Starlab Space

WP 6: Applications of new GMES data in value adding land services

LOTUS – RV4, Brussels
04/02/2016

Starlab Living Science

WP6 – Objectives and Applications

Objectives

- O1: Development new and improved land services by utilizing the data features emerging from Sentinel-3
- O2: Services global applicability and demonstration in selected case study regions

Targeting following applications:

- Monitoring **river and lake levels**: Agriculture & hydrology
- Monitoring **snow depth**: Hydrology & SWE
- Monitoring **soil moisture**: Agriculture & hydrology

WP6 – List of Activities and Outputs

List of activities:

- Task 6.1: Monitoring river and Lake levels
- Task 6.2: Monitoring snow depth
- Task 6.3: Monitoring soil moisture
- Task 6.4: Hydrological modelling and data assimilation

Expected outputs

- D6.1 Lake and river level monitoring service [Starlab, CLS] – M30
  - Deliverable **submitted**

- D6.2: Snow depth monitoring service [Starlab] – M33
  - Deliverable submitted and **accepted**

- D6.3: Soil moisture monitoring service [Starlab, UNEW] – M33
  - Deliverable **submitted**

- D6.4: Prototype modelling and data assimilation system [DHI] – M33
  - Deliverable **submitted**

- D6.5: Demonstration of water resources management services for selected basins [DHI] – M36
  - Deliverable **submitted**

WP6 General Overview

- **Timing**: M20 → M36

Activity	Starlab	DTU	DHI	UNEW	CLS
6.1 Def river & Lakes	X + Coord	X			X
6.2 Def. Snow depth	X + Coord				
6.3 Def. Soil Moisture	X + Coord			X	
6.4 Prot. mod. and data assimilation system		X	X (+Coord)		
6.5 Demonstration		X	X		
Total PM to contribute	9.5	6	10	3	4

Task 6.1 Monitoring river and lakes level [STARLAB, CLS]

- **Timing**: M20 → M30

- **Objective**: Definition of a downstream service capable to monitor river and lake levels

- **Activities**:
  - (a) Service definition

- **Expected Output**:
  - D6.1 Rivers and Lakes monitoring services

Task 6.2 Monitoring snow depth [STARLAB]

- **Timing**: M20 → M33

- **Objective**: Definition of a downstream service capable to monitor snow depth

- **Activities**:
  - (a) Service definition

- **Expected Output**:
  - D6.2 Snow depth monitoring services

User needs and requirements

Weather and climate

- Useful for surface irradiative exchange and heat transfer investigations for climate studies

→ **Historical data and global coverage**

Water Resources

- Monitoring snow depth to estimate snow water equivalent (SWE) and the availability of water during snowmelt for hydrological companies

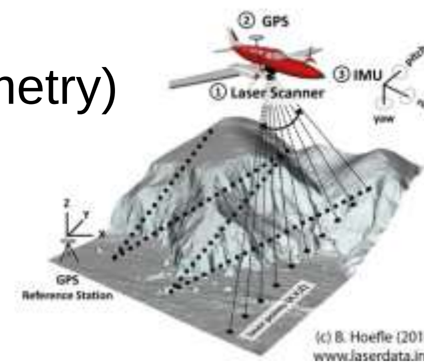
→ **Accurate measurements**

	Minimum requirements
Temporal resolution	10 days
Spatial resolution	100 meters
Accuracy	0.1 meter
Coverage	Local scale

Review of the state of the art technologies

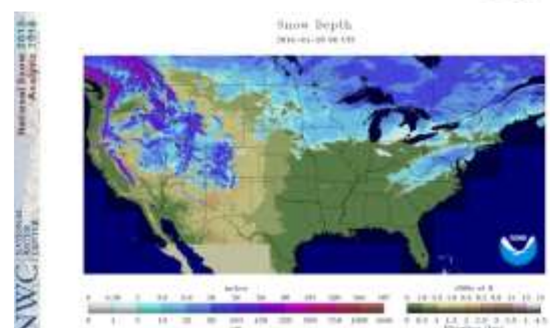
Snow ruler (Human reading of snow depth)
•Accurate measurements
•Only in accessible areas
•Impossible in hard weather

Ultrasonic ranging system (On site remote sensing)
•Wide beam
•Good range
•Low-cost ultrasonic sensors



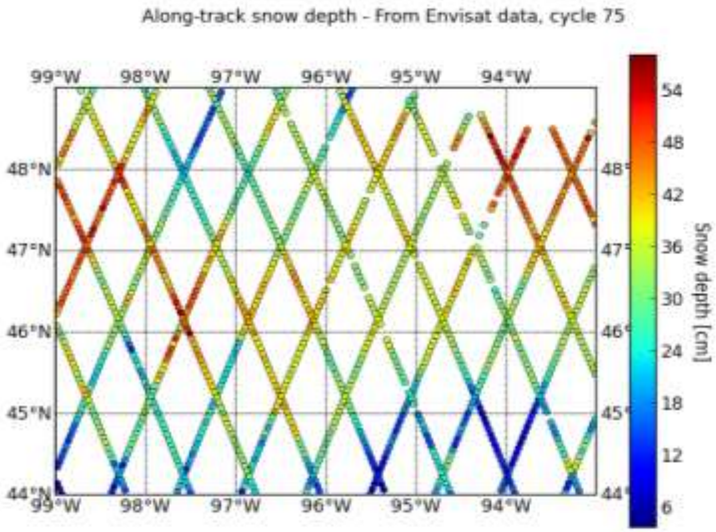
Airborne laser scanning (flying campaigns using lidar altimetry)
•Two phase campaigns (elevation change)
•Only for study campaigns – Not for repetitive acquisitions
•Local acquisitions

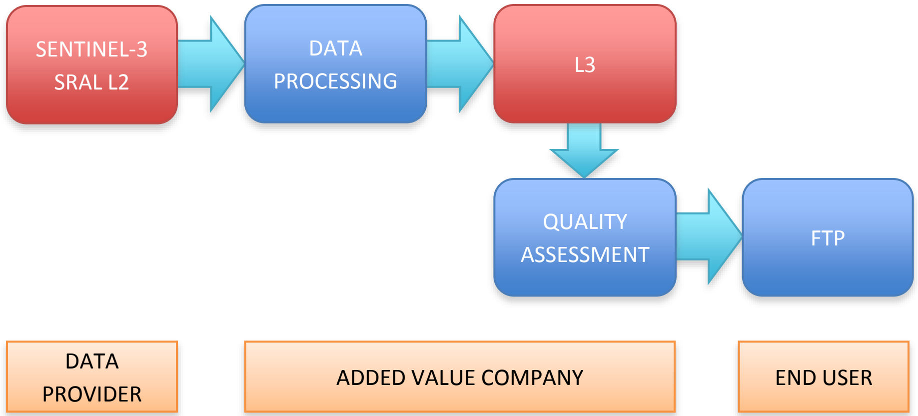
Statistical models
•Mostly based on human snow depth measurements
•Several inputs from different sources required
•Only at local scale



Task 6.2 Monitoring snow depth [STARLAB]

Snow depth Service:





- Provide with snow depth products
- Snow depth along track products

Delivery format	Network Common Data Format – Climate and Forecast metadata conventions (NetCDF CF 1.6)
Inputs needed to elaborate the product	Sentinel-3 – SRAL Level 2 Enhanced – 20 Hz Ku band SAR mode
Geographical coverage	Global coverage, -81.5N – 81.5N
Time coverage	Daily product
Geographic projection - Coordinate reference system	Along-track product - Latitude/Longitude coordinates

Task 6.3 Monitoring soil moisture [UNEW, STARLAB]

- **Timing**: M20 → M33
- **Objective**: Definition of a downstream service capable to monitor soil moisture
- **Activities**:
  - (a) Service definition
- **Expected Output**:
  - D6.3 Soil moisture monitoring services

User needs and requirements

- **Importance of global measurement of soil moisture** has been recognized by **ESA** with the successful SMOS mission (ESA SMOS) and by **NASA** with the forthcoming SMAP mission (NASA SMAP).
- Soil moisture was recognized as an **Essential Climate Variable** (ECV) in 2010.

Water Resources

- Monitoring soil moisture conditions for protection and understanding of local and regional water resources.

  → **High spatial resolution at local scale**

Agriculture

- Monitoring soil moisture for optimized crop irrigation to protect from runoff, save costs (resources, energy, fertilizer) and increase farm profitability.

  → **High spatial and temporal resolution**

Weather and climate

- Needed for temperature and precipitation forecasts

  → **Near Real Time information**

Disasters/floods and Hazards

- Prevent and forecasting of floods

  → **Historical data and Near real time information**

	Minimum requirements
Temporal resolution	10 days
Spatial resolution	100 meters
Accuracy	1 % on soil moisture content
Coverage	Local scale

Soil moisture state of the art – In situ

Frequency Domain Reflectometry (FDR) Sensors (Propagation an electromagnetic signal through a metal line or other waveguide – Difference between input and output wave frequencies)

- Fast response, standard connections
- Need good contact between sensors and soil
- Relatively inexpensive

Time Domain Reflectometry (TDR) Sensors (Propagation of a pulse down a line into the soil – Time duration of two-way propagation)

- Very high accuracy
- Repeat measurements needed for high accuracy
- Expensive

Capacitance Sensors (FDR sensor with single frequency)

- Less accurate than FDR and TDR
- Very Cheap, easy integration with data loggers and wireless system

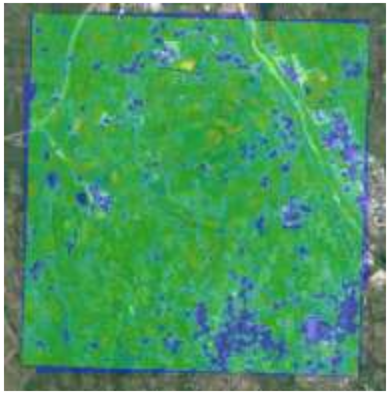
  → Very used – Accurate enough for desired application

Soil moisture state of the art – Remote sensing - SAR

- **Microwave radiation backscattered** from sparsely vegetated surfaces is related to:
  - Dielectric properties of the illuminated area
  - Surface characteristics (roughness, topographic conditions)
  - Instrument characteristics

- Soil's **dielectric constant** is highly dependent on soil moisture:
  - Typical dielectric constant of dry soil: around 3
  - Typical dielectric constant of water: around 80

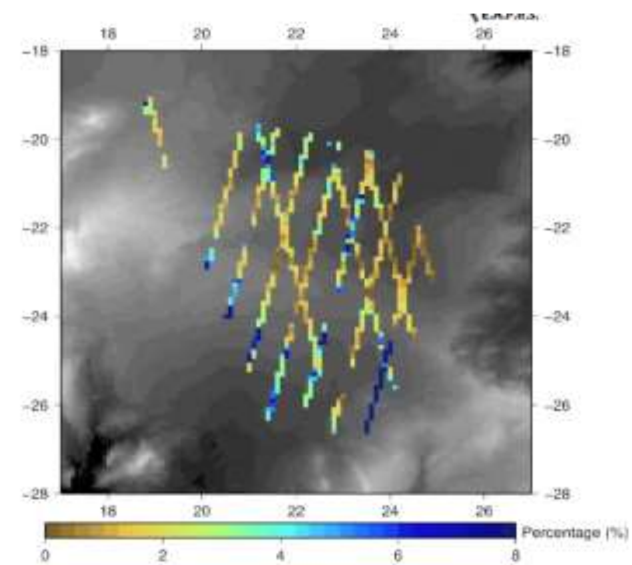
- **Modelling**
  - **Theoretical** models → able to represent the backscattering variations due to changes in soil moisture content, surface roughness, and vegetation attenuation
  - **Empirical** models → more useful and robust to estimate soil moisture **operationally**

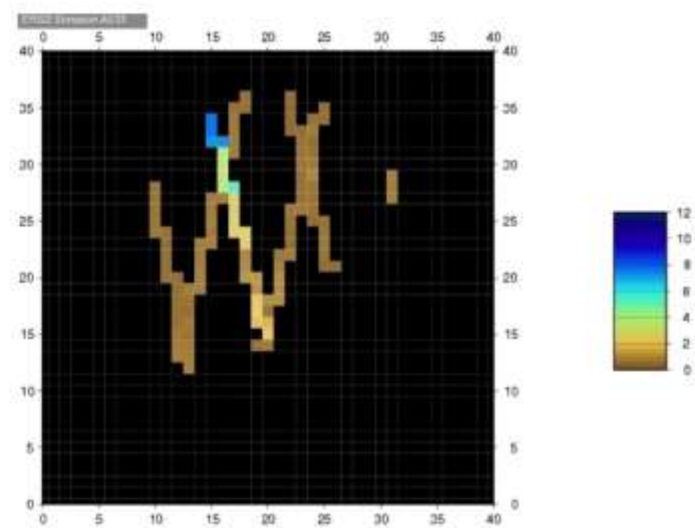


Soil moisture maps from SAR (Sentinel-1)

Soil moisture state of the art (Technology) - Remote sensing – Altimeter

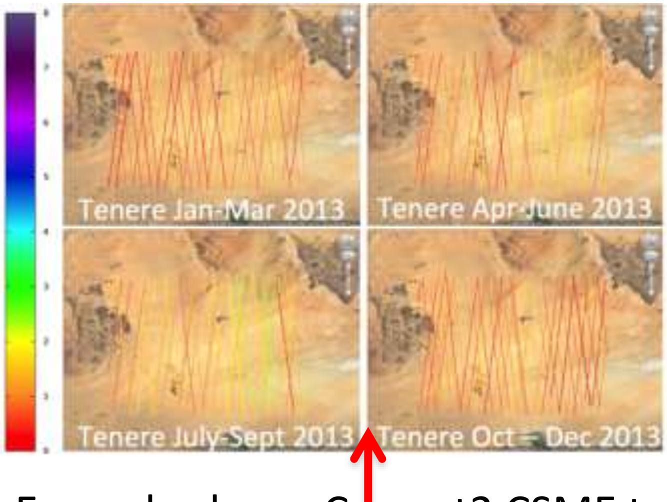
- Soil moisture from satellite altimetry is a recent and rapidly evolving application
  - Surface brightens when wet, backscatter increases. Hence get soil moisture.
  - backscatter changes rapidly with surface roughness and composition so can't just use repeat arcs.
- Concept study ESA SMALT project (2012-2014) using detailed Dry Earth Models (DREAMS) to capture this variation: need dry surface for 1-2 months so DREAM building to date in desert and semi-arid terrain
- SMALT Jason2 soil moisture products only created over Tenere and these data found to be erroneous. SMALT ERS2 product plots for one cycle for Kalahari (below left, scale in degrees) and Simpson desert (below right, 4 x 4 degrees, scale in pixels) show extent of along-track 'pixels' over which each averaged soil moisture estimate was made





Product definition

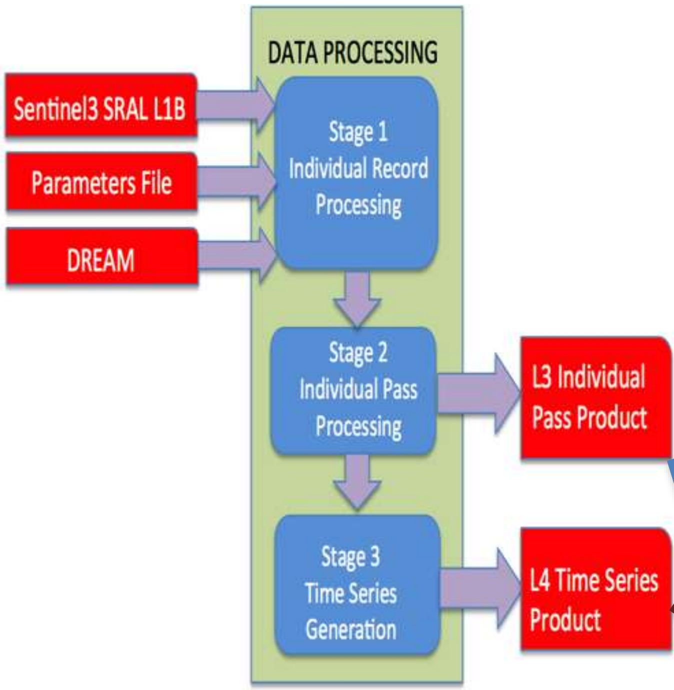
- User community has requirement for time series.
- Altimeter makes measurements along-track (below left are CSME products over Tenere for validation year as track averaged soil moisture estimates)
- Much finer spatial sampling as 'pixels' along-track confirmed possible for Sentinel3 from Cryosat2 work
  - 18" (0.005 degrees) Simpson
  - 27" (0.0075 degrees) other desert regions
- This gives finer along-track resolution than other remote sensing products



Example shows Cryosat2 CSME track-based products over Tenere: now being redone reducing pixel size from 'track' towards 0.0027 degrees

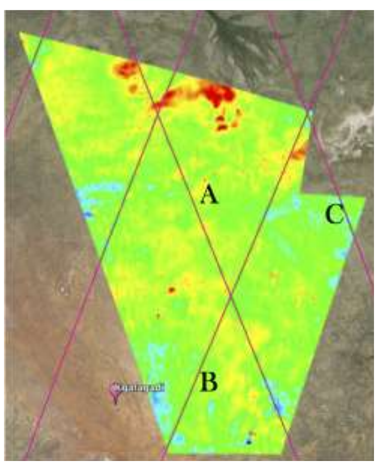
- L3 product as individual 'pixel averages' **along-track** so:
  - multiple values for each track
  - Each record holds pixel lat, long, time, soil moisture values plus statistical information
- L4 product for Sentinel3 as **timeseries** for pixels
  - Lat/Long information in header
  - Pixel time, soil moisture and statistical information for time series
  - Separate product for each pixel along-track

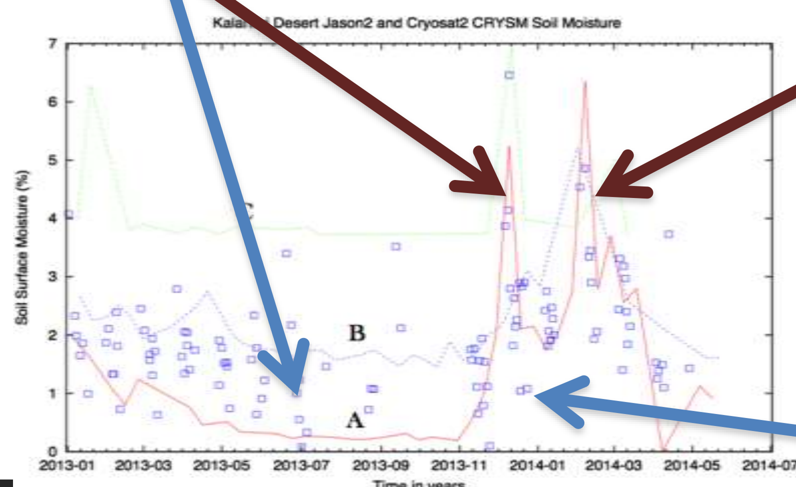
Global architecture of the service



3 stages of processing

- Input SRAL L1B records processed to individual soil moisture estimates. These too noisy for release
- Soil moisture estimates created for 'pixels' along-track; output as along-track sequence as L3 products (blue dots below)
- Time series generation from multiple repeat passes for each pixel as L4 products (red, green, blue lines below)
- Example from Cryosat2 validation shows Kalahari DREAM with Jason2 track locations ((left) individual CSME estimates and Jason2 timeseries (right)





Here, LOTUS L4 track averaged soil moisture time series from Jason2 repeat arcs over Kalahari DREAM (A, B, C) shown with L3 geographically dispersed **Cryosat2 track averages (blue)** for validation year

Service inputs / service outputs

Inputs:

- Sentinel3 SRAL L1B data
- Re-crafted DREAMs (filtered and fused with extensive ground truth to enhance high frequency modelling)
- Parameters file holding calibration outcomes

Outputs:

•L3: ‘Pixel-based’ soil moisture estimates along-track

•L4: Time series for each ‘pixel’

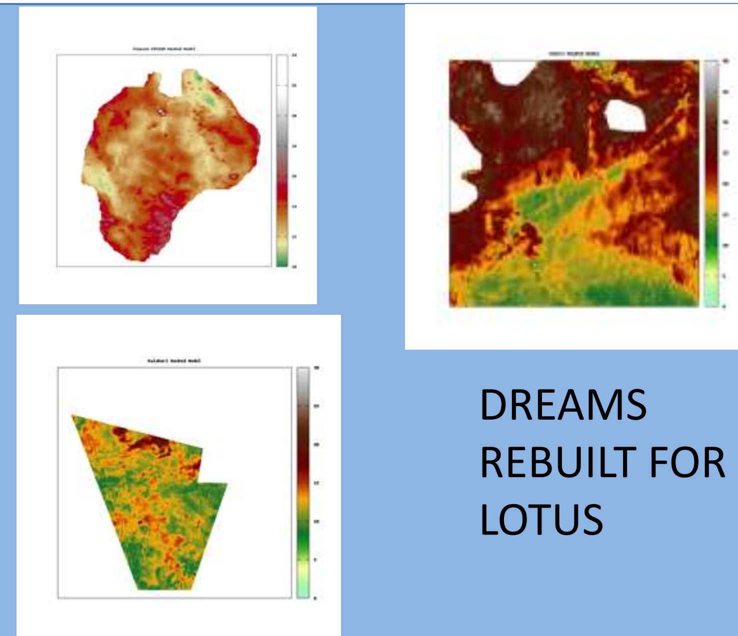
DREAM CRAFTING

Completed for LOTUS: Simpson, Tenere, Kalahari

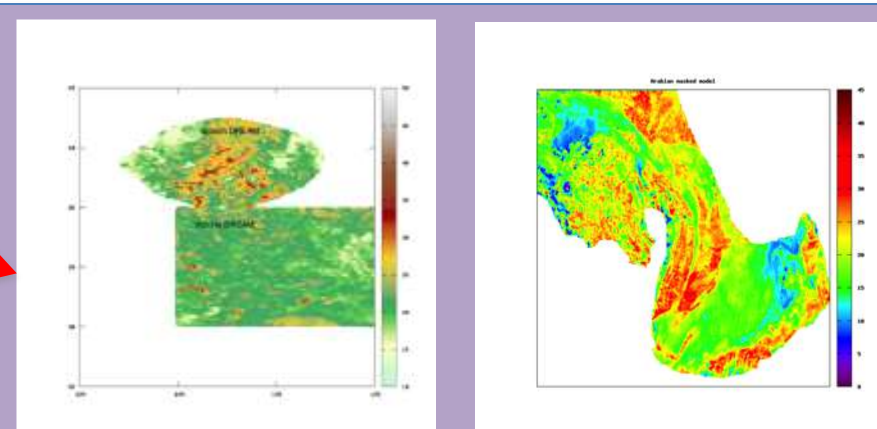
Existing DREAMS, re-crafting underway for Sentinel3: Victoria, Gibson, Arabian

Currently building: most of Sahara as individual desert areas

Then wetter areas with third party data…

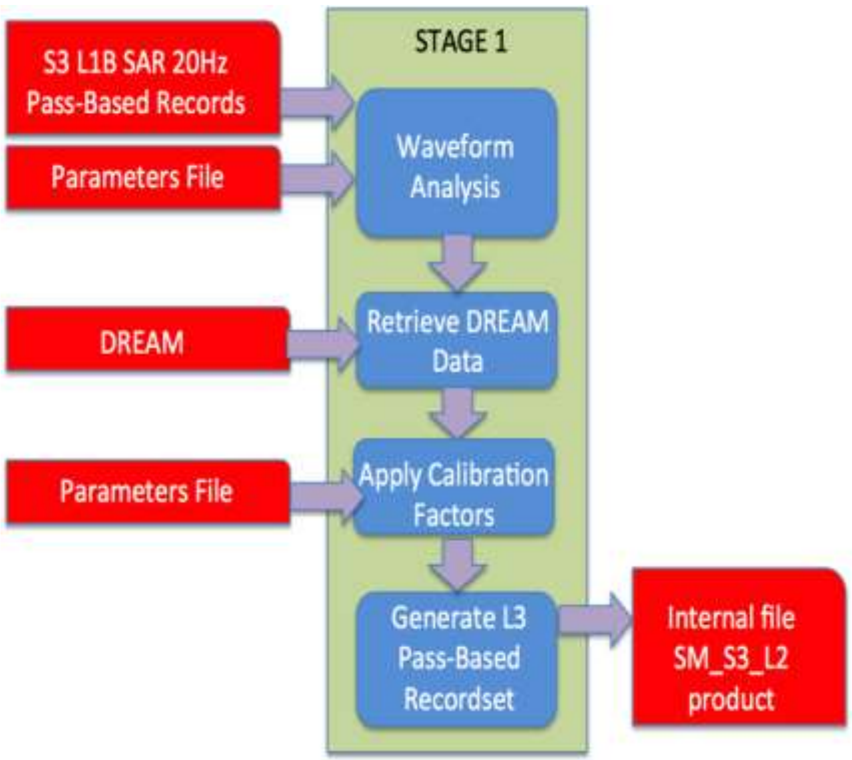


DREAMS REBUILT FOR LOTUS

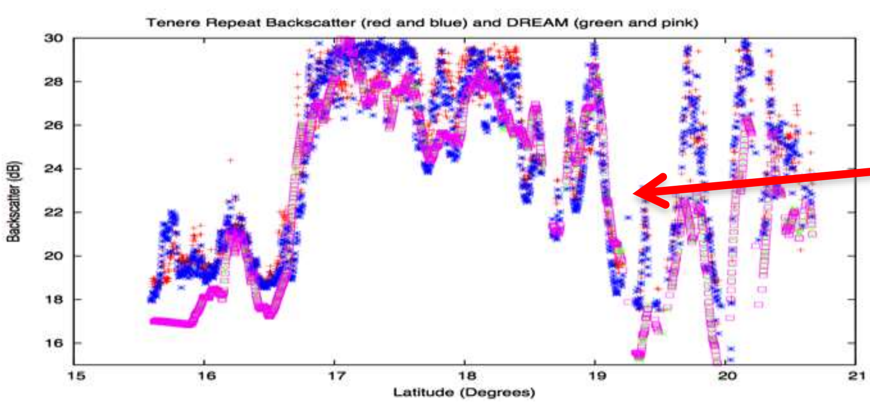


DREAMS BEING REBUILT FOR SENTINEL3

Stage 1 Processing

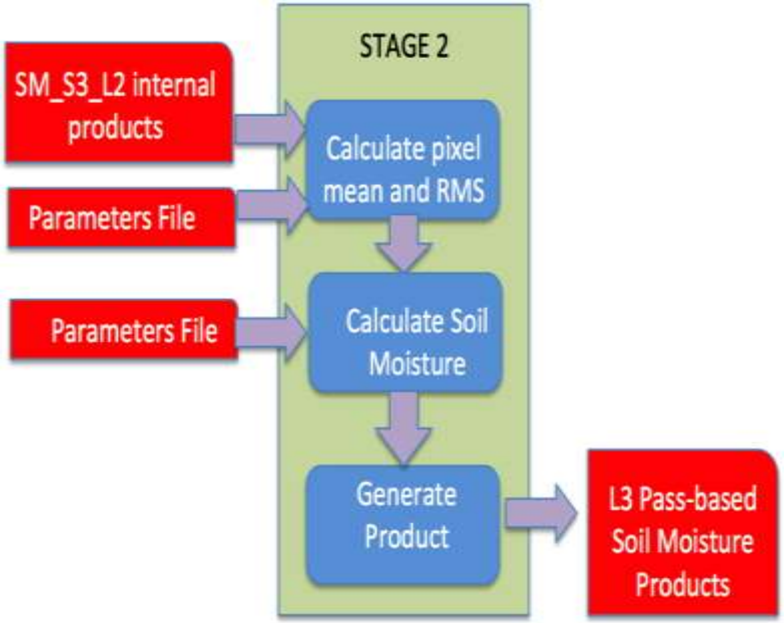


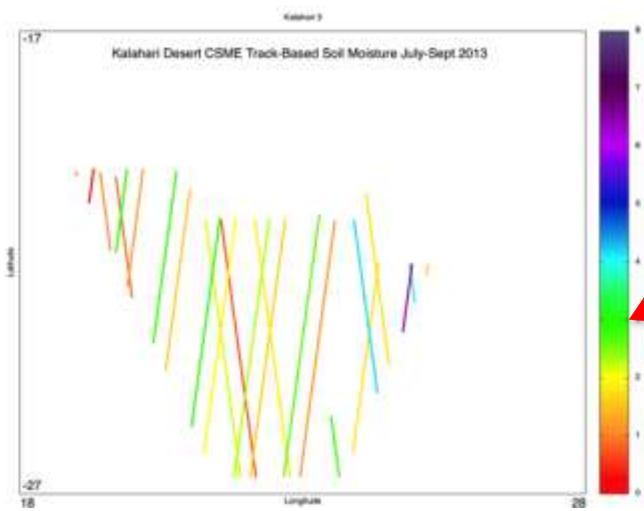
- Analyse waveform shapes, recalculate backscatter
- Get underlying DREAM value
- Apply cross-calibration factors
- Generate pass-based record set



Example shows internal files: 2 repeats of a Cryosat2 pass over Tenere with underlying DREAM pixels

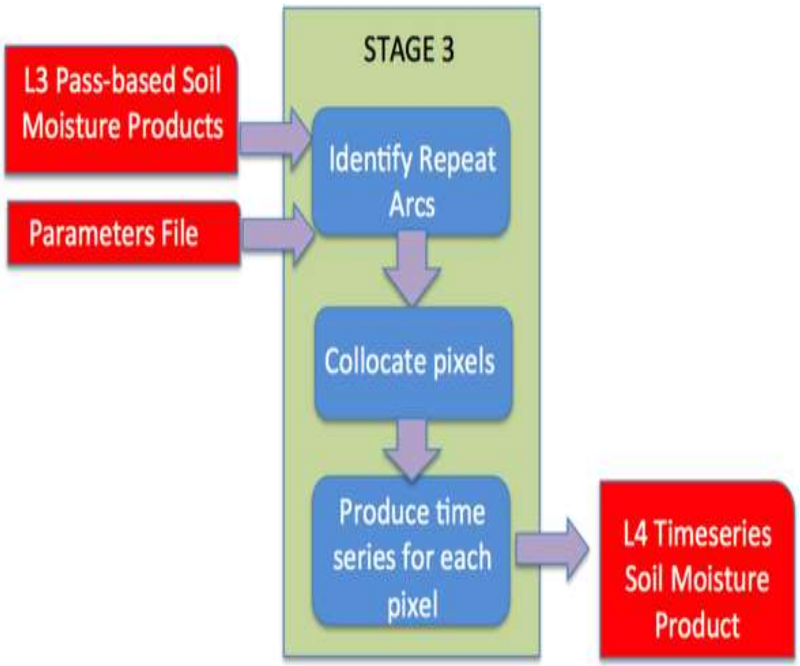
Stage 2 Processing





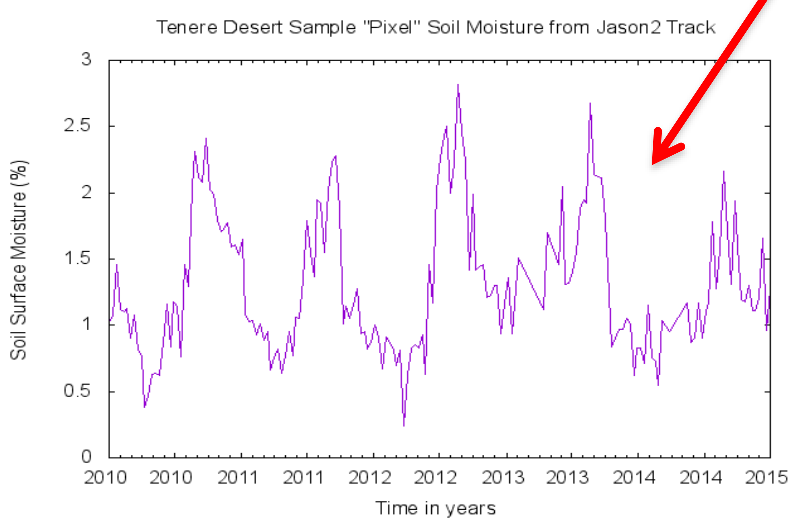
- Subtract DREAM from point backscatter
- merge points to pixel averages, calculate statistics for each pixel
- Calculate soil moisture for pixel
- Generate product for each pixel along the track
- Example shows track based (single pixel) CSME products over Kalahari

Stage 3 Processing



- Identify repeat arcs
- check lat/long locations to identify corresponding pixels from repeat cycles
- Form time series

Example shows pixel-based soil moisture timeseries over Tenere from Jason2



These now being generated for extended period towards Sentinel3 validation

Task 6.4 Hydrological modelling and data assimilation [DTU, DHI]

- **Timing**: M20 → M33
- **Objective**: Development of hydrological models and data assimilation
- **Activities**:
  - (a) Development of a hydrological modelling approach
  - (b) Development of assimilation approaches in the hydrological modelling system
  - (c) Case study application in selected basins
  - (d) Assessment of the hydrological modelling and data assimilation approach and comparison of this result to the conventional hydrological model output.
- **Expected Outputs**:
  - D6.4 Prototype modelling and data assimilation system
  - D6.5 Demonstration of water resources management services for selected basins

Thank you for your attention