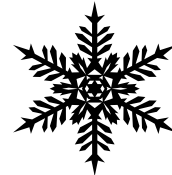


Snow Modelling

Richard Essery
Institute of Geography and Earth Sciences
University of Wales Aberystwyth

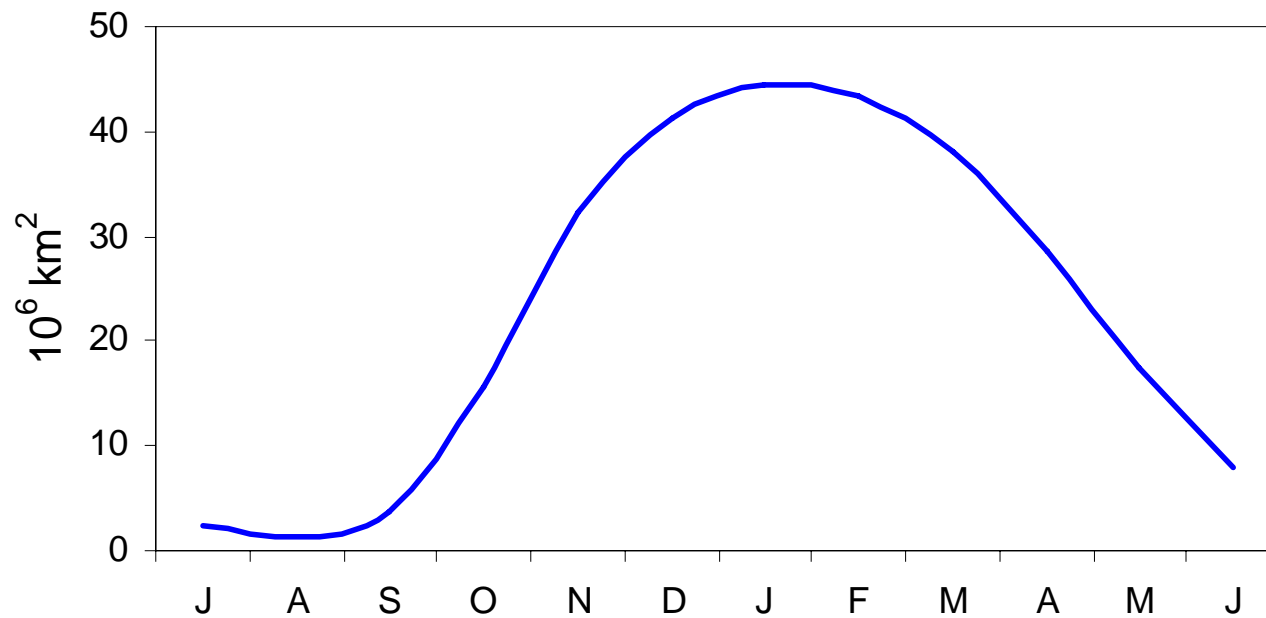
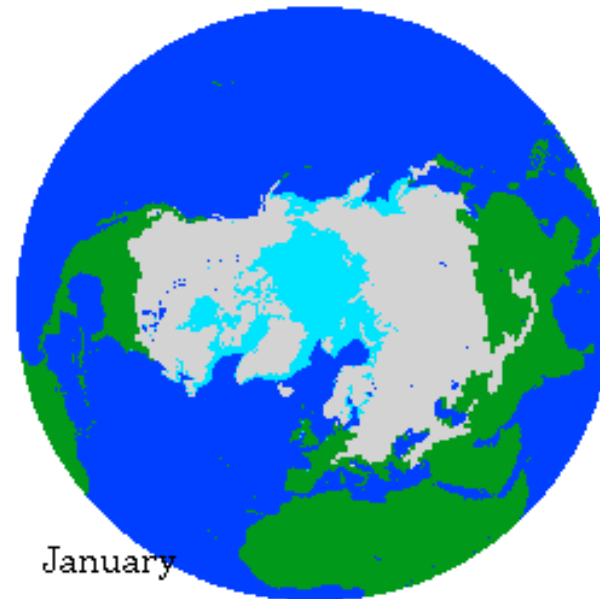
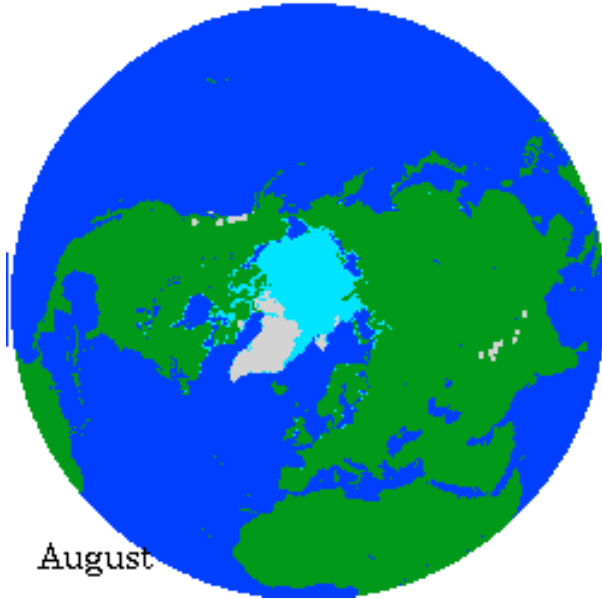
CENTRE FOR GLACIOLOGY

Institute of Geography and Earth Sciences

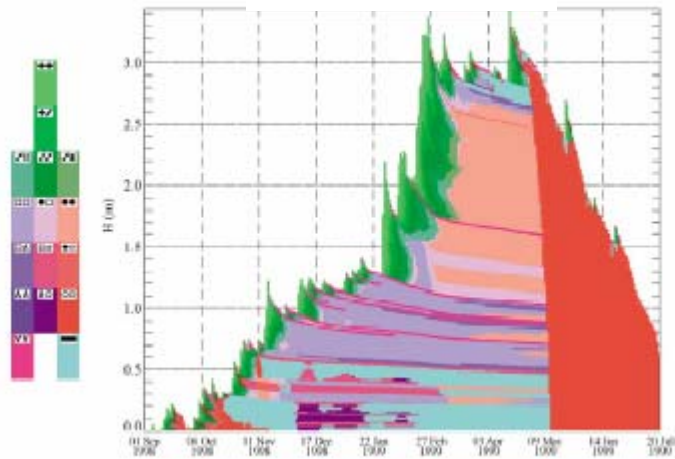


Prifysgol Cymru
Aberystwyth
The University of Wales

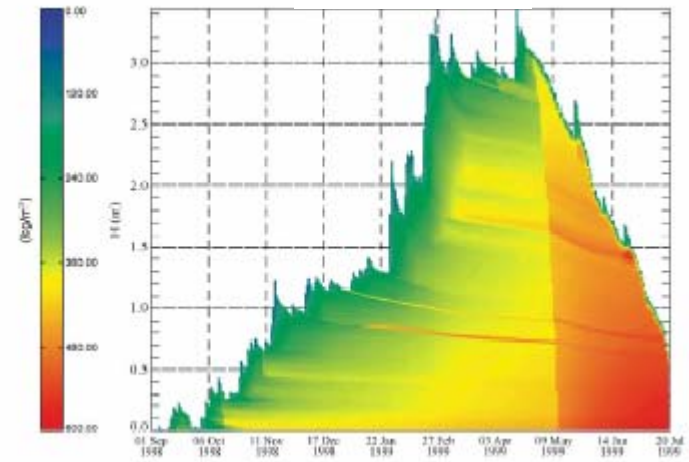
Northern Hemisphere Snow Extent



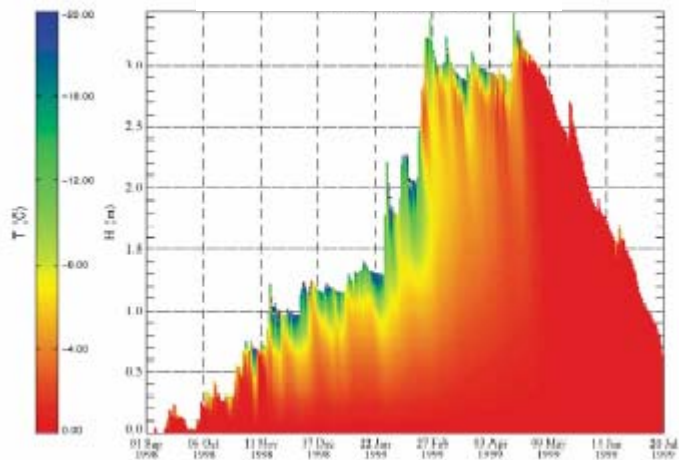
Grain type



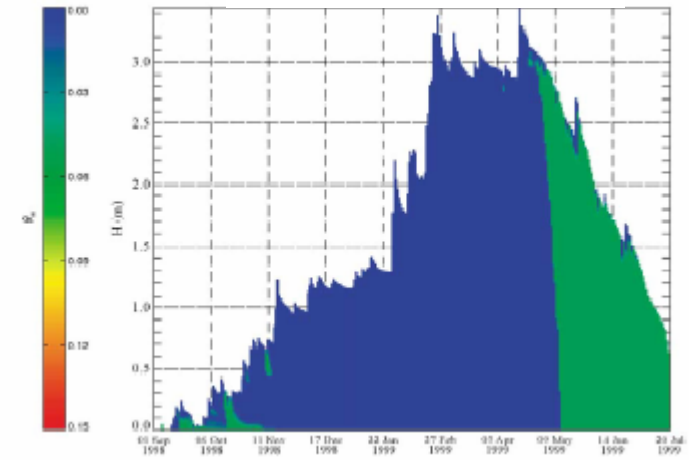
Density



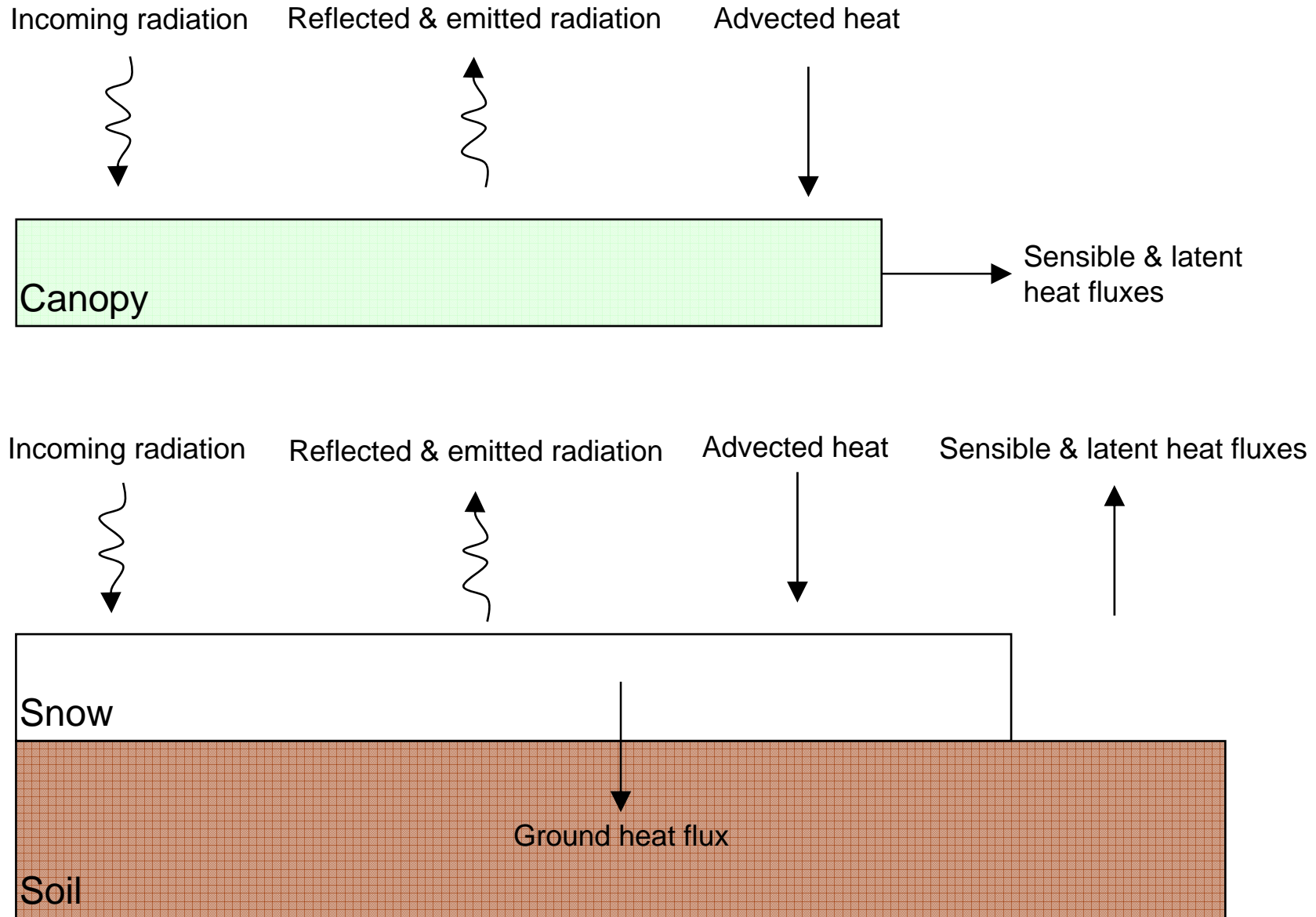
Temperature



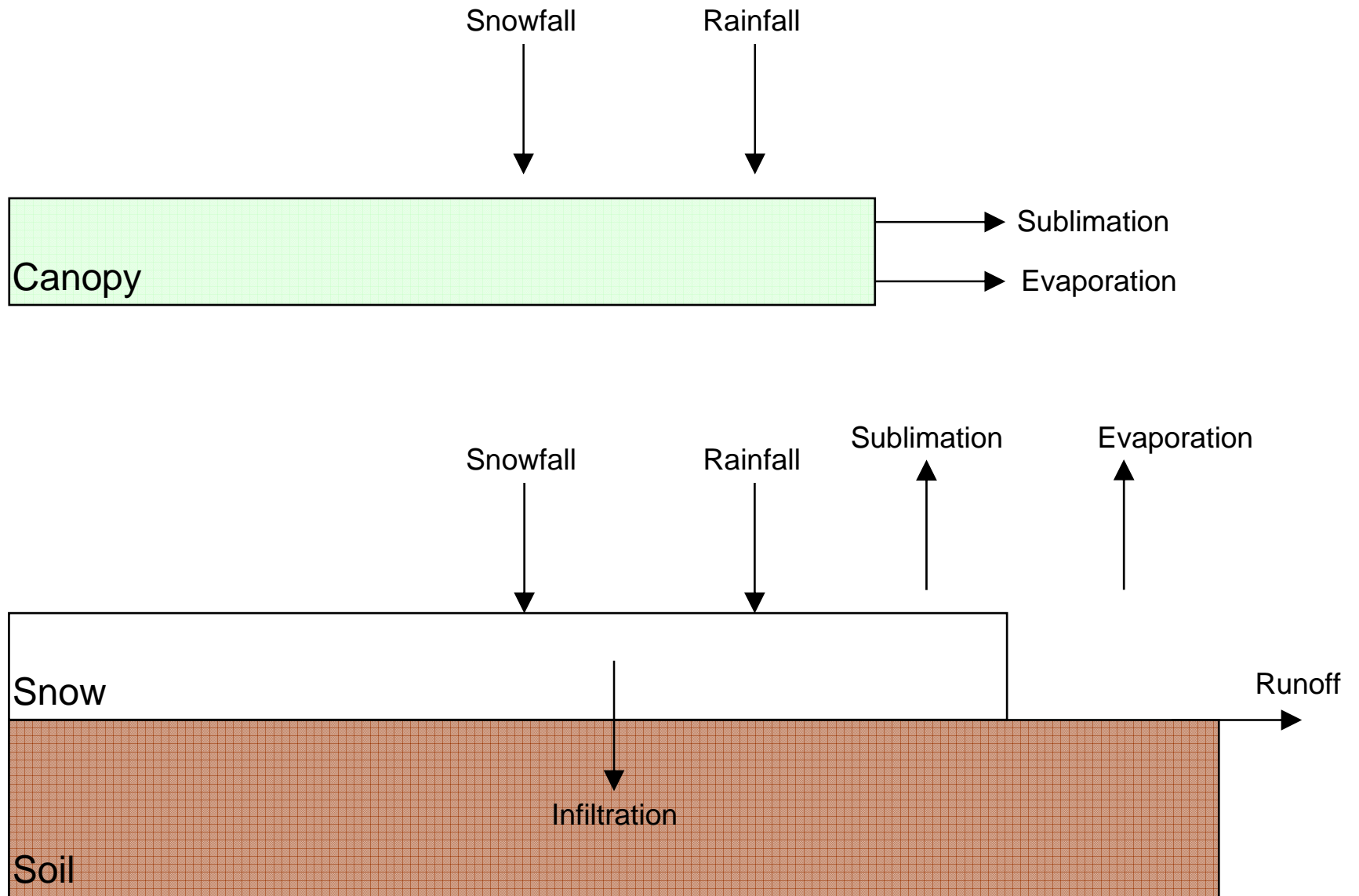
Water content



Energy Balance Components

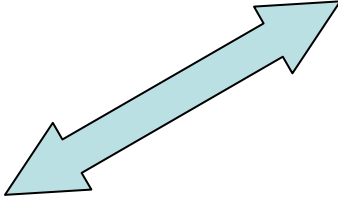


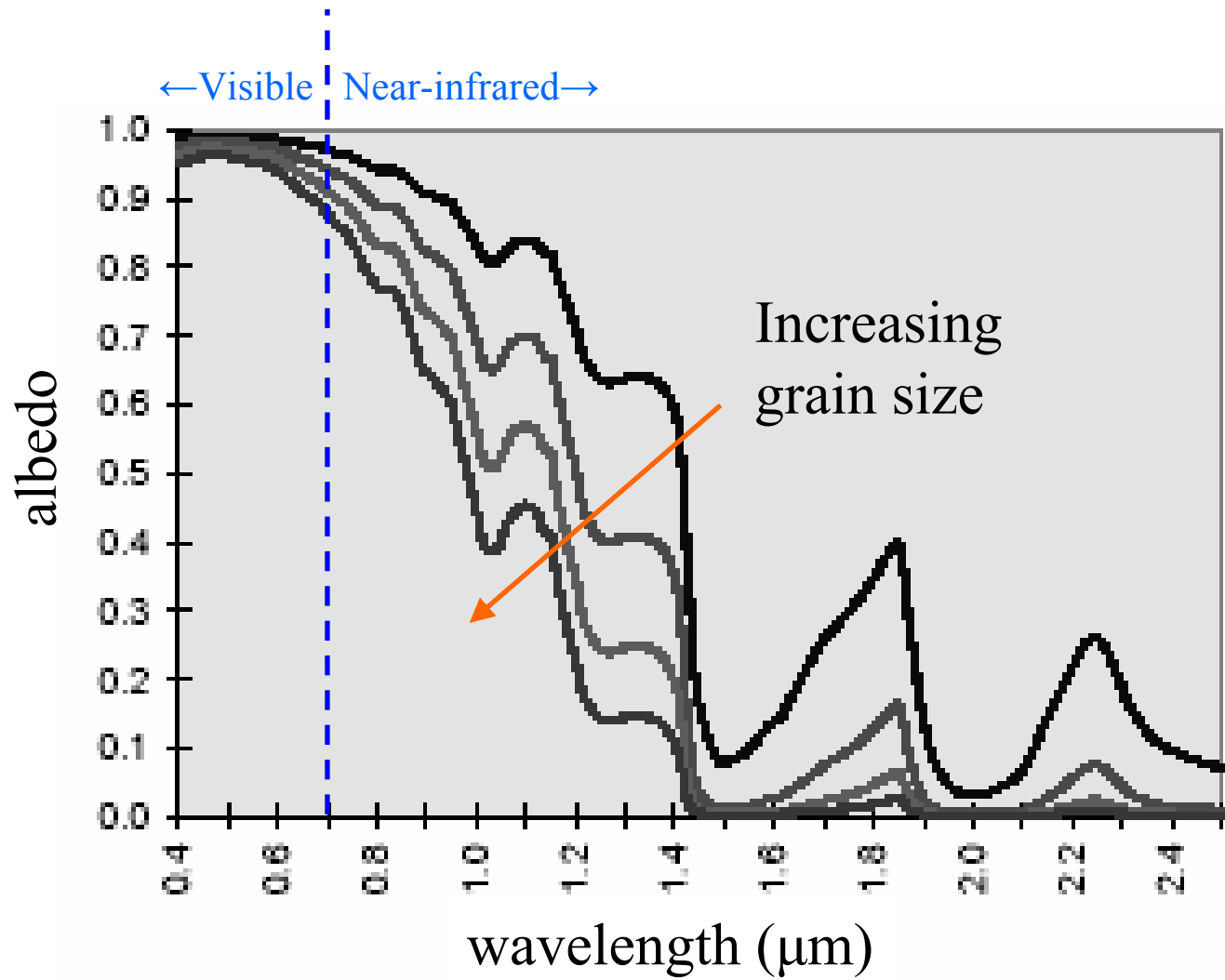
Water Balance Components

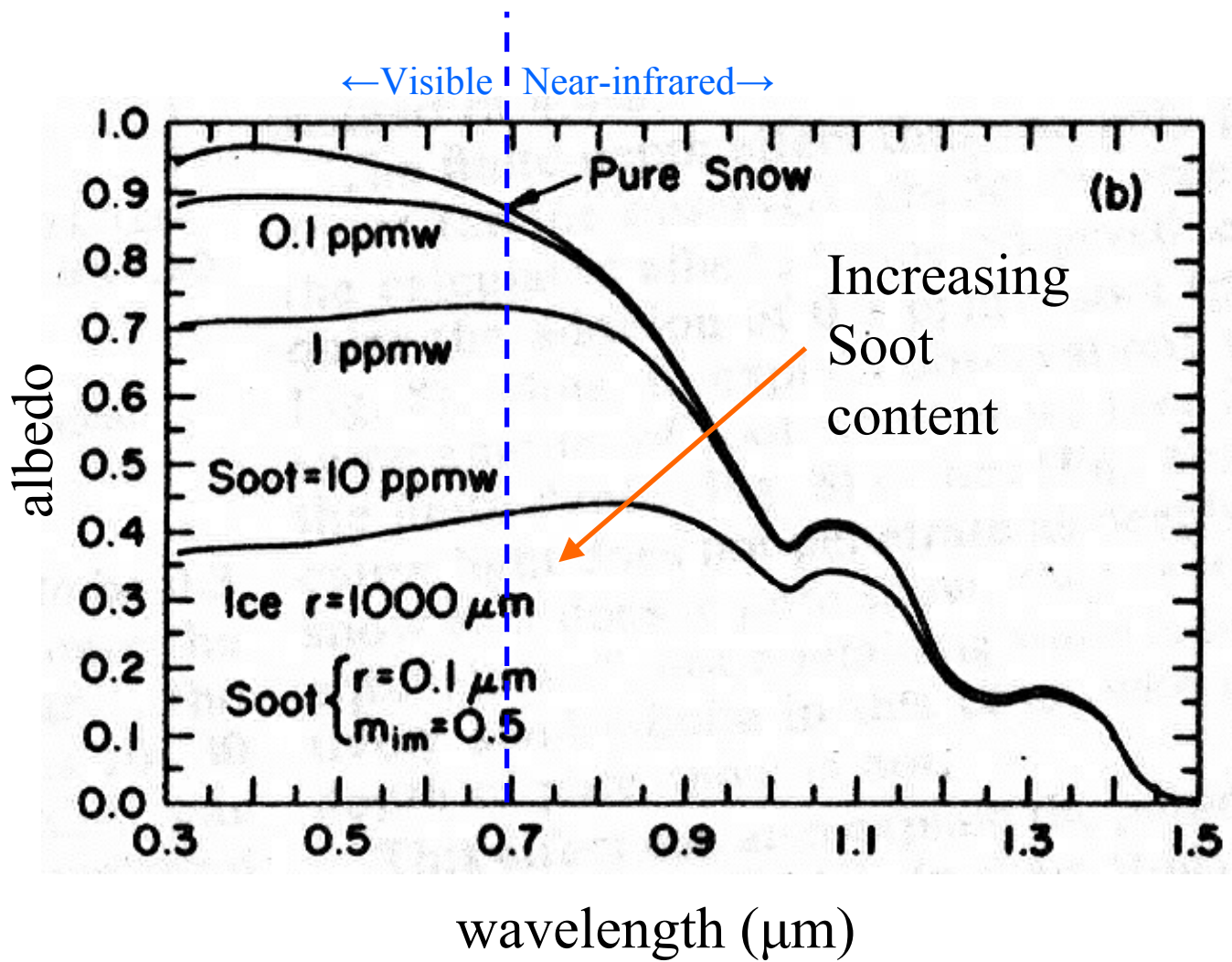


Energy and Mass Balance Equations

$$\frac{dU}{dt} = (1 - \alpha)SW_{\downarrow} + \varepsilon(LW_{\downarrow} - \sigma T^4) + Q_a - H - L_s E - L_f M$$

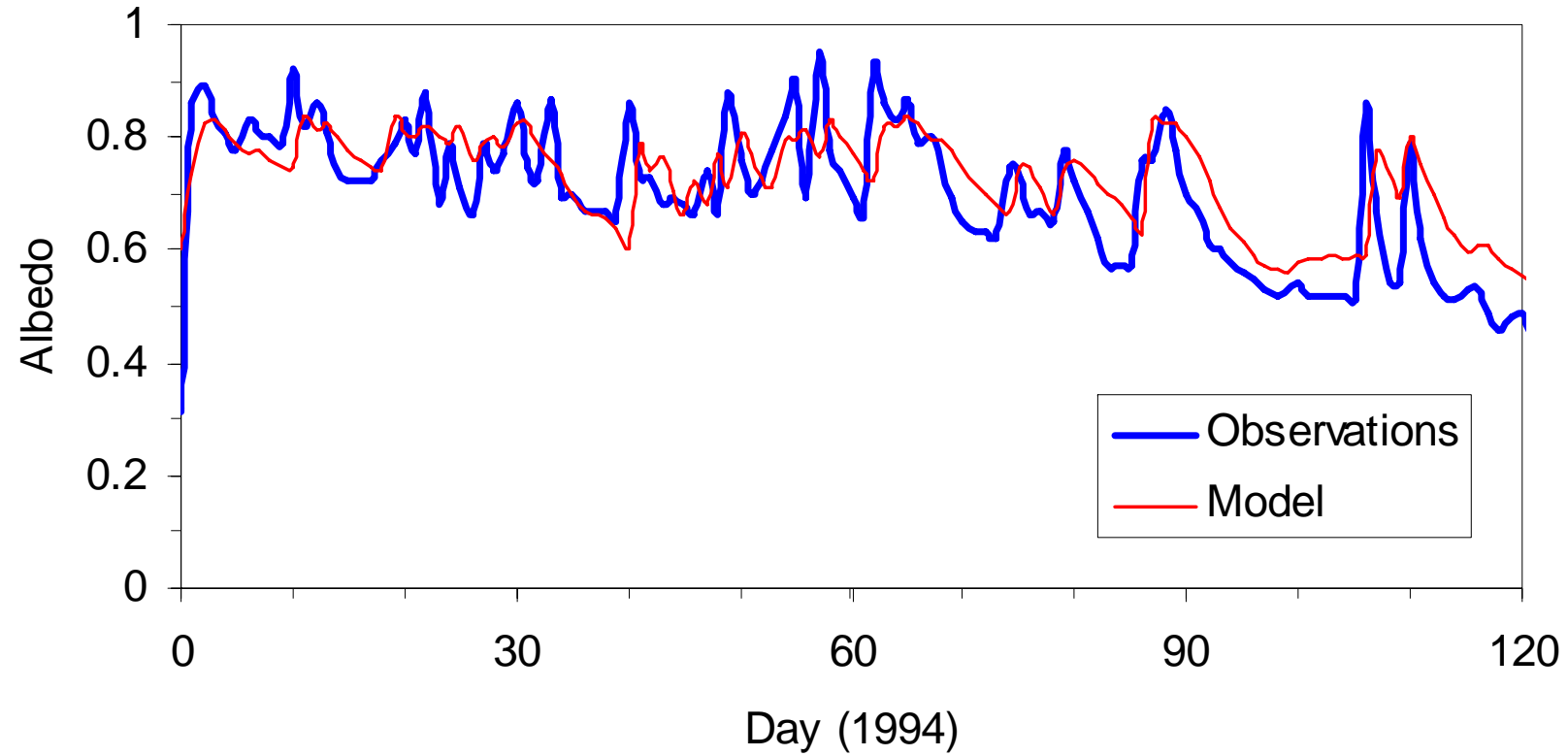
$$\frac{dM}{dt} = S_f - E - M$$








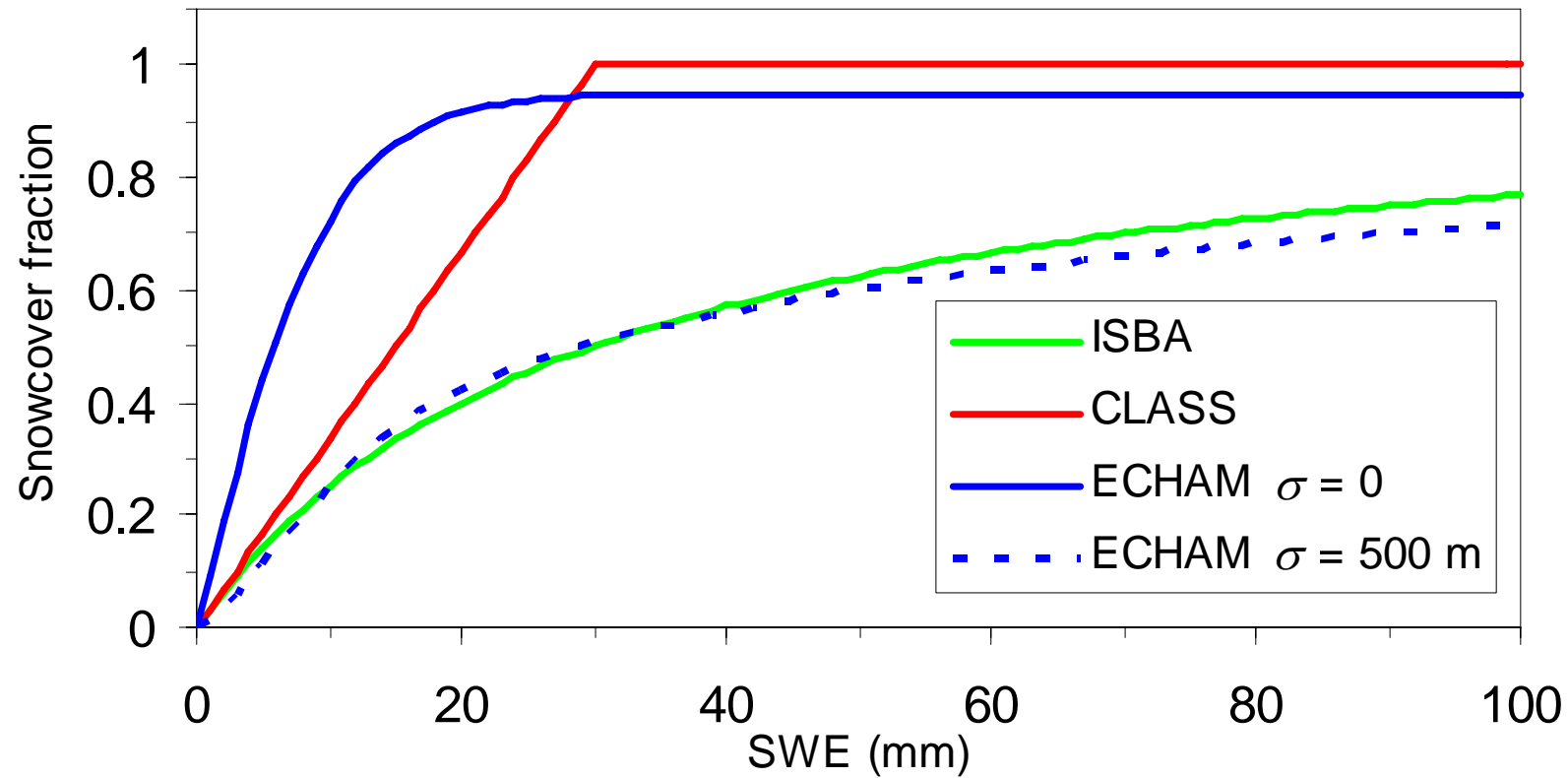
Snow albedo parametrization



$$\alpha(t + \delta t) = \alpha_{\min} + [\alpha(t) - \alpha_{\min}] \exp\left(-\frac{\delta t}{\tau}\right) + [\alpha_{\max} - \alpha(t)] \frac{S_f}{S_0}$$



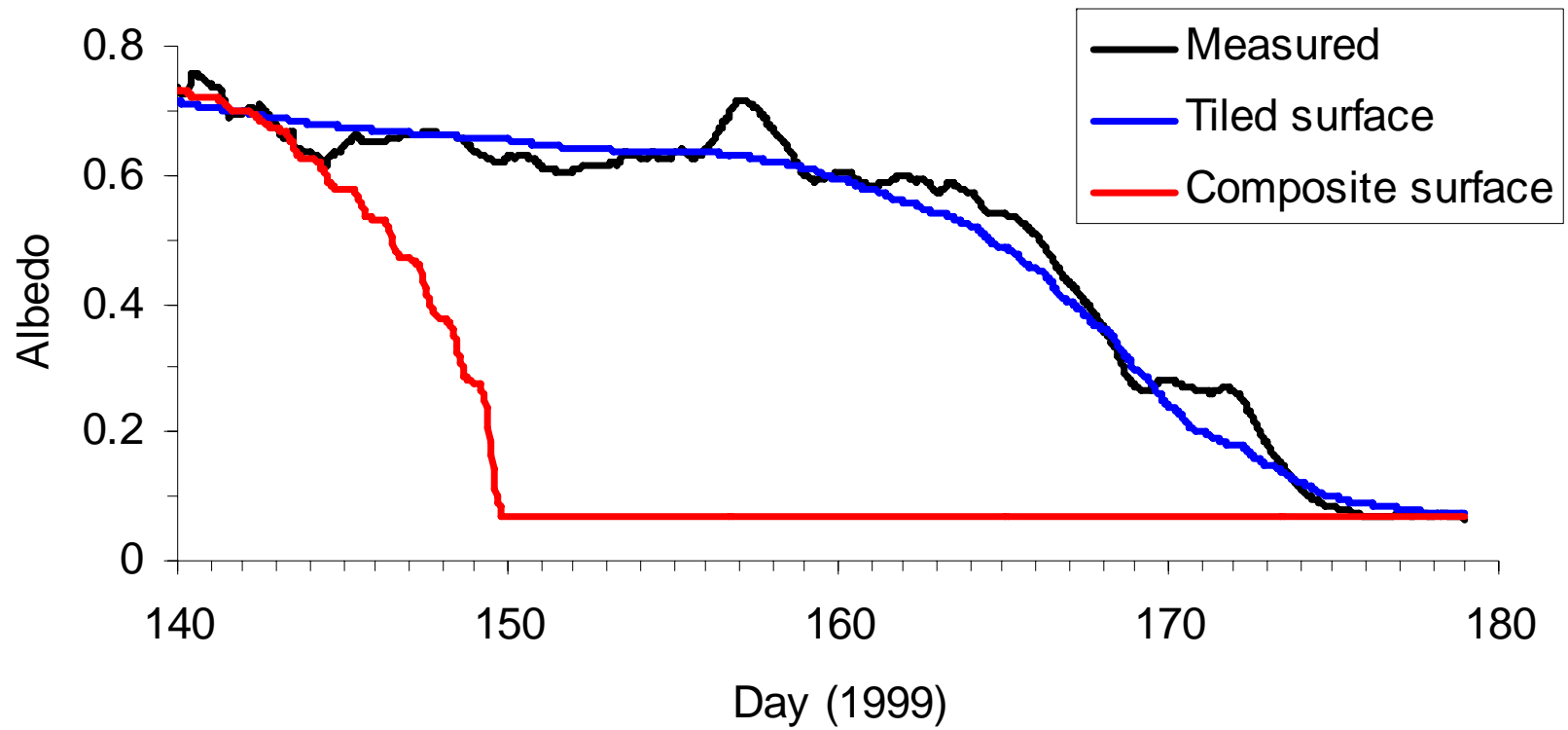
Snow fraction parametrization



$$f_s = \frac{S}{S + 5\rho z_0}$$

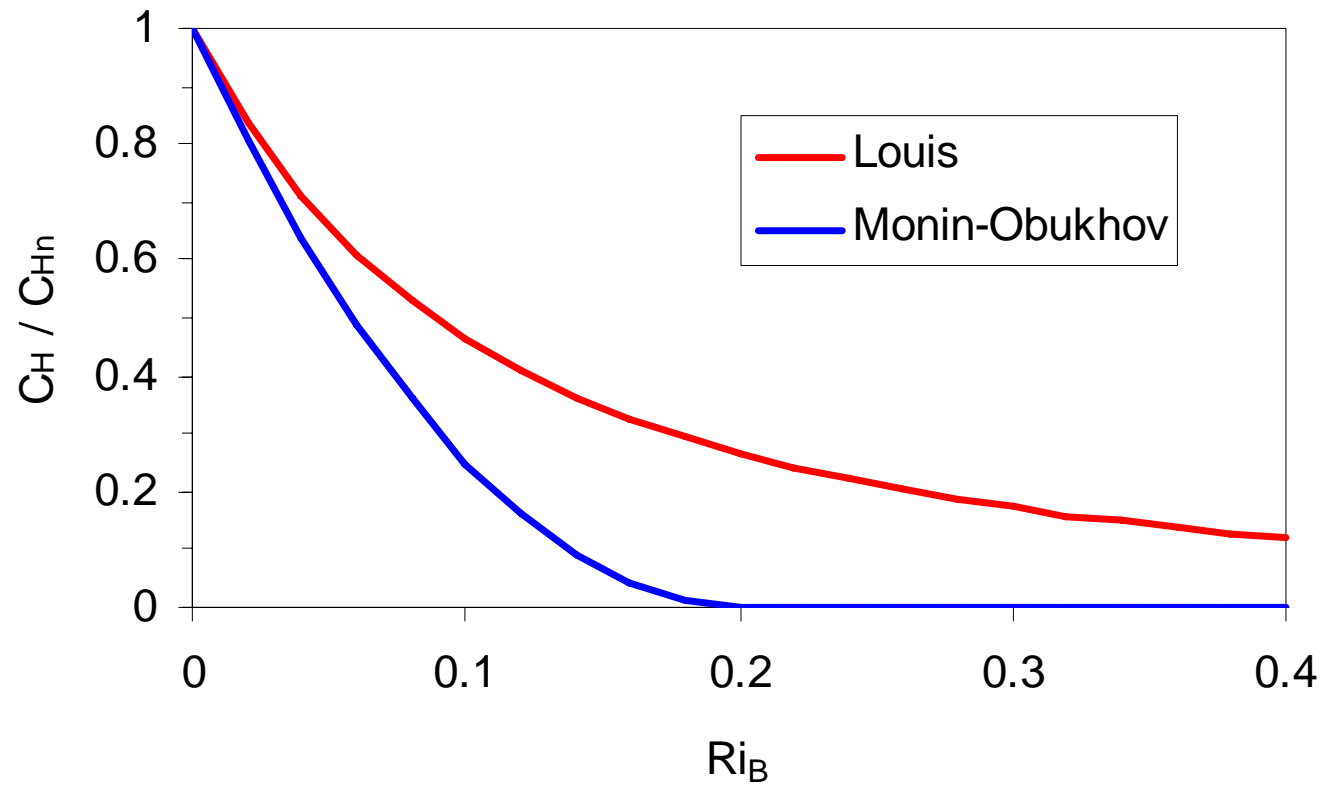
$$f_s = \min\left[\frac{10S}{\rho}, 1\right]$$

$$f_s = 0.95 \tanh(0.1S) \left(\frac{S}{S + 0.15\sigma_z} \right)^{1/2}$$



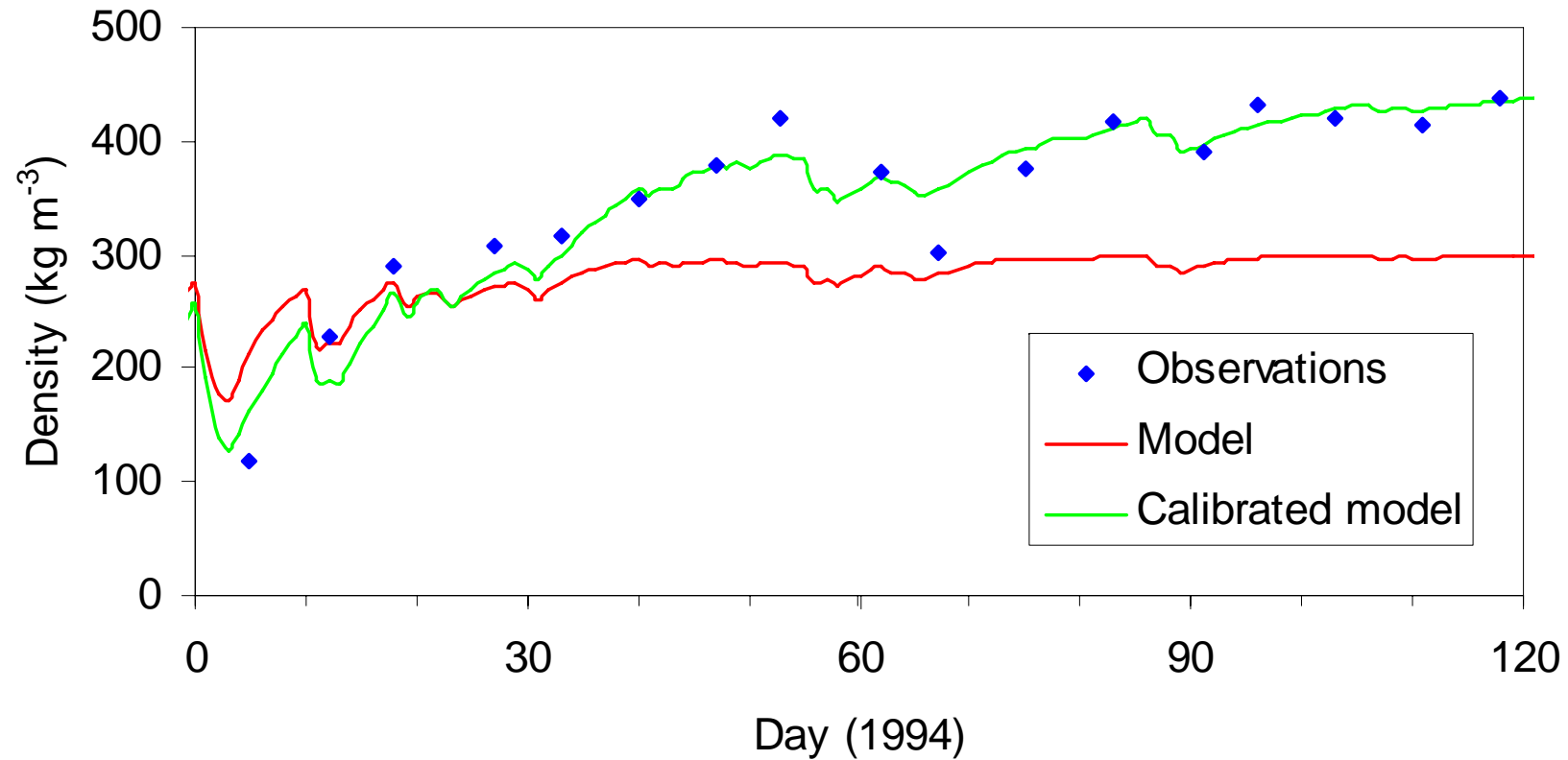
Essery, Blyth, Harding and Lloyd, 2005. *Nordic Hydrology*, **36**, 207 - 218

Stable exchange coefficients



After King and Connolley, 1997. *J. Clim.*, **10**, 1273 – 1287.

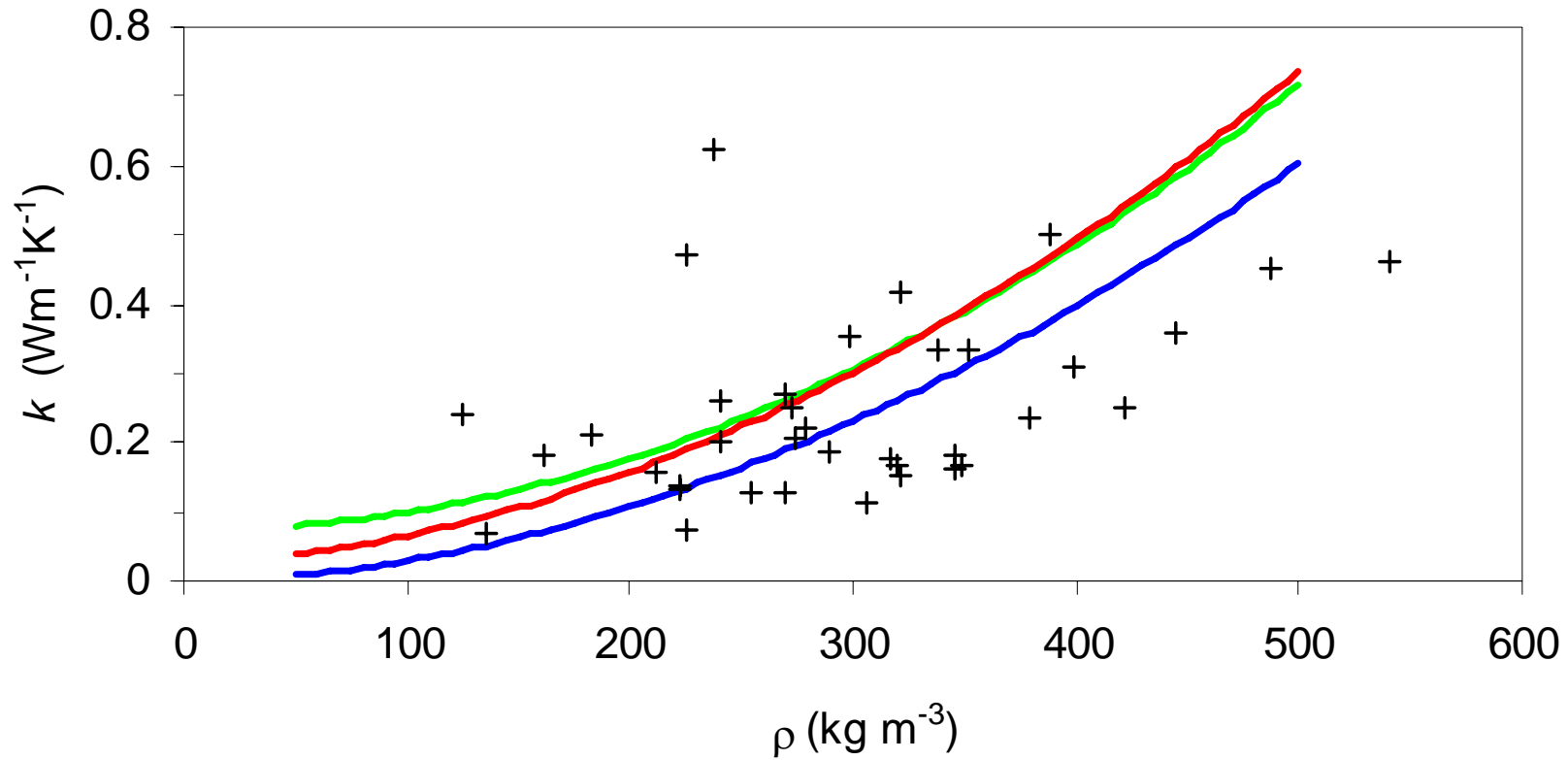
Snow density parametrization



$$\rho(t + \delta t) = \rho_{\max} + [\rho(t) - \rho_{\max}] \exp(-\delta t / \tau)$$

$$\rho(t + \delta t) = [S\rho(t) - S_f \rho_{\text{fresh}}] / (S + S_f)$$

Snow thermal conductivity



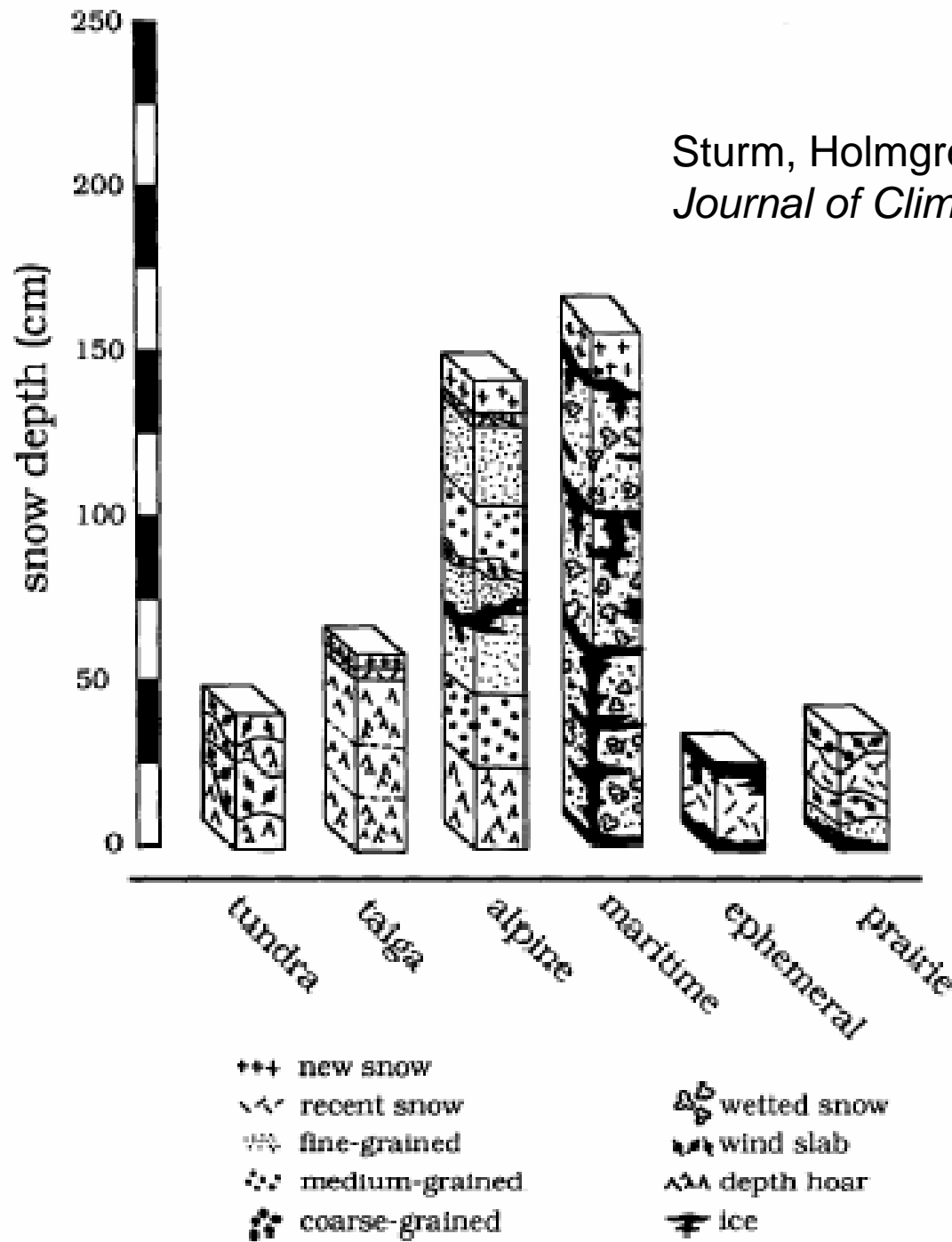
$$k = a + b\rho^2$$

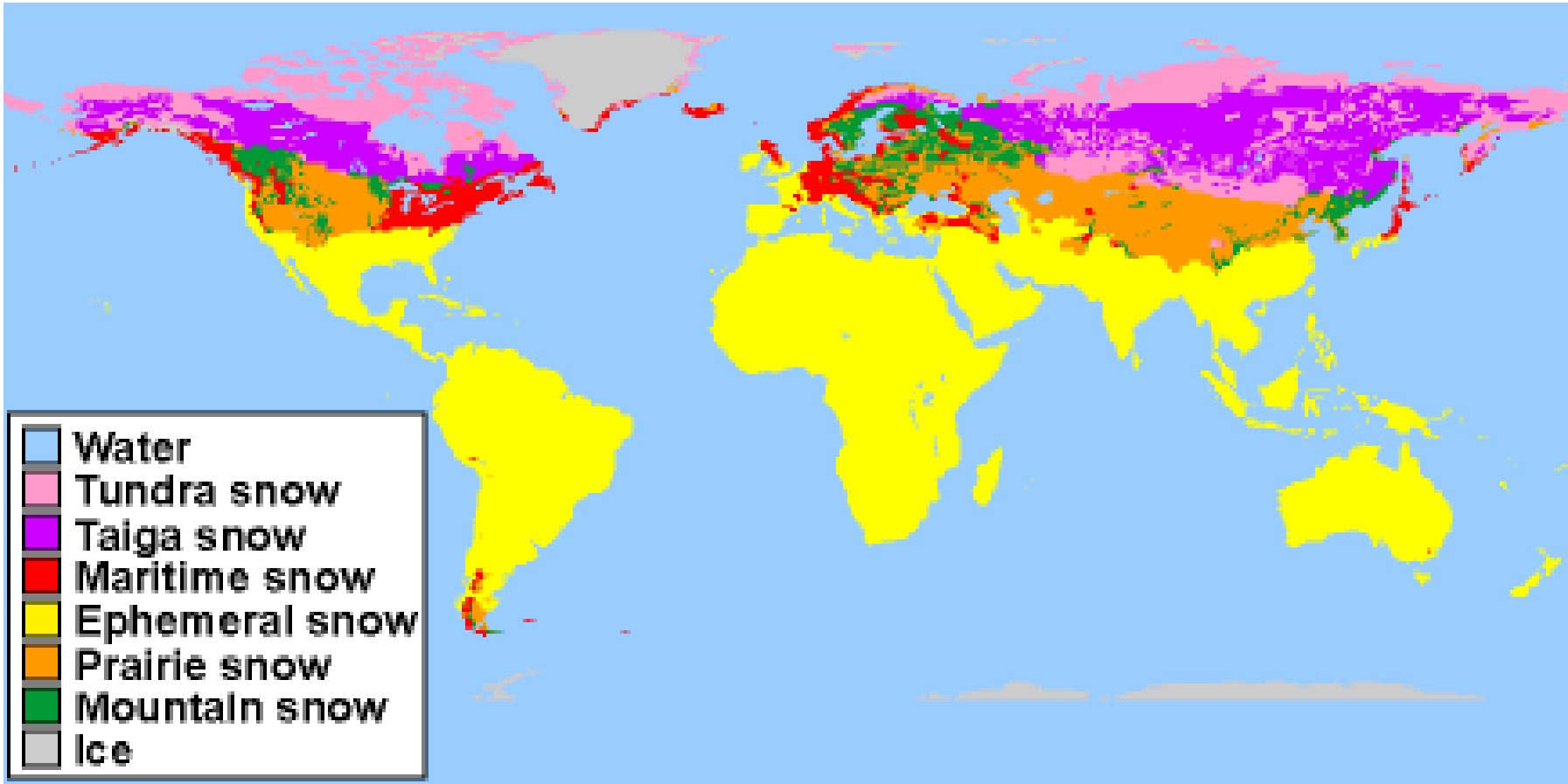
$$k = a + b\rho + c\rho^2$$

$$k = a\rho^b$$

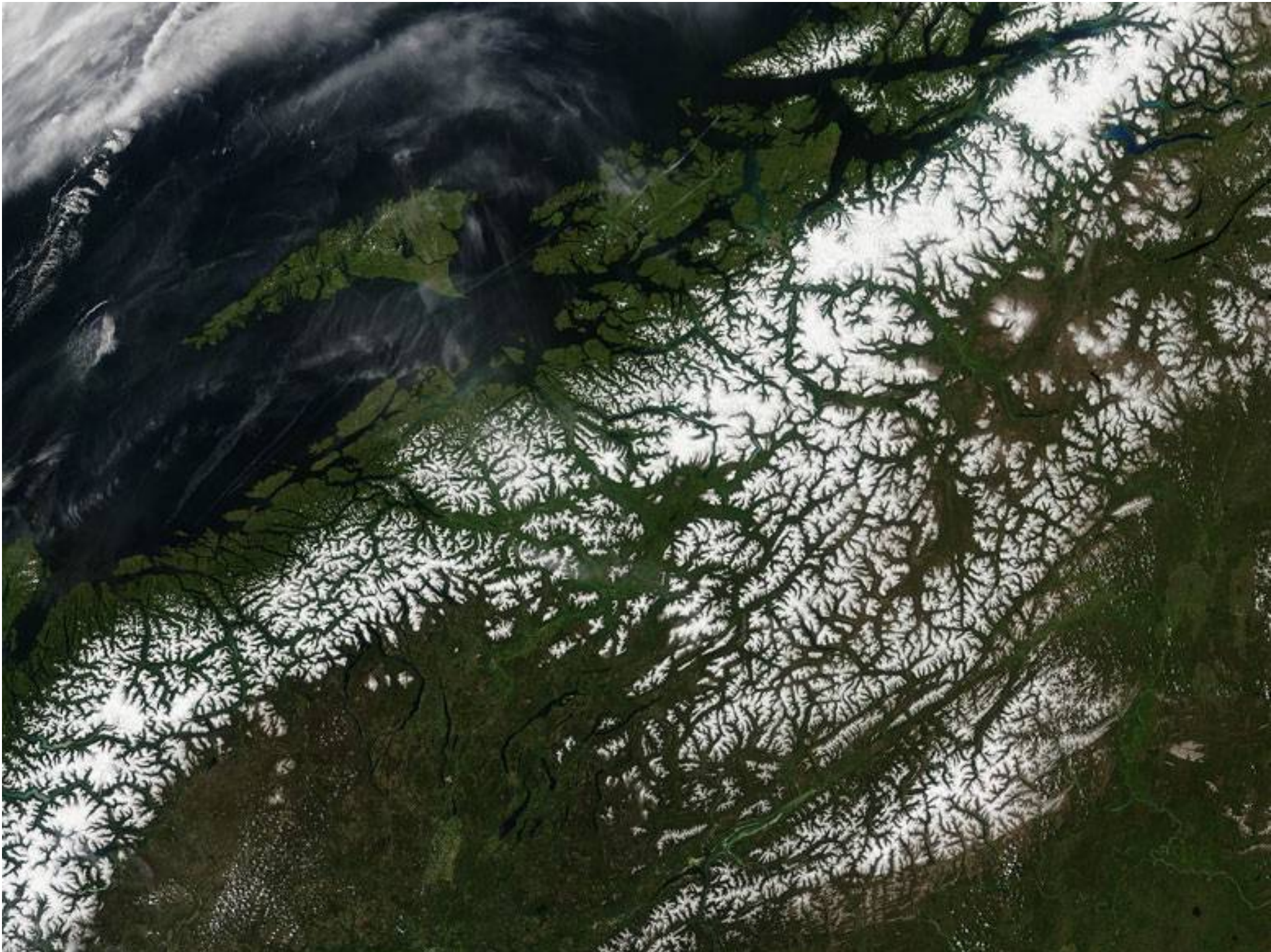
Observations from Sturm et al. (1997). *J. Glaciol.*, **43**, 26 - 41

Sturm, Holmgren and Liston, 1995.
Journal of Climate, 8,1261-83.



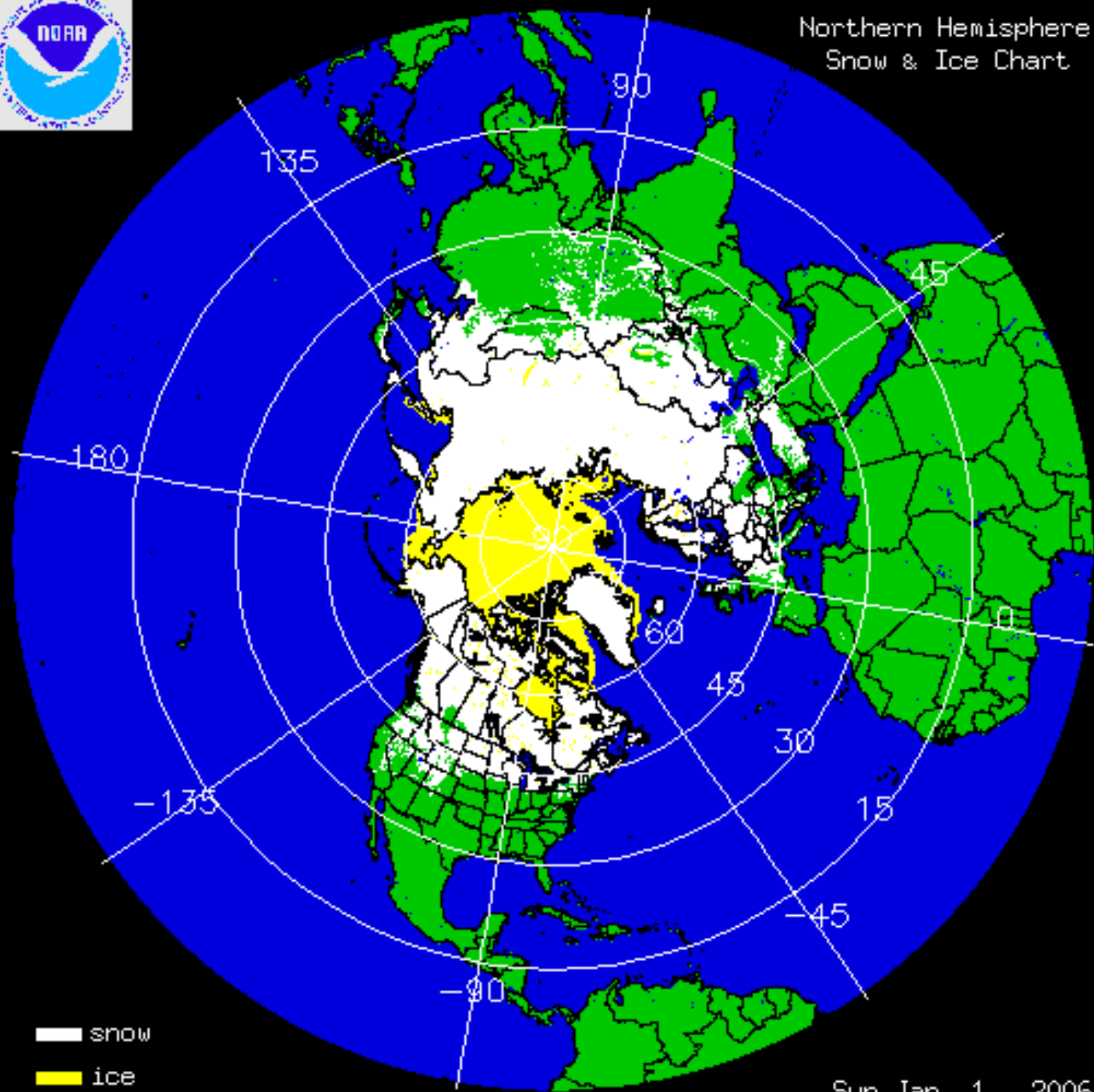






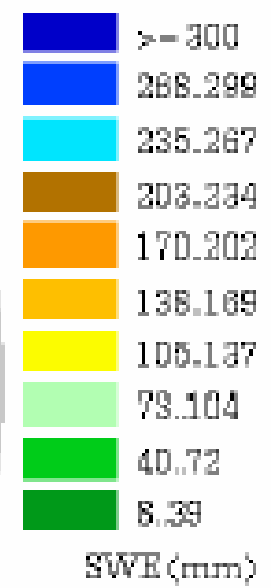
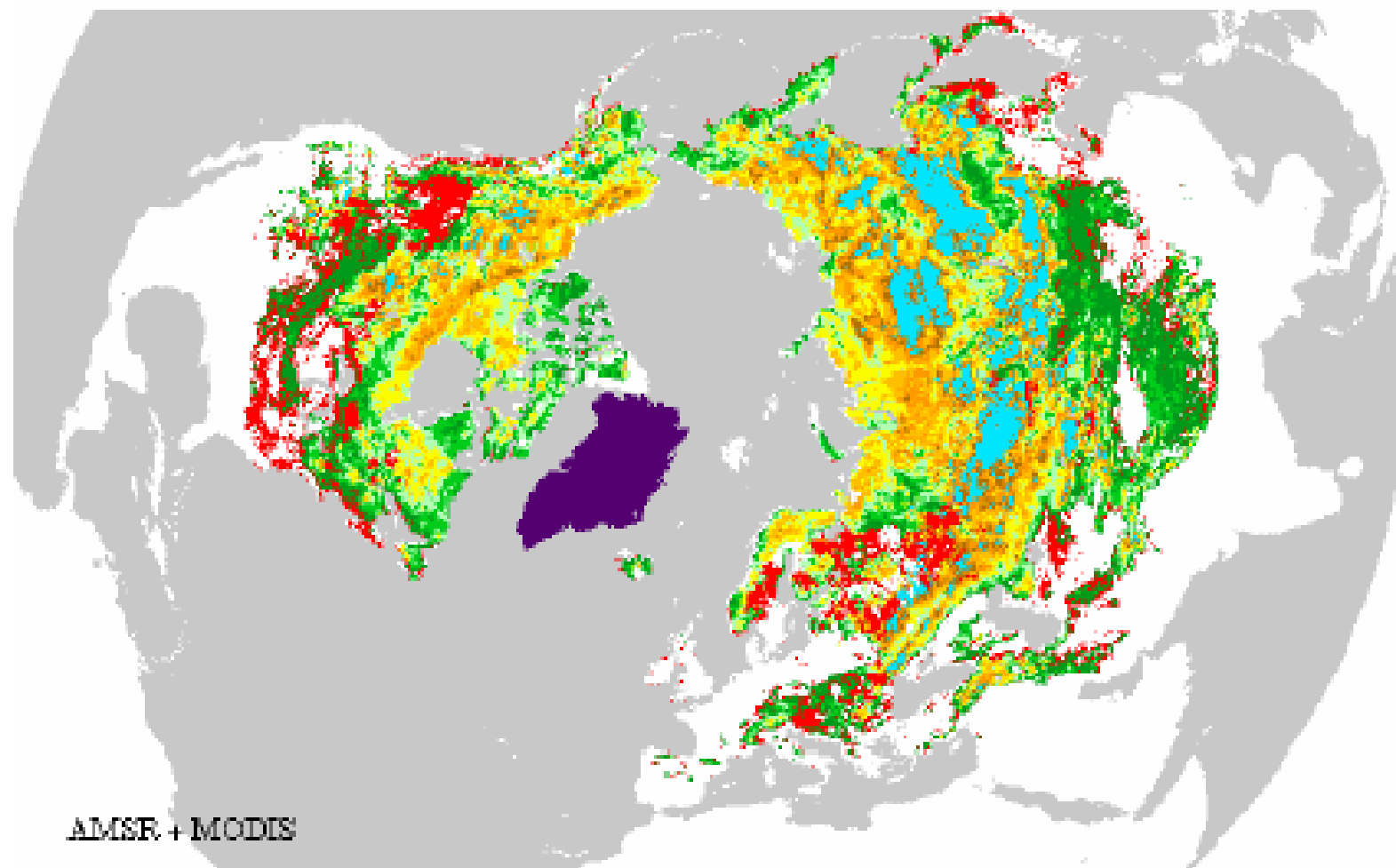


Northern Hemisphere
Snow & Ice Chart



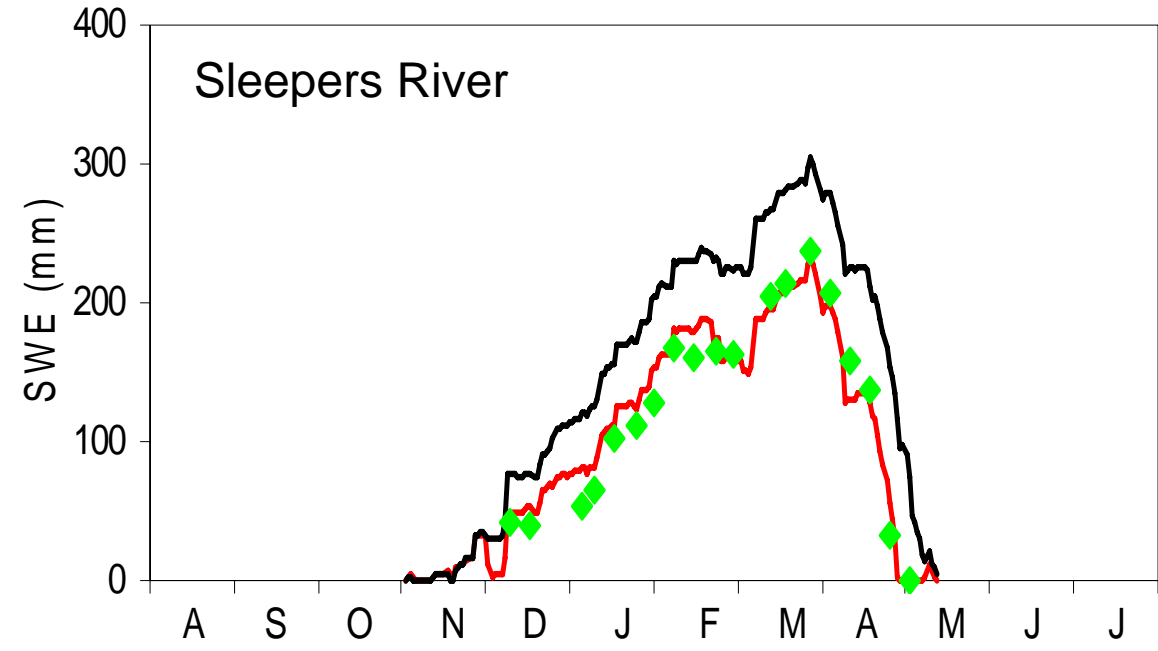
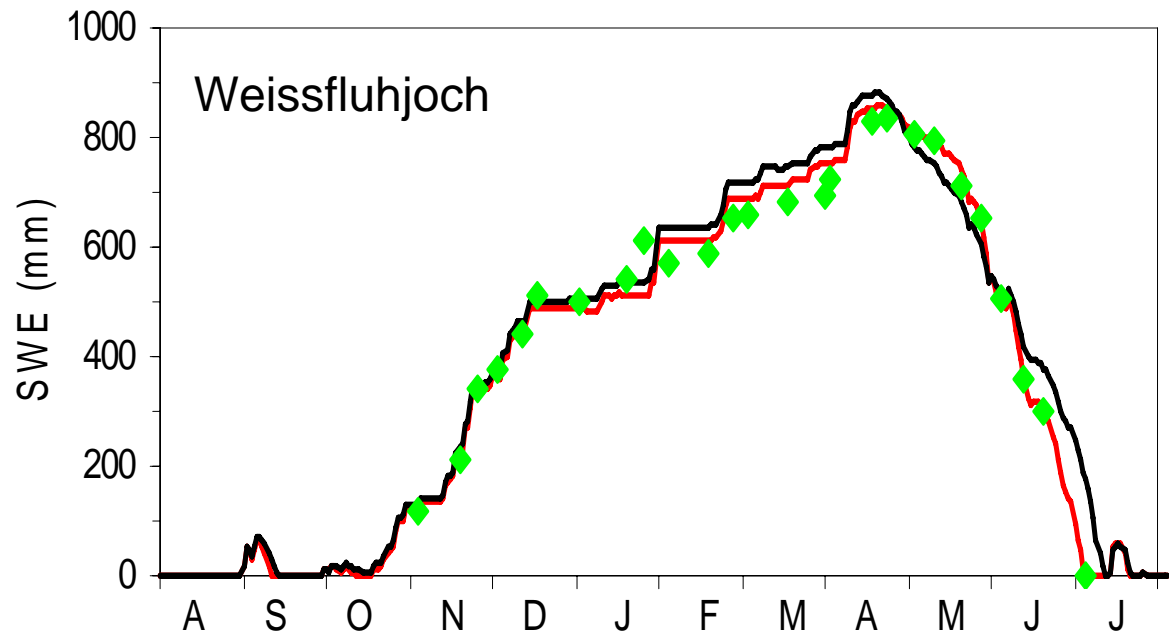
■ snow
■ ice

Sun Jan 1 2006

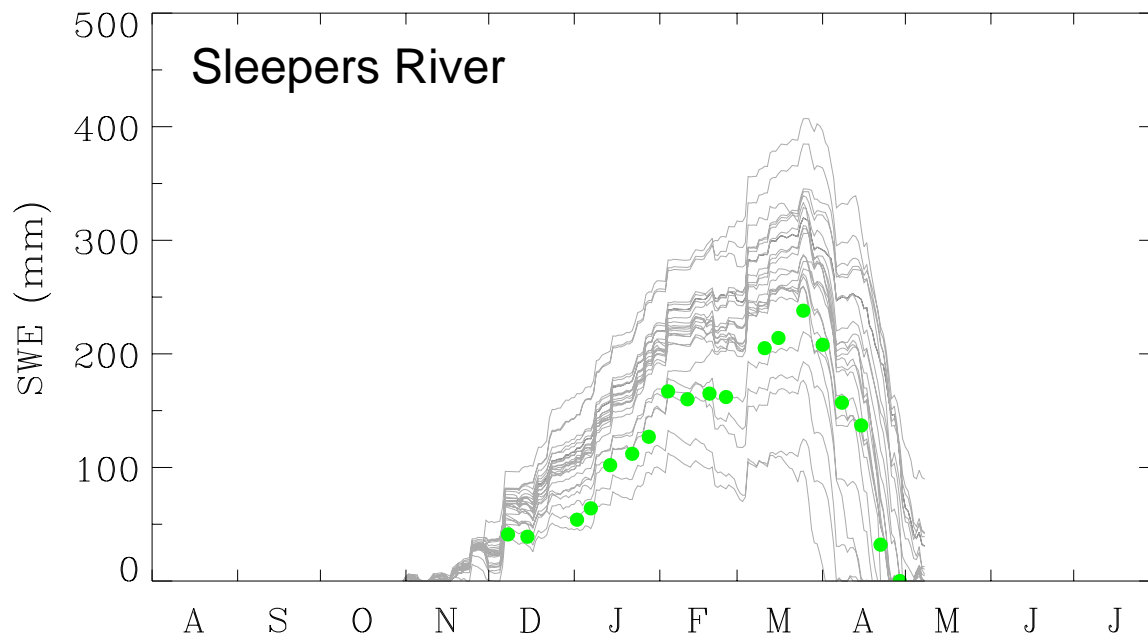
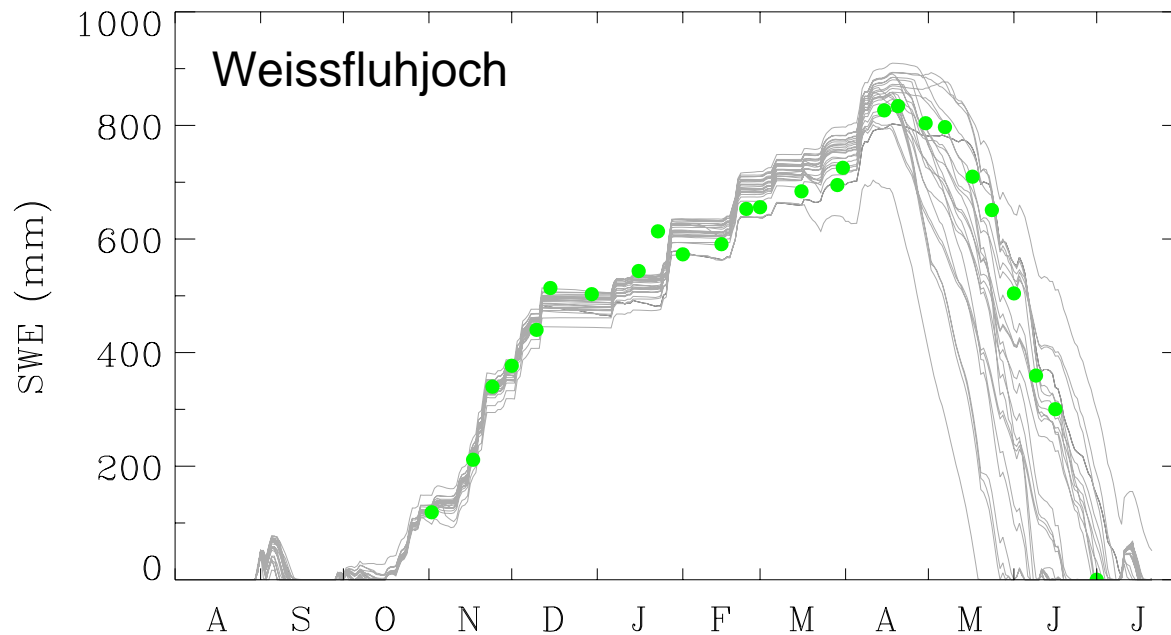


AMSR + MODIS





SnowMIP



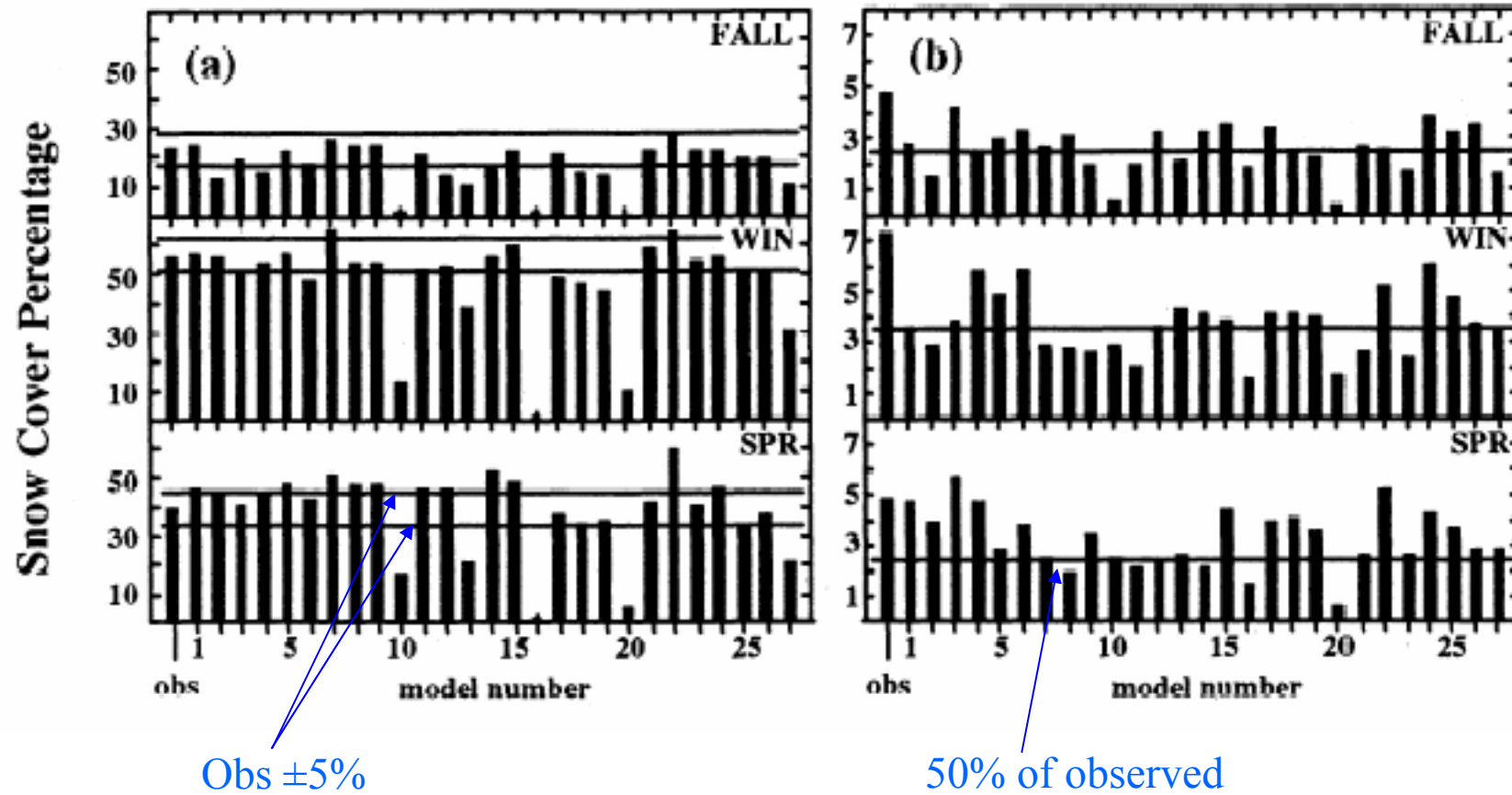
AMIP-1

Frei and Robinson, 1998. *J. Geophys. Res.* **103**(D8)

Northern Hemisphere snow extent

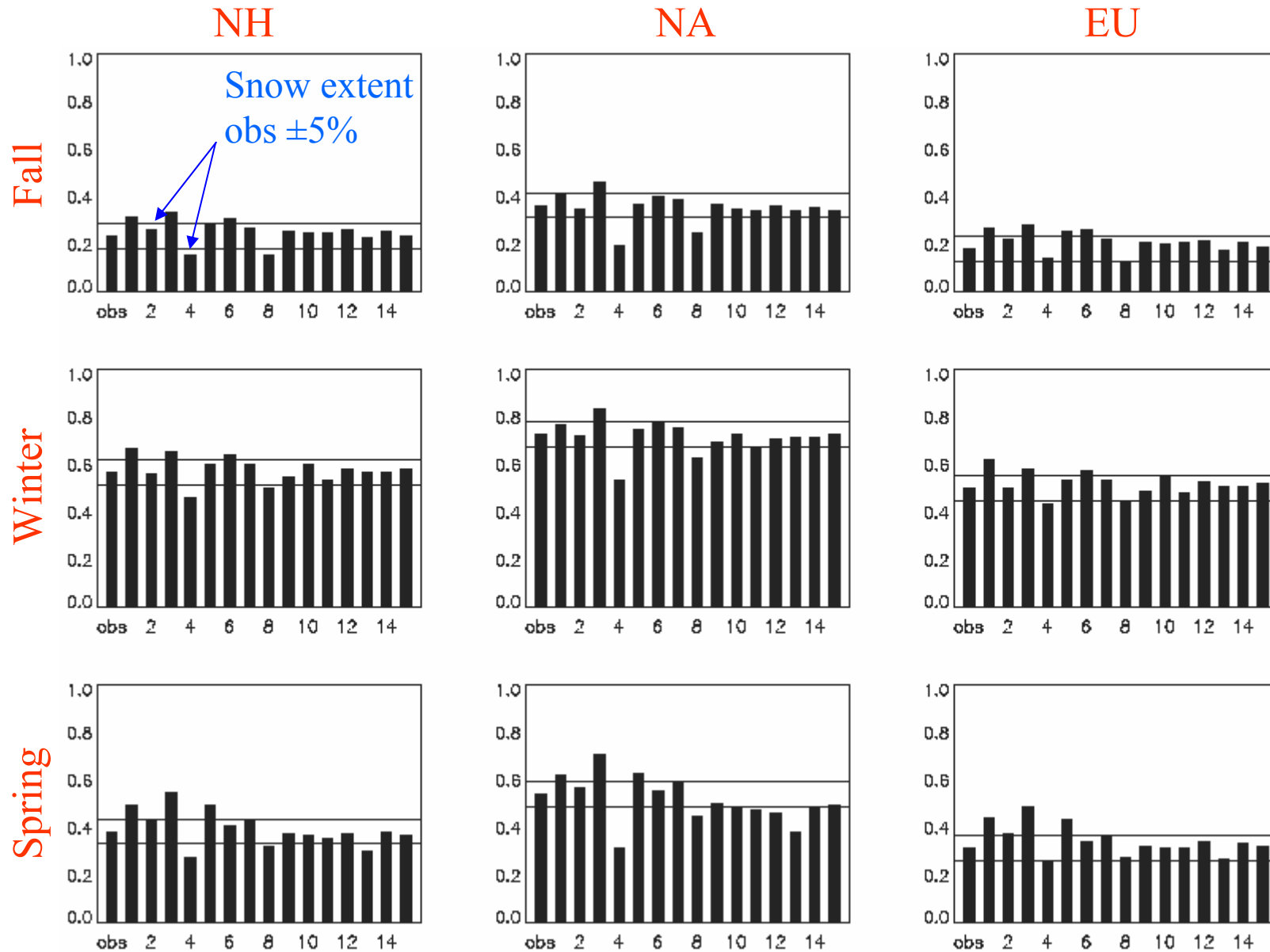
Seasonal cycle

Interannual range



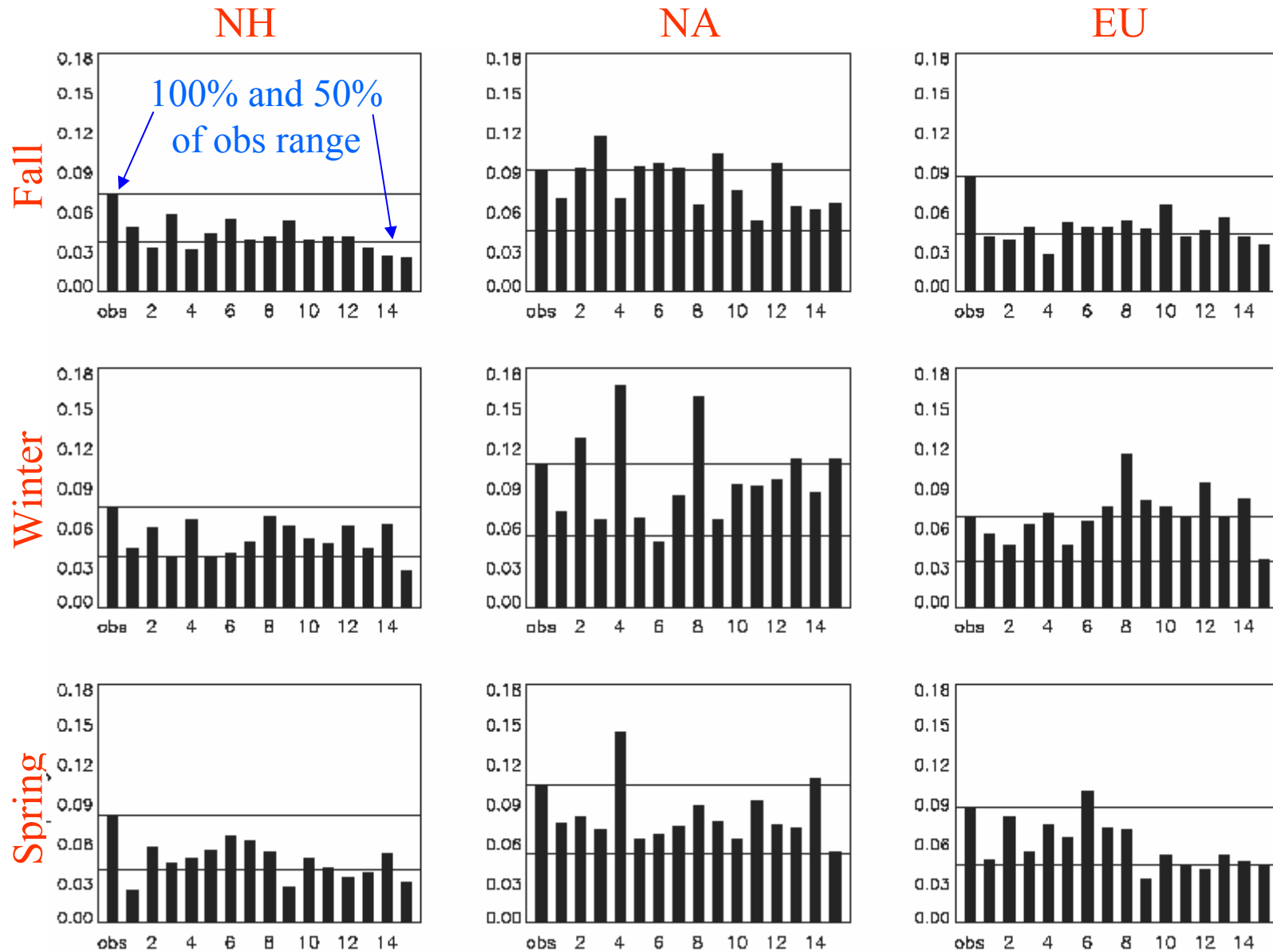
AMIP-2

Frei, Miller and Robinson, 2003. *J. Geophys. Res.* **108**(D12)

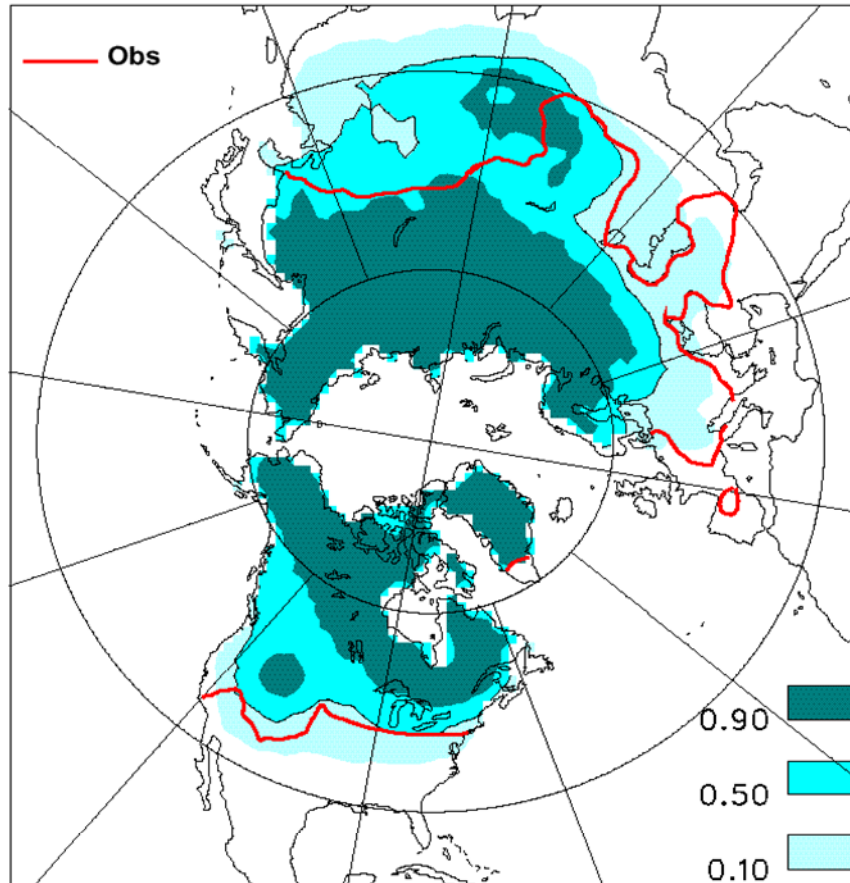


AMIP-2

Frei, Miller and Robinson, 2003. *J. Geophys. Res.* **108**(D12)

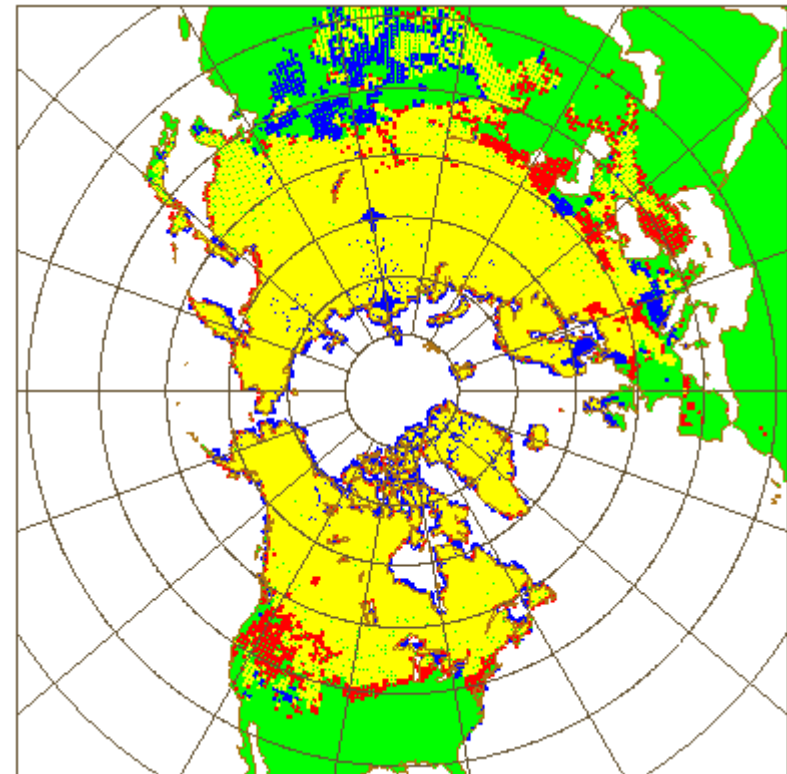


DJF snow extent
% of 14 CMIP simulations



G.M. Flato for IPCC Third Assessment Report

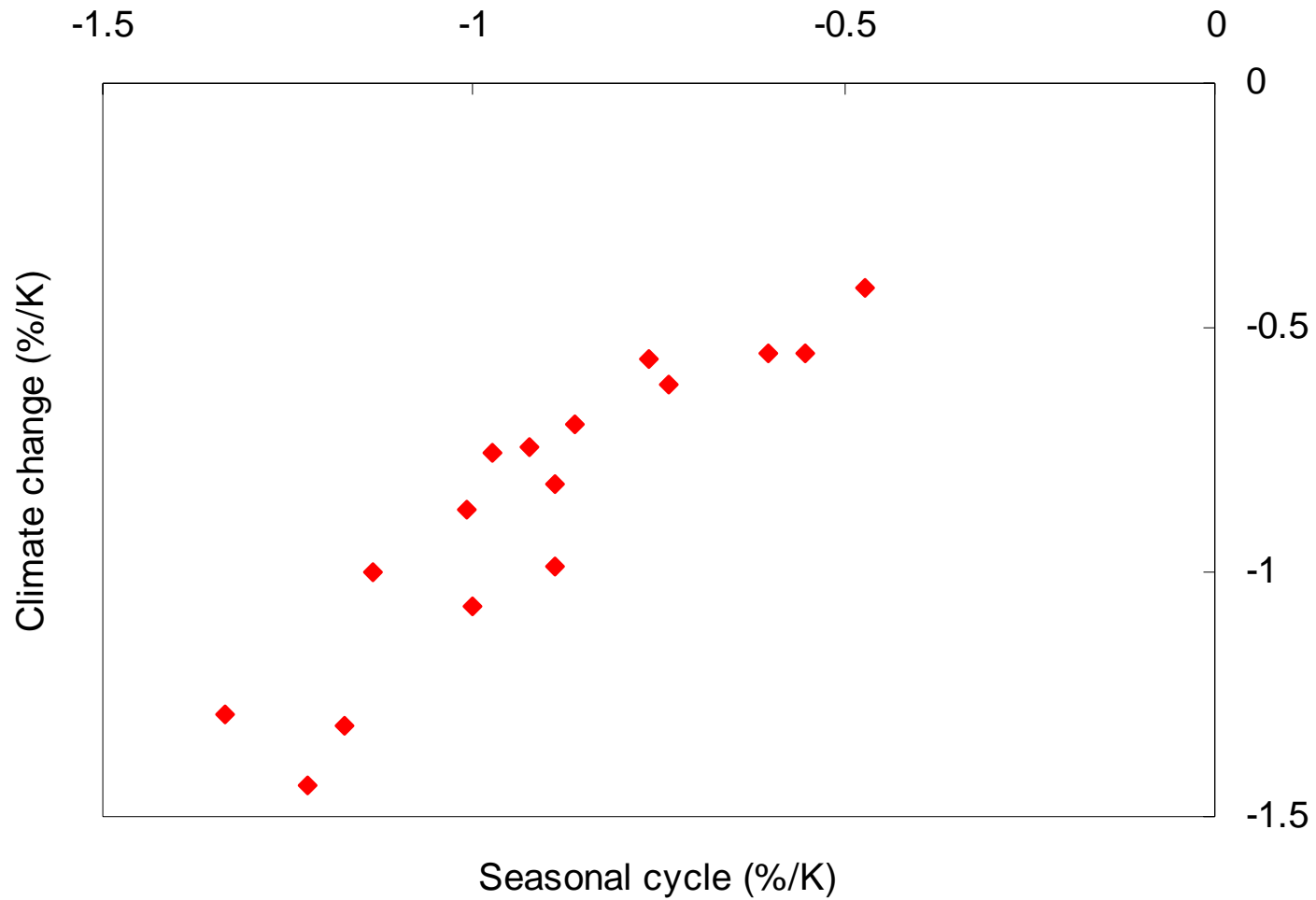
UKMO forecast 26/2/01
cf observations



Data from Jeff Ridley

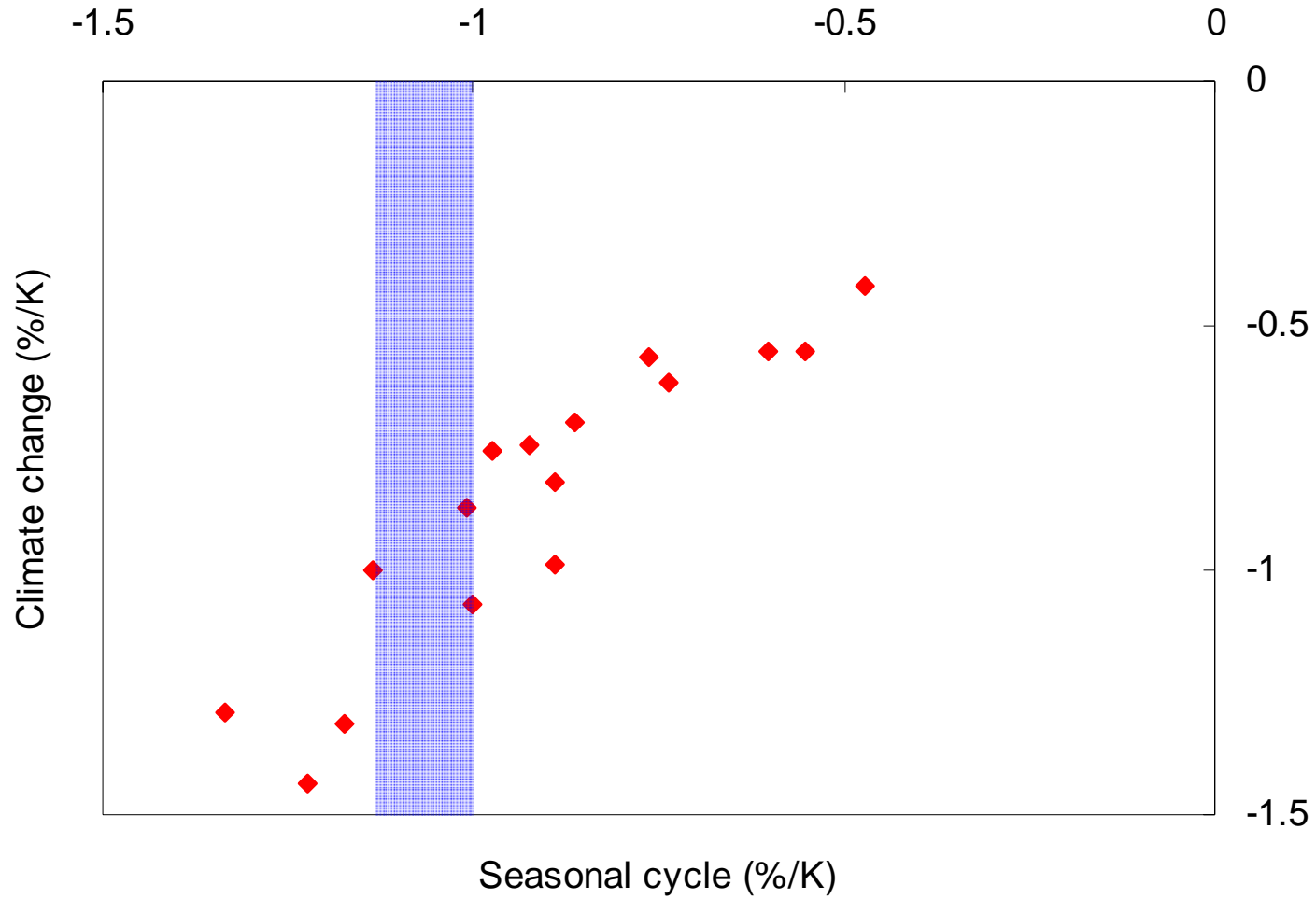
Model underestimate
Model overestimate

Surface albedo sensitivity $\Delta\alpha / \Delta T$



After Hall and Qu, 2006. *Geophys. Res. Lett.*, **33**, L03502

Surface albedo sensitivity $\Delta\alpha / \Delta T$



After Hall and Qu, 2006. *Geophys. Res. Lett.*, **33**, L03502