High spatiotemporal radar observation of PMSE using MAARSY in a MIMO configuration

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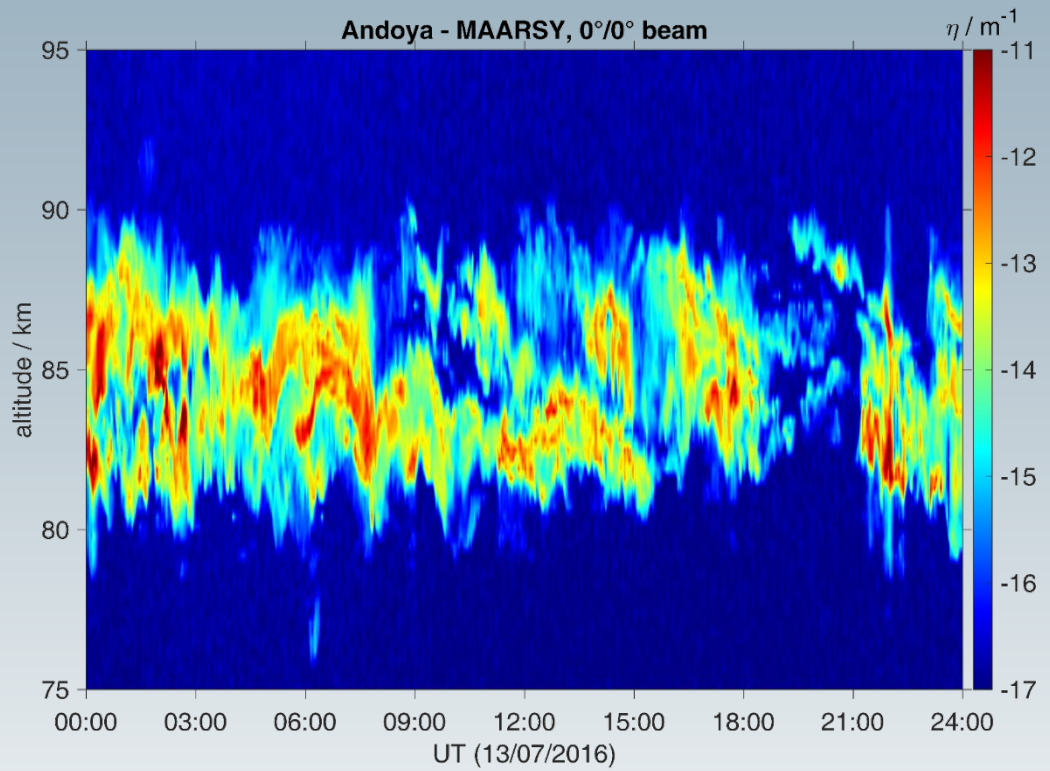
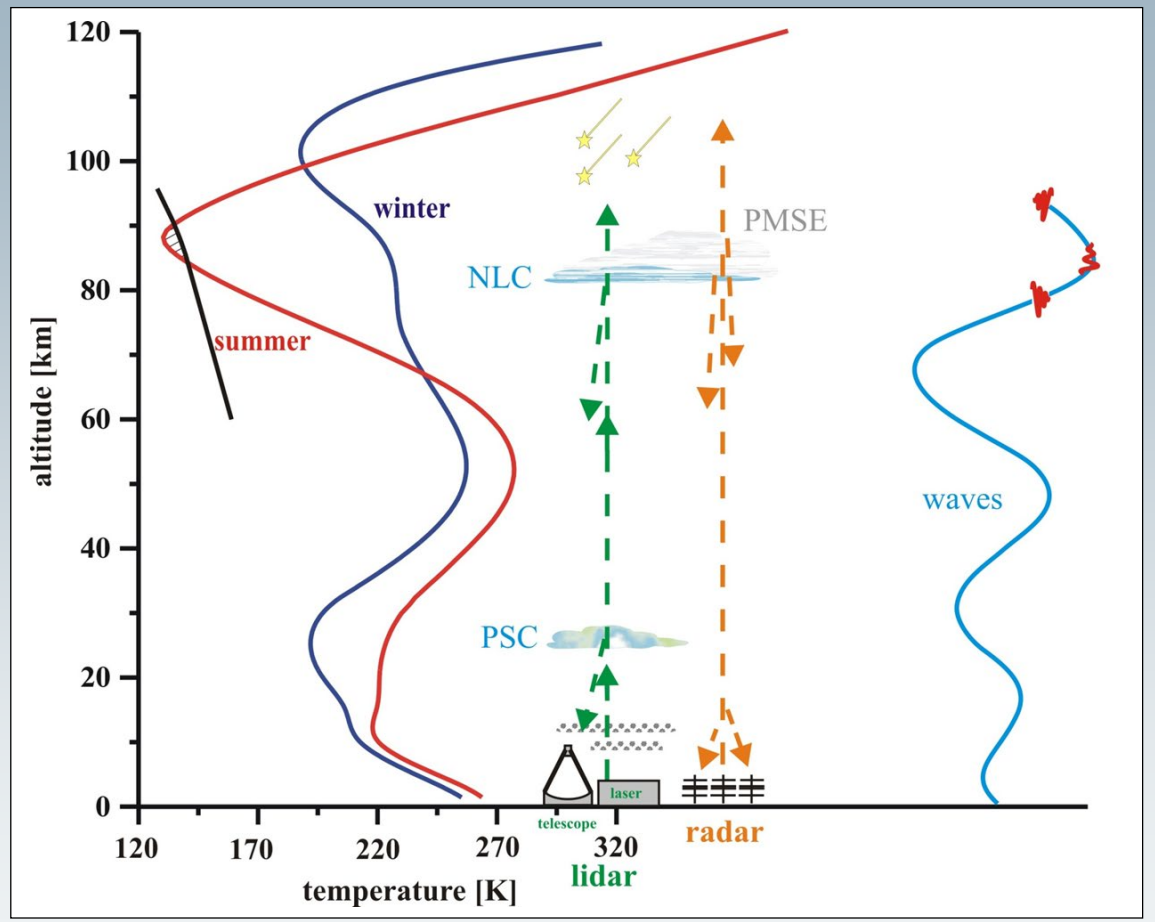
Polar Mesospheric Summer Echoes



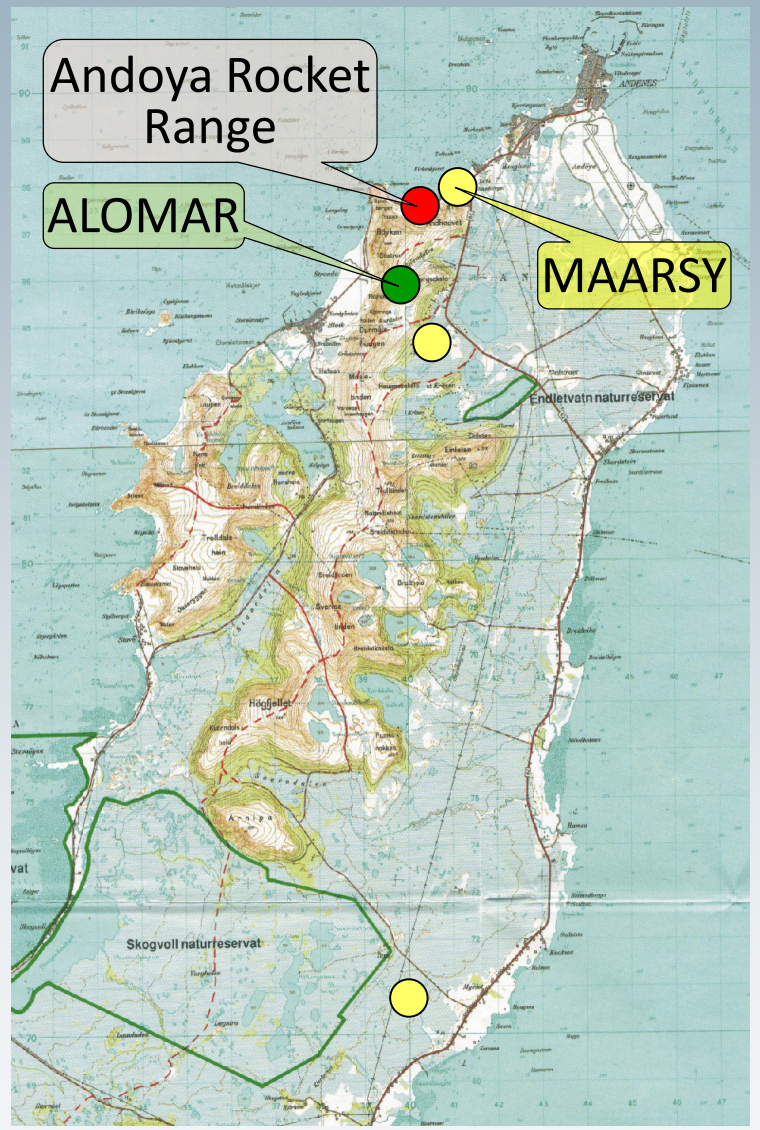
Characteristics of PMSE are determined by e.g.

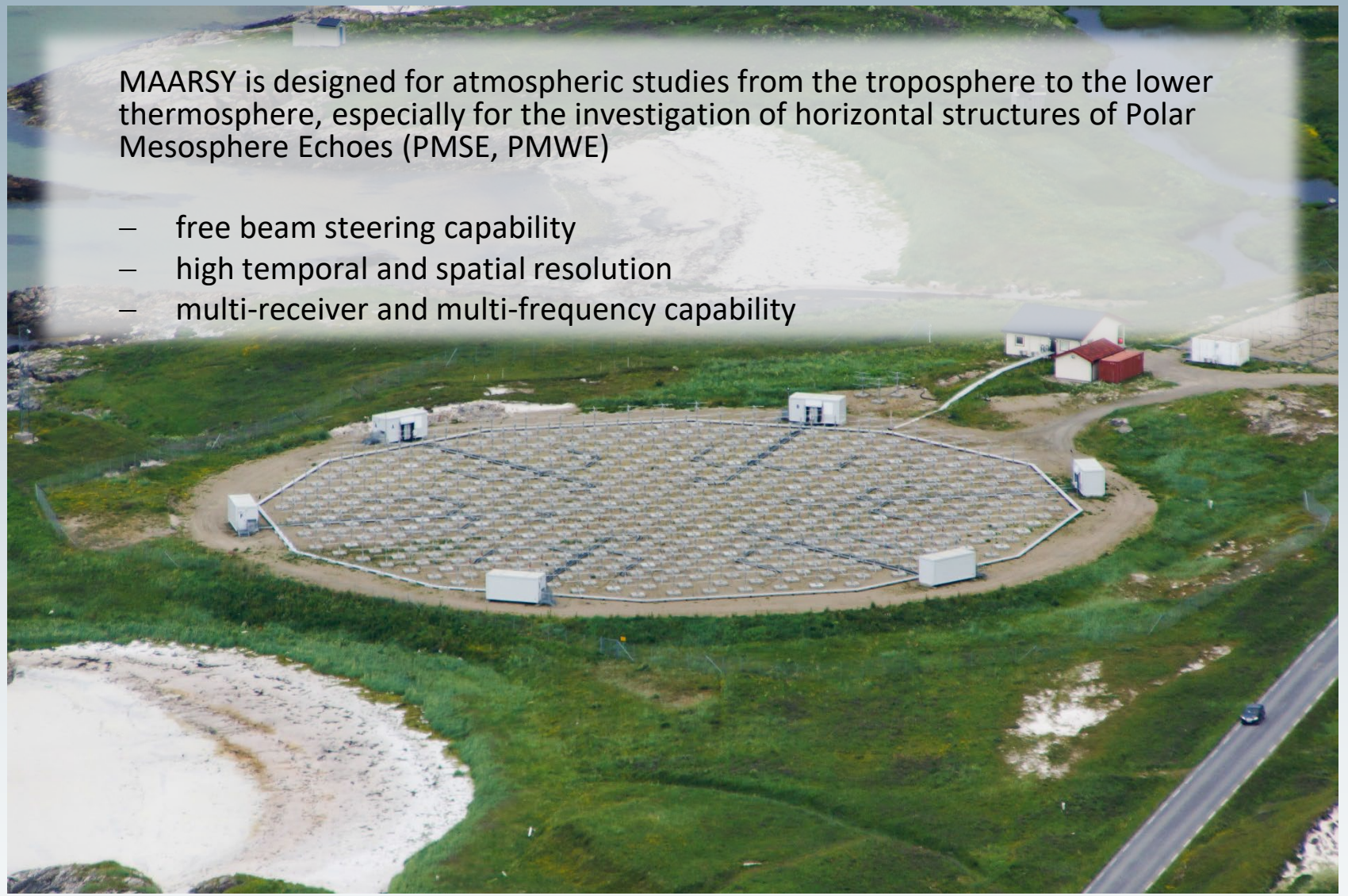
- electron density
- water vapor concentration
- Temperature
- turbulence



MAARSY

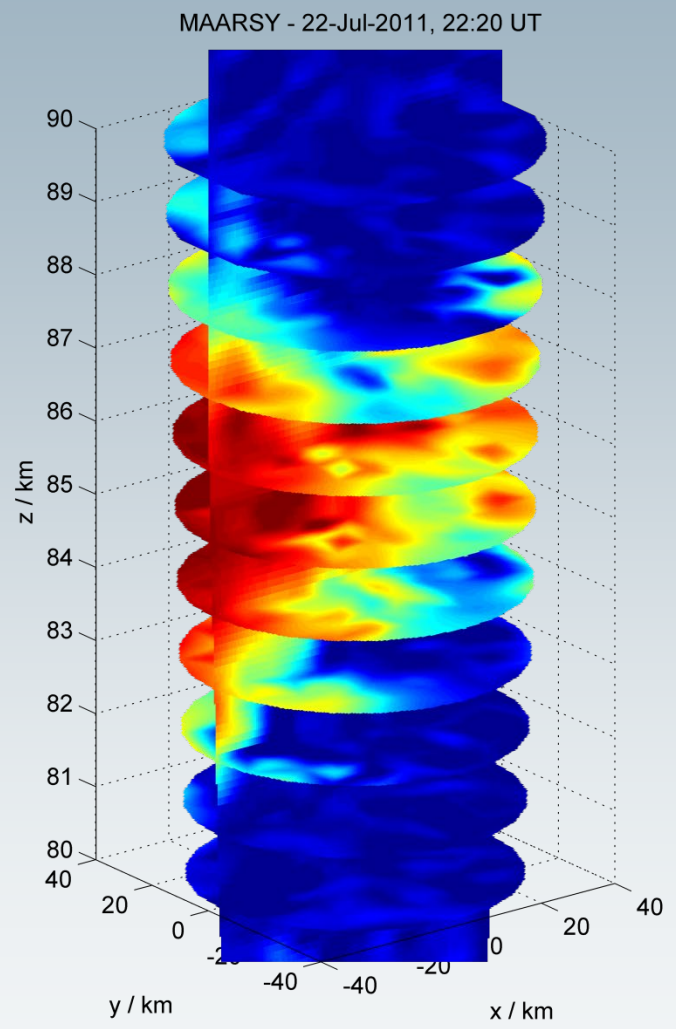
Middle **A**tmosphere **A**lomar **R**adar **Sy**stem on Andøya island (69°N)

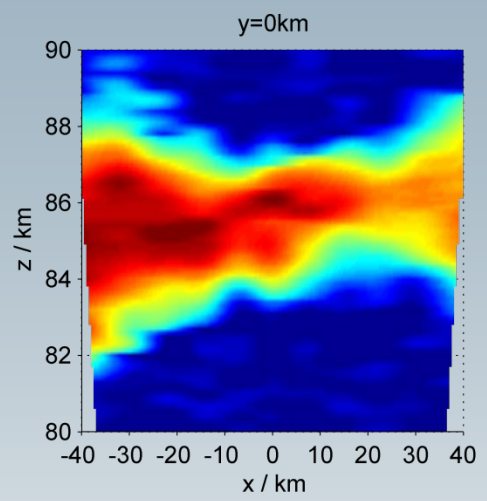


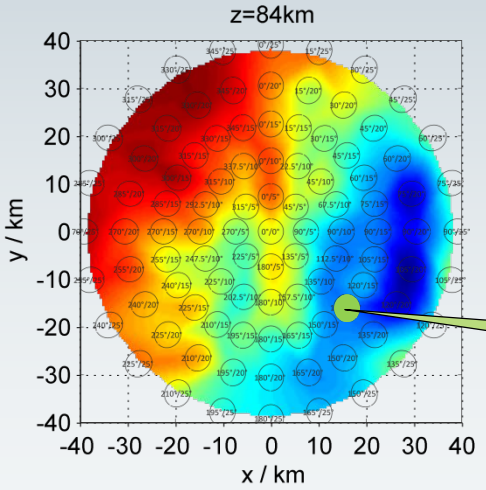


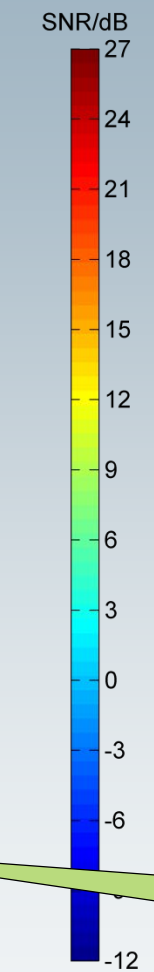
PMSE observation from Andøya

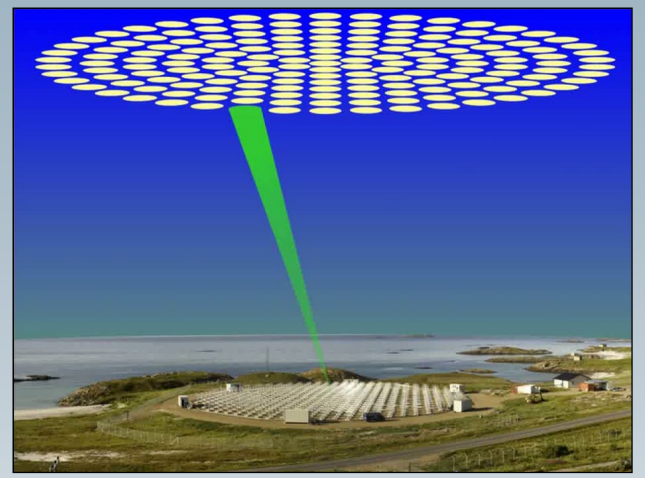
Vertical and horizontal structure of PMSE on July 22nd, 2011











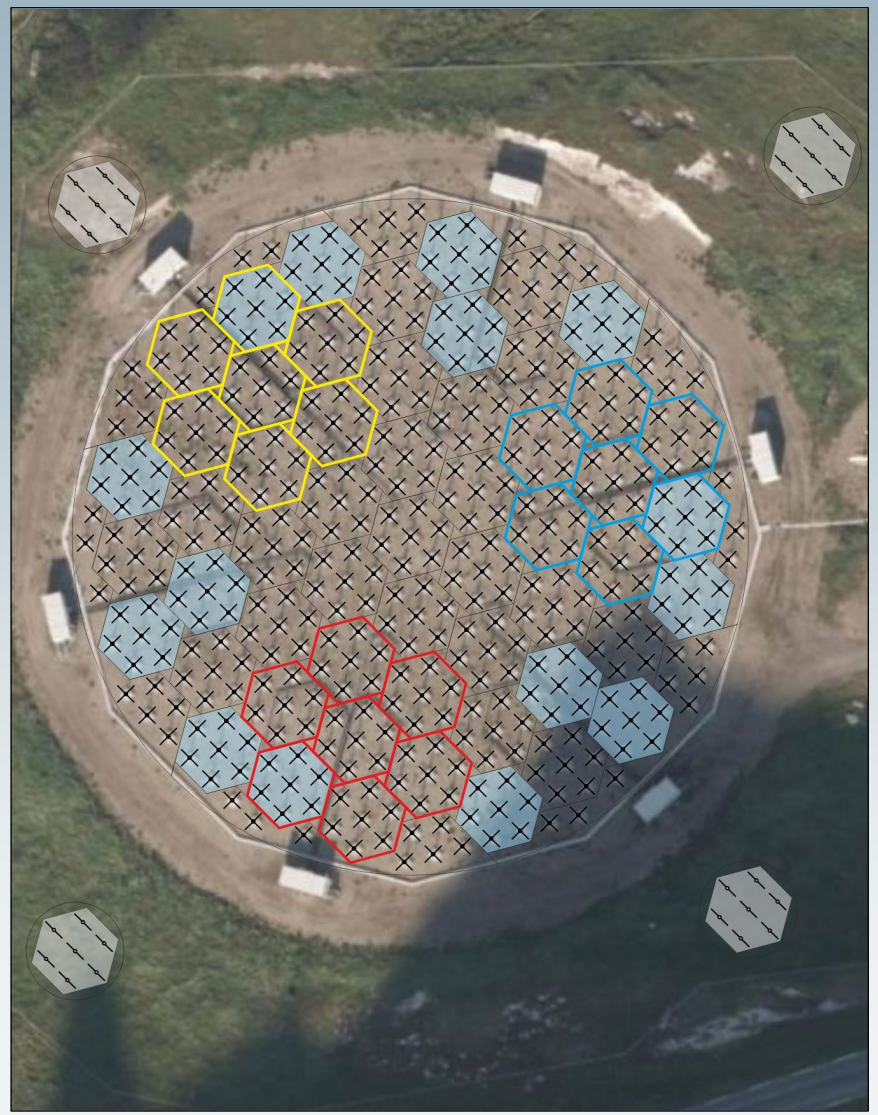
- **97 different beam positions**
- scheduled in 4 experiments with 25 beam positions each (24 oblique + vertical)

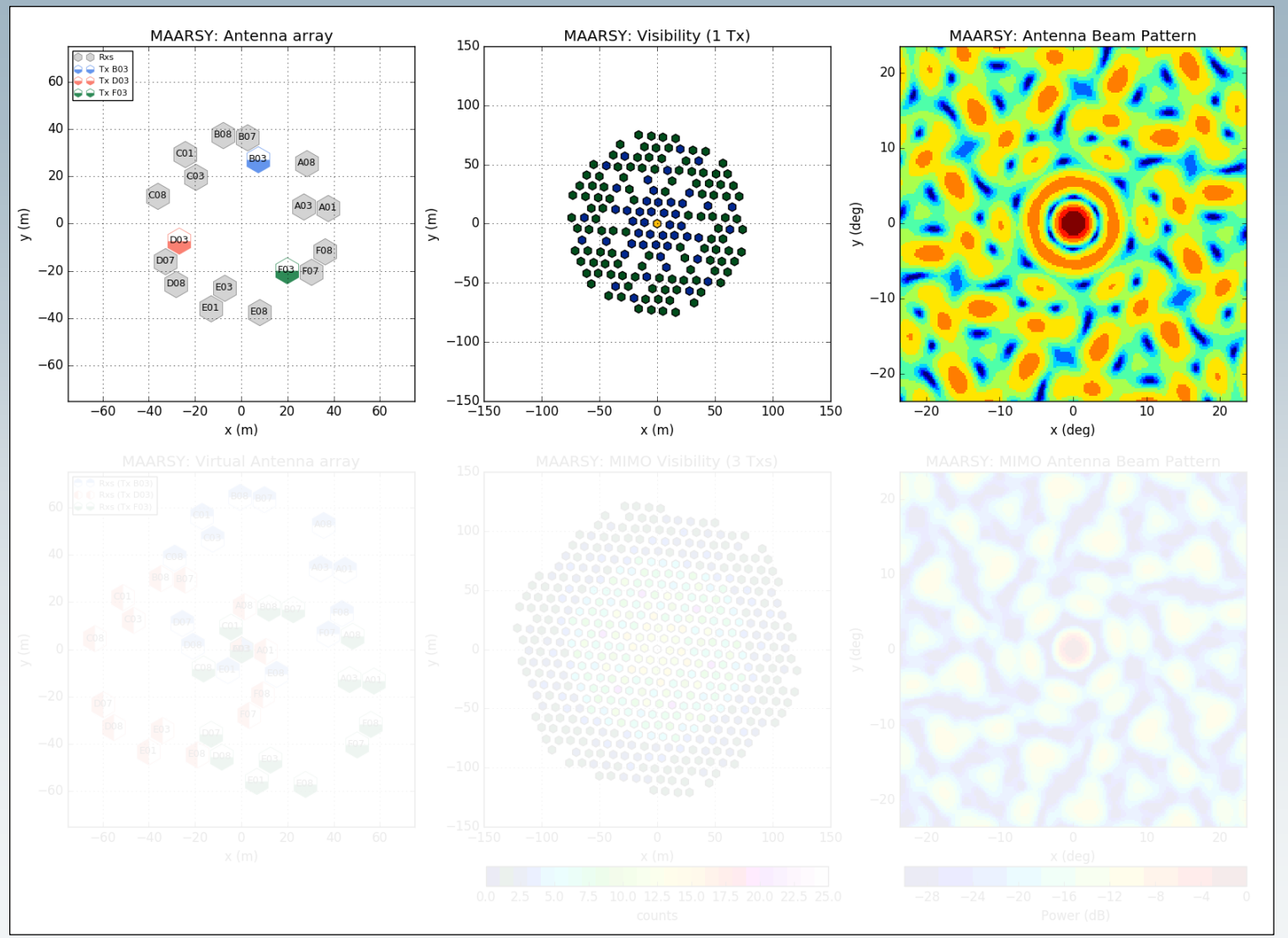
➢ a complete scan required 4 experiments runs a 21s

- large beam volume
- side lobe contributions

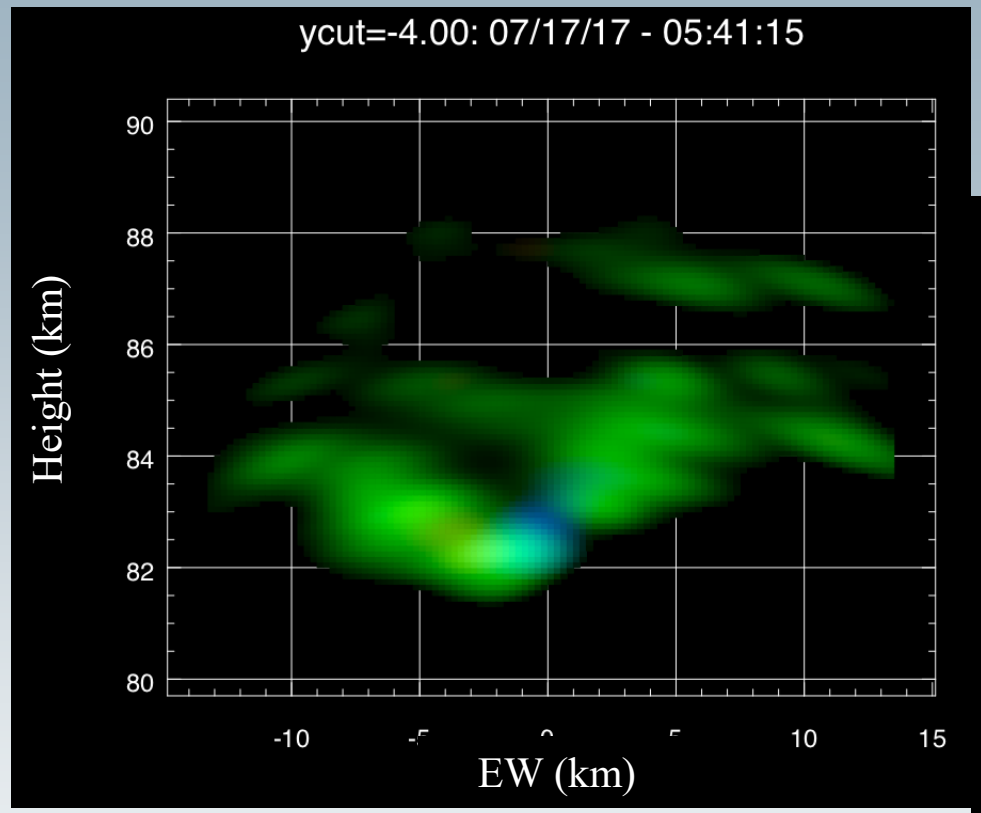
PMSE Radar Imaging - SIMO Experiment

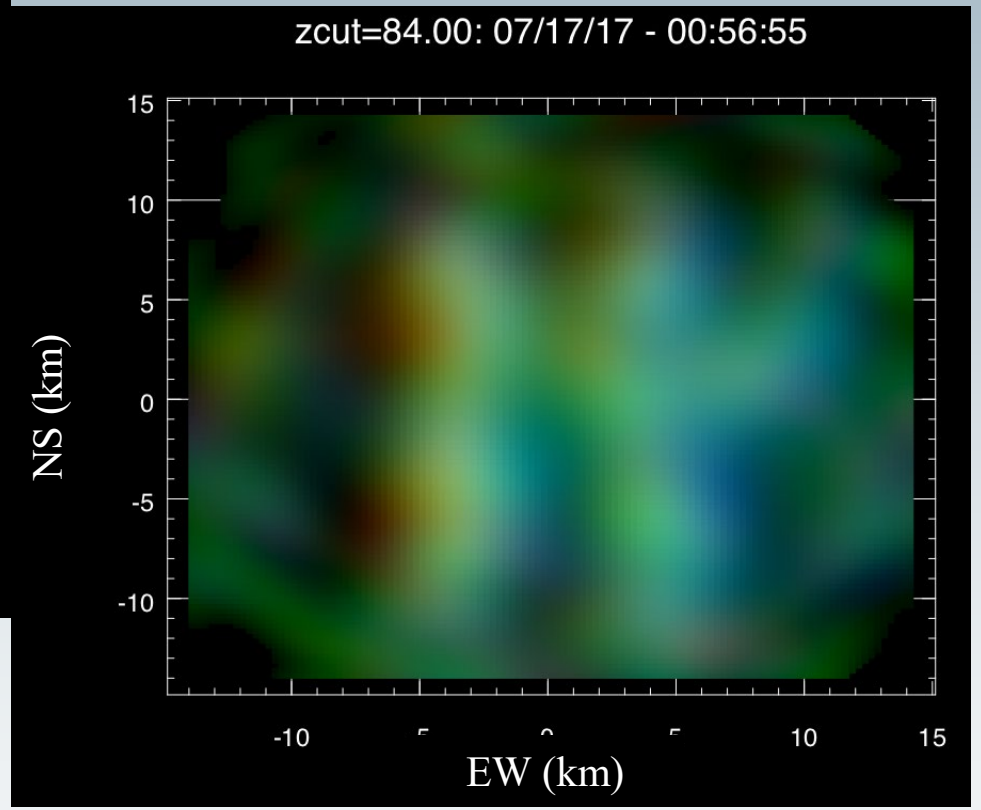
(from Urco et al., 2019)





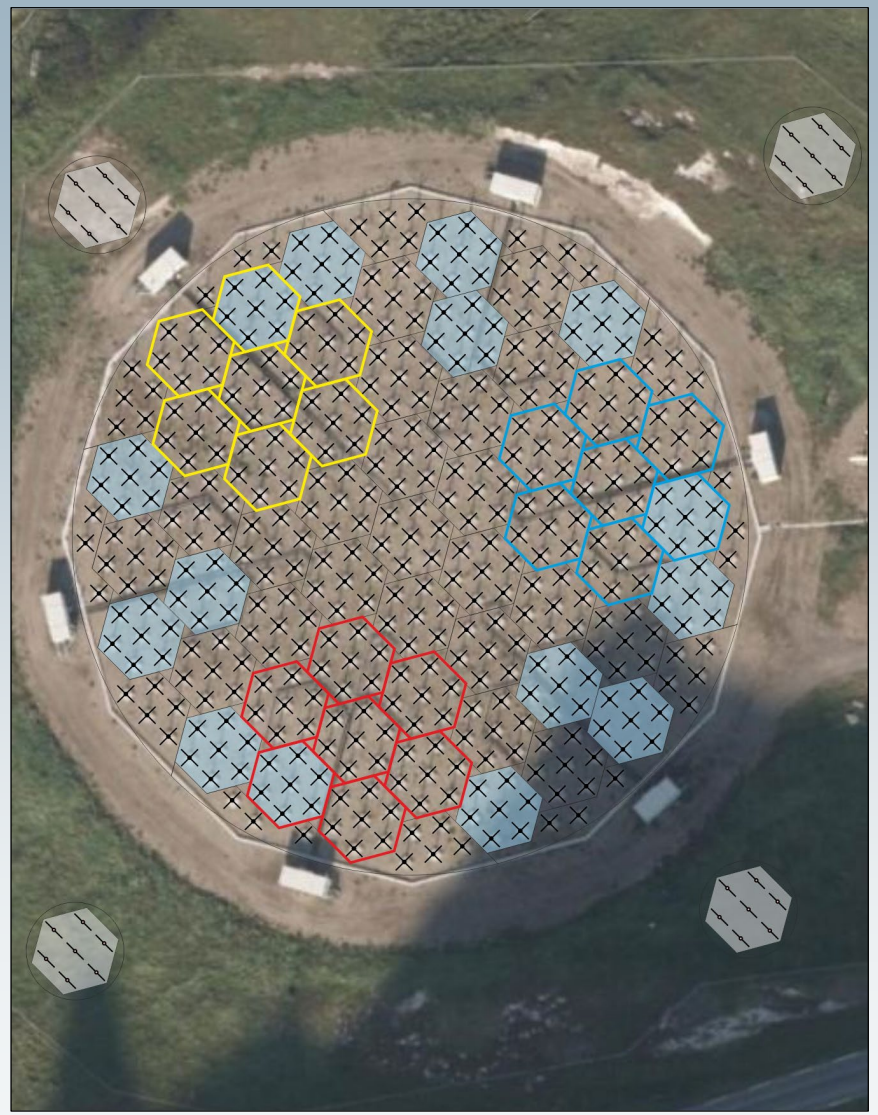
MaxEnt - SIMO

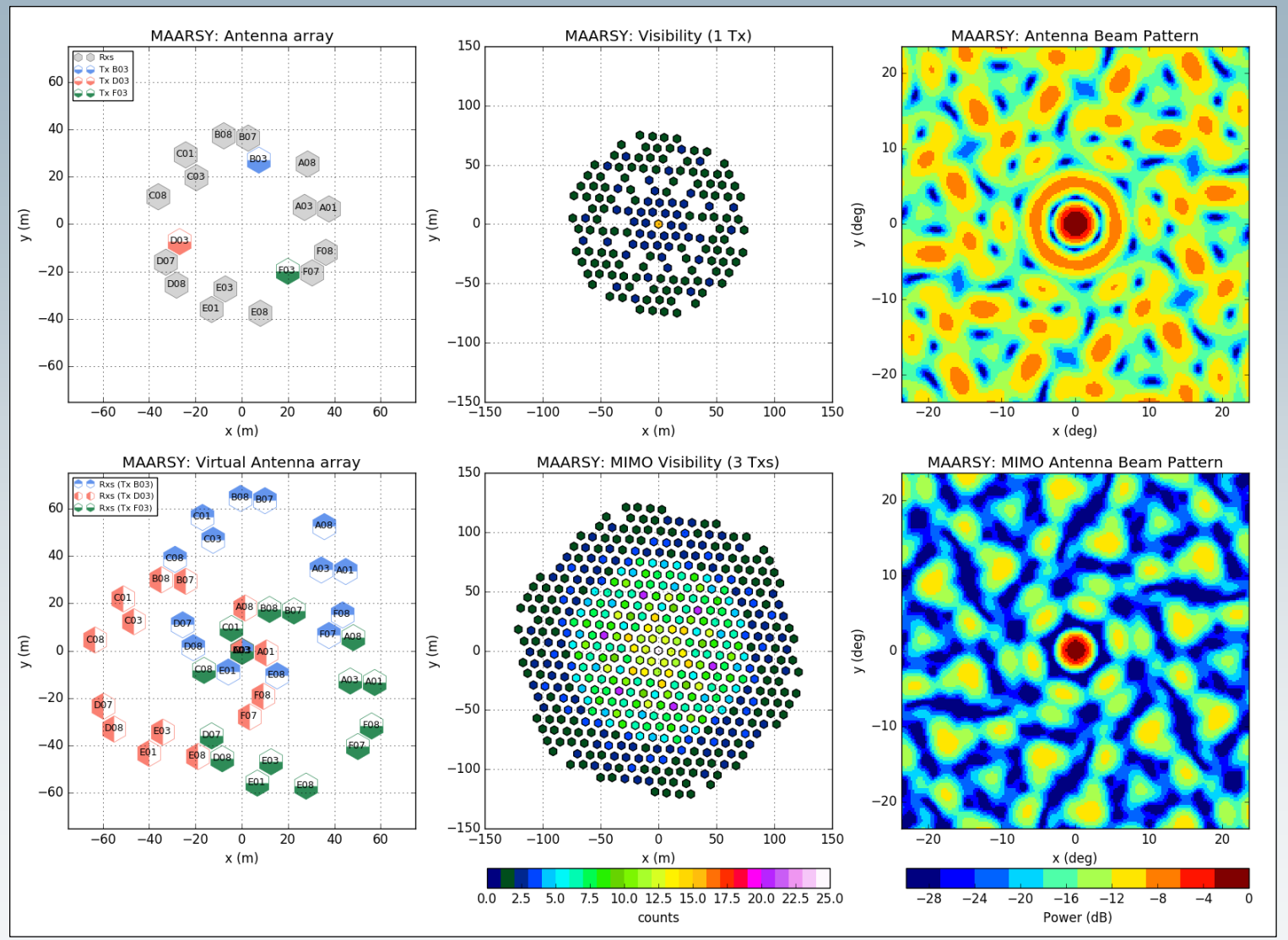

ycut=-4.00: 07/17/17 - 05:41:15
Height (km)
90
88
86
84
82
80
-10
10
15
EW (km)


zcut=84.00: 07/17/17 - 00:56:55
NS (km)
15
10
5
0
-5
-10
-10
10
15
EW (km)

PMSE Radar Imaging - MIMO Experiment

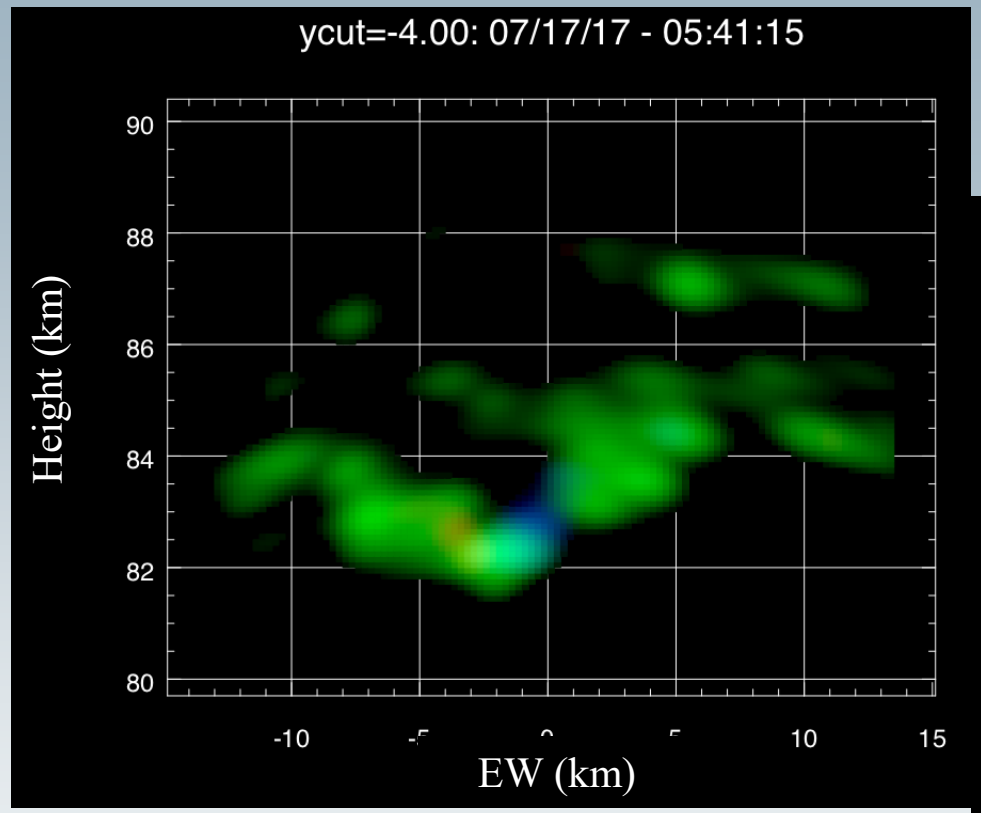
(from Urco et al., 2019)

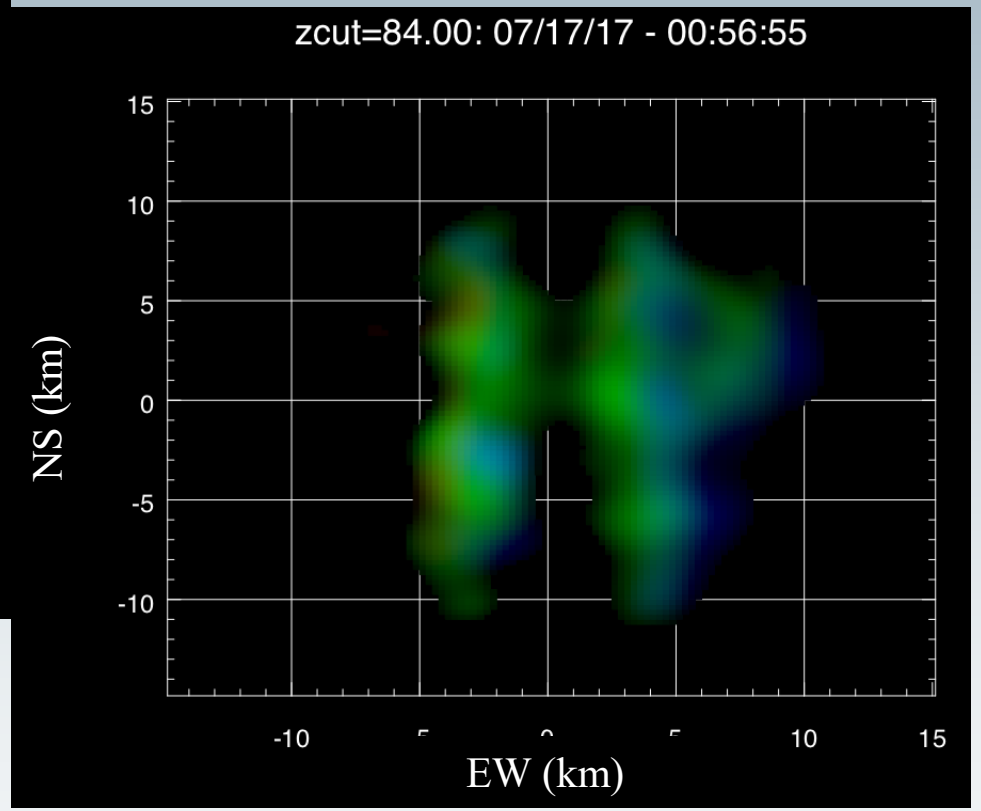




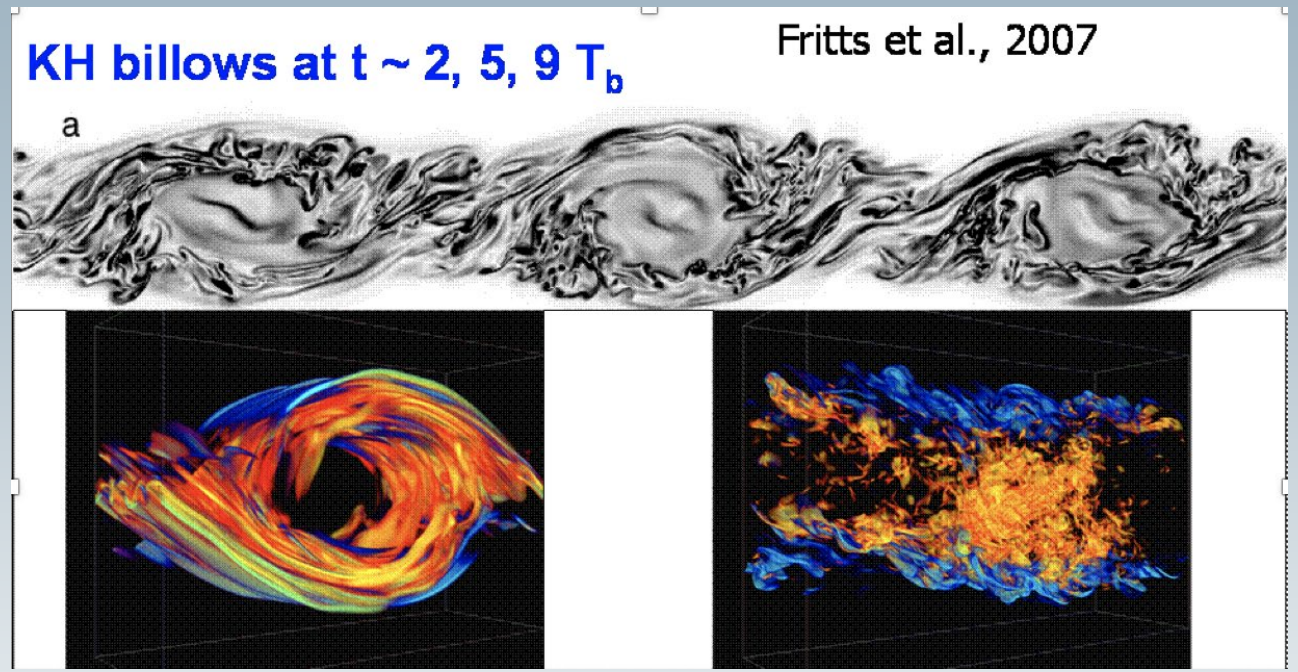
MaxEnt - MIMO

(from Urco et al., 2018)



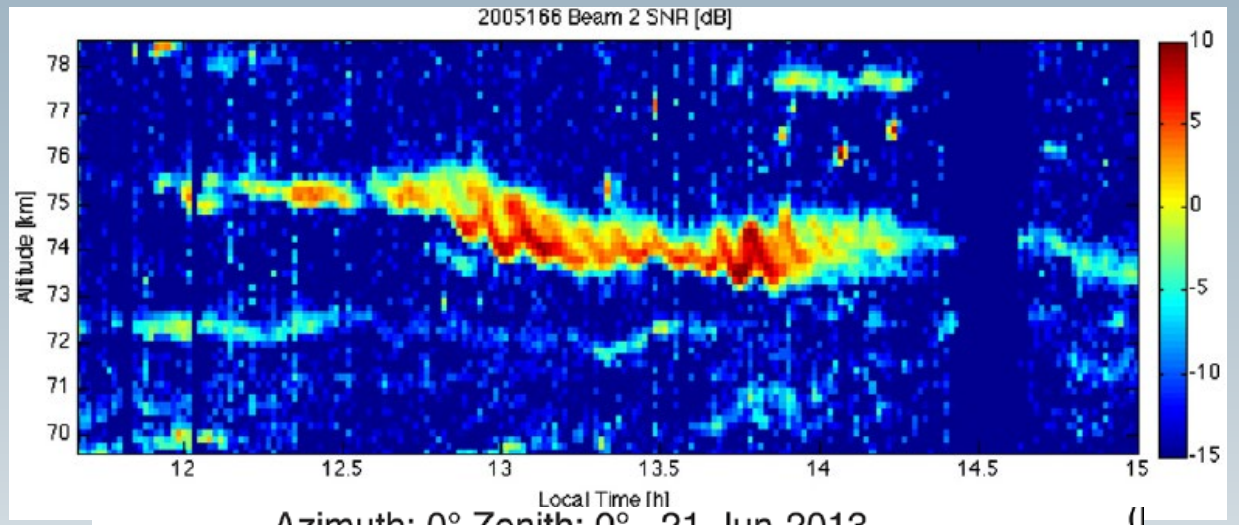


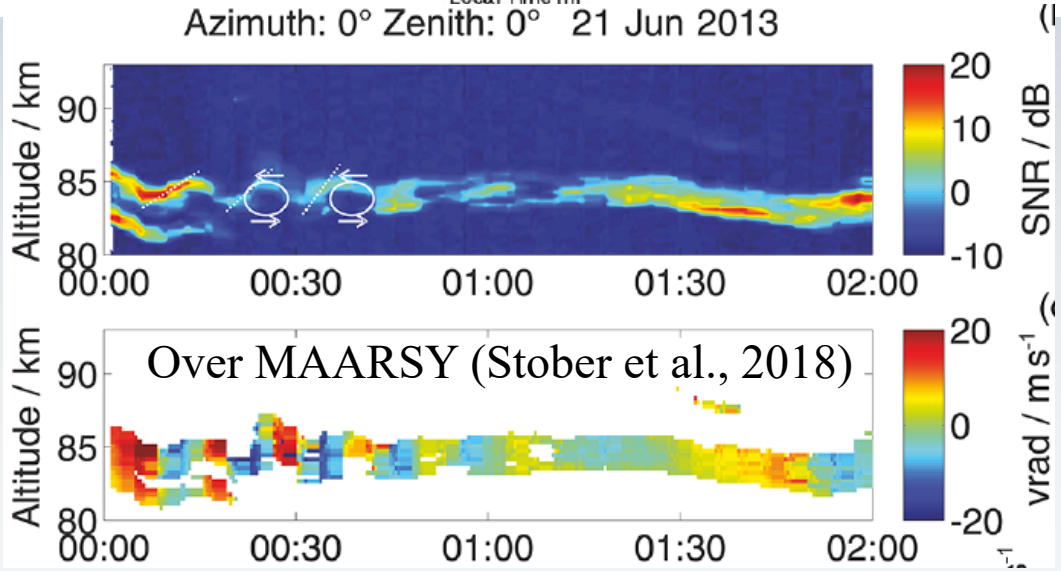
Mesospheric Kelvin Helmholtz Instabilities: Radar Observations



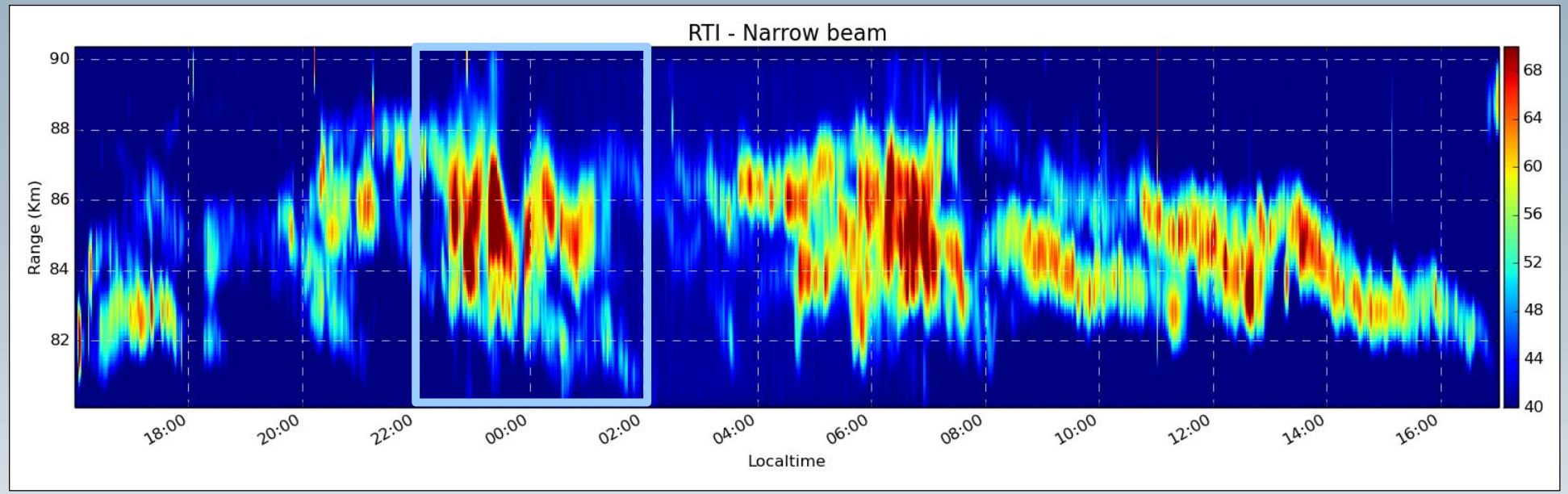
Possible signatures in radar echoes (Gossard and Hooke, 1975)

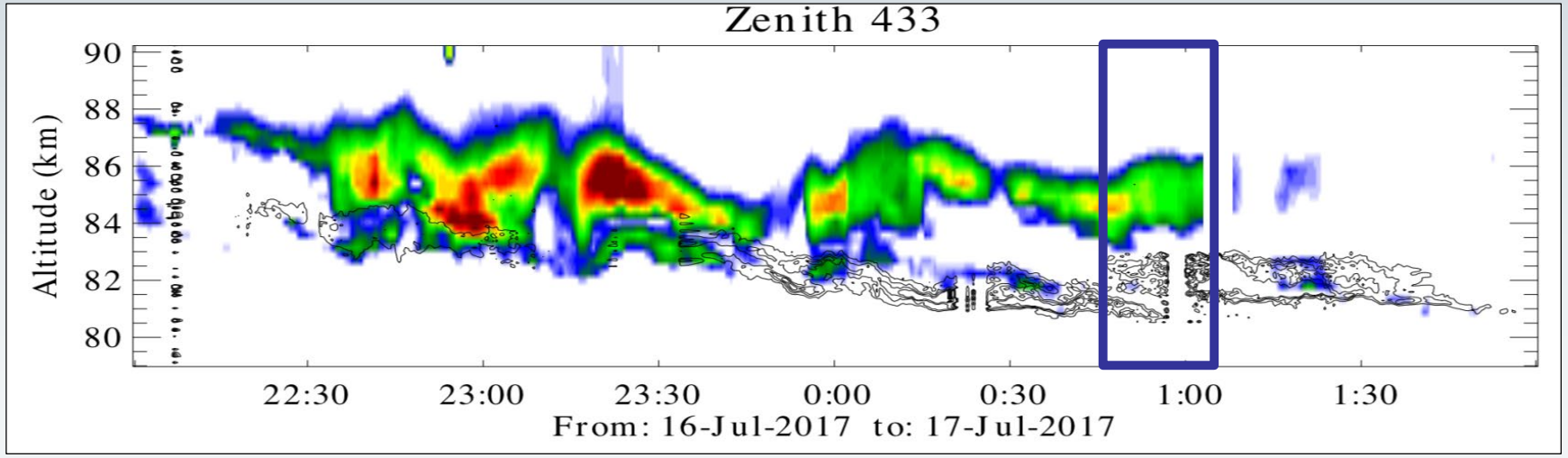
Over Jicamarca (Lehmacher et al., 2007)





PMSE Observations: 16-17 July 2017

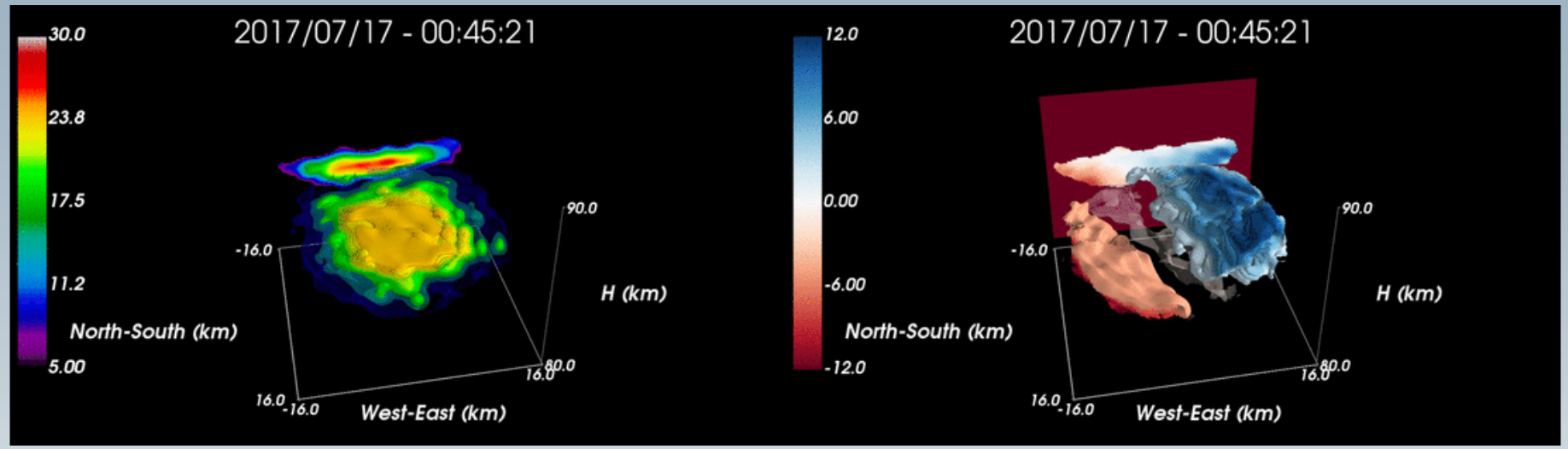


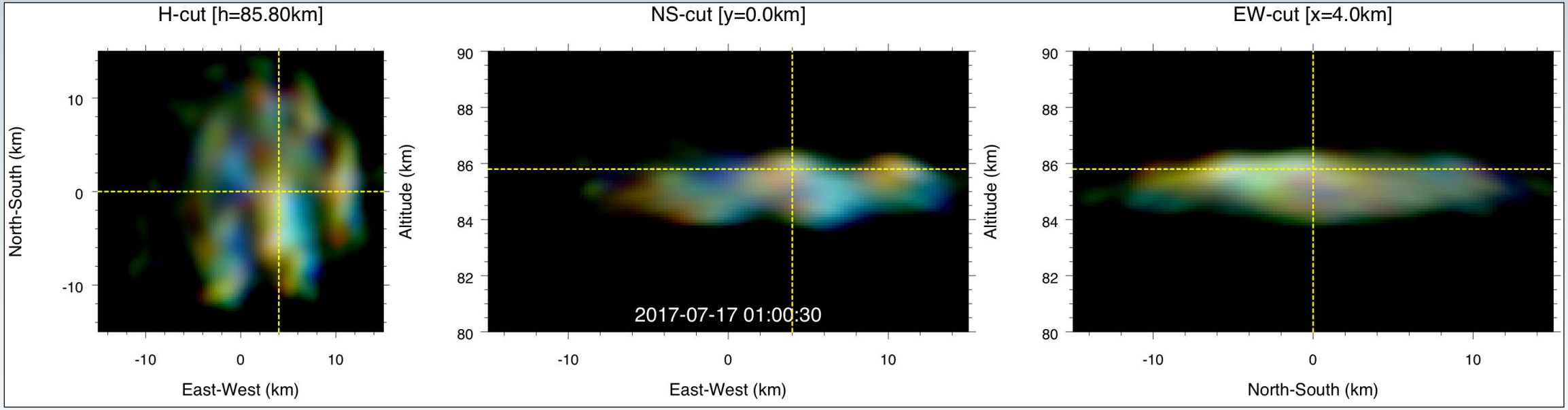


Considerations

- 3-m irregularities are good tracers of the background dynamics.
- Brightness changes are a combination of Schmidt number, Ne, temperature, turbulence, …
- Magnetospheric/ Ionospheric forcing do not modify the neutral dynamics, but they could modulate the echo brightness.

PMSE 4D visualization: Brightness, radial velocity





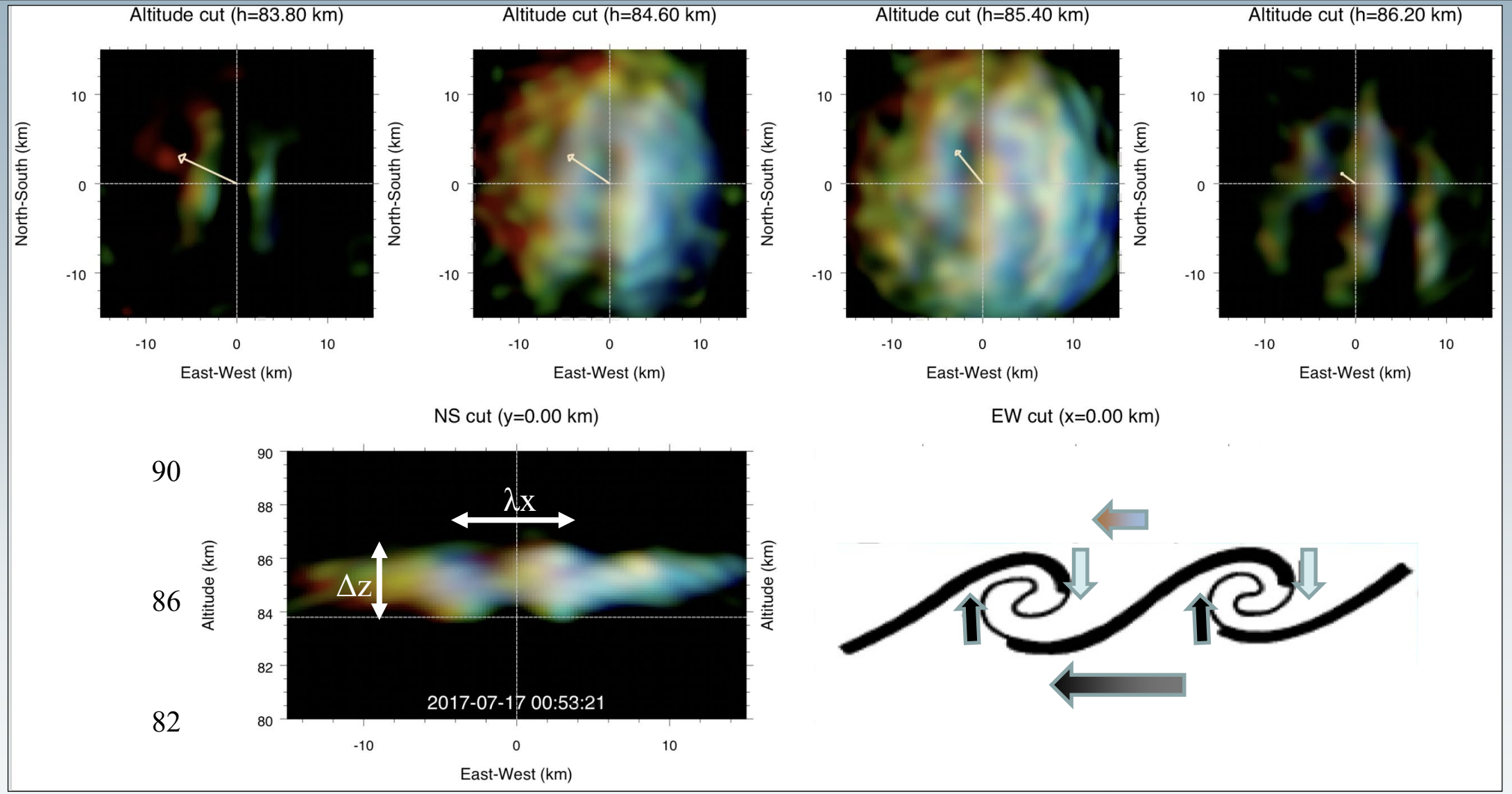
Event 1: Ripples propagating drifting with neutral wind

Doppler veloc
- red: veloc
  from the
- blue: velo
  the radar
- green: ve
  to zero.

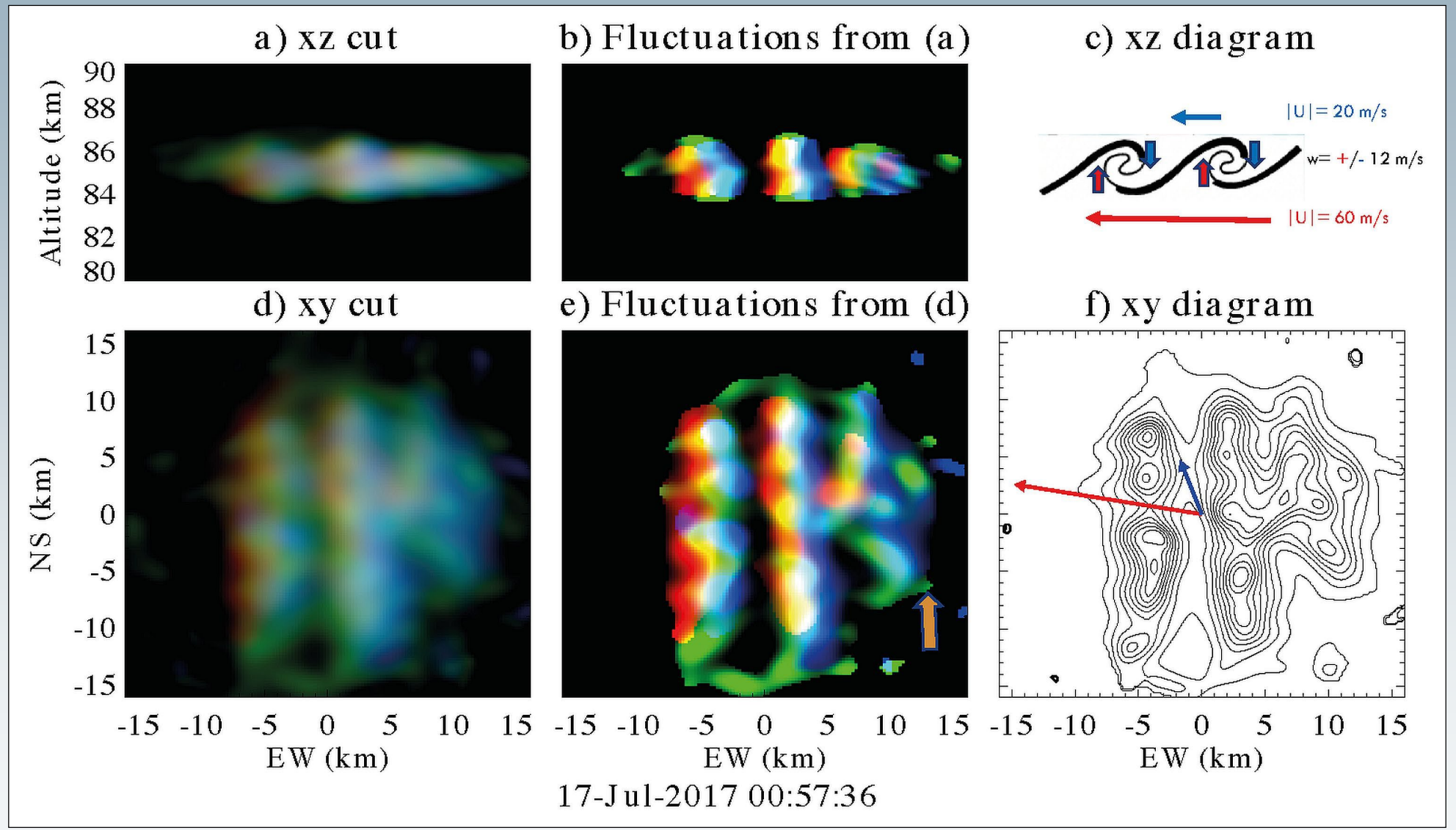
SNR
- intensity

Horizontal wi
- yellow ar
  the horizo
  direction
  near-by s
  meteor ra

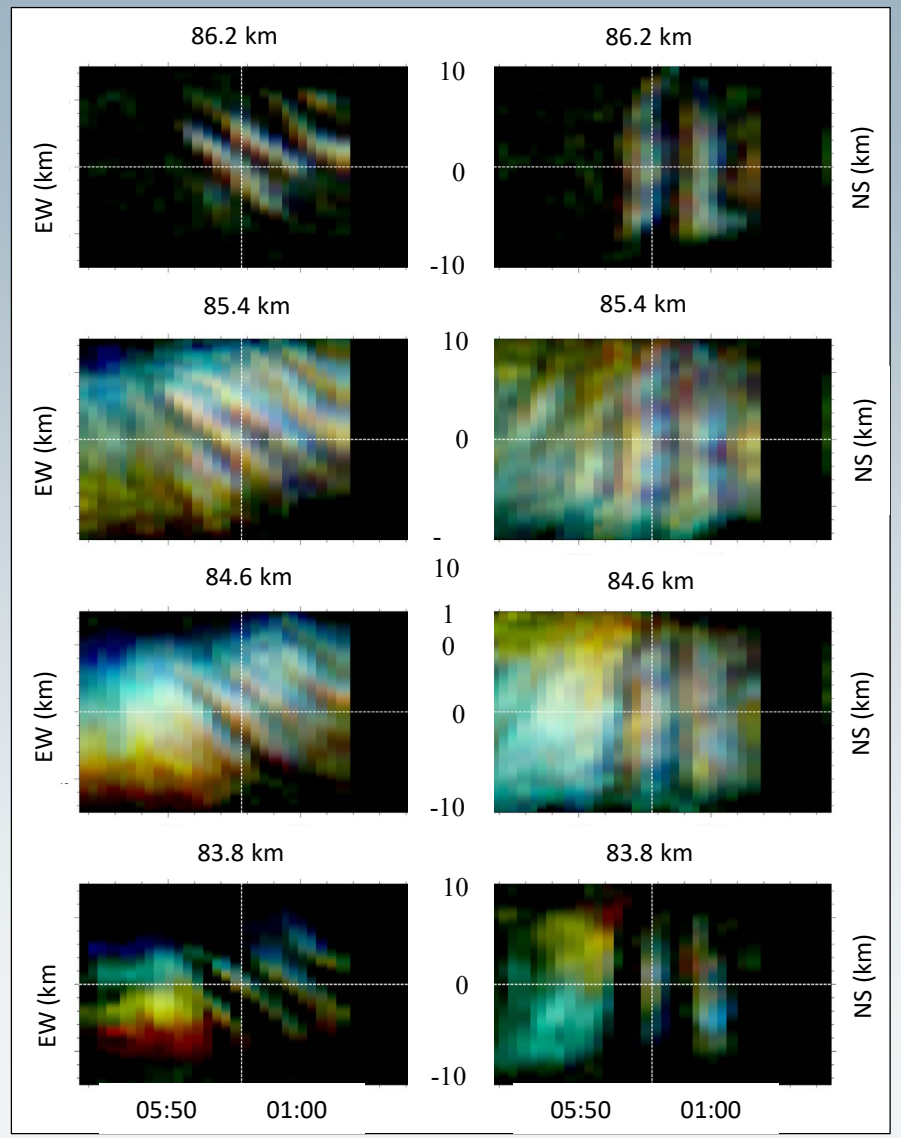
Event 1 @ 00:53:21UT



Event 1 @ 00:57:36 UT



Event 1: Summary of parameters



λy = large (i.e., elongated along y)
Δz = 1.8-2.1 km
λx = 6-8 km
Δt = 4-5 min
u = -28 m/s
v = 20 m/s
BV period ~ 4 min

$s=\Delta z/\lambda x = 0.25\text{-}0.35$
Assuming high Re
Ri = 0.08-0.13

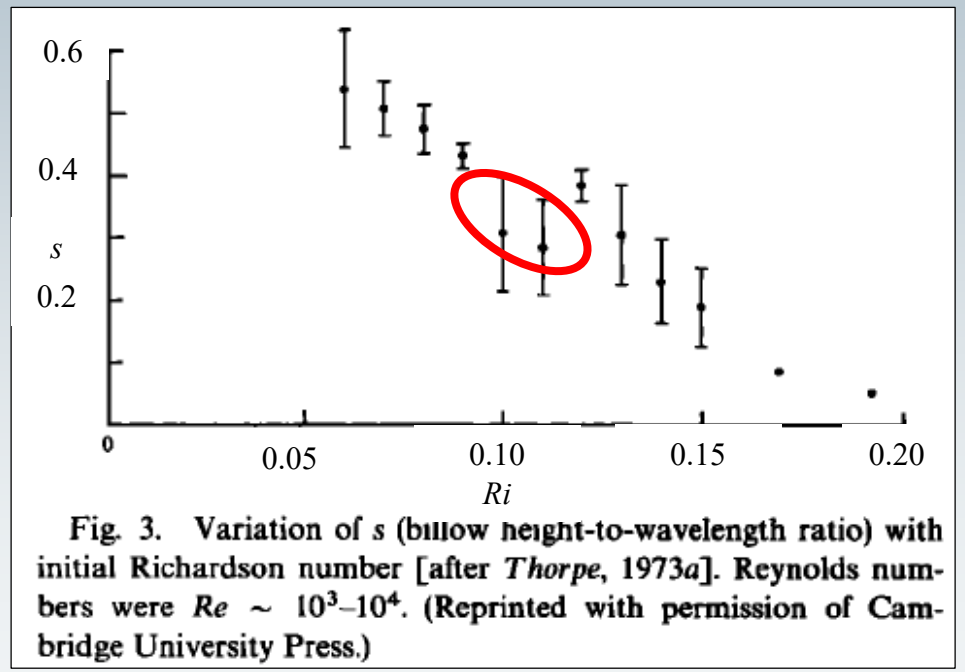
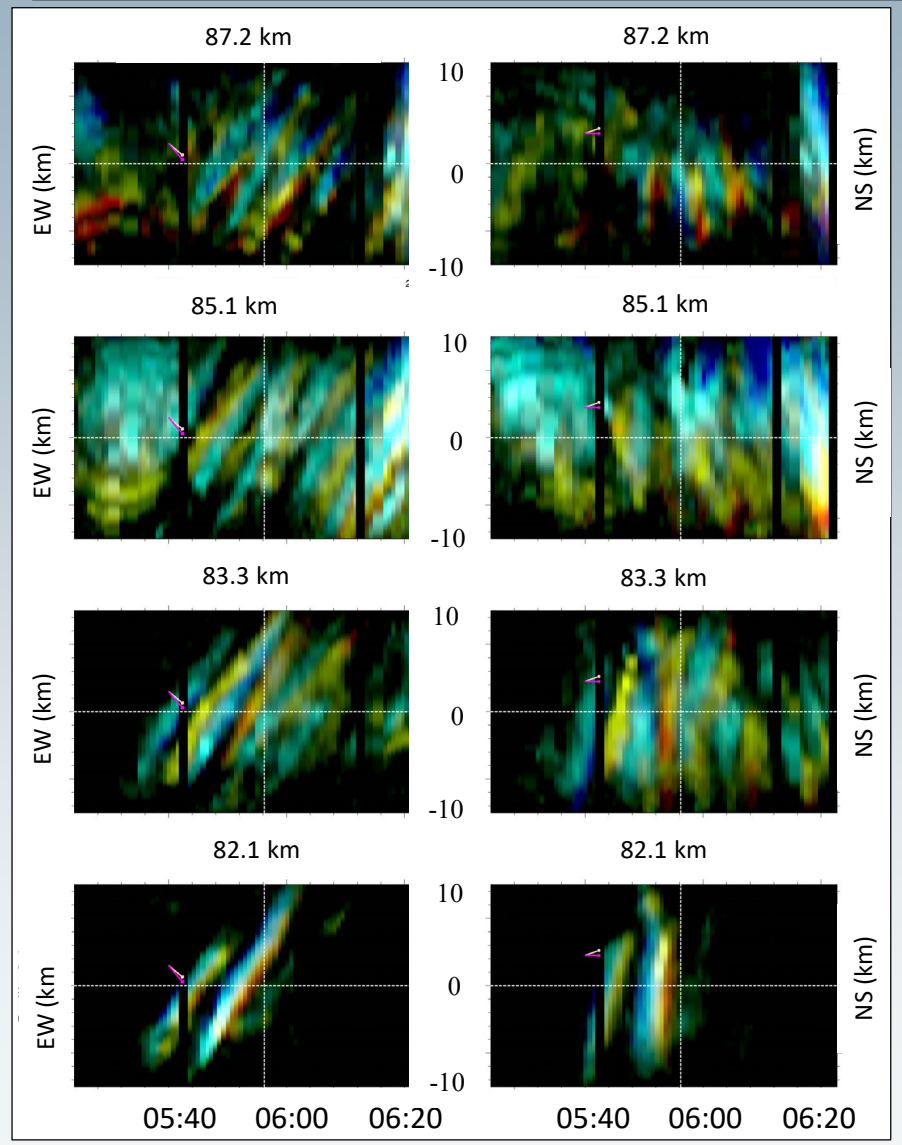
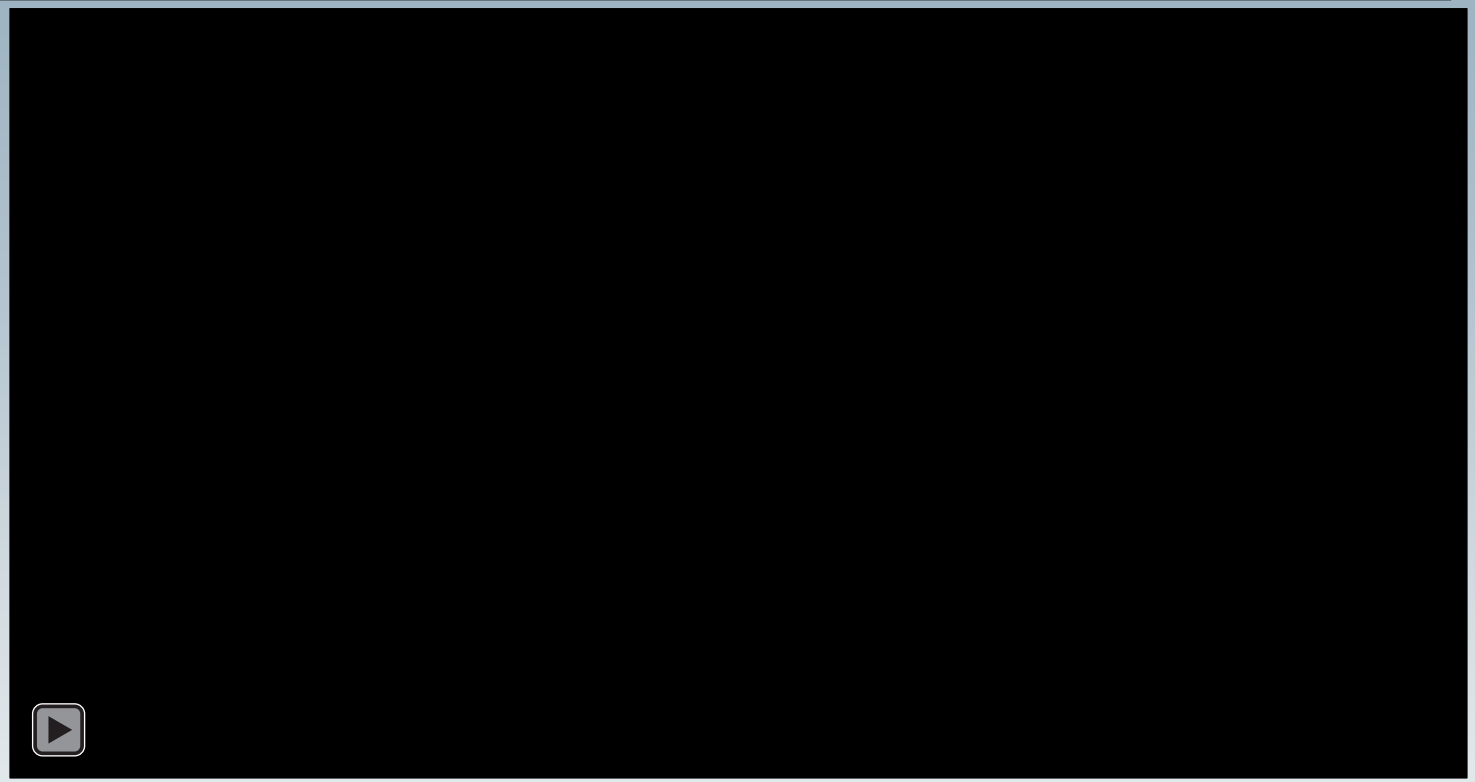


Fig. 3. Variation of s (billow height-to-wavelength ratio) with initial Richardson number [after *Thorpe*, 1973*a*]. Reynolds numbers were $Re \sim 10^3$–10^4. (Reprinted with permission of Cambridge University Press.)

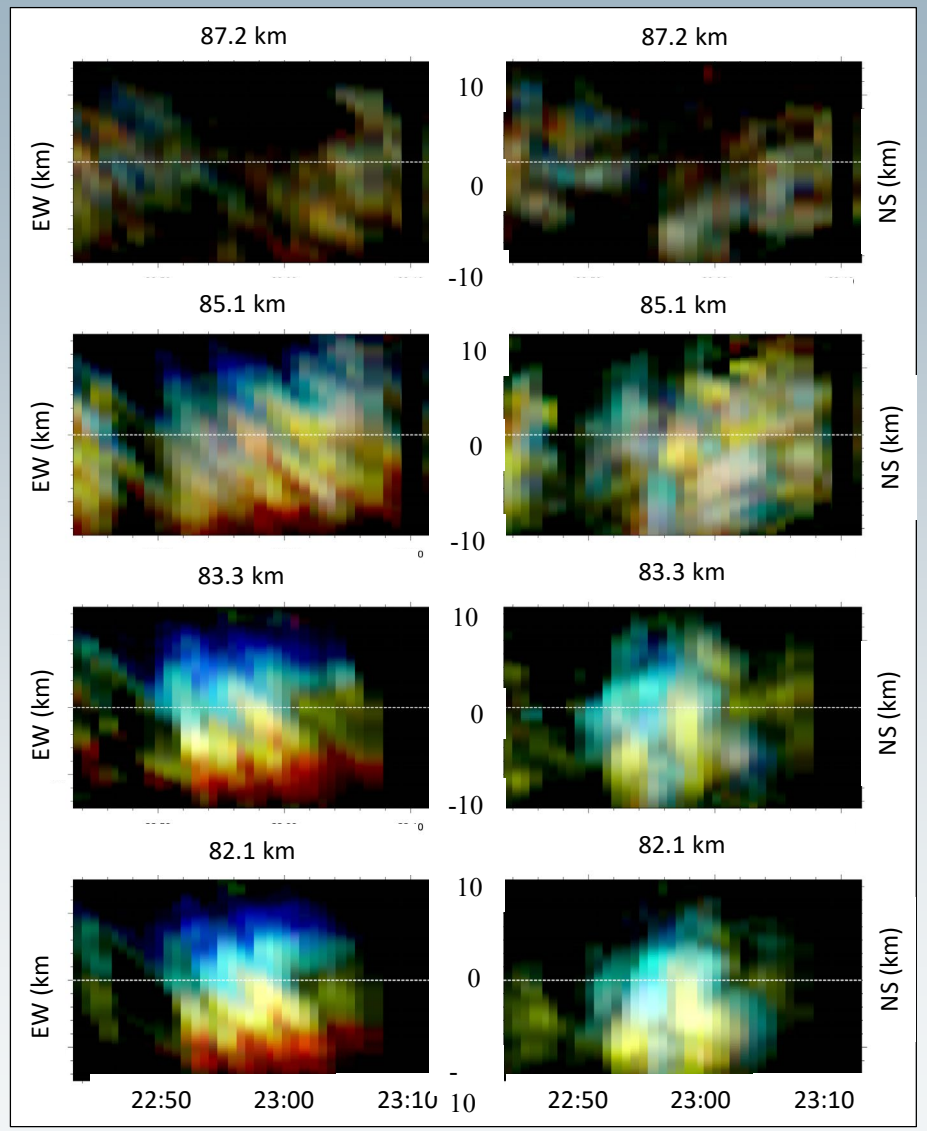
(from Fritts and Rastogi, 1985)

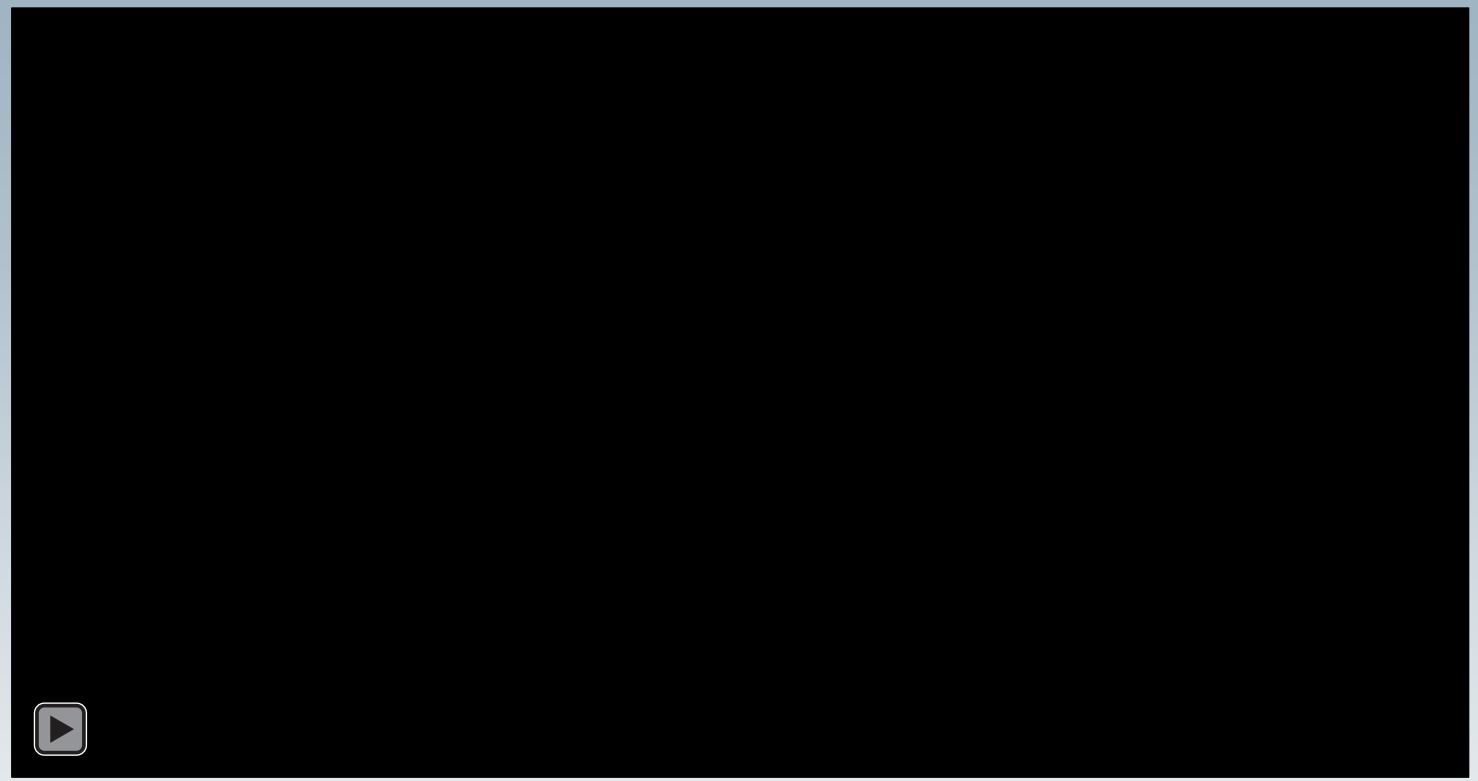
Event 2: Propagating waves against the wind?





Event 3: ????


87.2 km
87.2 km
85.1 km
85.1 km
83.3 km
83.3 km
82.1 km
82.1 km
EW (km)
NS (km)
10
0
-10
22:50
23:00
23:10



Summary

- Radar imaging (+MIMO) observations of PMSE allow exploring the polar mesospheric summer region with high spatio-temporal resolutions of: Brightness, Doppler, spectral width, whenever PMSE is strong enough!

- 4D measurements of PMSE, including altitude, are possible quasi continuously, independent of ground weather conditions.

- A text-book KHI event has been fully characterized. Other wave events, not limited to monochromatic waves, are waiting to be explored.

Thank you