The First Sundowner Winds Experiment – SWEX-I: the answer, my friends, is blowin' in the wind… and now we are trying to catch it!

So...Why is it so important to study "Sundowners"?

- Gusty winds that blow from the Santa Ynez Mountains (NORTHERLY WINDS)
- Typically peak from late afternoon through early morning.
- Can increase temperature and decrease relative humidity.
- Associated with Mountain Waves and Wave Breaking -

- **The Most important fire weather regime in SB.**
- **Hazards for aviation and navigation (small crafts)!**

THE FIRST SUNDOWNER WINDS EXPERIMENT SWEX-I

- **Launch weather balloons (radiosondes) every 3 hours to:**

a) Enhance understanding of profile of winds, temperature, humidity and other thermodynamic variables;

b) Evaluate the temporal variability of these profiles;

c) Identify the nocturnal low-level jet and temporal variability;

d) Improve understanding of Sundowner mechanisms

e) Investigate the forecast skill of these profiles with WRF

SWEX-I Experiment: lessons learned

- It takes a village, lots of coordination, collaboration, a great enthusiastic team and $$$ to have an experiment like SWEX:

a) We need $$ for the balloons and radiosondes (~200,00 each)

b) We need Helium to fill the balloons (hard to find vendors $$)

c) We need a radiosonde tracker (an antenna $$$$)

d) We need quite a few people (4-5 per launch) night and day! $

e) We need a good location for the launch (with facilities for the team)

f) <u>AND, OF COURSE, WE NEED A GOOD FORECAST OF SUNDOWNERS!</u>

SWEX Amazing team:

UCSB:

- Charles Jones
- Gert-Jan Duine
- Katelyn Zigner
- Brandi Gamelin
- Garret Bell
- Isabelle Runde
- Leila Carvalho

San Jose State University :

- Craig Clements
- Heather Kane
- Chloe Gore

Financial Support:
UCSB Faculty Research Grant - $ 7000,00

SWEX Logistic support:

Logistics support:

Santa Barbara County Fire Dept.

- Rob Hazard and Woody Enos

SBC Fire Dept. Headquarters:

National Weather Service/Oxnard

- Dave Gomberg, Todd Hall, Mark Jackson, John Dumas, Eric Boldt:
- FORECAST FOR THE EVENT

SWE X MISSION: IMPOSSIBLE

1) Wait for a phone call from the NWS : Get Ready! Sundowners may happen in two days!!!
2) Mobilize SJSU team
3) Contact the Fire Department
4) Clear with airports
5) Gather the team
6) GO! GO! GO!

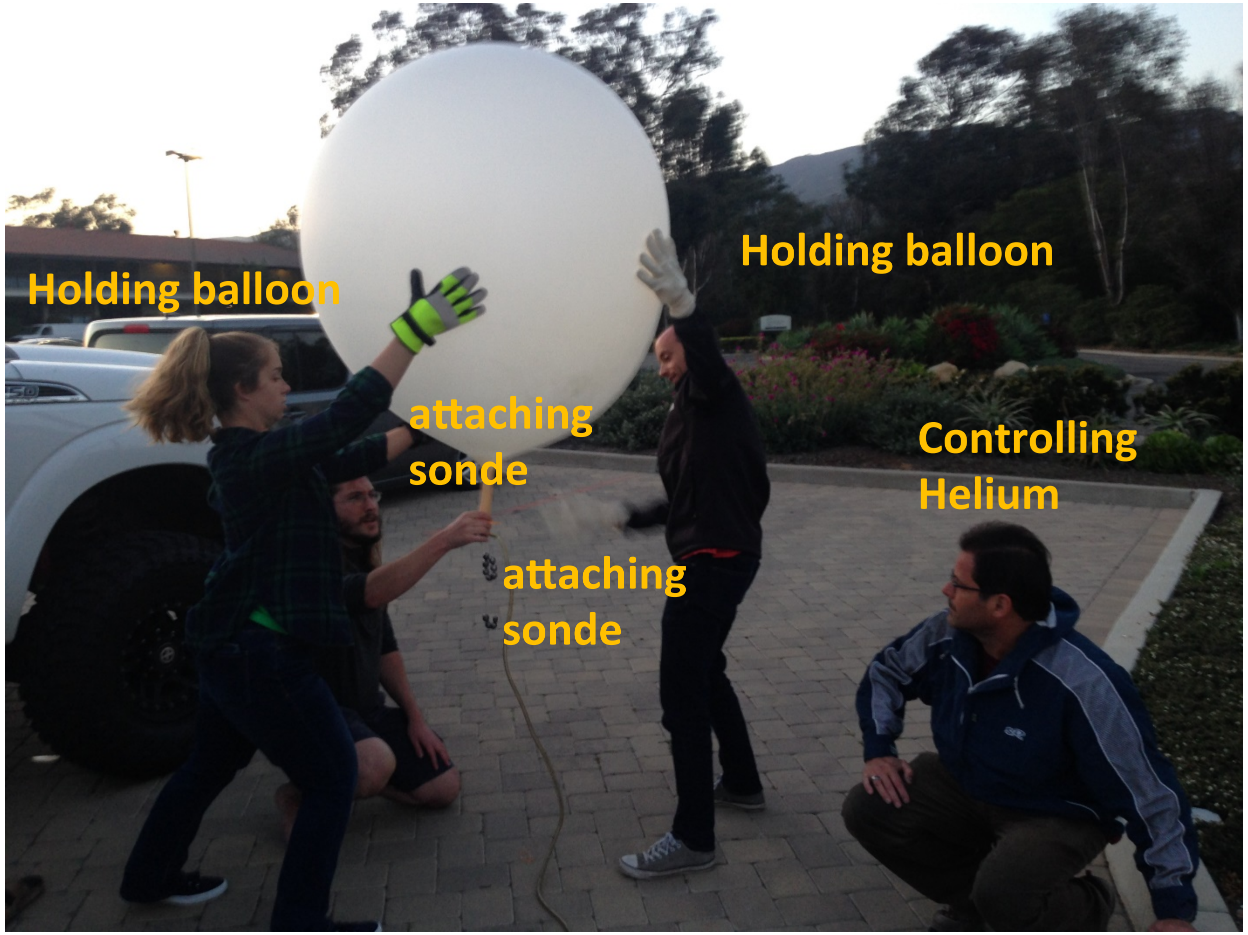
What exactly happened during SWEX?

California State University Mobile Atmospheric Profiling System (CSU-MAPS) **(equipped with a portable sonde system**

Radiosonde:

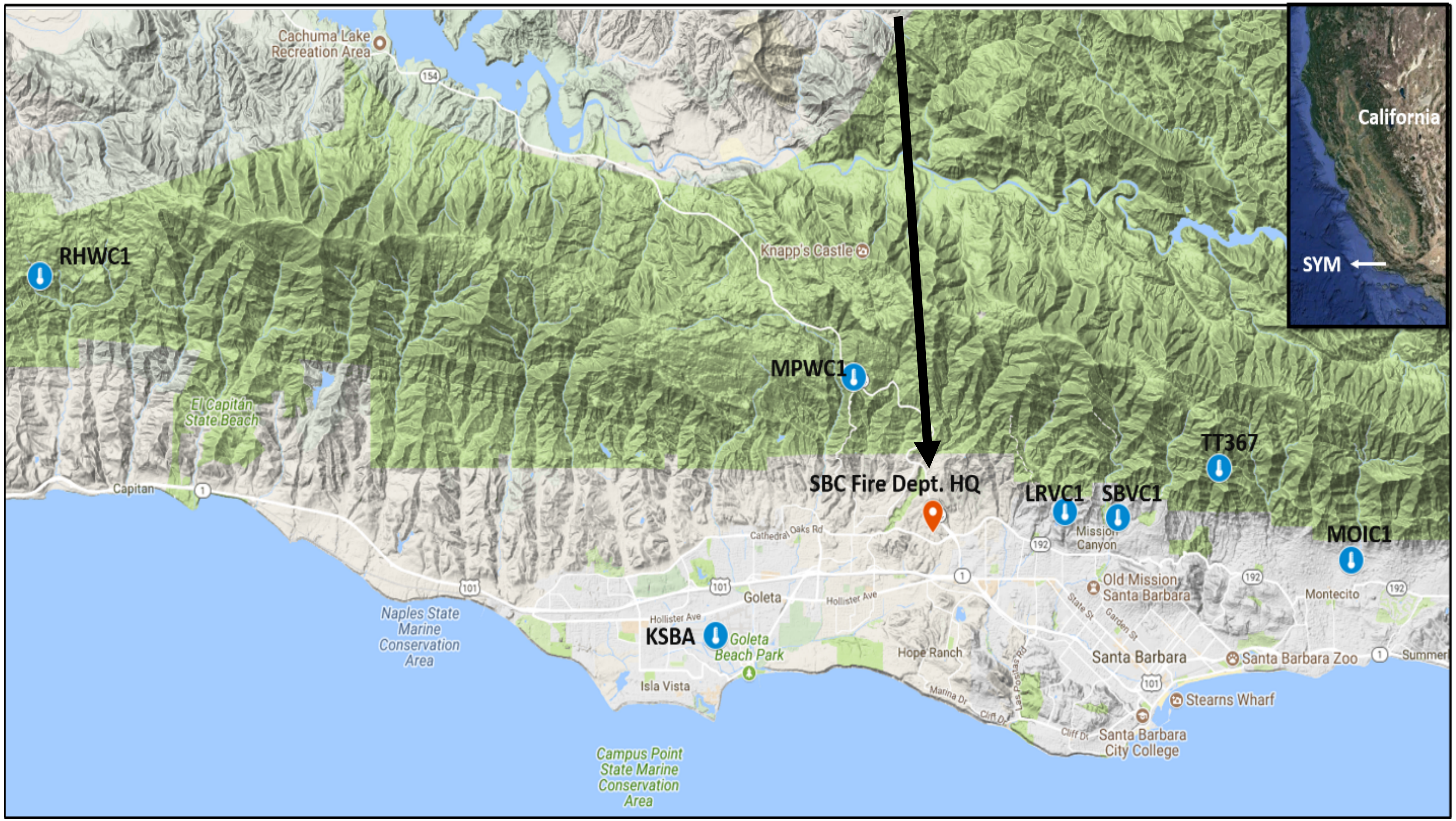
- **Sensors Temperature,**
- **Relative humidity**
- **Winds**
- **GPS**
- **Recorded in a computer**

It takes a village to launch balloons in windy conditions!



SWEX: 13 successful radiosondes, one balloon exploded, one lost radiosonde

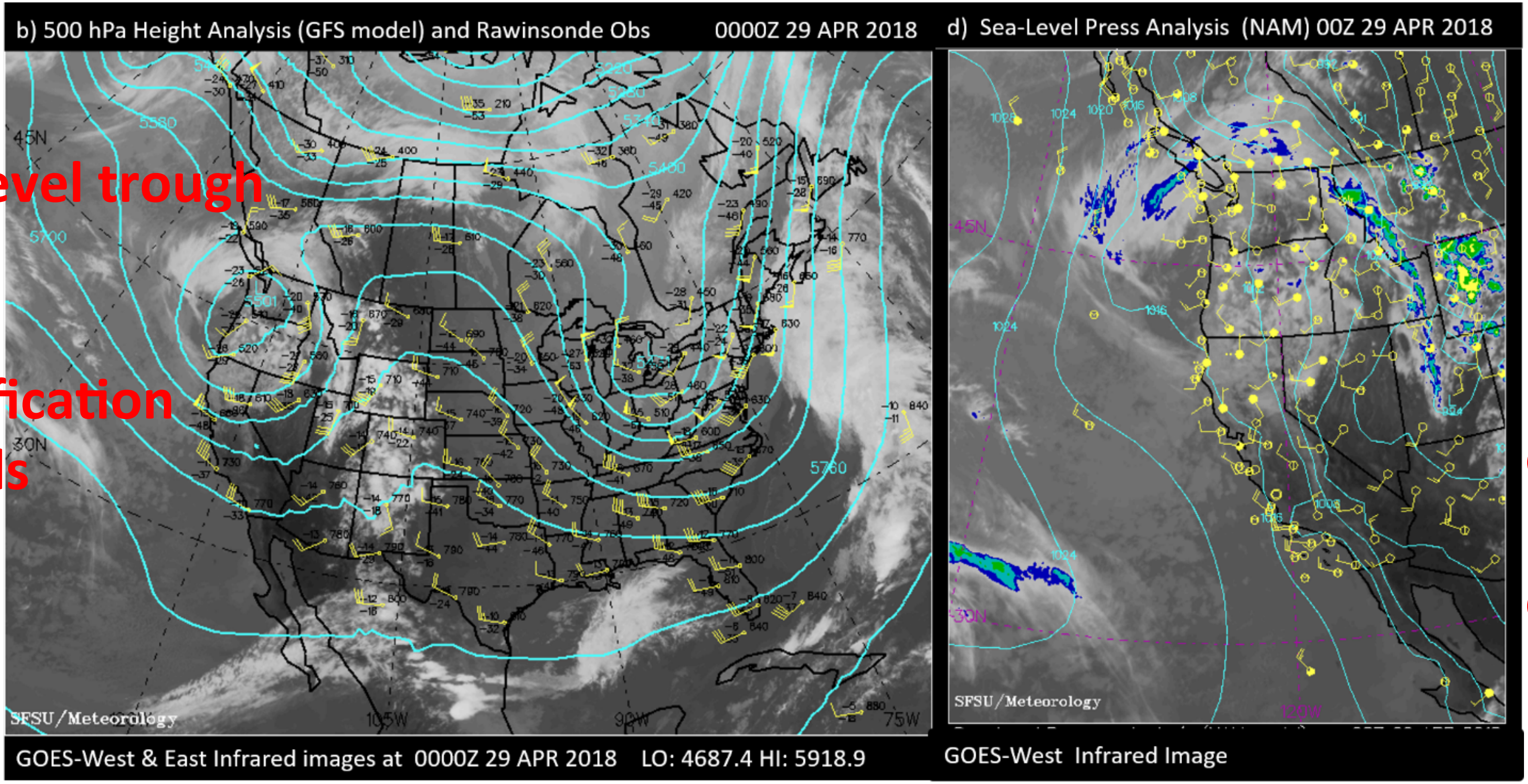
Launch site and stations leeward of the SYM:



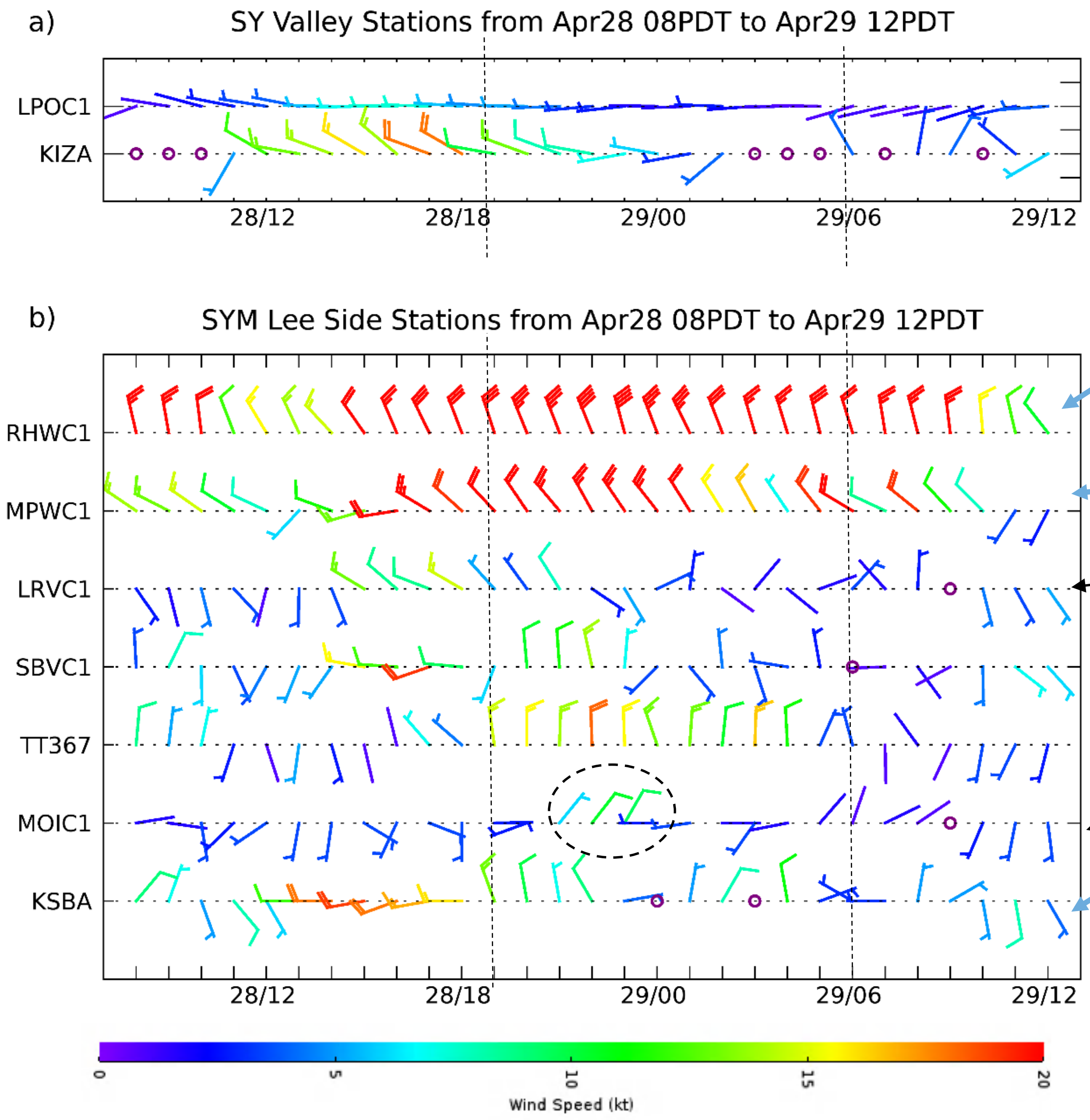
Synoptic Conditions: Strong pressure gradients

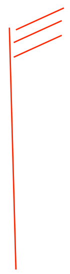
Upper level trough

Intensification of winds



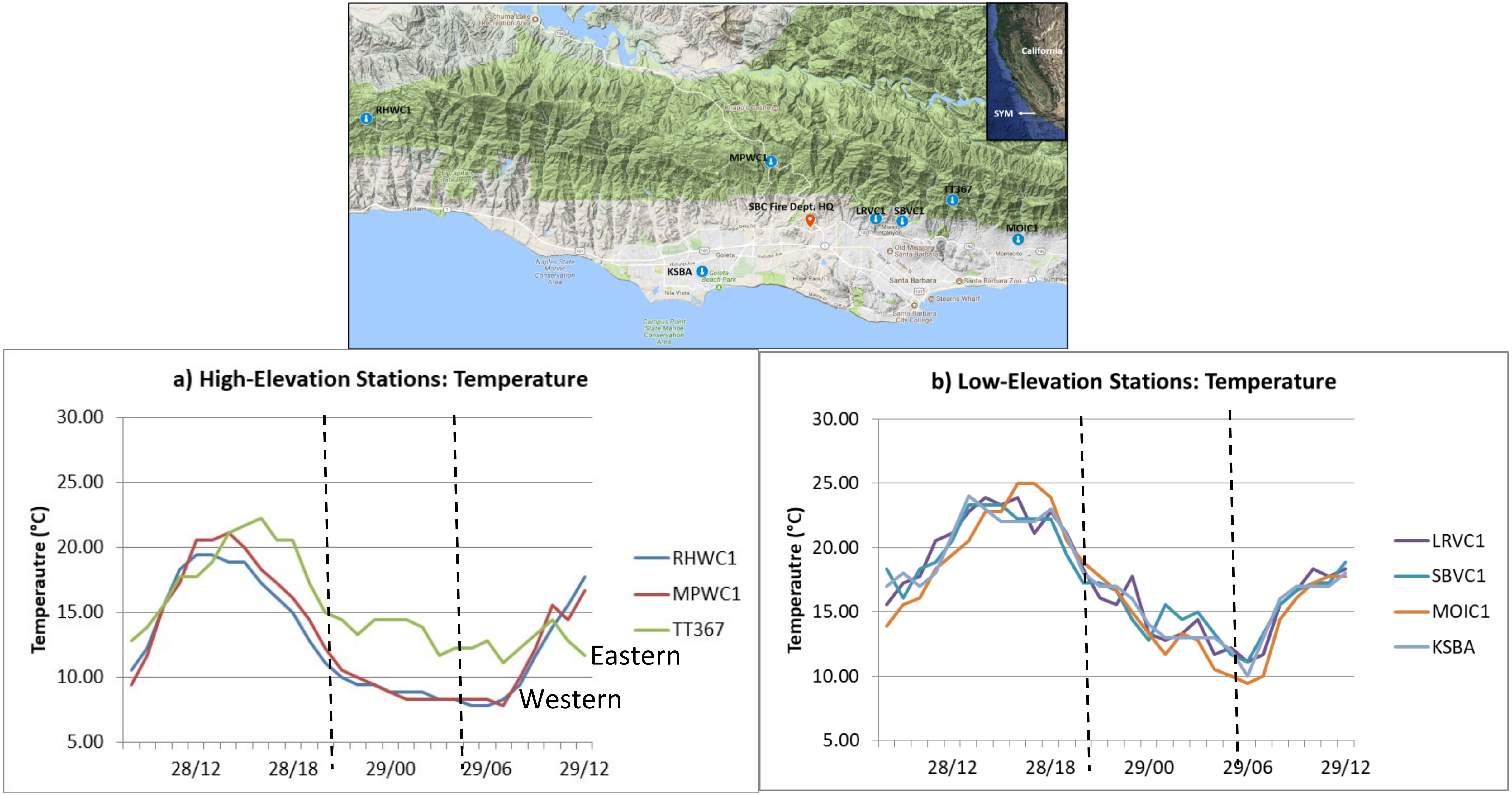
Intensification of winds near SB coast



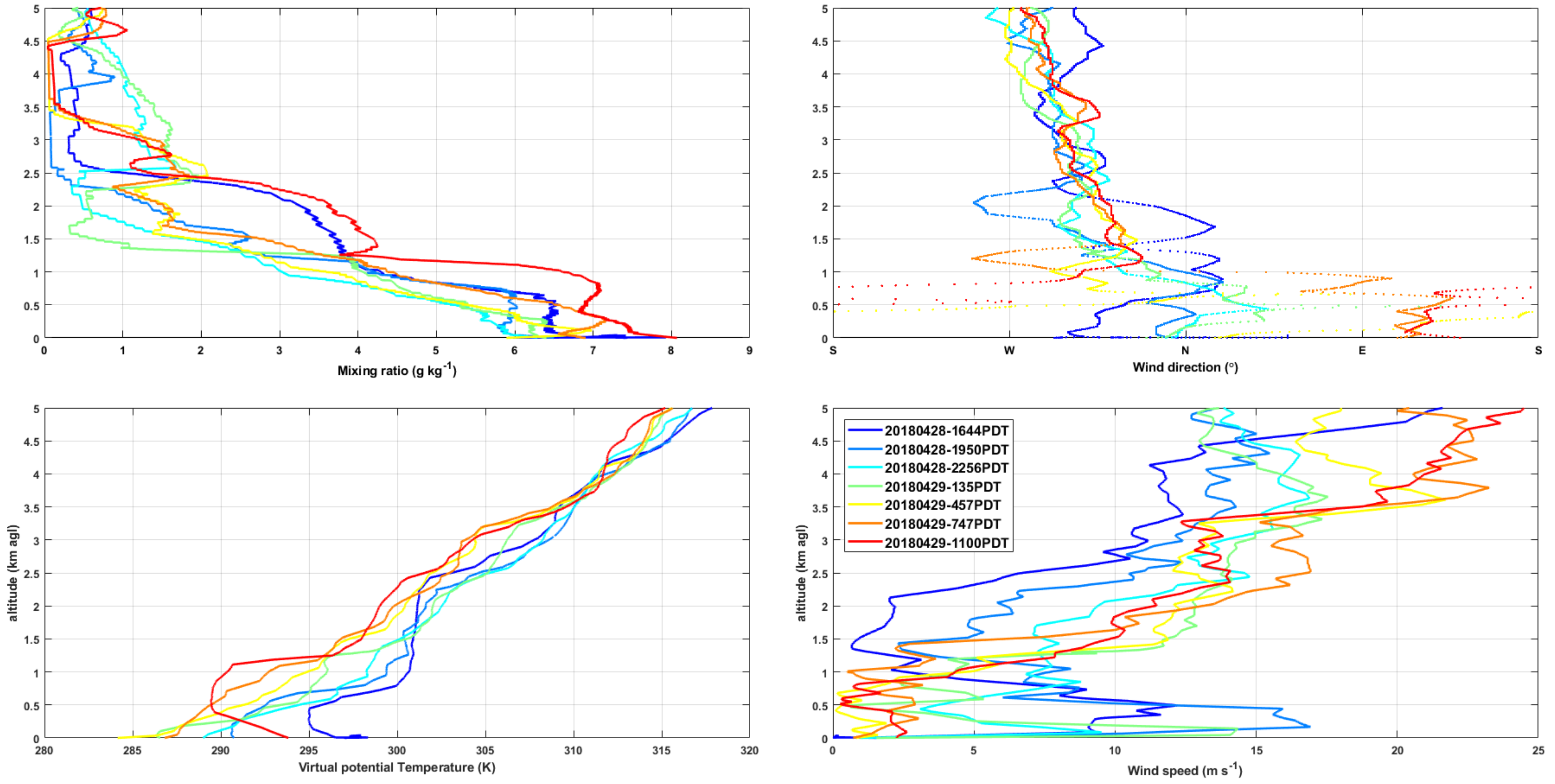


Northerly winds, 30 knots

35 kn ~ 40mph

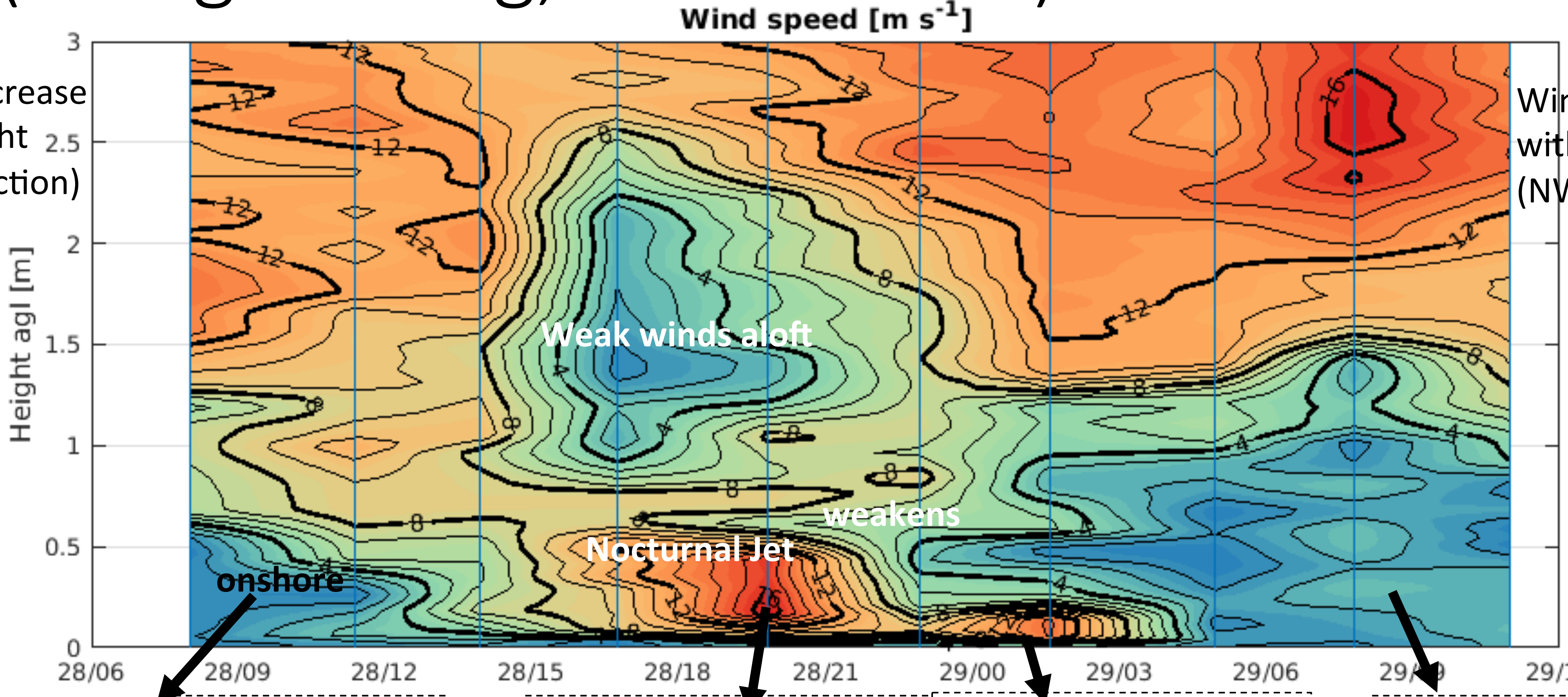

California
SYM
RHWC1
MPWC1
TT367
SBC Fire Dept. HQ
LRVC1
SBVC1
MOIC1
KSBA
Goleta
Santa Barbara
Montecito
a) High-Elevation Stations: Temperature
Temperaure (°C)
30.00
25.00
20.00
15.00
10.00
5.00
28/12
28/18
29/00
29/06
29/12
RHWC1
MPWC1
TT367
Eastern
Western
b) Low-Elevation Stations: Temperature
Temperaure (°C)
30.00
25.00
20.00
15.00
10.00
5.00
28/12
28/18
29/00
29/06
29/12
LRVC1
SBVC1
MOIC1
KSBA

Example: radiosonde profiles



Main Results from the radiosondes: wind speed (orange strong, blue weaker)

Winds increase with height (NW direction)



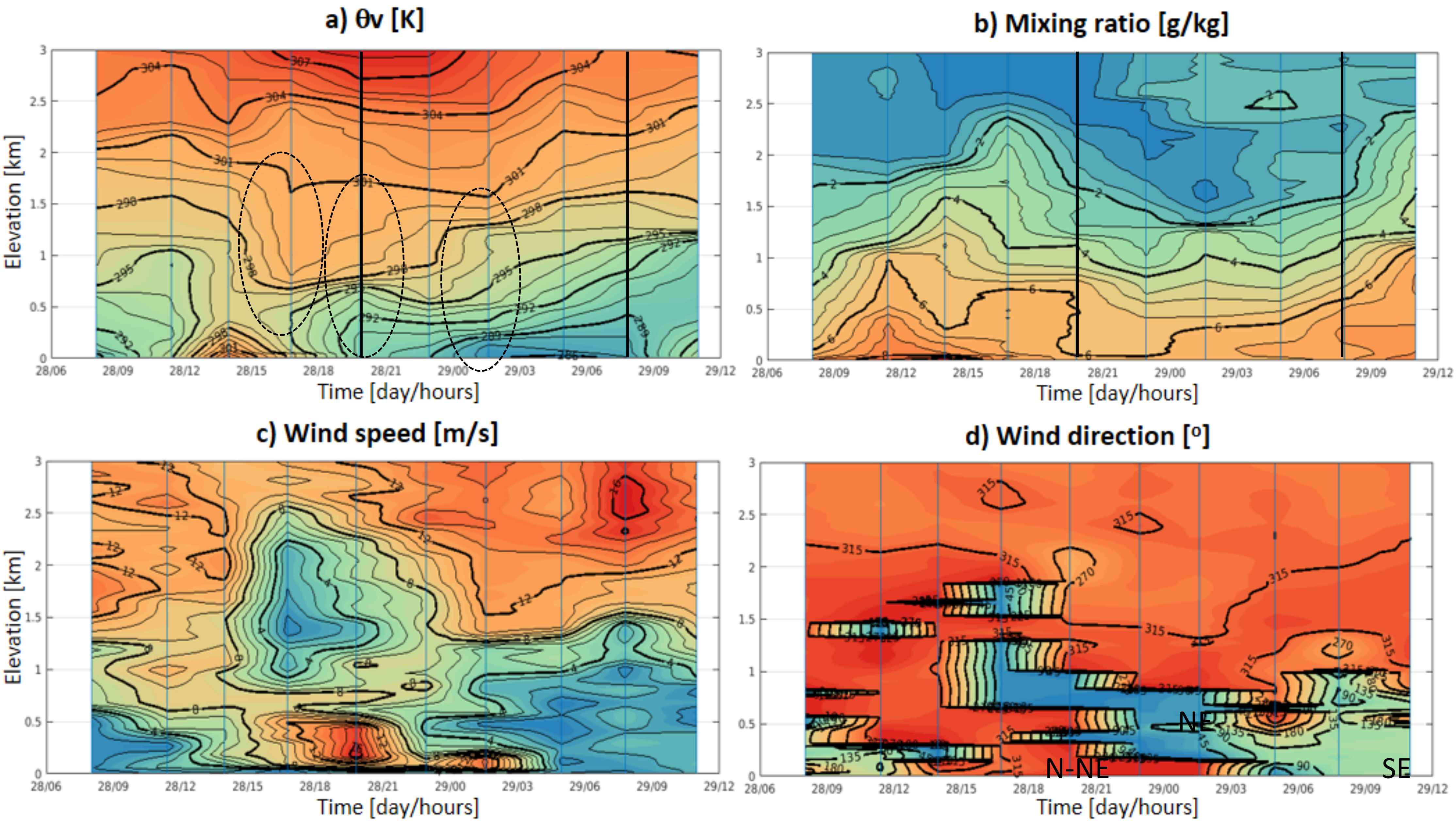
Winds increase with height (NW direction)

Onshore winds (Sea breeze) Early in the morning

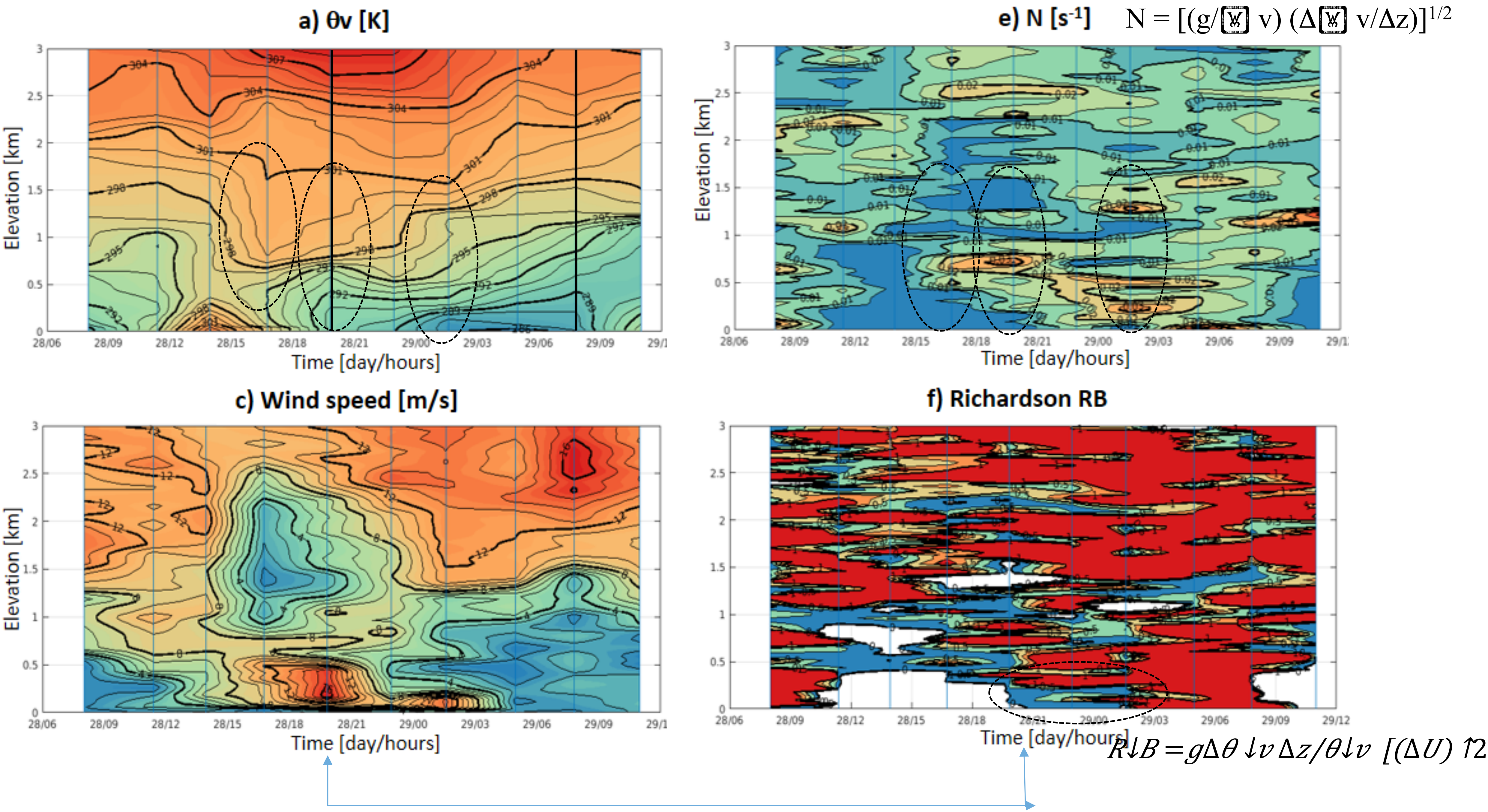
Nocturnal Northerly jet forms below 600m (~20:00 PDT– speed ~ 40mph) – increase gusts

Jet intensifies again, now at much lower levels ~ 2:00 AM:

Weak onshore winds in the morning



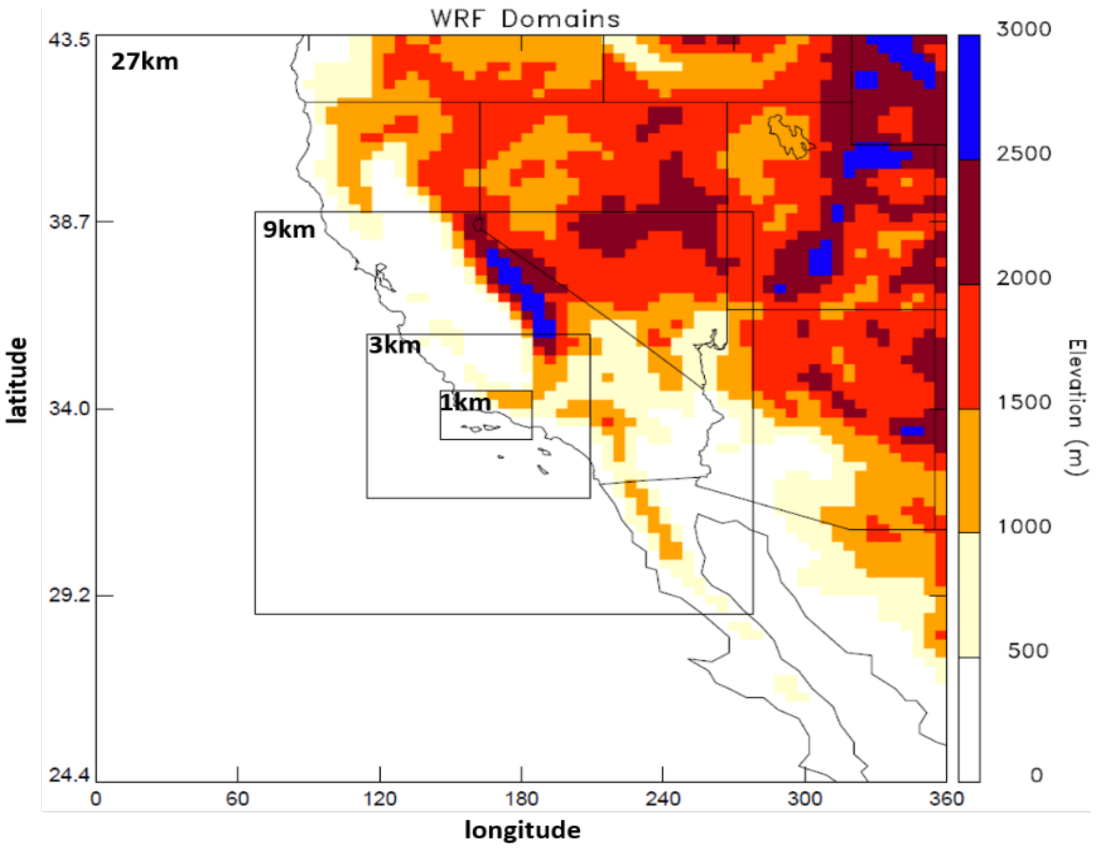
a) θv [K]
b) Mixing ratio [g/kg]
c) Wind speed [m/s]
d) Wind direction [º]
Elevation [km]
Time [day/hours]
28/06
28/09
28/12
28/15
28/18
28/21
29/00
29/03
29/06
29/09
29/12
N-NE
NE
SE



$N = [(g/\theta_v)(\Delta\theta_v/\Delta z)]^{1/2}$

$R_B = g\Delta\theta_v \Delta z / \theta_v [(\Delta U)^2$

Forecast of the event with WRF (1km res).



Initial and lateral boundary conditions: Forecasts from the North American Mesoscale Forecast System (NAM) (12 km grid spacing).

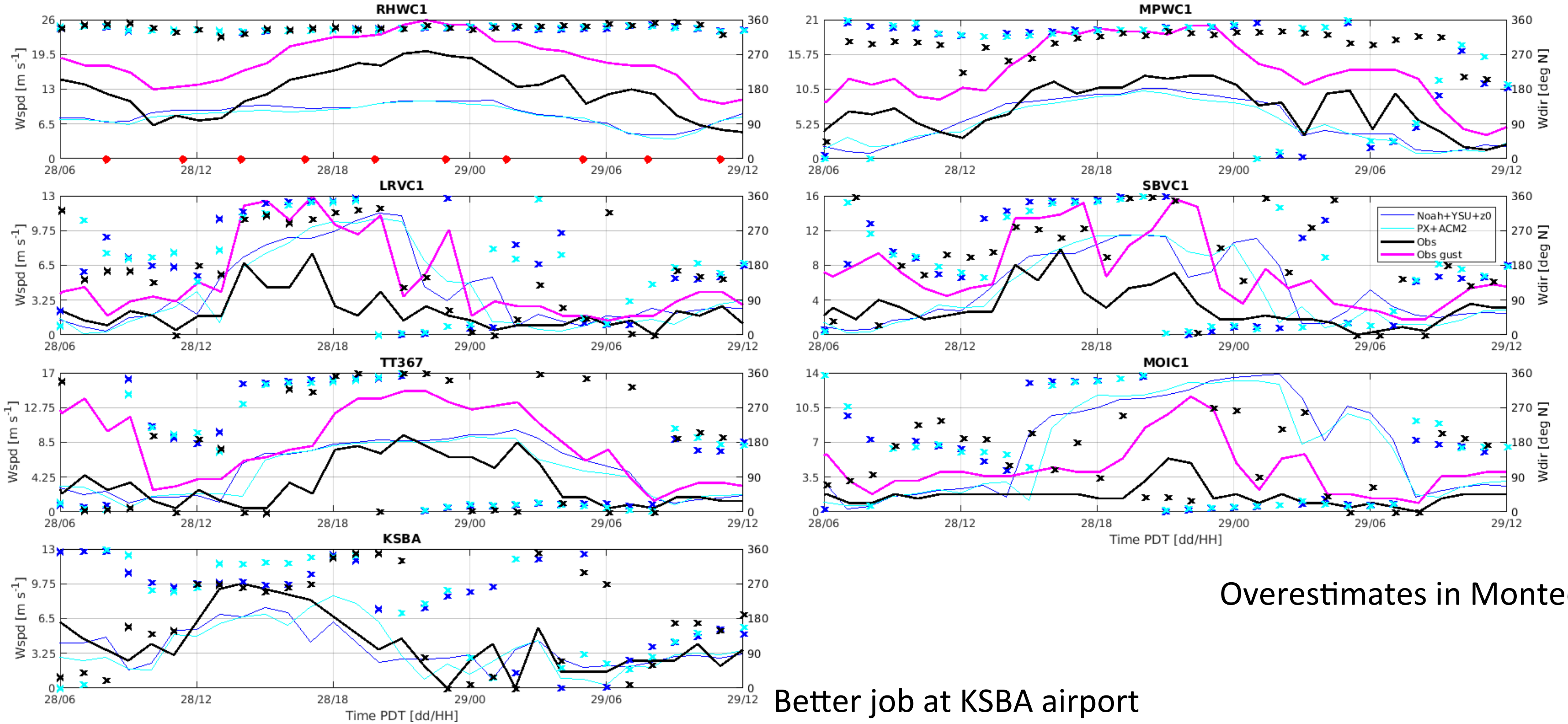
A 60-hour forecast initialized on April 28 at 00UTC (April 27 17:00PDT) was performed

we focus here on the validation period 28 April 06PDT- 29 April 12 PDT

Comparison between WRF and stations:

Understimates western speeds

Better job at central regions

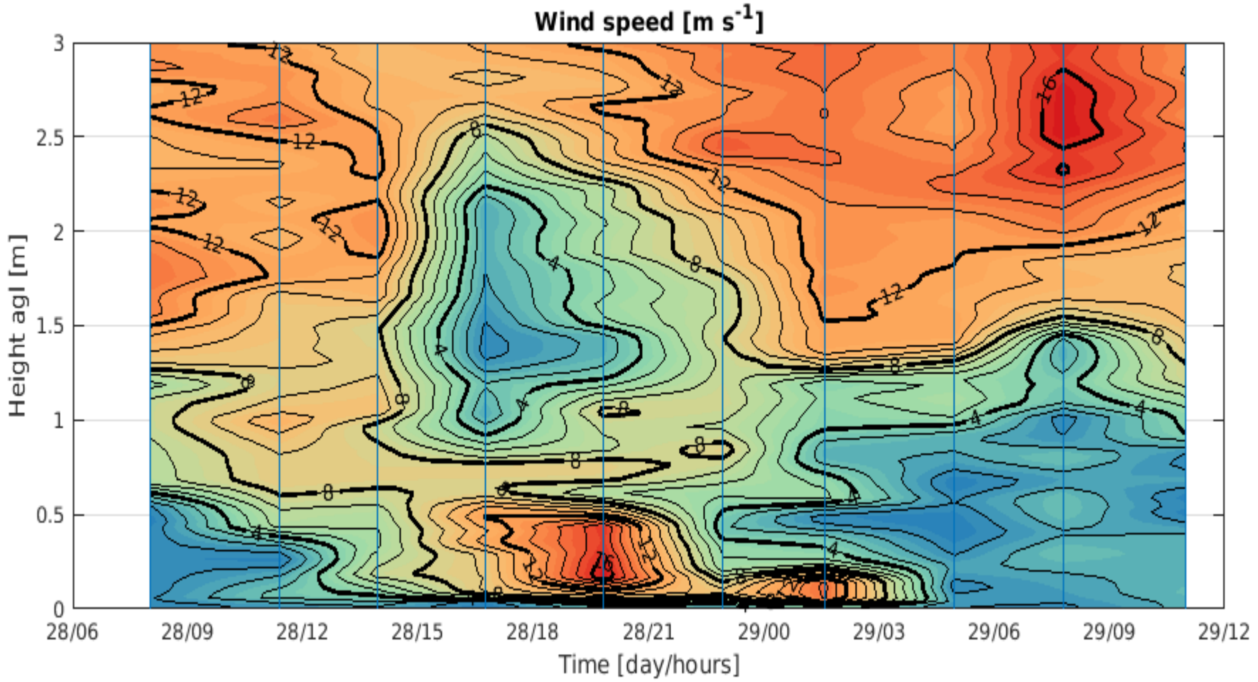


Overestimates in Montecito

Better job at KSBA airport

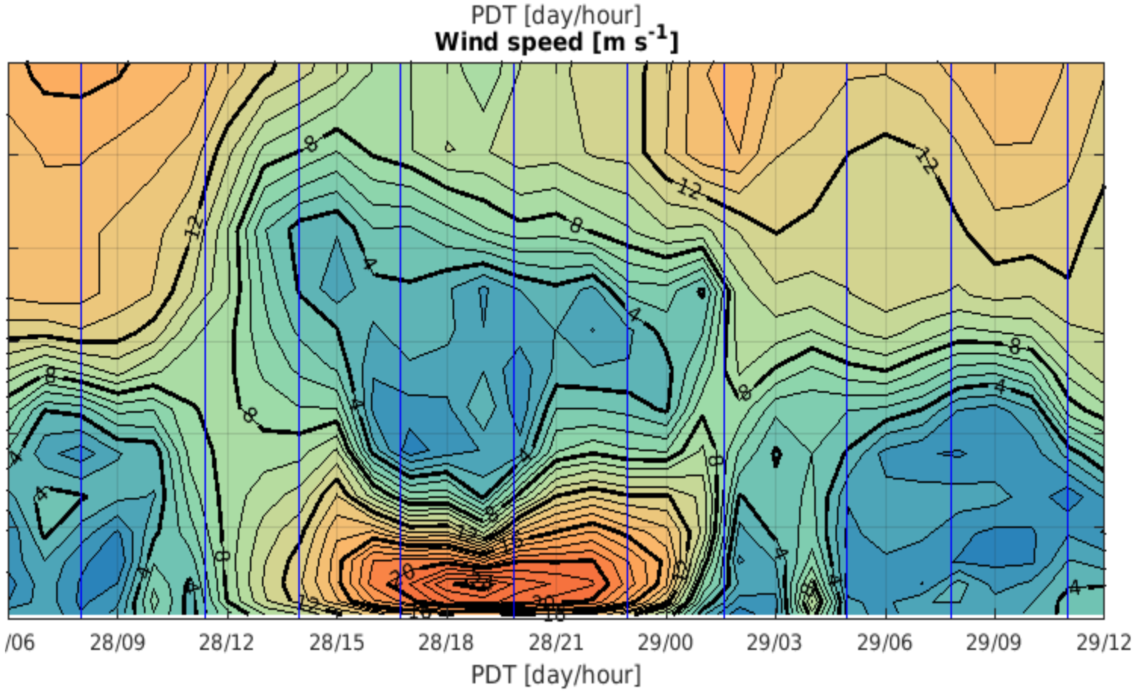
How good was the WRF forecast (1km res) of

Observations Radiosonde



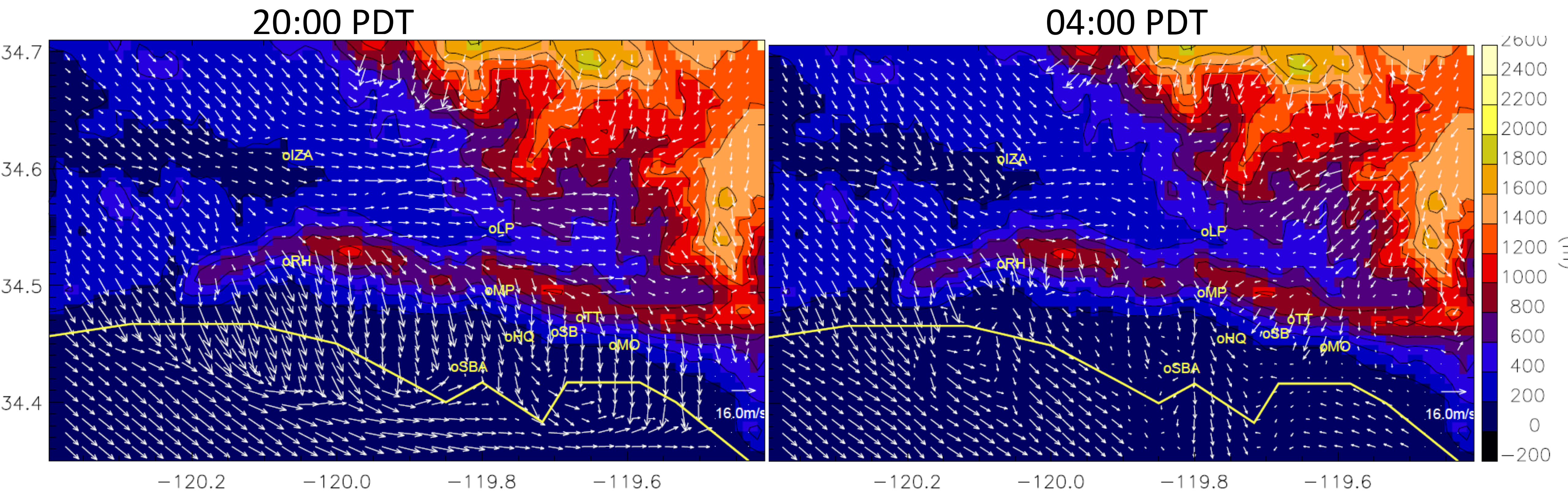
Two peaks of Nocturnal Northerly jet forms below 600m (right around sunset – speed ~ 40mph)

WRF Forecast



Stronger nocturnal Northerly jet forms below 600m (right after sunset – speed > 40mph)

Secondary jet: one hour later than observed


20:00 PDT
04:00 PDT
34.7
34.6
34.5
34.4
oIZA
oLP
oRH
oMP
oTT
oHQ
oSB
oMO
oSBA
16.0m/s
−120.2
−120.0
−119.8
−119.6
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
−200

Transition: Hydraulic Jump

Transition from subcritical to supercritical

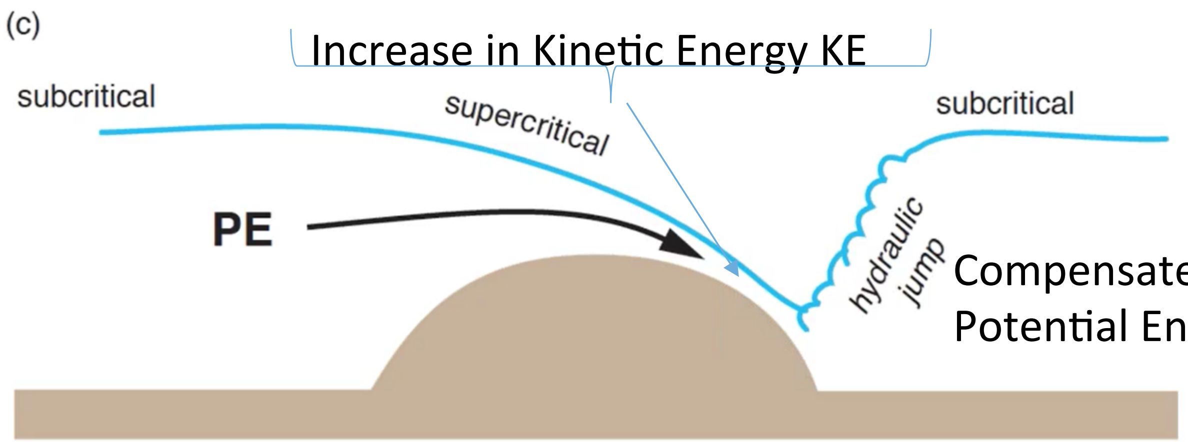
Subcritical: Fr < 1 **Supercritical: Fr > 1**

Shallow water equation

Continuity equation

D ≡ fluid thickness

h ≡ obstacle height



Compensate by increasing Potential Energy, PE

$$Fr^2 = \frac{u^2}{gD}$$ Froude Number $= \dfrac{\text{Fluid velocity}}{\text{Shallow water gravity waves speed}}$

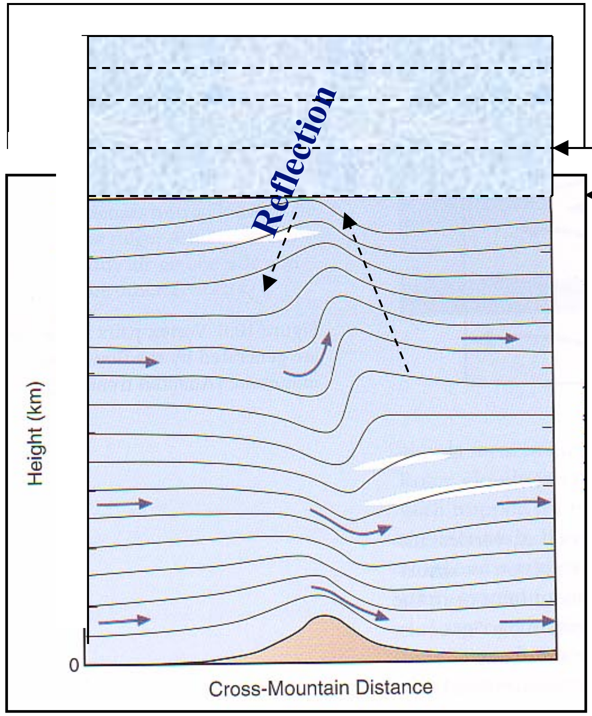
Fluid fastest in the lee

By D. Durran

Acceleration all the way down the lee slope
No standing gravity wave in the lee; no deceleration until jump

Reflection of Vertically Propagating Internal Gravity Waves

Klemp and Lilly (1975)



Critical layer: stability or shear changing rapidly

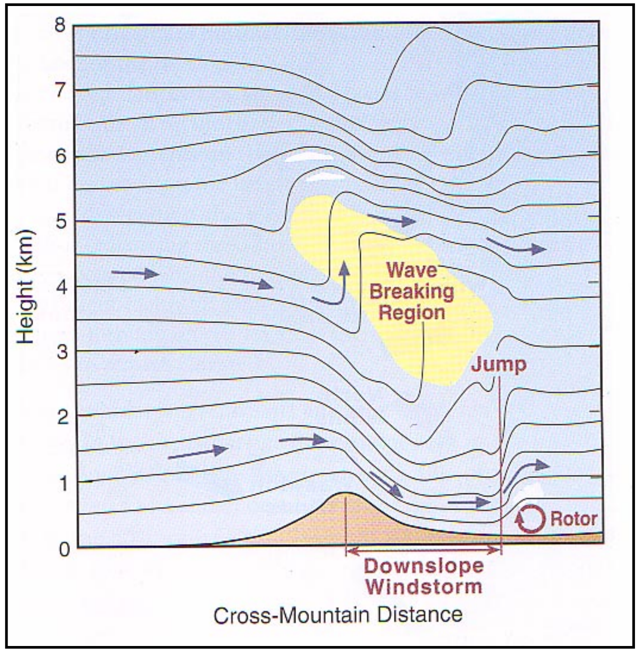
Critical level

Wave Induced Critical Layer

Clark and Peltier (1977, 1984)

Figure 10.11 Hydraulic flow produces a distinctive flow pattern in the lee of a mountain barrier that is characterized by a region of wave-breaking aloft and a sudden jump in the streamline pattern (*hydraulic jump*) downwind of the barrier. A turbulent rotor cloud may form behind the hydraulic jump. Downslope windstorms may occur during hydraulic flow. (Adapted from Carney et al., 1996)

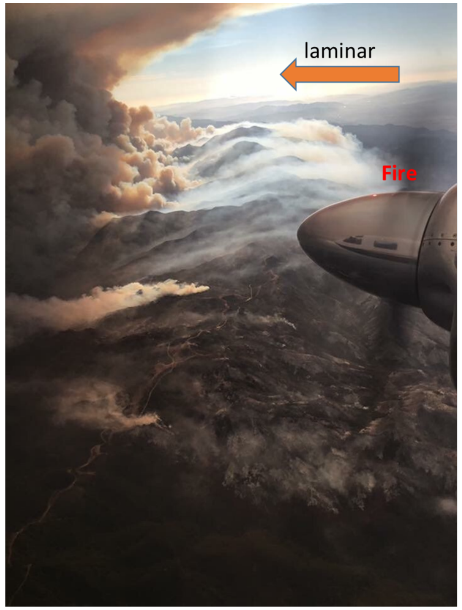
Hydraulic flow



Turbulent

South

Coast



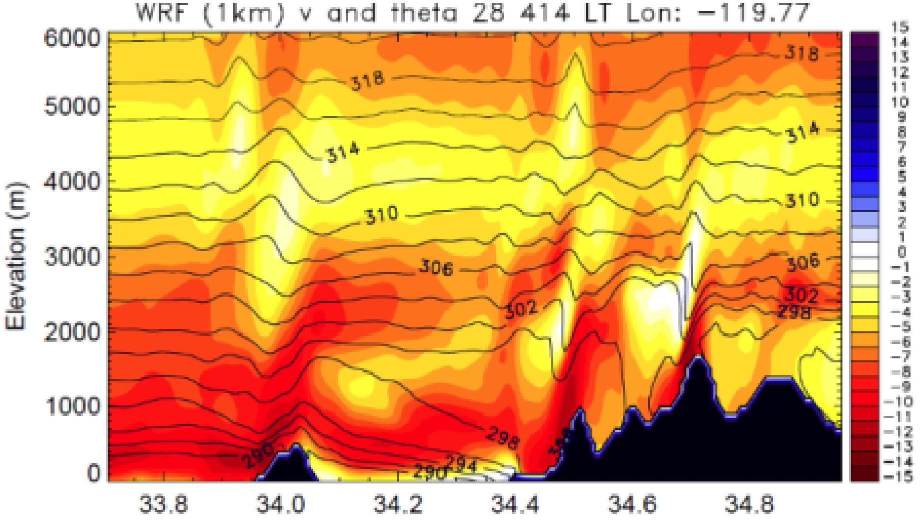
North

Santa Ynez Valley

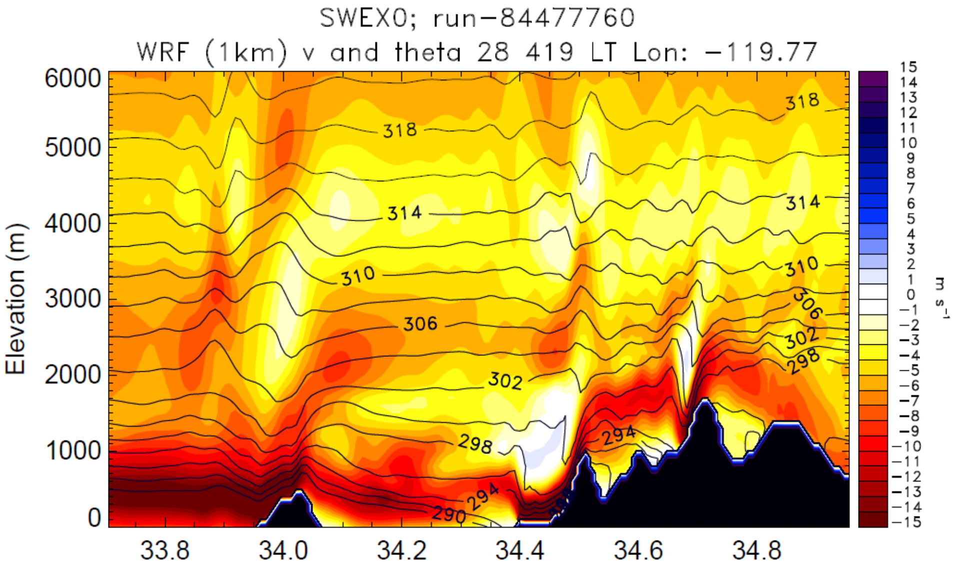
Provided by Mark Von Tillon (Incident Commander) Taken from the Air attack pilot

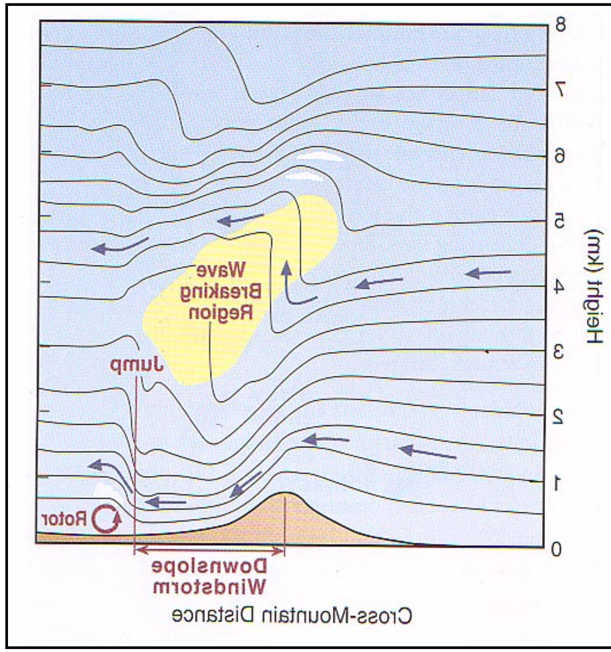
Cross section at the launching site .

SWEX Site : 17:00 PM



SWEX Site : 20:00 PM





Primary mechanisms that induce downslope windstorms: trapped lee gravity waves:

Generally, the primary mechanisms that induce downslope windstorms within an environment that supports lee gravity waves

a) an inversion above the mountaintop
b) either velocity or directional shear of the cross-barrier wind

✓ Trapped leewaves, confined to the lower troposphere on the lee side of the mountains result from:

a) increase in wind speed, a decrease in stability, or an increase in the curvature of the wind speed profile.

These atmospheric conditions inhibit the buoyancy-driven oscillation of a gravity wave and thus its energy is reflected back to the surface.

Scorer parameter, defined by Scorer (1949)

$$l^2 = \frac{N^2}{U^2} - \frac{1}{U}\frac{\partial^2 U}{\partial z^2}$$

where N(z) is the Brunt Vaisala frequency, and U(z) is the mean cross barrier horizontal wind speed, and z is the vertical coordinate.

when l^2 decreases with height,

a) an increase in crossmountain wind speed,
b) a decrease in stability
c) increase in the curvature of the wind speed profile

Self-induced critical layer:

- forms due to turbulence from gravity wave breaking.
- A critical layer impedes the vertical propagation of wave energy at certain wavelengths, thus deflecting considerable energy into near-surface wind speed on the lee slope (Durran, 2003).

(Gradient) Richardson Number, defined as:

$$Ri = \frac{\frac{g}{\theta_v}\frac{\partial \overline{\theta_v}}{\partial z}}{\left[\left(\frac{\partial \overline{U}}{\partial z}\right)^2 + \left(\frac{\partial \overline{V}}{\partial z}\right)^2\right]}$$

Stability term

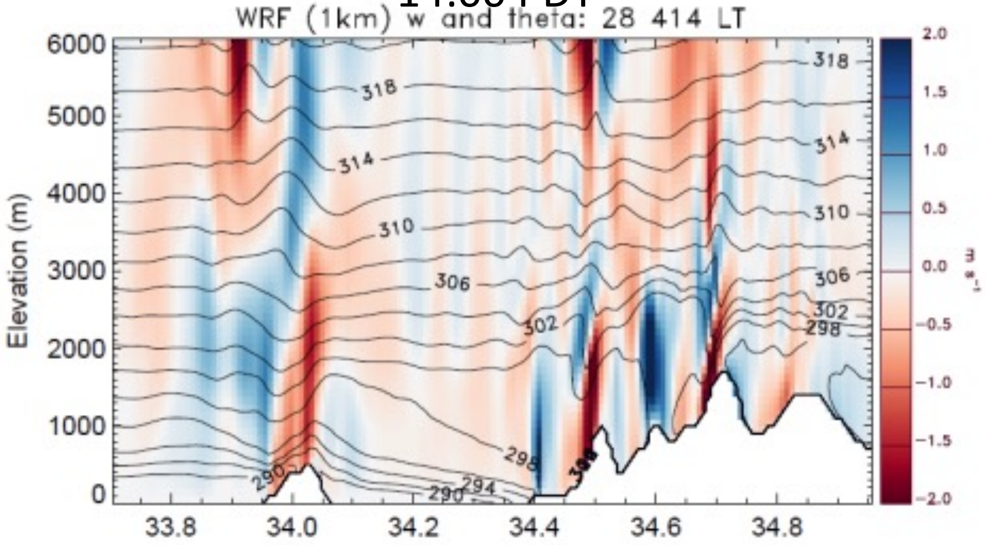
Shear term

Laminar flow becomes turbulent when Ri < 0.25

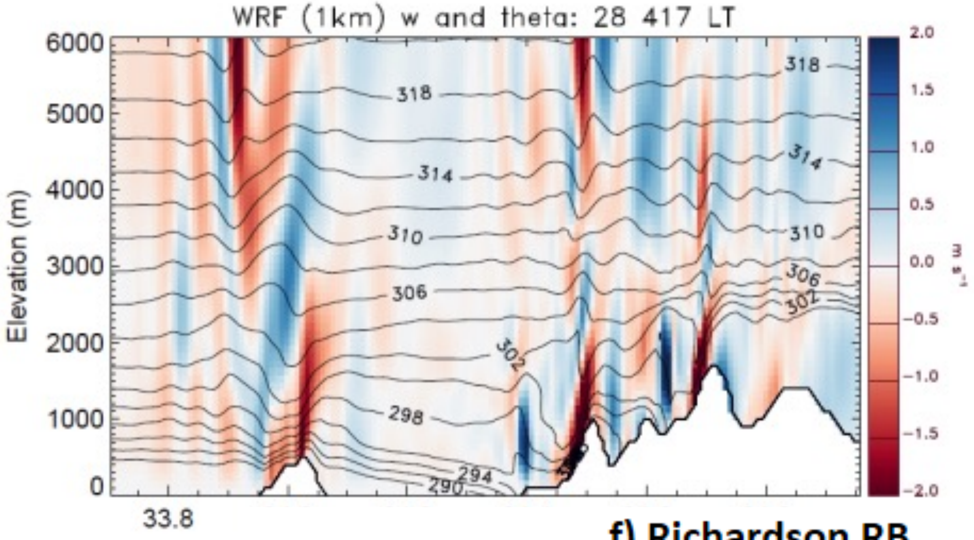
Turbulent flow becomes laminar when Ri > 1

Gravity waves

14:00 PDT

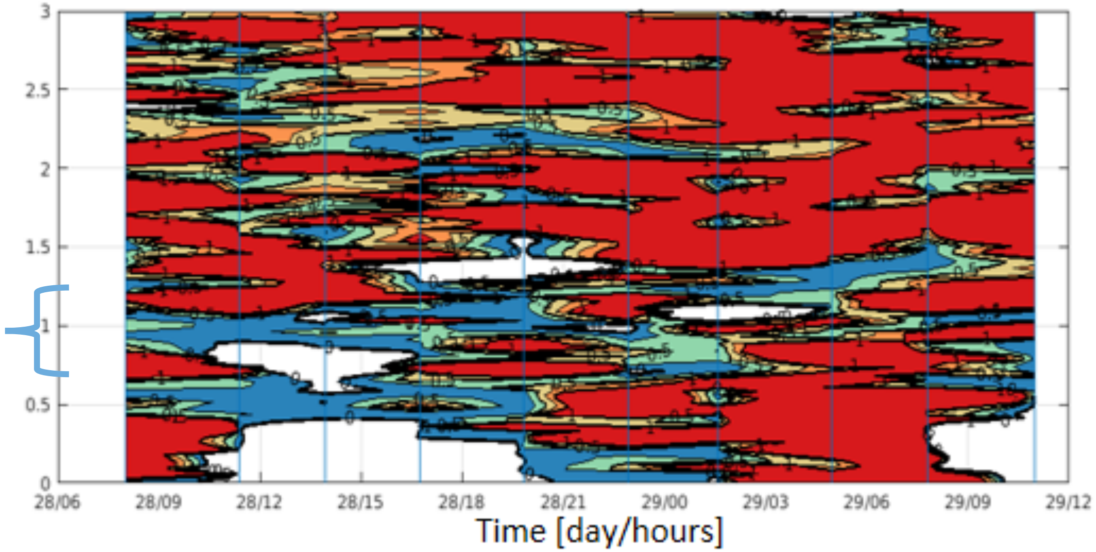


17:00 PDT



f) Richardson RB

RB < 0.5 at crest level



Lessons learned from SWEX

- Sundonwers exhibit spatial and temporal characteristics that depend on topography
- Wind gusts at ground level are associated with the presence and behavior of the nocturnal low-level jet
- The behavior of the nocturnal jet is determined by the combination of radiative cooling, stability and mechanic turbulence
- Wave breaking and critical layer may be important
- These issues are difficult to predict.
- WE NEED A COMPREHENSIVE CAMPAIGN TO IMPROVE UNDERSTANDING AND INCREASE RESILIENCE

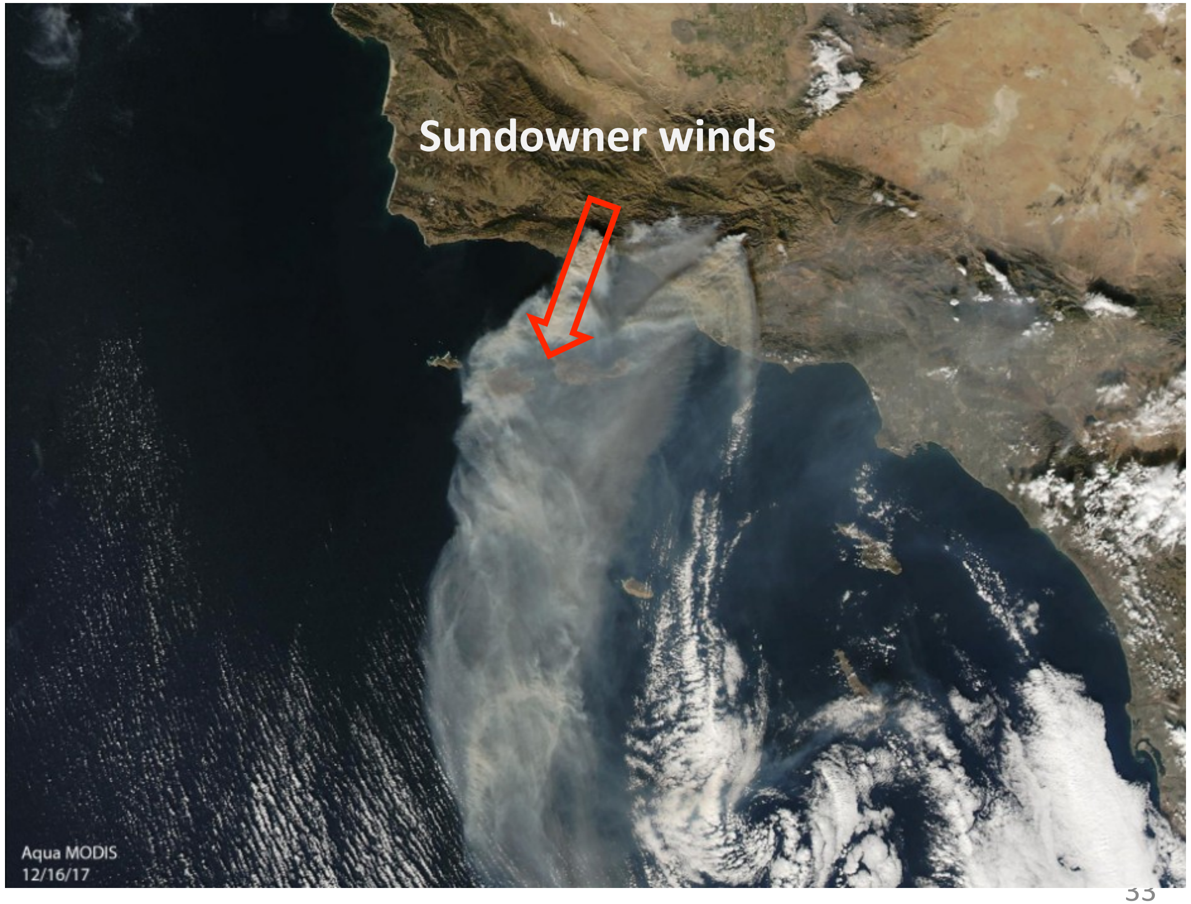
Thanks everyone that participated , collaborated and supported the SWEX mission!

Why do these winds really matter??

Sundowners vs Santa Ana winds

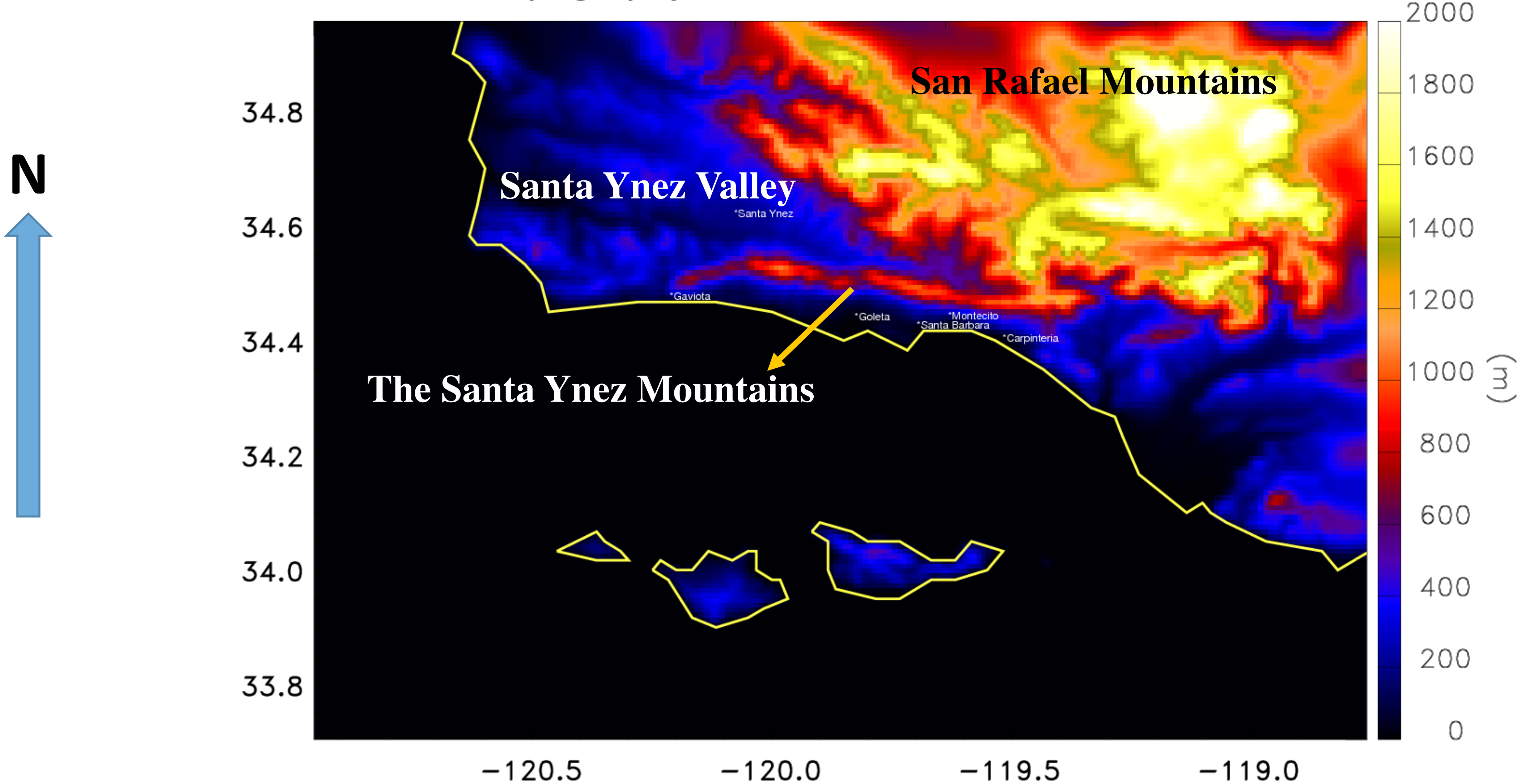
Thomas Fire December 05 2017: Driven by hurricane winds in Ventura: <u>weak onshore winds in Santa Barbara</u>

Thomas Fire affects Montecito: Dec 16 2017: sundowners with gust > 50mi/h

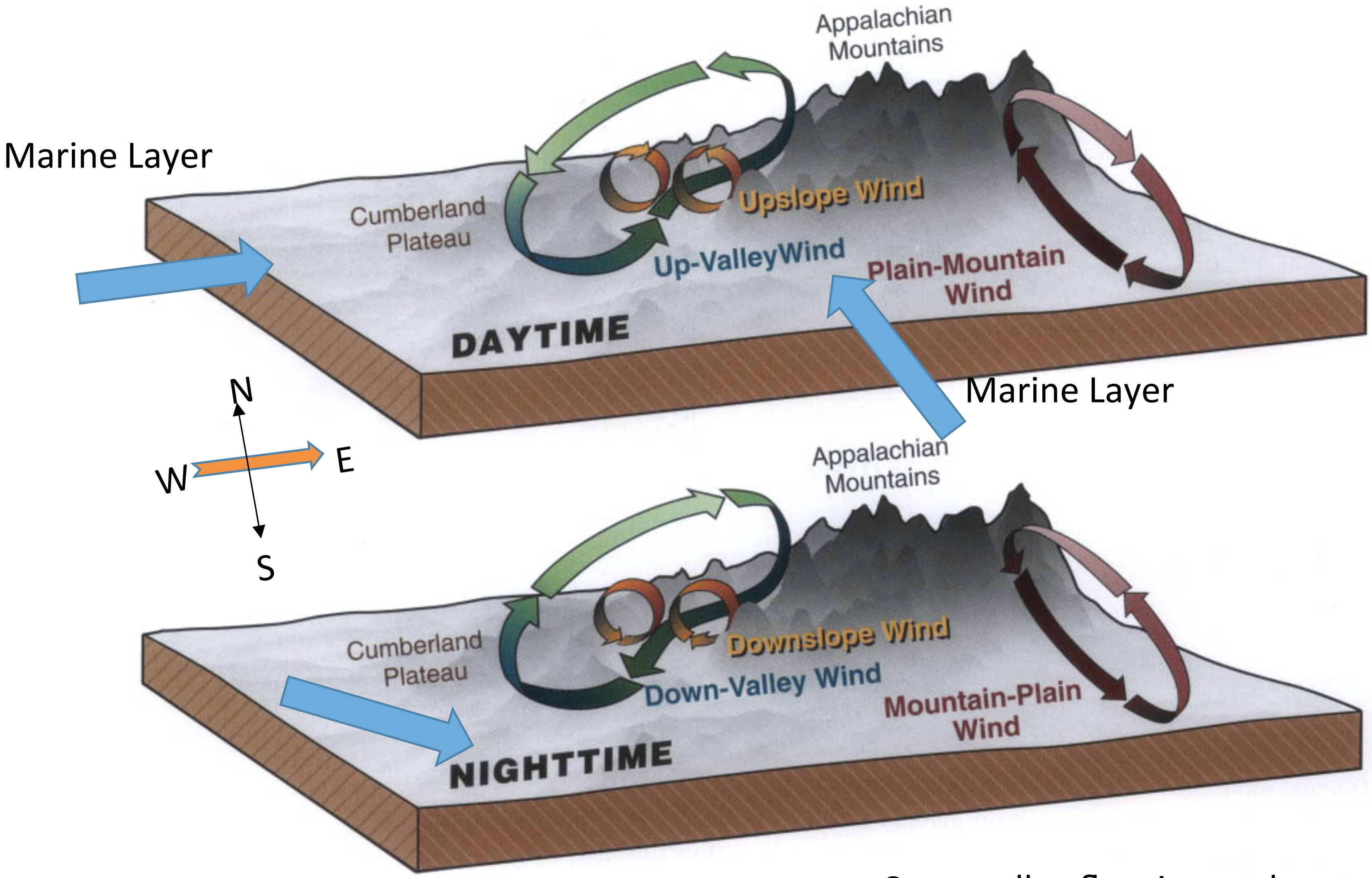


TOPOGRAPHY OF THE SB COAST

WRF 1km topography



Mountain circulation under weak synoptic forcing



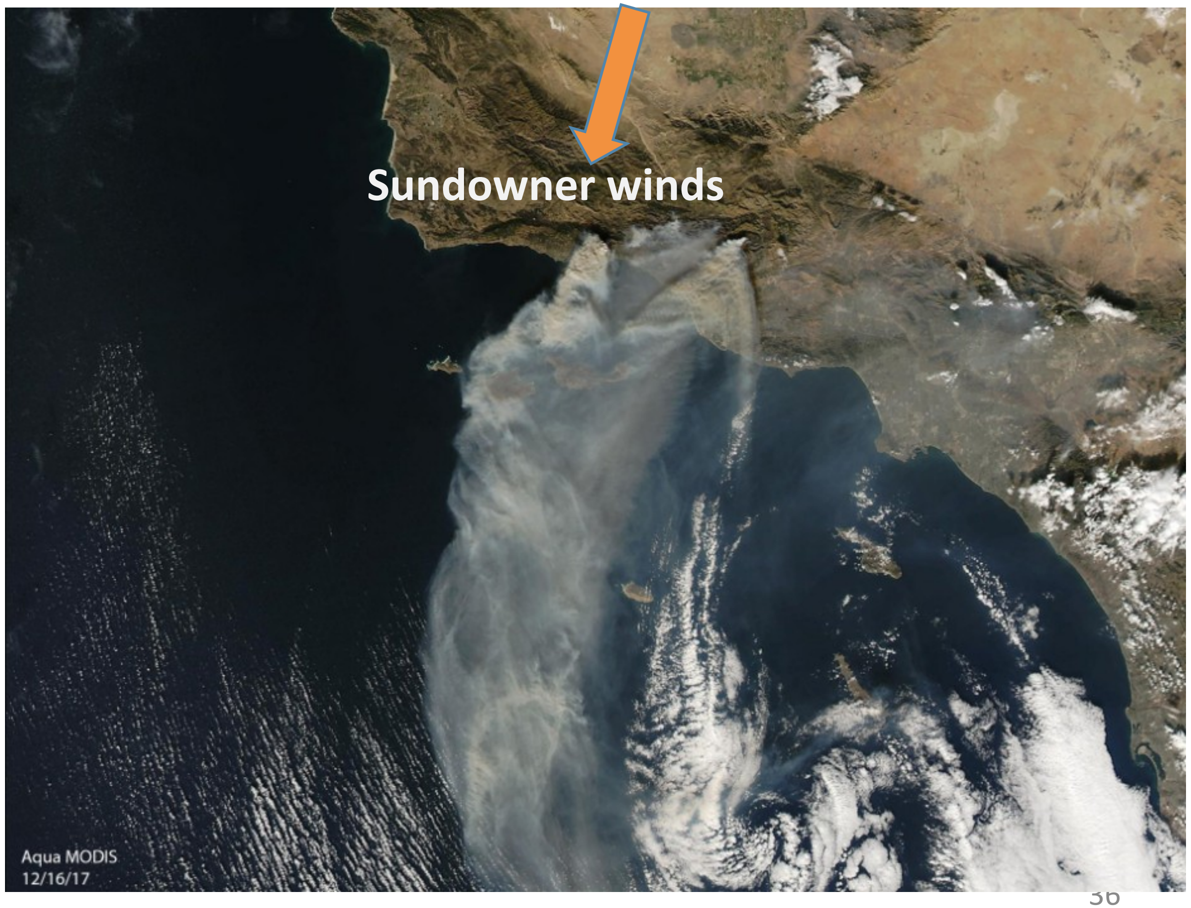
Cross-valley flow is not shown

STRONG SYNOPTIC FORCING

Sundowners vs Santa Ana winds

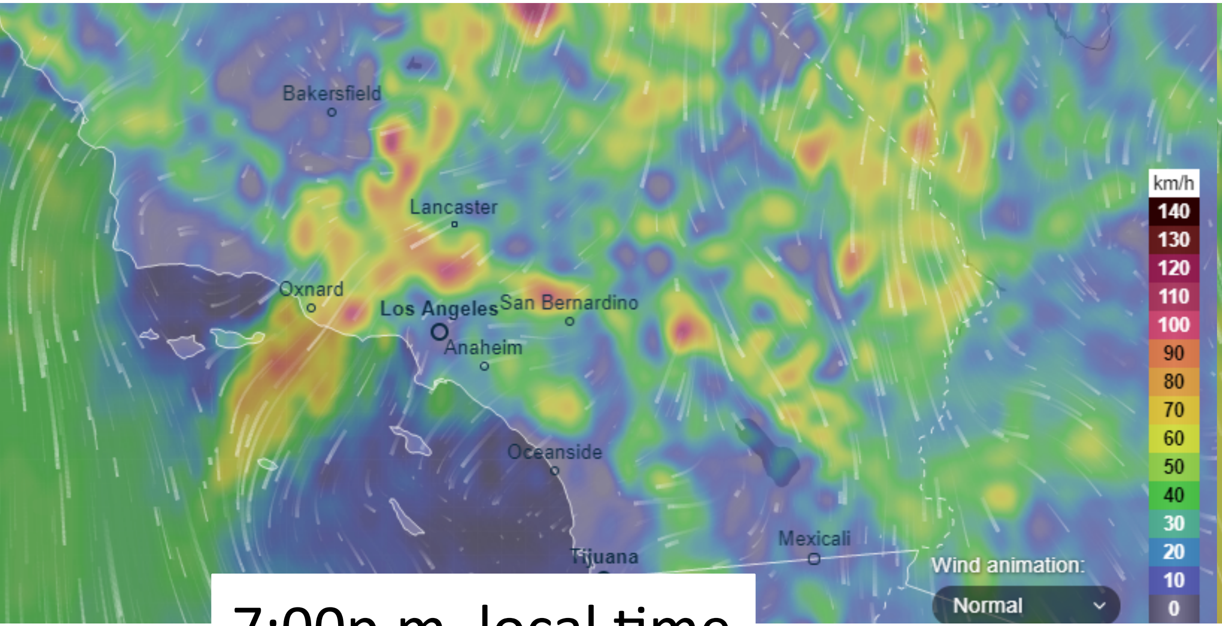
Thomas Fire December 05 2017: Driven by hurricane winds in Ventura: weak onshore winds in Santa Barbara

Thomas Fire affects Montecito: Dec 16 2017: sundowners with gust > 50mi/h



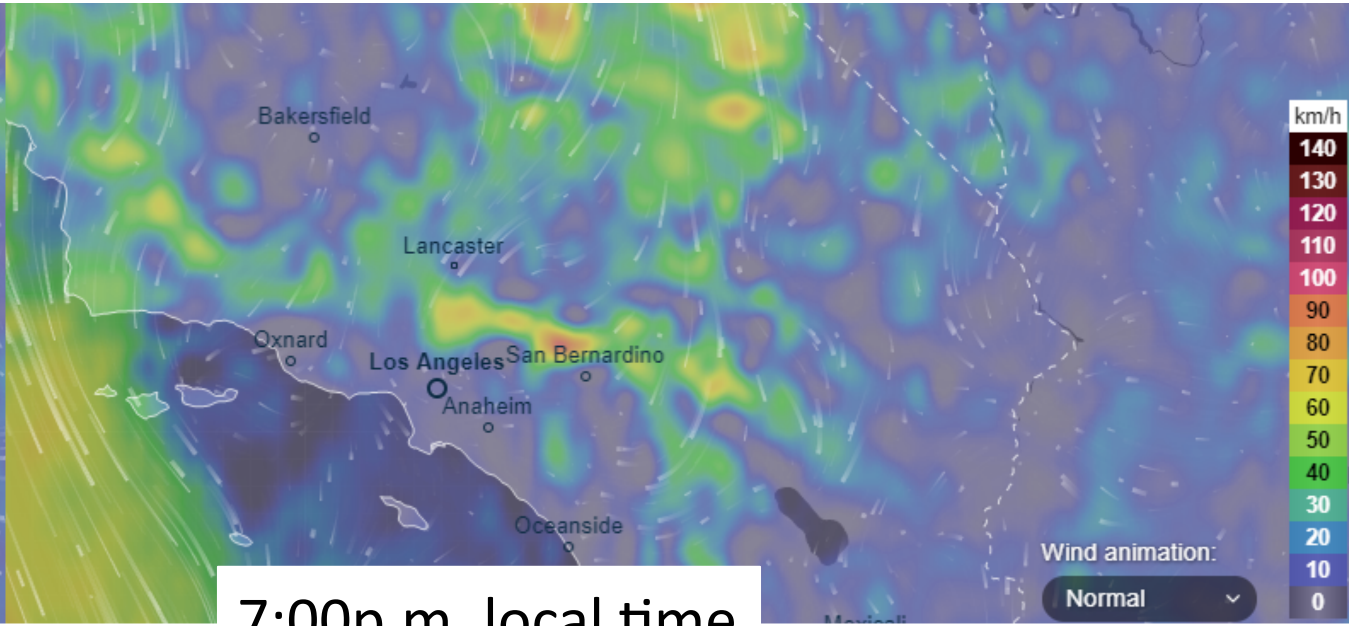
Santa Ana – to – Sundowners (wind gusts km/h)

Santa Ana Wind Regime December 05 2017



7:00p.m. local time

Sundowner wind regime December 16 2017



7:00p.m. local time