

The altimeter and radiometer product suite for the Sentinel-6/Jason-CS mission

Remko Scharroo, Carolina Nogueira Loddo,
Cristina Martin-Puig



Ocean Surface Topography Science Team Meeting (OSTST)

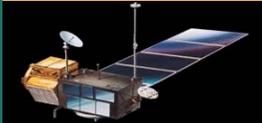
October 23-27, 2017

“The 25th Anniversary of TOPEX/Poseidon”



Satellite altimetry instruments/missions

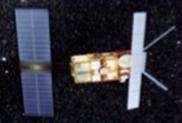
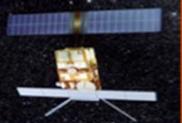
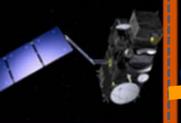
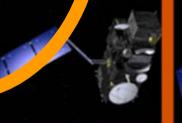
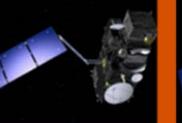
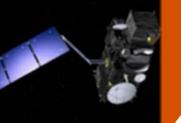
Reference Missions

Poseidon	Poseidon-2	Poseidon-3	Poseidon-3B	Poseidon-4	Poseidon-4
					
1992 TOPEX/ Poseidon	2001 JASON-1	2008 JASON-2	2016 JASON-3	2020 S6/J-CS A	2026 S6/J-CS B

copernicus

Product heritage

Polar Orbit Missions

RA	RA	RA-2	SIRAL	Altika	SRAL	SRAL	SRAL	SRAL
								
1992 ERS-1	1995 ERS-2	2002 Envisat	2010 CS-2	2013 SARAL	2016 S3-A	2018 S3-B	2023 S3-C	2026 S3-D

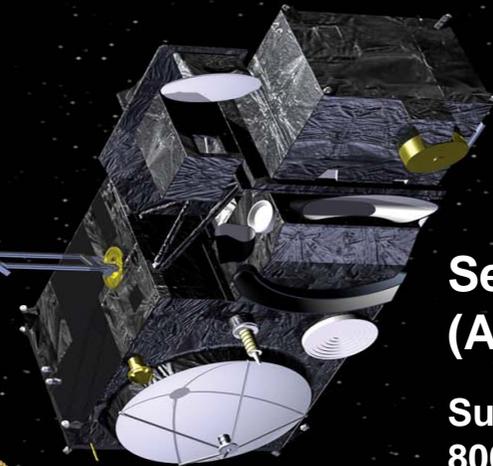
copernicus

The Copernicus high-resolution altimetry constellation (current and future)



Sentinel-6/Jason-CS

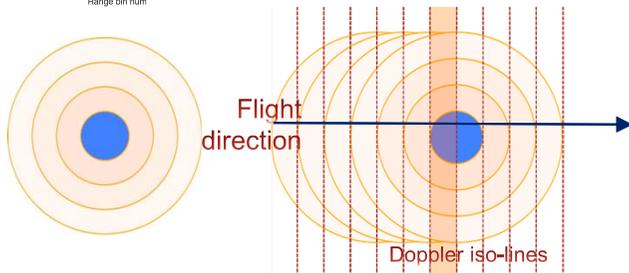
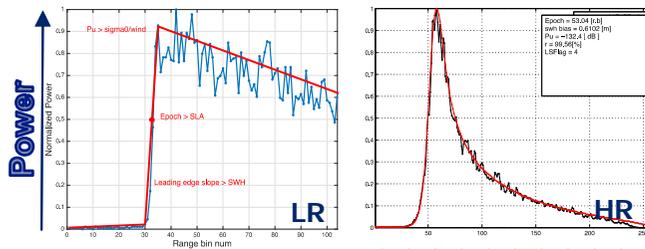
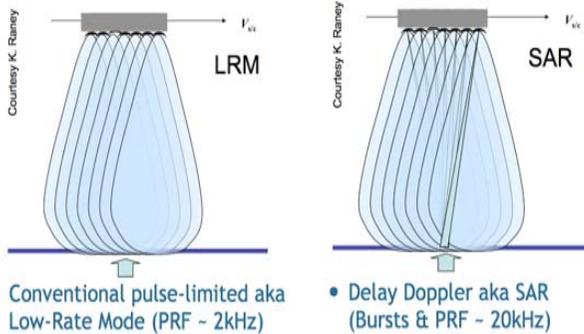
Non-sunsynchronous
1335 km
66° inclination
(to be launched 2020)



Sentinel-3 (A,B,C,D)

Sunsynchronous
800 km
98° inclination
(launched 2016)

Delay/Doppler or SAR Altimetry – quantum leap

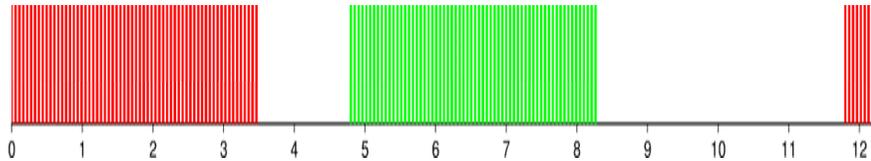


The **improvements** w.r.t. conventional ('LR' – Low Resolution) altimetry:

- More “**looks**” → higher SNR → more precise
- **Finer along-track spatial resolution**
 - ~ 300 meters along-track
- **Less contamination** close to land
 - Very well suited for coastal altimetry

Sentinel-3 and -6 in **HR altimetry over all ocean surfaces!**

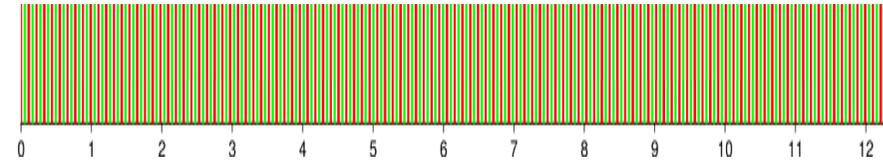
Closed-burst and open-burst SAR



CLOSED-BURST

SENTINEL-3 AND CRYOSAT-2

- In a **closed-burst** HR altimetry (S-3 and CS-2) **transmit** and **receive** are not interleaved and are not continuous.
 - N (= 64) echoes are tx @ a high PRF = 18 kHz → give a burst duration of ~3.5 ms.
 - But the burst-to-burst interval is ~11.8 ms.
- **70%** of the opportunity to make measurements **is not used**.
- This pulsing scheme does not allow for statistical equivalent Low Resolution measurement (pseudo-LRM).

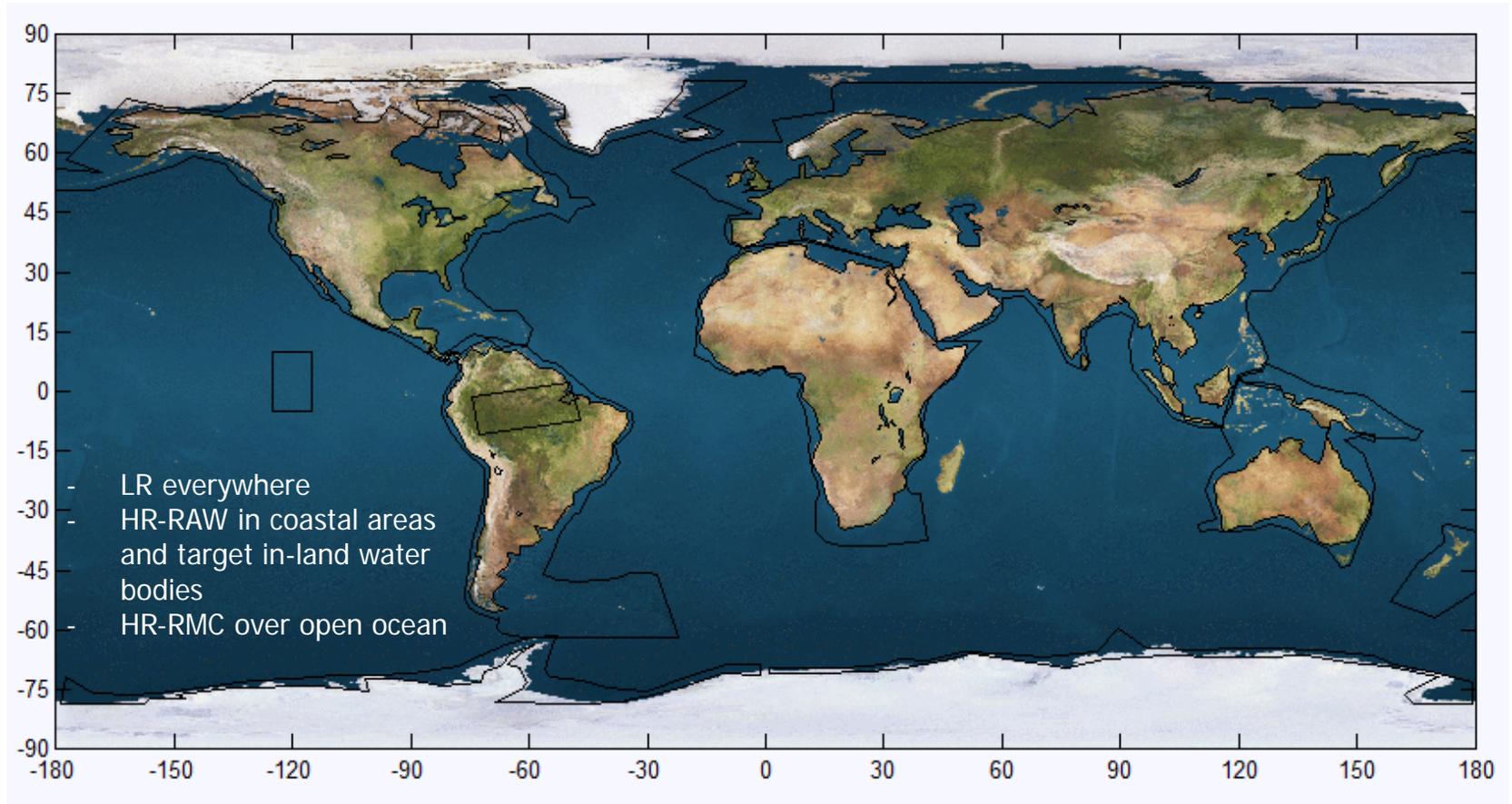


OPEN-BURST

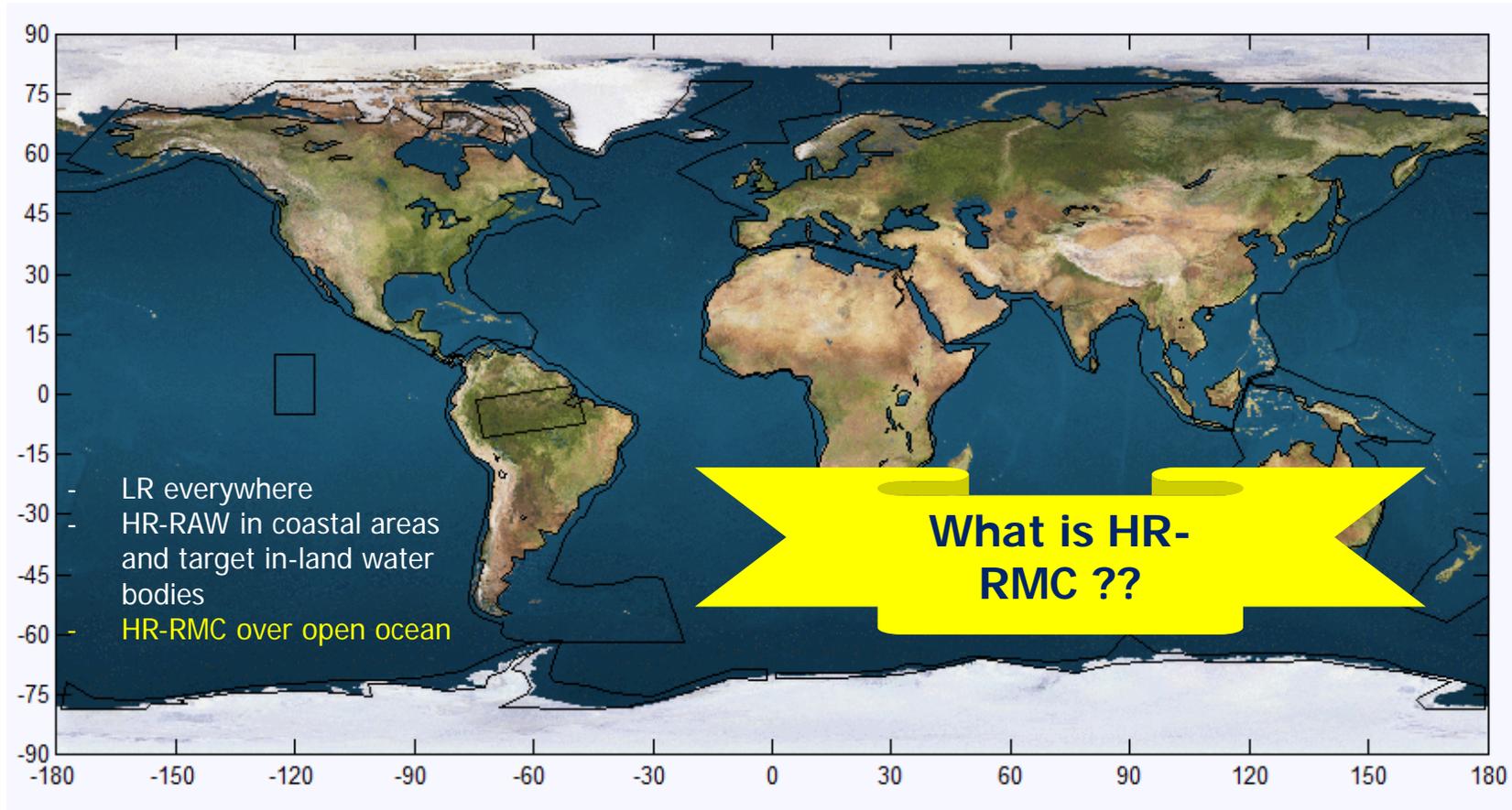
SENTINEL-6 / JASON-CS

- PRF ~ 9 kHz and continuously interleaved **transmit** and **receive**.
- All possible statistically independent measurements are made.
- HR and LR altimetry measurements can both be made from the same echoes, under the same conditions.
- LR from simple sequential averaging of all echoes yields optimal LR everywhere, both coastal and open ocean.
- Since all individual echoes will be downlinked, HR products can be generated on-ground.

Sentinel-6/Jason-CS data budget

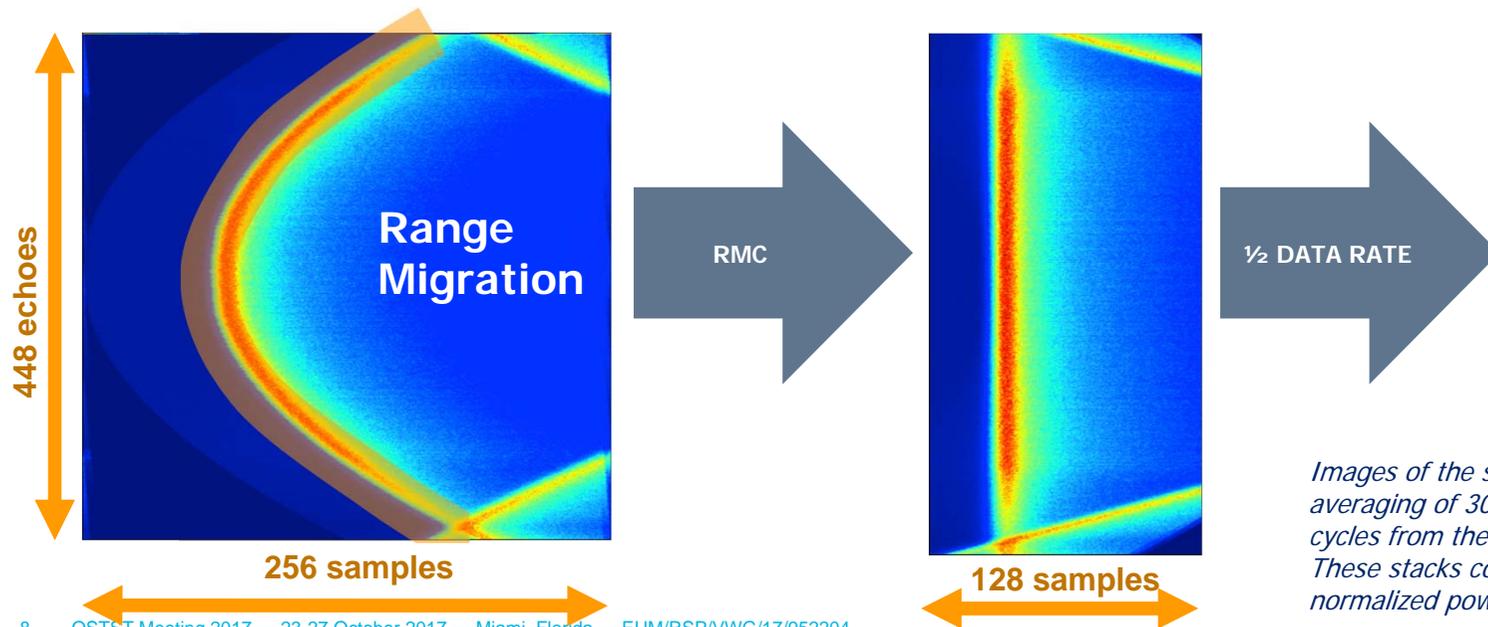


Sentinel-6/Jason-CS data budget



Sentinel-6/Jason-CS HR operational modes

- Jason-CS will operate in “HR-RAW” over coastal areas. That means that the delay/Doppler map of 256 samples will be available for creating a HR multi-looked waveform.
- Note however the Doppler ambiguities.
- Jason-CS will operate in “HR-RMC” over open ocean. The number of samples is reduced to 128 in order to reduce on-board storage and downlink, while retraining most useful information.
- **The range migration correction is done on board and un-done on ground**



Sentinel-6 data product overview

- **Level 0**
 - Time-sorted binary data packets (limited access)
- **Level 1A**
 - Individual echoes; instrumental calibrations applied (CAL1; no need of CAL2 in J-CS due to digital architecture)
 - From this the user can create L1B-S with software provided (ESA)
- **Level 1B**
 - Calibrated waveforms, to be combined with L2 to form equivalent of Jason Sensor Geophysical Data Records (SGDR)
- **Level 2**
 - Similar to Geophysical Data Records (GDR)
 - Provided also in **reduced format** (1-Hz only) and in BUFR format
- **Level 2P**
 - As Level 2, with updated corrections, models (reduced)
- **Level 3**
 - Harmonised with other missions (reduced)

Near-Real time	Short Time Critical	Non Time Critical
<ul style="list-style-type: none"> Mainly for operational Met agencies (wind and wave mainly) Products split by satellite dump/granules NetCDF and BUFR 	<ul style="list-style-type: none"> For ocean modelling and assimilation Product split by pass (pole to pole) NetCDF 	<ul style="list-style-type: none"> For climate studies and research Products split by pass (pole to pole) NetCDF
JASON-2/3		
<ul style="list-style-type: none"> 3-hour latency OGDR 1-Hz and 20-Hz measurements (sea level, wind speed, wave height, etc.) 	<ul style="list-style-type: none"> 48-hour latency IGDR, 1- to 2-day latency 1-Hz and 20-Hz measurements SIGDR (including waveforms) 	<ul style="list-style-type: none"> 60-day latency GDR 1-Hz and 20-Hz measurements SGDR (including waveforms)
SENTINEL-6/JASON-CS		
<ul style="list-style-type: none"> 3-hour latency Level 2: Low- and high-resolution products <ul style="list-style-type: none"> Standard: 1-Hz and 20-Hz Reduced: 1-Hz Level 2P: Harmonised L2 (1-Hz) Also in BUFR format (including 20-Hz; definition on going) 	<ul style="list-style-type: none"> 36-hour latency Level 1A: Individual echoes (HR only) Level 1B: LR and HR Level 2: LR and HR <ul style="list-style-type: none"> Standard (1-Hz and 20-Hz) Reduced (1-Hz only) Level 2P: Harmonised L2 (1-Hz) Level 3: With orbit error correction, error information (1-Hz) 	<ul style="list-style-type: none"> 60-day latency Level 1A: Individual echoes (HR only) Level 1B: LR and HR Level 2: LR and HR <ul style="list-style-type: none"> Standard (1-Hz and 20-Hz) Reduced (1-Hz only) Level 2P: Harmonised L2 (1-Hz) Level 3: With orbit error correction, error information (1-Hz)

• **Level 2P and 3** products are produced with some delay with respect to the timeliness shown above.

Sentinel-6/Jason-CS Product Baseline

Product	Latency	Format	User Data Access		
			EUMETCast	GTS	Archive
ALT Low Resolution (LRM)	NRT	BUFR	L2	L2	L2
		NetCDF	L2*, L2P	–	L0, L2*, L2P
	STC	NetCDF	L2P	–	L1b, L2*, L2P, L3
	NTC	NetCDF	–	–	L1b, L2*, L2P, L3
ALT High Resolution (SAR)	NRT	BUFR	L2	L2	L2
		NetCDF	L2*, L2P	–	L0, L2*, L2P
	STC	NetCDF	L2P	–	L1a, L1b, L2*, L2P, L3
	NTC	NetCDF	–	–	L1a, L1b, L2*, L2P, L3
MWR	NRT	NetCDF	–	–	L2
	STC	NetCDF	–	–	L2
	NTC	NetCDF	–	–	L2

* ALT Level 2 NetCDF products: reduced (1-Hz only) and standard (1-Hz and 20-Hz)
L2P and L3 products have slightly different latency; for LRM TBC.

Performance budgets for sea level (NRT/STC/NTC)

Requirement (cm)	Jason-3 O/I/GDR	Sentinel-3 NTC	Jason-CS Requirement	Jason-CS Goals
Altimeter noise (LR) (a)	1.8	1.7	1.5	1.0
Altimeter noise (HR) (a)		1.3	0.8	0.5
Ionosphere (b)	1.0/0.5/0.5	0.5	0.5	0.3
Sea state bias	3.5/2.0/2.0	2.0	2.0	1.0
Dry troposphere	1.0/0.7/0.7	0.7	0.8/0.7/0.7	0.5
Wet troposphere	1.2	1.4	1.2/1.2/ 1.0	0.8
Orbit error (c)	5.0/2.5/1.5	1.9	5.0/ 2.0 /1.5	3.0/1.5/1.0
SSH error (LR)	6.8/3.9/3.4	3.6	5.79/3.53/3.20	3.46/2.29/1.99
SSH error (HR)		3.5	5.65/3.29/2.94	3.35/2.12/1.80
SWH	50/40/40 cm or 10%	20 cm or 4% (d)	15 cm + 5%	10 cm + 5%
Wind speed (m/s)	1.6/1.5/1.5	2	1.5	1.0
Sigma naught (dB)	0.7	1	0.3 (e)	0.3 (e)

Product heritage

Jason-3

- Maintain as much as possible variable names
- Same pole-to-pole pass numbering

Sentinel-3

- Level 1A and Level 1B products
 - L1A for HR, L1B as separate product linked to L2 (no longer SGDR)
- HR data variables
- SAFE packaging
 - Manifest (xml) and data files in directory per product (e.g. pass)
 - Internal name could be adapted to Jason convention (TBD)
- Internal netCDF data compression
 - Reduced data volume without need for zipping/unzipping

Product novelties

New in Sentinel-6

- Separate HR and LR products
 - To be able deliver LR ahead of HR
 - Because of 100% versus ocean-only coverage
- NetCDF data grouping
 - For more convenient variable naming
 - Compartmentalise data
- Separate Level 2 MWR product
 - At original data rate
 - Includes antenna temperatures and brightness temperatures

Grouping variables

Not grouped

- Requires stringed variables like *time_20_ku*, *time_20_c*
- Creates confusing names like *sea_state_bias_c_20_ku*

Grouped

- All variables of same posting rate contained in groups with same dimension name (time)
- Variable names can be reused in groups: e.g. *com_altitude* in **data_01** and **data_20/ku**

/ (root)			
Global attributes, common dimensions			
data_01		data_20	
1-Hz time dimension, 1-Hz variables common to Ku- and C-band (time, location, tides, MSS)		(Few, if any)	
ku	c	ku	c
1-Hz Ku-band measurements and corrections	1-Hz C-band measurements and corrections	20-Hz Ku-band time, location, measurements and corrections	20-Hz C-band time, location, measurements and corrections

Example of netCDF variable grouping (Level 2)

Variable Name (dim)	Units	Scale factor	Format	LR		HR		Contained in groups
				data_01	data_20	data_01	data_20	
time	s	-	double	x	ku, c	x	ku	1-Hz: data_01 20-Hz: data_20/ku, data_20/c
latitude (time)	degrees_north	1.e-6	int	x	ku, c	x	ku	
longitude (time)	degrees_east	1.e-6	int	x	ku, c	x	ku	
com_altitude (time)	m	1.e-4	int	x	ku, c	x	ku	
range_ocean (time)	m	1.e-4	int	ku, c	ku, c	ku	ku	1-Hz: data_01/ku, data_01/c 20-Hz: data_20/ku, data_20/c
range_ocean_used (time)	flag	-	byte		ku, c		ku	20-Hz only: data_20/ku, data_20/c
range_ocean_numval (time)	count	-	byte	ku, c		ku		1-Hz only: data_01/ku, data_10/c

Conclusions

- Sentinel-6 will introduce HR on the reference altimeter missions
 - “Interleaved mode” will allow LR/HR **simultaneously**, thus excellent to ensure continuity and a lot of R&D
 - More data products, larger volumes, than any previous mission → addressed with the RMC
 - New type of data products
 - 1-Hz range noise will be below 1 cm!
- Sentinel-6 will produce STC data faster than previous Jason missions
 - This will mainly benefit ocean modelers
- All Sentinel-6 data produced by EUMETSAT
 - Availability through EUMETCast and EUMETSAT Data Archive
 - BUFR provided in NRT (through GTS, mainly for Met Offices)