G-EVAP – An observation-based global terrestrial evapotranspiration reconstruction
Contact: gionata.ghiggi@epfl.ch

ET is the sum of the water lost to the atmosphere from plant tissues via transpiration and that lost from the land surface elements, including soil, plants and open water bodies, through evaporation. Processes controlling ET play a central role in linking the energy (latent heat), water (moisture flux) and carbon cycles (photosynthesis–transpiration trade-off) in the Earth system. Over 60 % of precipitation on the land surface is returned to the atmosphere through ET and the accompanying latent heat (λET) (λ is the latent heat of vaporization) accounts for more than half of the solar energy received by the land surface. ET is also an important parameter controlling hydrological extreme events, when considering the development of heatwaves and flash droughts, through coupling with soil moisture process. Additionally, key impact variables such as irrigation water demand or agricultural productivity are physically controlled by the partitioning of energy at the land surface, which largely depends on ET. Furthermore, ET is also coupled with the carbon dioxide (CO_2) exchange between the canopy and the atmosphere through vegetation photosynthesis.

Despite its relevance, ET is the less monitored variable of the water cycle, with a few hundred ET measurements from FLUXNET eddy covariance towers around the world. Additionally, no representative measurements are available at large spatial scales, such the ones employed by global hydrological models (GHMs) which runs with grid-cell resolution of tens of kilometers. Consequently, ET remains the most poorly constrained component of the global hydrological cycle, with large uncertainty in its spatial and temporal variability (Fig. 1), despite extensive research (Mueller et al., 2013; Miralles et al., 2016; Wartenburger et al., 2018).

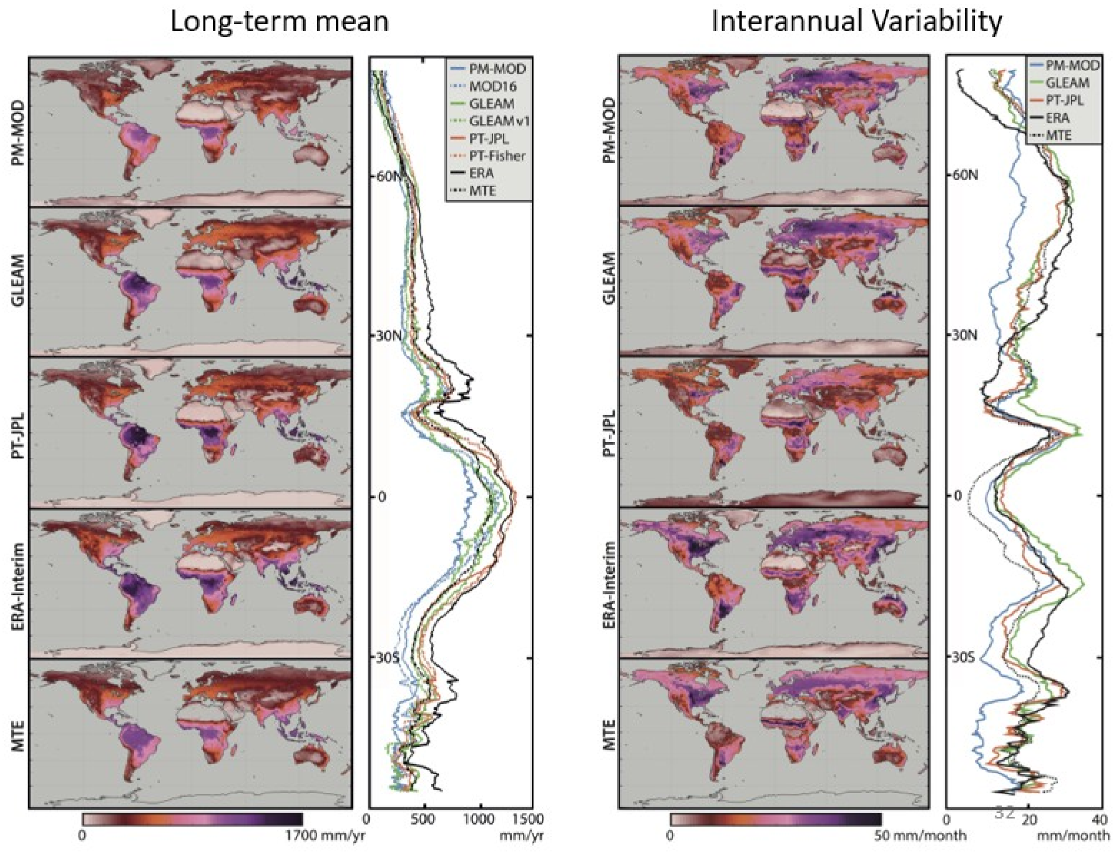

Figure 1. Uncertainty in long-term mean ET and interannual variability (adapted from Miralles et al., 2016)

Accurate global gridded estimates of ET are therefore highly needed to improve the understanding of terrestrial water, carbon, and surface energy exchanges, in addition to being required for model evaluation and development of climate projection of water resources and agricultural productivity.

Current methods to constrain ET fluxes can be summarized as:

- Physics-based ET parametrizations (i.e. Penman-Monteith, Priestley-Taylor or Hargreaves equations) in GHMs
- Simplified physics-based process models combined with remote sensing land-surface reflectance in the VIS/IR range for parameter estimations (Zhang et al., 2010) such as GLEAM (Miralles et al., 2013)
- Empirical vegetation index - ET relationships (i.e. NDVI-ET, SIF-ET)
- Surface energy balance (SEB) approaches based on thermal (IR) remote sensing
- Upscaling FLUXNET ET point-scale measurements using machine learning and satellite VIS/IR reflectance and climate data as predictors (FLUXCOM)(Jung et al., 2019)
- Multi-model synthesis/combinations of ET datasets: LandFLUX (Mueller et al., 2013), DOLCE (Hobeichi et al. 2018)

This Master Thesis Projects aims to create a global reconstruction of monthly terrestrial evapotranspiration (ET) rates via the water balance equation, which is defined as

$\Delta TWS/\Delta t = P(t) - ET(t) - R(t)$ ✉ $ET(t) = P(t) - R(t) - \Delta TWS/\Delta t$

with the terrestrial water storage (TWS) that can be constrained by GRACE-REC (Humphrey et al., 2019); the runoff flux that can be constrained by GRUN (Ghiggi et al., 2019); and the precipitation flux (P) that can be derived from satellites or atmospheric reanalysis. The new ET dataset will then be benchmarked against the independent FLUXNET-ET measurements as well as a large set of ET products either derived from satellite data or GHMs simulations. Finally, once observations-based ET estimates are derived and validated for the full globe by means of the water balance equation, the student will be able to train a ML algorithm to establish a link between observed ET dynamics to a set of predictors such past monthly precipitation and monthly temperature, following an approach like the one detailed in Ghiggi et al., 2019. This will allow the generation of century-long ET reconstructions, fostering the understanding of freshwater dynamics and climate variability.

Objectives

- Production of a new ET-dataset using GRUN and GRACE-REC by means of the water balance equation
- Development of a machine learning model to predict monthly ET as function of predictors such past precipitation and temperature
- Benchmarking against current state-of-the art ET products (i.e. LANDFLUX, GLEAM, FLUXCOM, …)

Requirements

- Basic knowledge in hydrology and statistics
- Good programming skills in python or R

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