Planetary boundary layer height determination from GPS radio occultation measurements

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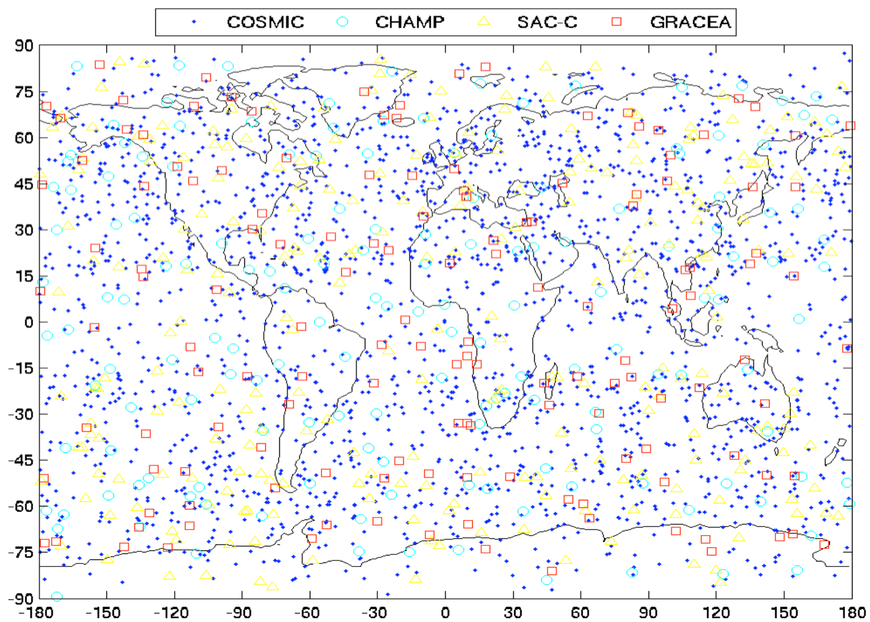
PBL Height/Depth

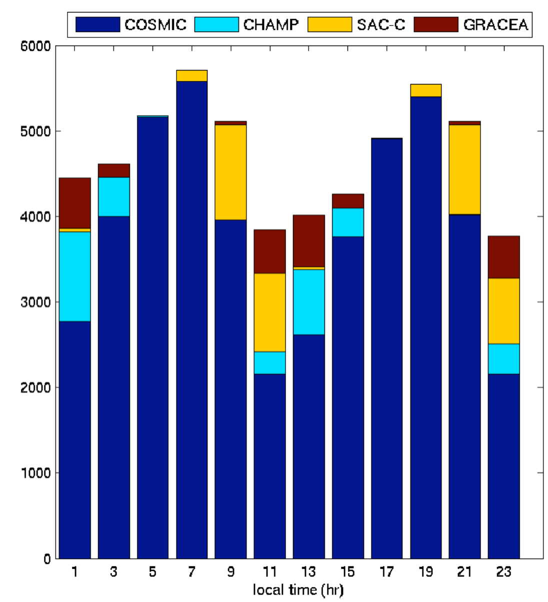
- PBL height is a crucial parameter that describes various processes affecting the PBL.
- Global climatology of PBL is poorly established due to lack of observations, esp. over the oceans.
- PBL top is often finely delineated: difficult to model and hard to resolve with most remote sensing observations.

Why GPS RO?

- Global, diurnal sampling
- All-weather profiling
- High vertical resolution (~ 100-200 m)



spatial coverage in one day

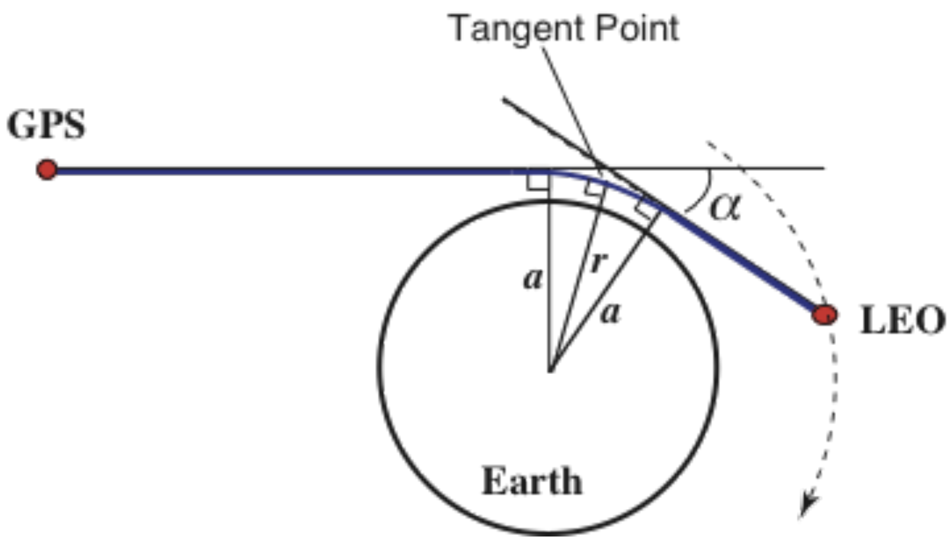


local time coverage in one month

Study Objectives

1. Develop a reasonable algorithm for determining PBL height from GPS RO profiles
2. Validate algorithm
3. Construct global PBL height climatology
4. Compare with models (apply same algorithm!)

GPS RO: Introduction



$$\ln n(r) = \frac{1}{\pi}\int_{a}^{\infty} da' \, \frac{\alpha(a')}{\sqrt{a'^2 - a^2}}$$

$$a = r\, n(r)$$

GPS Signal Amplitude & Phase at LEO

Canonical transform (CT)

Impact Parameter *a* & Bending Angle α

Abel inversion

Refractivity profile *N(r)*

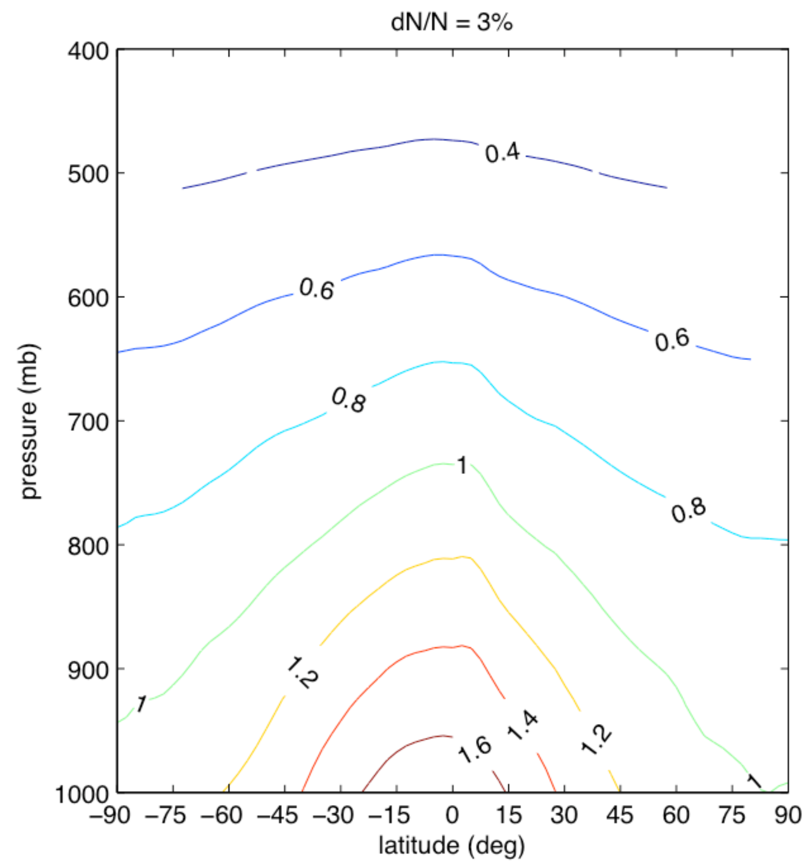
Lower Tropo WV Retrieval

$$N = a_1 \frac{P}{T} + a_2 \frac{P_w}{T^2}$$

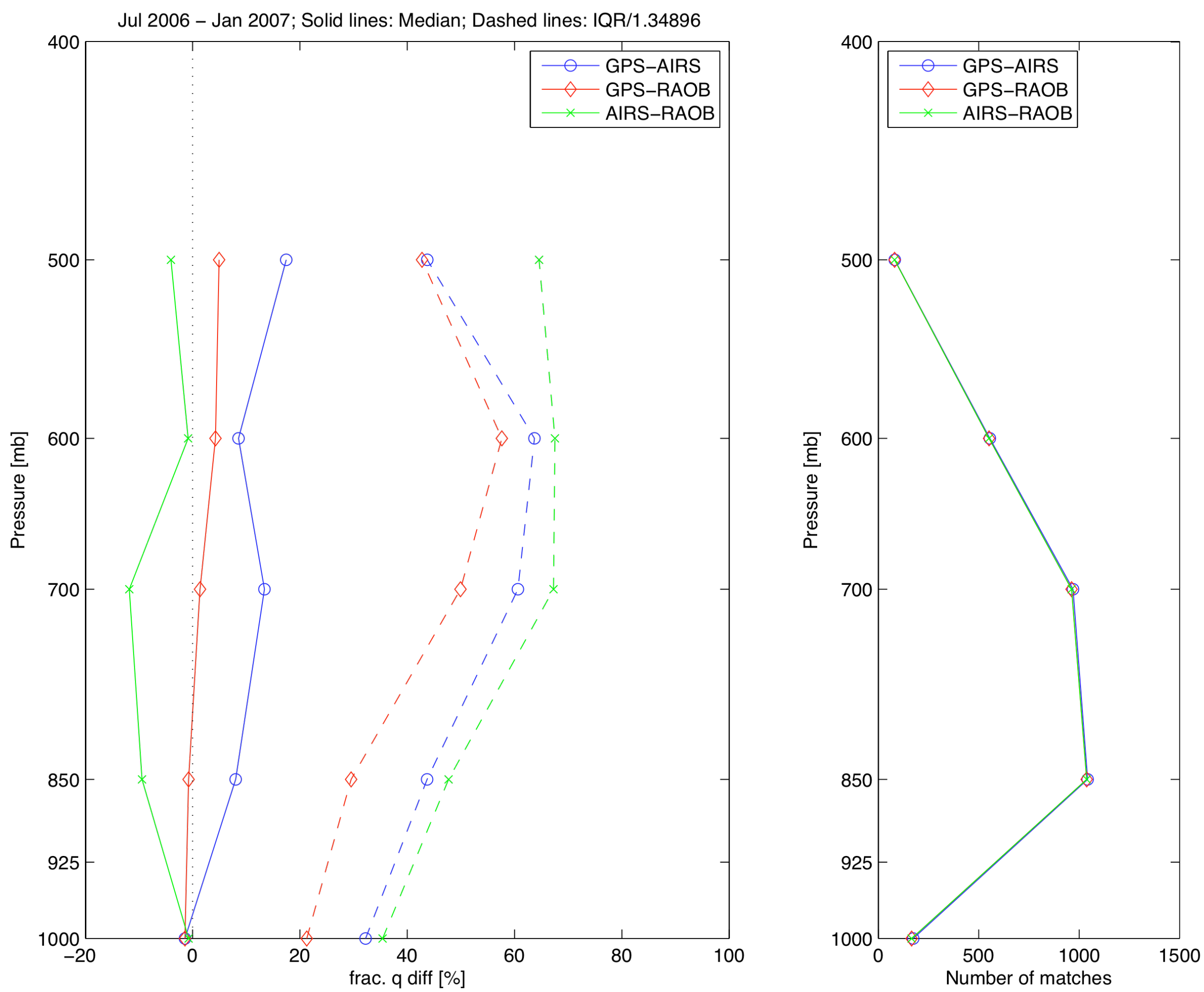
$$\frac{dP}{dz} = -\frac{m_d g}{R}\frac{P}{T} - \frac{(m_w - m_d) g}{R}\frac{P_w}{T}$$

Solve for *P*, *Pw* by assuming *T* from weather analyses

Spec humidity RMS error (theoretical estimate)



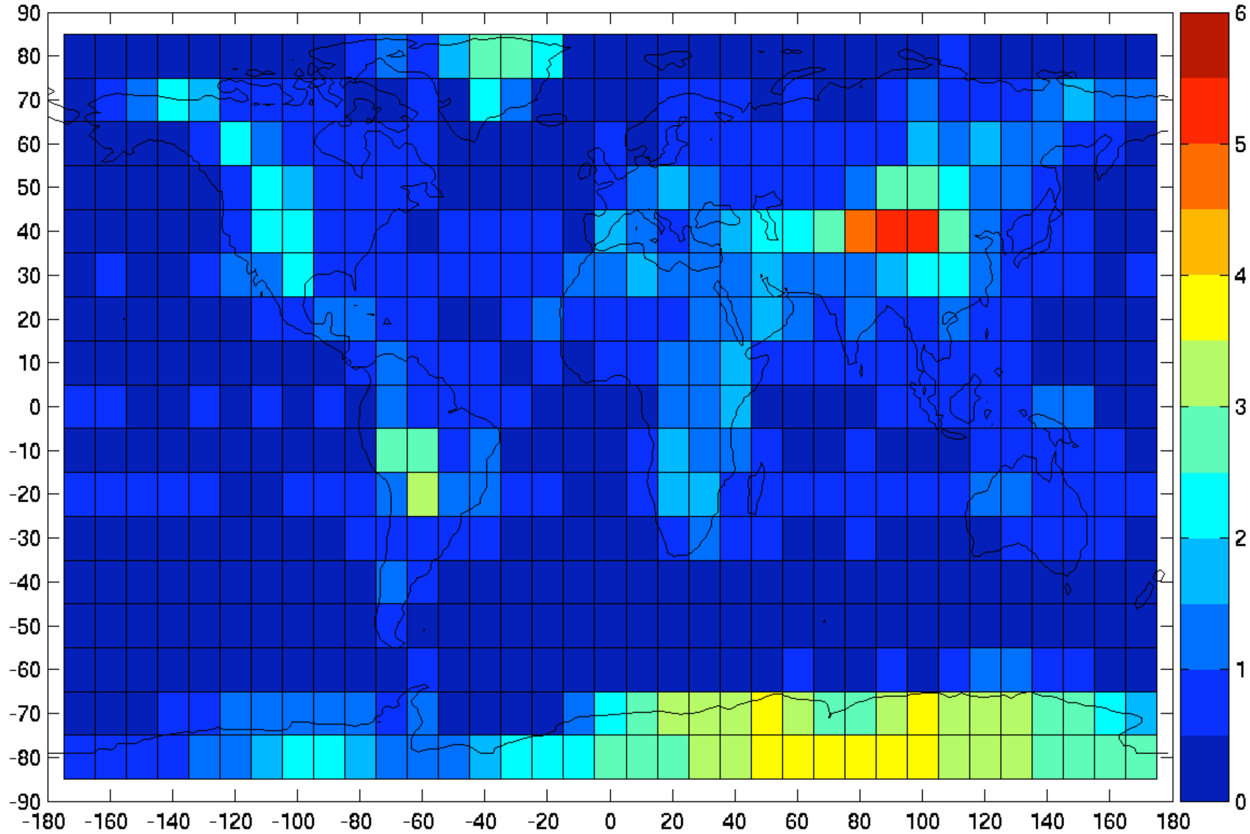
Validating WV retrievals (GPS/AIRS/RAOB)



Algorithm

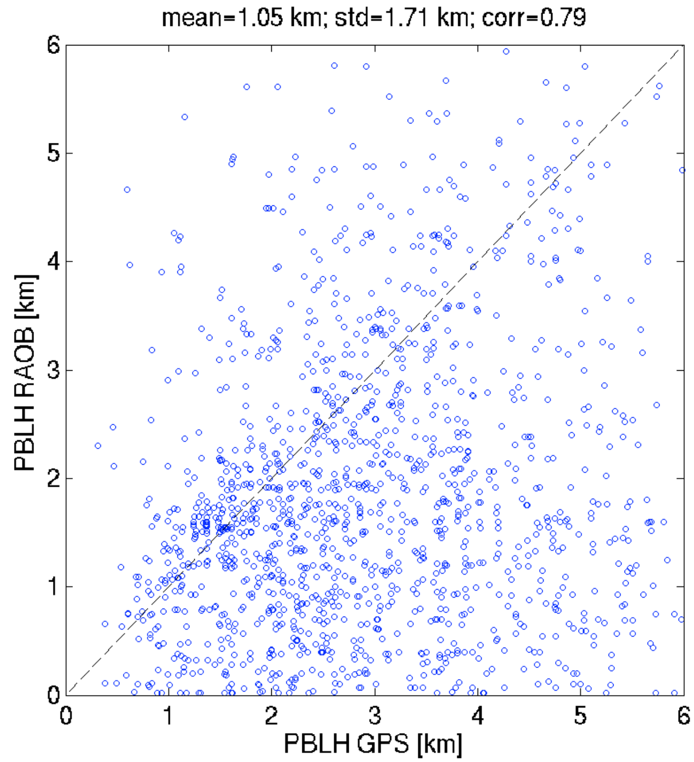
- Use specific humidity profile *q(z)* for more direct comparison with models
- Define PBL top as height where *dq/dz* is minimum (most negative)
  - Best when PBL is capped with strong inversion layer
- Caveats
  - Not truly global (high latitudes are excluded)
  - Ambiguous when no sharp transition occurs (e.g. deep convective regions) or when multiple layers exist (surface layers, residual layers)
  - Not all profiles reach the surface (height bias)

Depth Penetration (Open Loop)

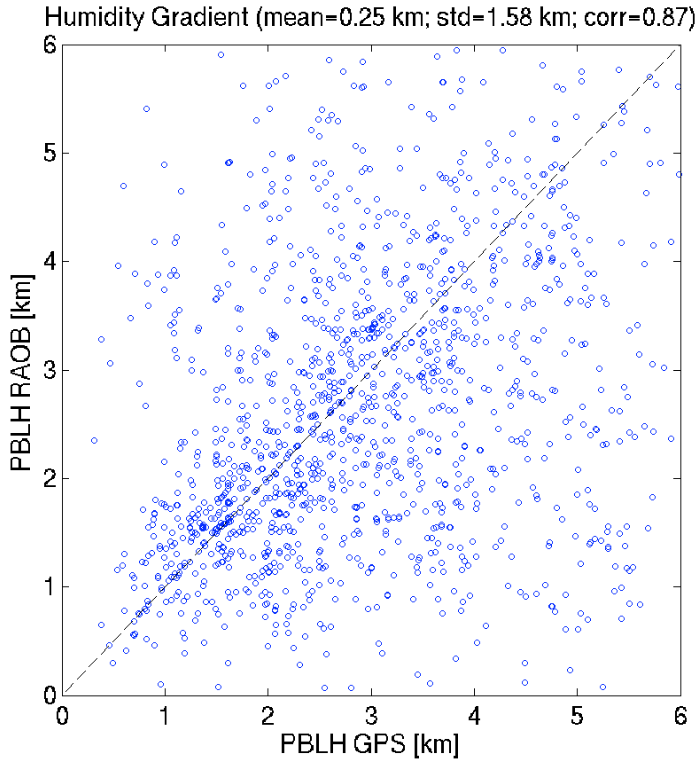


Median minimum profile height (mean sea level)
~ 80% profiles reach < 2 km in the tropics
~ 50% profiles reach < 1 km in the tropics

Comparison with RAOB

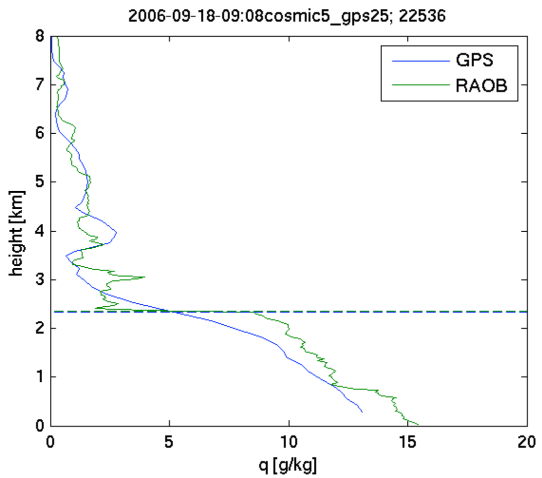


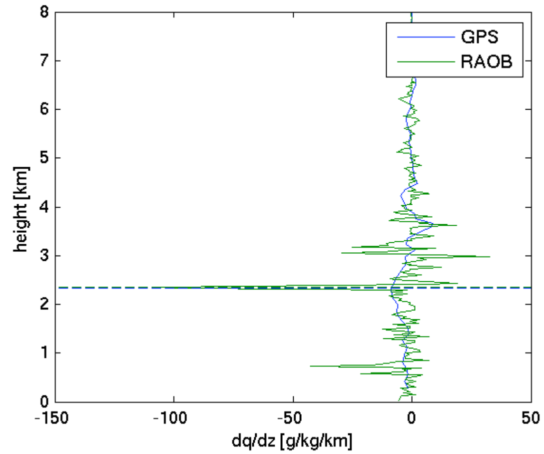
GPS heights are biased high due to profiles not reaching the surface



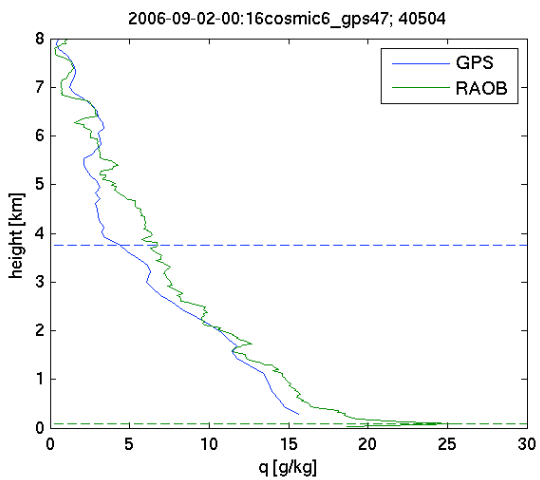
Limiting the RAOB minimum profile height to GPS's eliminates bias

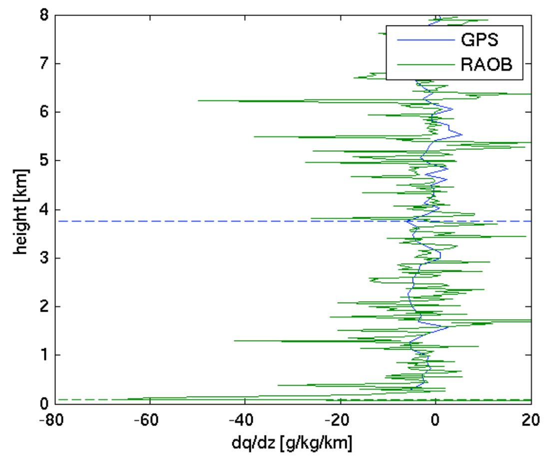
Examples





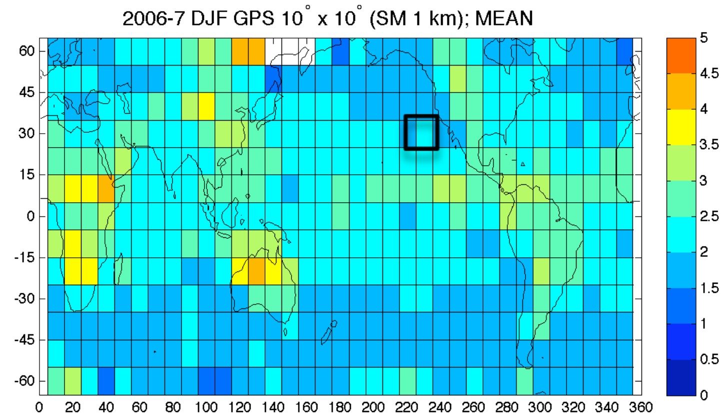
21.98 N, 159.35 W
~ 1 am LT
dr = 167.0 km
dt = 2.9 hr

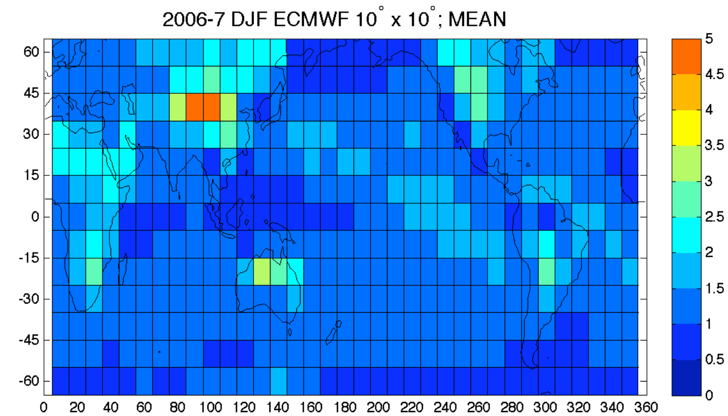


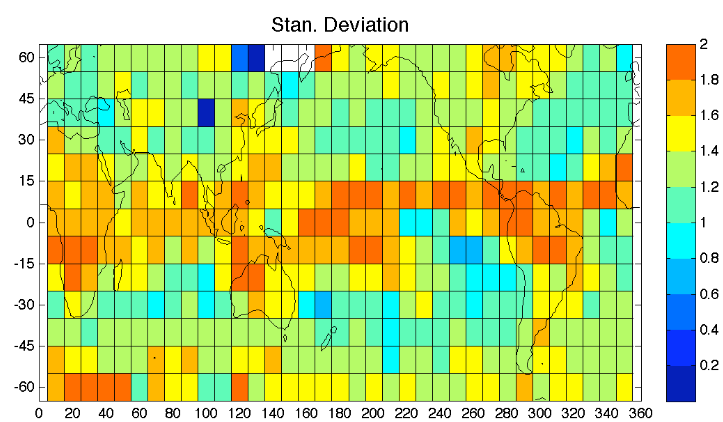


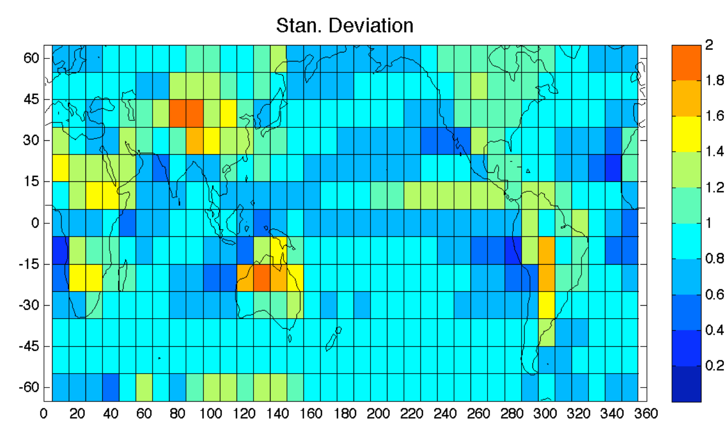
7.47 N, 151.85 E
~ 10 am LT
dr = 189.6 km
dt = 0.3 hr

Comparison with ECMWF

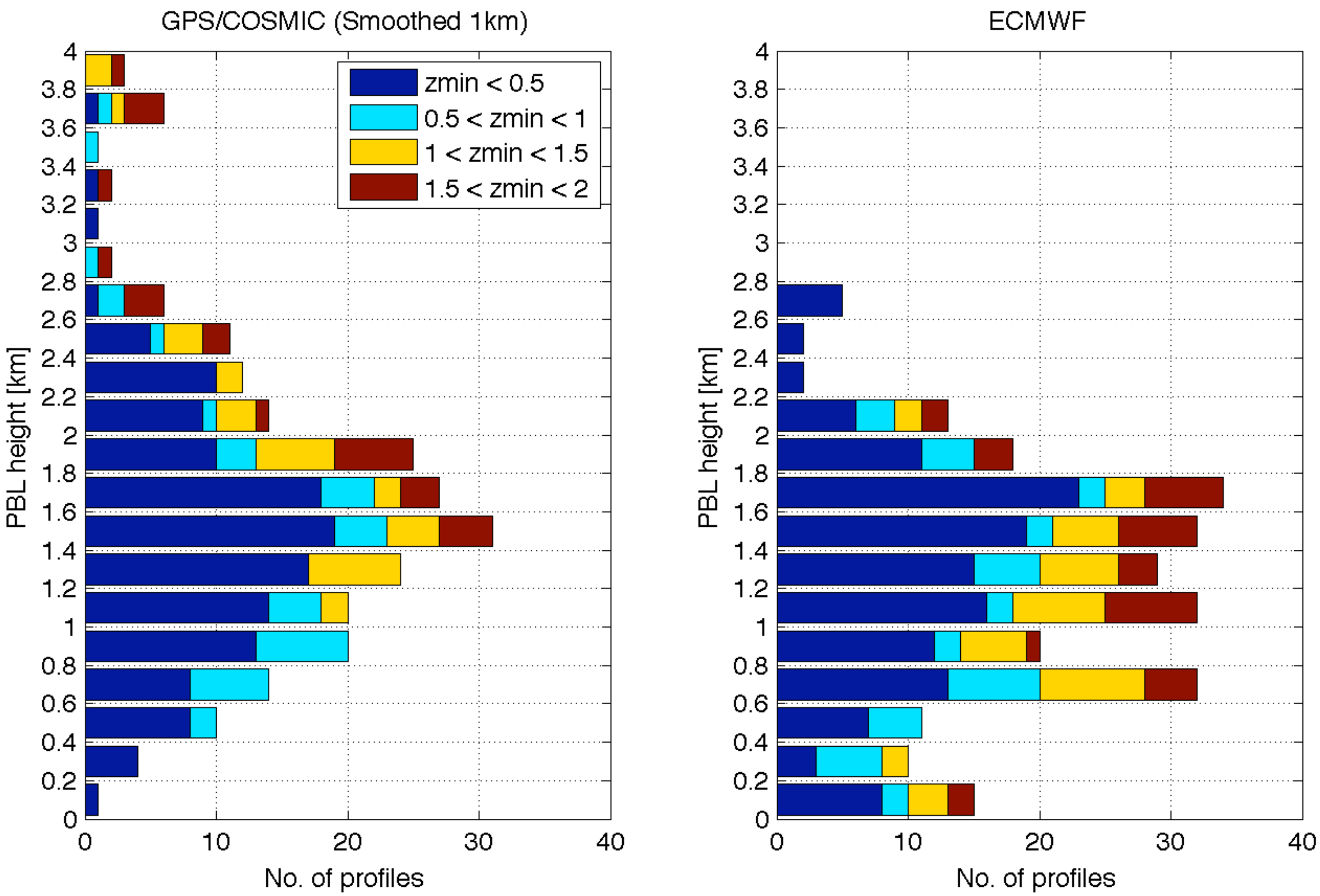




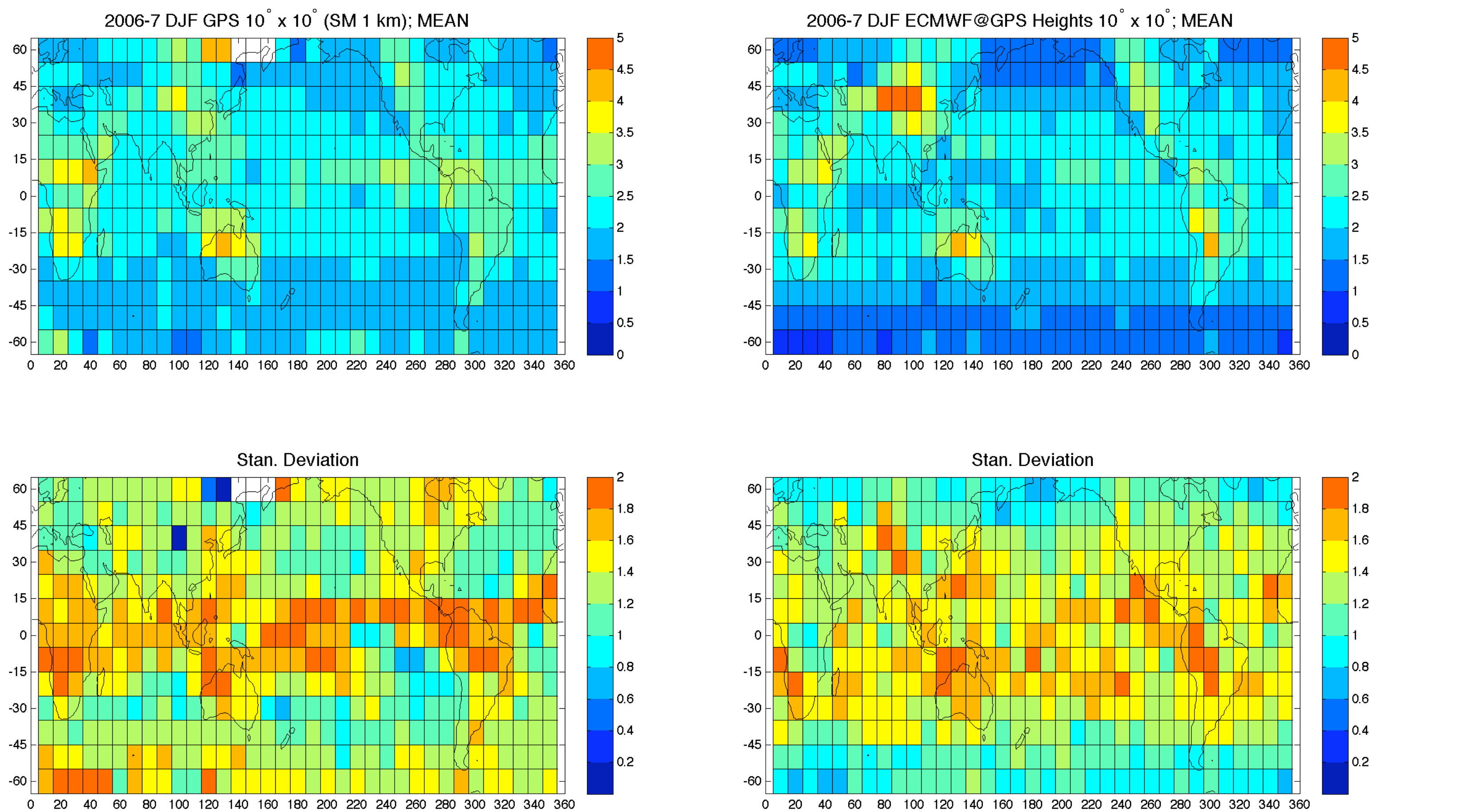




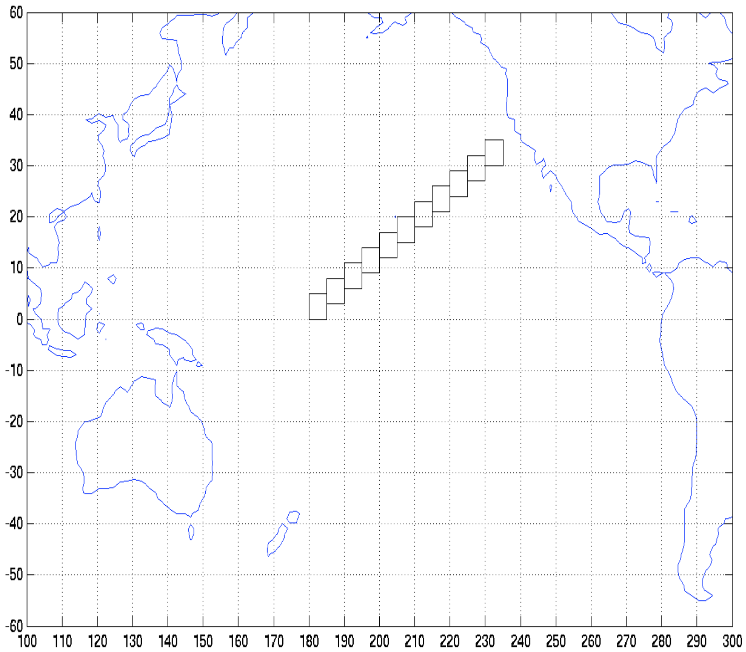
Height Distribution in NE Pacific

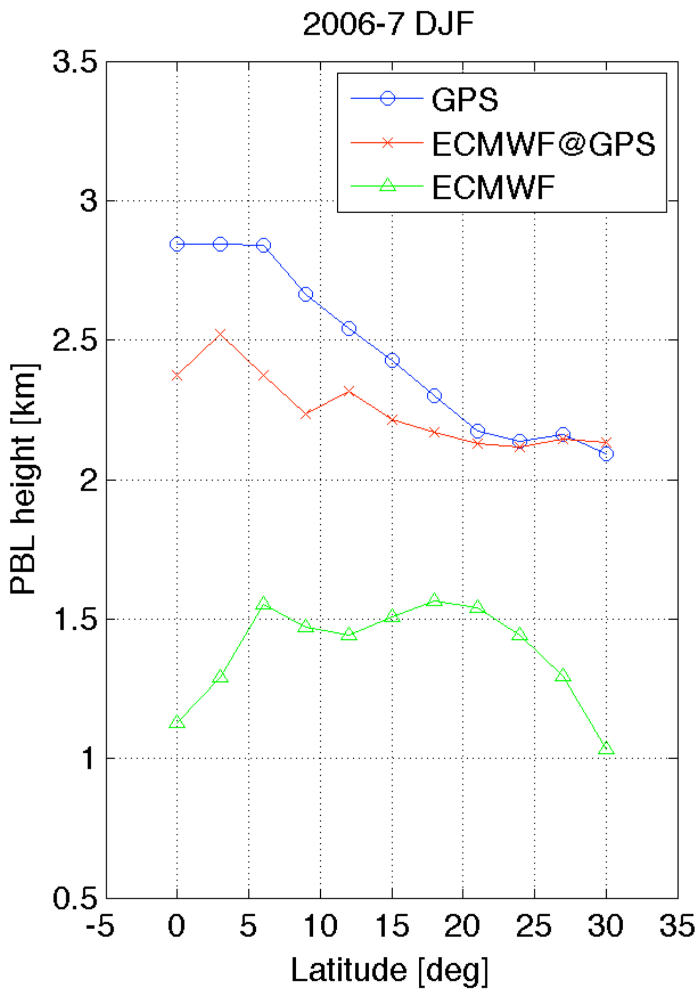


Comparison at GPS sampling



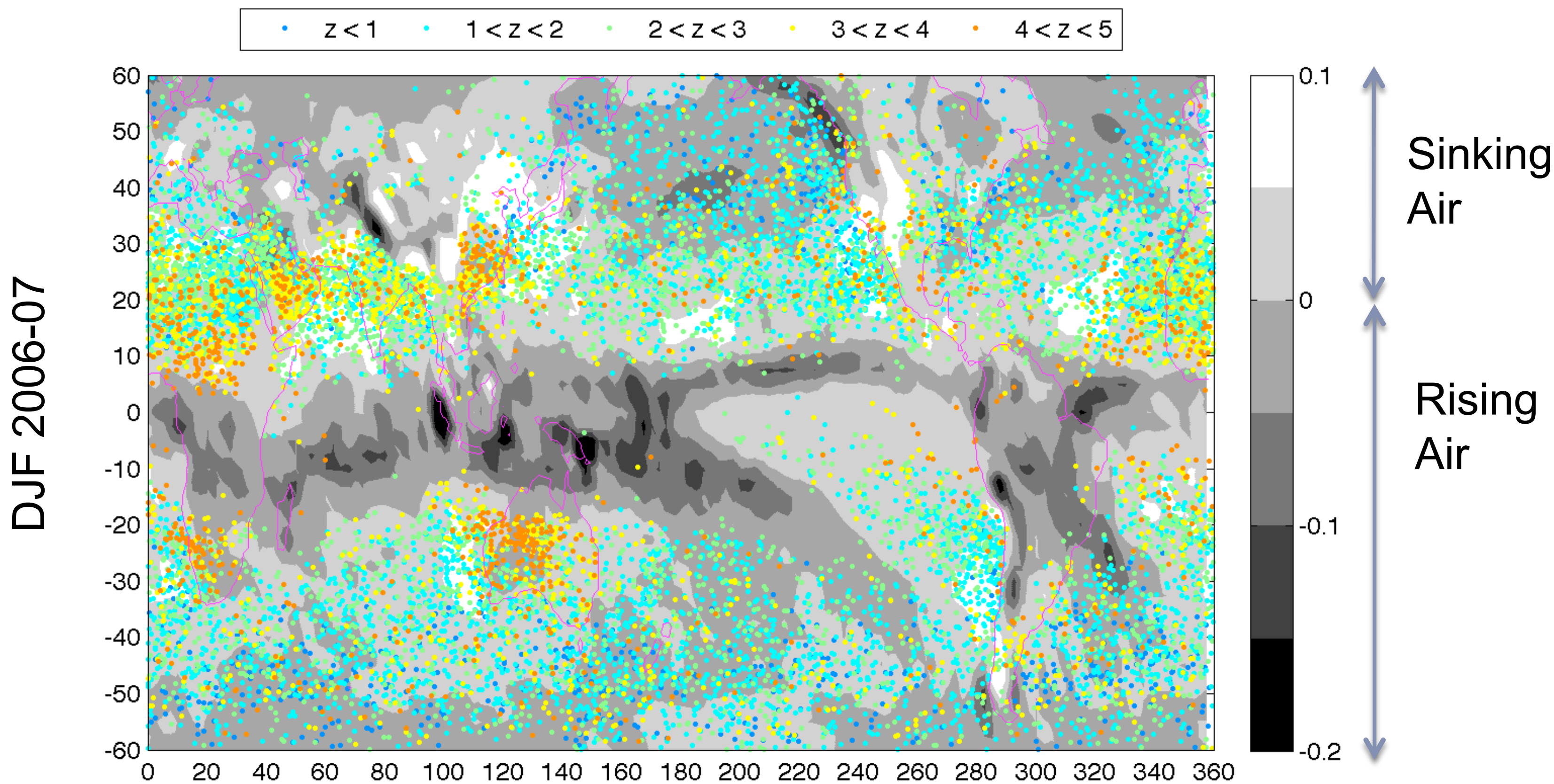
Pacific Cross Section Comparison





“Sharp” PBL Tops

Distribution of top 25 %-tile in humidity gradients at PBL height



Summary

- GPS RO provides unique opportunities in sensing the PBL
- Moisture-based PBL height definition was proposed and investigated.
- Comparison with RAOB and ECMWF shows potential but certain issues need to be addressed:
  - Bias caused by profiles not reaching the surface
  - Robustness of local gradient approach: absence of well-defined inversion layer, multiple sharp layers, small-scale structures
- Future work: algorithm refinement, validation (RAOB, MISR, AIRS, CloudSat), extensive model comparisons