# CryoSat-2 precise orbit determination in ITRF 2020

Ernst Schrama Delft University of Technology, The Netherlands e.j.o.schrama@tudelft.nl



#### Content

- Satellite status
- How POD is carried out
- Observation Residuals, Empirical accelerations,
- Coordinate Frame parameters
- Time variable gravity, TWS and AOD1B
- IDS special issue

### CryoSat-2 status

- All looks ok, no major problems reported from ESA
- Alignment maneuvers with ICESAT-2 (change in SMA)
- Regular maneuvers (short), debris maneuvers (long)
- Occasional download issues at the ground terminal(s)
- ESA approved budgetary support for CS2 until end of 2025. (new)

# Input to the modelling process

- Coordinates
  - Transition to ITRF2020 for all DORIS beacons and SLR stations
  - Several beacons are not in ITRF2020 (ROZC SJVC SVBV FUUC NOXC)
- Ocean loading by station/beacon
  - Chalmers ocean loading calculator based op FES2012 or later
- For Doppler IDS format 2.2 ten second data is used
  - Doppler beacon frequency offset estimated by pass
  - Tropospheric zenith delay parameters estimated by pass
- Earth rotation parameters from IERS EOP 2020 CO4
- Initial state vector from DIODE navigator orbits
- DORIS stations weights, determined by screening the data residuals (new)

## Input to the modelling process

- Gravity models, static part is EIGEN-6S4-V2 at reference 1-jan-2016 (new)
- Solar radiation pressure modelling, scaling constant estimates once, CNES model
- Drag modelling, MSIS reference model, 3 hourly patches with constraints
- Ocean tides affecting the orbit: via FES 2012 model (or later)
- Atmospheric and Oceanic part TVG : AOD1B is the 3 hourly model outputs (new)
- Terrestrial water storage: several model choices GRACE and GRACE-FO (updated)
- Generalized accelerations modelling, 6 hourly, piecewise modelling.
- IDS beacon coordinates, adjust some that are not in ITRF 2020, or adjust all?

#### 10s Doppler residuals for one of the runs (84)







Median mm/s years: 2010-2023 run86





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#### SLR residuals for one of the runs (84)











#### Radial rms 1.45 cm POE ITRF2020 (83)

# TVG modelling for TWS component

- AOD1B is always used for each arc,
- Without doubts residuals both for DORIS and SLR benefit from this
- TWS part comes from GRACE and GRACE-FO
- Data gap in GRACE is from 23-5-2017 to 15–6-2018
- GRACE-FO: 15-6-18 -> 19-7-18; 31-10-18 -> 31-12-21
- Former discussion on whether there is a beauty

## TVG model strategy

- Fit a polynomial + harmonic function to the data
- Harmonic on multiples of 2 year period
- Polynomial: 3 or 6 terms
- Select those SH terms where the explained variance of the model is greater than 99%
- Most of the TVG information is contained up to degree and order 30 with some resonant bands at higher degree

#### Variance explained model (window 2002-2019)



#### TVG models vs Residuals

RUN	start	stop	Doppler	SLR	TWS	AOD1B	#pars
81	2010.42	2023.09	0.4074	1.273	GR+FO	Y	14
82	2010.42	2023.09	0.4073	1.252	GR+FO	Y	14
83	2010.42	2023.09	0.4081	1.315	GR	Y	11
84	2010.42	2023.09	0.4073	1.268	GR+FO	Y	11
85	2010.42	2023.09	0.4078	1.298	GR+FO	Y	11
86	2010.42	2023.09	0.4058	1.203	N/A	Y	N/A
87	2010.42	2023.09	0.4059	1.222	N/A	Ν	N/A

## External orbit comparisons

RUN	POE	MOE	NAV
81	1.46	1.51	3.44
82	1.49	1.54	3.44
83	1.45	1.51	3.42
84	1.69	1.76	3.56
85	1.47	1.52	3.47
86	1.50	1.53	3.41
87	1.53	1.52	3.41



Mean radial orbit error CryoSat-2, differences to POE orbit

### Empirical accelerations (nm/s<sup>2</sup>)

RUN	Ac	As	Ab	Сс	Cs	Cb	var
81	2.107	1.435	1.317	4.426	5.563	7.715	118.3
82	2.118	1.434	1.316	4.379	5.621	7.692	118.2
83	2.185	1.461	1.317	4.536	5.859	7.735	123.4
84	2.094	1.430	1.318	4.423	5.622	7.697	118.6
85	2.102	1.446	1.318	4.560	5.461	7.764	119.1
86	2.127	1.405	1.315	4.473	5.216	7.806	116.4
87	2.167	1.401	1.317	4.518	5.545	7.855	121.3

# Summary

- ITRF 2020 implementation, for SLR and IDS, also affects the EOPs, New CRD V2 format on SLR data that includes calibration data.
- DORIS residuals in the South Atlantic Anomaly region appear to be correlated with the solar cycle.
- CryoSat-2 POD depends for a part on TVG modelling, need to bridge the 2017-2018.5 GRACE to GRACE-FO transition gap, Ocean/Atmosphere is a separate activity, AOD1B always available, currently in 3 hourly steps
- Cryosphere/Hydrology/Ocean effect comes from GRACE/GRACE-FO, Most combinations of GRACE and GRACE-FO show empirical accelerations compatible with a GRACE only result. How to avoid importing GRACE GRACE-FO noise into the POD
- AOD1B: yes include it, TWS: I'm not all too convinced yet.

### Special issue ASR on DORIS

- Denise Dettmering and Ernst Schrama (we) are ASR guest editors
- 8 papers are accepted in the special issue
- Final wording on the preface, galleys should be there soon.