Impact of the 1D sea-ice model GELATO in the global model ARPEGE.

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1 Introduction.

In the global model ARPEGE, used in operations for numerical weather prediction (NWP) at Météo-France the sea-ice representation is still very simple. There is no specific model activated and the temperature over the sea-ice, which remains constant over the forecast, is based on a climatology. With the recent introduction of the SURFEXv8 (July 2019) platform in the Météo-France system, the use of the GELATO-1d sea ice model (Salas y Mélia, 2002) in the ARPEGE NWP became possible. Several technical modifications were necessary in the surface assimilation to ensure a coherent treatment between observations of sea-surface temperature, sea-ice fraction and new prognostic variables of GELATO.

Within the APPLICATE project and the Year Of Polar Prediction (YOPP) program, the coupling of the sea-ice model has been evaluated first with the "previous" operational configuration of ARPEGE T1198c2.2L105 (high resolution over Europe 7.5km) for the two Special Observing Periods (SOP) and with the denied YOPP-SH experiment done with the 4DVar ARPEGE-SH (high resolution area over Antarctica 7.5km) for the SOP3 (15 Nov. 2018 - 15 Feb. 2019).

The evaluation is achieved in the current operational configuration of ARPEGE T1798c2.2L105.

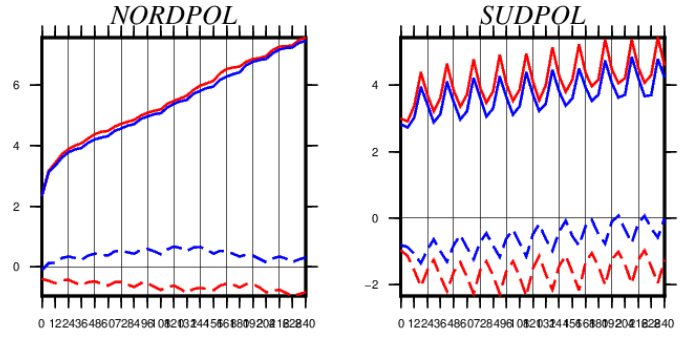

Figure 1: *YOPP-SH SOP3 ARPEGE-SH with GELATO (blue) versus ARPEGE-SH (red). Full line: RMS, dashed line: bias. 60 Forecasts: 10 days lead time*

2 The GELATO-1d model

GELATO-1d is a sea-ice model implemented in the SURFEX platform. It is the 1d version of GELATO 6, the sea-ice component of the CNRM-CM6-1 global coupled climate model (Voldoire et al., 2019). Only one category of ice is considered and no horizontal processes are represented.

The model considers 10 layers of ice of equal thickness characterized by their enthalpy and one possible layer of snow covering the ice. The ice fraction per grid cell is constant throughout the forecast and is updated at each analysis (6h) through a weighting of 10% toward the SAF-OSI product. The SST, which corresponds both to the lower condition of the sea-ice slab and the skin temperature of the ice free fraction of the cell, is also constant and follows the OSTIA product.

The surface temperature of the cell is then calculated by weighting the SST and the sea ice temperature calculated by GELATO using the sea-ice fraction.

3 Evaluation during the YOPP period

The coupling between the GELATO-1d sea-ice model and ARPEGE has been evaluated with the operational configuration used in 2018 for the YOPP SOP1 and SOP2 period. In addition, two 4Dvar with the ARPEGE-SH configuration (with and without GELATO) have been performed for the YOPP-SH SOP3. The results for the three SOPs are rather similar with a clear warmer sea-ice surface temperature with a positive impact in the boundary layer over the North and South Pole ($|lat| > 60$). Figure 1 shows clearly the improvement of the T2M for the North and the South Pole, the improvement is more significant in Antarctica with more stations along the coast where the sea-ice fraction is non-zero.

For the Emma station in the Ross Ice Shelf area (Fig. 2), the impact of GELATO on the T2M is also very positive and follows the observed values well, except at the end of January by missing the cold event.

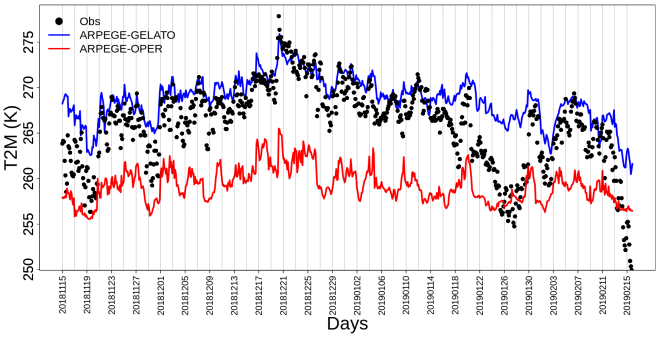

Figure 2: *T2M for the Emma Station (Lat:-84, Lon:-175.01). YOPP-SH SOP3 period (15/11/2018-15/02/2019) with ARPEGE-YOPP-SH*

4 Evaluation in the operational configuration

An ARPEGE 4DVar e-suite in T1798L105 (5.5km over Europe) with GELATO has begun the 1st Dec. 2019 with some specific output for the MOSAIC field ex-

periment (https://mosaic-expedition.org/). Figure 3 illustrates the impact of GELATO on the temperature compared to the ECMWF operational analysis considering normalized RMS calculated with 68 forecast from 15 Jan. 2020 to 26 Mar. 2020 Blue lines mean positive impact (%). For the North Pole, the improvement is really significant with a RMS error reduced by 30% below 700hPa. To a lesser extent, the temperatures are also improved over the Antarctic region (Fig. 3) and no clear impact is seen in the tropics (not shown).

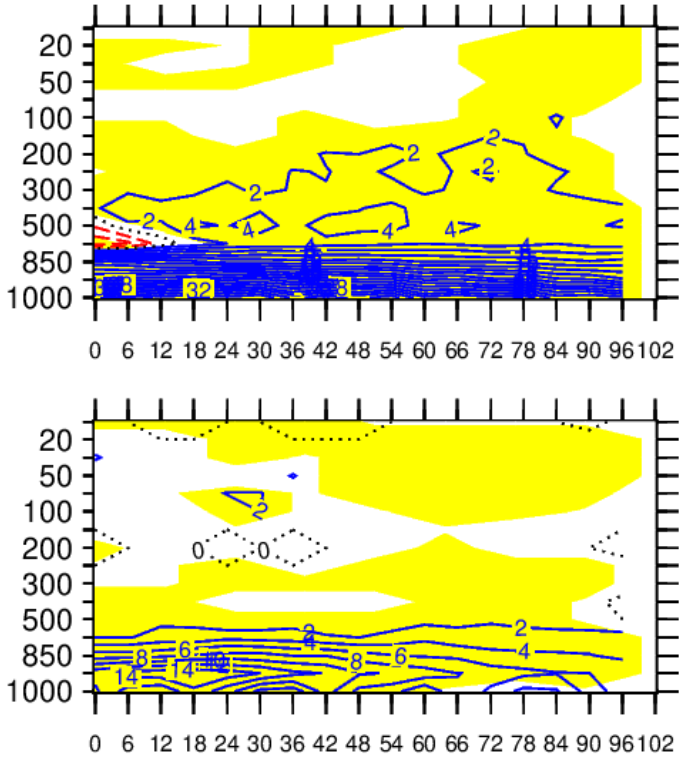

Figure 3: *Impact of the GELATO experiment for the temperature against ECMWF analysis for 20200115-20200326. Blue line: positive impact. X-Axis: lead time (h). Y-Axis: vertical (hPa). Top: North Pole. Bottom: South Pole.*

Thanks to the MOSAiC expedition, a comparison of the T2M is done for the Polarstern track between the 1st Dec. 2019 and 15th Mar. 2020 for the 24h forecast (Fig. 4). This comparison shows clearly the positive impact of the sea-ice model, especially now, the new system is able to follow quite well the warm-cold jump of the T2M seen in observation. However, a warm bias exists (Fig. 2 and 4) notably at the beginning of the period which may be due to an underestimation of the ice/snow thickness or an overestimation of cloud cover. This issue is still under investigation. Figure 5 shows the large impact of the sea-ice model on the T2M for all the area, also seen in Fig. 3 with a warmer boundary layer. During this period (19-21 Feb. 2020), the signature of the warm and moist air advection can be seen only in the ARPEGE-GELATO system.

5 Conclusions and perspectives

The coupling of the sea-ice model with the ARPEGE global NWP system has a significant positive impact in the polar regions and over North America. Over Europe (not shown) the improvement is less with a reduction of the temperature RMS by about 4 %. Nowadays, sea-ice thickness observations become available almost in real time and can probably be used in the near future in the sea-ice surface analysis. In addition, thanks to a better sea-ice surface temperature, new satellite channels might be assimilated in Polar Regions. This update will be used in operations beginning of 2021.

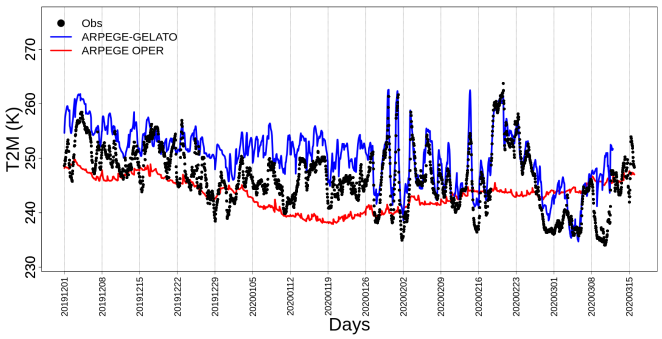

Figure 4: *MOSAIC expedition. T2M from the German icebreaker Polarstern (black). ARPEGE Ref: red. ARPEGE with the sea-ice model: blue.*

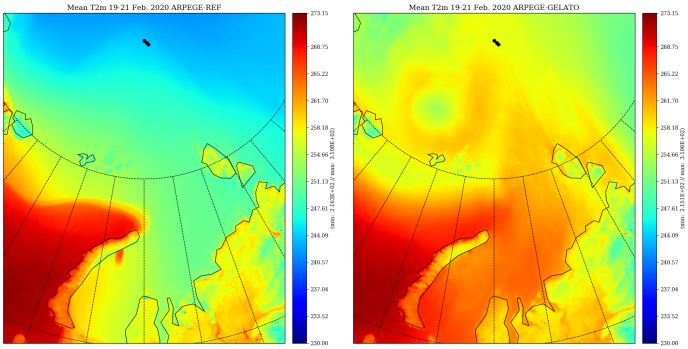

Figure 5: *Mean T2m for 19-20-21 Feb. 2020. Left: ARPEGE Ref. Right: ARPEGE with the sea-ice model. Black dot: Polarstern position for those dates.*

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