Ship-based Doppler lidar studies of atmospheric decoupling under a Sc-topped MABL

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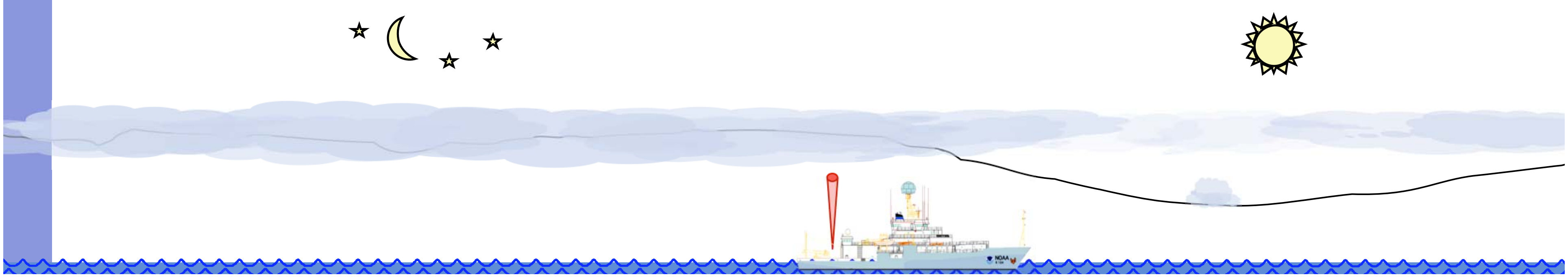
With thanks to Derek Coffman, Dave Covert, Graham Feingold, Hailong Wang and scientists and crew of the RHB VOCALS cruise



Atmospheric Decoupling during VOCALS

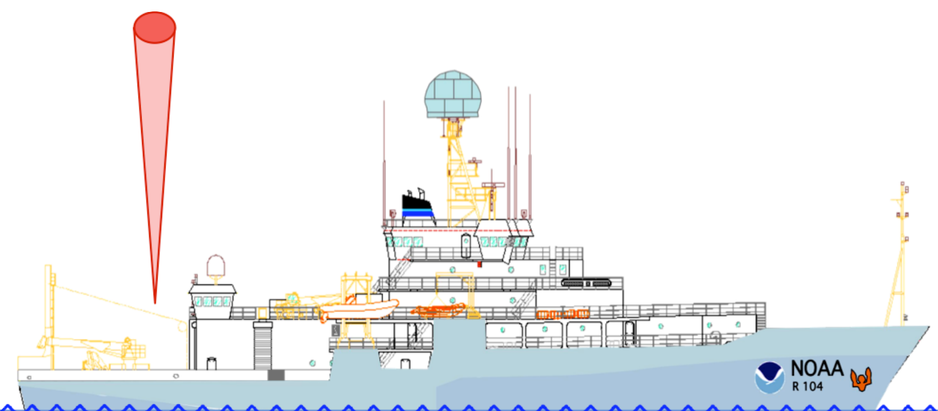
AMS: When one layer of the atmosphere stops interacting with an adjacent layer.

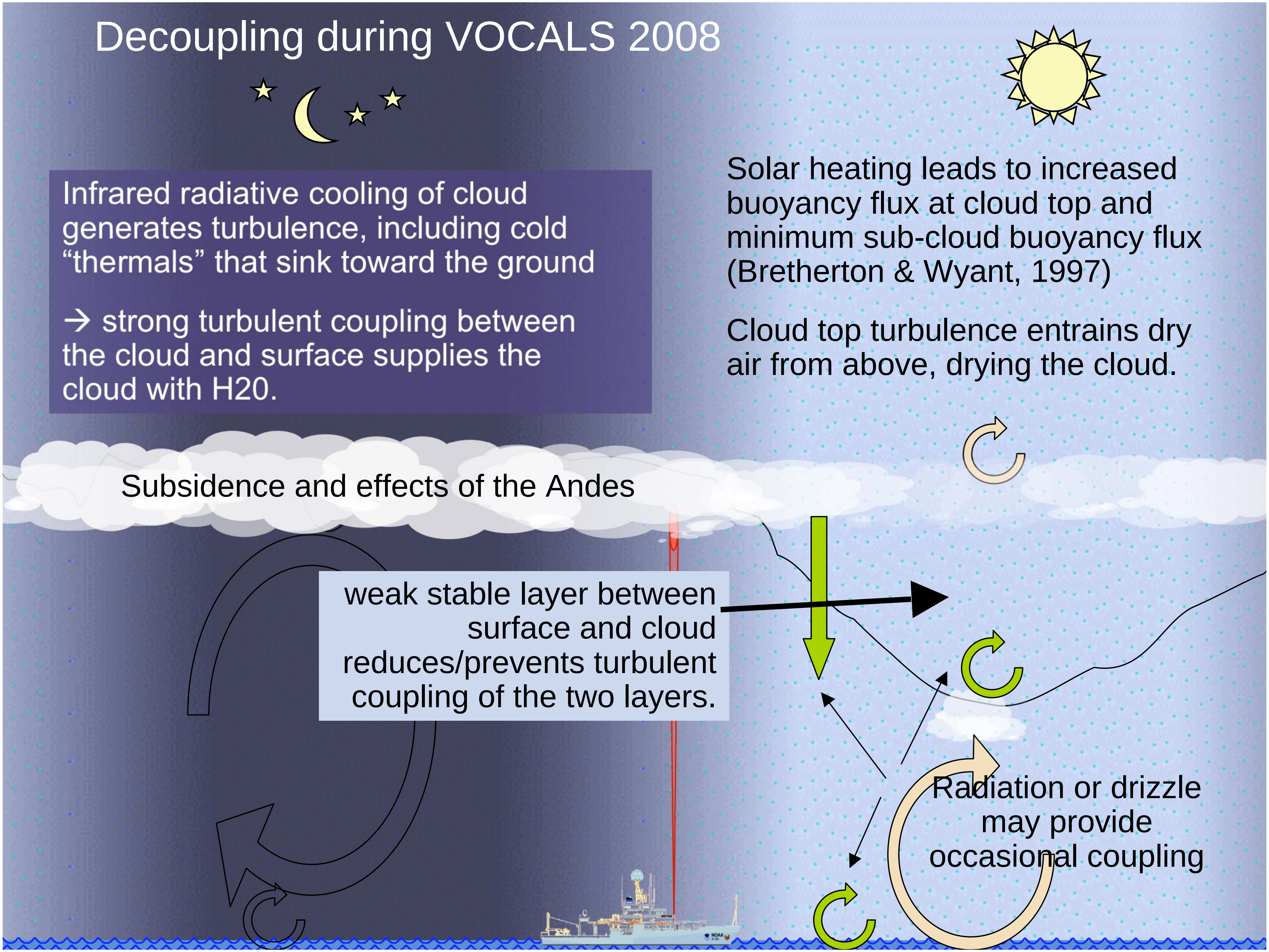
Proposed definition: When the atmospheric mixing layer connected to the surface stops interacting with the Sc-cloud layer/level aloft,…

…defined (for this study) to occur on time scales of ~10 minutes.

Why do we care?

- Maintenance of the Stratocumulus deck
- Relationship between surface (ship) in-situ measurements and clouds aloft
- Aircraft/ship measurement comparisons
- …

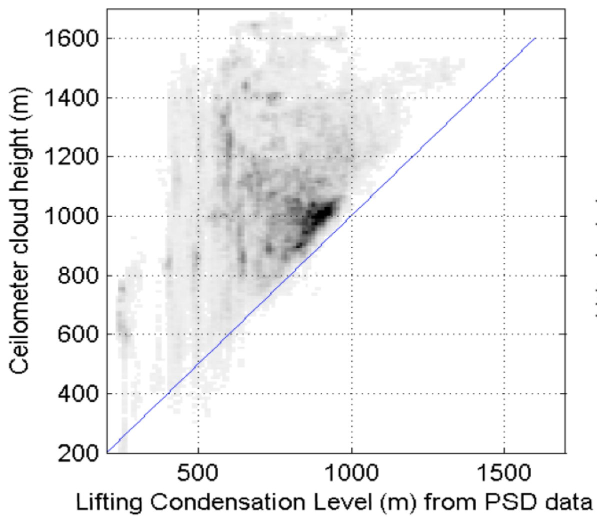



Decoupling during VOCALS 2008
Infrared radiative cooling of cloud generates turbulence, including cold "thermals" that sink toward the ground
→ strong turbulent coupling between the cloud and surface supplies the cloud with H20.
Solar heating leads to increased buoyancy flux at cloud top and minimum sub-cloud buoyancy flux (Bretherton & Wyant, 1997)
Cloud top turbulence entrains dry air from above, drying the cloud.
Subsidence and effects of the Andes
weak stable layer between surface and cloud reduces/prevents turbulent coupling of the two layers.
Radiation or drizzle may provide occasional coupling

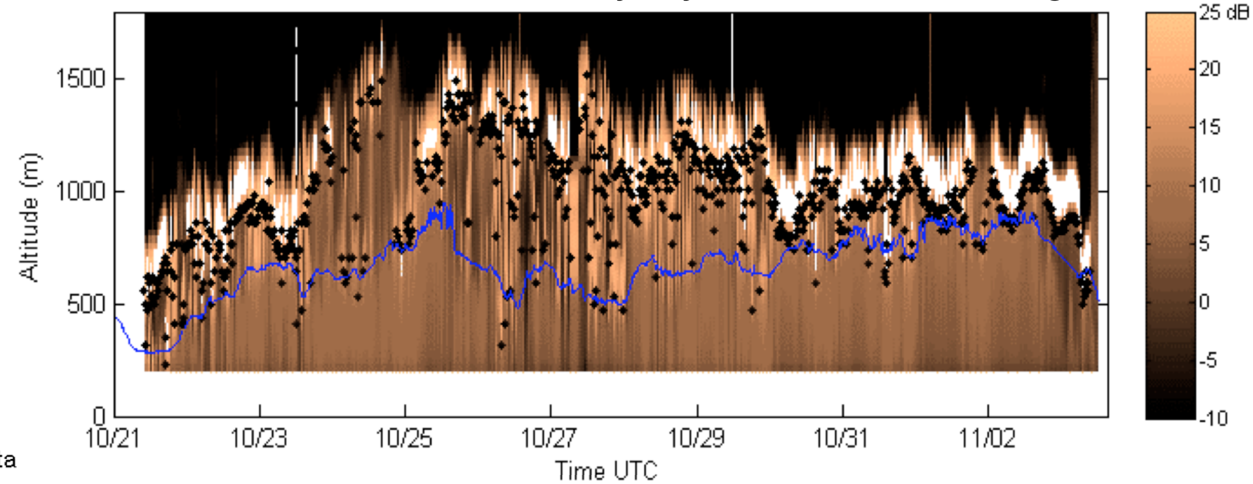
How can we define, characterize, and/or parameterize decoupling? (regularly)

- Cloud-base height - lifting condensation level (CBH-LCL)
- **Cloud-base height - mixing height (CBH-MH)**
- Where **mixing height** is determined using
  - Lidar velocity variance (turbulence) profiles
  - Lidar aerosol backscatter gradient

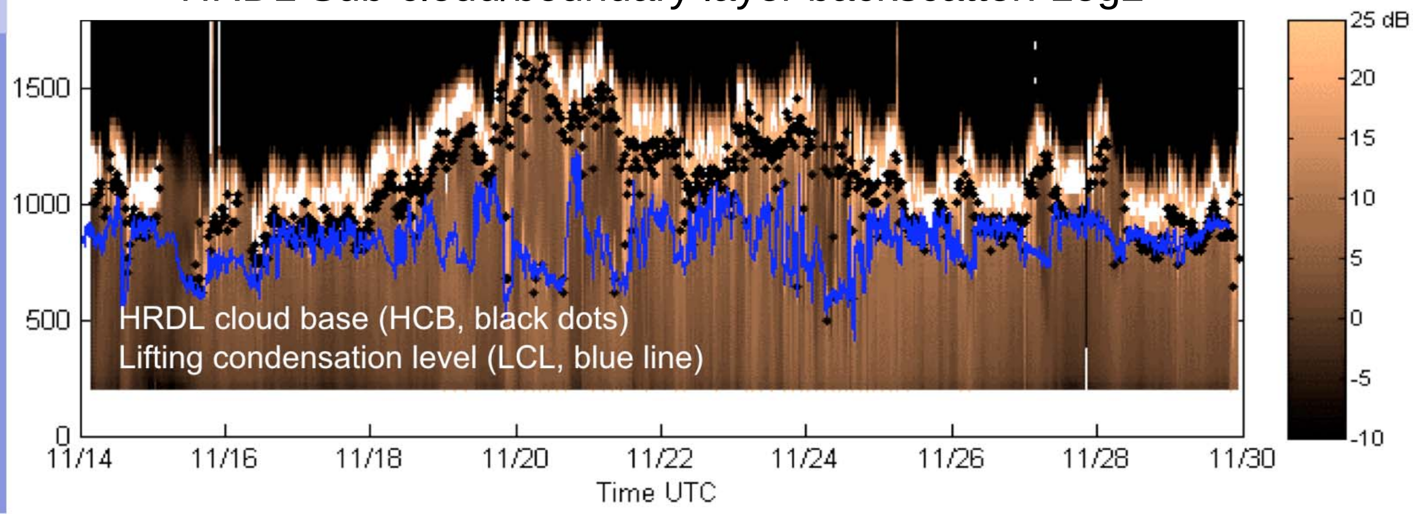
HRDL backscatter, HRDL/CL31 cloud-base, and lifting condensation level (LCL)



HRDL Sub-cloud/boundary layer backscatter: Leg1



HRDL Sub-cloud/boundary layer backscatter: Leg2



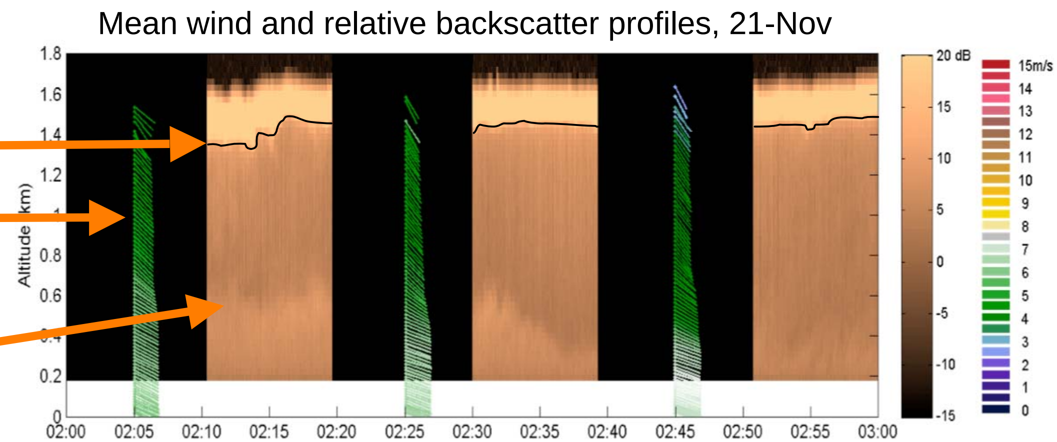
Says nothing about mixing, i.e. transport of water to cloud

Let’s look at dynamics…

Cloud base

Mean horizontal wind profiles

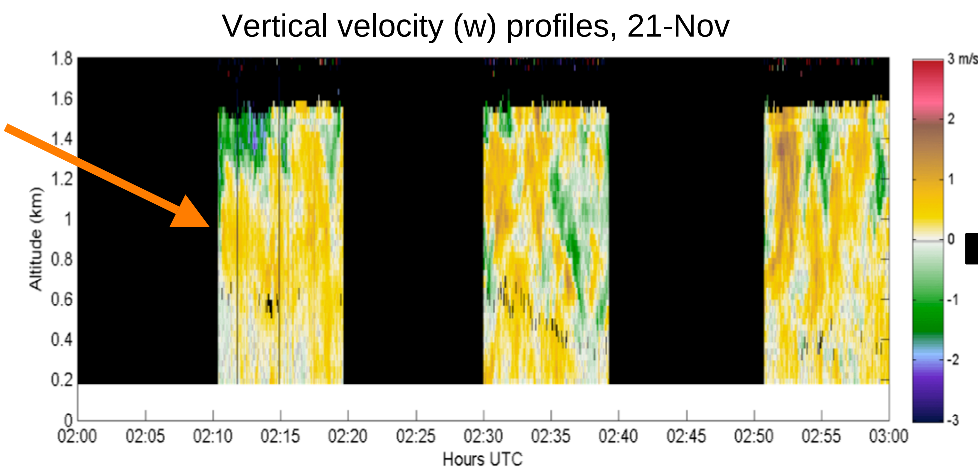
Aerosol gradients

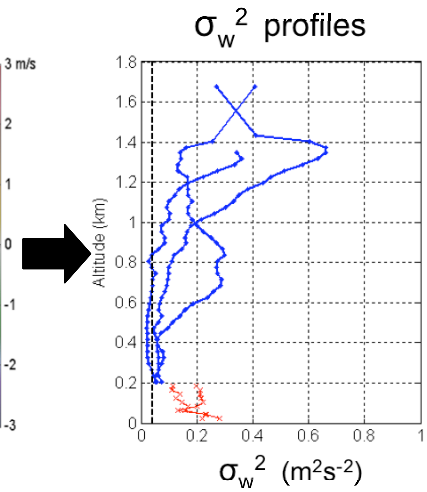


Vertical velocities in "clear" air

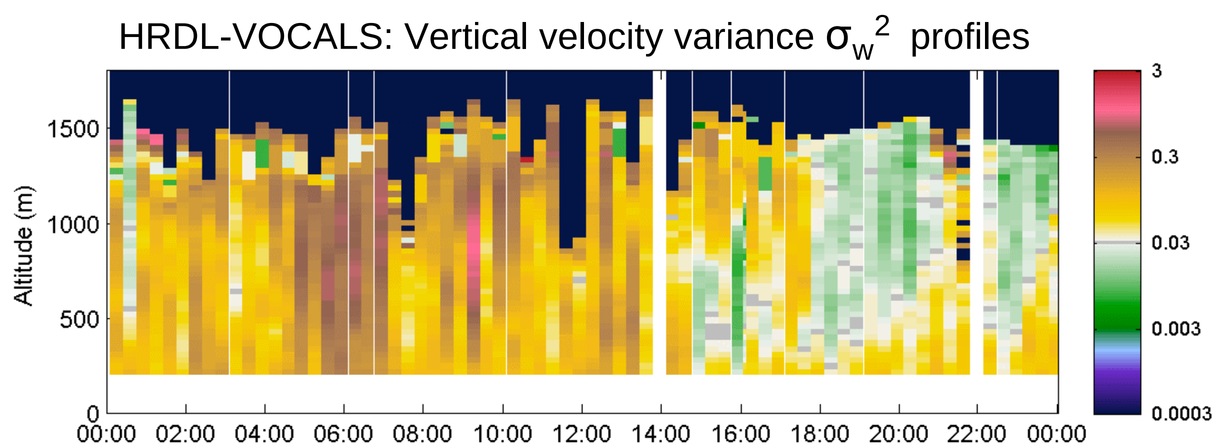
Cool colors → falling air and/or droplets

Warm colors → rising air



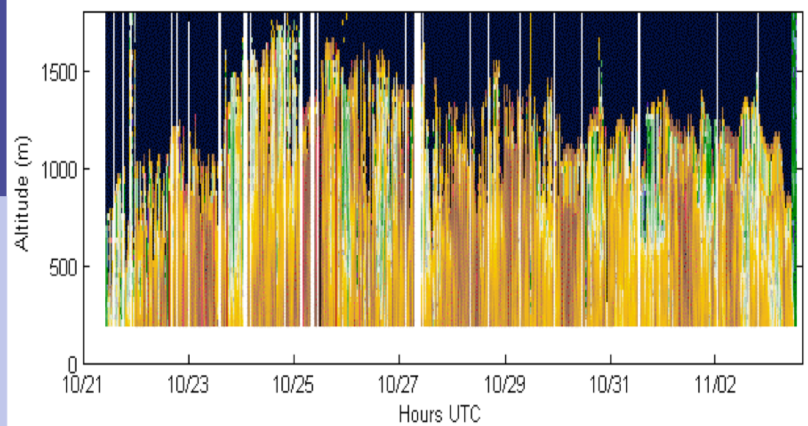


Example HRDL observations of sub-cloud turbulence including the diurnal cycle

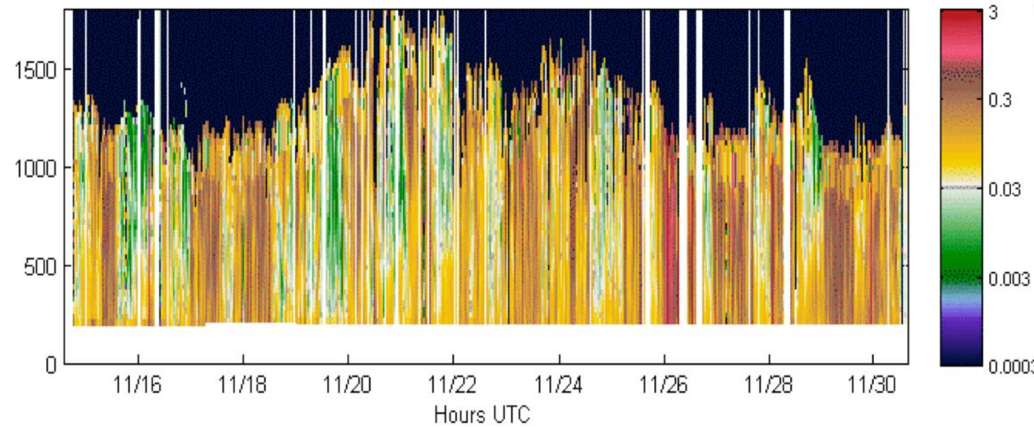


Diurnal cycle in velocity variance

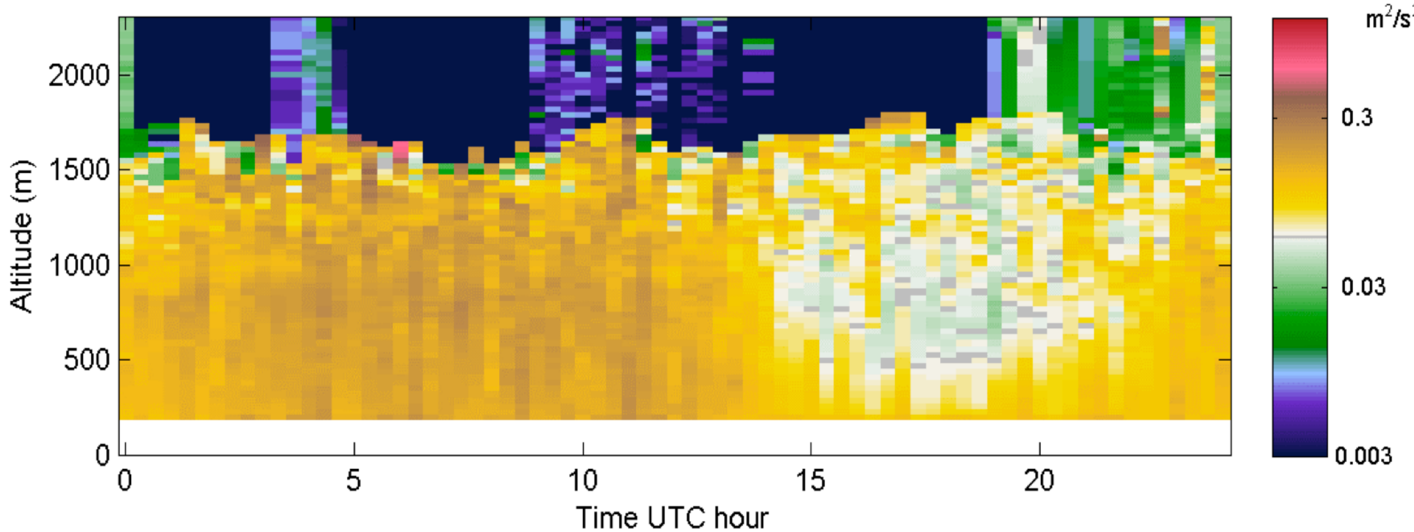
σ_w^2 profiles Leg1: 21 October to 03 November 2008



σ_w^2 profiles Leg 2: 14 to 30 November 2008

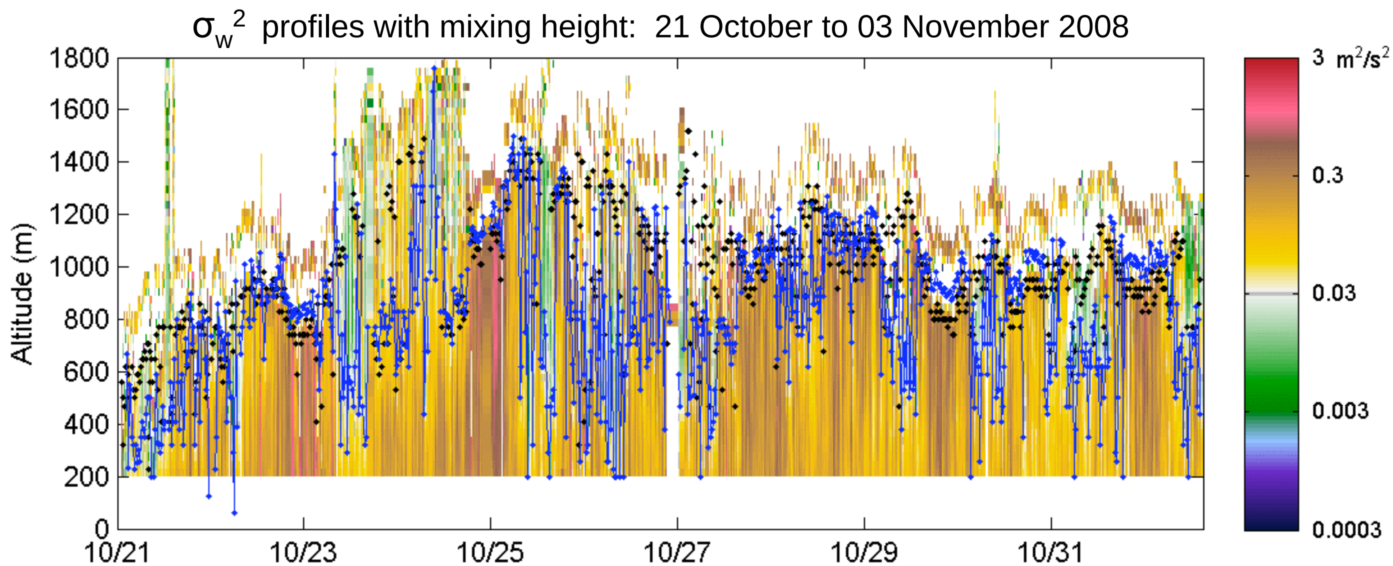


Diurnal Cycle: Average σ_w^2 profiles:
21 October to 30 December 2008



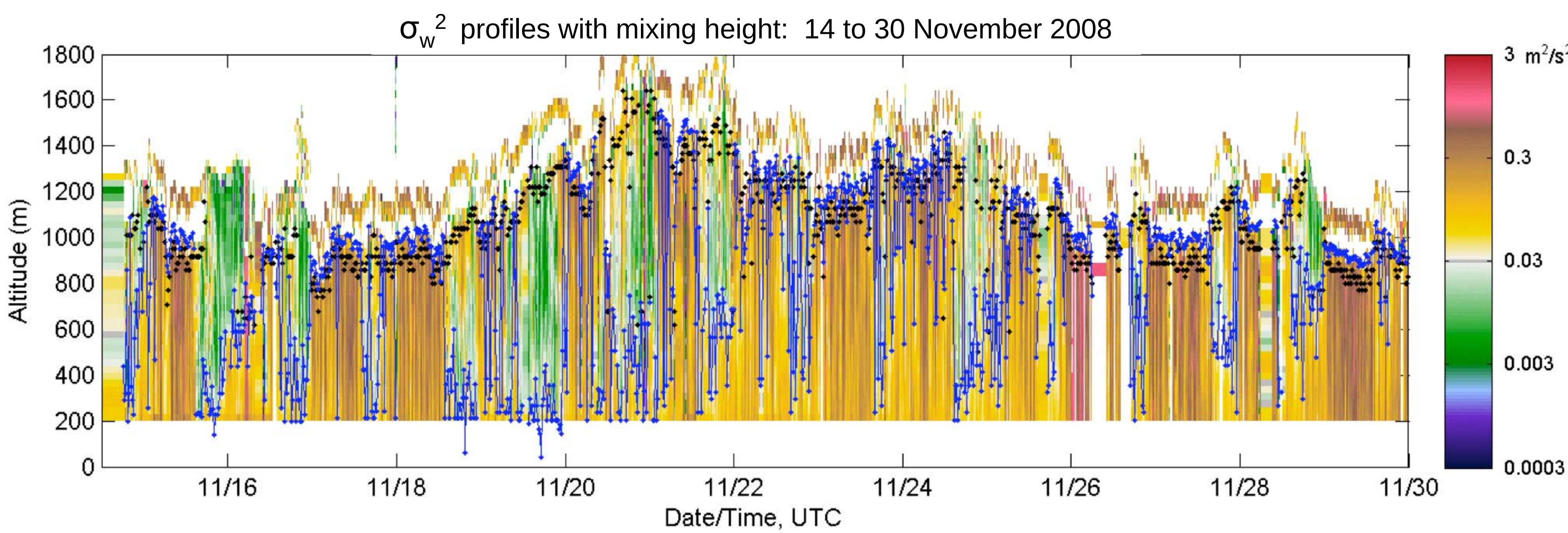
Average daytime σ_w^2 is ~50% lower

HRDL-VOCALS: σ_w^2 Profiles and Mixing Height (MH)

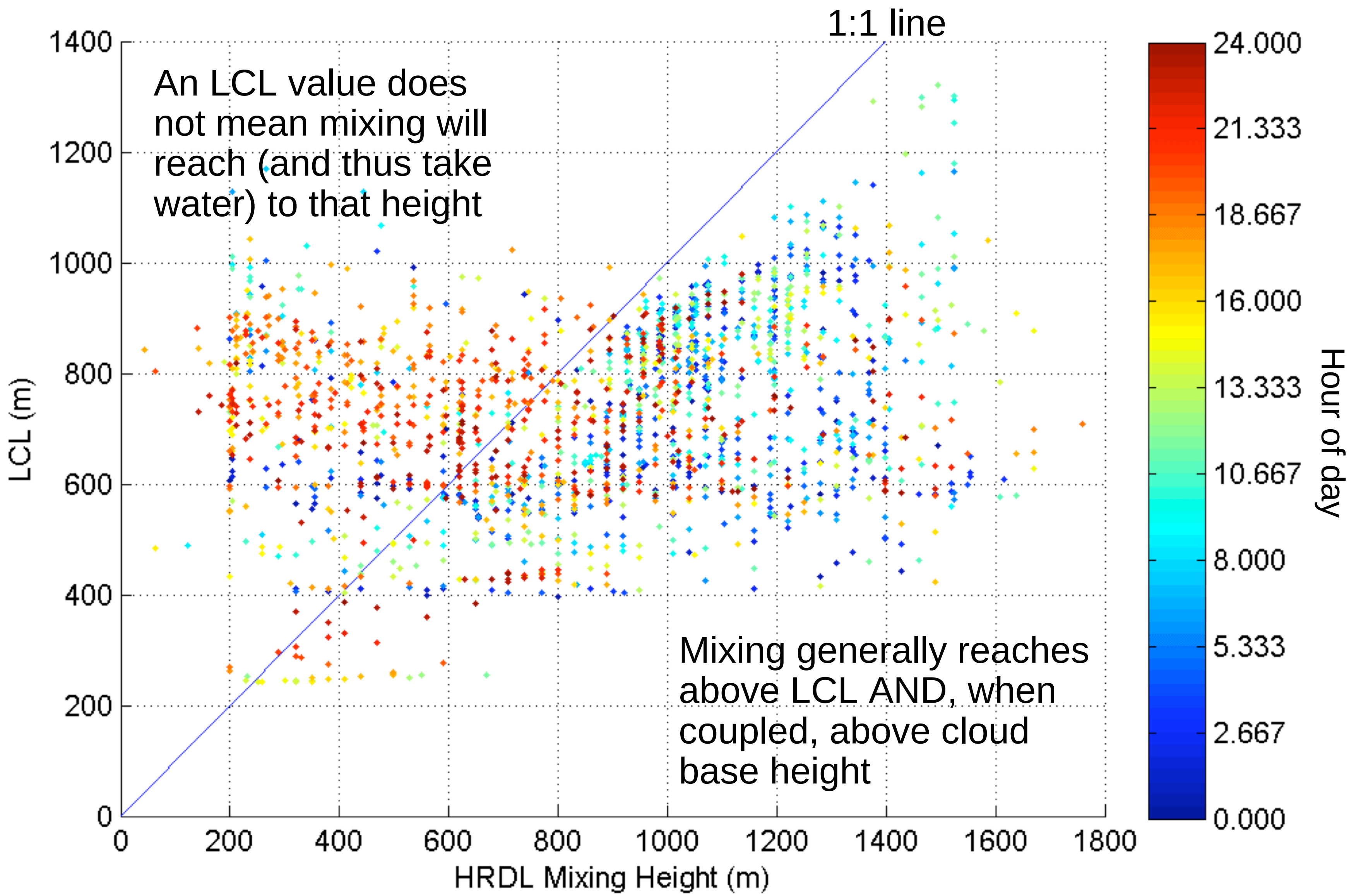


We defined decoupling as CBH-MH.

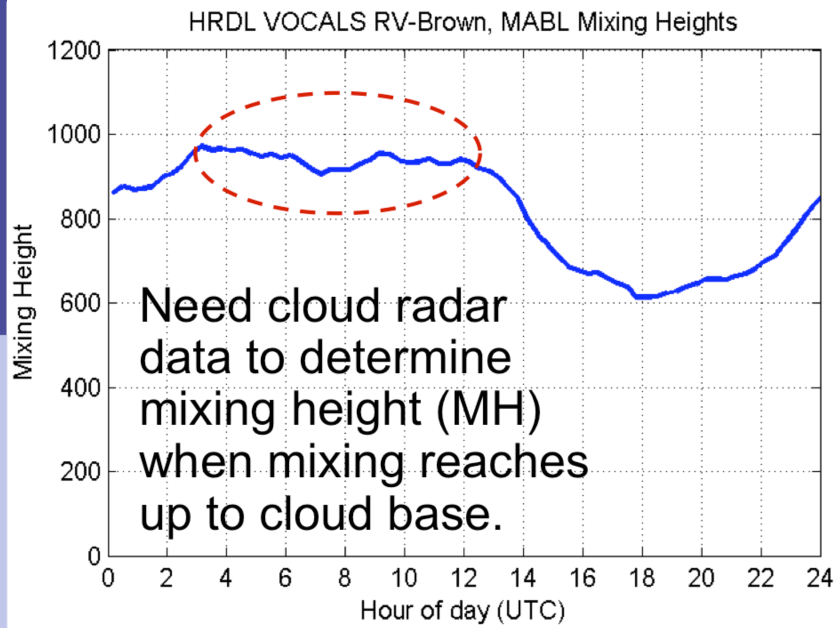
So how does MH compare to LCL?

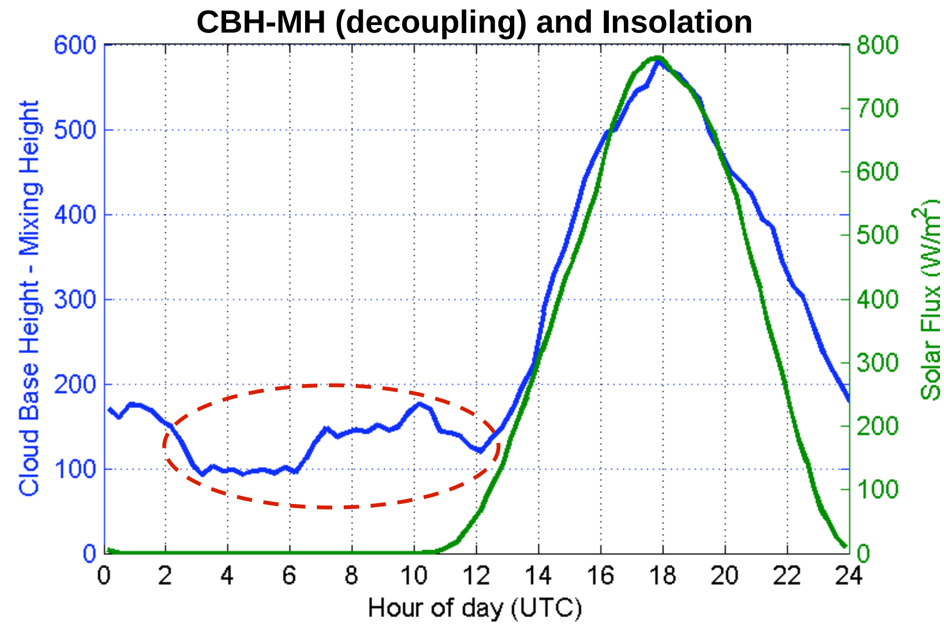


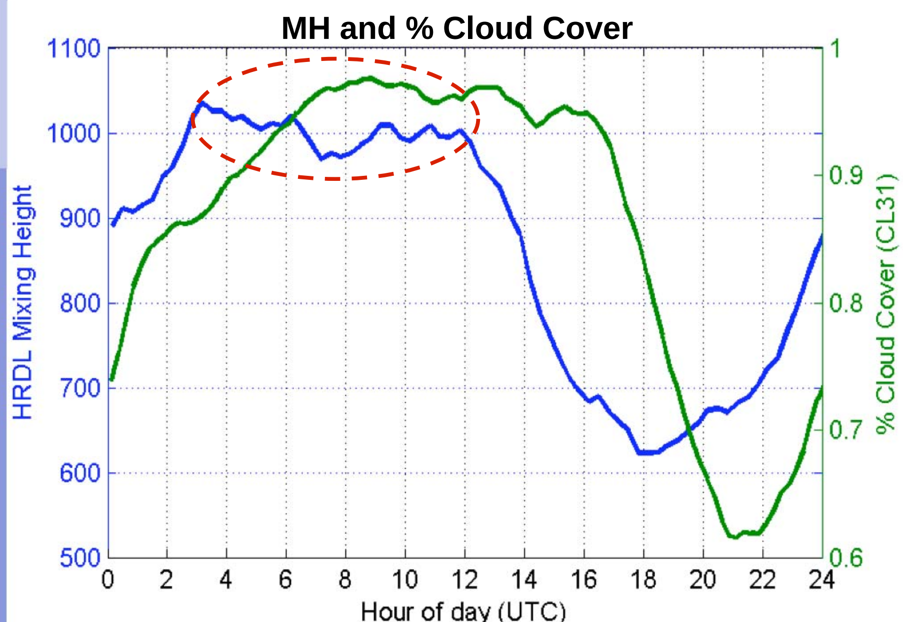
LCL vs Mixing Height

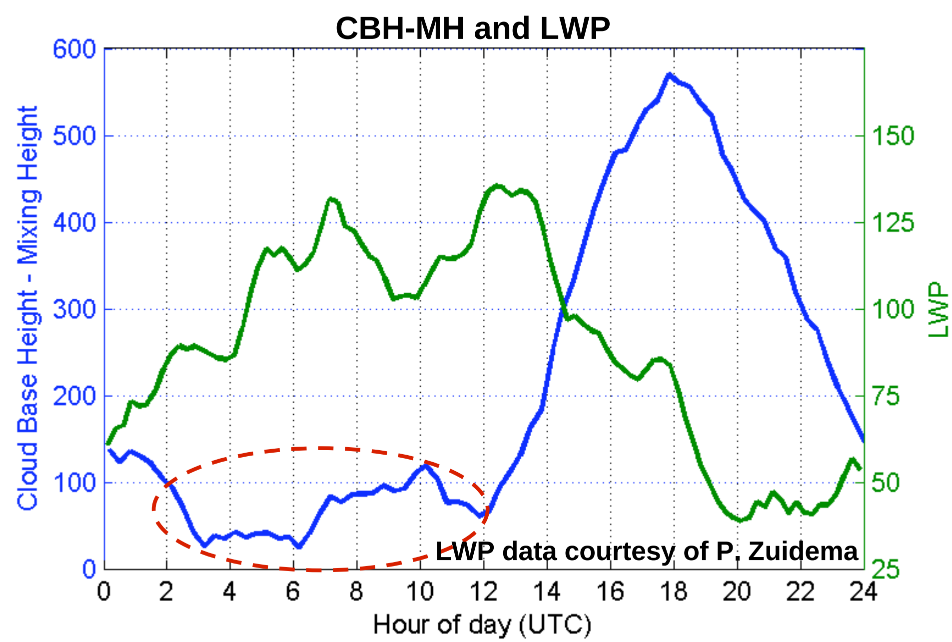


Diurnal Cycles: MH, Decoupling (CBH-MH), cloud cover, LWP, etc.









Conclusions

- Doppler lidar velocity measurements provide an alternative method to study coupling/decoupling between the surface (water source) and Sc layer.
- This method reveals a strong diurnal cycle in decoupling.

Ongoing HRDL-VOCALS MABL studies

- Characterize mechanisms for supplying Sc layer with water.
- Study velocity variance properties (cell size, magnitude, etc.) as a function of
  - Altitude, cloud height
  - Longitude/distance from shore
  - Wind Speed/direction, Surface RH, Temperature, latent heat flux
  - Synoptic scale conditions
  - Buoyancy flux (at surface and aloft using θ_v and HRDL variance profiles)
- Compare sub-cloud variance to radar & a/c measurements aloft

Thanks to NOAA/CPPA, NASA, and NOAA/HOA for funding this work