Land Surface Modeling in the Extra-tropics

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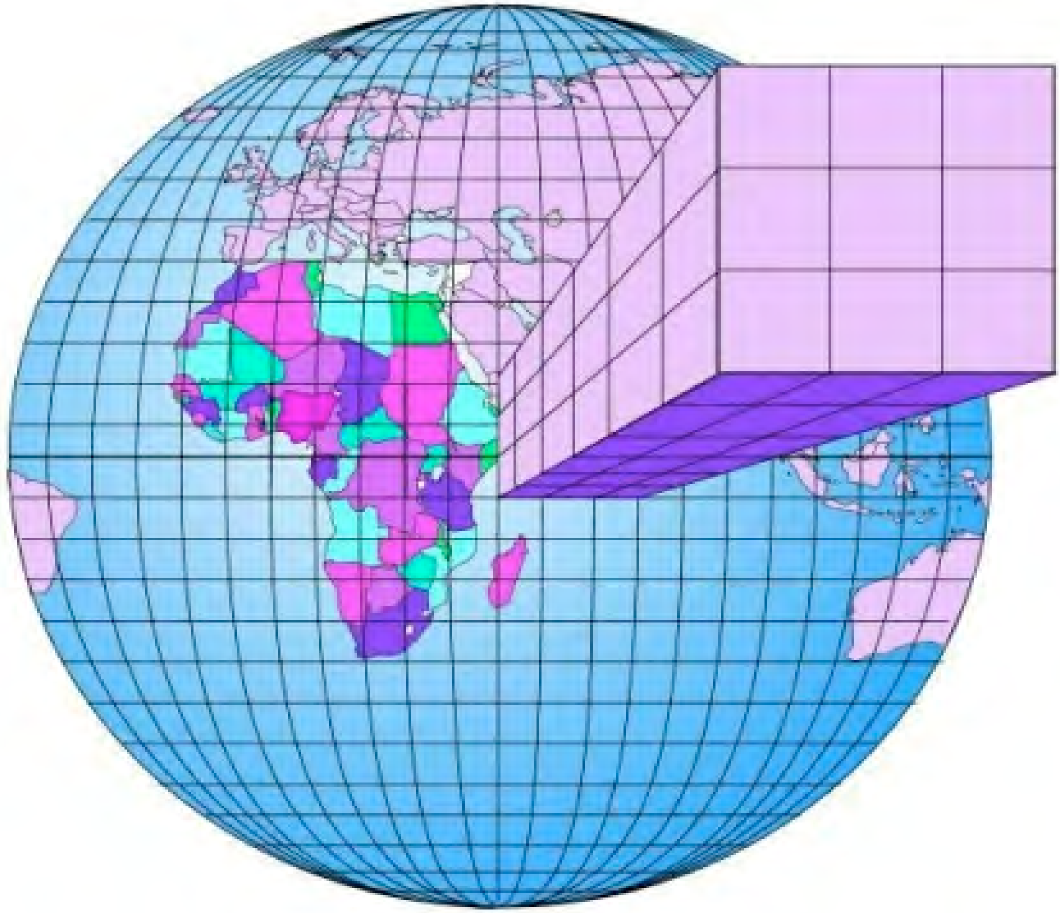
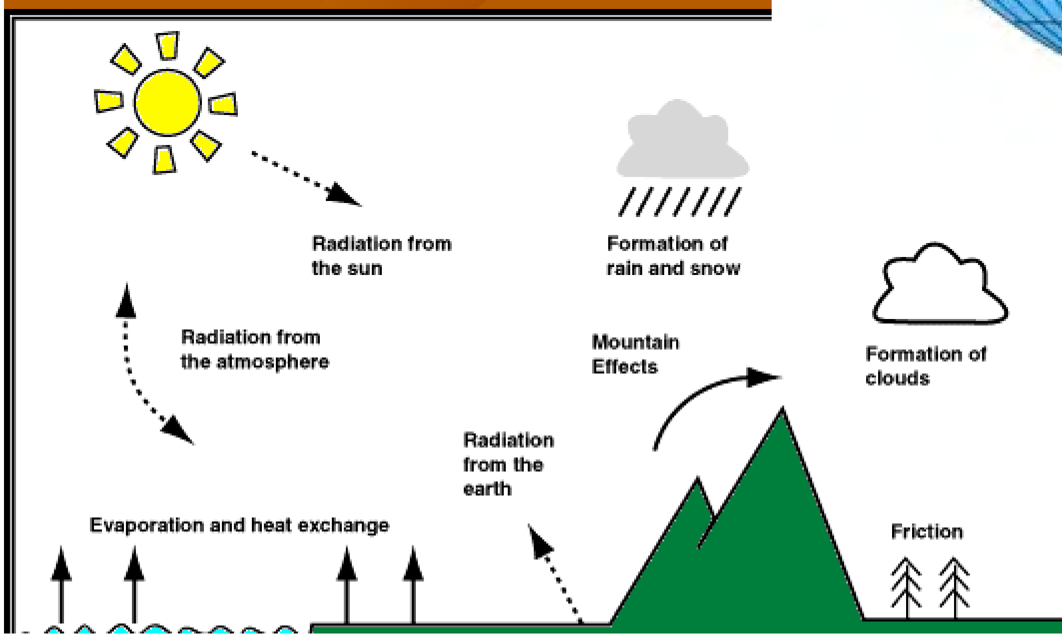
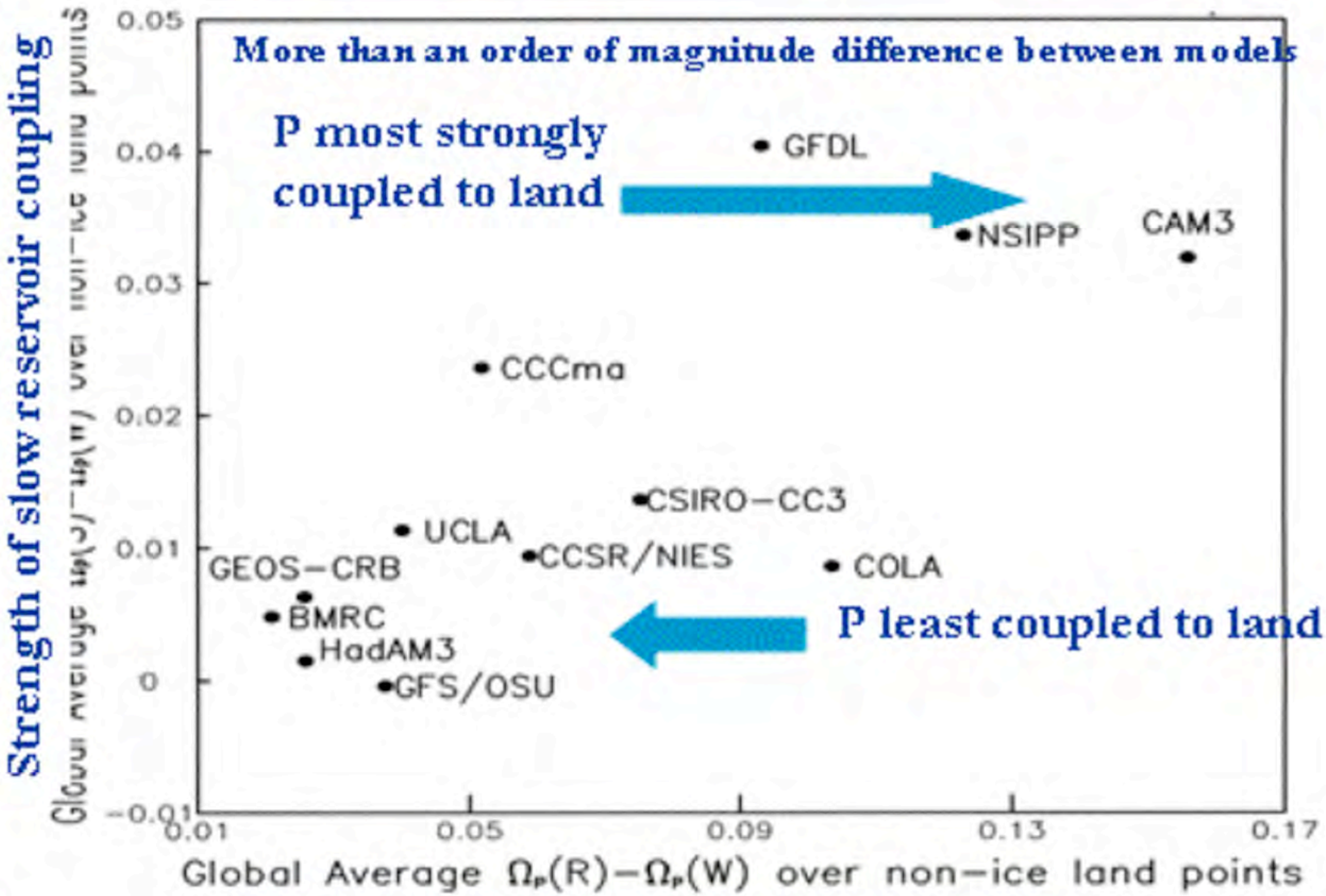
Climate Model





Scaling/parameterization

Need to describe details within the grid boxes



Strength of all reservoir coupling

Fig. 7 Global ave[illegible] points for all twelve models.

Outline

- Processes to be modeled
- What's right and wrong with current state of the art?
- Emphasis on: a) canopy- soil or snow interaction; b) treating complexity of land surface.

Processes to be modeled?

- Basic Physical Constraints
  - Energy Conservation
  - Water Conservation
- What comes in and goes out?
- What interacts with and is stored at land surface?
- Where can substantial errors be made?

Solar –highly variable input

- Geometry
  - Latitude
  - Time of year
  - Diurnal
- Cloud properties
- Aerosols
- Atmospheric Composition (H20, O3, CO2)

Interaction of solar input with "land surface"

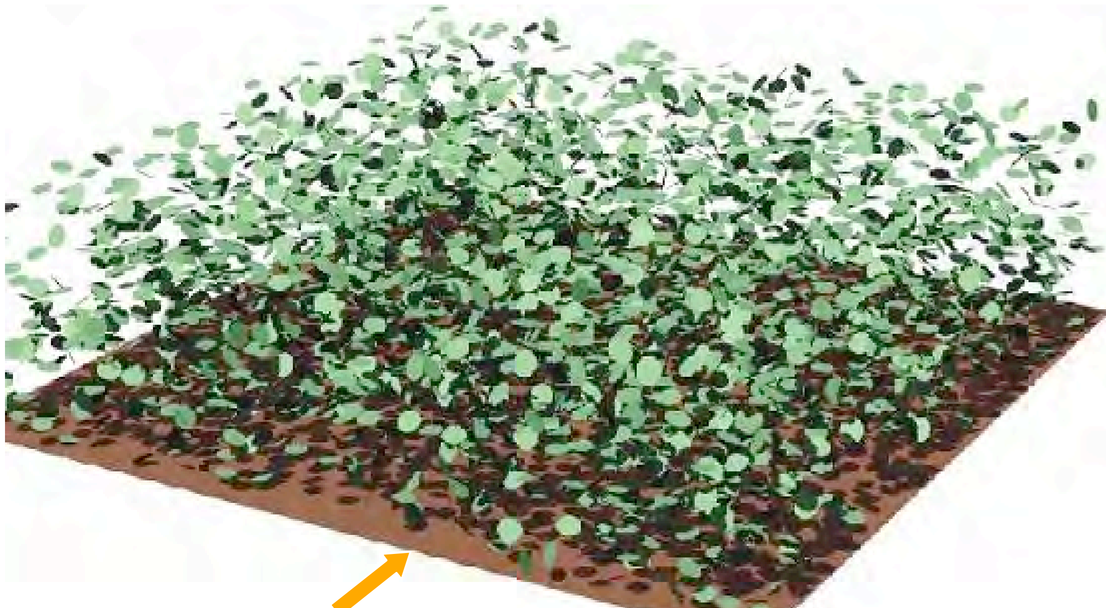
- Land surface is a complex system of surfaces
  - Canopy consisting of leaves, stems and their geometric properties
  - Soil surface –can be overlain by snow
  - Other surfaces – water, ice
- Each of these surfaces has its own energy and water balance.
- How much to include-what to lump together?

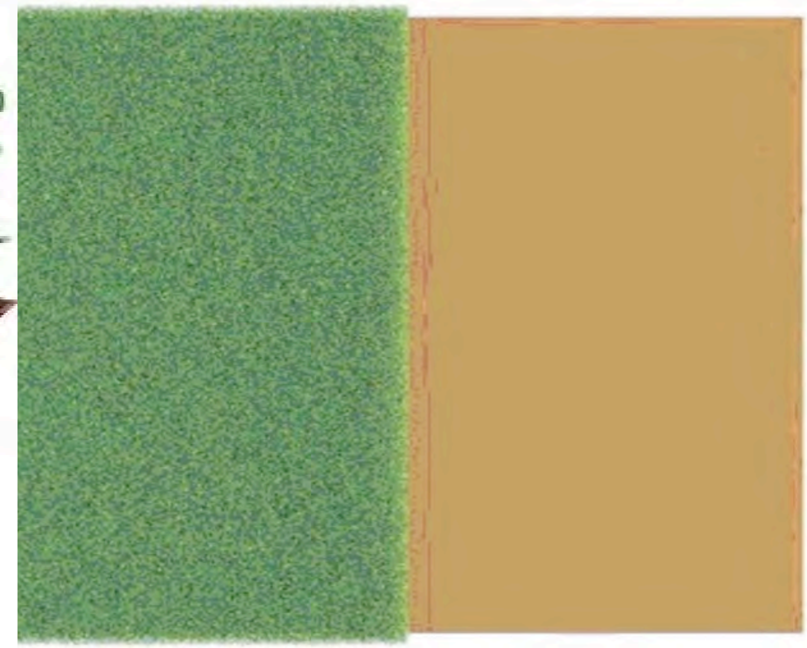
Lumping together

- Simplifies but leads to error – how much?
- Albedo describes the total system reflected solar –
  - models now attempt to construct from individual elements
  - leaves, canopy and their geometries
  - -large compared to wavelengths so logic is mostly that of ray-tracing between objects with partial absorptions when a ray hits an object
  - leaves assigned single scattering albedos.

How now done?

- Describing mutual shading of leaves a key element.
- Leaves treated as a plane parallel scattering cloud – this adds up to canopy albedo – combines with albedo of surface under canopy by adding principle.
- Soil or other underlying surface not vertically under canopy is treated as radiatively separate

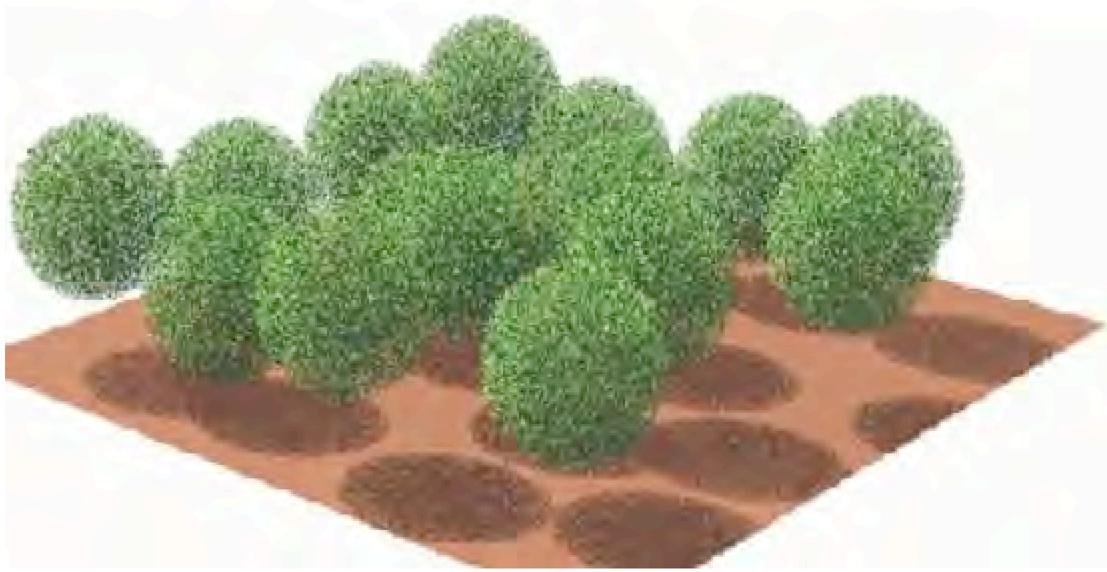


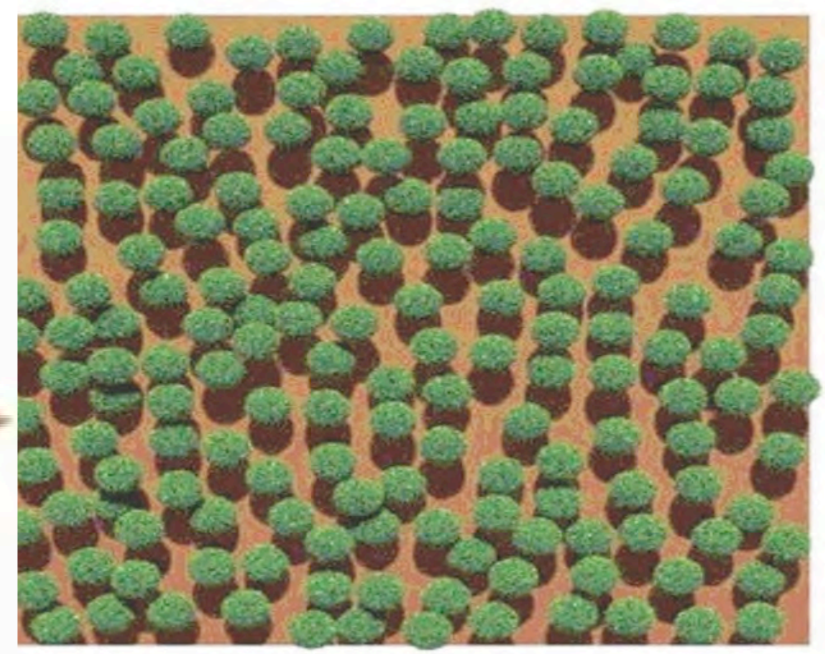


Current models

Thanks to B. Pinty for fig.

Reality





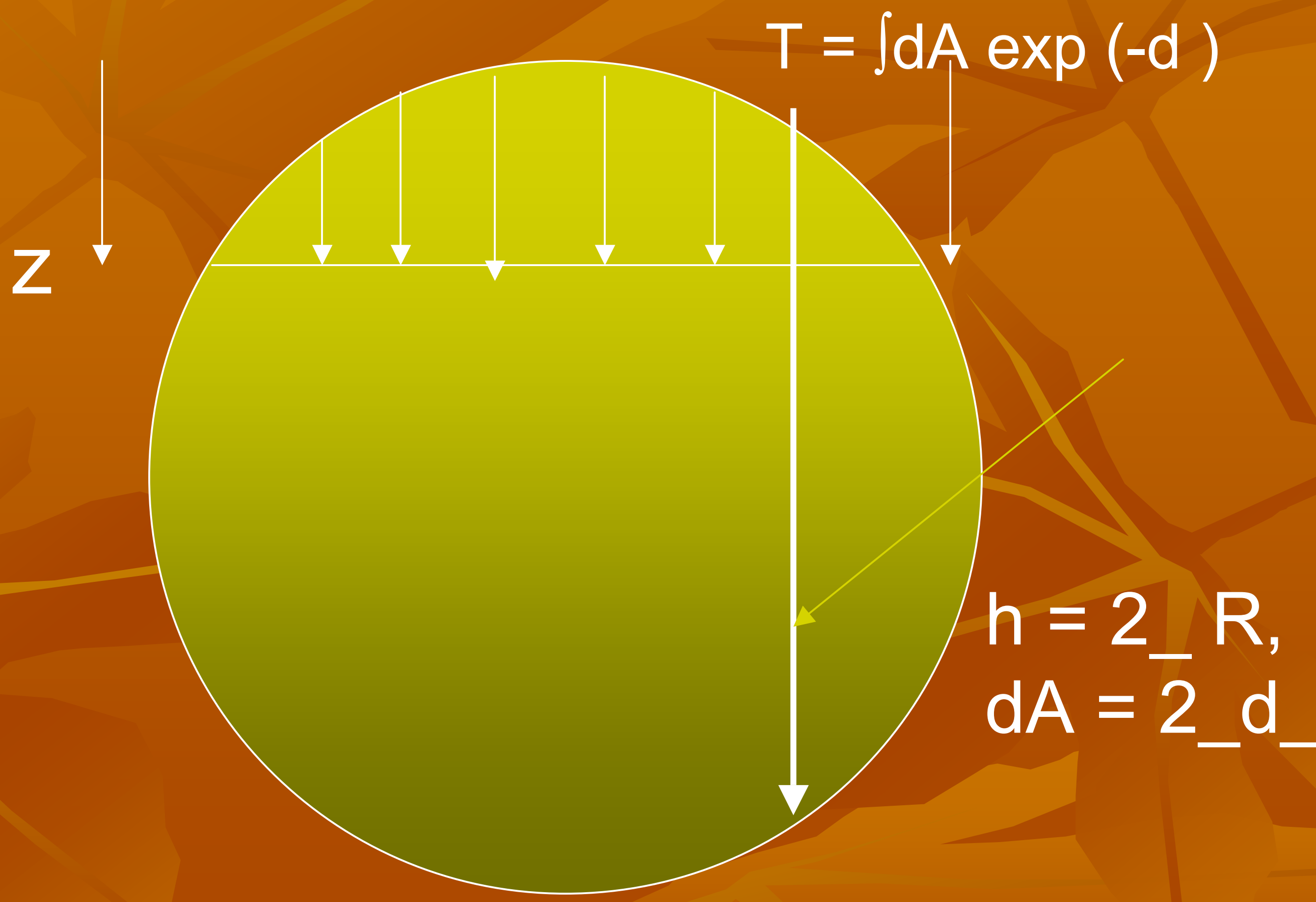
Thermal Infrared –"Long-wave"

- Downward spectral from atmosphere – atmospheric model lumps into total.
- All land surface objects have commonly been treated as black bodies but spectral emissivity of soils far from black body
- If emissivity included, overlying leaves treated with same logic as in solar – i.e a cloud.

Spherical Bush – an alternative to cloud of leaves

- Spherical geometry nearly as simple as planar.
- Can see the strong analytic differences between this idealization of a canopy and the cloud of leaves view.
- Through statistical modeling, can treat interactions between bushes and in limit of closed canopy recover the homogeneous cloud view.

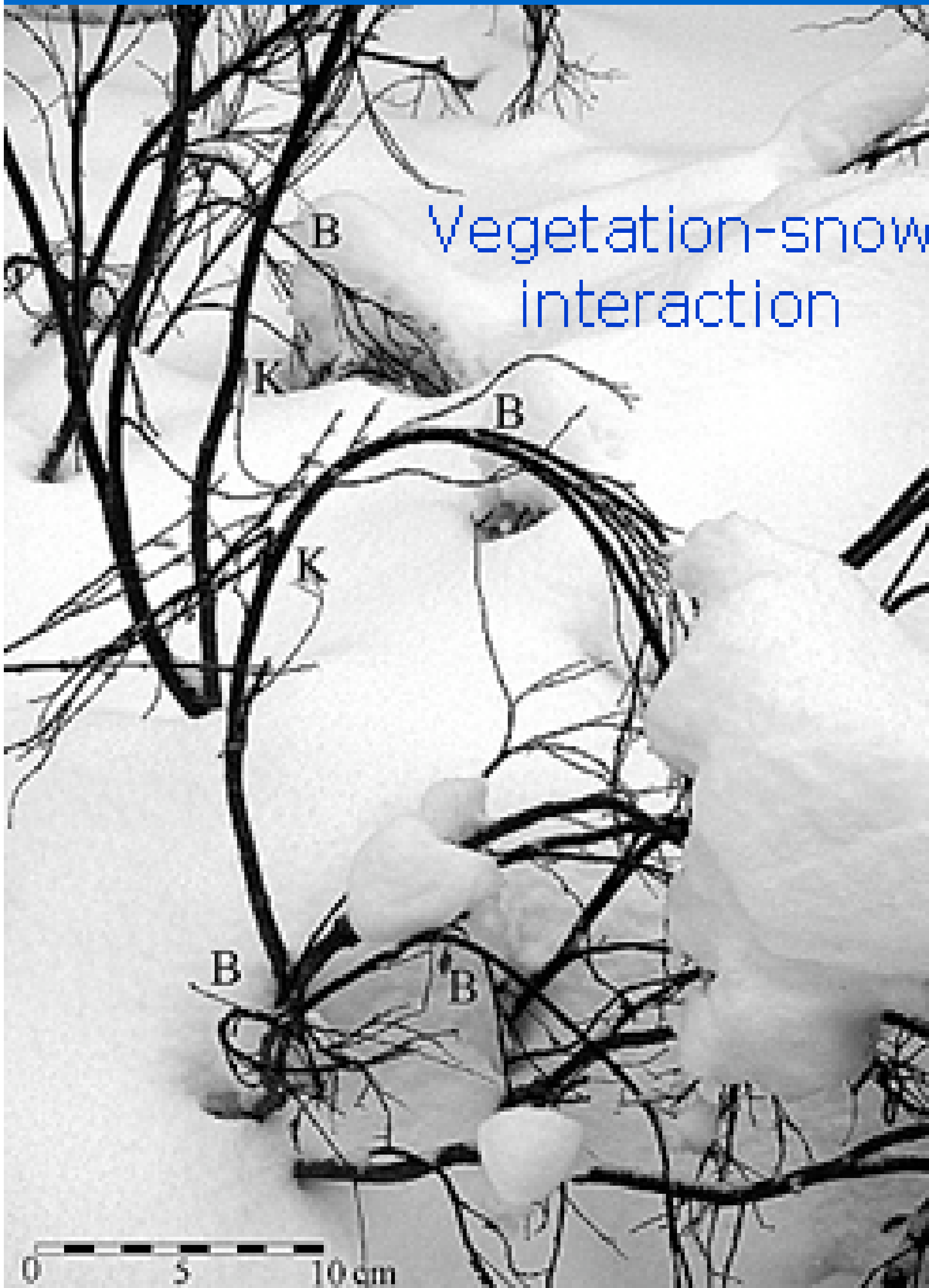
Bush distribution of paths –linear.

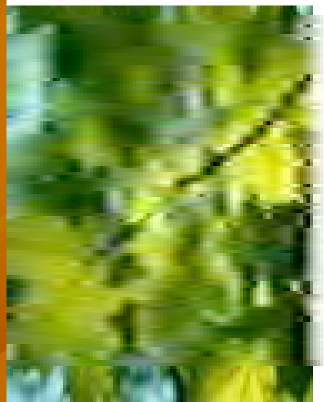


What and where makes a difference?

- Most important is the simple geometric effect of shadows – the radiative transfer issues within canopy alone make less difference but also important.
- Canopy open and underlain by bright soil –semiarid – or by snow.
- Factors of two or more differences and description of energy loading between canopy and soil/snow

Vegetation-snow interaction





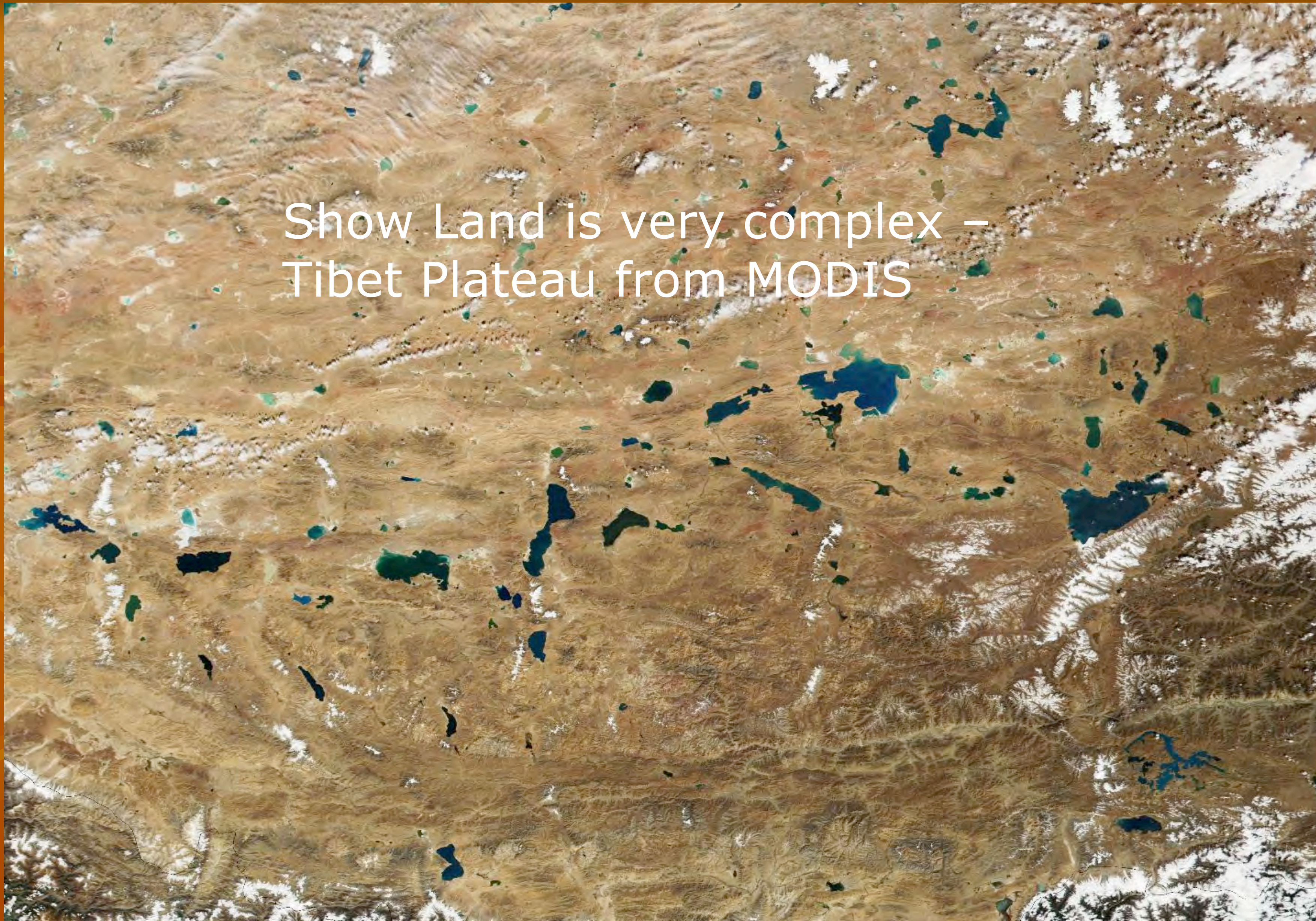
Leaf Scale

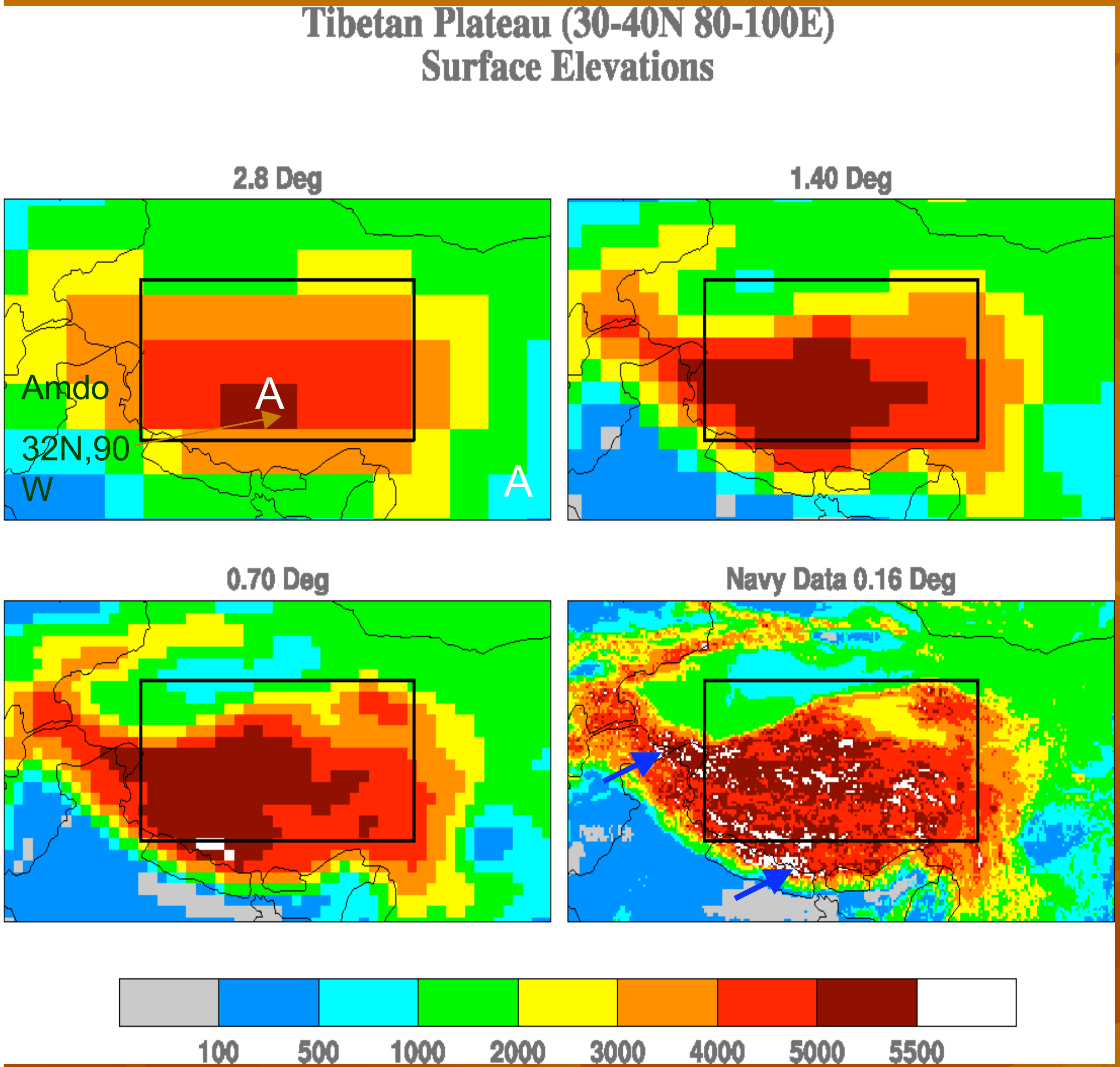
Plot Scale

PFT fractions

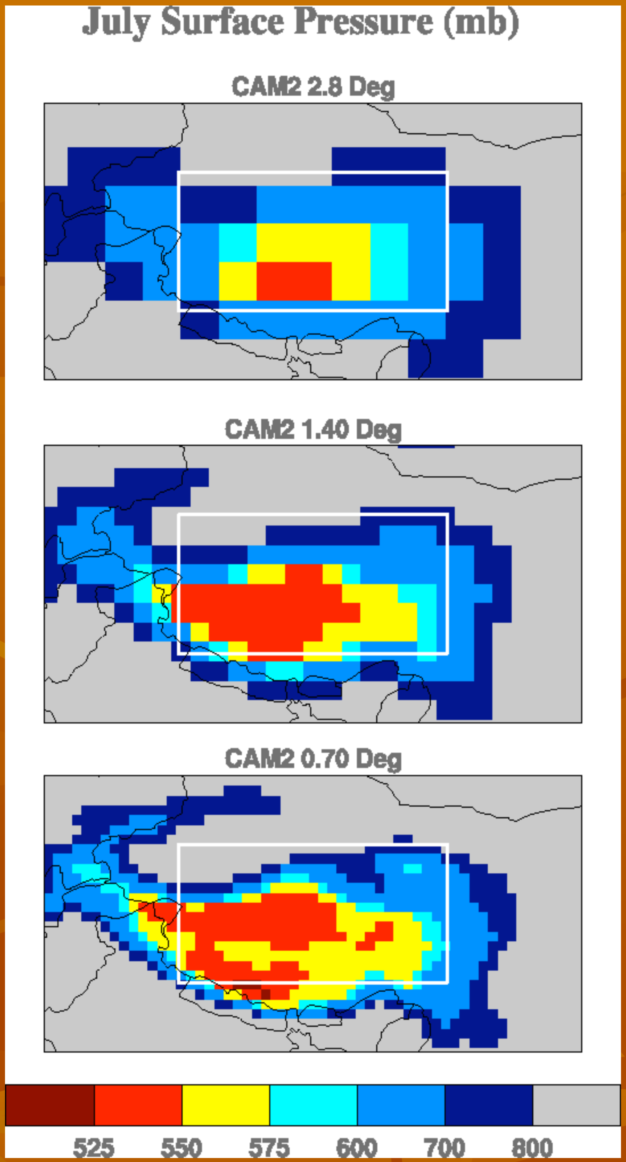
Major source of error?

- Models do separate energy budgets for canopy and underlying surface but details have large errors.
- Very difficult to get the turbulent flux energy exchanges with better than order of magnitude accuracy without a lot of research, e.g. 3-D fluid modeling- that appears not to have been done.
- Statement that adding trees decreases snow cover probably right but as a quantified feedback –very flimsy.


Show Land is very complex –
Tibet Plateau from MODIS

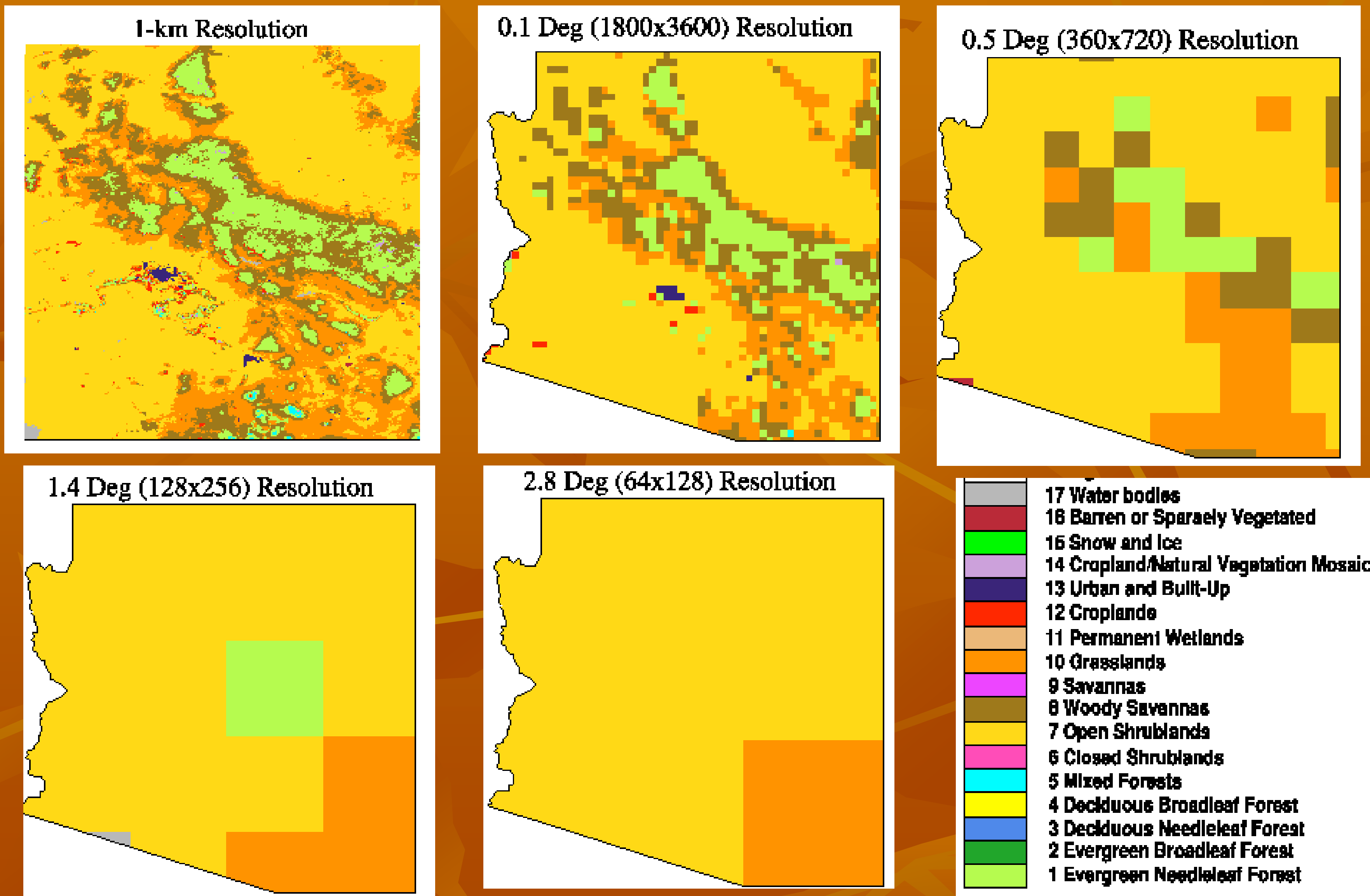


Tibetan Plateau (30-40N 80-100E)
Surface Elevations
2.8 Deg
1.40 Deg
Amdo
A
32N,90
W
A
0.70 Deg
Navy Data 0.16 Deg
100
500
1000
2000
3000
4000
5000
5500



July Surface Pressure (mb)
CAM2 2.8 Deg
CAM2 1.40 Deg
CAM2 0.70 Deg
525
550
575
600
700
800

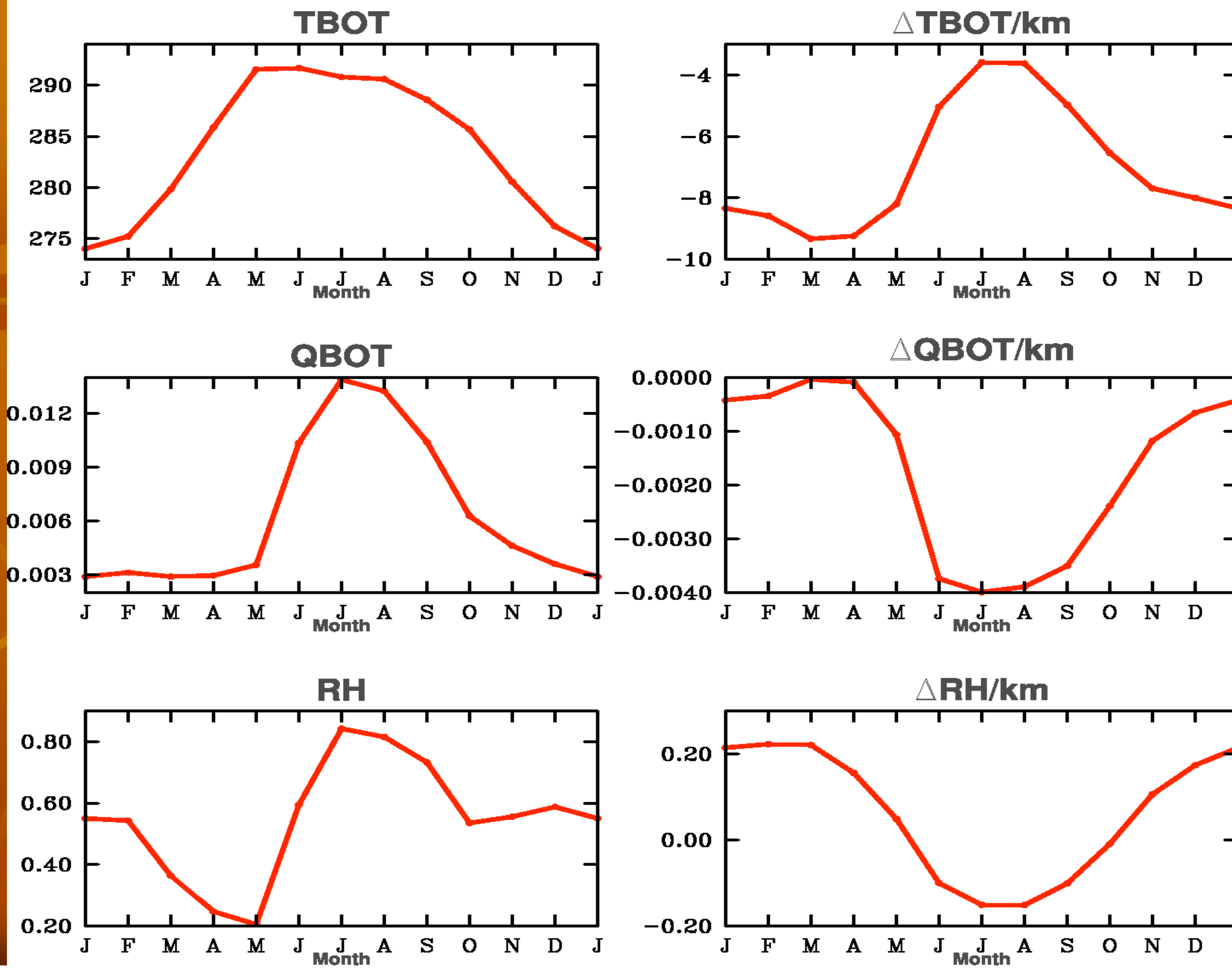
Example: land cover from satellite pixel scale to Climate model

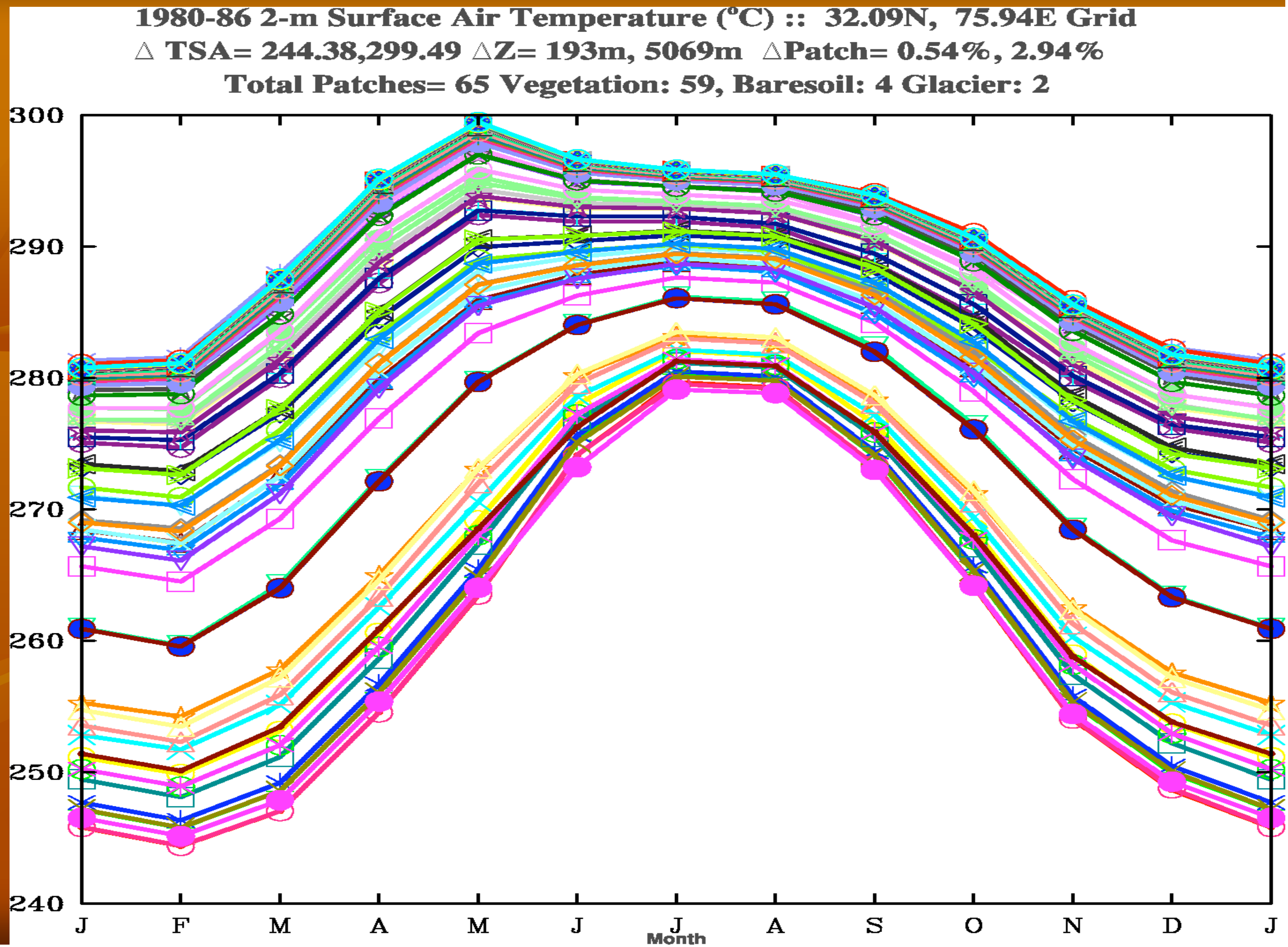


Arizona: 53.1%Open shrubs 19.6%Grasslands 15.8%Woody Savanna
9.7% Evergreen Needle-leaf 0.5%Croplands 0.27% Urban (900 km2)

22 Year Average :: Lowest Layer Model Fields and Vertical Gradients

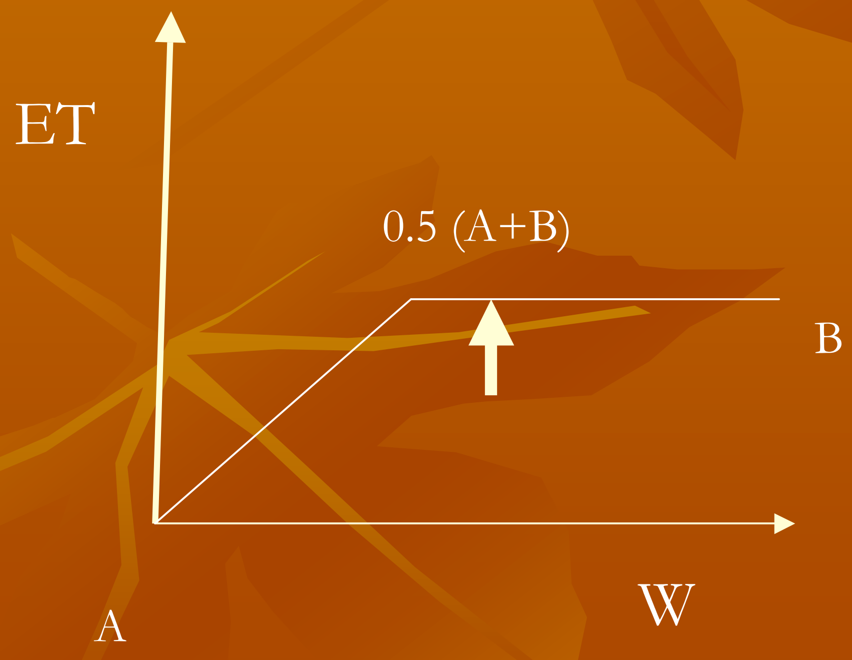
Himalaya :: 32.09, 75.94




1980-86 2-m Surface Air Temperature (°C) :: 32.09N, 75.94E Grid
△ TSA= 244.38,299.49 △Z= 193m, 5069m △Patch= 0.54%, 2.94%
Total Patches= 65 Vegetation: 59, Baresoil: 4 Glacier: 2
300
290
280
270
260
250
240
J
F
M
A
M
J
J
A
S
O
N
D
J
Month

Simple example of scaling issue

- Wet versus dry surface



ET(A/2 + B/2) = ET(B)

(ET(A) +ET(B)) = 0.5 ET(B)

Conclusions

- Land surface processes in climate models is still a frontier area.
- Many different ideas as to what is most impootant and not enough quantification as to what is wrong and what are the most important errors to address.
- Climate models have become easier to use but the land component still have pitfalls for the inexperienced