AN EQUATION OF STATE FOR AQUEOUS SODIUM SULFATE USING LOCAL BASIS FUNCTIONS, WITH APPLICATIONS TO OCEAN WORLDS. R. James[1], S. D. Vance[2], and J. M. Brown[3], [1]Occidental College (jamesr@oxy.edu), [2]Jet Propulsion Laboratory, California Institute of Technology (svance@jpl.nasa.gov), [3]Department of Earth and Space Sciences, University of Washington, Seattle (brown@ess.washington.edu).

Introduction: The thermodynamics fluids in ocean worlds determine how much ice is present and how the oceans transport materials and heat [1,2,3]. Sodium sulfate is identified as a possible ocean constituent on the basis of chemical models and observations [4]. Detailed models of the influence of salinity in ocean worlds rely on available thermodynamic data. To date, models of high-pressure chemistry in ocean worlds have considered only $MgSO_4$ [5,6]. Here, we develop a new equation of state for Na_2SO_4 incorporating available measurements of sound speed, density, and specific heat capacity.

Creating the Equation of State:

Basis Splines. We use basis splines, or b-splines, to construct a regularized fit to available sound speed measurements. Conventional equations of state use weighted polynomials to create semi-localized fits, which fail to decouple the influence of one region in P, T, and m from the behavior in other regions. B-splines solve this problem, allowing new data to be added trivially without needing to refit the original data.

Creating the Spline. Using the b-spline approach, sound speed data from Wiryana [7] and Mantegazzi [8] were fit to surfaces in P, T, and m. The global fit in P and T revealed systematic error in pressure measurements by [8] , which was corrected with a constant offset in pressure along each isotherm.

Equation of State. Using the sound speed surfaces created from the data, surfaces for density, heat capacity, and Gibbs energy were created using a recursive equation of state algorithm. These surfaces were then used the Matlab implementation [9], spgft, to fit the surfaces to intermediate concentrations, and to create the comprehensive equation of state for the Na_2SO_4 (aq).

Equation of State Accuracy and Applications: Output densities as partial molal volumes match well with the available densities and partial molal volumes for Na_2SO_4. The equation of state encompasses a pressure range beyond the 1.6 GPa relevant to Ganymede, temperatures from the freezing point to 600 K and concentrations up to 1.5 mol kg^{-1}. Work in progress is formulating equations of state for crystalline salts and for water ices to more accurately and comprehensively compute phase equilibria and haline mixing in ocean worlds.

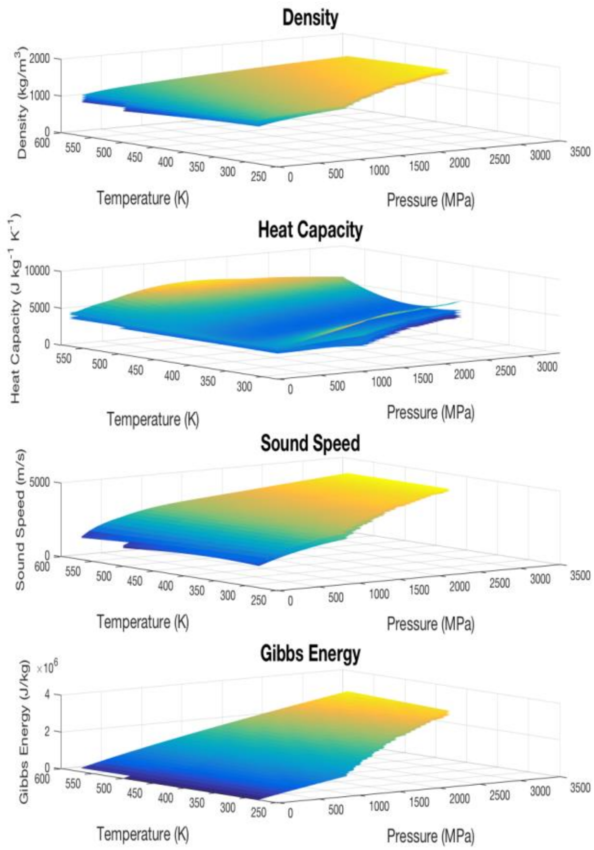

Figure 1: Density, heat capacity, sound speed, and Gibbs energy for aqueous Na_2SO_4.

References: [1] Vance, S. and Brown, J.M. (2005). *Icarus*, **177**(2):506–514. [2] Travis, B., Palguta, J., and Schubert, G. (2012). *Icarus*, **218**:1006–1019. [3] Travis, B. and Schubert, G. (2015). *Icarus*, **250**:32–42. [3] Vance, S., Bouffard, M., Choukroun, M., and Sotin, C. (2014). *Planetary And Space Science*, **96**:62–70. [4] Zolotov and Kargel (2009), Europa, pp 431-458. [5] Vance, S.D. and Brown, J.M. (2013). *Geochimi. Cosmochim. Acta*, **110**:176–189 [6] Vance, S., Bouffard, M., Choukroun, M., and Sotin, C. (2014). *Plan. Space Sci.*, **96**:62–70. [7] Wiryana (1998) *University of Washington*. [8] Mantegazzi (2012) *The Journal of Chemical Physics*, **137**:224501. [8] J.M. Brown (2016) *Submitted Journal of Fluid Phase Thermodynamics.*