Mozambique flooding from cyclone Idai – NCEO response and lessons learned

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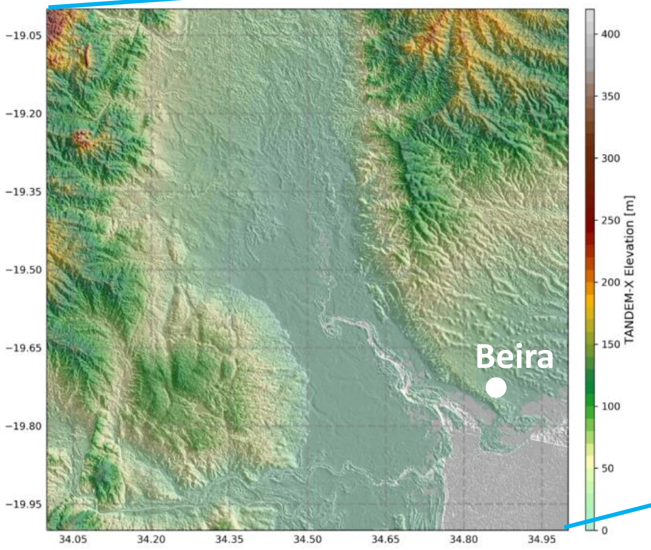
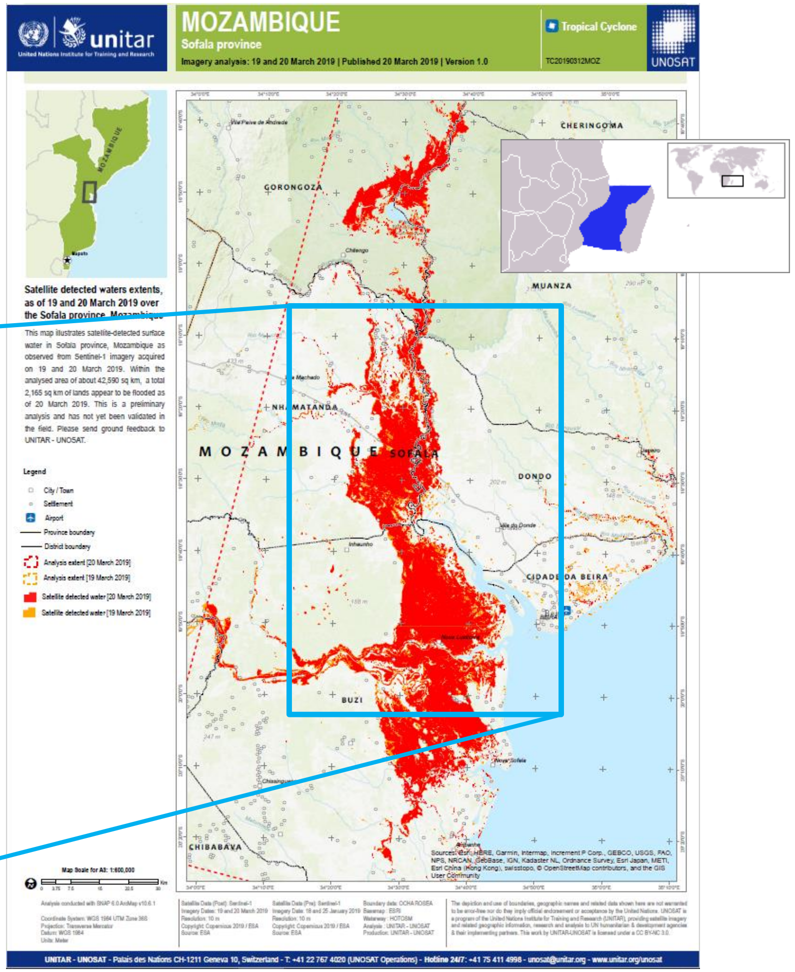
Mozambique flooding

- In March 2019, cyclone Idai developed into one of the worst tropical cyclones on record to affect Africa
- The NCEO were approached the UK Government Department for International Development (DFID) to provide expertise on the analysis of satellite data to monitor the extent of flooding in Mozambique.
- Our work tried to differ from that done in the framework of the Copernicus Emergency Management Service but it was used for guidance.
  - Different local regions chosen, according to requests from national authorities
- We also recommended other UK sources of expertise such as the Environment Agency
- Information provided would be used to help prioritise the relief effort from the UK

Cyclone Idai

- Originated from a tropical depression that formed off the east coast of Mozambique on 4th March 2019.
- Later that day the storm made landfall over Mozambique and remained a tropical cyclone for the next 5 days over land
- By 9th March the depression moved back over water, the Mozambique channel, and strengthened to moderate tropical storm Idai.
- Rapid intensification then occurred with sustained winds of 175 km/h (110 mph) on 11th March, reaching peak intensity of 14th March with winds up to 195 km/h (120 mph)
- On 15th March the system made landfall again, near Beira, Mozambique.
- Severe flooding affected more than 3 million people and 1,303 people lost their lives as a direct result of the storm.



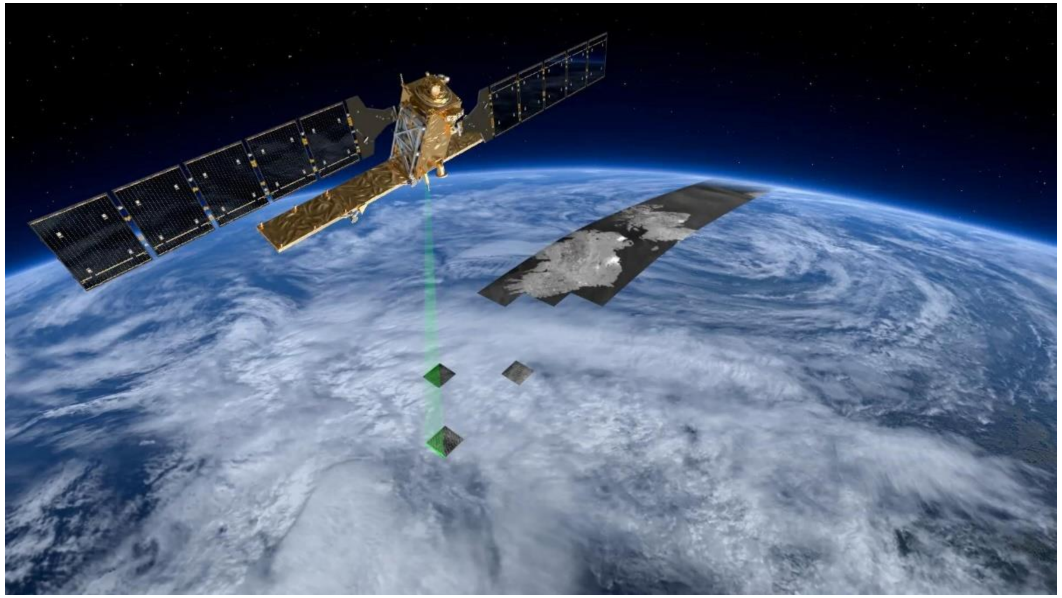


Mapping the flooding

- A small team from NCEO quickly assembled and were granted access to a number of commercial and non-commercial satellite imagery data of the event and aftermath through the International Charter (Space & Major Disasters) website.
  - The Charter is set up to achieve the co-ordinated use of space facilities in the event of natural and technological disasters
- The team provided detailed flooding maps across the regions of Chinde and Buzi in Mozambique.

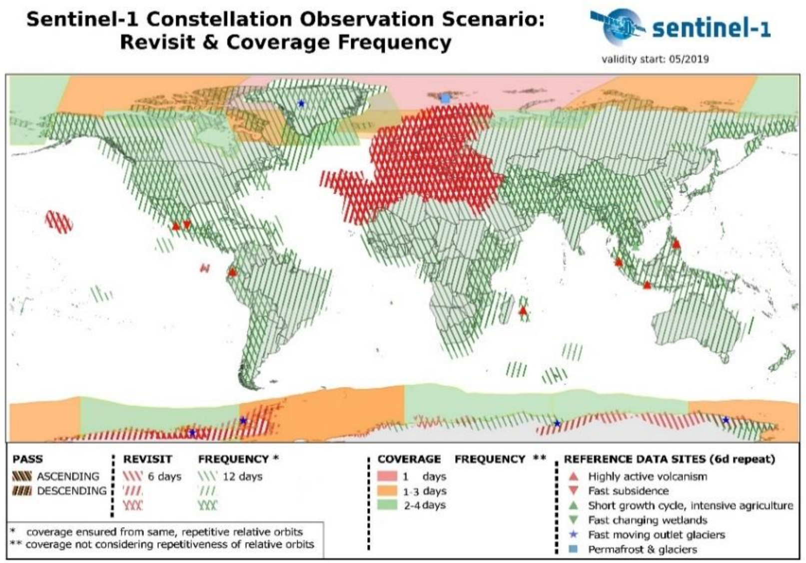
Identifying the flooding extent with Sentinel-1

- Sentinel-1 is an ESA Copernicus programme pair of satellites (1-A and 1B)
- C-band synthetic aperture radar which collects data irrespective of weather conditions
- Spatial resolution down to 5mx20m and a swath width of 250 km.
- 12-day repeat cycle orbit at 693 km altitude
- 2-4 day coverage over Africa
- uses include sea and land monitoring, emergency response due to environmental disasters, and economic applications
- Data users (public, scientific, commercial) can all access the data for free



Sentinel 1 radar modes - https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1/Instrument

Technique (1)



- Use the “HV” polarization to perform the analysis
  - More sensitive to changes on the land surface
  - “VV” polarization susceptible to vertical structures
- Processing via Google Earth Engine (GEE)
  - Holds Sentinel-1 collection => no local download required
- Filter data by instrument mode polarization, pass direction, spatial resolution
- GEE imagery are already pre-processed
  - Apply-orbit-file (updates orbit metadata, geolocation)
  - ARD border noise removal (removes low intensity noise and invalid data on the scene edges)
  - Thermal noise removal (removes additive noise in sub-swaths)
  - Radiometric calibration (computes backscatter intensity using sensor calibration parameters)
  - Terrain-correction (orthorectification)
  - Conversion of the backscatter coefficient (σ°) into decibels (dB)

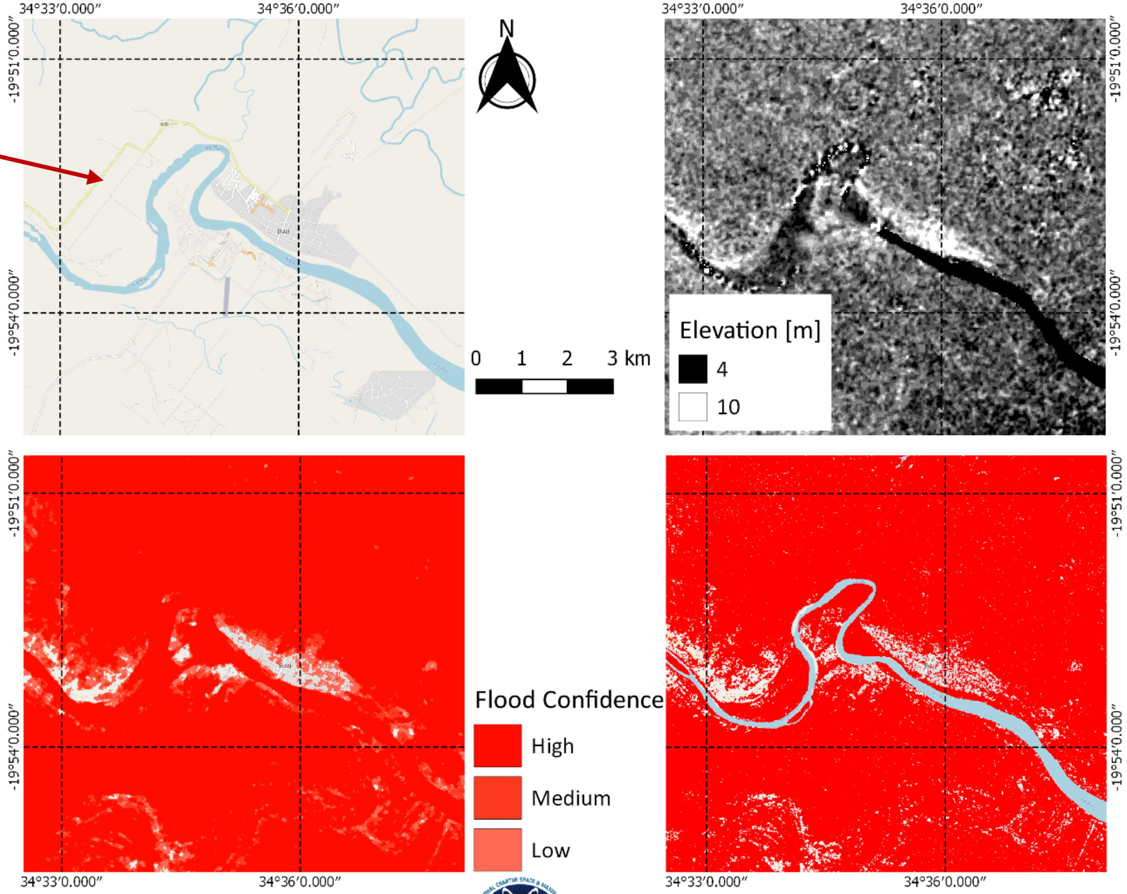
Technique (2)

- Use a change detection approach, dividing the “after” flood mosaic by the “before” flood mosaic, resulting in a raster layer showing the degree of change
- Define a threshold of 1.5, derived through trial and error to reduce false negatives
- Map the results in GEE
- Future refinement could also incorporate other datasets such as
  - JRC global surface water to mask out areas covered by water for more than 10 months a year (30 m resolution).
  - WWF HydroSHEDS digital elevation model to remove areas with over 5% slope

Mapping flooding extent with Sentinel-1

Buzi region of Mozambique

- Comparison of NCEO (UoL) and UoE results, with slightly varying techniques, show a robust comparison of flood extent (typical river extent removed in NCEO data)



Flooding in Buzi and the surrounding area as shown from Sentinel-1 difference images before and after flooding event on the 14th March 2019.

NCEO (UoL) and UoE flood detections both show consistency.

Areas that appear unflooded may be due to effects of tree and building heights on radar signal in both flood maps. It is likely that even in these areas there is flooding beneath the canopy.

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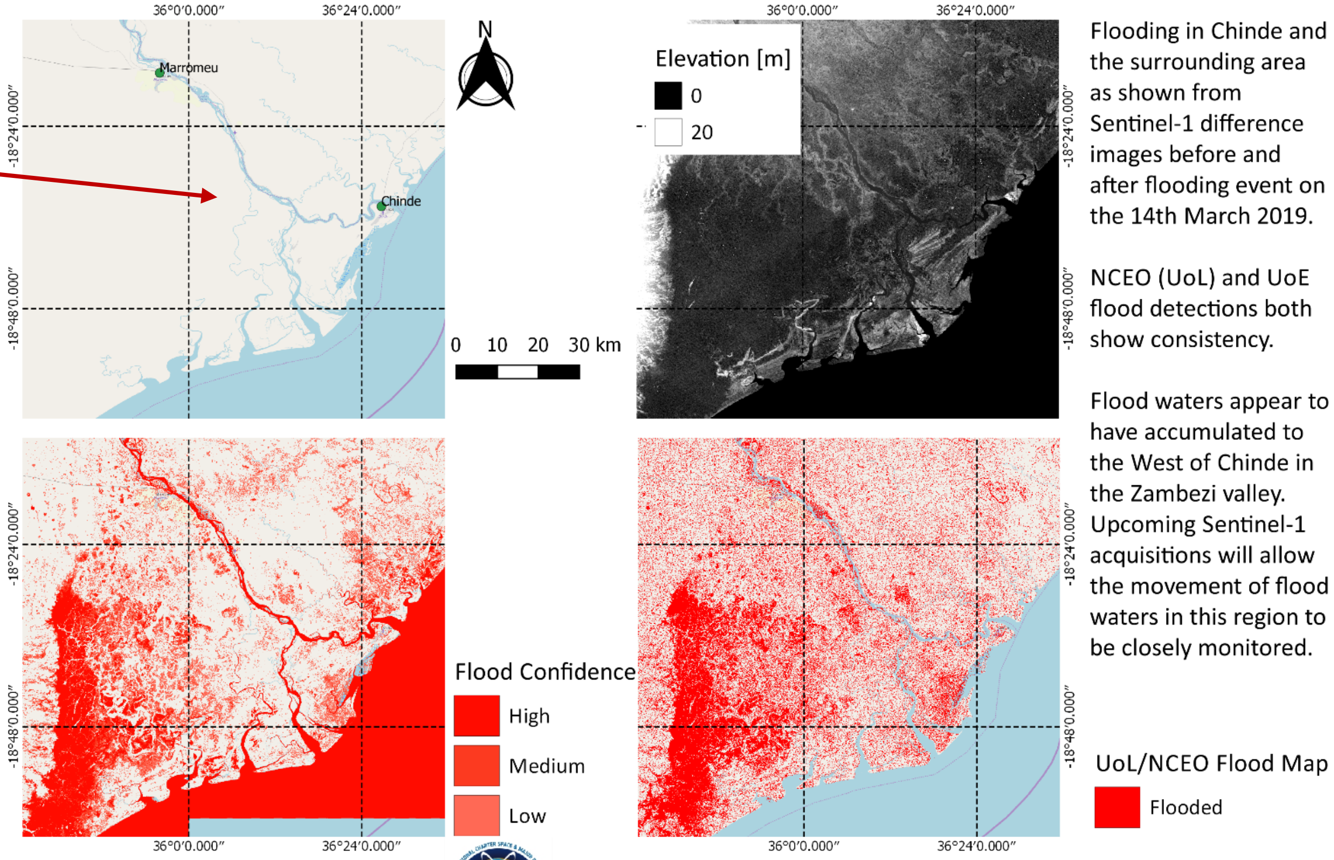
Mapping flooding extent with Sentinel-1

Chinde region of Mozambique



Flooding in Chinde and the surrounding area as shown from Sentinel-1 difference images before and after flooding event on the 14th March 2019.

NCEO (UoL) and UoE flood detections both show consistency.

Flood waters appear to have accumulated to the West of Chinde in the Zambezi valley. Upcoming Sentinel-1 acquisitions will allow the movement of flood waters in this region to be closely monitored.

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Lessons learned

1. **NCEO response overall**.
   - We were very pleased to respond rapidly through the formation of a small NCEO team mainly working in Leicester although one staff member contributed whilst on a trip to Japan.
   - Required staff to devote time which would have been spent on other projects.
   - Forming of a team (availability of staff, progressing the availability of tools and data sets within shared computing environments) needs more thought for more efficient initial response.
2. **Clarity of contributions**.
   - It took some time to work out what NCEO and others could contribute beyond what might be provided elsewhere.
   - any system for disasters such as flooding needs to account for the Copernicus Emergency Management Service.
   - A natural network could begin to exist over time but needs nurturing.
   - We remain concerned to understand what can really help users at the point of delivery and see that other systems could also struggle in this respect.
3. **Wider system capability**.
   - As a team we felts some unsureness of what people in the field would find most useful and in what form.
   - we did not know how other groups in the UK and abroad could support each other with information.
   - It was clear that any activity could liaise with other “large-scale” services such as the Copernicus Emergency Management Service but this systems approach needs development.
   - At the moment, it feels like more of an ecosystem of response rather a systematic approach in least in the EO area.
   - Users and beneficiaries could very usefully input into system design in non-crisis times.

Lessons learned

4. **Platform for data and tools.**
   - Success in producing maps at the scale required require pre-knowledge/optical/street maps.
   - We had not anticipated floods in Mozambique and were able to work quickly with easily accessible data but preparedness in terms of auxiliary data, tools and processes could lighten the load considerably.
   - important that we begin to assess how we can gather information beforehand on risk areas. Capability, capacity and rehearsal using potentially available satellite data is vital. This includes detailed topography, street maps, pre-event optical imagery etc.
5. **Protocols**.
   - It would make a significant difference to have a knowledge of protocols in advance with a system for call out of staff who already know their responsibilities
   - Access through the Disasters Charter is efficient if there is clarity about who should be given access (no single point delays).
   - We probably would have benefited from access by more than one person.
   - Data download speeds seemed slow from the Disasters Charter site.
   - A protocol should include a file access space, document sharing and an access point for meetings.
6. **Sustained team efforts**.
   - Initial impetus to address events work well but a sustained effort (say beyond 3-4 days) is difficult to maintain at the current time.
   - All staff are fully employed on existing projects so ability to respond depends to delaying other work and avoiding deadlines.
   - As a distributed centre, we can call on a number of staff flexibly but we then need systems which are clearly inter-operable between locations and organisations.
   - Development of such systems would of course be an advantage for DFID-related projects.

The future

1. **Capability development.** Clearly defining national (NCEO and UK) and international (EC etc.) capability for action and doing short-term developments/training to upskill. Training in this area could enable more effective and efficient support, especially for those new to using EO data during disasters.
2. **System for triggering support**. The next step seems (to us) to involve developing an agreed system between key partners to maintain readiness, including a trigger mechanism and a roster of available people.
3. **Improved preparedness**. This seems best focussed first on a particular type of event (could be a couple). We understand flooding is the best target. Certainly whilst there might be some generic system development, we feel that at the moment it would be necessary to develop an effort to meet a particular type of hazard.
   a) General Training
   b) Testing of techniques and software on past events (upskilling)
   c) Rehearsal for specific events
   d) System development at national and international level

   It is possible that the Committee on Earth Observation Satellites (CEOS) Working Group on Disasters could be used as a forum for improving international EO data access and exploitation.
4. **Improved co-ordination mechanisms**. During events, it’s best if colleagues have access to and are familiar with a co-ordination system including electronic requests, document and plot sharing, meeting connection systems.
5. **Bigger connectivity to users**. Time could be set aside to gather user inputs and to design data feeds that could be easier to use and clearer in information. Clarity of requests during emergencies is of course very important and it would be invaluable at this stage to have better sharing of experiences through feedback post-event.
6. **NCEO ASSIST**. NCEO is designing a government assistance facility into its new HQ in Leicester (2021) so it would be very timely to design, exercise and implement responsive systems.