

# Cholera risk and climate observations: a case study in coastal regions of the northern Indian Ocean

## SUMMARY



### Key Points

- Key climate data records of ECVs for forecasting cholera risk have been identified and used to develop an outbreak risk model
- The case highlights the importance of including socio-economic data and extreme events for further developments
- A web portal has been developed as a proof-of-concept, and it has been presented to the UNFCCC COP26 Earth Information Day.

### Service

- Adaptation
- Coastal management
- Health
- Marine ecosystems

### End User(s)

- Government agencies
- Local communities
- Policymakers
- Researchers

### Intermediate User(s)

- Health services and response
- Environmental managers

### Application(s)

- Forecasting climate-sensitive disease cholera outbreaks in coastal waters in India to inform early health interventions and reduce mortality

### Essential Climate Variables

#### — Atmosphere

- Precipitation
- Temperature

## – Land

- Soil moisture

## – Ocean

- Ocean color
- Sea level
- Sea surface salinity
- Sea surface temperature

## Climate Data Records

- ESA CCI Sea-surface temperature v2.1 (Merchant et al., 2019).
- CMEMS AVISO Sea Surface Height above sea level (aviso.altimetry.fr).
- ESA CCI Sea surface salinity (Reul et al., 2020).  
ESA CCI ocean color - Chlorophyll-a concentration v5 (Sathyendranath et al., 2019).
- 5. ESA CCI Land Surface Temperature (Ghent et al., 2019). The Version 2.0 release of the LST\_cci products is complete with all products publicly available on the JASMIN facility. [http://gws-access.ceda.ac.uk/public/esacci\\_lst/](http://gws-access.ceda.ac.uk/public/esacci_lst/).
- ERA Interim Synoptic Means of Total Precipitation (cds.climate.copernicus.eu) (Hersbach et al., 2020).

## Agencies

- ECMWF (ERA-interim)
- ESA (Climate Change Initiative program)
- European Commission (Copernicus Marine Service CMEMS)

## Satellite Observations

All 5 ECVs use multiple missions. Data is merged from missions:

- MODIS AQUA & TERRA
- ENVISAT MERIS
- Poseidon/-2/-3
- SMOS
- Nimbus-7
- DMSP
- WindSat
- Cryosat-2
- ERS-1/-2
- GFO
- AltiKa/SARAL
- SeaWiFS
- VIIRS
- Sentinel-3 OLCI
- SMAP
- ASCAT
- Metop-A/-B Sustainability

## Sustainability

The demonstration project that linked the science research to users was led by Plymouth Marine Laboratory with funding from the ESA-Future Earth Joint Programme grant for the PODCAST-DEMONstrator project (2020–2021), and the United Kingdom Research and Innovation (UKRI) Towards a Sustainable Earth (TaSE) program to the PODCAST project (2019–2021). and the United Kingdom Research and Innovation (UKRI) Towards a Sustainable Earth (TaSE) program to the PODCAST project (2019–2021). Funding to explore the model's applicability to other regions is being sought.

## DESCRIPTION

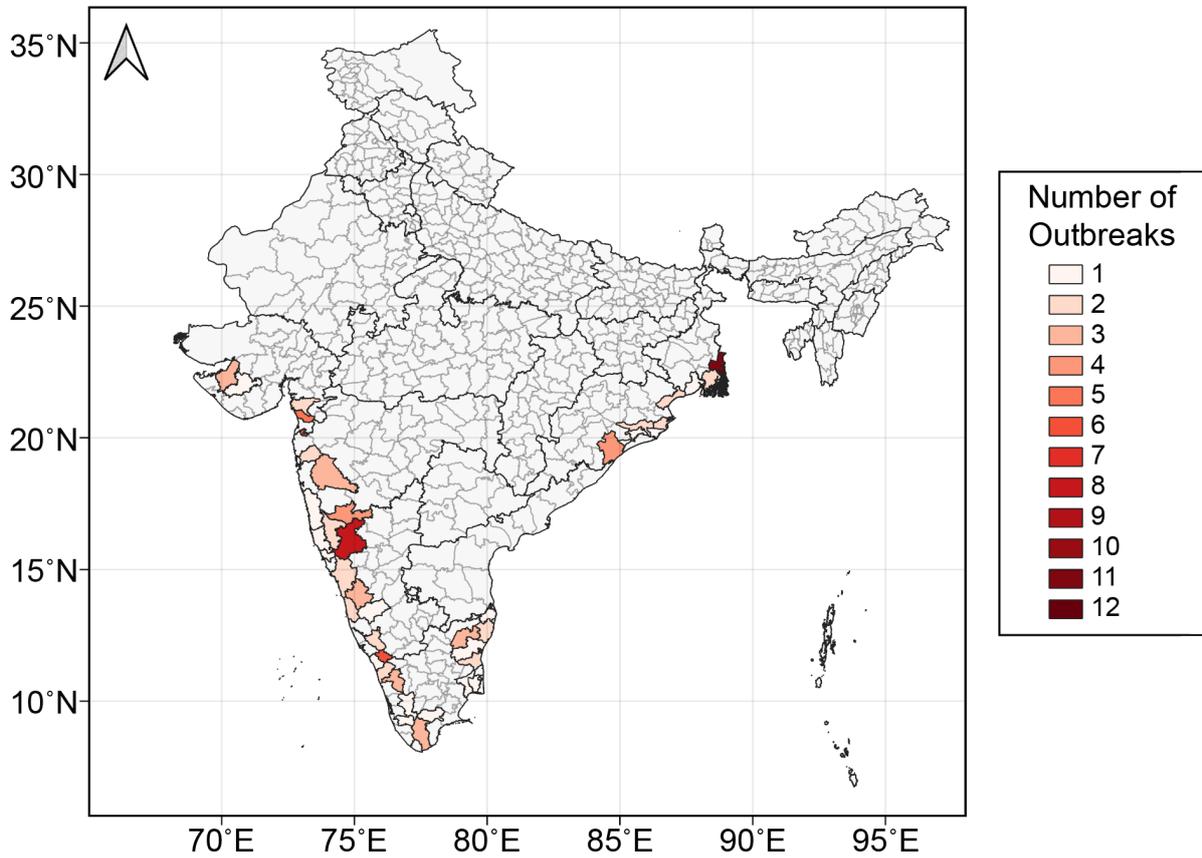
Earth observations play a major role in helping coastal communities to adapt to climate change, for example by providing early-warning systems for sea-level rise and extreme weather events (storm surges, coastal flooding, hurricanes, heat waves). In addition to these climate hazards to coastal communities, there are severe impacts and threats linked to food security and human health. For example, cholera is a climate-sensitive waterborne disease affecting 1.3 to 4 million people each year worldwide, with up to 143,000 reported fatalities (Ali et al., 2015; World Health Organization, 2017). Global warming and an increase in extreme weather events poses major risks to wastewater and sanitation infrastructures, and access to safe water, which combined with changes in environmental conditions drives *Vibrio cholerae* pathogen emergence and associated cholera disease outbreaks.

Here, the main objective was to develop a proof-of-concept web-based visualization and analysis tool to provide decision makers with information on climate-driven cholera risk in coastal regions of the northern Indian Ocean with a particular focus in India. The information products have been developed based on pilot models that use systematic observations of key climate indicators from ESA's Climate Change Initiative (CCI), Copernicus Marine Environment Monitoring Service (CMEMS) and reanalysis product ERA-Interim from the European Centre for Medium-Range Weather Forecasts (ECMWF), together with epidemiological clinical data from publicly available archives of the Integrated Disease Surveillance Programme (IDSP) in India. The web-based demonstration tool has been designed in consultation with end users and decision makers to provide them with the ability to access environmental, climate, and health datasets and to display them on a map in an intuitive manner.

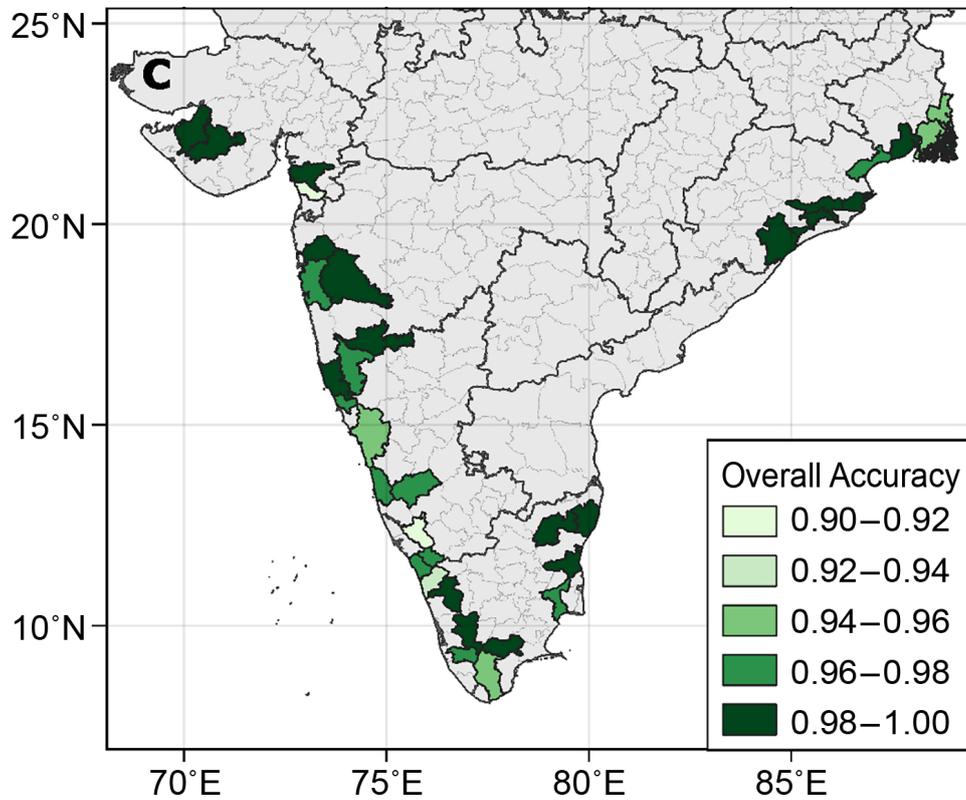
User consultation: A mapping of stakeholders and end users has been carried out to identify and prioritize target users and the main dissemination channels to reach them for the user consultation. Specifically, a survey was designed and carried out to: 1) define users' requirements (ranging from data resolution, web tool options to risk uncertainty requirements), and 2) establish the value and limitations of the proof-of-concept products and web-based tools to support policy information and practice interventions. The online survey was conducted using cloud-based software.

Pilot model for cholera-risk: As part of a collaborative research work between ESA and Plymouth Marine Laboratory (PML, UK), we have demonstrated a novel application of machine learning to detect cholera-risk in coastal districts in India based on analyses of epidemiological data and a suite of climate variables measured by satellites (Campbell et al., 2020). For this work, we constructed a new district-level dataset of disease outbreaks using the India Government Integrated Disease Surveillance Programme (IDSP) weekly epidemiological records between 2010 and 2018 (Figure 1). We used the Random Forest classifier machine learning technique with a 10:1 oversampling ratio and ability to function in the conditions of endemic cholera patterns reported in the input datasets (Campbell et al., 2020). We showed that the five satellite-derived climate variables that contributed most strongly to the Random Forest cholera-risk model in coastal communities, included ECVs of one-month and two-month lagged values of Chlorophyll-a Concentration (ChlorA), and non-lagged monthly Sea Surface Salinity (SSS), Land Surface Temperature (LST), Sea Level Anomalies (SLA) and Soil Moisture (SM), in order of their contribution strength to the model performance results respectively. The pilot model was able to detect with 89.5% accuracy endemic-cholera outbreaks in coastal India (Figure 2). We are investigating the potential of transferring the model to other regions and possible inclusion of socio-economic data.

In particular, we showed that the variables contributing most strongly to the Random Forest model cholera prediction included the one-month and two-month lagged values of chlorophyll-a concentration, sea surface salinity, land surface temperature and sea level anomalies, in order of their contribution strength to the model performance results respectively.



**Figure 1:** Number of cholera outbreaks reported in the weekly epidemiological reports published by the Integrated Disease Surveillance Programme of India (IDSP) during the period January 2010 to December 2018 for the 40 coastal districts of India selected in the project study (Campbell et al., 2020).



**Figure 2:** A machine learning tool to identify cholera risk currently identified 89.5% of outbreaks across all coastal Indian districts reporting cholera outbreaks during 2010-2018. Campbell et al., 2020.

Web portal prototype development and functionality: The project prototype of a web-based portal (Figure 3) is based on Open Geospatial Consortium standards and was built on existing functionality within an open source web-GIS portal that had been developed at the Plymouth Marine Laboratory (PML, UK). To improve usability, the data products are presented using well-known variable names, which can be selected from dropdown lists sorted by high level metadata, such as location, district, as well as keywords like environmental suitability, climate and health indicators, and common grouping such as model, satellite, or epidemiological data. Options for further analysis such as timeseries plots and comparisons between datasets are available. Users are able to select a geospatial area, either by manually drawing one or selecting one from a predefined vector layer, and choose the type of analysis. The portal prototype can then present the analysis to the user and provide easy-to-use options for downloading the data used in the analysis. These data are available to download in commonly used formats such as Comma Separated Variable (CSV) files, which can be opened by most if not all spreadsheet applications.

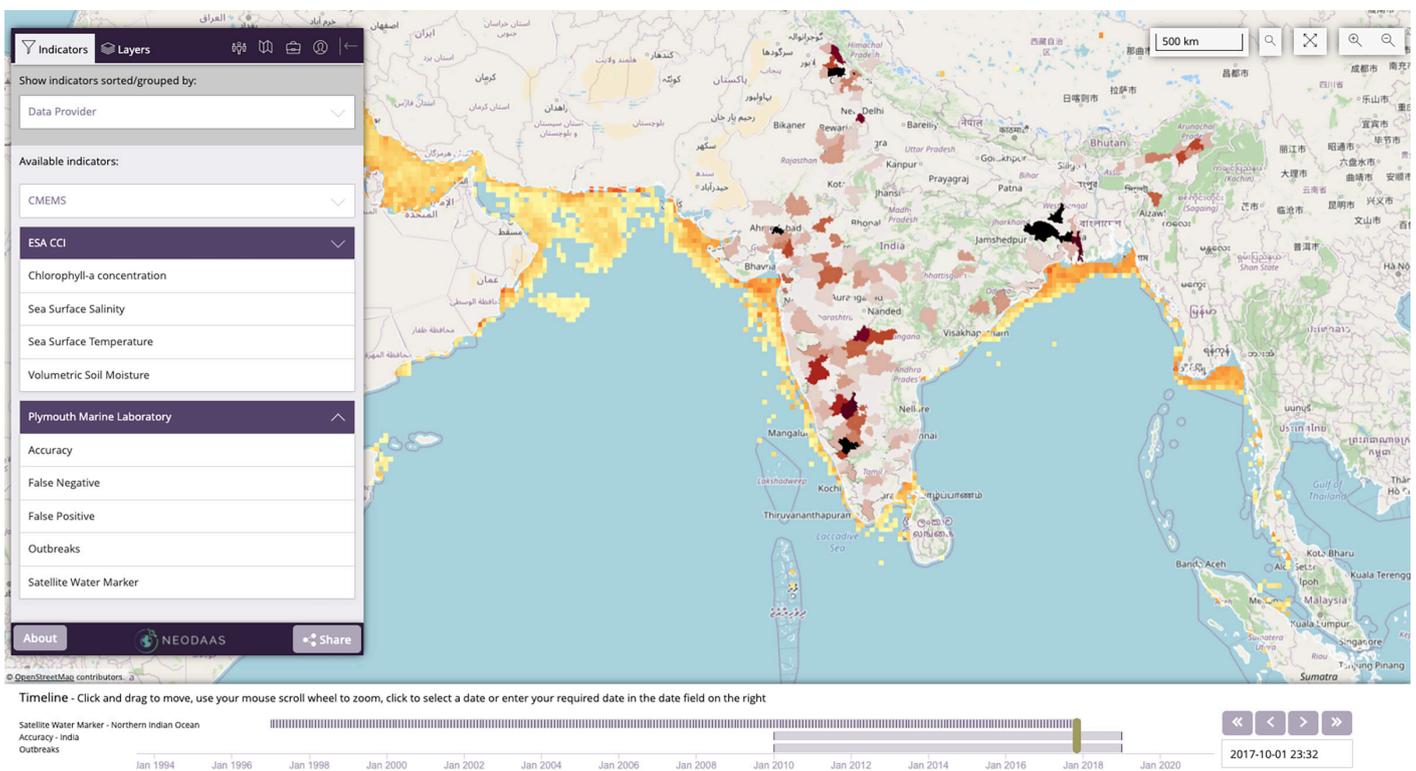
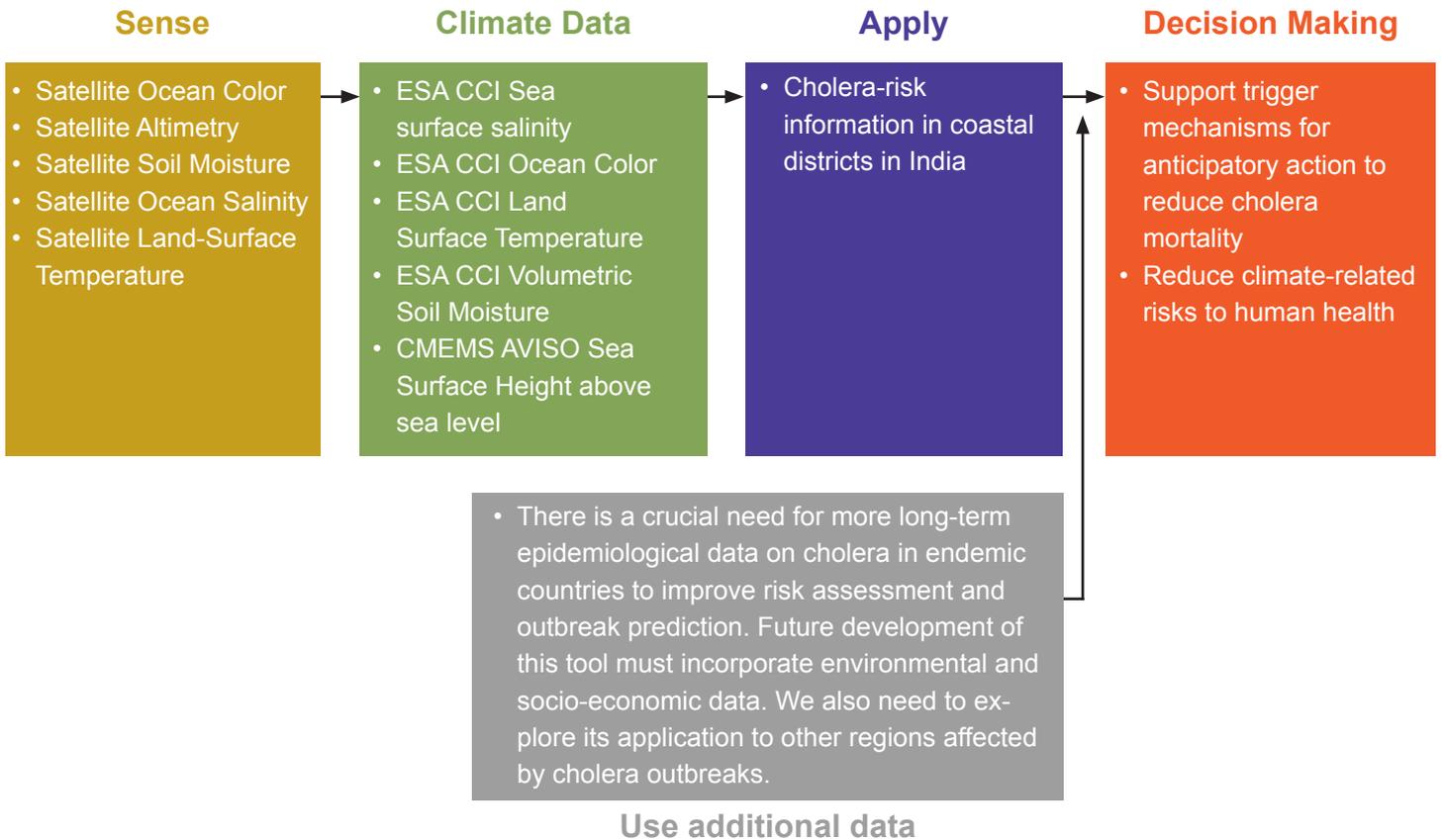


Figure 3: Web-based portal prototype developed for the PODCAST-DEMO project.

# INFORMATION FLOW



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