Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SGD22-03 Room:303 Time:May 28 14:45-15:00

Precise ocean dynamic topography measurements by satellite altimetry

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A satellite altimeter is an instrument to measure a distance between the satellite and ocean surface from propagating delay time between transmitting and receiving pulse of a microwave. A sea surface height (SSH) with respect to a reference ellipsoid is then derived by determining satellite orbit precisely.

Satellite altimetry started observations since Seasat satellite launched in 1978 after the experimental operation of GEOS-3. At the time, since the accuracy of orbit determination exceeded several tens of centimeters, which is larger than an ocean-dynamic related signal of 10 cm, Seasat had a limitation to detect ocean dynamic topography. On the other hand, it provided valuable information to improve bathymetry and geoid as SSH variance induced by them exceeds an order of meters.

The launch of TOPEX/POSEIDON (T/P) in 1992 brought significant changes to oceanography. It was carefully designed to enable precise ocean dynamic topography measurements: it carried a dual frequency altimeter to evaluate ionospheric path delay and its altitude was set high for rapid changes of gravity fields not to affect orbit determination. These preparations resulted in improving a measurements accuracy of 2-3cm and T/P yielded many oceanic findings such as the distribution and propagation of mesoscale eddies. In addition, altimeters revealed global sea level rise (3mm/year) and its regional distribution, which are not an initial scope of altimetry mission, thanks to continual operations by several altimeters and careful cal/val activities. In the present, the precision of orbit determination drastically improves reaching up to 1 cm due to the improvement of geiod models by altimeters themselves and other gravity missions.

The next target of satellite altimetry is improving spatio-temporal resolution. Even if the current altimeter observes SSHs at a 7km interval, its measurements are only along satellite tracks and zonal intervals between adjacent tracks reach up to several tens and several hundreds of kilometers in the mid- and low-latitudes. It has also been reported that effective spatial resolution of along-track SSHs is roughly 100km due to an instrumental noise. Thus the current altimeters can't detect relative fine spatial phenomena such as coastal and submesoscale (10-100km) SSH variations. In order to tackle these problems, state-of-art satellite altimeters use high frequency (ka-band) microwave to improve footprints and/or have a function of 'SAR mode' to improve along-track spatial resolution (250m). The next-generation wide-swath altimeters, which observing concept is different from traditional nadir-type one, are also planned by NASA/CNES and JAXA named as SWOT and COMPIRA, respectively. They can measure 2-D SSHs based on an interferometric technique using two SAR antennas to be mounted. They are expected to depict ocean phenomena which spatial scale is less than 100km and drive greater innovation since the T/P era.

Keywords: Satellite altimetry, Ocean Dynamic Topography