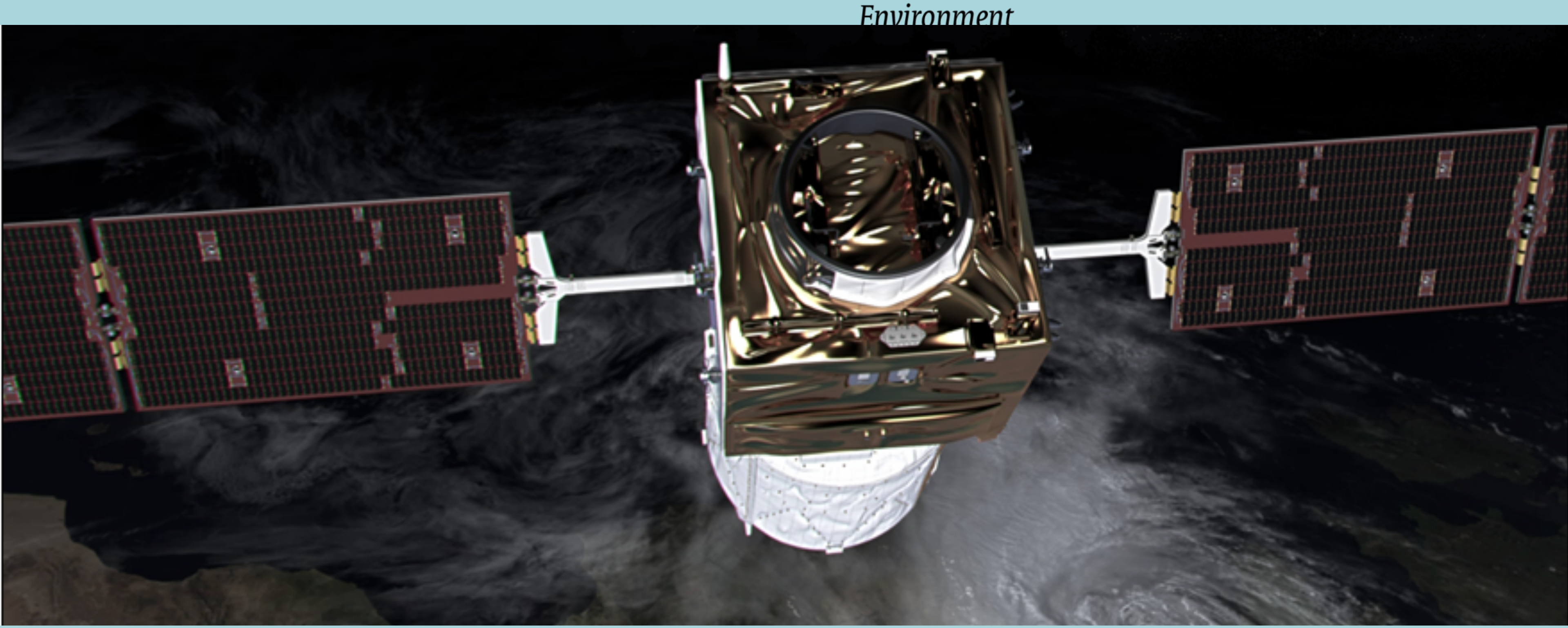
Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment



Application of Aeolus Winds

Ad.Stoffelen@knmi.nl
Gert-Jan Marseille, KNMI
Harald Schyberg, Met No

aeolus
because wind matters

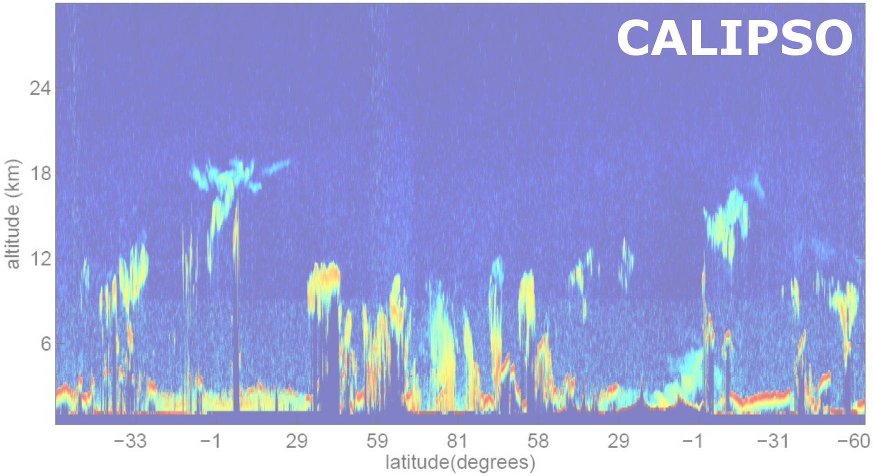
Overview

1. High vertical resolution radiosonde clouds and implications for Aeolus measurements

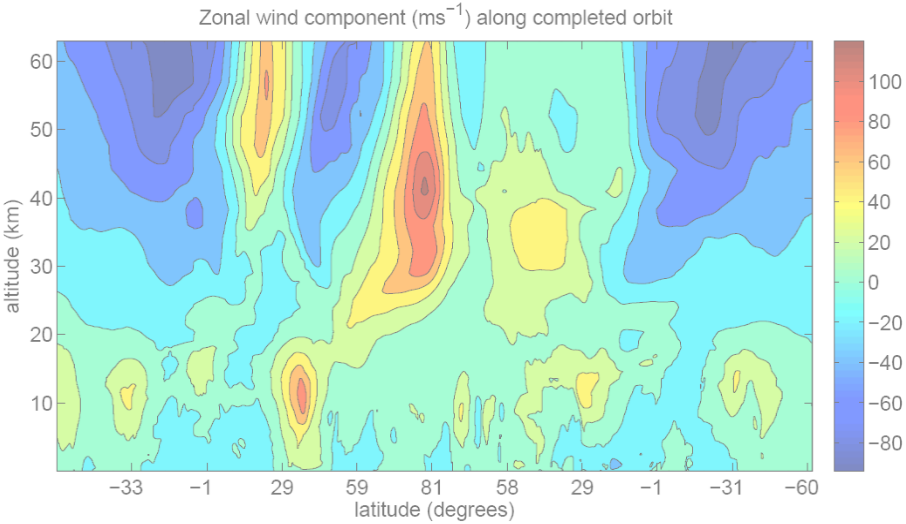
2. Theoretical tool for testing all the things we fancy so much in data assimilation: thinning, QC, bias, correlated error

LIPAS - Aeolus wind simulation

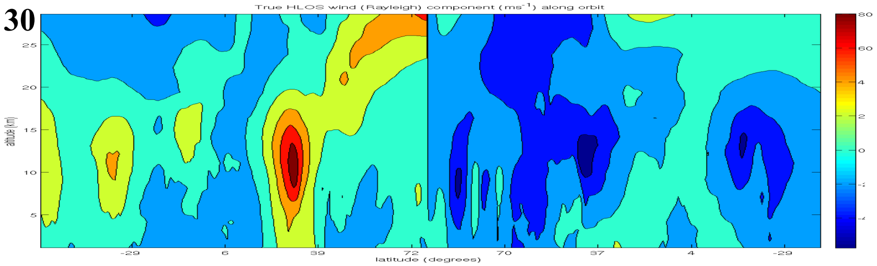
1 orbit on 1/1/2007



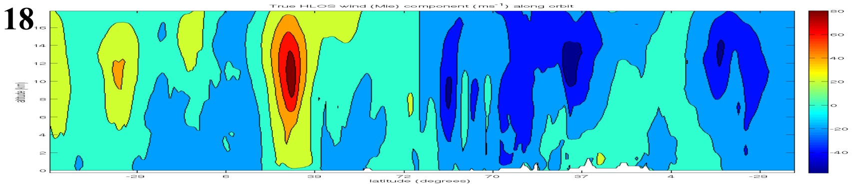
true zonal wind (UKMO)



true HLOS wind (Rayleigh channel)



true HLOS wind (Mie channel)

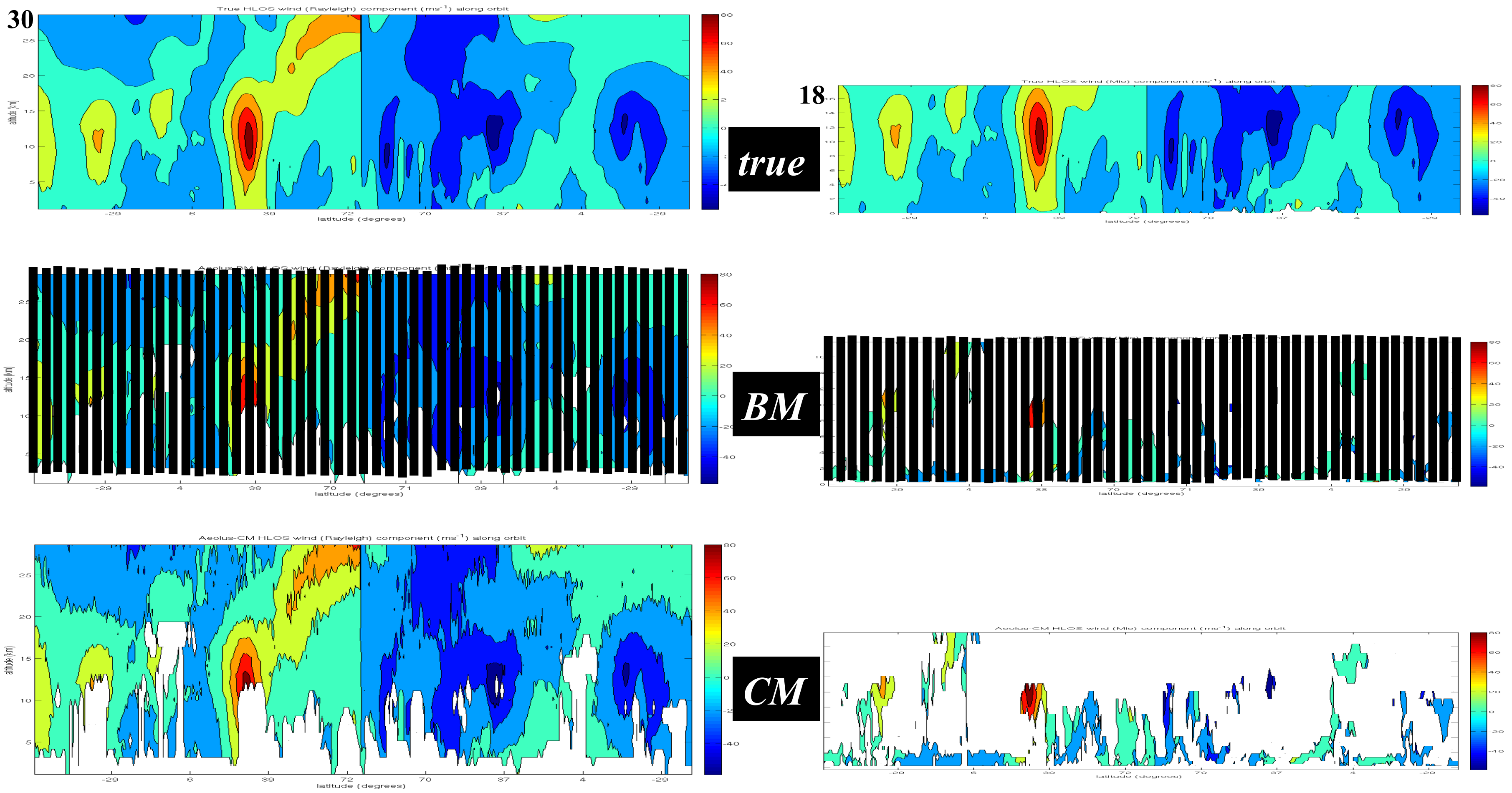


aeolus
because wind matters

110 mJ Aeolus BM/CM HLOS winds

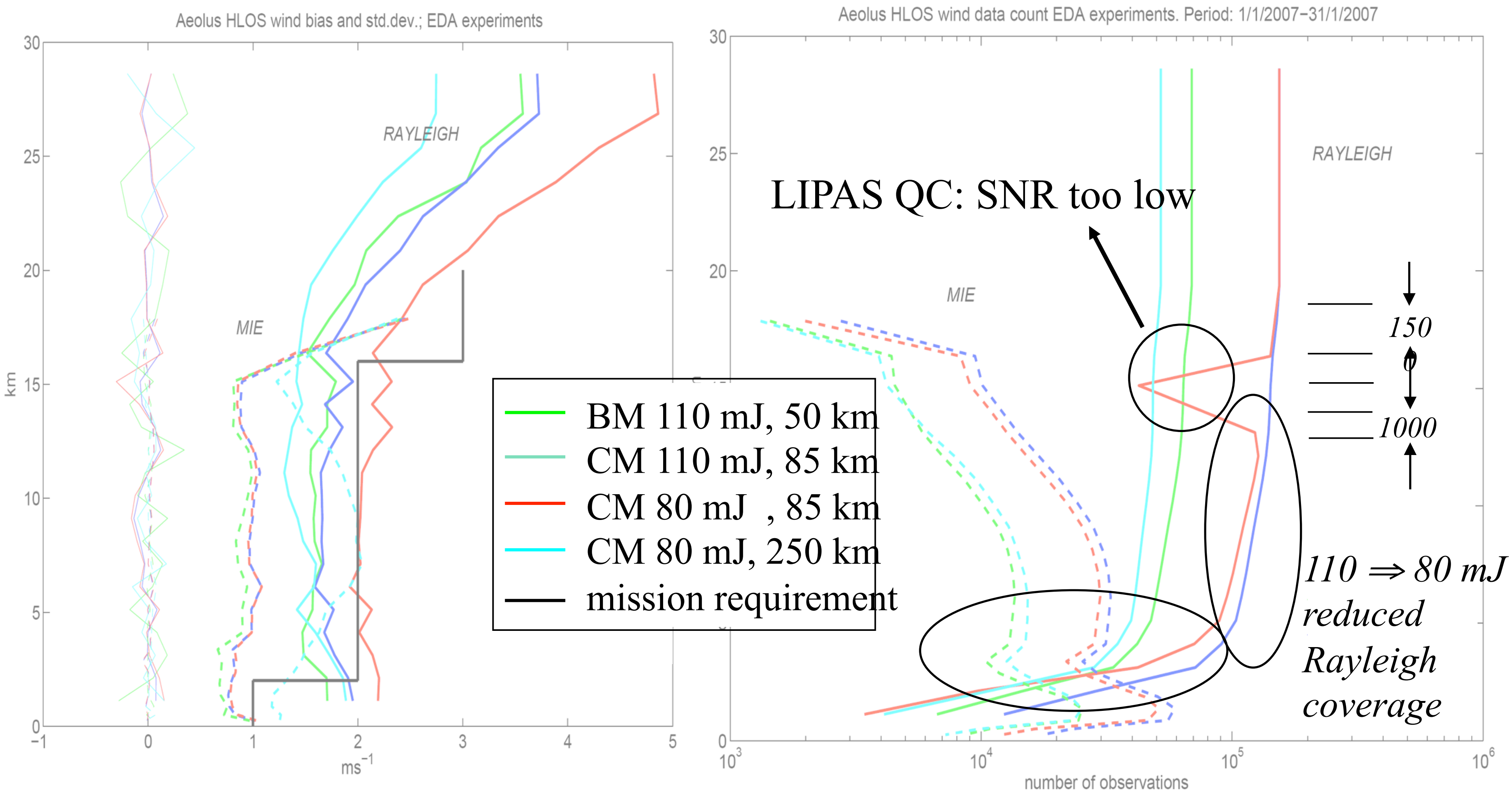
HLOS wind (Rayleigh)

HLOS wind (Mie)



- CM more noisy but larger coverage

HLOS wind statistics; 1 month



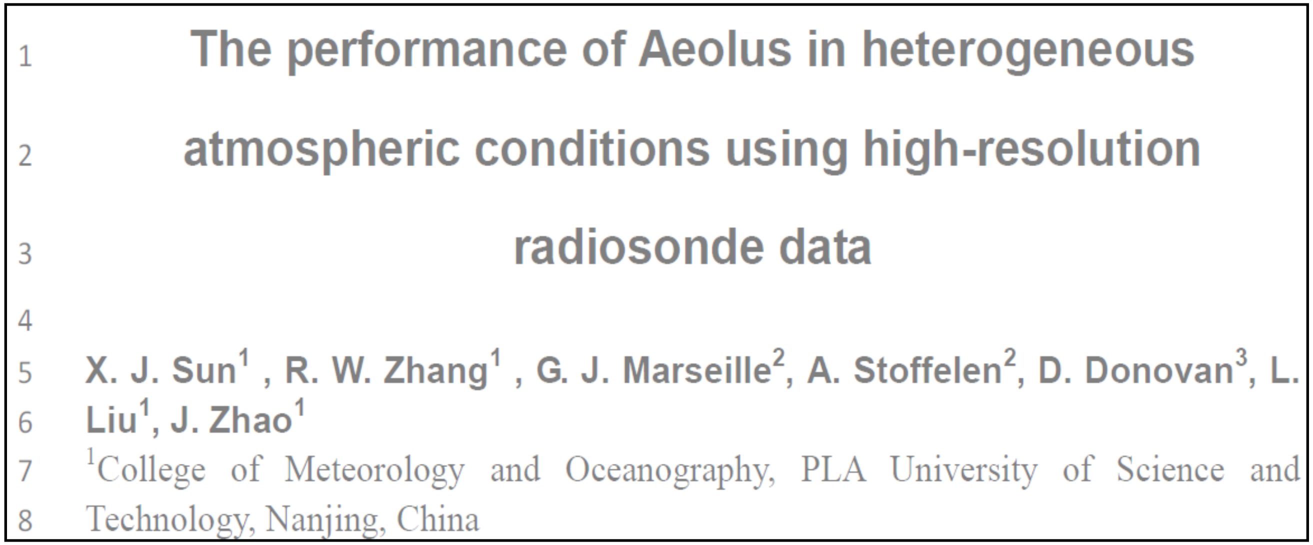
- BM 110 mJ, 50 km
- CM 110 mJ, 85 km
- CM 80 mJ , 85 km
- CM 80 mJ, 250 km
- mission requirement

LIPAS QC: SNR too low

150
0
1000

110 ⇒ 80 mJ reduced Rayleigh coverage

Hi-res radiosonde and Aeolus



The performance of Aeolus in heterogeneous atmospheric conditions using high-resolution radiosonde data

X. J. Sun[1] , R. W. Zhang[1] , G. J. Marseille[2], A. Stoffelen[2], D. Donovan[3], L. Liu[1], J. Zhao[1]

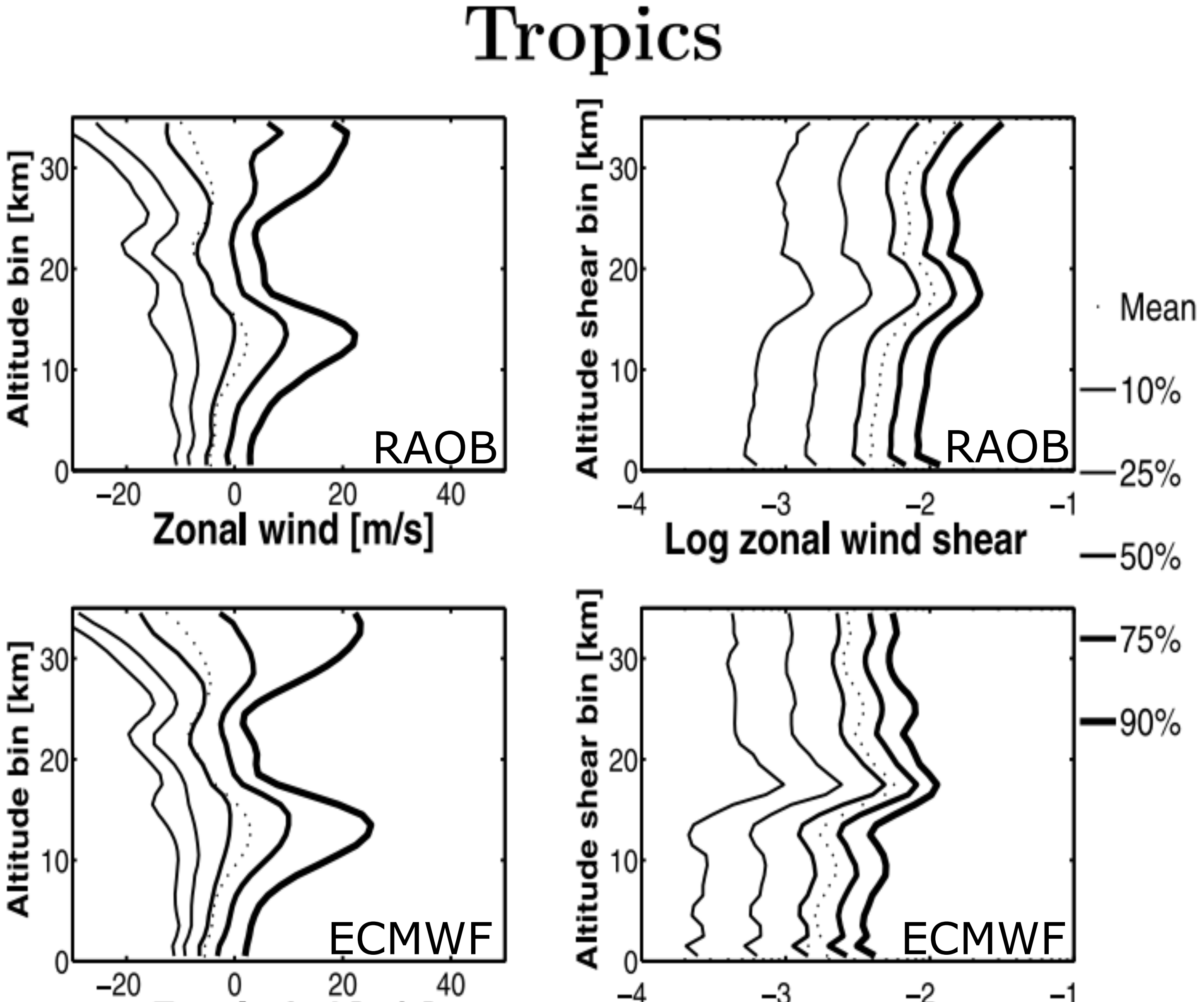
[1]College of Meteorology and Oceanography, PLA University of Science and Technology, Nanjing, China

- Radiosondes provide high-resolution vertical variability
- Houchi et al. (2010) studied wind and shear
- Extended now with cloud vertical variability (and aerosol)
- Radiosondes also provide T and p
- Zhang et al. (2010) applied to De Bilt for 2007

Hi-res radiosonde shear

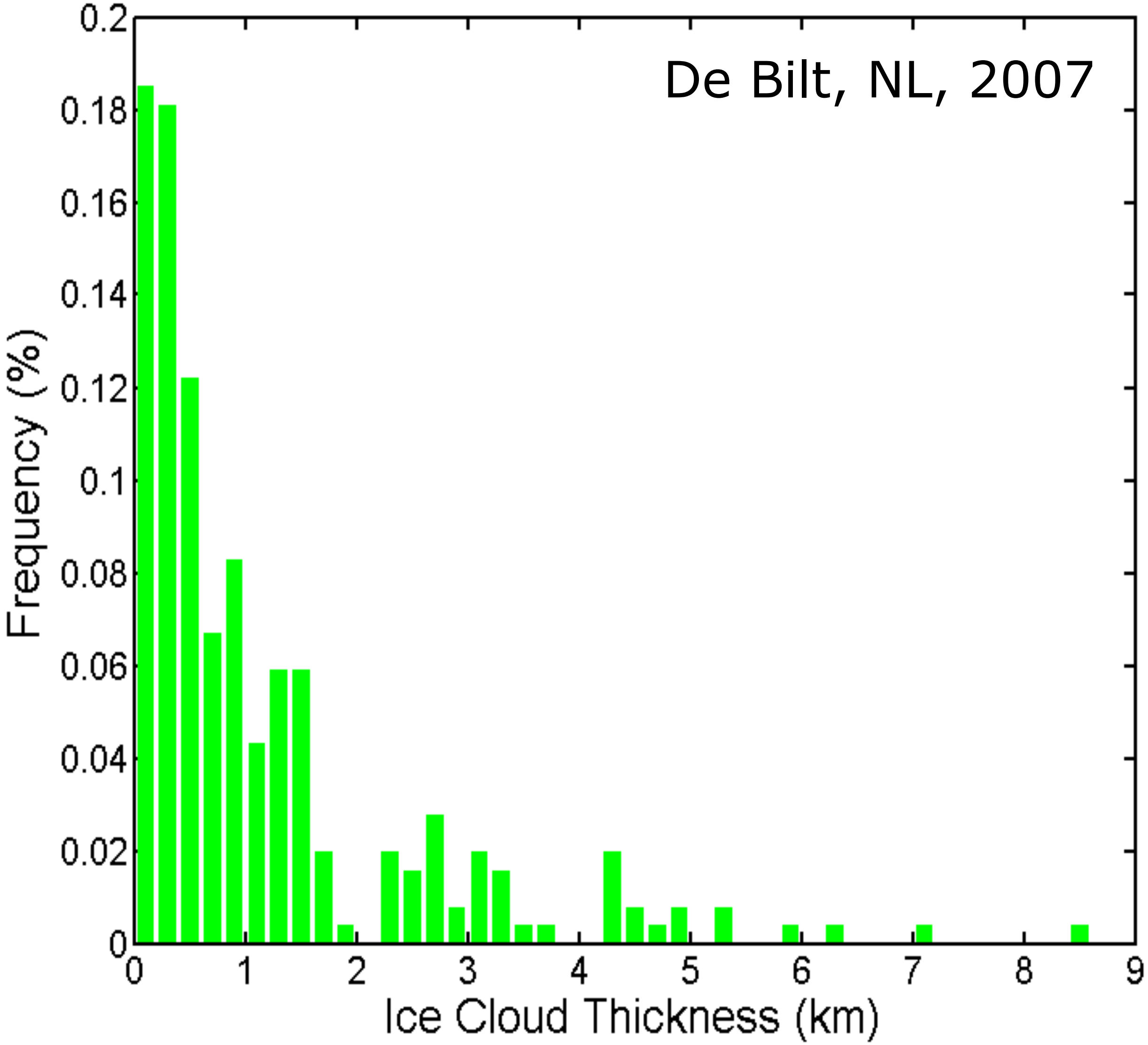
- Tropical tropopause shear in ECMWF model strongly variable in 2006

Houchi et al. 2010



Cloud layer statistics

- 1/3 of cloud layers are thinner than 400m
- Such layers cause non-uniform backscatter and extinction
- Mean backscatter height will be uncertain
- Wind and wind shear will be biased



Centre-of-Gravity (COG)

$$\mathrm{COG} = \frac{\int_{z_0}^{z_1} z w_k(z)\,\mathrm{d}z}{\int_{z_0}^{z_1} w_k(z)\,\mathrm{d}z}, \qquad k = \{p, m\}$$

w(z) is the signal strength inside the Aeolus bin as a function of altitude *z*

1. Particle-free bin

- Analytical calculation (no T,p dependence)
- Using LIPAS and (T,p) from hi-res radiosondes

2. Bins including cloud/aerosol layer

- Analytical
- Using LIPAS and (T,p, cloud, aerosol) from hi-res RAOB

aeolus
because wind matters

Particle free bin – analytical

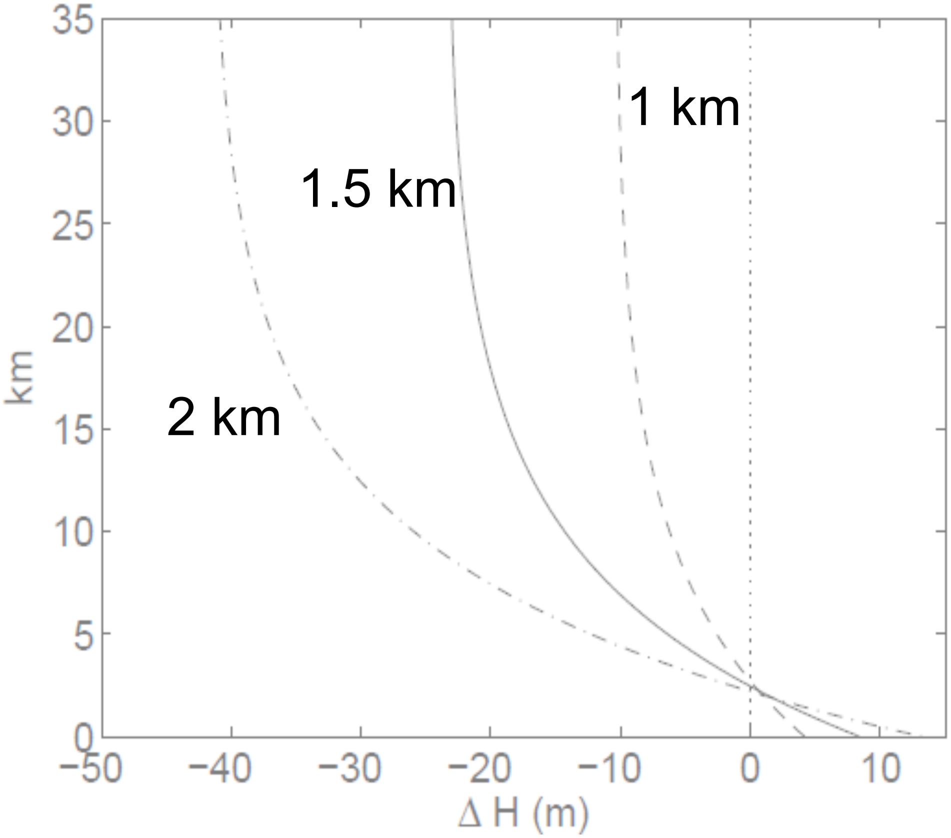
Rayleigh height assignment error is height dependent (currently a constant correction factor of 0.47 is used in L2Bp)

Typical atmosphere

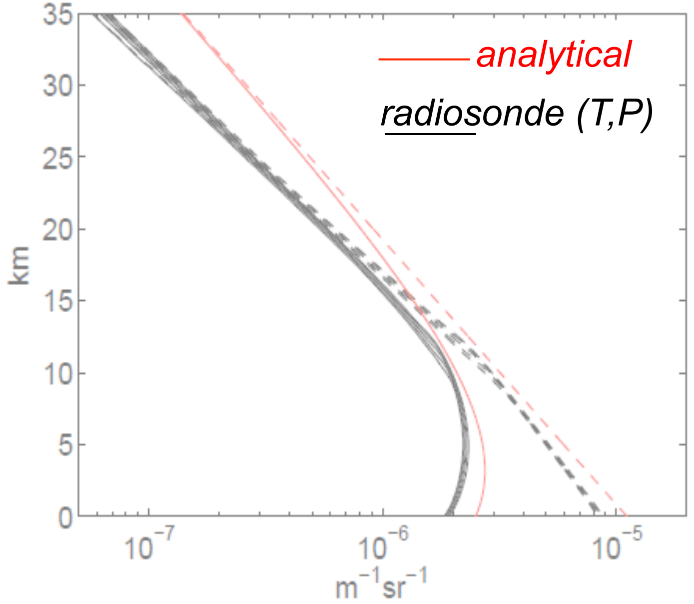
- Stratosphere, 2 km Rayleigh bin, wind-shear 0.01 s^{-1}
- ΔH=40 m ~ 0.4 ms^{-1} bias

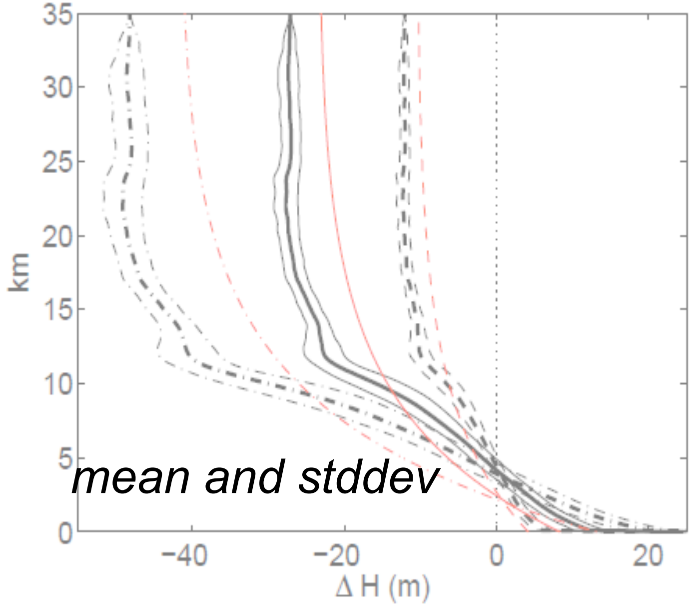
➢Biases exceed mission requirement in more extreme scenes (tropopause jet stream, PBL) if height assignment error is not corrected

height assignment error as function of Rayleigh channel bin size



(T,p) from radiosonde database

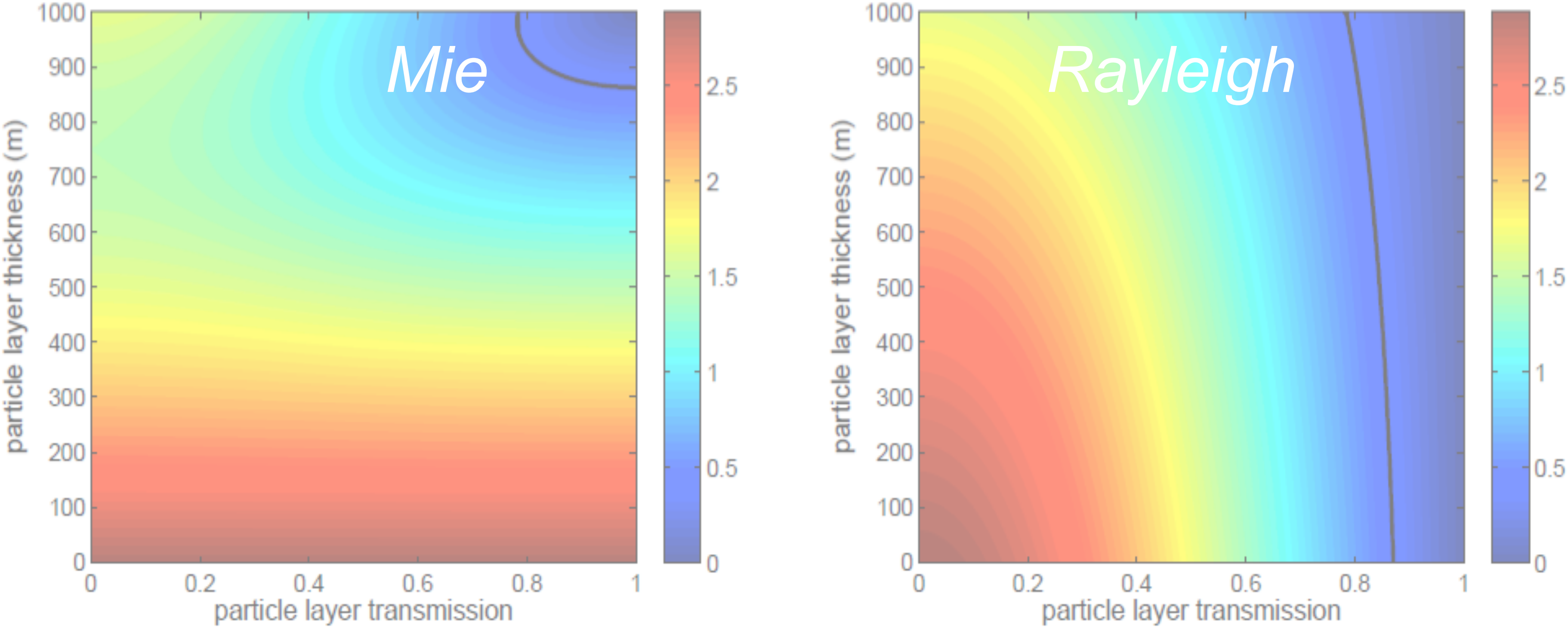


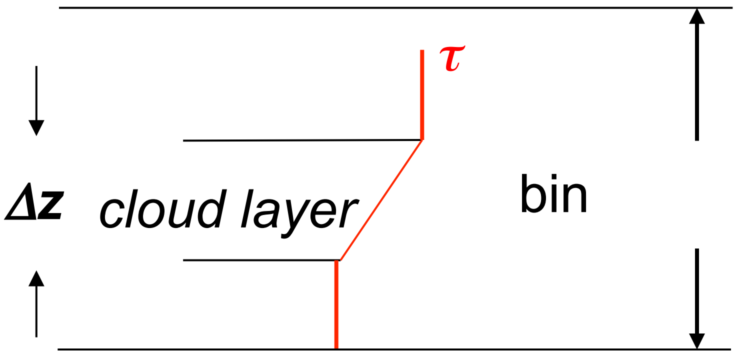


- 1 year radiosonde data over De Bilt => (T,p) => $\beta_m(z)$ => $w(z)$ => COG
- Height assignment errors are slightly larger than from analytical expressions
- Not very sensitive to T,p errors and predictable

Use AUXMET to correct for Rayleigh channel height assignment errors in L2B optical properties code

RMSE wind error (systematic)

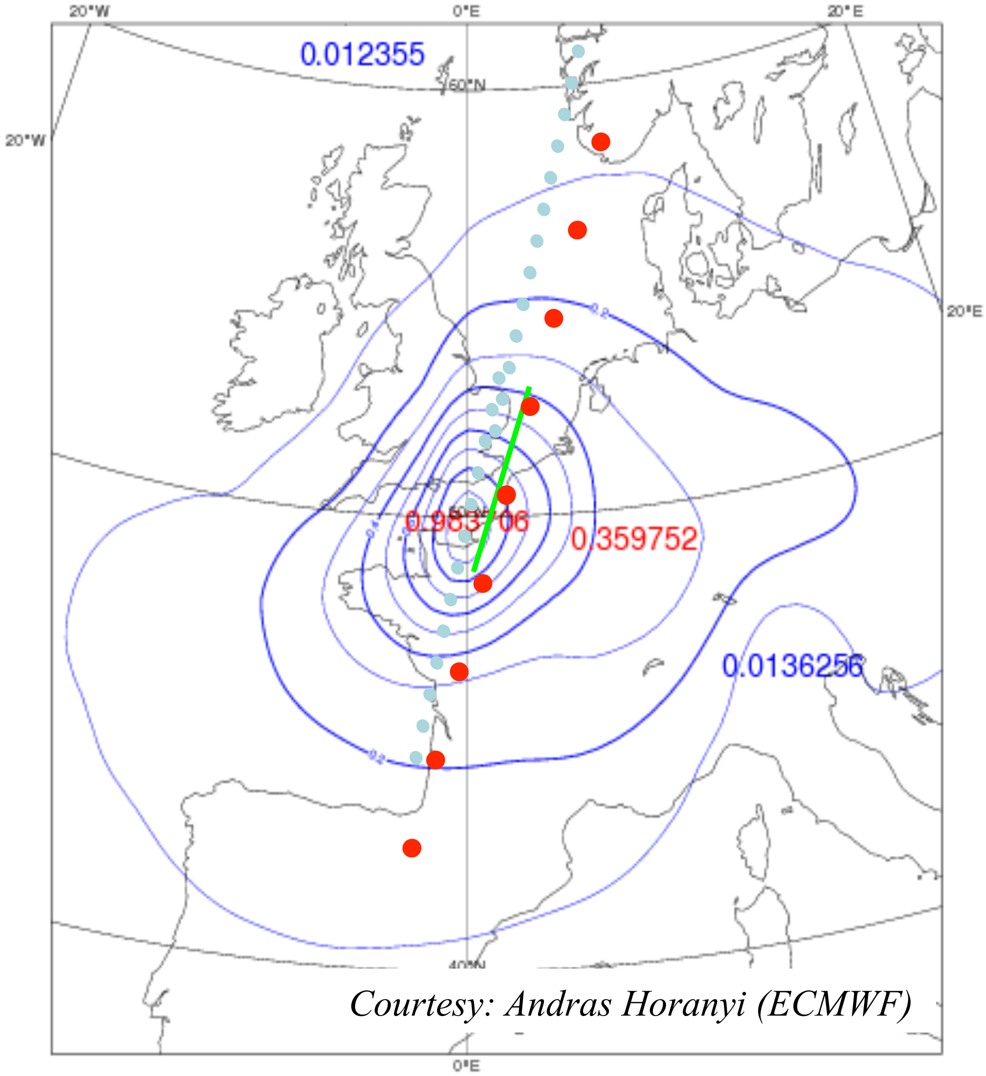




- Rayleigh ΔHLOS insensitive to Δz
- τ_c can be obtained from Aeolus optics
- Mie ΔH sensitive to Δz

Results largely confirmed for LIPAS applied to the radiosonde database

Aeolus data assimilation



Courtesy: Andras Horanyi (ECMWF)

Single obs. Experiment

Over the English channel

500 hPa analysis increment

Background error length scale ~ 400 km

Aeolus burst-mode observation separated by 200 km (< **B** length scale)

Aeolus continuous mode observation separated by 86 km

Representativeness error

From ODB ECMWF T1279

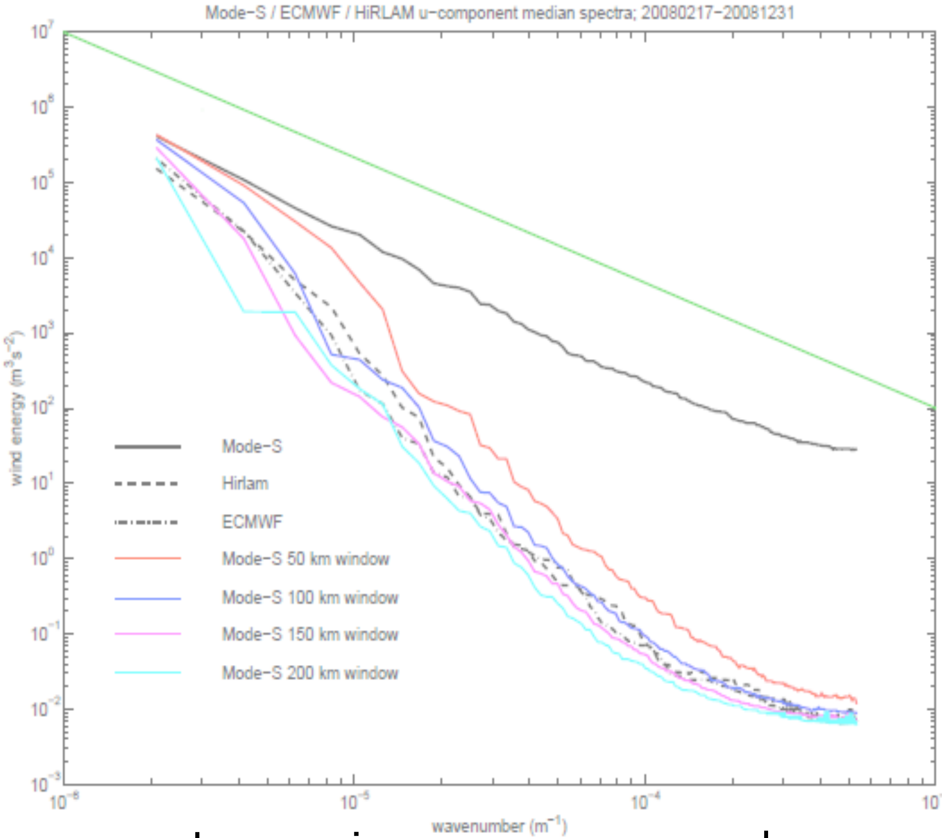
- 0.8 m/s on ASCAT 12.5 km wind
- Upper troposphere: 2.1 m/s on aircraft components

Along-track accumulation reduces the representativeness error

Accumulation length of observations such that the resulting spectrum matches the model spectrum:

(1) Upper troposphere: aircraft accumulation along 100-150 km track

(2) Ocean surface: ASCAT accumulation along 85-100 km track



Log variance vs wave number

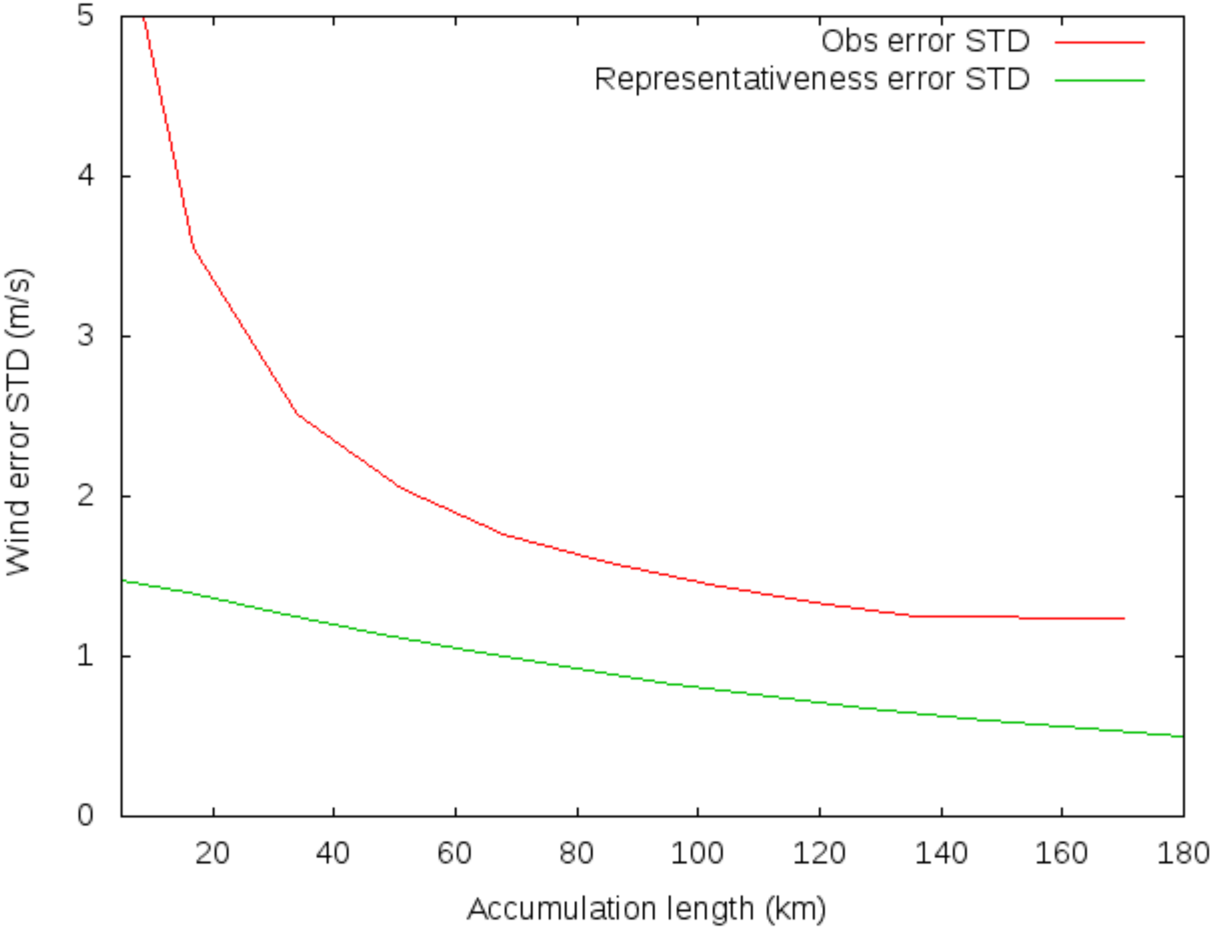
➢ *Aeolus representativeness error negligible for ~ 100 km along-track accumulation*

1D theoretical tool

- Usual meteorological analysis equations
- Fully solved
- 1D = horizontal
- Horizontal characteristics from ECMWF and HARMONIE model and (LIPAS) Aeolus observations
- Introduction of bias, correlation, averaging, thinning and misspecification

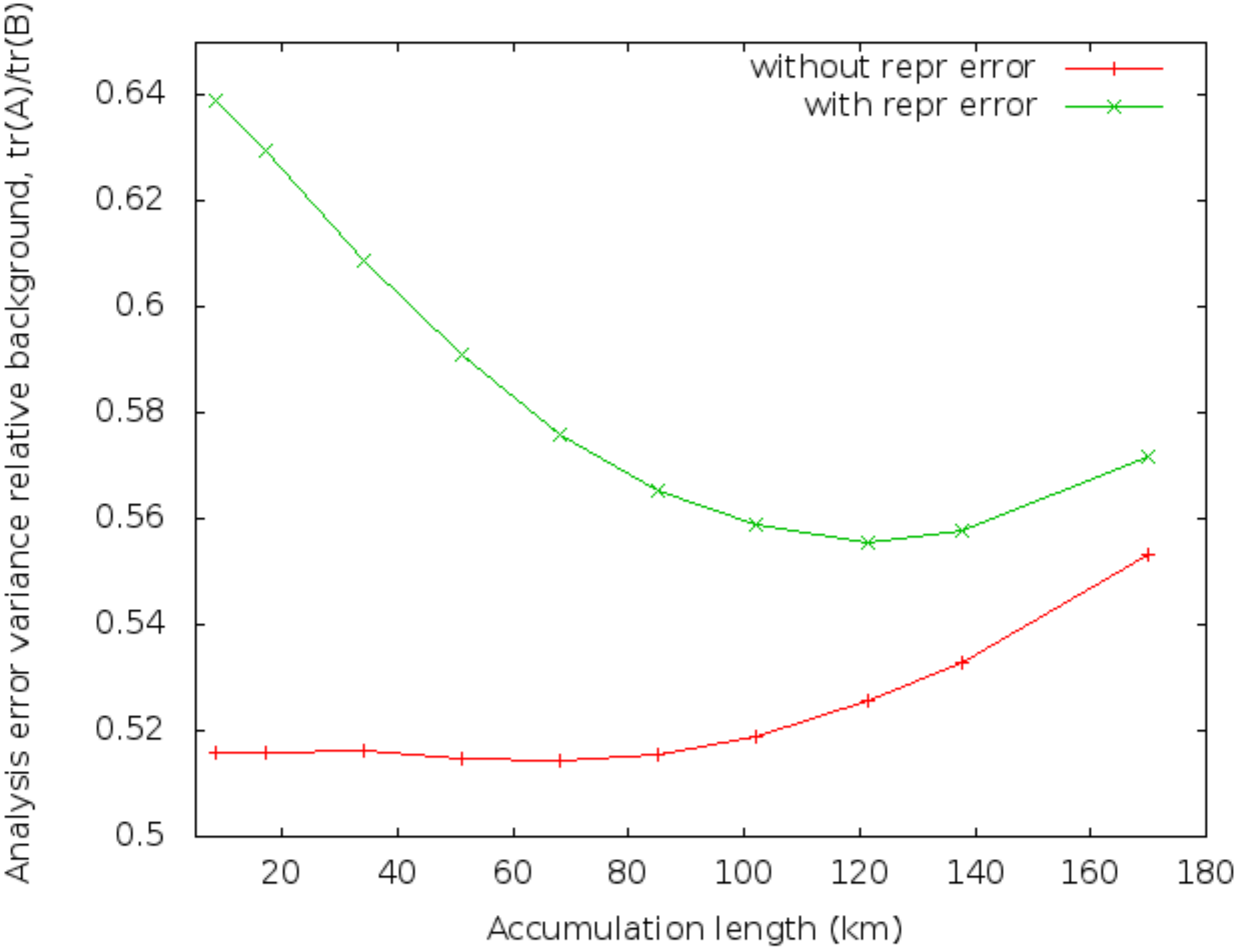
Effect of accumulation distance on analysis quality

- Assume obs error ~ 1/ SQRT(accumulation length)
- Longer accumulation → more accuracy, but fewer samples
- Example: 60N background statistics, continous 110 mJ, 500hPa (Rayleigh channel average obs error data from LIPAS)
- *Obs errors assumed uncorrelated*
- *Representativeness error not included*



Correlated representativeness error

- 60N background statistics, continous 80 mJ, 500hPa (Rayleigh channel average obs error data from LIPAS), 2/3 B bandwidth
- Representativness error variances based on assuming global model effective resolution 7*Δx (112 km)
- Triangular O correlation structure with half basis of 112 km
- Much lower analysis quality
- Optimal accumulation length is now about the effective model resolution



Conclusions theoretical tool

Tr(A)/tr(B)	Burst 110 mJ	Cont 110 mJ	Cont 80 mJ
50 hPa	0.4004	0.3240	0.4067
250 hPa	0.3676	0.2472	0.3140
500 hPa	0.4557	0.3099	0.4269
700 hPa	0.4758	0.3927	0.4727

Latitudinal dependence

500hPa tr(A)/tr(B)	Burst 110 mJ	Cont 110 mJ	Cont 80 mJ
60N	0.4557	0.3099	0.4269
45N	0.3997	0.2664	0.3712
Equator	0.3120	0.2045	0.2856

From BM ⇒ CM increases impact substantially

From 110 mJ ⇒ 80 mJ reduces impact substantially (CM 80 mJ ~ BM 110 mJ)

Aeolus impact is maximum around 250 hPa

Aeolus impact is maximum in the Tropics

Impact is maximized for ~85 km accumulation length

aeolus
because wind matters

Main conclusions theoretical tool

- Observation error correlation up to 0.1-0.15 not very detrimental
  - Correlation of 0.1 corresponds to an increase of random error of 0.2 m/s
  - Correlation of 0.38 corresponds to an increase of random error of 0.7 m/s
- Biases > 0.5 m/s are detrimental
  - Negative impact for biases exceeding 1 m/s
- Impact of non-optimal B-matrix is substantial

ESA VHAMP, TN8

	Burst 110 mJ	Cont 110 mJ	Cont 80 mJ
Obs error std (m/s)	1.5678	1.5889	2.1315
Perfect B tr(A)/tr(B)	0.4557	0.3099	0.4269
Imperfect B tr(A)/tr(B)	0.5775	0.4035	0.5274

Table 7-9. Effect of non-perfect B matrix. Background error data are for 60N, 500 hPa.

Summary

- Hi-res radiosondes are very useful for Aeolus simulation

- A theoretical data assimilation tool can be useful to comprehend data assimilation system characteristics