APS Topical Group on the Physics of Climate
GPC

GPC Newsletter

Issue #19

October 2023

IN THIS ISSUE

APS TOPICAL GROUP ON THE PHYSICS OF CLIMATE

Message from the Editor

This is the nineteenth GPC Newsletter, published twice per year. You, the GPC membership, can be of enormous value. We invite comments, event notices, letters, and especially specific suggestions for content. Any of the above, addressed to GPCnews@aps.org, will be gratefully acknowledged in a timely fashion.

Message from the GPC Chair

Hussein Aluie, U. Rochester

This year, GPC has led or been involved in a significant array of activities, events, and initiatives. Below, I will attempt to give a brief update on some of our collective efforts.

APS-level Award

GPC is currently one of the few APS units without an APS-level award. Such a prize would help us recognize and encourage impactful research in climate physics. *Continued on p. 2*

2024 APS March Meeting

The 2024 March Meeting will take place in Minneapolis, MN March 3-8. The meeting will be in-person with virtual components. GPC is planning three Focus Sessions, each with both invited and contributed presentations: "Extreme Events, Tipping Points, and Abrupt Changes in the Climate System," "Statistical and Nonlinear Physics of Earth and its Climate," and, for the first time, "Diversity of planetary circulation regimes: our solar system and beyond."

Contributed abstract submission deadline is October 20, 2023. It is emphasized that although abstracts consistent with the Focus Session topics are certainly desired, *any climate physics related contribution will be welcomed.*

ARTICLE: GPC to add Planetary Atmospheres and Oceans as sixth Area of Interest

William Newman, UCLA

Until the turn of this century, we generally thought of our solar system has having terrestrial planets, such as Earth, Mars, Venus, and Mercury, and gas giant planets, such as Jupiter, Saturn, Uranus, and Neptune. We have come to appreciate many aspects of our planet's atmosphere *Continued on p. 3*

ARTICLE: Computing Response Operators Using Koopman Formalism: A Climate Science Perspective

Valerio Lucarini, University of Reading

Response theory is a framework designed to anticipate the change in the statistical characteristics of a system of interest resulting from the application of weak external perturbations. Within the classical realm of linear approximation and near equilibrium systems, a key ingredient is the fluctuation-dissipation theorem (FDT). *Continued on p. 3*

ARTICLE: Recollections from the 2023 Aspen Center for Physics Fluids Workshop (Part I)

Peter B. Weichman, BAE Systems FAST Labs

During the (somewhat chilly) two-week period May 28 – June 11, 2023 the Aspen Center for Physics hosted a workshop on *Geometric and Field Theoretic Methods for Astro-, Geo-, Bio-physical Fluids* organized by B. Helen Burgess, James Cho, Albion Lawrence, and Jane Wang and attended by approximately 20 participants (happily including your author). *Continued on p. 5*

Message from the GPC Chair – *continued from p. 1*

In July, the GPC executive committee voted unanimously to approve kick starting this effort and authorize me as GPC chair to initiate discussions with APS toward establishing such an award. Undertaking this effort was also endorsed by several past GPC chairs. Mary Silber, who is a past GPC chair and currently serves on the GSNP executive committee, connected me with past GSNP chairs who were involved in establishing the Onsager Prize and the Kadanoff Prize. They kindly explained the process to me and offered valuable advice.

I started discussions with APS leadership, including APS Director of Membership and the APS Campaign & Donor Relations Manager, APS Honors Program Manager, and APS Director of Development. We formed an ad-hoc GPC Honors Committee to focus on this effort, which currently consists of GPC member Morgan O'Neill, GPC vice-chair Geoffrey Vallis, and GPC chair-elect Valerio Lucarini. Others in GPC have also been helping in an unofficial capacity. We recently submitted a formal proposal to APS for establishing an award honoring an early pioneer in climate physics. Once approved by the APS Council, we would then transition to fundraising for the endowed award. I am hopeful that we can launch the award in January 2025.

Proposal Amendments to the GPC Bylaws

The GPC executive committee is proposing a few important changes to the GPC Bylaws.

First, to encourage participation from junior scientists in GPC leadership, we are proposing to introduce two new positions on the Executive Committee for Junior Scientist Members-at-Large elected to one-year terms. The Junior Scientist Members-at-Large shall be graduate student or early career members, as defined by the APS, at the time of the election. The two positions would replace the current Member-at-Large 3-year student position. I have been told that GPC was the first APS unit to introduce a student position on its executive committee, but many of us in GPC now regard 3-years as too long for a student position. This proposed amendment was supported unanimously by the GPC executive committee. We are hoping that a 1-year position would encourage more engagement from junior scientists in our activities and governance.

A second key proposed amendment modifies the GPC "Areas of Scientific Inquiry" to include understanding climates of other planets within our solar system and beyond. This change was spurred by William Newman (GPC past-chair – see his article in this Newsletter issue) and unanimously supported by the executive committee. This area includes exploring different climate parameter regimes, which helps in gleaning insight into fundamental physical processes and their feedbacks. We believe that this broadening of our scope will benefit our understanding of climate physics by encouraging engagement from the planetary science community, which has been witnessing remarkable advances recently (Cassini, Juno, JWST, exoplanet discovery).

A third key proposed amendment changes the "Terms of Office" of Officers and Members-at-Large of the Executive Committee to begin at the close of the "Regular Meeting" of GPC following their election. Regular Meeting is the principal meeting held once a year by the unit, which for GPC is the APS March meeting. Currently, the Terms of Office start on January 1 and end on December 31. The GPC executive committee voted unanimously in support of this change. Adhering to the calendar year has many undesirable and contrived ramifications to our unit's governance. This is becoming more of a problem as GPCgrows in size and expands its activities, which requires different office holders to coordinate. I note that many of the large units (divisions) have their Terms of Office begin at the end of their Regular Meeting, e.g., DCMP and DFD.

I have been in correspondence with the APS Corporate Secretary on the language details of the amendments. I am optimistic that the revised bylaws will be approved by the APS Council at its October meeting. If approved, they would be put to a ratification vote by all GPC members.

APS March Meeting

GPC has been making use of tutorial sessions at the APS March meeting to (i) benefit our members and (ii) expand our in-reach within the APS community for those interested in climate physics. At the APS 2023 March meeting, GPC organized a half-day tutorial session comprising four 1-hour lectures on the basics of climate physics by Nadir Jeevanjee (GFDL/Princeton), Tiffany A. Shaw, (U. Chicago), Allison Wing (Florida State U.), and Michael Mann (UPenn), which were moderated by William Newman (UCLA). Nadir gave a first-principles dive into basics of radiation and balances. Tiffany presented an introduction to global atmospheric circulation and its role in climate. Allison discussed small-scale processes, including moist convection physics, asymmetry in small scale circulation, and precipitation. Michael walked us through the basic physics of a warming climate and surveyed its global and local impacts.

At the upcoming 2024 March meeting, GPC is co-sponsoring a day-long tutorial comprising eight 1-hour lectures on the basics of machine learning, one of which, by GPC Member-at-Large Ching-Yao Lai (Stanford), will highlight geophysics and climate applications.

At the APS 2023 March meeting, we also had two engaging Focus Sessions. The first, titled "Extreme Events, Tipping Points, and Abrupt Changes in the Climate System", was chaired by William Newman (GPC past-chair) and featured invited talks by Ian Eisenman (UC San Diego), Alexander Robel (Georgia Tech), Yi Zhang (UC Berkeley). The second, titled "Statistical and Nonlinear Physics of Earth and its Climate," was chaired by Mara Freilich (Brown Univ.) and featured invited talks by Lynne Talley (Scripps Institute of Oceanography), Luc Deike (Princeton Univ.), Samuel Stechmann (UW-Madison).

Following the GPC Focus sessions on Monday, we held our annual Business meeting, which is open to everyone, including non-members and those not registered for the March meeting. At the meeting, our treasurer Xiyue (Sally) Zhang gave us an update on the GPC budget. There were also good ideas exchanged, including the need to facilitate involvement by students in our activities and a suggestion to incorporate into the GPC Virtual Seminar Series talks about career paths for students considering the field of climate physics.

After the GPC Business meeting, we held our traditional Climate Café. This year, we gathered at a local pizzeria for pleasant conversations and many good laughs while sharing food and drinks.

Valerio Lucarini, as the current GPC chair-elect, is leading our preparations for the upcoming 2024 March Meeting, taking place in Minneapolis, MN March 3-8, which will include an exciting expansion of the topics we cover. For the first time, the GPC program will include a third Focus Session titled "Diversity of planetary circulation regimes: our solar system and beyond."

GPC Seminar Series

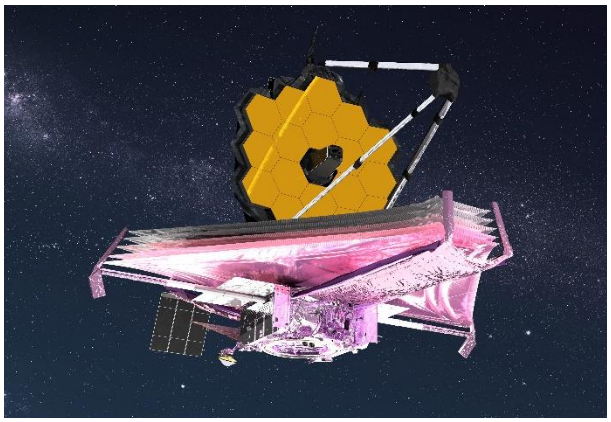
An important GPC initiative that started in 2022 and continues strongly into 2023 is the GPC virtual seminar series. I am grateful for the GPC Virtual Seminar Series Committee members for maintaining a vibrant and fresh series of talks. The series was quite successful in 2022, with 1-hour seminars occurring approximately every month. We aim for the seminars to connect with physicists, including those in their early careers, who are interested in climate but who are not necessarily experienced in the subject. Therefore, we request that our invited speakers include sufficient introductory materials in the talks and discuss open problems physicists can contribute to, in addition to surveying new results and discoveries. In addition to being broadcast live, the talks are available on demand. The seminar schedule is online at (https://engage.aps.org/gpc/resources/seminar-series). You can also sign up for the GPC seminar mailing list, to receive communication regarding the seminars. If you would like to suggest a speaker or are interested in giving a talk yourself, please contact the committee members.

GPC Membership

During the 2023 APS March meeting, we coordinated with APS meeting organizers to set up a membership table for recruiting new members. We were able to add 69 new GPC members, which amounts to an approximately 11% increase in our membership. Invariably, there will be some attrition during the renewal cycle of APS membership, but I am hopeful that a significant fraction of the new members will remain. I am grateful for Xiyue (Sally) Zhang, Mara Frielich, and Justin Burton for their help with this effort. I believe that increasing our membership numbers is an important component of our efforts to expand GPC's inreach within APS and outreach beyond, to members of other societies such as AGU, AMS, and SIAM.

ARTICLE: GPC to add Planetary Atmospheres and Oceans as a sixth Area of Interest– *continued from p. 1*

through observations of other terrestrial atmospheres. They are characterized by predominantly carbon dioxide, with only the Earth's atmosphere undergoing compositional change owing to the emergence of life. The initial understanding of the Earth's greenhouse effect originated in the investigation of Venus's carbon dioxide atmosphere, while our appreciation for atmospheric aerosols emerged from the study of global Martian dust storms. Investigations of the atmospheres of the gas giants has exposed remarkably different behaviors owing to their radically different composition. During the past two decades, we have also come to appreciate the role of atmospheres and oceans on some of the major satellites of the Jovian planets. Jupiter's satellites Europa, Ganymede, and Callisto have tenuous atmospheres of carbon dioxide and oxygen and even have subsurface oceans, while Saturn's satellites Enceladus and Titan also appear to have such oceans. The behavior of these atmosphere-ocean systems is dominated by chemistries that are radically different from those of Earth but has garnered substantial interest owing to their presenting conditions possibly similar to pre-biotic Earth and for dramatically different dynamics.



NASA JWST Artist's Conception

During the past two decades, a major focus of scientific investigation arose from the search for Earth-like planets in extra-solar planetary systems. Dramatic advances were made as the outcome of new instrumentation and technologies, particularly those employed in space in many different wavebands. The Kepler and Tess spacecraft missions, especially, as well as CoRoT, HARPS, ESPRESSO, and ANDES have revealed a constellation of very different solar system types.

The launch and deployment of the James Webb Space Telescope (JWST) to the L_2 Lagrange point 1.5 million kilometers from Earth has opened a new era of exploration.

The JWST has given us the ability to investigate and resolve at infrared wavelengths planetary atmospheres, especially those enveloping planets that could harbor life. Beginning with observations and theory developed to understand the atmospheres of our solar system planets and their satellites, we are presently exploring more than 5490 extrasolar planets, 4052 planetary systems, and 876 multiple planet systems. The day-to-day discovery of new extrasolar planetary systems and the investigation of a multitude of different types of atmospheres has already led to a bewildering array of climates and physical processes, often very unlike those present on Earth. Indeed, evidence is steadily increasing that our solar system is somewhat unique in its disposition of planetary sizes and distances from their host stars. Incorporating the study of climates of other worlds is a natural and compelling addition to our initial areas of inquiry. The space age has truly captured the potential for new discoveries in the physics (and chemistry) of climate on our world and large numbers of others.

At the last meeting of the Executive Members of the Group on the Physics of Climate, we proposed and unanimously approved the incorporation of planetary atmospheres and oceans as an additional area of interest for our topical group.

ARTICLE: Computing Response Operators Using Koopman Formalism: A Climate Science Perspective – *continued from p. 1*

This theorem establishes a dictionary allowing one to reconstruct the response of the system to perturbations – seen as change in the expectation value of a given observable of interest - in terms of the unperturbed fluctuations. Specifically, the FDT enables the representation of the system's response using a causal Green's function, which is expressed as a correlation between physically intuitive observables in the absence of external perturbations (Kubo 1966).

Things become considerably more complicated when one considers nonequilibrium systems. If the system obeys deterministic, phase-contracting dynamics and its asymptotic state lives on a strange attractor, the correspondence between forced and free fluctuations is only partial (Ruelle 1998, 2009). If, instead, the dynamics is stochastic, generalizations of the FDT can be proposed, but the price one must pay is that the formulas one obtains are more convoluted and of less obvious physical interpretability (Marconi et al. 2008).

This issue is of special relevance in the context of climate change studies, because response theory provides a powerful tool for performing flexible climate change projections (Lucarini et al. 2017, Lembo et al. 2020). Additionally, one has a general framework for linking free and forced climate variability between and across multiple scales of motions (Ghil and Lucarini 2020), thus allowing for relating climate change signal to changes in the occupation statistics of the modes of natural climate variability (Corti et al. 1999). The overall scientific framework we consider here is the stochastic viewpoint pioneered by Hasselmann (1976); see further discussion in Majda et al. (2001) and Franzke et al. (2015).

In order to use response theory to perform climate projections using climate models, one has to derive the Green function G_Ψ for the observable of interest Ψ and convolve it with the temporal pattern of forcing $T(t)$ applied to the system, e.g., CO_2 concentration increase:

$$\langle\Psi\rangle(t) - \langle\Psi\rangle_0 \approx (G_\Psi * T)(t) \qquad (1)$$

where $\langle\Psi\rangle(t) - \langle\Psi\rangle_0$ is the climate change signal (in an ensemble sense) and $\langle\Psi\rangle_0$ is the background climatology. One way to derive the Green function, following Leith's (1975) seminal work, relies on exploiting the free fluctuations of the system, see e.g. North et al. 1993 Cionni et al. 2004). Another approach bypasses the need to apply the FDT and derives the Green function by performing an ensemble of selected perturbed model runs (Lucarini et al. 2017, Lembo et al. 2020).

In all cases, a major bottleneck is that one does not automatically derive an explicit functional form for the Green function, nor is it easy to associate it to the acting feedbacks of the system, to the various scales of motion, nor to its (unperturbed) natural internal modes of variability. In

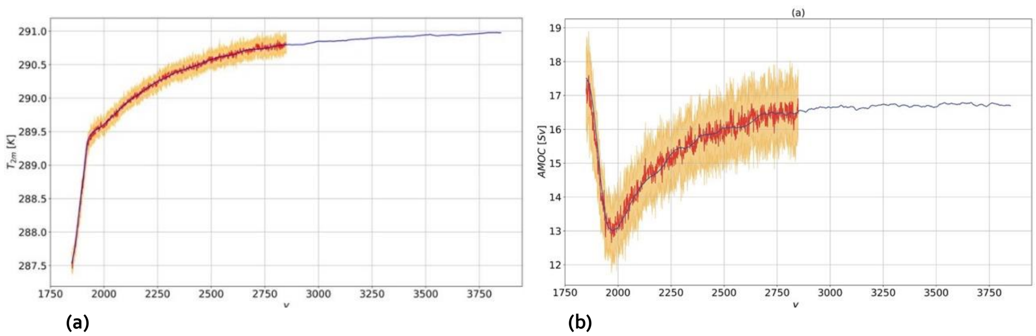


Figure 1: Prediction of a) Globally averaged surface temperature and b) Atlantic Meridional Overturning Circulation (AMOC) strength as a result of an annual 1% increase of the CO2 concentration from pre-industrial conditions up to doubling. In each panel the blue curve indicates the prediction by application of response theory while the thick red curve shows the ensemble mean of the model runs (yellow curves).

contemporary scientific language, we are facing a problem of interpretability of the response operator that links forcings and response. Hasselmann et al. (1993) proposed heuristically that the relaxation of a climate model to steady state Green function written as a weighted sum of N decaying exponentials:

$$G_\Psi(t) \approx \Theta(t)\sum_{j=1}^{N}\alpha_j e^{\lambda_j t} \qquad (2)$$

where the $\lambda_j{}'s$ (whose real part is, in the case of our interest, strictly smaller than zero) were conjectured to be associated with the acting feedbacks of the system. This route has been recently taken by Torres Mendonça et al. (2021) and Bastianseen et al. (2021), who fitted Green functions describing the response of a climate model to perturbations as a weighted sum of exponentials as in Eq. (2), where the information on the decay rates $\lambda_j{}'s$ was extracted from the natural variability of the unperturbed model. Finally, Lembo et al. (2020), building on Chekroun et al. (2014), proposed that the amplified response of the Atlantic Meridional Overturning Circulation to increasing CO_2 concentration (see Fig. 1) could be seen as indicating the proximity to a tipping point (Boers 2021; Ditlevsen and Ditlevsen 2023).

In Santos, Gutierrez and Lucarini (2022) it was shown, following Chekroun et al. (2020), that one can elucidate the properties of the Green function of a general stochastic dynamical system and explain thoroughly the observations above by linking response theory with the so called *Koopmanism (*Budišić et al. 2012). This angle provides a means to represent complex systems using a linear operator – the Koopman operator (also known as Kolmogorov operator in the case of stochastic systems) – acting in an infinite-dimensional functional space that evolves observables of the system over time. The Koopman operator is the adjoint of the Fokker-Planck operator.

By identifying relevant observables and their corresponding Koopman eigenfunctions, we can unveil the underlying modes of variability and capture, in a hierarchical manner, the statistical properties of the system (Mezic 2005, Kutz et al. 2016, Lusch et al. 2018). These eigenfunctions and the corresponding eigenvalues offer a valuable basis for understanding its response to perturbations. Indeed, one can derive that rather general assumption, any Green function $G_\Psi(t)$ (regardless of the chosen observable and of the acting forcing) takes a form that, in special cases reduces to what has been presented in Eq. (2). The fascinating thing is that the $\lambda_j{}'s$ do not depend on the choice of the observable and on the acting forcing, and are indeed the eigenvalue of the Koopman operator. Instead, the coefficients α_j do depend on the on the choice of the observable and on the acting forcing. This provides strong support for the Hasselmann et al. (1993) original intuition.

What happens if the real part of one of the $\lambda_j{}'s$ – say λ_1 – gets dangerously close to zero as a result of a parametric modulation of the system (e.g., shifting climate conditions)? Things become clearer if one takes the Fourier transform of Eq. (2), whereby one derives the expression for the so-called susceptibility.:

$$\chi_\Psi(\omega) \approx \sum_{j=1}^{N}\frac{\alpha_j}{i\omega - \lambda_j} \qquad (3)$$

If $Re(\lambda_1) \to 0$, the susceptibility diverges for $\omega = \mathrm{Im}(\lambda_1)$. In the case of $\mathrm{Im}(\lambda_1) = 0$ this implies that the (static) sensitivity of the system diverges. This is a key feature of tipping points. Additionally, as discussed in detail in Lucarini and Chekroun (2023), Eq. (3) allows to derive the early warning signals that allow one to anticipate critical transitions, namely the critical slowing down (slow decay of the autocorrelation of given observable) and (with some caveats) the increase in the variance of the observable of interest.

Concluding, the Koopman operator theoretical framework complements rather efficiently the response theory formalism by clarifying the link between forced and free fluctuations, thus substantiating the fluctuation-dissipation theorem for general stochastic dynamical systems. In the case of climate, this provides a formidable tool for linking free and forced modes of climate variability and for deriving conditions conducive to the occurrence of tipping points in much greater generality than previously discovered.

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ARTICLE: Recollections from the 2023 Aspen Center for Physics Fluids Summer Program (Part I) – *continued from p. 1*

As is standard for Aspen "summer" events, there were a limited number of presentations on a rather wide variety of topics, but with most of the time reserved for personal scientific exploration, collaboration, and networking.

The workshop was motivated by numerous rapidly developing, high impact results spanning astrophysical, geophysical, and biophysical fluids, including a wealth of new data, computational challenges, and conceptual puzzles. The goal of the workshop was to bring together an interdisciplinary group of scientists studying astrophysical and geophysical fluid dynamics, climate science, theoretical fluid and plasma physics, biological physics, turbulence, and field theory to form new connections that will drive these fields forward. More specific to the theoretical approaches of special interest to the workshop, the systems of interest can reside in parameter regimes (e.g.,

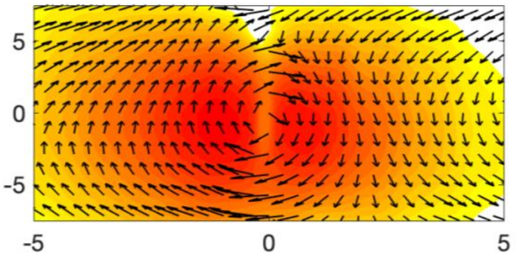

Figure 1: Atmosphere height-velocity cross-correlation of ERA5 satellite data in the zonal-meridional wavenumber plane at fixed frequency 1.8 cycles per day. The observed vortex in the complex phase of the correlation function is a topological signature. (**https://doi.org/10.48550/arXiv.2306.12191**)

strong rotation, stratification, viscosity, or magnetization) that allow analytical control, and are thus amenable to quantitatively accurate applications of modern geometric and field-theoretic techniques, such as asymptotic methods for path integrals, renormalization group and effective field theory approaches, generalized symmetries, holographic "gauge/gravity" duality, geometric phases, and topologically protected excitations. In return, specific fluid systems can also provide a context for new formal developments in classical, quantum, and statistical field theories.

This article, separated into two parts due to length limitations, aims to summarize some of the key features of the remarkably broad array of invited talks, hopefully motivating readers to delve deeper and perhaps inspiring some of those desired connections to their own fields of interest.

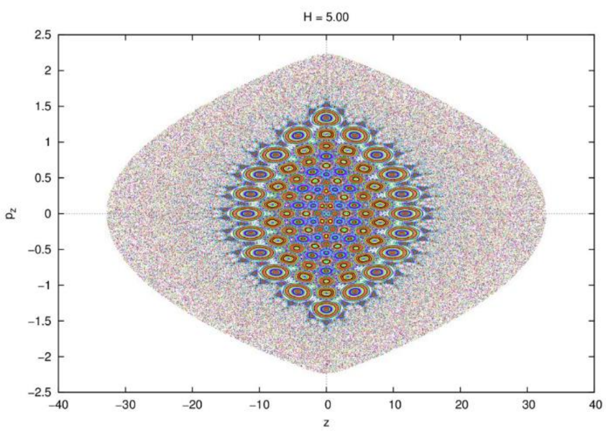

Figure 3: Poincaré sections (phase space orbit intersection with cylinder angle $\varphi = \pi$) corresponding to the dynamics of two equal mass gravitationally interacting point particles (in the center of mass frame, and fixed conserved center of mass momenta) on the unit radius cylinder in the (z, p_z)-plane for energy level $E = 5$. Non-integrability is exhibited here by a central region organized into a web of periodic orbits and an external chaotic region. (**https://link.springer.com/article/10.1134/S1560354720010086**)

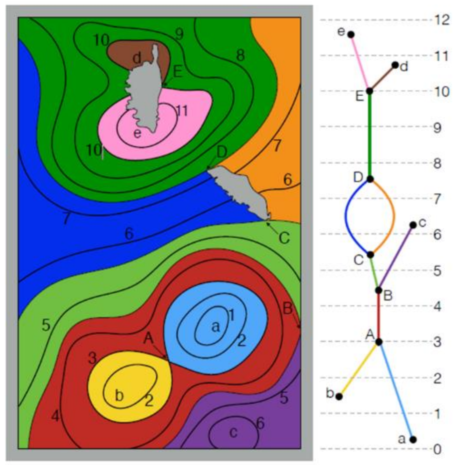

Figure 2: Contours and Reeb graph (right) of the pressure on a neutral surface, interrupted by grey islands. Leaf nodes (small letters) indicate extrema of p, while interior nodes (capital letters) indicate saddles of p. Each arc in the Reeb graph has an associated region in physical space, shown in matching color. The position of the bottom island here is such that it creates a cycle in the Reeb graph. (**https://arxiv.org/abs/1903.10091**)

Brad Marston (Brown University) *"Waves of Topological Origin in the Fluid Earth System and Beyond"*

Brad and his collaborators have for several years now been generating new insights into planetary wave systems that have been covered by a couple of generations (at least) of textbooks. These systems emerge as linear wave solutions to various formulations of the shallow water equations on a rotating sphere. What escaped notice until recently is that different classes of these solutions (equatorial trapped inertia-gravity, Kelvin, and Yanai waves) are tied together by topological signatures, analogous to those in quantum systems, related to sign reversal of the Coriolis effect across the equator. Recent work (**Figure 1**) has succeeded in directly extracting topological signatures from satellite cross-correlational data. Ongoing experimental work on magnetically trapped plasma systems is seeking to verify analogous topological wave predictions.

Geoffrey Stanley (University of Victoria), *"Untangling multi-valued functional relations using the Reeb graph on oceanic neutral surfaces"*

Most of the earth's oceans are strongly stratified, inhibiting vertical transport of important tracers. Ideally one seeks to identify associated two-dimensional (generally curved) surfaces, known as neutral surfaces, within which oceanic flows efficiently mix tracers but across which mixing is strongly suppressed. Although a conceptually simple idea, they turn out to be mathematically ill-defined due to nonlinearity of the seawater equation of state.

There is a long history of defining such surfaces locally, but consistently tying them together globally remains a challenge. Geoff presented a fresh theoretical perspective on this problem, by studying the *topology* of hypothetical neutral surfaces that are well-defined. On such surfaces, there is a multi-valued relationship between the density and the pressure, with the result that a level set of pressure on a neutral surface can be the disjoint union of multiple connected components with distinct densities. Topological information about changes in the connectedness of these level sets is captured, as a collection of nodes and arcs, by the Reeb graph (**Figure 2**). This tool is used to develop a new class of approximately neutral surfaces in the real ocean, called topobaric surfaces, which are very close to neutral, possess an exact geostrophic stream function, and are efficiently computable.

Stefanella Boatto (Federal U. of Rio de Janeiro) "*Vortex and gravitational modeling: a long journey with a rich mathematical history"*

The dynamics of a very large number of point vortices (or even continuous vorticity field) in the plane is a very familiar problem in fluid dynamics related to modeling of the turbulent inverse cascade in the Euler equation. Stefanella's presentation demonstrated that there is still some rather interesting mathematics to be done for a much smaller number of point particles, even two particles when confined to topologically nontrivial manifold. The motion of two gravitationally interacting particles in flat 2D or 3D space is, of course, integrable, displaying the usual circular, elliptical, parabolic, or hyperbolic solutions. On the other hand, for particles confined to the surface of an infinite cylinder of radius R the natural gravitational potential

$$U = \gamma m_1 m_2 \log[\sin^2(\varphi/2) + \sinh^2(z/2R)]$$

for particles with angular separation φ and cylinder axis separation z, reducing to the 2D Coulomb result at small separation and the 1D Coulomb result for large $|z|$, does not lead to an integrable dynamics with stable orbits. Rather, as seen in the example displayed in **Figure 3**, the dynamics displays a transition to chaos for larger initial particle separations or relative z-momenta. There are various limits, such as approximately planar 2D dynamics for small separations and 1D dynamics for large $|z|$, where the dynamics is near-integrable, and the Poincaré sections display slightly distorted periodic orbits (compared to their flat space counterparts) that may be interpreted as local signatures of the cylinder topology.

Stepping slightly into the realm of many body physics, Stefanella also investigated stability results for a horizontal 1D ring of N identical, equally spaced masses (attractive gravity), charges (repulsive Coulomb), or vortices (self-advecting). The equilibrium configuration was proven to be linearly unstable, for all three types of dynamics, for any $N \geq 2$.

Joonas Nattila (Columbia/Flatiron) *"Neutron Star Weather Forecasting"*

Neutron stars are enveloped by a plasma atmosphere and a Coulomb-liquid Ocean (**Figure 4**). Their envelopes are extremely thin, stratified, and inviscid and hence support a nearly two-dimensional description, including highly turbulent (internal and surface) gravity waves. Such turbulent envelopes have long been studied in geophysical and planetary fluid dynamics. Joonas' presented initial steps to

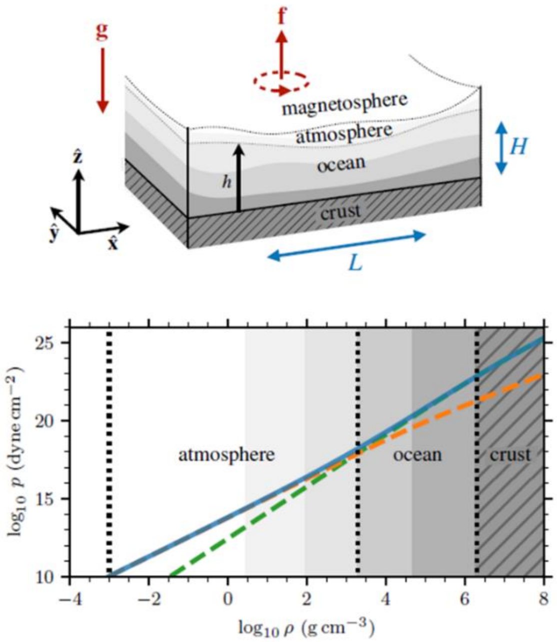

Figure 4: Neutron star atmosphere-ocean layers. Top panel illustrates the geometry of the stratified fluid layers. The physical height of the atmosphere (~20 cm) is much less than that of the ocean (~500 cm). Bottom panel shows the pressure as a function of density (blue curve). The pressure has two main components: an ideal gas law (orange dashed curve) and a degenerate electron gas pressure (green dashed curve). **https://arxiv.org/abs/2306.08186)**

extending such studies to neutron stars, identifying the important physical parameters, and estimating their values. Thus far, the focus in neutron star studies has been on understanding thermonuclear X-ray bursts and their propagation. Significantly, all phenomena modeled have been treated as perturbations on a uniform and stationary ocean. The aim of Joonas's presentation was to highlight the inhomogeneous and dynamic nature of both the atmosphere and ocean on neutron stars.

From a geophysical fluid dynamics point of view, it is very interesting how similar the underlying 2D fluid equations are to those of the earth's ocean and atmosphere, but with vastly different length (meters) and velocity (significant fractions of the speed of light) scales, and of course with additional magnetohydrodynamic degrees of freedom. As a result, simple scaling estimates and well-understood mechanisms from geophysical and planetary fluid dynamics allow one to deduce large-scale flow patterns expected for the atmosphere-ocean layers on neutron stars. Roughly speaking, neutron star atmosphere-ocean layers can be separated into a thick hydro-like ocean overlayed by a thin MHD atmosphere which itself is enveloped by a very thin "chromosphere." Long-lived spots (vortices or plasmoids) are predicted to appear. Long-lived jets (bands) should also emerge on rapidly-rotating neutron stars.

To be continued in Part II:

Muni Zhou (Princeton University), *"Inverse energy transfer in non-helical turbulence enabled by magnetic vortex merger.*

Glen Stewart *(U. Colorado), "Dynamical Surprises in Saturn's Rings"*

Alexander (Shura) Grosberg (NYU), *"Nuclear Chromodynamics (hydrodynamics of genetic material inside the nucleus of a live cell)"*

Luca Comisso *(Columbia) and* Albion Lawrence *(Brandeis), "Geometry and symmetries in relativistic MHD"*

2023 APS Fluid Dynamics Meeting

The 76th Annual Meeting of the APS Division of Fluid Dynamics meeting will take place November 19-21, 2023 in Washington, DC. The DFD meeting features a broad range of topics related to fluid mechanics, including several sessions devoted to geophysical fluid mechanics. These sessions include atmospheric and oceanic flows, sediment transport, glacial dynamics, turbulent flows, and microphysical process at the air-sea interface.

As such, the GPC has made a sustained effort in the last several years to support and maintain a presence at the DFD annual meeting. This has included sponsoring Mini-symposia and Focus sessions and sorting abstracts related to geophysical fluid dynamics.

We also started a new tradition in 2021, of an informal get-together on Monday evening during the meeting for all geophysical-interested conference participants. The GPC plans to continue this tradition in 2023!

For the 2023 DFD Meeting, the list of geophysical fluid dynamics sessions include:

Geophysical Fluid Dynamics: General

Geophysical Fluid Dynamics: Atmosphere

Geophysical Fluid Dynamics: Air-Sea Interaction

Geophysical Fluid Dynamics: Climate

Geophysical Fluid Dynamics: Cryosphere

Geophysical Fluid Dynamics: Ocean

Geophysical Fluid Dynamics: Transport and Mixing

Geophysical Fluid Dynamics: Sediment Transport

Geophysical Fluid Dynamics: Rotating Flows

Geophysical Fluid Dynamics: Stratified Flows

Geophysical Fluid Dynamics: Air-Sea Interactions

GPC Elections

The upcoming GPC election features openings for Vice Chair and two regular Members-at-Large. The election is to be held in late November and elected candidates would begin their terms in January 1, 2024. We strongly encourage you to help shape your GPC by voting.

The nominating committee is headed by William Newman (GPC Past Chair). Prospective candidates will be considered for their scientific standing and activity, their history of involvement with GPC and the APS, their perspective on the activities of the Group, and their likelihood of service to GPC if elected. Diversity in the GPC leads to vitality and innovation.

The position of the Vice Chair of GPC (currently held by Geoffrey Vallis) is a four-year commitment: after a year as vice chair the officer becomes in successive years the chair-elect (currently Valerio Lucarini), chair (currently Hussein Aluie), and then past chair (currently William Newman) – each with distinct duties. The chair officers play a crucial role in providing leadership in organizing the scientific content of the March Meeting and other meetings and in representing climate physics within the American Physical Society.

The members-at-large serve a three-year term; they constitute the fellowship committee; help select the invited symposia and invited talks for the March Meeting and provide advice on issues important to the GPC. Identifying excellent candidates who can provide a broad view of the diverse field that is climate physics is key to maintaining the vitality of GPC.

GPC Students and Early Career Investigators Awards

Four years ago, GPC created a scholarship for early career GPC members to attend the APS March Meetings and participate in the GPC sessions. For the upcoming 2024 APS March Meeting, GPC is offering two $1,000 awards. The first award will be "The GPC Student Prize" and will be given to a graduate student member of the APS who is pursuing work related to the GPC mission. The second award will be "The GPC Early Career Investigators Award" and will be given to an early career investigator (less than 5 years out of Ph.D.) who is a member of the APS GPC. Both awards will help defray the costs of attending and participating in a GPC related session at the March Meeting. To apply for the awards, applicants should submit a single pdf file containing: (1) a maximum one-page statement that includes a brief description of the applicant's research, how participation would benefit them, and how their work fits with the GPC mission, (2) a CV, (3) an abstract submitted to the upcoming APS March meeting.

Please send an email with the heading: "APS GPC Scholarship Application 2024" with the pdf file attached to the GPC Vice Chair, Geoffrey Vallis <g.vallis@exeter.ac.uk>.

Deadline for applications: December 17, 2023.

Other News Links of Interest and Upcoming Events Calendar

1. The September 2023 issue of APS News contains a Back Page Opinion article Is Climate Science Physics? by GPC Executive Committee member Nadir Jeevanjee (NOAA GFDL). The article details his journey from graduate student in theoretical physics, interested in quantum gravity, to the earthlier realm of atmospheric science, and his efforts to incorporate the back-of-the-envelope style of fundamental physics to gain better insight into results from large-scale geophysical modeling. He also describes his well-received outreach efforts, both to the wider physics community and to the public.
2. UN Climate Change Conference 2023 (UNFCCC COP 28), November 30-December 12, 2023, United Arab Emirates.
3. AGU Fall meeting, Dec. 11-15, 2023, San Fransisco, CA.
4. 104th American Meteorological Society Annual Meeting, Baltimore, MD, January 28-Feb 1, 2024.
5. European Geosciences Union General Assembly 2024, April 14-19, 2023, Vienna, Austria & Online.
6. ASLO Aquatic Sciences Meeting 2024, *Adapting to a Changing World*, June 1-7, Madison, WI. The world is rapidly changing. The accelerating tempo of climate change, eutrophication, altered hydrological regimes, overharvest, and biodiversity loss are threatening aquatic ecosystems, water resources, and resultant human well-being. Effectively adapting to meet these challenges will require major transitions in both our thinking and how we manage aquatic ecosystems to build resilience. Sustainable solutions—those that work across sectors, nations, and generations—will emerge from a foundation of actionable aquatic science.
7. 2024 Ocean Sciences Meeting, February 18-23, 2024, New Orleans, LA.
8. KITP workshop on The Physics of Changing Polar Climate is planned for May 13 - Jul 18, 2025. The associated conference The Future of Earth's Polar Regions will take place June 23-26, 2025. Polar regions are hotspots of rapid surface warming, cryospheric melt, and oceanic transformation. Scientists' weak physical understanding of these regions limits confidence in projections of polar climate change and its global impacts. This program will bring together experts from atmospheric, oceanic, cryospheric and fundamental-physics perspectives to consider the physics of past, present, and future polar climate.
9. The One World Mathematics of Climate is an online platform with the aim of gathering the best scientists from all over the world on the subjects of mathematics, theoretical physics, and statistical mechanics for modelling and understanding climate. The aim is to provide the best possible scientific discussions to a wide international audience. The next speaker is Paul O'Gorman (MIT) on "A new theory for extratropical storms in the limit of purely moist dynamics," October 3 (9 am PST). Future speakers include: Bedartha Goswami (University of Tübingen), November 7, 2023; Martin Rypdal (UiT The Arctic University of Norway), December 5, 2023; Pierre Gentine (Columbia University) February 6, 2024.
10. The 19th International Conference on Clouds and Precipitation (ICCP) will be held July 14- 19, 2024 in Jeju, South Korea. Note that the International Cloud Modeling Workshop is planned for the week before the ICCP, on 8 to 12 July 2024, at Yonsei University. In addition, workshops on cloud instrumentation and cloud chambers are planned in Jeju the weekend before the ICCP meeting (July 13-14, 2024).