SPECIAL PROJECT PROGRESS REPORT

Reporting year	2019/20
Project Title:	Coupled energy and freshwater budgets from and early upper air data enhancements for reanalysis
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. Balmaseda, S. Tietsche
Start date of the project:	1.1.2018
Expected end date:	31.12.2020

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

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10000	0.0	10000	0.0
Data storage capacity	(Gbytes)	2000	32	2000	32

Summary of project objectives

The special project accompanies an Austrian Science Funds project devoted to evaluating the global energy budget, with emphasis on the Arctic. For this purpose access to experimental or not yet publicly available reanalysis data are needed. It accompanies also a Copernicus activity (C3S 311c Lot2) to prepare early upper air data for assimilation into ERA5.

Summary of problems encountered (if any)

Summary of results of the current year (from July of previous year to June of current year)

Within a new Austrian Science funds project (start in Jan 2020) we are continuing our work on calculating high accuracy budgets from ERA5. The budgets are now available from 1985-2019, where the period 2000-2006 is taken from ERA5.1 (Simmons et al. 2020). The working group participated in writing a review paper (von Schuckmann et al. 2020) and analysed the ERA5 energy and moisture budgets in some detail (Mayer et al. 2020). Fig. 1 shows time series of ocean-land energy transports from various data sources. Not all changes appear natural. Net surface energy flux (F_S) over land, as parameterized by ERA5, is directed upward in the 1980s and 1990s, only then it goes to values close to zero. It should be slightly positive, since land surfaces are warming and ice bodies are melting. Energy transport from oceans to land is 2PW in the 1980s and 1990s, then increases to ~2.5PW. The top-of-the-atmosphere(TOA) net radiation is stable except for the months after the Pinatubo (1991) eruption, which also caused the strongest anomaly signals in F_S.

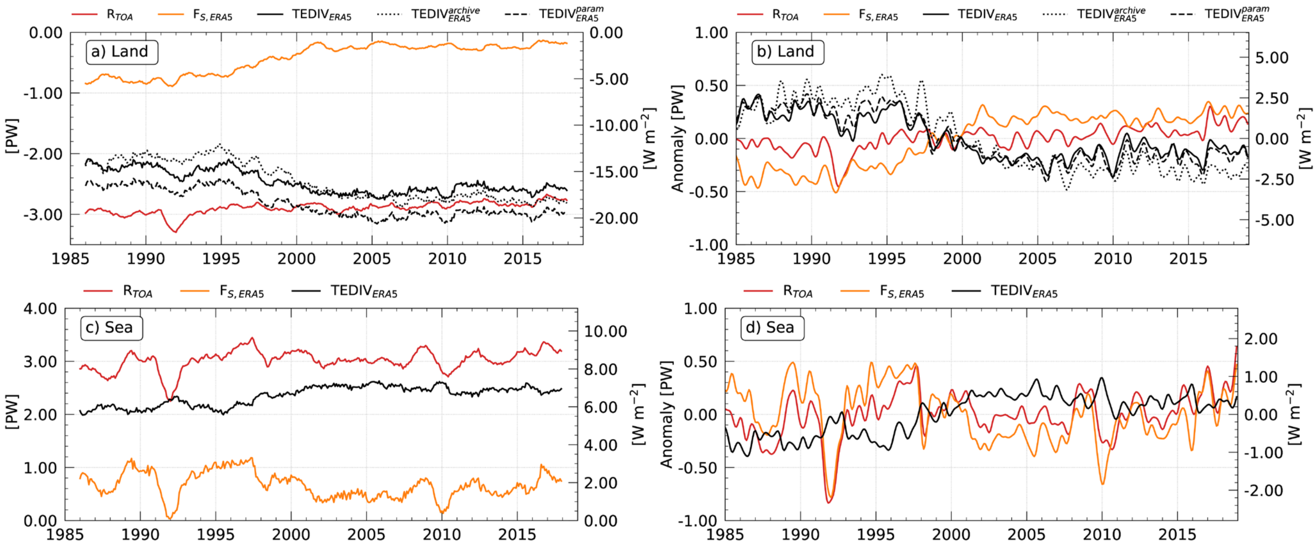

Fig. 1: Time series of individual atmospheric energy budget terms for the period 1985-2018. Land averages are shown at the top, ocean averages at the bottom. Absolute values are depicted in panel (a) and (c) using a 12-months running mean, while anomalies are shown in panel (b) and (d) using a 13-months Gaussian filter. Shown are: radiation at TOA from DEEP-C, which uses CERES-EBAF 4.0 from March 2000 and ingests TOA flux anomalies from ERA5 before that (solid red), TEDIV evaluated from ERA5 (solid black). In addition, we show in panel (a) and (b) the archived TEDIV as it is stored in MARS (black dotted), the indirectly estimated TEDIV derived from parametrized fluxes (black dashed) and the indirectly estimated F_S (orange). Units on the left axes are PW (10^{15} W) and on the right axes Wm^{-2}.

Fig. 2 summarizes a comparison of different budget approaches to estimate the surface energy flux over land. FS_{SAT} is the classical indirect approach using TOA fluxes from satellites and atmospheric energy flux divergence calculated from reanalyses. FS_{ERA} is the parameterized F_S from ERA5, $FS_{RIEMANN}$ and FS_{TRAPEZ} have been derived indirectly from analyzed changes of the soil state (snow melt and accumulation, soil freezing and melting, soil temperature changes). More detailed analysis is given in Seitner (2020). Fluxes estimated from soil state changes have the right direction (into the soil, albeit too strong) and tend to peak earlier in the season than the other fluxes. More work on this is needed but the flux estimated from soil state changes appears better in agreement with the parameterized fluxes than the classical indirect estimate.

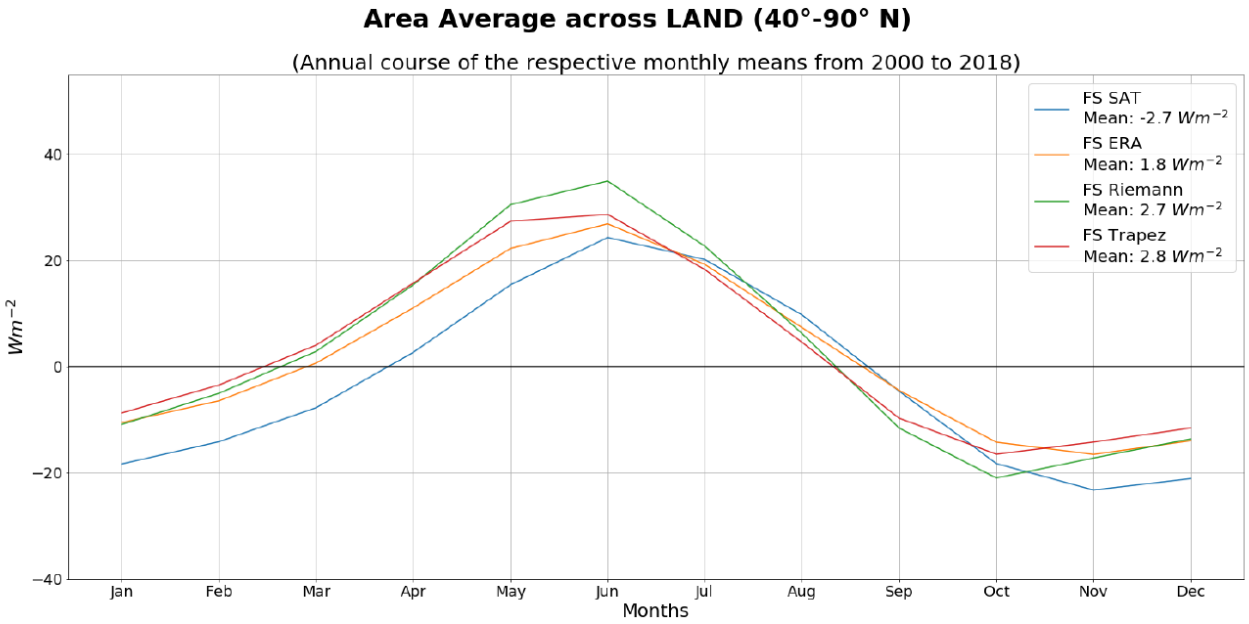

Fig. 2: Mean annual cycle of net surface energy flux over subarctic and arctic land masses (except ice sheets) averaged over period 1998-2018, estimated using different budget approaches. FS_{SAT} is F_S indirectly estimated from CERES TOA fluxes and ERA5 energy flux divergence, FS_{ERA} is F_S as parameterized in ERA5, $FS_{RIEMANN}$ is F_S indirectly estimated from tendencies of the soil state, where the vertical integration over layers was done using layer averages FS_{TRAPEZ} is the same, but with vertical integration using the trapezoidal rule. See Seitner(2020) for details.

In the Copernicus service C3S 311c Lot2 (early upper air data) we are developing a data portal that allows to extract daily and monthly upper air data together with bias adjustments and metadata information. The flow diagram is shown in Fig. 3. Currently data can already be downloaded via a Copernicus development server. In addition to operational data collected via GTS and obtained from various digital archives, the data from radiosonde intercomparison experiments will also be provided. The service should become operational in spring 2021.

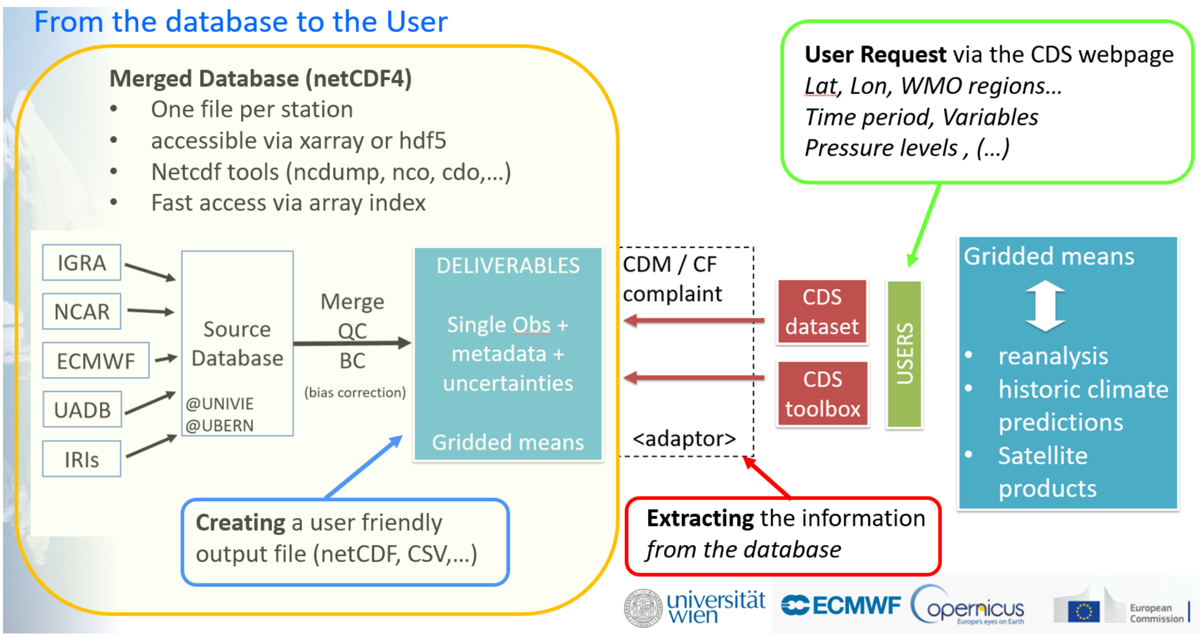

Fig. 3: Data flow diagram of C3S 311c service. The merged data base and the interface to CDS are already up and available for testing. Demonstration cases are being developed.

List of publications/reports from the project with complete references

Mayer, J., M. Mayer and L. Haimberger, 2020: Evaluation of the Atmospheric Energy and Mass Budget in ERA5. Manuscript in preparation.

von Schuckmann, K., Cheng, L., Palmer, M. D., Tassone, C., Aich, V., Adusumilli, S., Beltrami, H., Boyer, T., Cuesta-Valero, F. J., Desbruyères, D., Domingues, C., García-García, A., Gentine, P., Gilson, J., Gorfer, M., Haimberger, L., Ishii, M., Johnson, G. C., Killik, R., King, B. A., Kirchengast, G., Kolodziejczyk, N., Lyman, J., Marzeion, B., Mayer, M., Monier, M., Monselesan, D. P., Purkey, S., Roemmich, D., Schweiger, A., Seneviratne, S. I., Shepherd, A., Slater, D. A., Steiner, A. K., Straneo, F., Timmermans, M.-L., and Wijffels, S. E.: Heat stored in the Earth system: Where does the energy go? The GCOS Earth heat inventory team, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2019-255, in review, 2020.

Simmons, A., Soci, C., Nicolas, J., Bell, B., Berrisford, P., Dragani, R., Flemming, J., Haimberger, L., Healy, S., Hersbach, H., Horanyi, A., Inness, A., Munoz-Sabater, J., Radu, R. & Schepers, D., Global stratospheric temperature bias and other stratospheric aspects of ERA5 and ERA5.1: Tech. Memo 859, Jan 2020

Summary of plans for the continuation of the project

We are still working on the noise problem in the energy flux divergence fields. While we are able to filter it, it is still not eliminated to the extent we would desire. We now have a license to use openIFS, which enables us to use the IFS spectral routines for our evaluations. It remains to be seen whether this alleviates the noise problem. This is also the reason why we have postponed for now the comparison with CMIP6 climate model runs.

The special project account will be used for fulfilling the obligations accepted within the Copernicus C3S-311c Lot2 service is currently working and can be accessed from development servers.