Climate Model

Scaling/parameterization
Need to describe details within the grid boxes
More than an order of magnitude difference between models

P most strongly coupled to land

P least coupled to land
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.

\[ h = 2R, \]

\[ dA = 2dT \]

\[ T = \int dA \exp(-d) \]
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

End of winter

- woodland
- tall shrub
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
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)
Simple example of scaling issue

- Wet versus dry surface

\[
\text{ET}(A/2 + B/2) = \text{ET}(B)
\]

\[
(\text{ET}(A) + \text{ET}(B)) = 0.5 \text{ ET}(B)
\]
Conclusions

- Land surface processes in climate models is still a frontier area.
- Many different ideas as to what is most important 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.