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)

Karlsruhe Institute of Technology

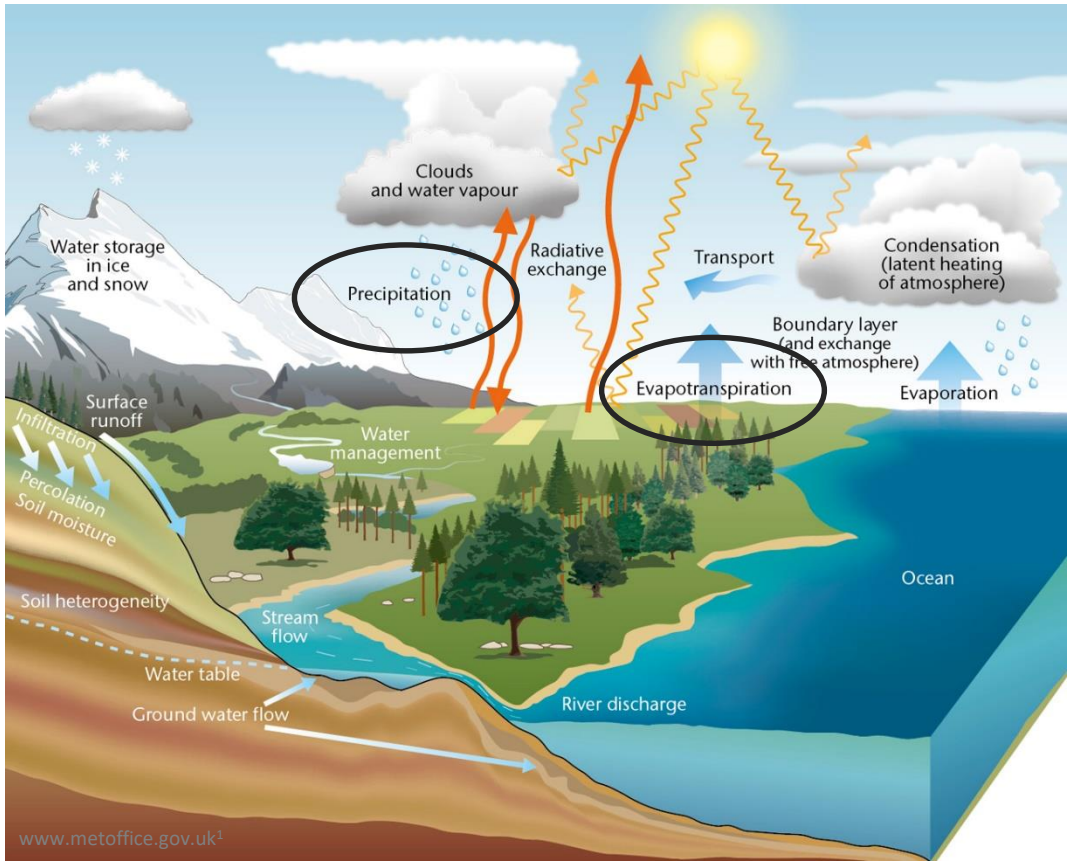
HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

DIGITAL EARTH

BRIDGET

BRIDGET aims to develop a tool
to integrate various ET flux measurements
across methods, disciplines and scales.

Why look at evapotranspiration (ET)?



Oki & Kanae (2006), *Science*:

- Total terrestrial precipitation: 111 km³/y
- Evapotranspiration: 65,5 km³/y

ET approximately 60% of terrestrial precipitation
→ important ecosystem flux

[1]Contains public sector information licensed under the Open Government License v1.0
Oki & Kanae (2006): Global Hydrological Cycles and World Water Resources. *Science*, Vol. 313(5790), doi:10.1126/science.1128845

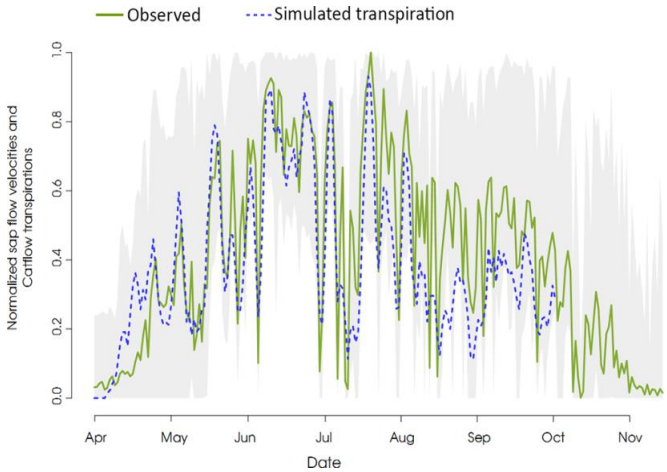
BRIDGET

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

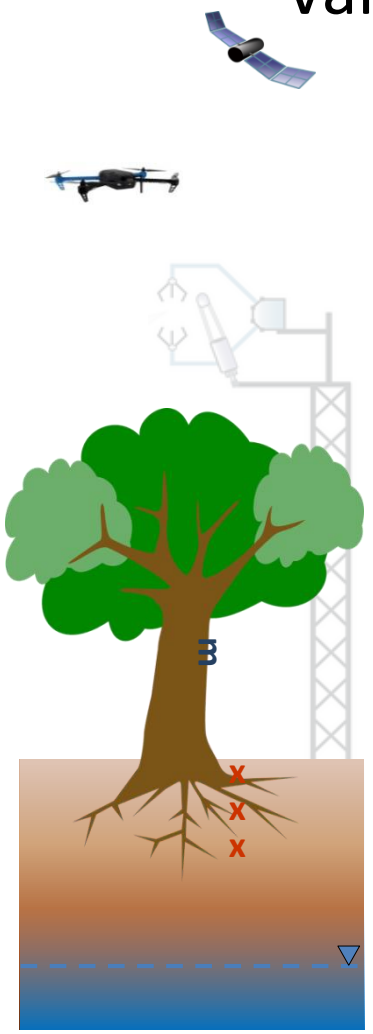


Loritz et al. (2018), *HESS*

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

Loritz et al. (2018): Picturing and modeling catchments by representative hillslopes. *HESS*, Vol. 22, doi: 10.5194/hess-22-3663-2018

Variety in ET data across disciplines

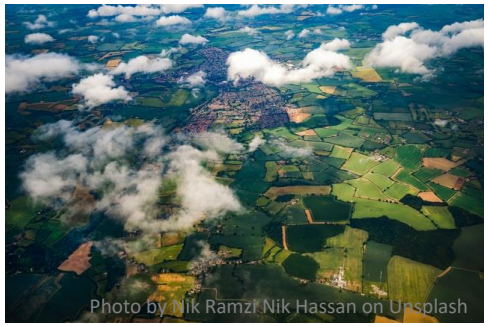


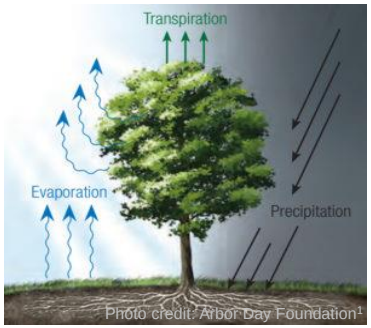
NDVI	**Remote sensing**
TIR	**Remote sensing**
Eddy flux data	**Micrometeorology**
Meteo data (models, eg. Penman-Monteith)	**Micrometeorology**
Sap flow	**Plant physiology/ecology**
Soil moisture (root water uptake)	**Soil science/physics**
Lysimeters	**Soil science/physics**
Water balance	**Hydrology**

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

Tree/point — Stand/plot — Landscape

Soil science/physics
Plant physiology

Micrometeorology
(Forest) ecology

Meteorology
Remote sensing

ET is estimated across a range of scales:
→ bridge scales, combine measurements & models, include uncertainties

[1]www.arborday.org [2]Illustration copyright LI-COR, Inc. Used by permission.

Example 1: Sap flow upscaling

Individual sensor

Tree transpiration

Transpiration of a stand

ET of a landscape

… needs to bridge the scales from individual sensor measurement to the landscape!

Example 1: Sap flow upscaling – uncertainties

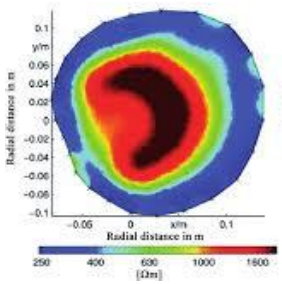


Fig. 1: Bieker & Rust (2010), *Silva Fennica*

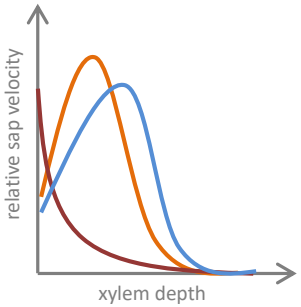


Fig. 2: sap velocity profiles, eg. in Gebauer et al. (2008), *Tree Physiology*

Individual sensor:

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

<u>Upscaling to tree transpiration:</u>

Sapwood area:

- DBH-based equations from literature
- uniformity (Fig. 1) / sensor location
- own measurement for each tree?

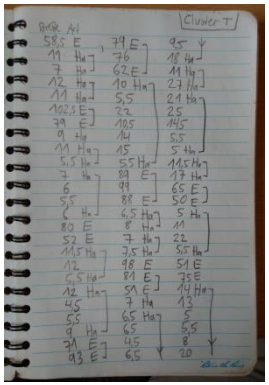
Sap velocity profile (Fig. 2):

- literature
- own measurements

Bieker D., Rust S. (2010). Non-destructive estimation of sapwood and heartwood width in Scots pine (Pinus sylvestris L.). *Silva Fennica*, Vol. 44(2), doi:10.14214/sf.153

Gebauer T., Horna V., Leuschner C. (2008). Variability in radial sap flux density patterns and sapwood area among seven co-occurring temperate broad-leaved tree species. *Tree Physiology*, Vol. 28(12), doi: 10.1093/treephys/28.12.1821

Example 1: Sap flow upscaling – uncertainties



Stand survey data and map

<u>Upscaling to stand transpiration:</u>

Stand composition data:

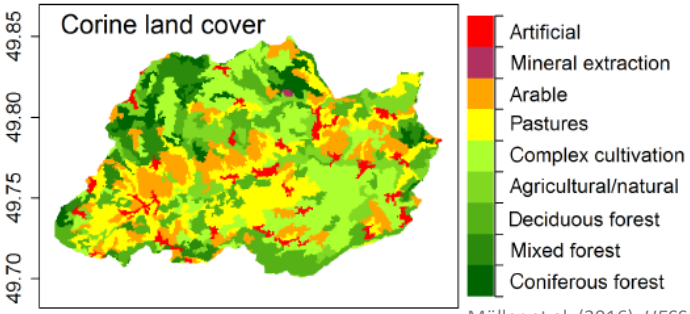
- own survey
- aerial photographs
- official forest inventory

Allometric relations:

- literature
- own measurements

Ground vegetation?
Soil evaporation?

Example 1: Sap flow upscaling – uncertainties



Müller et al. (2016), *HESS*

<u>Upscaling to landscape ET:</u>

Landscape composition:
- remote sensing
- mapping

T/ET partitioning

ET estimates for land uses:
- literature
- models
- own measurements

Müller et al. (2016): Estimating spatially distributed soil texture using time series of thermal remote sensing – a case study in Europe. *HESS*, Vol. 20, doi: 10.5194/hess-20-3765-2016

Challenges in different ET measurements

- Water balance:
  - point measurements in rainfall
  - accuarcy 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

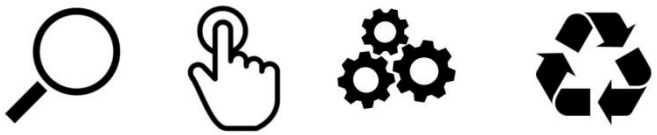
- **knowledge about uncertainties in measurements is domain-specific**
- **comparisons are rare**
- **scaling functions non-existent**
- **remote sensing → necessity to have ground truth at the appropriate scale**

→ **AIM:** Develop ET package to combine and compare these measurements, address challenges and uncertainties.

BRIDGET

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

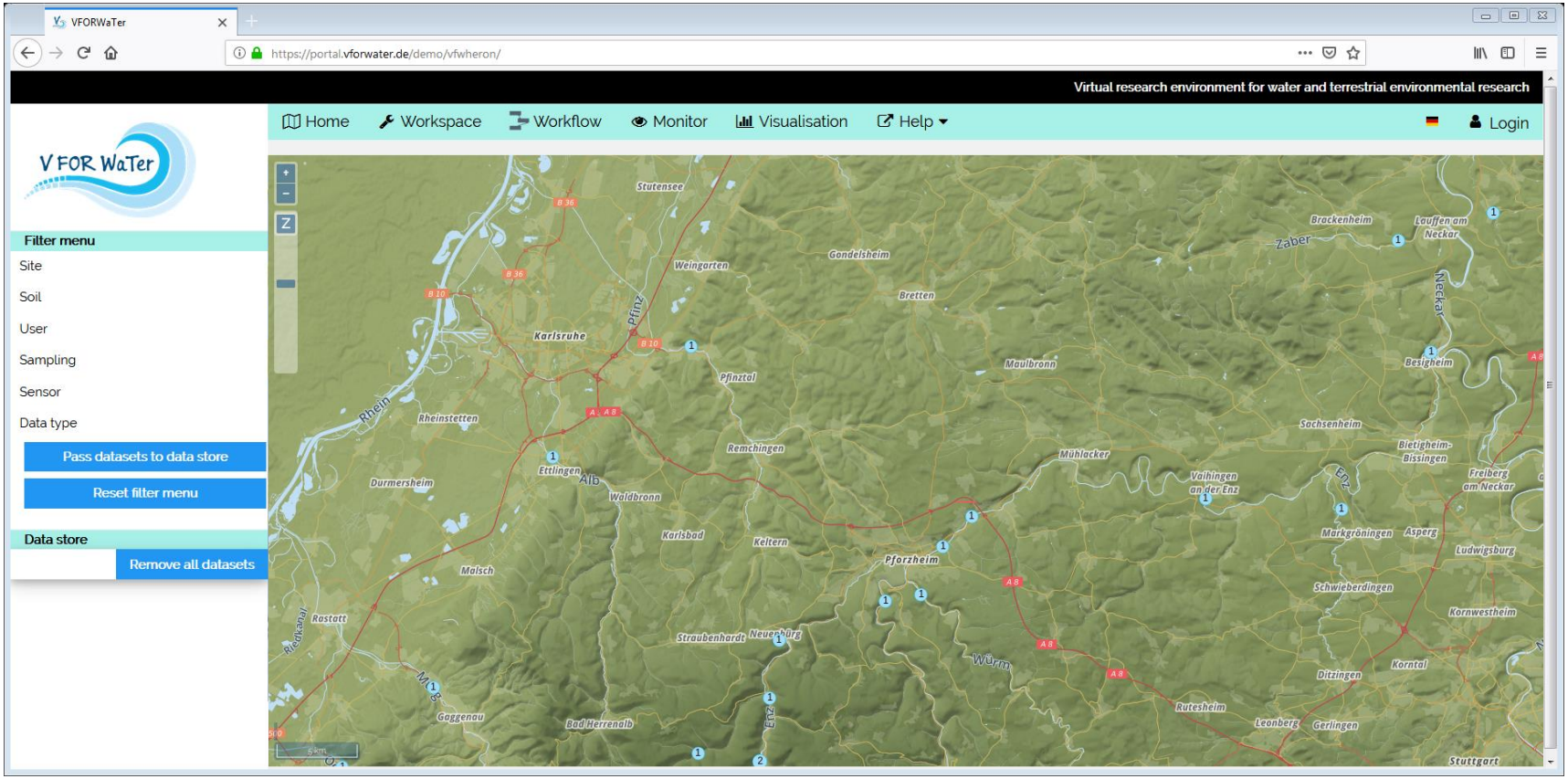
  → allows cross-compartment analyses for environmental science

- tools and workflows standardised and transferrable
- and saveable → reproducibility

V FOR WaTer

BRIDGET

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)

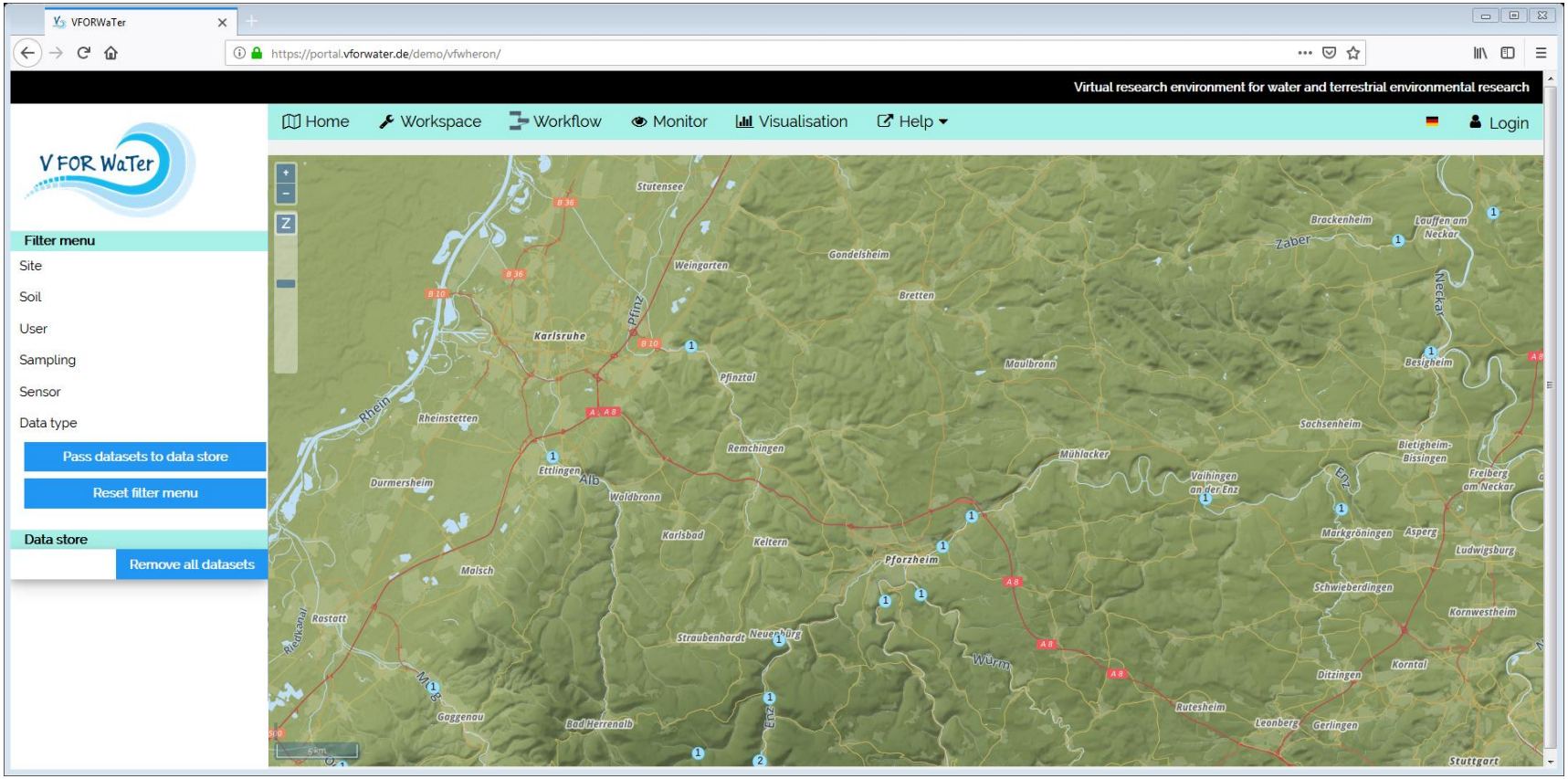
Requirements for the ET package

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:

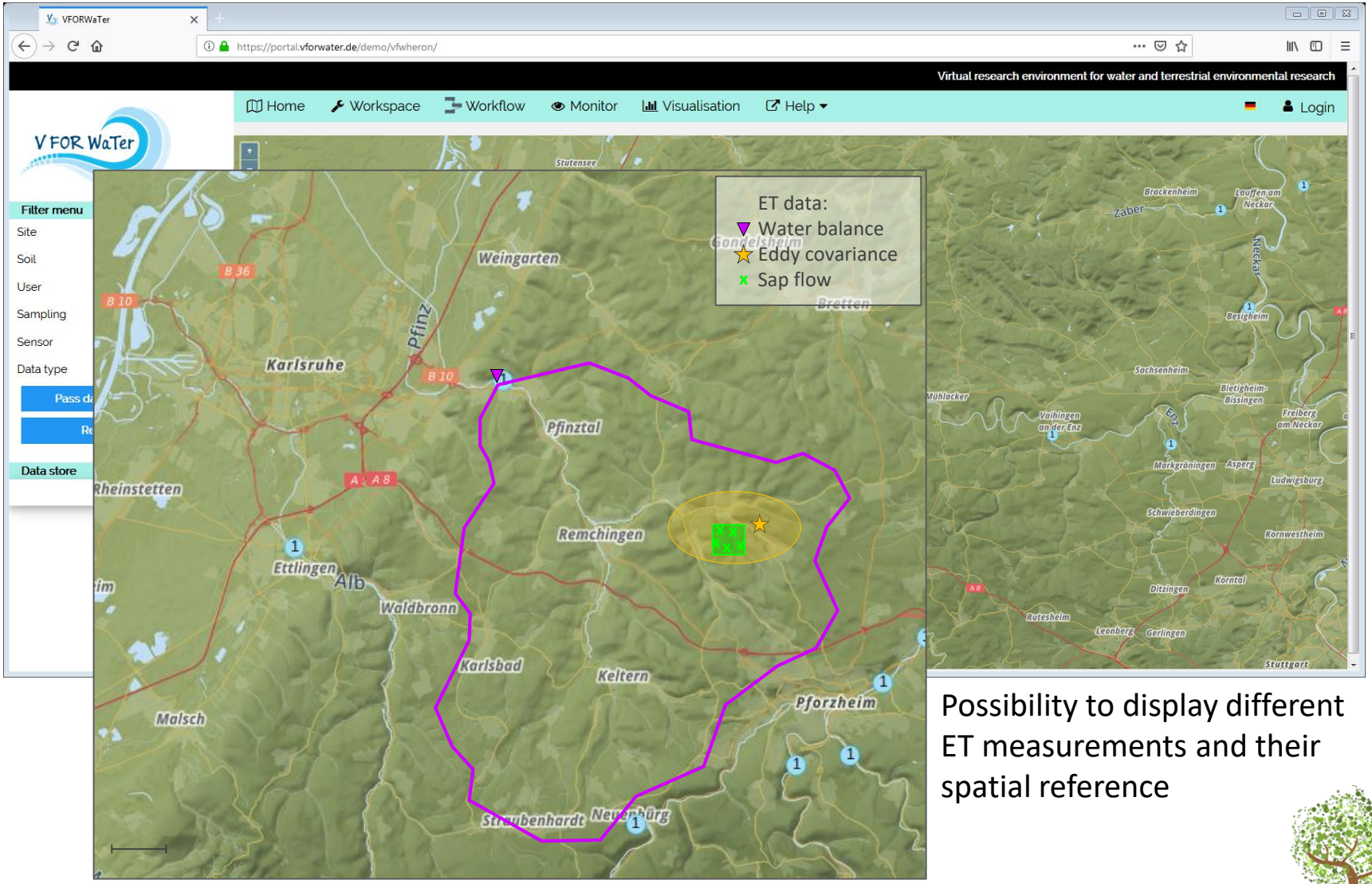
- stand-alone: python
- part of virtual research environment: WPS

BRIDGET package vision



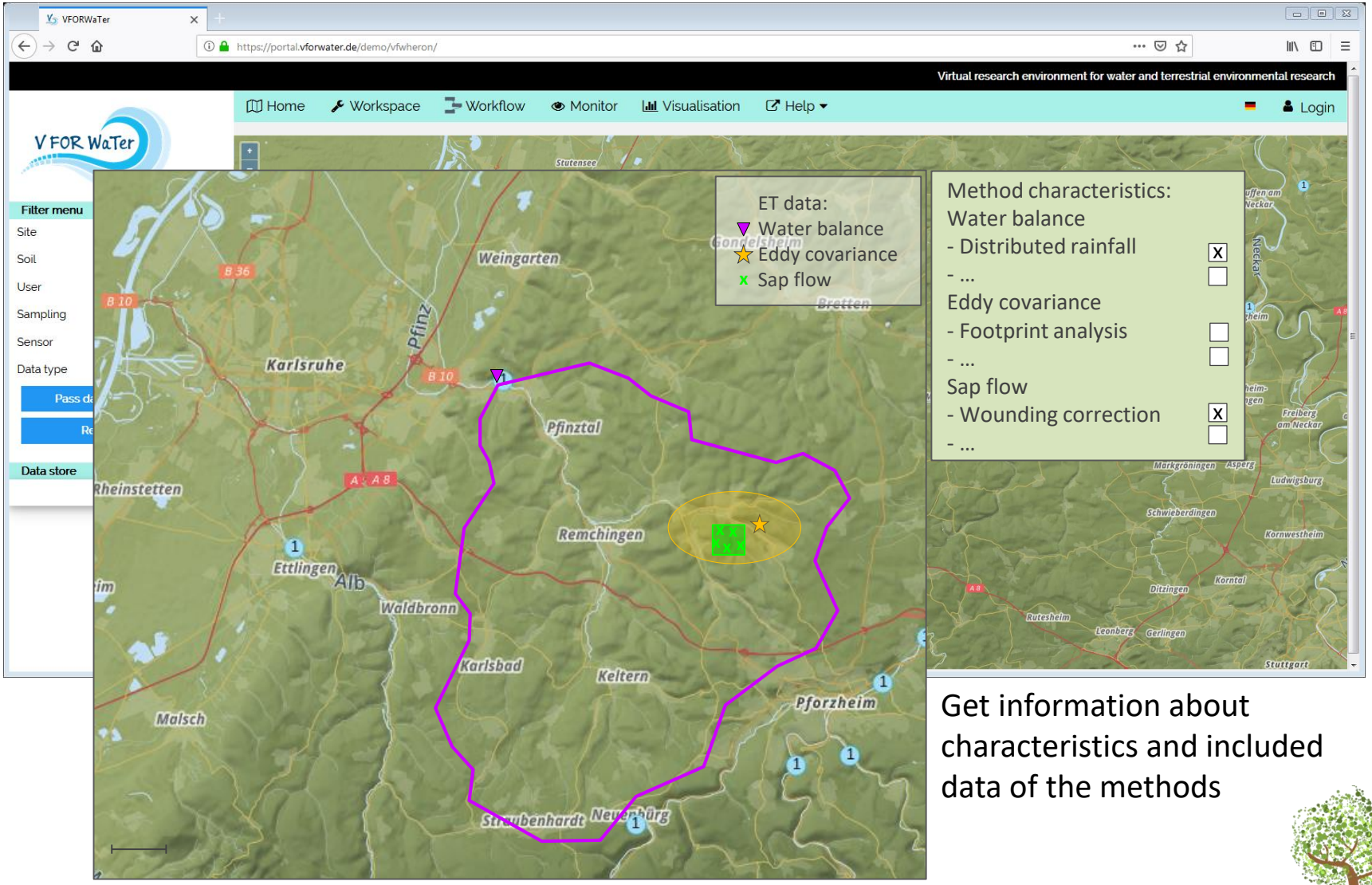
V-FOR-WaTer portal

BRIDGET package vision



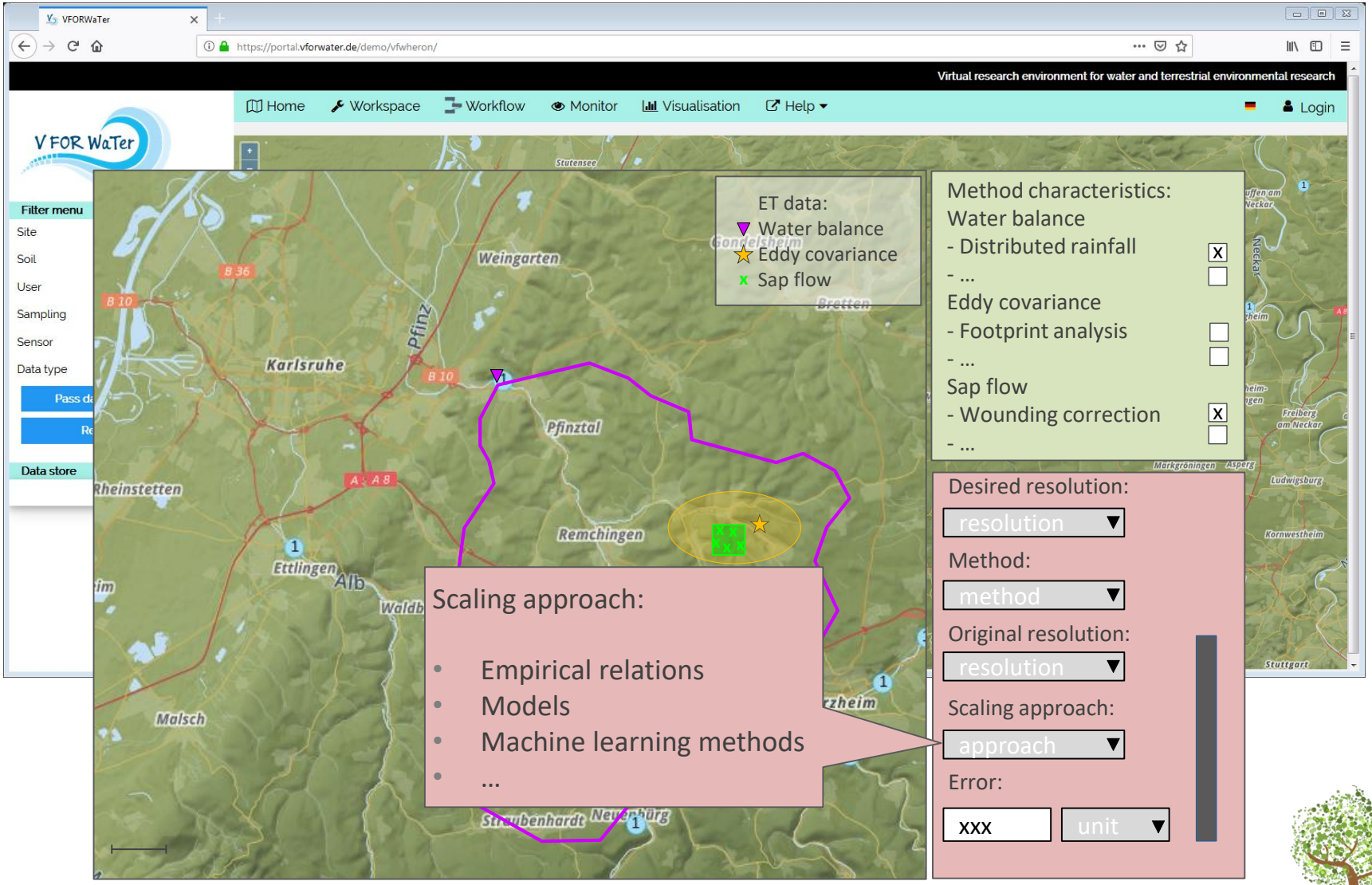
Possibility to display different ET measurements and their spatial reference

BRIDGET package vision



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

BRIDGET

Show case TERENO


TERENO site Harz / Central German Lowland Observatory

- Peter Dietrich, Corinna Rebmann (UFZ)

Data:

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



http://teodoor.icg.kfa-juelich.de

TERENO site Bavarian Alps / pre-Alps Observatory

- Matthias Mauder, Ralf Kiese (KIT)

Data:

- Fendt:
  - eddy covariance
  - lysimeters
- (potentially) Höglwald:
  - eddy covariance

BRIDGET

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)

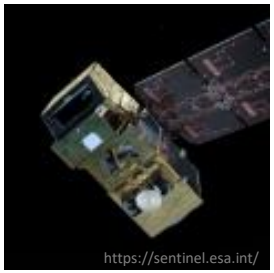
BRIDGET

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

BRIDGET