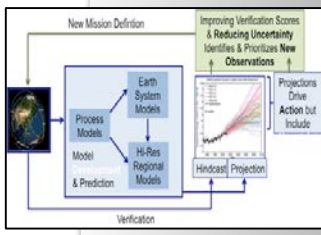
Duane Waliser

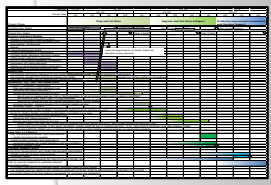
Chief Scientist

Earth Science and Technology Directorate

Jet Propulsion Laboratory

California Institute of Technology

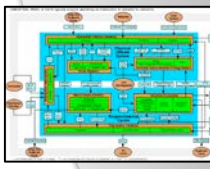




Cal Poly Pomona

CWEA-AWWA CPP Meeting

March 3, 2016



From Caltech students testing rockets to exploring the planets in our lifetime

Jet Propulsion Laboratory
California Institute of Technology

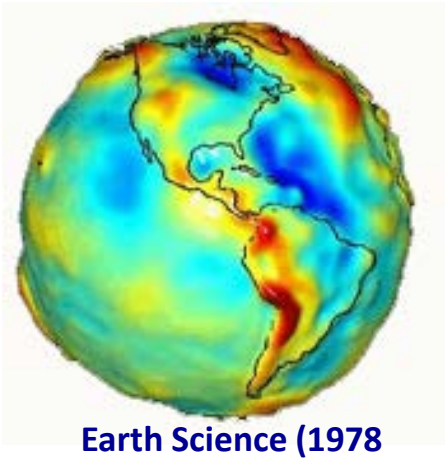
Caltech students (1936)

Missiles (1940s)

Explorer 1 (1958)

Mars Exploration Rovers (2004 – present)

Spitzer Space Telescope (2004 – present)

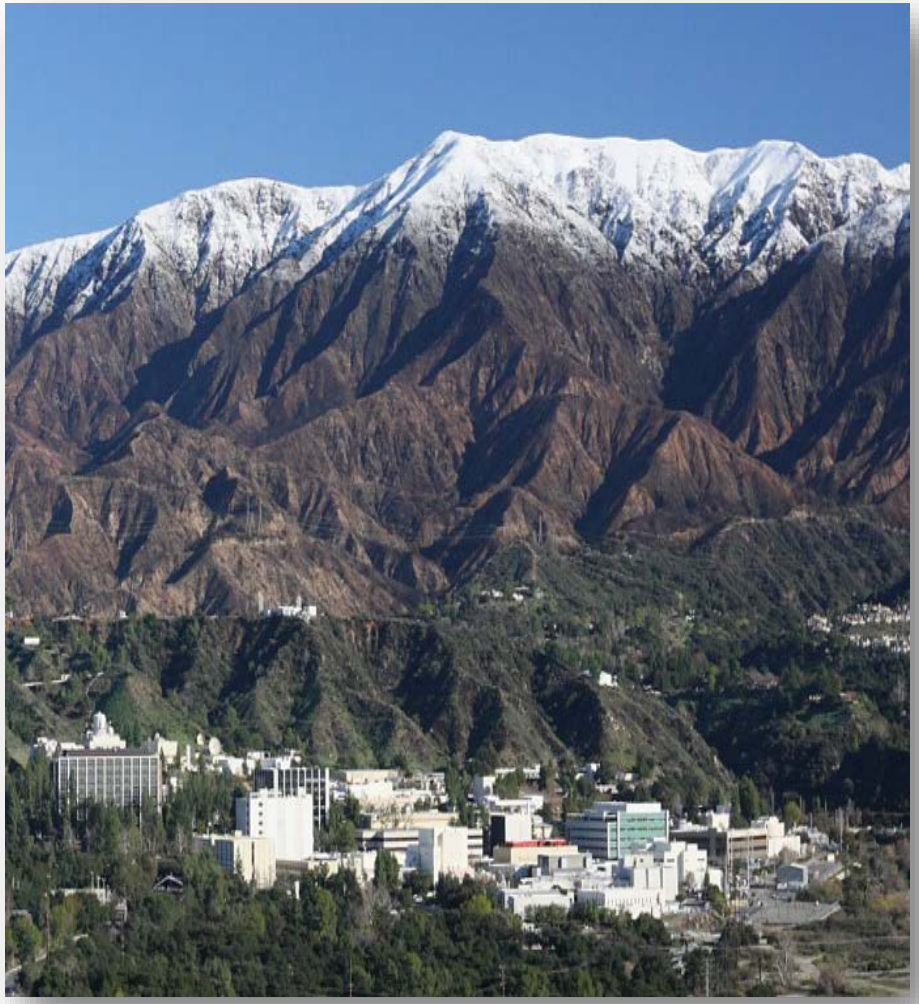


Earth Science (1978 – now)

JPL is part of NASA and Caltech

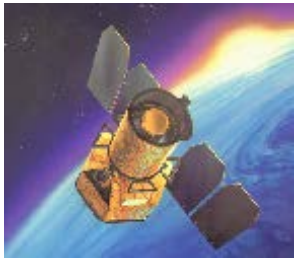
Jet Propulsion Laboratory
California Institute of Technology

- **Federally-funded (NASA-owned) Research and Development Center (FFRDC)**
- **University Operated (Caltech)**
- **$1.5B Business Base**
- **5,000 Employees**
- **177 Acres (includes 22 acres leased for parking)**
- **139 Buildings; 36 Trailers**
- **673,000 Net Square Feet of Office Space**
- **906,000 Net Square Feet of Non-Office Space (e.g., Labs)**

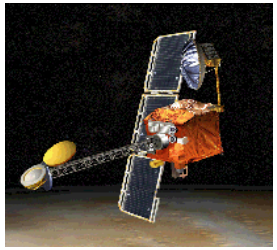


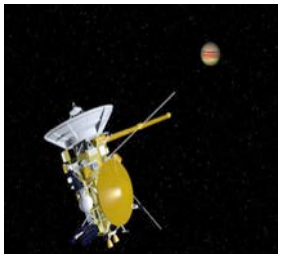
22 Spacecraft and 10 Instruments Across the Solar System and Beyond

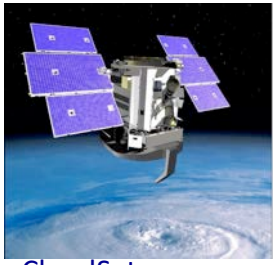
Jet Propulsion Laboratory
California Institute of Technology

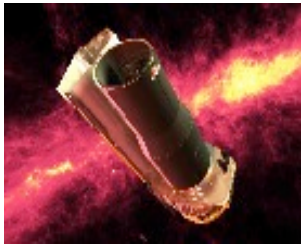

GALEX

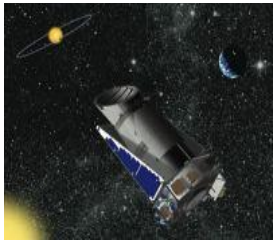
ACRIMSAT

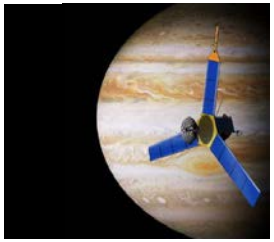

Mars Odyssey

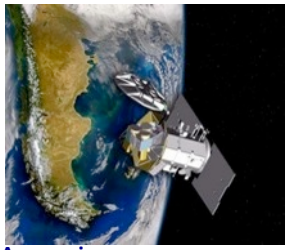

Cassini

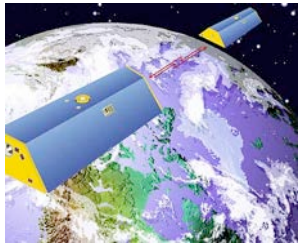

CloudSat

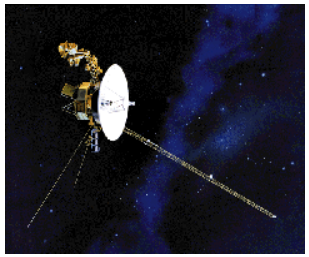

Spitzer


Kepler

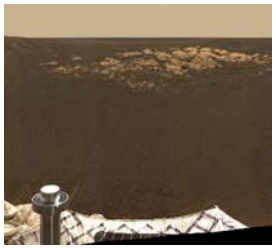

Juno

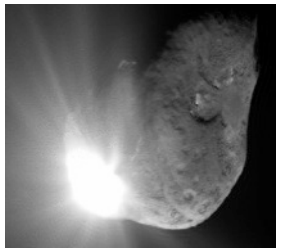

Aquarius

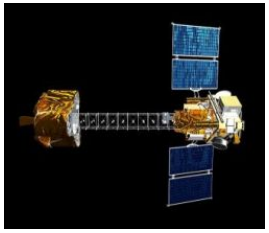

GRACE


Two Voyagers

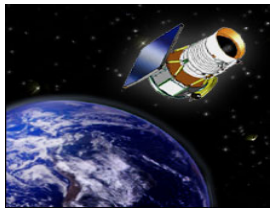
Dawn


Opportunity


EPOXI-Deep Impact


Nuclear Spectroscopic Telescope Array (NuSTAR)

Mars Science Laboratory


Wide-field Infrared Survey Explorer (WISE)

Mars Reconnaissance Orbiter

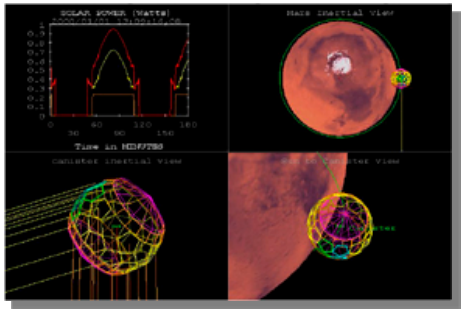
Jason 2

SMAP

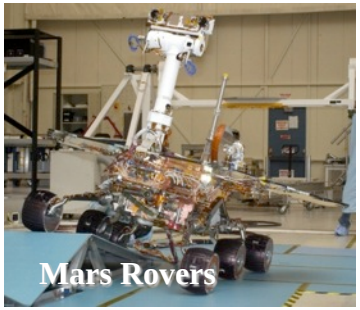
End-to-End Capabilities Needed to Implement Missions

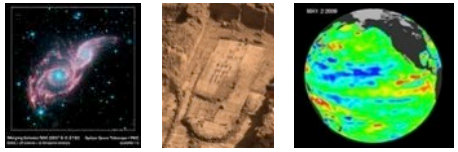
Jet Propulsion Laboratory
California Institute of Technology

Project Formulation - Team X

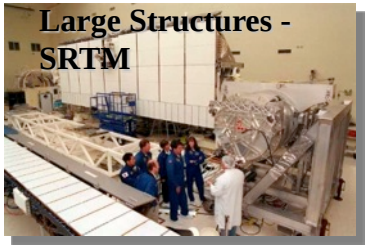


Mission Design





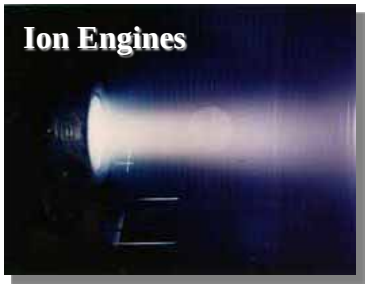
Scientific Research



Real Time Operations

Environmental Test

Integration and Test

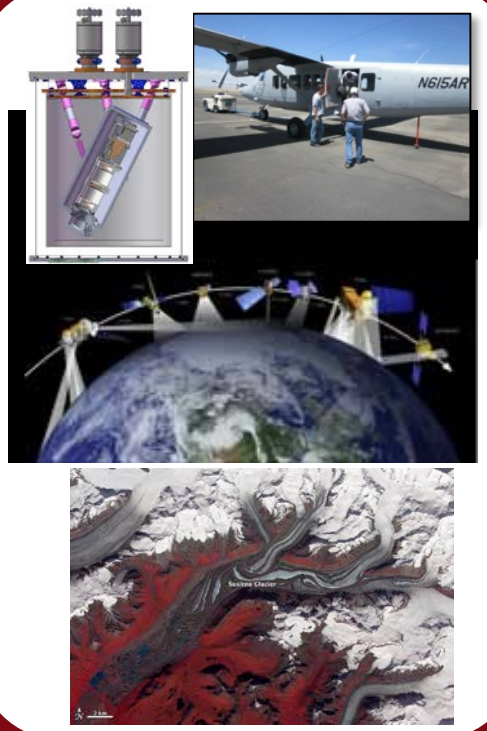


Spacecraft Development

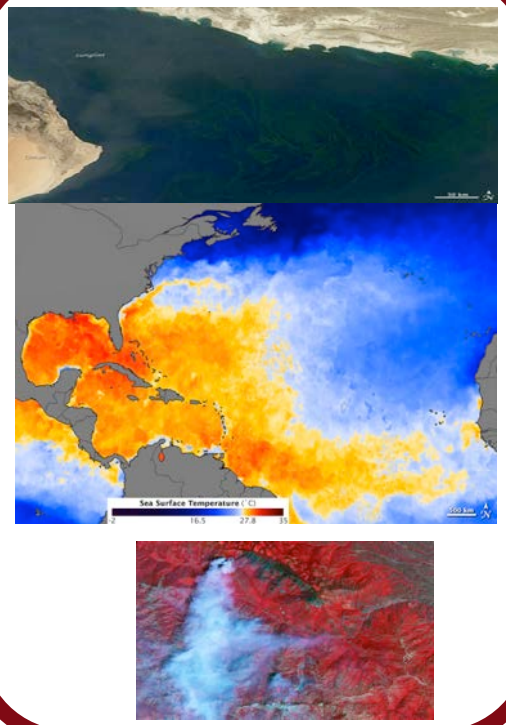
NASA Science And Technology Creating Societal Benefits

Going beyond "discovery" in Earth Science

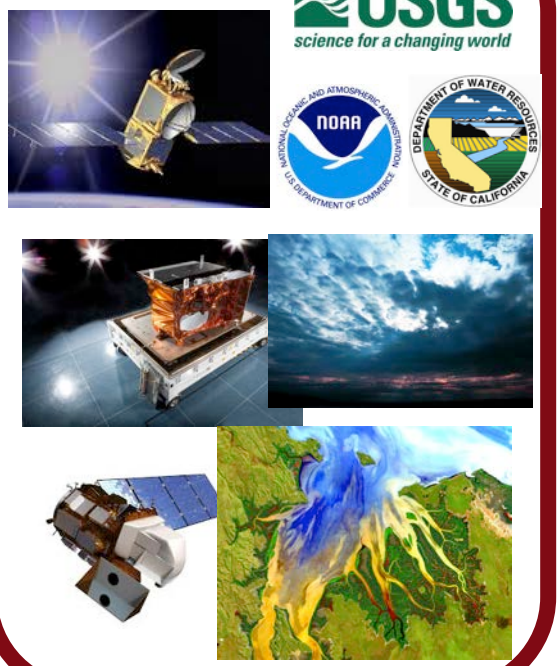
NASA → **Operational Entities**



Science, Technology



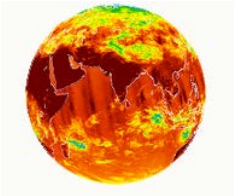
Applications

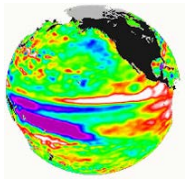


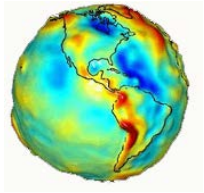
Operations

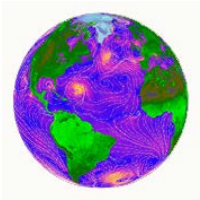
Multiple Ways to View a Changing Earth

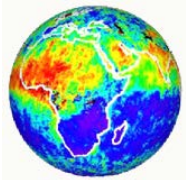
Satellites

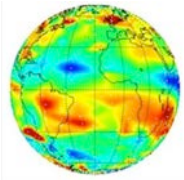

AIRS – atmospheric temperature

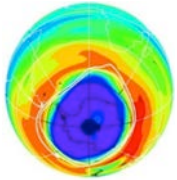

JASON – sea surface height

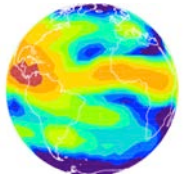

GRACE – gravity

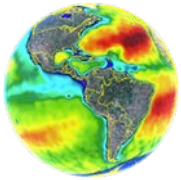

QUIKSCAT – wind

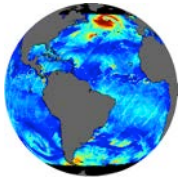

MISR - aerosols

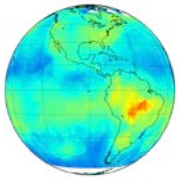

TES – trace gas

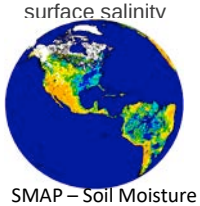

MLS – ozone layer


CLOUDSAT – water content

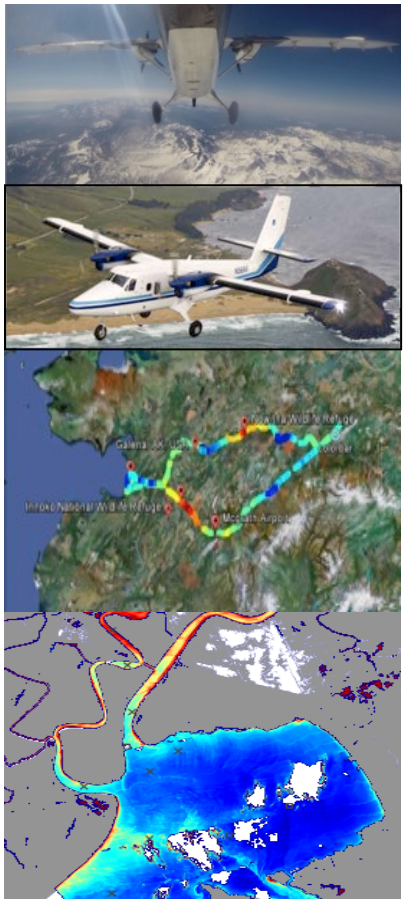

Aquarius - sea surface salinity


RapidScat – wind


OCO-2 – Carbon Dioxide


SMAP – Soil Moisture Freeze/Thaw

Airborne



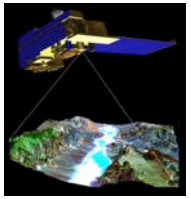
In Situ

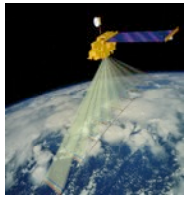
Global **Regional** **Local**

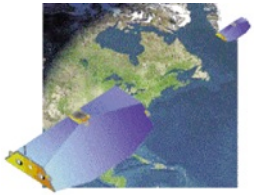
JPL Earth Science Flight Projects

Operational

QuikSCAT
(1999)


ASTER
(1999)

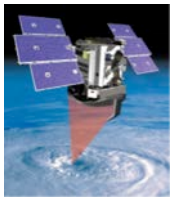

MISR
(1999)

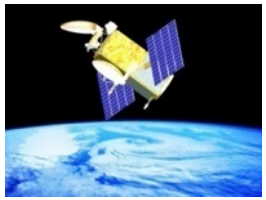

GRACE
(2002)

AIRS
(2002)

TES
(2004)

MLS
(2004)


CloudSat
(2006)

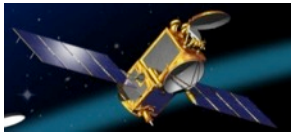

Ocean Surface
Topography Mission
(2008)

Carbon Cycle: OCO-2
(2014)

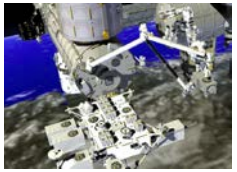
ISS – RapidSCAT
(2014)

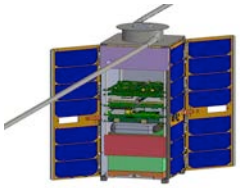
Soil Moisture: SMAP
(2015)

Formulation/Development

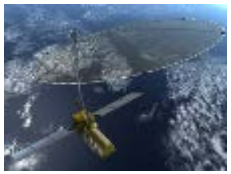

Jason 3[1]
(2015)

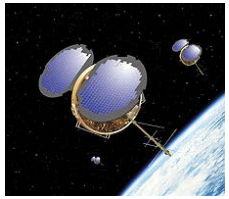
TEMPEST
(2016)


OCO-3
(~2017)

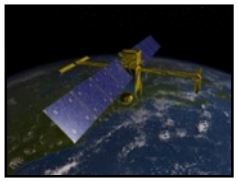

HF Research
(DHFR) Testbed[3]
(2018)

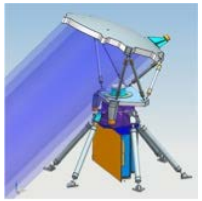
Altimeter FO
(2020/2025)

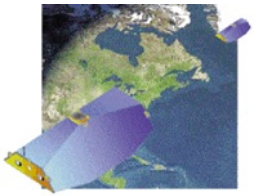

NISAR
(~2020)

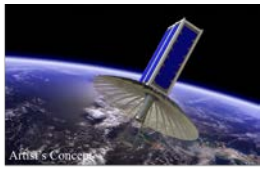

COSMIC-2 A/B[1][2]
(2016/2018)

ECOSTRESS
(2017)


SWOT (2020)


COWVR[2]
(~2017)


GRACE-FO
(2017)



RaInCube (2016)

[1]NOAA
[2]USAF
[3]DARPA

- Water from snow melt
- Amount & timing of runoff
- Precipitation & forecasts

- Water conveyance infrastructure
- Levee Integrity

Future Water Availability

- Ecosystem health
- Salinity intrusion
- Integrated modeling/prediction

- Evapotranspiration
- Groundwater storage
- Soil Moisture

The way we've measured snow in the West since 1910

Tom Painter/JPL

Tom Painter/JPL

The way we want to see it

…. 39 million times more coverage

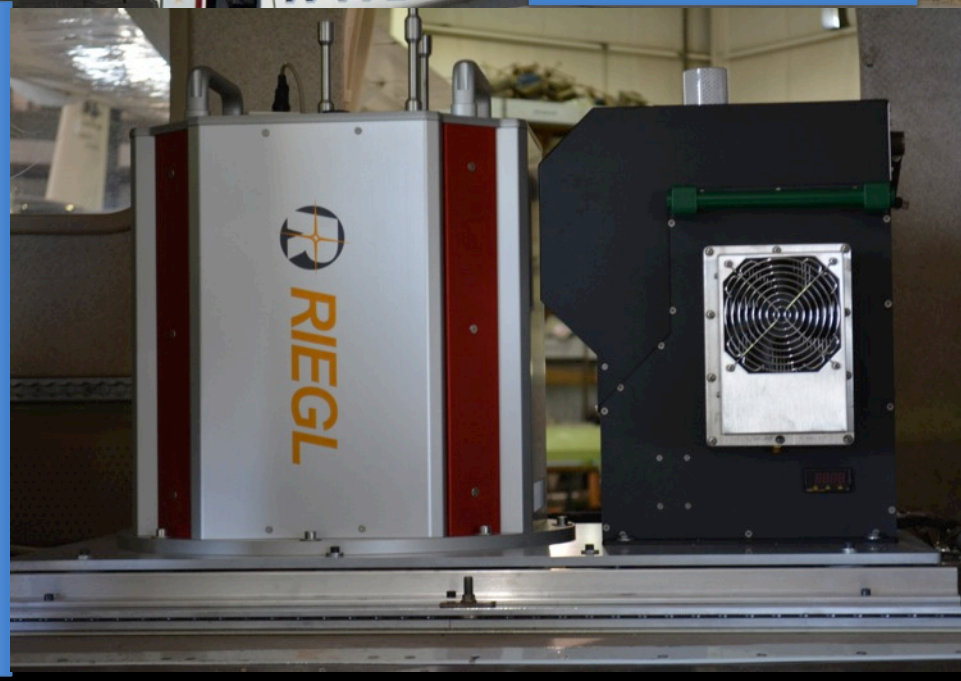
Snow Water Equivalent

Riegl Q1560 3D Scanning lidar
1064 nm, canopy penetration
1 m spatial resolution

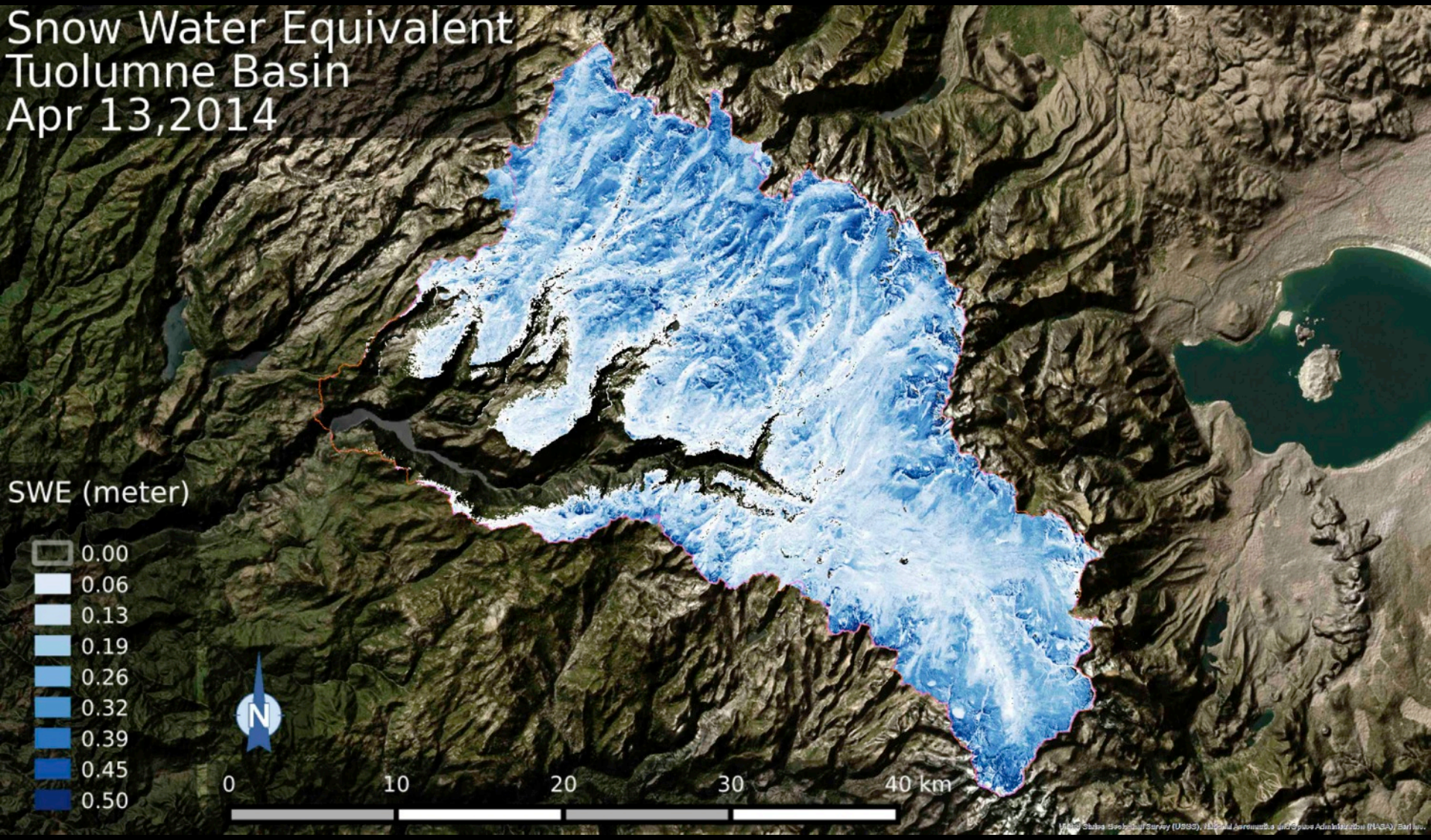
Albedo

CASI-1500 Imaging Spectrometer
0.35-1.05 µm
2 m spatial resolution from 4000 AGL

Tom Painter/JPL



- < 24 hour turnaround of products
- Quantification of snow volume
- Quantification of snowmelt timing
- Quantification of snowfall
- Much improved allocations
- Much improved runoff forecasting



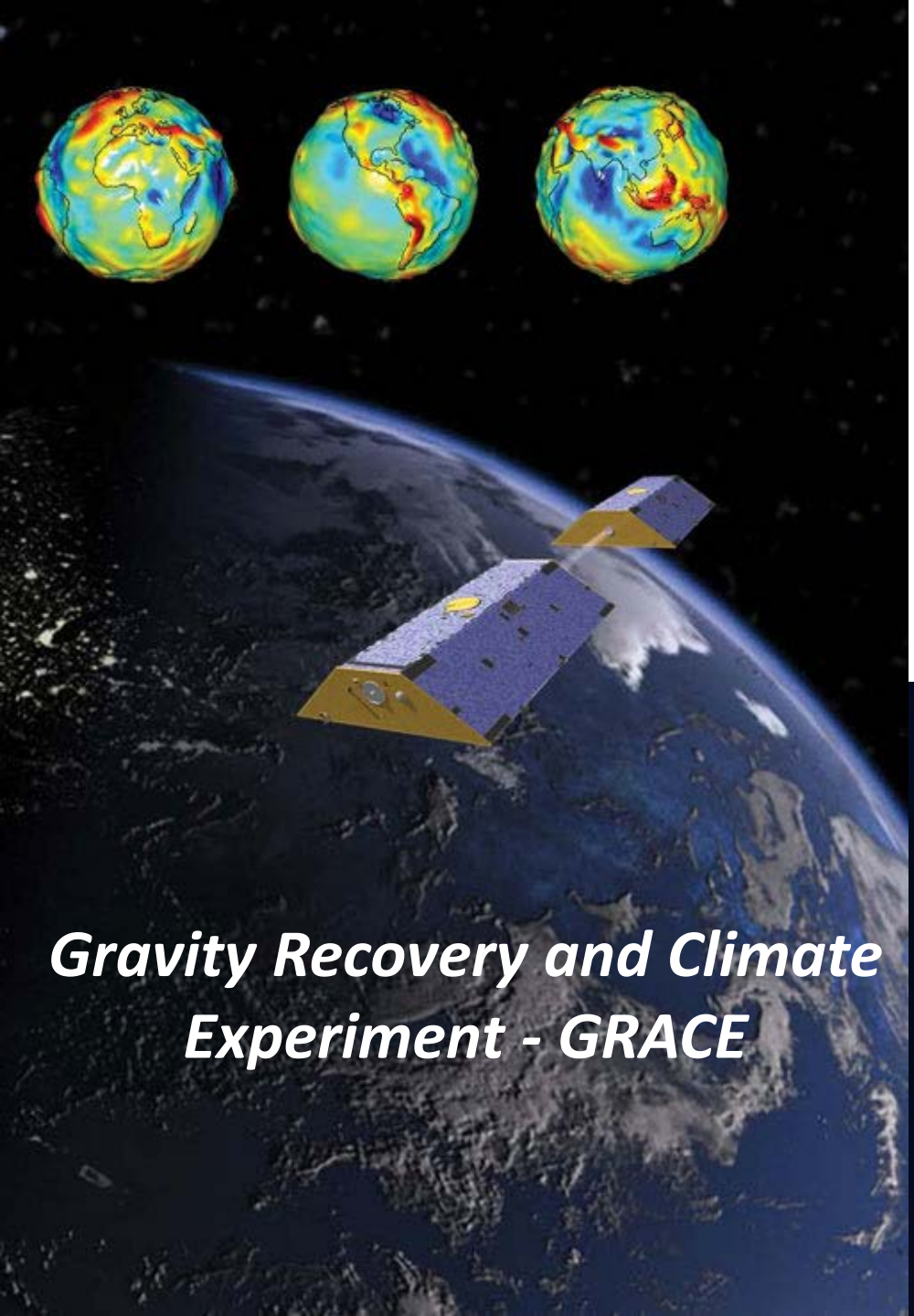
Tom Painter/JPL

Jet Propulsion Laboratory
California Institute of Technology

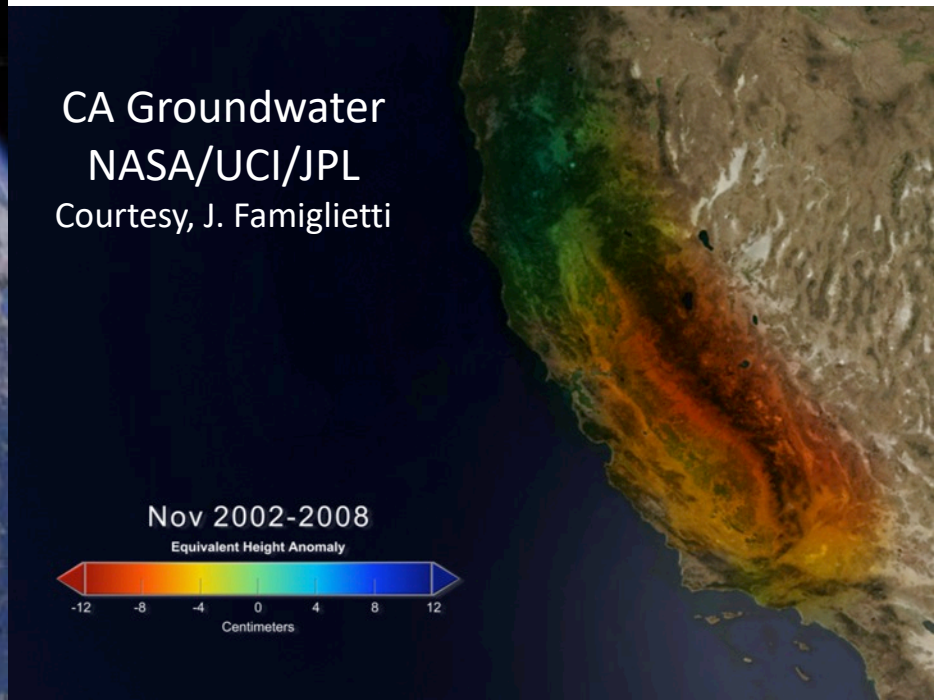
Measurement: Δx between 2 satellites

Infer: mass change at the surface

Units: represented as cm of H_2O

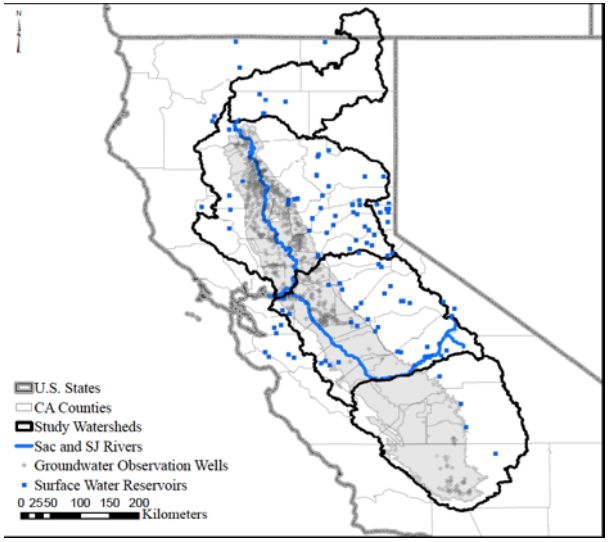


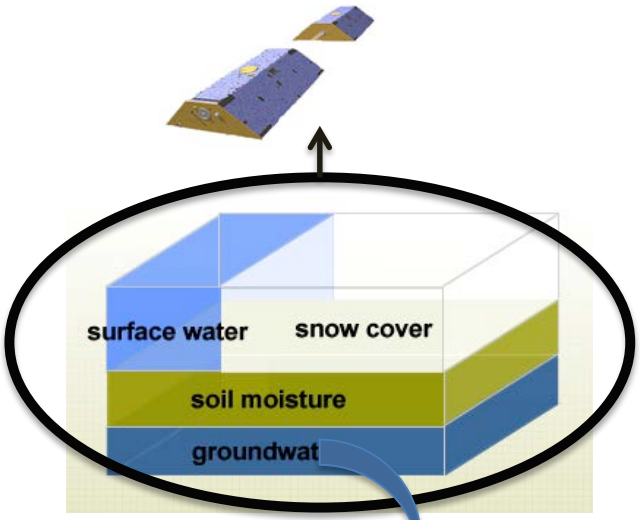
Gravity Recovery and Climate Experiment - GRACE



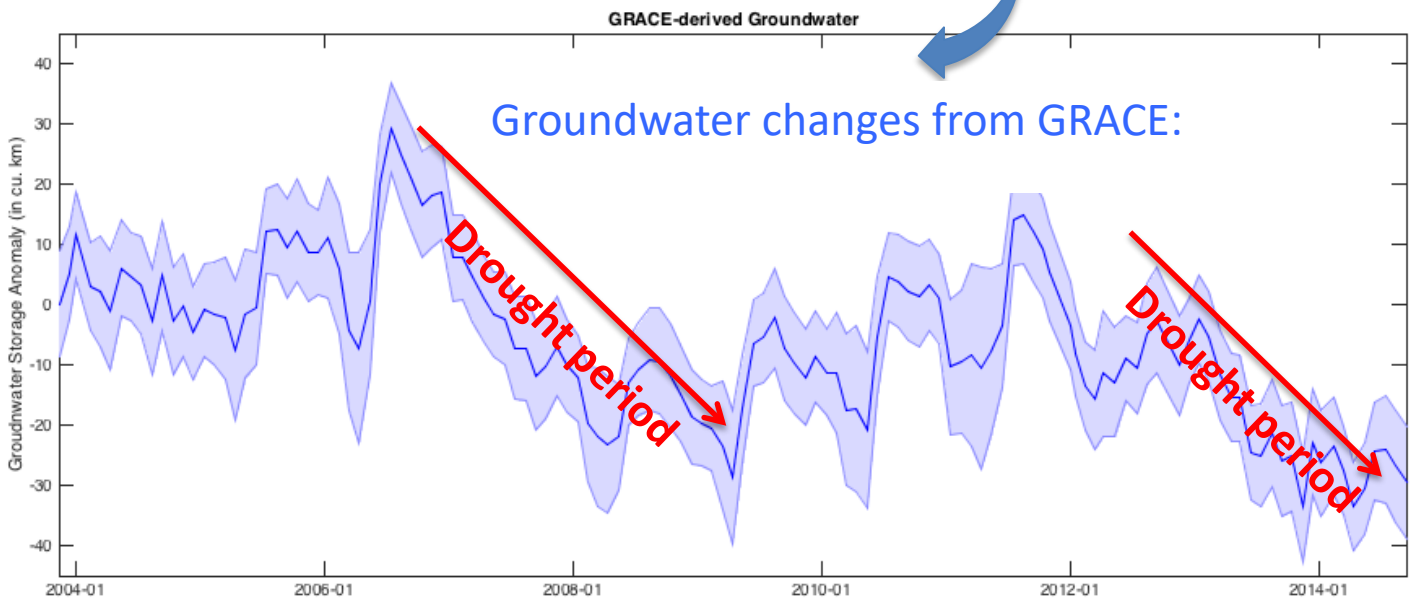
California's Central Valley 2004 - 2014: Groundwater changes from GRACE

Jet Propulsion Laboratory
California Institute of Technology



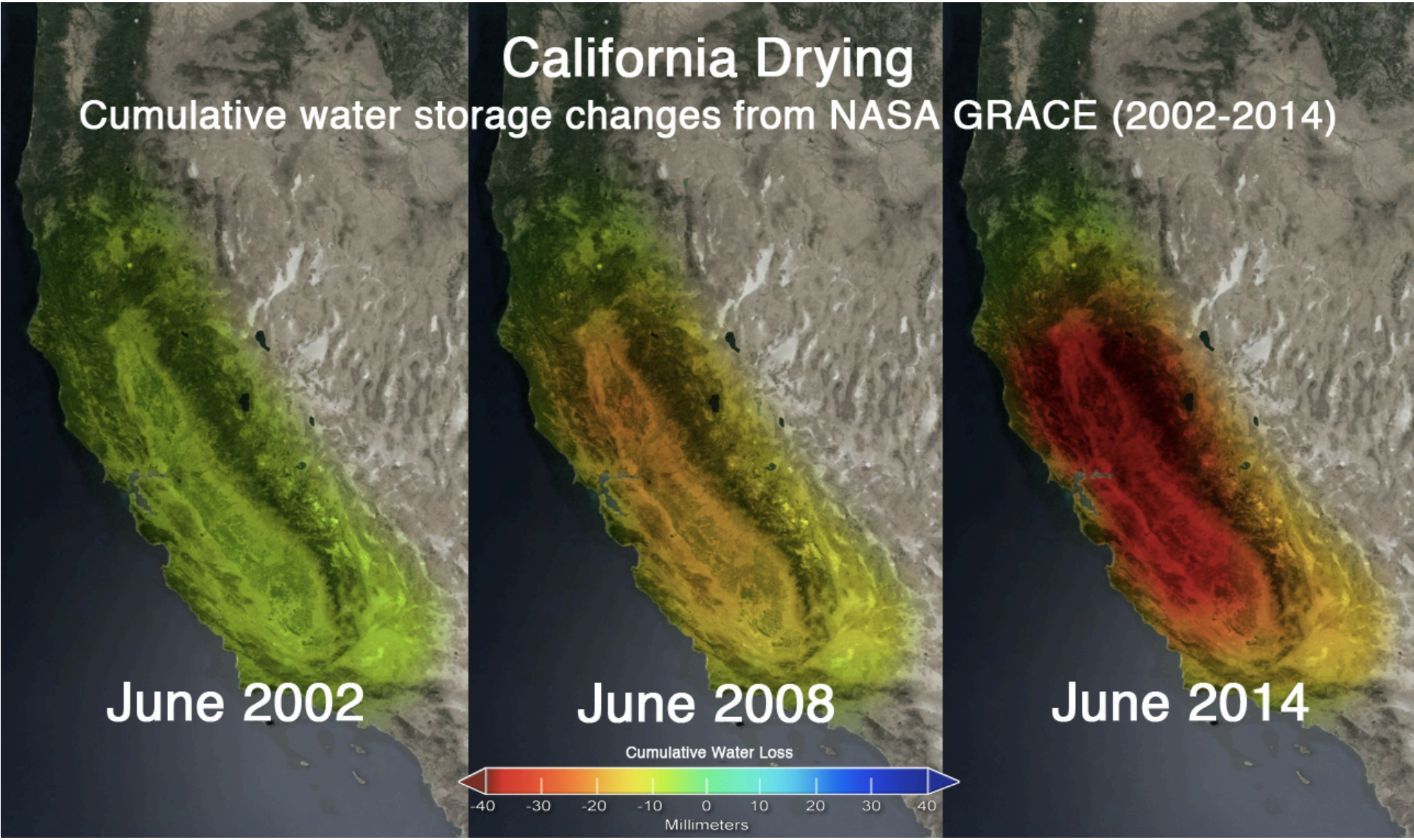


- GRACE measures all the water storage changes on land
- To estimate groundwater, the snow, surface water and soil moisture changes must be subtracted



Brian Thomas & F. Landerer, JPL

Jet Propulsion Laboratory
California Institute of Technology



UAVSAR

UAVSAR

A High Resolution, Low Noise, Fully Polarimetric L-band SAR

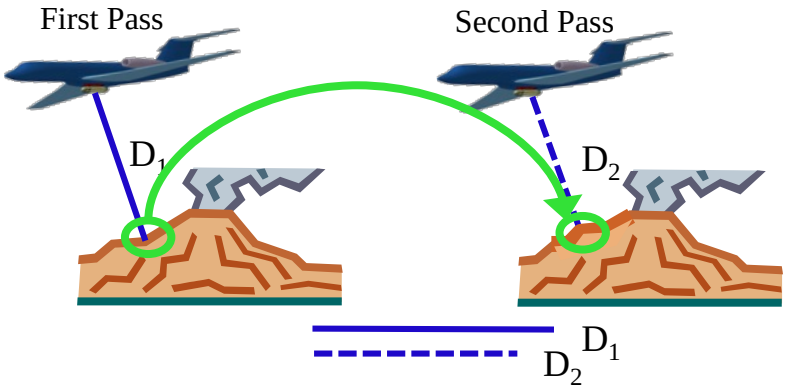
(UAVSAR = Uninhabited Aerial Vehicle Synthetic Aperture Radar)

Designed for repeat track differential interferometry & optimized for change detection.

Sacramento Delta / false color UAVSAR POLSAR image / 7 m resolution

POC: Cathleen E. Jones (cathleen.jones@jpl.nasa.gov)

Differential Interferometry (DINSAR)



$$\Delta\phi = \frac{4\pi}{\lambda}(D_2 - D_1)$$

$\lambda =$ wavelength of radar

Application: Levee Monitoring

UAVSAR
Uninhabited Aerial Vehicle Synthetic Aperture Radar

Project Overview

Monitoring Levees and Subsidence in the Sacramento-San Joaquin Delta

NASA Program: Applied Science - Natural Disasters
Collaboration: JPL, Ca. Dept. of Water Resources, USGS, HydroFocus
Instrument: UAVSAR, near-monthly collections over the entire Sacramento-San Joaquin Delta since July 2009

Objectives:

1. *Disaster Mitigation and Response: Use DINSAR to monitor movement of and seepage through levees.*
2. *Water Resource Management: Measure subsidence rates across the entire area to inform future long-term solutions to water management issues in the area.*

Scientific Impact:

Major Findings:

1. *Cracks in levees identified with DInSAR.*
2. *Post-repair settlement along levees detected and monitored.*
3. *Seeps identified with coherence change detection; detection methodology developed.*
4. *Subsidence rates within the islands show general subsidence trends in the region.*

POC: Cathleen E. Jones (cathleen.jones@jpl.nasa.gov)

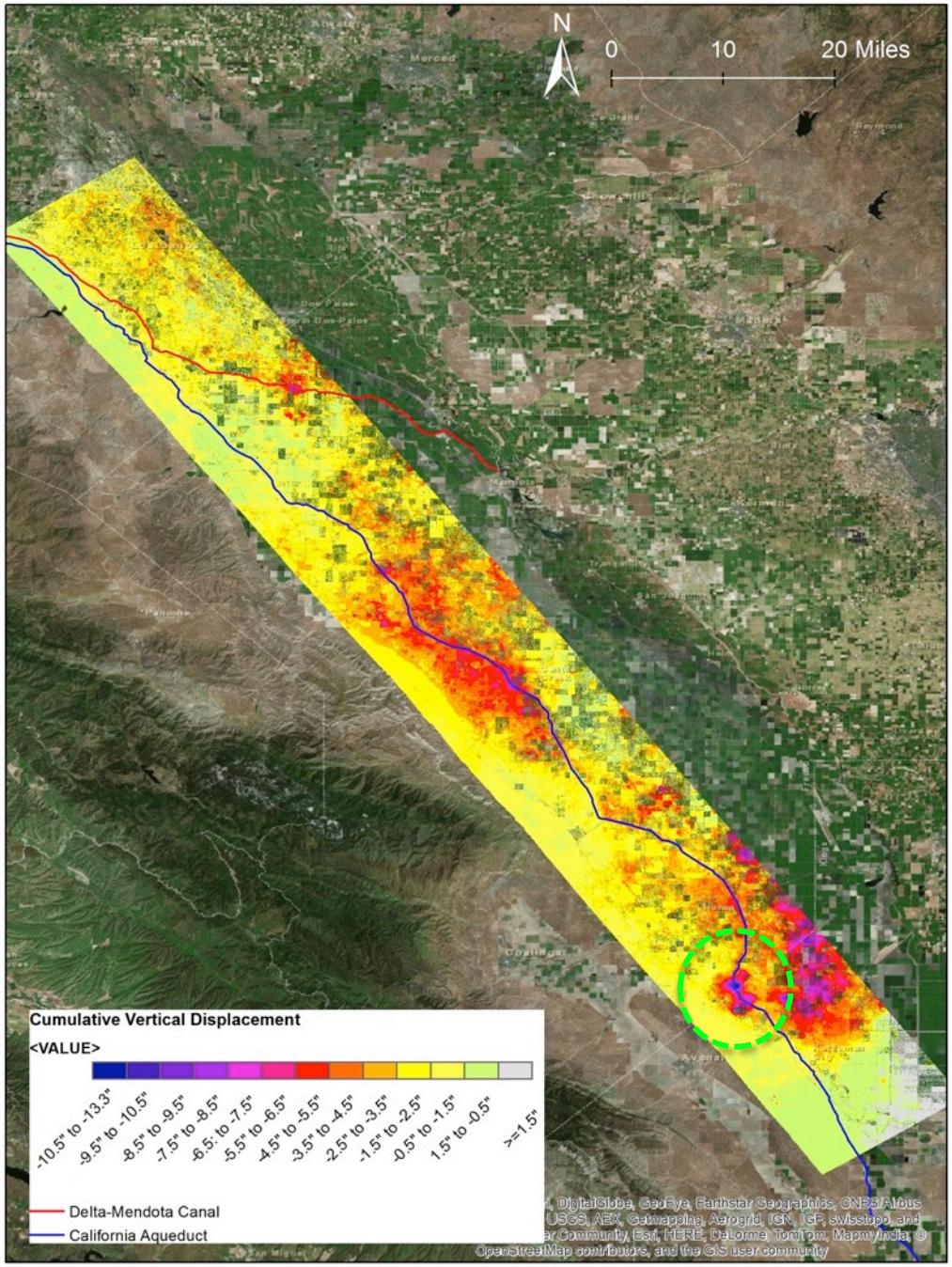
Levee Crown, Slope, and Toe Movement

Seep Detection

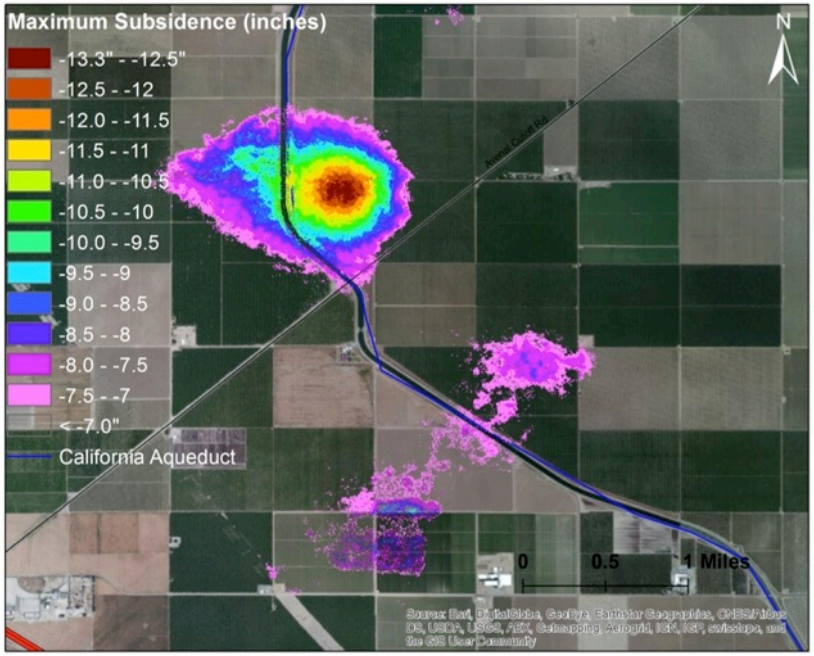
Continuing Subsidence in the Central Valley

PALSAR-1 (Japan)

Zhen Liu, Vince Realmuto, Tom Farr (JPL)



Highest subsidence directly affecting the California Aqueduct:



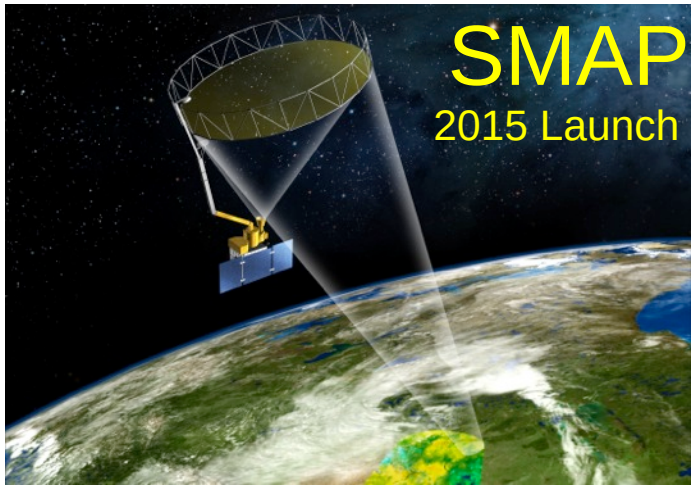
Subsidence bowl immediately north of the junction of the Ca. Aqueduct with Avenal Cutoff Rd.

A 1.3 mile stretch of the aqueduct experienced >7" of subsidence, with maximum reaching 11.5" closest to the center of the subsidence feature.

Courtesy, Cathleen Jones/JPL

Soil Moisture

Soil Moisture Active Passive Mission



Combined Radar and Radiometer

3km Radar footprint
40km Radiometer footprint
6am/6pm orbit
2-3 Day Revisit

Better weather & climate Forecasting

Informing agriculture practices

Drought early warning

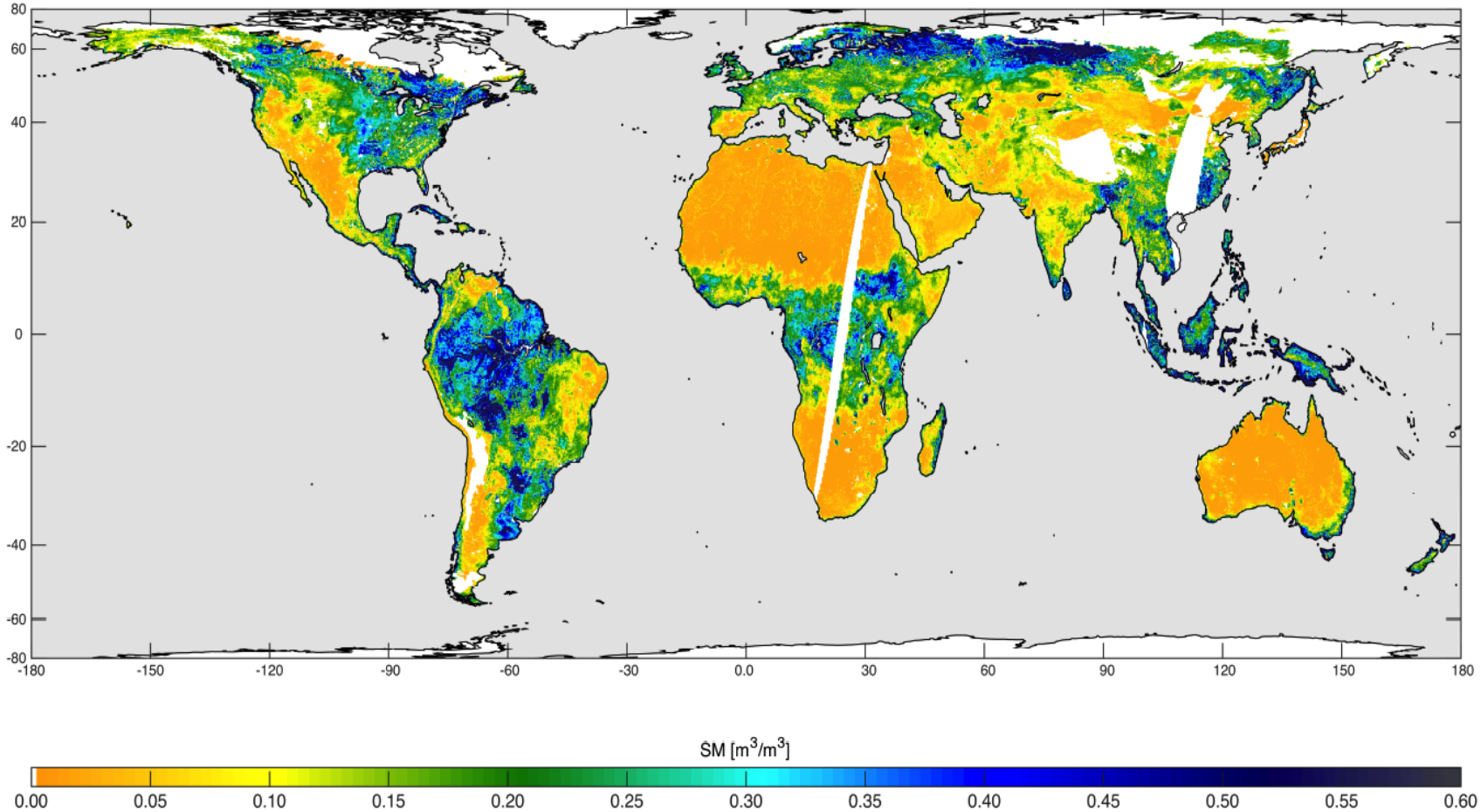
Extent of flooding

Human health: Vector borne disease

Transportation: Air (Dust), Sea (Ice), Land (Mud)

First SMAP Global Soil Moisture Map

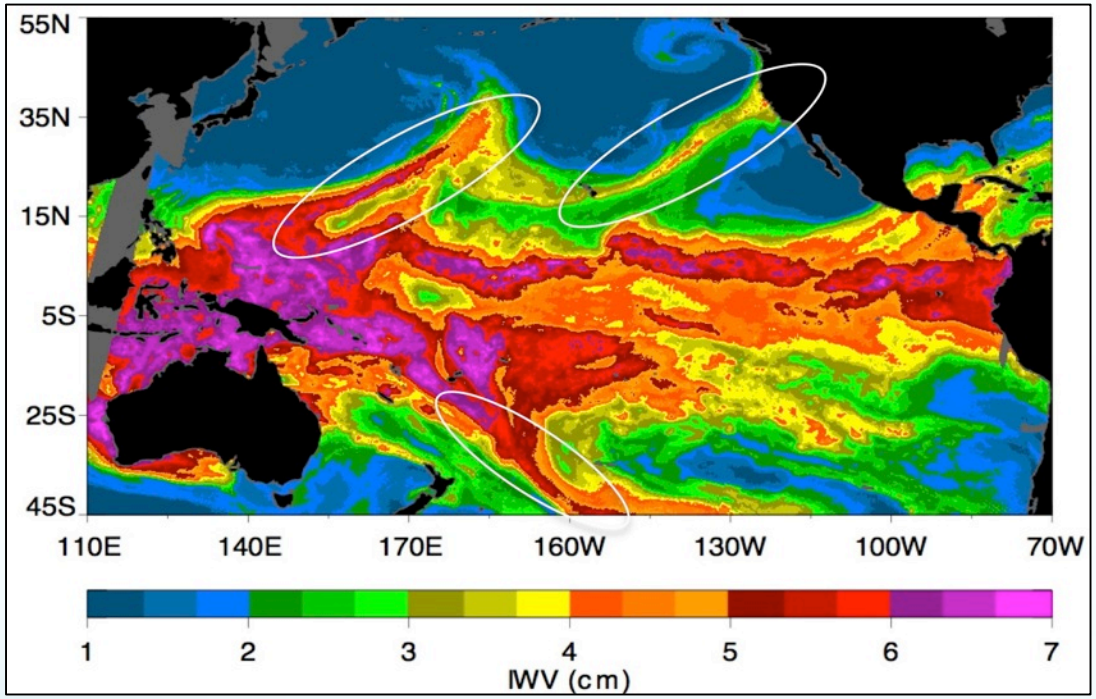
May 4 to May 11, 2015



Combined Radar and Radiometer

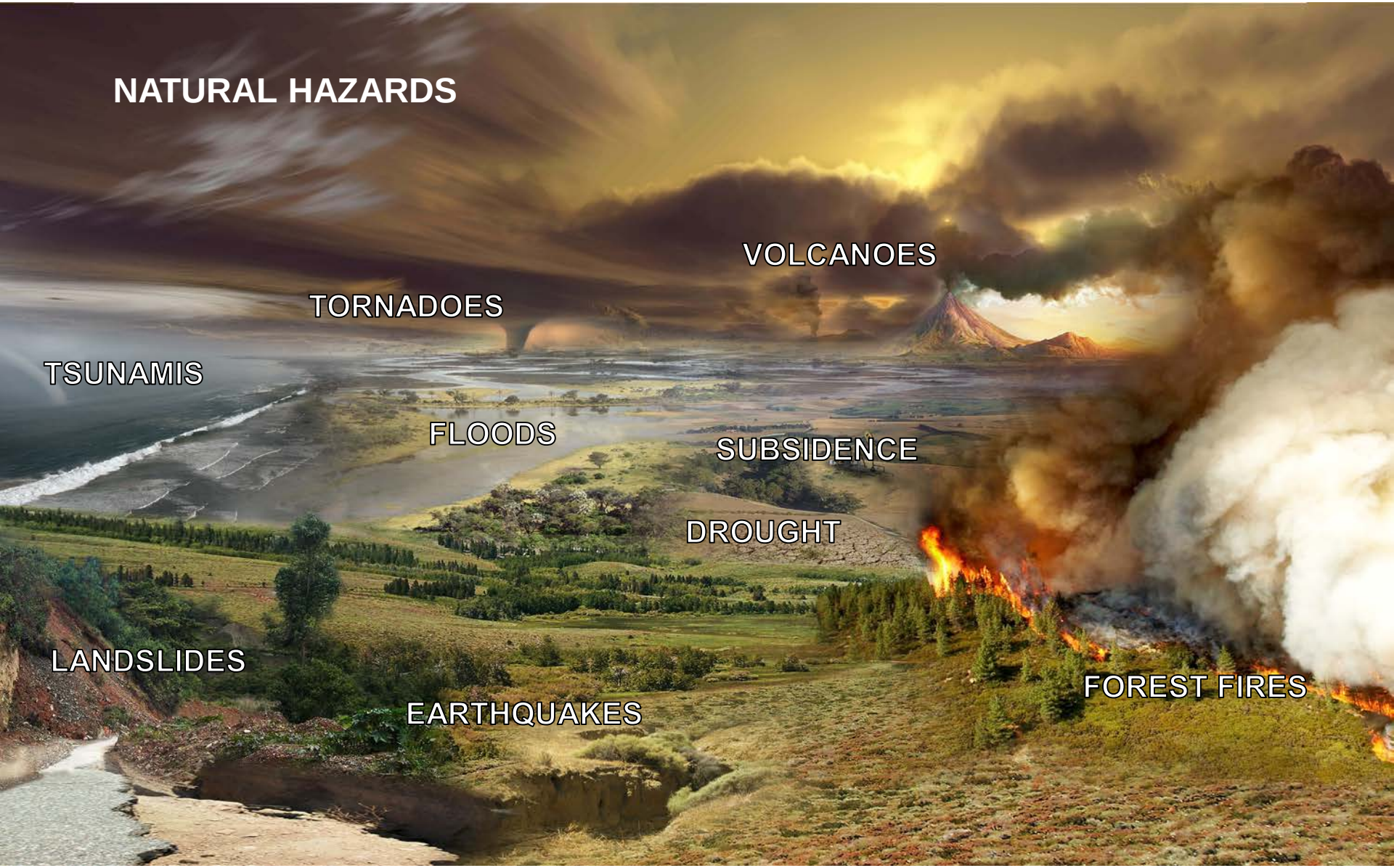
Importance of Atmospheric Rivers

Key to our water supply &
Responsible for our floods



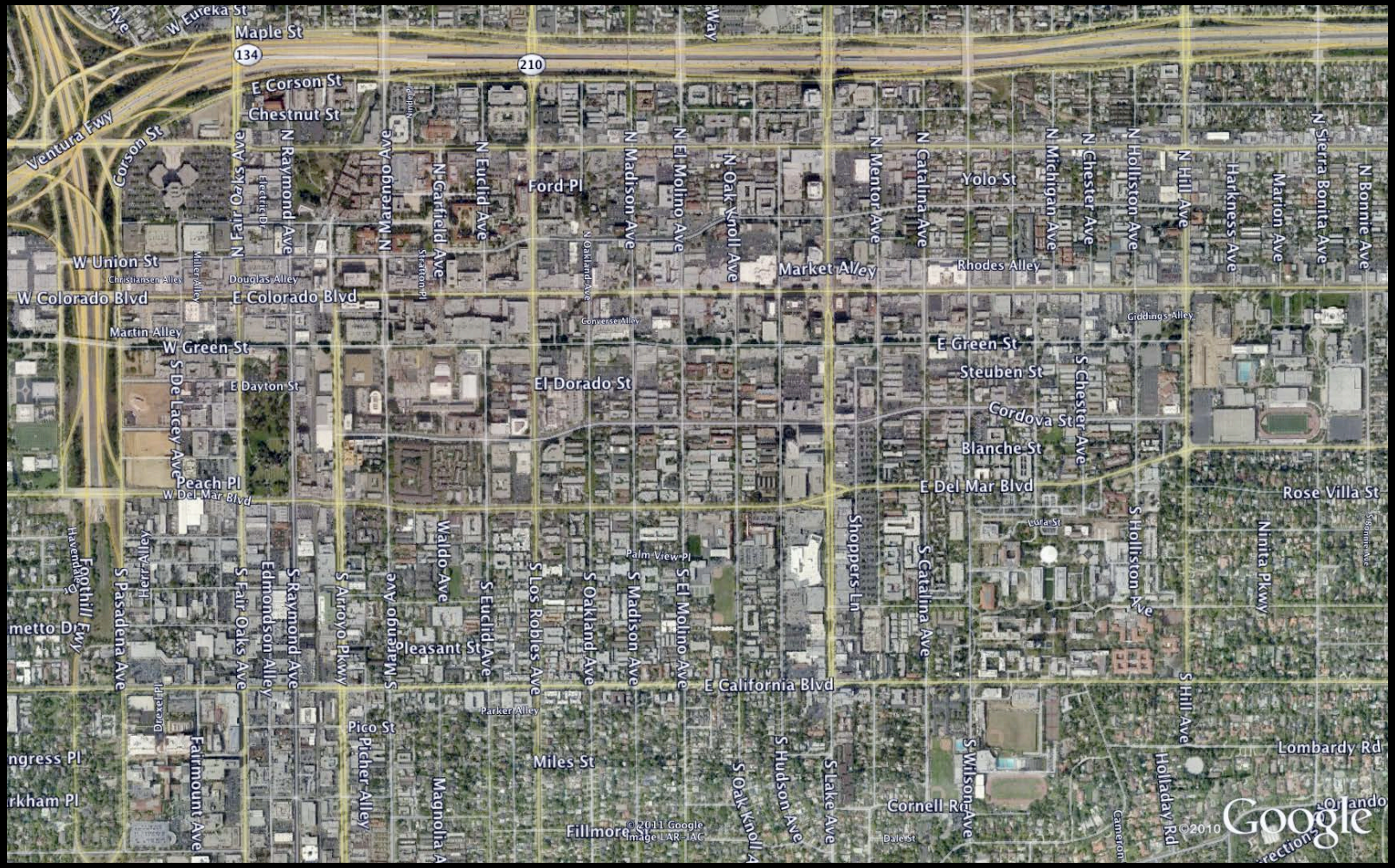
Working with National & International Programs to improve the accuracy and lead times of predictions of Atmospheric Rivers with

How can we better prepare and respond to Natural Hazards?

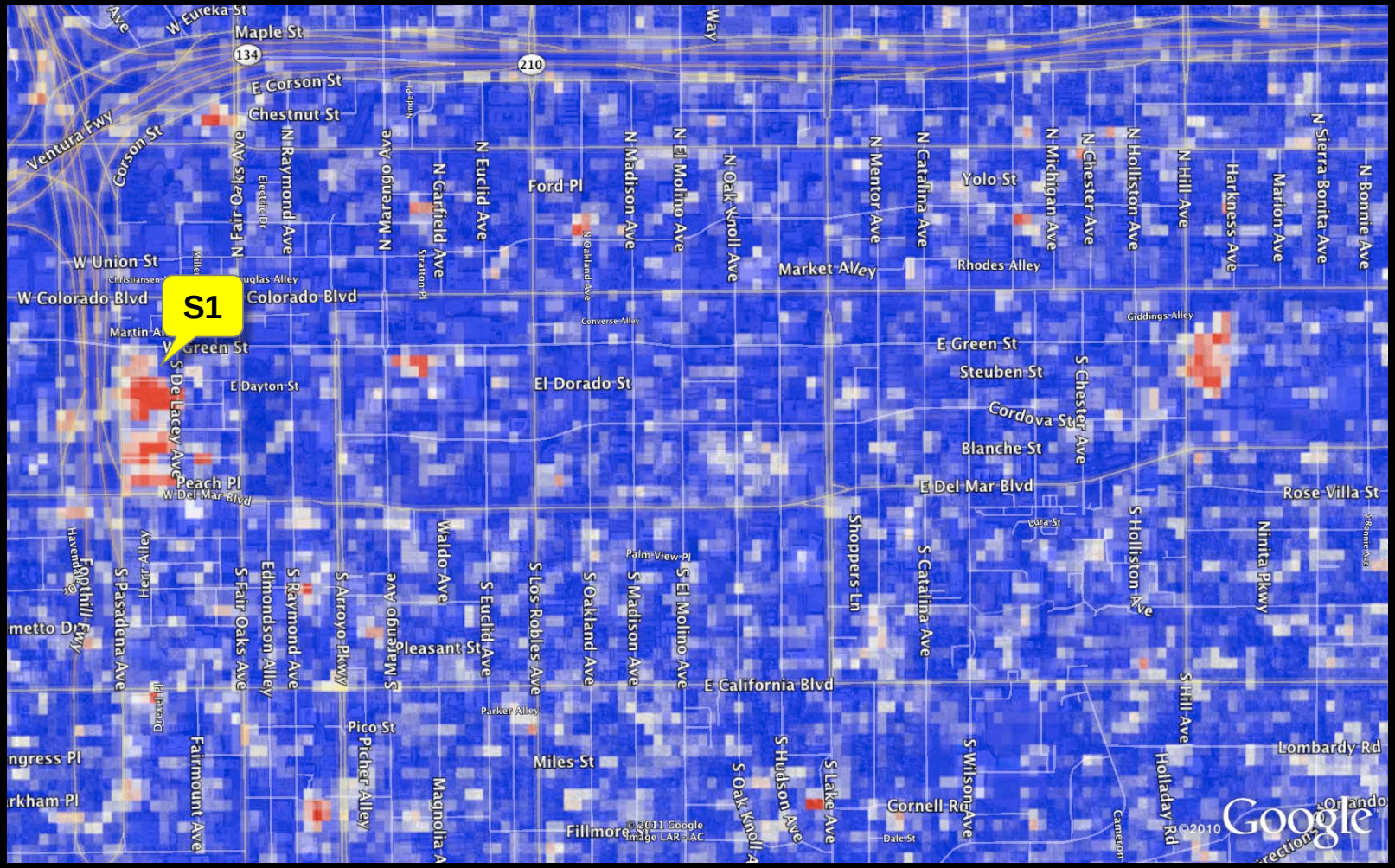


Building Demolition/Construction in Pasadena

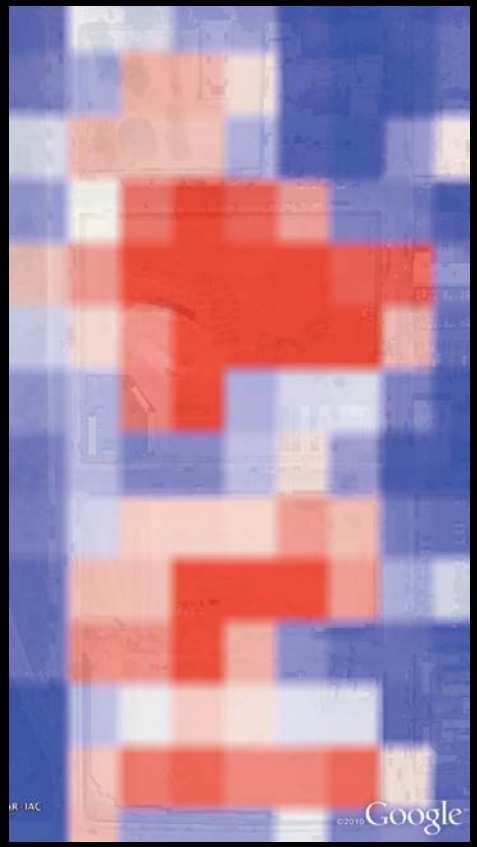
Google Earth Image (2008.01.09)



Damage Proxy Map (2006.12.31-2007.02.15-2008.02.18)

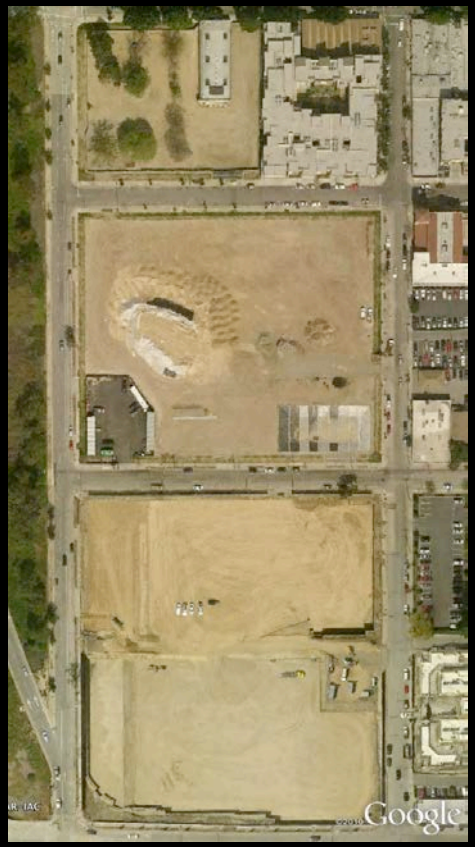


Site 1: Building blocks demolished



DPM

2007.10.23



2008.01.09

A

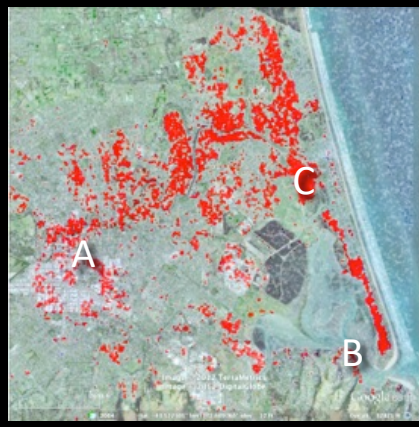
B

C

MEDIA

DPM

Google Earth



FINDER detects people trapped under debris

- Many people trapped beneath rubble for days in the village of Chautara

- FINDER detected 2 heartbeats beneath each of 2 different collapsed structures

- 4 men were rescued

(Photo: AP)

First real-world operational use of FINDER

http://www.jpl.nasa.gov/news/news.php?feature=4580

Pilot: Megacities Carbon Project

NATURE CLIMATE CHANGE | VOL 2 | AUGUST 2012 | www.nature.com/natureclimatechange

Measuring the carbon emissions of megacities

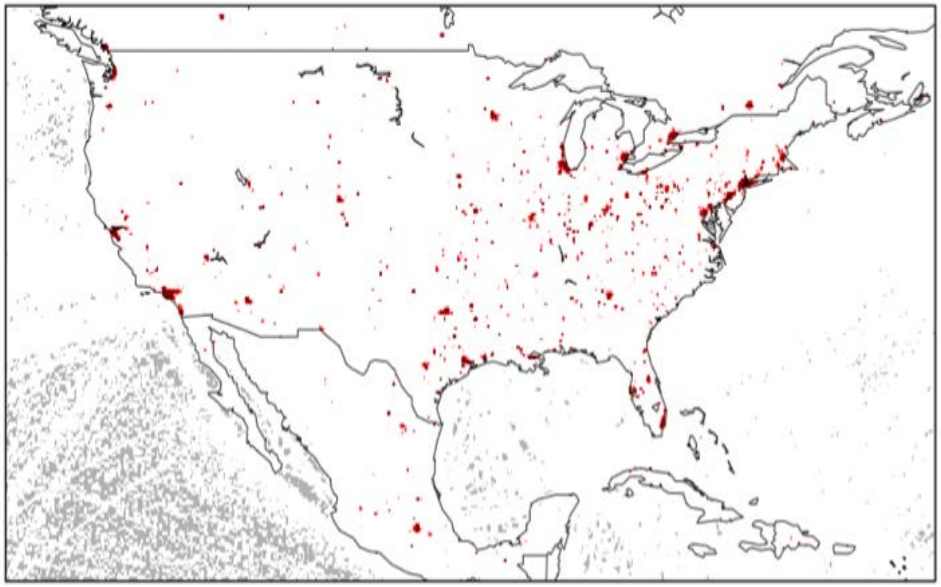
Riley M. Duren and Charles E. Miller

doi:10.1038/nclimate1629

Carbon emissions from cities represent the single largest human contribution to climate change. Here we present a vision, strategy and roadmap for an international framework to assess directly the carbon emission trends of the world's megacities.

- What are the carbon emissions of cities and how are they changing?
- Are mitigation efforts having the intended effect?

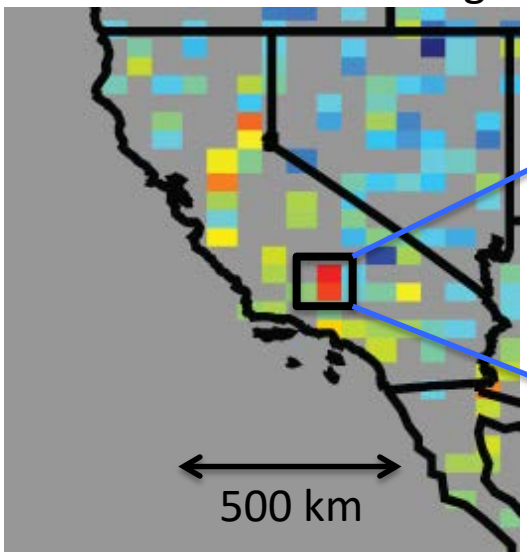
80% of fossil CO2 emissions from <3% of



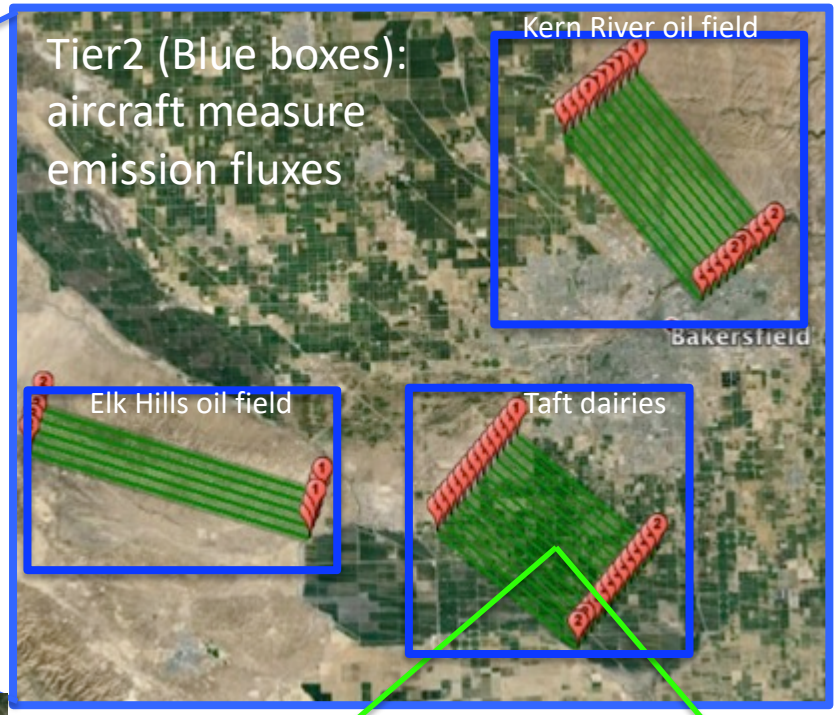
Co-benefits: enhance sustainable planning, air-quality, and public awareness

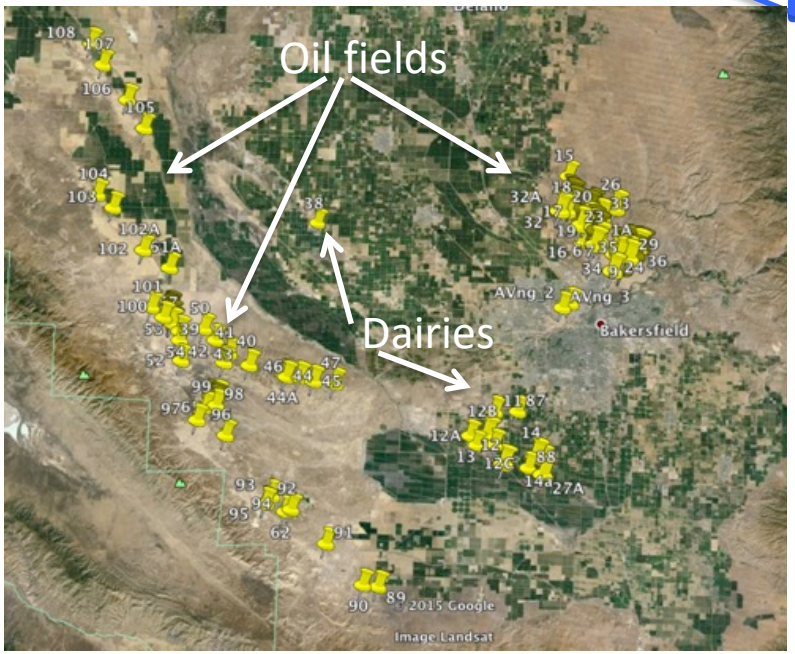
Methane tiered observing system

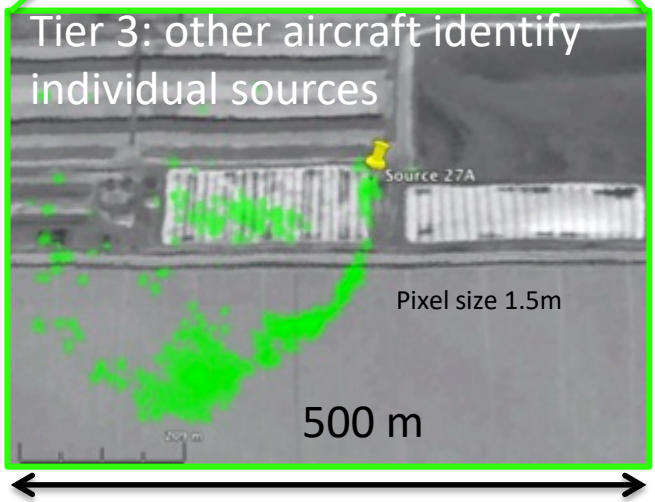
Tier 1: satellites detects hotspot
In Bakersfield region

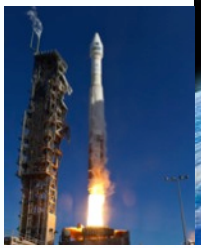
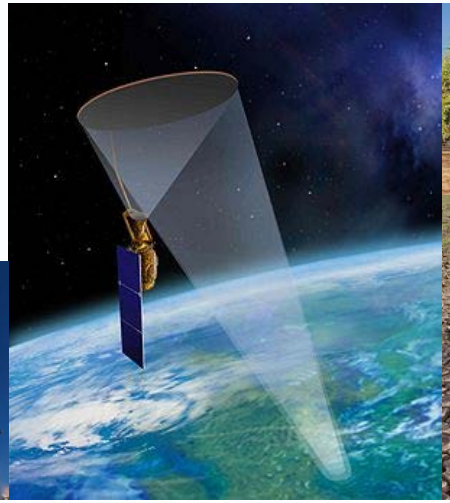
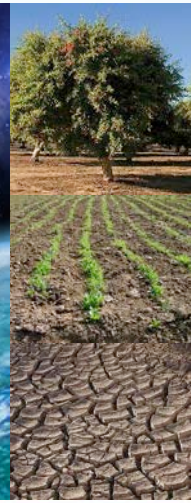
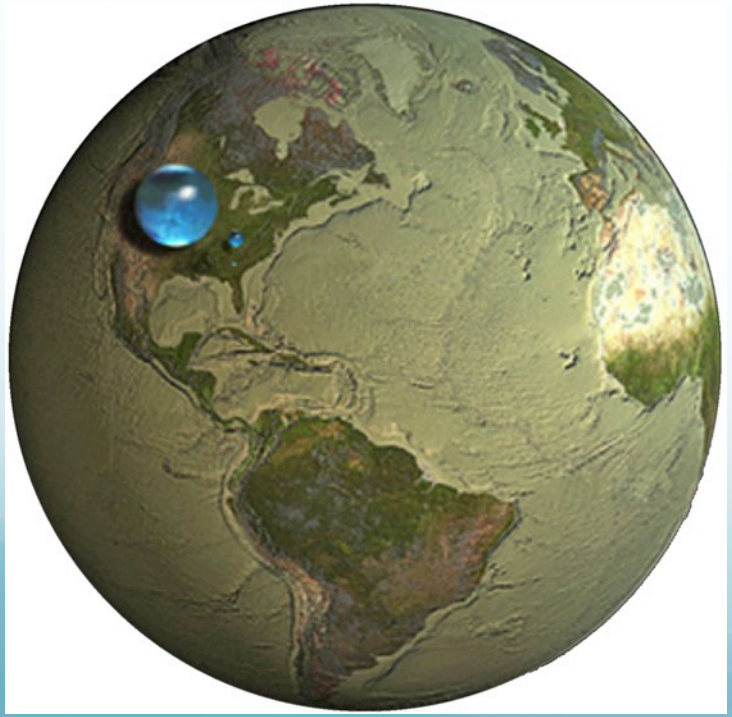


Turner et al 2015







Comprehensive Capabilities for Informing Sustainability Considerations

- New Instruments
- Airborne Science & Prototype Monitoring
- Routine Satellite Mapping
- Research, Synthesis & Modeling
- Deliver Capabilities for Operational Entities