Local and Synoptic-scale Characteristics of High- and Low-impact Atmospheric Rivers in California

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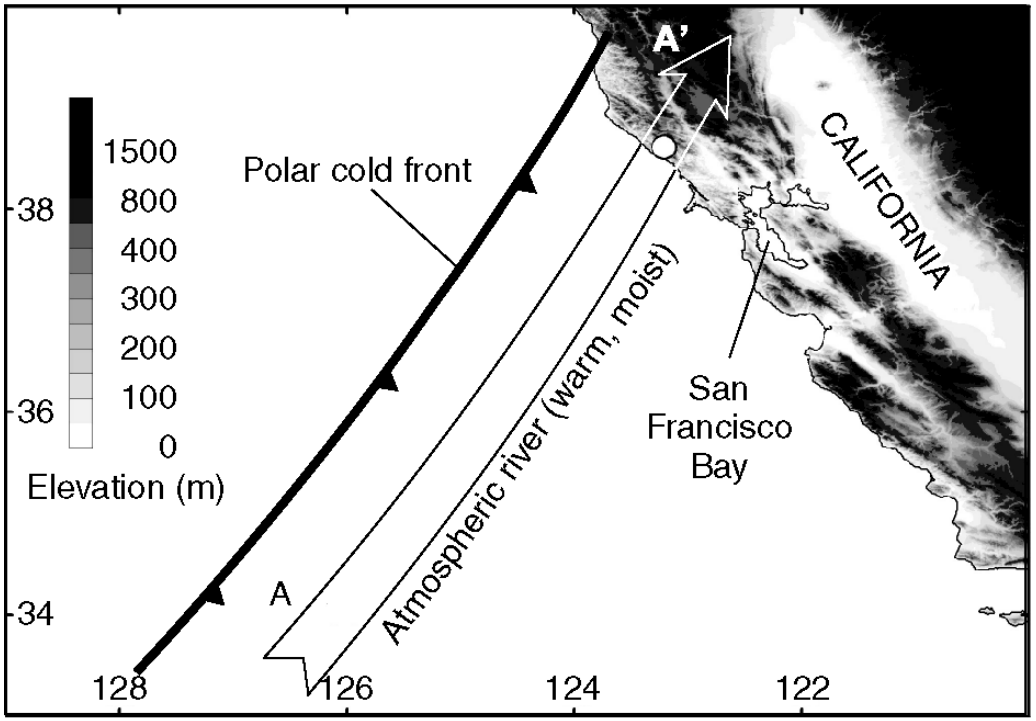
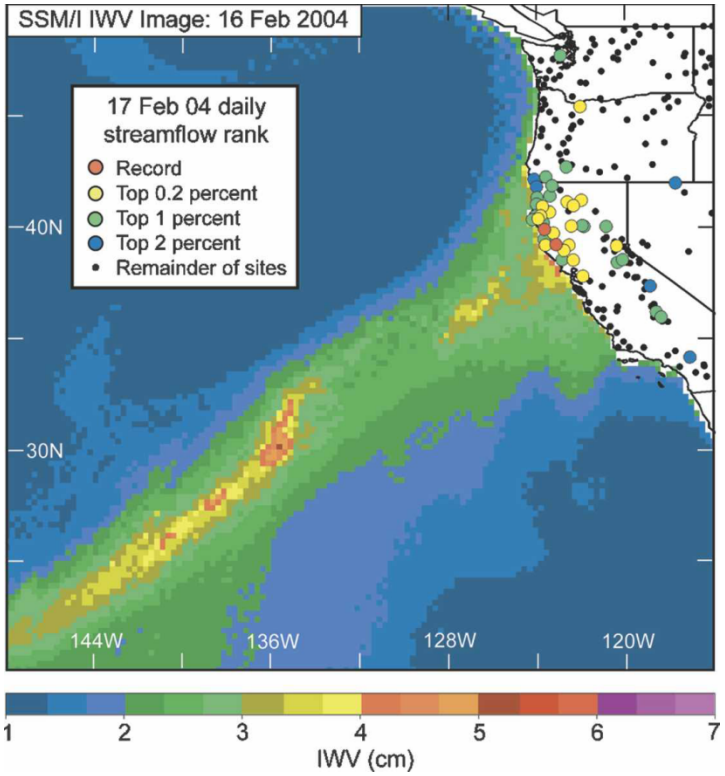




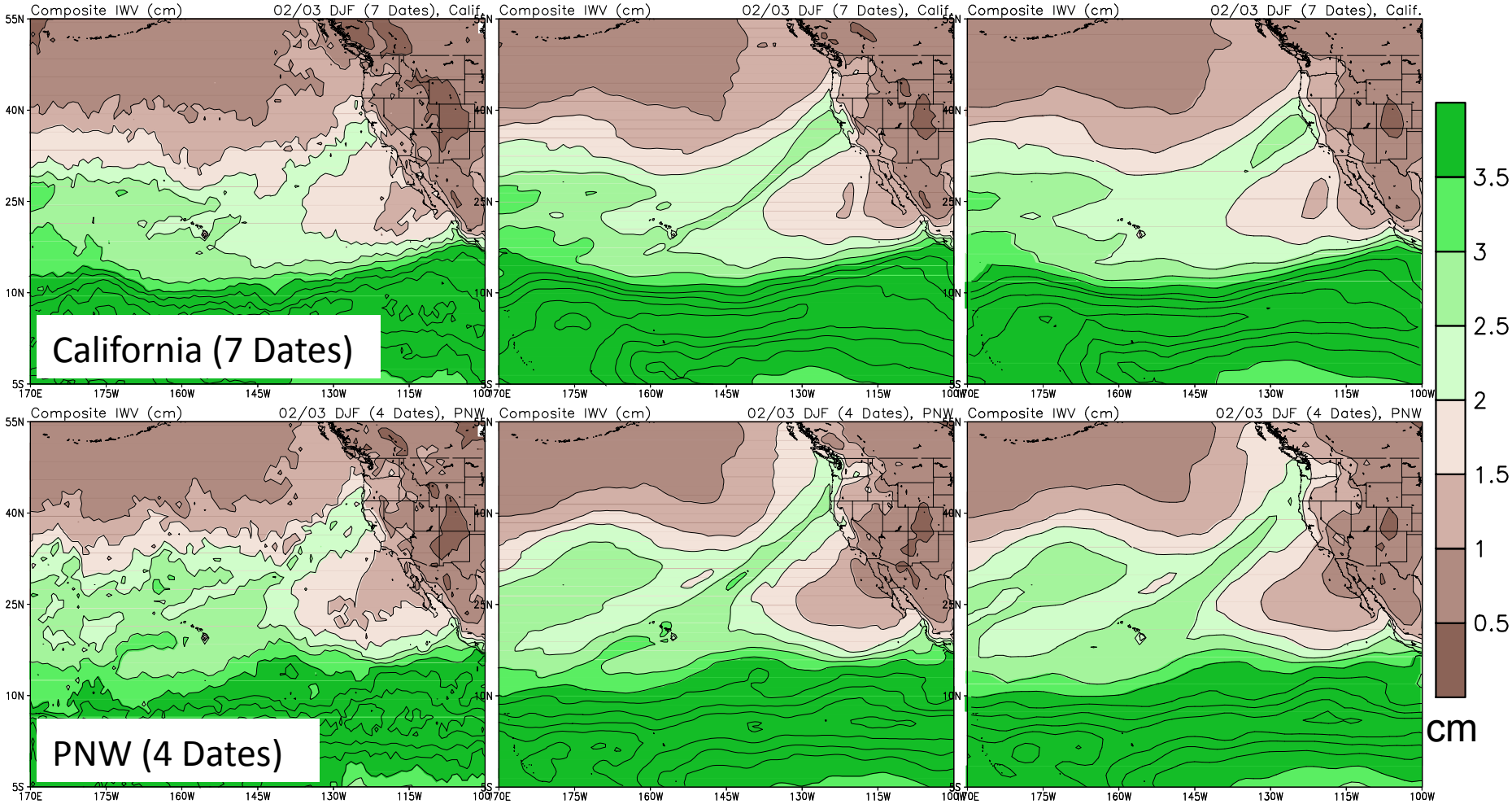
Atmospheric Rivers (ARs)

- ❑Narrow bands of strong moisture transport in the lower atmosphere
- ❑Three to five in each hemisphere at any one time
- ❑10% of the circumference at mid-latitudes
- ❑90% of the meridional moisture transport

Zhu and Newell (1998), Neiman et al. (2009), and others

Atmospheric Rivers in AIRS and Reanalyses

Composite precipitable water during DJF 2002/03



AIRS NASA Merra ERA Interim

Wintertime Atmospheric River Events

2003/04–2007/08 (NDJFM), California Coast

2003/04	2004/05	2005/06	2006/07	2007/08
09Nov2003	27Dec2004	07–08Nov2005	03Nov2006	11Nov2007
29–30Nov2003	09–10Jan2005	25Nov2005	13Nov2006	04Dec2007
05–07Dec2003	22Mar2005	29Nov2005	17Nov2006	05Jan2008
24Dec2003		01–02Dec2005	20Nov2006	10Jan2008
16–17Feb2004		22Dec2005	12Dec2006	
		28Dec2005	09–10Feb2007	
		30–31Dec2005		
		27Feb2006		
		06Mar2006		
		25Mar2006		
		28Mar2006		

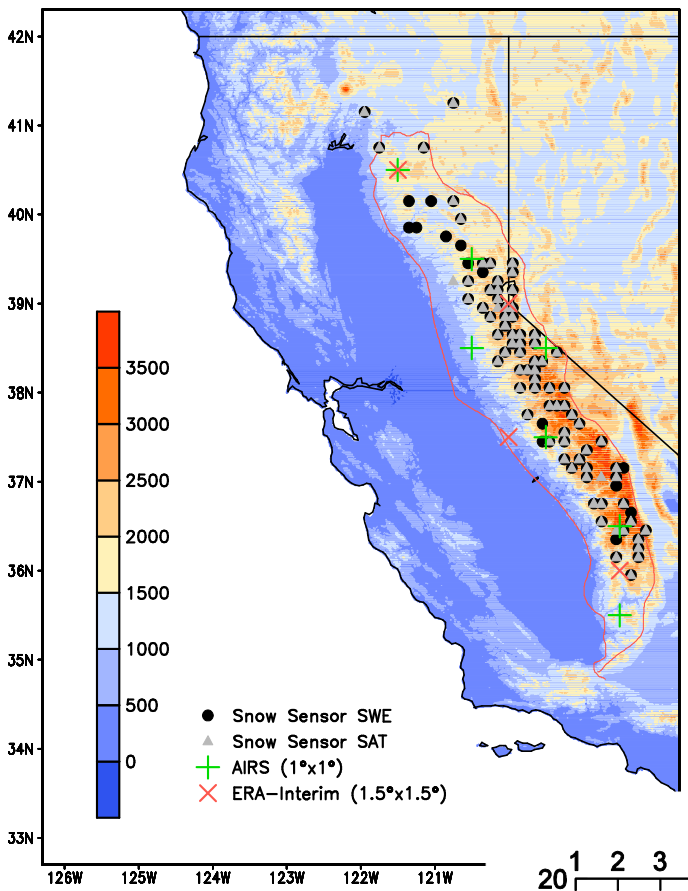
SSM/I integrated water vapor
- ❑>2cm
- ❑longer than 2000 km
- ❑narrower than 1000 km
- ❑intersects the West Coast between 32.5 and 41°N.

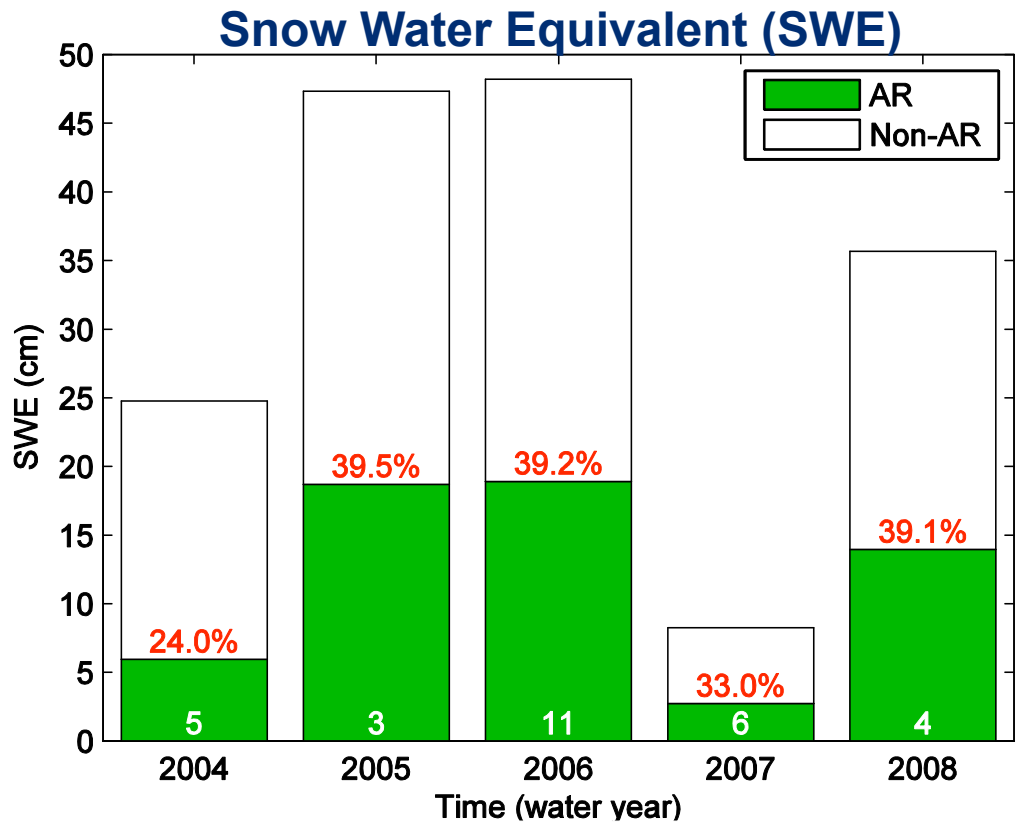
~6/yr on average, with large year-to-year variations

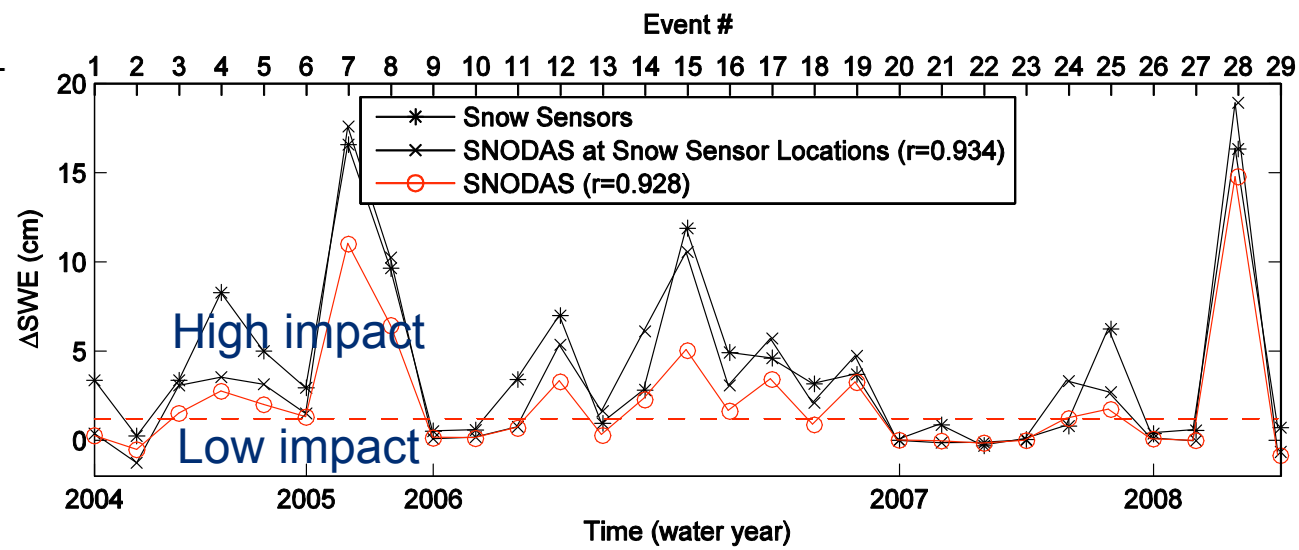
AR dates provided by Paul Neiman (NOAA/ESRL)

Potential Impacts of Landfalling ARs

- Extreme precipitation
- Flooding
- An important water resource

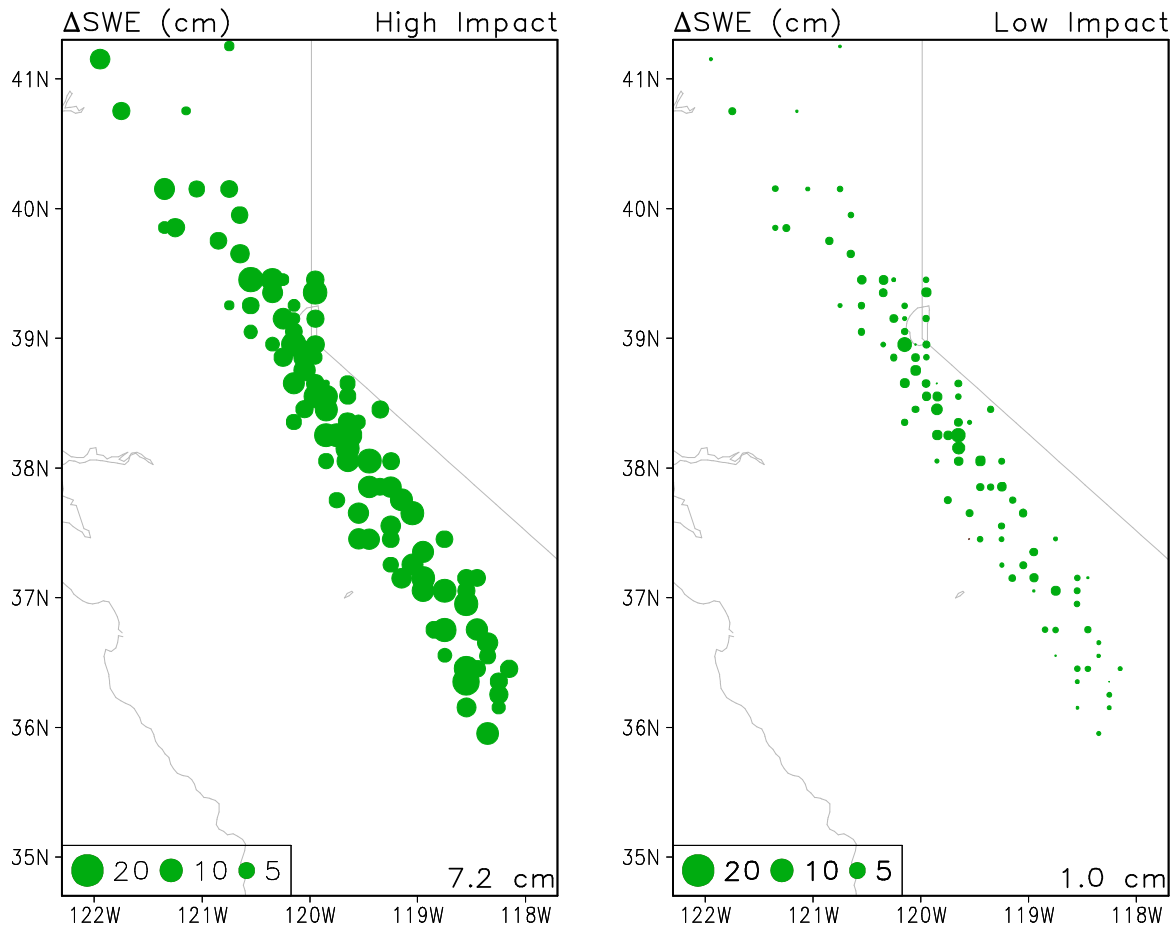

42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
126W
125W
124W
123W
122W
121W
3500
3000
2500
2000
1500
1000
500
0
Snow Sensor SWE
Snow Sensor SAT
AIRS (1°x1°)
ERA-Interim (1.5°x1.5°)

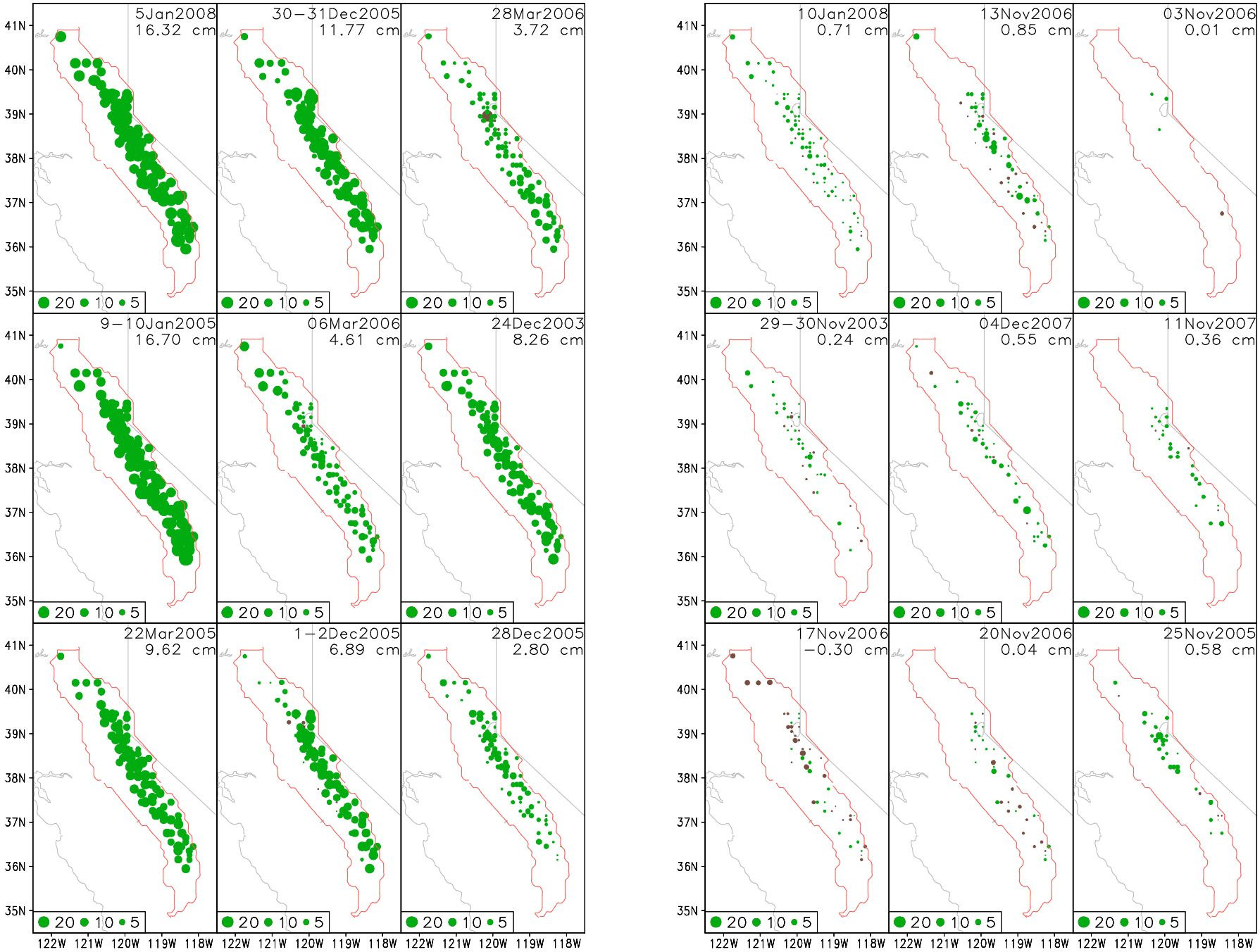

Snow Water Equivalent (SWE)
SWE (cm)
AR
Non-AR
24.0%
39.5%
39.2%
33.0%
39.1%
5
3
11
6
4
2004
2005
2006
2007
2008
Time (water year)


Event #
ΔSWE (cm)
Snow Sensors
SNODAS at Snow Sensor Locations (r=0.934)
SNODAS (r=0.928)
High impact
Low impact
2004
2005
2006
2007
2008
Time (water year)

High- vs. Low-impact ARs

Mean ΔSWE




5Jan2008
16.32 cm
30−31Dec2005
11.77 cm
28Mar2006
3.72 cm
9−10Jan2005
16.70 cm
06Mar2006
4.61 cm
24Dec2003
8.26 cm
22Mar2005
9.62 cm
1−2Dec2005
6.89 cm
28Dec2005
2.80 cm
10Jan2008
0.71 cm
13Nov2006
0.85 cm
03Nov2006
0.01 cm
29−30Nov2003
0.24 cm
04Dec2007
0.55 cm
11Nov2007
0.36 cm
17Nov2006
−0.30 cm
20Nov2006
0.04 cm
25Nov2005
0.58 cm
20 10 5
41N
40N
39N
38N
37N
36N
35N
122W 121W 120W 119W 118W

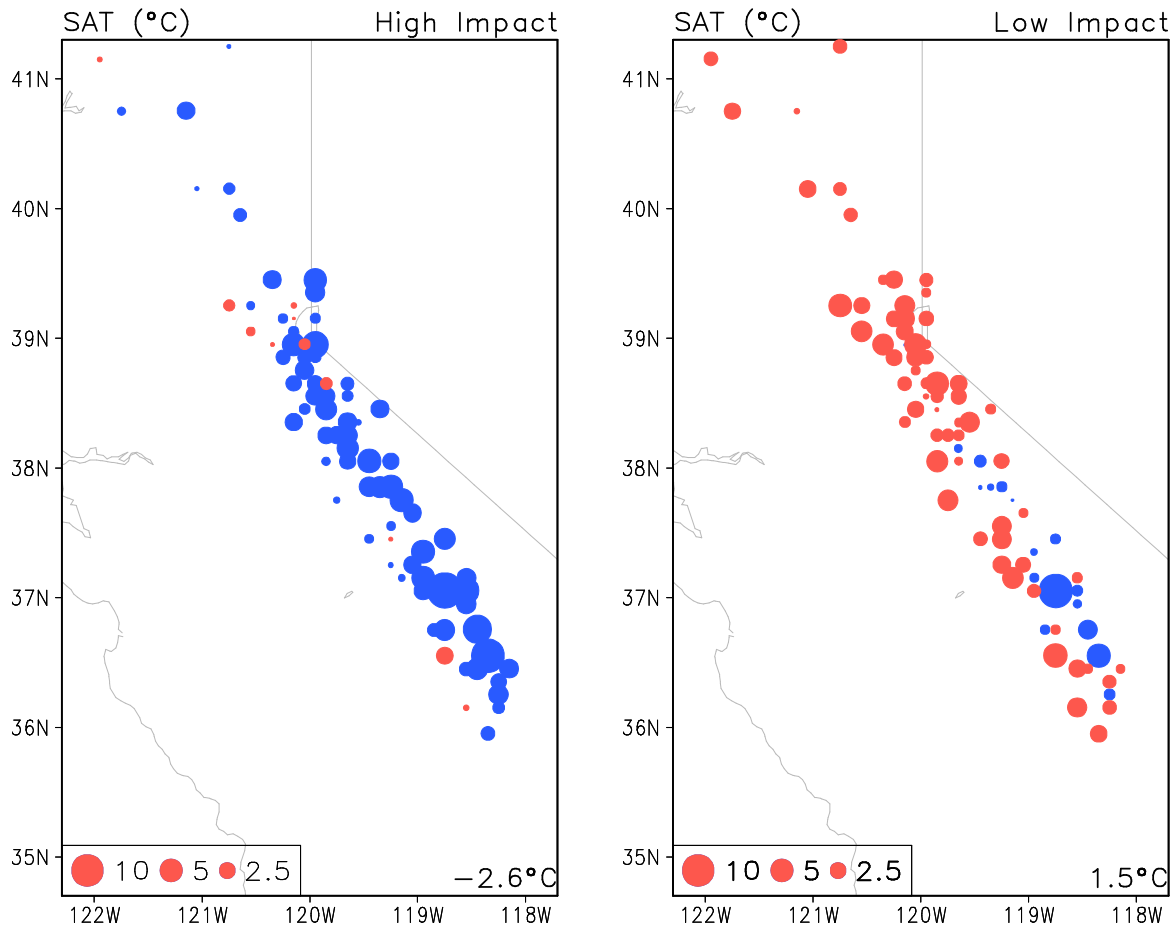
What controls the overland impacts of ARs?

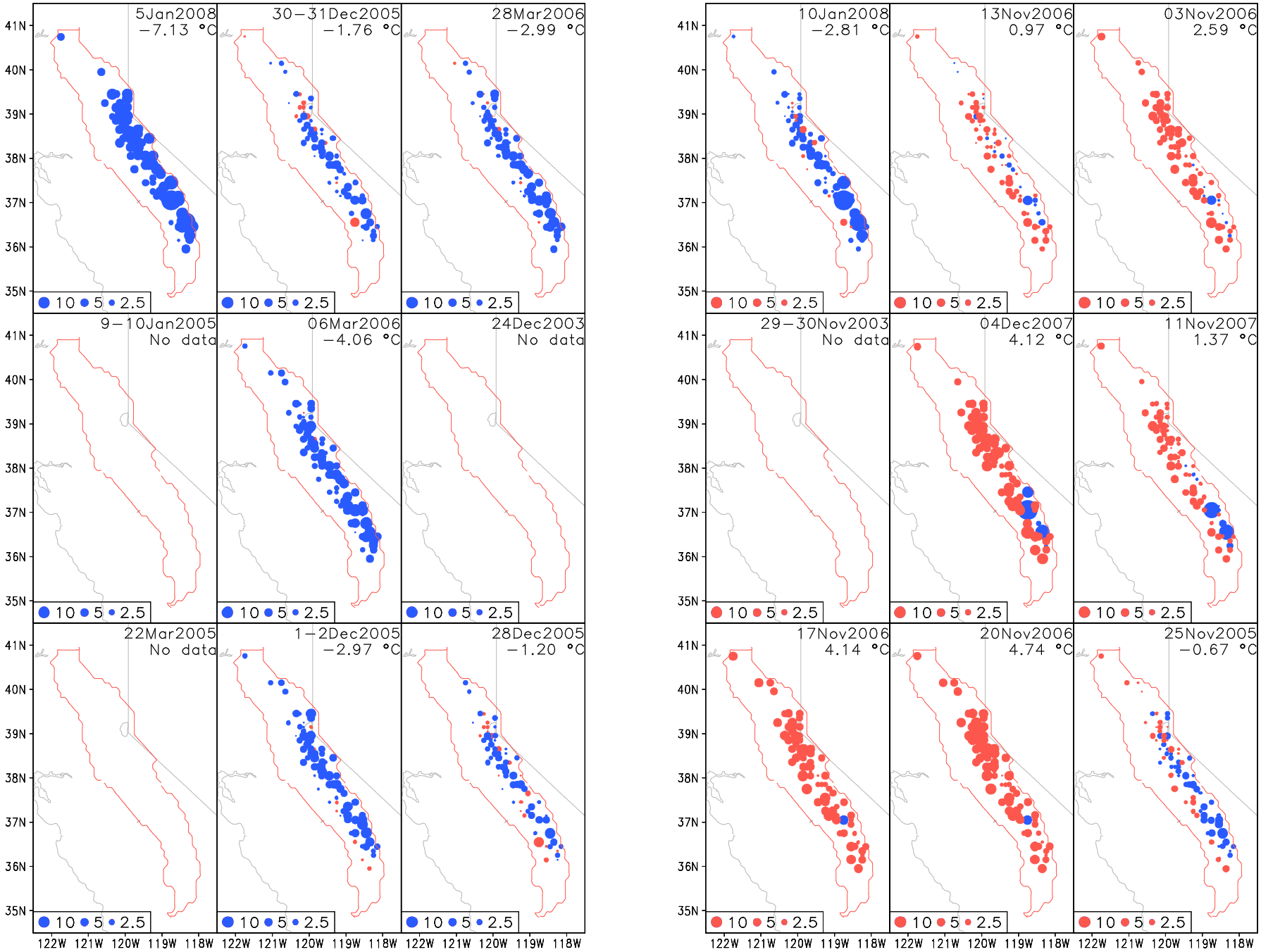
- ❑ Moisture content
- ❑ Wind speed
- ❑ Air temperature
- ❑ Atmospheric stability
- ❑ Orientation/location of ARs
- ❑ …

Atmospheric Rivers $\xrightarrow[\text{among others}]{\text{Surface T}}$ Snow Accumulation in the Sierra Nevada

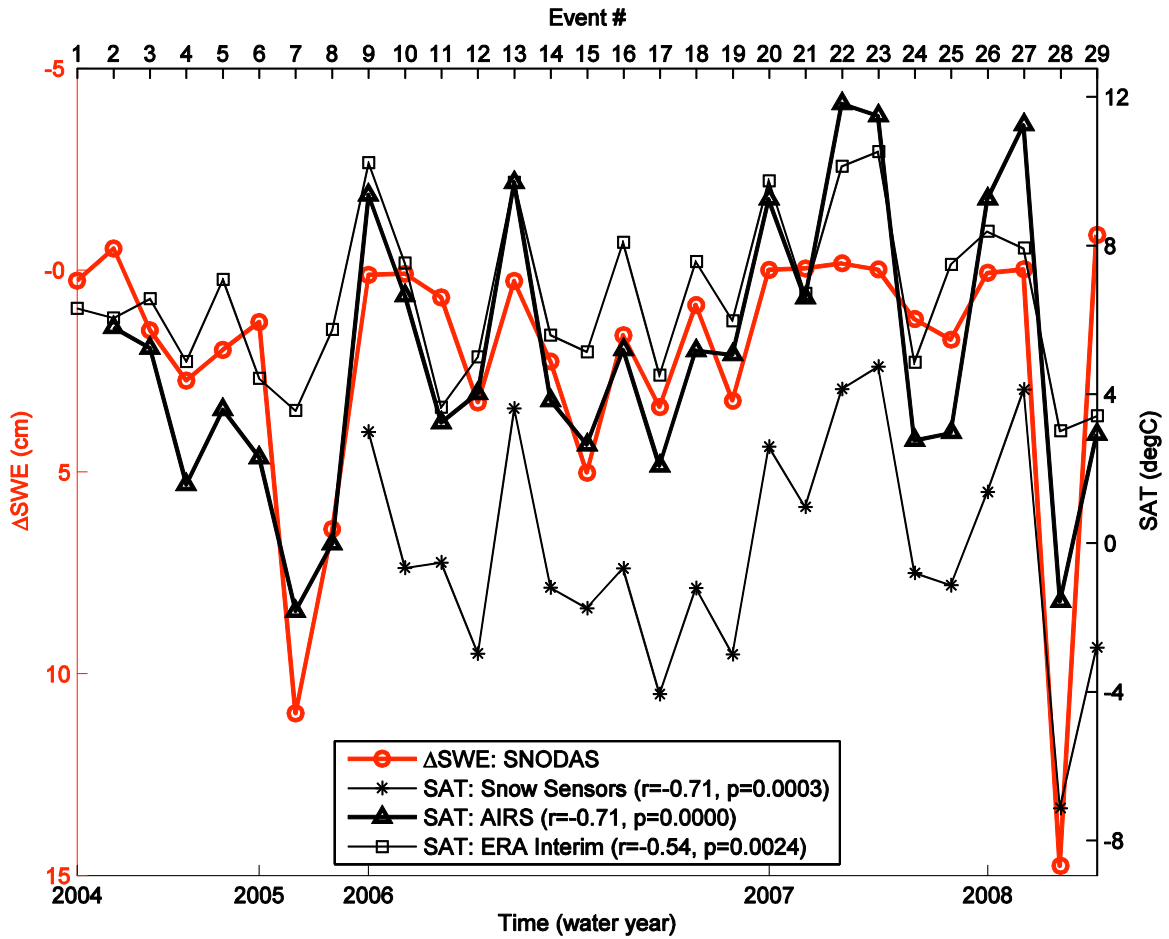
High- vs. Low-impact ARs

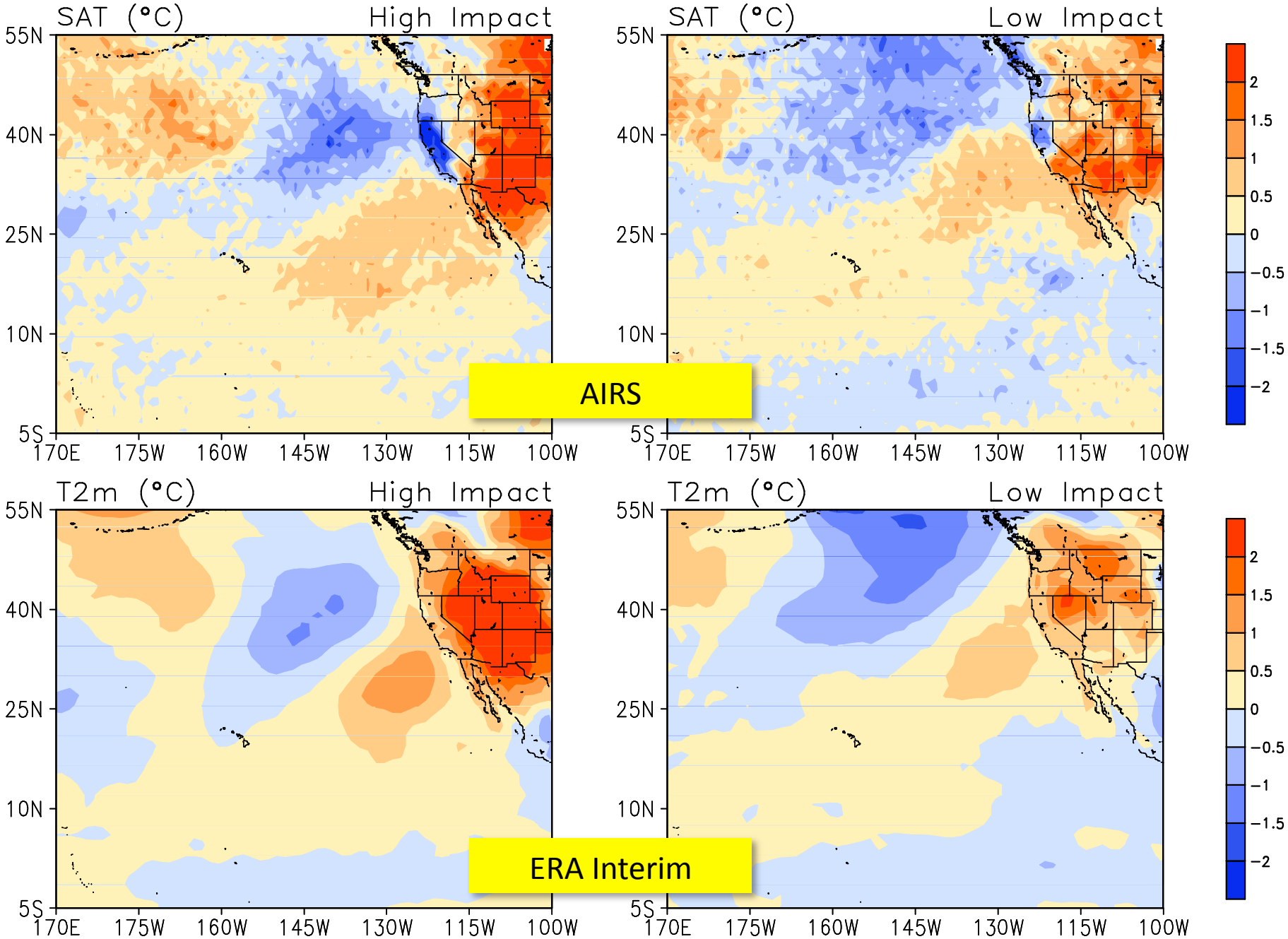
Surface Air Temperature (SAT)




5Jan2008
−7.13 °C
30−31Dec2005
−1.76 °C
28Mar2006
−2.99 °C
9−10Jan2005
No data
06Mar2006
−4.06 °C
24Dec2003
No data
22Mar2005
No data
1−2Dec2005
−2.97 °C
28Dec2005
−1.20 °C
10Jan2008
−2.81 °C
13Nov2006
0.97 °C
03Nov2006
2.59 °C
29−30Nov2003
No data
04Dec2007
4.12 °C
11Nov2007
1.37 °C
17Nov2006
4.14 °C
20Nov2006
4.74 °C
25Nov2005
−0.67 °C
10 5 2.5
41N 40N 39N 38N 37N 36N 35N
122W 121W 120W 119W 118W

ΔSWE and SAT


Event #
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
-5
-0
5
10
15
ΔSWE (cm)
12
8
4
0
-4
-8
SAT (degC)
2004
2005
2006
2007
2008
Time (water year)
ΔSWE: SNODAS
SAT: Snow Sensors (r=-0.71, p=0.0003)
SAT: AIRS (r=-0.71, p=0.0000)
SAT: ERA Interim (r=-0.54, p=0.0024)

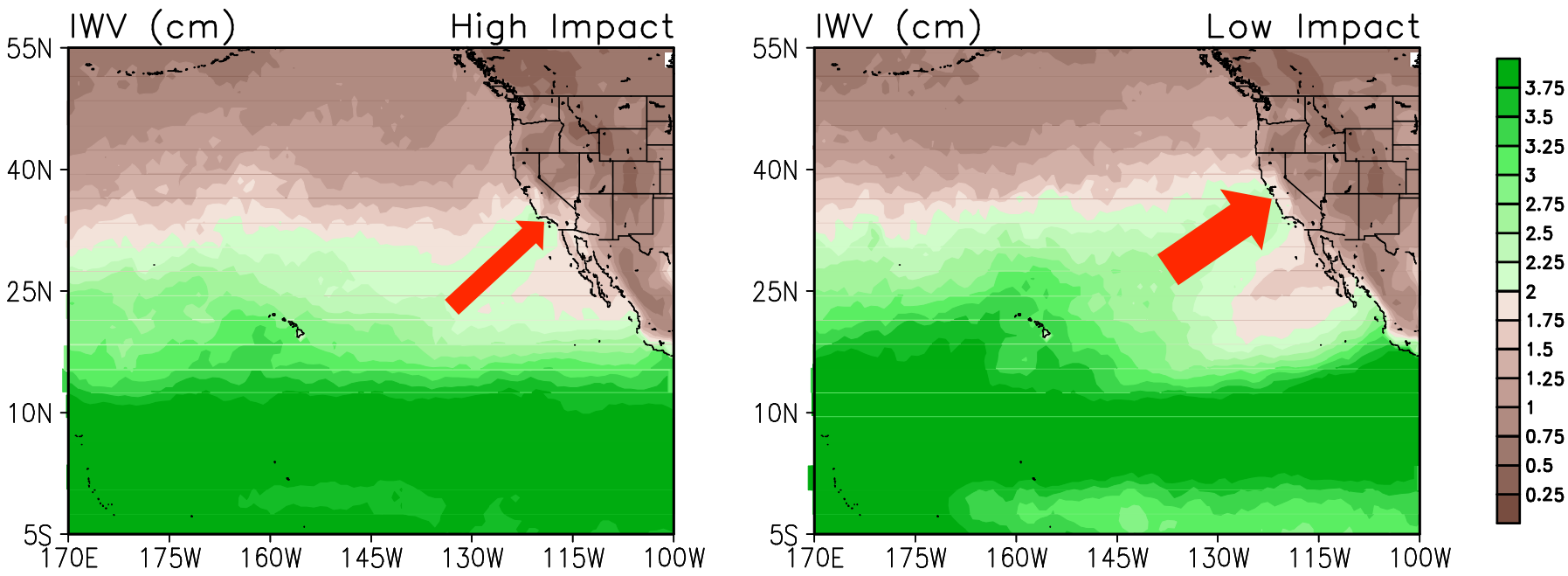

SAT (°C)
High Impact
SAT (°C)
Low Impact
AIRS
T2m (°C)
High Impact
T2m (°C)
Low Impact
ERA Interim
55N
40N
25N
10N
5S
170E
175W
160W
145W
130W
115W
100W
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2

Summary

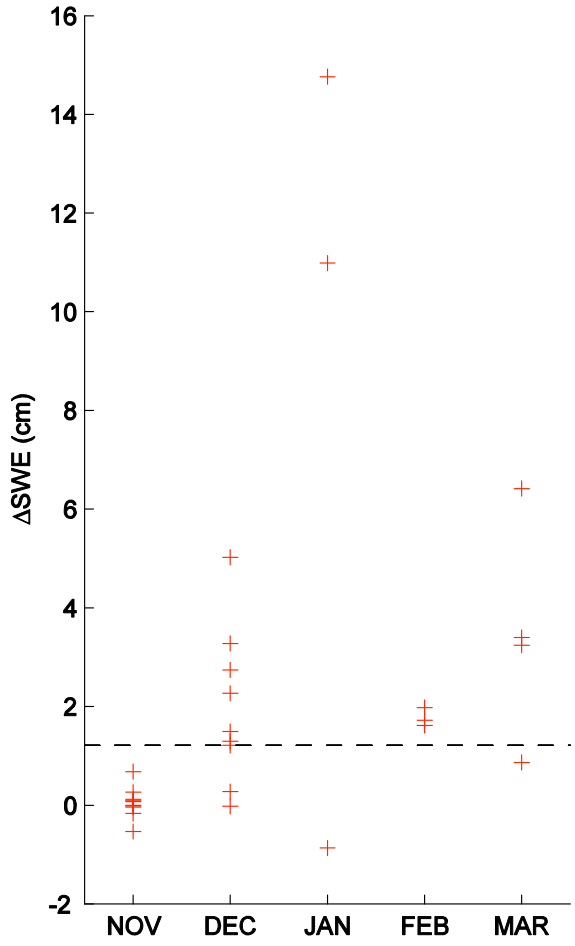
- Relationship between snow water equivalent (SWE) changes and surface air temperature (SAT) in the Sierra Nevada was investigated for 29 wintertime atmospheric river events in 5 water years
- ΔSWE and SAT were found closely related during these AR events based on in-situ observations and best available snow data assimilation products
- AIRS temperature retrievals and ERA Interim reanalysis show similar patterns of surface air temperature over the Pacific Ocean where ARs are formed, but dramatically different patterns over land, particularly in the Sierra Nevada mountains where snow accumulation is greatly affected by landfalling ARs
- AIRS temperature retrievals are more consistent with in-situ observations in representing the close relationship between SAT and ΔSWE

High- vs. Low-impact ARs

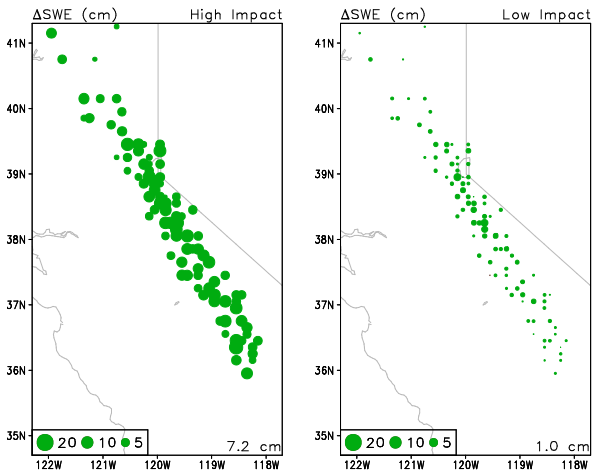
AIRS Precipitable Water



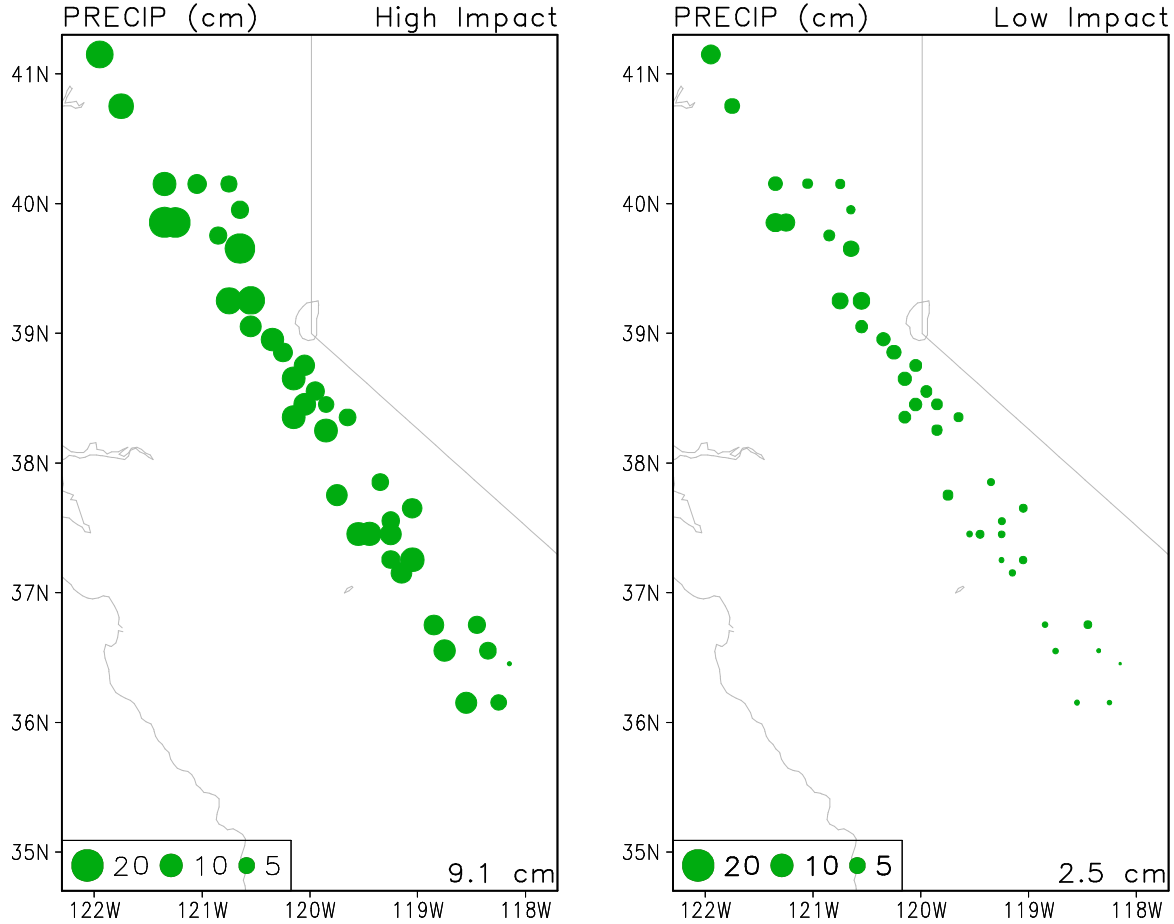
Thanks

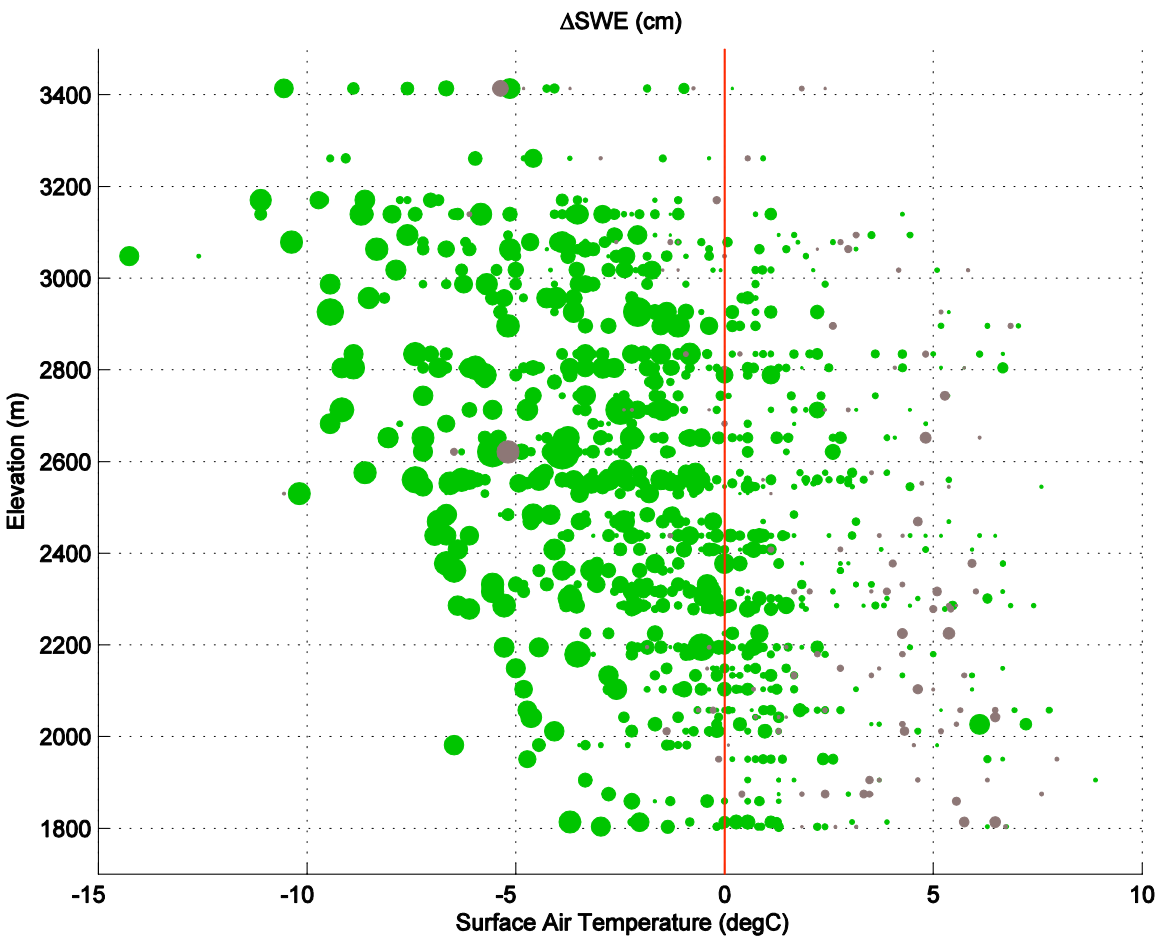

16
14
12
10
8
6
4
2
0
-2
ΔSWE (cm)
NOV
DEC
JAN
FEB
MAR

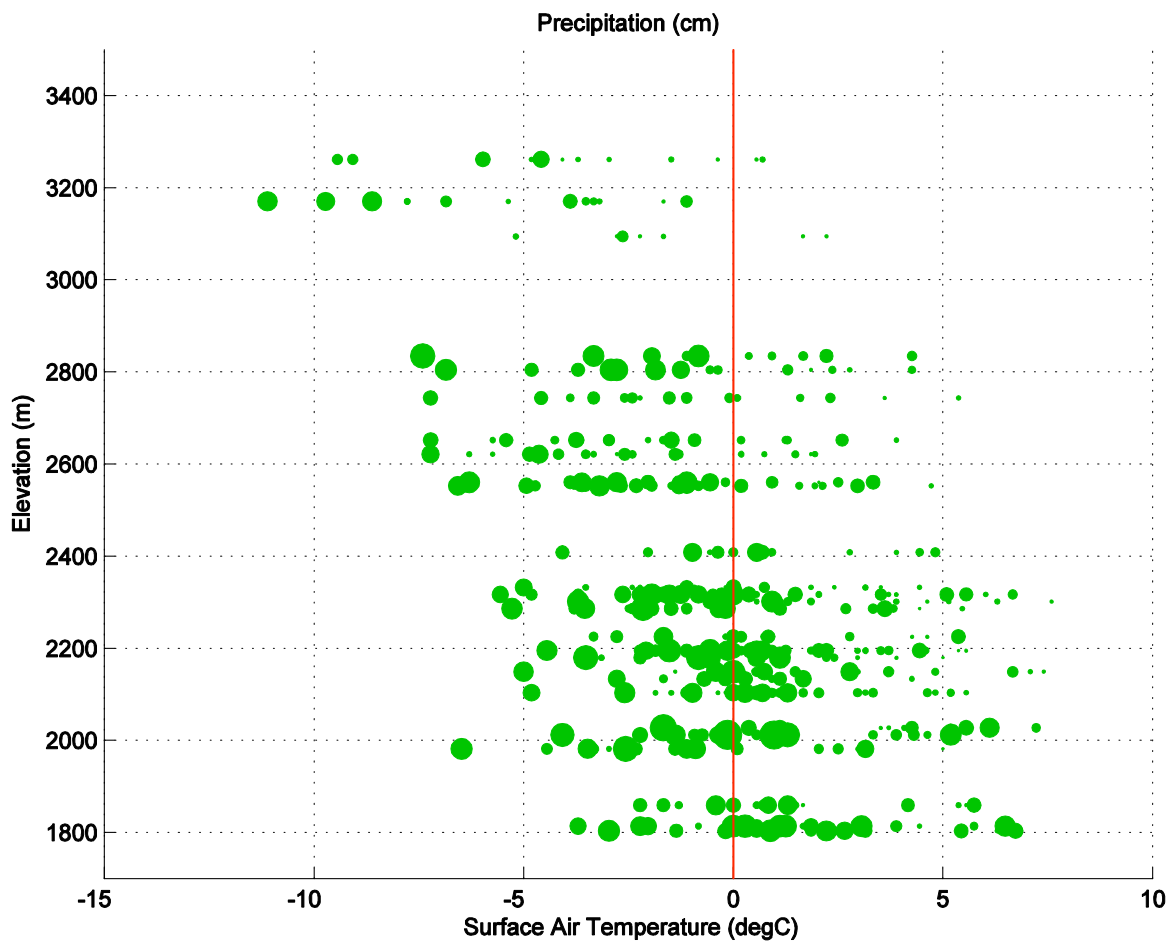
ΔSWE

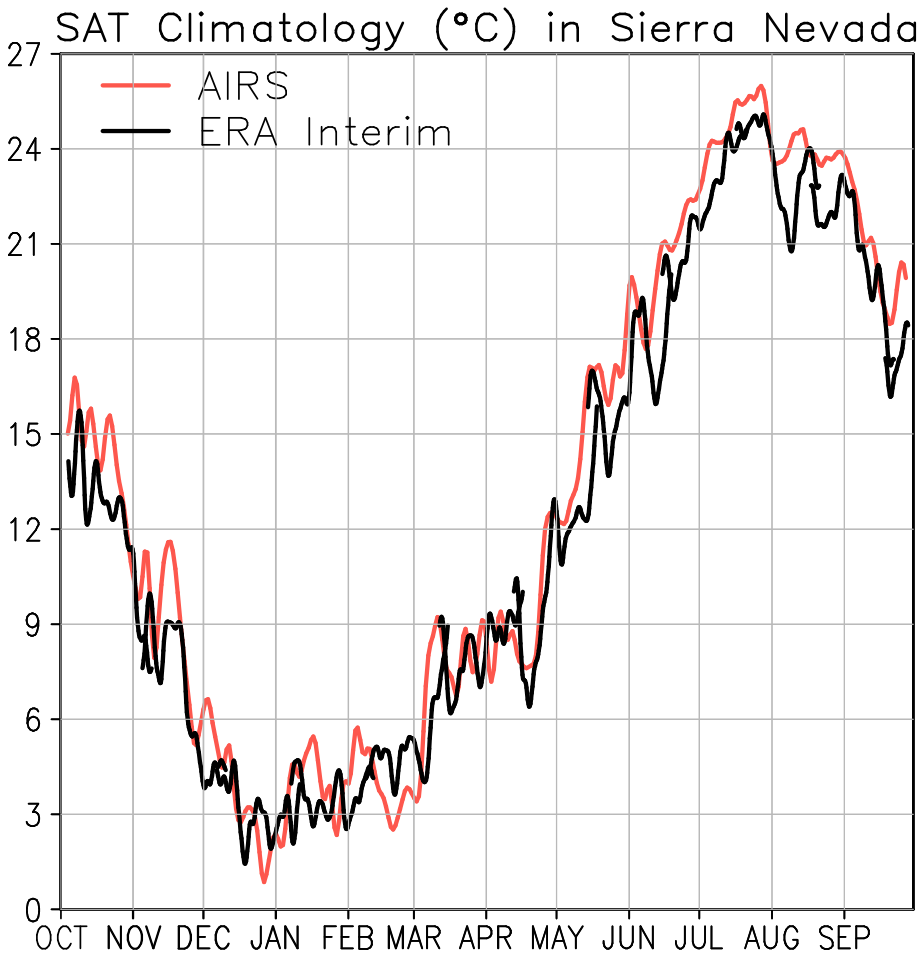
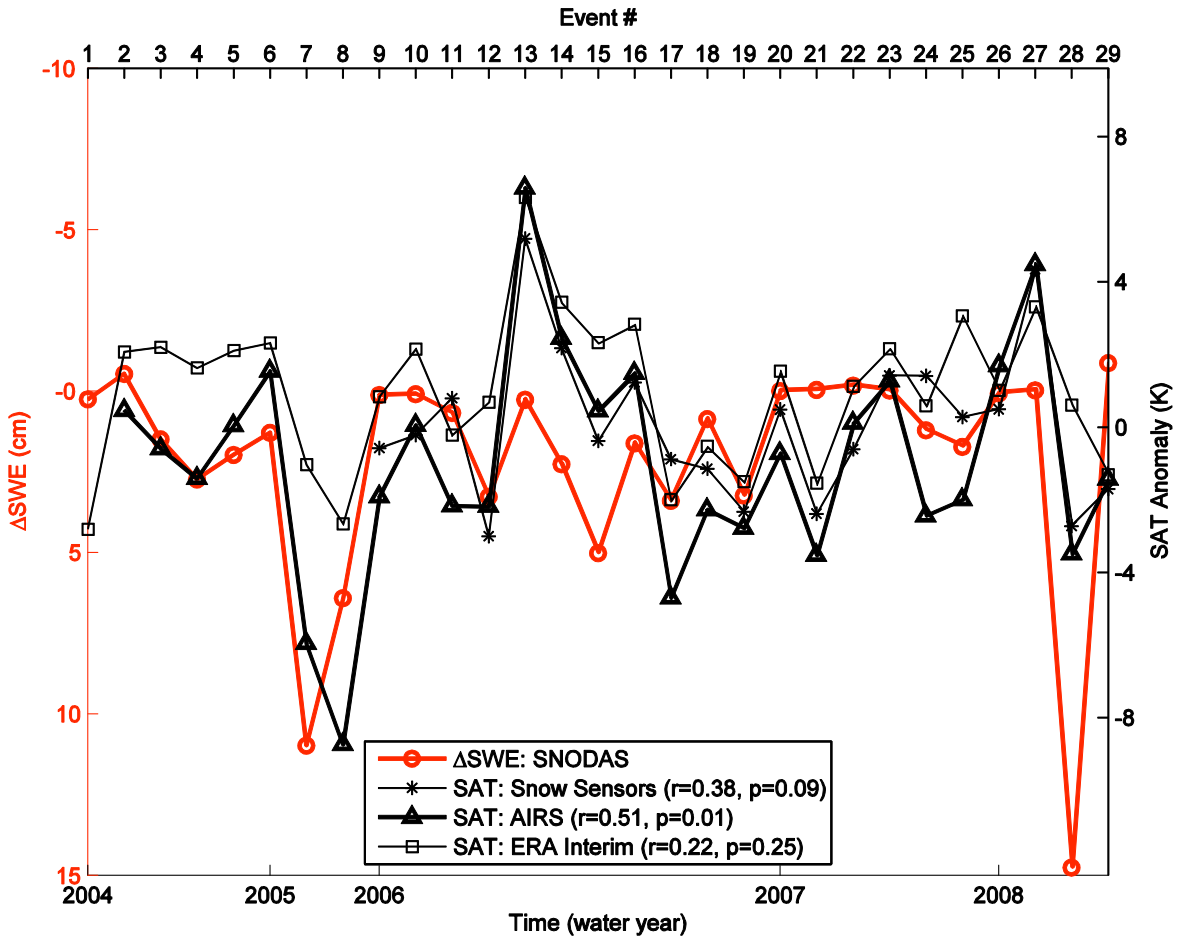

ΔSWE (cm)
High Impact
7.2 cm
ΔSWE (cm)
Low Impact
1.0 cm
20 10 5
41N
40N
39N
38N
37N
36N
35N
122W
121W
120W
119W
118W

PRECIP


PRECIP (cm)
High Impact
9.1 cm
PRECIP (cm)
Low Impact
2.5 cm
20 10 5
41N
40N
39N
38N
37N
36N
35N
122W
121W
120W
119W
118W


ΔSWE (cm)
Elevation (m)
3400
3200
3000
2800
2600
2400
2200
2000
1800
-15
-10
-5
0
5
10
Surface Air Temperature (degC)


Precipitation (cm)
Elevation (m)
3400
3200
3000
2800
2600
2400
2200
2000
1800
-15
-10
-5
0
5
10
Surface Air Temperature (degC)


SAT Climatology (°C) in Sierra Nevada
AIRS
ERA Interim
27
24
21
18
15
12
9
6
3
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP

ΔSWE and SAT Anomaly