THALES

Study of AMV Speed Biases in the Tropics

Final Meeting

EUMETSAT – 18 June 2020

Content

Observation-background speed bias in tropics

Basics of AMV extraction from satellite imagery

Meteosat-10 IR AMV performance

- Monthly statistics against ECMWF forecast winds
- Comparison to other reference observations
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Dual-Metop IR AMV performance

- Monthly statistics against ECMWF forecast winds
- Case study - Dual-Metop IR AMVs over “Boiler-Box” region

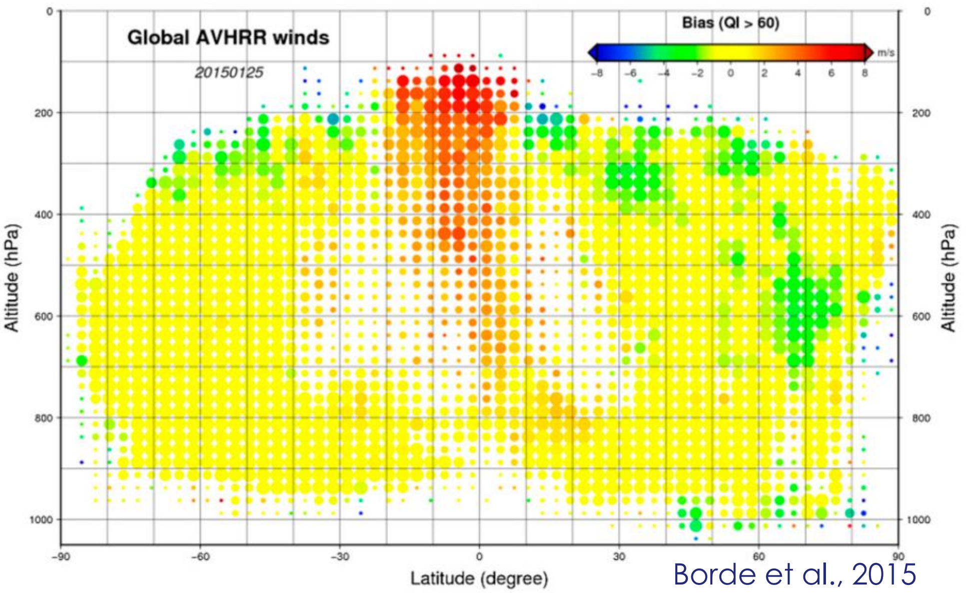
AMV performance against wind data from ADM-Aeolus

Summary & Conclusions

Outlook

The problem

- An important diurnal cycle in convection, cloudiness and surface temperature exists for all regions of the tropics.
- How do these tropical atmospheric specificities impact AMV extraction from satellite imagery?
- Observation minus Background (O-B) speed biases is commonly explained by erroneous heights assigned to AMVs
- However, fast speed biases are found for AMVs that are set already very high in the troposphere and it does not appear very realistic to consider that they are set too low.



Borde et al., 2015

Existence of a **positive O-B speed bias in the tropical region** of the upper troposphere for most satellite-channel combinations and of a **negative speed bias in the extra-tropics**.

AMV retrieval - basics

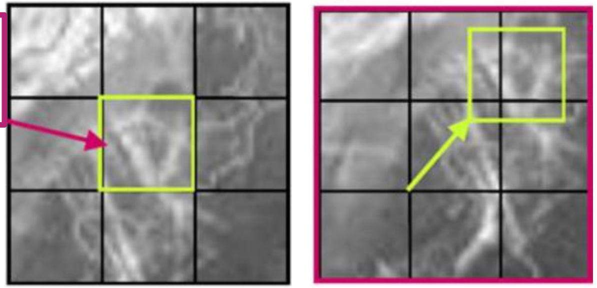
Different steps for one single vector displacement

1. Data initialisation & preprocessing
   - corrections, noise filtering ….
2. Tracer extraction
3. Target tracking
4. Calculate vector displacement
5. Height assignment
   - AMVs are treated as single-level data although imagers actually sense radiation emitted from a finite layer of the troposphere
6. Quality control
   - Assign quality indicator to retrieved AMV

Search Area centred on target box, e.g. 80 x 80 pixels

Image 1 Image 2

Target Box Tracer, e.g. 24 x 24 pixels

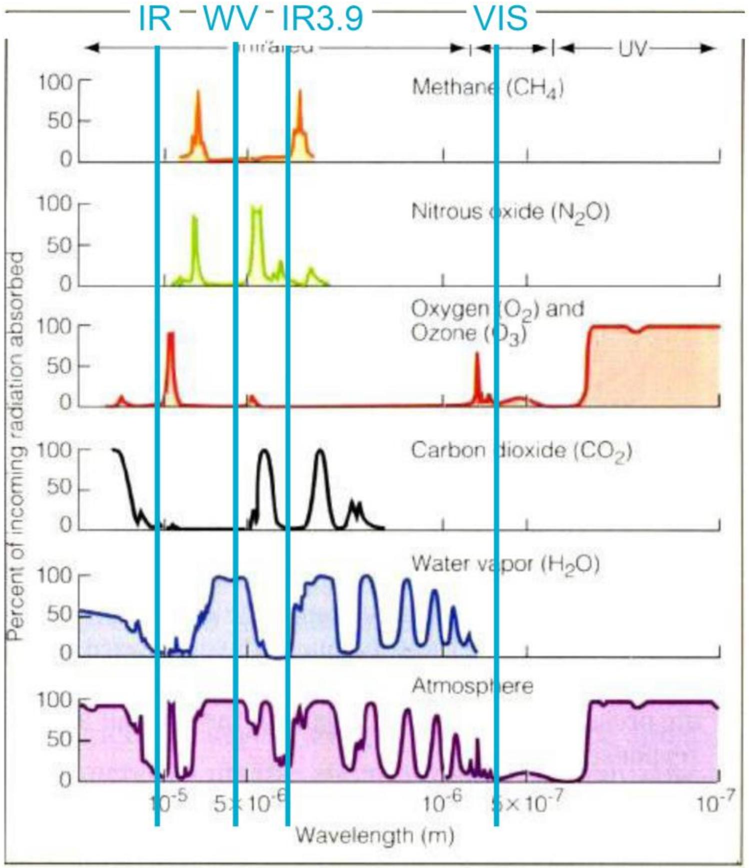


Adapted from Forsythe (2014)

T T+ΔT

- Identify cloud to be tracked (= define target box).
- Selection scheme relies on contrast
- Search for target in image 2. Comparison of individual pixel counts with all possible locations of the target box in search area to find best match.

Which channels are typically used?



Adapted from Forsythe (2014)

- AMVs derived from infrared (IR) window images typically capture flow features in both the upper and lower troposphere
- Mid- to upper tropospheric WV features are tracked in cloud-free scenes using imagery derived from WV-sensitive spectral bands
- AMVs derived from visible (VIS) images generally track cumuloform cloud motions in the lower troposphere.

AMV retrieval - Height (pressure) assignment

- AMVs provide single level data (=no wind profile)
- Generally, AMVs are assigned the height of the cloud top
- Method for height assignment depends on channel availability (EBBT, multi-channel approaches)
- Important source of error!
- Cloud tracking and height assignment are performed in stand-alone step
- Link between tracking and height can be achieved by cross correlation

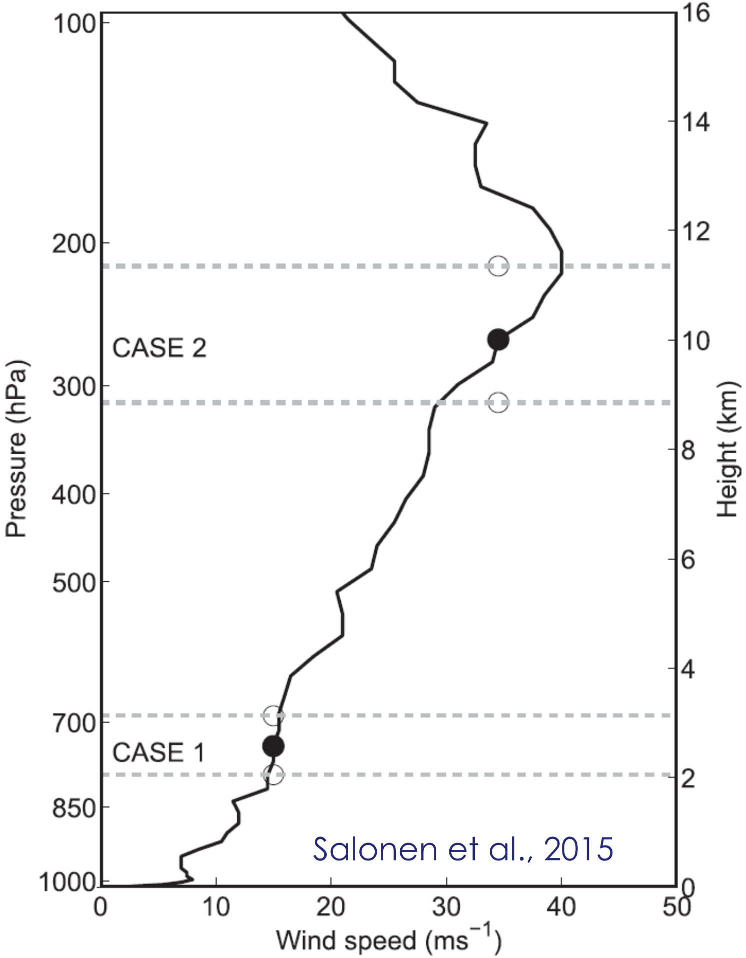


FIG. 1. Illustration of the impact of a ±50-hPa height error on wind error in two cases.

Meteosat-10 IR AMV performance

Monthly statistics against ECMWF winds

AMV performance against ECMWF forecast winds

Hourly ECMWF data

- Initialised at 00 and 12 UTC; +1,2,3,…,11 hour forecast wind fields
- 0.5°x 0.5° horizontal resolution
- 19 pressure levels (20, 30, 50, 70, 100 to 300 by 50, 400 to 800 by 100, 850, 900, 925, 950, 1000 hPa)

Requires spatio-temporal collocation criteria:

- Vertical collocation: $\Delta p = \pm 25$ hPa
- Temporal collocation: $\Delta t = \pm 30$ min
- Quality criteria:
  - QI > 80 for GEO, QI > 60 for polar satellites
  - Difference in wind directions between satellite observation and model must be < 60°
- If more than one AMV fall into same ECMWF grid cell, median of AMV speed is compared to model wind speed!

REF AMV-PRE-0011-TS – 18/06/2020
Thales Services / Modèle : 87211168-GRP-FR-004

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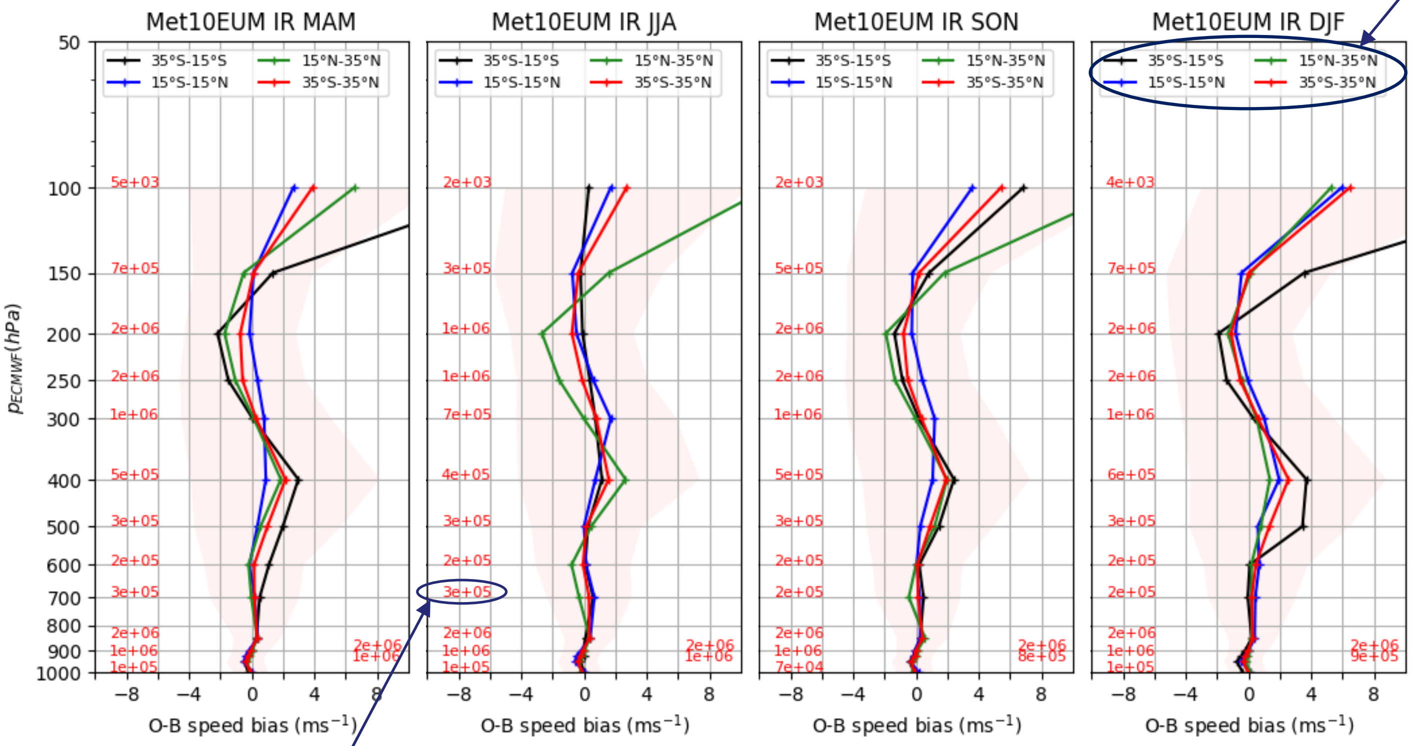
Met10EUM : O-B speed bias as function of pressure

Zonal bands

Wind speed difference profiles averaged over different zonal bands between 35°S and 35°N



- Largest O-B speed bias is typically found around 400-500 hPa (transition high- to mid-level winds)
- p > 600 hPa: speed bias close to 0 ms^{-1}.
- 300 < p < 600 hPa: Met10EUM observes 0.5 to 3 ms^{-1} faster winds than ECMWF.
- Small sample size at 100 hPa

Sample size to compute O-B speed bias at 700 ±25 hPa for 35°S-35°N

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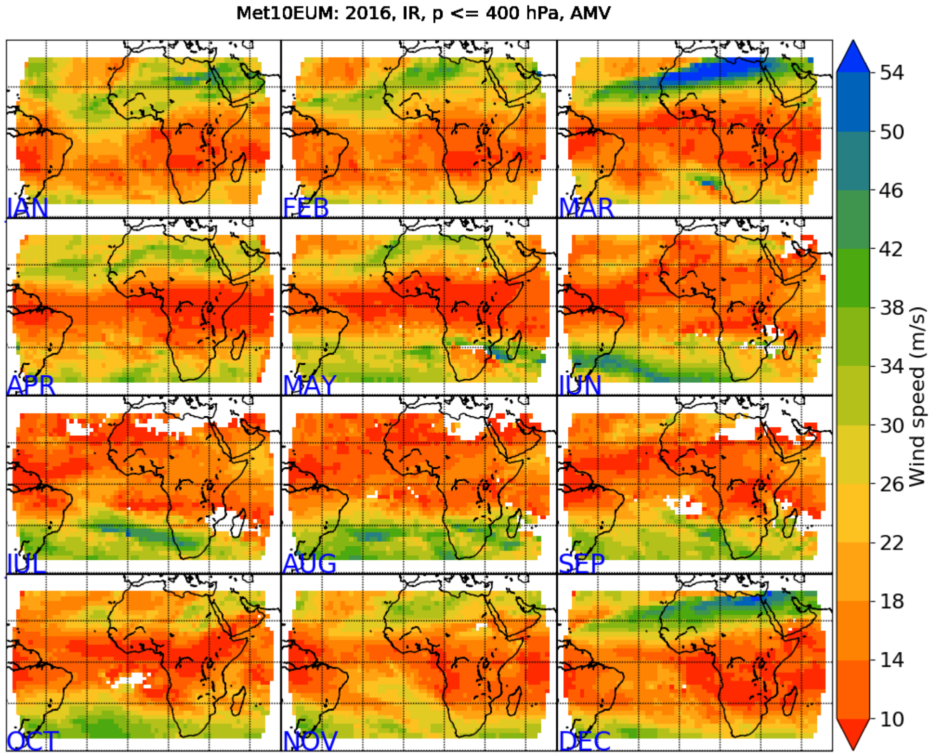
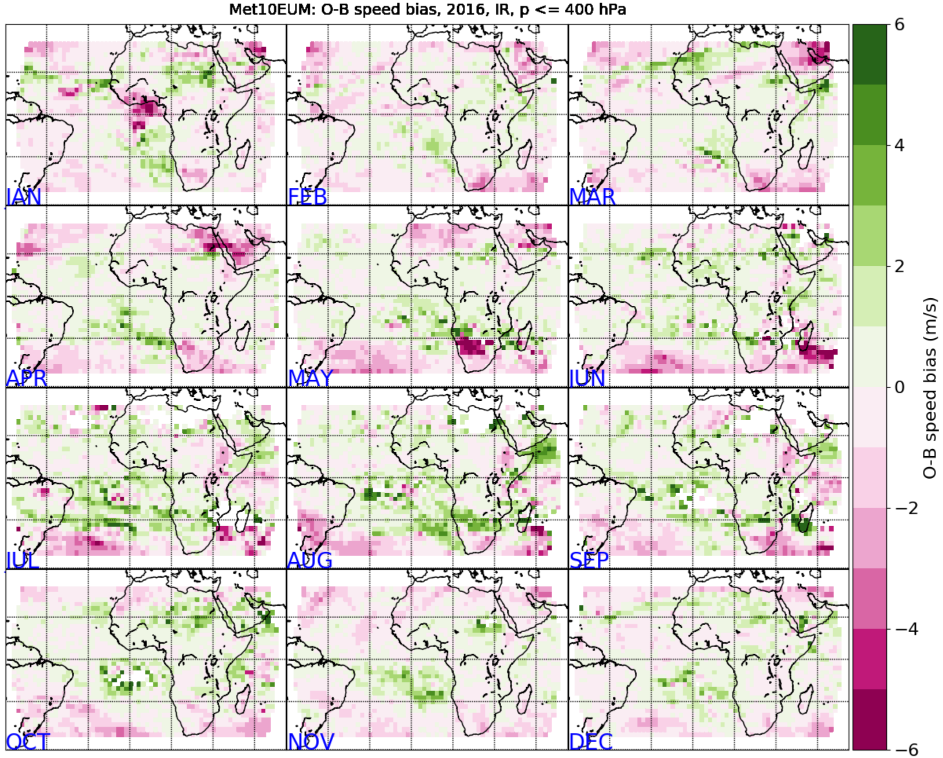
Met10EUM: Spatial distribution of O-B speed bias at high-levels (p ≤ 400 hPa)

ECMWF winds for p ≤ 400 hPa



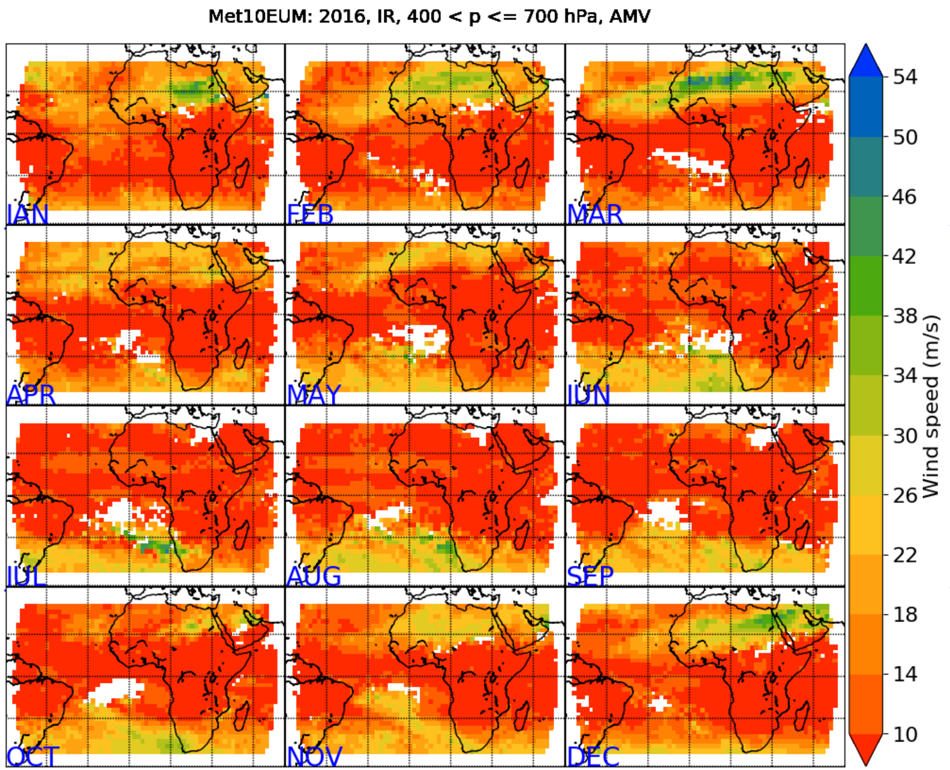
Speed bias (AMV-ECMWF)



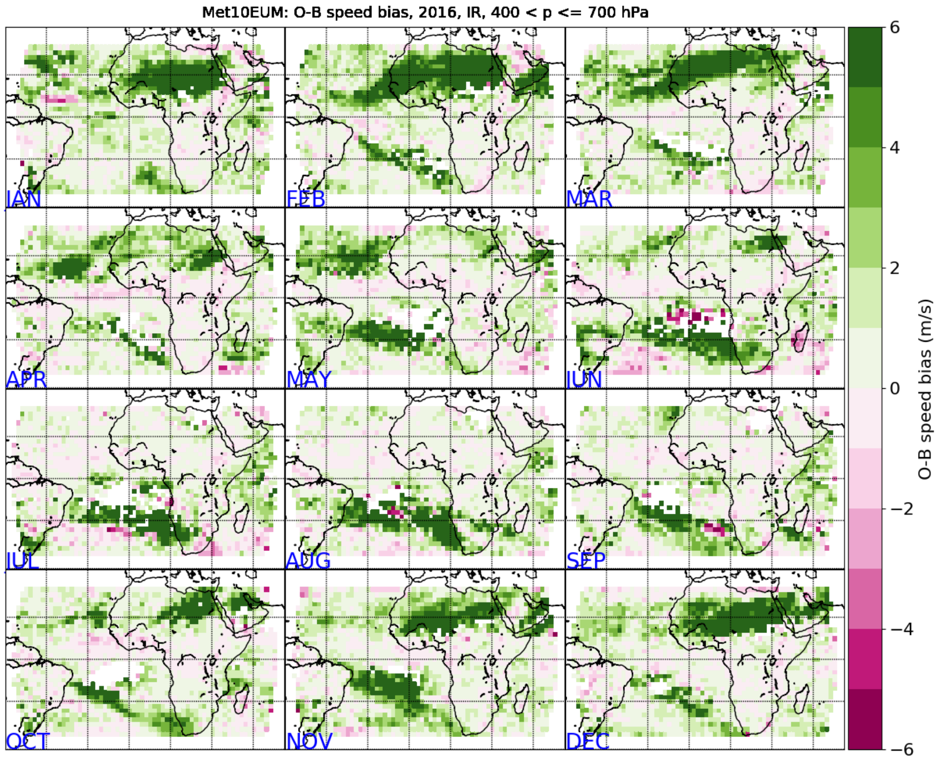
Regions of O-B speed biases ≥ ± 3 ms^{-1} coincide with position of subtropical jet, arid locations and oceans

Met10EUM: Spatial distribution of O-B speed bias at mid-levels (400 < p ≤ 700 hPa)

ECMWF winds for 400 hPa< p ≤ 700 hPa



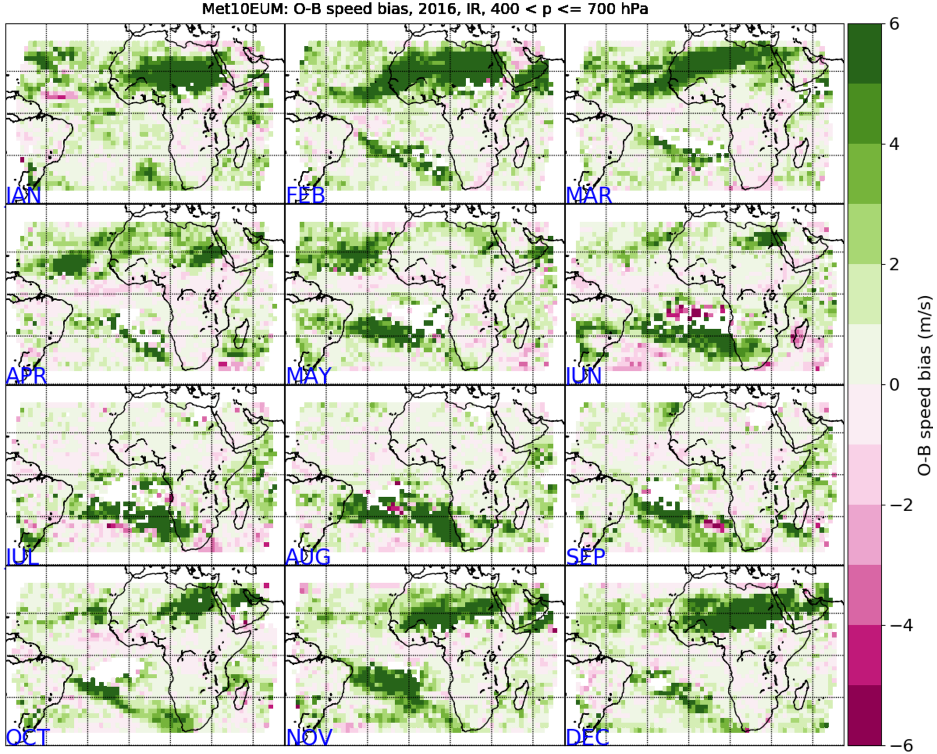
Speed bias AMV- ECMWF



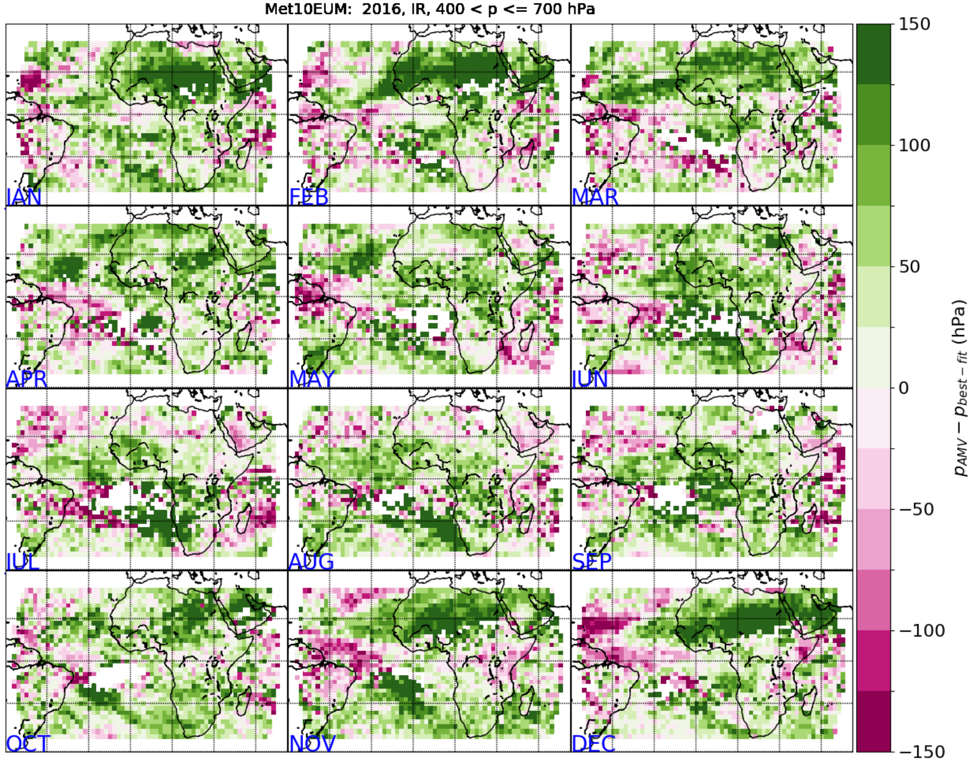
O-B speeds bias > 6 ms^{-1} regularly found over deserts and oceans

Met10EUM: Spatial distribution of O-B speed bias at mid-levels (400 < p ≤ 700 hPa) II

O-B speeds bias > 6 ms^{-1} regularly found over deserts and oceans



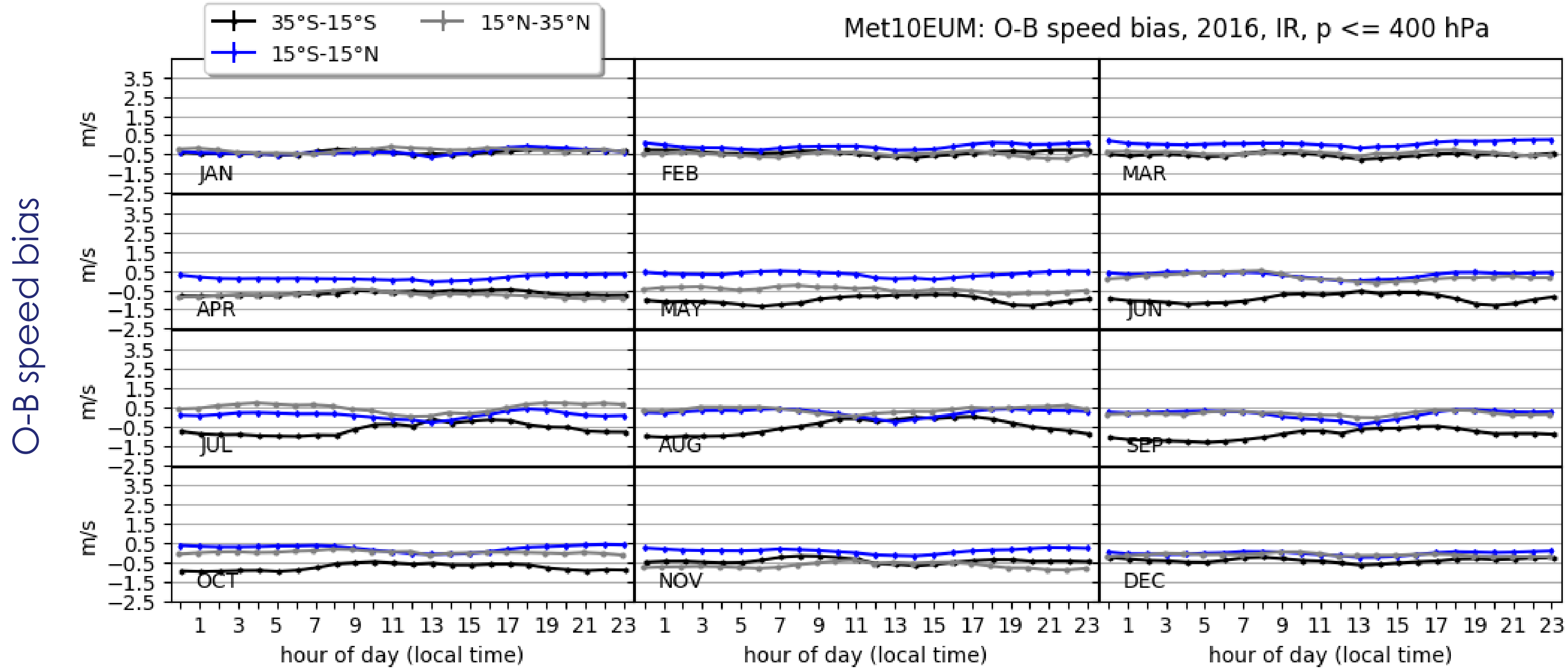
Best-fit pressure



- Bias found over desert coincides with best-fit pressure differences > 100 hPa. AMVs set too low in atmosphere lead to positive O-B speed bias
- Comparison against best-fit may be biased toward certain types of clouds or situations where the best-fit can be estimated

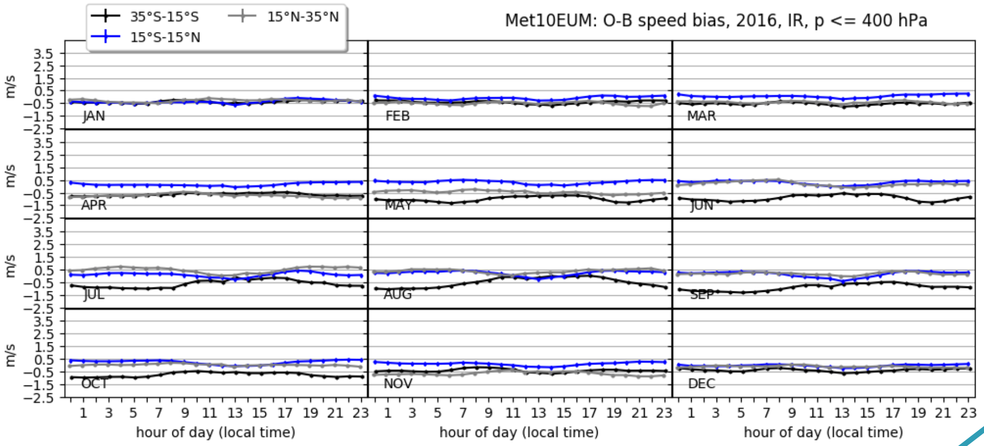
Comparison of AMVs to other reference observations

Impact of diurnal cycle of convection on O-B speed bias



Diurnal cycle of Met10EUM O-B speed bias for three zonal bands (35°S-15°S, 15°S-15°N, 15°N-35°S) and high-level winds.

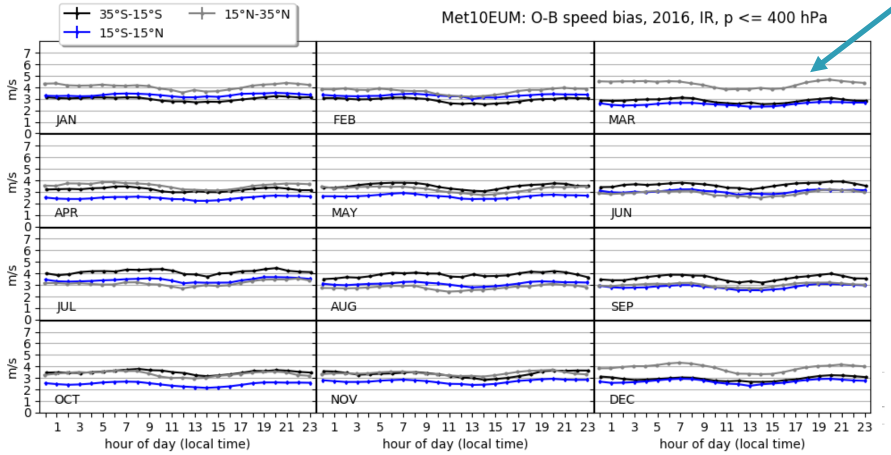
Met10EUM : Diurnal cycle of convection

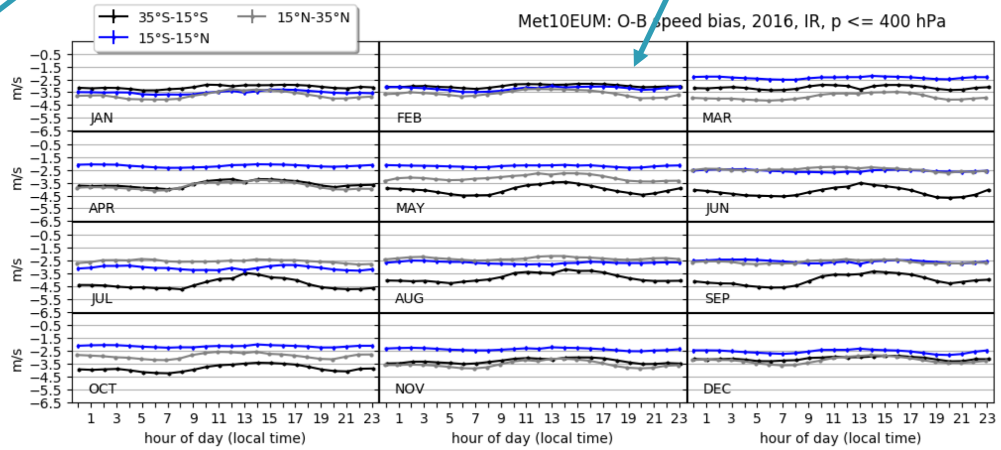


- Diurnal cycle of O-B speed bias for different zonal bands
- Variations in O-B speed bias as function of daytime are small (maximally up to 1 ms^{-1})

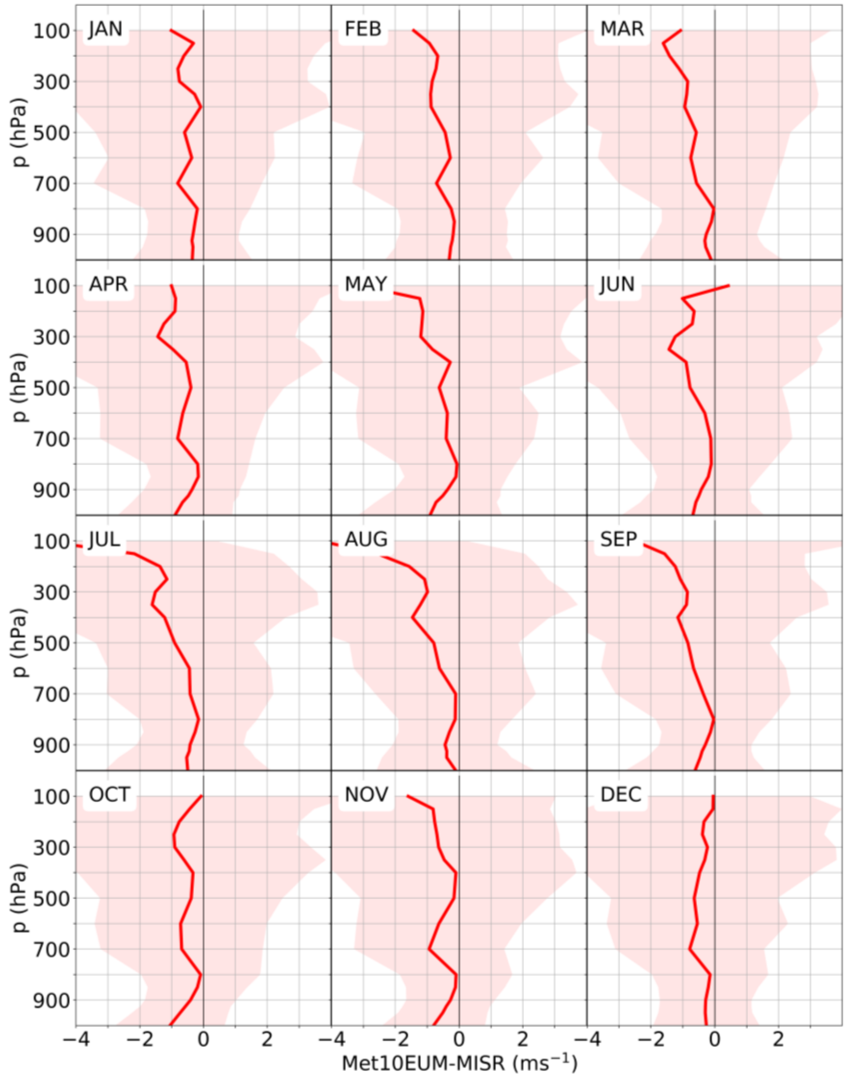
Only positive differences

Only negative differences





Comparison to MISR stereo winds



- The purely geometric MISR wind retrieval technique simultaneously determines cloud motion and height by tracking features in a triplet of 0.67-mm images

- low- to mid-level winds: MISR winds tends to be less than 1 ms^{-1} faster than Met10EUM AMVs.

- Slightly higher bias for high-level winds

- Attention: Comparison of IR winds to VIS winds

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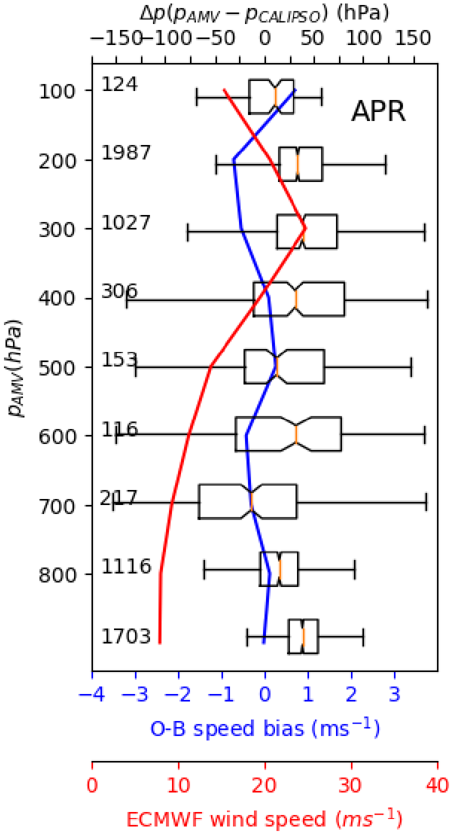
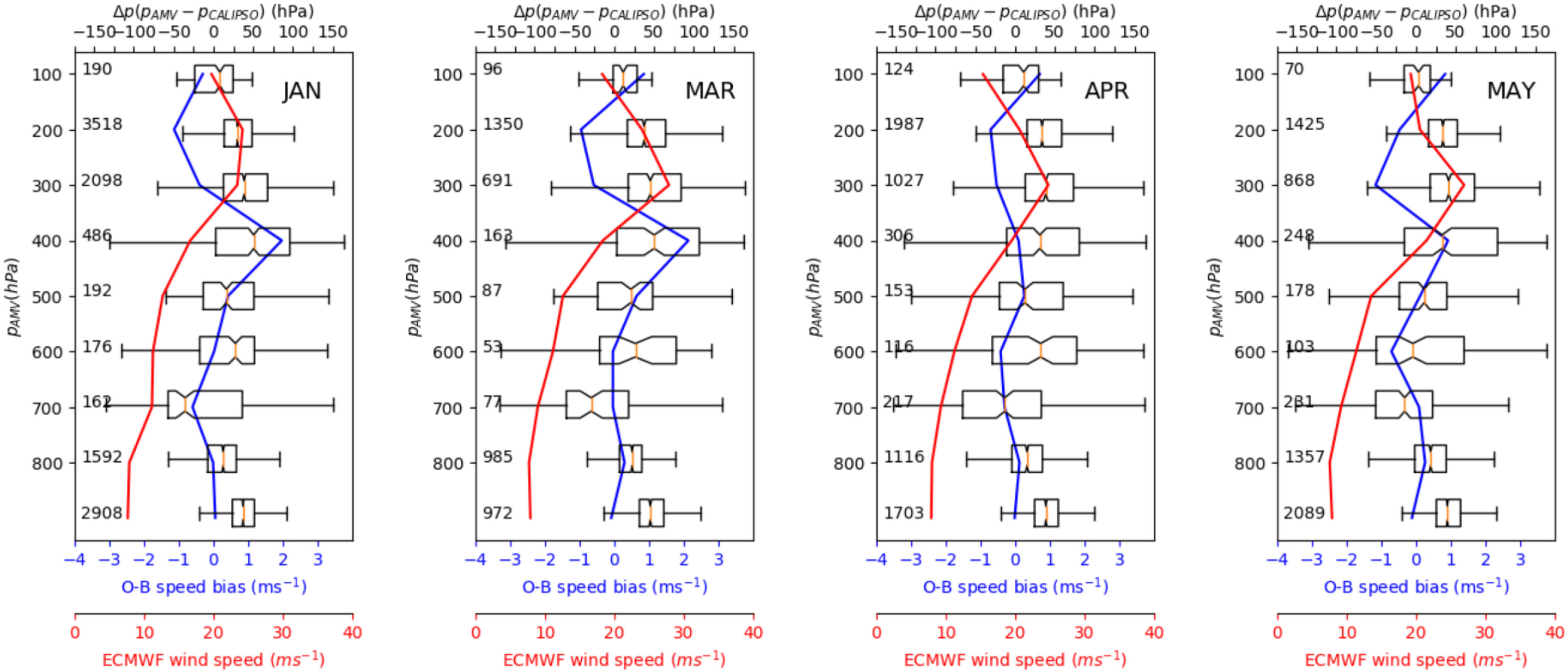
Comparison of Meteosat-10 IR AMV height to CALIPSO/CALIOP cloud top height



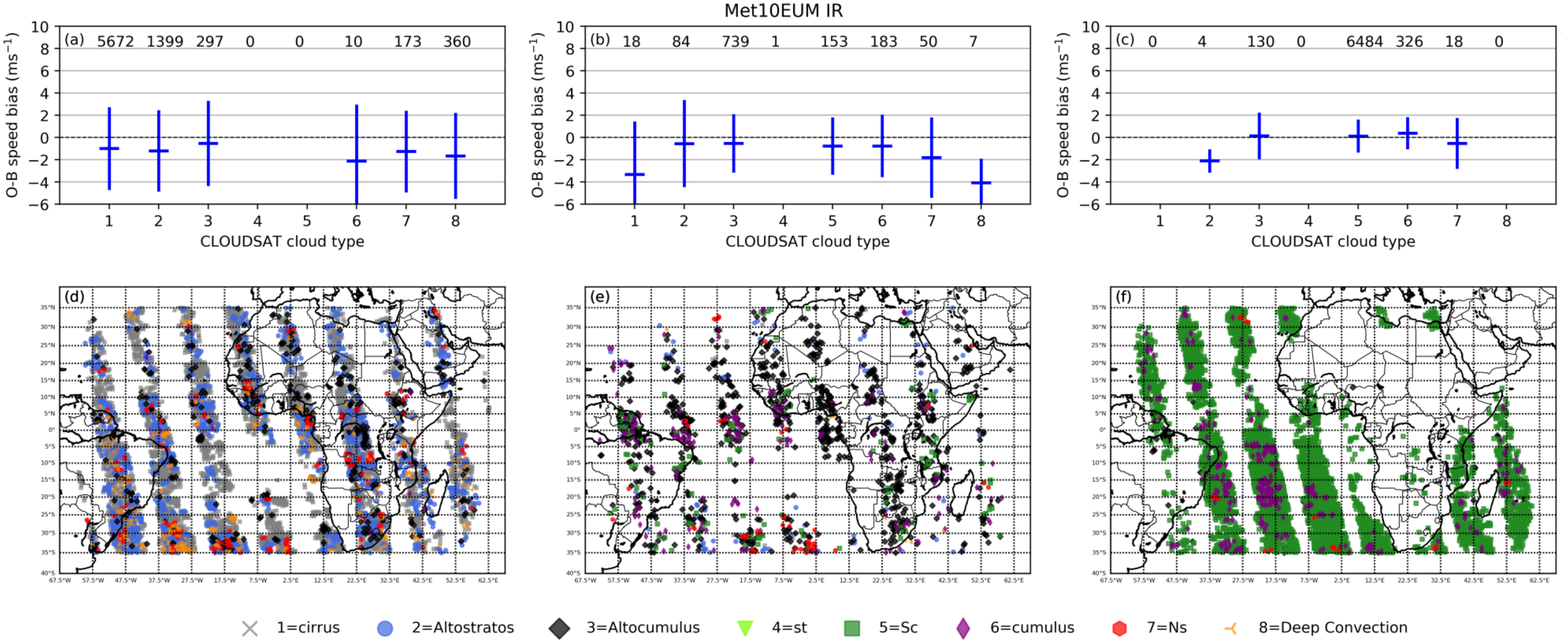
1) CALIPSO are collocated with AMVs if $\Delta x \leq 75$ km, $\Delta t \leq 45$ min
2) Take median value of all available (at least 20) CALIPSO cloud-top observations. Median is considered as representative cloud top height
3) Ensure CALIPSO and AMV see "same" cloud
   - root-mean-square differences between single LIDAR cloud observations and their median value must not exceed 100 hPa.
   - all multilayer cloud observations are discarded. Ensure that the detected lidar signal definitely represents a cloud ($QI_{CALIPSO} > 90$).
   - AMVs must be within 165 hPa of the CALIPSO cloud top height

Comparison of Meteosat-10 IR AMV height to CALIPSO/CALIOP cloud top height – cont.



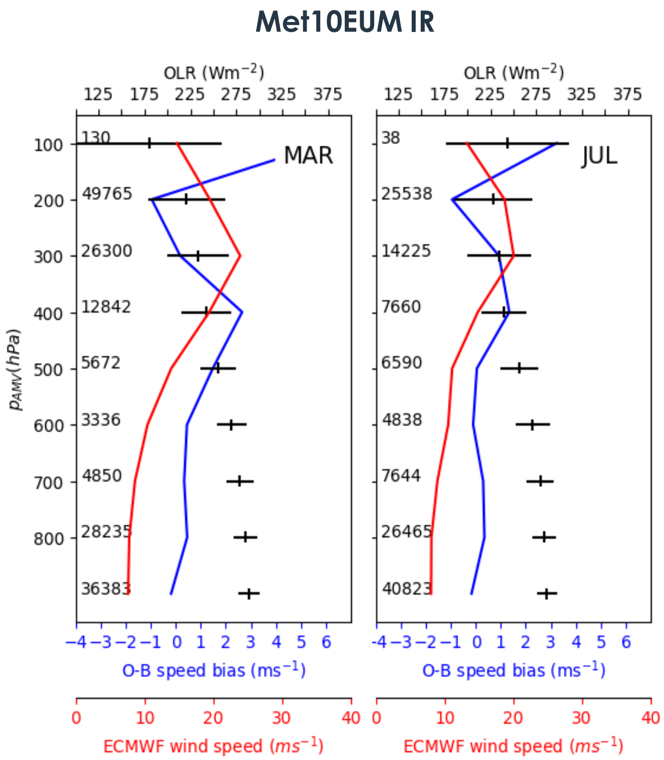
- Pressure difference > 0 hPa throughout the atmospheric → AMVs tend to have assigned too low altitudes.
- On average, pressure differences are largest at 300 and 400 hPa.

Comparison to CLOUDSAT/CPR cloud type classification



- Most clouds are cirrus clouds as they show radiance gradients can be readily tracked and they are likely to be passive tracers of the flow at a single level
- there is no clear correlation between cloud type and collocated O-B speed bias

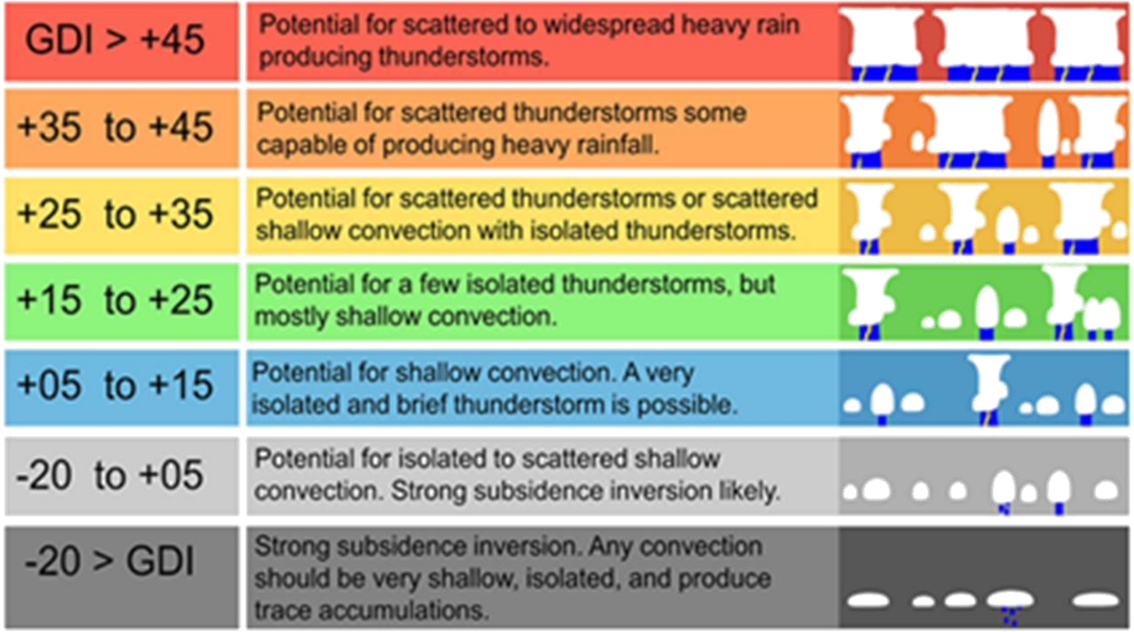
O-B speed bias against OLR from AIRS



- OLR decreases with altitude as blocking of long-wave radiation penetrating through clouds and cloud albedo increases with altitude
- Collocation of Metop/AIRS in stronger convective areas than Met10EUM/AIRS
- No clear dependency of bias on OLR values

Collocation requirements: dx ≤ 75 km; |dt| ≤ 30 min ; take closest AIRS OLR in case several AIRS data points meet collocation requirements

O-B speed bias against stability indices (GDI) computed from ECMWF fields



GDI > +45	Potential for scattered to widespread heavy rain producing thunderstorms.
+35 to +45	Potential for scattered thunderstorms some capable of producing heavy rainfall.
+25 to +35	Potential for scattered thunderstorms or scattered shallow convection with isolated thunderstorms.
+15 to +25	Potential for a few isolated thunderstorms, but mostly shallow convection.
+05 to +15	Potential for shallow convection. A very isolated and brief thunderstorm is possible.
-20 to +05	Potential for isolated to scattered shallow convection. Strong subsidence inversion likely.
-20 > GDI	Strong subsidence inversion. Any convection should be very shallow, isolated, and produce trace accumulations.

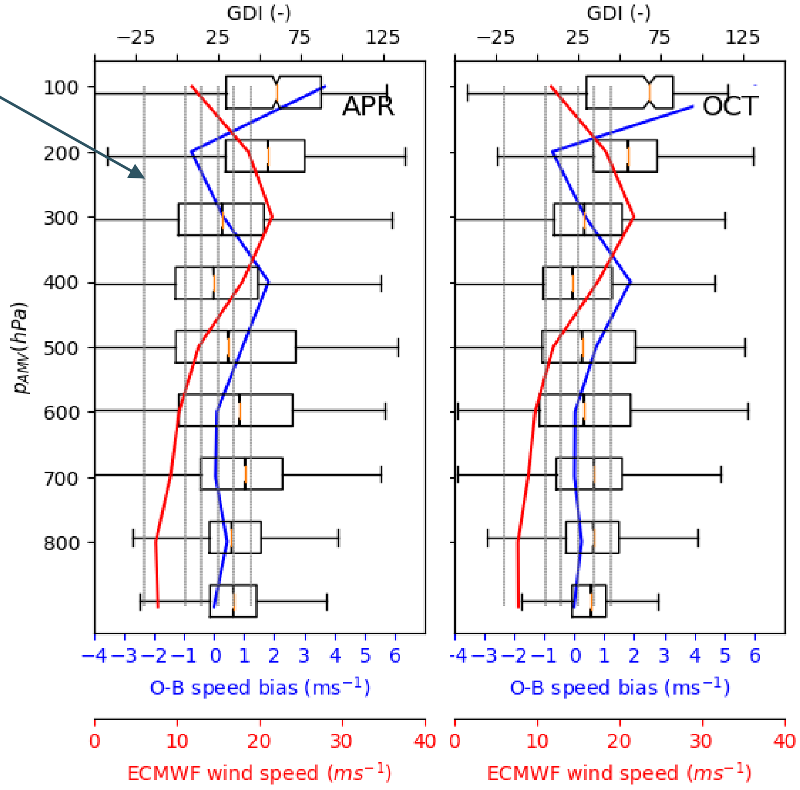
Galvez-Davison index (GDI) is a stability index adapted for a tropical atmosphere

Correspondence between GDI values and expected type of convection.
Figure adapted from http://www.wpc.ncep.noaa.gov/international/gdi/.

O-B speed bias against GDI computed from ECMWF fields

Vertical grey lines: Change to a different convection type

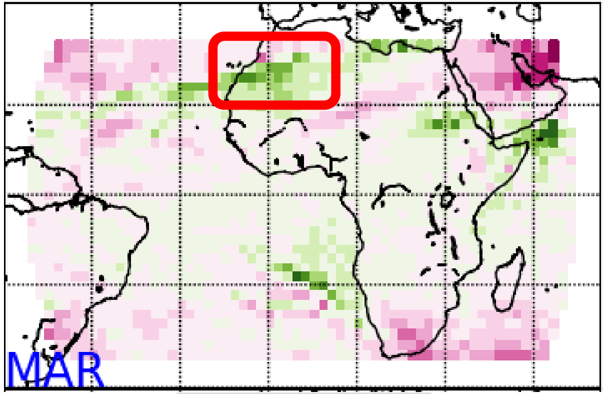
Met10EUM IR channel



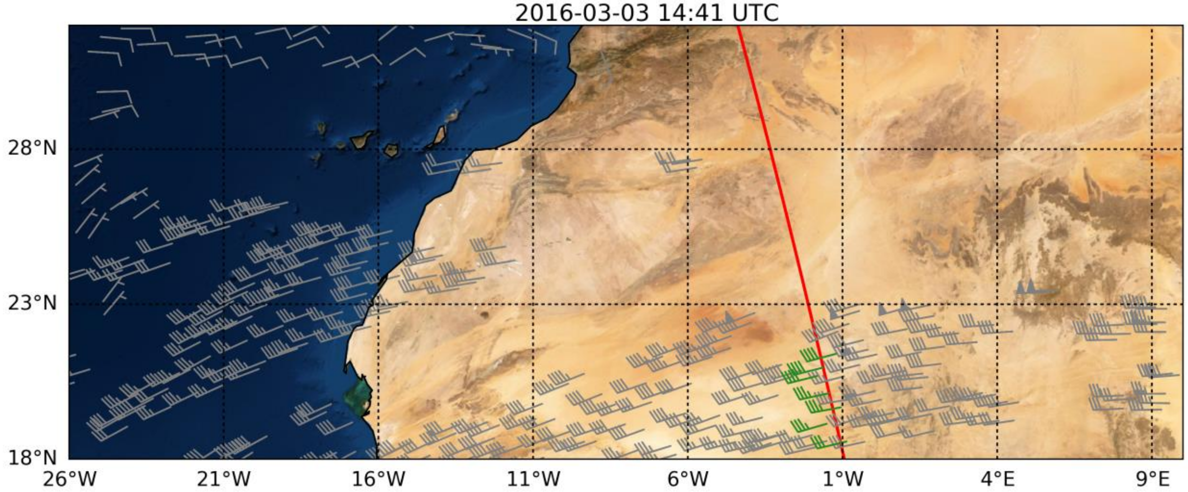
- Use database of collocated AMV and ECMWF
- Difficult to deduce dependency of speed-bias on GDI

REF AMV-PRE-0011-TS – 18/06/2020
Thales Services / Modèle : 87211168-GRP-FR-004

Case study - Met10EUM IR AMV mid- and high-level speed bias over Saharan desert in March 2016 during westerly jet



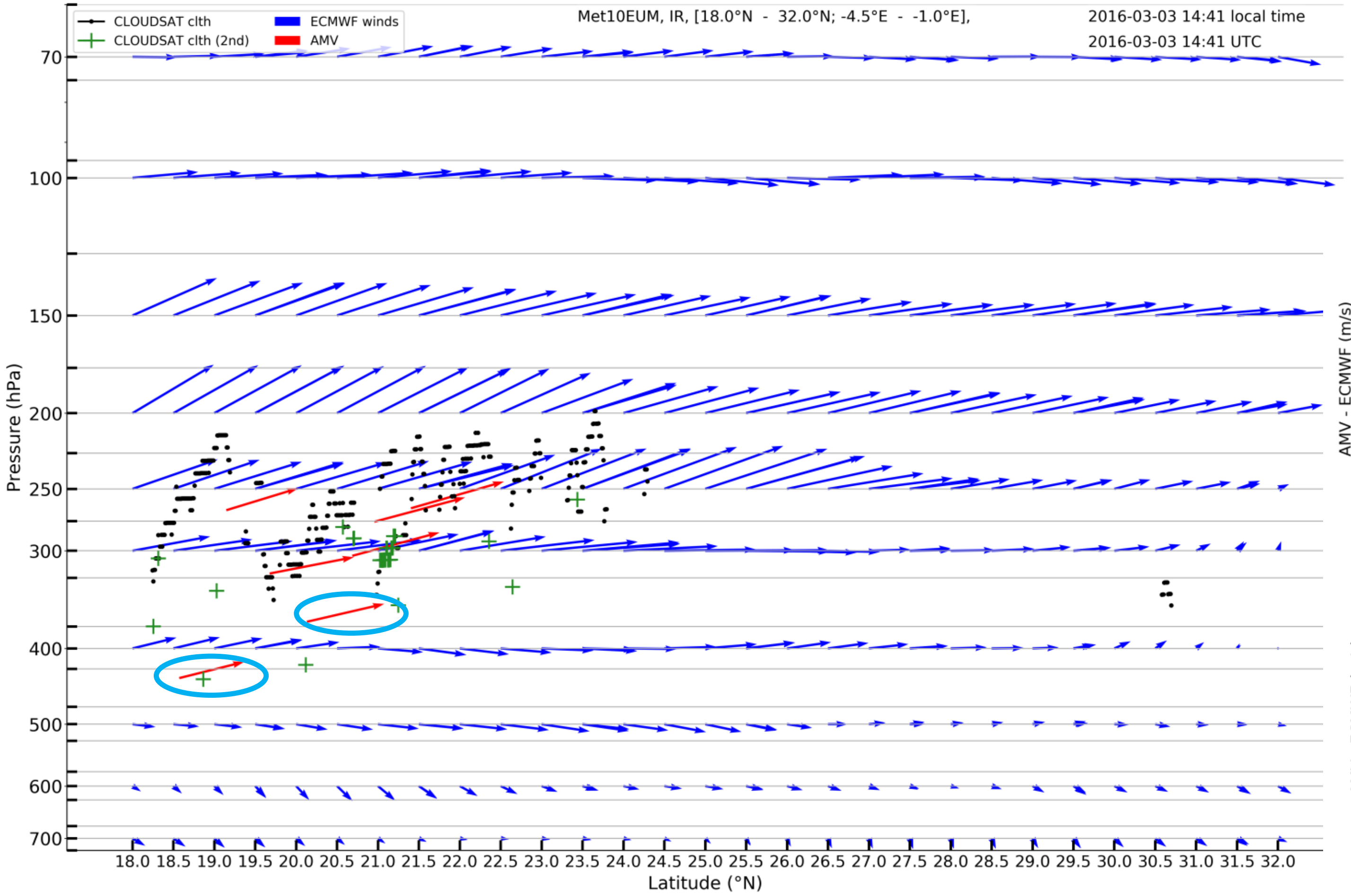
Case 1 - Met10EUM IR AMV performance over Sahara desert



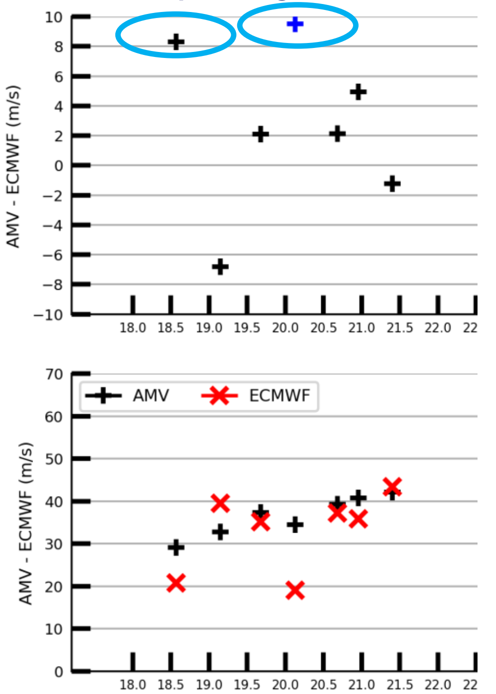
CLOUDSAT overpass on 3 March 2016 at 14:41 UTC. Wind barbs denote the Met10EUM found within ±30 min of the CLOUDSAT overpass. Green wind bars are within ±0.4° longitude of the CLOUDSAT overpass.

- **METHOD: Visual comparison** of ECMWF and AMVs along CLOUDSAT orbit or north-south transects
- SEVIRI and CLOUDSAT do not necessarily observe same clouds
- CPR/CLOUDSAT is used to assess AMV height assignment

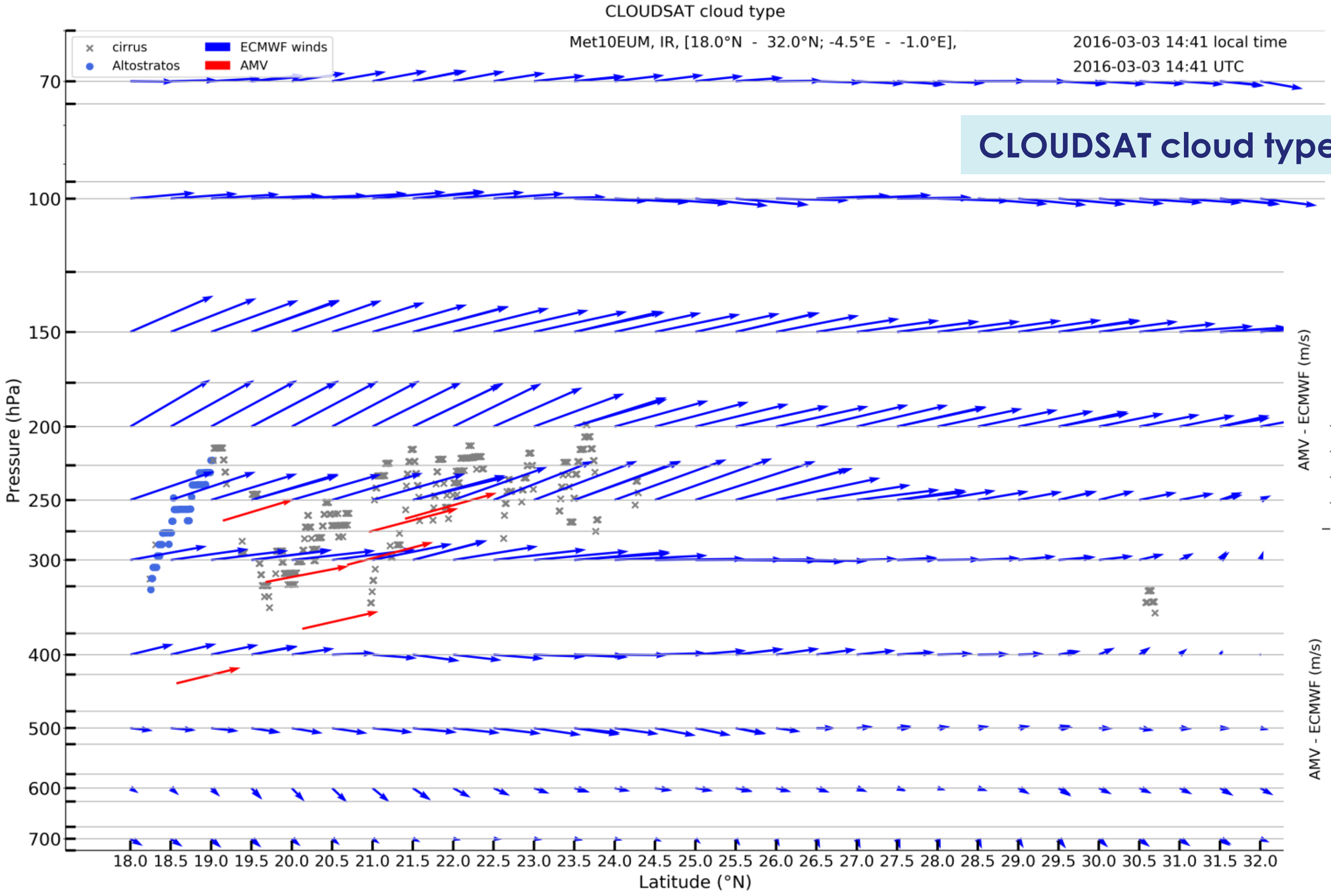
Case 1 - Met10EUM IR AMV performance over Sahara desert



Wind speeds & corresponding differences

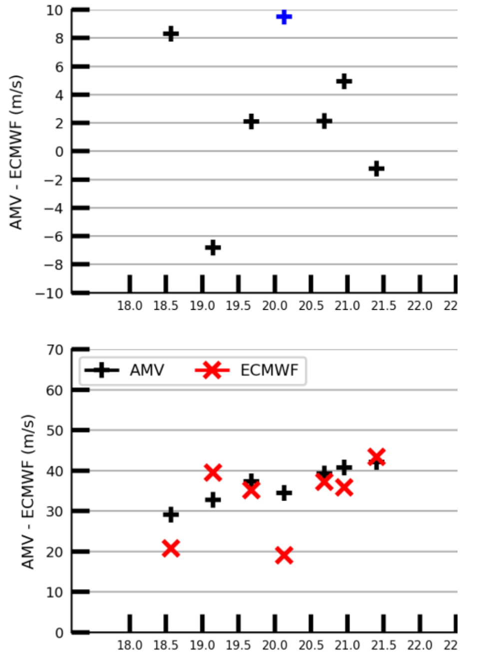


Case 1 - Met10EUM IR AMV performance over Sahara desert

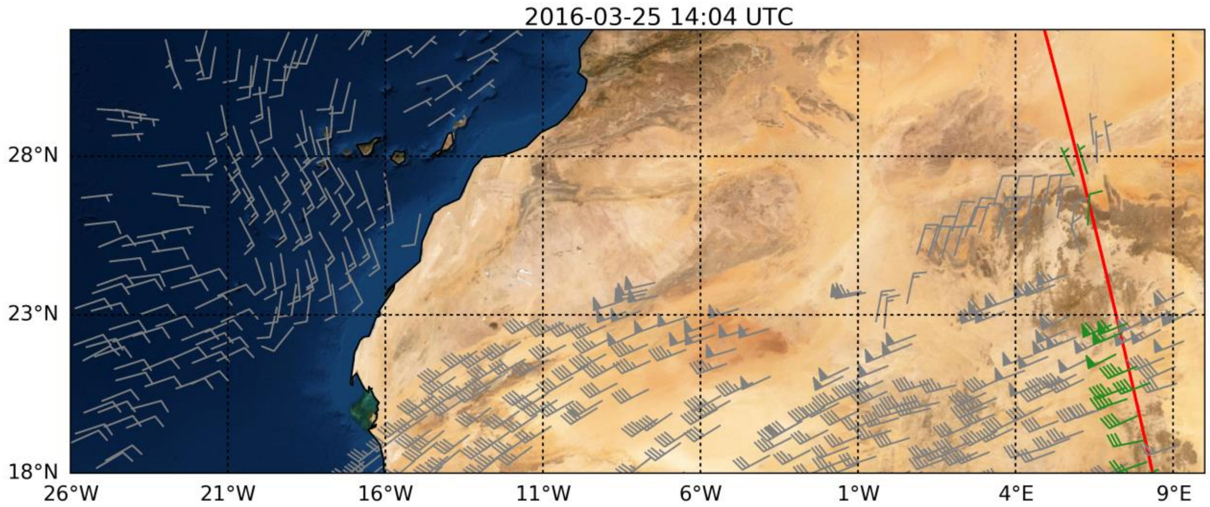


CLOUDSAT cloud type

Wind speeds & corresponding differences



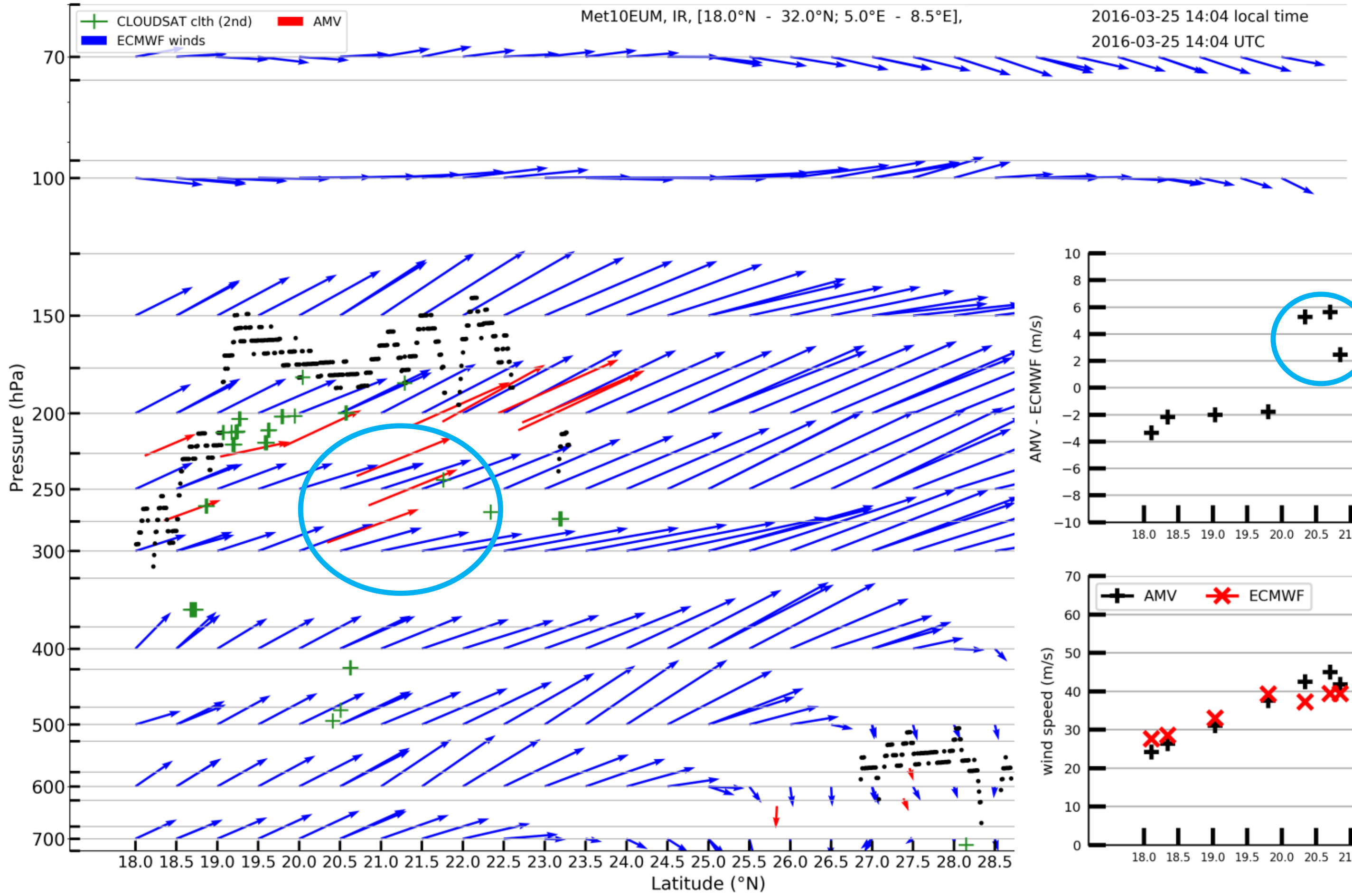
Case 1 - Met10EUM IR AMV performance over Sahara desert



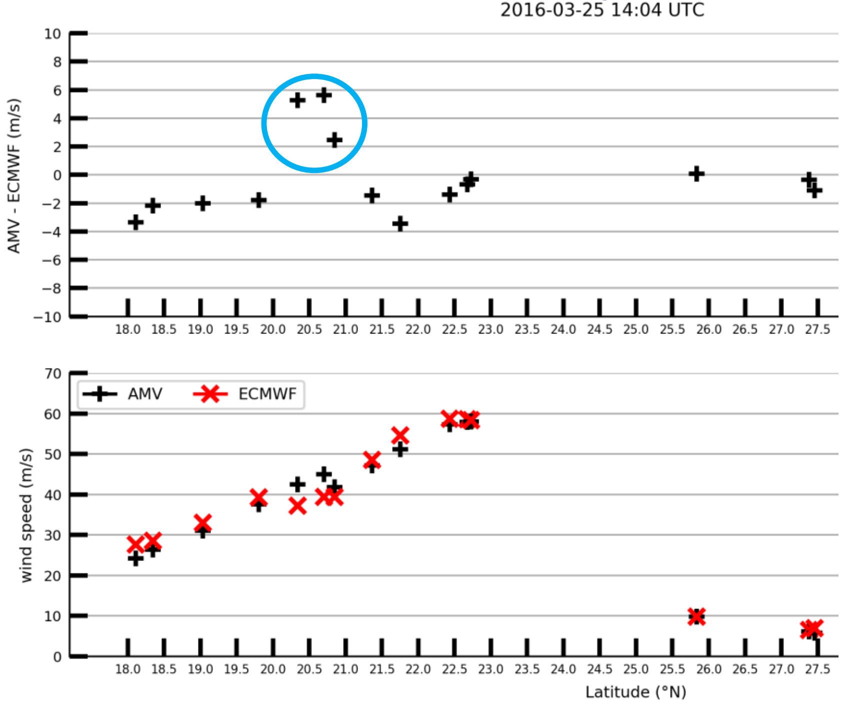
CLOUDSAT overpass on 25 March 2016 at 14:04 UTC. Wind barbs denote the Met10EUM found within ±30 min of the CLOUDSAT overpass. Green wind bars are within ±0.4° longitude of the CLOUDSAT overpass.

- **METHOD: Visual comparison** of ECMWF and AMVs along CLOUDSAT orbit or north-south transects
- SEVIRI and CPR/CLOUDSAT do not necessarily observe the same clouds
- CPR/CLOUDSAT is used to assess AMV height assignment

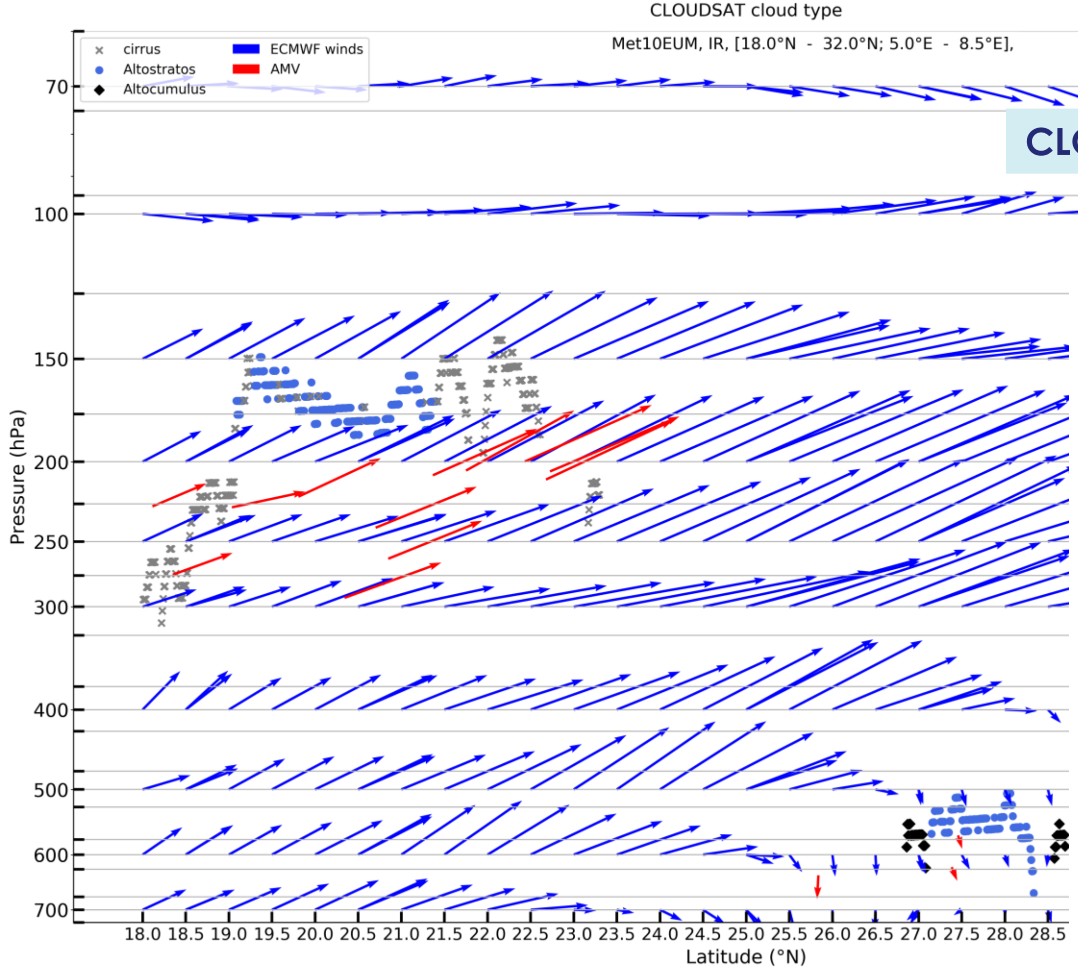
Case 1 - Met10EUM IR AMV performance over Sahara desert



Wind speeds & corresponding differences

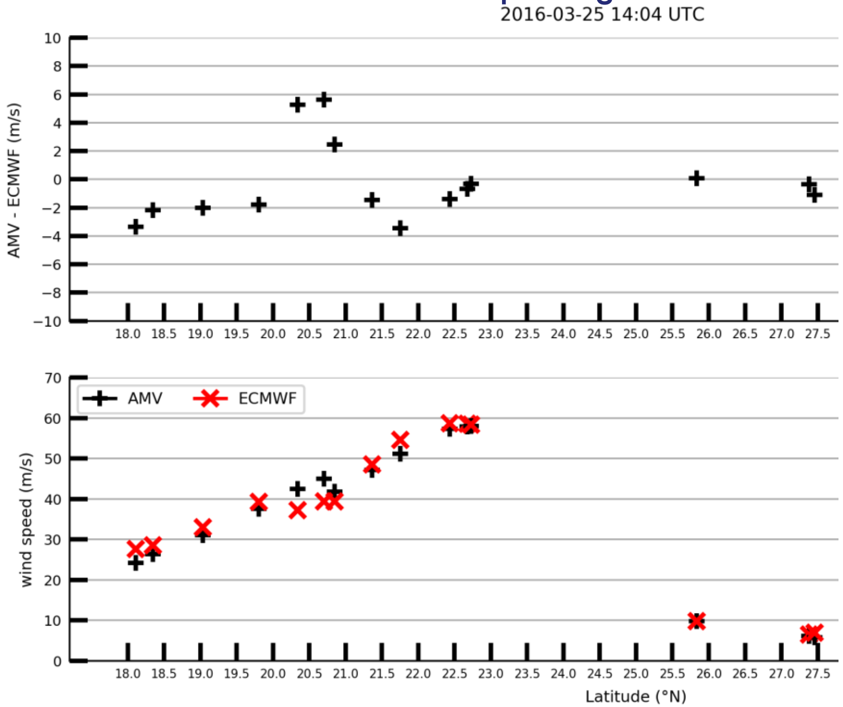


Case 1 - Met10EUM IR AMV performance over Sahara desert

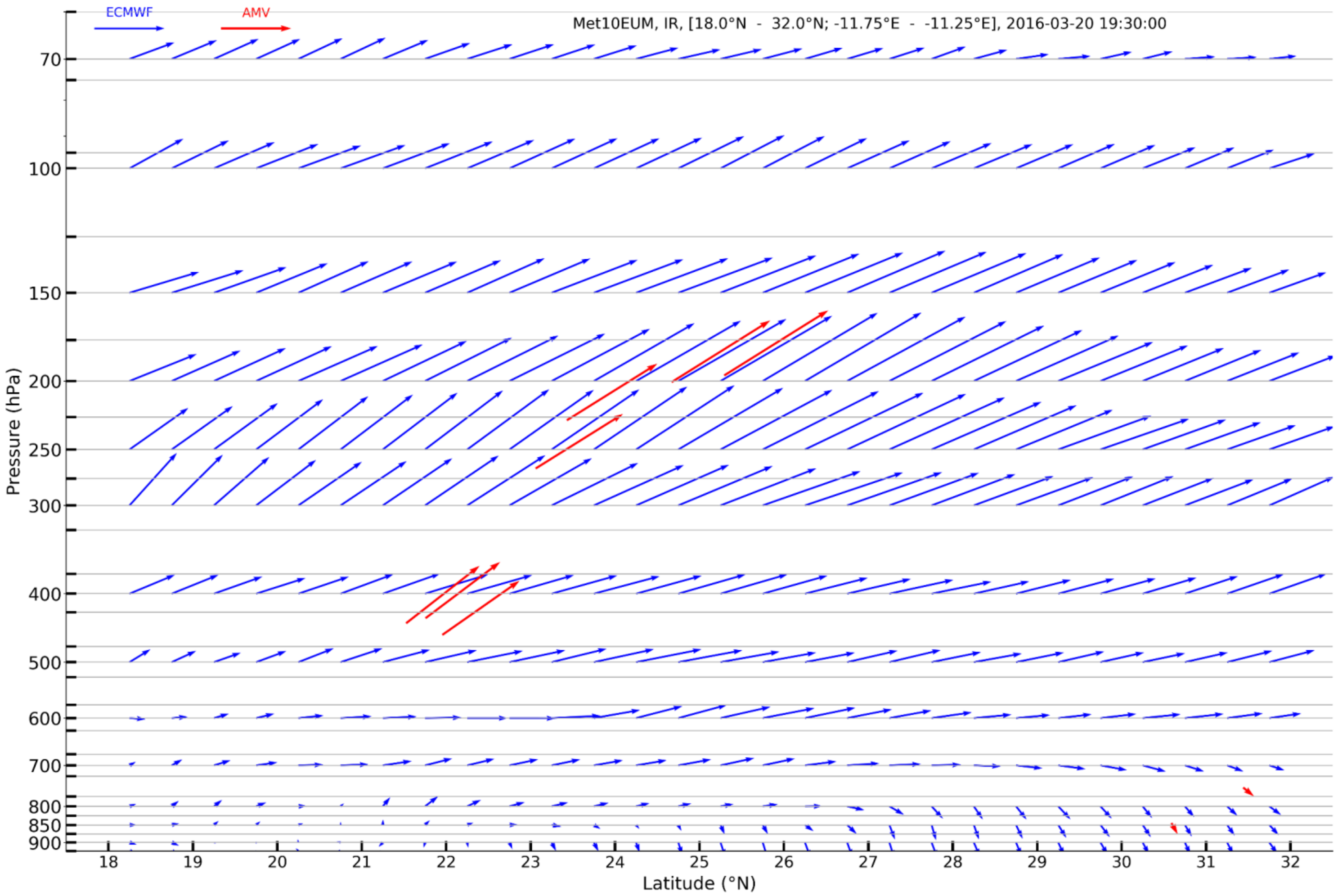


CLOUDSAT cloud type

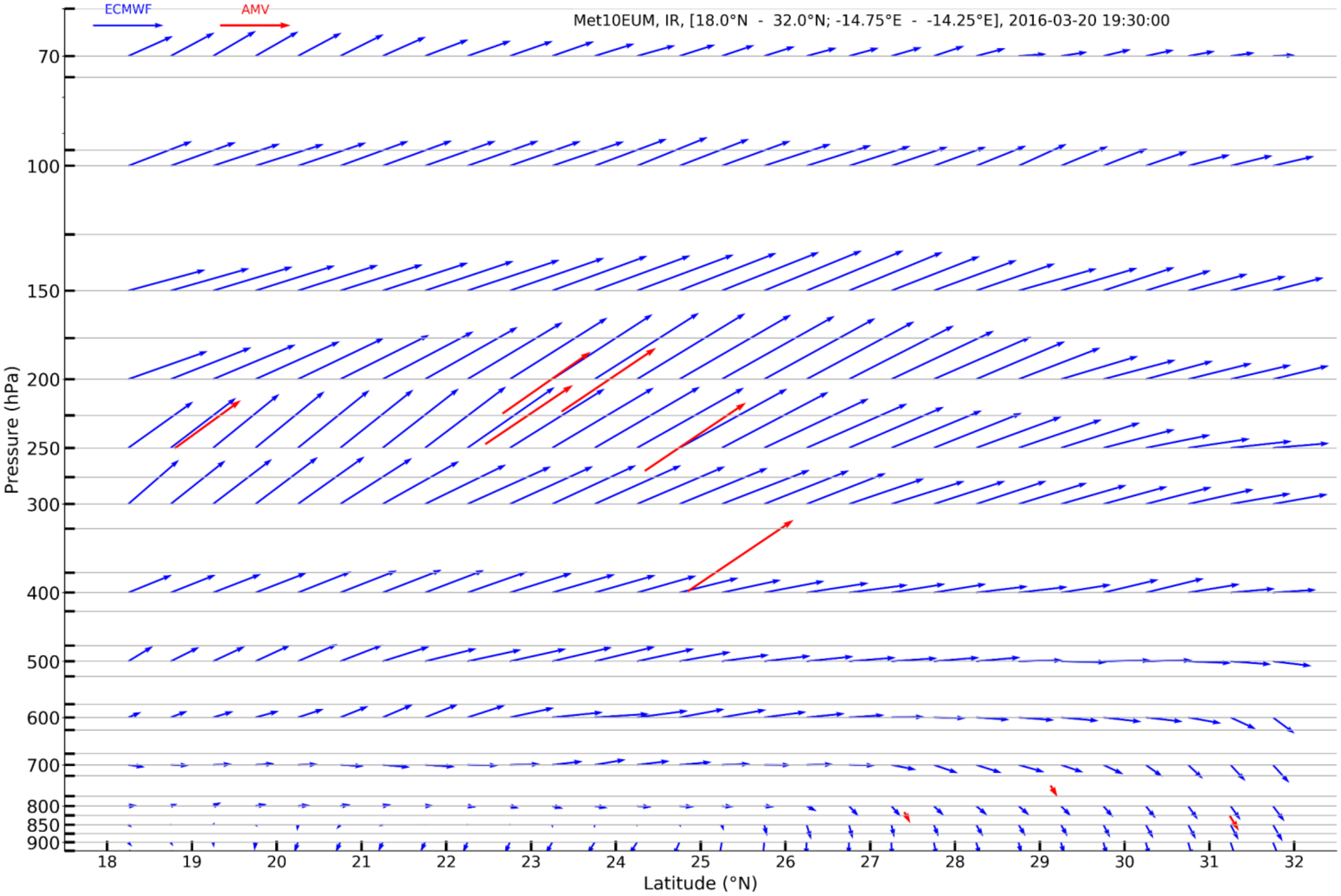
Wind speeds & corresponding differences



Simple north-south transect. No CPR/CLOUDSAT:



North-south transect. No CPR/CLOUDSAT:



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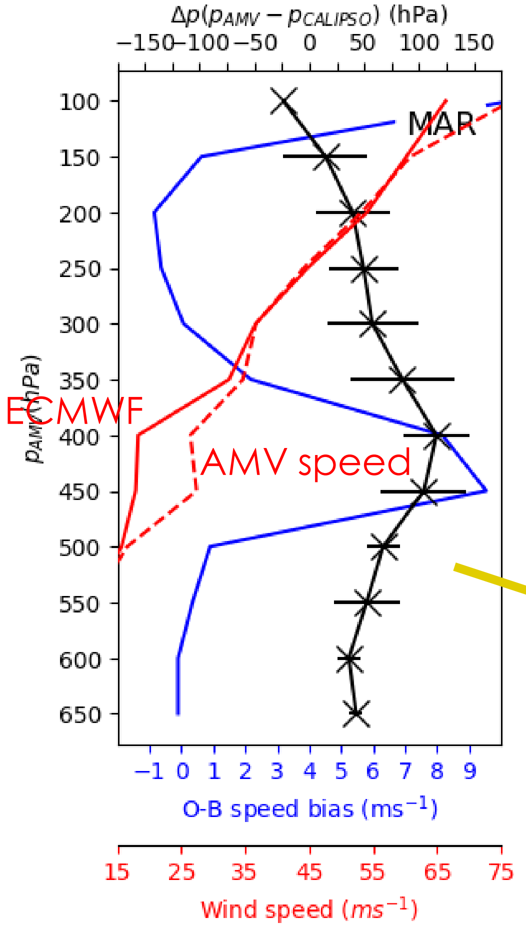
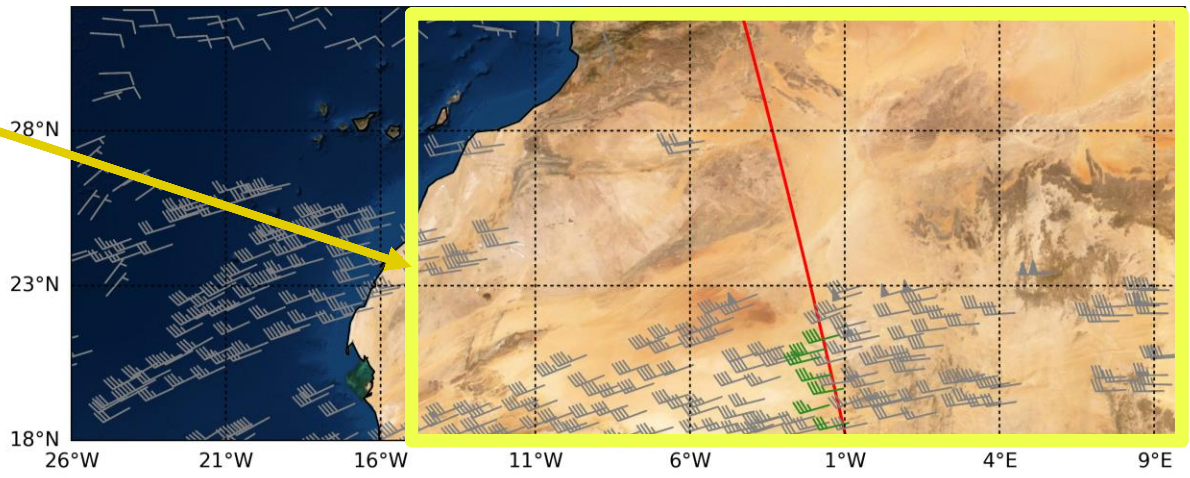
Case 1 - Met10EUM IR AMV performance over Sahara desert

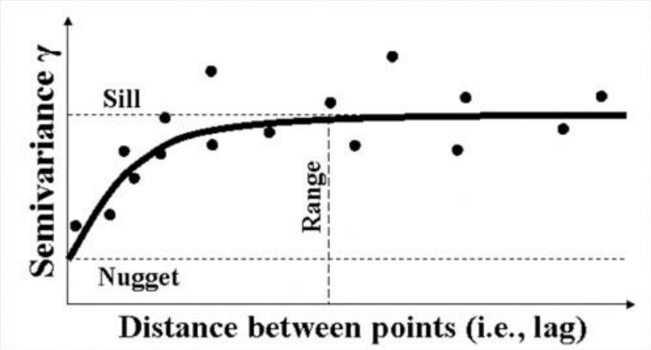


- CALIOP/CALIPSO cloud top height vs AMV pressure during **two weeks** in March '16
- Method of Folger and Weissmann (2014) is used:
  - Discards multilayer cloud scenes
  - Ensures lidar signal represents cloud
  - Median value of all available CALIOP CTH ($\Delta r \lesssim 75$km; $\Delta t \lesssim \pm$ 45 min) is taken as representative CTH and compared to AMV pressure
- As wind speed increases strongly for $p < 400$ hPa, (positive) pressure differences between AMV and CALIPSO of 50-100 hPa translate to speed biases of > 5 ms^{-1} during jet situations over deserts



Analyses of semivariances

- analysis of Speed bias as function of time of day, OLR, GDI, CLOUDSAT cloud classification indicate little dependency of O-B speed bias on the strength and type of convection and on cloud type.
- Comparison of Met10AMV pressures to CALIPSO/CALIOP cloud top heights revealed that AMVs tend to have assigned too low altitudes at high levels., which leads to too fast AMVs at 400-500 hPa.
- the geographic pattern of O-B speed bias suggest a different location of the subtropical jet in observed & model winds
- Analyse the spatial variance of AMV and model speed over a region to verify similarity of wind fields (e.g. position and strength of jet). In spatial statistics, this is commonly achieved by plotting the semivariances as function of lag distance ("semivariogram").



Analyses of semivariances - continued

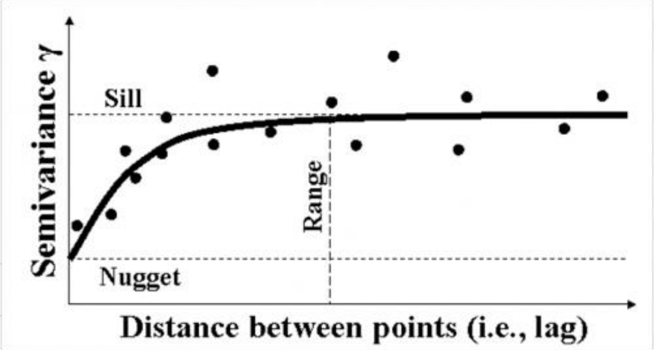
- In spatial statistics, this is commonly achieved by plotting the semivariances as function of lag distance ("**semivariogram**").

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i}^{N(h)} \left(z(x_i) - z(x_i + h)\right)^2$$

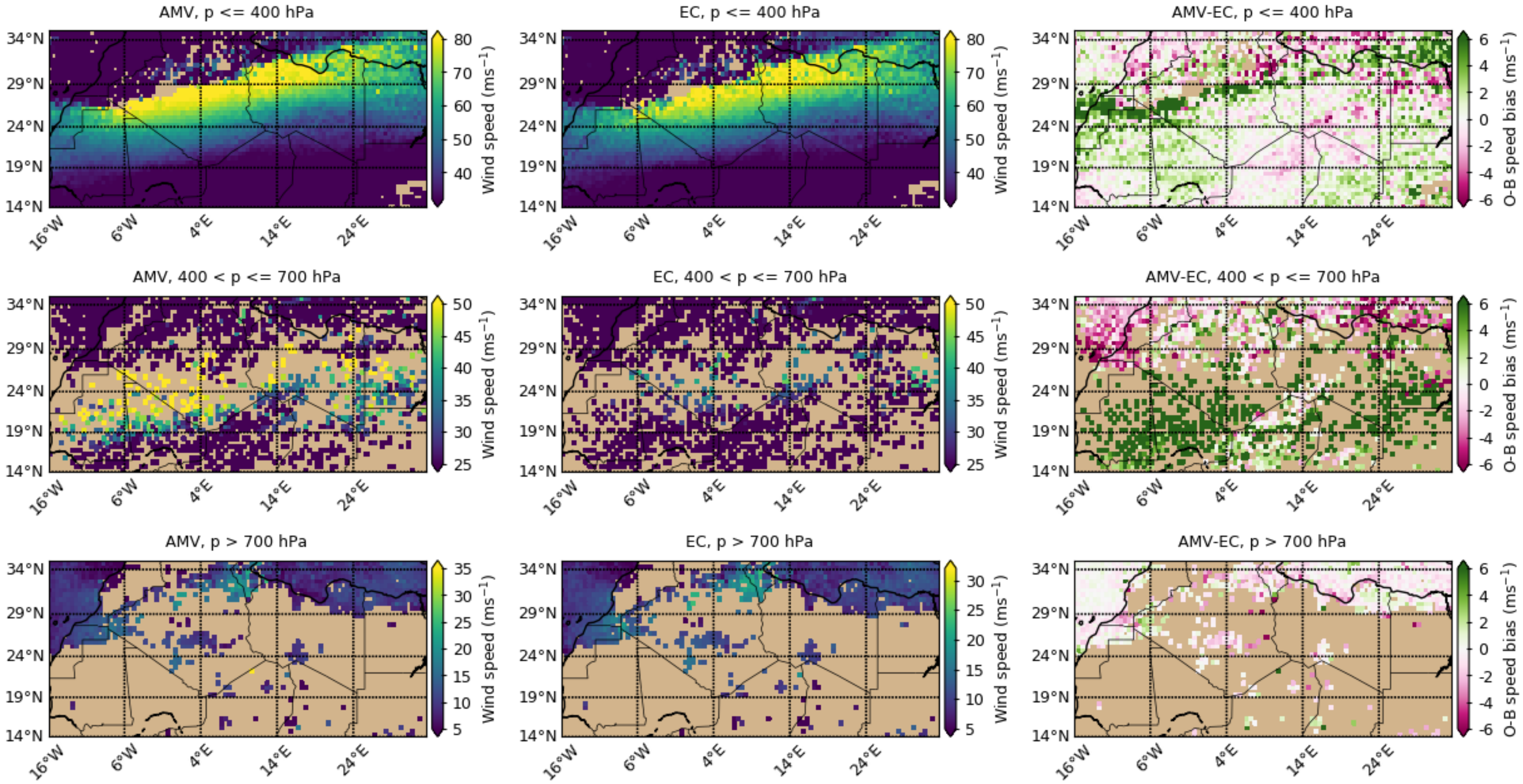
h is a distance, and *z*(x_i) and *z*(x_i + *h*) are two data points (e.g. model wind speed at the same pressure level and time) at locations x_i and x_i + *h*. The *N(h)* term is the number of points we have that are separated by the distance h.

- The semivariogram analysis use the collocation database established earlier.

- ECMWF semivariances thus comprise only purely horizontal variances at a given time, while AMV semivariances also include a small portion of vertical variances, which are introduced by the vertical matching criterion of 25 hPa.

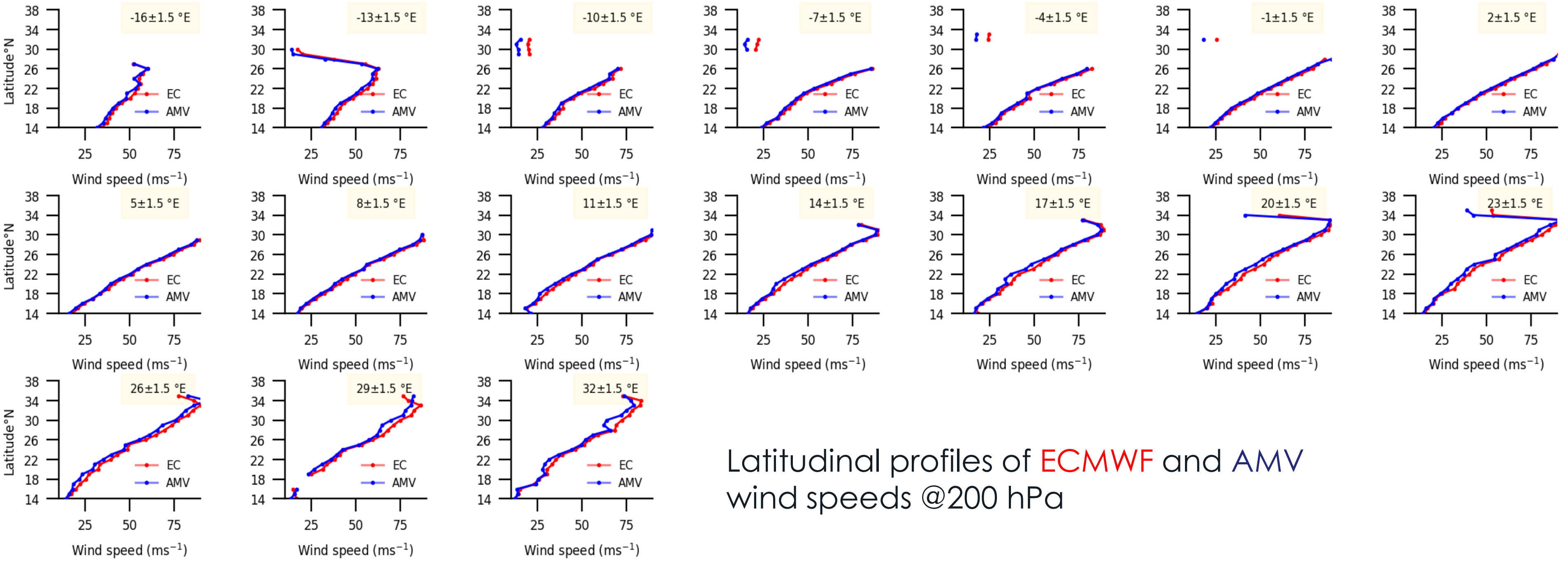


Application to a 7-day westerly jet situation over Northern Africa



7-day jet situation (22.3 – 28.3.2016) over Northern Africa as seen by Met10EUM & ECMWF. At high levels, the geographic pattern of O-B speed bias – positive speed bias along northern edge of jet, negative bias along southern edge of jet – suggest a different location of the subtropical jet in observed & model winds.

Observed and model winds over the Sahara desert at the 200 hPa



Latitudinal profiles of ECMWF and AMV wind speeds @200 hPa

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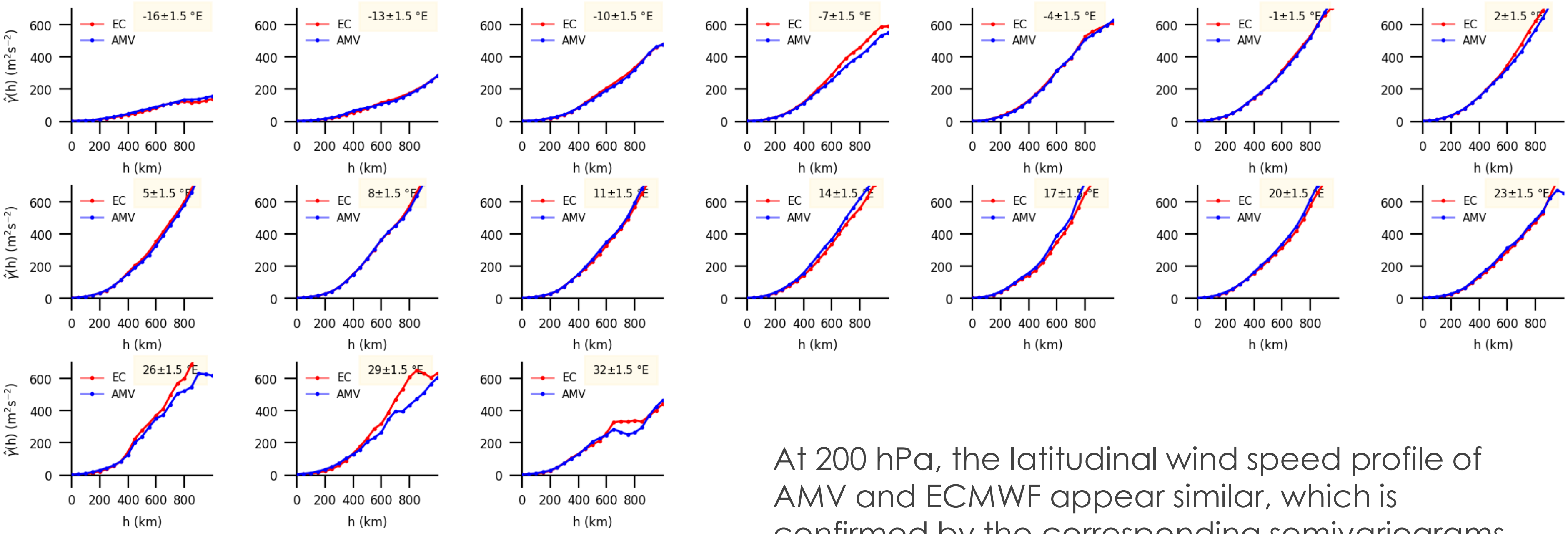
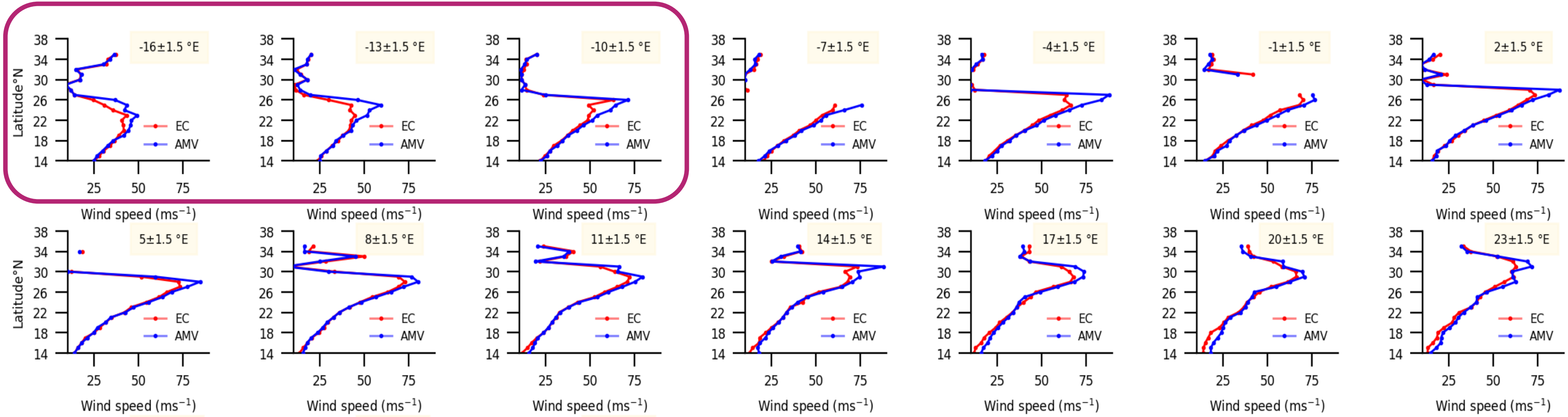
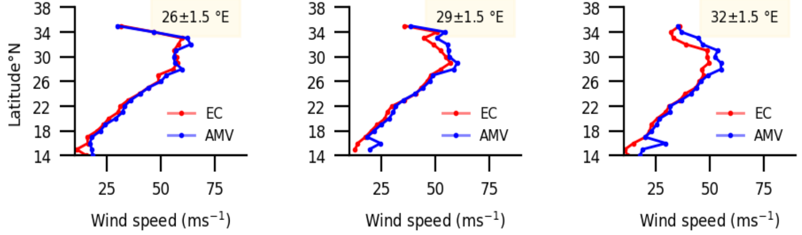
Corresponding semivariograms



At 200 hPa, the latitudinal wind speed profile of AMV and ECMWF appear similar, which is confirmed by the corresponding semivariograms

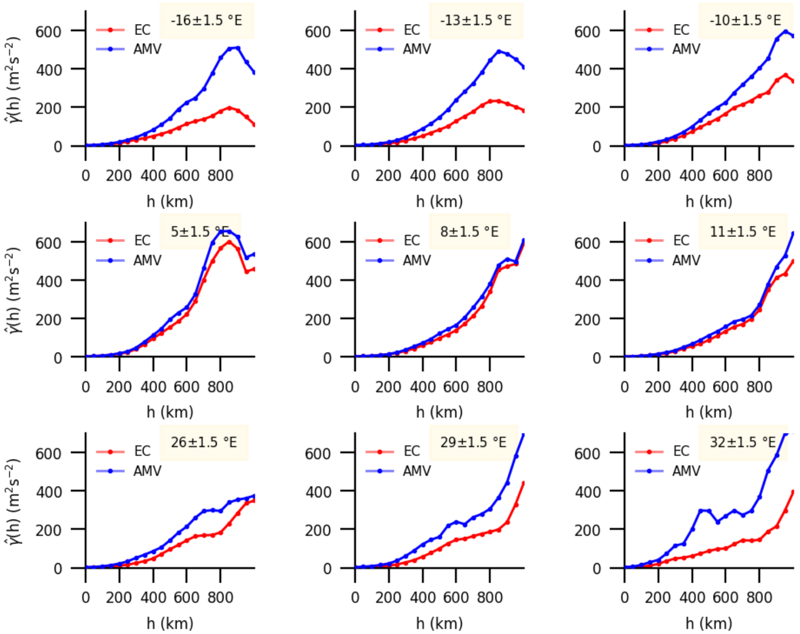
Observed and model winds over the Sahara desert at the 300 hPa





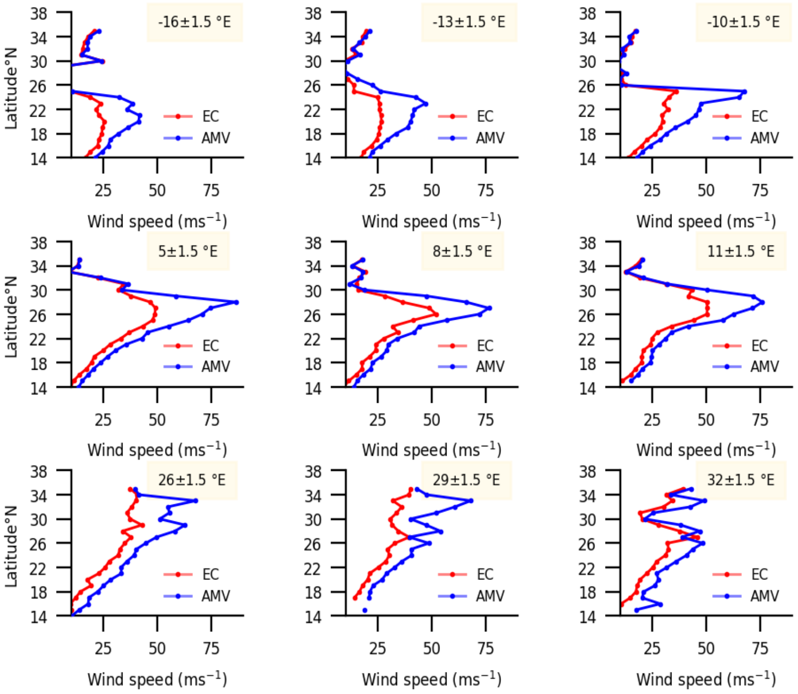
Latitudinal profiles of ECMWF and AMV wind speeds @300 hPa indicate faster AMVs than model winds, particularly between -16° to 10°E/°20 to 26°N differences amount to 10 ms-1

Corresponding semivariograms



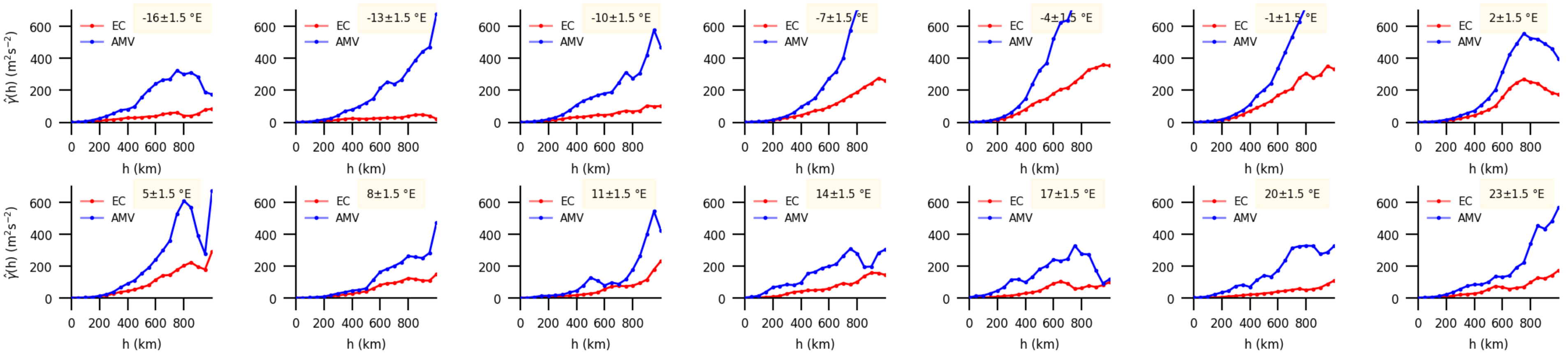
- relatively similar pattern of semivariances for AMVs & ECMWF (position of lows & peaks, evolution of semivariances with lag distance).
- AMV semivariances increase much faster with distance h than ECMWF semivariances, which may be interpreted that
  - the jets observed by AMVs reach higher speed levels (i.e. faster winds) than ECMWF
  - the jet observed by AMVs peak at slightly different locations.

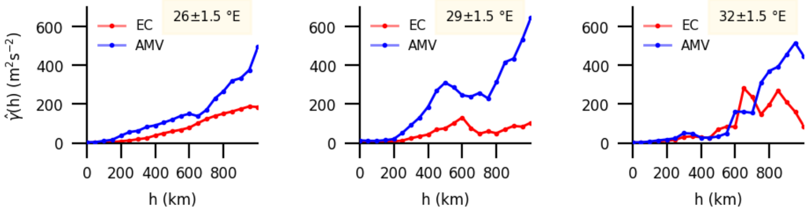
Observed and model winds over the Sahara desert at the 400 hPa



At 400 hPa, latitudinal wind profiles of AMV & model winds are regularly found different, with AMV wind speeds frequently reaching speed levels that have been found also at 300 hPa.

Corresponding semivariograms





- AMV semivariances increase much stronger with increasing distance than ECMWF semivariances
- Structure of the semivariances is quite different between model and observed winds, indicating that rather than the horizontal position of the jet, differences in the vertical position of the jet lead to the observed O-B speed biases of up to 20 ms^{-1}.

Dual-Metop IR AMV performance

Monthly statistics against ECMWF winds

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AMV deduced from AVHRR aboard MetOp

EUMETSAT derives AMV operationally from Meteosat geostationary satellites and the polar satellite system MetOp

Global AMV product from MetOp:

- Tandem configuration of two MetOp satellites (A and B) in the same orbital plane allows extracting global information using the 10.8 µm channel of AVHRR imaging instrument
- Use pair of images taken successively by the tandem satellites within their swath overlap (~1500 km width at the equator)
- Temporal gap between 2 images of ~50 min
- Unique AMV data set: represents only satellite-wind dataset offering complete day-night global coverage
- Operational since February 2015

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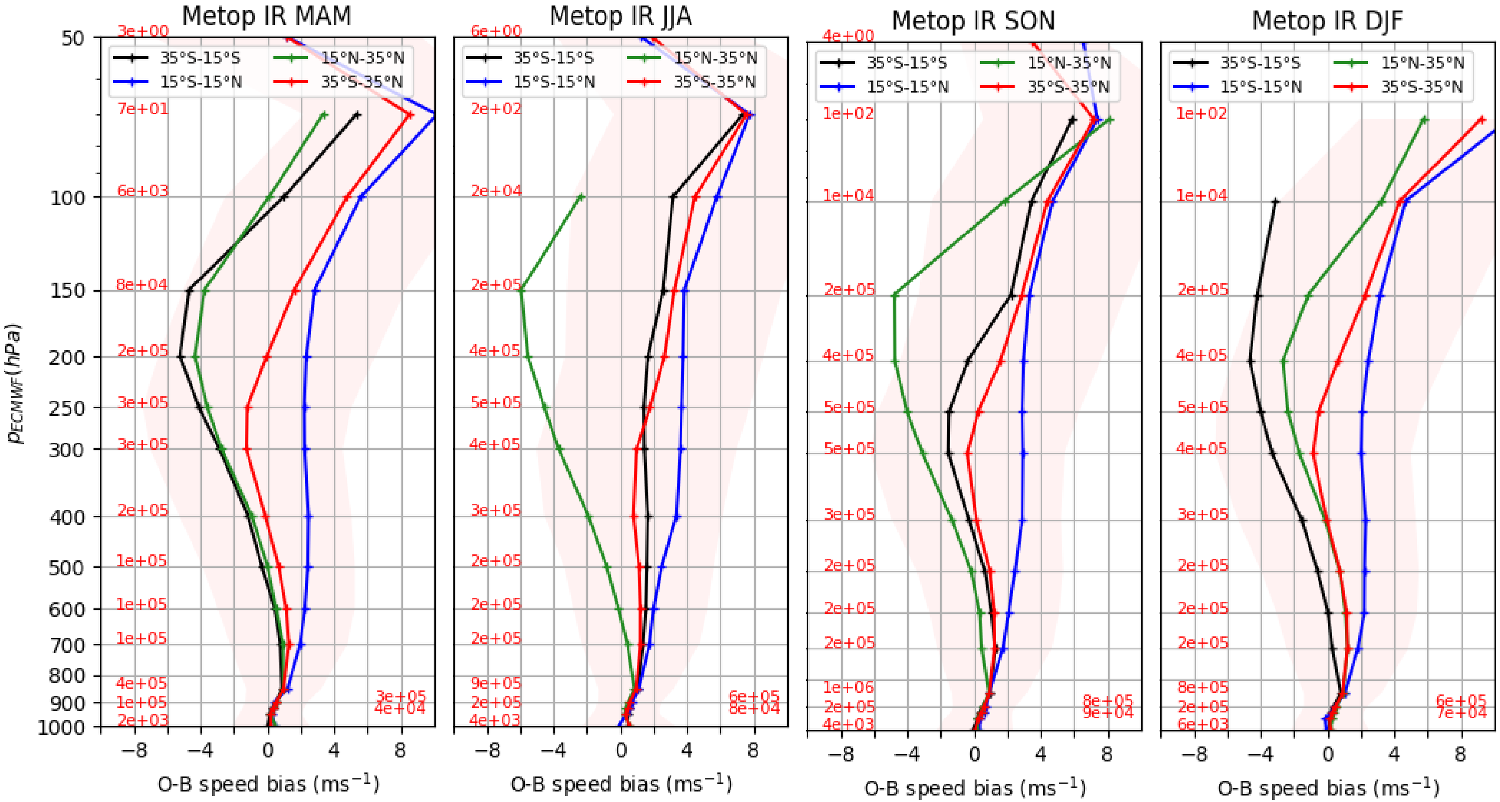
Metop : O-B speed bias as function of pressure

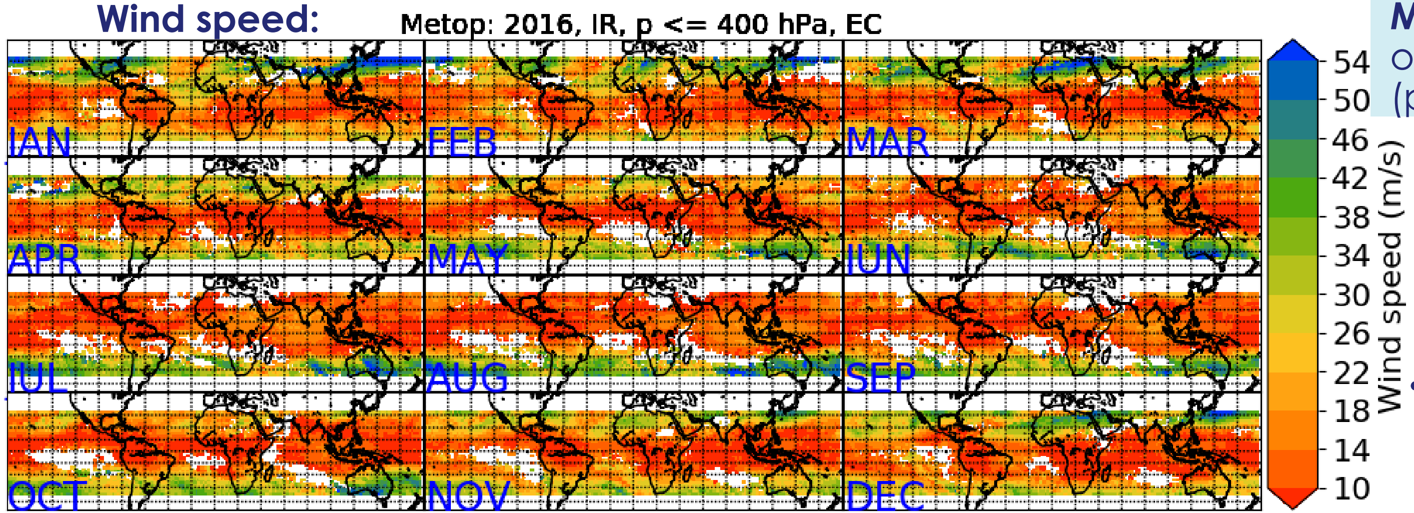
Wind speed difference profiles averaged over different zonal bands



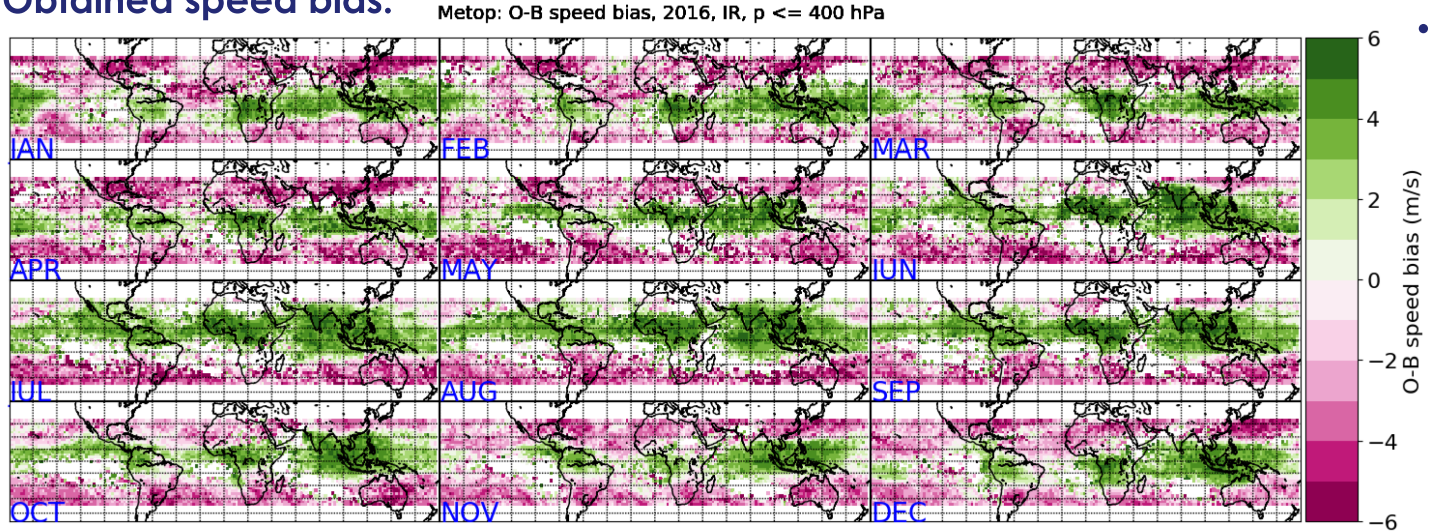
- Data up to 50 hPa
- p > 800 hPa: differences in wind speed are close to 0, ±1 ms^{-1}, i.e. similar to Met10EUM
- p < 800 hPa: Depending on latitudes, O-B speed biases increase with altitude. Sign of bias depends on zonal band.

Metop: Spatial distribution of speed bias at high-levels ($p \leq 400$ hPa)

Wind speed:



Obtained speed bias:



- Fast winds coincide with negative O-B speed biases (< 3 ms^{-1})
- Conversely, positive O-B speed biases are obtained for equatorial region where mean winds are typically slower than 20 ms^{-1}

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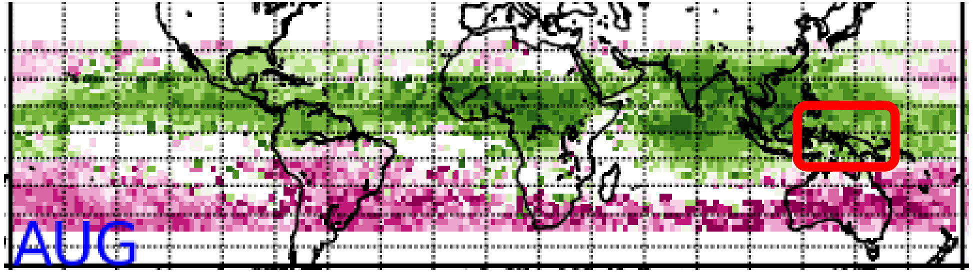
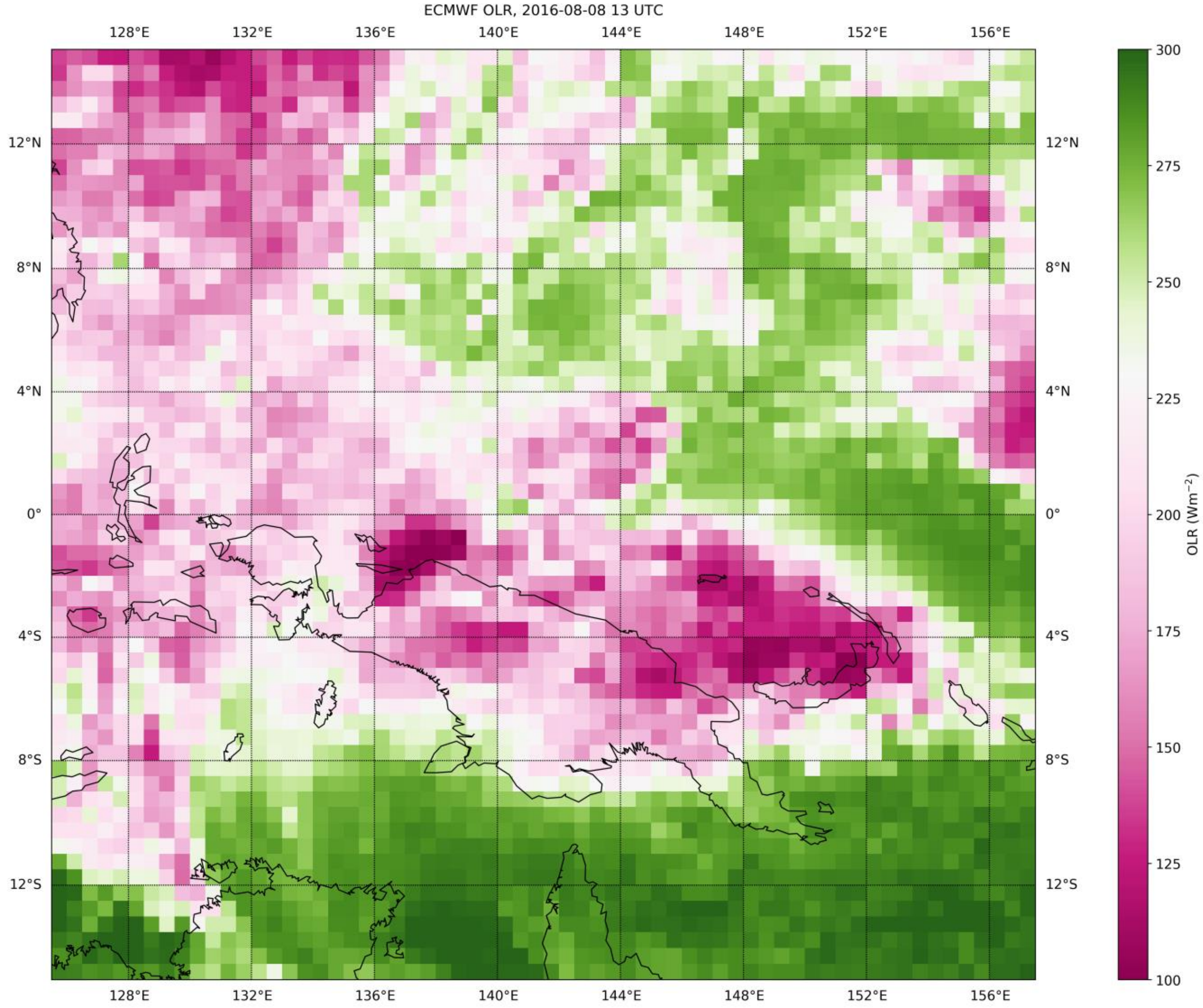
Case study - Dual-Metop IR AMV mid- and high-level speed bias over the Boiler-Box region in August 2016

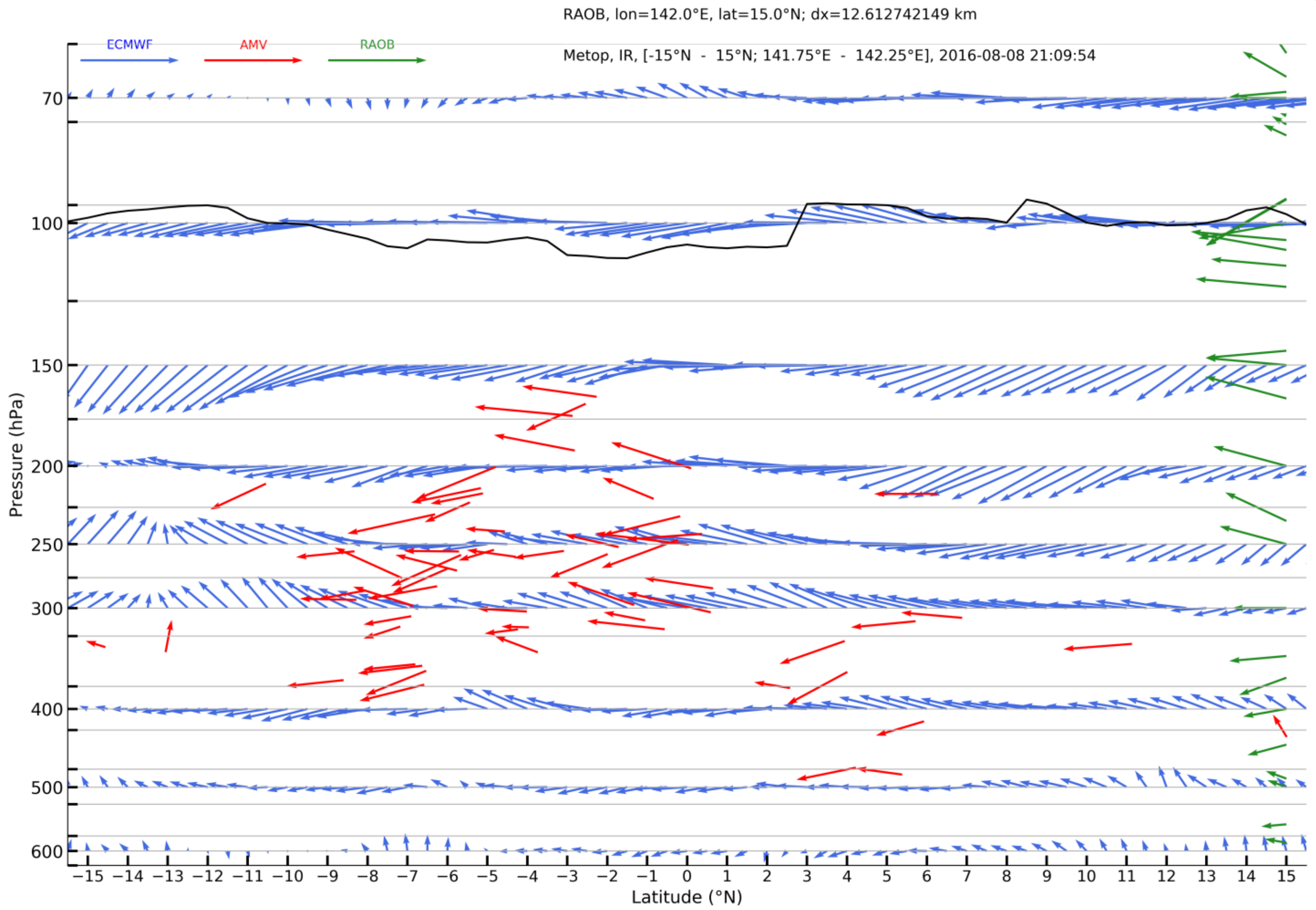




Case 2 - Metop performance over "Boiler-Box" region

- Metop A/B sense in a highly convective region
- Almost no reference data available

Case 2 - Metop performance over “Boiler-Box” region



- **North-south transect** during a Metop **overpass in evening** (local time)
- **Metop AMVs are faster than model winds at all altitudes.**
- Compared to the jet situation over the Saharan desert **wind directions change frequently with altitude**
- RAOB radiosondes disagree with both AMV and model winds

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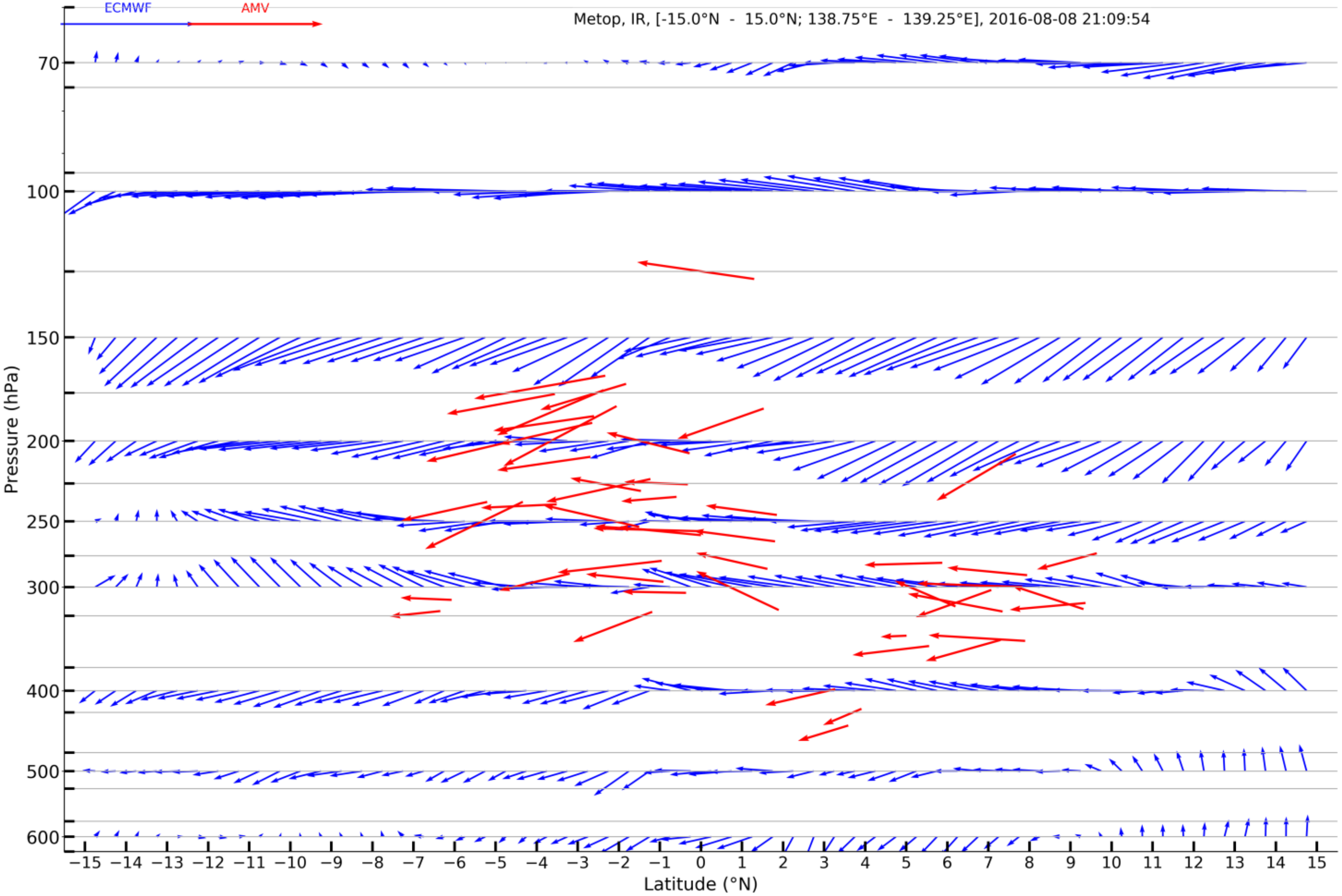
Case 2 - Metop performance over “Boiler-Box” region



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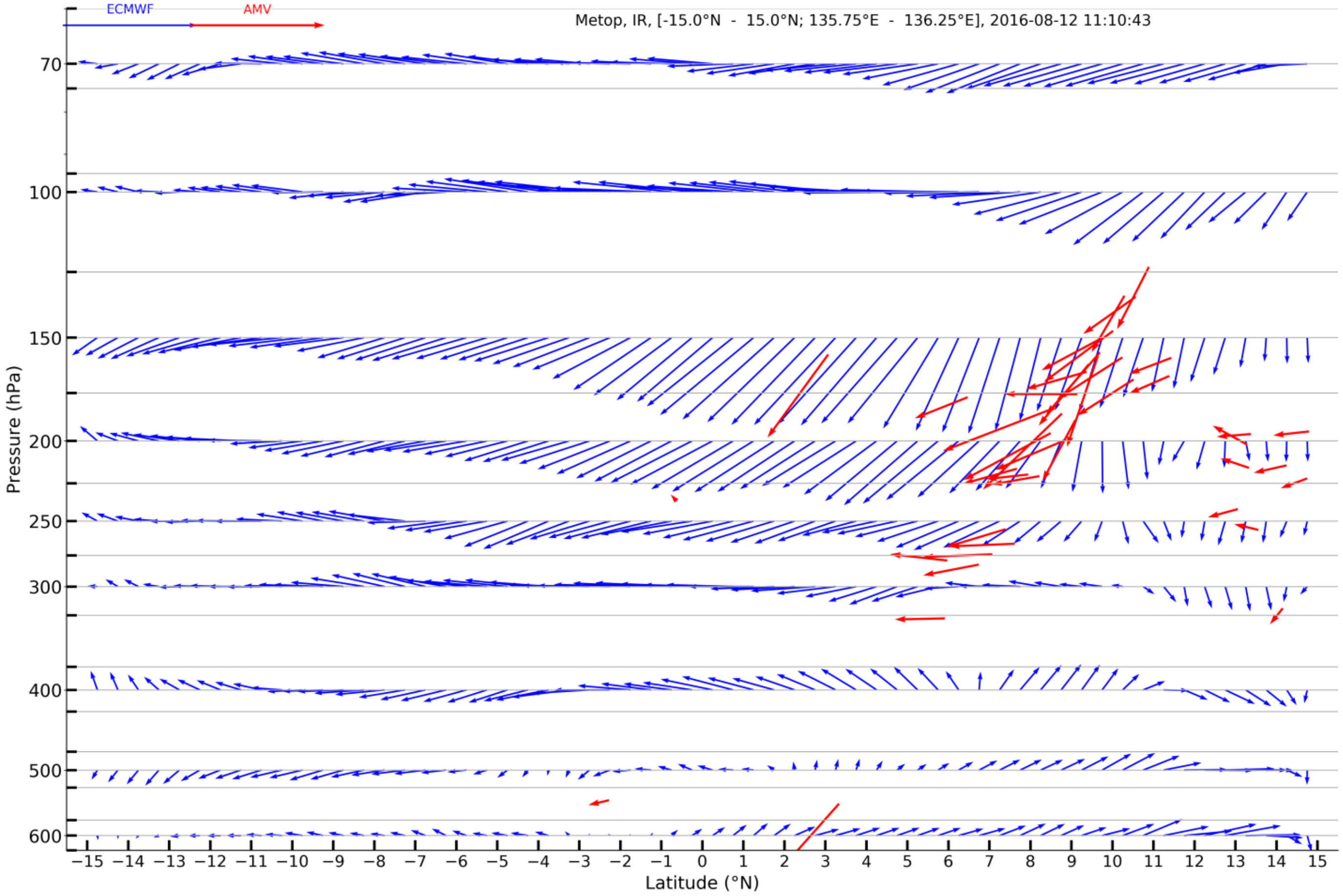
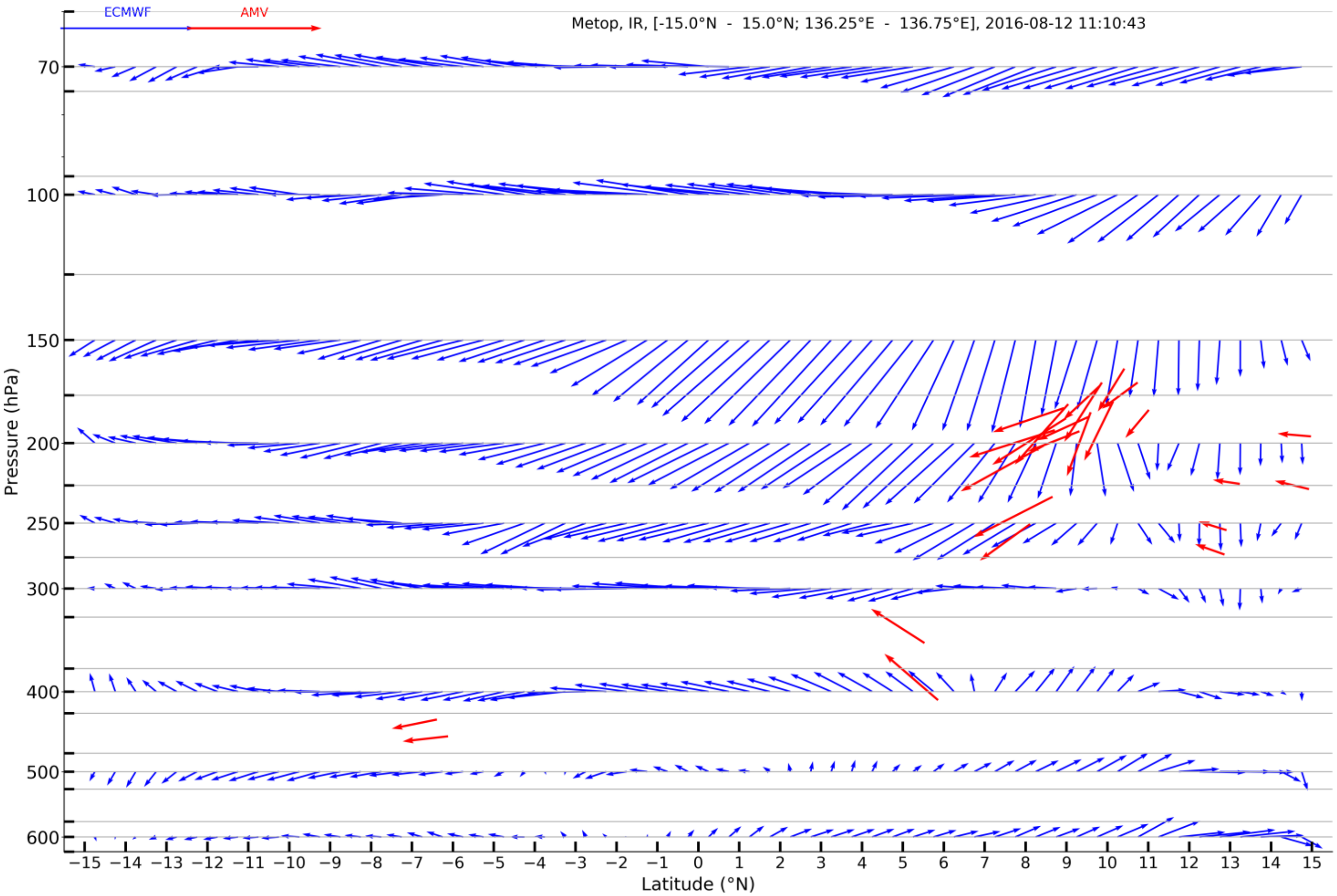


- **North-south transect** during a Metop **overpass in morning**(local time)
- Metop AMVs are faster than model winds at all altitudes.
- Compared to the jet situation over the Saharan desert wind direction changes frequently with altitude

Case 2 - Metop performance over “Boiler-Box” region



North-south transect during a Metop **overpass in morning**(local time)

Metop AMVs are faster than model winds at all altitudes.

Compared to the jet situation over the Saharan desert wind direction changes frequently with altitude

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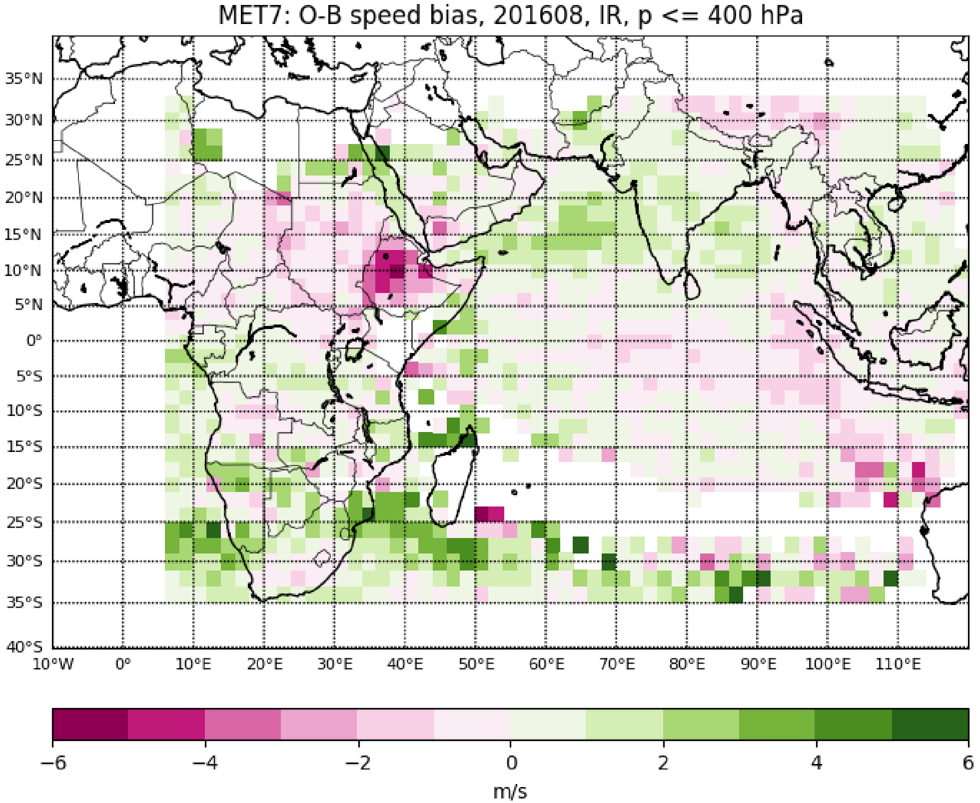
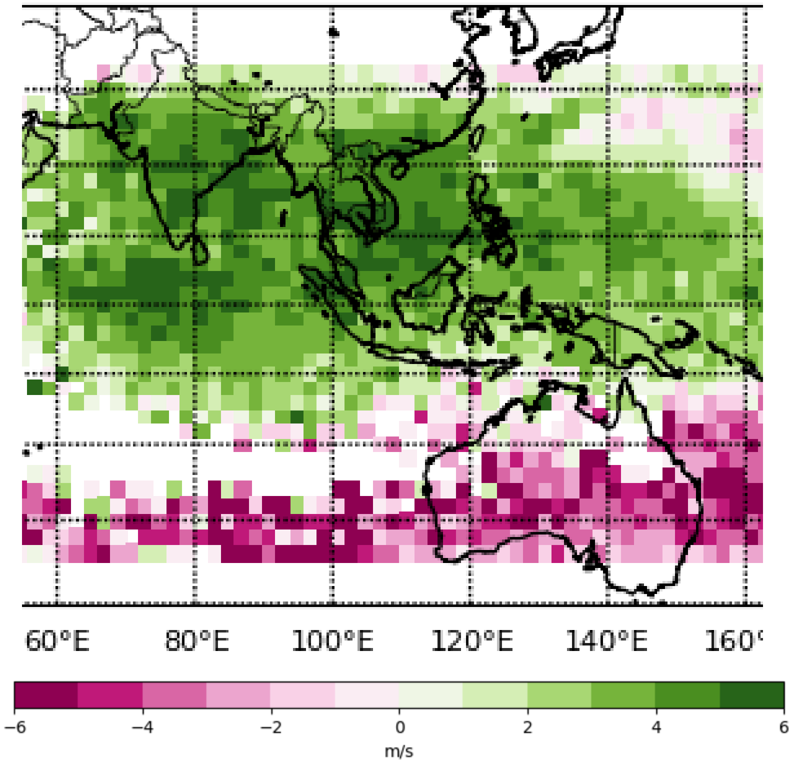
How do other AMVs perform over Boiler Box?

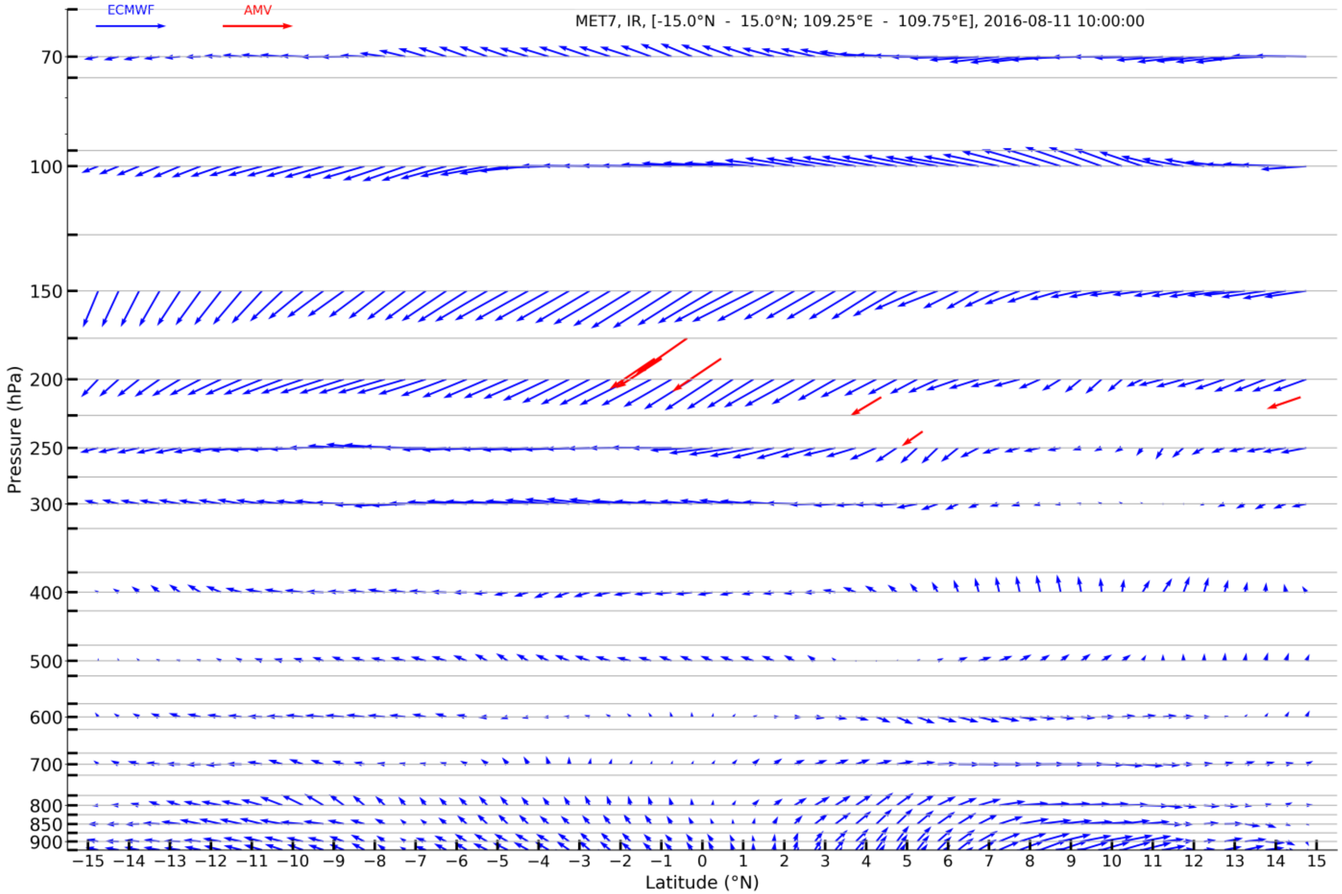
CIMSS Meteosat-7 IR AMVs at high levels



Dual-Metop IR AMVs at high-levels

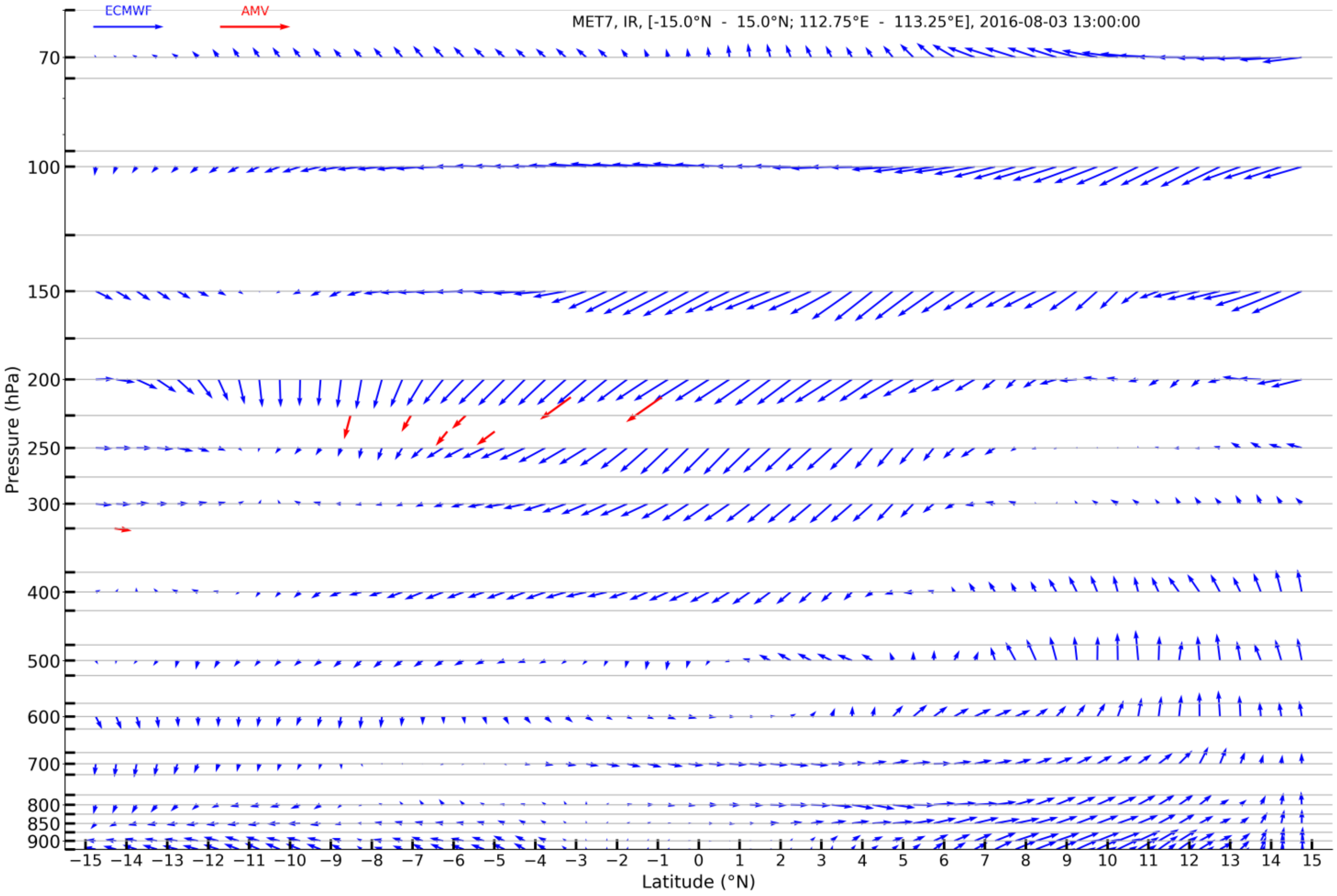


North-south transects. CIMSS Meteosat-7, IR channel



- Not exactly same region and time as Metop
- But AMVs wind field appears much better in agreement with ECMWF

North-south transects. CIMSS Meteosat-7, IR channel



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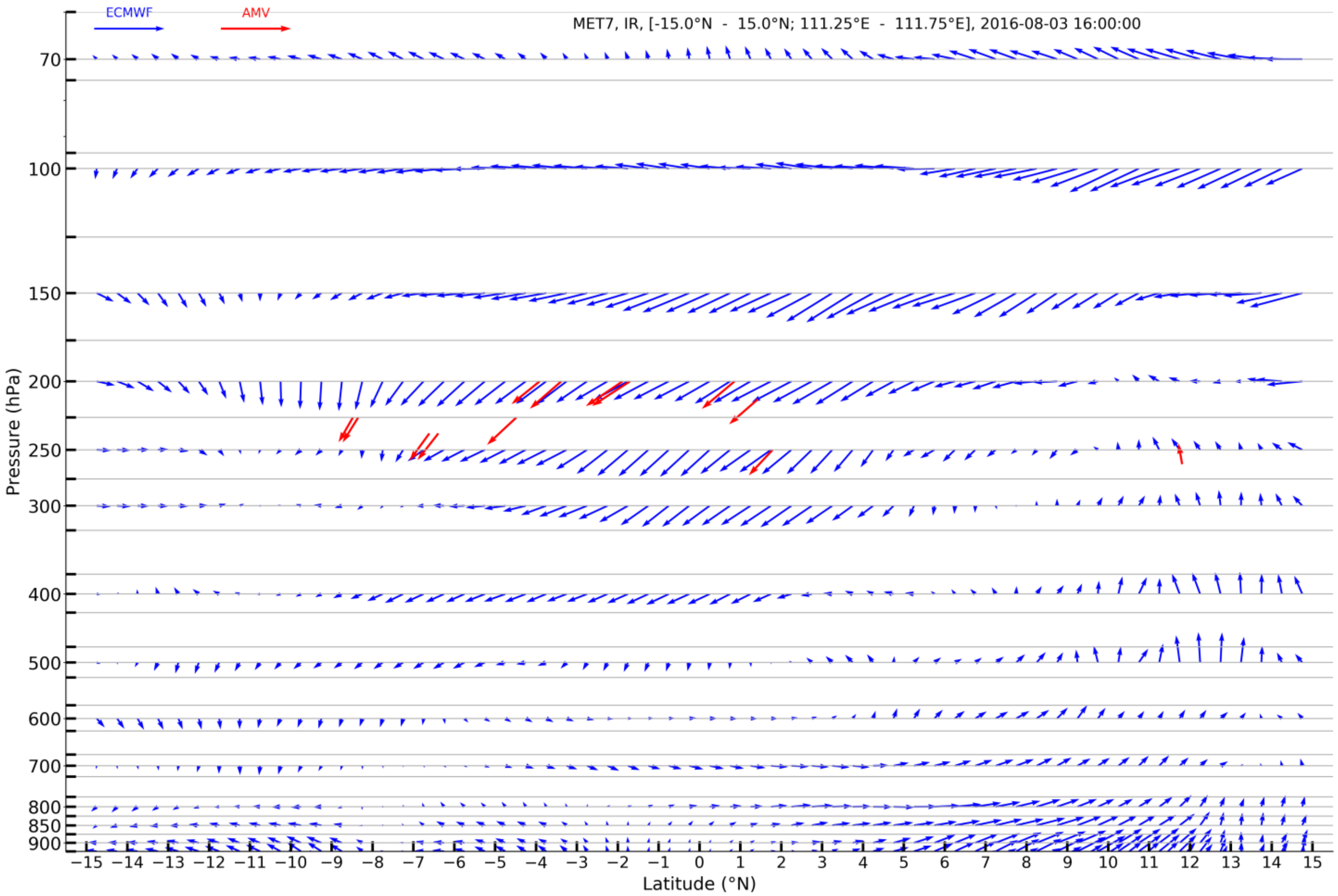
THALES

North-south transects. CIMSS Meteosat-7, IR channel



- Not exactly same region and time as Metop
- But AMV wind field appears much better in agreement with ECMWF

What causes the disagreement between Metop and ECMWF in tropics?

Horvath et al., 2017

TABLE 1. Characteristics of the wind datasets.

Dataset	Label	Nadir pixel size (km)	Target box size (km^2)	Image frequency (min)	No. of images/total tracking time (min)
GOES-15 CIMSS	G15c	4	60 × 60	15–30	3/30–60
GOES-13 CIMSS	G13c	4	60 × 60	15–30	3/30–60
Meteosat-10 CIMSS	M10c	3	60 × 60	15	3/30
Meteosat-10 EUMETSAT	M10e	3	72 × 72	15	4/45
Meteosat-7 CIMSS	M7c	5	60 × 60	30	3/60
Meteosat-7 EUMETSAT	M7e	5	160 × 160	30	3/60
MTSAT-2 CIMSS	MT2c	4	60 × 60	15	3/30
MTSAT-2 JMA	MT2j	4	64 × 64	15	3/30
Himawari-8 JMA	HI8j	2	34 × 34	10	3/20
MODIS *Terra* CIMSS	MDTc	2[a]	26 × 26	~100	3/~200
MISR	MISR	0.275	17.6 × 17.6	1.5–2.0	5/7
Global AVHRR EUMETSAT	MetOp	1	30 × 30	~50	2/~50
Raob IGRA	Raob	—	—	—	—
ERA-Interim	ERAI	—	—	—	—

[a] Remapped from 1 km.

CIMSS uses a smaller target box of 12 x 12 pixels than Metop (30 x 30 pixels) and the temporal gap is approximately 20 min smaller compared to AVHRR images (50 min)

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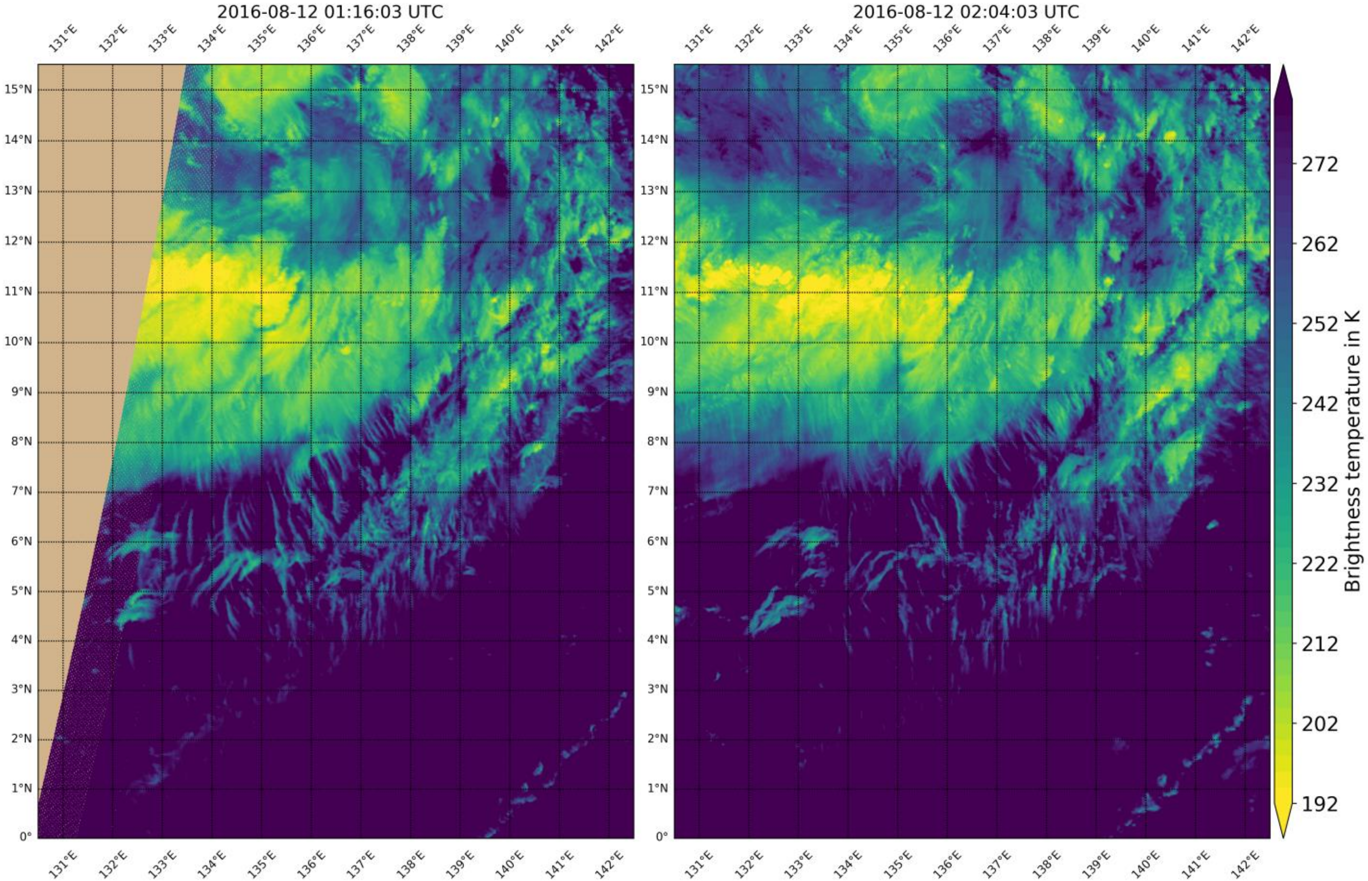
A look at the 2 images used two derive AMVs – morning overpass



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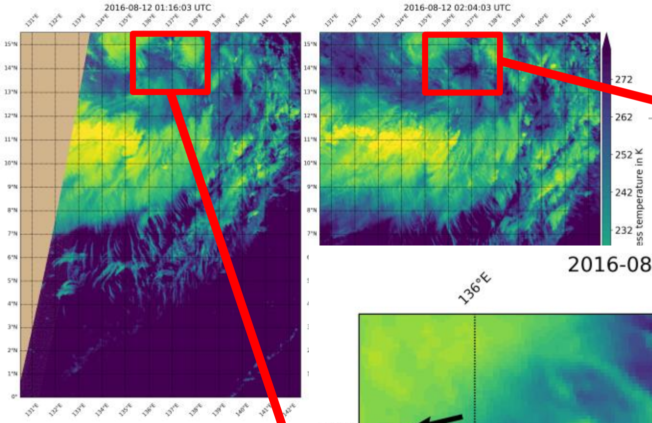
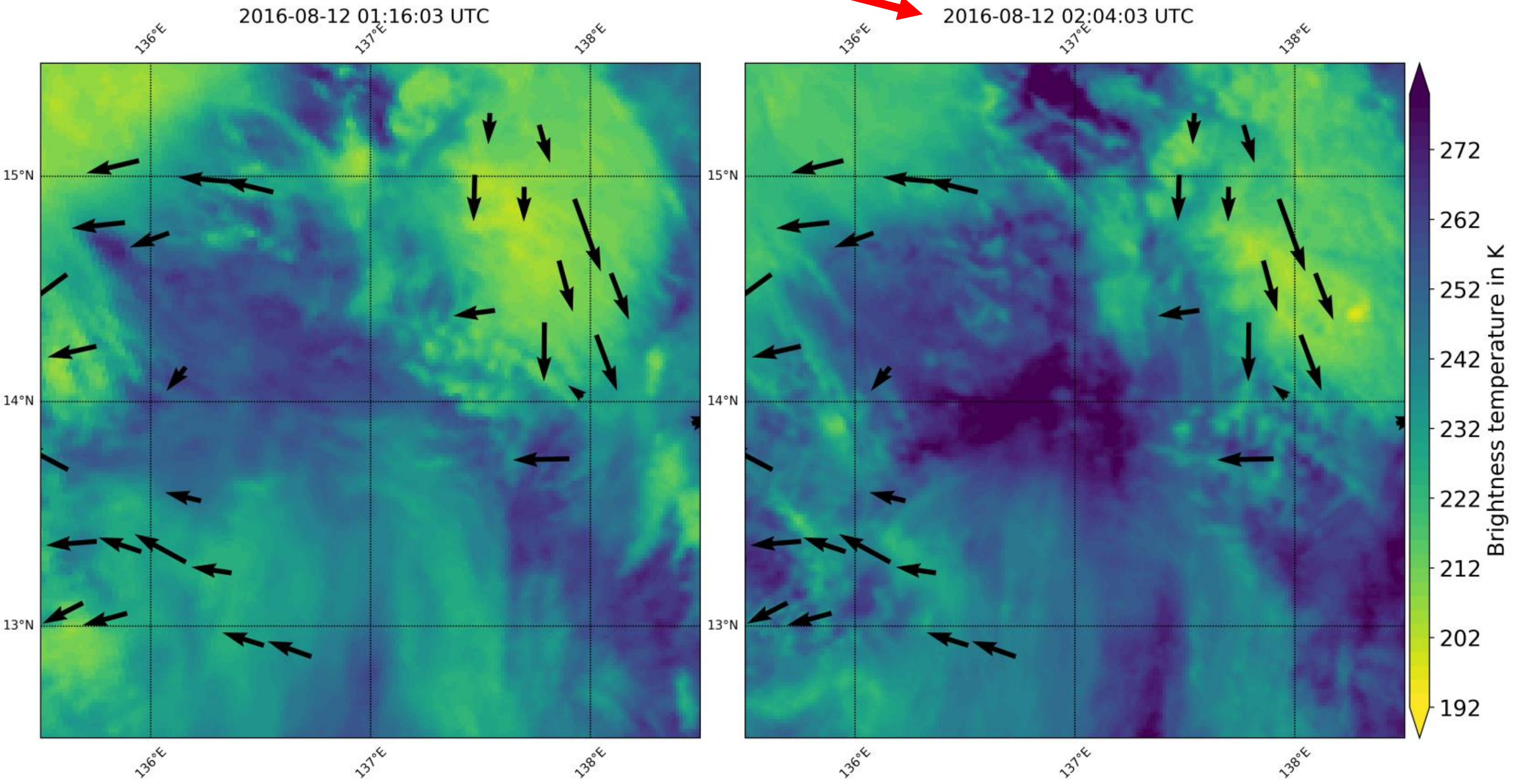
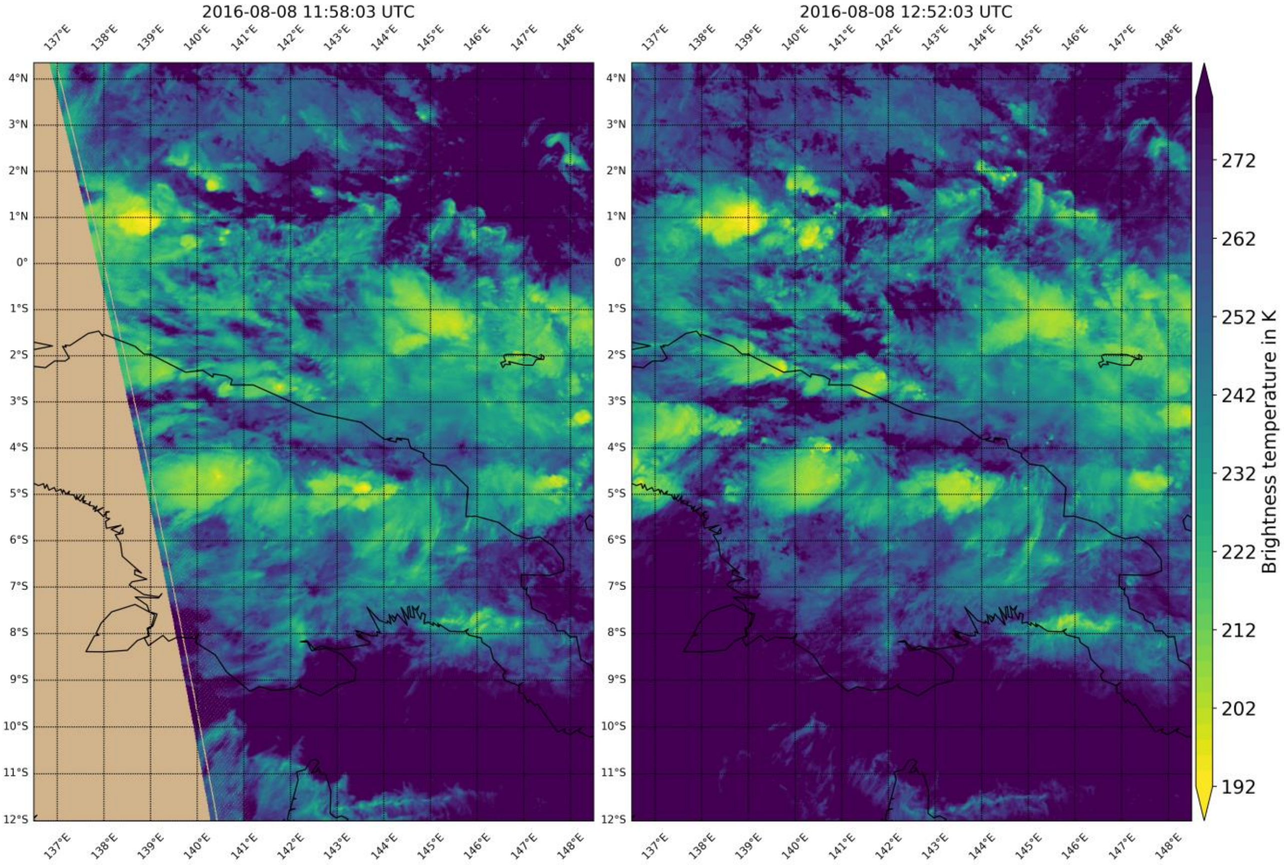
Zoom into region of large wind speed & direction differences





A look at the 2 images used two derive AMVs – evening overpass



- **How much correlation is between the two images taken ~50 minutes apart?**
- As strong convection alters the shape of clouds, the feature to be tracked is difficult to relate accurately between two AVHRR images

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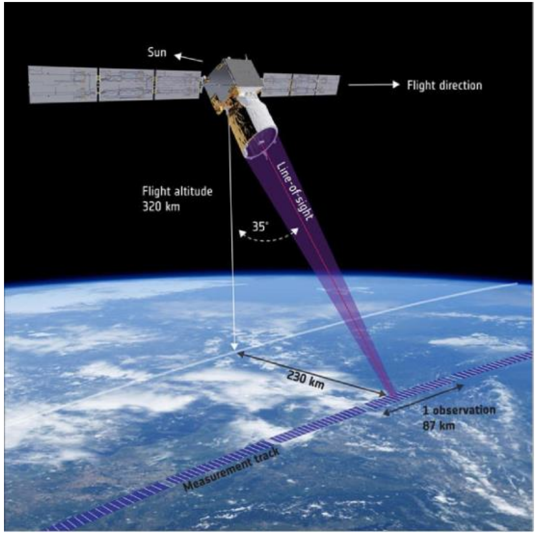
Thales Services / Modèle : 87211168-GRP-FR-004

AMV performance against ADM-Aeolus

- ADM-Aeolus data availability: 1 October 2019 – 19 November 2019
- AMVs derived by EUMETSAT from Meteosat-11 and Meteosat-8 images are used
- No comparison to Dual-Metop due to different equator crossing times (6:00 vs 9:30)
- ALADIN instrument is designed to probe the lowermost 30 km of the atmosphere by its molecular (Rayleigh) and particle (Mie) channels to provide profiles of wind, aerosols and clouds along the satellite's orbital path.
- The wind information of ADM-Aelous is the horizontal line-of-sight (HLOS) component, i.e. the wind component in the direction perpendicular to the satellite's velocity.
- Use corrected L2B data
- ECMWF geopotential heights are used to convert ADM-Aeolus heights to pressure



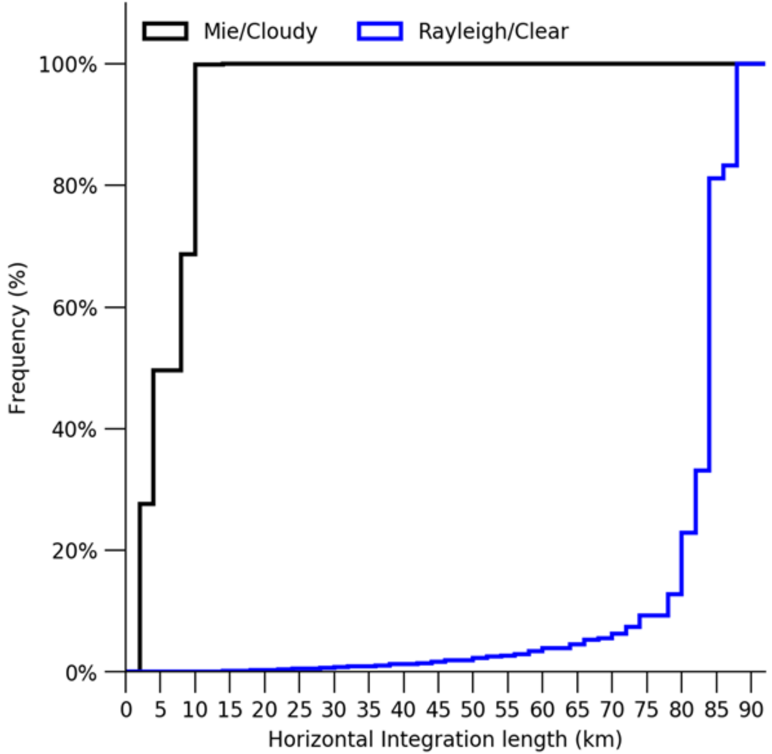
Aeolus data screening

Criteria regarding height	The height difference between the Top and the Bottom observation level shall be greater than 300 m.
	The height above the surface shall be greater than 250 m
Validity of HLOS winds	Only valid winds are considered, i.e. the field confidence flag must be 0 in the bufr file.
Quality of HLOS winds	For the Mie-channel and data classified as cloud, only data where the error is < 5 m/s are considered. Likewise, for the Rayleigh channel and data classified as clear sky, for pressure < 200 hPa only data with an error < 12 m/s are considered. For pressure ≥ 200 hPa, only data with an error < 8.5 m/s are considered.

AMV data screening

As in the previous analysis QI > 80 for AMVs from geostationary satellite imagery

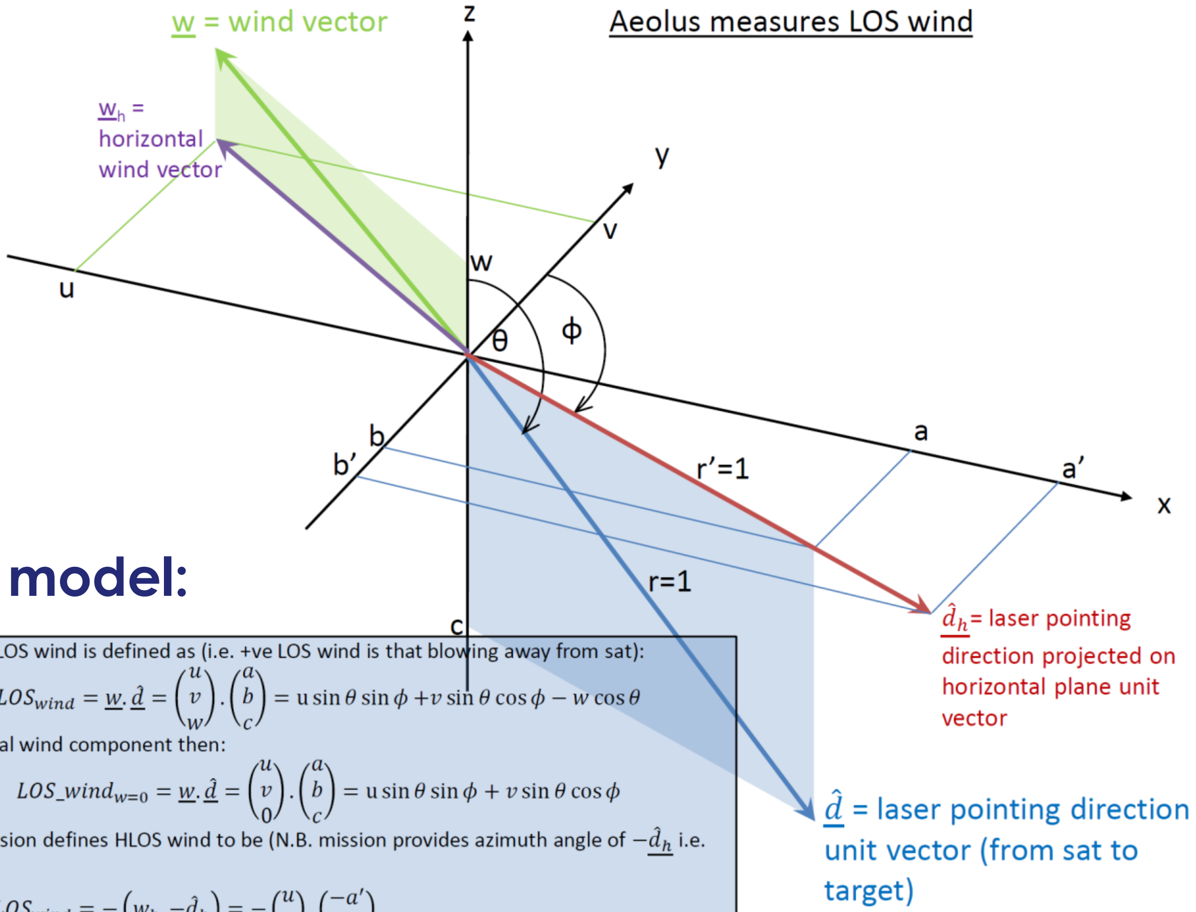
Aeolus data screening - continued



Cumulative frequency of horizontal integration length for Mie and Rayleigh channel in October 2019 in the tropics (35°S < latitude < 35°N).

- The Level-2B HLOS winds are averaged over a certain length-scale
- In order to be able to use at least 50% of the data, we chose a minimum integration length of 80 km for the Rayleigh/clear case and 10 km for the Mie/cloudy case.

Aeolus measures LOS wind



HLOS forward model:

Complete LOS wind is defined as (i.e. +ve LOS wind is that blowing away from sat):

$$LOS_{wind} = \underline{w}.\underline{d} = \begin{pmatrix} u \\ v \\ w \end{pmatrix}.\begin{pmatrix} a \\ b \\ c \end{pmatrix} = u \sin\theta \sin\phi + v \sin\theta \cos\phi - w \cos\theta$$

If no vertical wind component then:

$$LOS\_wind_{w=0} = \underline{w}.\underline{\hat{d}} = \begin{pmatrix} u \\ v \\ 0 \end{pmatrix}.\begin{pmatrix} a \\ b \\ c \end{pmatrix} = u \sin\theta \sin\phi + v \sin\theta \cos\phi$$

Aeolus mission defines HLOS wind to be (N.B. mission provides azimuth angle of $-\underline{\hat{d}_h}$ i.e. φ'):

$$HLOS_{wind} = -\left(\underline{w_h}.-\underline{\hat{d}_h}\right) = -\begin{pmatrix} u \\ v \end{pmatrix}.\begin{pmatrix} -a' \\ -b' \end{pmatrix}$$

$$= -u \sin(\phi + \pi) - v \cos(\phi + \pi) = -u \sin\phi' - v \cos\phi' = \frac{LOS\_wind_{w=0}}{\sin\theta}$$

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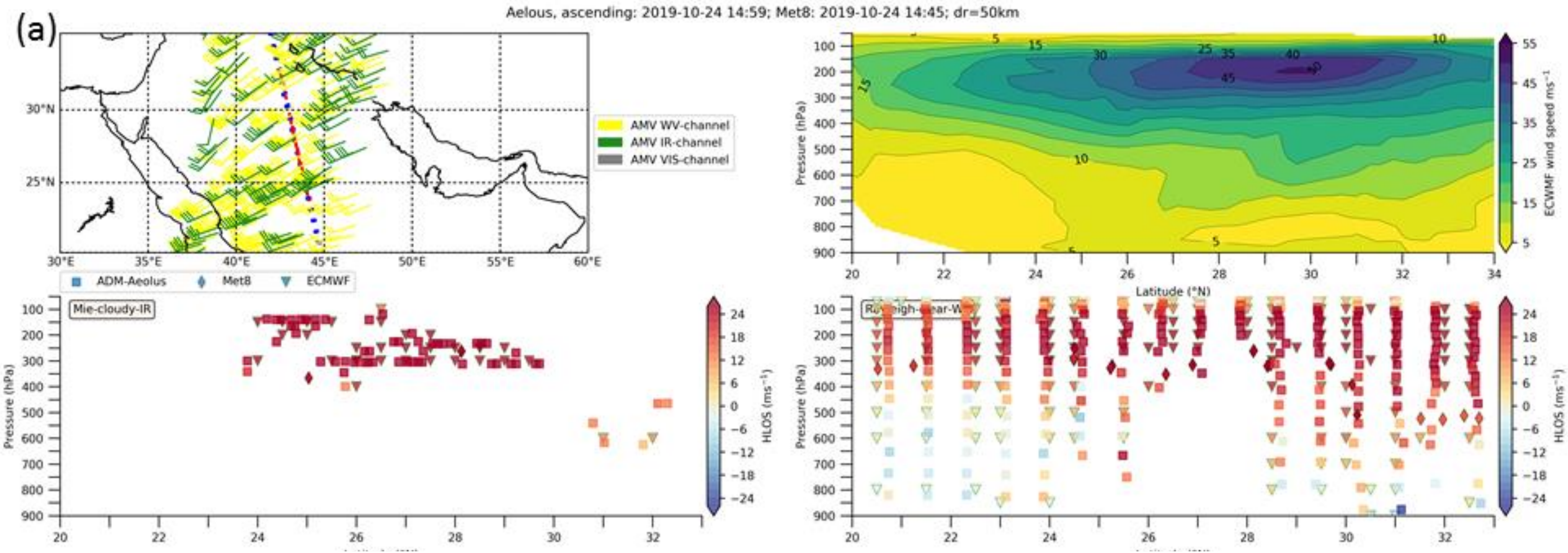
Collocation criteria

- For the comparison of AMVs to ECMWF winds and reference observations a temporal separation of maximal 1.5 hours was allowed
- AMVs are extracted approximately every 15 minutes from images by geostationary Meteosat satellites, a much tighter temporal collocation criterion can be used to compare HLOS winds



Altitudes to which IR AMVs are set agree mostly better than 25 hPa of the altitude of collocated AMD-Aelous winds

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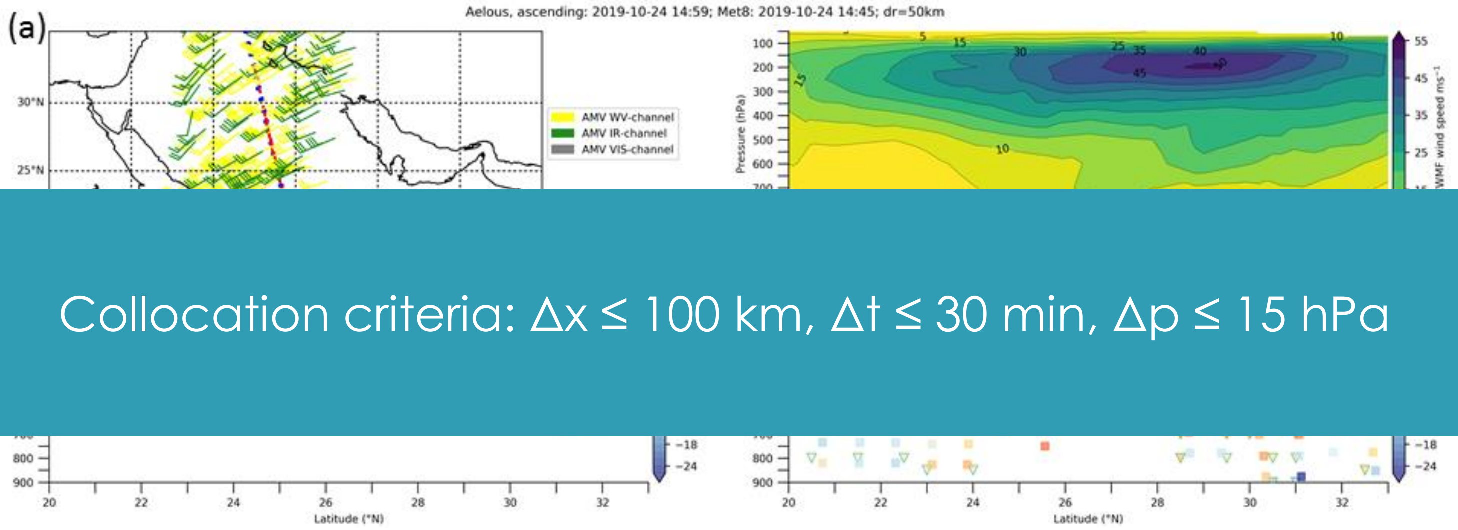
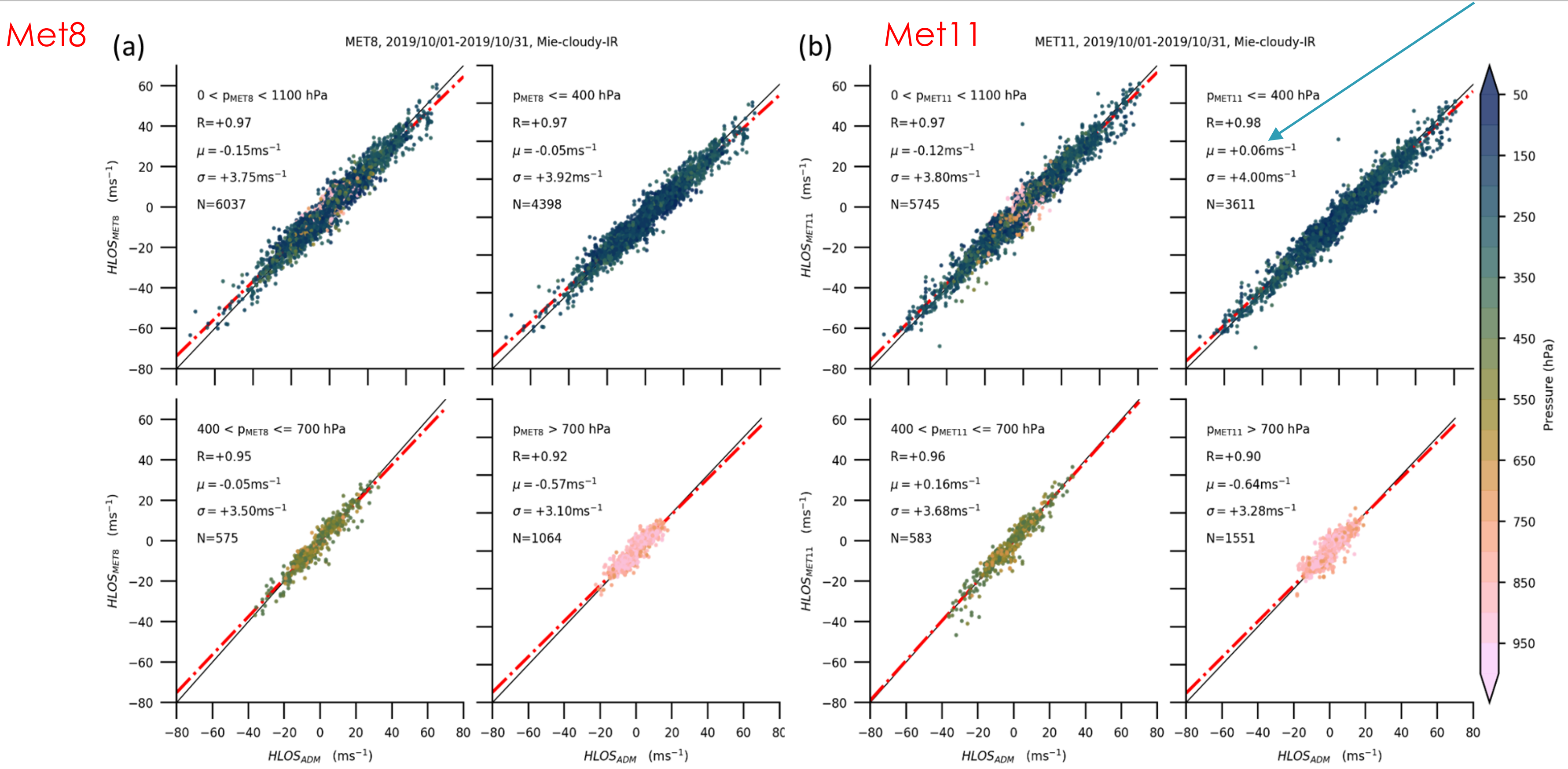


Collocation criteria: $\Delta x \leq 100$ km, $\Delta t \leq 30$ min, $\Delta p \leq 15$ hPa

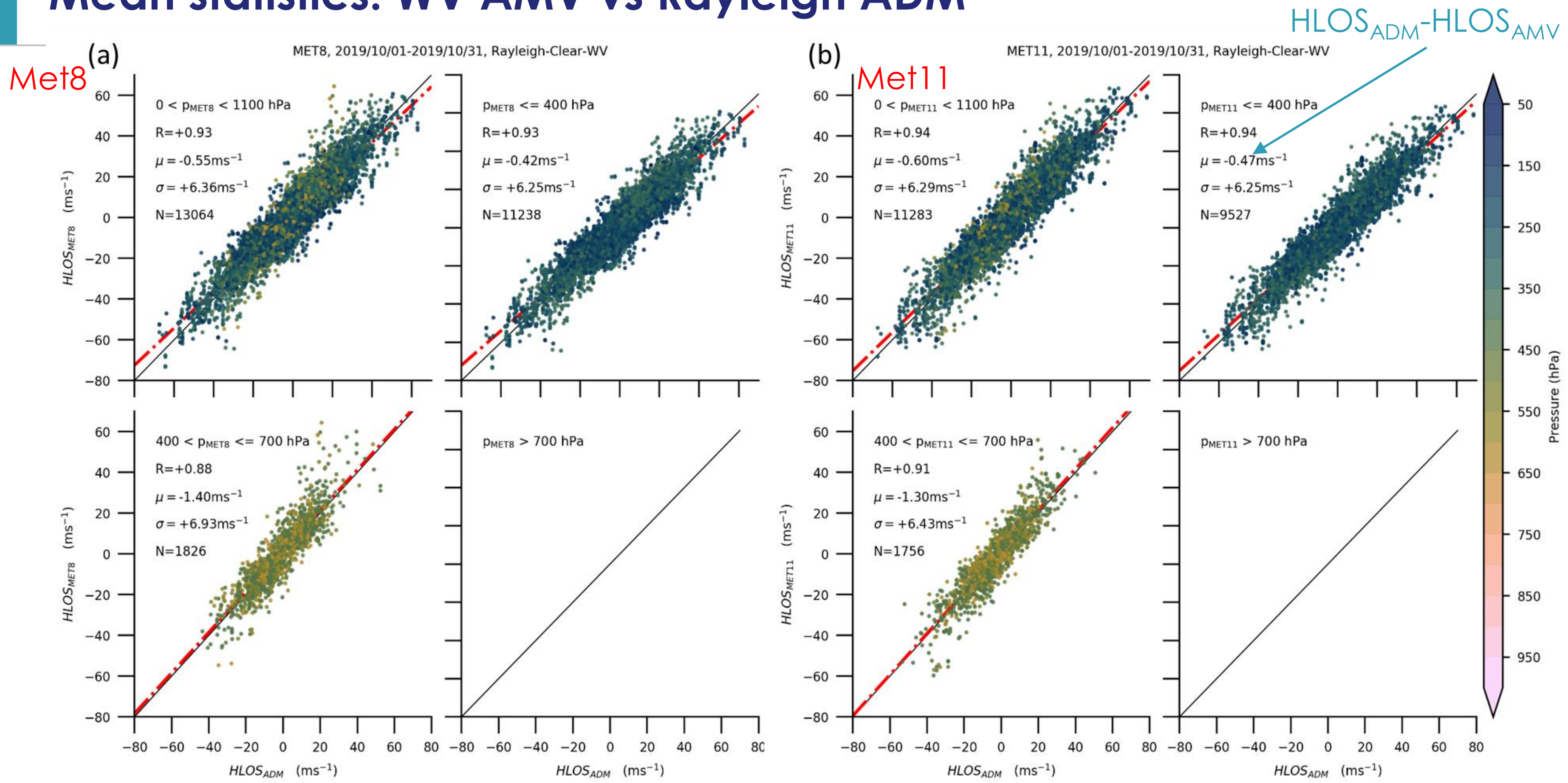
Altitudes to which IR AMVs are set agree mostly better than 25 hPa of the altitude of collocated AMD-Aelous winds

Mean statistics: IR AMV vs Mie ADM

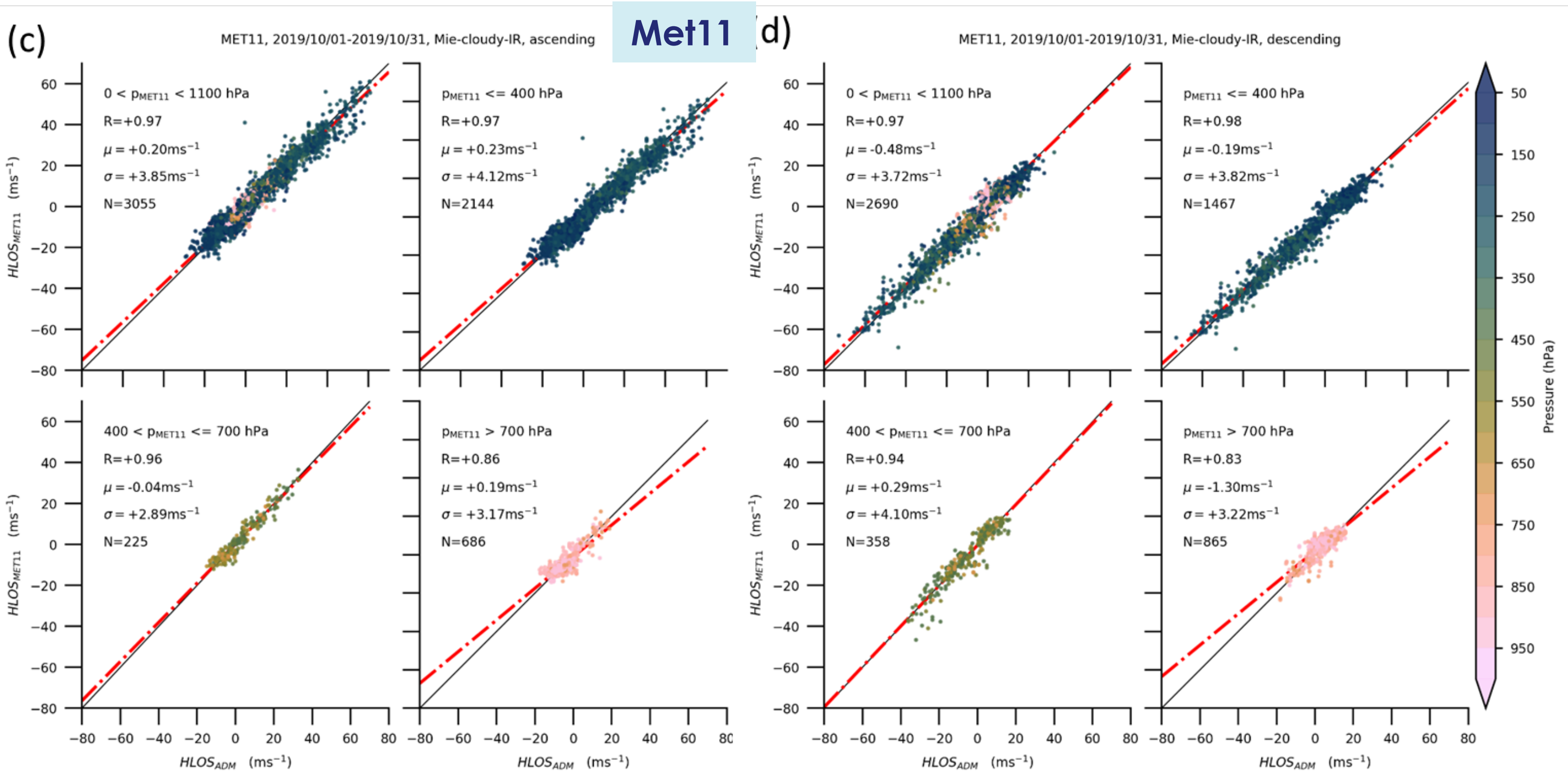
$HLOS_{ADM}$-$HLOS_{AMV}$



Mean statistics: WV AMV vs Rayleigh ADM



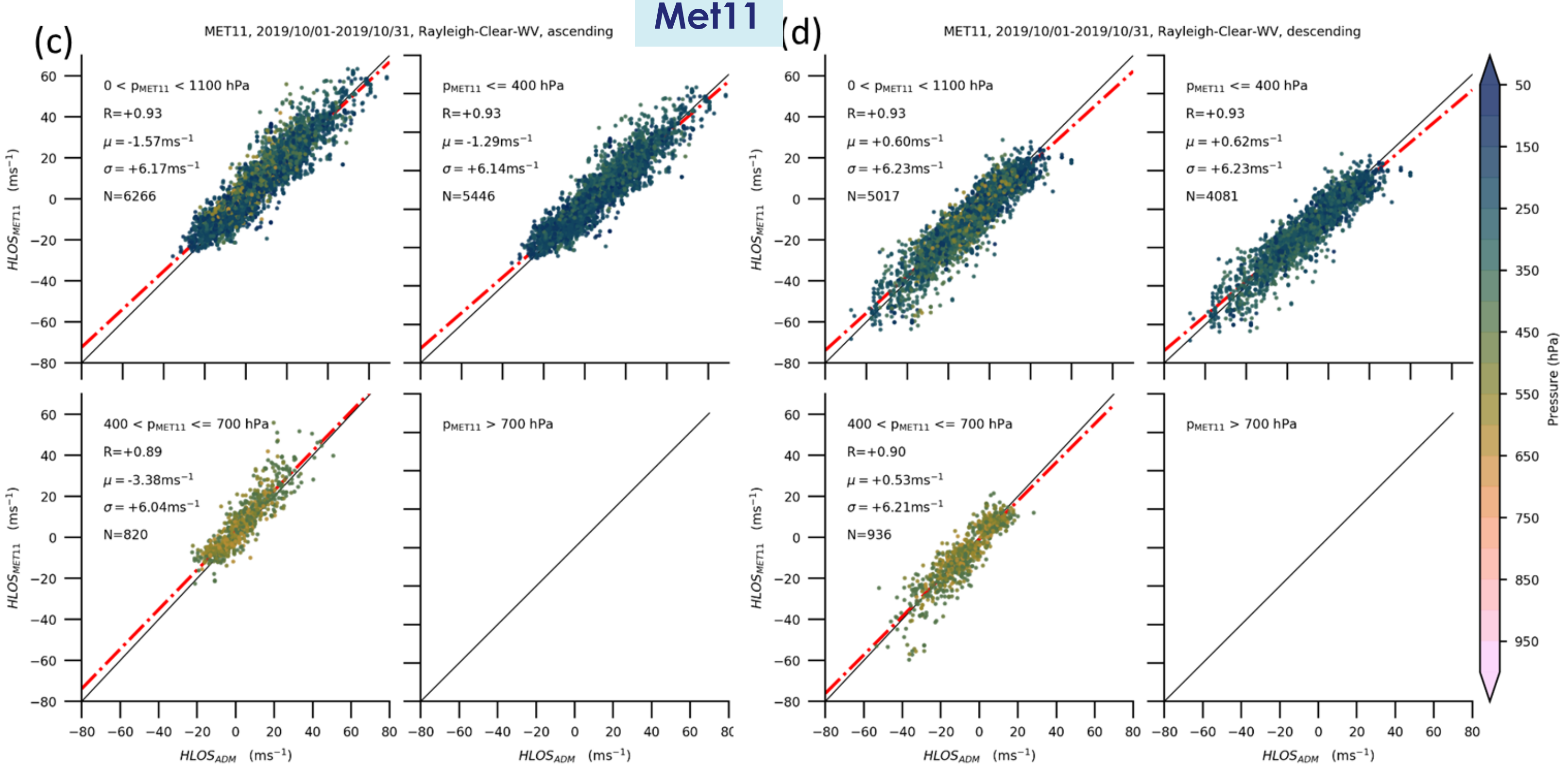
Ascending vs descending Aeolus orbit – Mie channel



IR/Mie case: Little differences in mean statistics between ascending and descending orbit

Ascending vs descending Aeolus orbit – Rayleigh channel

Met11



WV/Rayleigh case: Better agreement between Met11 & ADM for descending orbit!

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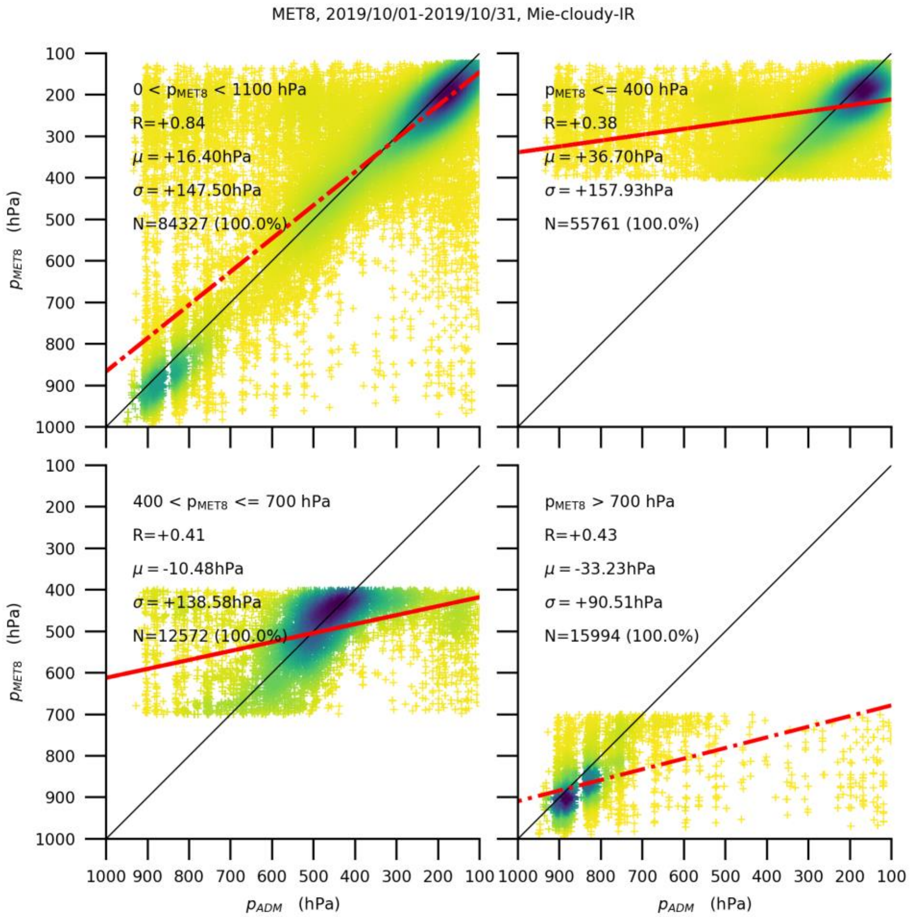
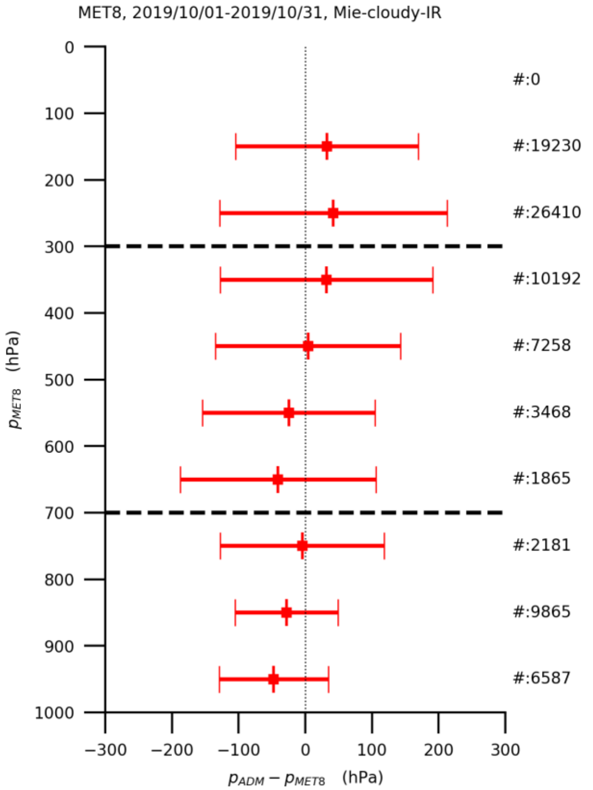
Best-fit pressure statistics – Mie/cloudy v Met-8 IR AMV





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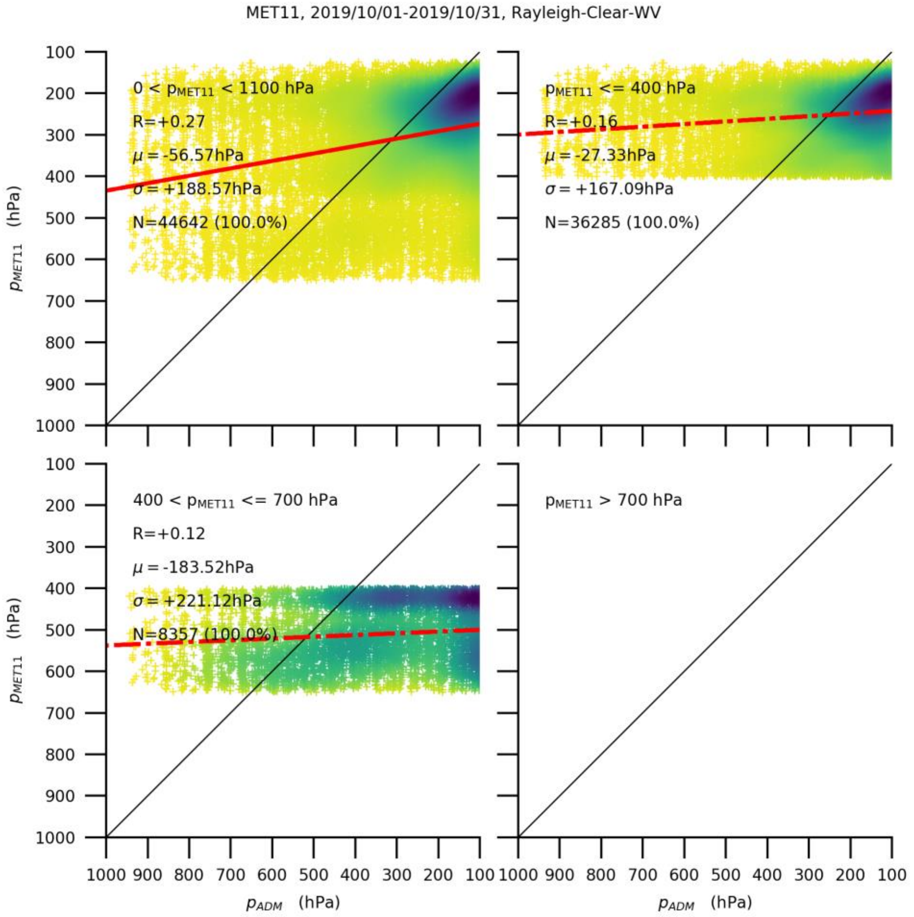
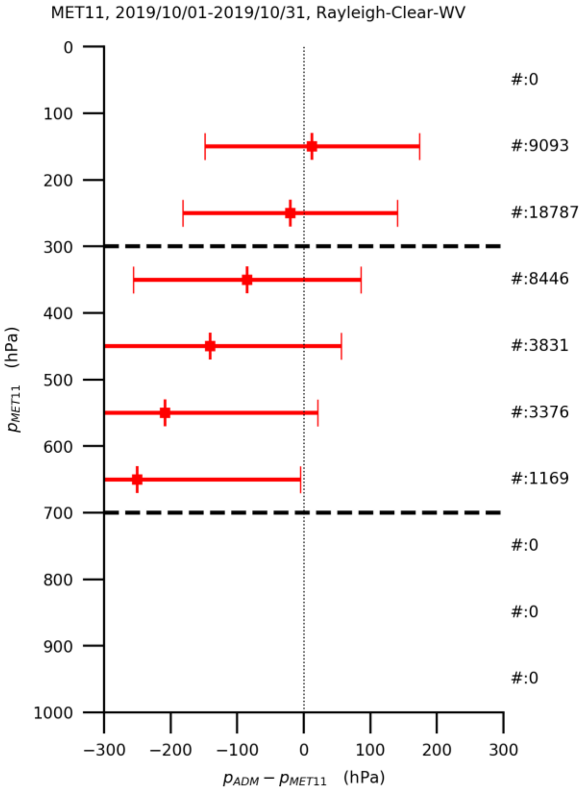
Best-fit pressure statistics – Rayleigh/clear v Met-11 WV AMV





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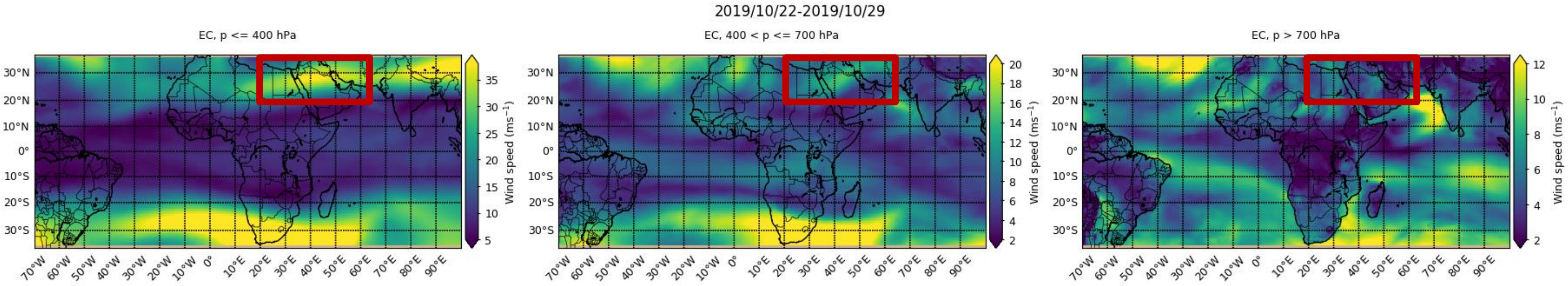
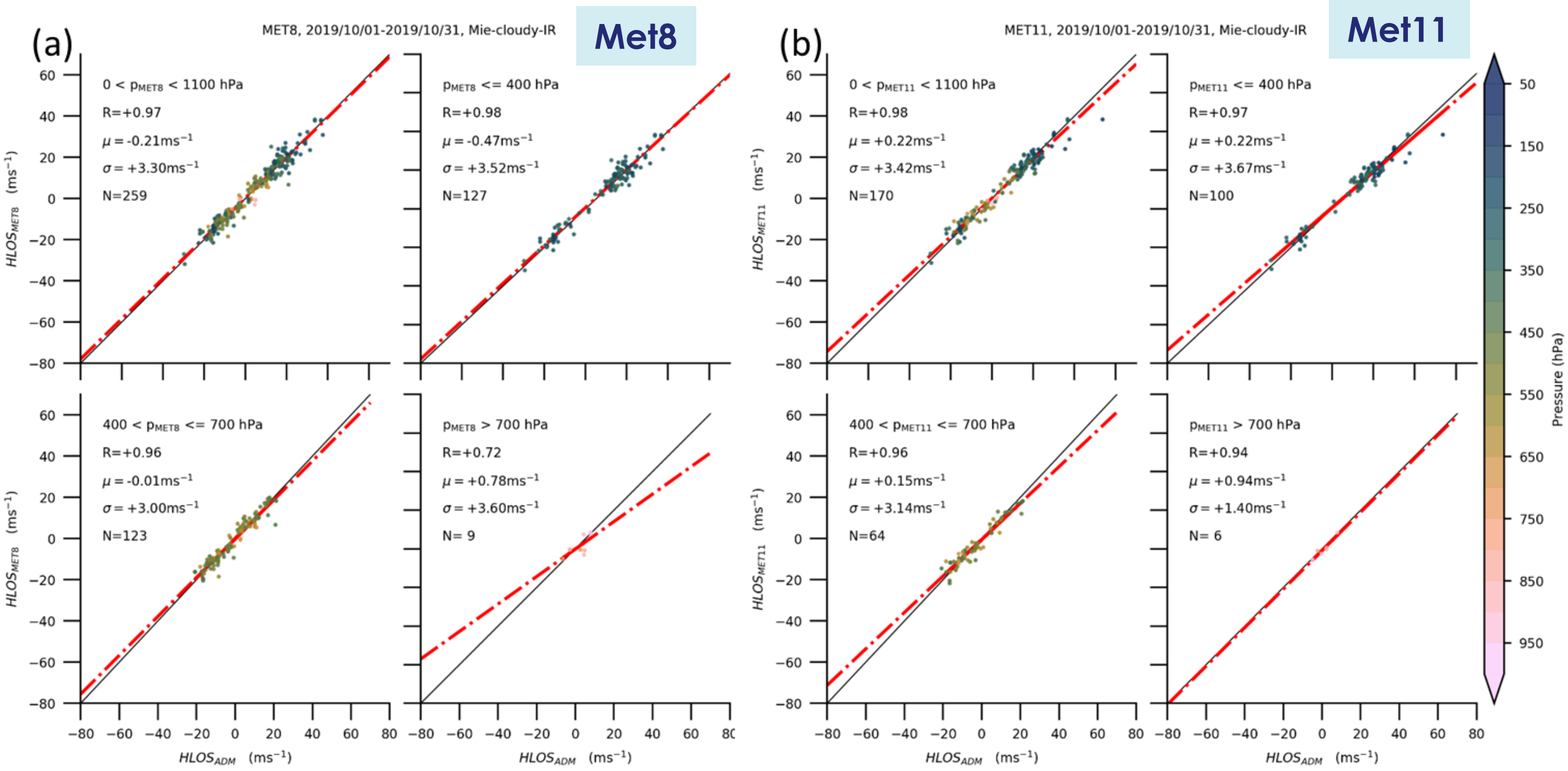
Case 1 - Winds over Arabian peninsula in October 2019

- Seen earlier, that AMVs derived over the Saharan desert and during jet situations are frequently assigned to erroneous (too low) altitudes, leading to a positive monthly O-B speed bias against ECMW winds



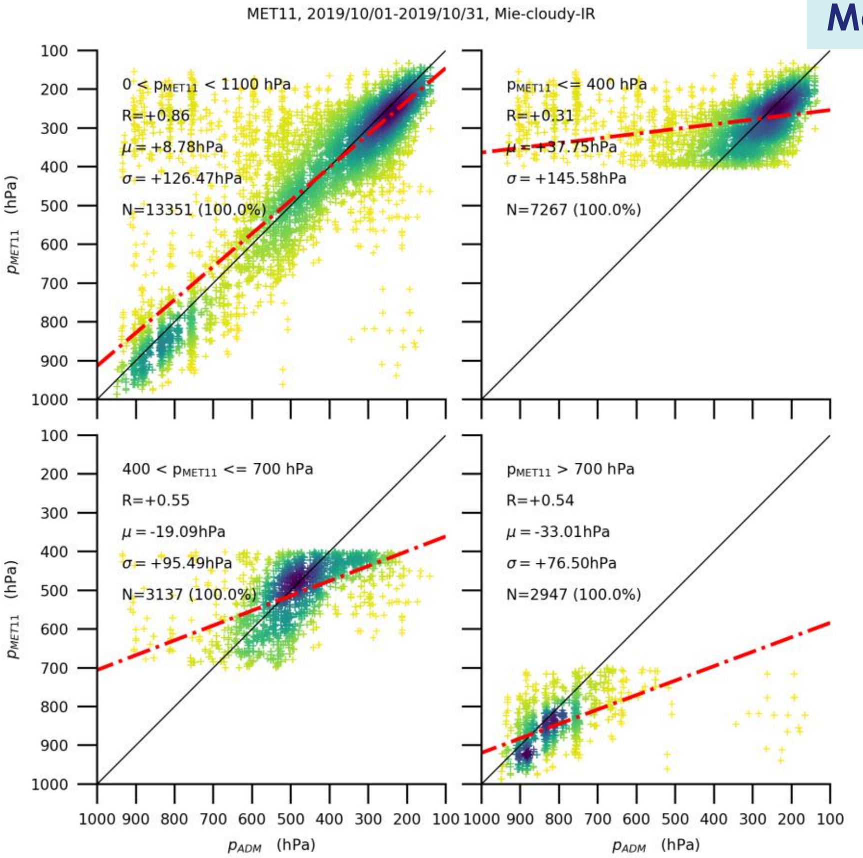
High-, mid-, and low-level winds from ECMWF, averaged over the period 22 October 2019 to 29 October 2019.

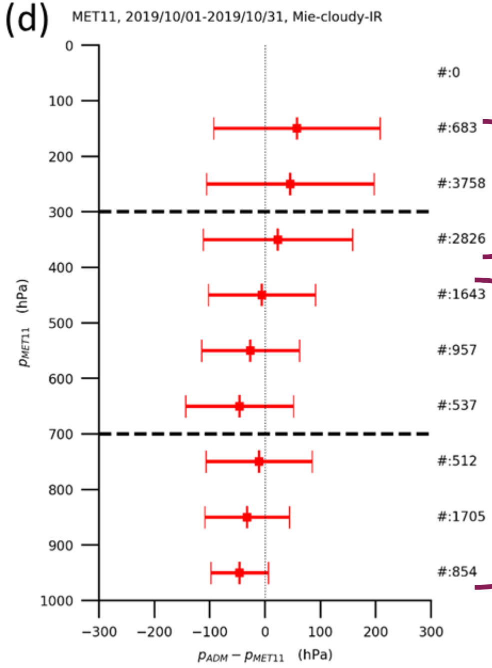
IR AMV vs ADM-Aeolous – Mie channel



Best fit pressure statistics – IR AMV/Mie channel ADM-Aeolus

Met11



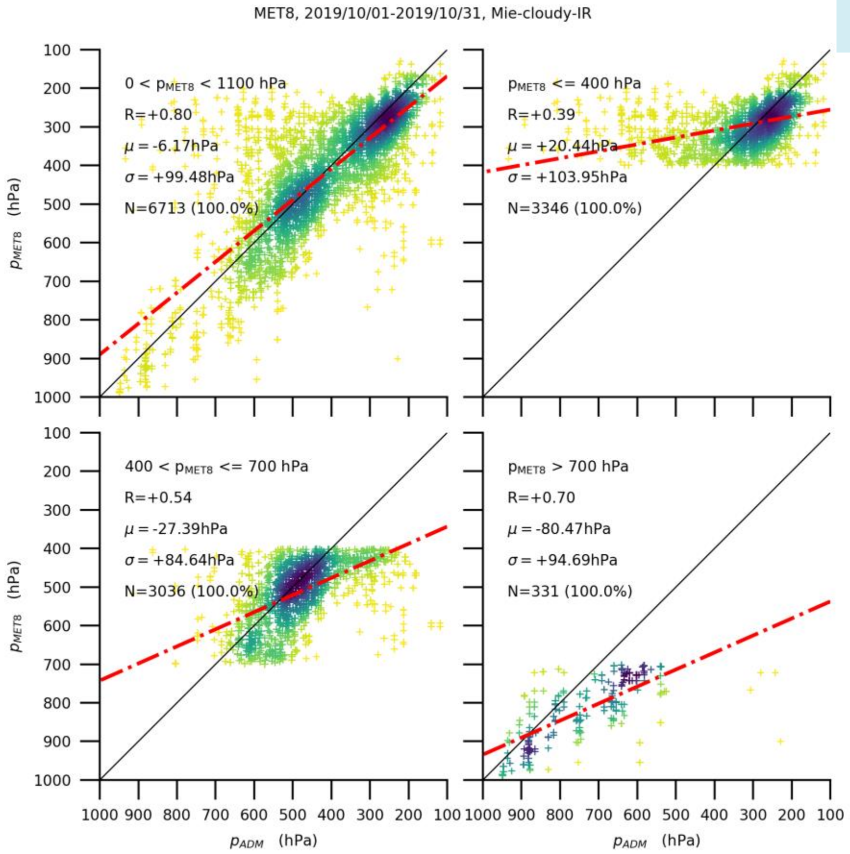


$p_{ADM} > p_{AMV}$: tendency that high-level AMVs are assigned to too high altitudes

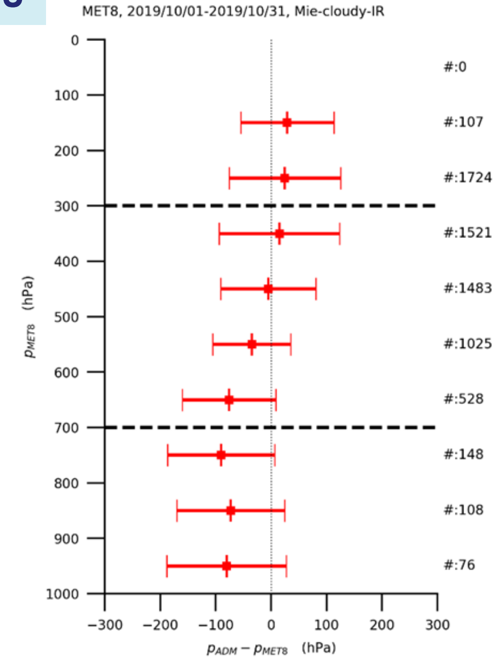
$p_{AMV} > p_{ADM}$: tendency that AMVs are assigned to too low altitudes

THALES

Best fit pressure statistics – IR AMV/Mie channel ADM-Aeolus



Met8



$p_{ADM} > p_{AMV}$: tendency that high-level AMVs are assigned to too high altitudes

$p_{AMV} > p_{ADM}$: tendency that AMVs are assigned to too low altitudes

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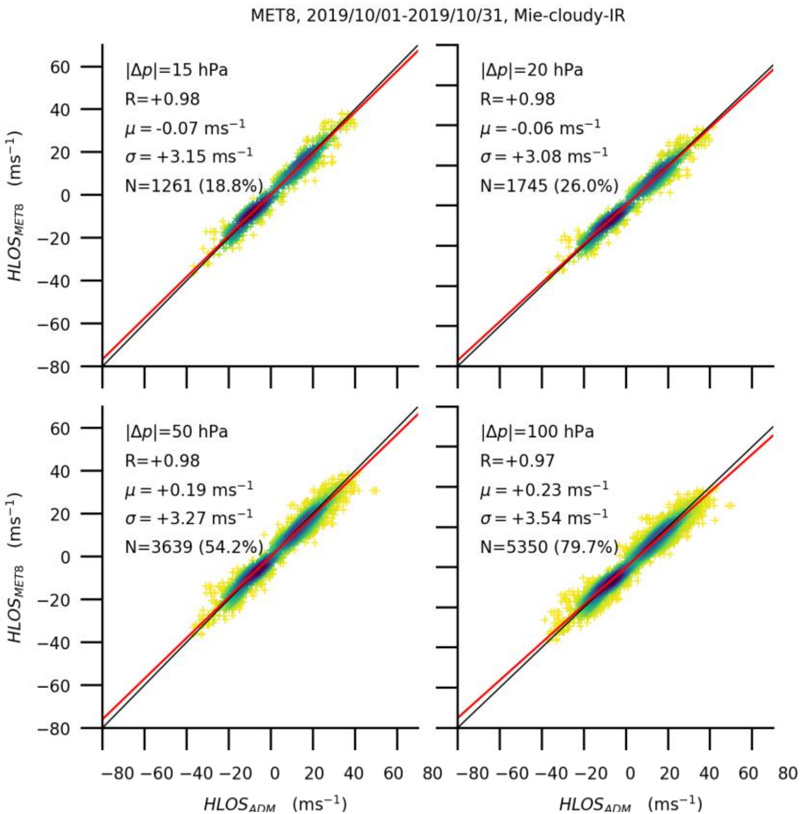
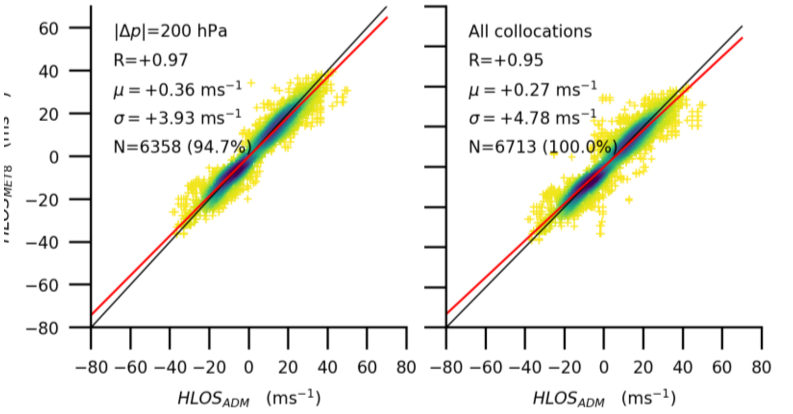
Most collocations are within 50 to 100 hPa

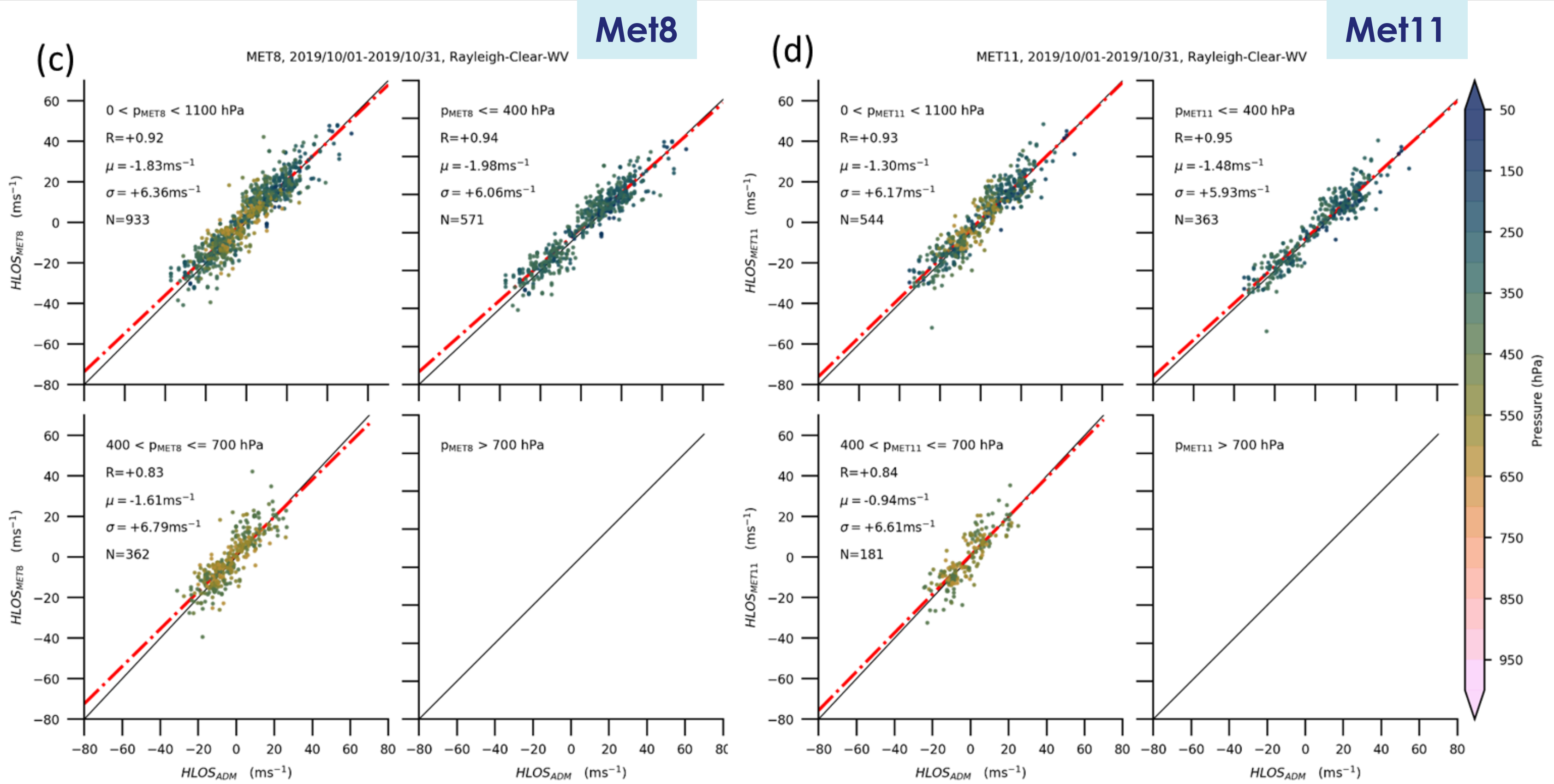


- About 50% of collocations within 50 hPa
- About 80% of collocations within 100 hPa

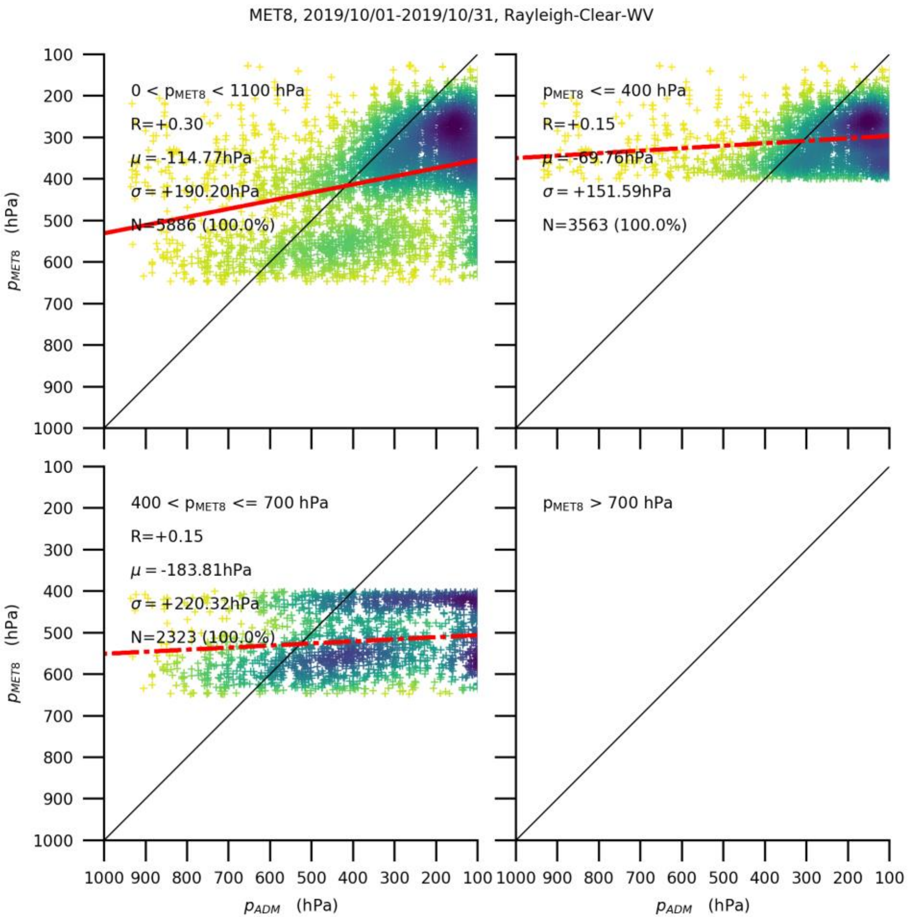


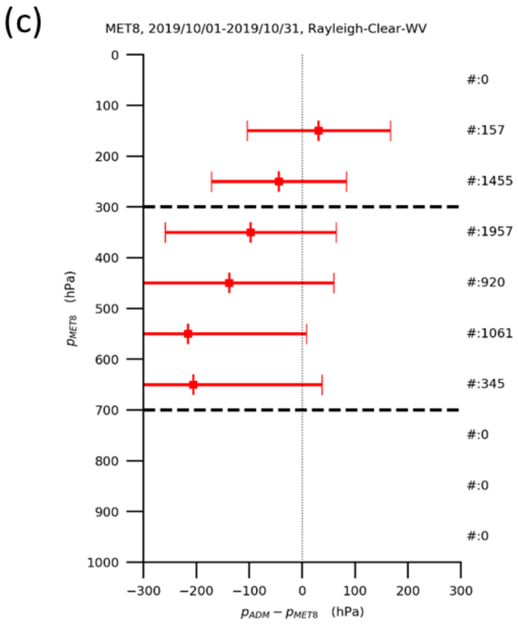
HLOS winds from Mie/cloudy ADM-Aeolus against HLOS winds derived from Meteosat-8 IR AMVs over the Arabian Peninsula in October 2019. AMVs were searched for a collocated wind profile of ADM-Aeolus and the element of this wind profile that minimizes the HLOS difference to the AMV within an allowed pressure difference Δp is plotted against the HLOS AMV.

WV AMV vs ADM-Aeolous – Rayleigh channel



Best fit pressure statistics – WV AMV/Rayleigh channel ADM-Aeolus



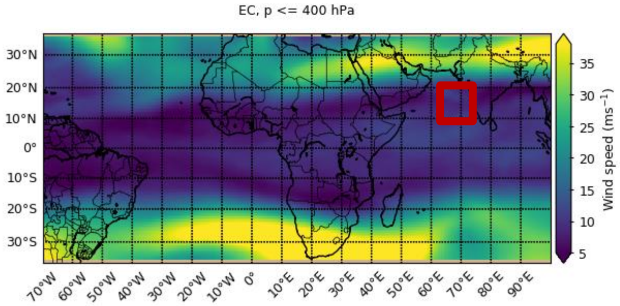


Larger variability in best fit pressure compared to IR AMVs

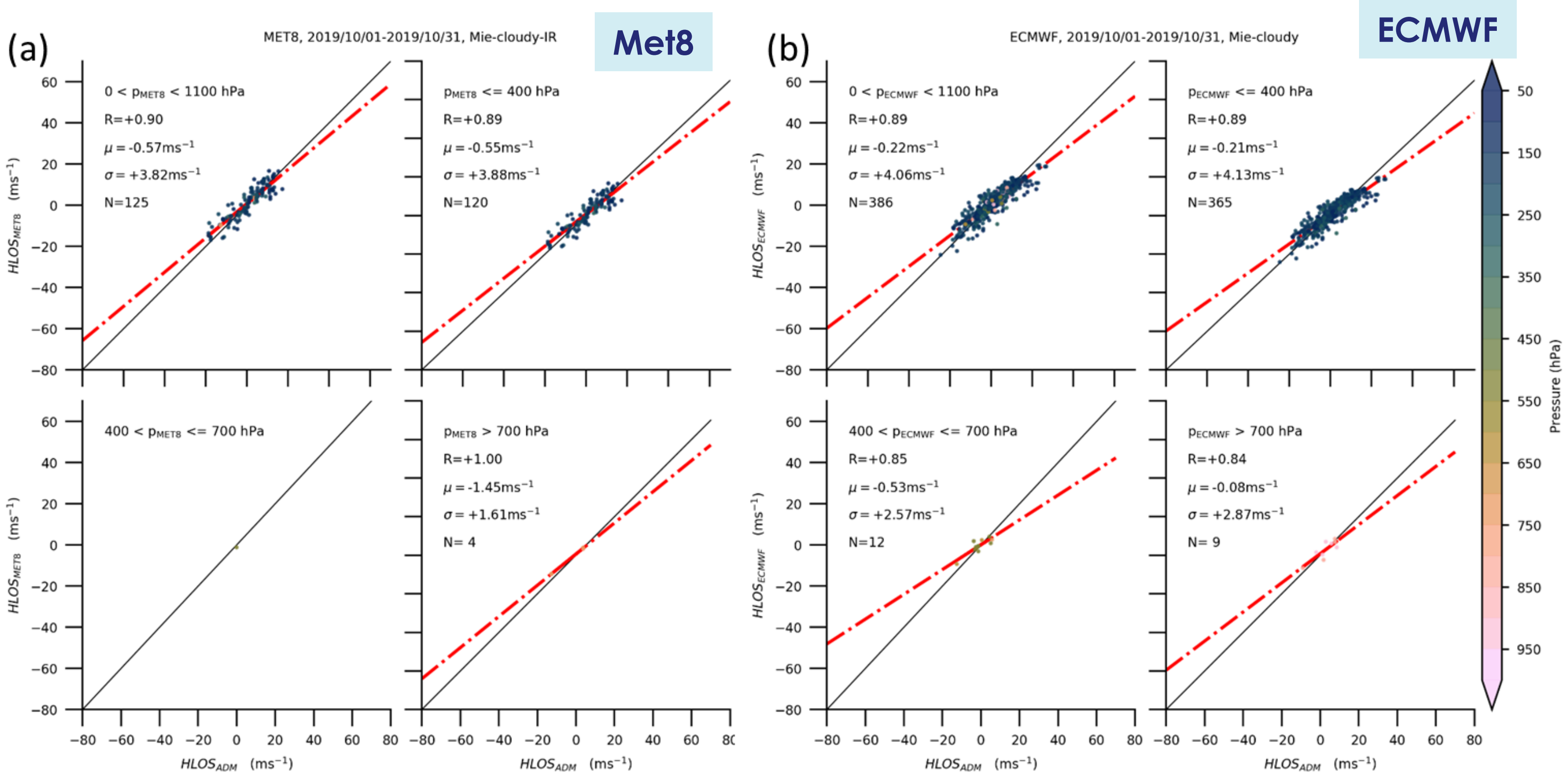
Case 2 - Winds over Indian Ocean

October-November 2019

region extends from 10°N to 20°N and from 65°E to 75°E



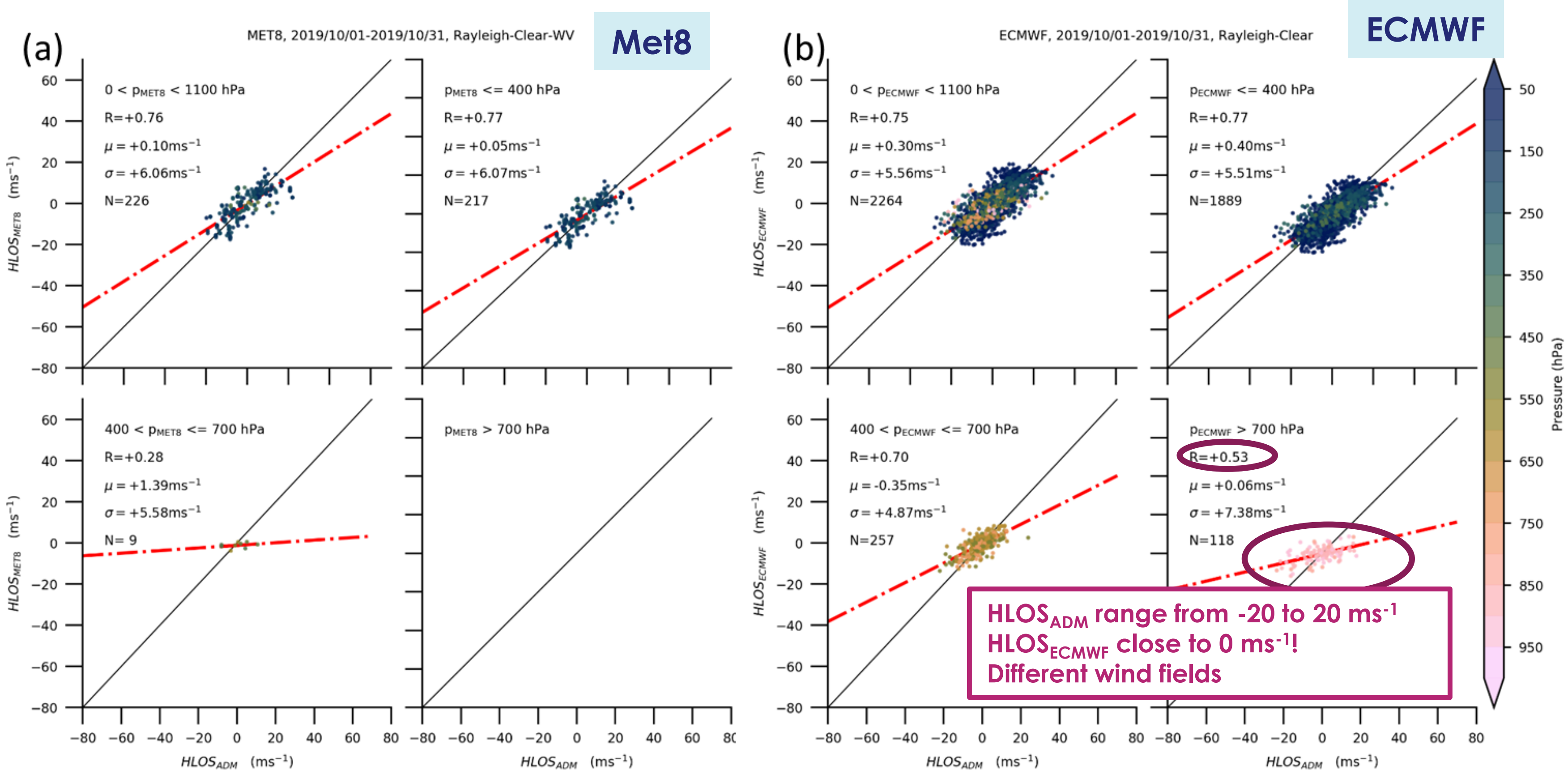
IR AMV/ECMWF against Mie ADM-Aeolus



WV AMV/ECMWF against Rayleigh ADM-Aeolus

Met8

ECMWF



HLOS$_{ADM}$ range from -20 to 20 ms^{-1}
HLOS$_{ECMWF}$ close to 0 ms^{-1}!
Different wind fields

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Summary & Conclusions - Mean statistics I

- **AMV performance against ECMWF forecast winds:**
  - **A different pattern of O-B speed bias was found for Metop and Meteosat-10 IR AMVs**
  - **Met10:** obtained speed bias was typically smaller than 2 ms^{-1}, while differences larger than 3 ms^{-1} were commonly found over desertic areas, particularly if large wind speeds occur (subtropical jets).
  - **Dual-Metop AMVs** report 3-5 ms^{-1} faster winds than ECMWF for the low wind speed regions around the equator and 3-5 ms^{-1} slower winds than ECMWF for regions north of 15°N and south of 15°S, with some dependency of the bias on altitude.
- **AMV performance against MISR stereo-winds**:
  - **Met10**: For low-level to mid-level winds, Met10EUM obtains < 1 ms^{-1} slower winds than MISR. A higher bias was obtained for high-level
  - **Metop** winds are typically faster than MISR winds. Between 200 and 400 hPa, Metop winds are 0.5-2 ms-1 faster than MISR winds. For p < 200 hPa, wind speeds differences are typically larger.

Summary & Conclusions - Mean statistics II

- **AMV performance against RAOB radiosondes (not show):**
  - **RAOB data are few and distributed very uneven in time and space** and only matches with Metop AMVs were found. Between surface and 600 hPa RAOB winds are 2 ms^{-1} faster than Metop, while above 600 hPa ($p < 600$ hPa) Metop winds are faster than RAOB, up to 5 ms^{-1}.
- **Impact of diurnal cycle of convection and convection parameters**:
  - Comparison of observed O-B speed biases to the diurnal cycle of convection or to quantities describing strength and type of convection such **OLR, CLOUDSAT cloud type classification or stability indices revealed no clear dependency of the monthly O-B speed bias to these parameters.**
- **CALIPSO/CALIOP cloud top height**:
  - Due to their different orbits, CALIPSO/CALIOP could not be compared to **Metop** AMVs.
  - **Met10**: Difference between collocated AMV pressure and CALIPSO cloud top height is > 0 hPa throughout the atmospheric, which in turn means that AMVs tend to have assigned too low altitudes. On average, pressure differences are largest at 300 and 400 hPa. The latter altitude is also the altitude of largest O-B speed bias of up to 2 ms^{-1}.

Summary & Conclusions – case studies I

Met10 AMV IR performance over Saharan desert and subtropical jet

- Between 400-500 hPa, altitudes assigned too low lead in conjunction with vertical wind shear and generally fast winds to AMVs being frequently 4-6 ms^{-1} faster than ECMWF (semivariogrrams, calypso cloud top heights)
- @300 hPa: Semivariances indicate different pattern of wind fields. Location of jet different?
- **Outlook**: Can **OCA** cloud top heights alleviate the problem of having too low altitudes assigned to AMVs in such conditions (desert, fast wind speeds and large wind shear).
- General issue in CTH retrievals over the Sahara (Kealy et al., 2017): often a large portion of clouds have a horizontal extent smaller than the 3 km wide SEVIRI pixels. Consequently, in such cases the contribution from the warm desert surface lead to too warm cloud tops.

REF AMV-PRE-0011-TS – 18/06/2020
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Summary & Conclusions – case studies II

Dual-Metop AMV IR performance over "Boiler-Box" region

- AMVs are regularly faster than model winds over the Boiler-Box region
- Reason not fully clear:
  - Too large target box?
  - Too large image frequency?
  - Probably weak **correlation between pixels**: Strong convection alters the shape of clouds within ~50 min → How much correlation is between the two images taken ~50 minutes apart?
- **Outlook:** Derive correlation surface of two images. Flag AMV data if correlation in relevant area is low

REF AMV-PRE-0011-TS – 18/06/2020
Thales Services / Modèle : 87211168-GRP-FR-004

Summary & Conclusions – case studies III

Perfomance against ADM-Aelous HLOS winds

- Exceptional good agreement using collocation criteria of $\Delta x < 100$ km, $\Delta t < 30$ min and $\Delta p < 15$ hPa
- mean HLOS speed differences these AMVs and ADM-Aelous of 0-2 ± 3-4 ms-1 were typically obtained, depending on altitude, region and on channel
- However, best fit pressure indicates that wind profiles in WV-Rayleigh channel often disagree
- Wind profiles of ECMWF and $HLOS_{ADM}$ differ at low levels over Indian Ocean

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