Review of Land Surface Models

Nataliya Bulygina

Imperial College London

Talk outline

- Key roles by the Surface in Climate
- Evolution of Land Surface Models
  - First generation
  - Second generation
  - Third generation
- CWC: targeted limitations in JULES
- The limitations treatment in other LSMs

Key roles by the Surface in Climate

The surface energy balance

- sensible heat
- latent heat
- soil heat flux
- chemical energy (photosynthesis)

The surface water balance

- evapotranspiration
- runoff
- storage

Momentum exchange

- wind

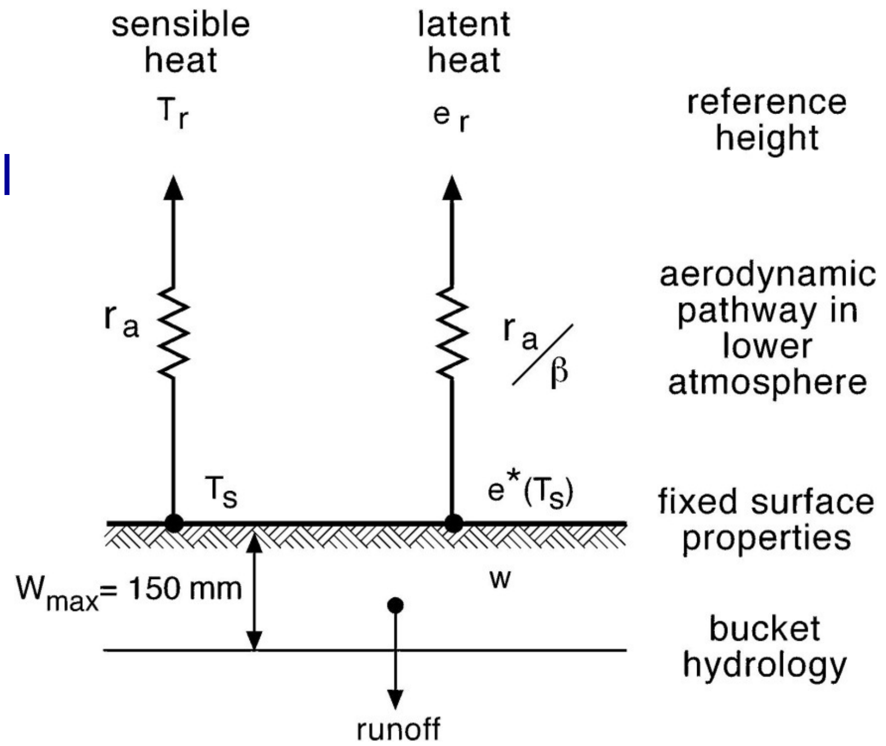
The carbon balance

Evolution of Land Surface Models: first generation

Manabe, 1969:

- No heat conduction into the soil
- Constant soil depth
- Fixed soil properties
- Water content limited AE
- Saturation excess runoff

('Manabe bucket model')

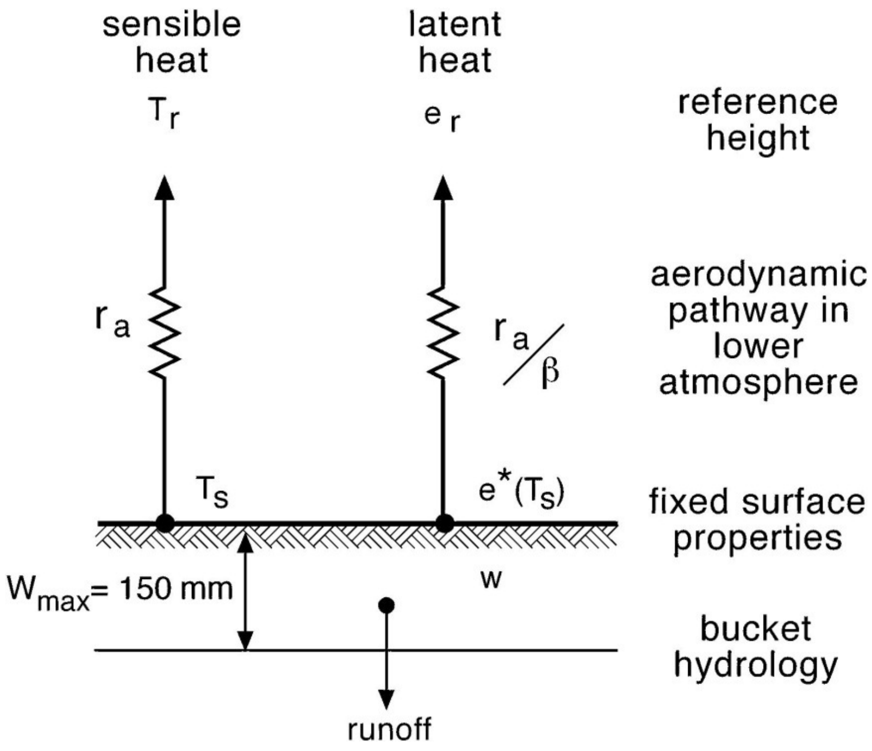


Pitman, 2003

Evolution of Land Surface Models: first generation

Manabe, 1969:

The *Project for Intercomparison of Landsurface Parameterisation Schemes* (PILPS) has shown that the model is *inadequate* for diurnal to multi-annual scale surface hydrology representation.



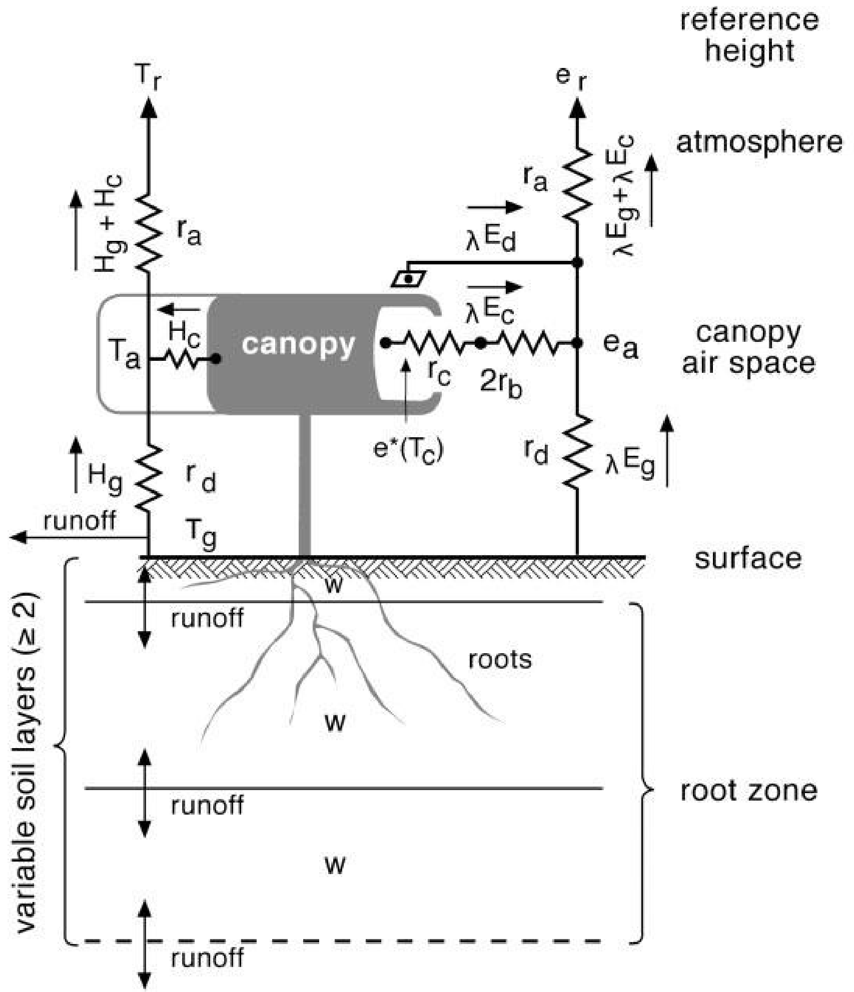
Pitman, 2003; Henderson-Sellers et al, 1995

Imperial College London

Evolution of Land Surface Models: second generation

Deardorff, 1978;
Dickinson, 1983 (BATS);
Sellers, 1986 (SiB):

- Vegetation impacts energy & water budgets, momentum transfer
- Several soil layers (>=2)
- Soil type specific Richards equation-based water transfer
- Saturation / infiltration excess surface runoff generation



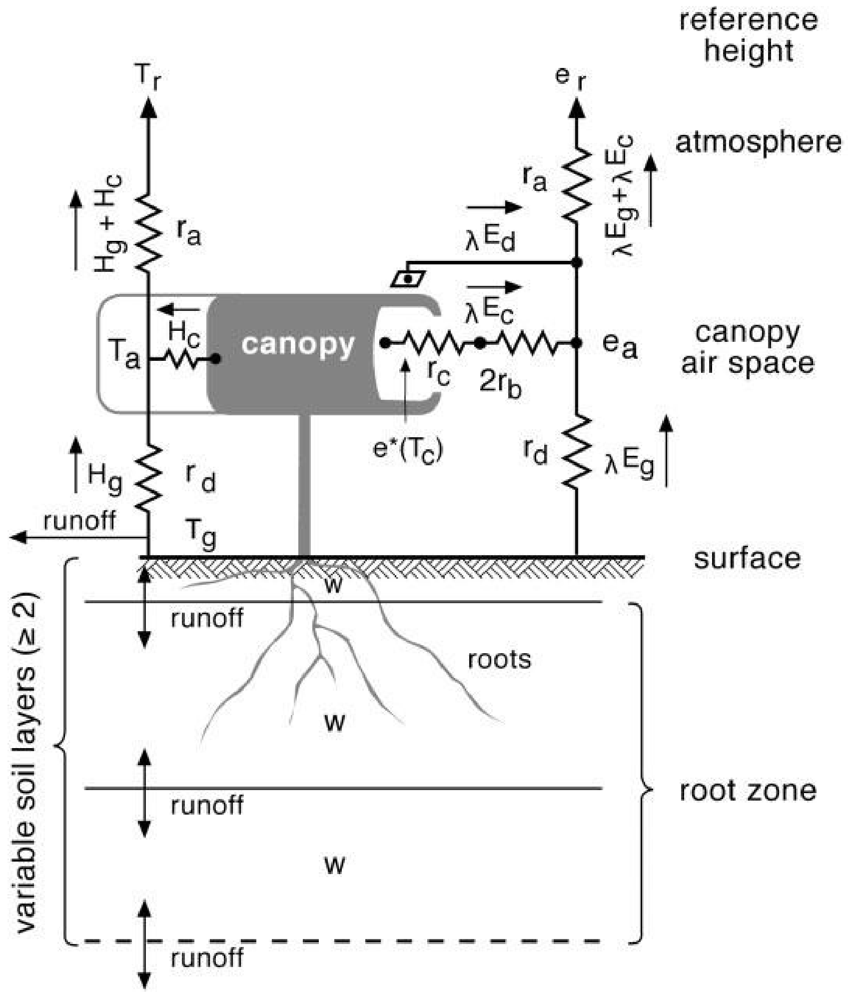
Pitman, 2003

Imperial College London

Evolution of Land Surface Models: second generation

Deardorff, 1978;
Dickinson, 1983 (BATS);
Sellers, 1986 (SiB):

- Outperform the first generation models (PILPS)
- Improve modelling of surface-atmosphere interactions on the time scale of days as shown by
  - Improved precipitation weather forecast (Beljaars et al, 1996)
  - Improved European soil temperature prediction (Viterbo et al, 1999)

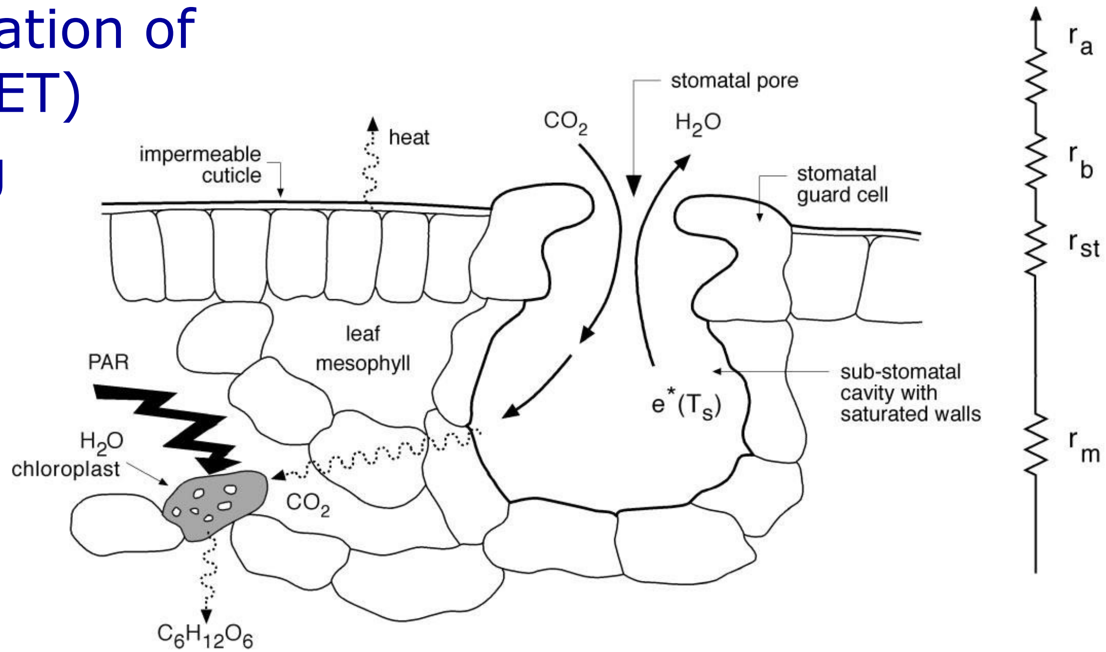


Pitman, 2003; Henderson-Sellers et al, 1995

Evolution of Land Surface Models: third generation

Collatz et al, 1991;
Sellers et al, 1992:

- Semi-empirical representation of vegetation conductance (ET)
- Carbon balance modelling



Pitman, 2003

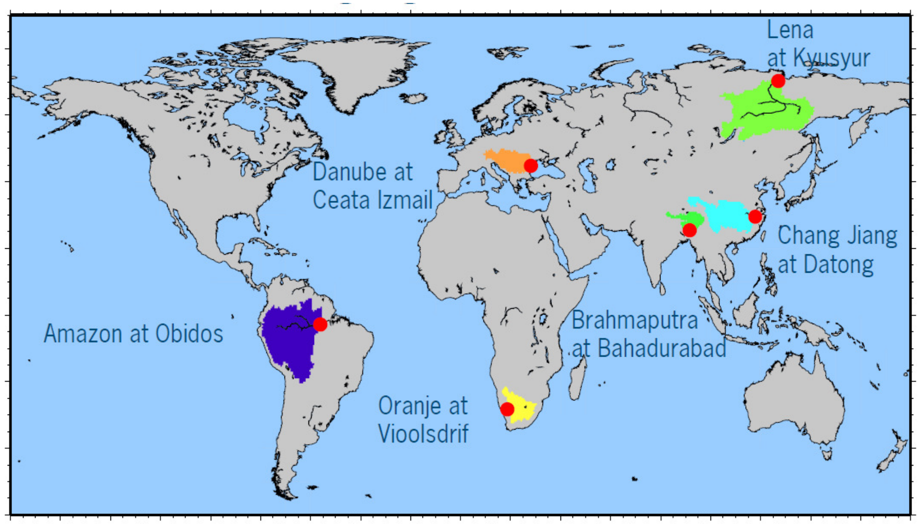
Imperial College London

Model uncertainty

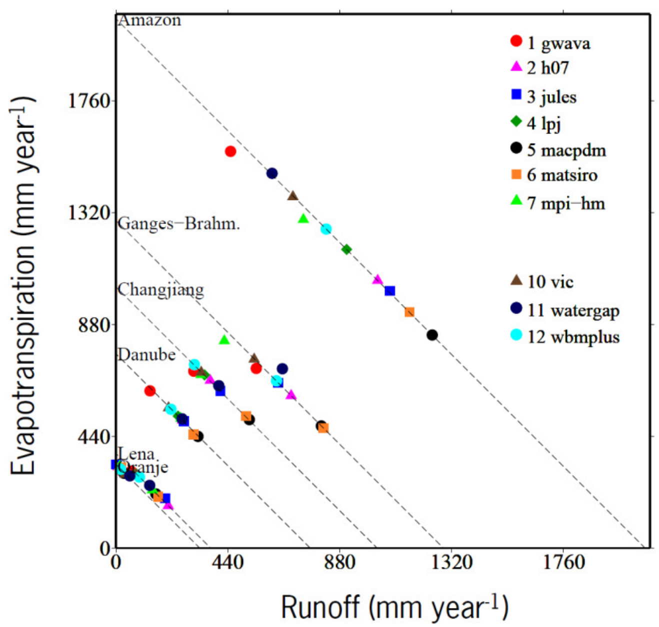
A comparison of 10 different surface exchange schemes was applied to six large catchments around the world

Each was driven with the same driving data

Differences in simulated evaporation and runoff were highly significant



Watch-GWSP model intercomparison



+/- 40 to 100 %

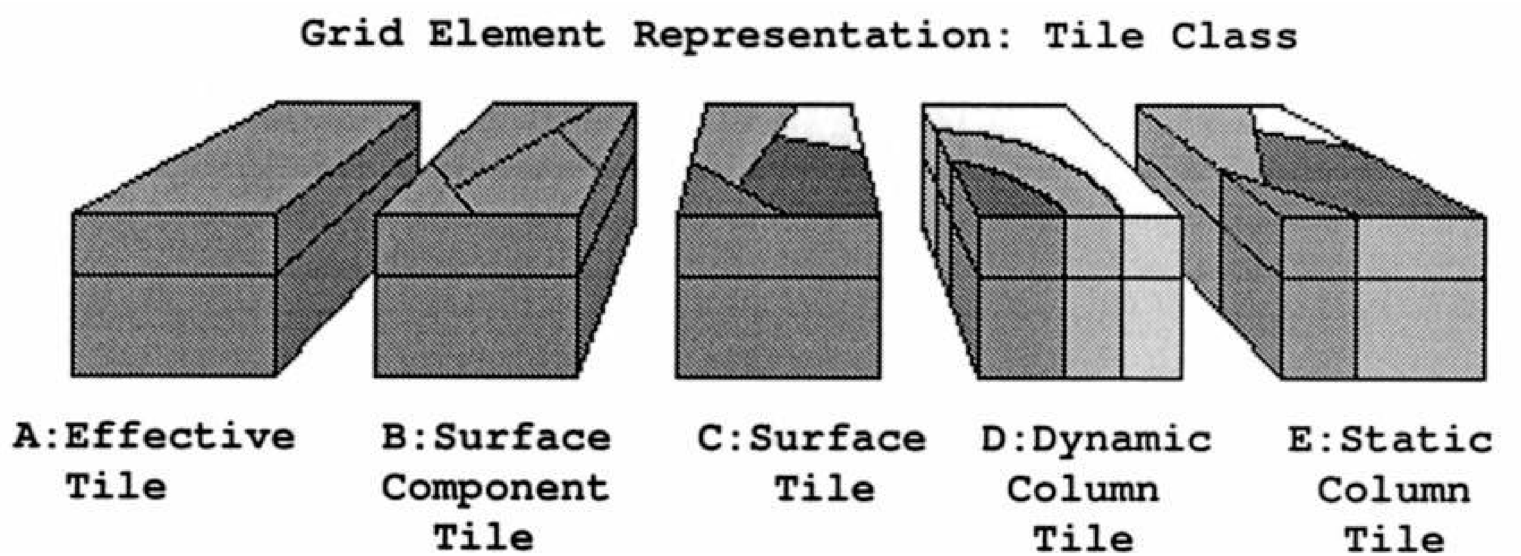
Imperial College London

CWC: targeted limitations in JULES

- Simple grid spatial *heterogeneity* treatment
- Model *dimensionality*: 1D vertical water movement
- No *interactions* between model soil columns
- *Parameterisation* via pedo-transfer functions
- No coupling with *groundwater*

Imperial College London

The limitations treatment in other LSMs: heterogeneity (1)



JULES, CEH

NSIPP, NASA

CLM4, NCAR
Mosaic, NASA
SiBUC, KyotoU
SECHIBA, France

Boone et al, 2004

The limitations treatment in other LSMs: heterogeneity (2) & interactions

- Heterogeneity(2)
  - Soil moisture
    - -PDM (JULES)
    - -TOPMODEL-based (JULES, CLM4, NSIPP, VISA)
  - Physical properties
    - -Pdf for K_{sat} (analytical eqns - SWAP)
- Interactions
  - Routing (ISBA)
  - Catchment-based modelling (NSIPP)
  - Sub-grid interaction
    - -Soil water in lower soil layer (SECHIBA)

Imperial College
London

The limitations treatment in other LSMs: parameterisation & groundwater

- Parameterisation
  - Pedo-transfer functions (JULES, CLM4, VISA, Mosaic)
  - Empirical eqns and ‘expert’ judgement (SWAP, NCIPP)
  - Some fixed parameters (for TOPMODEL)
  - K_{sat}– exponential change with depth (CLM4, NSIPP, VISA)

- Groundwater
  - Time-variable soil column depth (SWAP)
  - Additional layer for a coupled aquifer (CLM4)

Imperial College London

Summary

- State-of-the-art LSMs approximate large scale physical processes using point-scale laws
- Effects of various simplifying assumptions are not known
- No evaluation of prediction uncertainty