SPECIAL PROJECT PROGRESS REPORT

Reporting year	2014/2015
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)	D. Dee, P. Poli, Hans Hersbach, M.A. Balmaseda
Start date of the project:	1.1.2015
Expected end date:	31.12.2016

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	-	-	10000	0
Data storage capacity	(Gbytes)	-	-	500	100

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. Work package 4 of this 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 will now be extended to humidity. A comparison of DMSP MSU humidity data is ongoing

Better homogeneity of upper air data helps, after being assimilated, also to get improved evaluations of global energy budgets. The importance of the homogeneity issue for such evaluations has been shown by Mayer and Haimberger, 2012. Investigations of coupled energy budgets using the most recent ERA-Interim and ORAS-4 reanalyses have yielded quite enlightening results regarding the energy flow related to ENSO (Mayer and Haimberger, 2014). It is intended to expand these studies on coupled energy budgets to other regions, mainly the Arctic. Timely and convenient access to the 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) Homogenization of radiosonde temperatures of the early period using experimental assimilation runs as reference
2) Using ERA-Interim and DMSP Microwave radiances for checking the homogeneity of radiosondes
3) Estimating energy budget variability and comparing it with state of the art climate model runs

Ad 1)

Temperature homogenization back to beyond 1958 using a special assimilation experiment, ERA-preSAT, as well as JRA55 has yielded interesting results. The radiosonde network between 1950 and 1980 is relatively dense in the northern hemisphere and appears quite stable over the US but shows several shifts over the Former Soviet Union. These could only be partly homogenized so far using reanalysis background forecasts (RAOBCORE method) since they are so pervasive and therefore influenced also the ERA-preSAT and JRA55 reanalyses. Using neighboring radiosondes as reference worked better despite the large interpolation distances (RICH method). Fig. 1 shows the result of homogenization efforts in a very early period.

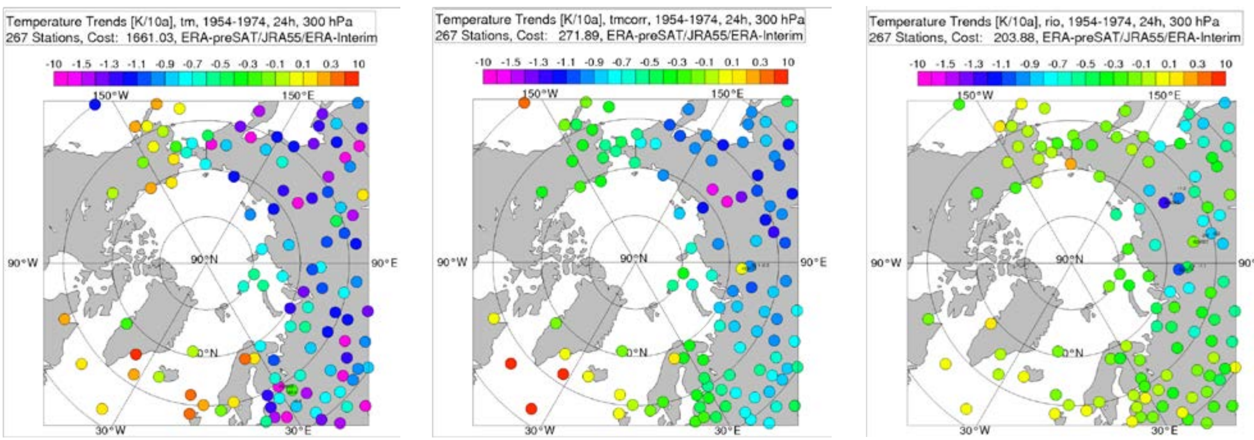

Fig. 1: Temperature trends in K/10a for period 1954-1974 for raw (left), RAOBCORE-homogenized (middle) and RICH-homogenized (right) radiosonde temperature time series at 300 hPa. 36 months missing data allowed. ERA-PreSAT and JRA55 used as reference for break detection. For details of homogenization methods see Haimberger et al. (2012)

Ad 2):

Work on homogenizing radiosonde humidity has started with comparing it with ERA-Interim as well as DMSP SSMIS microwave radiances. Brightness temperatures (BT) at humidity sensitive channels are calculated employing the Radiative Transfer for TOVS (RTTOV) v11.2 from atmospheric profiles of both ERA-Interim and radiosondes. The preliminary results show that BT in the upper atmosphere (Ch. 9-11) agree fairly well on a global basis (Fig.2). However, with higher levels larger deviations from ERA-Interim suggest biases in opposite directions for ERA-Interim and most radiosondes. ERA-Interim appears to be too dry, whereas radiosonde observations are too moist compared to satellite data. The spatial differences between ERA-Interim and F-16 show hemispherical biases for example in June 2010 (Fig. 3) as well as spatial inhomogeneity of radiosonde observations. It is planned to expand the temporal coverage of humidity sensing satellites (DMSP 11-15) back until 1992 based on the work of Kobayashi (in preparation, ERA Report of SSM/T-2 radiances) as a visiting scientist at the ECMWF. It is further planned to estimate humidity biases via quantile-matching from ERA-Interim and potentially GPS-RO.

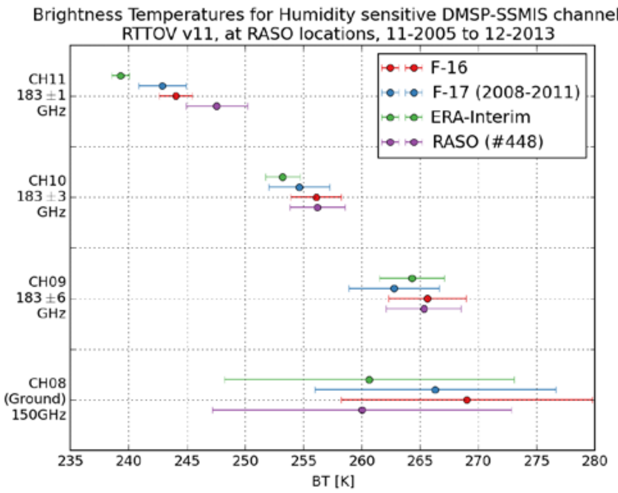

Fig. 2: Brightness temperatures (BT) from DMSP Satellites F-16 and F-17 as well as BT from ERA-Interim and radiosondes calculated using RTTOV. Shown are medians and standard deviations from four humidity sensitive channels (8-11) from Nov. 2005 to Dec. 2013.

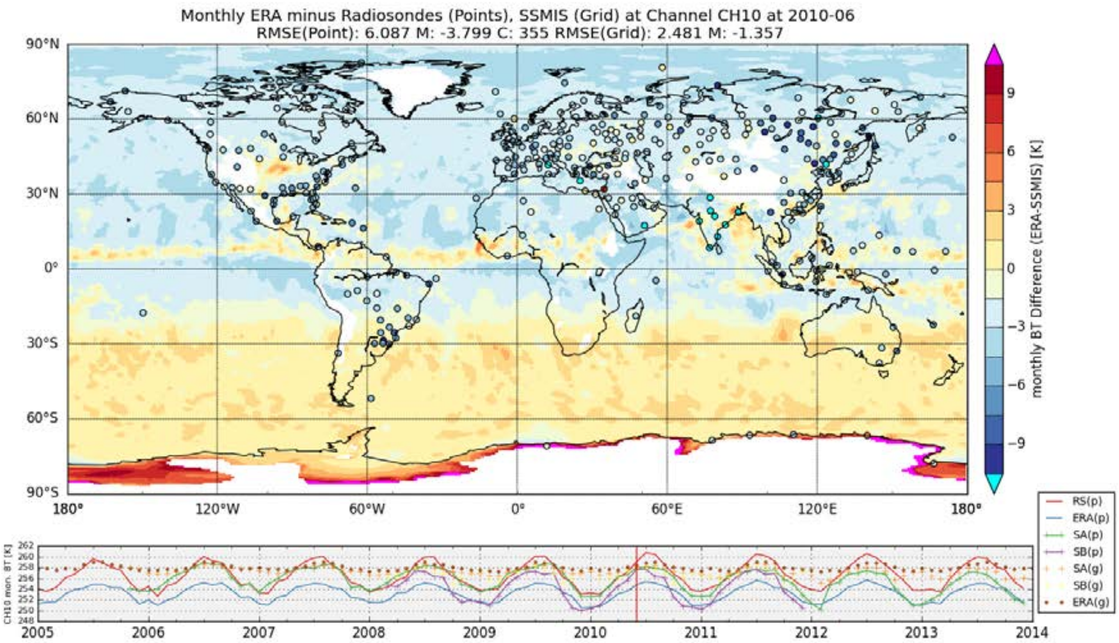

Fig. 3: Monthly brightness temperature (BT) departures from ERA-Interim for radiosondes and DMSP-Satellite F-16 at channel 10 (183±3 GHz) in June 2010. RS: RASO, ERA: ERA-Interim, SA: F-16, SB: F-17. (p) only at RASO locations, (g) global for the whole grid.

Ad 3):

The investigations on the global atmospheric and oceanic heat budgets have been continued from the previous special project. The ENSO related energy budget variability that was estimated by Mayer et al. (2014) has been compared to that of climate models. Fig. 4 shows that the ENSO-related heat content variability is underestimated in most climate models. Fig. 5 demonstrates that OHCT700 variability related to Nino 3.4 index over tropical Pacific is far too weak in climate models. The same holds for surface fluxes over the tropical Atlantic.

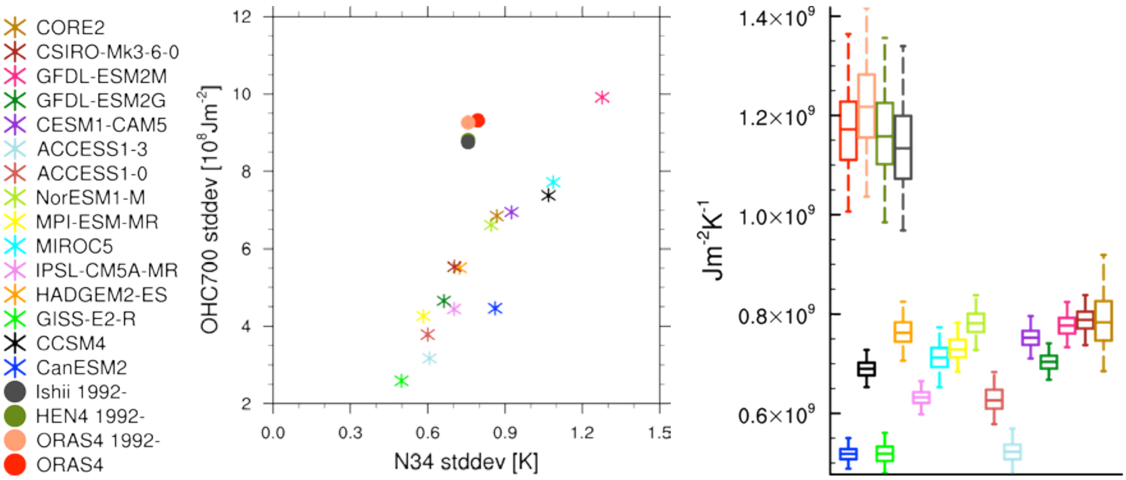

Fig.4: Niño 3.4 index standard deviation versus the temporal standard deviations of OHC700 averaged over the N3.4 region from ORAS4 (1979-2013 and 1992-2013), HEN4 (1992-2013), JMA (1992-2012) and CMIP5 models (left panel);

Fraction of the standard deviations of OHC700 in the N3.4 region and N3.4 index standard deviations (right panel). Boxes mark the inner quartiles and whiskers mark the 2.5 and 97.5% percentiles, respectively; uncertainties are estimated with a block bootstrap method (length of the blocks is set to 6 months);

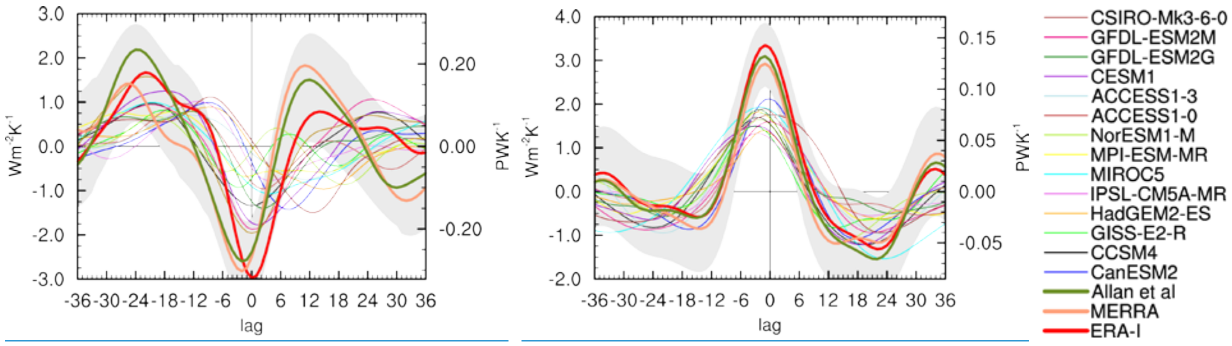

Fig. 5: Left panel: Pacific tropical belt (30N-30S) OHCT700 from ORAS4 (1979-2013 and 1992-2013), HEN4 (1992-2013), JMA (1992-2012) and CMIP5 models regressed against Niño 3.4 index for different lags; Right panel: As left panel but for Tropical belt Atlantic net surface energy flux. See Mayer et al. (2015) for details.

Progress was also made in the preparation of estimates of coupled energy budget variability and change in the Arctic. Indirect estimates of the surface energy flux employing RadTOA and atmospheric energy flux divergence using the budget evaluation methods described by Mayer et al. (2012) yielded much more realistic results than similar previous studies of the Arctic (Fig. 6). It is now intended to get oceanic energy budget estimates from advanced ocean reanalyses and to compare those with fluxes from the arctic ocean gateway array (Tsubouchi 2012).

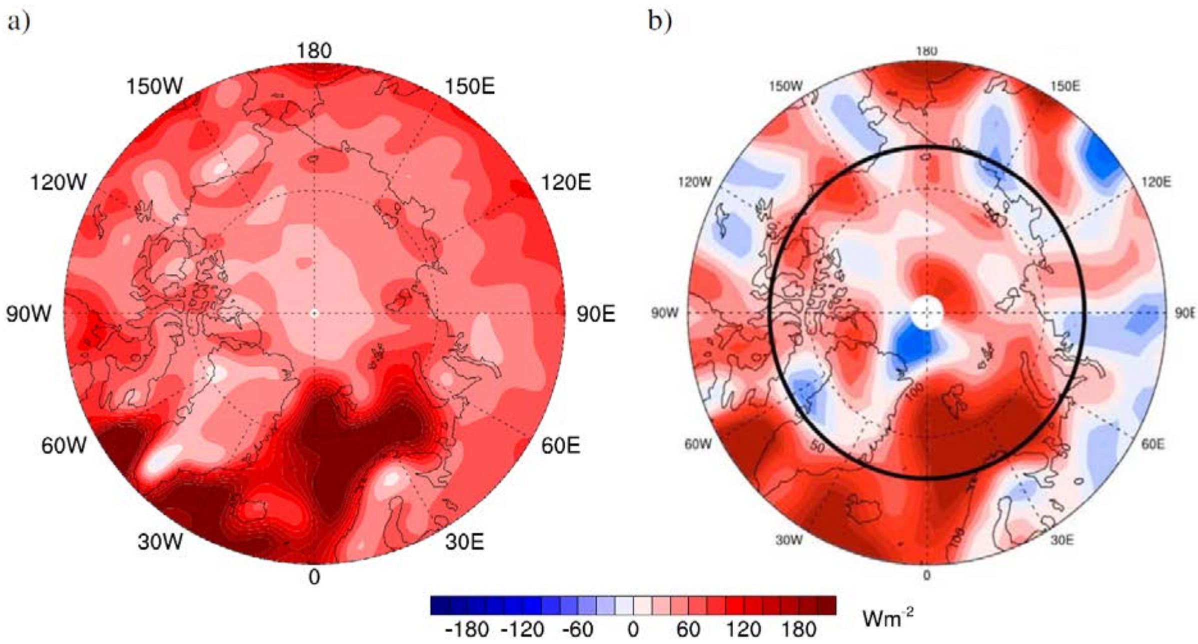

Fig. 6: Net surface energy flux (positive upward) for Januaries 2001-2005 estimated indirectly as residual from CERES RadTOA fluxes and atmospheric energy flux divergence. Upward fluxes are expected almost everywhere since both ocean and land are relatively warm and lose heat to the atmosphere. a) new estimate using the evaluation method described in Mayer et al. 2012 and ERA-Interim, b) earlier estimate from Porter et al. (2010).

List of publications/reports from the project with complete references

- 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.
- Mayer, M. & Haimberger, L., 2012. Poleward Atmospheric Energy Transports and Their Variability as Evaluated from ECMWF Reanalysis Data. *J. Climate*, **25**(2), pp.734–752.
- Mayer, M., Haimberger, L. & Balmaseda, M.A., 2014. On the Energy Exchange between Tropical Ocean Basins Related to ENSO. *J. Climate*, **27**(17), pp. 6393–6403.
- Mayer, M., J T. Fasullo, K. E. Trenberth and L. Haimberger, 2015: ENSO-Driven Energy Budget Perturbations in observations and CMIP models. Submitted to Clim. Dyn.
- Porter, D.F., J.J. Cassano, M.C. Serreze, and D.N. Kindig, 2010: New estimates of the large-scale arctic atmospheric energy budget. Journal of Geophysical Research, **115**, 1–16.
- Tsubouchi, T., S. Bacon, A. Naveira Garabato, Y. Aksenov, S. Laxon, E. Fahrbach, A. Beszczynska-Möller, E. Hansen, C.M. Lee, and R. Ingvaldsen, 2012: The arctic ocean in summer: A quasi-synoptic inverse estimate of boundary fluxes and water mass transformation. Journal of Geophysical Research: Oceans (1978–2012), **117**.

Summary of plans for the continuation of the project

A new version of RAOBCORE/RICH temperature adjustments including pre-1958 data will be published soon. Comparison and homogenization of radiosonde humidity data will be continued. Work on budgets will be extended to the Arctic. A research proposal on accurate estimation of arctic energy budgets has been submitted to the Austrian Science Funds.