The Assessment of the Influence of the Surface Fluxes on the Extended Weather Prediction

Djurdjević Vladimir [a] , Rajković Borivoj [a]

[a] Department for Meteorology, Collage of Physics, Belgrade University
, Yugoslavia

Abstract: The question wether we can improve long term forecast over a limited area, using coupled air-sea model has been considered. As a first parameter we look into the mean SST for the integrations whose length was about one months, for the summer of 1999. Sensitivity of the results to atmospheric model horizontal resolution were examined.

Keywords: Air-sea interaction; Coupling; Sea-surface temperature ; Regional climate

1 INTRODUCTION

The basic prerequisite for long term weather prediction (month and longer) even for a limited area is inclusion of the air-sea interaction. Therefore a regional coupled atmosphere-ocean model (RAOM in the further text) must be used. The first aim is correct simulation of the SST in the region. Once that achieved there is ”hope” for the rest of the results. In principal, an improvement of a General Circulation Model (GCM) results are possible if local forcing such as SST influence through air-sea energy exchange, land-air energy exchange and topography forcing are important but only locally. If on the other hand these forcing influencing atmosphere on the much larger scale than the area covered by the RAOM the prospect of success is smaller. Of course there is never clear cut in this matter and all regional climate studies (RCM) have shown some level of success.

2 MODEL DESCRIPTION

To create a coupled model we choose for its atmospheric component, (atmospheric model ,AM), the NCEP mesoscale model (whose principal author is Z. Janjić with contributions by F. Mesinger). For the ocean component, (ocean model, OM), the Princeton ocean model has been chosen (whose principal author is G. Mellor with contributions by A. Blumberg). The basic characteristics of the AM are that it is a limited area model on E grid with strict conservation of integral properties, Janjic [1984], strict conversion between potential and kinetic energy Janjic [1977], full physics package whose main features are treatment of PBL with M-Y-2.5 approach Mellor and Yamada [1974], Janjic [1990] ,Janjic [1994], convection with Betts-Miller-Janjić shallow and deep convection scheme Betts and Miller [1986] , Janjic [1990] ,Janjic [1994] and the radiation package developed in GFDL Fels and Schwarzkopf [1981], Schwarzkopf and Fels [1985]. The surface fluxes are computed using the Monin-Obukhov approach with the addition of viscous sub-layer over the ocean. For its vertical coordinate it has either classical sigma (σ) coordinate or the so called Eta (η) coordinate with the idea of having quasi horizontal vertical coordinate surfaces Mesinger et al. [1988]. The characteristics of the OM are, the grid is the C grid with splitting between external and internal mode. Boundary layer is treated using the M-Y-2.5 approach. The vertical coordinate is a version of the sigma (σ) coordinate, defined as $(z-h)/(z+H)$, where $H(x,y)$ is depth, $h(x,y)$ is local elevation and z is the vertical coordinate, positive upwards. Provisions are made for the erroneous vertical fluxes and pressure gradient force. For horizontal diffusion Samogorinsky diffusivity is used with diffusivity coefficient equal 0.1. The Parental number was set to $1.$. For more details about the numerical characteristics of the model such as time steeping etc. please see the references Blumberg and Mellor [1980], Mellor [1998]. The resolution of the AM was .25x.25 deg in latitude and longitude with 32 vertical levels from 100 mb’s at the top to the ground. The horizontal size of the domain was about 42 deg with the south-north size of 30 deg, with the lower left corner at $13.4; 41.5$ lon-lat coordinates. The OM we had

191 points in east-west direction, 58 in the south-north direction and 21 level in vertical. In comparison with the AM horizontal resolution was about four times higher in the OM. Domain was, in east-west from -5 deg to 36. deg and south-north from 30.35 deg to 46. deg. Horizontal resolution was about .2x.2 deg.

This particular combination of AO and OM is used at National Center for Environmental Prediction (NCEP) in Washington for operational prediction of the sea surface elevation for the region next to the Atlantic coast. For details of the project see Aikman et al. [1996], Mellor and Ezer [1994].

3 MODEL INITIALIZATION

The OM was initialized using the MODB initial temperature and salinity fields. The MODB is a Mediterranean data base that has climatological data, seasonal averages. The one we took was the summer data set. Its resolution is 1x1 deg in lat and lon and has 34 vertical levels.

For the AM initialization was done from NCEP's global data set with horizontal resolution of 1x1 deg lat-lon and with 23 standard pressure level from 1000. mb to 50 mb. although model top was set to 100 mb. Data from both data sets were linearly interpolated to the respective grids in horizontal and vertical.

When we have a limited area models we have also lateral boundaries. For the AM we took NCEP's global analysis whose time step was 6 hours and linearly interpolated in between. In principal for both component we should to specify inflows and outflows. But since in the area we have in mind, the South-East Europe, "dominant" sea surface is the Mediterranean Sea who is almost a lake, ocean boundaries are not so important. Of course from the modelling point of view having open boundaries is not a problem but the lack of data is. So as a first iteration, we choose to close Gibraltar and Dardanelles. The rest of the SST, the one for the Atlantic and the Black Sea were obtained from the global analysis and was kept constant.

4 THE RESULTS

The length of all runs was set to 40 days. In Figure 1 we show time evolution od the spatially averaged SST, over the whole Mediterranean area, for August 1999 (dashed thin line) and the observed one (thick line).

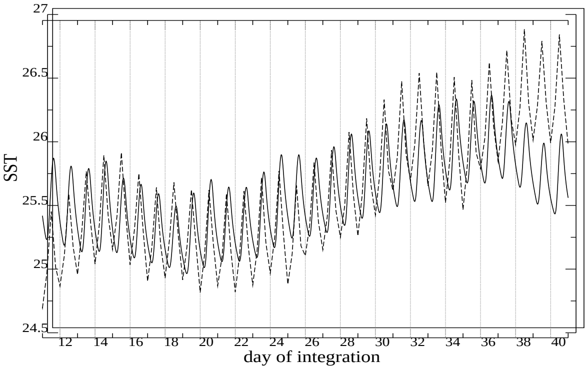


Figure 1: Time variations of the mean SST (^{o}C) over the whole Mediterranean Sea during 40 days, starting with August the 1st. 1999. Dashed thin line observations, while the thick line is the model results.

The reason we have chosen this particular month is that the observed SST, used for the initial fields, and the climatological SST (from MODB) were very close. Presumably deeper layer of the ocean were in the equilibrium with that SST. Visual inspection of the figure shows that the observed SST and the forecasted one at the end of the run differed about 0.6 ^{o}C. In more detailed analysis we see that the forecasted SST followed the observed SST quite well till the very end when the observations show increase by about .25 deg (rough estimate of daily average) while forecasted SST declines by about the same value, giving total difference of about .6 deg. In Table(1) we show values for each of the flux, for the whole integration period and spatially averaged over the whole Mediterranean Sea.

Once we were reasonable sure that our coupling is correct which indicates that both AM fluxes are correct and that OM reacts correctly to atmospheric fluxes we did a sensitivity experiment where we have considerably reduced resolution of the AM. From 0.25x.25 deg in the reference run (RR) to low resolution (LR) with 1x1 deg. lat-lon.

The results of both RR and LR are presented in Figure2. We see that the skill, for the low resolution case is still high though has slightly decreased compared with the RR. There were two episodes where LR showed an increase of the mean SST. The first one between 16-26 days of integration and the second one near the end. To trace the reason for this,

Table 1: Components of the energy balance for the SST averaged over the whole integration area and over the integration domain. The net flux is the average of all fluxes show here. All fluxes are in Wm^{-2}

flux	mean value Wm^{-2}
sensible heat	-11.63986
latent heat	-80.75194
incoming s.w. rad.	283.23843
atmospheric l.w. rad.	379.77249
black body l.w. rad.n	-451.90899
net	118.71013

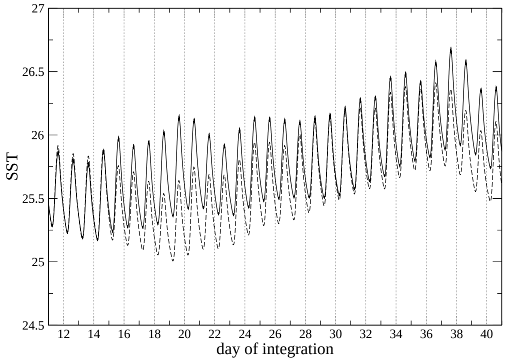


Figure 2: Mean SST, in ^{o}C, over the whole Mediterranean Sea for 40 days, starting with August the 1st. 1999. Dashed thin line is the reference run while the full line is the lower resolution run.

Table 2: Components of the energy balance for the SST averaged over the whole integration area and over the integration domain. The net flux is the average of all fluxes show here. All fluxes are in Wm^{-2}

	Case	
flux	RR	LR
sensible heat	-11.63986	-15.19394
latent heat	-80.75194	-77.70714
incoming s.w. rad.	283.23843	274.69039
atmospheric l.w. rad.	379.77249	385.35563
black body l.w. rad.	-451.90899	-452.87004
net	118.71013	114.2749

first we looked at each component of the energy exchanged between the AM and OM. Again in the Table(2) we show the fluxes, for the whole integration period averaged over the whole Mediterranean Sea, for both runs. We see that the energy exchange was very similar. The net fluxes differed only 4.5 Watts ! Looking at each component we see that radiation fluxes, long wave, short wave and outgoing, black body, radiation pretty much balance. So the relation between turbulent fluxes is decisive. The history of momentum (top), sensible (middle) and latent heat (bottom) flux is shown in Figure3. Thin dashed line is for the LR while thick line is for RR. Sensible heat flux, in the LR case, exceeds the Sensible heat flux for RR from day 20 to the end of the run, while the latent heat flux, for the LR shows a deficit in the range of 13-21 days and a weak one near the end. Two curves for the Sensible heat are so close that the difference cannot explain the increase of SST. The latent heat, in the first period is smaller in the LR case and that obviously does contribute to the effect. But in the case of momentum we see the strongest difference in the two runs. Most of the time differences between two curves are relatively small except for the first 3-4 days where we see that the RR produces a large peak, several times that for the LR. For the ocean model reduced momentum forcing mean less stirring which in turn means shallower penetration i of the energy fluxes coming from AM. Therefore flux convergence occurs in a shallower layer of water and therefore over-heating develops. Coming back to the Sensible heat flux, the atmosphere ”knows” that the ocean beneath is to warm and trays to release the extra heat, but it is not enough. What is the spatial structure of the momentum flux filed ? To see that we looked, for that period, in even greater detail at the distribution of the surface winds. In figures 4 and 5 we show the surface wind for days 11,13,15 and 17 of integration, for the RR and LR cases respectively. We see that the intensive surface winds were localized at the area south of the Ionian sea and that it moved to the west in the next few days. For day 13, when we had that peak in the wind-stress the intensive surface winds developed near the Turkey coast. Intensive winds stayed in that area, weakening in the next 3-4 days. So that strong raise in wind-stress was really rather local but was strong enough to cause differences between the RR and LR cases. It is also present in the LR and moves in a similar way, but the intensity lacks.

5 CONCLUSIONS

RAOM has shown success in predicting the SST on the time scale of a months, at least for a summer month, using the global analysis of NCEP. The relative success means that the AM has done a ”good

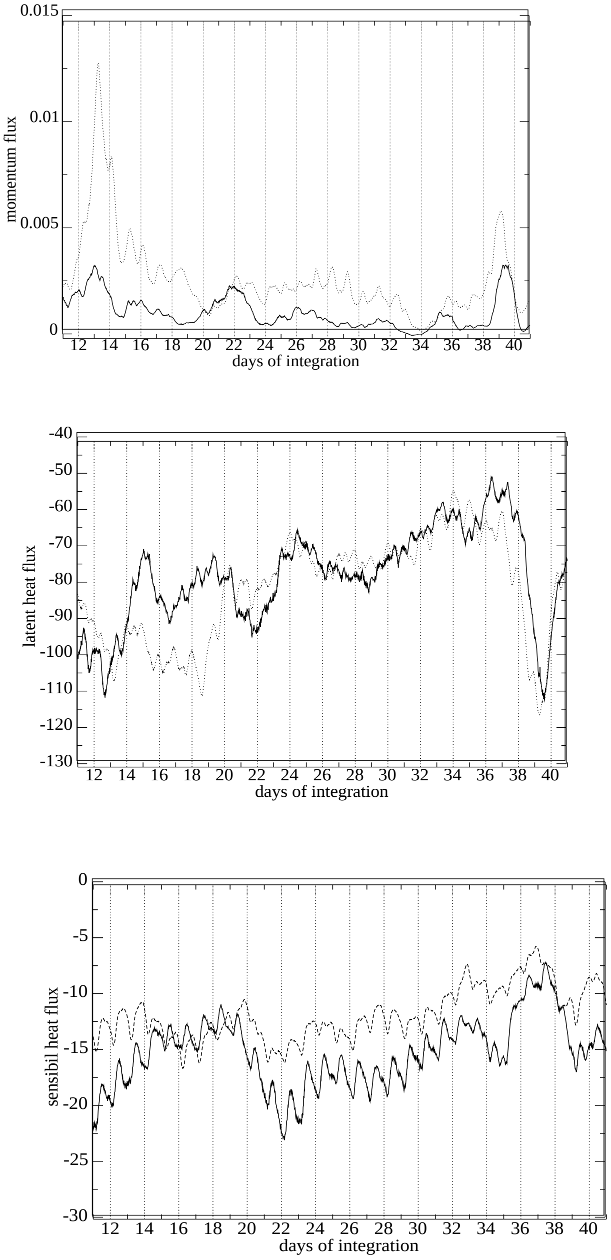


Figure 3: Time variations of the area average, momentum flux (top), latent heat flux (middle) and sensible heat flux (bottom). The reference (dashed thin line)e and the low resolution (thick line) run.

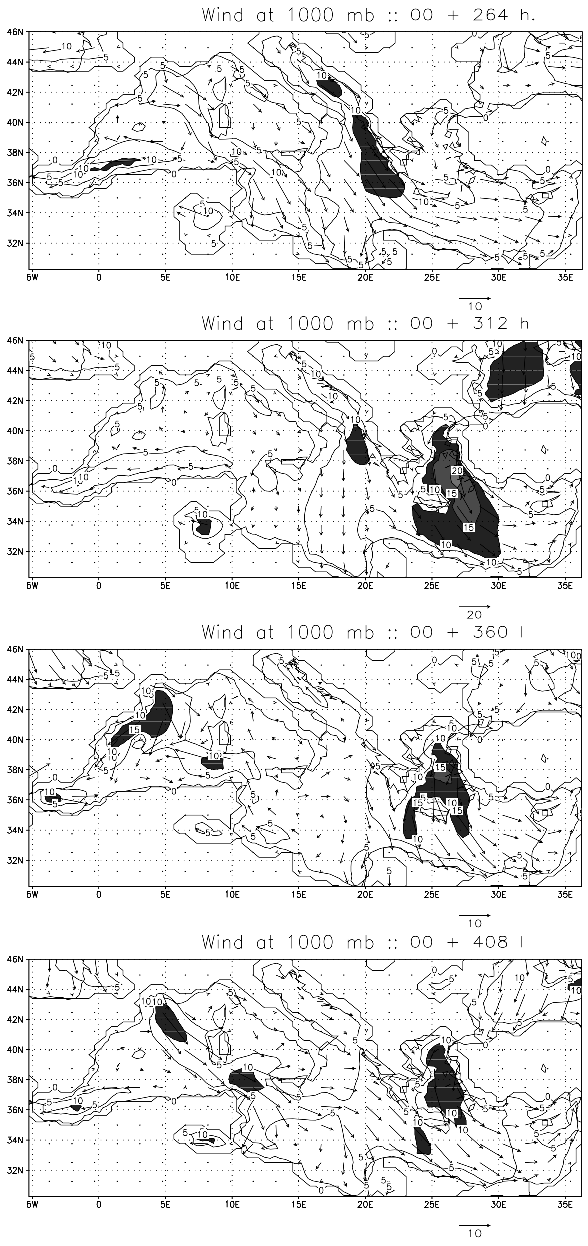
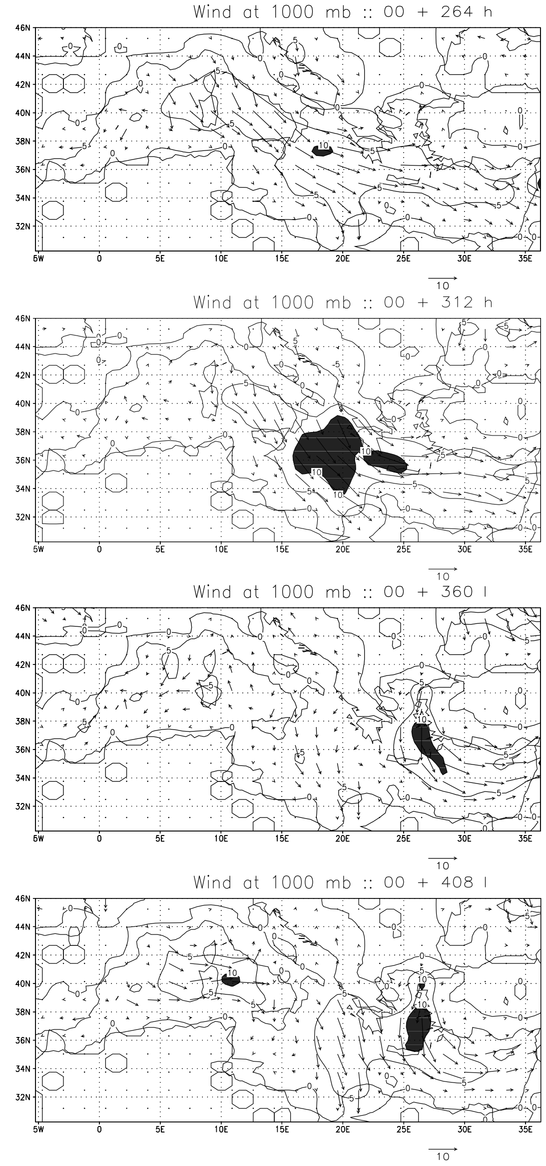


Figure 4: Surface winds for the 11th, 13th, 15th and 17th, top to bottom, of August 1999. for the RR case. Shaded areas indicate stronger winds.


Wind at 1000 mb :: 00 + 264 h

Wind at 1000 mb :: 00 + 312 h

Wind at 1000 mb :: 00 + 360 l

Wind at 1000 mb :: 00 + 408 l

Figure 5: Surface winds for the 11th, 13th, 15th and 17th, top to bottom, of August 1999. for LR case. Shaded areas indicate stronger winds.

job" in calculating surface fluxes. Mixing due to momentum forcing does play important role and depends on the horizontal resolution. Overall going from 1/4 of deg lat-lon to 1 deg. lat-lon we have not noticed major difference but still some skill was gained with the increase of horizontal resolution.

The major implication of this high/low resolution exercise is an indication that the GCM forecasts could be improved through the use of a RAOM since it would have much higher horizontal resolution then a GCM. To inference, further, the importance of the high ocean resolution one would have to analyze in a greater details and over smaller areas.

The next step is to try the same exercise for a late autumn or winter month and see wether a similar success is possible. In conclusion it is probably easier to forecast SST during the summer since the thermocline is shallower i.e. the mixing is restricted to the shallower part of the ocean.

6 ENQUIRIES AND CORRESPONDENCE

All enquires concerning papers, at any stage of the process of preparation, review and publication should be addressed to:

Mr Vladimir Djordjević, Department for Meteorology, Collage of Physics, Belgrade University Dobračina 16, 11000 Belgrade, Yugoslavia

Phone: +381 11 625 981

Fax: +381 11 3282 619

Email: vdj@ff.bg.ac.yu

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