SPECIAL PROJECT PROGRESS REPORT

Reporting year	2015/16
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
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10000	824	10000	0.6
Data storage capacity	(Gbytes)	10000	500	10000	500

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. 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
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)

Efforts in temperature homogenization back to before 1958 has been continued. Preliminary evaluations of CERA-20C (Laloyaux et al. 2016) showed that this new coupled surface data only reanalysis is quite homogeneous in terms of temperature and is therefore potentially useful as reference for the early period. This is particularly interesting since all full reanalyses are clearly contaminated by time varying biases in the Former Soviet Union Radiosonde network, which tended to have warm biases in the early days due to large errors in the pressure sensors. The upper panel of Fig. 1 shows a temperature difference plot (obs-CERA20C for the years 1958/1959) at 300 hPa. The warm bias of Former Soviet Union and Chinese radiosonde measurements at this level is rather strong (on the 3K and beyond) compared to CERA20C. Over the US the radiosonde station data also measure higher temperatures than those found in CERA20C, but the difference is much weaker. The lower panel, which depicts the difference ERApreSAT-CERA20C evaluated at radiosonde station locations, clearly shows the imprint of the warm bias on ERApreSAT (Hersbach et al. 2016) background temperatures. For ERApreSAT analyses temperatures the imprint would be even stronger.

Fig. 2 shows an example of offline solar elevation dependent adjustments using the annual cycle of ERA-Interim background temperatures as reference. The upper panel clearly indicates the high correlation of the solar elevation with background departures (obs-bg) at this station, where launches tend to be made around dawn so that the solar elevation varies between -15 and 15 degrees, depending on season. The lower panel contains again the background departures together with the adjustments (violet), which are a combination of stepwise adjustments calculated by the RICH method (Haimberger et al. 2012) and the mean obs-ERAInterim background departure at given months between breakpoints.

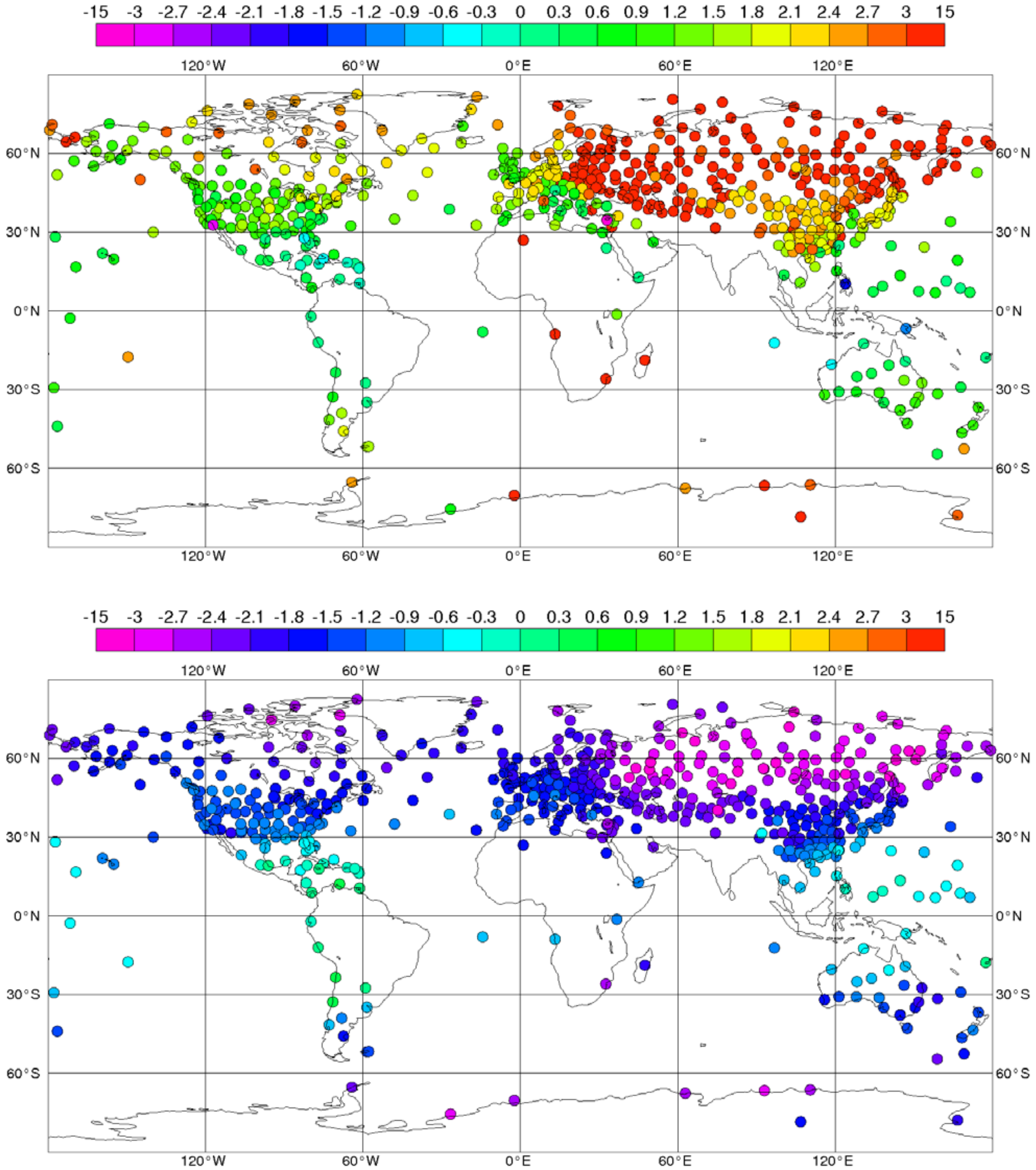

Fig. 1: obs-CERA20C (upper panel) and CERA20C-ERApreSAT temperature differences at the 300 hPa level averaged over 1958-1959, at least 18 months of data had to be available.

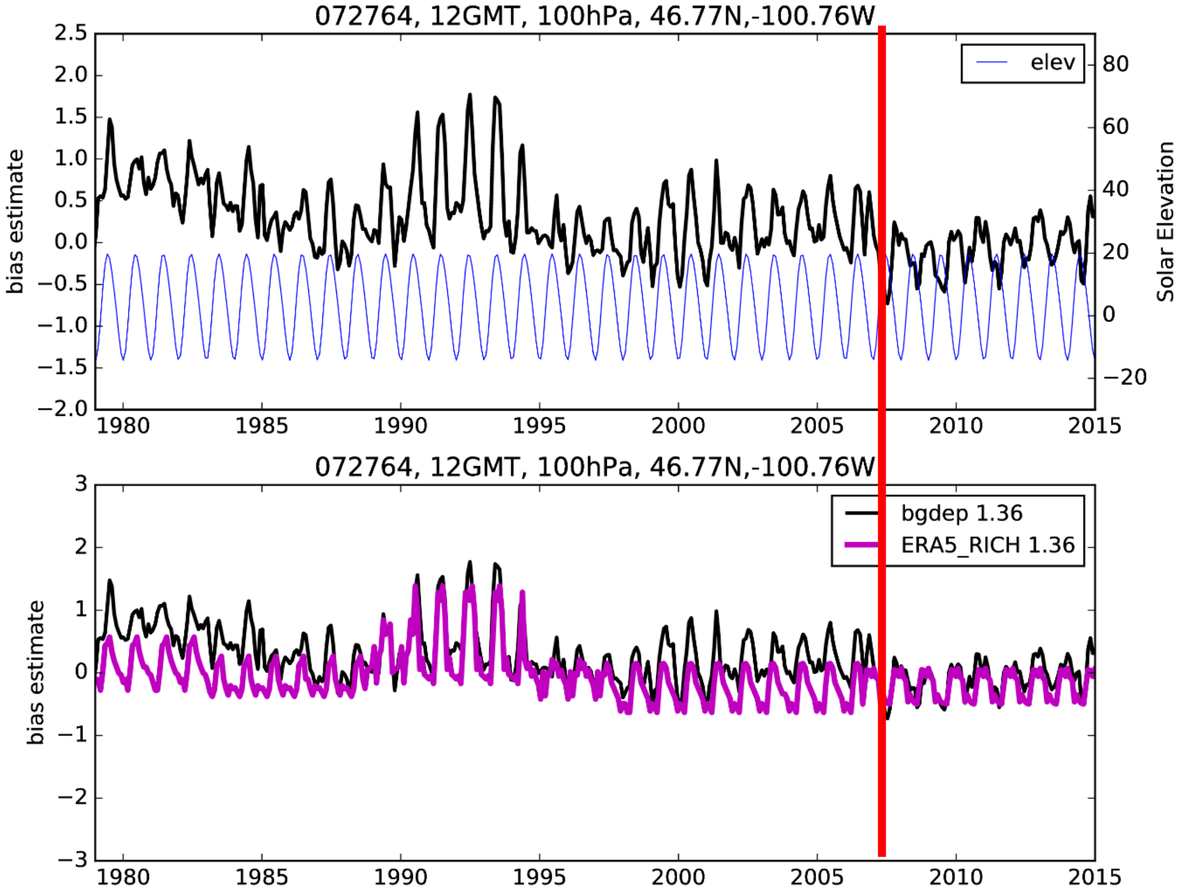

Fig. 2: Solar elevation dependent adjustment of radiosonde temperatures using the annual cycle of ERA-Interim background temperatures as reference. Upper panel: obs-bg (black), solar elevation (blue). Lower panel: obs-bg (black) and combined RICH+solar elevation dependent adjustment. Red vertical line depicts change from VIZ to Sippican radiosondes at this site.

Ad 2):

Work on homogenizing radiosonde humidity has made considerable progress in the past year (Blaschek and Haimberger, 2016). An algorithm based on matching the radiosonde humidity quantiles to humidity quantiles in ERA-Interim could greatly reduce spatial trend heterogeneity of homogenized humidity records compared to unadjusted records. This can be seen very clearly in Fig. 3. The very strong drying trends at 300 hPa over the US and China has been efficiently adjusted. Only a few spots still cause problems and need special investigation.

Fig. 4 shows the overall effect of the homogenization on global mean dewpoint depression trends. The very strong drying trend (grey profile) from unadjusted radiosonde measurements is mostly removed. Only in the mid troposphere a weak drying trend remains, which is consistent with the drying trend profile from ERA-Interim. This shows on the one hand that the homogenization algorithm works efficiently. On the other hand, however, this means that the shape of the homogenized trend profile is strongly determined by the reference used. Thus the resulting adjusted humidity records can no longer be used for independent validation of reanalysis humidity products. Nevertheless we consider the adjustments useful since they will likely improve humidity observations usage which may help getting sharper vertical gradients of moisture profiles in reanalyses. These tend to be smoothed at the capping inversions of e.g. the (sub)tropical shallow boundary layers.

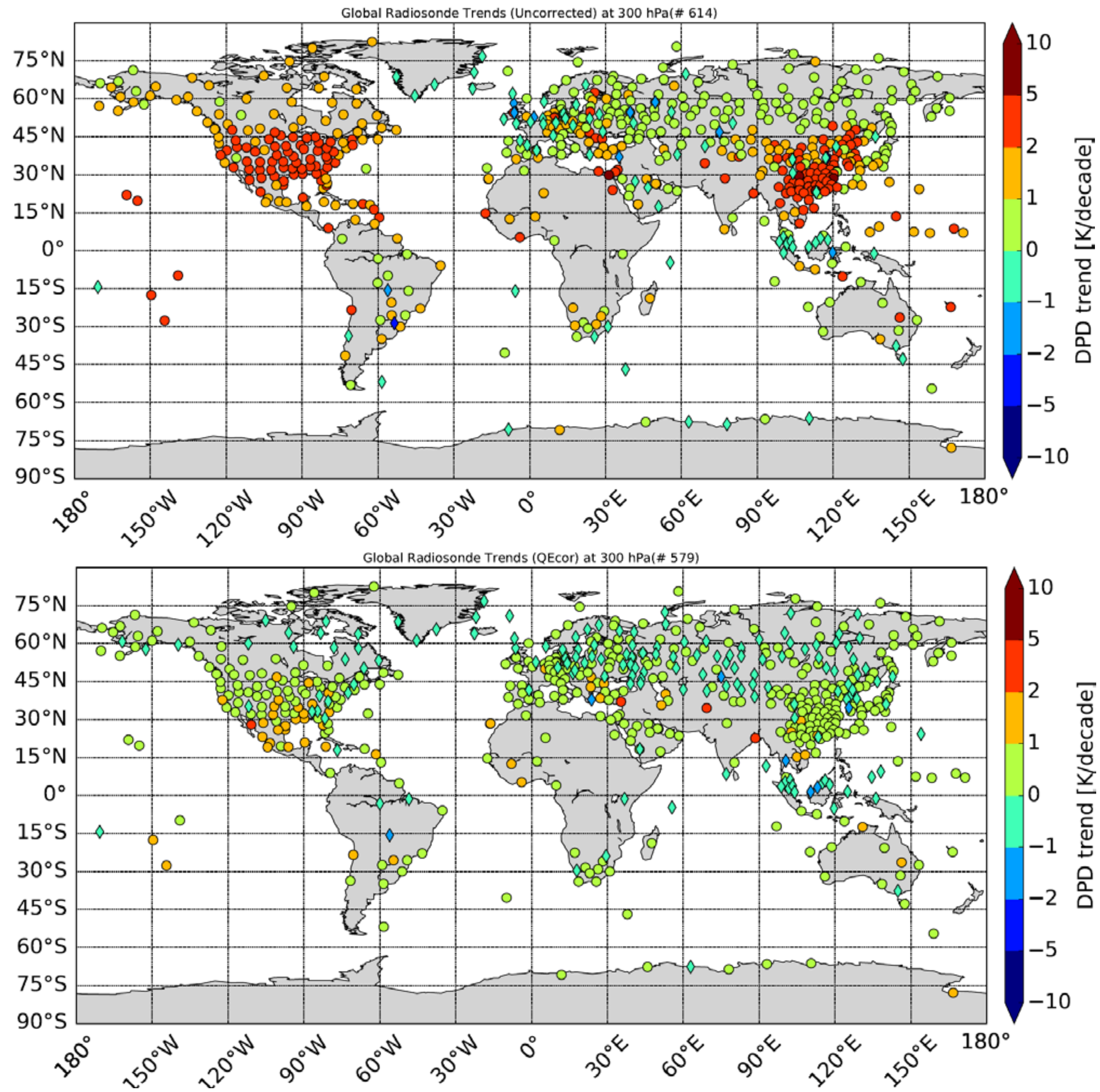

Fig. 3: Dewpoint depression trends 1979-2014 at 300 hPa level before (upper panel) and after (lower panel) homogenization with quantile matching method as described by Blaschek and Haimberger (2016).Number of points in lower panel is lower since some uncorrectable profiles had to be discarded.

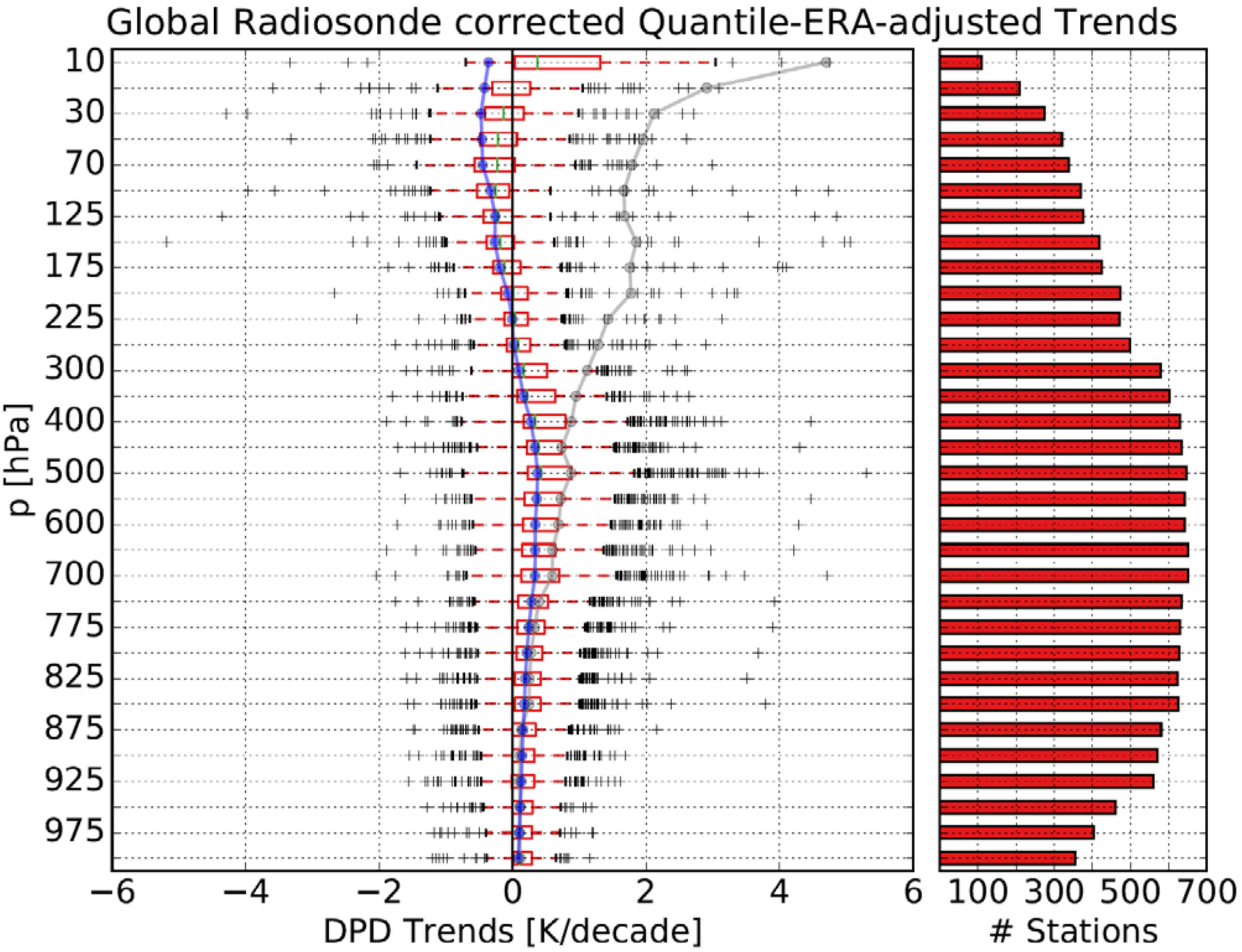

Fig. 4: Global average of all adjusted depoint depression trend profiles 1979-2014. Whiskers show 25th and 75th percentile, the crosses are the most extreme values found. Grey: unadjusted dewpoint deprssion trends. Blue: ERA-Interim dewpoint depression trends sampled at radiosonde sites.

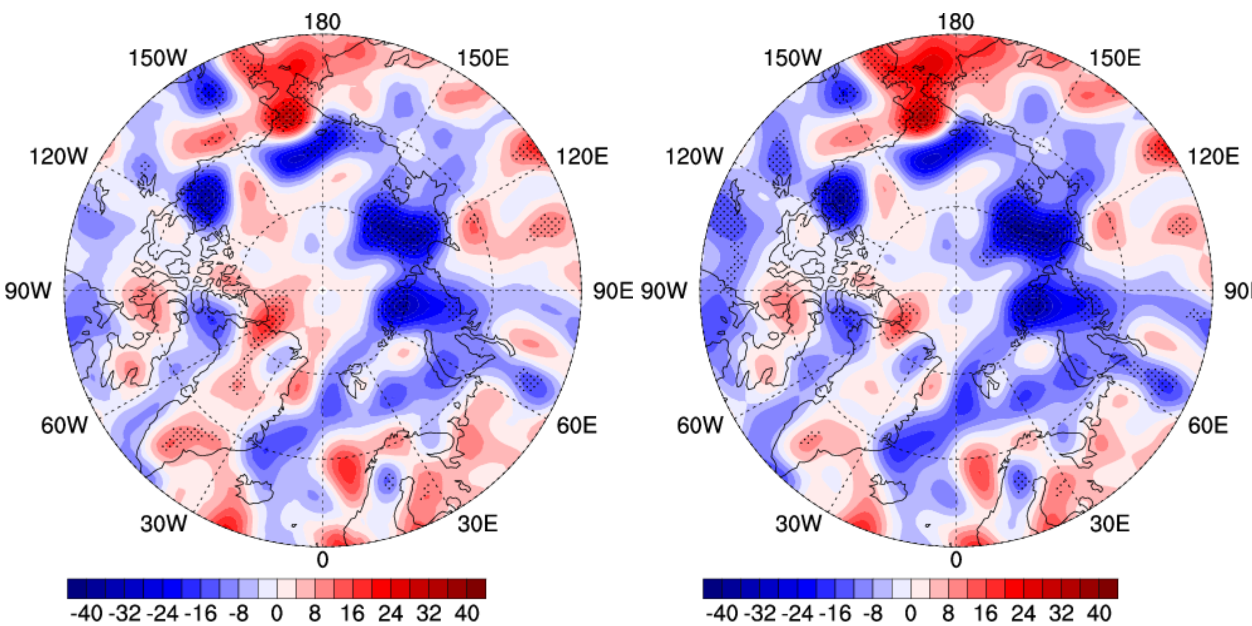

Fig. 5: Left panel: net surface energy flux (positive downward, units $Wm^{-2}decade^{-1}$) trends 2000-2015 for month October, estimated indirectly as residual from CERES RadTOA fluxes and atmospheric energy flux convergence and storage. Right panel shows trends of atmospheric energy flux convergence .

Ad 3):

The investigations on the global atmospheric and oceanic heat budgets have been continued. The comparison of observation based budget quantities with CMIP5 output has been completed (Mayer et al. 2016). Our research efforts are now more concentrated on the Arctic. Fig. 5 compares net surface energy flux trends 2000-2015 in October with trends of horizontal atmospheric energy flux divergence. One can see that these two fields closely match each other. Thus there is only a small trend in the radiation field at the top of the atmosphere during fall. Trends tend to be strongest at the ice edge where there is later refreezing in more recent years. More details can be found in Mayer et al. (2016)
This result is in stark contrast to summer trends of top of the atmosphere radiation which has been strongly enhanced during 2000-2015 associated with the ice-albedo feedback (not shown).

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. et al., 2016: The ERA-PreSAT experimental re-analysis: The value of using upper-air data in historical reanalyses. To be submitted.

- Laloyeux, P. et al., 2016: The CERA-20C reanalysis. In preparation.

- Mayer, M., J T. Fasullo, K. E. Trenberth and L. Haimberger, 2016: ENSO-Driven Energy Budget Perturbations in observations and CMIP models. Clim. Dyn., in press.

- Mayer, M., L. Haimberger, M. Pietschnig and A. Storto, 2016: Facets of Arctic energy accumulation based on observations 2000-2015. To be submitted.

Summary of plans for the continuation of the project

A new version of RAOBCORE/RICH temperature adjustments including pre-1958 data and the solar elevation dependent adjustment is under construction. Comparison and homogenization of radiosonde and satellite humidity data will be continued. Work on budgets in the Arctic is now funded by an Austrian Science Funds project and can be continued with high intensity. Since the EU project ERA-CLIM2 has been extended to 12/2017, also the planned duration of this special project has been extended to 12/2017.