On the benefit of assimilating denser geostationary water vapor radiances

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1. Approaching finer scales for SEVIRI in 4D-Var

Geostationary radiances provide a unique perspective of the dynamics in Earth's atmosphere with a very high spatial (3 km) & temporal (10 min) resolution. Radiances in water vapor bands may represent clear-sky & cloudy pixels of the atmosphere. As severe weather events evolve at these high spatial and temporal scales, a more accurate representation of observations at these time scales may significantly improve the forecast of these events (Figure 1).

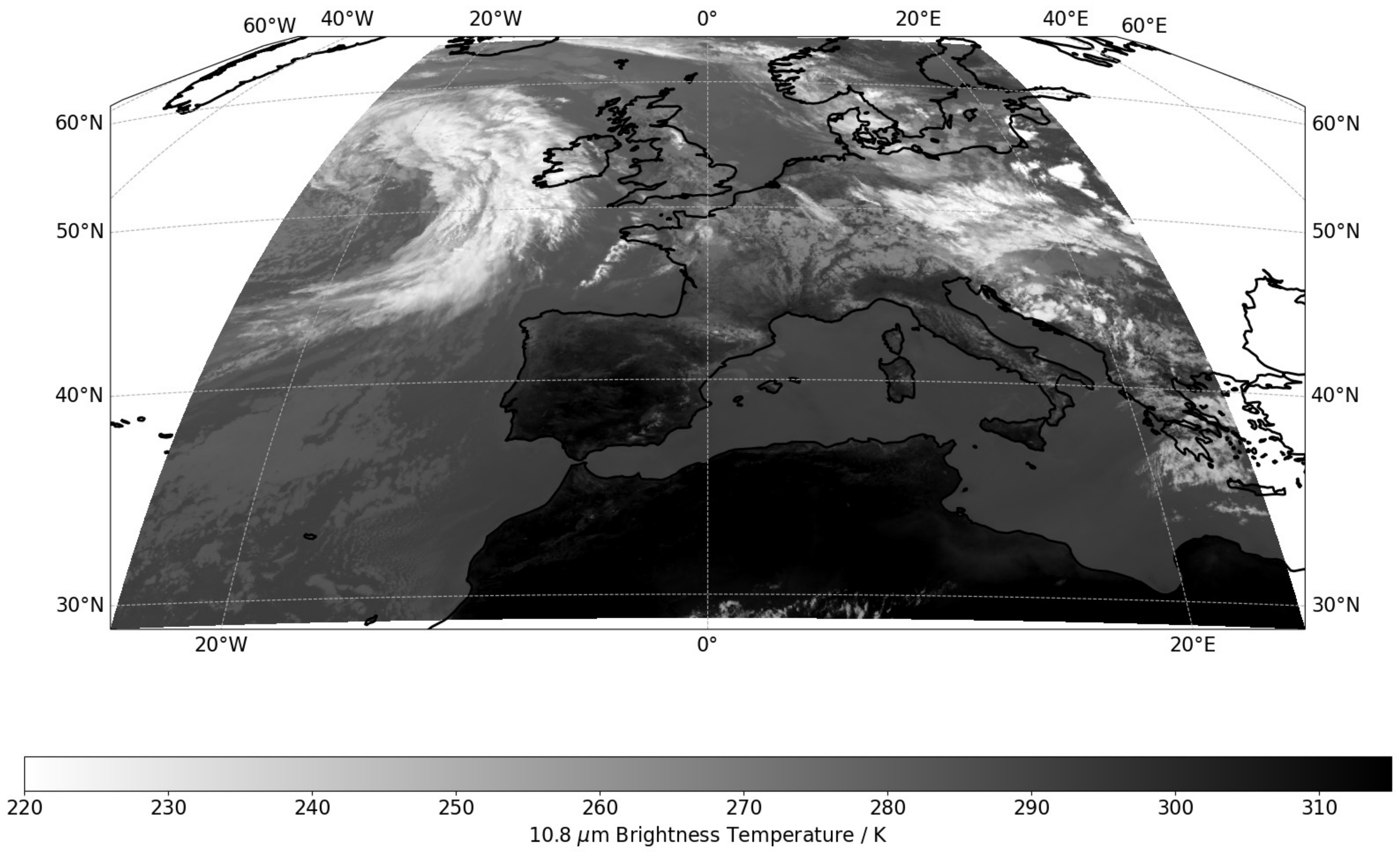

Figure 1) Infrared brightness temperature observations in the 10.8 µm band on 20th of June 2020 above Europe show a low-pressure system over the North Atlantic approaching the UK. This band is currently not assimilated in IFS & has been used to evaluate km-scale experiments for independent verification (Lledó et al. 2022).

2. Effect in comparison to other instruments

We incorporate smaller spatial scales via higher-resolution water-vapor radiances 6.2 µm & 7.3 µm bands (Figure 2). The assimilated radiance is an average over 48 km x 48 km.

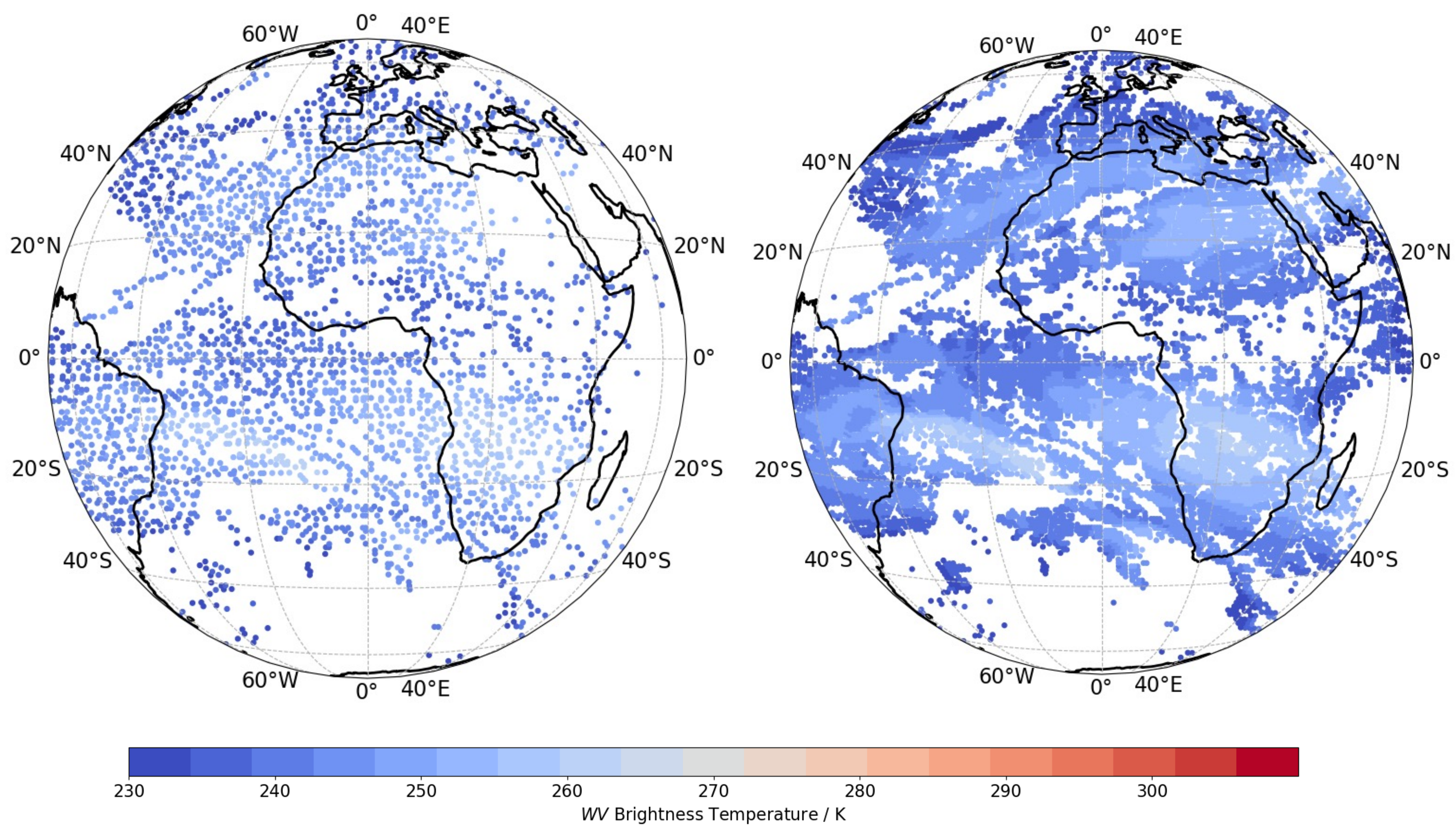

Figure 2) SEVIRI clear-sky radiances spaced at 125 km **(left)** versus 25 km **(right)** on 20th of June 2020 (12 o'clock timeslot).

Generally, a denser set of clear-sky SEVIRI radiances improves the short-range forecasts of humidity sensitive bands as measured by CrIS & ATMS. We find a slight tendency of the conventional wind to improve near 300 hPa. In order to better understand whether the improvements originate from the higher number of observations, or from better resolving their horizontal gradients, we perform experiments with the operational data mesh (125 km) but reduced error variance (Figure 3). The error variance is reduced by a factor of $1/\sqrt{n_{25\ km}/n_{125\ km}}$, taking into account the relative increase in number of observations.

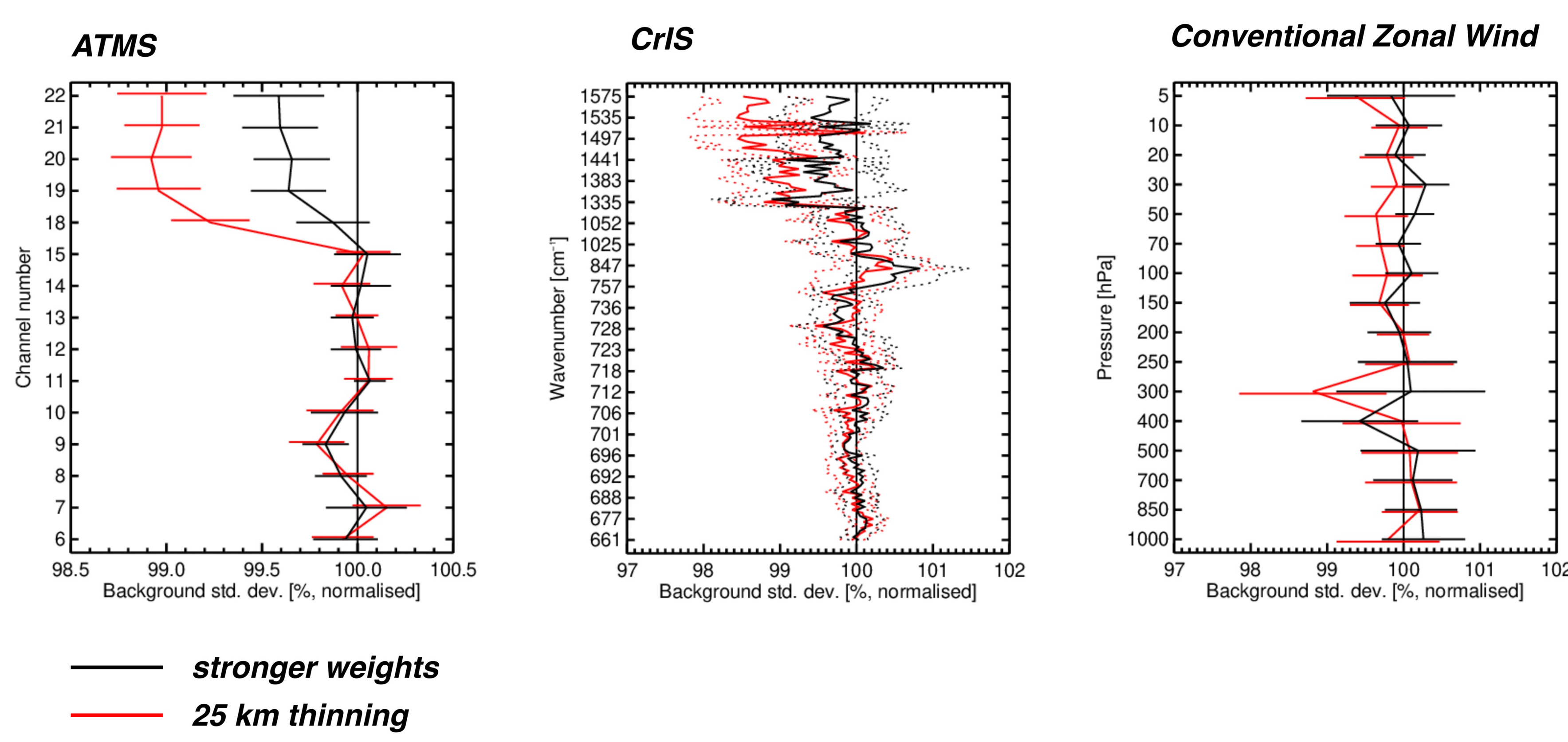

Figure 3) Improvements in ATMS, CrIS, & Conventional Zonal Wind observed quantities occur in comparison the short-range NWP forecasts beyond the impact of changing the observation error, only. The statistical quantities are calculated over the area covered by SEVIRI for 30 days in June 2020.

3. Assimilating higher frequency GOES observations

In a second set of experiments, we investigate the importance of the temporal resolution with the specific aim of improving model winds. The wind field naturally couples spatial and temporal scales through wind tracing (McNally, 2019; Peubey & McNally 2009). Assimilating geostationary radiances at relatively higher temporal resolutions has been explored in the past by Burrows et al. (2020) for GOES-16 data, while keeping the spatial density of assimilated radiances constant. To explore the effect of denser geostationary clear-sky radiances in the assimilation system in combination with a higher temporal resolution of 10 min, we assimilate GOES-16 & GOES-18 radiances in three water vapor bands with adjusted inter-channel error correlations (Figure 4). In these experiments off-diagonal elements are set in the observation error covariance matrix for GOES, specifically taking into account inter-channel error correlations.

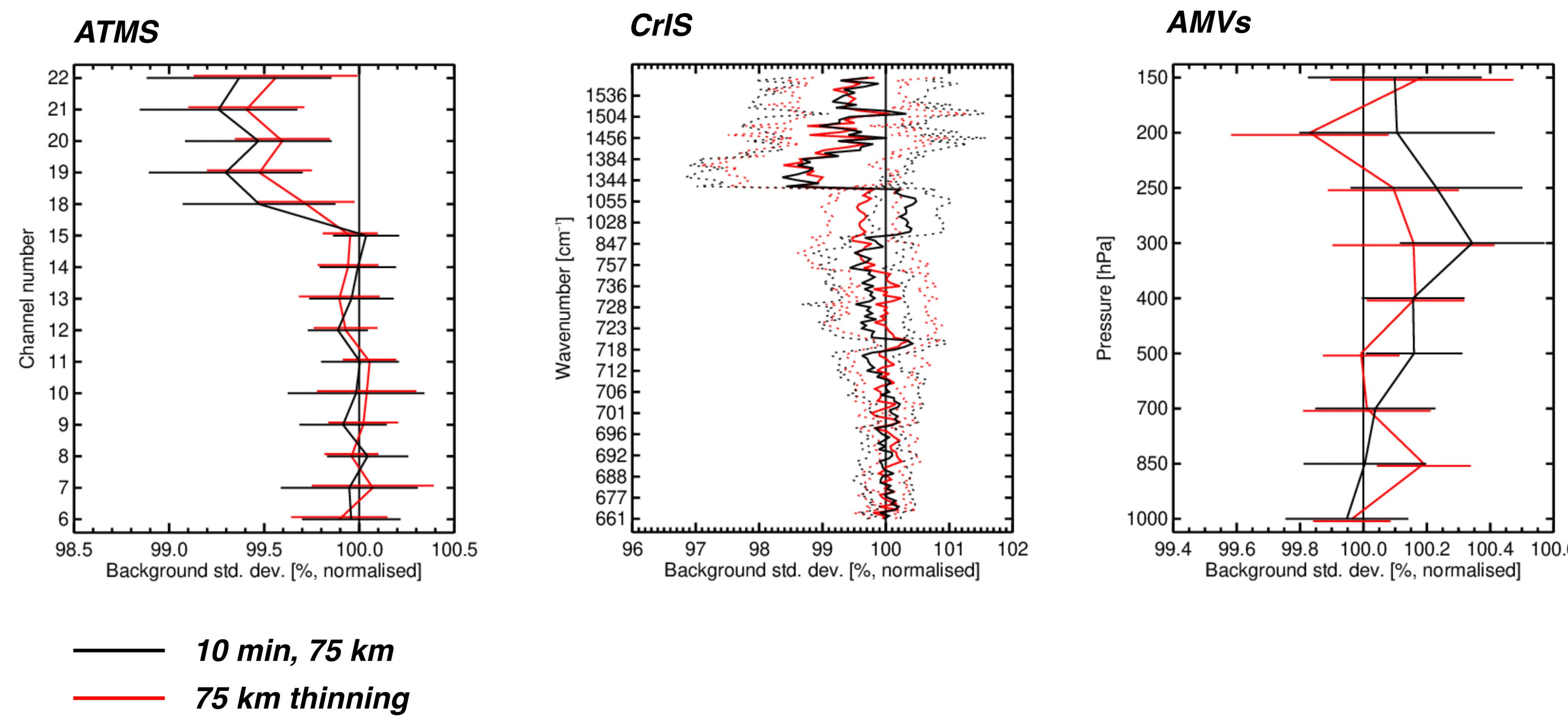

Figure 4) Improvements occur in short-range forecasts of water vapor sensitive model equivalents of ATMS & CrIS observations. The statistical quantities are calculated over the area covered by GOES for 10 days in January 2023.

A major challenge in exploiting this type of high-resolution observations are spatially correlated errors. These errors are known to increase towards smaller spatial scales (Bormann & Bauer, 2010). We provide a comparison between spatially correlated observation errors for METEOSAT SEVIRI & GOES ABI (Figure 5).

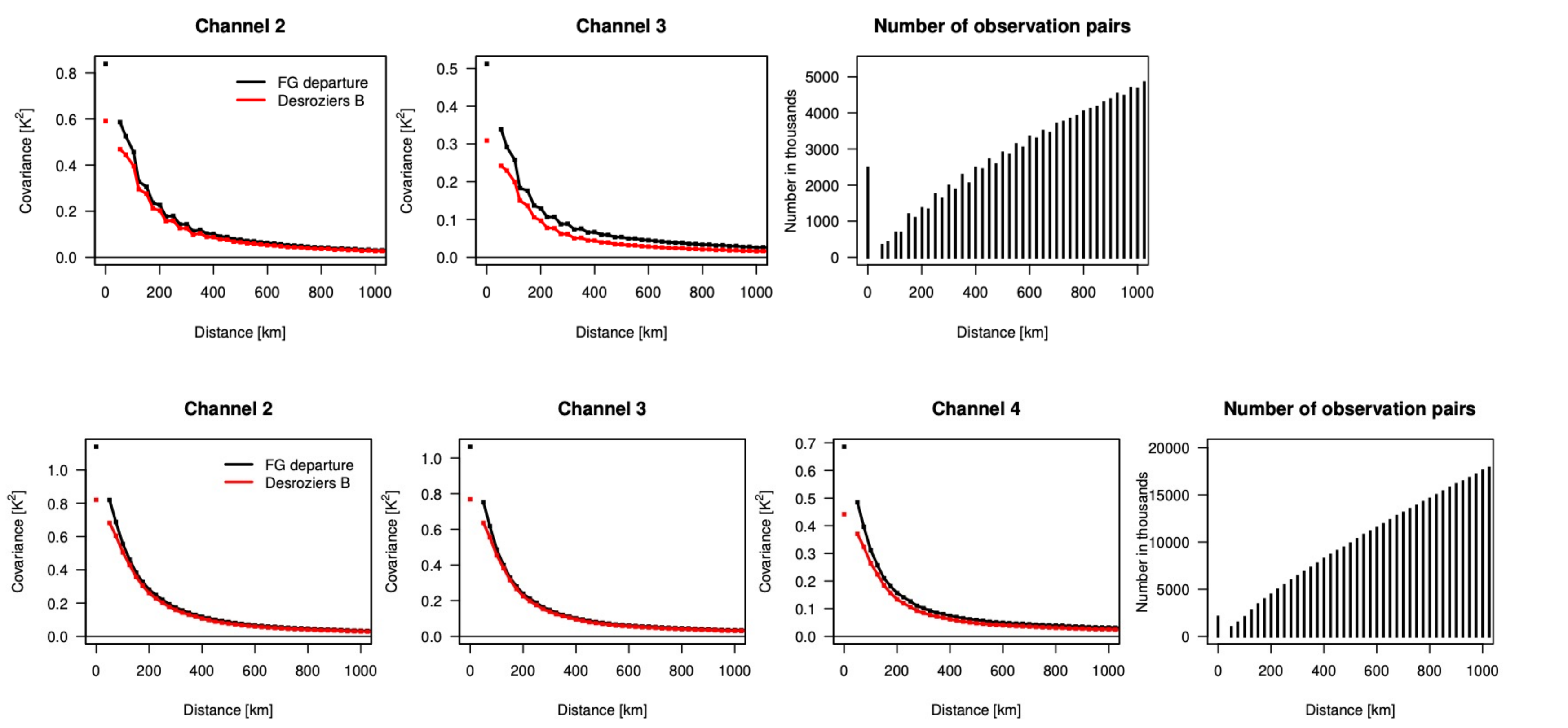

Figure 5) We compare spatially correlated errors of GOES-16 & METEOSAT-11 clear-sky observations. The statistical quantities are calculated over the area covered by SEVIRI **(top)** & GOES **(bottom)** for at least 10 days in a row.

4. Lessons learnt & brief outlook

i. SEVIRI clear-sky radiances are foreseen to be assimilated at 75 km in the next IFS cycle as the finer resolution improves the fit to other instruments in the short-range.
ii. Relatively smaller spatial error correlations for SEVIRI allowed us to assimilate with a spacing of 25 km.
iii. Currently, experiments are run to optimize the spatial sampling for HIMAWARI.
iv. Requirements for assimilating GOES observations at higher frequency, i.e., at 10-min time intervals were changing the observation error covariance matrix, using a 9 km resolution outer loop, as well as finer scale observations at 75 km.
v. For Destination Earth (DestinE), we begin to evaluate how the finer resolution of observations can improve the forecasts of extreme events in the future.

Literature

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