

A synthesis of published VOCALS studies on marine boundary layer and cloud structure along 20S

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Work summarized

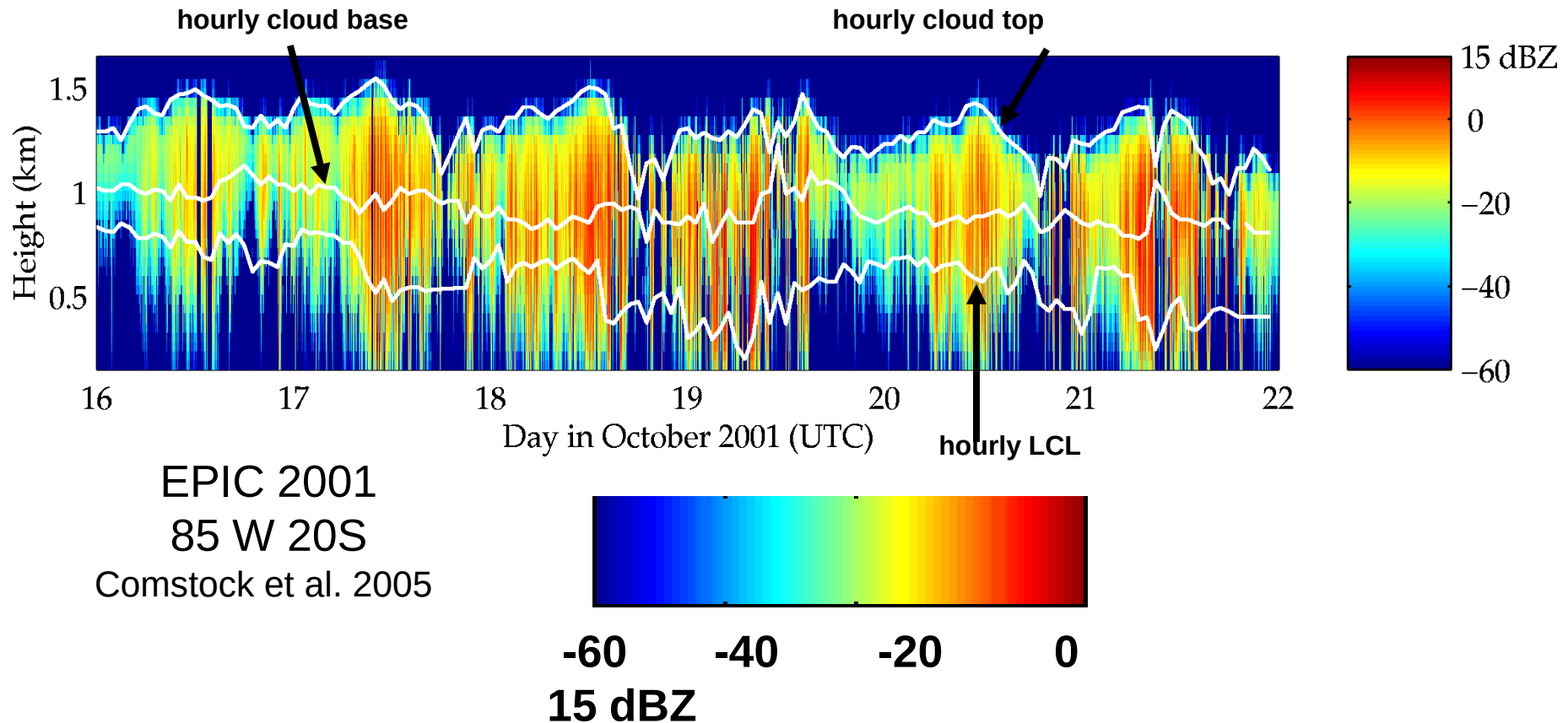
- Pre-REx
- Rahn and Garreaud, ACP, 10, 4491–4519, 2010 (Parts 1&2)
- Bretherton et al., ACP 2010
- Abel, Walters, Allen, ACP, 10, 10541–10559, 2010
- Jones, Breth, Leon, ACPD, 11, 8431-8460, 2011

Note: This is not comprehensive! Other relevant papers show interesting data analysis along 20S, esp. using Ron Brown data.

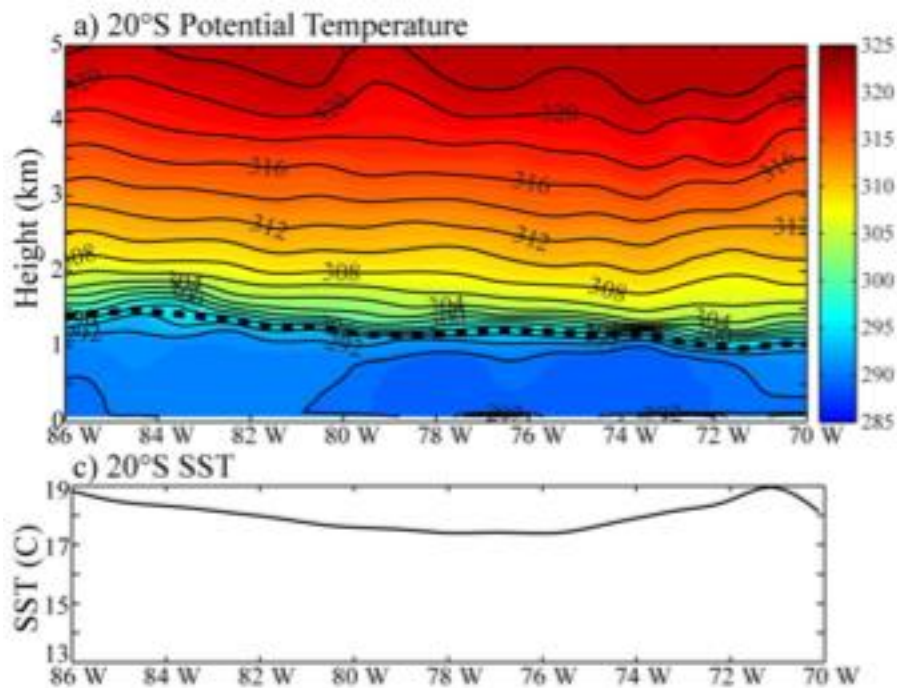
20S MBL/cloud structure studies support the VOCALS aerosol/cloud/precipitation theme and the modeling program

Key Pre-REx findings

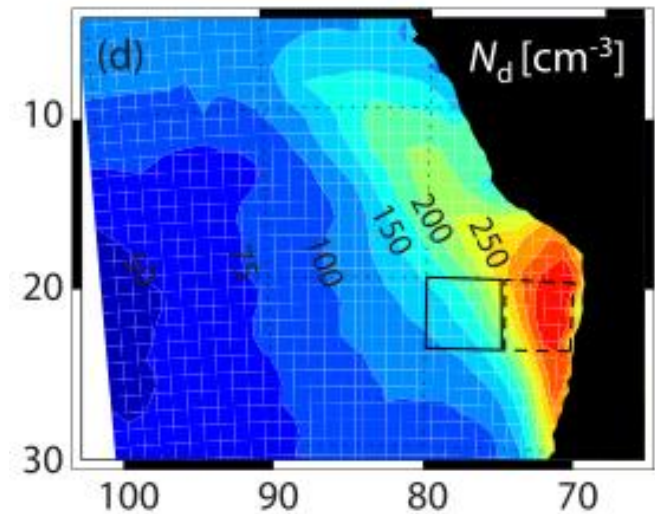
- Significant drizzle at 85W (Bretherton et al. 2004)
- Strong diurnal cycle of cloud thickness affected by Andean upsidence wave (Garreaud and Munoz 2004)



- More CCN/cloud droplets near coast
(Tomlinson et al. 2007; Wood et al. 2008)
- Boundary layer deeper offshore
(Serpetzoglou et al. 2008; Zuidema et al. 2009)



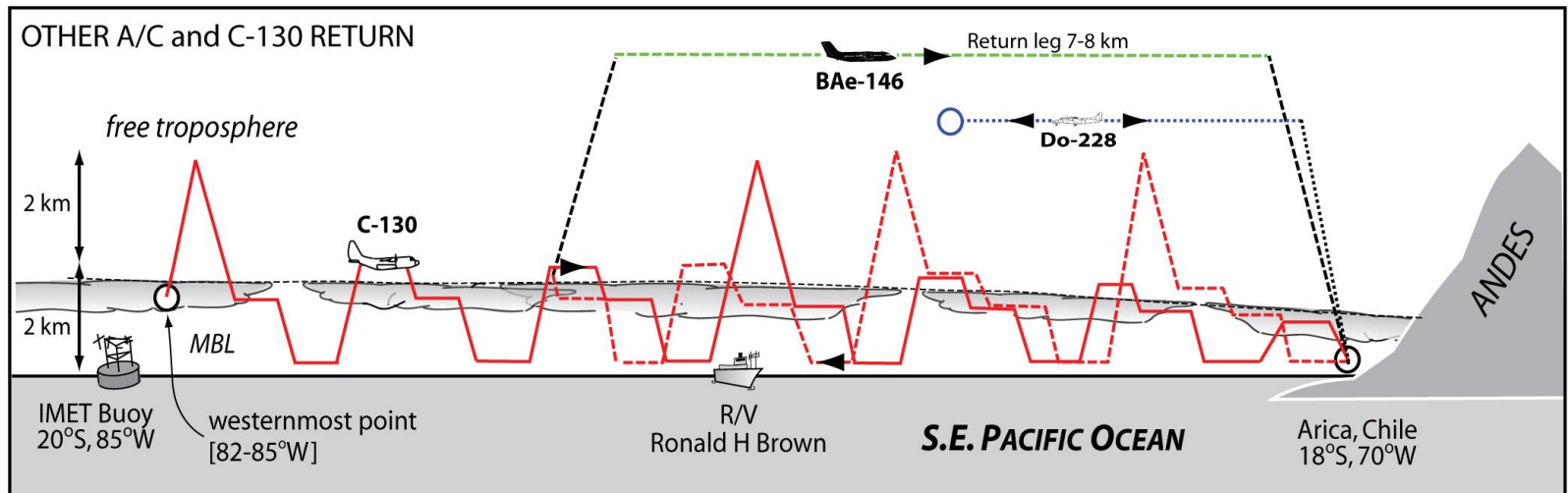
Rahn and Garreaud 2010



Wood et al. 2008

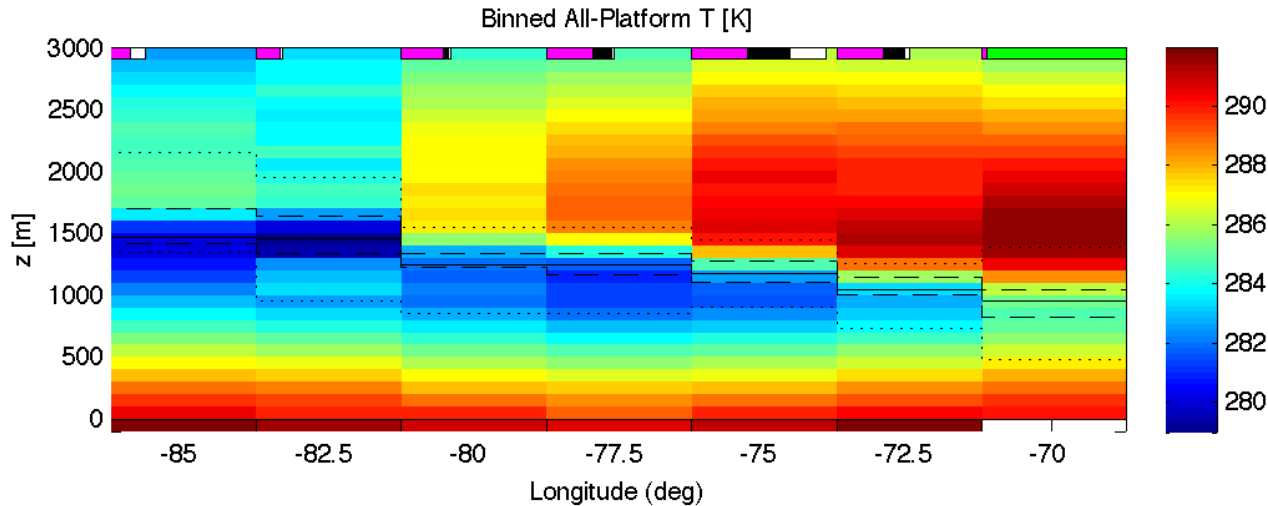
REx 20S measurements

- **Comprehensively** document structure of CTBL and lower troposphere along 20S - vertical structure, microphysics &/drizzle, aerosols & chemistry, radiation, turbulence.
- Use **multiplatform observations** (C130, BAe146, Twin Otter aircraft, Ron Brown ship, Iquique soundings).
- Repeat often enough to obtain a **climatologically representative** data set for comparison with climate models.



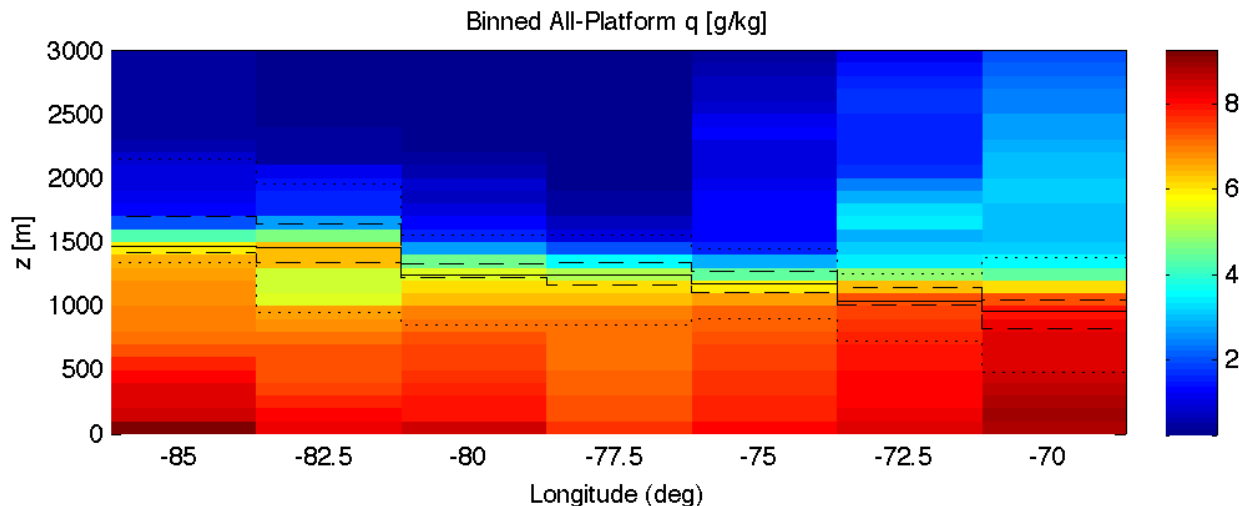
Monthly-mean T, q profiles

Weighted average of C130, 146 dropsonde, Brown, Iquique



10K inversion:
sharp,
~ 1000 m at coast
~ 1600 m at 85W

Free trop warmer
near S Amer coast

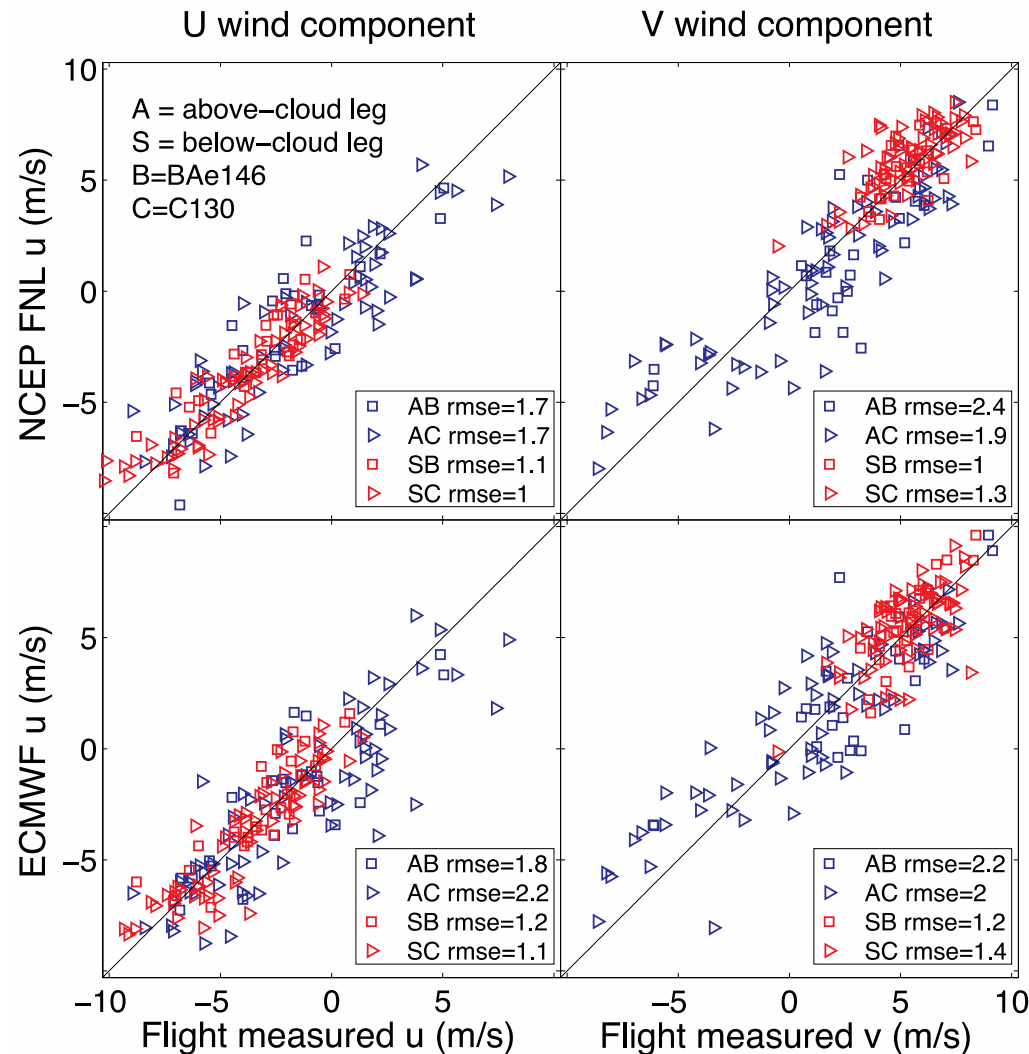


PBL well-mixed to 80W,
more decoupled in
'remote' 80-85W zone

Free trop moist near
coast but very dry
offshore

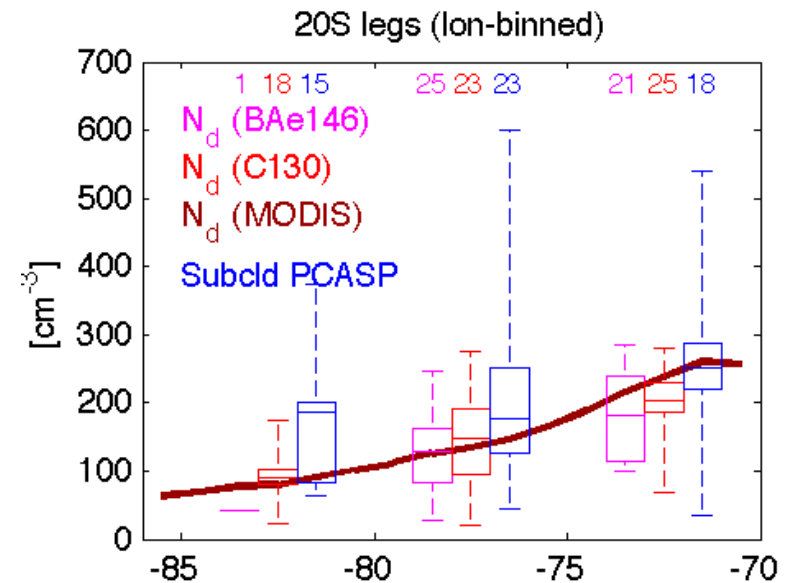
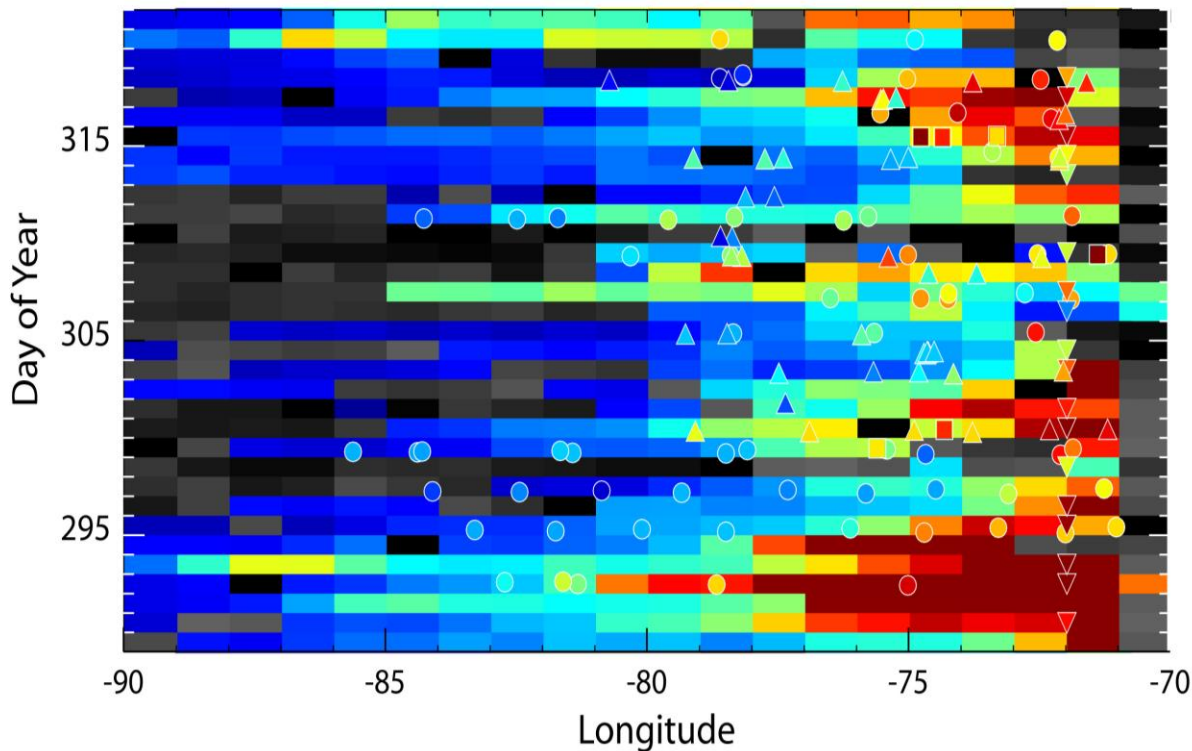
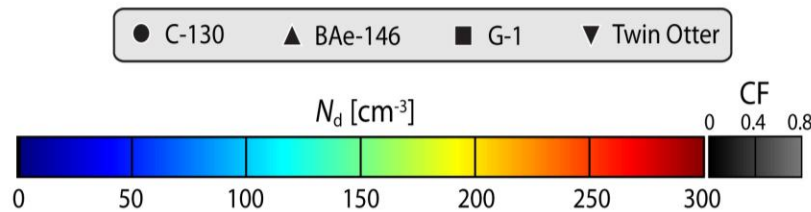
Leg wind comparisons with NCEP, ECMWF

Good agreement with operational analyses, even above boundary layer



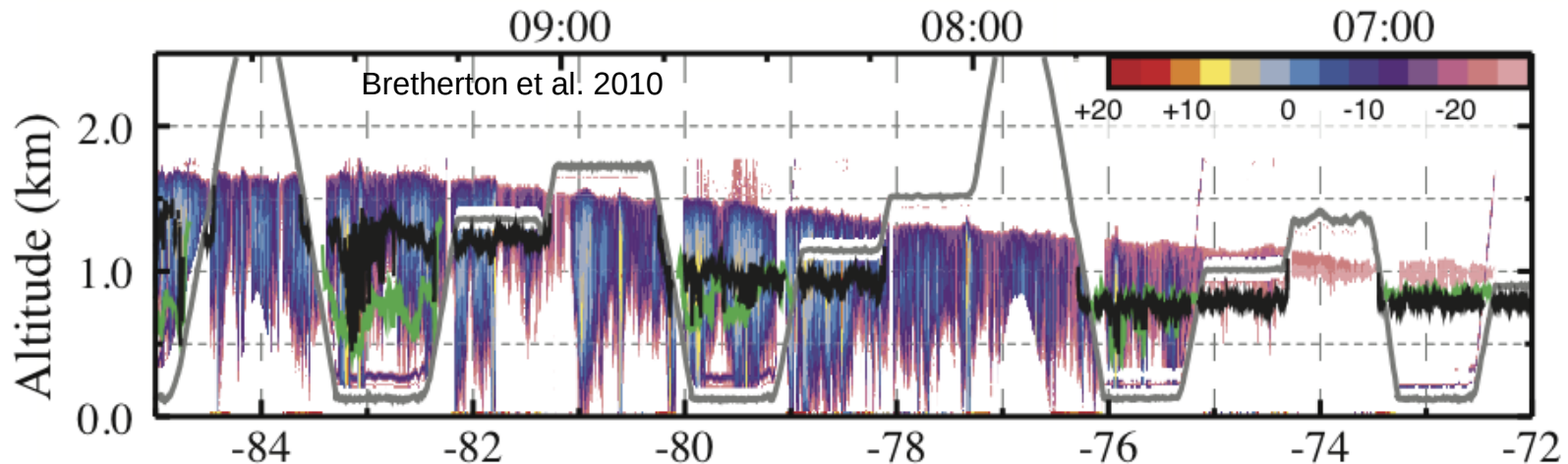
NCEP reanalysis is much worse, and a poor choice for trajectories

Cloud droplet conc. lon-time section: Aircraft vs. MODIS

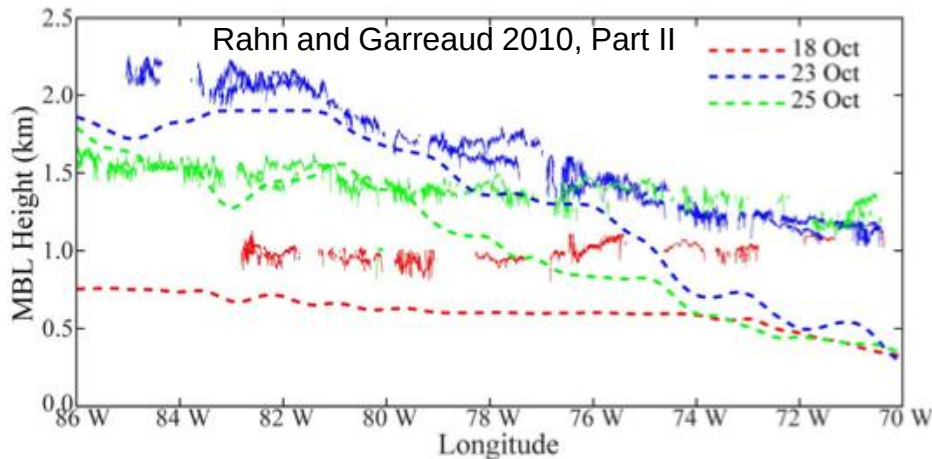


- Excellent sampling
- Aircraft measurements consistent with satellite estimates where $cf > 0.8$.
- N_d decreases westward from ~250 cm^{-3} near coast to ~100 cm^{-3} at 85°W

WCR/WCL cross-section for C130 RF03



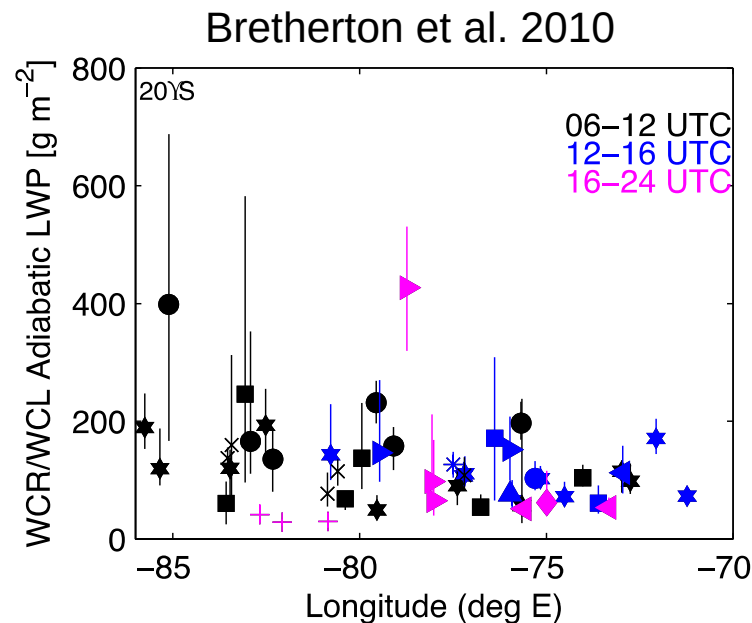
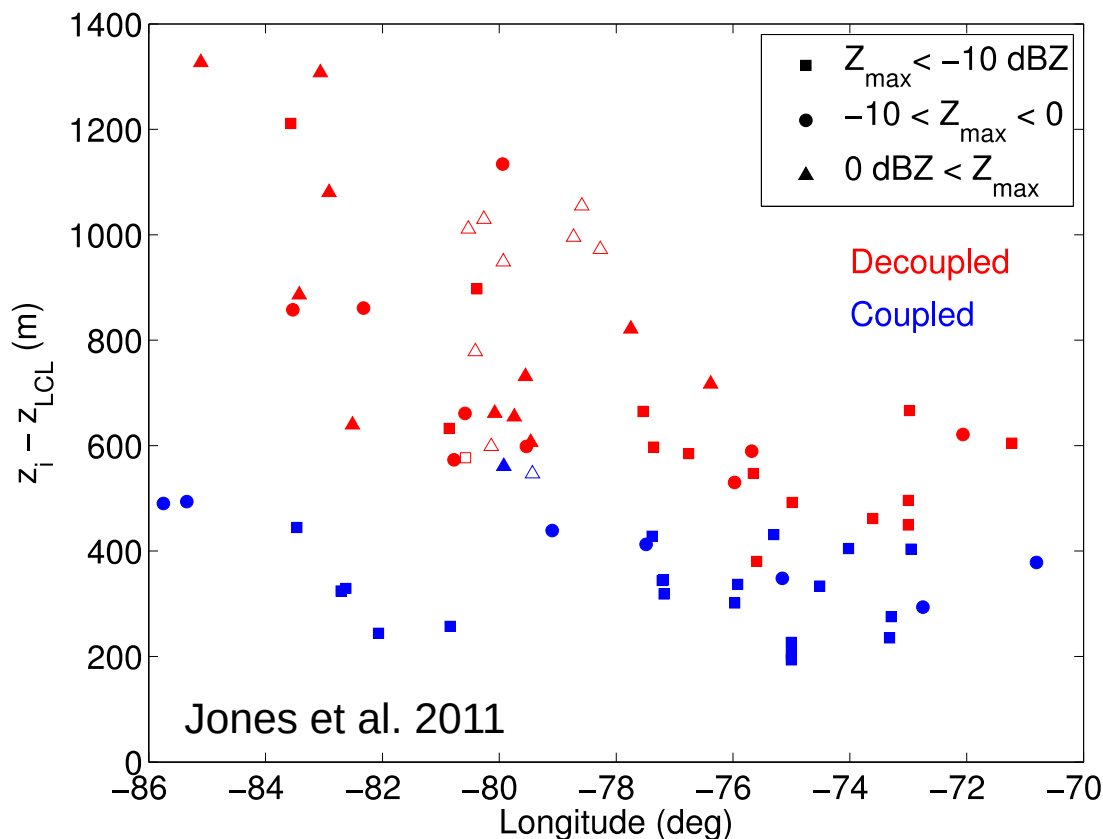
- Mesoscale drizzle cells ubiquitous west of 75W
- Cloud base coincident with 150 m LCL (well-mixed) near the coast.



C130 REx WCR cloud-top heights are a good test for forecast models.

Fig. 3. Examples of the MBL depth along 20° S from the WRF (dashed) and detected by the Wyoming Cloud Radar (solid) for 18 October (red), 23 October (blue), and 25 October (green).

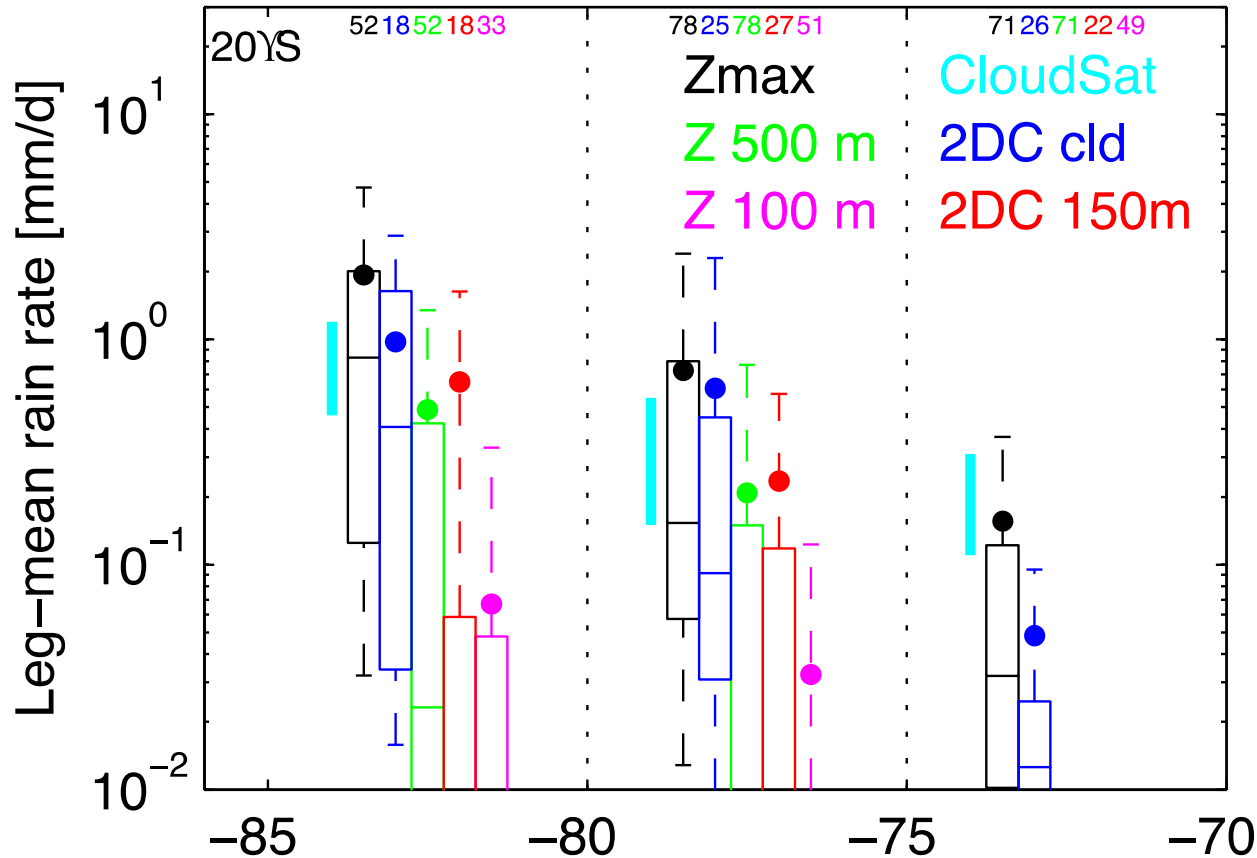
PBL decoupling $\leftrightarrow$ Max cld thickness $Z_{\text{inv}} - \text{LCL} > 500 \text{ m}$



- Macrophysics drives regional cloud structure contrasts:
Deeper inversion $\rightarrow$ decoupled, deeper Cu $\rightarrow$ more drizzle.

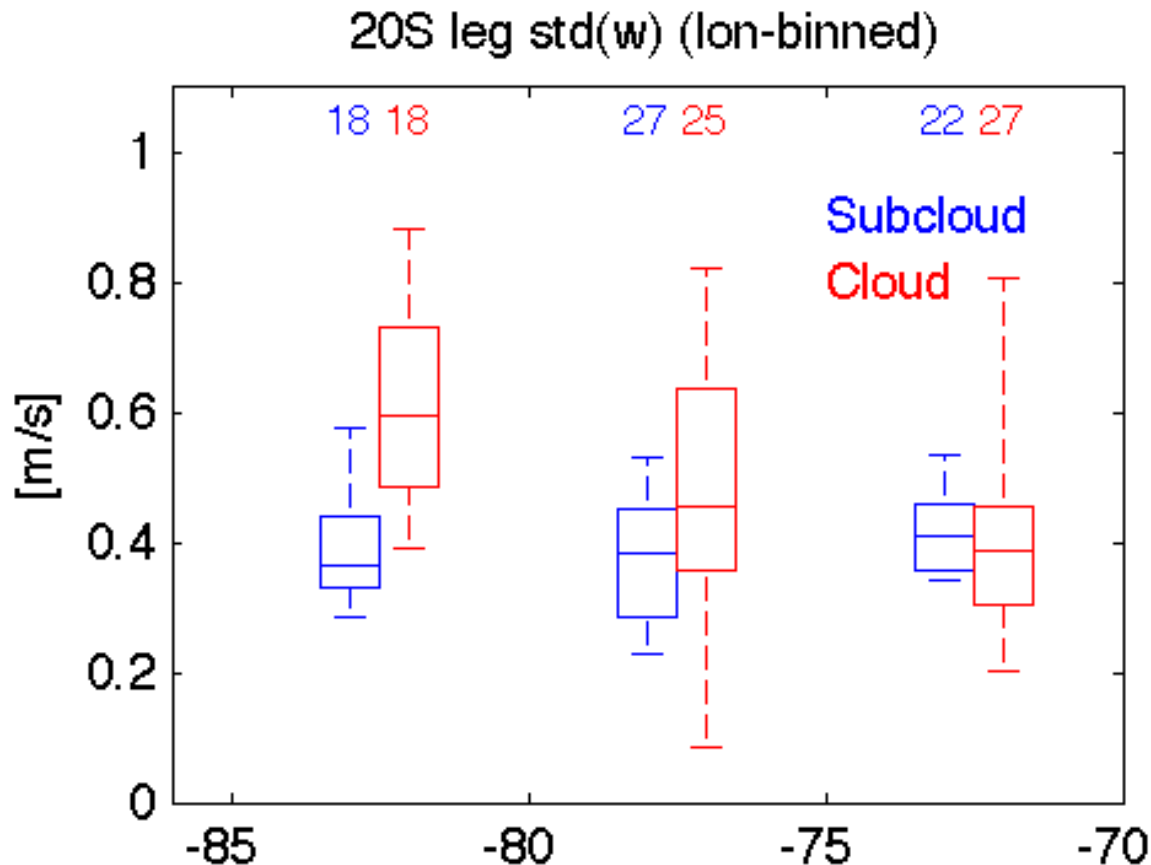
$\nwarrow \nearrow$ aerosols $\swarrow \searrow$

Precipitation rate estimates



- In cloud 2DC and radar Z-R rainrate estimates consistent
- Much more drizzle offshore (thicker clouds, lower N_d)
- Most rain evaporates above surface
- Near-surface Z-R rainrates less than 2DC - why?

Turbulence –useful comparison to models?

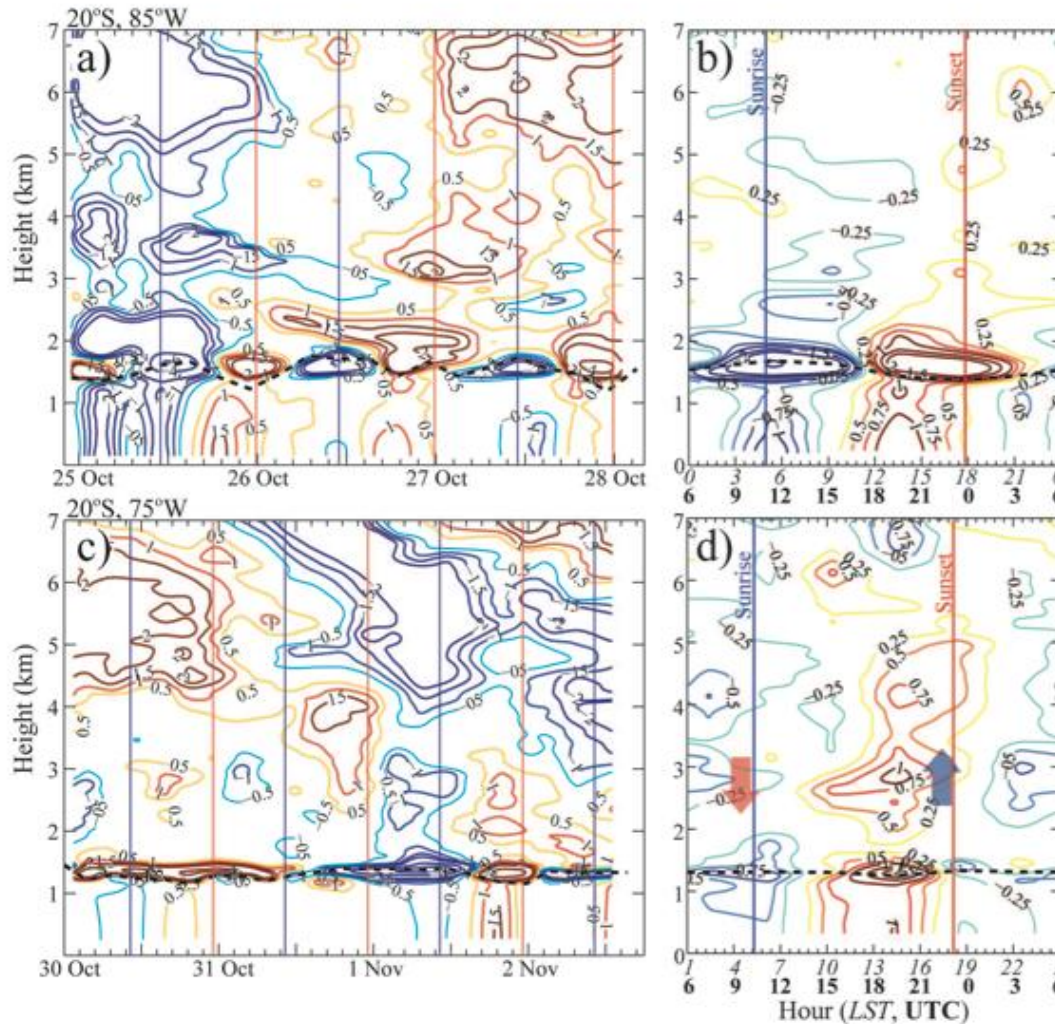


- Subcloud turbulence same in all longitude zones
- In-cloud turbulence strengthens to the west (thicker, deeper clouds, more longwave cooling)

The diurnal cycle along 20S

4502

D. A. Rahn and R. Garreaud: Marine boundary layer over Pacific during VOCALS-REx



Ron Brown sondes show diurnal upsidence wave is phased later at 85W (top) than 75W (bottom).

Fig. 12. Observed potential temperature anomalies from the mean state taken from R/V Ron Brown soundings during the stationary periods at 20° S, 85° W (upper panels) and 20° S, 75° W (lower panels). The anomalies are shown as a time series (a and c) and as an average diurnal anomaly (b and d). MBL depth is indicated by bold dashed line. Blue and red vertical lines indicate local sunrise and sunset, respectively. Arrows indicate vertical motion inferred from the WRF simulation.

GOES IR-based
cloud fraction
on 20S is a
useful model
comparison

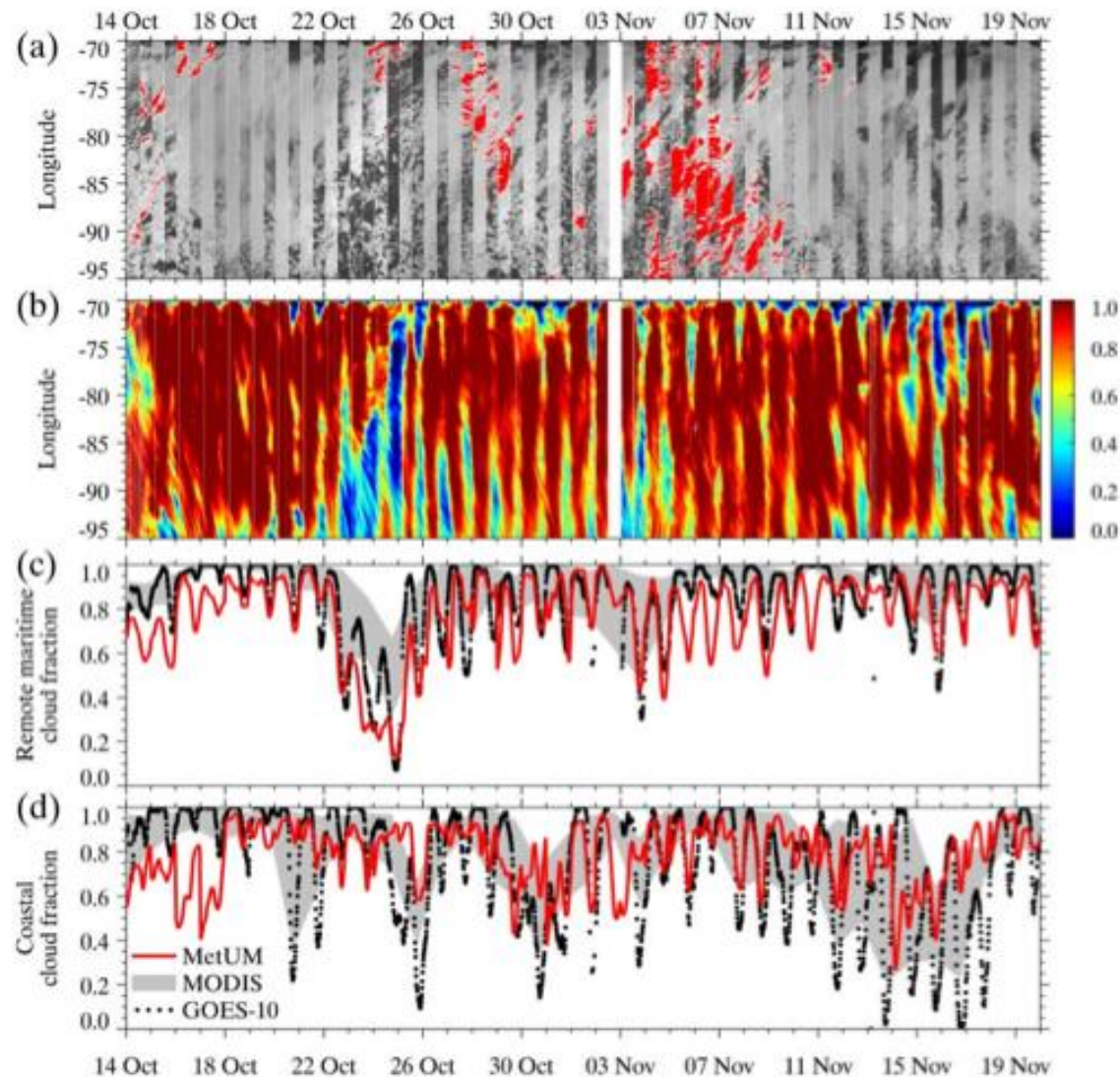


Fig. 5. Variability of low cloud cover along the 20° S latitude line from the 14 October to 19 November 2008. Panel (a) shows twice daily strips at ~ 07:30 and 19:30 UTC of the channel 4 BT from GOES-10. High cold clouds with a BT < 273 K are highlighted in red. Panel (b) shows a time-longitude plot of the GOES-10 low cloud fraction along 20° S derived from the channel 4 BT (data approximately every 30 min where available). Panels (c–d) compare the observed low cloud fraction from GOES-10 (black circles) and MODIS (grey band) with the MetUM forecast (red line) for the regions 80–90° W and 18–22° S in panel (c) and for 70–73° W and 18–22° S in panel (d).

Key new REx 20S insights

- Cloud macrophysics (the typically deeper and more decoupled PBL offshore) affects cloud optical properties and precipitation at least as strongly as aerosol gradients.
Deep PBL → high LWP cells, decoupling ↔ precipitation
- There are extensive regions of unbroken Sc which (like POCs) are decoupled and drizzling, yet maintain droplet concentrations of $60\text{-}100\text{ cm}^{-3}$ much higher than in POCs.
- In-situ cloud droplet conc. agrees with satellite estimates if the Sc cloud cover is not too broken.
- Winds from NCEP/ECMWF operational analyses agree with aircraft measurements → suitable for trajectory analysis.

REx has produced a comprehensive set of 20S physical/chemical measurements distilled and gridded for model comparison. How best to package it?



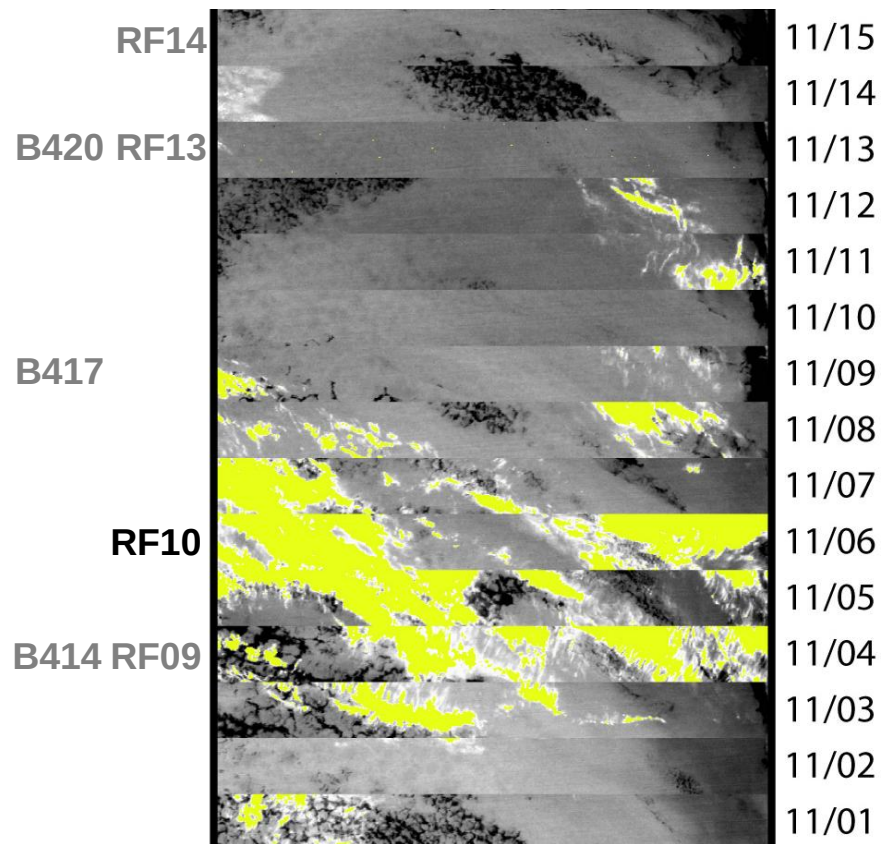
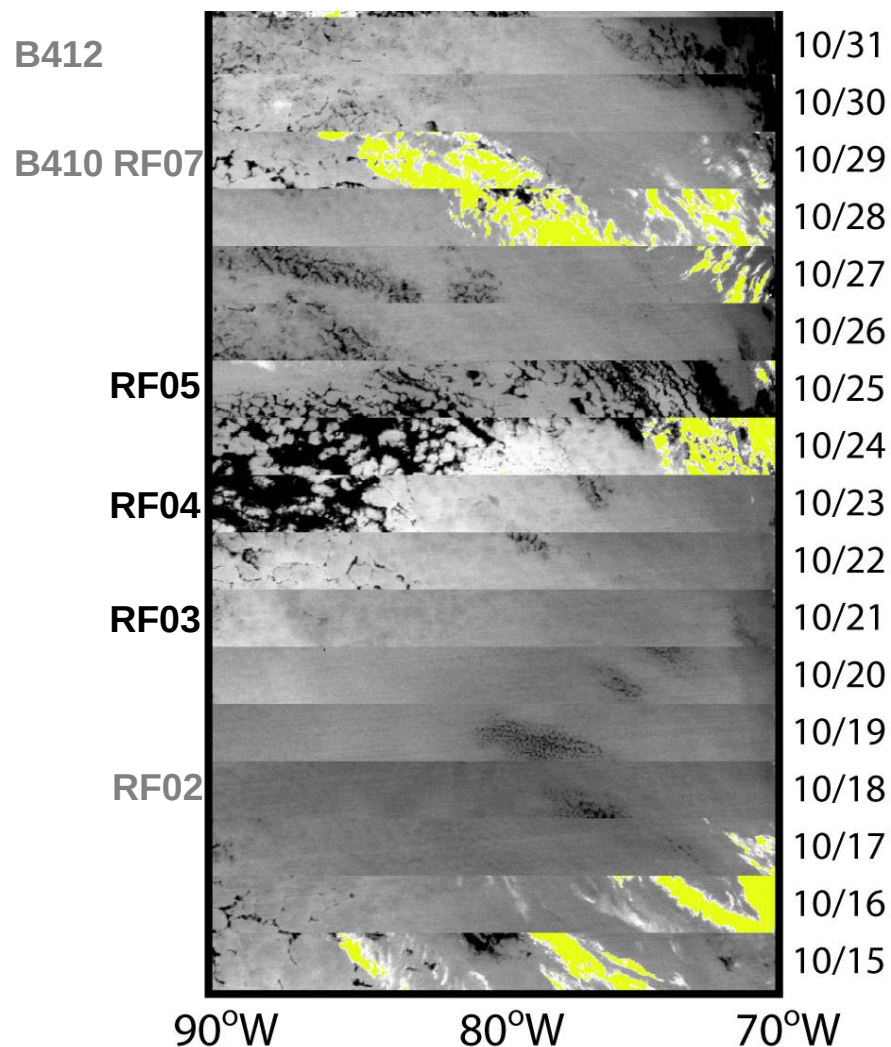
Conclusions



- 20S dataset provides an unprecedented integrated cross-section of boundary-layer structure, clouds and aerosols across mean gradients within a stratocumulus regime
- Clouds get cleaner, deeper, rainier, more decoupled , more turbulent further to the west.
- NCEP and ECMWF (but **not** NCEP reanalysis) winds are accurate enough for trajectory analysis in this region.
- Satellite microphysical retrievals (if appropriately restricted to nearly solid low cloud) agree well with in-situ REx observations.

20S IR strip charts (0845 UTC)

20S airborne obs cover a representative range of cloud conditions

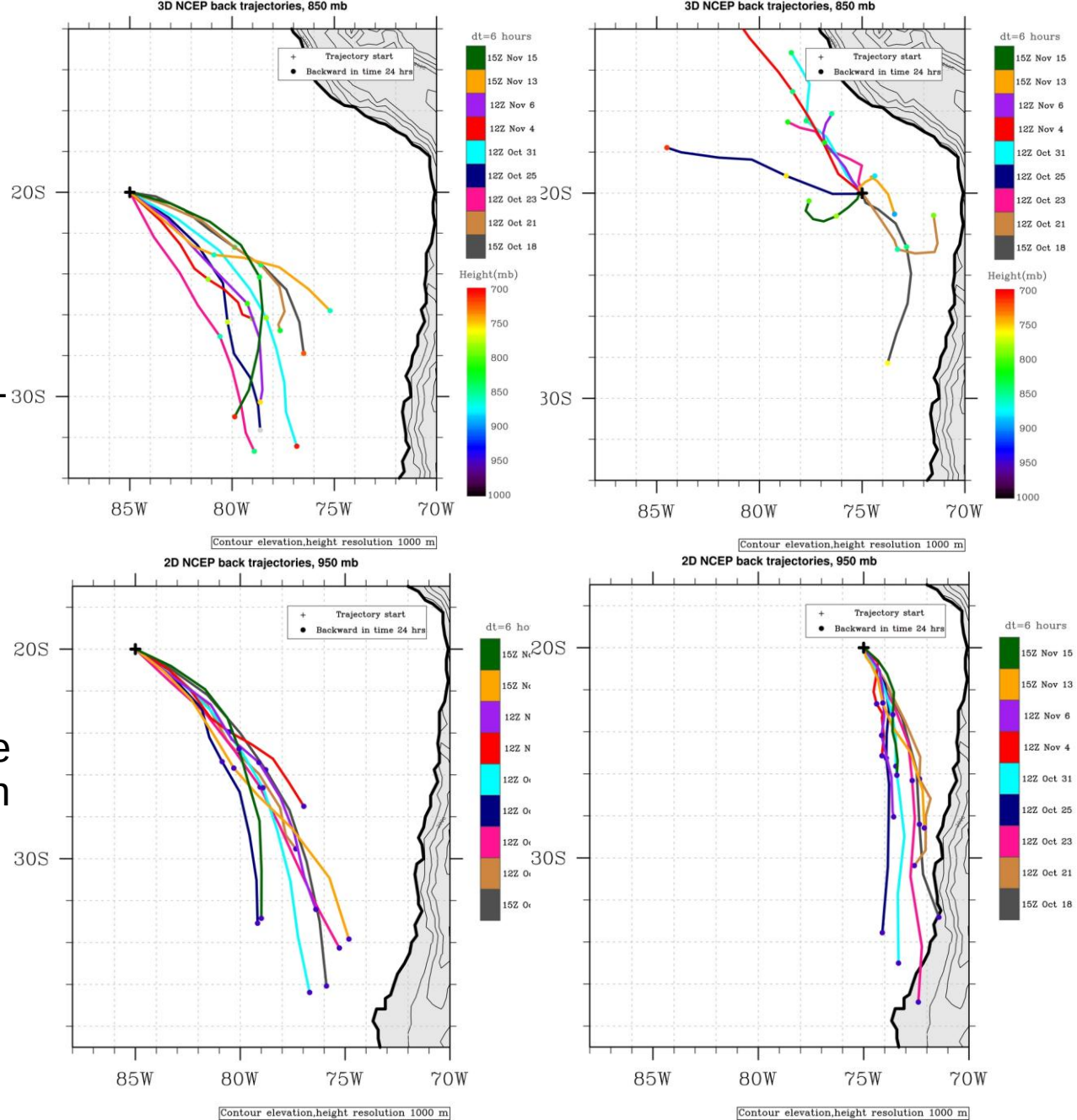


20S back-trajectories

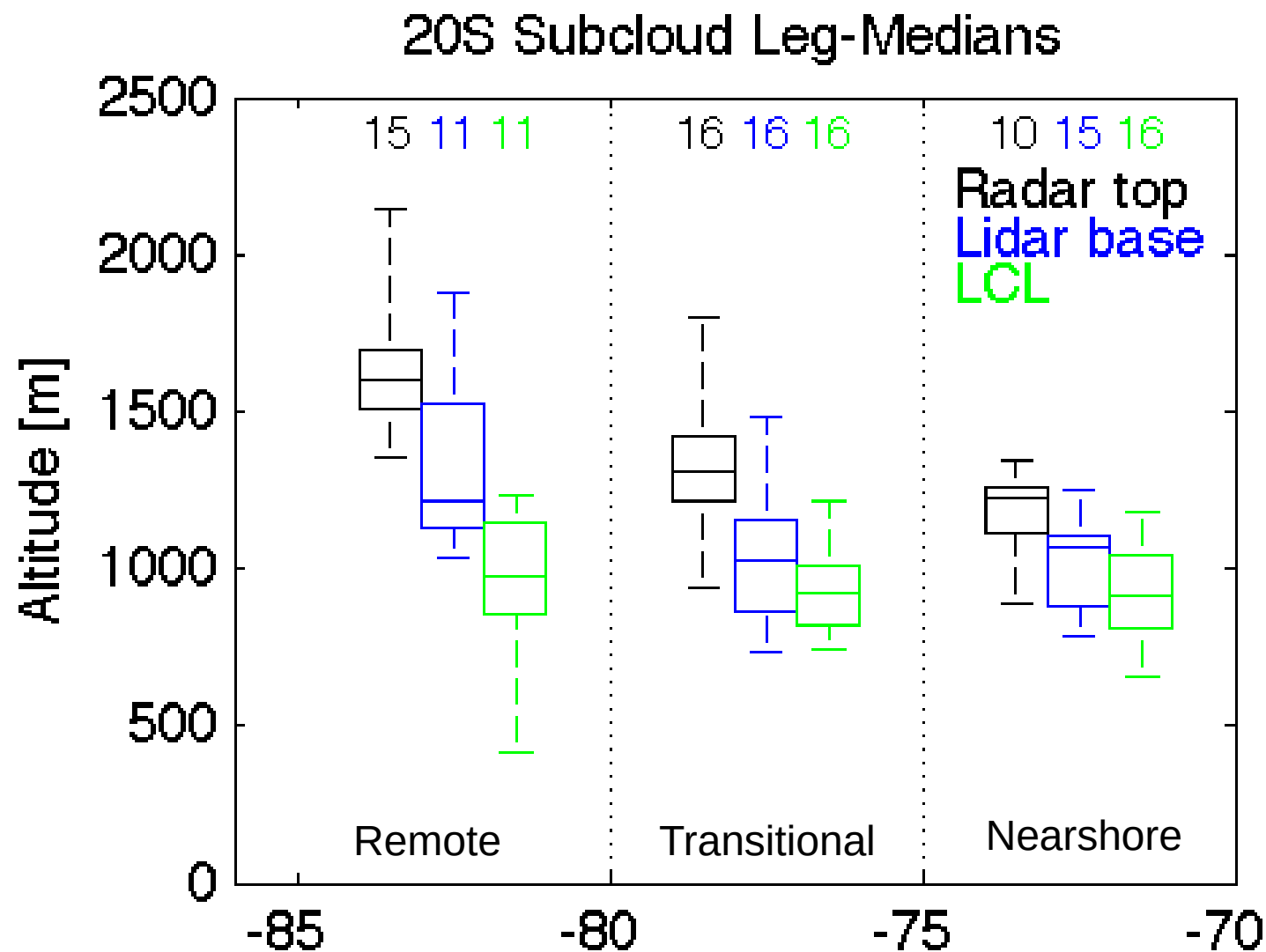
75W:
Directional variability
above inversion;
Coastal contact in PBL

85W:
Consistent SE flow,
stronger in PBL.

850 hPa trajectories:
0-75 hPa/d subsidence
generally weaker when
flow is more easterly.



Radar stats: Median cloud top, cloud base and LCL



Inversion deepens, Sc thickens, more decoupling further west