Scientific Report for STSM Cyprus-Isael for ES1402

Re-analysis on the mesoscale: tracking the Cyprus eddy

Researcher: Dan Hayes

Host: Hezi Gildor, hezi.gildor@mail.huji.ac.il, Hebrew University of Jerusalem, Edmond J. Safra Campus, Givat Ram, 91904, Jerusalem

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Background: The grantee is required to submit a scientific report (3-5 pages) to the host institution, MC Chair the STSM coordinator for approval within 30 days after the end date of the STSM containing:

- Purpose of the STSM
- Description of the work carried out during the STSM
- Description of the main results obtained
- Future collaboration with the host institution (if applicable)
- Foreseen publications/articles resulting from the STSM (if applicable)
- Confirmation by the host institution of the successful execution of the STSM
- Other comments (if any)

Purpose

At the University of Cyprus, Oceanography Center, thousands of profiles of temperature and salinity have been collected from gliders, and at the same time it has built up a system of data assimilation and operational modelling. In this STSM, Dr. Hayes, the scientist responsible for the above, visited Dr. Hezi Gildor at the Hebrew University of Jerusalem to conduct a thorough and accurate analysis and make significant progress on the associated journal publication. In particular, a short-term experiment was chosen in which glider data were assimilated into the operational system, and the results were compared to the output of the non-operational system in order to investigate the differences and possible improvement in accuracy of the analyses produced by the assimilative system. Such an improvement in short-term predictability would have implications on many real-time applications, such as oil spill response, or search and rescue. In addition, it demonstrates the advantages of assimilating glider data for better state estimate of the ocean hydrological structure.

Description of the work carried out

In this STSM, Dr. Hayes focused on the analysis of an operational data assimilation system he has

implemented at the Oceanography Center, University of Cyprus. A glider mission took place from mid-December 2011 until early June 2012 south of Cyprus, during which time an operational forecasting system was also initiated and monitored by Dr. Hayes. Temperature and salinity profiles were assimilated every day in the data assimilative run, but not in the control run. Both runs were initialized once at the beginning, and restarted every day with updated, identical surface and open boundary conditions. The output of these two runs were investigated in detail, based on a preliminary analysis done in 2013 and presented in GODAE (Hayes et al. 2013). In particular, the following were achieved:

1. Define the remaining steps to analyze the data sets in order to make the conclusions relevant and convincing. In this phase, it was important to choose a set of representative periods within the six months experiment to illustrate the differences between the runs when the glider was in a region of strong corrections (Cyprus eddy) compared to a region away from model errors. Once these periods were chosen (based on the animations produced in 2013), the parameters to be used to illustrate differences were chosen, based on how apparent they were (mid-depth salinity anomalies) and how influential in practical applications they were (surface currents).

2. Begin writing a journal publication describing the data sets, the methodology, initial results, with placeholders for the outcomes of the data analysis. In fact, the paper was mostly completed, since it was possible to investigate a subset of the data for the effect of the assimilation (parameters and periods identified above). Both graphics and and statistics were generated for the paper.

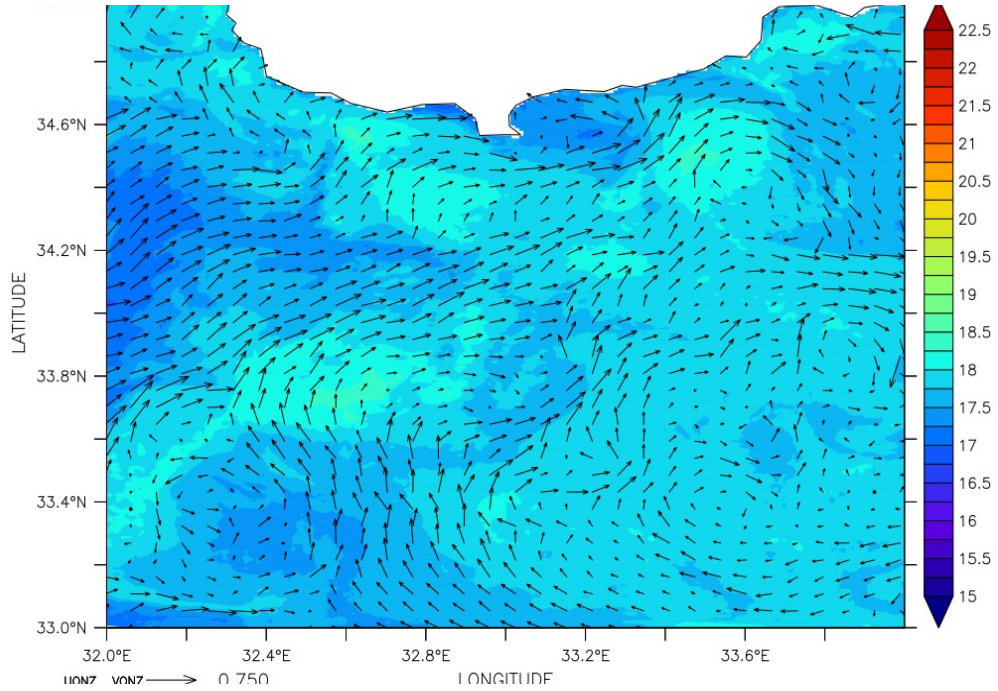
3. Visit facilities and colleagues. Discussions about forecasting model (Princeton Ocean Model), glider tools (flight simulator) and related data analysis (Sea Level Anomaly, Ocean Data View) took place with several colleagues and young students at HUJI. Prospects for future collaboration were also discussed (see below).

Description of the main results obtained

This STSM is relevant mostly to *WG3 Applications: from short-term predictability to climate studies*, since it examines the Cyprus eddy impact on local forecasts. The production of ocean analyses in near real time as been achieved in order to provide improved short-term predictability for marine researchers, managers, and citizens. However, until now, the predictability was not examined at this scale using glider data assimilation. The main results achieved (and written in the draft publication) are as follows.

1. Analyzed fields are significantly different from background fields in the region south of Cyprus in regions of the Cyprus eddy. Examining the surface current output of the two systems from 25 January, 2012, shows that the surface temperature and currents have a strong signature of the Cyprus eddy in the analysis, but not in the control run (see Fig. 1). This is even more evident in deeper layers, where the model T-S errors are highest because of the presence of the warm, salty eddy core.

2. Analyzed fields of temperature and salinity are more accurate than background fields. Examining the root-mean-square differences of the observed and model profiles of temperature and salinity at the glider location shows that the background is further from observations than the analysis (before assimilation). The same is true of salinity. Table 1 shows the RMS values averaged over all depths for the whole missions for each case. Error reduction of about 15% is seen in both. Note that the error is higher in the intermediate depths, where the core of the Cyprus eddy is located (not shown).



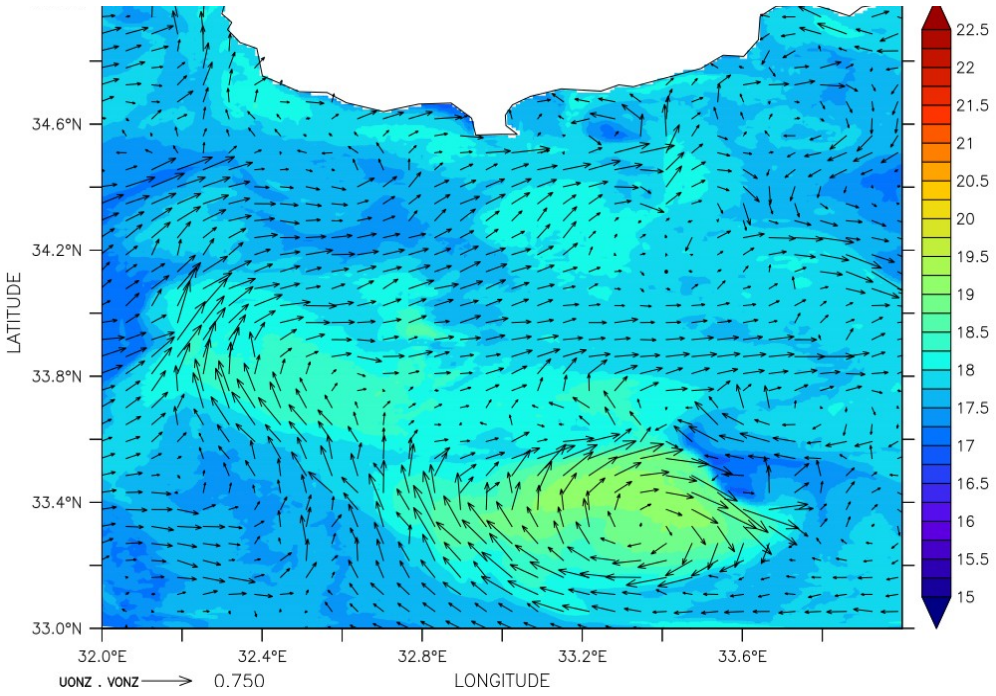


Figure 1. Currents direction and Temperature at 1 m for day 50 (24 January 2012) for control run (top) and data assimilative run (bottom). Region of Cyprus eddy is 33.5ºN, 33.5ºE.

Table 1. RMS differences between glider temperature and salinity observations and model fields before assimilation.

	RMS	% reduction
RMS-T-control	2.09	
RMS-T-d/a	1.78	15%
RMS-S-control	0.405	
RMS-S-da	0.355	13%

Future collaboration with the host institution

In the near future, the paper will be finalized and submitted with the addition of text from Dr. Hayes and the contribution of a figure from Dr. Gildor illustrating the trajectory of tracers for each of the runs. It is also planned that a paper presenting dynamics of the Cyprus eddy will be developed using glider data sets, and possibly data assimilation model data sets.

Future joint activities that could improve or refine the understanding of the circulation of the region, either by observing systems or analysis methods, are also expected. For example, the production of a long-term high resolution hindcast for the region using all 7 years of glider data, as well as float data could be produced.

Foreseen publications/articles

During the course of this STSM, significant progress was made in writing a journal publication titled "Operational Assimilation of glider temperature and salinity in a mesoscale flow field: Eastern Mediterranean test case." Authors include Daniel Hayes, Hezi Gildor, and Srdjan Dobricic. This paper was outlined three years ago, with only generic text, and was the focus of this STSM. Several pages of text were written, leaving only the abstract and a few literature discussion points. Also several figures were generated in order to show the short-term predictability increase that results from assimilating glider data. This paper will be submitted in the coming weeks to Ocean Science (Copernicus Publications).

Confirmation by the host institution of the successful execution (Dr. Gildor)

I hereby confirm that Dr. Hayes successfully carried out a short-term scientific mission (STSM) at the Hebrew University of Jerusalem. During this period, a number of achievements were made. In particular, the effect of assimilating glider data into a high resolution ocean forecast was investigated in detail. Dr. Hayes, with my feedback, made tremendous progress on a paper describing the methods and results of his data assimilation experiment. Future collaborative work on larger glider data sets, and how they can be used to produce regional analyses is expected. His discussions with my students were also very useful.

Comments

Dr. Hayes would like to take this opportunity to thank the COST Action ES1402 for providing this opportunity to focus on data analyses and writing a related publication. Although short, the STSM provided a "mini-sabbatical" that was much needed to resume work that was interrupted many times the last few years.