Accelerating the evolution of atmospheric structure in convective simulations

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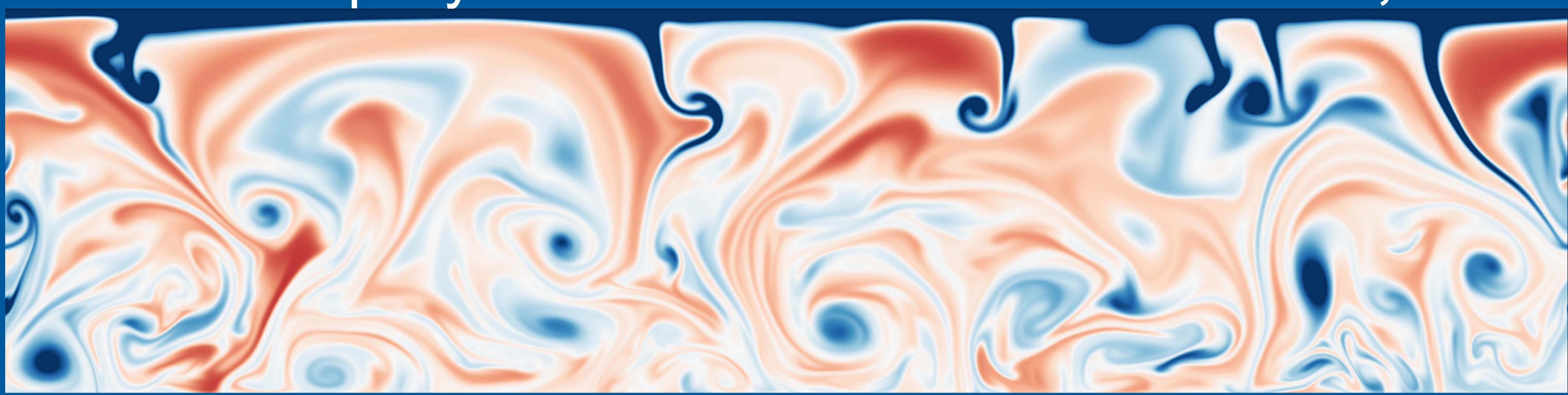
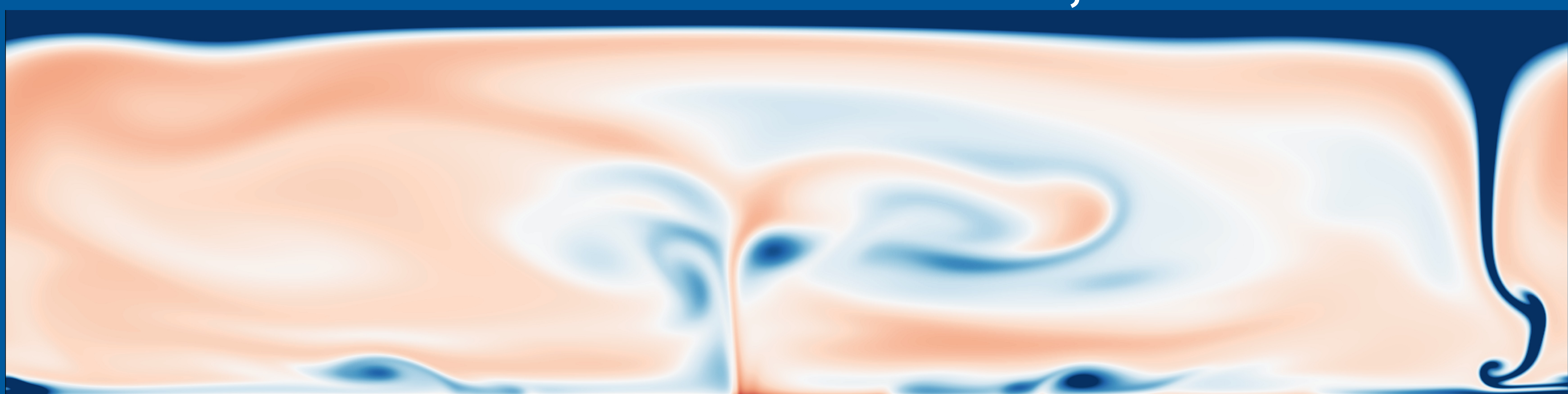
We have **accurately (to 1%) accelerated** the **thermal relaxation** of atmospheres using **1/10 the computational cost** of traditional methods.

We rapidly evolve from **this transient state,**



to **this relaxed state,**



by coupling direct numerical simulations and boundary value problems.

1. INTRODUCTION

In Anders, Brown, & Oishi 2018 [2018 AE Paper], we studied a procedure for coupling 2- or 3-dimensional convective simulations with 1-dimensional boundary value problems to accelerate the evolution of the thermal structure of the convective simulation. There, we studied this procedure for the simplest problem possible: Boussinesq, Rayleigh-Benard convection. We found that our accelerated evolution (**AE**) solutions achieved our desired O(1%) agreement with solutions which were evolved through a standard evolution (**SE**) of a thermal relaxation timescale while saving up to an order of magnitude of computational time.

In this work, we show first results of an extension of our accelerated evolution scheme to fully compressible, polytropic convection.

2. ACCELERATED EVOLUTION METHOD

Our AE method in fully compressible simulations is nearly identical to that in Boussinesq systems, as described in [2018 AE Paper]. We initialize a convective simulation from a superadiabatic polytropic stratification, and we measure information regarding fluxes **in excess of the flux carried by the adiabatic temperature gradient.** Using this information, we solve a mass-conserving boundary value problem for flux and hydrostatic equilibrium to adjust the simulation profiles, then we continue running our convective simulation. This procedure is performed iteratively until flux equilibration is achieved below a desired threshold.

3. RESULTS

While AE is useful at high Rayleigh number (e.g., Ra = 10^6, at a supercriticality of 10^5, as pictured above), the cost of standard evolution makes it difficult to compare our new, fully compressible method to SE simulations (which would take O(1 month) of wall time at Ra = 10^6).

We therefore compare SE and AE at Ra = 10^4 in this work, studying convergence of system energies in Fig. 1 and comparing probability distributions of evolved flows in Fig. 2. We find very good agreement between AE and SE in this more complex case, just as we did in Boussinesq convection.

4. FIGURES

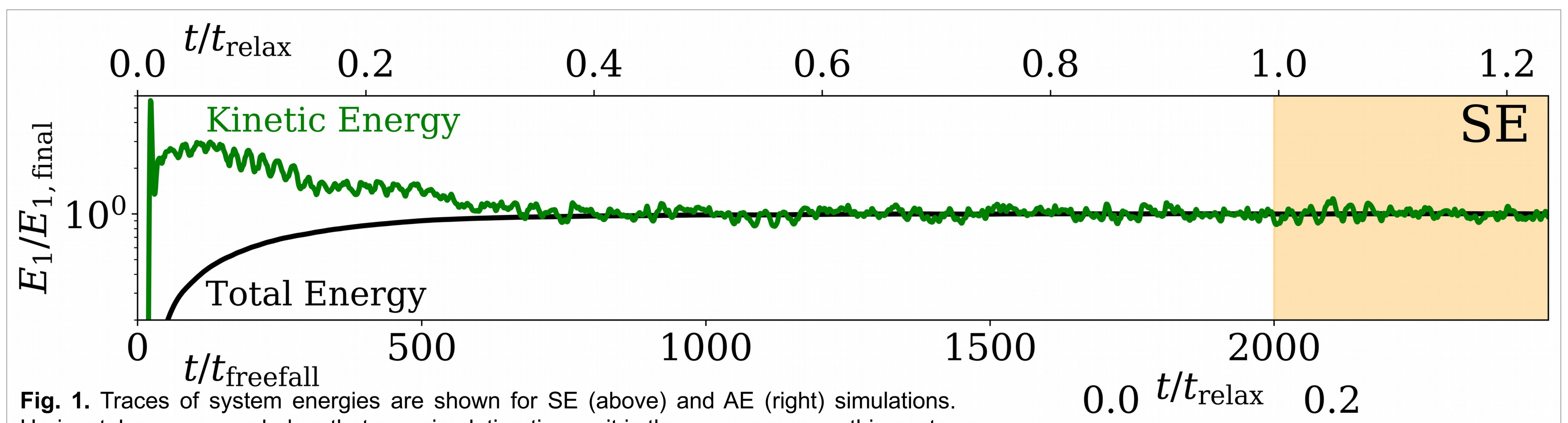
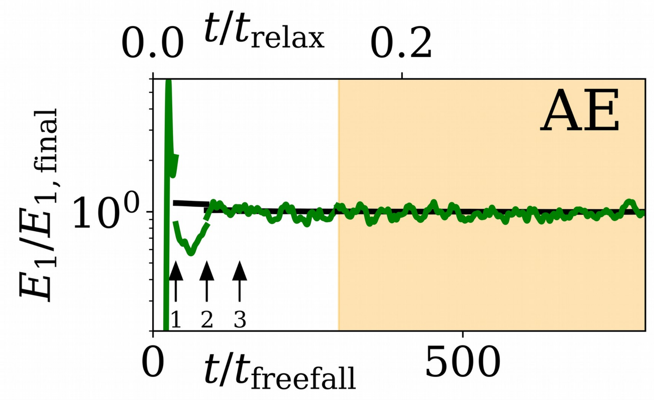
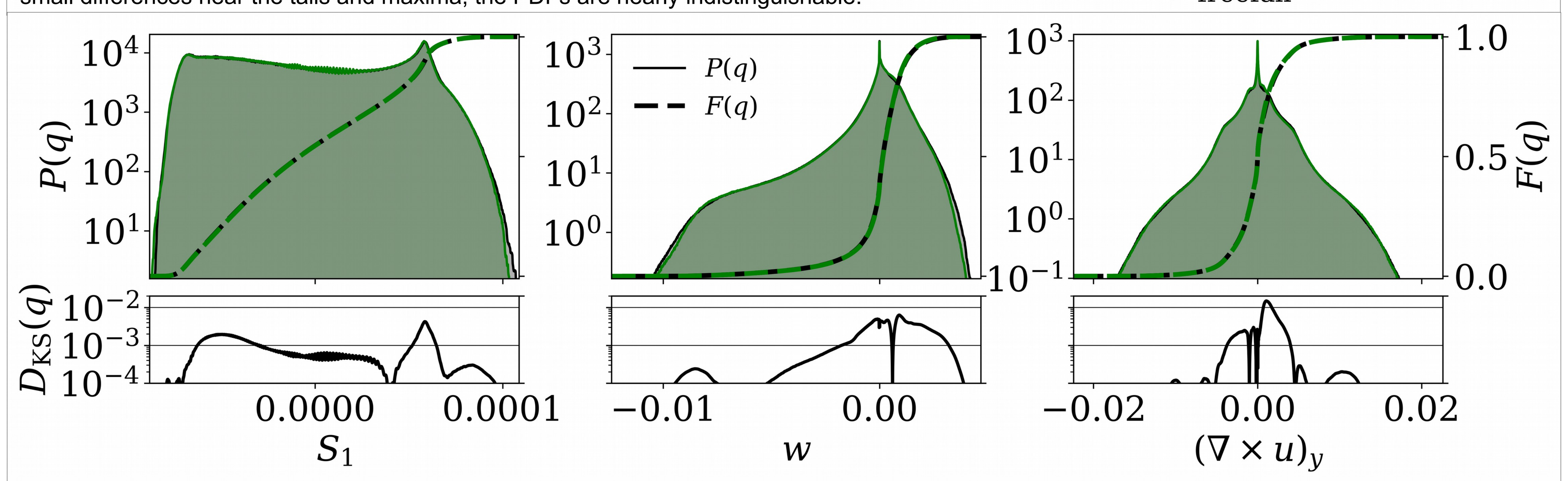


Fig. 1. Traces of system energies are shown for SE (above) and AE (right) simulations. Horizontal axes are scaled so that one simulation time unit is the same space on this poster for both simulations. While the SE simulation takes hundreds of dynamical overturn times to reach its final state at even this modest Rayleigh number, the use of our AE procedure, at times denoted by the arrows marked "1", "2", and "3", allow us to skip past this evolution.

Fig. 2. Probability distribution functions [P(q)] of entropy fluctuations (upper left), vertical velocity (upper middle), and vorticity (upper right) are shown for SE (black) and AE (green) cases over the time intervals highlighted in orange in Fig. 1. The cumulative distribution functions [F(q)] are overplotted, and compared using a Kolmogorov-Smirnov statistic (described in Anders, Brown, & Oishi 2018), which is plotted in the lower panels. Aside from small differences near the tails and maxima, the PDFs are nearly indistinguishable.





5. EXTENSIONS

This summer, we will extend AE to **overshooting convection,** and convection with **nonlinear opacities** (e.g., a Kramer's opacity). After sufficient exploration of AE in various physical regimes, the coupling of convective simulations with stellar structure codes using AE-like procedures should be feasible.

CONTACT ME

[2018 AE Paper]

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