Information Technology

Ionospheric Simulation System for Satellite Observations and Global Assimilative Model Experiments — ISOGAME

Modeling helps develop improved systems to study the ionosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

Modeling and imaging the Earth's ionosphere as well as understanding its structures, inhomogeneities, and disturbances is a key part of NASA's Heliophysics Directorate science roadmap. This invention provides a design tool for scientific missions focused on the ionosphere. It is a scientifically important and technologically challenging task to assess the impact of a new observation system quantitatively on our capability of imaging and modeling the ionosphere. This question is often raised whenever a new satellite system is proposed, a new type of data is emerging, or a new modeling technique is developed. An example is the proposed COSMIC-Follow-On mission (COSMIC stands for Constellation Observing System for Meteorology, Ionosphere, and Climate). The proposed constellation would be part of a new observation system with more low-Earth orbiters tracking more radio occultation signals broadcast by Global Navigation Satellite System (GNSS) than those offered by the current GPS and COSMIC observation system.

A simulation system was developed to fulfill this task. The system is composed of a suite of software that combines the Global Assimilative Ionospheric Model (GAIM) including first-principles and empirical ionospheric models, a multiple-dipole geomagnetic field model, data assimilation modules, observation simulator, visualization software, and orbit design, simulation, and optimization software.

The software system can assess the improvements to GAIM that assimilate data collected using a concerned observing system. The GNSS observation system, for instance, consists of the GNSS constellations that transmit L-band radio signals, low-Earth orbiting GNSS receiver constellations, and ground-based GNSS receiver networks. The satellites and ground networks can be designed with an existing, or any, distribution to meet user requirements, such as achieving global coverage with uniformly distributed observations. Under this system, an empirical ionospheric model or the GAIM physics model simulates a nominal or disturbed ionosphere for a specific experiment. The observation simulator uses the designed observing scenario (LEO constellations and ground-based receiver networks) to simulate total electron content (TEC) observations along receiver-transmitter radio links. An Observation System Simulation Experiment (OSSE) can then be conducted by assimilating the synthetic observations into GAIM to quantitatively assess the degree of improvement of modeled ionospheric specifications under the observing scenario. The model that is used for data assimilation assessment can differ substantially from the model that is used to simulate the observations. Visualization software is used to examine and analyze the assimilating model's performance.

This work was done by Xiaoqing Pi, Anthony J. Mannucci, Olga Verkhoglyadova, Philip Stephens, and Byron A. Iijima of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47626.

Airborne Tomographic Swath Ice Sounding Processing System

### This program enables 2D ice thickness measurement.

NASA's Jet Propulsion Laboratory, Pasadena, California

Glaciers and ice sheets modulate global sea level by storing water deposited as snow on the surface, and discharging water back into the ocean through melting. Their physical state can be characterized in terms of their mass balance and dynamics. To estimate the current ice mass balance, and to predict future changes in the motion of the Greenland and Antarctic ice sheets, it is necessary to know the ice sheet thickness and the physical conditions of the ice sheet surface and bed. This information is required at fine resolution and over extensive portions of the ice sheets.

The ice sheet has two major interfaces: the upper surface interface, between the air and the snow or ice; and the basal interface, between the ice and bedrock or subglacial water. In between, there are internal layers that originate from slight density changes or ancient volcanic deposits. Due to the broad antenna pattern of the sounding radar system, each image resolution cell will contain signals from the left and from the right of the antenna array, and originating from the surface and from the bed. To resolve these signals and to achieve swath sounding capability, an array of receiving antennas in the cross track direction is used. A tomographic algorithm has been developed to take raw data collected by a multiple-channel synthetic aperture sounding radar system over a polar ice sheet and convert those data into two-dimensional (2D) ice thickness measurements. Prior to this work, conventional processing techniques only provided one-dimensional ice thickness measurements along profiles.
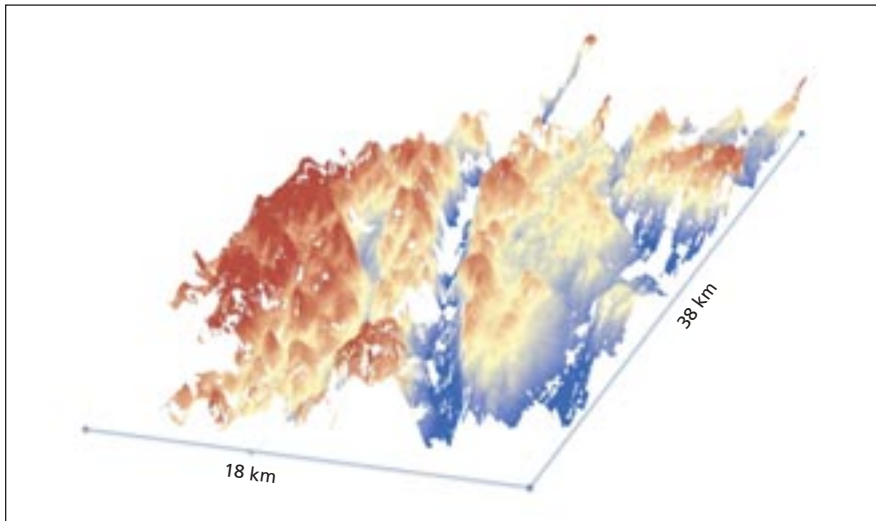
A 3D perspective of the Russell Glacier bed in Greenland produced from the 2011 Ice Bridge mission data using the **Tomographic Processor**.

to "see" through kilometers-thick ice sheets and measure the 3D bottom topography and its scattering properties, across a several-kilometers-wide swath. Validation with independent measurements indicates that this technique provides accurate topographic measurement of ice sheet surface and bed, and can be used for local ice sheet bed mapping.

The tomographic sounding processing system is composed of several major modules: a sub-aperture, back-projection azimuth compression with ray-bending correction; a MUSIC/ML arrival angle estimation to estimate surface/bed return arrival angles; and post-processing modules including data regrid and DEM (digital elevation model) mosaic. It produces the ice thickness map and the bedmap as the final product.

This work was done by Xiaoqing Wu, Ernesto Rodriguez, and Anthony Freeman of Caltech; and Ken Jezek of Ohio State University for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48638

flexplan: Mission Planning System for the Lunar Reconnaissance Orbiter

The tool can be configured for any mission without the need to modify or re-compile code.

Goddard Space Flight Center, Greenbelt, Maryland

flexplan is a mission planning and scheduling (MPS) tool that uses soft algorithms to define mission scheduling rules and constraints. This allows the operator to configure the tool for any mission without the need to modify or re-compile code. In addition, flexplan uses an ID system to track every output on the schedule to the input from which it was generated. This allows flexplan to receive feedback as the schedules are executed, and update the status of all activities in a Web-based client. flexplan outputs include various planning reports, stored command loads for the Lunar Reconnaissance Orbiter (LRO), ephemeris loads, and pass scripts for automation.

flexplan covers the end-to-end loop of MPS and allows users to adapt the system to their requirements quickly and easily. At the core of flexplan's scheduling process is a soft algorithm generation engine that requires no recompiling of the tool whenever flight rules change. This engine is largely responsible for the ease of adaptability of flexplan to the different

mission phases, requirements, and styles of planning and scheduling operations. flexplan's modular architecture allows its components to interact with each other via the database. This allows different components to be run at different times or concurrently by different operators. This architecture also allows flexplan to be easily extended with additional modules to support specific mission requirements or needs. The LRO MPS uses flexplan's core modules plus additional modules developed using existing flexplan capabilities to support LRO's flight software memory loads generation and modeling, a slew maneuver planning tool, and Web-based mission status reporting.

The flexplan components are divided into two categories: core components that are modules responsible for the generation of conflict-free schedules, and supporting components that are modules supporting additional requirements for the LRO and for the status awareness of planned activities.

flexplan offers three advantages over existing systems:
1. Use of soft algorithms to define mission scheduling rules and constraints. This allows the operators to define how planning and scheduling is accomplished, without the need for manufacturer modification to the software. All scheduling rules and constraints can be placed under configuration management, allowing the operation team to easily create and use rules for different phases of the mission.
2. Tracking ID. All inputs and outputs into and from flexplan are assigned a unique ID. This allows the operations team to identify the source of scheduled activities. It also allows flexplan to receive execution feedback for all schedule activities and update the activities status on a Web-based client for improved mission awareness.
3. Open XML format for all scheduling inputs. A single XML structure is used to ingest all scheduling inputs, regard-