AGU 09 Highlights

- Gtraj Poster
- Younger Dryas Boundary: Extraterrestrial Impact or Not?
- Observational and model evidence for positive low-level cloud feedback. A.C. Clement; R. Burgman; J.R. Norris
- The biggest control knob: carbon dioxide in Earth's climate history. R.B. Alley

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A Giga-particle Atmospheric Trajectory Model

Carlos Cruz[2], Thomas Clune[1], Leslie Lait[3], Shawn Freeman[2], Robert Burns[2], Udaya Ranawake[4]

Background

We present a new parallel implementation of an atmospheric trajectory modeling framework (G-trag) which provides improved numerical accuracy, greater flexibility for specifying experiments, and sufficient raw performance to simultaneously simulate billions of parcel trajectories on scalable computing platforms.

Model Implementation

The model is written in C++ for easy integration with other computing technologies. The application is parallelized using the Message Passing Interface (MPI) library and can scale efficiently on a wide variety of modern computing platforms.

How does G-trag work: Given wind fields specified on a regular lat-lon grid and at regular time intervals. How do we use this to advect parcels?
Perform vertical interpolation of wind fields from pressure surfaces to the potential/isentropic surfaces of interest >> wind data on an isobar/isentropic surface

GEOS wind fields → Isobar or isentropic

Interpolate isentropic surface to parcel position doing interpolation along latitude circles and meridians

Parcel position

Finally interpolate wind fields linearly in time to current model time.

$$F(t_i + \Delta t) = F(t_i) + \int_{t_i}^{t_i + \Delta t} \dot{u} dt$$

Integration schemes: Runge-Kutta, M&P, Euler

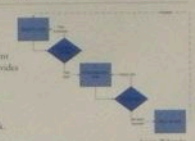
Data interpolation methods : linear, log-linear, nearest-neighbor

Significantly improved numerical accuracy, especially near the poles. This is done by expressing integration in terms of a curvilinear parallel transport scheme:

Output provided: parcel histories, summary statistics, min/max quantities

Model Validation and TDD

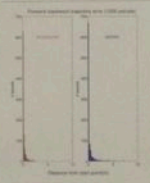
The entire package has been rigorously developed using Test-Driven Development (TDD) which both provides confidence in the implementation and should also assist other developers that wish to extend the framework.



Solid body rotation tests

Tilted solid body rotation provides a baseline synthetic wind field for assessing model performance and also allows testing of transport over the poles. A time-varying case is used to examine the errors introduced by interpolating linearly in time.

Model Accuracy



We perform full model runs with NCAR/NCEP reanalysis and MERRA wind fields to compute forward and backward trajectories of thousands of parcels. Accuracy and performance statistics from these runs show that the model efficiently generates highly reproducible trajectories.

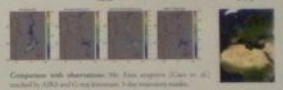
Effect of using different meteorological data sets (wind field) at different resolutions to simulate a 3-day trajectory.

NCAR/NCEP reanalysis (red) 2.5 degrees longitude, 2.5 degrees latitude, 17 pressure levels, 6hr time resolution

MERRA (yellow) 1.25 degrees longitude, 1.25 degrees latitude, 42 pressure levels, 3hr time resolution

Sample Runs: Volcanic Eruptions

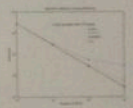
Comparison with an operational model. Kinematic trajectories from Hekla eruption (Rose et. al.) produced by HYSPLIT (left) model and G-trag results (right). Alternative red/white, blue/yellow/white, green/yellow respectively.



Comparison with observations: Mt. Etna eruption (Cuzzi et. al.) tracked by AIRS and G-trag kinematic 3-day trajectory results.

Future Work

The ability to treat a large numbers of parcels is expected to enable a new generation of future experiments to explore questions related to global stratosphere-troposphere exchange, age-of-air spectra, and transport of trace gases and aerosols. Also using a massively parallel trajectory model can soon open up new solutions of problems that are not well addressed by non-parallel programs.



References

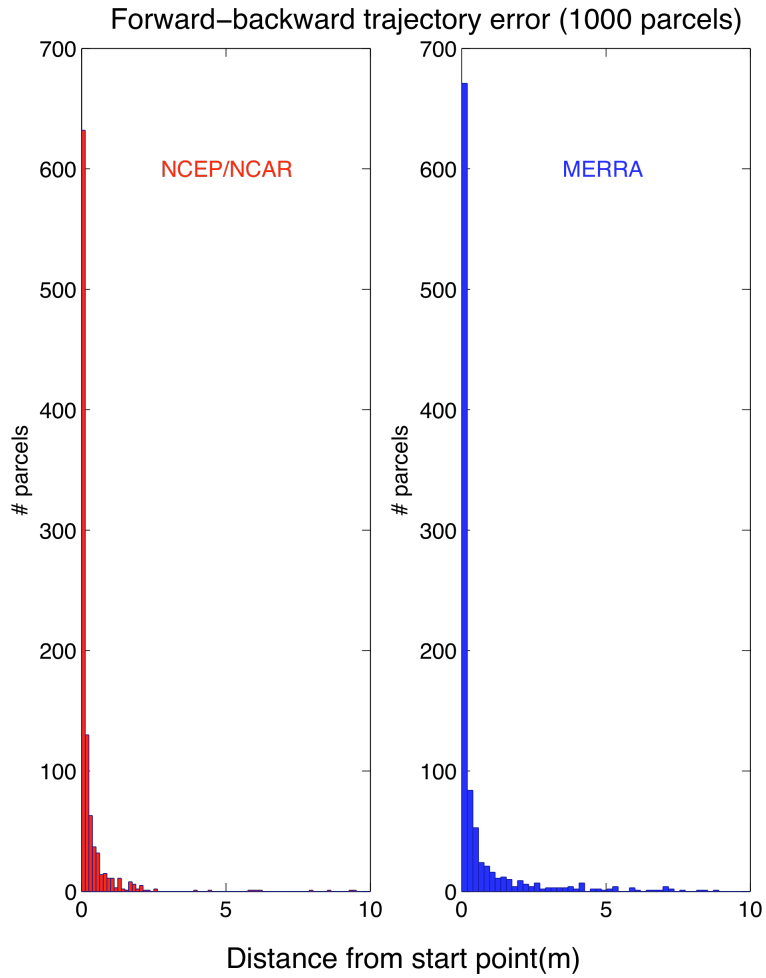
Cuzzi, S.A., et al. (2005), Quantifying stratospheric volcanic emissions with AIRS: The 2002 eruption of Mt. Etna (Italy), *Geophys. Res. Lett.*, 32, doi:10.1029/2004GL021076.

Rose, W.I., et al. (2006), Atmospheric chemistry of a 33–34 hour old volcanic cloud from Hekla Volcano (Iceland): Insights from direct sampling and the application of chemical box modelling, *J. Geophys. Res.*, 111, D20305, doi:10.1029/2005JD006872.

Scherhag, R.B., and L.C. Sperling (1951), "Trajectory Modelling" in Diagnostic Tools in Atmospheric Physics, *Proceedings of the International School of Physics "Enrico Fermi"*.

Model accuracy: reproducibility

We perform full model tests with NCAR/NCEP reanalysis and MERRA wind fields to compute <u>forward and backward trajectories</u> of thousands of parcels. Accuracy and performance statistics from these tests show that the model efficiently generates highly reproducible trajectories.



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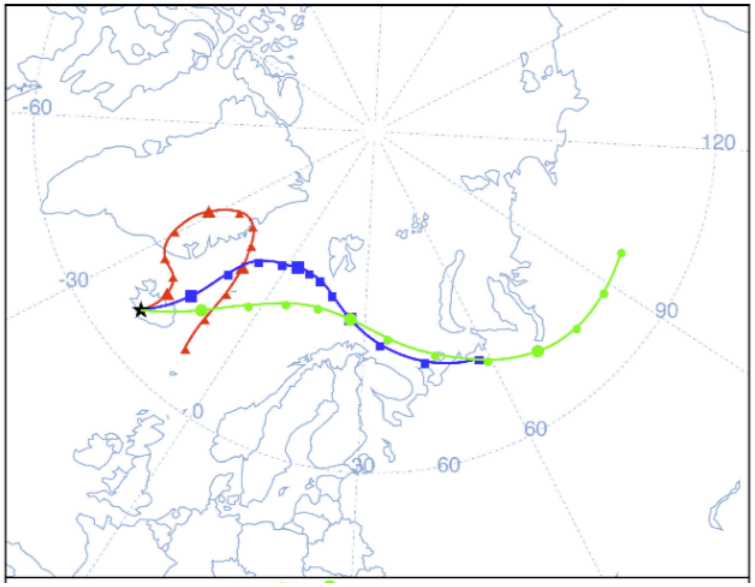
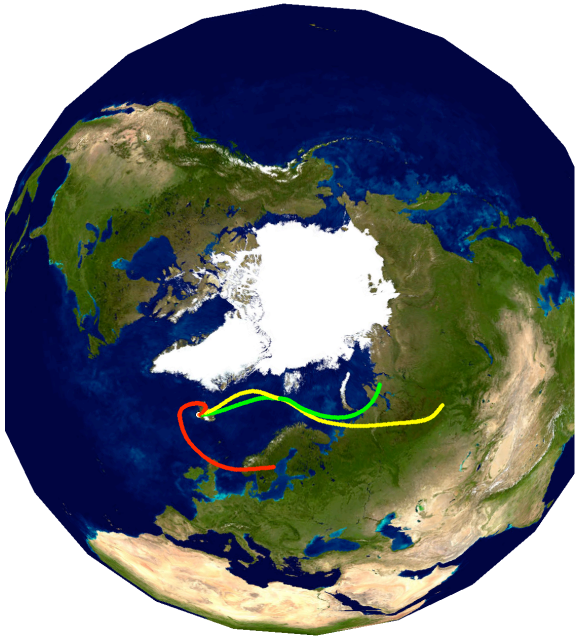
Sample runs: volcanic eruptions

HYSPLIT



G-traj

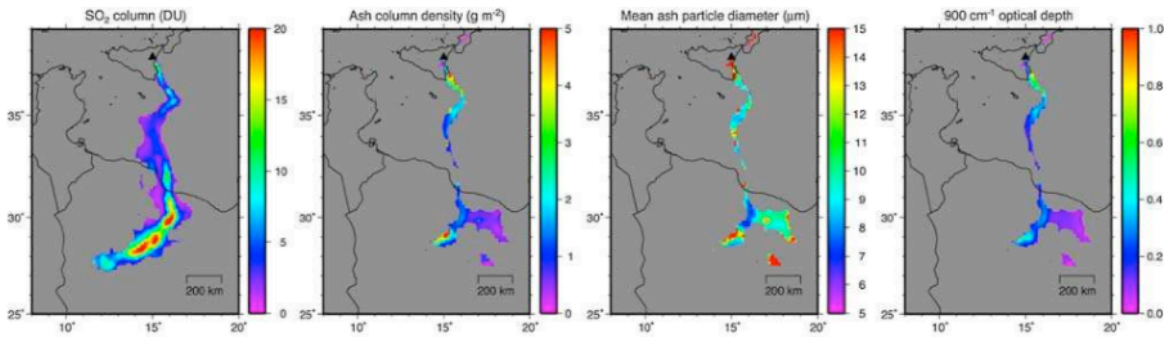


Comparison with an operational model: Kinematic trajectories from the Hekla volcano eruption (Rose et. al.) predicted by HYSPLIT (left) model and G-traj results (right).

Altitudes: red=6km, blue/yellow=9km, green=12km respectively.

Sample runs: volcanic eruptions

AIRS



G-traj

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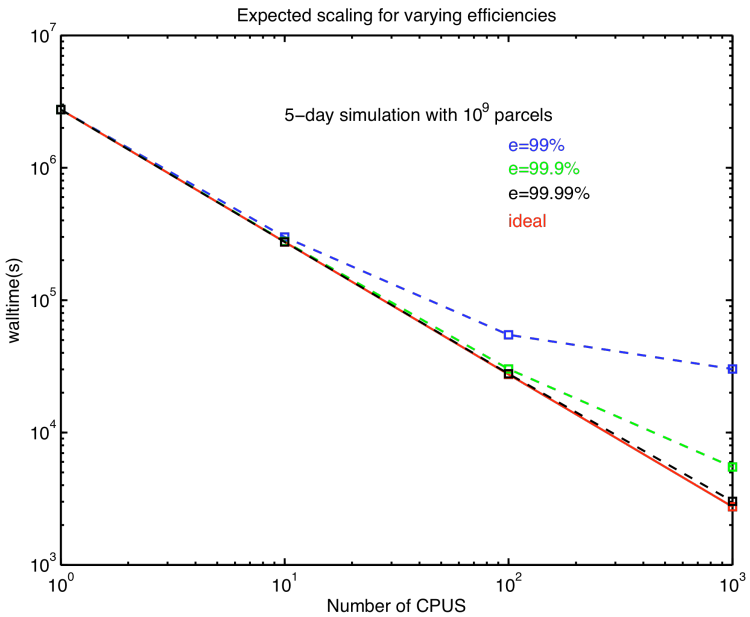
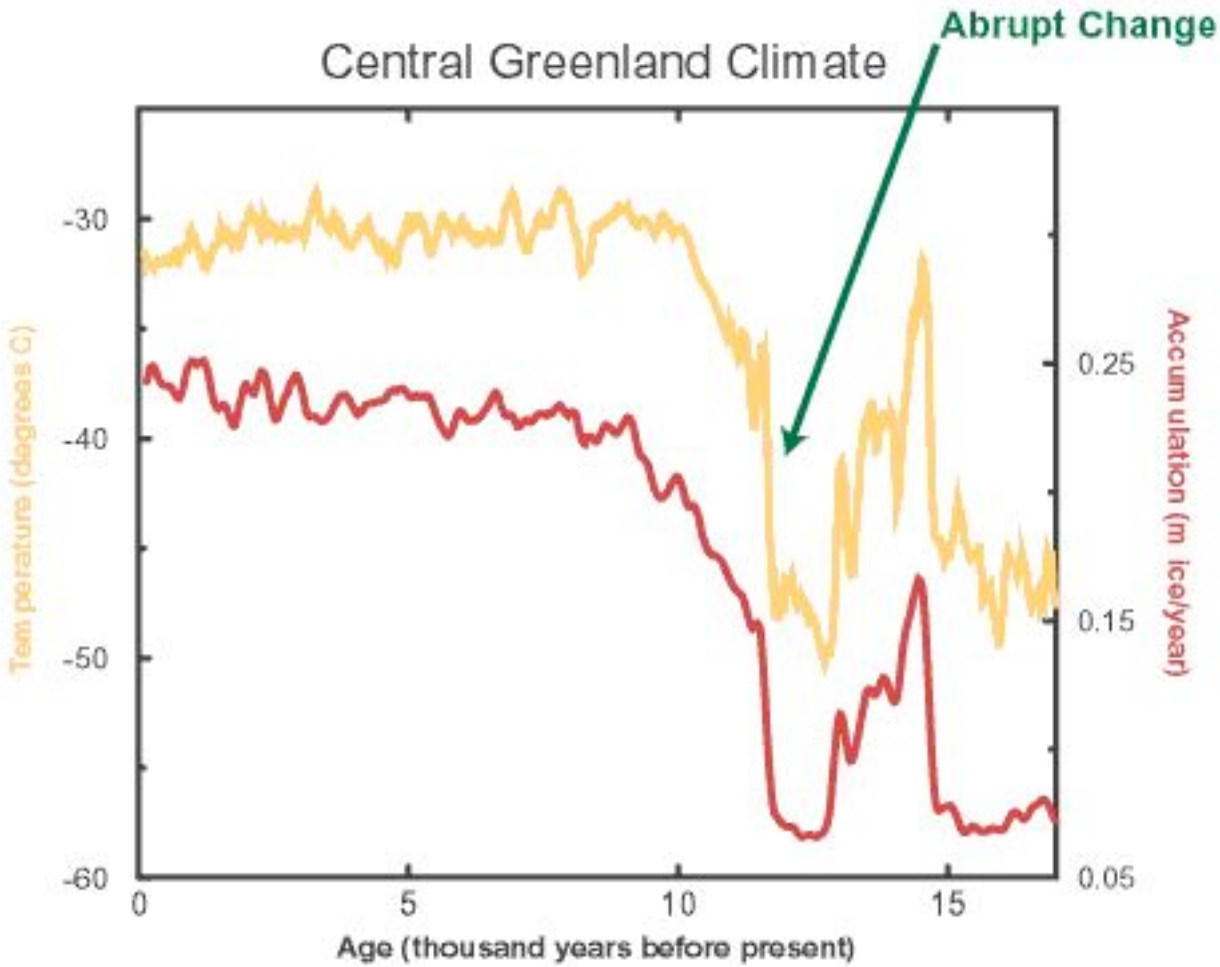


Younger Dryas Boundary: Extraterrestrial Impact or Not

- The **Younger Dryas** stadial, ~12,800 to ~11,600 years ago.
- **Likely** killed off the mammoths, saber-toothed cats, and other iconic ice-aged creatures.
- What caused it?
- 2 views : extraterrestrial vs terrestrial
  - Comet blast
  - THC



Observational and model evidence for positive low-level cloud feedback. A.C. Clement; R. Burgman; J.R. Norris (Science July 2009)

- Do low level clouds act as positive or negative feedback to climate change? Sign of feedback is unknown.
- Look at low level clouds over NE Pacific in observations and climate models.
- Observational evidence shows that this feedback is positive in the NE Pacific on decadal time scales.
- Use this as as a way to validate cloud simulation in current climate models.
- Only model in CMIP3 archive that "passed" this test showed that a reduction in cloud cover over much of the Pacific was possible only when greenhouse gases were increased (2xCO_2)

Bjerknes lecture:
The biggest control knob: carbon dioxide in Earth's climate history. R.B. Alley
(http://www.agu.org/meetings/fm09/lectures/lecture_videos/A23A.shtml)

An increasing body of science indicates that CO_2 has been the most important controller of Earth's climate.