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Climate Service Center
Germany

How can Machine Learning algorithms be used to develop innovative climate service products?

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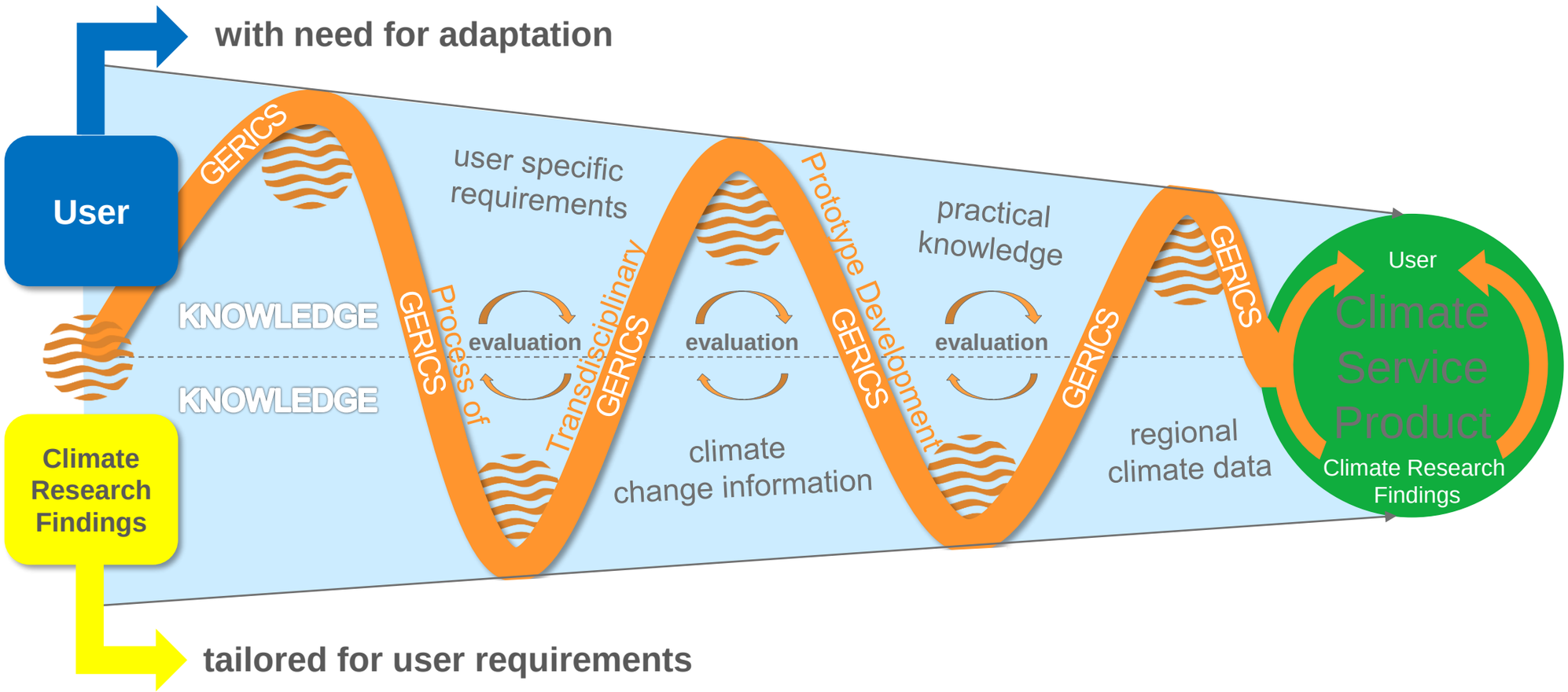
Climate Service Center Germany (GERICS)

GERICS offers **in a scientifically sound manner products, advisory services and decision-relevant information** in order to support government, administration and business in their efforts to adapt to climate change.

Development and expansion of networks	Development of prototype products	Development of training and capacity building programmes

Base: Models, data
& climate service infrastructure

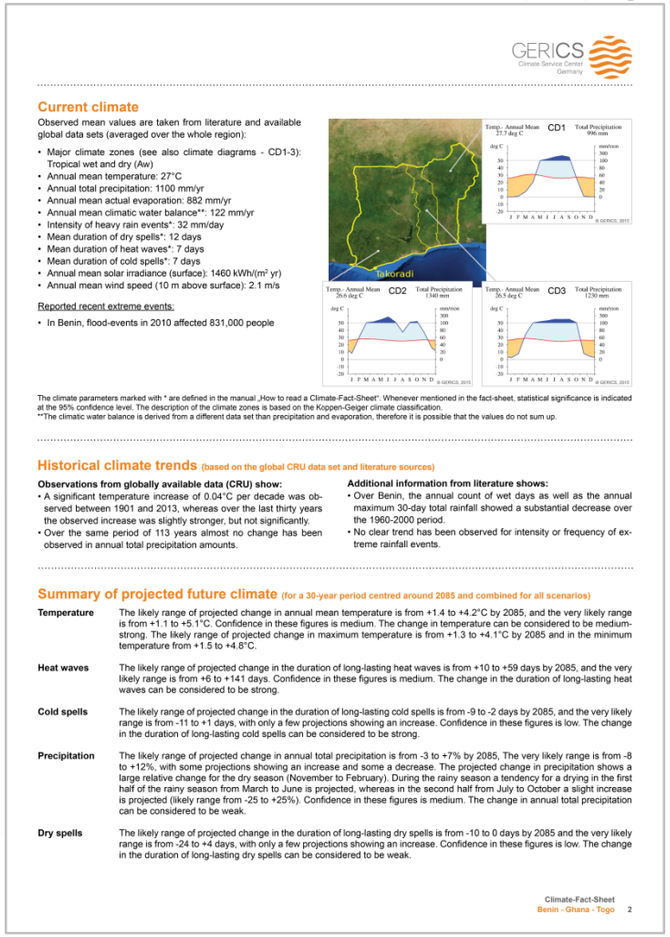
GERICS: Product development



Example: Climate Fact Sheets

Example-pages from CFS: Burkina Faso – Togo – Ghana

Concise climate characteristics of individual countries or regions



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Current climate

Observed mean values are taken from literature and available global data sets (averaged over the whole region):

- Major climate zones (see also climate diagrams - CD1-3): Tropical wet and dry (Aw)
- Annual mean temperature: 27°C
- Annual total precipitation: 1100 mm/yr
- Annual mean actual evaporation: 882 mm/yr
- Annual mean climatic water balance**: 122 mm/yr
- Intensity of heavy rain events*: 32 mm/day
- Mean duration of dry spells*: 12 days
- Mean duration of heat waves*: 7 days
- Mean duration of cold spells*: 7 days
- Annual mean solar irradiance (surface): 1460 kWh/(m² yr)
- Annual mean wind speed (10 m above surface): 2.1 m/s

Reported recent extreme events:

- In Benin, flood-events in 2010 affected 831,000 people

Tskoradi

CD1 Temp.- Annual Mean 27.7 deg C Total Precipitation 996 mm

CD2 Temp.- Annual Mean 26.6 deg C Total Precipitation 1340 mm

CD3 Temp.- Annual Mean 26.3 deg C Total Precipitation 1230 mm

The climate parameters marked with * are defined in the manual „How to read a Climate-Fact-Sheet". Whenever mentioned in the fact-sheet, statistical significance is indicated at the 95% confidence level. The description of the climate zones is based on the Koppen-Geiger climate classification.
**The climatic water balance is derived from a different data set than precipitation and evaporation, therefore it is possible that the values do not sum up.

Historical climate trends (based on the global CRU data set and literature sources)

Observations from globally available data (CRU) show:

- A significant temperature increase of 0.04°C per decade was observed between 1901 and 2013, whereas over the last thirty years the observed increase was slightly stronger, but not significantly.
- Over the same period of 113 years almost no change has been observed in annual total precipitation amounts.

Additional information from literature shows:

- Over Benin, the annual count of wet days as well as the annual maximum 30-day total rainfall showed a substantial decrease over the 1960-2000 period.
- No clear trend has been observed for intensity or frequency of extreme rainfall events.

Summary of projected future climate (for a 30-year period centred around 2085 and combined for all scenarios)

Temperature The likely range of projected change in annual mean temperature is from +1.4 to +4.2°C by 2085, and the very likely range is from +1.1 to +5.1°C. Confidence in these figures is medium. The change in temperature can be considered to be medium-strong. The likely range of projected change in maximum temperature is from +1.3 to +4.1°C by 2085 and in the minimum temperature from +1.5 to +4.8°C.

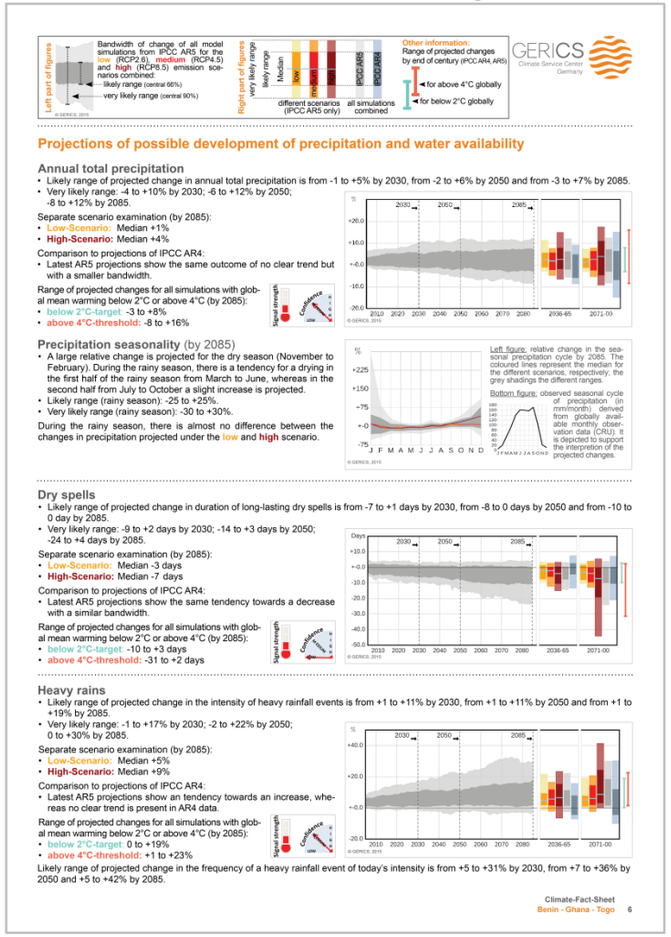
Heat waves The likely range of projected change in the duration of long-lasting heat waves is from +10 to +59 days by 2085, and the very likely range is from +6 to +141 days. Confidence in these figures is medium. The change in the duration of long-lasting heat waves can be considered to be strong.

Cold spells The likely range of projected change in the duration of long-lasting cold spells is from -9 to -2 days by 2085, and the very likely range is from -11 to +1 days, with only a few projections showing an increase. Confidence in these figures is low. The change in the duration of long-lasting cold spells can be considered to be strong.

Precipitation The likely range of projected change in annual total precipitation is from -3 to +7% by 2085, The very likely range is from -8 to +12%, with some projections showing an increase and some a decrease. The projected change in precipitation shows a large relative change for the dry season (November to February). During the rainy season a tendency for a drying in the first half of the rainy season from March to June is projected, whereas in the second half from July to October a slight increase is projected (likely range from -25 to +25%). Confidence in these figures is medium. The change in annual total precipitation can be considered to be weak.

Dry spells The likely range of projected change in the duration of long-lasting dry spells is from -10 to 0 days by 2085 and the very likely range is from -24 to +4 days, with only a few projections showing an increase. Confidence in these figures is low. The change in the duration of long-lasting dry spells can be considered to be weak.

Climate-Fact-Sheet
Benin - Ghana - Togo 2



Left part of figures: Bandwidth of change of all model simulations from IPCC AR5 for the low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emission scenarios combined: likely range (central 66%); very likely range (central 90%)

Right part of figures: very likely range; likely range; Median; low; med; high; RCP2.6; RCP4.5; RCP8.5; different scenarios (IPCC AR5 only); all simulations combined

Other information: Range of projected changes by end of century (IPCC AR4, AR5): for above 4°C globally; for below 2°C globally

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Projections of possible development of precipitation and water availability

Annual total precipitation

- Likely range of projected change in annual total precipitation is from -1 to +5% by 2030, from -2 to +6% by 2050 and from -3 to +7% by 2085.
- Very likely range: -4 to +10% by 2030; -6 to +12% by 2050; -8 to +12% by 2085.

Separate scenario examination (by 2085):

- Low-Scenario: Median +1%
- High-Scenario: Median +4%

Comparison to projections of IPCC AR4:

- Latest AR5 projections show the same outcome of no clear trend but with a smaller bandwidth.

Range of projected changes for all simulations with global mean warming below 2°C or above 4°C (by 2085):

- below 2°C-target: -3 to +8%
- above 4°C-threshold: -8 to +16%

Precipitation seasonality (by 2085)

- A large relative change is projected for the dry season (November to February). During the rainy season, there is a tendency for a drying in the first half of the rainy season from March to June, whereas in the second half from July to October a slight increase is projected.
- Likely range (rainy season): -25 to +25%.
- Very likely range (rainy season): -30 to +30%.

During the rainy season, there is almost no difference between the changes in precipitation projected under the low and high scenario.

Left figure: relative change in the seasonal precipitation cycle by 2085. The coloured lines represent the median for the different scenarios, respectively; the grey shadings the different ranges.

Bottom figure: observed seasonal cycle of precipitation (in mm/month) derived from globally available monthly observation data (CRU). It is depicted to support the interpretation of the projected changes.

Dry spells

- Likely range of projected change in duration of long-lasting dry spells is from -7 to +1 days by 2030, from -8 to 0 days by 2050 and from -10 to 0 day by 2085.
- Very likely range: -9 to +2 days by 2030; -14 to +3 days by 2050; -24 to +4 days by 2085.

Separate scenario examination (by 2085):

- Low-Scenario: Median -3 days
- High-Scenario: Median -7 days

Comparison to projections of IPCC AR4:

- Latest AR5 projections show the same tendency towards a decrease with a similar bandwidth.

Range of projected changes for all simulations with global mean warming below 2°C or above 4°C (by 2085):

- below 2°C-target: -10 to +3 days
- above 4°C-threshold: -31 to +2 days

Heavy rains

- Likely range of projected change in the intensity of heavy rainfall events is from +1 to +11% by 2030, from +1 to +11% by 2050 and from +1 to +19% by 2085.
- Very likely range: -1 to +17% by 2030; -2 to +22% by 2050; 0 to +30% by 2085.

Separate scenario examination (by 2085):

- Low-Scenario: Median +5%
- High-Scenario: Median +19%

Comparison to projections of IPCC AR4:

- Latest AR5 projections show an tendency towards an increase, whereas no clear trend is present in AR4 data.

Range of projected changes for all simulations with global mean warming below 2°C or above 4°C (by 2085):

- below 2°C-target: 0 to +19%
- above 4°C-threshold: +1 to +23%

Likely range of projected change in the frequency of a heavy rainfall event of today's intensity is from +5 to +31% by 2030, from +7 to +36% by 2050 and +5 to +42% by 2085.

Climate-Fact-Sheet
Benin - Ghana - Togo 6

Jointly developed with KFW

Available on request:
www.climate-service-center.de/climate-fact-sheets

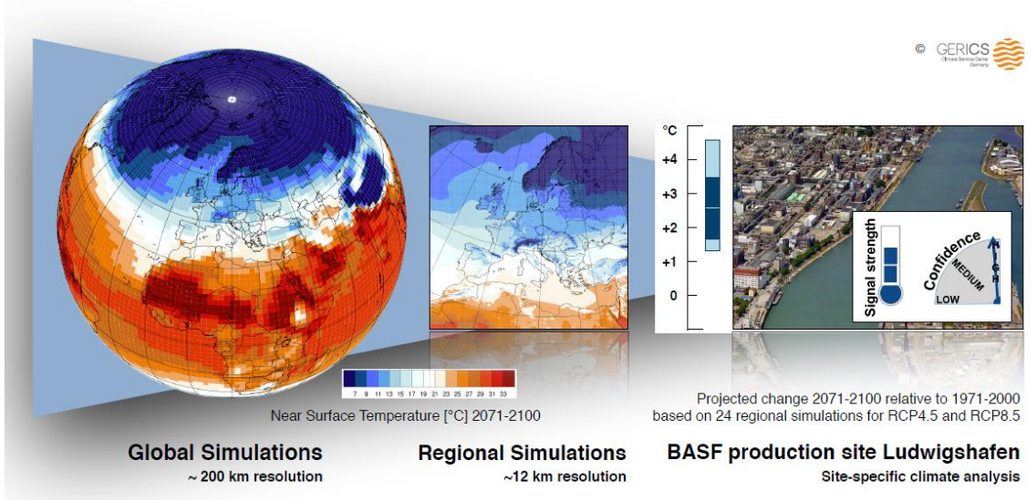
Data & data analysis

Climate model data:

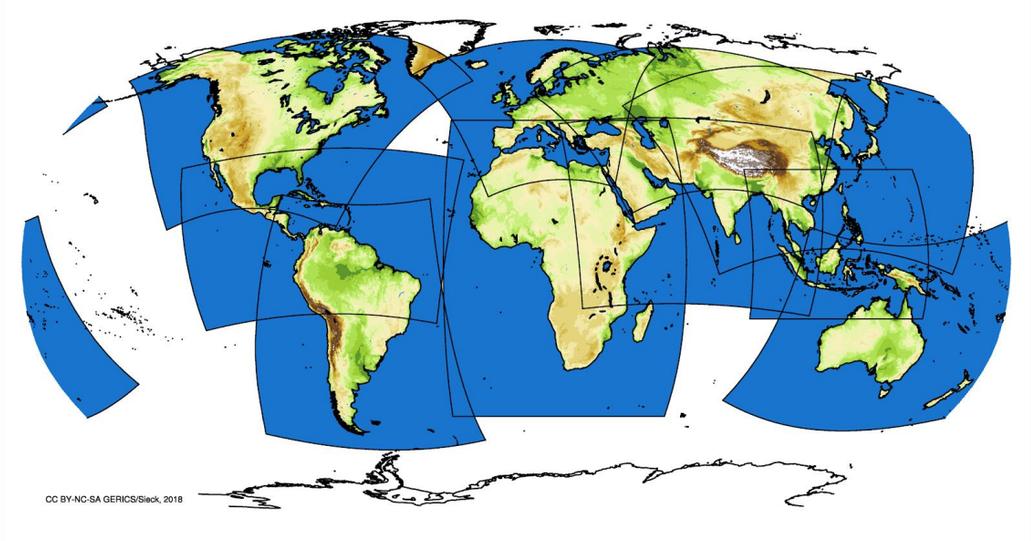
- Period 1950 to 2100, different emission scenarios
- >70 global climate model simulations (CMIP3/CMIP5)
- >50 regional climate model simulations for Europe

Data size:

- RCMs for globe (CORDEX-CORE):
- **~1.5 PB** in total for one regional climate model
- **~1.5 TB** for one climate variable (e.g. 2m Temp)



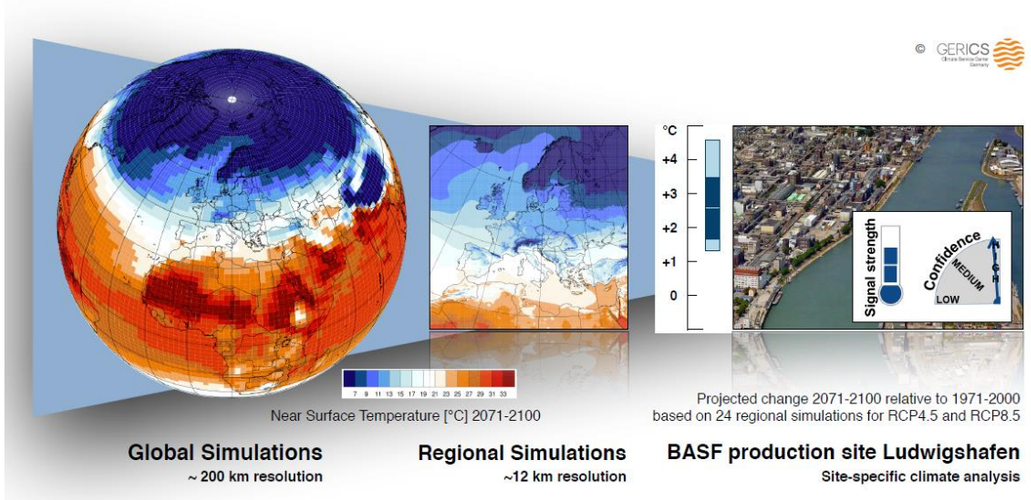
CORDEX-CORE



Data & data analysis

Data analysis:

- Statistical tools from standard (e.g. regression, sig. test) to more complex methods (e.g. cluster analysis)
  - **Quicker methods & detection of extremes**
- Computation of complex indices (e.g. drought indices)
  - **Improved indices for sectoral prediction of vulnerability**
- Future development: sectorial models using additional datasets (e.g. flood risk models, biol. models)
  - **Taking advantage of new large datasets**
  - **Going beyond to physical data & modeling**



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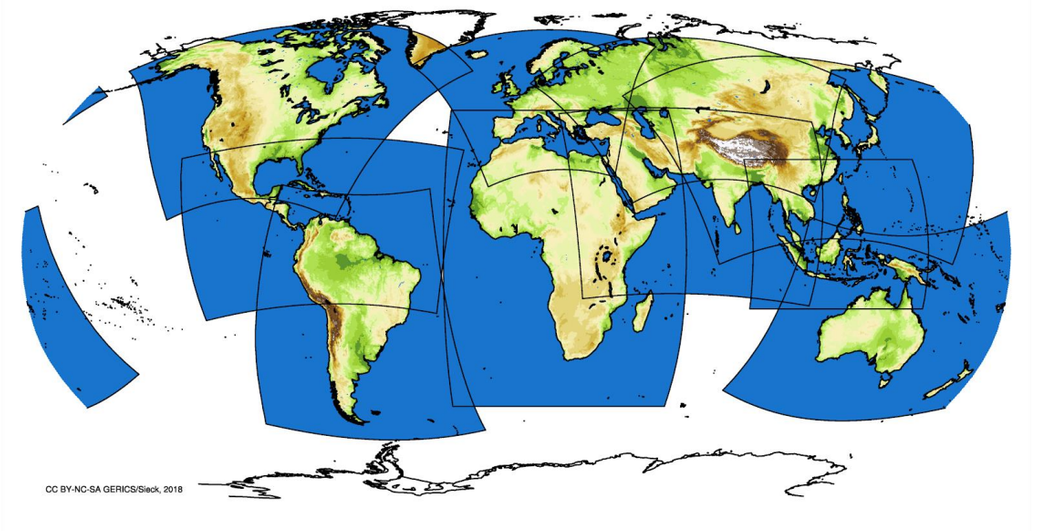


Example: ML in climate service for flood risk modeling

Aim:

- Compute damage function from storm surges

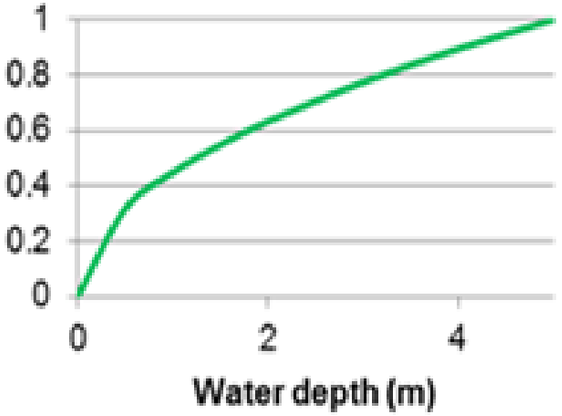
Opportunities:

- Using a range of additional datasets
- Possible new scientific insight

Deltares
Enabling Delta Life

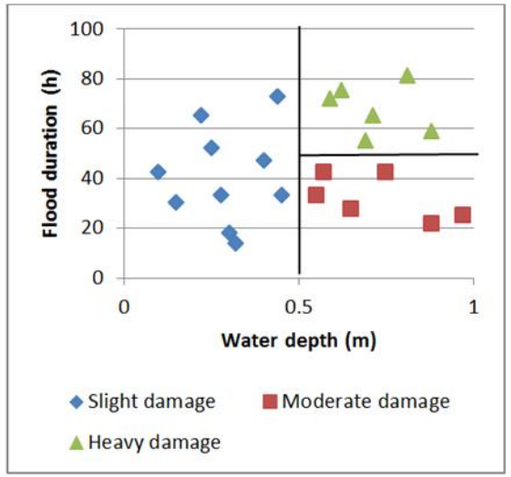
Going from:

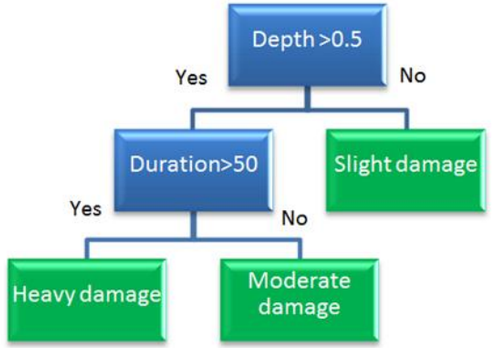
Damage Function = f(water depth)



to:

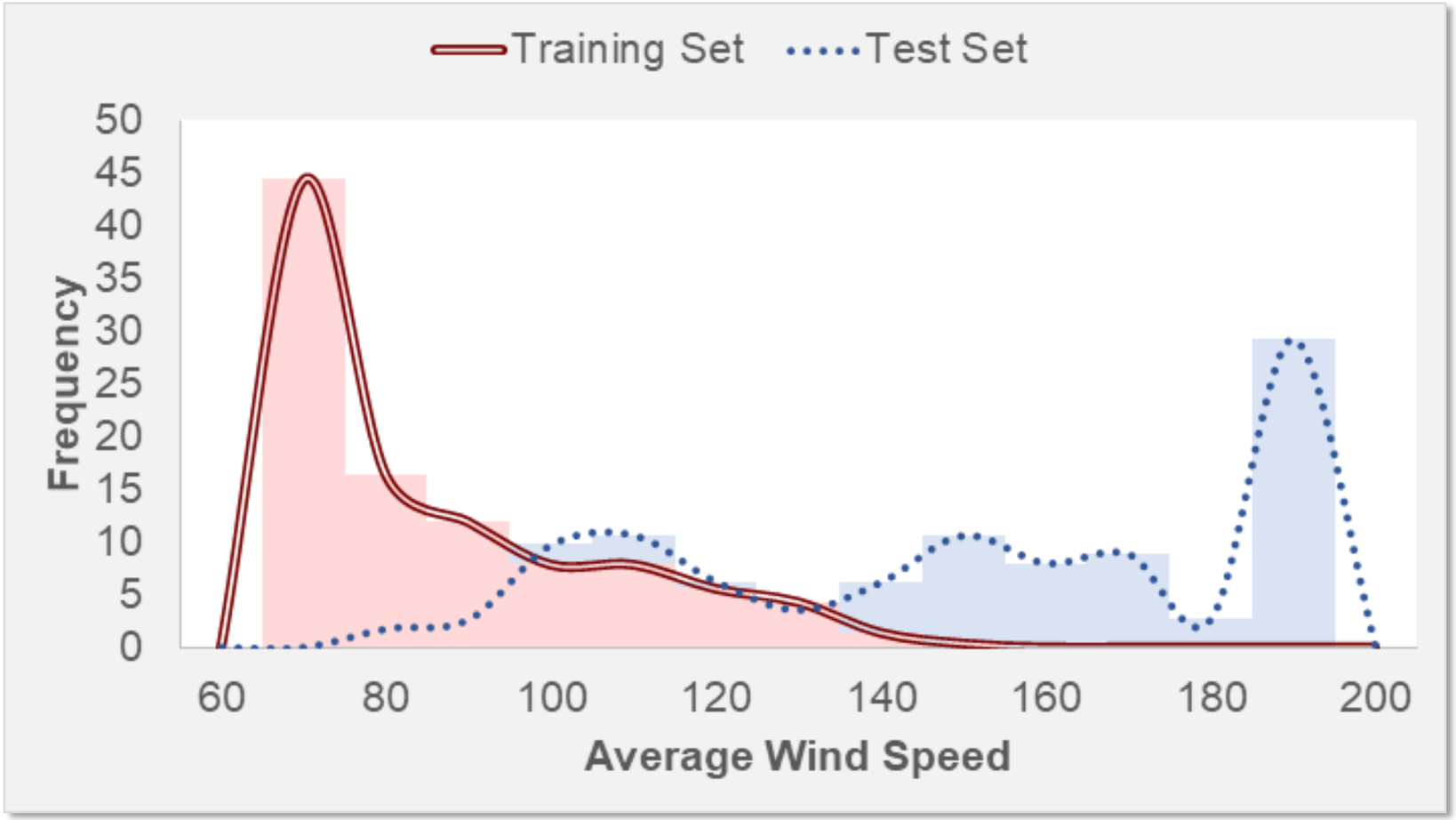
DF = f(water depth, warning time, waves height, …..)



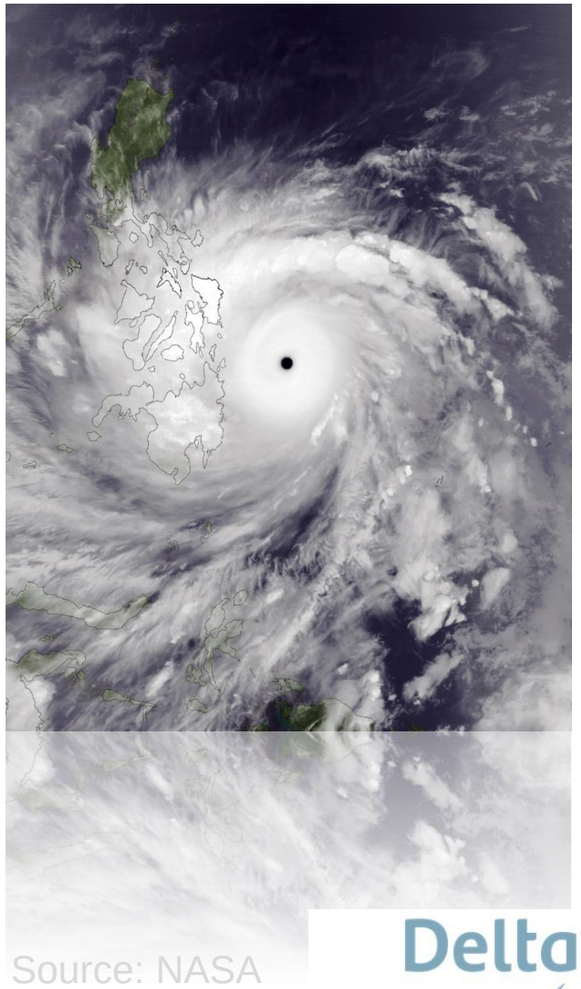


Challenges: Sample Bias Problem

3-minute gust speeds in Typhoon Haiyan versus other cyclones (Philippines)



From: Wagenaar et al. resubmitted, *Risk Analysis*



Source: NASA

Deltares
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Example: ML in climate service for health

Aim:

- Impact of future heatwaves on human health

Opportunities:

- Large amount of data from different sources available

Challenges:

- Complex interactions between health, society, environment and climate
  - What are appropriate ML tools to tackle this problem?
  - Quality of the different datasets needs to be tested!
  - New workflow for data provision and analysis

Exploring ML methods in joint project of GERICS and Helmholtz Zentrum München (HMGU)

Summary: Opportunities, Challenges and Risks for climate services

Opportunities

- Exploiting large climate model and sectoral datasets
- Integration of physical climate data with socio-economic data
- New innovative products using ML in addition to existing “standard” methods
- New scientific insights possible

Challenges

- Quality of heterogeneous input data from different sources
- Quality assessment of products based on ML methods
- Incorporate appropriate ML method in established workflow

Risks

- Incorrect use of ML methods might degrade products

need for transdisciplinary collaboration, e.g. climate science, data science, health etc.