Bay Area Environmental Research Institute
560 3rd Street West
Sonoma, CA 95476

FINAL REPORT

Time Period: October 15, 2001 through October 14, 2004

Project: Cooperative Agreement NCC2-1292 entitled "Particle Concentration and Aggregation by Turbulence and TES Spectra Classification, Visualization and Analysis"

Principal Investigator: Robert Hogan

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Table of Contents

1. Introduction

This report is the final report for the Cooperative Agreement NCC2-1292. It is a compilation of publications produced under this Cooperative Agreement and conference presentations. The tasks outlined in the various proposals are listed below with a brief comment as to the research performed.

2. NCC2-1292 Tasks and Accomplishments

A. Cascade Model

A highly parallelized computer code for following particle/gas turbulent cascades down to levels corresponding to a Reynolds number comparable to protoplanetary disk values was developed and tested. The code uses OpenMP calls to direct the calculation into many independent threads that run through the cascading pyramid. It currently runs on the SGI Origins 3000. The code includes physics that represents the mutual interaction between gas and particles that affects energy distribution. It predicts statistical distributions, averaged over the spatial domain of the computational box, for particle concentration, gas vorticity and dissipation. It also predicts the mutual correlations of these quantities between the gas and particle phases.

An essential input to the cascade code is an empirically derived function that controls the local partitioning of particle/gas energy as the cascade proceeds. This function was found with a DNS (Direct Numerical Simulation) code that solves the complete gas and particle equations at all turbulent scales. The code was originally written by Alan Wray and was modified to include additional processing of the particle/gas fields. This processing includes the determination of local 'multiplier' variables at the smallest turbulent scales the code can simulate. The function alluded to above represents a relationship between the local mass loading (the ratio of particle mass to gas mass) and the width of the statistical distribution of the multiplier variable. It was discovered that this function is universal over the range of turbulent scales simulated. The function indicates that the partitioning of gas energy becomes more uniform (less spotty) as the local mass loading increases.

A paper describing the cascade model and the results of the DNS calculations is in progress. This paper will demonstrate that the cascade model correctly predicts the distribution of particle concentration, gas vorticity and dissipation observed in DNS experiments at high Taylor scale Reynolds numbers (~200).

Publications

Cuzzi, J.N., Hogan, R.C., Blowing in the Wind – I. Velocities of chondrule-sized particles in a turbulent protoplanetary nebula. Icarus 164, 127-138 (2003)

B. Gravity modifications to the Lagrangian turbulence code

A DNS particle/gas turbulence code that evolves the particles in a Lagrangian fashion was modified to include forces from the mutual gravitational interactions of the particles and a constant uniform downward acceleration. A series of test runs that follows the development of a falling clump of particles was completed. IDL codes were written to view the clump from several perspectives as it fell through the computational box. The effects of mutual gravity, particle loading on the gas and downward acceleration were carefully analyzed. This effort will aid in the development of scaling relationships which are needed to relate the clump simulations to actual clumps moving through the protoplanetary nebula.

A paper describing the clump simulations and scaling relationships is in progress.

C. Cassini Data Visualization and Analysis

A suite of Graphical User Interfaces (GUI) designed to facilitate the visualization and analysis of data from the ISS, VIMS, HSP and UVIS instruments onboard the Cassini spacecraft was developed. The GUIs are written in IDL and interface with C libraries that extract and manipulate spacecraft trajectory and viewing geometry data. The ISS GUI has been used by several members of the Cassini community. It was extensively used by Dr. Cuzzi to assess the collision probability of Cassini with particles within the G ring prior to the spacecraft's first ring plane crossing.

The HSP and UVIS GUIs are designed to seek out ultra-violet events that exceed the ambient background levels and view data from both instruments acquired at or near the event times. IDL procedures to characterize the statistical distribution of the background and flag significant outlier events were written and tested using simulated and actual data.

The ISS and VIMS GUIs have the ability to compute flux within regions of the image plane defined along the radial and azimuthal directions of the ring plane. An efficient IDL code to compute the flux through an arbitrary polygon drawn over the image plane was developed. A similar code to efficiently create an image from the VIMS data array and 'vimsel' footprint polygons was also written.

The development of this suite of IDL codes is an ongoing effort.

D. SOM Classification of Mineral Spectra

A classification scheme based on self-organizing maps (SOM) was developed, tested and applied to the spectra of minerals. An IDL GUI was written to facilitate the SOM processing of the spectra and visualize the resulting SOM output layer and classes. The classification scheme is automated and unsupervised and does not require specifying the number of classes. It is designed to classify data without regard to external information which, in general, may not be available. IDL codes were written to evaluate and summarize the meaning and accuracy of the SOM classifications of several spectral libraries. Data from the Thermal Emission Spectrometer onboard the Mars Global Surveyor spacecraft was also classified.

Distinct classes were located in different regions of the Martian surface with unique spectral signatures indicating the presence of Hematite and Olivine.

A paper describing the SOM classification scheme and its application to the ASU (Arizona State University) and JHU (John Hopkins University) mineral spectral databases is nearly ready to be submitted for publication.

3. Appendix

A. Copies of Papers and Presentations