Study of AMV Speed Biases in the Tropics

Mid-term review

EUMETSAT – 17 April 2019

Content

Match/collocation of AMV wind and model wind (ECMWF)

- Collocation requirements
- Mean vertical profiles of wind speed differences
- Geographic distribution of O-B speed bias and best-fit pressure statistics

Comparisons of AMVs to reference observations

- Observed winds by MISR, RAOB
- CALIPSO cloud-top heights

Extract statistics against convection parameters

- Diurnal cycle of convection
- OLR, GDI, CLOUDSAT cloud type classification

Analysis of semivariograms

Summary

Mean statistics for IR channel of EUMETSAT's Meteosat-10 and Metop are mostly presented!

REF AMV-PRE-0005-TS – 17/04/2019
Thales Services / Modèle : 87211168-GRP-FR-004

Collocation of AMV wind and model wind (ECMWF)

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)

Match/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 < 60°
- If more than one AMV fall into same ECMWF grid cell, median of AMV speed is compared to model wind speed!

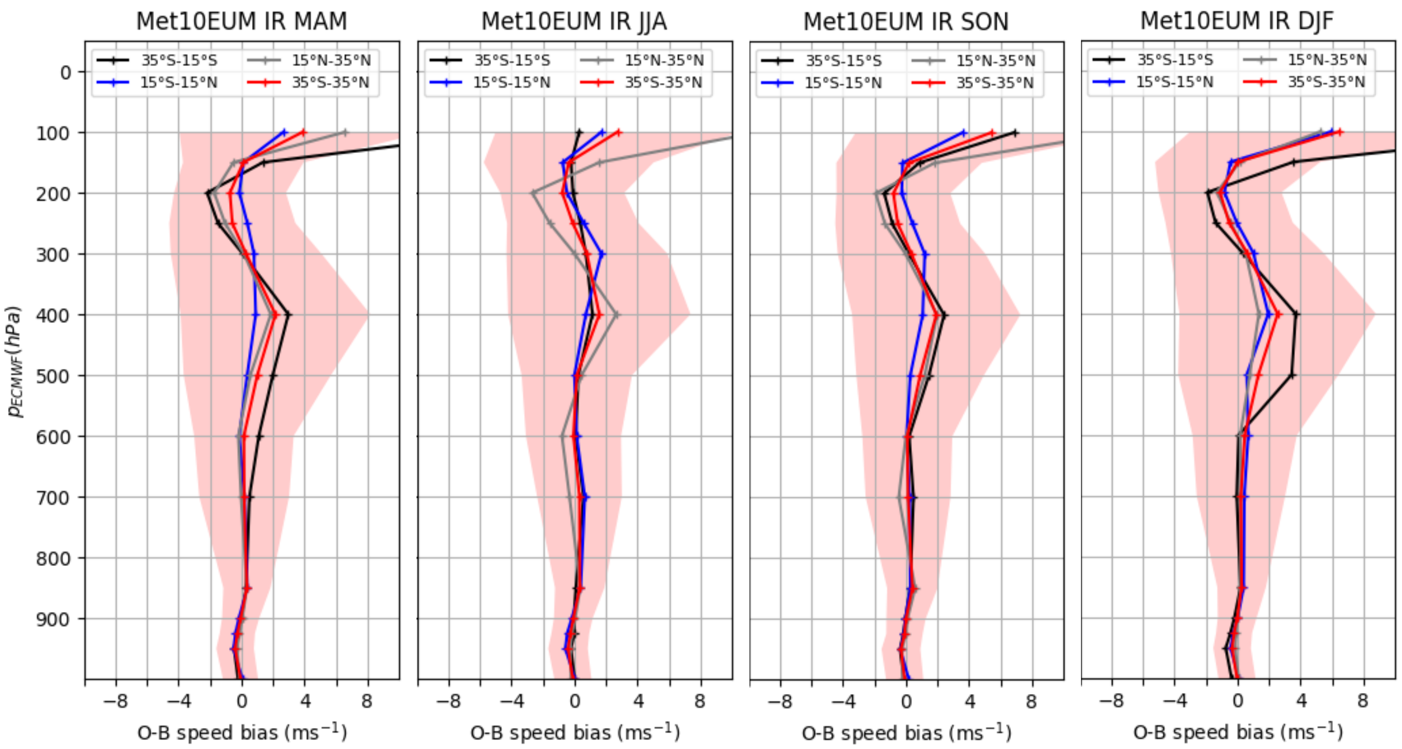
Separate results

- high-level winds (p <= 400 hPa)
- mid-level winds (400 hPa < p <= 700 hPa)
- low-level winds (p > 700 hPa)

Succeeding analysis are based upon this collocation database

Met10EUM : O-B speed bias as function of pressure

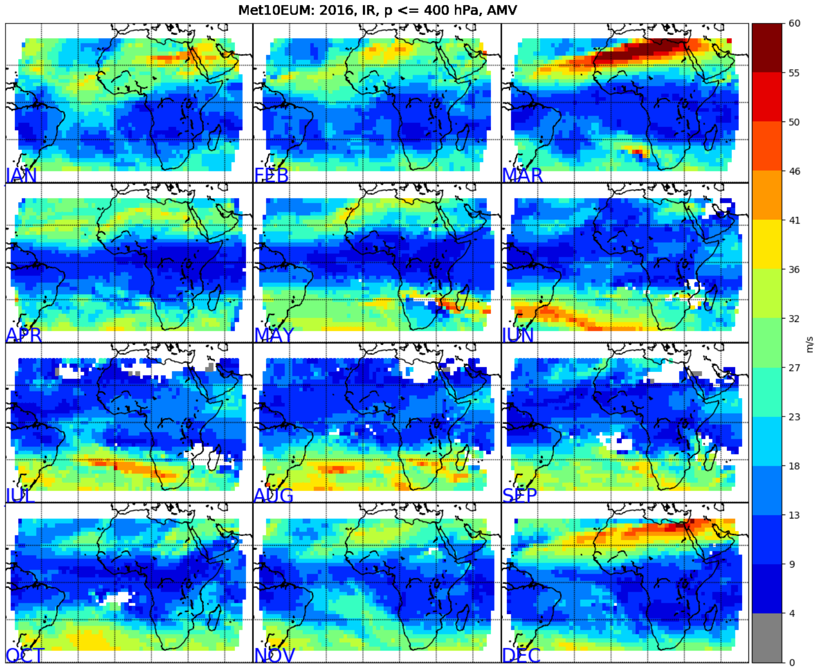
Wind speed difference profiles averaged over different zonal bands



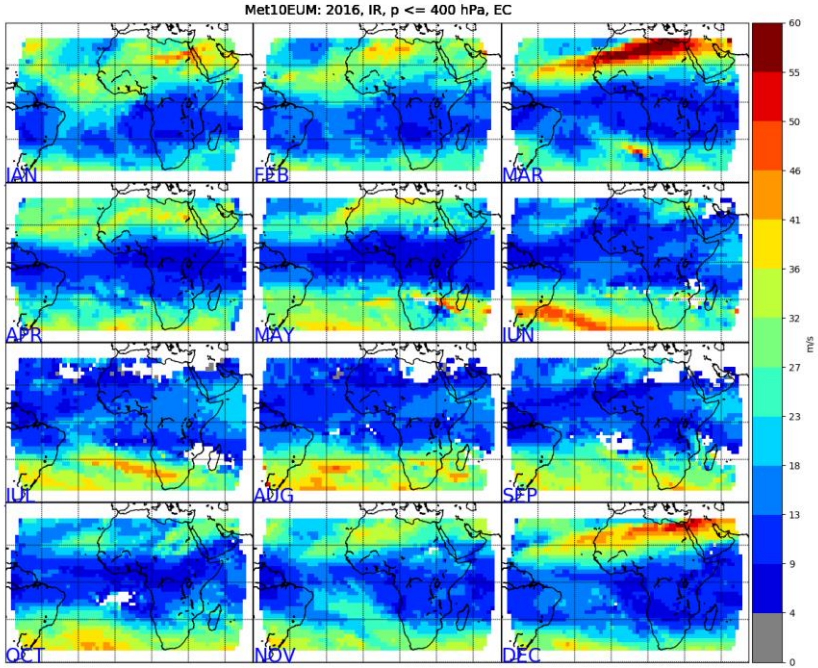
- p > 600 hPa: differences in wind speed are close to ±0 ms^{-1}
- 300 ≤ p ≤ 600 hPa : Met10EUM observers 0.5-3 ms^{-1} faster winds than ECMWF
- 200 ≤ p ≤ 300 hPa : ECMWF up to 2 ms^{-1} faster
- p < 200 hPa : Bias goes back to zero or becomes positive again, depending on season and latitude
- Highest variability for 400 hPa layer

Met10EUM: Spatial distribution of O-B speed bias at high-levels I

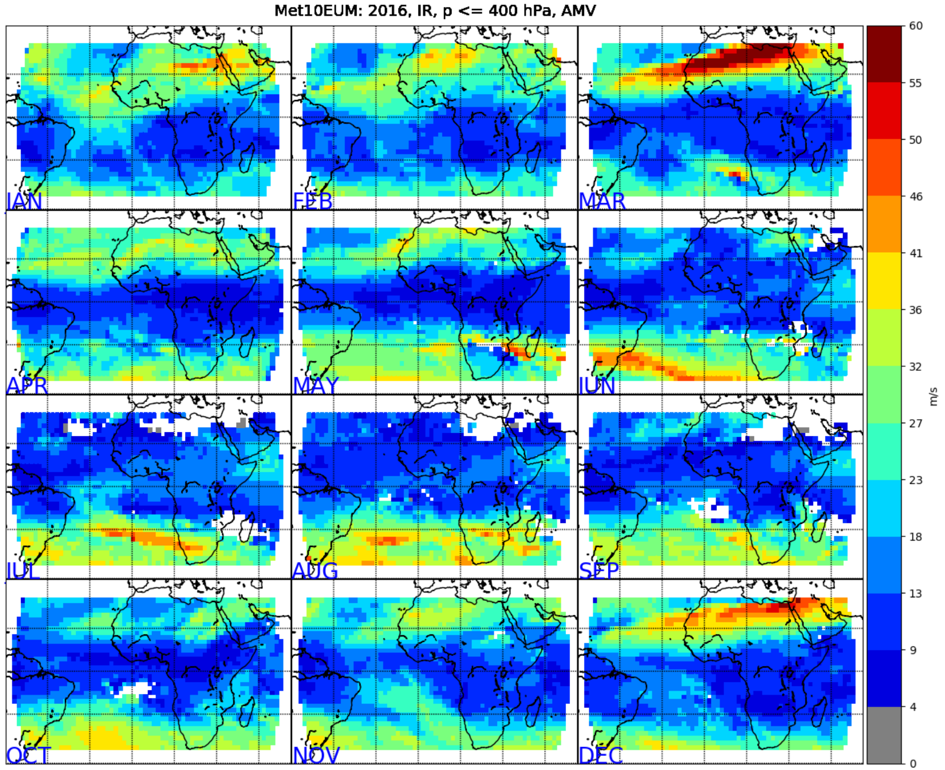
Met10EUM: Mean wind at high levels

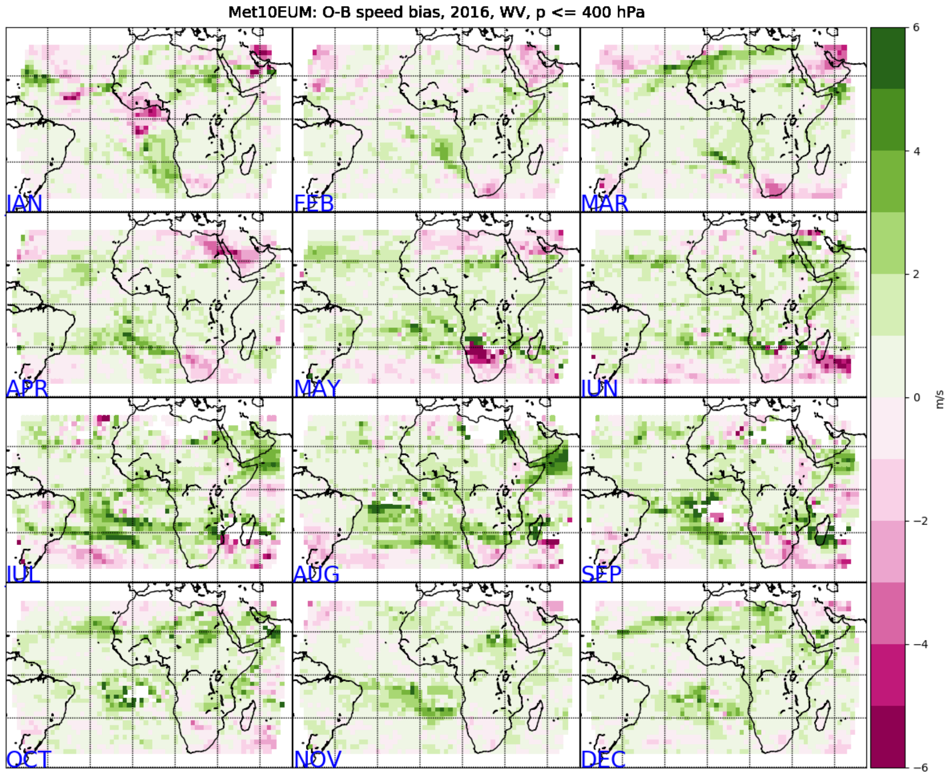


ECWMF: Mean wind at high levels



Met10EUM: Spatial distribution of O-B speed bias at high-levels II

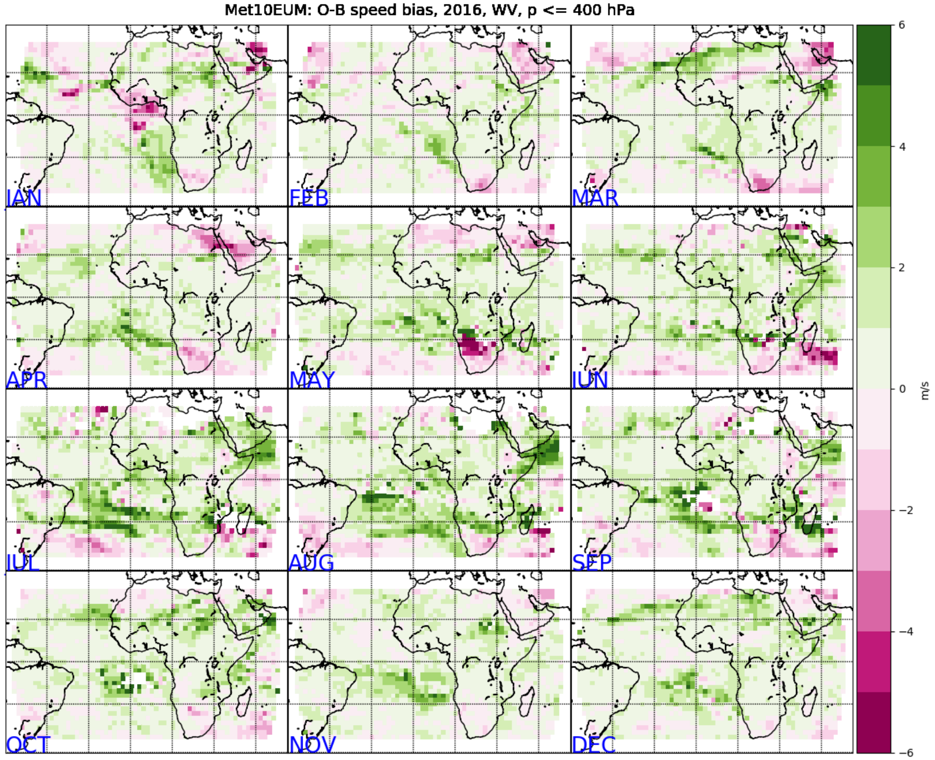


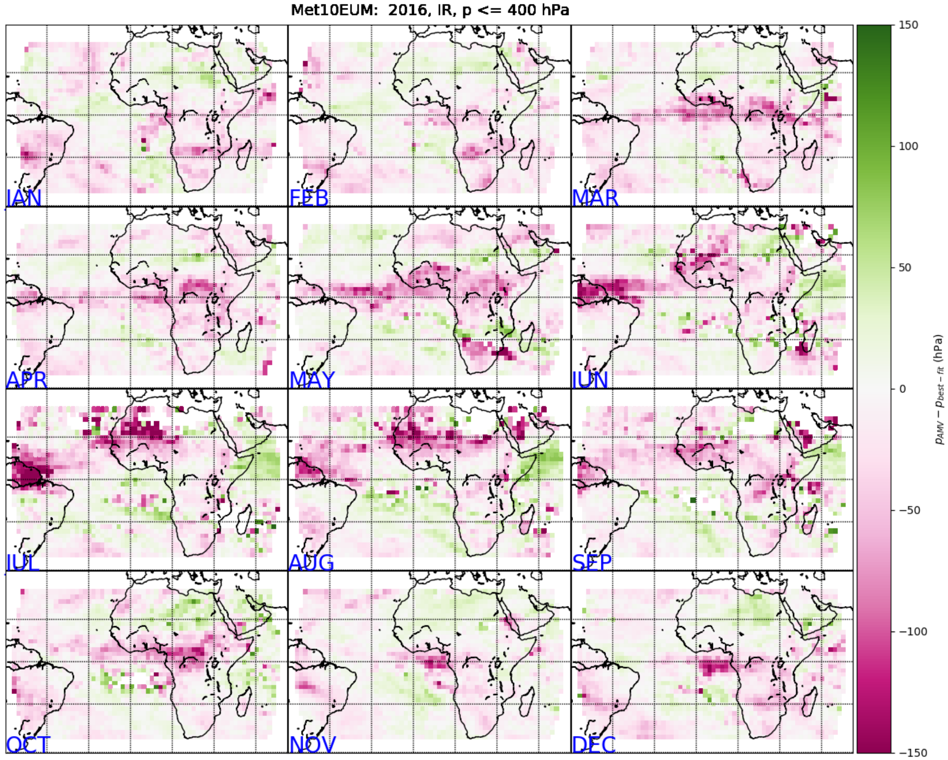


At high levels, regions of O-B speed biases ≥ ± 3 ms^{-1} coincide with

- high wind speed (subtropical jet)
- Arid locations (desert), e.g. Arabia in JUL, Iran in MAR
- Oceans

Met10EUM: Spatial distribution of O-B speed bias at high-levels III



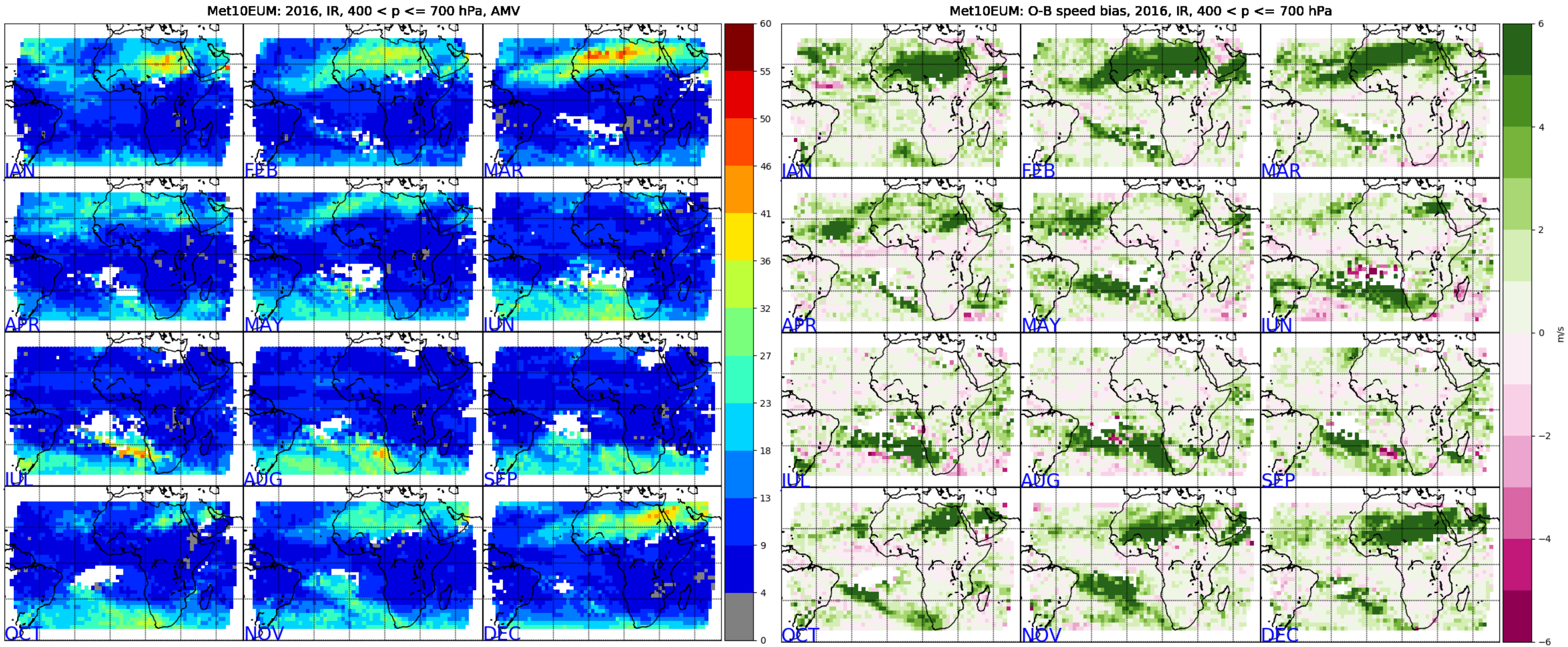


At high levels, regions of O-B speed biases ≥ ± 3 ms^{-1} coincide with

- high wind speed (subtropical jet)
- Arid locations (desert)
- Oceans

Weak indication of erroneous height assignment: AMV pressures obtained over these regions mostly do not exhibit substantial differences (|Δp| > 50 hPa) to best-fit pressure.

Met10EUM: Spatial distribution of O-B speed bias at mid-levels I



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

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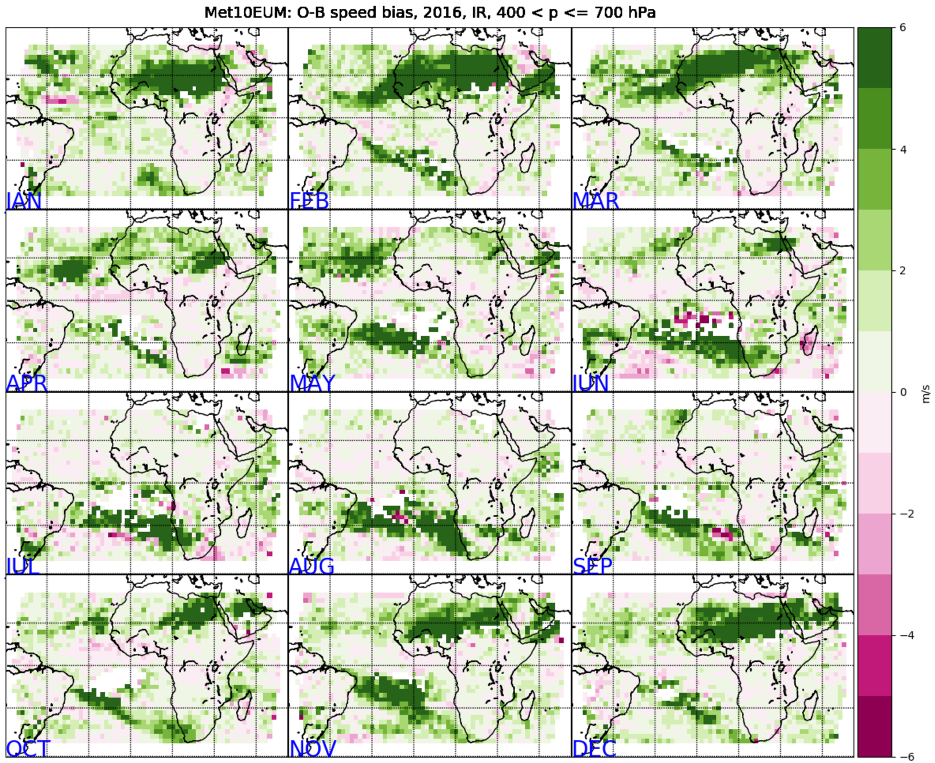
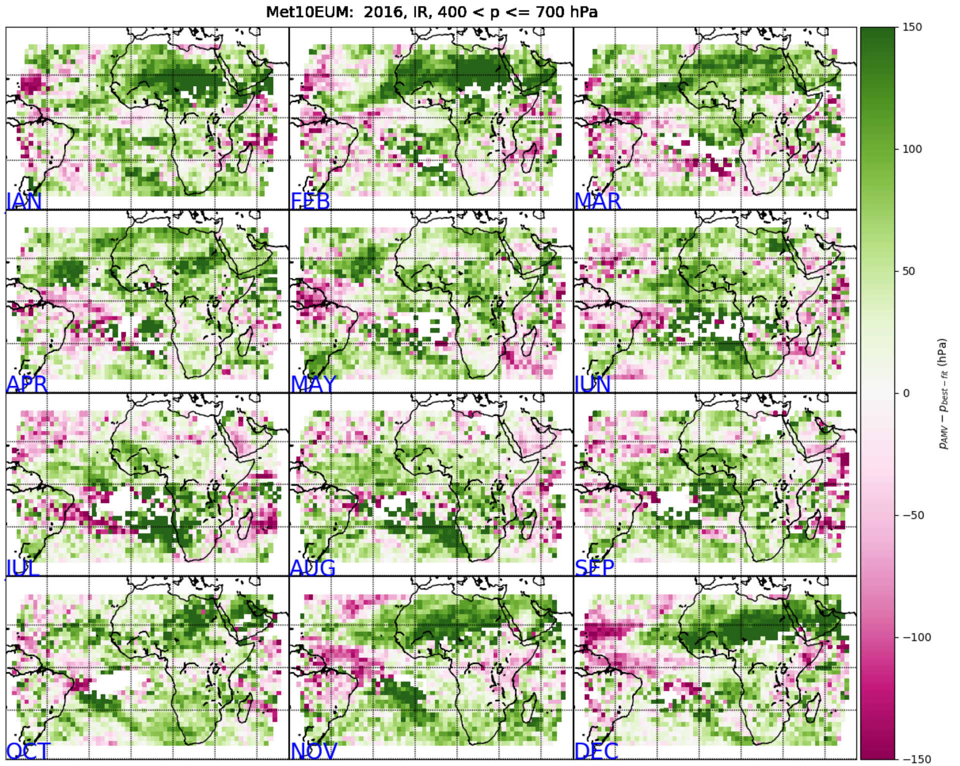
Met10EUM: Spatial distribution of O-B speed bias at mid-levels II

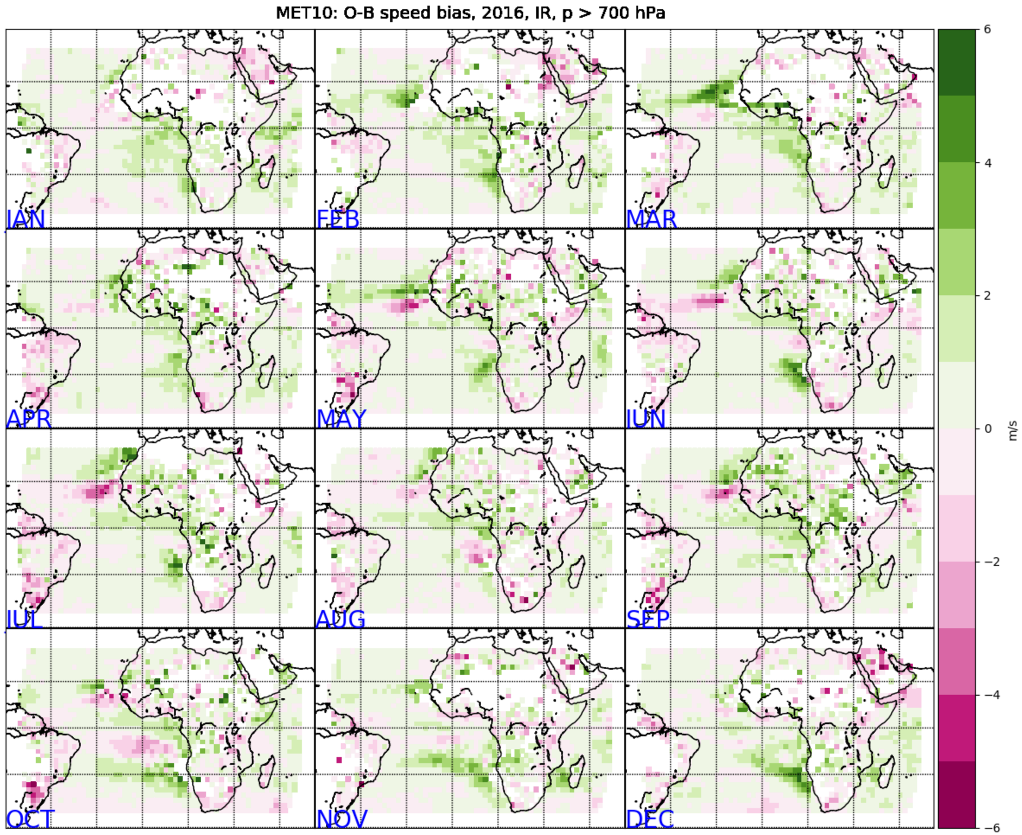




O-B speeds bias > 6 ms^{-1} regularly found over deserts and oceans

Bias found over desert coincides with best-fit pressure differences > 100 hPa. AMVs set too low in atmosphere leading to positive O-B speed bias

Met10EUM: Spatial distribution of O-B speed bias at low-levels



Bias mostly ≤ 1 ms^{-1}, except for some coastal/oceanic and arid regions

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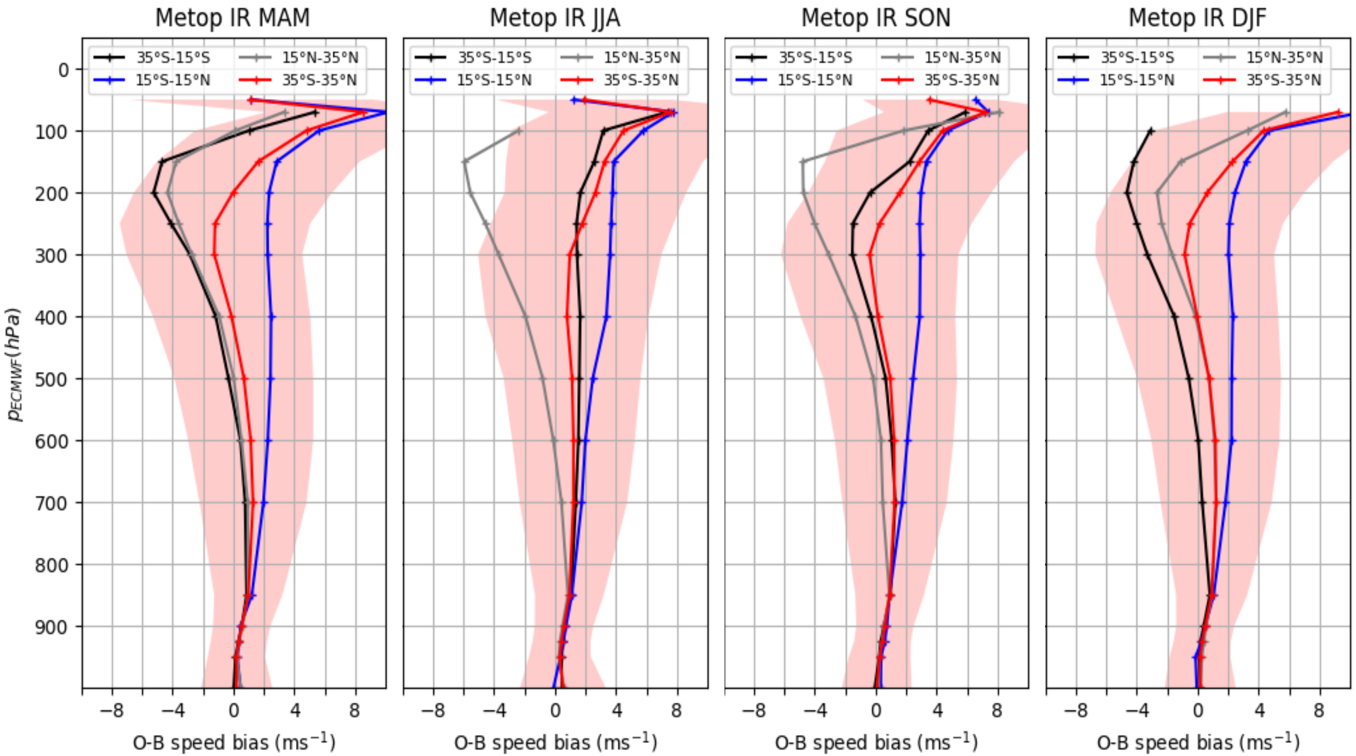
Metop : O-B speed bias as function of pressure

Wind speed difference profiles averaged over different zonal bands



- 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.

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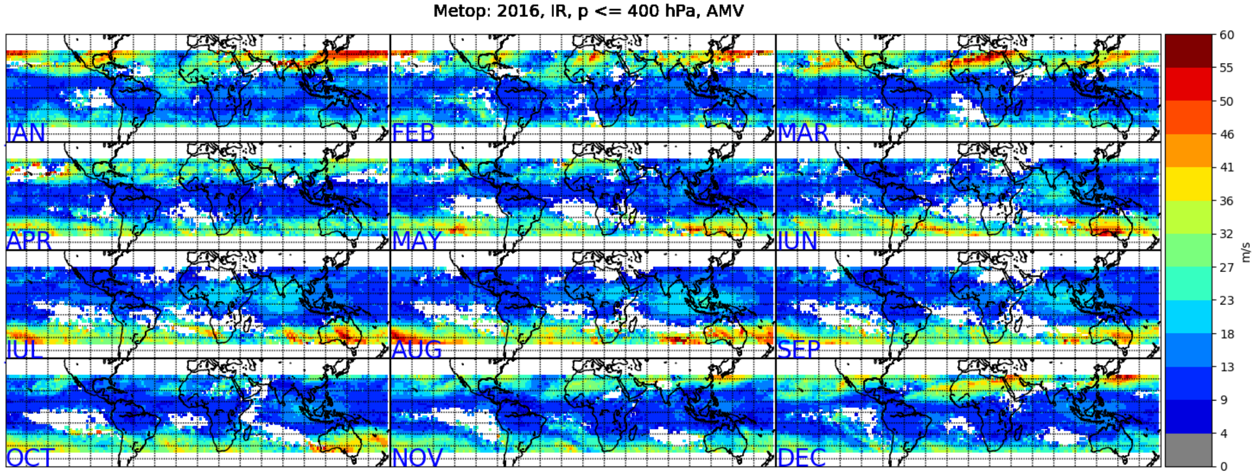
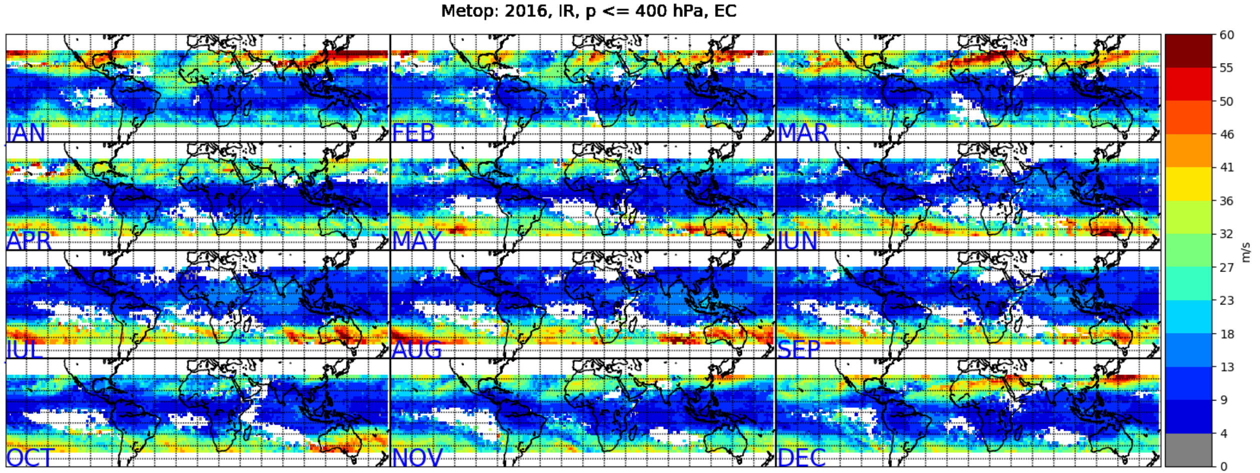
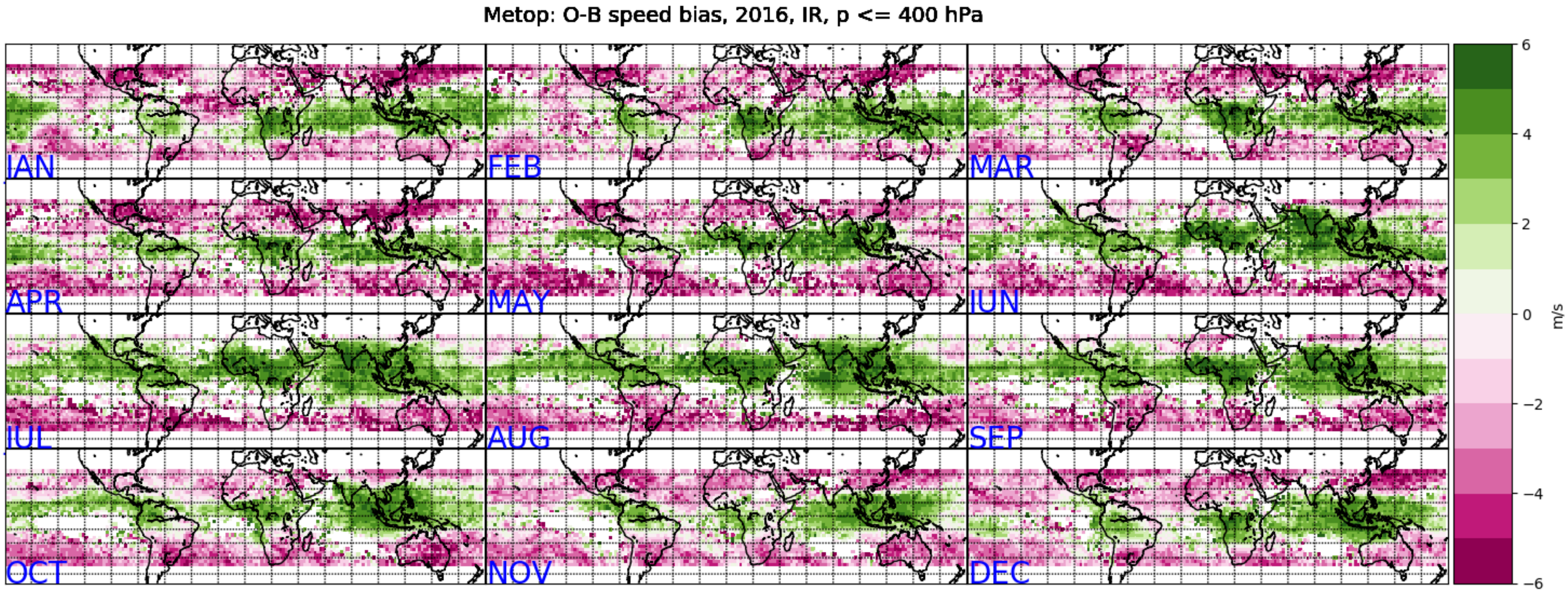
Metop: Spatial distribution of O-B speed bias at high-levels I





Metop: Spatial distribution of O-B speed bias at high-levels II



- In contrast to Met10EUM, large wind speeds coincide with negative O-B speed biases (< 3 ms^{-1})
- Conversely, O-B speed biases obtained for equatorial region where mean wind speed is typically ≤ 20 ms^{-1}

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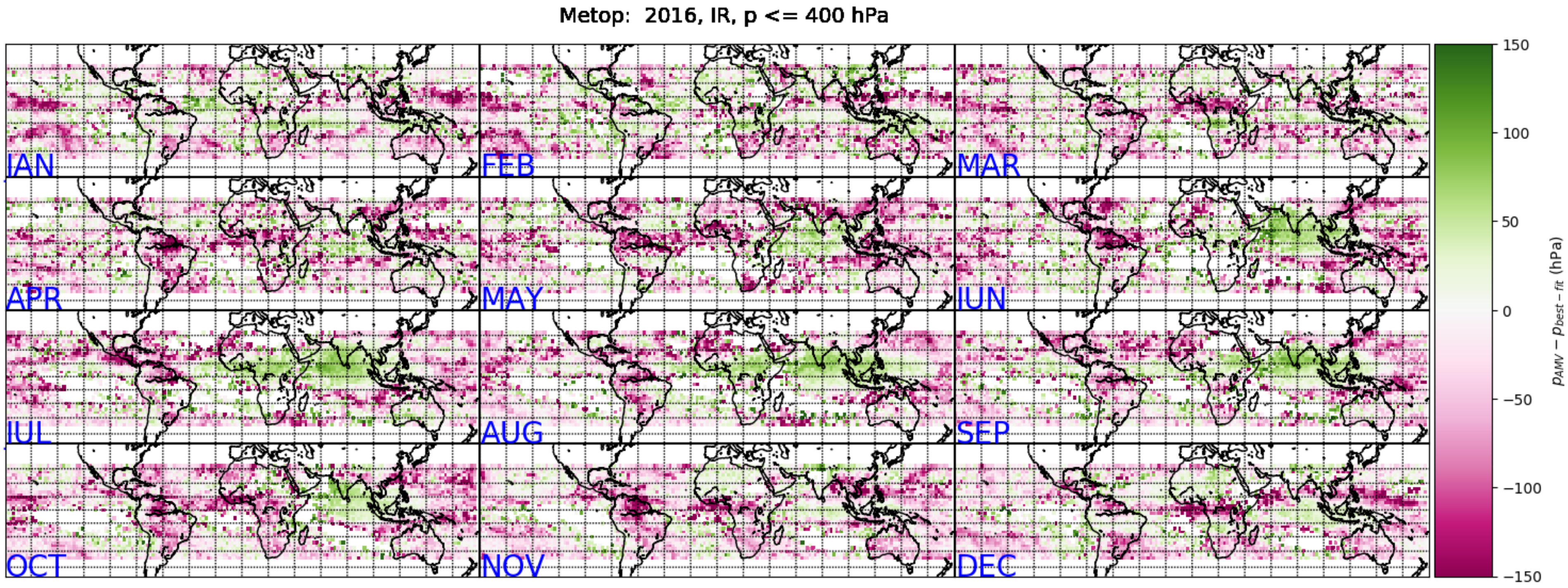
Metop: Spatial distribution of O-B speed bias at high-levels III



- Best-fit pressure vs p_{AMV} does not show spatial pattern seen in O-B speed bias
- Height-assignment uncertainties unlikely to (fully) explain observed O-B speed bias

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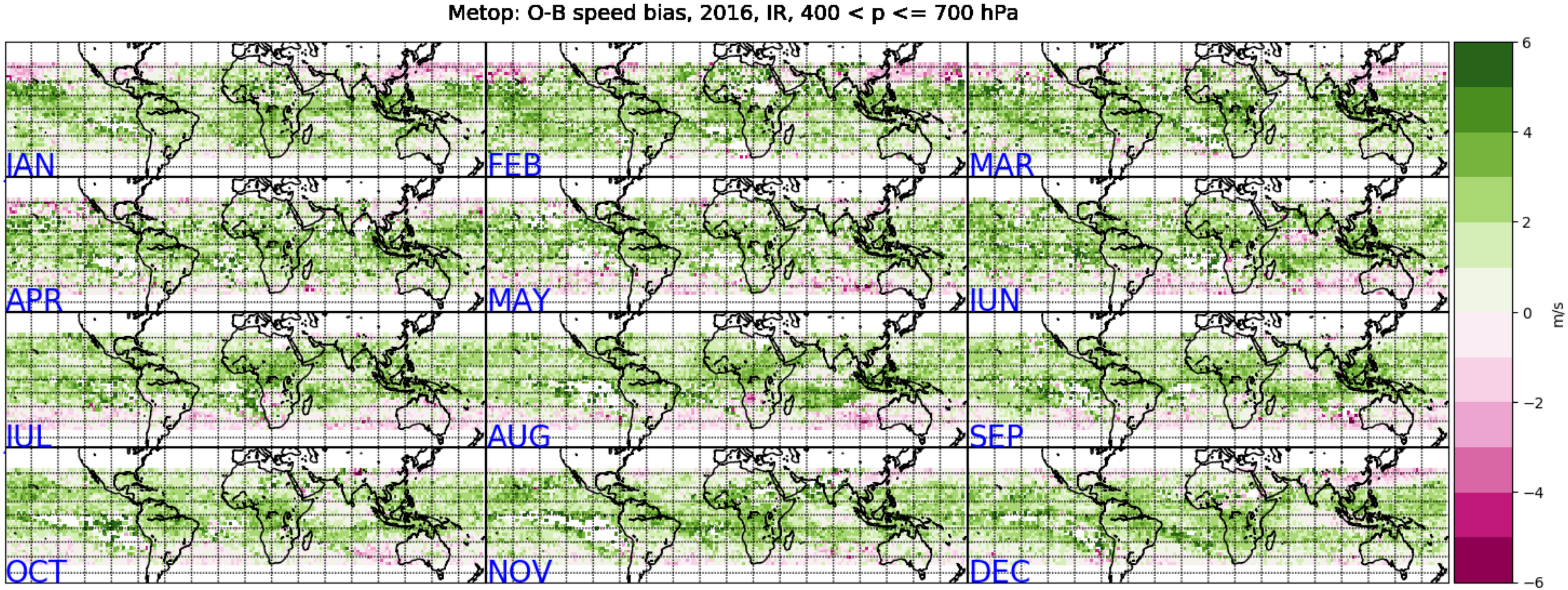
Metop: Spatial distribution of O-B speed bias at mid-levels



- Better agreement between Metop and ECMWF speed at this level
- O-B mostly positive, except for regions close to mid-latitudes where winds reach their maximum at these heights.

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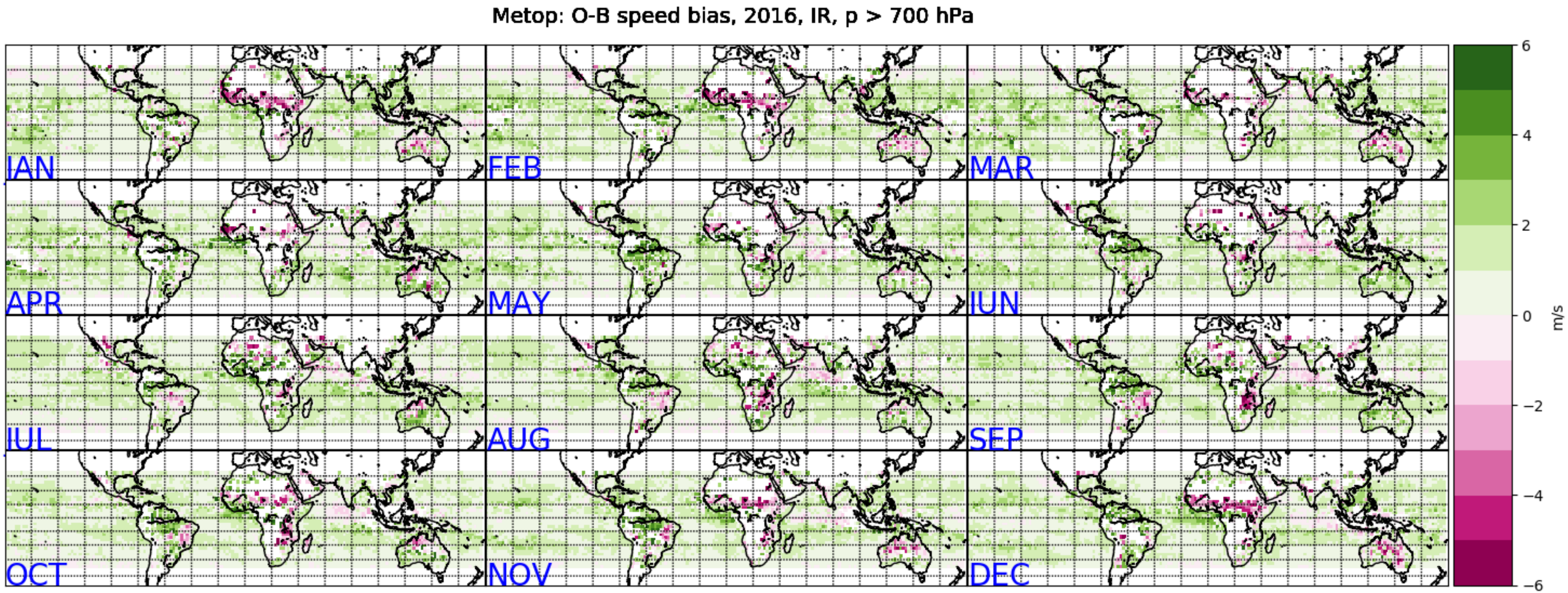
Metop: Spatial distribution of O-B speed bias at low-levels



- O-B mostly positive, except for arid regions and sub-Saharan region.

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Collocation of AMV wind with reference wind observations

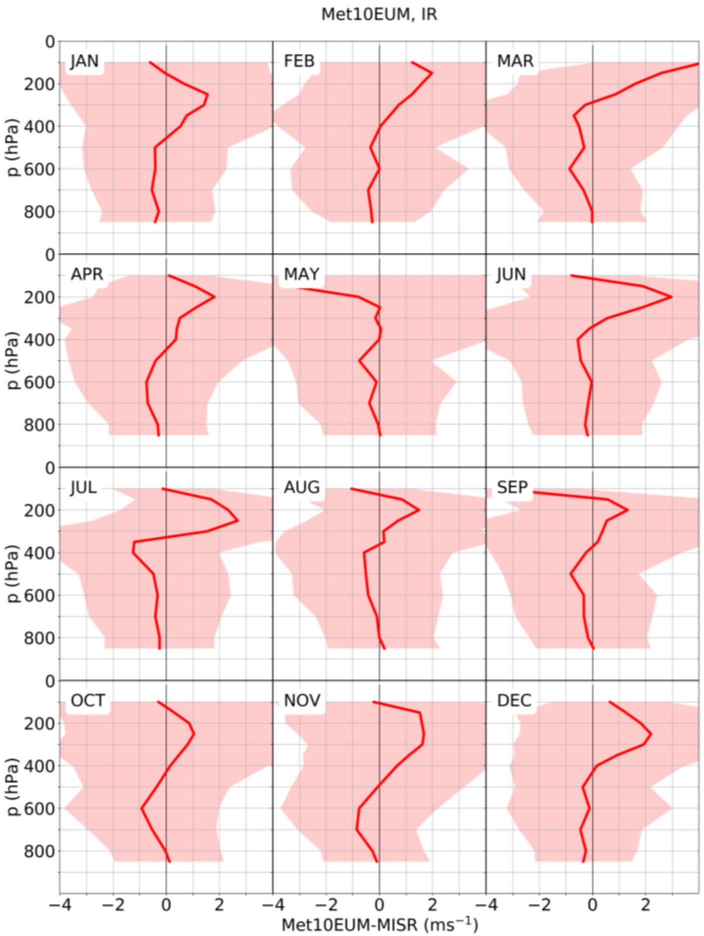
RAOB

- Radiosondes from IGRA database
- Temporally and spatially very inhomogeneously distributed

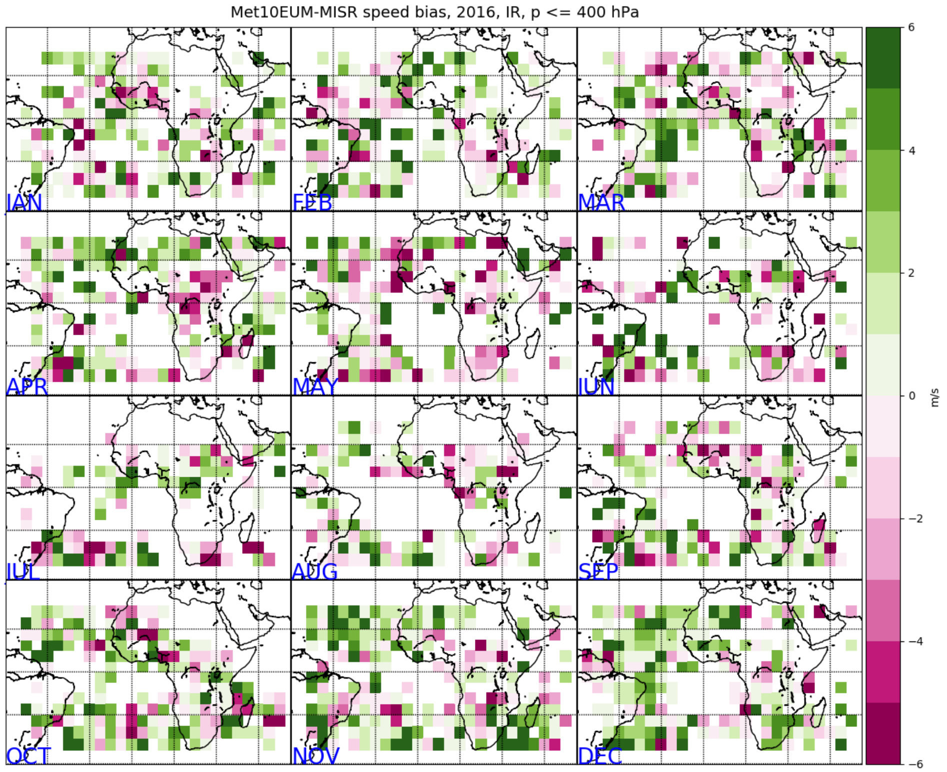
MISR stereo AMVs

- MISR AMV retrieval is independent of *a priori* atmospheric and humidity forecasts
- Simultaneous retrieval of cloud height and motion
- Conversion from geometric heights to pressure with temperature and pressure fields from spatially and temporally closest ECMWF grid cell
- Match/Collocation criteria:
  - Horizontal collocation: $\Delta x \leq 150$ km
  - Vertical collocation: $\Delta p \leq \pm 25$ hPa
  - Temporal collocation: $\Delta t \leq \pm 30$ min
  - Quality criteria: QI > 80 for GEO AMV , QI > 60 for AMV from polar satellites
  - If more than one MISR meets collocation criteria, median of MISR AMV speed is compared to Met10EUM or Metop AMVs

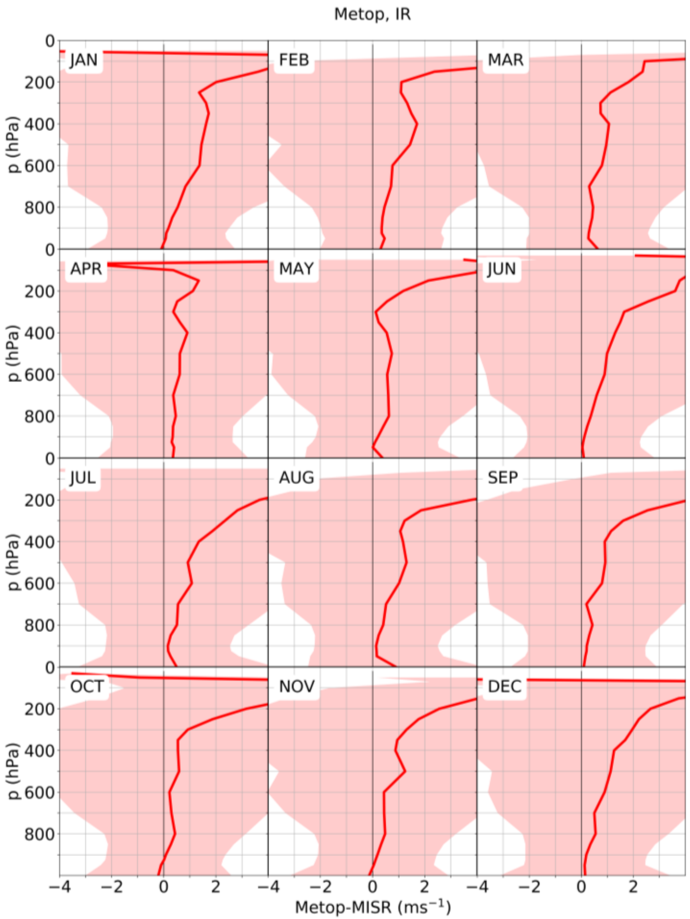
Met10EUM : Profiles of wind speed differences to MISR



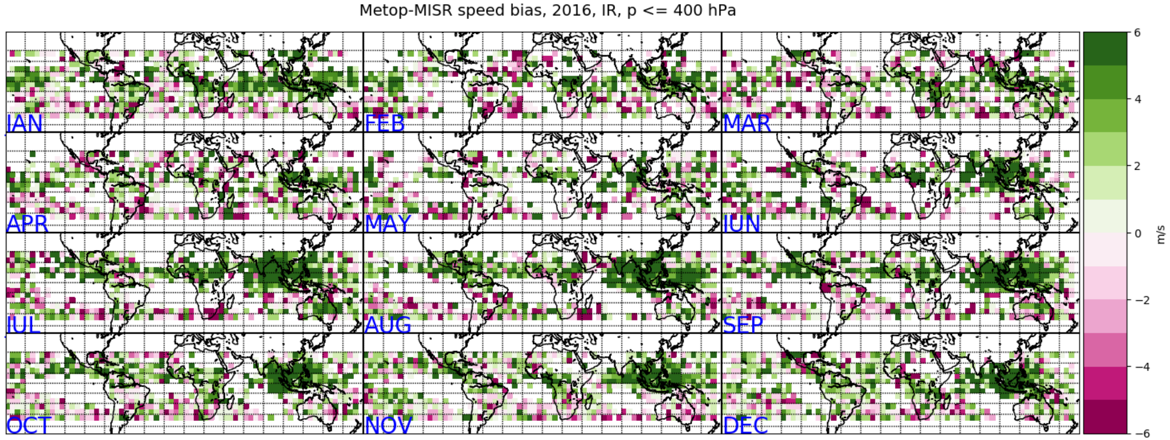
- For low-level to mid-level winds, MISR winds tends to be slightly faster than that of Met10EUM, up to 1 ms^{-1}.
- Conversely, at high levels, Met10EUM tends to be 1-2 ms^{-1} faster



Metop : Profiles of wind speed differences to MISR



- p>400 hPa: Metop winds are typically 0.5 to1.0 ms^{-1} slower than MISR winds.
- p<400 hPa, the spread between Metop AMV and MISR winds increases with altitude, with Metop winds being up to >4 ms^{-1} slower than MISR at altitudes of <200 hPa.



- At high levels, Metop winds are faster than MISR around equator, also seen in Metop-ECMWF wind speed comparisons.
- Metop-MISR sample size dominated by negative bias over ocean in southern tropics

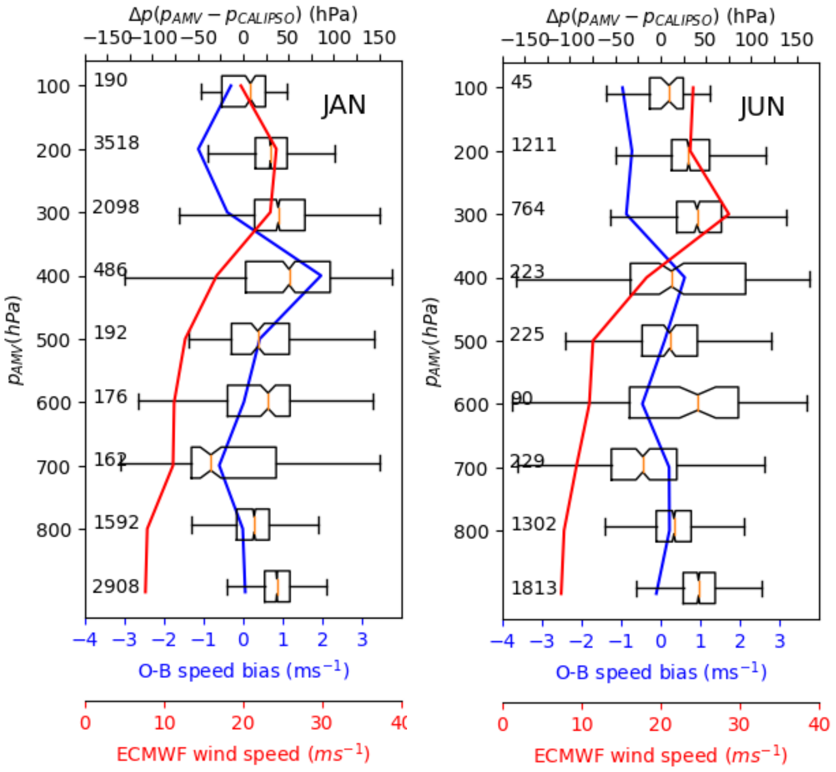
CALIPSO cloud top heights I

Apply method of Folger and Weissmann (2014) & Weissmann et al. (2013) to compare CALIPSO cloud top heights to pressures assigned to AMVs:

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
    1) root-mean-square differences between single LIDAR cloud observations and their median value must not exceed 100 hPa.
    2) all multilayer cloud observations are discarded. Ensure that the detected lidar signal definitely represents a cloud ($QI_{CALIPSO} > 90$).
    3) AMVs must be within 165 hPa of the CALIPSO cloud top height

Found only matches for Met10EUM!

CALIPSO cloud top heights II



- Most collocations are found for 300, 400, 800 and 900 hPa levels
- AMV pressure tends to be higher than CALIPSO cloud top heights. Too low altitudes assigned to AMVs?
- At the 400 hPa layer, this peak in Δp often coincides with largest O-B speed bias of up to 2 ms^{-1} (e.g. January, March, October, November) and high wind speed above (at 300 hPa).
- $p \leq 300$: Negative speed bias despite $\Delta p > 0$.

Observed bias related to a particular convection or cloud type?

- **In the tropics, oceanic deep convection tends to reach its maximum in the early morning, while convection over land reaches its maximum in the evening as a result of solar heating**
- **Extract statistics against ECMWF wind fields by hourly period to summarize impact of diurnal cycle of convection on observed O-B speed biases**
- **Other parameters for which statistics are extracted:**
  - Outgoing longwave radiation (OLR)
  - Galvez-Davison-Index (GDI):
    - Stability index to describe potential for convective development in tropics
    - Calculated from temperature and specific humidity profiles in lower troposphere
  - CLOUDSAT cloud type classification

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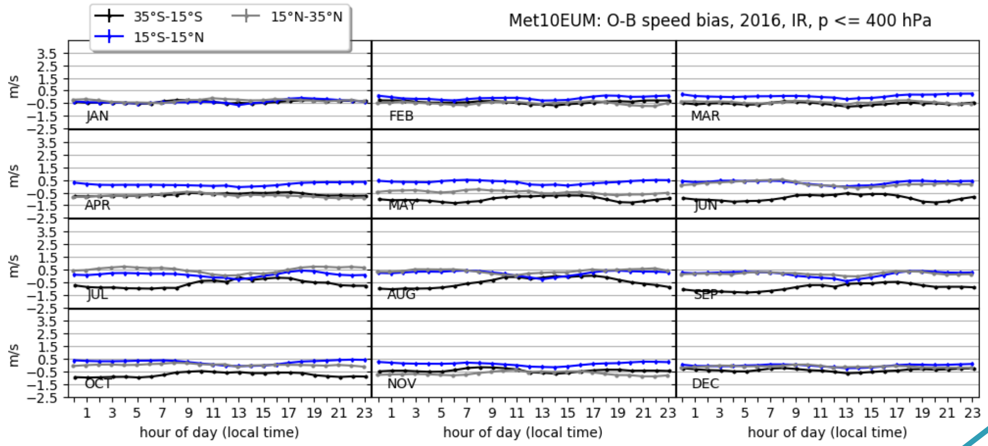
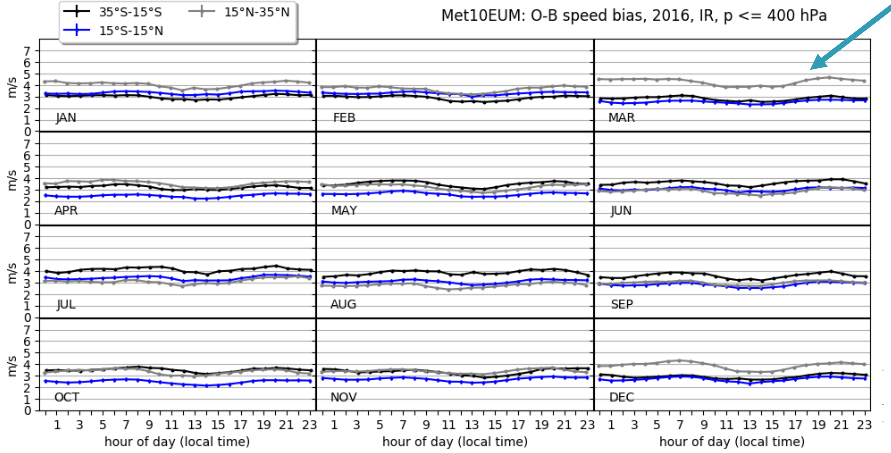
Met10EUM : Diurnal cycle of convection

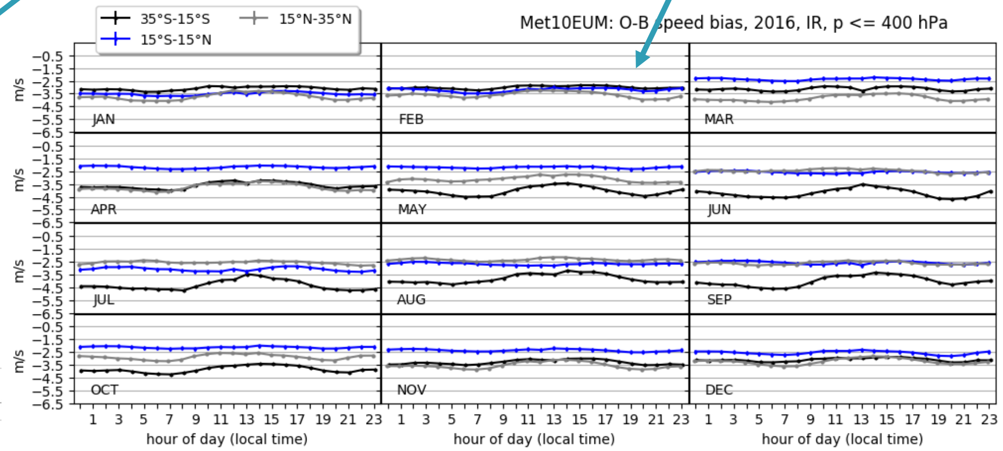


- Diurnal cycle of O-B speed bias for different zonal bands
- Variations in O-B speed bias as function of daytime are small (maximally up to 1 ms^{-1})

Only positive differences

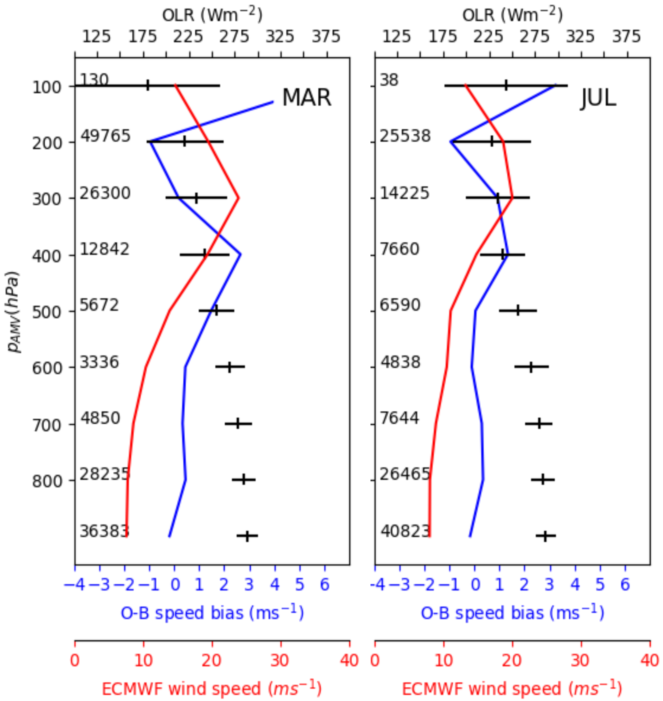
Only negative differences



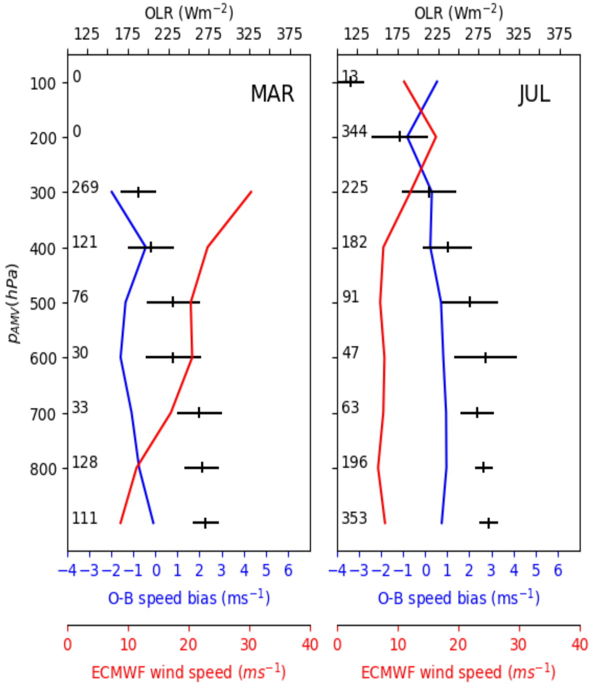


O-B speed bias against OLR from AIRS

Met10EUM



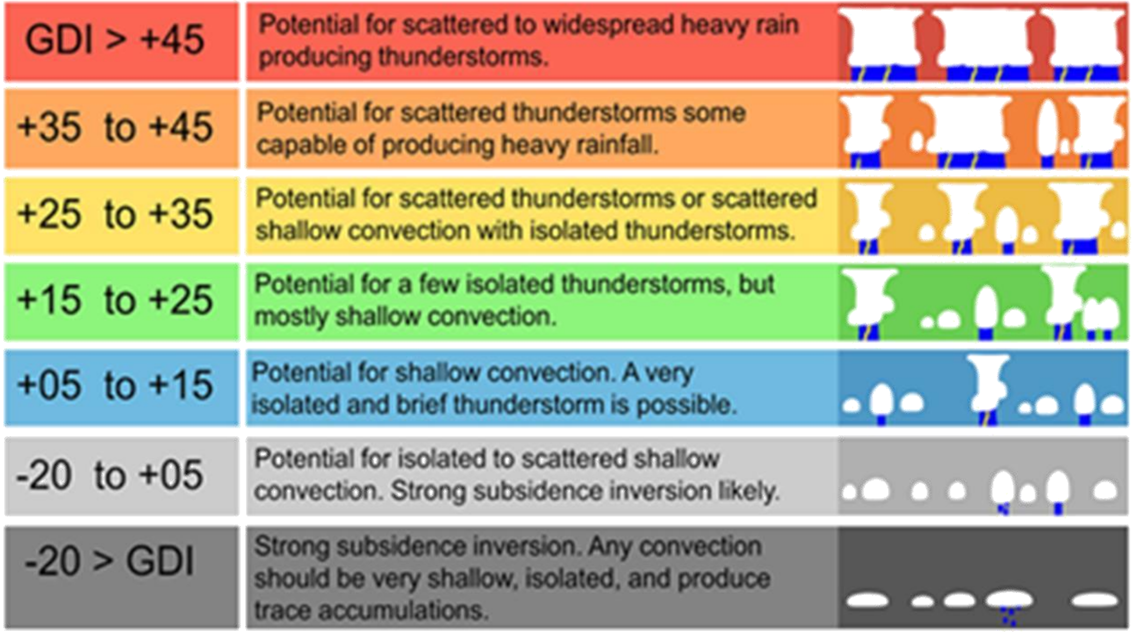
Metop



- OLR decreases with altitude as blocking 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

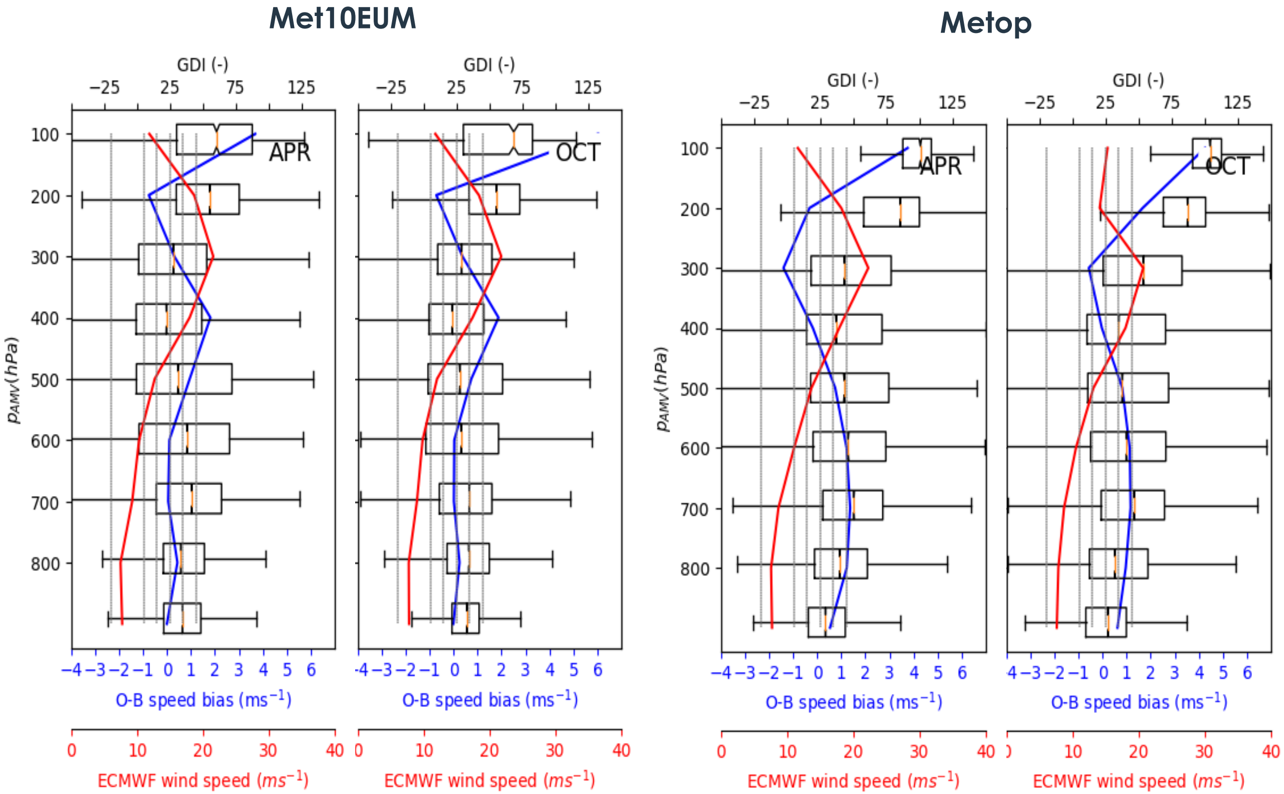
O-B speed bias against GDI computed from ECMWF fields



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.

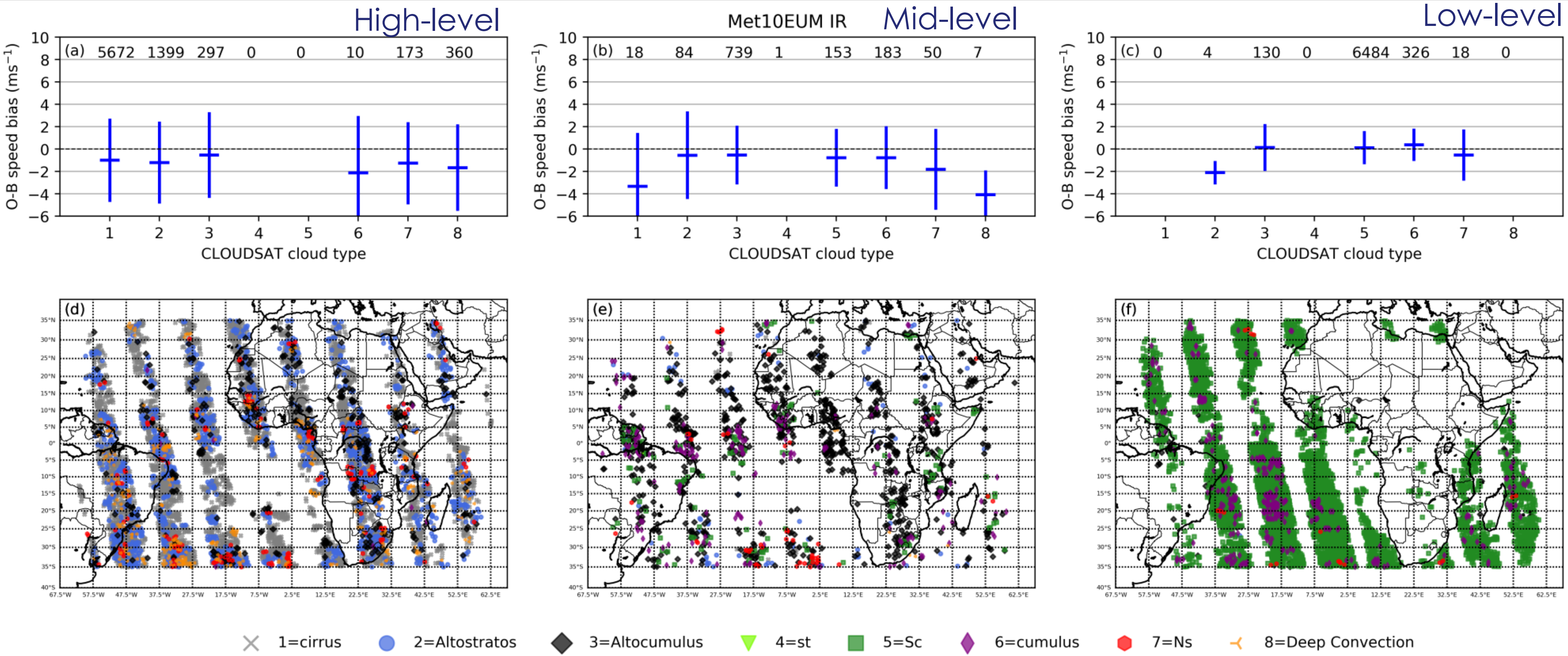
Correspondence between GDI values and expected type of convection.
Figure adapted from http://www.wpc.ncep.noaa.gov/international/gdi/.

O-B speed bias against GDI computed from ECMWF fields



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

Met10EUM : CLOUDSAT cloud type classification



Collocation requirements:
dx ≤ 75 km; |dt| ≤ 30 min;
|dp| ≤ 25 hPa

Similar mean wind speed differences for different cloud types

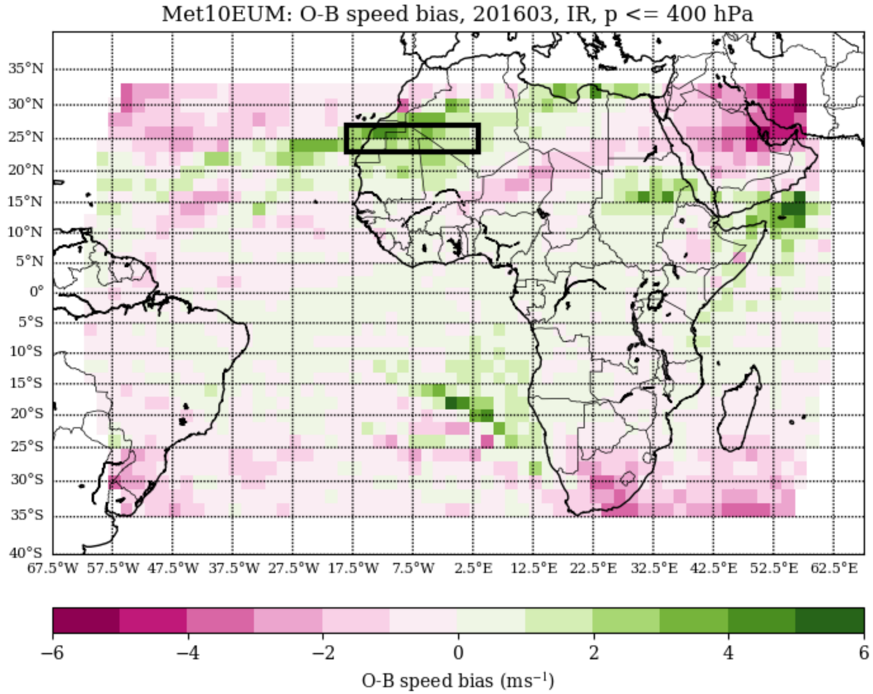
Semivariogram

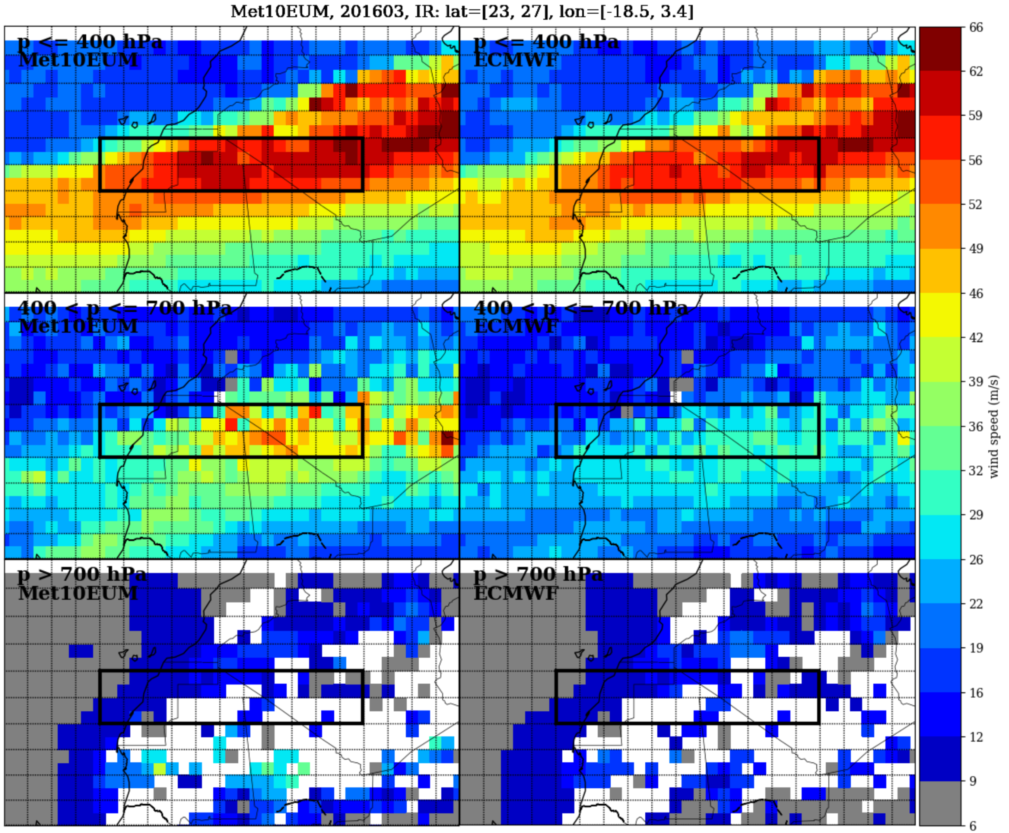
- The previous analysis (speed bias as function of daytime, OLR, GDI, CLOUDSAT cloud classification) indicate practically no dependency of O-B speed bias on the strength and type of convection and on cloud type
- Analysing the spatial variance of AMV and model speed over a region allows to verify the similarity of the wind fields (e.g. position and strength of jet).
- Semivariogram: semivariances γ as function of lag distance *h*:

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

- $z(x_i)$ 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.

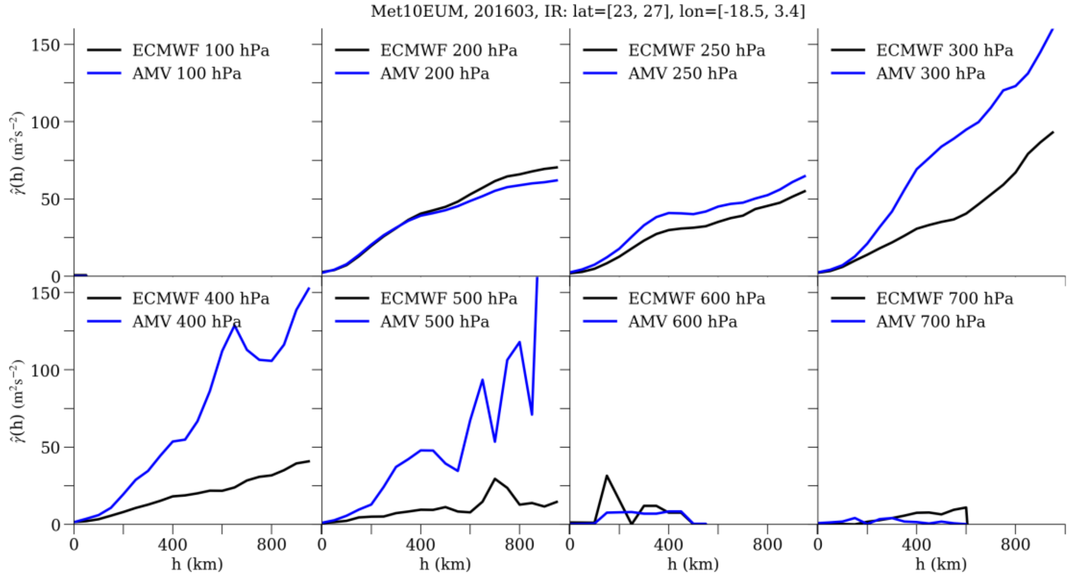
Example 1 – Location of subtropical jet

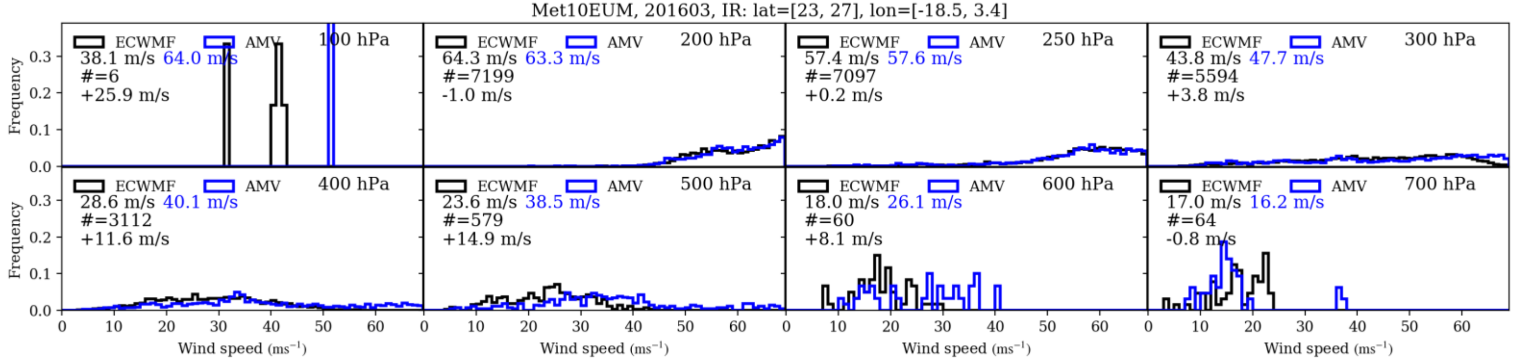




Geographic distribution of tropical Met10EUM wind speeds against collocated ECMWF winds for March 2016. (*Left*) O-B bias is averaged for high levels (p ≤400 hPa) and over an 2° x 2° latitude x longitude grid. Black box indicates a region of large wind speed discrepancies. (*Right*) Monthly averages of Met10EUM AMV and ECWMF wind speed for high-level, mid-level and low level winds for the black box and its surrounding are depicted.

Example 1 – Location of subtropical jet





- Similar semivariances/autocorrelation at 200 to 250 hPa levels and very close distribution of data
- 300 to 400 hPa: Met10EUM's much stronger decrease of correlation with distance than ECMWF. Wrong location of jet at these altitudes?

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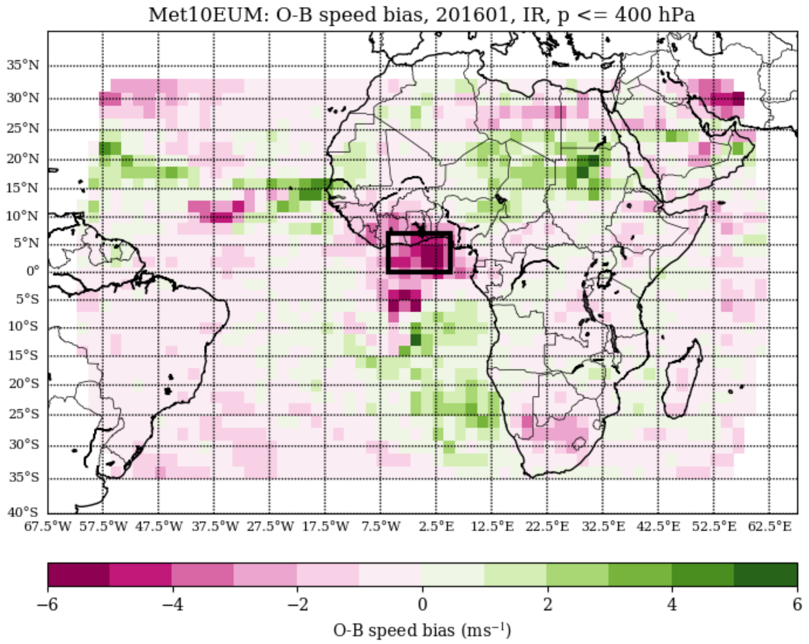
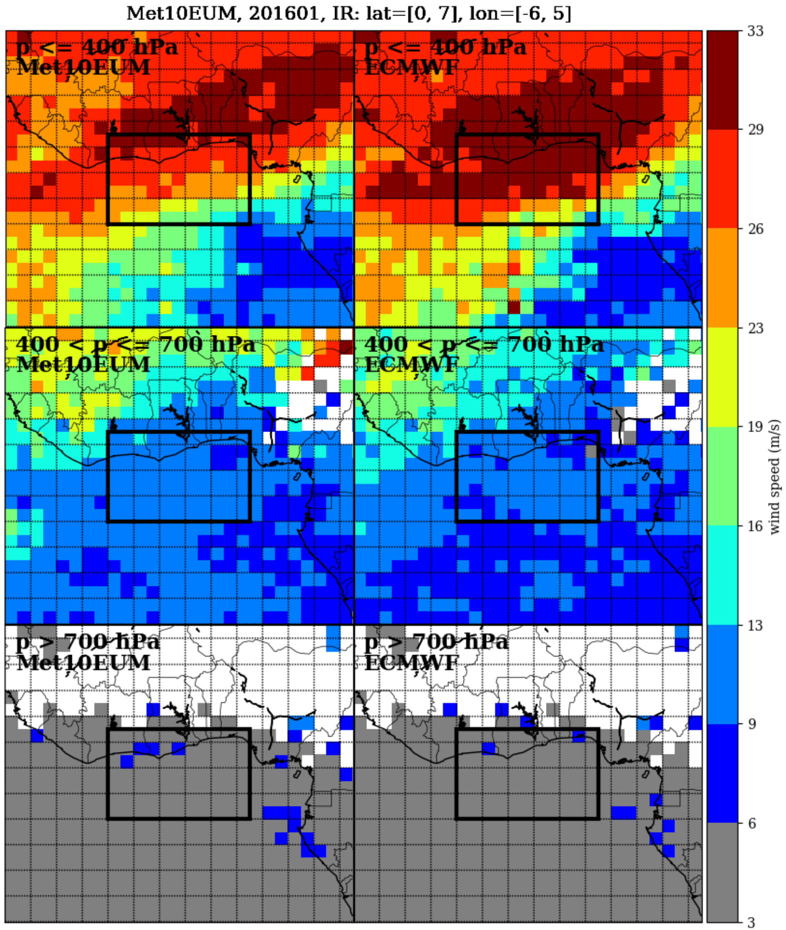
Example 2 – Large negative O-B speed bias over Gulf of Guinea





Geographic distribution of tropical Met10EUM wind speeds against collocated ECMWF winds for January 2016. (*Left*) O-B bias is averaged for high levels (p ≤400 hPa) and over an 2° x 2° latitude x longitude grid. Black box indicates a region of large wind speed discrepancies. (*Right*) Monthly averages of Met10EUM AMV and ECWMF wind speed for high-level, mid-level and low level winds for the black square and its surrounding are depicted.

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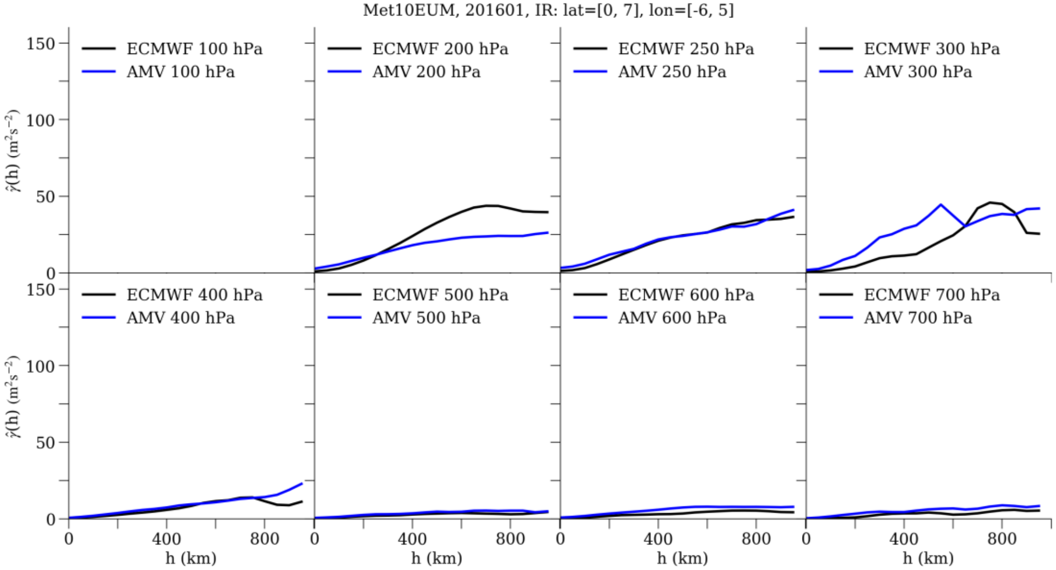
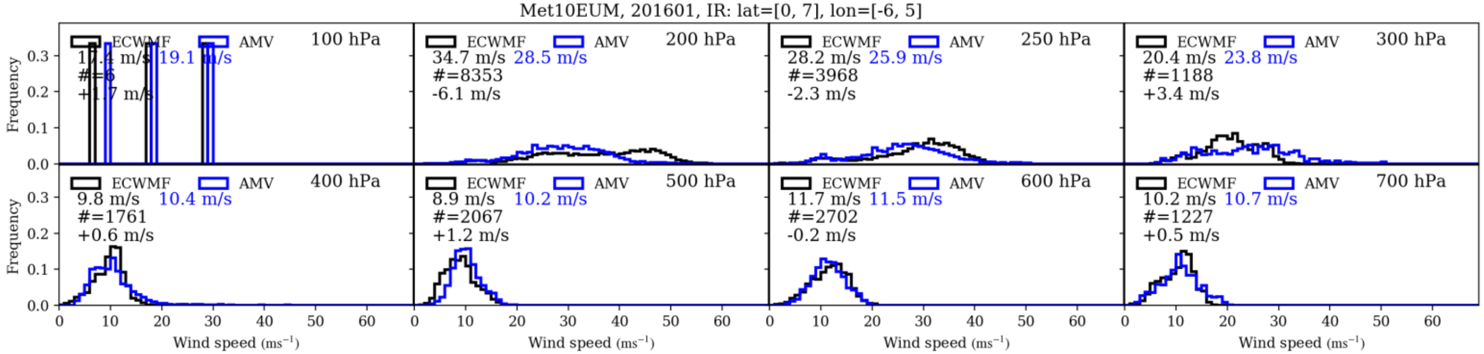


- ECWMF exhibits stronger increase of variances with distance than Met10EUM at 200 hPa
- Similar variances for 250 hPa
- At 300 hPa, AMVs tend to exhibit higher semivariances than model winds. This change in semivariance pattern is accompanied by change in the sign of the O-B speed bias.



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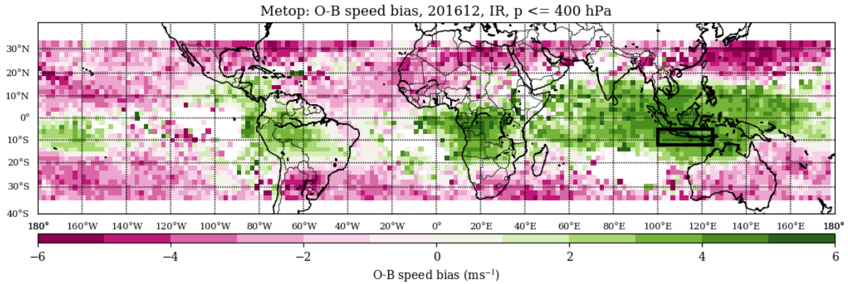
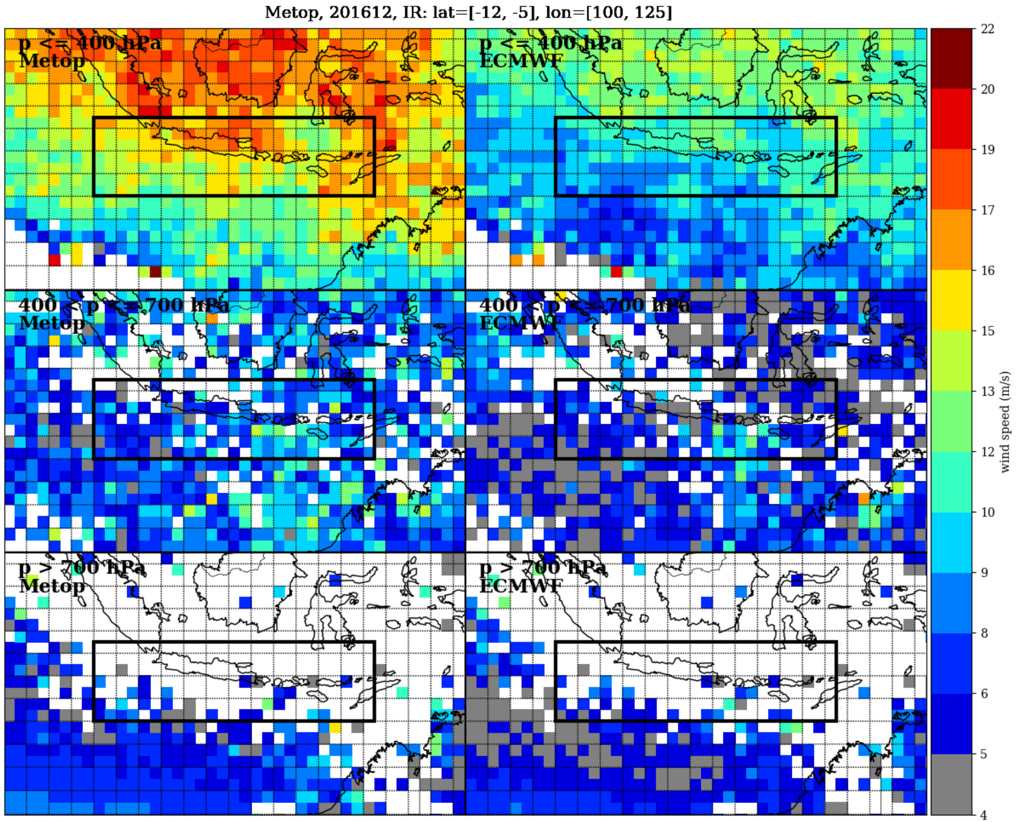
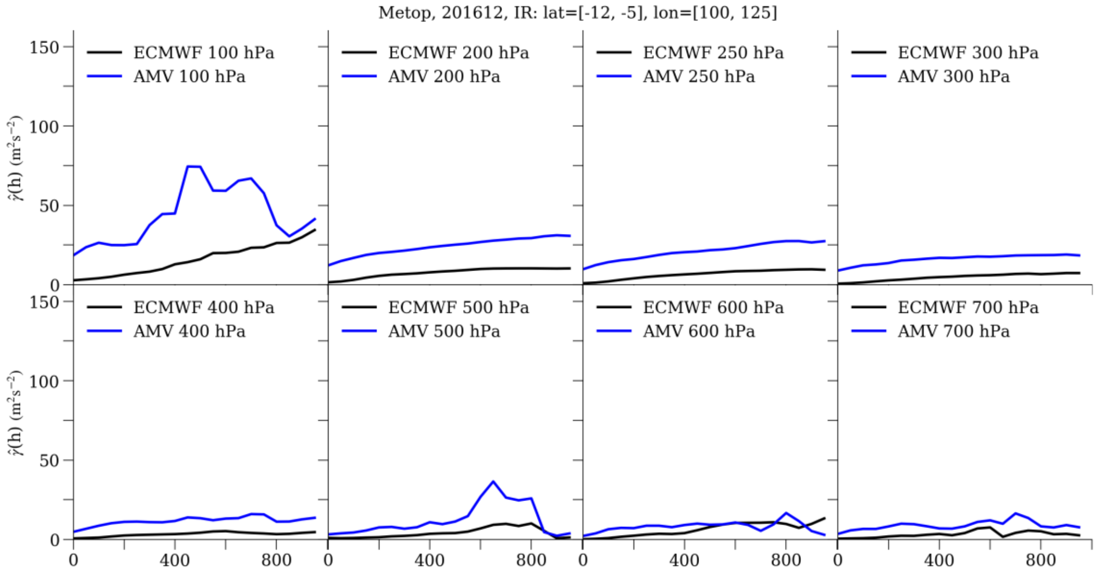
Example 3 – Metop's large O-B speed bias in tropical "boiler box"

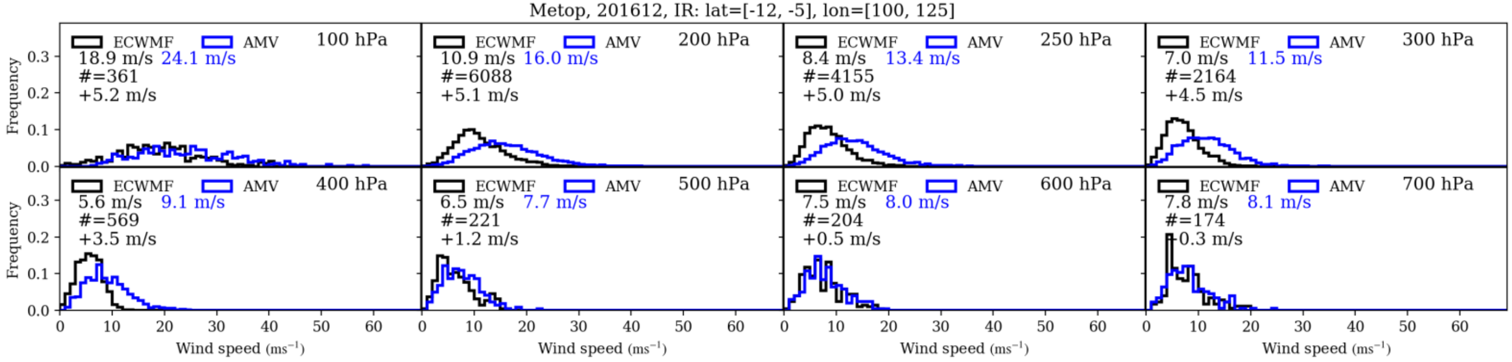




Geographic distribution of tropical Metop wind speeds against collocated ECMWF winds for December 2016. (*Left*) O-B bias is averaged for high levels (p ≤400 hPa) and over an 2° x 2° latitude x longitude grid. Black box indicates a region of large wind speed discrepancies. (*Right*) Monthly averages of Met10EUM AMV and ECWMF wind speed for high-level, mid-level and low level winds for the black square and its surrounding are depicted.

Example 3 – Metop's large O-B speeds in tropical "boiler box"





- Metop exhibits larger semivariances and thus smaller spatial autocorrelation than ECMWF and higher average wind speed than ECMWF.
- At 100 hPa, the semivariances for lag distances of 400 to 800 km is particularly large.
- In contrast to Met10EUM, Metop exhibits already semivariances > 0($ms^{-1})^2$ at lag distances close to 0 km, which represent wind speed variations at very small scale and within the ≤ ± 25 hPa vertical match criterion.

Summary

High–level: pattern of O-B wind speed bias obtained from Met10EUM and Metop AMVs differs

- Met10:
  - areas of positive O-B speed biases > 3 ms-1 commonly coincide with the location of the subtropical jet
  - Other areas of large wind speed discrepancies (>3 ms-1) are found over oceans
- Metop:
  - O-B speed bias negative for regions exhibiting mean wind speeds greater than ~30 ms-1,
  - positive O-B speed biases were obtained for low wind speed regions around the equator.

Height-assignment can explain Met10 positive O-B bias at mid-levels over deserts

Comparing observed O-B speed biases to parameters describing strength and type of convection such as GDI, OLR, to CLOUDSAT cloud type as well as to the diurnal cycle of convection revealed practically no dependency

Large O-B speed biases that the wind fields' spatial structure differ substantially (e.g. location and strength of subtropical jet). Reasons for this differences unclear. Who is wrong? Model or AMV?

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