Satellite Altimetry Over River Basins - Beyond Water Heights

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Context

- Satellite altimetry over land does more than measure inland water heights
- Additional information is encoded in waveforms returned from river catchments
- This paper presents analysis results from a range of targets, focussing on Africa
- Data from ERS1/2, Topex, Jason1/2, Envisat, Cryosat-2 and Sentinel-3A plus River and Lake time series were used

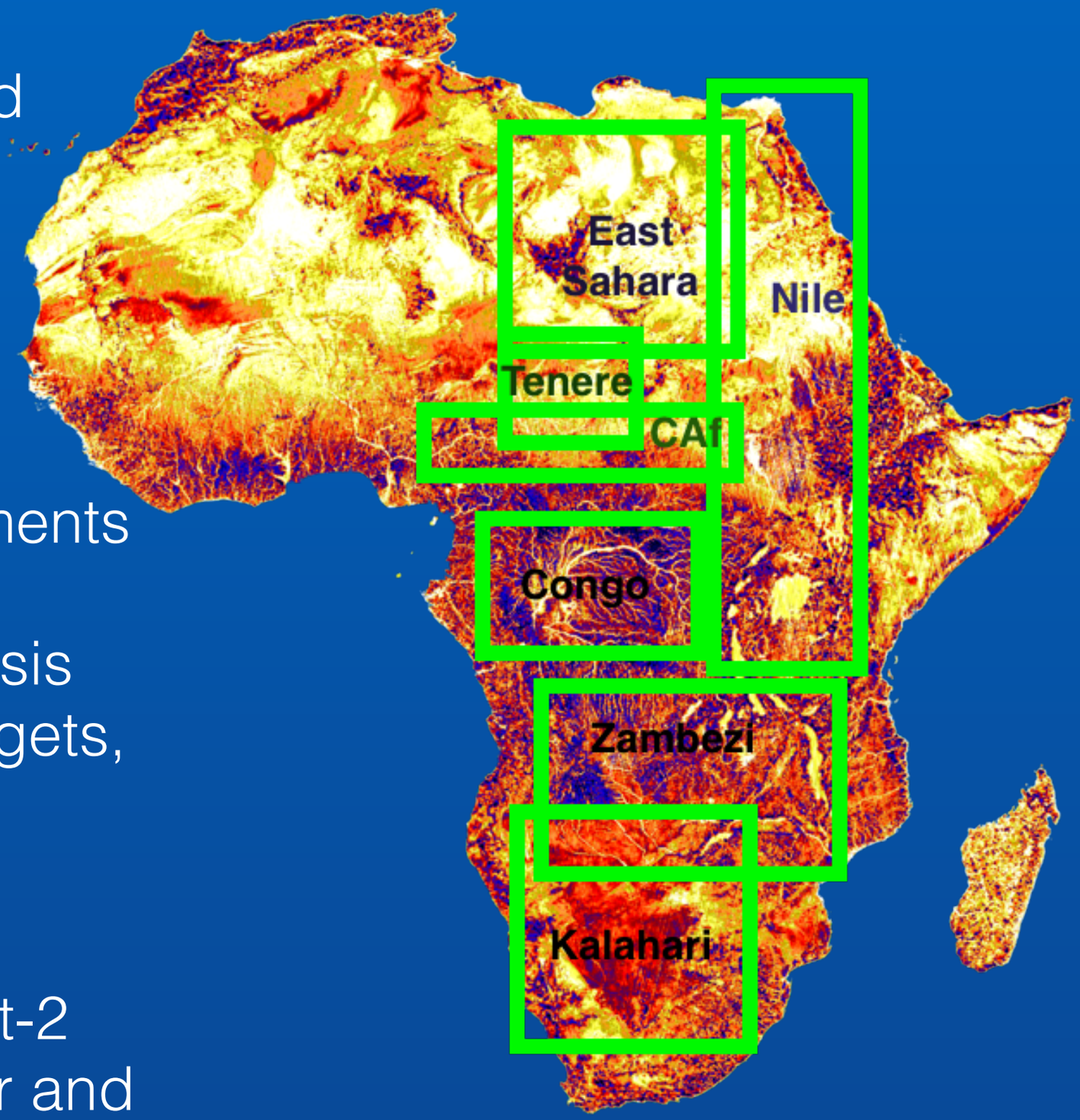
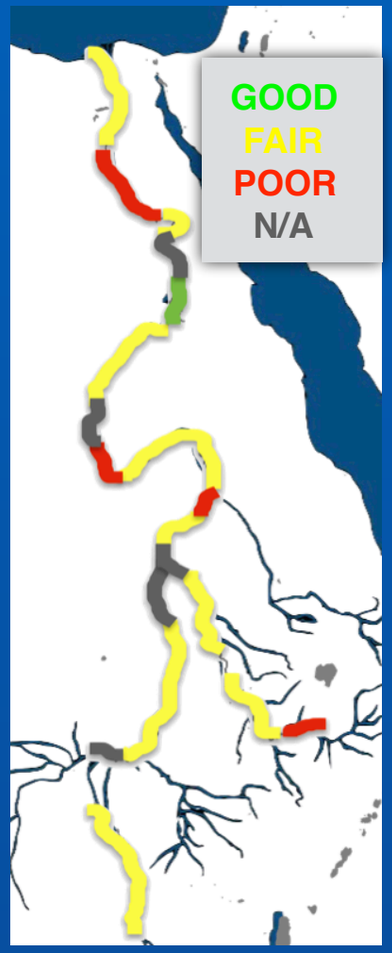


Image shows *resolution reduced* backscatter Mean Earth Model (MEAM) of all Africa illustrating targets featured in this paper

River Systems - NILE

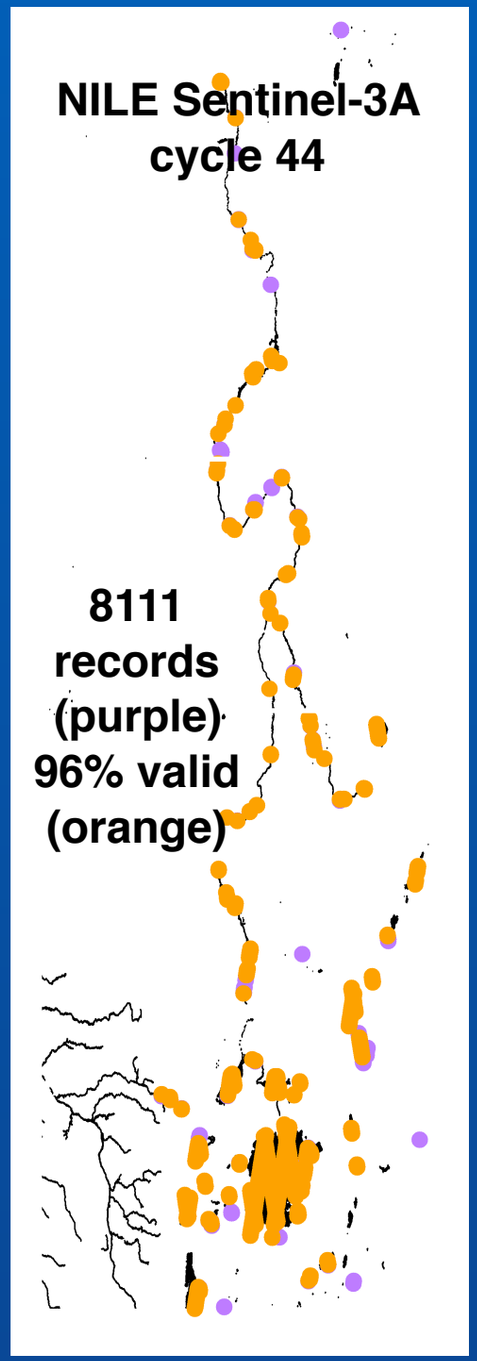
Nile Cryosat-2

Nile Dashboard



Nile ‘dashboard’ shows stylised accessibility map from multi-mission RL time series grading

Sentinel-3A



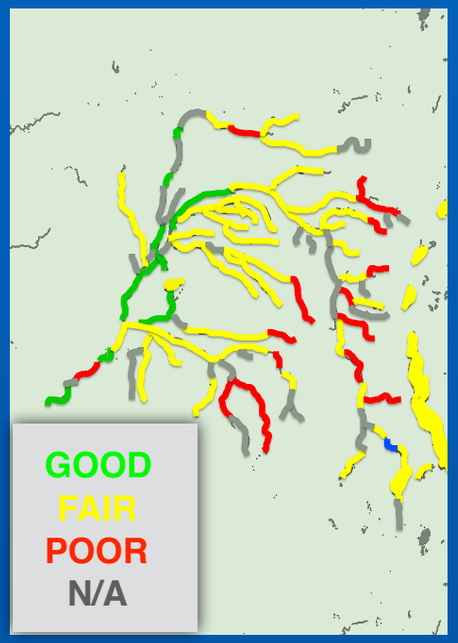
The Nile is a difficult target for radar altimeters primarily due to off-ranging to flooded areas. Waveform characterisation from one cycle of Cryosat-2 data (left) shows some ‘clean’ water echoes throughout system, and a large proportion of off-ranging affected water echoes. Slope affected echoes can also be identified.

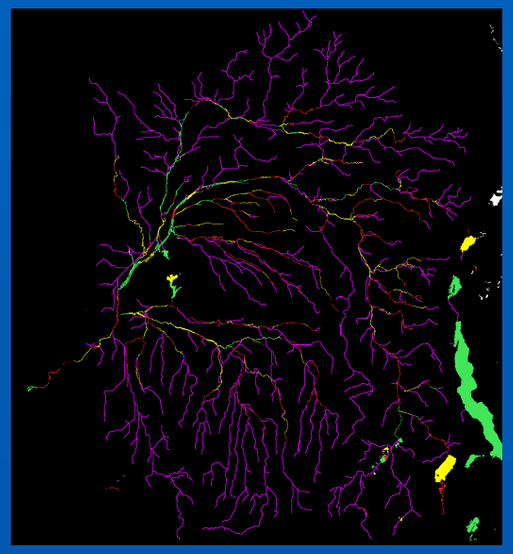
The ‘dashboard’ (centre) shows accessibility assessed from graded RL time series from prior missions.

Sentinel-3A cycle 44 example results (right) show datapoints over Nile. Broad agreement with dashboard is seen, but some missing data where Cryosat-2 succeeded. Three years of data will be required to grade S3A time series.

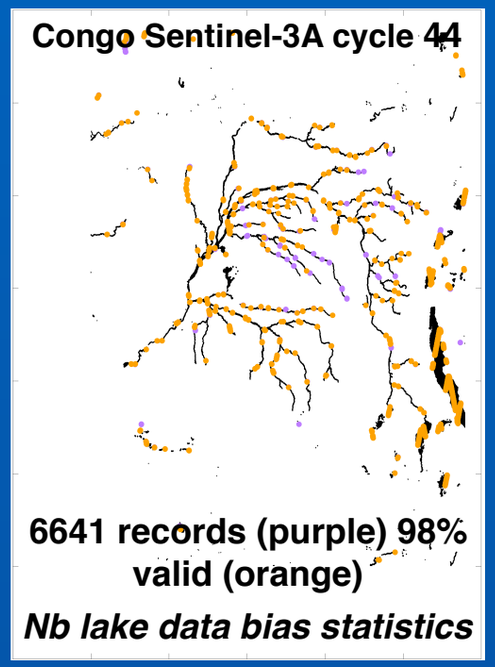
River Systems - Congo

Dashboard RL graphic allows quick assessment of data retrieval from Sentinel-3



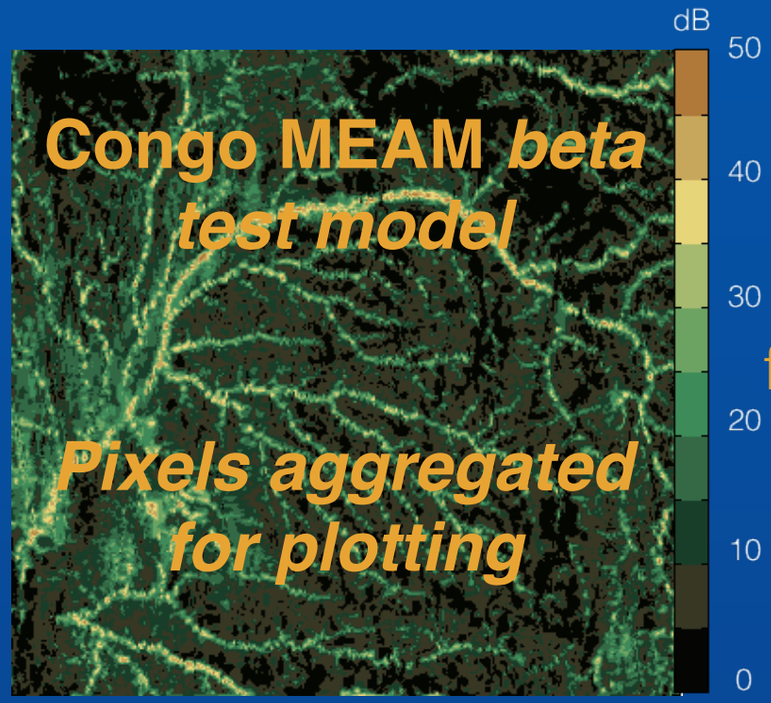


Detailed RL mask shows monitored rivers in context

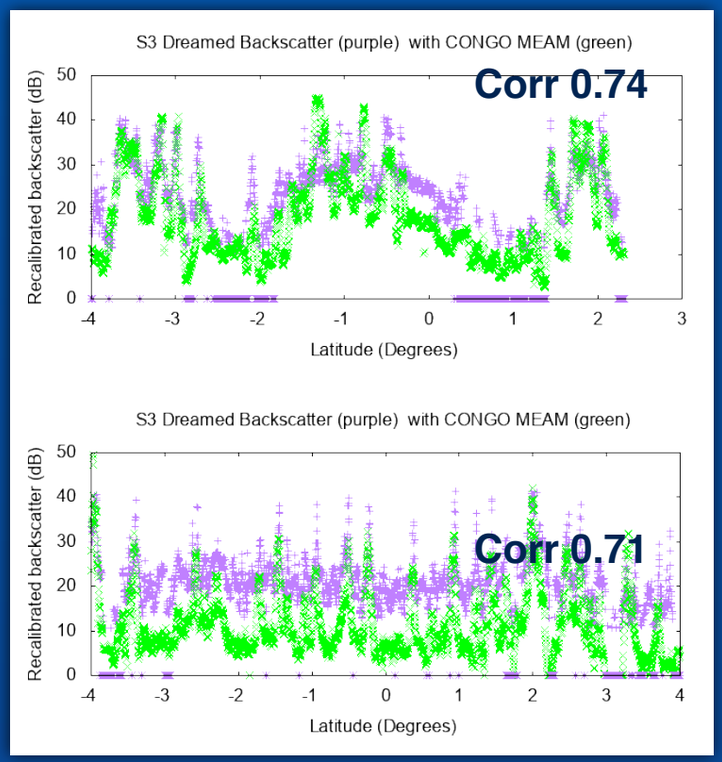


Sentinel-3A data retrieval broadly consistent with dashboard although some 'fair' graded tributaries not acquired

Mean Earth Model (MEAM) of Congo basin shows floodplains and river courses. Beta test model now being finalised. Example Sentinel-3A profiles shown from cycle 44 - 42% of 483088 records valid. Most fail power tests



Sentinel-3A backscatter rescaled to MEAM shows fair agreement - proceed to develop Congo DREAM



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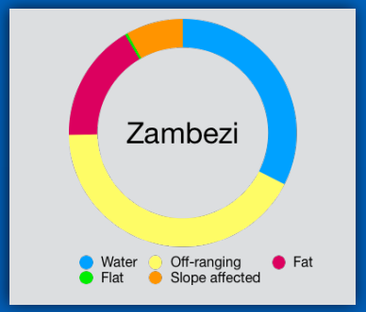
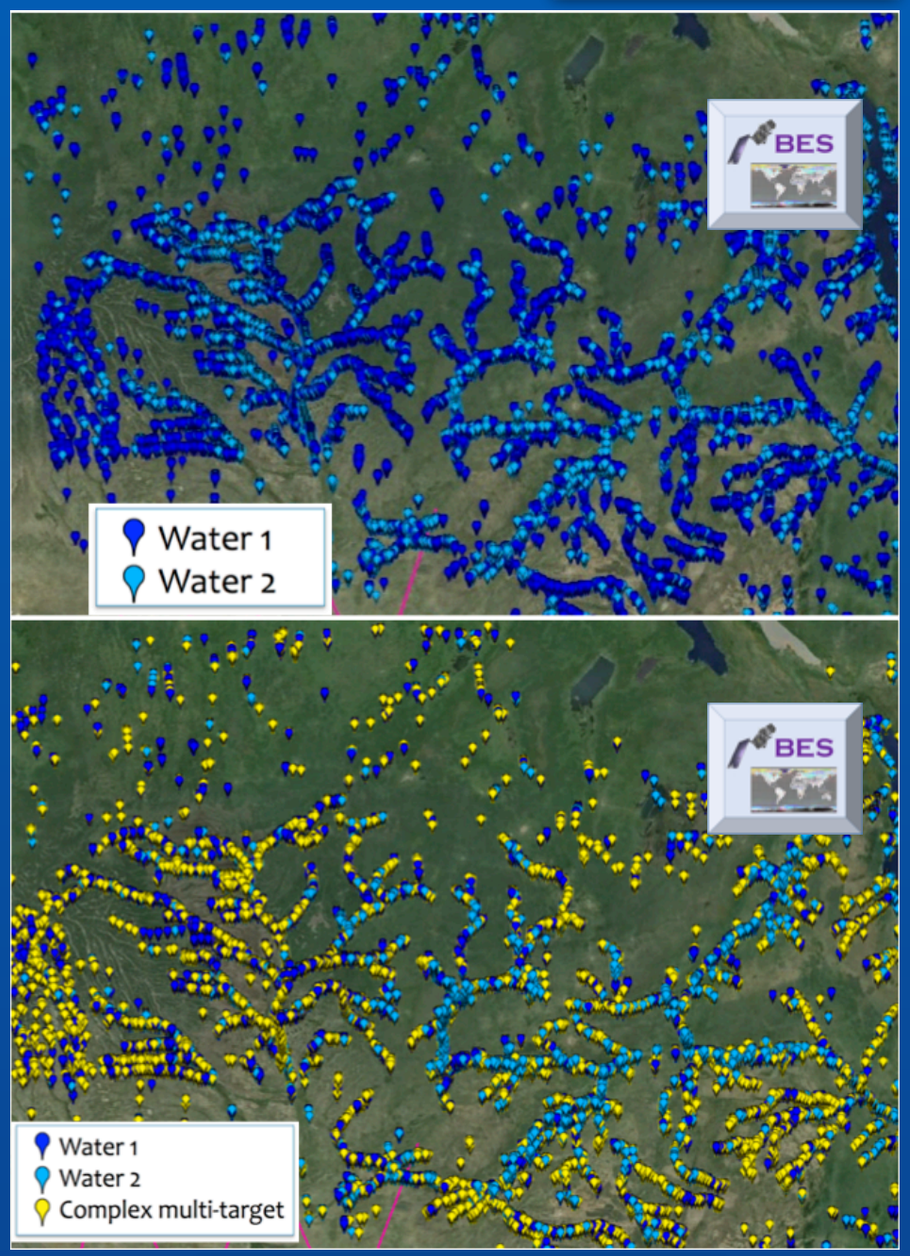
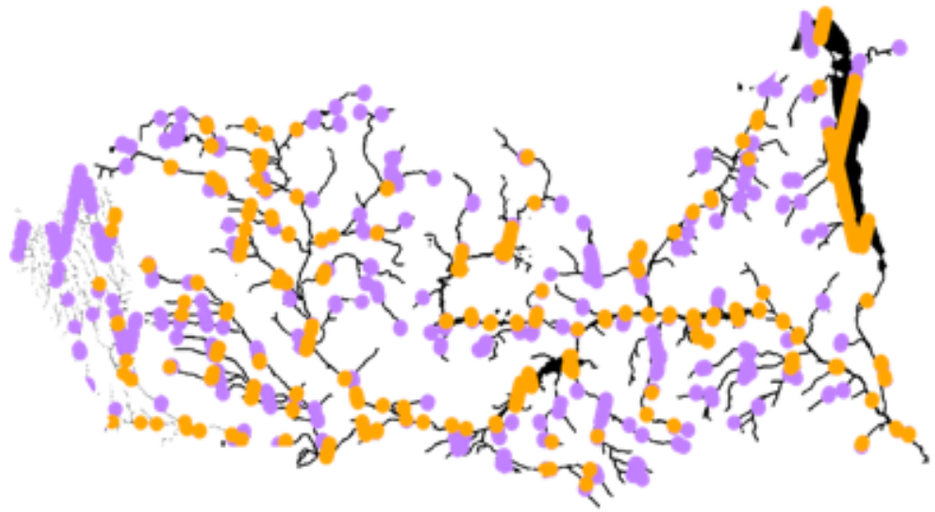
River Systems - Zambezi

Cryosat-2
Waveform characterisation and water echo distribution





Sentinel-3A Cycle 44

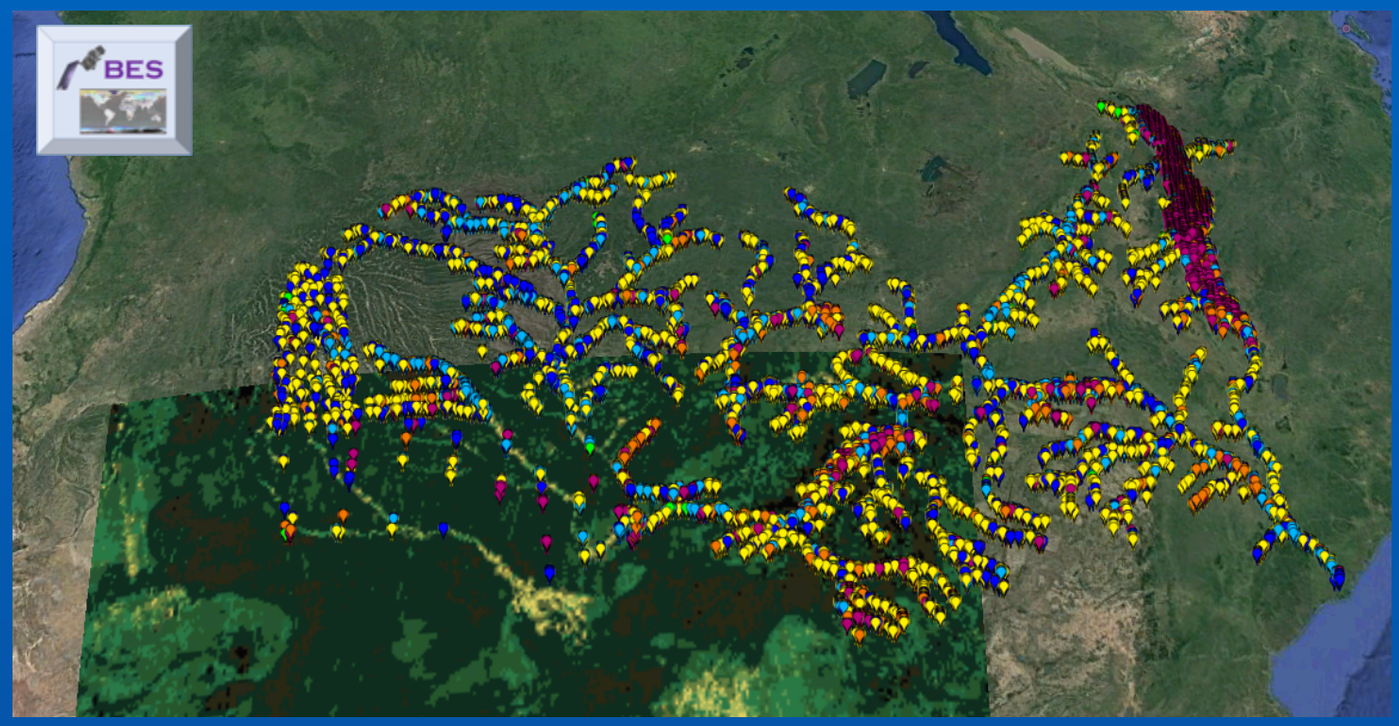


20235 Records (purple) 37% valid (orange)

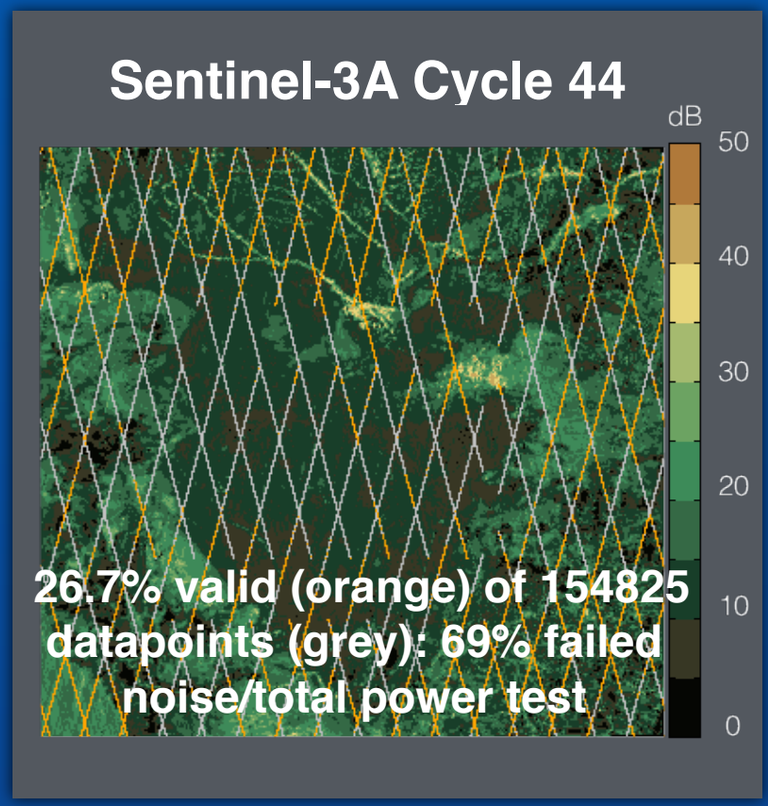
CryoSat2 analysis (left) shows small numbers of ‘clean’ water echoes throughout system (blue) and many complex water echoes with off-ranging components (yellow).

Sentinel-3A data scan of typical cycle 44 (above) shows that in areas where more complex water echoes are returned, altimeter does not retrieve valid waveforms. High proportion of failed echoes on total power and noise power tests, indicating waveforms not successfully captured

Okavango and Zambezi DREAMing



Kalahari Dry Earth Model (DREAM) shows Okavango river, with historical flood event apparent in changed surface texture/composition. DREAM encompasses parts of Zambezi river system (top right) allowing co-temporal soil moisture and river height time series analysis.



Sentinel-3A performs extremely poorly here, in sharp contrast to successful acquisition from prior missions. Example cycle 44 shown (left) Statistics indicate tracking issue.

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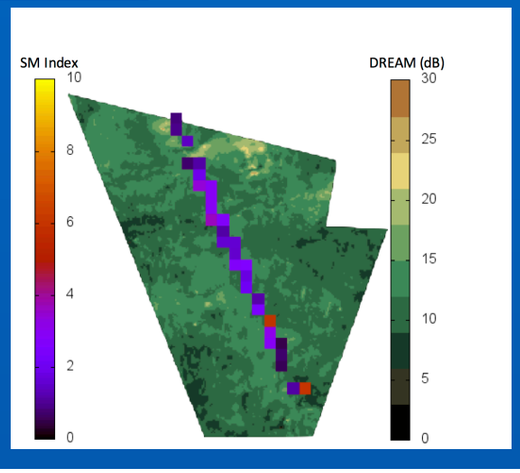
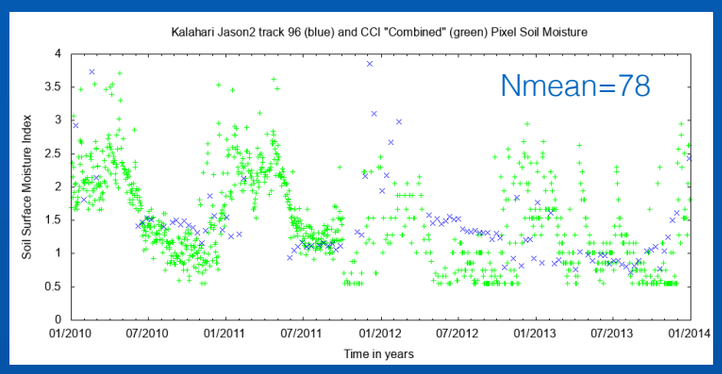
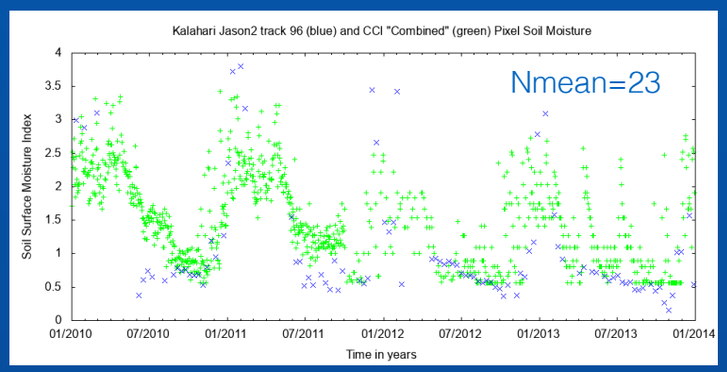
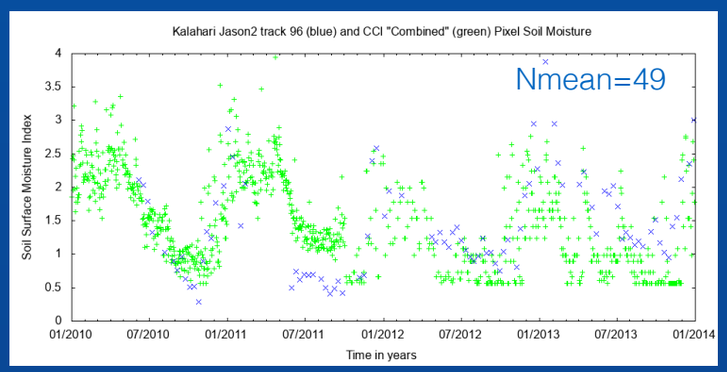
Kalahari DREAMing



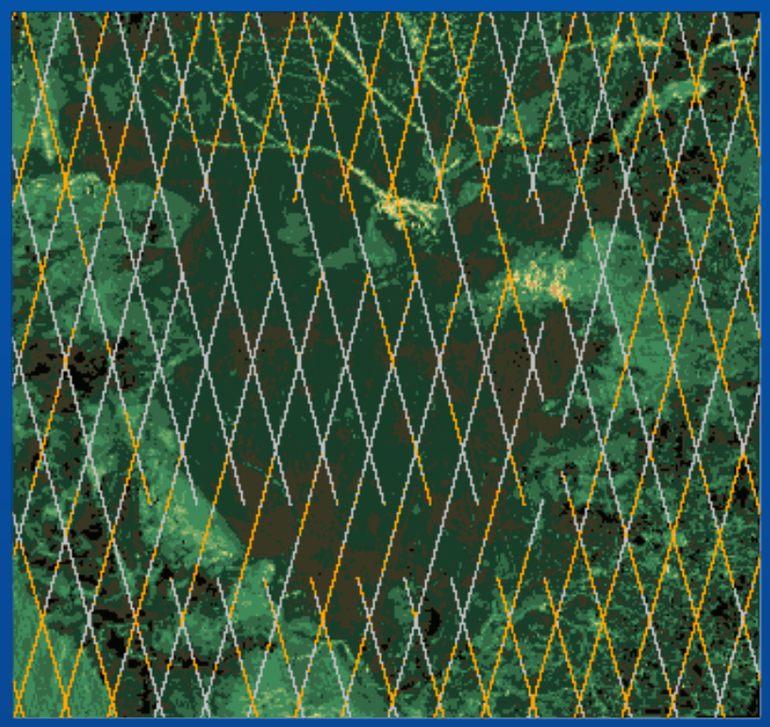






Soil Moisture Example

Jason2 soil moisture estimates were generated, averaged to ESA CCI pixel size for validation (left). Three example time series are shown for adjacent pixels, with average no. of altimeter values used for each pixel. Some missing datapoints - Jason2 is not an optimal altimeter for this application (problem handling high echo power). Altimeter measures surface soil moisture (top 5cms). Fair agreement with ESA CCI values.



Sentinel-3A is not successful in retrieving data over Kalahari desert (previous slide).

Unusable; soil moisture time series from ERS-2, Envisat, Jason1/2 and Cryosat-2 cannot be continued with Sentinel-3A

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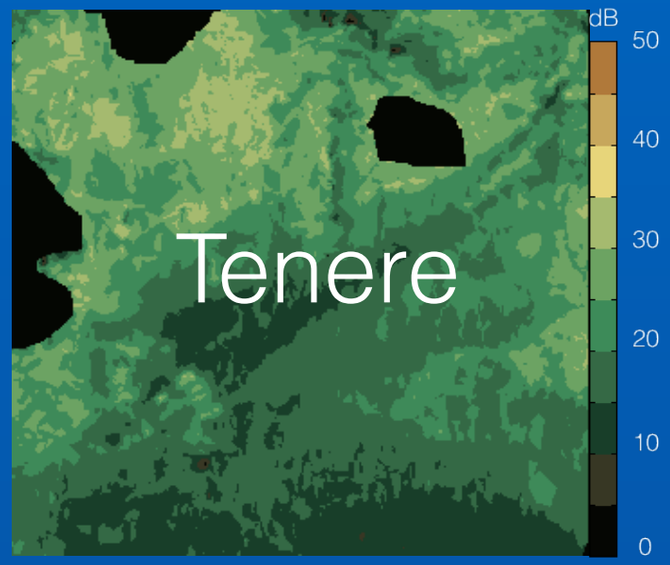
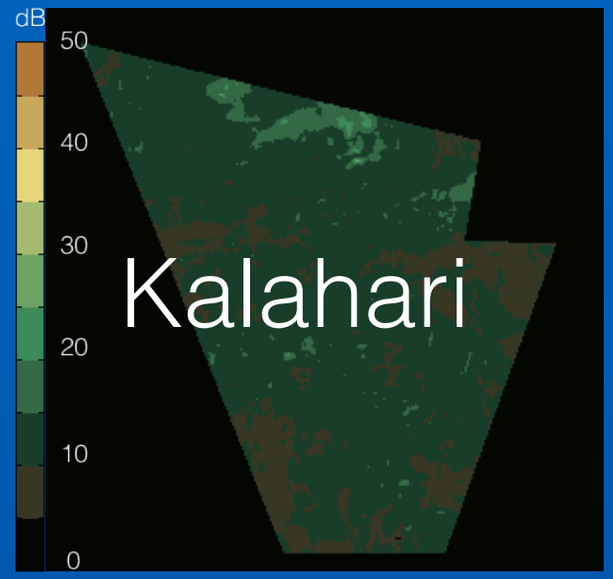
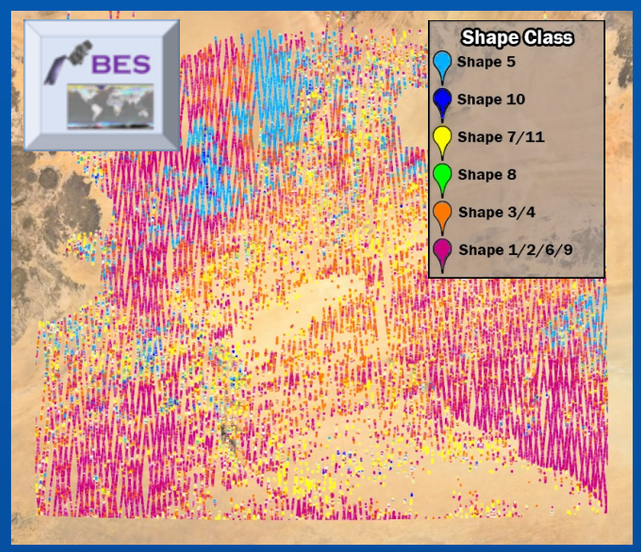
DREAMing with Cryosat-2

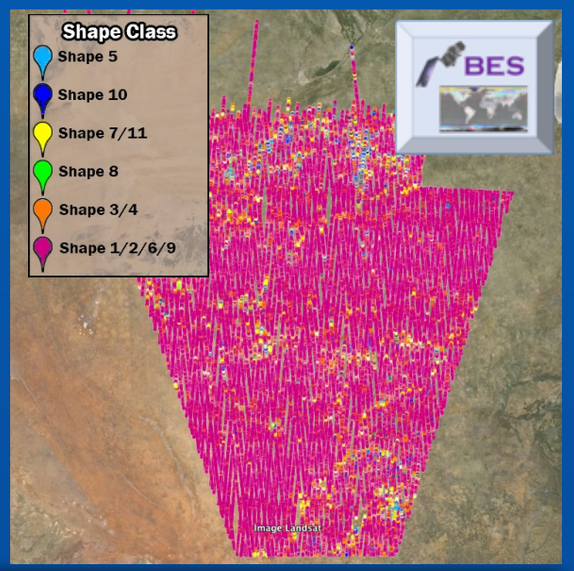


Africa DREAM 'calibration targets' of Tenere (left) and Kalahari (right) plus Australia calibration targets are used to derive the scale factor to DREAMs for soil moisture retrieval
Black areas are masked off (rough terrain, salt pans etc.)

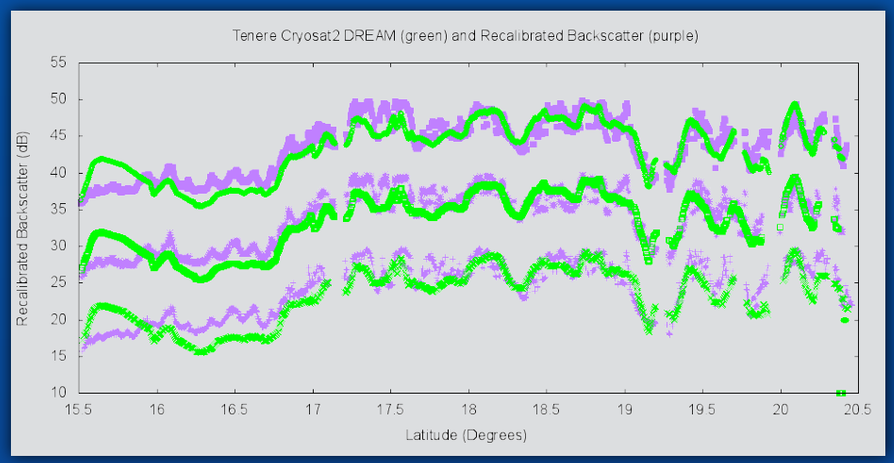




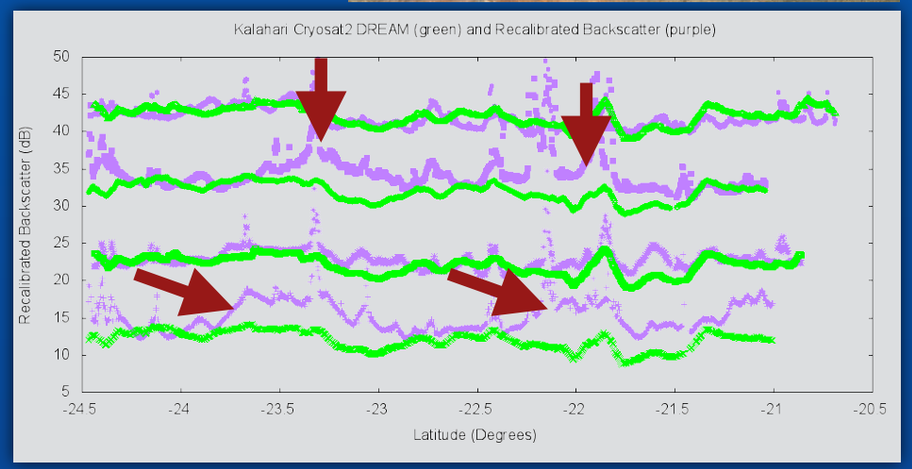
Cryosat-2 LRM waveform shapes show patterns related to surface texture, composition and roughness.



Example backscatter profiles (scaled to DREAM for soil moisture retrieval) agree well.



Kalahari profiles show soil moisture signatures (arrows)



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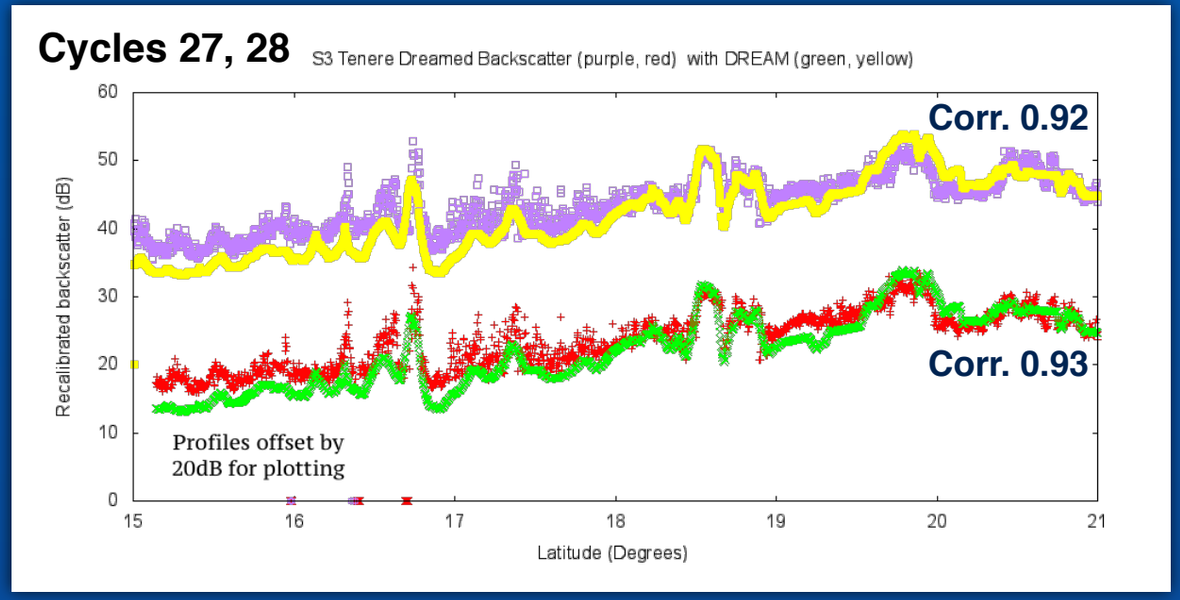
Africa Sentinel-3A DREAMing

S3A over East Sahara DREAM - cycle 44 total power/noise power test fail 82%

S3A over Central Africa DREAM - cycle 44 most failed total power/noise power test or no leading edge

African targets assessment - example cycle 44. EXTREMELY POOR acquisition over Kalahari, Tenere, East Sahara, and poor over Central Africa DREAMs. All these targets were well acquired by prior missions. Tenere was well sampled in Sentinel-3A early cycles (below). Tracker programming is assumed to be the reason for catastrophically poor data acquisition over DREAM regions



Cycles 27 & 28, good coverage over all Tenere, and excellent agreement of recalibrated backscatter with DREAM over entire DREAM (Corr. >0.9).

Conclusions

- Surface moisture, texture and roughness information is encoded in waveform shapes
- Building DREAMs/MEAMs allows access to soil moisture information even through dense vegetation canopy
- Most river basins and DREAM regions are accessible to multiple altimeter missions
- Sentinel-3 SRAL instruments have greater capability with increased along-track sampling BUT Sentinel-3A retrieves little data over many African river, wetland and desert targets due to current tracker programming. Focussed on a tiny number of large river basins, this strategy sacrifices new application potential and destroys long-period inland water and soil moisture time series for a small number of current ‘priorities’

- NEXT STEPS: Progress beta test MEAMs to DREAMs over more of Africa; build 25 year surface moisture time series over catchment basins from prior missions. Sentinel-3A currently unavailable over most DREAMs/MEAMs in Africa so focus on other missions

The authors wish to thank Robert Balmbra for his assistance in migrating code to new processors