Suggested Projects, Mentors and Mentor General Interest Areas for 2020 Los Alamos Space Weather Summer School

Please contact mentors to discuss either the projects listed or suggest your own (mentor's general interests are listed to aid in choosing a mentor for your suggested projects.)

Additional projects will be added, so check back before finalizing applications.

Project: Characterizing magnetic reconnection within global kinetic magnetosphere simulations.
Mentor: Adam Stanier (T-5) (stanier@lanl.gov)
General interests: PIC and hybrid algorithms, magnetic reconnection, global magnetospheric modeling
Suggested Project: This project will characterize the coupling between macro- and micro-scale physics of magnetic reconnection at the magnetopause current layer in one of several recently performed global PIC or hybrid magnetosphere simulations (either Ganymede, Mercury, or Earth-like). Results will be compared with existing local kinetic and global MHD reconnection models.

Project: SAMI3 ionospheric modeling of equatorial electrodynamics.
Mentors: Erin Lay (ISR-2) (elay@lanl.gov); Chris Jeffery (ISR-2) (cjeffery@lanl.gov)
General interests: Ionospheric modeling, specifically equatorial electrodynamics.
Suggested Project: We would like to investigate the sensitivity and resolution of the SAMI3 global ionospheric model with a regional embedded grid. Can the embedded grid allow the model more to accurately capture small scale currents and winds in example scenarios with electron density plumes and artificial heat sources? This project will involve designing and implementing SAMI3 runs, and analysis and visualization of the results.

Project: Magnetosphere-Ionosphere Coupling and Ion Outflow
Mentors: Erin Lay (ISR-2) (elay@lanl.gov); Vania Jordanova (ISR-1) (vania@lanl.gov)
General interests: Ionospheric/magnetospheric coupling, ionospheric conductivity in auroral regions
Suggested Project: Ionospheric electron density and conductivity in the auroral regions. This project will involve collection and analysis of ionospheric data, in support our modeling efforts in ionospheric/magnetospheric coupling, specifically ion outflow. Data sources of interest include GPS TEC receivers, the SuperDARN Network, and the PFISR radar.

Project: Data-Driven Radial Diffusion in Earth's Radiation Belt using Machine Learning

Mentor: Humberto Godinez (T-5) (hgodinez@lanl.gov)

Suggested Project: The Earth's radiation belts, formed by trapped energetic electrons in Earth's magnetic field, experience significant and abrupt changes due to acceleration, loss, and transport processes. Since high-energy particles can potentially damage space infrastructure, understanding and predicting the dynamics of the radiation belts is of particular importance. In this project we will used advanced machine learning techniques, including Gaussian processes, Support Vector Regression, and Deep Learning (multi-layer neural networks) to provide a data-driven estimate of the appropriate radial diffusion coefficients for Earth's radiation belt environment. Specifically, we will use the vast amount of data available from the Van Allen Probes (A and B) mission to derive, through the use of machine learning algorithms, a accurate empirical model of the diffusion coefficient. The project will involve both theoretical knowledge of radiation belt physics and dynamics, as well as practical knowledge of advanced machine learning techniques.

Project: Particle Injections During Storms and Substorms

Mentor: Vania Jordanova (vania@lanl.gov)

General Interests: Physics of the inner magnetosphere, energetic particles, wave-particle interactions, numerical modeling

Suggested Project: To understand the injection of energetic particles during storms and substorms, we will carry out simulations with our large-scale kinetic inner magnetosphere model RAM-SCB coupled with a Particle Tracing Model. The model results will be validated through comparisons with observations from the Van Allen Probes and GEO satellites.

Project: Solar Wind Composition

Mentor: Dan Reisenfeld (dreisenfeld@lanl.gov)

General Interests: Solar wind, solar corona, solar abundances, solar wind origins, comsochemistry

Suggested Project: Understanding the Drivers of Solar Wind Fractionation The elemental composition of the solar wind differs significantly from the composition of the solar photosphere. In order to understand why these differences, occur, we look for evidence for the underlying mechanisms that cause fractionation by analyzing data from the ACE Solar Wind Ion Composition Spectrometer (SWICS) and other solar wind composition instruments. Ultimately, we hope to come up with a means of correcting solar wind abundances to solar abundances in pursuit of the scientific goal of the Genesis solar wind sample return mission: to determine the composition of the primordial solar nebula.

Project: Kinetic Simulations of Plasma Heating and Particle Acceleration in Space Plasma Processes

Mentor: Fan Guo (guofan@lanl.gov)

General interests: Fully kinetic, hybrid (kinetic ions & fluid electrons), MHD, and particle transport simulations of heliospheric plasma processes including those in solar flares, coronal mass ejections and the solar wind. The main goal is to understand how particles are energized in such a weakly collisional space plasma system. The selected candidate will have opportunities to take advantage of the latest version of LANL's flagship VPIC code.

Suggested Projects:

(1) Kinetic Simulations Particle Acceleration in Collisionless Shocks (e.g., Guo et al. 2013, ApJ, 773, 158);
(2) Kinetic Simulations of Particle Energization during Magnetic Reconnection (e.g., Guo et al. 2014 PRL, 113, 155005)

Project: Radiation Belt Modeling Simulation and Modeling

Mentor: Greg Cunningham (cunning@lanl.gov)

General interests: modeling the evolution and remediation of natural and artificial radiation belts of MeV electrons using DREAM3D, a Fokker-Planck code

Project Ideas:

(1) Simulation -- Use DREAM3D code on LANL's high-performance computing cluster to model recent geomagnetic events and compare to observations from Van Allen Probes and other satellites, with an emphasis on comparing the model predictions to both low-altitude and high-altitude observations;
(2) Modeling -- Build a global specification of VLF wave properties that can be used in DREAM3D using observations and modeling (e.g. lightning-generated whistlers, ground-based transmitters, EMIC Theory: Develop an approach to include nonlinear wave-particle interactions in DREAM3D

Project: Hybrid simulations of EMIC wave growth

Mentor: Misa Cowee (mcowee@lanl.gov)

Project Ideas: Energetic (keV) ring current ions with anisotropic velocity distributions provide free energy for the excitation of EMIC waves in the inner magnetosphere which, in turn, can scatter the population into the loss cone. We have recently incorporated a new hybrid (kinetic ion, fluid electron) simulation-based model of EMIC growth into the Ring Current Atmosphere Interactions Model (RAM) to try to understand the global distribution and effect of these waves in a more self-consistent manner. This project involves further hybrid simulations to better quantify the threshold conditions for growth and the wave properties. Specific simulation studies could include:

(1) Understanding the role of a cold oxygen component in the wave growth, and re-deriving empirical scaling relations for wave amplitude and linear growth rate based on the methodology of Fu et al. 2016 (JGR, 121, 10954). The cold oxygen is expected to influence the He+ band waves and introduce a spectral gap near the O+ gyrofrequency.
(2) Understanding the role of continuous addition of free energy on the wave growth, saturation, and decay. Previous simulations of ion cyclotron waves at

Jupiter/Saturn/comets have shown how the instability behavior is influenced by the rates at which free energy accumulates over time due to dynamic changes in the ion density or anisotropy, sometimes yielding periodic cycles of growth and decay. This has yet to be quantified for EMIC in the ring current, but represents a potentially important growth pattern that should be accounted for in global models. Project would involve collaboration with Xiangrong Fu (NMC) and Vania Jordanova.

Project: Compressible turbulence in the solar wind
Mentor: Xiangrong Fu (NMC) (sfu@newmexicoconsortium.org)
General interests: MHD and hybrid simulation, turbulence, waves and instabilities, ion heating
Project Idea: The solar wind is believed to be a turbulent plasma environment where fluctuations of magnetic field, velocity and density spread across a wide spatial/temporal range, forming power-law spectra. In a simplified picture, the turbulence is considered Alfvenic and incompressible. However, there exists a fair amount of compressible turbulence, especially under low-beta conditions (close to the Sun). Compressible turbulence can be generated by nonlinear mechanisms like parametric decay. In this project, we will use 3D large-scale MHD and hybrid simulations to study the generation of compressible turbulence and associated ion heating in the solar wind. The simulation results can be compared to Parker Solar Probe measurements.

Project: Simulating ENA Images using the SHIELDS Modeling Framework
Mentor: Mike Henderson (ISR-1) (mghenderson@lanl.gov)
General interests: Data analysis and modeling of: Storms, Substorms, Ring Current, Radiation Belts, Global Auroral Imaging, Geomagnetically Induced Currents (GICs).
Project Idea: The SHIELDS modeling framework combines the Michigan Space Weather Modeling Framework with the LANL RAM/SCB Ring Current model. This modeling project would involve adding the capability to simulate Energetic Neutral Atom (ENA) images from the model runs and analyzing/interpreting results for modeled events.

Project: Magnetosphere/Data Analysis/Simulation
Mentor: Steve Morley (smorley@lanl.gov)
General Interests: Radiation belt, energetic charged particles, phase space density, statistical modeling, numerical simulation, radial diffusion
Suggested Project Topic: Understanding radiation belt dynamics at high time-resolution. The gold-standard instrumentation on board the Van Allen probes is still limited by only having two satellites in a geosynchronous transfer-like orbit. Key insights still rely on serendipitous timing and configurations of satellites. Augmenting Van Allen probes measurements of radiation belt dropouts and rapid enhancements using energetic particle data from the Global Positioning System allows further insight into the root causes of these dynamics. By including GPS particle data, and

exploring the evolution of the radiation belt in adiabatic coordinates, the dominant physical mechanisms can be disambiguated. Depending on the student's interest, this project can include use of the data-assimilative DREAM radiation belt model.

Project: Magnetosphere/Simulation
Mentor: Steve Morley (smorley@lanl.gov)
General Interests: Solar Wind-Magnetosphere interactions, magnetohydrodynamics, solar energetic particles, numerical simulation, scientific visualization
Suggested Project Topic: Simulating solar energetic particle access in the magnetosphere. Earth's magnetic field acts to shield the entry of energetic protons accelerated at the Sun or by interplanetary coronal mass ejections. Geomagnetic activity driven by the solar wind can significantly alter the current systems that determine where particles of a given energy can penetrate to. Simulating the magnetospheric configuration allows us to trace the motion of test particles to diagnose the access of solar energetic protons and compare with observations. Opportunities exist within the scope of the project to focus on scientific visualization of the 3D magnetosphere and particle access, as well as on the effects of different magnetospheric current systems on particle trajectories.

Project: Machine Learning Applications for Spacecraft Drag Studies
Mentor: Andrew Walker (awalker@lanl.gov)
General Interests: Spacecraft drag, machine learning.
Suggested Project Topic: Simulating solar energetic particle access in the magnetosphere.
In low Earth orbit, drag is the largest source of uncertainty in determining satellites' orbits. Mass density estimates derived from missions such as CHAMP and GRACE have provided important insights into the dynamics of the atmosphere. However, uncertainty of the mass density estimates driven by drag coefficient error and incomplete knowledge of gas-surface interaction (GSI) physics can impart errors into the inference made. Machine learning under the umbrella of data science can provide an effective approach to investigate GSI and drag coefficients and quantify its impact on the mass density estimates. This project would investigate different machine learning approaches towards addressing this challenge.

Project: Global simulations of Ganymede's magnetosphere
Mentor: Gian Luca Delzanno (T-5) (delzanno@lanl.gov), Vadim Roytershteyn (Space Science Institute), Oleksandr Koshkarov (T-5)
General interests: Kinetic simulations of space plasmas, planetary magnetospheres
Suggested Project: Global fully-kinetic simulations of systems like the Earth's magnetosphere remain a grand challenge because of the large scale separation between microscopic and system scales. We are developing a new framework based on a spectral approach that intrinsically allows effective micro/macro coupling and is especially suitable for global simulations that include microscopic (kinetic) physics accurately. The new code will be applied to investigate Ganymede's magnetosphere, with the objective of studying its formation and compare the results with previous published simulations and observations.

Project: Ray tracing studies in the Earth's magnetosphere
Mentor: Gian Luca Delzanno (T-5) (delzanno@lanl.gov), Chris Jeffery (ISR-2)
General interests: Radiation-belt remediation, wave-particle interactions
Suggested Project: Los Alamos National Laboratory is developing a computational framework to assess the feasibility of remediating an artificial radiation belt by injection of electromagnetic waves by antennas and electron beams. A critical component of the framework is ray tracing, which propagates the injected waves from their source to the global near-Earth environment accounting for the interaction with the local particle populations. This study will validate our ray tracing code against observational data during conjunctions between equatorial and low Earth orbit spacecraft.

Project: Kinetic instabilities coupling the ring current and cold plasma populations
Mentor: Gian Luca Delzanno (T-5) (delzanno@lanl.gov), Vadim Roytershteyn (Space Science Institute)
General interests: Kinetic simulations of space plasmas, instabilities, wave-particle interactions
Suggested Project: The cold (~eV) plasma particle populations control many phenomena that are critical to the dynamics of the near-Earth environment such as solar-wind/magnetosphere coupling, substorm dynamics, waves and wave-particle interaction physics. Typically, the cold plasma is considered a passive player, i.e. mainly providing the inertia of the medium. In this project, kinetic simulations and theory will be used to investigate how kinetic instabilities can transfer energy from the ring current to the cold plasma, suggesting a much more active role of the cold plasma in the Earth's magnetosphere.

Project: Spacecraft charging simulations
Mentor: Gian Luca Delzanno (T-5) (delzanno@lanl.gov), Brian Larsen (balarsen@lanl.gov), Joe Borovsky (Space Science Institute)
General interests: Spacecraft-plasma interaction, kinetic simulations
Suggested Project: The cold (~eV) plasma particle populations control many phenomena that are critical to the dynamics of the near-Earth environment such as solar-wind/magnetosphere coupling, substorm dynamics, waves and wave-particle interaction physics. However, the cold-plasma populations are hard to measure because spacecraft are almost always charged to potentials exceeding the cold plasma energy. This is especially true for electrons since spacecraft surfaces exposed to sunlight and bombarded by energetic particles emit secondary electrons with energies comparable to those of the cold electrons of the environment. In this project, we will perform Particle-In-Cell simulations of spacecraft-plasma interaction to evaluate new spacecraft configurations that will allow the measurement of the properties of the cold-plasma populations.