First results of combined ground- and rocket-based measurements for investigation of polar mesospheric winter echoes (PMWE)

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PMWE1 Liftoff: Photo by Trond Abrahamsen | ASC

Observations of PMSE & PMWE

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Fig: Ecklund and B. B. Balsley: *Long-term observations of the Arctic mesosphere with the MST radar at Poker Flat,* Alaska. Journal of Geophysical Research, September 1981.

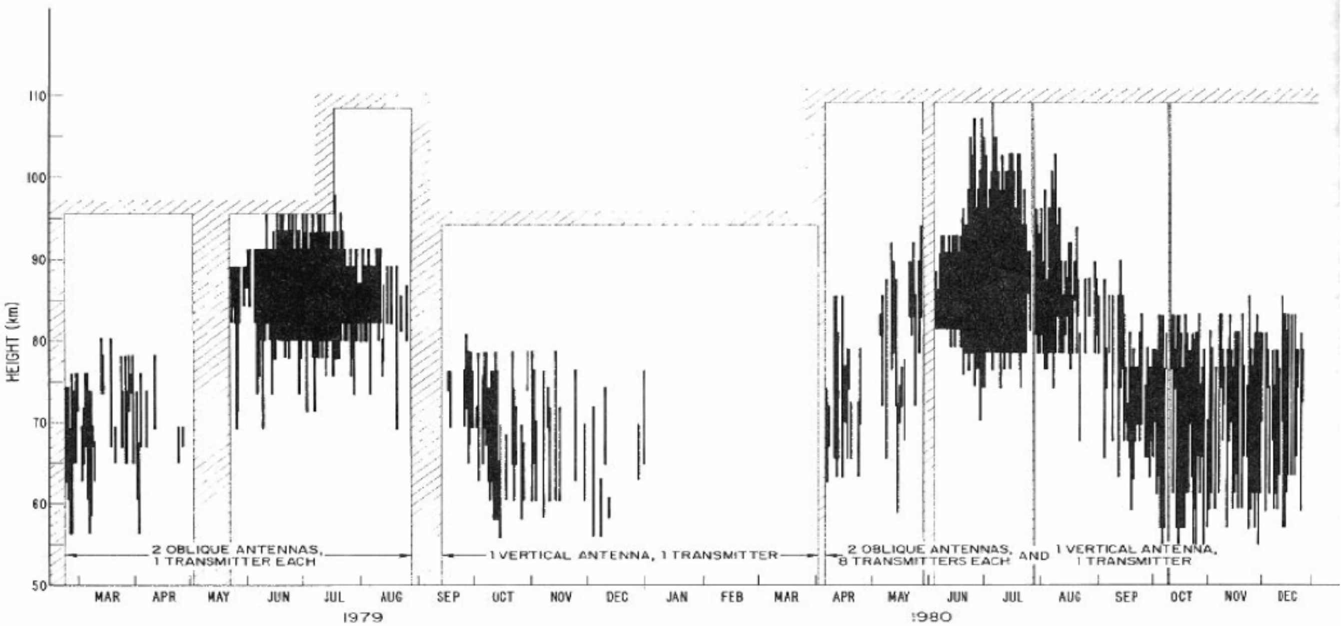
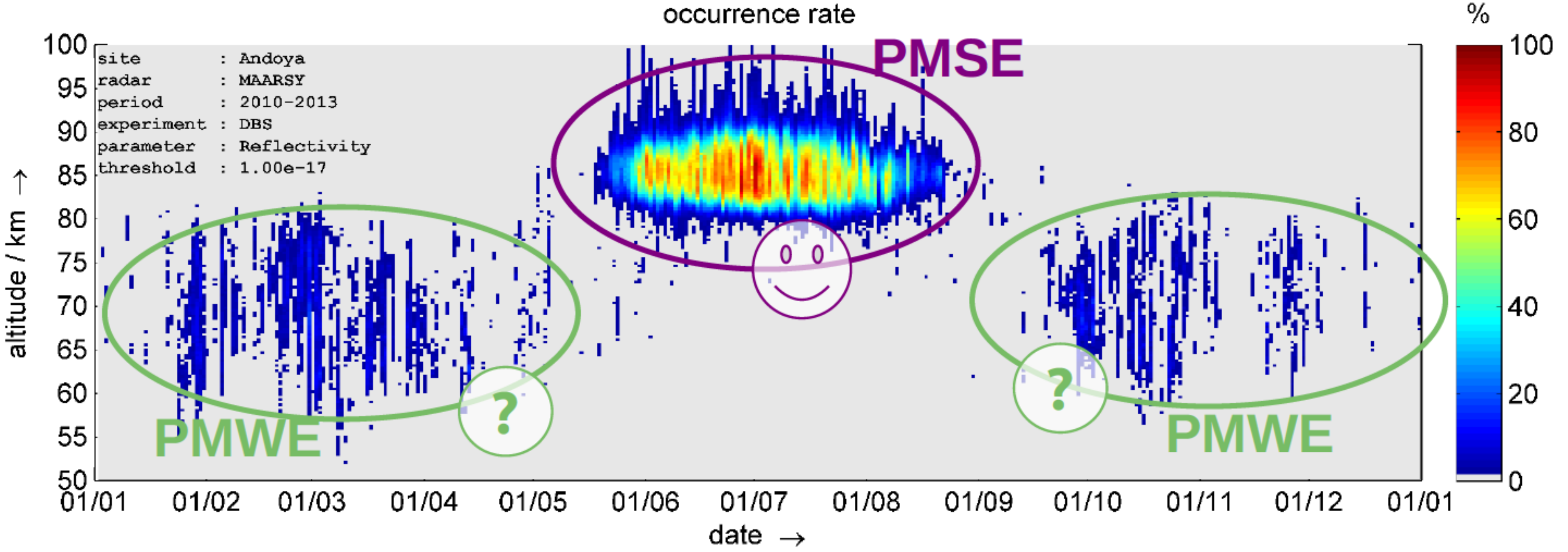


Fig. 1. Height of occurrence of mesospheric echoes on a daily basis from February 1979 to December 1980.

Observations of PMSE & PMWE



- PMSE: -mechanism understood! - charged ice particles structured by turbulence
- PMWE: ?

Fig.: R. Latteck and I. Strelnikova, Extended observations of polar mesosphere winter echoes over Andoya (69′N) using MAARSY, JGR, 2015

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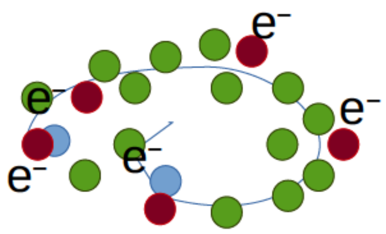
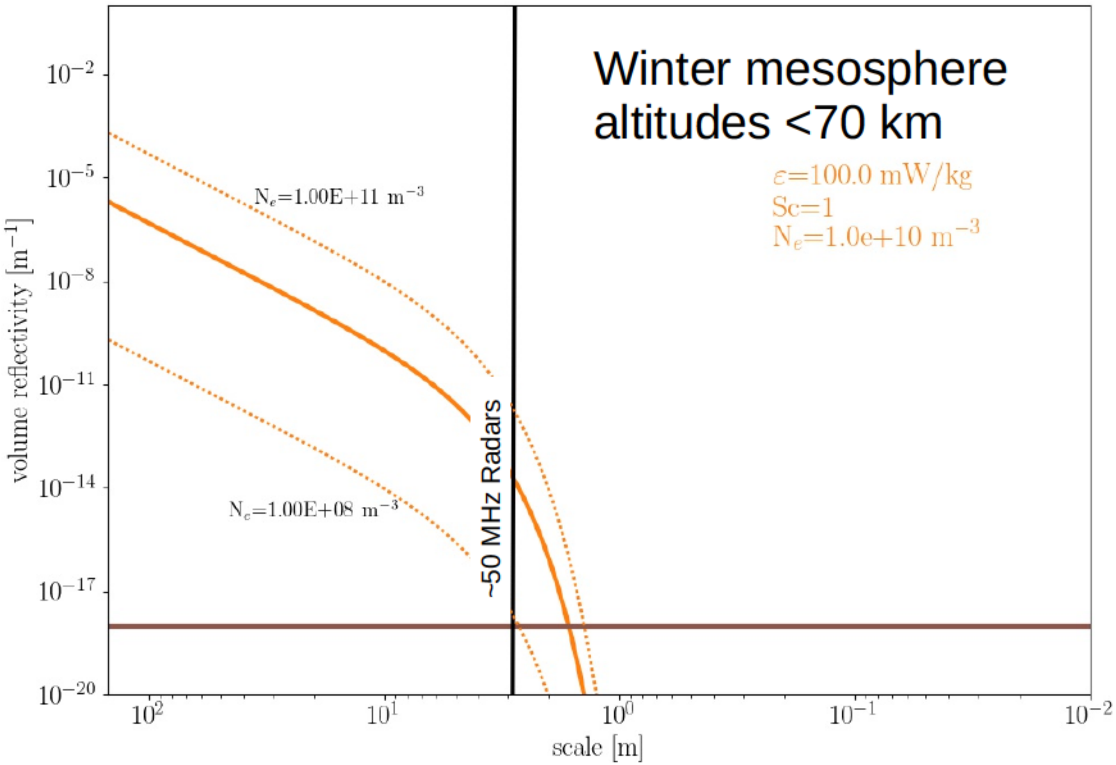
Turbulence





Electrons are bound to ions in a highly collisional plasma → electron structure is dominated by neutral dynamics, e.g. turbulence!

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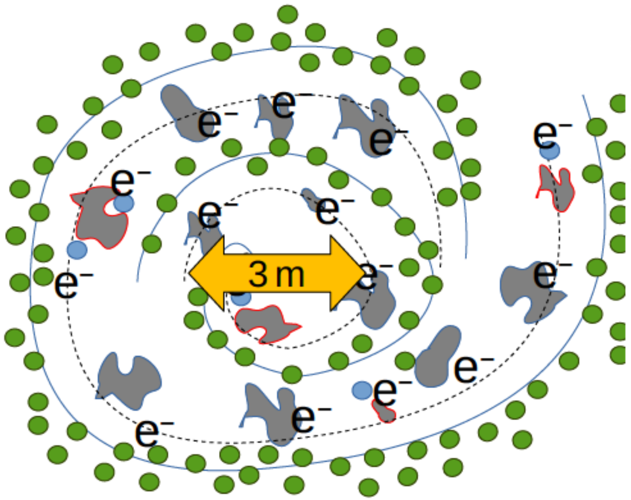
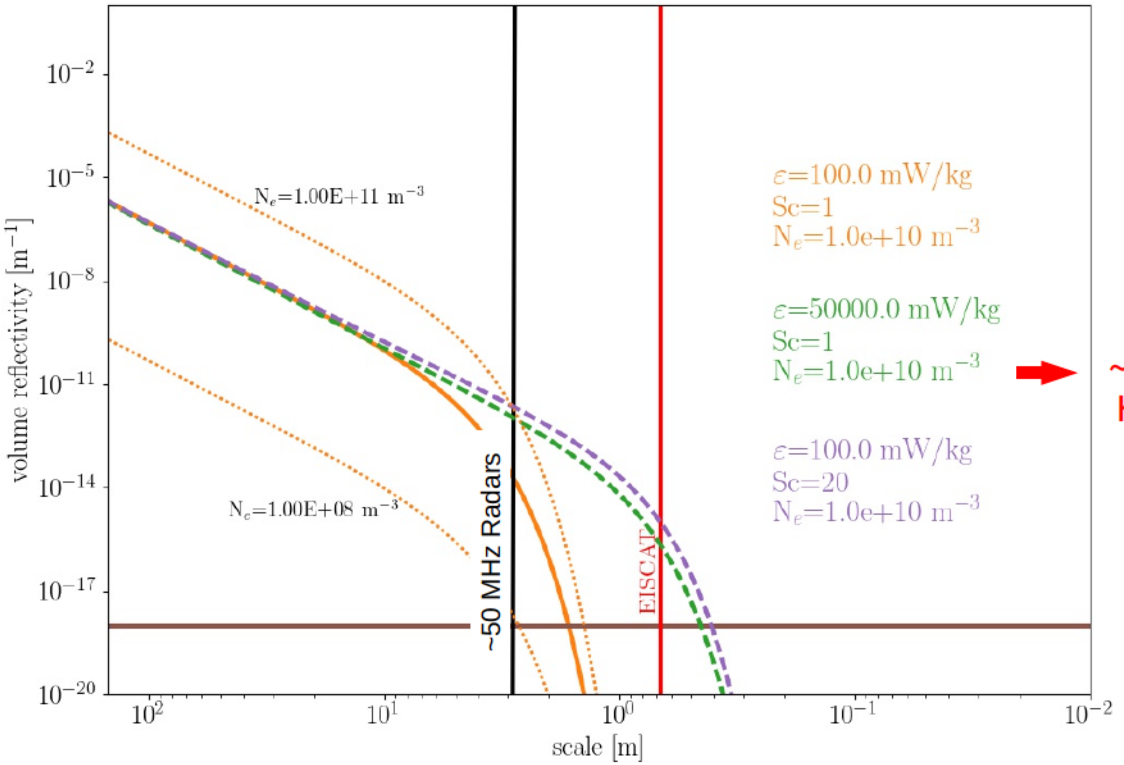
Turbulence + Dust





~ 4000 K/day

Electrons are bound to heavy (=inertial) dust particles. Diffusivity of electrons is dominated by dust particles!

Sc>1 =>

Leads to fluctuations on smaller scales than present in neutral turbulence field! (Batchelor, JFM, 1959)

Common Volume Measurements

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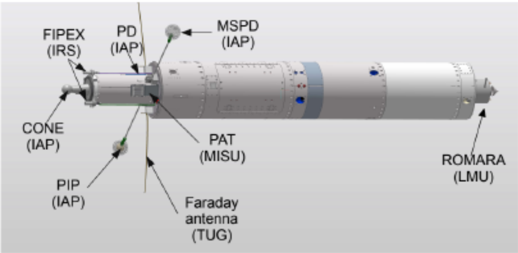
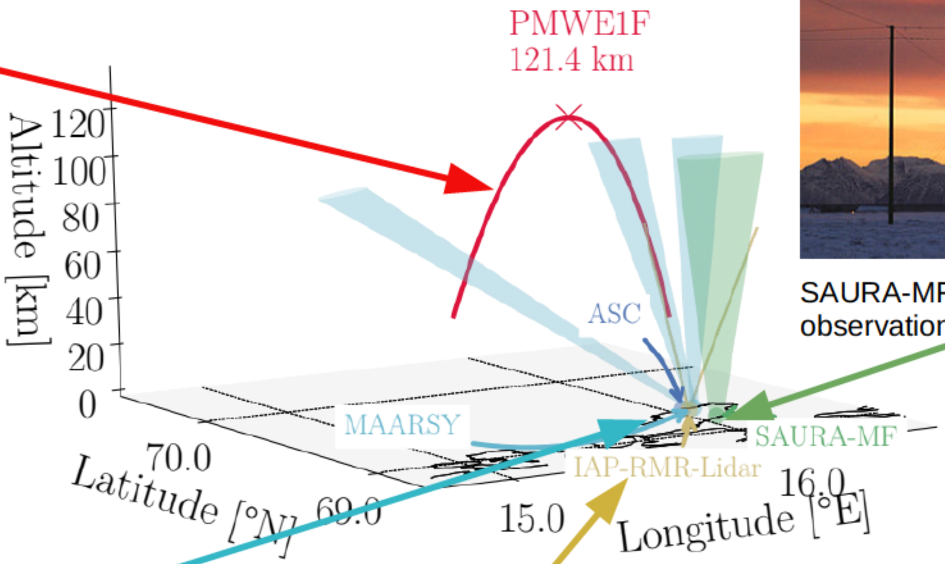
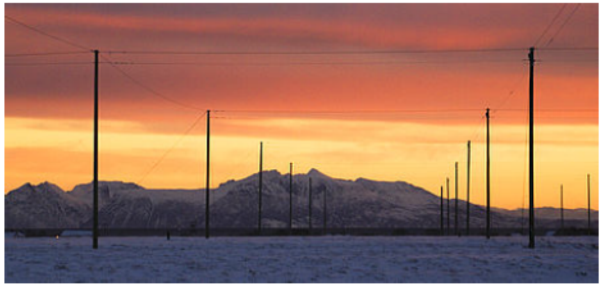


PMWE1F payload setup with instruments (corresponding institution abbreviation): ROMARA (LMU) on forward deck (FWD) and CONE (IAP), FIPEX (IRS), PD (IAP), two MSPD (IAP), PIP (IAP), PAT (MISU) and Faraday antenna (TUG) on aft deck (AFT).





SAURA-MF (3.17 MHz): Continous observations of electron density and winds.

MAARSY (53.5 MHz): Special configuration for common volume for up- and descending part of trajectory. PMWE detection was start criterion.

IAP-RMR-lidar: delivers continous sampling of density, temperature and winds.

Results: Radar Echoes (MAARSY)

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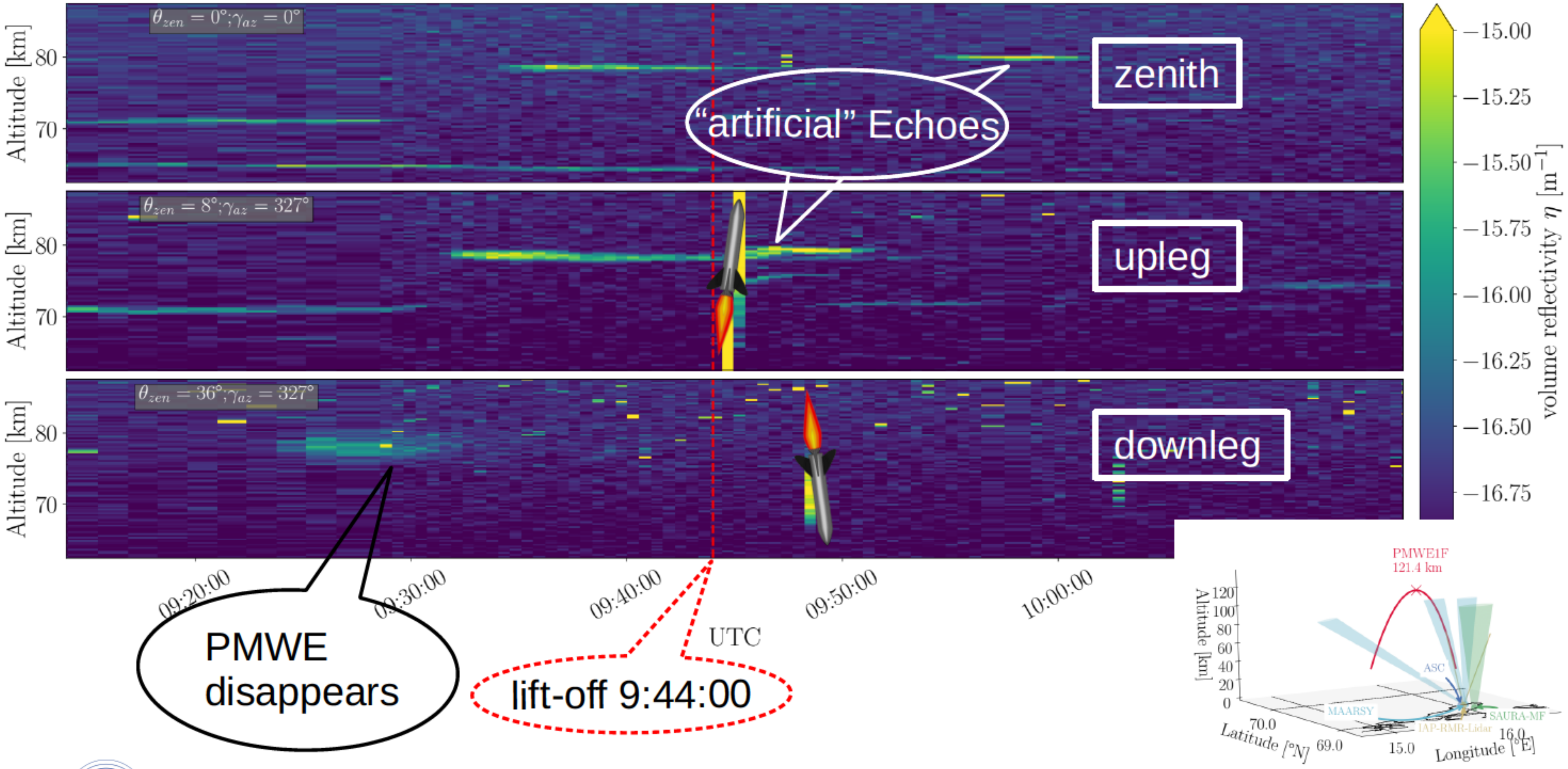
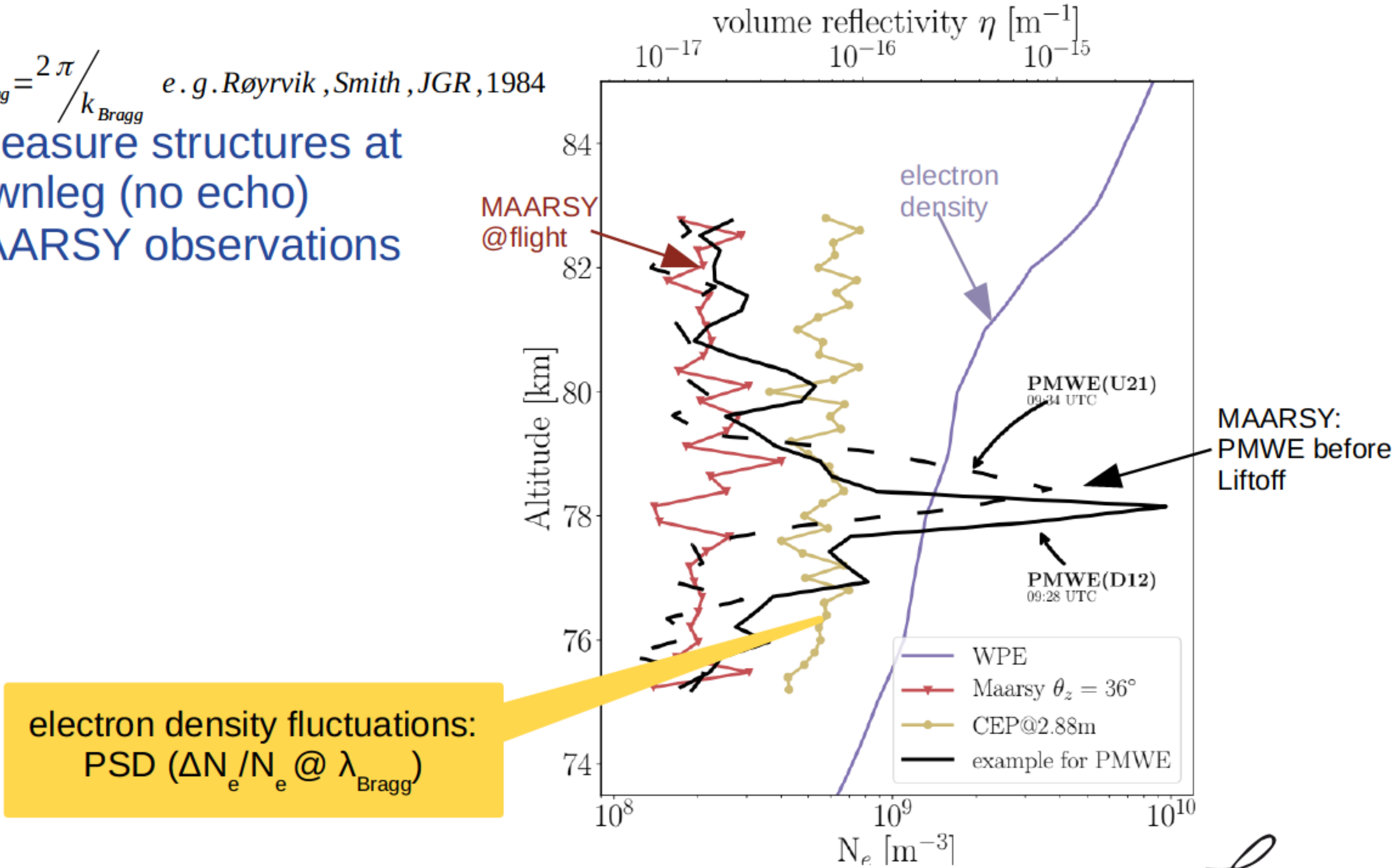
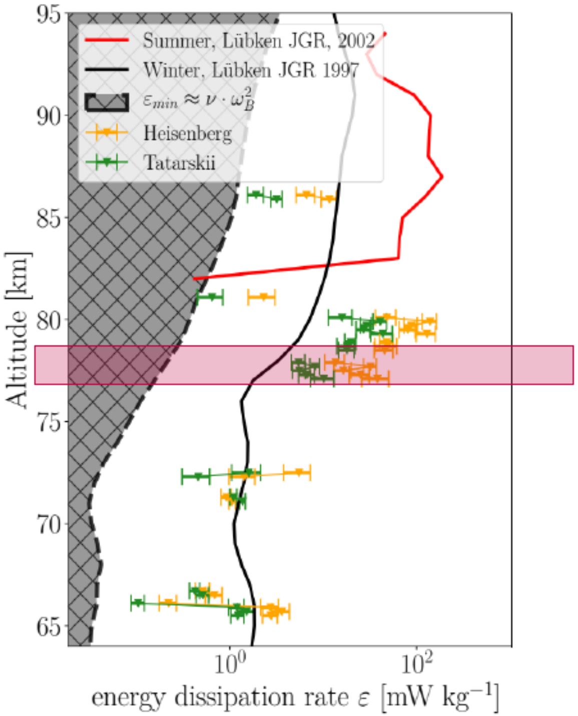


- $\eta \sim PSD(\delta N_e / N_e @ \lambda_{Bragg})$, where $\lambda_{Bragg} = 2\pi / k_{Bragg}$ e.g. Røyrvik, Smith, JGR, 1984
- Electron probe did not measure structures at radar bragg-scale on downleg (no echo)
- This is in accord with MAARSY observations



Results: Turbulence



- Turbulence was measured on downleg, where PMWE was observed 15-20 minutes before insitu measurements
- Feeding measured values (turbulence, background, and charged MSP (>1 nm)) into a model gives low volume reflectivity values: (1e-17 – 1e16)
- This is again in agreement with MAARSY observations.

→ Turbulence must have been much more intense before measurement.

(continous Ne measurements by SAURA show relatively constant values)

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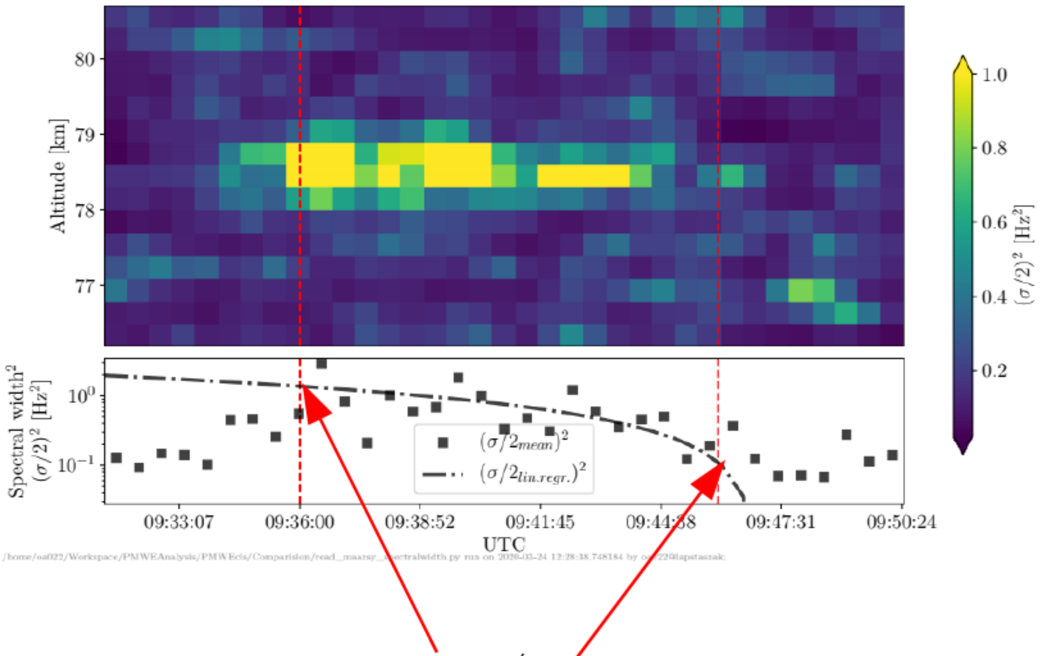
Spectral width evolution

- Spectral width measurements of the downleg echo shows a broadening (i.e. turbulence) at the beginning and smaller broadening effects at the end of echo (i.e. turbulence decay)
- Broadening effect was ~5-10 times stronger at the begin of echo



$$\left(\sigma/2\right)^2_{begin} \Big/ \left(\sigma/2\right)^2_{end} \approx 5-10$$

Results: Volume Reflectivity

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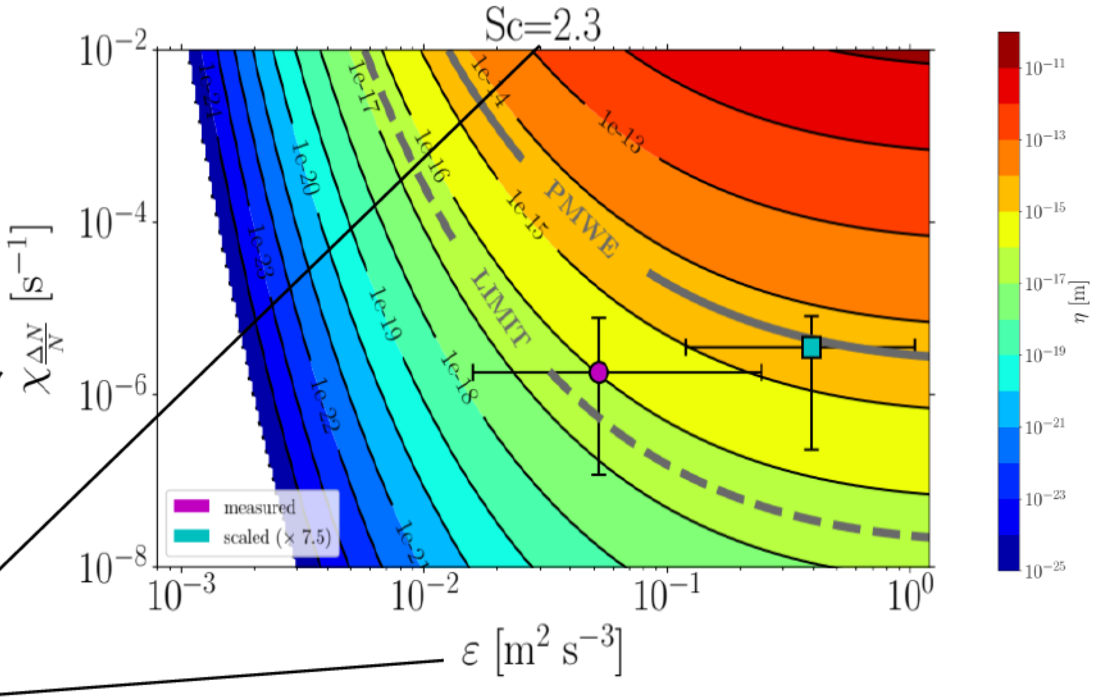
- Based on measurements reconstruct turbulence field for time when downleg-PMWE was detected (scaling of ε, χ)
- Inserting into model for variance dissipation rate, gives similar values to what MAARSY observed

** Schmidt-number (Sc) is related to charged particles (MSPs)



* $PSD_{model} \approx \chi \cdot f(k, \epsilon, Sc)$

Summary & Conclusions

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- We showed 1st results of the 1st PMWE campaign (1st payload only)
- Payload went through decaying PMWE and induced an „artificial“ echo
- In situ measured PSD of electron densities converted to volume reflectivity AND model calculations for measured turbulence and Sc, agree with NO PMWE observations on downleg.
- Based on in situ measurements of background parameters (Nn, Ne, kin. viscosity, Sc) and spectral width we conclude:
- - Pure turbulence could not explain the observed echo at 78 km
- - Charged Dust + turbulence quantitatively explains the observed PMWE