Observations of Polar Mesosphere Summer Echoes with absolute calibrated MST radars in the Northern and Southern hemisphere: Interhemispheric similarities and dissimilarities

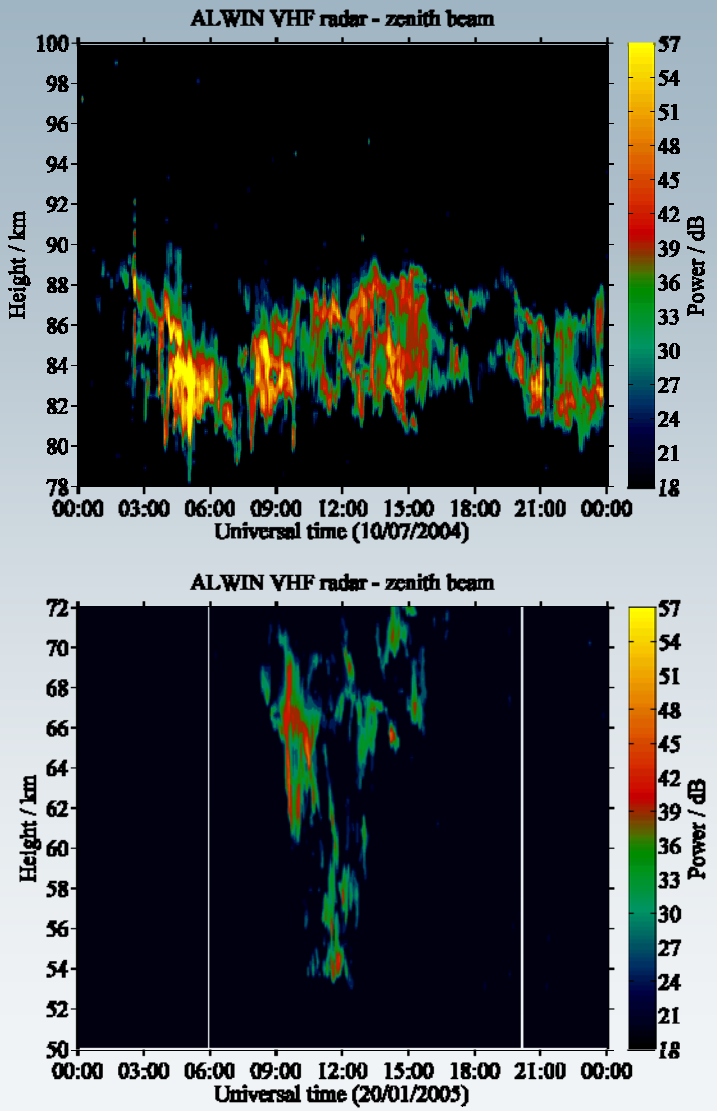
R. Latteck [1], W. Singer [1], R. Morris [2], D. Murphy [2], D. A. Holdsworth [2], W. K. Hocking [3]

(1) Leibniz-Institut für Atmosphärenphysik, Kühlungsborn
(2) Australian Antarctic Division, Kingston,Tasmania, Australia
(3) University of Western Ontario, London, Ontario, Canada

Outline

1. Motivation
2. Radar absolute calibration
   - 2 methods for receiver calibration
   - Minimum and maximum PMSE volume reflectivities from VHF radar observations at different sites
3. Comparison of PMSE observations from three VHF radar sites
   - Andenes/Norway (69°N) - Davis/Antarctica (69°S)
   - Andenes/Norway (69°N, 16°E) - Resolute Bay/Canada (75°N, 95°W)

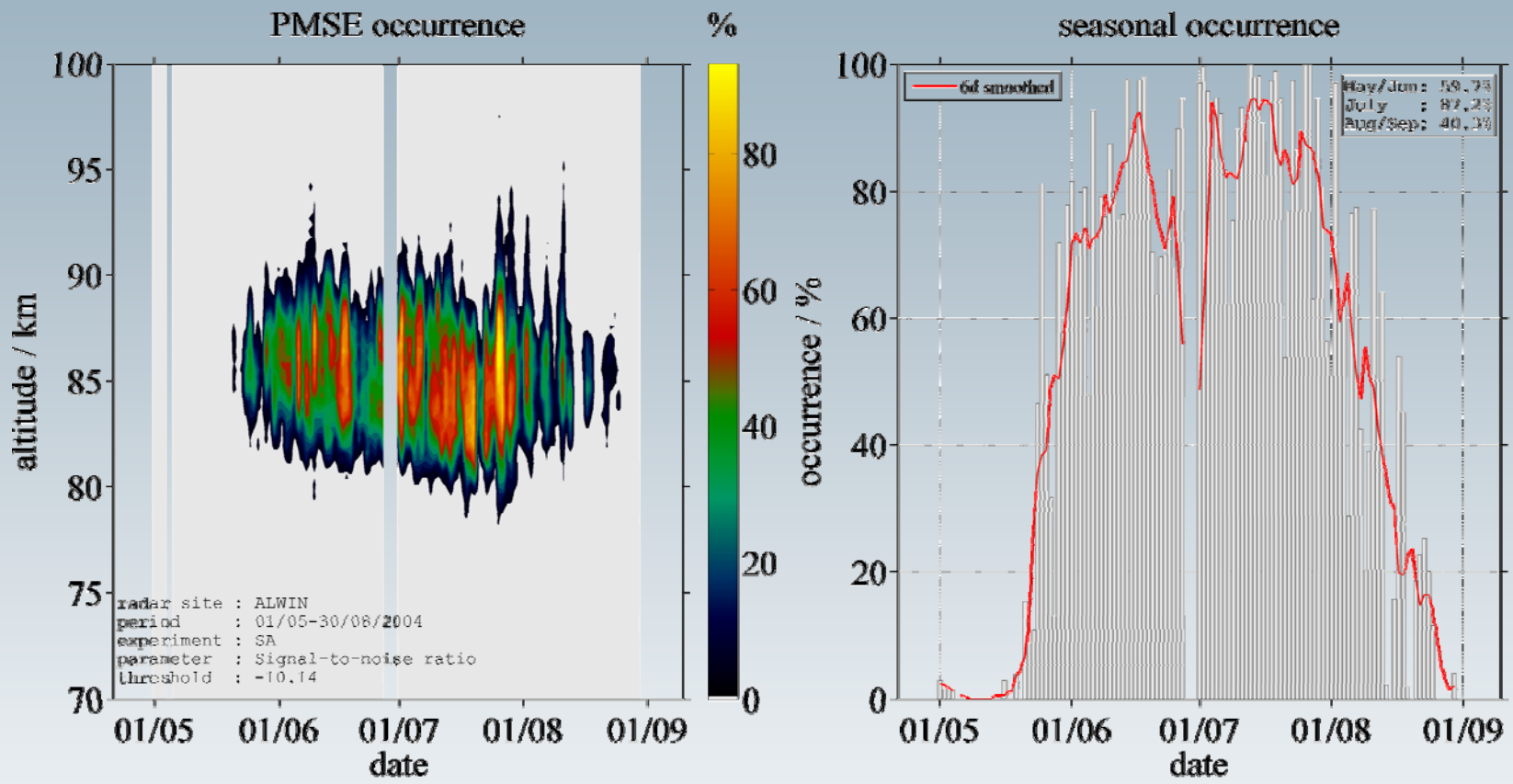
Motivation



- Mesospheric echoes are observed with VHF radars at 50 MHz since more than 20 years:
  - **PMSE** (polar NH in summer)
    Cho and Röttger, JGR, 1997
    Rapp and Lübken, ACP, 2004
  - **MSE** (mid-latitudes in summer)
    Czechowsky et al. GRL, 1979
    Zecha et al., JGR, 2003
  - **PMWE** (polar NH in winter)
    Kirkwood et al. AIPUAR, 2002
  - **PMSE** (polar SH in summer)
    Woodman et al., JGR, 1999
    Morris et al., GRL, 2004
- Comparison of observations from different stations are seldom:
  - *Balsley et al. JGR, 1995* (NH-SH)
  - *Huaman et al., RS, 2001* (PF-RB)
- Characteristics of PMSE are determined by e.g.
  - Electron density, temperature
  - Water vapour concentration
  - Earth's magnetic field

PMSE 2004 @ Andenes

diurnal variation of PMSE occurrence for SNR>SNR$_{min}$



Comparison of PMSE observations from different sites is affected by

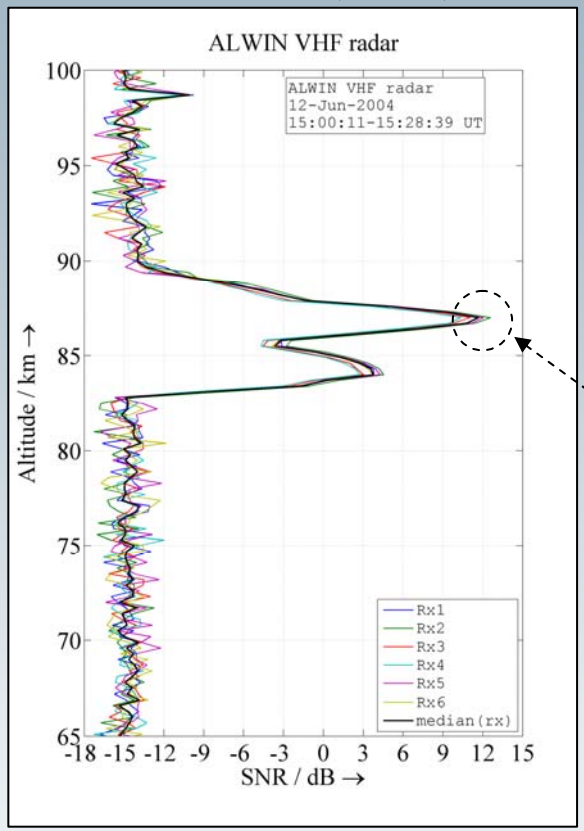
- **system parameters**: power, antenna gain, receiver bandwidth, …
- **experiment configurations**: coherent integrations, code lengths, pulse width, …

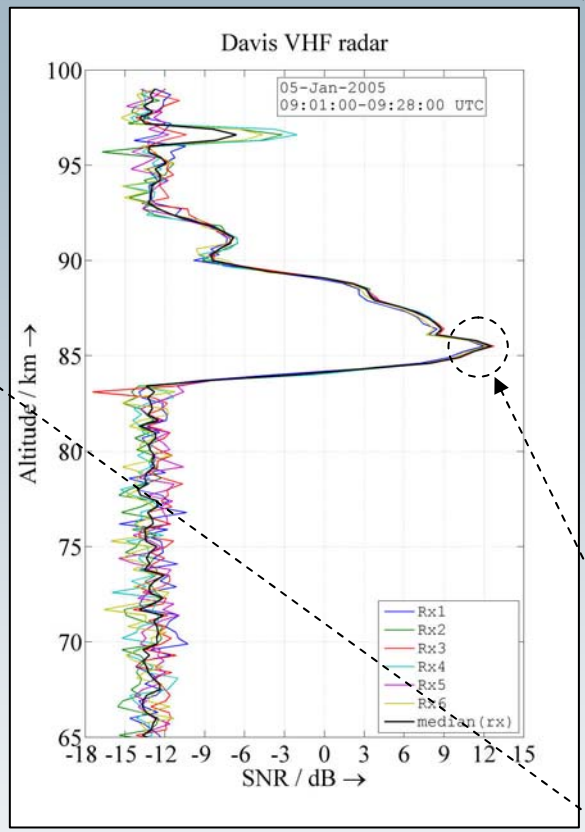
PMSE 2004 @ Andenes and Davis

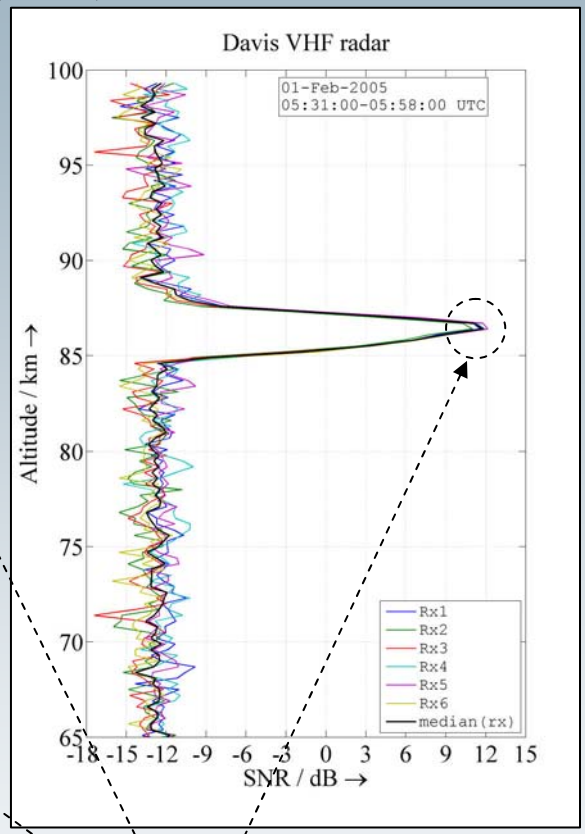
SNR profiles with similar peak value ~12dB

Andenes (69°N)

Davis (69°S)





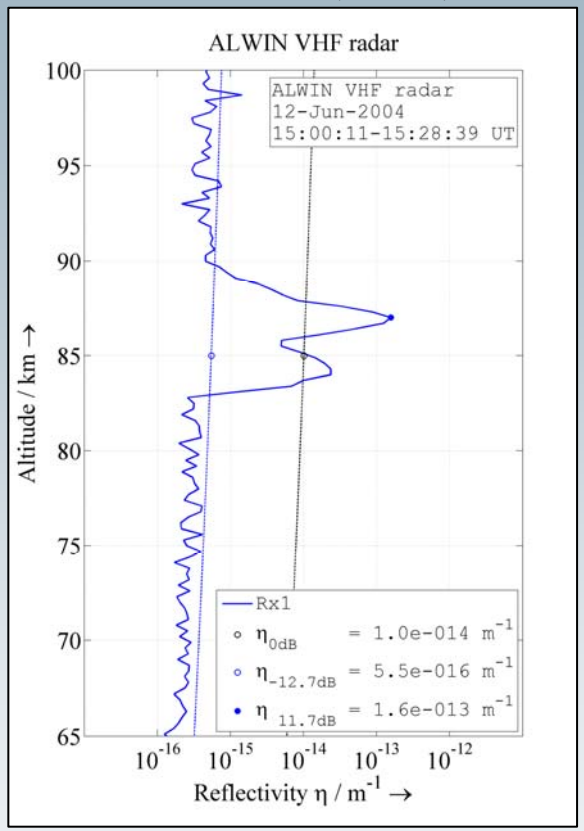


How comparable or how similar are the echoes ?

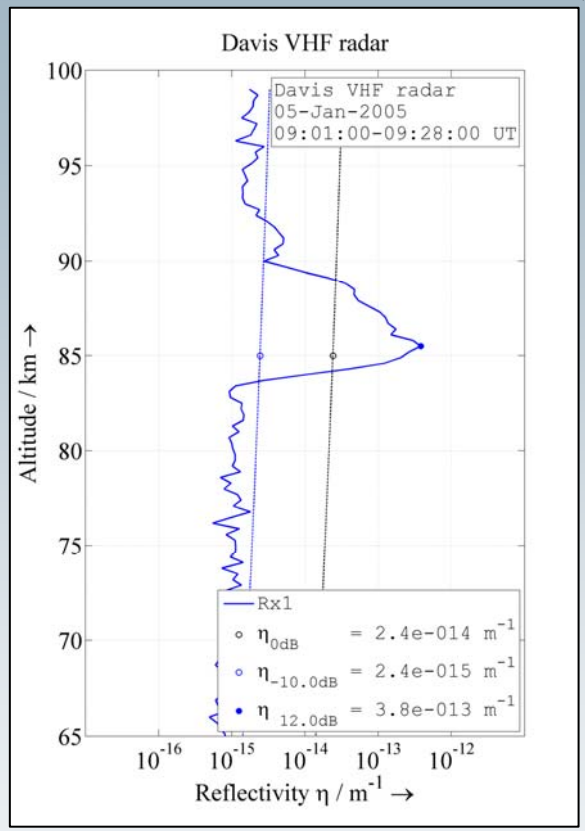
PMSE 2004 @ Andenes und Davis

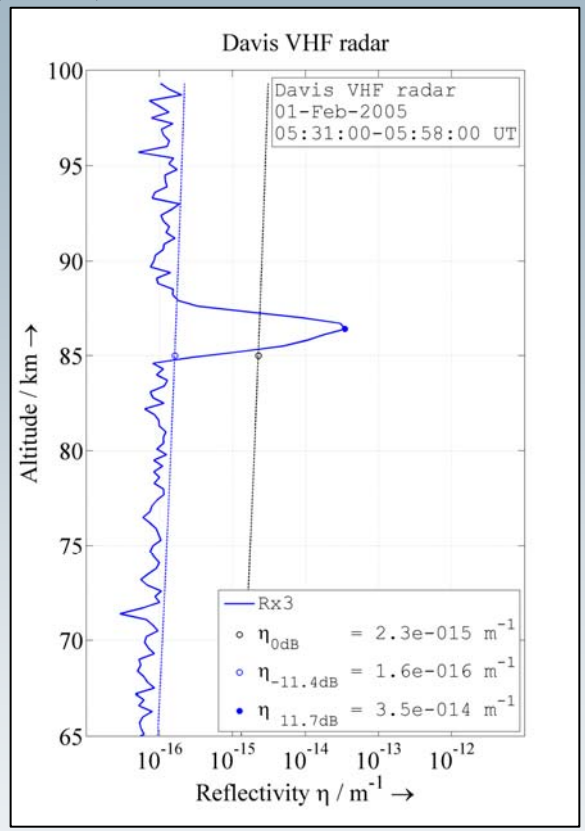
volume reflectivity

Andenes (69°N)



Davis (69°S)





Comparable signal-to-noise ratio **BUT**

- different volume reflectivity
- **different detection limits**

Volume reflectivity η

$$\eta_{radar}[m^{-1}] = \frac{P_r \cdot 128 \cdot \pi^2 \cdot 2 \cdot \ln(2) \cdot r^2}{P_t \cdot G_t \cdot G_r \cdot \lambda^2 \cdot e \cdot \Theta_{1/2}^2 \cdot c \cdot \tau}$$

$$\eta_{radar}[m^{-1}] = \sum_i \frac{\sigma_i}{1[m^{-3}]} = \frac{\sigma}{V}$$

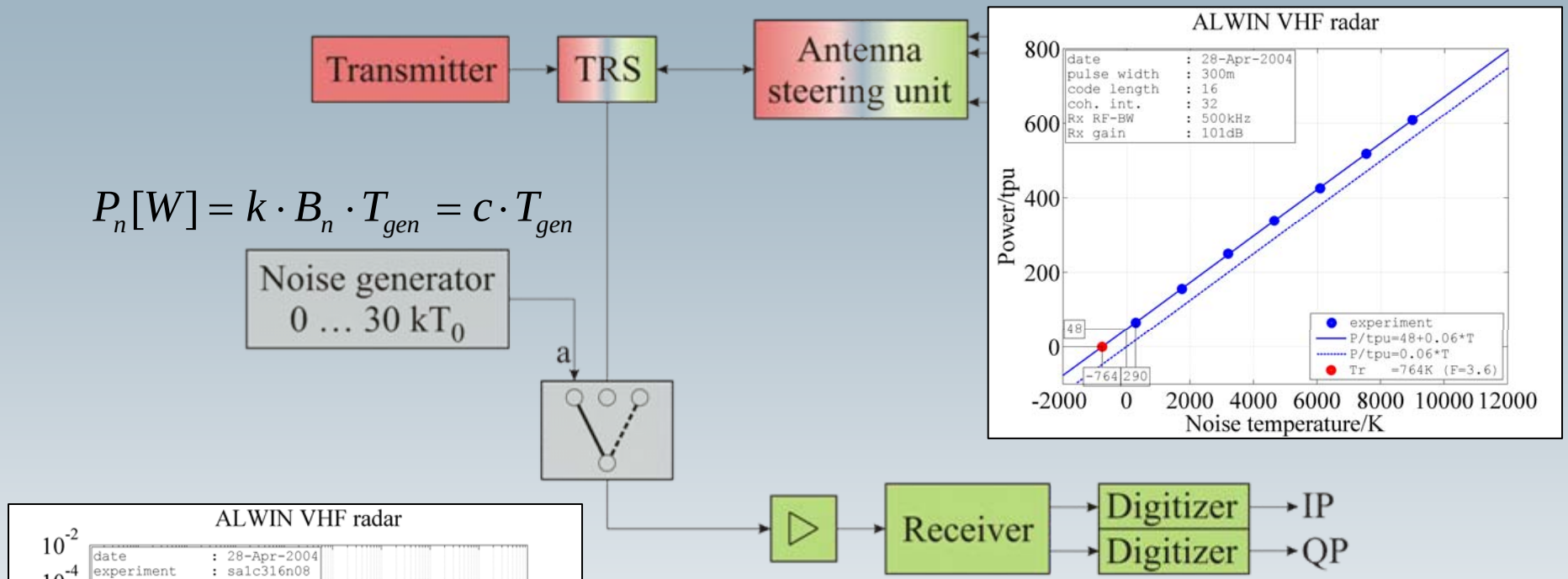
P_t	=	transmitted peak power [W]
P_r	=	received signal power [W]
G_t	=	gain of transmit antenna
G_r	=	gain of receive antenna
λ	=	radar wave length
e	=	efficiency
$\Theta_{1/2}$	=	half power half width of transmit antenna
r	=	range to volume center
$2\ ln(2)$	=	beam correction factor
c	=	speed of light
τ	=	pulse width

$$\Delta z = \frac{c \cdot \tau}{2}$$

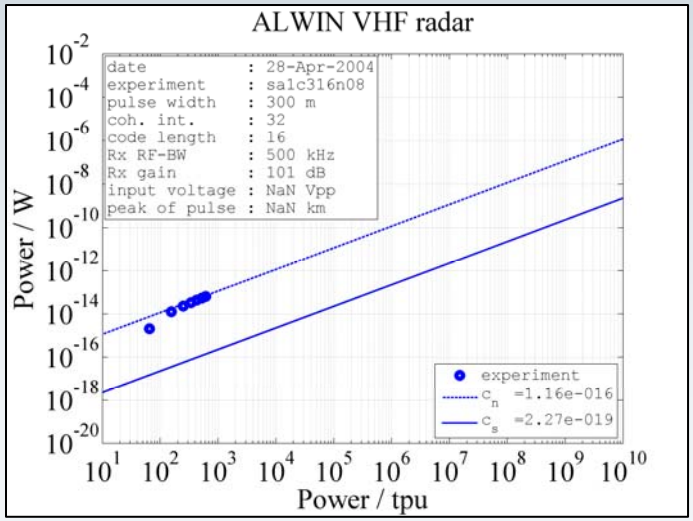
$$\eta_{radar} = P_r \cdot c_{sys} \cdot r^2$$

- volume reflectivity η
  (*Hocking and Röttger, RS, 1997*)
  - Sum of all backscatter cross sections σ_i per unit volume
  - includes all system parameters !
- determination of other physical parameters from absolute received power
  - Energy dissipations rates
- absolute calibration is required

Receiver calibration with calibrated noise source



$$P_n[W] = k \cdot B_n \cdot T_{gen} = c \cdot T_{gen}$$



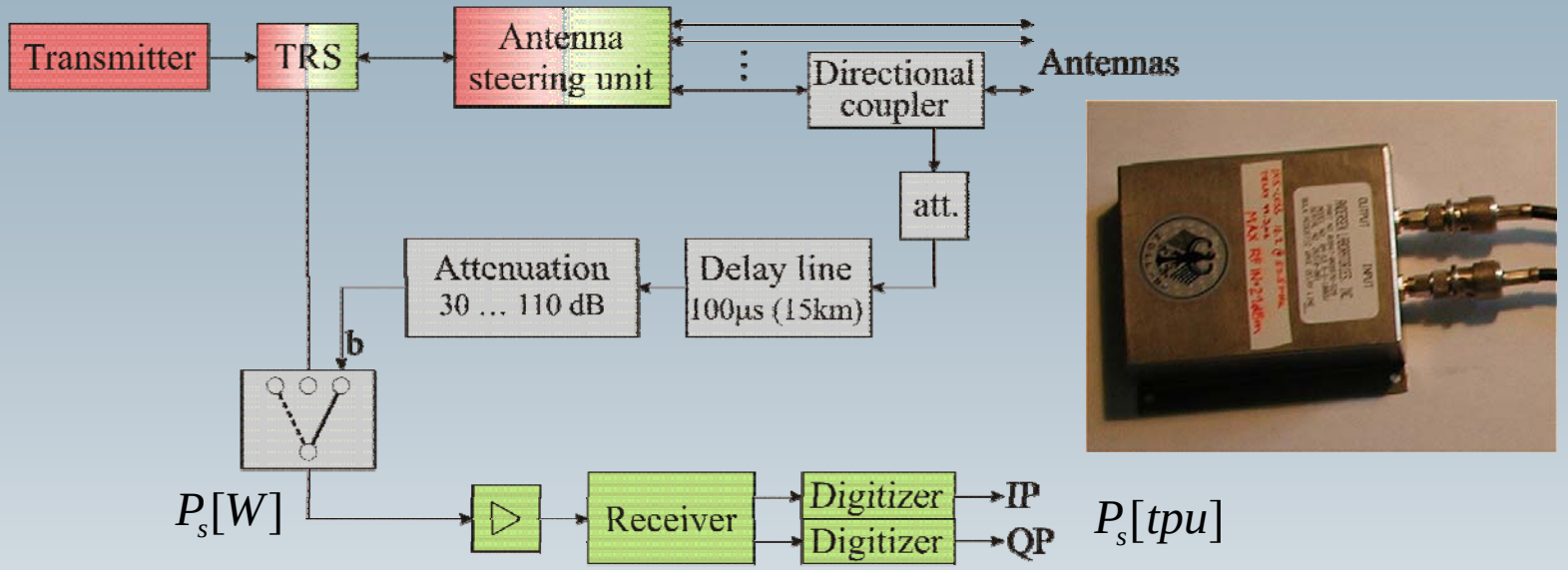
$$P_n[tpu] = a + b \cdot T_{gen}$$

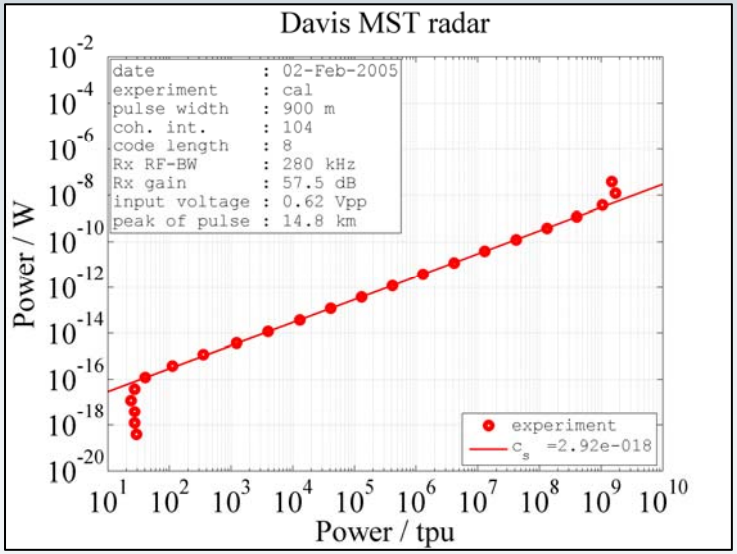
$$a = b \cdot T_{rec}$$

Calibration factor for noise signals

$$c_n = \frac{P_n[W]}{\left(P_n[tpu] - a\right)} = \frac{c}{b}$$

Receiver calibration with delay line





Calibration factor for coherent signals

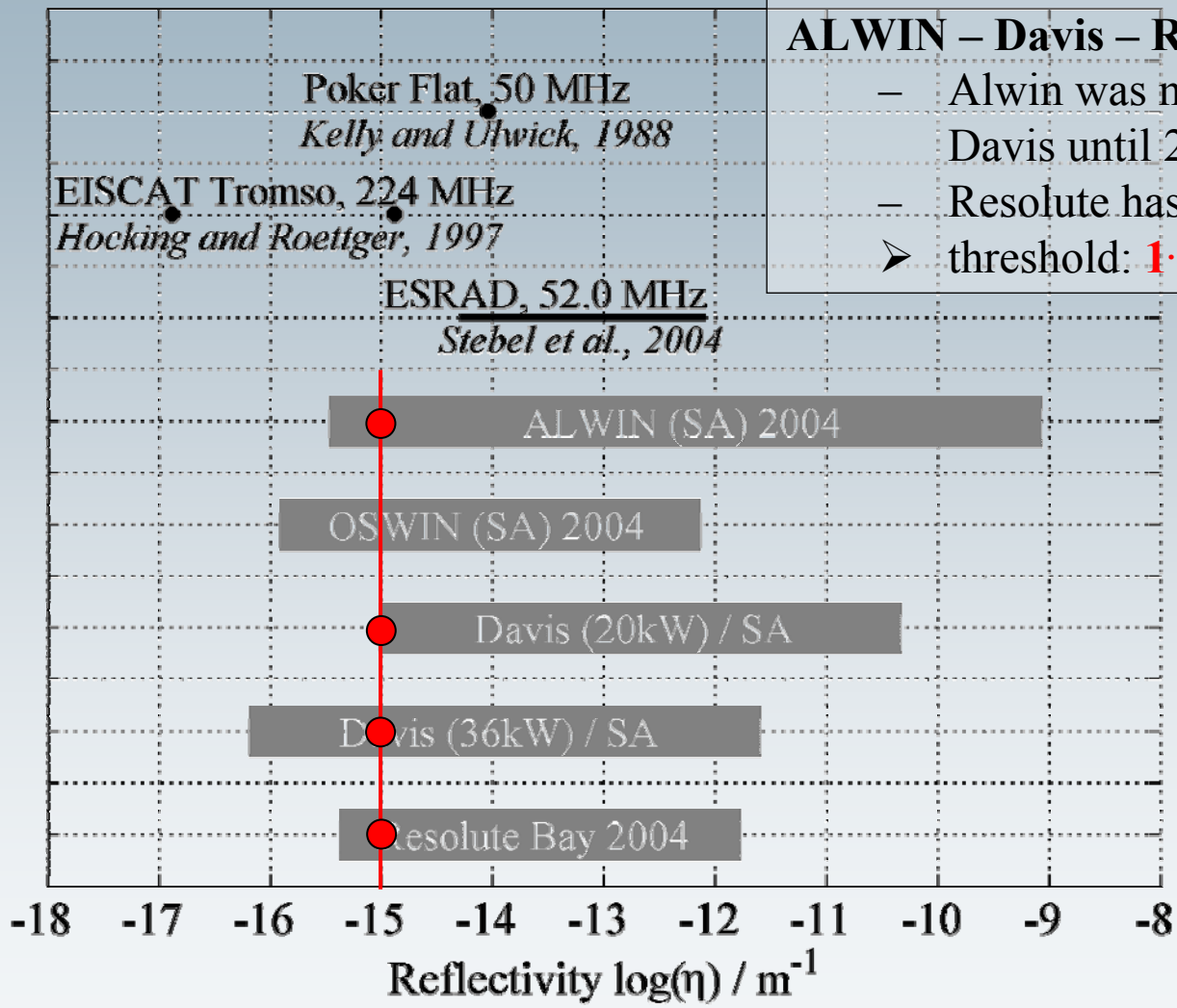
$$c_s = \frac{P_s[W]}{P_s[tpu]}$$

$$c_s = \frac{c_n}{M \cdot N}$$

M = number of coherent integrations
N = number of code elements

Volume reflecttivity

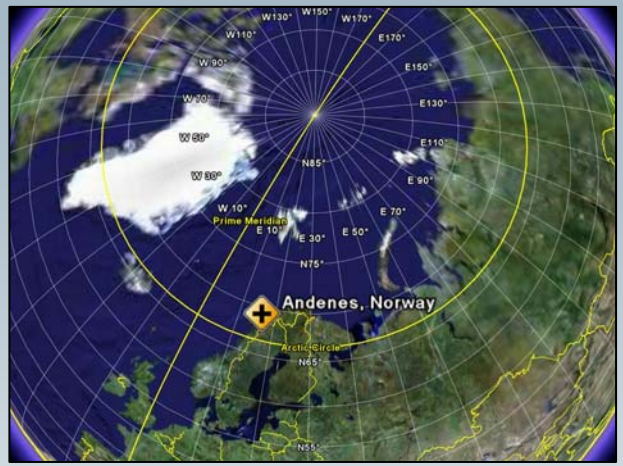
detektion limits of various VHF radars at different sites

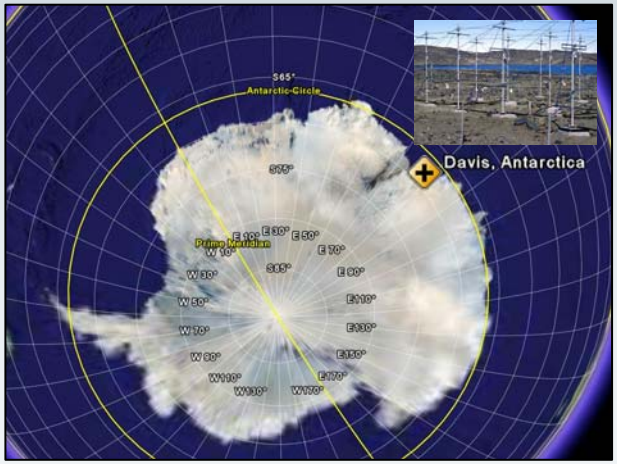


ALWIN – Davis – Resolute comparison

- Alwin was more sensitive than Davis until 24.1.2004
- Resolute has a similar sensitivity
  - ➢ threshold: $1 \cdot 10^{-15}$ m^{-1}

Comparison of PMSE observations from 69°N and 69°S
(Andenes 2004 – Davis 2004/2005)

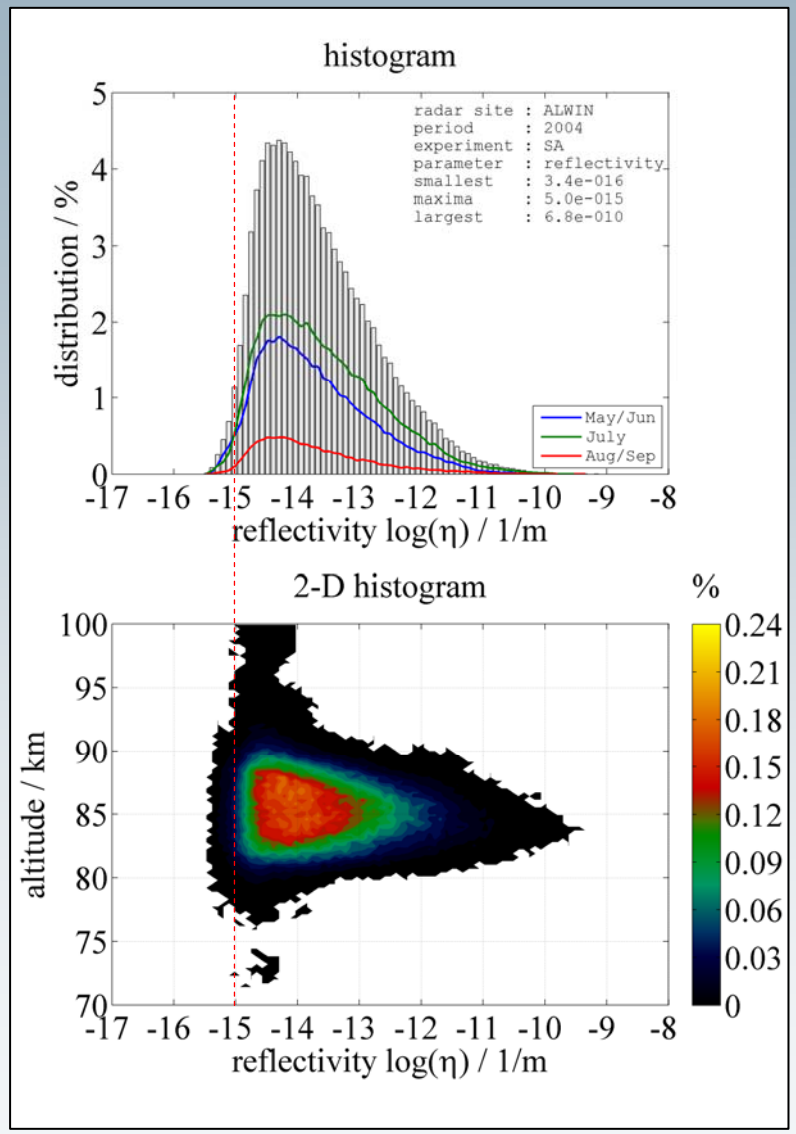


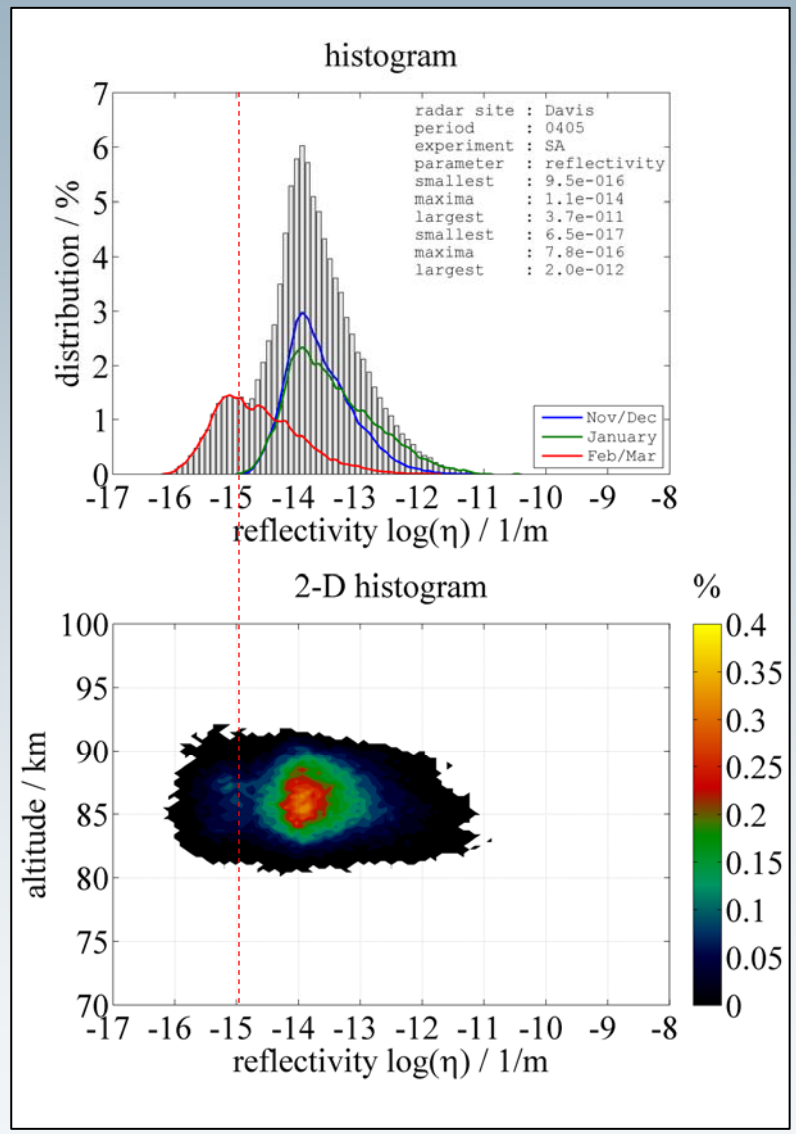


Parameters \ Radar	ALWIN 69°N; 16°E	Davis-VHF-Radar 69°S; 78°E	
Radar wavelength	5.6 m	5.5 m	
Peak power	36 kW	20 kW	36 kW
Gain of Tx antenna array	28.3 dBi	28.9 dBi	
Half-power beam width	6°	6°	
Gain of SA receiving antenna array	20.6 dBi	21.0 dBi	
Efficiency	0.6	0.5	
Effective pulse width	300 m	600 m	450 m
→ **system factor c_{sys}**	**2.1e-08**	**1.9e-08**	**1.4e-08**
Experiment parameters			
Number of coherent integrations	32	116	104
Number of code elementes	16	1	8
Receiver gain	101 dB	81 dB	81 dB
Receiver bandwidth	500 kHz	368 kHz	280 kHz
→ **signal factor c_s**	**2.3e-19**	**1.5e-21**	**1.5e-20**

Andenes (69N), 2004 – Davis (69°S), 2004/2005

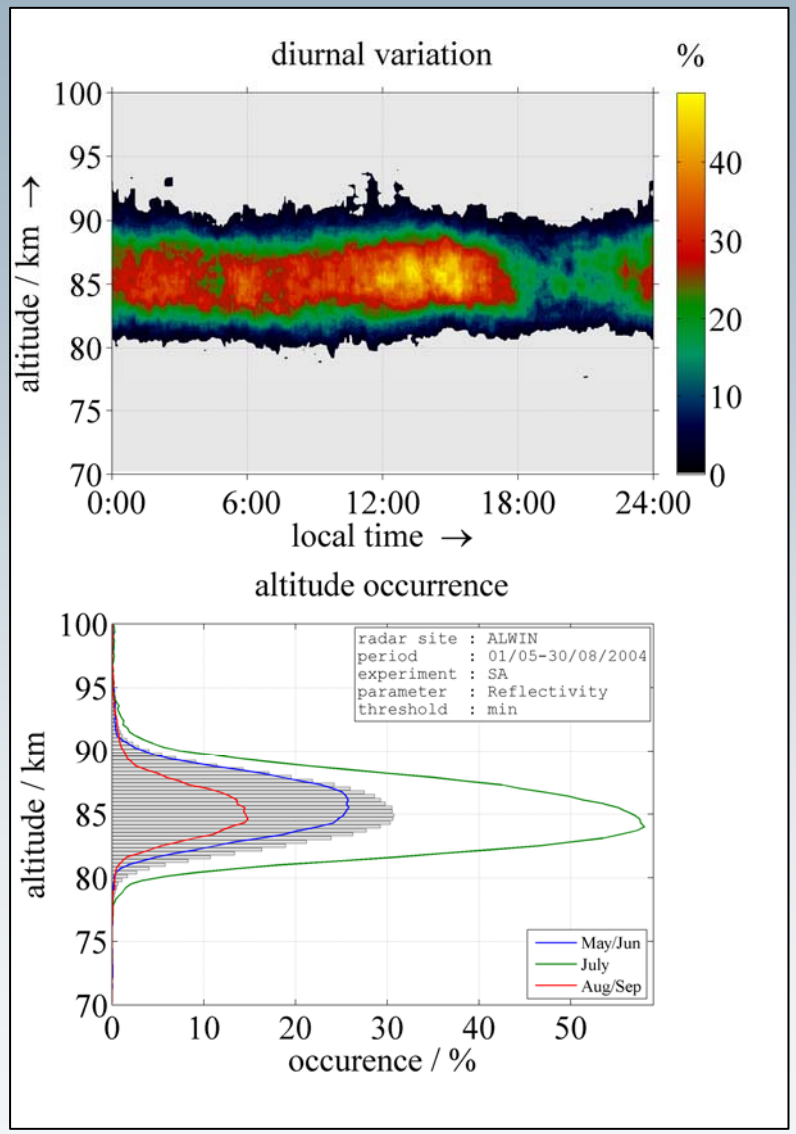
distribution of PMSE volume reflectivity

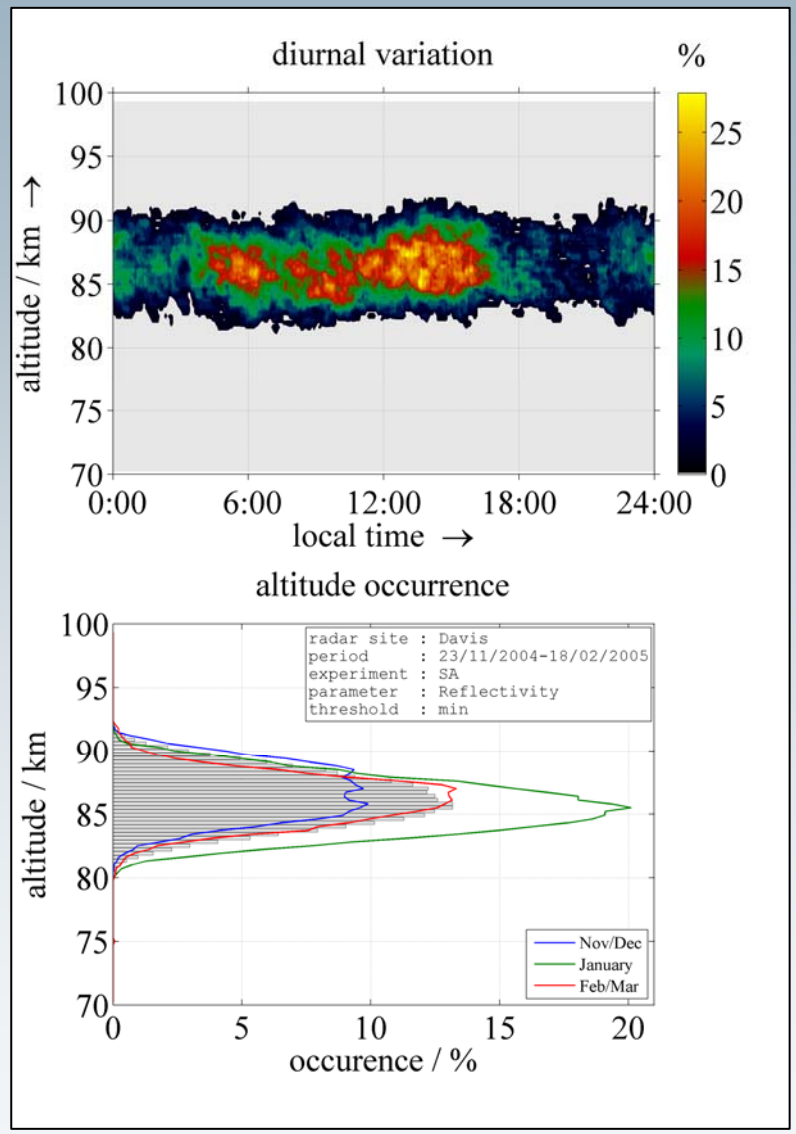




Andenes (69N), 2004 – Davis (69°S), 2004/2005

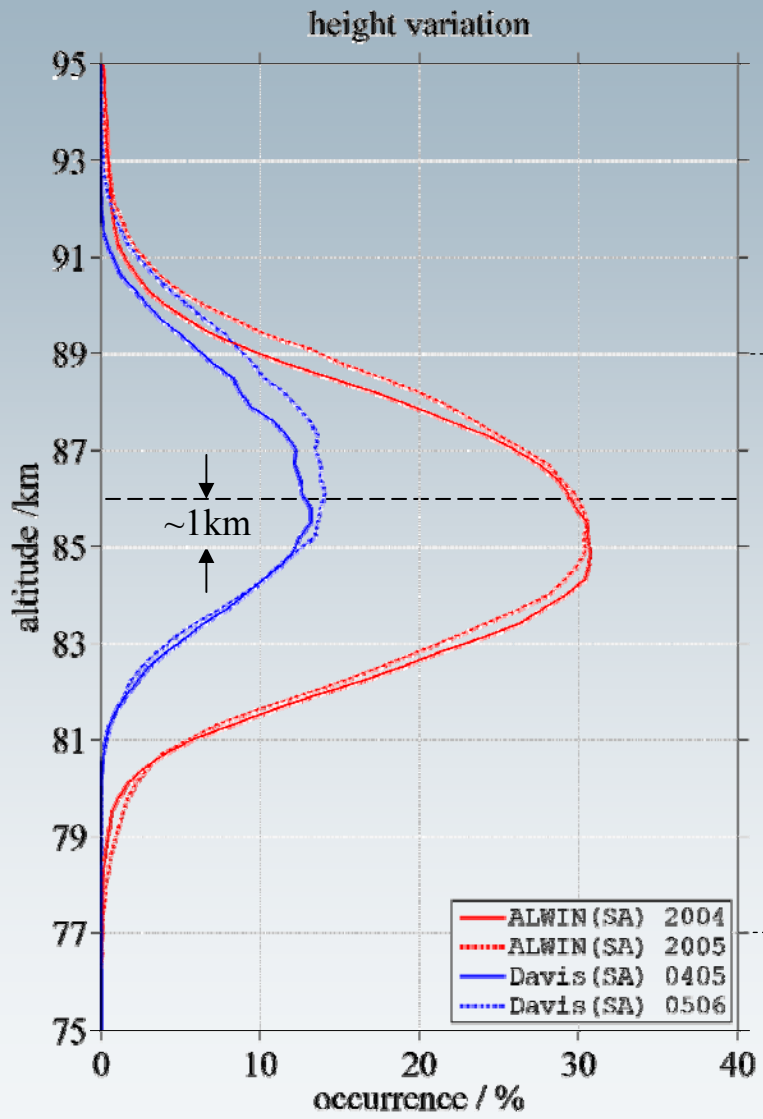
diurnal variation and height distribution of PMSE for $\eta > \eta_{min}$



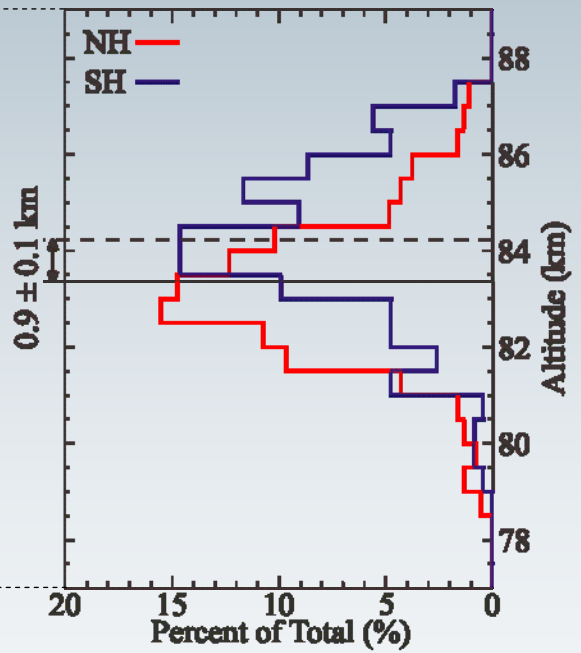


Andenes (69N) − Davis (69°S)

comparison of PMSE height distribution



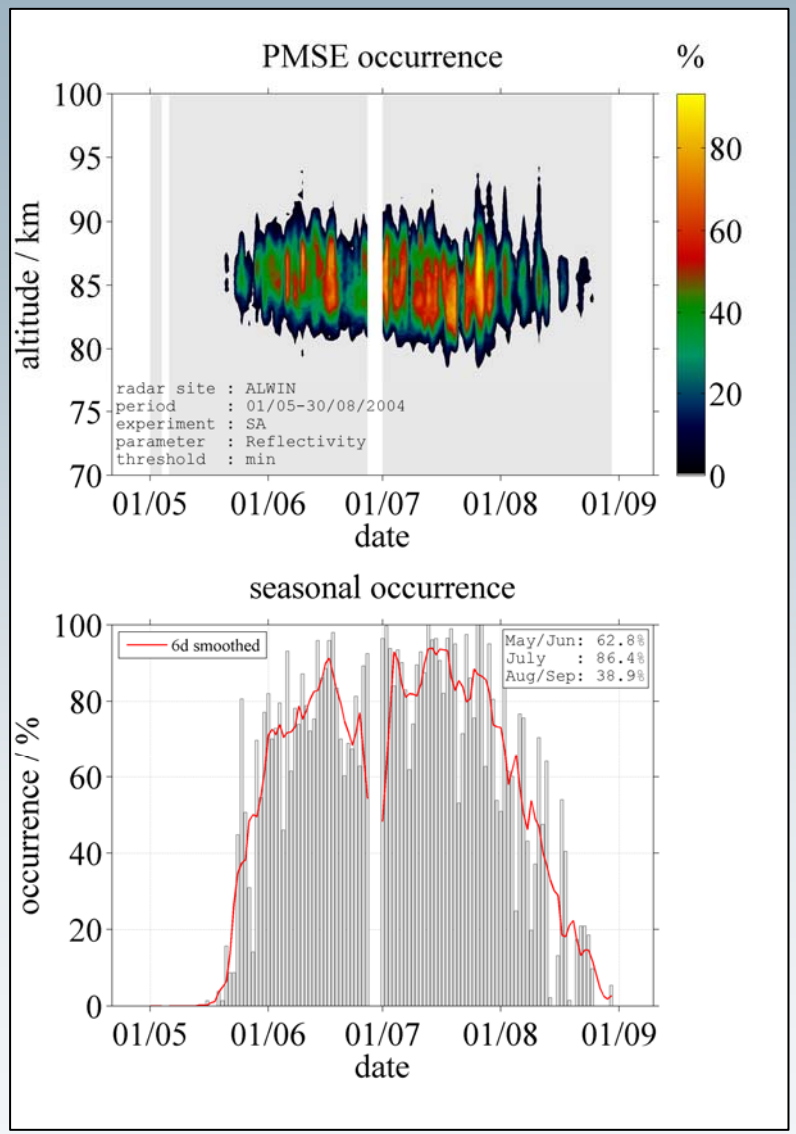
The PMC altitude distribution as a percentage of the total number of PMCs observed by HALOE from 1991 to 2005 and latitudes between 55° and 70°

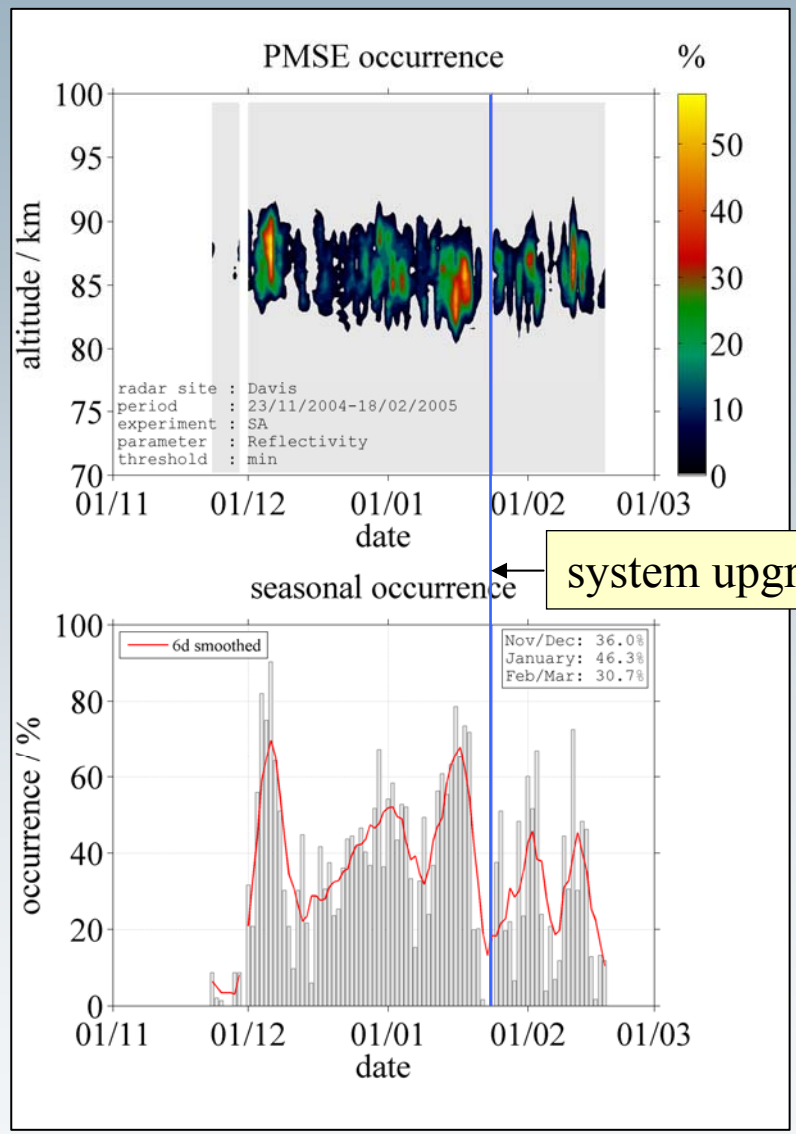


Wrotny et al., *JASTP*, 2006

Andenes (69N), 2004 – Davis (69°S), 2004/2005

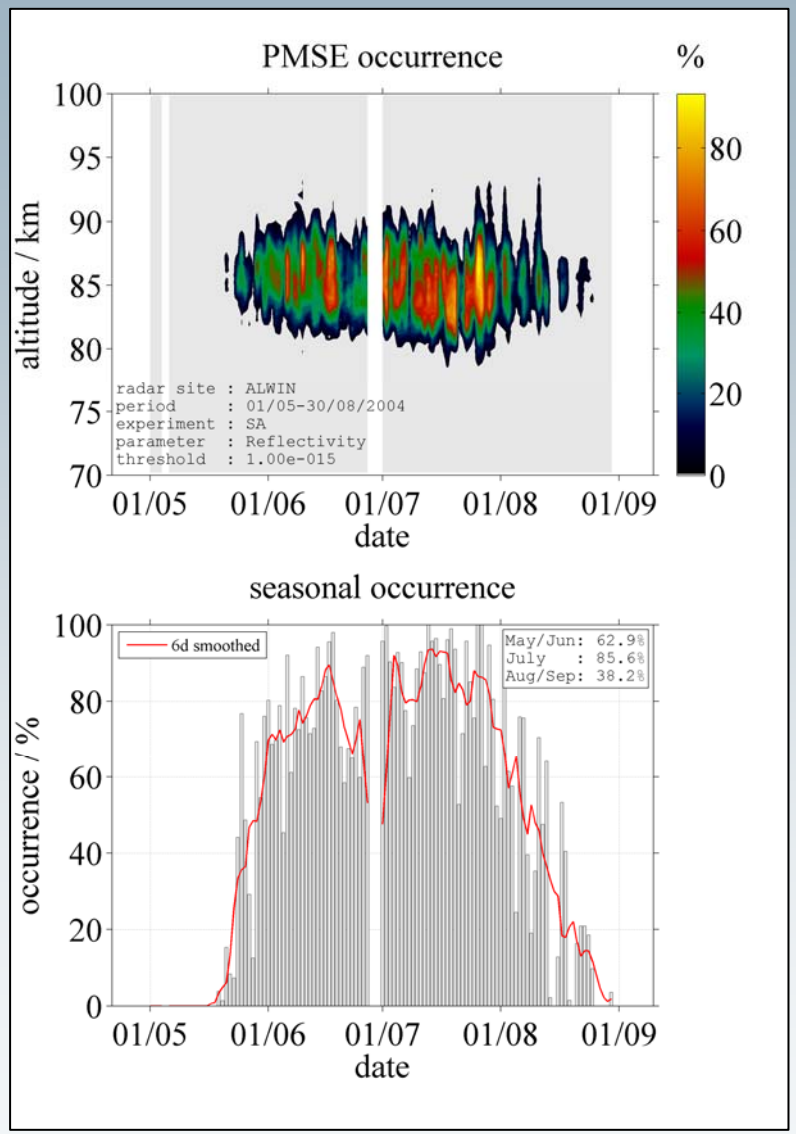
seasonal variation of PMSE occurrence for $\eta > \eta_{min}$

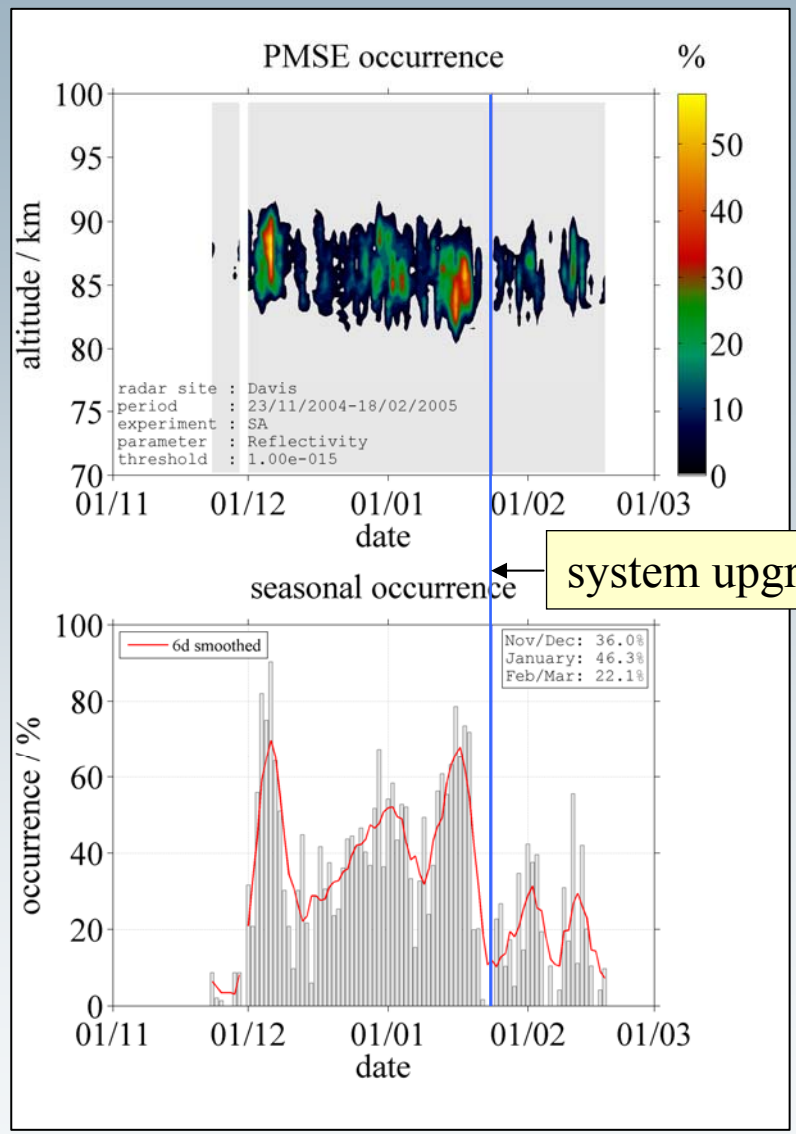




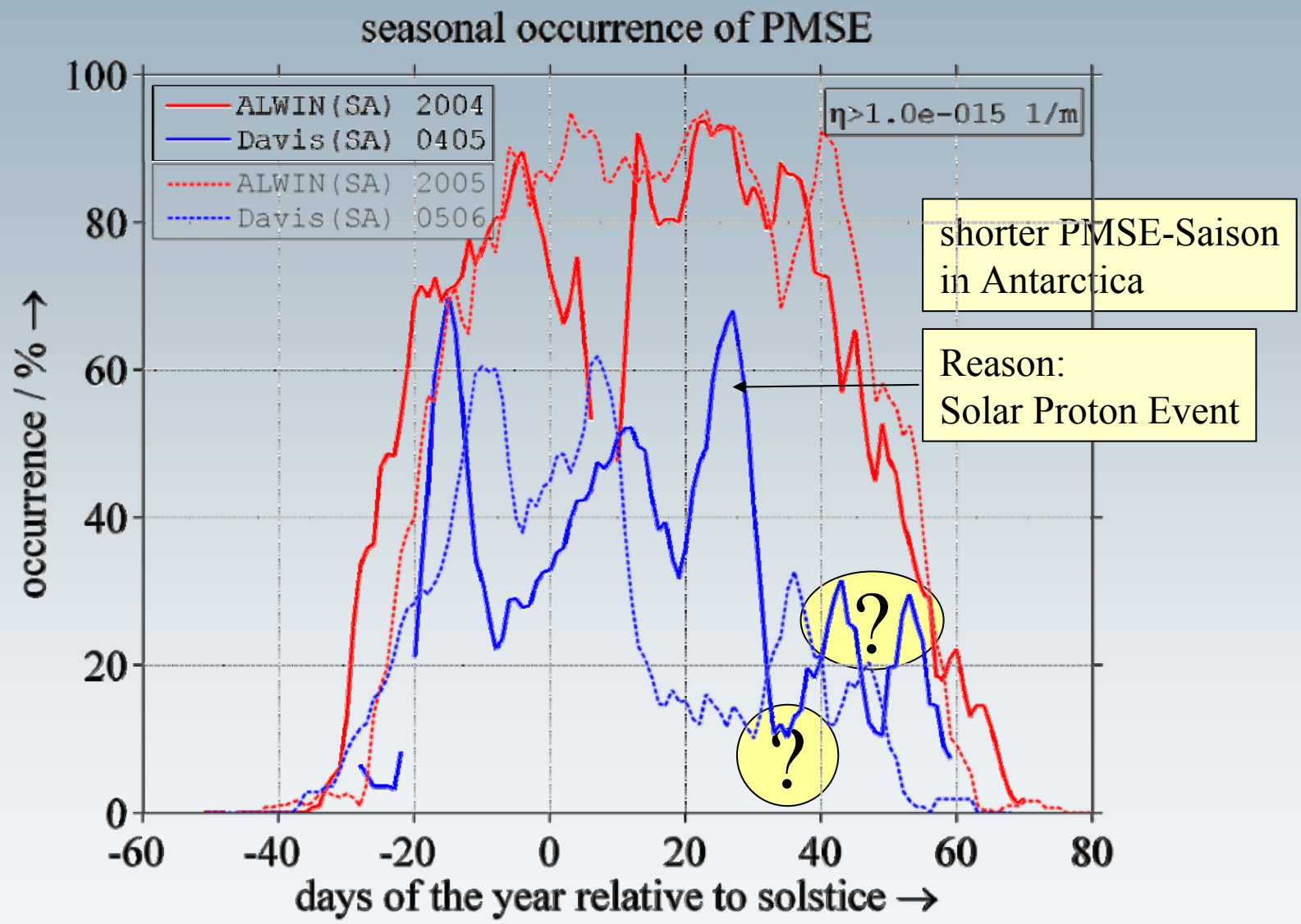
Andenes (69N), 2004 – Davis (69°S), 2004/2005

seasonal variation of PMSE occurrence for $\eta > 1 \cdot 10^{-15}$ m^{-1}





Andenes (69N) − Davis (69°S)

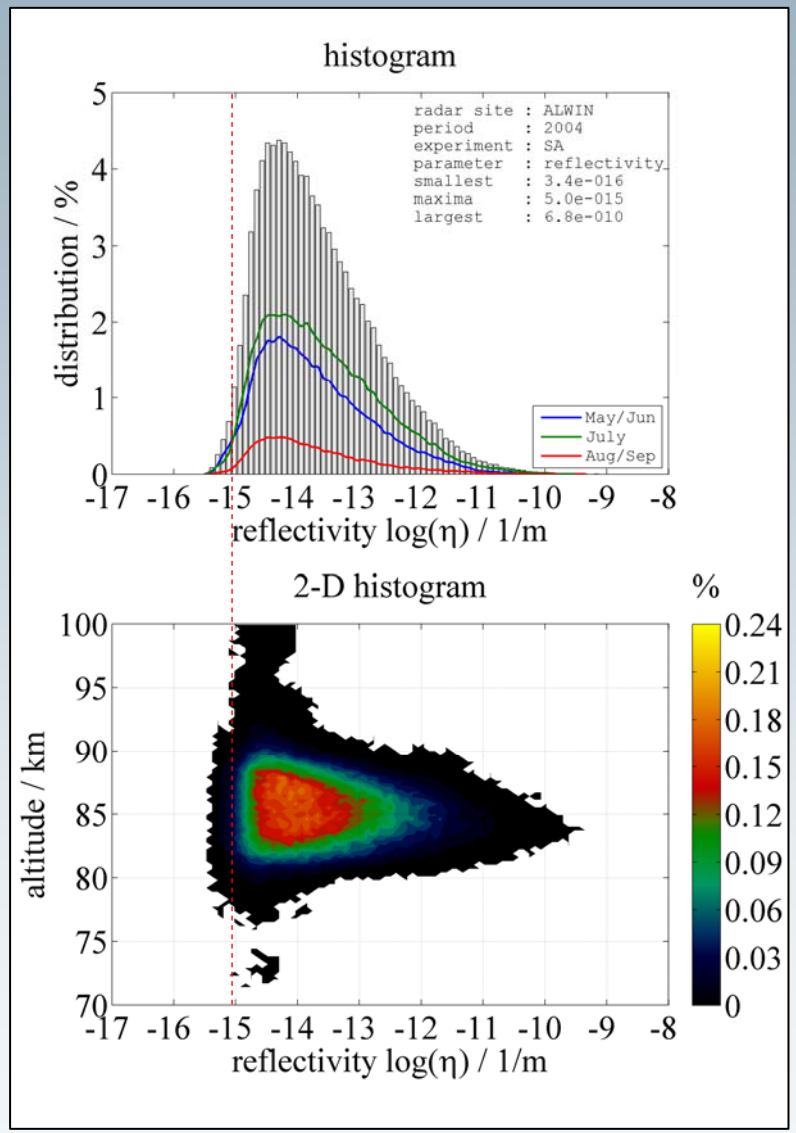


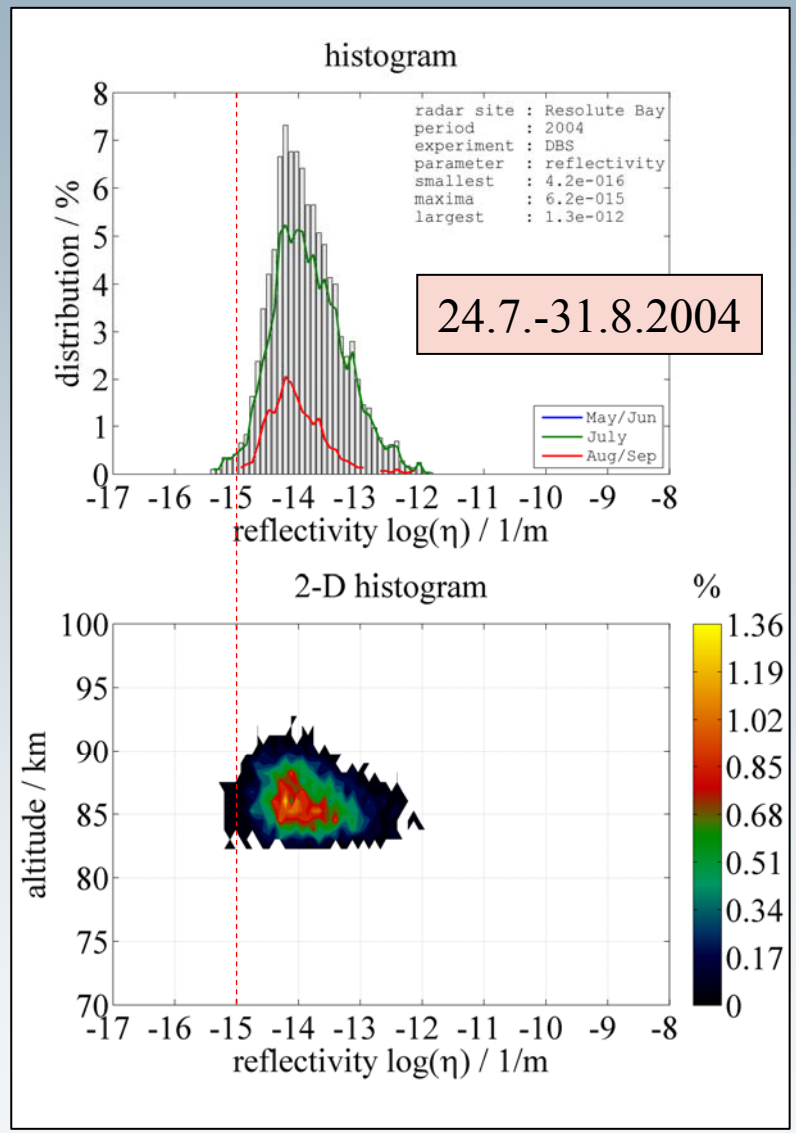
Comparison of PMSE observations from Andenes (69°N, 16°E) and Resolute Bay (75°N, 95°W)

Parameters \ Radar	ALWIN 69°N; 16°E	RB-VHF 75°N; 95°W
Radar wavelength	5.6 m	5.8 m
Peak power	36 kW	12 kW
Gain of Tx antenna array	28.3 dBi	24.0 dBi
Half-power beam width	6°	4°
Gain of DBS receiving antenna array	28.3 dBi	24.0 dBi
Efficiency	0.58	0.09
Effective pulse width	300 m	750 m
→ **system factor c_{sys}**	**3.6e-09**	**4.3e-07**
Experiment parameters		
Number of coherent integrations	32	16
Number of code elementes	16	1
Receiver gain	101 dB	116 dB
Receiver bandwidth	500 kHz	140 kHz
→ **signal factor c_s**	**5.9e-20**	**1.8e-21**

Andenes (69N, 16°E) – Resolute Bay (75°N, 95°W)

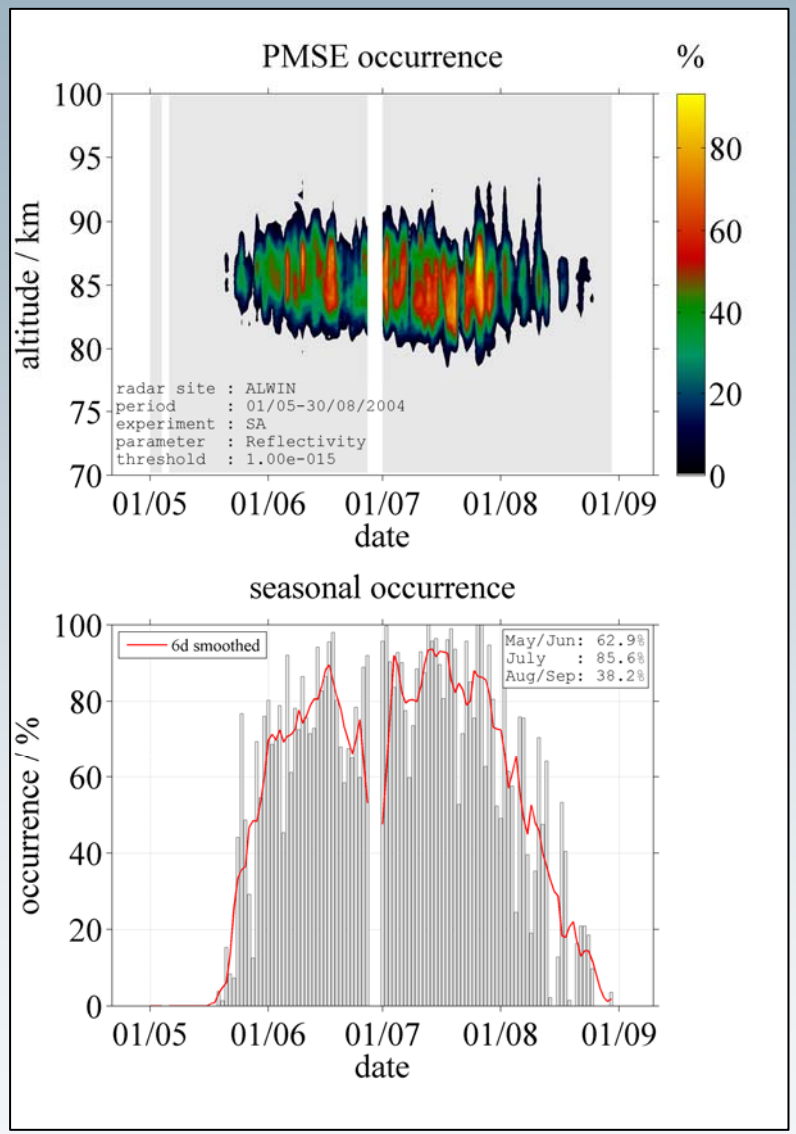
distribution of PMSE volume reflectivity in 2004

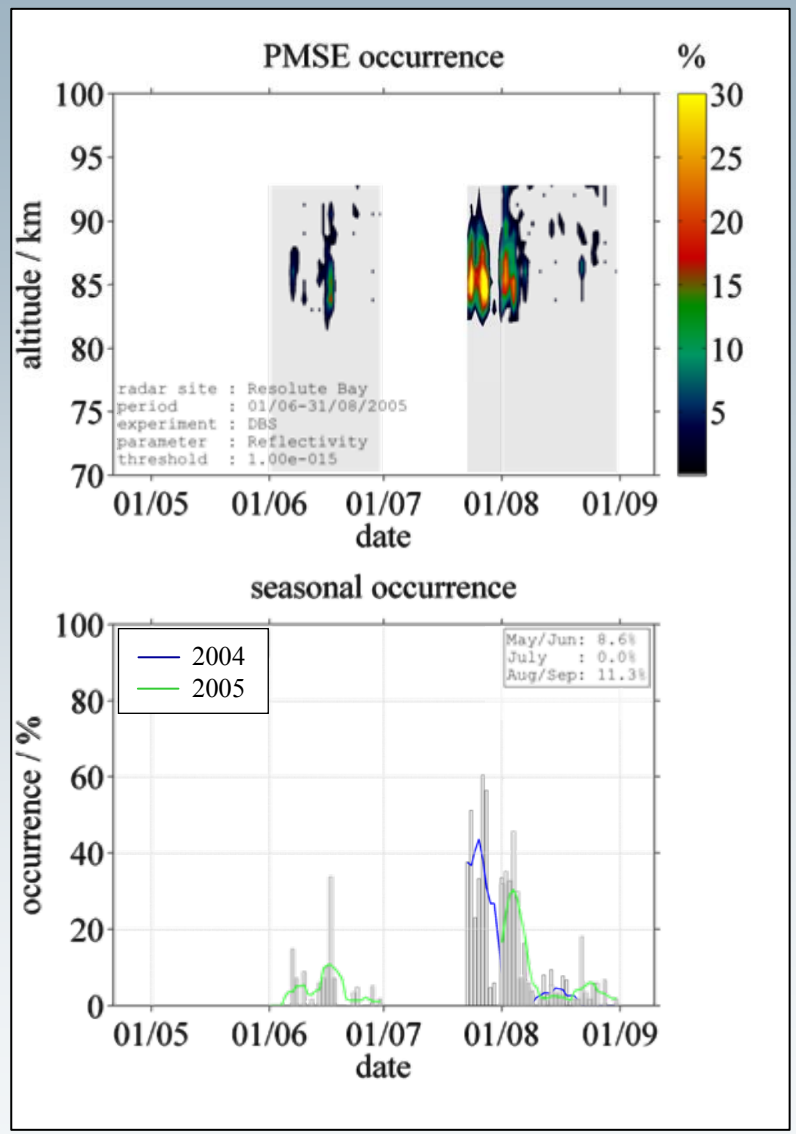




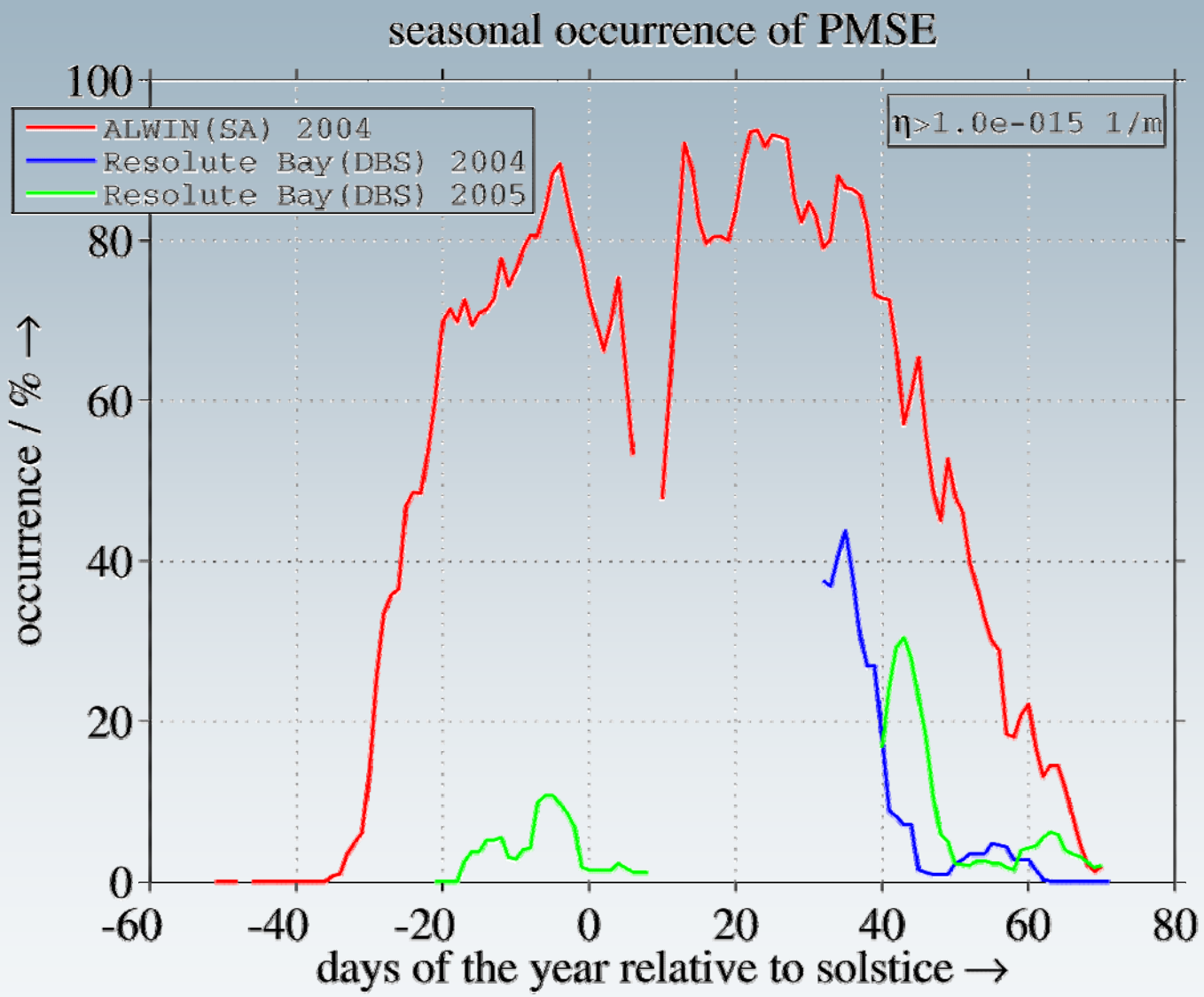
Andenes (69N, 16°E) – Resolute Bay (75°N, 95°W)

seasonal variation of PMSE occurrence for $\eta > 1 \cdot 10^{-15}$ m^{-1}





Andenes (69N, 16°E) − Resolute Bay (75°N, 95°W)



Summary

- The comparison of radar results based on signal-to-noise ratios is difficult
  - different system parameters
  - different experiment configurations
  - ➢ Volume reflectivity
- PMSE observed at Davis (69°S) in 2004/2005 have
  - a weaker volume reflectivity than PMSE observed at Andenes (69°N)
  - a peak in height distribution at ~86 km (85km at NH)
  - a less seasonal occurrence but more seasonal variation than comparable observations at Andenes (69°N) in 2004
- PMSE observed at Resolute Bay (75°N, 95°W) at the beginning and the end of the season have
  - a weaker volume reflectivity than PMSE at Andenes (69°N, 16°E)
  - a smaller seasonal occurrence (starts later, ends earlier)