A comparison of surface fluxes between atmosphere and ocean using coupled and uncoupled air-sea interaction model

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Abstract: Air-sea interaction in the Mediterranean area was analyzed using a two-way coupled atmosphere-ocean model. The length of simulation was one year (2002). The main topic was the verification of the surface fluxes, which come from the atmospheric part of the coupled model. This will presumably result in good prediction of SST. So the verification of the surface fluxes is done indirectly through the comparison between, area averages for the whole Mediterranean sea of the observed and simulated SST. Beside the verification of SST we looked in the verification of precipitation for a limited area where we had the precipitation data. The area is part of Serbia and Montenegro covering most of Serbia. Data was diurnal accumulated precipitation. Differences in precipitation between the coupled and the uncoupled integrations were small with slightly larger error for the uncoupled model. Differences were concentrated over the June, July and August period. During that period the SST in the uncoupled model was higher which led to larger latent heat fluxes and eventually to larger precipitations.

Keywords: Sea surface temperature (SST), energy fluxes, momentum flux, precipitation

1 Introduction

Starting with the climate modeling the air-sea interaction was introduced as the basic factor in the large scale and longer term simulations. With introduction of regional climate modeling, scales, spatial, have been reduced but still remained large in the time domain. Because of that there is a need for air sea interaction as well. Finally with the extension of weather forecast periods beyond 5-7 days the air sea interaction found its place in the models for weather prediction.

Almost all larger weather prediction centers now do long term predictions from 10 days to month or even season. Is it possible to embed limited area model who will get boundary conditions from such long term runs ? To approach such problem we have created coupled air sea interaction model for a limited area, by coupling NCEP mesoscale atmospheric model [3], [4], [5] , [6], [7], [1], as the atmospheric component with POM (Princeton Ocean Model) [2], [8] as the ocean component.

How good is such model depends on the success of the coupling, which means how good are fluxes of energy and momentum that are exchanged between the two components of the model. That is not so easy to verify against direct observations so one can look at the SST as a variable most directly dependent on these exchanges.

Beside the verification of SST verification of precipitation, over a certain area, could be another measure of the quality of the coupled model. Our area of verification was a sub domain of Serbia and Montenegro.

2 Model setup and boundary conditions

Air-sea interaction in the Mediterranean area was analyzed using a two-way coupled atmosphere-ocean model. The length of simulation was one

Table 1: Energy and momentum fluxes. Column (b) our results, column (c) numbers from Angelucci et.al. [9]

(a)	(b)	(c)
Flux	$Watt's/m^2$	Angelucci et.al.
Short wave	204	206
Long wave	86	80
Sensible heat	12	13
Latent heat	73	91
Net	33	22

year (2002). It is important to emphasize that the run was uninterrupted for whole year, which means: start with a single initial field for both, the atmosphere and the ocean, and then only do updating at the boundaries. The ocean part was initialized from the MODB data set, which is monthly climatology of the Mediterranean sea. For the atmosphere part the German meteorological service , (Deutshen Wetterdienst or short DWD) data was used both for the initial and for the boundary conditions. The atmospheric boundary conditions were updated every six hours. The boundaries for the ocean were kept constant i.e. no exchange through the boundaries.

3 Verification of the energy and momentum fluxes

The main topic is the verification of the surface fluxes, which come from the atmospheric part of the coupled model. As the first step we looked into mean values of all fields for the whole Mediterranean and averaged in time over the whole run period (one year). Up to now there were numerous papers concerning yearly (longer term) averages of surface fluxes for the Mediterranean area. These results are based on both measurements and various kinds of parameterization or model calculation. In the paper by Angelucci et.al. [9] we have found values for the fluxes coming from several methods of calculations and some for measurements. In table 1, column (b) we present our values of the mean fluxes averaged both in space and time. In column (c) we present numbers from the Angelucci et.al. paper. The numbrs are quite similar which means that our fluxes are within the reasonable limits.

4 Verification of the area averaged SST

Another way to verify the quality of computed fluxes is from the verification of SST. In figure 1 we show time evolution of the mean SST for the whole Mediterranean sea. We can see that the an-

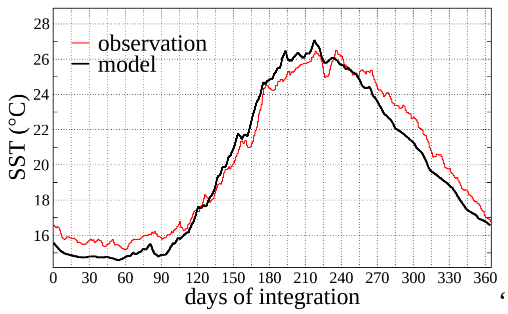

Figure 1: Mean SST

nual variation was reproduced with remarkable accuracy. Even at the shorter time scales model was able to follow short scale variations of SST.

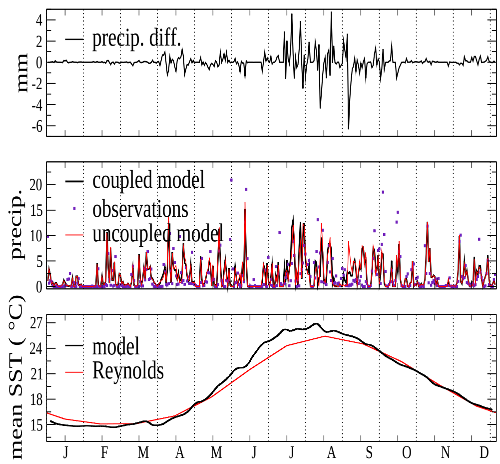

Figure 2: The bottom panel shows mean SST from the coupled run (black line) and, prescribed, climatological SST (red line). The middle panel shows precipitation (cumulative diurnal) from the coupled run, black line, the same for the run with the climatological SST, red line, and purple dots show observations of cumulative precipitation. The top panel shows differences in cumulative precipitation between coupled and uncoupled run.

To infer the influence of coupling on various results we have compared coupled and uncoupled runs, figure 2. For the uncoupled run we had specified the climatological SST, the is called Reynolds climatology. First we look in coupled versus uncoupled SST, which is presented in bottom panel of the figure. Differences are present but small. It is also clear that differences are seasonly dependent. They are stronger in the summer season.

5 Verification of the precipitation

What about other processes and their dependance on the coupling? Since atmosphere gets part of its moisture from the sea we looked into area averaged diurnal accumulations of precipitation as well, middle panel in the same figure. The precipitation data covers almost whole of Serbia, the area for which we had the data, for that particular year. In general, both runs had surprisingly good precipitation forecasts. The annual accumulation for the observations was 721 mm., for the coupled model it was 750 mm. while for the uncoupled it was 746 mm. Similar conclusions are true for the monthly accumulations which are shown in figure 3. Differences, top panel, were concentrated over the June, July and August period which was also true for the diurnal averages. In comparison with the observations there is some scatter but in overall coupled model is doing slightly better than the run with the climatological SST. This, of course, depends crucially how far or how close is the actual SST to the climatological one. Presumably the reason that differences in the SST calculations lead to differences in the precipitation forecasts indicates that these differences come from the differences in the latent heat fluxes so we have another indication of quality of flux calculations.

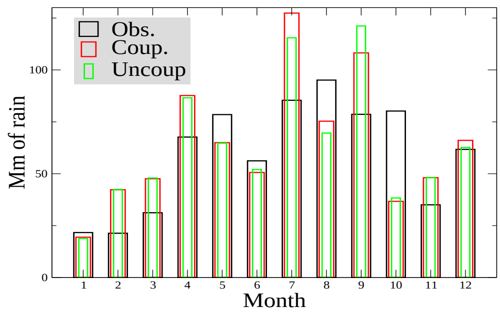

Figure 3: Monthly accumulations of precipitation. Black are observed accumulations, red are accumulations from the coupled run and blue are from the uncoupled model

6 Sensitivity to the horizontal resolution

In adition to model simulations one can get the atmospheric forcing from the centers that produce global analysis and forecasts. There are several such centers like NCEP, ECMWF etc. The problem with such forcing fileds is their relatively low spatial resolution, typically 1 degree latitude-longitude or more. When using forcing of such low resolution, sometimes, ocean models have tendency to produce to high SST. For that reason instead of using forecasted fluxes one can create new fluxes from the forecasted surface temperatures and winds and *forecasted* SST. Since forecasted SST may differ from those from the large scale run we may get different fluxes. In that way an additional feedback was introduced which reduced the problem of the overheating. Therefore we did some sensitivity test in which we have changed (increased) the horizontal resolution to the one comparable with the resolution of the global models. We did that only for the atmospheric component of the model. In figures 4, 5 and 6 we

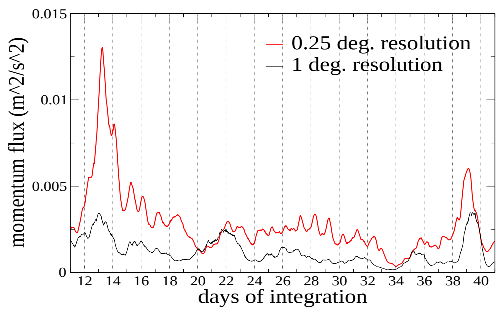

Figure 4: Momentum fluxes for the 1 degree resolution (black) and .25 degree resolution (red)

show differences in latent heat fluxes, momentum fluxes and the resulting SST for the 1 degree and 0.25 degree runs. This is a segment from the whole run where we think that lays the explanation of the problem. The largest differences are in the momentum fluxes. The momentum flux for the 0.25 degree run is about $4-5$ times bigger than that in the low resolution run. That will enhance turbulent fluxes of heat, in particular the latent heat flux. This will lead to the wrong SST, larger than both the observed and the one from the higher resolution run.

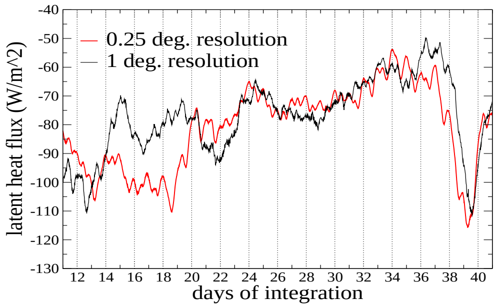

Figure 5: Same as in the previous figure but for the latent heat flux

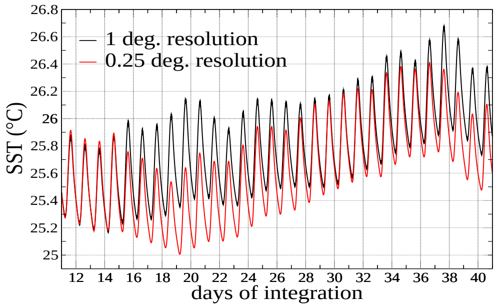

Figure 6: Same as in the previous figure but for the SST

7 Conclusions

Using coupled air-sea model the annual variation in average SST for the whole Mediterranean sea was reproduced with remarkable accuracy. That skill was maintained even at the shorter time scales.

Runs with prescribed climatological SST had also, surprisingly good, precipitation forecasts. Errors, in the annual accumulation, were less then 25 mm and 20 mm for coupled and uncoupled model respectively. Similarly is true for the monthly accumulations. Differences were concentrated over the June, July and August period. The same was valid in the case of diurnal accumulations.

Concerning the sensitivity to the horizontal resolution of the atmospheric model, the largest differences are in the momentum fluxes with 0.25 degree run having about $4-5$ times bigger flux than in 1 degree, low resolution run. That enhances turbulent fluxes of the latent heat flux which will eventually lead to the wrong SST, larger than both observed, and higher then in the high resolution run.

8 Enquiries and Correspondence

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