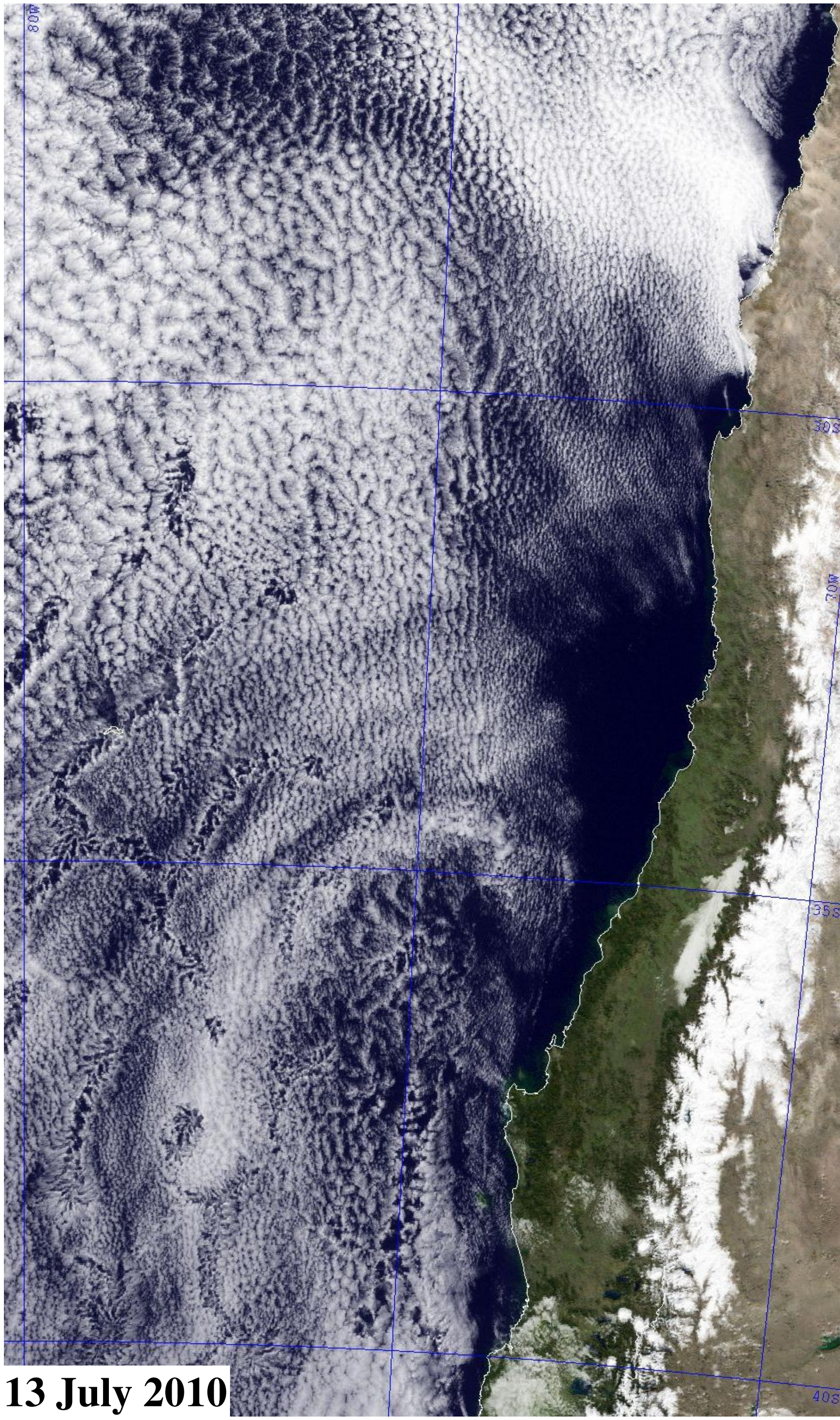

13 July 2010

Daytime coastal jet maximum in central Chile (30°S) during VOCALS-CUpEx

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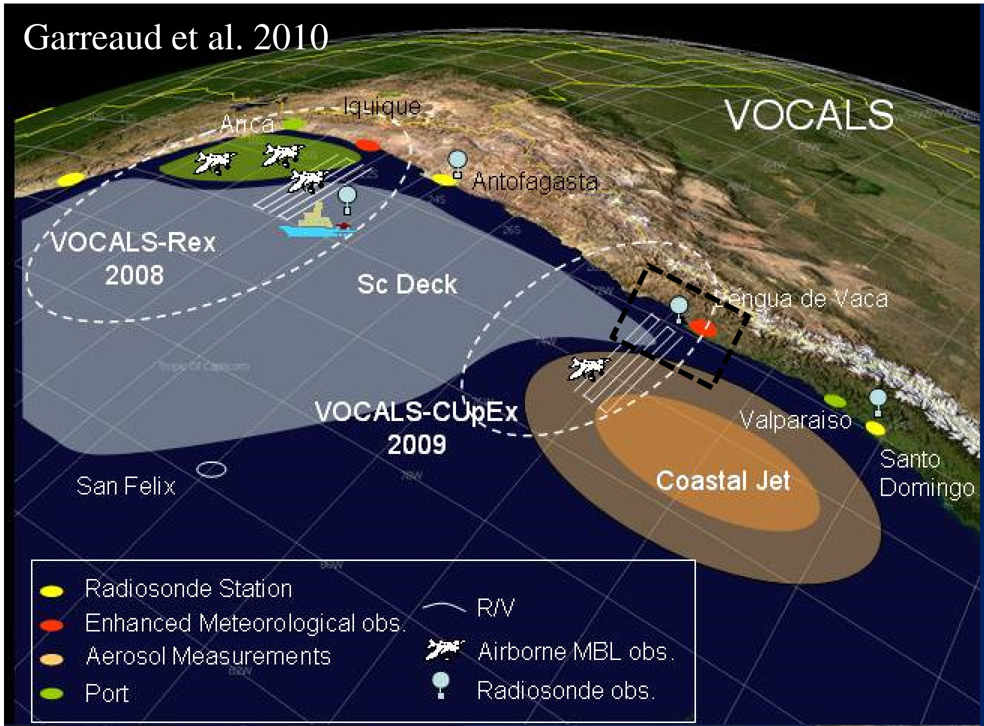
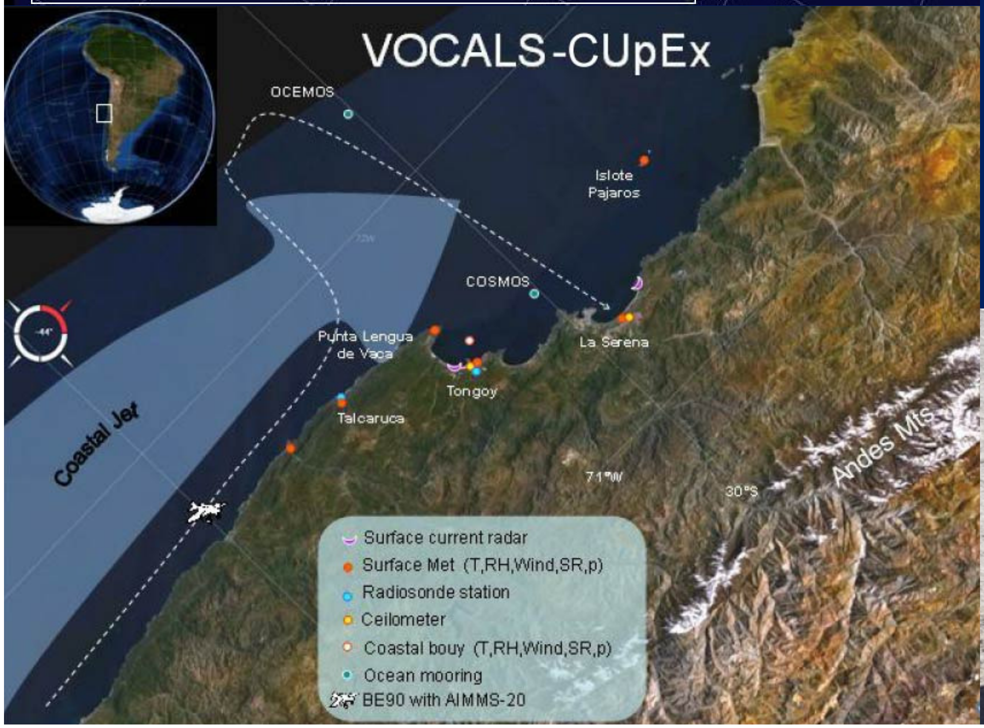




Field campaign

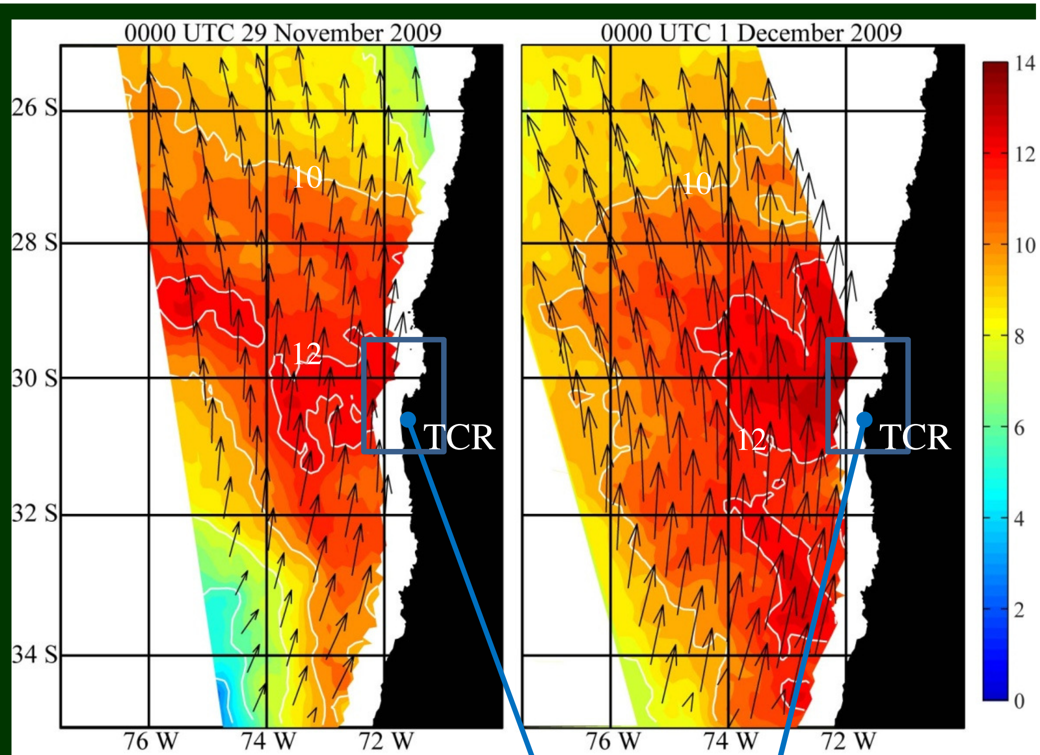
- VOCALS - Chilean Upwelling Experiment (CUpEx)
- Data in a previously under sampled region.
  - Buoy, Ship, Aircraft, Land stations, Radiosonde, Remote Sensing
  - High resolution numerical simulations.
- More details in Garreaud's talk.

- This work addresses the *near shore* coastal jet instead of the more-studied offshore features.

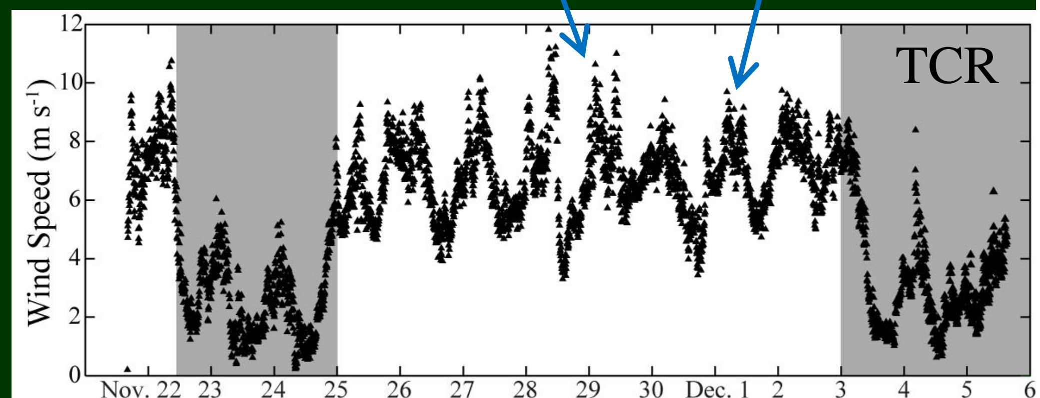
Coastal jet during CUpEx

- Typical offshore low-level jet structure:
  - High wind > 10 m s^{-1}
  - Extends a few hundred kilometers offshore
  - Centered around 30°S.
- High wind period during the intensive observation phase:
  - 25 Nov. – 3 Dec.

- Subsequent analysis is valid for the 8-day high wind period.
  - Characteristic of other high-wind events as indicated by long-term observations.



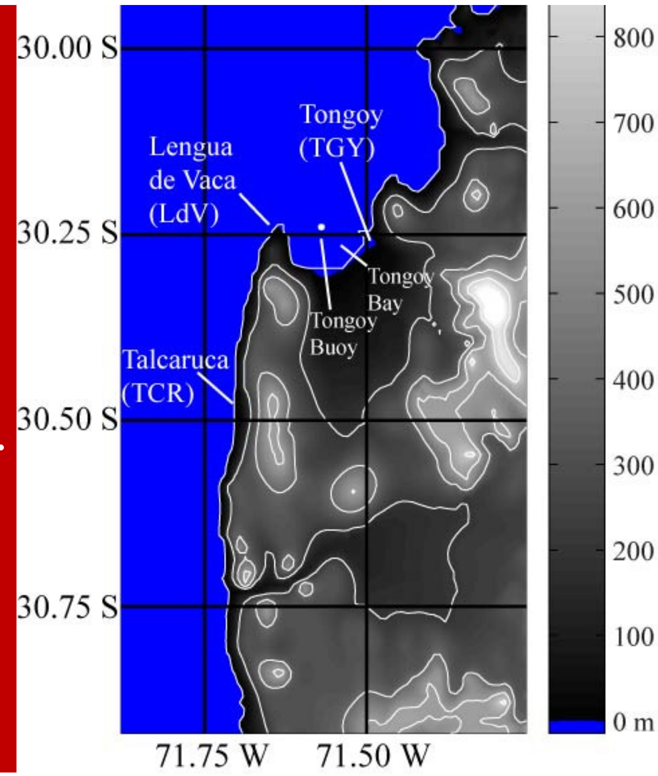
ASCAT 10-m winds (m s^{-1}) during the high wind period.

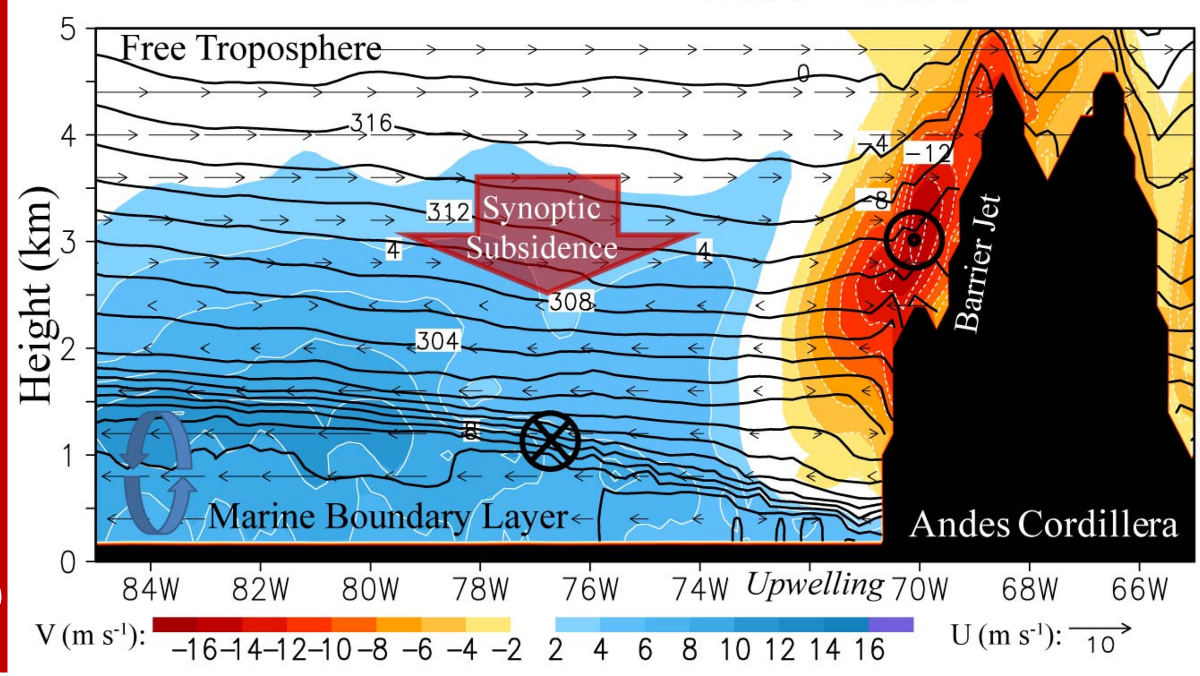


5-minute averaged wind speed (m s^{-1}) at Talcaruca (TCR) during the intensive phase of the field campaign. Shaded regions indicate low-wind periods.

Fluid System

- Three main features:
  - Marine Atmospheric Boundary Layer (MBL)
  - Free troposphere above MBL
  - Coastal mountains
- *Result:* Two layer fluid system with a lateral boundary.
- Supports a wide range of features including:
  - Coastal Lows
  - Coastal Jet
  - Barrier Jet
  - Coastally trapped wind reversals
    - Trapped density current
    - Kelvin wave
    - Ageostrophic response to topography
- Supercritical flow (Fr > 1) allows for hydraulic effects, often used to describe coastal features:
  - Compression bulges.
  - Expansion fans.

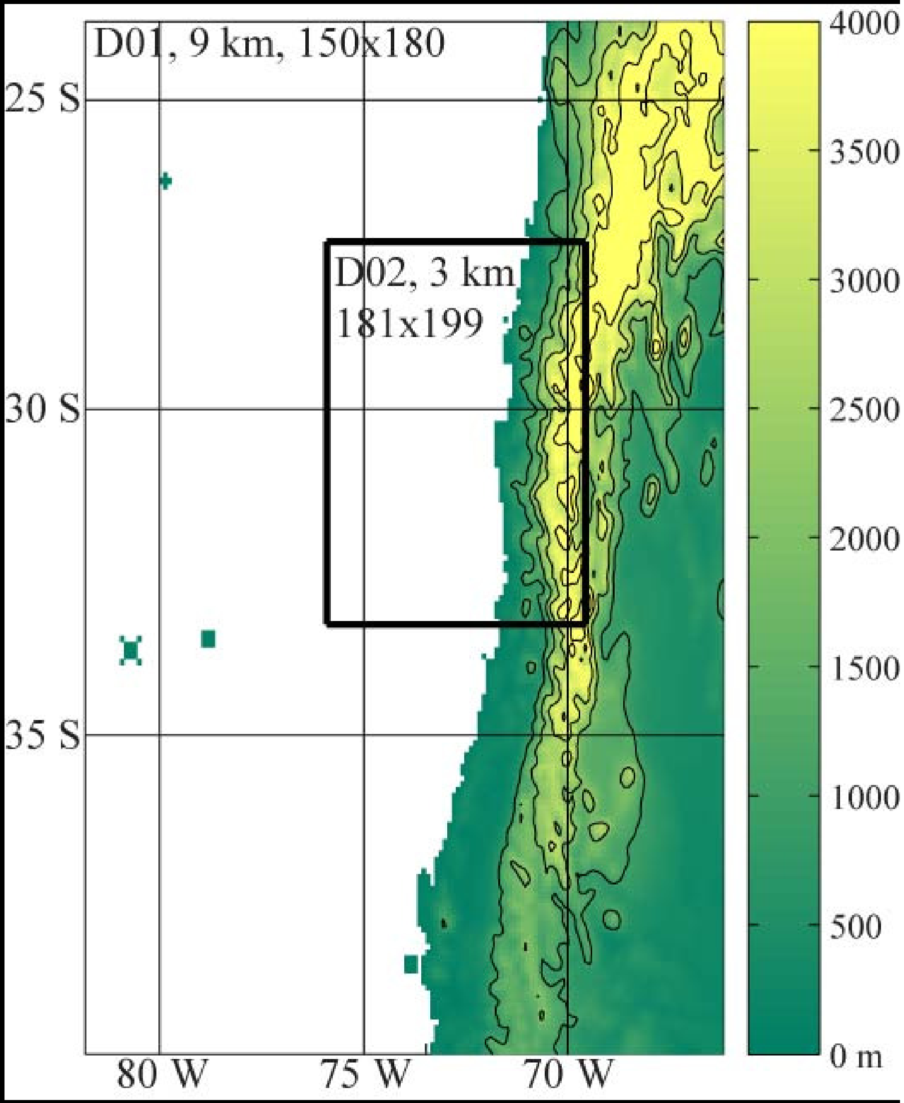




Right: Potential temperature (K, contour) and meridional wind (m s^{-1}, color).

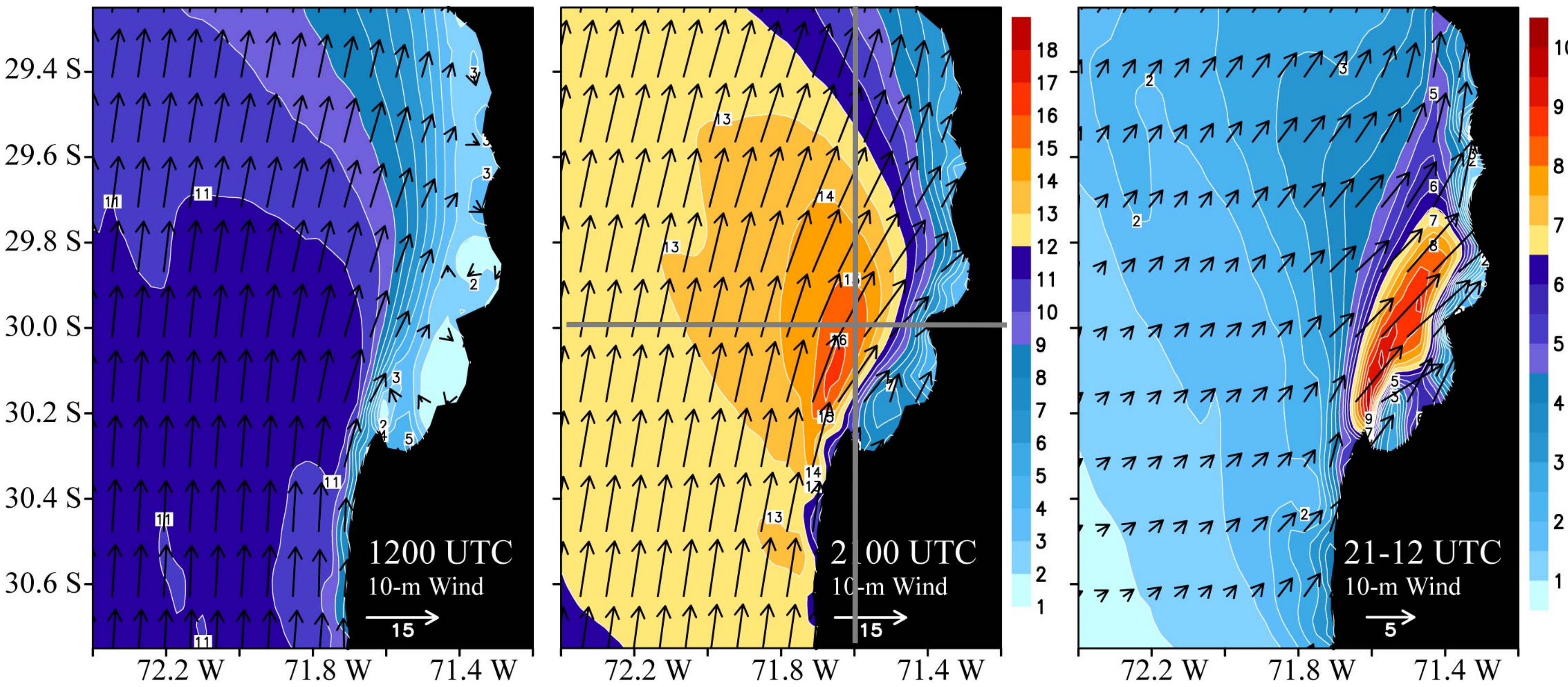
Numerical Simulation

- Weather and Research Forecasting (WRF, v3.1.1) model.
  - Global Forecast System (GFS) analyses (1°x1°) for initialization/B.C.'s
  - 0000 UTC 20 October 2009 to 0000 UTC 6 December 2009
  - Mother Domain: 9 km
  - Inner Domain: 3 km
  - Vertical Levels: 56 sigma
    - ~60 m at 1 km
    - ~100 m at 2 km
  - Parameters
    - Thompson microphysics
    - Rapid radiative transfer model for longwave radiation
    - Dudhia for shortwave radiation
    - Monin-Obukhov (Janjic) surface scheme
    - Pleim land-surface model
    - Mellor-Yamada-Janjic boundary layer
    - Betts-Miller-Janjic cumulus scheme
    - Second order turbulence and mixing
    - Horizontal Smagorinsky first-order closure eddy coefficient.



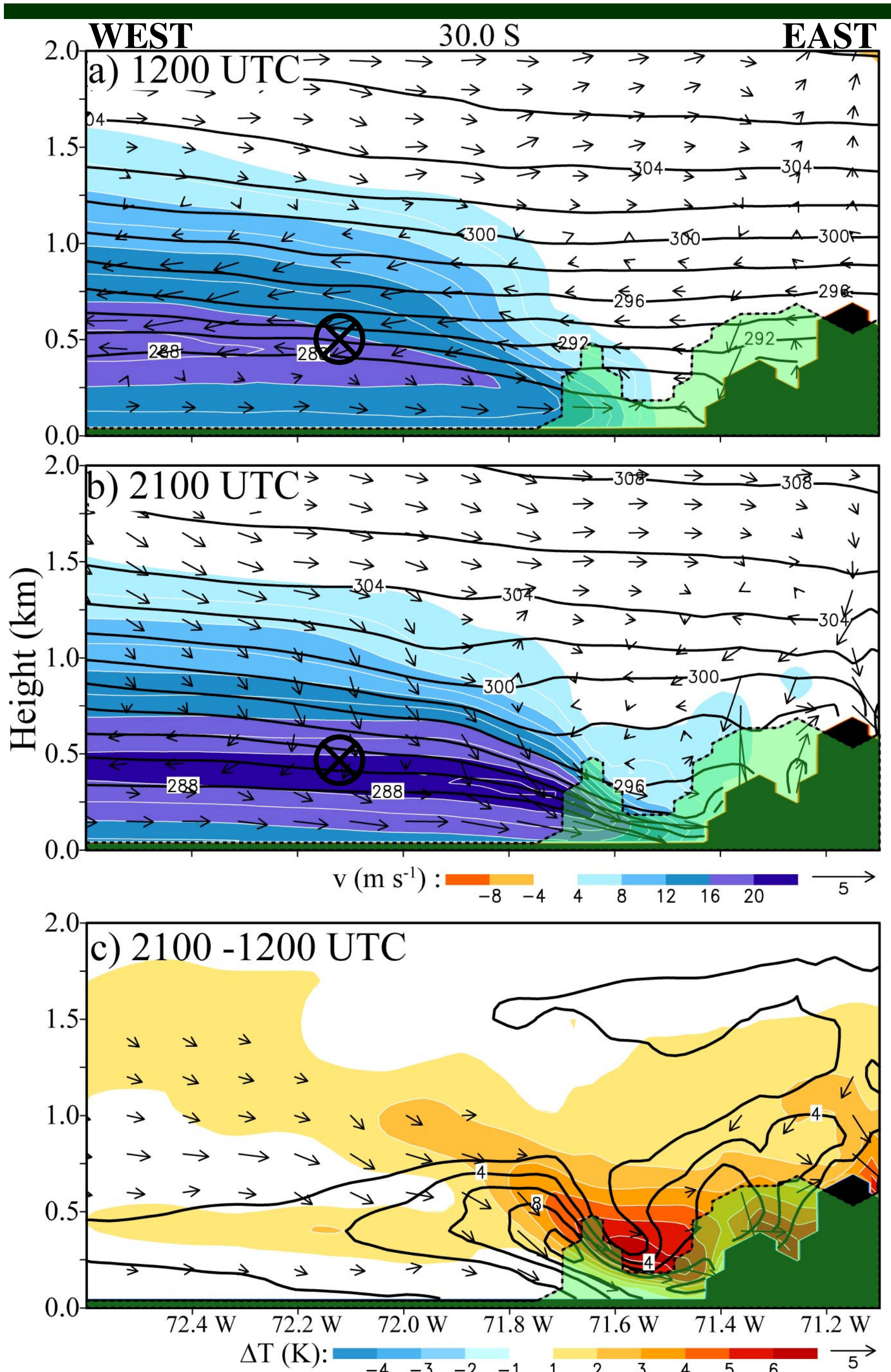
Mean simulated 10-m wind

- 1200 UTC
  - Minimum (~11 m s^{-1})
  - Acceleration (directional) into Tongoy Bay.
  - Large west-east gradient into bay.
  - Characteristics suggest an expansion fan.
- 2100 UTC
  - General increase ~2 m s^{-1} in the entire coastal region.
  - Development of *local* maximum (~16 m s^{-1}) north of Lengua de Vaca (LdV)
  - Increases 3-10 m s^{-1}
    - Increase of wind
    - Displacement into the Bay



Left: Average 10-m wind (m s^{-1}) from model.

1° ≈ 100 km



Mean zonal cross section

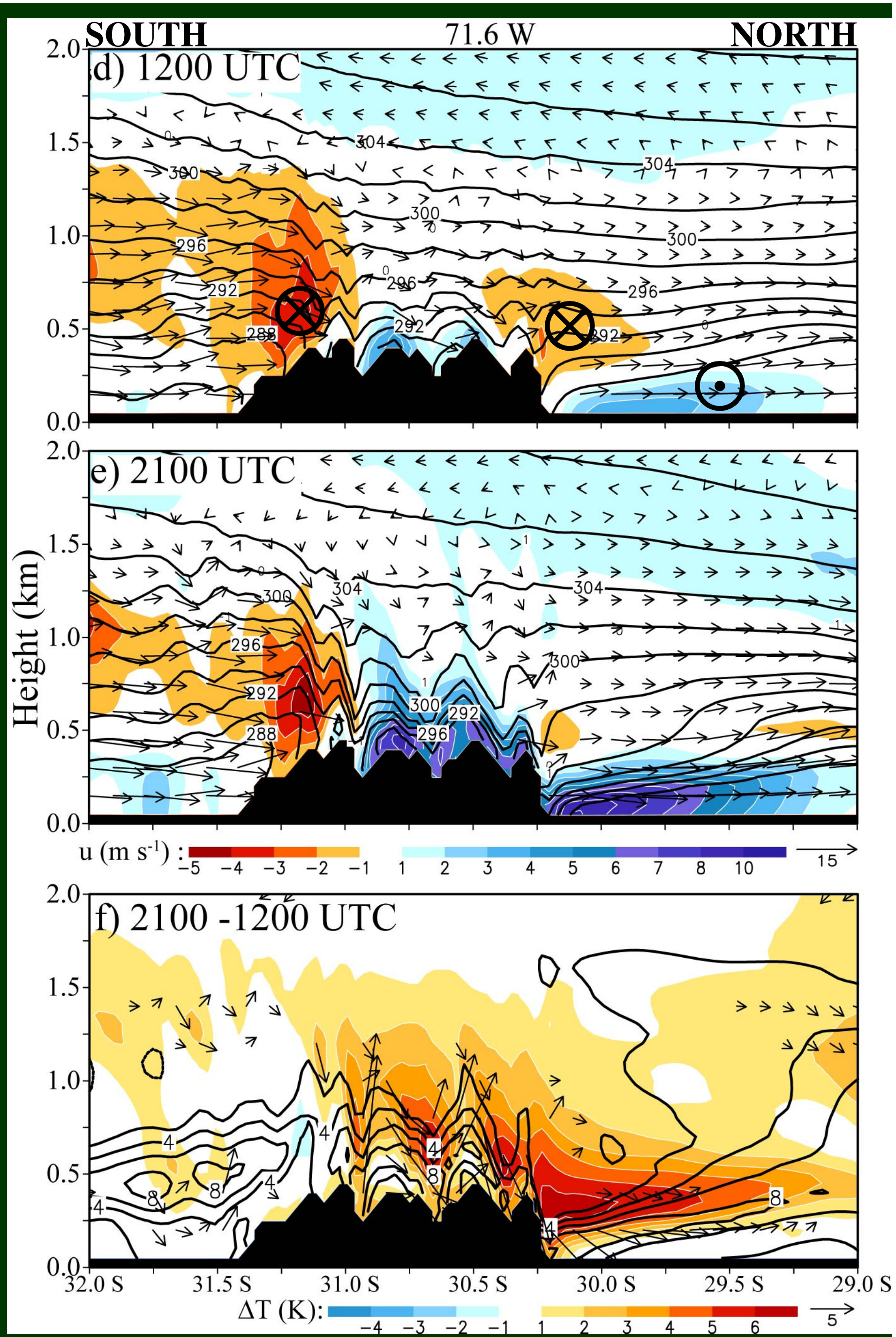
- Typical jet structure
  - Maximum at inversion base
  - MBL sloping down toward coast

- Diurnal difference
  - Maximum daytime heating (~6 K) over the bay collocated with the valley to the south.
  - Maximum increase in jet (10 m s^{-1}) concentrated north of point LdV.

Left: Meridional wind speed (m s^{-1}, color), in-the-plane (u, z) vectors (m s^{-1}), and potential temperature (K, contours) along 30°S (terrain at 30.4°S depicted by transparent green silhouette) at (a) 1200 UTC and (b) 2100 UTC. (c) 2100 – 1200 UTC potential temperature difference (K, color), meridional difference (m s^{-1}, contours), and in-the-plane (u,z) vector difference (m s^{-1}).

Mean meridional cross section

- General structure
  - Southerly wind under 1.5 km.
  - Westerly wind (onshore) in the bay.
  - Minimum in MBL depth in the southern part of the Bay.
- Diurnal difference
  - Daytime heating extends far offshore and rides above the MBL in the bay.
  - Increase in the westward wind over the bay (~6 m s^{-1}).

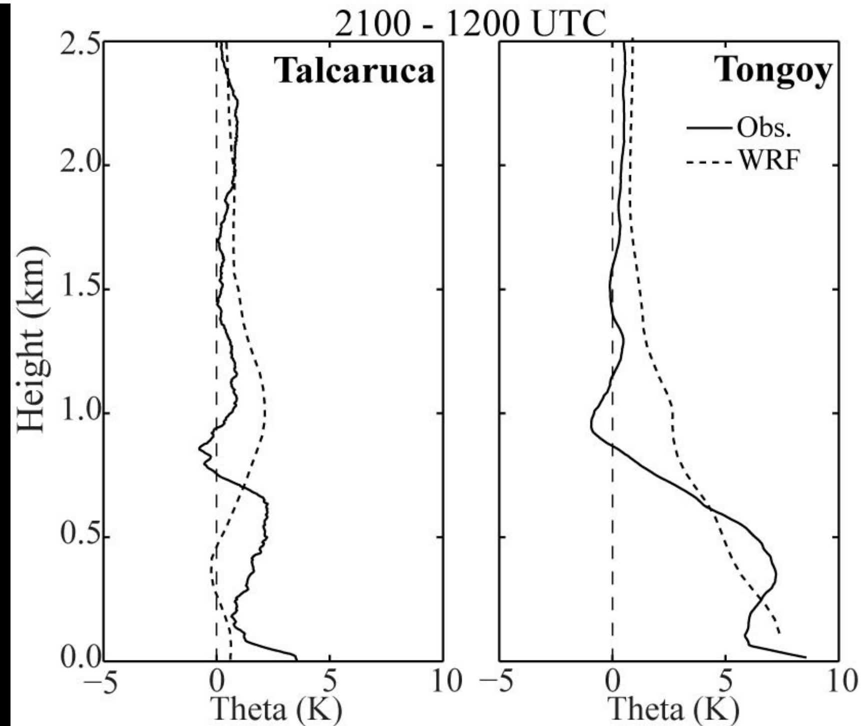


Right: Zonal wind speed (m s^{-1}, color), in-the-plane (v, z) vectors (m s^{-1}), and potential temperature (K, contours) along 71.6°W at (d) 1200 UTC and (e) 2100 UTC. (f) 2100 – 1200 UTC potential temperature difference (K, color), meridional difference (m s^{-1}, contours), and in-the-plane (v,z) vector difference (m s^{-1}).

Pressure response

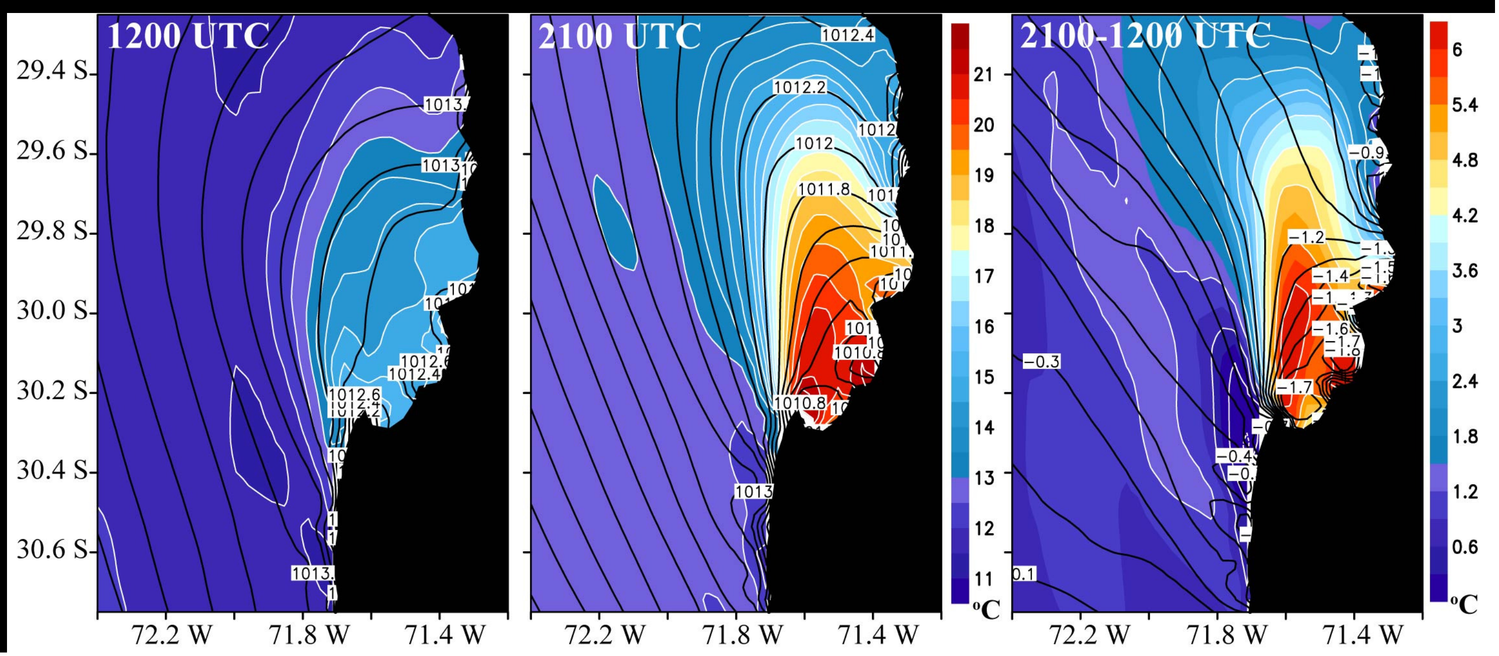
- Over Tongoy Bay
  - Afternoon surface pressure drops rapidly in the bay under the warming temperatures.
- Offshore
  - Small changes in temperature and surface pressure.
- *Result*: a large localized gradient along coastal range axis.

- 5 K warming in a 500 m column produces a surface pressure drop of ~1 hPa.



Above: Average diurnal temperature difference.

Right: The mean 300-m temperature (°C, color) and surface pressure (hPa, contours).

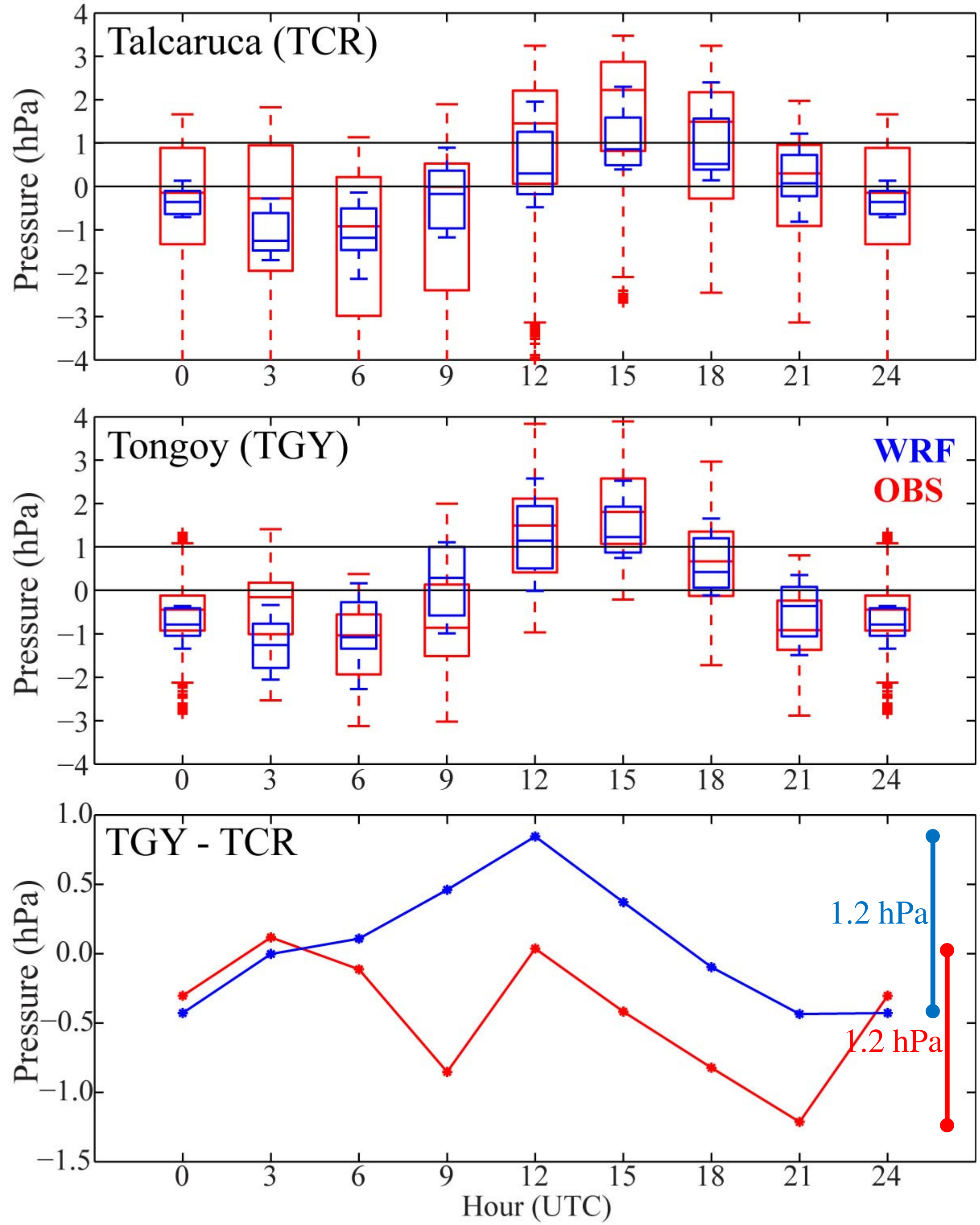


Diurnal pressure differences

- Data from high wind period.
- Mean removed from model and observations from both stations to remove offsets.

- Range and diurnal cycle of observations and model agree well from 12 to 21 UTC.
  - *Discrepancy at 0900 UTC.*

- From 12 to 21 UTC pressure difference decreases 1.2 hPa indicating pressure drops faster in TGY.
  - Remaining (~0.4 hPa) drop likely from regional diurnal tide that impacts both sites.



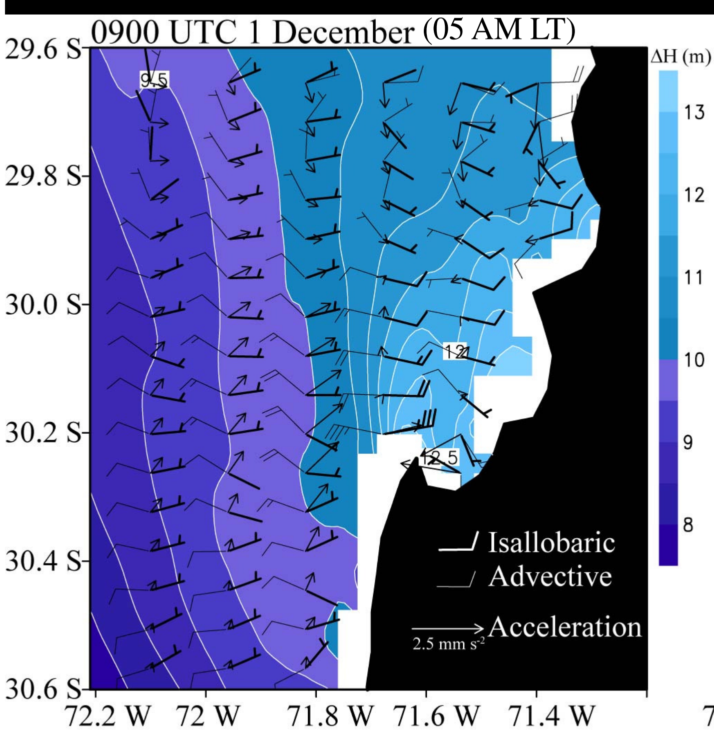
Ageostrophic Wind

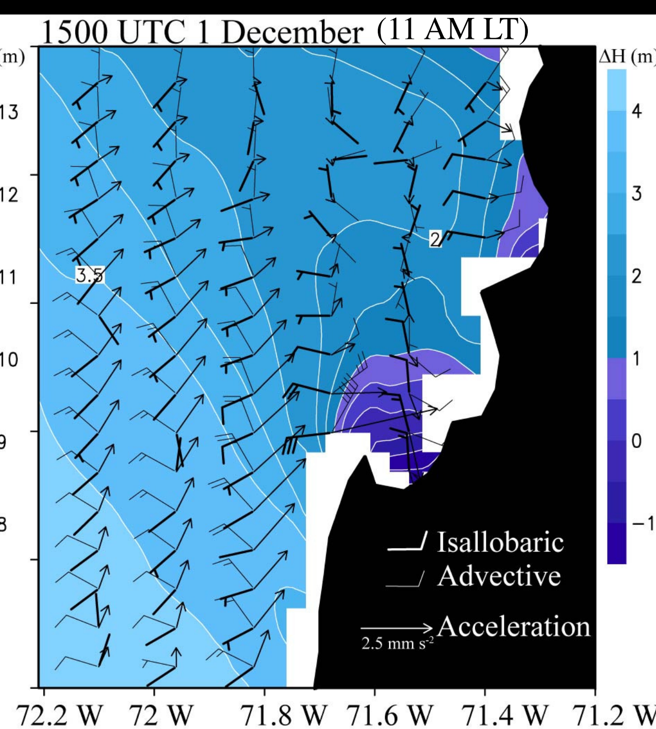
$$\mathbf{V_a} = \frac{1}{f}\left[\underbrace{\mathbf{k}\times\left(\mathbf{V}_g \bullet \nabla\right)\mathbf{V}_g}_{(1)} + \underbrace{\mathbf{k}\times\frac{\partial \mathbf{V}_g}{\partial t}}_{(2)}\right]$$

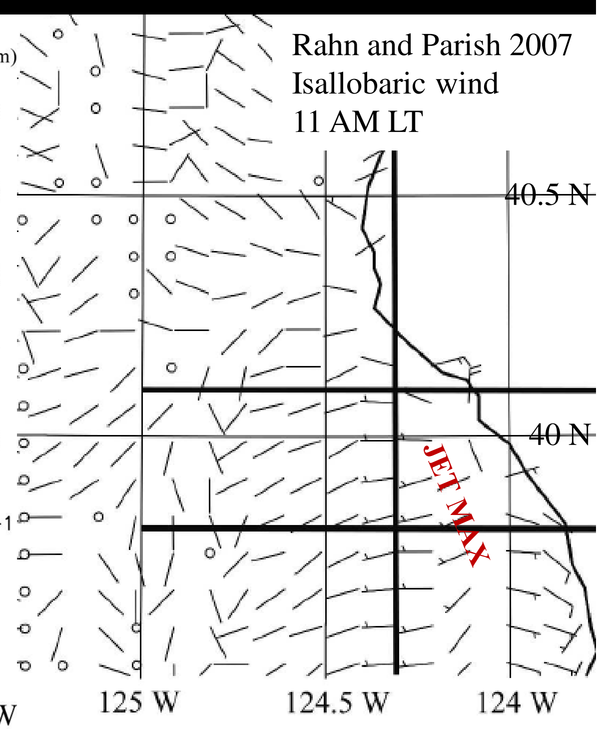
- Acceleration to the left of ageostrophic wind.
- Advective component: Northwest ~20 m s^{-1}
  - Large in the vicinity of large PGF gradients
- Isallobaric component:
  - Large changes indicates change in pressure gradient force over time.
  - Morning: east, acceleration southward
  - Afternoon: west, acceleration northward

$\mathbf{V_a}$: Ageostrophic wind
f: Coriolis Parameter
$\mathbf{V_g}$: Geostrophic Wind

(1) Advective Component
(2) Isallobaric Component

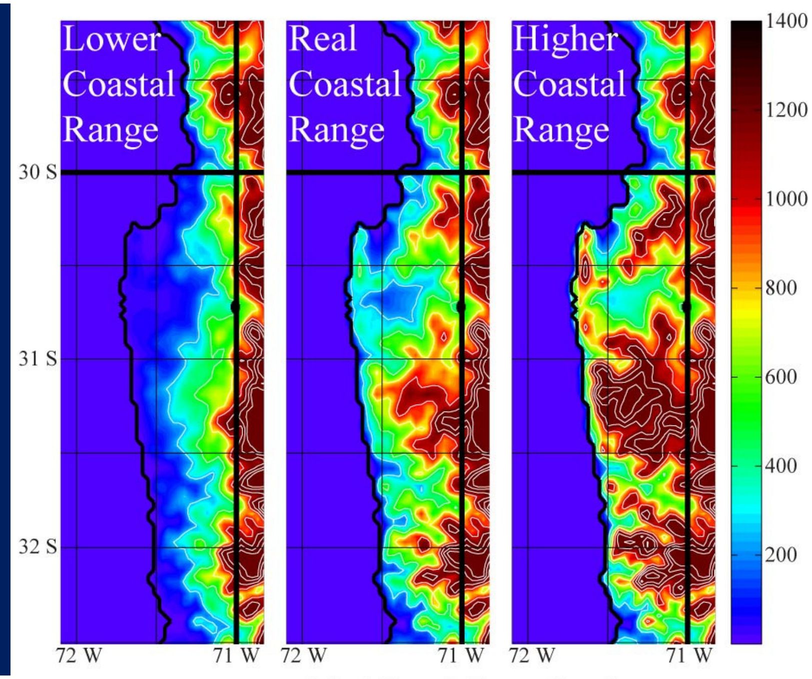


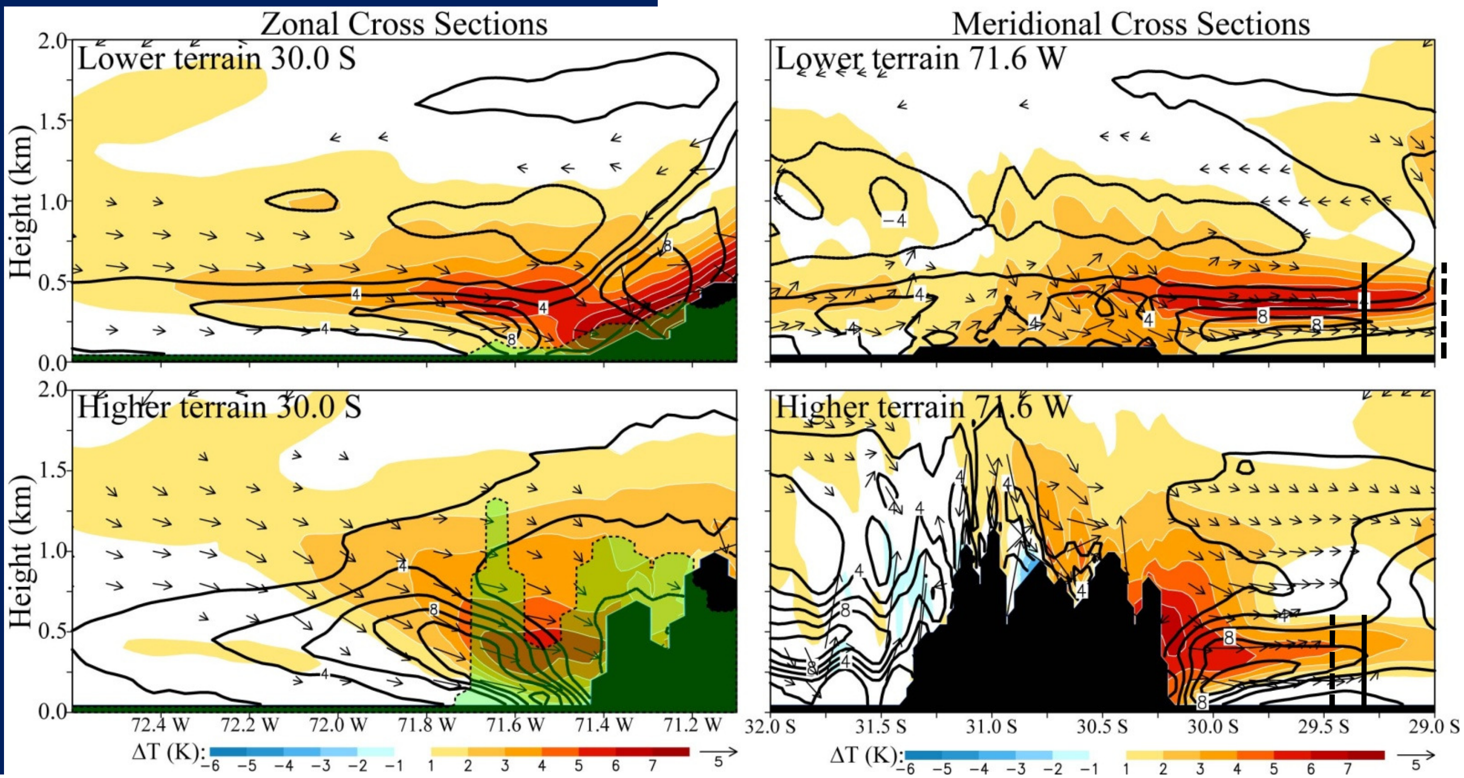




Topography Modification

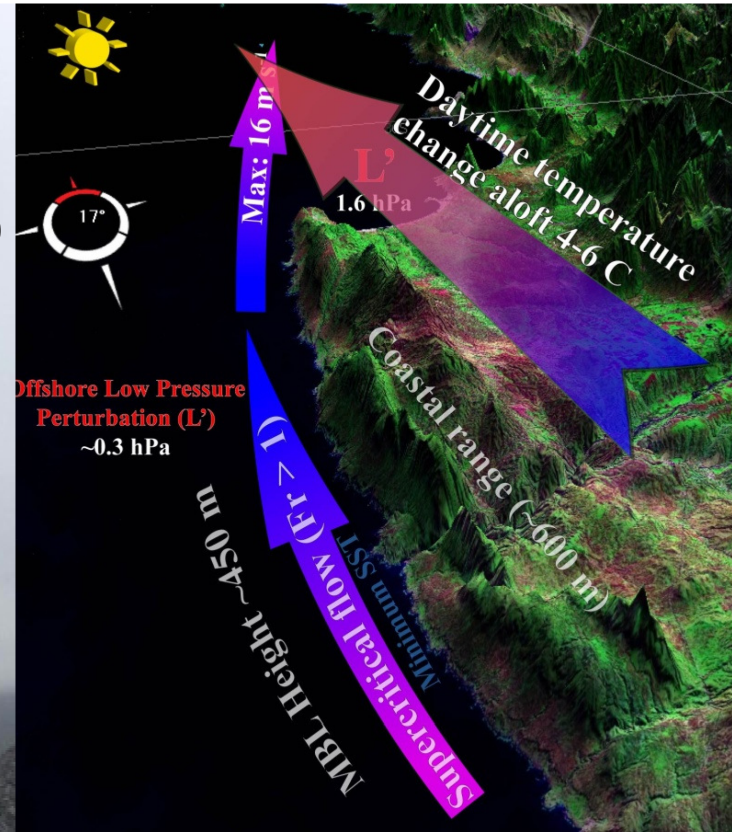
- Remove coastal range
  - Maximum change 8 m s^{-1}
  - Greater northward extent of warming
- Enhance coastal topography
  - Maximum change >10 m s^{-1}
  - Smaller northward extent of warming
- Even with modification, the maximum exists.
- Changes of topography impact the temperature gradient/ surface pressure.





Summary

- Local 10-m wind maximum (~16 m s^{-1}) in the afternoon extending ~60 km north of LdV.
- Induced by enhanced zonal gradient:
  - Small T/p changes offshore
  - Large T/p changes over the bay
    - Warm air (+4-6 K) advected above Tongoy Bay from the valley to the south.
    - Average pressure difference 1.6 hPa at TGY
      - ~1.2 hPa from ΔT
      - ~0.4 hPa from regional diurnal tides



- Isallobaric components illustrate the contribution of pressure changes over time.
  - Late Morning: Large northward acceleration
  - Late Night: Large southward acceleration

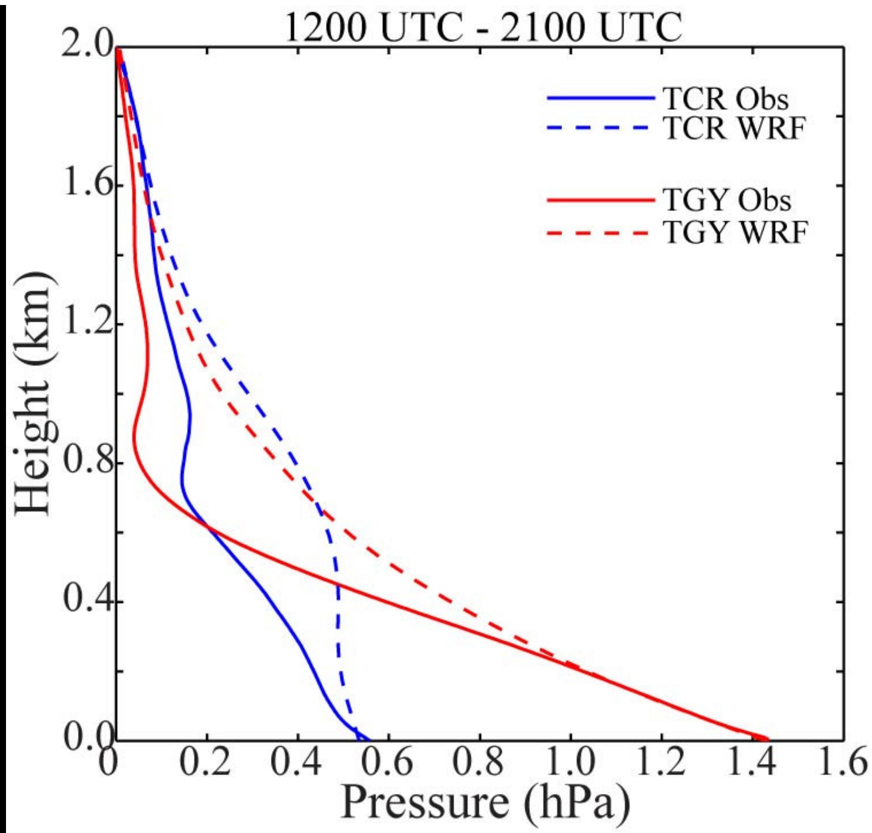
Conclusions

- Basic thermal differences dominate the forcing of the jet maximum in the afternoon.
  - Not dominated by expansion fan dynamics!
- Topography sensitivity tests suggest wind maximum exists regardless if the terrain is present, but:
  - Coastal range *enhances* the local temperature (pressure) gradient that drives the daytime maximum north of LdV.
  - Topography *inversely* proportional to northward extent of high winds.
    - High topography blocks southerly wind.
- Ongoing work…
  - Surface stations continue to record data
    - Long-term variability
  - Aircraft measurements along the coast and in Tongoy Bay.
  - Implication on ocean circulation in the bay.
    - Wind stress
    - Wind stress curl

http://www.dgf.uchile.cl/~darahn/

Pressure contribution calculated from ΔT

- Pressure profile calculated using the hypsometric equation and iterating down.
  - Same starting point, but using the different temperature profiles.
  - Note: Maximum change at coast! Farther north into the bay it decreases (especially were the MBL). Farther into the bay/offshore, more like 1 hPa.
- While the path is not equal, model and observations reach the same surface pressure change.
- Resulting pressure difference from morning to night: ~1 hPa.



$$\frac{p_1}{p_2} = e^{\frac{g}{RT_v}(z_2 - z_1)}$$

p: pressure
z: height
g: gravity
R: dry gas constant
T_v: virtual temperature

Froude Number

$$Fr = \frac{U}{\sqrt{g'H}}$$

$$g' = \frac{\theta_{inversion\_top} - \theta_{MBL}}{\theta_{MBL}}$$

– Supercritical (>1) can support hydraulic features.

- Both model and observations indicate supercritical numbers during the high-wind period.