Humidity structure in the subtropics

Louise Nuijens

Ilya Serikov, Holger Linné, Lutz Hirsch, Friedhelm Janssen,
Clara Herer, Irina Sandu and Bjorn Stevens

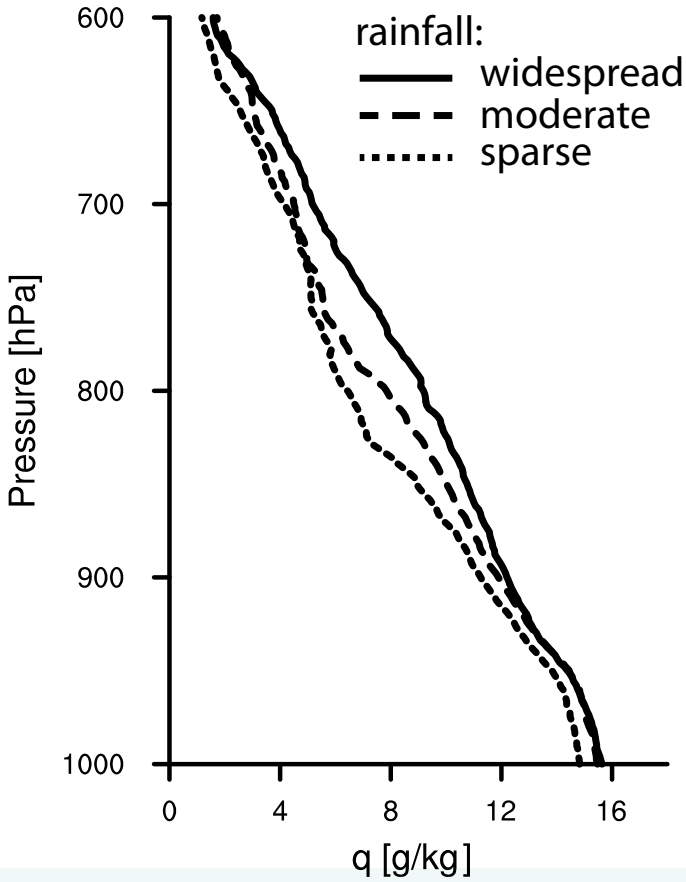
Relationships humidity and (shallow) convection

- **Relationships between humidity and rain from shallow cumuli (RICO) indicate that a higher humidity through the cloud layer promotes deeper clouds (that rain more)**
- **Similar relationships have been found in studies of deep convective rainfall**

Bretherton et al. (2004), Holloway and Neelin (2009)

- **Entrainment studies indicate the importance of humidity to cloud deepening**
- **Not just absolute humidity, but also its structure (gradients and inversion layer, transition layer) has been long recognized as an important control on convection and the coupling between the sub-cloud and cloud layer**

Betts (1973), Arakawa and Schubert (1974), Albrecht et al. (1979), Yin and Albrecht (1999) etc, etc.



Adapted from Nuijens et al. (2009)

Nothing new, but …

Can we further quantify how the humidity structure impacts convection? Ideas to be tested e.g.,

- **Sub-cloud layer humidity has a larger control on cloud occurrence than on cloud depth, (but what if convection gets deeper?)**
- **Transition layers are common features, and maintained through cloud activity (or not?)**
- **Integrated water vapor is more important than humidity gradients (or vice versa?)**

Relating cloudiness to humidity fits within the interest of MPI's Barbados effort, which is to:

1. **Improve process-level understanding of shallow convection**
2. **Study the role of large-scale forcings and importance of air mass history**
3. **Evaluate observations against NWP/GCM output**

Photo courtesy: Friedhelm Jansen

In this talk

I give an impression of how we have started exploring such questions using data from instruments deployed on Barbados (since April 2010). ECMWF analysis data for a single location upstream of Barbados is used complementary.

- **The Ceilometer is a 'low power' lidar, that measures the backscattered energy by cloud droplets (main product is cloud base height). Δt = 1 minute, Δr = 15 m**
- **The Raman ("green beam") lidar measures the backscattered energy by aerosol and cloud droplets, as well as water vapor molecules, who scatter energy at a (given) shifted frequency from the incident beam (main products ~ basically everything). Δt = 2 minutes, Δr = 60 m, max range = 15 km**

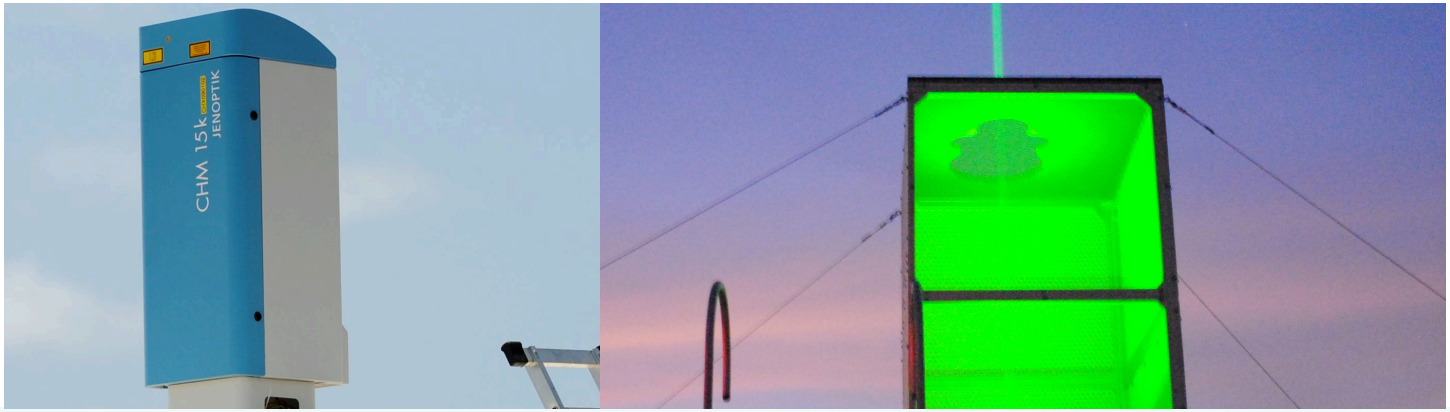
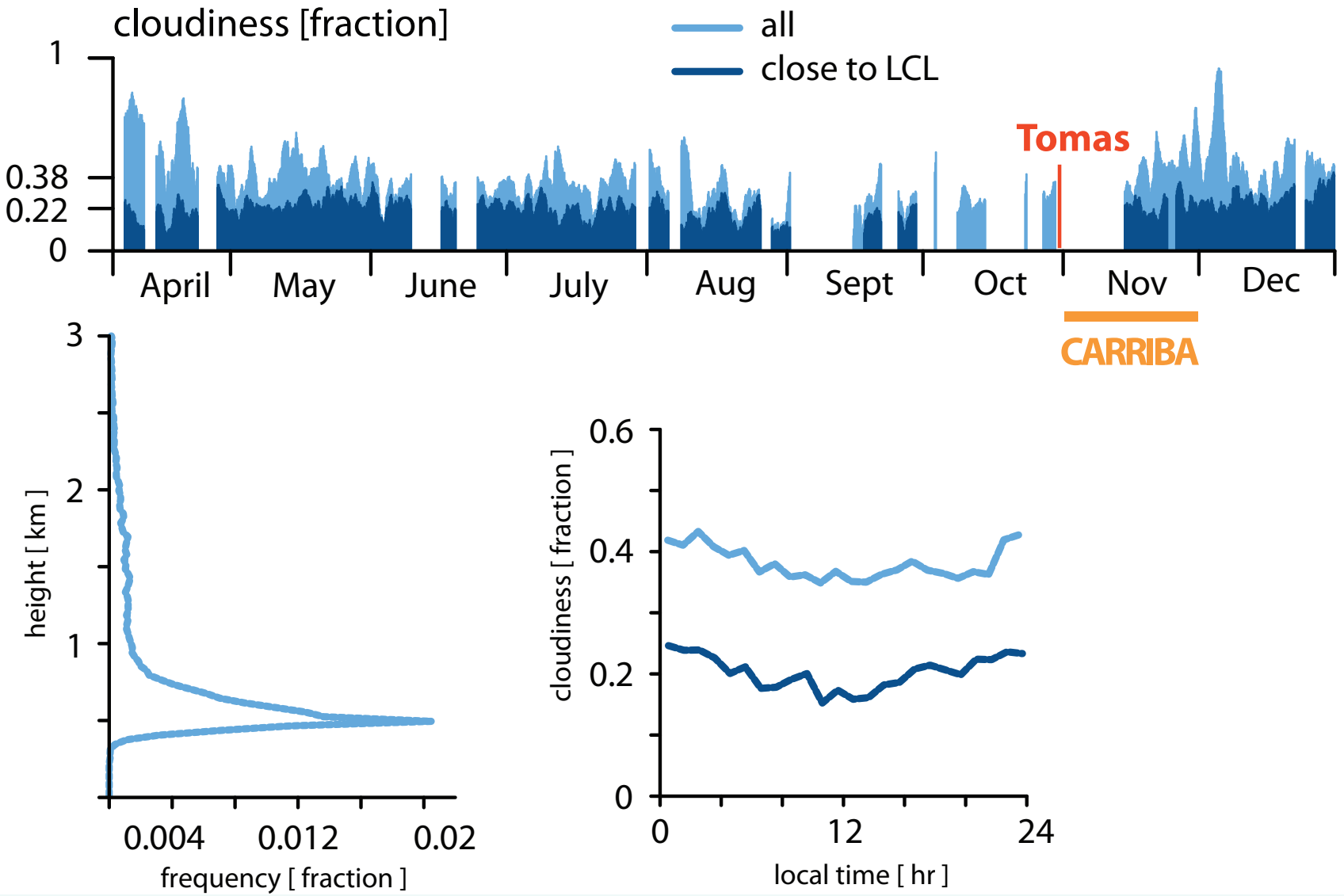
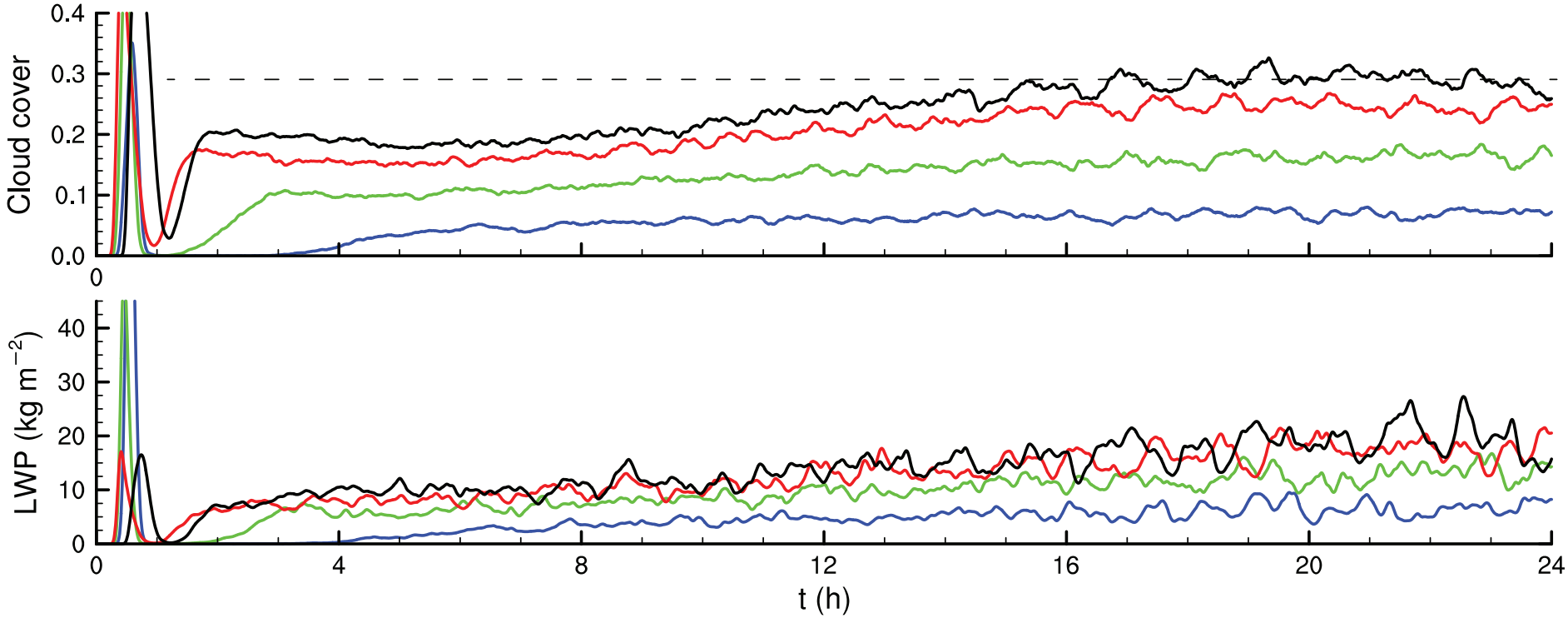


Photo courtesy: Friedhelm Jansen

Cloudiness


cloudiness [fraction]
all
close to LCL
1
0.38
0.22
0
Tomas
April
May
June
July
Aug
Sept
Oct
Nov
Dec
CARRIBA
3
2
1
height [km]
0.004
0.012
0.02
frequency [fraction]
0.6
0.4
0.2
0
cloudiness [fraction]
0
12
24
local time [hr]

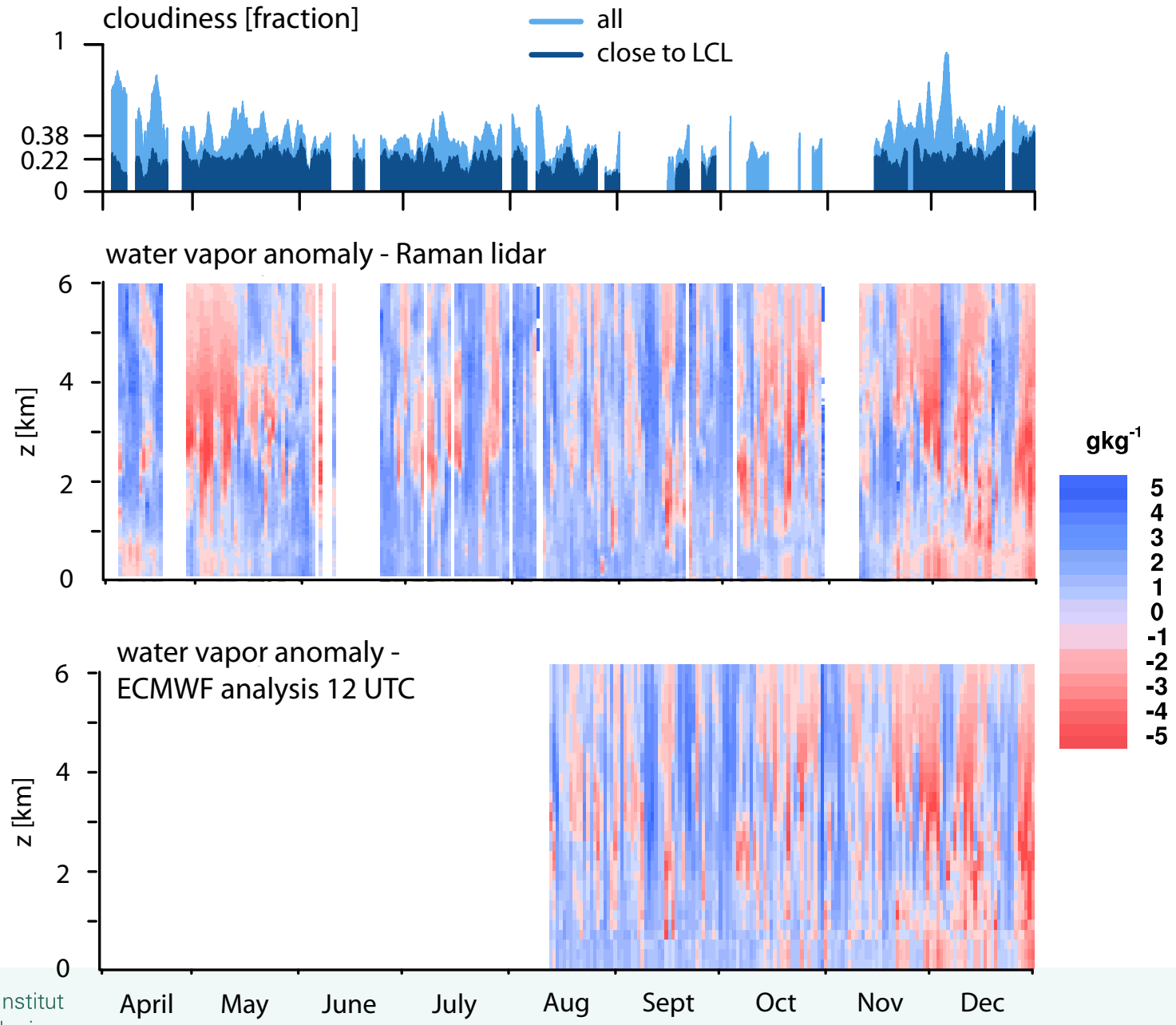
Cloudiness in LES



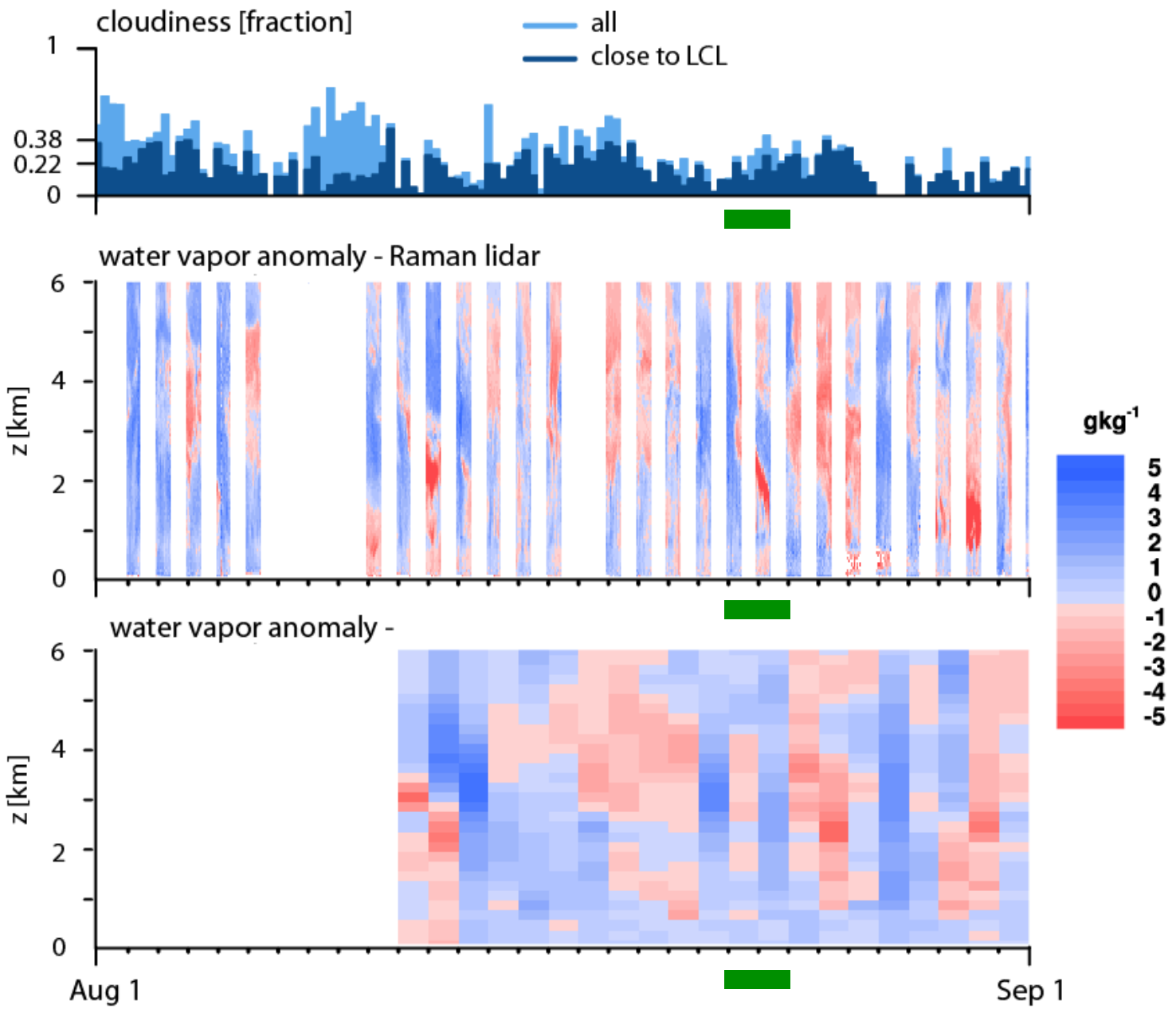
Δx = Δy = Δz = 10, 20, 40, 80 m

Adapted from: Matheou et al. (2011)

Cloudiness versus water vapor anomaly

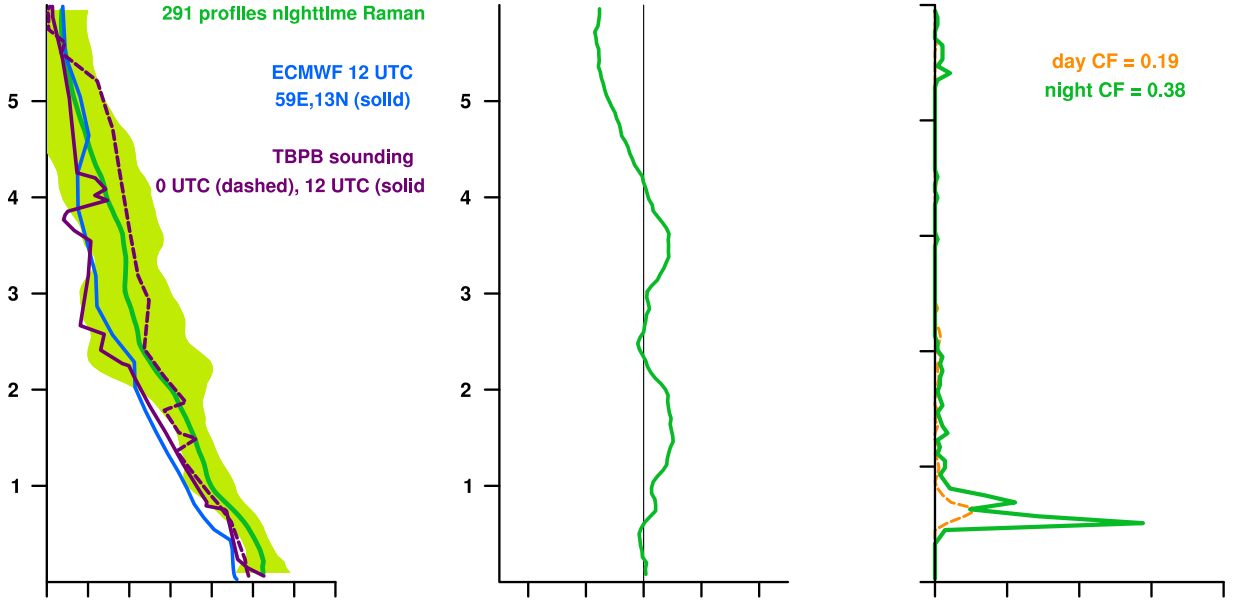


Zoom in on August

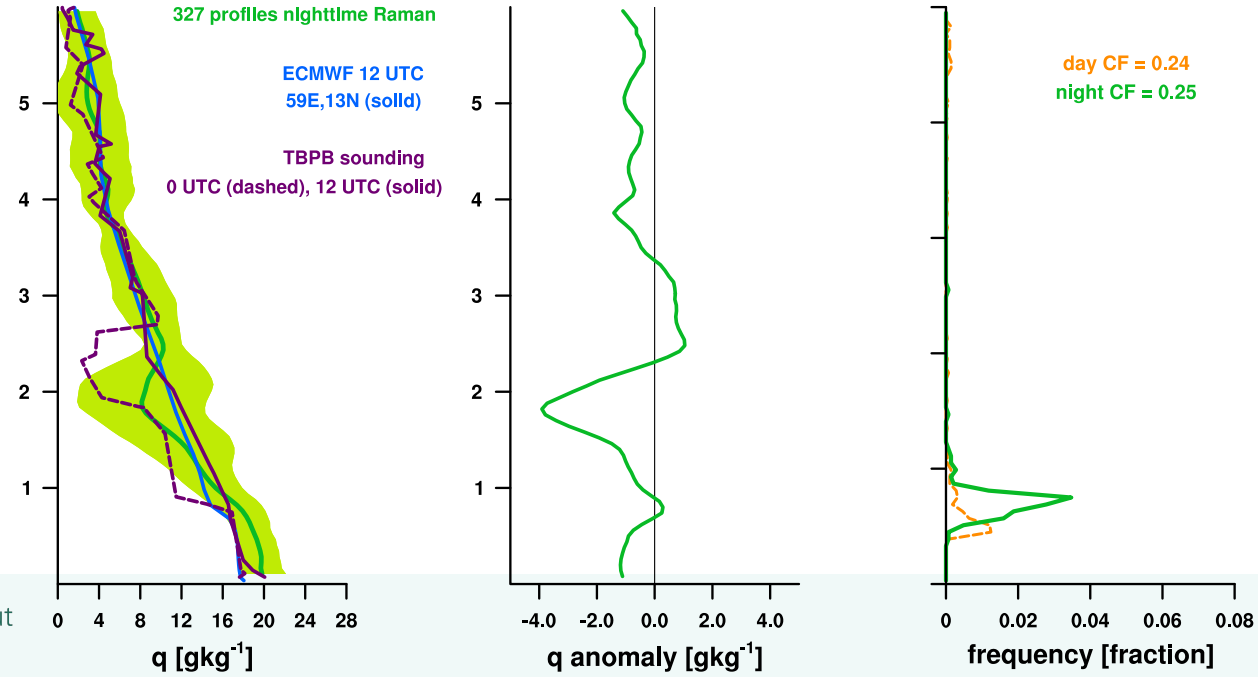


Vertical structure

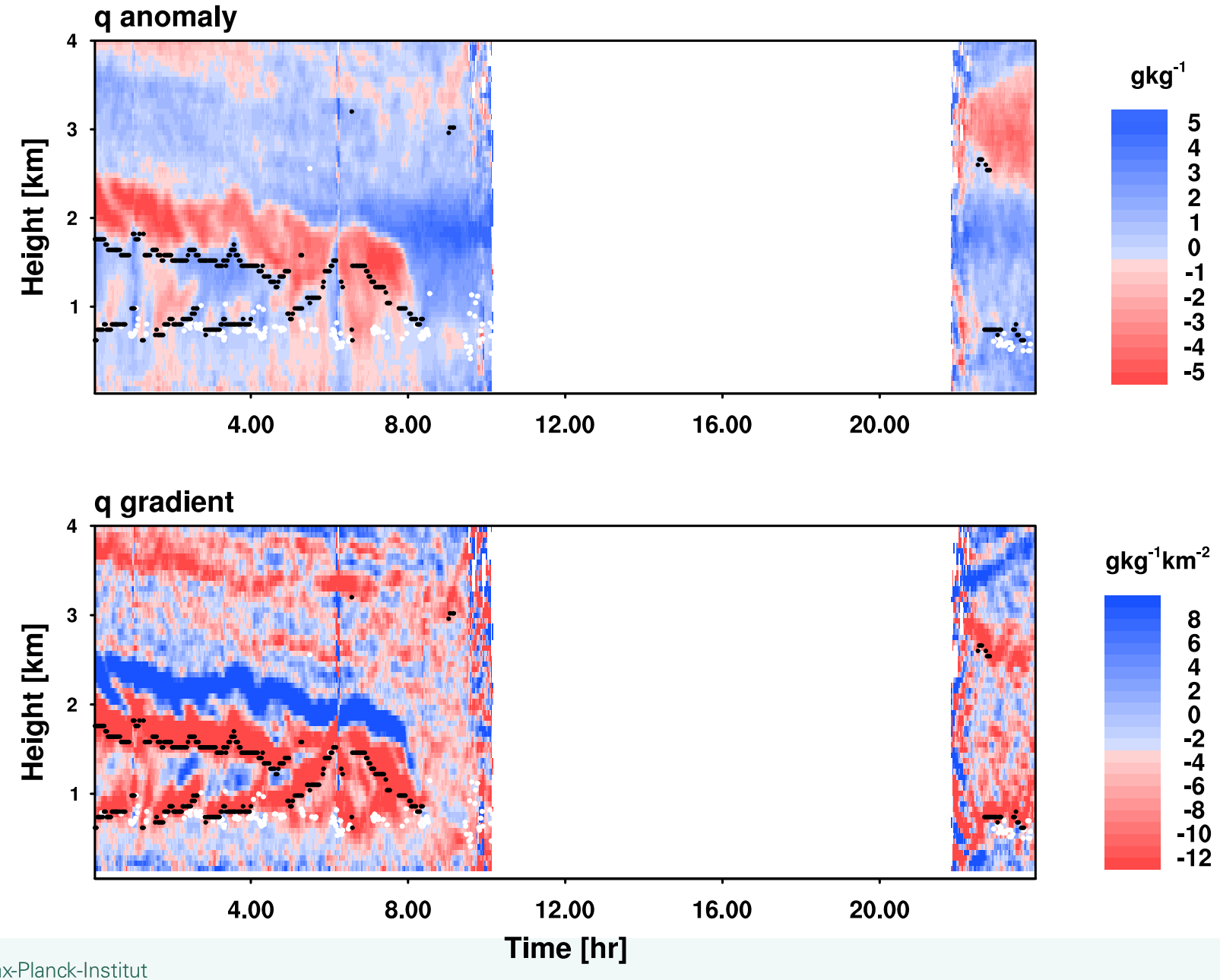
August 22



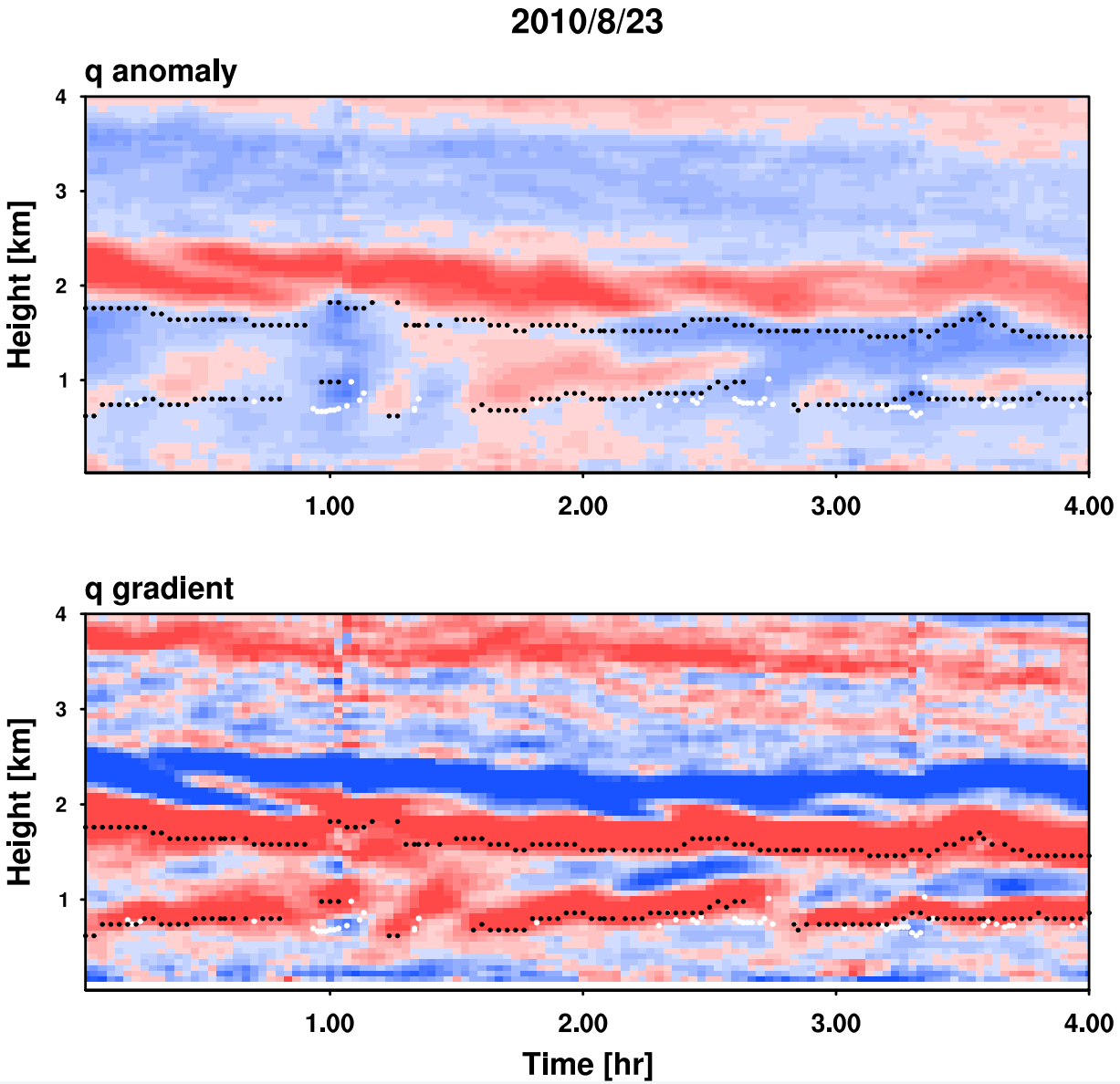
August 23

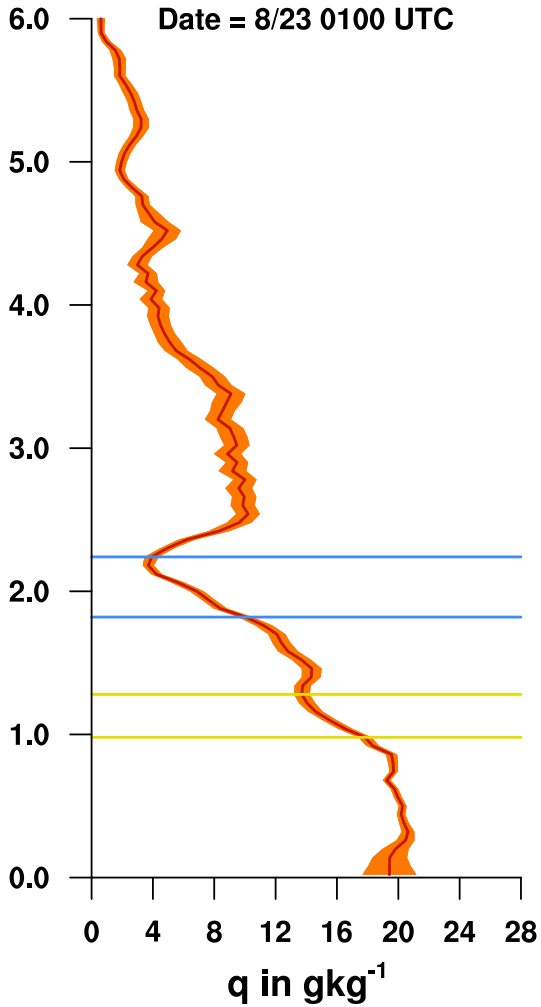


August 23rd

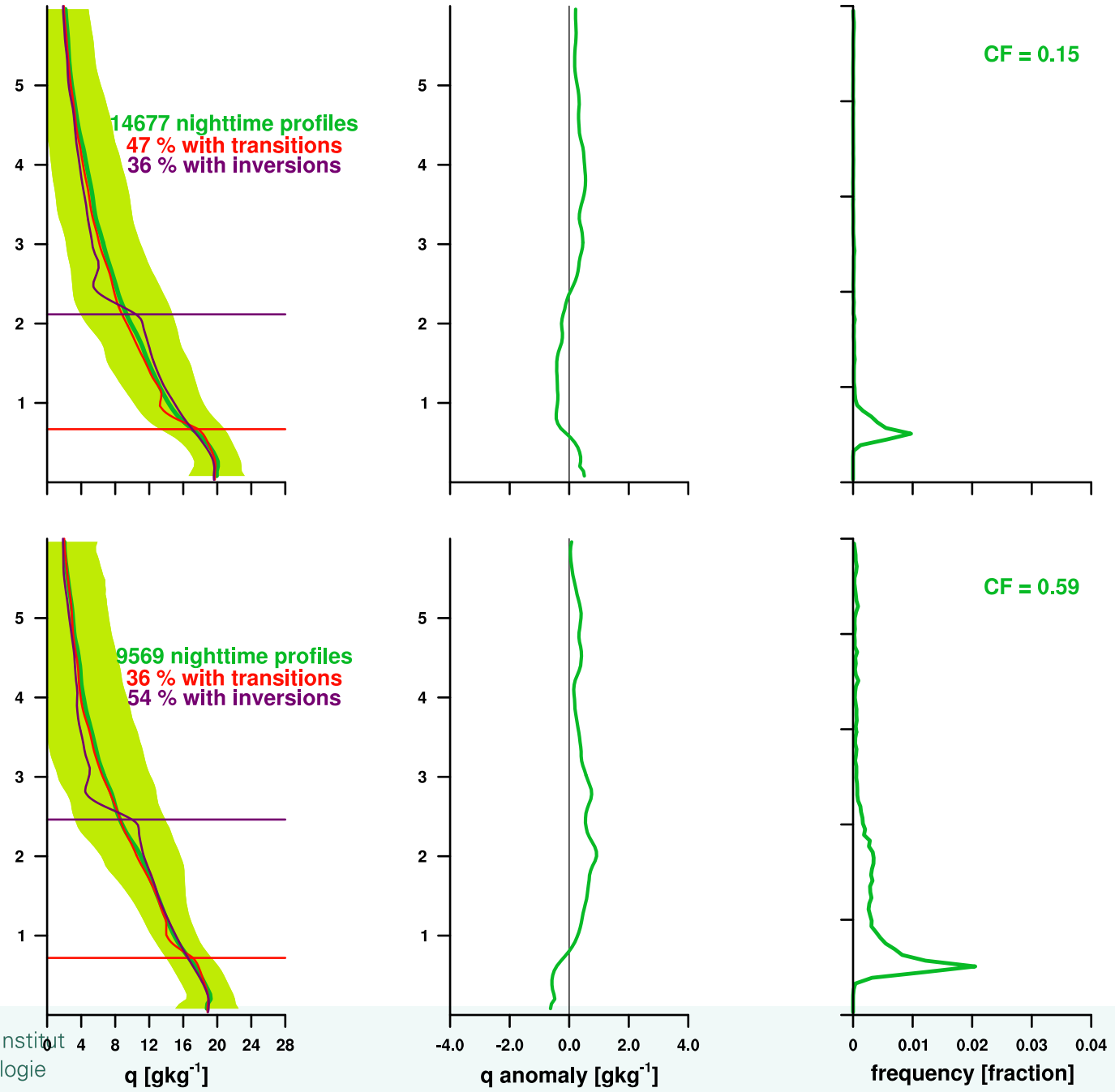

q anomaly
Height [km]
4
3
2
1
4.00
8.00
12.00
16.00
20.00
gkg-1
5
4
3
2
1
0
-1
-2
-3
-4
-5
q gradient
Height [km]
4
3
2
1
4.00
8.00
12.00
16.00
20.00
Time [hr]
gkg-1km-2
8
6
4
2
0
-2
-4
-6
-8
-10
-12

August 23rd

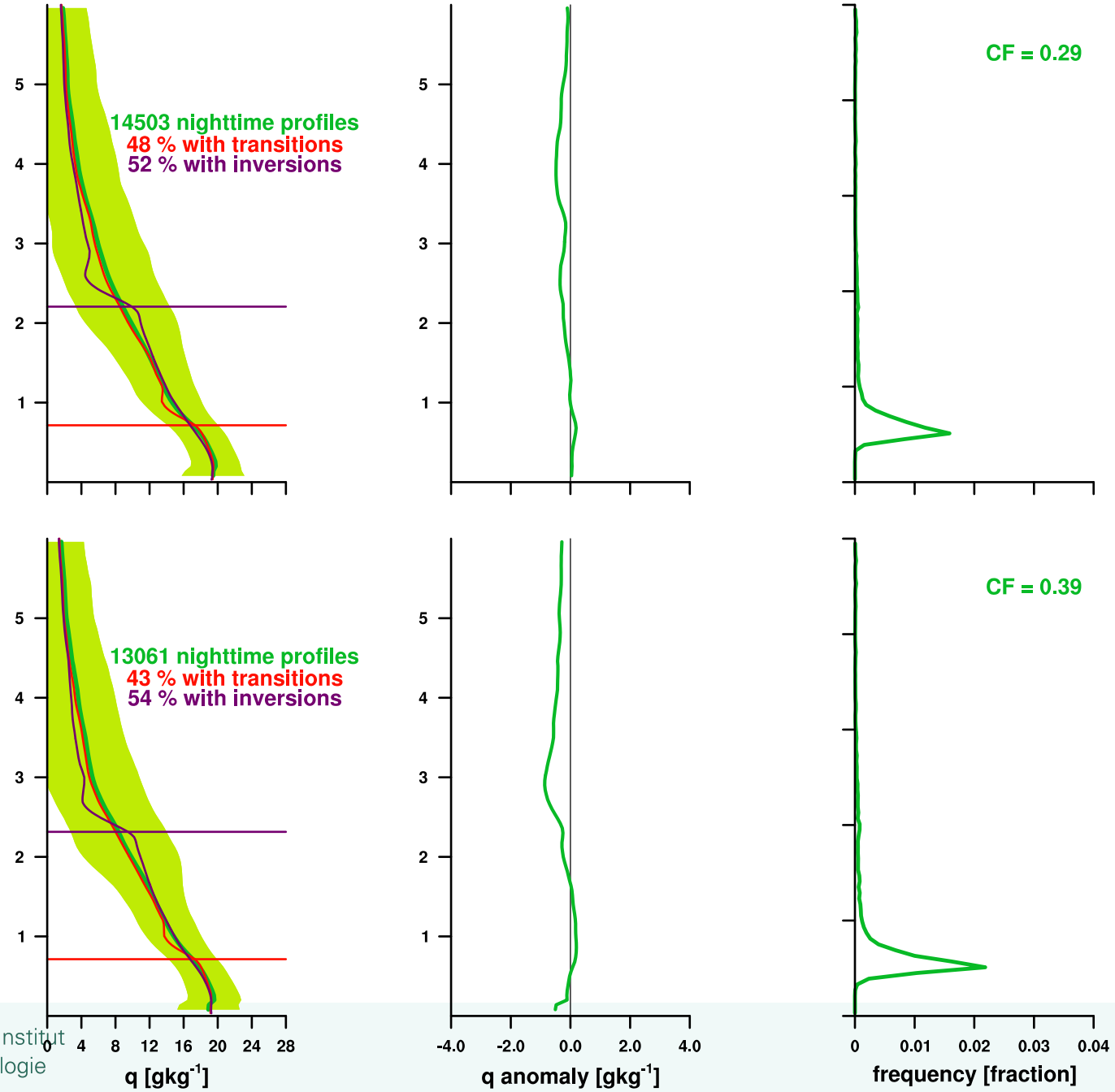

2010/8/23
q anomaly
q gradient
Height [km]
Time [hr]
1.00
2.00
3.00
4.00
1
2
3
4


Date = 8/23 0100 UTC
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
4
8
12
16
20
24
28
q in gkg-1

Conditioned on cloud fraction



Conditioned on cloud fraction



Summary & Outlook

- **Cloud cover is on average 38 %, if taking only cloud detections near LCL it reduces to 22 %**
- **There is a hint of reduced cloudiness during daytime (remains to be further evaluated)**
- **Many individual humidity profiles indicate the presence of well-mixed sub-cloud layers and a transition layer, (strong) inversions are more rare**
- **ECMWF analysis captures the day to day variability in humidity structure fairly well, but tends to be drier in the lower boundary layer (as are local airport soundings)**
- **Increased cloudiness tends to correspond to less frequent and less stable transitions layers, a more humid cloud layer (not a more humid sub-cloud layer)**
- **In the presence of clouds, transition layer bases are higher (and can be just as stable), and the air is locally more humid**

Stay tuned as …

- ➢ **We continue to exploit these and additional products to refine our observational analysis**
- ➢ **We start with (really) comparing GCM output / ECMWF analysis with the observations**