Storms, floods and atmospheric rivers-- Putting the extreme into California extremes

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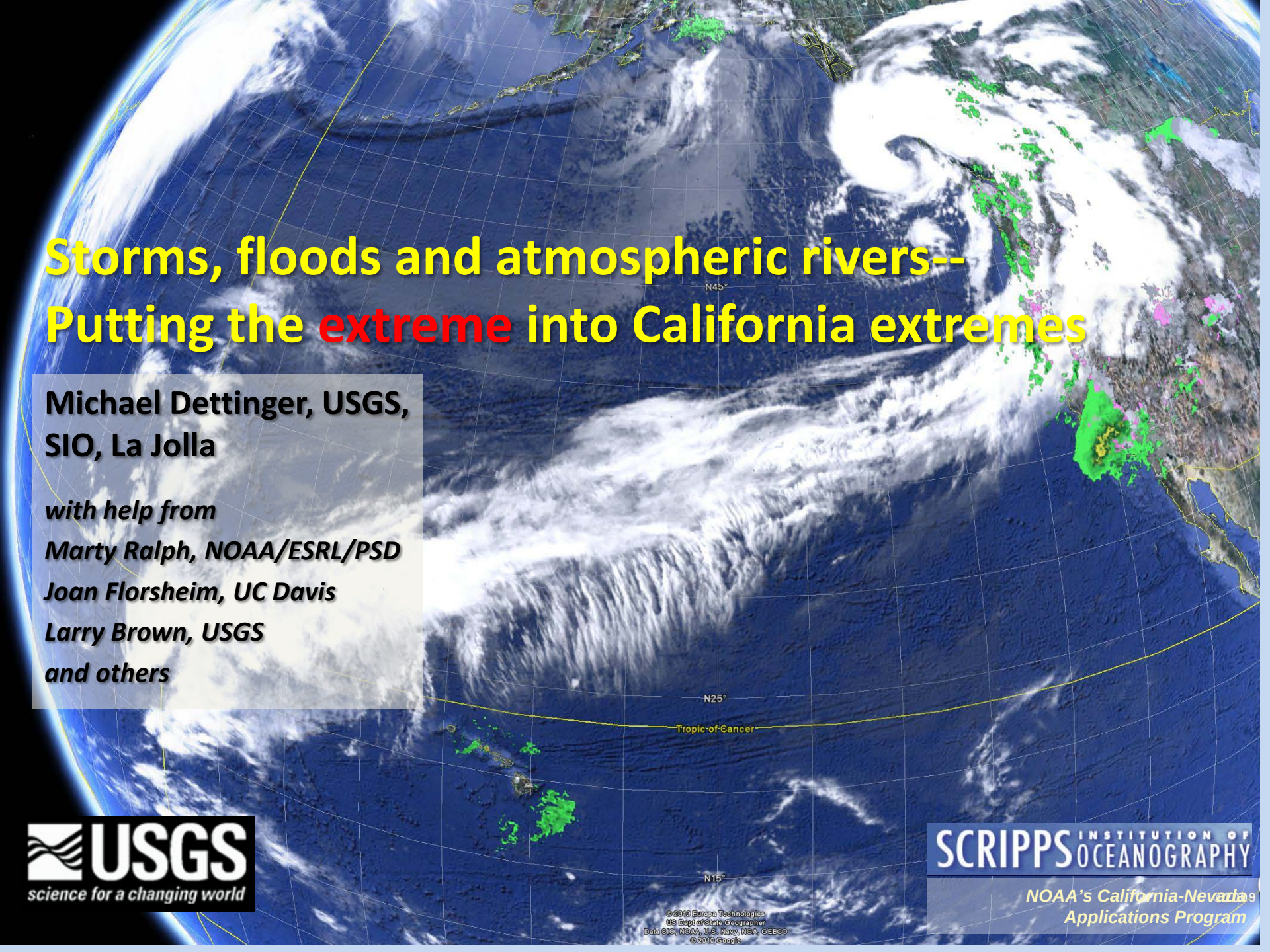
with help from
Marty Ralph, NOAA/ESRL/PSD
Joan Florsheim, UC Davis
Larry Brown, USGS
and others



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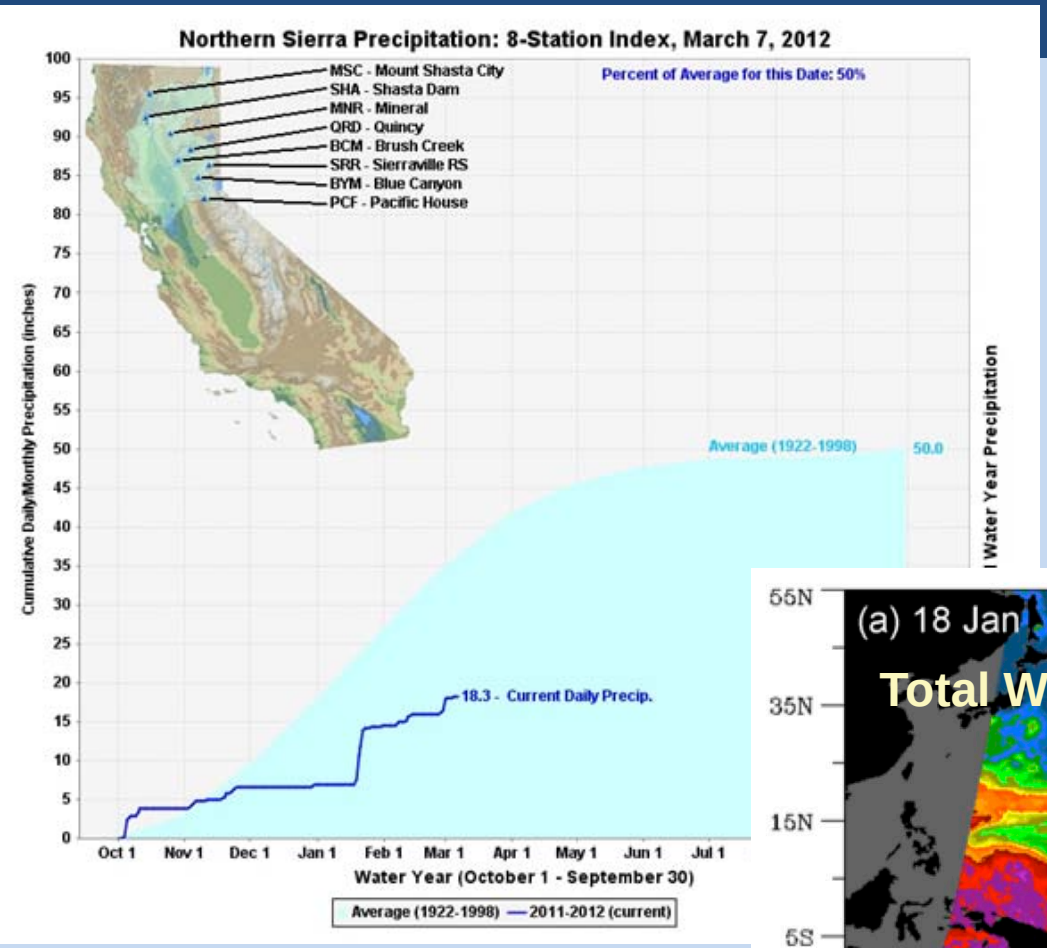
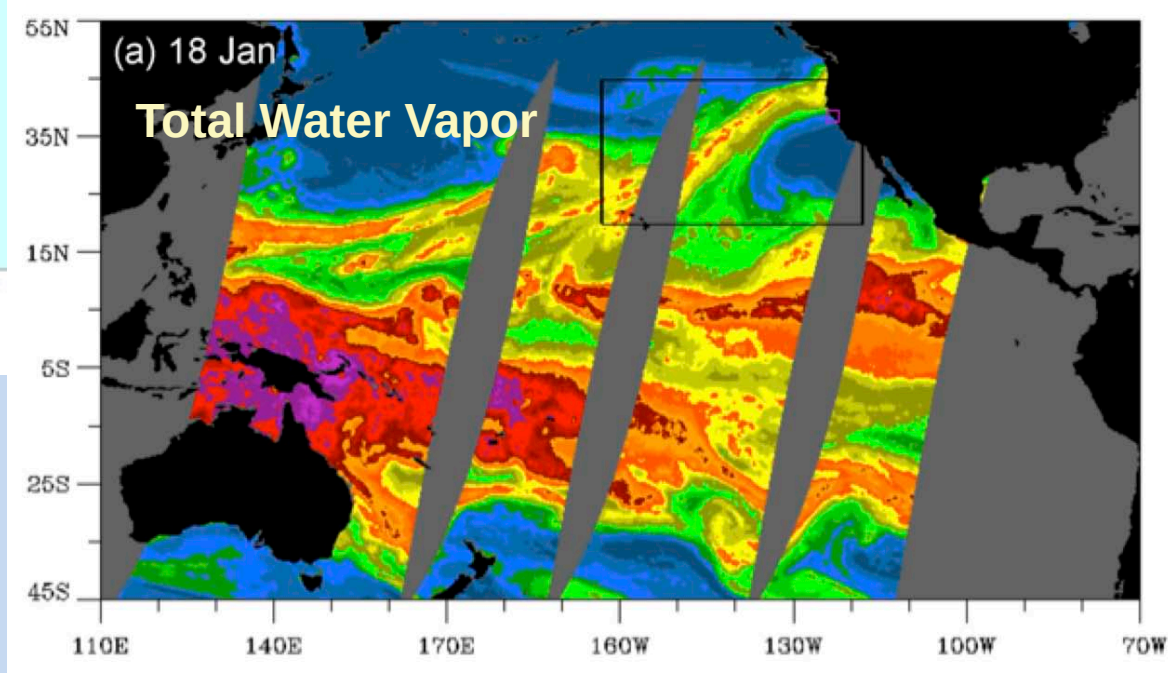
SCRIPPS INSTITUTION OF OCEANOGRAPHY

NOAA's California-Nevada Applications Program

California Precipitation



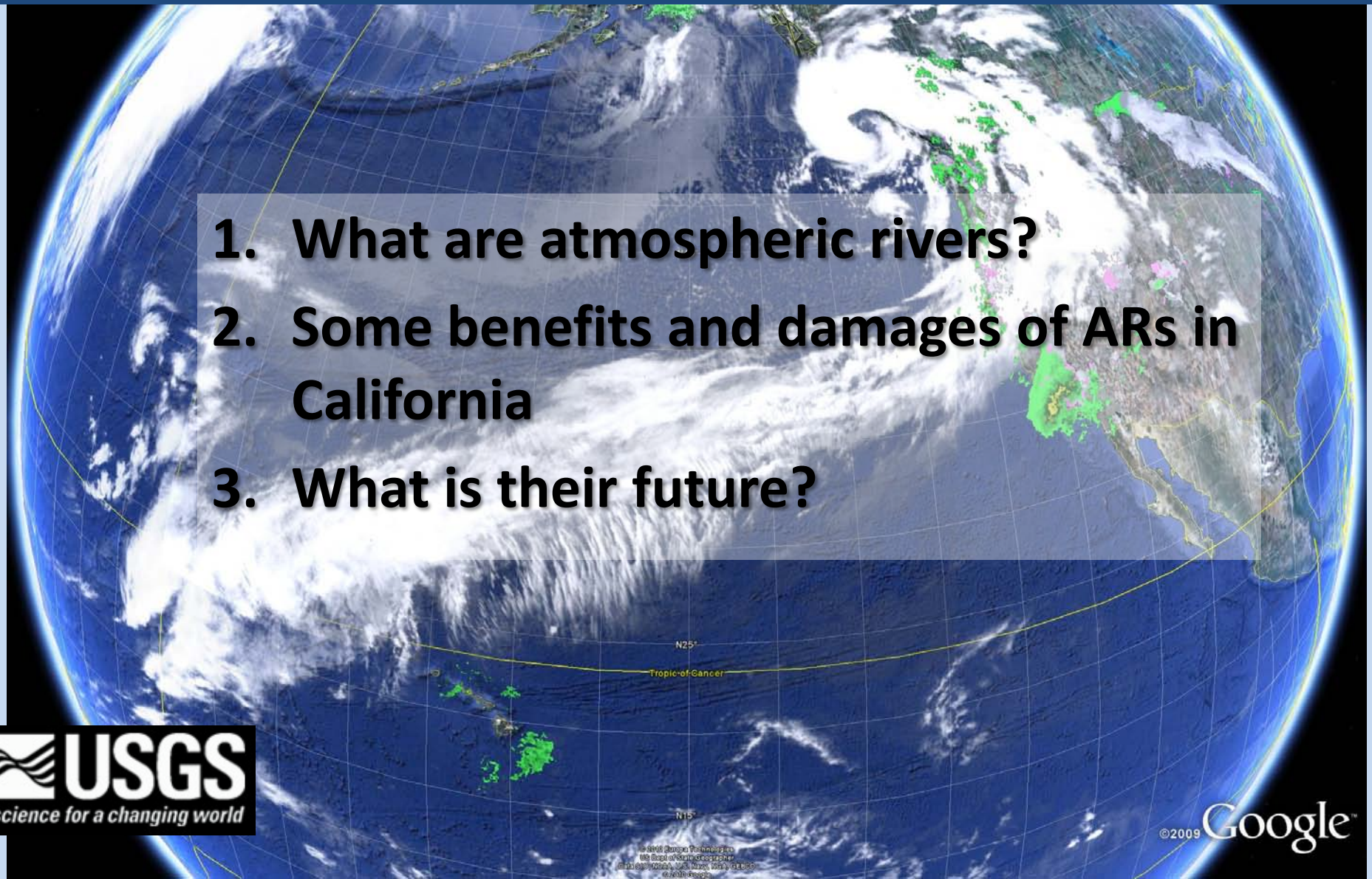
Precipitation
Water Year 2012



Moore et al, 2011

Outline

1. What are atmospheric rivers?
2. Some benefits and damages of ARs in California
3. What is their future?



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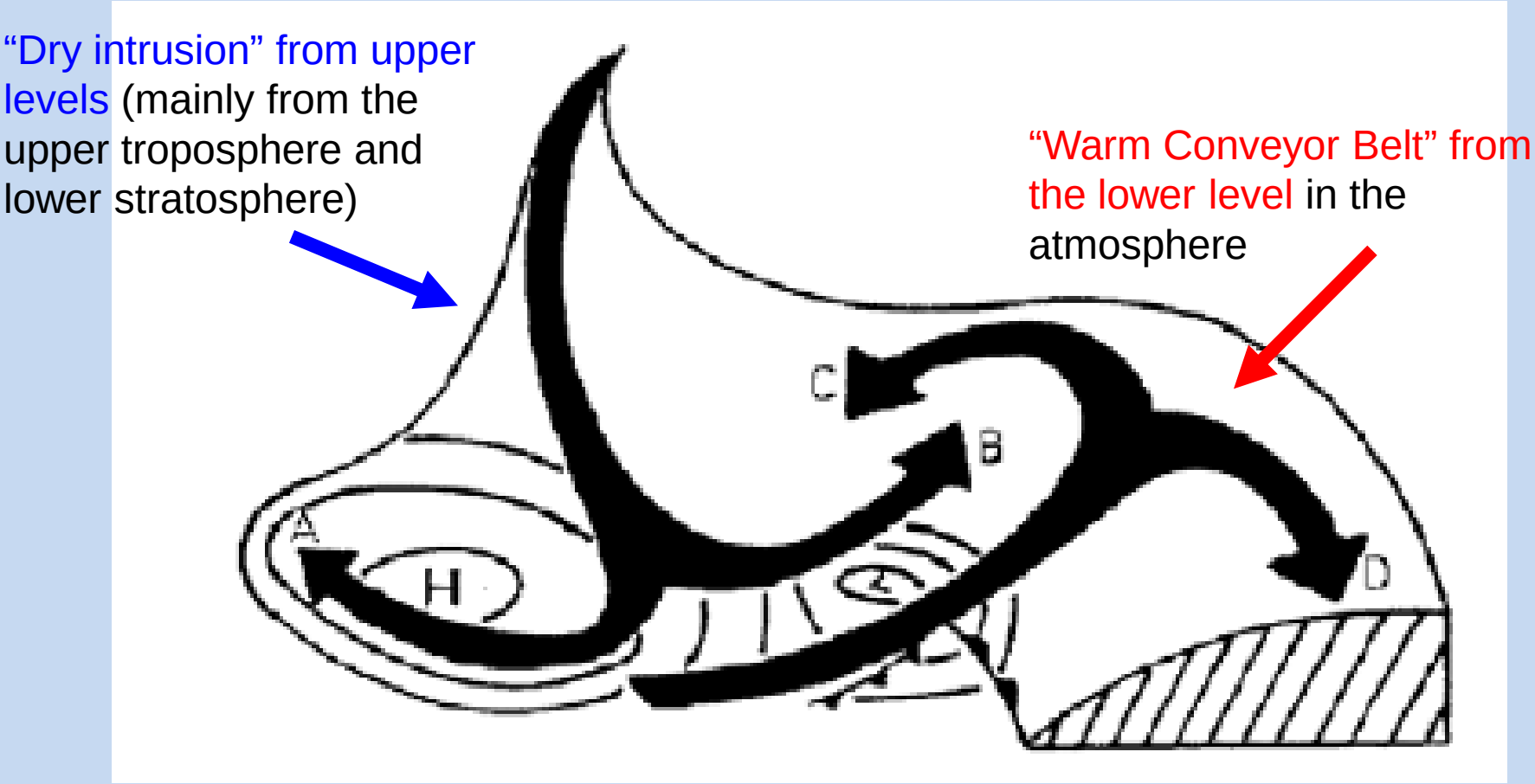
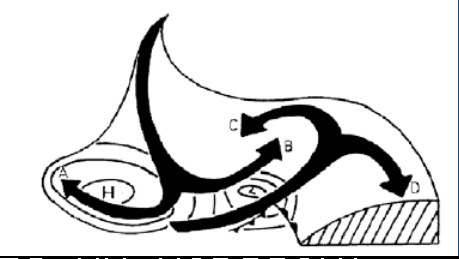
1. What are atmospheric rivers?

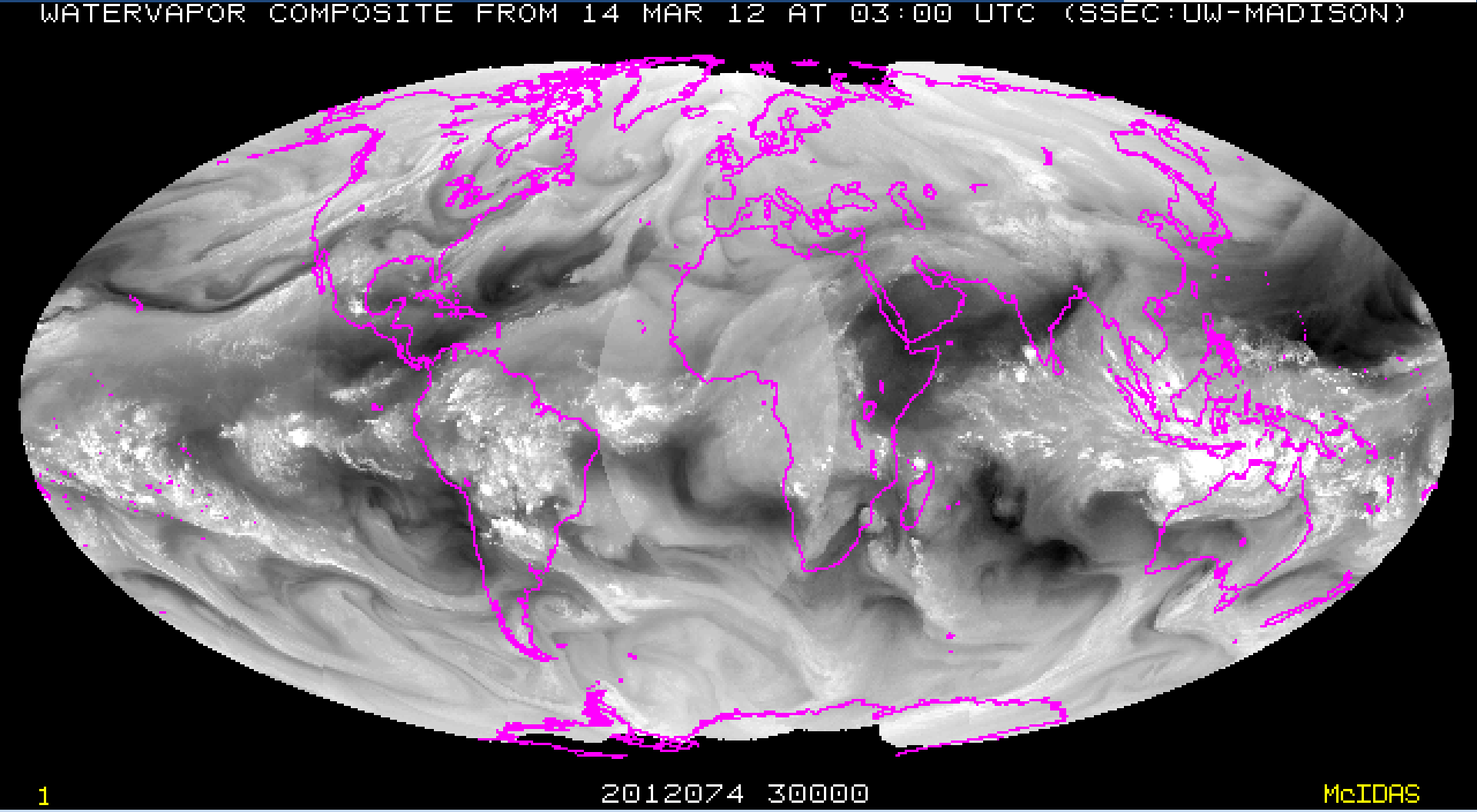
Classical MidLatitude Storm Geometry



A sketch of relative isentropic flow in a baroclinic life cycle, from Thorncroft et al. [1993]

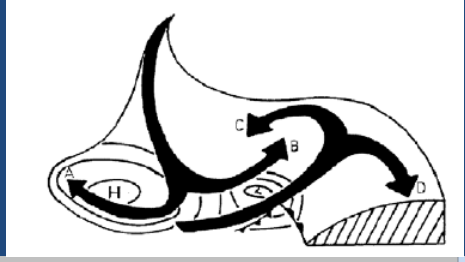
1. What are atmospheric rivers?

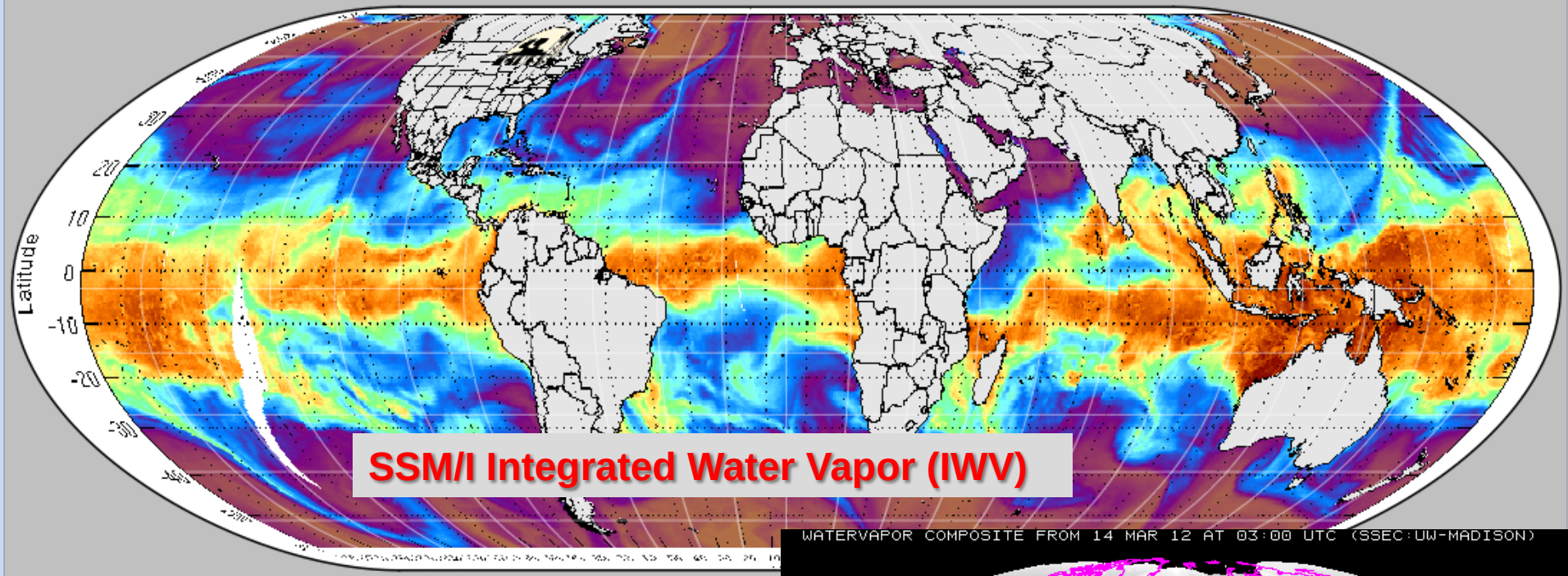




GOES Water Vapor Channel

1. What are atmospheric rivers?

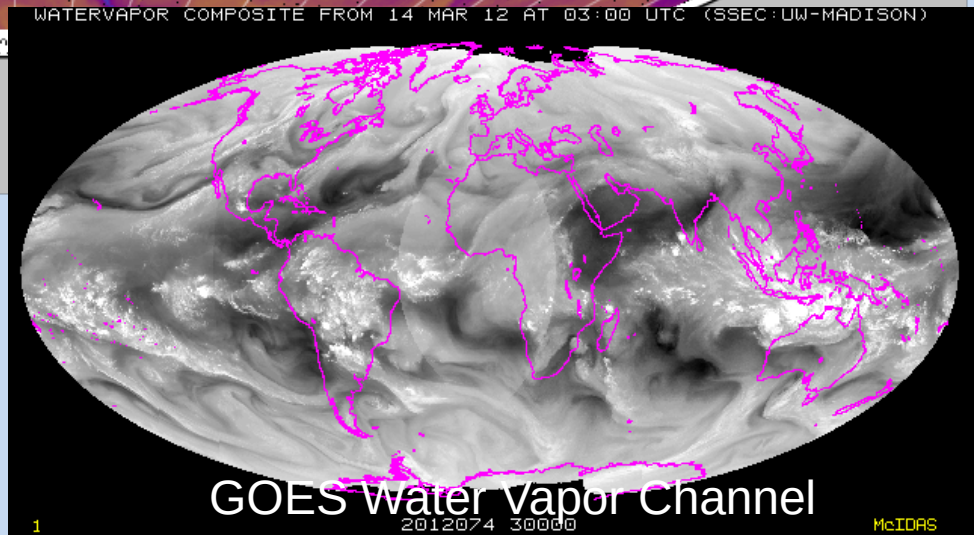




SSM/I Integrated Water Vapor (IWV)

SSM/I = Special Sensor Microwave Imager

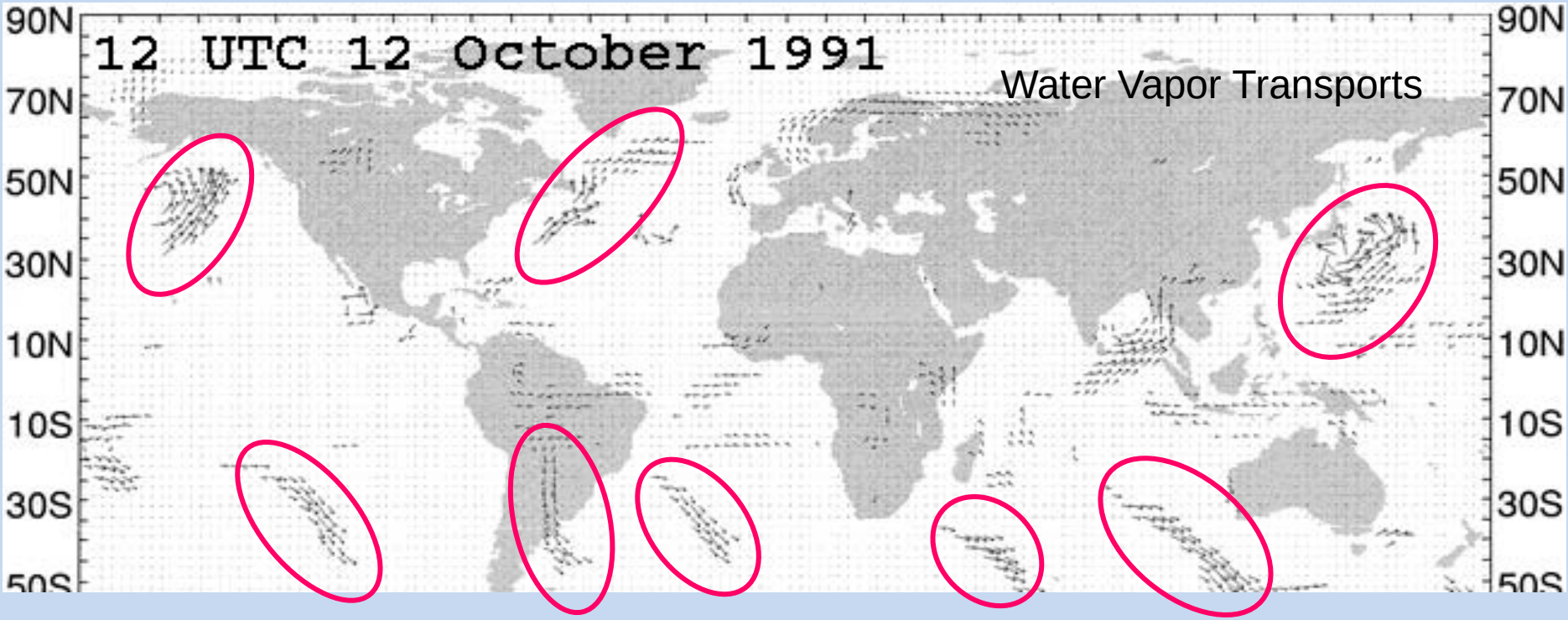
With SSM/I, regular (twice/day) global IWV coverage begins in 1998.



GOES Water Vapor Channel

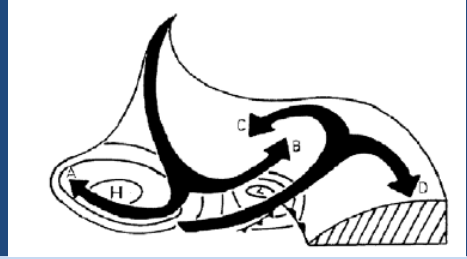
1. What are atmospheric rivers?

Zhu & Newell 1998: *Diagnostic study using weather-model forecasts*

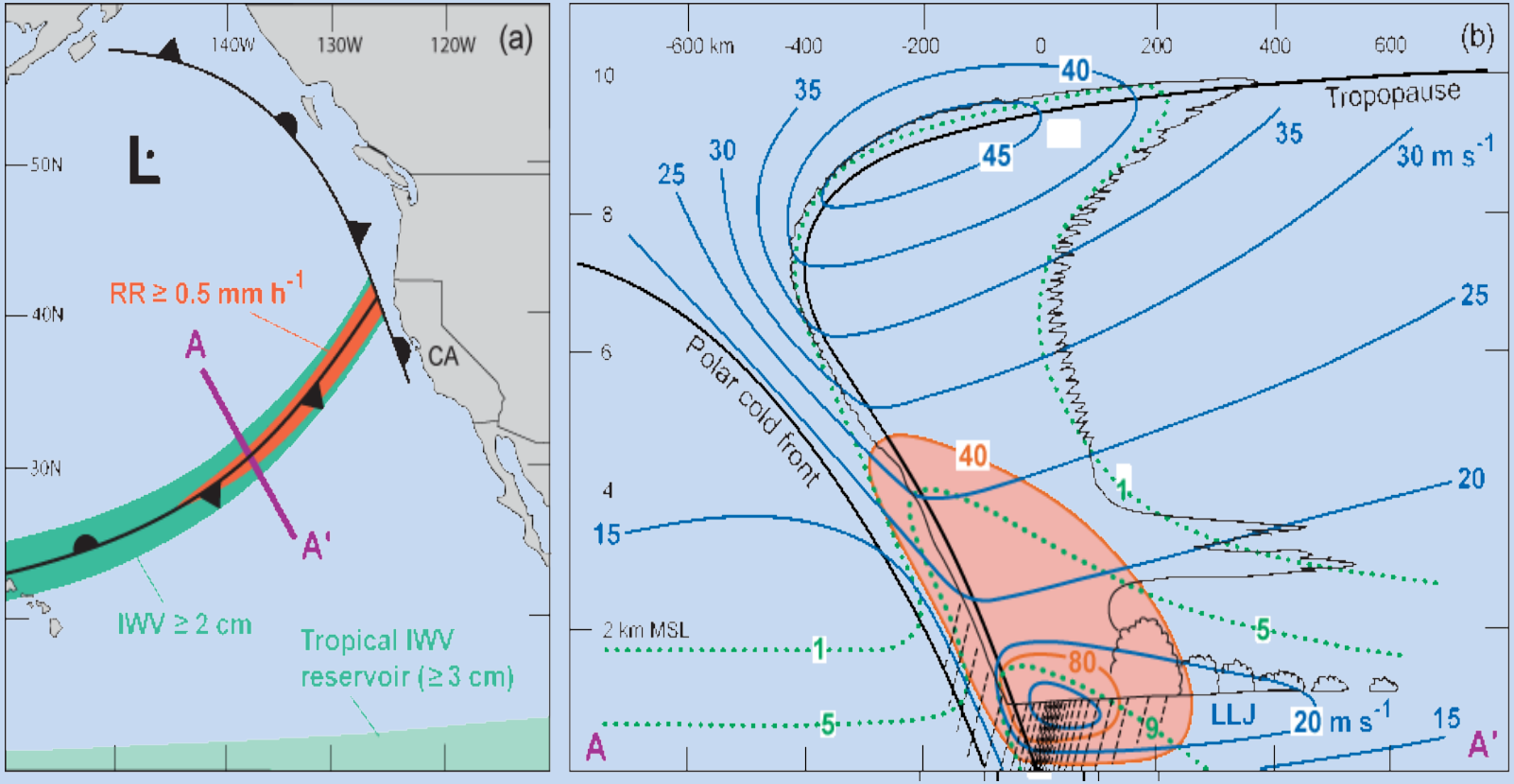


Atmospheric rivers contain 95% of poleward water vapor flux outside the Tropics, in <10% of the zonal circumference

1. What are atmospheric rivers?

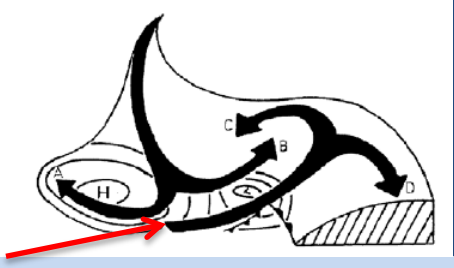


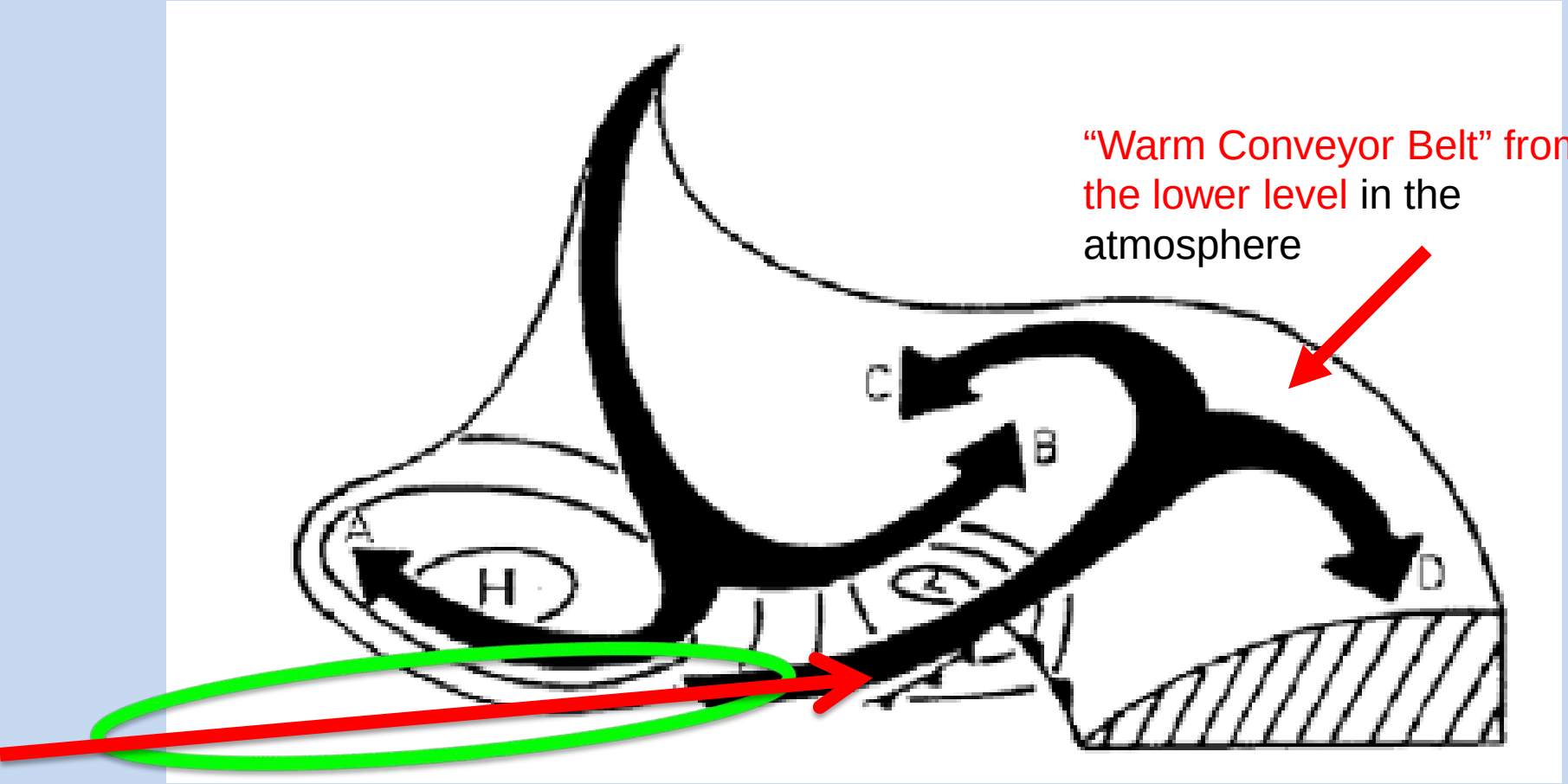
Ralph et al.: January 1998 NOAA CALJET field campaigns



-Flew out to meet an approaching Pacific storm & directly measured many basic elements of an atmospheric river.

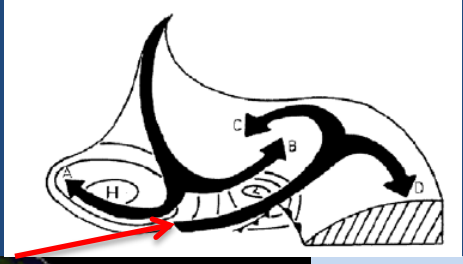
1. What are atmospheric rivers?

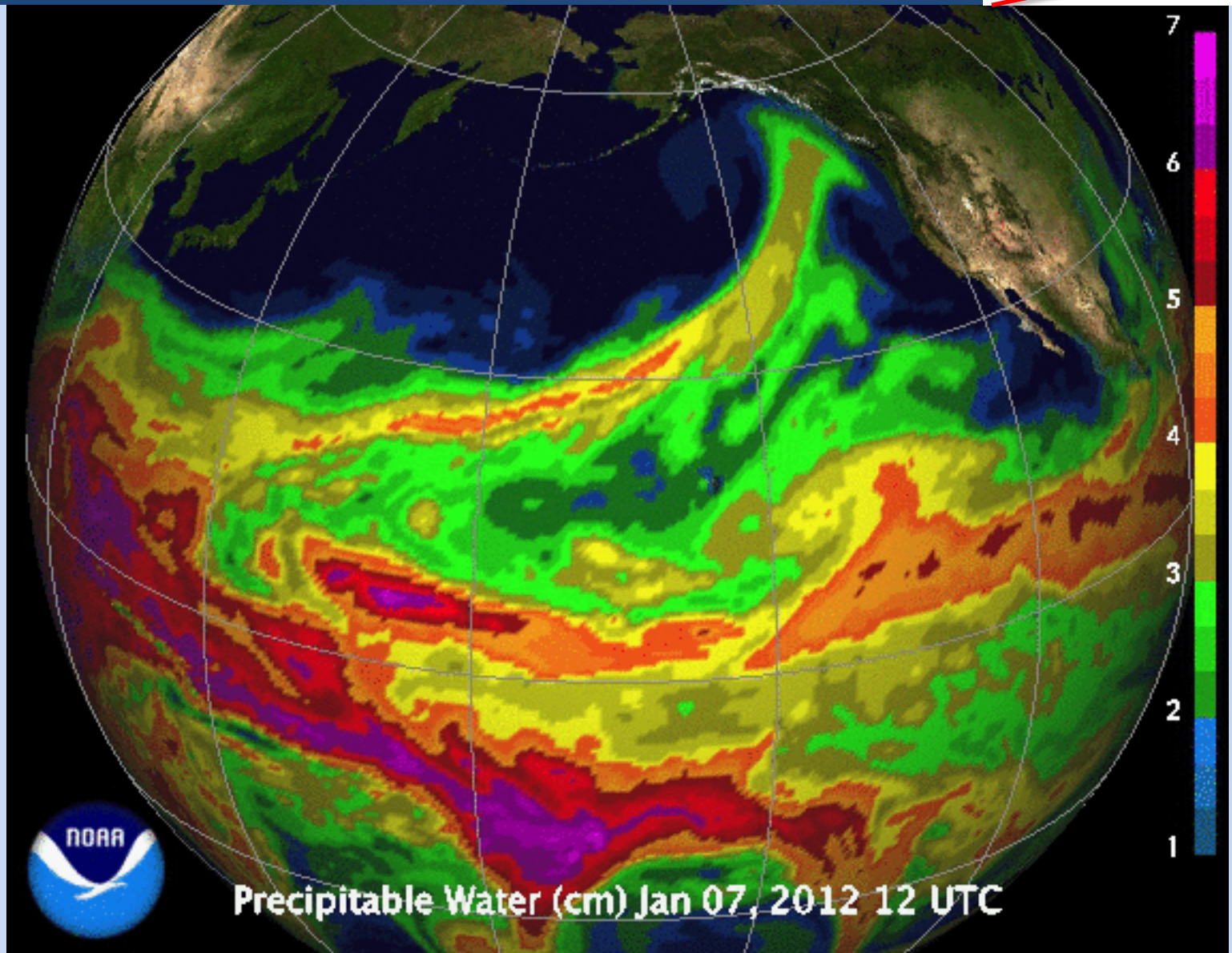




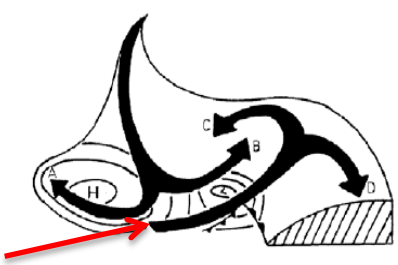
A sketch of relative isentropic flow in a baroclinic life cycle, from Thorncroft et al. [1993]

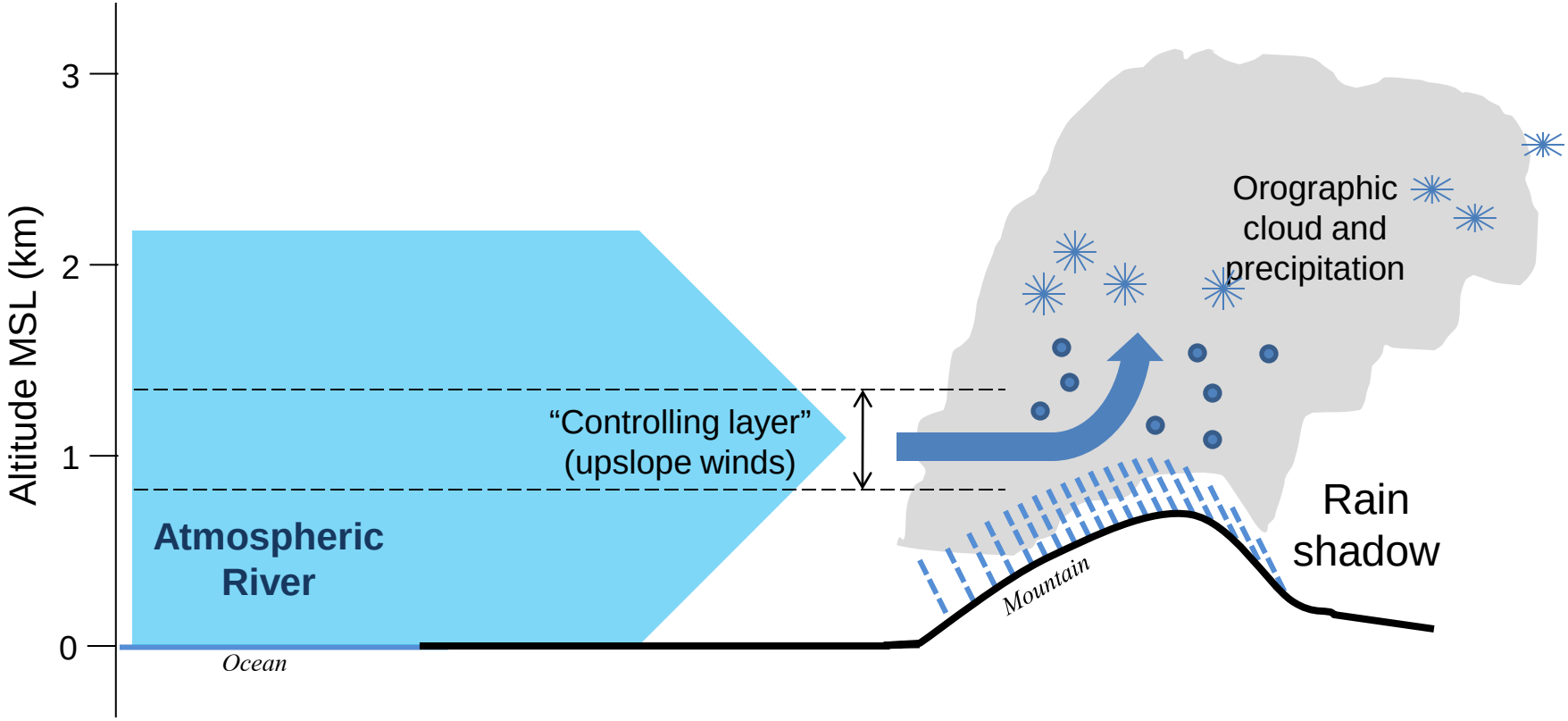
1. Atmospheric Rivers





1. Landfalling atmospheric riv

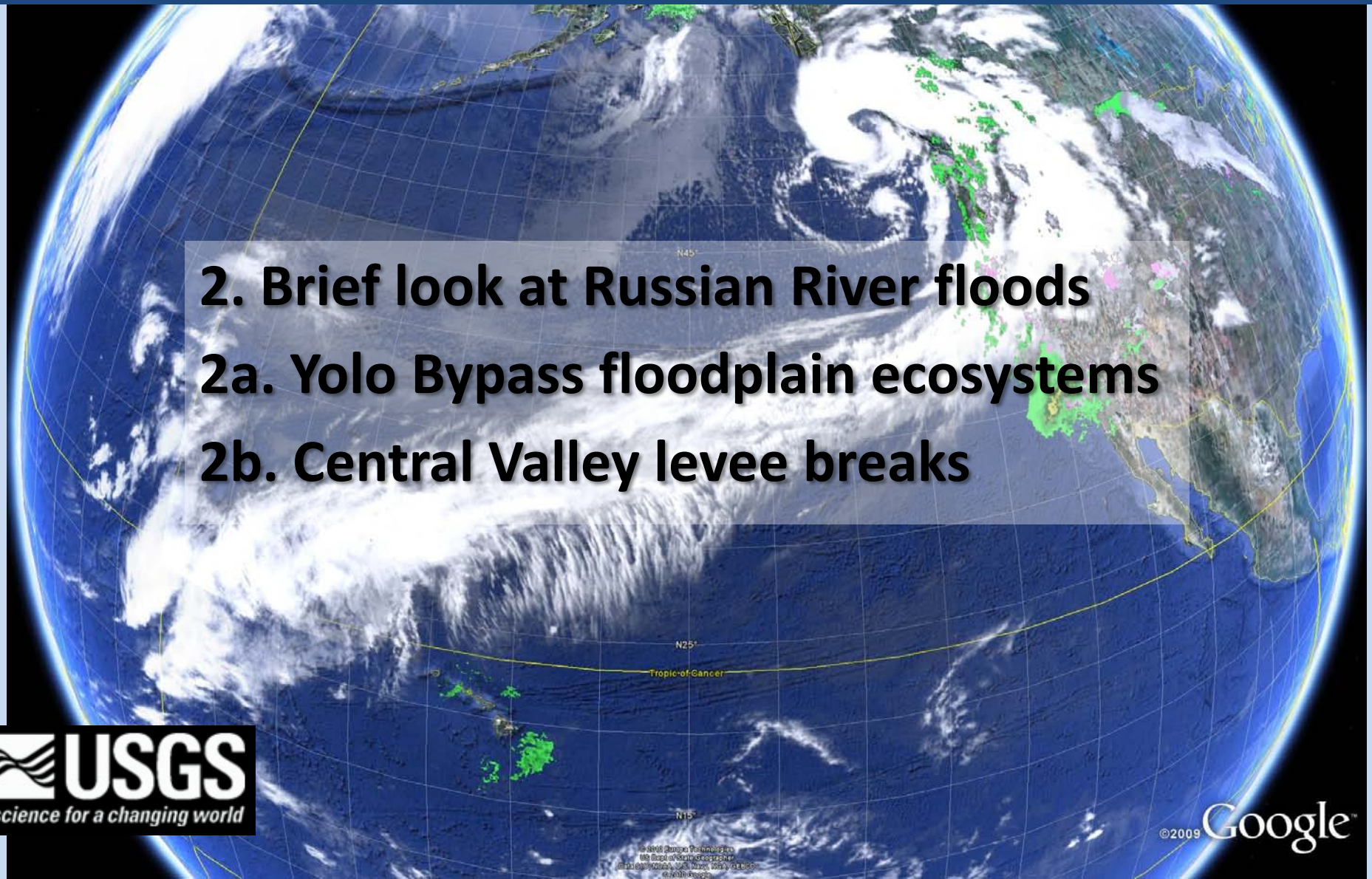




-**Lateral structure from satellite data** *(~400 km width & 2000 km long)*

-**Vertical structure from airplanes & radar** *(intense jet of vapor transport between 1 – 2 km above sea level; 10-20 Mississippis)*

2. Atmospheric rivers & flood benefits/impacts



2. Brief look at Russian River floods

2a. Yolo Bypass floodplain ecosystems

2b. Central Valley levee breaks

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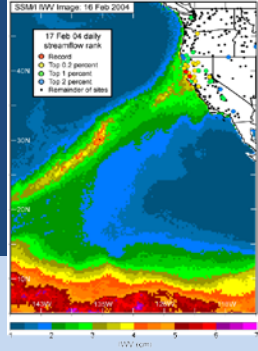
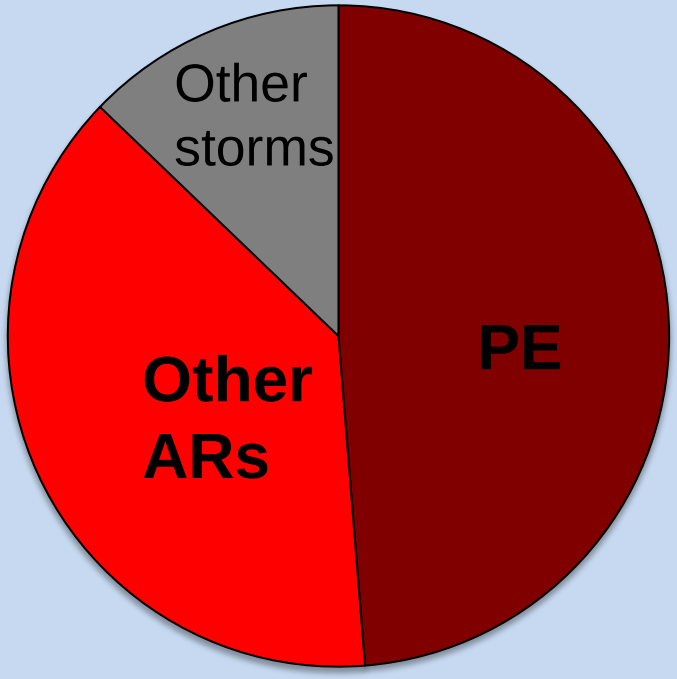
2. Atmospheric rivers and Russian River



- ***All 7 major floods of Russian River since 1997 have been atmospheric rivers*** *(Ralph et al, GRL, 2006)*

On the longer time scale from 1948-2011,

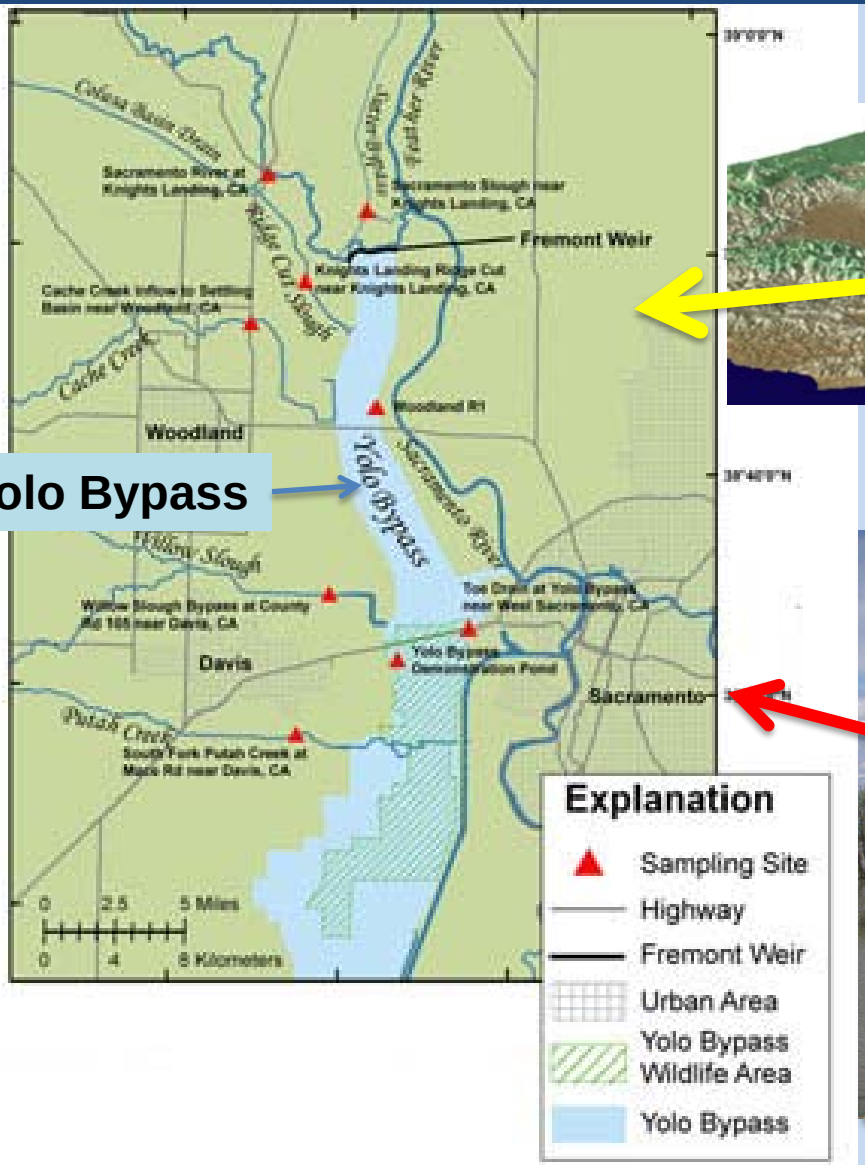


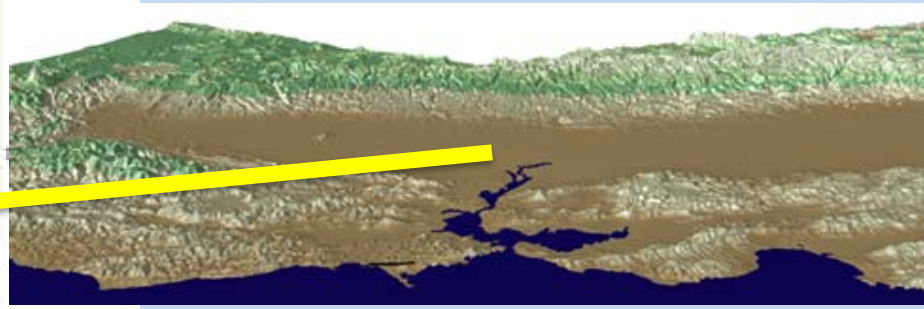
There have been 39 Russian River floods > 50,000 cfs. Thirty four have been caused by ARs.

PE Storm
AR Storm
Other

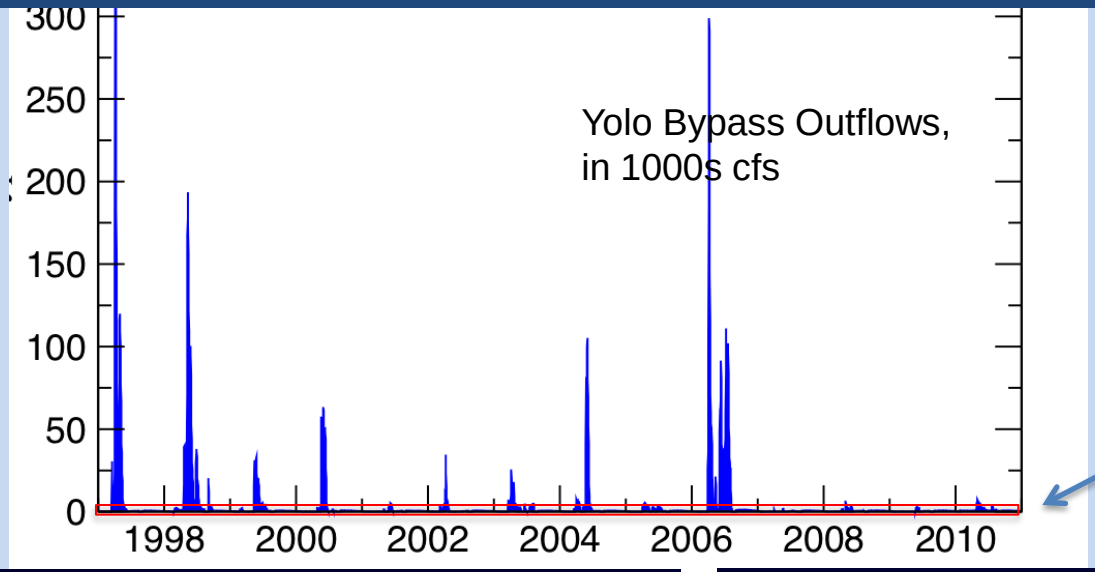
} 87% of floods

2a. ARs & Central Valley Floodplain Ecosytems

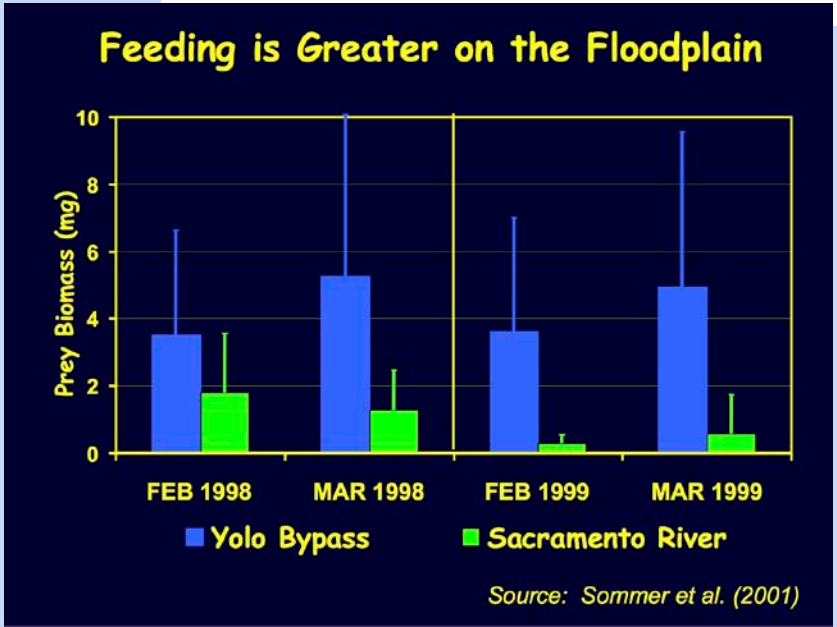


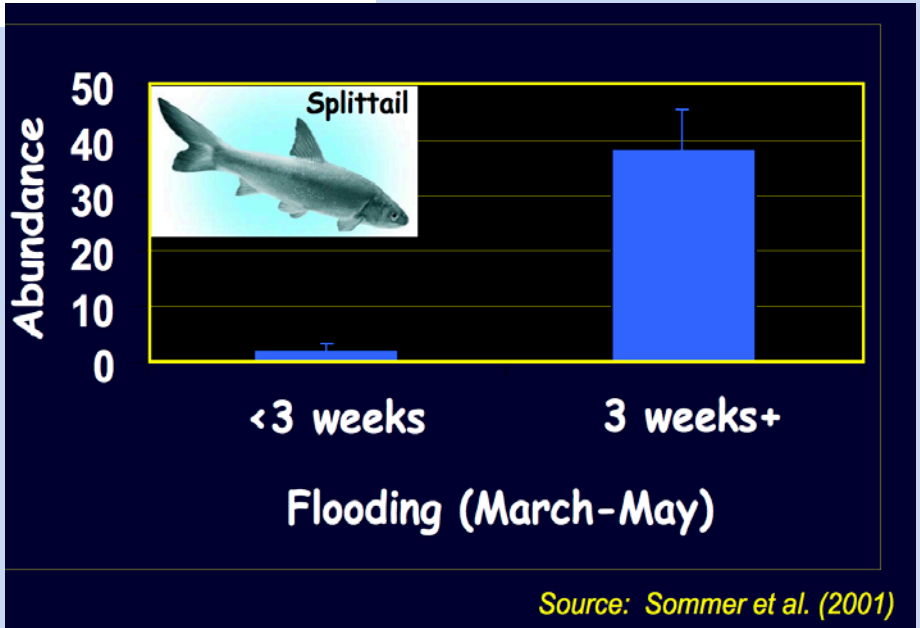


2a. Recent Yolo Bypass Outflows



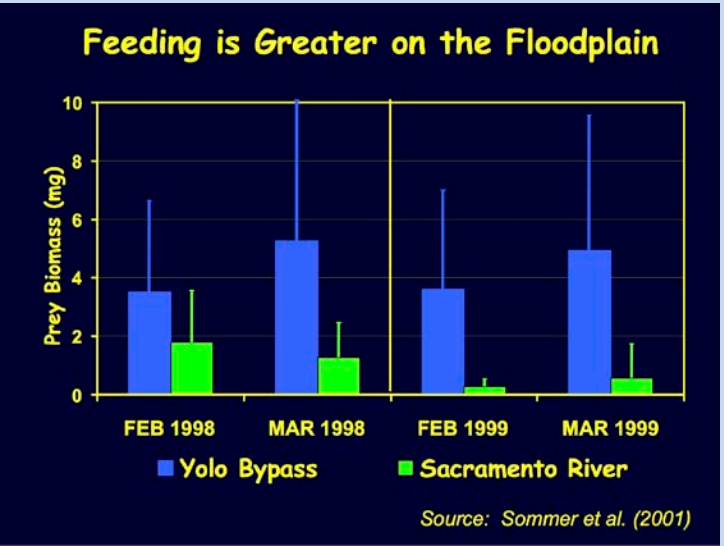
Bypass is inundated when Sacramento River flows > 4000 cfs





2a. Recent Yolo Bypass Outflows > 2 weeks

Of 10 occasions with outflows > 2 weeks from WY1998-2009, **9 of 10 periods of foodweb-energizing Yolo inundations were initiated by ARs**.

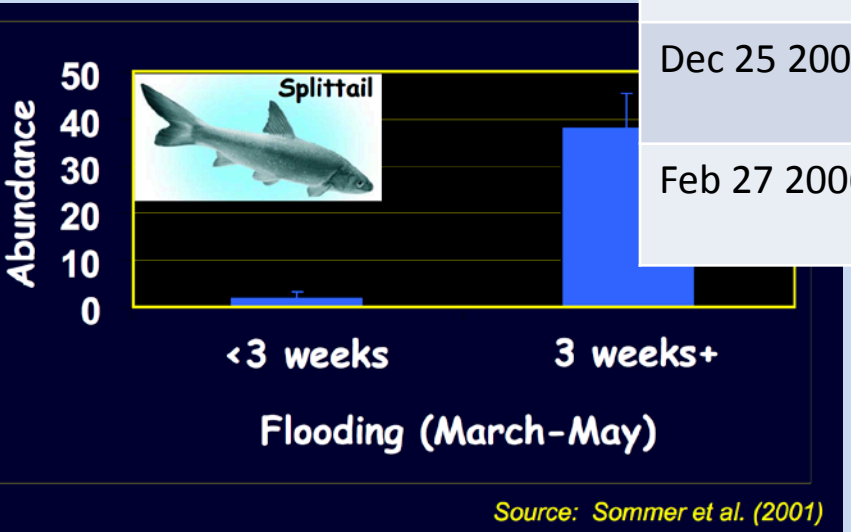


Begin date	Duration of >4000 cfs flows, in days	Initial AR	Additional ARs (maintaining inundation)
Jan 16 1998	87	1998 01 15	1998 02 02/03 1998 02 05 1998 03 22/23
Feb 10 1999	32	1999 02 07	1999 02 07
Feb 14 2000	33	2000 02 13	2000 03 05
Dec 30 2001	20	2001 12 29	2002 01 02 2002 01 06
Dec 17 2002	43	2002 12 16	2002 12 27 2003 01 12/13
Dec 30 2003	18	No AR	
Feb 18 2004	26	2004 02 16/17	
Jan 1 2005	16	2004 12 27	2005 01 10
Dec 25 2005	30	2005 12 22	2005 12 28 2005 12 30/31
Feb 27 2006	67	2006 02 27	2006 03 06 2006 03 25 …

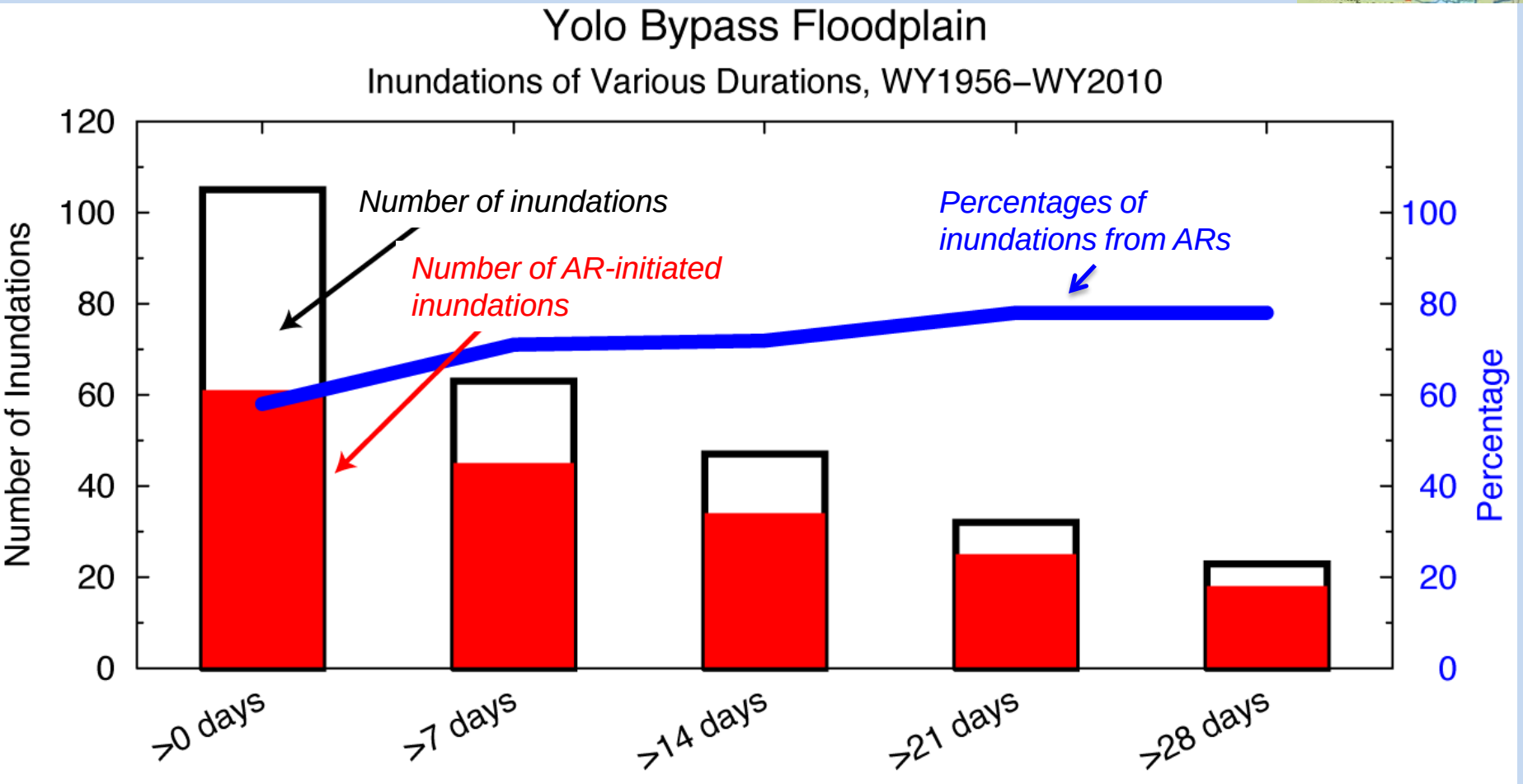
2a. Recent Yolo Bypass Outflows > 4 weeks

Of 6 outflows persisting > month from WY1998-2009, **6/6 periods of splittail-worthy Yolo inundations were initiated by ARs.**

Begin date	Duration of >4000 cfs flows, in days	Initial AR	Additional ARs (maintaining inundation?)
Jan 16 1998	87	1998 01 15	1998 02 02/03 1998 02 05 1998 03 22/23
Feb 10 1999	32	1999 02 07	1999 02 07
Feb 14 2000	33	2000 02 13	2000 03 05
Dec 17 2002	43	2002 12 16	2002 12 27 2003 01 12/13
Dec 25 2005	30	2005 12 22	2005 12 28 2005 12 30/31
Feb 27 2006	67	2006 02 27	2006 03 06 2006 03 25 …



2a. Based on 55 yrs of Yolo Bypass Outflows



2b. Central Valley levee breaks

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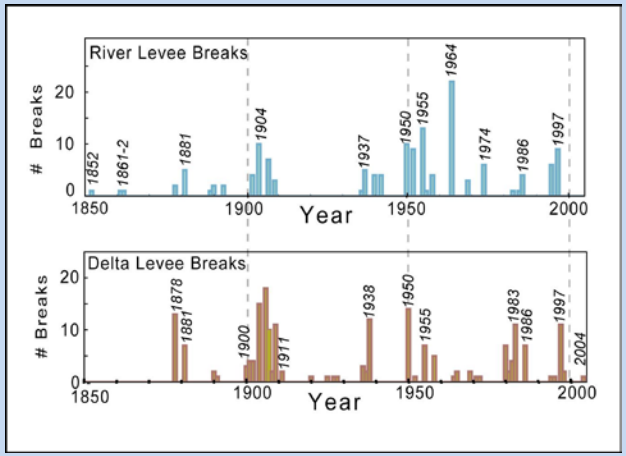
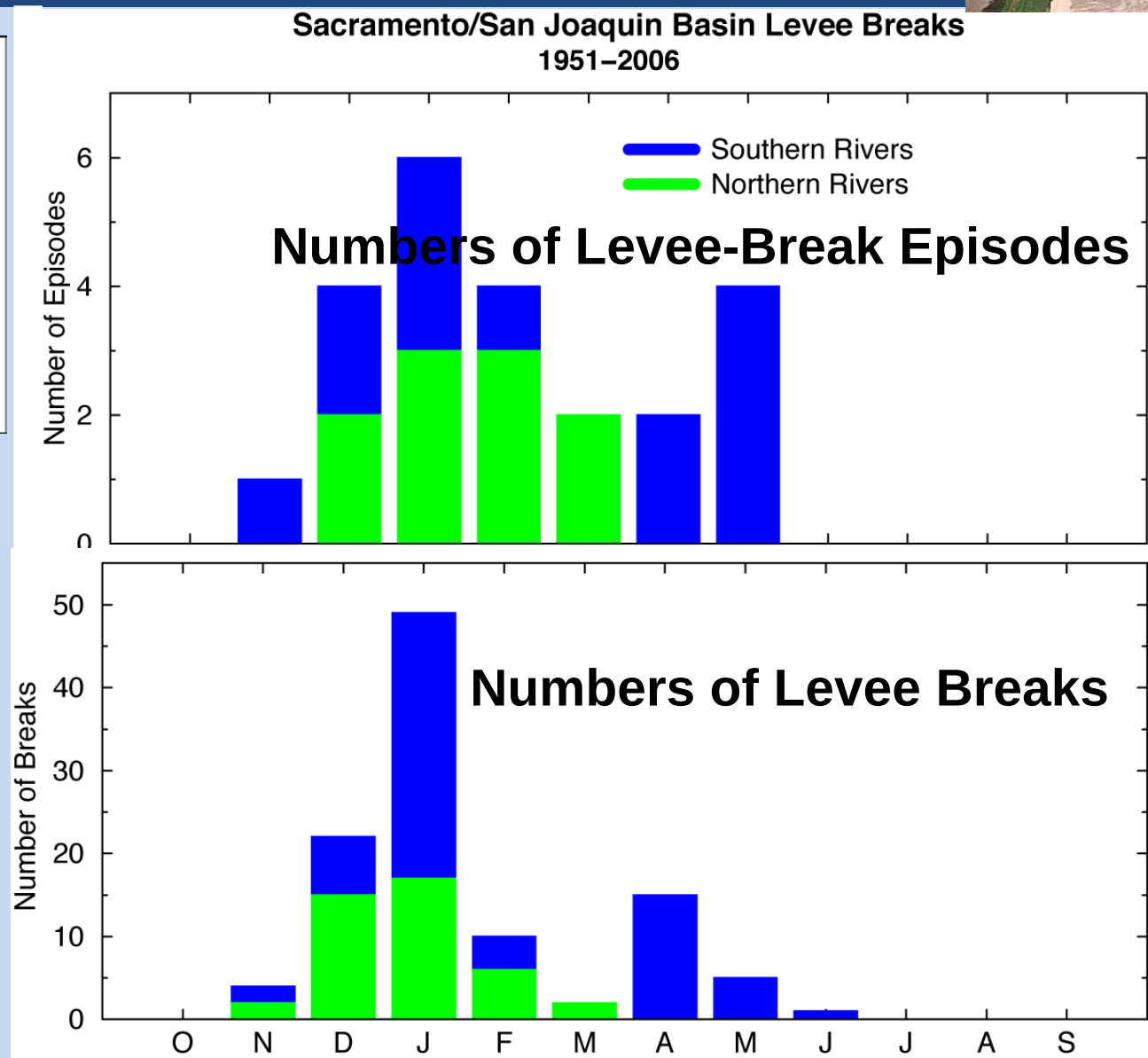


Levee break chronologies from Joan Florsheim, UC Davis
(described in Florsheim & Dettinger, 2005 & 2007)



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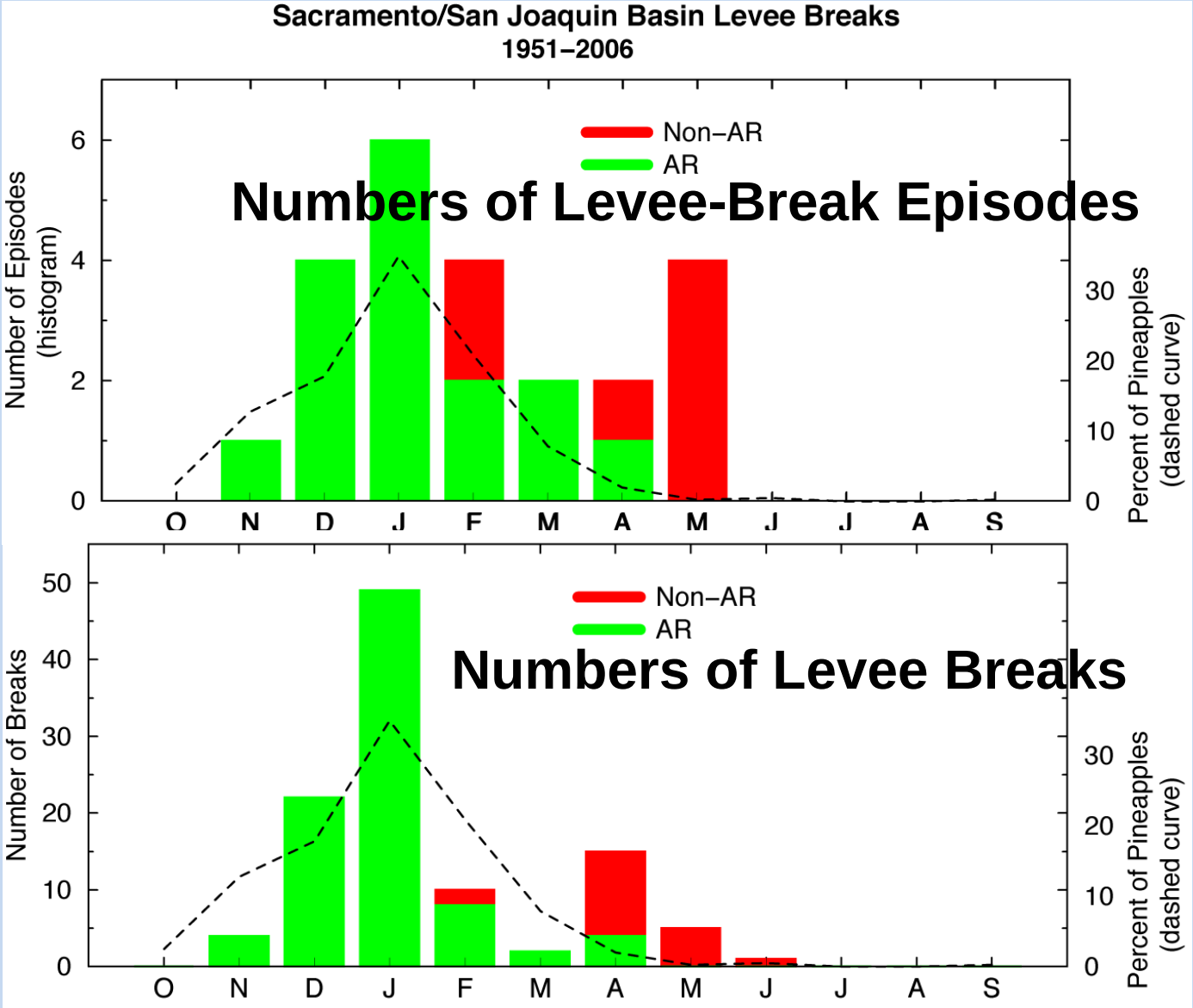

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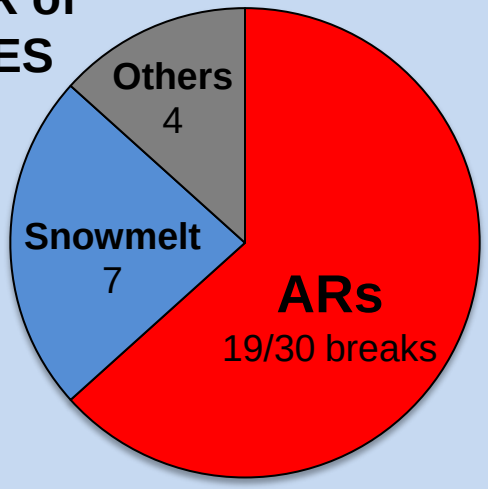
2b. Central Valley levee breaks

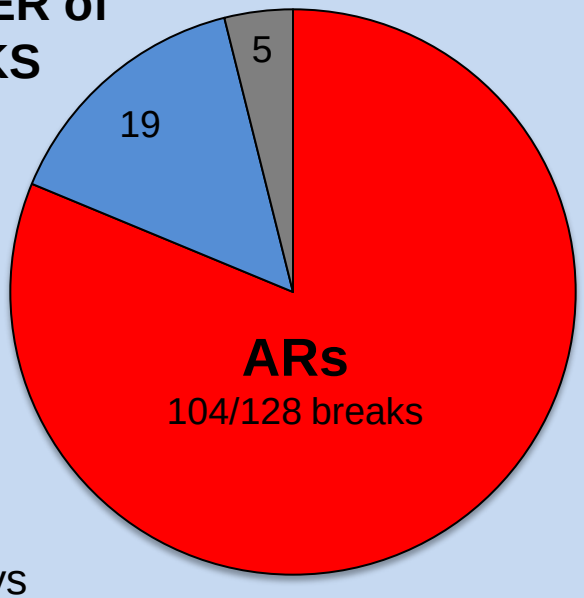
Reported Levee Breaks, Sacramento-San Joaquin Basins

(plus 20 Delta levee breaks), **1951-2006**

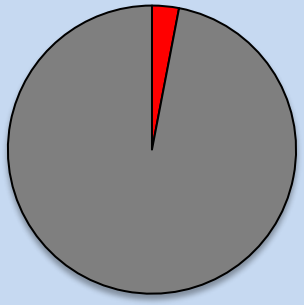
NUMBER of EPISODES



NUMBER of BREAKS



Numbers of
All Calendar Days



Levee break chronologies from Joan Florsheim, UC Davis (described in Florsheim & Dettinger, GRL, 2007)

The story continues…

- ARs as West Coast “drought busters”…
- ARs and Mojave River groundwater recharge…
- ARs and Lake Tahoe sediment & clarity variations…
- and more

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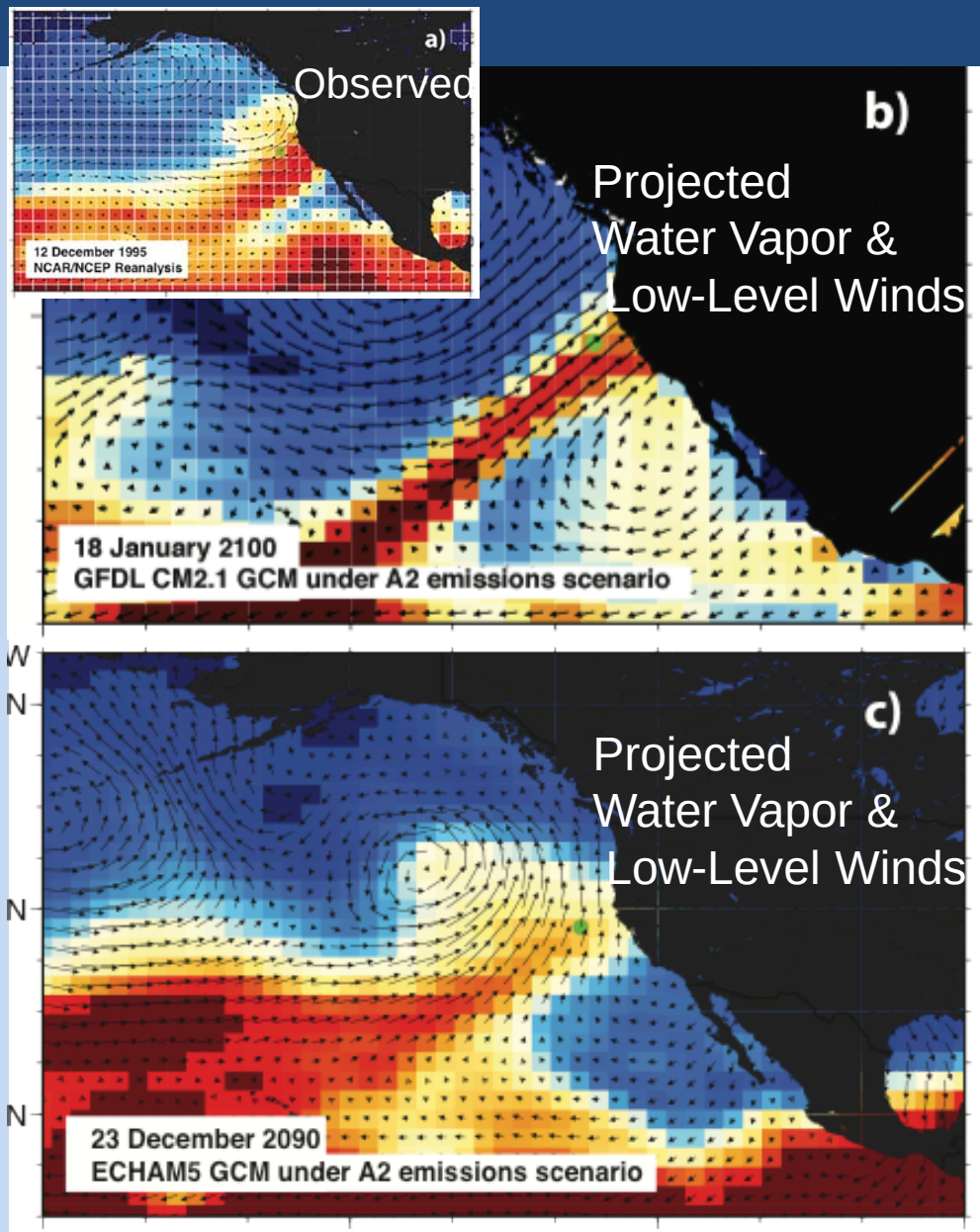
3. Atmospheric Rivers & Climate Change



By end of 21st Century, most GCMs yield:

- **More atmospheric vapor content, but weakening westerly winds**

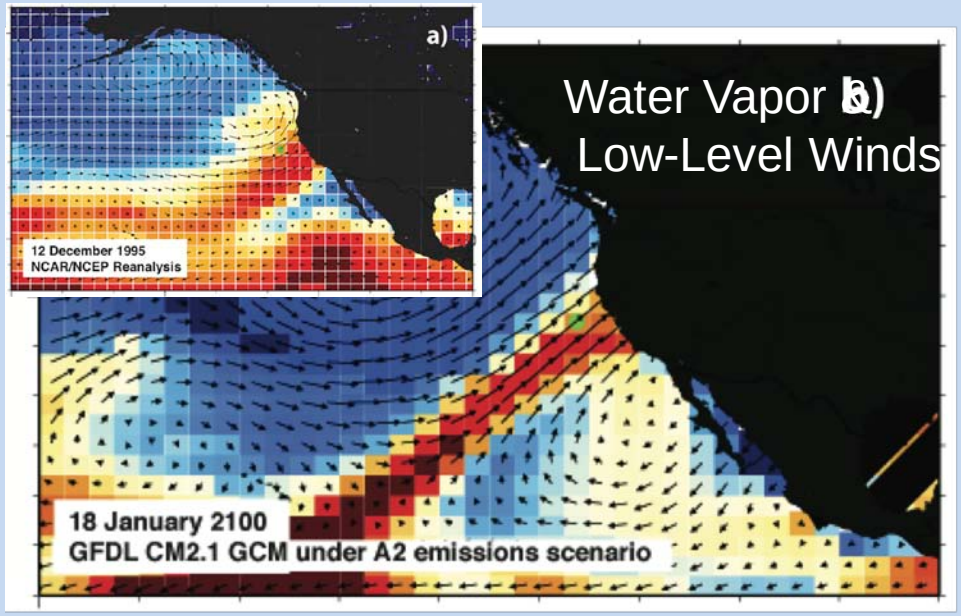
→Net increase in "intensity" of extreme AR storms

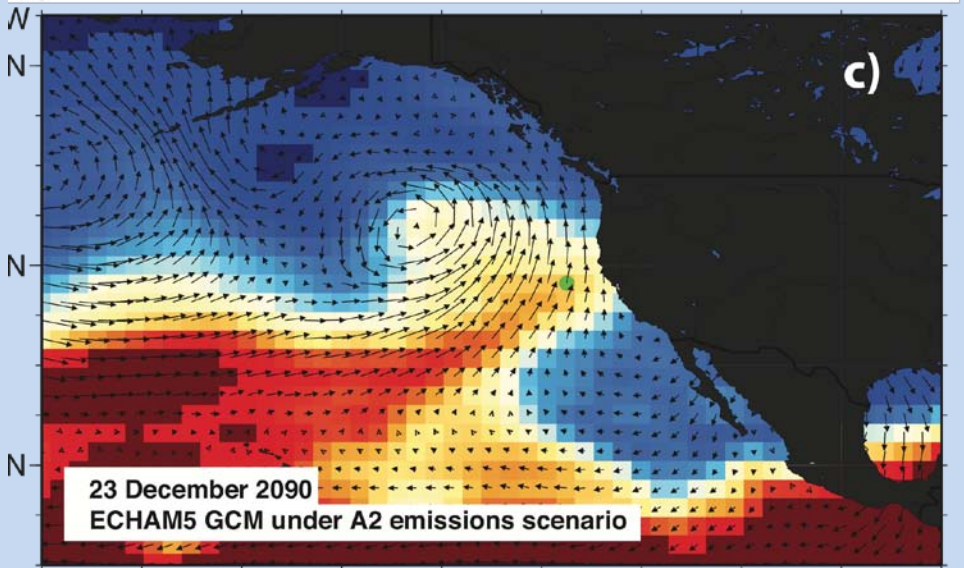
- **Warmer ARs (+1.8 C) → snowline raised by about 1000 feet on average**

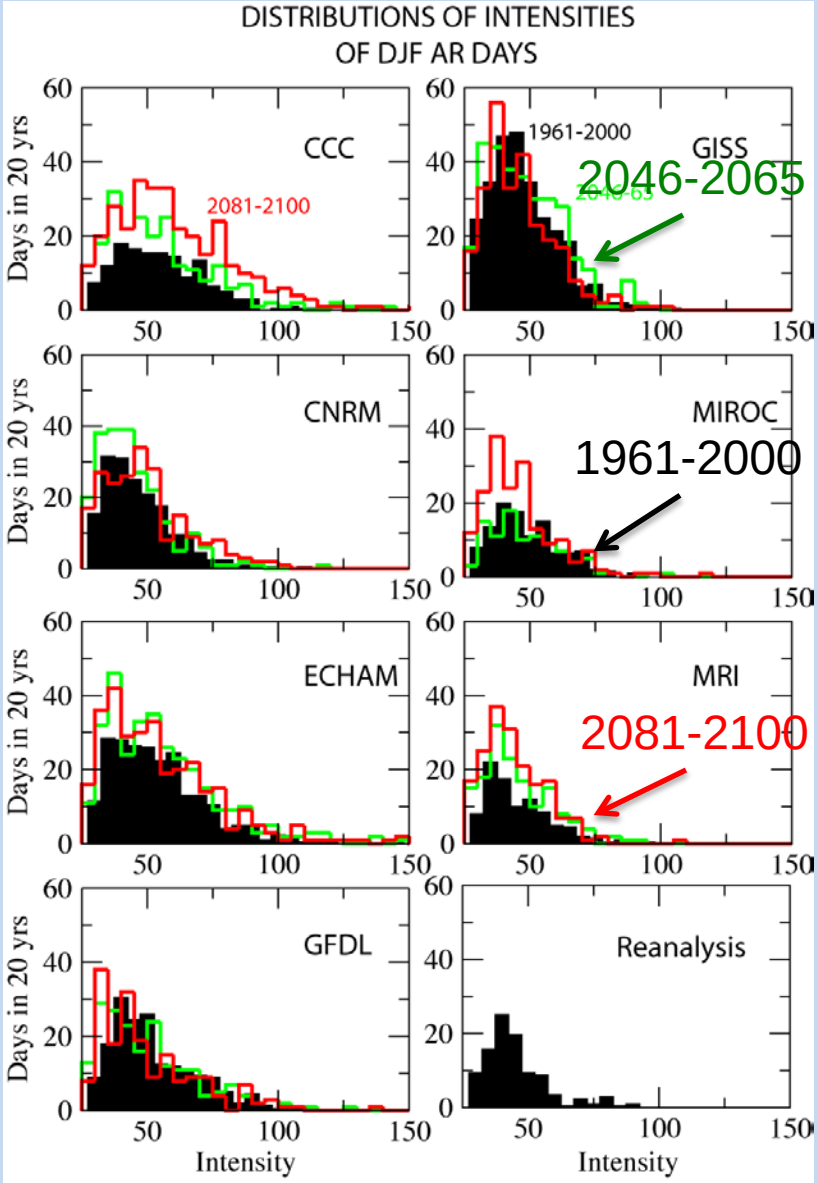
- **Lengthening of AR seasons (maybe?)**

Dettinger, Journal of American Water Resources Association, 2011.

3. Atmospheric Rivers & Climate Change







Conclusions

- ARs are major flood generators in California.
- ARs also contribute 25 to 50% of all precipitation in California.
- ARs play a key role in Yolo floodplain inundations and probably in many aquatic life histories.
- ARs have historically caused large majorities of Central Valley levee breaks.
- ARs projected to increase ~10% on avg, but also to include a few much more extreme cases, under 21st Century climate change.

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