3-D Land Energy Exchanges: Harnessing High Resolution Terrestrial Information to Refine Atmosphere-to-Land Interactions in Earth System Models

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RGMA 2020 PI Meeting

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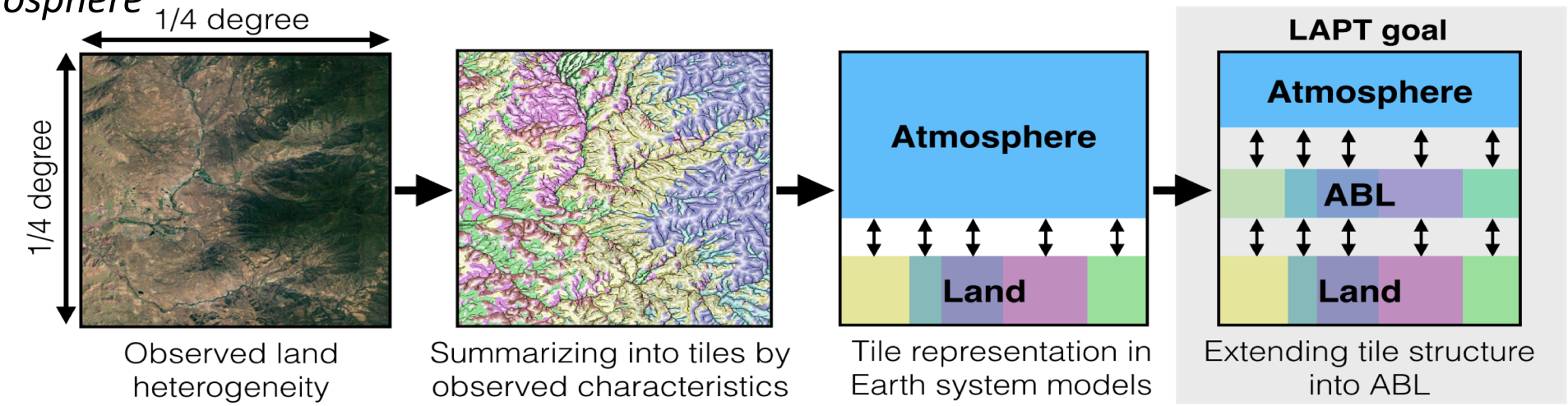
Land-Atmosphere Interactions and Sub-Grid Heterogeneities

- Heterogeneous processes are represented on land and in the atmosphere
- *Common challenge/limitation across modeling centers:*
  - *The distribution of sub-grid properties and states is lost in the exchange between the land and the atmosphere*



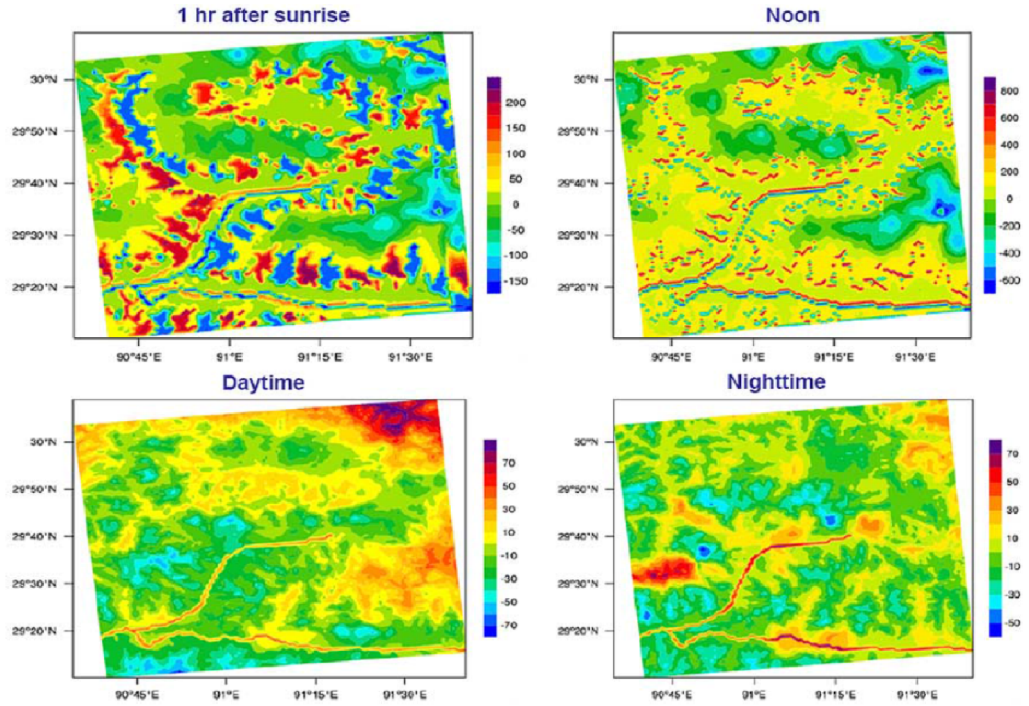
Objective

Advance the representation of atmosphere-to-land radiation exchange processes in the NOAA/GFDL ESM4, DOE/E3SM, and NCAR/CESM2, including:

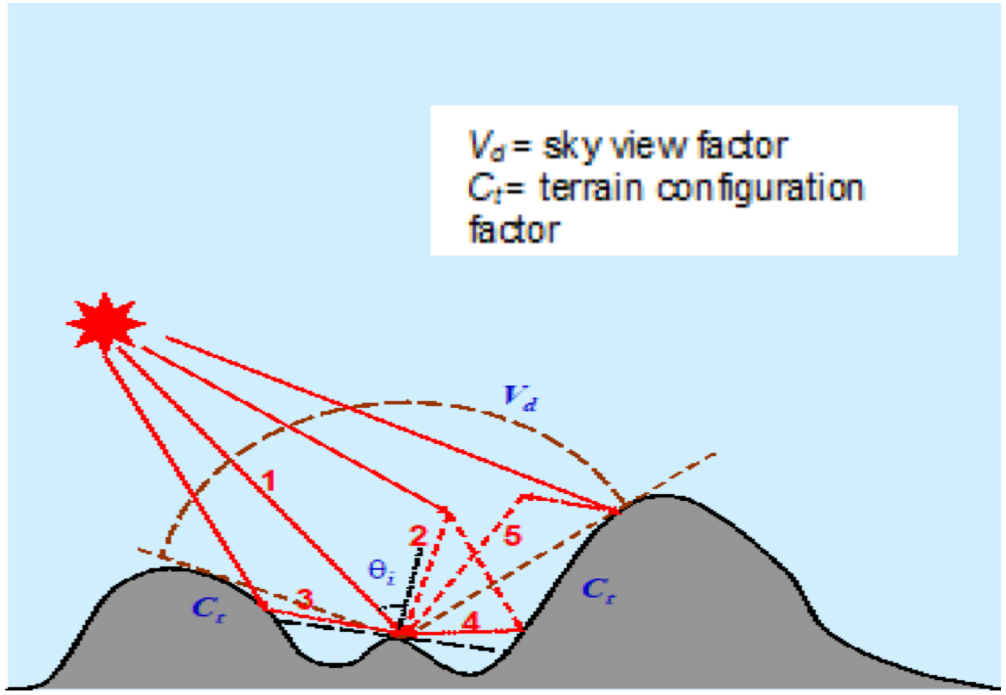
- radiation flux parameterization accounting for the effects of mountain and snow;
- parameterizations for black carbon (BC) and dust mixing in snow and associated radiation processes;
- multi-layer canopy energy transfer accounting for tracers (e.g. dust, BC) in the canopy air space;
- interactions of the above improvements with sub-grid land-heterogeneity (e.g., different vegetation/plant functional types, elevation bands, mountain aspects, hydrological hill-slopes, etc.)

Proposed parameterization improvements & Hypotheses

- **Improvement 1**: Implement/evaluate a parameterization accounting for the effects of mountain shading and multiple reflections between mountains and snow (i.e. 3D mountain effect).



Spatial distribution of deviations of the surface net solar (upper) and IR (lower) flux on mountains (Liou et al., 2007).

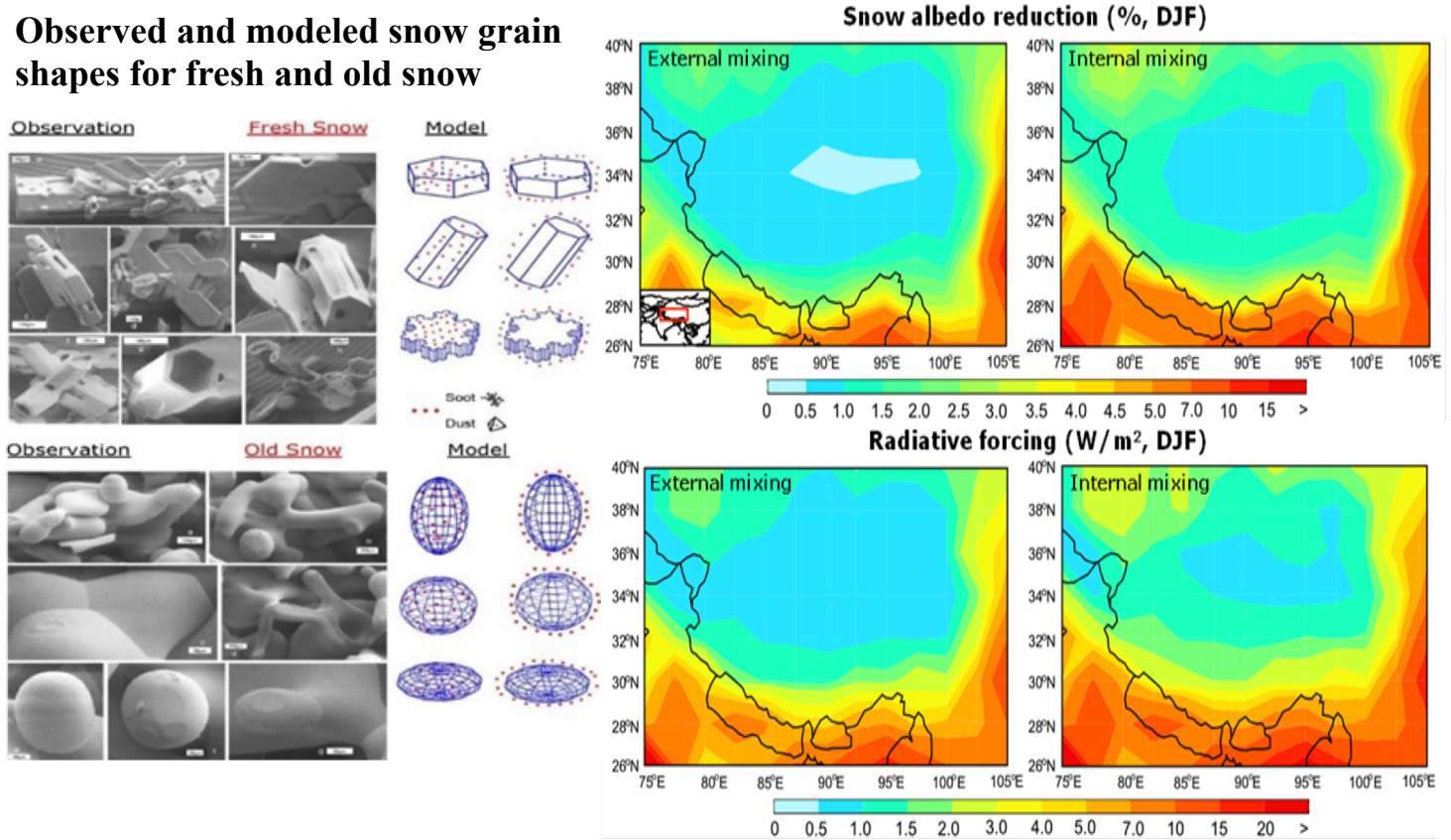


- ***Hypothesis I.*** *Improvement I will reduce climate model biases in mean temperature and surface fluxes as well as in their diurnal, interannual and decadal variability in regions with complex terrain.*

Proposed parameterization improvements & Hypotheses

- **Improvement 2:**
  Implement/evaluate a parameterization of dust and black carbon effects on snow: Verify Stochastic parameterization (Liou et al, 2014) for BC and dust mixing in snow as well as light absorption and scattering processes.

- ***Hypothesis II.*** *Improvement 2 will 1) reduce biases in surface albedo, snowpack seasonal cycle and surface temperature,* ***and*** *2) increase snow albedo feedback in climate warming experiments.*



Snow albedo reduction (%) at 0.55 μm and the associated radiative forcing (W/m^2) generated by the external and internal mixing of BC in snow grains in the form of hexagonal plates over the Tibetan Plateau during winter based on a GEOS-Chem simulation.

Proposed parameterization improvements & Hypotheses

- **Improvement 3:** Implement/evaluate a parameterization of in-canopy air tracer effects on radiation including dust and black carbon on surface climate.
- ***Hypothesis III****. Improvement 3 will improve diurnal temperature ranges, particularly in the arid and semiarid regions of the world and will reduce uncertainties regarding future prediction of temperature extremes and the impact on vegetations.*

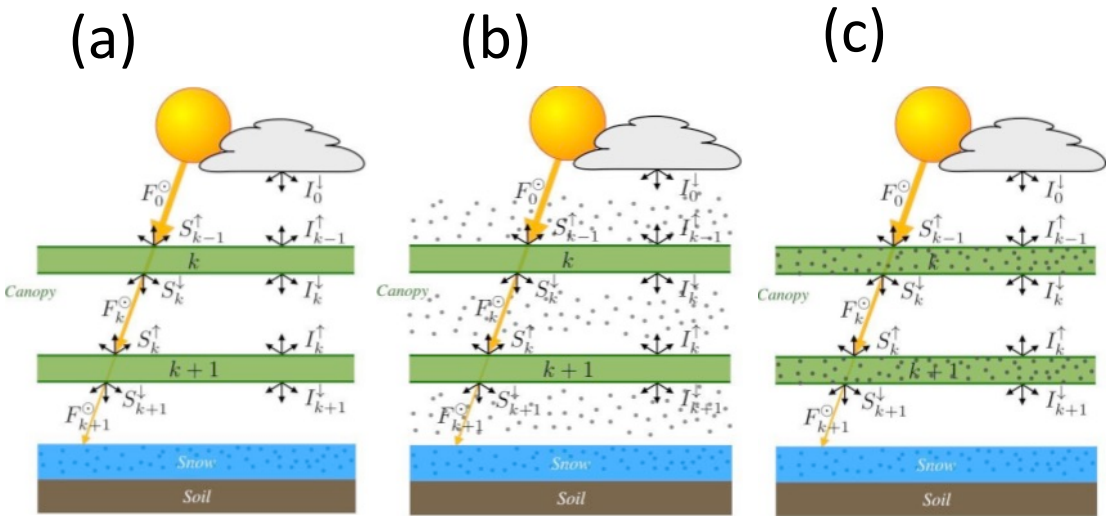
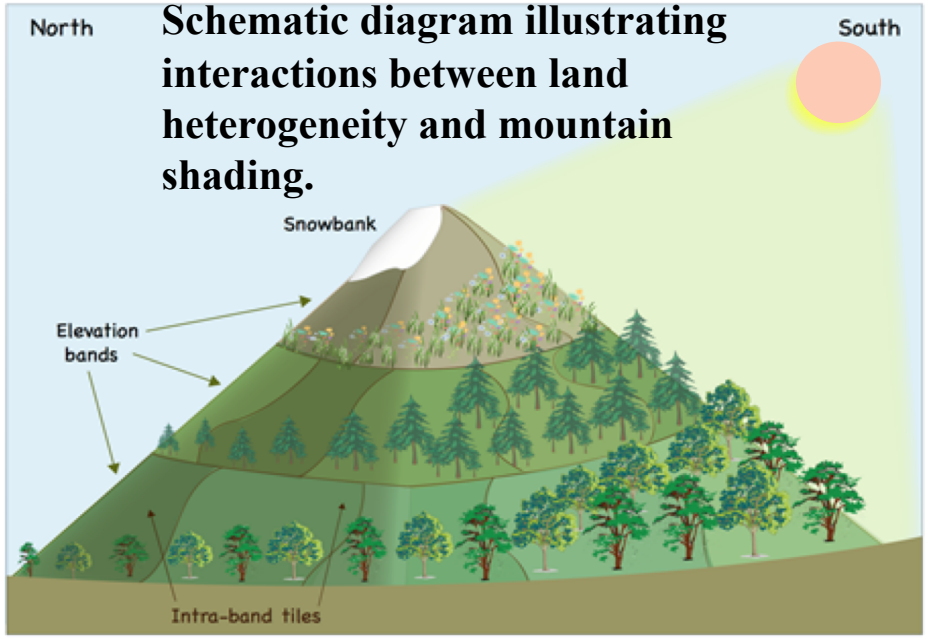
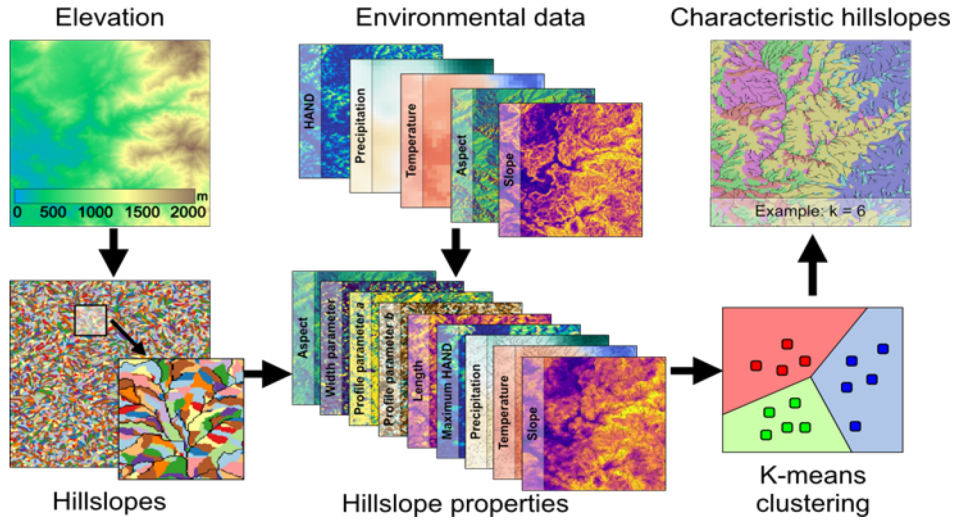


Diagram illustrating radiative transfer in multi-layer canopy model with a) clean air, b) "polluted" air using **layering** approach, and c) "polluted" air using **mixture** approaches.

Proposed parameterization improvements & Hypotheses

- **Improvement 4**: Implement/evaluate a parameterization for the canopy radiation exchanges with the above improvements for the combined effects of mountain shading and tracers in the snow and canopy air and aspect-aware land heterogeneity with reference to the explicit treatment of northward and southward facing vegetation tiles or land units.





- ***Hypothesis IV.*** *Improvement 4 will enhance representation of tree lines and boundaries between different ecotones in complex terrain and improve characterization of vegetation biophysical feedbacks on regional climate and enable the new generation of age-height structured vegetation components of ESMs to decrease biases in simulating onset of the evolution of growing season; greening and browning trends; and observed trends in the expansion of climate zones poleward.*