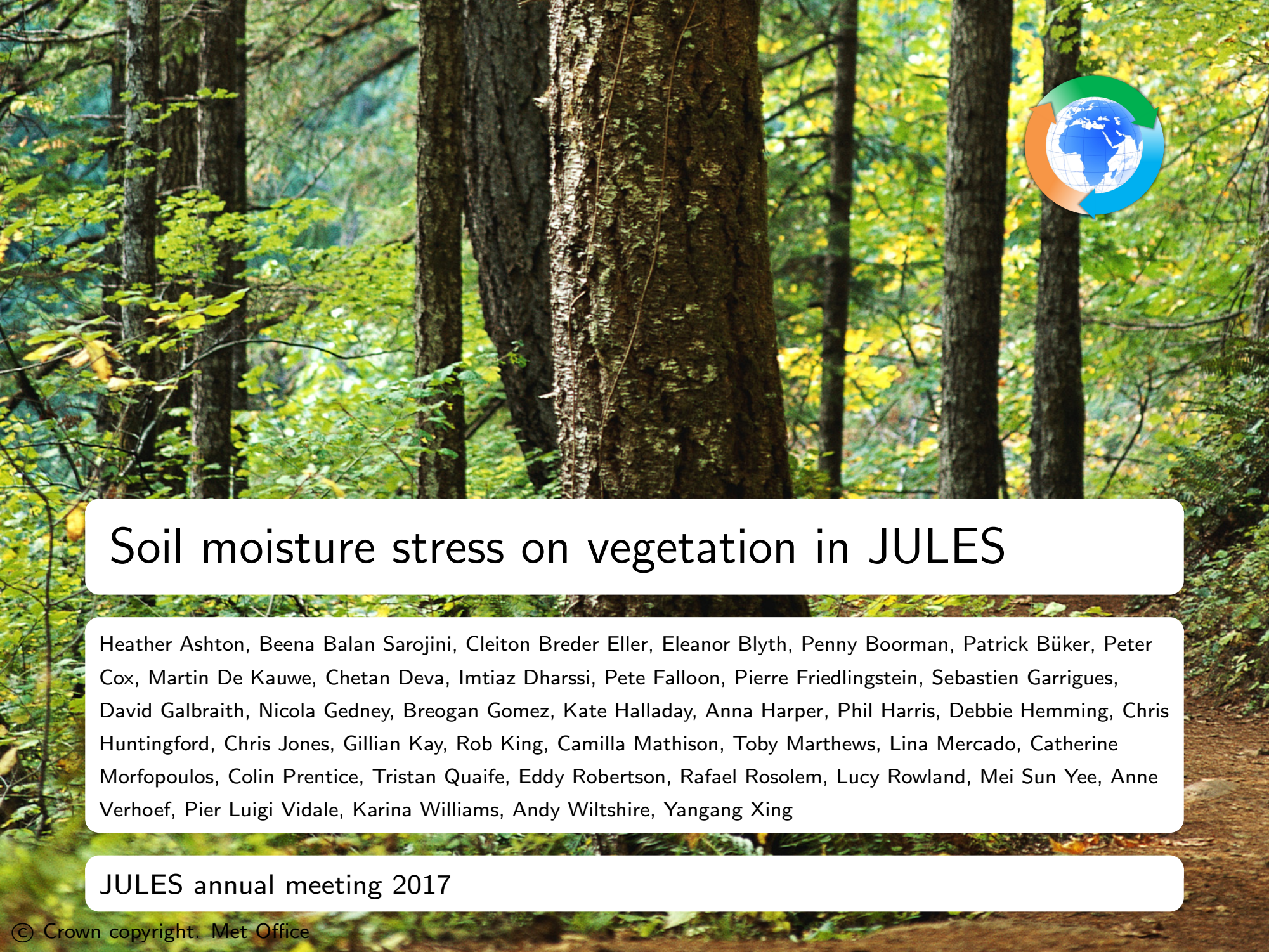


# Soil moisture stress on vegetation in JULES

Heather Ashton, Beena Balan Sarojini, Cleiton Breder Eller, Eleanor Blyth, Penny Boorman, Patrick Büker, Peter Cox, Martin De Kauwe, Chetan Deva, Imtiaz Dharssi, Pete Falloon, Pierre Friedlingstein, Sebastien Garrigues, David Galbraith, Nicola Gedney, Breogan Gomez, Kate Halladay, Anna Harper, Phil Harris, Debbie Hemming, Chris Huntingford, Chris Jones, Gillian Kay, Rob King, Camilla Mathison, Toby Marthews, Lina Mercado, Catherine Morfopoulos, Colin Prentice, Tristan Quaife, Eddy Robertson, Rafael Rosolem, Lucy Rowland, Mei Sun Yee, Anne Verhoef, Pier Luigi Vidale, Karina Williams, Andy Wiltshire, Yangang Xing

JULES annual meeting 2017

# Soil moisture stress on vegetation in JULES

- At the JULES 2016 meeting, a cross-community group was set up to discuss and evaluate this process within JULES.
- There were many groups within the community already working on this process, so made sense to combine efforts.
- Currently 38 members on the mailing list.
- 3 face-to-face meetings and 6 teleconference meetings so far (minutes available on the JULES wiki).
- This group has benefited from the involvement of experts in other parts of JULES, flux tower and satellite observations, plant physiology, other models.

# Progress so far

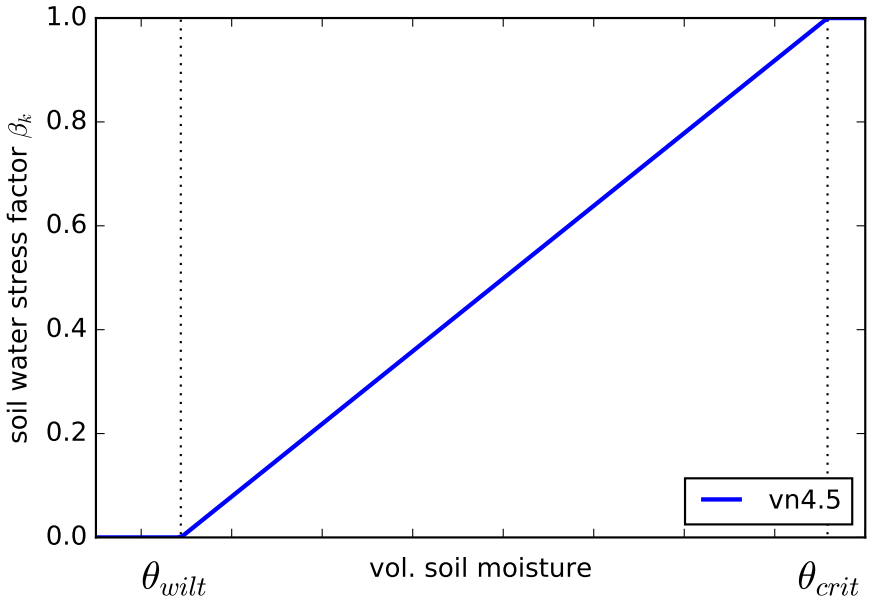
- Documenting and evaluating the current representation (JULES 4.8) using site observations - paper in progress.
- Sensitivity studies - regional and global runs (WFDEI), offline and online UKESM1 runs.
- Comparison to methods used in other models.
- New options introduced to JULES: pft-dependent wilting and critical soil water potentials, stress function can be linear in soil water potential, soil moisture can be prescribed (vn4.9 needs var_name=var='sthuf').
- In addition to the code added to the JULES trunk and the shared Rose suite, 11 extra python scripts (5000+ lines), have also been shared across the group.

# Beta function in JULES 4.5

In JULES, the soil moisture stress factor $\beta$ is calculated based on the water in each soil layer and the fraction of roots in that soil layer $r_k$

$$\beta = \sum_k r_k \beta_k$$

where the root distribution is exponential.




The wilting point and critical points usually correspond to -1.5 MPa and -0.033 MPa resp.

# Beta function in JULES 4.5

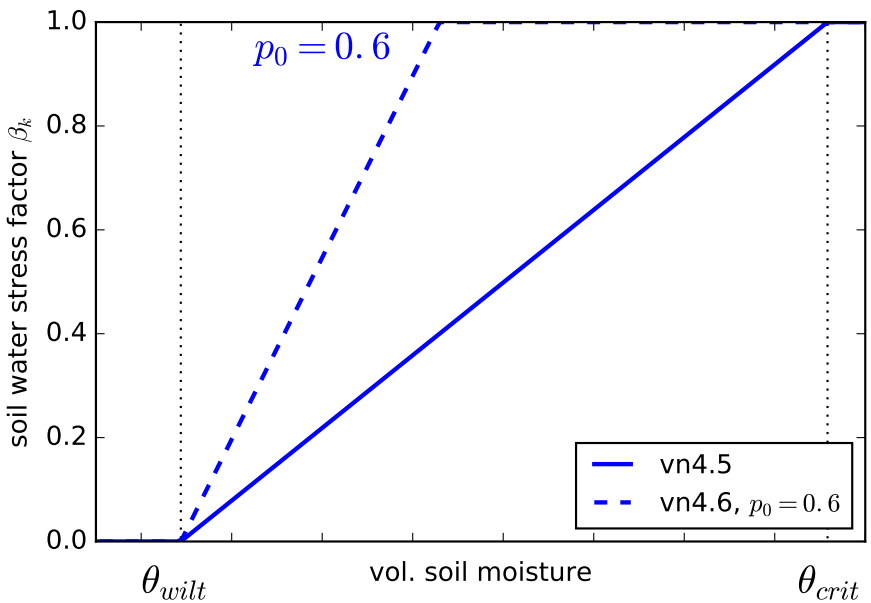
- $\beta$ is used to convert between the potential net leaf photosynthesis $A_P$ and the water-limited net leaf photosynthesis $A$:

$$A = A_P \beta$$

- Stomatal conductance to water vapour is proportional to A (and so also to $\beta$)
- Leaf maintenance respiration is proportional to $\beta$.

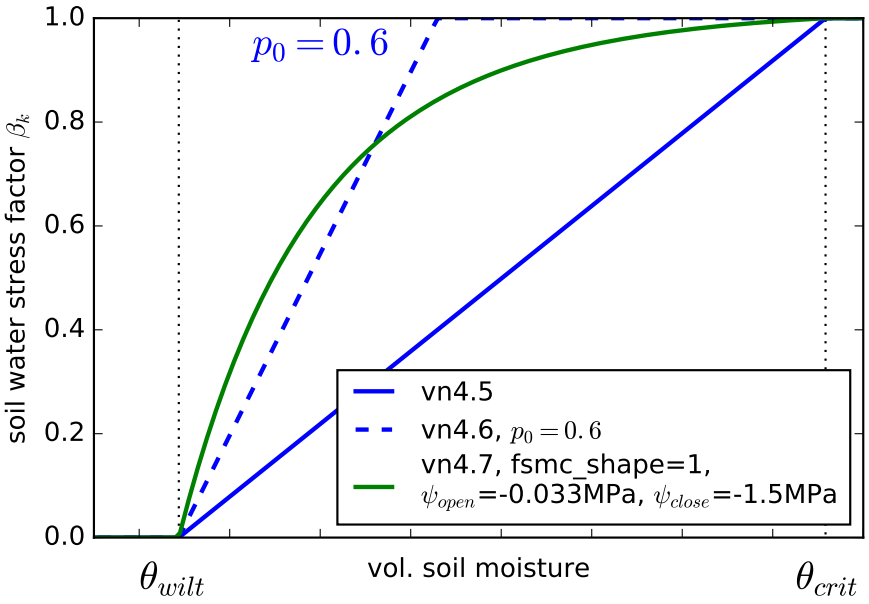
# New in JULES 4.6

- Soil moisture stress factor can be calculated based on the average soil properties in the root zone (as opposed to being weighted by root mass density).




- Soil moisture threshold at which plant starts to experience stress can be pft-dependent (new parameter $p_0$).
- Stem and root maintenance respiration can also be scaled by $\beta$

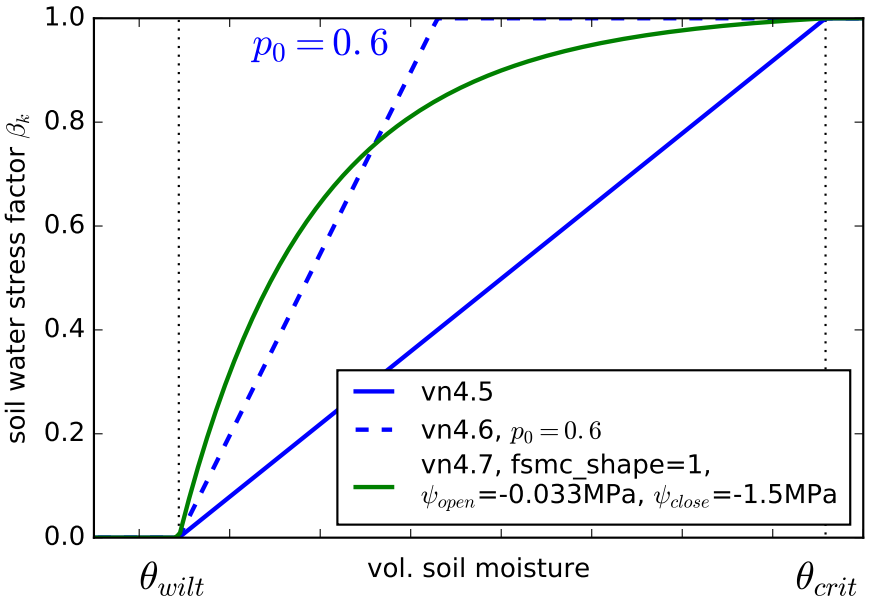
# New in JULES 4.9



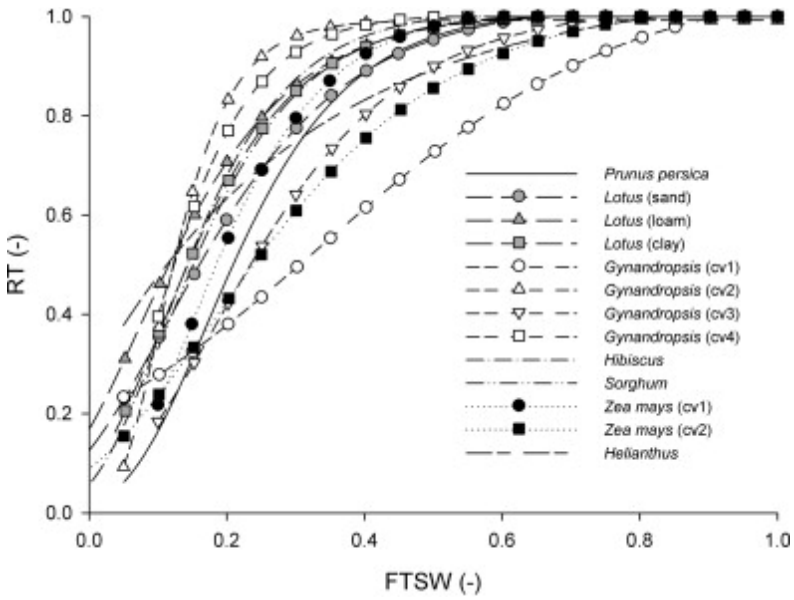

- $\beta$ can be linear in soil potential instead of vol. soil moisture
- Parameters $\psi_{open}$ and $\psi_{close}$ are PFT-dependent.

When $\psi_{open}$=0.0, this reduces to the approximation used in Sinclair et al 2005.

# New in JULES 4.9




Obs: Relative Transpiration (RT) against Fraction of Transpirable Soil Water (FTSW), Verhoef and Egea 2014.



# Other methods being investigated

- Relating plant stress to the concentration of abscisic acid (ABA) in the leaf.
- Where to apply the stress (stomatal, biochemical, mesophyll)
- Optimisation models.
- Changing the weighting of soil layers in the soil moisture stress factor.
- More fundamental changes to the modelling of plant hydraulics within JULES as in the Robust Ecosystem Demography model (RED).

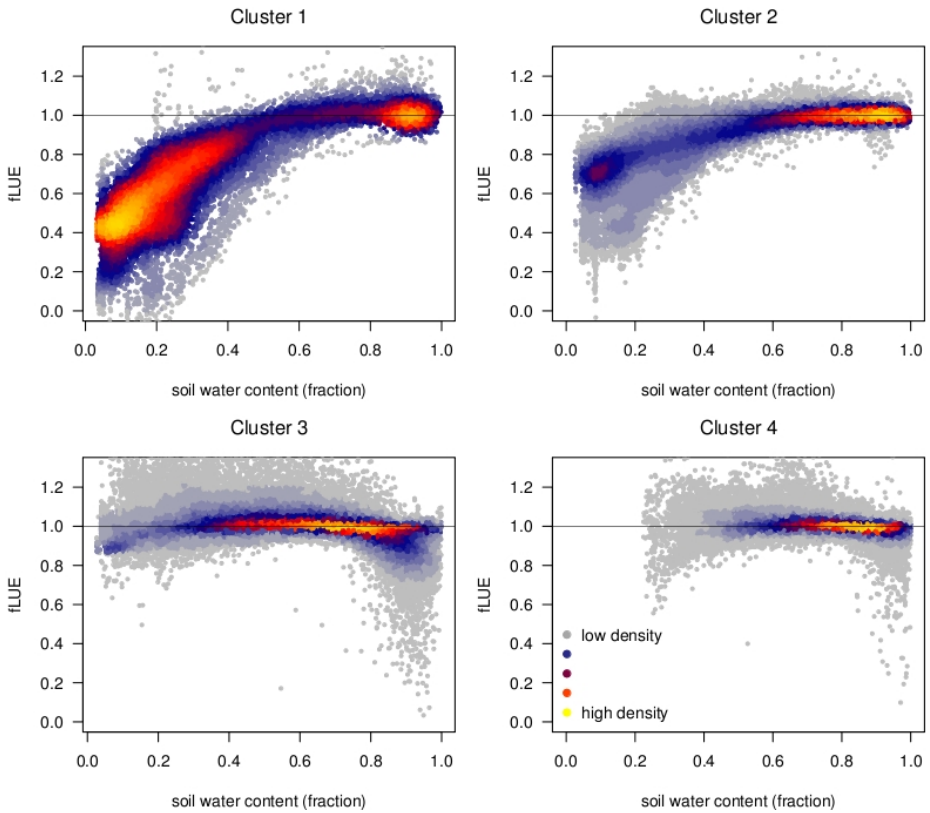
# Site observations

Aim: isolate effect of $\beta$ by using met, soil moisture and LAI obs to force JULES, and comparing to flux tower obs.

- 6 FLUXNET2015 sites (incl. Grasslands, Evergreen Broadleaf Forests, Deciduous Broadleaf Forests, Evergreen Needleleaf Forests)
- 4 Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) sites
- 15 year dataset of C3 and C4 crops, Avignon
- Irrigated versus non-irrigated maize and soybean, Nebraska
- Tallgrass prairie, FIFE, Kansas

# Water stress from Light Use Efficiency

Reduction in observed Light Use Efficiency (compared to the non-droughted situation) at flux sites as a function of soil moisture.

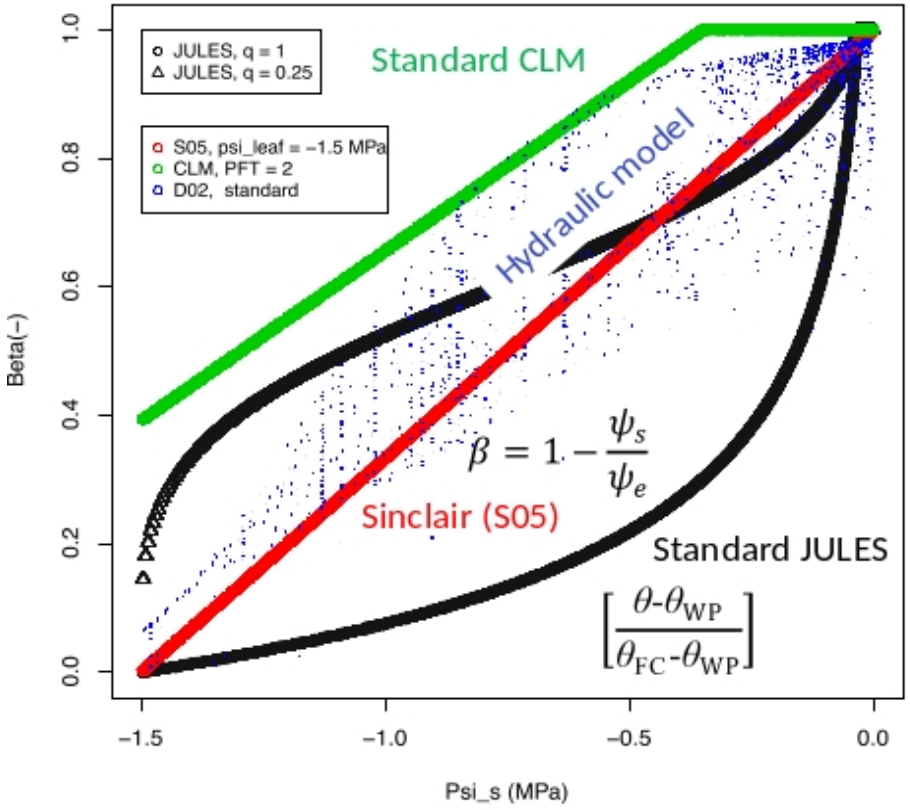



1. drought-deciduous vegetation, e.g. grasslands and savannas
2. evergreen vegetation
3. sites where, for some reason the vegetation shows little response to drought
4. sites where drought does not occur

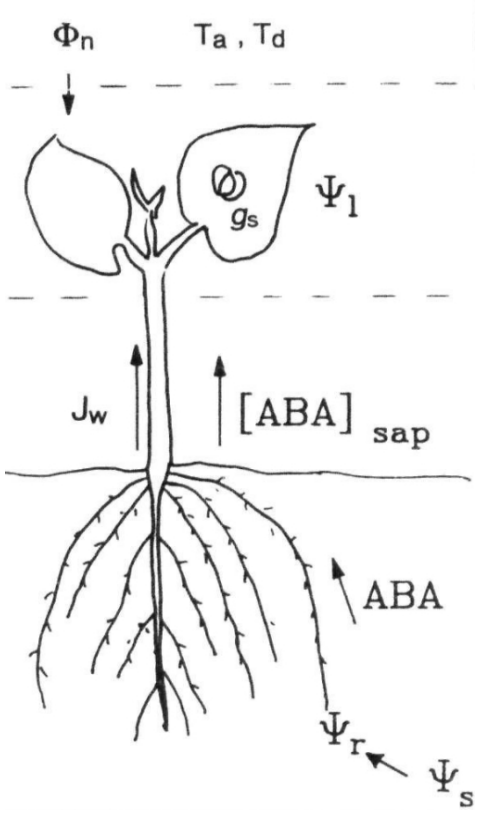
Beni Stocker, Colin Prentice, in prep.

# Hydraulic model using Avignon data

$$\beta = 0 \leq \frac{\psi_{s,c} - \psi_s}{\psi_{s,c} - \psi_{s,o}} \leq 1$$




Hydraulic model: Dewar 2002. (image: Tardieu and Davies 1993)




Verhoef, Egea, Garrigues, Vidale, Balan Sarojini, in prep.

# Future Plans

- Since there is still active work in this area and papers in progress, the group will continue to meet for the time being.
- Planned work for the next year by group members includes
  - detailed site modelling
  - sensitivity studies to the new options
  - how these options may be incorporated into JULES configurations
  - evaluation of regional runs using satellite data
  - work on the relative contributions of the soil layers to plant stress
  - interaction between the stomatal response to VPD and soil moisture
  - more explicit modelling of plant hydraulics

# Additional slides

# Runs and observational datasets

Site-level JULES runs forced by meteorological, soil moisture and LAI observations: **Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)**

- LBA-BAN: Bananal Island site, Pium - Tocantins State, Br., Seasonally flooded Forest-Savanna Ecotone
- LBA-K34: Manaus - Amazonas State, Br., Tropical Rainforest
- LBA-K83: Santarem, Tapajos National Forest - Para State, Br., Primary Tropical Moist Forest
- LBA-RJA: Rondonia State, Reserva Jaru forest site, Ji-Parana - Rondonia State, Br, Tropical Dry Forest

# Runs and observational datasets

Site-level JULES runs forced by meteorological, soil moisture and LAI observations: **FLUXNET sites in the FLUXNET2015 dataset**

- AT-Neu: Neustift, grasslands
- BE-Vie: Vielsalm, mixed forests
- CH-CHA: Chamau, grasslands
- GF-Guy: Guyaflux (French Guiana), evergreen broadleaf forests
- IT-CA1: Castel d'Asso 1, Deciduous Broadleaf Forests
- IT-Ren: Renon, Evergreen Needleleaf Forests

# Runs and observational datasets

Site-level JULES runs forced by meteorological, soil moisture and LAI observations

- US-Ne1: irrigated maize, Nebraska
- US-Ne2: irrigated maize-soybean rotation, Nebraska
- US-Ne3: rainfed maize-soybean rotation, Nebraska

and

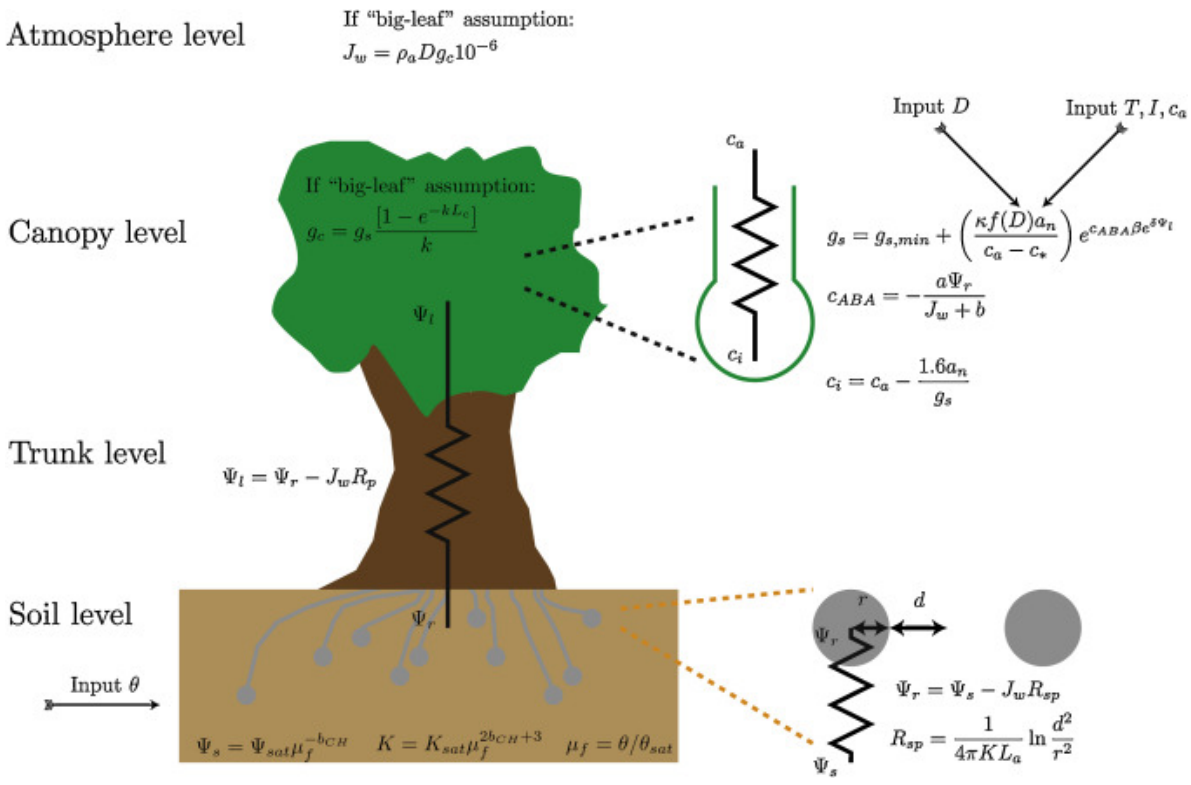
- The first International Satellite Land Surface Climatology Project (ISLSCP) field experiment, Kansas, US, temperate grassland (tallgrass prairie) - but still a question about the soil moisture obs

Group members are also working with data from

- The first International Satellite Land Surface Climatology Project (ISLSCP) field experiment, Kansas, US, temperate grassland (tallgrass prairie)
- Avignon, France, a 15 year dataset of C3 and C4 crops used in Kutsch et al 2010 and Garrigues et al 2015.
- Birmingham Institute of Forest Research (BIFoR) Free-Air Carbon Dioxide Enrichment (FACE) site, Staffordshire, UK, mature, unmanaged, temperate woodland
- The Agricultural Model Intercomparison and Improvement Project (AgMIP) maize evapotranspiration study, Ames, Iowa, US.

and JULES runs have been carried out for Europe forced by the 0.5 degree WFDEI dataset with different values of the water potential of the bulk leaf epidermis $\psi_e$.

# Huntingford et al, 2015



# Additional complications

- uncertainties in the soil moisture and LAI measurements
- the method used to convert soil moisture observations to data on JULES soil levels which can be used to force the model
- soil properties which effect the plant water stress (particularly the soil moisture content at absolute matric water potentials of 1.5 MPa and 0.033 MPa)
- the relation between soil potential and water content
- the method used to derive GPP 'observations' from carbon flux measurements.