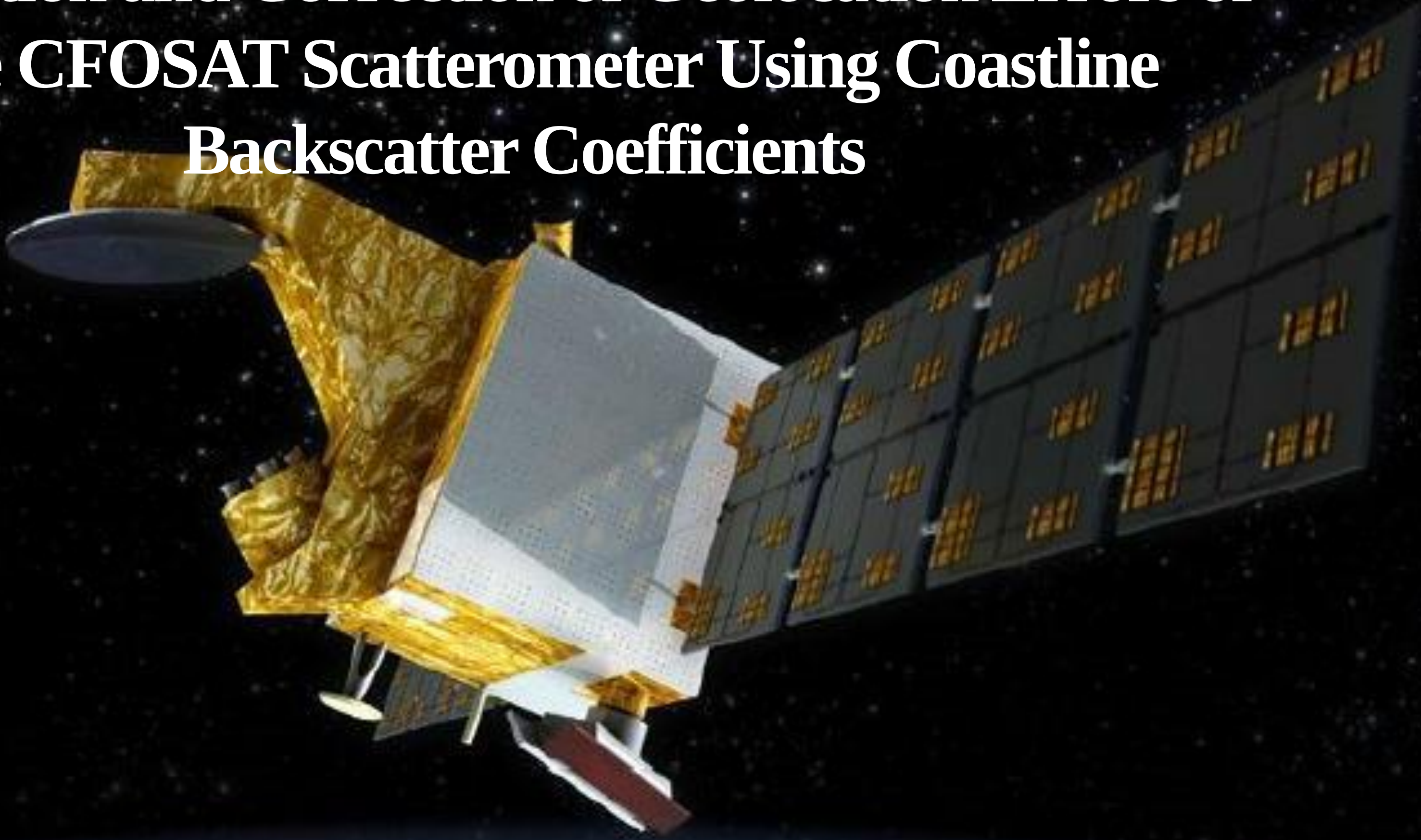
Estimation and Correction of Geolocation Errors of The CFOSAT Scatterometer Using Coastline Backscatter Coefficients



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Introduction

Technical Specifications of CSCAT

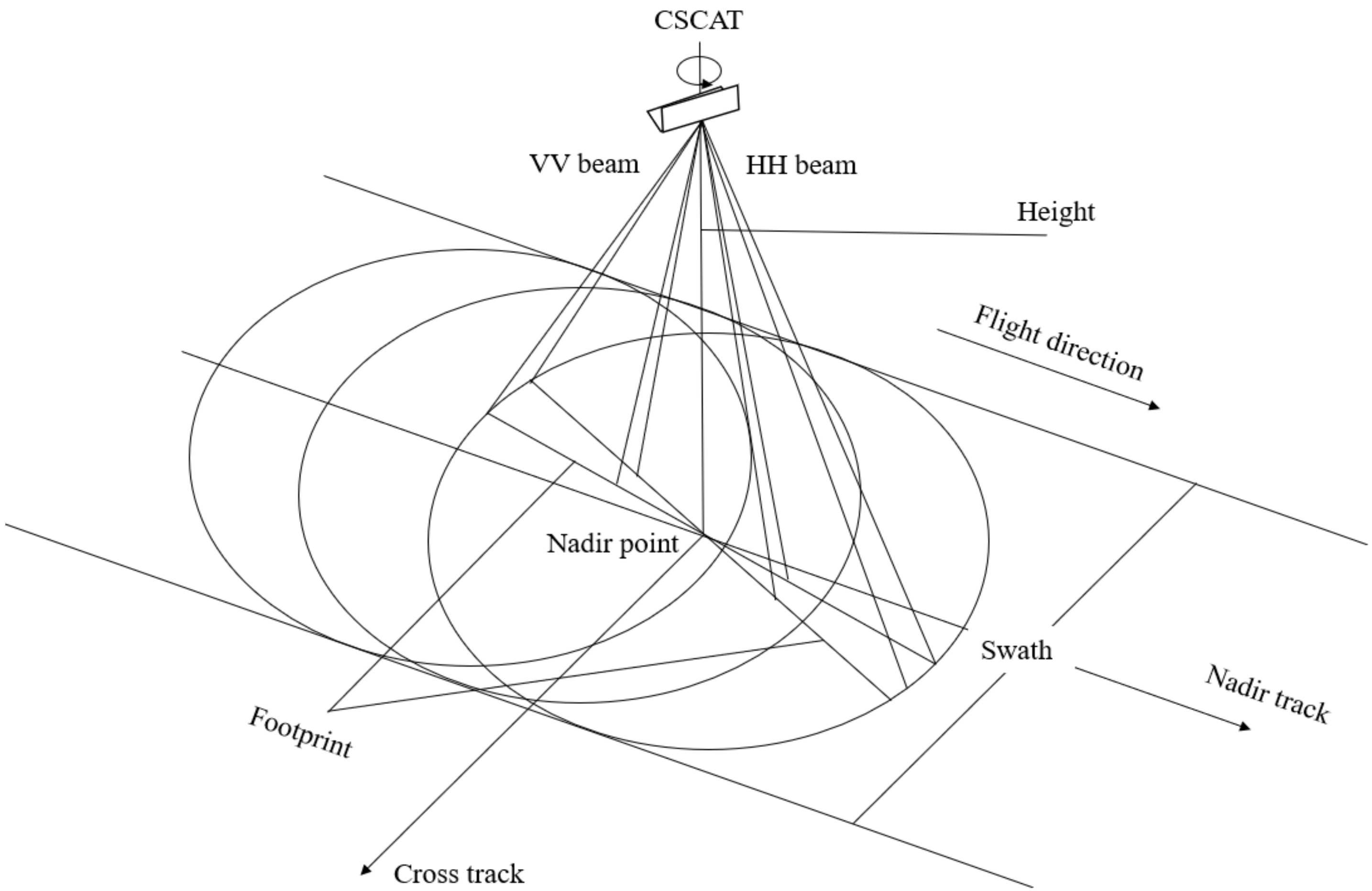
Operating parameters	
Frequency	13.256 GHz
Polarization	HH/VV
Bandwidth	0.5 MHz
Pulse duration	1.35 ms
Pulse repetition rate	150 Hz
Antenna spinning rate	3.4 rpm
Orbit parameters	
Orbit semi-major axis	6891.98 km
Eccentricity	0.00123
Orbit inclination	97.53°
Perigee angle	90°
Local time of descending intersection	7:00 AM
Orbital period	94.90 min

Introduction

The China-France Oceanography Satellite Scatterometer (CSCAT) is the first internationally-operated rotating scanning fan beam scatterometer . The CSCAT can observe in continuous azimuth and elevation. It has the characteristics of covering a large observation swath (> 1000 km) and having high resolution.

Geolocation errors provide an important reference index for the data measured by a satellite-based microwave instrument. For spaceborne measurement instruments, two methods are usually used to estimate geolocation errors, the image correlation method and the coastline inflection method.

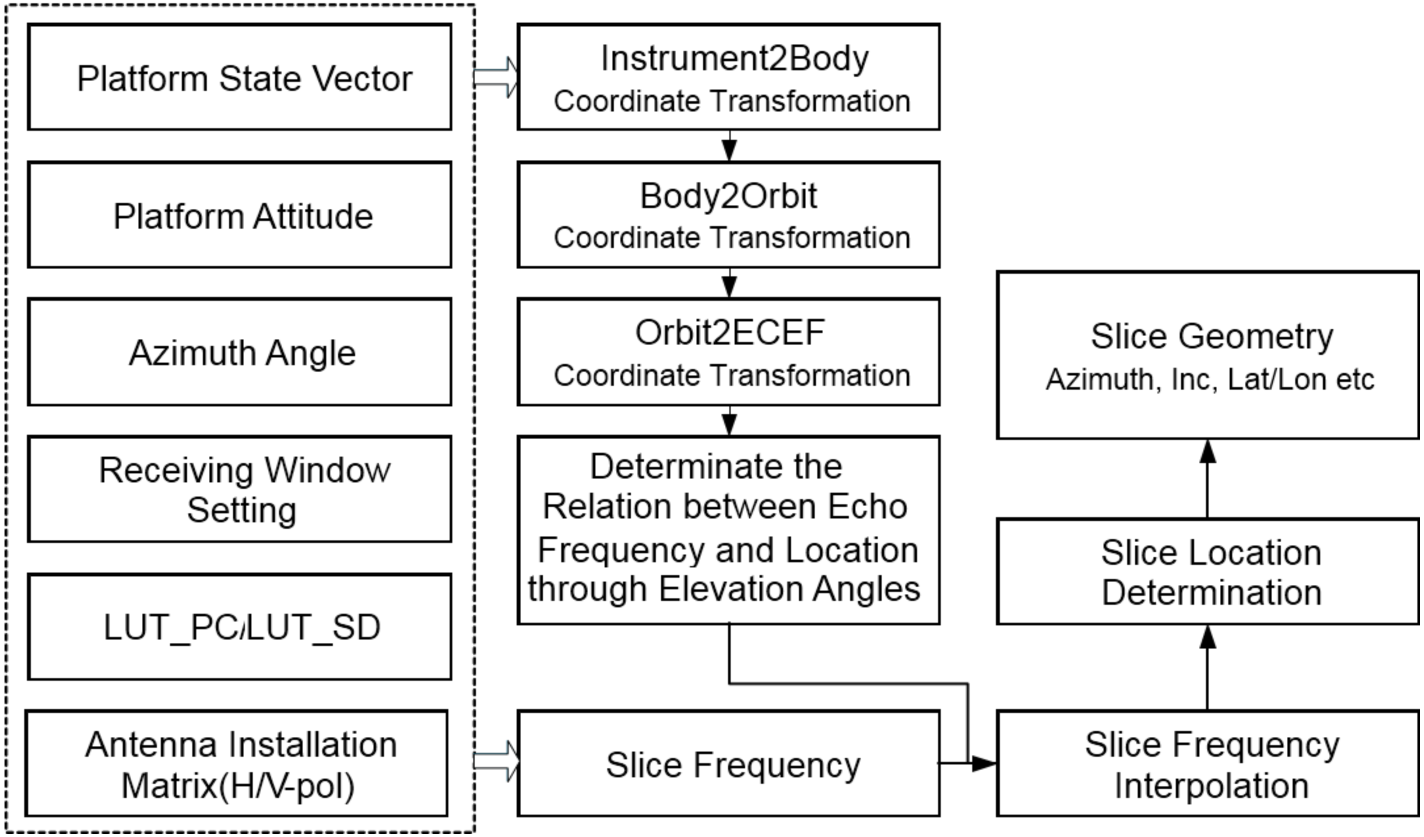
CSCAT Scan Geometry



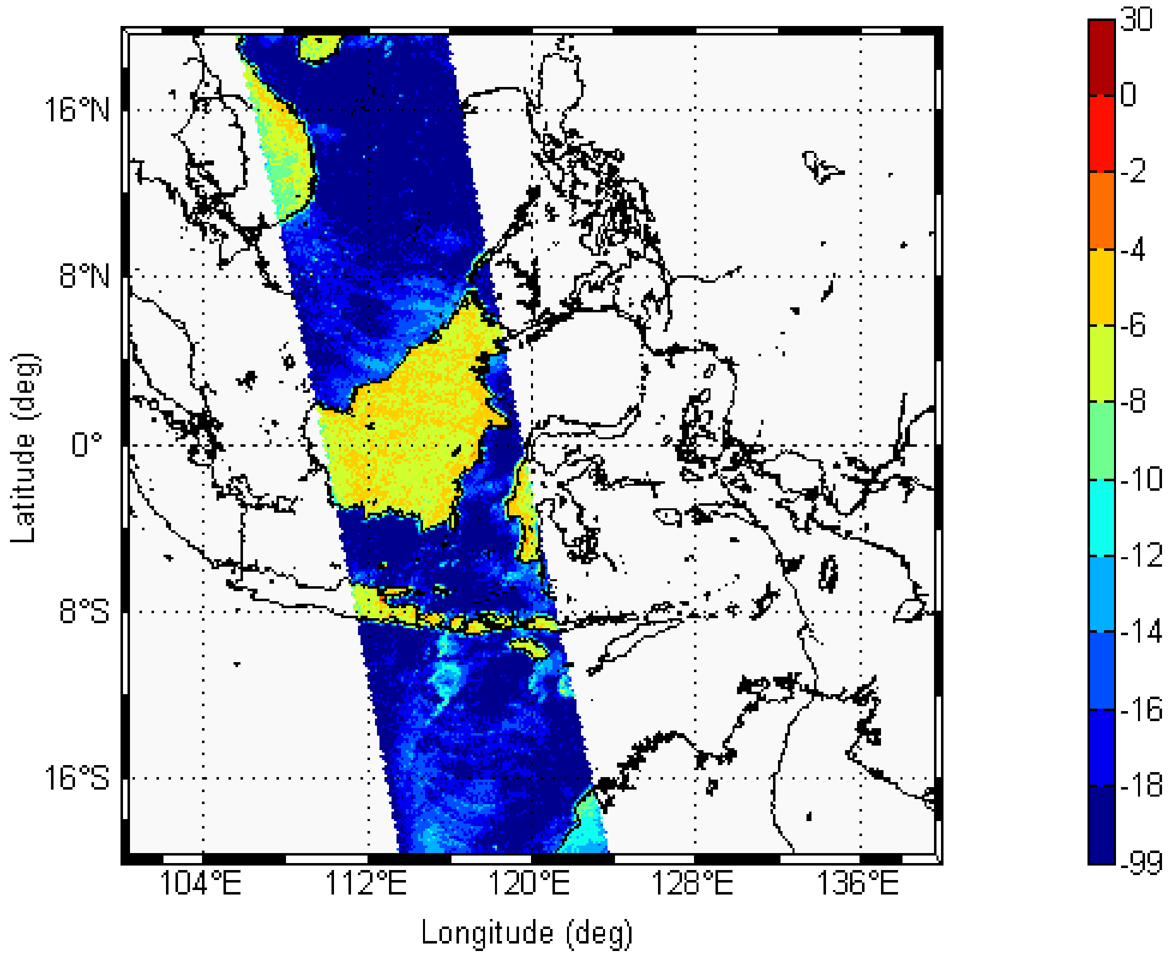
CSCAT Scan Geometry

The CSCAT orbits at an altitude of about 519 km. Its rotating scanning fan beam system features two 1.2 m × 0.4 m × 0.4 m waveguide slot array antennas. The antennas scan along the axis of the satellite nadir at a rate of 3.4 revolutions per minute with beamwidths of 14.5° and 15° corresponding to vertically polarized (V-pol) and horizontally polarized (H-pol) observations, respectively. The corresponding fan footprints on the ground are approximately 250 km. The effective elevation angle of the two beams is between 26° and 46°. With the rotation of the antenna, an observation swath determined by the incident angle of the outer edge of the beam is formed which is about 1000 km wide.

CSCAT Geolocation Algorithm



CSCAT Estimation of Geolocation Errors



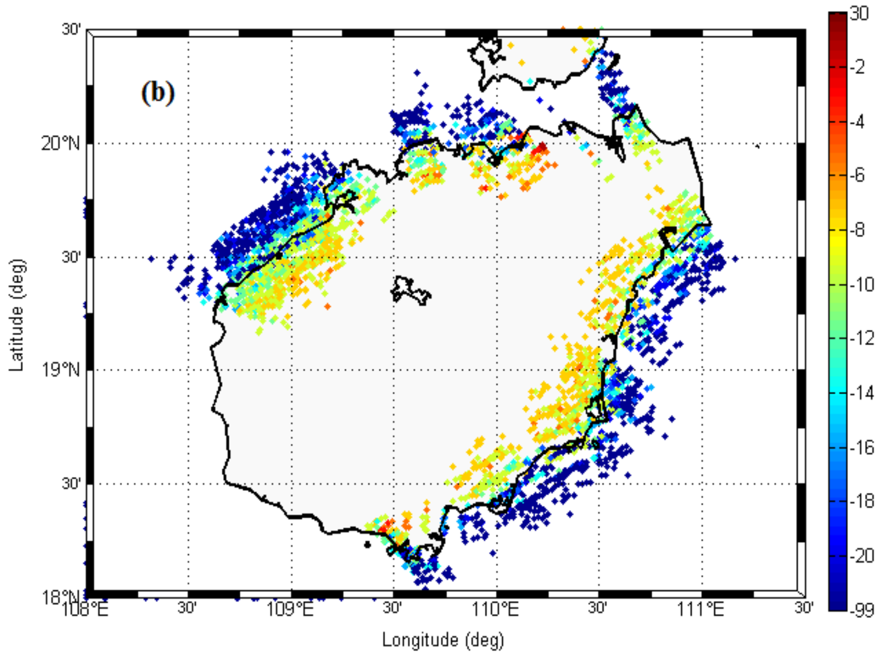
CSCAT Estimation of Geolocation Errors

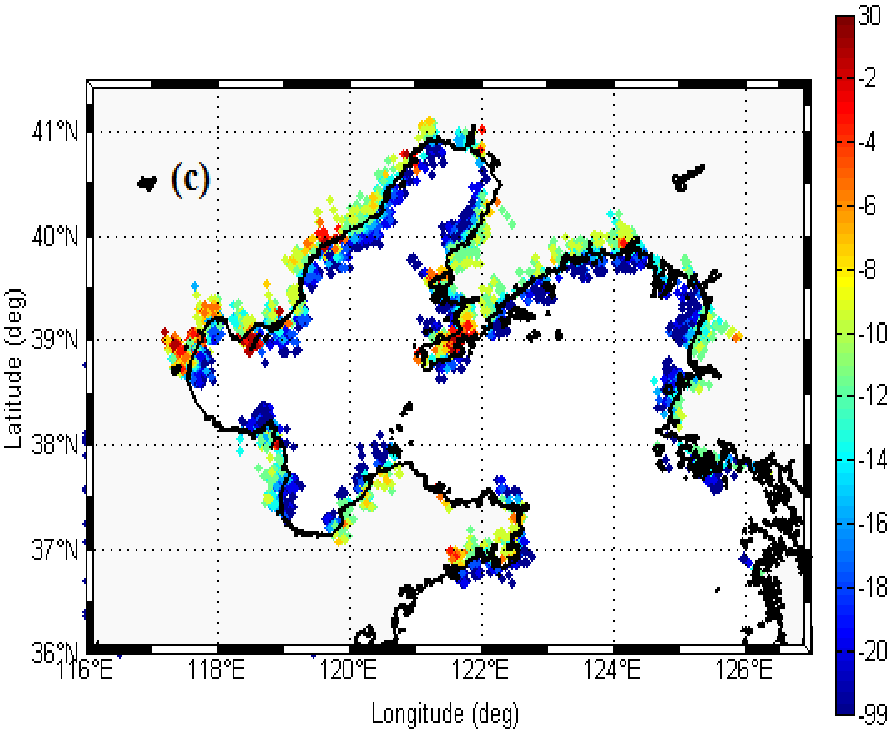
Using the coastline inflection method requires knowing the distribution characteristics of the backscatter from both the ocean and the land. Fig shows the backscatter of CSCAT L1B data passing through the ocean area near Indonesia; a significant change in gradient can be seen in the numerical values, indicating that the coastline inflection method can be used to estimate the CSCAT geolocation errors.

CSCAT Coastline Inflection Method

The method requires filtering the available data near the coastline during the estimation process. For CSCAT, when selecting data, the method finds the four slices closest to the coastline from the observation pulses as a group of measurements. However, each group of measured values must meet the relevant conditions before it can be used for geolocation error estimation. First, the backscatter coefficient value of each group must be increased or decreased appropriately; Second, the difference between the maximum and minimum backscatter coefficient of each group must meet a certain threshold. Last, the group with backscatter coefficients values are all lower than -14 dB.

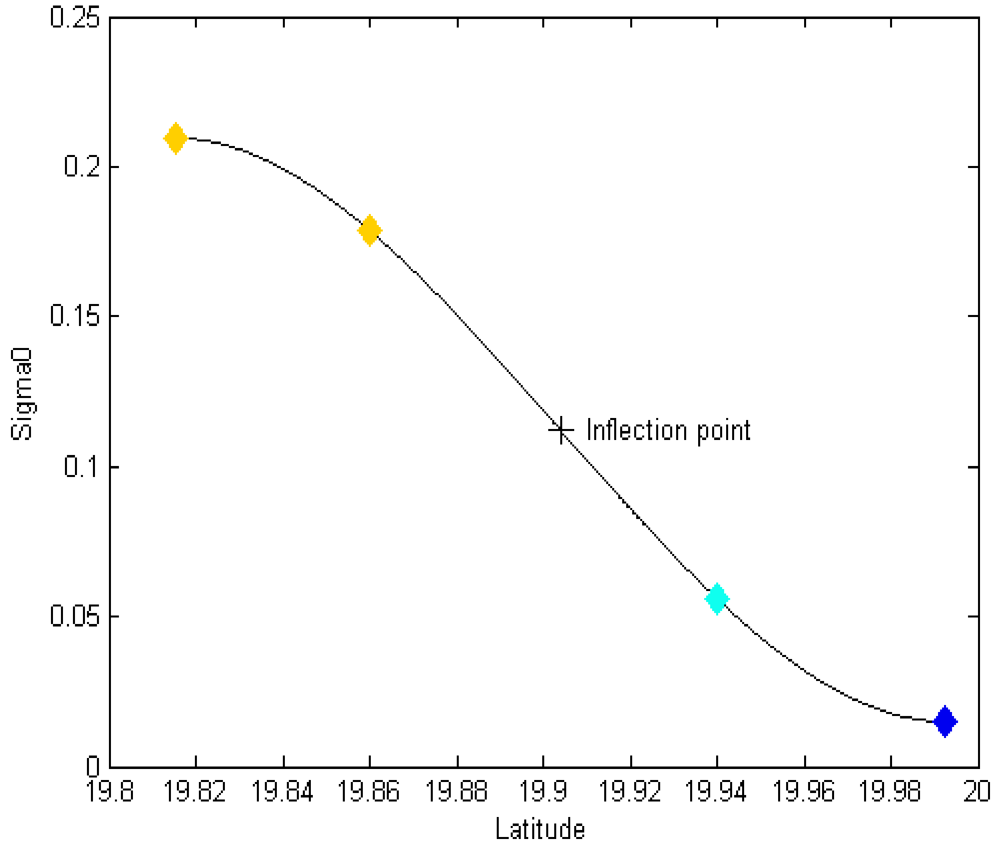
CSCAT Coastline Inflection Method





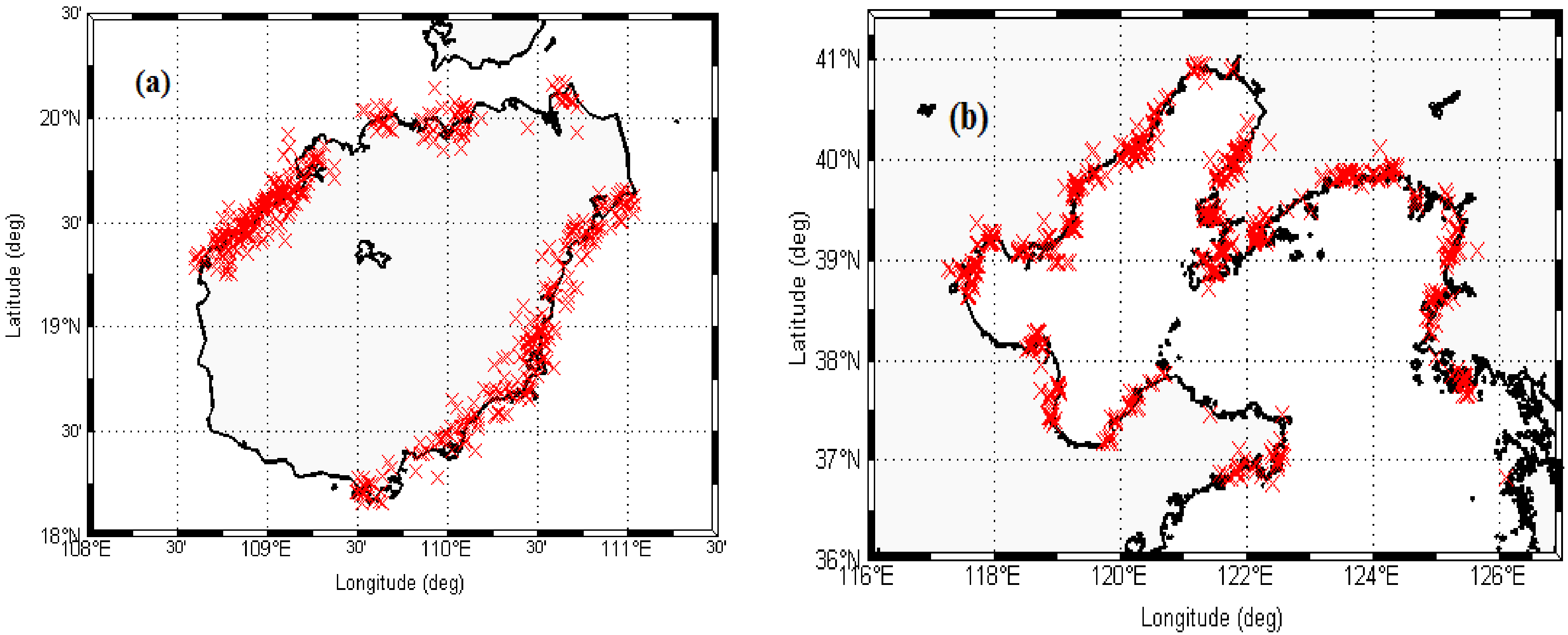
A fine-resolution database known as the Global Self-consistent, Hierarchical, High-resolution Geography Database GSHHS was used. Selection of a CSCAT group slice in Hainan Island and Liaodong Bay from February 27, 2019 to April 10, 2019.

CSCAT Coastline Inflection Method



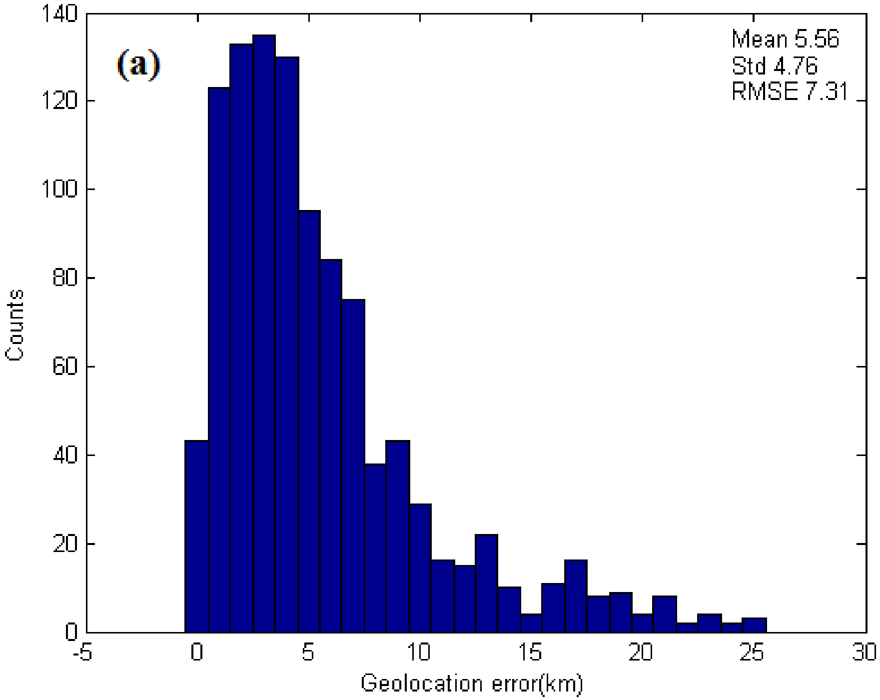
Example of determining the inflection point using four slices closest to the coastline from the observation pulse along the latitude fit by a cubic function.

CSCAT Coastline Inflection Method



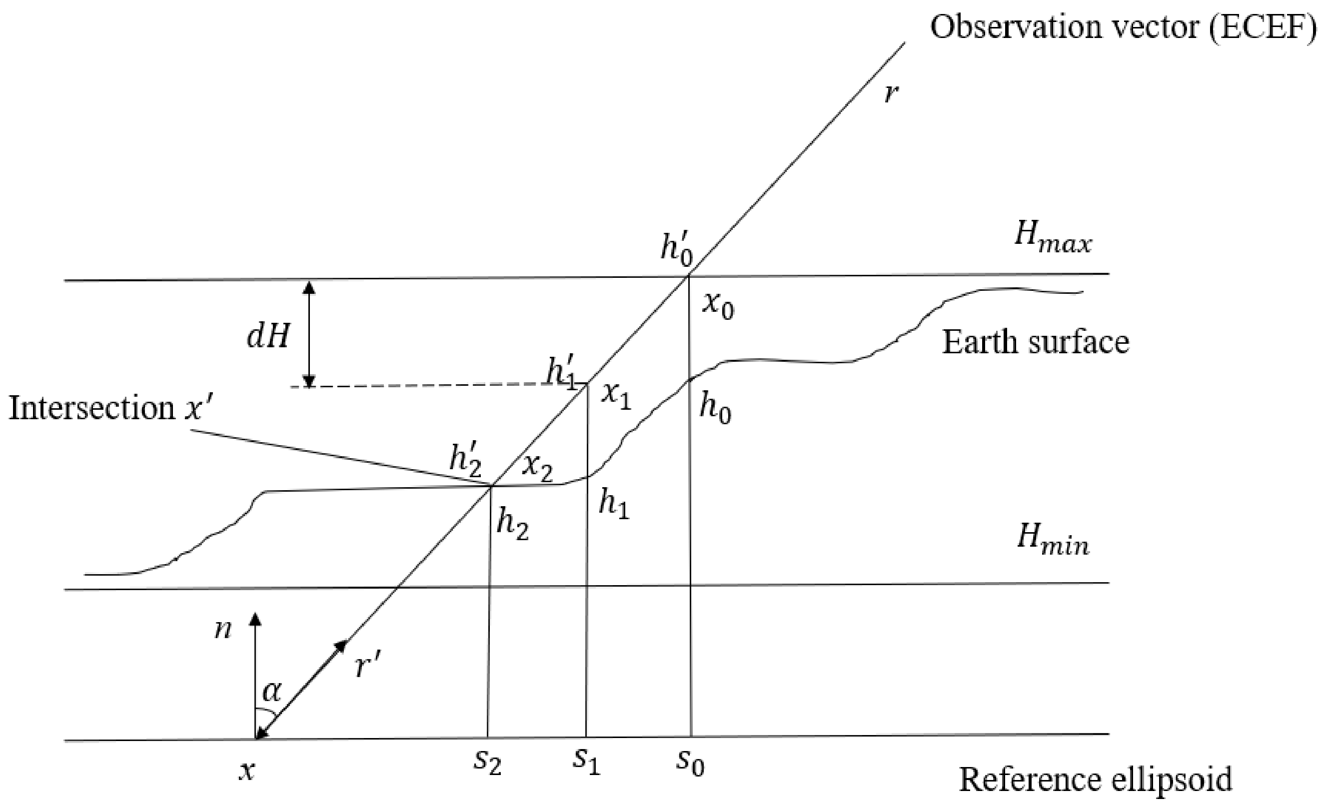
The distribution of all inflection points from February 27, 2019 to April 10, 2019. It can be seen that the trend of inflection points obtained by the coastline inflection method is basically consistent with the high-precision coastline data.

CSCAT Geolocation errors



After the intersection of the group slices line and the coastline was obtained, the distance between the intersection point and the inflection point was calculated and a statistical analysis is performed to obtain estimated geolocation errors. the currently estimated CSCAT geolocation errors is 7.31 km, which is less than half of the grid size of 25 km × 25 km wind field products (<10 km) and meets the requirements of 25 km × 25 km wind field retrieval.

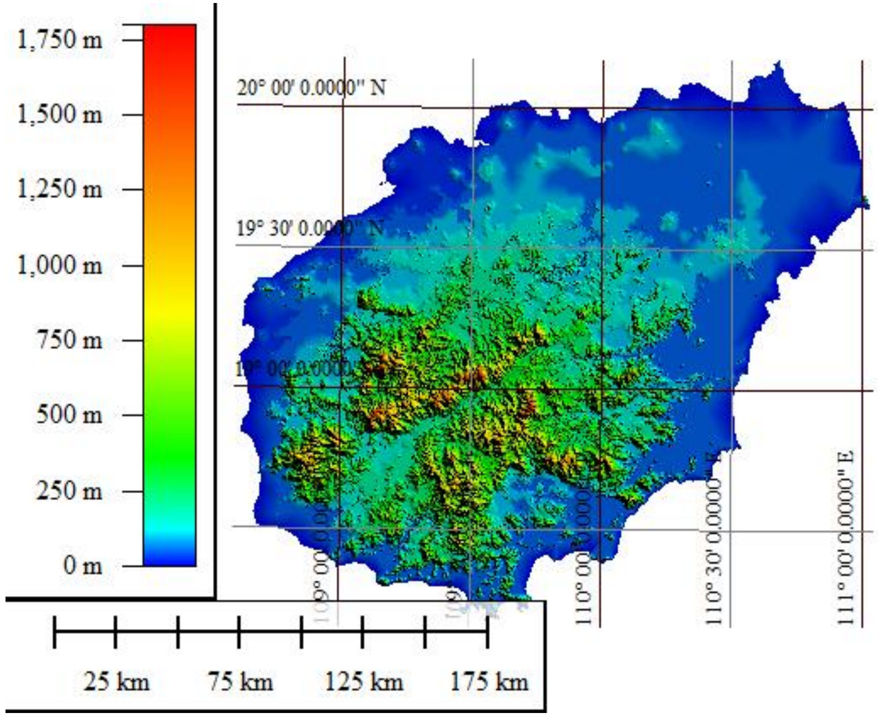
Correction method



Correction method

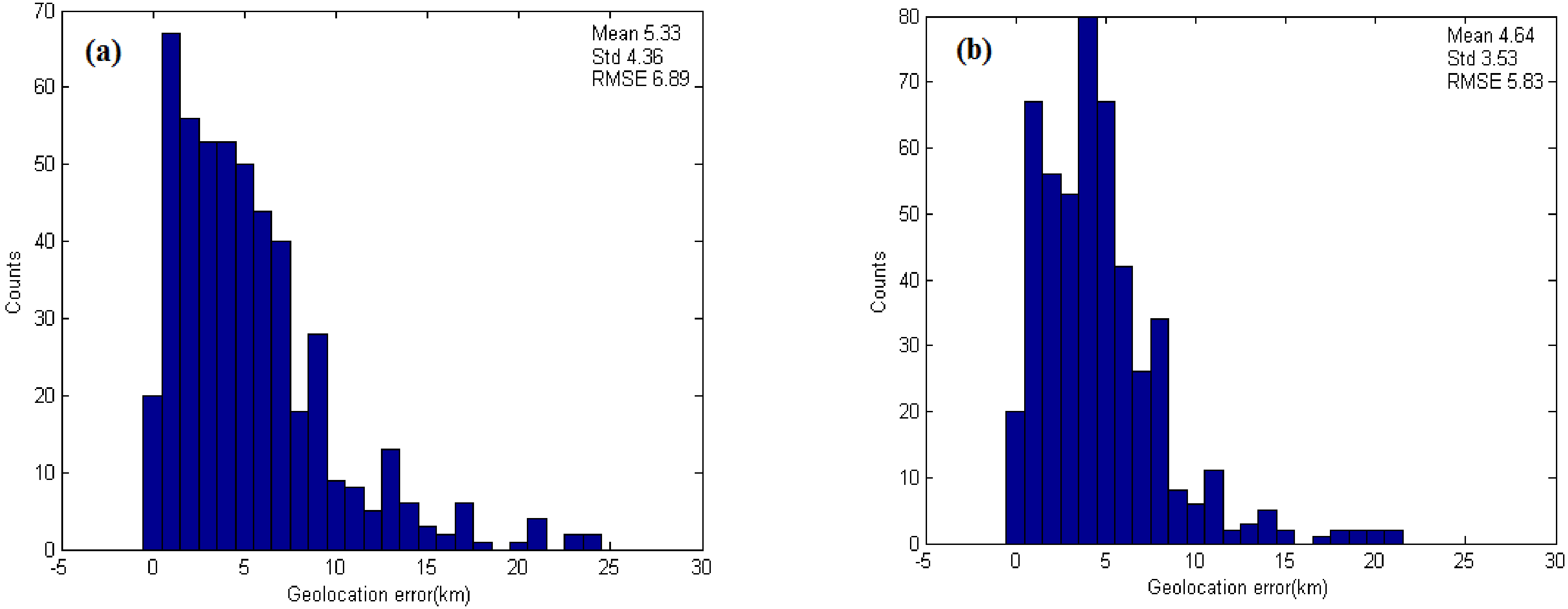
The changes in elevation across the terrain will also cause deviations in geolocation. In Fig, r is the observation vector in the ECEF coordinate system and x is the surface observation point on the reference ellipsoid. However, due to the influence of terrain, the backscatter coefficient measured is actually the value of the position of the intersection (x’) between r and the earth surface instead of x. As a result, the calculated latitude and longitude do not match the backscatter coefficient which causes geolocation deviation. Therefore, the DEM elevation data were used to optimize the geolocation algorithm

Correction method



The Shuttle Radar Topography Mission provided high-precision elevation data for the Hainan Island region, which was used to correct the geolocation errors. The data of Hainan Island region with elevation values above 200 m were selected to further reflect the effectiveness of the correction algorithm.

Correction results



Histogram distribution of geolocation errors. Using the original data and using the optimized data correction by DEM optimization algorithm.

Correction results

The level 1A data of CSCAT covering Hainan Island, corresponding to more than a month level 1B data used, were selected. The data were processed by the new geolocation algorithm which was added to the above correction algorithm. The new level 1B data generated were used to compare the geolocation errors with the original level 1B data. Fig shows the statistical and comparison results before and after the geolocation optimization. The error distributions of the two are basically the same. The root mean square errors of the two situations were obtained. The geolocation errors before and after optimization were 6.89 km and 5.83 km, respectively, so that the geolocation error was reduced by 1.06 km using DEM data.

Conclusion

Based on the scan geometry and geolocation algorithm of CSCAT, this study uses the coastline inflection method to estimate the geolocation errors of CSCAT. The GSHHS, a fine-resolution database, was selected. Hainan Island and Liaodong Bay in China were selected as the analysis areas. The geolocation errors were estimated using CSCAT L1B data collected from Hainan Island and Liaodong Bay from February 27 to April 10, 2019. A total of 1062 coastline inflection points were found that met the required conditions. The current geolocation errors of CSCAT were estimated to be approximately 7.31 km, which meets the conditions of 25 km $\times$ 25 km wind field retrieval. In addition, high-precision DEM data were used to optimize the geolocation algorithm; the geolocation errors were reduced by about 1.06 km after optimization, which shows the effectiveness of this method for using an optimized geolocation algorithm. The CSCAT geolocation errors primarily come from satellite ephemeris and attitude errors, geolocation algorithm errors, and errors introduced by the rotation of the fan beam antenna. In the future, the causes of geolocation errors will be further analyzed and geolocation algorithms will be improved in order to further improve the accuracy of wind field retrieval for the rotating scanning fan beam microwave scatterometer and to obtain higher resolution wind field products.


Thank you for reading!