The relationship between net and long-wave radiation: global application of the heating coefficient concept of Monteith and Szeicz (1961)

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***Coauthorship strategy**: Coauthorship will be extended to all members of FLUXNET who are willing to provide substantial academic input regardless of site selection (i.e. we extend coauthorship potential to the entire community, not merely those whose sites have the necessary partitioned radiation flux measurements listed in Table 1).*

The FLUXNET database is invaluable for examining the terrestrial carbon, water and radiation balances of terrestrial ecosystems. Most modern analyses focus on the former at the expense of the latter two. Yet there exists a large body of literature regarding terrestrial water and radiation fluxes, and the FLUXNET database can be used to both reexamine these classic studies in light of modern-day measurements and extend their scope to the global scale. This work includes a number of publications that may be considered 'ahead of their time', and it would be forthcoming to reintroduce these concepts into a number of contemporary debates. One pertinent example regards the role of landcover change in altering global temperature, an idea which has received considerable attention from the GCM community [*Bala, et al.*, 2007; *Betts*, 2000; *Gibbard, et al.*, 2005], but minimal response from the flux community [but note [*Juang, et al.*, in review]].

In particular, the idea of the 'heating coefficient' (β), the net long-wave loss per unit net radiation gain ($\beta = -dL/dR$), was introduced by [*Monteith and Szeicz*, 1961]. The heating coefficient is a simple yet powerful concept that succinctly describes how the long-wave radiation – a strong function of surface temperature – behaves with respect to available radiation. This idea remains highly cited and widely applied [see, e.g. [*Frede, et al.*, 2003]], but has never been applied on a global scale with such an extensive data set.

We propose to examine the temporal and spatial dynamics of Monteith and Szeicz's heating coefficient on a global scale using the FLUXNET database. Specifically, we hope to demonstrate similarities in the temporal dynamics of the heating coefficient among different ecosystem types as a further simplification of the partitioning of the radiation balance. For example, we envision that similar ecosystems (e.g. deciduous forests) in different climatic zones may exhibit similar dynamics of the heating coefficient during much of the annual cycle, and that this analysis may be useful for both the flux and modeling communities. As one example, proper representation (i.e. parameterization) of surface heating may efficiently extend GCM predictions both to the sub-pixel scale and below the 2 m height that often represents the lower boundary of the model atmosphere [*Gibbard, et al.*, 2005].

To demonstrate the feasibility of the proposed analysis on a subset of FLUXNET data, we examined the 2004 & 2005 periods at the OF (old field, grass), PP (planted pine) and HW (hardwood forest) ecosystems in the Duke Forest, NC, with a particular emphasis on day of year 234 & 235 of 2005 for illustration. Variables (e.g. β) were calculated on a daily basis.

The heating coefficient β is on average much higher at OF (Fig. 1) than the two forested ecosystems, consistent with outgoing long-wave (L_{out}) measurements plotted in Fig. 2. The surface temperature of the grass field is higher, and this result agrees with near-surface soil temperature measurements (not shown). Differences in the relationship between net shortwave ($(1-\alpha)S$) and R_n can be noted at the daily basis between sunny days (Fig. 3) and days with clouds and rain (Fig. 4).

It would be relatively easy to investigate β and other variables using all FLUXNET data. There are 85 sites in the current database that measure incoming and outgoing short- and long-wave components measured (see list below). It should be noted that this list contains many sites from Brazil and China in addition to the typical European and N. American sites, giving this project clear global scope.

List of Abbreviations

L (or L_n) – Net long-wave radiation
L_{in} – Long-wave incoming (downwelling) radiation
L_{out} – Long-wave outgoing (upwelling) radiation
L_0 – Long-wave radiation in the absence of short-wave radiation
S – Incident short-wave radiation
R_n – Net radiation
α – Short-wave albedo
β – 'Heating coefficient' = $-dL / dR_n$

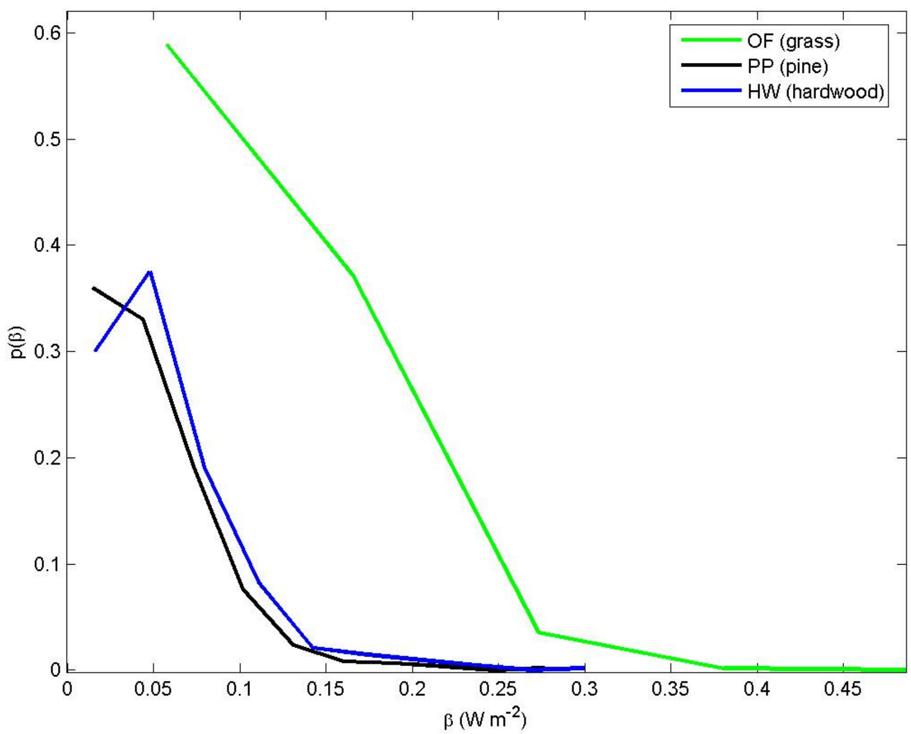

Figure 1: The probability distribution of the heating coefficient (β, = dL/dR_n) for the 2004-2005 period at the three Duke Ameriflux ecosystems.

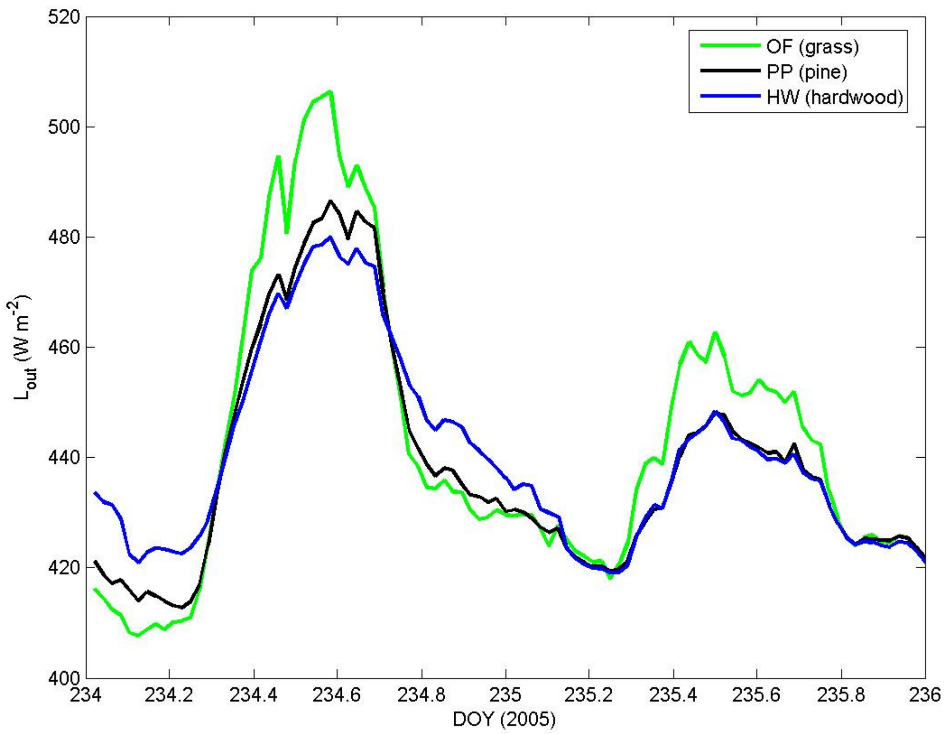

Figure 2: A time series of upwelling (outgoing) long-wave radiation for the DOY 234 & 235 (2005) period also examined in Figures 3 & 4. Note the higher values for OF which correspond to either higher emissivity or $T_{surface}$, likely the latter noting Fig. 1. Note that DOY 235 experienced a rain event in the morning.

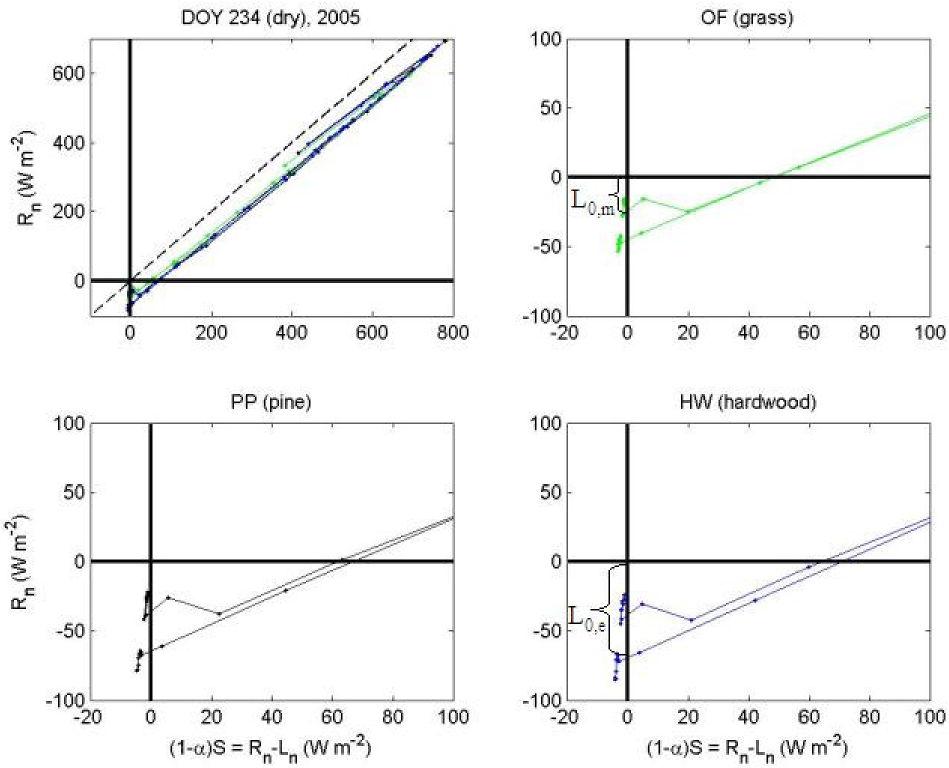

Figure 3: The relationship between net radiation (R_n) and net shortwave radiation [(1- α)S] for one rain-free day in summer, 2005 at the Duke Forest AmeriFlux ecosystems. The 1:1 line is plotted as a dashed line in the upper left subplot.

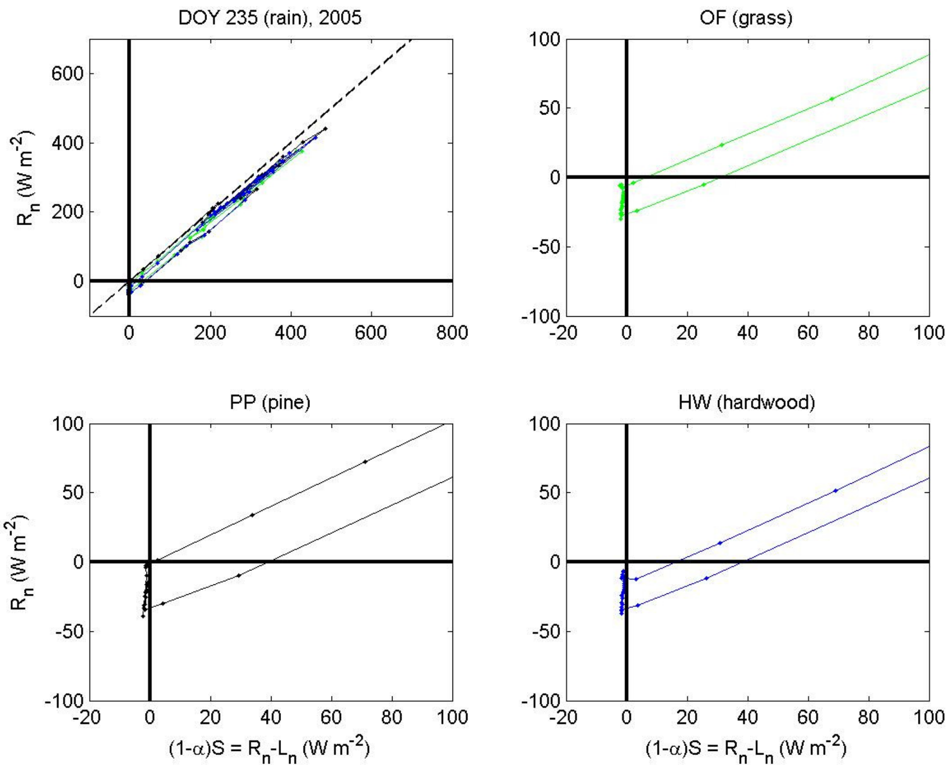

Figure 4: Same as Fig. 3, but for the following day, which experienced rain.

Table 1 (below): A simple list of FLUXNET sites with net radiation data partitioned into incoming and outgoing long and short-wave components. From the data present at the FLUXNET workshop, eighty-five sites are available for the proposed analysis.

AUHow
BRJi1
BRJi2
BRMa2
BRSa2
BRSa3
BWMa1
CACa1
CACa3
CAGro
CAMer
CANa1
CAOas
CAObs
CAOjp
CAQcu
CAQfo
CASF1
CASF2
CASF3
CASJ1
CASJ2
CASJ3
CATP4
CAWP1
CHOe1
CHOe2
CNCha
CNDo1
CNDo2
CNDo3
CZBK1
DEGeb
DEHai
DEHar
DEKli
DEMeh
DETha
DEWet
DKRis
ESES2
ESLMa
FRAur
FRFon
FRGri
FRLBr
FRLam
FRPue
IEDri
ILYat
ITAmp
ITCol
ITLav
ITMBo
ITNoe

ITRen
ITRo1
ITSRo
JPTak
NLCa1
NLHor
NLLoo
NLMol
PLWet
PTMi2
RUFyo
SENor
SESk2
UKPL3
USARM
USARR
USBo1
USBo2
USBro
USDk1
USDk2
USDk3
USFPe
USGoo
USMMS
USMOz
USNR1
USWCr
USWGK
USWRi

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