# Project Details

**ROSES ID:** NNH18ZDA001N
**Selection Year:** 2018
**Program Element:** Focused Science Topic

**Topic:** Understanding Global-scale Solar Processes and their Implications for the Solar Interior

**Project Title:**
Processes Shaping the Solar Meridional Circulation

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**Summary:**
Overview:
The Sun's deep-seated convective flows must ultimately sustain both the efficient EMF from which solar magnetism derives and the differential rotation and meridional circulation thought to imbue that magnetism with its remarkable spatiotemporal ordering. Exploration of the dynamo process ultimately requires knowledge of how these deep convective flows are structured, and yet present helioseismic techniques have only recently been able to image flows in the lower portion of the convection zone. Therefore, our understanding of the deep interior has been heavily predicated on numerical models. Such models have identified the structure and speed of the meridional circulation cells as crucial ingredients. Through the use of 3-D, nonlinear convection simulations, we propose to explore those dynamical processes that shape the solar meridional circulation, thus providing overlap between deep convection models and helioseismic observations.

Science Goals and Objectives:
The role that convective-flow speed plays in determining the morphology of solar meridional circulation is now well established, but the effects of boundary layers and magnetism on the circulation speed and morphology have yet to be systematically examined. Our science goals, which follow, center around exploration of these two effects.
1. We will examine how the convection zone's boundary layers impact the properties of meridional circulation, particularly the multi- or mono-cellular nature of the flow.
2. We will explore how Lorentz forces associated with deep-seated dynamo action impact the shape and speed of meridional circulation. We will assess what the form of meridional circulation implies about the underlying dynamo mechanisms at work.
3. Through direct comparisons with ongoing observations and modeling efforts from the broader FST science team, we will use our models of meridional circulation to place constraints on the mode of dynamo operating in the deep convection zone.

Methodology:
We will construct a suite of global, numerical convection simulations that encompass the bulk of the convection zone. Through these simulations, we will examine how magnetism and overshooting impact the structure of deep meridional circulation. In tandem with observations, these models will be used to constrain the structure of solar convection and mean flows throughout the convection zone.

Spherical simulations will be conducted using the Rayleigh convection code. Rayleigh is open-source software that solves the MHD equations of motion for a compressible fluid in a rotating spherical shell under the anelastic approximation. It has been performance tested extensively on NASA's SGI Pleiades system and Argonne's Blue Gene/Q system, Mira. Rayleigh exhibits efficient parallel scaling on up to 524,288 Mira cores for problems of size 2048^3 grid-collocation points.

Proposed Contributions to FST Effort:
Our team will provide a theoretical, dynamics-oriented component to the FST. Results arising from the pursuit of our scientific objectives will have synergy with multiple sub-teams of the FST. In particular, we envision that our first-principles models will provide a bridge between helioseismic observations and reduced models of the solar dynamo. Our data products will be used to test helioseismic techniques and to train and inform dynamo models that are capable of providing detailed predictions of magnetic field evolution in the photosphere and corona.

Relevance to NASA Objectives:
This work addresses the first and fourth challenges identified in the 2013--2022 Decadal Survey in Solar and Space Physics: "Determine the origins of the Sun's activity and predict the variations of the space environment," and "Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe." These questions frame the science objectives of many NASA missions, most notably the Solar Dynamics Observatory (SDO).

## Publication References:

no references