Evaluating DORIS station position seasonal corrections from DPOD2020 v3.0 with geophysical surface displacements from the GGFC

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Context

As one of the tracking systems used for the altimeter missions (such as TOPEX/Poseidon, Envisat, Jason-1/-2/-3, CryoSat-2, Saral/AltiKa, Sentinel-3A/-3B, HY-2A/C/D, Jason-CS/Sentinel-6A, SWOT), the position of the DORIS tracking stations provides a fundamental reference for the estimation of the precise orbits and so, by extension is fundamental for the quality of the altimeter data analysis and derived products. Due to the time evolution of the DORIS ground network, the International DORIS Service maintains the DORIS terrestrial reference frame for Precise Orbit Determination (DPOD) solutions. Since 2016, the DPOD products are computed by the IDS Combination Center (CC) as a DORIS cumulative position and linear velocity solution aligned to the latest available ITRF and using the latest IDS weekly combined series.

Since the release of the second version of DPOD2020, taking advantage of the new capabilities of the CATREF software from IGN, the IDS CC has estimated annual and semi-annual corrections of the DORIS station positions. These DPOD corrections are only determined from the analysis of DORIS coordinate time series. Thus, the DPOD2020 seasonal corrections may differ from the ITRF2020 corrections which are constrained by the GNSS coordinate time series. These differences raise some questions like (i) how these seasonal corrections compare to displacements due to atmosphere, hydrology and non-tidal ocean loading, (ii) are the DPOD2020 and ITRF2020 seasonal correction differences significant with respect to the variability from some of the atmospheric, hydrologic and non-tidal ocean loading models available by the IERS Global Geophysical Fluids Center (GGFC).

- ❑ Since the annual and semi-annual signals are almost negligible on the North and East directions, afterwards, we concentrate on the Up direction.
- ❑ The following maps show the seasonal coefficients by means of (cosine,sine) vectors.

Main Observations and Future Work

The annual signals of the sum of the ERA-5 and MERRA-2 atmospheric and hydrologic models (see Figure 2) shows a very good agreement in both amplitude and phase for almost all the DORIS sites, excepted for site with latitude larger than 45 degrees. These differences may be explained by the snow component.

The comparison of the ITRF2020 and DPOD2020 v3.01 annual signals with the ERA-5 and MERRA-2 ones show an overall good agreement even if we cannot avoid that the ITRF2020 and DPOD2020 annual signals may not be free of some technique-specific contributions. Compared to ITRF2020, larger discrepancies are shown by DPOD2020 with both models in the South Indian ocean around Kerguelen. Nevertheless, the DPOD2020 annual signals look consistent for the nearby stations (Amsterdam, Crozet, and Marion Is). So far, our analysis did not reveal a correlation between neither the observation time span nor the DORIS site configuration (building roof, concrete pedestal or pillar) and the discrepancy of the DPOD2020 v3.01 with both ERA-5 and MERRA-2 models.

From Figure A, we can see that half (resp. 80%) of the annual signals from ITRF2020 and DPOD2020 v3.01 differ in amplitude by less than 0.9 (resp. 1.6) mm and, in phase by less than 30 (resp. 60) degrees.

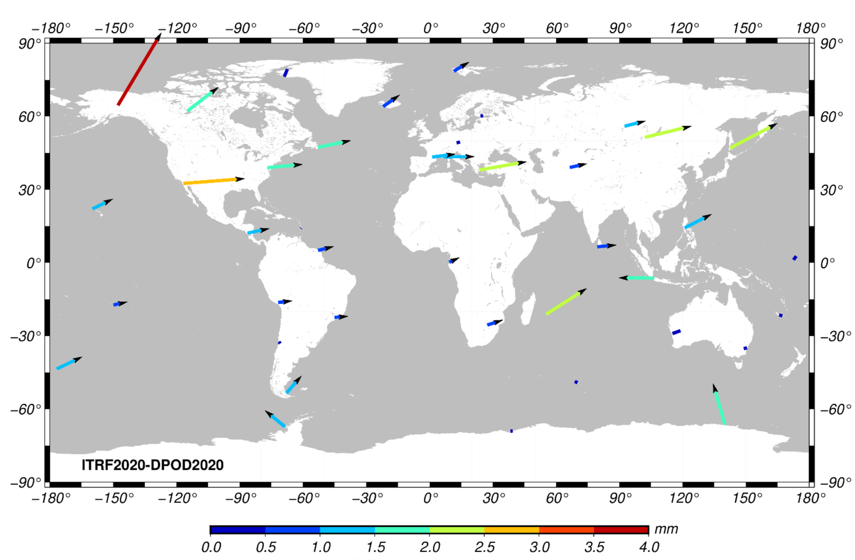

Figure A – Differences between the annual oscillations from ITRF2020 and DPOD2020 of, respectively, Figure 3 and 4.

- The vectors length are equal to the difference of amplitudes between the annual signals.
- The angle of the vector with the equator is equal to the phase shift between the annual signals.

Next, as some DPOD2020 users may prefer to use the ITRF2020 annual signals, especially when computing multi-technique orbits, we will assess the impact of using the ITRF2020 instead of the DPOD2020 v3.01 annual signals on the orbit of the Jason-3 and Sentinel-6A satellites.

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ERA-5 and MERRA-2

Among all the atmospheric and hydrological models available at GGFC, we selected the ERA-5 and MERRA-2 ones for two reasons: 1) both atmospheric and hydrologic components are available and, ii) the time spans of these series fully cover the time observations of the DORIS stations since 1993.0.

Then, from GGFC, we downloaded the ERA-5 and MERRA-2 atmospheric and hydrologic time series expressed in the CF for the 81 DORIS sites of Figure 1 and, for each site, we kept the mid-day estimations between January the 1st following the first observation epoch and the last DORIS observation epoch over the 1993.0-2024.0 time span.

After summing the atmospheric and hydrologic daily series, we estimated the annual and semi-annual coefficients (cosine, sine) of the North, East and Up time series at the 81 DORIS sites.

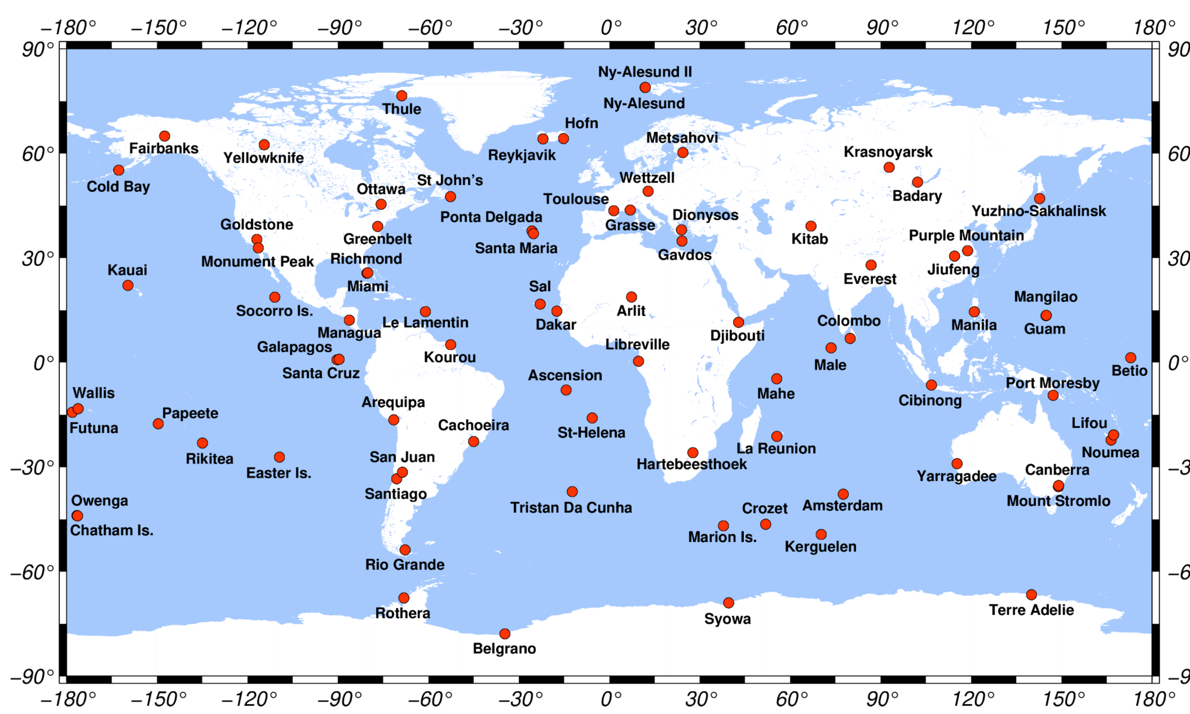

Figure 1 – DORIS sites with ERA-5 and MERRA-2 time series.

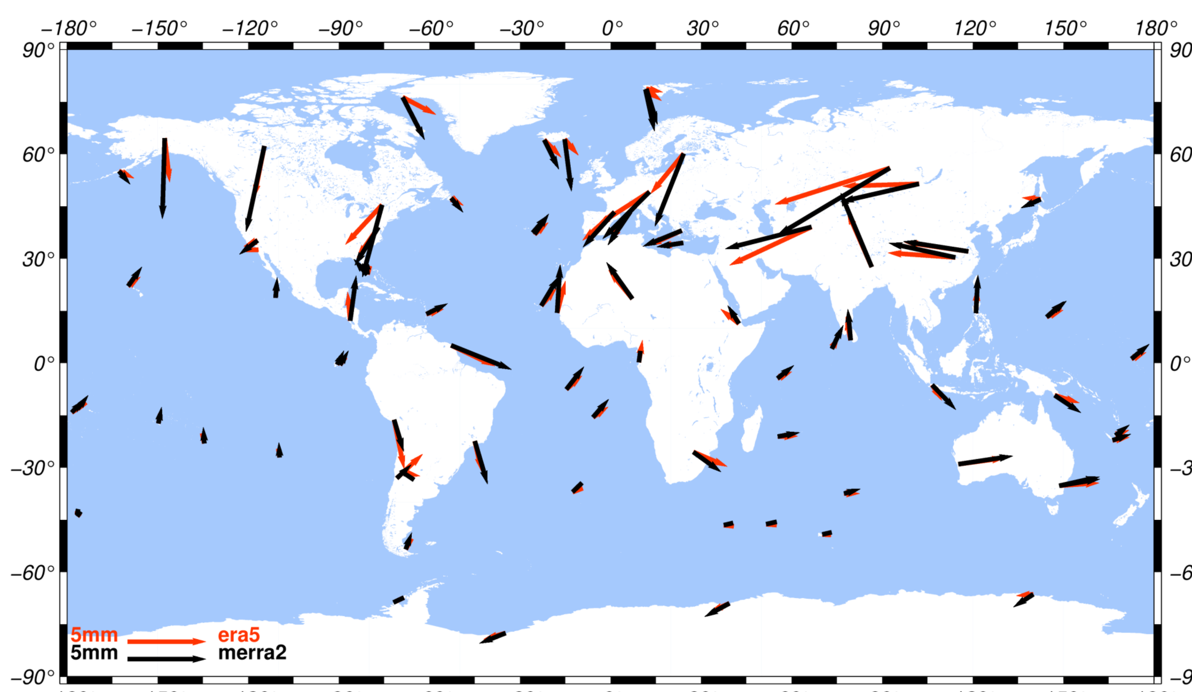

Figure 2 – Amplitudes of annual signals in the Up direction from ERA-5 and MERRA-2.

From Figure 2 which depicts the annual amplitudes from the sum of the atmospheric and hydrologic non-tidal ERA-5 and MERRA-2 time series, we observe:

- ❑ As expected, lower signals for island stations.
- ❑ Similar estimations in both amplitude and phase for almost all the sites, except for most of the sites with latitude larger than 45 degrees, such as in North America, Greenland, Scandinavia and Russia, for which MERRA-2 gives larger amplitudes.

The discrepancies in North America, Greenland, Scandinavia and Russia are explained by differences in the hydrologic time series and come from quite-different snow components between both models.

At the equator, because they do not include surface water, the hydrology models underestimate the seasonal variations.

ITRF2020

In addition to the mean positions and velocities of the DORIS stations operating between 1993.0 and 2021.0, the ITRF2020 solution gives access to annual and semi-annual corrections for the station positions. These seasonal terms (as well as the first 8 GPS draconitics) were estimated (at epoch 2015.0) from the DORIS weekly coordinate time series and constrained to the ones deduced from the co-located GNSS receivers. Moreover, for each site, the seasonal coefficients were constrained to be constant over time.

We only show seasonal coefficients with magnitude larger than two times their associated standard deviation. Thus, over the 87 DORIS sites with seasonal terms, 10 have null coefficients (i.e. due to short time spans) and 43 satisfy the above sigma condition. All of these 43 DORIS sites host at least one co-located GNSS receiver so, the DORIS coefficients may be driven by the GNSS data.

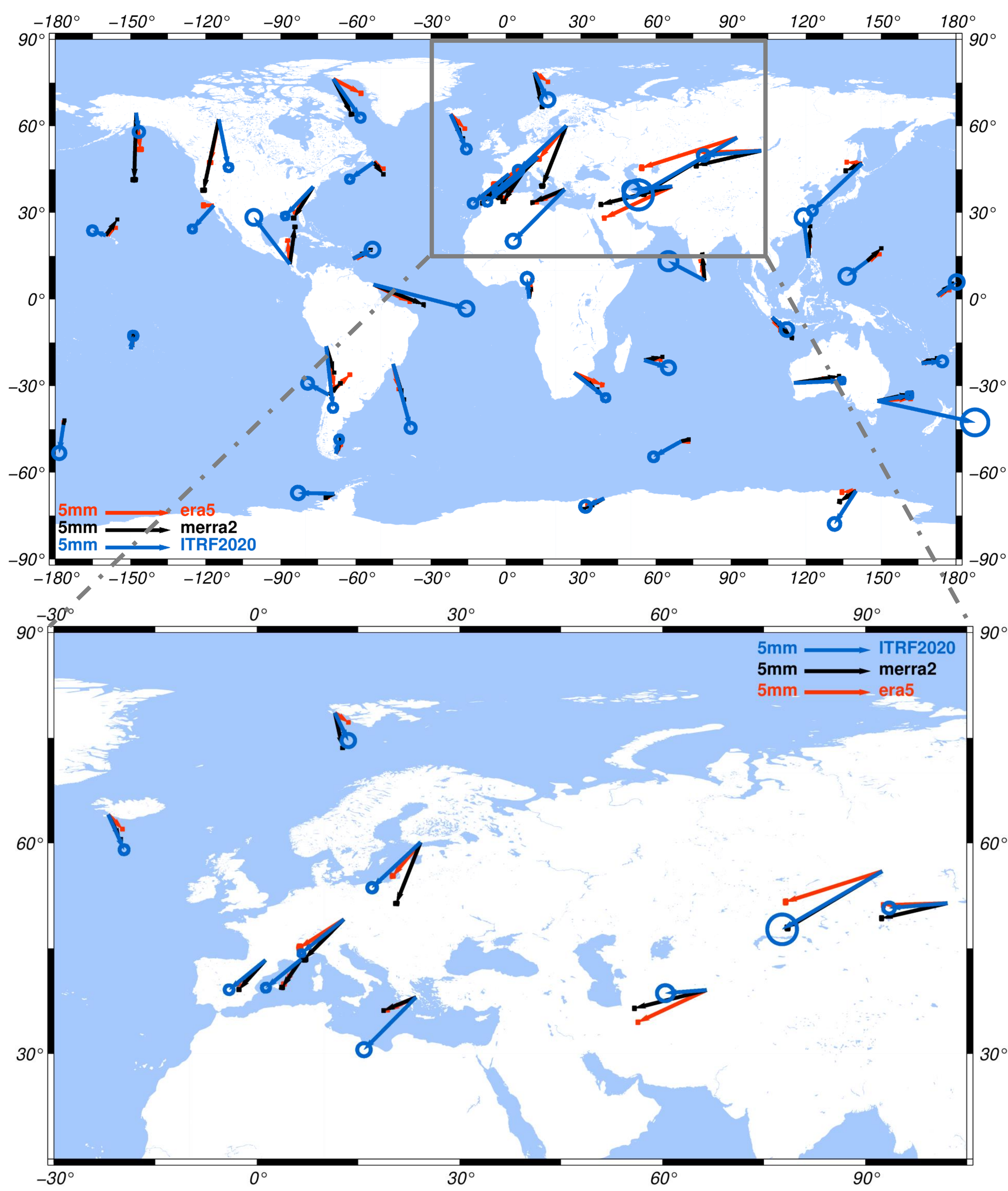

Figure 3 – Amplitudes of annual signals in the Up direction from ITRF2020, ERA-5 and MERRA-2.

From Figure 3 which depicts the annual amplitudes from the ITRF2020 solution, we observe:

- ❑ Lower signals for the island stations. However, we notice discrepancies at Chatham, Kerguelen and Mangilao (for both the DORIS and co-located GNSS stations).
- ❑ Good agreement in phase and amplitude in Australia except for Canberra where no constrain with GNSS seems to have been used.
- ❑ Good agreement in phase with ERA-5 and MERRA-2 in South-America but with larger amplitudes for ITRF2020 at Cachoeira, Kourou and Arequipa (for both the DORIS and co-located GNSS stations) and a different direction at Santiago (for both the DORIS and co-located GNSS stations).
- ❑ Good agreement in amplitude and phase at latitudes larger than 45 degrees, except for Fairbanks, St-John's and Yuzhno-Sakhalinsk (for both the DORIS and co-located GNSS stations).
- ❑ Good agreement in amplitude and phase in Europe, excepted for Dionysos (for both the DORIS and co-located GNSS stations).

DPOD2020 Version 3.01

With the version 3.01 of the DPOD2020 based on the weekly IDS combined solutions from 1993.0 to 2024.0, the IDS CC computed annual and semi-annuals (as well as first two draconitics of the Jason satellites, i.e. 118 and 59 days) station position corrections for the DORIS sites with more than 2.5 years of observations. Furthermore, due to the higher scatter of the DORIS coordinate time series before mid-2002 (observations realized with receivers only able to track one beacon at a time), we did not estimate the periodic corrections for the DORIS sites with only observations before mid-2002. Like the ITRF2020, we constrained the periodic coefficients to be constant over time at each site. Keep in mind that the DPOD2020 periodic coefficients are only deduced from DORIS observations.

We only show seasonal coefficients with magnitude larger than two times their associated standard deviation.

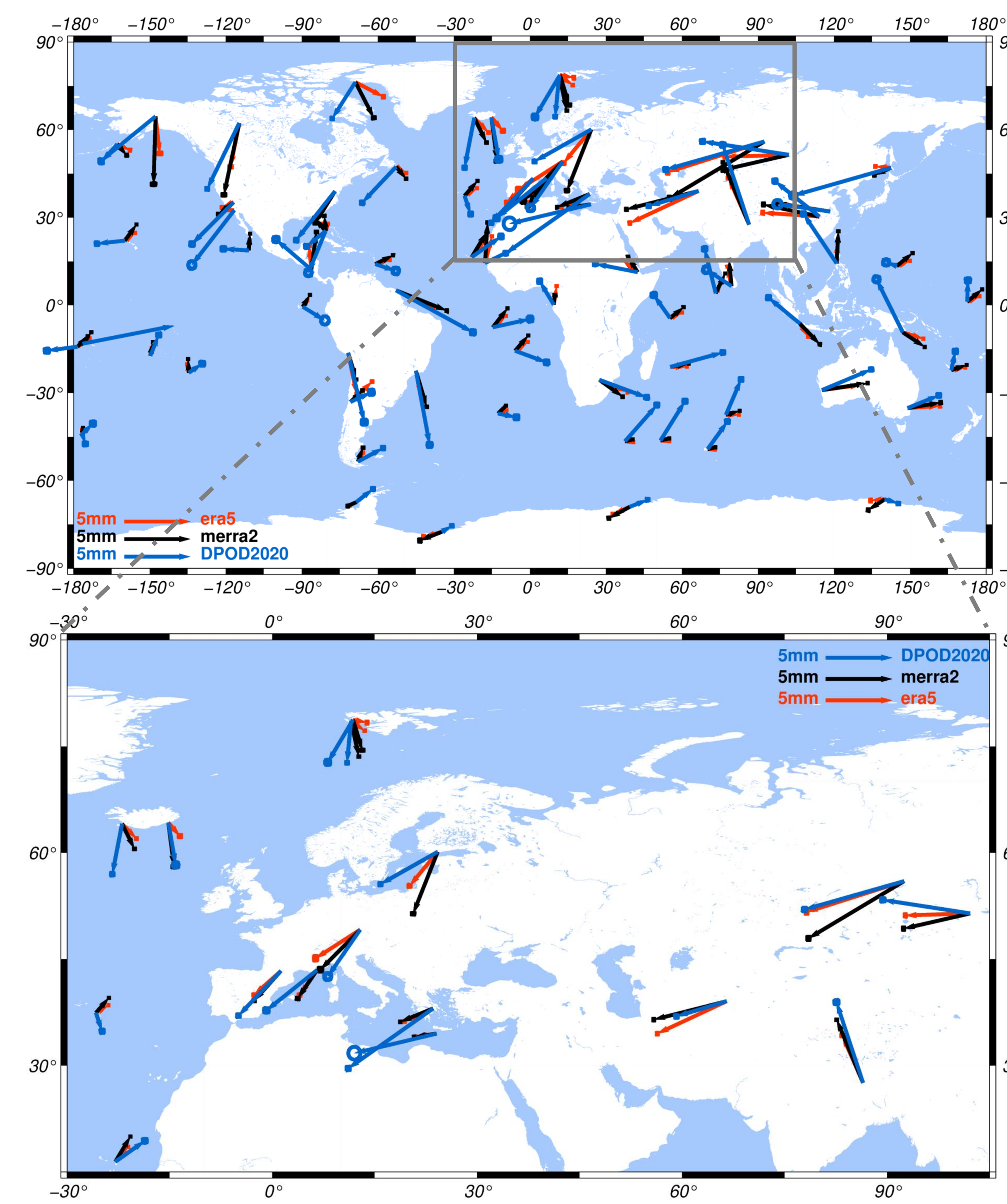

Figure 4 – Amplitudes of annual signals in the Up direction from DPOD2020 v3.01, ERA-5 and MERRA-2.

From Figure 4 which depicts the annual amplitudes from the DPOD2020 v3.01 solution, we observe:

- ❑ Lower signals for the island stations. However, like ITRF2020, we see discrepancies with ERA-5 and MERRA-2 but internal consistencies at Kerguelen and nearby islands (Amseterdam, Croze and Marion Island) in the Indian ocean.
- ❑ Good agreement in phase and amplitude in Australia.
- ❑ Like ITRF2020, good agreement in phase with ERA-5 and MERRA-2 in South-America but with larger amplitudes for DPOD2020. Unlike ITRF2020, DPOD2020 shows a good agreement in amplitude and phase with both models at Santiago.
- ❑ Good agreement in amplitude and phase at latitudes larger than 45 degrees, except for Fairbanks, St-John's and Yuzhno-Sakhalinsk. Note that the DPOD2020 annual amplitude agrees well at Höfn with MERRA-2 which shows a different amplitude at Reykjavik.
- ❑ Good agreement in amplitude and phase in Europe and Central Asia, except for Dionysos and Gavdos where we get larger amplitudes compared to both models.