Bridging the scales of evapotranspiration (ET)

Sibylle K. Hassler (KIT, sibylle.hassler@kit.edu), Peter Dietrich (UFZ), Ralf Kiese (KIT), Matthias Mauder (KIT), Jörg Meyer (KIT), Corinna Rebmann (UFZ), Erwin Zehe (KIT)
BRIDGET aims to develop a tool to integrate various ET flux measurements across methods, disciplines and scales.
Why look at evapotranspiration (ET)?

ET approximately 60% of terrestrial precipitation → important ecosystem flux

Oki & Kanae (2006), Science:
- Total terrestrial precipitation: 111 km³/y
- Evapotranspiration: 65.5 km³/y
ET in hydrological modelling

- Standard are equations like Penman-Monteith (PM)
  - usually based on very few meteorological station data
  - lacks feedback to atmosphere

- Questions:
  - Can spatial patterns and dynamics be addressed appropriately?
  - Could physiological adaptations result in transpiration that is different than based on atmospheric demand alone?
  - models tailored to discharge
    - What about ungauged basins?
    - water balance approach not feasible
    - How can we gain better ET process knowledge?

- Remote sensing data increasingly available
  - appropriate ground truth often missing

Loritz et al. (2018), HESS

Dynamics of sap flow (green) similar to the simulated PM approach, but discrepancy for example in Aug/Sep
Variety in ET data across disciplines

- NDVI
- TIR
- Eddy flux data
- Meteo data (models, eg. Penman-Monteith)
- Sap flow
- Soil moisture (root water uptake)
- Lysimeters
- Water balance

**Remote sensing**

**Micrometeorology**

**Plant physiology/ecology**

**Soil science/physics**

**Hydrology**

Flux at the interface of soil, plants and atmosphere → links ecosystem compartments and research disciplines
Scaling challenge

Challenges:
- support
- representativeness

Needed to bridge:
- Algorithms
- Uncertainties
- Models

ET is estimated across a range of scales:
→ bridge scales, combine measurements & models, include uncertainties
Example 1: Sap flow upscaling

... needs to bridge the scales from individual sensor measurement to the landscape!
Example 1: Sap flow upscaling – uncertainties

Individual sensor:
- thermistor accuracy
- zero flow criterion (some methods)
- wounding correction

Upscaling to tree transpiration:
Sapwood area:
- DBH-based equations from literature
- uniformity (Fig. 1) / sensor location
- own measurement for each tree?

Sap velocity profile (Fig. 2):
- literature
- own measurements

Fig. 1: Bieker & Rust (2010), Silva Fennica
Fig. 2: sap velocity profiles, e.g., in Gebauer et al. (2008), Tree Physiology

Example 1: Sap flow upscaling – uncertainties

Upscaling to stand transpiration:
Stand composition data:
- own survey
- aerial photographs
- official forest inventory

Allometric relations:
- literature
- own measurements

Ground vegetation?
Soil evaporation?
Example 1: Sap flow upscaling – uncertainties

Challenges in different ET measurements

• Water balance:
  – point measurements in rainfall
  – accuracy of discharge rating curve
• Eddy covariance:
  – energy balance gap
  – surface heterogeneity
• Lysimeters:
  – signal noise of weighing data
• Sap flow:
  – zero flow assumption
  – upscaling to tree and stand
• Partitioning T/ET

• knowledge about uncertainties in measurements is domain-specific
• comparisons are rare
• scaling functions non-existent
• remote sensing → necessity to have ground truth at the appropriate scale

→ AIM: Develop ET package to combine and compare these measurements, address challenges and uncertainties.
Why use a virtual research environment for the task?

- Findable, Accessible, Interoperable, Reusable data initiative

- Data increasingly available in digital data centres / virtual research environments

- Data variety and data amount best brought together in one system, together with algorithms for analysis

- Temporal consistency of different measurements → allows cross-compartment analyses for environmental science

- Tools and workflows standardised and transferrable

- And saveable → reproducibility
Which research environment? V-FOR-WaTer!

Features of V-FOR-WaTer: (green: especially relevant for BRIDGET)

- Authentication/authorisation
- Fine-grained user management
- Database with spatial reference
- Adaptable metadata scheme (compatible with int. standards)
- Varied filter options
- Workspace with toolbox
- Pre-processing/scaling & special tools
- Connection to repository
- Workflow manager (reproducibility)
Requirements for the ET package

1. discipline-specific metadata from all relevant disciplines
2. method-specific pre-processing tools
3. uncertainty estimates / quality control approaches
4. T/ET distinction where applicable
5. scaling tools within and between methods
6. visualisation of data, support, uncertainty
7. (workflow) documentation

Language:
- stand-alone: python
- part of virtual research environment: WPS
BRIDGET package vision

V-FOR-WaTer portal
BRIDGET package vision

Possibility to display different ET measurements and their spatial reference
BRIDGET package vision

Method characteristics:
- Water balance
- Distributed rainfall
- Eddy covariance
- Footprint analysis
- Sap flow
- Wounding correction

ET data:
- Water balance
- Eddy covariance
- Sap flow

Get information about characteristics and included data of the methods
BRIDGET package vision

Use scaling approach from one scale to the other using available data and scaling approaches, get estimates of uncertainty
Show case TERENO

TERENO site Harz / Central German Lowland Observatory
- Peter Dietrich, Corinna Rebmann (UFZ)

Data:
- Hohes Holz:
  - eddy covariance
  - sap flow
  - soil moisture

TERENO site Bavarian Alps / pre-Alps Observatory
- Matthias Mauder, Ralf Kiese (KIT)

Data:
- Fendt:
  - eddy covariance
  - lysimeters
- (potentially) Höglwald:
  - eddy covariance
Show case TERENO

• Open research questions:
  – correction routines of the different measurements
  – scaling functions
  – comparison among sub-sites and land uses
  – scaling functions different between sites?
  – comparison of upscaled ET fluxes between site
    → variability of ET in different landscapes
BRIDGET steps

1) Data and methods (in collaboration with TERENO colleagues)
   – compile data and metadata requirements for each ET method in the TERENO data
   – identify formats, access, uncertainties
   – collect method-specific pre-processing and quality control algorithms

2) Implementation (in collaboration with V-FOR-WaTer team)
   – expand V-FOR-WaTer metadata model, include TERENO data and metadata
   – design visualisation
   – assess and display associated uncertainties
   – test the already included tools for scaling/interpolation, design ET-specific ones
   – establish workflows to include and upload relevant (meta)data of various sources

3) Present tools and functionalities to data providers → feedback round:
   – refine package accordingly
   – joint analyses of datasets

4) Wider dissemination (for example EGU 2021)
Feedback to us:
- Which features and tools do you need in BRIDGET?
- Where are your datasets? / which connection to BRIDGET would you need?
- Would you use such a toolbox? (within V-FOR-WaTer or the python package?)
- Which reasearch questions would you address with it?
we will speak all these languages