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Ocean Winds and Waves from Chinese SAR Mode Sensors

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GF-3 SAR

GF-3 (GF stands for GaoFen, which means High Resolution in Chinese) is the China's first C band multi-polarization high resolution microwave remote sensing satellite. It was successfully launched on Aug. 10, 2016 in Taiyuan satellite launch center. The synthetic aperture radar (SAR) on board GF-3 works at incidence angles ranging from 20 to 50 degree with several polarization modes including single-polarization, dual-polarization and quad-polarization. GF-3 SAR has 12 imaging modes consisting of some traditional ones like stripmap and scanSAR modes and some new ones like spotlight, wave and global modes. GF-3 SAR is for both land and ocean observation.
GF-3 SAR wind retrieval

(a) Polarization=VV / $\theta=36.0$ degree
- CMOD4
- C-SARMOD
- CMOD_IFR2
- Fit on GF3 NRCS
- CMOD5
- GF3 NRCS
- CMOD5.N

(b) Polarization=VV / $\theta=36.0$ degree / $U_{10}=7.0$ m s$^{-1}$
- CMOD4
- C-SARMOD
- CMOD_IFR2
- Fit on GF3 NRCS
- CMOD5
- GF3 NRCS
- CMOD5.N

Wind speed (m s$^{-1}$)

Azimuth angle (degree)
GF-3 SAR wind retrieval

CMOD5.N + NCEP direction + lookup table

\[ \sigma^0 = au^\gamma [1 + b(\theta) \cos \phi + c(\theta) \cos(2\phi)]^p \]

-SAR
Wind speed: 13.9 m/s
Wind direction: 254.0°

-Buoy
Wind speed: 12.0 m/s
Wind direction: 269°
GF-3 SAR wind retrieval

**GF3_MYN_SS_991247_20161104_L1A_HHHV**

- SAR
  Wind speed: 7.1 m/s

- Buoy
  Wind speed: 5.7 m/s
  Wind direction: 45°

**GF3_KAS_SS_002121_20170104_L1A_HHHV**

- SAR
  Wind speed: 6.6 m/s

- Buoy
  Wind speed: 8.3 m/s
  Wind direction: 74°
传感器：GF-3/SAR
观测模式：标准条带
观测时间：2017年02月02日 02:05:57 UTC

海面雷达后向散射系数（左）、海面风场反演产品（右）

制作单位：国家海洋局第二海洋研究所
GF-3 SAR wind retrieval

高分三号卫星全极化条带模式海面风场专题图

传感器：GF-3/SAR
观测模式：全极化条带 1
观测时间：2017年03月15日10:24:42 UTC

海面雷达后向散射系数（左）、海面风场反演产品（右）

制作单位：国家海洋局第二海洋研究所
GF-3 SAR wave retrieval

Sub-image

Cut-off wavelength

Image spectrum

Wave spectrum
GF-3 SAR wave retrieval

高分三号卫星标准条带模式海面浪场专题图

传感器：GF-3/SAR
观测模式：标准条带
观测时间：2017年01月21日 02:02:39UTC

-SAR
SWH: 3.8m wavelength: 146.0m wave direction: 265.2°

-NDBC (46012)
4.6m 139.9m 277.0°
GF-3 SAR wave retrieval

高分三号卫星全极化条带模式海面浪场专题图

传感器：GF-3/SAR
观测模式：全极化条带 1
观测时间：2017 年 03 月 15 日 10:24:03 UTC

-SAR
SWH: 1.7m
wavelength: 120.9m
wave direction: 68.3°

-WW3
SWH: 2.1m
wavelength: 112.7m
wave direction: 54.0°
GF-3 SAR wave retrieval

Compared to Buoy data

Bias = 0.3 m
RMSE = 0.5 m
Error = 17.8%

Bias = 2.2 m
RMSE = 20.8 m
Error = 9.5%

Bias = 13.2 deg
RMSE = 14.8 deg
GF-3 SAR wave retrieval

Compared to Altimetry data
GF-3 SAR internal wave retrieval and ship wake detection

Amplitude: ~5 m
Pycnocline depth: ~32 m
Water depth: ~100 m
TG-2 InIRA

TG-2 (Tiangong-2) is a Chinese space laboratory which was launched on Sept. 15, 2016 from Jiuquan Satellite Launch Centre. The onboard Interferometric Imaging Radar Altimeter (InIRA) is a new generation radar altimeter developed by China, which combines the function of interferometric radar altimeter and Synthetic Aperture Radar (SAR).

The dominate scattering mechanism for sea surface is quasi-specular scattering due to the small incidence angle range (3 ~ 8 deg).

TG2 InIRA geometry
TG-2 InIRA wind and wave retrieval
TG-2 InIRA wind and wave retrieval

The TG2 InIRA normalized radar cross section $\sigma_0$ along with incidence angle is consistent with the quasi-specular model

$$\sigma_0 = \frac{\rho \pi}{\cos^4 \theta} p(\tan \theta, 0)$$
TG-2 InIRA wind and wave retrieval

\[ \sigma_0(\theta, U_{10}) = a(\theta) + b(\theta)U_{10} + c(\theta)U_{10}^2 \]

Ku-band low incidence backscatter model (KuLMOD)


\[ P(k) = (T^t + T^h + T^{vb})k^2 F(k) \]

\[ T^t = \cot \theta - 4 \tan \theta - \frac{1}{\cos^2 \theta} \frac{\partial \ln p(\tan \theta, 0)}{\partial \tan \theta} \]

\[ T^{vb}_k = -\beta k_a w(\cos \theta - i \sin \theta \frac{k_r}{k}) \]

\[ T^h = \frac{\omega - i \mu}{\omega^2 + \mu^2} (4.5) K \omega \left( \frac{k_y^2}{K^2} \right) \]
TG-2 InIRA wind and wave retrieval

Compared to GFS wind: Wind speed RMSE: 1.5 m/s
TG-2 InIRA wind and wave retrieval

Image spectrum

Retrieved wave spectrum

2016-09-22 12:22
TG-2 InIRA wind and wave retrieval

S1B Ocean Wave X Spectrum (Re)
2016-09-22 23:51:07

WW3 Ocean Wave Spectrum
2016-09-23 00:00:00

U10 = 10.62 m/s

U10 = 8.47 m/s

Wl: 321.69 m  Wl: 443.33 m
Dir: 44.44 °  Dir: 325.27 °
Hs: 3.35 m  Hs: 1.40 m
Lon : -78.41 deg  SnR : 34.06  NRCS : -5.86 dB  Az. Cut Off : 240.00 m
Lat : -37.09 deg  Nv : 1.70  Track : 345.29 deg  Incidence : 23.41 deg

Courtesy: Bertrand Chapron, Alexis Mouche, He Wang
TG-2 InIRA wind and wave retrieval

TG-2 InIRA:
Average Wavelength: ~282 m

WW3:
Wavelength: ~305 m

Compared to WW3 wave:    SWH RMSE: 0.42 m
Thanks for your attention