

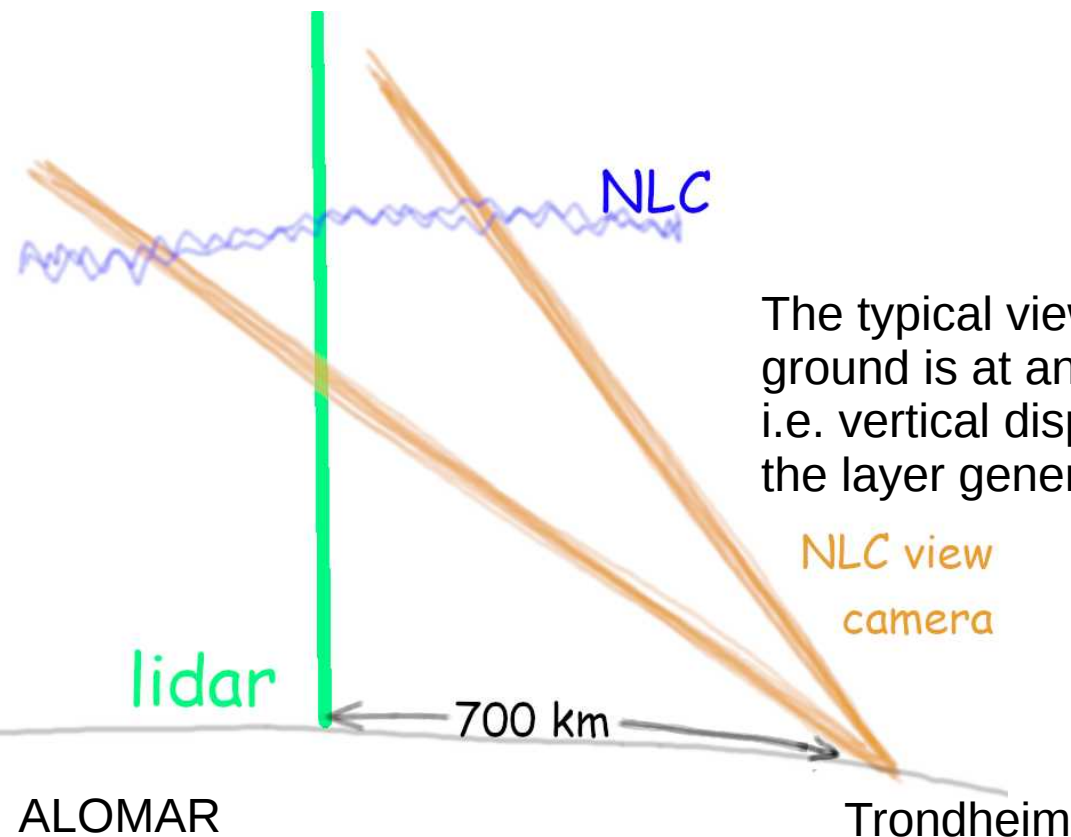
# Revealing small scale dynamics at the altitude of noctilucent clouds (NLC)

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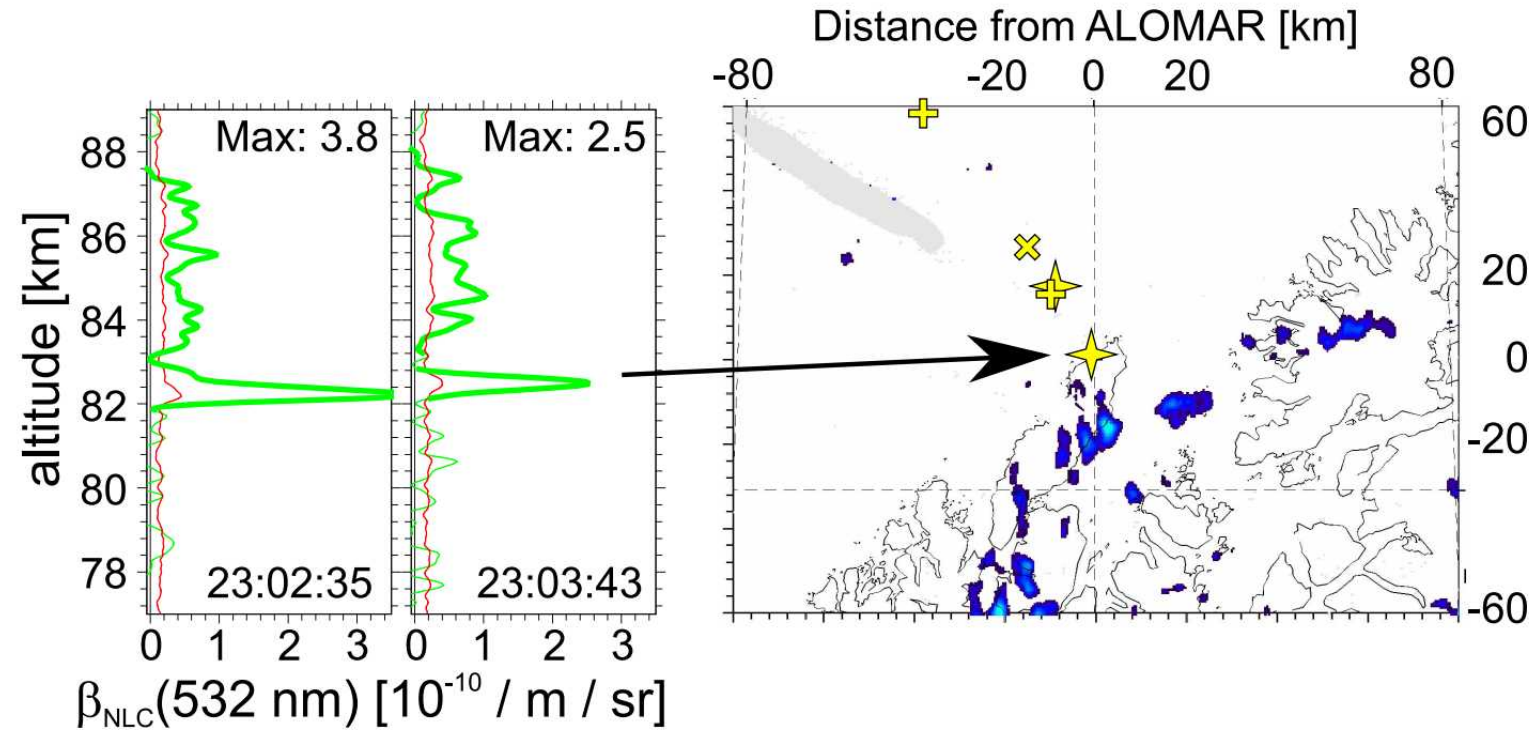
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# Simultaneous lidar and camera observations



# First simultaneous lidar and camera observations (2007)



NLC display during  
a rocket campaign.  
Used as launch  
decision for the  
ECOMA rocket

Super support by  
Patrick Espy

IAP NLC Camera TROND 63N 10E 2007-08-03\_23:23:07 Sol: -09.2

Baumgarten et al., AG, 2009



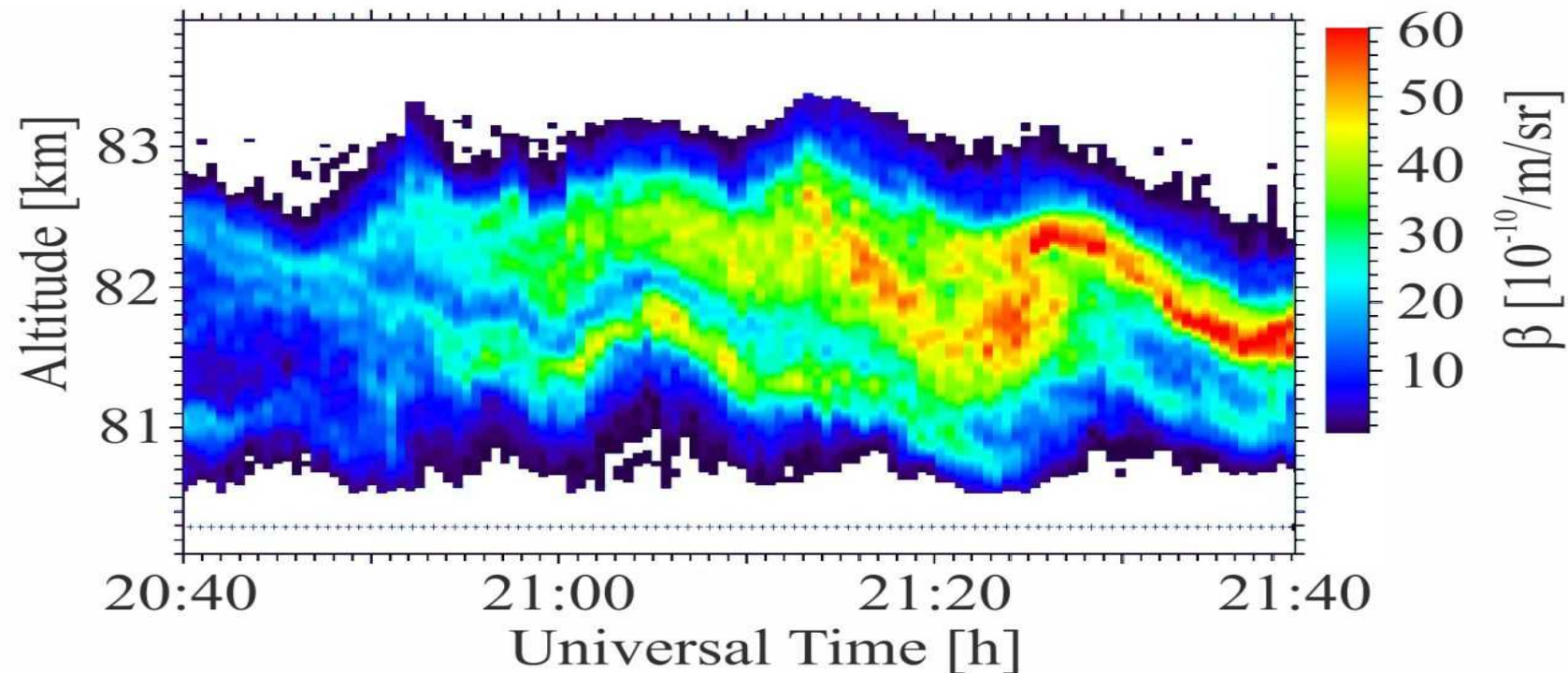
What causes the structures seen in NLC?

gravity waves?

turbulence?



# How does a NLC look like in lidar (ALOMAR, 69N)

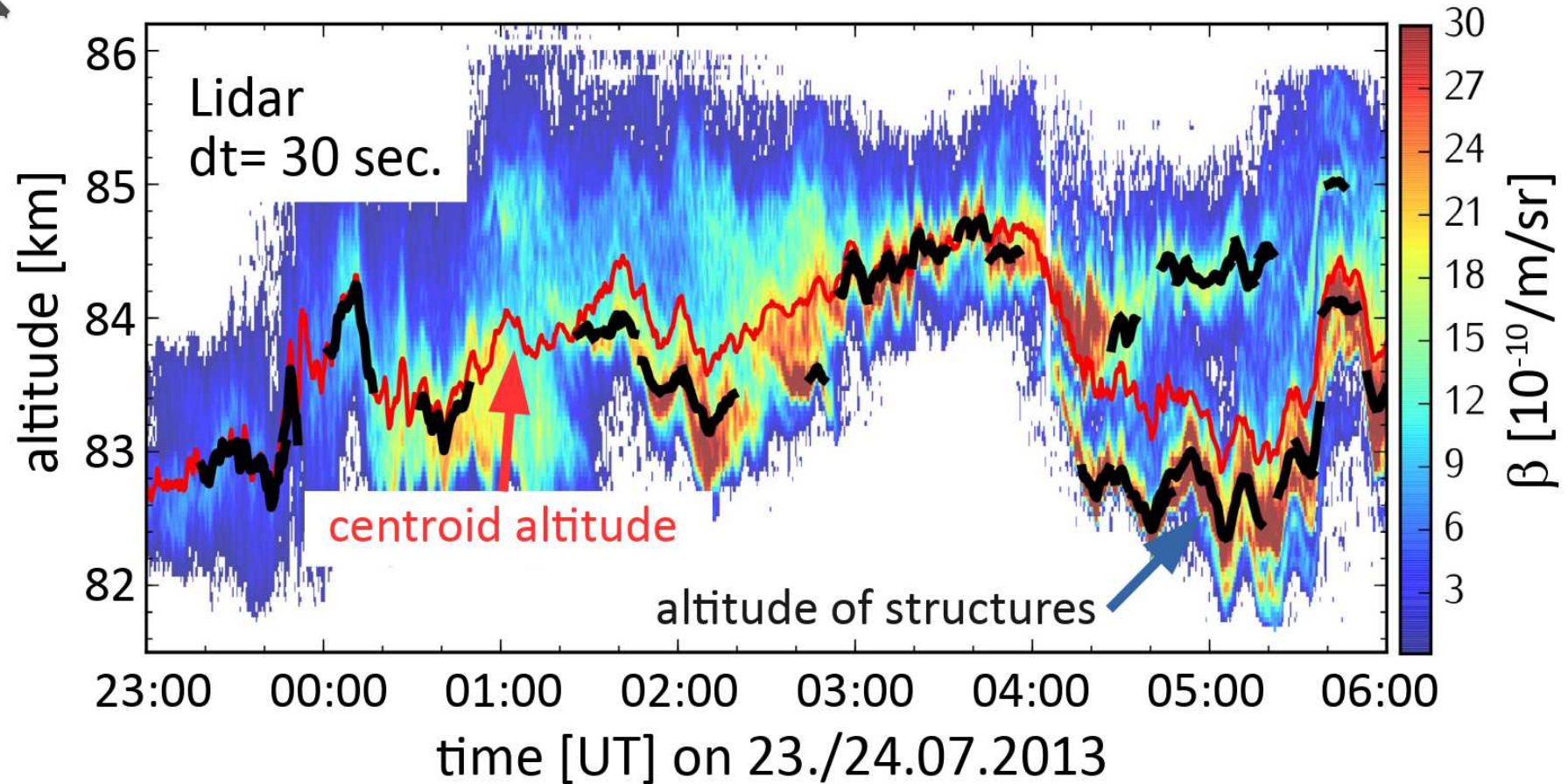


$\Delta t = 10 \text{ min}$   
 $\Delta z = 300 \text{ m}$



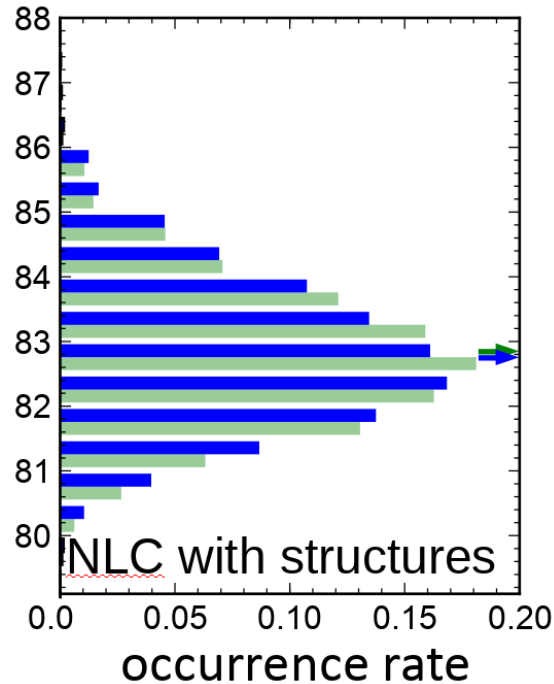
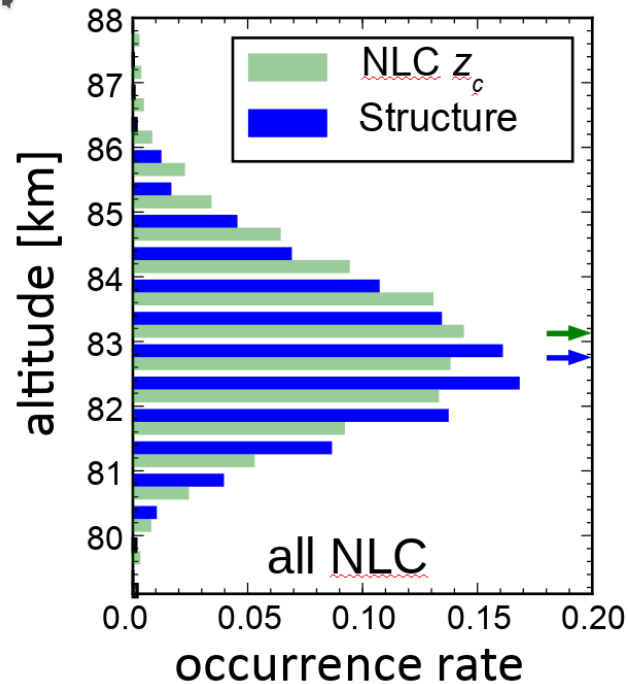
$\Delta t = 0.5 \text{ min}$   
 $\Delta z = 50 \text{ m}$

# What is a structure in lidar observations of NLC?



Ridder et al., JASTP, 2017

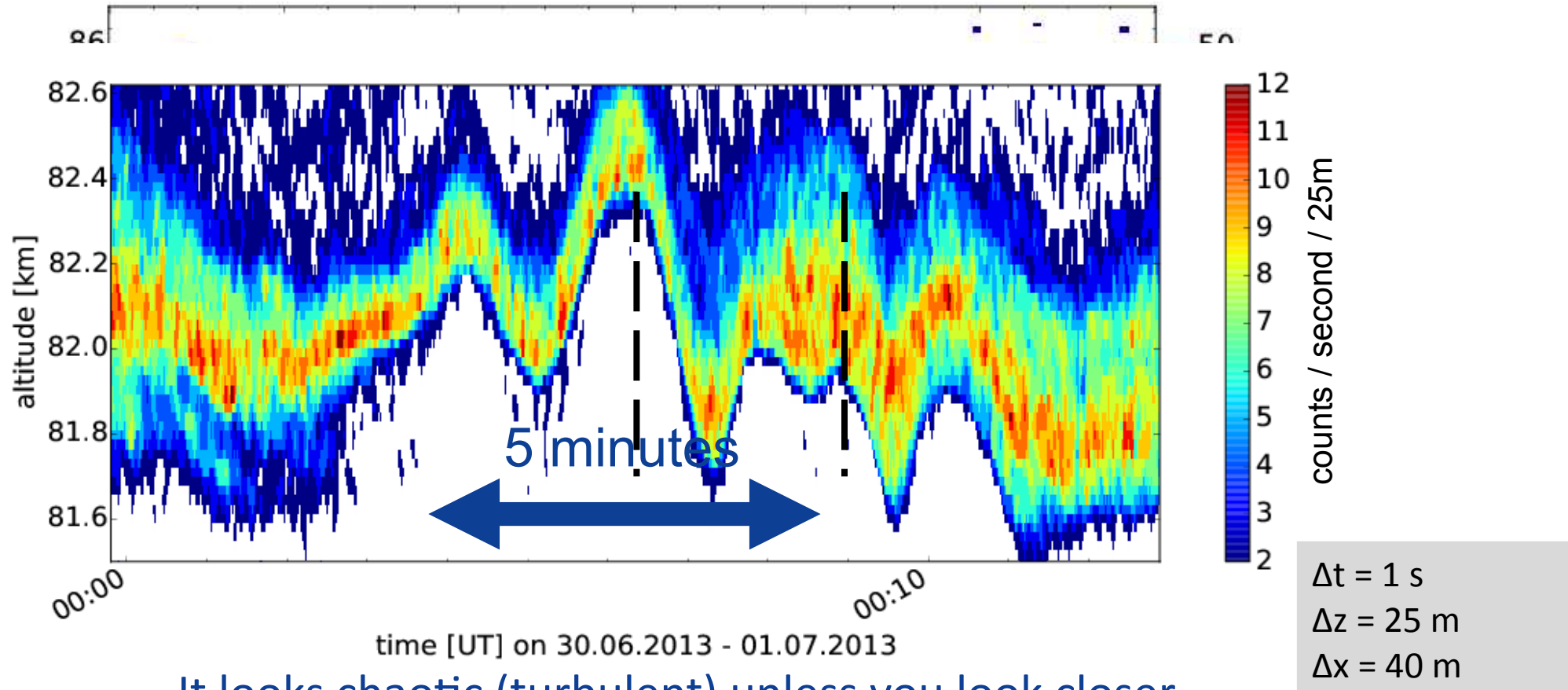
# Altitude of structures in NLC



- about 40% of NLC observations show structures on timescales of about 10 minutes
- Structures found often at the peak of the layer
- Altitude of structured NLC about 300 m below the altitude of all NLC

Ridder et al., JASTP, 2017

# Do NLC show chaos or harmony?



It looks chaotic (turbulent) unless you look closer.



# How narrow are NLC layers?

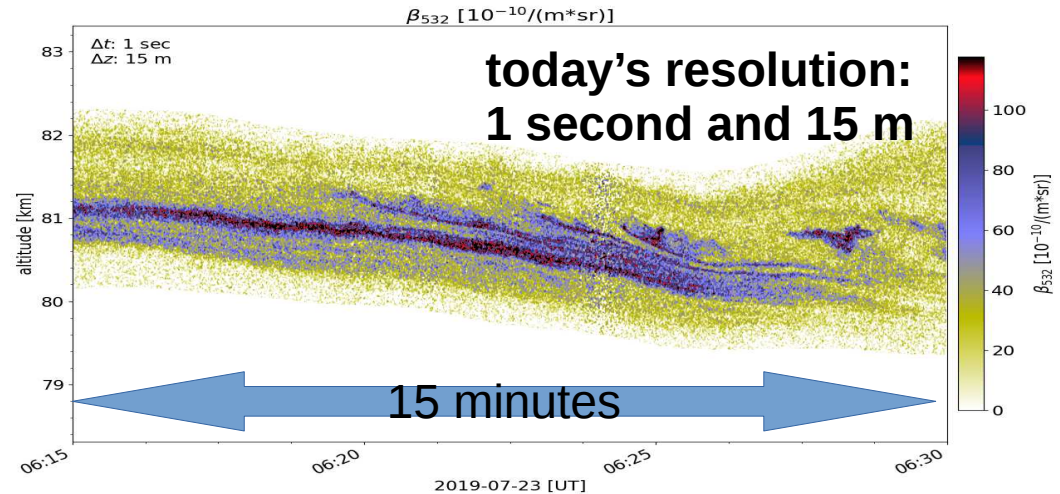
Extremely narrow layers are more valuable tracers as they are easier to understand when observed by camera.

How often do they exist?

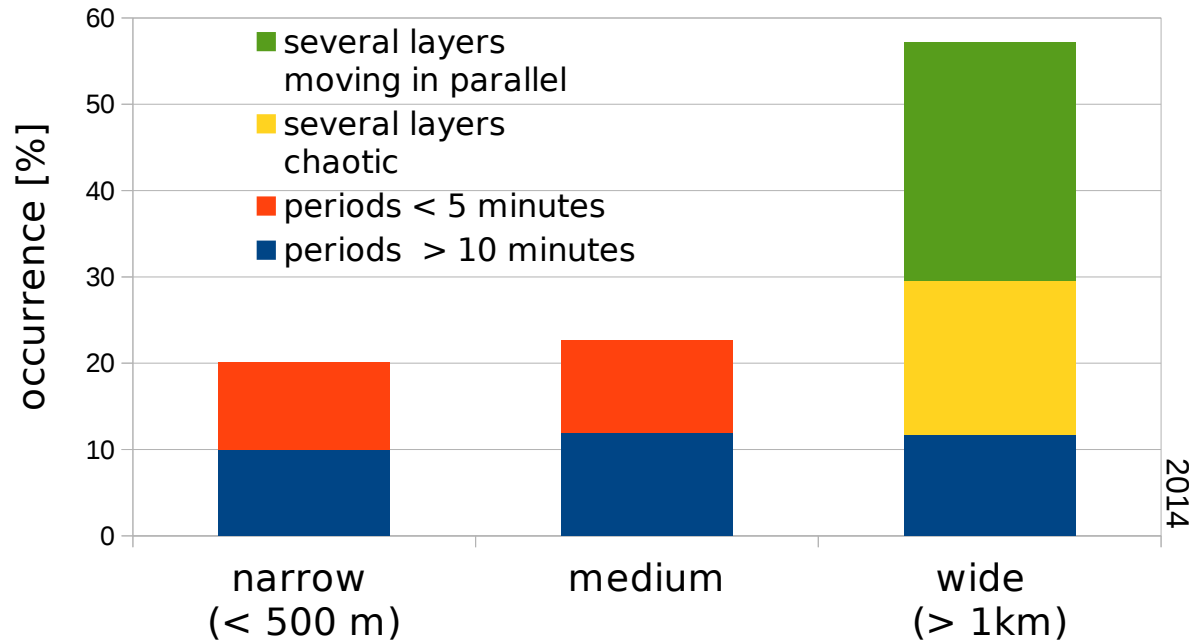
You need both, high time and high spatial resolution

Recent upgrades of lasers and detection system:

We store arrival time of photons with 10 ns precision ( $\sim 1.5$  m)  
Repetition rate:  $2 \times 100$  Hz

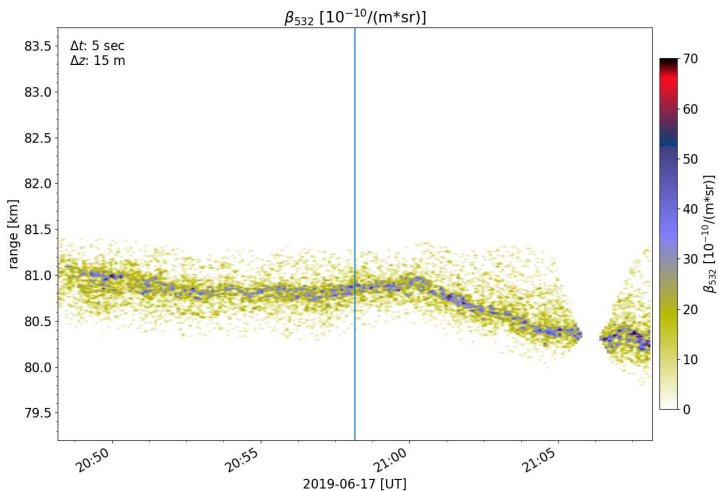


# How narrow do NLC get?

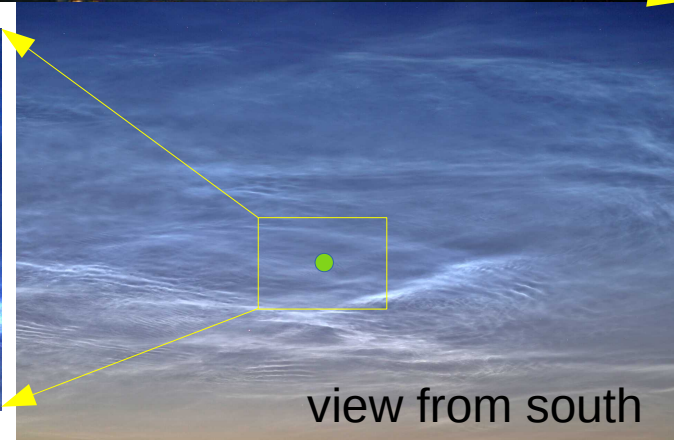
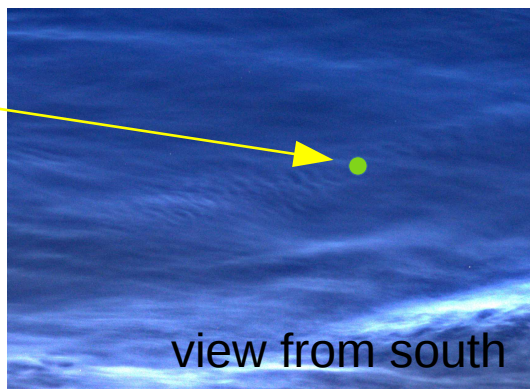
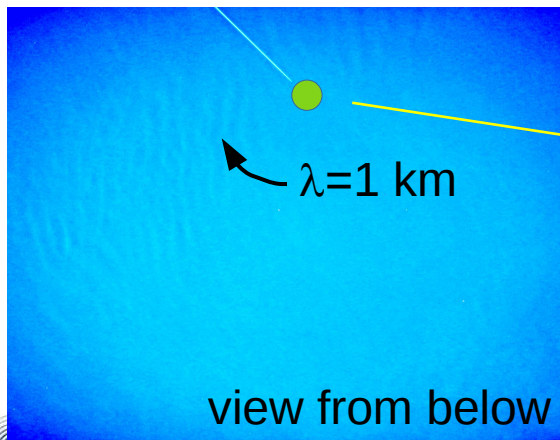
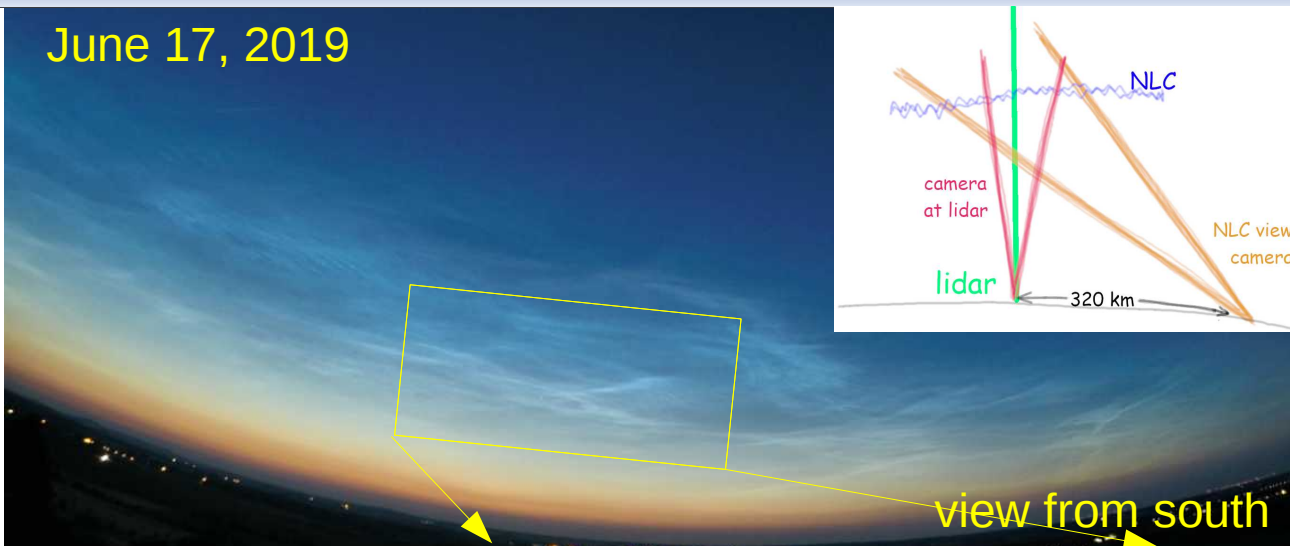


- We defined a new classification scheme based on the vertical and temporal evolution (lidar measurements).
- No templates available for automated detection (yet).
- Extremely narrow layers occur frequently (~20 %).
- Multi layer NLC with chaotic or harmonic variations of layers observed most often (~45 %).

# thin layered NLC above Kühlungsborn reveals multi scale dynamics

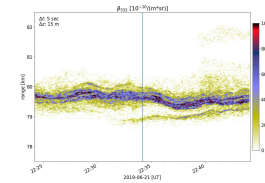
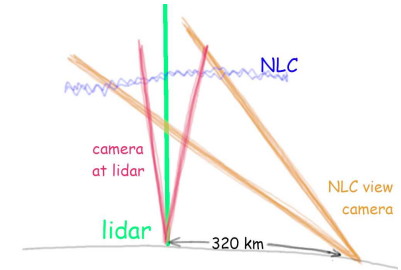


June 17, 2019



# Summary

- lidar and camera: high resolution measurements of dynamics with resolutions of a few meters and seconds.
- observations show gravity waves and their transition to turbulence:
  - short period wavy structures likely due to local instabilities (turbulence generation).
  - chaotic behaviour sometimes vanishes if investigated in more detail (< 30 seconds).
  - multiple layers of less than 50 m vertical extent (each) moving in parallel. How are they created?



5 minutes

