Intra-component coupling infrastructure

Some of the geospace physics will be on the same grid as other physics/chemistry. For those we will use the default coupling/regriding mechanism between dycore and the physics grid.

Other other geophysics fields need to be solved on geomagnetic field lines, which are described by a different grid system (usually geomagnetic latitude/longitude). They are likely a subcomponent under atmosphere (WACCM-X), so the intra-component coupler should be able to handle that.

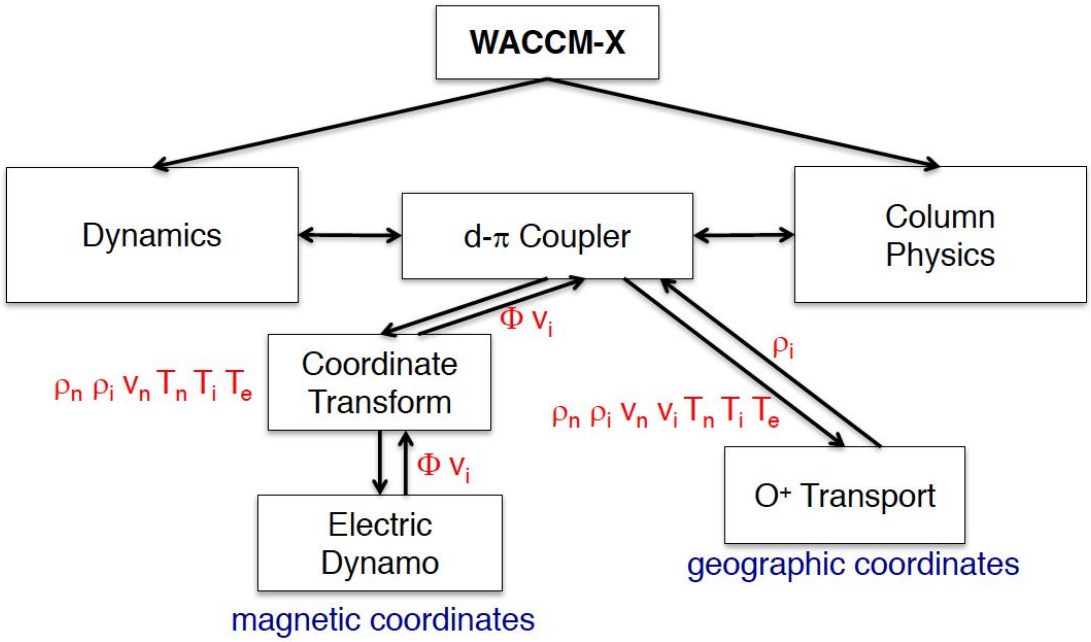
Ideally ionospheric physics is solved along geomagnetic field lines, and indeed the plasmasphere model our colleagues at NRL developed uses this approach. Each field line can then be regarded as a column, but of course it is different from the default vertical column. They have coupled this plasmasphere model to WACCM-X, and they use ESMF to map between the two grids. This approach is also used by the NOAA to couple their whole atmosphere model (WAM) and their plasmasphere model.

In current WACCM-X with "in-line" ionosphere, we use the TIE-GCM methodology: ionospheric transport is solved in the geographic lat/lon/pressure coordinate system. When running with FV dynamics, WACCM-X uses the same grid and decomposition as the FV dycore. Then, for the electrodynamics, we regrid certain variables to a geomagnetic grid (using ESMF) in order to solve the global electric potential. In the near term, regriding between an unstructured dycore grid (such as cubed-sphere or hexagonal) to conventional geographic lat/lon grid will allow us to use these dycores in WACCM-X. In the long-term, a universal regriding between an arbitrary unstructured dycore grid and geographic lat-lon grid and/or a geomagnetic grid would be desirable, and most relevant in the spirit of SingleTrack.

What we need is a generalization of the current DP coupler that allows for generic components to work on their own grid. Those generic components would likely make use of the CPD for executing calculations that can be broken into columns. There is nothing to say we cannot think of doing things in a column that might be along a field line. But we cannot assume that everything outside of the base dynamical core can be broken into columns.

This is not only a WACCM-X problem. It could be applied to the creation of diagnostic grids, or even reading in and regridding forcing / nudging datasets.

Integrating Ionospheric Dynamics into WACCM-X



d-π Coupler: dynamics-physics-ionosphere-electrodynamics (D-PIE) coupler
Electric Dynamo: calculates global electric potential resulting from wind-driven ions
ρ: density v: velocity T: temperature n: neutral i: ion e: electron Φ: electric potential

Schematic of Geospace Implementation (from Stan Solomon)

Further Detail:

Much of the 'physics' we are talking about here are really dynamics. But, we still use column physics in actual vertical columns. Much of the "physics" in WACCM-X are just like the other physics - solar irradiance, chemistry, RT, etc., and we do them in CAM/WACCM column physics. Even the aurora is on columns. These things could be done on any grid.

However, in the case of ion transport, it is similar to minor species transport, except that there is some feedback to the neutral dynamics. In principle, ion transport could be done in any coordinate system. It is most elegant to do it in geomagnetic coordinates, because the magnetic field organizes the ion motions, but for historical reasons we do it in geographic coordinates. We could do it in some other coordinate system, but this would require an entirely new code development. One complication is that much of the ion transport occurs in the vertical.

In addition to ion transport, there is the electrodynamical calculation of the global electric potential. This depends on ions, neutrals, and magnetospheric inputs as well. It also could be done, in principle, in any coordinate system, but we do it in geomagnetic coordinates, since that is by far the most straightforward approach.

This obviously necessitates that we repeatedly go back and forth between geographic and geomagnetic coordinates. Therefore, we have software that does this, currently using ESMF. So, all we really need is a way to get to/from the dycore grid from/to geographic lat-lon. Longer term, it would be better to have generalized and direct geographic/geomagnetic/unstructured transforms.

This is the sort of thing that ESMF is supposed to do. We have had a lot of trouble with ESMF, so I don't know if it is the answer, but we are already knee-deep in it, and I don't see why we should have to re-invent it.