Challenged with Problems in Biometeorology: What Would Ray Do?

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University of California, Berkeley
Agricultural and Forest Meteorology Conference, May 2014, Portland, OR

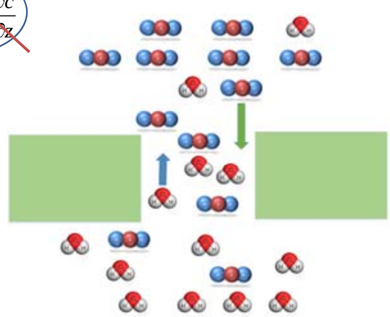
Key Contributions

- Leaves
  - Theory on Viscous and Diffusive Transport
  - Stomatal Models
  - Energy Balance and Frost
  - Ozone Deposition
- Canopies
  - Pioneering CO_2 and CH_4 Flux measurements
  - Webb-Pearman-Leuning Theory on Density Corrections
  - Treatise on Energy Balance
  - Coupled Theory on Soil-Vegetation-Atmosphere Exchange
  - Scaling Fluxes with Light and Nitrogen
- Landscapes/Regions
  - Coupling Remote Sensing and Eddy Covariance

Problem 1: Bi-Directional Diffusion of Gases Through Pores

$$F_c = -D_c \frac{\partial c}{\partial z}$$

Fick's Law



Plant, Cell and Environment (1983) 6, 181–194

Transport of gases into leaves

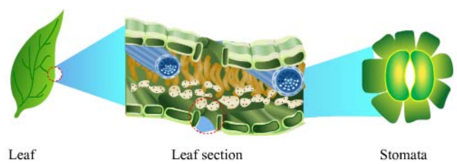
R. LEUNING CSIRO Division of Environmental Mechanics, Canberra, ACT, Australia

For Diffusion of multi-component gas mixtures through Pores you must use the Stefan Maxwell law, rather than the simpler Fick's Law

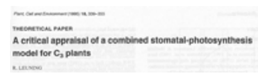
The viscous and diffusive flux densities must be added to obtain the total flux density, thus

$$N_1 = -\left[\frac{D_{12}D_{11}^K}{D_{12}+D_{12}^K}\right]\frac{p}{RT}\frac{\partial x_1}{\partial z} - \left[\frac{D_{11}^K(D_{12}+D_{22}^K)}{D_{12}+D_{12}^K}+\frac{B_k p}{\mu}\right]\frac{x_1}{RT}\frac{\partial p}{\partial z}. \quad (12)$$

Problem 2: Modeling Stomatal Conductance



http://www.meritnation.com/ask-answer/question/13-what-are-stomata-write-theie-structure-and-their-function/tissues/2738665


THEORETICAL PAPER

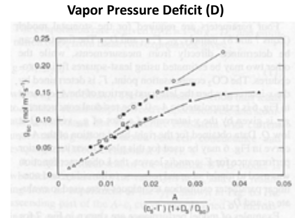
A critical appraisal of a combined stomatal-photosynthesis model for C_3 plants

R. LEUNING

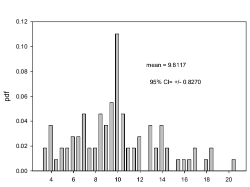

Modelling Stomatal Behaviour and Photosynthesis of *Eucalyptus grandis*

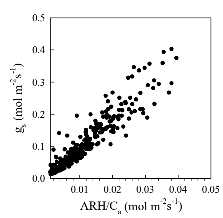
$$g_s = g_0 + a_1 A / (C_s - \Gamma)(1 + \frac{D}{D_0})$$

Stomatal Conductance Scales with Photosynthesis (A) and Vapor Pressure Deficit (D)



Leuning vs Ball-Berry Model

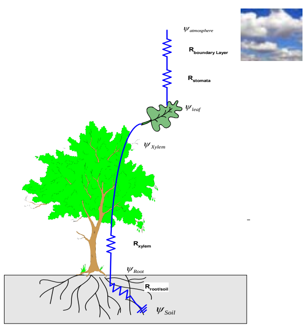


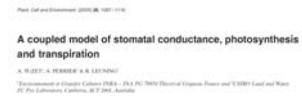


Critique

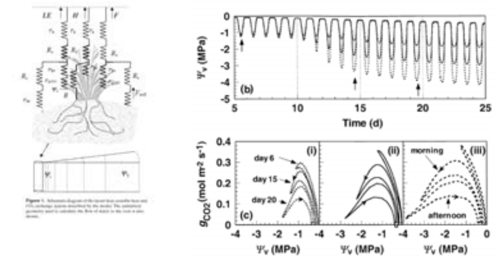
- Parsimony
  - BB has one unknown, ~10 +/- 0.8; Leuning has two unknowns
- Mechanism
  - Water Moves across humidity gradients, so gs should be a function of D (R. Leuning)
  - But RH =(1-D/es(T) (ddb)
- Validation
  - BB works across wide range of leaf water potentials (0 to -5.0 MPa) (Ball, dissertation; Xu and ddb)
- Prediction
  - BB leads to accurate predictions of H, LE and Fc in leaf to canopy scaling models
  - Leuning will do better for global change assessments; D is a function of es(T), while BB is a function of RH;
  - RH is assumed constant, or conservative, with climate change (Katul, personal communication)

Problem 3, Modeling Soil-Plant-Atmosphere Continuum





A coupled model of stomatal conductance, photosynthesis and transpiration



Problem 4, How to Measure and Interpret Eddy Fluxes of CO2 and Water?

1st Commandment of Biometeorology:
'Know Thy Site'

Quart. J. R. Met. Soc. (1980), 106, pp. 85-100

551.510.3 : 551.511.61

Pearman

Correction of flux measurements for density effects due to heat and water vapour transfer

By E. K. WEBB, G. I. PEARMAN and R. LEUNING*

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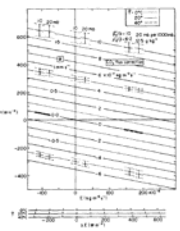
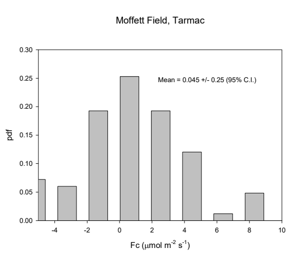


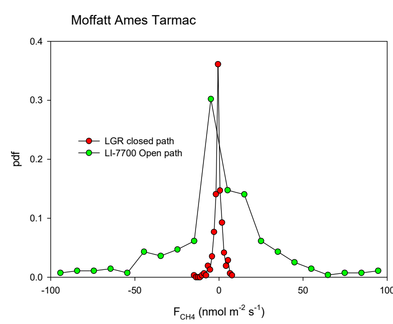
$$F = \overline{w'\rho_c'} + \mu(\bar{\rho}_c/\bar{\rho}_a)\overline{w'\rho_v'} + (1+\mu\sigma)(\bar{\rho}_c/\bar{T})\overline{w'T'}.$$

'I wish I had a correction named after me'

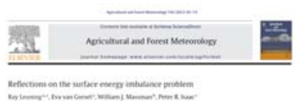
P. Jarvis, author of the Jarvis Stomatal Conductance Model

Testing Density Fluctuation Corrections at Moffatt Field



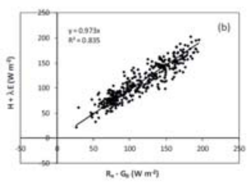


While Fch4 is sensitive to H, as on Tarmac, H is relatively Small over Wet, Methane Producing Wetlands


Agricultural and Forest Meteorology

Reflections on the surface energy imbalance problem

‘Closure of the energy balance is possible at half-hourly time scales by careful attention to all sources of measurement and data processing errors in the eddy covariance system and by accurate measurement of net radiation and every energy storage term needed to calculate available energy’.

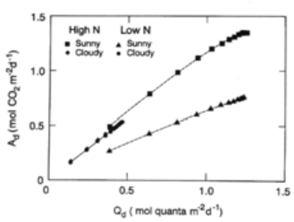


Problem 5: How Do We Extrapolate Leaf-Level Information to the Canopy Scale, and Elsewhere?

Plant, Cell and Environment (1995) 18, 1183–1200

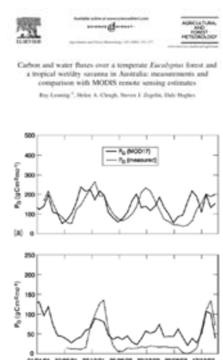
Leaf nitrogen, photosynthesis, conductance and transpiration: scaling from leaves to canopies

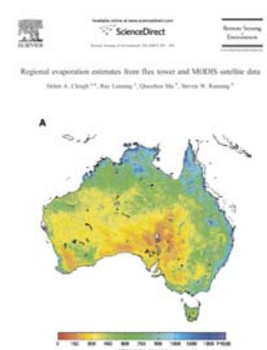
R. LEUNING, F. M. KELLIHER, D. G. G. DE PURY & E.-D. SCHULZE



Non-Linear Photosynthesis-Light Response Curve becomes Linearized; Its slope is a function of Nitrogen

Up Scaling Fluxes with Remote Sensing





Ray Leuning, International Collaborator + Advisor

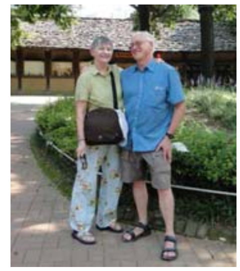
FLUXNET La Thuile, 1995 + 2007

AsiaFlux, 2010

Asia Flux, Korea

Fluxnet, Lake Tahoe

Thanks Ray, Job Well Done!



Agricultural and Forest Meteorology, 42 (1988) 135-155
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

LEAF TEMPERATURES DURING RADIATION FROST PART II. A STEADY STATE THEORY

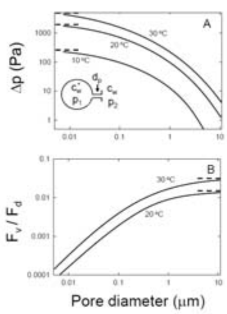
115

Agricultural Meteorology, 20(1979) 115—135
© Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

OZONE UPTAKE BY CORN (*ZEA MAYS* L.): A GENERAL APPROACH

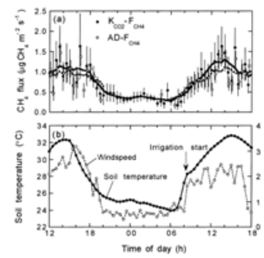
R. LEUNING[1], H. H. NEUMANN[2] and G. W. THURTELL[1]

Viscous vs Diffusive Fluxes are a Function of Pore Diameter



Modified from Leuning, 1983

Other Trace Gas Fluxes



$$F_{CH4} = \frac{\Delta s_{CH4}}{\Delta s_{CO2}} F_{CO2}$$