## Observations of Polar Mesosphere Summer Echoes in the northern and southern hemisphere

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## Outline

- 1. Motivation
- 2. Volume reflectivity  $\eta$ 
  - 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, 2007
- 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



#### Motivation Polar Mesosphere Summer Echoes 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 $\eta$

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

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

$$P_t = \text{transmitted peak power [W]}$$
  

$$P_r = \text{received signal power [W]}$$
  

$$G_t = \text{gain of transmit antenna}$$
  

$$G_r = \text{gain of receive antenna}$$
  

$$\lambda = \text{radar wave length}$$
  

$$e = \text{efficiency}$$
  

$$\Theta_{1/2} = \text{half power half width of transmit antenna}$$
  

$$r = \text{range to volume center}$$
  

$$2 \ln(2) = \text{beam correction factor}$$
  

$$c = \text{speed of light}$$
  

$$\tau = \text{pulse width} \quad \Delta z = \frac{c \cdot \tau}{2}$$
  

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

volume reflectivity η

 (Hocking and Röttger, RS, 1997)

- Sum of all backscatter cross sections  $\sigma_i$  per unit volume
- includes all system parameters !
- determination of other physical parameters from absolute received power
  - Energy dissipations rates

5

• absolute calibration is required



## Volume reflectivity

#### detection limits of various VHF radars at different sites





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





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
$\rightarrow$ 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
$\rightarrow$ signal factor c <sub>s</sub>	2.3e-19	1.5e-21	1.5e-20



# Comparison of PMSE observations from 69°N and 69°S distribution of PMSE volume reflectivity







# Comparison of PMSE observations from 69°N and 69°S distribution of PMSE volume reflectivity



#### Comparison of PMSE observations from 69°N and 69°S seasonal variation of PMSE occurrence for $\eta > 1.10^{-15} \text{ m}^{-1}$







%

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





















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





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

#### PMSE height distribution





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



Radar	ALWIN	RB-VHF	
Parameters	69°N; 16°E	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	28.3 dBi	24.0 dBi	
antenna array			
Efficiency	0.58	0.09	
Effective pulse width	300 m	750 m	
$\rightarrow$ system factor $c_{sys}$	3.6e-09	4.3e-07	
Experiment parameters			
Number of coherent	37	16	
integrations	52	10	
Number of code elementes	16	1	
Receiver gain	101 dB	116 dB	
Receiver bandwidth	500 kHz	140 kHz	
$\rightarrow$ 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)





### 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)

