SPECIAL PROJECT PROGRESS REPORT

Reporting year	2016/17
Project Title:	Homogeneous upper air data and coupled energy budgets
Computer Project Account:	Spatlh00
Principal Investigator(s):	Leopold Haimberger
Affiliation:	University of Vienna
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Hans Hersbach, M.A. Balmaseda, D. Dee, P. Dahlgren
Start date of the project:	1.1.2015
Expected end date:	31.12.2017

Computer resources allocated/used for the current year and the previous one

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10000	2	10000	0
Data storage capacity	(Gbytes)	10000	200	10000	2000

Summary of project objectives

The special project is intended to support the participation of University of Vienna in the EC 7th framework programme project ERA-CLIM2 as well as a new research project on Arctic energy budgets funded by the Austrian Science Funds (FWF). Work package 4 of the EC project deals with the assessment of the observation uncertainties of historic in situ data, especially those who have recently been digitized but never have been assimilated. If possible, observation records shall be improved through homogenization, either offline or online with variational bias estimation methods. In previous projects, the main candidates for homogenization back to the early 1940s were radiosonde temperatures and winds. This is now being extended to humidity.

Better homogeneity of upper air data improves, when assimilated, evaluations of global energy budgets. The research on coupled energy budgets is now extended to the Arctic. Significant advances on their evaluation could be made in the past year.

Timely and convenient access to the atmospheric and oceanic reanalysis archives, especially the observations databases is needed for this purpose. The requested computer time will be needed mostly for statistical analysis of the observation data and background/analysis departures as well as for short assimilation runs.

Summary of results of the current year

Since project start the users of the special projects were active in three fields:

1) Solar elevation dependent homogenization of radiosonde temperatures, back to the 1940s
2) Using ERA-Interim and quantile matching for homogenizing radiosonde humidity data
3) Estimating energy budget variability in the tropics and in the Arctic using atmospheric and oceanic reanalyses

Ad 1)

Homogenization of radiosonde temperatures can now be based not only on full reanalyses or data assimilation experiments that have assimilated upper air data (ERA-Interim, JRA55, ERA-preSAT, Hersbach et al. 2017) but also on surface data only reanalyses such as CERA-20C (Laloyaux et al. 2016). For surface data only reanalyses it has been necessary to calculate departure statistics offline, interpolating the gridded temperature data to observation locations both in space and time. It could be demonstrated that these surface data only reanalyses can be useful as reference for break detection and adjustments to correct pervasive biases in large station networks such as over the Former Soviet Union. Fig. 1 shows temperature trends from unadjusted station series (upper left), RAOBCORE using CERA-20C reanalyses as reference for break detection and adjustment (upper right), and RICH using CERA-20C for break detection (lower left) and RAOBCORE using full reanalyses as reference. It is evident that the strong trends over Russia are artificial, caused by changes in the observing system. After adjustment with RAOBCORE using CERA-20C as referenc trends are a lot more consistent with those in neighbouring countries. Using full reanalyses, which ingested unadjusted radiosonde temperature data, appears not advisable in this case since there was too few independent information to offset the negative effect of the biased radiosonde temperatures. Consequently the adjustments are too weak to remove the spurious trends (lower right panel). It even seems that due to the biased background forecasts from those full reanalyses, trends at stations next to the Former Soviet Union are wrongly adjusted. The RICH, method (Haimberger et al. 2012), which uses only radiosonde stations surrounding Russia as reference, also removes the signal but appears to leave more noise than RAOBCORE with CERA20C as reference. This can be seen from the “Cost” values given in the panel titles, which are lowest in the upper right panel.
While this results looks promising, it should be noted that surface data only reanalyses can have spurious trends as well. Also the standard deviation of departure time series from observations minus the surface data only reanalyses can be large at high altitudes and latitudes, since surface data only reanalyses may not capture Stratospheric Sudden Warmings (not shown).

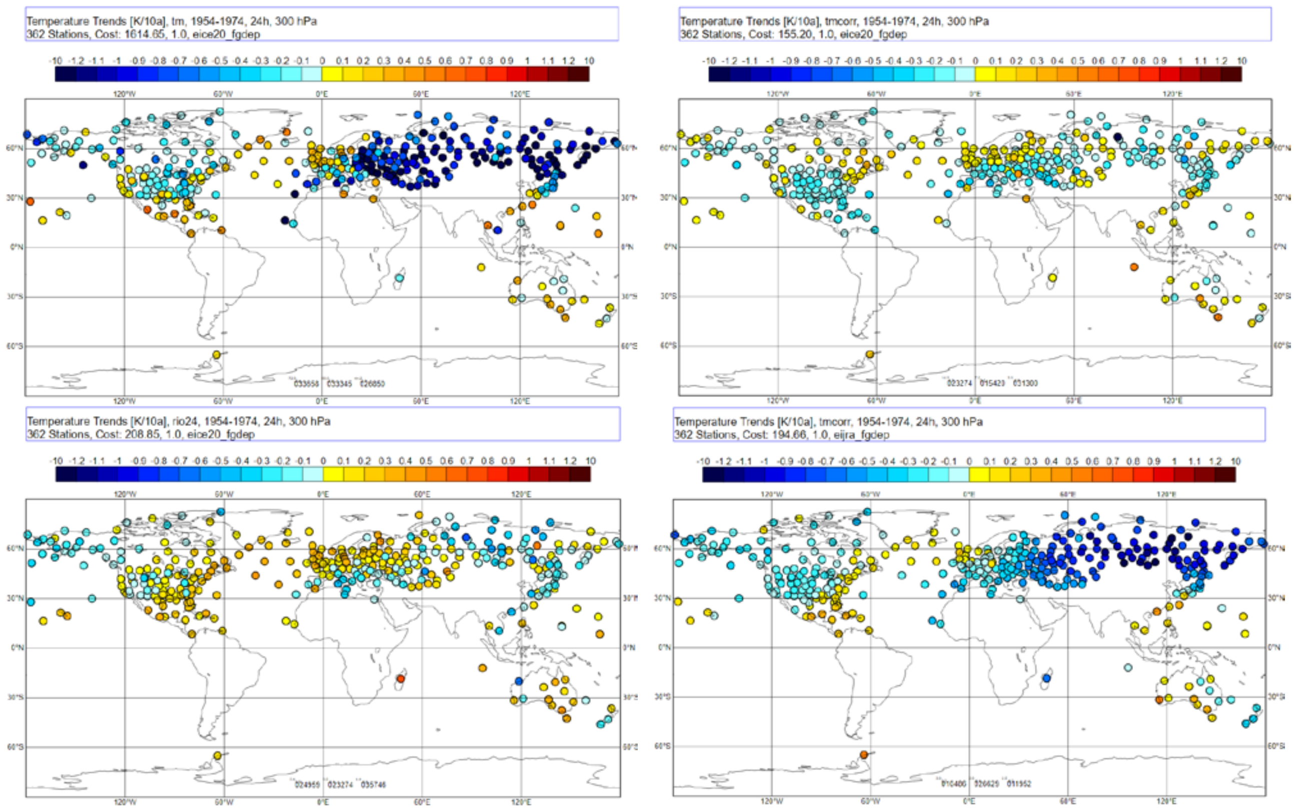

Fig. 1: Temperature trends at 300 hPa over the period 1954-1974, upper left from unadjusted radiosonde temperatures, upper right from temperatures adjusted with CERA20C surface data only reanalysis as reference, lower left from temperatures adjusted using neighboring radiosonde series (RICH) as reference, lower right from temperatures adjusted with background fields from ERA-preSAT/JRA55, both of which have assimilated radiosonde data.

Ad 2):

It could be shown that humidity trends from ERA-Interim are affected by the biases in the radiosonde humidity data. In Fig. 2 a clear imprint of the strong radiosonde humidity biases over the US and China on the resulting analysed humidity is evident on the ERA-Interim reanalysis trends, although the trends in ERA-Interim are much less extreme than in the undadjusted radiosonde data. The homogenization method for humidity has been further improved to be able to adjust more stations than until now. In the remaining months we plan to further improve the adjustment method such that more breaks in the humidity time series are detected. We also plan test assimilations with IFS that ingest the newly developed radiosonde humidity bias adjustments.

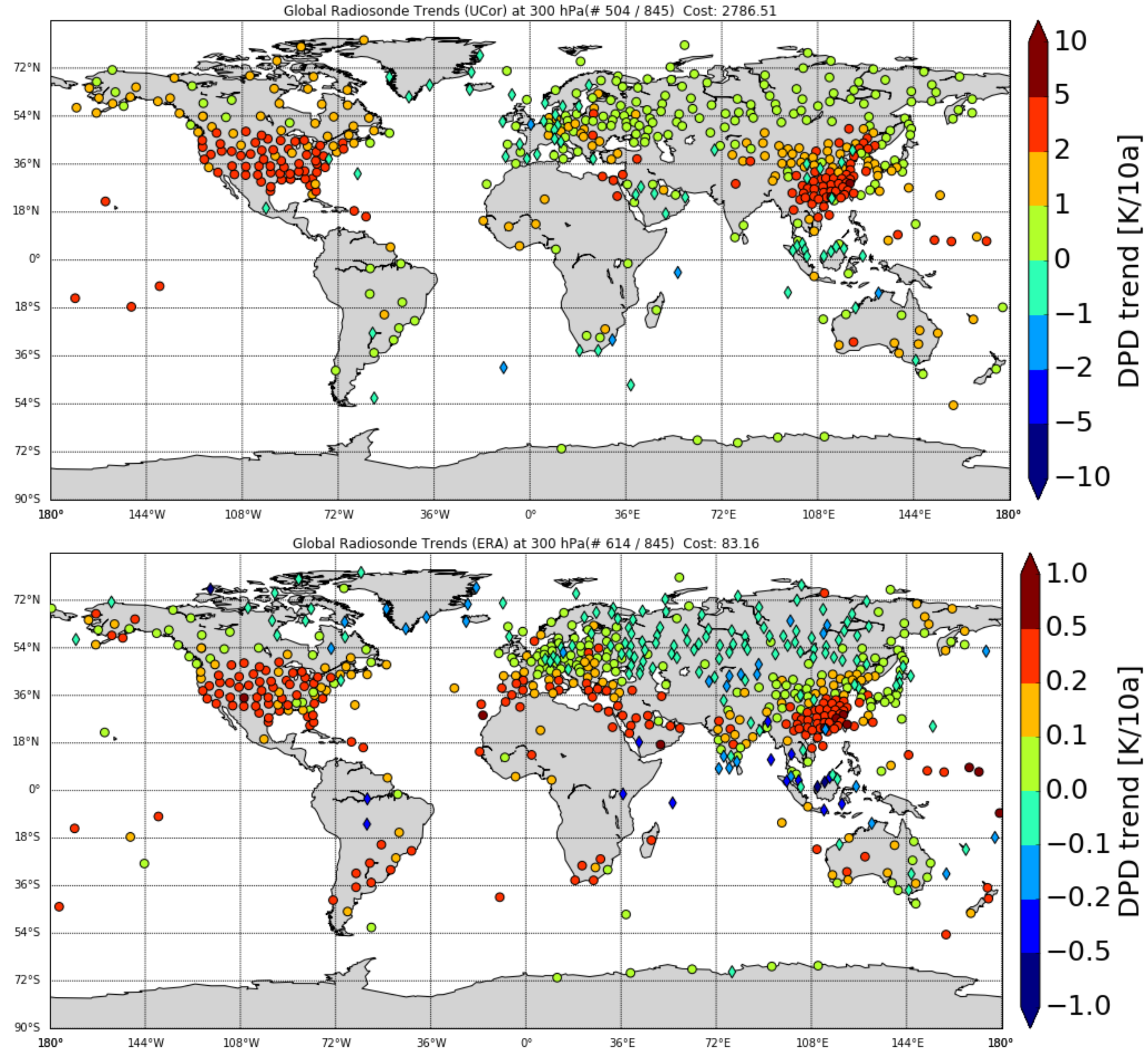

Fig. 3: Dewpoint depression trends 1979-2016 at 300 hPa level from unadjusted radiosondes (upper panel) and ERA-Interim (lower panel). Note scaling is one order of magnitude smaller in the lower panel.

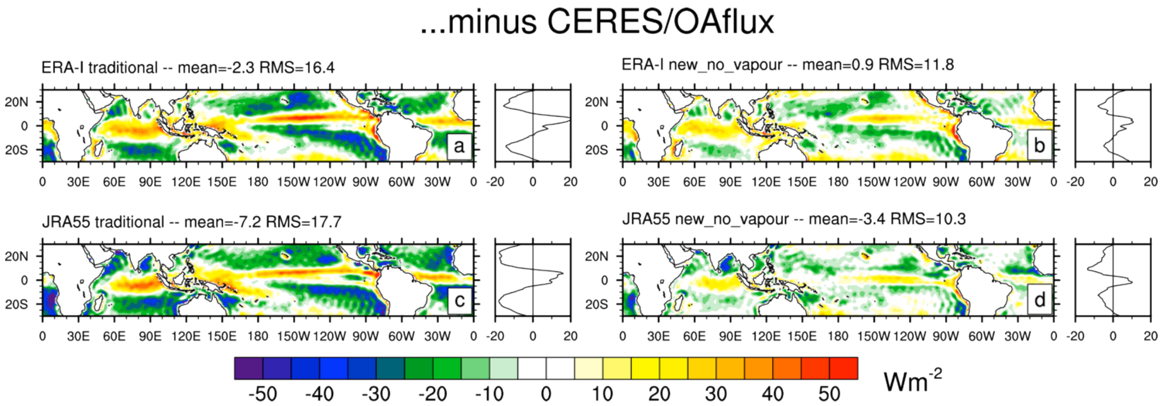

Fig. 4: Difference of implied net surface energy flux based on top of atmosphere radiation from CERES (Wielicki et al. 1996) and a) ERA-I based "traditionally" computed energy divergence, b) ERA-I based energy divergence with the effect of water vapor removed, c) JRA55-based "traditionally" computed energy divergence, d) JRA55-based energy divergence with the effect of water vapor removed, and net surface energy based on RadS from CERES and OAflux (Jin and Weller, 2008) turbulent fluxes. Units are Wm-2. From Mayer et al. (2017)

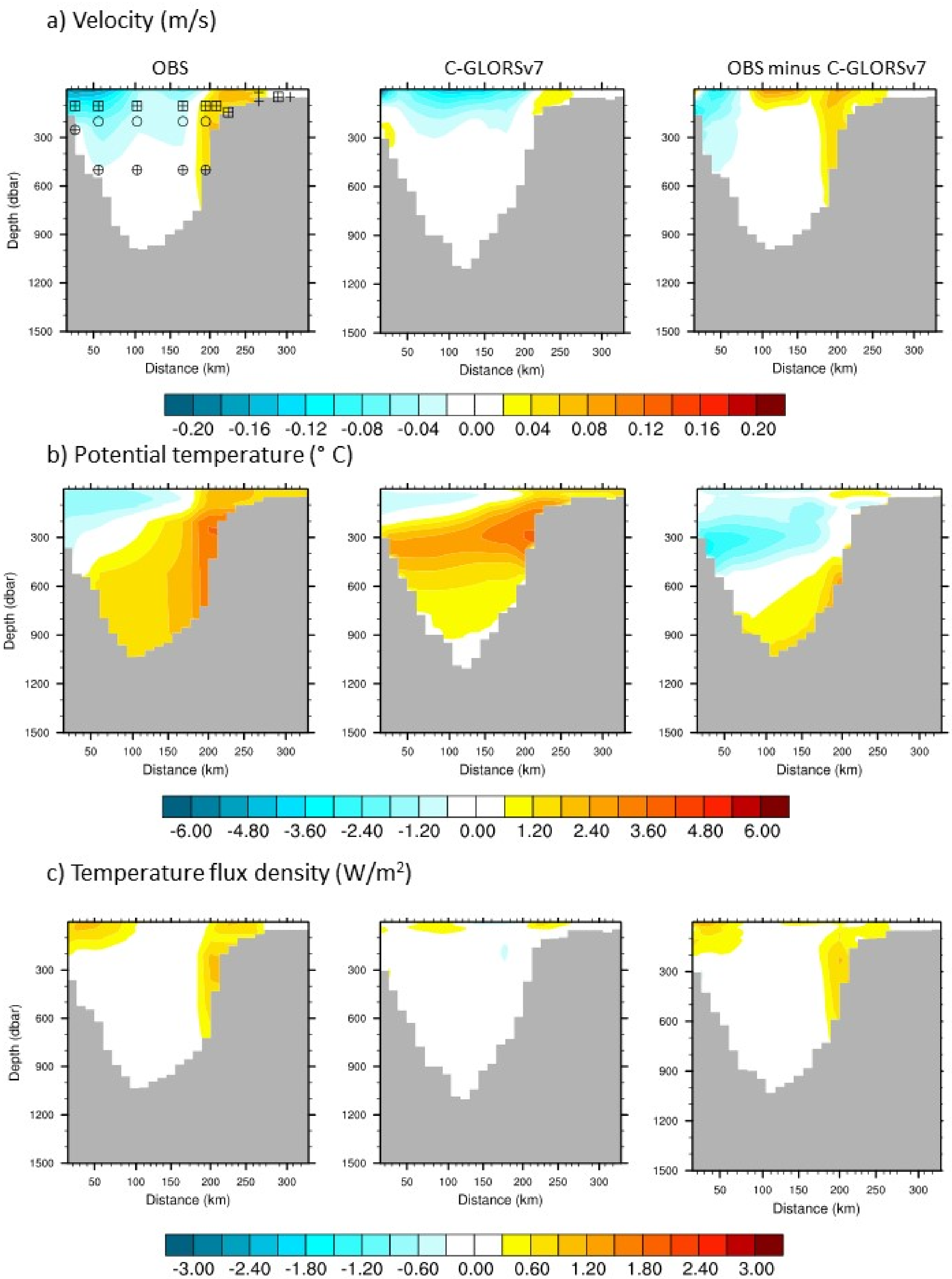

Fig. 5: Velocity (a), temperature (b) and temperature flux density (c) cross-sections for Davis Strait obtained from the observation-based dataset (OBS), C-GLORS version 7 and the difference between the two. The plots show averages of the fields over the one-year study period. Distance (x-axis) is the great circle distance to a point on the coast of Baffin Island (66.6° N and 61.3° W). Positive velocities signify Arctic inflow and are directed into the paper. The symbols in the observation-based cross-section show the locations of moored instruments in the strait: Circle = RCM (different types of Aanderaa current meters measuring temperature and velocity, and in some locations also salinity), plus sign = SBE (SeaBird instruments measuring temperature and conductivity) and square = ADCP (Acoustic Doppler Current Profiler measuring velocity profiles). A combination of two symbols signifies locations of both instrument types (for example, a plus sign in a circle). From Pietschnig et al. (2017)

Ad 3):

Substantial advances could be made in terms of atmospheric budgets. Mayer et al. (2017) could show that moist enthalpy budgets so far have been affected by an inconsistent treatment of horizontal moisture fluxes in the moist enthalpy divergence term, which made this quantity dependent on reference temperature. After fixing this much more realistic indirect estimates of the net surface energy balance particularly in the tropics could be gained(see Fig.4), leading to a reduction of the imbalance between directly and indirectly estimated net surface energy fluxes . In another effort, the arctic mass, energy and freshwater budgets have been studied. The unique data set of subsurface transports through Arctic gateways by Tsubouchi et al. (2017) has been used to compare those with state of the art oceanic reanalyses. Pietschnig et al. (2017) compared those fluxes with CMCC C-GLORS v5 and v7 data (Storto et al. 2016) in the framework of ERA-CLIM2 and found sizeable differences, particularly in Davis strait. The ECMWF oceanic reanalysis (ORAS5) has also be included a preliminary intercomparison and results are currently evaluated. It appears to perform better than C-CLORS in many cases, although substantial differences compared to the observations-based estimates, which require further investigations, occur also there.

List of publications/reports from the project with complete references

- Blaschek, M. and Haimberger, L., 2016: Global radiosonde humidity data bias-corrected with ERA-Interim background departures. In preparation.
- Haimberger, L., C. Tavolato, and S. Sperka, 2012: Homogenization of the global radiosonde temperature dataset through combined comparison with reanalysis background series and neighboring stations. J. Climate **25**, 8108–8131.

- Hersbach, H., S. Brönnimann, L. Haimberger, M. Mayer, L. Villiger, J. Comeaux, A. Simmons, D. Dee, S. Jourdain, C. Peubey, P. Poli, N. Rayner, A. Sterin, A. Stickler, M. A. Valente, S. Worley, 2017: The potential value of early (1939-1967) upper-air data in atmospheric climate reanalysis. Quart. J. Roy. Meteorol. Soc., in press.

- Jin, X., and R. A. Weller, 2008: Multidecade Global Flux Datasets from the Objectively Analyzed Air-sea Fluxes (OAFlux) Project: Latent and Sensible Heat Fluxes, Ocean Evaporation, and Related Surface Meteorological Variables Lisan Yu. OAFlux Project Tech. Rep. OA-2008-01
- Laloyeux, P. et al., 2016: The CERA-20C reanalysis. In preparation, short description at https://climatedataguide.ucar.edu/climate-data/cera-20c-ecmwfs-coupled-ocean-atmosphere-reanalysis-20th-century
- Mayer, M., L. Haimberger, J. M. Edwards, P Hyder, 2017: Towards consistent diagnostics of the coupled atmosphere and ocean energy budgets. J. Climate, under review.

- Pietschnig, M., M. Mayer, T. Tsubouchi, A. Storto, L. Haimberger, 2017: Comparing reanalysis-based volume and temperature transports through Arctic Gateways with mooring-derived estimates. J. Geophys. Res. Oceans, under review.
- Storto, A., and S. Masina (2016a), C-GLORSv5: an improved multipurpose global ocean eddy-permitting physical reanalysis, Earth Syst. Sci. Data, 8(2), 679–696, doi:10.5194/essd-8-679-2016.
- Tsubouchi, T., S. Bacon1, A. C. Naveira Garabato, Y. Aksenov, U. Schauer, A. Beszczynska-Möller, E. Hansen L. de Steur, C. M. Lee and B. Curry, 2017: The Arctic Ocean seasonal cycle: an observation-based inverse estimate. Submitted to JGR Oceans
- Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment. Bull. Am. Meteorol. Soc., 77, 853–868.

Summary of plans for the continuation of the project

The objectives of the project have been mostly achieved. The remaining 6 months will be devoted to quality assurance and publication of results. A new special project that in essence continues and enhances the efforts of the now almost finished special project has been submitted.