Jonathan L. Mitchell

Statement of Research Interests

My current research interests cover a broad range of topics including planetary and exoplanetary atmospheres and climate, fundamental geophysical fluid dynamics, surface-interior coupling on water rich moons, and Earth's paleoclimate and regional climate sensitivity.

A primary focus of my research is the ***weather and climate of Titan***, which has led to some important discoveries that are detailed in my publications. I coauthored a recent review on Titan's climate, a sign that the field has begun to mature.[1] In a recent paper, I demonstrated how Titan's methane precipitation can be an order of magnitude more intense than previous predictions based on global average energy balance due to lateral heat transport by the atmosphere.[2] I also showed how planetary-scale waves organize moist convection in Titan's atmosphere, much as they do in Earth's tropics, which further enhances precipitation rates.[3] These studies indicate that surface erosion could plausibly be the result of an intermittent, intense precipitation cycle currently operating on Titan rather than a remnant of an earlier, wetter climate.

In my earlier work on Titan's climate, I identified methane thermodynamics as an important mechanism controlling the latitudinal positions and seasonality of convective methane clouds in Titan's lower atmosphere[4]; previous work had largely dismissed this effect. I additionally identified a seasonally oscillating overturning circulation, or Hadley cell, as the mechanism that dries the low-latitude surface and supports equatorial deserts.[5] In ongoing work, my group and I are extending our Titan modeling framework in order to better capture the dynamics controlling surface-atmosphere interactions, with the aim of coming to a robust understanding of processes that shape Titan's diverse surface features. As the Cassini mission ages, I am also exploring opportunities to be involved in potential future missions to study the Titan environment.[6]

A second of my research interests is the ***geophysical fluid dynamics of atmospheres in large-Rossby-number regimes***. Titan and Venus are classical examples of this category. Their atmospheric circulation is characterized by superrotation, with zonal winds exceeding solid-body rotation. In a series of idealized numerical experiments, we identified a clear transition to a superrotating climatology, and identified a new, unstable wave mode that is responsible for the transition.[7] In recent work, we are studying the interplay of seasonal cycles and the waves responsible for maintaining superrotation.[8] We now have a linear instability theory for the wave mode responsible for superrotation in our numerical experiments,[9] which is a key development toward understanding the necessary conditions for the development of superrotation.[10][11]

A third research interest is in the ***dynamics and deformation of icy shells of synchronous moons***. My collaborator and I discovered an overlooked restoring torque on icy shells due entirely to their elastic deformation.[12] The elastic torque dominates over other processes tending to spin shells non-synchronously. Our result brings into question the interpretation of the origin of cracks on Europa's surface due to so-called non-synchronous rotation. In ongoing work, my student and I are collaborating with Bruce Bills (JPL) to characterize the physical libration of Europa under elastic restoring of a layered, visco-elastic shell. We have also begun collaboration with the Ice Sheet System Model (ISSM) development group at JPL, with the goal of connecting observed modes of surface deformation on icy bodies like the Galilean moons of Jupiter to the sources of deformation (tides, convective stress, etc.).

A fourth, new focus of my research interests is ***Earth's paleoclimate and regional climate sensitivity***. In collaboration with UCLA geochemists, we are exploring regional climate sensitivity during the last glacial maximum (LGM) using climate models and new proxy data. Our work is currently focused on the West Pacific Warm Pool[13] and the East Asian monsoon[14], and we have plans to extend our work to mid-Holocene continental climates with dry lake sediments. A goal of our research is to leverage the regional climate sensitivity in global models of paleoclimate to provide additional constraints on how to improve climate prediction in the modern.

Finally, I am interested in ***extrasolar planetary atmospheres and climate***. As an astronomer with the training of a geoscientist, my interests are at the intersection of astrophysical environments and planetary phenomena. The study of exoplanets is bringing astronomers and geoscientists into close collaboration, which presents challenges that I have the expertise to address. The vast numbers of exoplanets to be discovered requires a new way of thinking about planetary environments. Instead of a having detailed and complex information about a few planetary archetypes of our Solar System, we will soon have very basic information about vast numbers of exoplanets. With Venus, Earth, Mars and Titan as archetypes, I have begun the process of using idealized climate models to map the area of parameter space inhabited by these "planetary archetypes". This is certainly only a small subset of the possible range of planetary climates, but it is the only starting point for developing a broader perspective of exoplanet climate. I envision creating a sort of climate "phase diagram", not unlike the type used by chemists, to undertake this mapping of climate. This is a large and daunting task, but the process has already led us to discover and understand new atmospheric phenomena, and the process will surely lead to many more.

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