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TAKING THE PULSE OF OUR PLANET FROM SPACE

Tributary reactivation of ephemeral river by groundwater rise: monitoring the Kuiseb River in Namibia from Sentinel missions

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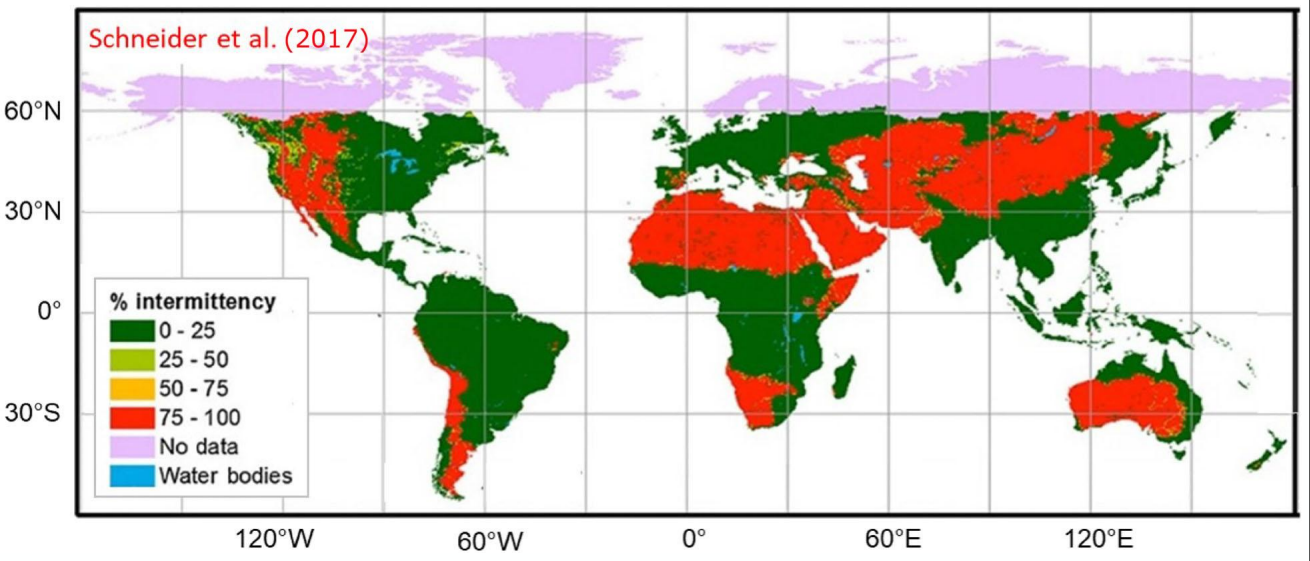
Introduction - *Context*

- **Arid/semi-arid environment:**
  - 41% of the Earth surface, 1/3 of the world population
  - Water resources: rainfall, fog, dew and **ephemeral rivers**
    - **Increase of ephemeral rivers in the world : climate change**
    - River discharges <10 % of the year, water flow from few hours to few days
    - **Water losses :** infiltration, evaporation, recharging, pumping
    - **Infiltration -> recharge of groundwaters**



- **Study of ephemeral river dynamic and groundwater recharge** is essential for **human needs, ecosystems and economic activities**

- **Water resources and their dynamics in arid regions** -> poorly known
  - *In situ* data (expensive, punctual), modelisation (calibration with *in situ* data)
  - **Space remote sensing = unique contribution**

Introduction - *Objectives*

- **Sentinel-1-2-3 flying missions** = EU Copernicus program
  - Unique and rich multi-sensors dataset for Earth observations
  - **Long-term time series of measurements**
  - Spatial and temporal coverage

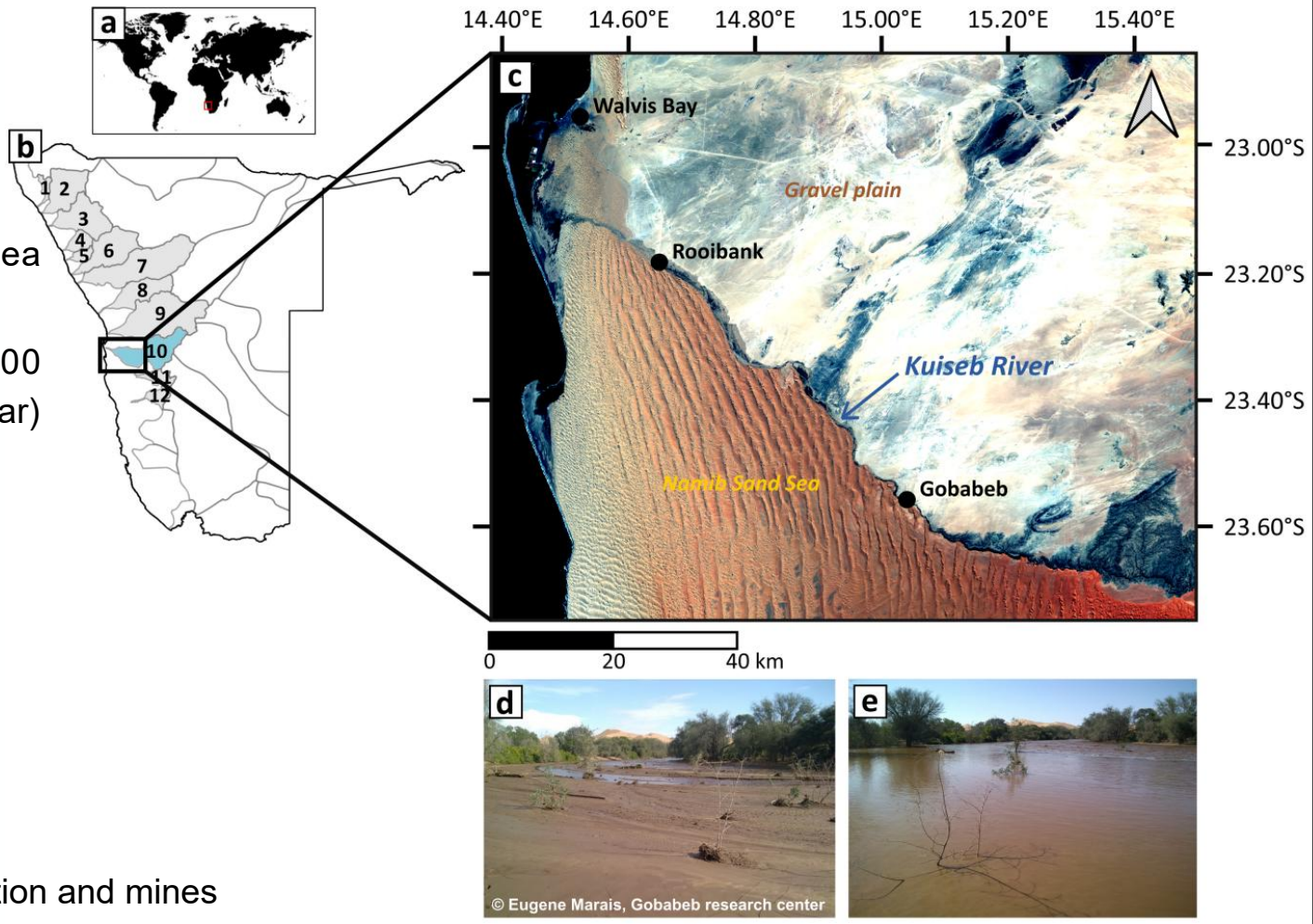
Objectives:

- To show the usefulness of **combining multi-sensor** data provided by the **Sentinel missions (multispectral, radar and SAR)**

- To **understand and monitor the dynamic of ephemeral rivers and the link with groundwaters**

Study site - *Kuiseb River*

- **Namibia, South-West of Africa**
  - 12 ephemeral rivers including the Kuiseb river
- **Kuiseb river :**
  - 560 km (longest of Namibia), 15,500 km²
  - Border between gravel plain (North) and Namib Sand Sea (South)
  - **Climate gradient :** plateau located in the East with 500 mm/year of rainfall to the coast with no rainfall (<50 mm/year)
- **Thunderstorms (January – April)**
  - Main source of water
  - **Floods :** Mean ~ 12 days, a big flood every 25 years
  - **Last 20 years : 3 floods (2011, 2021, 2022)**
- **Groundwaters : « hidden treasure »**
  - 100,000 boreholes in the last century
  - Drinking water to man, livestock, irrigation for crop production and mines



Materials & methods - *Multispectral imagery*

➢ Sentinel-2

- **Sentinel-2A (June 2015) + 2B (March 2017)**
- **122 images (June 2015 and December 2021) without clouds**
- Downloaded freely on: https://peps.cnes.fr/rocket/#/home
- **Level-2A:** atmospherically corrected using MAJA algorithm (processing chain developed by CNES and CESBIO)
- **Multi Spectral Imagery (MSI) :** 13 spectral bands,10 to 60 m spatial resolution, 5 days
- **Vegetation NDVI and Water NDWI** spectral indexes

$$NDVI = \frac{NIR - red}{NIR + red}$$

Tecker, 1979

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$$

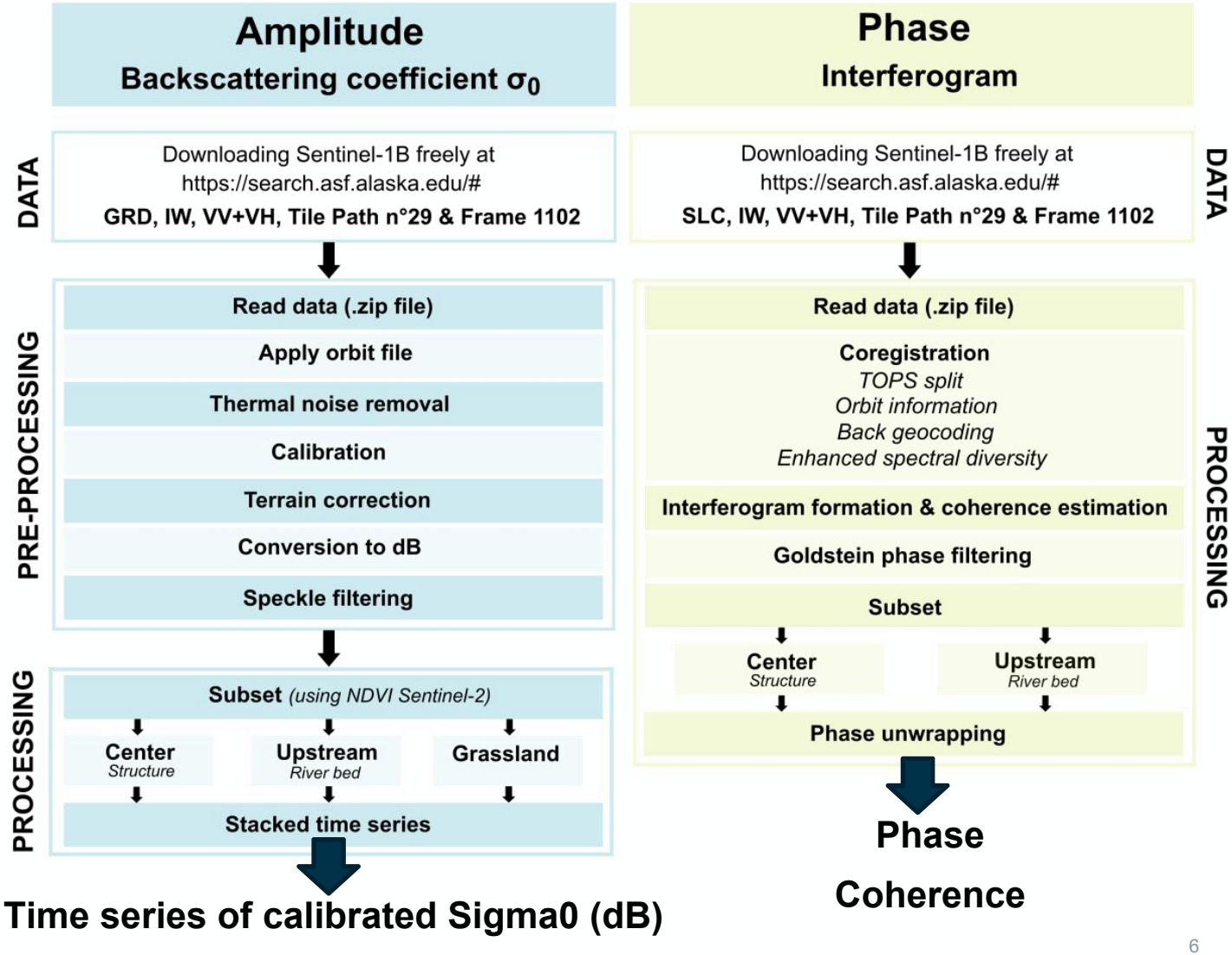
Gao, 1996

Materials & methods - *Radar and SAR*

➢ Sentinel-1B

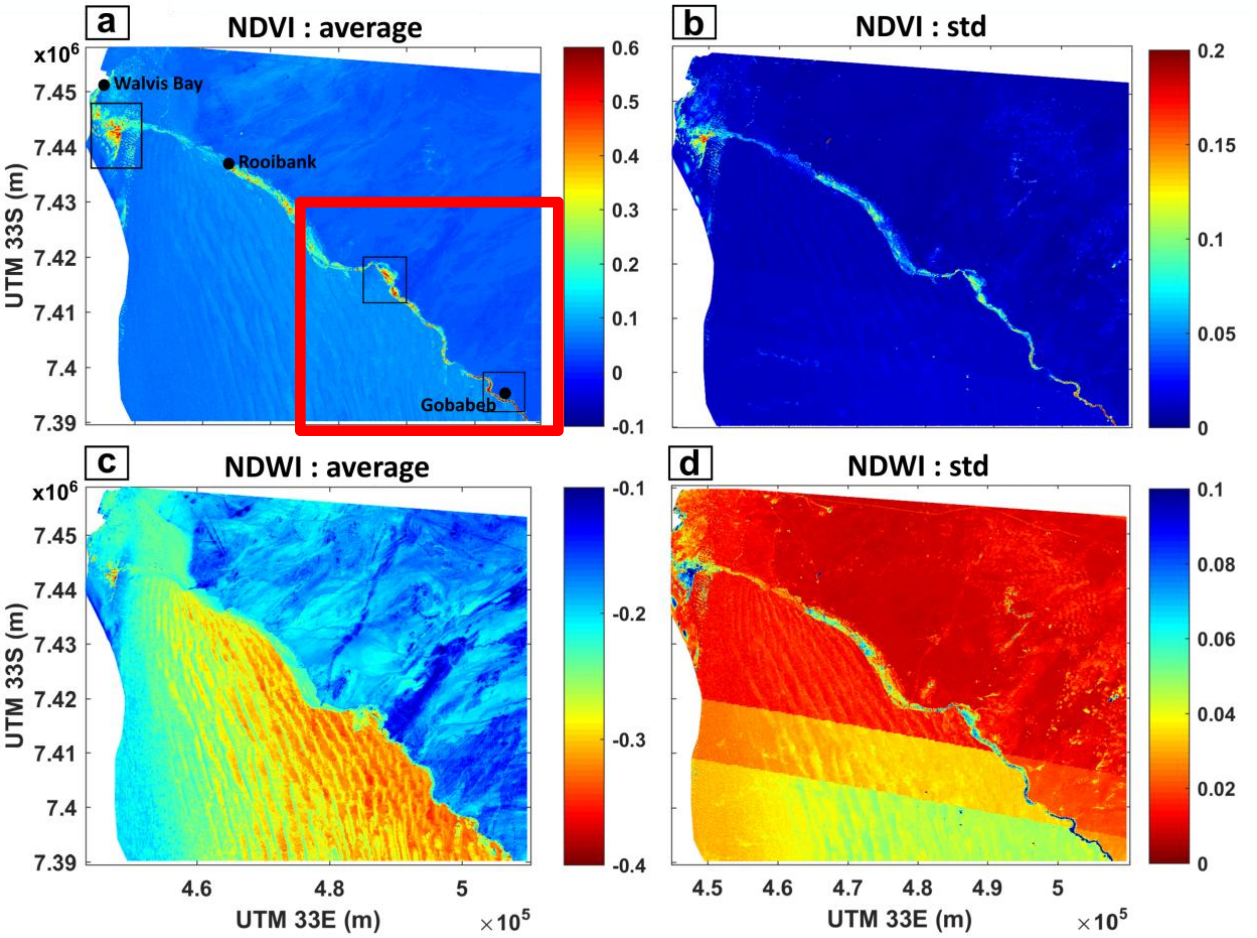
- **153 images (April 2016 and December 2021)**
- Downloaded freely on : https://search.asf.alaska.edu/#/
- C-band (5.4 GHz), 10 days
- Ground Range Detected (GRD) + SLC (Single Look Complex)
- Interferometric Wide Swath (IW)
- VV+VH polarizations

- **SNAP software**



Results & discussion - *Vegetation and water maps*

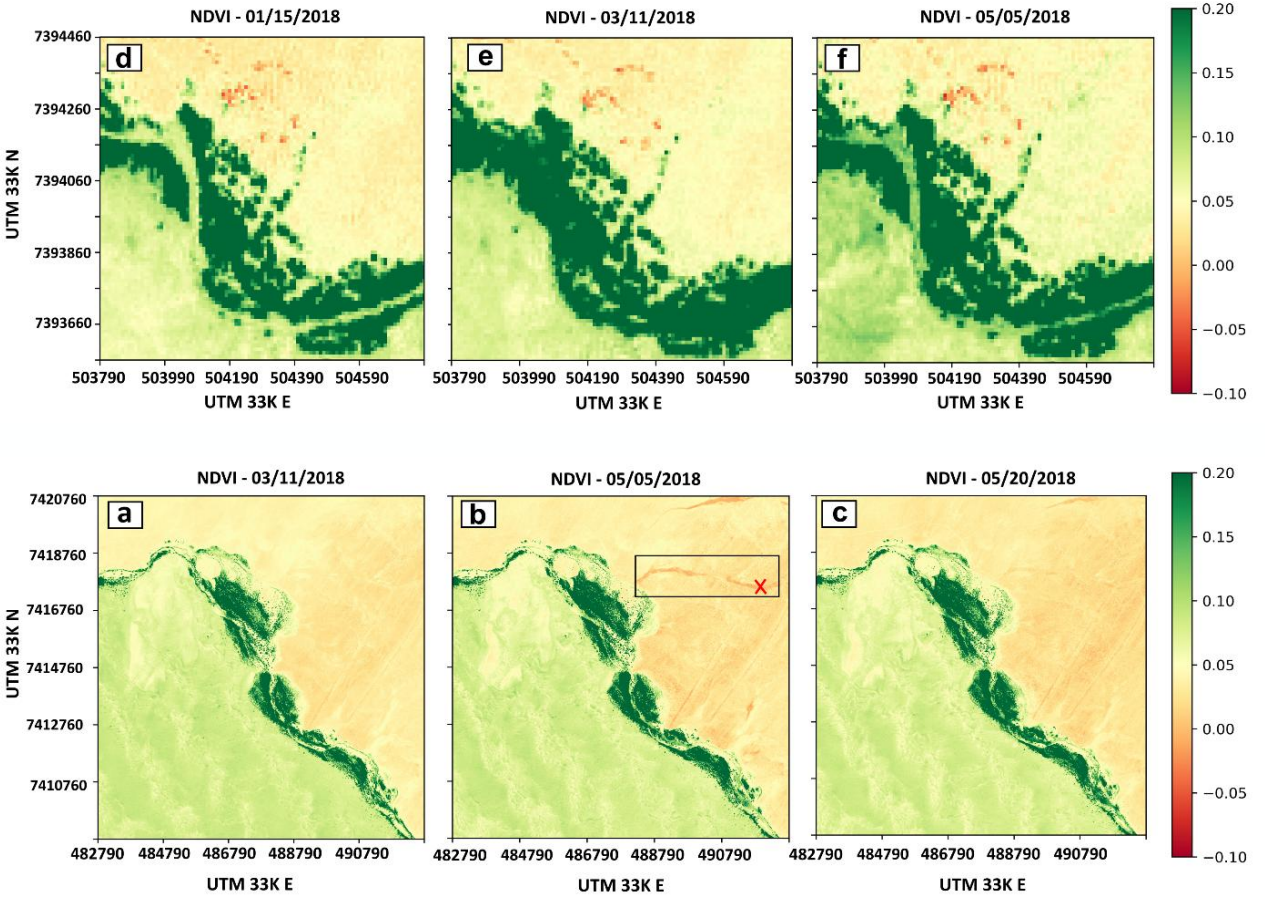
- NDWI pattern ≠ NDVI pattern
- **NDVI :**
  - Highest values near Gobabeb (more often flood)
  - **3 sub-parts with high NDVI values (black boxes)**
    - **downstream**
    - **center**
    - **upstream (Gobabeb)**
- **NDWI :**
  - High values in the Northern part in the gravel plain: **« humid structure » composed of small ephemeral rivers**



Results & discussion - *Vegetation and water maps*

- **2018**

➢ Box located near Gobabeb (upstream):
  - **High values of NDVI in the Kuiseb River on the second date**



➢ Box located in the center :
  - **Channel appears with low values of NDVI**

➢ Shift of 2 months between the upstream - center when the NDVI increases

NDVI variations are linked to rainfall events that occured few weeks before

Results & discussion - *Temporal variations*

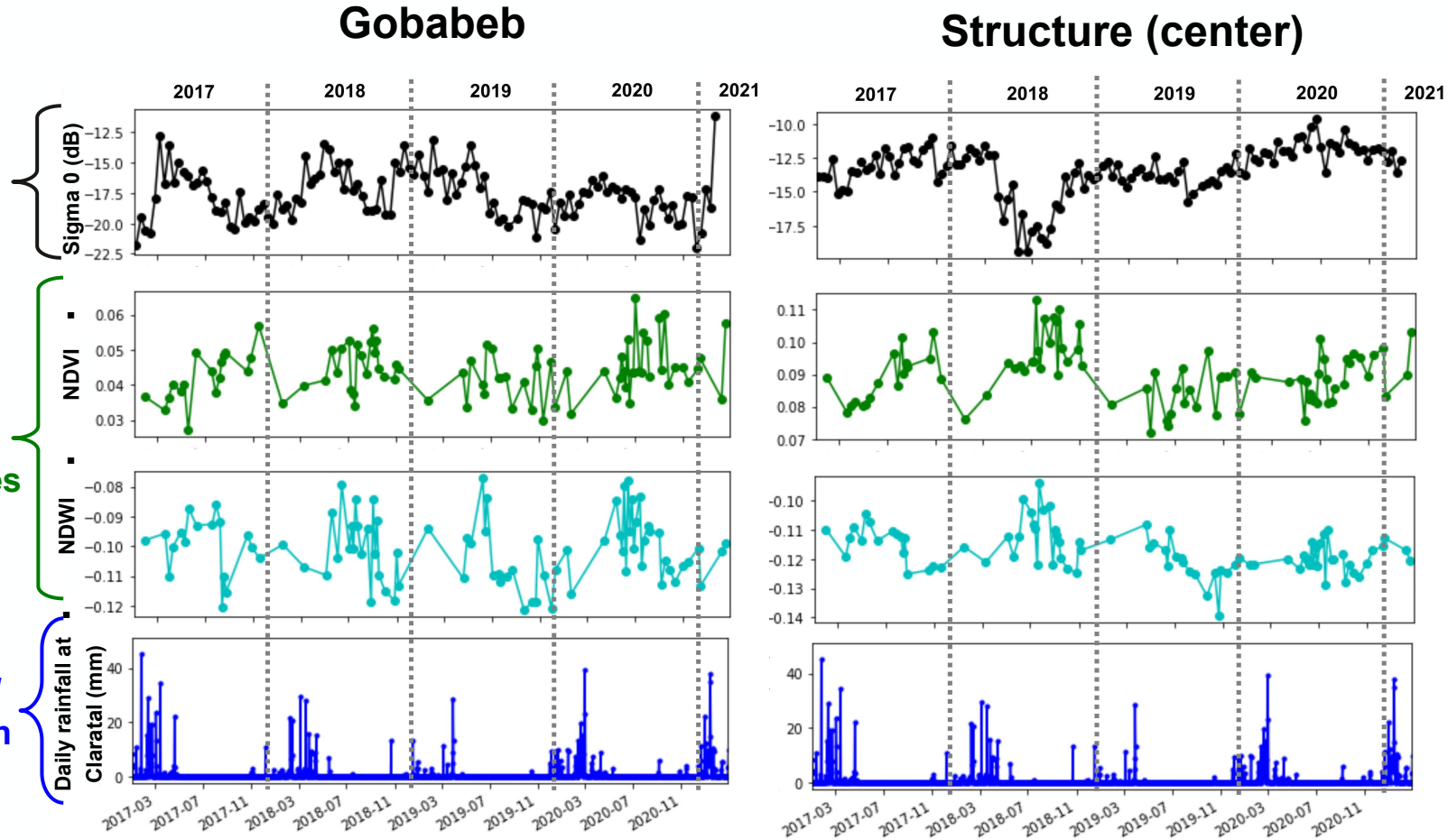
➢ **Combination of S1 + S2 between 2017-2021 (275 images)**

➢ **Gobabeb**

- Peaks in March-April
- Peaks correlated to rainfall
- Shift of 1 month between NDVI and NDWI

➢ **Structure (center)**

- Variations in 2018
  - ➢ Rainfall event of March 2018
- Negative peak of Sigma0



What happened in the structure? What can explain these variations?

Results & discussion - *Temporal variations*

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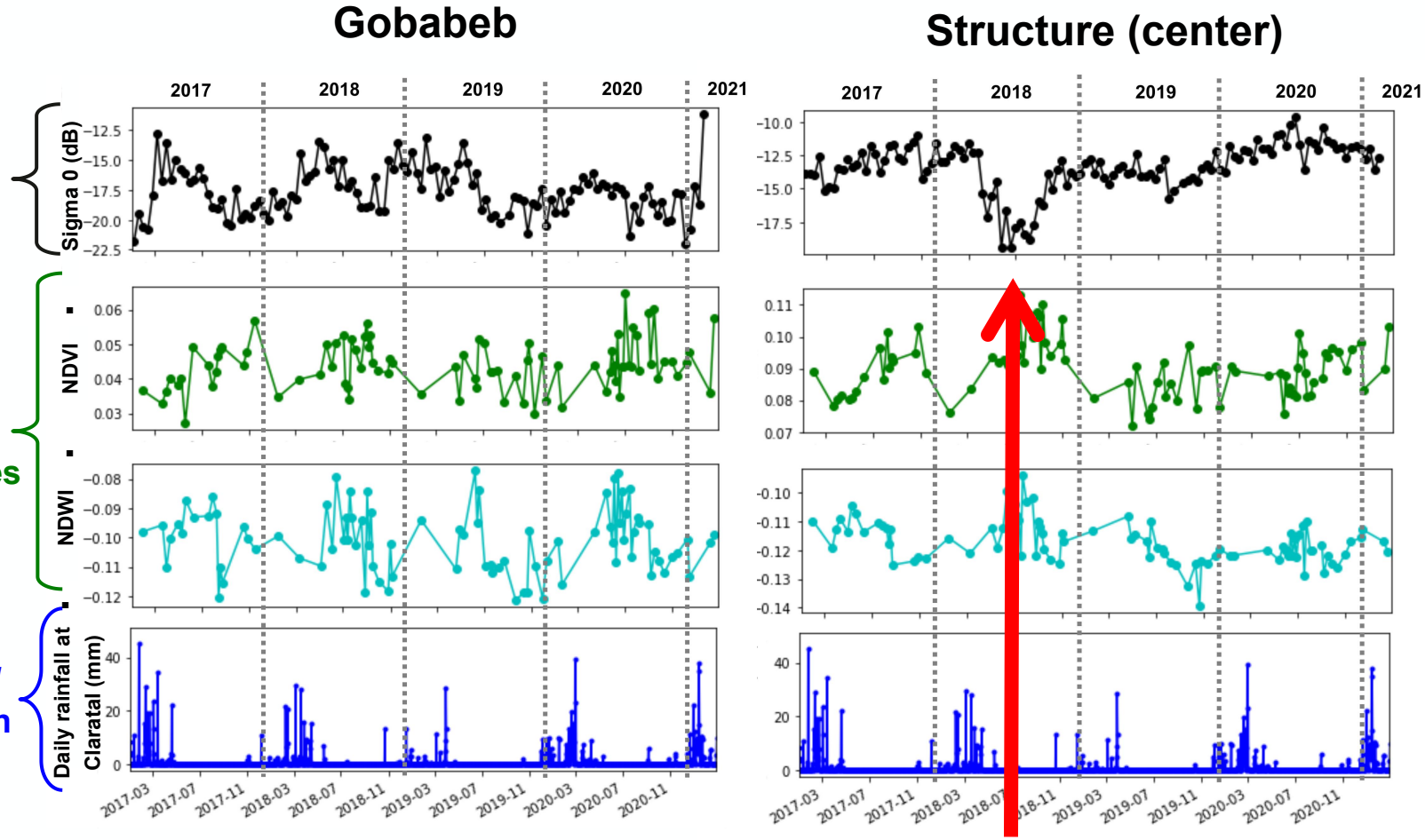


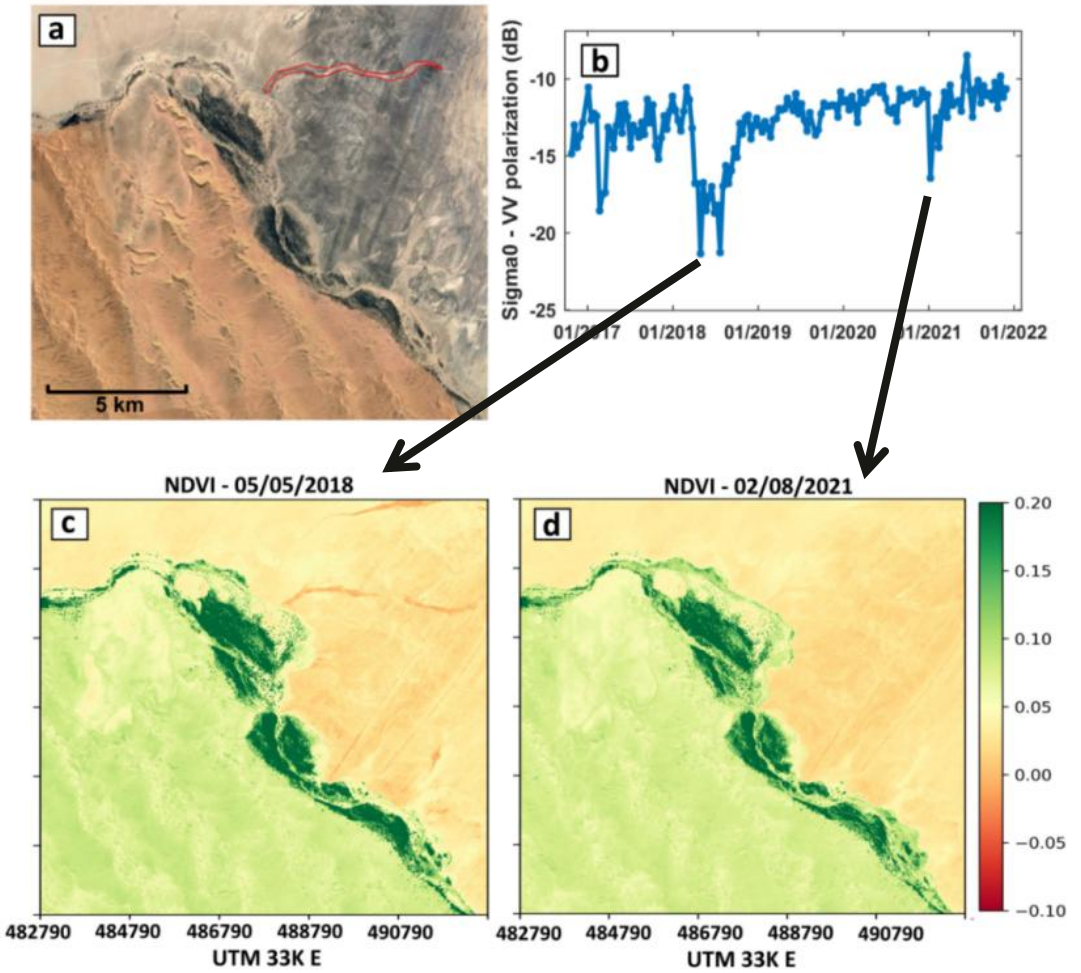
What happened in the structure? What can explain these variations?

Results & discussion - *Kuiseb tributary*

- **Structure =** tributary of the Kuiseb River in the central part

- **Sigma 0 (fig.b) :**
  - **Negative variations:** 2017, 2018 and 2021
  - Between -15 dB and -20 dB

- **NDVI (fig. c and d):**
  - **Negative variations of vegetation index for 2017, 2018**
    - **Rainfall events**
  - **No visible variations for 2021**
    - **No rainfall**

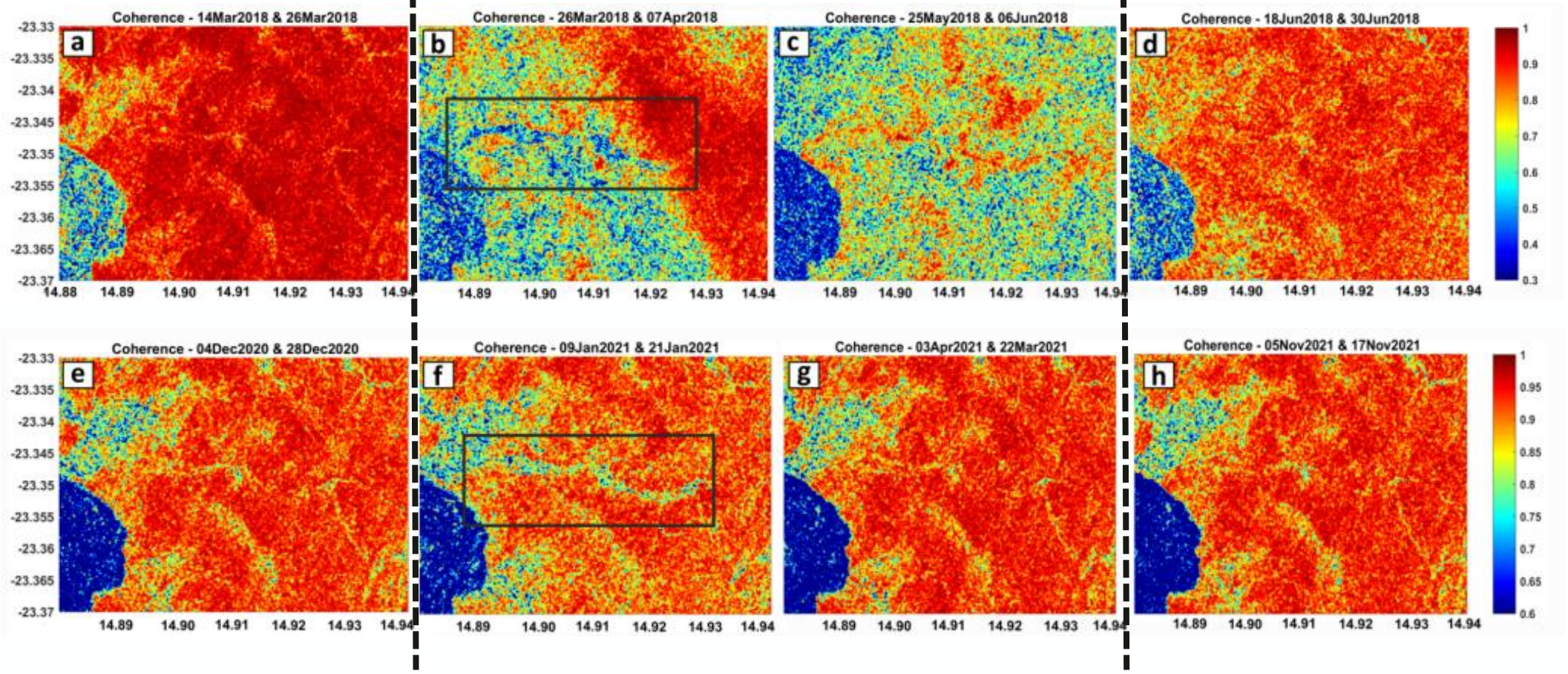


How can we explain a visible decrease in the Sigma 0 amplitude in 2021 and no change in the NDVI?

Results & discussion - *Kuiseb tributary*

➢ **Interferograms and coherence**

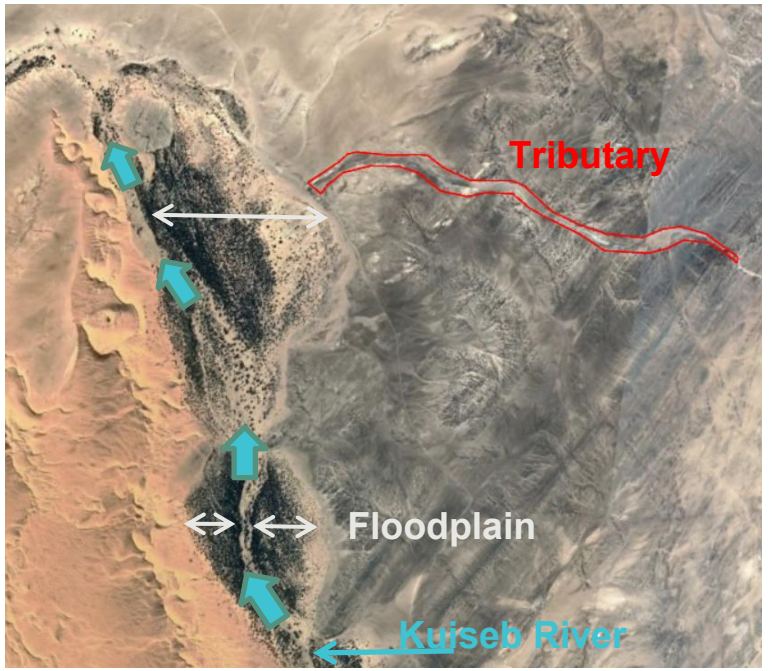
	Before the disturbance	During the disturbance	After the disturbance
2018 Local rainfall event	a: Coherence - 14Mar2018 & 26Mar2018	b: Coherence - 26Mar2018 & 07Apr2018	c: Coherence - 25May2018 & 06Jun2018
			d: Coherence - 18Jun2018 & 30Jun2018
2021 No local rainfall event	e: Coherence - 04Dec2020 & 28Dec2020	f: Coherence - 09Jan2021 & 21Jan2021	g: Coherence - 03Apr2021 & 22Mar2021
			h: Coherence - 05Nov2021 & 17Nov2021



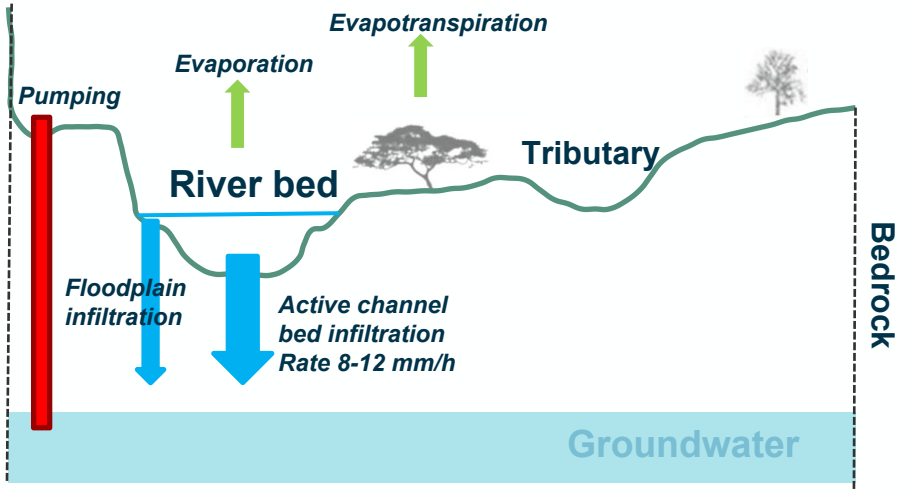
Results & discussion - *Kuiseb tributary*

➢ Reactivation of the Kuiseb tributary

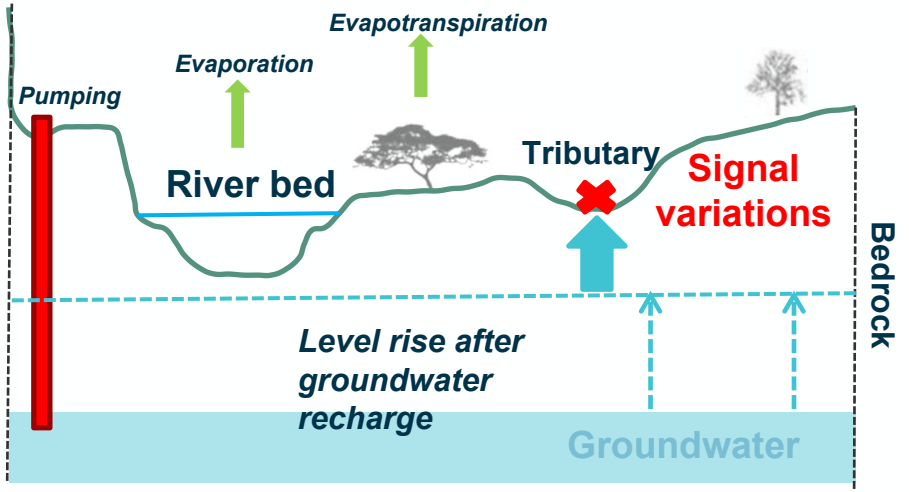
- Flood 2021
- ~ 1 week duration



During flood event



After flood event



Modified, after Grodek et al., 2020

Conclusion and perspectives

Conclusion

- Combination of multi-sensor data Sentinel-1 + Sentinel-2
- **Long time series** of vegetation and water spectral indexes, radar and SAR
- **Validation with *in situ* groundwater levels**

Perspectives

- Other ephemeral rivers in Namibia and in the world
- Hydrogeological modelisation


Thank you for
your attention!
NASA, ISS, 31/05/2016