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

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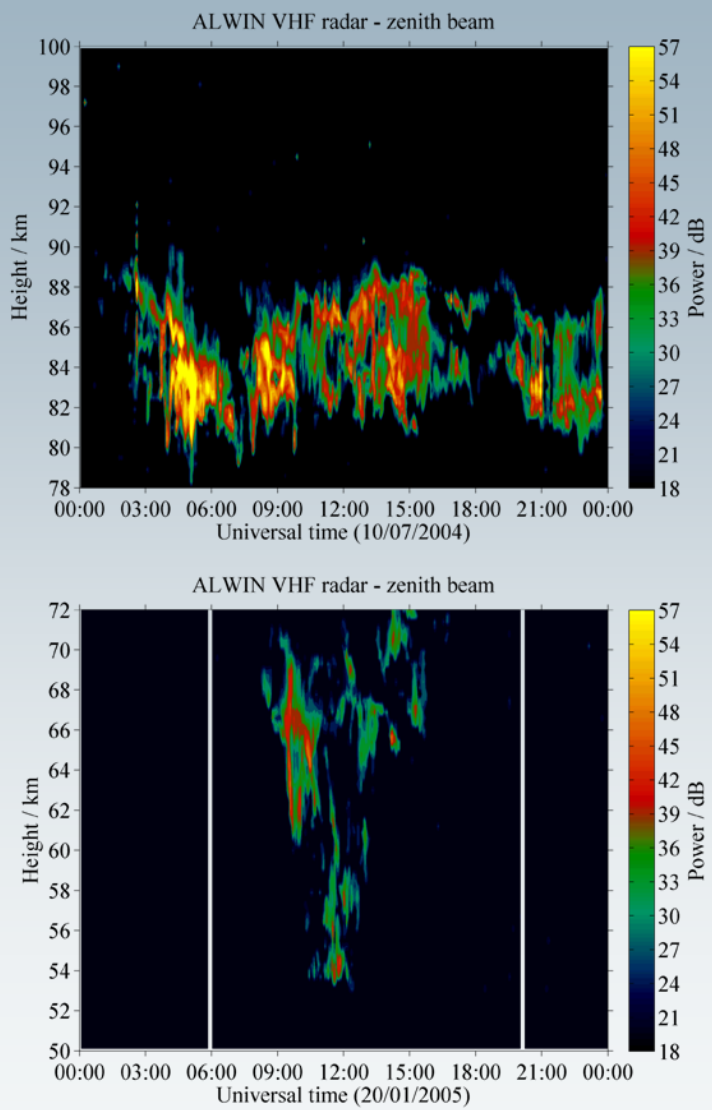
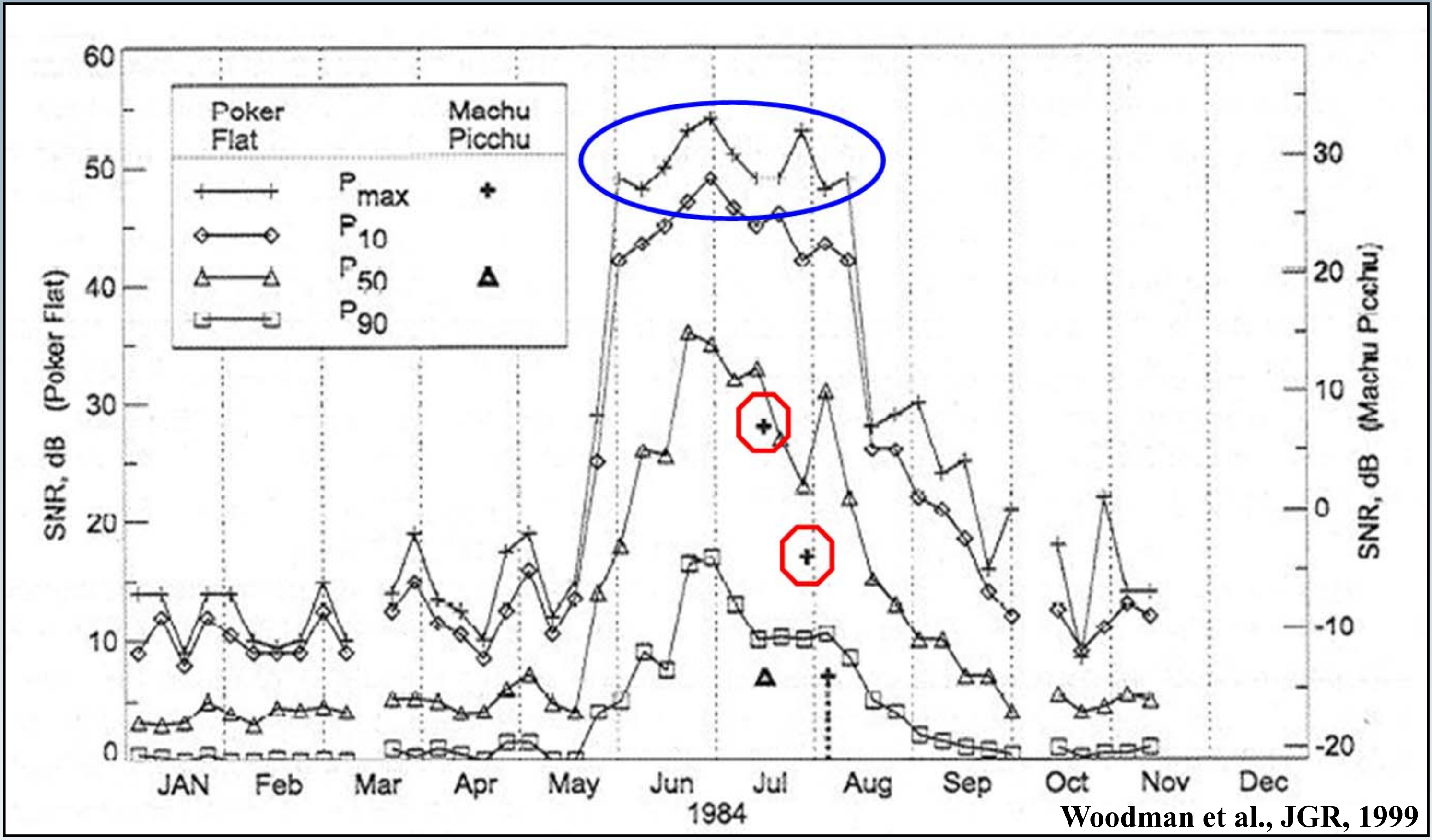
Introduction



- Polar mesosphere summer echoes (PMSE) are strong enhancements of signal power at very high radar frequencies that occur between about 80 and 95 km in altitude at polar and middle latitudes during summer.
- PMSE are caused by inhomogeneities in the electron density of a size comparable to the radar Bragg scale in the presence of charged particles.
- PMSE are observed with VHF radars at 50 MHz since more than 20 years in the northern hemisphere
  - **PMSE** (polar NH in summer)
  - **PMWE** (polar NH in winter)
- Characteristics of PMSE are determined by e.g.
  - Electron density, temperature
  - Water vapour concentration
- Very rare PMSE observations in SH

Motivation

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



Woodman et al., JGR, 1999

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

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

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

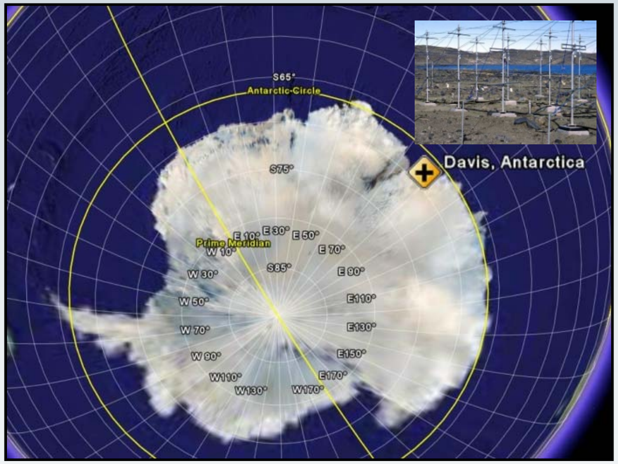
P_t	=	transmitted peak power [W]
P_r	=	received signal power [W]
G_t	=	gain of transmit antenna
G_r	=	gain of receive antenna
λ	=	radar wave length
e	=	efficiency
$\Theta_{1/2}$	=	half power half width of transmit antenna
r	=	range to volume center
$2\ln(2)$	=	beam correction factor
c	=	speed of light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

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



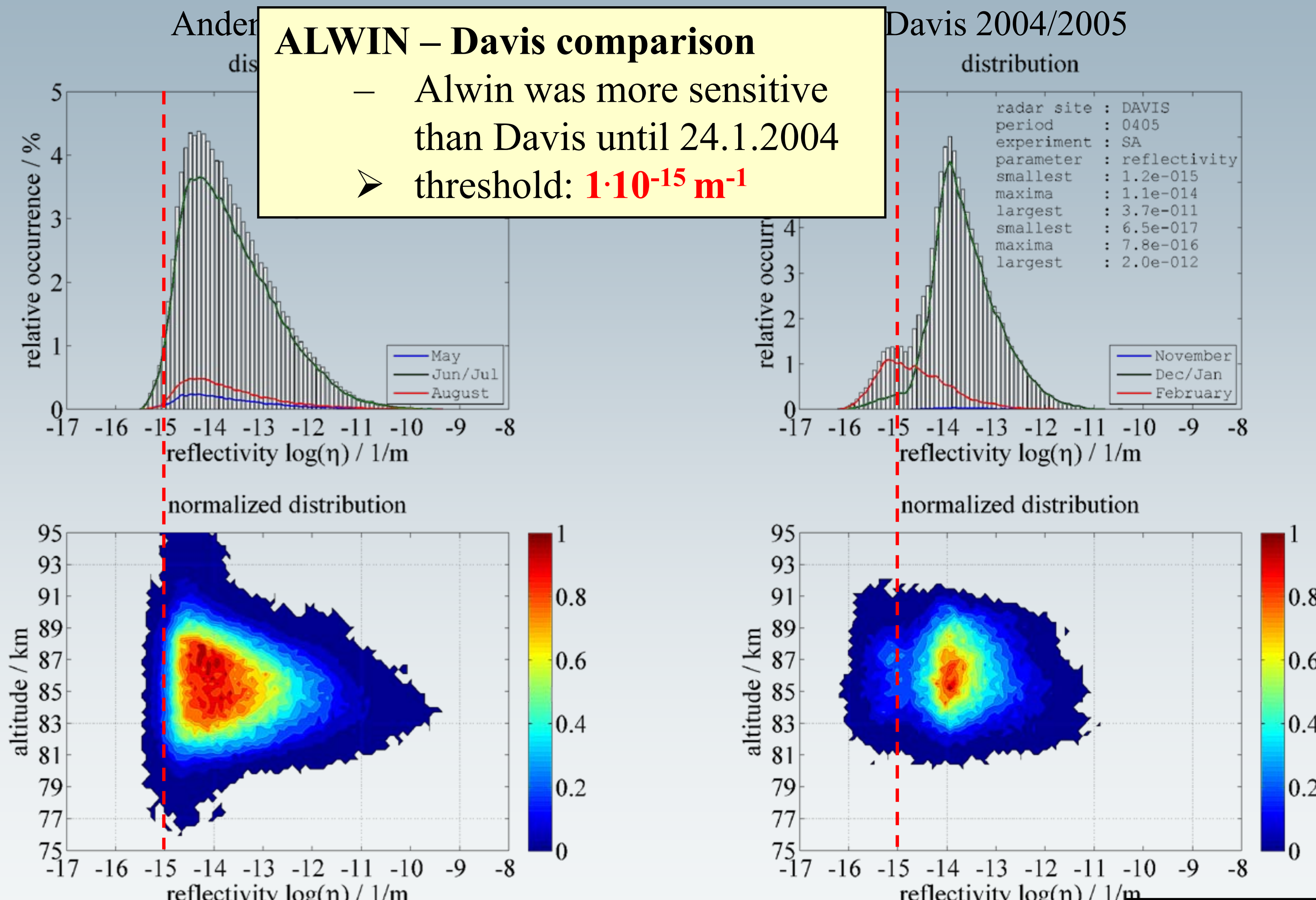
Parameters \ Radar	ALWIN 69°N; 16°E	Davis-VHF-Radar 69°S; 78°E		
Installation / upgrade	1998	2003	2005	2006
Radar wavelength	5.6 m	5.5 m		
Peak power	36 kW	20 kW	36 kW	41 kW
Gain of Tx antenna array	28.3 dBi	28.9 dBi		
Half-power beam width	6°	6°		
Gain of SA receiving antenna array	20.6 dBi	21.0 dBi		
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

ALWIN – Davis comparison

- – Alwin was more sensitive than Davis until 24.1.2004
- ➢ threshold: **$1 \cdot 10^{-15}$ m^{-1}**

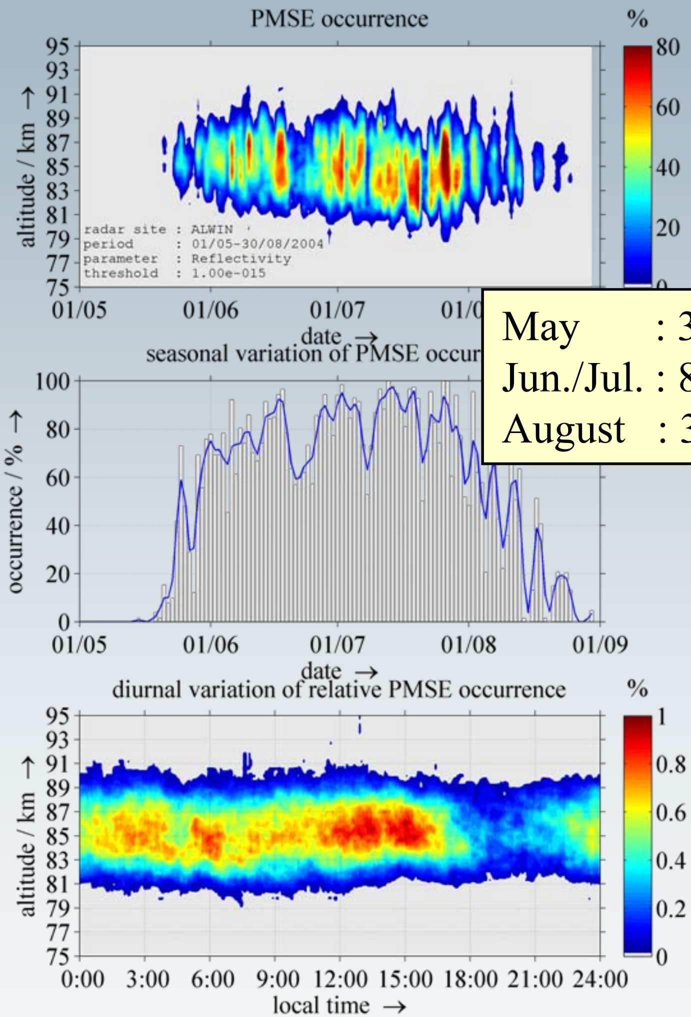


Latteck et al., GRL, 2007

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

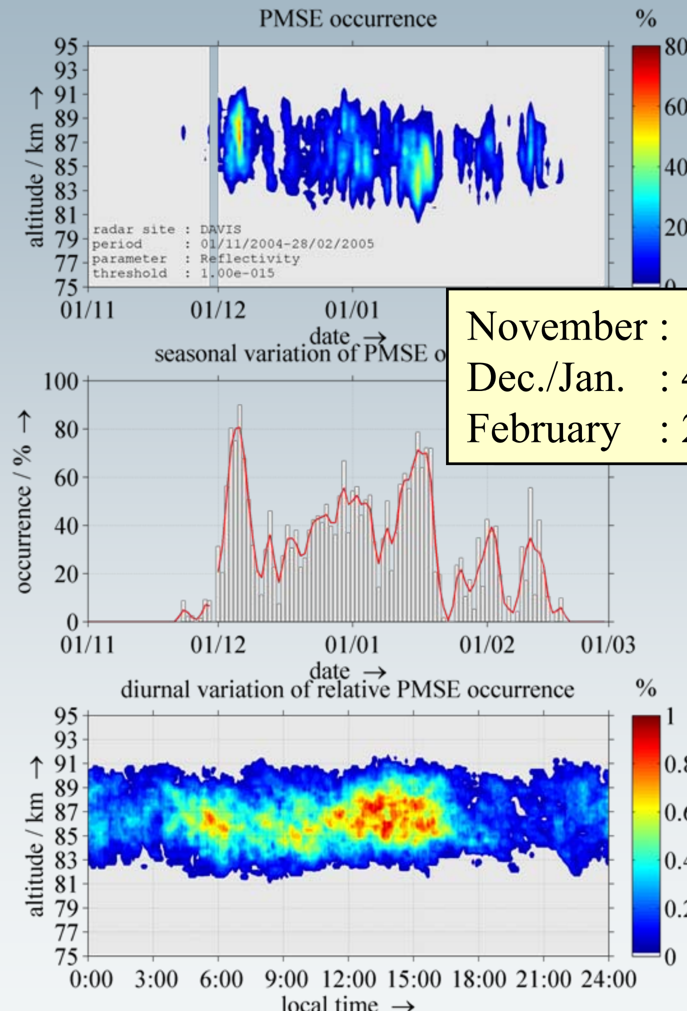
seasonal variation of PMSE occurrence for $\eta > 1 \cdot 10^{-15}\ \mathrm{m}^{-1}$

Andenes 2004



May : 31.6 %
Jun./Jul. : 80.3 %
August : 38.2 %

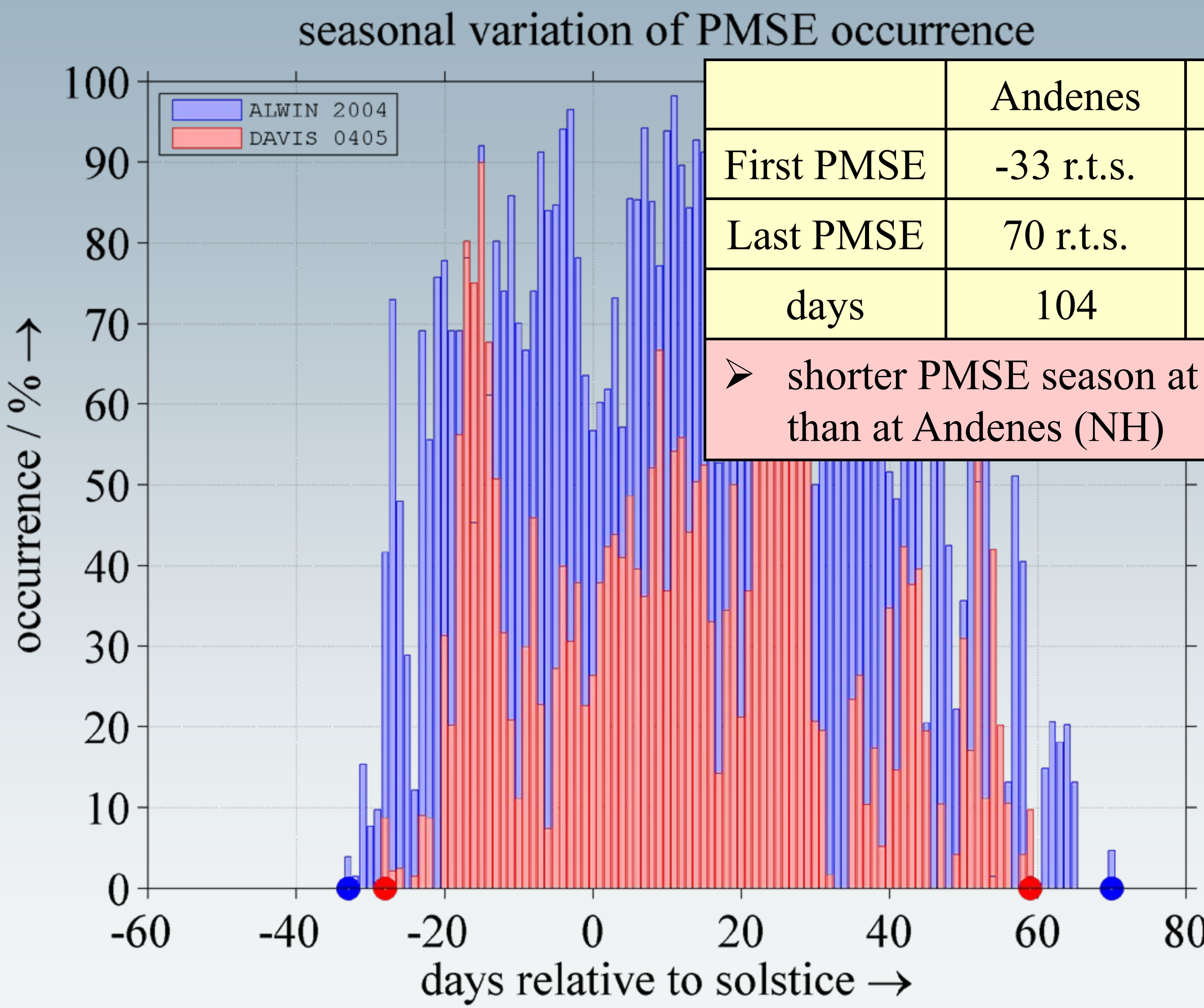
Davis 2004/2005



November : 5.4 %
Dec./Jan. : 40.2 %
February : 23.6 %

Latteck et al., GRL, 2007

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

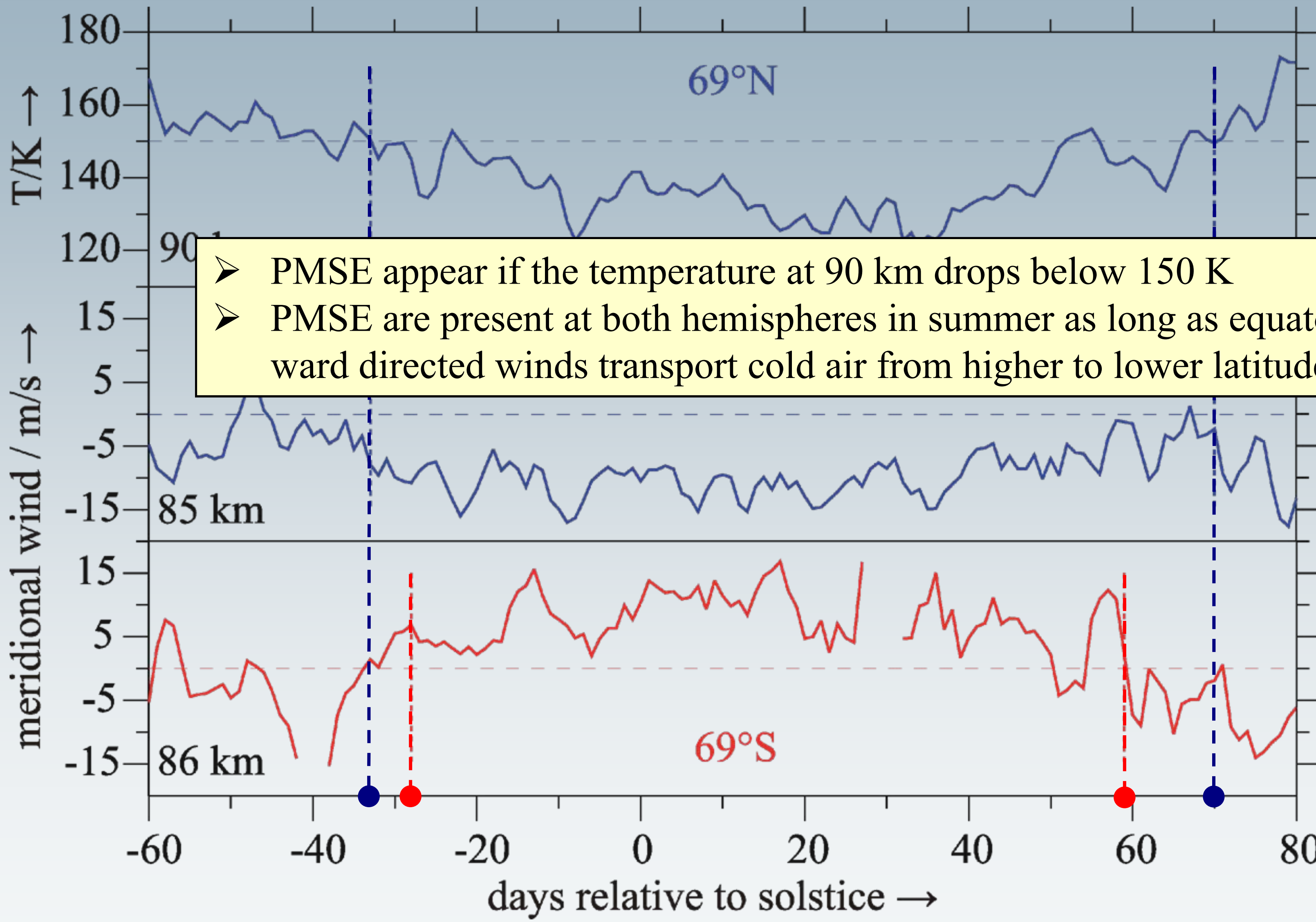


	Andenes	Davis
First PMSE	-33 r.t.s.	-28 r.t.s.
Last PMSE	70 r.t.s.	59 r.t.s.
days	104	88

- shorter PMSE season at Davis (SH) than at Andenes (NH)

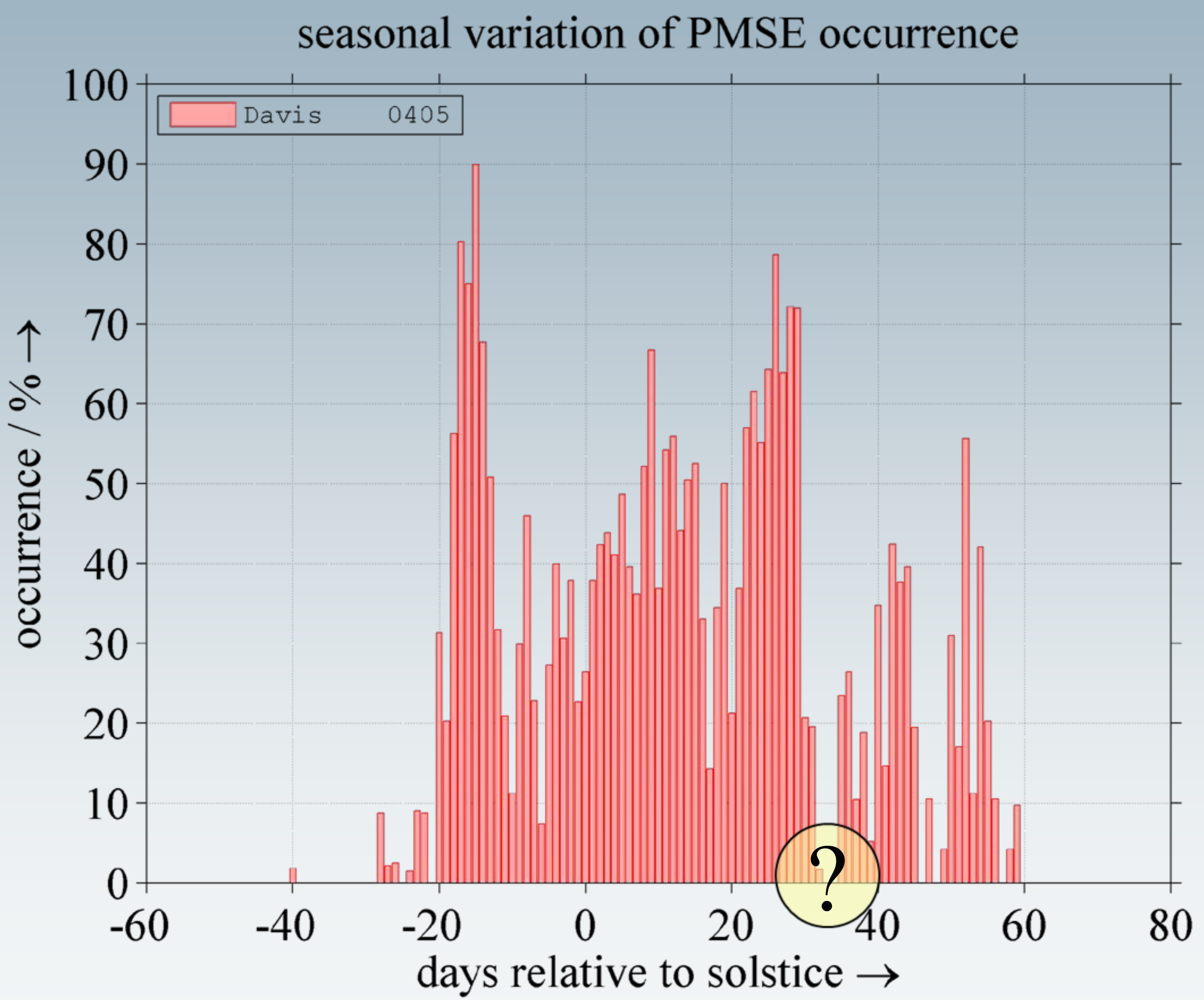
Comparison of PMSE observations from 69°N and 69°S

mean temperatures and mean meridional winds



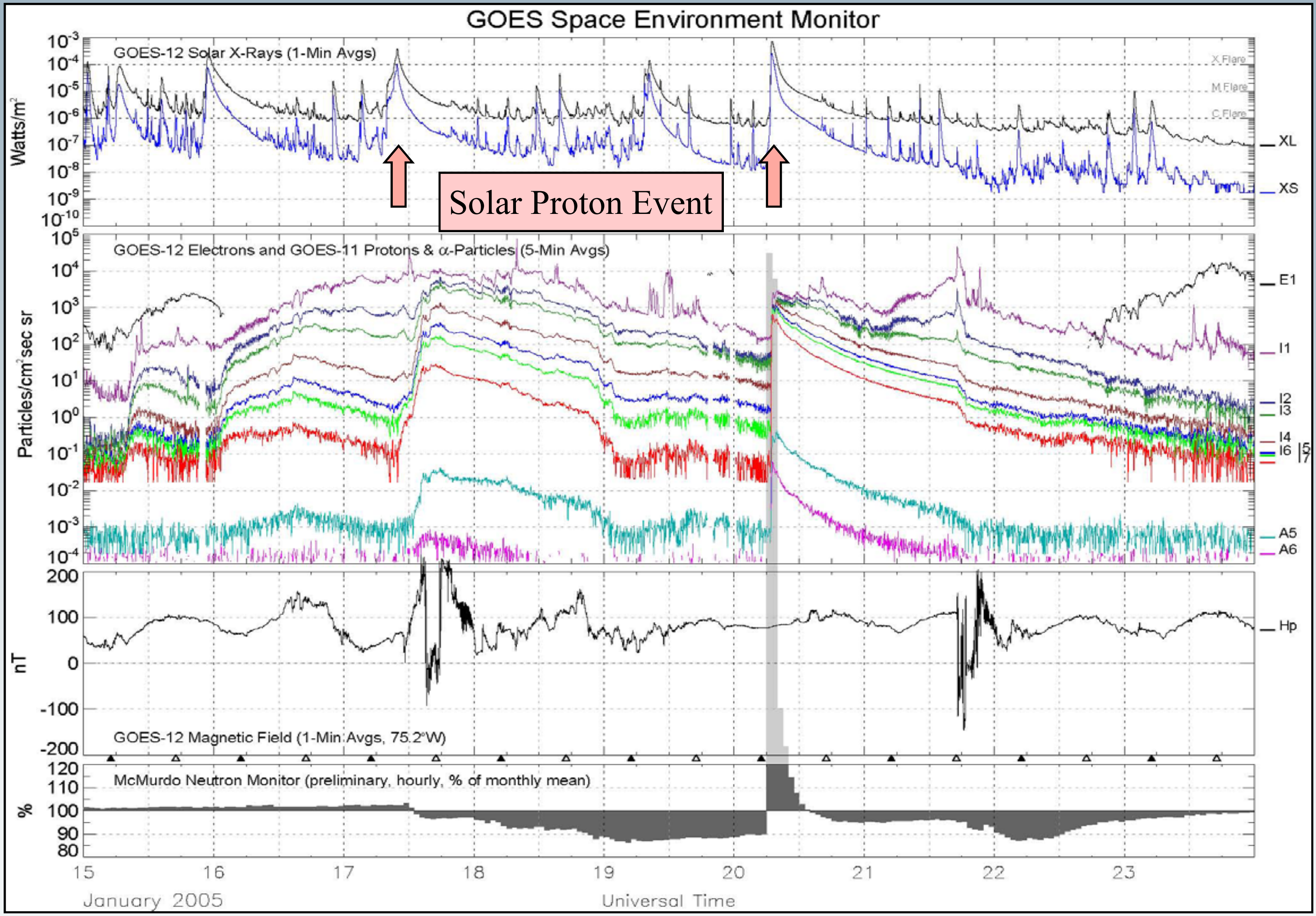
- ➢ PMSE appear if the temperature at 90 km drops below 150 K
- ➢ PMSE are present at both hemispheres in summer as long as equator ward directed winds transport cold air from higher to lower latitudes.

PMSE observations at 69°S in 2004/2005

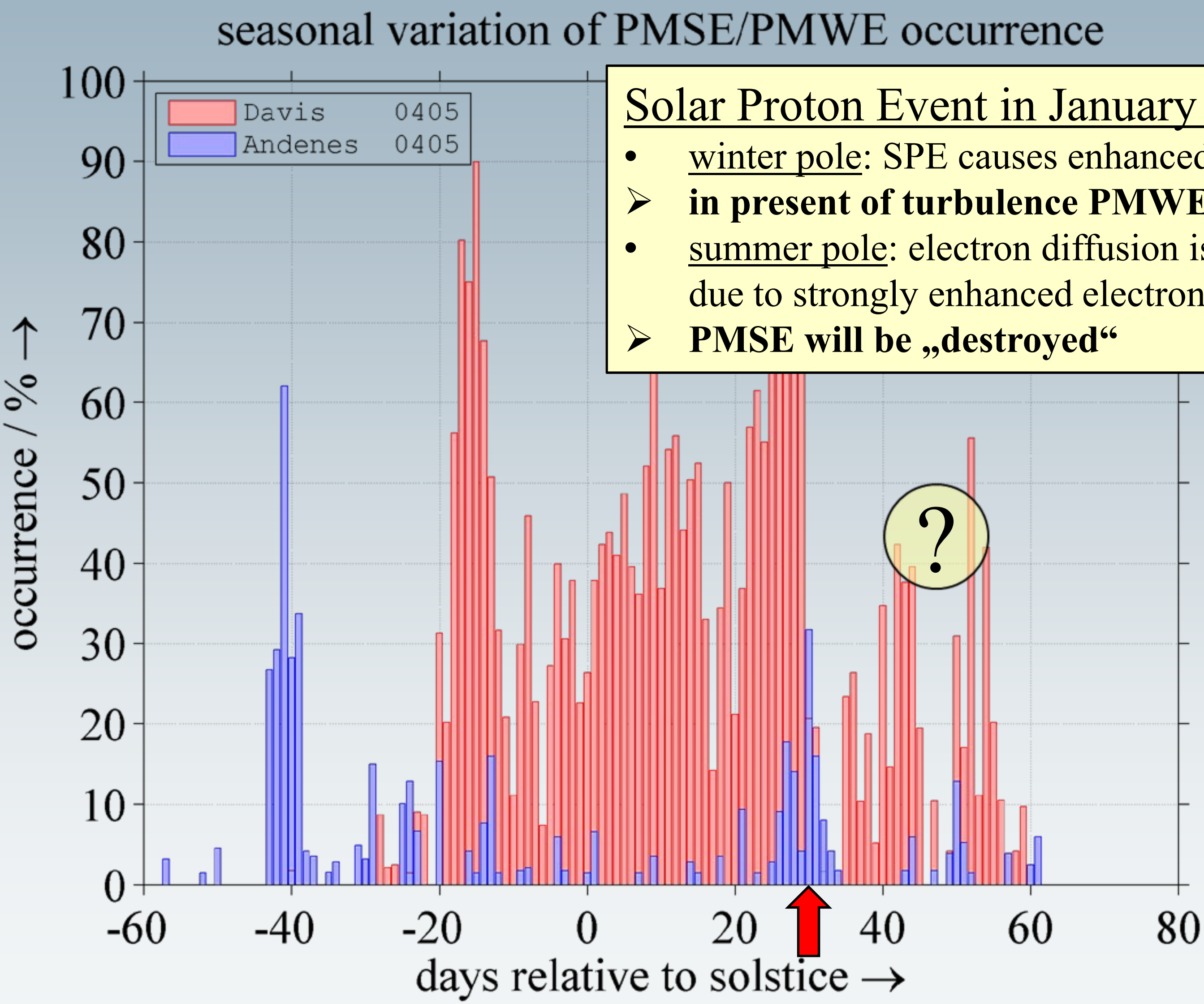


Solar activity after observations of the GOES-satellite

increased X-ray radiation and high energetic particles on 17 and 20 Jan. 2005



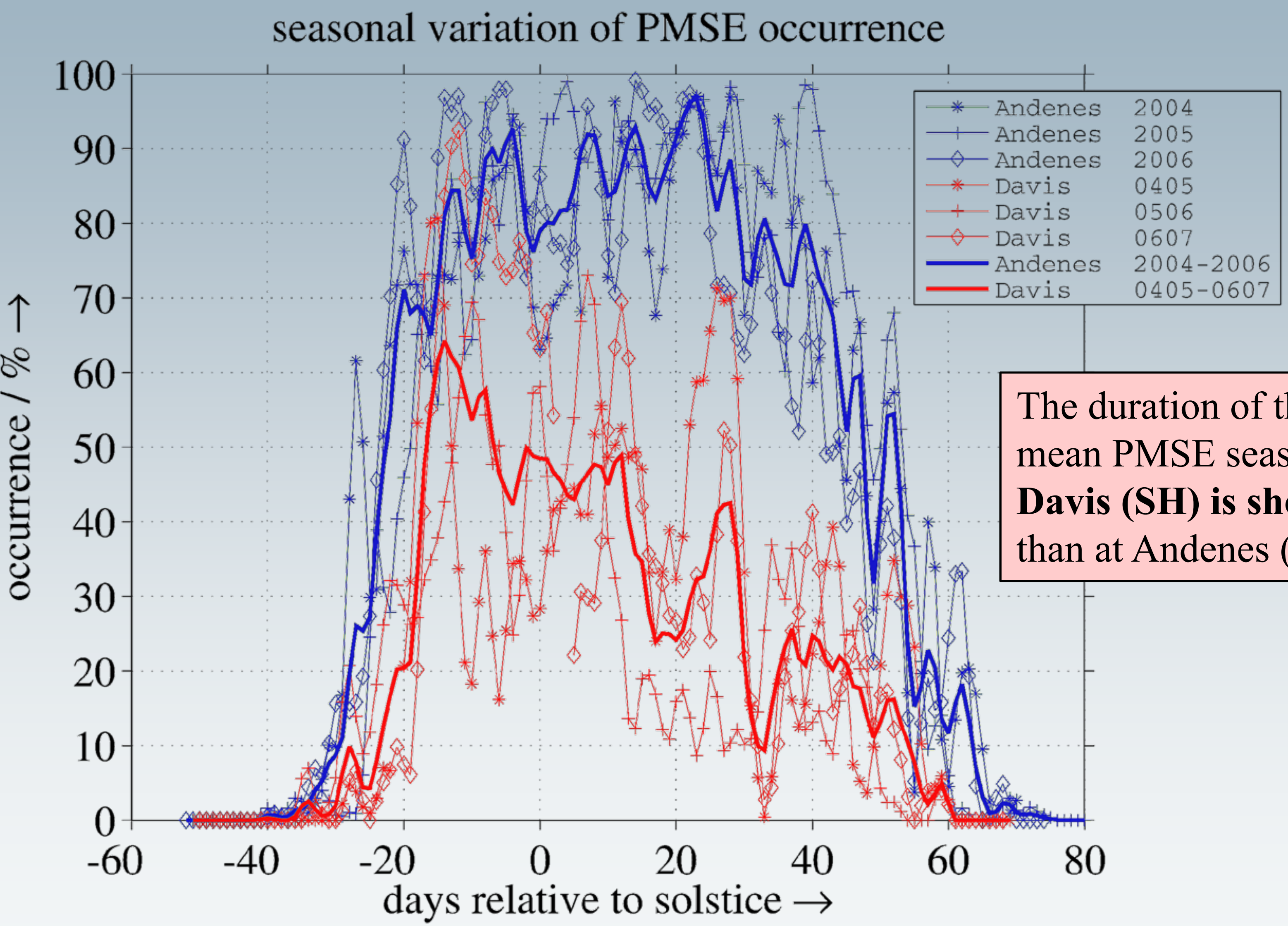
PMWE/PMSE observations at 69°N and 69°S



Solar Proton Event in January 2005

- winter pole: SPE causes enhanced ionisation
- ➢ **in present of turbulence PMWE**
- summer pole: electron diffusion is not reduced due to strongly enhanced electron density
- ➢ **PMSE will be „destroyed“**

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



The duration of the mean PMSE season at **Davis (SH) is shorter** than at Andenes (NH)

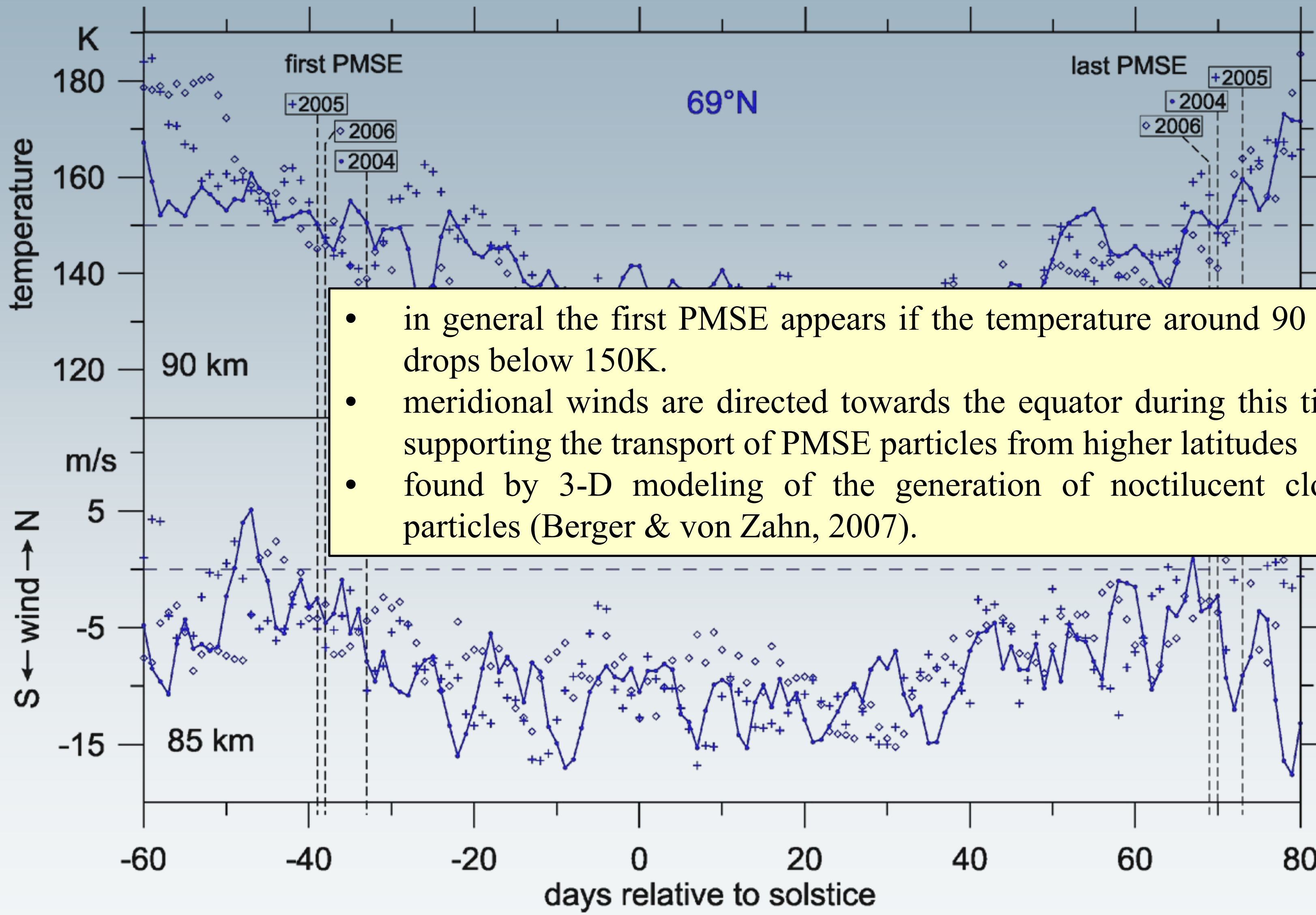
Andenes (69N) – Davis (69°S)

First and last PMSE

Radar site	Year	First PMSE		Last PMSE	
		Date	day relative to solstice	Date	day relative to solstice
Andenes	2004	19 May	-33	30 Aug	70
Andenes	2005	13 May	-39	02 Sep	73
Andenes	2006	14 May	-38	29 Aug	69
mean Andenes	2004-2006	15 May	**-37**	28 Aug	**70**
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
mean Davis	2003-2006	18 Nov	**-33**	18 Feb	**59**

➢ the PMSE season **at Davis (SH) is shorter** than at Andenes (NH)

Comparison of PMSE observations from 69°N
mean temperatures and mean meridional winds

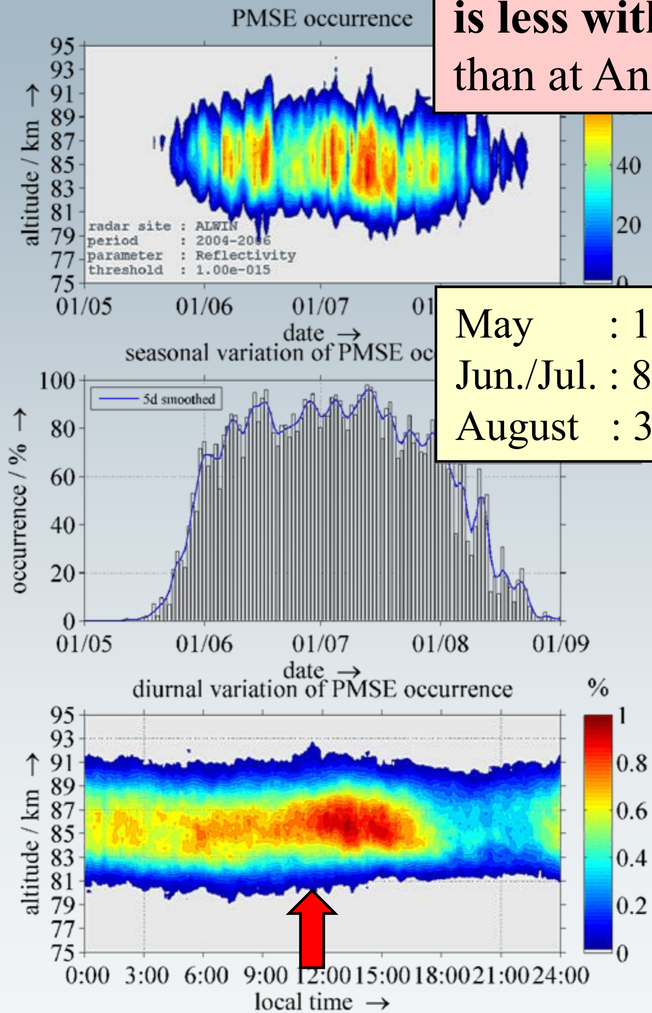


- in general the first PMSE appears if the temperature around 90 km drops below 150K.
- meridional winds are directed towards the equator during this time supporting the transport of PMSE particles from higher latitudes
- found by 3-D modeling of the generation of noctilucent cloud particles (Berger & von Zahn, 2007).

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

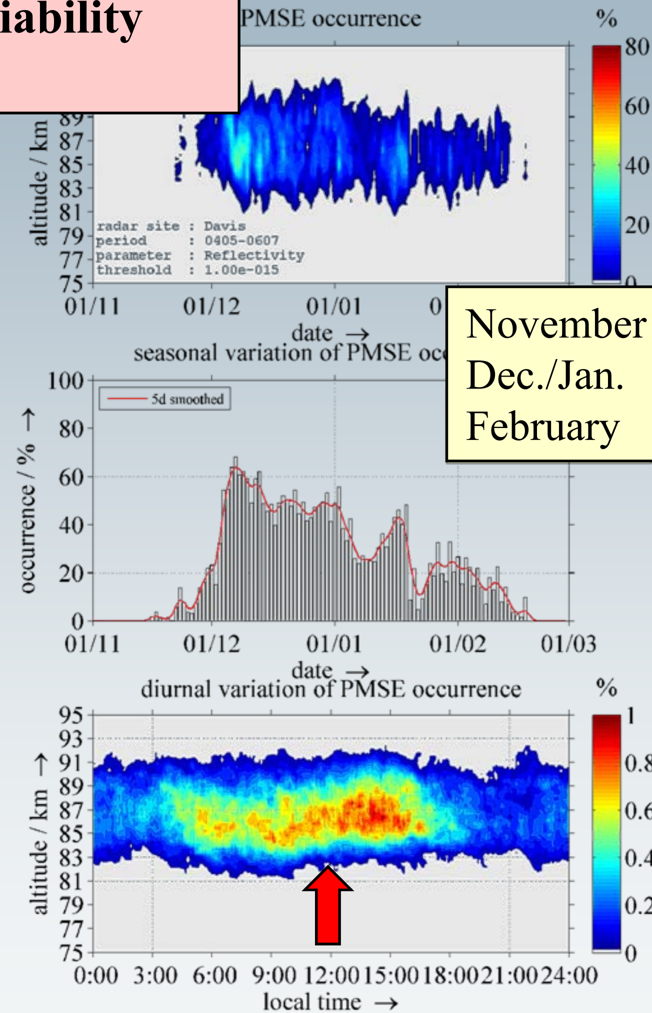
mean seasonal and diurnal variation of PMSE occurrence for $\eta > 1 \cdot 10^{-15}$ m^{-1}

Andenes 2000-2



PMSE occurrence **at Davis (SH) is less with more variability** than at Andenes (NH)

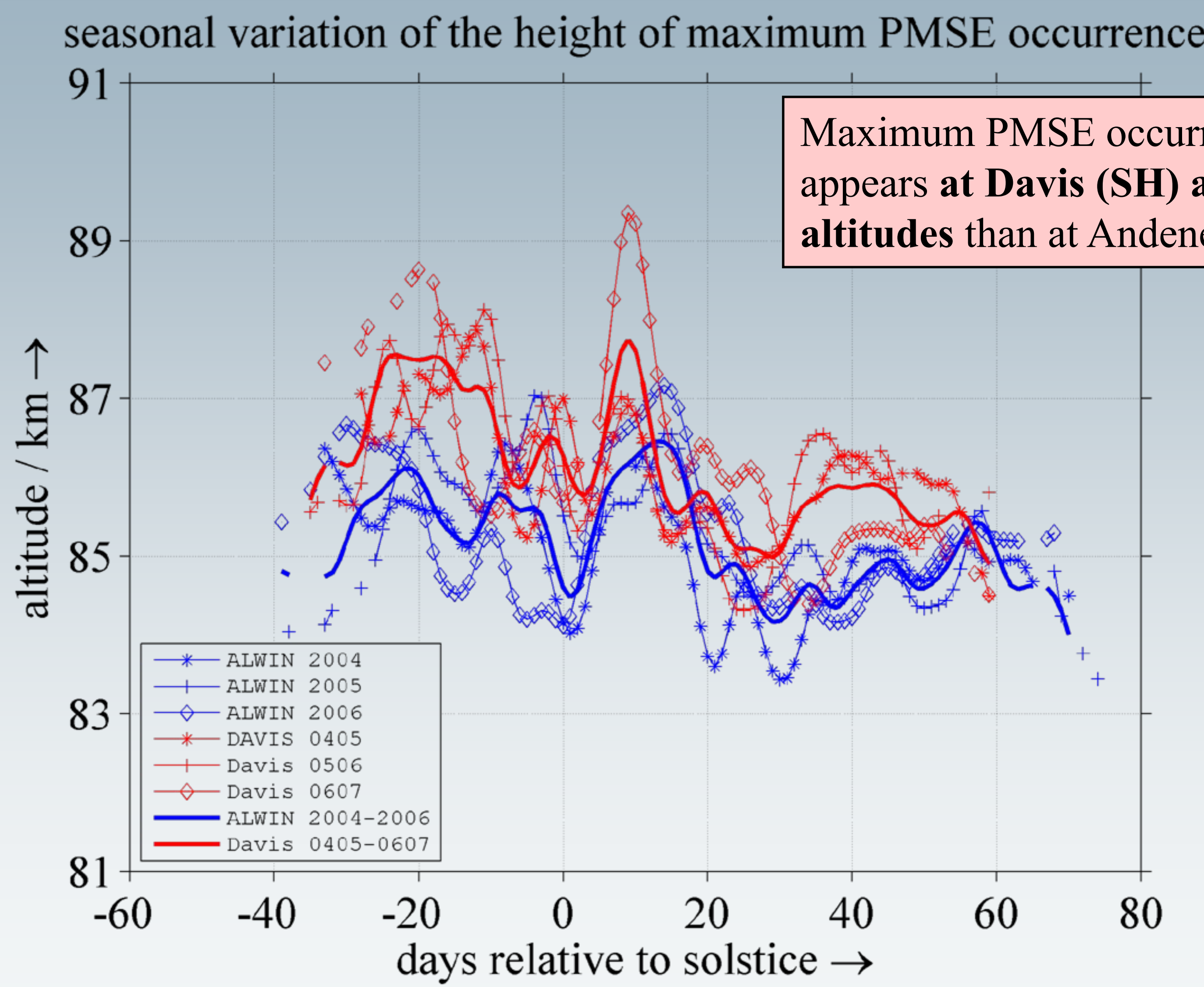
vis 04/05-06/07



May	: 19.3 %
Jun./Jul.	: 82.6 %
August	: 30.9 %

November	: 7.2 %
Dec./Jan.	: 39.0 %
February	: 13.7 %

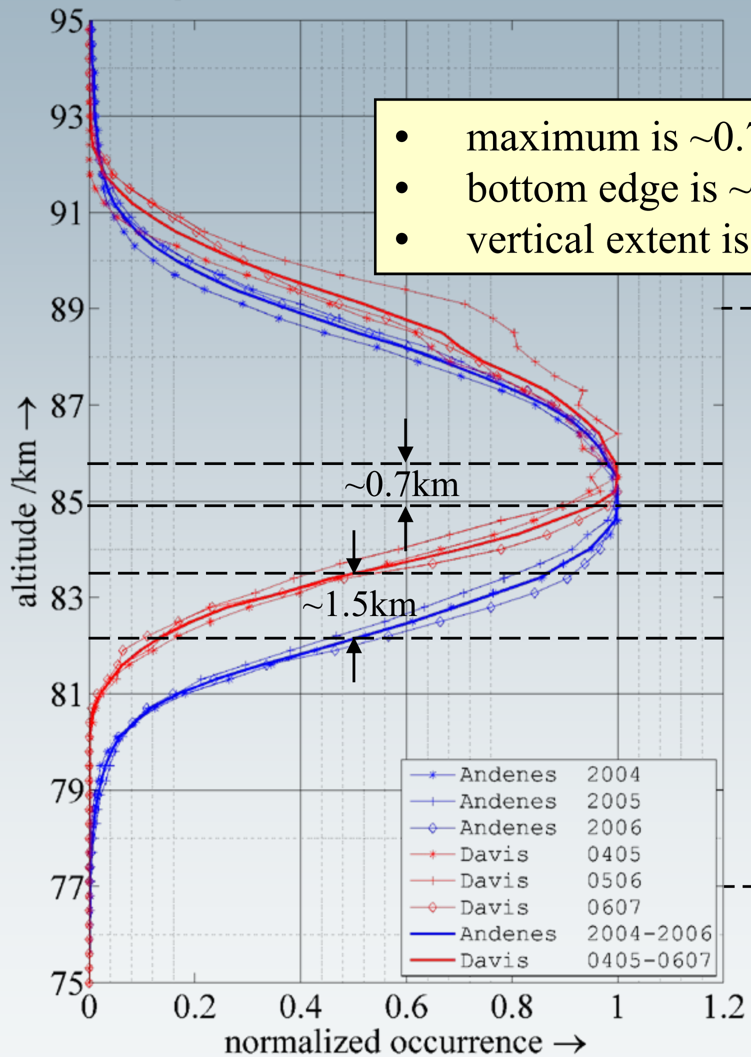
Comparison of PMSE observations from 69°N and 69°S



Maximum PMSE occurrence appears **at Davis (SH) at higher altitudes** than at Andenes (NH)

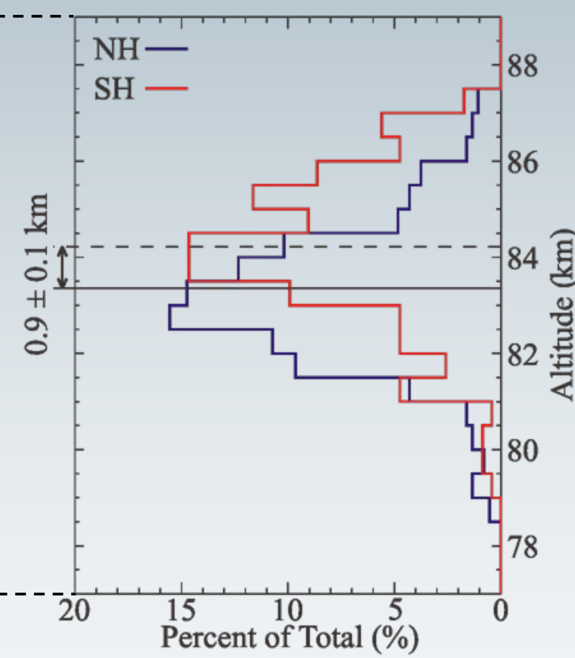
Comparison of PMSE observations from 69°N and 69°S

PMSE height distribution



- maximum is ~0.7 km higher at Davis (SH) than at Andenes (NH)
- bottom edge is ~1.5 km higer at Davis than at Andenes
- vertical extent is ~ 0.9 km smaller at Daivs than at Andenes

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°

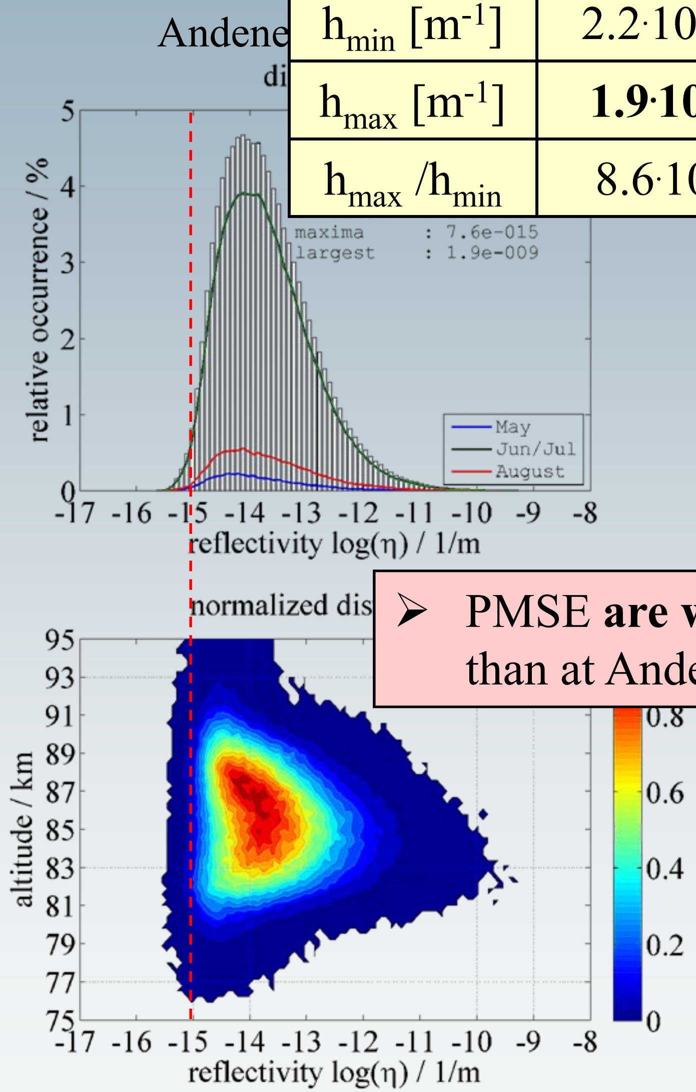


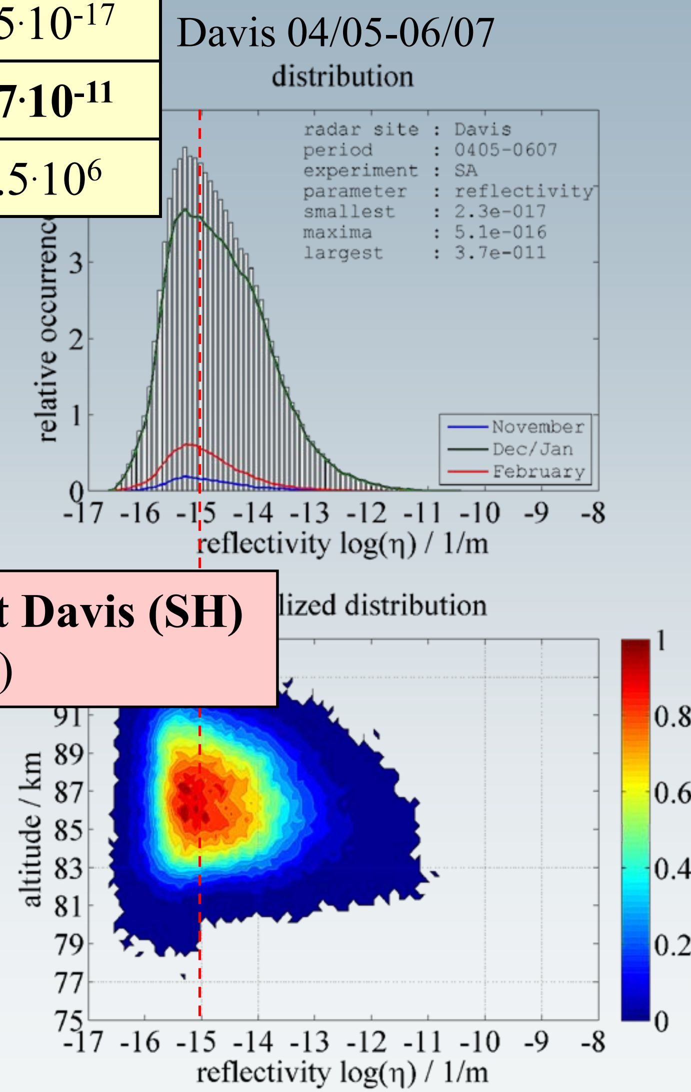
Wrotny et al., *JASTP*, 2006

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

e reflectivity

	Andenes	Davis
h_{min} [m^{-1}]	$2.2 \cdot 10^{-16}$	$1.5 \cdot 10^{-17}$
h_{max} [m^{-1}]	**$1.9 \cdot 10^{-9}$**	**$3.7 \cdot 10^{-11}$**
h_{max} / h_{min}	$8.6 \cdot 10^{6}$	$2.5 \cdot 10^{6}$





- PMSE **are weaker at Davis (SH)** than at Andenes (NH)

Summary

- The comparison of radar results based on signal-to-noise ratios is difficult
  - different system parameters, different experiment configurations
  - ➢ volume reflectivity
  - ➢ requires radar calibration
- PMSE observed at Davis (69°S) have
  - a weaker volume reflectivity ($4 \cdot 10^{-11}\ m^{-1}$) than PMSE observed at Andenes (69°N, $2 \cdot 10^{-9}\ m^{-1}$)
  - a less seasonal occurrence but more seasonal variation than comparable observations at Andenes (69°N)
  - a peak in height distribution at ~86 km (85 km at Andenes)
- The duration of the mean PMSE season at Davis is about 14 days shorter than at Andenes.
  - the shorter PMSE season observed at Davis is related to earlier change of the mesospheric circulation to winter conditions.