National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Atmospheric River precipitation from space: Composite assessments and case studies over the western United States

Ali Behrangi

NASA Jet Propulsion Laboratory,
California Institute of Technology

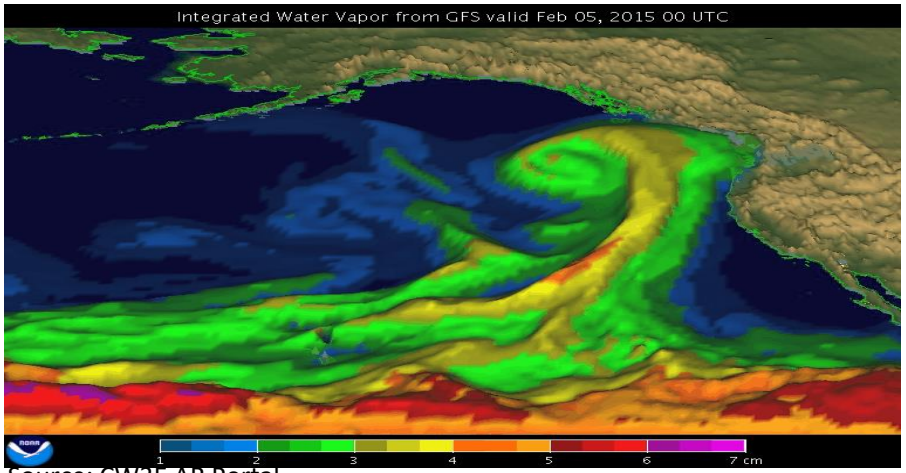
Thanks to :
Bin Guan; Paul Neiman, Bjorn Lambrigtsen,
Berry Wen, Beatriz Aguilar

2016 International Atmospheric Rivers Conference
8-11 August 2016, Scripps Institution of Oceanography

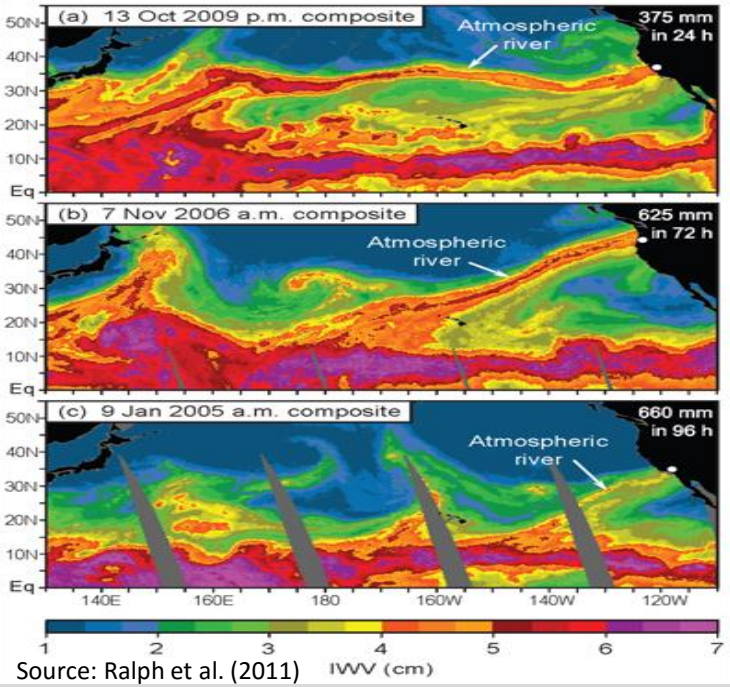
Atmospheric Rivers (AR): Rivers in the sky

ARs are relatively narrow regions in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics.

- *Can carry **more water than 7-15 Mississippi Rivers***
- *ARs impacts are most prominent when they **make landfall and interact with the topography of the west coast areas** of mid-latitude continents*
- ***Account for >90% of the poleward water vapor transport** at mid-latitudes*
- ***> 2cm precipitable water ; <1000km wide (average=200-400km) ; > 2000km long.***
- *Key impacts: flood, drought, water supply, fishery*
- *On average 9 AR/winter producing ~37% snowfall*



Source: CW3E AR Portal

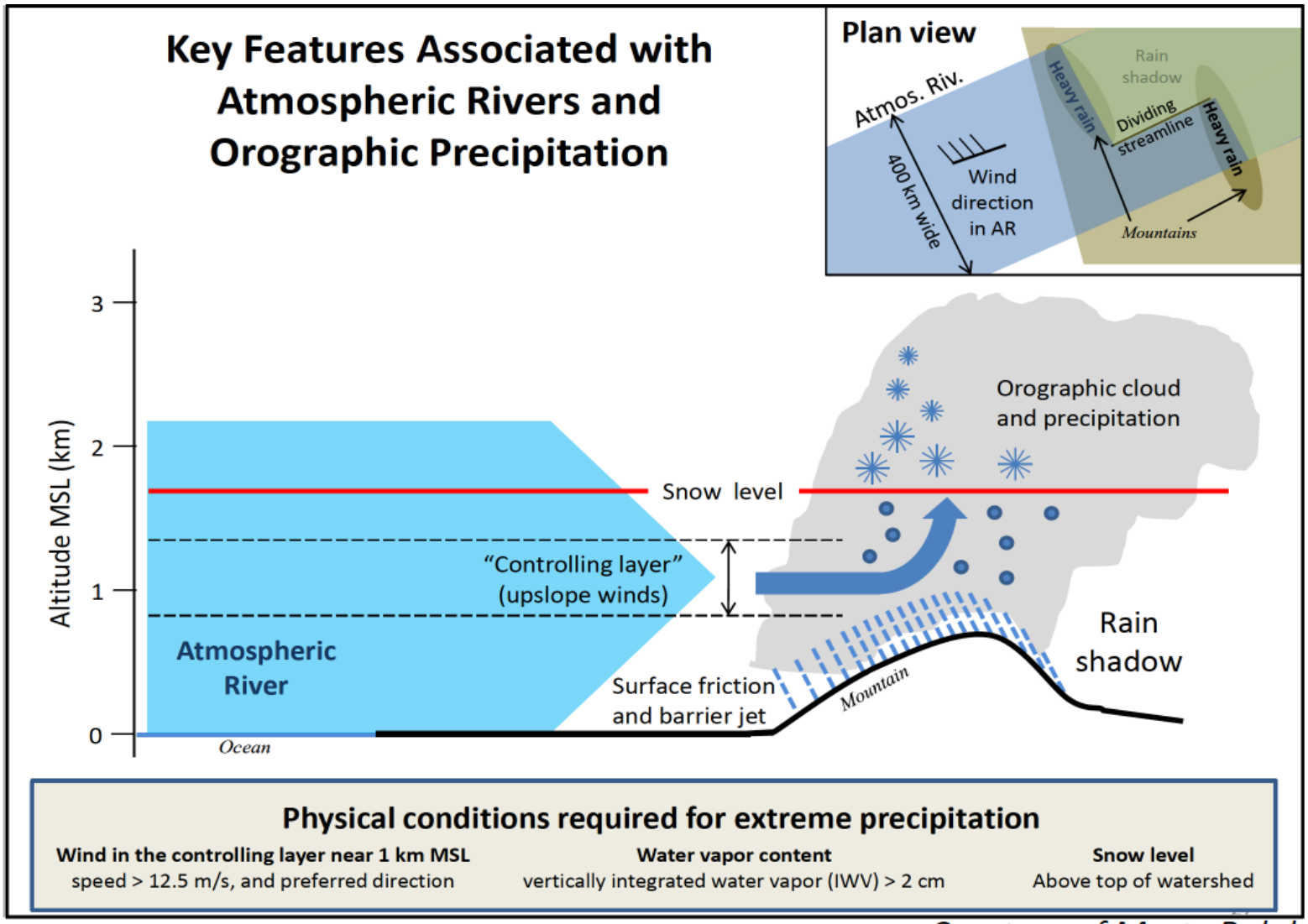


Source: Ralph et al. (2011)

Zhu and Newell 1994, 1998; Ralph et al. 2004; Neiman et al. 2008

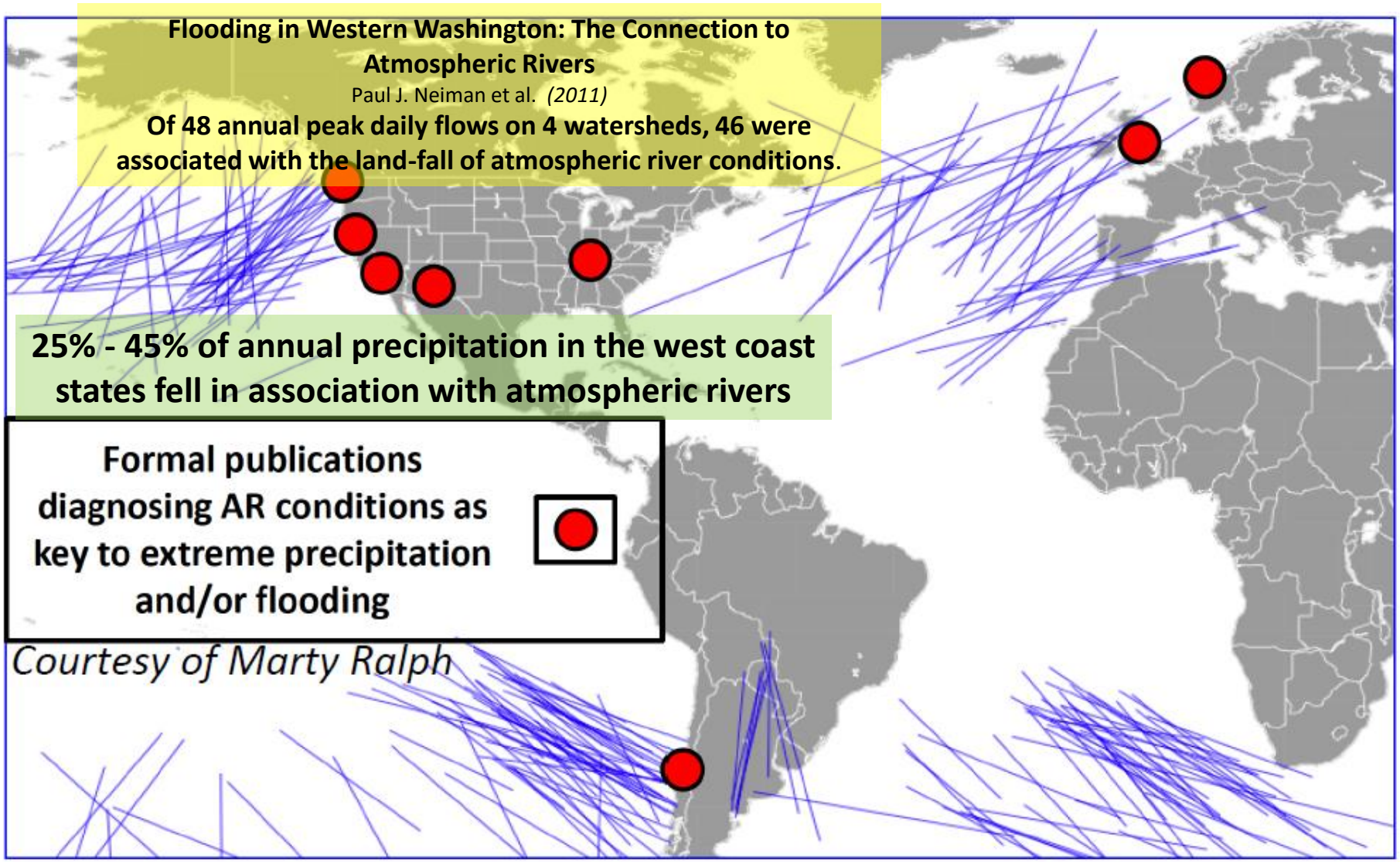
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

AR and orographic precipitation

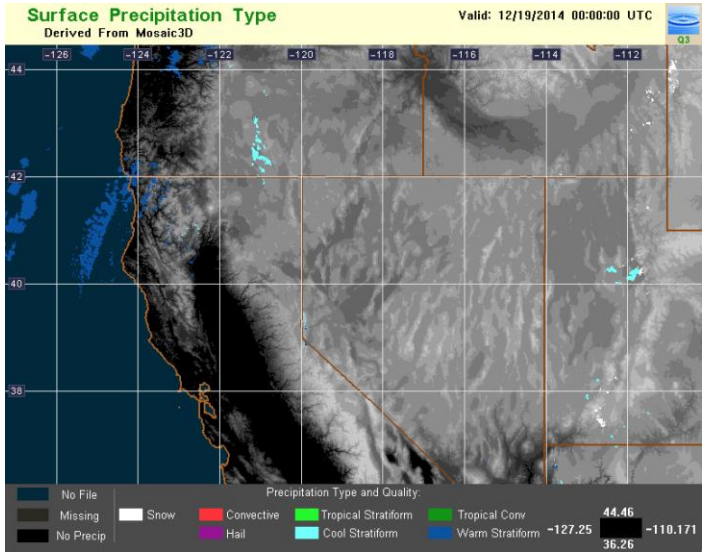


Courtesy of Marty Ralph

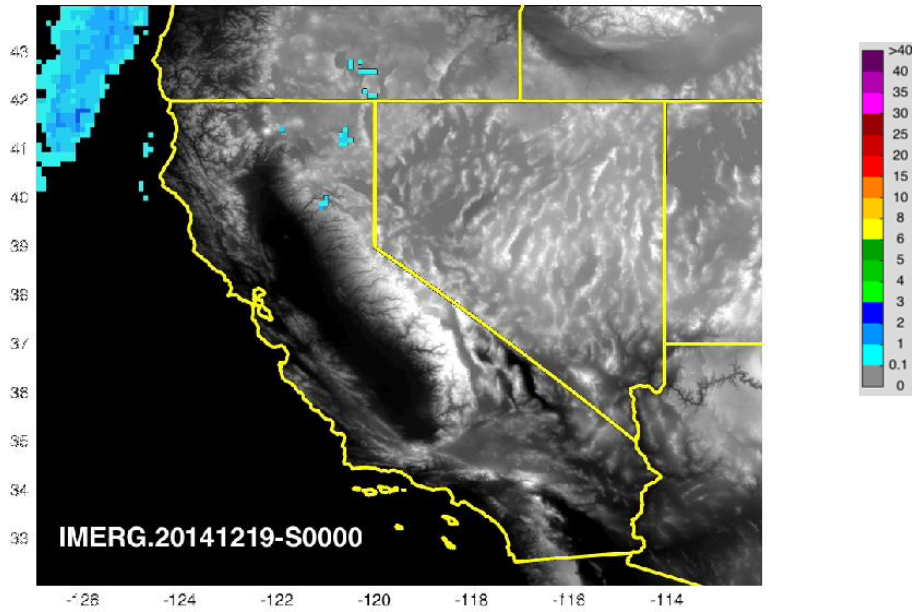
ARs matter globally

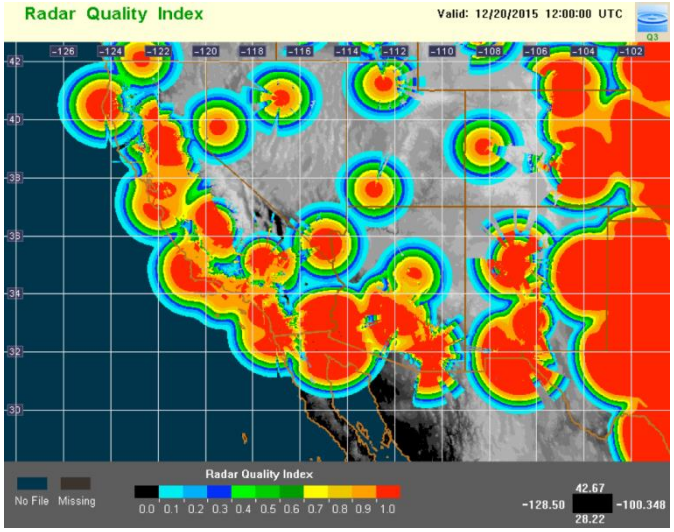


Remote sensing of AR precipitation



Satellite



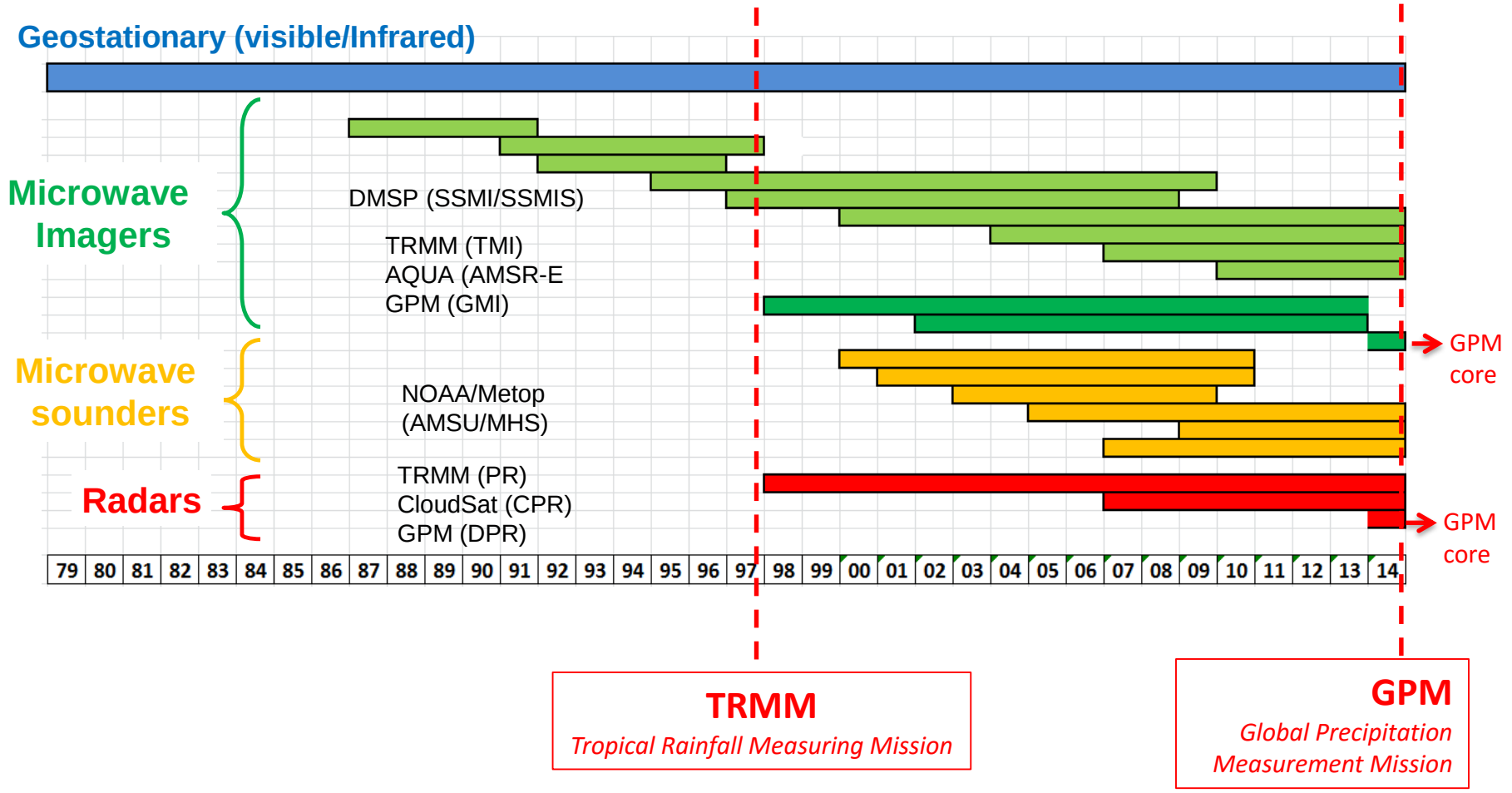


Performance of satellite precipitation products ?

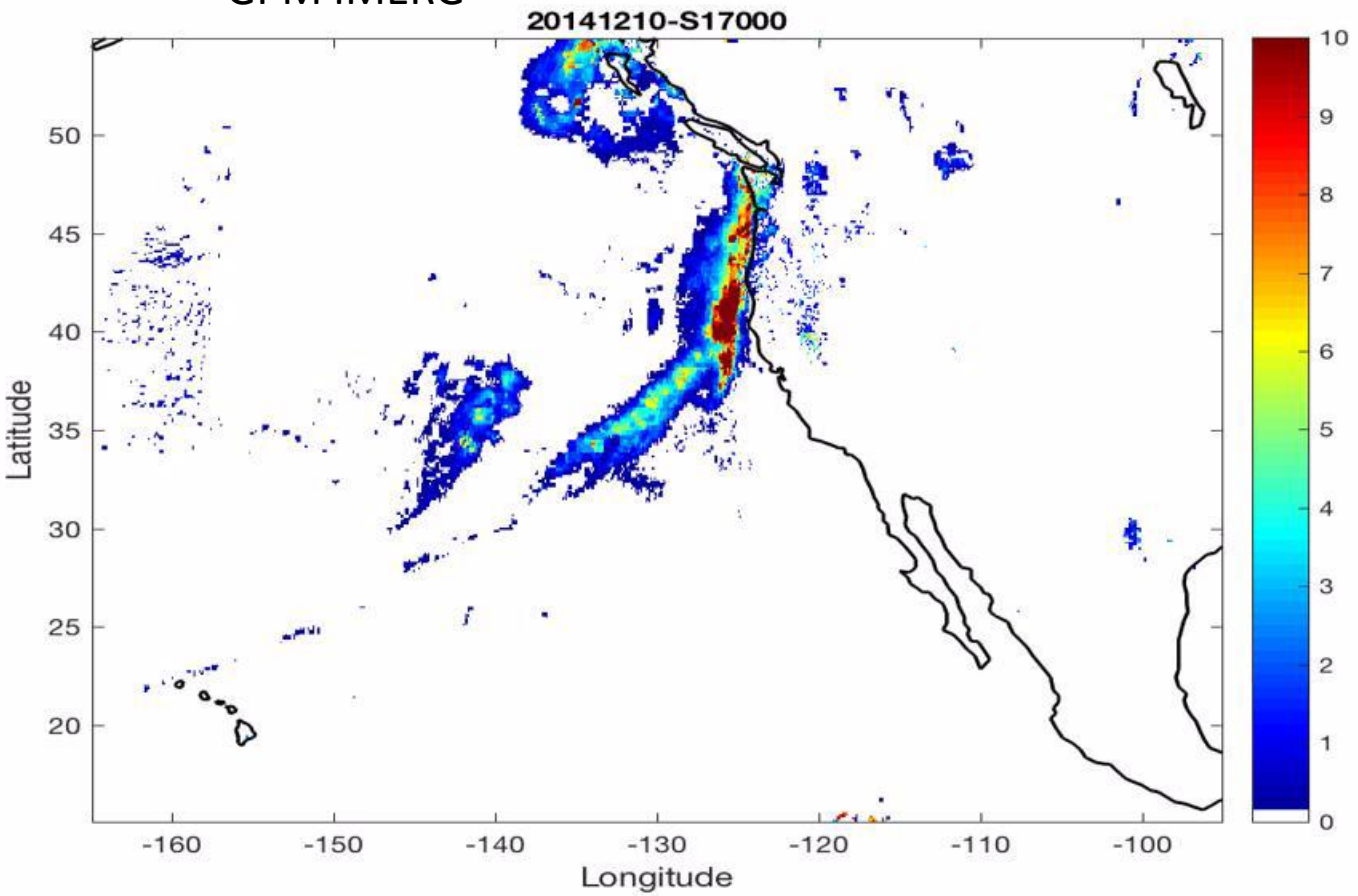
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

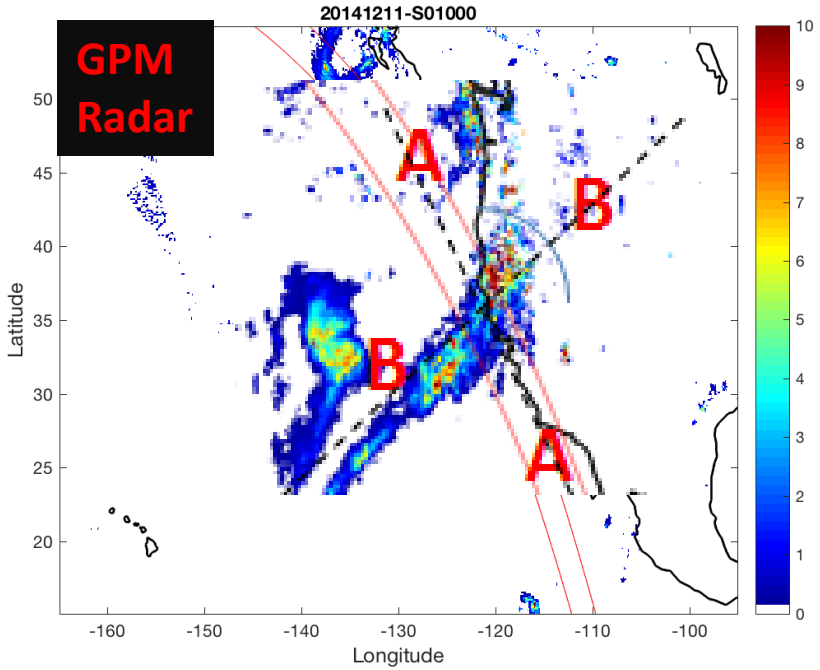
What type of precipitation sensors do we have ?

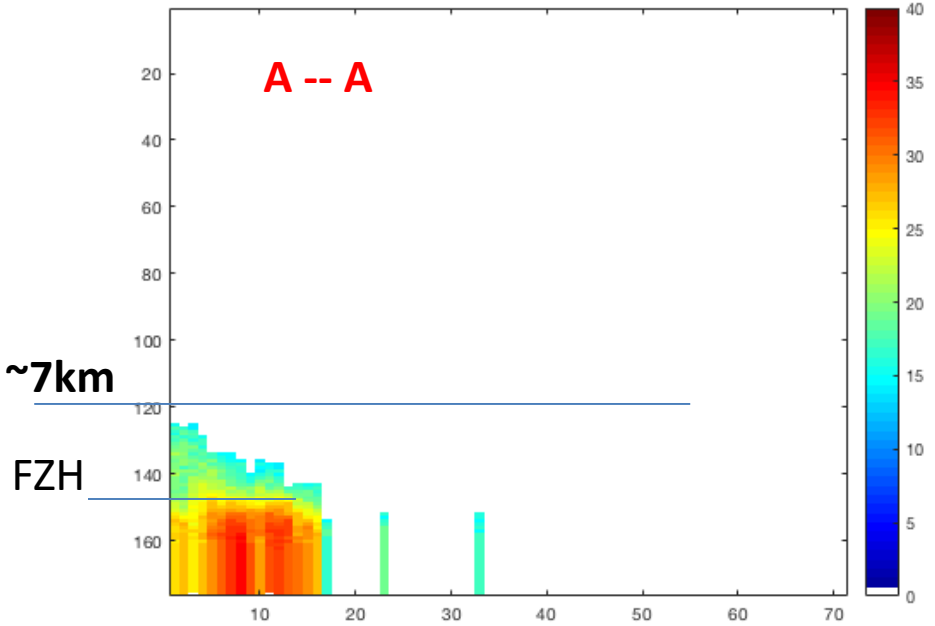
Since 1979 we use satellites to estimate precipitation from space

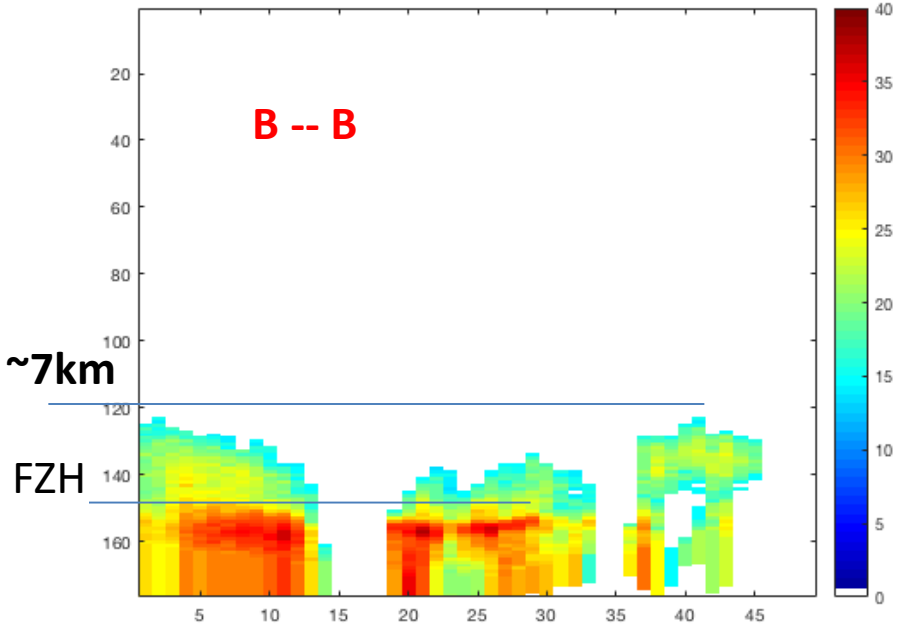


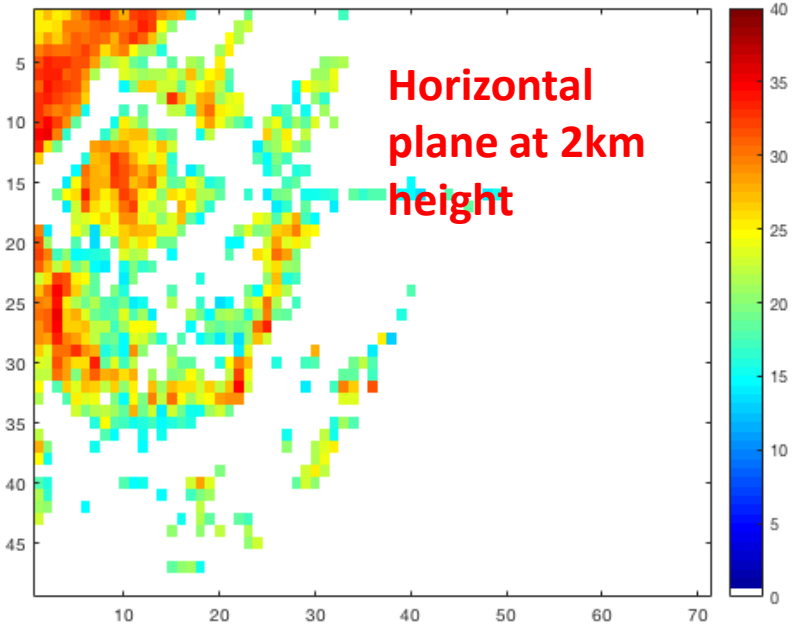
GPM IMERG


20141210-S17000
Latitude
Longitude
50
45
40
35
30
25
20
-160
-150
-140
-130
-120
-110
-100
10
9
8
7
6
5
4
3
2
1
0


20141211-S01000
GPM Radar
A
B
B
A
Latitude
Longitude
50
45
40
35
30
25
20
-160
-150
-140
-130
-120
-110
-100
10
9
8
7
6
5
4
3
2
1
0

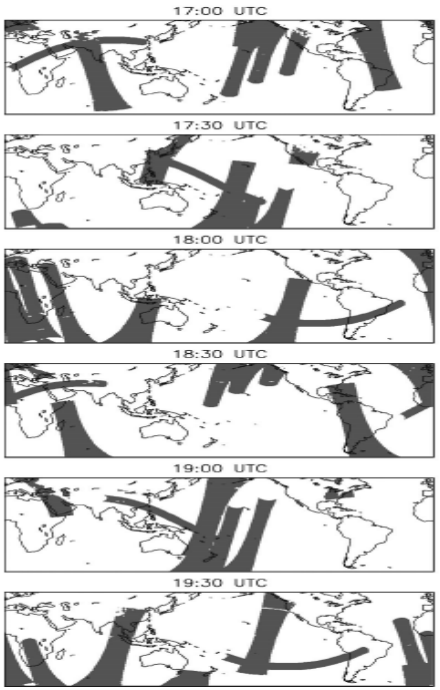

A -- A
~7km
FZH
20
40
60
80
100
120
140
160
10
20
30
40
50
60
70
40
35
30
25
20
15
10
5
0

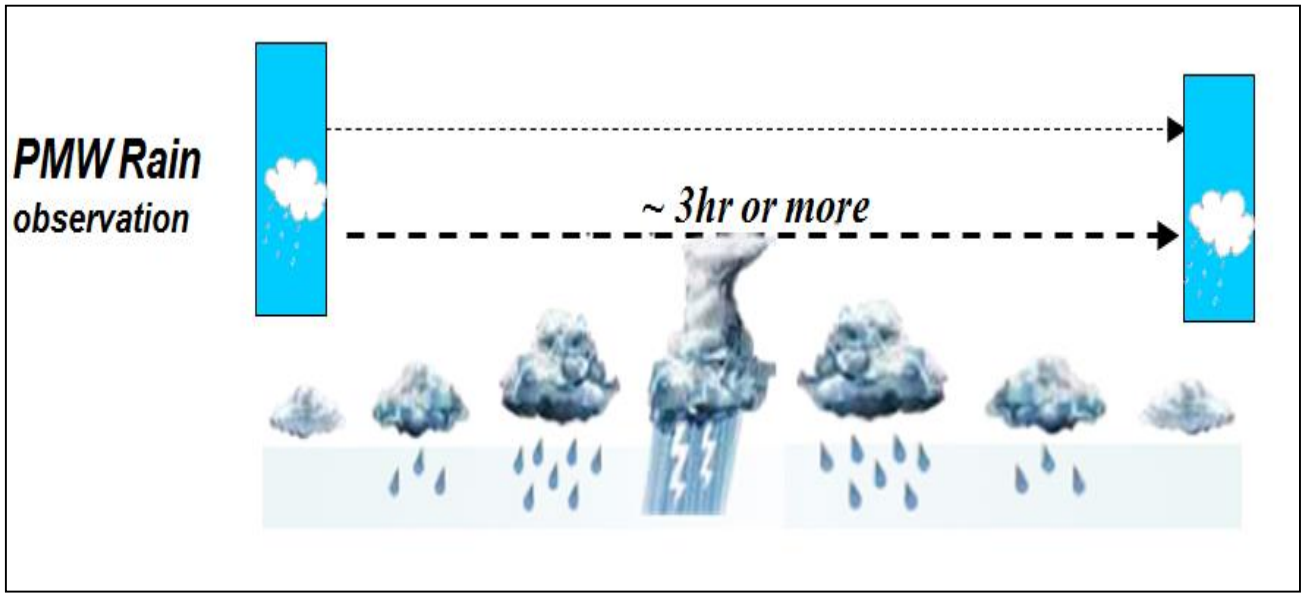

B -- B
~7km
FZH
20
40
60
80
100
120
140
160
5
10
15
20
25
30
35
40
45
40
35
30
25
20
15
10
5
0


Horizontal plane at 2km height
5
10
15
20
25
30
35
40
45
10
20
30
40
50
60
70
40
35
30
25
20
15
10
5
0

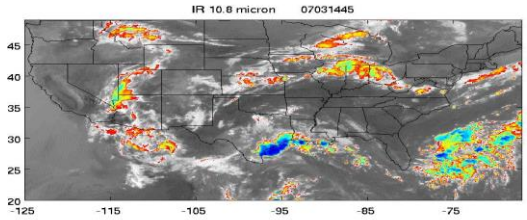
Improving the temporal sampling of precipitaiton

Satellite coverage from low orbit MW sensors (every ½ hour)





Infrared from Geostationary satellites



Combined satellite products :

- TRMM 3B42 (since 1998)
- PERSIANN (since 2000); CDR since 1983
- CMORPH (since 2004)
- IMERG for GPM (since 2014)
- Few more …..

AR precipitation: most challenging over land !

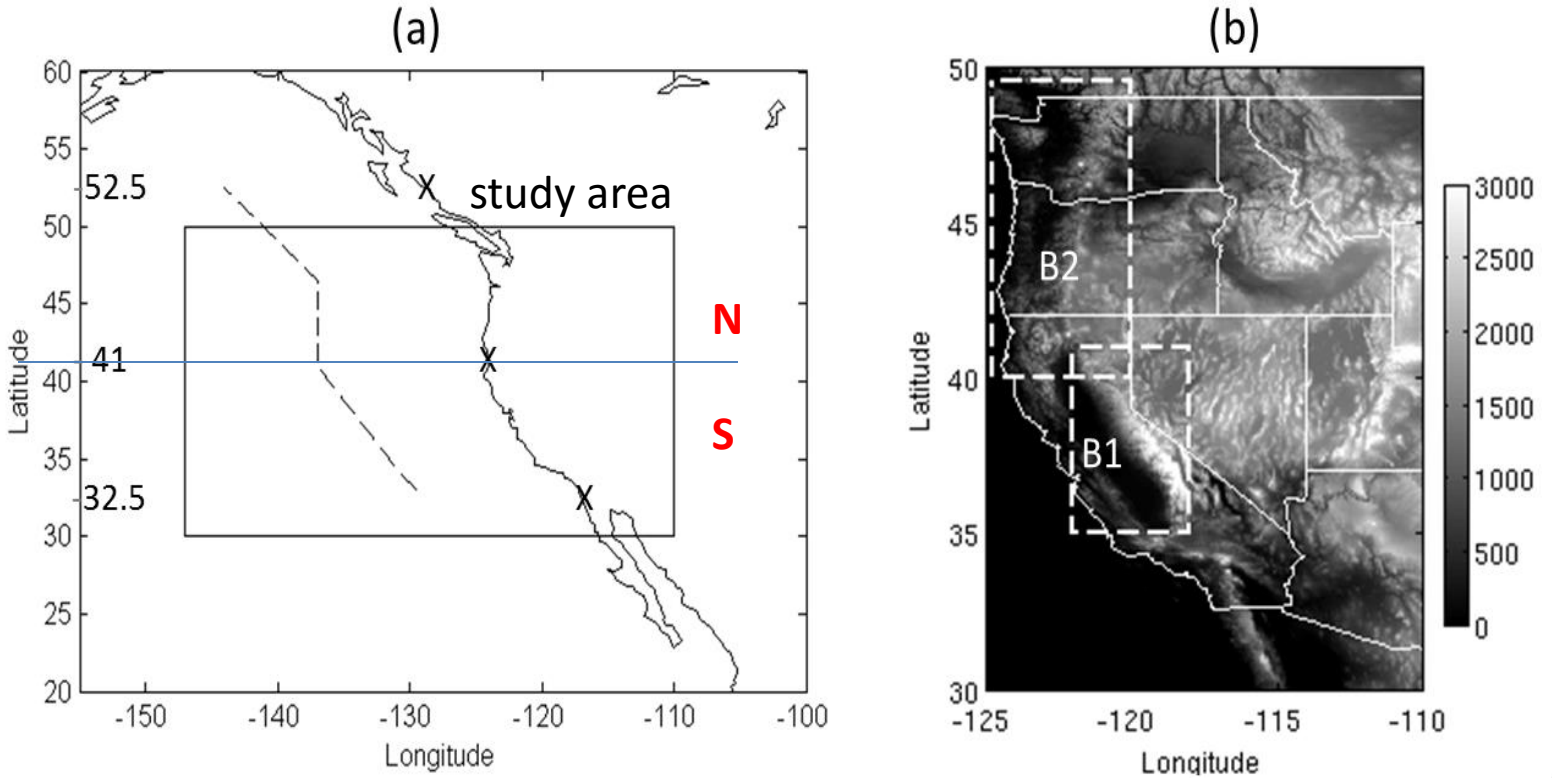
In the western United States, a large fraction of ARs occurs in winter in the form of snowfall or rainfall over snow and ice surfaces and they can come from shallow/warm precipitation systems. These makes it very difficult for retrieving precipitation from IR (e.g., due to poor contrast between cloud-top temp and land surface) and MW (e.g., due to snow unknown emissivity and lack of sufficient scattering ice particles) sensors:

- **IR : high false alarm** *(Behrangi et al. 2012; 2014);*
- **MW: rely on high frequency channels over land; missing data over cold regions** *(Behrangi et al. 2014a, 2014b, 2015, 2016)*
- **Radars have limited spatiotemporal coverage**

Capturing the orographic precipitation is still a big challenge!

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Study domain to study satellite precipitation skill



Period of study : A decade (**2003–2012**)

Region of study: land falling ARs impacting the **North American west coast**

AR Data : Inventory of land falling ARs in the west coast of North America since WY1998.

The dotted line: ~1000 km offshore, bounds a North American West coast domain in which landfalling ARs are observed and collected in the **AR database**

Long-term average

(2003–2012).

gauge correction :

* Gridded gauge

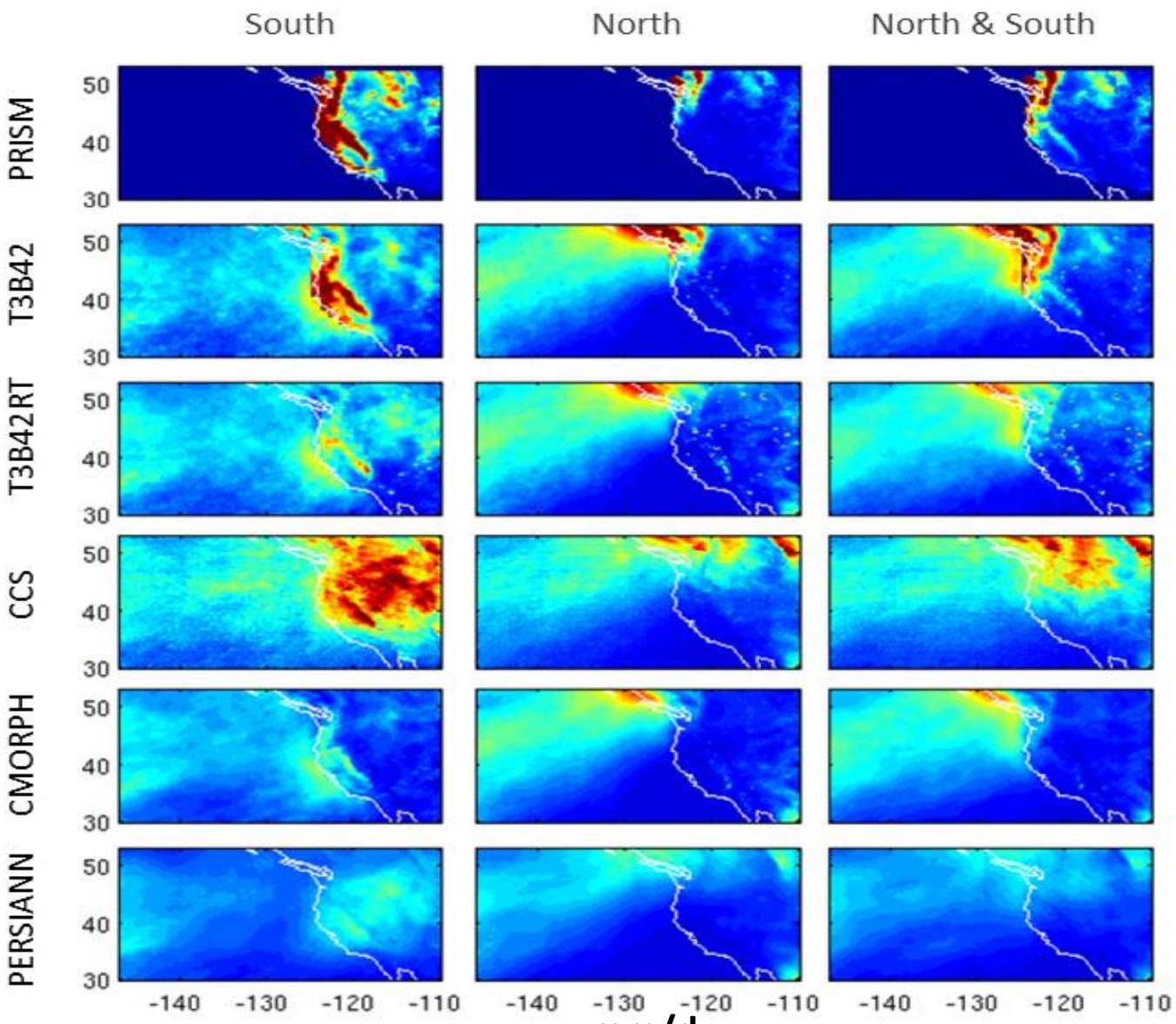
* IR+MW Gauge Corrected

IR+MW Not corrected

IR Not corrected

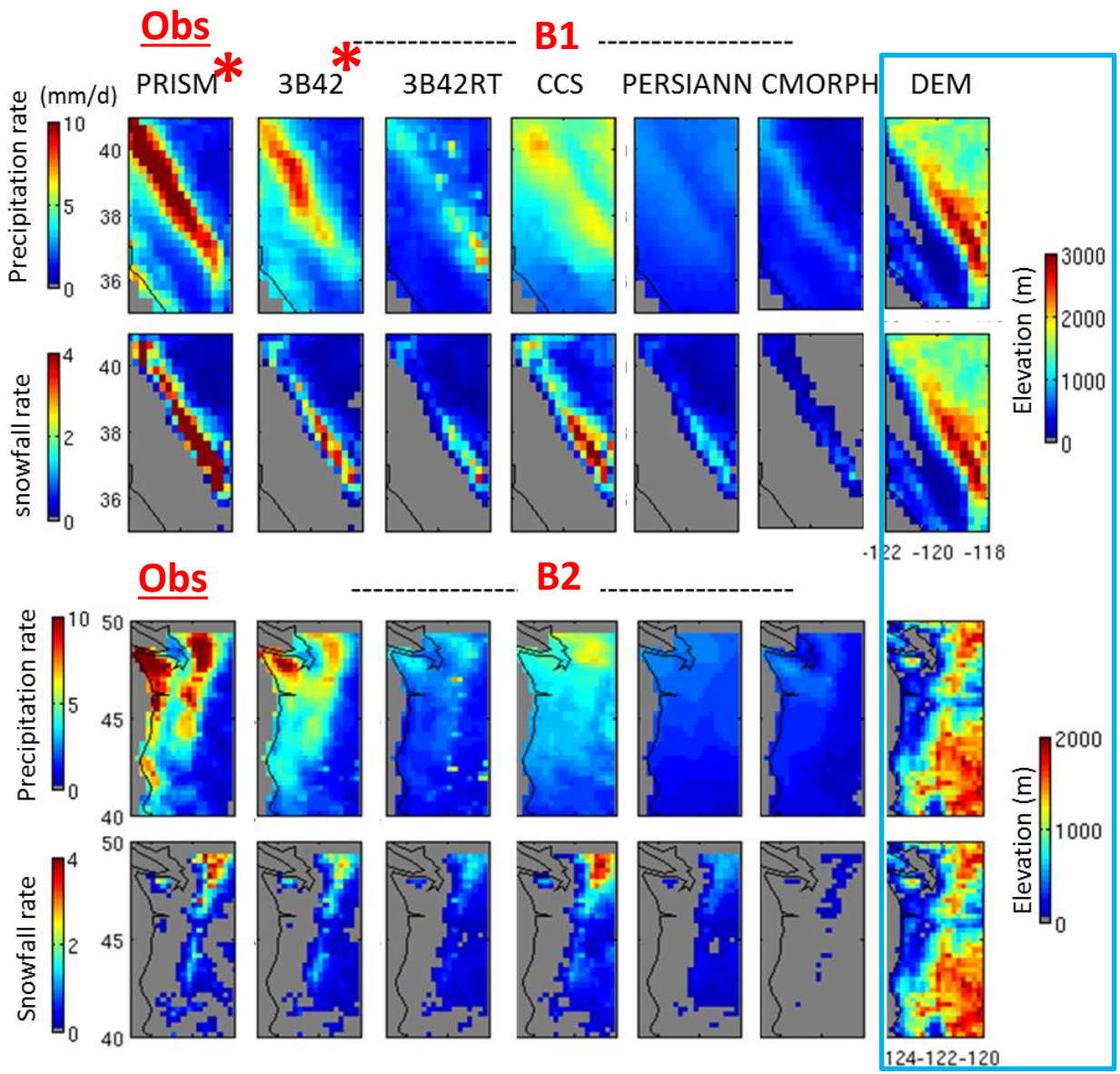
MW Not corrected

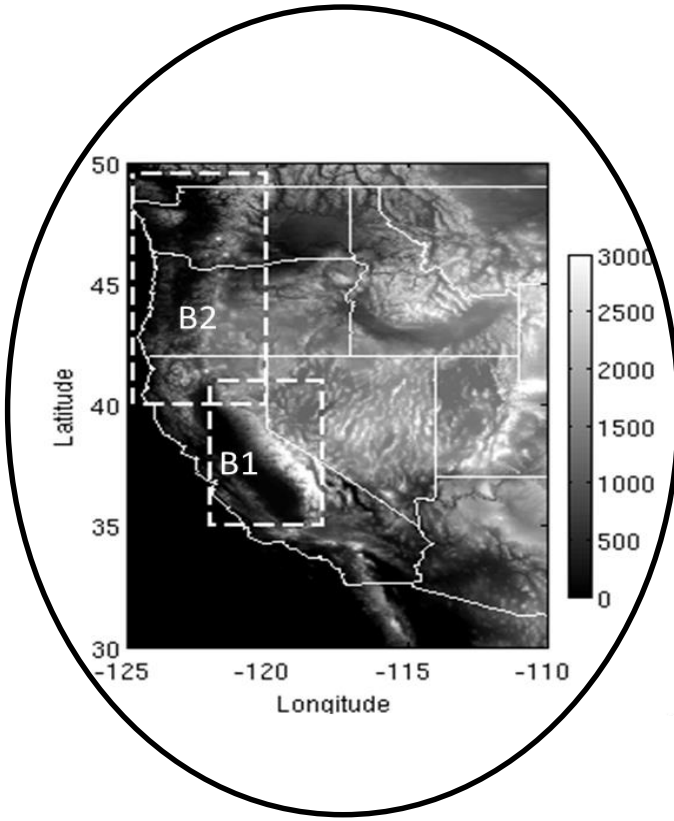
IR Not corrected



Behrangi et al. 2016 (JHM)

AR precipitation climatology in South- and North-west



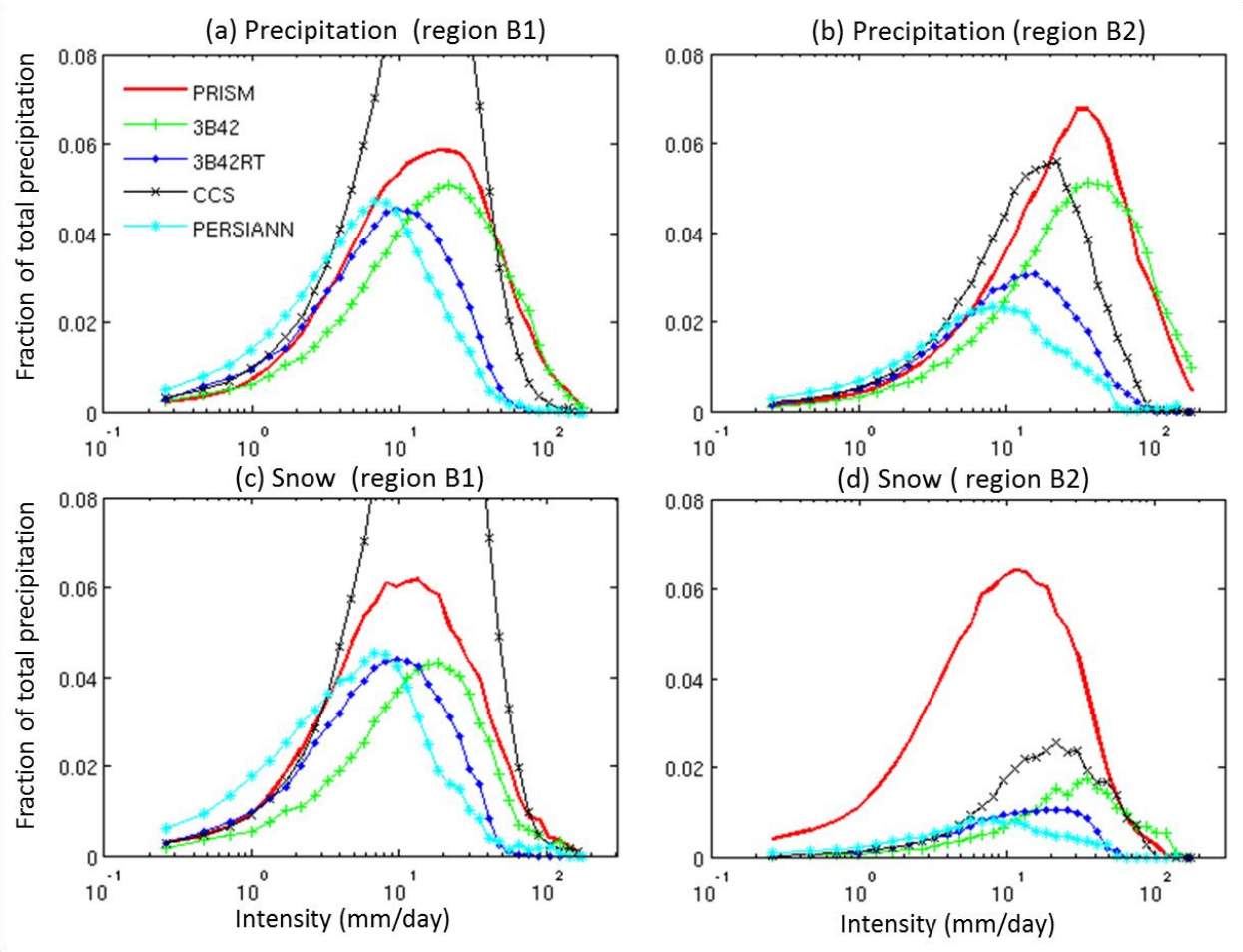


Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Box B1 (South) **Box B2 (North)**

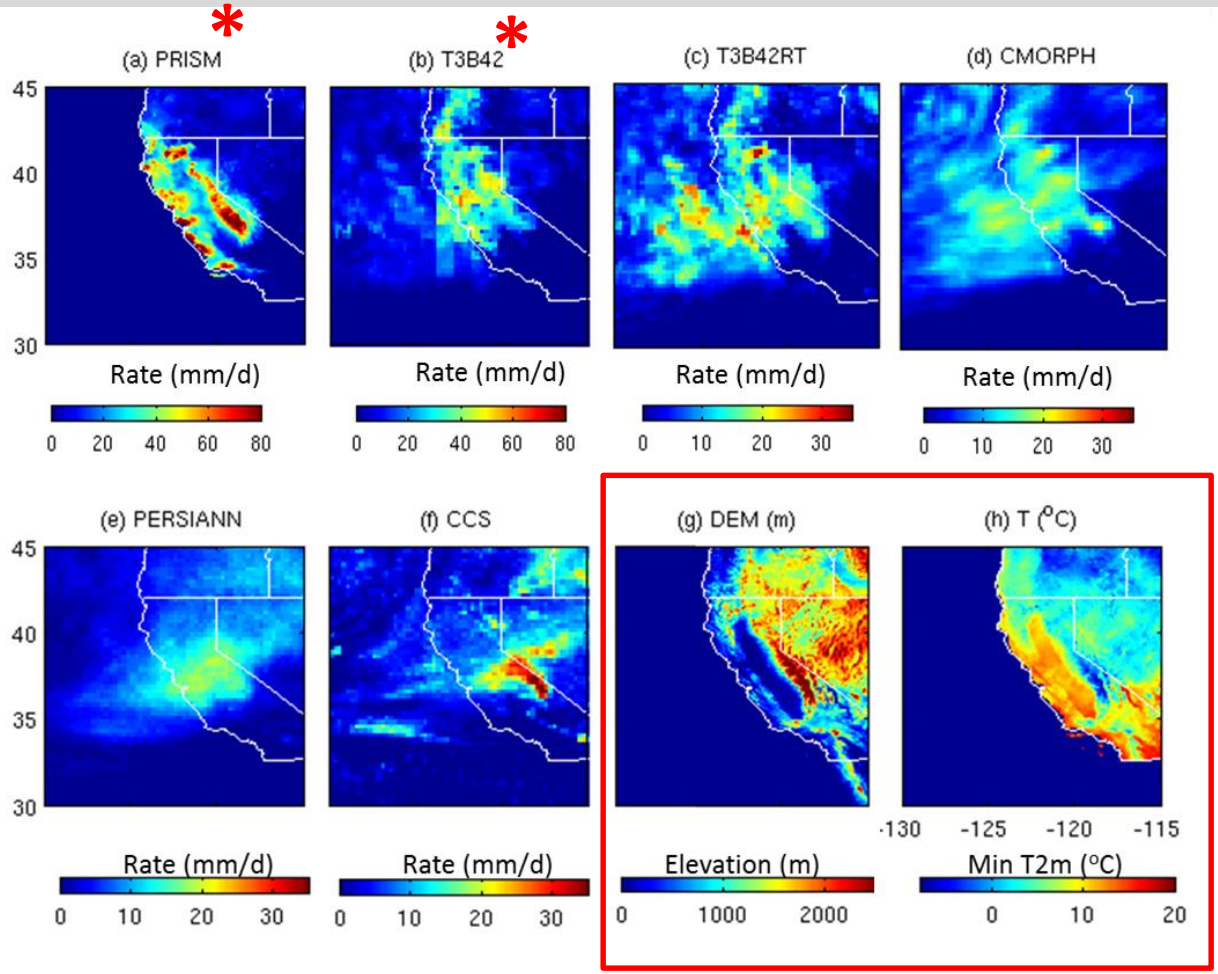
Precipitation

snowfall



Behrangi et al. 2016 (JHM)

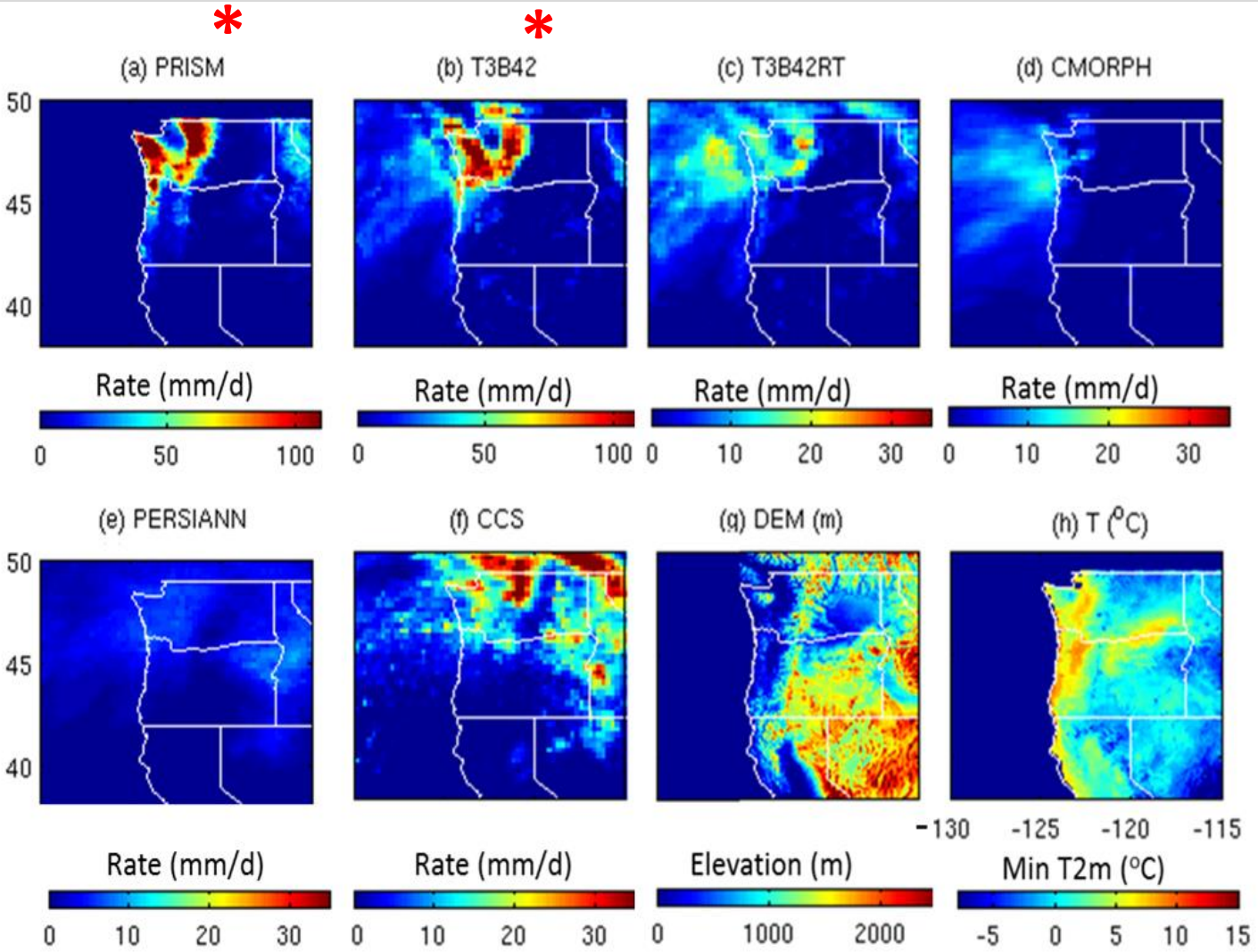
AR Event: October 13 and 14 2009:



Maps of average precipitation rate (mm day^{-1}) resulting from an AR that hit northern and central California on October 13 and 14 2009:

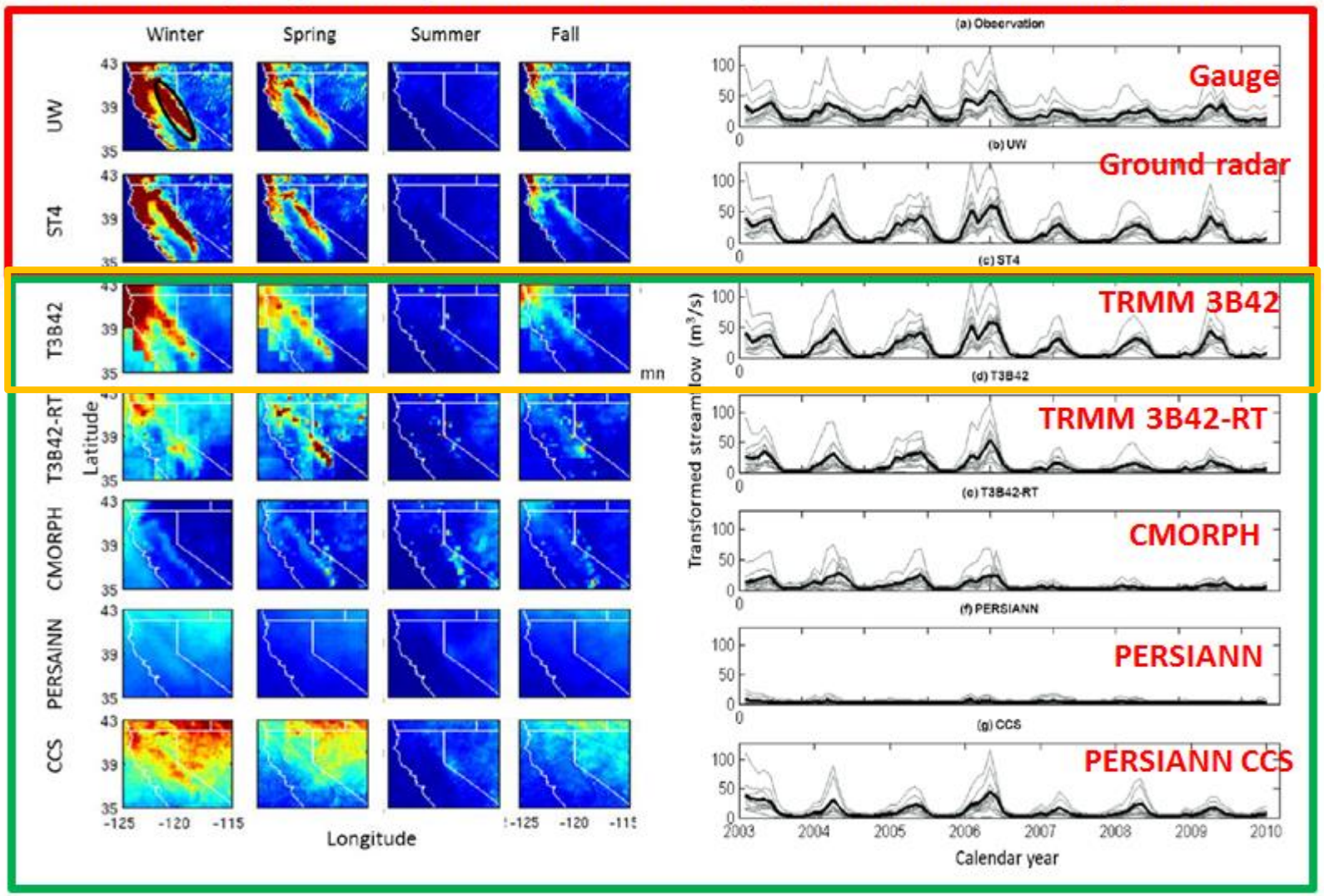
Behrangi et al. 2016 (JHM)

AR event: on January 6–8 2009



Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Hydrologic impact : Stream flow simulation



Interpolated Gauge (PRISM)

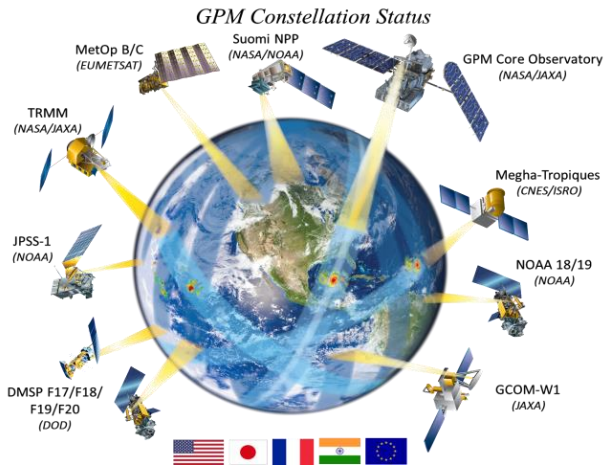
Radar + gauge

Satellite + gauge

Satellite only

Behrangi et al. JAMC (2014)

GPM ERA
2014-present



Main differences compared to TRMM Era:

1- coverage : 65 deg S/N VS. 35 deg S/N

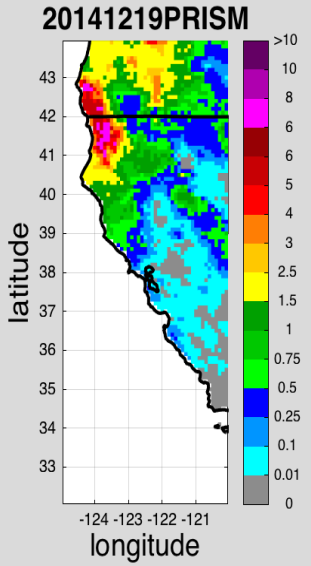
2- Higher Frequency MW channels (for snow)

3- Dual Freq. Radar
(light rain and snow and precip. phase)

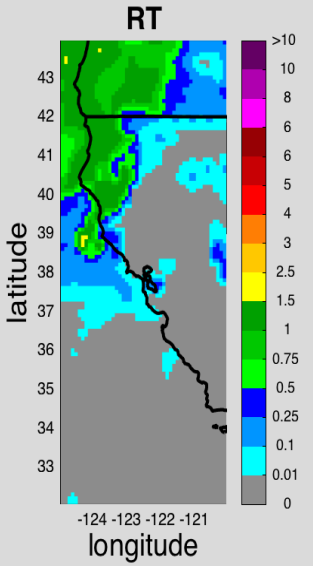
4- Retrieval consistency across all sensors

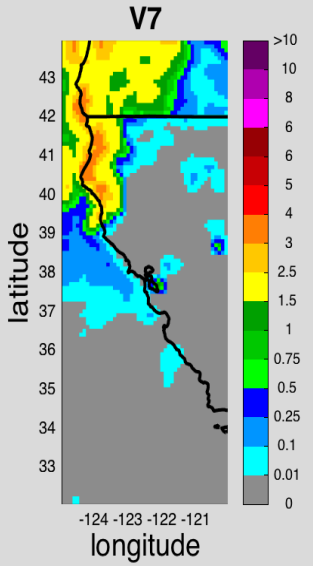
5- More physically-based over land enabling snow retrieval from microwave sensors

TRMM

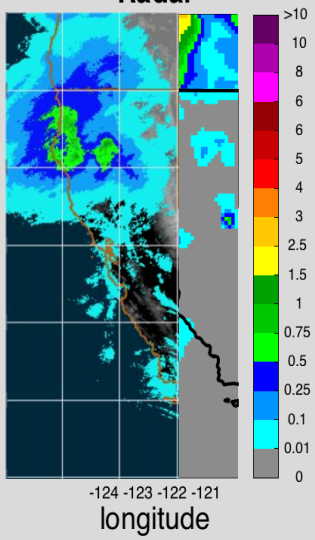


TRMM

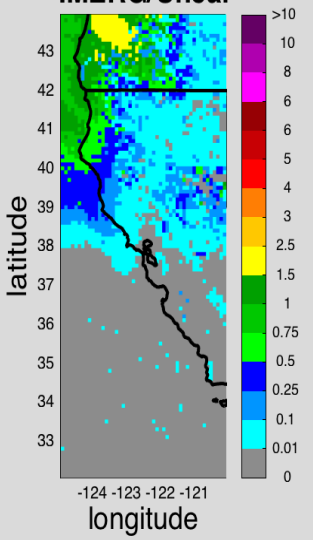


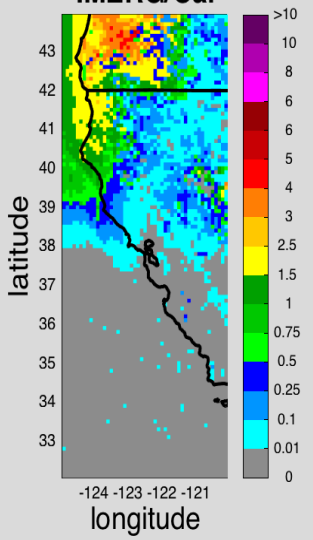


GPM



GPM





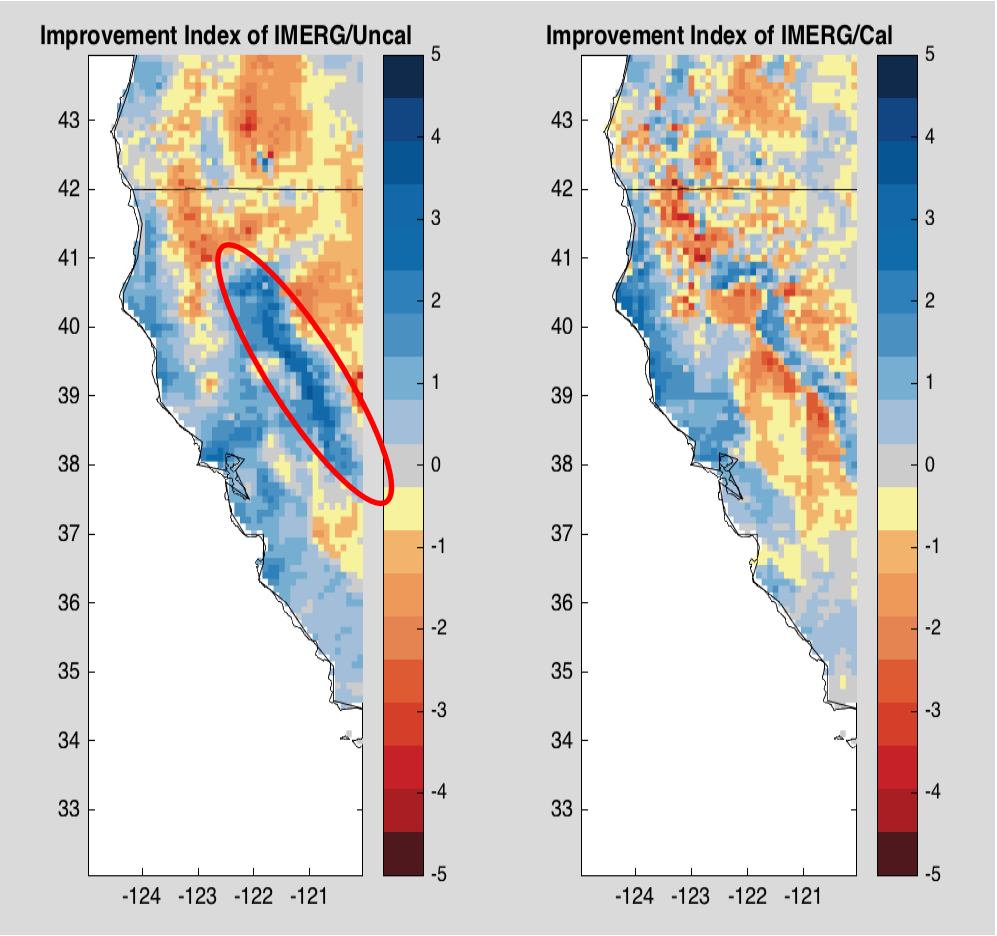
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

A. Behrangi

Comparing GPM IMERG with TRMM 3B42 products

Without Bias correction

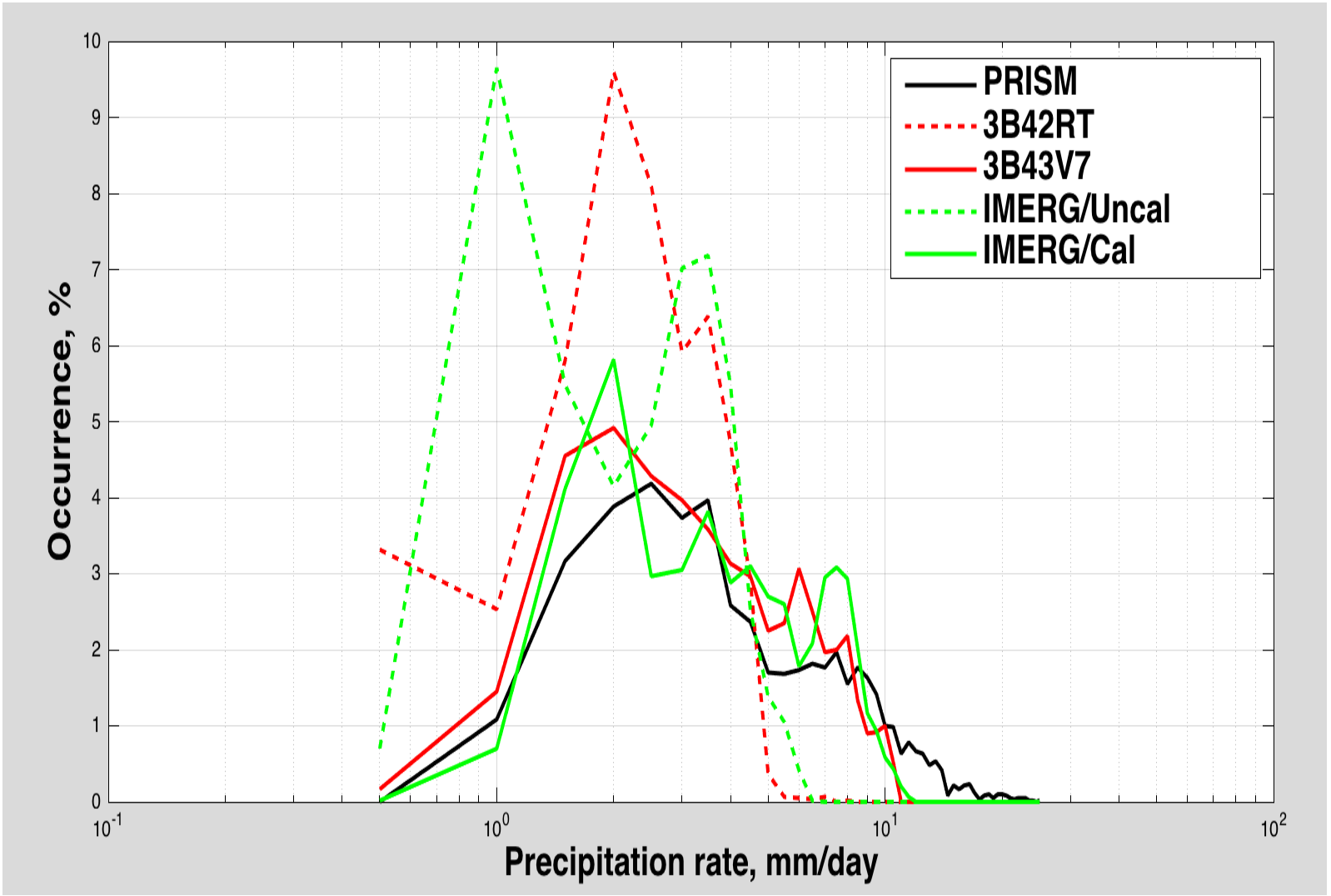
With Bias correction



Blue shows GPM IMERG is improved over TRMM 3B42

`Improvement index = abs(RT-PRISM)-abs(IMERG-PRISM)`

IMERG shows improvement over coastal and high mountain regions


PRISM
3B42RT
3B43V7
IMERG/Uncal
IMERG/Cal
Occurrence, %
Precipitation rate, mm/day
0
1
2
3
4
5
6
7
8
9
10
10^{-1}
10^{0}
10^{1}
10^{2}

Concluding remarks

Satellite products capture overall precipitation pattern, but details are not captured well. ARs are difficult events !

- Orographic precipitation is barely captured
- Bias correction is critical
- Over ocean satellites agree more among themselves, but over land they display a great spread.

In future:

- *RS of orographic precipitation needs to be improved*
- *More effective bias correction needs to be performed; using climatology for near real-time.*
- *Establishing relationship between ocean and land precipitation conditioned on environmental features*

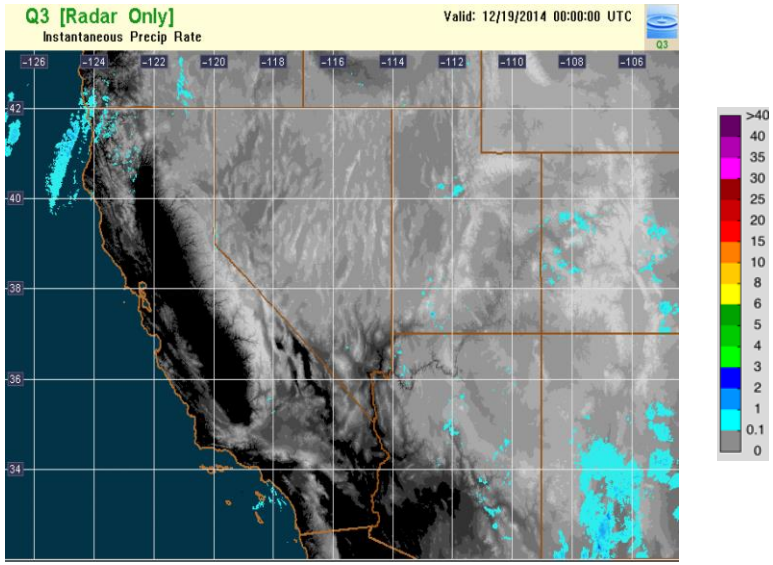
Looking at GPM products and see what they will reveal!

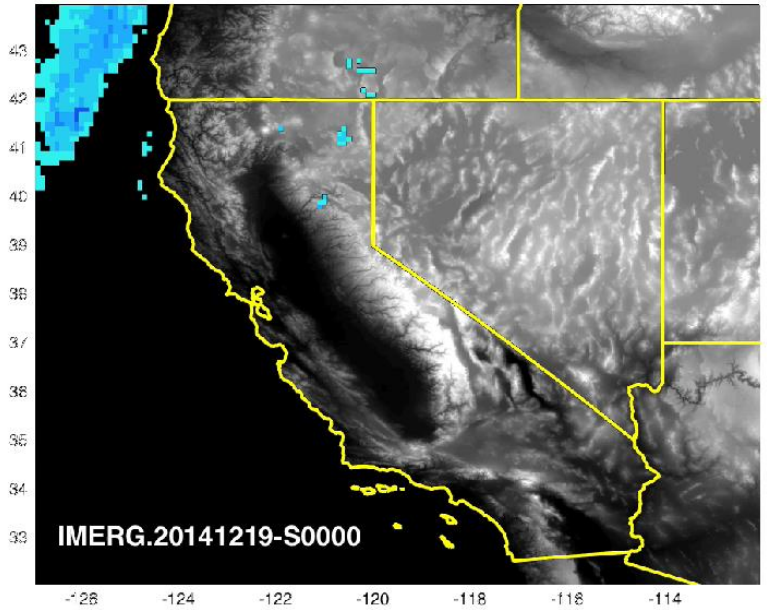
Thanks !

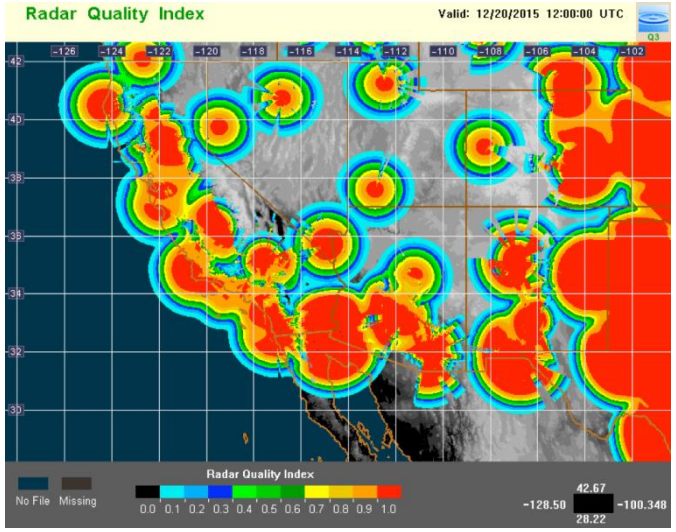
Contact info:

Ali.Behrangi@jpl.nasa.gov

Remote sensing of AR precipitation







Performance of satellite precipitation products ?