VAMP –
Vertical Aeolus Measurement Positioning

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Space Shuttle, '84, 3 pm LT

Vertical sampling restrictions

Vertical sampling scenario can be changed 8 times per orbit

- 24 levels for the Fizeau (Mie) and Fabry-Perot (Rayleigh)
- Weekly commanding, set 3 weeks ahead, i.e., no weather dependence
- Fizeau ground calibration over land (when possible)
- Fabry-Perot and Fizeau cross calibration of wind (@2-3 km height)
- Mie cross talk correction on Fabry-Perot by Fizeau measurements
- Mie contamination for Fabry-Perot only (stratosphere)

- Bin size limitation: multiples of 250 m with a maximum of 2000 m.

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Optional vertical sampling scenarios and many more ....

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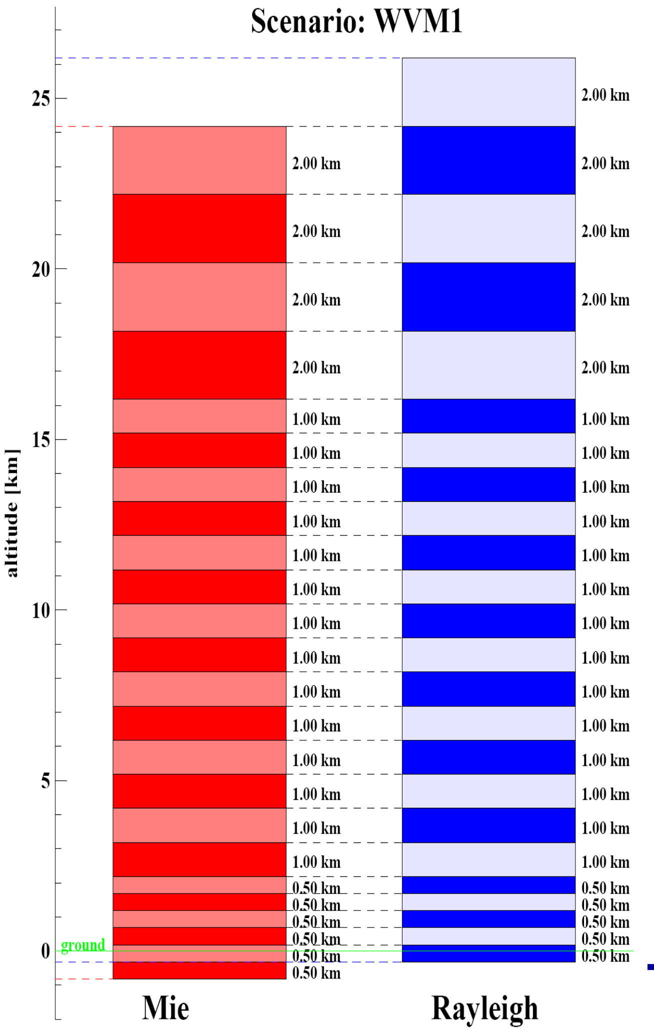
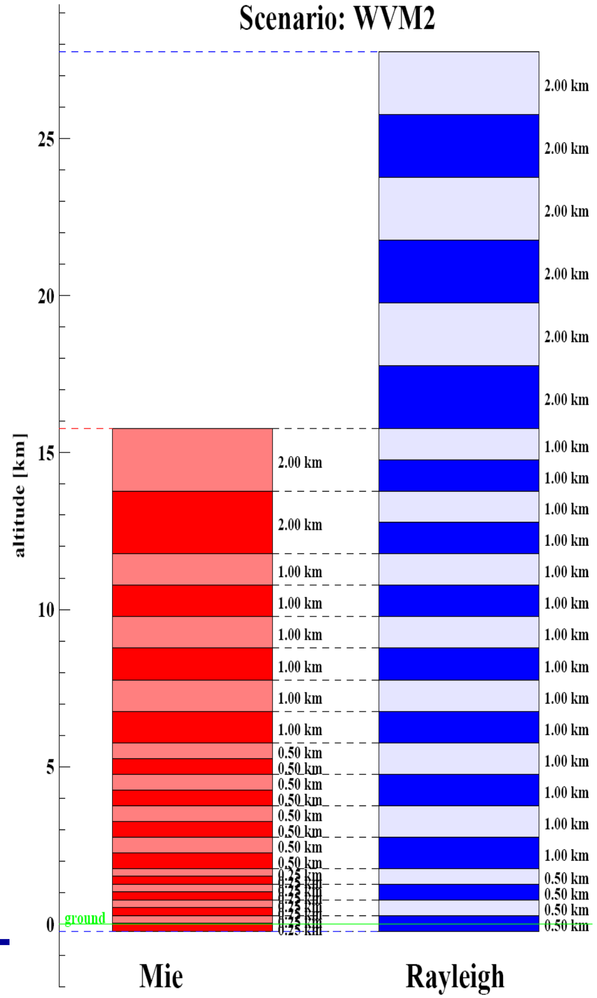
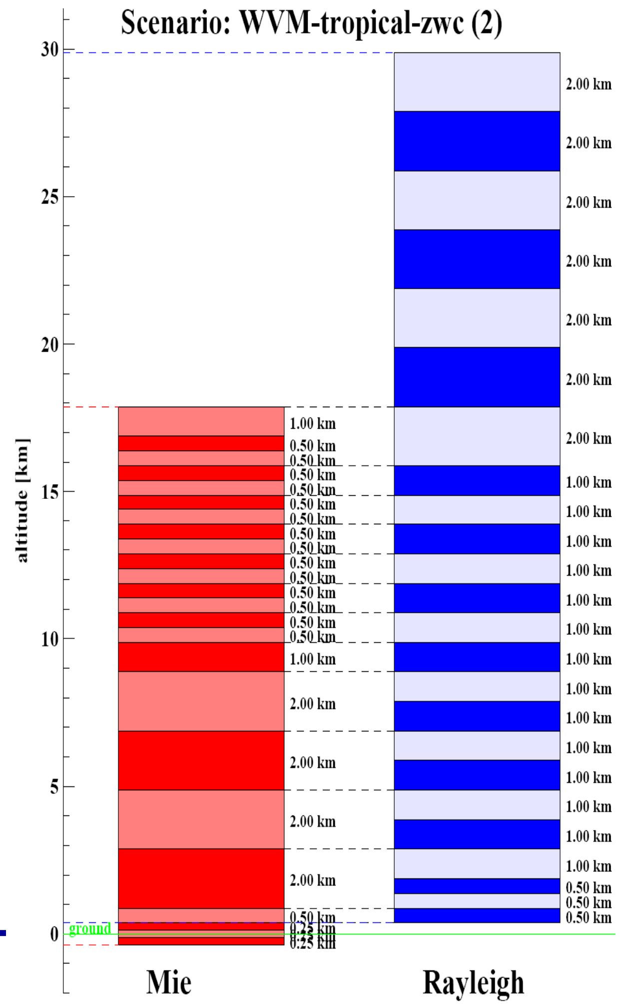
Maximum Mie/Rayleigh overlap



Mie focus on PBL/troposphere



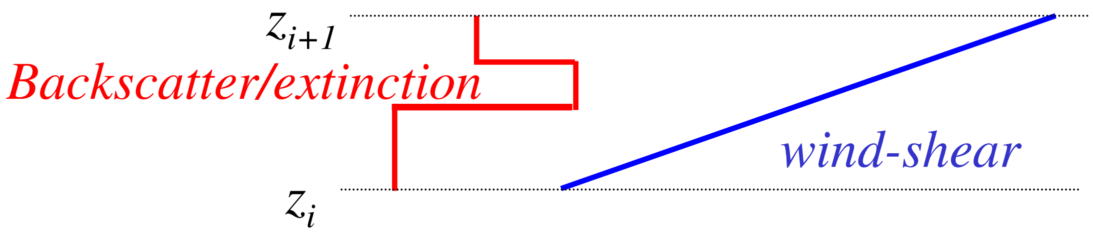
Mie oversampling in Tropics (cirrus)



ESA VAMP study

- VAMP – *V*ertical *A*eolus *M*easurement *P*ositioning
- Consider the atmospheric dynamical and optical characteristics and their interaction with the ADM-Aeolus measurement system in order to optimize the user benefit of the Aeolus system
- The study will conclude with a recommendation for the operation of the instrument spatial and temporal sampling, to provide maximum mission benefit

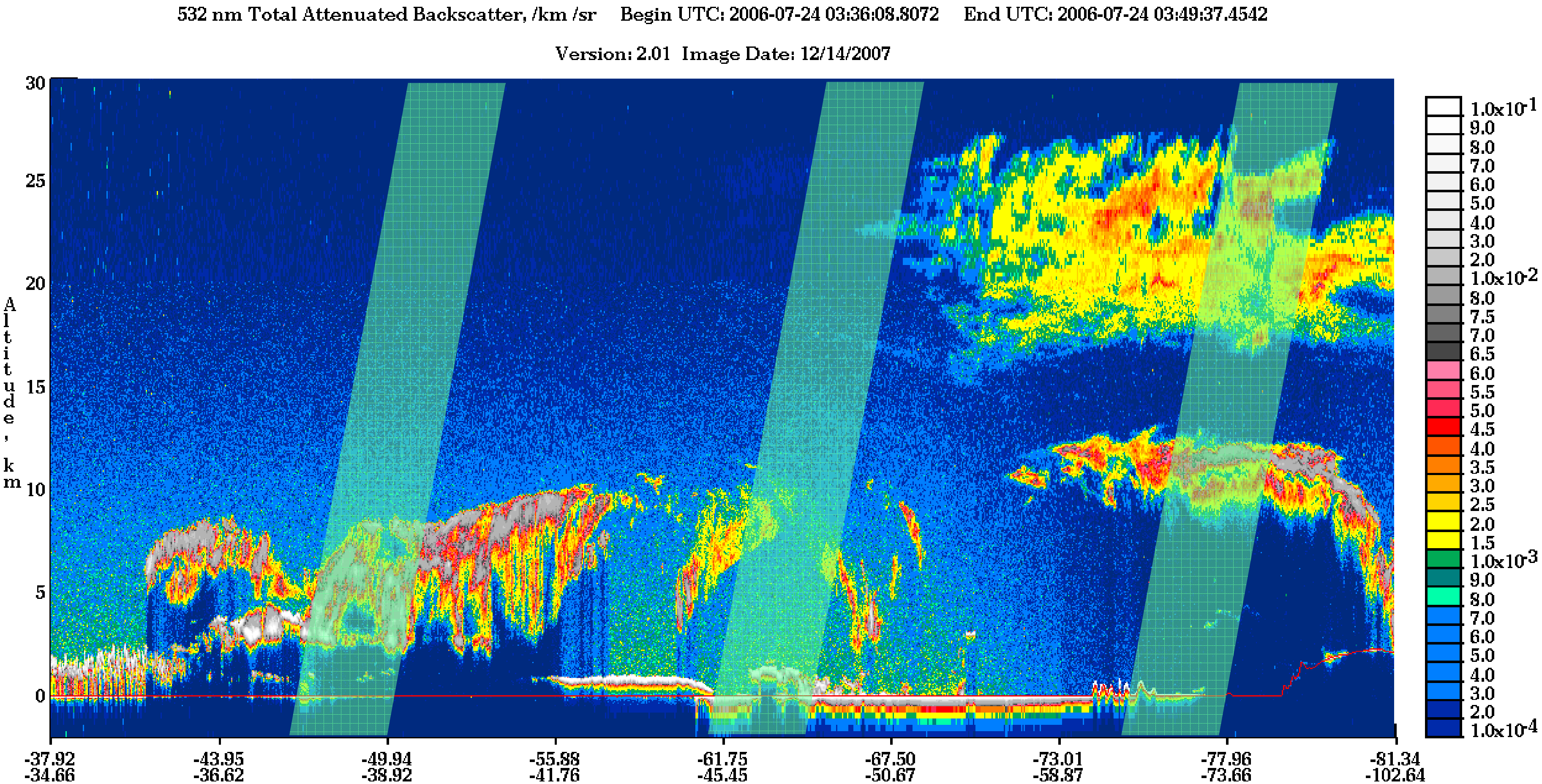
Issues



Combined wind shear and optical (backscatter/extinction) variability over bin causes height assignment errors; mean wind in bin ≠ measured wind

- Combined wind and optical variability
  - Height assignment
  - QC
- Mie contamination (no Fizeau) / correction (Fizeau)
- Ground calibration and terrain-following vertical sampling
- Vertical motion (correct HLOS?)
- Atmospheric state / climate dependence
- Expected beneficial impact in PBL, free troposphere, tropopause and stratosphere regions at different vertical sampling ?
- Data assimilation method

ADM sampling in heterogeneous atmosphere



Atmospheric optics

- CALIPSO level-2 aerosol product
  - Too coarse (40 km horizontal resolution)
- CALIPSO level-1 product
  - Convert attenuated backscatter @532nm to particle backscatter @355nm
  - Averaging to 3.5 km (horizontal), 125 m (vertical)
  - i.e. compatible with ADM sampling
- Cloud detection and optical properties computation
- Use night-time orbits only; to reduce noise contamination

➢ *Aerosol backscatter @355nm at 3.5 km horizontal and 125 m vertical resolution*

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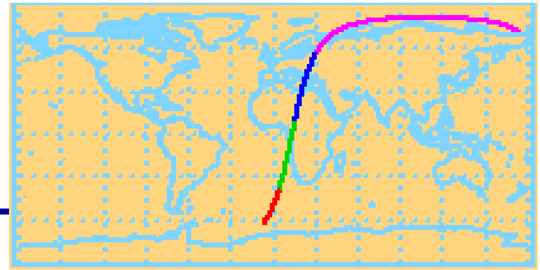
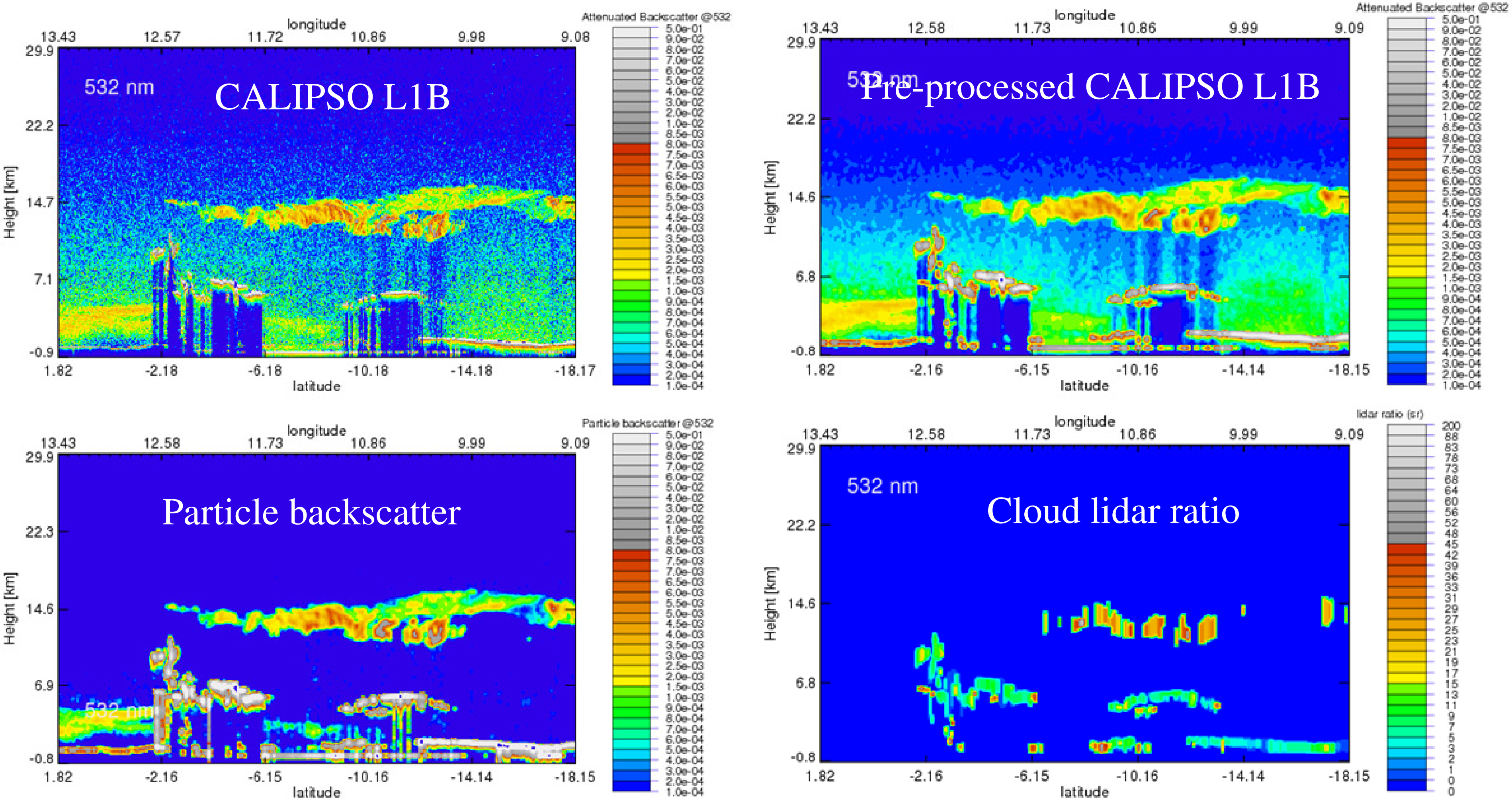
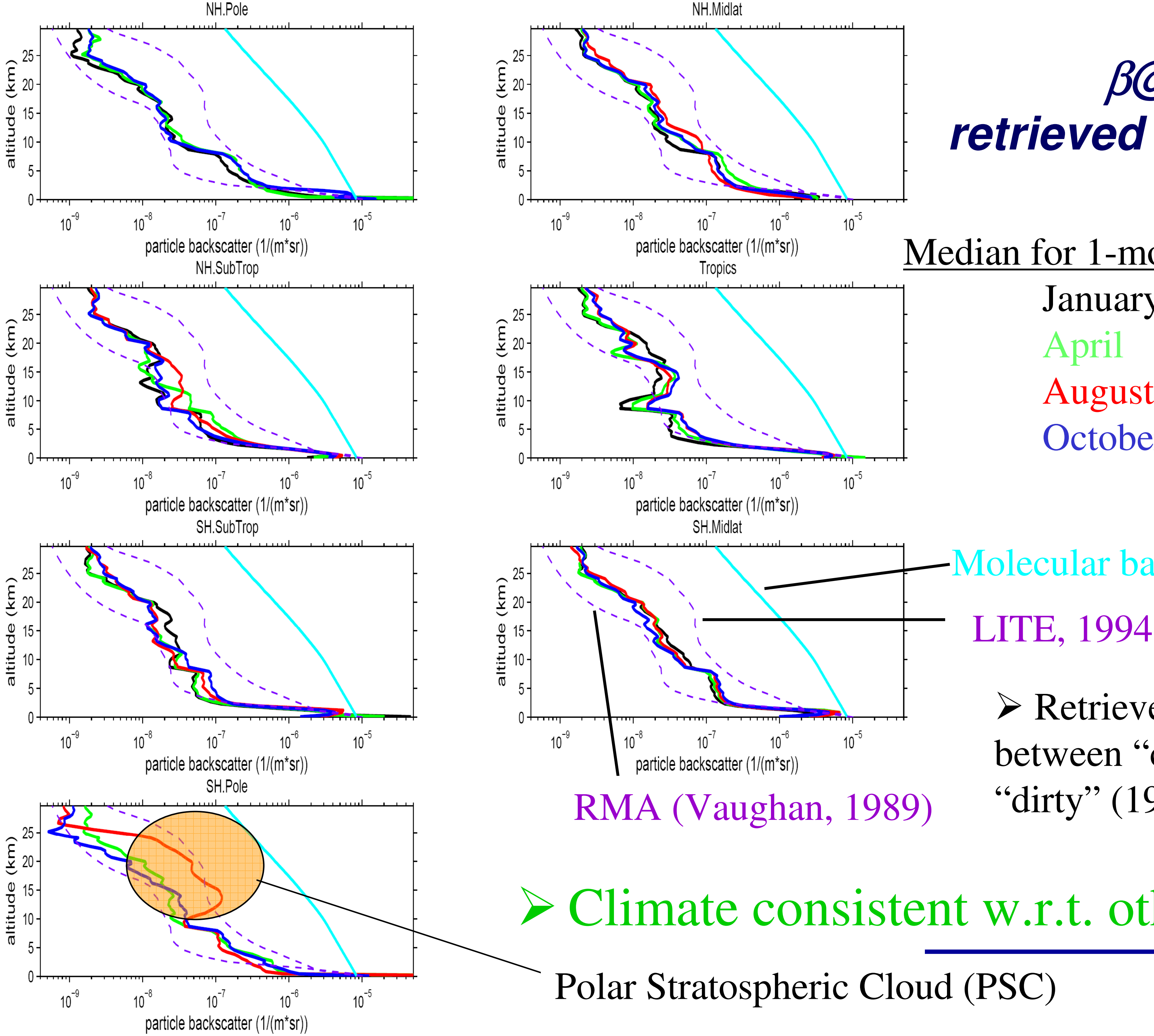
KNMI retrieval





β@355nm retrieved from CALIPSO



Median for 1-month seasonal periods

January 2007
April 2007
August 2007
October 2007

- Retrieved backscatter in between "clean" (1989) and "dirty" (1994) periods

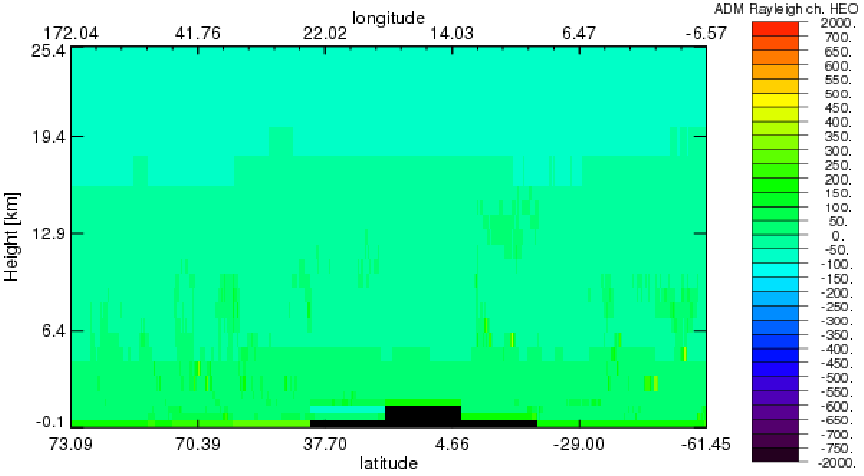
- Climate consistent w.r.t. other sources

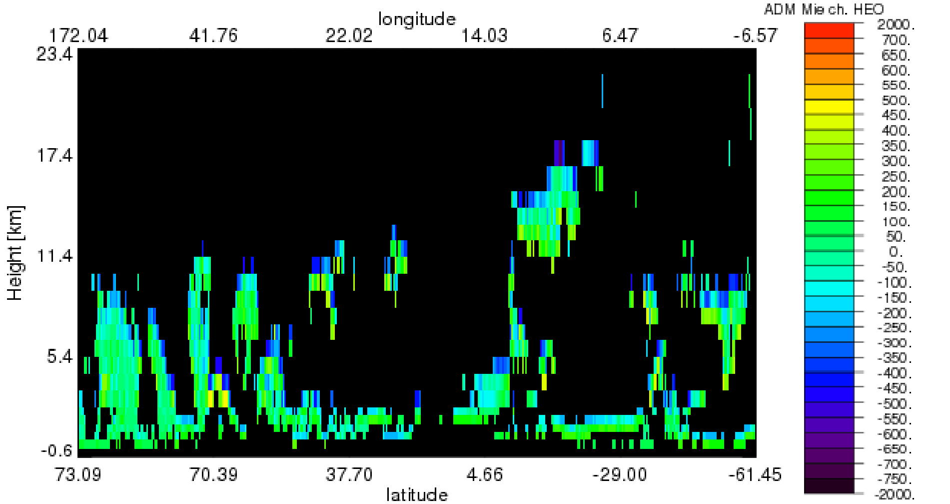
ADM height assignment and HLOS wind error

Rayleigh

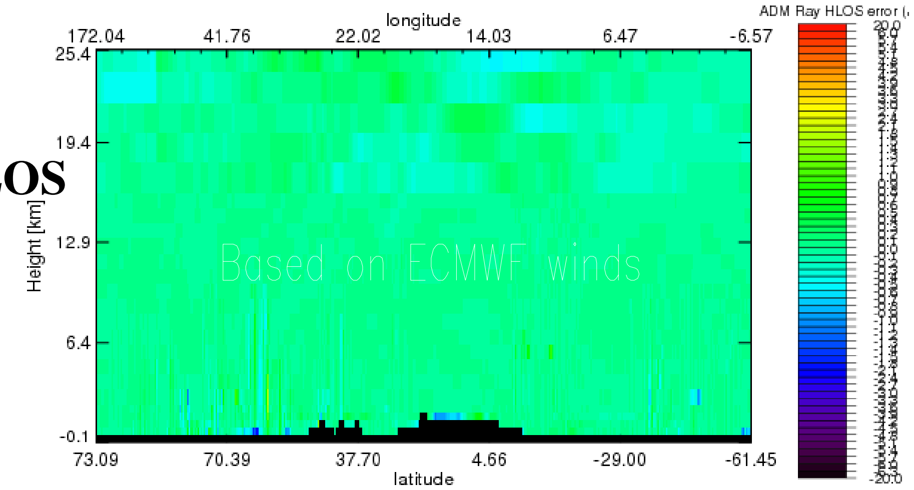
Mie (high SNR only)

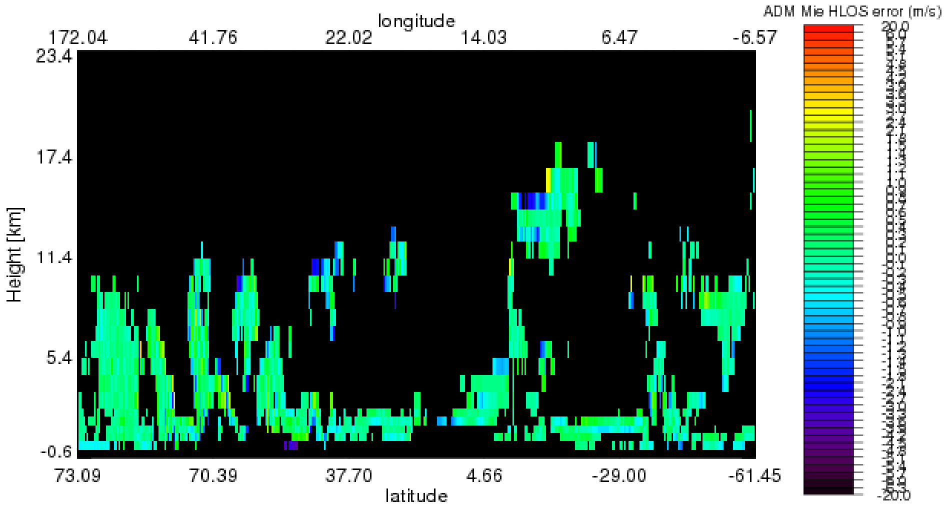
ΔH





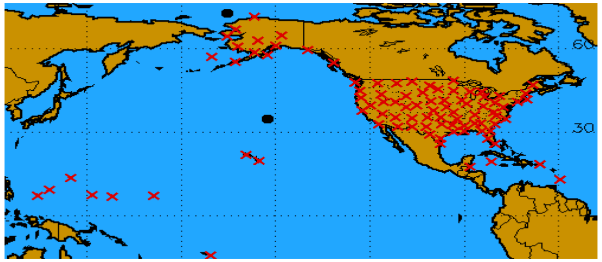
Δ HLOS



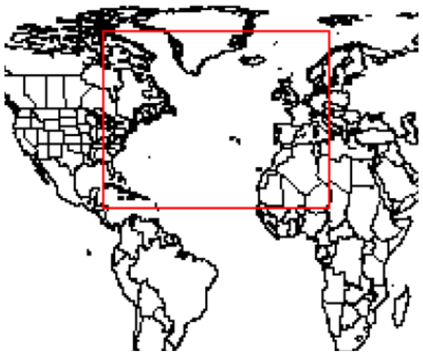


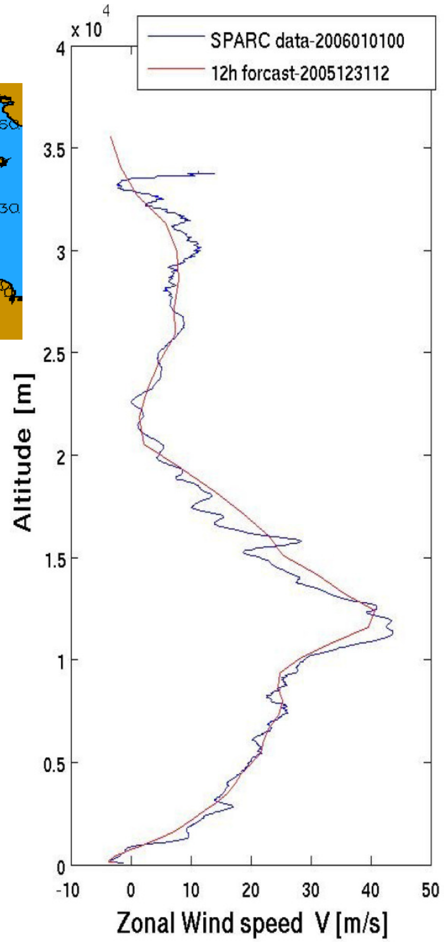
High Resolution radiosondes and ECMWF winds

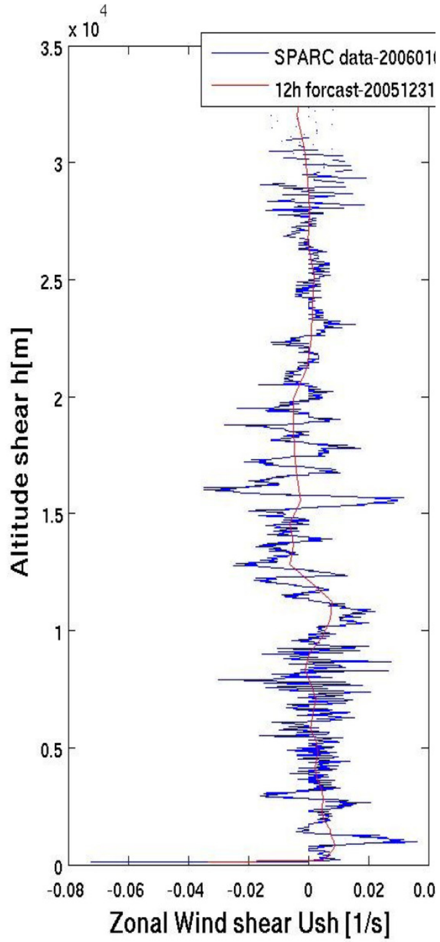
NOAA/NCDC-UCAR SPARC Project (USA)

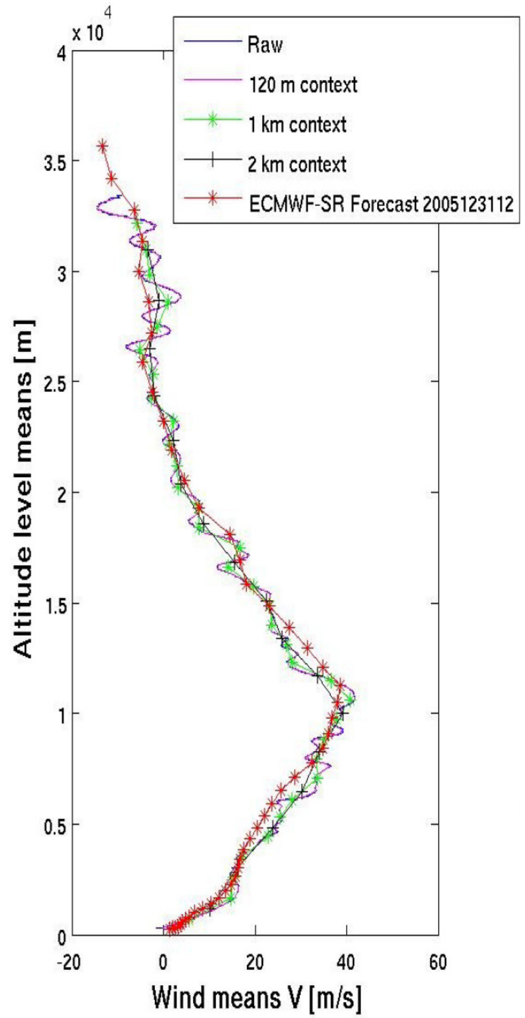


NCAR -FASTEX Project(USA)









ECMWF effective vertical resolution ~ 1.7 km

Error multiplier method

- Generate wind-shear statistics of from Hi-Res radiosondes and collocated ECMWF model winds
- Determine the variability of both datasets as a function of height
- Error multiplier equals the ratio of both variabilities

$$\mathrm{EM}(z) = \frac{[\sigma(z)]_{\mathrm{RS}}}{[\sigma(z)]_{\mathrm{EC}}}$$

- The error multiplier is used to simulate a random wind adaptation for the model winds such that the wind-shear statistics of the adapted winds agree with those of the radiosondes

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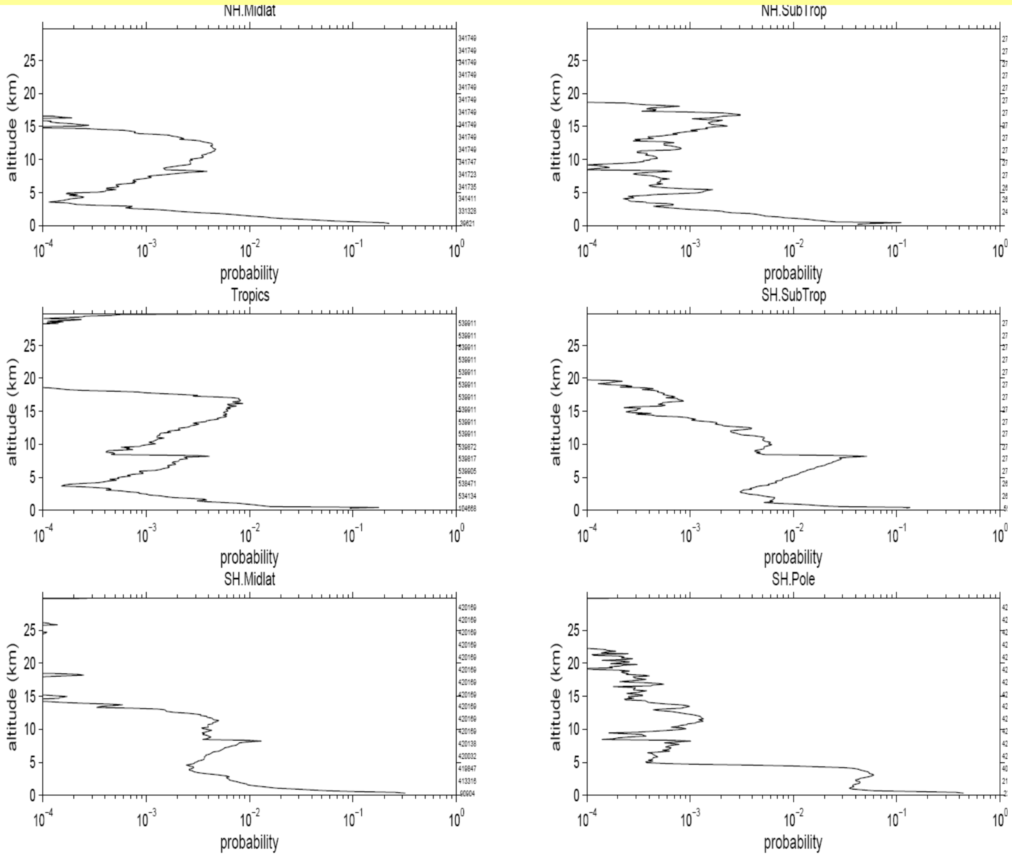
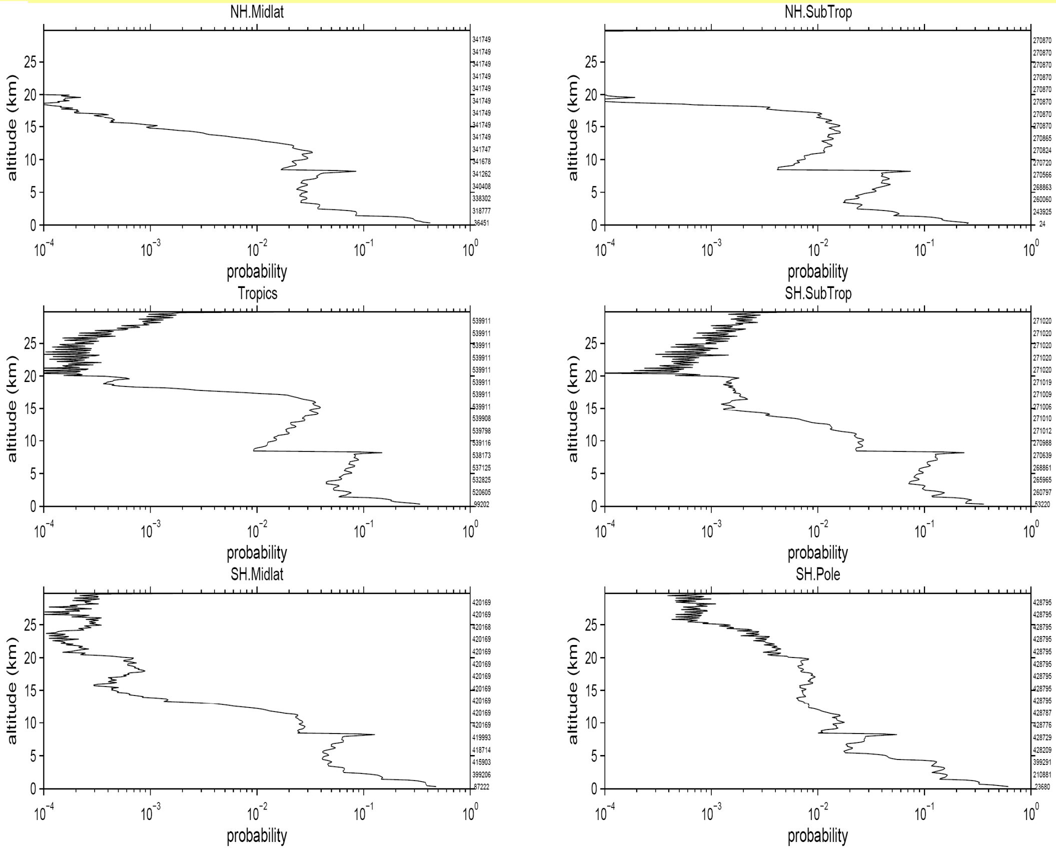
Error multiplier method – application to database
(Extreme events August 2007)

Model wind

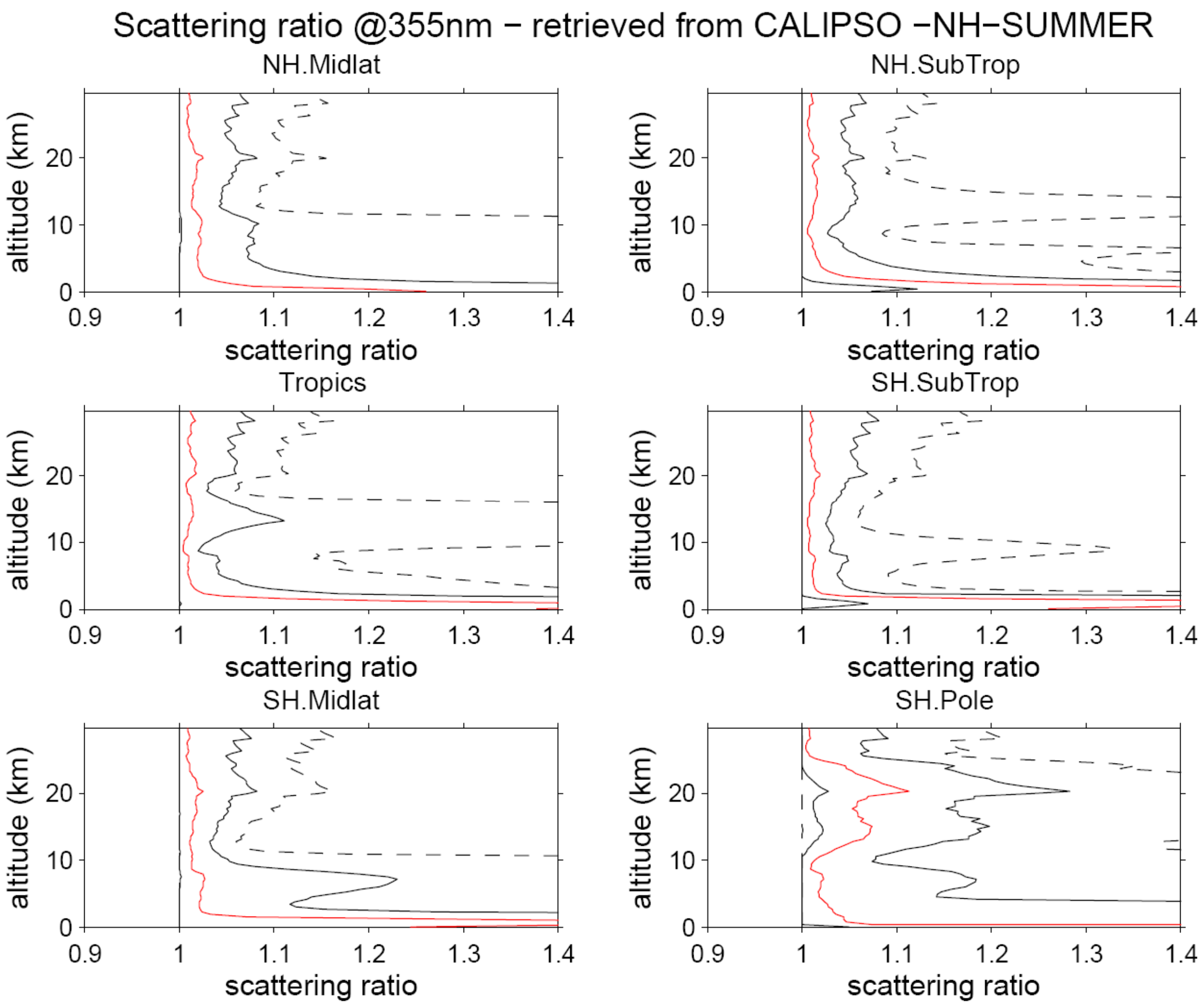


Adapted model wind (error multiplier)



Application of the error multiplier method increases the number of extreme events by a factor of ~10 to about 1-10% in the free troposphere, decreasing with altitude

Mie contamination statistics – August 2007



- Red: median profile
- black: upper deciles
- Average scattering ratio is ~ 1.03
- Scattering ratio exceeds 1.1/3 in 25/10% of cases in the Tropics UTLS
- Scattering ratio exceeds 1.1 in 10% of cases in Subtropical UTLS
- Relative large cloud cover over SH Polar area (>60S)
- PSC exceed scattering ratio of 1.2/1.5 in 25/10% of cases

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Vertical winds

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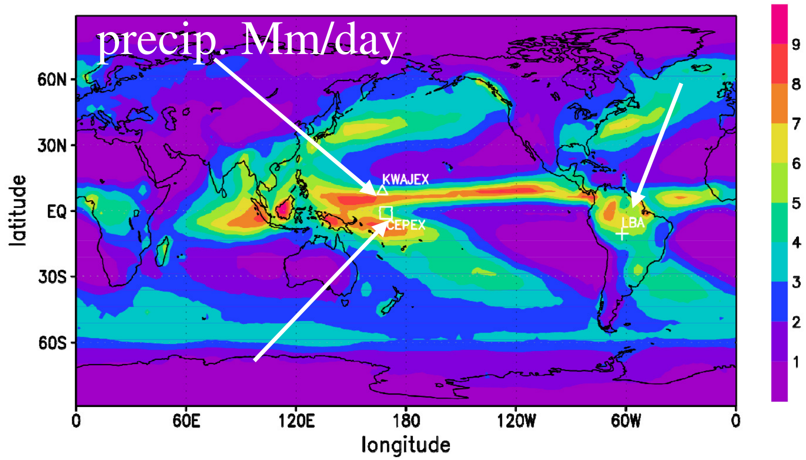
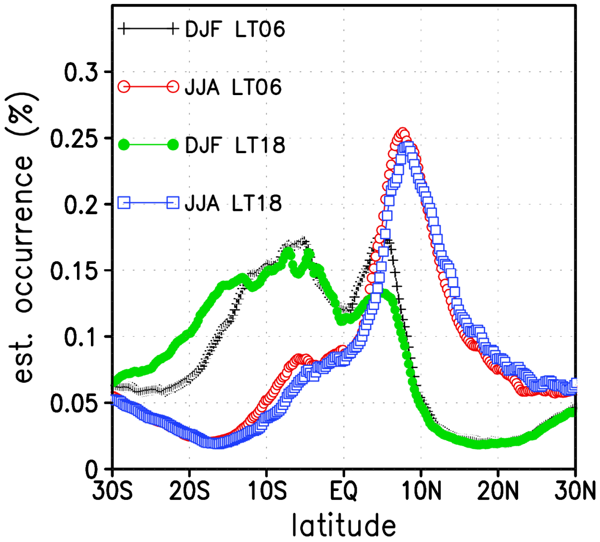
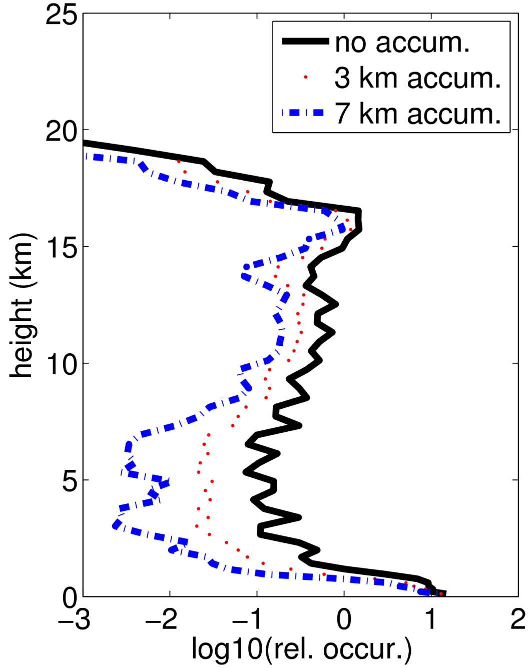
CRM: high horizontal and vertical resolution



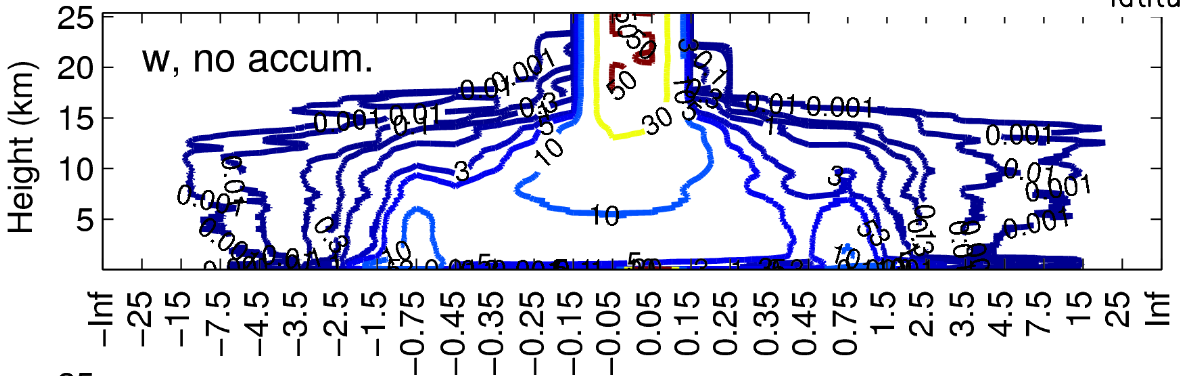
vertical wind velocity > 1 m s[-1]



wind-shear > 0.01 s[-1]



vertical wind velocity occurrence



- Vertical winds up to 30 m/s in tropical CRM, but always covered by clouds

Sensitivity study

Otto Hooghoudt

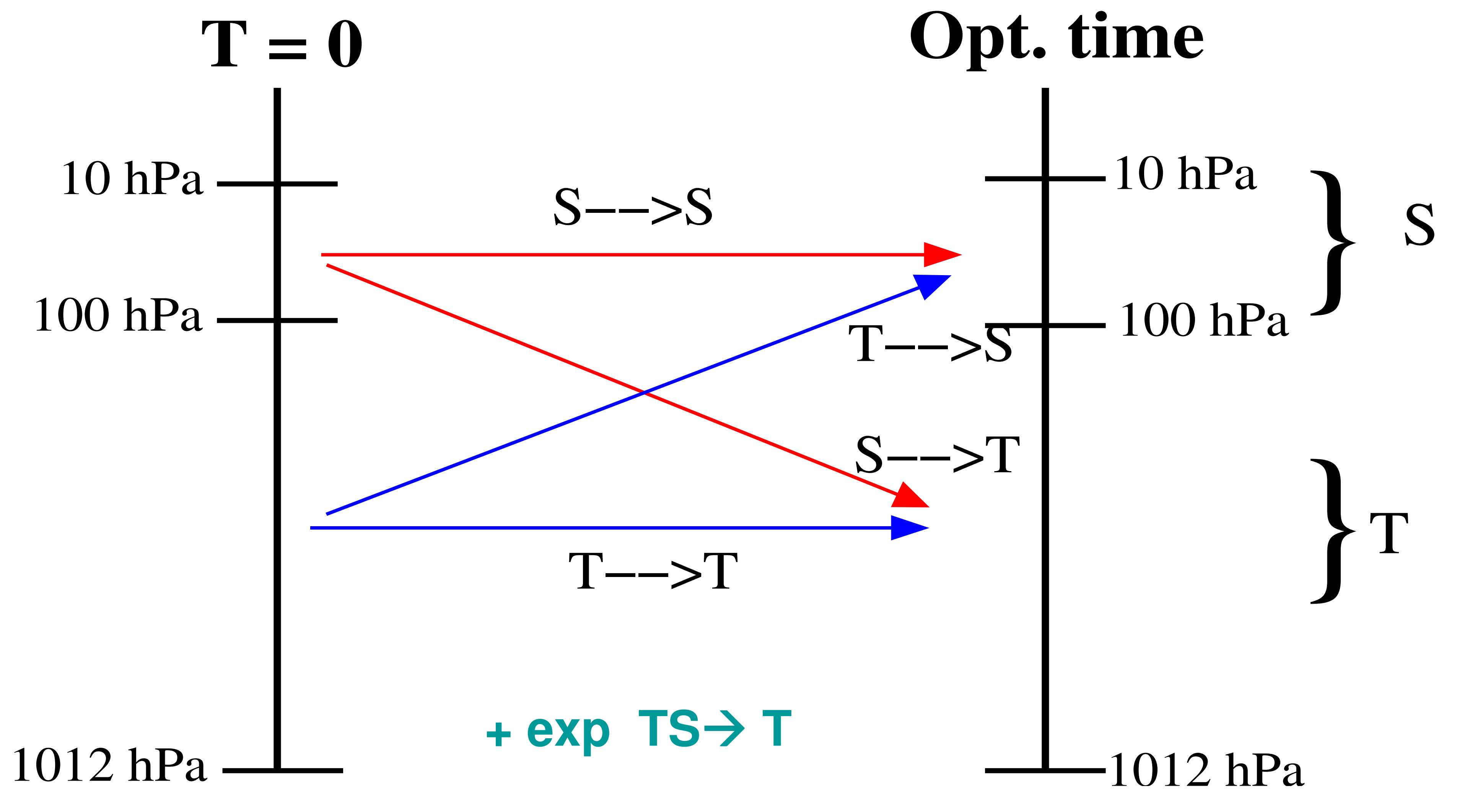
Perturbations are studied that are initially confined to:

i) the troposphere T
ii) the stratosphere S
iii) both T+S

and after 5 days linearly transfer most of their energy
in the troposphere or stratosphere → see figure.

We study the following properties of these perturbations:
- amplification
- preferred geographical position

Schematic of experimental set up

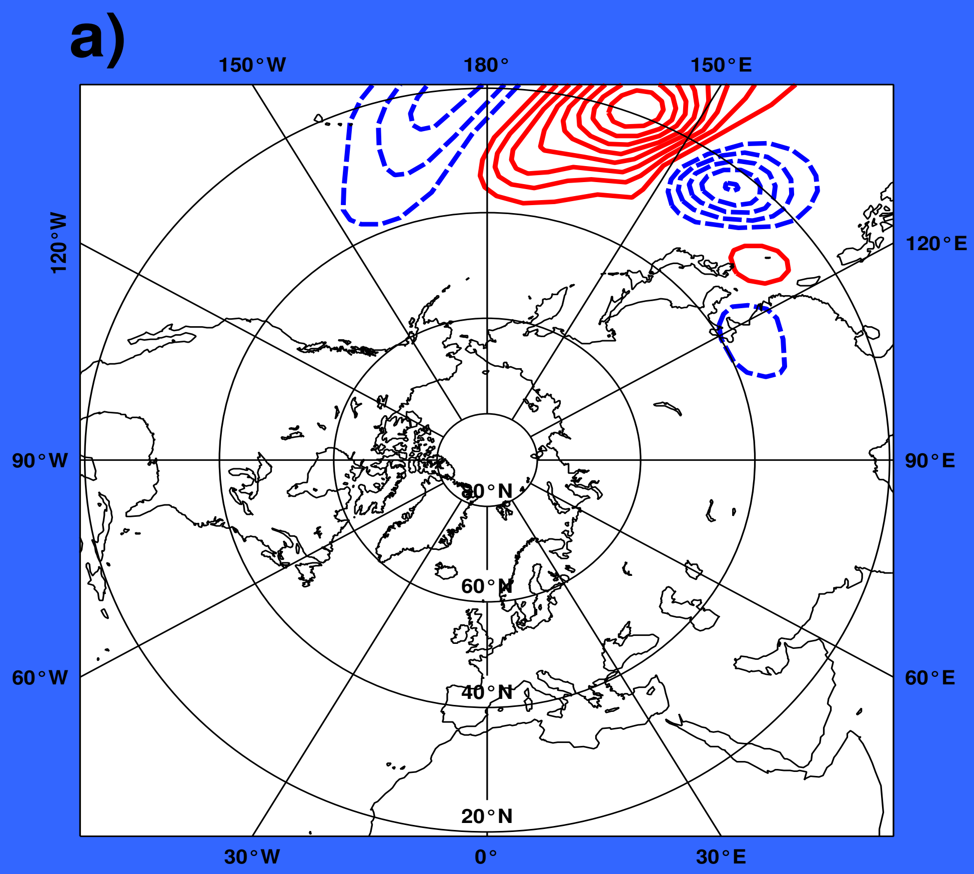


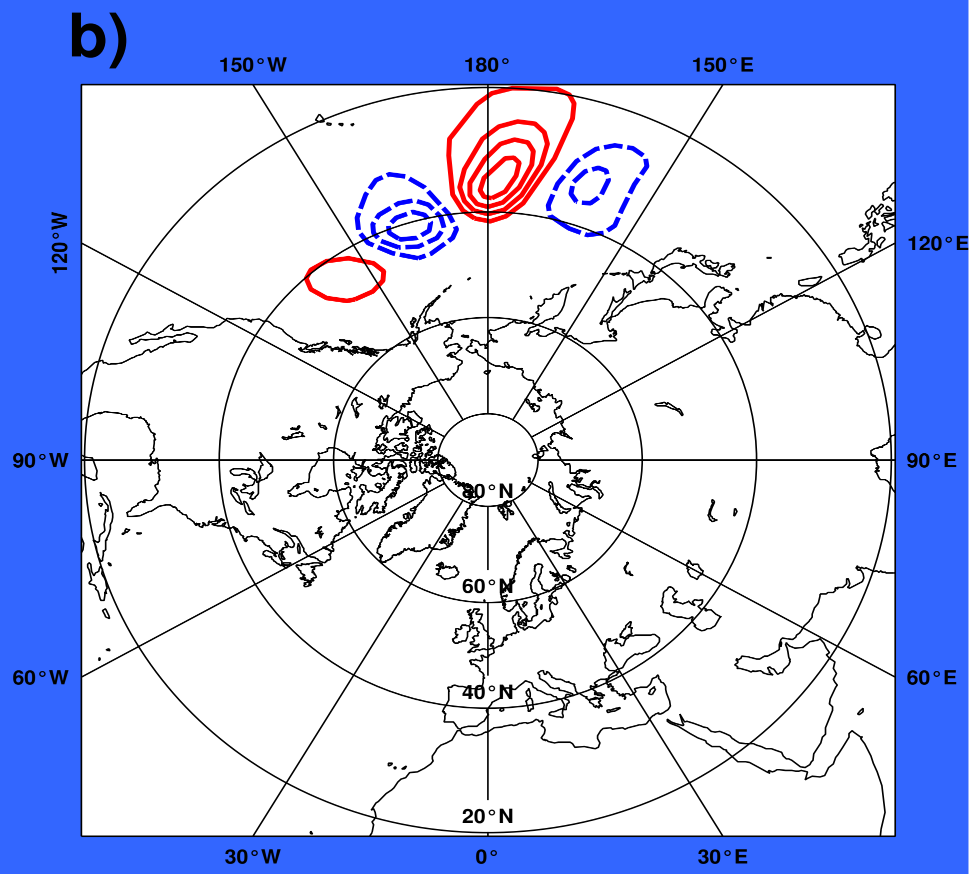
+ exp TS→ T

Streamfunction field of a typical individual S->T SV

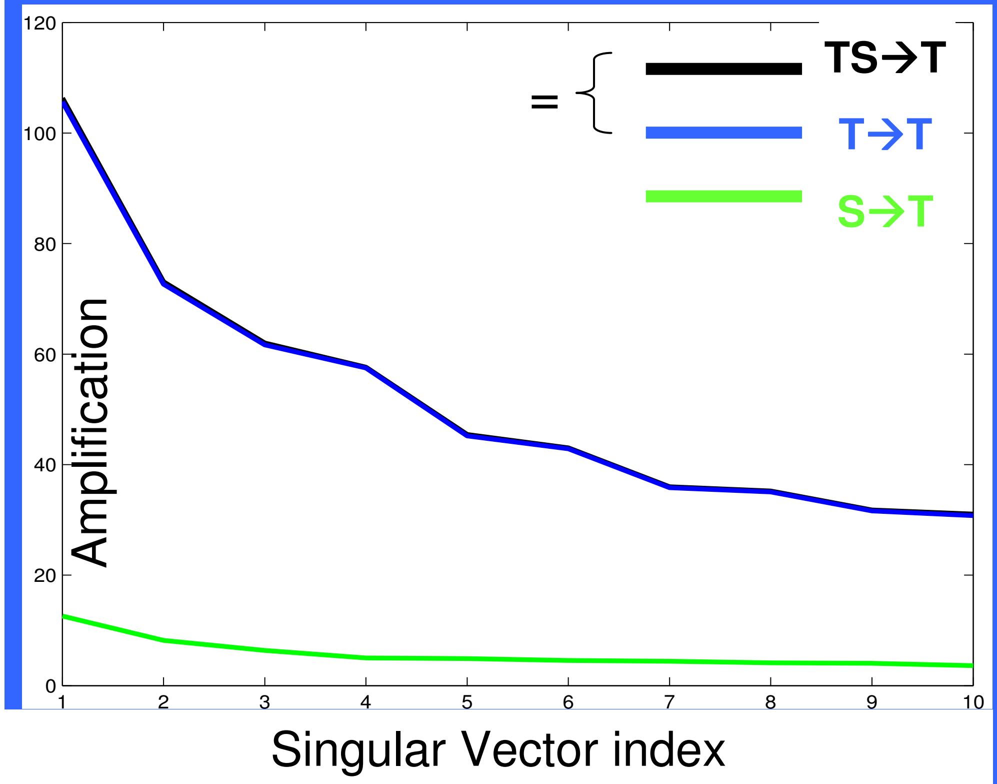
a) Initially at 55 hPa

b) After 5d at 500 hPa



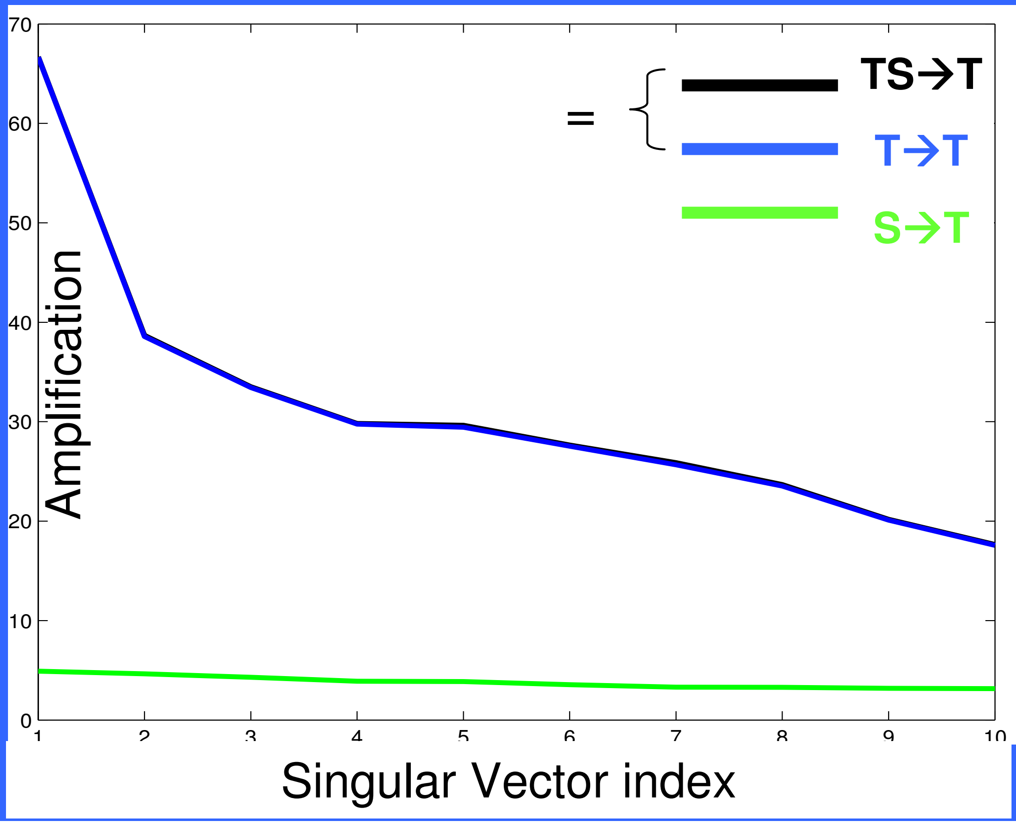


Extra-tropical singular values



January 07

- Initial S ptbs are not much amplified into T after 5 days
- Initial T ptbs dominate 5-day T structures



July 07

Mean amplification factors

	2 days	5 days
(S)T→T	14	45
S→S	4	6
S→T	1	9
T→S	1.5	-

- **Great amplification**
- **Limited S amplification**
- **Negligible i.p.o. T -> T**
- **Relevant w.r.t. S -> S**

- Extra-tropics

Conclusion

- For ADM an advanced vertical sampling scenario needs to be elaborated due to the limited number of vertical range gates.
- Issues of instrument wind calibration, zonal wind variability climate, atmospheric heterogeneity, expected beneficial impact, and data assimilation method are all at interplay.
- Collocated CALIPSO and EM-enhanced ECMWF data provide realistic test data to study processing and sampling options
- Tropospheric observations appear most relevant for defining tropospheric and stratospheric flow

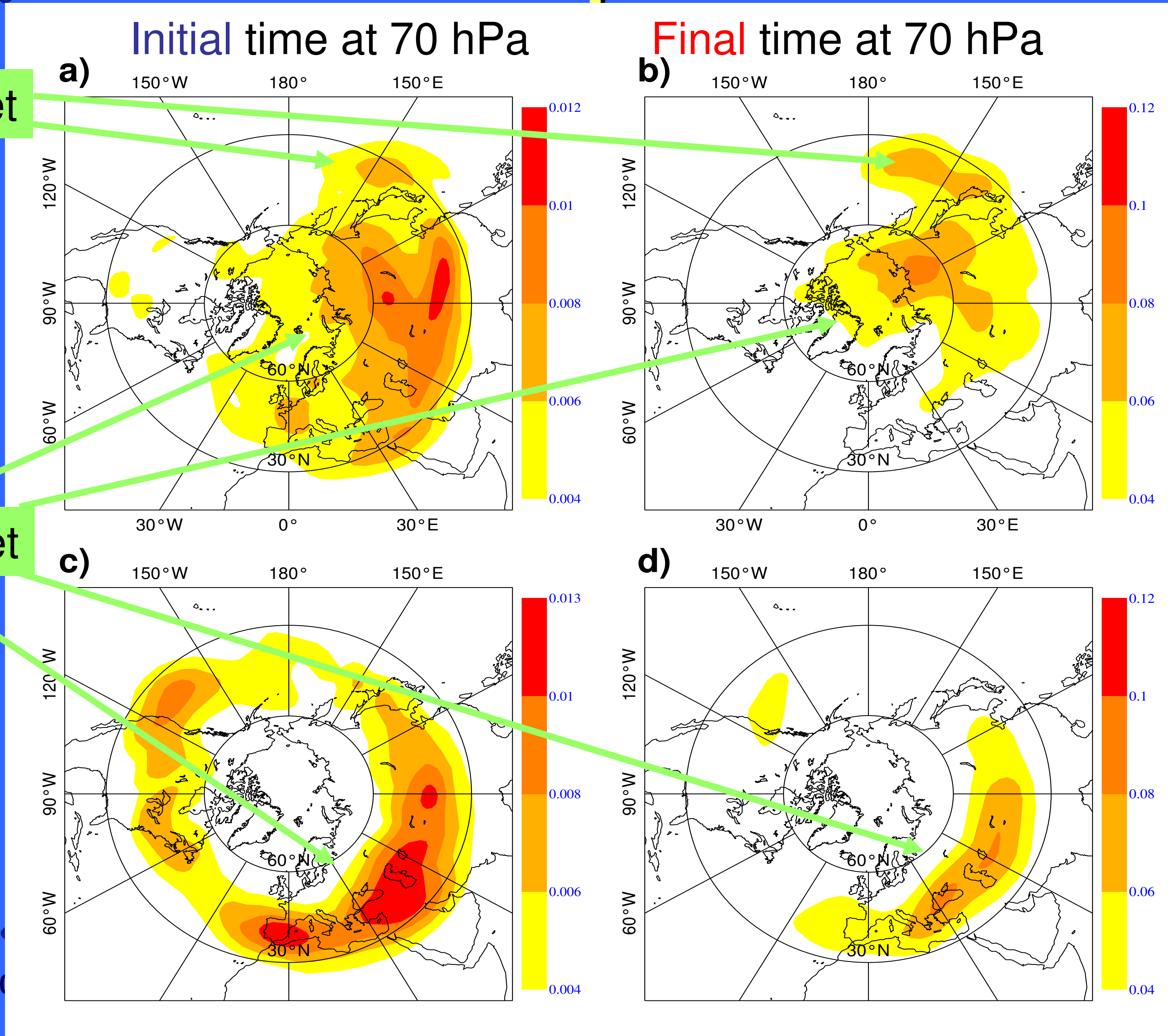
- GS preparation is forthcoming; provision of RT wind profiles being looked at with EUMETSAT
- Be patient with the Aeolus satellite; we are getting there !

- Backup slides

Preferred geographical location extra-tropical S→S svs

Tropo jet

Strato jet



January 2006

Final=5d

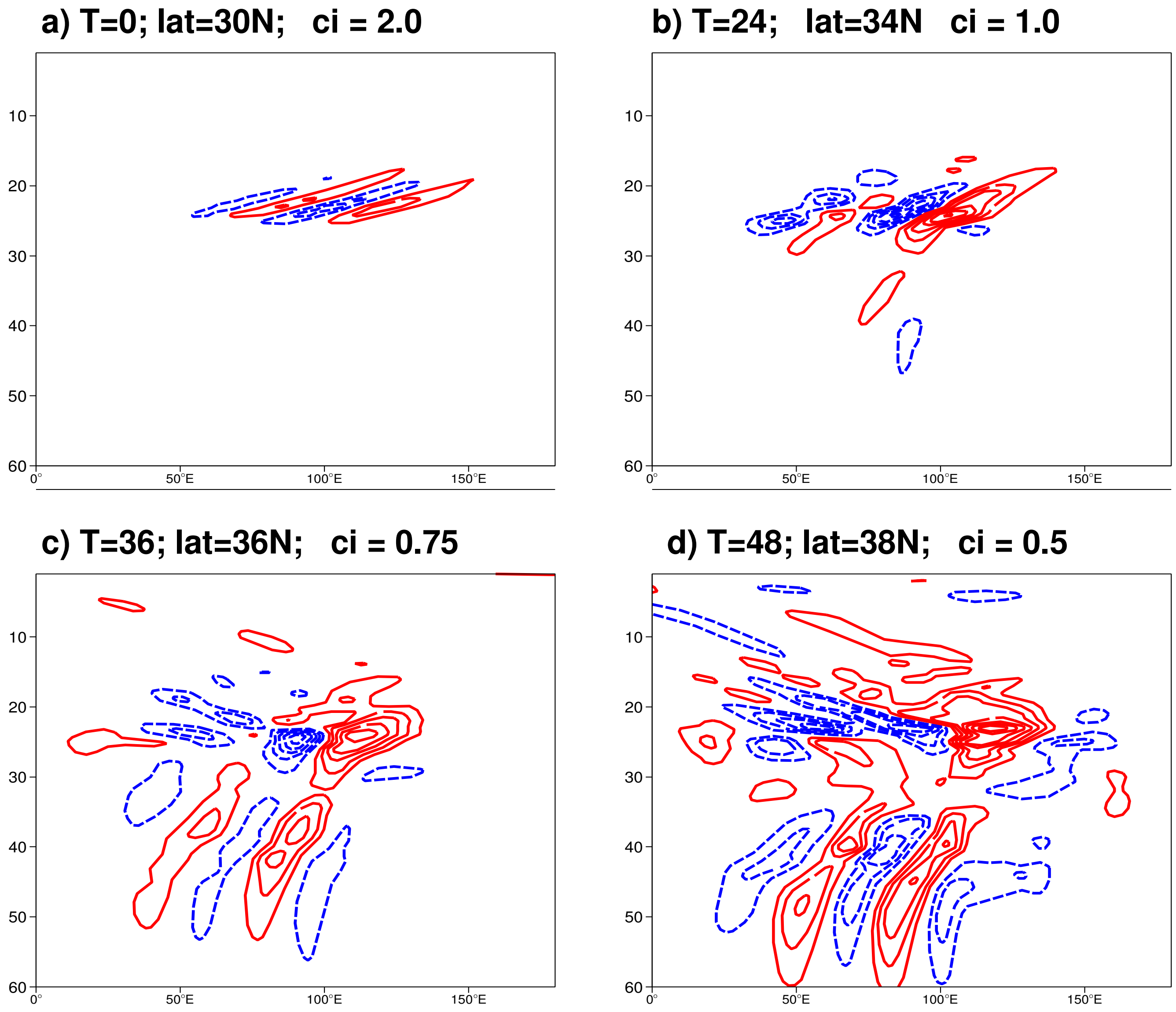
10 SVs
10 days
RMS

July 2006

Final =5d

10 SVs
10 days
RMS

Vertical X-section with time of July S→T SV

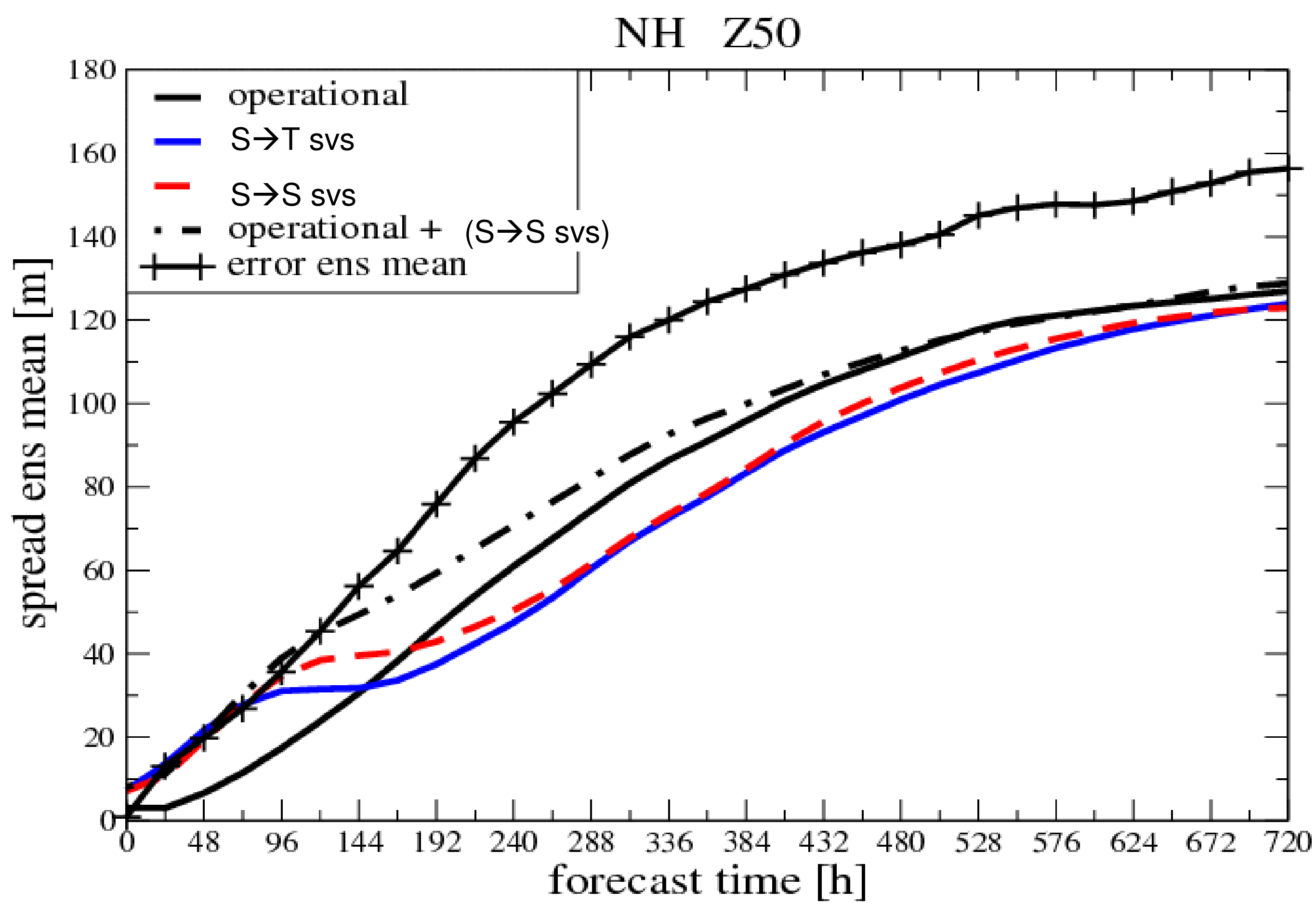


a) T=0
b) T=24 hrs
c) T=36 hrs
d) T=48 hrs

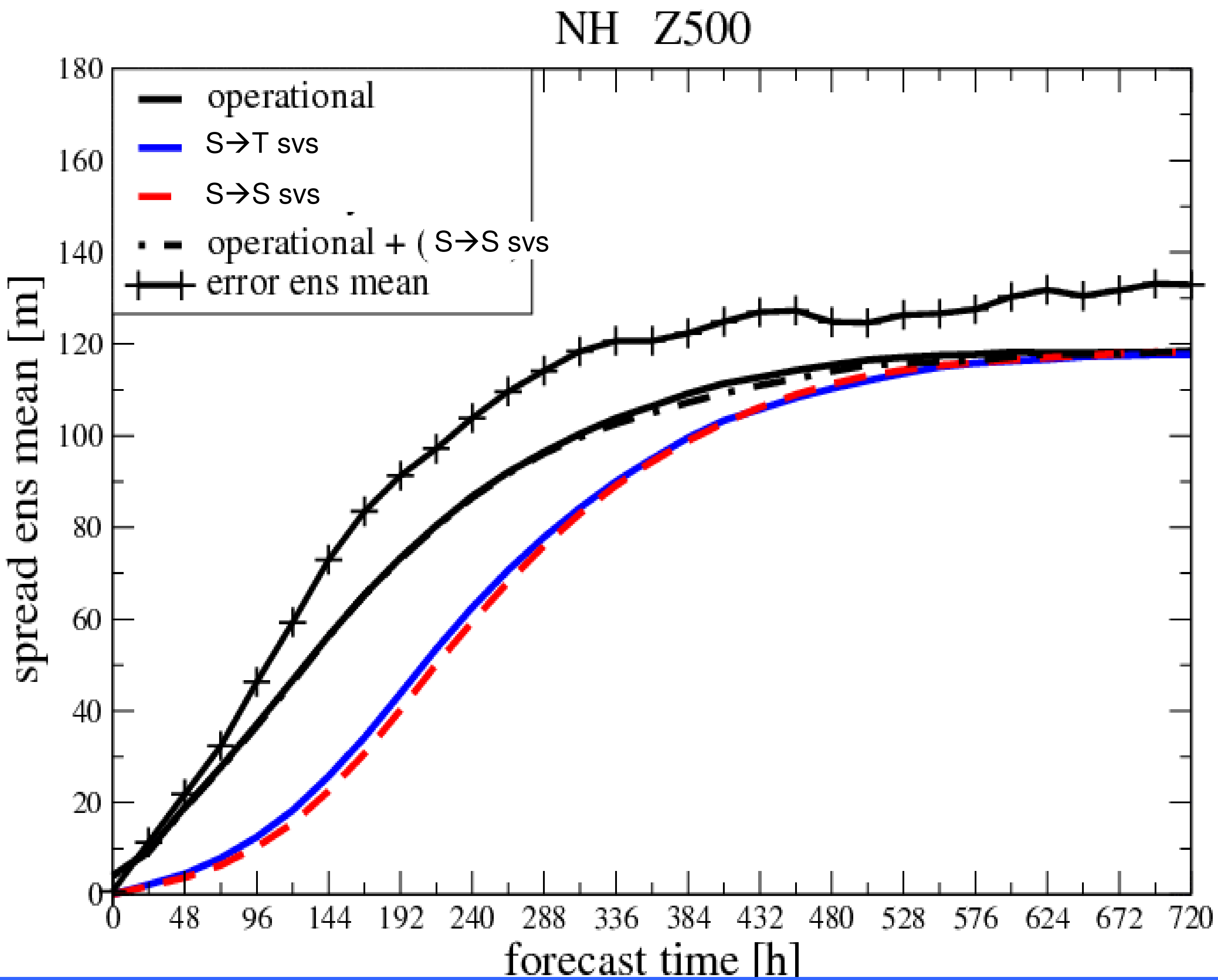
X-section over all 60 model levels (0.1 to 1012 hPa)

Untilting of structures by shear

Ensemble runs Z50



Ensemble runs Z500

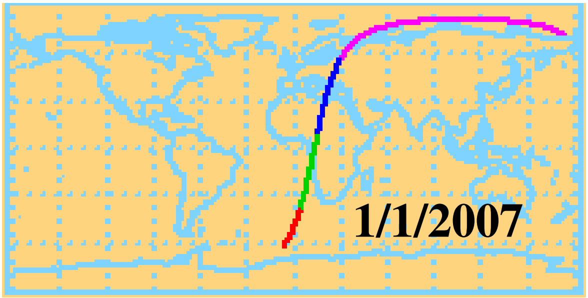


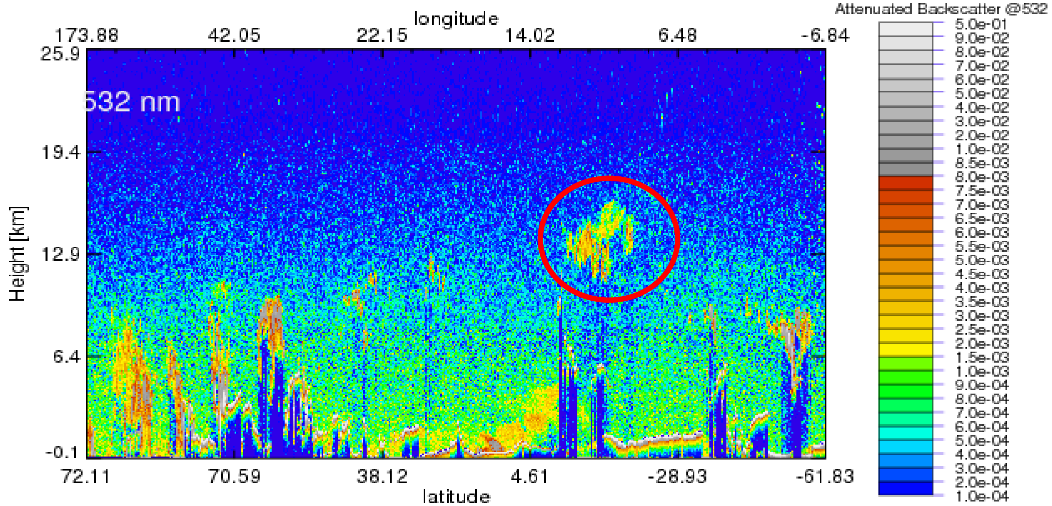
Harmonizing Radiosonde/CRM/NWP

- Assessment of horizontal and vertical sampling of ADM
  - Atmospheric optics: CALIPSO
  - Atmospheric dynamics: collocated global model
- However, model dynamics too smooth, lacking small-scale atmospheric scales, thus underestimating the number of challenging events
- Use additional data sources to adapt the model dynamics
  - CRM: horizontal and vertical atmospheric variability
  - Hi-Res Radiosonde: vertical atmospheric variability

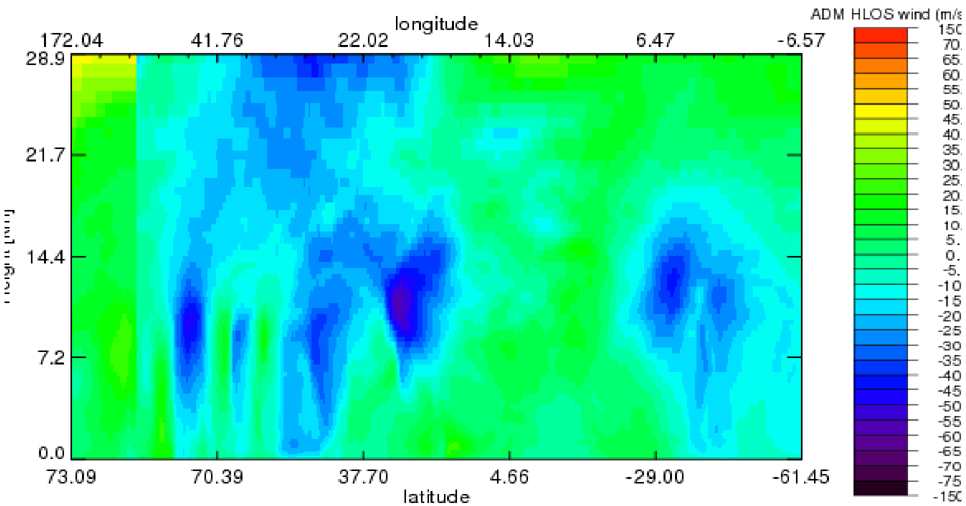
➢ Proposed solution: *error multiplier method*
  - add random winds to the model winds such that the wind-shear statistics of the Hi-Res wind and adapted model wind are compatible

Combined optical and dynamical variability

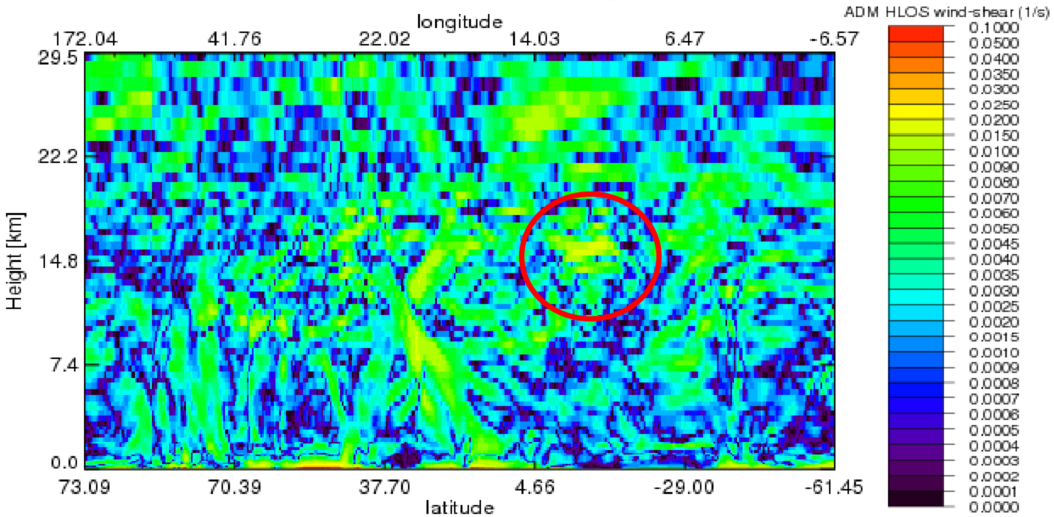




ECMWF HLOS wind along orbit



HLOS wind-shear along orbit



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Retrieval algorithm validation – CALIPSO L2 aerosol product

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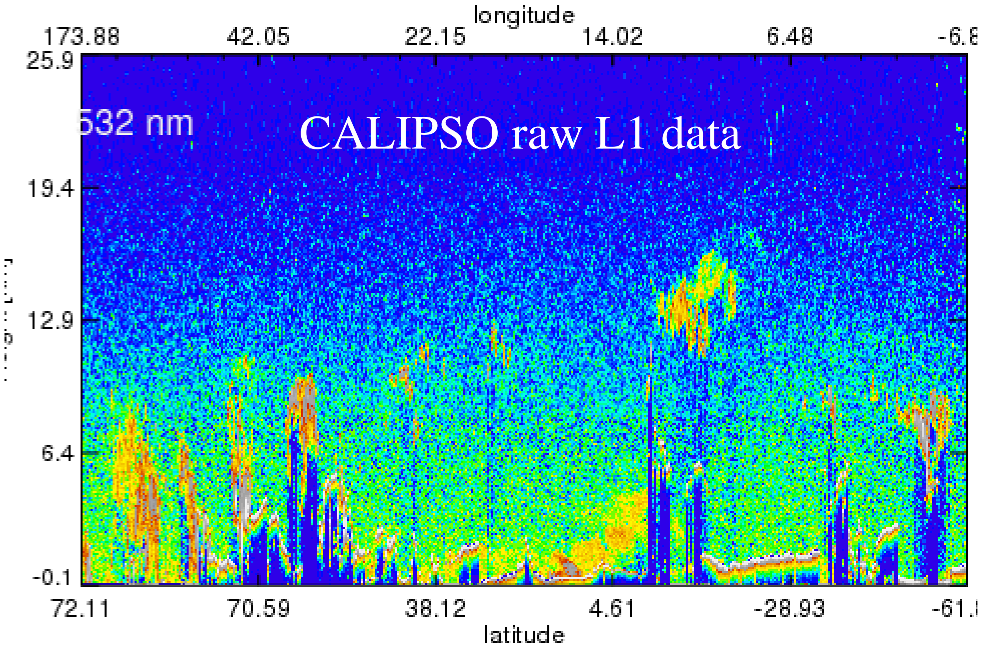
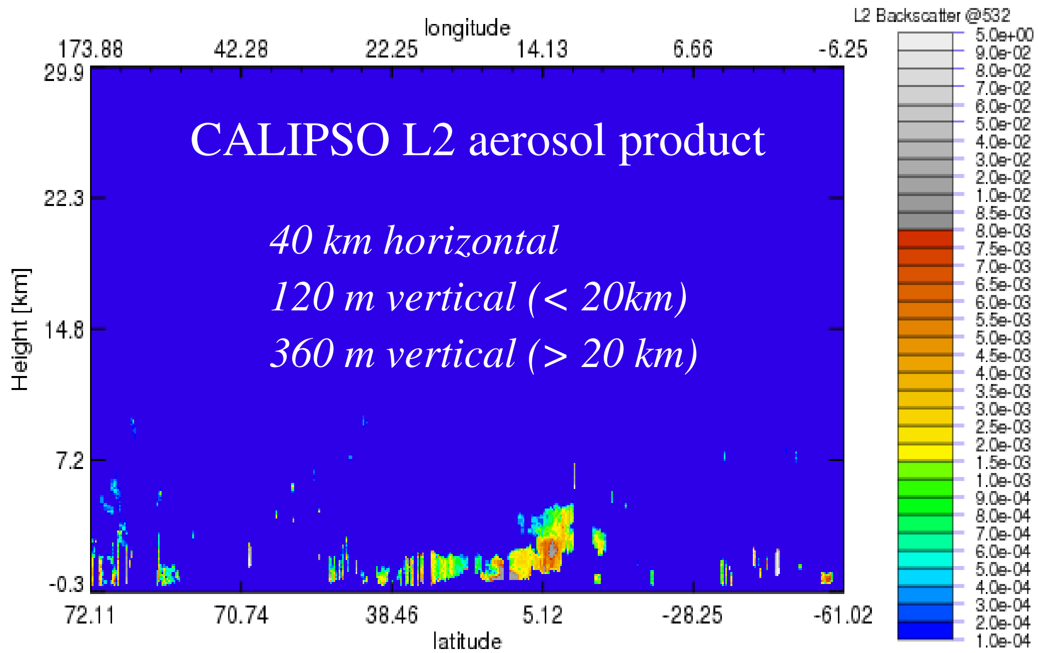
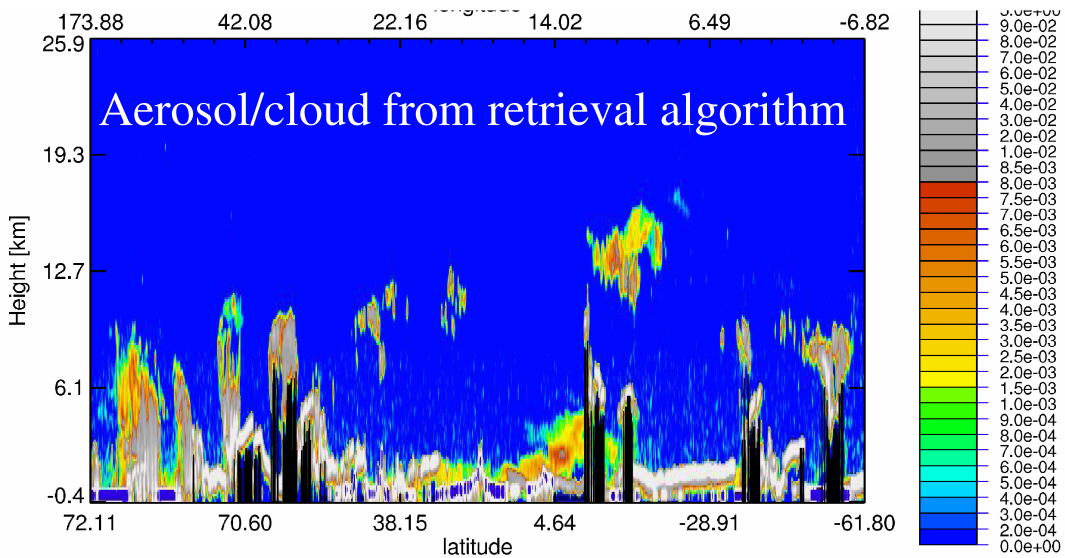




- ➢ Validation with CALIPSO level-2 aerosol product limited to large aerosol loadings



Error multiplier method – ctd.

- Model wind shear: $s(i) = [u(i)\text{-}u(i\text{-}1)]/[z(i)\text{-}z(i\text{-}1)]$; radiosonde resolution (30m)
- Adapted model wind shear: $\hat{s}(i) = s(i) + \delta s(i)$
- $\delta s(i)$ must be such that the variance of $\hat{s}(i)$ equals that of radiosondes

EM is at 1000 m resolution

procedure for each model wind profile

For each EM resolution bin

1. *gather all model shear values in this bin*
2. *determine the variance* $\Rightarrow \sigma_{EC}^2$
3. *correct for EM and keep this value constant in the EM resolution bin* $\Rightarrow$ *var* $\delta s|_{EM}$

$$\text{var}\,\hat{s}(i) = \text{var}\,s(i) + \text{var}\,\delta s(i)$$

$$\sigma_{\text{RS}}^2(i) = \sigma_{\text{EC}}^2(i) + \text{var}\,\delta s(i)$$

$$\text{EM}(i)^2\sigma_{\text{EC}}^2(i) = \sigma_{\text{EC}}^2(i) + \text{var}\,\delta s(i)$$

$$\text{var}\,\delta s(i) = [\text{EM}(i)^2 - 1]\sigma_{\text{EC}}^2(i)$$

- For each EM bin, $\delta s(i)$ is obtained using a random number generator, for each i (30 m resolution), based on a Gaussian distribution with zero mean and var = var $\delta s|_{\text{EM}}$
- Adapted wind: $\hat{u}(i) = \hat{u}(i-1) + [z(i) - z(i-1)]\hat{s}(i)$

To do: dataset integration/data assimilation issues

- Integrate NWP/CRM/Hi-Res radiosonde statistics
  - Global statics of the occurrence of heterogeneous atmospheric scenes
  - Input for the selection of vertical sampling scenarios
- Recapitulate measures of expected ADM impact as a function of height and climate zone. Anticipated background and observation error variances should be compared to estimate the "information content" of different vertical sampling scenarios. O-B and O-A statistics of other wind observation types could provide further guidance.
- A simple vertical analysis model to simulate the effect of shear data assimilation should be tested. Realistic NWP experiments can be conducted for existing wind profile data.
- Assimilation ensemble experiment (Tan and Andersson, 2005) with a focus on the stratospheric dynamics for selected sampling scenarios

VAMP approach

- Generate statistics of atmosphere dynamical and optical variability as a function of season/climate zone/land/sea
  - Atmospheric optics: CALIPSO; global coverage
  - Atmospheric dynamics: ECMWF global model, collocated at CALIPSO locations
- However, model dynamics too smooth, lacking small-scale atmospheric scales, thus underestimating the number of large shear events
- Use additional data sources to adapt the model dynamics
  - Cloud Resolving Models: horizontal and vertical atmospheric variability
  - Hi-Res Radiosonde: vertical atmospheric variability
- Recapitulate measures of expected ADM impact as a function of height and climate zone. Anticipated background and observation error variances should be compared to estimate the "information content" of different vertical sampling scenarios. O-B and O-A statistics of other wind observation types could provide further guidance.
- Assimilation ensemble experiment (Tan and Andersson, 2005) with a focus on the stratospheric dynamics for selected sampling scenarios

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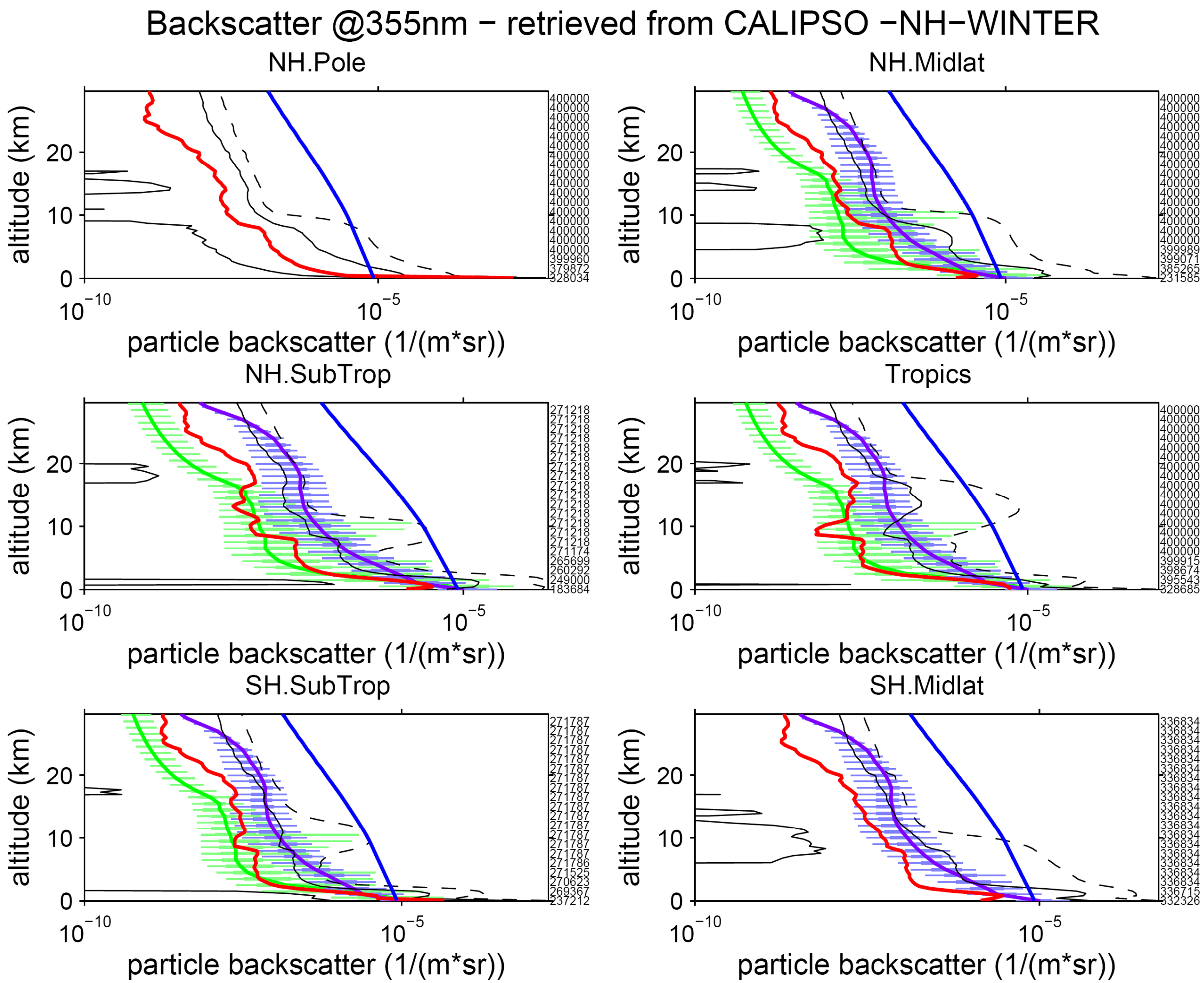
CALIPSO retrieval validation with LITE/RMA

AEOLUS



January 2007

355 nm aerosol backscatter

Green: Vaughan 1989 data (RMA)

Purple: LITE 1994

Red/black: CALIPSO 2007

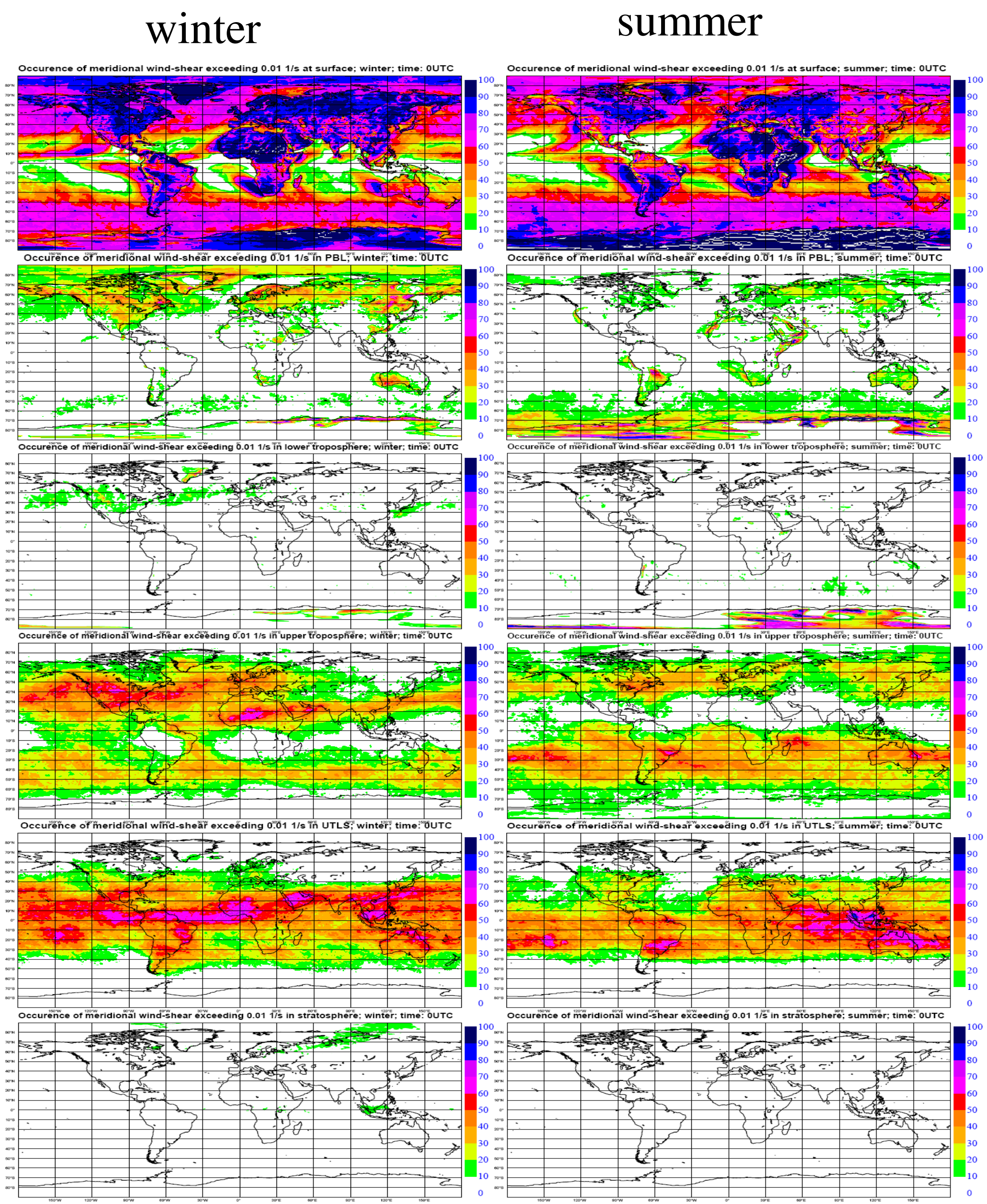
Blue: molecular backscatter

CALIPSO retrieval is in between "clean" Vaughan and "dirty" LITE period

Occurrence of large wind-shear and vertical wind events

- Based on ECMWF analyses
  - Diurnal variation by considering 0/6/12/18 UTC analyses
  - Seasonal variation by considering 4 3-month seasonal periods

- Statistics as a function of height level:
  - *Surface* : from earth surface up to 250 m above surface
  - *PBL* : from top of *Surface* up to 3 km
  - *Lower troposphere* : from top of PBL to 7 km
  - *Upper troposphere* : from top of lower troposphere to 15 km
  - *UTLS* : from top of upper troposphere to 22 km
  - *Stratosphere* : above top of UTLS



Extreme meridional wind-shear

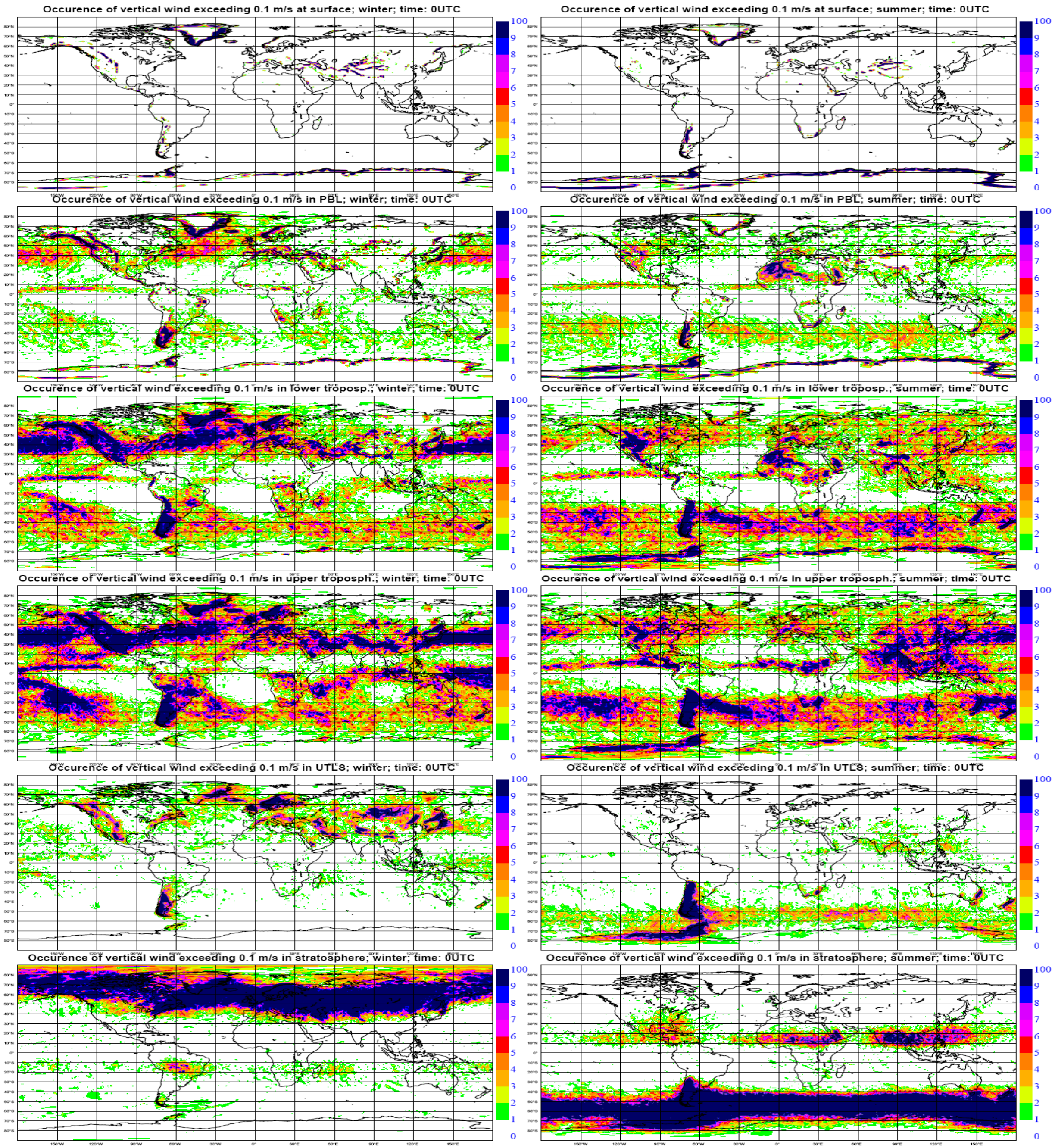
Occurrence of *meridional* wind-shear exceeding 0.01 s^{-1}

<u>Seasonal dependence</u>

DJF 2006/7 vs. JJA 2007 (00UTC)

- less shear in meridional than zonal wind component
- Also at higher latitudes where the meridional wind component contributes substantially to HLOS

winter summer



“Extreme” vertical winds

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Occurrence of Vertical wind speed exceeding 0.1 ms^{-1}

- generally well below 10%

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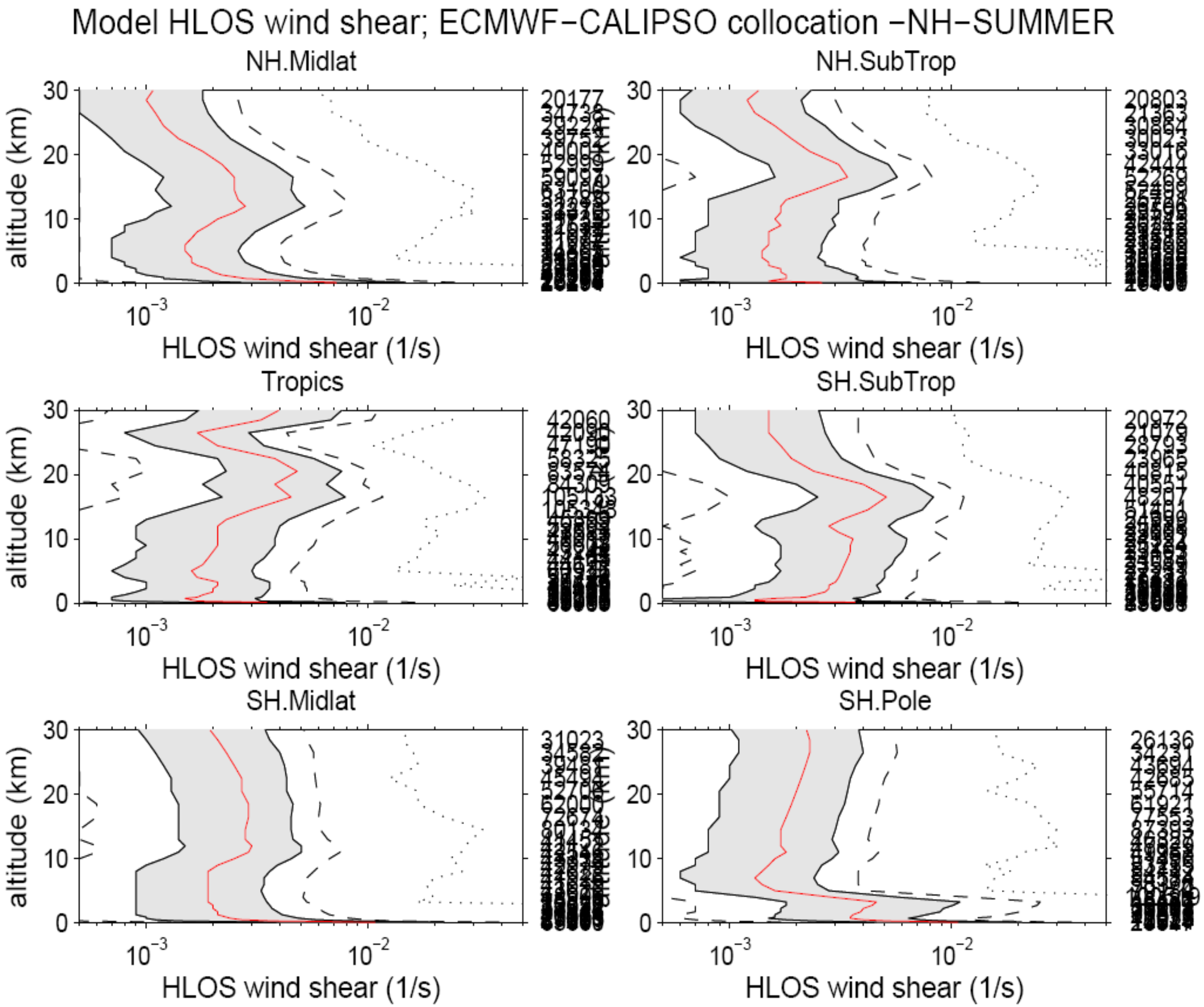
Atmospheric dynamics (HLOS wind-shear statistics)

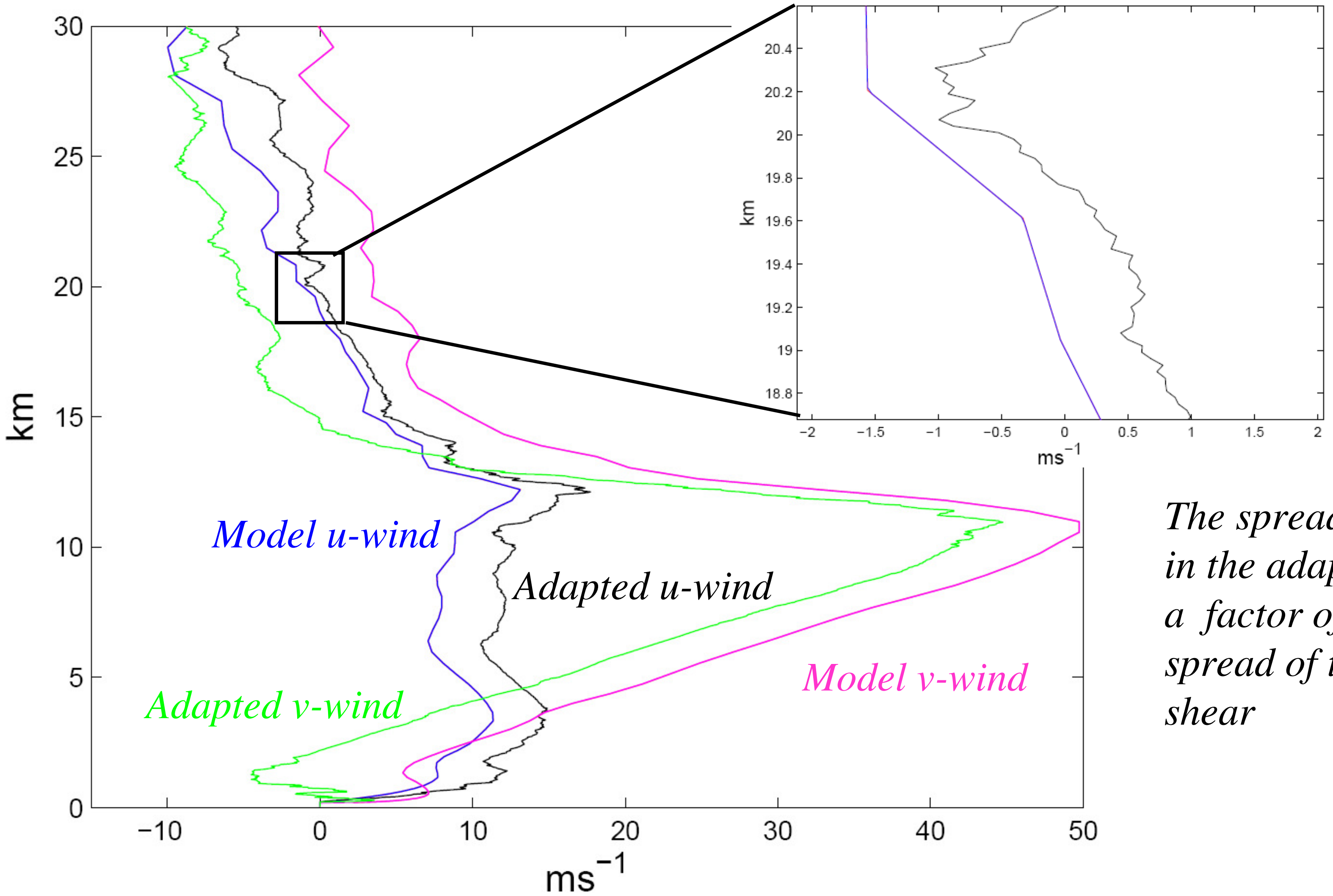
AEOLUS



<u>*August 2007*</u>

- ECMWF model (T799L91)
- Mean HLOS wind shear ≈ 0.002-0.003 s^{-1}, i.e. 2-3 ms^{-1} /km,
- maximum wind shear ≈ 0.04 s^{-1} near surface and tropopause height

Error multiplier method – example



The spread of the wind-shear in the adapted wind profile is a factor of 2 larger than the spread of the model wind-shear