Predicting evapotranspiration in a successional forest without eddy covariance measurements

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Introduction

The hydrology of ecosystem succession gives rise to new challenges for the analysis and modeling of the components of the water balance. Recent large-scale alterations of forest cover across the globe (Hansen et al., 2010) suggest that a significant portion of the new biophysical environment will determine the long-term dynamics and limits of water fluxes compared to pre-succession conditions.

This study explores the potential of modeling summer evapotranspiration (AET) along a successional forest by using observed soil moisture dynamics. AET estimated with this approach could complement the scarce and expensive direct measurements from eddy-covariance.

Study site and data

1) The FLUXNET experimental Douglas-fir chronosequence located in Campbell River, BC, Canada (Jassal et al., 2009). Summers are warm and dry

- Water vapor and carbon fluxes measured using the eddy-covariance technique over three different stands of varying age
- Soil water content at 30, 60 and 100cm depths measured using TDR probes

Stand stage	Young	Intermediate	Mature
Abbreviation	YS	IS	MS
Year of est.	2000	1988	1949
Latitude	49°52'20"N	49°31'11"N	49°52'8"N
Longitude	125°17'32"W	124°54'6"W	125°20'6"W
Elevation (masl)	175	170	300
Height (m)	2.4	7.5	33
Stand density (Ha^{-1})	1400	1200	1100
LAI (-)	1.1	5	7.3
Annual AET (mm)	253	362	398
Summer AET	126	161	168

Research questions

1) Can a data-driven model using soil moisture measurements be used for predicting summer *AET* in forested ecosystems?

2) Is the prediction with this model sensitive to forest age, interannual climatic variability, and computational time step?

Modeling approach

We tested two data-driven soil water balance models at the chronosequence and we validated the results using water vapor measurements during summer periods (100 days from the end of June till the end of September) from 2001 to 2007.

MODEL I

$$AET(t) = P(t) - q(t) - Z_r \frac{d\theta(t)}{dt}$$

MODEL II

$$AET(t) = \text{Model 1} + I(t)$$

where $P(t)$ is the precipitation, $q(t)$ is the percolation, Z_r is the active rooth depth and $\theta(t)$ is the volumetric soil water content

We assume:

Zr = 30cm and I(t) = 0.5mm/h when P(t) > 0.5mm/h
I(t) = P(t) when P(t) < 0.5 mm/h

Two different time steps (Δt): 30min and 1day

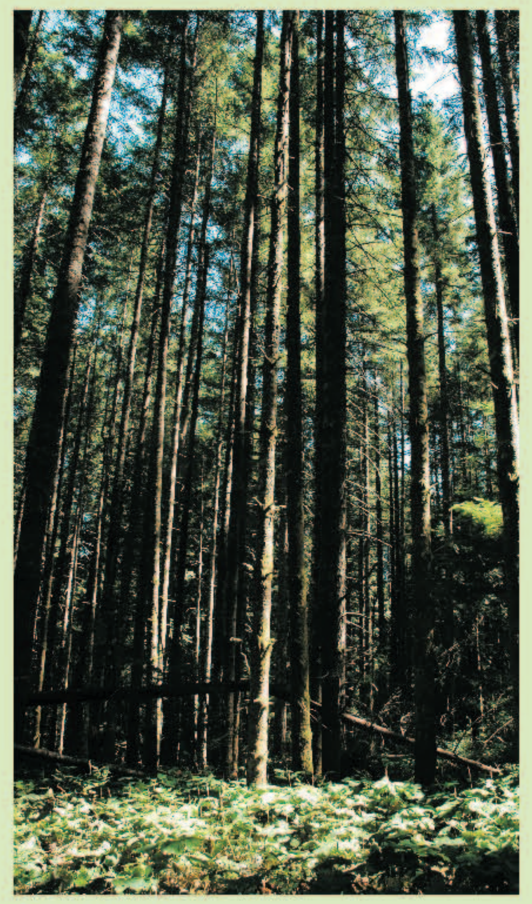
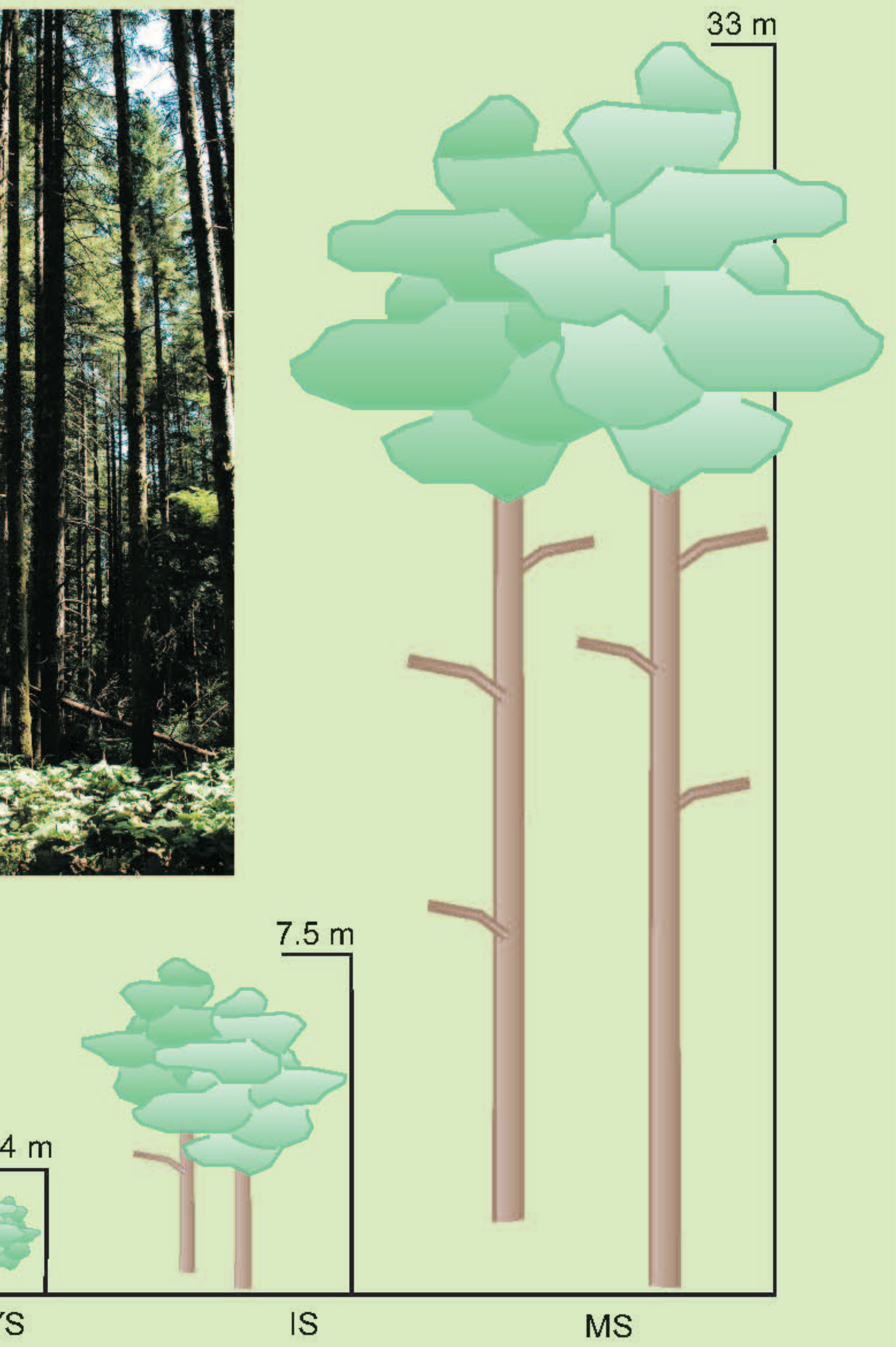


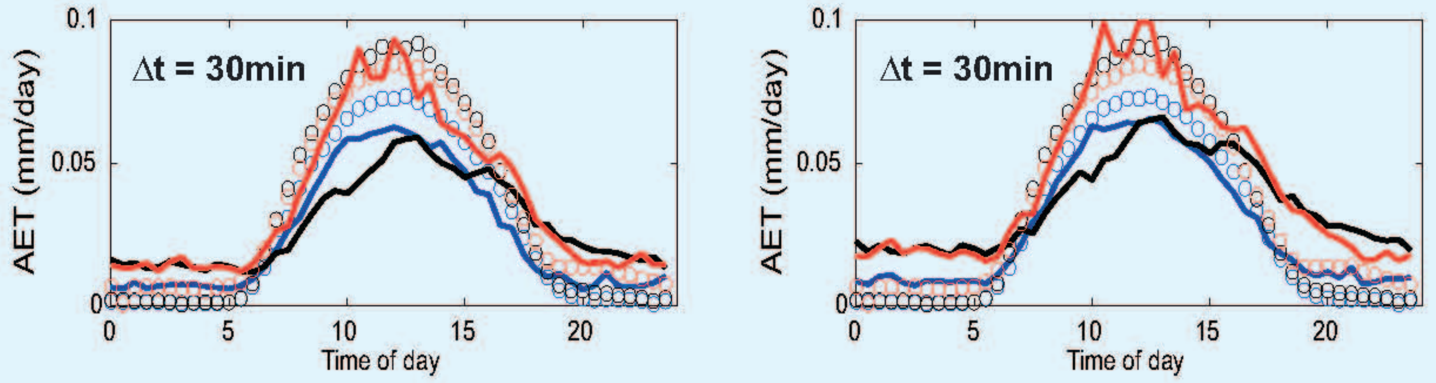
Photo: A. Christen



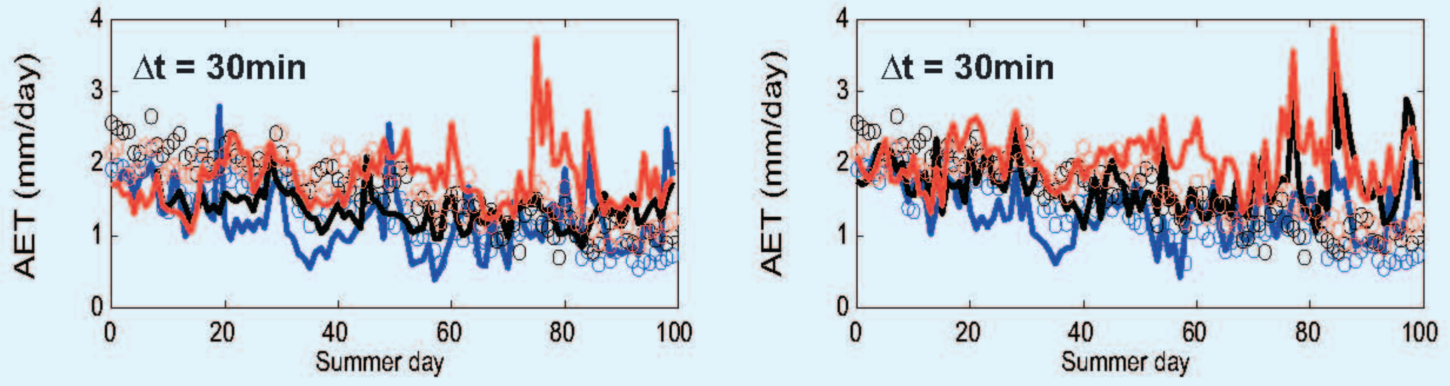
Sensitivity to interception and time step

MODEL I **MODEL II**

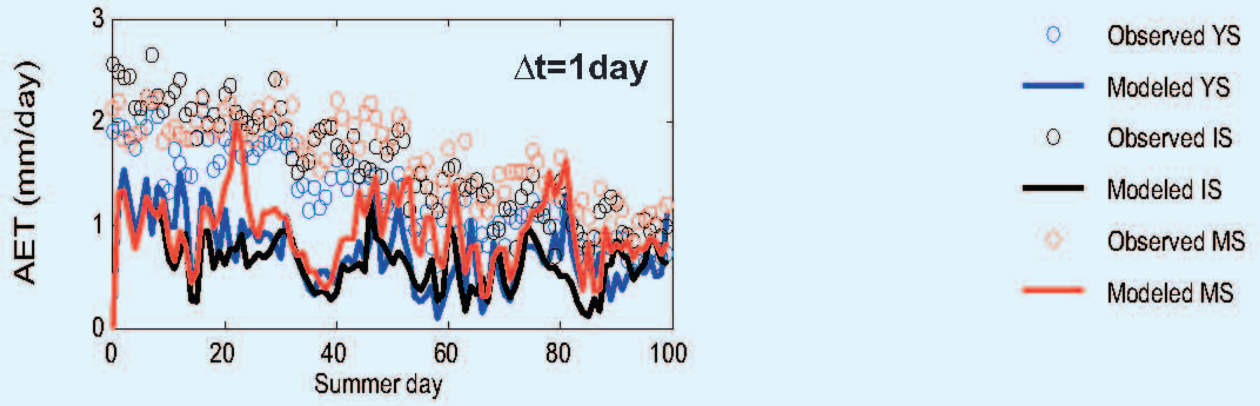
Modelled and observed mean 30-min summer AET (2001-2008)



Modelled and observed mean daily summer AET (2001-2008)



Modelled and observed mean daily summer AET (2001-2008)



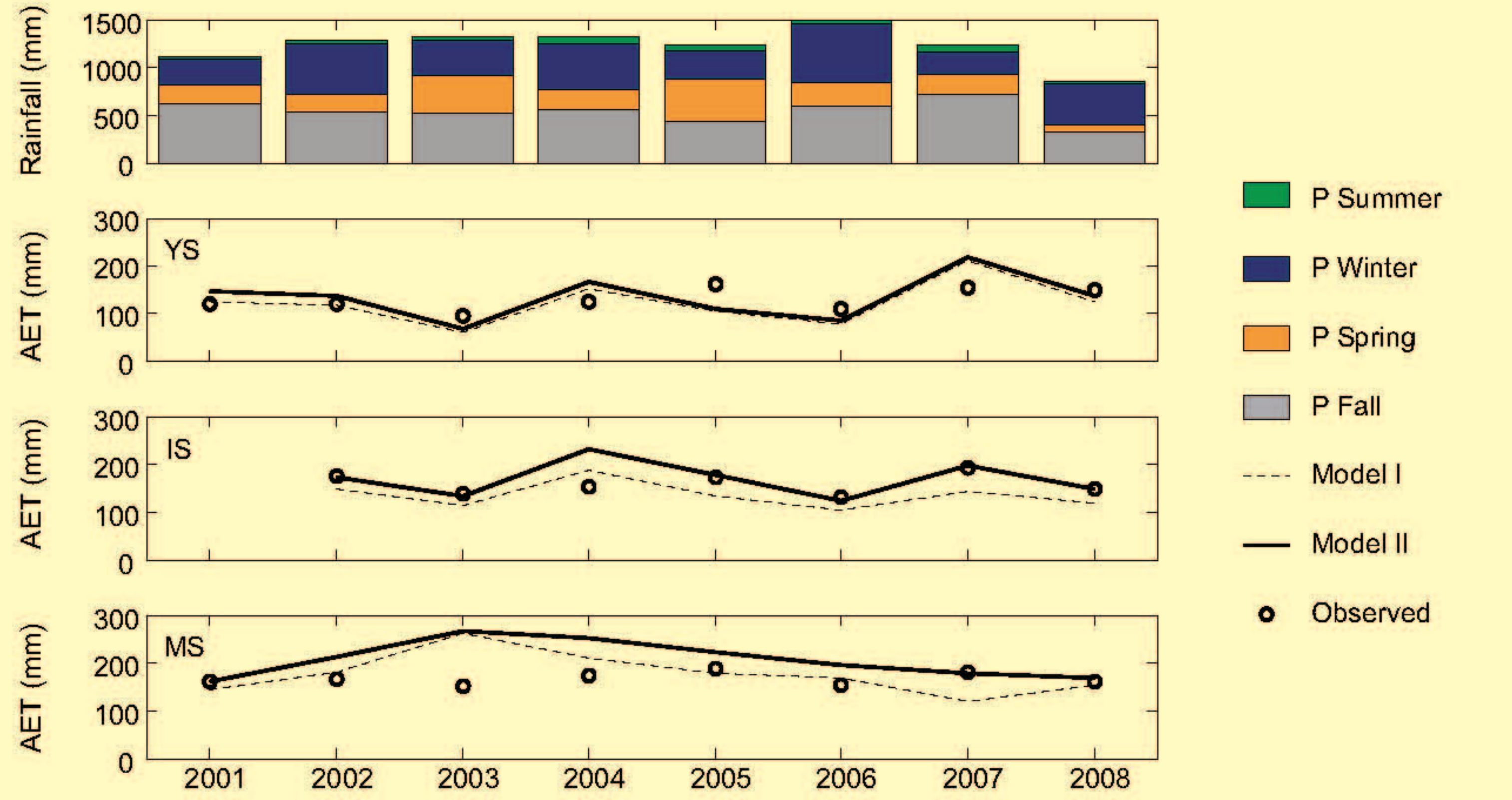
- Δt = 30min: low AET values during the day compensate large values at night
- Δt = 1day: error can be large due to rainfall events during time step

Mean summer AET (and standard deviation) for 2001-2008 by model, computation time step and forest age

Stand	AET (mm)	AET (mm) - Model I		AET (mm) - Model II	
	Obs	Sim Δt=30min	Sim Δt=1day	Sim Δt=30min	Sim Δ=1day
YS	129 (23)	121 (46)	73 (24)	133 (47)	73 (24)
IS	159 (22)	136 (28)	63 (13)	170 (38)	63 (13)
MS	167 (13)	177 (44)	96 (28)	207 (39)	96 (28)

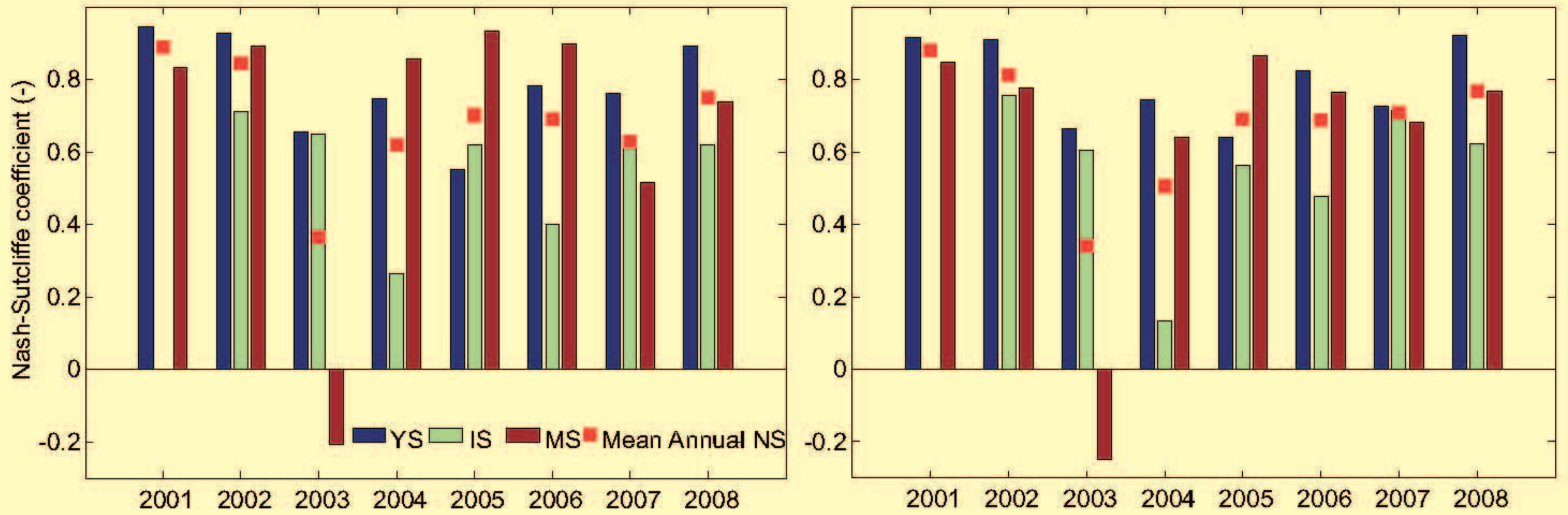
- First, error in both models with Δt = 30min are acceptable (+/- 3 to 28%)
- Second, error in both models with Δt = 1day are unsatisfactory (+/- 43 to 60%)
- Third, standard devation decreases with forest age (observations and Model II)

Sensitivity to interannual variability



- The model provided acceptable seasonal estimates at YS and IS. In both stands, soil moisture and AET responded in a similar way to climate variability
- The behavior at MS was more difficult to predict in extreme years. During 2003 (unusually warm and dry) AET was largely overestimated

MODEL I Δt = 30min **MODEL II Δt = 30min**



Conclusions

The results confirm both data-driven models as reliable methods to predict summer AET within an ecosystem successional chronosequence. The main advantages of this method are:

1) Soil moisture measurements in summer can help to constrain AET within an acceptable error range

2) Summer AET can be predicted without eddy-covariance measurements by using a soil water balance data-driven approach and a computational time step Δt of 30min

3) No calibration is necessary (e.g. LAI and root depth parameterization)

4) The long time period of 8 years (2300 summer days) used improved results compared to previous studies which used shorter periods (Schwärzel et al., 2009; Schelde et al., 2010)

Acknowledgments & References

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