Assessment of sea surface temperatures provided in the coupling files from ARPEGE and IFS

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Abstract

Sea surface temperature (SST) influences the model forecast. For example it is important for the correct modelling of land/sea breeze and influences the intensity of precipitation downstream. In numerical weather prediction (NWP) model Aladin, SST is taken from initial file and remains constant during the model forecast (up to 72 hours). There is no assimilation of SST in operational forecast using Aladin model in Meteorological and Hydrological Service (MHS) of Croatia. But, there are two sets of SST fields provided in the coupling files provided to MHS from operational forecasts of IFS and ARPEGE, provided by ECMWF and Meteo-France respectively. Several national meteorological services have switched from coupling their operational limited area models from Arpege to IFS, however they overwrite the SST field in IFS file with the one from ARPEGE file. Here we briefly analyse the SST fields from the coupling files.

Introduction

Coupling files are files necessary to run a limited-area model (LAM) forecast. These files contain forecast lateral boundary conditions (LBC) for the LAM provided from a global model (or larger scale LAM). A number of surface fields from the coupling files can be used in the analysis using LAM. One of these fields is sea surface temperature (SST).

In MHS of Croatia, operational forecast is run operationally 4 times a day (starting from 00, 06, 12 and 18 UTC analyses) up to 72 hours using Aladin LAM, currently run in 8 km horizontal resolution.

There are two sets of coupling files available operationally in the Croatian MHS. The first one is from the global model ARPEGE run in Meteo France and it was used to run the operational LAM forecast until the end of 2013. Alternative files are available from global IFS run in ECMWF for the period since 27th October 2010, and these are used for operational forecast since 1st January 2014.

The operational LAM forecast uses SST provided in the coupling files, in the absence of better solutions since we do not run an operational ocean model to couple to. SST in the coupling files of ARPEGE varies from one analysis to the next one, but remains constant during the forecast run. SST in the coupling files of IFS changes only between 00 and 06 UTC analyses and remains constant during each forecast run. This means that SST in the coupling files from IFS remains unchanged with respect to 06 UTC analysis in the next 12 and 18 UTC analyses as well as in the 00 UTC analysis of the next day.

Several meteorological services are using coupling files from IFS in the operational forecast, but some of them (including CMHS) overwrite the SST field with the field provided in the ARPEGE files (personal communication). Also, there are several strange features in the surface temperature field close to coastline that appear when using IFS coupling files. This has encouraged a brief validation of SST fields provided in the coupling files in order to inform the choice for the SST used for operational forecast. The comparison of measured and model SST has revealed a significant bias in SST provided in IFS coupling files during winter months for a number of stations where in-situ measurements of SST are available.

In this report, we compare the SST from the coupling files with the measured values on coastal stations. Here we show some inconsistencies in SST provided in the coupling files that could be attributed to low resolution of the global models and vicinity of the coastline as well as some strange phenomena that can hardly be explained by physical reasoning. Several of these unnatural features in SST have been fixed, as will be reported in this document (see Appendix B). However, there are still large discrepancies in measured and model SST in certain regions, especially in autumn and winter along western Adriatic coastline.

Measured data and SST from model fields

SST is measured on a number of stations on the Adriatic, including a number of stations on the islands (Figure 1). Most of the stations on eastern Adriatic coast are the regular “climate” stations that measure SST in conventional way at 7, 14 and 21 hours local time (at 06, 13 and 20 UTC) each day. The stations are Božava, Sv Ivan na pučini, Komiža, Krk, Lastovo, Mljet, Opatija, Pula, Rab, Rabac, Senj, Šibenik, Split, Zadar, Dubrovnik, Hvar, Bakar and Cres (see locations in Figure 1, some names are abbreviated). Since SST does not change rapidly in time, these measured values were compared to the analyses at 06, 12 and 18 UTC.

Several automatic stations on the eastern Adriatic coast measure SST on buoys anchored close to the coastline with an hourly interval (Zadar, Mljet, Malinska, Opatija, Dubrovnik and Crikvenica, see location in Figure 1). On stations Zadar, Dubrovnik and Opatija, there are both, conventional and automatic measurements available.

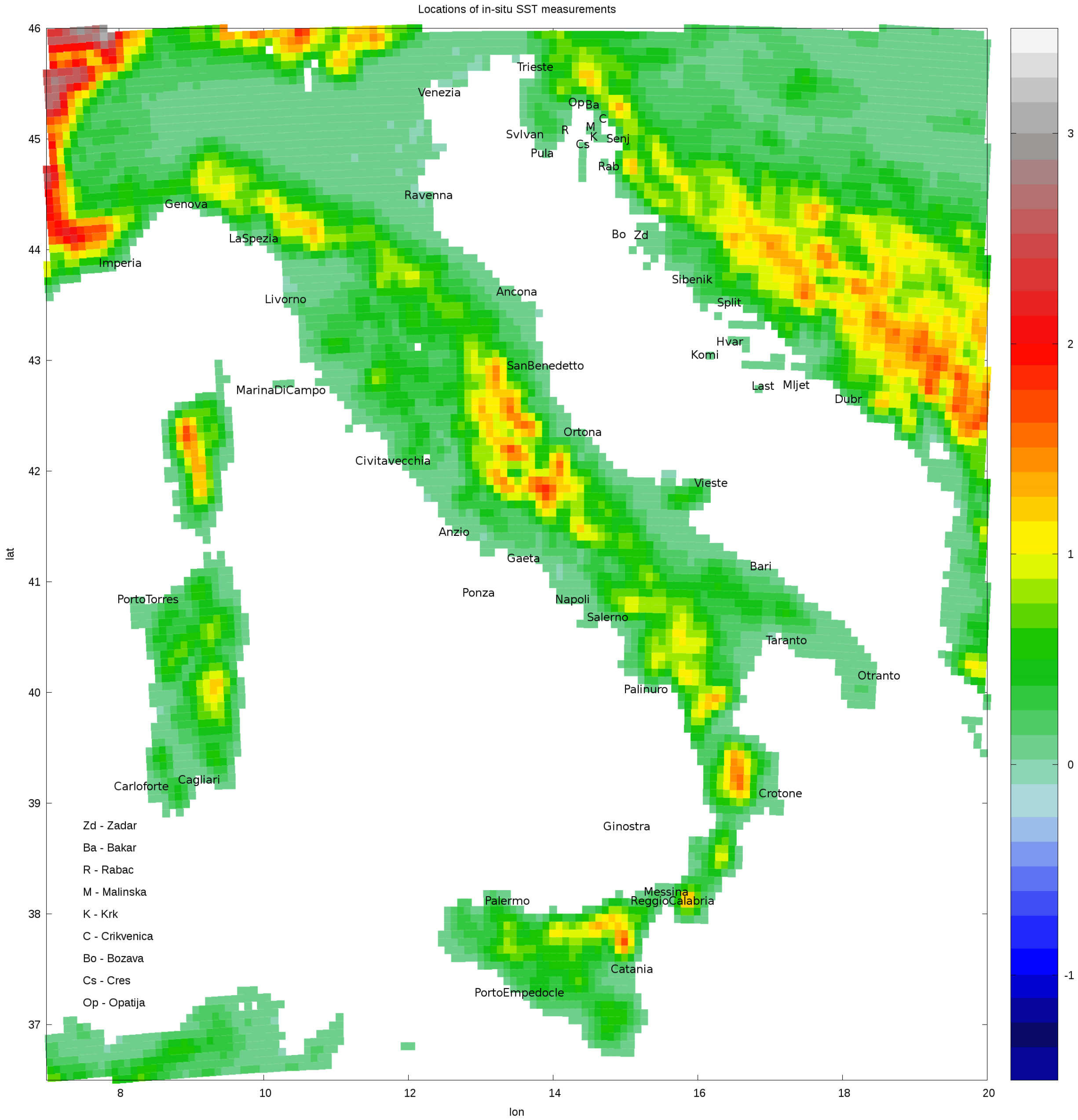


Figure 1. Map of Adriatic and Italian area with the locations of stations. The names of stations in Croatia are truncated due to large spatial density. The names are explained in the lower left corner in the figure. The background is terrain height from 8km resolution Aladin file, white means that land-sea mask is zero (sea or lake point in the model).

There are operational SST measurements available for a number of stations in Italy from ISPRA web page www.mareografico.it. SST measurements from the stations in Italy are mostly available with an hourly interval. The measured data was downloaded using web interface for the whole period when available.

SST fields from IFS and ARPEGE

Coupling files of Arpege contain data in 10.6 km resolution and IFS data are in 15.4 km resolution. The land-sea mask is different in the two models and there is a different source of SST used in the two models. There are examples of fields shown in Appendix B. The plots in Appendix B were created in a way that avoids any interpolation in order to detect a possible source of error.

The measured values were compared to the SST values provided in the coupling files in the nearest sea point (where the land sea mask in the coupling file is equal to zero) from the grid as provided without any interpolation. The coupling files contain data on a Lambert conformal grid that is not native to the IFS and Arpege global model, so there is some horizontal interpolation involved, but we wanted to avoid any additional interpolation. SST in the forecast coupling files is the same to the field in the initial file. Therefore, SST was taken only from files from the analysis fields of ARPEGE and IFS.

In order to distinguish when and where are the measured and model SST different, time series of measured and model SST were plotted for each station. The following pages show figures where the measured data are plotted against SST from initial coupling files (analyses) of ARPEGE and IFS from the nearest sea point for the period from 27th October 2010 until 16th October 2014. There are plots for 6 stations in separate panels in each figure. The measured SST is plotted as red dots for stations in Italy and as red lines for stations in Croatia. The SST from IFS is shown as green line and SST from ARPEGE is shown as blue line.

The figures reveal several characteristics:

- On most stations, there is a good agreement in temporal changes in SST on scales longer than several weeks, (e.g. see Rab and Božava in Figure 8, Hvar, Komiža and Lastovo in Figure 9) even for stations with complex coastline and surrounded by islands unresolved in global models (there are exceptions to this, see below).
- Measured SST shows larger temporal variability than the models (e.g. see La Spezia and Genova in Figure 2, Trieste and Venezia in Figure 6, Malinska in Figure 7, Šibenik in Figure 8).
- In Messina/Reggio Calabria (Figure 5) and Senj/Bakar (Figure 8) where measured SST is lower and far more variable during summer than in models, possibly due to local ocean dynamics.
- In La Spezia, Imperia and Genova (Figure 2) there are changes in SST on time-scales of about one month and several degrees in amplitude that are not present in model data.
- There was a warm bias in SST from IFS (not present in ARPEGE data) that started abruptly on 1st November each year and reduced on 1st April next year on a number of stations (e.g. see Taranto in Figure 5, Ravenna in Figure 6, Cres, Rabac, Opatija in Figure 7, Bakar in Figure 8, Split in Figure 9), this feature stopped after summer 2013 (see Appendix B).
- There was a strange feature in SST fields on 28th June 2014 (see Appendix A).
- In autumn and winter, SST is much lower than in both models than measured for the west coast of Adriatic Sea (see Ancona, San Benedetto del Tronto, Ortona in Figure 6 and Bari in Figure 5) due to cold Western Adriatic Current (WAC) that is possibly too narrow to be resolved in global models used for operational weather forecast.
- Similar can be observed on plot of measured and model SST for Mljet island in south-eastern Adriatic, and this was not associated to any ocean current so far, Dubrovnik and Lastovo stations nearby do not show similar features (see Figure 9).
- In February 2012, there were several weeks of extremely cold weather accompanied with severe wind and snow that caused intensive cooling of the sea (not just SST but the whole column of sea water was very cold), however this event was not recognized in model SST (see Genova and Imperia in Figure 2, Krk in Figure 8 and there are less pronounced cold extremes many other stations) on western Adriatic this cold event is superimposed on SST that is already much colder than in models.

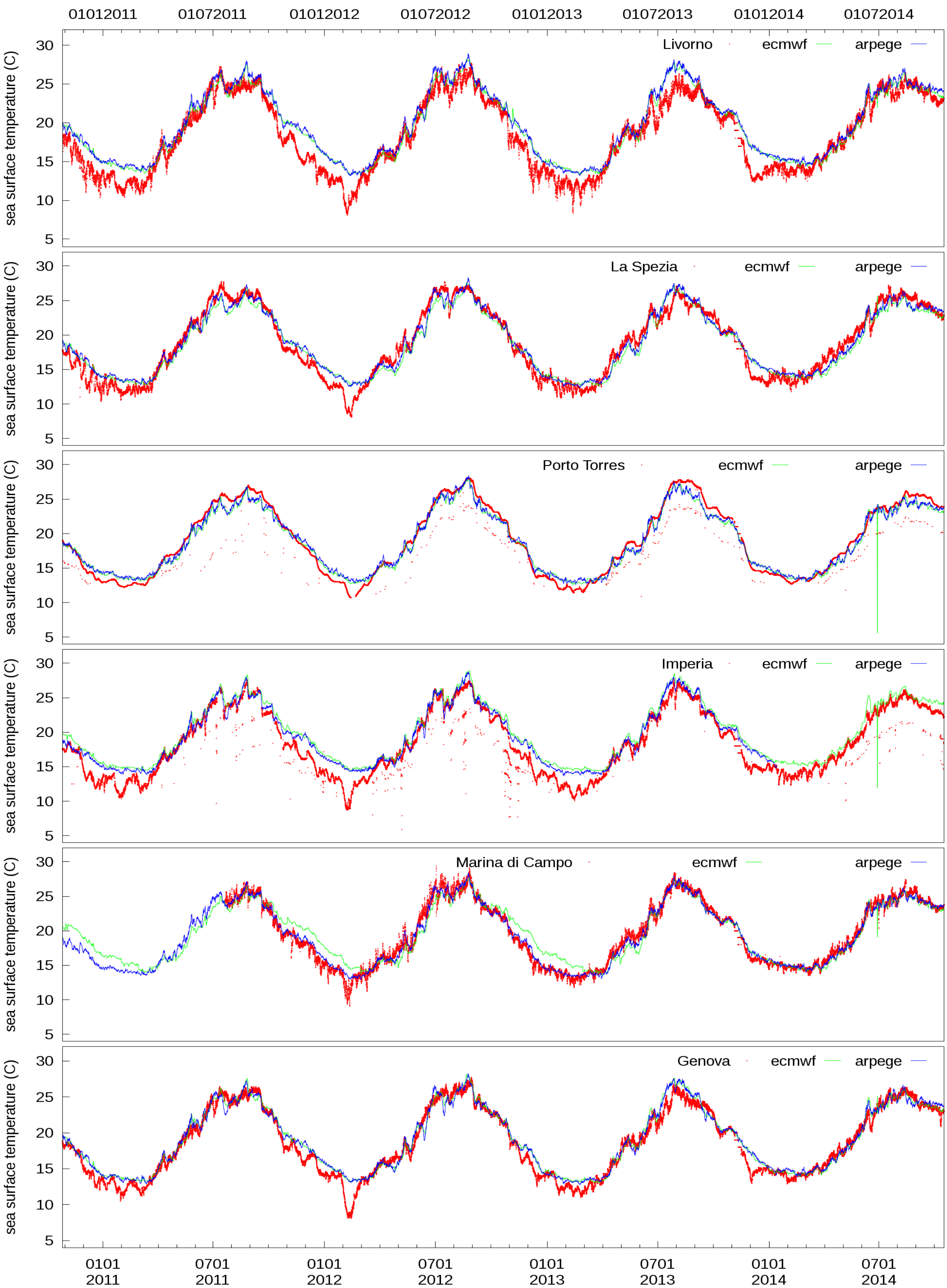


Figure 2. SST measured on stations (red), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Italy on Ligurian Sea for the period from 27th October 2010 to 16th October 2014.

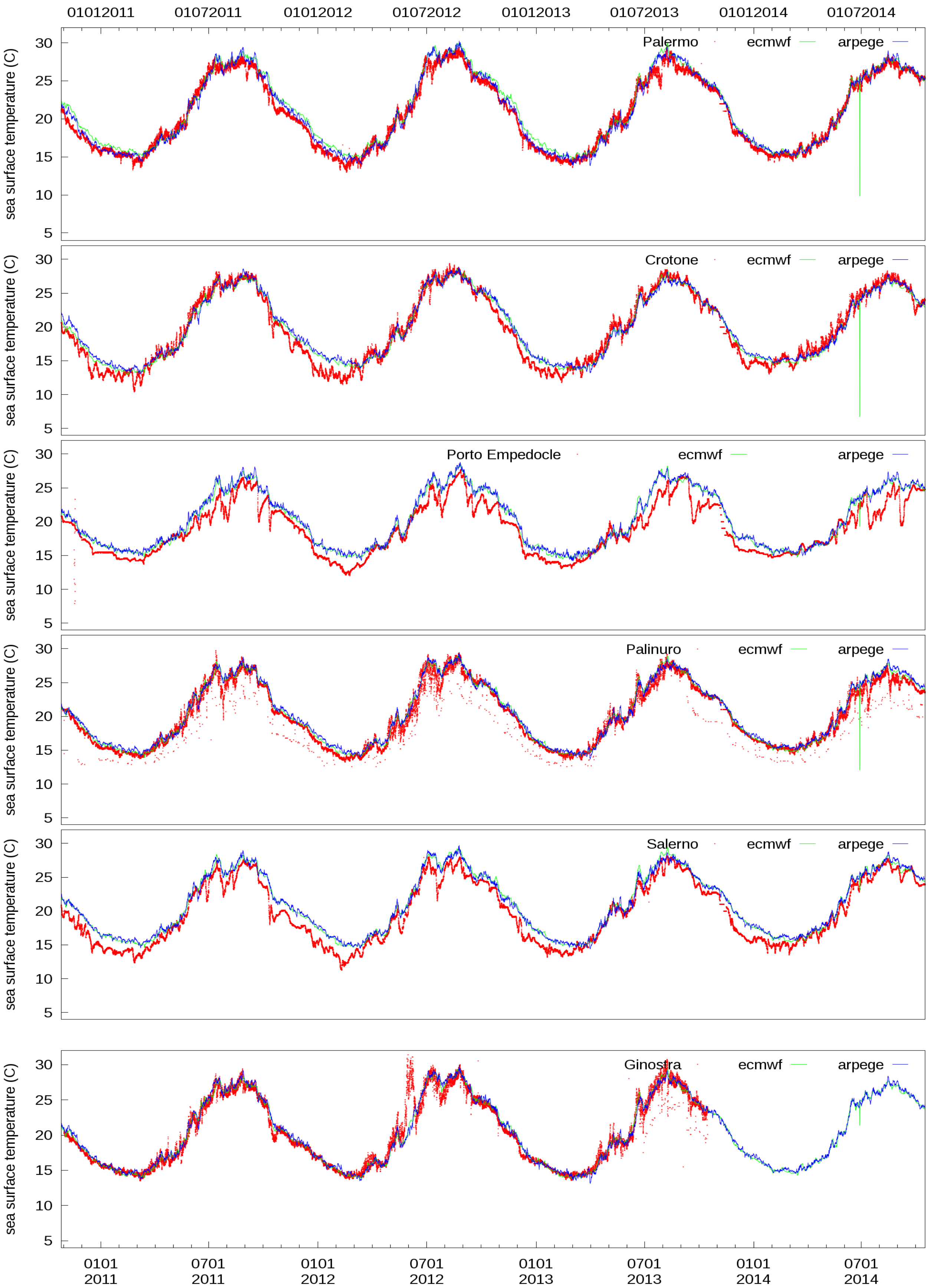


Figure 3. SST measured on station (red), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in southern Italy for the period from 27th October 2010 to 16th October 2014.

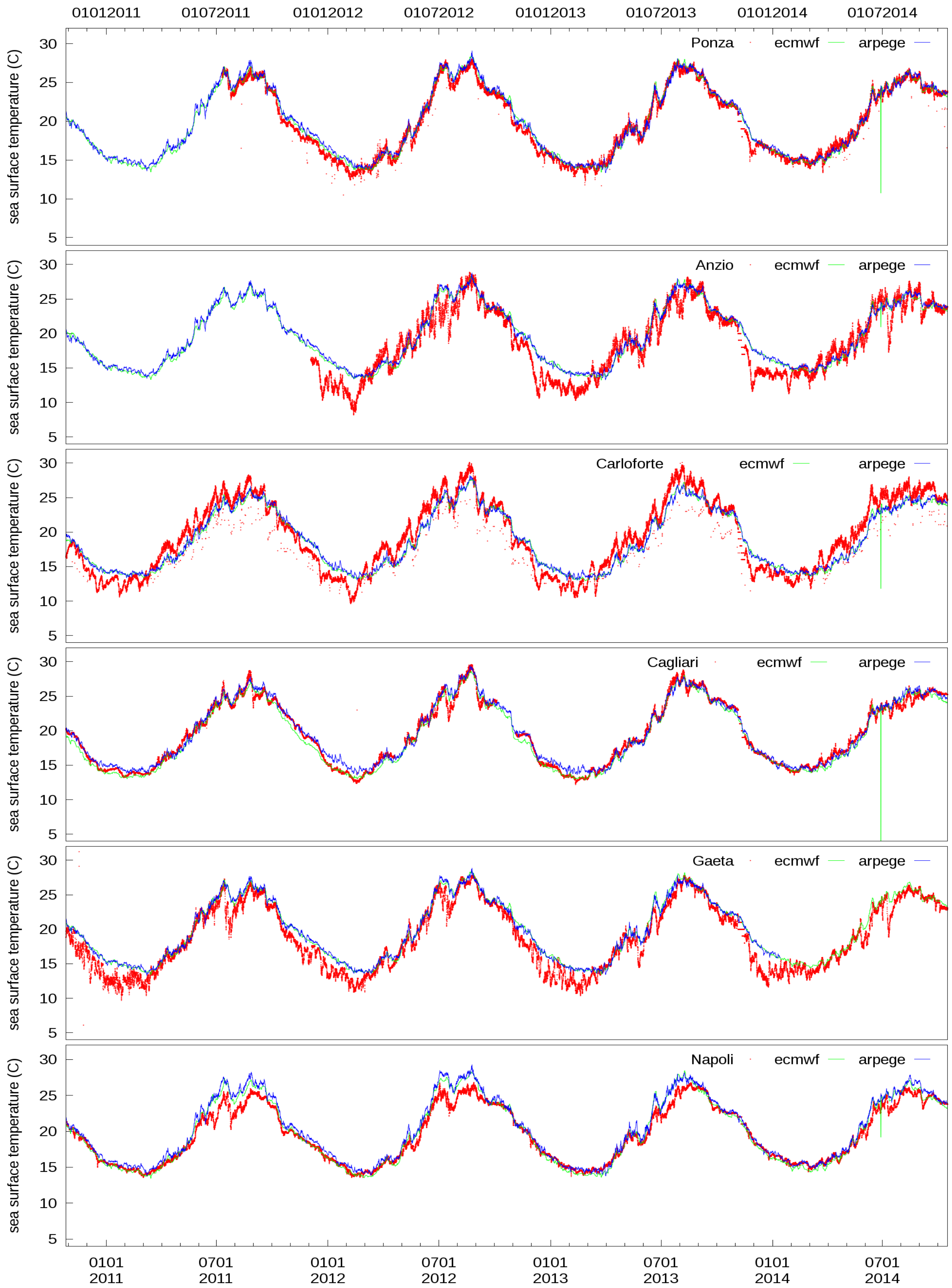


Figure 4. SST measured on station (red), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Italy on Tyrhennian Sea for the period from 27[th] October 2010 to 16[th] October 2014.

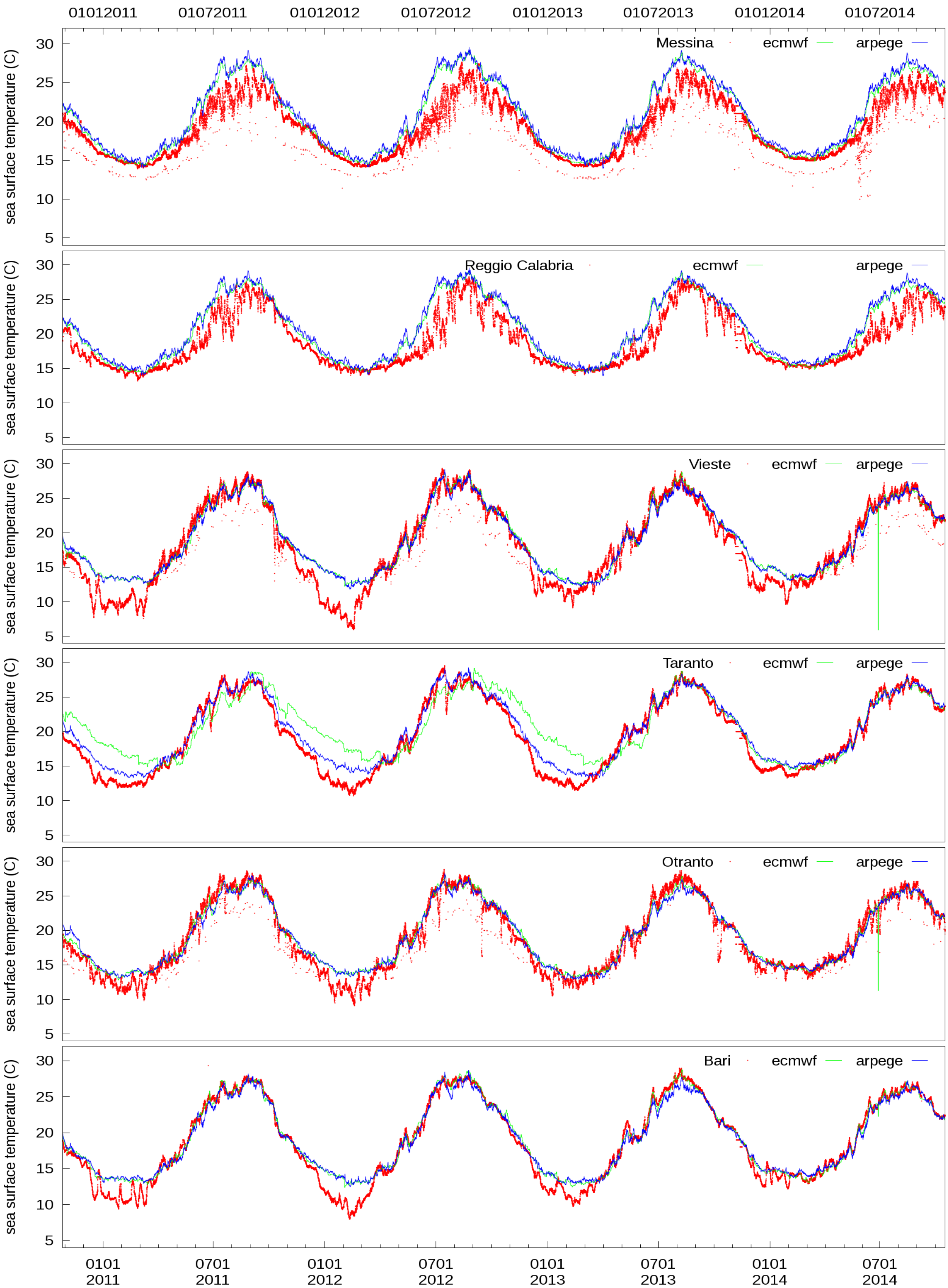


Figure 5. SST measured on station (red), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in southern Italy for the period from 27th October 2010 to 16th October 2014.

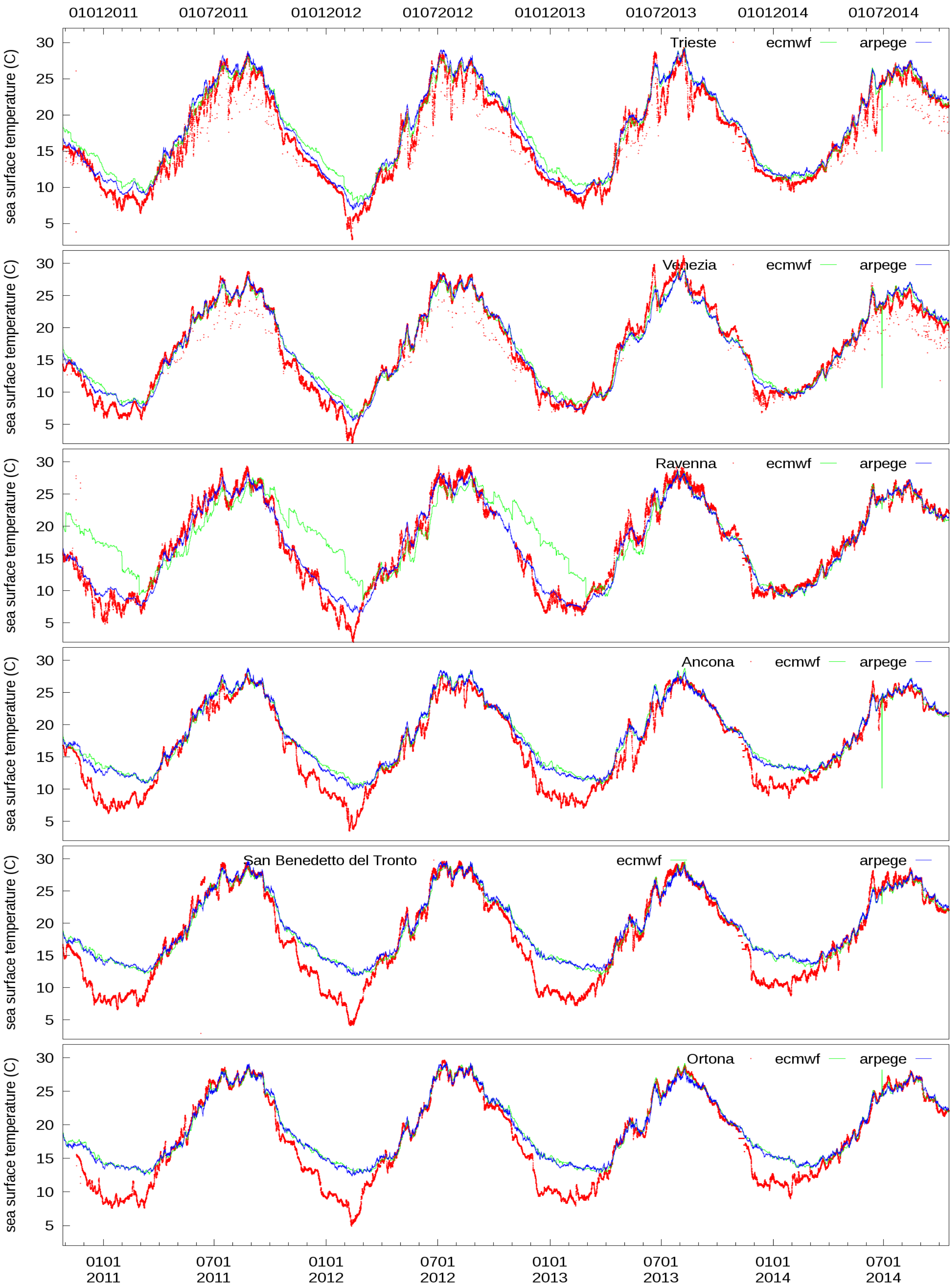


Figure 6. SST measured on station (red), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Italy on Adriatic for the period from 27th October 2010 to 16th October 2014.

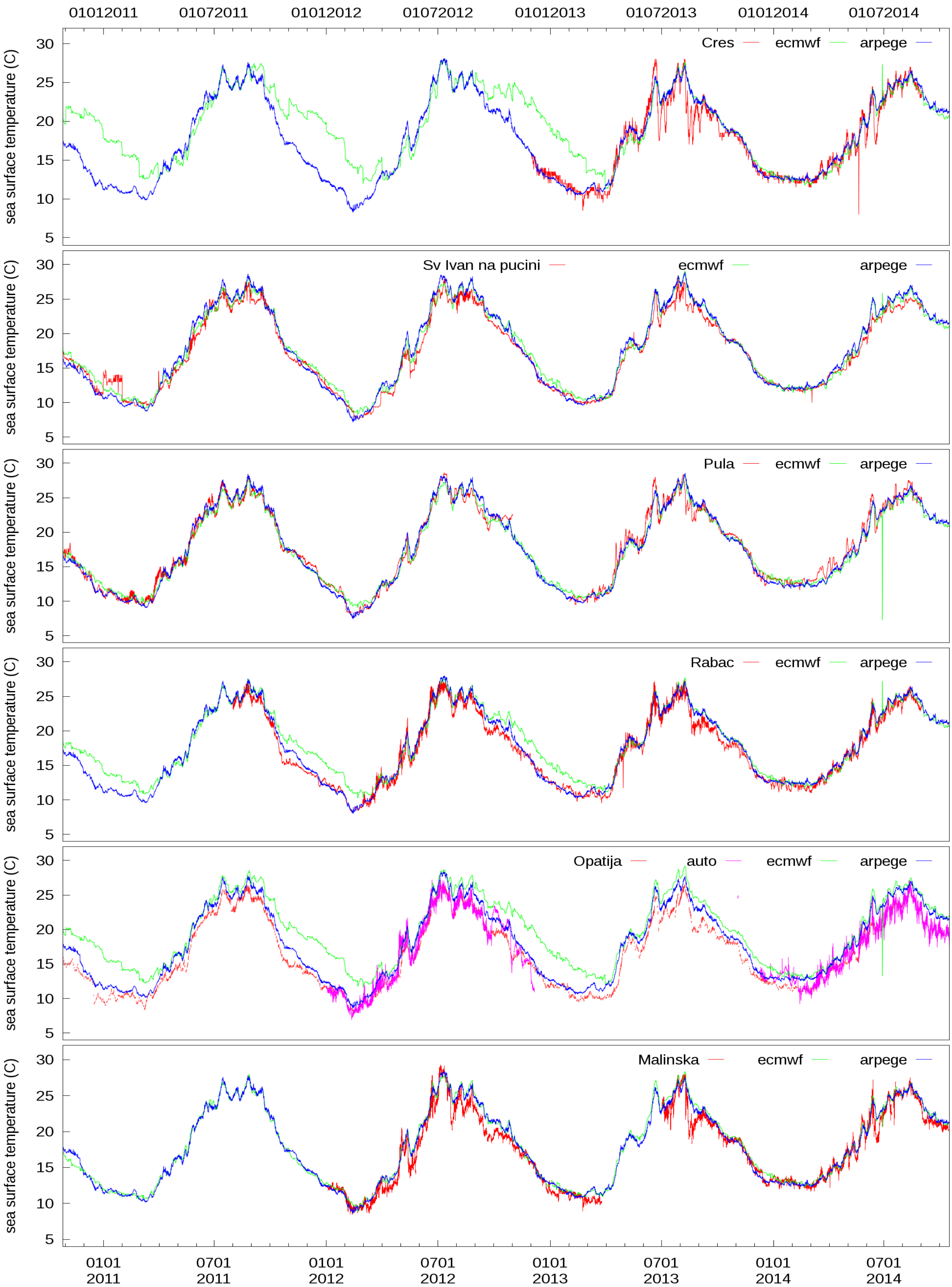


Figure 7. SST measured on “clim” station (red, data available 3 times a day) and automatic station (purple, hourly data), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Croatia for the period from 27th October 2010 to 16th October 2014.

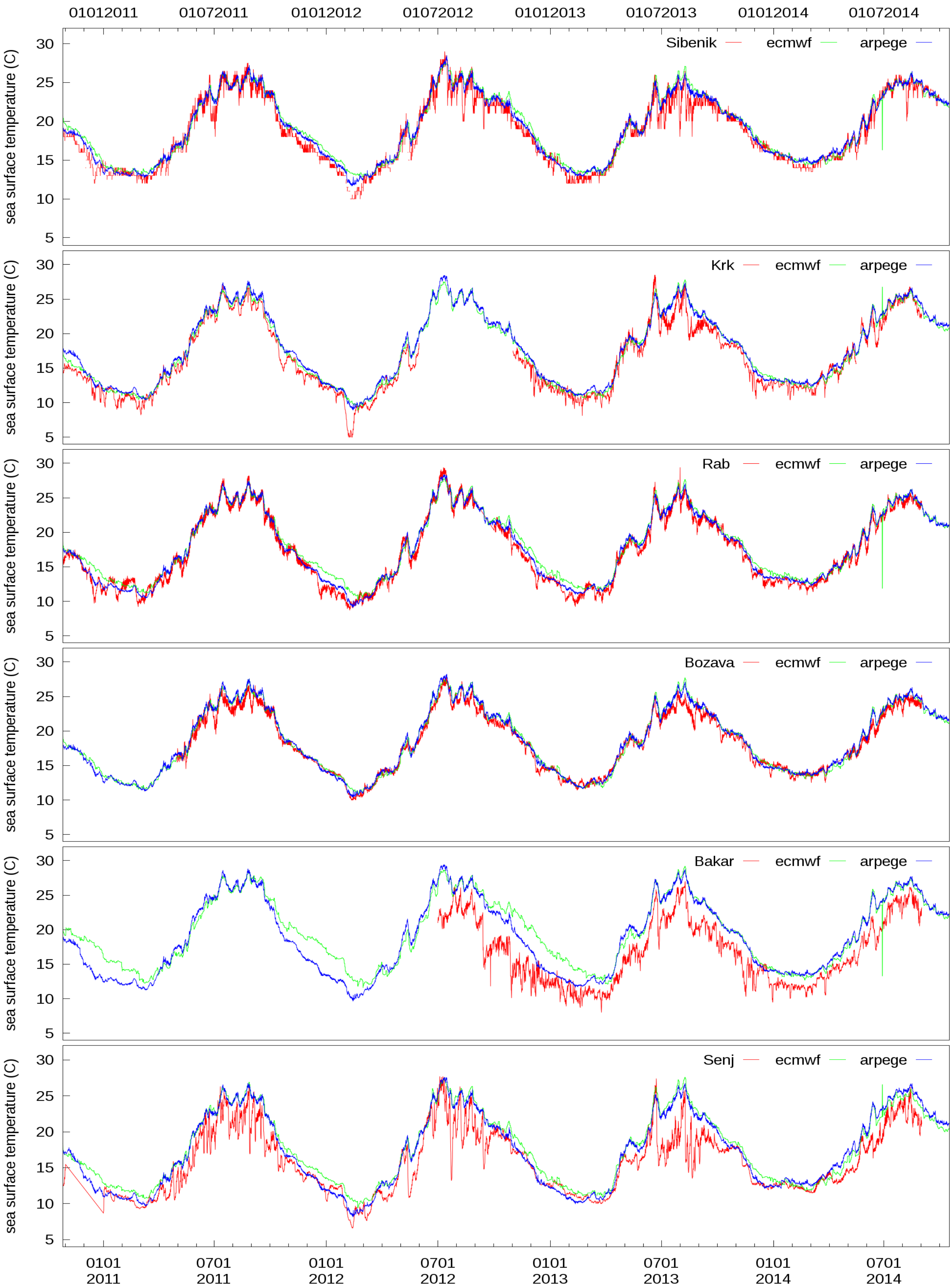


Figure 8. SST measured on “clim” station (red, data available 3 times a day) and automatic station (purple, hourly data), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Croatia for the period from 27th October 2010 to 16th October 2014.

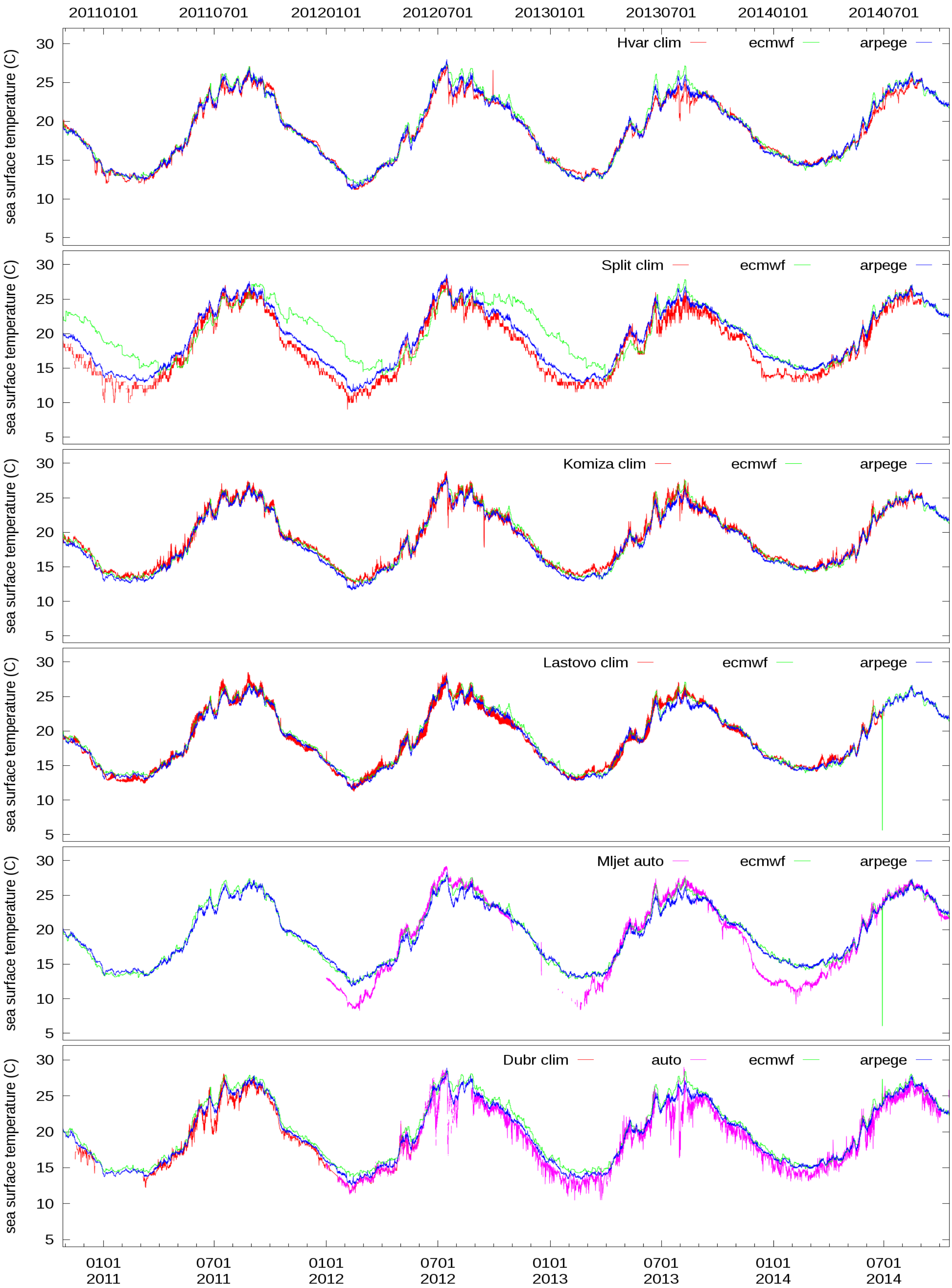


Figure 9. SST measured on "clim" station (red, data available 3 times a day) and automatic station (purple, hourly data), and from the nearest sea point in ARPEGE (blue) and ECMWF (green) coupling files for stations in Croatia for the period from 27th October 2010 to 16th October 2014.

Although we compare SST fields from the closest sea point and in-situ measurements that are done on coastline there is a good agreement in measured and model SST for a number of stations. Measured SSTs and those provided in the coupling files are in good agreement for the stations on Croatian islands (Rab and Božava in Figure 8, Hvar, Komiža and Lastovo in Figure 9) but also for several stations that are on mainland and several of them with islands between the station and the open sea (Sv Ivan na pučini, Pula, Rabac, Opatija). These islands are not resolved in any of the global models. Therefore the values in the coupling files are values for the open sea. Measured values of SST were measured very close to the (real) coastline of these islands, but this did not spoil the results.

Good agreement in measured SSTs and those in the coupling files can be noticed on many of the coastal stations. SST changes on a scale of several weeks are represented in the SST in the coupling files for many events (but not all, unfortunately not for the most intense one). Several events with rapid cooling and then warming of SST of local character are not represented in the changes in the SST provided in the coupling files, but this is not surprising. There are locations where measurements of SST on several stations exhibit similar intensive variations that are not present in SST data from models.

Measured SST values are much lower on the Italian (west) coast of Adriatic than those provided in the coupling files during winter due to a cold current along the west Adriatic. This west Adriatic current (WAC) flows in a relatively narrow stream close to the shoreline and it is possibly not resolved by the analysis that contributes SST to the global models. The discrepancy between measured and model SST first increases from the north (Trieste, Venice) and reaches maximum in the central Adriatic (Ancona to Vieste) but then the difference in measured and coupling files SST decreases going southeastward along the Italian shore as WAC mixes with the open sea waters and becomes warmer (Bari, Brindisi, Otranto).

Conclusions and further work

SST fields from IFS and ARPEGE corresponds well to the values measured in-situ on the operational stations in Italy and Croatia and reflects changes in SST on the scale of several days that affect considerable geographical area. This is very good since the area under study is rather small compared to the whole domain of the global models and isolated from the rest of the sea surface.

There were problems with SST from IFS during cold part of the year for a number of stations. The warm bias starts abruptly on 1st November each year and reduces by 1st April the next year. It can be observed on data at some stations but not on the neighbouring ones. This issue was solved during summer of 2013 and did not appear since. See Appendix B for more details.

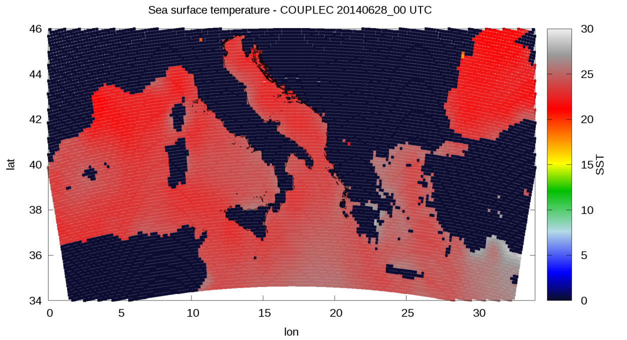
If the process in the ocean is more localized, then SST from the model fields differs to the measured values on stations. Also, during extended periods of extremely cold weather, such as the February 2012, SST in models was considerably warmer than measured. The impact of this significant difference in lower boundary condition on the LAM forecast in the area will be estimated in a subsequent study.

The west Adriatic current is much colder than the rest of the Adriatic sea during winter. It is not resolved in the SST fields provided from both ARPEGE and IFS. WAC is narrow (less than 10 km) and close to coastline. It is not surprising that it is missed in the SST fields on the resolution of the coupling files (and the global NWP models used to create the files). See Appendix C for more details as well as figures in Appendix B. This cold current has an impact on the local weather and on the meteorological parameters measured on the stations on the coastline, especially 2m temperature and humidity. Using SST from a high resolution database where this current is resolved and well represented could have a positive impact on the overall forecast performance on the Adriatic area.

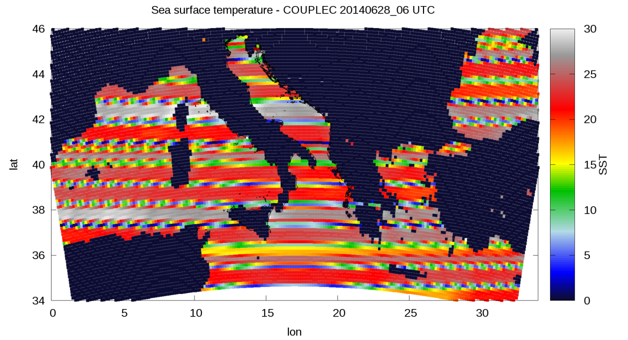
Sudden and intensive cold air outbreaks can reduce SST by several degrees on a time scale of less than one day. One of those events was in the beginning of February 2012. SST remains constant during the model forecast. Allowing SST to change during the forecast run could improve the forecast which is rather important in such severe weather events.

Appendix A

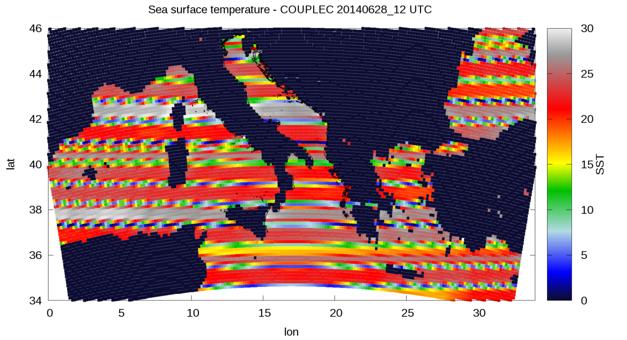
There has been a problem with SST (and possibly other fields) on 28th June 2014 (see fields plotted in Figure A1, temperature over land points has been set to zero). Since SST provided in ECMWF files is overwritten by SST from ARPEGE coupling file during the procedure for data assimilation in Croatian MHS, this did not cause problems in operational forecast.



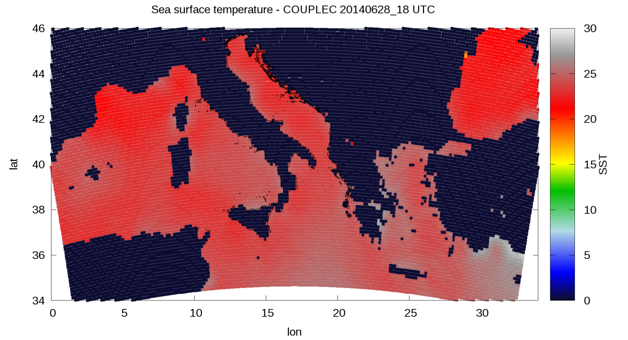
SST 00 UTC analysis 28 June 2014



SST 06 UTC analysis 28 June 2014



SST 12 UTC analysis 28 June 2014



SST 18 UTC analysis 28 June 2014

Figure A1. SST from ECMWF coupling files for different analysis times on 28th June 2014, temperature over land points has been set to zero.

Appendix B – Hot spots

Unfortunately there were some features in SST that could not be physically explained. The most striking examples were Marina di Campo (Figure2) Taranto (Figure 5), Ravenna (Figure 6) Cres, Rabac and Opatija (Figure 7), Bakar (Figure 8) and Split (Figure 9) where measured and model SSTs agree well for the period from 1st April until 1st November each year, but then SST in coupling files from ECMWF suddenly increases for several degrees. This warm bias in SST of up to 5°C (depends on station) remains, or changes suddenly on the 1st day of a calendar month. On 1st April, the bias disappears. Other stations nearby do not exhibit this strange feature.

In order to detect possible reason for this period, SST from IFS and ARPEGE coupling files was plotted in a way that avoided any interpolation. Simply a small square was plotted in appropriate colour in the lat-lon position of the grid point on a map (see example of SST from ARPEGE for 00 UTC analysis on 1st January 2013 in Figure B1). The figures appear to be smooth because of the smooth colour scale. Grid-points representing land-surface were plotted as black squares. Small but resolved islands are shown as squares or rectangles.

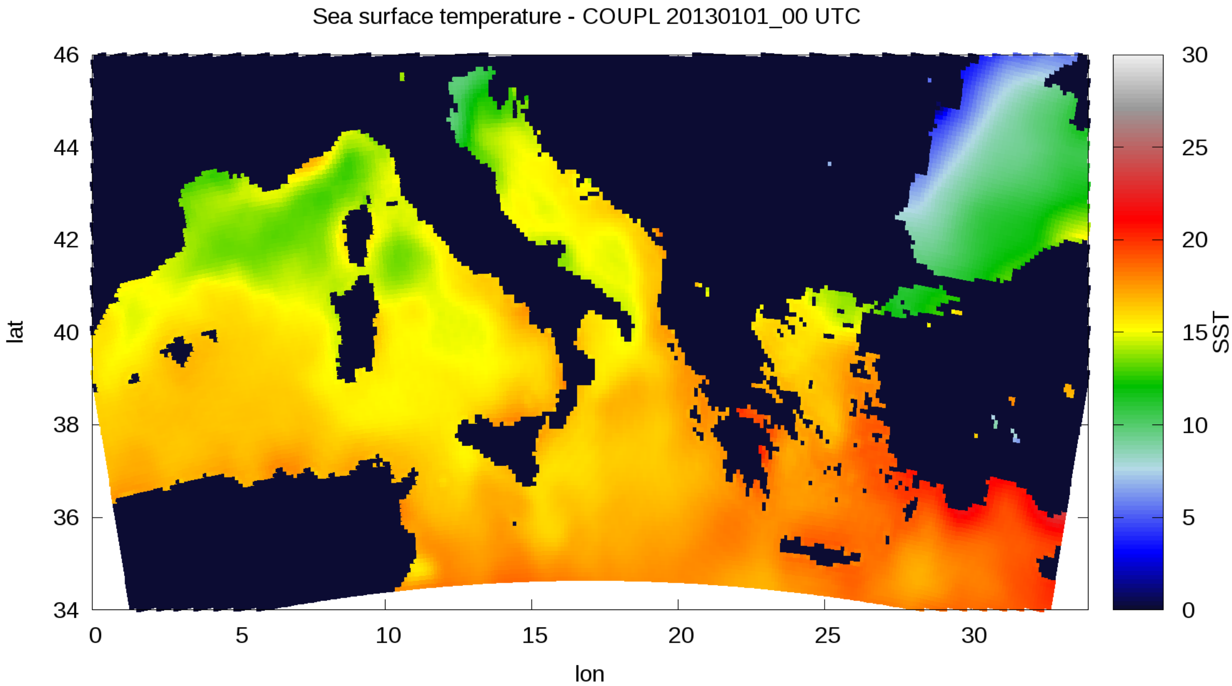


Figure B1. SST from the analysis coupling file of operational ARPEGE on 00 UTC 1st Jan 2013. The figure was drawn by plotting a small square in the colour determined by the SST value in the location of the grid-point, avoiding any interpolation.

Figure B2 shows SST from IFS analysis file for 00 UTC on 1st January 2013. One can immediately see warm spots along coastlines, much warmer than the surrounding sea. These hot spots appear on many grid-points along the coastline and close to unresolved islands. Apparently there was an error in interpolation of SST, that was removed after reporting this feature in the summer of 2013. This can be seen in Figures C1 and C2 that show SST fields from ARPEGE and IFS from analysis on 00 UTC 1st January 2014. As one can see in Figure C2, there were no hot spots along coastlines and unresolved islands in SST field of IFS during last winter (2013/2014).

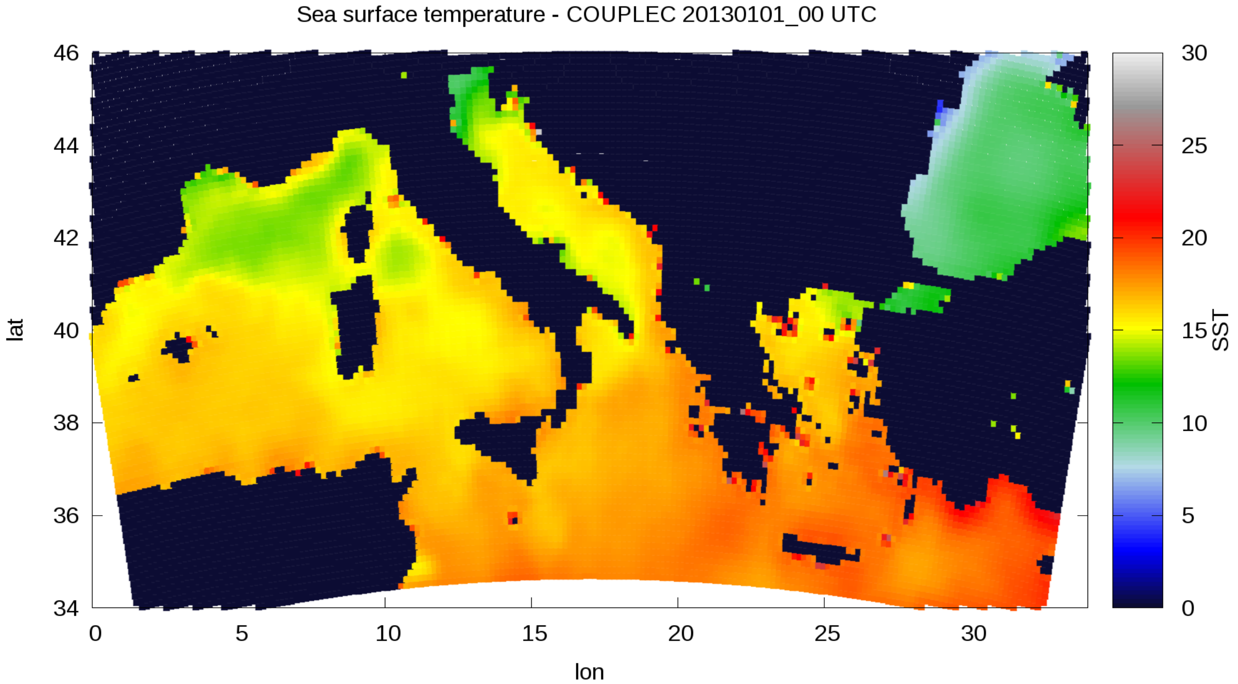


Figure B2. SST from the analysis coupling file of operational IFS on 00 UTC 1st Jan 2013. The figure was drawn by plotting a small square in the colour determined by the SST value in the location of the grid-point, avoiding any interpolation.

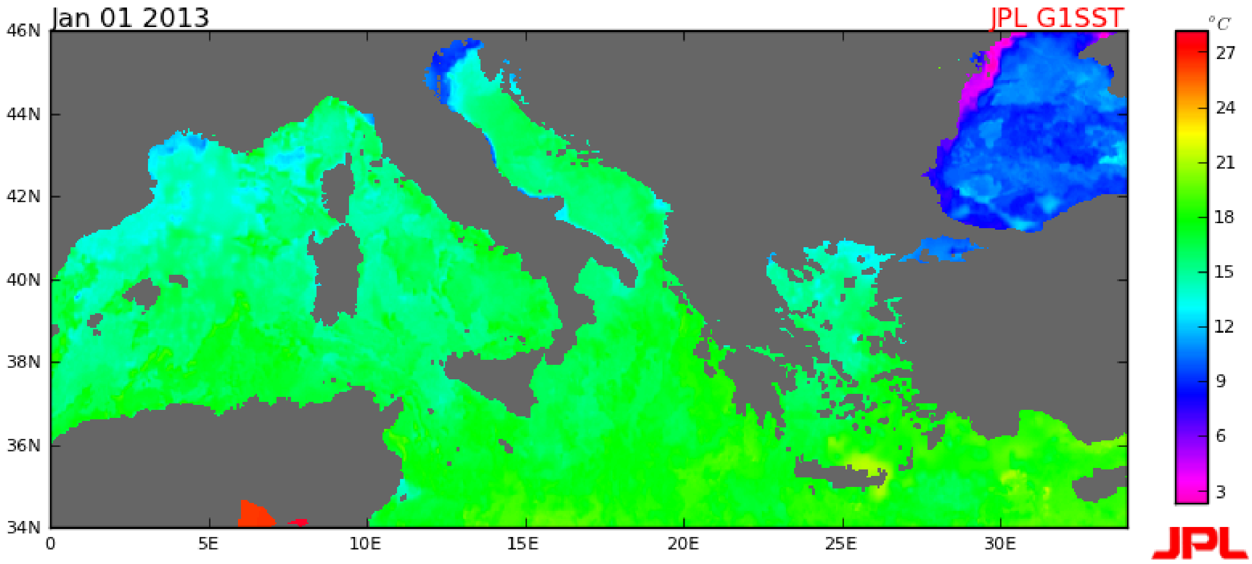


Figure B3. SST for 1st January 2013 from daily ocean analysis run in 1 km resolution by NASA's JPL ROMS group (see text in Appendix C for further details).

Appendix C – Unresolved WAC

The prevailing current system flows counter-clockwise from the Strait of Otranto, along the eastern coast and back to the strait along the western (Italian) coast. The western branch of this circulation is called western Adriatic current (WAC). Several kilometres from the Italian coast, it can be few degrees colder than the rest of the Adriatic Sea surface (See figures B3 and C3). The SST fields of IFS and Arpege do show that sea surface is colder close to the Italian coast of Adriatic than at the open sea, but when these values are compared to the in-situ measurements, one can see that WAC is still much colder than in models. This cold current is probably too narrow to be resolved by the global models IFS and ARPEGE and therefore not present in the analysis. It is possible that there are other high-resolution features in SST that are not well represented in the data from the global NWP models. This cold sea current considerably affects 2m temperature and humidity measured on meteorological stations nearby which in turn could be rejected in the subsequent procedure for data assimilation.

A daily, global Sea Surface Temperature (SST) analysis data set is produced at 1-km (also known as ultra-high resolution) by the NASA's Jet Propulsion Laboratory (JPL) ROMS (Regional Ocean Modeling System) group. More descriptions of the SST input data and the blending algorithm can be found at http://ourocean.jpl.nasa.gov/sst/introduction.html. The zoom of the analysed fields for the area of Adriatic and part of Mediterranean is shown in figures B3 and C3.

IFS, ARPEGE and high resolution SST analysis available from NASA's JPL show cold SST in northern Adriatic. SST there is also close to in-situ measurements in Venezia, Trieste and Ravenna (Figure 6), but at Ancona and further south along the western Adriatic coast (Figures 5 and 6) in winter SST measured in-situ is much colder than in IFS and ARPEGE and on maps of high resolution SST analyses (Figures B3 and C3) one can see a thin stream of cold SST along western Adriatic coast (up to now we did not obtain SST data from JPL's analysis fields for the whole period, but only for several dates). This cold stream in WAC has an impact on measured air temperature along Italian coast as well as other features in local weather. It remains to be evaluated if inserting this cold stream into Aladin SST fields can improve the weather forecast.

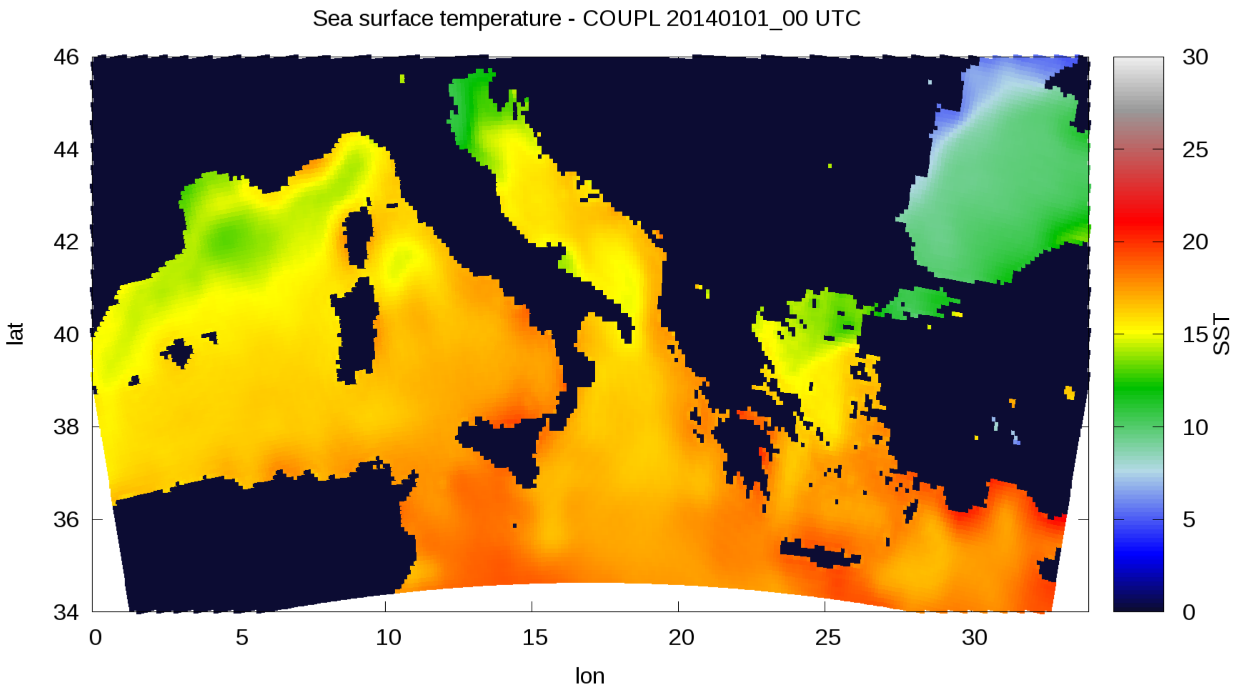


Figure C1. SST from the analysis coupling file of operational ARPEGE on 00 UTC 1st Jan 2014. The figure was drawn by plotting a small square in the colour determined by the SST value in the location of the grid-point, avoiding any interpolation.

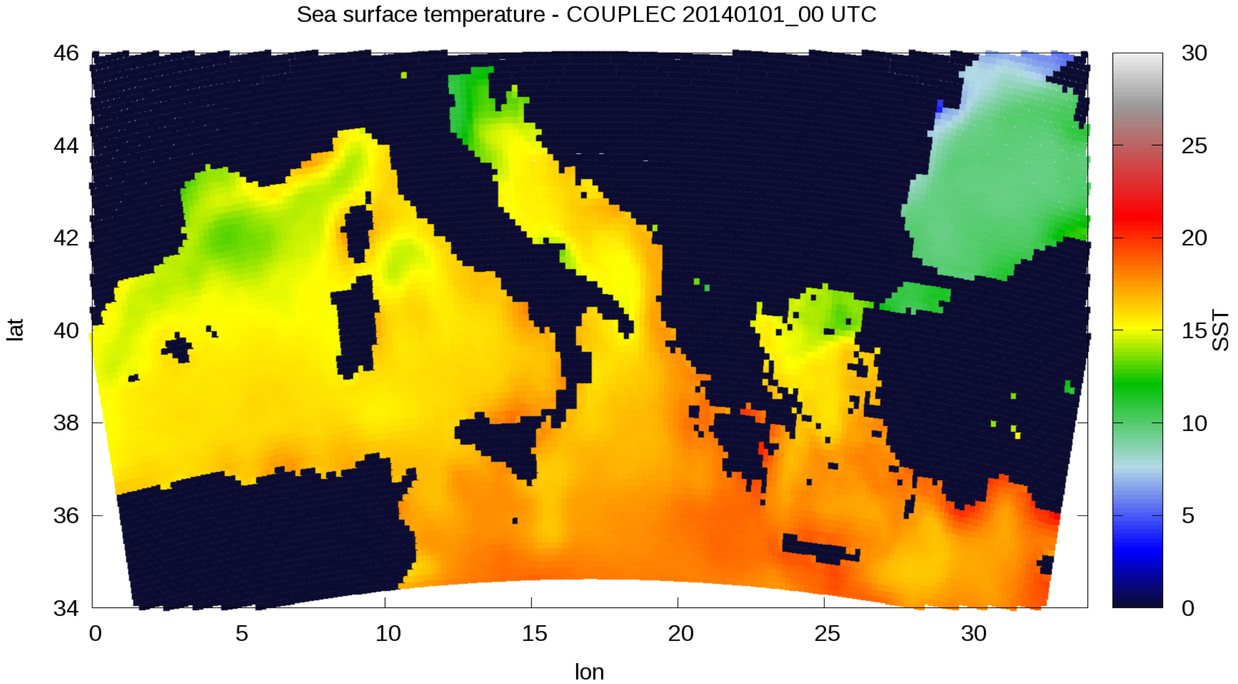


Figure C2. SST from the analysis coupling file of operational IFS on 00 UTC 1st Jan 2014. The figure was drawn by plotting a small square in the colour determined by the SST value in the location of the grid-point, avoiding any interpolation.

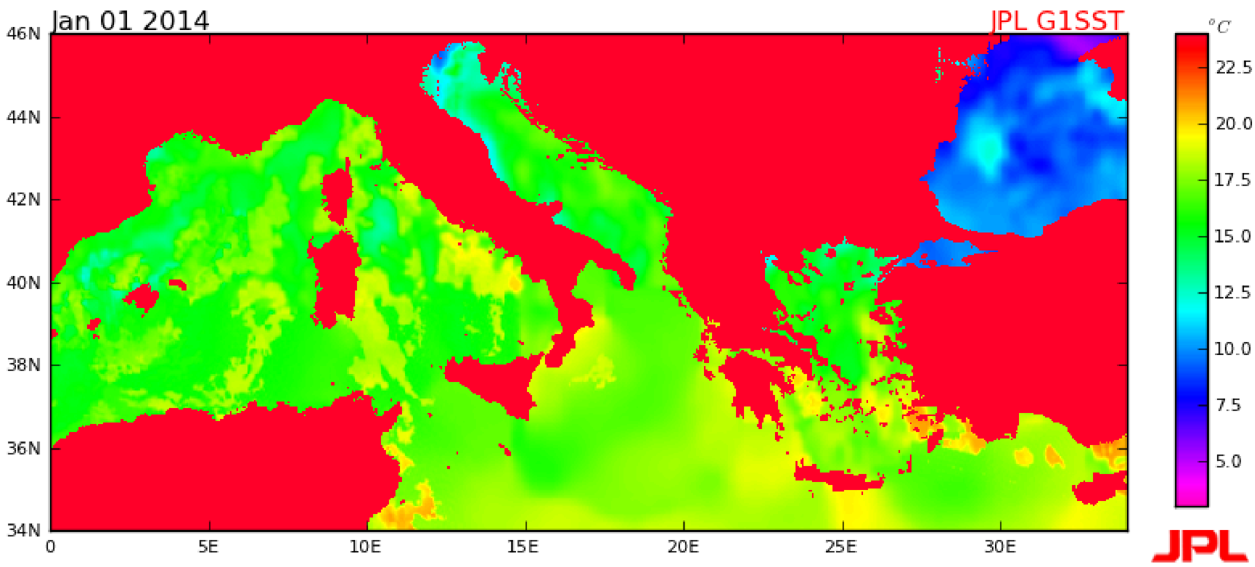


Figure C3. SST for 1st January 2014 from daily ocean analysis run in 1 km resolution by NASA's JPL ROMS group.