

OLAM-SOIL Workshop

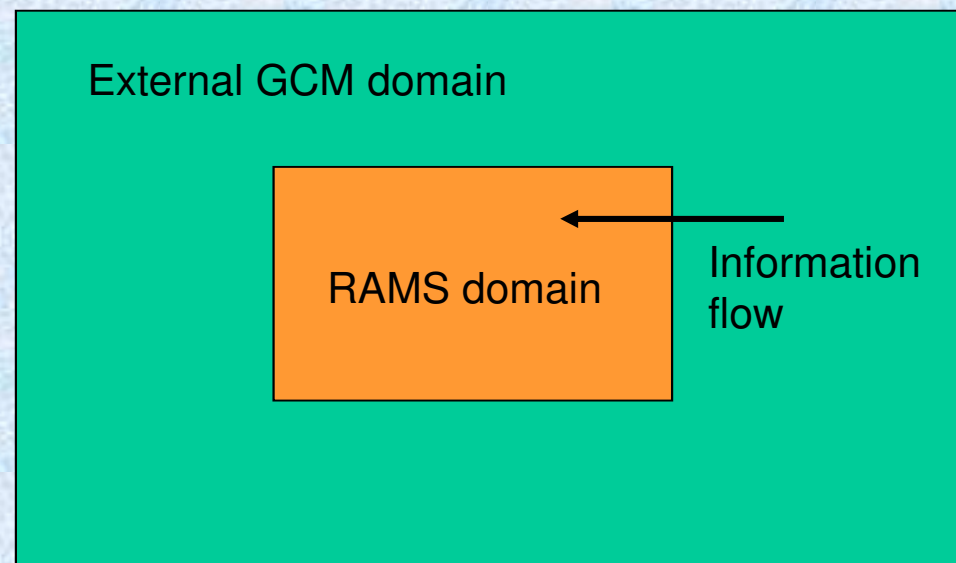
EGU 2018, April 8

Robert Walko
Simone Fatichi
Dani Or

- Motivation for the project and OLAM-SOIL workshop – ISMC and GEWEX links
- Introduction to OLAM and OLAM-SOIL (and brief history of RAMS and OLAM)
- Focus on new developments in OLAM-SOIL
- Vegetation and soil biogeochemistry
- Soil structure effects

Before **OLAM**, there was **RAMS** (the Regional Atmospheric Modeling System), begun in 1986 at Colorado State University

- Limited-area mesoscale/microscale model similar to WRF and MM5
- Designed for high resolution simulations of clouds, thunderstorms, hurricanes, flow over mountains, continental-scale weather
- 2-way interactive grid nesting, explicit (bulk) microphysics, vegetation/soil model, ocean model
- There are significant disadvantages to limited-area models

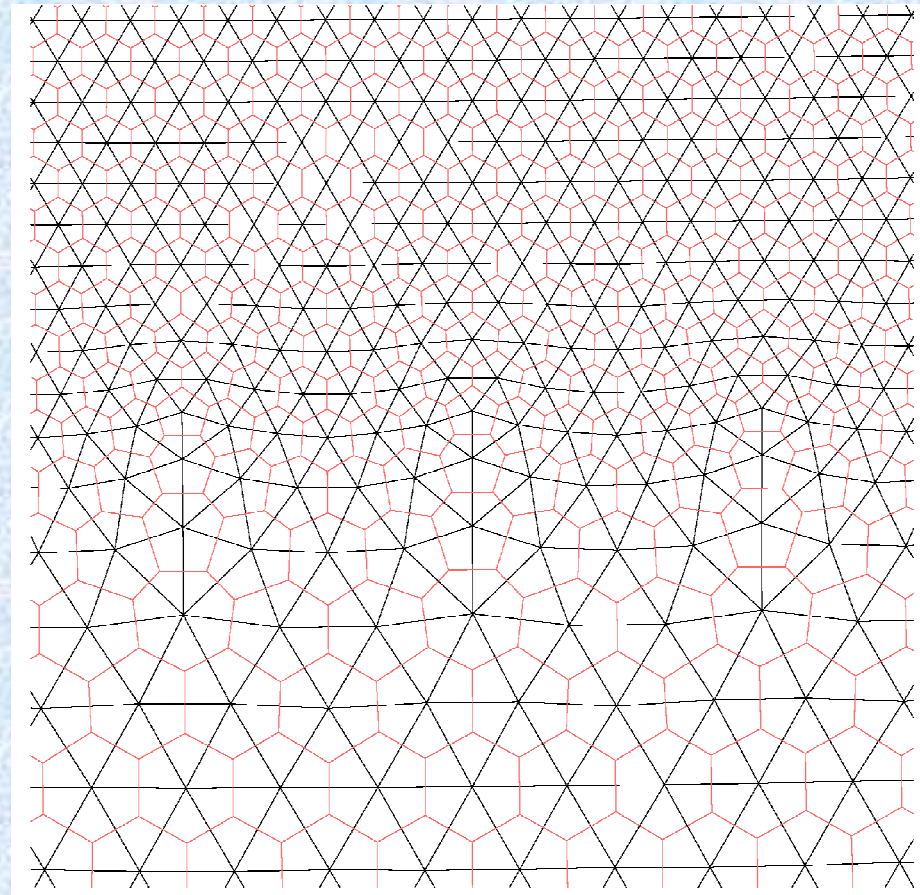
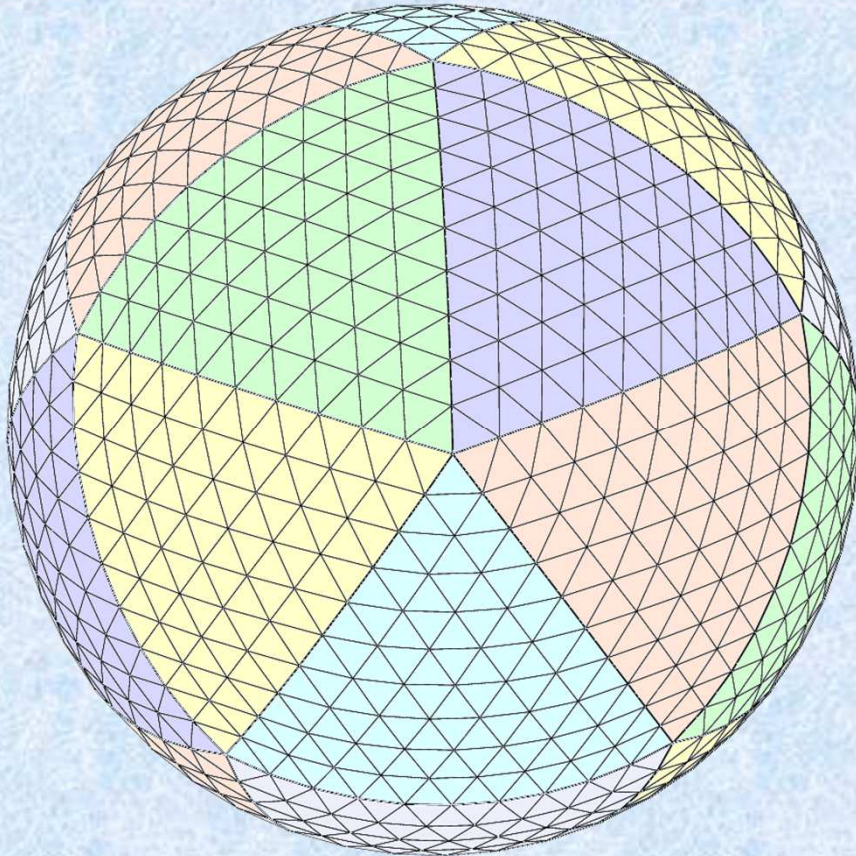


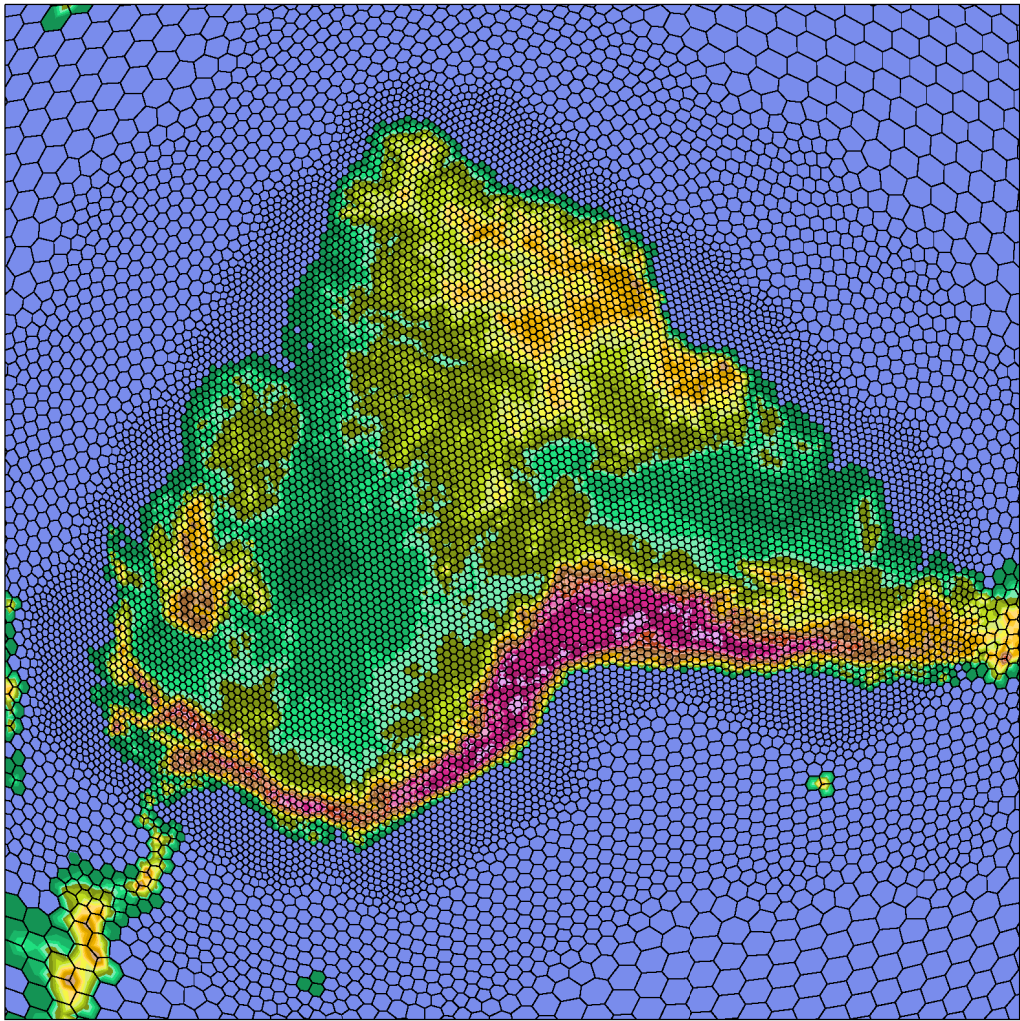
Ocean-Land-Atmosphere Model (OLAM)

Duke University 2001-2009; University of Miami 2009-present

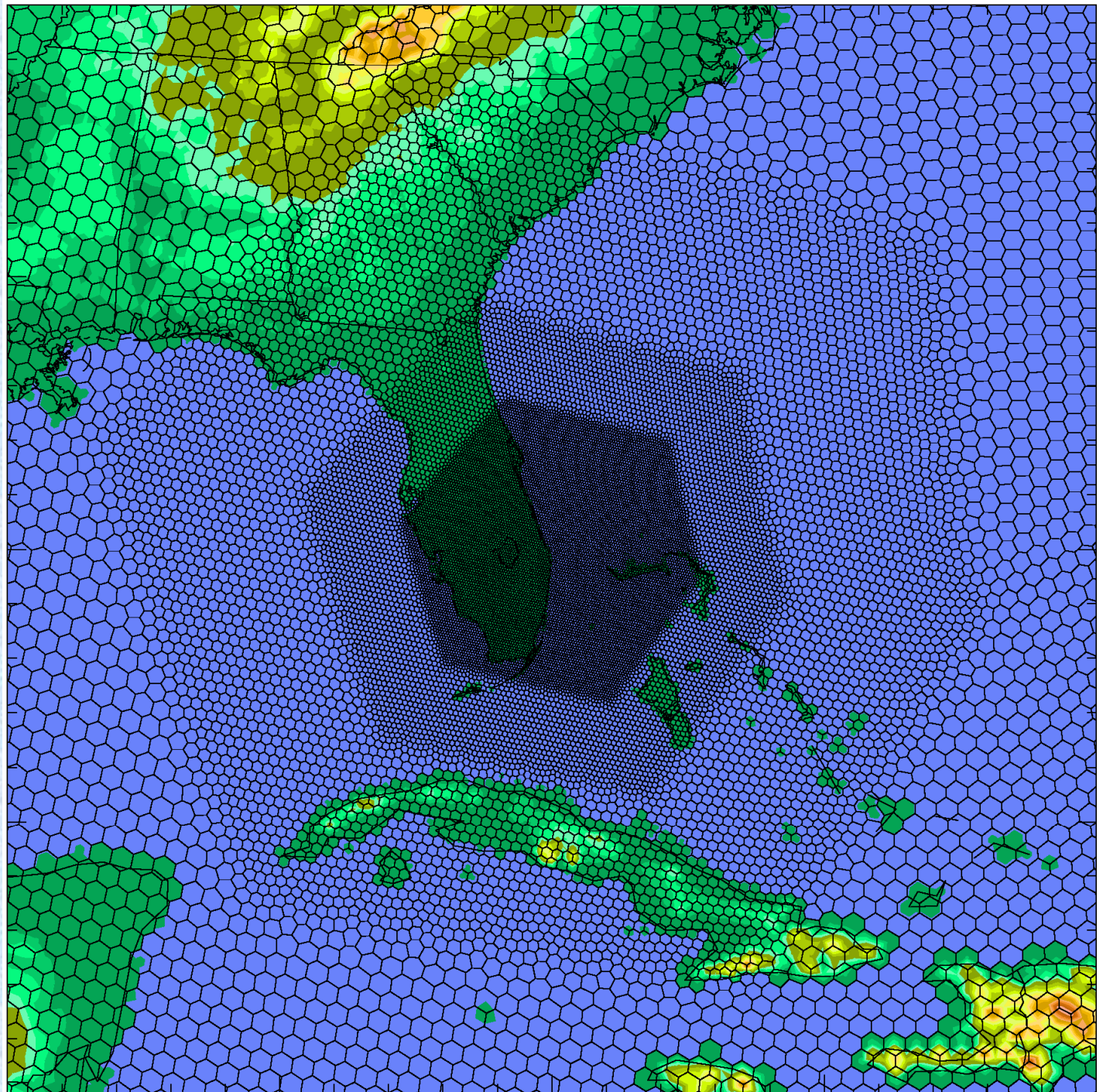
Developers: Robert Walko, Martin Otte, David Medvigy

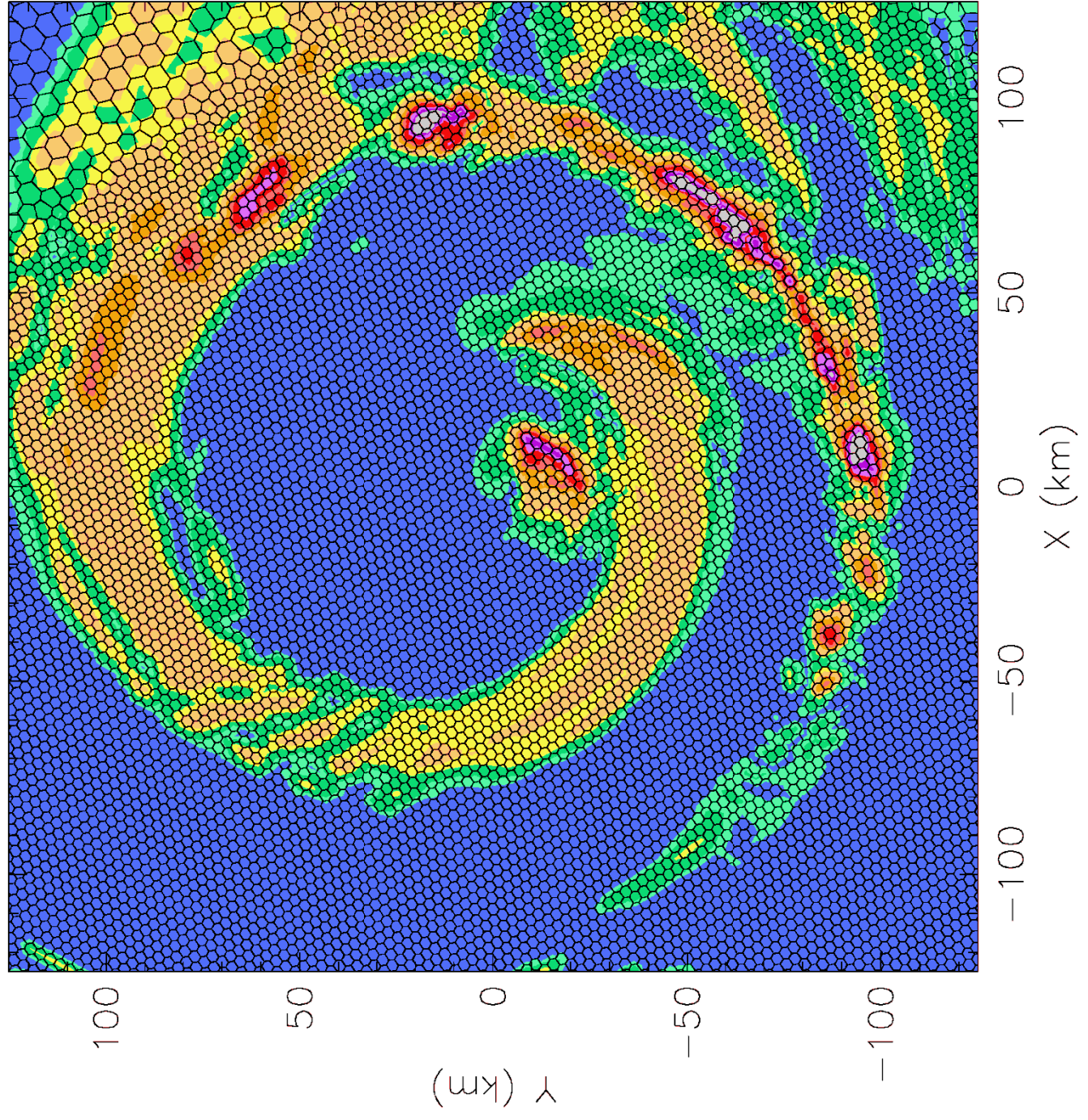
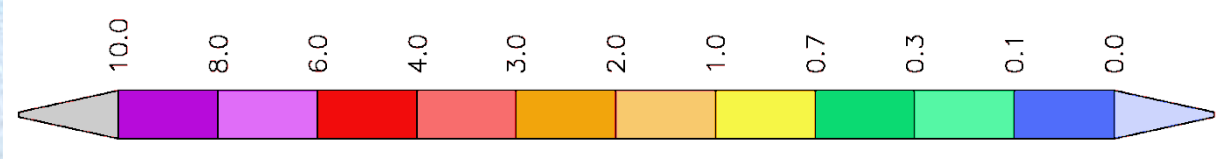
Project Leader: Roni Avissar

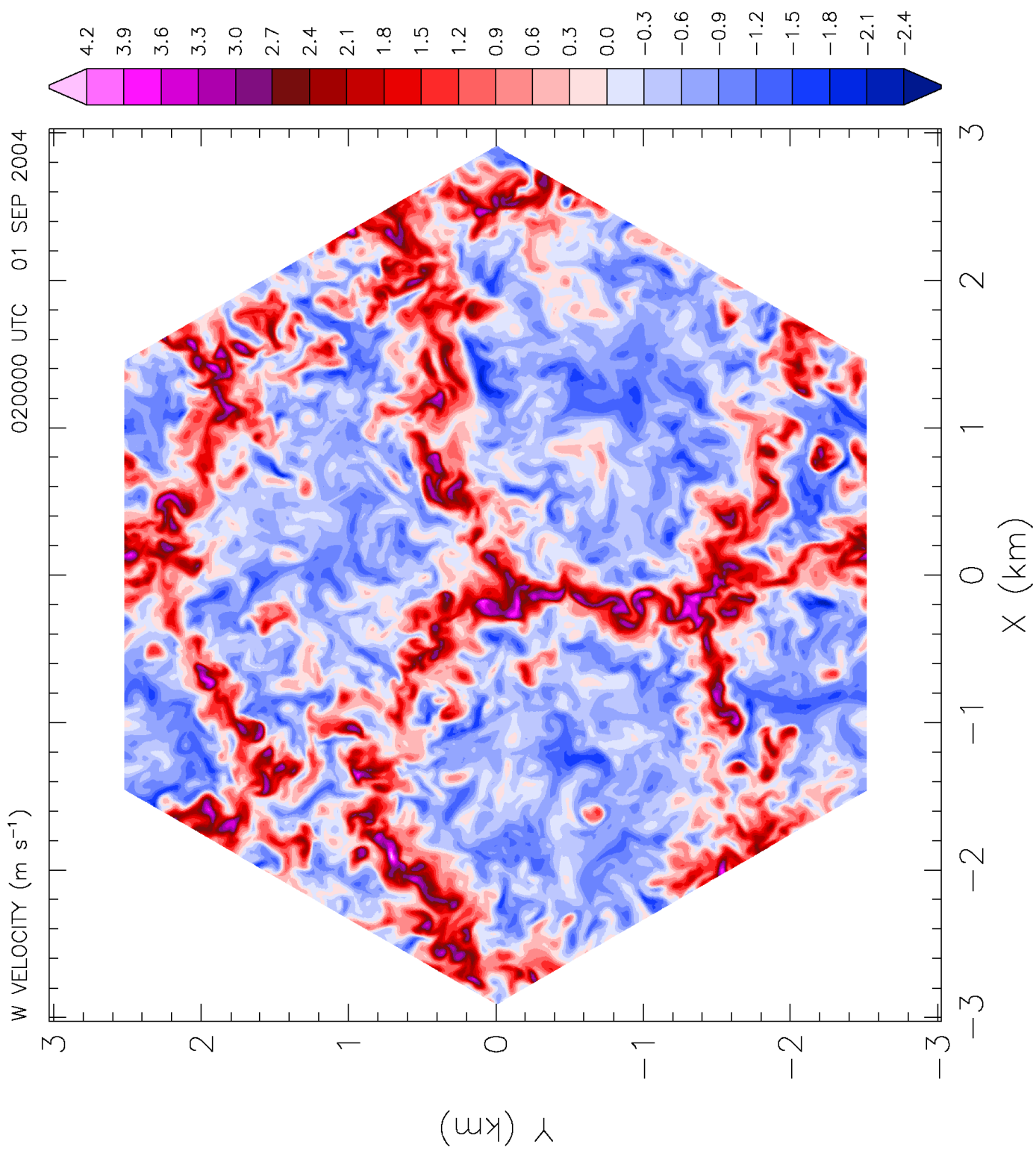




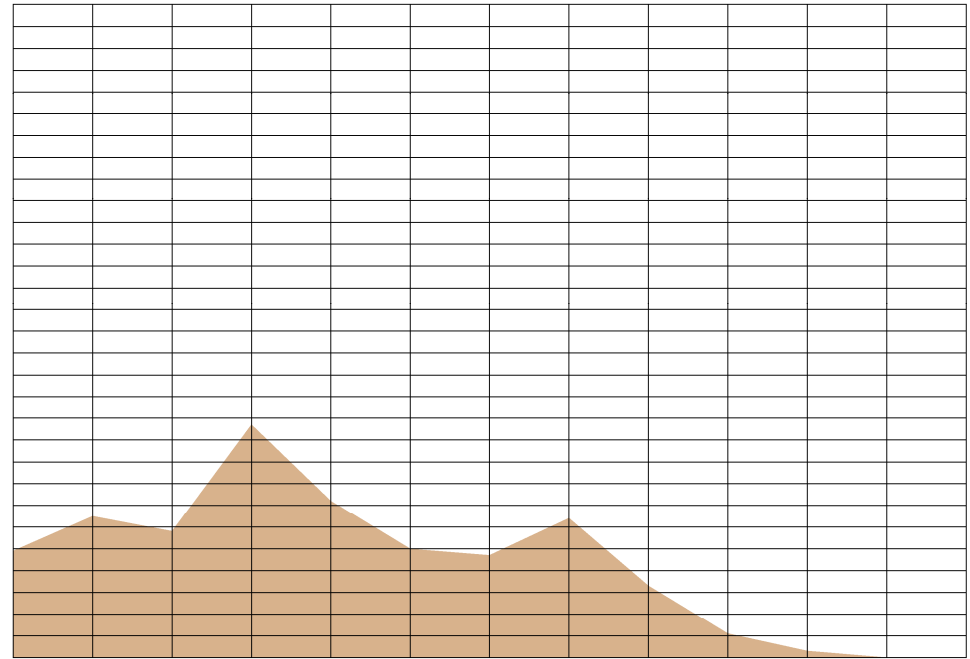
OLAM:
Hexagonal grid
cells



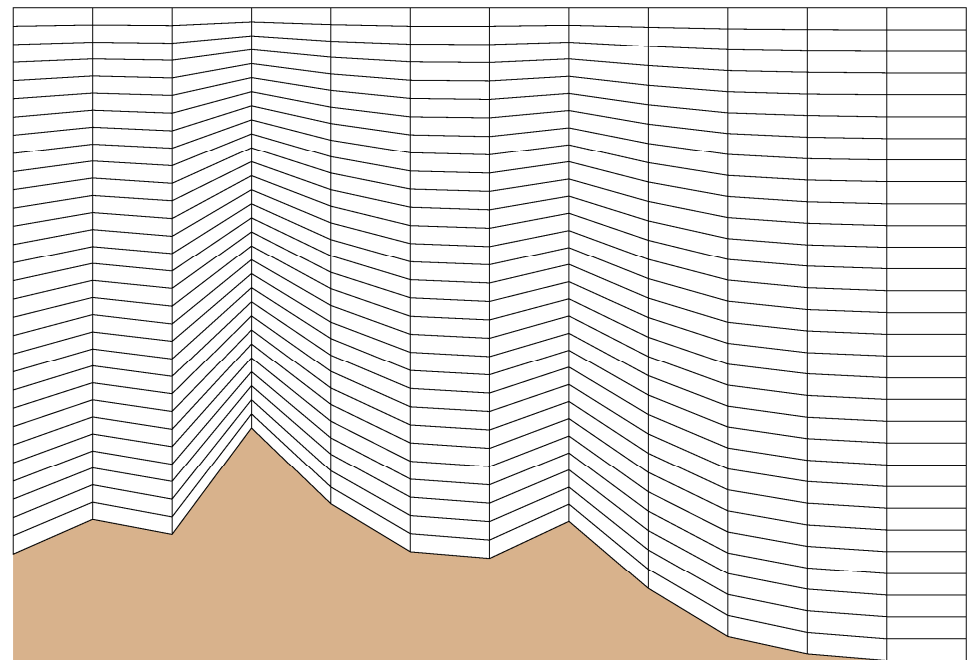




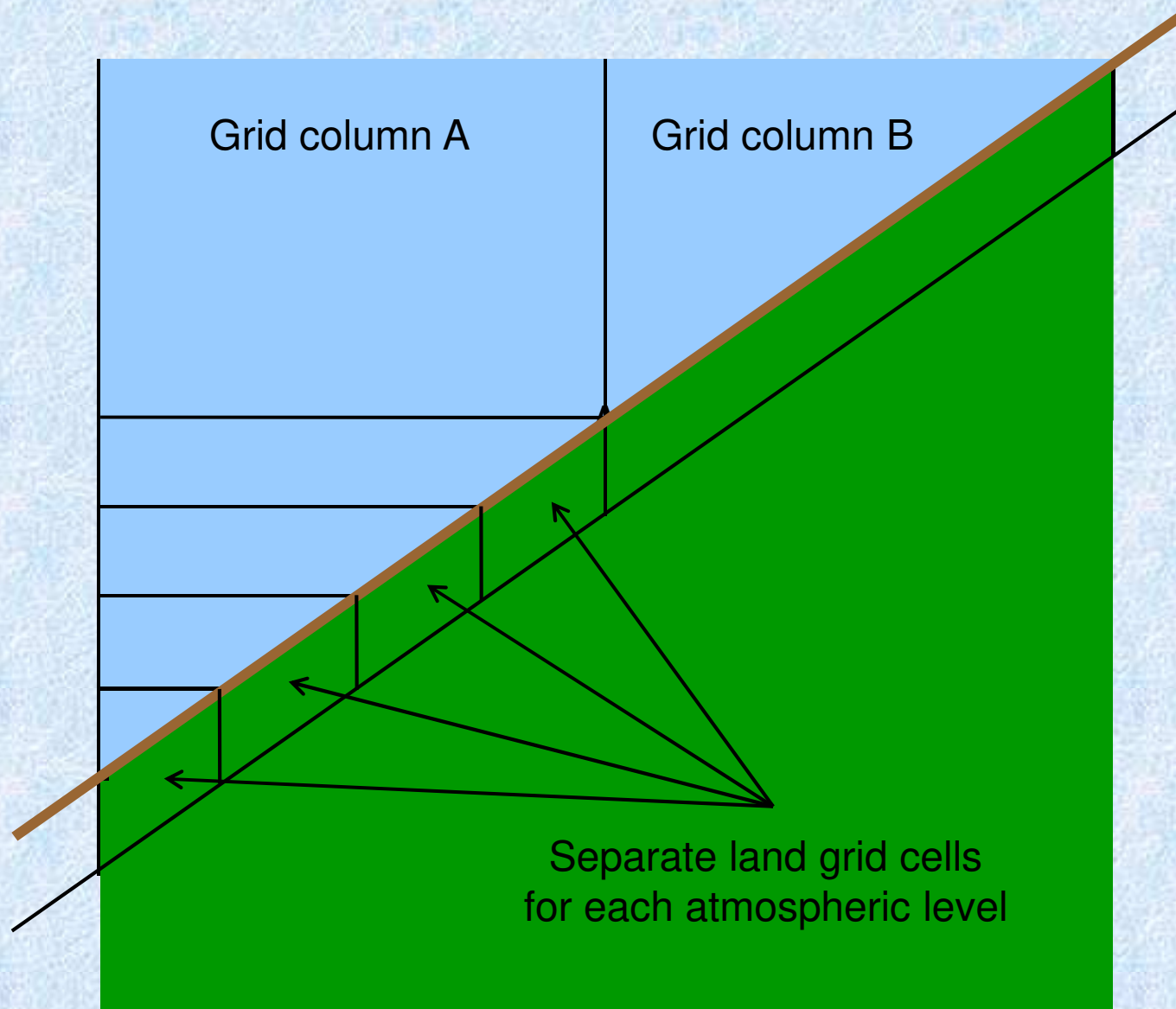
OLAM atmosphere grid uses **horizontal levels** that intersect topography, resulting in “**cut cells**”

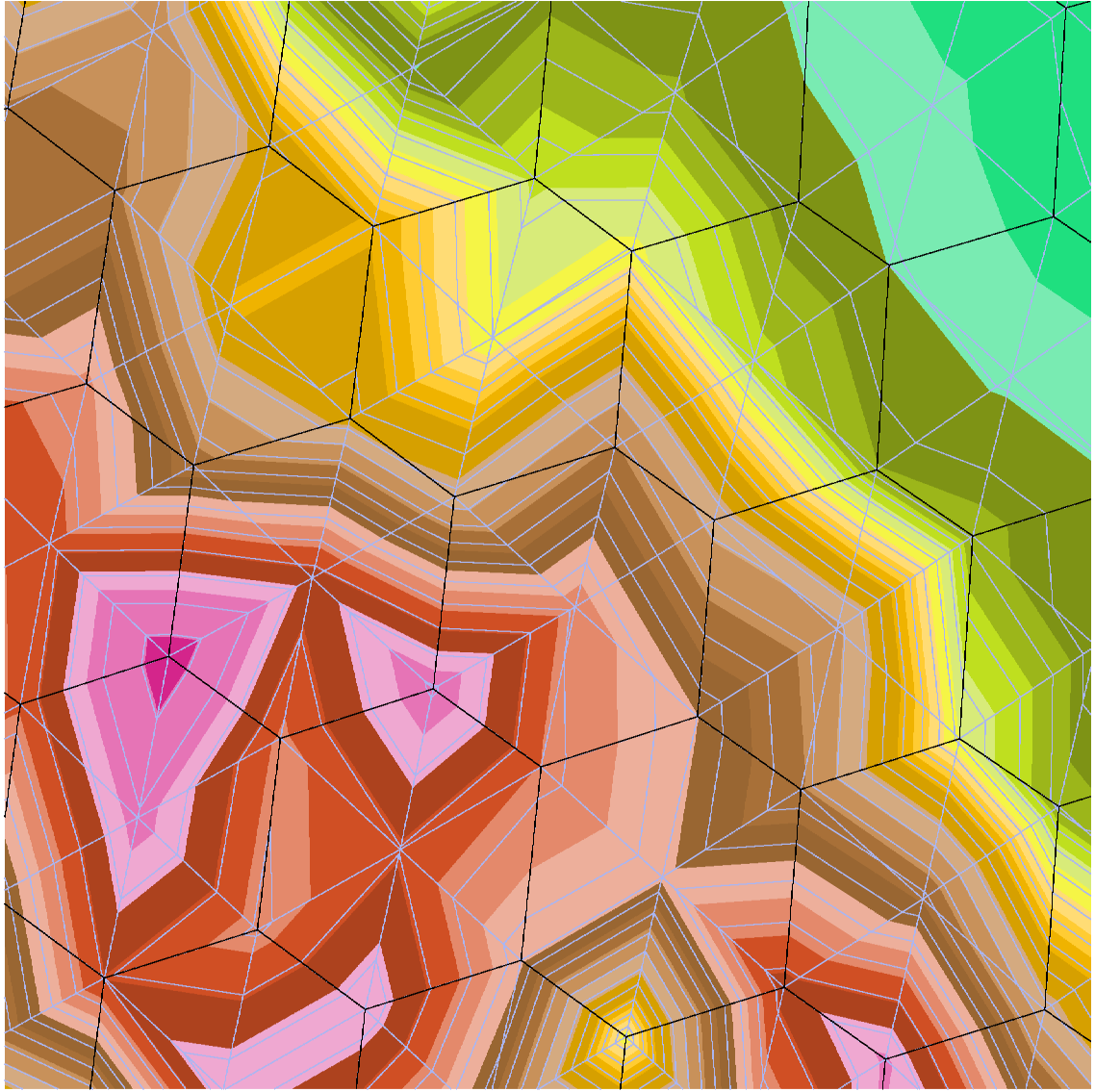


Terrain-following coordinates are almost universally used in atmospheric models.

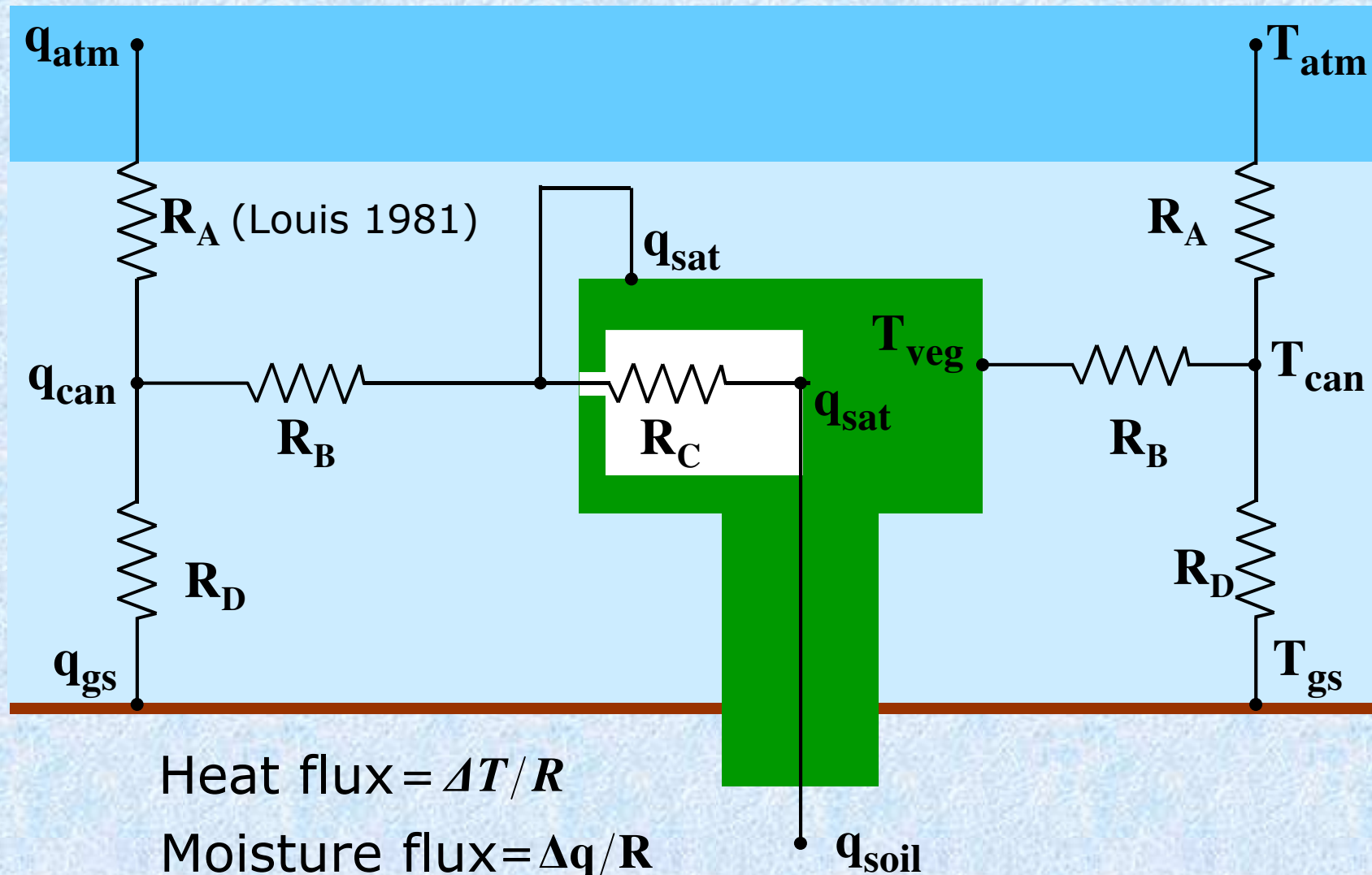


Before OLAM-SOIL, surface grid was same as atmosphere grid, except that finer divisions were used on topographic slopes





LEAF-3 Canopy Fluxes

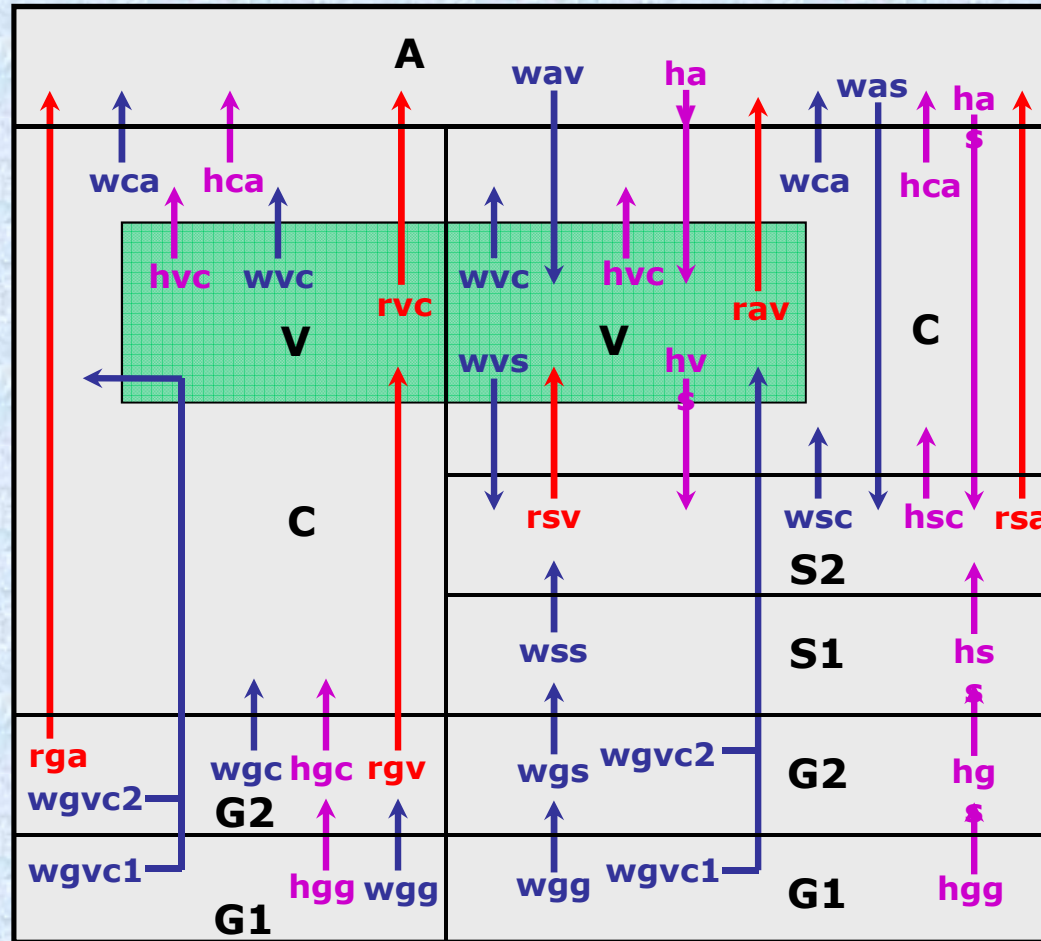


LEAF-3 fluxes

longwave
radiation

sensible
heat

water



OLAM-SOIL Project – Accomplishments to date

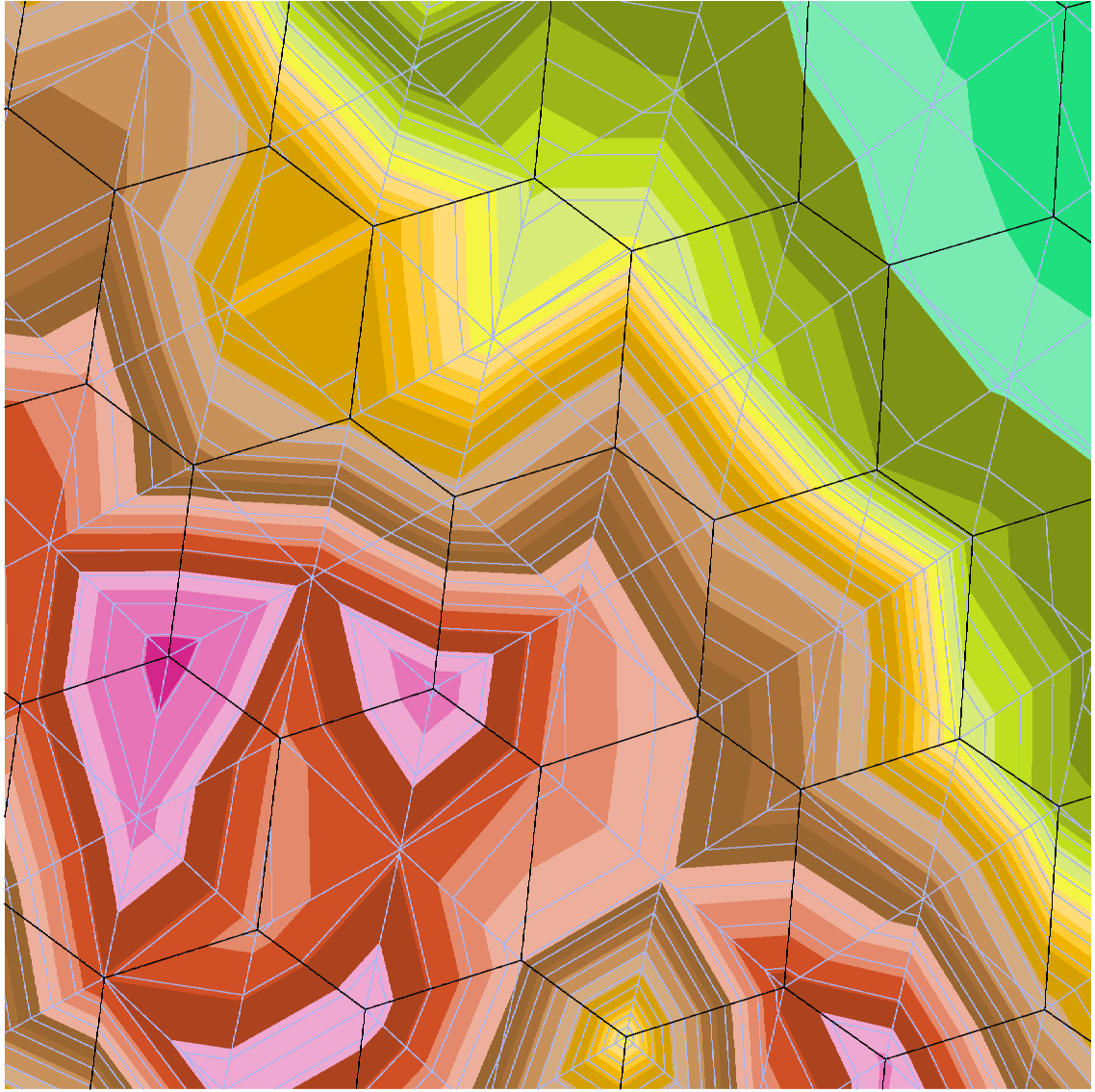
1. Coupling to atmospheric (Earth-System) model
2. 3-D groundwater modeling
3. Horizontal resolution can be (much) higher than atmosphere model
4. Local spatial refinement of surface grid (soil + lake + ocean)
5. Utilize SoilGrids datasets (in uppermost 2 m) and other available datasets at deeper levels for groundwater modeling
6. Implement one or more sets of Pedotransfer Functions to obtain hydraulic properties from these datasets
7. Implement soil structure effect on hydraulic conductivity
8. Full parallelization (both OpenMP and MPI) of soil/groundwater model

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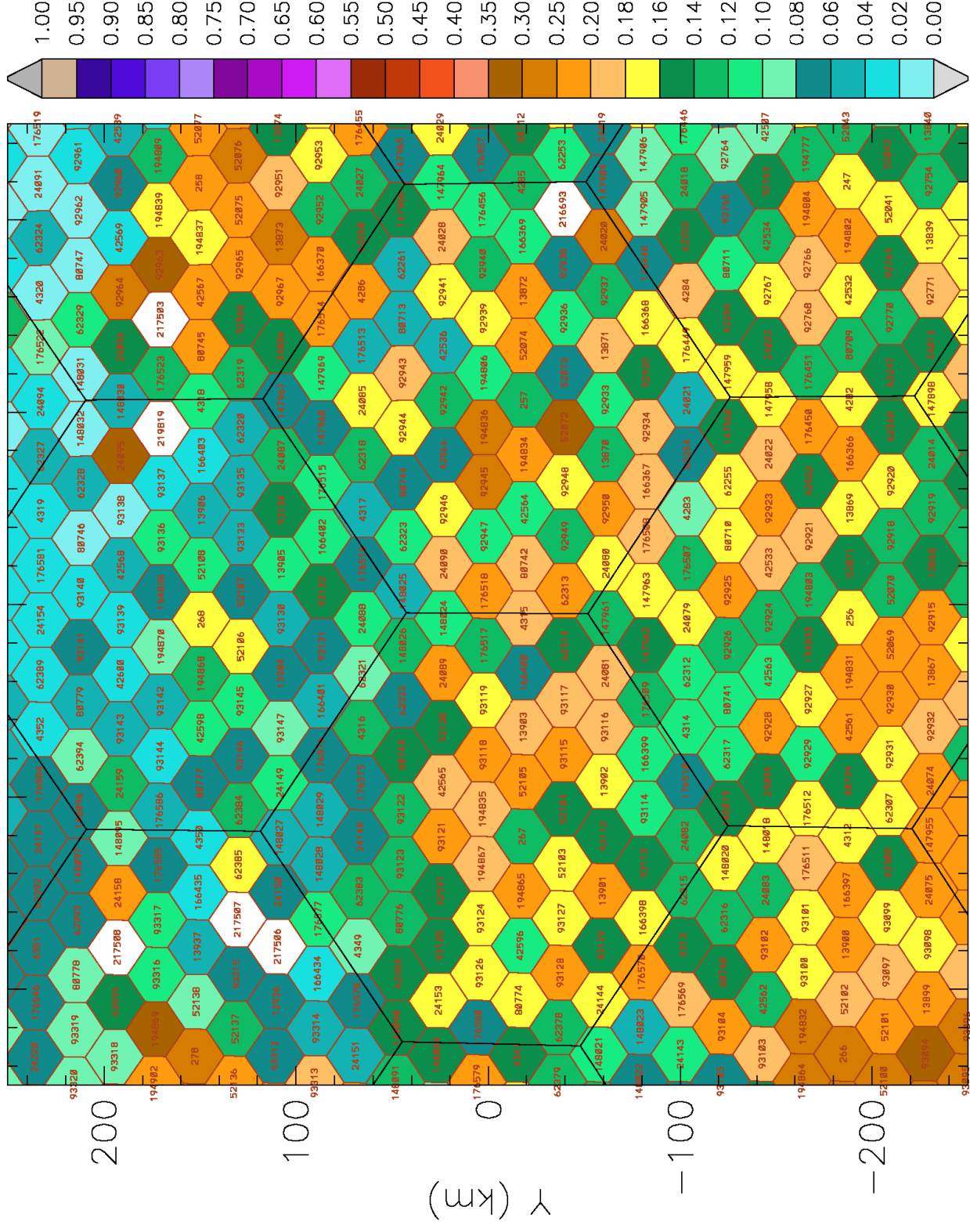


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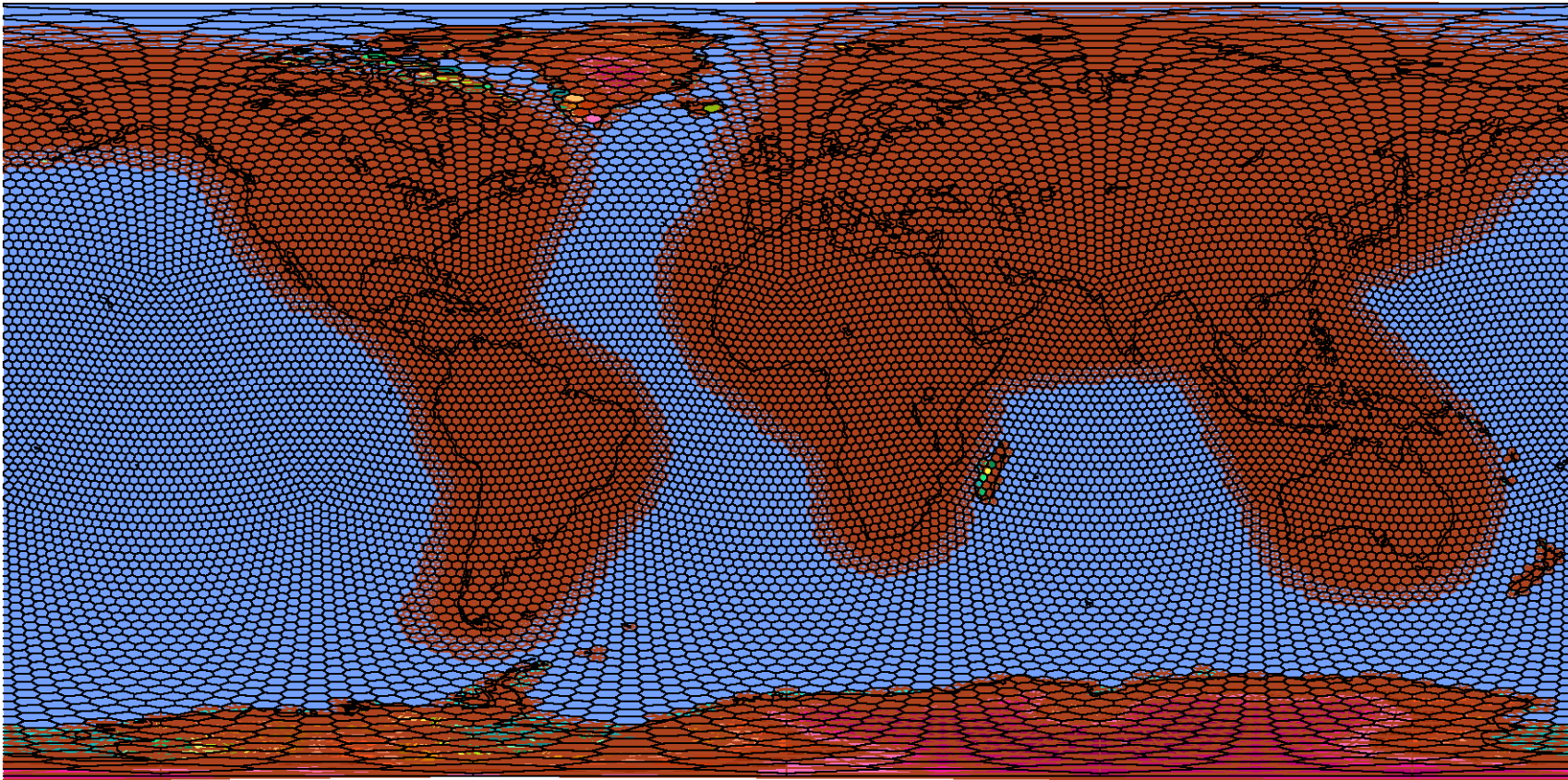
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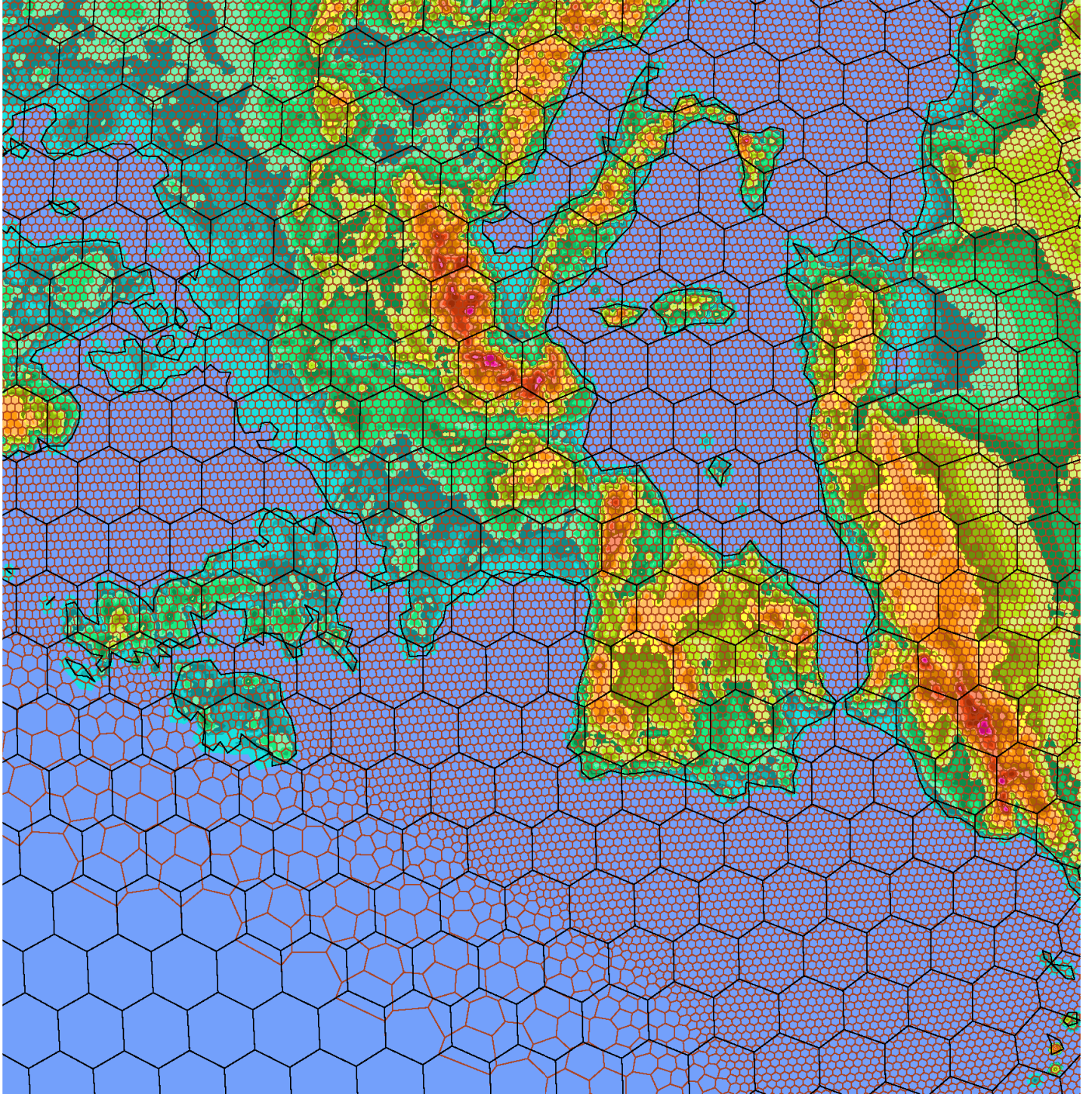
SOIL CLAY FRACTION ()

000200 UTC 01 JAN 2000



Surface grid refinement over major land areas

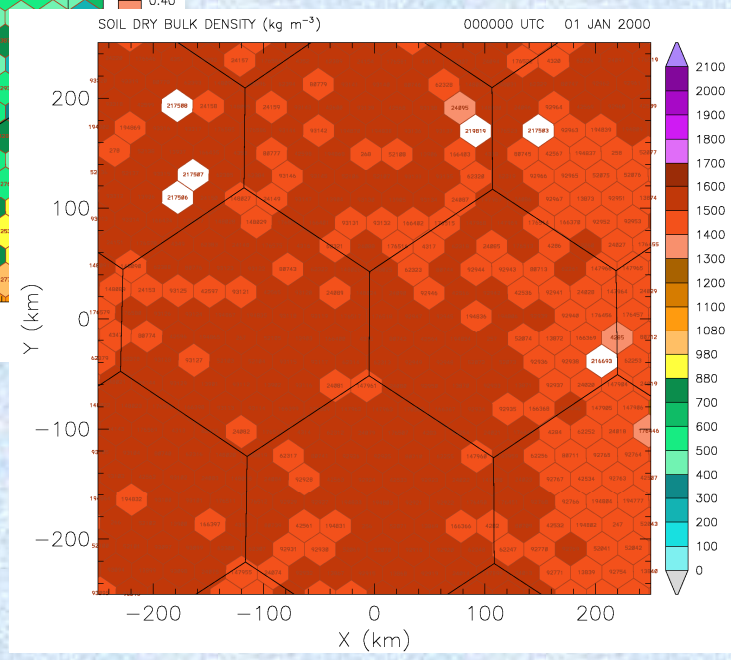
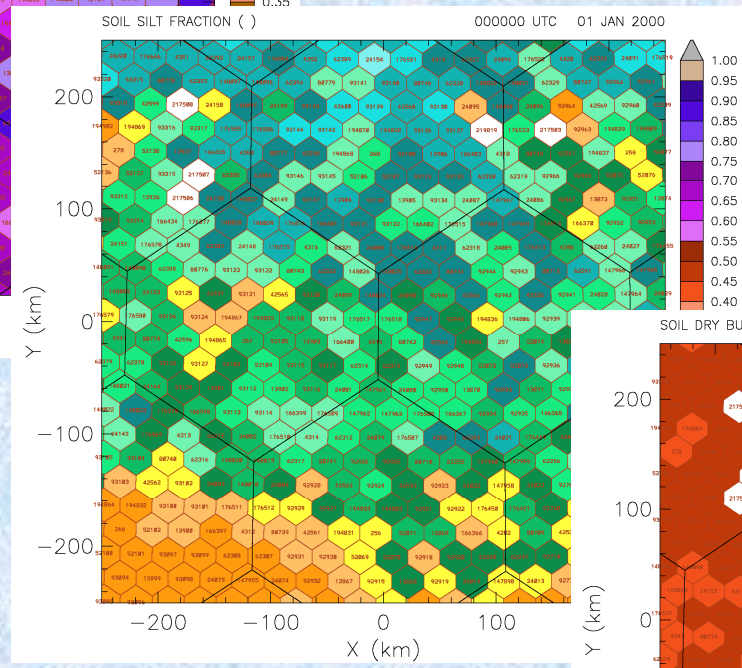
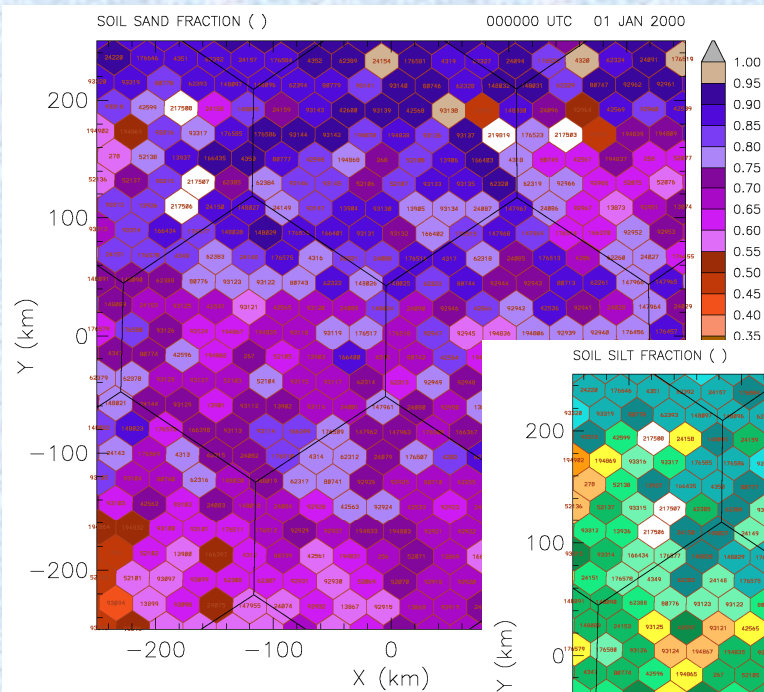




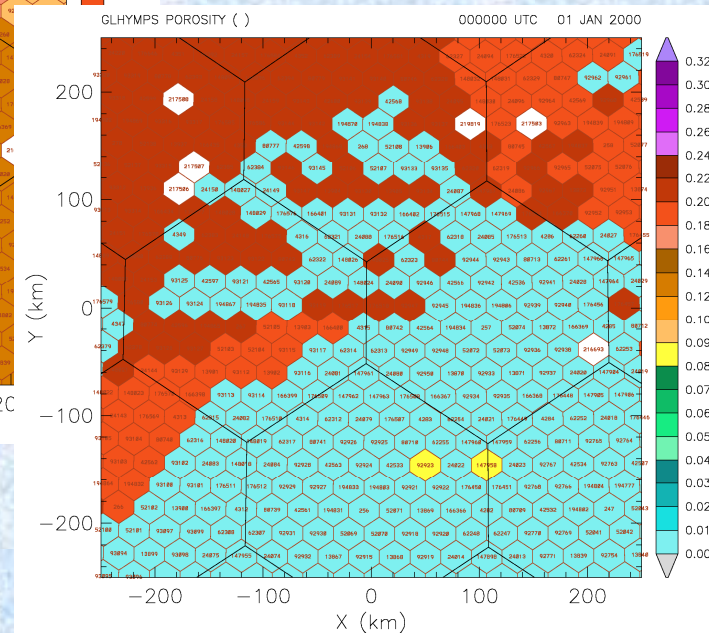
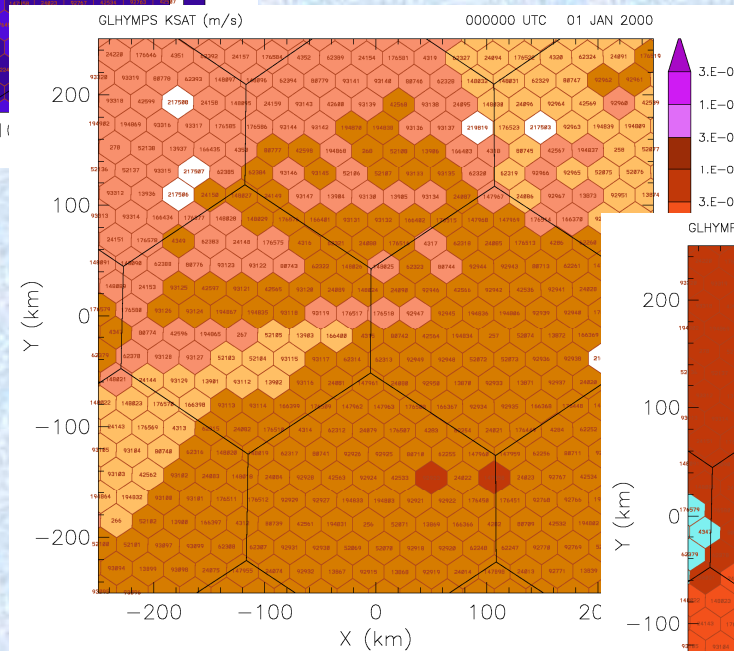
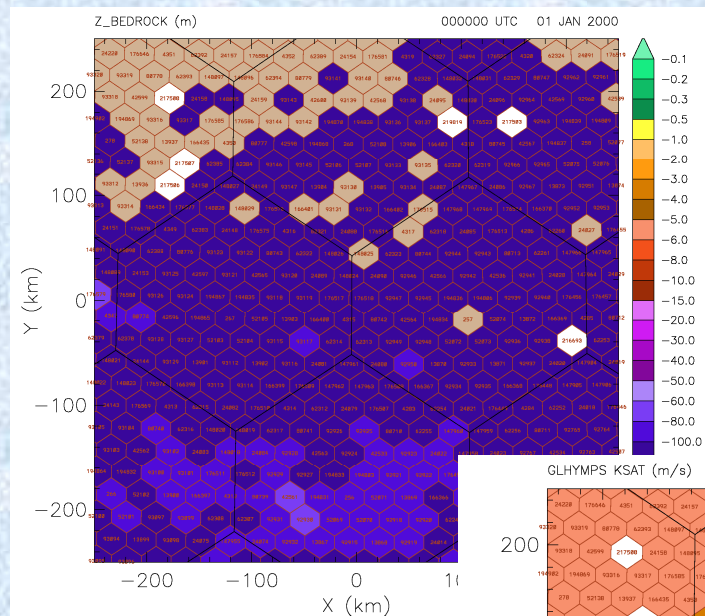
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SoilGrids Parameterization and Gridding



Groundwater Parameterization (GLHYMPS) and Gridding



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Pedotransfer Functions in OLAM-SOIL

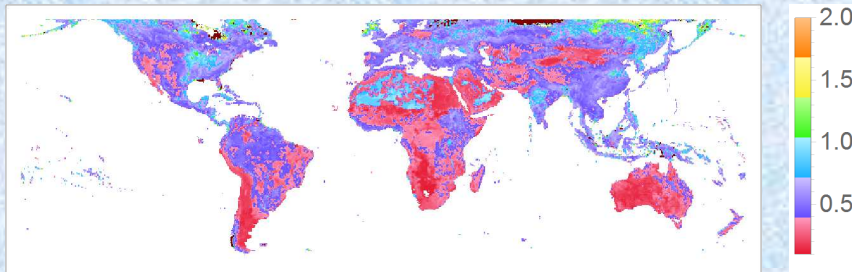
Weynants, Vereecken, and Javaux (2009)

de Boer (2016) (HiHydroSoil, based on SoilGrids)

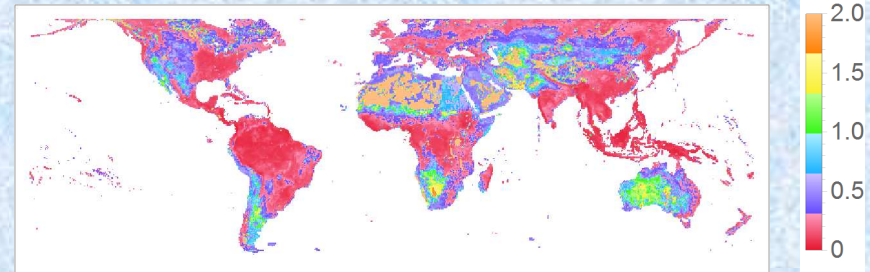
USDA van Genuchten parameters (from LEAF4)

HiHydroSoil, based on SoilGrids

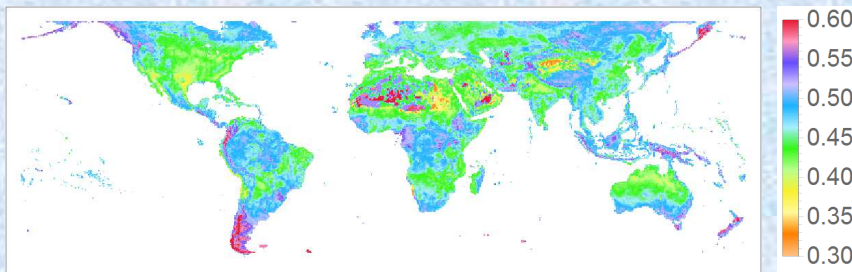
Characteristic pressure $1/\alpha$ [m]



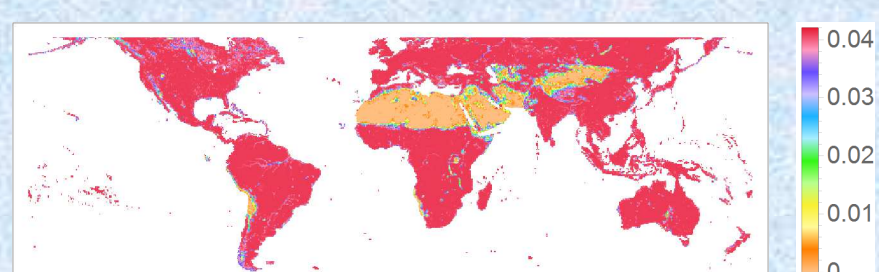
Saturated hydraulic conductivity [m/day]



Saturated water content [m³/m³]

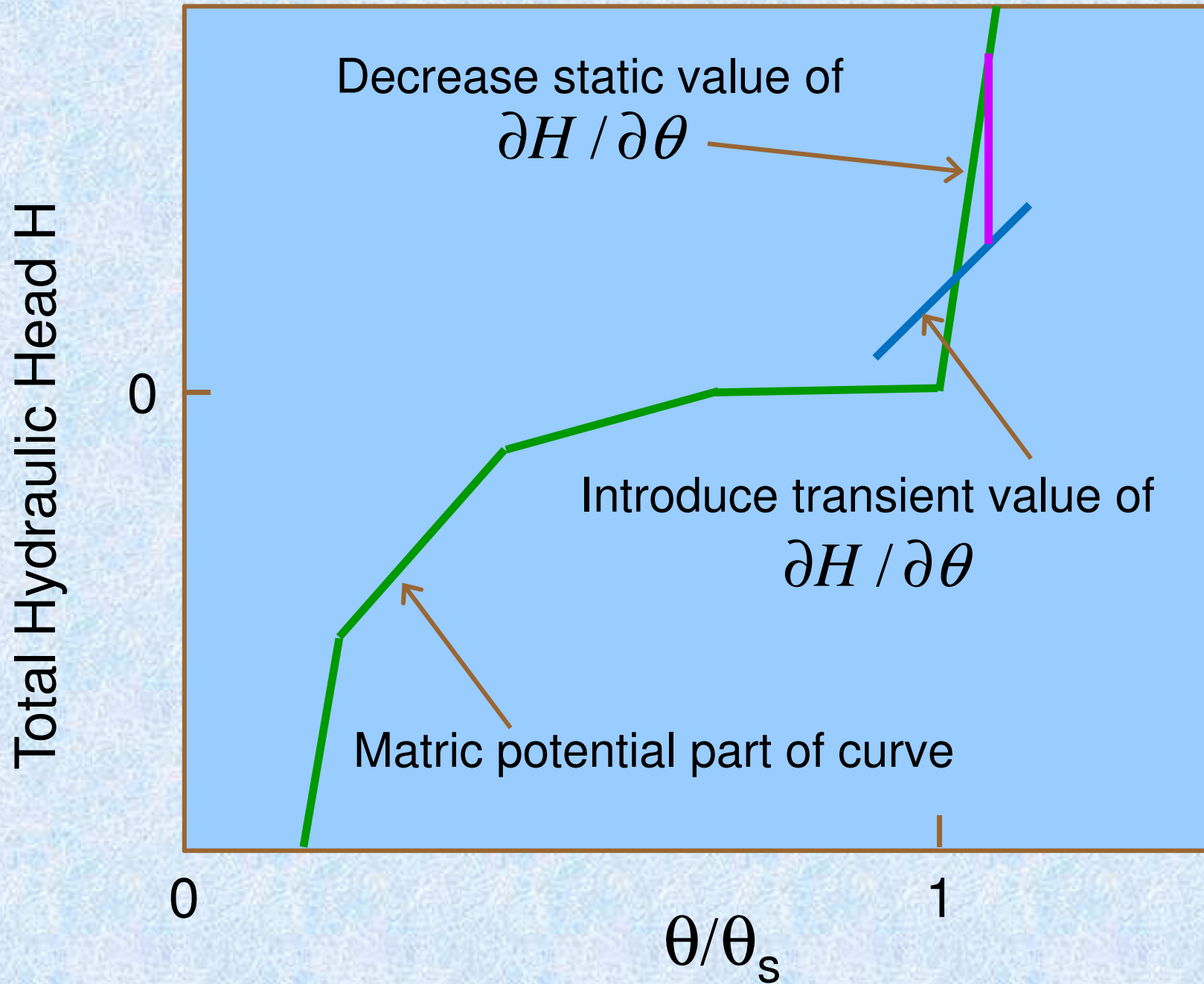


Residual water content [m³/m³]



Richards Equation – Going from 1D to 3D

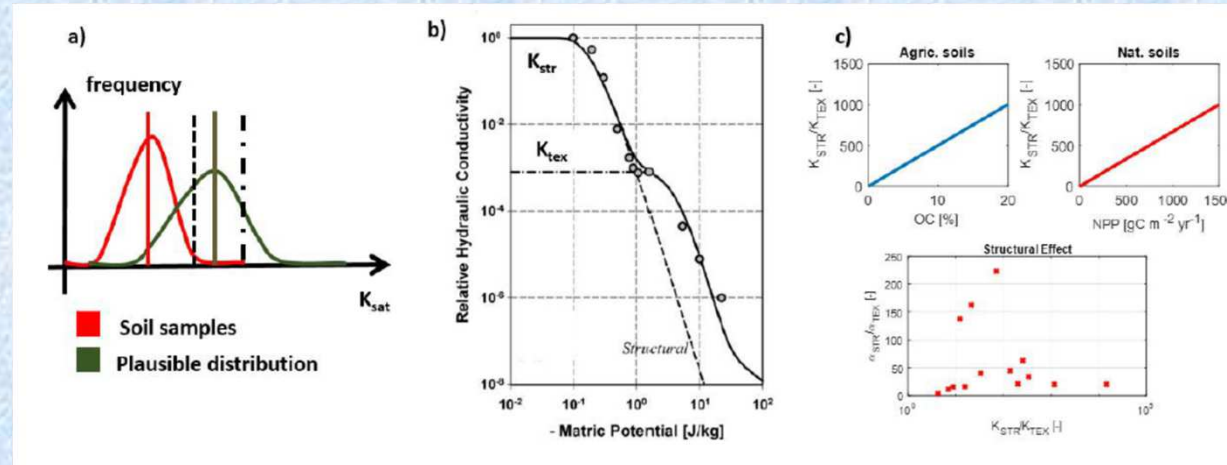
- Discussions with Stefan Kollet – PARFLOW references
- PARFLOW solves 3D-implicit formulation of Richards Equation (in order to accommodate fast-moving sound waves – stiff problem)
- Requires matrix pre-conditioning
- Matrix solver adds large number of computations to the problem
- More difficult to parallelize (with MPI) – much more data to transfer between nodes
- OLAM-SOIL avoids these complications by making system more elastic so that solver can be horizontally explicit (nearest-neighbor communication only)



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The influence of soil structure on global climate...



- A simple addition of soil structure information by adjusting Ks for structured soils (correlated with vegetation cover) – changes the energy balance of surfaces globally!

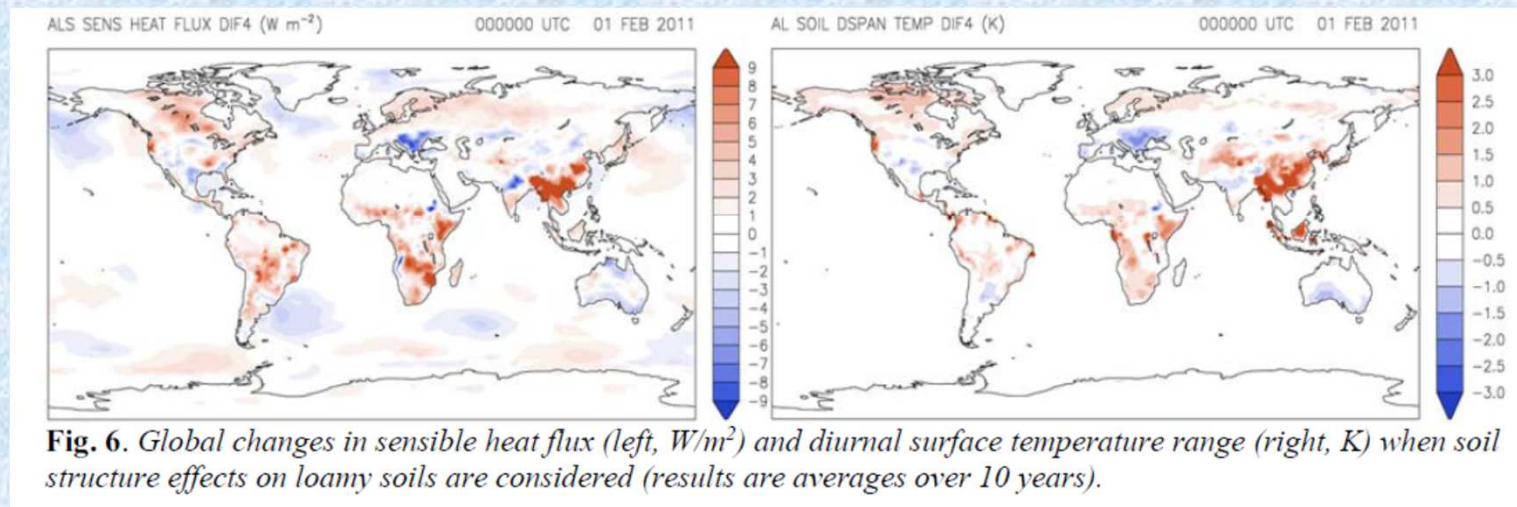


Fig. 6. Global changes in sensible heat flux (left, W/m^2) and diurnal surface temperature range (right, K) when soil structure effects on loamy soils are considered (results are averages over 10 years).

Soil Structure Effect – increased hydraulic conductivity

Expressed as multiplicative factor on hydraulic conductivity

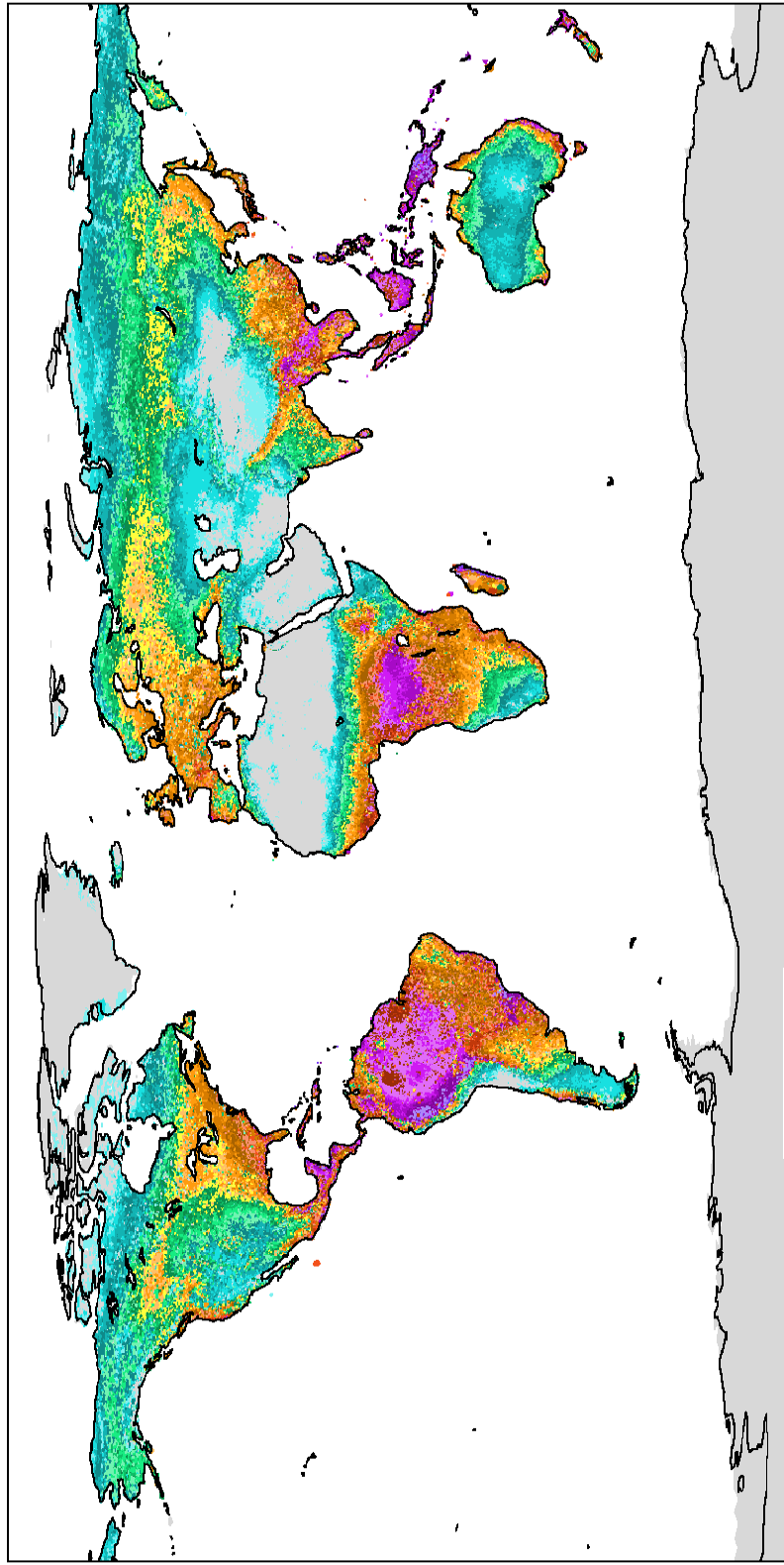
Can have a value up to 1000

Only applicable when soil is near saturation (matric head > -10 cm)

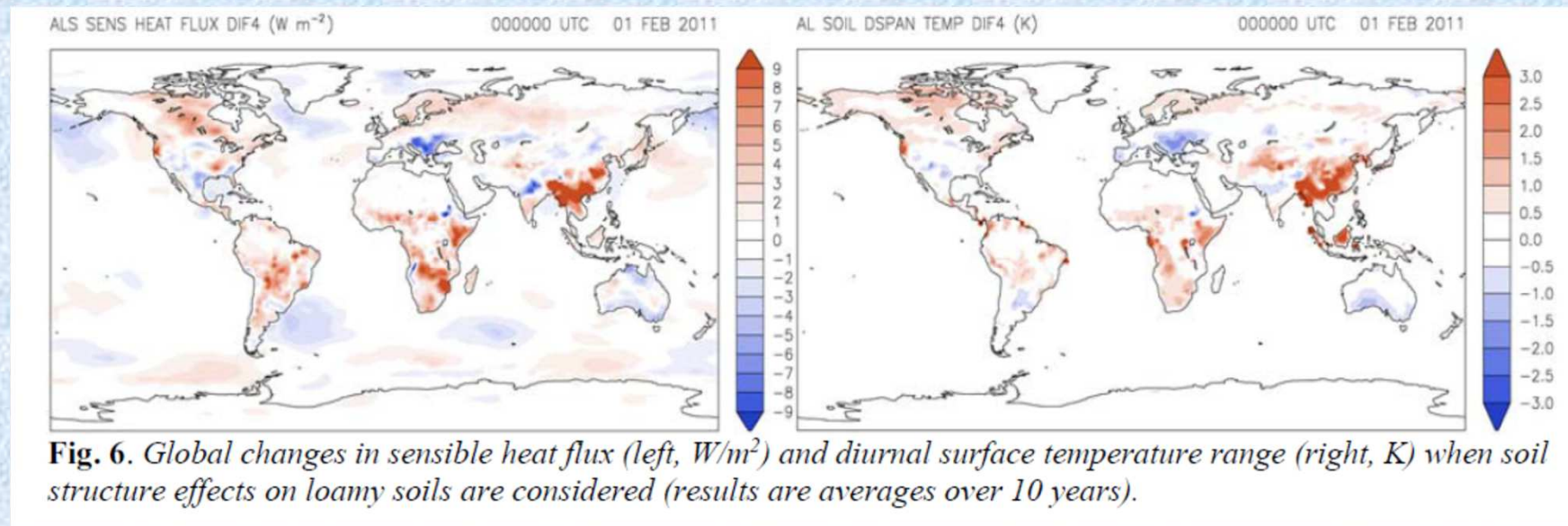
Important in root zone where vegetation is active: decreases linearly from surface to zero value at bottom of root zone

Proportional to annual mean GPP (a proxy for vegetation activity)

GROSS PRIMARY PRODUCTION OF CARBON ()



A preliminary exploration of the effect of soil structure on climatology was conducted with OLAM/LEAF (before OLAM-SOIL was ready) and showed the following differences in mean sensible heat flux and mean surface diurnal temperature range.



Determining the climatological effect of physical changes such as soil structure is a very challenging endeavor because of the natural variability of the atmosphere.

Even with zero year-to-year change in external forcing to the atmosphere (i.e., same solar flux, same ocean, land, and lake surface temperatures and other properties, same atmospheric composition and chemistry on any given date over all years), the atmosphere will proceed on a course in any given year that is different from all other years.

Q: How much of the difference seen between a control simulation and an experiment (with soil structure added) is merely a part of the natural variability of the atmosphere and how much is a real physical impact of soil structure?

Finding out (with confidence) requires an ensemble of long simulations and statistical analysis.

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Key Datasets and Formats (and how to get them into OLAM-SOIL)

Input datasets for OLAM-SOIL can be classified into 3 types:

- (1) Constant in time (e.g., topographic height, soil porosity)
- (2) Varying in time but with a repetitive annual cycle (SST, SEAICE, NDVI, ATM)
- (3) Time-dependent and different each year (SST, SEAICE, NDVI, ATM)

A complete set of datasets for types (1) and (2) is available with OLAM-SOIL.

Type (3) datasets are obtainable by downloading from archive sites (NOAA, NCAR, ECMWF, etc.) and must first be converted to hdf5 format to be read into OLAM-SOIL.

OLAM-SOIL directory structure

Create 'olam' directory on your computer, and copy the following tarfiles there:

olam_5.3.tar
olamdata1.tar
olamdata2.tar
olamdata3.tar

'Untar' these files, which gives the following directory tree:

Olam

5.3 (source code and build directories, and ATM climatological dataset)
olamdatah5 (surface datasets)
dpfiles (a few atmospheric datasets for specific dates)
grib2olam (to convert archived grib datasets into hdf5 format for input)

Major Datasets Required to run OLAM (surface)

[olam/olamdatah5/](#) – surface data directory (most files are 30 deg x 30 deg tiles)

dem30s – topography

gmted30s – topography (newer, better)

fao – soil textural class (still used but now less important)

soilgrids – sand, silt, clay, organic content, bulk density, pH, cation exchange capacity at 7 levels in the uppermost 2 meters; depth to bedrock, GPP

glhymps – permeability and porosity at deeper levels

sst6190, sst7100 – monthly sea surface temperatures averaged over 30 years

Ice8100 – monthly sea ice averaged over 20 years

wtd – water table depth

oge2 – landuse type (mostly vegetation class or absence of vegetation)

ndvi – monthly (composited) NDVI (used in vegetation model)

Major Datasets Required to run OLAM (atmosphere)

[olam/5.3/etc/](#) - OLAM subdirectory

ZONAVG_CLIMATE – contains monthly mean zonally (longitudinally) averaged atmospheric wind and temperature as a function of height and latitude. This can be used to initialize any global OLAM simulation (by setting INITIAL = 3 in OLAMIN).

To begin a simulation for a specific date/time in history, download a global gridded analysis (Reanalysis-2, CFSR, ECMWF, etc), which contains atmospheric wind, temperature, relative humidity, and geopotential height at several different pressure levels from the surface to the upper atmosphere, and also contains some surface quantities. (<ftp://nomads.ncdc.noaa.gov>) For this option, set INITIAL = 2 in OLAMIN.

Translate this dataset to hdf5 format with the grib2olam software provided in order to produce input file for OLAM to read. OLAM interpolates these fields to its grid as a set of initial atmospheric conditions and then proceeds with the time integration.