Bridging the scales of evapotranspiration (ET)

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DIGITAL EARTH

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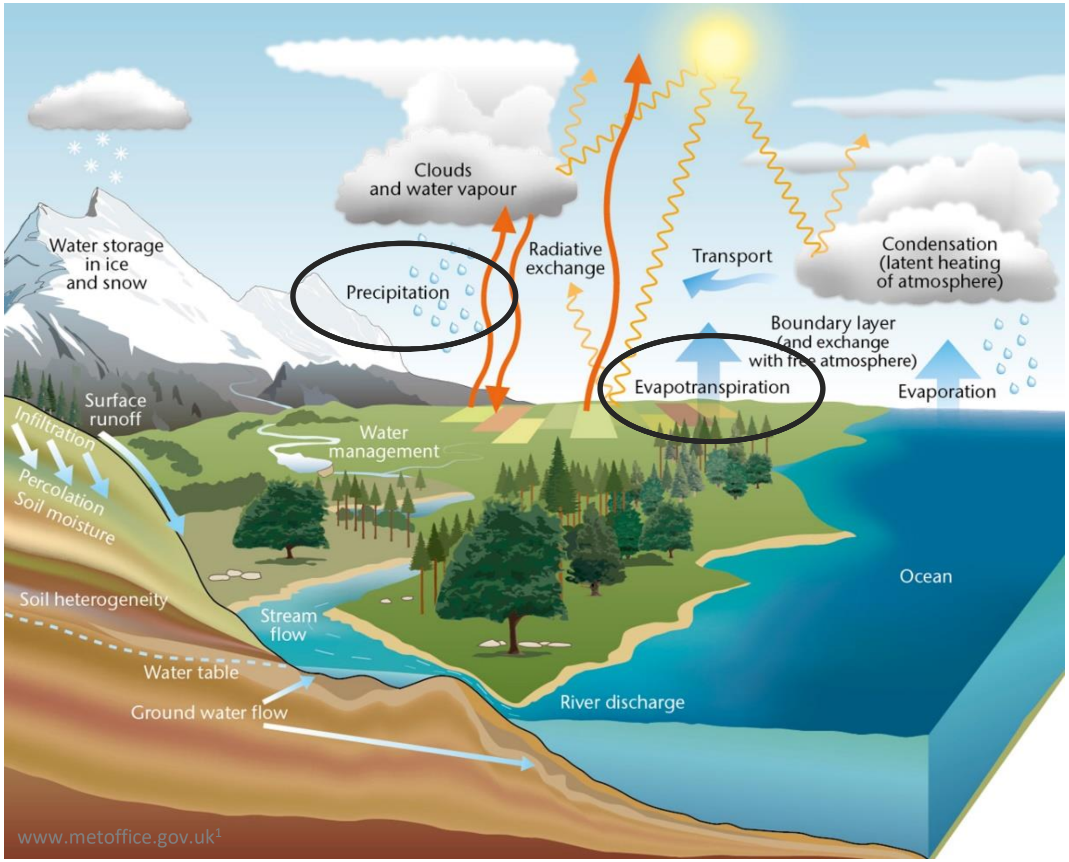
BRIDGET aims to develop a tool
to integrate various ET flux measurements
across methods, disciplines and scales.

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

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Oki & Kanae (2006): Global Hydrological Cycles and World Water Resources. *Science*, Vol. 313(5790), doi:10.1126/science.1128845

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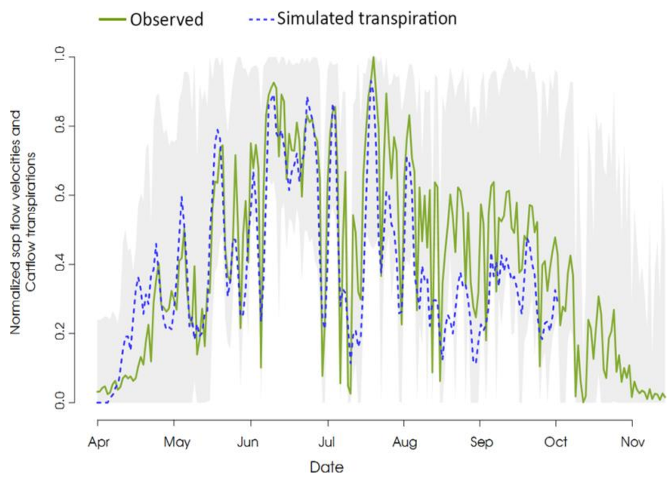
ET in hydrological modelling

- 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

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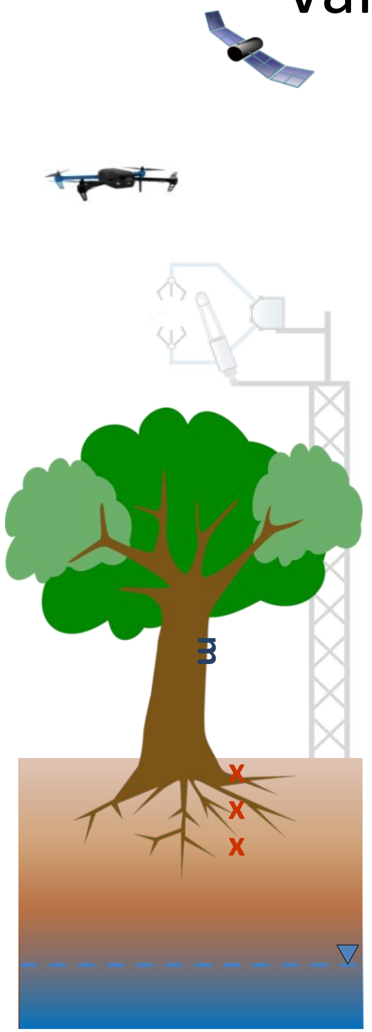
Loritz et al. (2018): Picturing and modeling catchments by representative hillslopes. *HESS*, Vol. 22, doi: 10.5194/hess-22-3663-2018

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

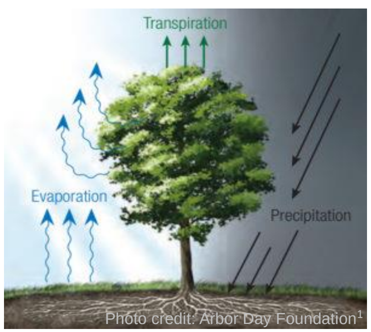
Landscape

Stand/plot

Tree/point

Challenges:

- support
- representativeness



Needed to bridge:

- Algorithms
- Uncertainties
- Models

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. [3]used with kind concession of the TRUSTEE project.

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!

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Example 1: Sap flow upscaling – uncertainties

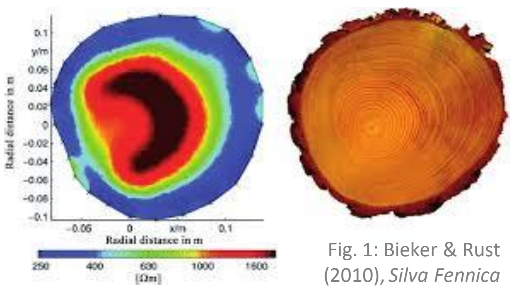


Fig. 1: Bieker & Rust (2010), *Silva Fennica*

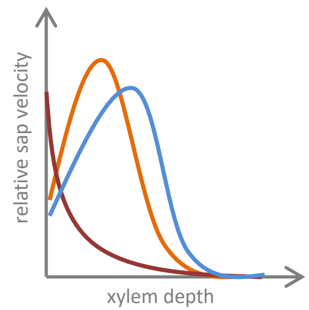


Fig. 2: sap velocity profiles, eg. in Gebauer et al. (2008), *Tree Physiology*

Individual sensor:

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

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

Sapwood area:

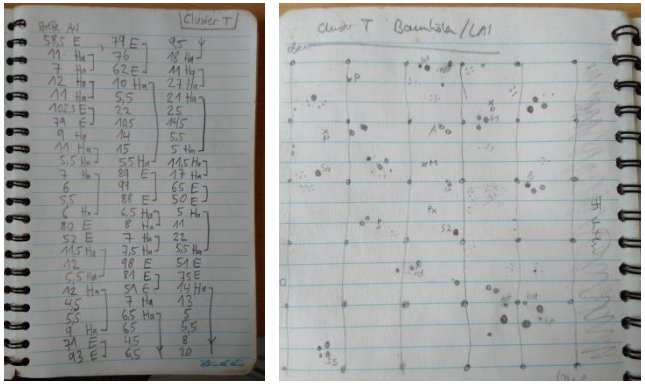
- DBH-based equations from literature
- uniformity (Fig. 1) / sensor location
- own measurement for each tree?

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

Upscaling to stand transpiration:

Stand composition data:

- own survey
- aerial photographs
- official forest inventory

Allometric relations:

- literature
- own measurements

Ground vegetation?
Soil evaporation?

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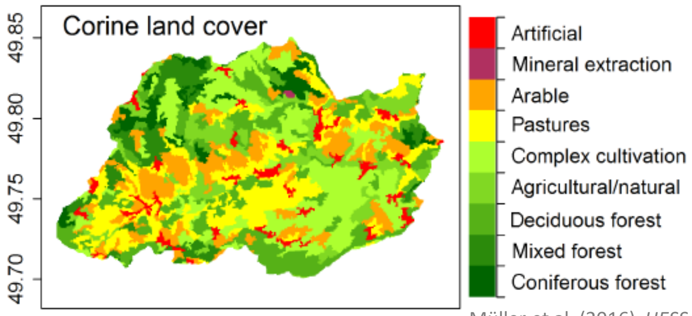
Example 1: Sap flow upscaling – uncertainties



Müller et al. (2016), *HESS*

Upscaling to landscape ET:

Landscape composition:

- remote sensing
- mapping

T/ET partitioning

ET estimates for land uses:

- literature
- models
- own measurements

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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.

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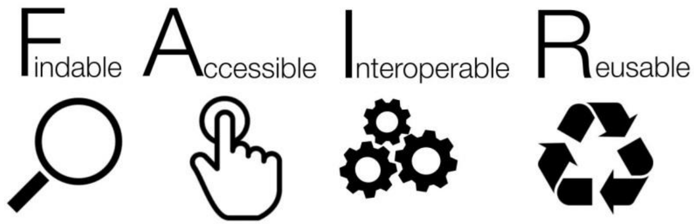
Why use a virtual research environment for the task?

- 

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

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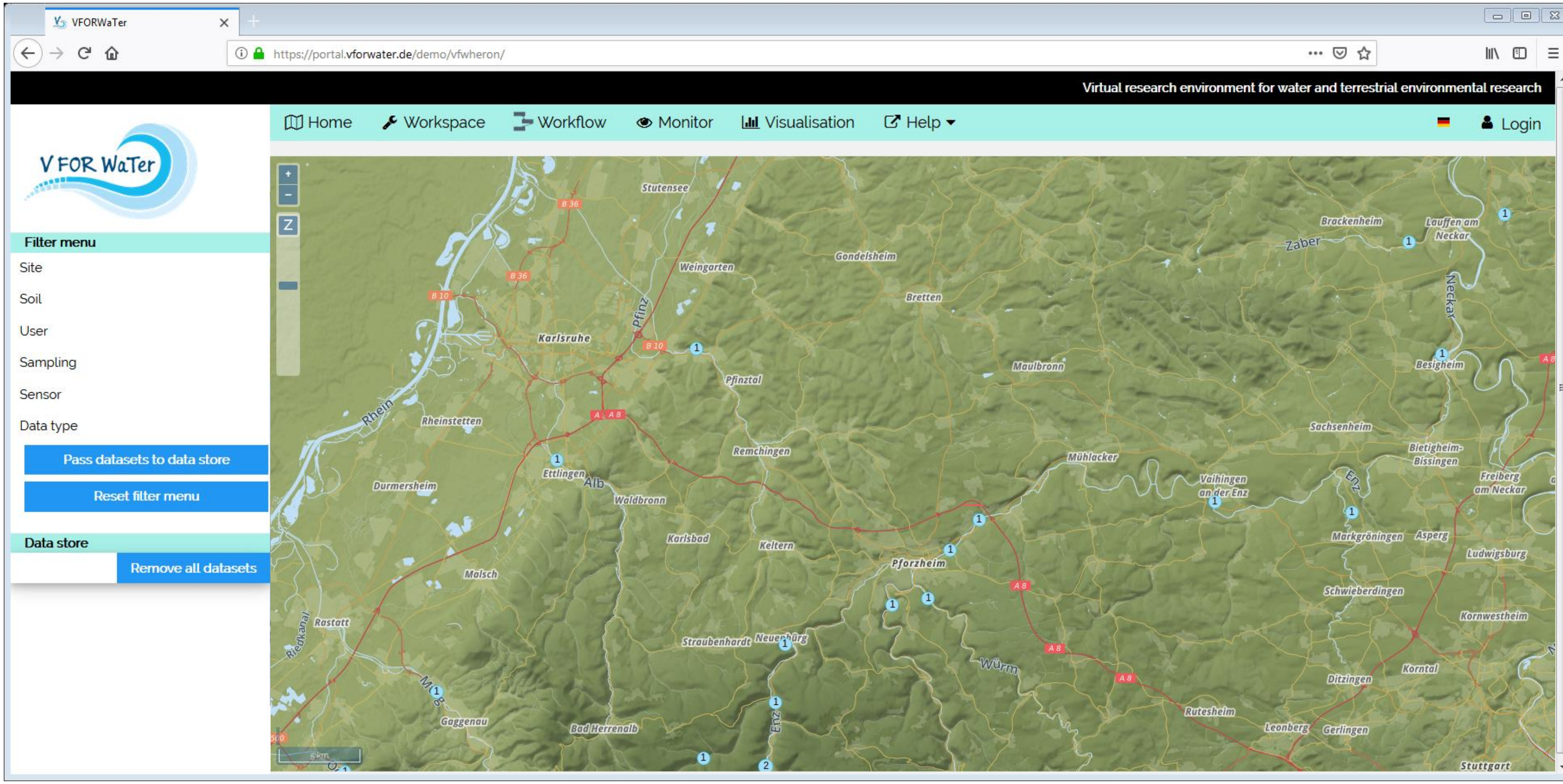
Which research environment? V-FOR-WaTer!



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)

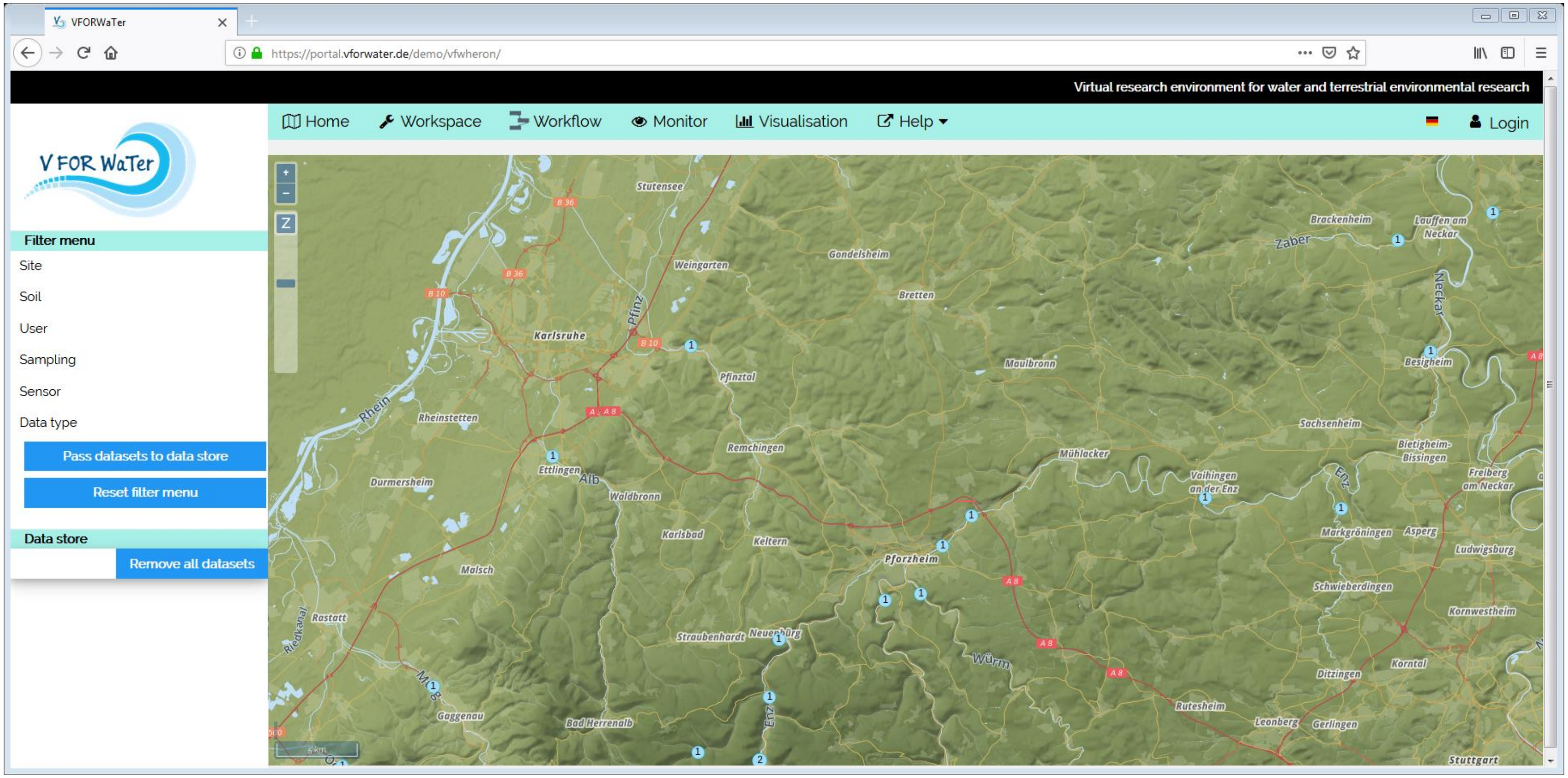
Requirements for the ET package

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:

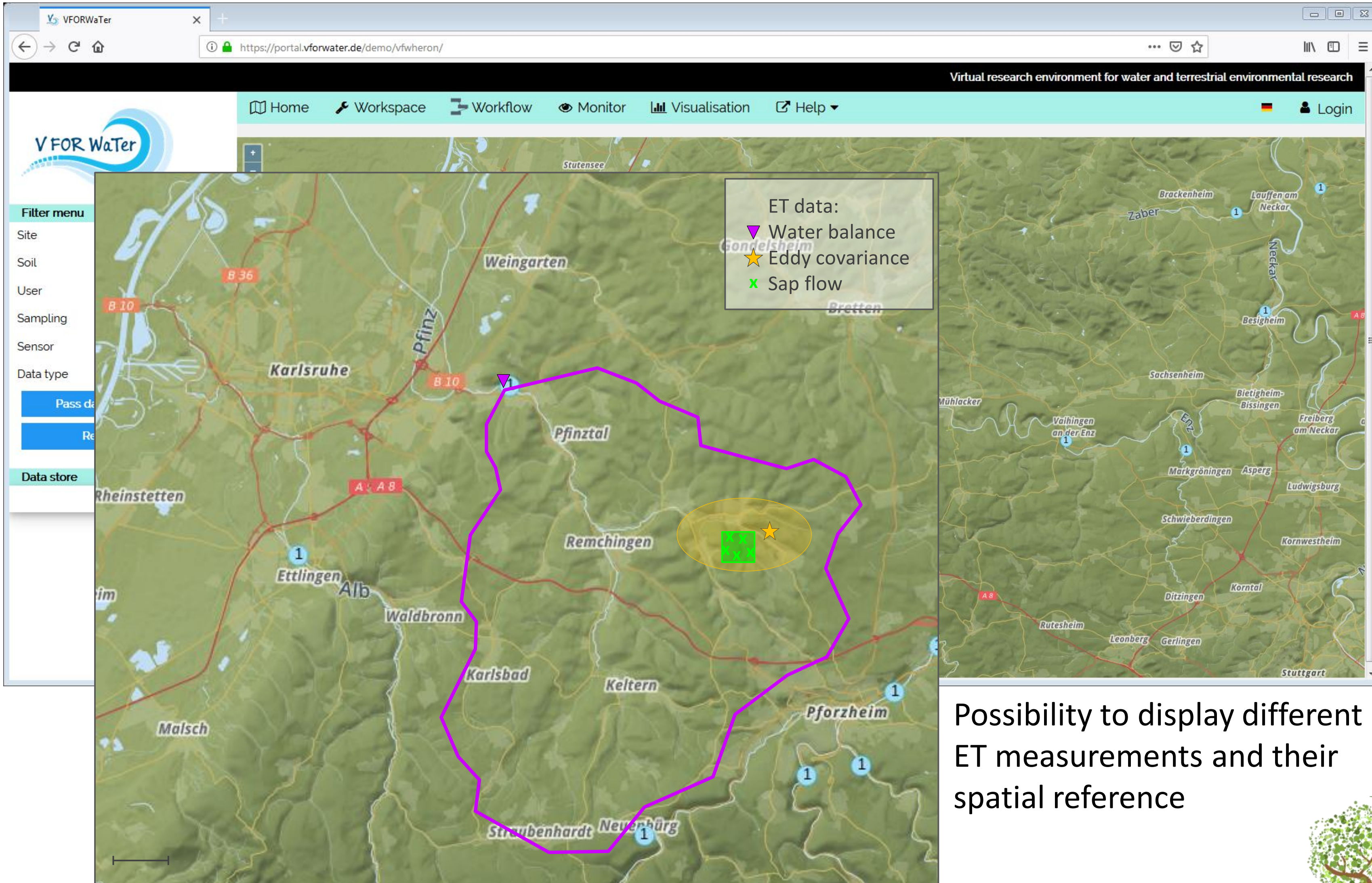
- stand-alone: python
- part of virtual research environment: WPS

BRIDGET package vision



V-FOR-WaTer portal

BRIDGET package vision



Possibility to display different ET measurements and their spatial reference

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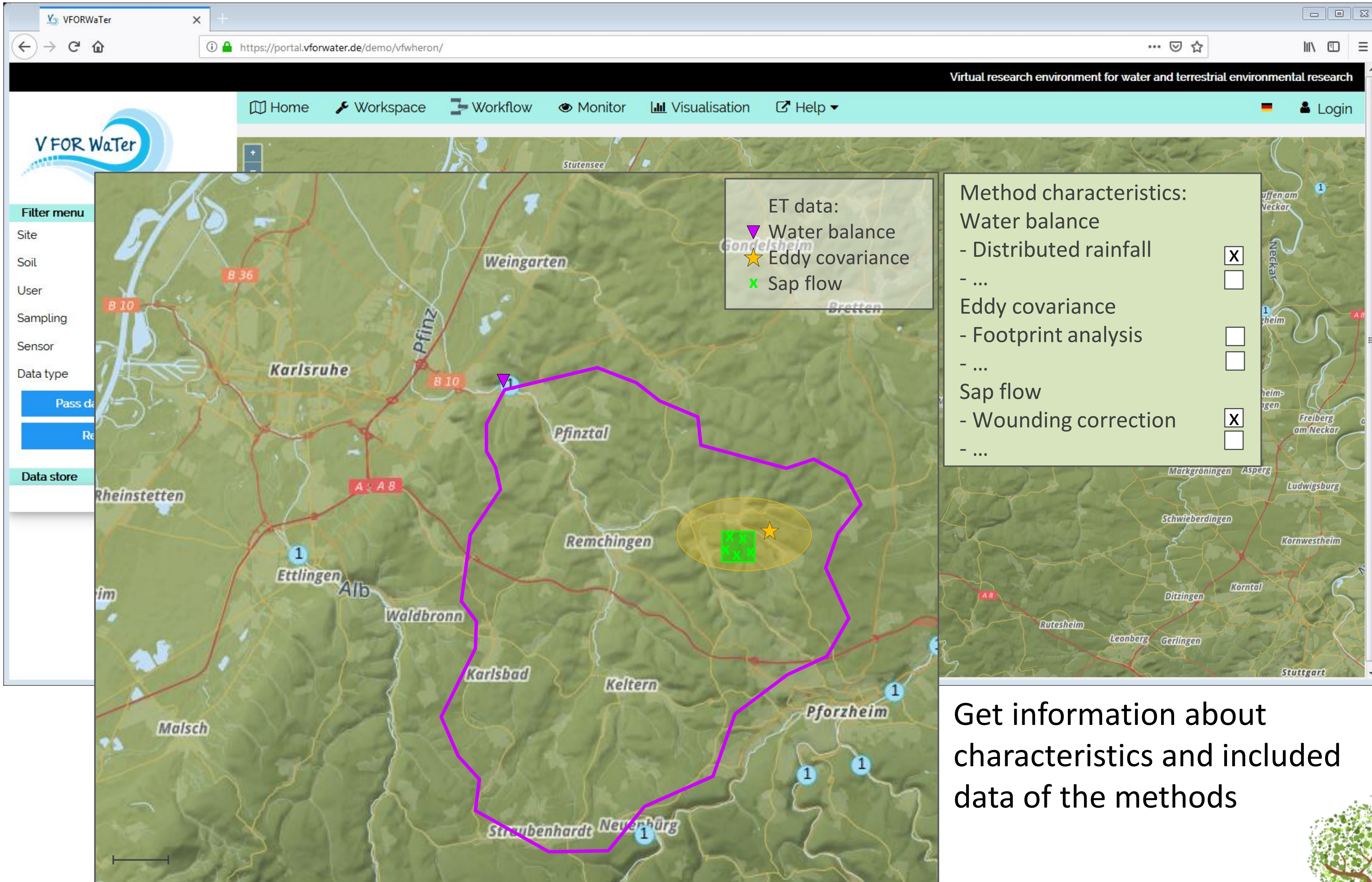
BRIDGET package vision



Get information about characteristics and included data of the methods

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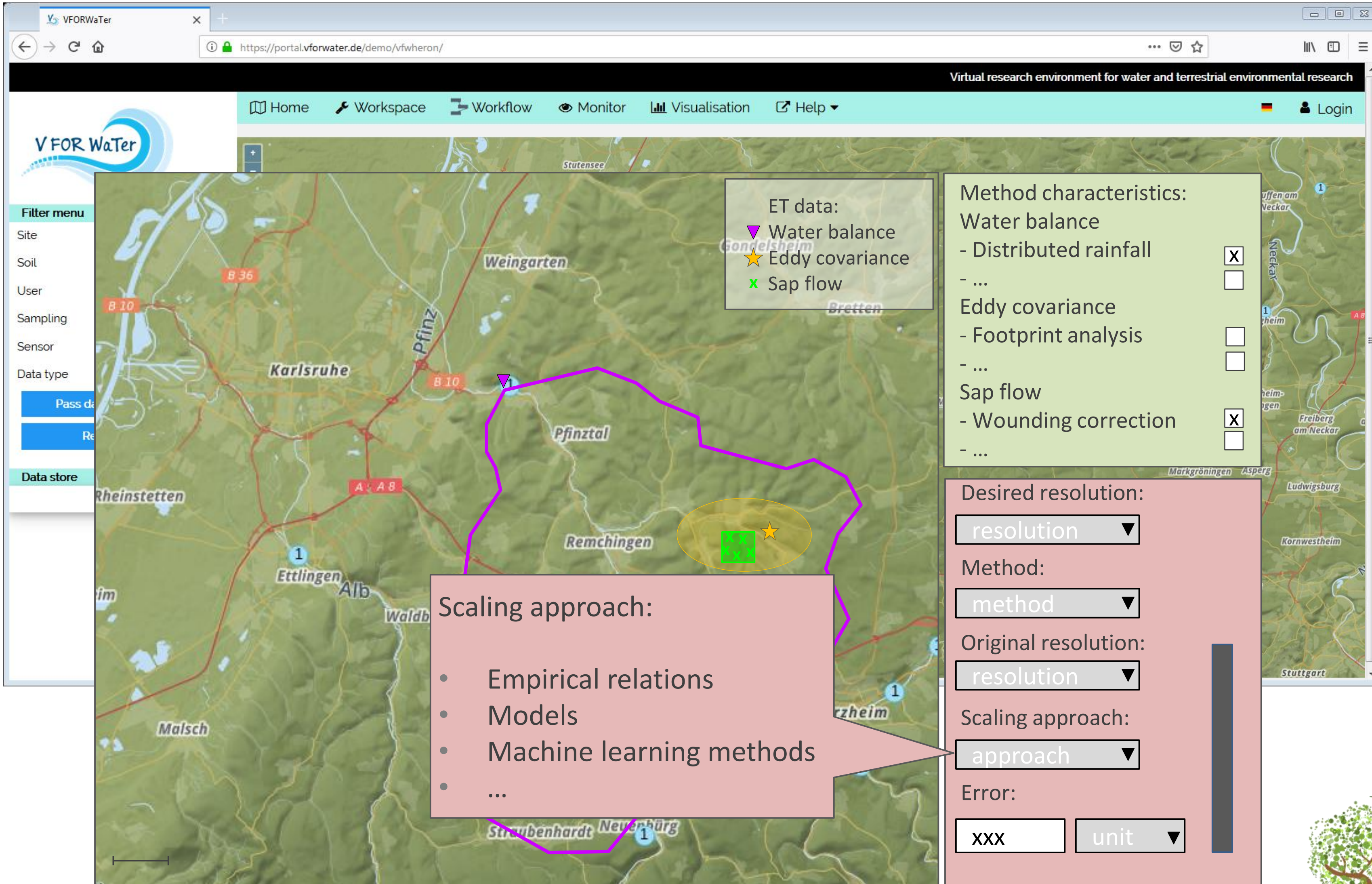
BRIDGET package vision



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

Show case TERENO





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

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

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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?

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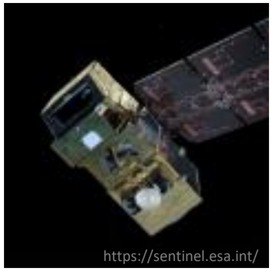

we will speak
all these
languages

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