SPECIAL PROJECT FINAL REPORT

Project Title:	Homogeneous upper air data and coupled energy budgets
Computer Project Account:	Spatlh00
Start Year - End Year :	2015 - 2017
Principal Investigator(s)	Leopold Haimberger
Affiliation/Address:	Institut für Meteorologie und Geophysik Universität Wien Althanstraße 14, 1090 Wien Austria
Other Researchers (Name/Affiliation):	Michael Mayer, Marianne Pietschnig, Michael Blaschek, Johannes Mayer Dick Dee, Hans Hersbach, Per Dahlgren, Magdalena Alonso-Balmaseda, Steffen Tietsche, Patrick Laloyaux

Summary of project objectives

The special project was intended to support the participation of University of Vienna in the EC 7th framework programme project ERA-CLIM2. Work package 4 of this project dealt with the assessment of the observation uncertainties of historic in situ data, especially those who had been digitized but never had been assimilated. It was tried to improve observation records 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. In this special project this was also extended to humidities.
Better homogeneity of upper air data helps, after being assimilated, also to get improved evaluations of global energy budgets. Investigations of coupled energy budgets using the most recent ERA-Interim and ORAS-4 reanalyses had yielded quite enlightening results regarding the energy flow related to ENSO. This work on coupled energy budgets was extended to other regions, mainly the Arctic.

Summary of problems encountered

The project went quite smoothly from a technical point of view.

Experience with the Special Project framework

Both the application and reporting procedures are straightforward. Also the required frequency and detail of reports is acceptable.

Summary of results

The special project considerably facilitated the work of the P.Is research group, particularly in relation to project funded by the Austrian Science Funds (FWF) and EU (ERA-CLIM2). The years 2015-2017 were exceptionally fruitful for the working group in terms results achieved and in terms of publications (see below). In order to avoid unnecessary repetition, only a few highlights are presented here.

From a research point of view, progress in the simultaneous estimation of global energy budgets, led to important new insights in the mechanisms of variability in the tropics as well as in the Arctic. Following the paper of Mayer et al. (2014) who showed that the anomalous heat released from the tropical Pacific during El Nino is mostly not lost to space immediately but largely stored in the neighbouring Atlantic and Indian Ocean reservoirs, it was investigated if this behaviour is reproduced by climate models (Mayer et al. 2015). At the same time, a coupled analysis of the Arctic revealed an enhancement of the seasonal energy cycle, mostly because of the increasing open ocean area, which leads to enhanced heat release into the atmosphere in Autumn. The diagnostic budget method itself has been improved in collaboration with experts from UK Metoffice, which has helped to achieve 40% better consistency between estimates of the oceanic surface energy balance either indirectly from TOA net radiation and vertically integrated total energy flux divergence or directly from satellite/parameterized fluxes (Mayer et al. 2017). Fig. 10 from this publication is reproduced here as Fig. 1. The new method has since been used for comparison of the strong but still rather different El Nino events of 1997/98 and 2015/16. (Mayer et al. 2018).

Another study devoted to subsurface energy transports through Arctic gateway is still under discussion (Pietschnig et al. 2017).

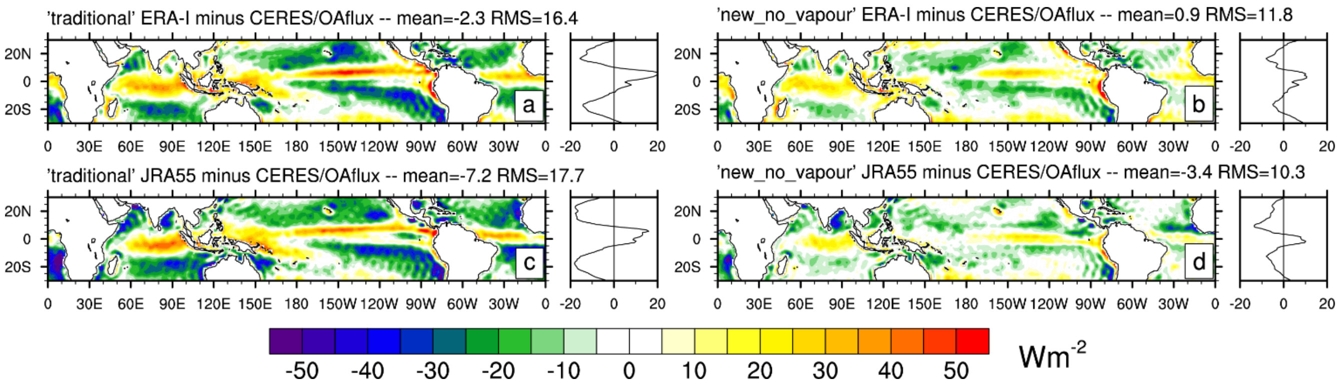

Fig. 1 Difference of inferred net surface energy flux based on Rad_{TOA} from CERES-EBAF and a) ERA-Interim based "traditionally" computed energy divergence, b) ERA-Interim based energy divergence with the effect of water vapor removed, c) JRA55-based "traditionally" computed energy divergence, d) JRA55-based energy divergence with the effect of water vapor removed, and net surface energy based on net surface radiation from CERES-EBAF and OAflux turbulent fluxes.

The digitization, evaluation and archiving of early radiosonde data also has profited from ECMWF resources. An experimental assimilation of upper air data from 1939 onward showed promising performance but also revealed difficulties in the processing of these data, which are highly asymmetrically distributed and are also affected by pervasive warm biases (Hersbach et al. 2017). The latest digitized data have been integrated into the ECMWF ODB2 archive in July 2017 and have been the basis for an updated homogenized radiosonde data set (Haimberger et al. 2017). They are also an essential resource for extending ERA5 backward to 1950. Fig.2 shows how spuriously strong cooling trends due to a change in the radiosonde observing system over the Former Soviet Union have been reduced or removed by adjusting a strong shift in the temperature records in 1961, using JRA55 and ERA-preSAT (Hersbach et al. 2017) as reference.

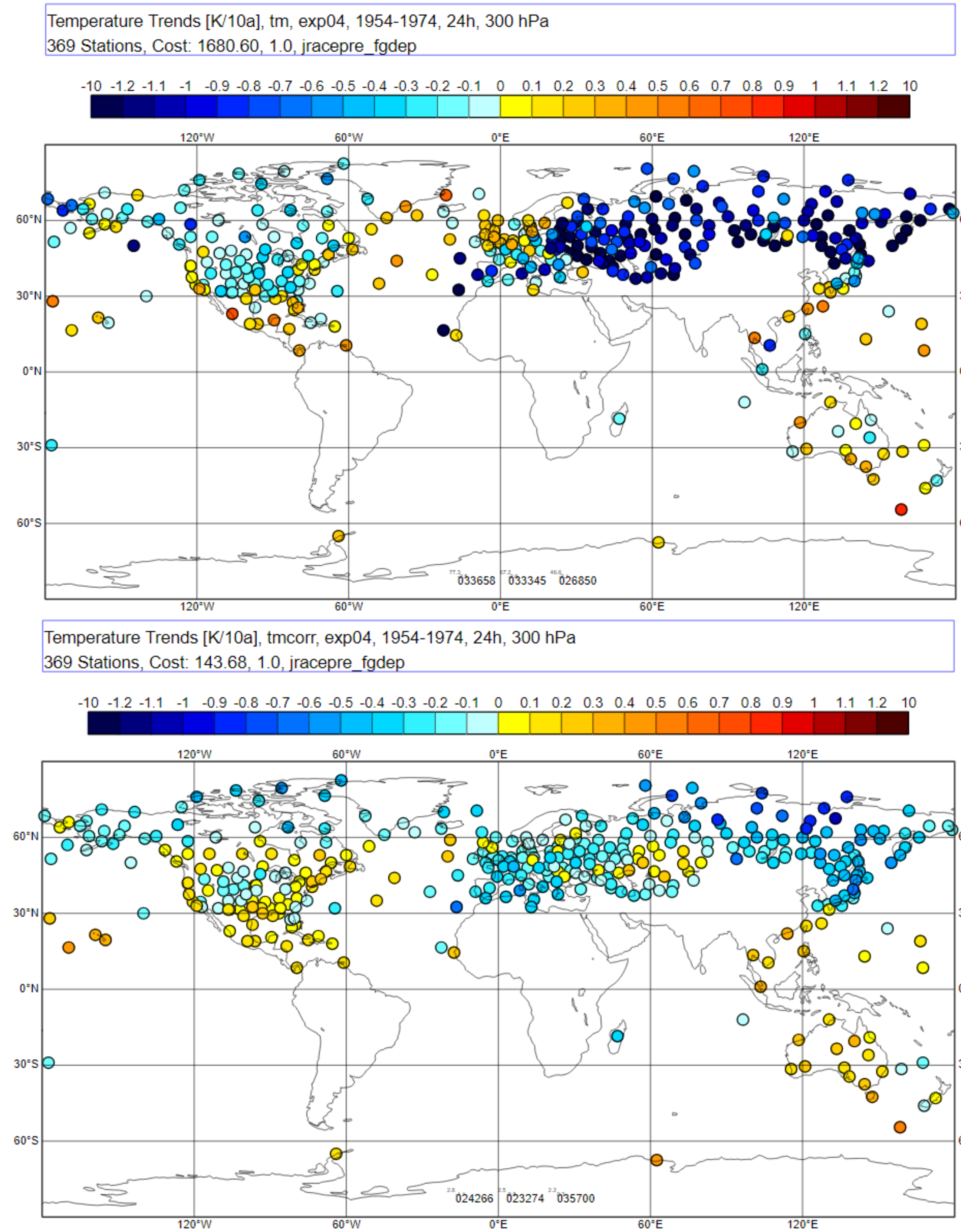

Fig. 2: Temperature trends in K/10a for the period 1954-1974 from unadjusted (upper panel) and adjusted (lower panel) radiosonde records. RAOBCORE v1.7 has been used for adjustment. Note much better spatial consistency (measured by "Cost"). Only radiosonde sites with less than 24 months missing in the 21 year record are shown with bullets.

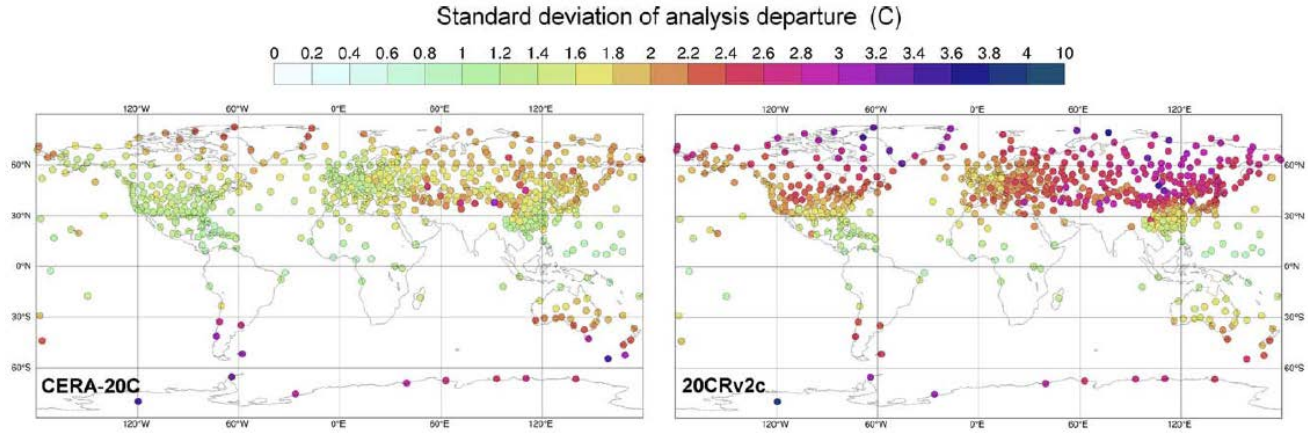

Fig. 3 Monthly standard deviation of the analysis departure for (left) CERA-20C and (right) 20CRv2c ensemble means with respect to unadjusted temperature observations from radiosondes at 700 hPa, averaged over years 1959–1960. From Laloyaux et al. 2018 (their Fig. 6)

Early access to CERA20C (Laloyaux et al., 2018) data helped producing some quality assessment of this pioneering coupled (sub) surface data only reanalysis. The standard deviation of differences between radiosonde observations and corresponding reanalysis fields from CERA20C and NOAA-20CR clearly demonstrated superiority of CERA20C over the Northern Hemisphere. Fig. 6 from this publication is shown here as Fig. 3.

ECMWF data from MACC as well as some parameters related to boundary layer properties were used as input and reference for analysing the activation of dust sources over Iraq and neighbouring countries (Nabavi et al. 2016, 2017).

List of publications/reports from the project with complete references

Peer reviewed publications:

• Mayer, M., M. A. Balmaseda and L. Haimberger, 2018: Unprecedented 2015/16 Indo-Pacific heat transfer speeds up Tropical Pacific heat recharge. Geophys. Res. Lett. 45, in press
• Brönnimann, S., R. Allan, C. Atkinson, R. Buizza, O. Bulygina, P. Dahlgren, D. Dee, R. Dunn, P. Gomes, V. O. John, S. Jourdain, L. Haimberger, H. Hersbach, J. Kennedy, P Poli, J. Pulliainen, N.Rayner, R. Saunders, J. Schulz, Al. Sterin, A. Stickler, H. Titchner, M. A. Valente, C. Ventura and C. Wilkinson, 2018: Observations for Reanalyses. Bull. Amer. Meteorol. Soc. 99, accepted.
• Buizza, R., S. Brönnimann, L. Haimberger, P. Laloyaux, M.J. Martin, M. Fuentes, M. Alonso-Balmaseda, A. Becker, M. Blaschek, P.Dahlgren, E. de Boisseson, D. Dee, M. Doutriaux-Boucher, F. Xiangbo, V. John, K. Haines, S. Jourdain, Y. Kosaka, D. Lea, F. Lemarié, M. Mayer, P. Messina, C. Perruche, P. Peylin, J. Pulliainen, N. Rayner, E. Rustemeier, D. Schepers, R. Saunders., J. Schulz, A. Sterin, S. Stichelberger, A. Storto, C.-E. Testut, M.-A. Valente, A. Vidard, N. Vuichar, A. Weaver, J. While, M. Ziese, 2018: The EU FP7
ERA-CLIM2 project contribution to advancing science and production of Earth-system climate reanalyses. Bull. Amer. Meteorol. Soc. 99, https://doi.org/10.1175/BAMS-D-17-0199.1
• Laloyaux, P., M.Alonso-Balmaseda, S. Brönnimann, R. Buizza, P. Dalhgren, E. de Boisseson, D. Dee, Y. Kosaka, L. Haimberger, H. Hersbach, M. Martin, P. Poli and D. Schepers, 2018:
CERA-20C: A coupled reanalysis of the Twentieth Century. Journal of Advances in Modeling Earth Systems, DOI: 10.1029/2018MS001273.
• Pietschnig, M., Mayer, M., Tsubouchi, T., Storto, A., Stichelberger, S., and Haimberger, L.: Volume and temperature transports through the main Arctic Gateways: A comparative study between an ocean reanalysis and mooring-derived data, Ocean Sci. Discuss., https://doi.org/10.5194/os-2017-98, in review, 2017.
• 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. 143, 1197–1210
• Mayer, M., L. Haimberger, J. M. Edwards and P. Hyder, 2017: Toward Consistent Diagnostics of the Coupled Atmosphere and Ocean Energy Budgets. J. Climate 30.
• Nabavi, S.O., Haimberger, L., Samimi, C., 2017: Sensitivity of WRF-chem predictions to dust source function specification in West Asia. Aeolian Research, 24, pp. 115-131.
• Mayer, M., L. Haimberger, M. Pietschnig, and A. Storto (2016), Facets of Arctic energy accumulation based on observations and reanalyses 2000-2015, Geophys. Res. Lett., 43.
• Hantel, M. and Haimberger, L. 2016: Grundkurs Klima. Springer, 404pp. ISBN 978-3-662-48193-6, DOI: 10.1007/978-3-662-48193-6
• Nabavi, S.O., Haimberger, L., Samimi, C., 2016: Climatology of dust distribution over West Asia from homogenized remote sensing data. Aeolian Research, 21, pp. 93-107.
• Mayer, M., Fasullo, J. T., Trenberth, K. E., and Haimberger, L. 2016: ENSO-Driven Energy Budget Perturbations in Observations and CMIP Models. Climate Dynamics 47,4009-4029.

Reports:

The deliverables from EU project ERA-CLIM2 contributed by the University of Vienna are listed here as well:

• Haimberger, L., M. Blaschek, S. Brönnmann, P. Dalgren, H. Hersbach, S. Jourdain, P. Laloyaux, A. Sterin and M. A. Valente, 2017: Bias adjustments for global radiosonde data back to 1939. *ERA-CLIM2 Deliverable 4.2*, 56pp.
• Haimberger, L., M. Mayer, E. de Boisseson, H. Hersbach, P. Laloyaux, P. Peylin, N. Vuichard, E. Rustemeier, S. Stichelberger, A. Storto and M. Ziese, 2017: Improving estimates of Energy, Water and Carbon Cycles. *ERA-CLIM2 Deliverable 4.8*, 48pp.
• Haimberger, L., D. Schepers, S. Brönnimann, E. de Boisseson, Y. Kosaka, P. Laloyaux, M. Mayer and M. Blaschek, 2017: Intercomparison of Reanalyses. *ERA-CLIM2 Deliverable 4.10*, 18pp.
• Haimberger, L., P. Laloyaux, M. Mayer, S. Brönnimann and E. de Boisseson, 2017: Assessment of low frequency variability and trends in ERA-CLIM2 data products. *ERA-CLIM2 Deliverable 4.11*, 19pp.

Future plans

The work on both energy budget evaluation and data homogenization is continued in the new special project „Coupled energy and freshwater budgets from and early upper air data enhancements for reanalysis“, which runs from 2018-2020.