

Alejandro Soto

1050 Walnut Street, Suite 300, Boulder, CO 80302
(720) 240-0128, asoto@boulder.swri.edu, www.alejandrosoto.net

A planetary scientist and aerospace engineer involved in Solar System exploration.

Expertise

I have over two decades of experience developing and using atmospheric models to study the atmospheric dynamics of planets with solid surfaces. I have used and helped develop atmospheric models for Mars and Titan, including working with existing models such as NCAR's WRF, MarsWRF, TitanWRF, and GFDL's FMS. I also have experience in space instrument development and operations for planetary spaceflight missions, including the Mars Reconnaissance Orbiter and the Deep Impact mission.

Professional Appointments

- Oct. 2019 - present, Southwest Research Institute, Lead Research Scientist
- Oct. 2019 - Sept. 2023, Southwest Research Institute, Senior Research Scientist
- Jan. 2015 - Sept. 2019, Southwest Research Institute, Research Scientist
- Jan. 2013 - Dec. 2014, Southwest Research Institute, Postdoctoral Scholar
- Aug. 2012 - Dec. 2012, California Institute of Technology, Postdoctoral Scholar
- Feb. 2012 - July 2012, Colorado School of Mines, Postdoctoral Scholar
- Apr. 2000 - July 2004, NASA Jet Propulsion Laboratory, System Engineer
- Sept. 1997 - Sept. 1998, Lockheed Martin Missiles & Space, Technical Staff

Education

Ph.D., Planetary Science, **California Institute of Technology**, 2012.
Dissertation: *Dynamical Paleoclimatology of Mars*. (Defended Nov. 2011).

M.S., Aeronautics & Astronautics, **Stanford University**, 2000.

B.A., Physics & Astronomy, with Honors, **Dartmouth College**, 1997.
Senior Thesis: *A Kinematic Study of the Galactic Supernova Remnant 3C58*.

Vatican Observatory Summer School, Castel Gandolfo, Italy, 1997.
"Observations and Theoretical Understanding of Comets, Asteroids, and Meteorites".

Featured Papers

My scientific career started with studying the paleoclimate dynamics of Mars. In particular, I explored how the Martian atmosphere's tendency to "collapse" at lower obliquities generates pathways of meridional transport of energy that are more important on Mars, and possibly Pluto, than on Earth.

- **Soto, A.**, M.A. Mischna, T. Schneider, C. Lee, M.I. Richardson (2015), "Martian atmospheric collapse: Idealized GCM studies", *Icarus*, Volume 250, Pages 553-569, doi:10.1016/j.icarus.2014.11.028.

With collaborators E.G. Rivera-Valentin and V.F. Chevrier, I have been investigating the potential habitability of current Mars, with a focus on brine environments at a very localized scale. Our first two papers, for which I did all of the atmospheric modeling, looked at the global-scale habitability of surface brines. We are following up this research with investigations into the possible habitable conditions for brines at the smaller-scale (mesoscale), e.g., within craters like Jezero and Gale.

- Chevrier, V. F., Rivera-Valentín, E. G., **Soto, A.**, and Altheide, T. S. (2020). Global Temporal and Geographic Stability of Brines on Present-day Mars. *The Planetary Science Journal*, 1(3):64, doi:10.3847/PSJ/abbc14.

- Rivera-Valentín, E. G., V. F. Chevrier, **A. Soto**, and G. Martínez (2020). Distribution and habitability of (meta)stable brines on present-day Mars. *Nature Astronomy*, 4:756–761, doi:10.1038/s41550-020-1080-9.

I am also investigating the mesoscale atmospheric dynamics of Titan. My collaborator S.C.R. Rafkin and I have modeled the air-sea interactions over the lakes of Titan. I am continuing this work, as part of a Cassini Data Analysis project for which I am the Principal Investigator and in collaboration with J. Soderblom, J. Steckloff, and P. Corlies, where we are integrated the unique thermodynamics of the Titan lakes into our mesoscale modeling.

- Steckloff, J. K., Soderblom, J. M., Farnsworth, K. K., Chevrier, V. F., Hanley, J., **Soto, A.**, Groven, J. J., Grundy, W. M., Pearce, L. A., Tegler, S. C., and et al. (2020). Stratification Dynamics of Titan's Lakes via Methane Evaporation. *The Planetary Science Journal*, 1(2):26, doi:10.3847/PSJ/ab974e.
- Rafkin, S. C. and **Soto, A.** (2020). Air-sea interactions on Titan: Lake evaporation, atmospheric circulation, and cloud formation. *Icarus*, 351:113903, doi:10.1016/j.icarus.2020.113903.

Beyond the atmospheric and climate modeling, I am also involved in the development of novel instruments for future spaceflight missions. For example, I led the development of a semiconductor-based neutron spectrometer that will provide new capabilities for surface observations of thermal and epithermal neutrons on airless bodies, such as the moon and asteroids.

- **Soto, A.** R. G. Fronk, K. Neal, B. Ehresmann, S. L. Bellinger, M. Shoffner, D. S. McGregor (2020). “A semiconductor-based neutron detection system for planetary exploration”, *Nuclear Instrument and Methods in Physics Research, A*, in press, doi:10.1016/j.nima.2020.163852.

Project Experience

- Co-Investigator on Project ESPRESSO, a SSERVI virtual institute. 2017 – present
- Payload Sys. Engineer, Phase A/B/C, Mars Reconnaissance Orbiter (MRO). 2001 – 2004.
- Instrument Sys. Engineer on the Terrestrial Planet Finder (TPF) program. 2003 – 2004.
- Science Sys. Engineer, Phase C/D, Deep Impact Mission. Launch: 2002 – 2004.
- Lead Instrument Engineer for JPL's MATMOS instrument. 2002 – 2004.
- Integration and Test Engineer, Phase C/D, Stanford's OPAL satellite. Launch: 1998 –1999.

Instrument Projects

Grain Velocimetry and Tomography Analysis System (GraVeTAS). As a member of Project ESPRESSO, a Solar System Exploration Virtual Institute (SSERVI) team, Dr. Soto is investigating the dynamical processes associated with impact ejecta formation and how impact ejecta processes affect the small body surface environment, with a focus on the consequences for robotic and human operations. Dr. Soto and his team are developing the Grain Velocimetry and Tomography Analysis System (GraVeTAS), an instrument to simultaneously measure the size, shape, 3D velocity, and optical-NIR spectrum of ejecta particles with sizes from 0.25 micron to 3 millimeter in free flight traveling at speeds up to a kilometer per second launched from laboratory impact experiments.

- **Soto, A.**, Nowicki, K., Whizin, A., Parker, A., Durda, D., Cintala, M., II, C. C., and Walsh, K. (2020). Development of Novel Instrumentation for Impact Experiments. In *NASA Exploration Science Forum*, number NESF2020-085.

Hura: An Integrated Anemometer, Nephelometer, and Tomographer to Study Planetary Atmospheres. Dr. Soto is the Principal Investigator leading the development of Hura, an *in situ* instrument designed to characterize dust and aerosols in a variety of planetary atmospheres, including Mars, Titan, and comet atmospheres. Dr. Soto is involved in developing the science and system level requirements and in analyzing the performance of various prototypes of an optical instrument for in situ measurement of atmospheric properties. Currently, a field version of the instrument has been tested in a basaltic aeolian region in Iceland.

- **Soto, A.**, Nowicki, K., Pyke, B., and Shoffner, M. (2020). Hura: An Instrument for Atmospheric and Aeolian Science. In *Sixth International Planetary Dunes Workshop*, volume 2188, page 3046.

Flight Projects

Deep Impact. Dr. Soto was a science system engineer on the Deep Impact mission during Phase C & D. During that time, he helped develop the science operations sequences for the lunar flyby observations as well as the comet encounter observations. Dr. Soto also participated in the pre-launch science planning, balancing spacecraft resources with scientific objectives and requirements.

Mars Reconnaissance Orbiter. Dr. Soto was a payload systems engineer on the Mars Reconnaissance Orbiter (MRO) during Phase A through C. He participated in designing the interfaces, both physical and operational, between the MRO spacecraft and the MCS, MARCI, and CTX instruments. As a member of the MRO engineering team, Dr. Soto was an advocate for the instruments.

Stanford's OPAL spacecraft. Dr. Soto was an integration and test engineer for Stanford's Orbiting Picosatellite Automated Launcher (OPAL) during Phase C & D. OPAL launched in January 2000.

Funding as Principal Investigator

"Martian dynamic habitability from the recent past to the present day", NASA's Habitable Worlds program, Grant No. 80NSSC24K0077, role: Principal Investigator.

"The Habitability of Exoplanets with Land and Oceans", NASA's Habitable Worlds program, Grant No. 80NSSC22K0096, 2021-10-13 to 2024-10-12, role: Principal Investigator.

"Investigating Clouds on Titan", NASA's Cassini Data Analysis Program (CDAP), Grant No. 80NSSC18K0967, 2018-05-22 to 2021-05-21, role: Principal Investigator.

Funding as Co-Investigator

"Micro/Mesoscale Growth Mechanisms of Martian Dust Storms", NASA's Solar System Workings (SSW), Grant No. 80NSSC23K0364, PI: Mark Richardson.

"Constraining the Structure, Evolution, and Dynamics of Titan's Atmospheric Boundary Layer", NASA's Solar System Workings (SSW), Grant No. 80NSSC22K1378, PI: Scot Rafkin.

"Linking Crater Basin Winds, Dune Morphology, and Stratigraphy", NASA's Mars Data Analysis Program (MDAP), Grant No. 80NSSC21K1090, PI: Ryan Ewing.

"The Role of Moist Convection in Titan's Hydrological Cycle and General Circulation", NASA's Solar System Workings (SSW) program, Grant No. 80NSSC17K0722, PI: Juan Lora.

"Project for the Exploration Science Pathfinder Research for Enhancing SS Observations (Project ESPRESSO)", a Solar System Exploration Research Virtual Institute (SSERVI) team, PI: Alex Parker.

"The biologic potential of the martian subsurface via brine production through atmosphere-regolith interactions", NASA's Habitable Worlds program, Grant No. 80NSSC17K0742, PI: Edgard Rivera-Valentin.

"Environmental Consequences of Asteroidal Bombardment on Early Mars", NASA's Habitable Worlds program, Grant No. NNX16AR87G, PI: Simone Marchi.

"The Hydrology, Climate, and Sedimentary Deposits of Meridiani Planum and Gale Crater", NASA's Solar System Workings (SSW) program, Grant No. NNX15AH34G, PI: Jeffrey Andrews-Hanna.

"Climatic control of explosive volcanism on Mars", NASA's Solar System Workings (SSW) program, Grant No. 80NSSC17K0059, PI: Jeffrey Andrews-Hanna.

Service to the Science Community

- Reviewer for articles in *Icarus*, *Journal of Atmospheric Science*, *Journal of Geophysical Research*, *Geophysical Research Letters*, *Nature Geoscience*, *Science*, *Space Science Reviews*, and the *Planetary Science Journal*.
- Served on various NASA ROSES, NASA Mission Senior Reviews, and NSF review panels in 2014, 2015, 2016, 2018, 2020, and 2022. Also provided external reviews to a variety of review panels from 2014 to the present.

- Member of the science organizing committee for the Mars Workshop on Amazonian and Present-Day Climate held in Denver, CO in June 2018.
- Co-Chair for the Comparative Climatology of Terrestrial Planets III conference held in Houston, TX in August 2018.
- Member of the Division for Planetary Science (DPS) Prize Subcommittee, 2018-2019.
- Member of MEPAG's Ice and Climate Evolution Science Analysis Group (ICE-SAG), 2018-2019.
- Member of the science organizing committee for the Division of Planetary Science meeting, virtual meeting in October 2020.
- Member of the American Astronomical Society Sustainability Committee, 2018-2020.
- Member of the Division for Planetary Science Professional Culture & Climate Subcommittee, 2018-2020.
- Member of the Science Organizing Committee for the 7th International Planetary Dunes Workshop which will be held in May 2022.
- Co-convener of the Optimizing Planetary In Situ Surface-Atmosphere Interaction Investigations workshop held in June 2022.
- Guest editor for the Planetary Science Journal Focus Issue (i.e., Special Issue) titled, "Towards in situ observations of planetary surface-atmosphere interactions".

Memberships

- Division of Planetary Science (DPS) of the American Astronautical Society (AAS).
- American Institute of Aeronautics and Astronautics (AIAA).
- American Geophysical Union (AGU).
- American Meteorological Society (AMS).

Science Communication and Outreach

- From 2015 to 2020, I volunteered as a [producer](#) for KGNU's How on Earth science radio show, producing a number of shows on a [variety of science topics](#), including [planetary science](#).
- I was interviewed in Spanish and English as part of the MU69 observation campaigns in Mendoza, Argentina and Comodoro Rivadavia, Argentina, including an interview with [ADN Sur - Agencia de Noticias de Comodoro Rivadavia y Chubut](#) and an interview with [Texas Public Radio](#).
- Wrote an article for the Planetary Society about the [MU69 campaign](#).
- I participated in science outreach panels at the 2016 and 2017 Denver Comic Con, including a panel about the science of *The Martian* and a panel about pursuing a career in planetary science and exploration.
- In March 2019, I spoke at the San Antonio Astronomy on Tap event co-sponsored by the Witte Museum in San Antonio. As part of the "Mars Attacks!" event, I spoke about "Dust Storms on Mars".
- Panel participant for the Latinx Heritage Month: Latinx STEM Faculty/Industry Professionals Panel hosted by CLaSP GUSTO (Climate and Space Sciences and Engineering Graduate and Undergraduate Student Organization) and SHPE Grad (Society of Hispanic Professional Engineers Graduate Chapter) at the University of Michigan. This was a virtual event on September 22, 2020.
- Participated in the CLaSP en Español event sponsored by the Climate and Space Sciences and Engineering department at the University of Michigan. Virtual event on March 30, 2021.
- Panelist for a UNAVCO Career Circle event for UNAVCO interns. Virtual event on July 10, 2020.

Refereed Papers

Marvin, M. C., Lapotre, M. G., Gunn, A., Day, M., and **Soto, A.** (2023). Dune interactions record changes in boundary conditions. *Geology*, 51(10):947–951.

Rubanenko, L., Gunn, A., Perez-Lopez, S., Fenton, L. K., Ewing, R. C., **Soto, A.**, and Lapotre, M. G. A. (2023). Global Surface Winds and Aeolian Sediment Pathways on Mars From the Morphology of Barchan Dunes. *Geophysical Research Letters*, 50(18):e2022GL102610, e2022GL102610.

Farnsworth, K. K., **Soto, A.**, Chevrier, V. F., Steckloff, J. K., and Soderblom, J. M. (2023). Floating Liquid Droplets on the Surface of Cryogenic Liquids: Implications for Titan Rain. *ACS Earth and Space Chemistry*, 7(2):439–448.

- Chatain, Audrey, Scot C. R. Rafkin, **Alejandro Soto**, Ricardo Hueso and Aymeric Spiga (2022). Air–Sea Interactions on Titan: Effect of Radiative Transfer on the Lake Evaporation and Atmospheric Circulation. *The Planetary Science Journal*, 3, 232, doi: 10.3847/PSJ/ac8d0b.
- Battalio, J. M., Lora, J. M., Rafkin, S., and **Soto, A.** (2022). The interaction of deep convection with the general circulation in Titan’s atmosphere. Part 2: Impacts on the climate. *Icarus*, 373:114623, 114623.
- Rafkin, S. C., Lora, J. M., **Soto, A.**, and Battalio, J. M. (2022). The interaction of deep convection with the general circulation in Titan’s atmosphere. Part 1: Cloud resolving simulations. *Icarus*, 373:114755.
- Wu, Z., Richardson, M. I., Zhang, X., Cui, J., Heavens, N. G., Lee, C., Li, T., Lian, Y., Newman, C. E., **Soto, A.**, Temel, O., Toigo, A. D., and Witek, M. (2021). Large Eddy Simulations of the Dusty Martian Convective Boundary Layer With MarsWRF. *Journal of Geophysical Research (Planets)*, 126(9):e06752, e06752.
- Chevrier, V. F., Rivera-Valentín, E. G., **Soto, A.**, and Altheide, T. S. (2020). Global Temporal and Geographic Stability of Brines on Present-day Mars. *The Planetary Science Journal*, 1(3):64, doi:10.3847/PSJ/abbc14.
- Rafkin, S. C. and **Soto, A.** (2020). Air-sea interactions on Titan: Lake evaporation, atmospheric circulation, and cloud formation. *Icarus*, 351:113903, doi:10.1016/j.icarus.2020.113903.
- Rivera-Valentín, E. G., V. F. Chevrier, **A. Soto**, and G. Martínez (2020). Distribution and habitability of (meta)stable brines on present-day Mars. *Nature Astronomy*, 4:756–761, doi:10.1038/s41550-020-1080-9.
- Soto, A.** R. G. Fronk, K. Neal, B. Ehresmann, S. L. Bellinger, M. Shoffner, D. S. McGregor (2020). “A semiconductor-based neutron detection system for planetary exploration”, *Nuclear Instrument and Methods in Physics Research, A*, in press, doi:10.1016/j.nima.2020.163852.
- Steckloff, J. K., Soderblom, J. M., Farnsworth, K. K., Chevrier, V. F., Hanley, J., **Soto, A.**, Groven, J. J., Grundy, W. M., Pearce, L. A., Tegler, S. C., and et al. (2020). Stratification Dynamics of Titan’s Lakes via Methane Evaporation. *The Planetary Science Journal*, 1(2):26, doi:10.3847/PSJ/ab974e.
- Farnsworth, K. K., Chevrier, V. F., Steckloff, J. K., Laxton, D., Singh, S., **Soto, A.**, and Soderblom, J. M. (2019). Nitrogen Exsolution and Bubble Formation in Titan’s Lakes. *Geophysical Research Letters*, doi:10.1029/2019gl084792.
- McDonald, G. D., A. G. Hayes, R. C. Ewing, J. M. Lora, C. E. Newman, T. Tokano, A. Lucas, **A. Soto**, G. Chen, “Variations in Titan’s dune orientations as a result of orbital forcing”, *Icarus*, Volume 270, Pages 197-210, doi:10.1016/j.icarus.2015.11.036.
- Soto, A.**, M.A. Mischna, T. Schneider, C. Lee, M.I. Richardson (2015), “Martian atmospheric collapse: Idealized GCM studies”, *Icarus*, Volume 250, Pages 553-569, doi:10.1016/j.icarus.2014.11.028.
- Guo, X., M. I. Richardson, **A. Soto**, and A. Toigo (2010), “On the mystery of the perennial carbon dioxide cap at the south pole of Mars”, *Journal of Geophysical Research*, 115, E04005, doi:10.1029/2009JE003382.
- Fesen, R., G. Rudie, A. Hurford, and **A. Soto** (2008), “Optical Imaging and Spectroscopy of the Galactic Supernova Remnant 3C 58 (G130.7+3.1).” *The Astrophysical Journal Supplement Series*, 174:2, pages 379-395, doi:10.1086/522781.
- Anderson, M.S., J.M. Andringa, R.W. Carlson, P. Conrad, W. Hartford, M. Shafer, **A. Soto**, A.I. Tsapin, J.P. Dybwad, W.Wadsworth, and K. Hand (2005), “Fourier Transform Infrared Spectroscopy for Mars Science.” *Review of Scientific Instruments*, volume 76, doi:10.1063/1.1867012.

Selected Conference Talks

- Soto, A.**, Rivera-Valentn, E. G., and Chevrier, V. (2021). Stability of Surficial Brines on Mars During Recent Orbital Cycles. In *LPI Contributions, volume 2614 of LPI Contributions*, page 6015.
- Soto, A.**, Nowicki, K., Whizin, A., Parker, A., Durda, D., Cintala, M., II, C. C., and Walsh, K. (2020). “Development of Novel Instrumentation for Impact Experiments.” In *NASA Exploration Science Forum*, number NESF2020-085.

- Soto, A.**, Nowicki, K., Pyke, B., and Shoffner, M. (2020). Hura: An Instrument for Atmospheric and Aeolian Science. In *Sixth International Planetary Dunes Workshop*, volume 2188 of LPI Contributions, page 3046.
- Soto, A.** and Rafkin, S. C. R. (2018). Atmospheric Circulations of Lakes and Seas on Earth and Titan. In *Comparative Climatology of Terrestrial Planets III: From Stars to Surfaces*, volume 2065 of LPI Contributions, page 2028.
- Soto, A.** (2017). How Ocean-Land Fraction and Distribution Affects Habitable Conditions on Earth-Like Planets. In *Habitable Worlds 2017: A System Science Workshop*, volume 2042 of LPI Contributions, page 4027.
- Soto, A.**, Nowicki, K., Howett, C., Feldkhun, D., and Retherford, K. D. (2017). Remote microscopy and volumetric imaging on the surface of icy satellites. In *AAS/Division for Planetary Sciences Meeting Abstracts #49*, volume 49 of AAS/Division for Planetary Sciences Meeting Abstracts, page 224.02.
- Soto, A.** and Rafkin, S. (2015). Mesoscale Circulations over Titan's Lakes. In EGU General Assembly Conference Abstracts, *EGU General Assembly Conference Abstracts*, page 6146.
- Soto, A.**, Mischna, M. A., and Richardson, M. I. (2014). Martian Atmospheric Collapse: Meridional Transport and Polar Heat Balance. In Forget, F. and Millour, M., editors, *Mars Atmosphere: Modelling and Observation, 5th International Workshop*, page 4301.
- Soto, A.**, Mischna, M. A., and Richardson, M. I. (2012). Climate Dynamics of Atmospheric Collapse on Ancient Mars. In *43rd Annual Lunar and Planetary Science Conference, Lunar and Planetary Science Conference*, page 2783.
- Soto, A.**, Mischna, M. A., and Richardson, M. I. (2012). Meridional Transport of Energy during Atmospheric Collapse on Ancient Mars. In *AGU Fall Meeting Abstracts*, volume 2012, pages P23A–1921.
- Soto, A.**, Richardson, M. I., and Newman, C. E. (2010). Global Constraints on Rainfall on Ancient Mars: Oceans, Lakes, and Valley Networks. In *41st Annual Lunar and Planetary Science Conference, Lunar and Planetary Science Conference*, page 2397.
- Soto, A.**, Guo, X., and Richardson, M. I. (2009). On the Mystery of the Perennial Carbon Dioxide Cap at the South Pole of Mars. In *Third International Workshop on Mars Polar Energy Balance and the CO₂ Cycle*, volume 1494 of LPI Contributions, pages 51–52.
- Soto, A.**, Mischna, M. A., and Richardson, M. I. (2007). Atmospheric Dynamics of Early Mars. In *Seventh International Conference on Mars*, volume 1353 of LPI Contributions, page 3327.