Using MODIS Data to Characterize Climate Model Land Surface Processes-Impacts of Land Cover/Use Change on Surface Hydrological processes

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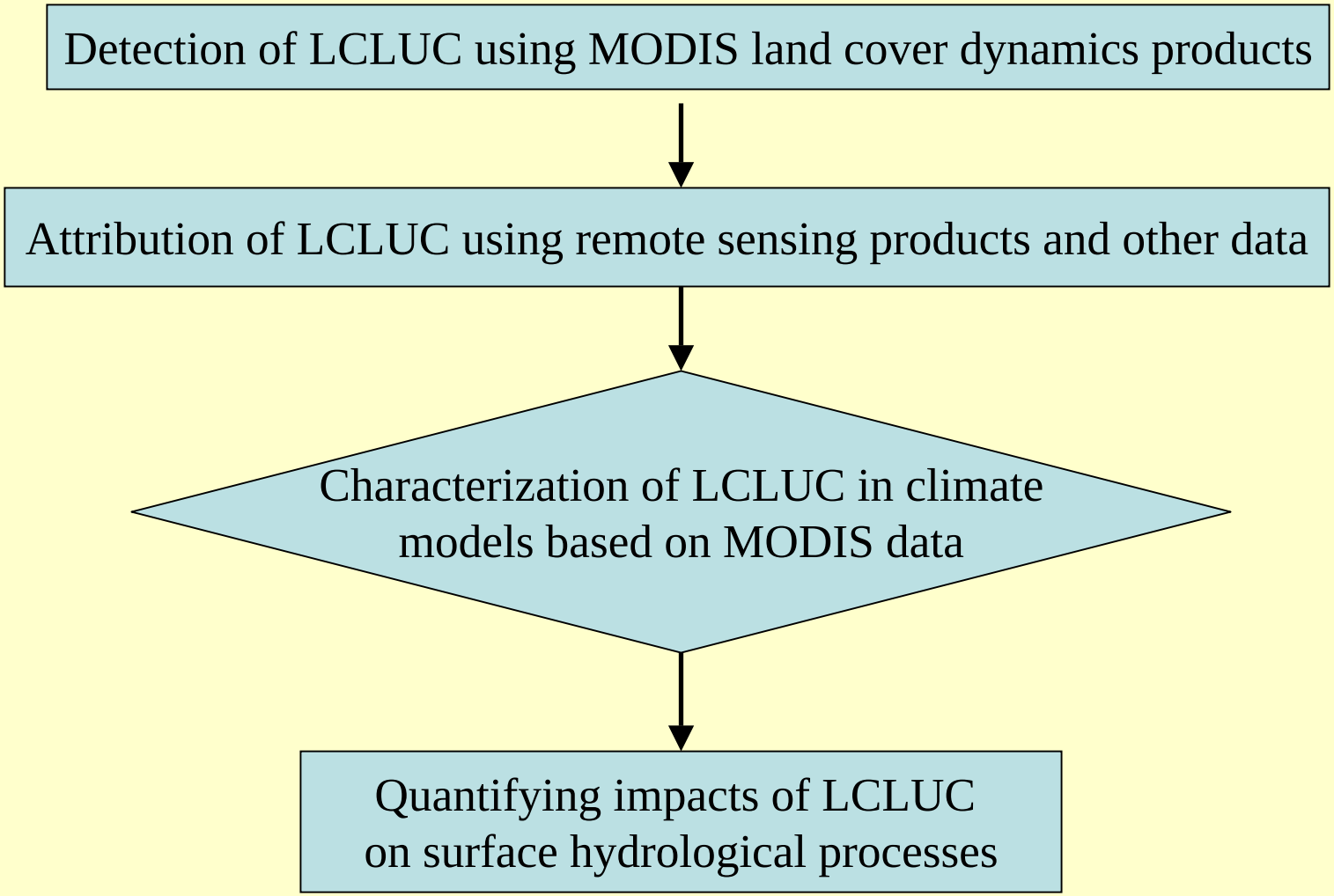
Personnel

- **PI: R.E. Dickinson,** Georgia Tech
- **Coinvestigators**:
  - **Climate modelers**: Georgia Tech, NCAR, U. Arizona, U. Texas at Austin
  - **MODIS land teams**: albedo/BRDF, fractional vegetation cover, LAI/FPAR, and land cover/land cover change
  - **Others**: Institute for Environment and Sustainability, Potsdam Institute of Climate Impact Research, U. Maryland
- **Collaborators**: some major groups working on related fields

Outline of Proposal



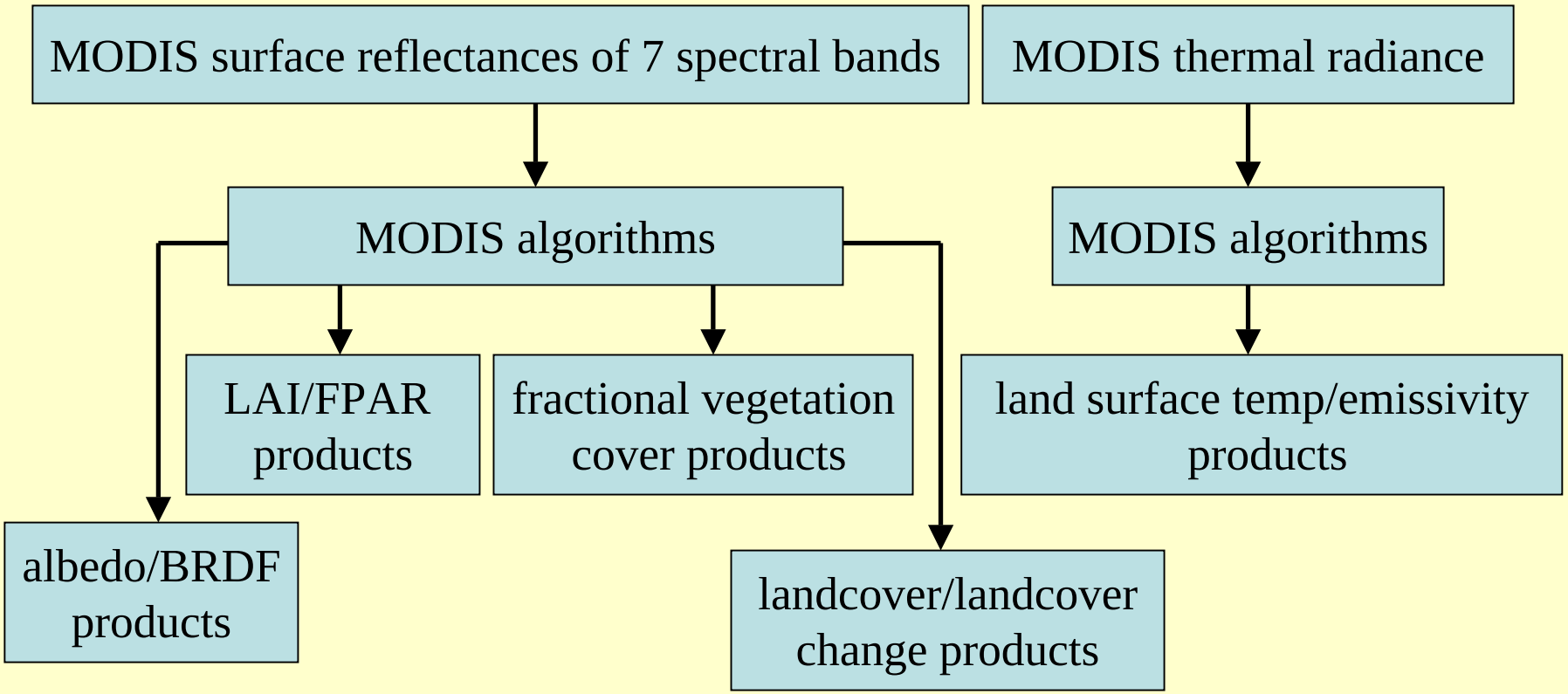
Major Issue for This Proposal

How to Better Characterize and Model LCLUC in Climate models?

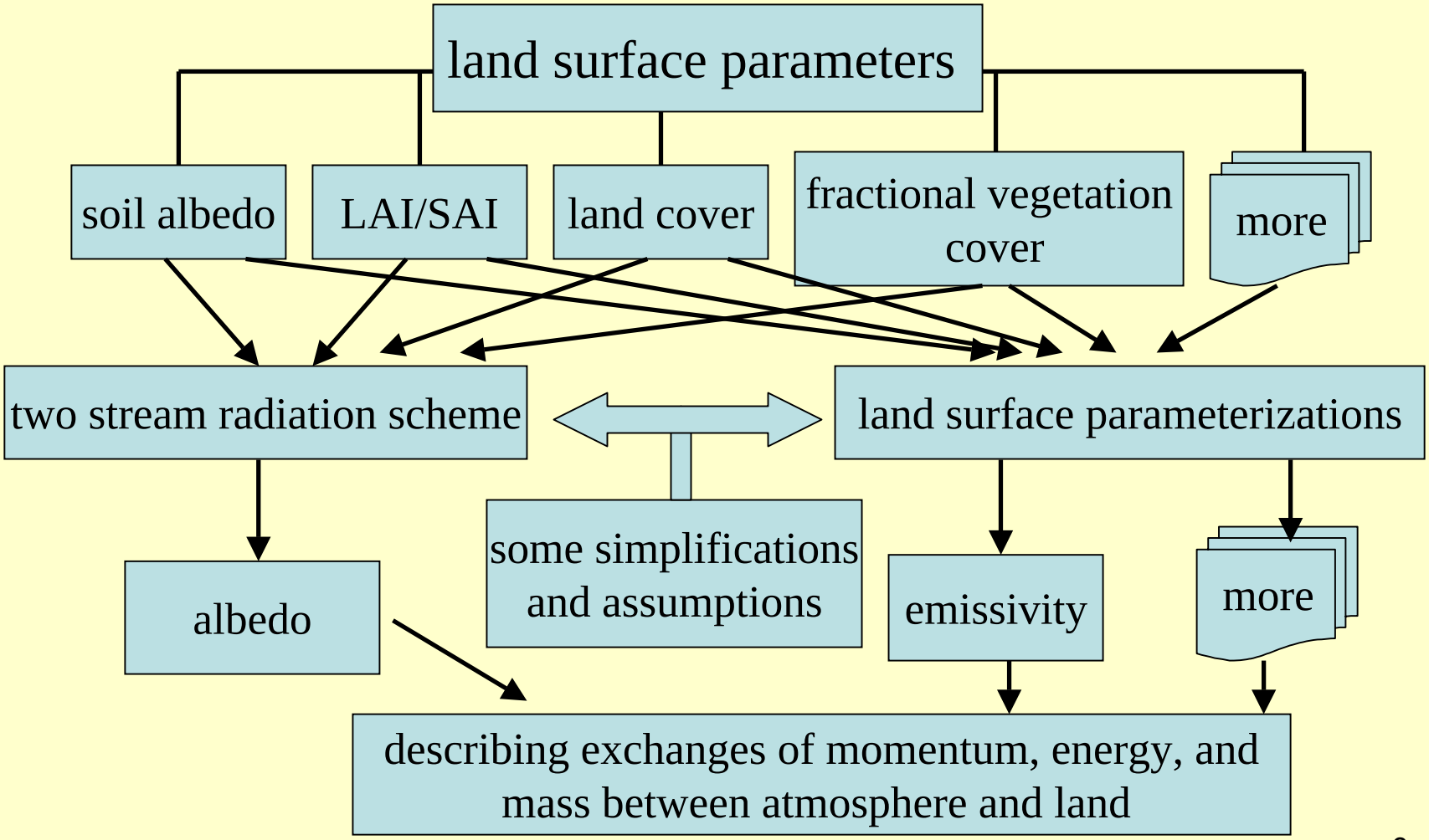
One best way is to reformulate climate model processes so that they are consistent with MODIS observations

here I focus on albedo/emissivity
in the NCAR Community Land Model (CLM)

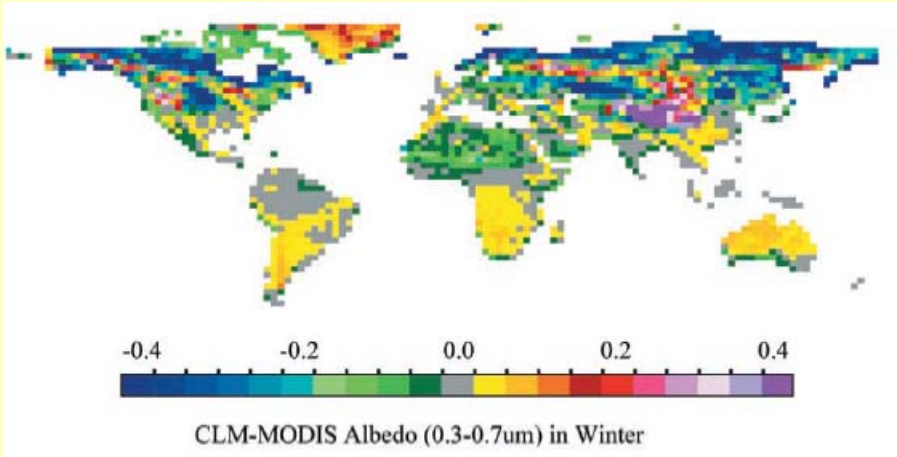
MODIS Framework



Modeling Framework

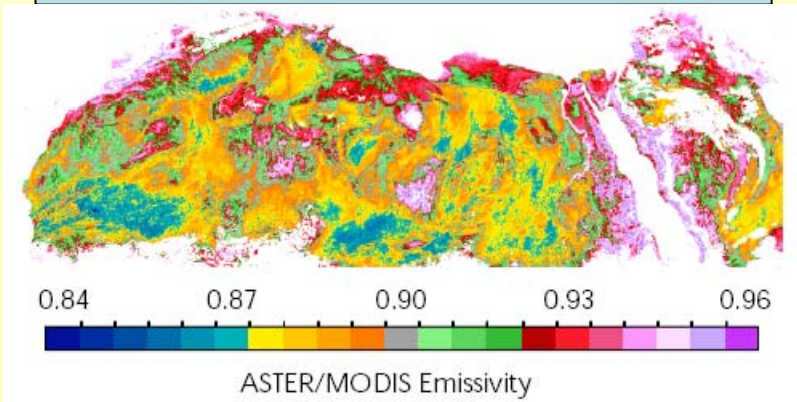


Albedo and Emissivity: Model versus MODIS: Inconsistent



Albedo differences (CLM-MODIS)
(*Zhou et al., JGR, 2003a)*

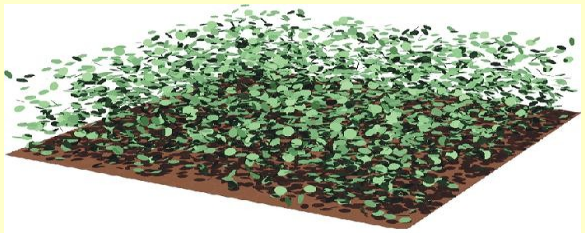
CLM soil emissivity = 0.96



ASTER/MODIS emissivity
(*Zhou et al., JGR, 2003b)*

So What is the Essential Problem

- MODIS in principle, is producing all the pieces needed by climate models to generate their albedo and emissivity from the same radiation, but some of the pieces may be inconsistent (differences in algorithms).
- Climate models wish to return the same radiation using these pieces, but their radiation formulation is inconsistent with that used by any of the MODIS algorithms.



climate model view of vegetation

what it looks like for semi-arid system

Climate models: two-stream radiation scheme

Accurate for horizontally homogeneous canopies but large errors for semiarid and snow-covered vegetated surfaces.

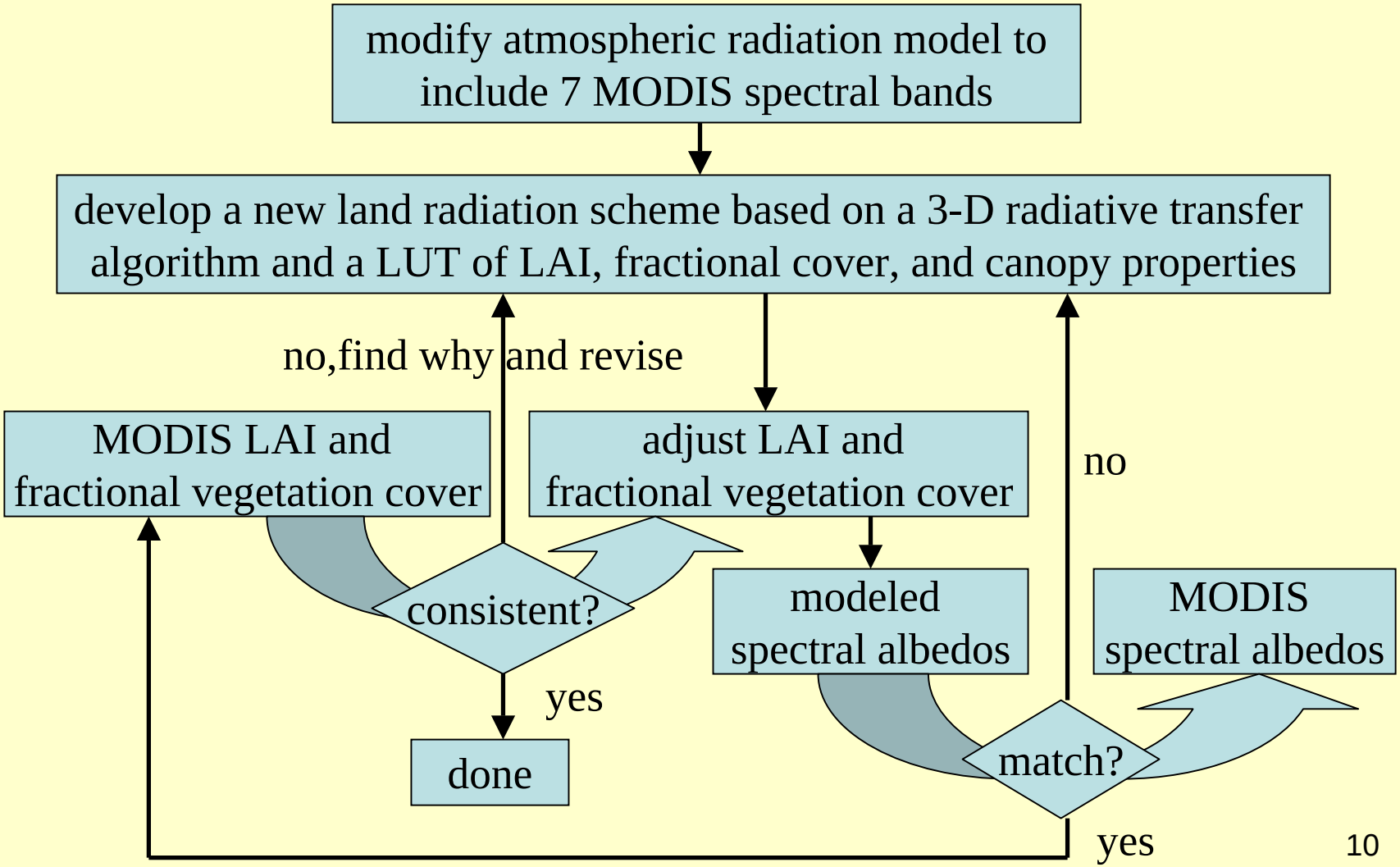
Best Way to Improve Climate Models

- An optimal connection between models and observations: reformulating climate model processes so that they are consistent with MODIS observations.

- Establishing a new radiation model in such way that it is able to reproduce the observed spectral albedos.

  - most directly related to MODIS observed reflectances
  - most directly related to other model parameters
  - key constraint on energy balance

Reformulate Model Radiation Treatments



Components of New Radiation Scheme

- Use of spherical bushes and learn what they do with such bushes – then in principle can solve for any shape plant – but probably will themselves be accurate enough.
- albedo consists of 3 pieces:

  a) Soil minus shadows: black leaves

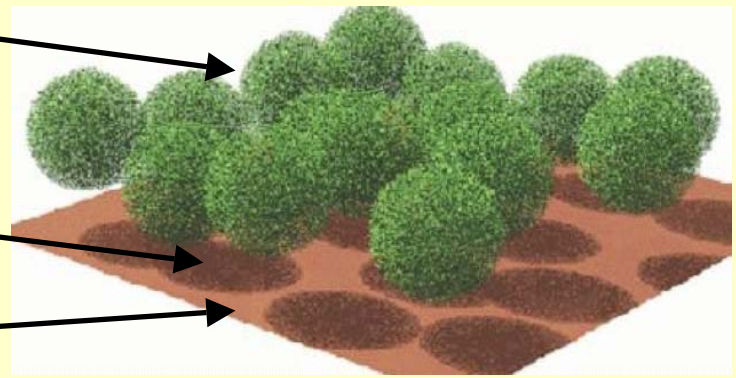
  b) Bush with underlying black soil

  c) Multiple photon scatters between soil and bush – small

bush albedo: 3-D radiative transfer

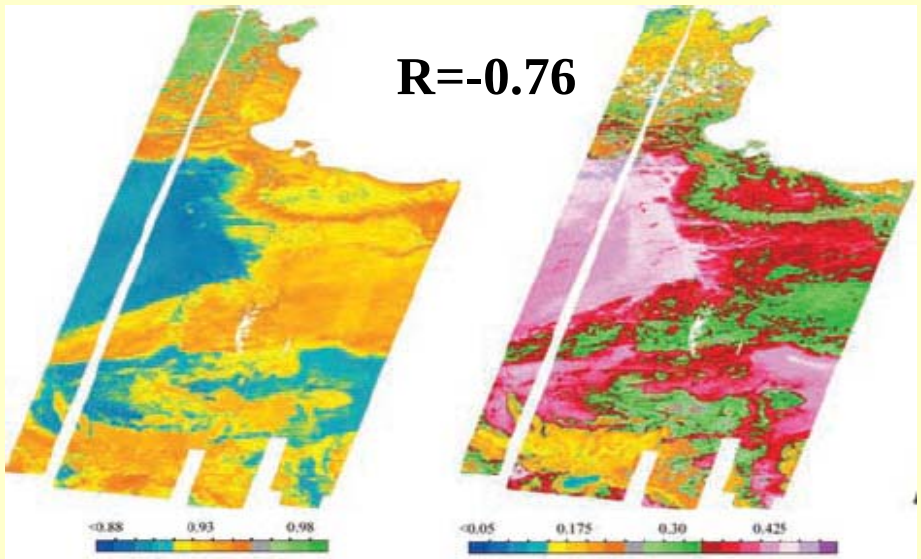
shading effects

soil albedo



Connecting Emissivity to Albedo

ASTER emissivity MODIS broadband albedo



CLM: soil emissivity=0.96

Observations: emissivity varies in space and is highly correlated with albedo

MODIS bands	1	2	3	4	5	6	7
Correlation (R)	-.76	-.74	-.16	-.52	-.77	-.77	-.85

(*Zhou et al., GRL, 2003)*

Modeling of LCLUC

- Quantify the LCLUC identified by MODIS land cover dynamics products in terms of spectral albedos and other related model variables, mainly focusing on deforestation in Amazon, fires in boreal forests, and urbanization in China.
- Design some scenarios for LCLUC to model their impacts on regional and global hydrology and climate using the improved radiation schemes in NCAR climate models.
- Understand relationships and interactions between hydrological processes and the LCLUC through examining water cycle variables (e.g., precipitation, soil moisture, runoff).

Other Work Done or Doing

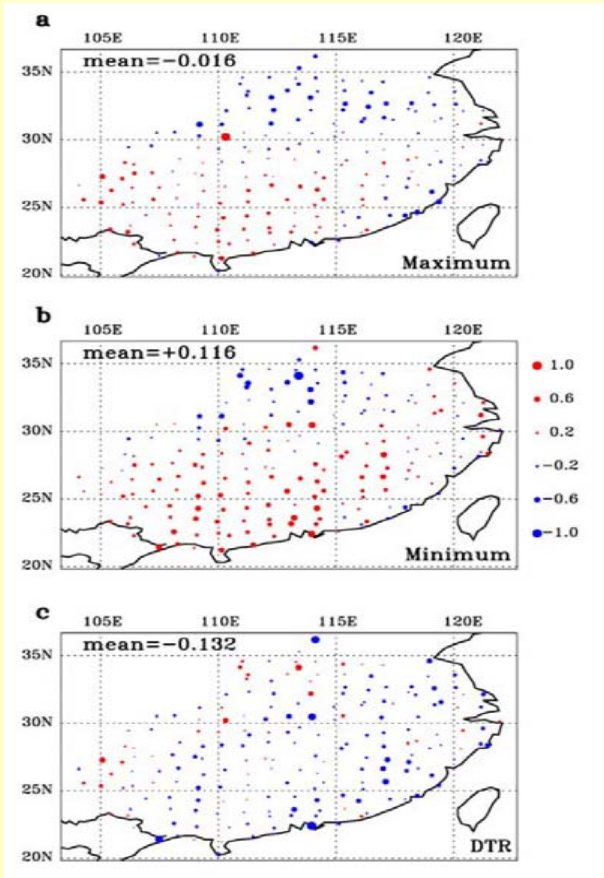
- Assessment of urbanization effects on climate in China
- A new land surface dataset derived from MODIS land products for use in climate models
- Other land model components improved and continuing to be improved using MODIS Data (not discussed here)
- MODIS land products improved and continuing to be improved (not discussed here)

Urbanization in China - background

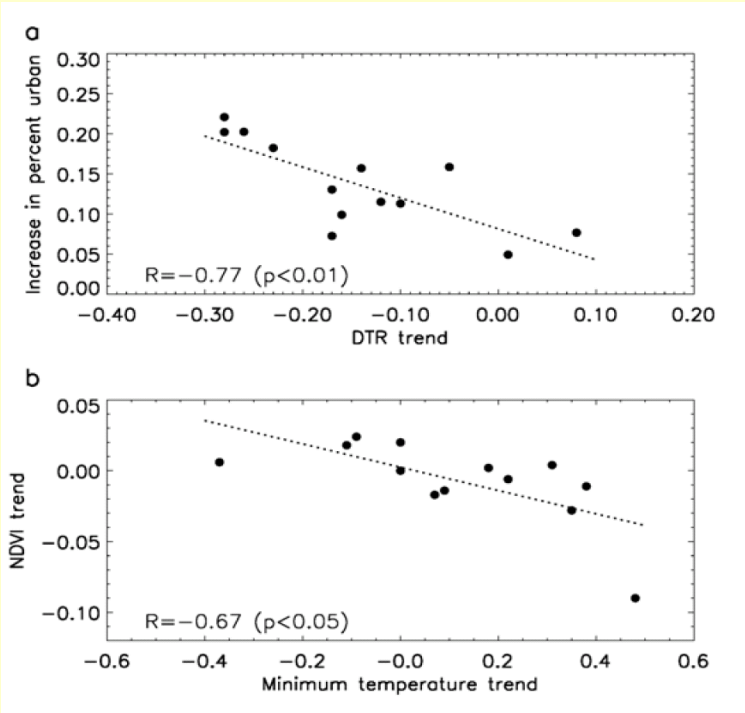
- Rapid urbanization in China - a good case study to quantify the urbanization effect on climate.
- *Kalnay and Cai* (2003) estimated the impact of urbanization and other land use changes on climate by comparing trends in observed and reanalysis surface temperatures – the latter is insensitive to changes in land surface.
- We adopted the same method but paid more attention to its problems and deficiencies: using an improved new reanalysis dataset (*Kanamitsu et al*., 2001) and focusing only on southeast China winter to ensure the best quality in both observational and reanalysis data.

(*Zhou et al., PNAS, 2004)*

Urbanization in China - results



Observed minus reanalysis winter temperature trends (°C/10yrs) from 1979 to 1998



Relationship for (a) DTR trends versus changes in the percent of urban population and (b) minimum temperature trends (°C/10yrs) versus summer NDVI trends (/10yrs) at provincial level.

(*Zhou et al., PNAS, 2004)*

Urbanization in China - conclusions

- Our estimated warming of mean surface temperature of 0.05°C per decade is much larger than previous estimates for other periods and locations, including the estimate of 0.027°C per decade for the continental US (*Kalnay and Cai*, 2003).
- The spatial pattern and magnitude of our estimate are consistent with those of urbanization characterized by changes in the percent of urban population and in satellite-measured greenness.

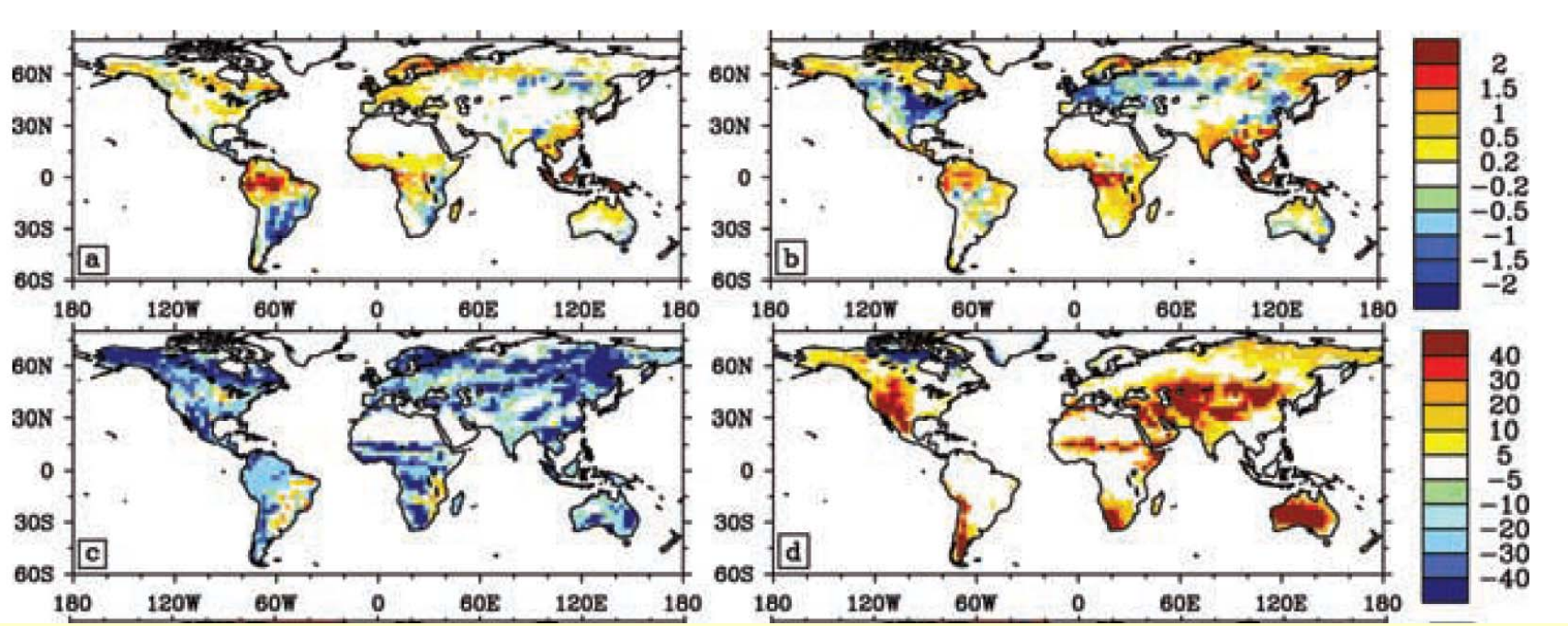
(*Zhou et al., PNAS, 2004)*

New Land Surface Dataset - background

- Previous land surface datasets were generally derived from AVHRRs and lack consistency due to different data sources
- A new land surface dataset was created from multiple high quality Collection 4 MODIS data of LAI, plant function type (PFT), and vegetation continuous field.
- This new dataset has higher quality and is more consistent among model parameters.

(Tian et al., GRL, 2004; Tian et al., JGR, 2004)

New Land Surface Dataset - results

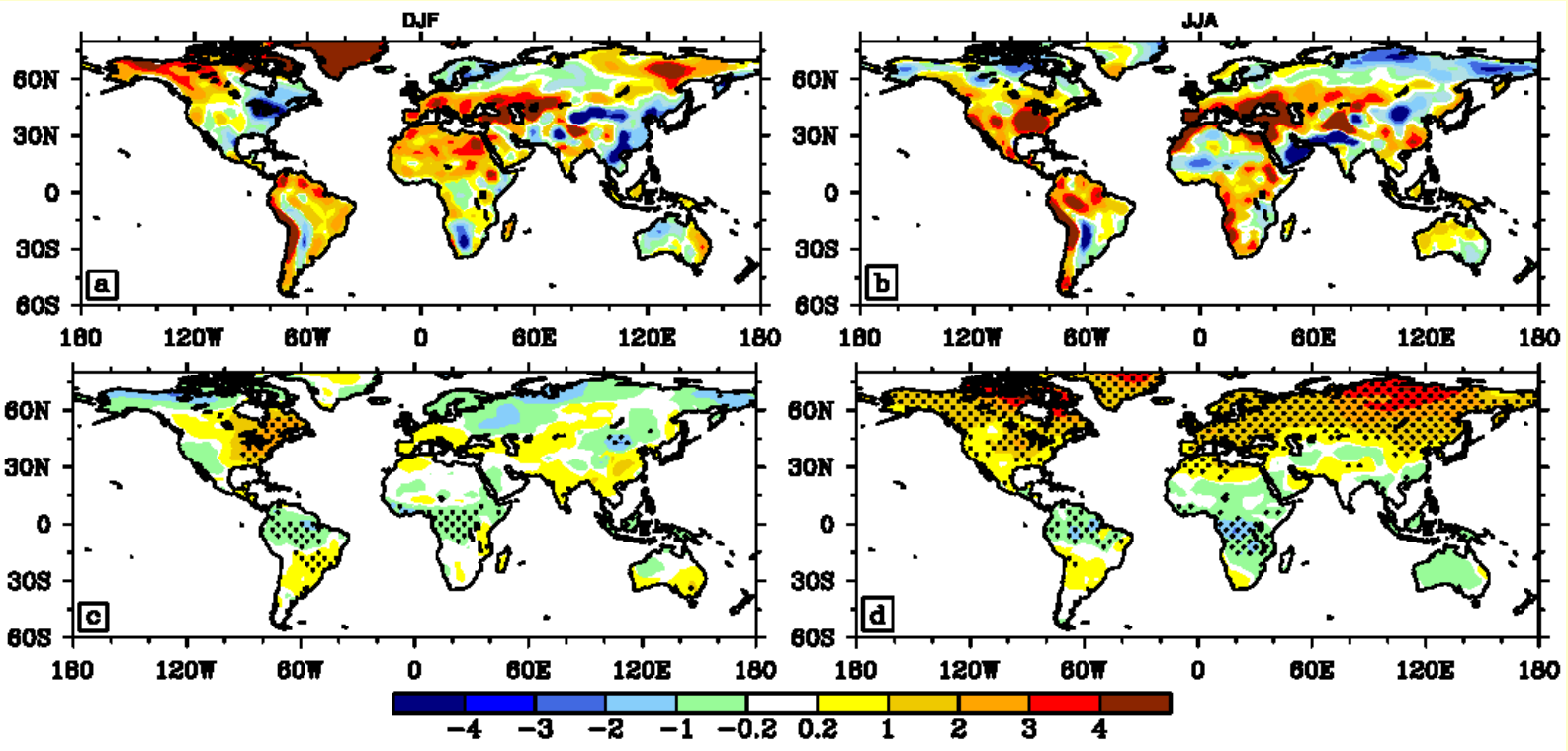


LAI differences (MODIS-CLM2) in (a) Feburary and (b) July
Fractional cover differences (MODIS-CLM2) in (c) grass/crop and (d) bare soil

(Tian et al., GRL, 2004)

New Land Surface Dataset - results

DJF JJA



Upper: temperature differences (CLM2-observed) using the old dataset
Lower: temperature differences in CLM2 (new dataset – old dataset)

(Tian et al., JGR, 2004)

New Land Surface Dataset - conclusions

- The old land surface dataset in CLM2 underestimates LAI and overestimates the percent cover of grass/crop globally over most areas compared to the new dataset.

- The new dataset improved CLM2 by:
  - largely reducing most of the model positive albedo bias.
  - reducing most of the model cold bias over snow-cover regions.
  - decreasing most of the model warm bias over snow-free regions
  - making the simulated ground evaporation and canopy evapotranspiration closer to reality

(Tian et al., GRL, 2004; Tian et al., JGR, 2004)

Summary

- Current climate models only consider horizontally homogeneous vegetation and use a constant soil emissivity, this makes most serious errors for sparsely vegetated surfaces.
- The tight connection between MODIS data and climate models provides a best way to establish more realistic albedo and emissivity schemes for the models: this is more difficult but has potentially higher impact in improving climate models.
- These improvements will help better characterize and model LCLUC by including more accurate descriptions of land surface processes in climate models.