Improved Level 3 Precipitation Products from dual frequency altimeters

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Introduction

Rain detection by dual-frequency altimeters is well established and operationally used to flag Jason and Envisat data for rain. Rain rate estimate is possible but limitation because no estimate of the Rain height (assimilated to freezing level) and low time and space sampling. New method to estimate the freezing level from the radiometer (TMR, JMR and MWR used primarily for wet tropospheric correction) brightness temperature T_B. Merging of the three altimeters Topex, Jason and Envisat is also presented.

1 Dual-frequency altimeter Data

Satellite	Altimeter frequencies		Radiometer frequencies		
	GHz	GHz	GHz	GHz	GHz
	Ku	C/S	1	2	3
Topex	13.6 (Ku)	5.3 (C)	18	21	37
Jason	13.6 (Ku)	5.3 (C)	18.7	23.8	34
Envisat	13.575 (Ku)	3.2 (S)		23.8	36.5

Table 1: Altimeters and radiometers frequencies

2 Rain and freezing level

2.1 Detection of rain

Detection of rain events : Detection of occurrences where the Ku band σ_0 is significantly attenuated compared to C or S band σ_0. The measured σ_0^{Ku} is compared to σ_0^{Ku} expected from the measured σ_0^C or σ_0^S through a rain free relationship. The rain free Ku/C (Ku/S) relation, f determined by binning the σ_0^{Ku} data in intervals of 0.1 dB of C (or S) band σ_0 The mean, f($\sigma_0^{C/S}$), and standard deviation, rms($\sigma_0^{C/S}$), are then computed in each bin.

Detection criteria:

$$\Delta\sigma_0 = f(\sigma_0^{C/S}) - \sigma_0^{Ku} > 1.8 * rms(\sigma_0^{C/S}) \quad (1)$$
$$L_z > 200\mu m \quad (2)$$

$\Delta\sigma_0$: Ku band rain attenuation, σ_0^{Ku} : Ku band backscatter coefficient, $\sigma_0^{C/S}$: C or S band backscatter coefficient, L_z : radiometer liquid water content.

(2) is used to insure the presence of cloud and thus to minimise the possibility of false alarm [1]

Rain rate estimated using the Marshal-Palmer relation [2]

$$R = \left(\frac{\Delta\sigma_0}{2Ha}\right)^{\frac{1}{b}} \quad (3)$$

H: rain height, a and b: coefficients dependent on the frequency. ($a = 0.0238$ dB/km and $b = 1.203$ [3])

R strongly depends on the rain height (assimilated to the freezing level).

2.2 Freezing level and rain rate determination

The method is based on the work of Wilheit et al (1977) [4] on SSM/I data. A Radiative Transfer model is used to compute the T_B in presence of rain using a simplified atmosphere. The Rosenkranz (2002) [5] RTM is used .

Simplified atmosphere:

- US standard atmosphere
- Constant lapse rate
- constant rain from O to FL (with Marshall-Palmer drops distribution)
- Relative humidity 100% at 0 to 80% at FL
- Surface Temperature fixes the FL.

T_B are computed for the TMR, JMR and MWR channels for FL from 0.25 to 6 km (step of 0.25 km) and R from 0 to 50 mm/hr, resulting for each freezing level in a relationship between rain rate and T_B (R-T relationship). Figure 1 presents the modelled T_B for TMR channels.

For the rain samples detected by altimeter, the T_B are inverted in terms of FLl and radiometer rain rate by minimising the distance between observations and modeled T_B for the two lower radiometer frequencies. If the algorithm does not converge (i.e. distance between modeled and observed $T_B > 2K$), FL is flagged as missing. The proportion of valid freezing level estimate is about 50% for small rain rate (< 3mm.hr^{-1}) and rapidly increases with rain rate to 80-90% for rain rate greater than 5 mm.hr^{-1}. This shows the importance of the difference of resolution between the two kinds of sensor for the rain detection.

R is then estimated using the radiometer FL.

3 Validation

3.1 Validation of FL estimates

The radiometers valid FL's have been systematically co-located with the NCEP and SSM/I F13 ones for 2003.The mean latitudinal FL distributions for 2003 presented in fig. 1 show the very good consistency of the three radiometers estimates as their difference is always less than 250 m. The TMR and JMR FL are almost identical whilst MWR gives higher values in the Tropics. Compared to SSM/I F13, the radiometer estimates are in better agreement with NCEP ones. As the principle of FL determination is essentially the same for SSM/I and altimeter radiometers, the observed differences result certainly from the fact that altimeters allow a better discrimination between rain and no rain samples. FL estimated from altimeter and radiometer are of a quality at least comparable to SSM/I ones.

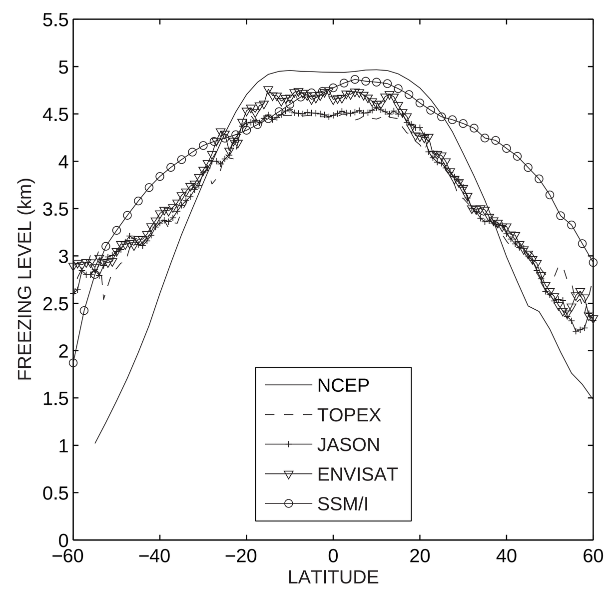


Figure 1: Mean latitudinal altitude of the FL for 2003 for Topex, Jason; Envisat, NCEP and SSM/I F13.

3.2 Inter-comparison of altimeters rain rate and FL

A statistical comparison of rain rate and FL estimates ensembles for three altimeters has been conducted for the year 2003. The distributions of rain rate and FL are presented in fig. 2. The FL distributions are almost identical for Topex and Jason with a strong maximum at 4.5 km corresponding to tropical rains. The Envisat distribution is very close to the two others up to 3.5 km but the peak is shifted toward 5 km and is more spread out with a much larger number of FL's above 4.5 km. This difference of behavior results from the use of the 37 GHz channel which saturates much faster than the 18 GHz one resulting in an overestimation of the FL for rain rate above 5 mm.hr^{-1}.

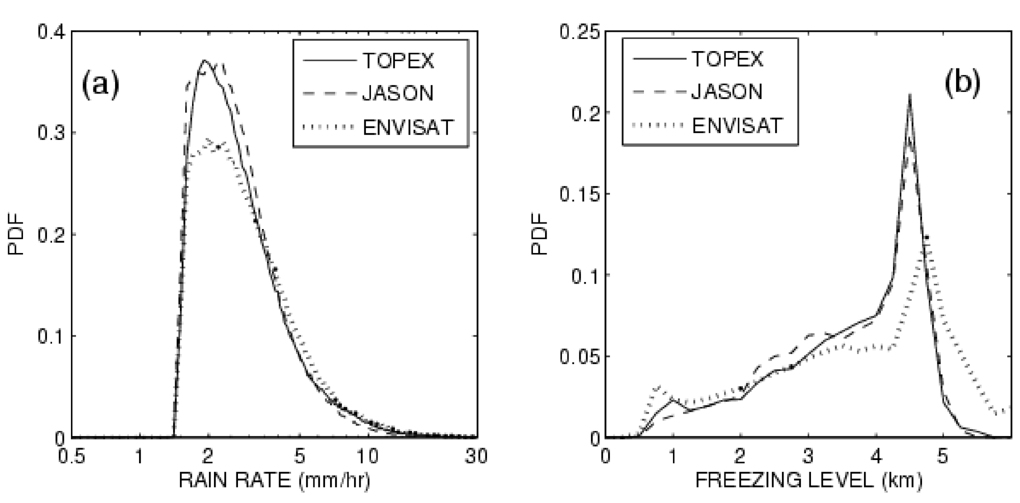


Figure 2: Comparison of the Topex, Jason and Envisat rain rate (a) and FL distributions (b) for 2003.

4 Mean field estimate

The rain climatology is estimated using the same approach as in [6] and [7] for SSM/I. A mixed probability distribution function combining a lognormal distribution describing the positive rainfall values and a spike at zero describing the observations indicating no rainfall is used to compute mean values. The lognormal density is a non-linear function of two variables, μ and σ.

$$P(R,\mu,\sigma) = \frac{p}{r\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2\sigma^2}(\ln r - \mu)^2\right], R > 0 \quad (4)$$
$$P(0,\mu,\sigma) = 1 - p, R = 0 \quad (5)$$

where p is the probability of non-zero rainfall value. The mean μ and variance $sigma$ of the mixed lognormal distribution are expressed by

$$E(R) = \hat{p}\exp\left(\hat{\mu} + \hat{\sigma}^2/2\right) \quad (6)$$
$$var(R) = \hat{p}\exp\left(2\hat{\mu} + \hat{\sigma}^2\right)\left[\exp(\hat{\sigma}^2) - \hat{p}\right] \quad (7)$$

The maximum-likelihood estimate of the parameters μ and σ are given by

$$\hat{\mu} = \frac{1}{n}\sum_{i=1}^{n} \ln R_i \quad (8)$$
$$\hat{\sigma}^2 = \frac{1}{n}\sum_{i=1}^{n} [\ln R_i - \hat{\mu}]^2 \quad (9)$$

R_i : ensemble of valid instantaneous rainfall estimates for a given cell of the grid during the period of time considered. The rain probability (p) is computed as the ratio of the number of rainy altimeter samples to the total number of ocean valid altimeter samples within the considered grid cell.

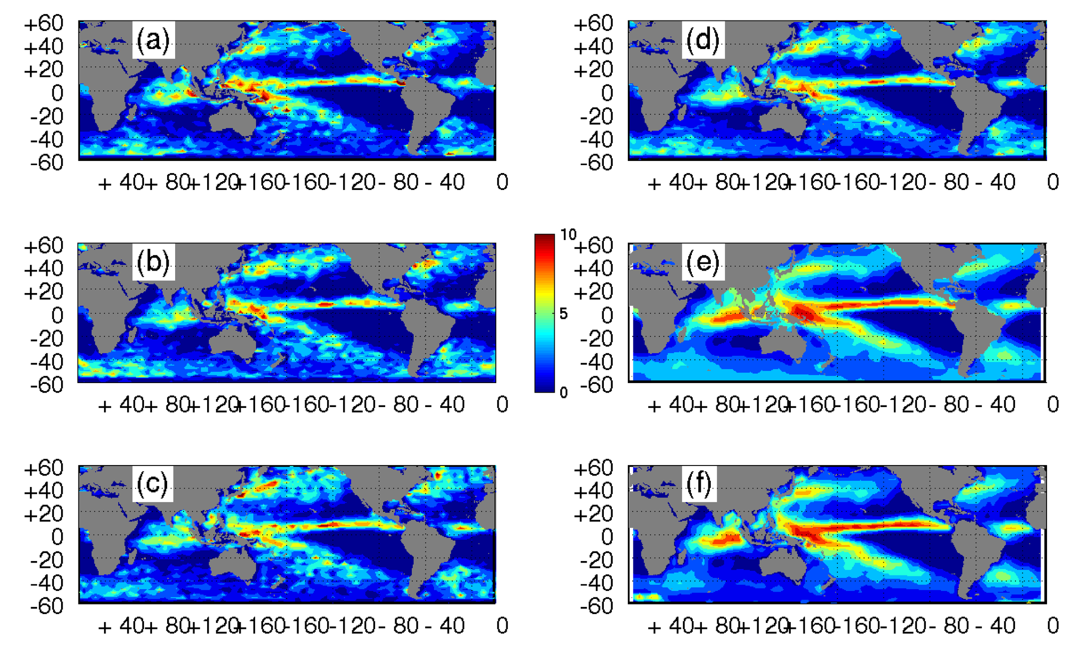


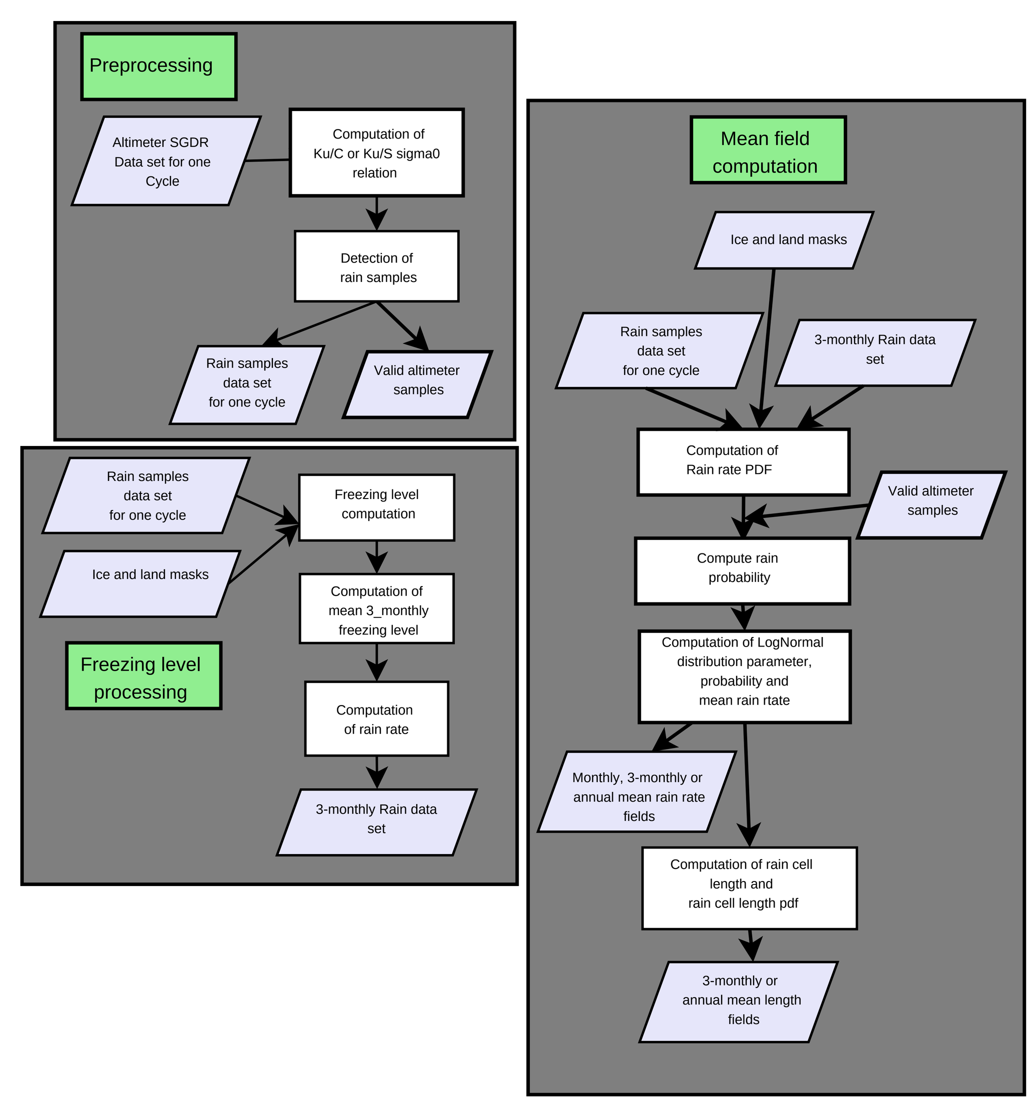
Figure 3: Mean rain rate for 2003 for (a) Topex, (b) Jason and (c) Envisat, (d) merged (e) GPCP, (f) SSM/I F13.

5 ALTRAIN products at IFREMER/CERSAT

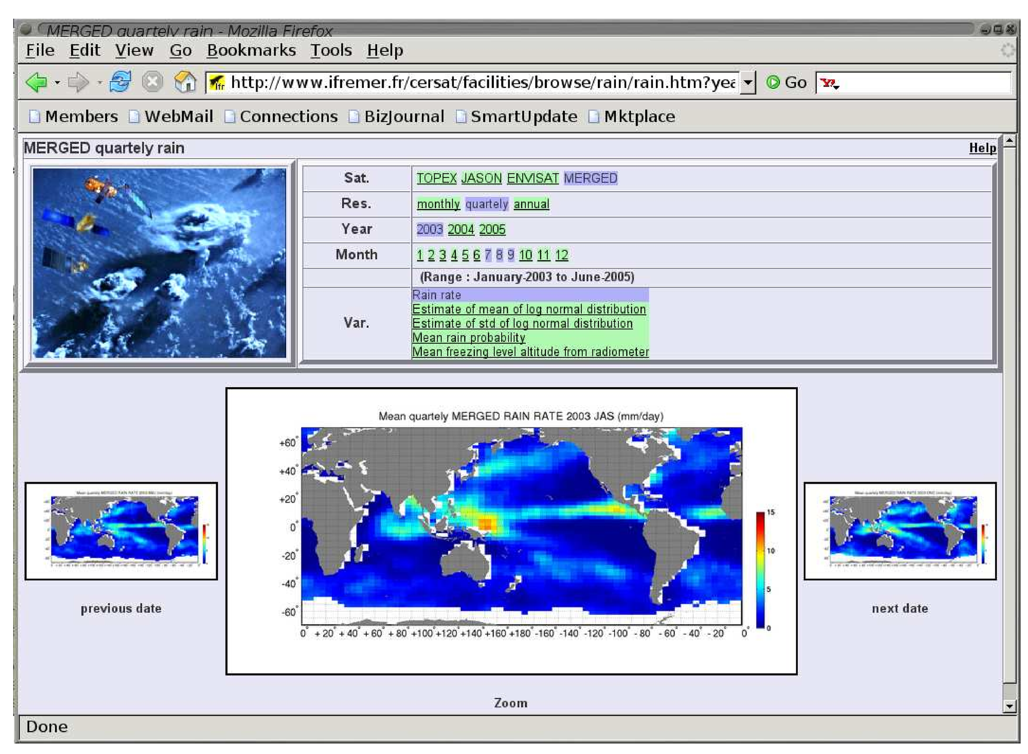
The Topex, Jason and Envisat archives have been processed and the data set are available at CERSAT.

Image Browser:
http://www.ifremer.fr/cersat/facilities/browse/rain/rain.htm
netcdf files on ftp at
ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/rain-alt/

Processing scheme



RAINALT Web browser



References

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