

Appendix D : Analysis of difference in marine emission strength in fully-coupled and atmosphere-only simulations

Dirk Olivié

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Abstract

Natural marine emission strengths are underestimated in the atmosphere-only simulations compared to the fully-coupled simulations. The marine emissions accounted for in NorESM2 are sea-salt, POM, and DMS. We attribute this difference partially to an underestimation of the near-surface (10 m) wind.

1 Main findings

1. The difference seen in monthly mean U_{10m} seems to explain large parts of the difference in marine emissions strengths between the fully-coupled and the atmosphere-only simulations. This is the case for emissions of sea-salt, POM, and DMS.
2. For the DMS emission strength, the flux=1& Δ DMS approach for the atmosphere-only simulations gives the best agreement with the fully-coupled simulations. The remaining difference in DMS emission strength correlate well with the difference in $(U_{10m})^{3.74}$.
3. The difference in monthly U_{10m} fields does not completely explain the difference in monthly emission strength. Possibly variations on shorter timescales the a month (weekly, daily, hourly) might contribute to this bias.
4. The fully-coupled simulations seems to allow still some sea-salt and POM emissions when the ocean is ice-covered, whereas emissions in the atmosphere-only simulations seem to be 0 (DJF in the Arctc, JJA in the Antarctic).

2 Introduction

Natural marine emissions of DMS, POM, and sea-salt seem to be consistently lower in the atmosphere-only simulations compared with the fully-coupled ones. Here we try to give some explanation for this phenomenon.

Although global- and annual mean differences in the near-surface (10 m) wind seem to be small, the regional differences might explain large parts of the lower marine aerosol emissions in the atmosphere-only simulations.

Table 1 gives an overview of the existing fully-coupled and atmosphere-only simulations which can be compared. We concentrate here on the 2°x2° piControl (fully-coupled) and piClim-control (atmosphere-only) simulation. We assume that the conclusions are also valid for the other atmosphere-only simulations.

Table 1: Overview of the experiments and periods used in the evaluation.

Resolution	Years	Fully coupled	Atmosphere-only		
			flux=0	flux=1	flux=1& Δ DMS
2°x2°	1751–1780	piControl	piClim-control	piClim-control	piClim-control
1°x1°	1351–1380	piControl	–	piClim-control	–
2°x2°	1850–1879	historical	histSST	histSST	–
2°x2°	1985–2014	historical	histSST	histSST	–
2°x2°	2071–2100	ssp370	–	ssp370SST	–

We analyse here the differences in marine emissions and near-surface (10 m) wind between the fully-coupled and atmosphere-only simulations. For the piControl/piClim-control combinations, we look at the period on which the SST, sea-ice and DMS climatologies are based, i.e., year 1751–1780 for *2circx2circ*.

3 Emission parameterisations

The sea-salt emissions (E_{ss}) have a dependence on the wind speed

$$E_{ss} \sim (U_{10m})^{3.74}. \quad (1)$$

The POM emissions have the same dependence on the wind speed. However, the emission strength is also proportional to the POM concentration in sea-water C_{POM} , which is given as a climatology. This climatology is the same in the coupled and fSST simulations. The emission strength of the POM emissions (E_{POM}) can be written as

$$E_{POM} \sim C_{OM} (U_{10m})^{3.74}. \quad (2)$$

The DMS emissions (E_{DMS}) have a quadratic dependence on the wind speed, a slight dependence on the temperature, and a dependence on the DMS upper ocean concentration (C_{DMS}). The emission strength can be written as

$$E_{DMS} \sim C_{DMS} (U_{10m})^2. \quad (3)$$

In the coupled simulations, C_DMS is calculated by iHAMOCC, whereas in the fSST simulations C_DMS is a climatology (based on the coupled results).

4 Results

Wind at 10 m Figure 1 shows the wind in the coupled and fSST experiments, for DJF and JJA. The relative difference plot indicates that differences are almost everywhere smaller than 5%. There is possibly a systematic underestimation in the atmosphere-only simulations in the 30°N-60°N region in DJF, and in the 60°S-30°S region both in DJF and JJA.

Sea-salt emissions Figure 2 shows the sea-salt emissions in the coupled and fSST experiments, for DJF and JJA.

In the Arctic in DJF, the sea-salt emission in the atmosphere-only simulation are probably exactly 0, whereas they are non-zero in the fully-coupled simulations.

The pattern seen for the relative difference in sea-salt emissions and in $(U_{10m})^{3.74}$ are rather similar.

Organic matter emissions Figure 3 shows the surface organic matter emissions in the coupled and fSST experiments, for DJF and JJA. These are the emissions which happen in the lowest layer of the model. There are also POM emissions which have a profile, but those are not included in the figures here. E.g., shipping emissions and biomass burning emissions have an emission profile, and are therefore not represented in these figures.

One contribution of the surface POM emissions comes from the ocean.

Similar to seasalt, POM emissions in the Arctic in DJF in the atmosphere-only simulations seem to be 0, whereas there is still some emission happening in the fully-coupled simulations. A same feature is visible around the Antarctic in JJA.

The relative difference in $(U_{10m})^{3.74}$ seems to correspond reasonably well with the relative difference pattern in POM emissions.

DMS emissions [flux=1] Figure 4 shows the DMS emissions in the coupled and flux=1 fSST experiments, for DJF and JJA.

DMS emissions [flux=1 & ΔDMS] Figure 5 shows the DMS emissions in the coupled and flux=1&ΔDMS fSST experiments, for DJF and JJA. The relative difference in DMS emission strength seems to correlate better with the relative difference in U_{10m}^2 in flux=1&ΔDMS than in flux=1 (see Fig. 4).

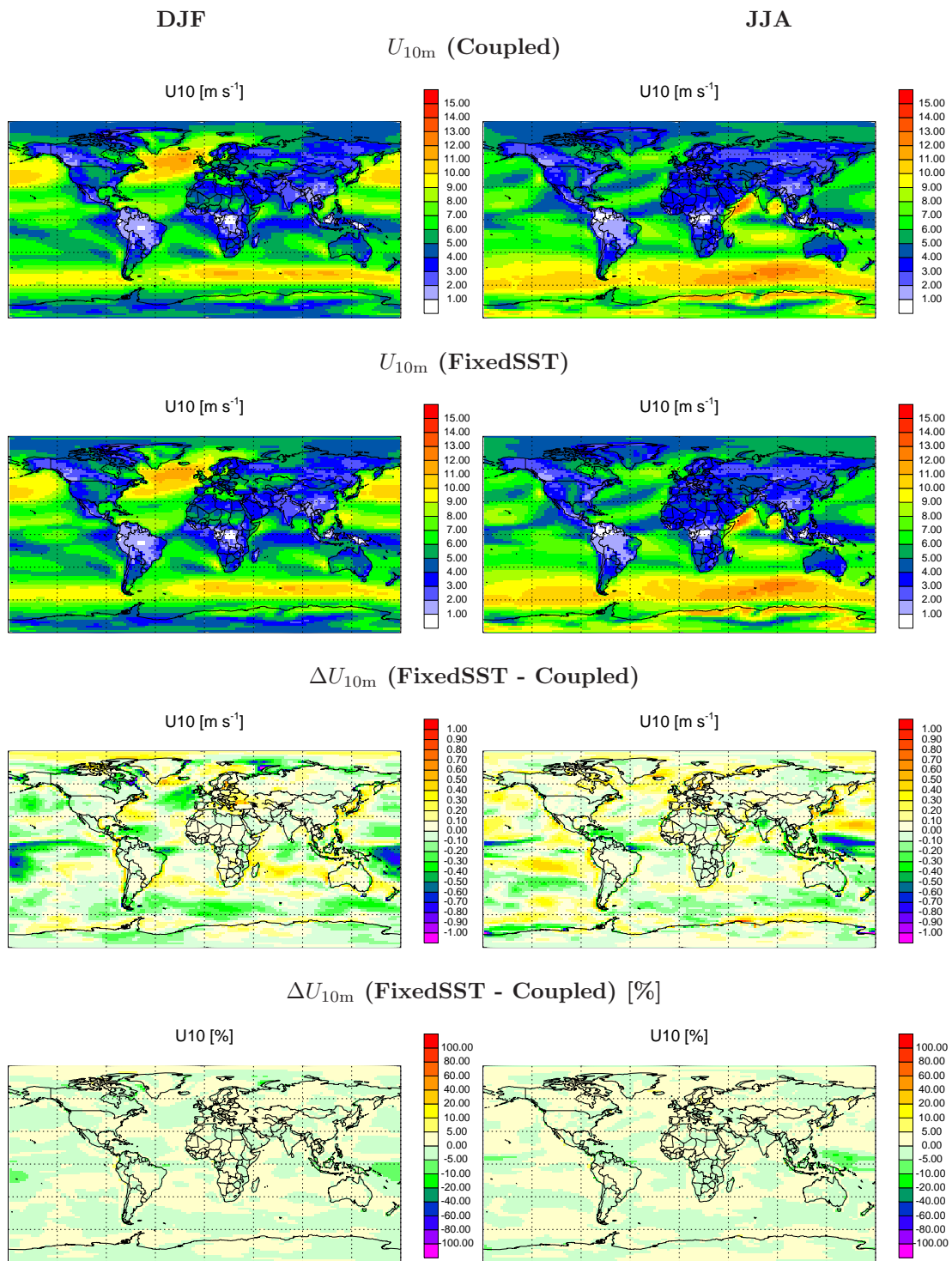


Figure 1: Wind strength (at 10m height) in DJF (left) and JJA (right) : fully-coupled simulation (top row), atmosphere-only simulation (second row), difference between atmosphere-only and fully-coupled (3rd row), and relative difference between atmosphere-only and fully-coupled.

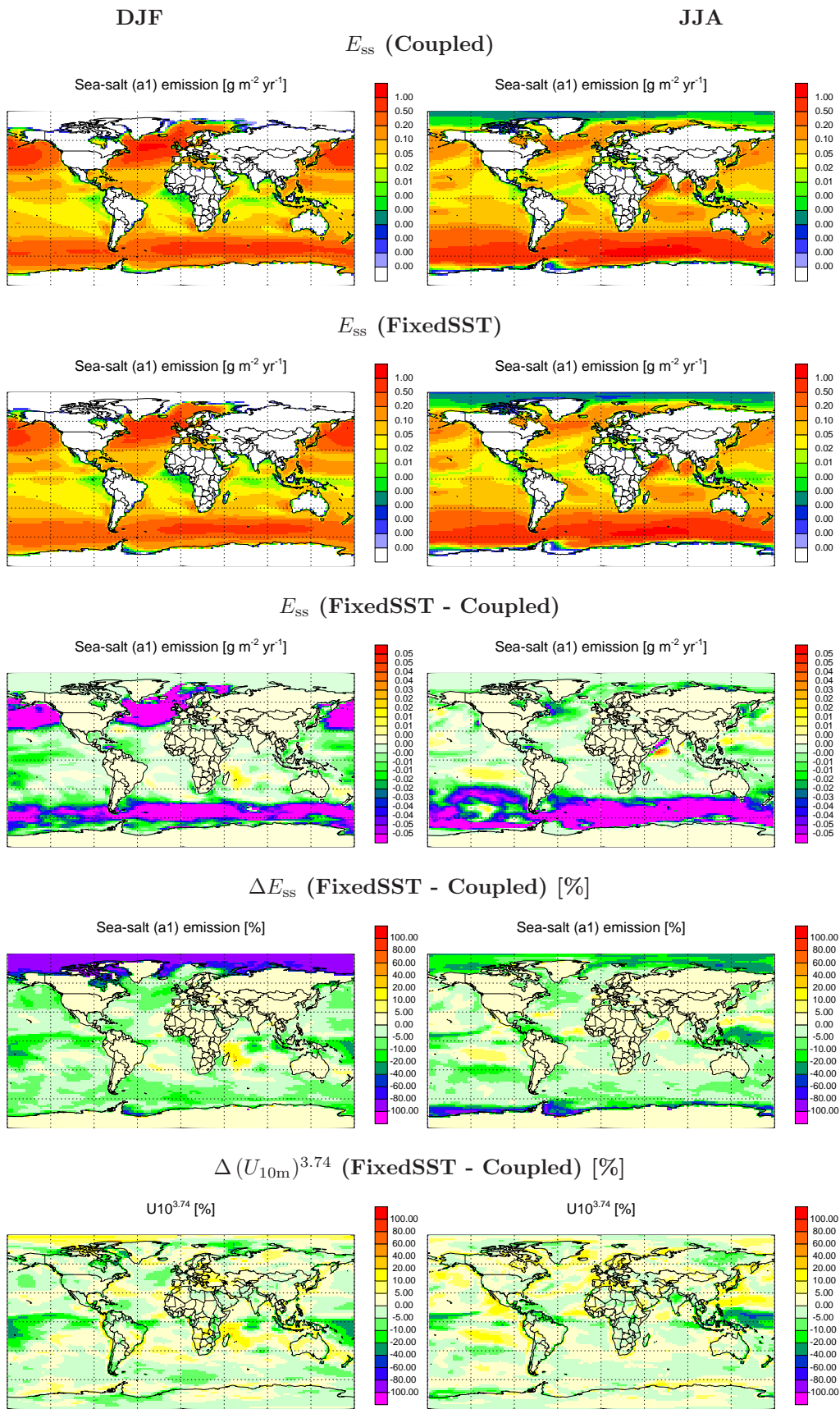


Figure 2: Sea-salt emission in DJF (left) and JJA (right) : fully-coupled simulation (top row), atmosphere-only simulation (second row), difference between atmosphere-only and fully-coupled (3rd row), and relative difference (4th row). The relative difference in $(U_{10m})^{3.74}$ is shown in the bottom row.

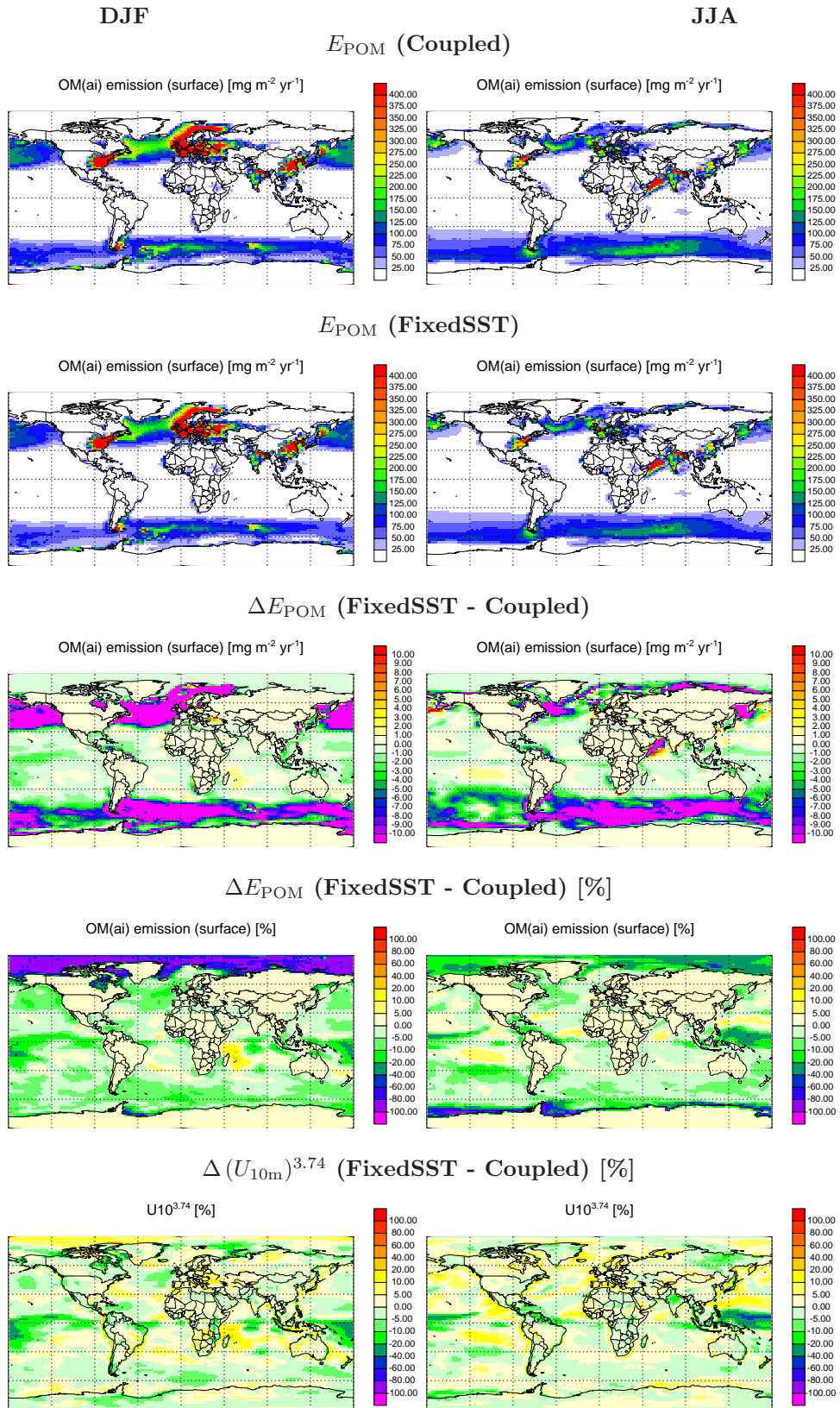


Figure 3: Organic matter emission strength in DJF (left) and JJA (right) : coupled simulation (top row), fSST simulation (second row), difference between fSST and coupled (3rd row), and relative difference between fSST and coupled.

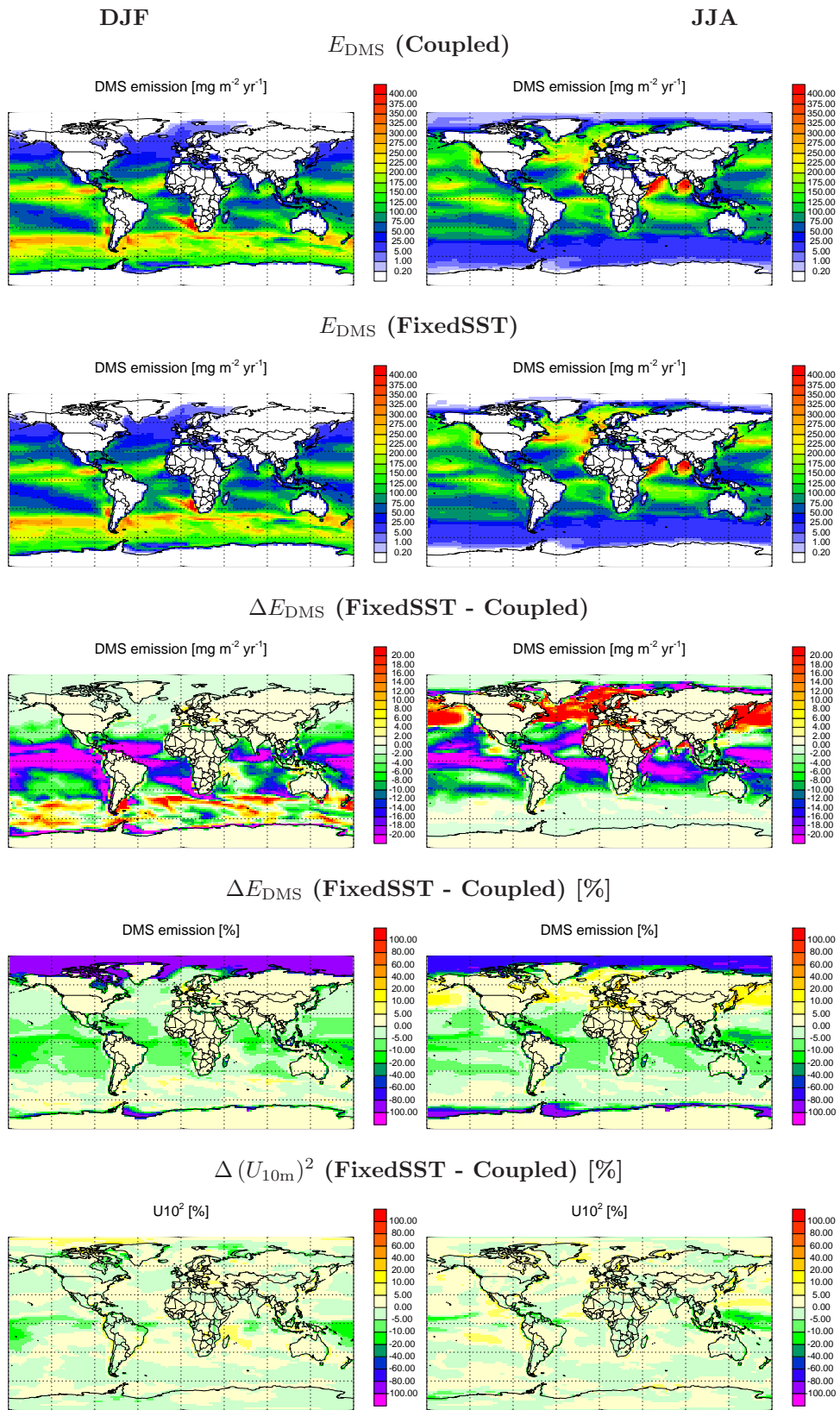


Figure 4: DMS emission strength in DJF (left) and JJA (right) : coupled simulation (top row), fSST simulation (second row), difference between fSST and coupled (3rd row), and relative difference between fSST and coupled.

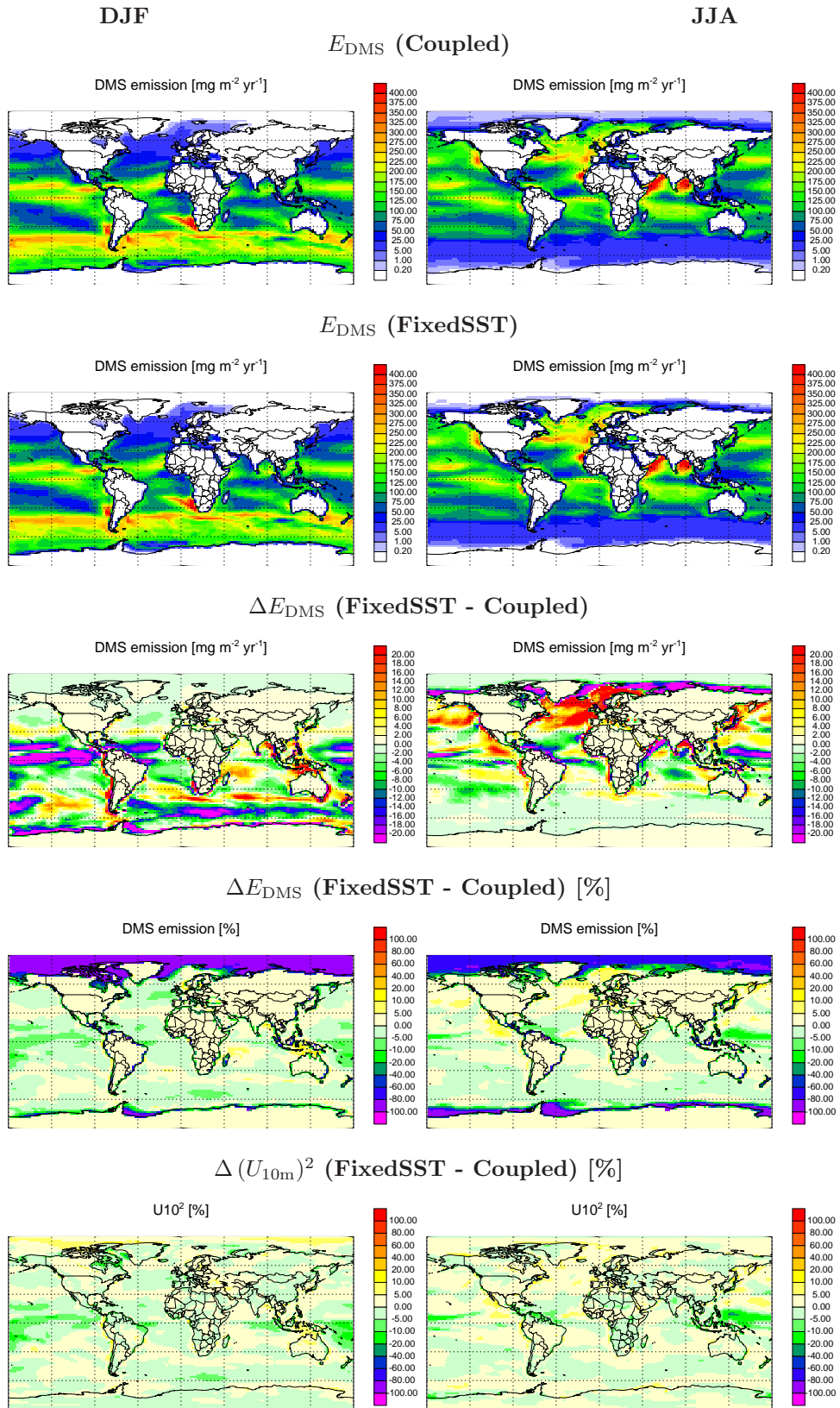


Figure 5: DMS emission strength in DJF (left) and JJA (right) in the flux=1& Δ DMS setup : coupled simulation (top row), fsST simulation (second row), difference between fsST and coupled (3rd row), and relative difference between fsST and coupled.

5 Discussion and conclusions

We did not try to attribute any bias to the temperature as the temperature dependence of the the emission strength is rather low.