USING MODEL SIMULATIONS TO IMPROVE THE CHARACTERIZATION OF CURRENT ATMOSPHERIC MOTION VECTORS

A. Hernandez-Carrascal (ECMWF), N. Bormann (ECMWF),
R. Borde (EUMETSAT), H.-J. Lutz (EUMETSAT),
S. Wanzong (CIMSS)

Contents

SimulAMV2 project

- Main objective:
  - To improve the understanding of the characteristics and origins of AMV errors, to improve the use of AMVs in NWP.
- ECMWF and EUMETSAT collaboration, CIMSS contribution.
- 13-month study – end in March 2012.
- Earlier pilot simulation study (von Bremen, 2008).

SimulAMV2 - motivation and approach

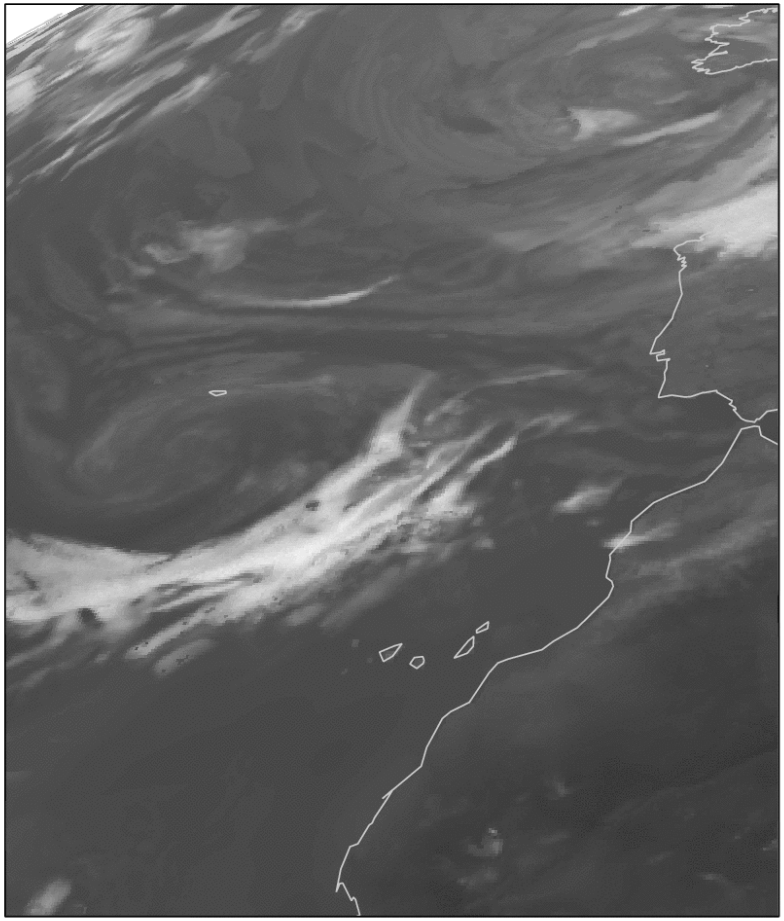
- It is known that AMVs are affected by large systematic errors.
  - Important difficulty: scarcity of collocated wind / cloud observations.
- Open questions e.g. how should AMVs be interpreted?
  - As a single level observation of wind, or as a vertical average?
- Approach in this study: simulation framework
  - NWP model simulations : data and images.
  - Derive AMVs from simulated images
    - Done by EUMETSAT (prototype derivation system)
  - Model data represent a “ground-truth”.
  - Wind and clouds known – this allows detailed analysis.

Model simulations

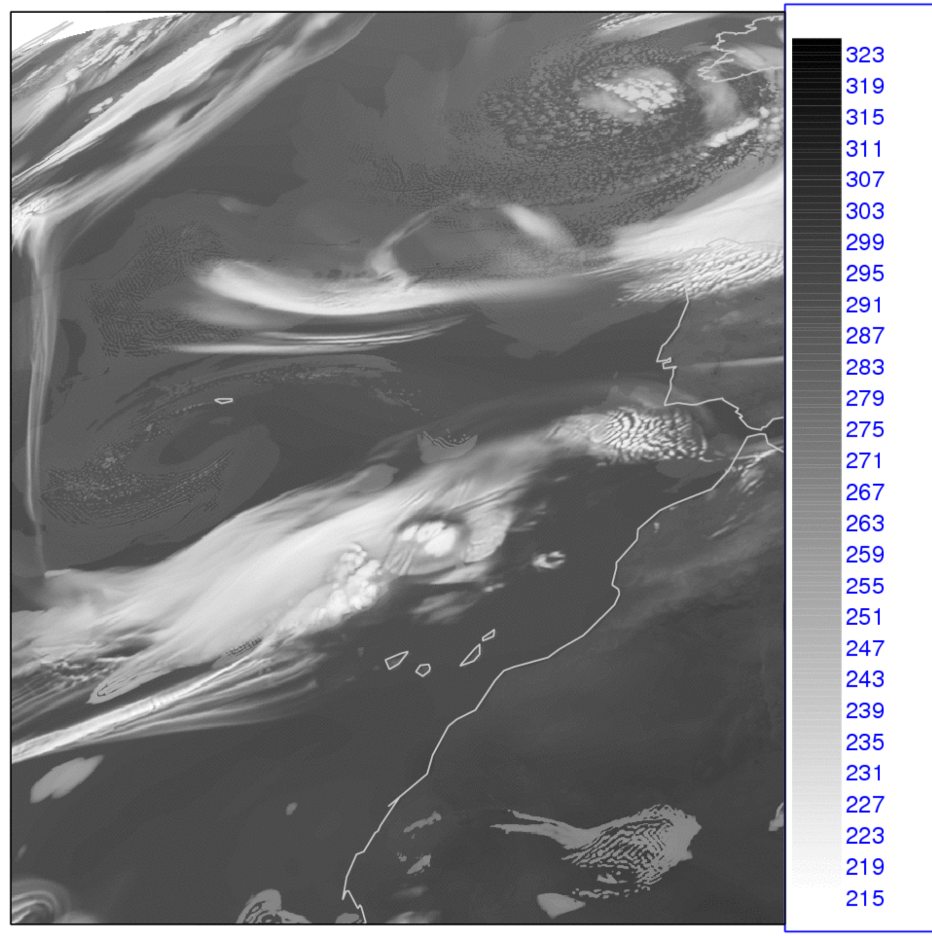
- Study period: 24 h starting 16 Aug 2006 at 00 UTC.
- Study area: (almost) full view of MSG at 0 lon (Meteosat-8).
- Model fields and simulated images stored every 15 min.
- WRF simulation (we will present results about WRF only).
  - Kindly provided by CIMSS (Otkin et al., 2009).
  - Version 2.2 of the WRF regional model (Skamarok et al., 2005).
  - Full area of MSG at 0 lon almost covered (N and S boundaries at 58.5 deg)
  - Forecast model: 3 km nominal horizontal res at equator, 52 vertical levels.
  - Simulation is a 6-30 h forecast – spin up period 6 h.
- ECMWF simulation:
  - Forecast model: 10 km nominal horizontal resolution, 91 vertical levels.
  - Simulation is a 24-48 h forecast – spin up period 24 h.

SimulAMV2 - Simulated images: IR 10.8 µm

IFS global model



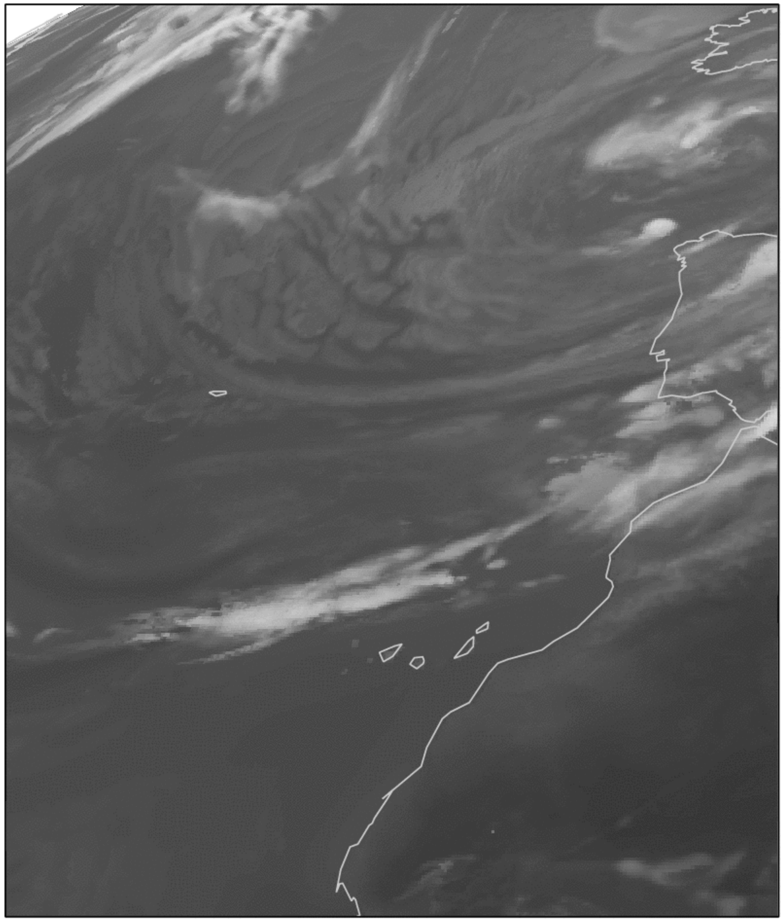
WRF regional model



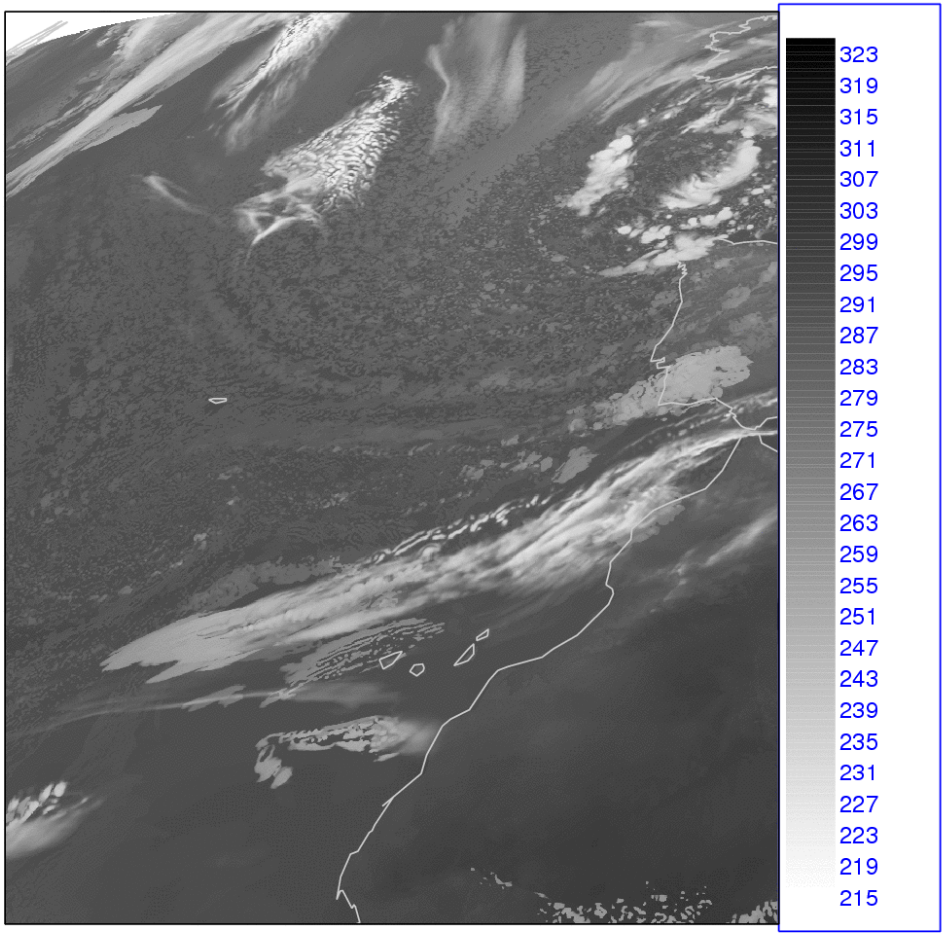
ECMWF

SimulAMV2 - Simulated images: 10.8 µm IR

IFS global model



WRF regional model

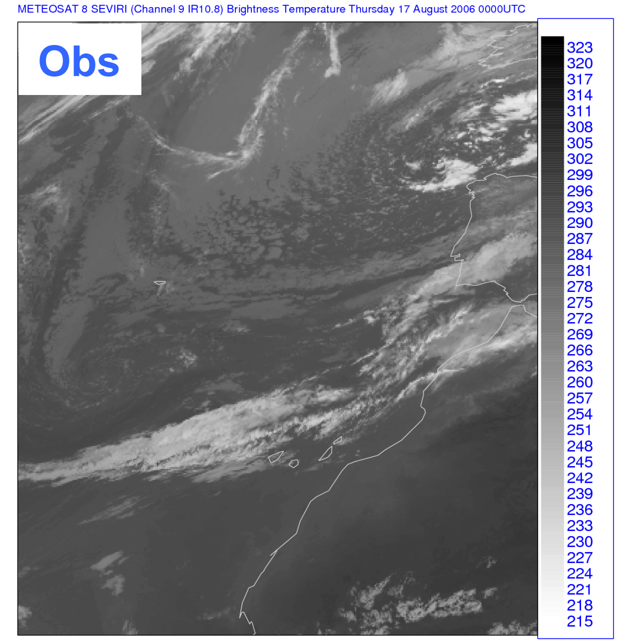


(last image)

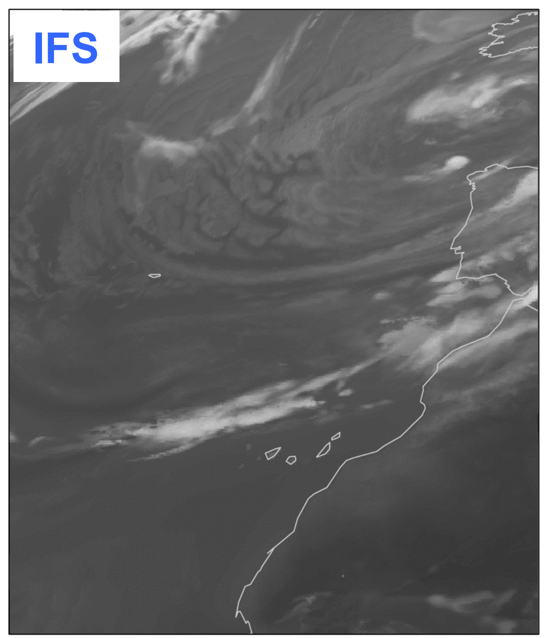
Simulated images: cloud structures

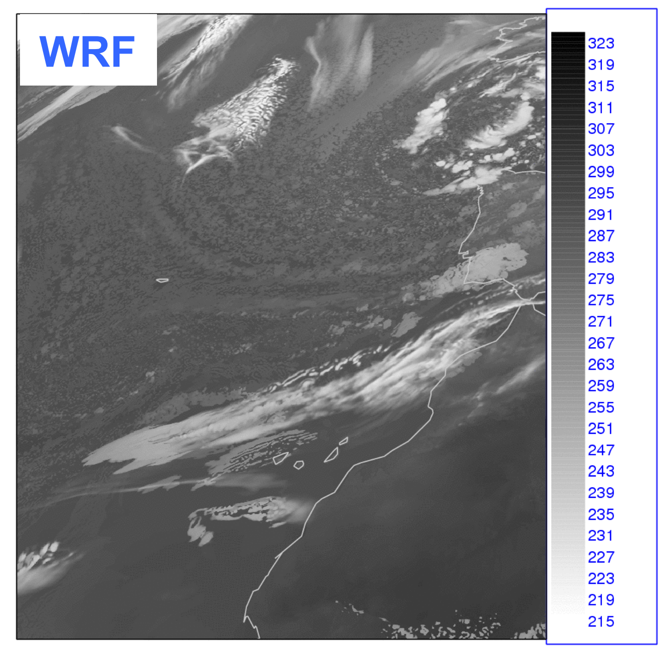
- **Are simulated images realistic?**
  - Interested in general variability of cloud structures.
  - Agreement at a location and time not relevant.

IR 10.8 µm



- **WRF images: more detailed spatial structure than IFS.**



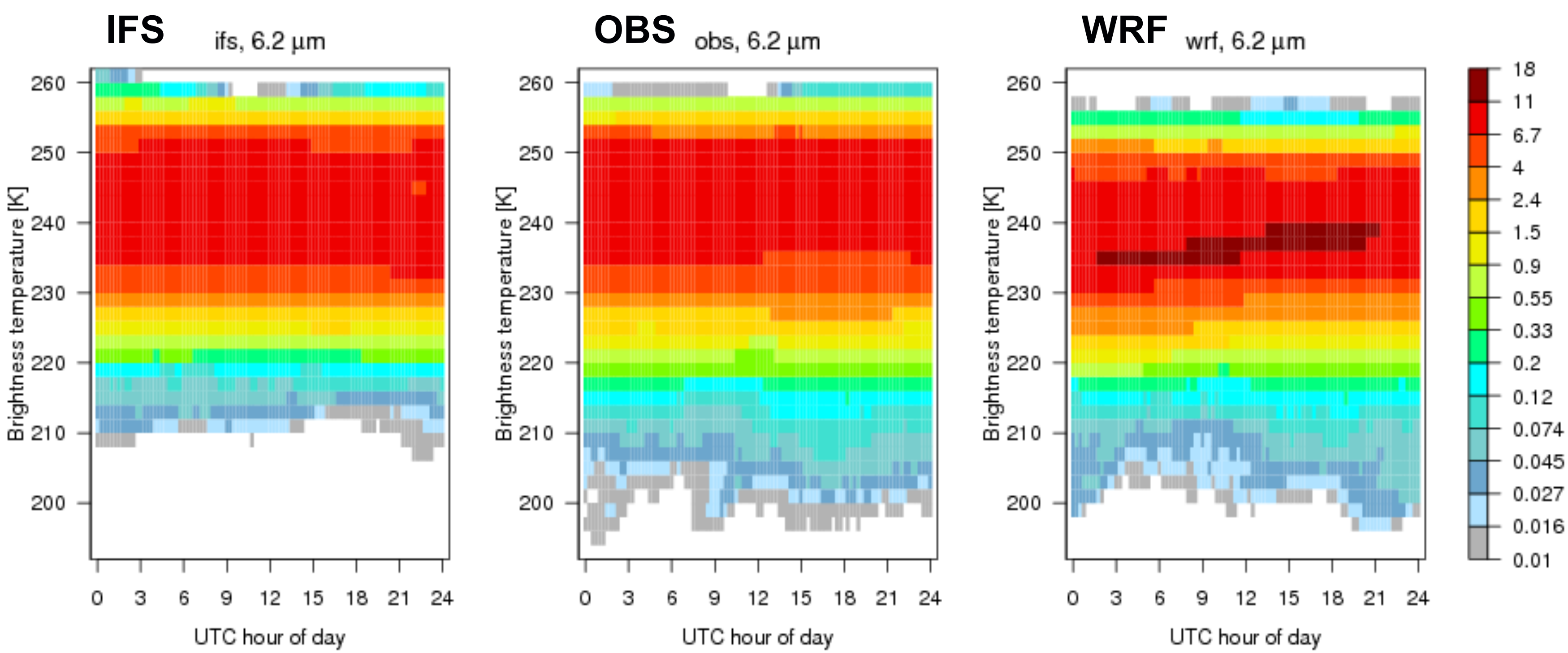


ECMWF

Simulated images: cloud structures

- Cold tail: WRF similar to OBS (ice clouds)
- WRF spin-up during first ~9-12 h (known problem)

Temporal evolution of BT histograms – WV 6.2



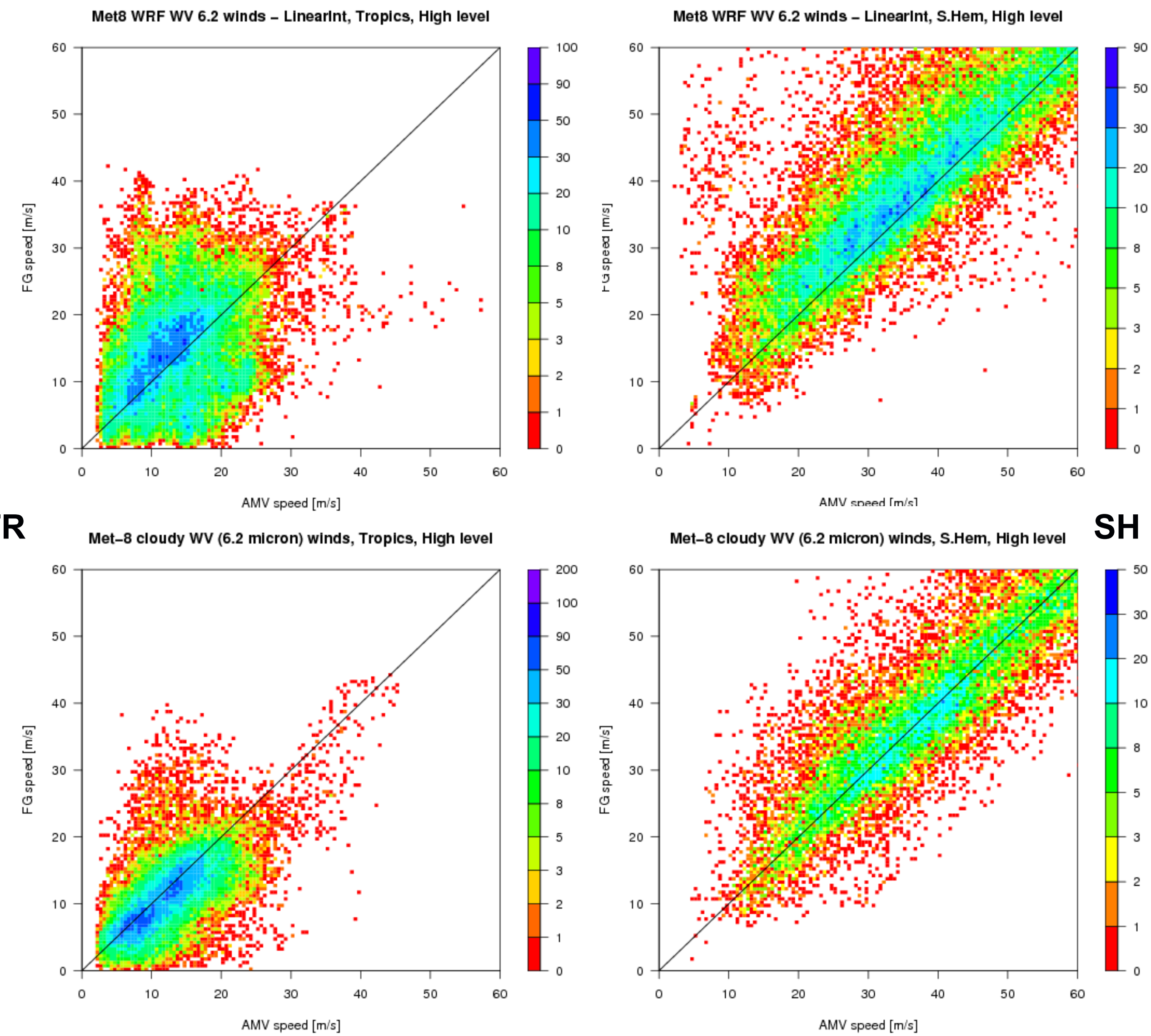
ECMWF

Evaluation of AMVs as single-level estimates of wind

- WRF AMVs, WV 6.2
- High level
- X axis: AMV speed
- Y axis: model wind speed. Model wind is linear interpolation of model wind profile at the original AMV pres.

TR

SH



- AMVs from OPS at the day, WV 6.2
- High level
- X axis: AMV speed
- Y axis: FG wind speed.

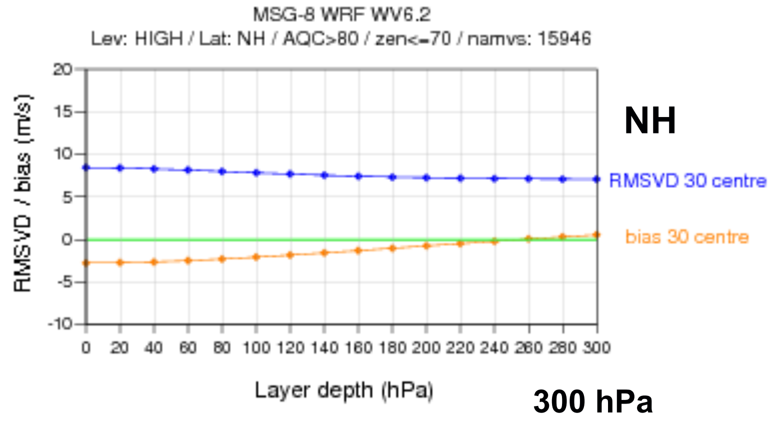
ECMWF

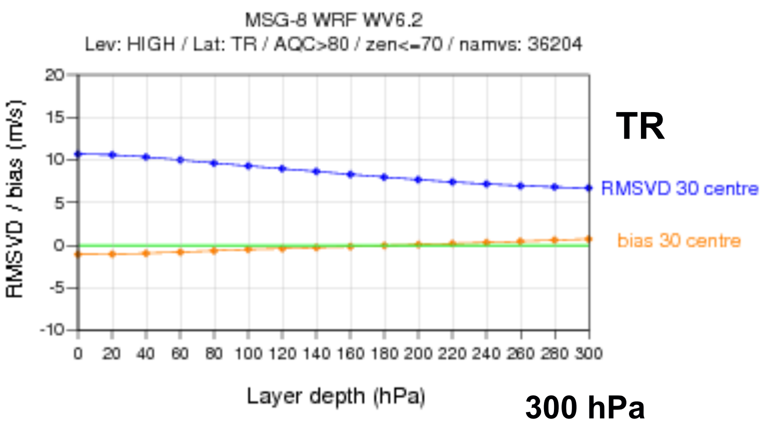
Evaluation of AMVs as horizontal and vertical averages

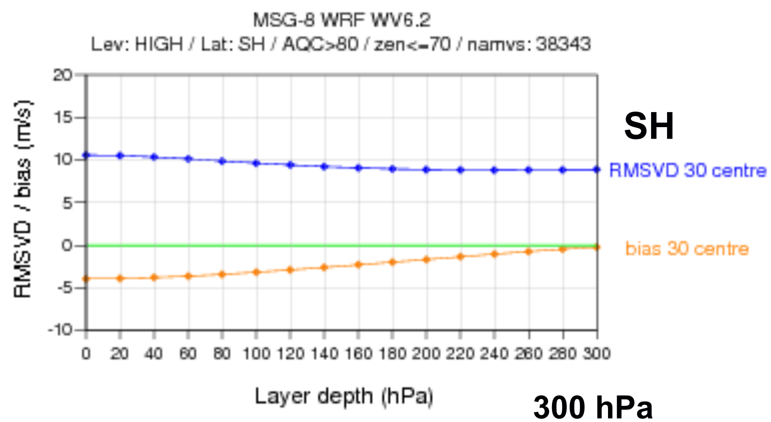
Test: each AMV paired with model profile of horizontal-averages (radius: 0 / **30** / 40 km)

- Vertical ave:
  - Boxcar filter / layer pos: centre
  - Interval chopped if not within profile int.

- RMSVD / bias improve with depth
- Stats for NR = 0, 30, 40 km very similar
- Similar results for IR10.8 high level





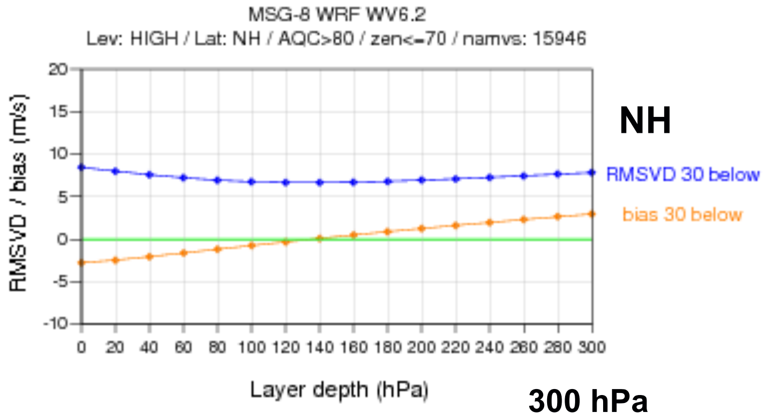


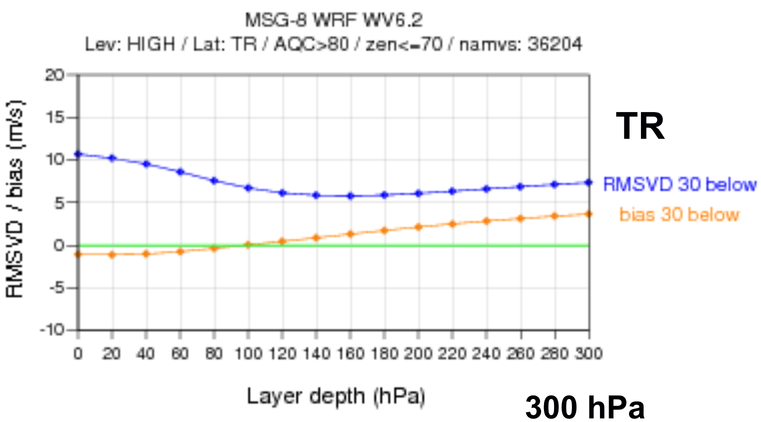
WRF WV 6.2 / nr:30 / layer pos: centre

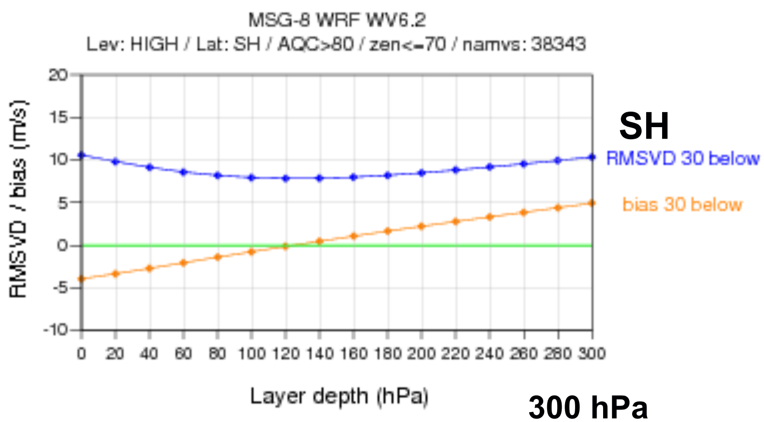
Evaluation of AMVs as horizontal and vertical averages

Similar test: layer pos now is **below** original amv pressure.

- Better than with layerpos = centre.
- RMSVD / bias best for depth =~ 140/160 hPa.
- Similar results for IR10.8 high lev
- **... does the improvement come from the average or the new location in the vertical?**







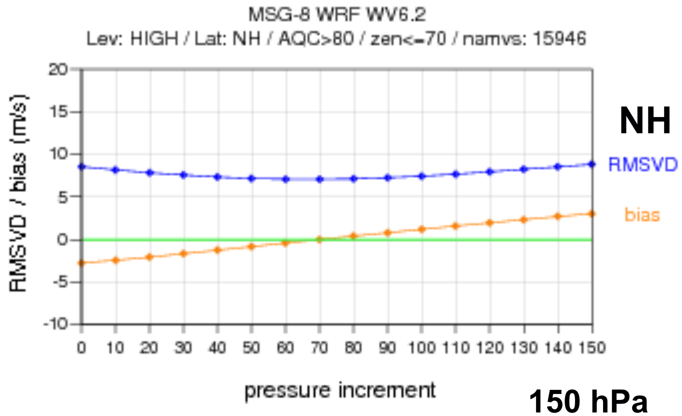
WRF WV 6.2 / nr:30 / layer pos: below

ECMWF

Evaluation of AMVs as horizontal and vertical averages

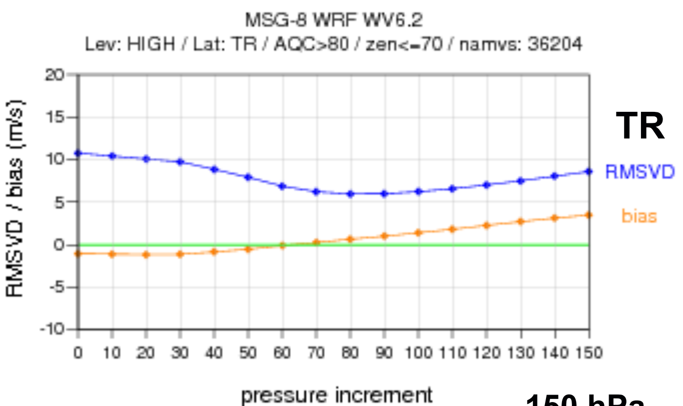
Test: reassign AMV to a level below the original amv pressure.

- Best RMSVD / bias similar to vertical average: the improvement comes mainly from the new heigh.
- Best RMSVD / bias around ΔP = ~ 70/80 hPa.



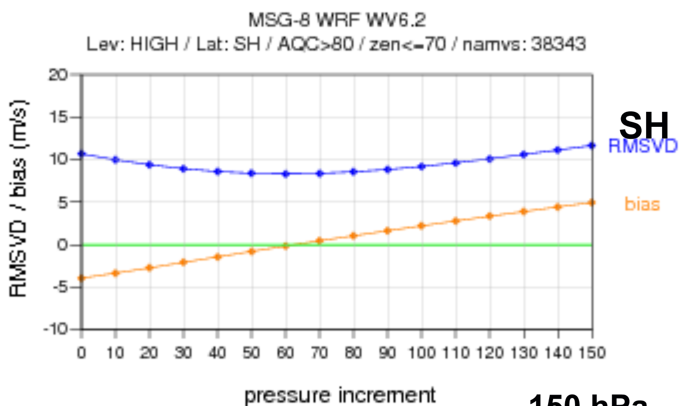
NH

150 hPa



TR

150 hPa



SH

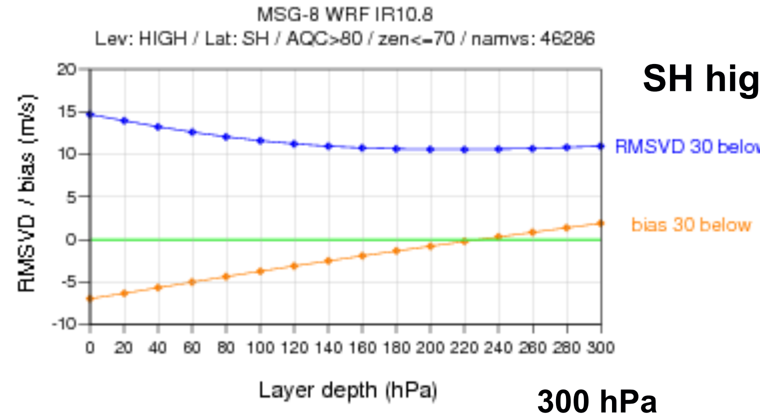
150 hPa

WRF WV 6.2 / AMV reassigned to higher pressure

Evaluation of AMVs as horizontal and vertical averages

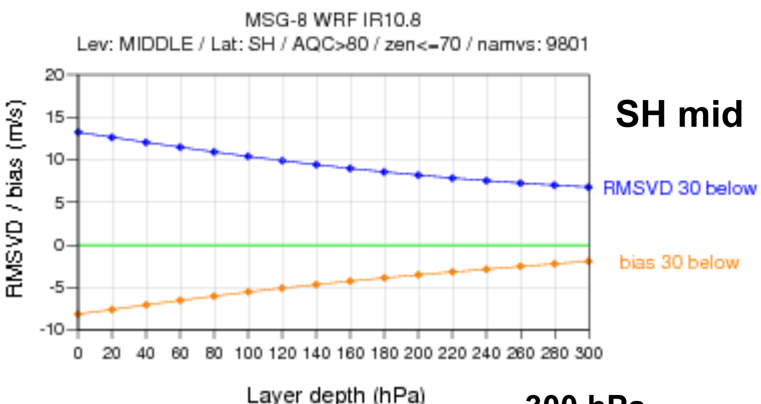
IR 10.8: horizontal (30 km rad) and vertical (boxcar, layerpos = below) average.

- Better results all levels.
- Shown SH (clearer improvements).



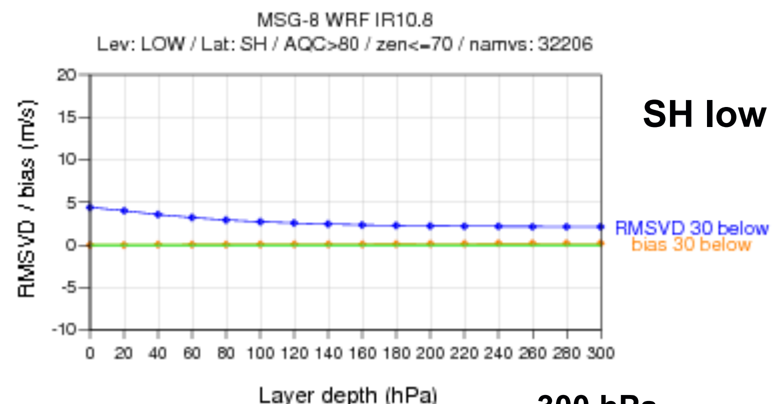
SH high

300 hPa



SH mid

300 hPa



SH low

300 hPa

WRF IR 10.8 / nr:30 / layer pos: below

ECMWF

Evaluation of AMVs as horizontal and vertical averages

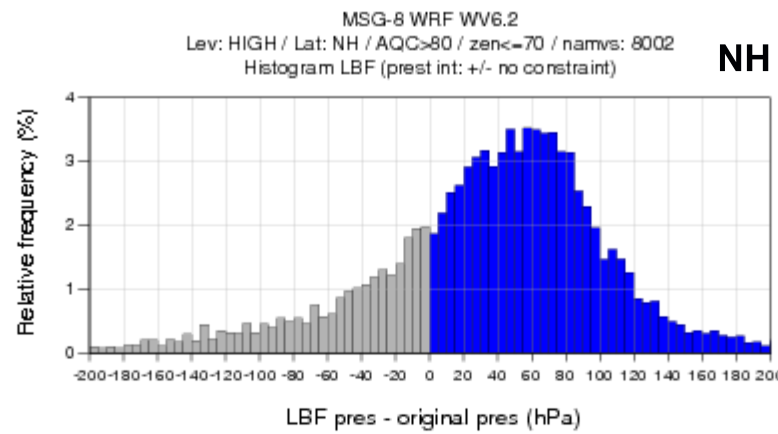
Test: calculate the level of best fit (min VD from AMV wind to model profile).

– AMV skipped if secondary/broad min.

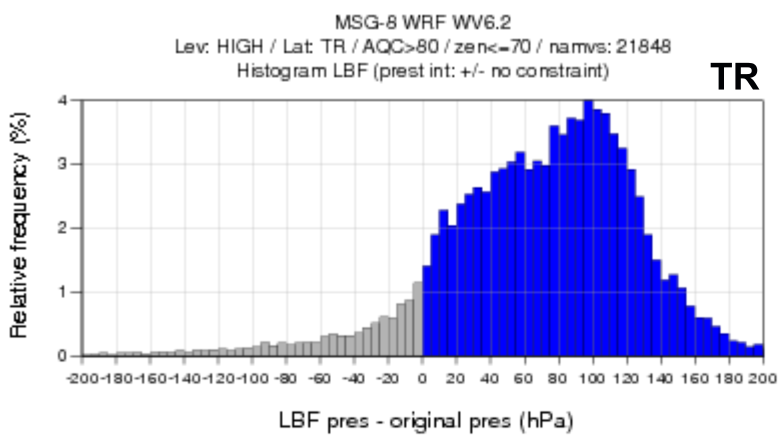
- Blue: lbf_pres > amv_pres
- WV 6.2 - high level winds
- IR similar all levels (not shown)

HISTOGRAMS (LBF_pres – amv_pres)

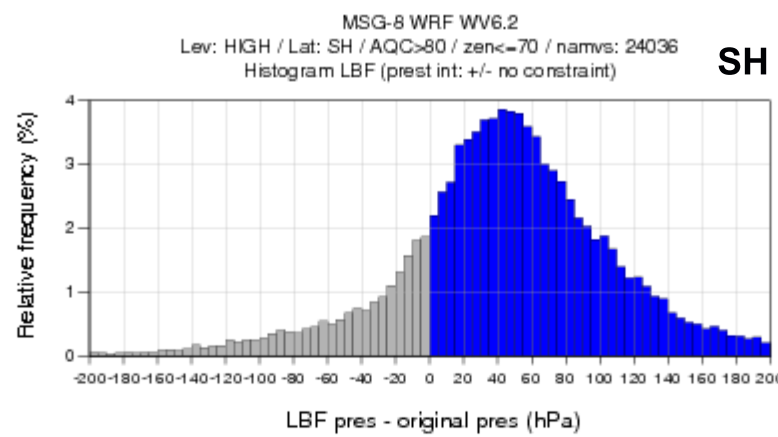
NH



TR



SH



ECMWF

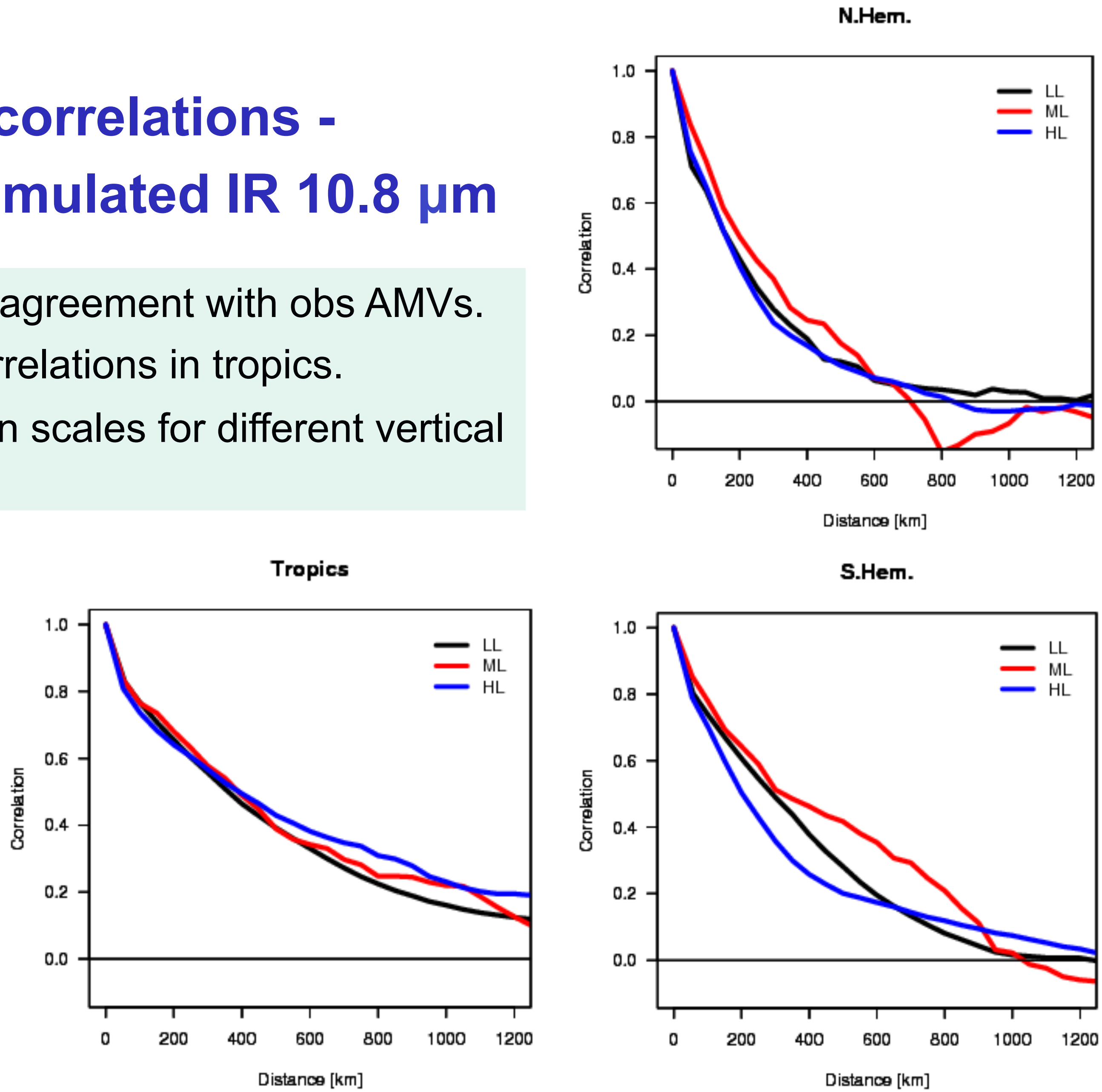
Error correlations from simulated AMVs

- Sources of error correlation (EC) in AMVs:
  - Height assignment, QC methods,
  - Use of forecast data in the derivation,
  - Interpretation of AMVs as single-level data.
- Estimates of error correlations
  - For real data: available for spatial EC, but not for temporal or vertical EC.
  - Straightforward in a simulation framework: truth is available.
- Calculations based on datasets of pairs of AMVs, generated by pairing up each AMV with all other AMVs.
  - Subject to constraints designed to focus on either spatial, vertical or temporal EC.

Spatial error correlations - AMVs from simulated IR 10.8 µm

- Good qualitative agreement with obs AMVs.
- Broader error correlations in tropics.
- Similar correlation scales for different vertical layers.

- Similar for WV

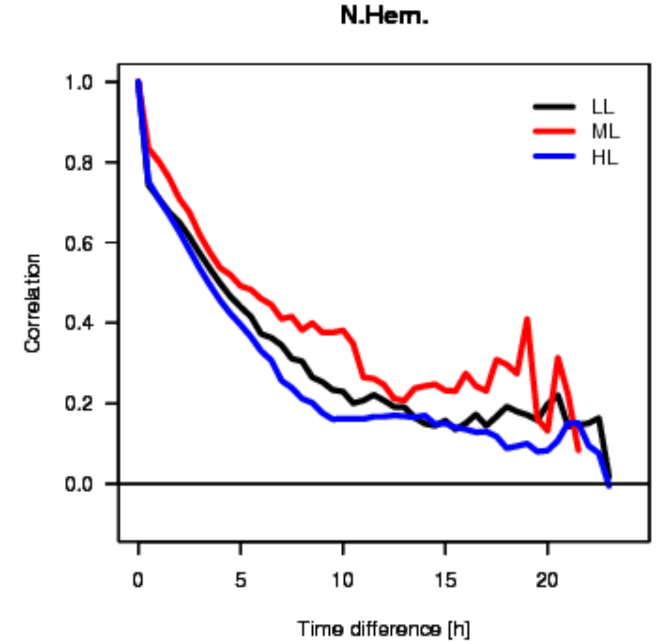


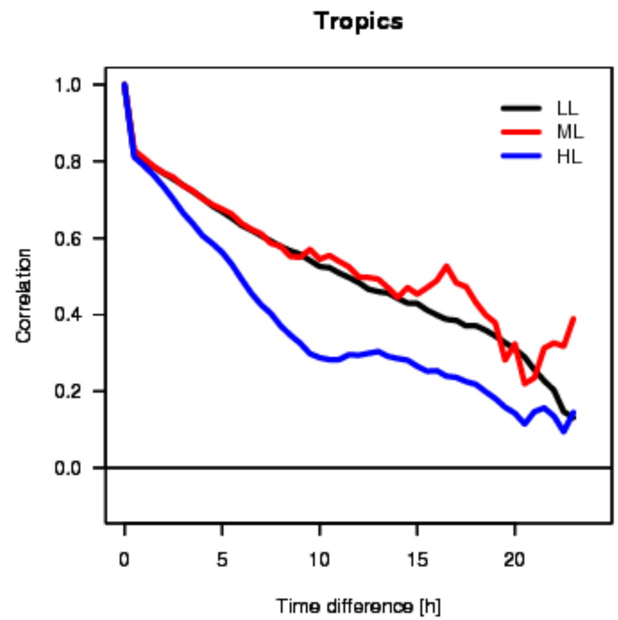
ECMWF

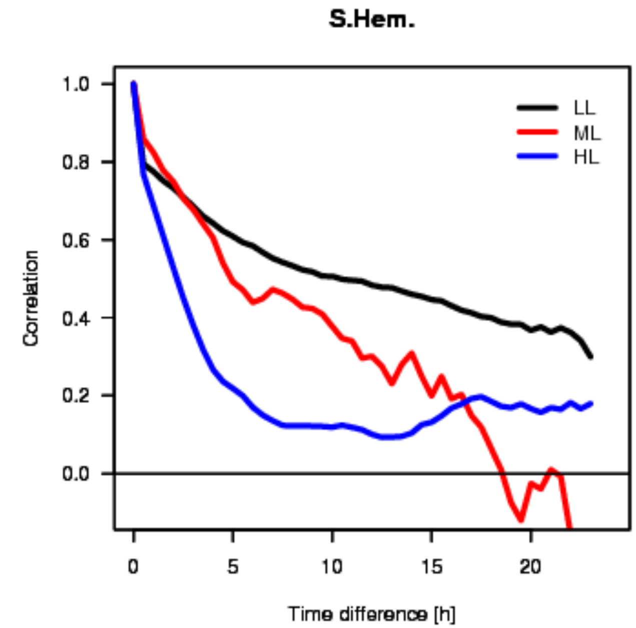
Temporal error correlations - AMVs from simulated IR 10.8

- Broad temporal EC, esp for mid and low levels.
- Likely related to persistent regional biases during the 24h period.
- Indication of a temporally uncorrelated error component.

- Similar for WV







ECMWF

Role of clouds

- **Data from the WRF simulation available (15 min timestep):**
  - Each AMV paired with model profiles at nearest grid point – variables: specific humidity, ice content, liquid water content , cloud cover, w.
  - Point values and horizontal average (radius = 30, 40 km) available.
- **Classify AMVs according to cloud profile of nearest grid point.**
  - Note: for WV, cloudy levels below 700 hPa are ignored.

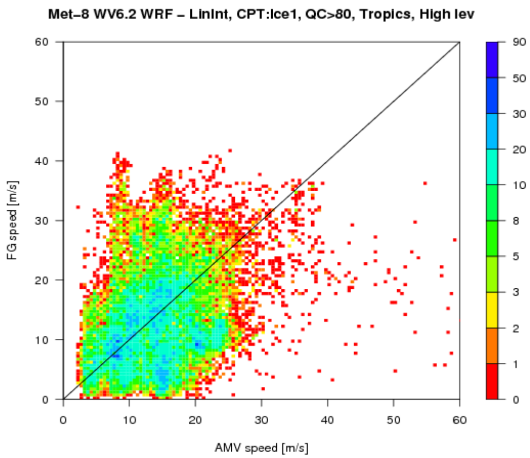
	IR 10.8 (%)	WV 6.2 (%)
Clear	6.4	29.9
Ice1	11.7	43.6
Ice1Liq1	31.3	15.4
Multi ice	0.7	3.1
Liq1	29.9	2.3
Multi Liq	4.8	0.03
The rest	15.2	5.7

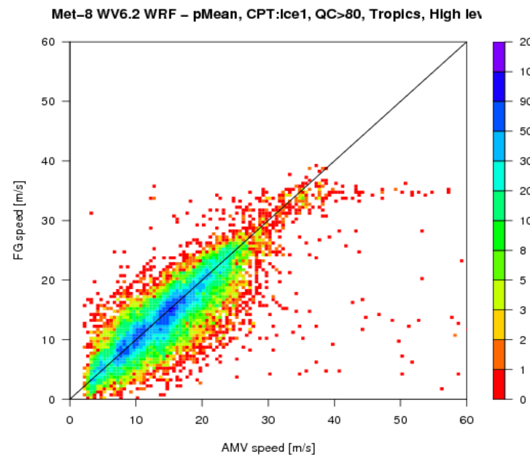
ECMWF

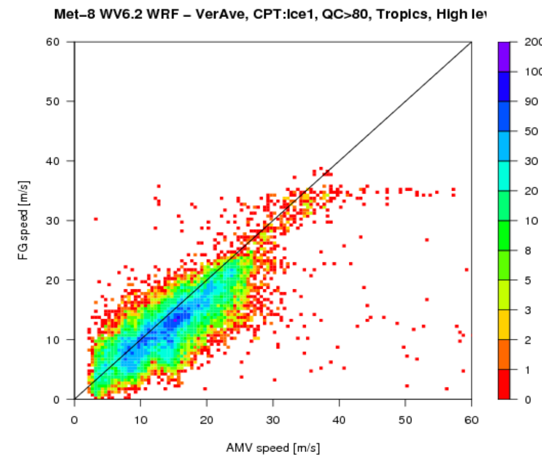
Role of clouds – new ways of calculating model wind

1 ice layer Lin Int to amv_pres (ref)	1 ice layer Lin Int to cloud pMean	1 ice layer Ver Ave: ptop - pbottom

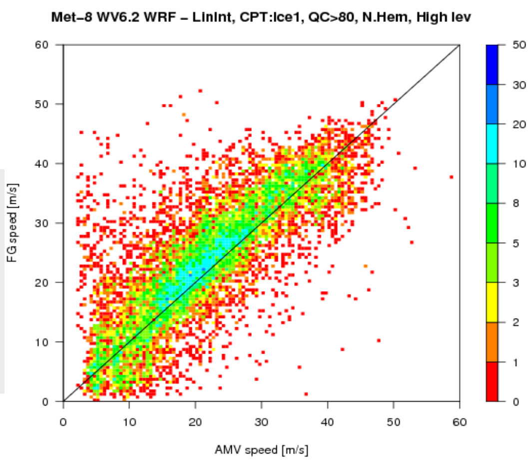
WV 6.2
HIGH
TR

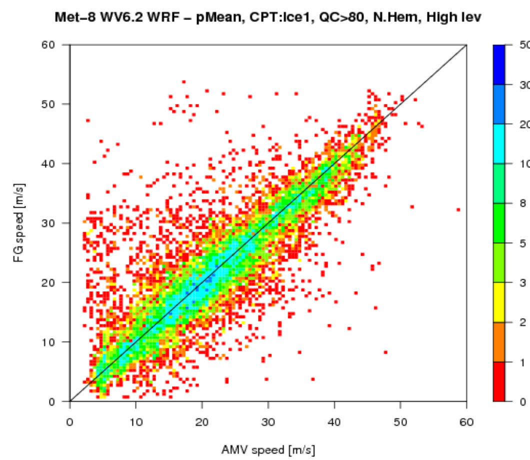


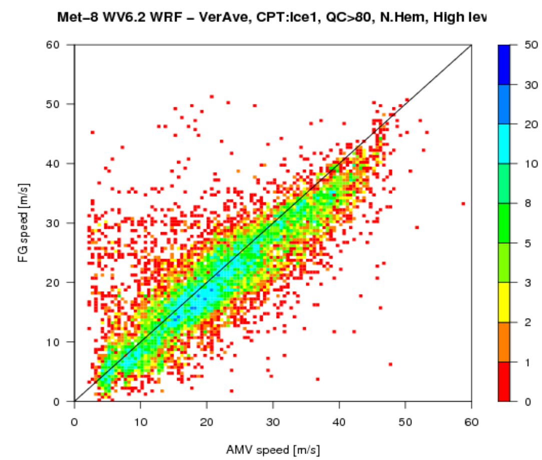




WV 6.2
HIGH
NH







ECMWF

Conclusions 1 - SimulAMV2 study

- Vertical and horizontal averaging leads to (slightly) better AMV stats.
  - The main improvement seems to come from assigning AMV to a lower level (the best for high level winds is around 70 / 80 hPa).
- Estimates of error correlation:
  - Horizontal – good qualitative agreement with AMVs from ops.
  - Vertical and temporal – simulation framework makes it possible to estimate them.
- Role of clouds
  - Cloud profile classification: possible to obtain stats for each type.
  - Better stats for single layer - now possible to quantify.
  - Multilayer situations tricky, but frequent (above 50% in this study).

Conclusions 2 - simulation framework

- **Simulation framework is a very powerful approach.**
  - Wind ground truth.
  - Model fields (clouds, ...) allow detailed analysis.
- **It opens new avenues for progress in AMV derivation:**
  - How do specific conditions affect AMV statistics?
  - Height assignment analysis.
  - Case studies.
- **... and also in data assimilation:**
  - What is the best interpretation of AMVs?
  - Estimates of horizontal, temporal and vertical error correlations possible.
- **But this is early days – the approach has its limitations:**
  - NWP model: resolution, realistic cloud structures, spin-up, ...
  - Study period: one day is a very short period (but a huge amount of data!)
  - A range of new possibilities - we have just started to scratch the surface.

Thank you for your attention

Final project report coming soon (= end of April)

References

- Borman et al., 2003: The Spatial Structure of Observation Errors in Atmospheric Motion Vectors from Geostationary Satellite Data. Mon. Wea. Rev.,131, pp 706-718.
- Von Bremen, 2008: Using simulated satellite images to improve the characterization of Atmospheric Motion Vectors and their errors for Numerical Weather Prediction. Report NWPSAF-EC-VS-015.
- Otkin et al. 2009: Validation of a Large-Scale Simulated Brightness temperature Dataset Using SEVIRI Satellite Observations. J. Appl. Meteor. and Clim., 48, 1613-1626.
- Skamarok et al. 2005: A description of the Advanced Research WRF version 2. NCAR Tech. Note TN-4681STR, 88 pp.
- Tiedtke, 1989: A comprehensive max flux scheme for cumulus parameterization in large scale models. Mon. Wea. Rev, 117, 1779-1800.
- Tiedtke, 1993: Representation of clouds in large-scale models Mon. Wea. Rev., 121, 2040-3061.

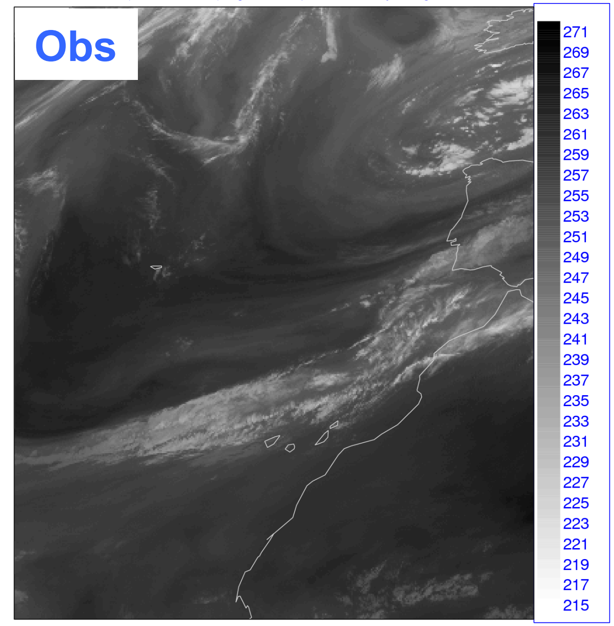
Model simulations

- **WRF simulation:**
  - Forecast model: v 2.2 of the WRF regional model (Skamarok et al., 2005)
    - Model area: 58.5 N / 80 W / 58.5 S / 80 E
    - Horizontal res: 3km at equator to 1.7km at N and S boundaries
    - 52 vertical levels, up to 28 hPa
    - Clouds explicitly resolved
  - Simulation is a 6-30 h forecast – spin up period 6 h.
  - Initialization: 15 Aug at 18 UTC from 1 deg analyses from GDAS
- **ECMWF simulation:**
  - Forecast model: cycle 36r4 of global IFS model
    - Run at T2047 (~10 km nominal horizontal) , 91 levels up to 0.01 hPa
    - Cloud parameterization (Tiedtke, 1989 and 1993)
  - Simulation is a 24-48 h forecast – spin up period 24 h
  - Initialization: 15 Aug at 00 UTC, cycle 30r1

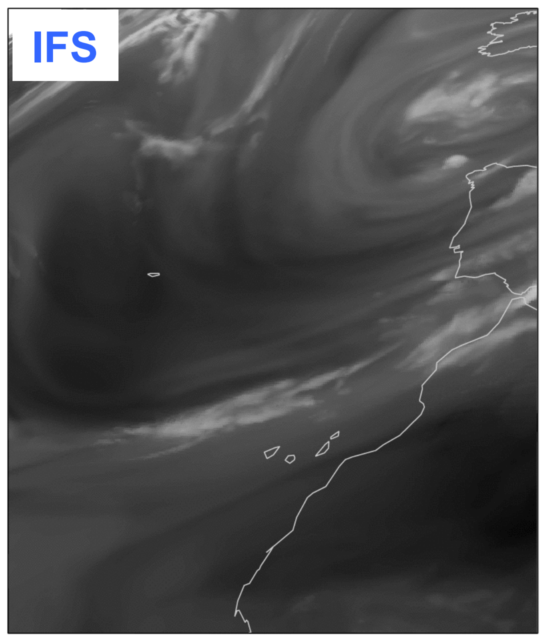
SimulAMV2 – Cloud Structures
Simulated images: WV 7.3 µm

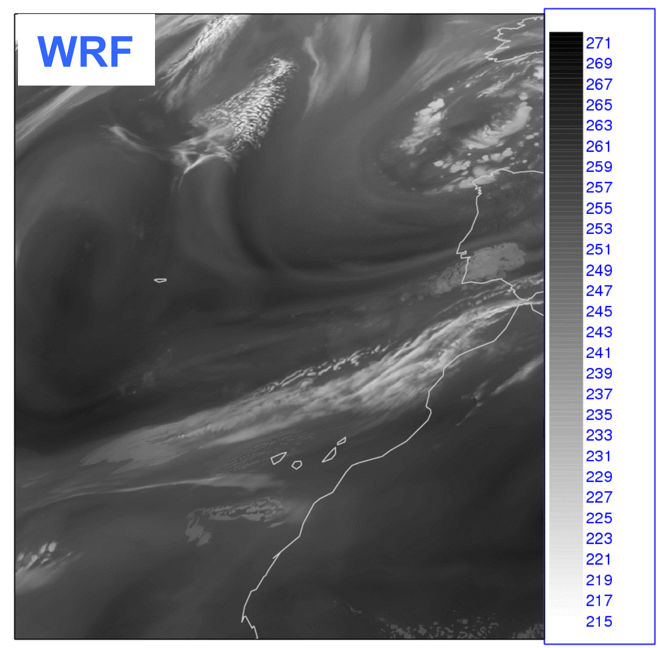
- Images from both models appear realistic.
- But some characteristics to take into account

METEOSAT 8 SEVIRI (Channel 6 WV7.3) Brightness Temperature Thursday 17 August 2006 0000UTC



- WRF more detailed spatial structure (higher horizontal resolution).
- WRF apparent spin-up during first 9-12 h.
- Better representation of ice-clouds in WRF images.



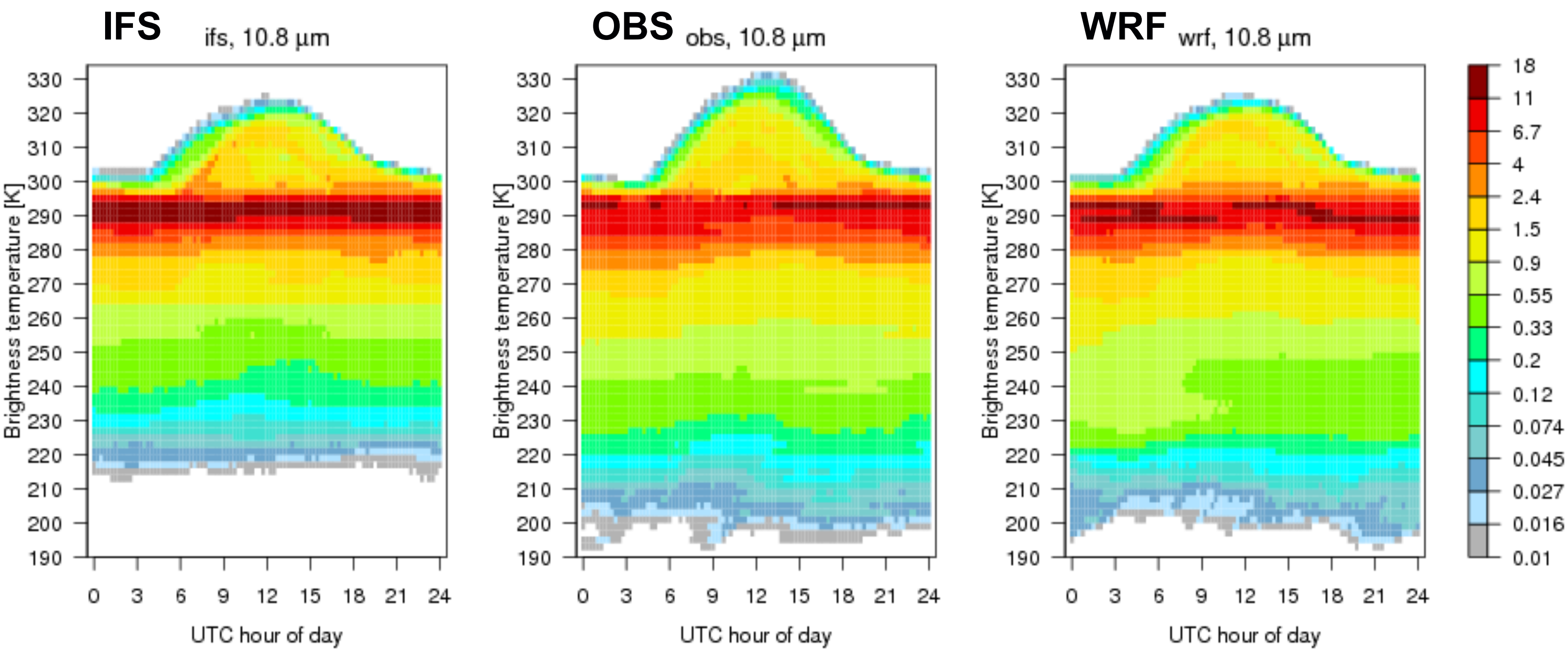


ECMWF

Simulated images: cloud structures

- Cold tail: WRF similar to OBS (ice clouds)
- WRF spin-up during first ~9 h.

Temporal evolution of BT histograms – IR 10.8



AMVs from simulated IR - spatial error correlations

- For comparison with results from real data, the Second Order Autoregressive (SOAR) function has been fitted:

$$R(r) = R_0 \left(1 + \frac{r}{L}\right) e^{-\frac{r}{L}}$$

with length scale *L* and intercept R_0.

- There is reasonable agreement between the estimates of *L* from the simulated data and past results for real data:

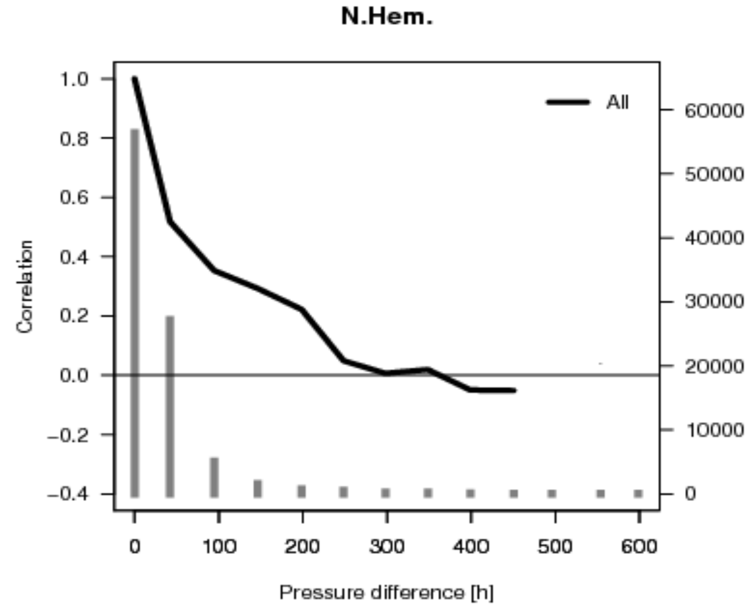
	Simulated data	Real data (from Bormann et al 2003)
Extra-tropics	140-280 km	150-260 km
Tropics	310-490 km	260-370 km

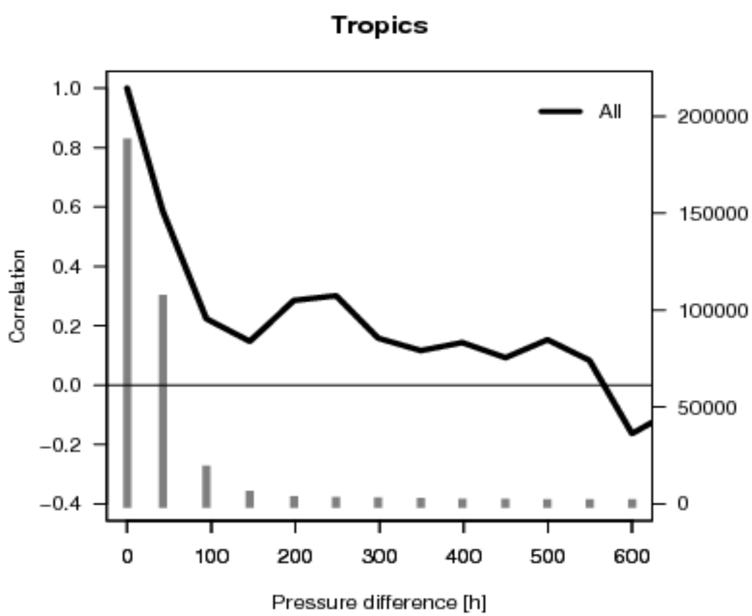
- But: values for σ_O are much larger for simulated data.

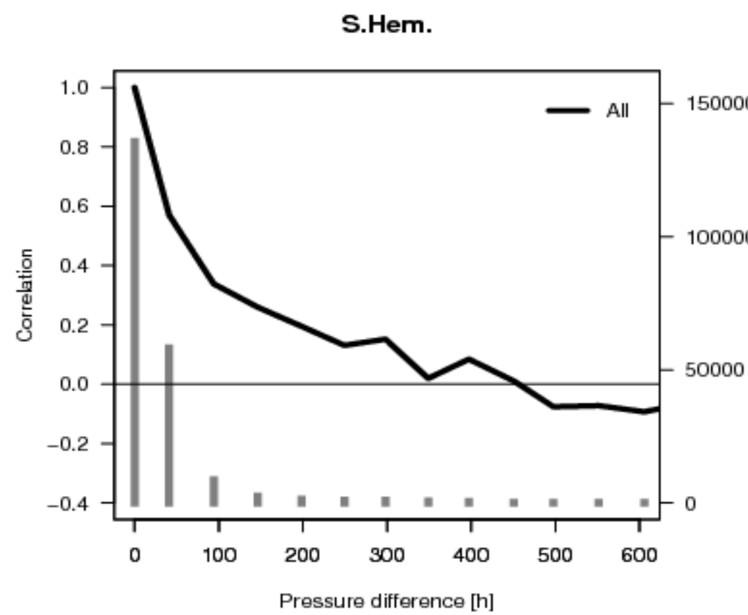
Vertical error correlations

- **IR and WV winds, all levels combined.**

- Error correlations reach 0.2 for pressure differences between 100 and 200 hPa.







ECMWF