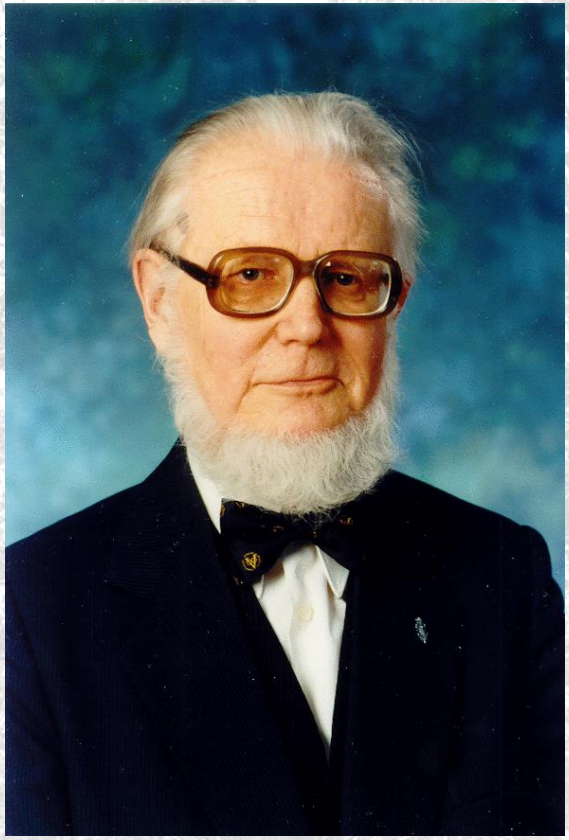
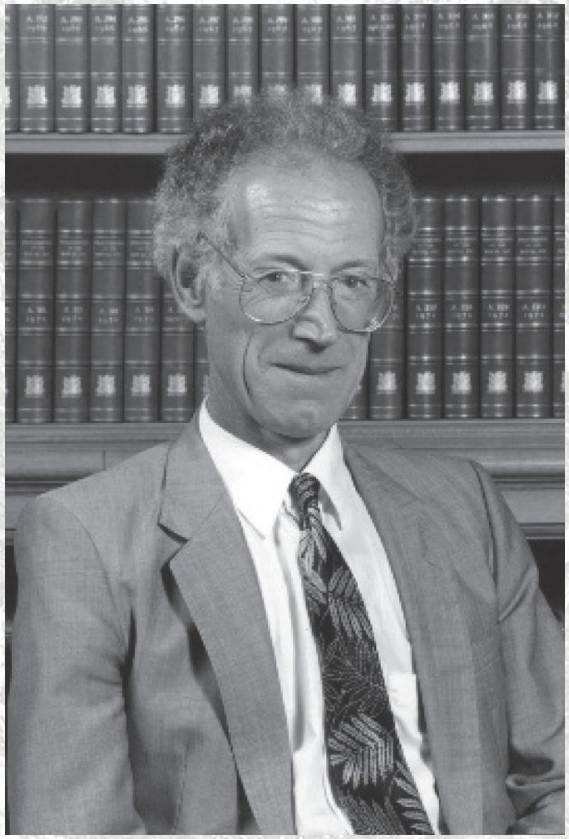
Legacies of

Juhan Ross (1925-2002) Paul Jarvis (1935-2013) Piers Sellers (1955-2016)





in Earth System Models

Richard Essery
School of GeoSciences, University of Edinburgh

Radiative Transfer in Plant Communities (Ross, 1975)
Radiation Regime and Architecture of Plant Stands (Ross, 1981)

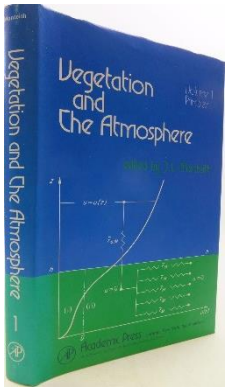
"More than 70% of solar radiation absorbed by plants is converted into heat and used *for transpiration and for convective heat exchange* with the surrounding air"

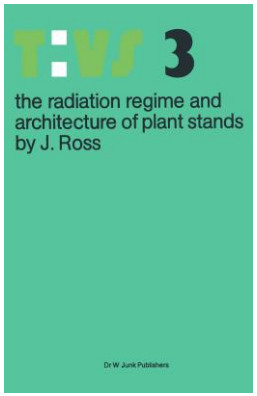
"A component of solar radiation … is used in photosynthesis and stored chemically"

"One of the most important problems in current photoactinometry is how the architecture of a stand determines radiation conditions within it"

"Is it possible to determine from radiation measurements such biometric characteristics as the amount of leaves?"

"no satisfactory and fairly simple method for the mathematical description of clumped dispersions has yet been found owing to the complexity of the problem"

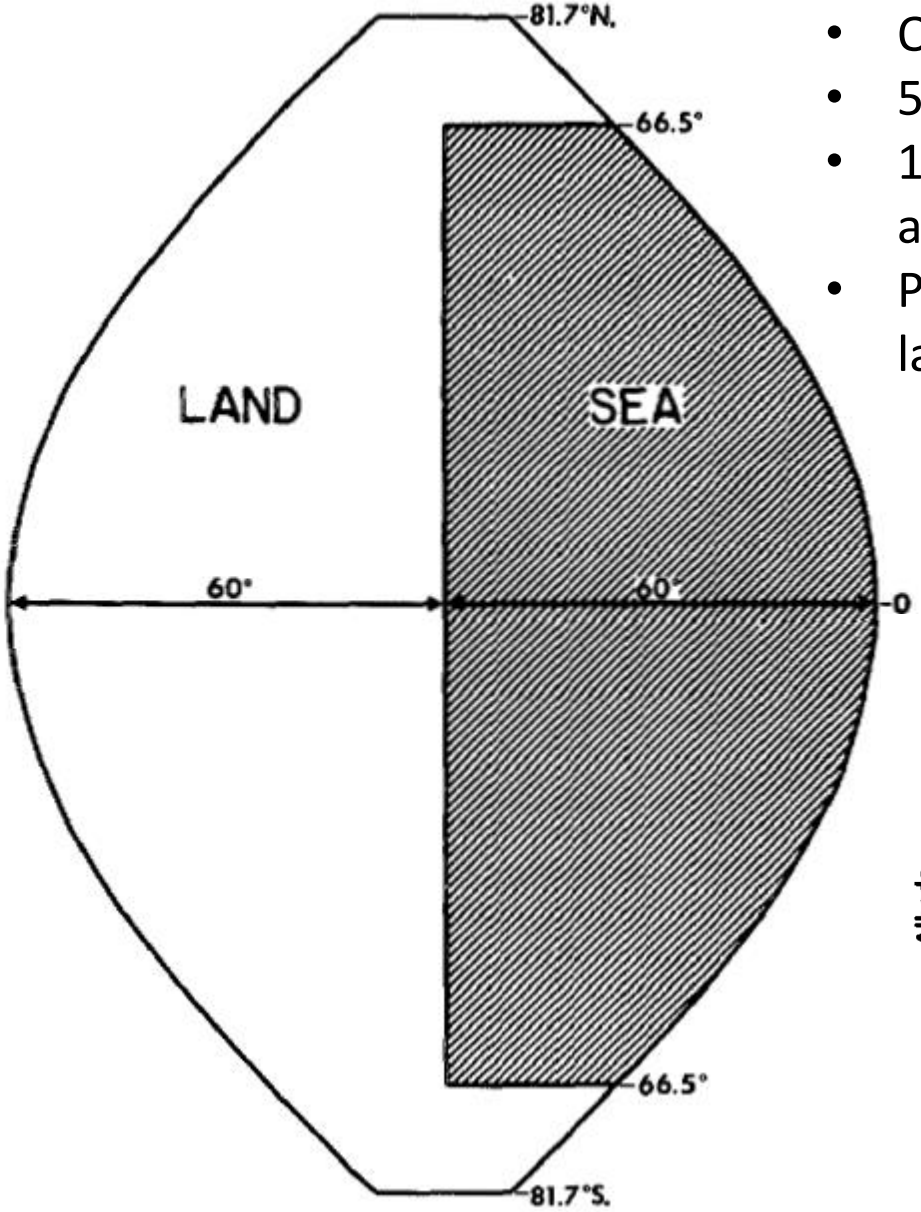




Development of Climate and Earth System Models

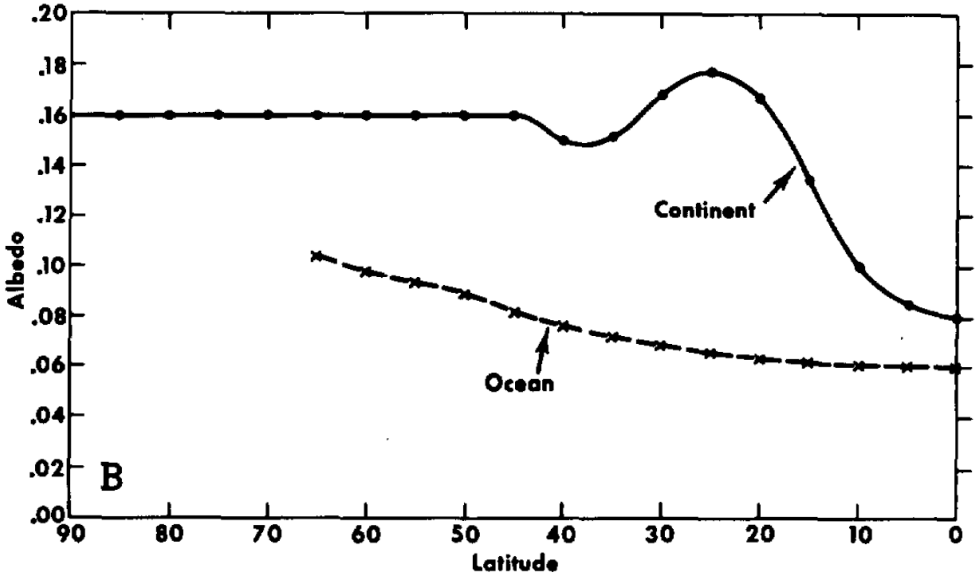
IPCC AR3 (2001)

GFDL Coupled Climate Model (Manabe, Bryan,1969)



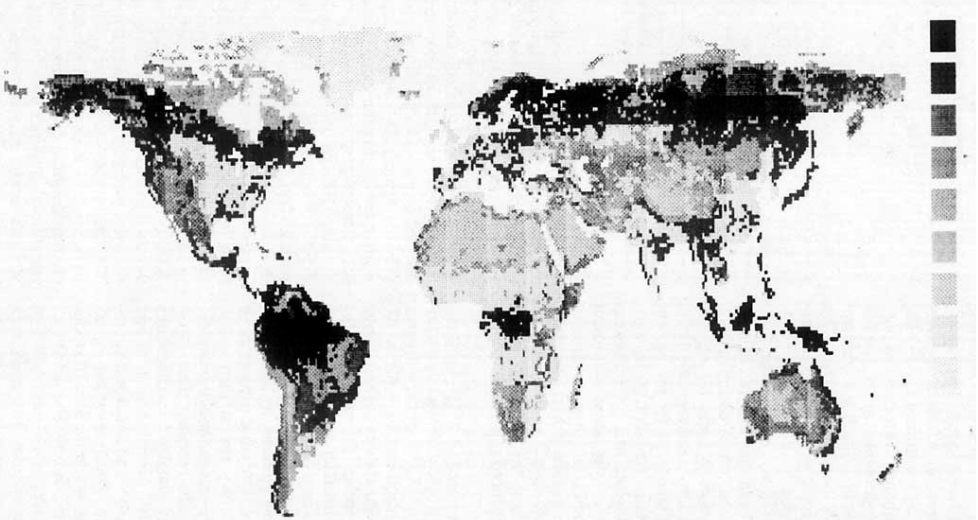
- One continent, one ocean, no seasonal cycle
- 5220 atmospheric grid cells
- 1200 hours computation / simulated year on a UNIVAC 1108
- Permanent glaciation predicted above 53° latitude

Albedos of land and ocean from Budyko (1956, in Russian)



GISS Global Climate Model II (Hensen et al., 1983)

- 7128 atmospheric grid cells (8° × 10° × 9 levels)
- 30 hours computation / simulated year on an IBM 360/95
- 8 vegetation classes, mapped at 1° resolution by Matthews (1983)
- VIS and NIR albedos (from literature review) with and without snow
- Potential evaporation scaled by soil moisture as a fraction of field capacity



Modelling Stomatal Conductance

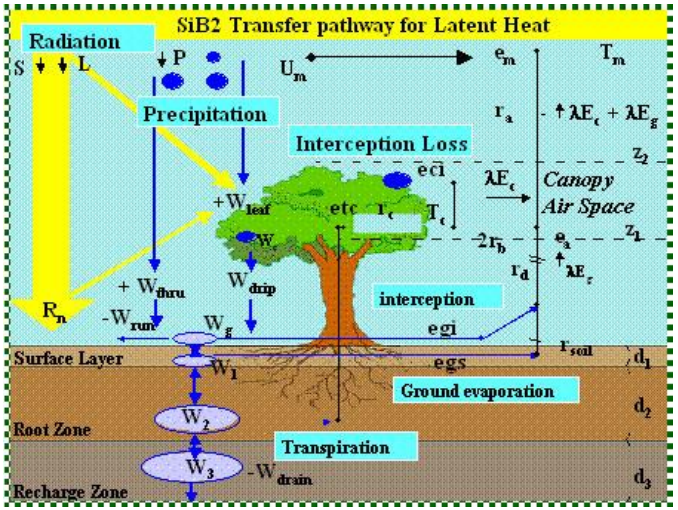
Jarvis (1976). The interpretation of the variations in leaf water potential and stomatal conductance found in canopies in the field. *Phil. Trans. R. Soc. B*, **273** – 1645 citations

- empirical stress function of environmental variables (PAR, temperature, humidity deficit, soil moisture, atmospheric CO_2)
- still used in many land surface models (e.g. BATS, CLSM, ISBA, Noah, VIC), but largely superseded by mechanistic models of photosynthesis in Earth System Models

A Simple Biosphere Model (Sellers et al., 1986)

Sellers et al. (1986). A Simple Biosphere Model (SiB) for Use Within General-Circulation Models – 1289 citations

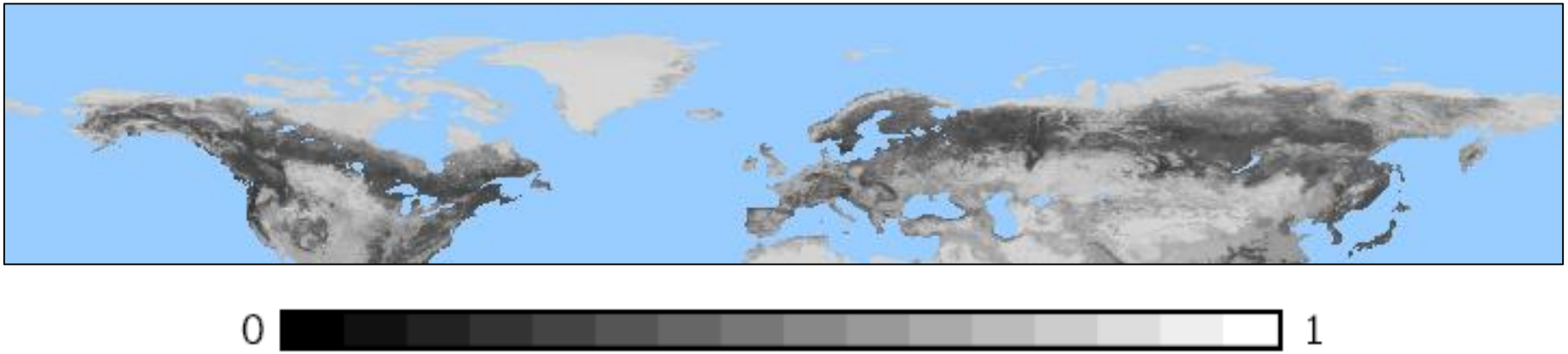
- 2-stream canopy radiative transfer model (direct and diffuse, NIR and VIS), citing Ross (1975) for leaf angle distributions
- Jarvis (1976) stomatal conductance model
- implemented in NASA / Goddard GCM (Sud et al. 1989) with Matthews (1983) vegetation
- Sellers et al. (1993) – vegetation parameters generated from AVHRR NDVI



Snow Albedo Masking by Forests

MODIS needleleaf tree fraction

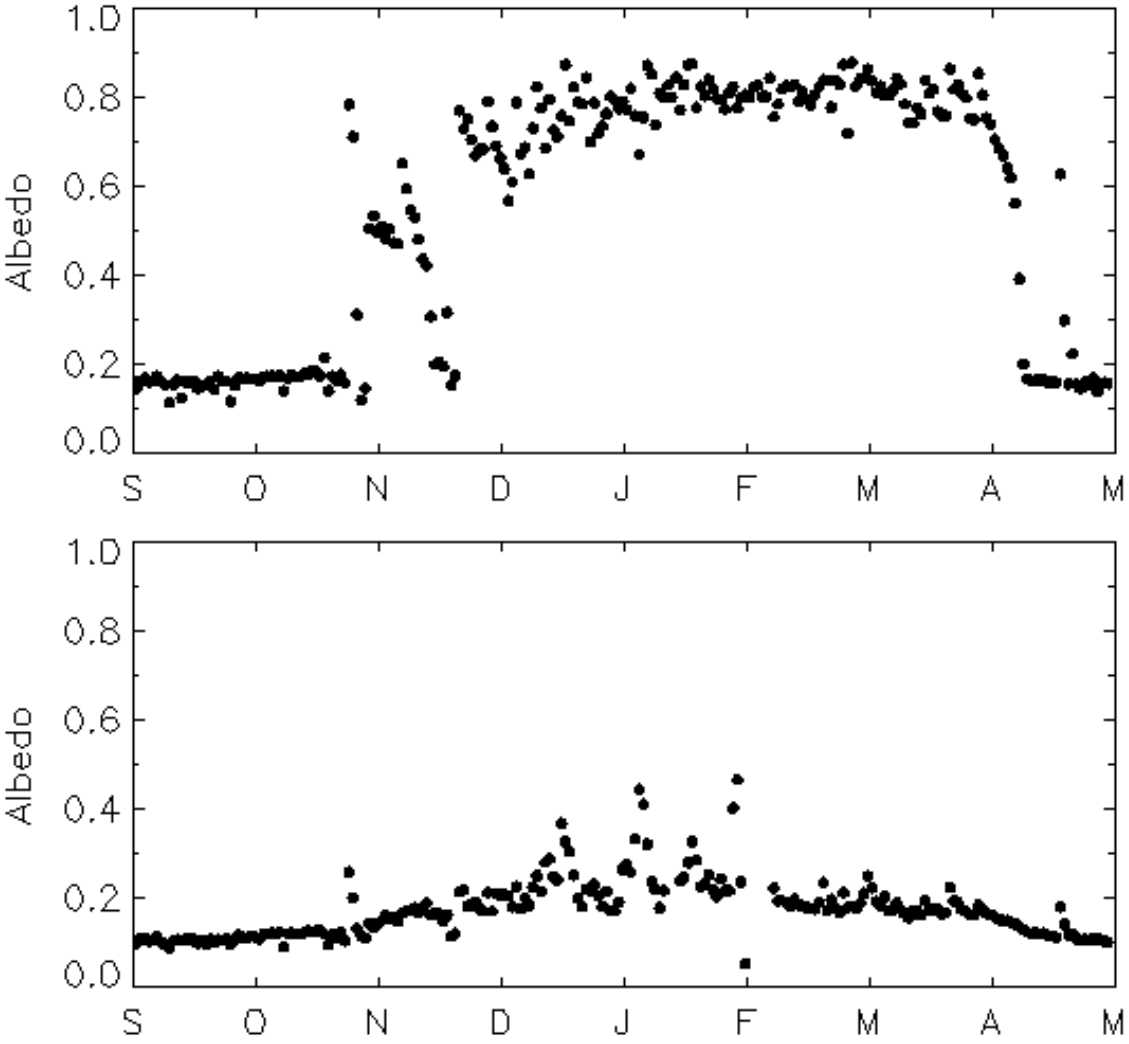
MODIS maximum albedo

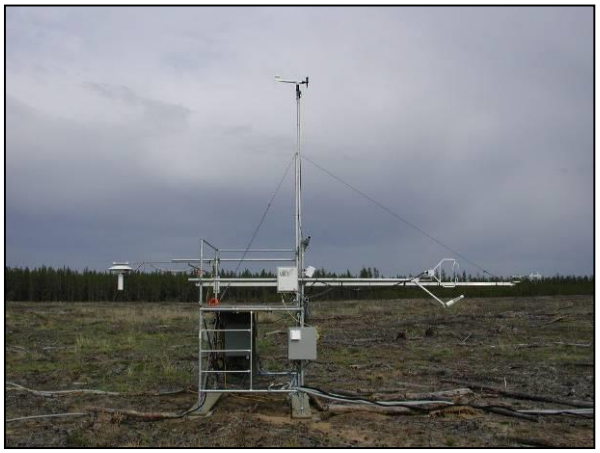


Barlage et al. (2005). *Geophysical Research Letters*, doi:10.1029/2005GL022881
Essery (2013). *Geophysical Research Letters*, doi:10.1002/grl.51008

Snow Albedo Masking by Forests

BERMS clearing and pine forest (LAI ~ 1.8), Canada



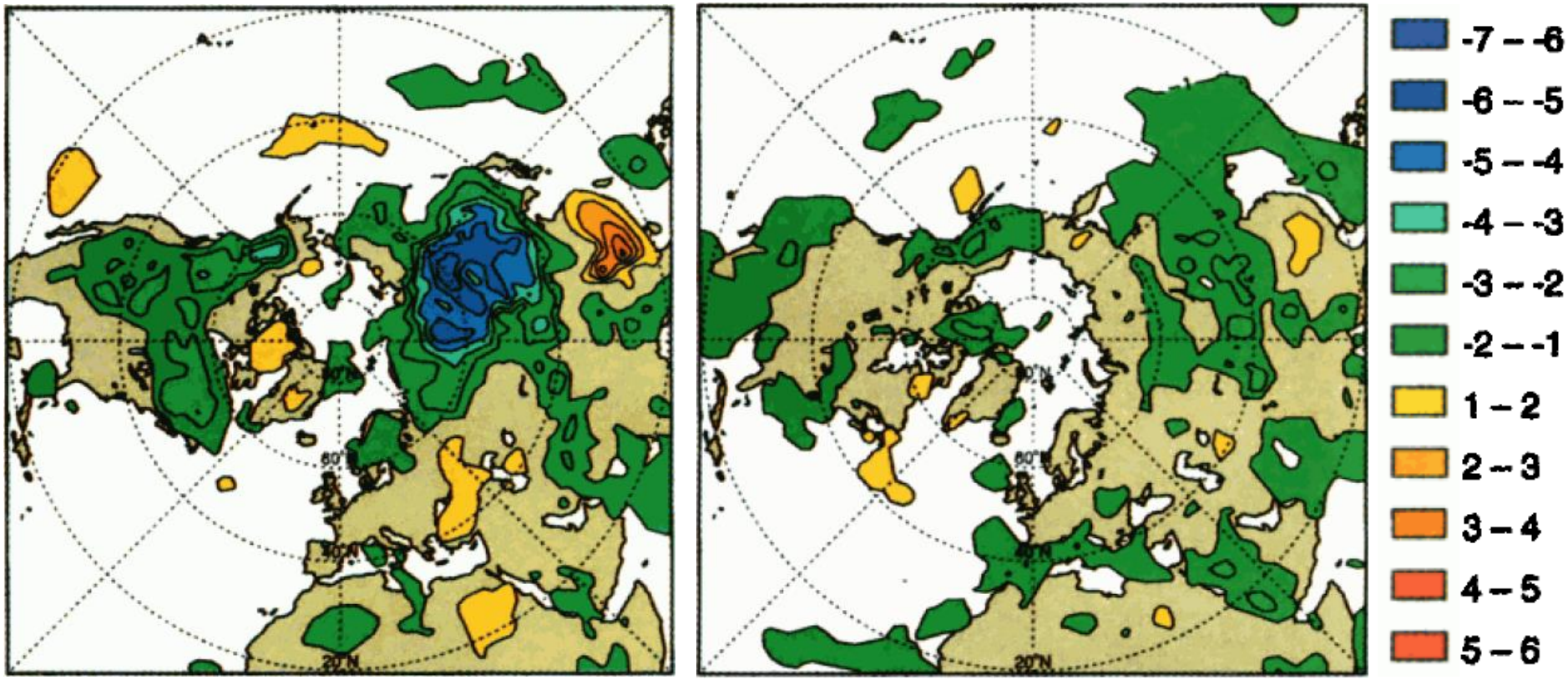


Data from Alan Barr, Environment Canada

Snow Albedo Masking by Forests

March – April 1996

March – April 1997

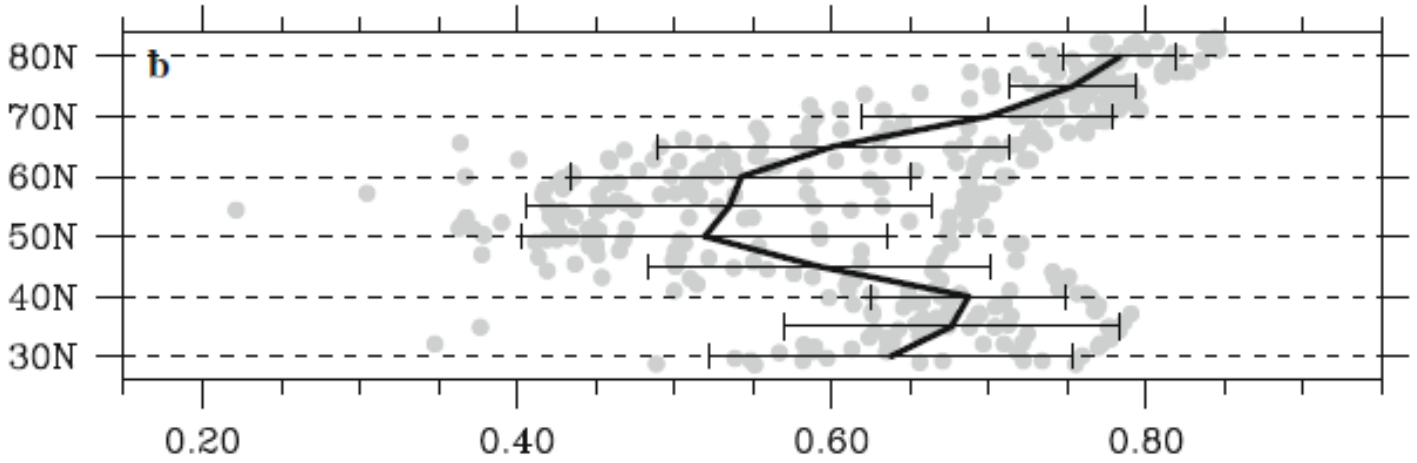


ECMWF 850 hPa temperature day 5 error

Viterbo and Betts, 1999. *Journal of Geophysical Research*, **104**, 27803 – 27810

Snow Albedo Feedback Masking by Forests

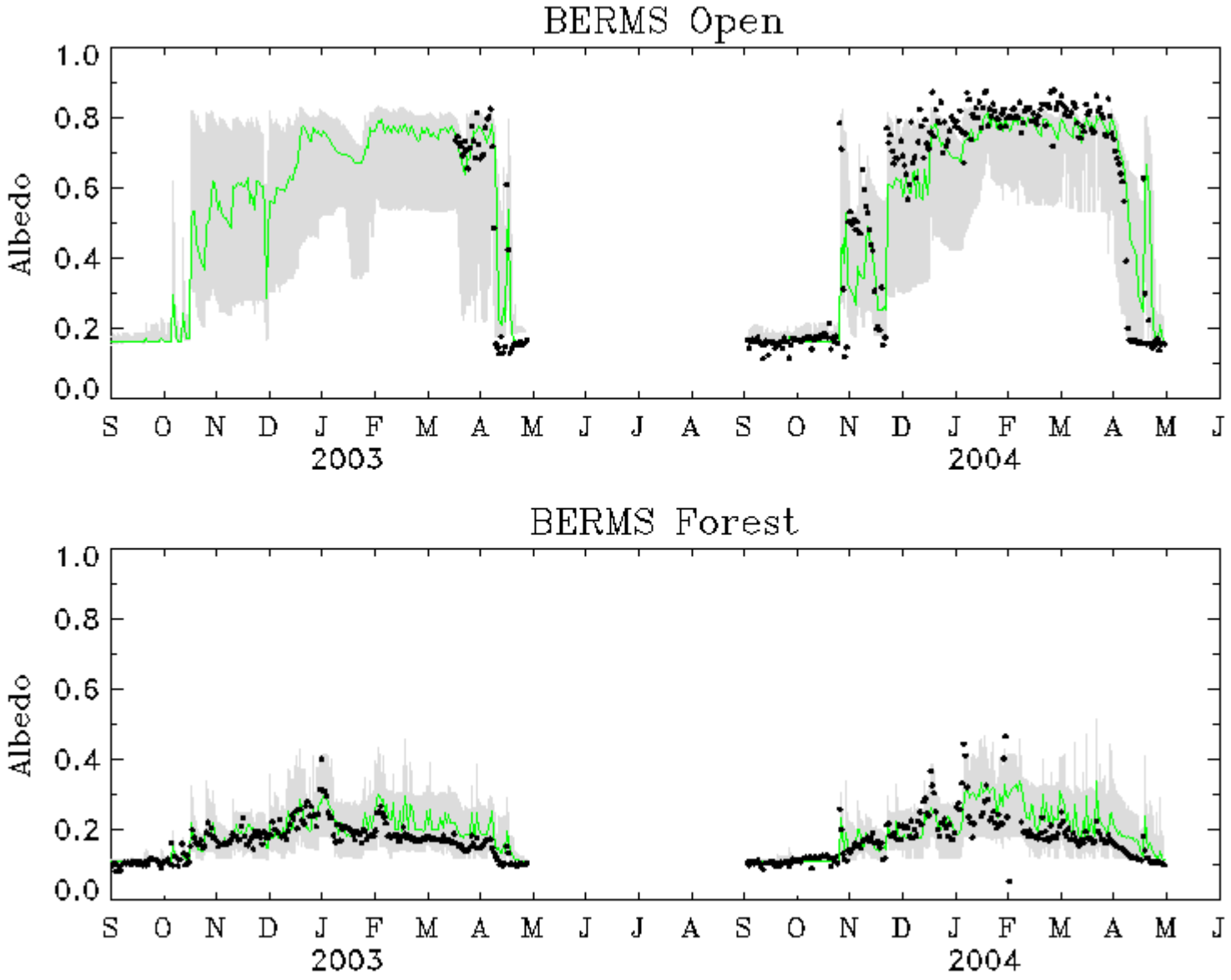
Qu and Hall (2007, 2014):
CMIP3 and CMIP5 models have highest spread in snow-covered albedo where it is lowest (boreal forest zone)



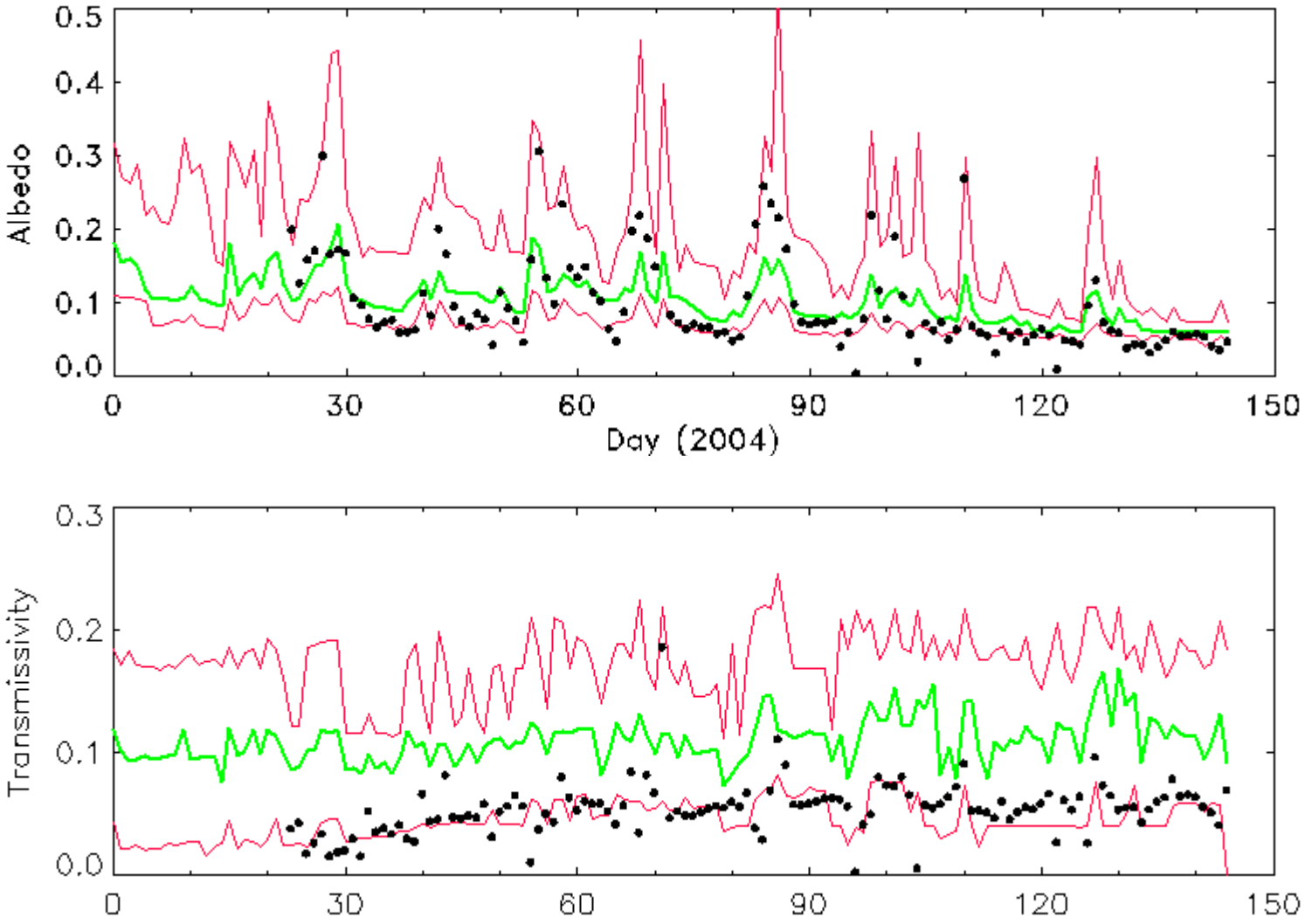
Significance and sources of spread reviewed by Thackeray and Fletcher (2016). *Progress in Physical Geography*, **40**(3)

1. canopy radiative transfer model (5 models in CMIP3)
2. mean of canopy and ground albedos, with and without snow (7 models)
3. canopy and ground albedos not treated separately (3 models)
4. snow-covered albedo independent of vegetation type (3 models)

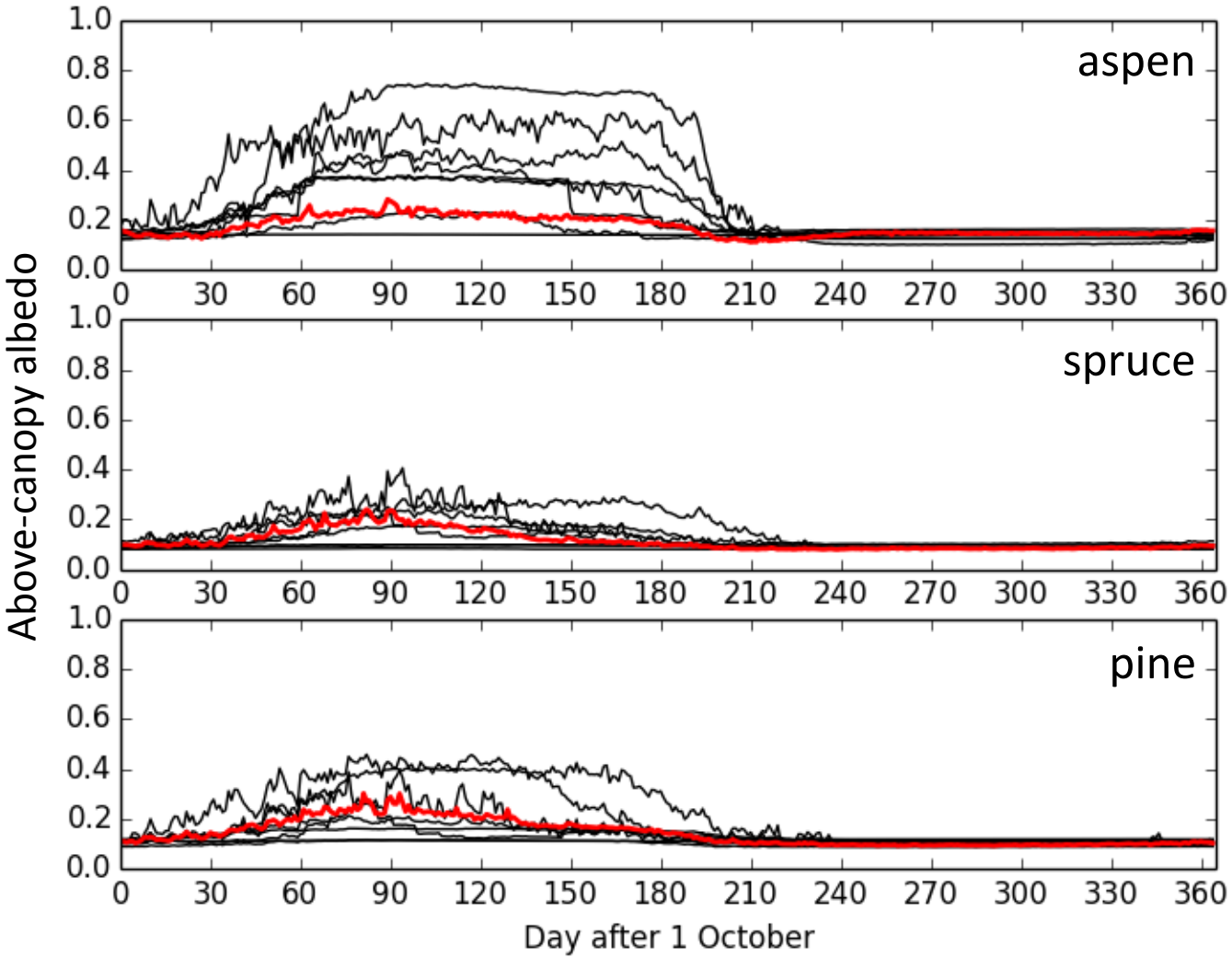
SnowMIP2 Results: BERMS Clear-cut and Pine Sites



SnowMIP2 Results: Alptal Forest Site



ESM-SnowMIP Results: BERMS Sites



Conclusions

- Jarvis (1976) model of stomatal conductance was influential in development of biophysics for Earth System Models, but has been largely superseded by models based on photosynthesis

- Work of Sellers (1980s) building on work of Ross (1970s and earlier) remains pretty much state-of-the-art in canopy radiative transfer for Earth System Models

- Challenges remain:
  - large-scale determination of canopy parameters
  - representation of 3D canopy structure in 1D models (Pinty et al. 2006)
  - influence of snow on and below canopies