A Scale to Characterize the Strength and Impacts of Atmospheric Rivers

F. Martin Ralph
Center for Western Weather and Water Extremes
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Contributors
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FIRO Science Task Group Meeting
Boulder, CO, 30 May 2017

California Central valley in flood on 21 January 2017 near Sacramento

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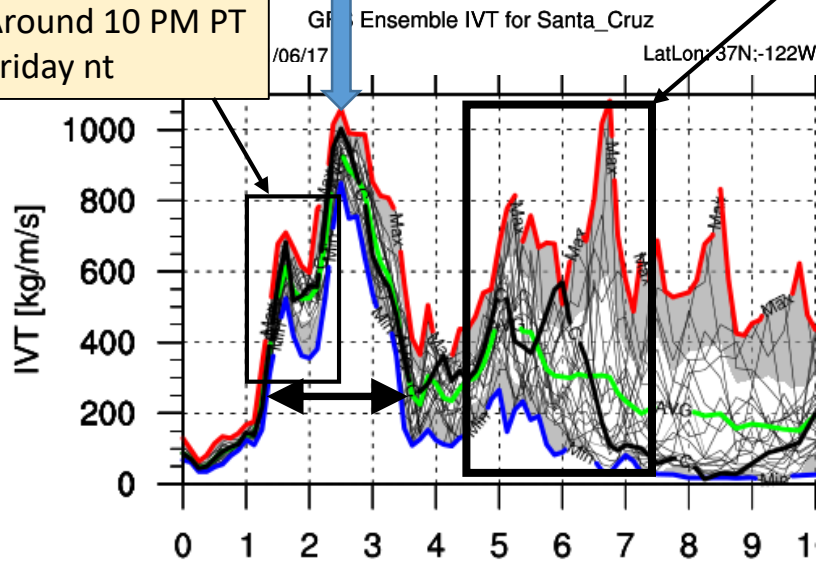
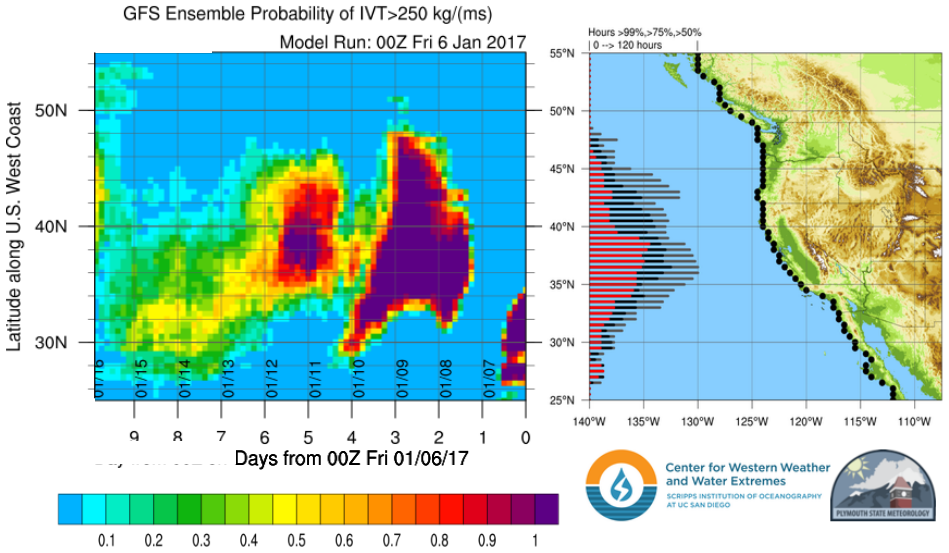
Max IVT 950 kg/ms +/- 10%

2nd AR highly uncertain

Start time +/- 3 h
Around 10 PM PT
Friday nt



IVT > 250 kg/ms
For >48 h



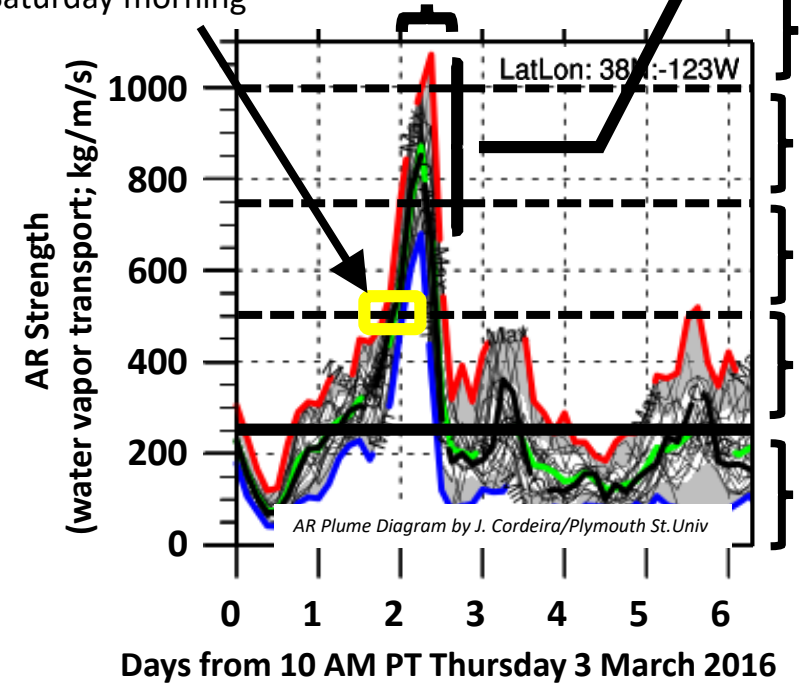
A Scaling for Atmospheric River Intensity

Example is from a CW3E "AR Outlook" posted 4 March 2016 for Pt Reyes, CA area, including the Russian River

Onset of moderate-strength AR conditions Saturday morning

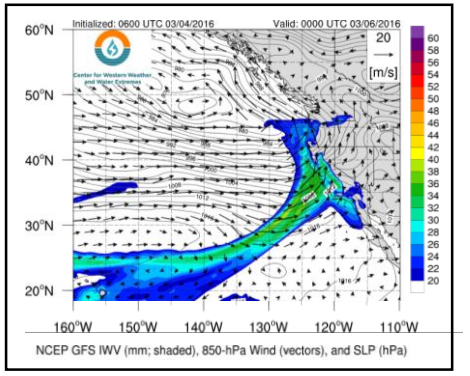
Normal-duration AR landfall (12-24 hours)

Max AR strength is uncertain by +/- 20%



General Impacts

Extreme AR	**Hazardous**
Strong AR	**Hazardous & Beneficial**
Moderate AR	**Beneficial & Hazardous**
Minimal AR	**Beneficial**
Not an AR	



By F. Martin Ralph 2016

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Atmospheric River West-Coast Landfall Intensity and Impact Scale - Concept

AR Category	AR Strength	Max IVT* (kg/m/s)	+ AR Duration**	Beneficial impacts on water***	Hazardous impacts***
	Not an AR	< 250	N/A	90-99%	1-10%
AR CAT 1	Minimal	250-500	< 24 hours	75-90%	10-25%
	*Defined as the instantaneous maximum value at landfall **Duration of at least minimal AR conditions (IVT>250) at landfall; if the duration differs from this range, then adjust the AR Category by 1 ***Range represents affects of preconditions (wet vs dry)				

Process to assign strength at landfall (either predicted or observed)

For each position along the coast, over the next 5 days, assess the following

Step 1 (IVT): What is the max IVT at landfall at that location? Does IVT continuously exceed 250 for at least 8 hours?

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Step 3 (Adjust AR CAT based on duration): If the AR duration is outside the range Noted in the scaling, adjust the AR CAT by 1 (e.g., Max IVT 800, but duration < 24 h means event is AR CAT 2 rather than 3, or if duration is > 48 h, then it is assigned AR CAT 4 rather than 3.

Step 4 (impact risk range): If soils are wet, reservoirs full, impacts are more hazardous

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AR CAT 5	Exceptional	>1250	> 48 hours	1-10%	90-99%
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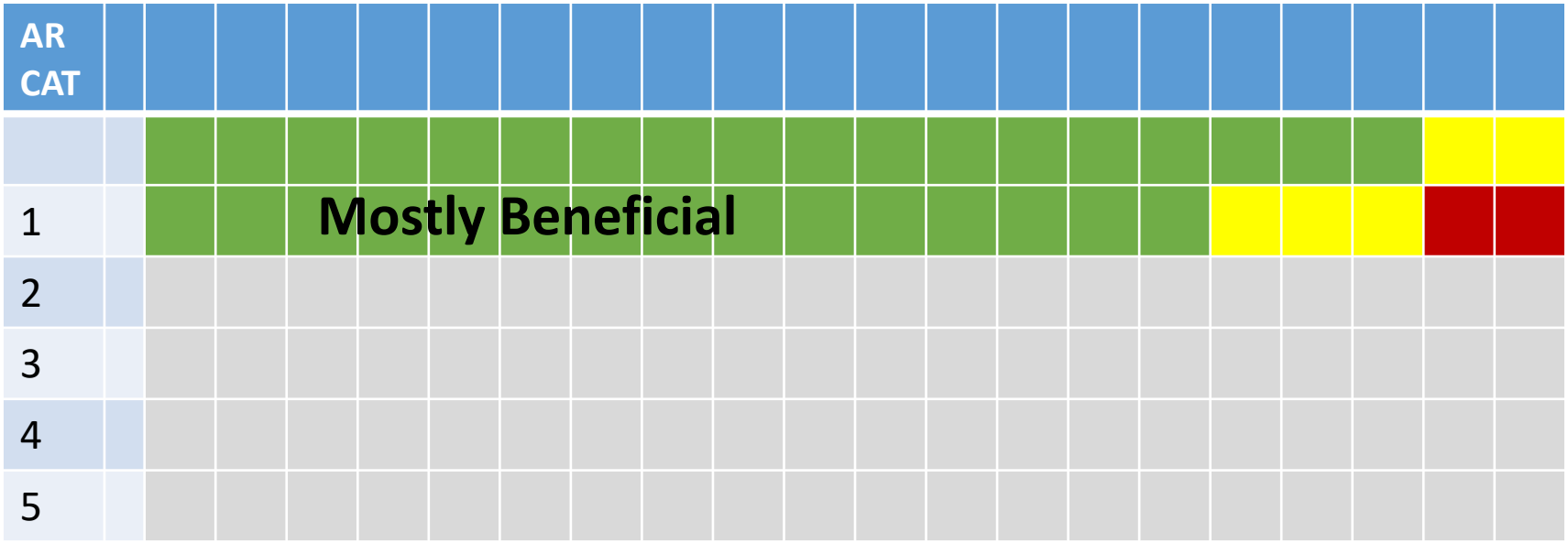

Approximate fraction of impacts that are primarily beneficial (e.g., better water supply)

Adjustable fraction of impacts that are either beneficial or hazardous

Approximate fraction of impacts that are primarily hazardous (e.g., flooding)

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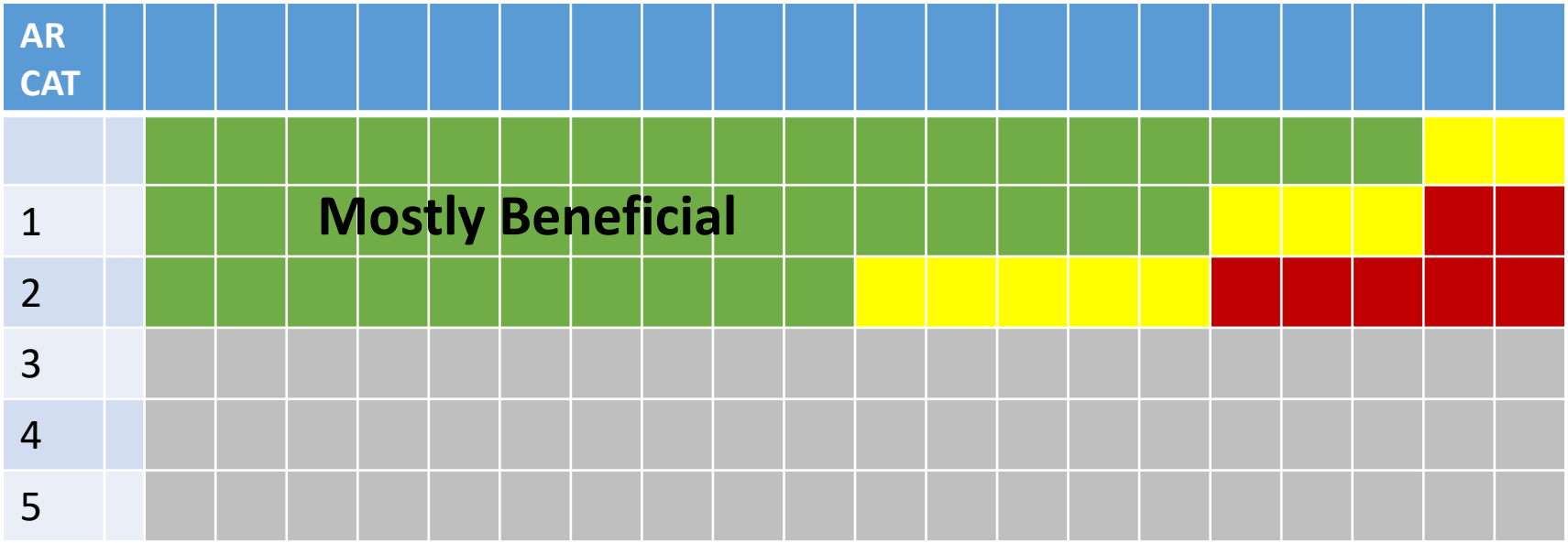

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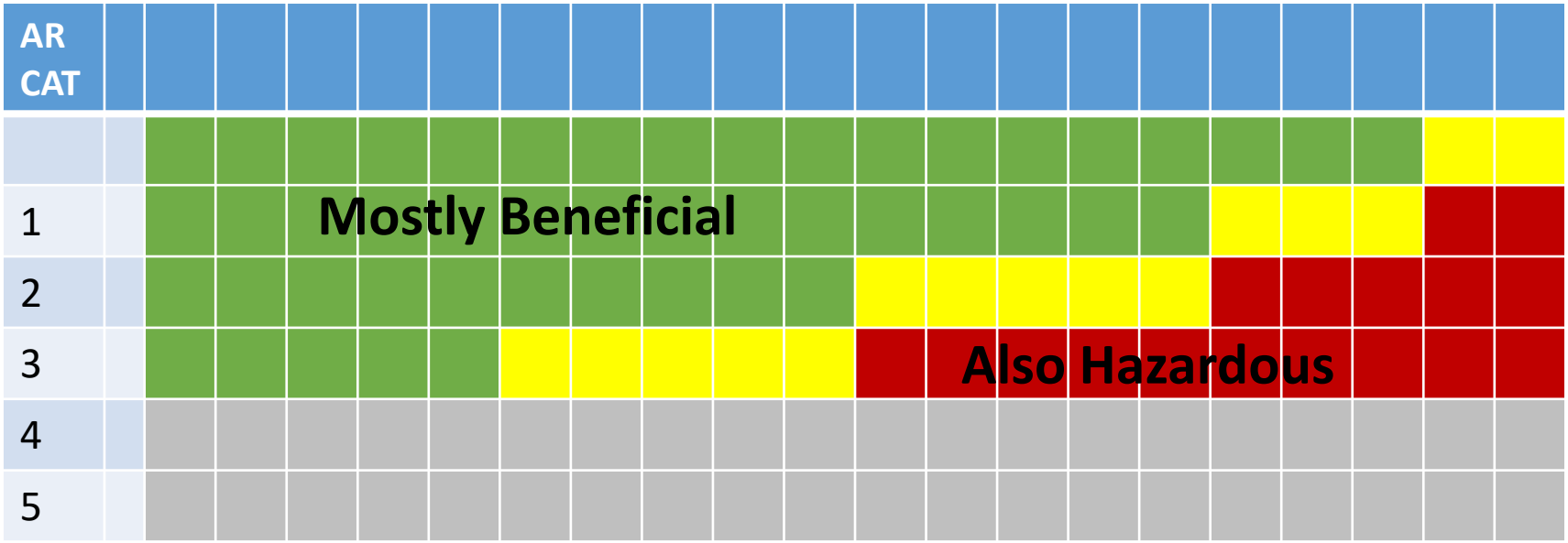

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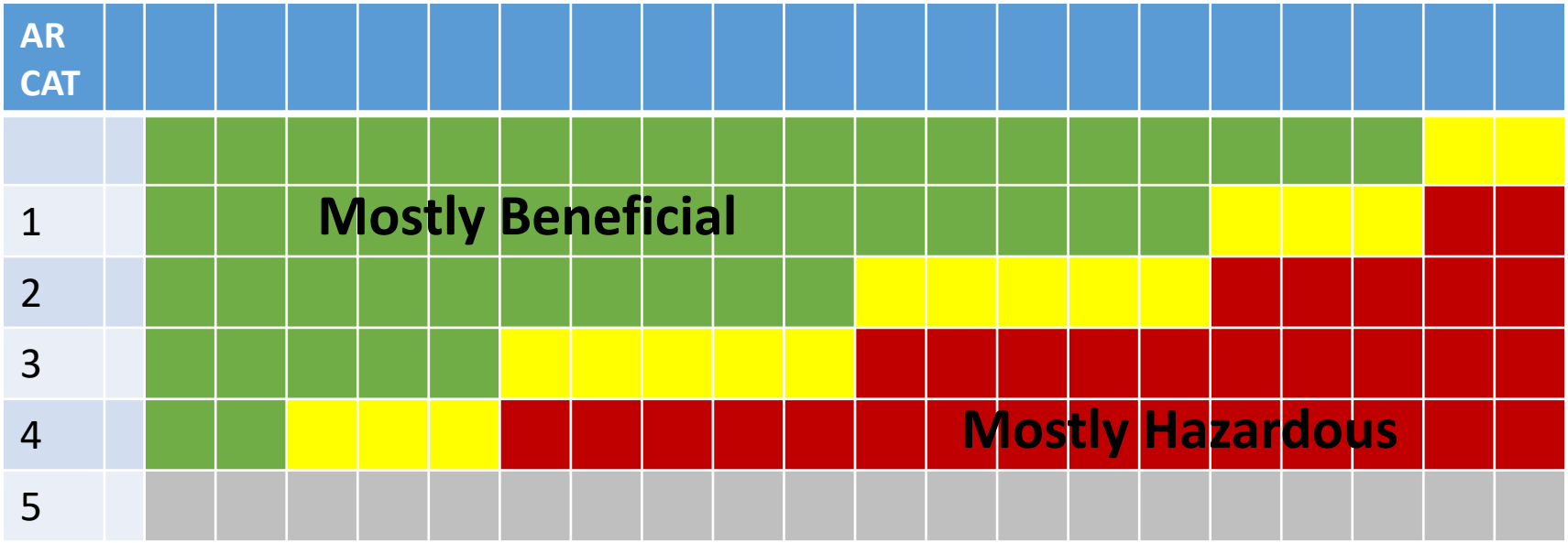

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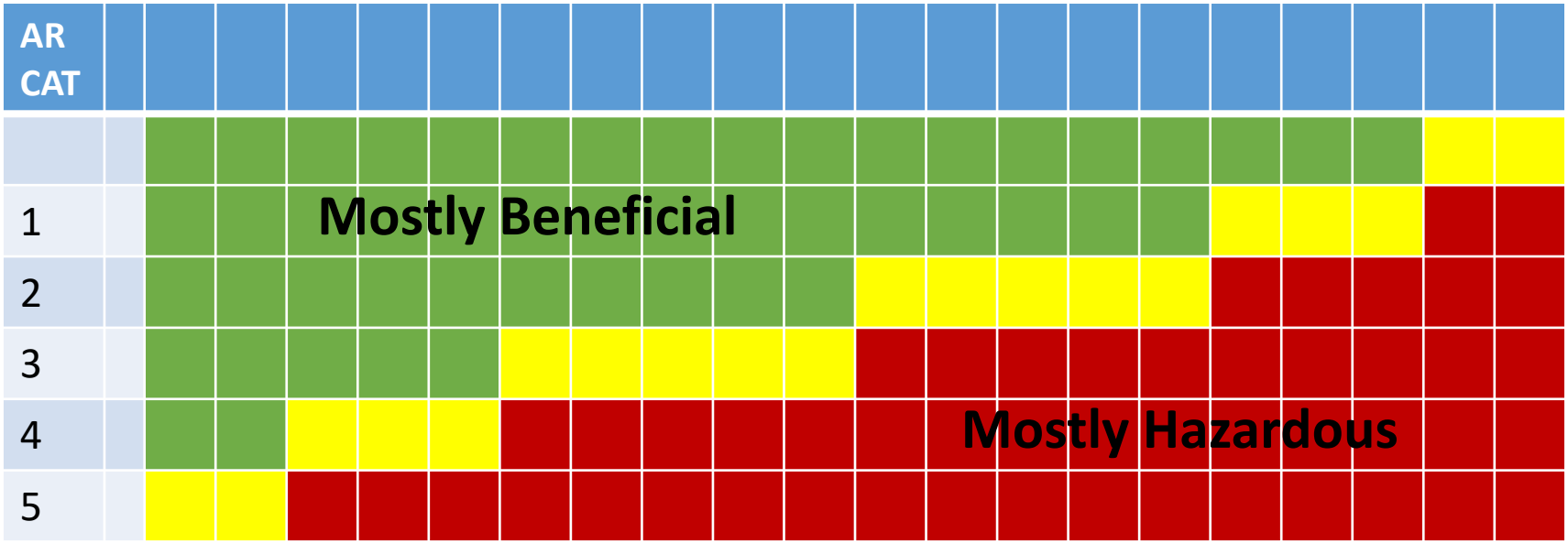

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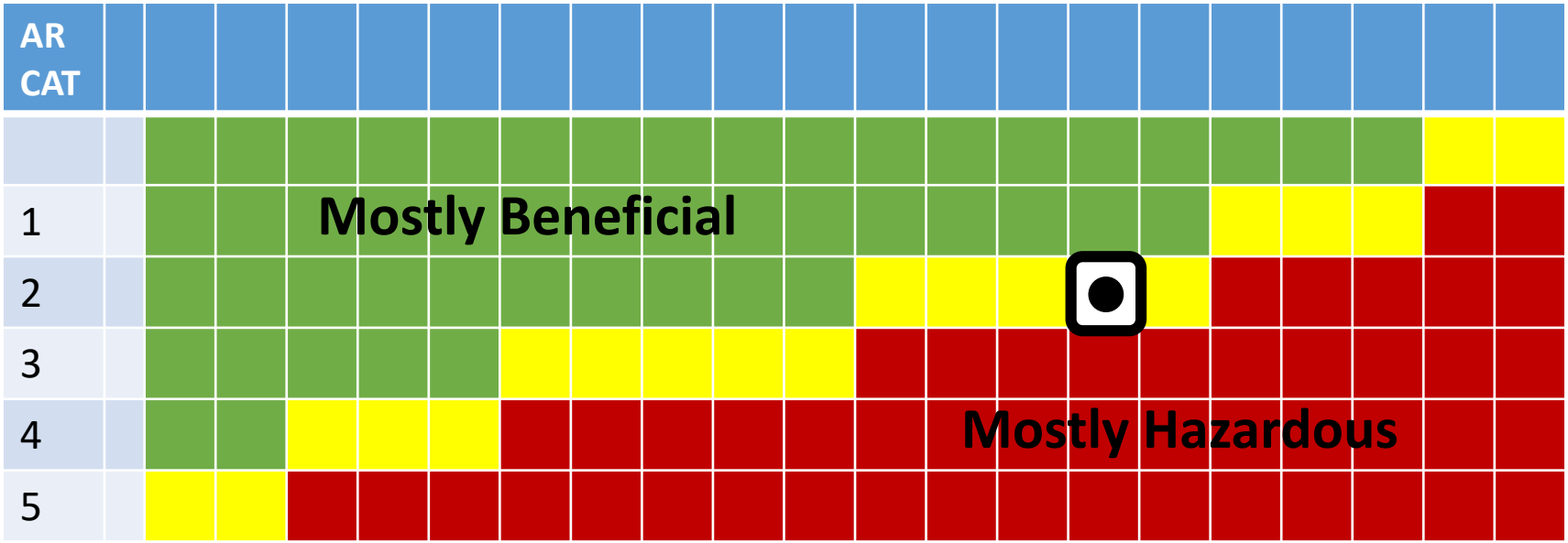

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Approximate fraction of impacts that are primarily hazardous (e.g., flooding)

Assessment for a hypothetical actual AR landfall event
(in this example the impacts are more toward Beneficial than Hazardous, relative to most AR CAT 2 landfalls)

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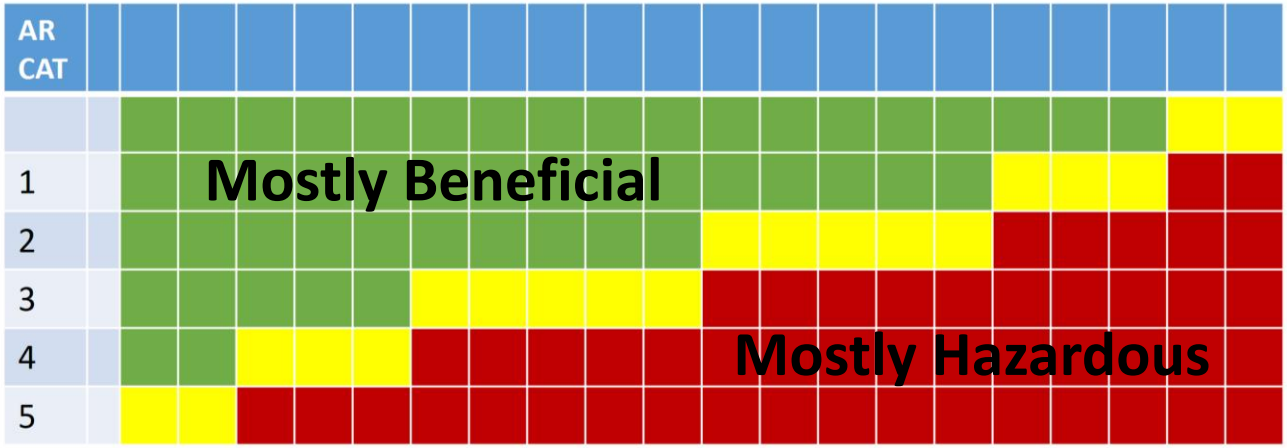
General character of AR Landfall Impacts (benefits vs hazards)



Approximate fraction of impacts that are primarily beneficial (e.g., better water supply)

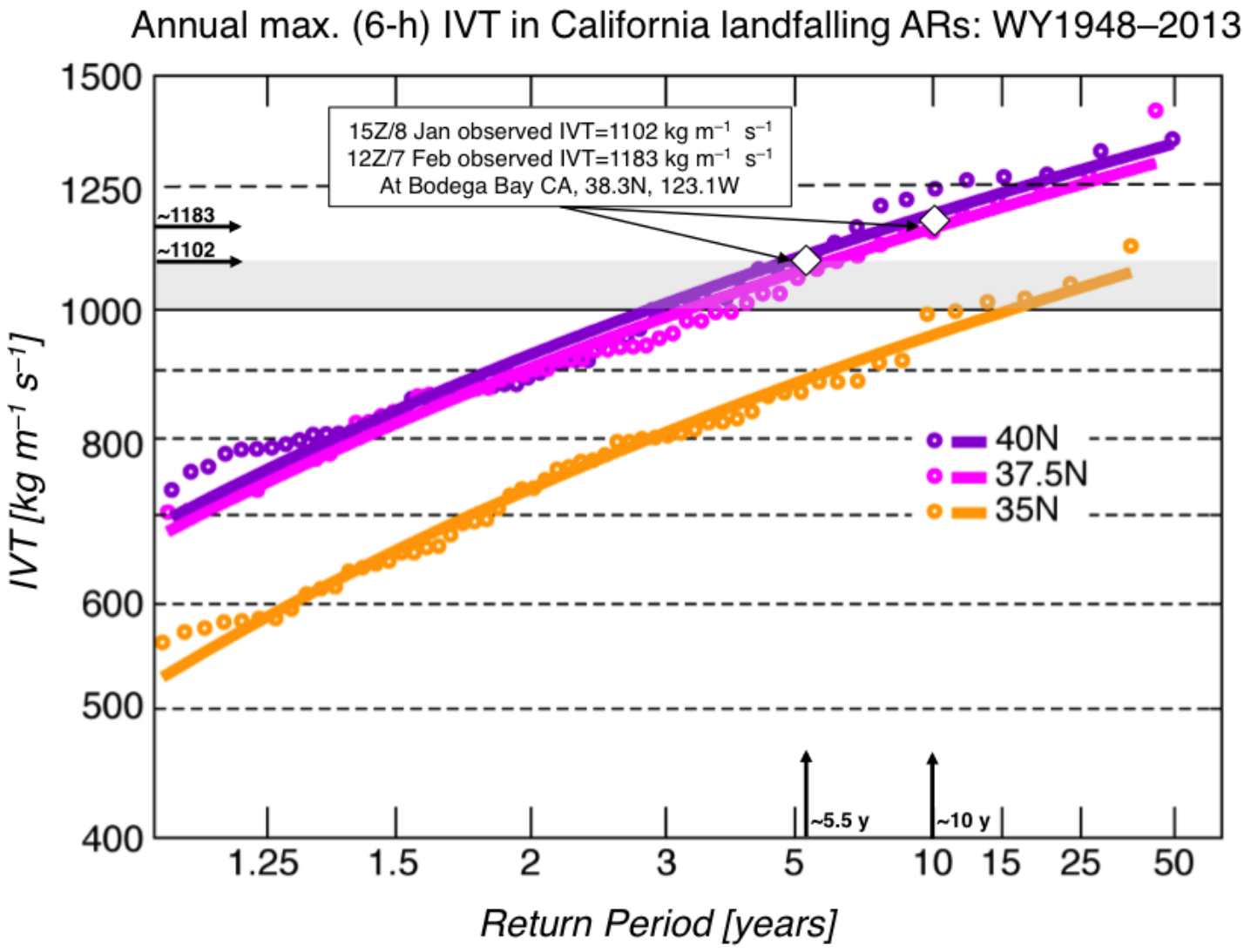
Adjustable fraction of impacts that are either beneficial or hazardous

Approximate fraction of impacts that are primarily hazardous (e.g., flooding)

Return periods (years)

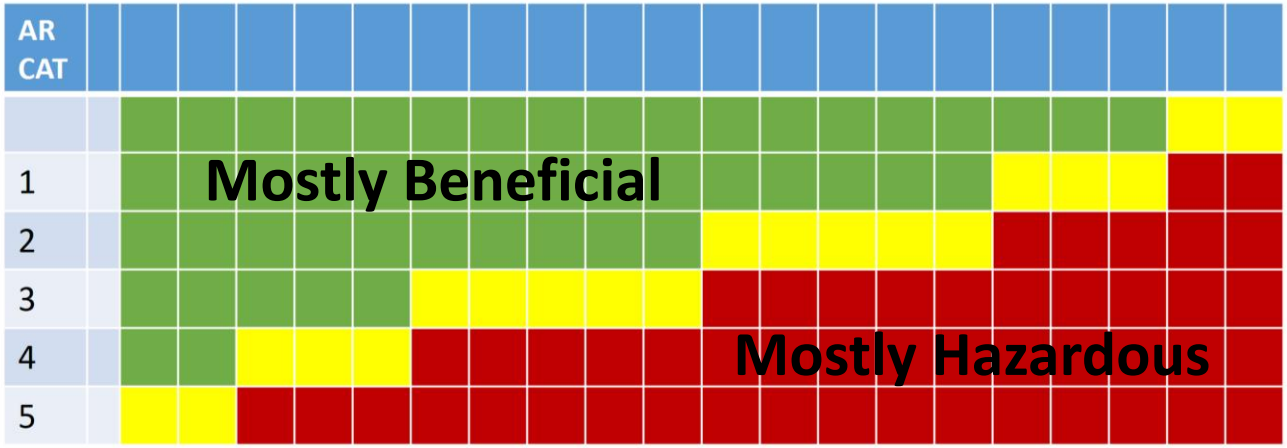
48 N SEA	42 N OR/CA	38 N SanFr	34 N LosAn	32 N SanD
--	--	--	--	--
--	--	--	1	1.25
1.5	1	1.4	2.2	5
9	3	3	15	75
>75	35	25	>75	>100

Based on 66 yr NCEP-NCAR reanalysis



From Dettinger, Ralph, Rutz (submitted)

General character of AR Landfall Impacts (benefits vs hazards)



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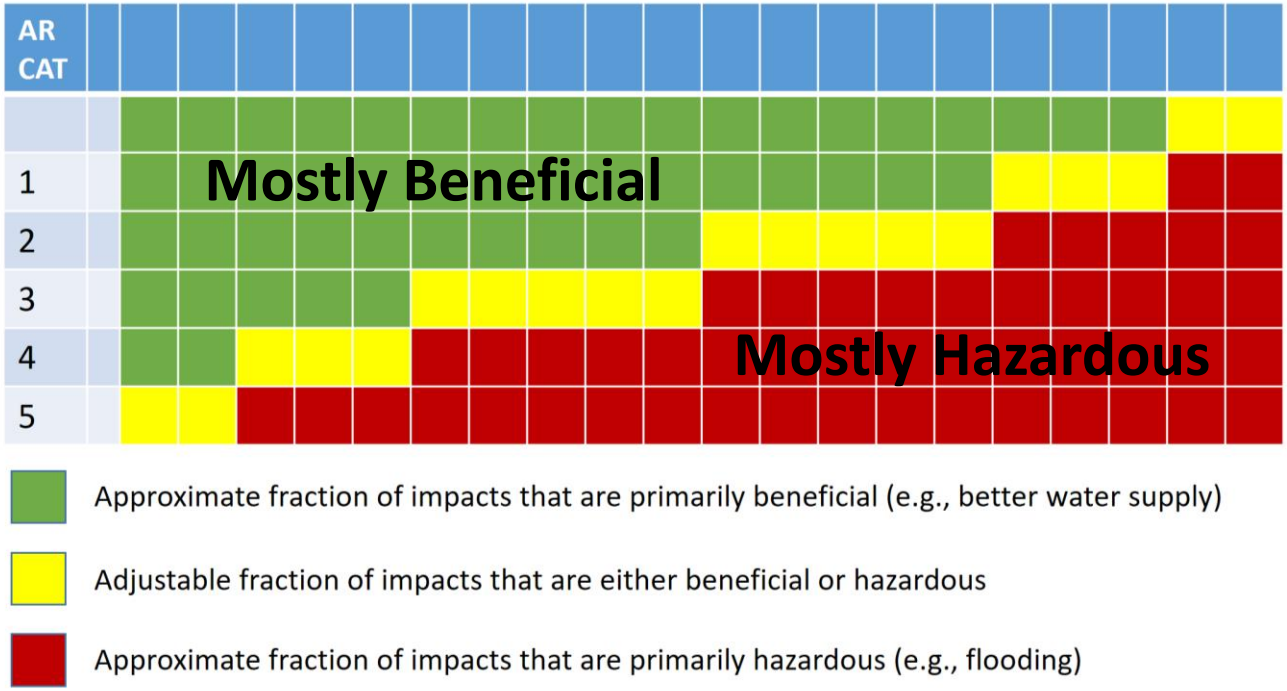
Typical NWS Warnings

SvrThndr St	Urban Flood	Flood Warn	Wintr Storm	Blizzd
		Rare		
		Some		
		Most		
		All		
		All		
		All		

General character of AR Landfall Impacts (benefits vs hazards)



Typical NWS Warnings

SvrThndr St	Urban Flood	Flood Warn	Wintr Storm	Blizzd
Rare	Rare	Rare	Rare	Rare
Some	Some	Rare	Some	rare
Some	Most	Some	Most	Some
Most	All	Most	Most	Some
Most	All	All	All	Most
All	All	All	All	All

Could go back to about 2005 and track what actual NWS warnings were for events.
And develop the table from those events.
WCMs at WFOs file monthly a list of all their warnings.

AR Categories Concept Overview

Focuses on conditions at the coast at landfall

For simplicity, thresholds are defined by fixed values of IVT and duration, which means some AR prone locations have more events than areas where ARs typically are not as strong or common.

Can be applied to forecasts (e.g., over 5 days) or can be assessed retrospectively using observed conditions

Considers two main attributes:

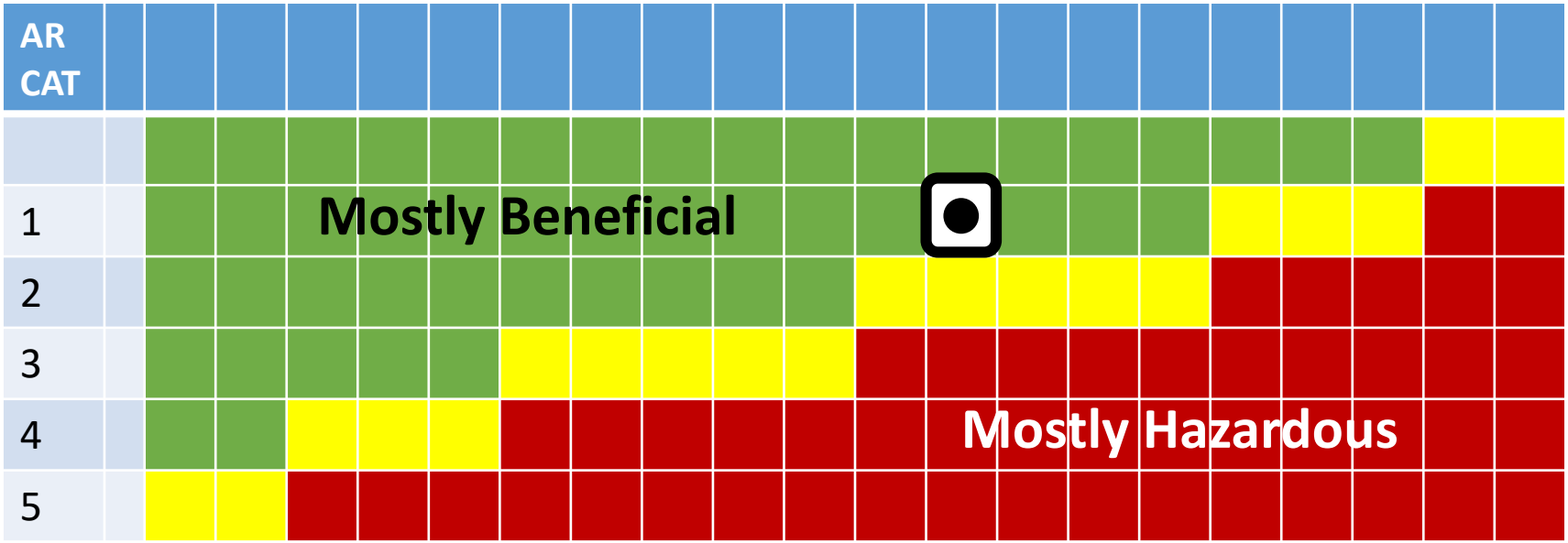
- Instantaneous strength (IVT)
- Duration of at least minimal AR conditions (IVT > 20 kg/m/s)

Recognizes that AR impacts include major benefits to water supply and various hazards

The scaling shifts from largely beneficial impacts for AR CATs 1-2, to largely hazardous for AR CATs 4-5 (the public and decision makers are interested in knowing both the benefits and hazards)

The benefit/hazard balance is adjusted due to antecedent conditions (e.g., soil moisture, river and reservoir levels), and due to 3-day IVT and nearby max 3-day precip (forecasted or observed)

Atmospheric River ALERT | **Bay Area** | **AR CAT 1**



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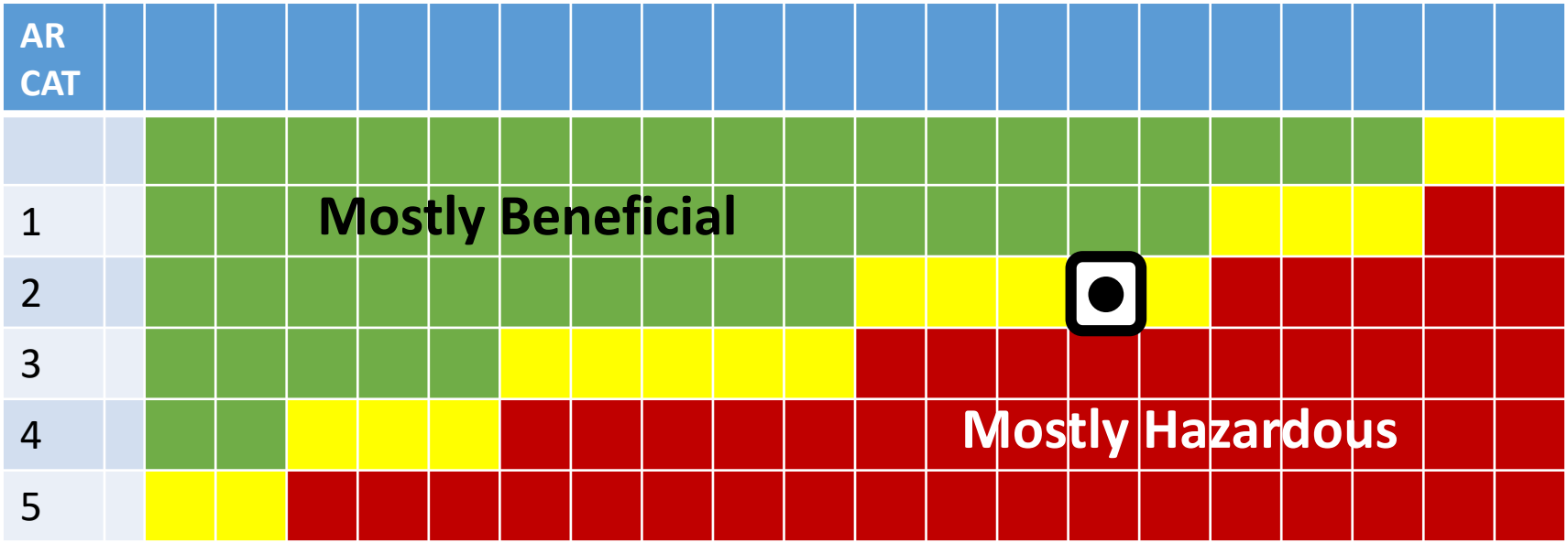
Atmospheric River ALERT | **Bay Area** | **AR CAT 2**



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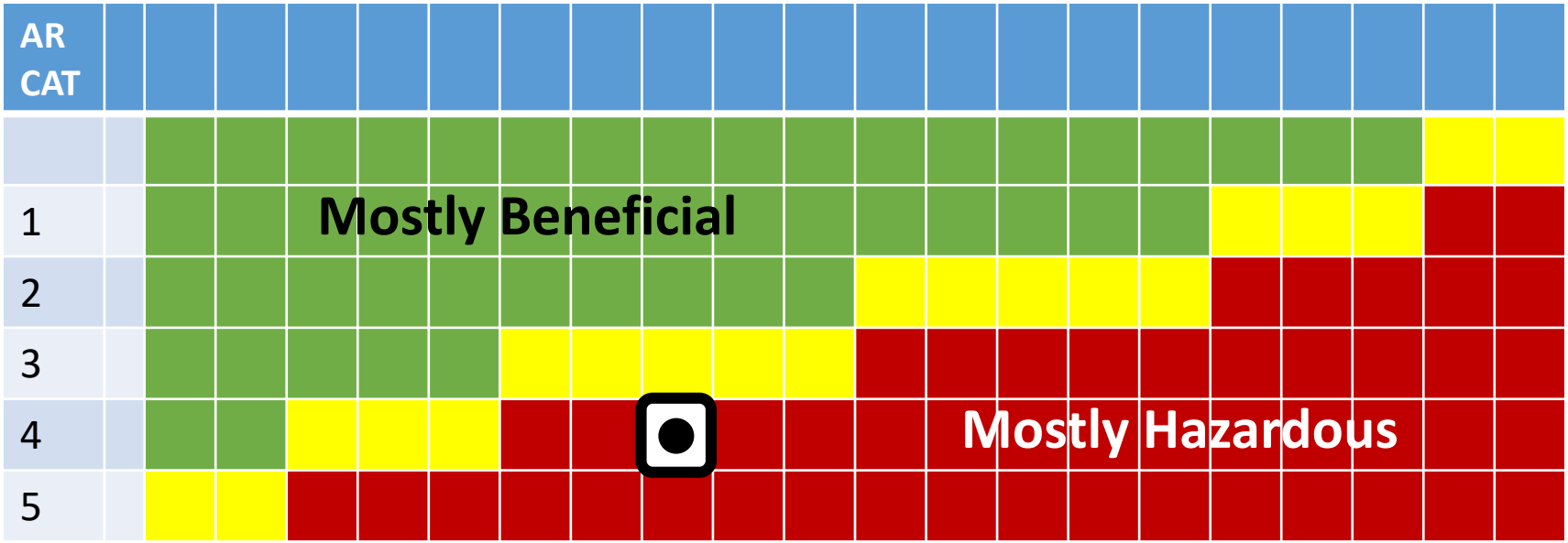
Atmospheric River ALERT | **Location** | **AR CAT 4**



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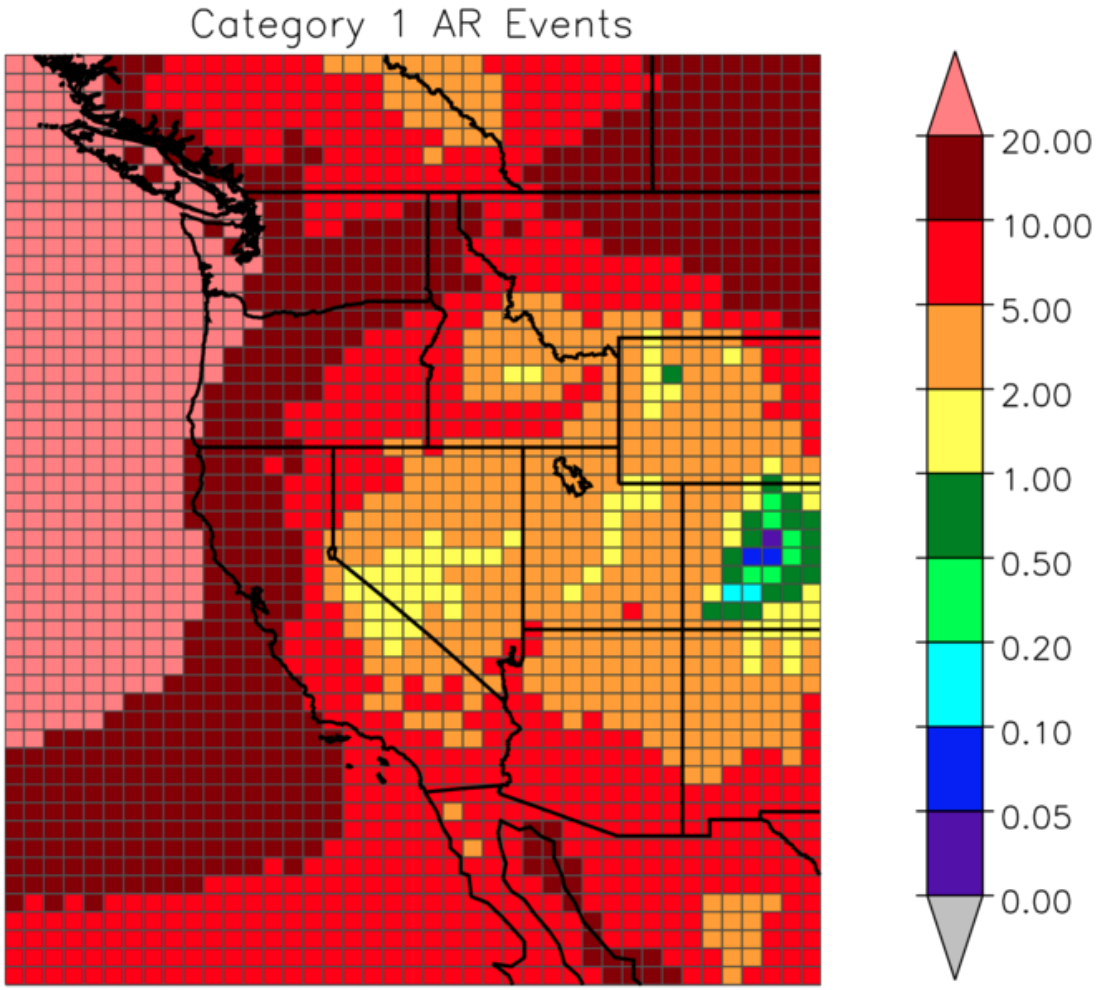
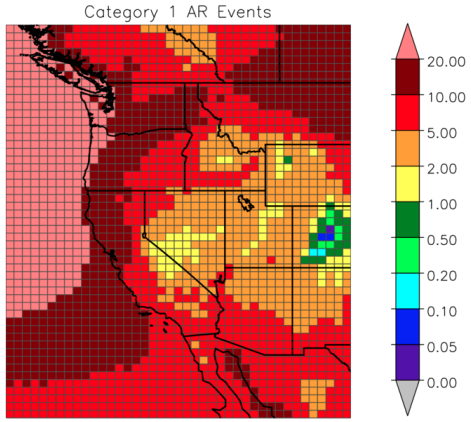
Number of Category 1 ARs per year based on MERRA Reanalysis (1980-2016)

12-h minimum duration of IVT > 250 kg m^{-1} s^{-1}

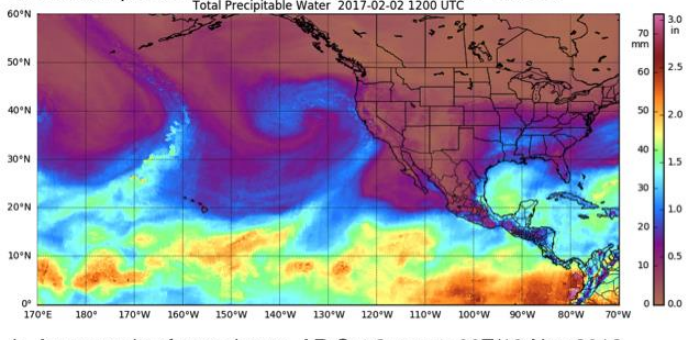


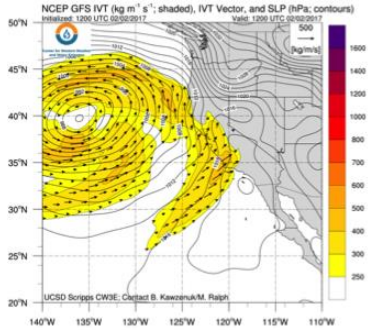
Number of AR Events Per Year Based on MERRA Reanalysis (1980–2016)

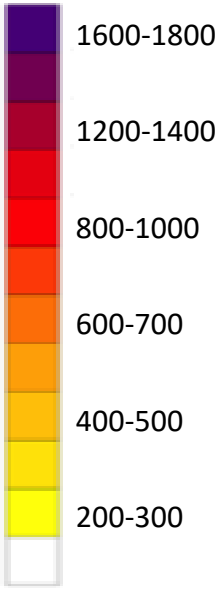
12–h Minimum Duration IVT > 250



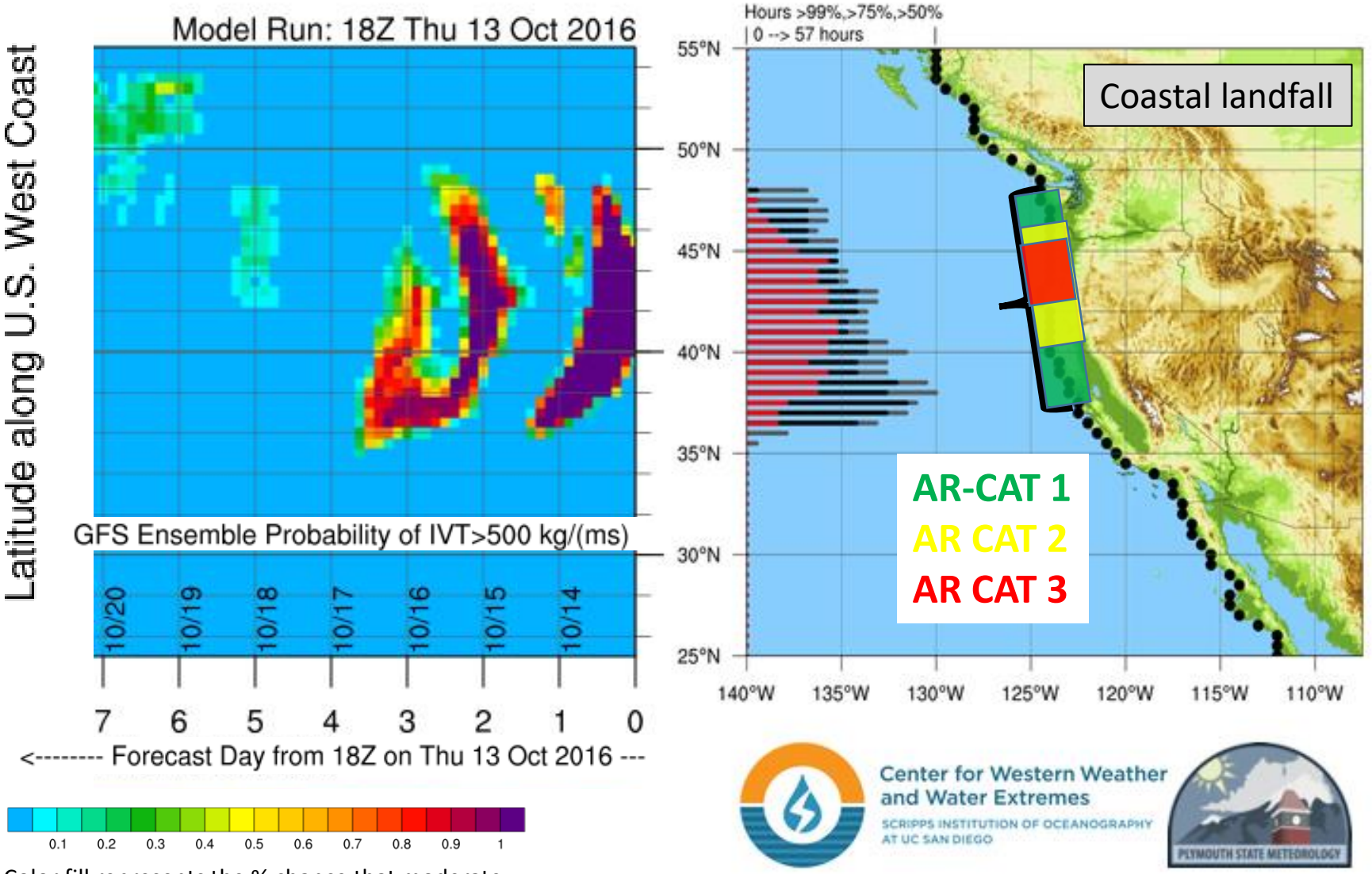
a. An example of a weak, AR Cat 1 event: 12Z/2 Feb 2017







AR Landfall and Inland Penetration Probabilities (as of midday Thursday 13 Oct)



Color fill represents the % chance that moderate strength (>500 kg/m/s) atmospheric river will hit at that time and the latitude corresponding to the black dots in the right panels

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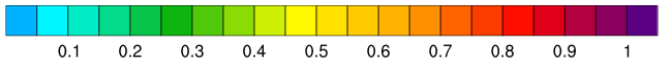
PLYMOUTH STATE METEOROLOGY

AR Landfall and Inland Penetration Probabilities

(as of midday Thursday 13 Oct)

Odds of a moderate strength atmospheric river making landfall (top panel), or penetrating inland to the Cascade and Sierra Nevada Mountains (bottom panel)



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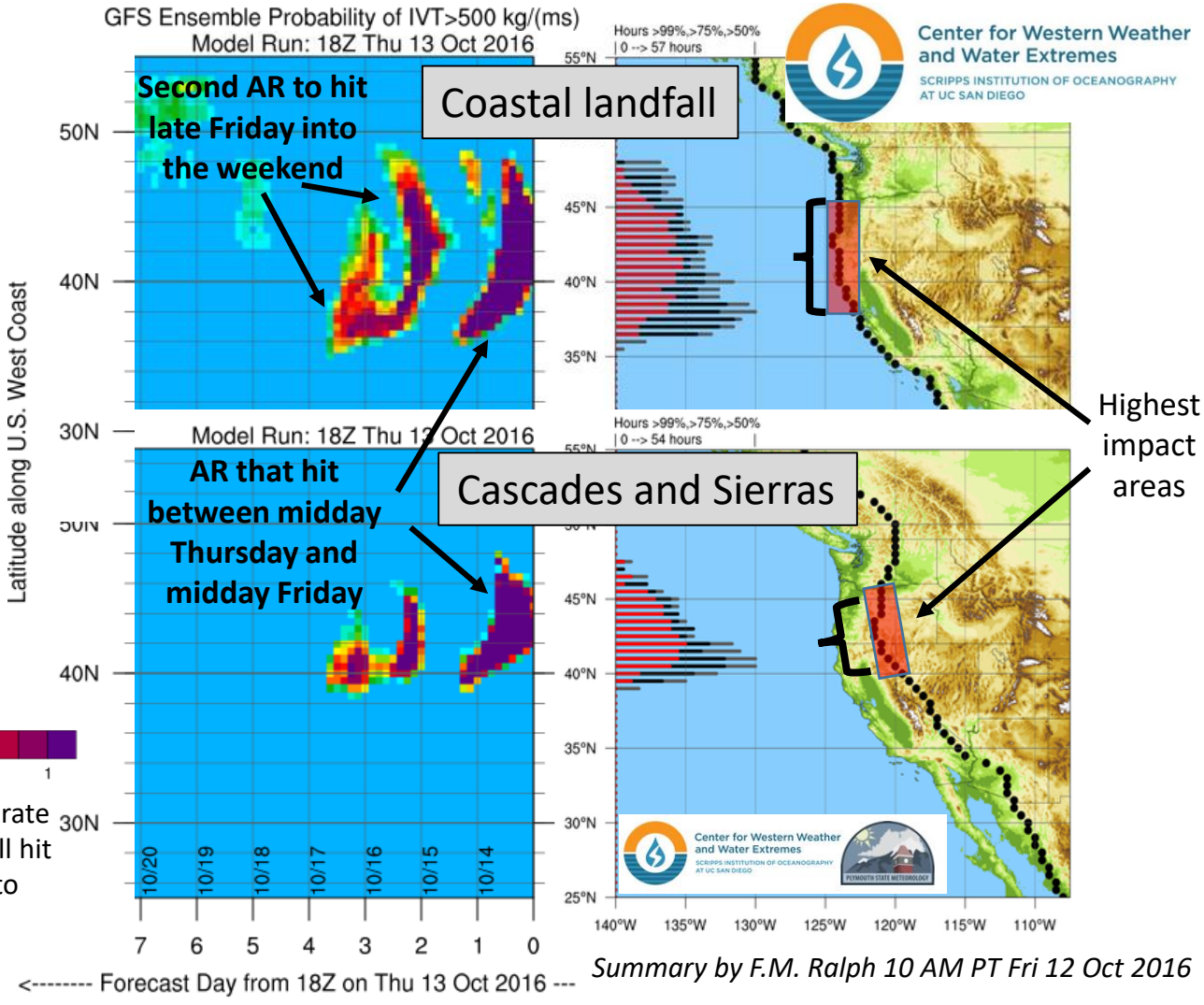

Summary by F.M. Ralph 10 AM PT Fri 12 Oct 2016

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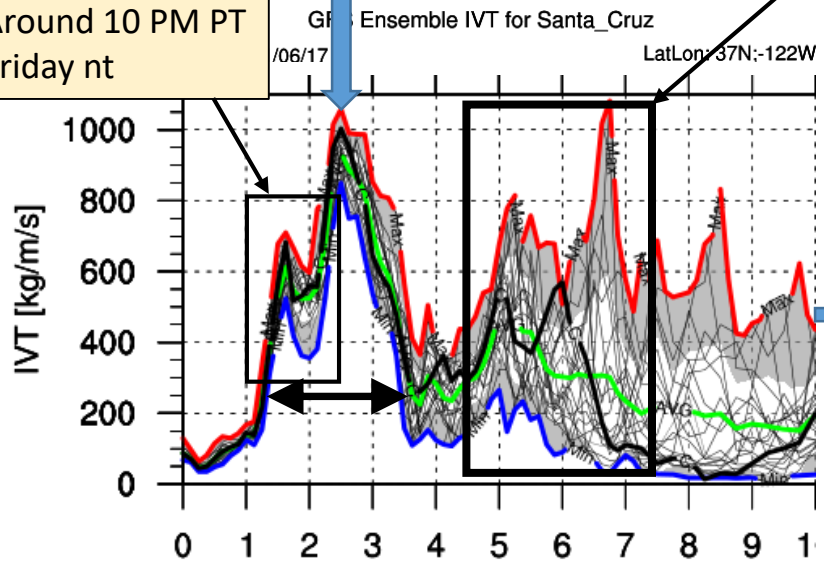

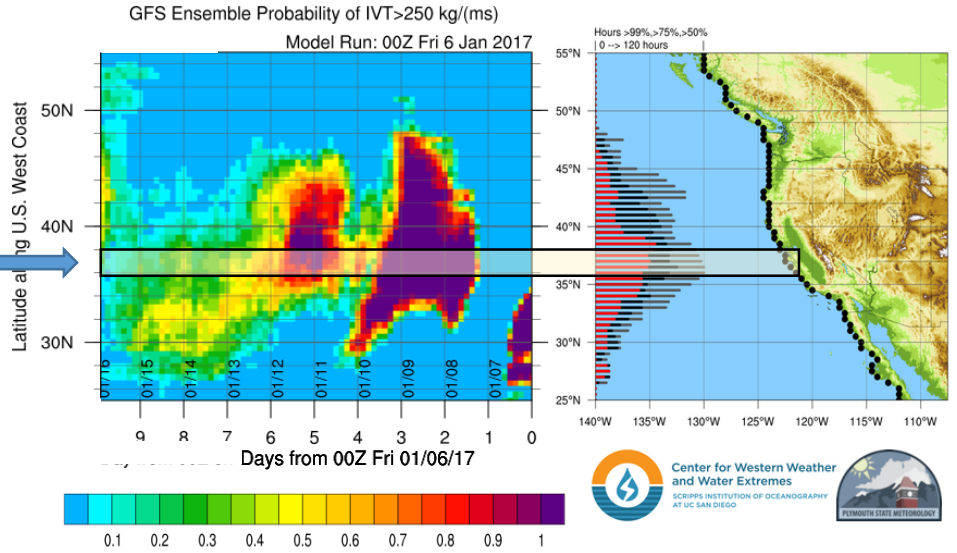

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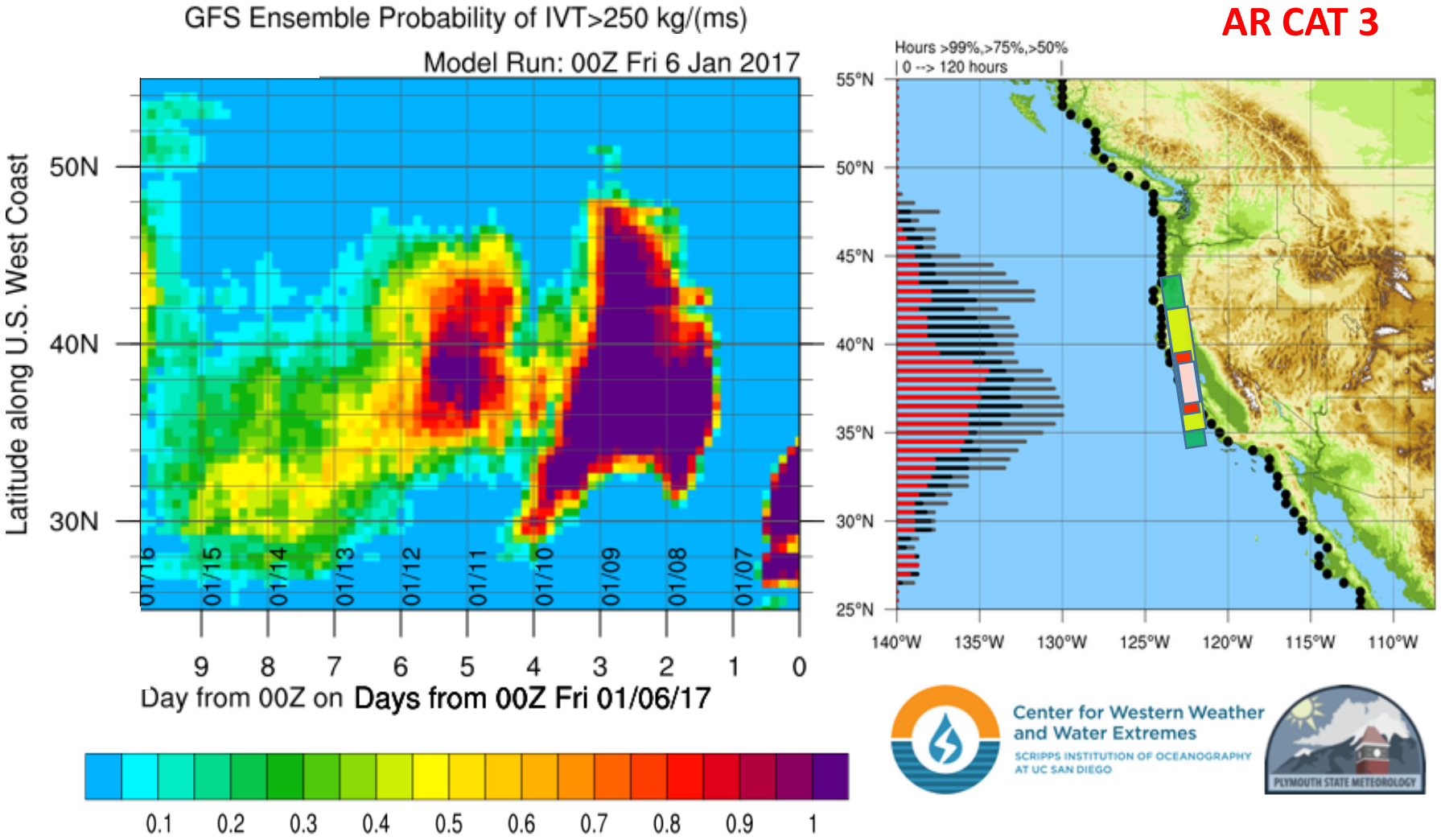
AR-CAT 1

AR CAT 2

AR CAT 3



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PLYMOUTH STATE METEOROLOGY

Atmospheric River West-Coast Landfall Intensity and Impact Scale - Concept

AR Category	AR Strength	Max IVT* (kg/m/s)	+ AR Duration**	Beneficial impacts on water***	Hazardous impacts***	3-day IVT/return period	3-day Precip (in)/ R-CAT****
	Not an AR	< 250	N/A	90-99%	1-10%		
AR CAT 1	Minimal	250-500	< 24 hours	75-90%	10-25%		
AR CAT 2	Moderate	500-750	24-48 h	50-75%	25-50%		
AR CAT 3	Strong	750-1000	24-48 h	25-50%	50-75%		
AR CAT 4	Extreme	1000-1250	24-48 h	10-25%	75-90%		
AR CAT 5	Exceptional	>1250	> 48 hours	1-10%	90-99%		

*Defined as the instantaneous maximum value at landfall
**Duration of at least minimal AR conditions (IVT>250) at landfall; if the duration differs from this range, then adjust the AR Category by 1
***Range represents affects of preconditions (wet vs dry)
****Within 200 km of the coastal location

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Process to assign strength at landfall (either predicted or observed)

For each position along the coast, over the next 5 days, assess the following

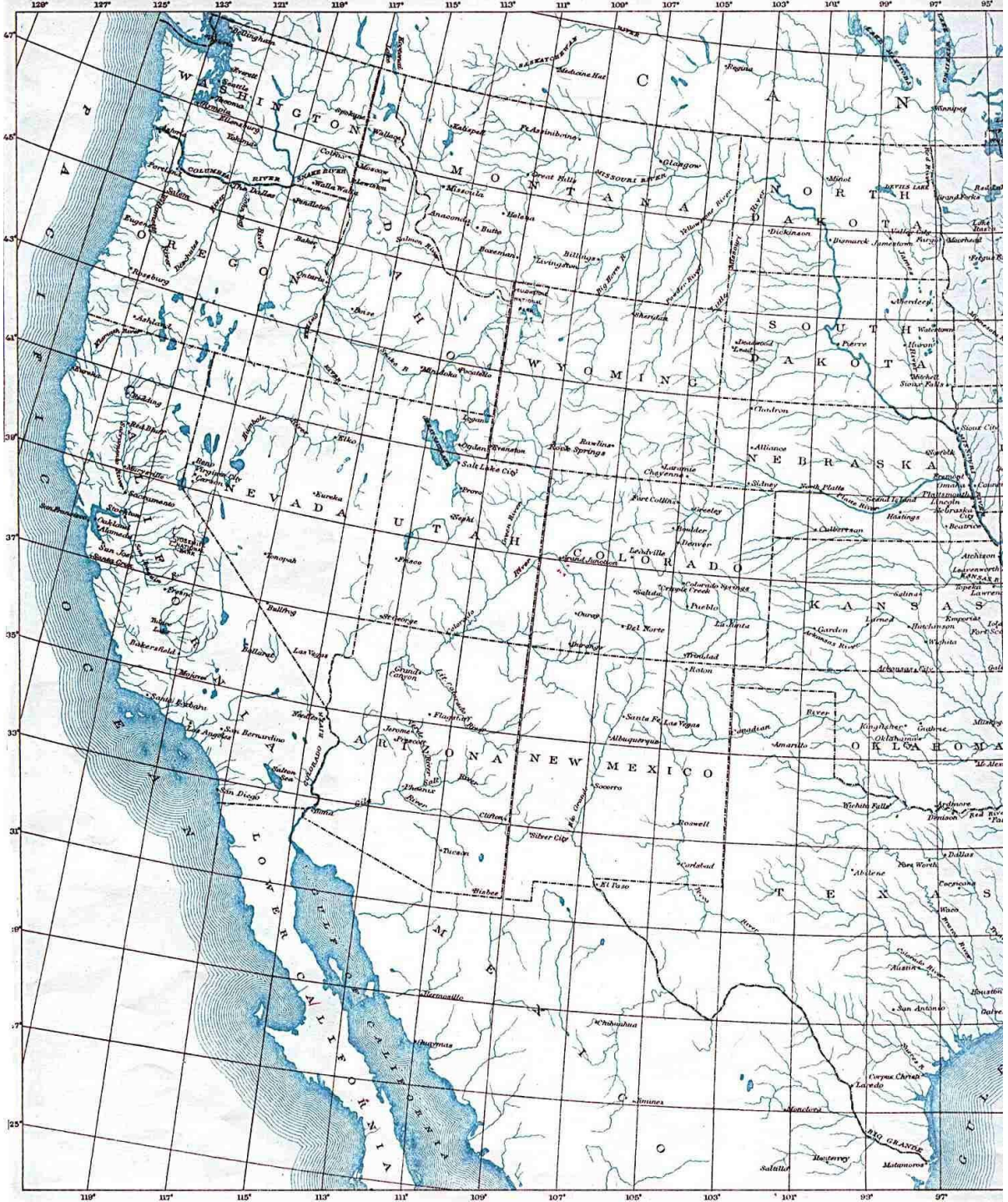
Step 1 (IVT): What is the max IVT at landfall at that location?

Step 2 (AR Duration): How long does IVT continuously exceed 250 kg/m/s at that location?

Step 3 (Adjust AR CAT based on duration): If the AR duration is outside the range noted in the scaling, adjust the AR CAT by 1 (e.g., Max IVT 800, but duration < 24 h means event is AR CAT 2 rather than 3, or if duration is > 48 h, then it is assigned AR CAT 4 rather than 3.

Step 4 (impact risk range): If soils are wet, reservoirs full, impacts are more hazardous

F. Martin Ralph 2016

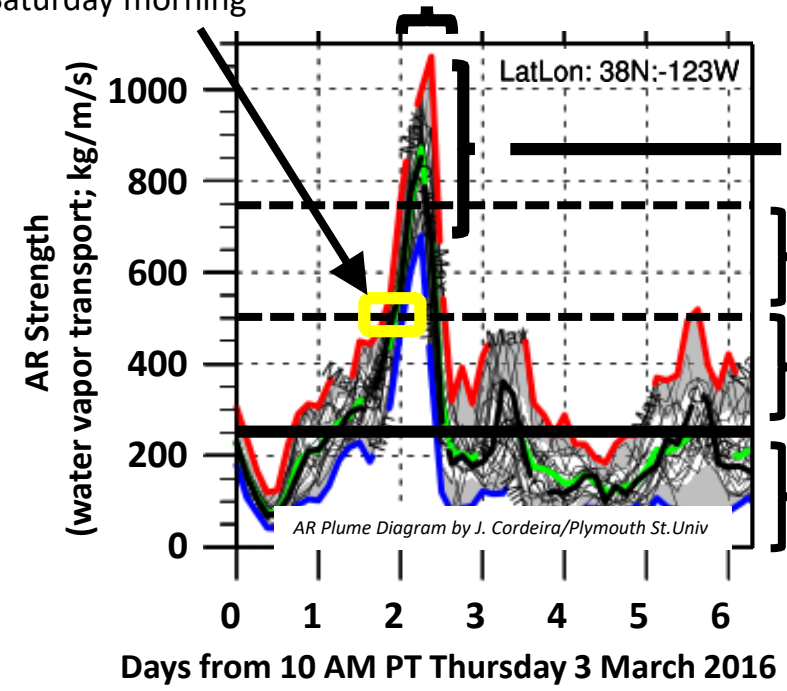

WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
CANADA
MEXICO
PACIFIC OCEAN
GULF OF CALIFORNIA
LOWER CALIFORNIA
Seattle
Portland
Spokane
San Francisco
Los Angeles
San Diego
Salt Lake City
Denver
Albuquerque
Santa Fe
Phoenix
El Paso
Dallas
Houston
San Antonio
Chihuahua
Monterey
Matamoros
RIO GRANDE
COLUMBIA RIVER
SNAKE RIVER
MISSOURI RIVER
COLORADO RIVER

AR Outlook for Pt Reyes, CA area, including Russian River

Summary by F.M. Ralph 8 AM PT Fri 4 March 2016

Onset of moderate-strength AR conditions Saturday morning

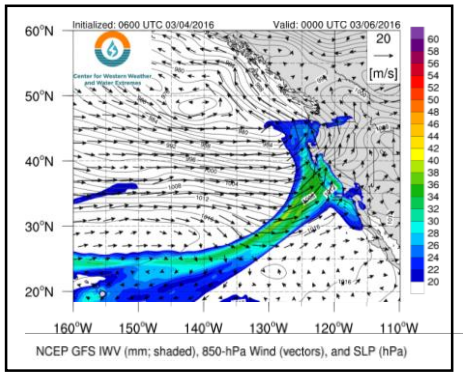
Normal-duration AR landfall (12-24 hours)



Max AR strength is uncertain by +/- 20%

General Risk Levels

- **Hazardous**
- Moderate strength AR — **Beneficial & Hazardous**
- Minimal strength AR — **Beneficial**
- Not an AR



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