

# Thermosphere/Ionosphere Coupling in WACCM-X

Ben Foster  
(with Hanli Liu and Joe McInerny)  
NCAR/HAO

Whole Atmosphere Working Group  
February 18, 2015

# HAO Thermospheric GCM's TIEGCM and TIMEGCM

- Global, 3d, time-dependent simulation of dynamics, temperature, composition and electrodynamics from first principles (Roble, Ridley, Richmond)
- Self-consistent aeronomic scheme for coupled Thermosphere/Ionosphere system via electro-dynamo.
- Parallelized with pure MPI, with a basic blocked domain decomposition on geographic and geomagnetic grids.
- Goal of this project is to install the dynamo code in the WACCM environment to improve T-I coupling.

# Major WACCM/WACCM-X Components

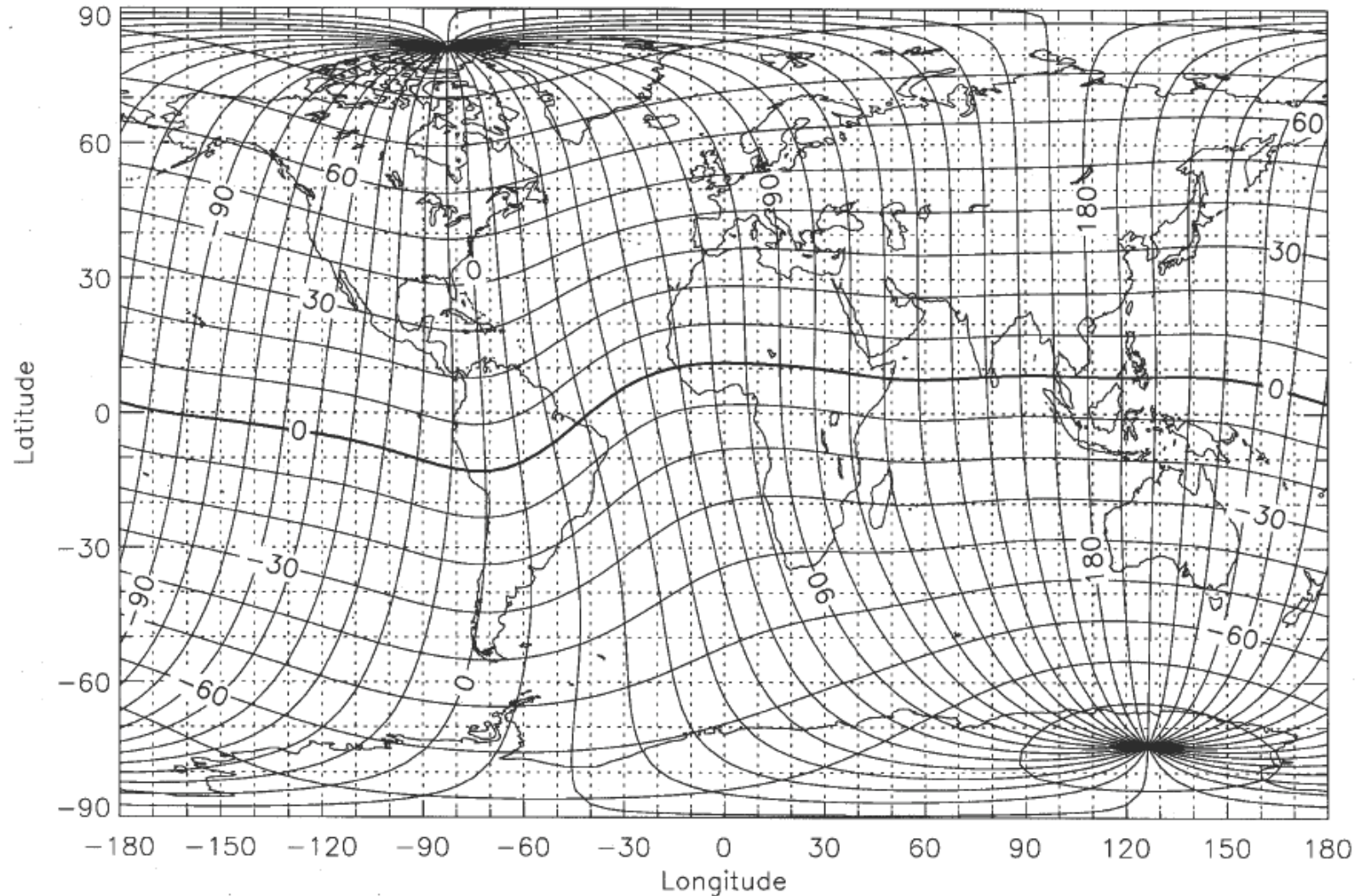
Model Framework	Chemistry	Physics	Physics	Resolution
<p>Extension of the NCAR Community Atmosphere Model (CAM)</p> <p>Finite Volume Dynamical Core</p>	<p>MOZART+ Ion Chemistry (~60 species)</p> <p>Fully-interactive with dynamics.</p>	<p>Long wave/short wave/EUV</p> <p>RRTMG</p> <p>IR cooling (LTE/non-LTE)</p> <p>Modal Aerosol</p> <p>CARMA</p> <p>Parameterized GW</p> <p>Major/minor species diffusion (+UBC)</p> <p>Molecular viscosity and thermal conductivity (+UBC)</p> <p>Species dependent <math>C_p</math>, <math>R</math>, <math>m</math>.</p>	<p>Parameterized electric field at high, mid, low latitudes. IGRF geomagnetic field.</p> <p>Auroral processes, ion drag and Joule heating</p> <p>Ion/electron energy equations</p> <p>Ambipolar diffusion</p> <p>Ion/electron transport</p> <p>Ionospheric dynamo</p> <p>Coupling with plasmasphere/magnetosphere</p>	<p>Horizontal: 1.9° x 2.5° (lat x lon configurable as needed)</p> <p>Vertical: 66 levels (0-140km) 81/125 levels 0--500km</p> <ul style="list-style-type: none"> <li>• &lt; 1.0km in Upper Troposphere/ Lower Stratosphere</li> <li>• 1-2 km in strat.</li> <li>• 0.5 scale height in mesosphere/thermosphere (0.25 scale height in mesosphere/thermosphere with 125 levels)</li> </ul>

# Mapping the geomagnetic field

Solid lines: 10x10 degree geomagnetic coordinates

Dotted lines: 10x10 degree geographic coordinates

M(110) Coordinates at 110 km for 1995.0



## Earth's magnetic field could flip within a human lifetime

By [Robert Sanders](#), Media Relations | October 14, 2014

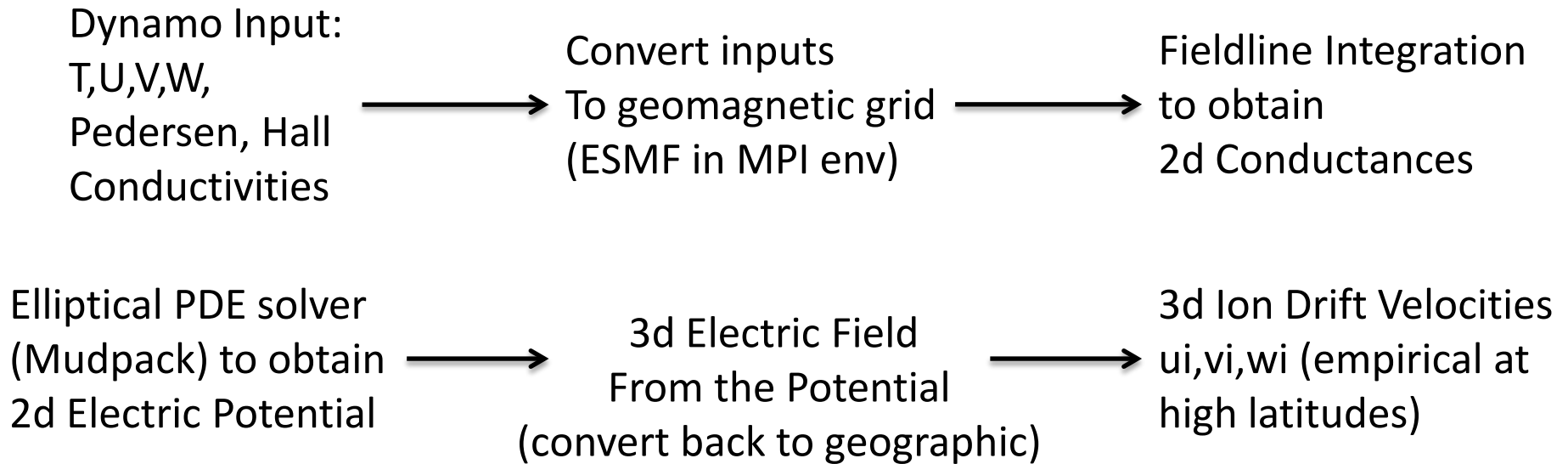
**BERKELEY** — Imagine the world waking up one morning to discover that all compasses pointed south instead of north.

...”demonstrates that the last magnetic reversal 786,000 years ago actually happened very quickly, in less than 100 years”

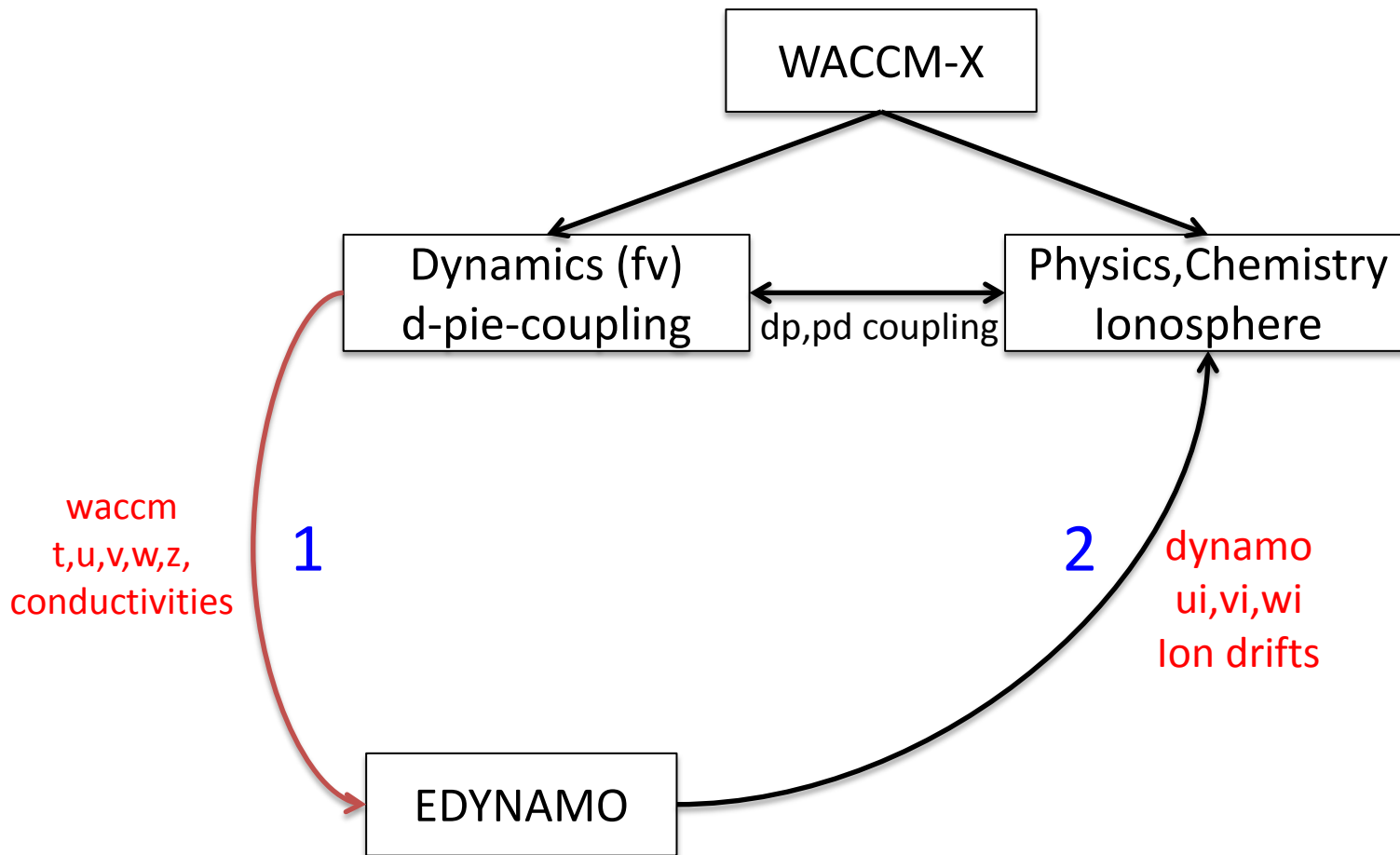
“The discovery comes as new evidence indicating that the intensity of Earth’s magnetic field is decreasing 10 times faster than normal, leading some geophysicists to predict a reversal within a few thousand years.”

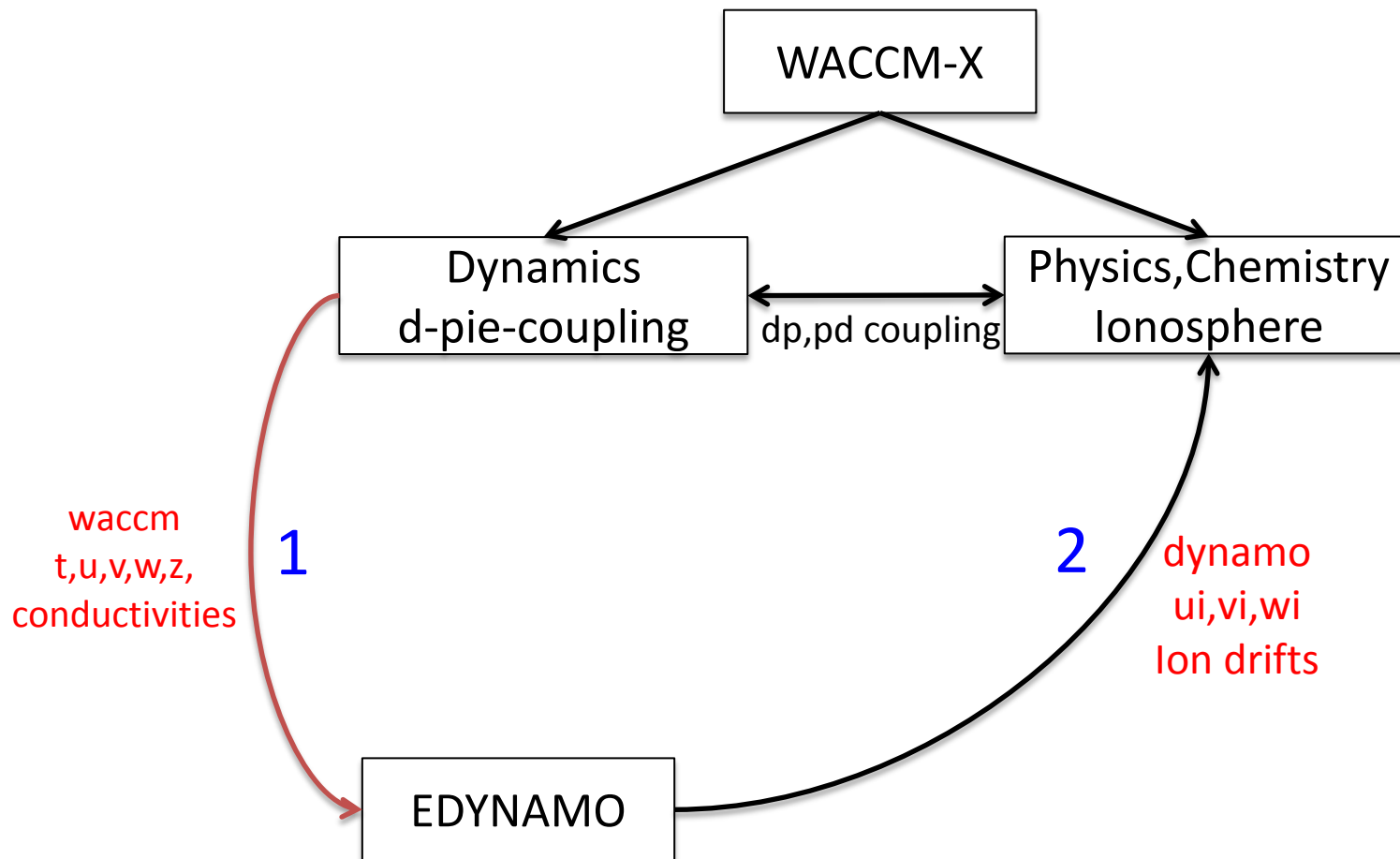
Leonardo Sagnotti, et.al., Extremely rapid directional change during Matuyama-Brunhes geomagnetic polarity reversal  
Geophys. J. Int. (November, 2014) 199 (2): 1110-1124

# T-I Coupling via Electro-Dynamo:



Electric field is regridded to geographic, ion drifts are calculated and passed back to the ionosphere, where they interact with neutral wind velocities for self-consistent ion/neutral coupling (ion drag, ion transport, joule heating, etc)

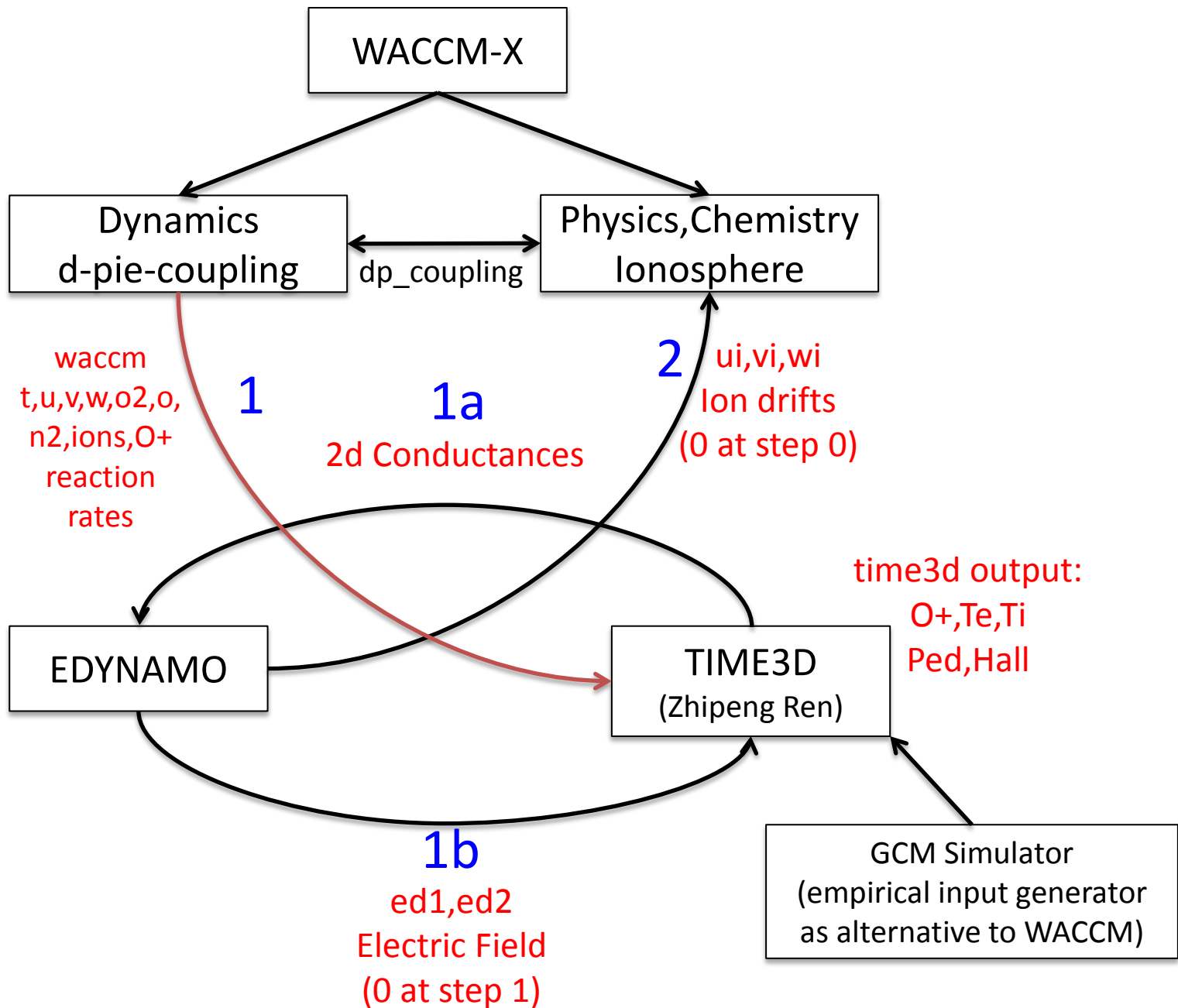




BUT, this scheme has limitations:

- No horizontal transport of  $O^+$  (yet), resulting in unrealistic ion/electron densities and conductivities
- Requires imposed upper boundary on  $O^+$  at 500 km.
- Empirical potential at high latitudes.





## References:

TGCM website:

- [www.hao.ucar.edu/modeling/tgcm/](http://www.hao.ucar.edu/modeling/tgcm/)

TIEGCM/TIMEGCM model description:

- [www.hao.ucar.edu/modeling/tgcm/doc/description/model\\_description.pdf](http://www.hao.ucar.edu/modeling/tgcm/doc/description/model_description.pdf)

WACCM branch-tag:

- waccmx\_edyn\_ionosx\_cam5\_3\_42

Ben Foster email:

- foster@ucar.edu