SCALING THE PIPE: NASA EOS TERRA DATA SYSTEMS AT 10

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ABSTRACT

Standard products from the five sensors on NASA's Earth Observing System's (EOS) Terra satellite are being used world-wide for earth science research and applications. This paper will describe the evolution of the Terra data systems over the last decade in which the distributed system that produces, archives and distributes high quality Terra data products was scaled by two orders of magnitude.

In the late 1990s when the initial version of the distributed Terra data systems was being developed, a research data system that produced such a large number and volume of research products was unprecedented. The Terra satellite carries five instruments: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Clouds and Earth's Radiant Energy System (CERES), Multi-angle Imaging SpectroRadiometer (MISR), MODerate Resolution Imaging Spectrometer (MODIS) and Measurement Of Pollution In The Troposphere (MOPITT). Over 70 calibration and geophysical science algorithms with complex inter-dependencies had to be integrated and tested before the first on-orbit Terra data from these instruments were available. Two of the instruments involved the additional complexity of collaborating with international partners: Japan for ASTER and Canada for MOPITT. At the time of the Terra launch in December 2009, the Terra data system was the most complex component of the distributed EOS Data and Information System (EOSDIS) and involved a distributed set of production, archive and distribution facilities. Once the Terra instruments data became available in early 2000 the data systems helped the instrument science teams to continuously improve the science algorithms. Multiple reprocessing campaigns have continuously improved the algorithms giving the community stable high quality validated earth science products. Over the last decade, the data systems needed to be scaled to keep up to support these activities. For example, the data archive system went from primarily a tape-based archive to an on-line multi-petabyte disk archive that greatly eased user data access and reprocessing activities.

Several factors were key to the success of the initial Terra data systems and evolution of the systems over the last decade. The most important were strong leadership of the Terra project, EOSDIS, and instruments' science team leaders. This leadership helped coordinate the large NASA science teams and keep the data system development focused on the science goals and objectives. Second was an evolvable and scalable data system that was developed through close interaction with science teams. The data system evolved over time and grew by two orders of magnitude in terms of processing and storage to allow for the forward processing, science testing and reprocessing rates needed to meet of the science teams' and the community's expectations. Finally, active applications and outreach activities facilitated a rich and varied set of Terra products that is widely used by the global community for near real-time and regional research and applications. The feedback from this community was also invaluable in the continual improvement of the standard algorithms as well as the data system capabilities.

Part of this data system evolution occurred before the launch of Terra. In an effort to make the data system more distributed and reduce its components to more manageable "chunks", the generation of standard products was moved, in most cases, from the EOSDIS Core System (ECS) to Science Investigator-led Processing Systems (SIPSs) developed and operated by the respective instrument teams. The approach to the development of ECS was also modified to result in more frequent releases of its Science Data Processing Segment based on priorities expressed by the science community. These steps led to the successful completion of all subsystems needed to support Landsat-7 (launched in April 1999) and Terra. Given the experience in getting ready for Landsat-7 and Terra, especially the multiple end-to-end tests (dubbed Mission Operations and Science System or MOSS tests), the overall readiness of the data systems for the Aqua, ICESat and Aura missions was better and so the initial production data flows went much more smoothly.

The evolution of the data system has continued over the last few years. During 2005, a focused study was conducted by a NASA Head Quarters sponsored external Study Team in collaboration with a Technical Team consisting of members involved in the development and operation of EOSDIS. A vision of 2015 was developed and an implementation plan for the first step towards the vision was prepared. The implementation was completed during 2006-2008. From the point of view of Terra, the significant changes that occurred as a part of this step were:

- Simplification of ECS at the Atmospheric Science Data Center (NASA Langley Research Center), Land Processes DAAC (USGS EROS), and the National Snow and Ice Data Center;

- Transition of responsibility for MODIS Level 1 processing as well as archiving and distribution of level 1 products and atmospheric products from the Goddard Earth Science DAAC to the MODIS Data Processing System (MODAPS)/Level 1 and Atmosphere Archiving and Distribution System (LAADS);
- Movement of most of the data into on-line archives (with tape back-up) to provide improved access and on-line services upon request;
- Improvements in operational capabilities of the EOS Clearing House (ECHO) and the Warehouse Inventory Search Tool (WIST) as a search and order client.

As indicated above, many of the lessons learned from Terra were applied to facilitate getting ready for the follow-on EOS missions. It is also expected that NASA's upcoming Earth Science Decadal Survey missions will benefit from the Terra and EOSDIS experience.

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