NASA Technical Memorandum 2002–206892, Volume 16

SeaWiFS Postlaunch Technical Report Series

Stanford B. Hooker, Editor
NASA Goddard Space Flight Center
Greenbelt, Maryland

Elaine R. Firestone, Senior Scientific Technical Editor
Science Applications International Corporation
Beltsville, Maryland

Volume 16, Navigation Algorithms for the SeaWiFS Mission

Frederick S. Patt
Science Applications International Corporation
Beltsville, Maryland

Abstract

The navigation algorithms for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS were designed to meet the requirement of 1-pixel accuracy—a standard deviation (σ) of 2. The objective has been to extract the best possible accuracy from the spacecraft telemetry and avoid the need for costly manual renavigation or geometric rectification. The requirement is addressed by postprocessing of both the Global Positioning System (GPS) receiver and Attitude Control System (ACS) data in the spacecraft telemetry stream. The navigation algorithms described are separated into four areas: orbit processing, attitude sensor processing, attitude determination, and final navigation processing. There has been substantial modification during the mission of the attitude determination and attitude sensor processing algorithms. For the former, the basic approach was completely changed during the first year of the mission, from a single-frame deterministic method to a Kalman smoother. This was done for several reasons: a) to improve the overall accuracy of the attitude determination, particularly near the sub-solar point; b) to reduce discontinuities; c) to support the single-ACS-string spacecraft operation that was started after the first mission year, which causes gaps in attitude sensor coverage; and d) to handle data quality problems (which became evident after launch) in the direct-broadcast data. The changes to the attitude sensor processing algorithms primarily involved the development of a model for the Earth horizon height, also needed for single-string operation; the incorporation of improved sensor calibration data; and improved data quality checking and smoothing to handle the data quality issues. The attitude sensor alignments have also been revised multiple times, generally in conjunction with the other changes. The orbit and final navigation processing algorithms have remained largely unchanged during the mission, aside from refinements to data quality checking. Although further improvements are certainly possible, future evolution of the algorithms is expected to be limited to refinements of the methods presented here, and no substantial changes are anticipated.

1. INTRODUCTION

The navigation processing for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data is performed as part of the level-0 to -1a conversion. The level-0 to -1a software extracts and converts the required telemetry from the data stream and passes it to the navigation code, which produces per-scan-line spacecraft position and instrument pointing information. The output of navigation is stored in the level-1a data products for use by downstream processing.

The navigation code is composed of two, largely independent subsystems: orbit processing, which filters the data from the onboard global positioning system (GPS) receiver to produce orbit vectors; and attitude processing, which filters the spacecraft attitude control system (ACS) telemetry and instrument tilt telemetry to determine the SeaWiFS sensor orientation.

The remainder of this section defines constants, reference frames, and transformations which are used in the algorithm descriptions.

1.1 Constants

The following constants are defined here for later use:

- R_E, Earth equatorial radius (6,378.137 km);
- R_M, Earth mean radius (6,371 km);
- f, dimensionless Earth flattening factor (1/298.257);
- ω_E, Earth rotation rate ($7.29211585494\times10^{-5}\,\mathrm{s}^{-1}$);
- ω_O, nominal Orbit angular rate ($2\pi/5940$);
- G_m, Earth gravitational constant ($398600.5\,\mathrm{km}^3\,\mathrm{s}^{-2}$); and
- J_2, dimensionless Earth gravity field perturbation term (1.08263×10^{-3}).

1.2 Reference Frames

In order to describe the navigation algorithms, several basic reference frames (all frames have orthonormal axes) are defined below.

a. *Earth-Centered Inertial (ECI):* This reference frame has its origin at the Earth's center and is inertially fixed. The axes are defined as: x on the equator at the vernal equinox; z at the North Pole; y orthogonal to z and x in the right-hand sense.

b. *Earth-Centered Earth-Fixed (ECEF):* This reference frame also has its origin at the Earth's center and rotates with the Earth. The axes are defined as: x at 0° latitude and longitude (Greenwich meridian at the equator); y at 0° latitude and 90° longitude; and z at the North Pole (also known as Earth-Centered Rotating, or ECR).

c. *Orbital:* This frame has its origin at the spacecraft position and is defined as: x-axis along the geodetic nadir vector; y-axis perpendicular to x and opposite the spacecraft velocity vector; and z-axis toward the orbit normal.