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Using HIRLAM data to forecast weather radar propagation conditions

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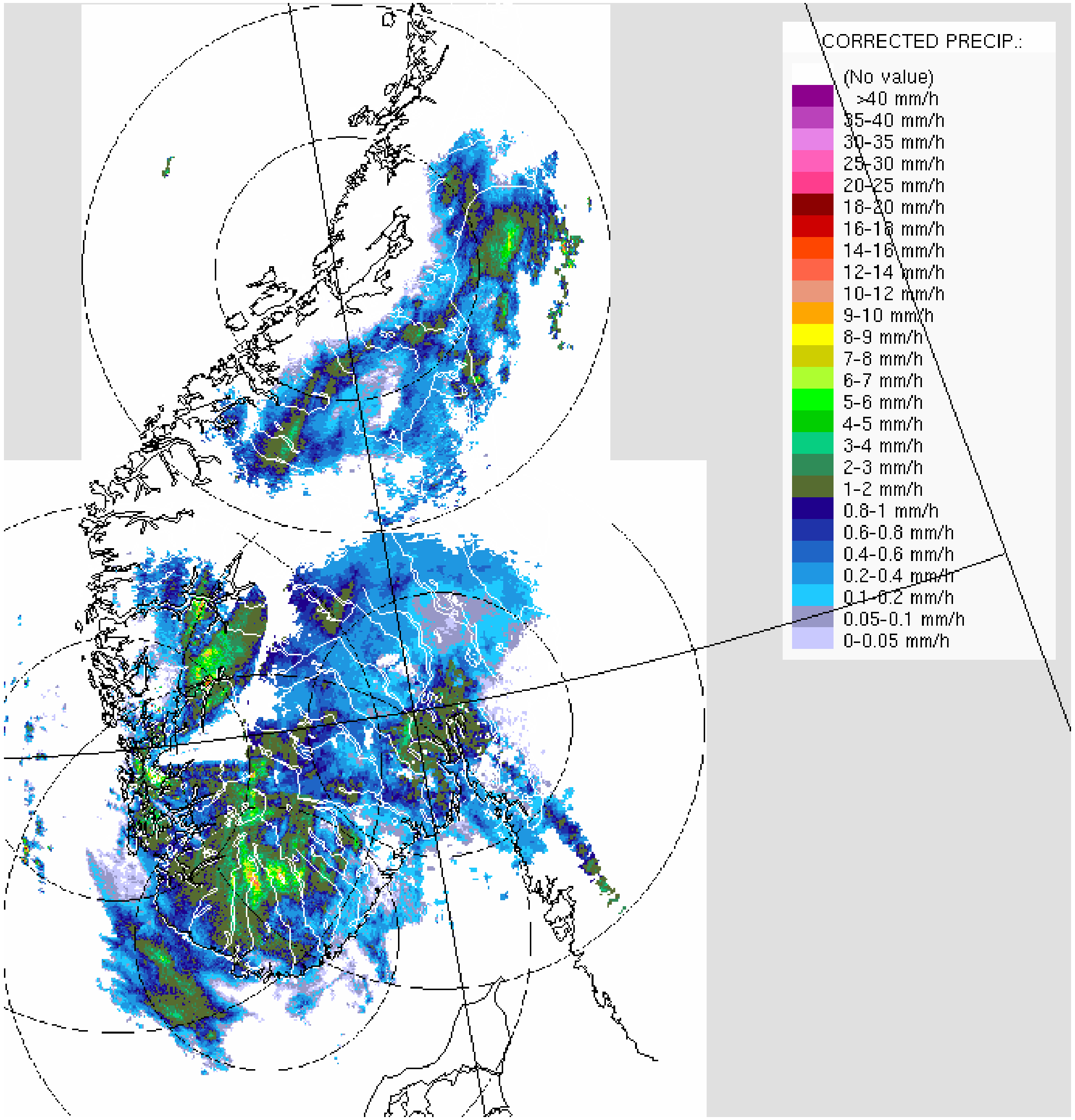
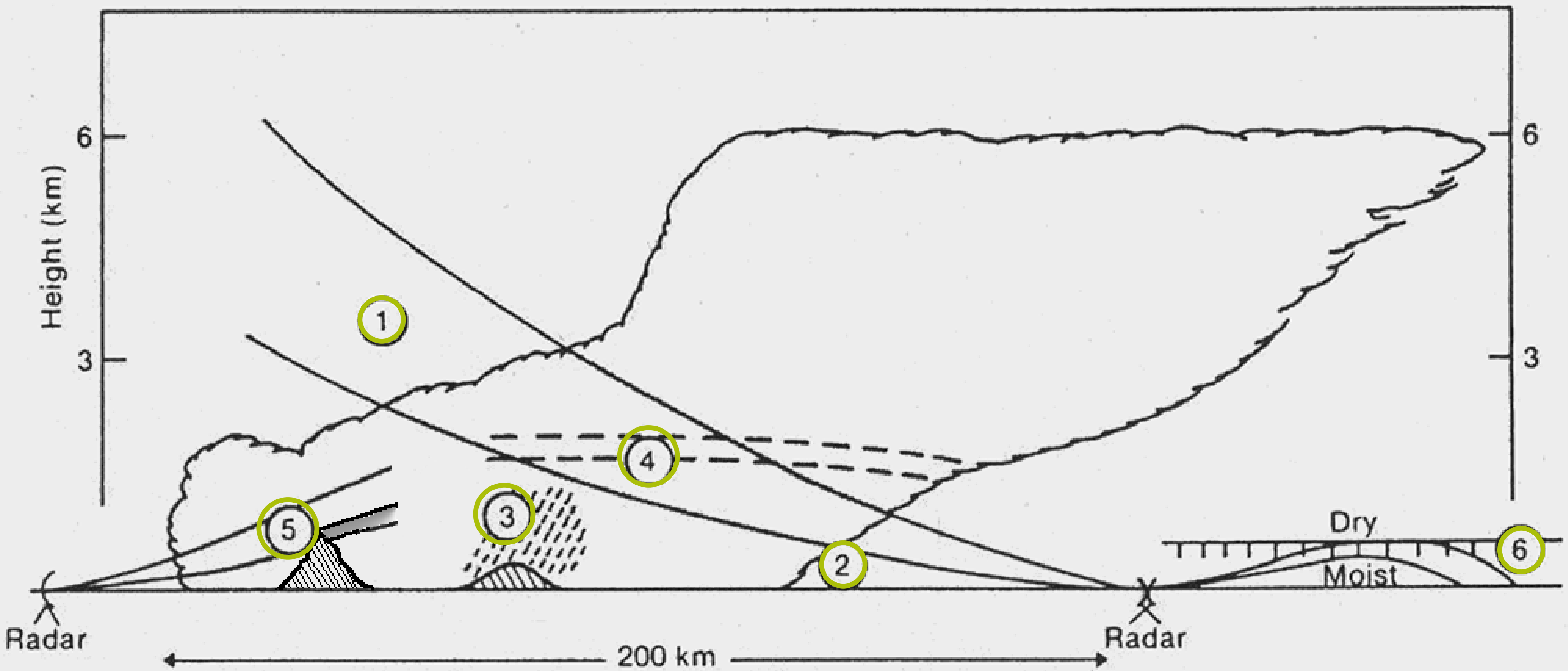
Why radar data quality?

- Composite of radar-derived precipitation
- Do we trust the spatial distribution?
- What about blockages, overshooting, anaprop, etc?



Some generic factors (apart from Z-R relationships) affecting radar observations

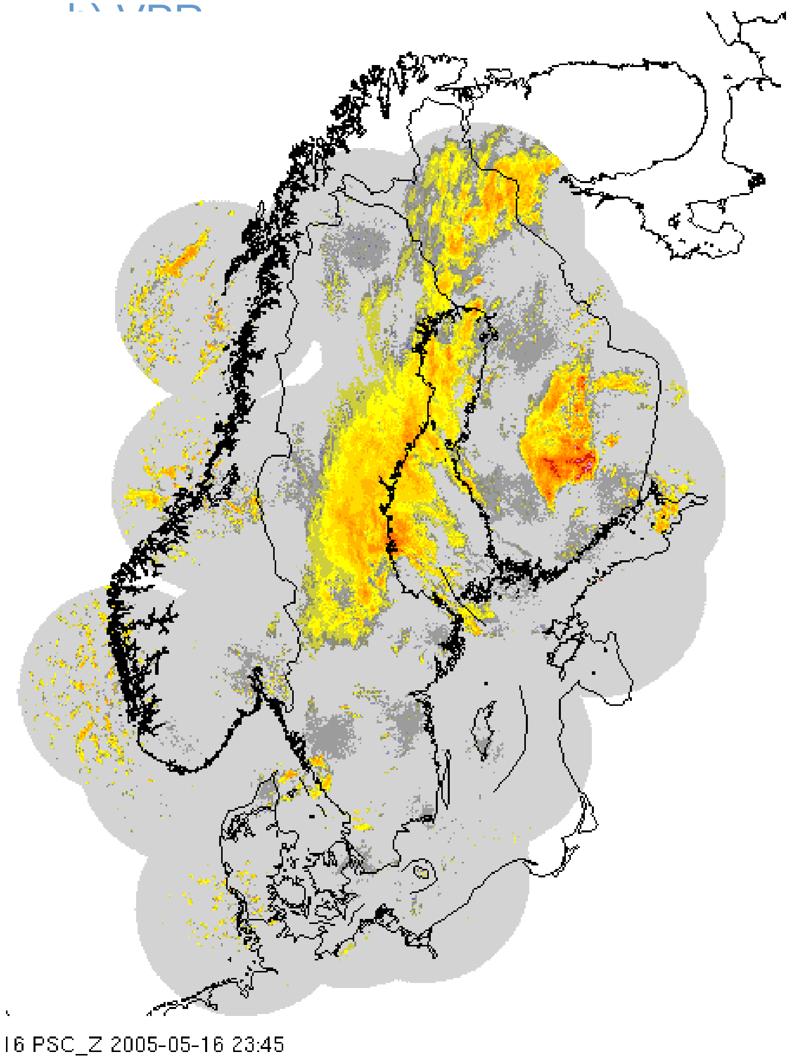


(Adapted from Collier, 1996, after Browning, 1978)

1. Beam overshooting
2. Evaporation
3. Orographic enhancement
4. Bright band
5. Beam blockage
6. Anomalous propagation

Suggested NORDRAD RADAR APPLICATIONS (NORA) quality projects:

a) Beam Propagation Project



Background: Issues concerning the propagation of the radar beam are identified as being of great importance for the quality of radar reflectivity and precipitation products.

Objective: The objective of the proposed project is to **coordinate the work** carried out in the NORDRAD member countries to define **common algorithms** for addressing these challenges.

Deliverables: **site maps** for each NORDRAD radar in polar coordinates to **correct beam blockage**

implementation of the correction fields in the NORDRAD2 system to improve the accuracy of precipitation estimates in blocked regions

AIR REFRACTIVE INDEX n :

In general m = n - i k; for air only n is considered

n = c / v

Near ground n 1,0003 (typically 1,000450 to 1.000250)

REFRACTIVITY N :

$$N \quad (n \quad 1)10^6 \quad \frac{77.6}{T} p \quad \frac{4810 \; e}{T}$$

p,e (hPa)

T (K)

(Bean and Dutton, 1968)

$$N \quad \frac{77.6}{T} p \quad \frac{4810}{T} e \quad 4.03 \quad 10^7 \frac{N_e}{f^2}$$

N_e electronic density, /m^3

f radar frequency, Hz

(Rinehart, 1991)

MODIFIED REFRACTIVITY M

: $M \quad N \quad h / a$

H, height considered

a, Earth radius

VERTICAL REFRACTIVITY GRADIENT (VRG)

VRG1km (ITU, 1997), (USA, Steiner & Smith, 2002), (Italy, Alberoni et al. 2001), ...

$$\frac{N}{z} \quad 0 \quad km^{1}$$

$$\frac{N}{z} \quad 40 \quad km^{1}$$

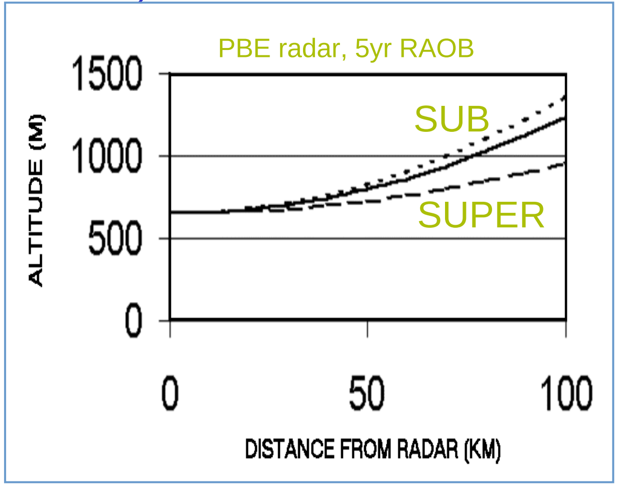
$$\frac{N}{z} \quad 157 \quad km^{1}$$

SUB REFRACTIVE

NORMAL

SUPER REFRACTIVE

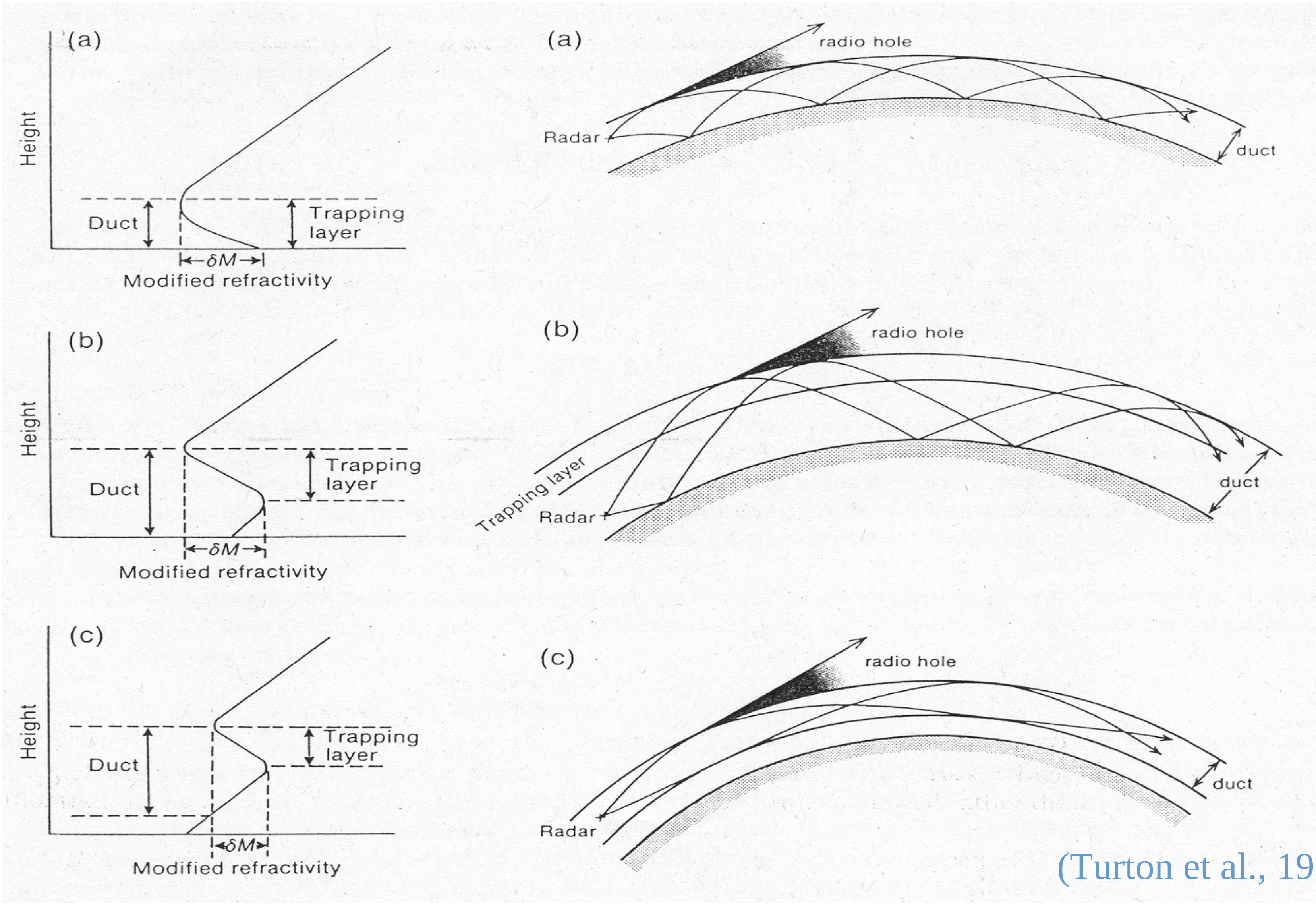
DUCT *ANAPROP*



Radar beam height = H (r, , K),

K=K(dN/dZ)

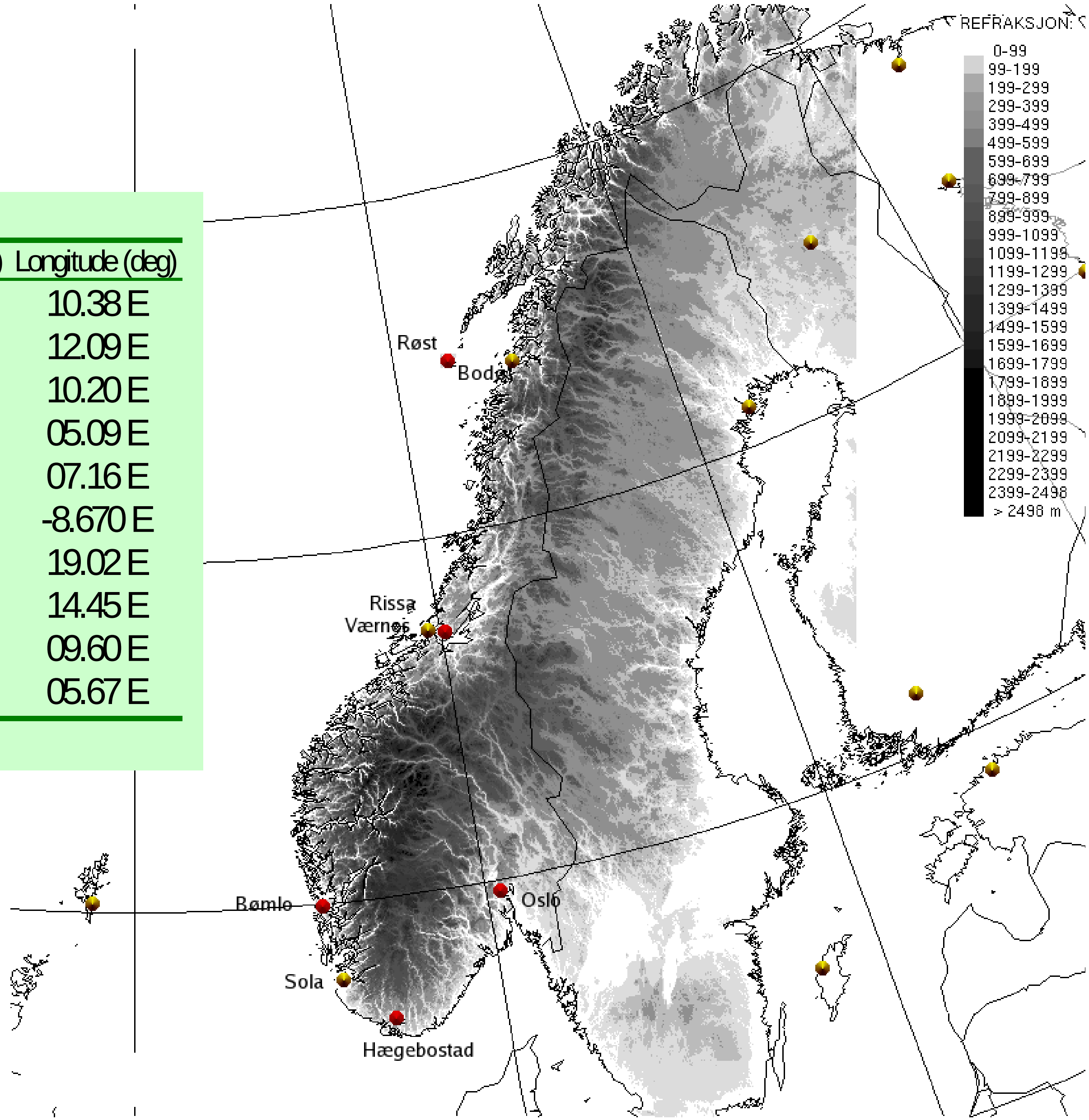
I_D = max{78 z - M} Ducting Index Johnson et al. (1999)



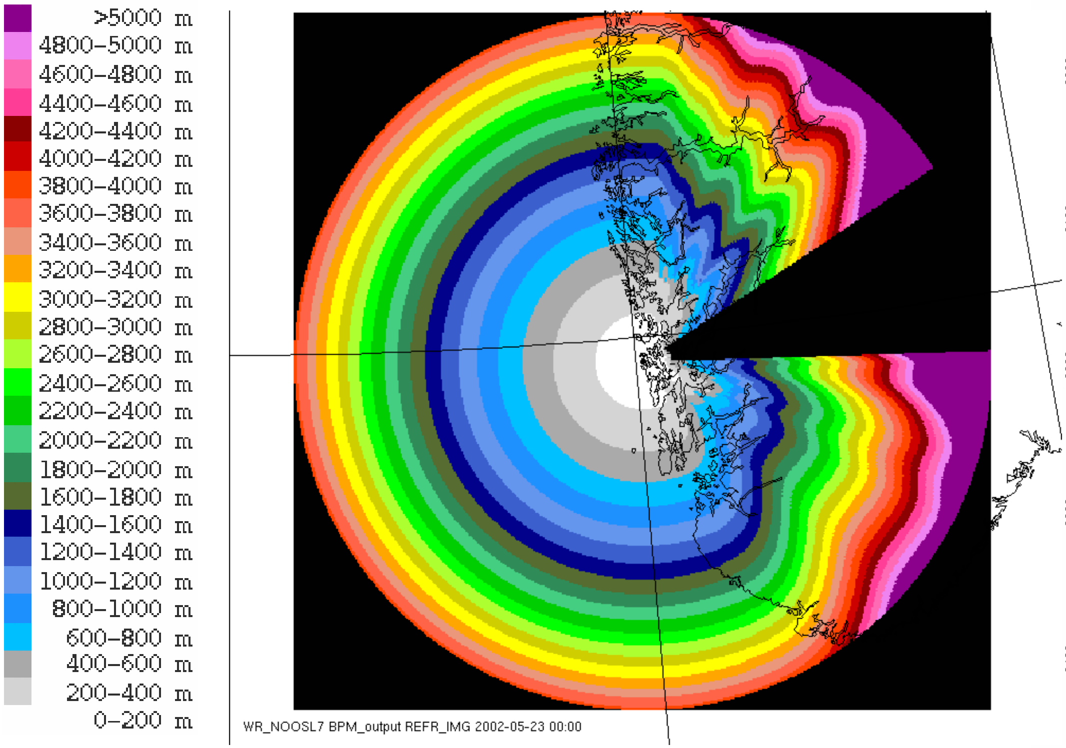
(Turton et al., 1988)

Area of study

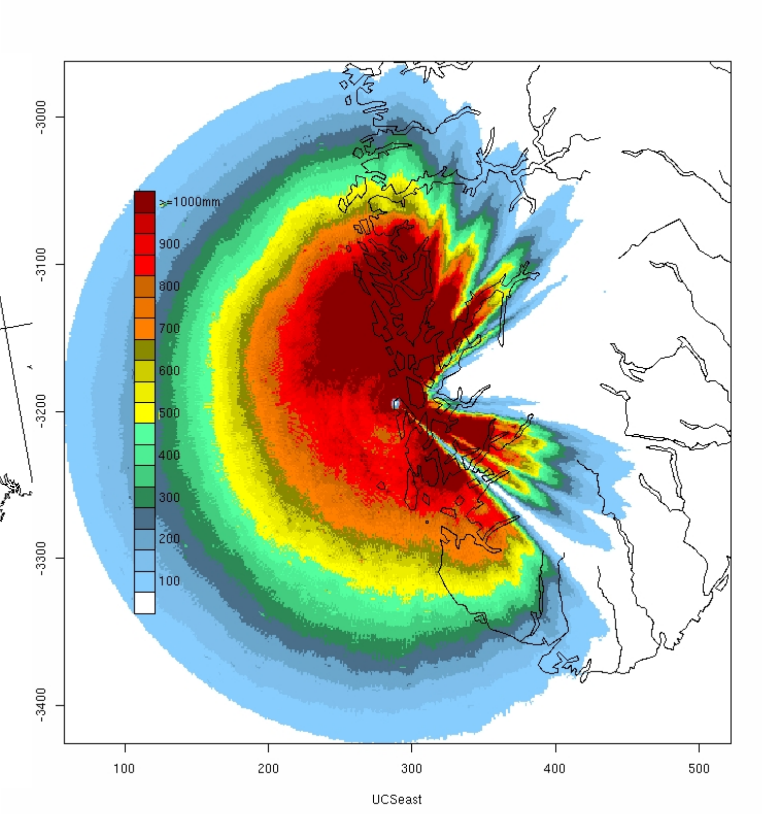
Site Name	Type	WMO Code	Latitude (deg)	Longitude (deg)
Oslo	Radar	01499	59.85 N	10.38 E
Røst	Radar	01104	67.52 N	12.09 E
Rissa	Radar	01247	63.69 N	10.20 E
Bømlo	Radar	01405	59.85 N	05.09 E
Hægebostad	Radar	01438	58.36 N	07.16 E
Jan Mayen	Radiosonde	01001	70.93 N	-8.670 E
Bjornoya	Radiosonde	01028	74.50 N	19.02 E
Bodø	Radiosonde	01152	67.28 N	14.45 E
Værnes	Radiosonde	01241	63.07 N	09.60 E
Sola	Radiosonde	01415	58.87 N	05.67 E



1-year accumulation for radar Bømlo and BPM output

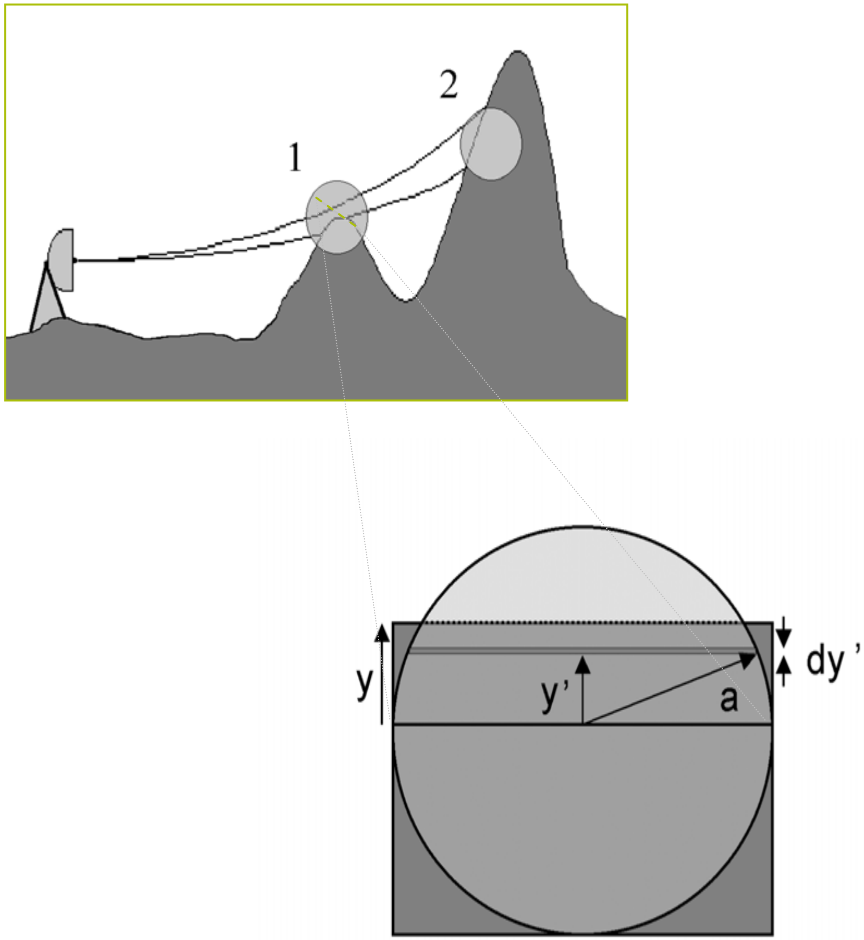


Height of lower beam edge 0.5 degree elevation



accumulated precipitation for 2004

A Simplified Radar Beam Blockage Interception function (1)



$$dBB \quad dy' \quad 2\sqrt{a^2 \quad y'^2}$$

$$BB \quad {}_{a}^{y} \; 2\sqrt{a^2 \quad y'^2} \quad dy'$$

$$2 \quad \frac{y'^2}{2}\sqrt{a^2 \quad y'^2} \quad \frac{a^2}{2} \; \arcsin\frac{y'}{a} \quad {}_{a}^{y}$$

$$y\sqrt{a^2 \quad y^2} \quad a^2 \arcsin\frac{y}{a} \quad \frac{\pi \quad a^2}{2} \; .$$

$$PBB \quad \frac{y\sqrt{a^2 \quad y^2} \quad a^2 \arcsin\frac{y}{a} \quad \frac{\pi \quad a^2}{2}}{\pi \quad a^2} \; .$$

A Simplified Radar Beam Blockage Interception function (2)

$$k_e \qquad \frac{1}{1 \qquad R \; \frac{dN}{dh}} \; .$$

$$PBB \quad \frac{1}{} \; \frac{4 \quad z \quad k_e R \quad \sqrt{r^2 \quad k_e^2 R^2 \quad 2\, r\, k_e\, R \sin} \quad H_a}{r^2 \quad {}^2}$$

$$\sqrt{\frac{r^2 \quad {}^2}{4} \quad z \quad k_e R \quad \sqrt{r^2 \quad k_e^2 R^2 \quad 2\, r\, k_e\, R \sin} \quad H_0 \quad {}^2}$$

$$\arcsin \frac{2 \quad z \quad k_e R \quad \sqrt{r^2 \quad k_e^2 R^2 \quad 2\, r\, k_e\, R \sin} \quad H_0}{r} \qquad \frac{}{2} \qquad .$$

k_e : Earth's Radius Equivalent Factor.

dN/dh: Vertical Refractivity gradient.

R: Earth's Radius

z : Terrain altitude.

r : Distance from the Radar.

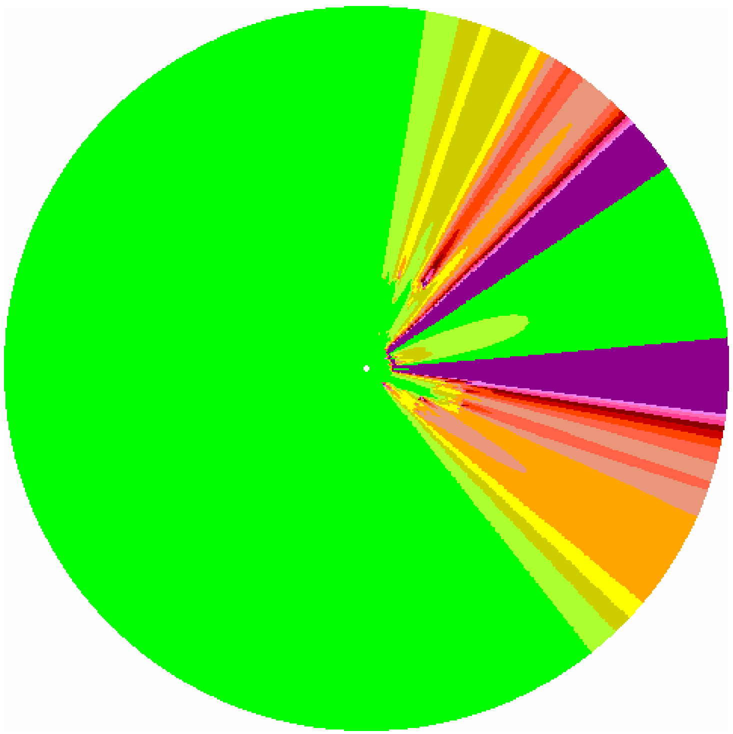
: Antenna elevation angle.

H_0: Antenna altitude.

: Antenna beam width.

(Bech et al, 2003)

Correction field for precipitation



$$BB \quad \frac{y\sqrt{a^2 \quad y^2} \quad a^2 \arcsin\frac{y}{a} \quad \frac{*\,a^2}{2}}{*\,a^2}$$

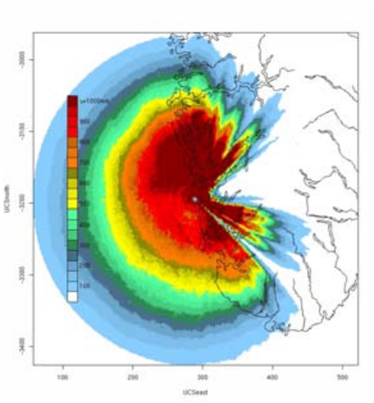
(BB=beam blockage, y=distance center beam - topography, a=radius radar beam cross section)

$$bcorr \quad \left(\frac{1}{1 \quad BB}\right)^{\frac{1}{b}}$$

(bcorr=correction factor for precipitation, b=Marshall-Palmer b coefficient)

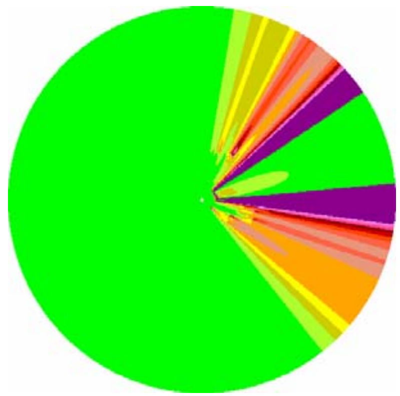
50%	1.54
60%	1.77
70%	2.12

Radar Bømlo



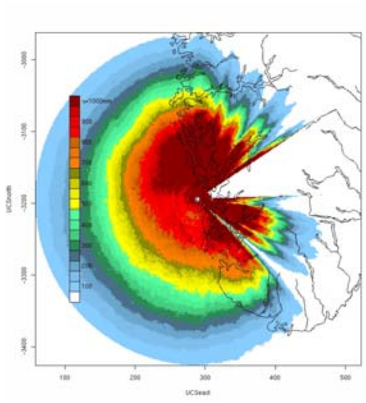
Uncorrected precipitation

*

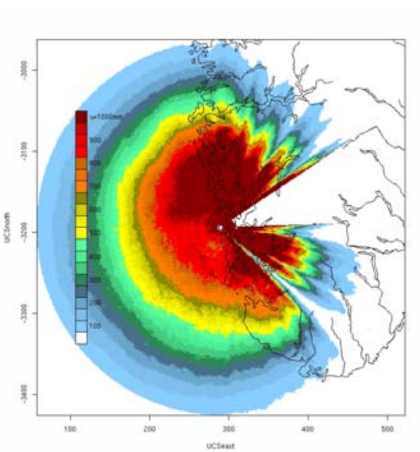


Correction field factor

=

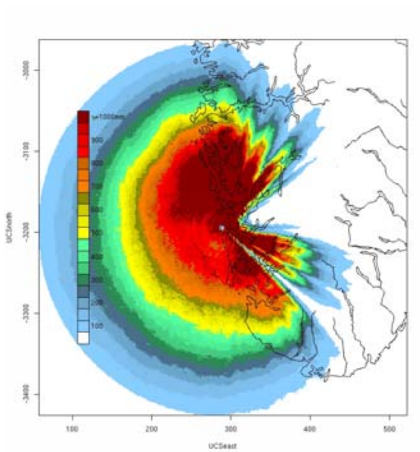


Corrected precipitation



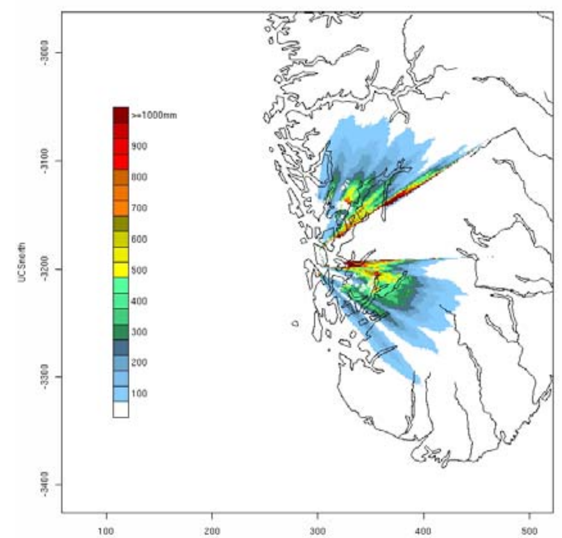
Corrected precipitation

-



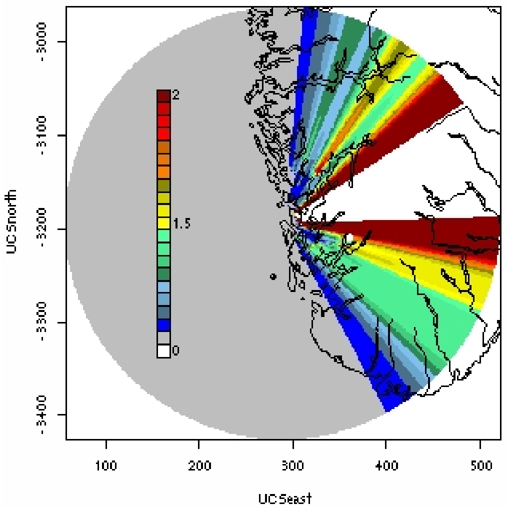
Uncorrected precipitation

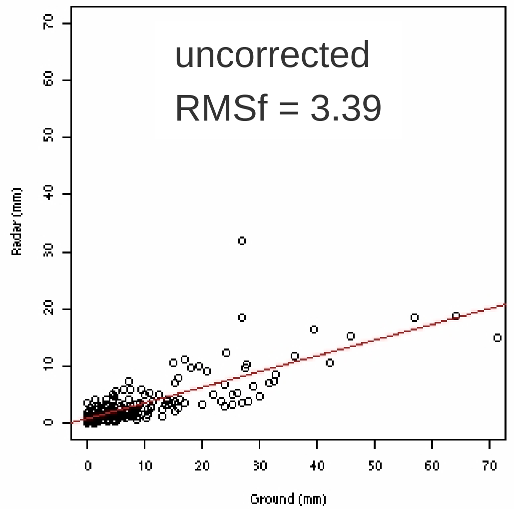
=

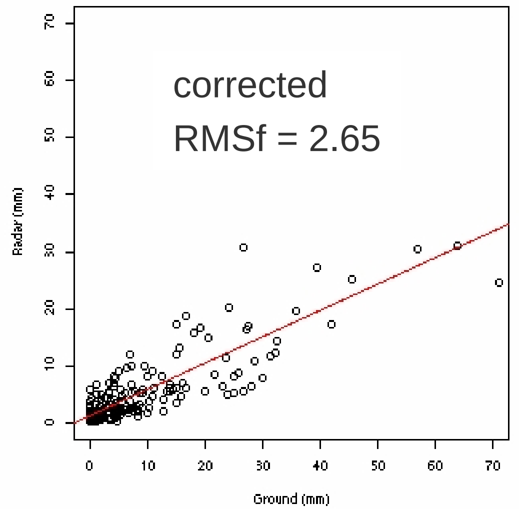


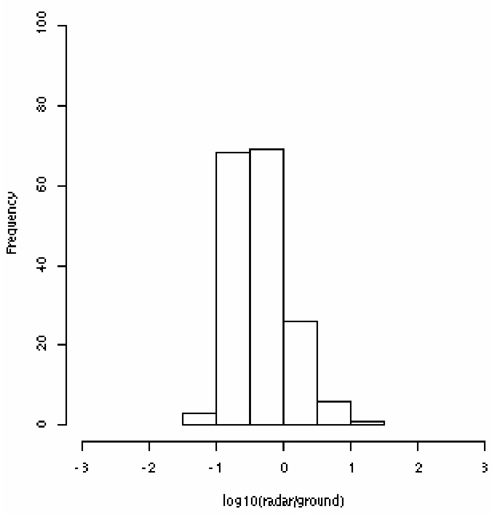
Corrected areas

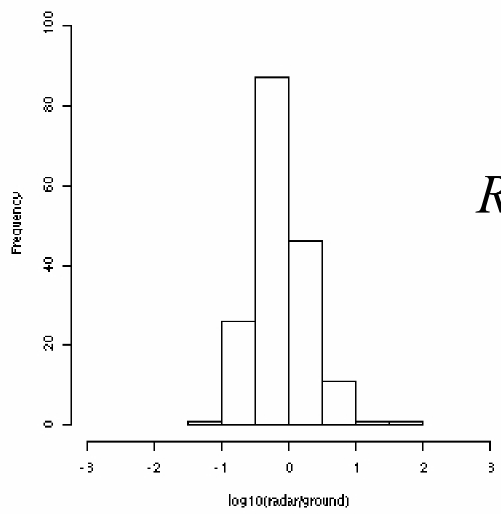
Blockage correction at station 46610, 75 km from radar, daily accumulations 2004





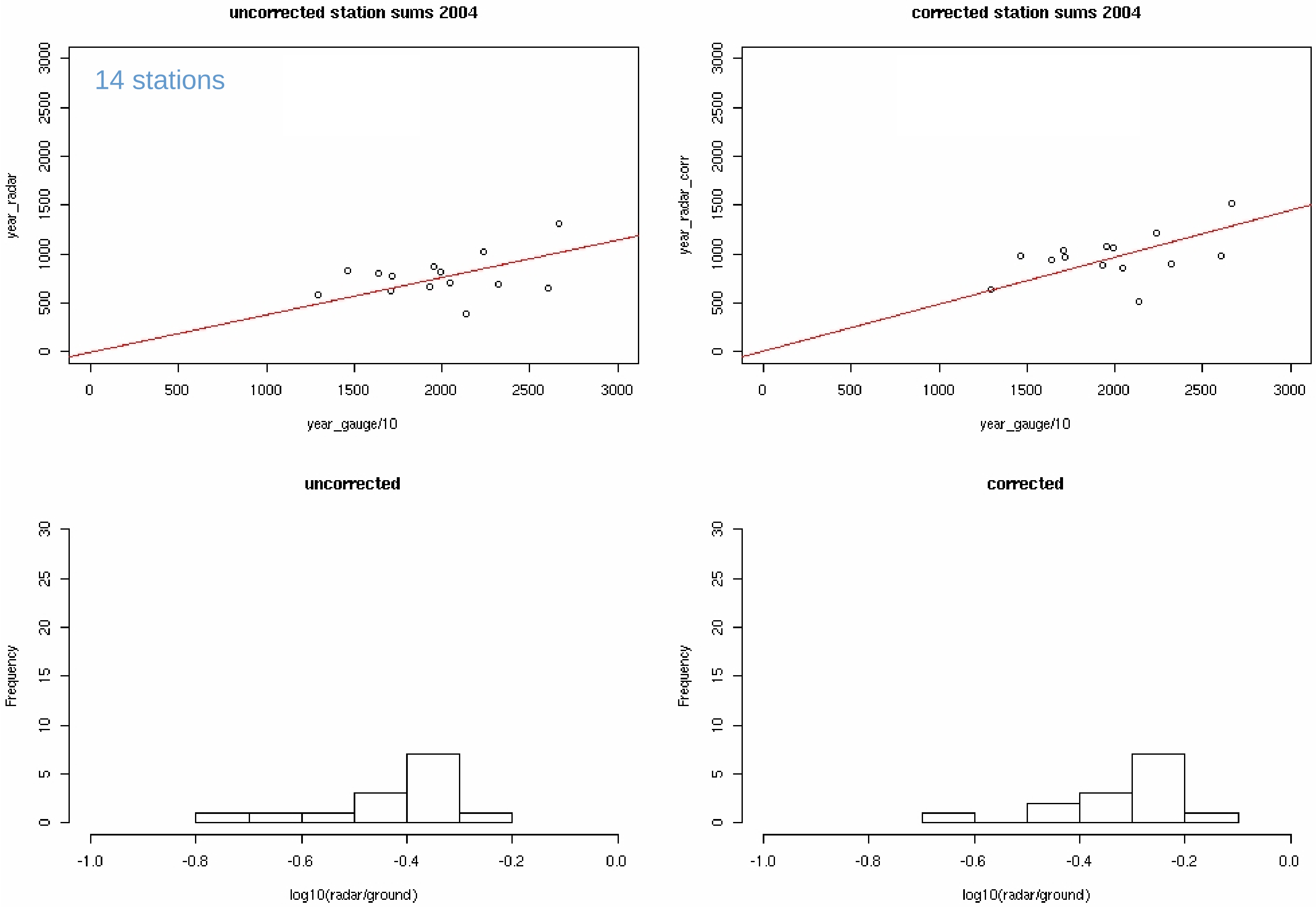




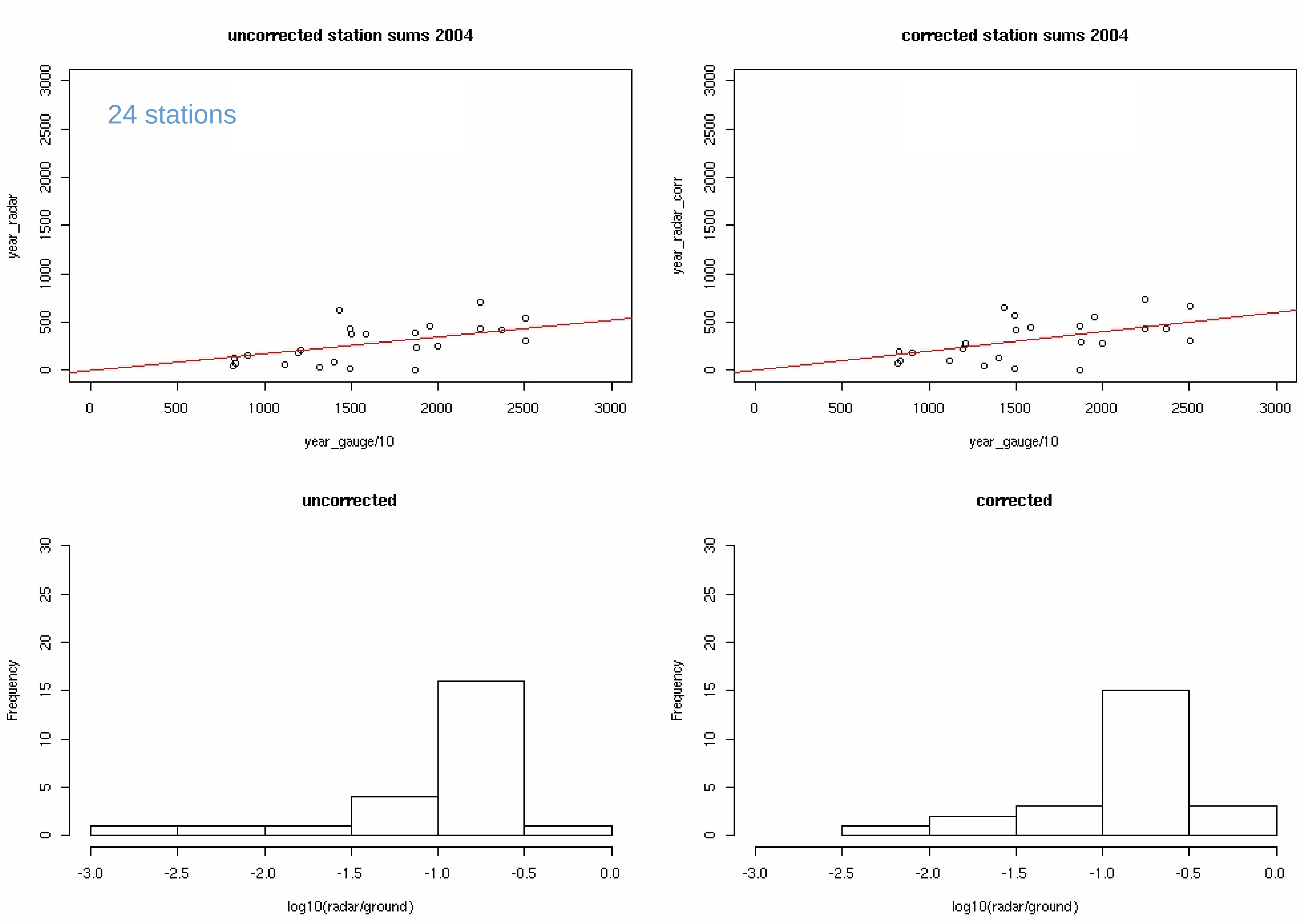


$$RMSf = \exp\left[\left(\frac{1}{N}\sum_{i=1}^{n}\left(\ln\frac{R_i}{G_i}\right)^2\right)^{\frac{1}{2}}\right]$$

40-100 km from radar



100-160 km from radar



RMSf and mean bias for different distances and blockages

RMSf

bb \ km	40-100	100-160	160-240
0%	1.73	3.45	14.58
1 - 50%	2.73 2.19	11.75 9.70	37.16 30.70
50-70%	8.27 4.57	40.70 22.75	167.50 97.19

BIAS(dB)=10*$\log_{10}$(radar/gauge)

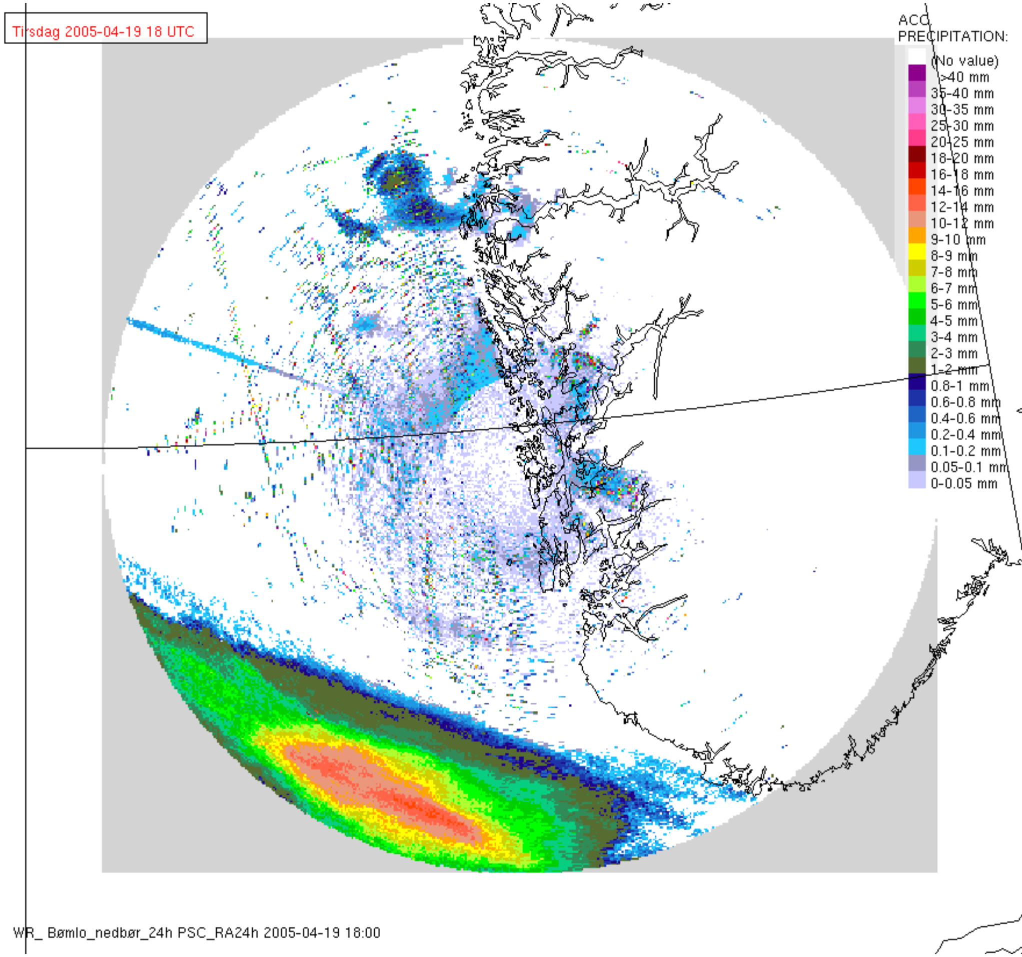
bb \ km	40-100	100-160	160-240
0%	-2.33	-5.19	-11.17
1 - 50%	-4.17 -3.22	-9.33 -8.50	-15.00 -14.17
50-70%	-9.3 -6.5	-14.96 -12.29	-21.44 -19.05

Black=uncorrected

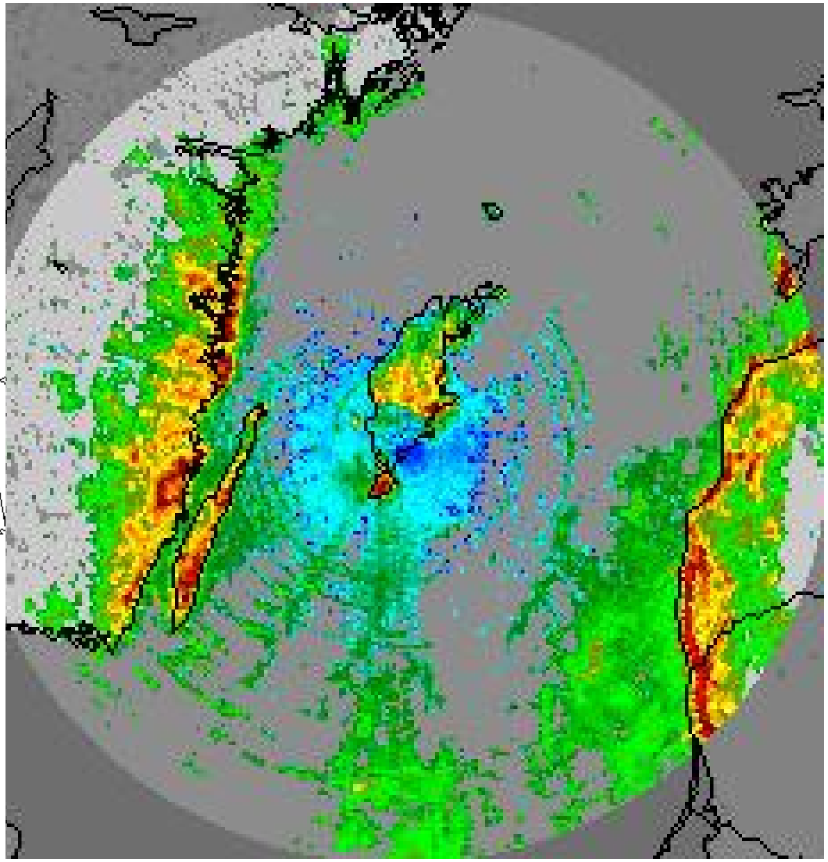
Blue= corrected

What about anaprop?

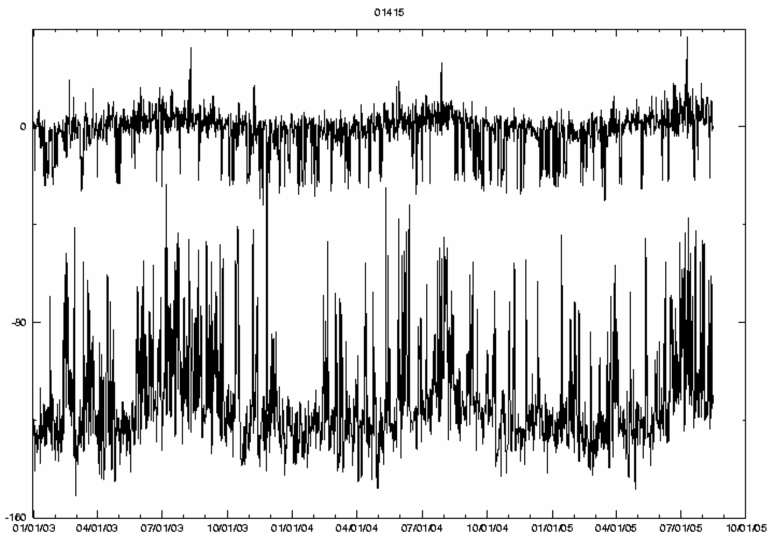
Radar Bømlo, Western Norway



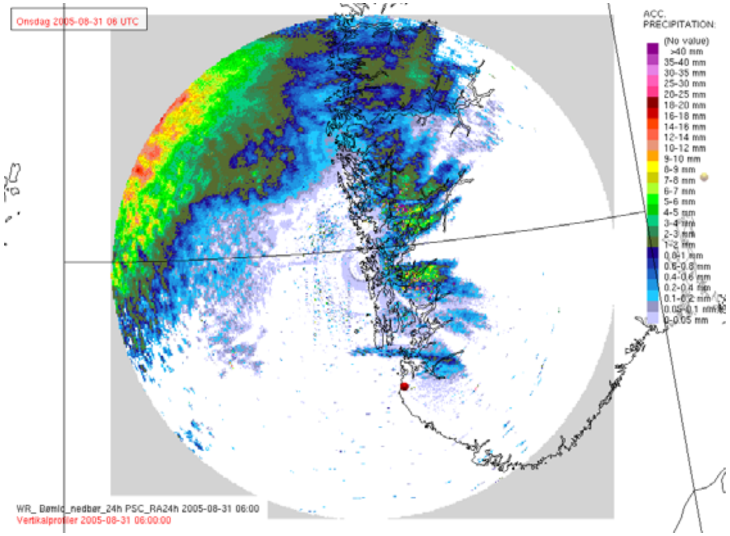
Radar Hemse, Gotland, Sweden

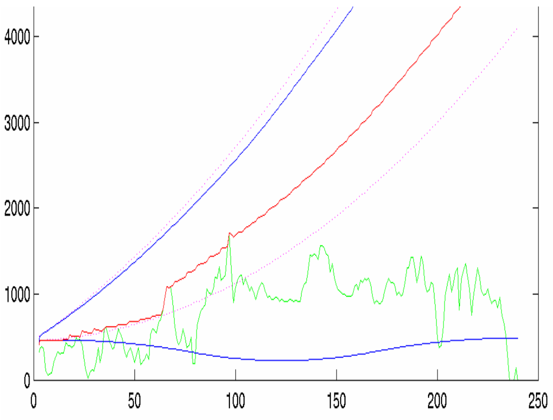


Radar Bømlo and radiosonde Sola 1415



Time series of IDmax and IDmin for station Sola

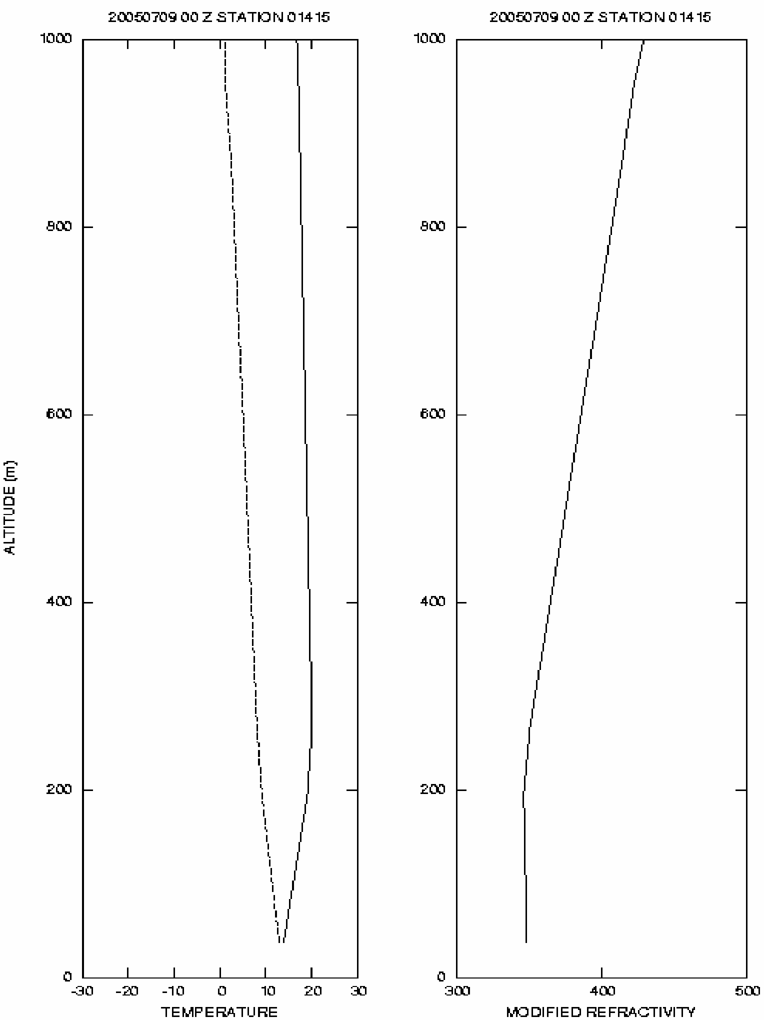




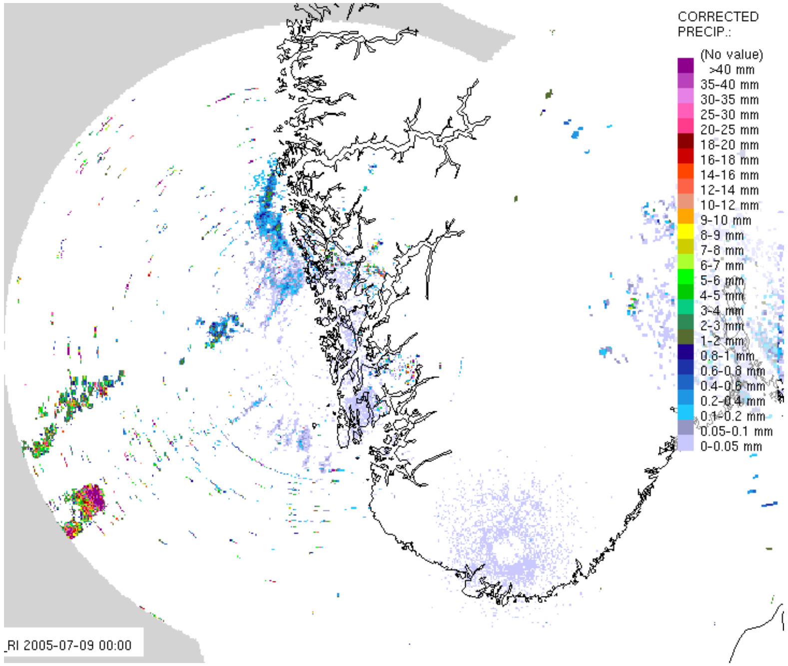
Radiosonde data from closest station is used to identify anaprop cases; the cases are studied to assess the influence of propagation changes on the degree of blockage.

The importance of using temporally/spatially variable correction fields should also be examined.

anaprop case 9.7.2005, 00:00 UTC
Radar Bømlo

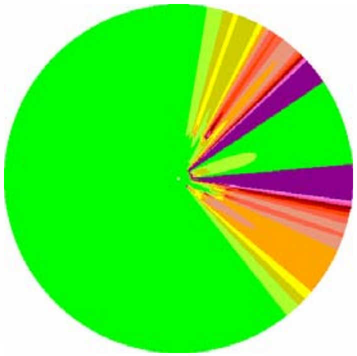


Precipitation intensity product

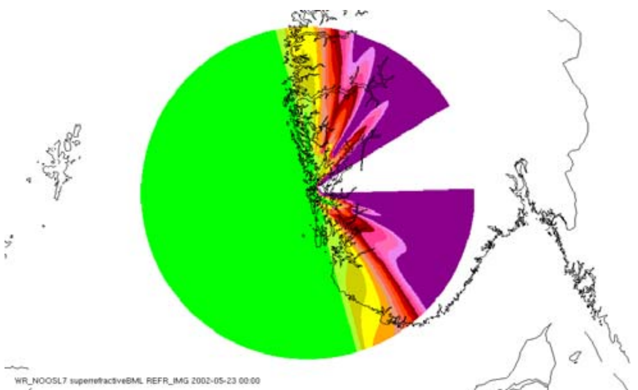


Correction factor field

Normal atmosphere



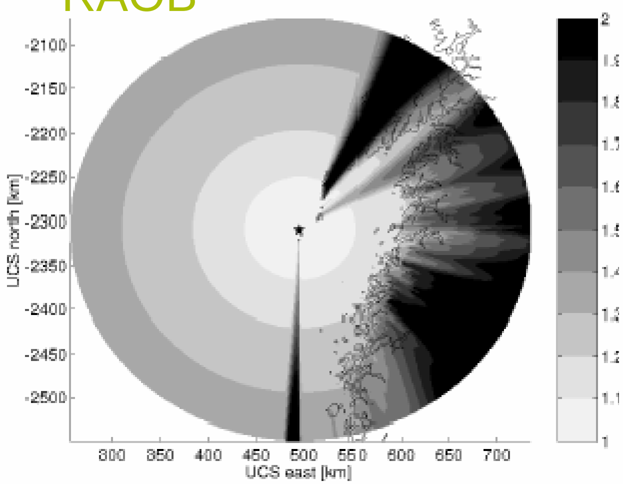
Radiosonde data



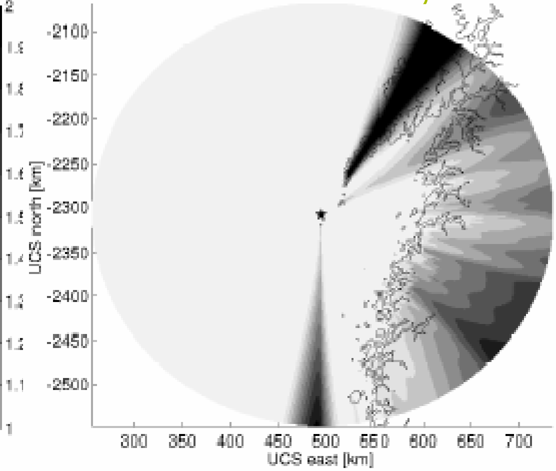
Anaprop case 5.7.2005, 00:00 UTC

Radar Røst : different general pattern NWP-RAOB; different model resolutions

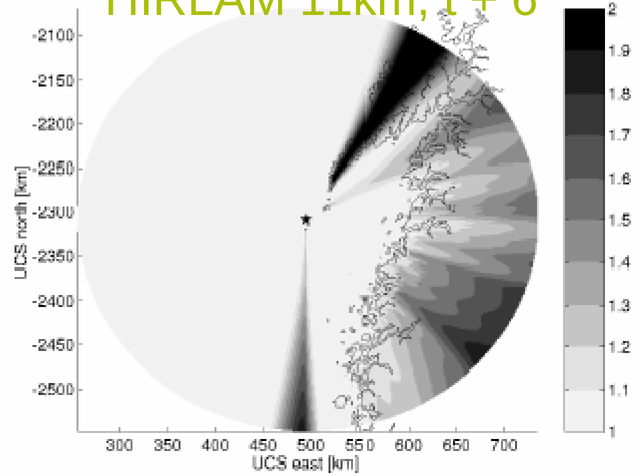
RAOB

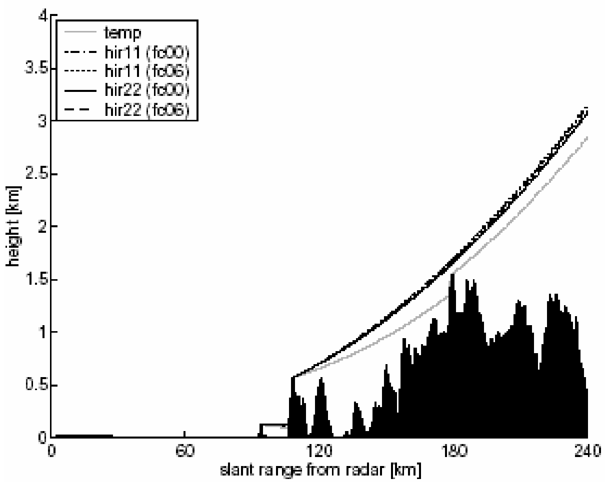


HIRLAM 11km, t+ 0

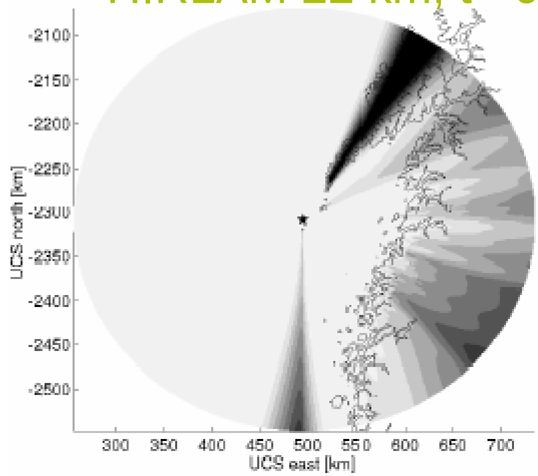


HIRLAM 11km, t + 6

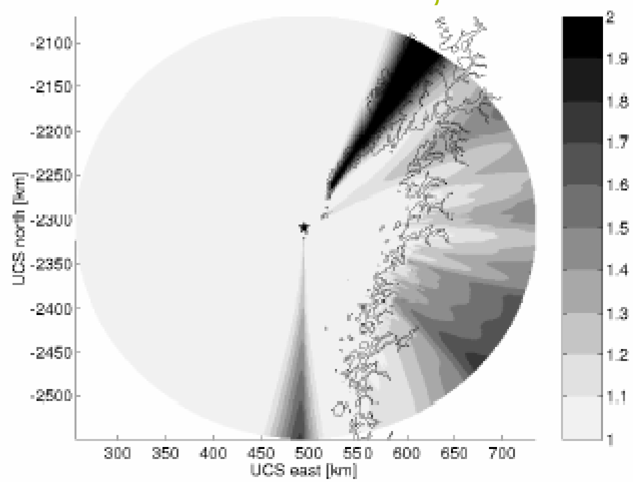




HIRLAM 22 km, t+ 0



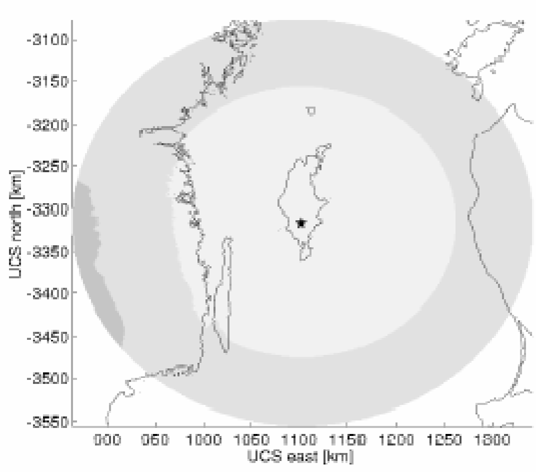
HIRLAM 22 km, t + 6



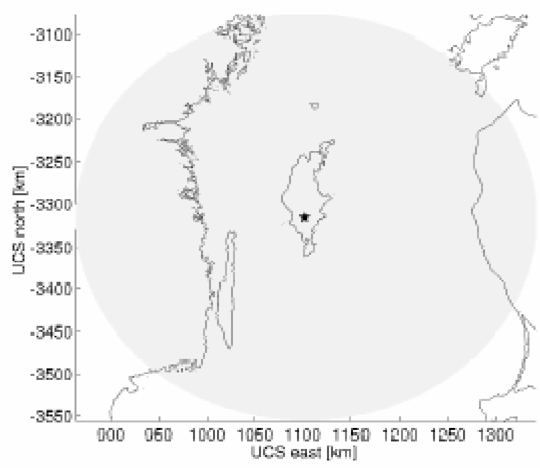
Anaprop case 5.7.2005, 00:00 UTC

Radar Visby : different general pattern but similar local blockage

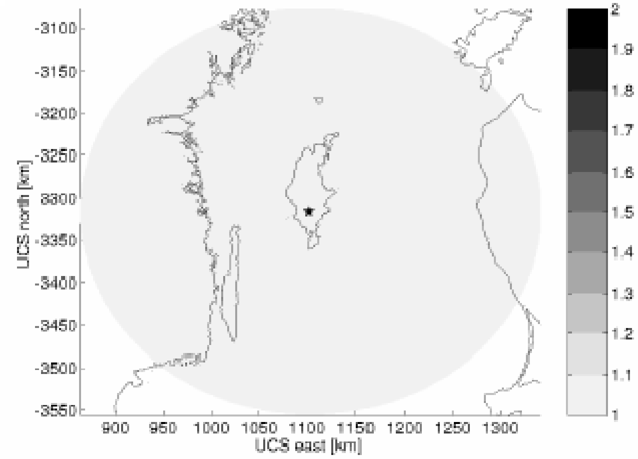
RAOB

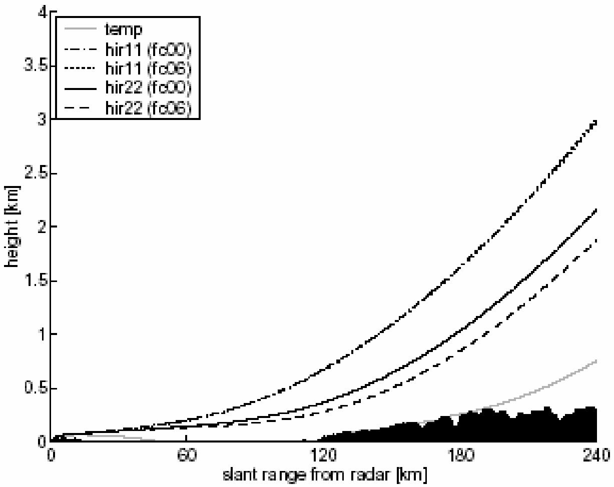


HIRLAM 11km, t+ 0

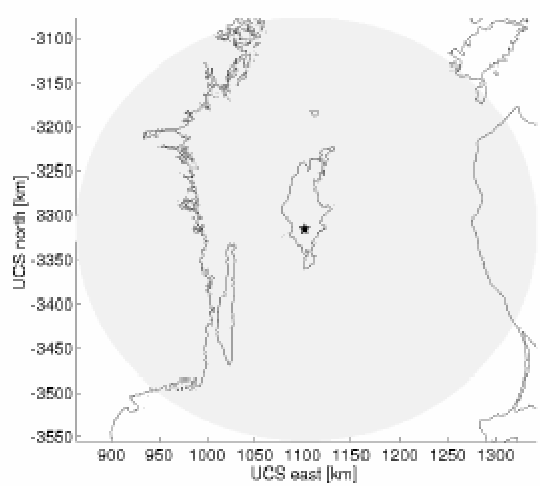


HIRLAM 11km, t + 6

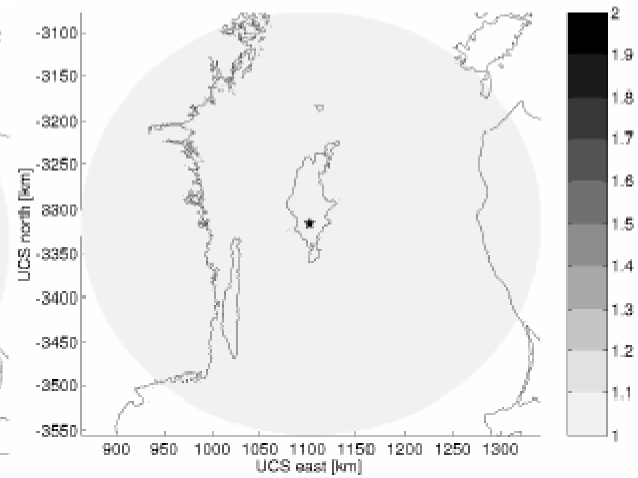




HIRLAM 22 km, t+ 0



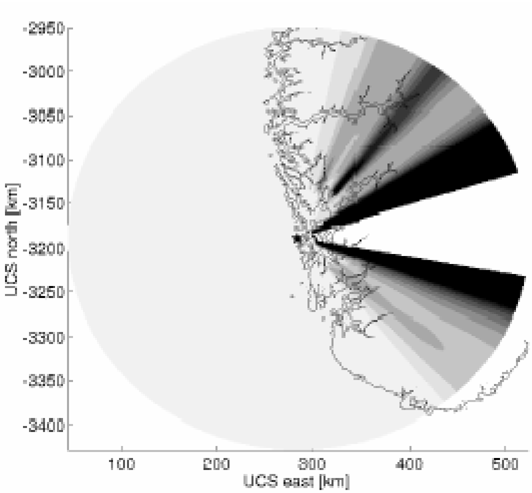
HIRLAM 22 km, t + 6



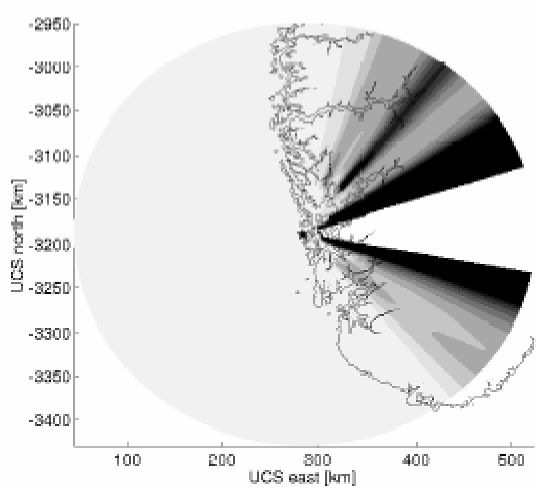
Anaprop case 6.7.2005, 00:00 UTC

Radar Bømlo similar general pattern but different local blockages between HIRLAM 11, t+0 and t+6

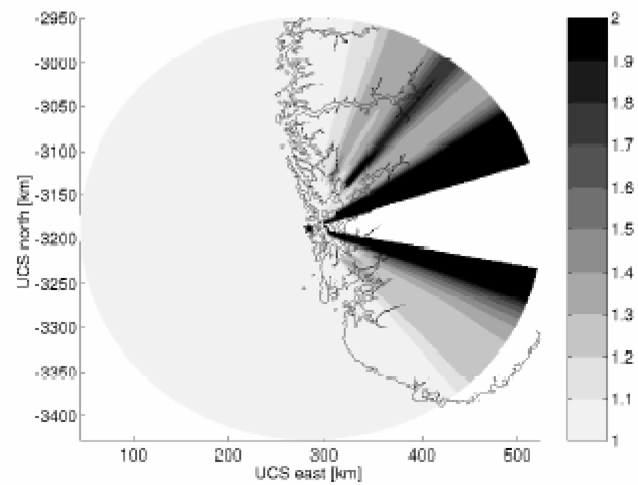
RAOB

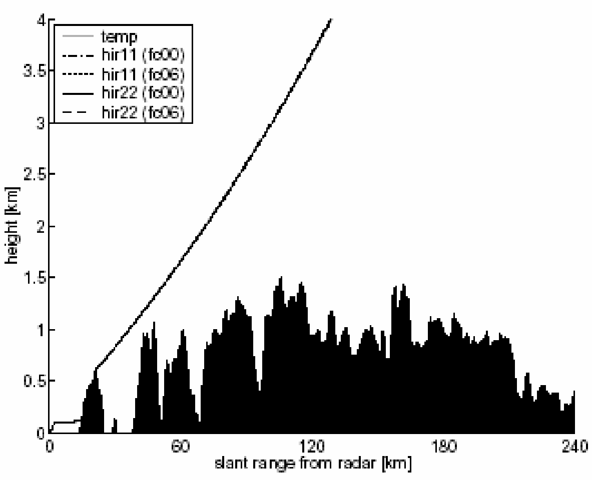


HIRLAM 11km, t+ 0

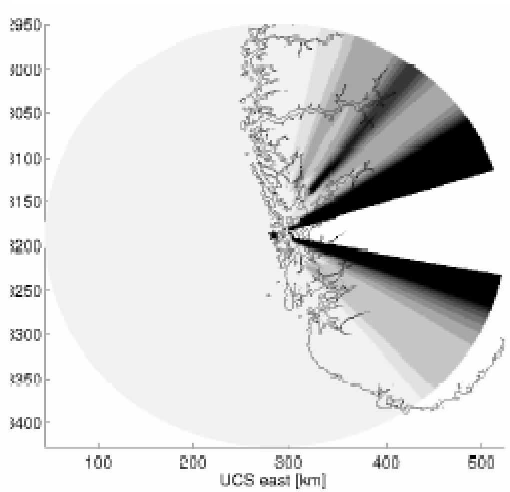


HIRLAM 11km, t + 6

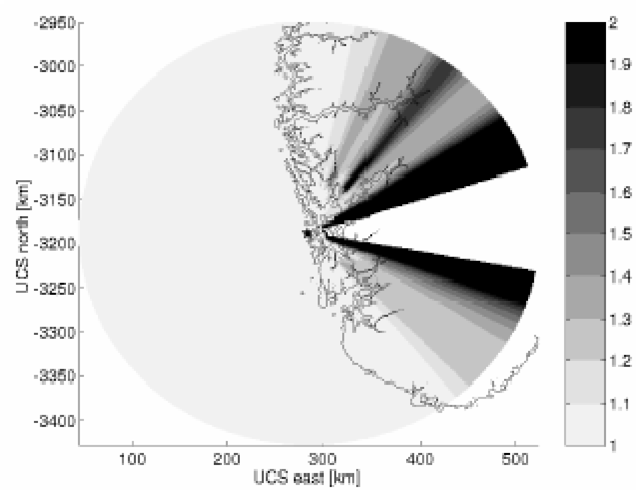




HIRLAM 22 km, t+ 0



HIRLAM 22 km, t + 6



Summary and conlusions (1)

- Correction fields produced by BPM reduce the gauge/radar bias at radar Bømlo
- The improvement is dependent on the distance from the radar and the degree of blockage
- The BPM seems to give realistic output for normal conditions and cases with anaprop
- The effect of anaprop on the degree of blockage is being investigated to see whether spatially/temporally variable correction fields are necessary

Summary and conlusions (2)

- The use of radiosonde and NWP data (HIRLAM) as input to the BPM has been examined in several cases
- HIRLAM t+0 & t+6 usually produce similar results (more cases should be analyzed). More differences observed in model resolution (11 & 22 km) (AP sea-clutter can be forecasted)
- NWP based BPM output usually smoother than RAOB based
- Need to examine vertical variability of partial precipitation beam-filling (low developed precip)