Observations of Polar Mesosphere Summer Echoes with calibrated VHF radars in the Northern and Southern hemisphere.

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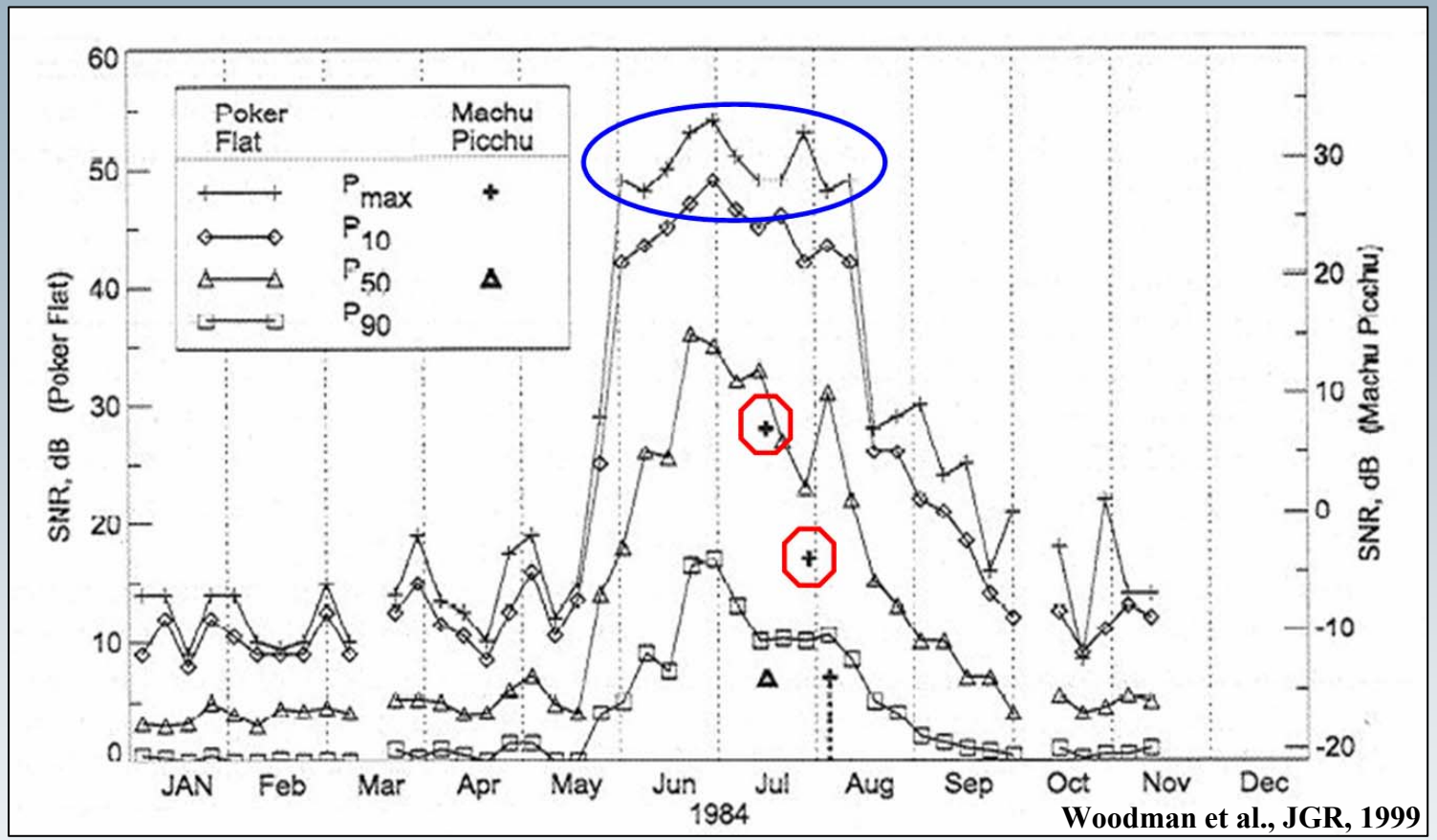
Outline

1. Motivation
2. Volume reflectivity η
   - 2 methods for receiver calibration
   - 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

Polar **M**esosphere **S**ummer **E**choes at 65°N and 62°S



Comparison of PMSE observations from different sites based on SNR is affected by

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

Volume reflectivity η

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

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

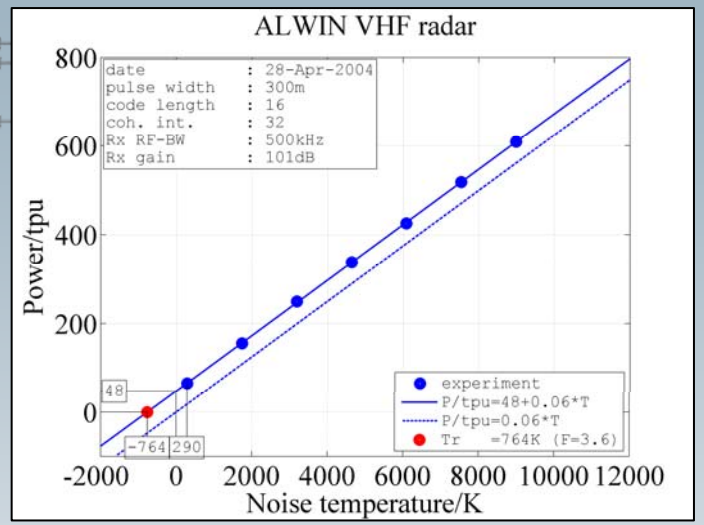
P_t	=	transmitted peak power [W]
P_r	=	received signal power [W]
G_t	=	gain of transmit antenna
G_r	=	gain of receive antenna
λ	=	radar wave length
e	=	efficiency
$\Theta_{1/2}$	=	half power half width of transmit antenna
r	=	range to volume center
$2\ ln(2)$	=	beam correction factor
c	=	speed of light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

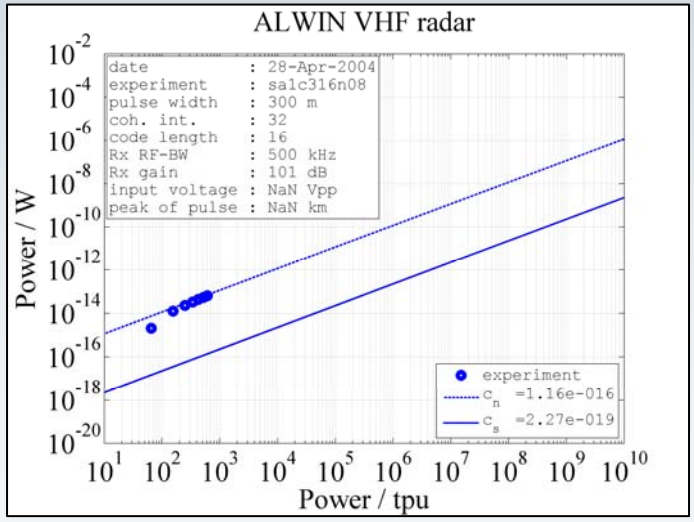
$$\Delta z = \frac{c \cdot \tau}{2}$$

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

- 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





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

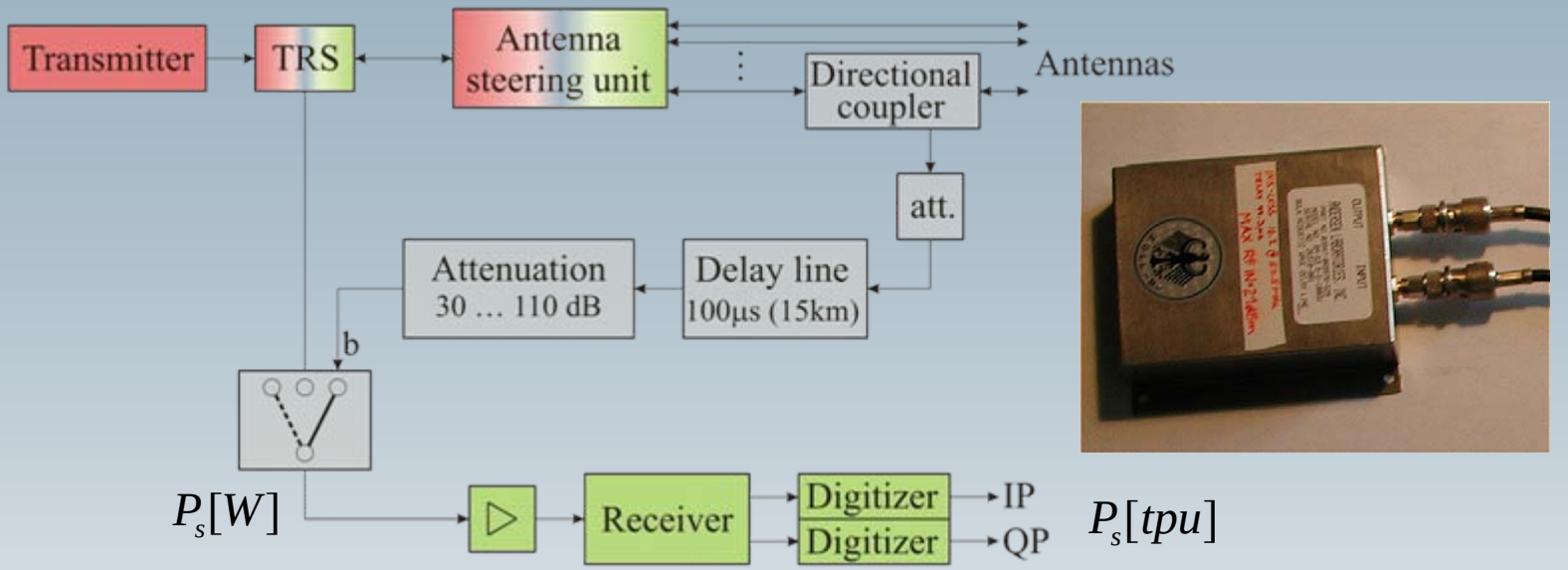
$$P_n[tpu] = a + b \cdot T_{gen}$$

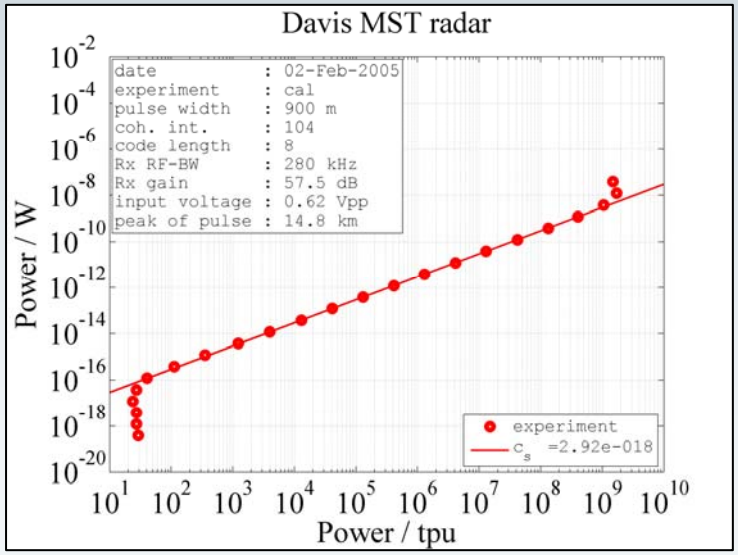
$$a = b \cdot T_{rec}$$

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

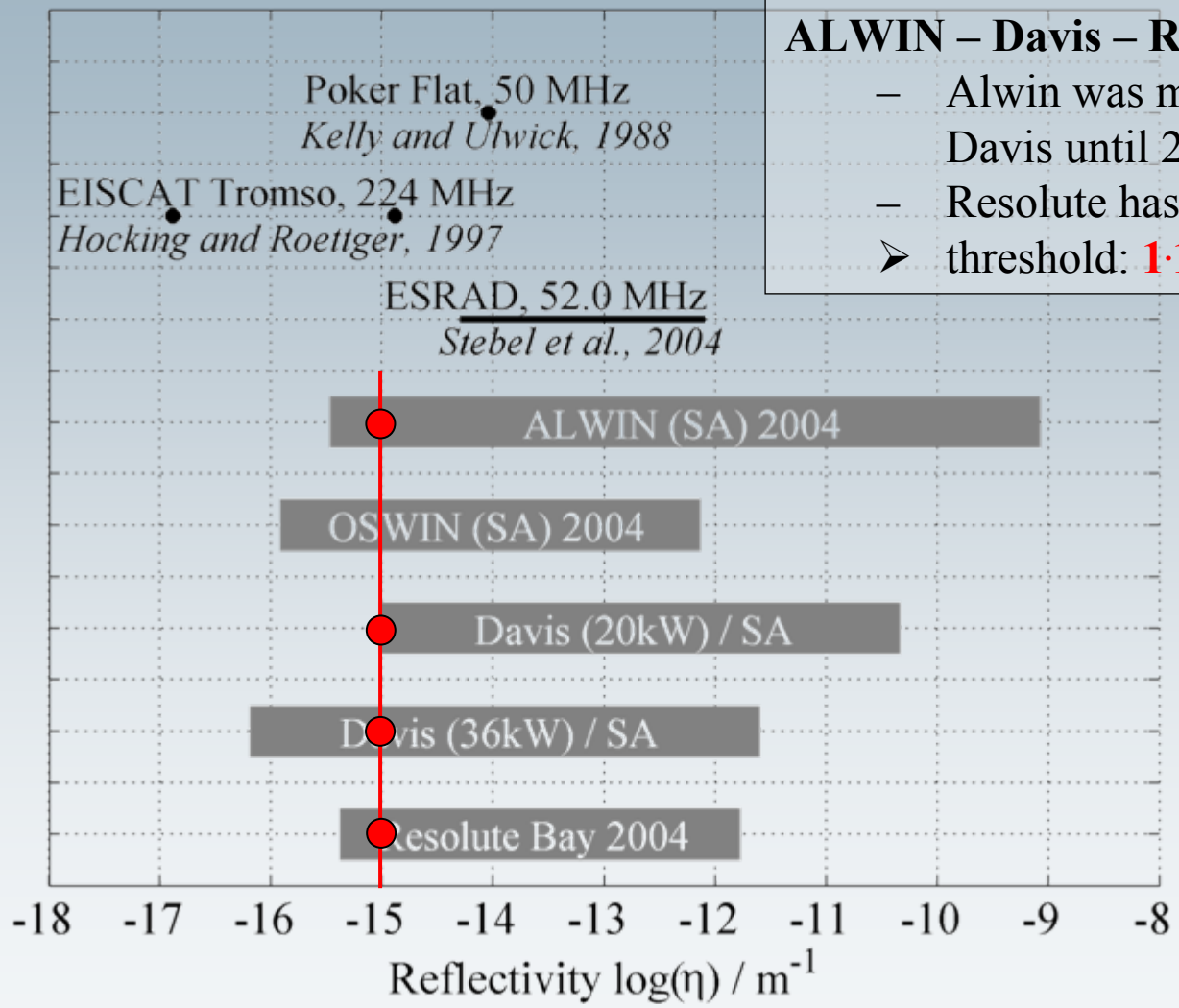
$$c_s = \frac{P_s[W]}{P_s[tpu]}$$

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

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

Volume reflectivity

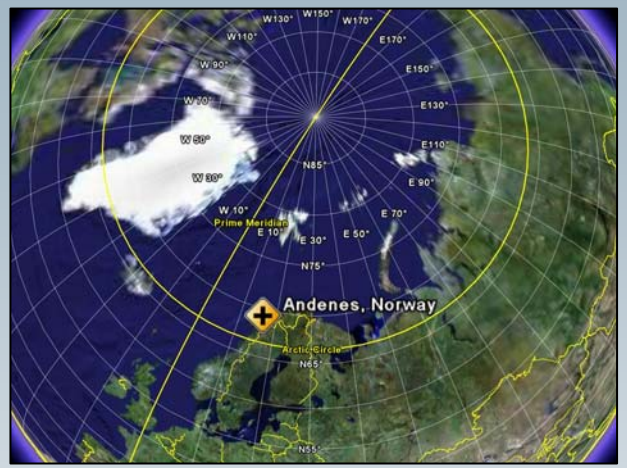
detection limits of various VHF radars at different sites

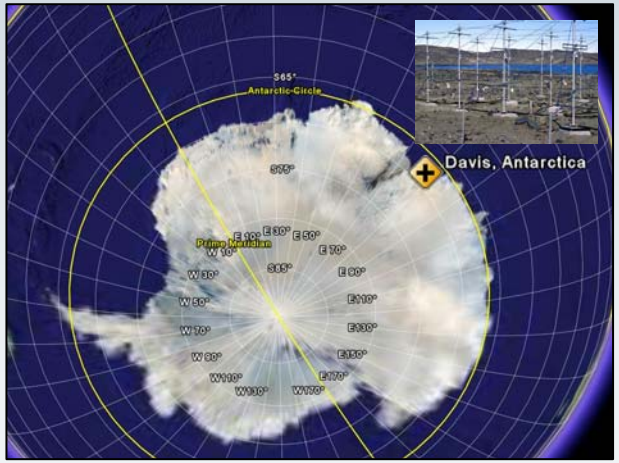


ALWIN – Davis – Resolute comparison

- 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)



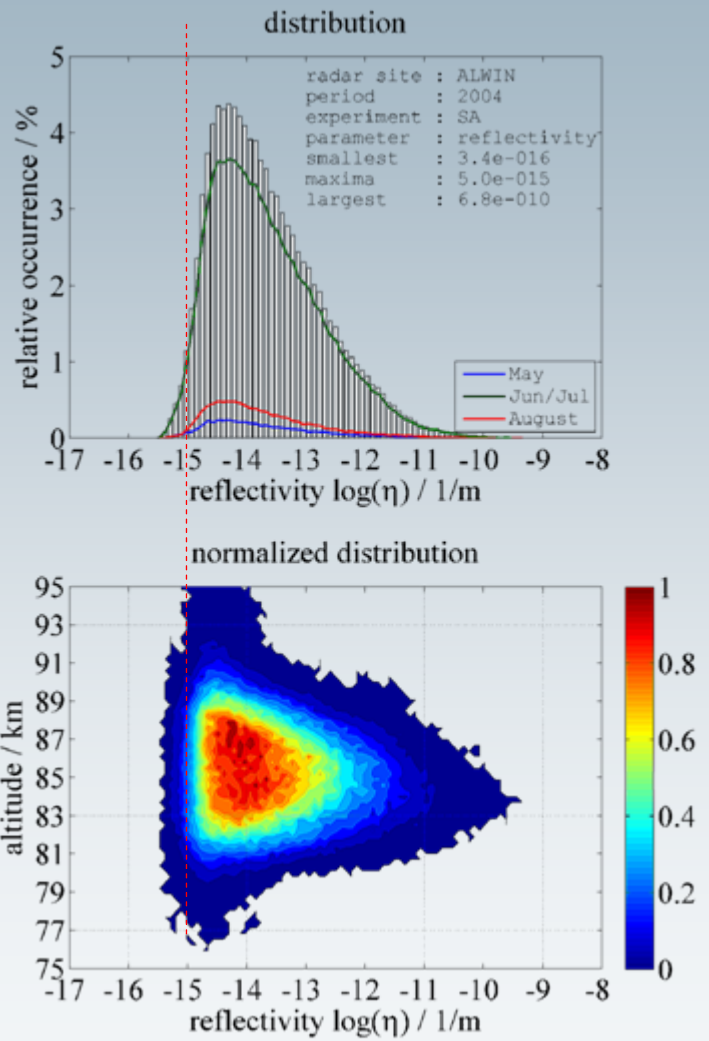


Parameters \ Radar	ALWIN 69°N; 16°E	Davis-VHF-Radar 69°S; 78°E		
Radar wavelength	5.6 m	5.5 m		
Peak power	36 kW	20 kW	36 kW	41 kW
Gain of Tx antenna array	28.3 dBi	28.9 dBi		
Half-power beam width	6°	6°		
Gain of SA receiving antenna array	20.6 dBi	21.0 dBi		
Efficiency	0.6	0.5		
Effective pulse width	300 m	600 m	450 m	
→ system factor c_{sys}	**2.1e-08**	**1.9e-08**	**1.4e-08**	**1.2e-08**
Experiment parameters				
Number of coherent integrations	32	116	104	
Number of code elements	16	1	8	
Receiver gain	101 dB	81 dB	81 dB	
Receiver bandwidth	500 kHz	368 kHz	280 kHz	
→ signal factor c_s	**3.5e-19**	**1.5e-21**	**1.5e-20**	

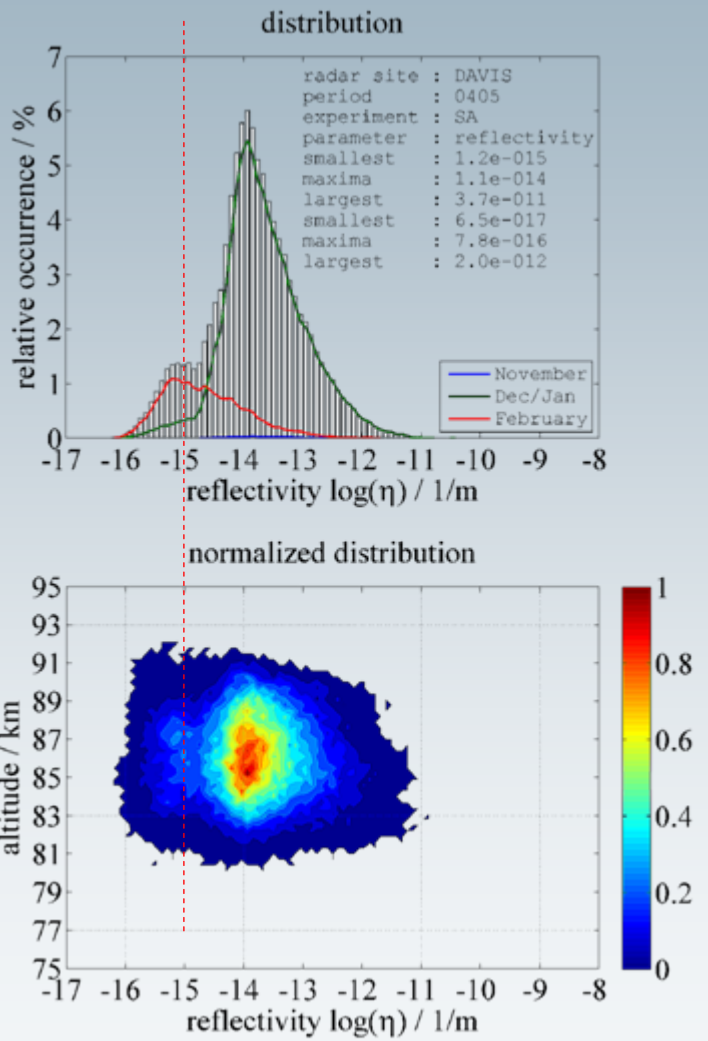
Comparison of PMSE observations from 69°N and 69°S

distribution of PMSE volume reflectivity

Andenes 2004

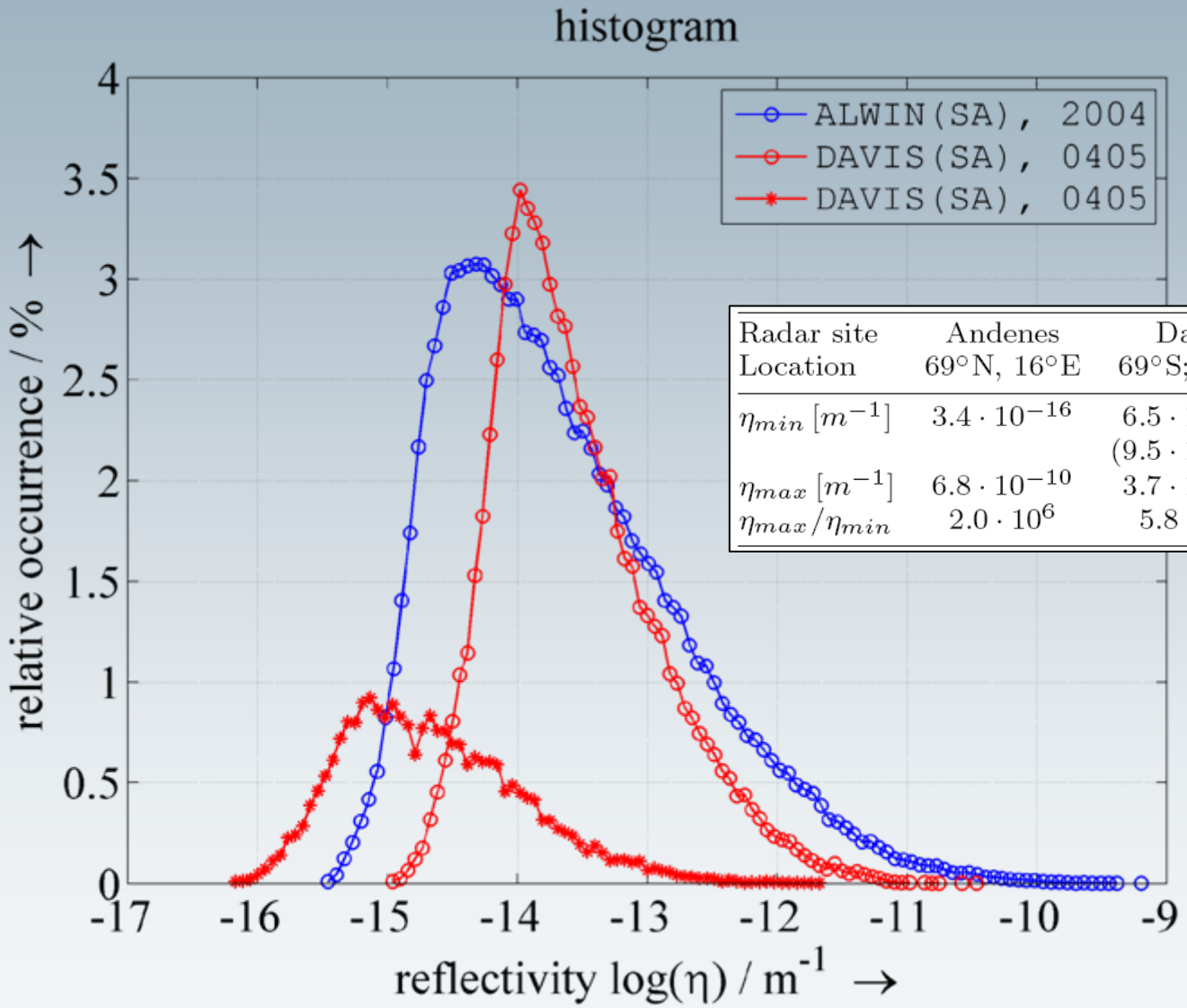


Davis 2004/2005



Comparison of PMSE observations from 69°N and 69°S

distribution of PMSE volume reflectivity

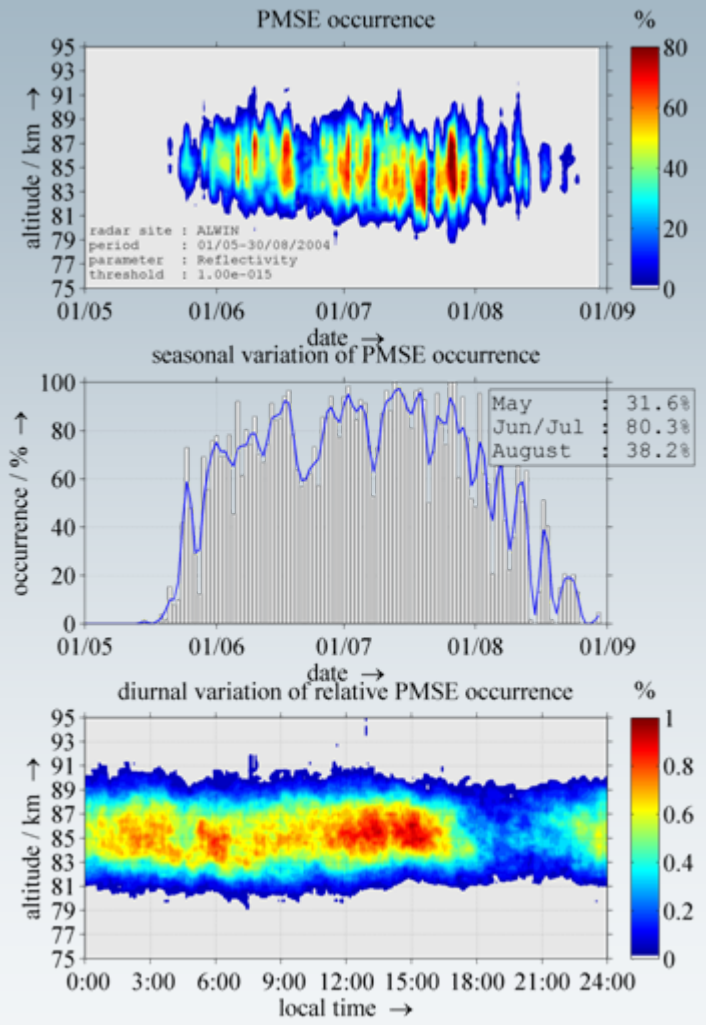


Radar site	Andenes	Davis
Location	69°N, 16°E	69°S; 78°E
$\eta_{min}\,[m^{-1}]$	$3.4 \cdot 10^{-16}$	$6.5 \cdot 10^{-17}$ ($9.5 \cdot 10^{-16}$)
$\eta_{max}\,[m^{-1}]$	$6.8 \cdot 10^{-10}$	$3.7 \cdot 10^{-11}$
η_{max}/η_{min}	$2.0 \cdot 10^{6}$	$5.8 \cdot 10^{5}$

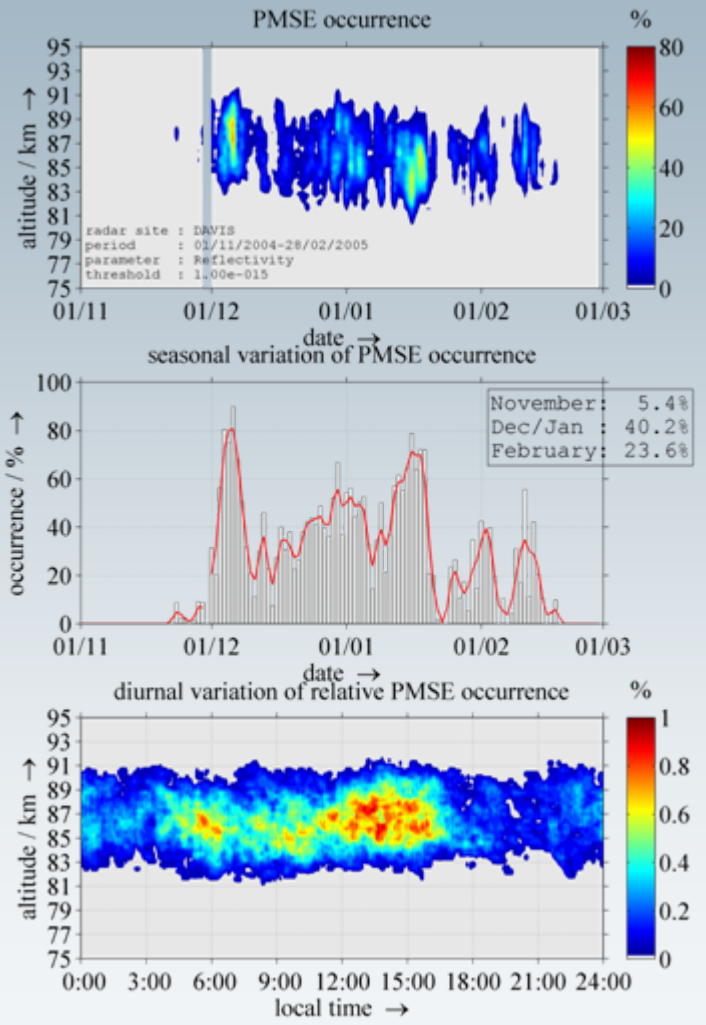
Comparison of PMSE observations from 69°N and 69°S

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

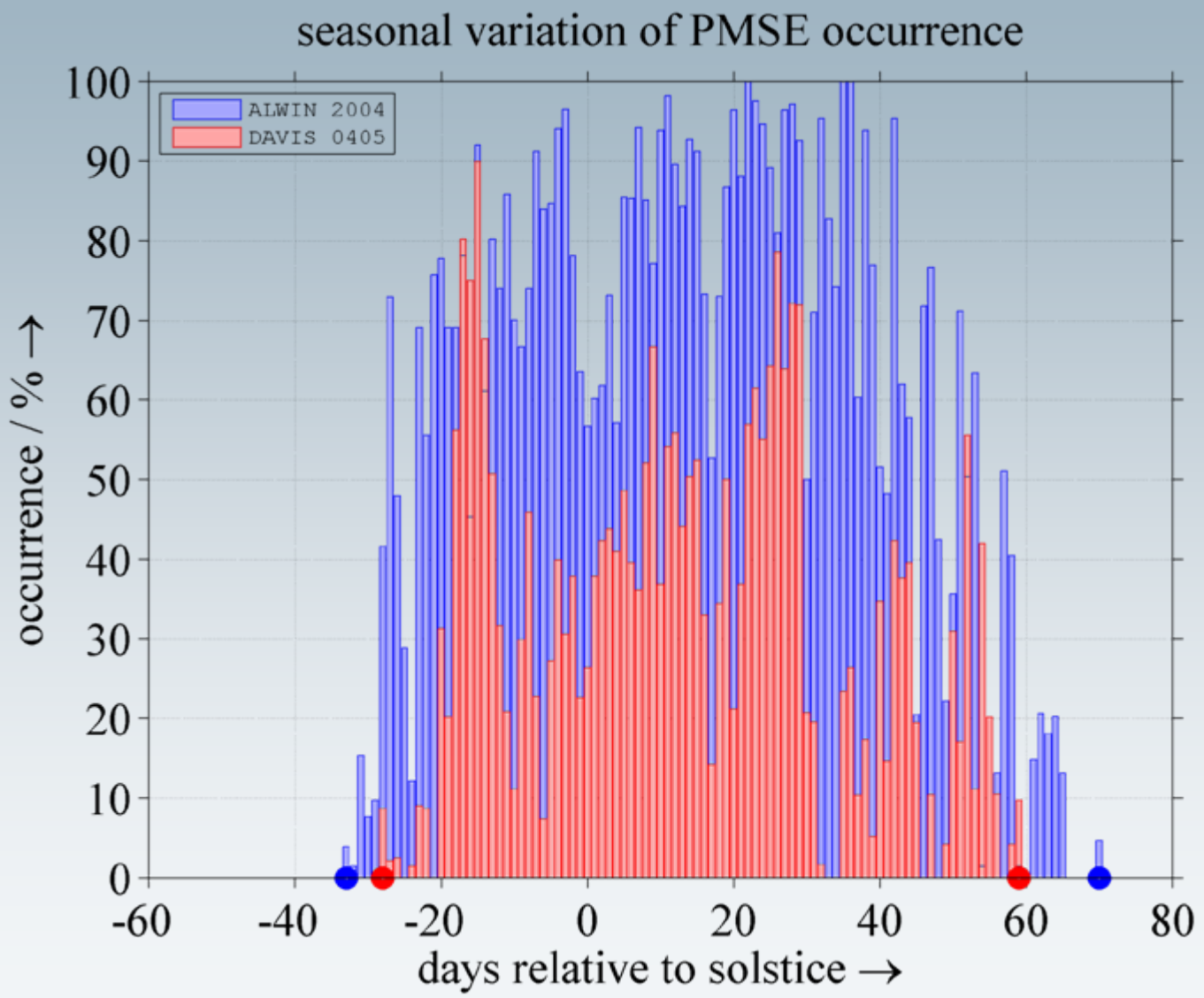
Andenes 2004



Davis 2004/2005

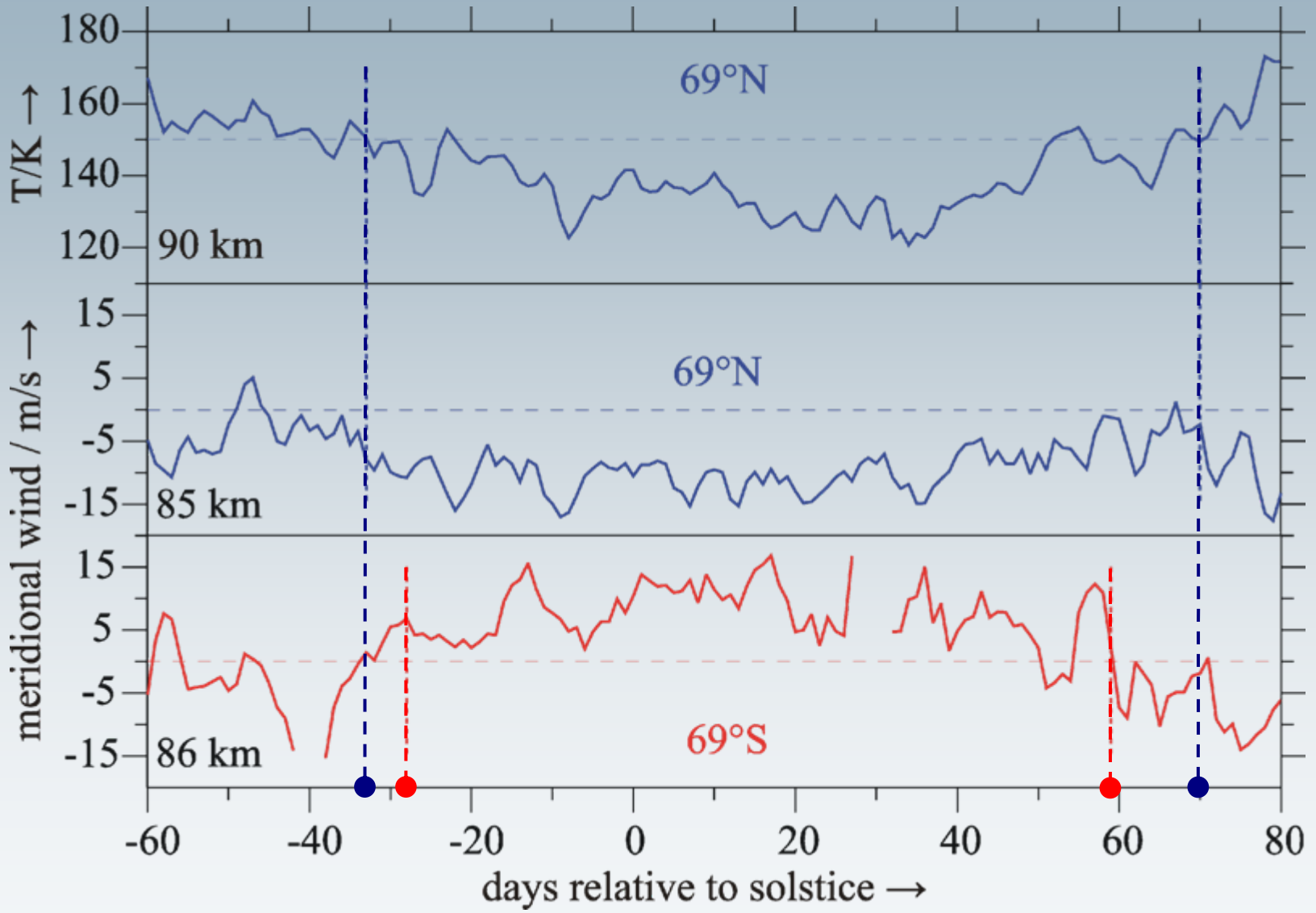


Comparison of PMSE observations from 69°N and 69°S



Comparison of PMSE observations from 69°N and 69°S

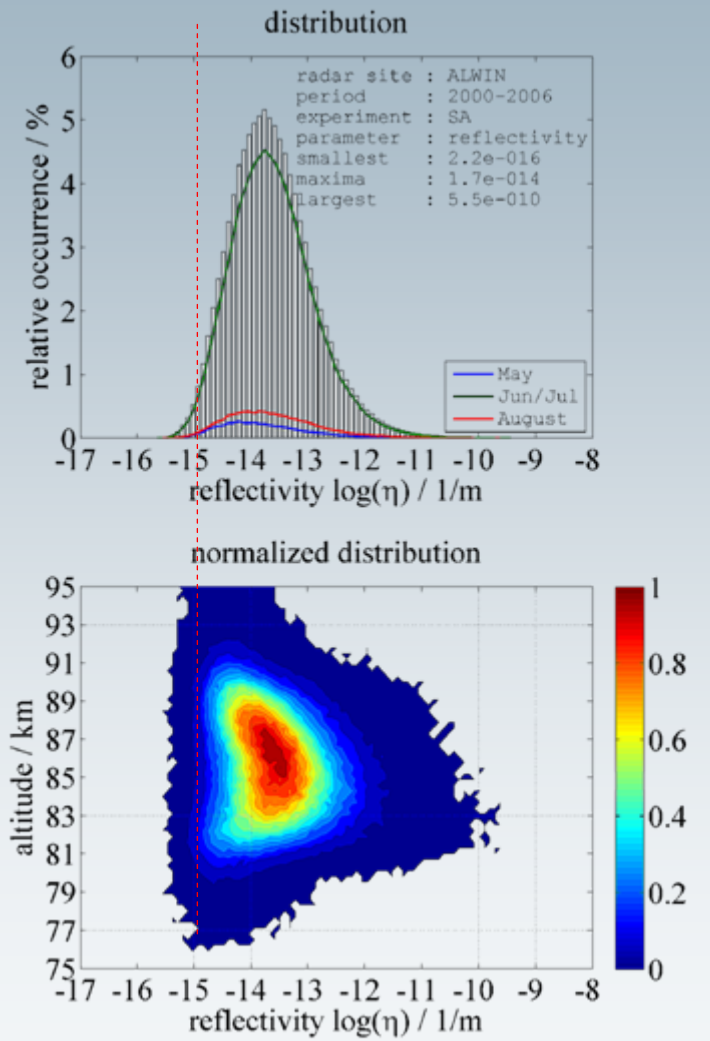
mean temperatures and meridional winds



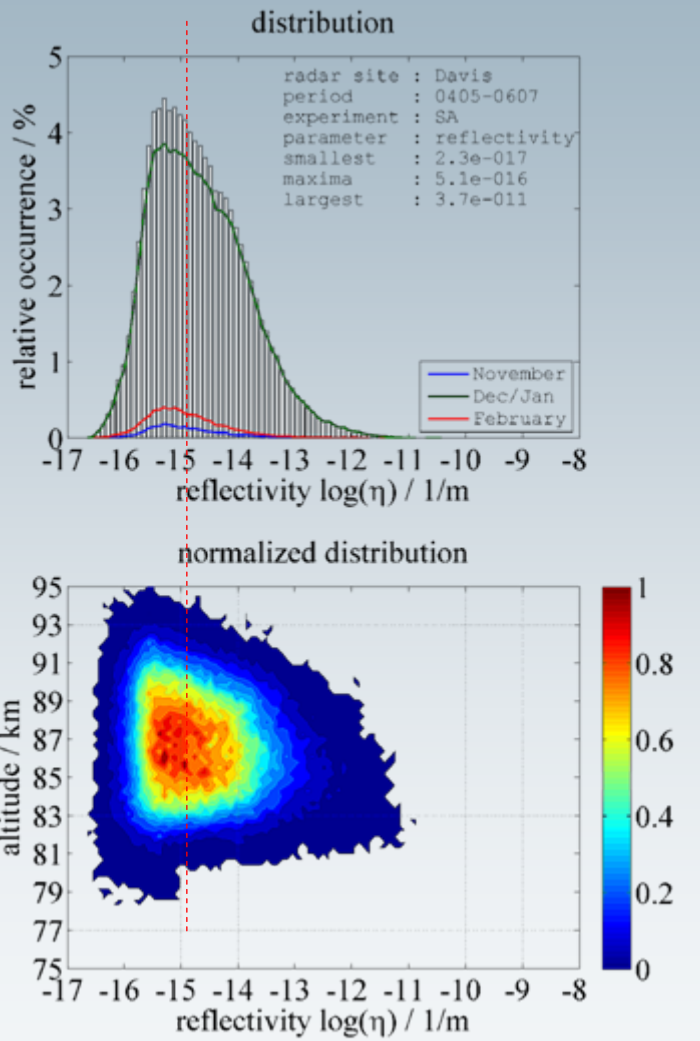
Comparison of PMSE observations from 69°N and 69°S

mean distribution of PMSE volume reflectivity

Andenes 2000-2006



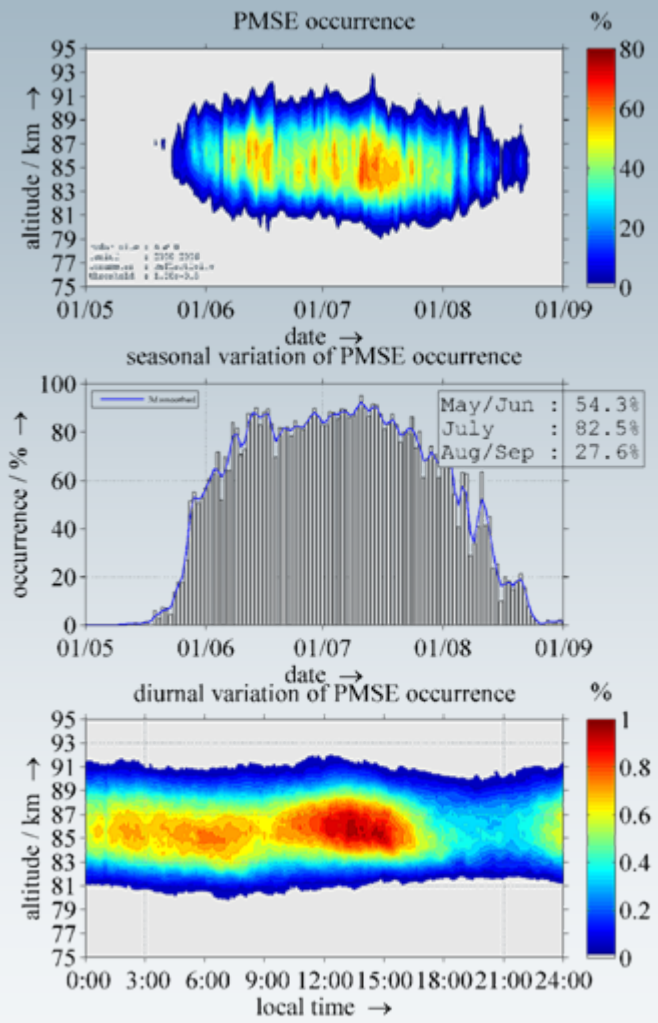
Davis 04/05-06/07



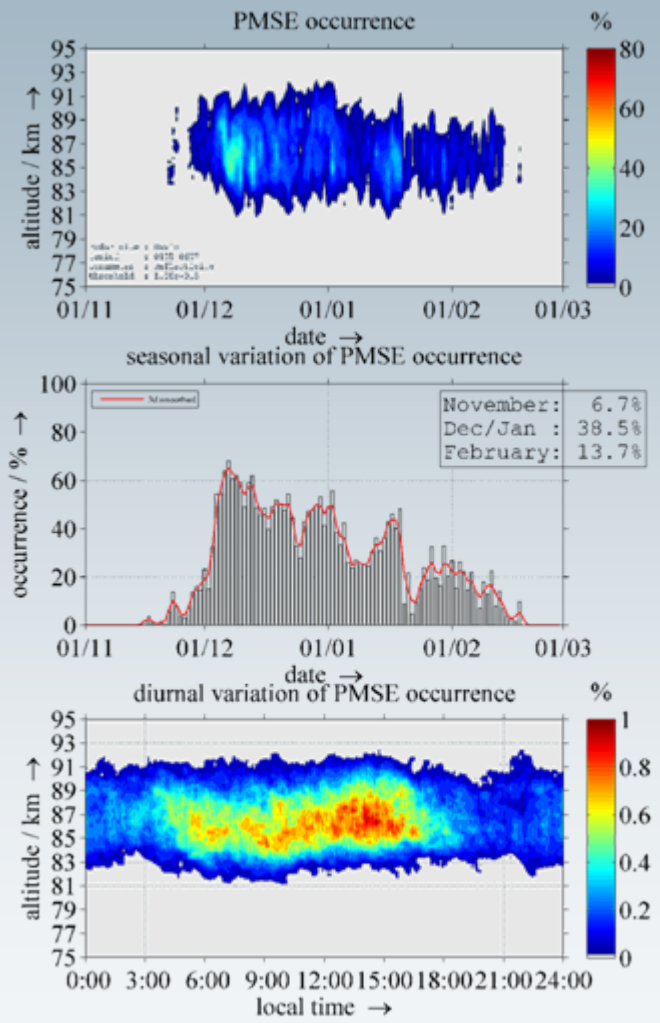
Comparison of PMSE observations from 69°N and 69°S

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

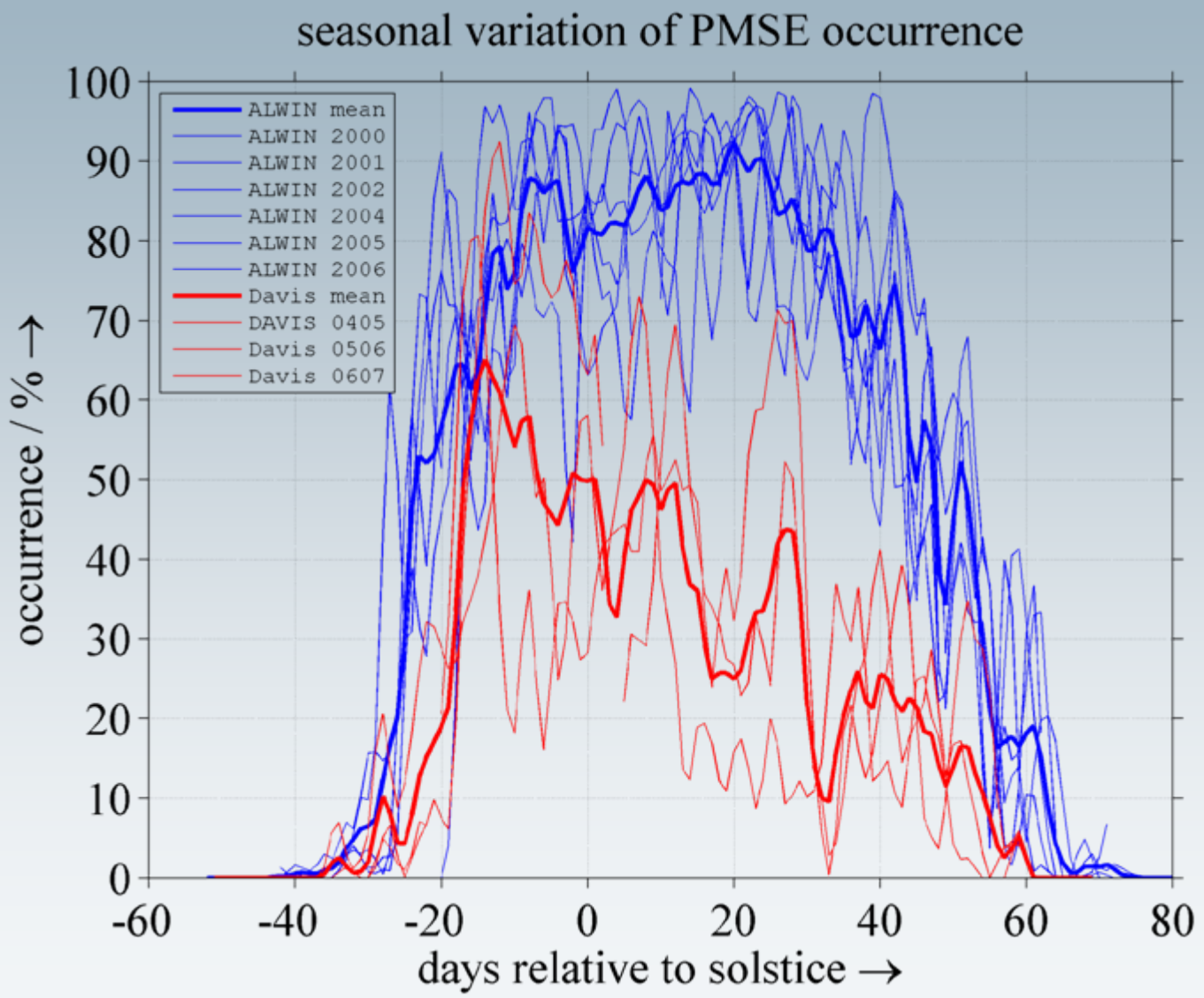
Andenes 2000-2006



Davis 04/05-06/07



Comparison of PMSE observations from 69°N and 69°S

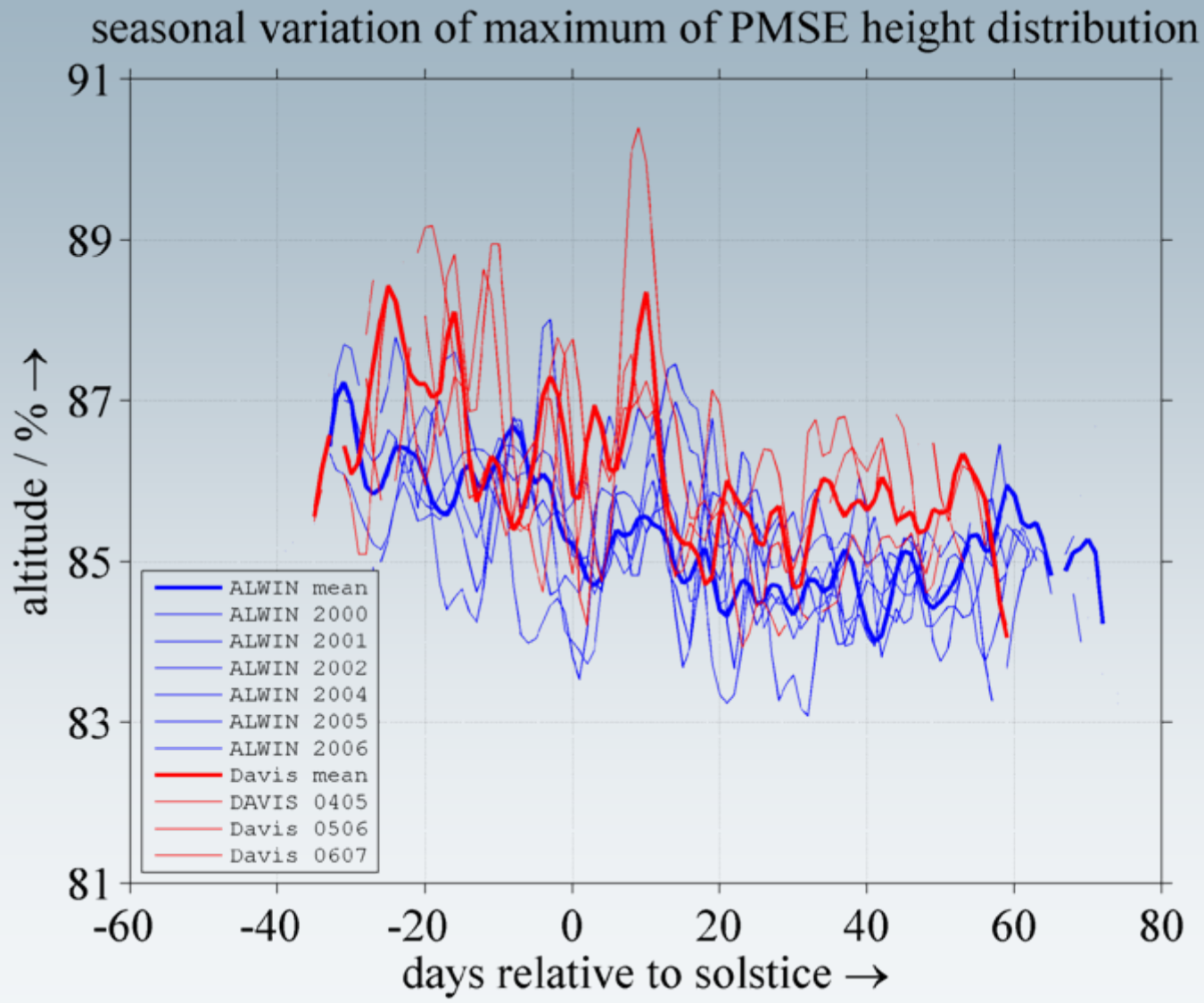


Andenes (69N) – Davis (69°S)

First and last PMSE

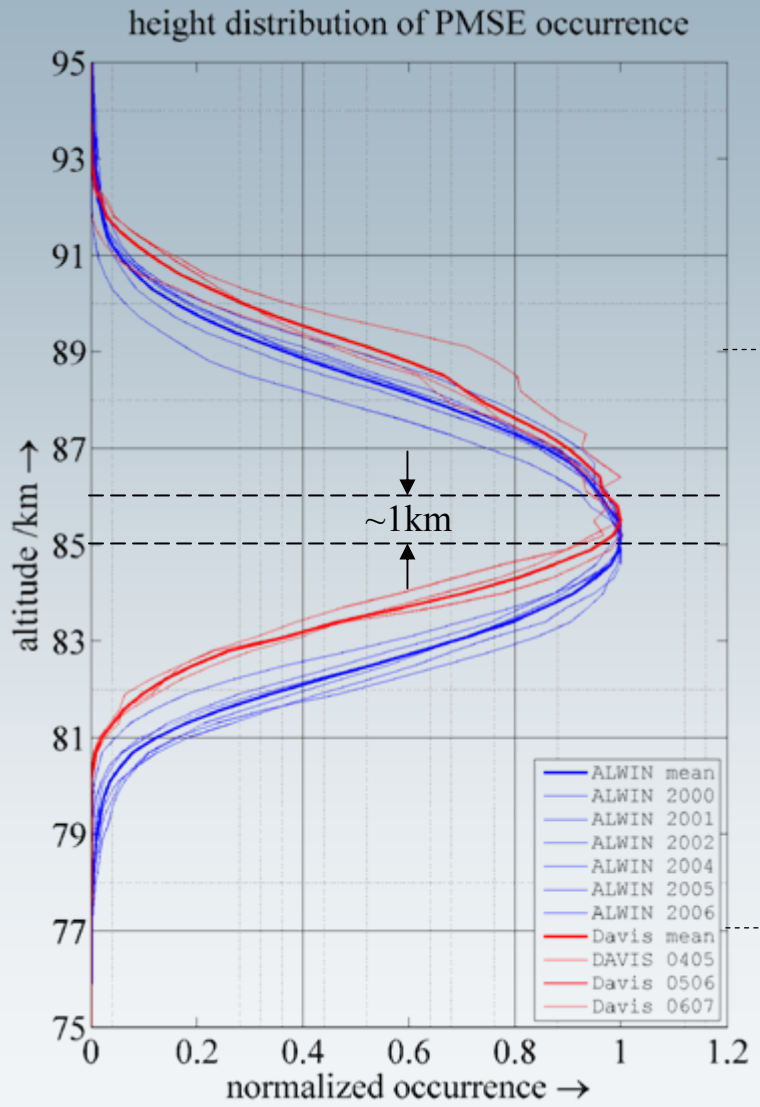
Radar site	Year	First PMSE		Last PMSE	
		Date	r.t.s.	Date	r.t.s.
Andenes	1995-2001	19 May	-33	28 Aug	68
Andenes	2000-2006	13 May	-39	28 Aug	68
Andenes	2004	19 May	-33	30 Aug	70
median Andenes	1995-2006	18 May	-34	28 Aug	68
Davis	2003/2004	19 Nov	-32	16 Feb	57
Davis	2004/2005	23 Nov	-28	18 Feb	59
Davis	2005/2006	17 Nov	-34	19 Feb	60
Davis	2006/2007	19 Nov	-32	18 Feb	59
median Davis	2003-2006	18 Nov	-33	18 Feb	59

Comparison of PMSE observations from 69°N and 69°S

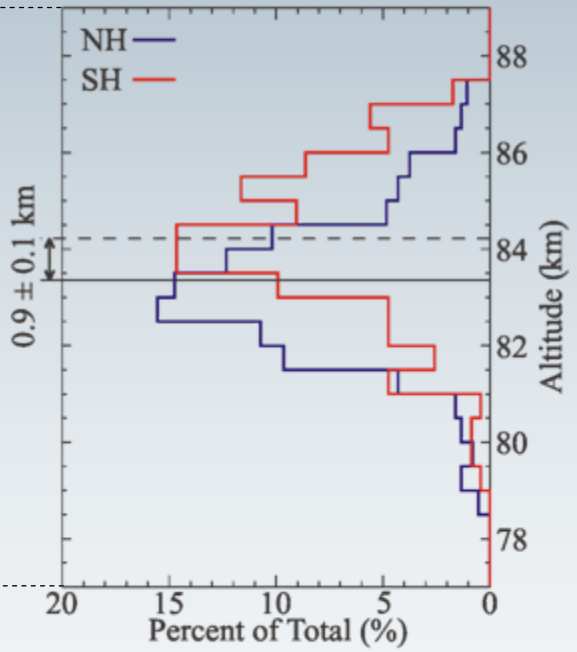


Comparison of PMSE observations from 69°N and 69°S

PMSE height distribution

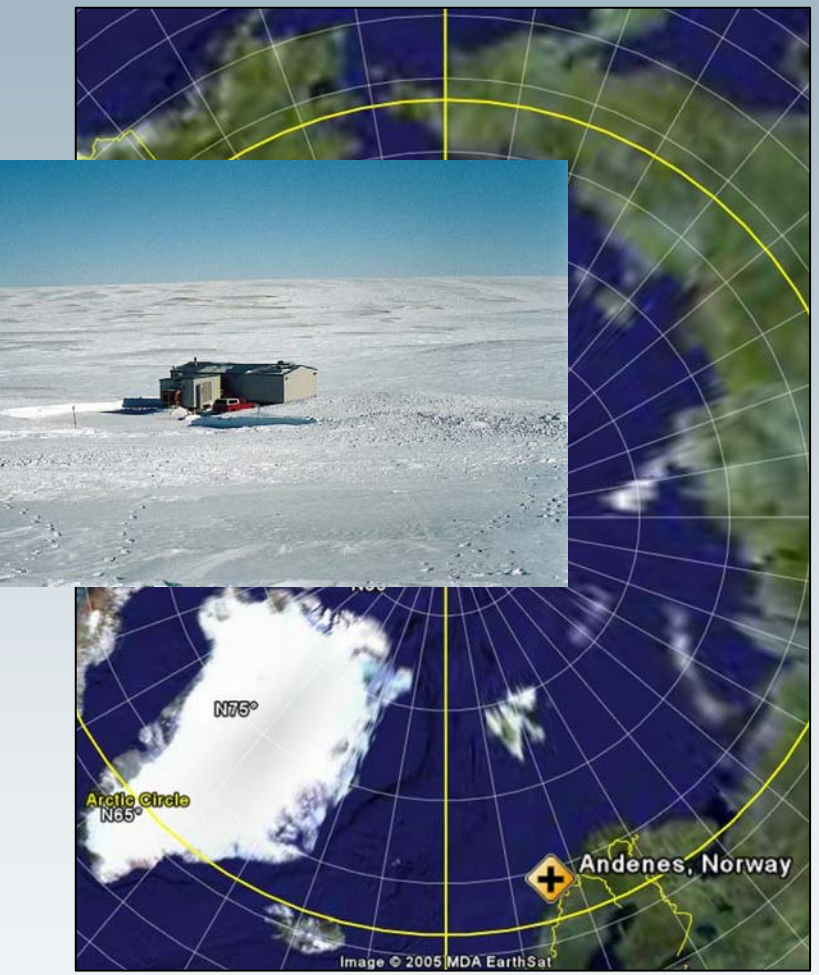


The PMC altitude distribution as a percentage of the total number of PMCs observed by HALOE from 1991 to 2005 and latitudes between 55° and 70°



Wrotny et al., *JASTP*, 2006

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

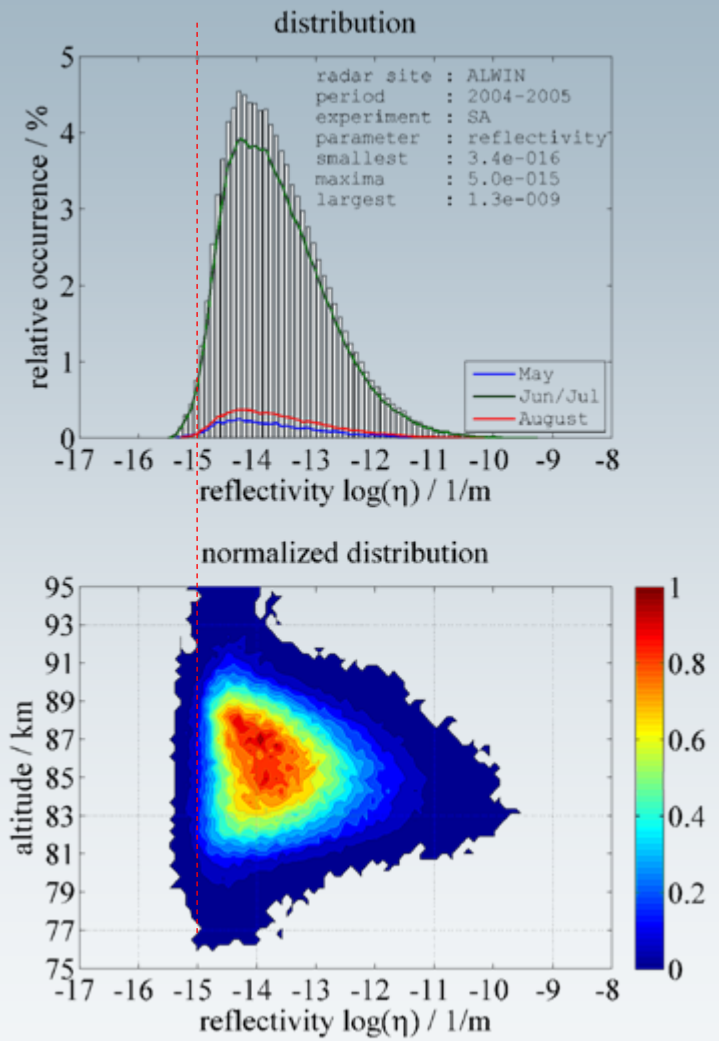


Parameters \ Radar	ALWIN 69°N; 16°E	RB-VHF 75°N; 95°W
Radar wavelength	5.6 m	5.8 m
Peak power	36 kW	12 kW
Gain of Tx antenna array	28.3 dBi	24.0 dBi
Half-power beam width	6°	4°
Gain of DBS receiving antenna array	28.3 dBi	24.0 dBi
Efficiency	0.58	0.09
Effective pulse width	300 m	750 m
→ system factor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

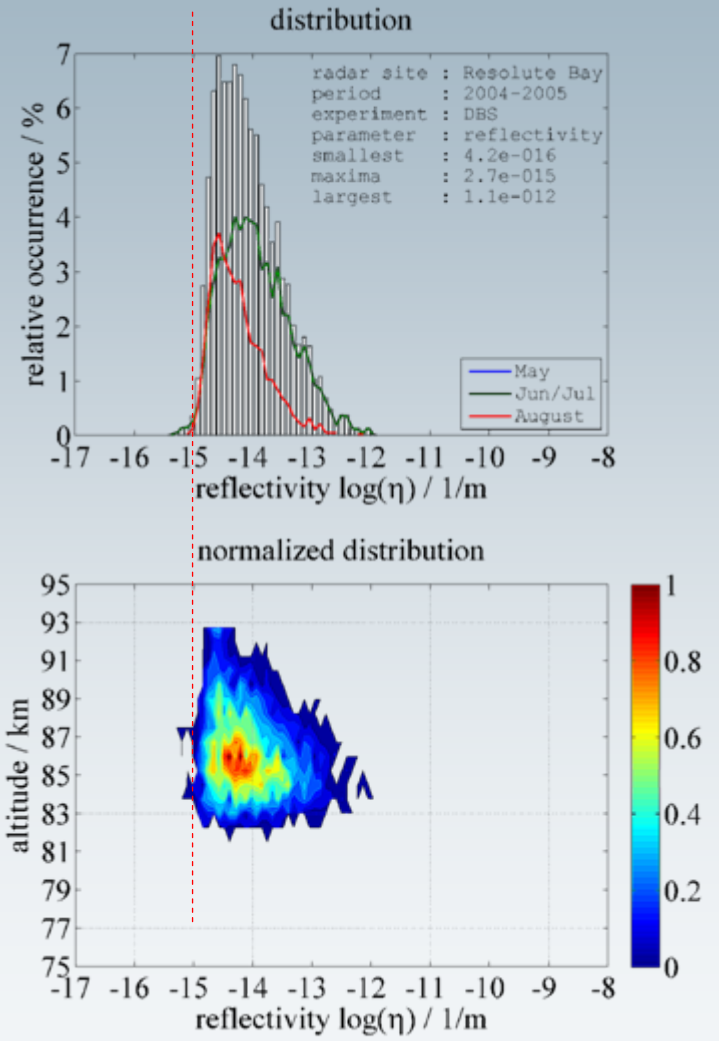
Andenes (69N, 16°E) – Resolute Bay (75°N, 95°W)

mean height distribution of PMSE volume reflectivity in 2004-2005

Andenes 2004-2005



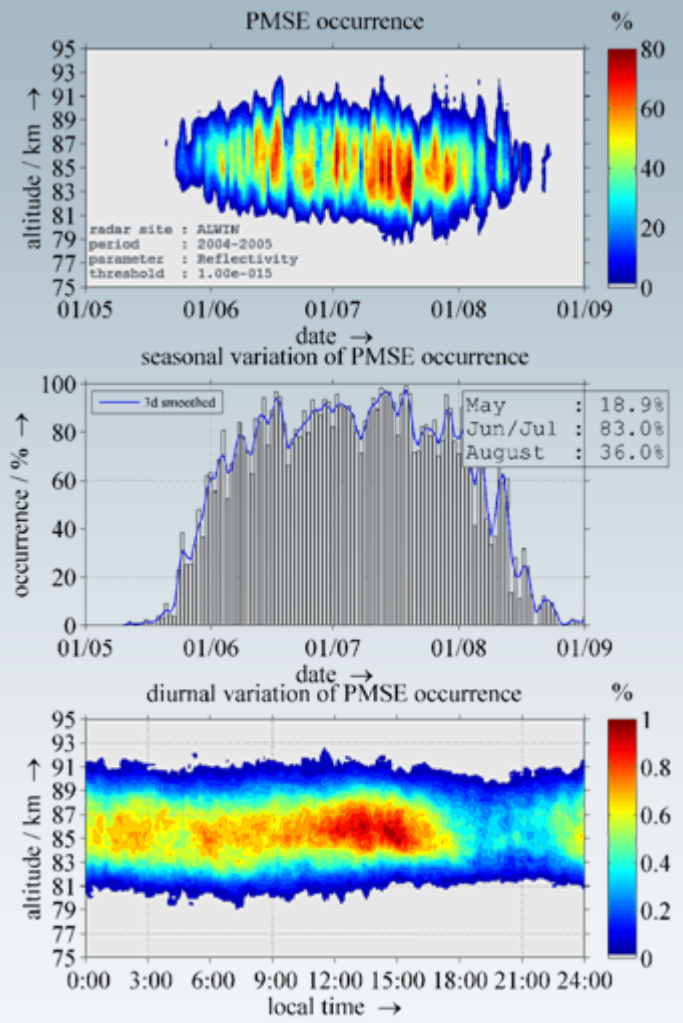
Resolute Bay 2004-2005



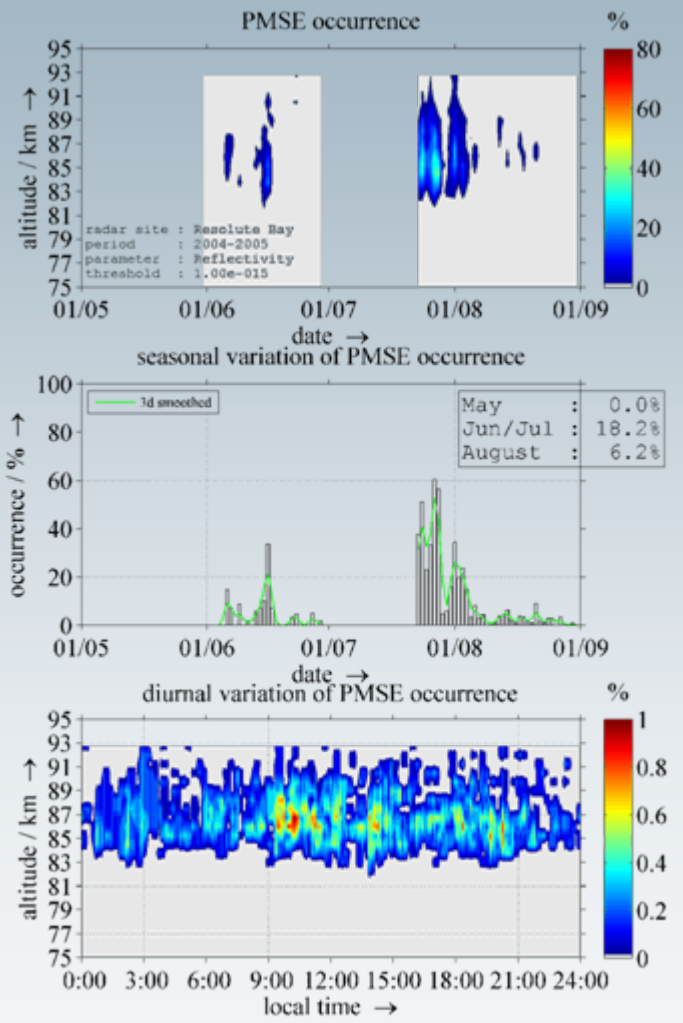
Andenes (69N, 16°E) – Resolute Bay (75°N, 95°W)

mean seasonal variation of PMSE occurrence for $\eta > 1 \cdot 10^{-15}$ m^{-1} in 2004-2005

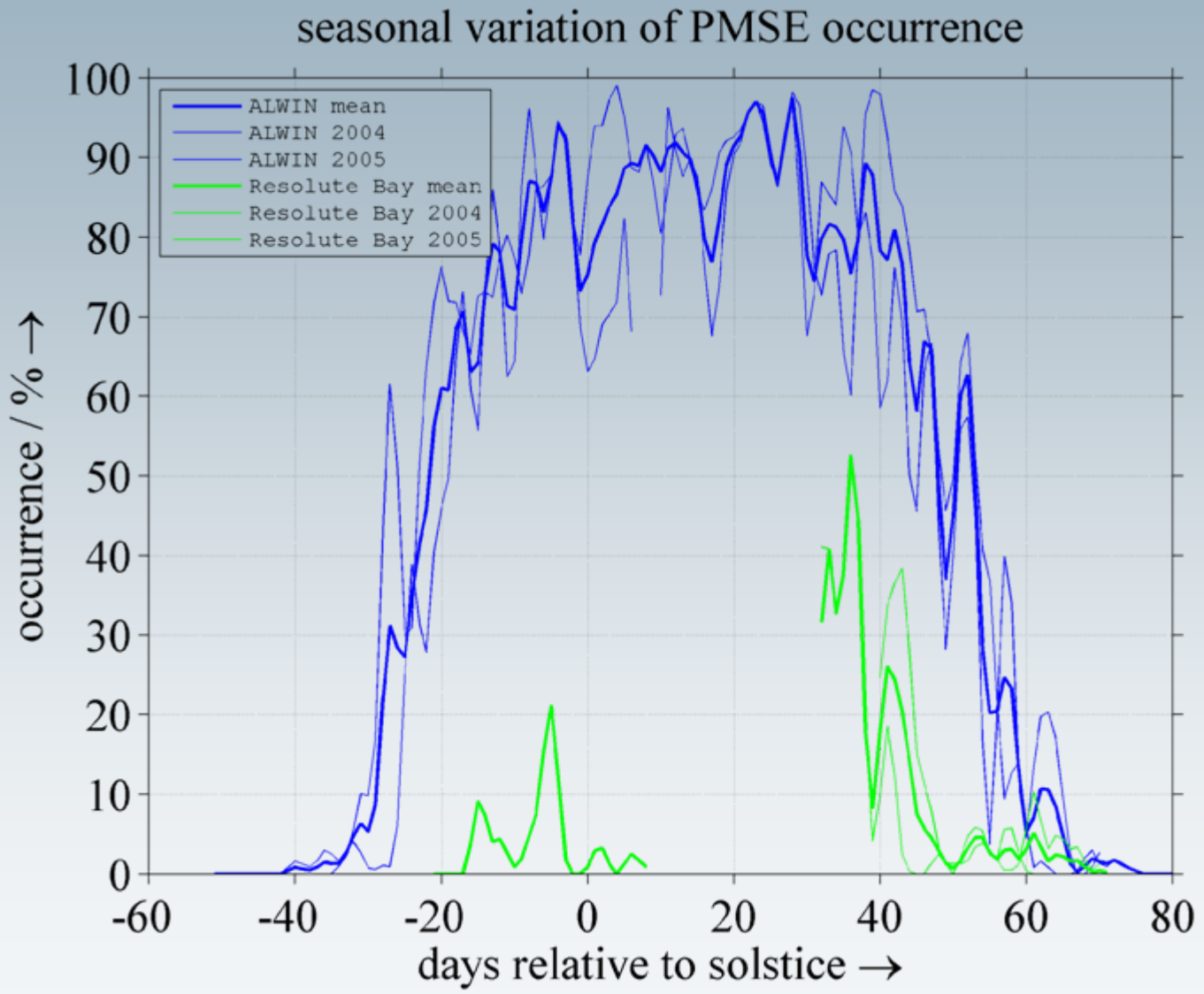
Andenes 2004-2005



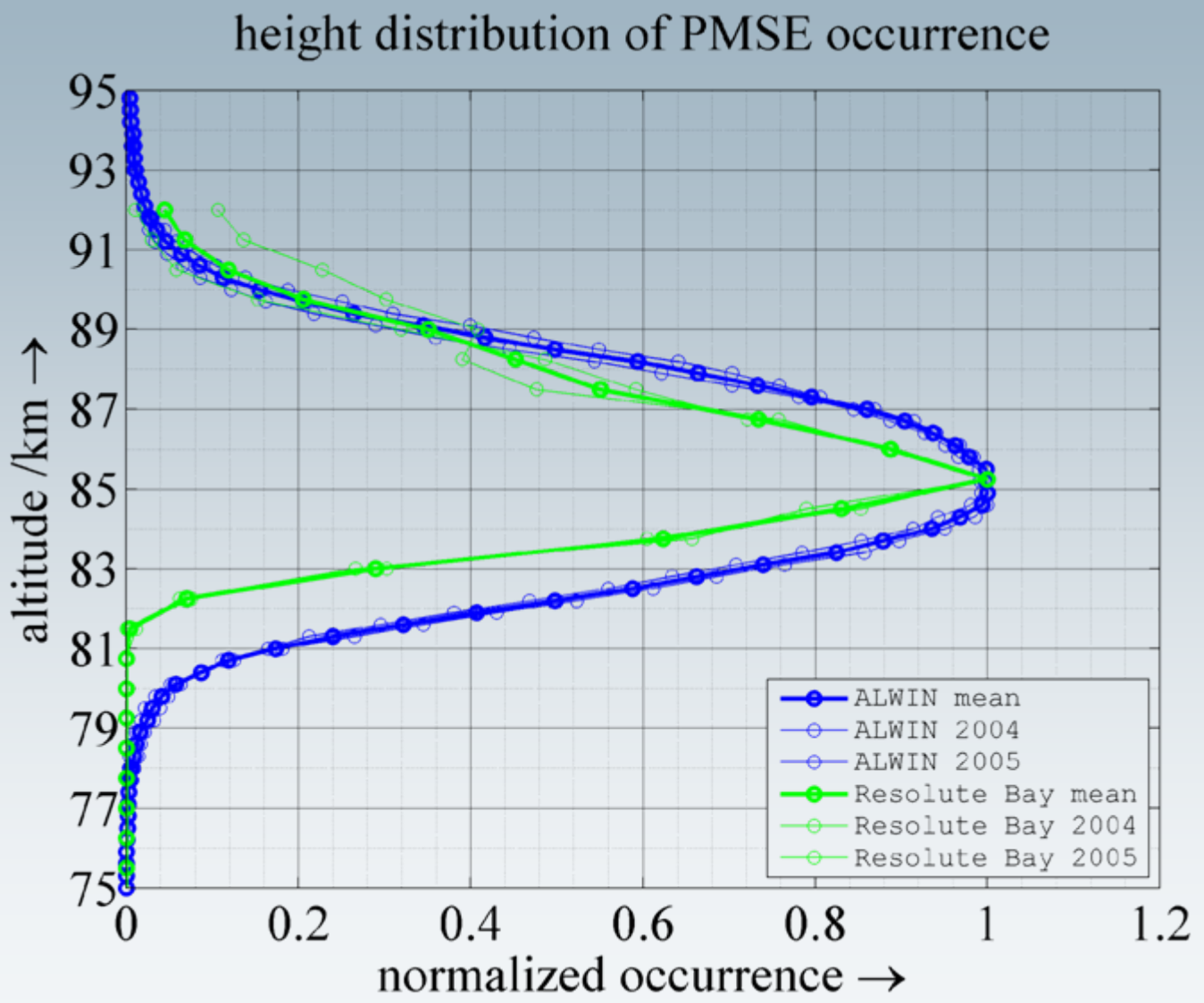
Resolute Bay 2004-2005



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



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
  - ➢ radar absolute calibration
- PMSE observed at Davis (69°S) 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)
- 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)