

# Cluster Analysis of Air Quality Data for CCOS Study Domain

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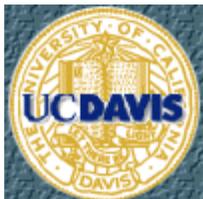
University of California, Davis

Dept. Chemical Engineering & Materials Science

## CCOS Technical Committee Meeting

Cal/EPA Building, 1001 I St., Sacramento, CA

Thursday 31 March 2007



# Overview

- Project: Cluster Analysis for CCOS Domain
  - I. Intra-basin analyses: wind patterns & synoptic regimes
  - II. Inter-basin meteorological response of O<sub>3</sub> levels
- Intra-basin analyses:
  - Completed Bay Area analysis
    - Strong synoptic influence; seabreeze cycles
  - Preliminary North SJV wind field clustering
    - Synoptic & ventilation effects
  - Preliminary Central SJV wind field clustering
    - Synoptic & mesoscale (Fresno eddy) effects
  - Preliminary South SJV wind field clustering
    - Synoptic effects; mesoscale variability difficult to capture
  - Initial Sacramento Valley & Mountain Counties analysis
- Future work and recommendations

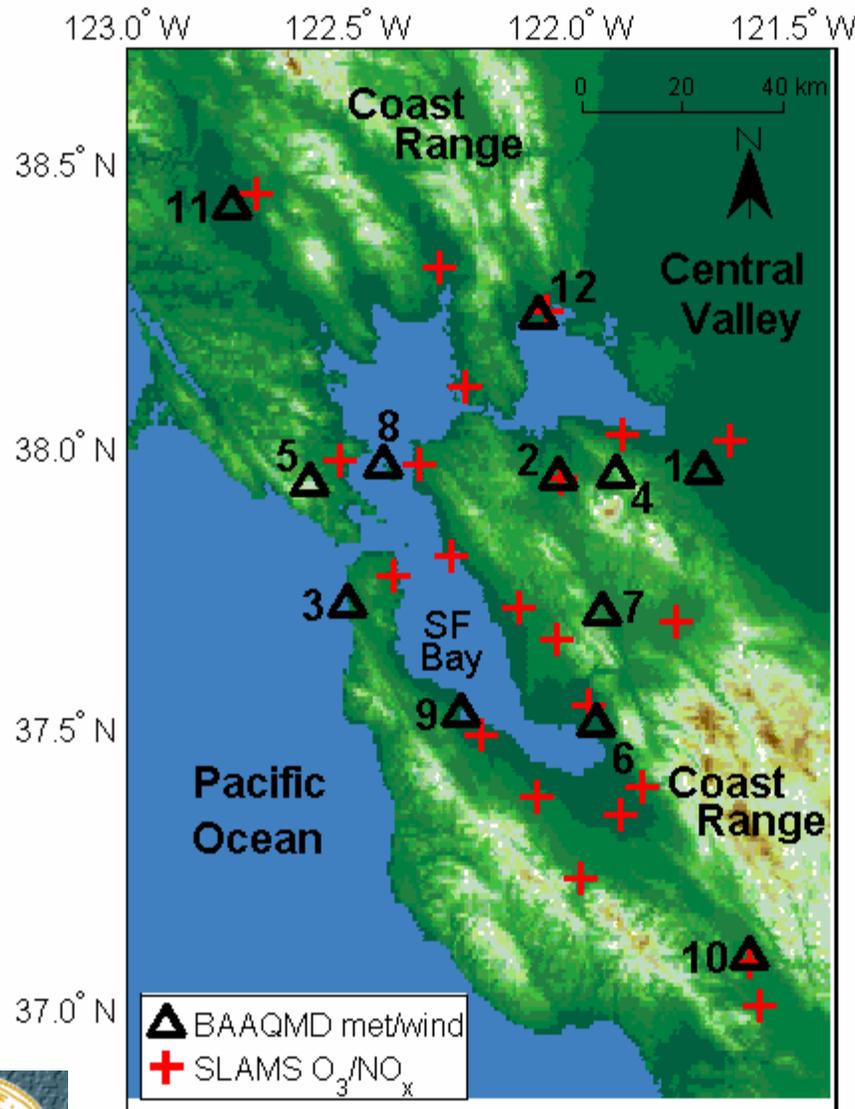


# Cluster Analysis for CCOS

- Scope of 2-year project
  - I. Intra-basin wind field cluster analyses
    - Requires continuous, hourly surface wind data
    - Days grouped by diurnal wind field patterns
    - Reveals synoptic and mesoscale flow regimes
  - II. Inter-basin analysis
- Study Domain
  - 6 CCOS air basins
    - San Francisco Bay Area
    - SJV: split into North, Central, & South
    - Sacramento Valley
    - Mountain Counties
  - 1996-2004 ozone seasons (1 May – 31 October)

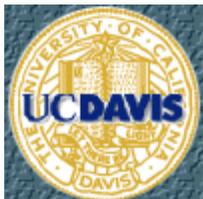


# San Francisco Bay Area

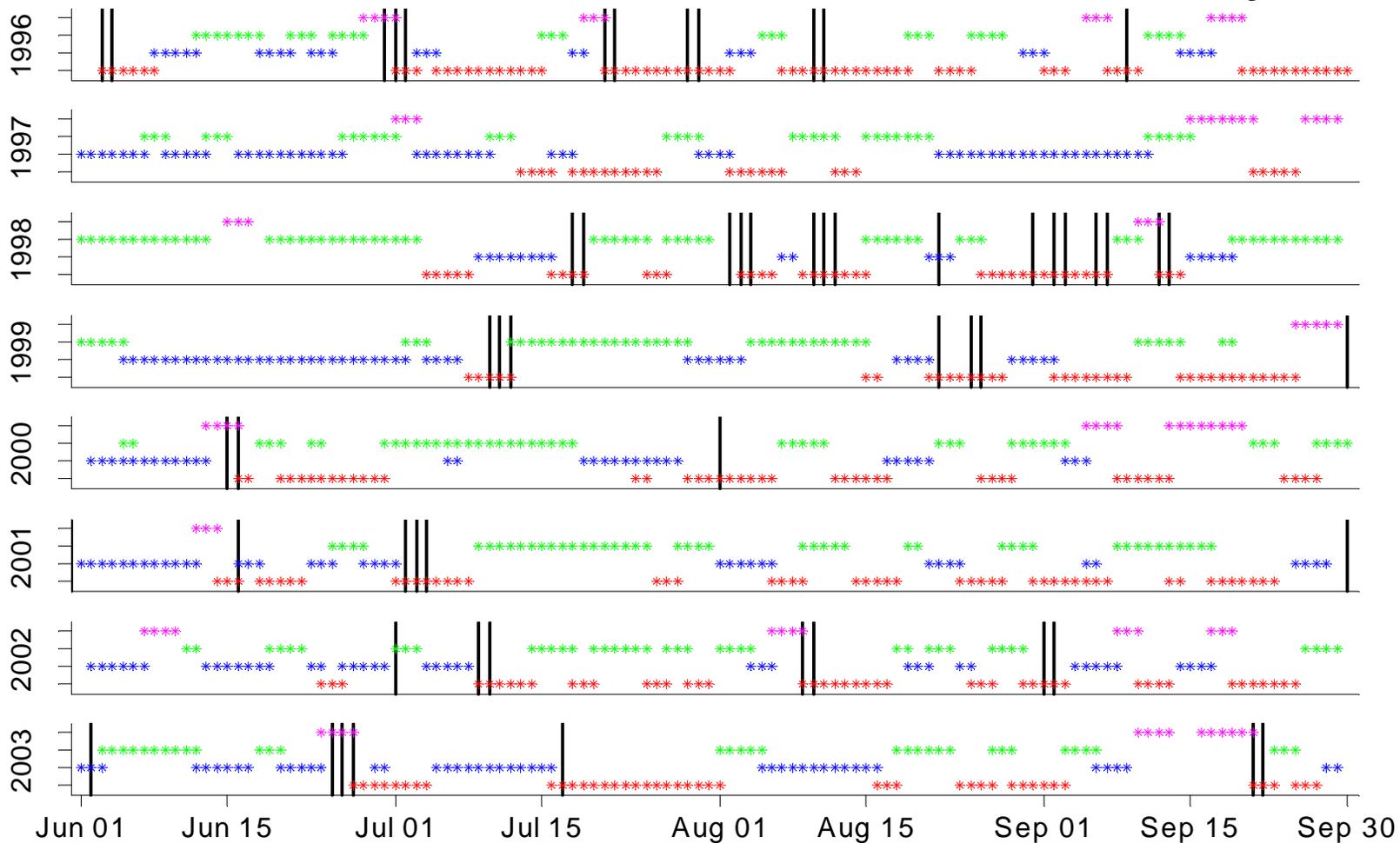


## Surface Wind Monitors

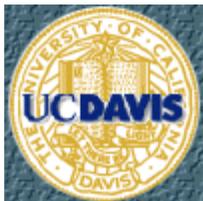
1	Bethel Island	-2 m
2	Concord	24 m
3	Fort Funston	57 m
4	Kregor Peak	577 m
5	Mt. Tamalpais	762 m
6	NUMMI	9 m
7	Pleasanton	99 m
8	Pt. San Pablo	70 m
9	San Carlos	1 m
10	San Martin	85 m
11	Santa Rosa	29 m
12	Suisun	5 m



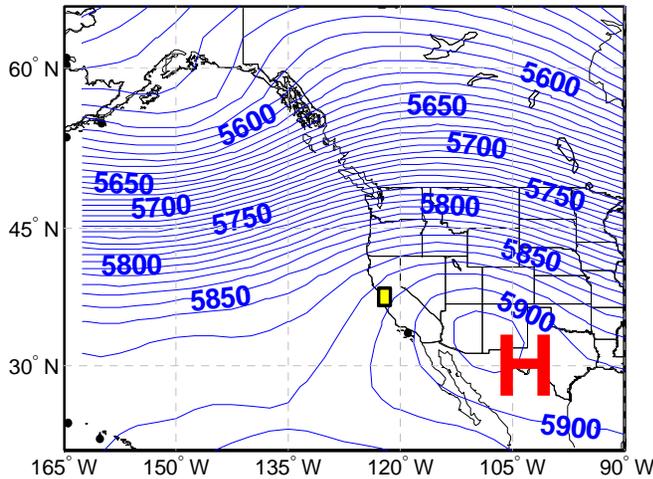
# SFBA: 4 clusters for 976 days



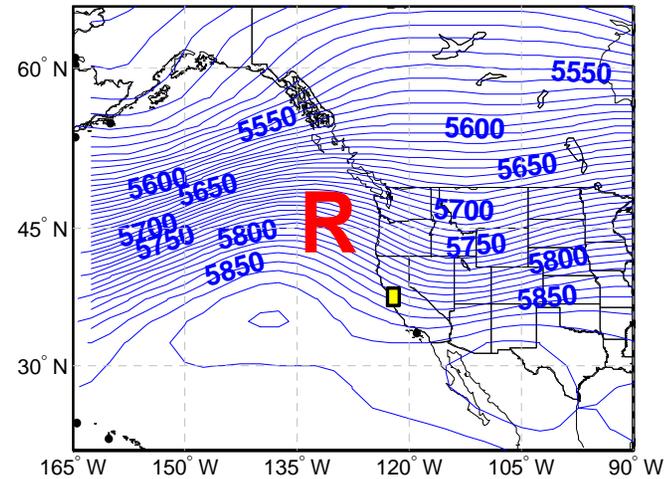
\*Beaver and Palazoglu, 2006: Cluster analysis of hourly wind measurements to reveal synoptic regimes affecting air quality. *Journal of Applied Meteorology and Climatology*, **45**, 1710—26.



# SFBA clusters = synoptic regimes



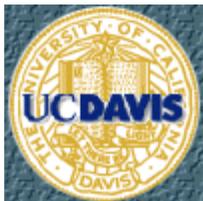
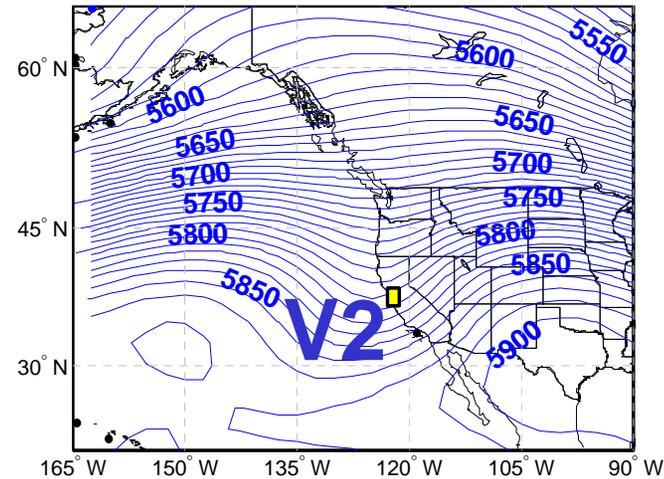
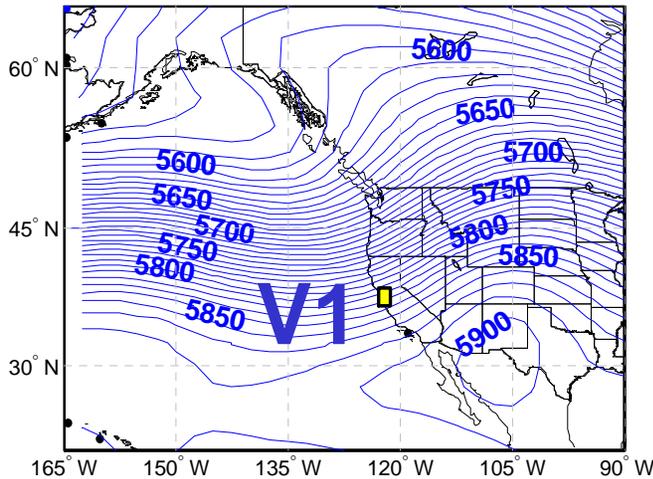
↑ Onshore High: 353 d, 13% episodes



↑ Offshore High: 86 d, 13% episodes

↓ Weaker Trough: 309 d, 0% episodes

↓ Deeper Trough: 309 d, 0% episodes



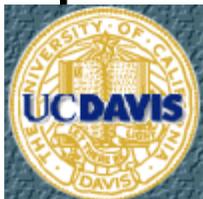
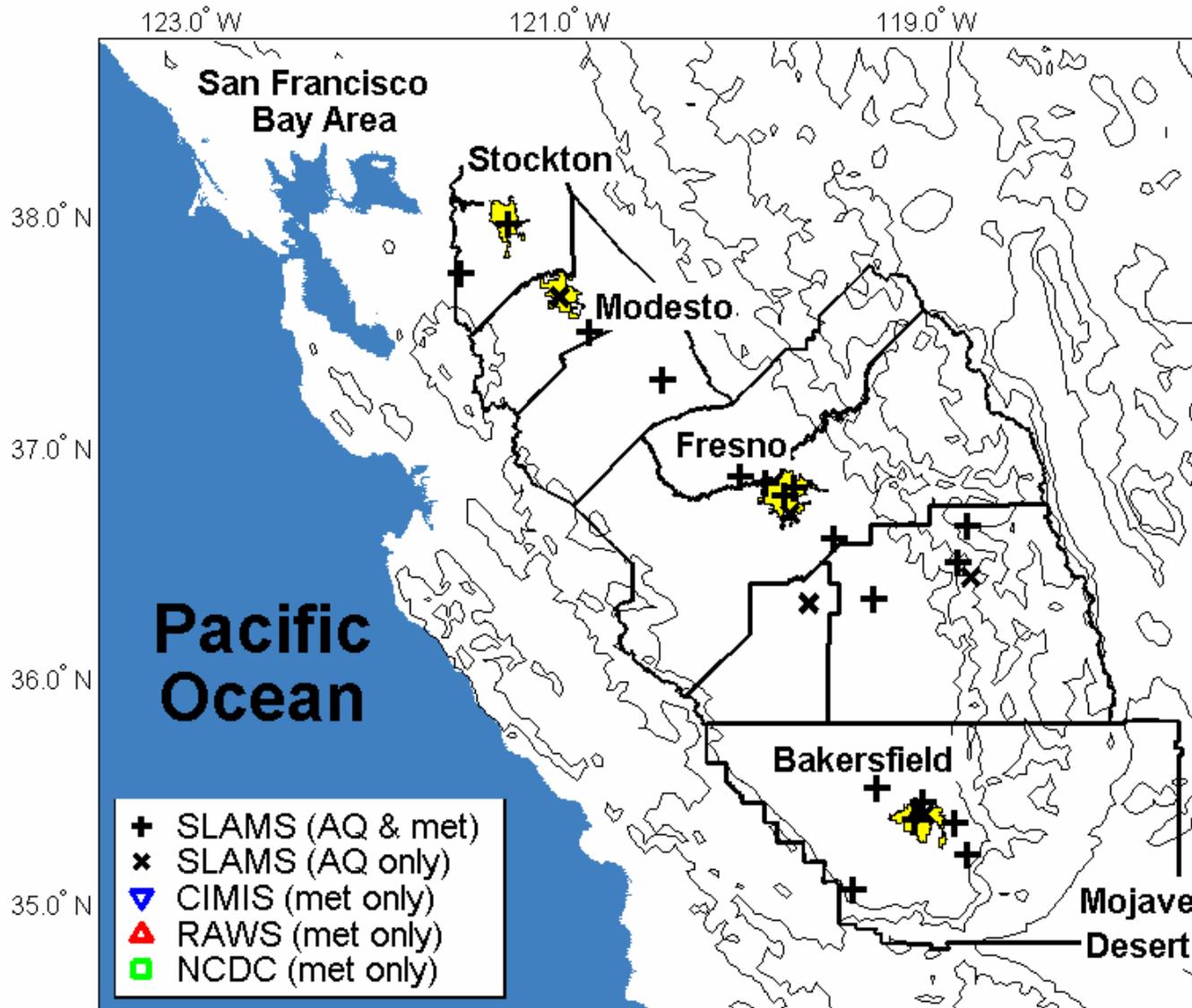
# Synoptic Transition Probabilities

- **R** transitions rapidly to **H**
  - Severe, multi-day episodes
  - Reverse **H**→**R** does not occur
  - Polar low may “save” SFBA from episode
- Persistence of **H** indicates stability
  - Displaced by sufficiently deep trough (e.g. **V2**)
  - Bulk of episodes during persistent **H**
- Transitions from **V1** & **V2** driven by global met.
  - Troughs may persist for long periods; low O<sub>3</sub> levels
  - Transition to **H** or **R** will occur unless O<sub>3</sub> season ends

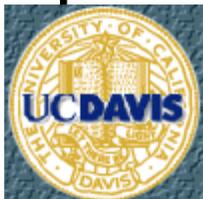
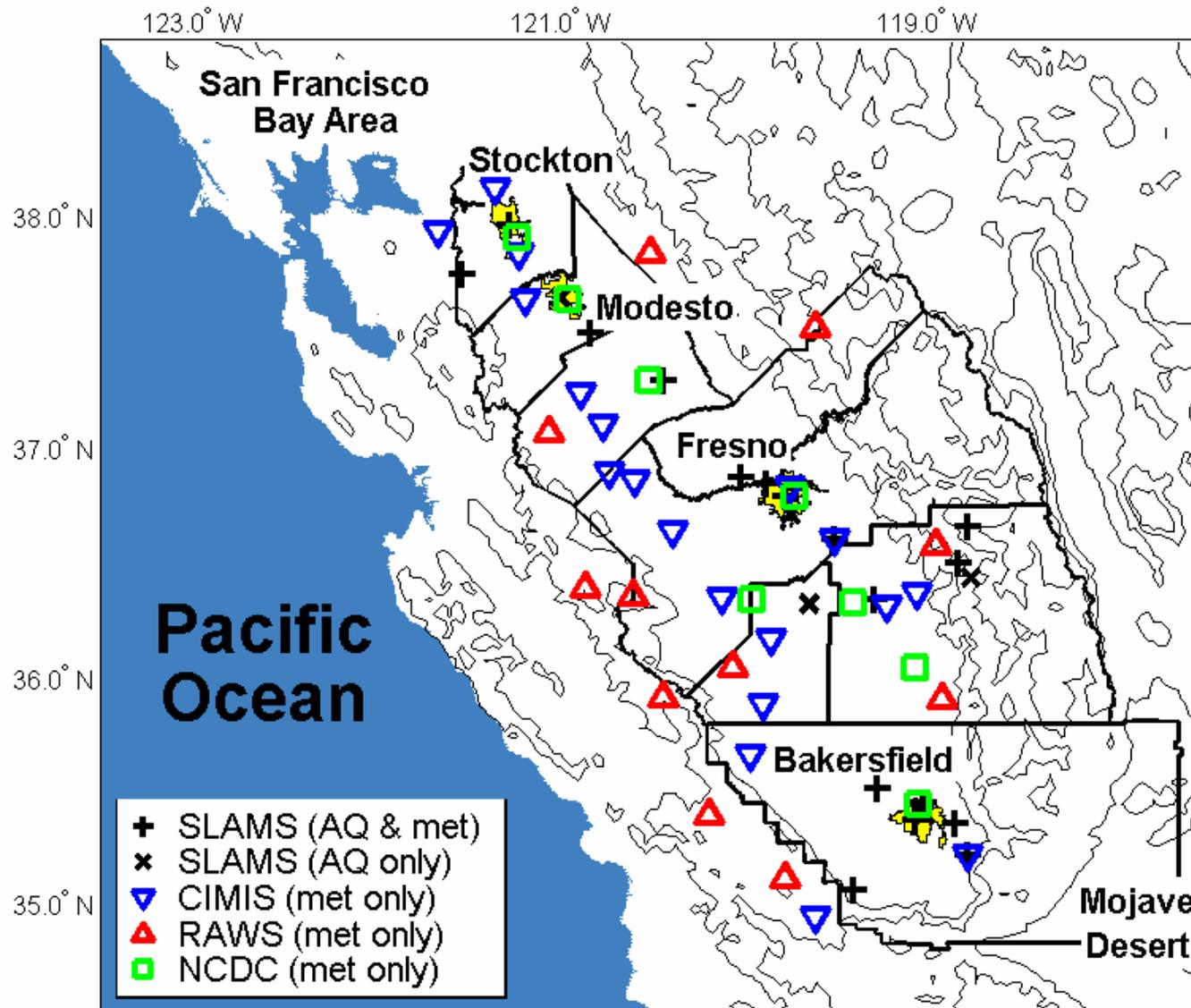
\*Beaver, Palazoglu and Tanrikulu, 2007: Cluster sequencing to analyze synoptic transitions affecting regional ozone. *Journal of Applied Meteorology and Climatology*, in press.



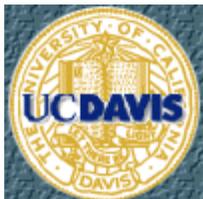
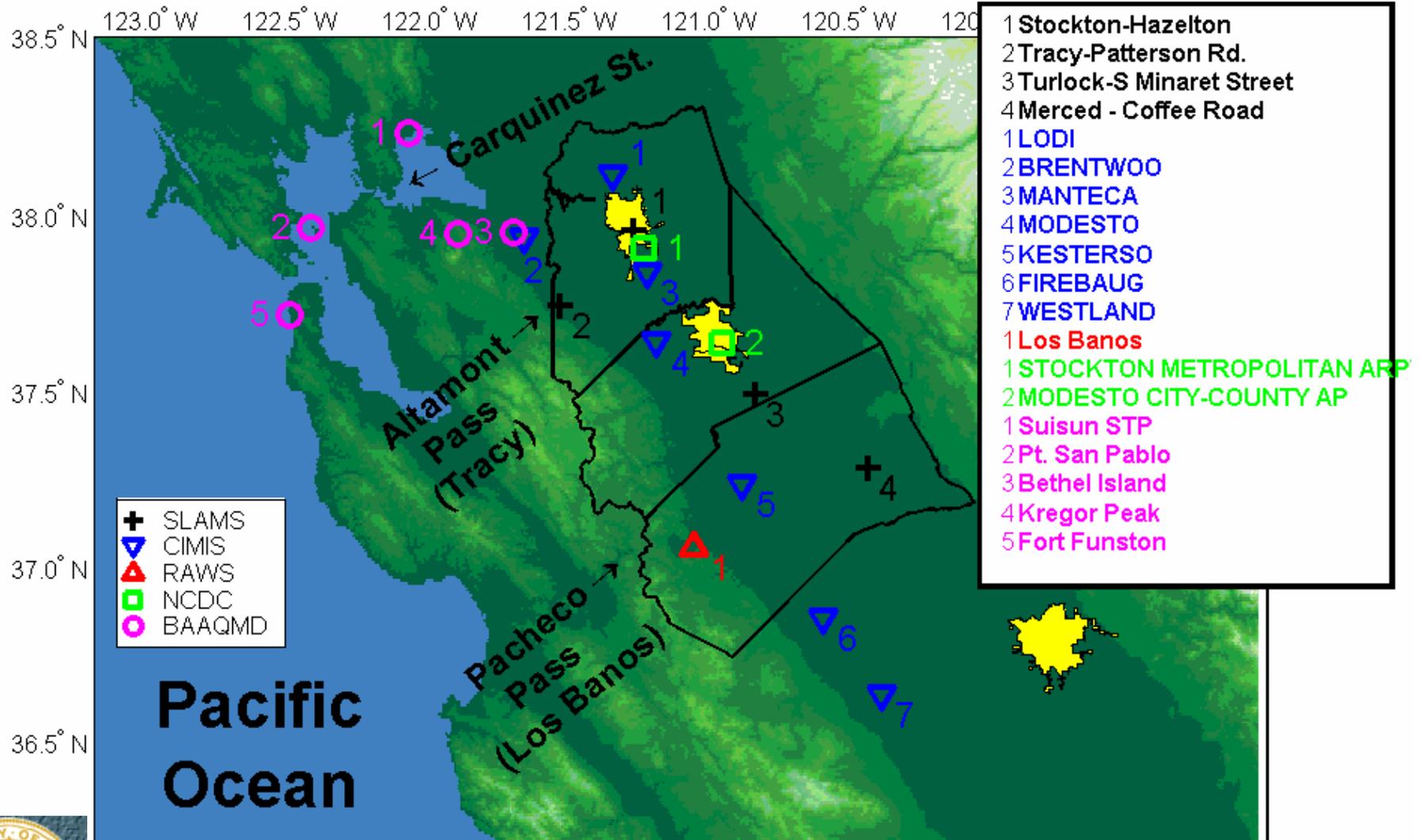
# SJV SLAMS network



# SLAMS, CIMIS, RAWS & NCDC

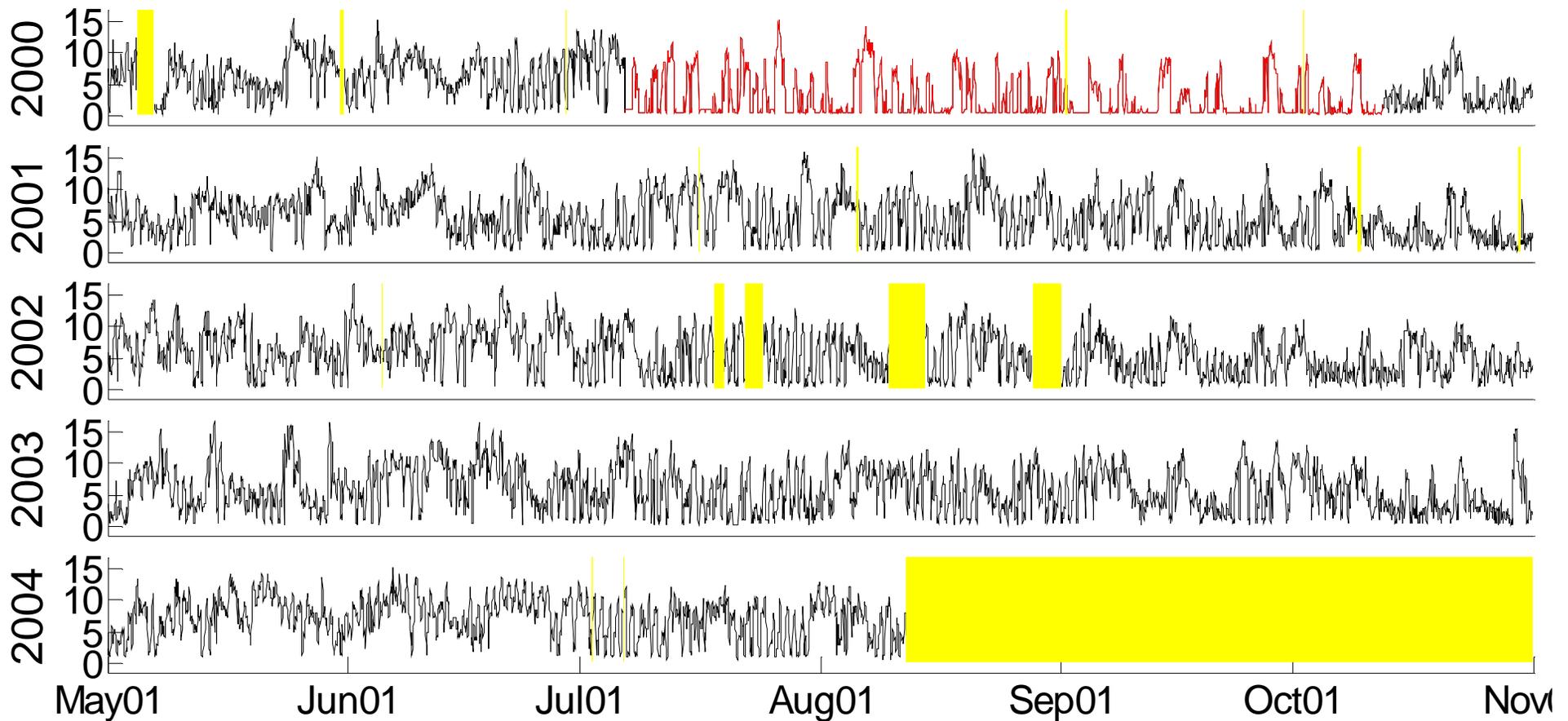


# North SJV Wind Monitors

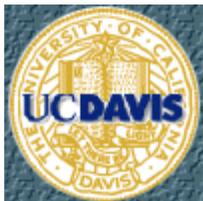


# Wind Speed Errors at Tracy

Tracy-Patterson Rd. -- Wind Speed

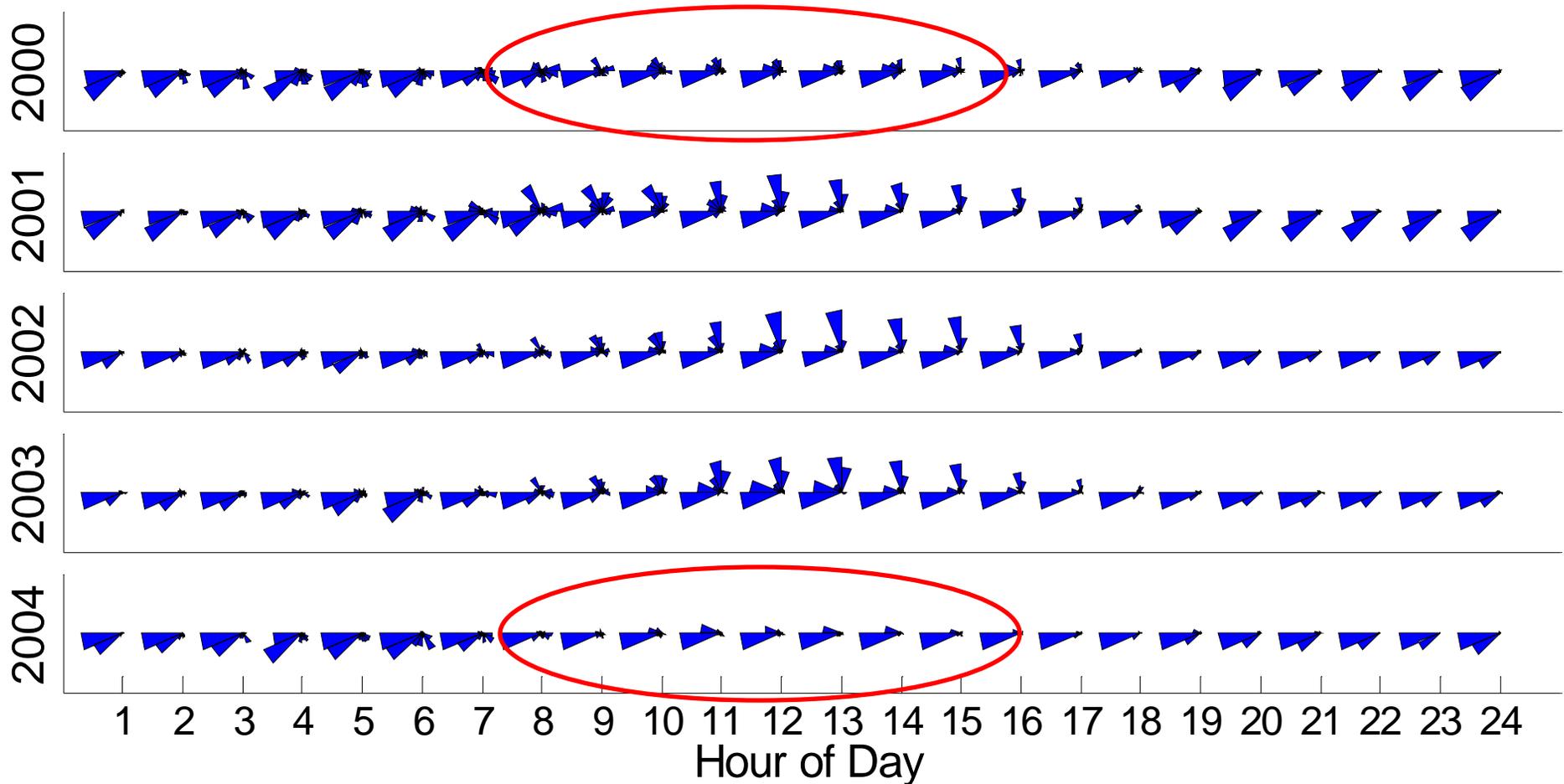


1996—1999 are similar to 2001—2004.

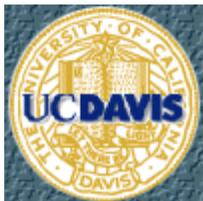


# Wind Direction Errors at Tracy

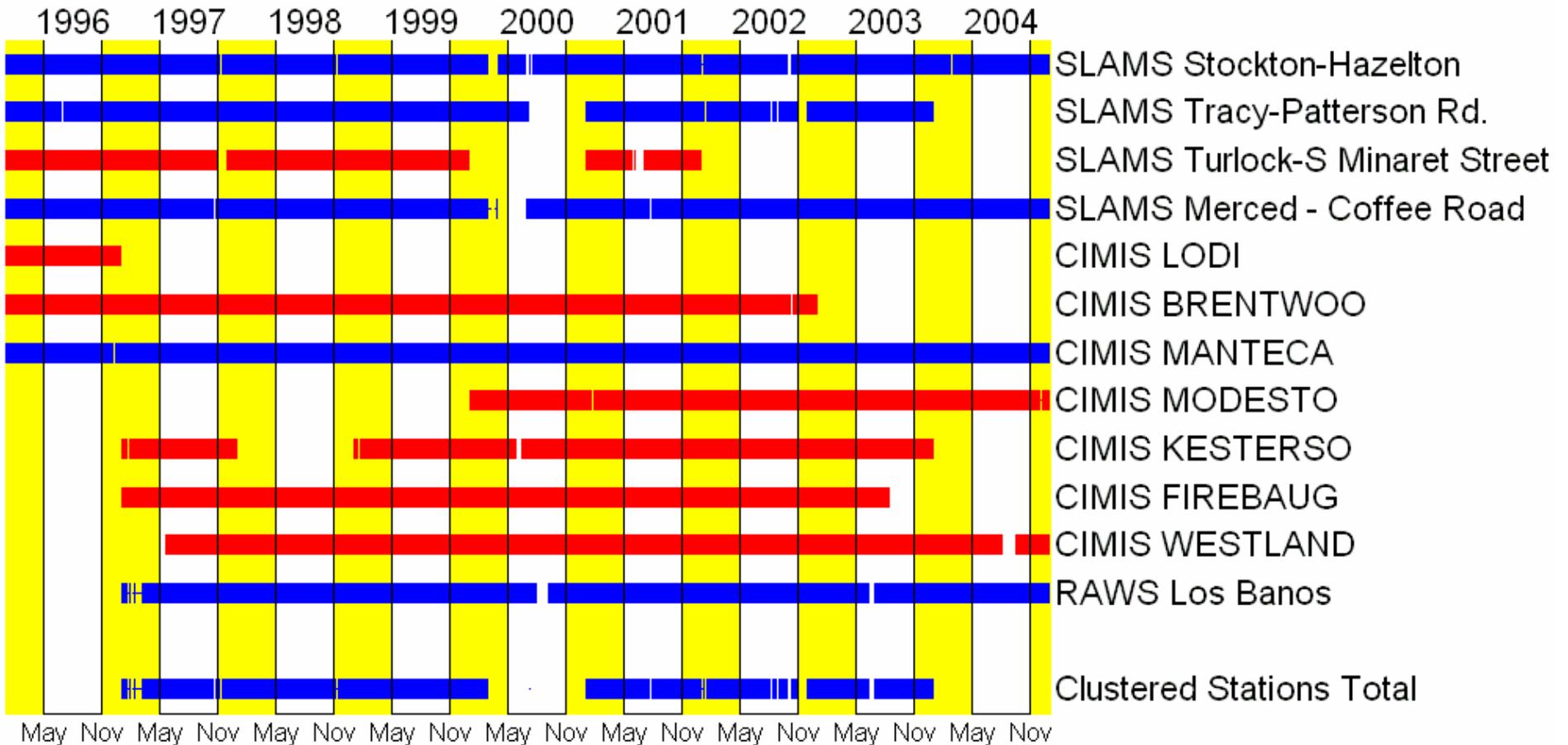
Tracy-Patterson Rd. -- Wind Direction Hourly Distribution



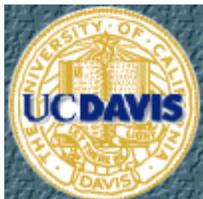
1996—1999 are similar to 2001—2003.

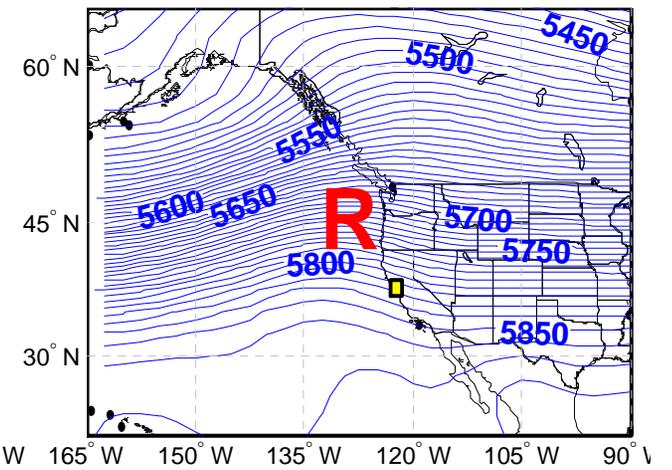
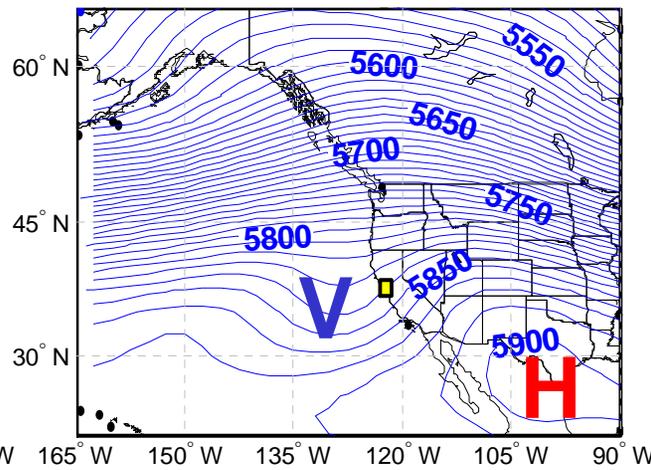
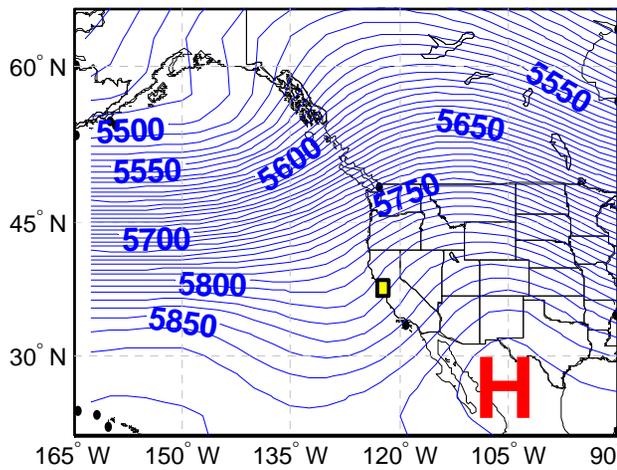


# Gantt chart for N-SJV



Yellow = 1 Nov—30 Apr winter data (not clustered)  
 Blue = clustered stations (included in Total)  
 Red = non-clustered stations (excluded from Total)





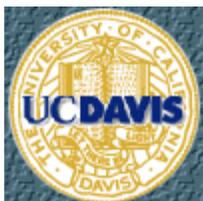
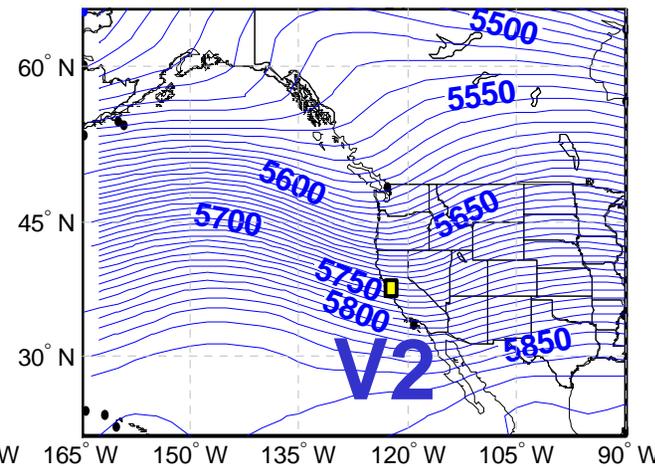
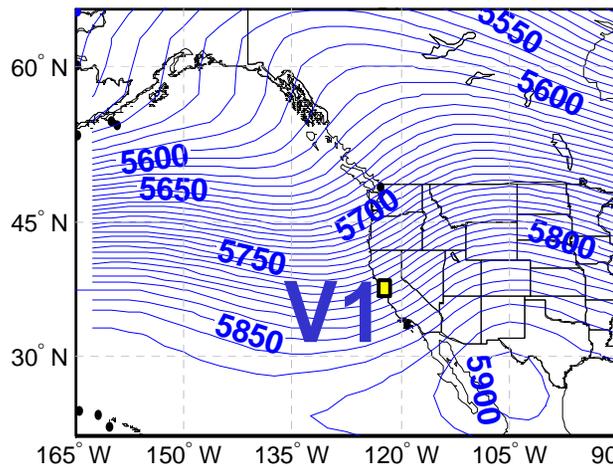
H: 179 days, 42%

H/V: 212 days, 25%

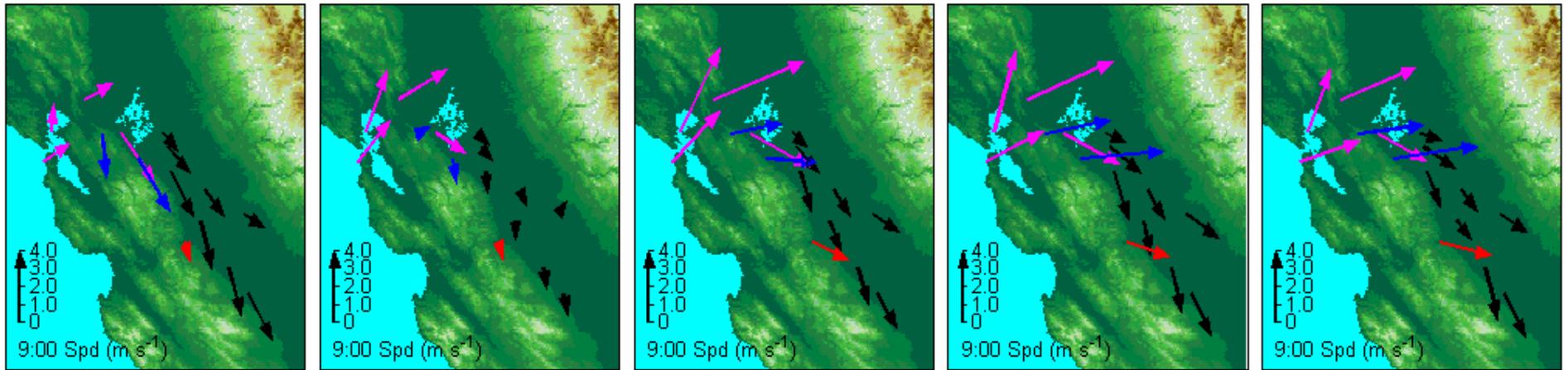
R: 264 days, 19%

V1: 299 days, 12%

V2: 108 days, 6%



# N-SJV 0900 PST Wind Field



**R**

**H**

**H/V**

**V1**

**V2**

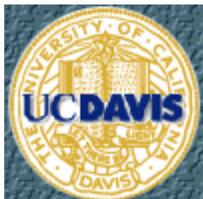
Increasing marine ventilation: **R** < **H** < **H/V** < **V1** < **V2**

Magenta: Carquinez Strait— Ft. Funston, Pt. San Pablo,  
Suisun, Bethel Is.

Blue: Altamont Pass— Kregor Peak, Tracy

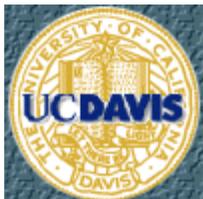
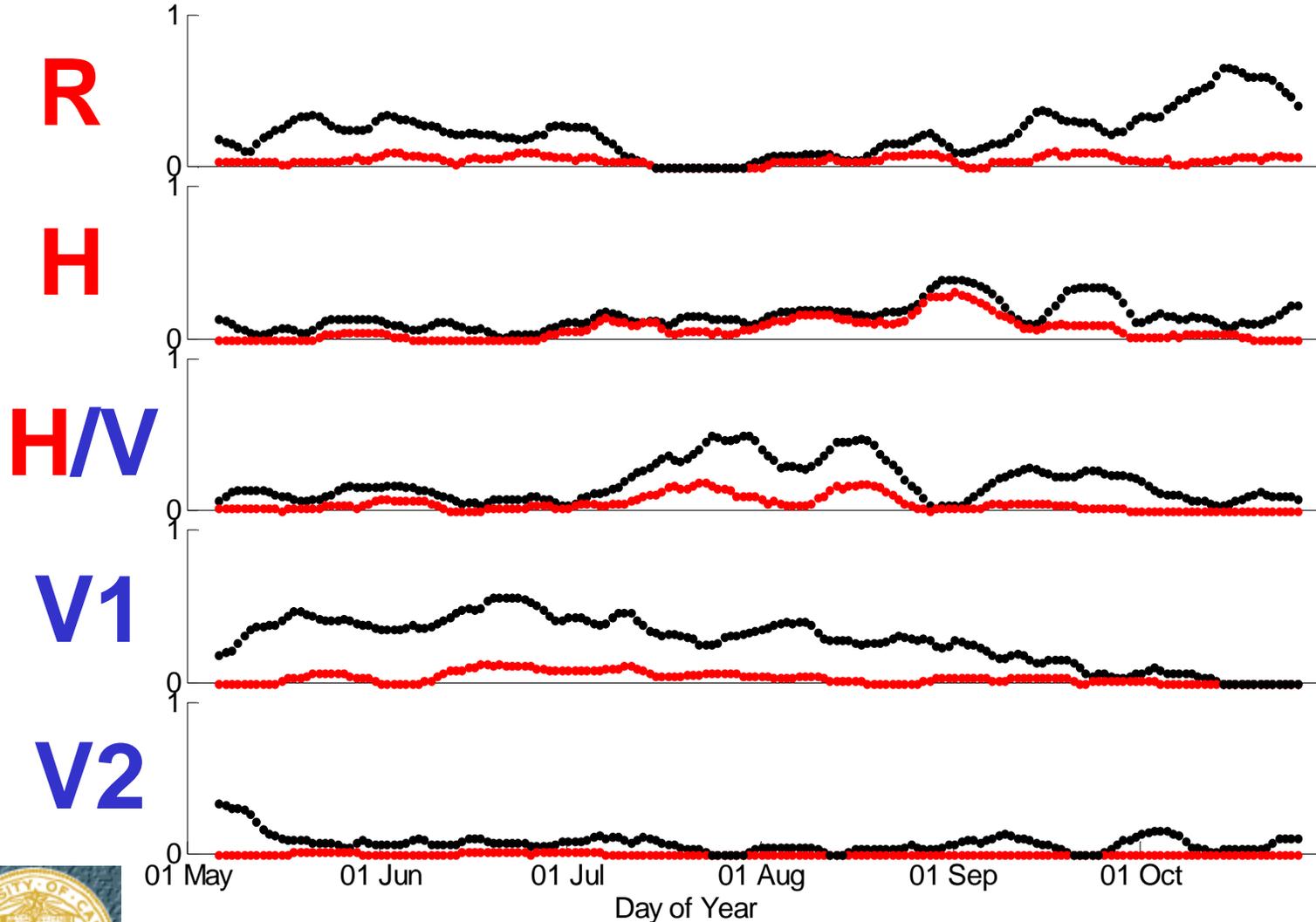
Red: Pacheco Pass— Los Banos

Black: SJV floor



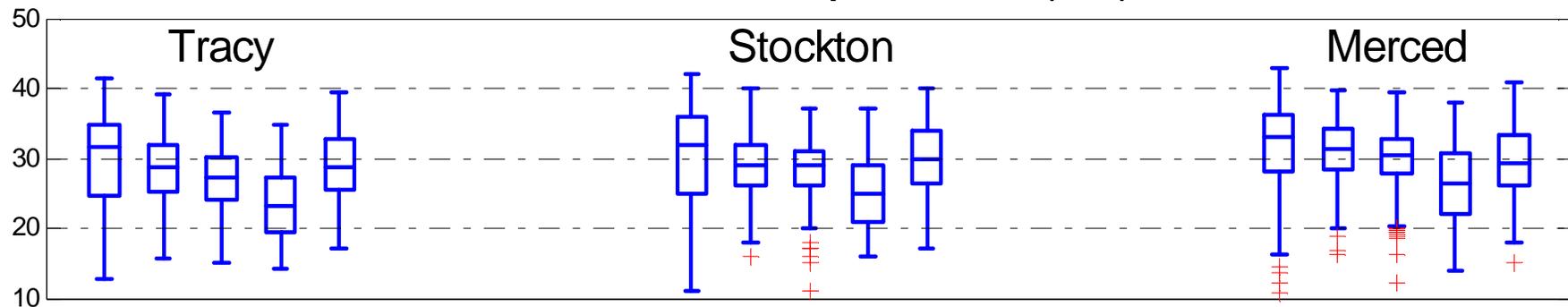
# N-SJV Seasonal Distribution

Black: Probability a Cluster is Realized Within 5 Days of Any Day of Year  
Red: Probability a Cluster is Realized as Exceedance Within 5 Days of Any Day of Year



# N-SJV Ventilation

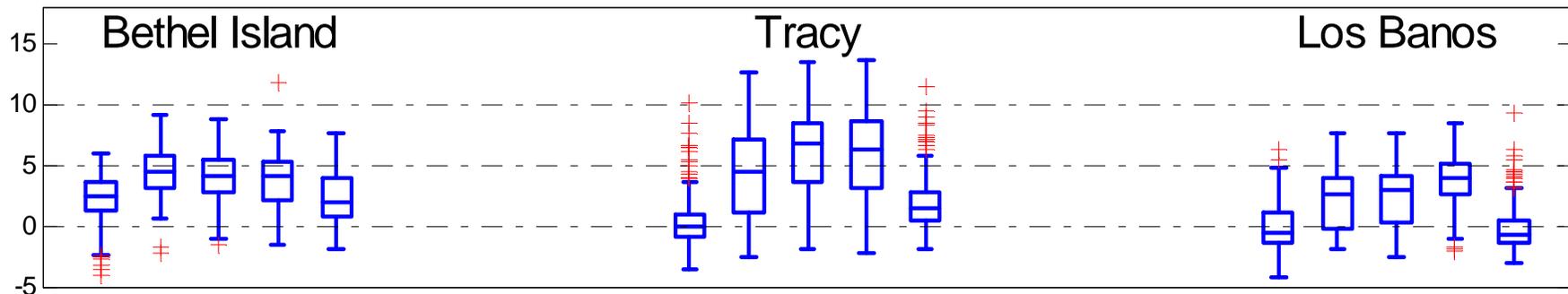
1500 PST Temperature ( $^{\circ}\text{C}$ )



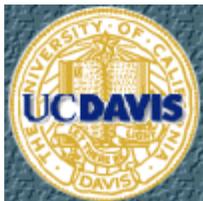
H H/V V1 V2 R

H H/V V1 V2 R

H H/V V1 V2 R

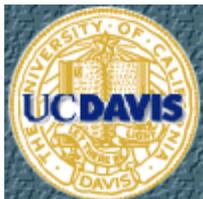
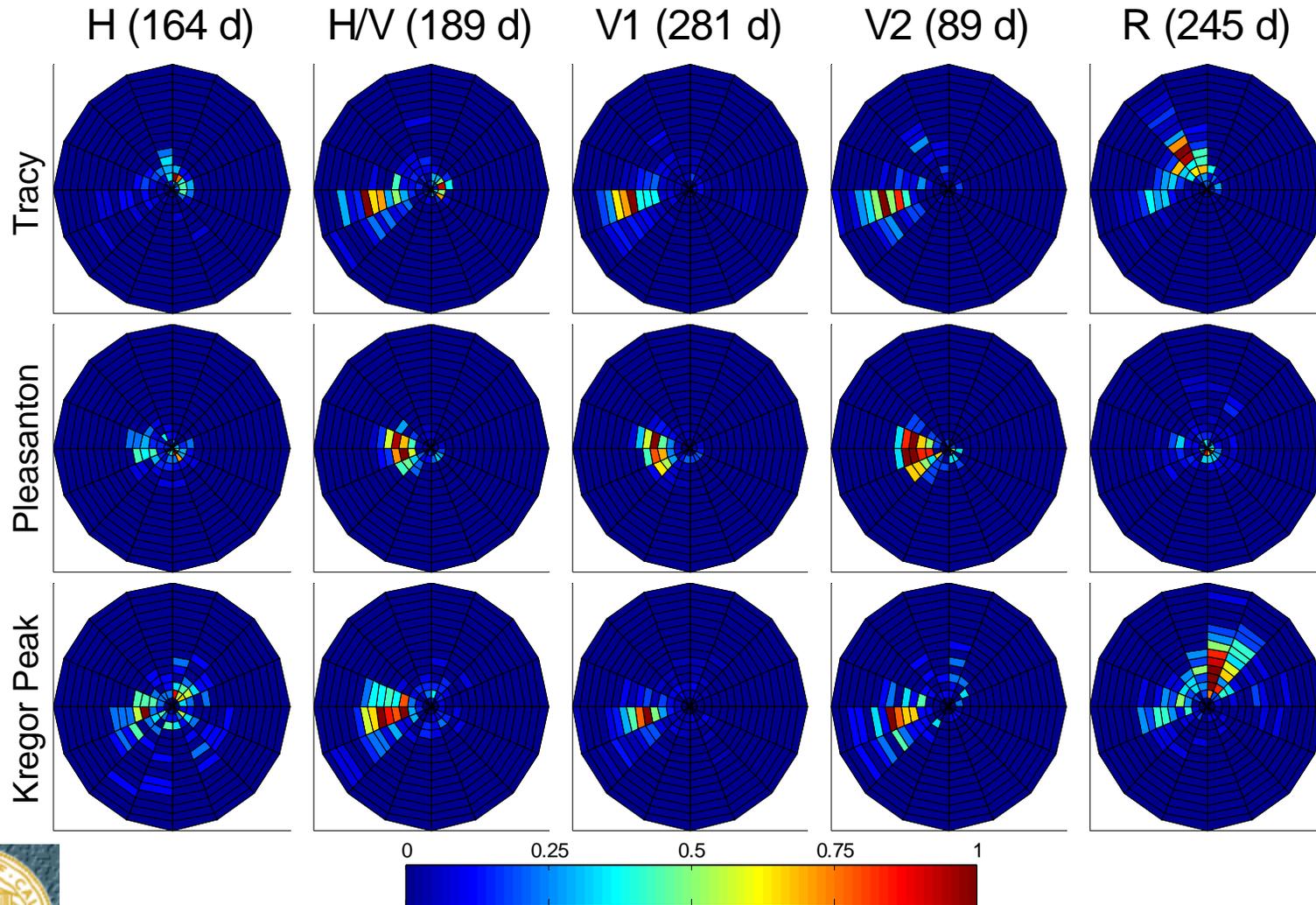


1000 PST Westerly Speed (m/s)



# Altamont Pass Wind Distribution

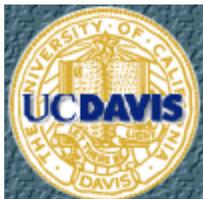
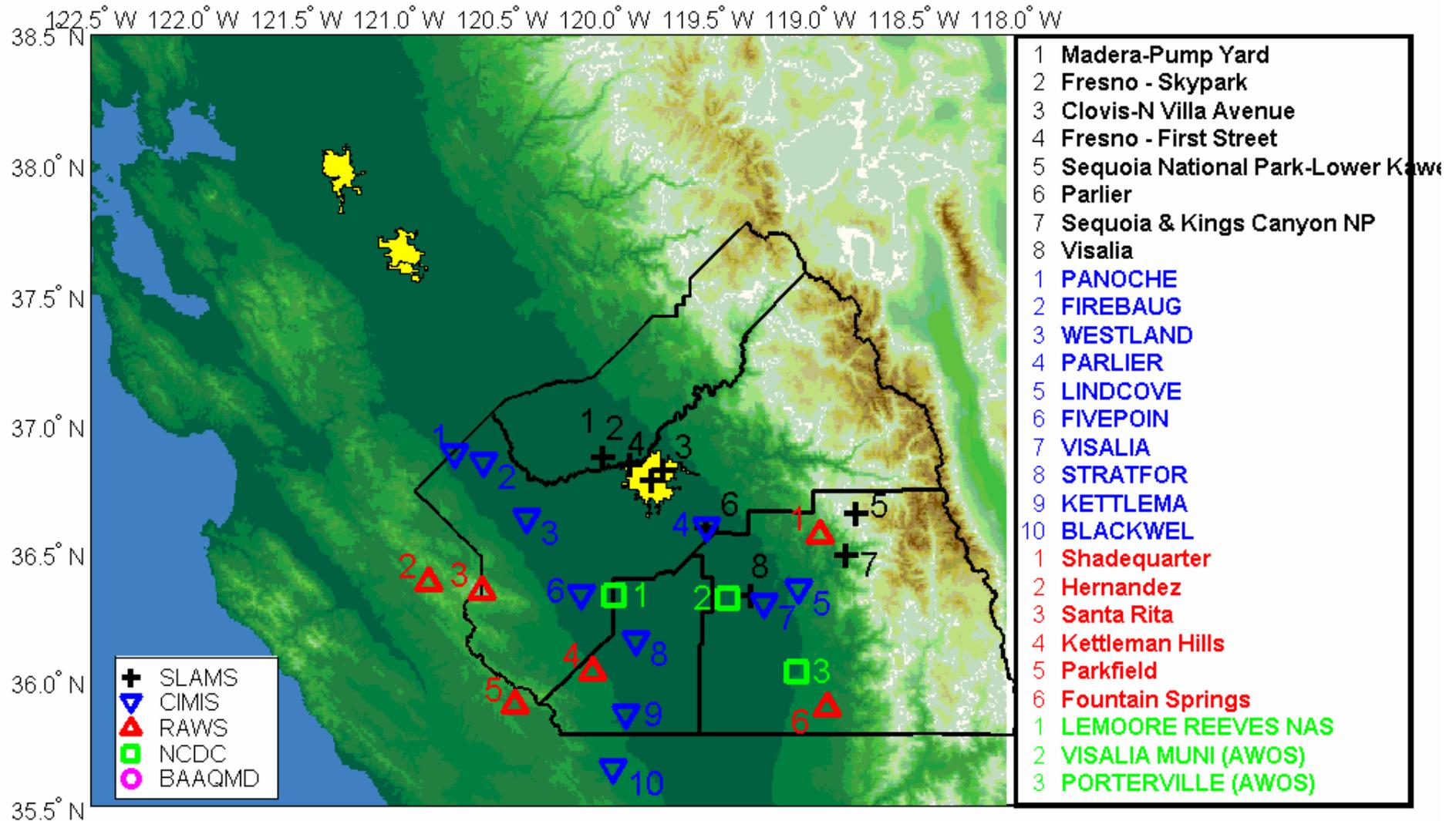
0800PST Wind Distribution



# N-SJV Synoptic Sequencing

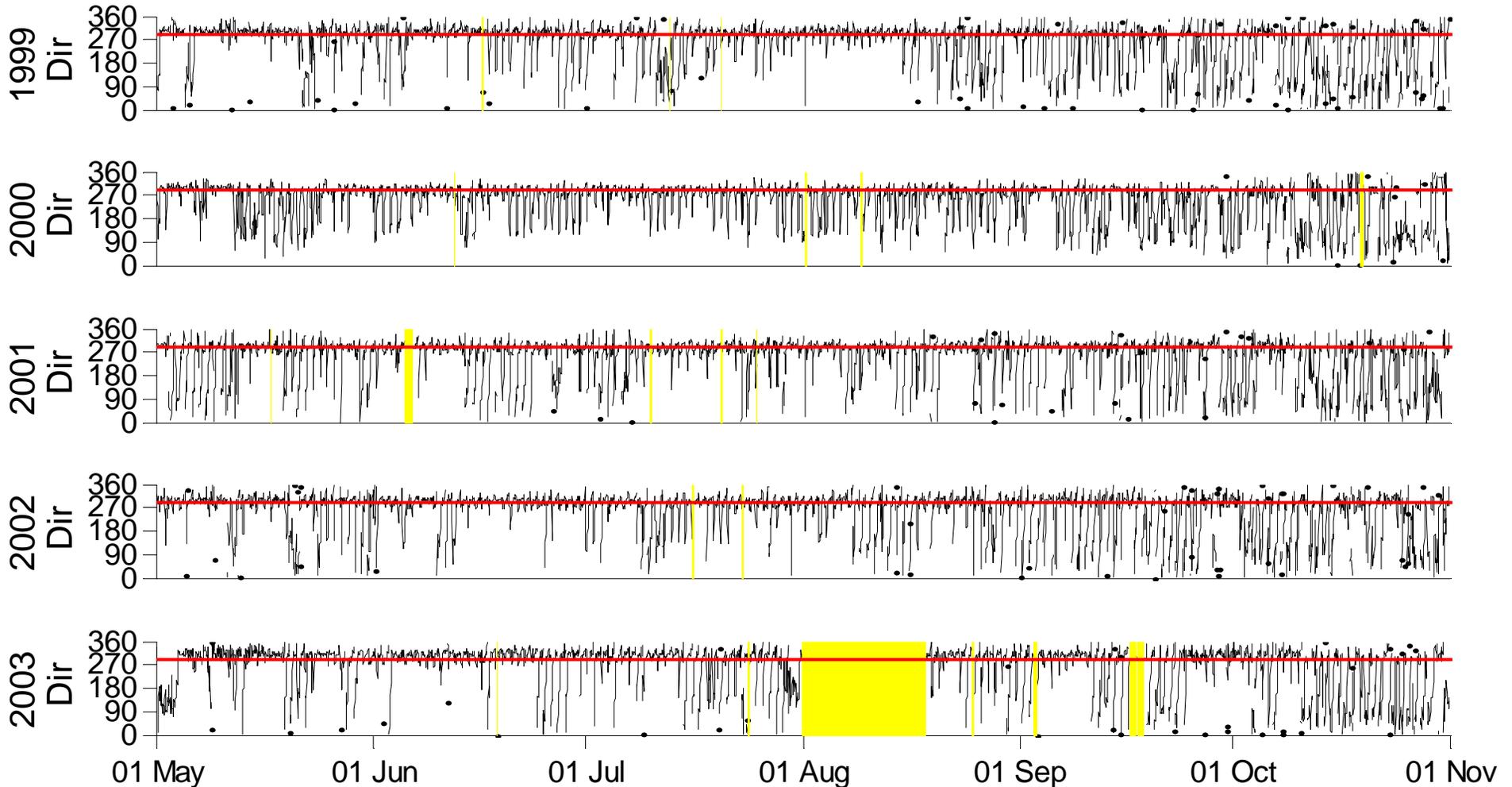
- $\alpha = 0.05$ 
  - $R \leftrightarrow H/V$  disfavored
  - Clusters occur in different seasons (trivial result)
- $\alpha = 0.15$ 
  - $R \rightarrow H$  favored
  - $H \rightarrow H/V$  favored
  - $H/V \rightarrow V$  favored
  - $V \rightarrow R$  favored
- Compare to Bay Area
  - Transitions significant at  $\alpha < 0.02$
  - Stronger synoptic influence than N-SJV

# Central SJV Wind Monitors

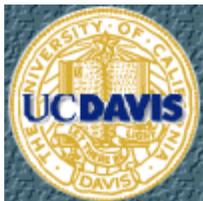


# Annual Biases in Wind Direction

Clovis-N Villa Wind Direction

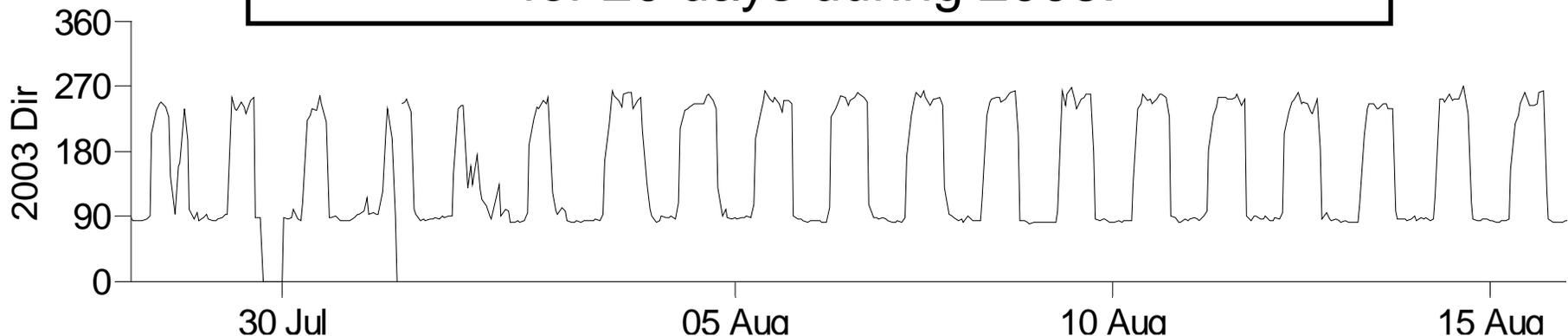


2000—02 are  $\sim 15^\circ$  more westerly than other years.



# Upslope/Downslope Cycle

Wind direction at SLAMS Sequoia monitor  
for 20 days during 2003.

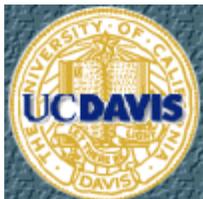


Flow switches from easterly to westerly.

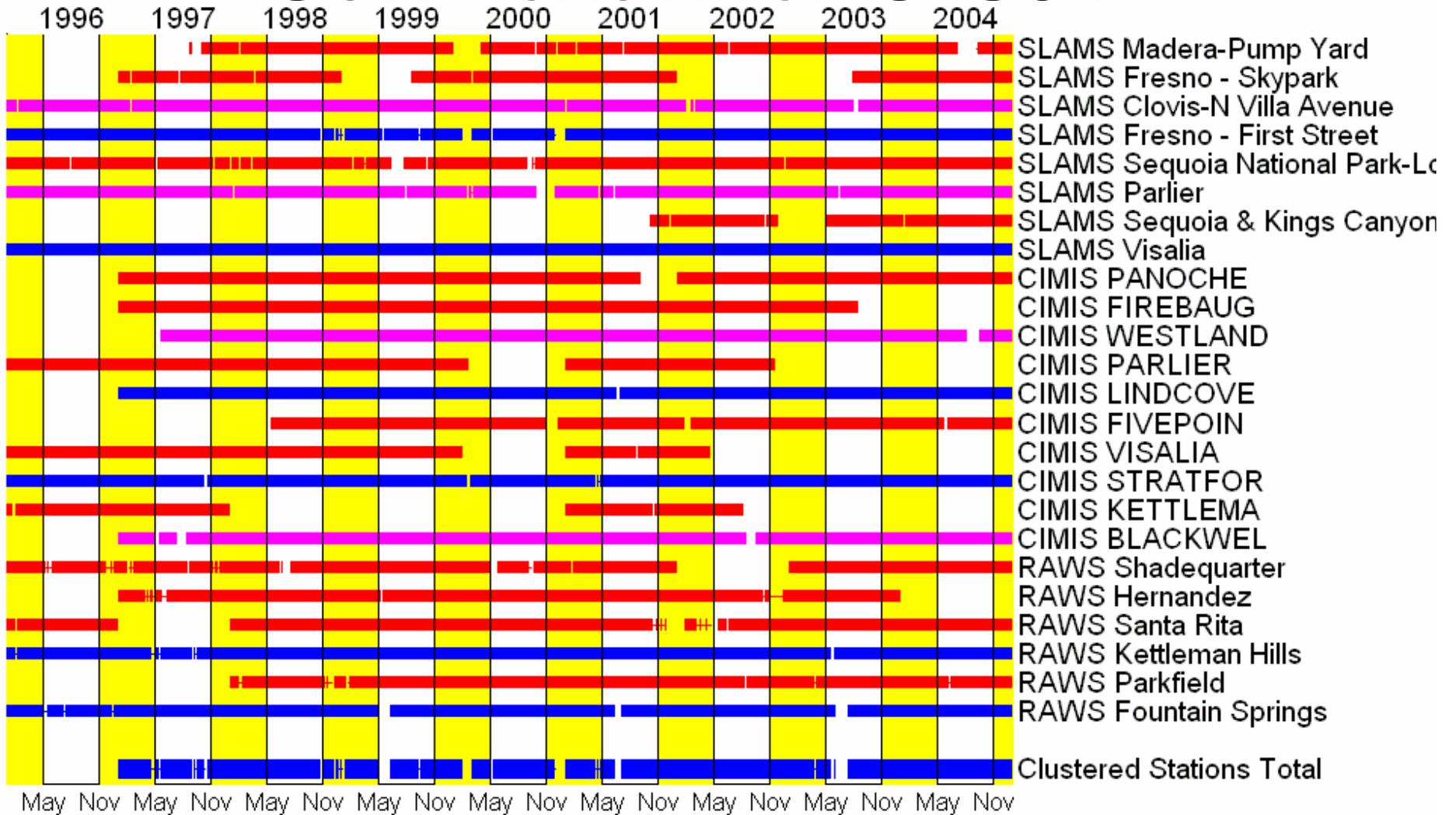
Daytime upslope flows; nighttime drainage flows

Diurnal cycle largely captures local effects.

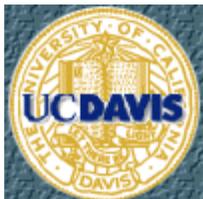
Signal is not well modeled by clustering algorithm.

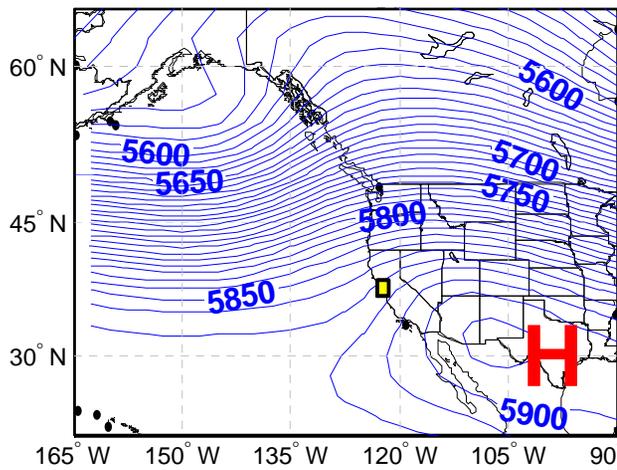


# Gantt chart for C-SJV

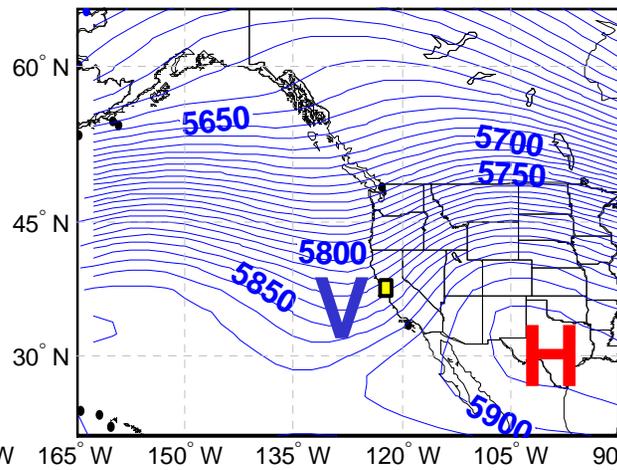


Magenta: stations with annual biases

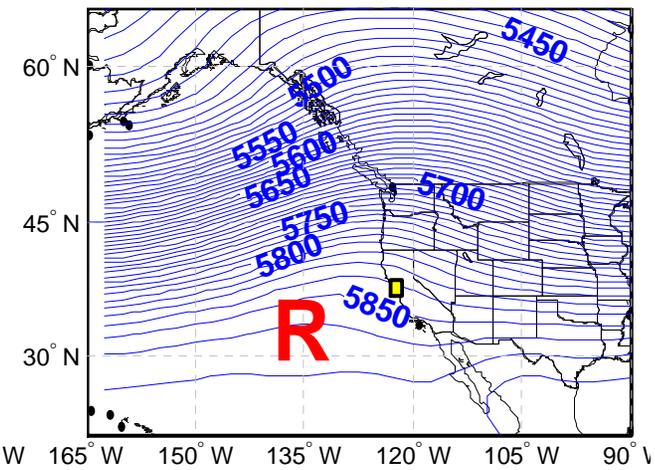




H: 203 days



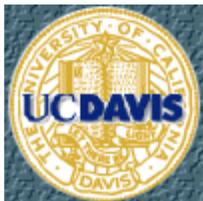
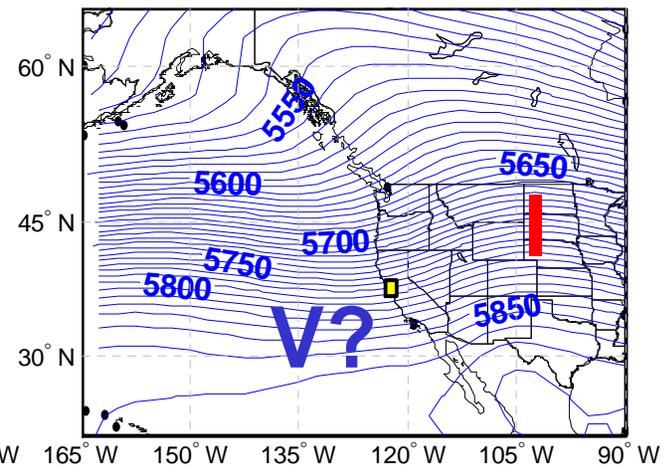
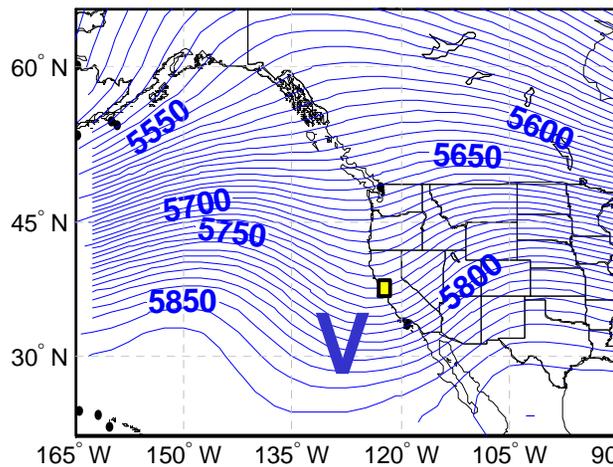
H/V: 169 days



R: 341 days

V: 279 days

V/I: 378 days



# C-SJV 8-hr O<sub>3</sub> Exceedances

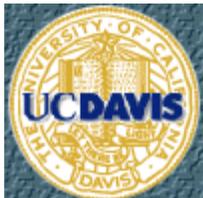
Percentage of days in each cluster that are 8-hr O<sub>3</sub> exceedances

V      V/I      H/V      H      R

	279 d	378 d	169 d	203 d	341 d
Total	40%	32%	64%	92%	59%
SJV floor	29%	17%	34%	84%	52%
Parlier	20%	15%	28%	73%	43%
Clovis	18%	6%	12%	62%	33%
Sequoia	25%	25%	57%	64%	33%
SJV floor & Sequoia	14%	10%	27%	56%	26%

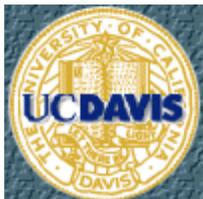
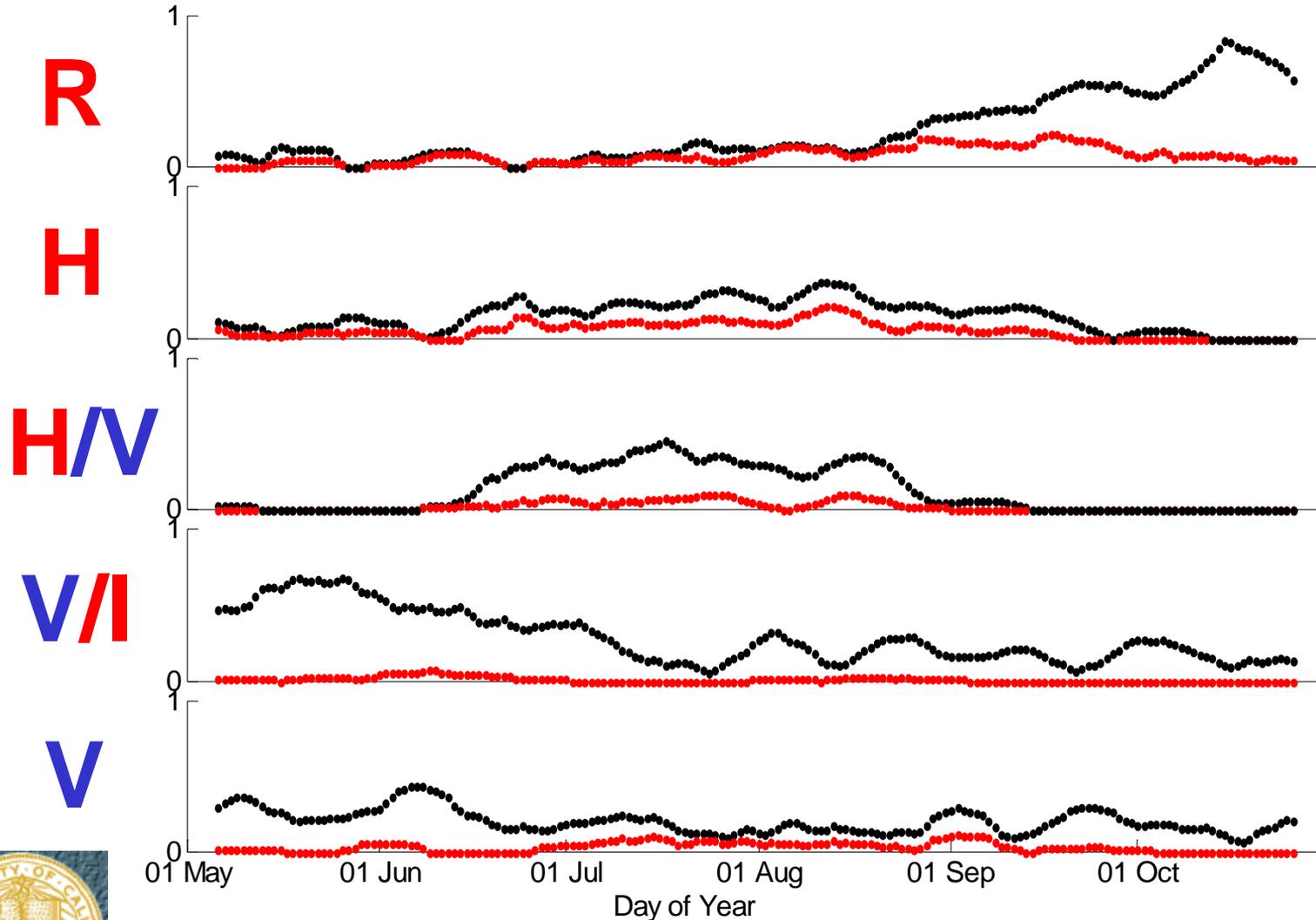
Ventilated regime episodes favor Sequoia.

Anti-cyclonic regime episodes favor SJV floor.



# C-SJV Seasonal Distribution

Black: Probability a Cluster is Realized Within 5 Days of Any Day of Year  
Red: Probability a Cluster is Realized as Exceedance Within 5 Days of Any Day of Year

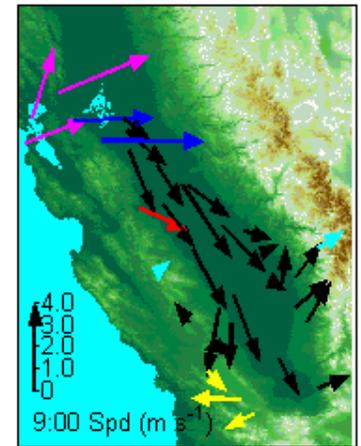
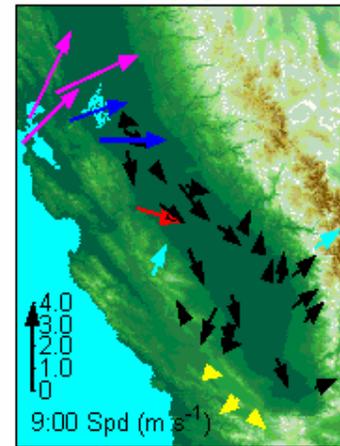
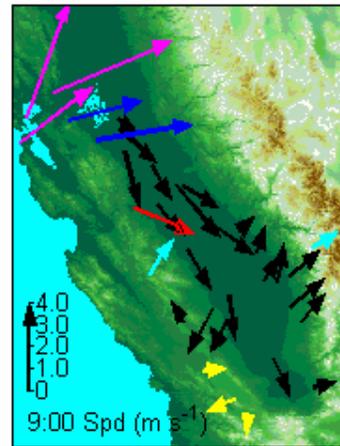
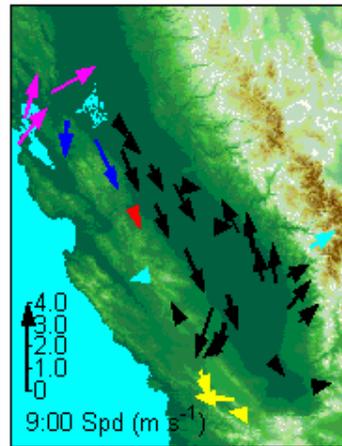
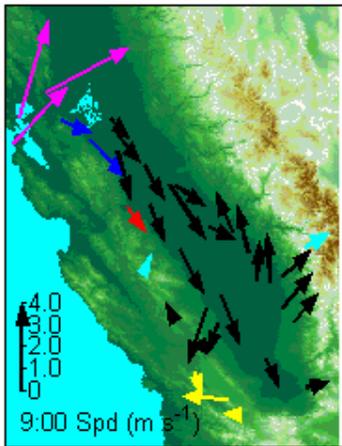


# C-SJV Synoptic Sequencing

- Direct transitions between **H**, **R**, and **V** occur infrequently
- **H/V** and **V/I** are “intermediate” states
  - C-SJV is buffered from synoptic effects
  - Synoptic transitions have less effect on  $O_3$  levels than for N-SJV (than for Bay Area)
- Mesoscale effects important for C-SJV



# The Fresno Eddy



**H**

**R**

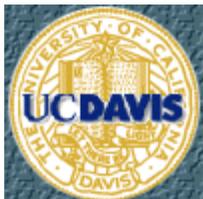
**H/V**

**V**

**V/I**

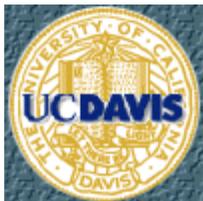
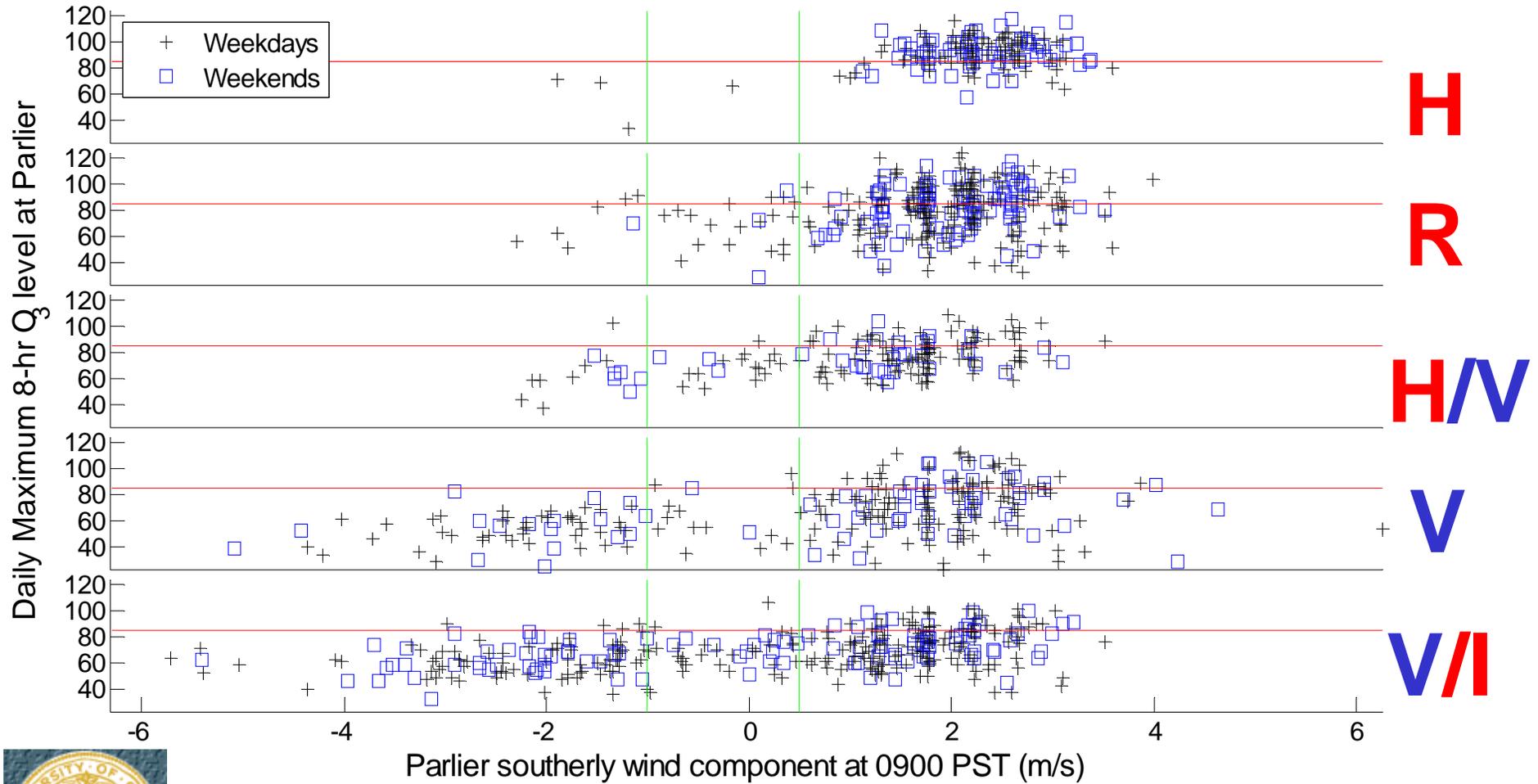
Decreasing eddy strength:  $H > R > H/V > V > V/I$

Magenta: Carquinez Strait— Ft. Funston, Pt. San Pablo, Suisun  
Blue: Altamont Pass— Kregor Peak, Tracy  
Red: Pacheco Pass— Los Banos  
Cyan: Parkfield (west) & Sequoia (east)  
Yellow: Carrizo Plain



# Eddy Strength and O<sub>3</sub> Levels

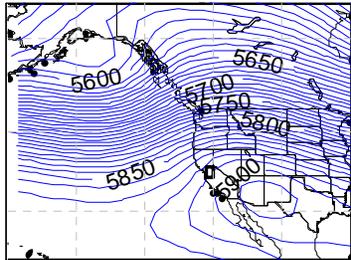
← No/weak eddy      ?      Strong eddy →



# Eddy Strength & Marine Ventilation

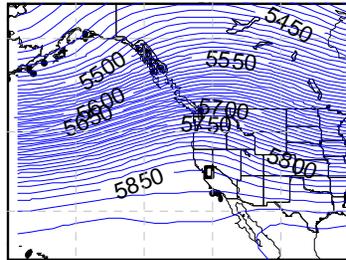
**H**

Eddy (193 d)



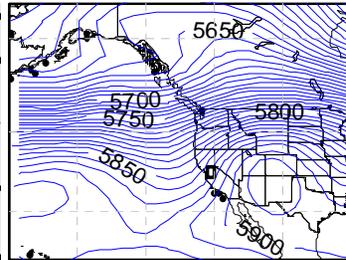
**R**

Eddy (296 d)



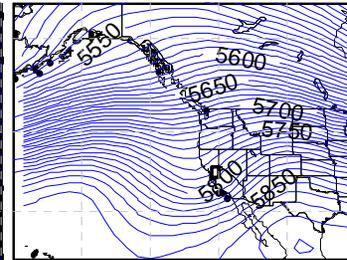
**H/V**

Eddy (133 d)



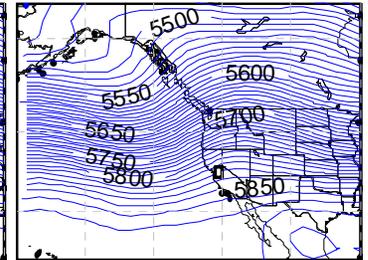
**V**

Eddy (188 d)

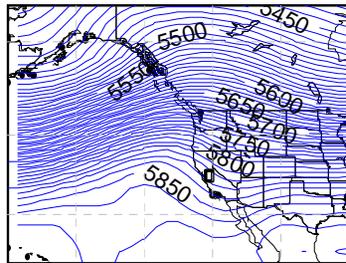


**V/I**

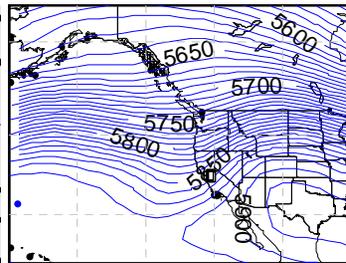
Eddy (207 d)



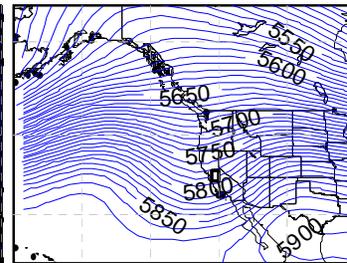
Stagnant (21 d)



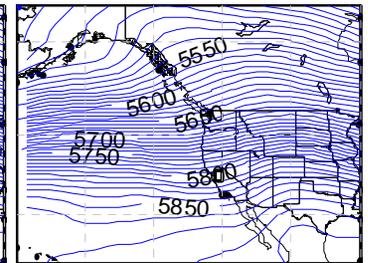
Stagnant (19 d)



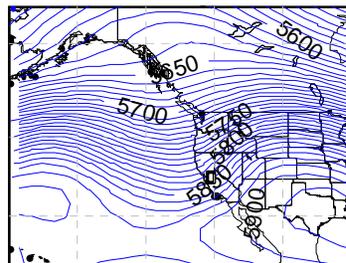
Stagnant (15 d)



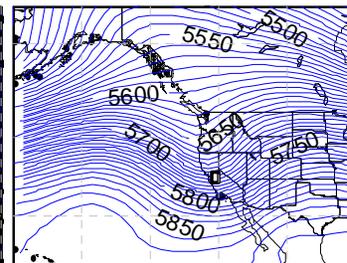
Stagnant (43 d)



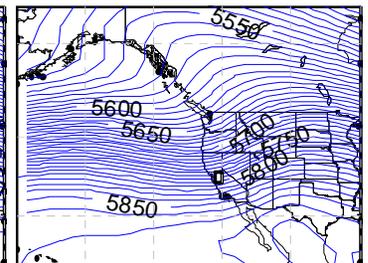
No eddy (14 d)



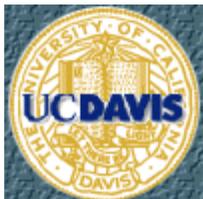
No eddy (60 d)



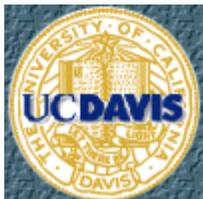
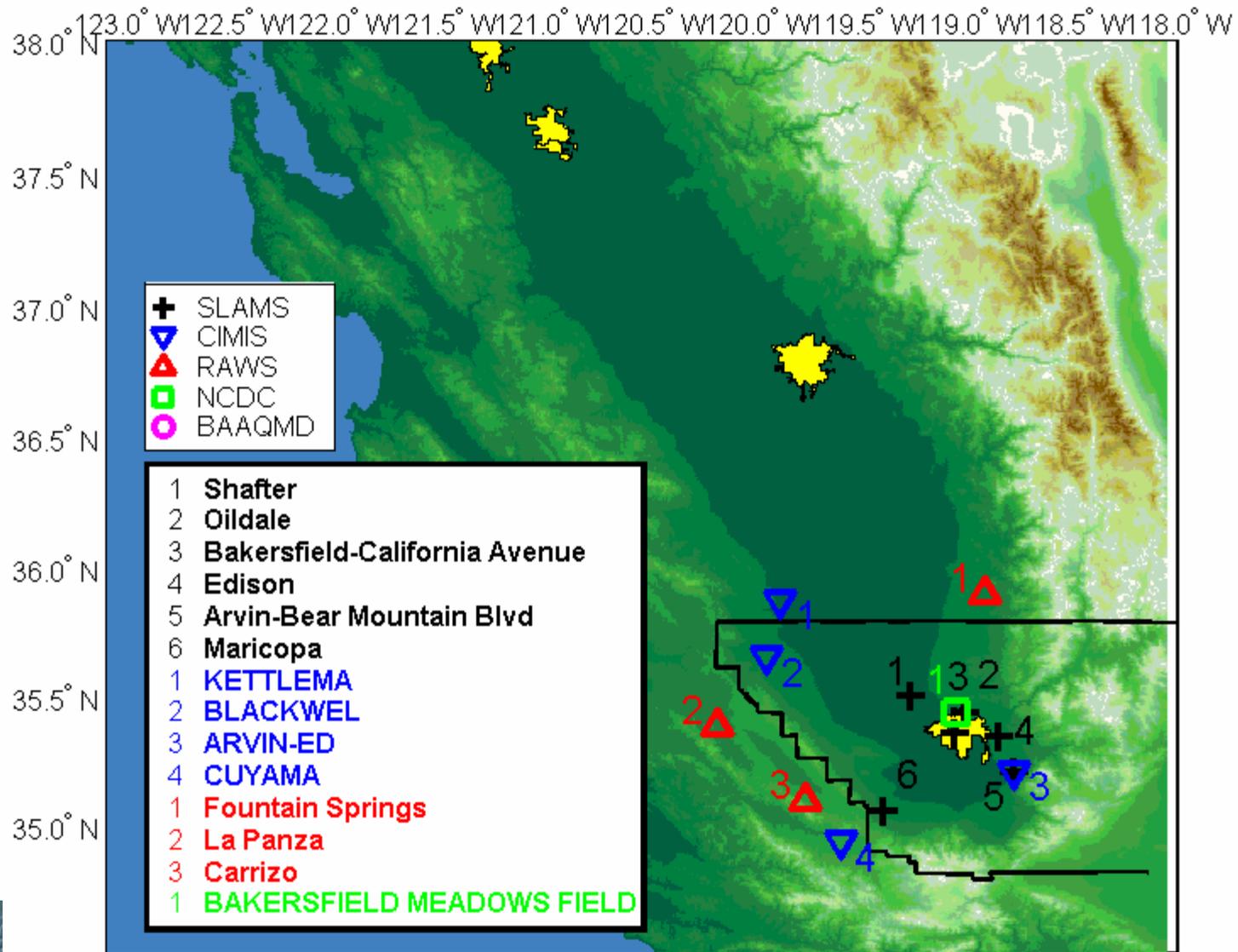
No eddy (118 d)



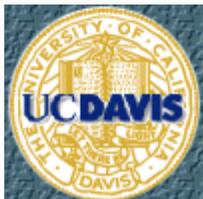
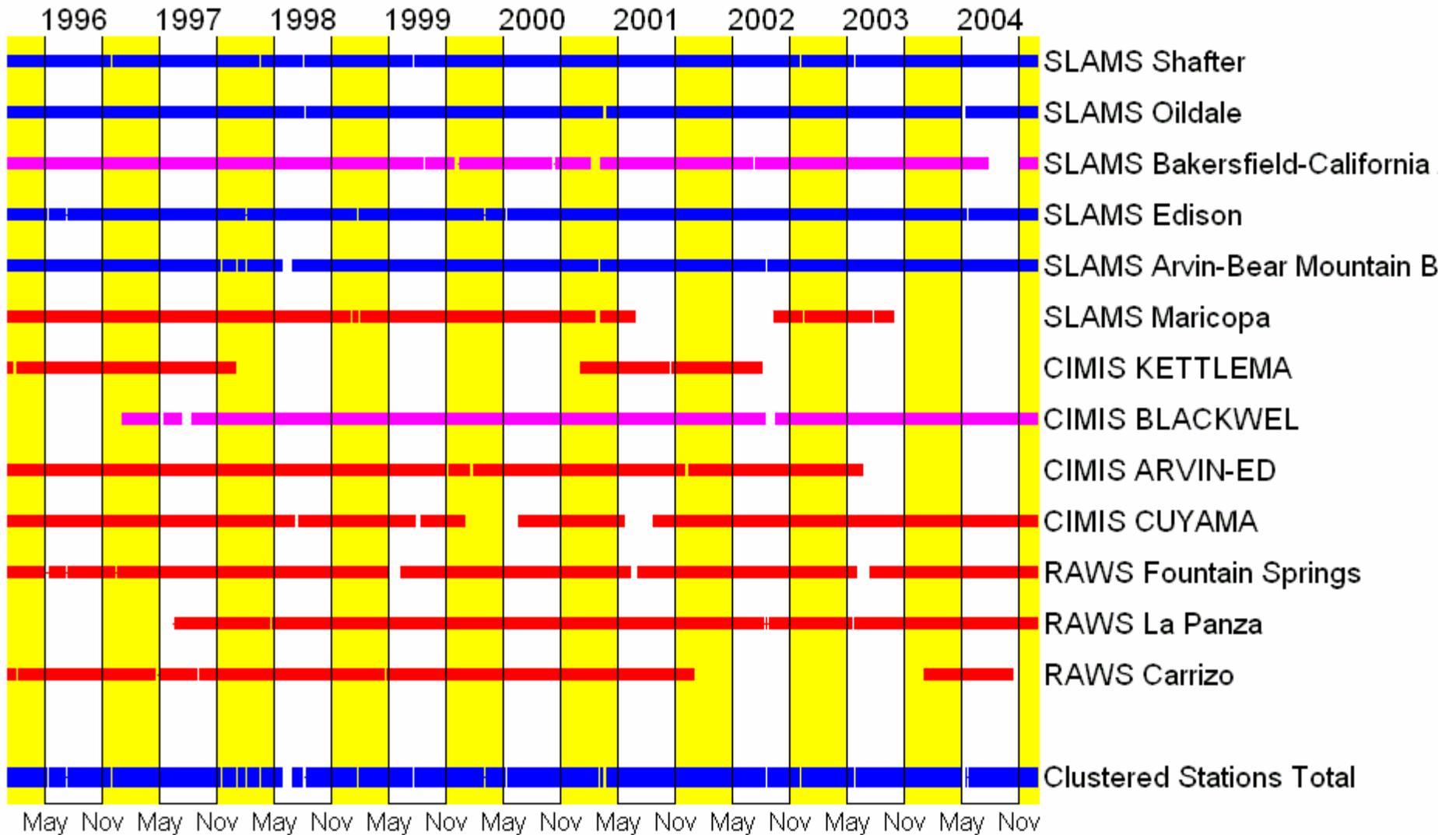
Within each regime, enhanced marine ventilation can suppress eddy formation

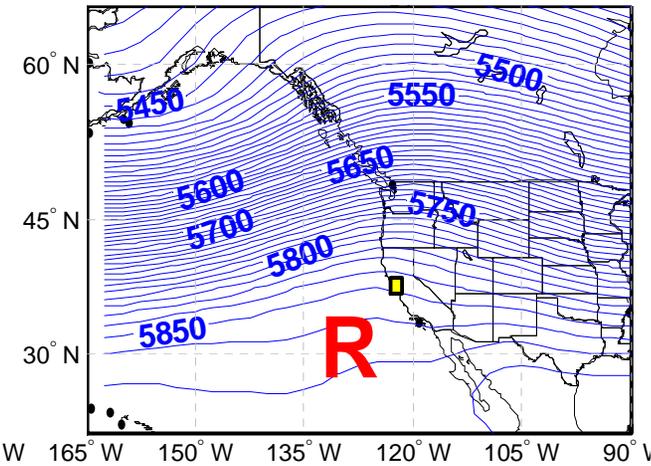
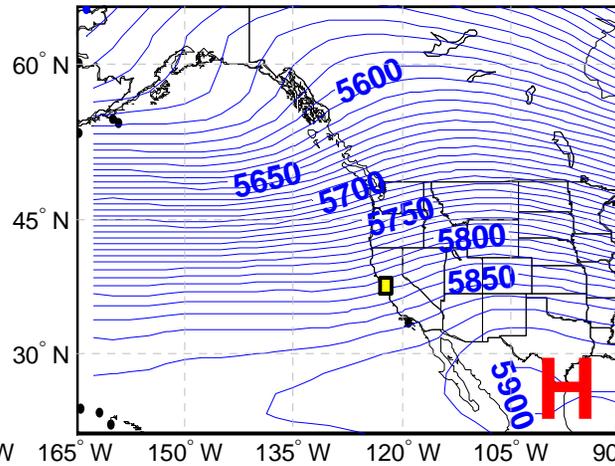
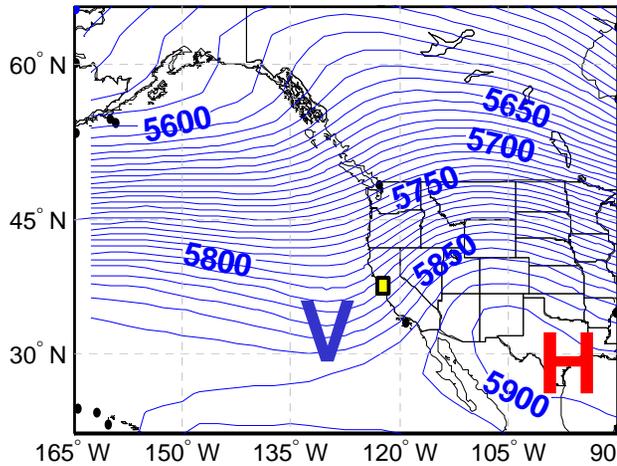


# South SJV Wind Monitors



# Gantt chart for S-SJV





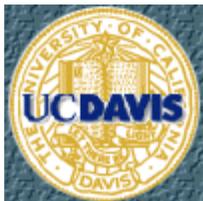
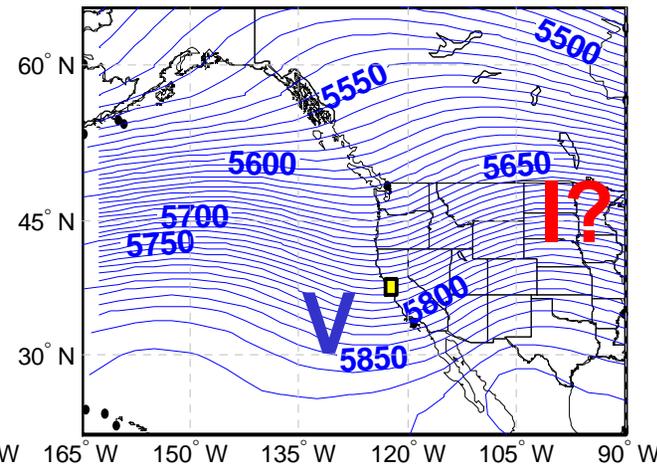
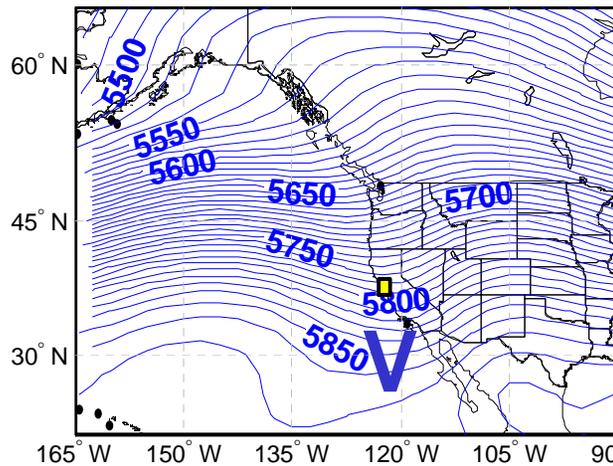
H/V: 206 days, 64%

H: 354 days, 58%

R: 373 days, 62%

V: 160 days, 36%

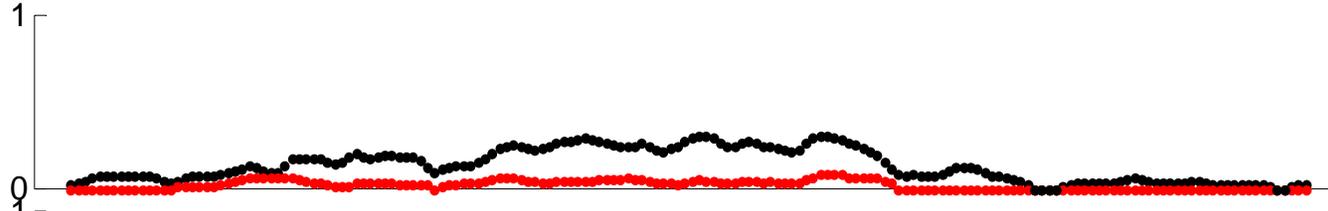
V/I: 317 days, 22%



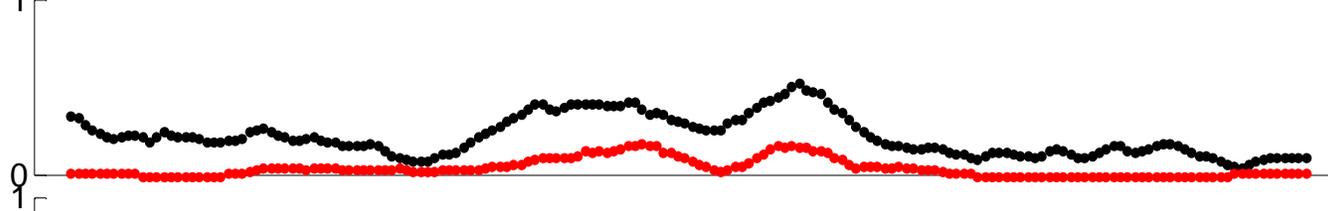
# S-SJV Seasonal Distribution

Black: Probability a Cluster is Realized Within 5 Days of Any Day of Year  
Red: Probability a Cluster is Realized as Exceedance Within 5 Days of Any Day of Year

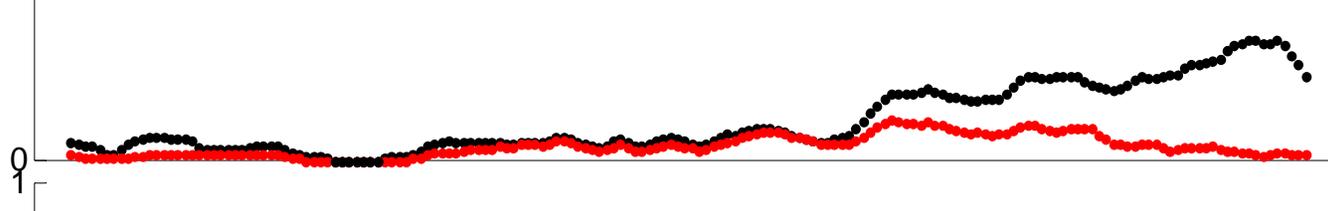
H/V



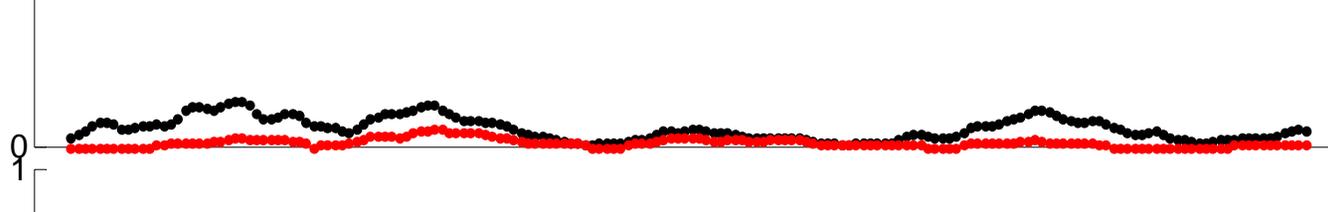
H



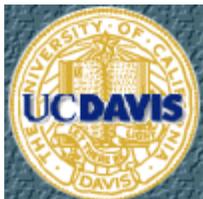
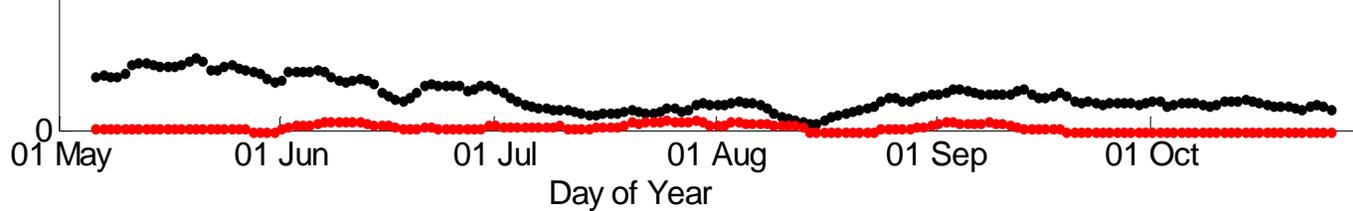
R



V



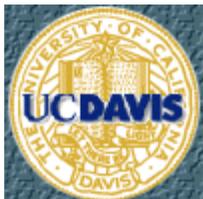
V/I



# Progress

	Phase I						Phase II			
	Obtain data	Quality assurance	Wind field clustering	Ozone clustering	Intra-basin report		Synoptic sequencing	Relate wind and ozone clusters	Inter-basin synoptic analysis	Inter-basin temporal analysis
San Francisco Bay Area	X	X	X	X	X		X	X		
SJV North	X	X	X	\	\		X			
SJV Central	X	X	X	\	\		X			
SJV South	X	X	\				\			
Sacramento Valley	X									
Mountain Counties	X									

Non-contracted quality assurance is a critical but time consuming step which has delayed Phase I progress.



# Recommendations

- Transport analysis for identified met regimes using a (back-trajectory) transport model.
  - Transport through gaps in Coastal Range
  - Transport patterns from major source areas
- $\text{NO}_x/\text{VOC}$  ratio and  $\text{O}_3$  sensitivity
  - Role of meteorology
- El Nino effects
- Wild fire analysis
- Vertical analysis
  - Visalia profiler
  - Limited soundings?
- AQM performance evaluation
- ... and others from project work plan ???

