July 2019

Newsletter of the *Digital Earth* Project

Contributions of the Karlsruhe Institute of Technology to Digital Earth

This newsletter presents the projects of the institutes of the Karlsruhe Institute of Technology being involved in activities within the Show Cases or Work Packages of Digital Earth.

Bridging the scales of evapotranspiration (ET) – BRIDGET

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Cross-compartment fluxes of mass and energy play a key role in the functioning of the earth system. Yet their understanding is largely hampered by the fact that related observations occur on multiple scales, involve multiple sensors, and data are collected across different research disciplines.

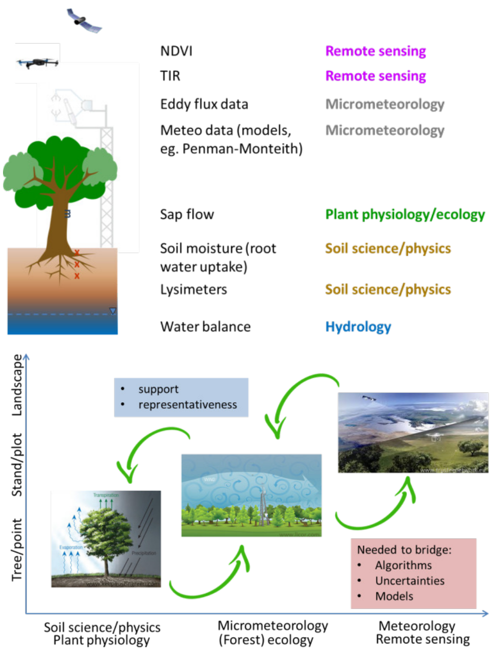

Figure 1: Top panel: Variety of different ET measurements and the disciplines they originate in. Lower panel: multi-scale ET measurements and involved research disciplines.

In line with the overall goals of Digital Earth, BRIDGET aims to overcome this fragmentation by providing tools for a digital research data centre that will allow storage, merging and visualisation of multi-scale and multi-sensor data and ultimately facilitate their scientific analysis.
We develop this research environment using evapotranspiration (ET) as an example a) due to the key importance of this flux for the Earth's water and energy cycle and consequently its climate, and b) because approaches to estimate ET are manifold with respect to the underlying observations, scales, footprints and uncertainties.
In collaboration between KIT and UFZ within BRIDGET we will advance an already existing and tested virtual research environment (V-FOR-WaTer) to host a variety of multi-scale ET observations, develop the necessary metadata catalogue with special emphasis on uncertainty, using mainly data from the UFZ and KIT TERENO observatories. This will be completed by the development of tools for visualisation and (geo-)statistical analysis of these data in a specific ET package.
The final system will ultimately facilitate merging different ET estimates across sensors and scales and thus provide a blueprint for software solutions handling other important inter-compartment fluxes, including particularly trace and greenhouse gas emissions.

Rainfall measurements using commercial microwave links

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Commercial microwave links (CMLs) from cellular communication networks can be used to estimate path-integrated rainfall information. In the frequency bands most network providers use for their CMLs (10 - 40 GHz), the attenuation caused by rainfall relates linearly to the rainfall intensity. With the growth of modern communication infrastructure over the last twenty years, nowadays CML networks are set up in almost all inhabited regions of the world. Hence, deriving rainfall information from CML network attenuation data, has a large potential to improve spatial and temporal rainfall information in many countries, in particular where observation network density is coarse.
Together with the network provider Ericsson Germany, KIT (IMK-IFU) is collecting data from 4000 CMLs spread over whole Germany since September 2017. Our aims are to derive near-real time rainfall data for Germany as-well as the refinement and development of CML data processing methods. The dataset then can be used for comparison and adjustment of traditional rainfall data sets from rain gauges and weather radars.

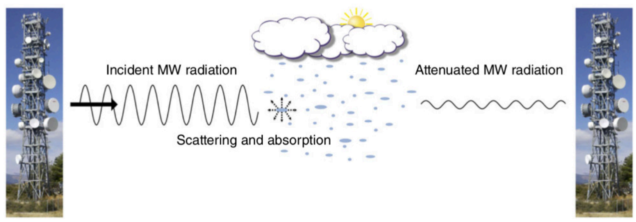

Figure 2: Illustration of the basic operating principle of CML rainfall estimation. CMLs (with the drum-shaped antennas) are typically used to interconnect cell phone towers. Due to scattering and absorption the transmitted microwave (MW) radiation is attenuated by raindrops. This leads to an attenuated signal level at the receiver, from which the rain rate along the path can be estimated (Chwala and Kunstmann, 2019).

Within Digital Earth we will integrate CML-derived rainfall as an opportunistic sensing system in WP 1. In the showcase flood, this data can be used and compared against traditional rainfall data set e.g. from the German meteorological service. To deal with the large size of our dataset and the heterogeneous data quality we develop and use fast parallelized workflows for data processing and visual exploration, providing also synergies with Digital Earth WP2.

Reference: Chwala, C., and H. Kunstmann (2019). Commercial microwave link networks for rainfall observation: Assessment of the current status and future challenges. Wiley Interdisciplinary Reviews: Water, 6(2), e1337, https://doi.org/10.1002/wa

Simulations of Methane Emissions from the North Sea Region with ICON-ART

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Methane (CH4) is the second most important greenhouse gas after CO2 affecting global warming. Its global budget is balanced by various sources and the reaction with the OH-radical as its main sink. For this work ICON-ART 2.3 was used. ART (Aerosols and Reactive Trace Gases) is an online-coupled model extension for ICON that includes chemical gases and aerosols. This model aims at simulating interactions between the trace substances and the state of the atmosphere by coupling the spatiotemporal evolution of tracers with atmospheric processes (Schroeter et al., GMD, 2018). Explorations at the sea floor of the North Sea showed an release of CH4 near the boreholes of the oil and gas carrying platforms. The scientific goals of this Show Case A (Methane) related study are the adjustment of the CH4 emission fluxes from the North Sea, the evaluation of the differences compared to established emission data bases like EDGAR (Janssens-Maenhout et al., NAS, 2010) and the investigation of the impact of the adjusted emission fluxes for the CH4 budget in Europe and global. CH4 has been initialised with a globally constant initialisation value of 1850 ppbv CH4 at the lowest model level. The simulation period is January to December 2018 with a horizontal resolution of the global grid of about 80 km and 90 vertical levels. The input emission inventory is EDGARv4.3.2 with a horizontal resolution of 0.1°x0.1°. The ICON-ART output has a temporal resolution of 12 hours and a 0.5°x0.5° grid. The simulations were computed with a simplified OH-chemistry taking into account the main reactions controlling the OH concentration (Weimer et al., GMD, 2017).

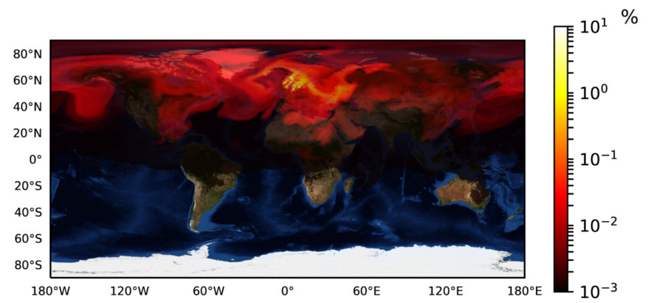

Figure 3: Difference in CH4 in ICON-ART simulations (1) and (2) after 26 days. See text for details.

Two different simulations were made with ICON-ART. First with unmodified EDGAR emission (1) and second with the North Sea mean value of EDGAR appended to all grid cells in the corresponding region (2). The well-known anti-correlation of CH4 and OH is visible in the ICON-ART simulation results as the methane difference of run (1) and (2) is positive and the OH difference is negative for the same area. Figure 3 shows the difference of methane Volume Mixing Ratio between (1) and (2) after 26 days. I can also remark a good match of the simulation results to values from measurement sites around the North Sea Region although the initialisation of the model was slightly too low. The variability of heterogeneous distributed CH4 sources matters and leads to small differences in the methane as well as OH distribution.

Atmospheric monitoring of Ice Nucleating Particles

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On a global scale, most precipitation events are initiated by ice particles in clouds (Mülmenstädt et al., GRL, 2015). These ice particles are formed when a cloud is cooled to temperatures below 0°C, e.g. in rising air parcels. During this process, cloud droplets are formed by water condensation on aerosol particles and remain in a super-cooled liquid state to temperatures as low as -35°C. In this temperature range, they can only freeze by the action of so-called ice nucleating particles (INPs), a very minor fraction of all atmospheric aerosol particles. Knowing the INP abundance is of central importance to better understand and predict precipitation development and intensity.
The atmospheric abundance of INPs is not well constrained from measurements because available methods are either time consuming or have low time resolutions of hours to days. We have developed an innovative and automated mobile measurement device to continuously detect the INP concentration at high sensitivity and time resolution, and in a wide temperature range from -10°C to -60°C. The PINE (Portable Ice Nucleation Experiment) instrument is developed in collaboration between KIT, the University of Leeds and the Bilfinger Noell GmbH. It is based on the adiabatic cooling of humid and aerosol-laden air as given in the atmosphere for a raising air parcel. The temperature, pressure and humidity conditions as well as the particle concentrations are continuously measured and analyzed for the INP concentration of the sampled air.
Two prototype versions of PINE were successfully operated in two field campaigns. Fig. 4 shows an example one of those measurements. The operation cycles of air sampling, cloud formation and refilling can be seen in the time series of the chamber pressure and temperature (upper panel). The single particle counter (lower panel) can distinguish between small aerosol particles, intermediate-sized droplets, and large ice crystals.
Currently, we are developing within the WP SMART Monitoring Designs and for the Show Case B (Floods) a data system for the automated near-real time data analysis and exchange of INP concentrations at the operation site.

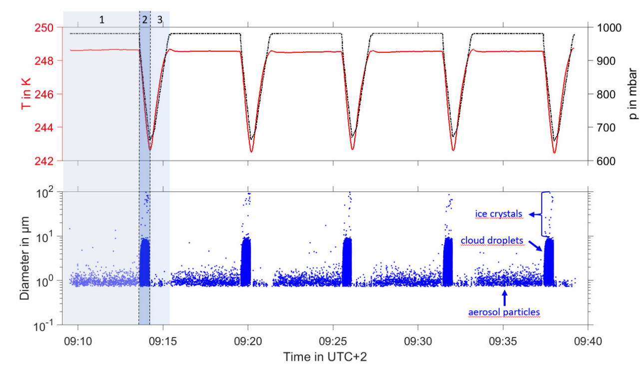

Figure 4: Example of automated measurement cycles with PINE. One cycle lasts about 6 minutes and consist of (1) sampling of ambient air into the chamber, (2) expansion with cloud droplet and ice formation, and (3) refilling of the chamber. Size ranges of cloud droplets and ice crystals are also indicated.