FFI Forsvarets forskningsinstitutt

Utseende av lysende nattskyer (NLC), deres bevegelser, og PMSE avslører hvordan luftpakker beveger seg i den øvre atmosfæren

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FFI og UiT

NGF, 11.09.2009

Noctilucent Clouds - NLC

why do they look like this?

rather than this?

(w' observation, 1 hour.
8 km; resolution 10 min. 300 m;
Hoppe & Fritts, 1995)

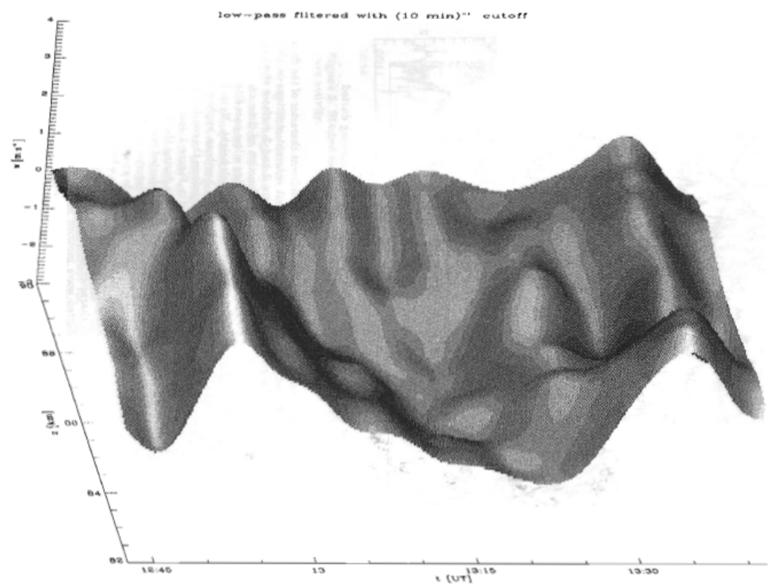
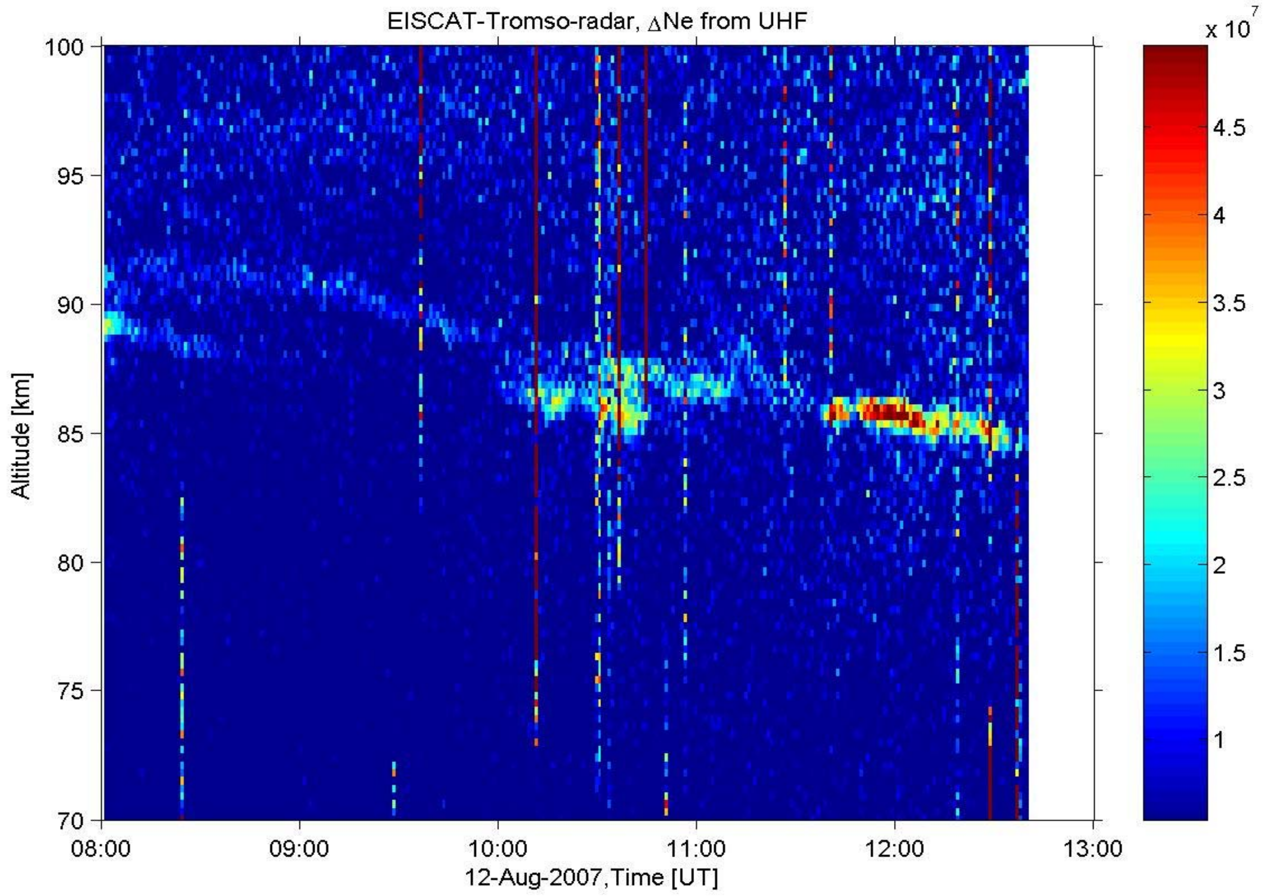


Figure 3. Shaded surface plot of ducted waves (1/10 min^{-1} cutoff).

HOPPE AND FRITTS: VERTICAL VELOCITIES, 1. MEASUREMENT BIASES

16,817

PMSE- Polar Mesosphere Summer Echos

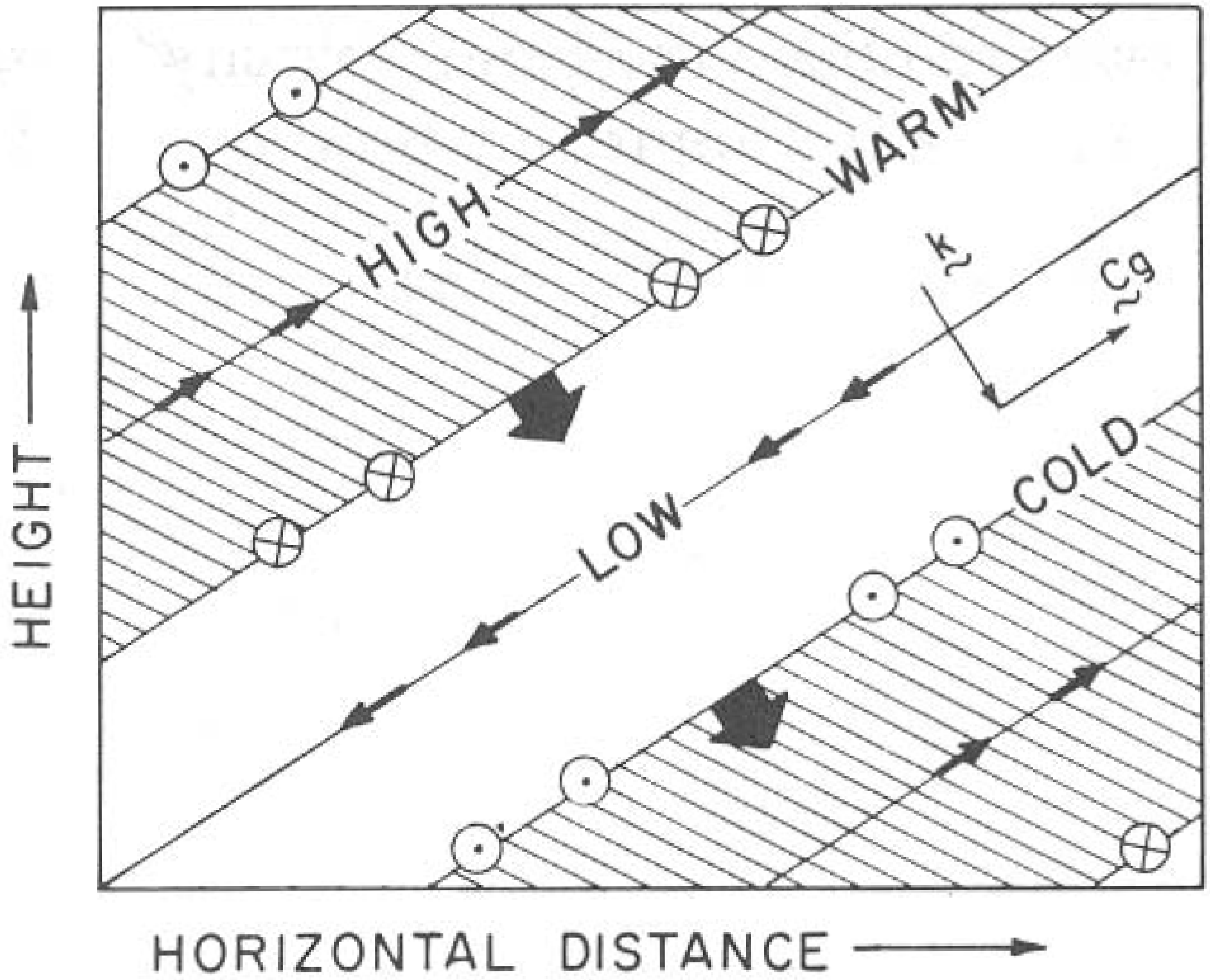


why this motion?

(Li Qiang, personal comm. 2007)

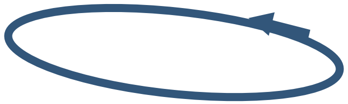
typ. -0,4 m/s

Gravity wave, Eulerian sketch



Andrews et al., 1987

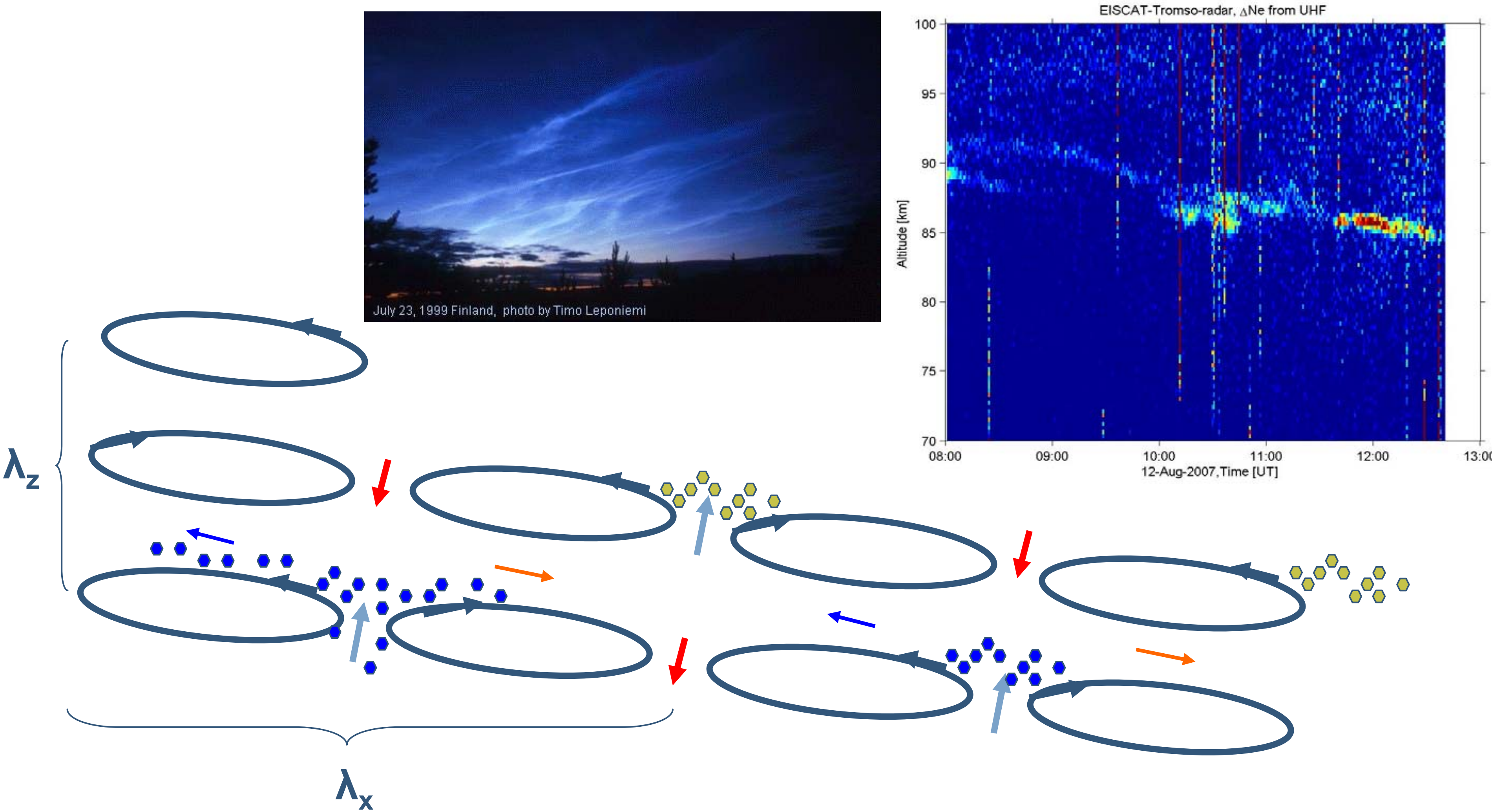
Gravity waves in Lagrange view



- The air parcels describe elliptic trajectories.
- Compressible atmosphere: The ellipses expand above and compress below (reversibly).
- Saturated gravity waves in a compressible atmosphere: Energy is dissipated in the upper (expanded) half of the trajectory.
  - As a result the air parcel does not return to its starting location.
  - This is the Stokes Drift, mostly horizontal, but with a small vertical component.
- Dimensions of ellipses $\propto$

  oscillation period · (horizontal perturbation amplitude) by oscillation period · (vertical perturbation amplitude)

Gravity wave field with trajectories



discovered by UPH at ECOMA Data Workshop, Kühlungsborn, 20.11.2007

NLC and gravity wave trajectories

- Bright NLC in grooves between the trajectory ellipses
  - upward w'
  - horizontal wind slightly divergent
  - The grooves with bright NLC particles propagate horizontally (slant) with the gravity wave.
- Between the grooves there are horizontal regions with weak NLC.
  - visibility $\propto$ (particle size)^6
- Near the center between the grooves the trajectories are downward. The NLC become weak or disappear due to adiabatic heating.

Darker regions mark downward w'

PMSE and gravity wave trajectories

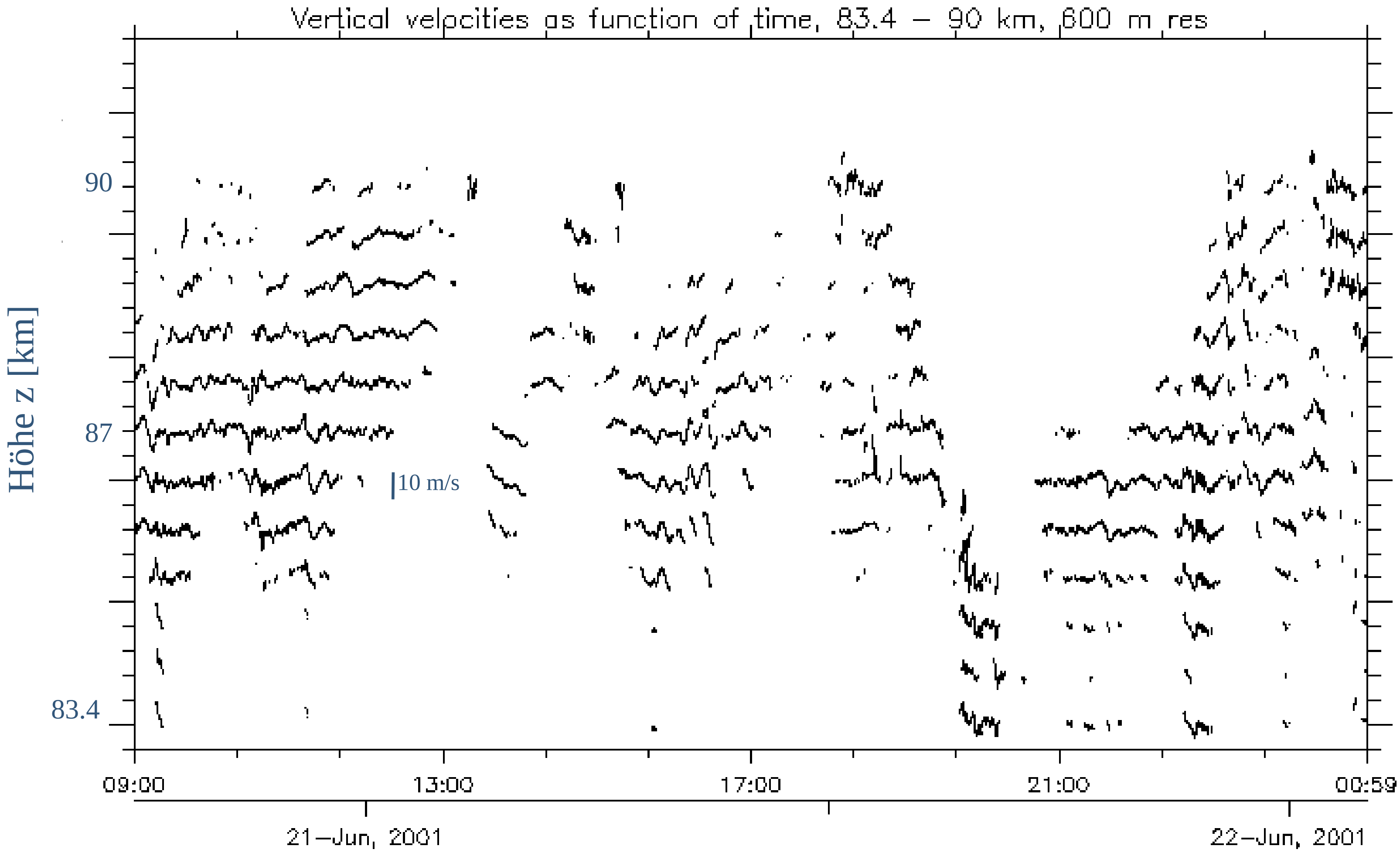
- PMSE often appear in two layers or more.
- PMSE usually descend slowly.
- The strongest PMSE occasionally jumps to the next higher layer.

- PMSE occur preferentially in regions with vertical convergence (and horizontal divergence)

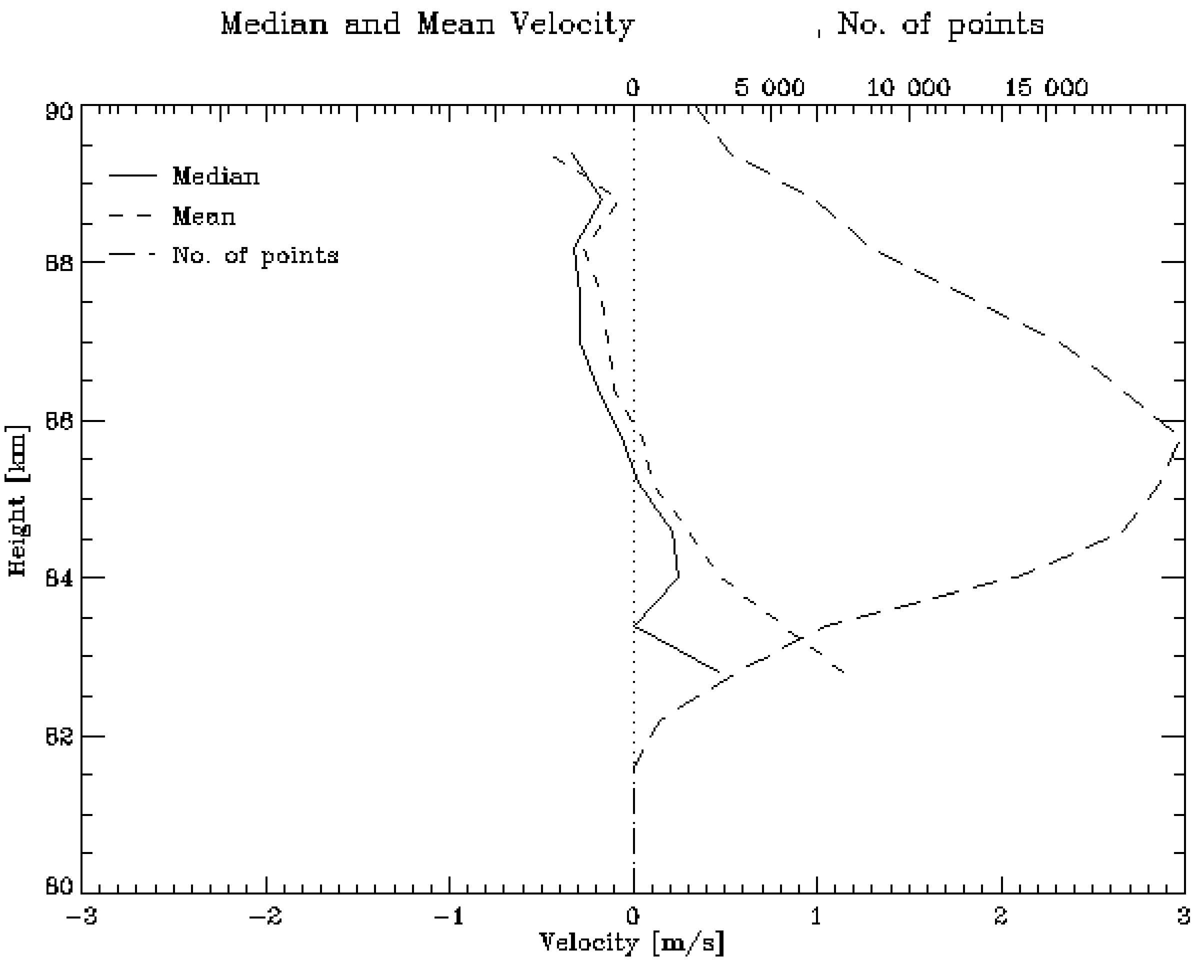
EISCAT D-layer-V

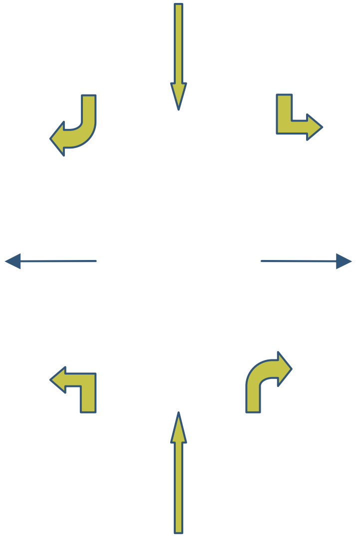
- Approx. 65 hrs of data from EISCAT VHF Radar during PMSE
- 70ºN
- Observations during campaigns
  MIDAS Solstice 2001 and MIDAS MacWave 2002
- 600 m height resolution, 5 s temporal resolution
- 10 cm/s and better
- Scattering volume ~1 km x ~2 km
- We observe the fine-scale w’ variations and compare them with variations of PMSE-power.

w(z,t); 5 s; 600 m; 10 cm/s

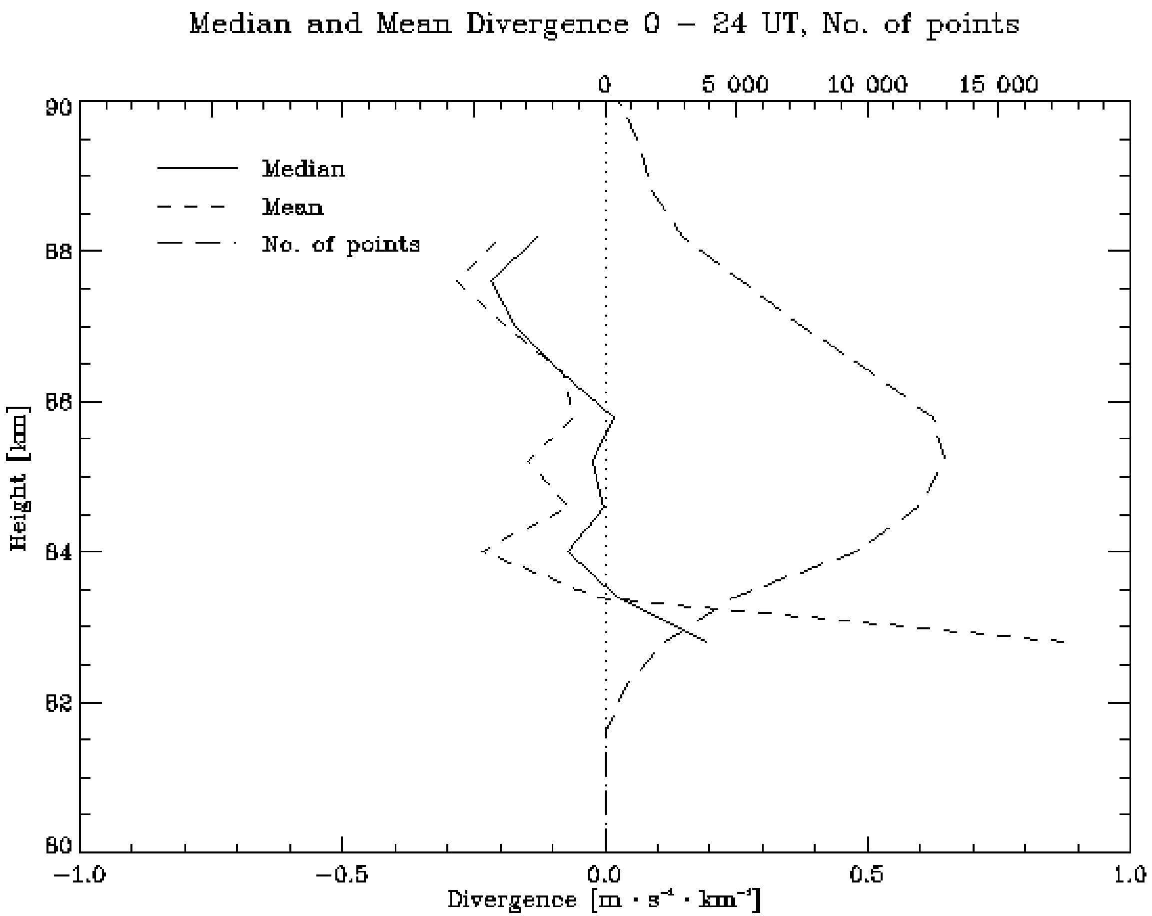


w converges near PMSE maximum

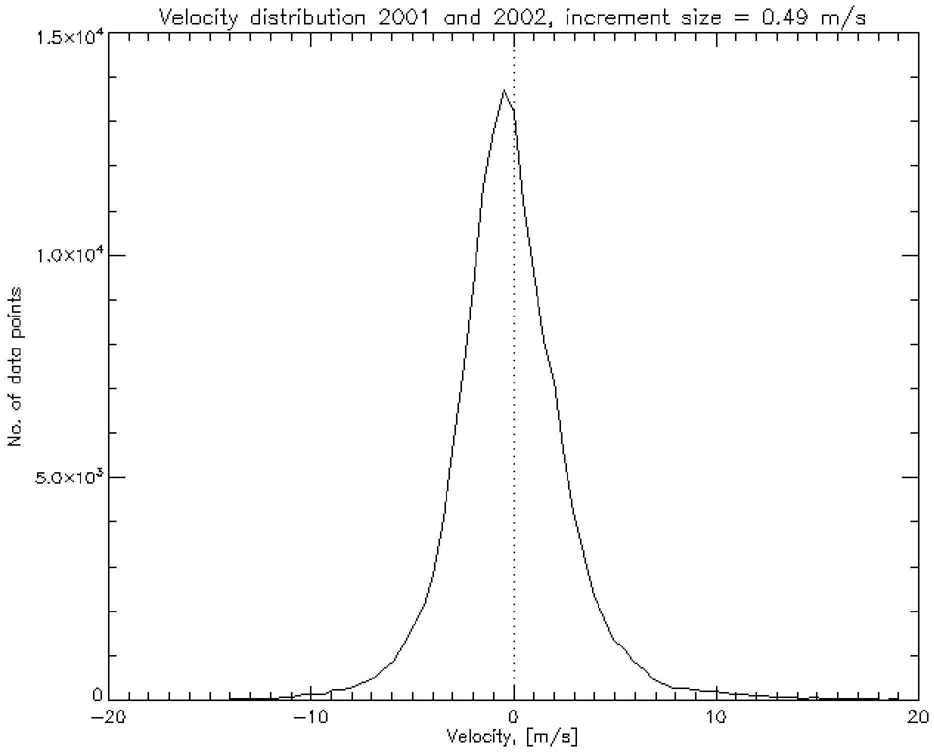


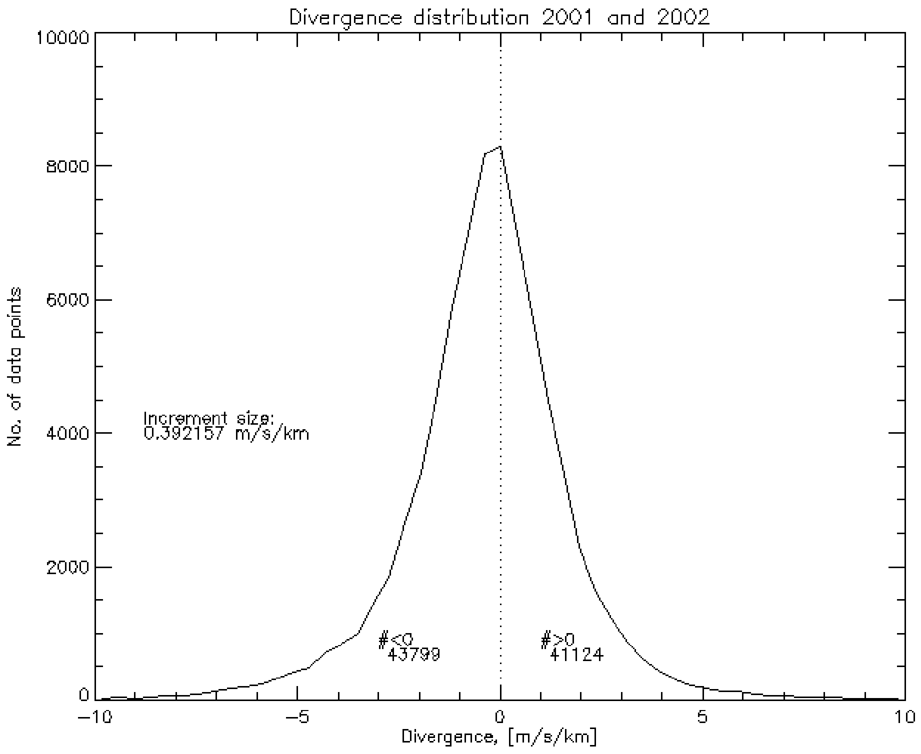


vertical convergence at PMSE height



Histograms





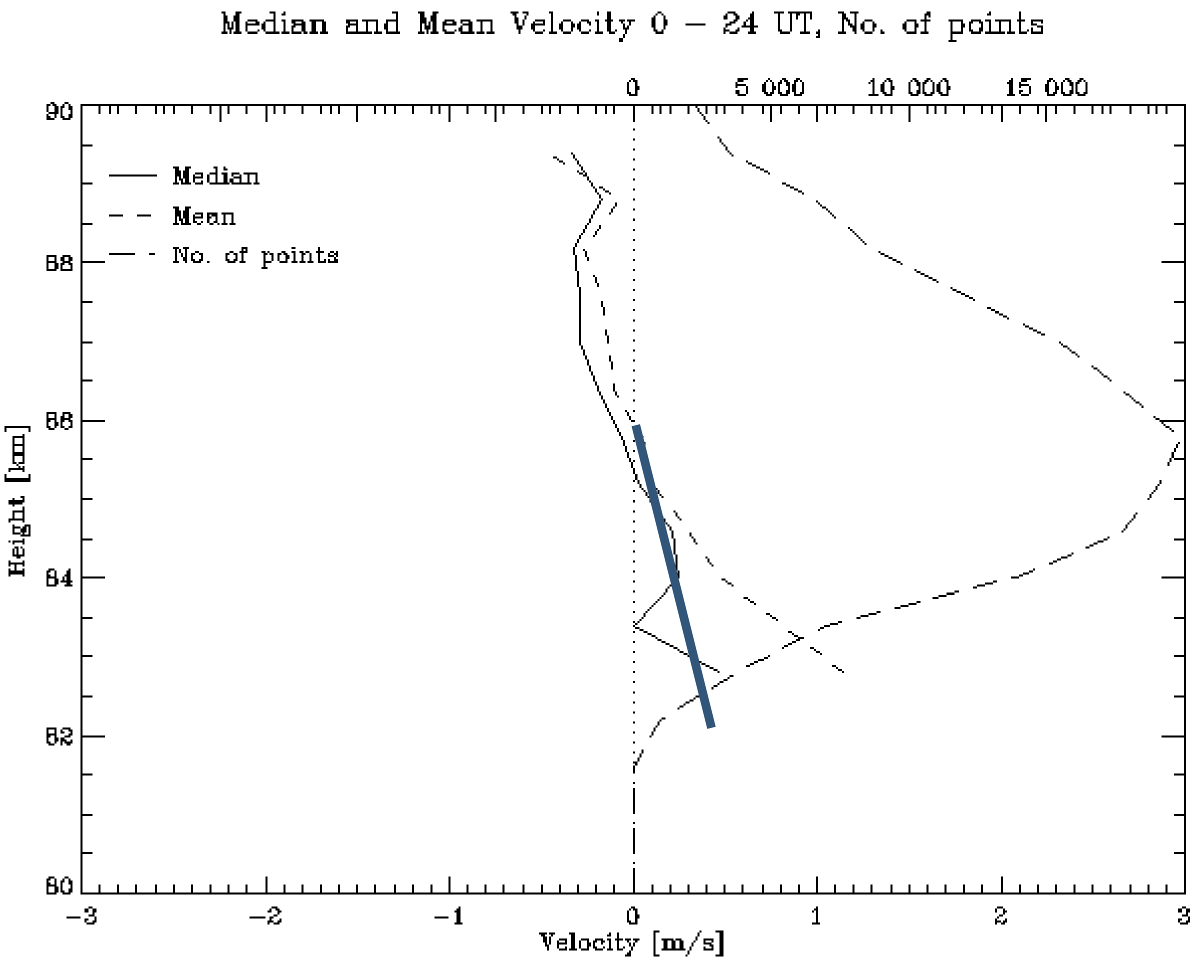
typ. -0,4 m/s

Euler <-> Lagrange

- The radar observes in a Eulerian system (fixed geometric location).
- Transport is a Langrange process (the coordinate system follows the air parcel).
- Lagrange = Euler + Stokes (Longuet-Higgins, 1969; 1972)
- Height regions with predominantly upward gravity waves show an upward Stokes drift (Coy et al., 1986). The mesosphere at high latitudes in summer has this characteristic.

- Note! We are neglecting horizontal motions.

Lagrange = Euler + Stokes



The vertical convergence is stronger in Lagrangean coordinates!

Conclusions

- Actual atmospheric motions are independent of the coordinate system (Eulerian or Lagrangean)!
- When we use one or the other of these, we emphasize certain aspects and neglect others.
- We often think Eulerian.
- Adding the Lagrangean view facilitates understanding several observations:
  - NLC-morphology, brightness distibution and motion
  - PMSE height distribution, intensity distribution and motion
  - The apparent vertical convergence in PMSE