

Cloud, Drizzle and Turbulence Observations in Azores

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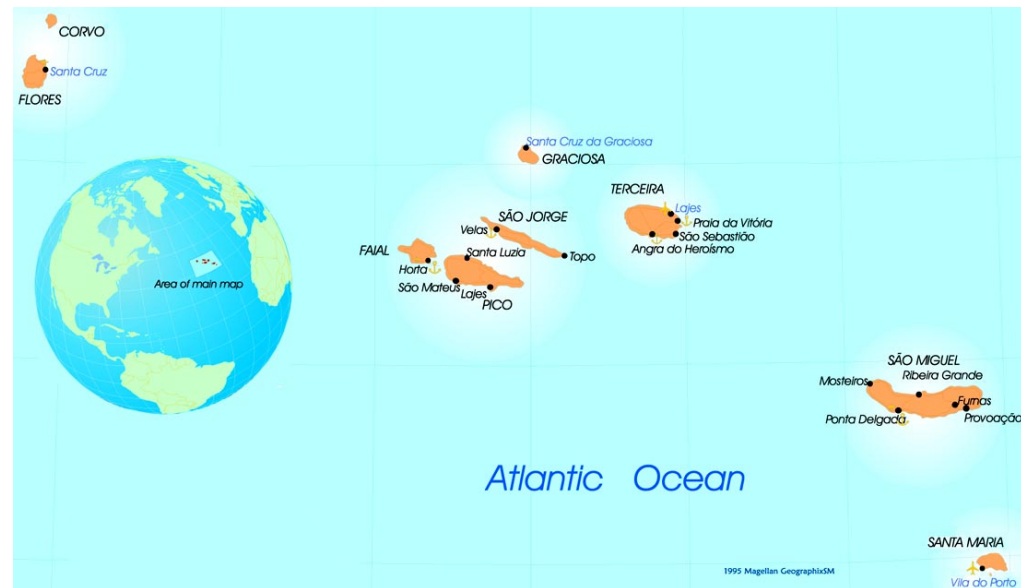
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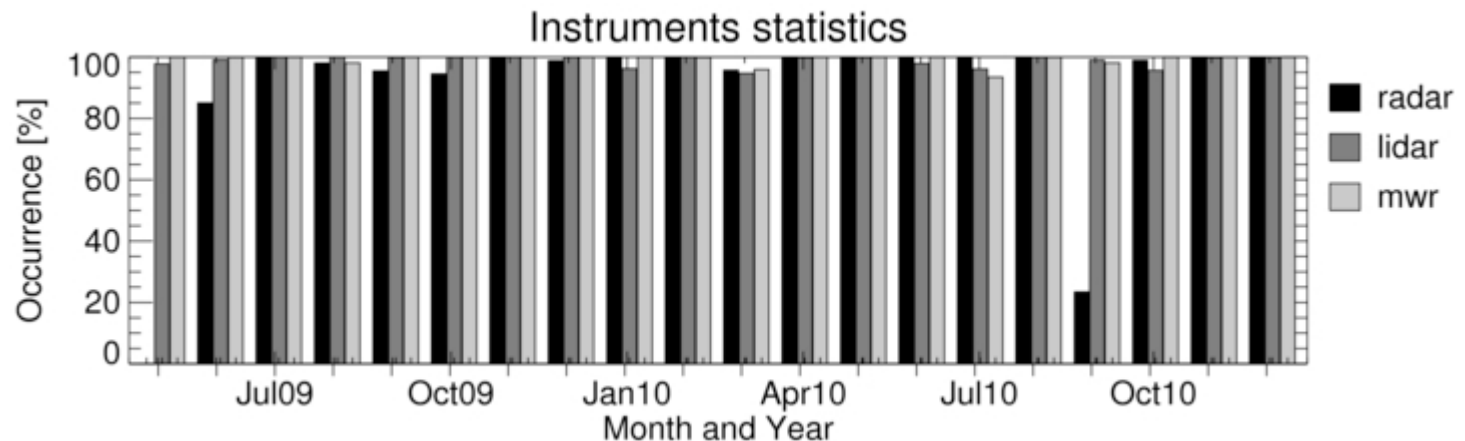
CAP-MBL campaign

- unprecedented data set focused on the marine boundary layer (radiation and microphysics)
- 20-month deployment of the AMF1 on Graciosa Island

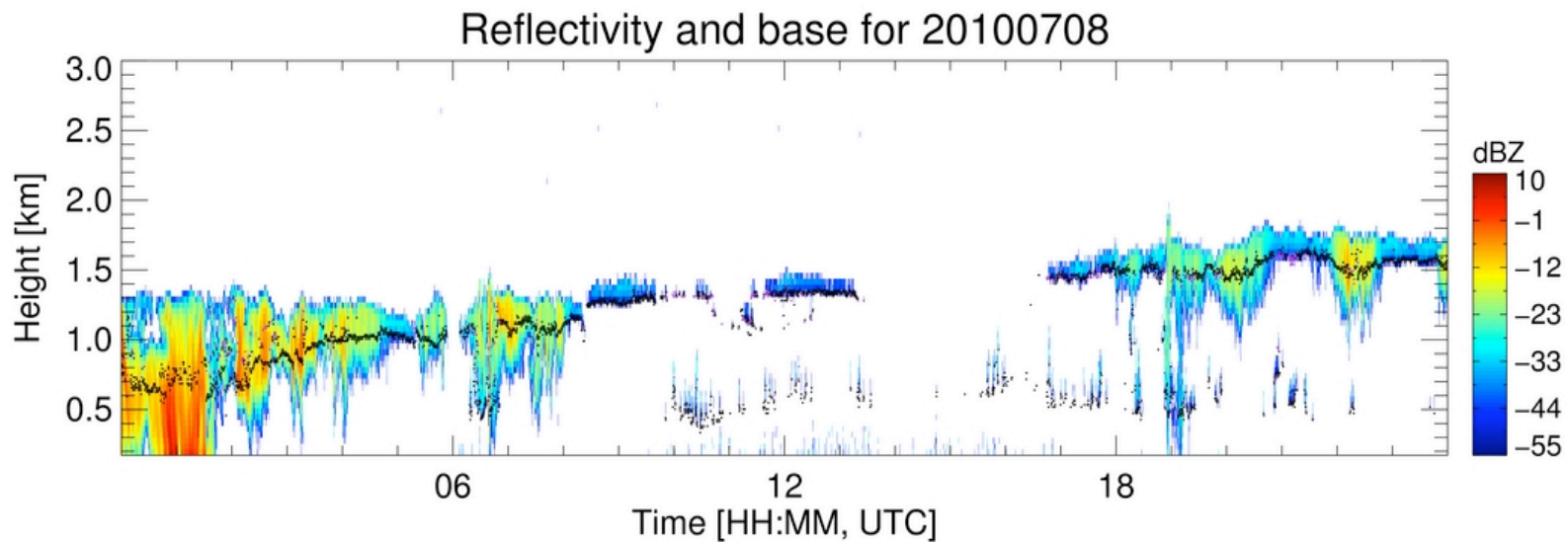


Data set

- WACR: hydrometeors boundaries, intensity, vertical velocities
- Vaisala ceilometer: liquid cloud base (up to 7.5 km)
- MWR: column-integrated amount of water (liquid and vapor)
- Radiosondes: in situ measurements of the thermodynamic state and winds

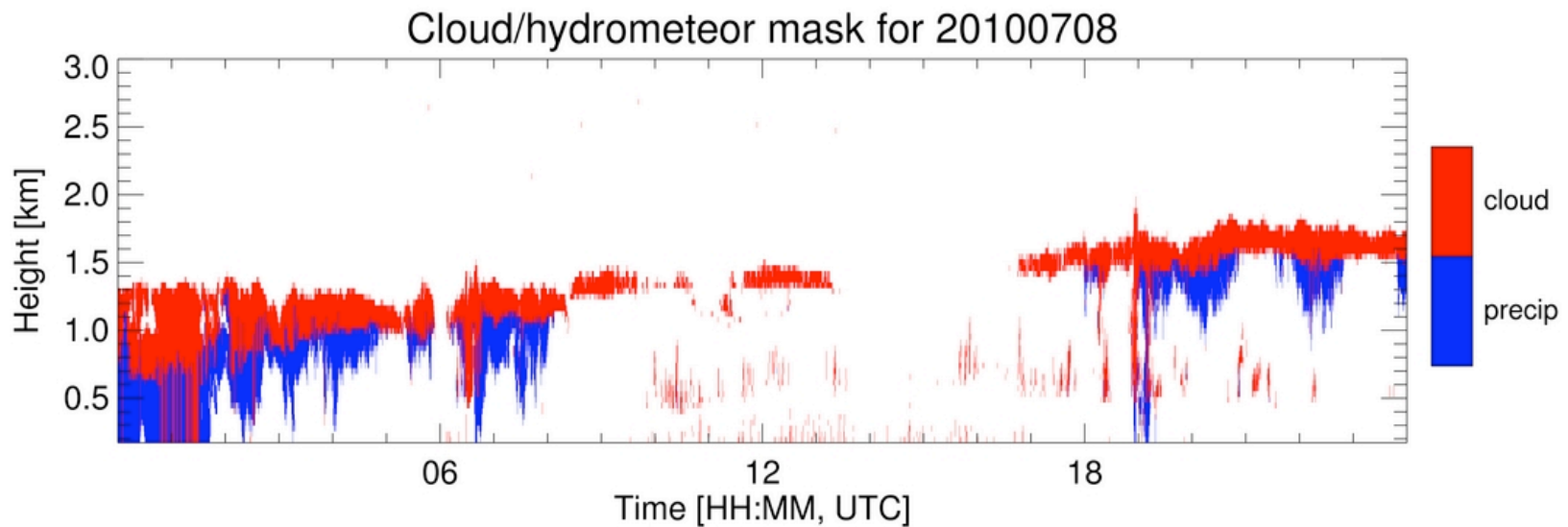


Example



- WACR reflectivity (colors) and ceilometer bases (black dots)
 - Radar echoes below lidar base indicate precipitation

Example



- Regions containing only precipitation (blue), and those with cloud particles (red)

Cloud and precipitation

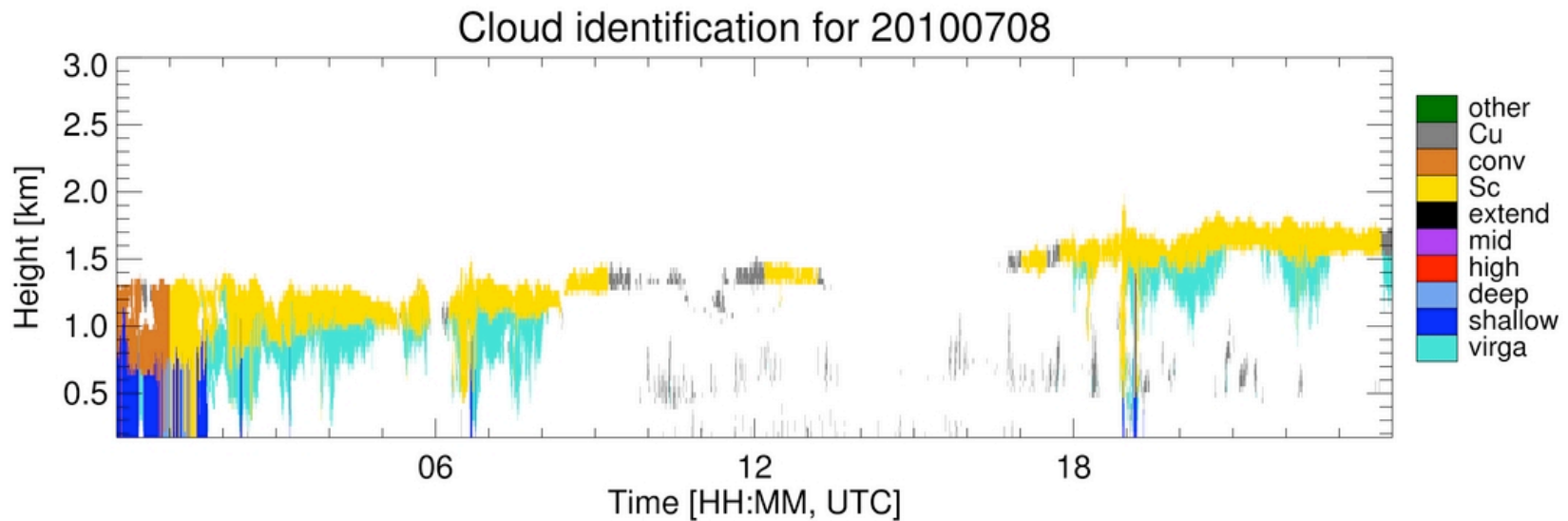
Cloud identification → done daily by cloud clusters
(each analyzed by hours)

Type	High	Middle	Extending	Cu	Sc	Other
CB	> 7km	> 3km	< 3km	—	—	—
CT	—	—	> 3km	< 3km	< 3km	< 3km
Duration	—	—	—	< 20min	> 20min	> 20min
CT variability	—	—	—	—	< 100m	> 100m

Precipitation identification → done profile by profile

Type	Virga	Light	Intense
Echo base	> 200m	< 200m	< 200m
Base reflectivity	—	< 0dBZ	> 0dBZ
Echo below CB	Yes	Yes	Possible

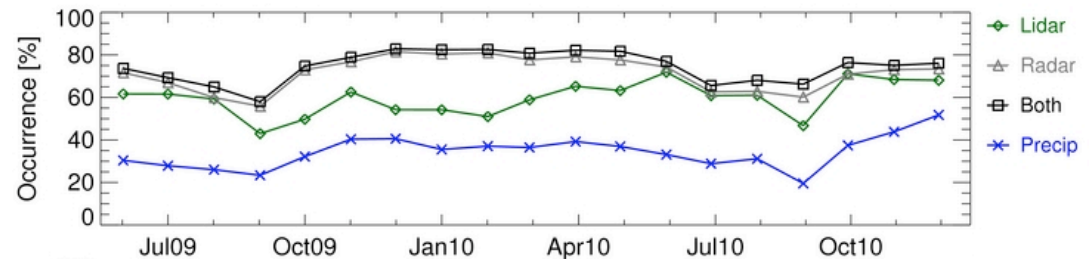
Example



- Identification of cloud and precipitation types (showing only in the BL)

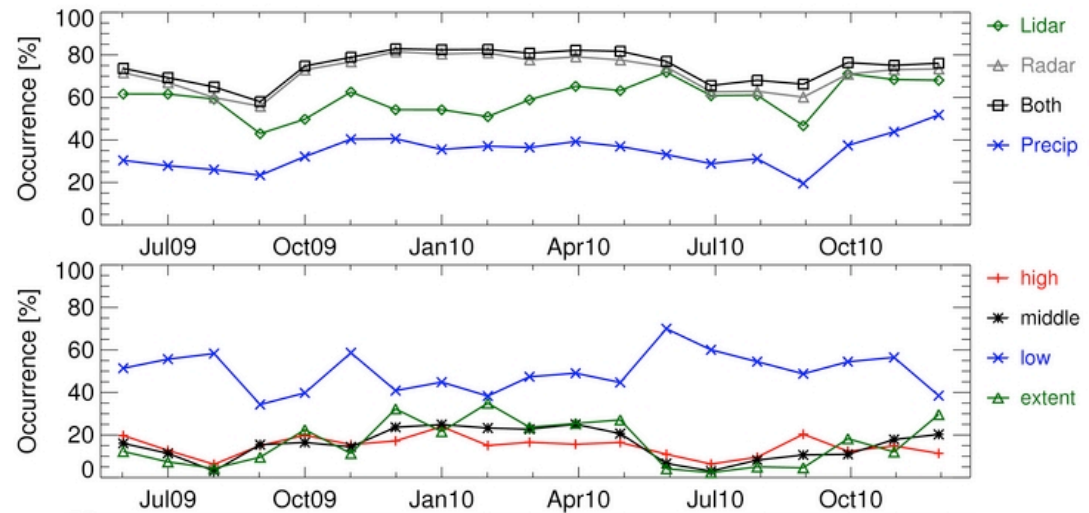
Full results

Minimum cloud coverage in late summer / early fall, and around half of the cloudy profiles had also liquid precipitations



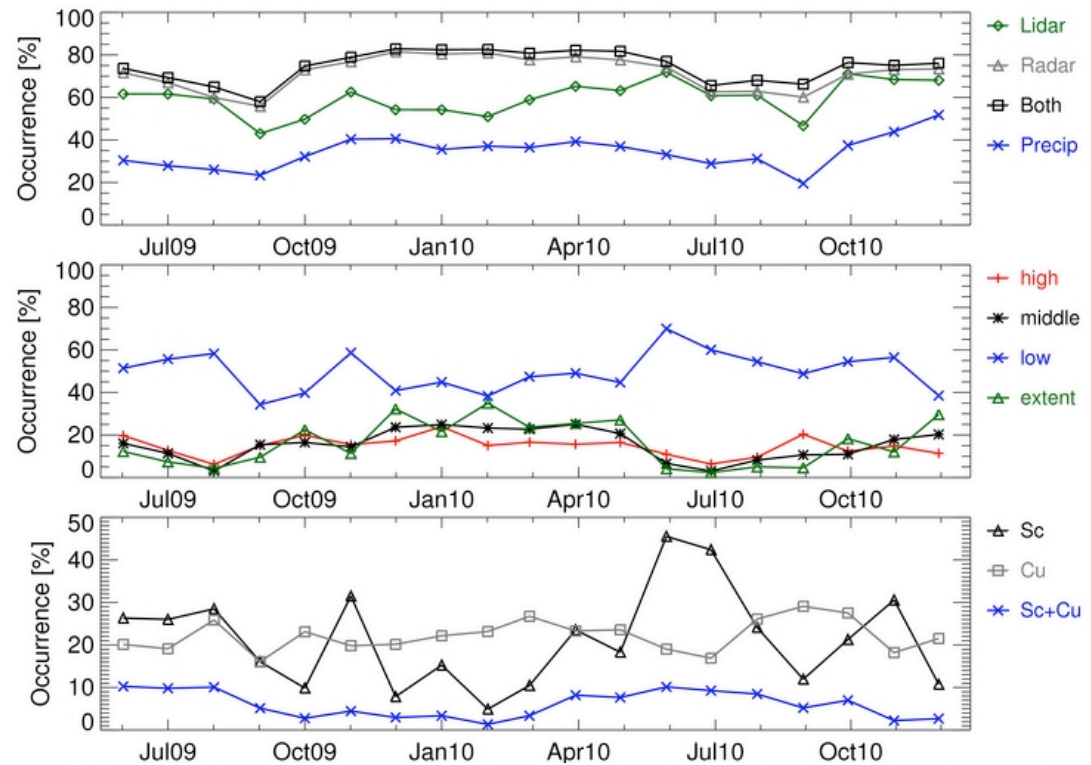
Full results

BL clouds dominate the atmosphere, especially in spring and summer, while higher clouds have minima occurrences in summertime.

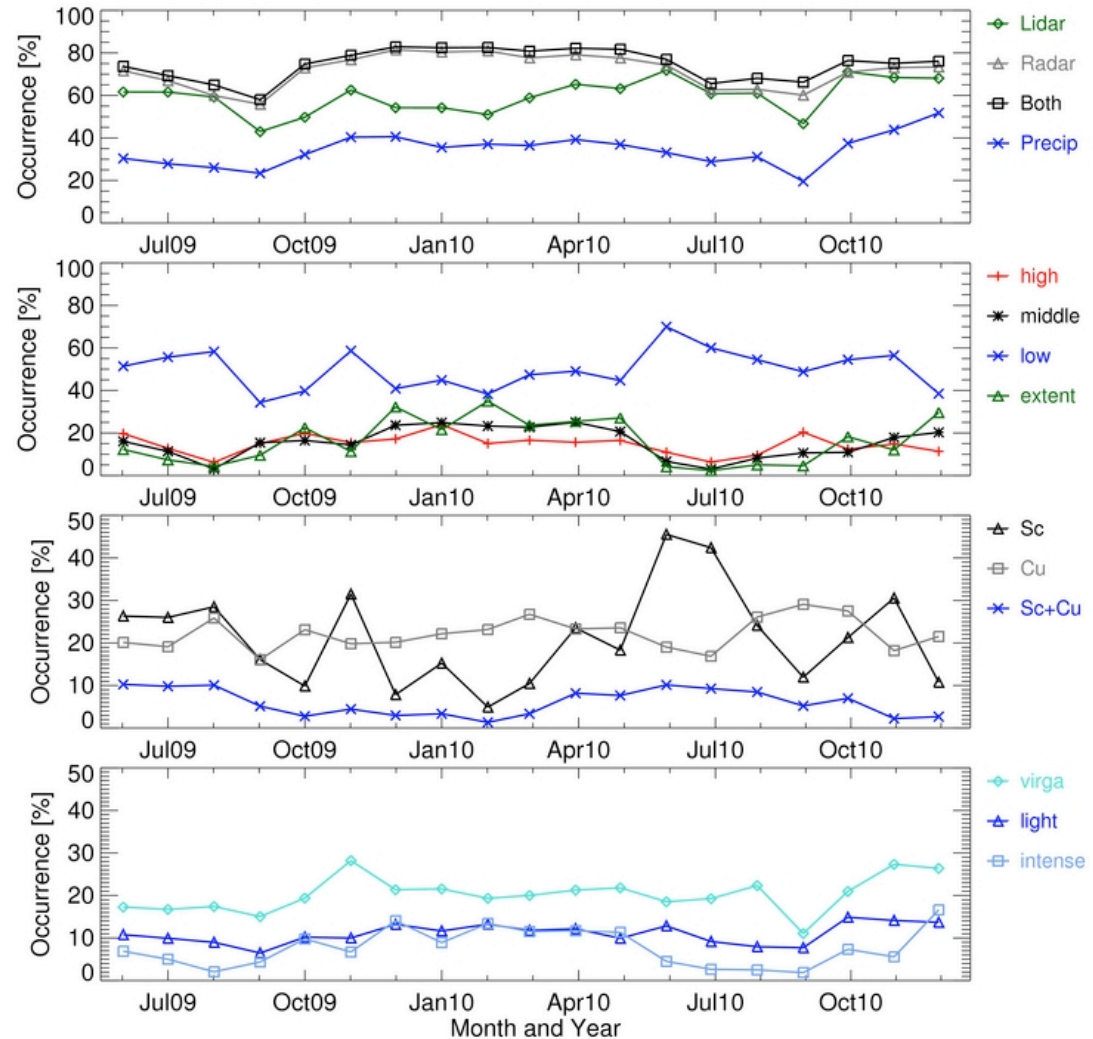


Full results

BL clouds are mostly Cu or Sc, and they often coexist within an hour (especially in spring and summer)



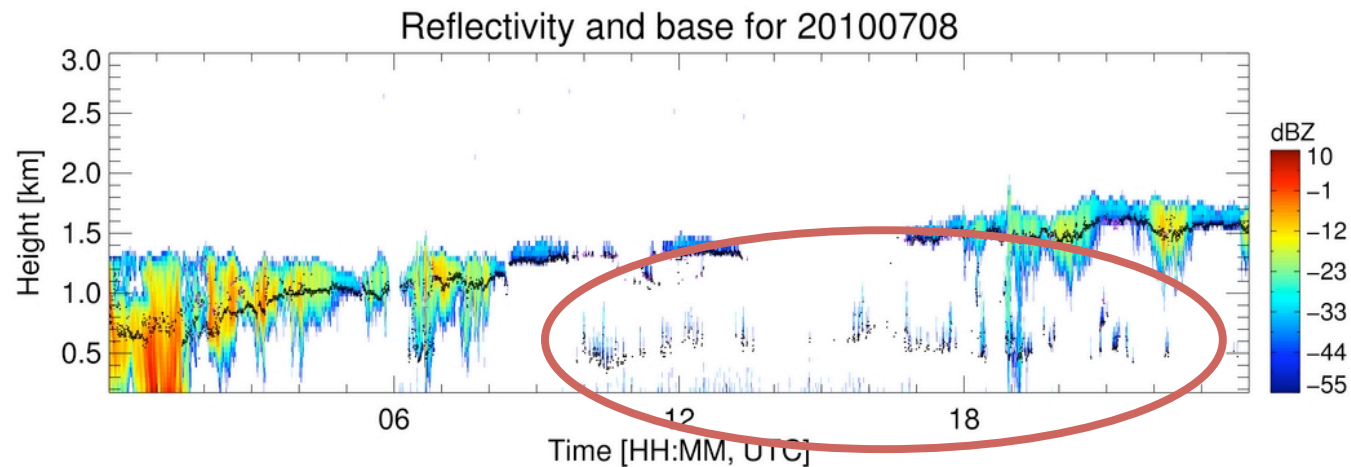
Full results



Most precipitation evaporates before reaching the ground, and intense precipitation at the ground occurs mainly in winter.

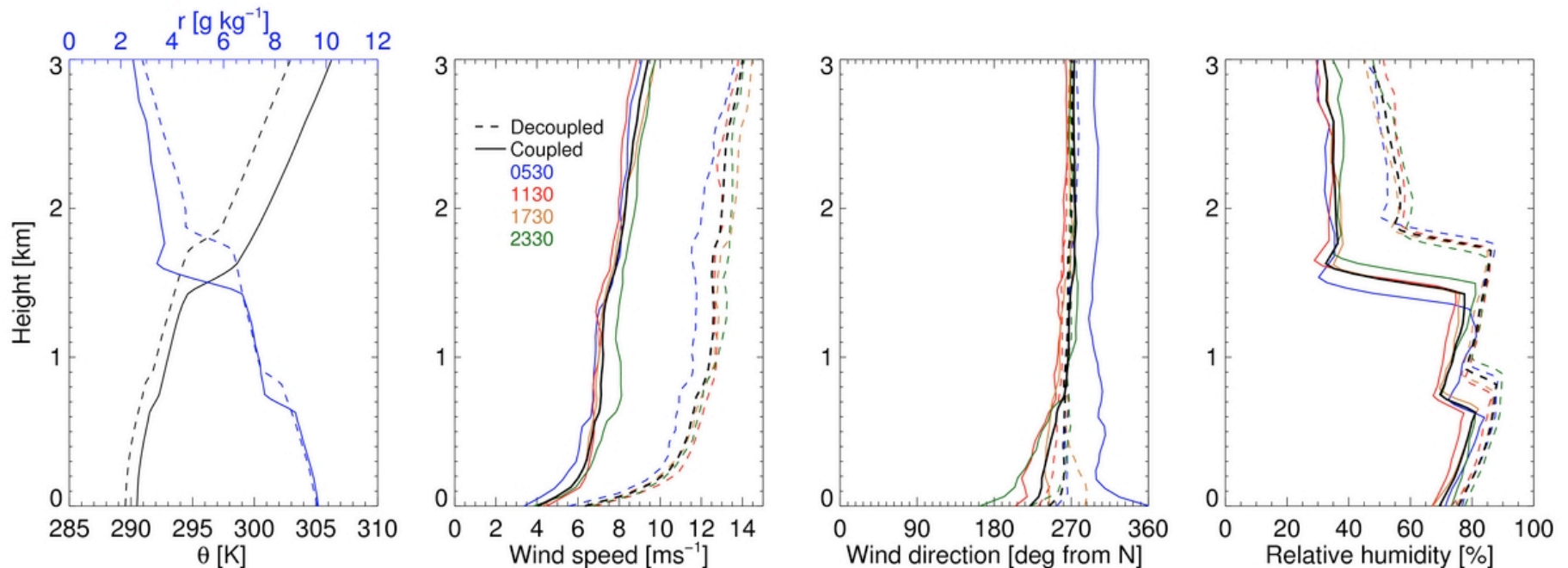
Detection of decoupling in the BL

- Multiple cloud layers are most likely forming in a decoupled BL
 - Decoupled/coupled hours selected based on the multi-layer statistics in the BL ($> 10\%$ vs. 0%) and the cloud base variability in the BL ($> 300\text{m}$ vs. $< 100\text{m}$)



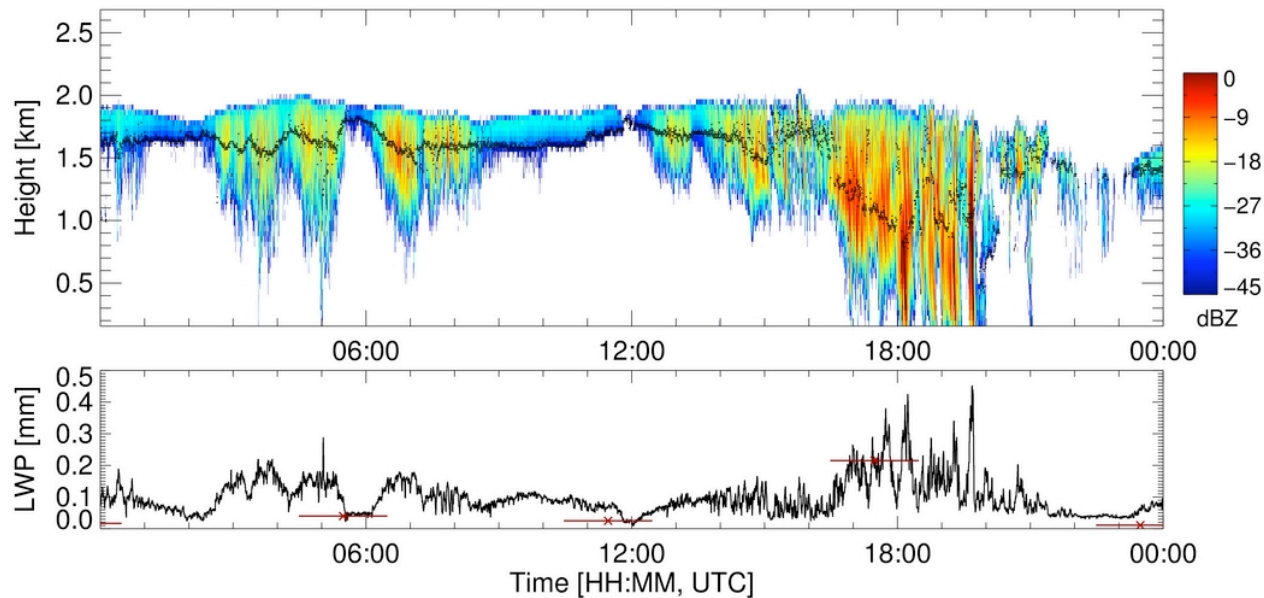
Thermodynamic state

- Layer-by-layer averaging was performed on the soundings linked to decoupled/coupled hours
 - Both usually have a transition layer
 - Coupled cloud layer found either at the inversion or the transition (about 50-50, resulting in lower averaged RH)

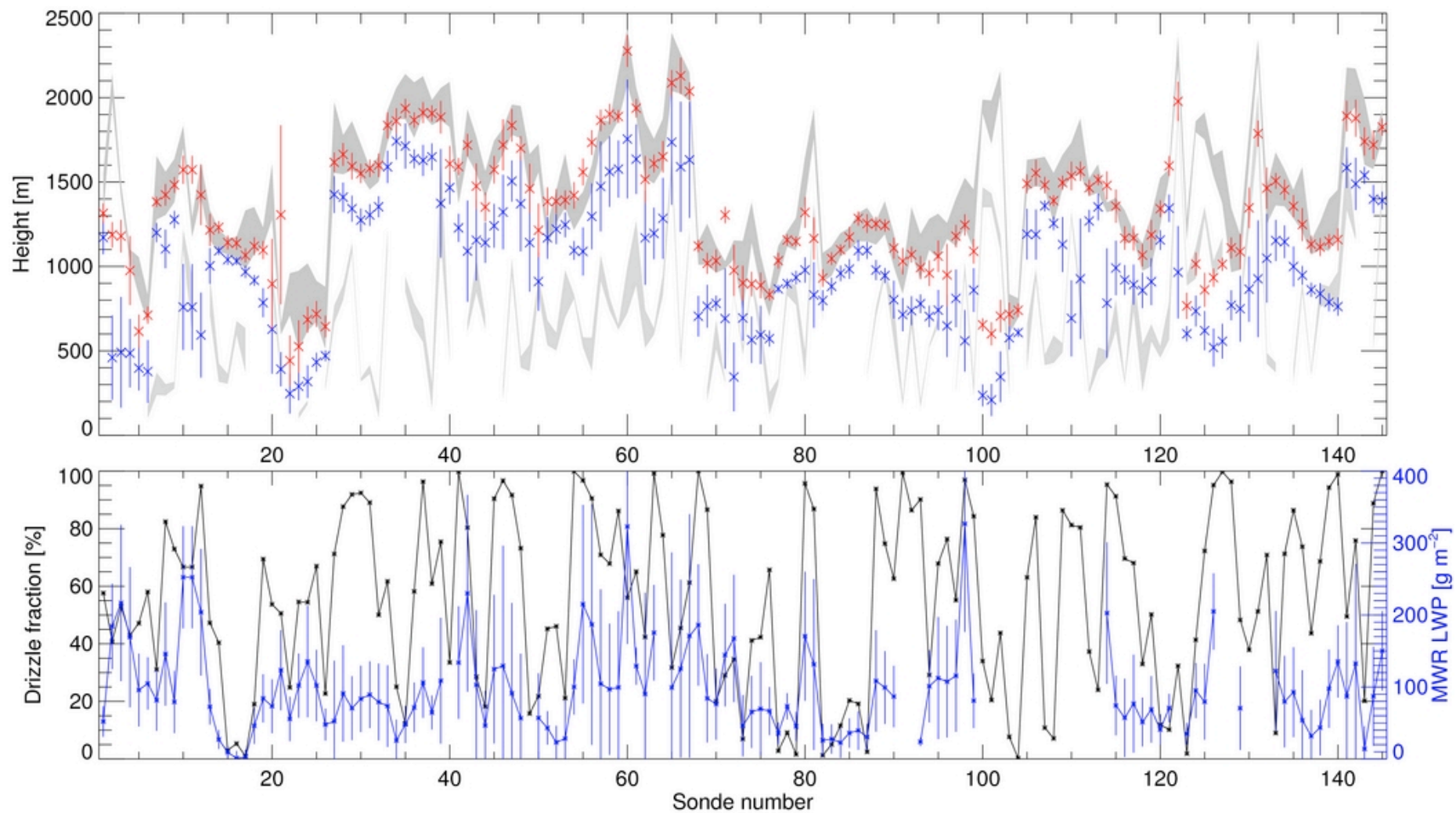


Selection of good Sc cases

- Persisting for the most part of a day ($> 50\%$)
- Most of the Sc is single-layer ($> 90\%$)



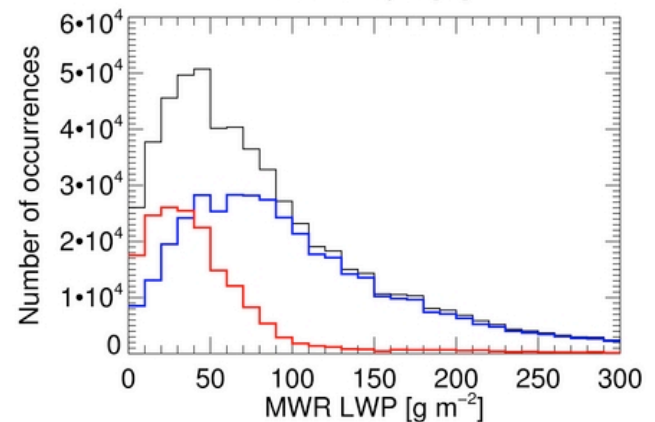
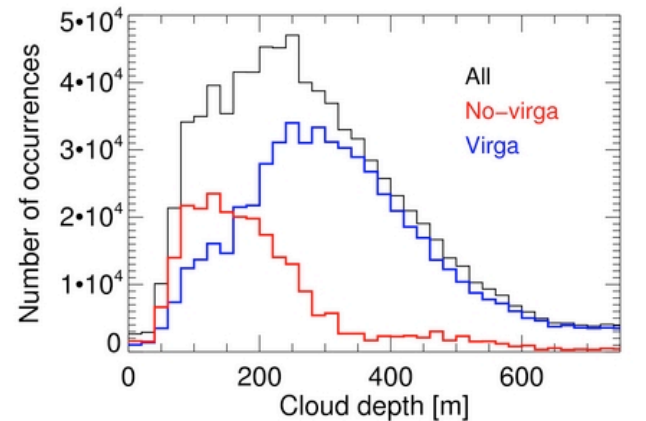
→ 35 days selected



Non-drizzling vs. Drizzling

The Sc coverage can be divided into periods when drizzle is falling from the cloud, and periods without virga (or very limited).

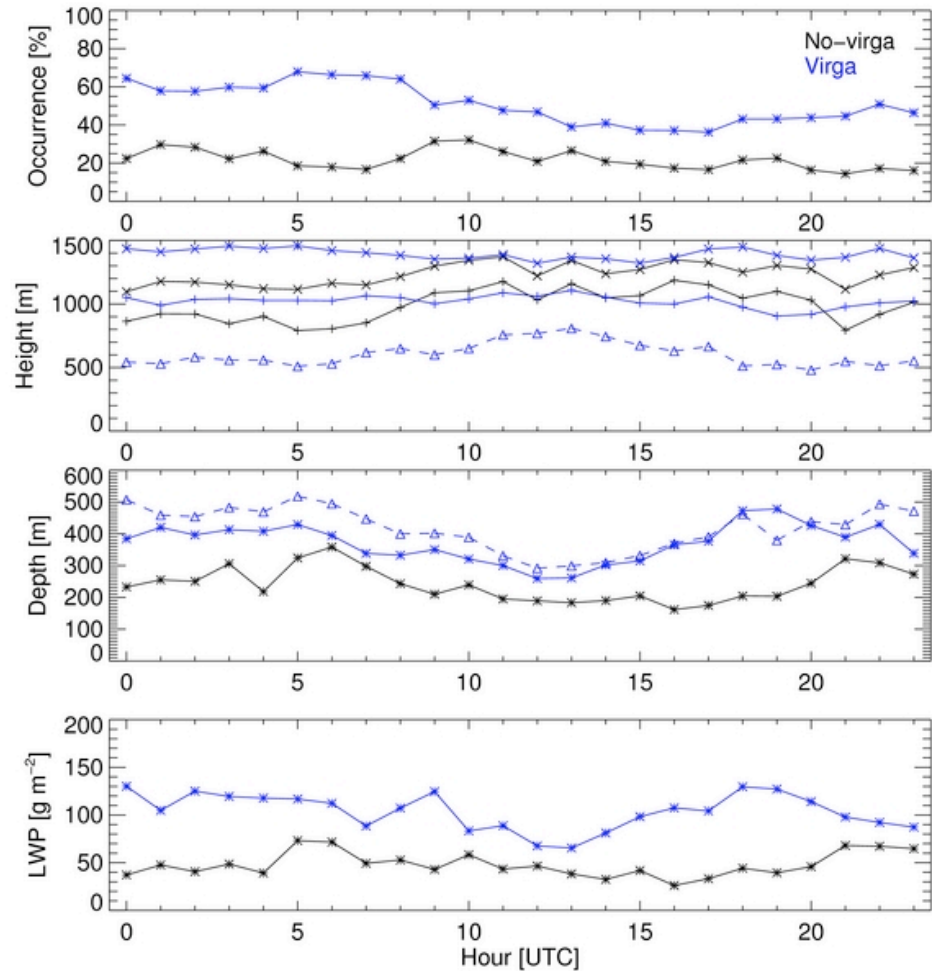
Precipitating periods are characterized by thicker clouds, and stronger liquid water paths.



Composited daily cycle

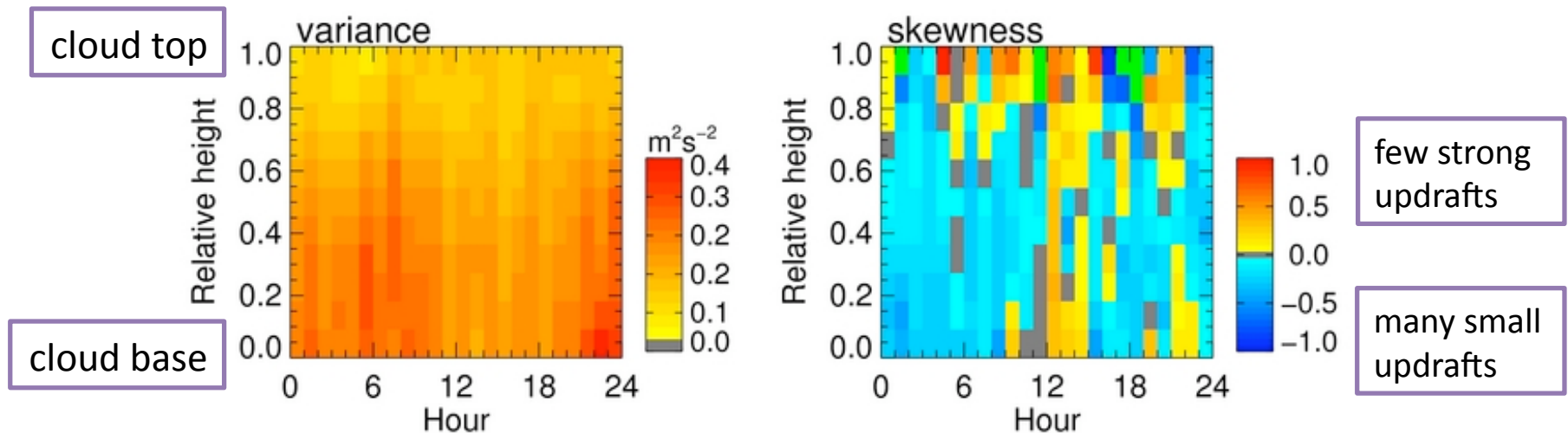
Compositing the hourly statistics from the 35 selected days, a daily cycle is obtained.

- blue: falling drizzle detected
- black: no virga detected



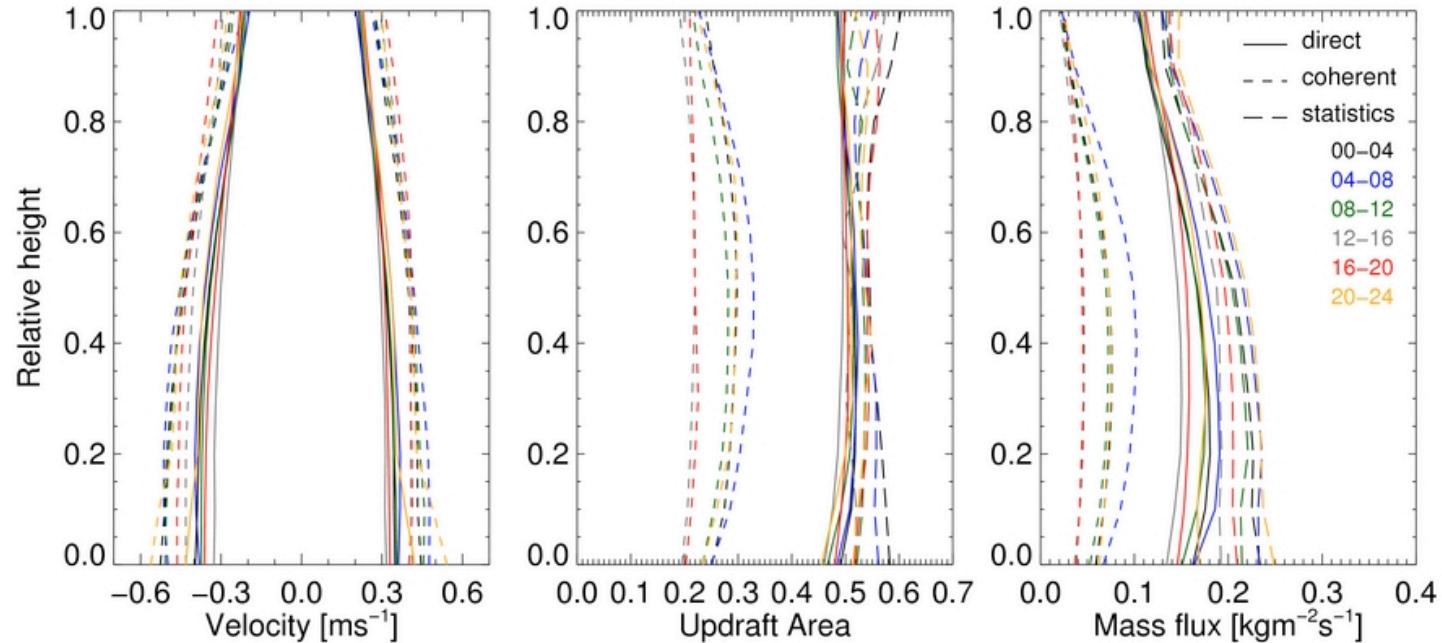
Turbulence

Hourly statistics of the radar velocities during the Sc periods without radar echoes below the ceilometer base provide information about the turbulence and drafts.



Updrafts and mass fluxes

- 3 different views
 - Direct sampling
 - Coherent structures
 - Statistical method (Randall et al., 1992)



Summary

- The Azores are cloudy, with many BL clouds, including a lot of Sc clouds.
- It is hard to detect real coupled BL periods using only cloudiness measurements.
- Drizzling Sc clouds are thicker and higher, and contain more liquid than their non-drizzling counterparts.
- Sc clouds have a propensity to precipitate, although it doesn't reach the ground often.

Summary

- Sc clouds are linked to the inversion at the BL top.
- The marine Sc observed were rather calm.
- Coherent structures account for about half of the mass flux in those marine Sc, with a maximum observed around sunrise.

(Near) future work

- Retrieval of drizzle microphysics and cloud dynamics from the WACR Doppler spectra
- Characterization of the factors influencing drizzle production and growth in marine Sc clouds