Exploring Alternate Instrumentation in the Three-Meter Spherical Couette Experiment

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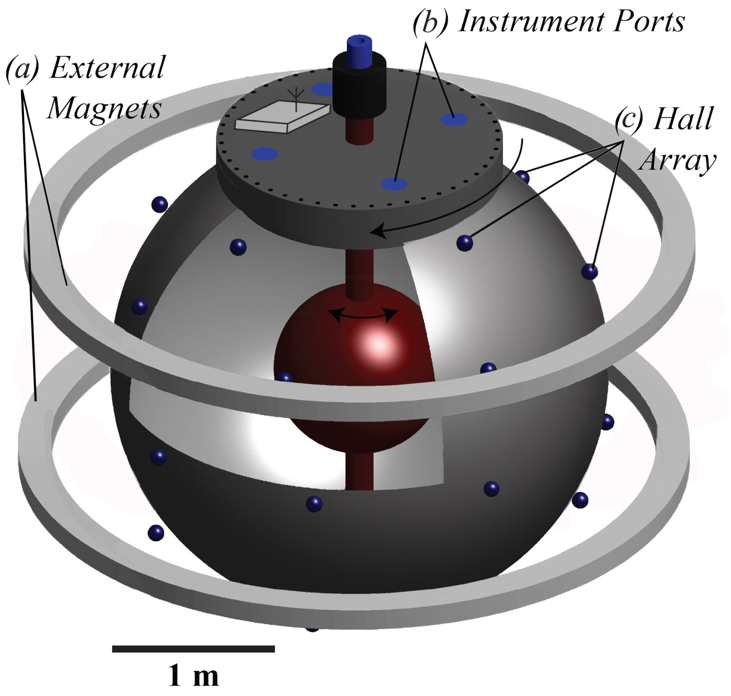
[1] D.S. Zimmerman, et. al. Jor. of Geophy. Res. 119: 4538-4557 (2014).

The Three-Meter Spherical Couette Experiment

- **Purpose**: To replicate the dynamics of the interactions between Earth's liquid outer core and the present magnetic field.
- Driving factor is the differential rotation of the independent shells and an external electromagnetic field.
- **33 hall probes** measuring magnetic field components, 4 pressure probes, and torque measurements on each sphere.



[2] EJ Kaplan, et. al. Physical Review Fluids, 3(3):034608, (2018).
[3] N. Schaeffer, Geochem. Geophys. Geosyst. 14, 751-758, (2013)

Research Goals and *Current Status*

1) To increase helicity in the experiment to achieve a dynamo.

- *Experiment*
  - Undergoing research training and developing protocols for draining 3-meter.
  - Designing baffles to add the inner sphere to increase helicity. (Ruben)
  - Removing inner and outer motors.

2) To study techniques to predict the magnetic fields of the experiment in time (which can motivate current geodynamo magnetic field prediction techniques).

- *Simulations and data analysis* of the 3-meter using \`XSHELLS' [2,3] to analyze if data assimilation on the experiment has promise with potential measurements.
- *Machine learning* to predict the 3-meter magnetic field.

Data Analysis of Simulations

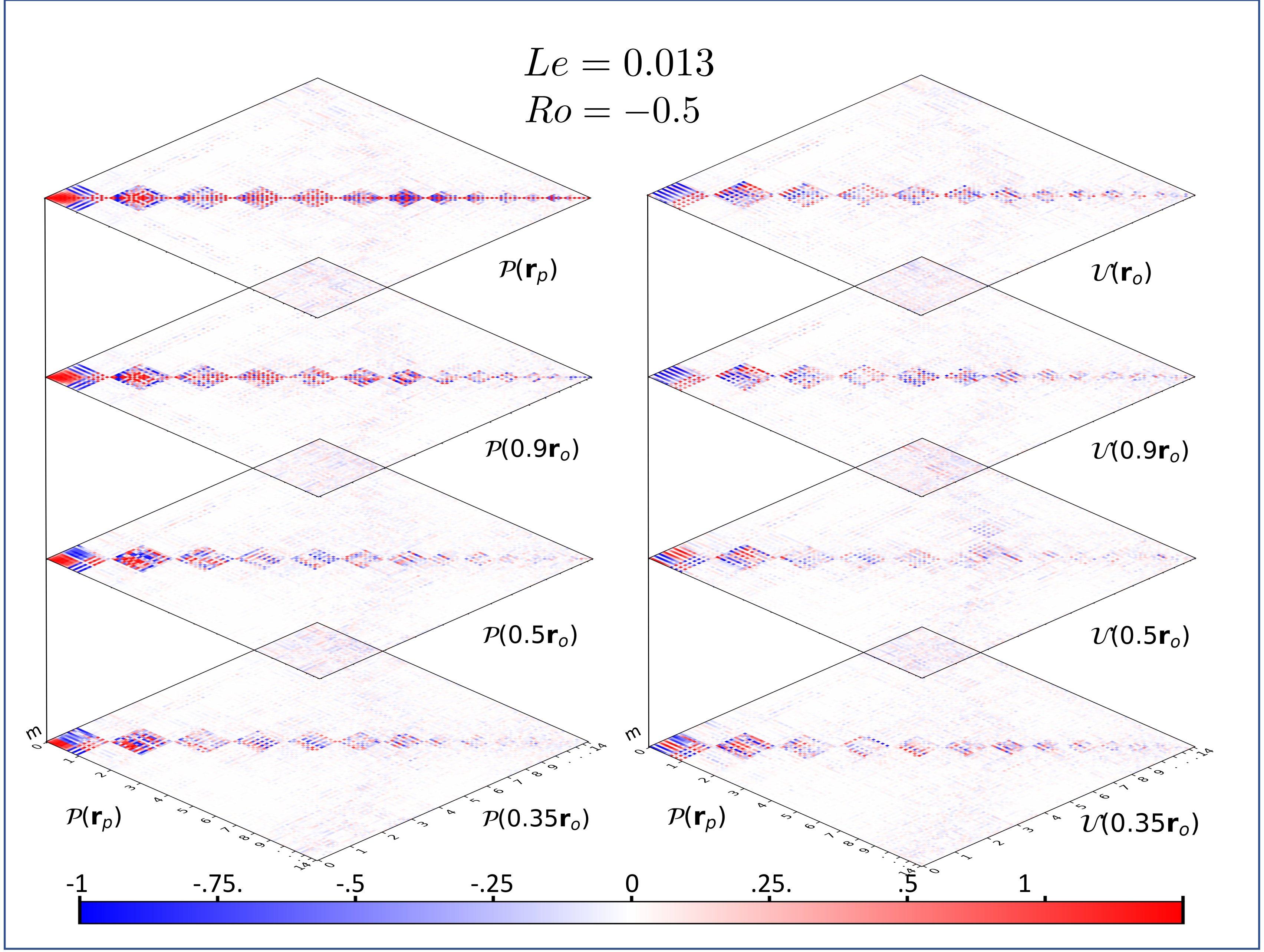
The magnetic field and velocity field can be decomposed into their Poloidal and Toroidal components respectively,

$$\mathbf{B} = \nabla \times \nabla \times [\mathcal{P}(\mathbf{r})\mathbf{r}] + \nabla \times [\mathcal{T}(\mathbf{r})\mathbf{r}]$$
$$\mathbf{V} = \nabla \times \nabla \times [\mathcal{V}(\mathbf{r})\mathbf{r}] + \nabla \times [\mathcal{U}(\mathbf{r})\mathbf{r}]$$

where $$\mathcal{P}(r,\theta,\phi) = \sum_{\ell=0}^{\ell_{\max}} \sum_{m=-\ell}^{\ell} \mathcal{P}_{\ell m}(r) Y_\ell^m(\theta,\phi)$$

and Y is spherical harmonics functions are orthonormalized basis of the 2-sphere built from Legendre polynomials.

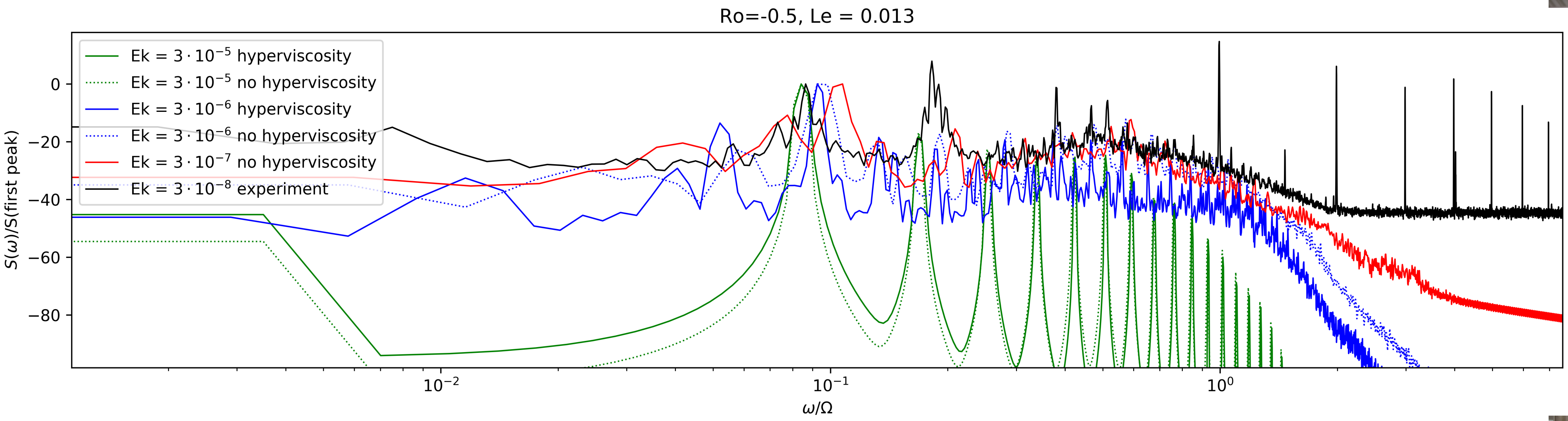
Covariances between the **real poloidal component at the location of the hall probe measurements**, r_p, and another field are computed at various depths using a sample of 512 snapshots truncated at $\ell_{max} = 14$. The left column is with the **real poloidal magnetic field components** and the right is the **real toroidal velocity components** at depths corresponding to the outer radius, r_o. (Referring to figure on next slide).

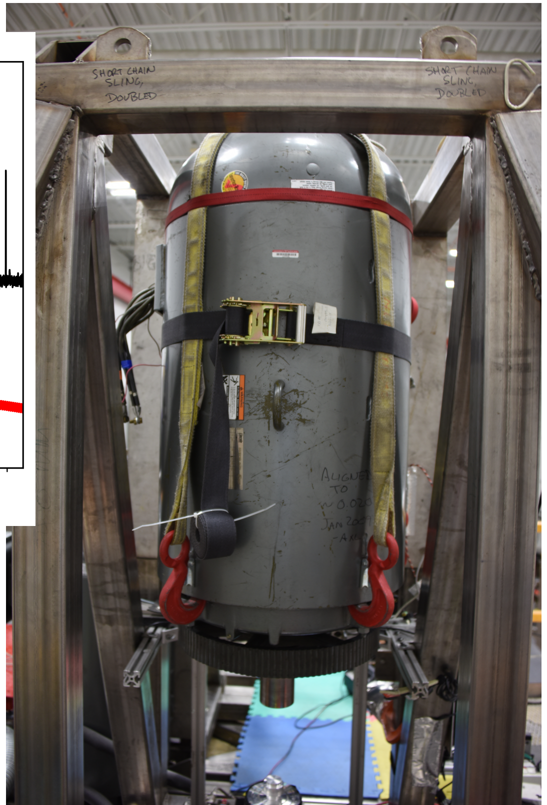


Conclusion: The surface magnetic field measurements are strongly correlated/anti-correlated with low m-harmonics across different ℓ-harmonics even at greater depths. **Meaning we can retrieve at least m = 0 and 1 from the surface magnetic field.**

Future Plans

- Testing acoustic measurement for adding zonal acoustic doppler velocimetry. (Heidi)
- Data assimilation with OSSEs to justify adding more hall probes.
- Magneto Coriolis-modes simulation and experimental studies.





- Draining the 3-meter experiment (Team).