PROPOSAL FOR FLUXNET SYNTHESIS PUBLICATION

Initial coordinators:: Name : Almut Arneth (1,2), Belinda Medlyn (3)

Collaborators needing access to data: Colin Prentice (3), Remko Duursma (3)

Affiliations: (1) Karlsruhe Institute of Technology/Institute of Meteorology and Climate Research, Garmisch-Partenkirchen, Germany
(2) Lund University/Physical Geography and Ecosystem Analysis, Lund Sweden.
(3) Dept of Biological Science, Macquarie University

DATASET PROPOSED

LaThuile

TITLE OF PAPER AND OUTLINE

Title: Testing a unified model of stomatal conductance

Aims

In this project, we aim to use flux data to test predictions made by a novel unified model of stomatal conductance very recently developed by Medlyn et al. (2011), and associated theory under development by Prentice et al. We are in the process of testing the theory with a wide range of leaf-level gas exchange data and have found that it explains very well patterns in stomatal behavior across species and in response to environmental conditions. We now want to test this theory at ecosystem scale as well, to find out whether the patterns we observe at leaf-level also emerge at ecosystem scale.

Theory

The body of theory underlying our proposal can be summarized as follows. The basis for the model is the coupled equations for the Farquhar-von Caemmerer photosynthesis model and the Cowan & Farquhar optimal stomatal control theory presented by Arneth et al (2001). Medlyn et al. (2011) demonstrated that these equations give rise to a simple expression for stomatal conductance that is similar in form to the widely-used empirical models of Ball et al. (1987) and Leuning (1995):

$$g_s = g_0 + (1 + g_1/\mathrm{sqrt}(D))\ A / C_a \qquad (1)$$

The major difference between this model and the empirical models is that the parameter g_1 has a now a clear theoretical basis: it is proportional to the combination of terms ($\mathrm{sqrt}(\Gamma^* \lambda)$), where Γ^* is the temperature-dependent CO_2 compensation point and λ is the marginal carbon cost of water. Medlyn et al. (2011) tested this model with leaf-level gas exchange data and demonstrated that there were clear differences in the parameter g_1 among datasets. The parameter increased with temperature, as predicted, and appeared to vary among species, with larger values occurring in evergreen broadleaf species than conifers. The parameter was also shown to be independent of atmospheric [CO_2] at the Duke Forest FACE experiment.

Furthermore, Prentice et al. are currently developing theory to predict the parameter g_1 from first principles, based on the trade-off between costs of carbon assimilation and water transport. This theory yields predictions for g_1 in terms of key hydraulic parameters and soil moisture availability.

Application

We hypothesise that equation (1) will scale from leaf to ecosystem level. The equation is linear and therefore should apply equally well to individual leaves or entire canopies. We have evidence from whole-tree chamber experiments that this is the case (Barton et al. in prep). Where soil fluxes are relatively low, therefore, eqn (1) should extend to ecosystem-scale fluxes, enabling a value for g_1 to be estimated from whole-system carbon uptake and transpiration. We will estimate values of g_1 for a range of sites and use them to test the following specific predictions arising from the theory:

(1) Variation in g_1 among species at ecosystem level is consistent with variation among species at leaf level.

(2) The parameter g_1 increases with mean annual temperature.

(3) The parameter g_1 varies among species. Among trees highest values will be obtained for evergreen broadleaves and lowest for conifers. More generally, values are high for species with high sapwood permeability or low sapwood density. Values for grasslands and crops will span the same range as for trees, with the exception that C4 communities will have much lower values of g_1.

(4) Within a site, values of g_1 decrease during periods of soil drought, but are otherwise stable over time.

(5) The parameter g_1 is unaffected by rising CO_2.

PROPOSED SITES TO BE INVOLVED

All sites in the La Thuile dataset.

PROPOSED RULES FOR CO-AUTHORSHIP

The rules as proposed in the disclaimer for the FLUXNET2007 synthesis/La Thuille dataset will be applied (as in (2) at http://www.fluxdata.org/Shared%20Documents/Policy_LaThuile_Final.pdf.)

REFERENCES

Arneth A, Lloyd J, Santruckova H, Bird M, Grigoryev S, Kalaschnikov YN, Gleixner G, Schulze ED. 2002. Response of central Siberian Scots pine to soil water deficit and long-term trends in atmospheric CO_2 concentration. *Global Biogeochemical Cycles* **16**(1).

Ball JT, Woodrow IE, Berry JA 1987. A model predicting stomatal conductance and its contribution to the control of photosynthesis under different environmental conditions. In: Biggins J ed. *Progress in Photosynthesis Research*. Dordrecht, The Netherlands: Martinus-Nijhoff Publishers, 221-224.

Leuning R. 1995. A critical appraisal of a coupled stomatal-photosynthesis model for C_3 plants. *Plant Cell and Environment* **18**: 339-357.

Medlyn BE, Duursma RA, Eamus D, Ellsworth DS, Prentice IC, Barton CVM, de Angelis P, Crous KY, Freeman M, Wingate L. 2011. Reconciling the optimal and empirical approaches to modelling stomatal conductance. *Global Change Biology* doi: 10.1111/j.1365-2486.2010.02375.x