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→ EO4SD - EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Climate Resilience | Earth Observation data for water management

climate resilience
eo4sd

ACRONYMS

UN	United Nations
EO	Earth Observation
EO4SD	Earth Observation for Sustainable Development
ESA	European Space Agency
IFI	International Financial Institution
UHI	urban heat island
IPCC	International Panel on Climate Change
NEX-GDDP	NASA Earth Exchange Global Daily Downscaled Projections
CGLS	Copernicus Global Land Service
CCI	Climate Change Initiative
GHS	Global Human Settlement
TEP	Thematic Exploitation Platform
EC	European Commission
WSF	World Settlement Footprint
RCP	Representative Concentration Pathway
SMOS	Soil Moisture Ocean Salinity
HR	High Resolution
C3S	Copernicus Climate Change Service
GPM	Global Precipitation
IMERG	Integrated Multi-satellitE Retrievals for GPM
GPCP	Global Precipitation Climatology Project
SM2RAIN	Soil Moisture to Rain
ASCAT	Advanced SCATterometer
PRD	Pearl River Delta
ADB	Asian Development Bank
LVB	Lake Victoria Basin
WRIS	Water Resources Information System
GIS	Geographic Information System
RS	Remote Sensing
NOAA	National Oceanic & Atmospheric Administration
STAR	Satellite Rainfall Estimates
AR5	Fifth Assessment Report 5
SPEI	Standardized Precipitation Evapotranspiration Index
SLR	Global Sea Level Rise
IFAD	International Fund for Agricultural Development

INTRODUCTION

Earth Observation (EO) data and services are vital tools for assessing the problems and exposure to future risks for the water sector by identifying structural constraints, informing modelling activities, and identifying development opportunities. The EO4SD Climate Resilience Cluster has worked on several projects to integrate EO services into decision making and design processes to help solve a range of problems for the water sector. One significant application for EO data is in mapping projected flood impacts for extreme weather events, river flooding, coastal flooding and sea level rise in rural and urban areas. But EO data can be used for an even greater range of problem solving to help build climate resilience in many different contexts. Through an ongoing, multi-year engagement with several International Finance Institutions (IFIs), the EO4SD CR cluster, has identified real-world use cases for EO data in projects from IFIs. A selection of these cases is presented here. Table 1 shows some of the EO data and services that have been made available for water projects by the European Space Agency's Earth Observation for Sustainable Development Climate Resilience Cluster (EO4SD CR).

EARTH OBSERVATION FOR WATER CLIMATE RESILIENCE: USE CASES

Managing flood impacts from extreme weather events

Where: Changde, China

IFI: Asian Development Bank (ADB), World Bank (WB)

The problem: Changde city is home to numerous rivers and waterbodies, all of which are subject to regular flooding during the East Asian monsoon season. Changde is located on the northern floodplain of the Yuanjiang River, which flows into Lake Dongting, the second largest freshwater lake in the PRC. Since the 1990's in particular, Changde has seen considerable urbanisation and economic development, underpinned by significant investment in infrastructure as part of an economic program aimed at reviving inland China. Large increases in population (estimated at 5.72 million in 2010) and demand for housing has fuelled the rapid construction of extensive high-density buildings which has significantly increased the urban footprint of the city. The risks associated with natural disasters have been exacerbated by unsuitable land use planning, including urban development in flood-prone areas. Large areas of impermeable surfaces have increased the risk of surface flooding across the city during the storm season; a risk that has increased due to more severe extreme rainfall events observed during recent decades. Current technical standards for urban planning do not adequately incorporate climate change projections nor the risks associated with a changing climate.

How might EO data be deployed? EO data can be used to provide flood extent maps of historical flood events, which can then help authorities to prepare the most effective actions to manage flood risk and develop plans to tackle flooding. Flood maps can also support a more sustainable approach to managing flood risk by considering where natural flood management could be most effective and enable better planning decisions to avoid unnecessary development in flood risk areas. Flash-flood risk and runoff maps can help to pinpoint areas exposed to current and projected flash-flood hazard, make robust decisions about the location and design of future assets, and build the case for climate resilience investment.

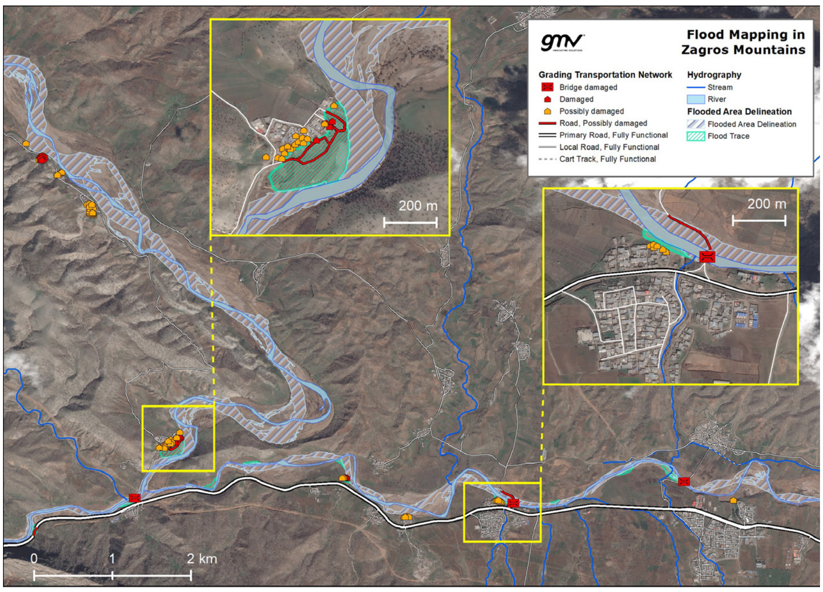

Image 1: Grading damage map related to a flood event in Zagros Mountains in 2020. Source: GMV

Managing impacts from coastal flooding and sea level rise

Where: Zhuhai, China and Monrovia, Liberia

IFI: ADB and WB

The problem: The coastal city of Zhuhai is situated in the southwest of the Pearl River Delta (PRD) and is widely recognized as one of China's most liveable cities. As one of the country's first four Special Economic Zones created in 1979, Zhuhai's population has rapidly expanded from 100,000 to c. 1.6 million (2015).[1,2] However, due to both its coastal geography, population density and urban development, the city is also extremely vulnerable to the effects of rising sea levels[3], typhoons and flooding. If sea levels rise 1m, over 1000 km2 of the PRD land will be lower than the sea level with cities like Zhuhai being seriously affected[4]. To tackle these challenges, the government of Zhuhai has placed resilience, with a specific focus on climate change adaptation and disaster risk reduction, as a core objective of urban planning. In Monrovia, since 2013, sea level rise and coastal erosion has displaced more than 6,500 and destroyed 800 houses in the West Point township of Monrovia. Sea level rise leads to erosion and causes the shoreline to retreat landwards, increasing the risk of displacement. Dwellings built in 2010, favoured by land gains due to the shoreline and river dynamics, are at a high risk of coastal flooding. An ongoing World Bank project aims to identify adaptation policies that can help Monrovia be better prepared to absorb urban growth in a context of extreme poverty, fragility and increasing risks from climate change.

How might EO data be deployed? Sea-level rise models and maps provide the fundamental data and tools at-risk communities need to make planning decisions. EO data includes the historical records of sea levels and can model mean sea level changes. It can also map assets, critical infrastructure and urban land subsidence which allows decision makers to understand and mitigate against the risks of sea level rise and make informed decisions about adaptation options. Similarly, for coastal flood management, EO data can help to identify the most effective actions to manage flood risk by considering where natural flood management could be most effective.

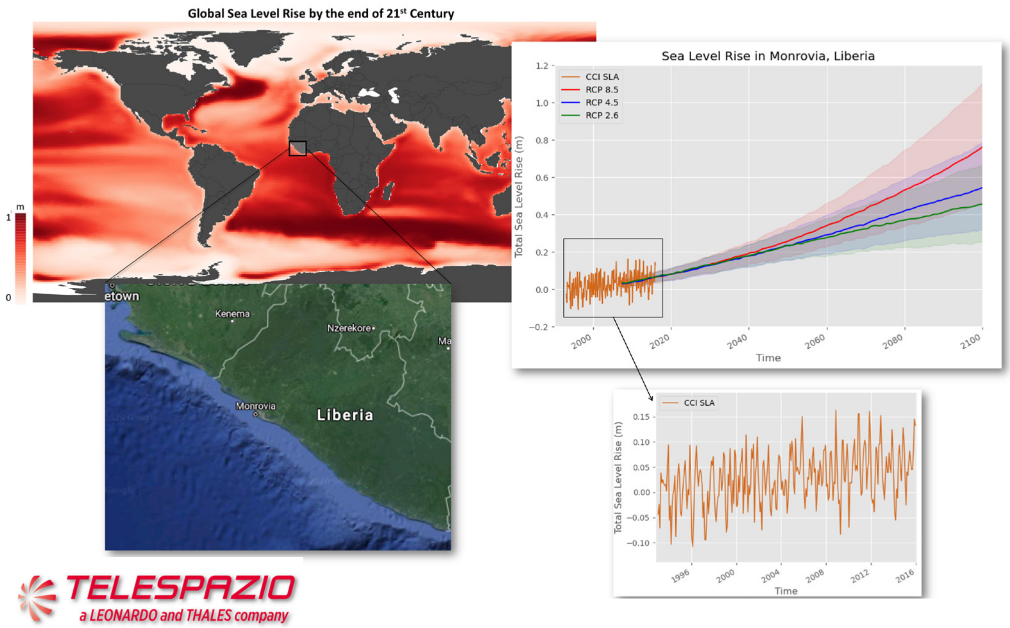

Image 2: Global Sea Level Rise (SLR) map and SLR time series for the coastal regions of Monrovia, Liberia. The graph shows SLR time series obtained from ESA CCI Sea Level Anomaly (1993-2015) and AR5 SLR under climate change scenarios (2007-2100). Shaded area presents the upper and lower 90% confidence interval. Source: Telespazio Vega UK

1 City Population (2010) "China: Guǎngdōng (Prefectures, Cities, Districts and Counties) - Population Statistics, Charts and Map". Available from: http://www.citypopulation.de/php/china-guangdong-admin.php [Accessed October 2019].
2 China Daily (2016) 'Zhuhai' Available from: www.chinadaily.com.cn/regional/2016-10/11/content_27021065.htm [Accessed October 2019].
3 Tracy, A., Trumbell, K, and Loh, C. (2007) The Impact of Climate Change in Hong Kong and the Pearl River Delta. Available from: https://journals.openedition.org/chinaperspectives/pdf/1173 [Accessed October 2019].
4 Yang, L., Scheffran, J., Qin, H., You, Q. (2015) Climate-related flood risks and urban responses in the Pearl River Delta, China. Reg. Environ. Chang: 15, 379–391.

Improving availability and accuracy of flood early warning systems

Where: The Philippines

IFI: ADB

The problem: As for many countries, the Philippines' most densely populated areas are in river basins and coastal areas. These areas can be particularly vulnerable to flooding. With a changing climate, typhoons and heavy rainfalls are likely to increase in intensity and frequency, exacerbating flooding in existing flood-prone areas. Flood risk management in the Philippines has been ineffective due to a lack of integrated flood risk management planning, suboptimal flood protection infrastructure, limited investment, and inadequate local flood risk management. The ADB's Integrated Flood Risk Management Sector Project aims to reduce flood risks in six river by improving flood risk management planning through strengthening data acquisition and data management, and improving flood protection asset management; rehabilitating and constructing flood protection infrastructure; and raising community awareness, and preparing and implementing flood risk reduction and management plans to reduce different groups' vulnerabilities.

How might EO data be deployed? Employing a mix of Earth Observation and climate projection derived information can support the integration of climate resilience into investments under the Integrated Flood Risk Management Sector Project. EO data can be integrated into Water Resources Information Systems to enable them to produce near real-time information on flood risk, and can take account for a whole catchment area. EO data can also be used to collect and store up-to-date and accurate spatial data from hydro-meteorological stations, which is essential for hydrodynamic models and designing flood management infrastructure. By automating strategic weather stations and telemeters, and integrating into other early warning systems, emergency responses to flash flooding can be greatly improved, and at the local level.

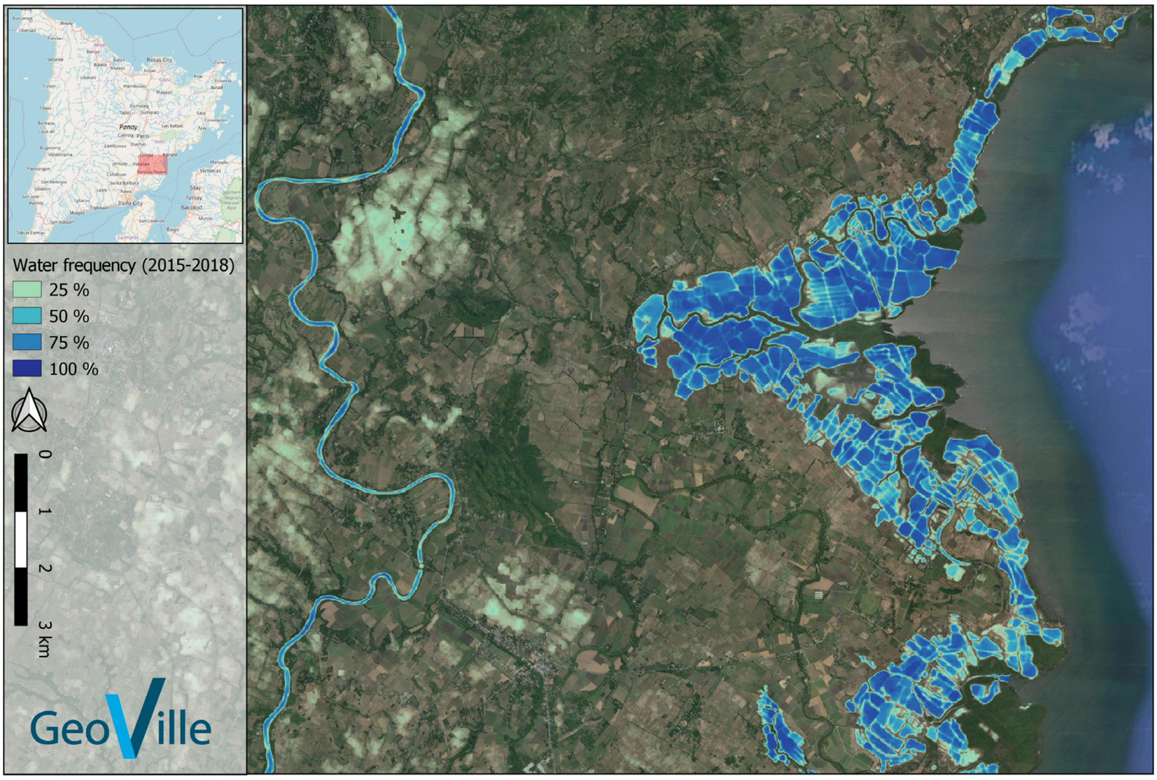

Image 3: Inundation frequency in Panay Island, the Philippines, calculated according to the share of total occurrences within the period between 2015 and 2018. Water frequencies allow to derive the recurrence intervals of flooding zones, indicating the likelihood of inundation. Source: GeoVille

Nature-based flood protection solutions

Where: Lake Victoria river basin, Rwanda, Kyrgyzstan and the Philippines

IFI: WB, ADB, International Fund for Agricultural Development (IFAD)

The problem: Rwanda is one of the most densely populated African countries and its capital, Kigali, is expanding rapidly with significant population growth and industrial development. Kigali sits within the catchment of the Lake Victoria Basin, on the banks of the Nyabugogo river. The city's growing population, and industrial expansion has negatively affected the water quality of the Nuabugogo, which flows eastward into Lake Victoria. Exacerbated by inadequate wastewater management processes, this situation is likely to get worse due to increasing temperatures and changing rainfall patterns that will result in more frequent droughts and flooding. In response, the World Bank, in partnership with the Lake Victoria Basin Commission, has developed environmental management plans for the Lake Victoria Basin. These plans include nature-based solutions that offer flood protection and water quality improvements such as wetland conservation and restoration. Similarly, in the Philippines, ADB is working to restore riverine landscapes through setting back dikes, increasing the river channel depth, creating natural water storage 'sponges', that can help with flood reduction. In Kyrgyzstan, IFAD is implementing community-based, integrated, forest-rangeland ecosystem management projects that provide a wide range of benefits, including contributing to flood risk reduction. These nature-based solutions can have a large impact on flood risk management, but it can be difficult to work out where they can best be applied, and monitor the impact they are having.

How might EO data be deployed? EO data can help map and model the best locations for rehabilitating and constructing nature-based solutions, as well as monitoring and evaluating the impact of them on catchment hydrology and river baseflow. For example, in the Nyabugogo Catchment in Rwanda, the Lake Victoria Basin Water Resources Information System (LVB WRIS) could be enhanced by producing real time ground and satellite derived data. Establishing an operational GIS-RS laboratory in partnership with technology owner and innovators, data can also include, for example, lake levels, lake water quality, water hyacinth, land use/land cover changes and biodiversity trends among others. This information can then help inform decision makers about the types of impacts that may still affect populated areas and how much risk is being avoided by the wetlands. Flood risk management plans informed by EO data can help to alleviate flooding in urban areas, and raise awareness and help implement land use management practices, preventing the loss of soil by erosion which can further deteriorate water quality. Other adaptation measures such as monitoring stations can also help identify key points and sources of pollution too.

With a changing climate, different ecosystem-based flood risk management options may become more or less vulnerable. Using EO data and climate projections to assess and monitor the vulnerability to baseline and future flood risk in a dynamic climate can help decision makers to choose nature-based solutions that will continue to provide benefits and protection in a changing climate. EO data sets can be combined and processed to produce an index that could grade areas according to their climate resilient investment potential.

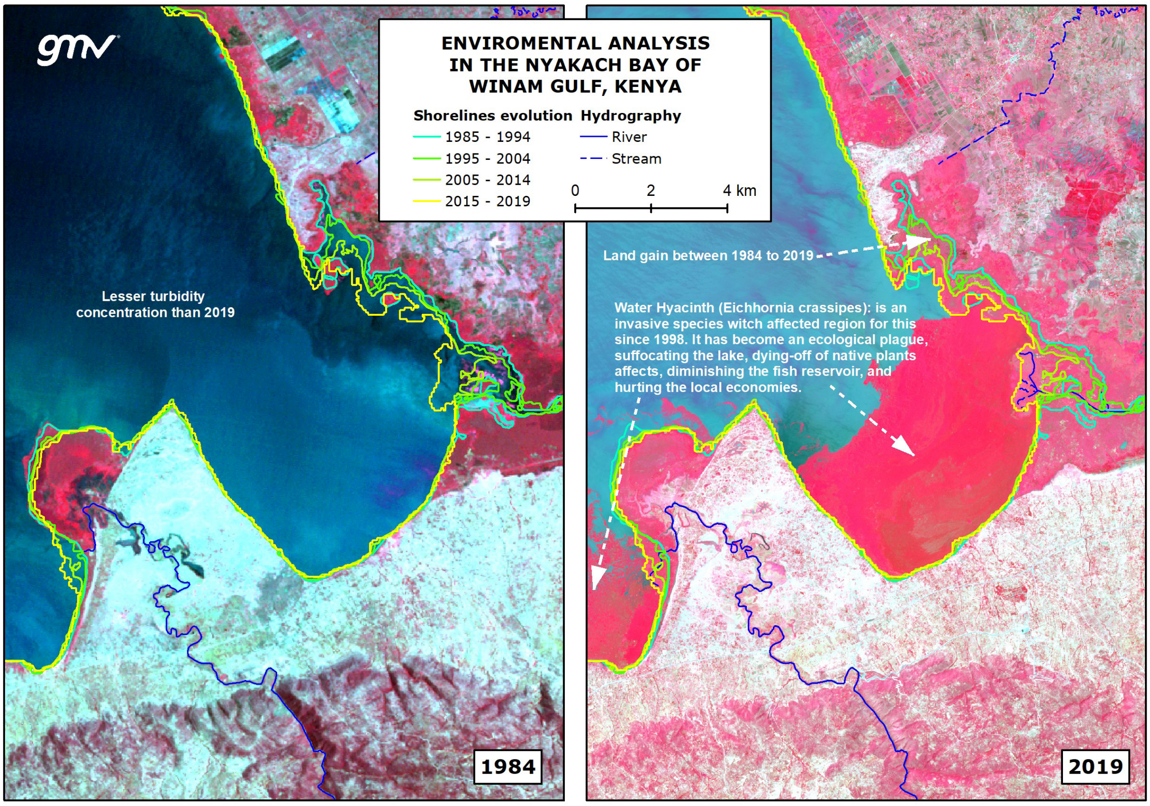

Image 4: Environmental changes in the mouth of the Nyando River between 1984 and 2019. The false colour composition emphasises changes in vegetation. Plant-covered land is red. Plants growing quickly (more photosynthetic activity) are brighter red. Water bodies are dark blue, while turbid water appears in cyan shades.

Ensuring safe and climate-resilient water supply and wastewater management system

Where: Yanji City (People's Republic of China)

IFI: ADB, WB

The problem: Yanji City, People's Republic of China, has a population of over half a million (2015). The city suffers from inadequate urban infrastructure and provision of basic services in the areas of flood protection, storm water management and drainage, water supply, wastewater management, urban roads and public transport, causing inconvenience and disruptions to daily life, especially affecting women[1]. Extreme rainfall and water run-off present a problem, affecting the management of wastewater as well as the wellbeing and livelihoods of populations. Climate change, particularly the risk of increased flooding and water stress, will only exacerbate these issues. In order to improve the city's infrastructure and increase climate resilience of vulnerable people, the ADB and Chinese government embarked on the Jilin Yanji Low-Carbon Climate-Resilient Urban Development project in order to create a climate resilience plan for a 'sponge city', improve water support and wastewater management systems, and increase institutional capacity for carbon and climate resilient urban infrastructure planning.

How might EO data be deployed? EO data can be used to assess and monitor the hydrologic and socio-economic implications of changes in extreme precipitation and inform decision makers about changes that may need to be made to sanitation infrastructure in order to cope. For example, feeding into 'sponge city' infrastructure planning that includes an integrated flood risk management system, river rehabilitation, drainage system improvement, and integrating green infrastructure with grey infrastructure. Measuring surface porosity, reservoir surface area, baseline flooding and combining with projected precipitation, and flood extent can help to identify vulnerable areas and places for infrastructure improvement. Therefore, employing a mix of Earth Observation and climate projection derived information can support the integration of climate resilience into investments under the Jilin Yanji Urban Development Project.

1 Climate Risk Assessment: Jilin Yanji Low-Carbon Climate-Resilient Urban Development, November 2018

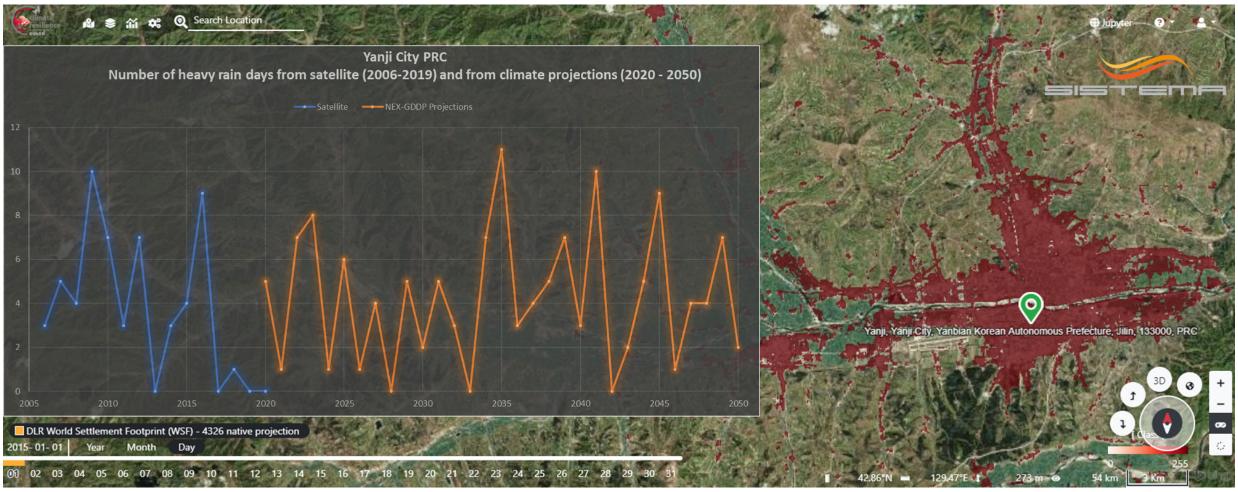

Image 5: Analysis of satellite historic and projected heavy rains for Yanji, China, performed with the EO4SD CR platform powered by ADAM. Source: Sistema

Drought trends and monitoring

Where: Armenia

IFI: WB

The problem: Armenia's agricultural economy is highly dependent on irrigated agriculture. High demand for water, degraded soils, and insufficient water supply can result in drought in many areas. In its assessment of the gaps and needs of the Armenia Hydrometeorological Service, the World Bank highlighted important data gaps concerning hydrological statistics, including seasonal water availability. In Scenario 3 of its recommended upgrade programme, the World Bank assessment identifies a range of priorities, including the improvement of drought forecasts and warnings and the development of a digital library of climate-relevant information.

How might EO data be deployed? EO data can provide continuous datasets that can be used to detect the onset of drought as well as its duration and magnitude. This can be used to both monitor the drought over time and issue early warnings. Such information can help decision makers take appropriate actions in a timely manner, reduce the impact of drought conditions, and mitigate drought's adverse effects on the environment. It may also assist the development or improvement of water infrastructure to ensure long-term water security.

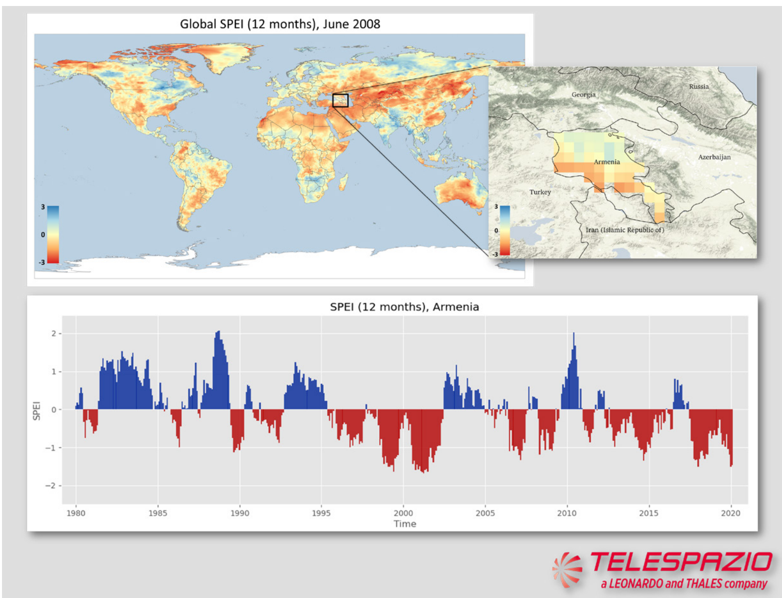

Image 6: Analysis of climate droughts in Armenia. Drought is usually defined as period when Standardized Precipitation Evapotranspiration Index (SPEI) values fall below -1. Source: Telespazio Vega UK

Table 1: Examples of relevant earth observation data and services provided by the EO4SD climate resilience cluster and possible matched land data layers. This table is illustrative only of the types of data and information available. Source: EO4SD Climate Resilience Cluster

Climate shocks & stresses	EO Climate Data
Flooding from extreme weather events	**Flood extent** • Flood extent analysis of historic events. • Continuous monitoring of flood extent. • Baseline flood extent (including water extent fluctuations over a certain 'baseline' time period from a time-series of images with each pixel showing an inundation frequency, and a classification of water body type).

Sea level rise and coastal flooding	**Sea Level data**
	• 0.25 degree sea level anomaly from C3S (1993 – present).
	• 0.25 degree sea level rise projection (RCP 4.5 and RCP 8.5) from NEX-GDDP (present - 2099).
	
	Coastal erosion
	• Mapping of historical shoreline positions
	• Estimation of annual average erosion rates
	• Monitoring of coastal erosion
	• Projection of the shoreline change
	
	Soil moisture
	• Soil moisture from SMOS (0.1 degree, 2010 - present) and C3S (0.25 degrees, 1978 - present)
	Precipitation
	• 30 min global satellite observations from GPM IMERG (0.1 degree) from 2000 to present.
	• Daily global satellite observations from GPCP (1 degree) from 1996 to present.
	• Daily global satellite observations from SM2RAIN-ASCAT (0.11 degree) from 2007 to 2019.
	• Hourly reanalysis data from ERA5-Land (0.1 degree) from 1979 to present.
	• 0.25 degree rainfall projection (RCP 4.5 and RCP 8.5) from NEX-GDDP (present - 2099).
	• Precipitation anomalies with reference to a baseline period (e.g. projected changes compared to the 1980-2010 average for each month) from satellite or reanalysis data. Example indicators are:
	  ○ *Projected change (%), 1-day rainfall at various return periods (10, 20, 50, 100 years)*
	  ○ *Projected change (%), 5-day rainfall at various return periods (10, 20, 50, 100 years)*

Land use – Nature-based solutions	**Land cover**
	• Land use / land cover maps from the CGLS Global Land Cover (100m, 2015) and the CCI Land Cover (300m, 1992-2015)
	Vegetation Indexes
	• 30m/10m vegetation indexes from Landsat and Sentinel-2 data (1982 - present)
	Water coverage
	• Baseline water storage area (including water extent fluctuations over a certain 'baseline' time period from a time-series of images with each pixel showing an inundation frequency, a classification of water body type and surface soil wetness).
	• Continuous monitoring of water coverage
	Soil moisture
	• Soil moisture from SMOS (0.1 degree, 2010 - present) and C3S (0.25 degrees, 1978 - present)
	Precipitation
	• 30 min global satellite observations from GPM IMERG (0.1 degree) from 2000 to present.
	• Daily global satellite observations from GPCP (1 degree) from 1996 to present.
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	  ○ *Projected change (%), 5-day rainfall at various return periods (10, 20, 50, 100 years)*

Flooding / Riverine Erosion	**Runoff**
	• Maps – timeseries line graph: Full monthly timeseries
	  ○ Mean: 1986 – 2005
	  ○ Mean: 2010 – 2019
	  ○ Anomaly: 1986 – 2005/2010 – 2019
	Rainfall
	• Maps – timeseries line graph: Full monthly timeseries
	  ○ Mean: 1986-2005
	  ○ Mean: 2010-2019
	  ○ Anomaly: 1986-2005/2010-2019
	Max 5-day rainfall
	• Maps-timeseries line graph: full monthly timeseries
	  ○ Mean: 1986-2005
	  ○ Mean: 2010-2019
	  ○ Anomaly: 1986-2005/2010-2019
	1-20 return period 5-day rainfall
	Temperature (average/minimum)
	• Maps-timeseries line graph: full monthly timeseries
	  ○ Mean: 1986 – 2005
	  ○ Mean: 2010 – 2019
	  ○ Anomaly: 1986 – 2005/2010-2019
	Snowfall
	• Maps-timeseries line graph: full monthly timeseries
	Projections (RCP 8.5)
	• Rainfall
	• Max 5-day rainfall
	• 1-20 return period 5-day rainfall
	• Rainfall of very wet days
	• Minimum temperature
	• Average temperature
	• Average snowfall
	• Average rainfall
	• Maps
	  ○ Anomaly:2021-2040 vs. 1986-2005

Flood hazard	• Baseline flood extent OR • Provide water extent fluctuations over a certain 'baseline' time period, e.g. 20 year. Baseline product would be provided as a composite of images over this time with each pixel classified either by percent of time inundated, or by class (e.g. permanent water, infrequently flooded, etc.)

Partners of the Climate Resilience Cluster

For more information, please contact:
ESA Technical Officer: Anna Burzykowska - Anna.Burzykowska@esa.int
Project Lead: Carlos Doménech - cdomenech@gmv.com

Website: eo4sd-climate.gmv.com/
Twitter: @ClimateEo4sd