Adding support for new atmosphere grids

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(With help from Peter Caldwell, Noel Keen, Paul Ullrich, Charlie Zender, Mark Taylor, Gautam Bisht, Robert Jacob, Walter Hannah, and others)

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Overview

- Supporting (or even just testing) a new atmosphere resolution requires generating a handful of inputdata files on the new resolution
- Has become somewhat of a mysterious process with a chain of different, seldom-used tools
- Documentation on Confluence: Adding support for new atmosphere resolutions, NE512 and NE1024 configurations
- Workflow is under development

Adding support for new atmosphere resolutions

Created by Ben Hillman
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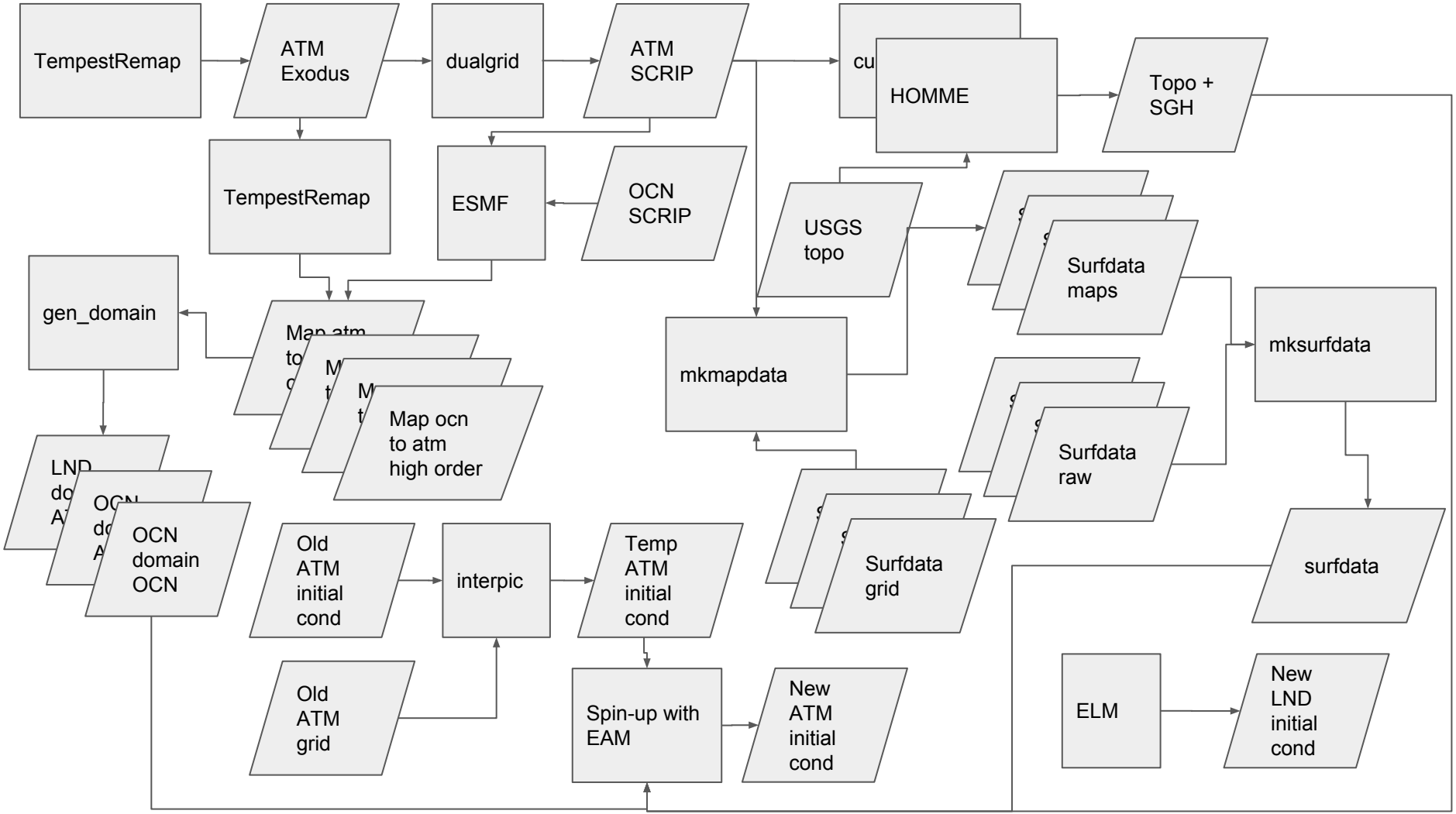
Why this is difficult

- String of many different tools, most of which are *untested*, and somewhat awkward to work with
- Documentation often outdated, and difficult to find expert help for some steps when things go wrong
- Uncharted territory with switch to using maps generated by TempestRemap as opposed to ESMF


TempestRemap
ATM Exodus
dualgrid
ATM SCRIP
HOMME
Topo + SGH
TempestRemap
ESMF
OCN SCRIP
USGS topo
Surfdata maps
gen_domain
mkmapdata
mksurfdata
Map ocn to atm high order
Surfdata raw
OCN domain OCN
Old ATM initial cond
interpic
Temp ATM initial cond
Surfdata grid
surfdata
Old ATM grid
Spin-up with EAM
New ATM initial cond
ELM
New LND initial cond

Outline of steps

1. Generate a grid descriptor file (Exodus-formatted file)
2. Generate “dual-grid” finite volume representation of the spectral element grid (SCRIP-formatted file) -- needed for certain preprocessing tools
3. Generate mapping files between components on different grids
4. Generate domain files
5. Downscale topography
6. Interpolate atmosphere dry deposition input data
7. Generate new atmosphere initial conditions
8. Generate interpolated land surface data
9. Generate interpolated land initial condition file
10. Add support for new grid to CIME

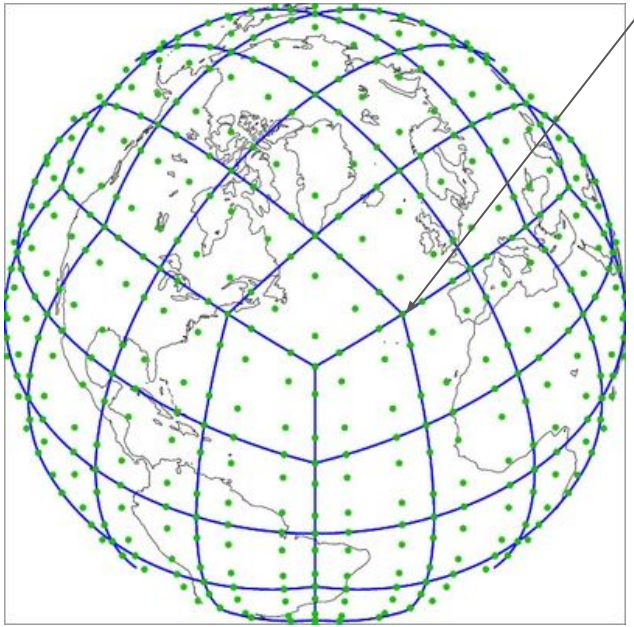
Generate grid descriptor file

- Describes spectral element quadrilaterals (no information about GLL nodes)
- Used for preferred mapping tool TempestRemap (and used at runtime for RRM)

```
bhillma@cori07:~/codes/e3sm/e3sm_grids> ./generate_mesh.sh configuration.ne4np4.sh
tempestremap/bin/GenerateCSMesh --alt --res 4 --file /project/projectdirs/acme/bhillma/grids/ne4np4/descriptor_files/ne4.g
Parameters:
  --res <integer> [4]
  --alt <bool> [true]
  --file <string> ["/project/projectdirs/acme/bhillma/grids/ne4np4/descriptor_files/ne4.g"]
============================================================
..Generating mesh with resolution [4]
..Writing mesh to file [/project/projectdirs/acme/bhillma/grids/ne4np4/descriptor_files/ne4.g]
Nodes per element
..Block 1 (4 nodes): 96
..Mesh generator exited successfully
============================================================
```

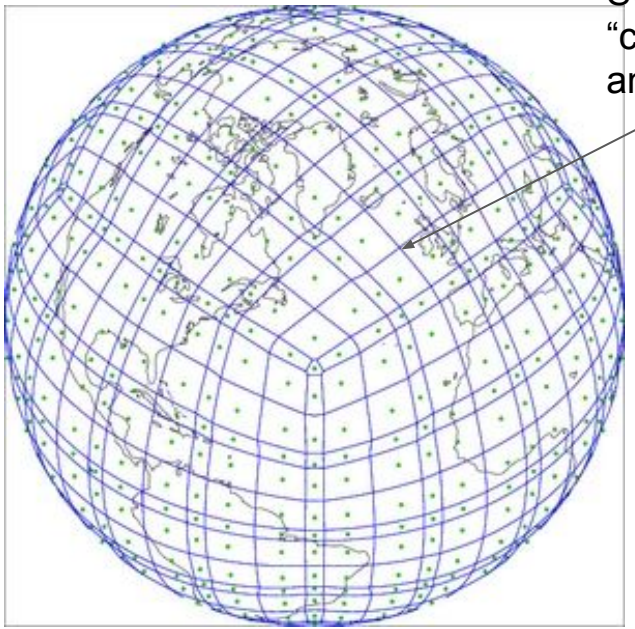
The “dual grid”

Exodus file: element corners



Spectral element GLL grid

SCRIP file: “cell” corners and centers



Finite volume “dual” representation of the SE grid

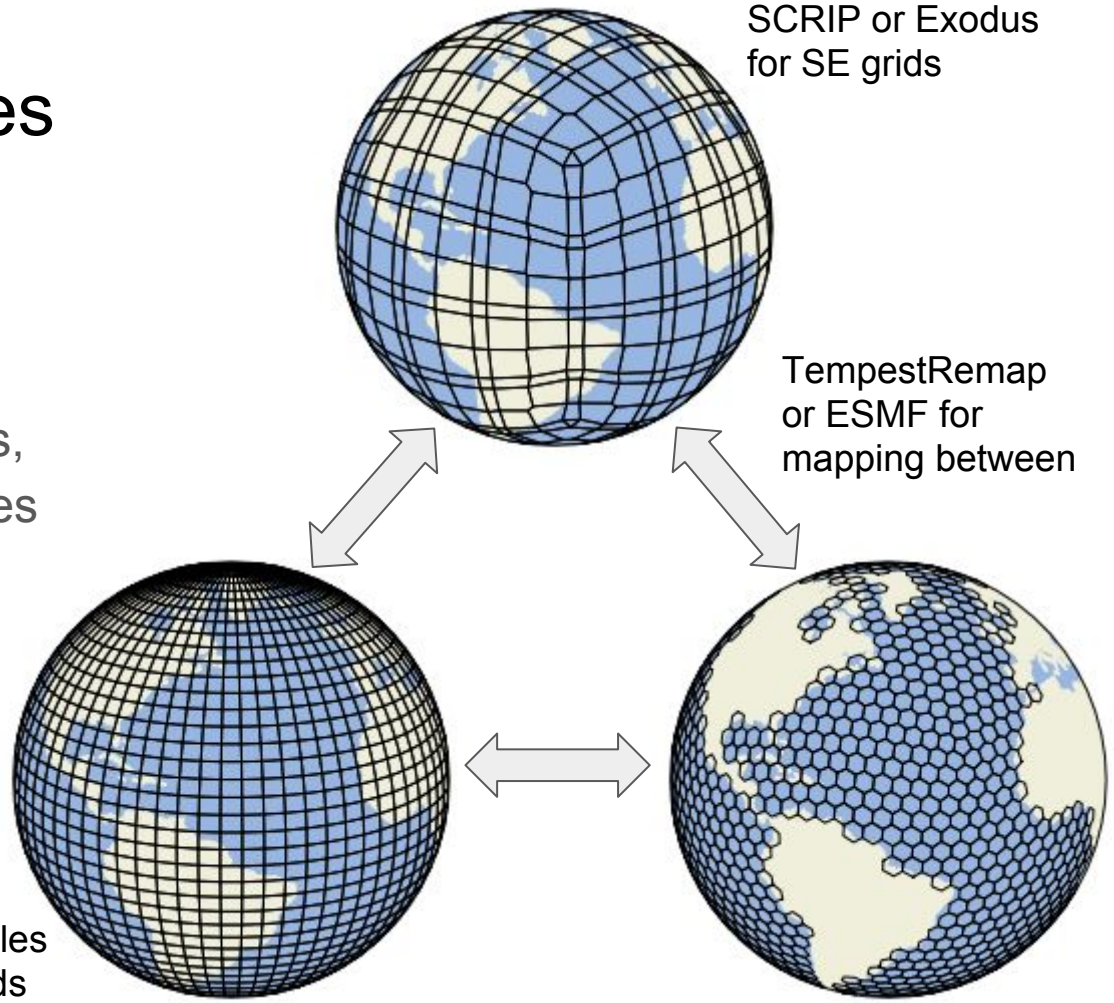
See CAM-SE Grid Overview for more information

Generate the “dual-grid”

- Dual grid is a finite-volume representation of the spectral element GLL grid
- Still required for topography tool and for interpolation of land surface data
  - Requirement for topography tool is probably going to stay for now; difficult to change
  - Requirement for land surface data likely to stay as well, until we have a parallel version of Tempest; land surface input data has LARGE source grids that will exhaust memory in serial application
- Two possible tools for generating the dual grid:
  - Matlab code: interates to optimize cell area to exactly match the GLL weights; SLOW, but accurate; produces nice-looking volumes for RRM grids and control volumes that are suitable for flux mapping
  - Fortran/NCL tools in HOMME: FAST, but inaccurate; does not optimize area to match GLL weights; resulting grid is NOT suitable for remapping fluxes (just for RRM?)

Generate mapping files

- Mapping weights between different component grids
- Needed for running components on different grids, *and* for generating domain files
- We can use TempestRemap with the SE grid, OR ESMF with the dual grid
- TR or ESMF wrapped in ncremap calls



Generate mapping files

Example usage:

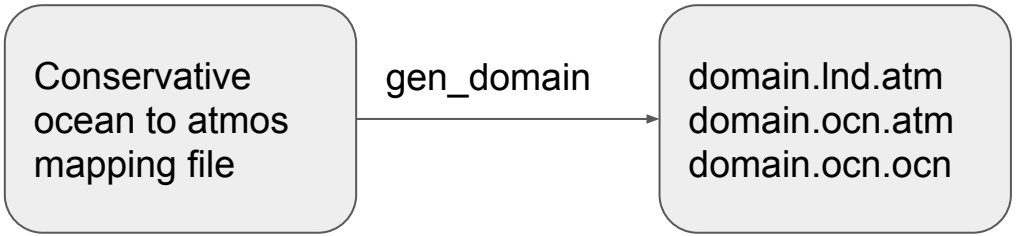
```
ncremap -P mwf -s $input_root/ocn/mpas-o/oQU480/ocean.QU.480km.scrip.181106.nc -g
$output_root/descriptor_files/ne4.g --nm_src=oQU480 --nm_dst=ne4np4 --dt_sng=190319
```

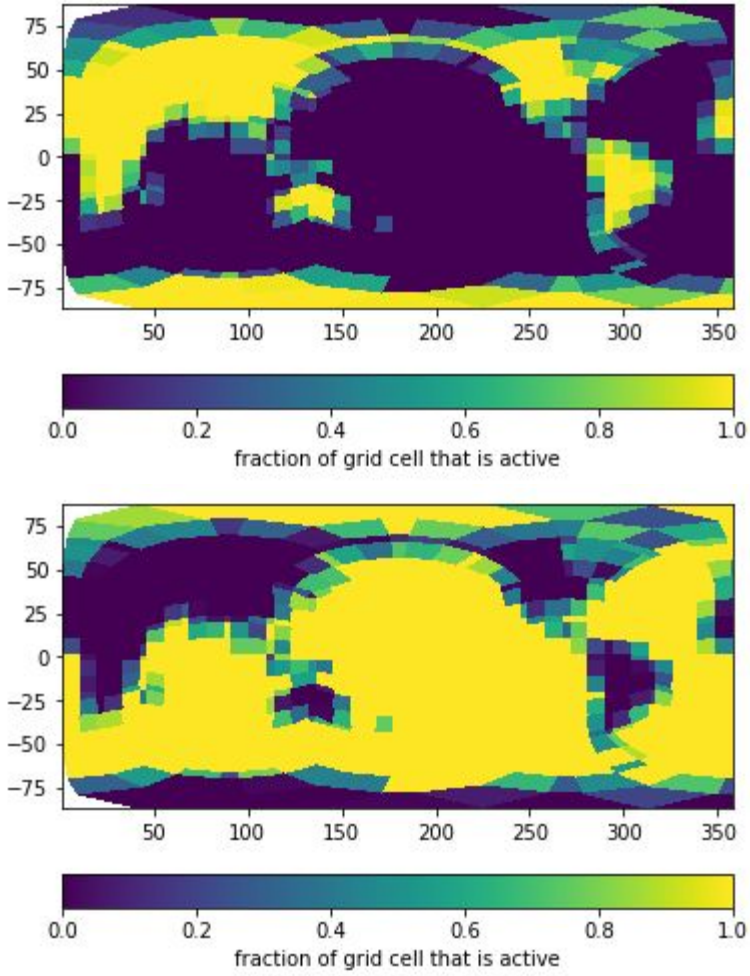
Will produce:

```
map_ne4np4_to_oQU480_highorder.190319.nc  map_ne4np4_to_oQU480_mono.190319.nc
map_oQU480_to_ne4np4_mono.190319.nc       map_ne4np4_to_oQU480_intbilin.190319.nc
map_oQU480_to_ne4np4_highorder.190319.nc  map_oQU480_to_ne4np4_monotr.190319.nc
```

Generate domain files

- Describe fractions and masks of components active on desired grid
- Stand-alone fortran code
- Uses conservative mapping files (generated via TempestRemap or ESMF)





Generate domain files

Example usage:

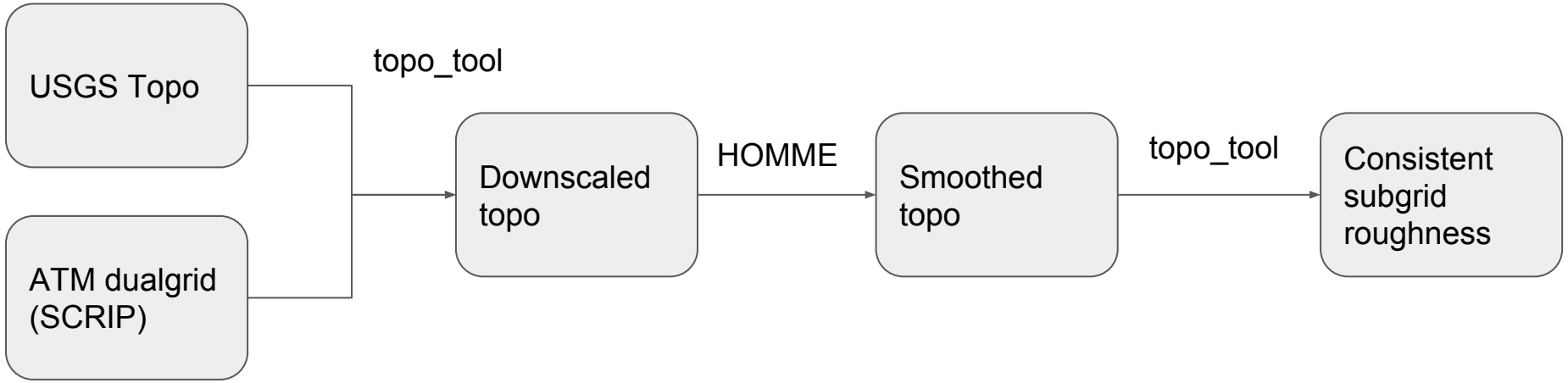
```
$e3sm_root/cime/tools/mapping/gen_domain_files/gen_domain -m
/project/projectdirs/acme/bhillma/grids/ne4np4/mapping_files/map_oQU480_to_ne4np4_monotr.19
0319.nc -o oQU480 -l ne4np4 --fminval 0.1 --fmaxval 1.0
```

Will produce:

```
domain.ocn.oQU480.190319.nc
domain.ocn.ne4np4_oQU480.190319.nc
domain.lnd.ne4np4_oQU480.190319.nc
```

Generate interpolated topography

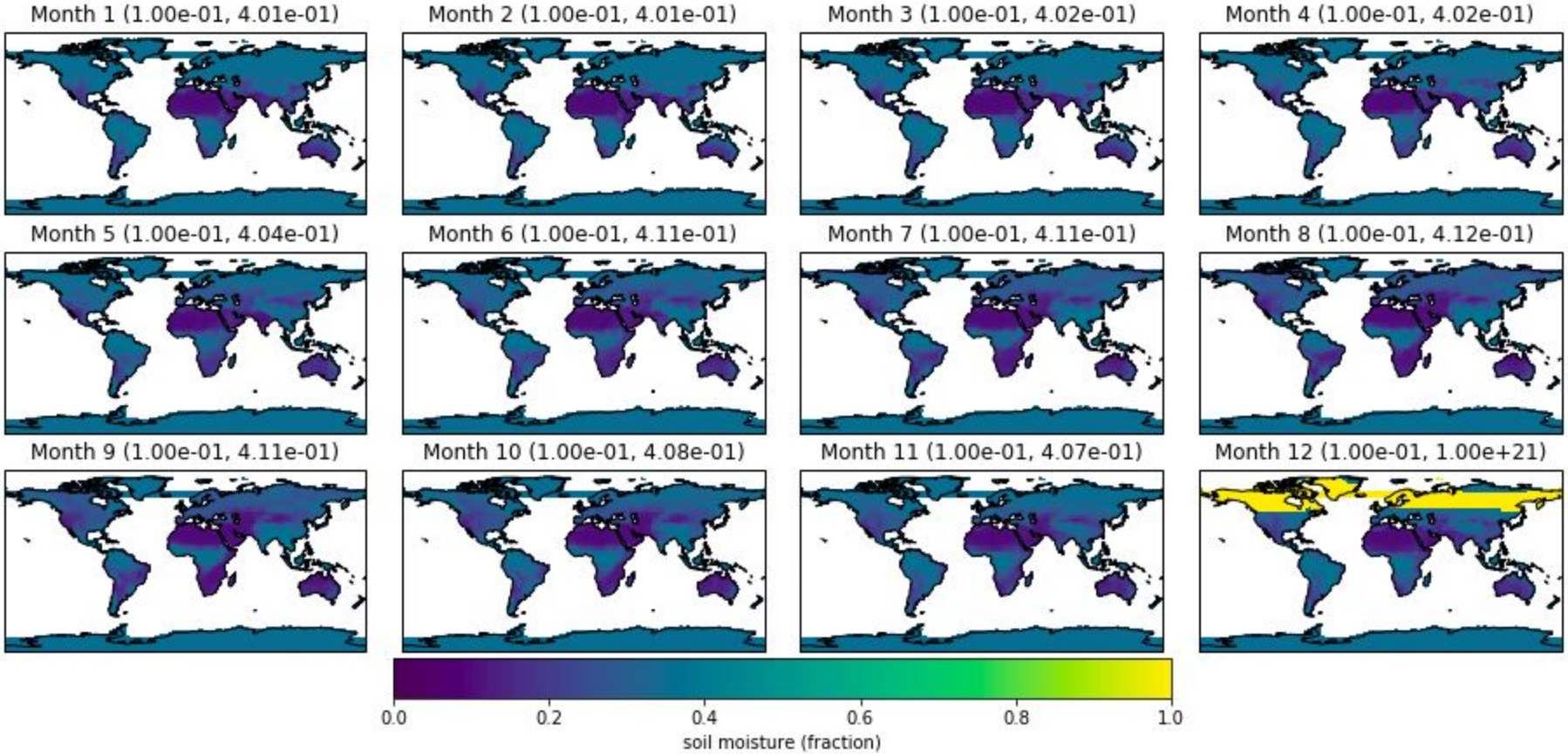
- Downscale USGS topography and recompute subgrid surface roughness
- Fortran code (topo_tool) to downscale topography, standalone HOMME to apply smoothing, re-run topo_tool to recompute surface roughness
- Caveats: there are some choices to be made in applying the smoothing; should be re-evaluated for higher resolution grids



Generate interpolated drydep file

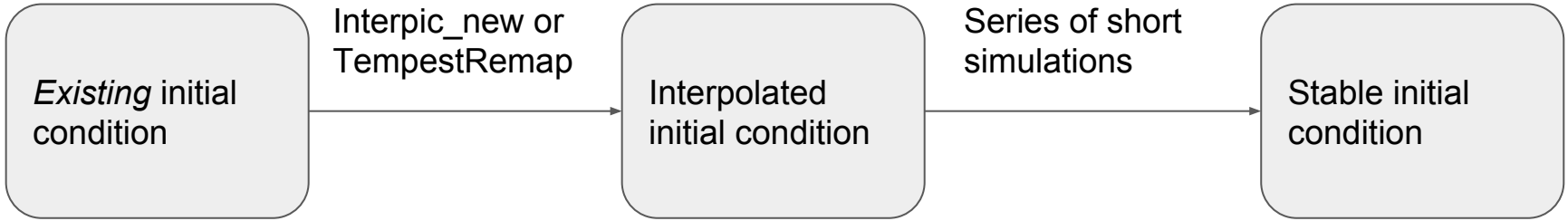
- According to README, needed for computing atmosphere dry deposition when using modal aerosol
- Standalone fortran code, but depends on libraries from a previous CAM build
- Appears to be broken/unsupported in master?!
- Problems with raw inputdata (see issue #2803)
- Is this still needed?

#2803 drydep file has bogus values



Generate new atmosphere initial condition

- Interpolate existing initial condition
  - Interpic_new: horizontal *and* vertical interpolation, but no unstructured input grids
  - TempestRemap: only horizontal interpolation, but we can interpolate existing SE initial conditions
- Spin-up interpolated initial condition: series of short simulations stepping up from a smaller timestep and stepping down from higher hyperviscosity until solution stabilizes



Generate new land surface data (for land model)

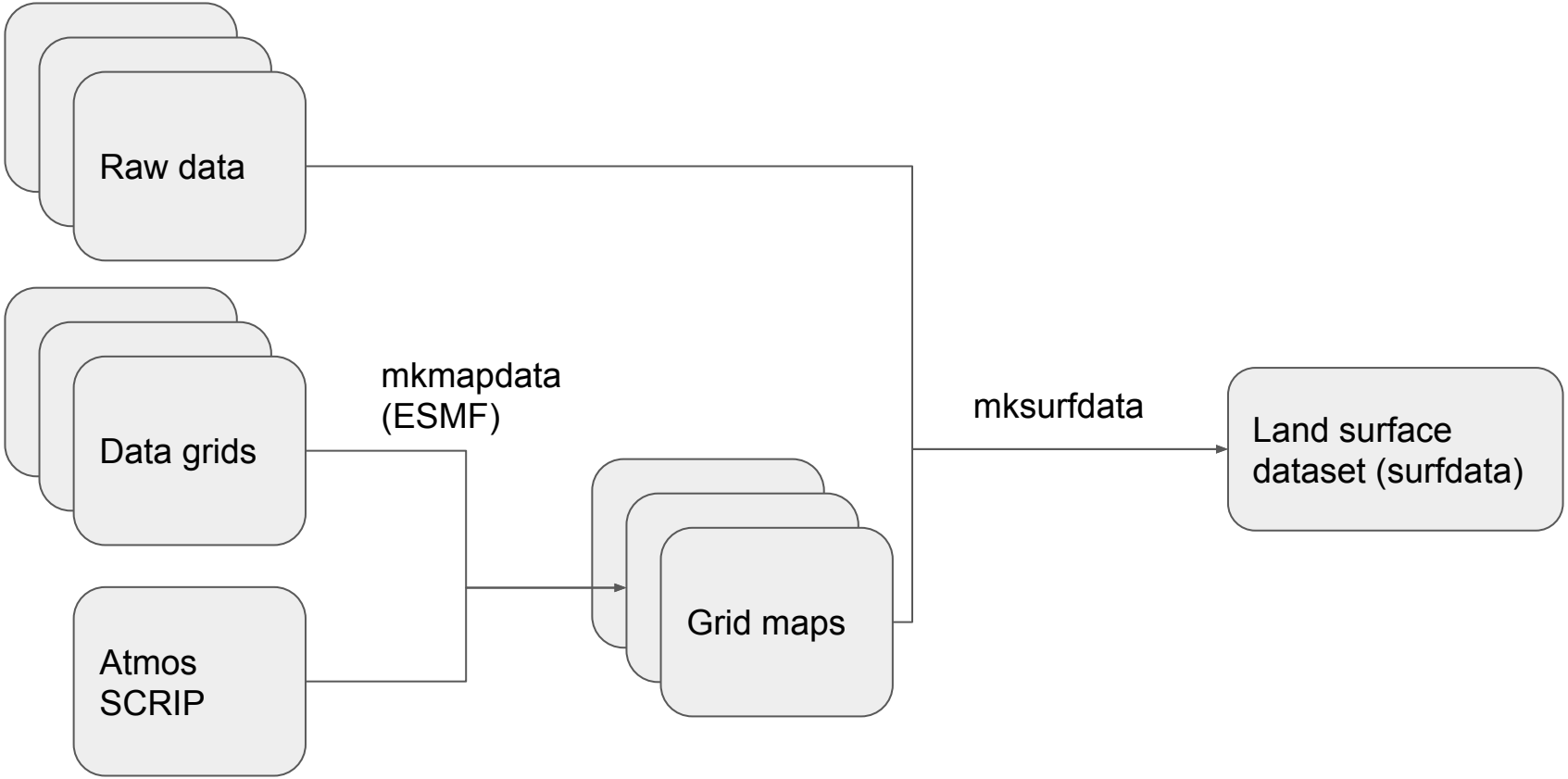
Land model typically run on same grid as atmosphere -- need land surface data on new grid to do this (plant functional types, fraction of different surface types, etc)

Steps:

1. Generate mapping weights from different raw input data grids (~15) to target grids (uses dual grid + ESMF)
2. Run mksurfdata tool to create a single land surface dataset

Adding support for new atmosphere resolutions

Generate new land surface data



Generate new land initial condition

Three options:

1. cold start: finidat="", no file necessary. Lets us get up and running, but not suitable for climate science applications
2. Interpolate a spun-up state from a previous simulation. This is reasonable for many applications, but not suitable for official published E3SM simulations.
3. spin-up a new initial condition following best practices from land model developers.

Add support for new resolution to CIME

Modify config_grids.xml

Add namelist defaults for atmosphere model

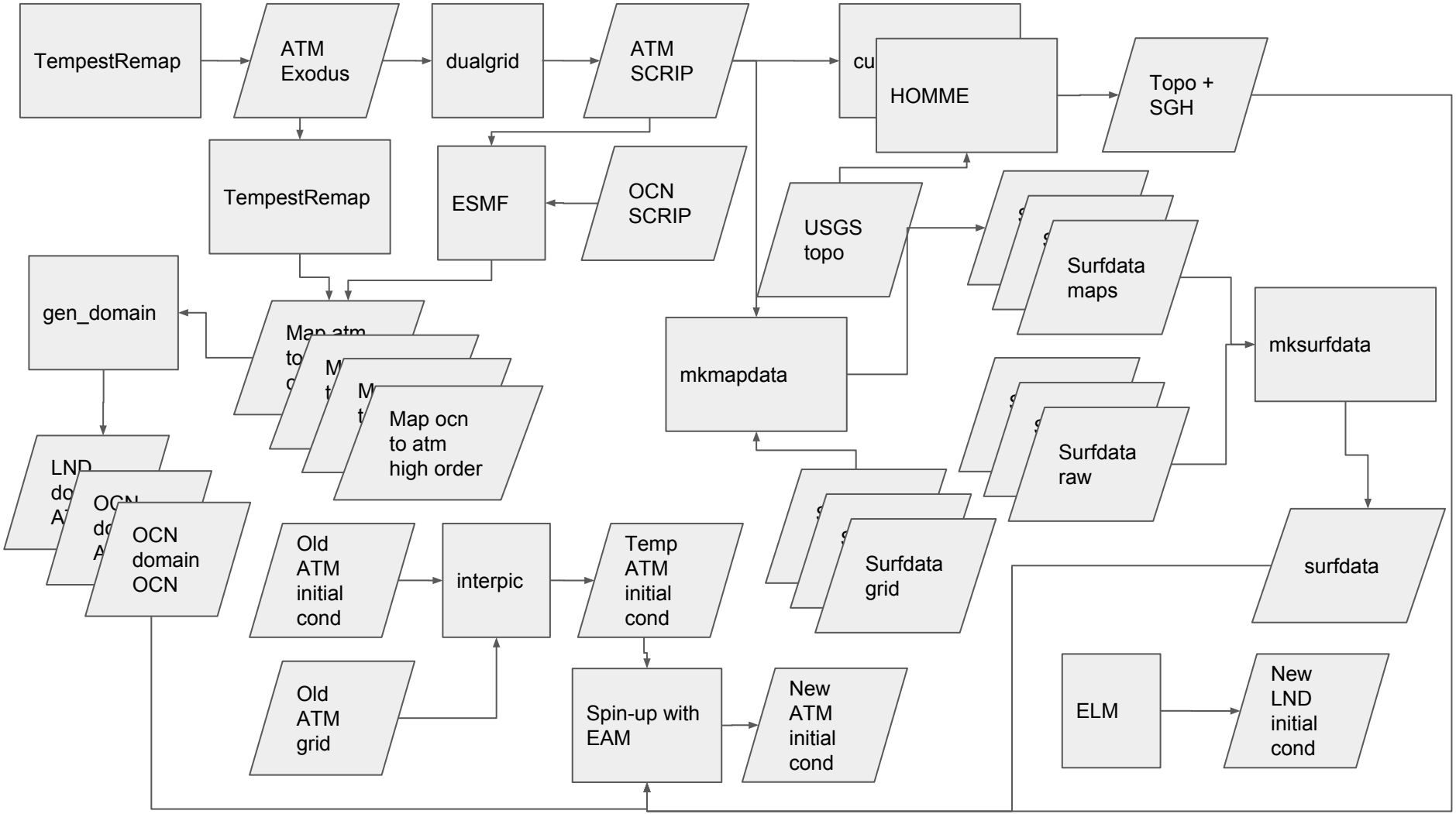
Add namelist defaults for land model

Things we’d like to improve

Documentation

Testing

Automation (see Noel’s talk)


TempestRemap
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OCN SCRIP
USGS topo
Surfdata maps
gen_domain
mkmapdata
mksurfdata
Map ocn to atm high order
Surfdata raw
OCN domain OCN
Old ATM initial cond
interpic
Temp ATM initial cond
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Spin-up with EAM
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