

The Large Scale Collaborative Science of the COFFIES DRIVE Science Center

Shea A. Hess Webber¹, Lisa Upton², Todd Hoeksema¹, Dave Lauben¹, Rock Bush¹ and the COFFIES Team



ABSTRACT

The National Research Council published a report on Enhancing the Effectiveness of Team Science in 2015. This report identified 7 fundamental challenges that large research teams, such as the NASA DRIVE Science Centers (DSC), might face including: high diversity of membership, deep knowledge integration, large size, goal misalignment, permeable boundaries, geographic dispersion, and high task interdependence. In Phase I, the COFFIES DSC formed a Center Effectiveness Team (CET) to identify and help overcome these and other unique challenges, including those introduced by the COVID-19 pandemic. COFFIES has now been selected to proceed into Phase III! We will present the CET initiatives and implementations, review some lessons learned for future large-scale science collaborations, and give an overview of COFFIES science.

Fundamental Challenges [1]

1. Diversity of Team Membership

- o **Potential Challenges:**
 - Identify community partners and establish positive relationships with them.
 - Foster effective communication and coordination of tasks among individuals from different scientific disciplines and communities with their own languages and cultures.

2. Deep Knowledge Integration

- o **Potential Challenges:**
 - Require more time and effort than other research approaches.
 - Integrate knowledge across social, behavioral, and biological disciplines with different values, terminology, methods, traditions, and work styles.

3. Large Team Size

- o **Potential Challenges:**
 - Coordinate the work of many individuals at different locations.
 - Foster effective communication among physicists of different subdisciplines.

4. Goal Alignment Across Teams

- o **Potential Challenges:**
 - Fund, manage, and align multiple academic and industry teams

5. Permeable Team and Organizational Boundaries

- o **Potential Challenges:**
 - Engage collaborators in the project, many of whom may need to bring external funding to do their science research.
 - Gain understanding of the kinds of information needed so that scientific findings can be tailored to meet needs of different participants.

6. Geographic Dispersion of Team Members

- o **Potential Challenges:**
 - Build cohesion among experts who rarely meet face-to-face and rely heavily on electronic communication.
 - Develop shared understanding of project goals and individual roles among scientists from nations and research institutions with different cultures, work routines, and politics.

7. High Task Interdependence

- o **Potential Challenges:**
 - Foster a shared appreciation of the importance of two types of highly interdependent tasks: "service" work (managing the Team, impact broadening activities, etc.) and "physics" work (analysis of data leading to publications).
 - Reach agreement among groups and individuals over new research approaches (e.g., modifications to models or data analysis methods).

COFFIES Effectiveness Team (CET)

One of COFFIES' strategic strengths is the formation of the COFFIES Effectiveness Team (CET). The primary objective of the CET is to identify and build the infrastructure to overcome the fundamental challenges of our large science center, a critical factor in achieving our scientific goals. The unique approach of having a CET makes COFFIES a stronger Center, so we can deliver on our full promise and potential.

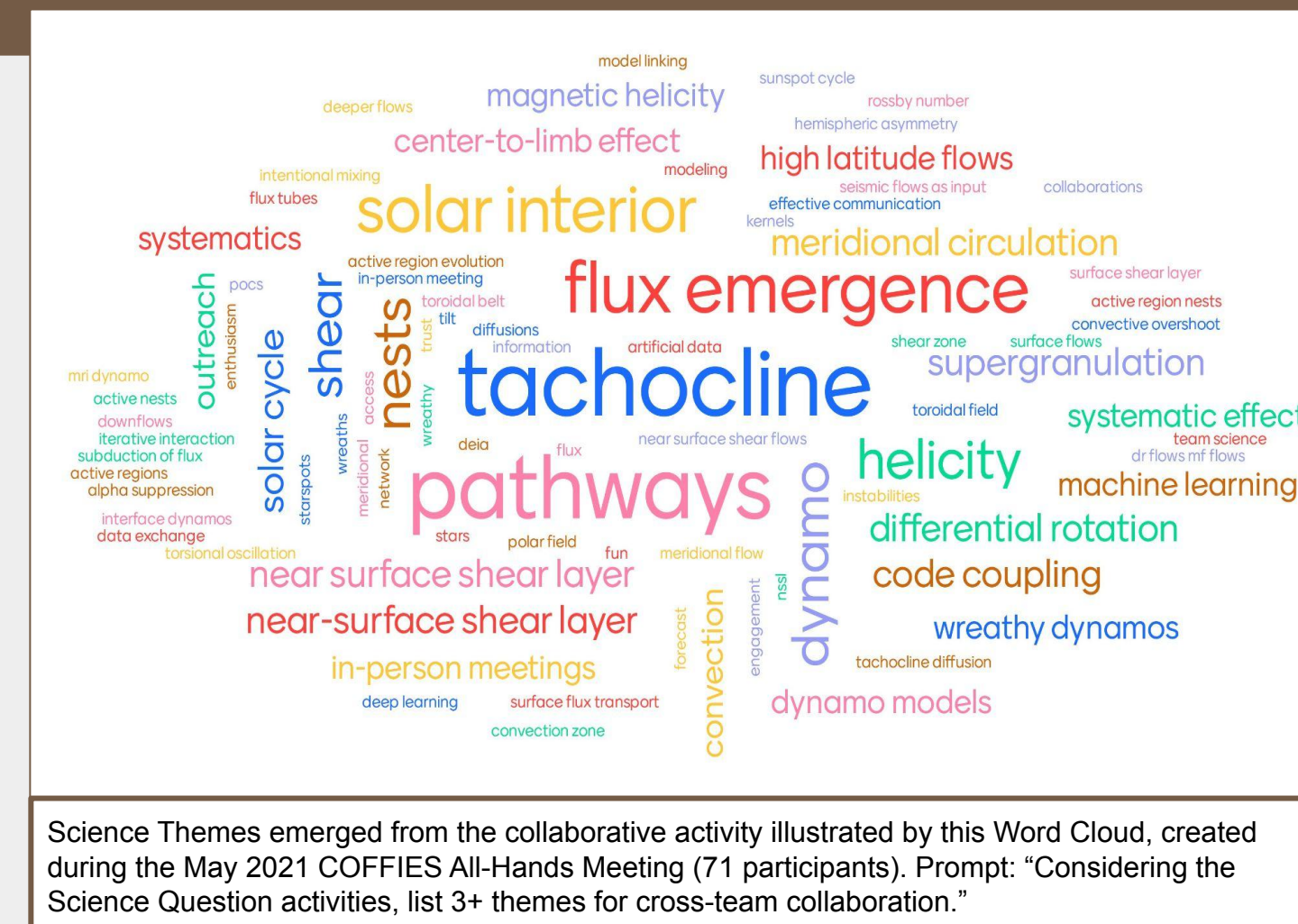
The CET (*Leads: Upton and Hess Webber*) began with three core members, and growing to (currently) include six early career members in addition to other **Baristas** (Team Leads) and the **Executive Leadership** (PI and PM). Membership rotates, allowing CET members to adapt their focus as necessary and providing management opportunities for many early career members.

The CET has identified multiple key objectives for their Phase II work to successfully alleviate the challenges noted above and allow COFFIES to become a benchmark of success for future NASA Centers in terms of collaboration, communication, Diversity-Equity-Inclusion-Accessibility (DEIA) integration, Workforce Development (Beans) and STEM Engagement (REU), and Outreach/Science Communication (POISE).

Addressing Challenges

CET Goals and Objectives include:

- **Reporting** directly to and advising the COFFIES Executive Leadership.
- **Focusing** on finding and exploring novel ways to align and direct the Science Teams with the goal of enabling breakthrough science.
- **Providing** structural support (such as maintaining ongoing transparent communications between all COFFIES members) to reduce ambiguity and provide stability.
- **Working** with COFFIES Team leads to facilitate COFFIES-wide collaboration, knowledge integration, goal alignment, and task interdependence.
- **Organizing** activities to promote engagement with the broader scientific community.
- **Facilitating** growth of the COFFIES Center and onboarding of new members.
- **Monitoring** Center progress and helps develop/implement interventions when problems arise.
- Working with the **DEIA Team** to help implement training and tools for all members.
- Working with the **Workforce Development, STEM Engagement, and Science Communication Teams** to help organize and coordinate COFFIES' academic opportunities, professional development activities, and public engagement initiatives



Below, we outline some of our various approaches to mitigating the fundamental challenges of our Center.

1. Diversity of Team Membership - COFFIES strives to be inclusive in all aspects of our work

- We use of Sprints and similar collaborative methods to encourage participation of traditionally underrepresented voices (such as students, early career scientists, and introverts)
- We aim to forge connections between our members on a more personal level (made particularly challenging by the pandemic and our inability to gather)
 - Examples:
 - The "Member Highlights" feature in the *COFFIES Press* quarterly newsletter
 - We developed COFFIES-specific internal terminology that bolsters our shared identity across disciplines, e.g. *Beans* for early career scientists; *Baristas* for the Leadership Team; *Coffinators* for all COFFIES members, etc.
 - We hold various team-building activities including monthly virtual happy hours and ice-breakers at the start of all-hands meetings.
- We have started a living "shared language dictionary" with terms and definitions that range from acronyms, to "beginners language" (aimed at REU students), to technical jargon that may not be known between our cross-disciplinary sciences.
- We hold bi-weekly virtual office hours to offer ongoing support and technological assistance for anyone less versed in our chosen collaborative software tools.

2. Deep Knowledge Integration

- The CET facilitates cross-collaboration of the Science Teams using agile, inclusive, and well-tested ideation methodologies (e.g. the Google Sprint [2]);
- COFFIES hosts monthly Center-wide (and beyond) science seminars on COFFIES-relevant topics.

3. Large Team Size

- Strongly overlaps with initiatives in 1., 2., 4., and 7.

4. Goal Alignment Across Teams

- COFFIES provides frameworks to focus research efforts into clear and actionable plans.
- Baristas convene with the Executive leadership and CET monthly for planning and reporting.
- Smaller regular meetings are held by Teams, Science Themes, and more directed Working Groups.

5. Permeable Team and Organizational Boundaries

- Member Onboarding:** We welcome and prepare new members by introducing them to their scientific peers and the greater community as early as possible. We have an onboarding communication plan to assist new members in accessing the necessary communication tools and becoming integrated in the COFFIES community.
- Funding/Support:** Much of the science in COFFIES is leveraged through other grants and funding sources. Center resources are mainly used to support programs such as the REU program, member training (e.g. mentorship), and student/postdoc researchers.

6. Geographic Dispersion of Team Members

- Due to COVID-19 and our distributed nature, much of our collaboration is necessarily virtual and asynchronous, carried out through deliberately chosen platforms:
 - **Slack** for asynchronous messaging,
 - **Subscription Mailing Lists** for synchronous communication,
 - **Miro** for collaborative ideation activities,
 - **Google Calendar** to coordinate meetings/events,
 - **Zoom** for hosting virtual meetings and events,
 - **ADS Libraries** for easy access to COFFIES publications,
 - **Google Drive** for file-sharing,
 - **GitHub** for shared code-repositories,
 - **COFFIES Website** for access to all other tools,
 - **And more....**
 - **YouTube** to share event recordings,
 - **COFFIES Website** for access to all other tools,
 - **Overleaf** for collaborative publications,
 - **Trello** for task management,

7. High Task Interdependence

- The CET has developed and continues to grow COFFIES' *living* Collaboration Plan
- All COFFIES members are expected to participate in Center Impact Broadening activities. Dedicated staff members lead Teams addressing components of these efforts.
- While final authority for the project resides with the executive leadership, they consult with Baristas to inform key decisions.
 - Science decisions are generally made democratically, by reaching consensus among Science Team Baristas.
 - Center-functionality and effectiveness decisions are made in consultation with the CET.

COFFIES Science

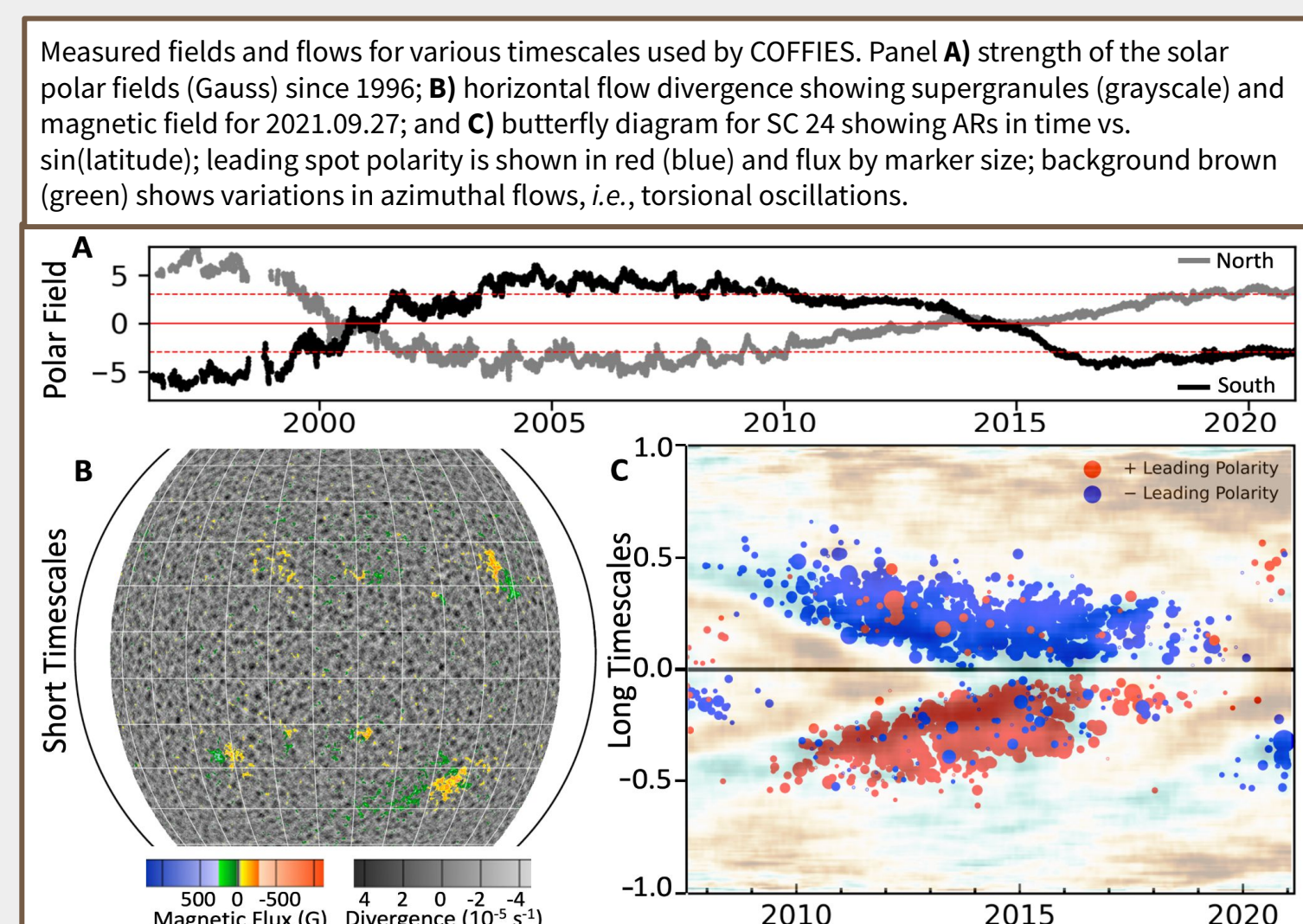
Solar activity is the direct Consequence Of Fields and Flows in the Interior and Exterior of the Sun (COFFIES). Our vision is to expand the understanding of the Sun to develop the capability to forecast activity cycles and magnetic field variability by creating a diverse and inclusive center of excellence in Solar Physics. COFFIES establishes a collaborative science community that will develop comprehensive models of solar dynamics and, using high-fidelity helioseismic and photospheric measurements of flows and fields as constraints, substantially improve physical understanding of the ways internal plasma flows affect the origin and evolution of magnetic activity cycles of the Sun and stars like it.

Breakthrough Science THEMES. Three pivotal science THEMES are both critical for understanding the physical mechanisms of the activity cycle and poised for near-term transformational progress:

The **TACHOCLINE**, a thin layer of rotational shear at the bottom of the convection zone, potentially holds the key to connecting the dynamo field that operates on large temporal and spatial scales with medium-scale features such as active region complexes and evolving zonal flows.

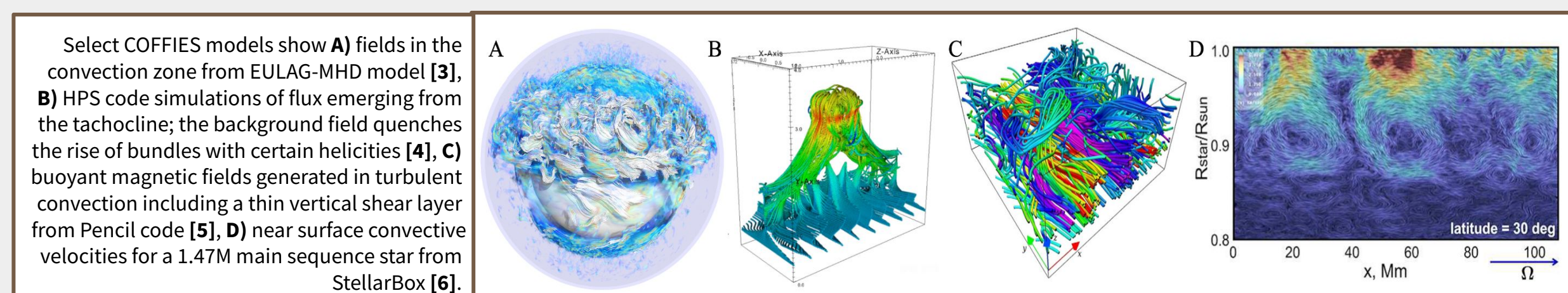
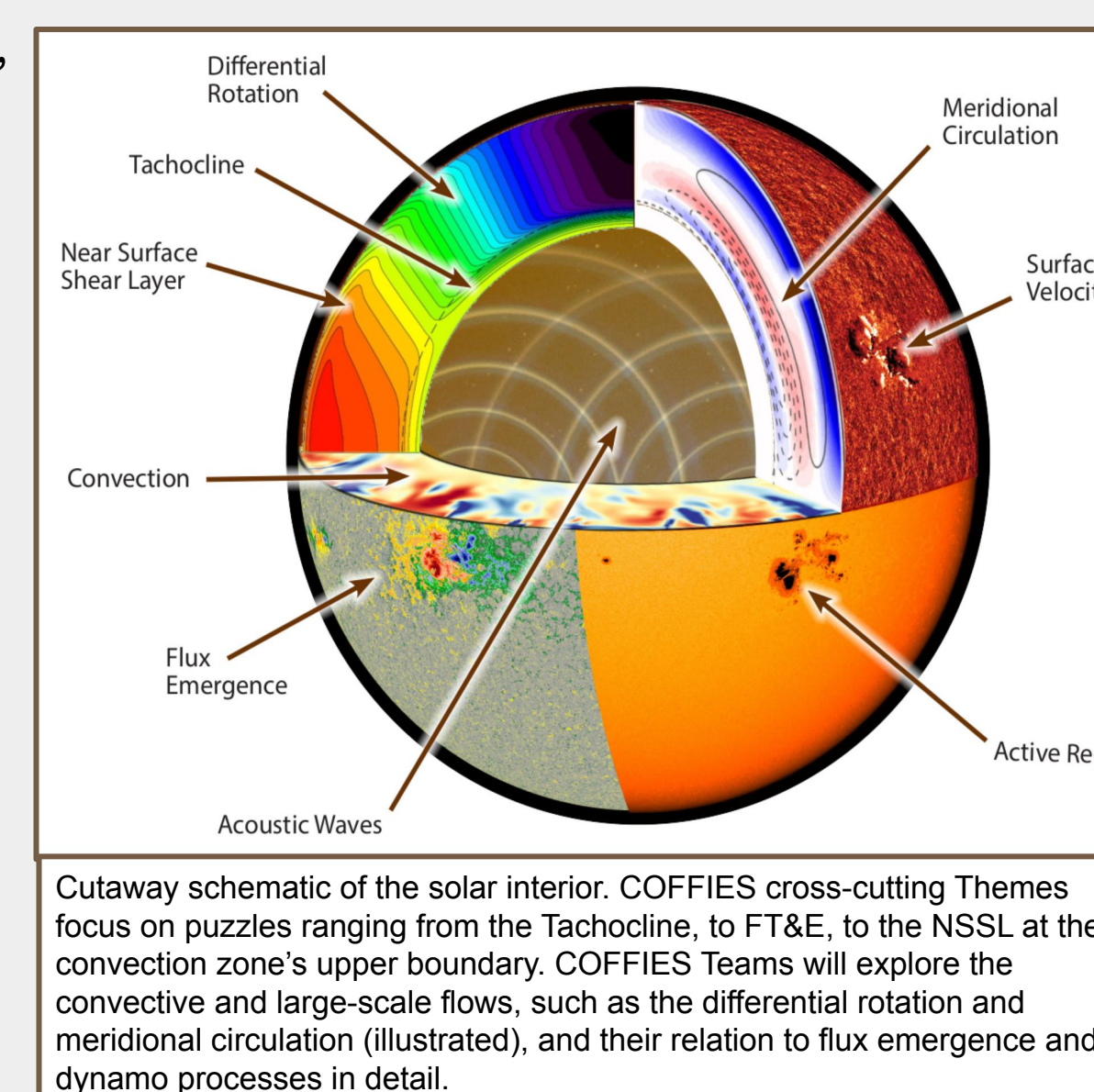
FLUX TRANSPORT & EMERGENCE throughout the convection zone connects the deep interior dynamo with magnetic field and flow patterns observed at and near the surface.

The **NEAR-SURFACE SHEAR LAYER** filters and possibly creates many of the observed surface and near-surface convection and flux features; however, it is not well understood, and its role in the activity cycle is unclear.



COFFIES Four Key Motivating Science Questions:

1. What drives varying large-scale plasma motions, e.g. meridional flow and differential rotation?
2. How do flows interact with magnetic fields to create varying solar activity cycles?
3. What causes active regions to emerge when and where they do during the solar cycle?
4. How is our understanding of solar activity informed by fields and flows on other stars?



Broadening Impacts Initiatives

Diversity, Equity, Inclusion, Accessibility (DEIA) -- Lead: B. Mendez

Incorporating DEIA is the shared duty of all COFFIES members. Research shows that having a management-level team member focused on DEIA creates social accountability and boosts inclusion throughout the organization [7].

In alignment with NASA's charge to attract, develop, and leverage the full spectrum of intellectual talent in the U.S., we aim to diversify our membership and that of space sciences more broadly by making the Center equitable, inclusive, and accessible. The space sciences have historically prioritized assimilation of diverse people into the existing culture. We will shift our mindset to one of growth, asking members what they need to succeed and providing it. We will allow people to bring their authentic selves and let COFFIES' culture evolve as the Center grows.

Workforce Development -- Lead: J. Jackiewicz

COFFIES early career scientists (Beans) include graduate students, postdocs, and other members who have not yet reached their anticipated final career position. COFFIES Beans will carry out a significant portion of the proposed research, while also preparing for future steps in their careers. The pandemic has slowed down career progress for many in this group. The Beans Mentorship Initiative will help rebuild momentum, foster professional identities, and establish multi-dimensional mentoring relationships with COFFIES members. COFFIES will provide professional development opportunities and a supportive community for early career scientists involved in the Center.

STEM Engagement -- Lead: D. Zevin

COFFIES' REU program will provide diverse undergraduates with authentic research experiences to spark their interest in STEM; increase their understanding of modern research methodologies and practices; inspire and support their higher education trajectories; and cultivate a sense of possible self that includes careers in solar research, NASA science, academia, and industry. All participating staff will receive training in how to successfully work with URG/under-resourced students.

We will recruit 8-10 REU participants each year who meet at least two of the following criteria: 1) first generation in their family to attend college, 2) economically disadvantaged, 3) from a population significantly underrepresented in STEM disciplines, or 4) student at a community college or state university without significant undergraduate STEM research opportunities. These students will participate in an eight-week, mentor-led and *paid* summer REU program. We will encourage and support students in showcasing their mentor-led research at the AGU Fall meeting.

Science Communication -- Lead: D. Zevin

Our Public Outreach and Informal Science Education (POISE) initiative aims to advance enthusiasm and support for NASA science among the general public; make the public aware of and interested in the intricacies of the Sun and our research; and help motivate and guide the next generation in STEM.

The Lawrence Hall of Science's J. Erickson (Director of the Planetarium and Digital Theaters) will run the POISE program, translating COFFIES data sets for delivery to general public audiences through NOAA's Science on a Sphere® (SOS) interactive projection system, which is used by education institutions around the country. SOS visualizations make the science more intuitive [8], and COFFIES is uniquely suited to incorporate many assets for impactful SOS programming.

As COFFIES generates new data and we create new programmatic elements for the SOS system, we will continue working with our researchers to refine public messaging. Ultimately, we aim have enough formative evaluation within two years to produce 30+ SOS public engagement presentations for national dissemination during the remainder of Phase II.

Lessons Learned

o Ongoing Challenges

- o **Bridging between diverse age and experience groups**
 - There is an innate tendency for people to cluster with those they 1) already have a relationship with and 2) identify most closely with. This leads to unconscious segregation by age and experience.
 - Part of COFFIES broadening impact initiative is to create networks between researchers of different levels and experience. COFFIES leadership is still working towards paving the way for more natural interactions and connections between these habitual cliques.
- o **Technological readiness**
 - It is always difficult to learn and habituate the usage of new technologies.
 - We continue to try to remove any/all barriers that might prevent our membership from making use of the full potential of all our software tools.
- o **Participation and engagement**
 - With such a large Team, it is challenging to promote and ensure the enthusiastic participation of all members.
 - We expect that this aspect will strengthen as we continue to enable more connections and successful collaborations.
- o **Meeting in-person**
 - While virtual meetings are useful and inclusive in many ways, there is no replacement for being able to meet and collaborate face-to-face.
- o **Complex Scheduling**
 - An innate challenge of geographic dispersion as having to contend with timezones. In addition, with many members being students or teaching staff on a quarterly or semester schedule, availability across the Team changes every several months.

o Moving Forward

- o The CET has several ideas for make progress on the above, as well as the other fundamental challenges COFFIES faces, including (but not limited to):
 - Teams that *play* together, stay (and collaborate better) together [9] -- we will enable and encourage our Center members to engage with each other in play as well as work.
 - We will host in-person annual Science Workshops, which will allow our members to make deeper and more effective connections.

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