문서번호 APCC-출장-18-0440(2018-05-14)

결재	선임연구원	팀장	부서장	원장직무대행
	05/14 이승수	05/14 문자연	05/14 유진호	05/14 유진호
협조				

TRAVEL REPORT FORM
출장보고서

I. Travel Overview 출장개요

1. Traveler(s) 출장자

Department 소속	Position 직위(직급)	Name 성명	Note 비고
예측기술팀	선임연구원	이승수	

2. Travel Period 출장기간

: 2018. 5. 5. ~ 2018. 5. 11

3. Occasion and destination 행사 및 출장지
: WMO Hydroconference 참여 (제네바, 스위스)

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동
  - 5/7 ~ 5/9 (3일간) 제네바에 위치한 WMO에서 개최된 Hydroconference 참석

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- Data management에 있어서는 단순 정보 수집에만 집중할게 아니라 data uncertainty 를 고려하여 신뢰도와 정확도가 높은 자료를 수집하여야 함을 강조함.
- 또한 개발도상국에서의 데이터 확보를 위해서 infrastructure에 대한 국제적인 투자가 있어야 하며, 그 데이터를 수집/관리 하기 위하나 지역 전문가들을 키우기 위한 capacity building이 수반 되어야 함.
- 추가적으로 data의 범위는 관측정보뿐만 아니라 modeling output도 포함된다는 것으로 보고 있으며 meteorologist, climatologist, hydrometeorologist 들 사이의 gap이 매우 크다는 점을 지적하며 서로간의 gap을 줄이기 위한 노력이 매우 시급하다는 언급이 있었음.
- 그러나 구체적으로 어떠한 원인으로 인하여 그들의 gap이 큰지 (global scale and local scale 의 차이 수준의 지적 밖에 없었음), 그 gap을 줄이기 위한 구체적인 노력에 대한 언급은 없었음 (ex, how to treat modeling output data, how to reduce the gap among downscaling method, probabilistic(or ensemble) approach of climatologist and deterministic approach of engineer etc.) -> 매우 아쉬움, 그러나 아직은 이정도 수준의 이야기 밖에 나눌 수 없을 정도로 상호간의 협업이 아직 이루어지고 있지 않다고 판단되며 이러한 점에서 현재 APCC에서 수행하고 있는 융합연구를 통해 best practice를 만들어 (APCC의 정체성과 역할 중 하나인)이 분야의 주도권을 가질 수 있는 가능성이 매우 높다고 판단

됨.

- Data delivery에 관해서는 data의 표준화가 (meta data standardization) 필요하며 수집된 자료의 보관을 위한 서버, 송수신을 위한 network 유지에 관한 투자가 필요함.
- Hydrological products에 대해서는 기본적으로 end user의 needs가 반영된 product가 생산되어야 한다는 의견이 주류를 이루고 있으나 provider가 자체 생산한 자료의 활용성에 관한 필요성을 만들어 user들로 하여금 생산물을 활용하게 만드는 노력도 필요하다는 의견이 있었음.
- 또한 활용성 증진을 위하여 수집된 정보의 불확실성을 고려한 best practice가 필요함.
- Best practice를 참고로 하여 실제 생산된 hydrological product가 어떤 식으로 end user와 decision maker들에게 도움이 될 수 있는지를 보여주는 것이 필요함.
- 추가적으로 hydrological products delivery에서 최우선으로 고려되어야 하는 것은 don't kill local experts의 기조가 있음.
- 아무리 좋은 정보를 효율적으로 생산하여 공유한다고 할지라도 국제적 차원에서 제공하는 정보가 지역 전문가들이 하는 역할을 위협하게 된다는 개별지역에서 전문가들의 지지를 얻지 못하게 될 것임.

Keywords : stakeholder engagement, data management, end user, decision maker, data uncertainty, standardization, local expert, communication with end user.

3. Suggestions and Remarks 건의사항

- 융합연구의 과제화가 시급한 것으로 판단되므로 향후 연구계획에 반영되어야 하여 기후자료를 활용한 best practice를 만들 필요가 있음.

III. References (Presented and Collected Materials) 주요 수집자료

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

- 발표 자료 첨부

Water, disasters & climate change

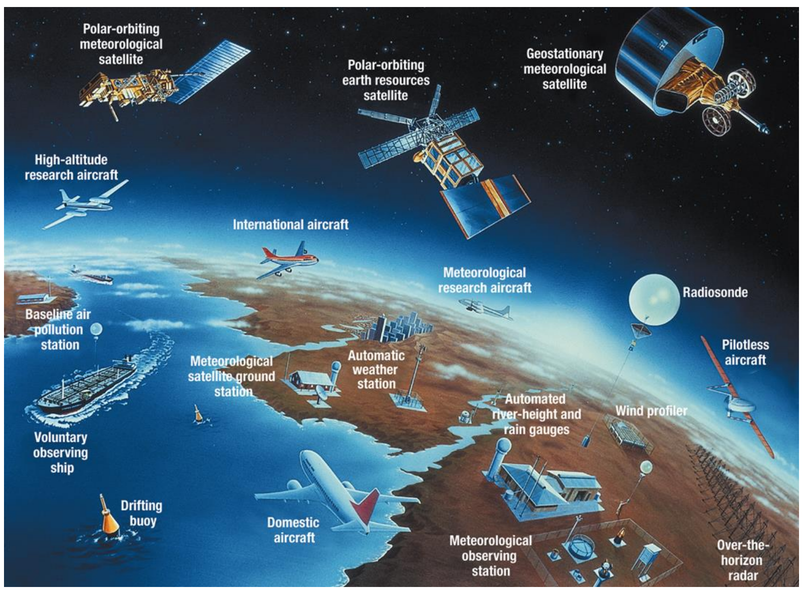
Prof. Petteri Taalas
Secretary-General

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

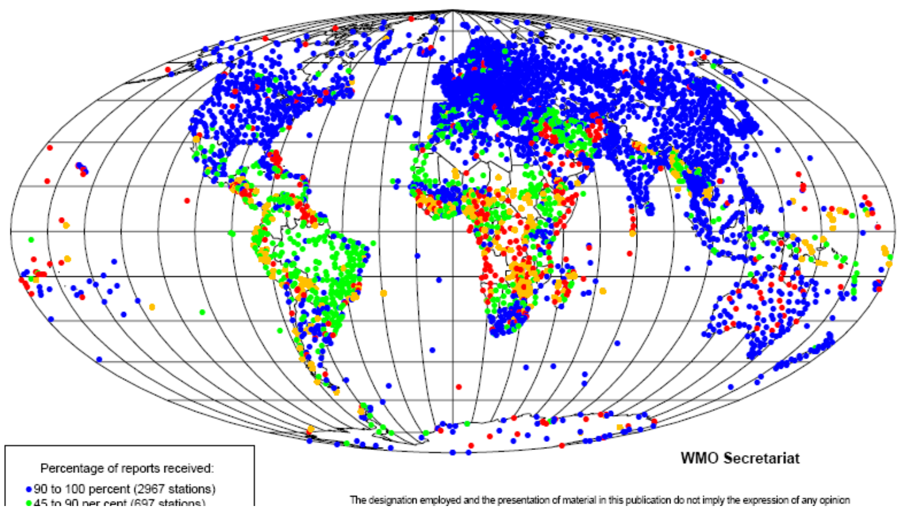
World Meteorological Organization



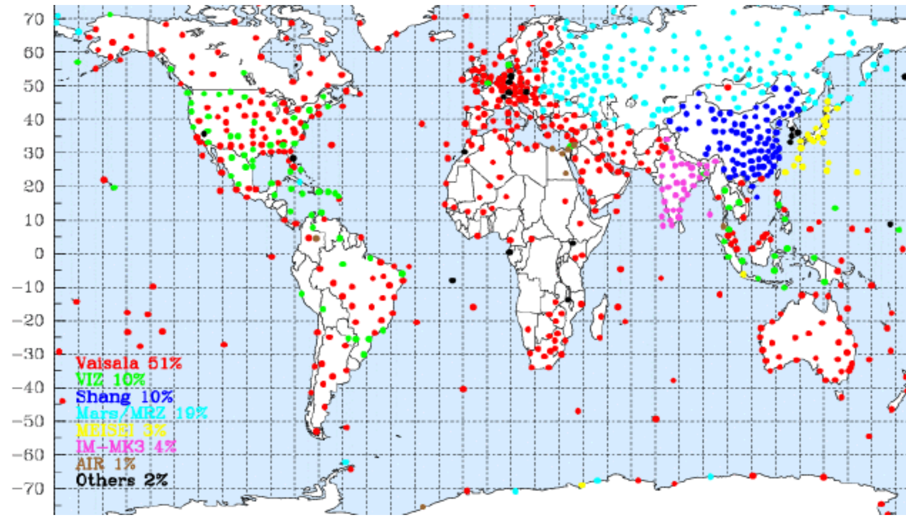
- UN Specialized Agency on weather, climate & water
- 191 Members, HQ in Geneva
- Coordinates work of > 200 000 national experts from meteorological & hydrological services, academia (& private sector)
- Co-Founder and host agency of IPCC (1st World Climate Conference)
- Co-Founder of UNFCCC (2nd World Climate Conference)

WMO OMM

WMO Global Observing Networks >10000 stations

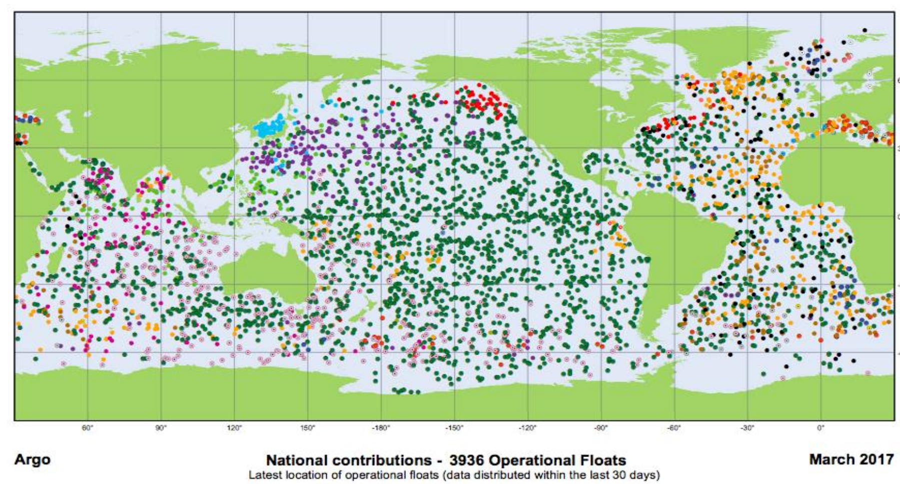


Surface observations



Balloon soundings

Air quality and greenhouse gases



Ocean weather (with IOC UNESCO)

Figure 3.17.

contributions.

national

SUSTAINABLE DEVELOPMENT GOALS/WMO

1 NO POVERTY
Weather resilience

2 ZERO HUNGER
Climate change & -services

3 GOOD HEALTH AND WELL-BEING

4 QUALITY EDUCATION

5 GENDER EQUALITY

6 CLEAN WATER AND SANITATION
Water resource management

7 AFFORDABLE AND CLEAN ENERGY
Solar, wind & hydro use

8 DECENT WORK AND ECONOMIC GROWTH
Climate resilience

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
Big data, innovations

10 REDUCED INEQUALITIES

11 SUSTAINABLE CITIES AND COMMUNITIES
Air quality, heat waves, flooding

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION
DRR, Adaptation, carbon & climate monitoring

14 LIFE BELOW WATER
Sea level rise, climate<->oceans

15 LIFE ON LAND
Climate change <->ecosystems

16 PEACE, JUSTICE AND STRONG INSTITUTIONS
Climate driven conflicts

17 PARTNERSHIPS FOR THE GOALS
Resources for climate adaptation & DRR

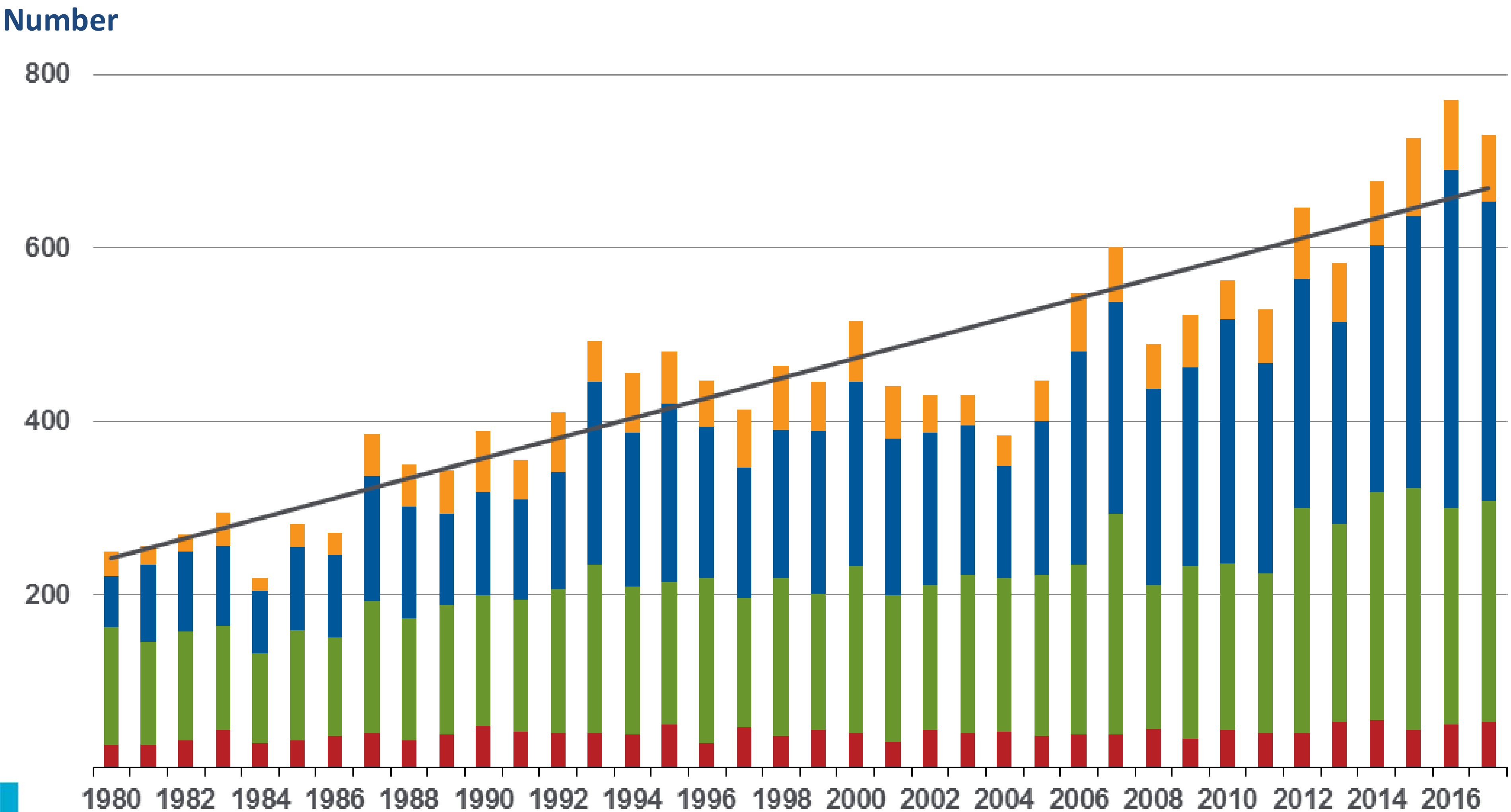
Weather & water risks are the top economic risks

World Economic Forum, Davos - Global Risk Landscape 2018

WMO OMM

Source: World Economic Forum (2018)

Loss events worldwide 1980 – 2017



Geophysical events (Earthquake, tsunami, volcanic activity)

Meteorological events (Tropical storm, extratropical storm, convective storm, local storm)

Hydrological events (Flood, mass movement)

Climatological events (Extreme temperature, drought, forest fire)

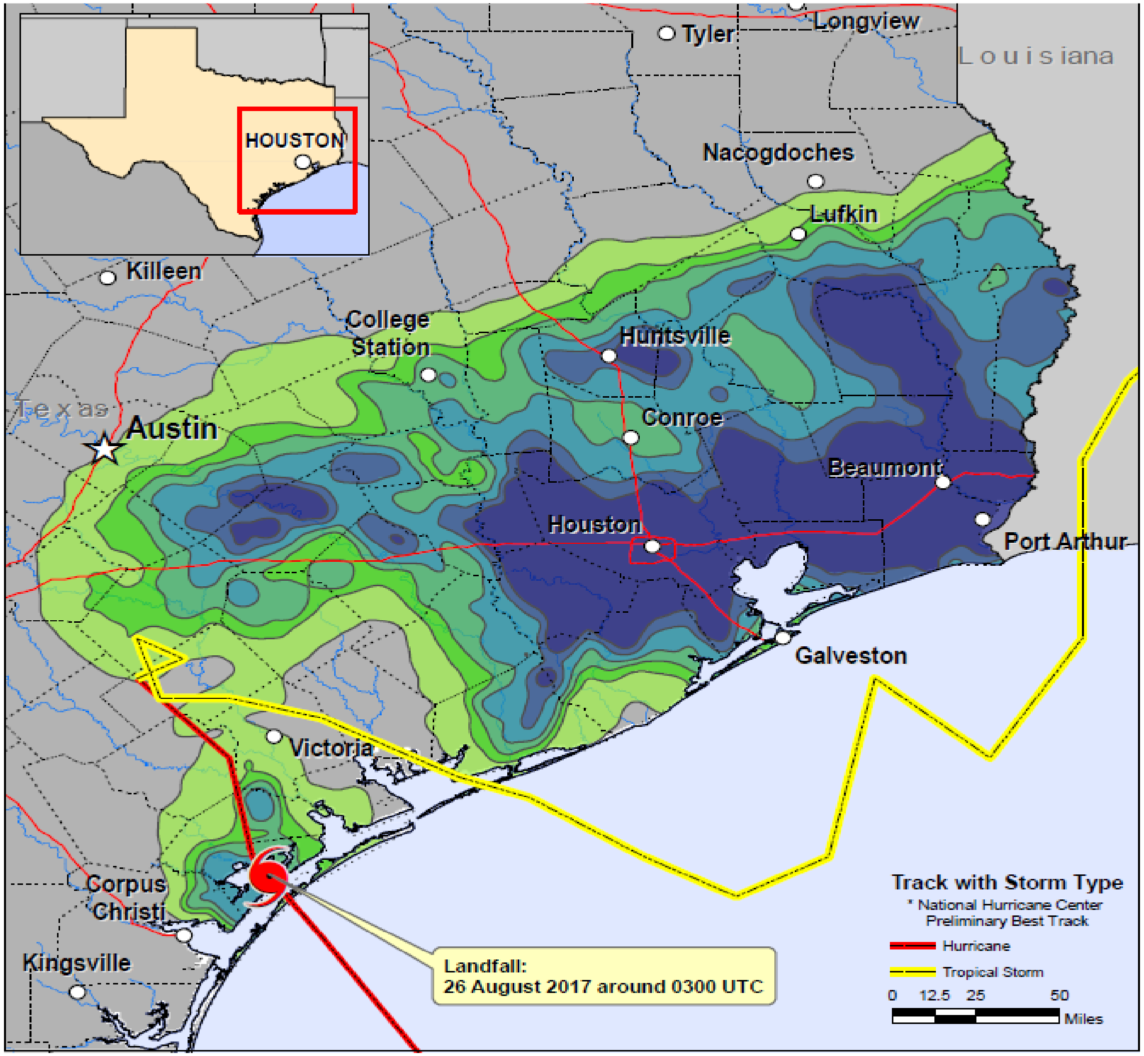
Accounted events have caused at least one fatality and/or produced normalized losses ≥ US$ 100k, 300k, 1m, or 3m (depending on the assigned World Bank income group of the affected country).

WMO OMM

2017 Record breaking economic losses

WMO OMM

Flooding in Houston August 2017



Hurricane Harvey, 25 - 31 August 2017
Annual Exceedance Probabilities (AEPs) for the Worst Case 4-day Rainfall

Hydrometeorological Design Studies Center
Office of Water Prediction, National Weather Service
National Oceanic and Atmospheric Administration

http://www.nws.noaa.gov/ohd/hdsc/

Created 16 November 2017
Rainfall frequency estimates are from preliminary NOAA Atlas 14, Volume 11, Version 1.
Rainfall values come from 6-hour Stage IV data.

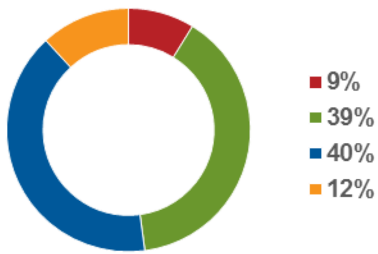
N

- > 1/10
- 1/50 - 1/10
- 1/100 - 1/50
- 1/200 - 1/100
- 1/500 - 1/200
- 1/1000 - 1/500
- < 1/1000

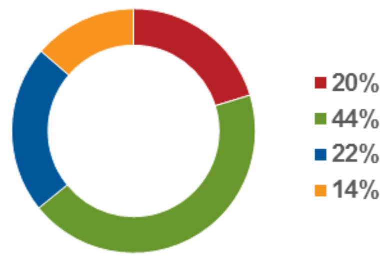
Loss events worldwide 1980 – 2017

Percentage distribution

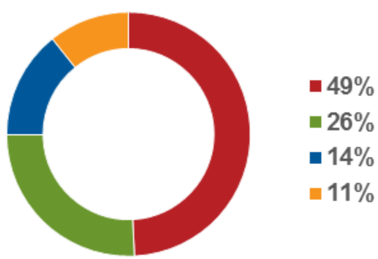
Number of relevant events: 17,300



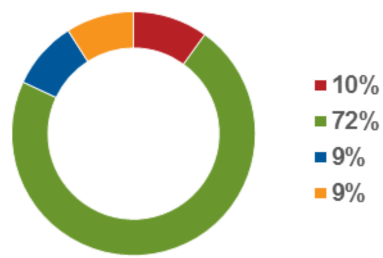
Overall losses: US$ 4,600bn



Fatalities: 1,720,000



Insured losses: US$ 1,300bn



- **Geophysical events** (Earthquake, tsunami, volcanic activity)
- **Meteorological events** (Tropical storm, extratropical storm, convective storm, local storm)
- **Hydrological events** (Flood, mass movement)
- **Climatological events** (Extreme temperature, drought, forest fire)

Accounted events have caused at least one fatality and/or produced normalized losses ≥ US$ 100k, 300k, 1m, or 3m (depending on the assigned World Bank income group of the affected country).

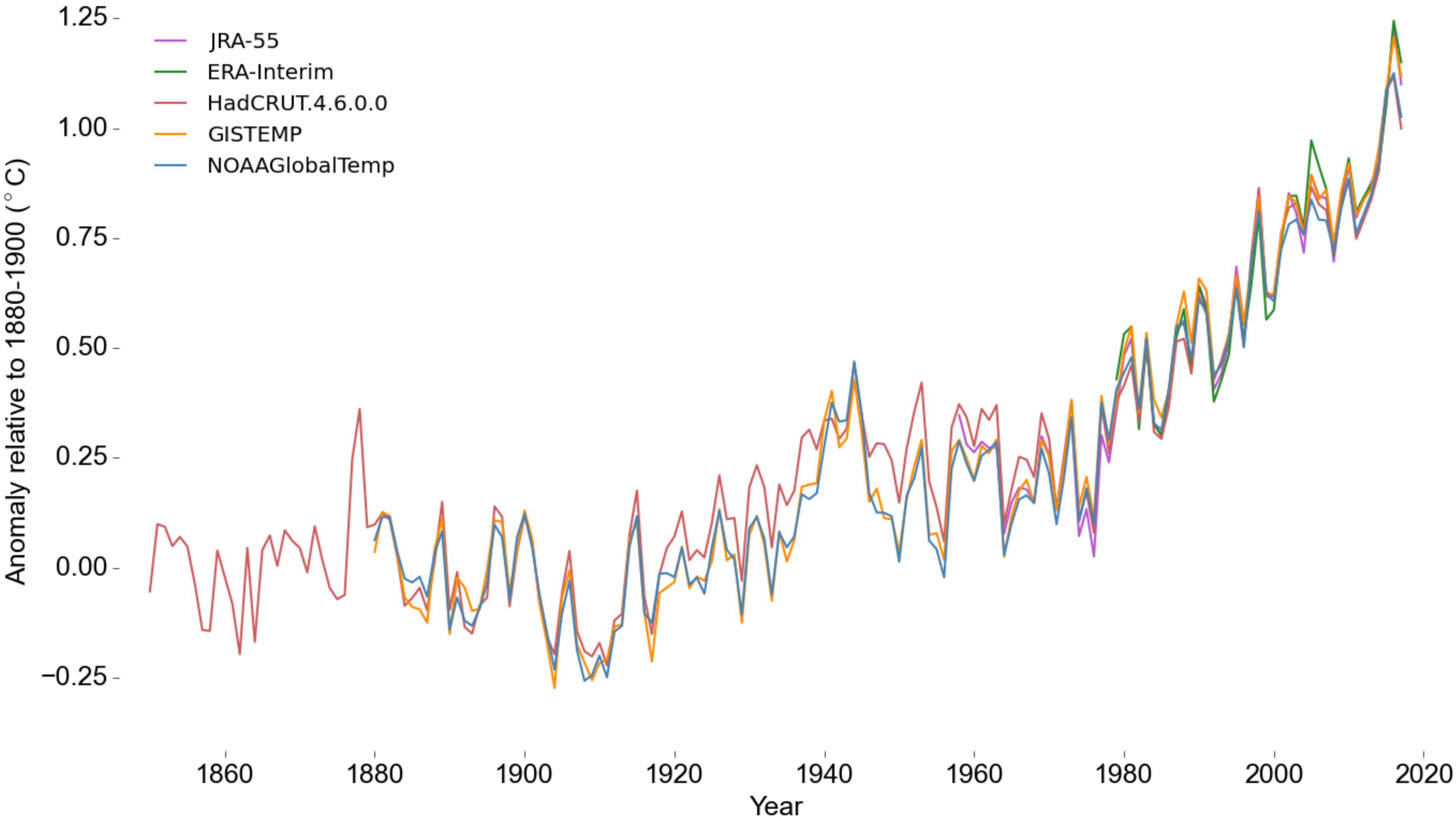
Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US$.

Global adaptation index

Univ. Notre Dame

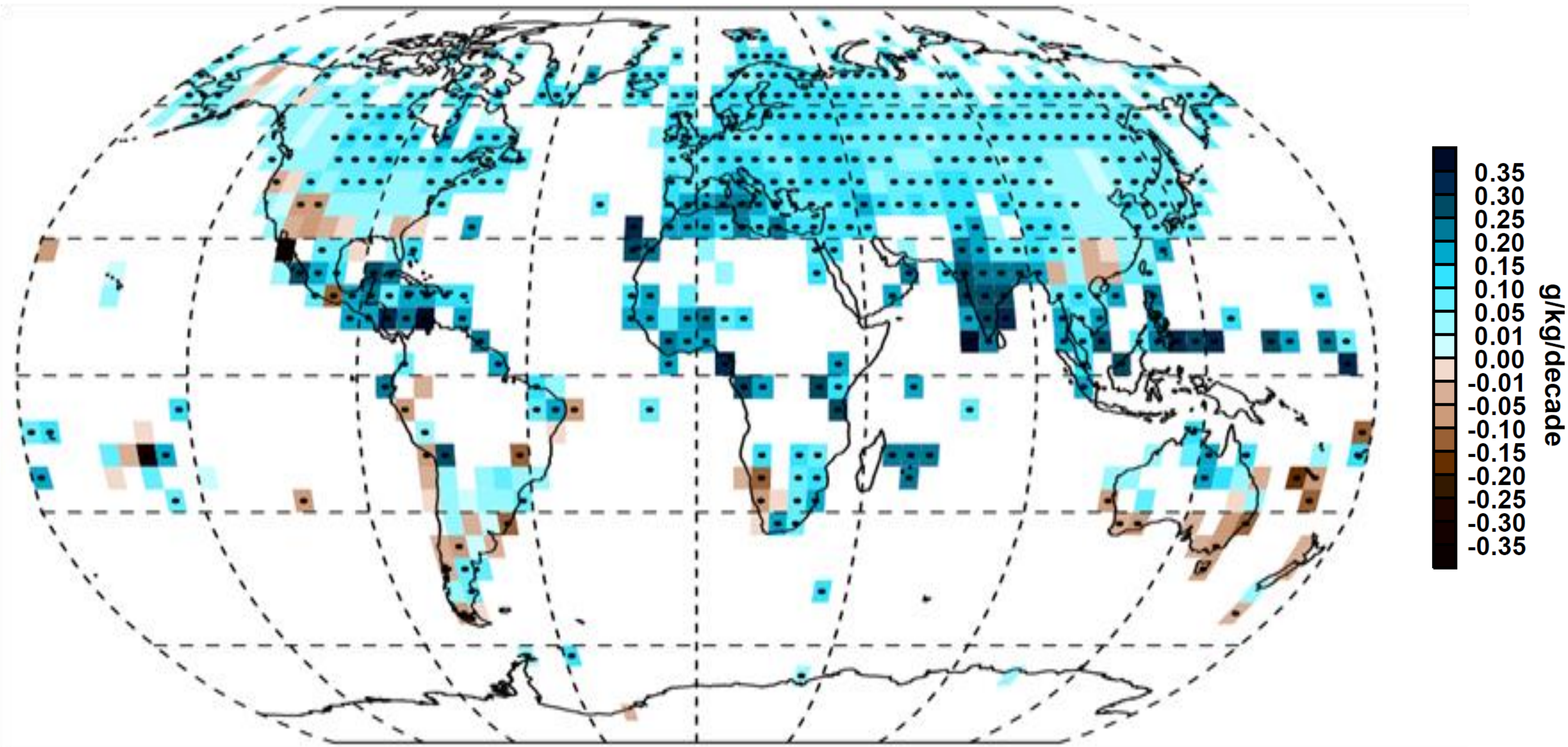
WMO OMM

Global temperature deviations 1850-2017



WMO OMM

Specific humidity has risen in large parts of the Northern Hemisphere

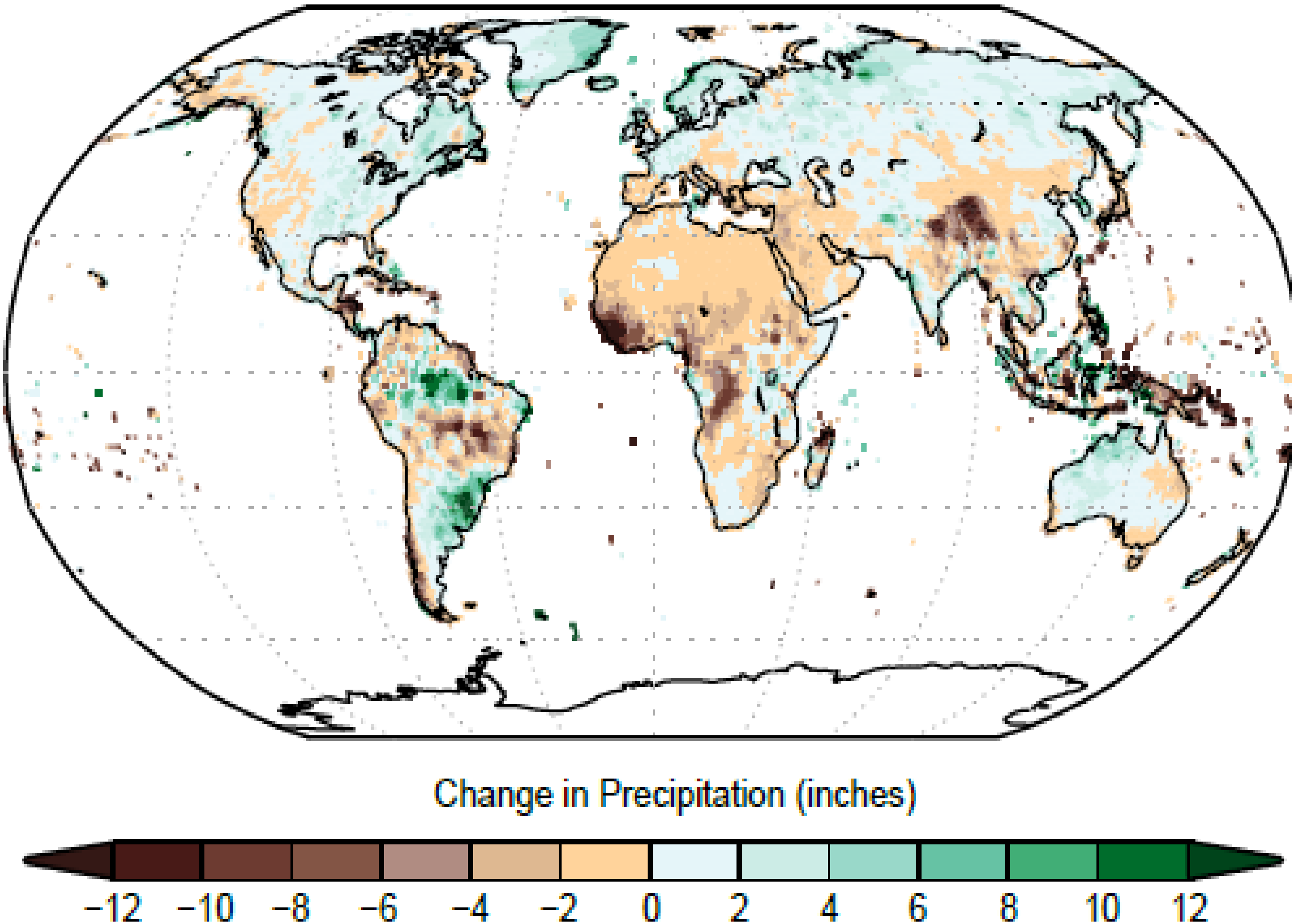


Change in near-surface specific humidity over time in the northern hemisphere 1973–2012 (Source: Willett et. al. (2013), Clim. Past, 9, 657–677.Black dots: trends significant at the 95% level

WMO OMM

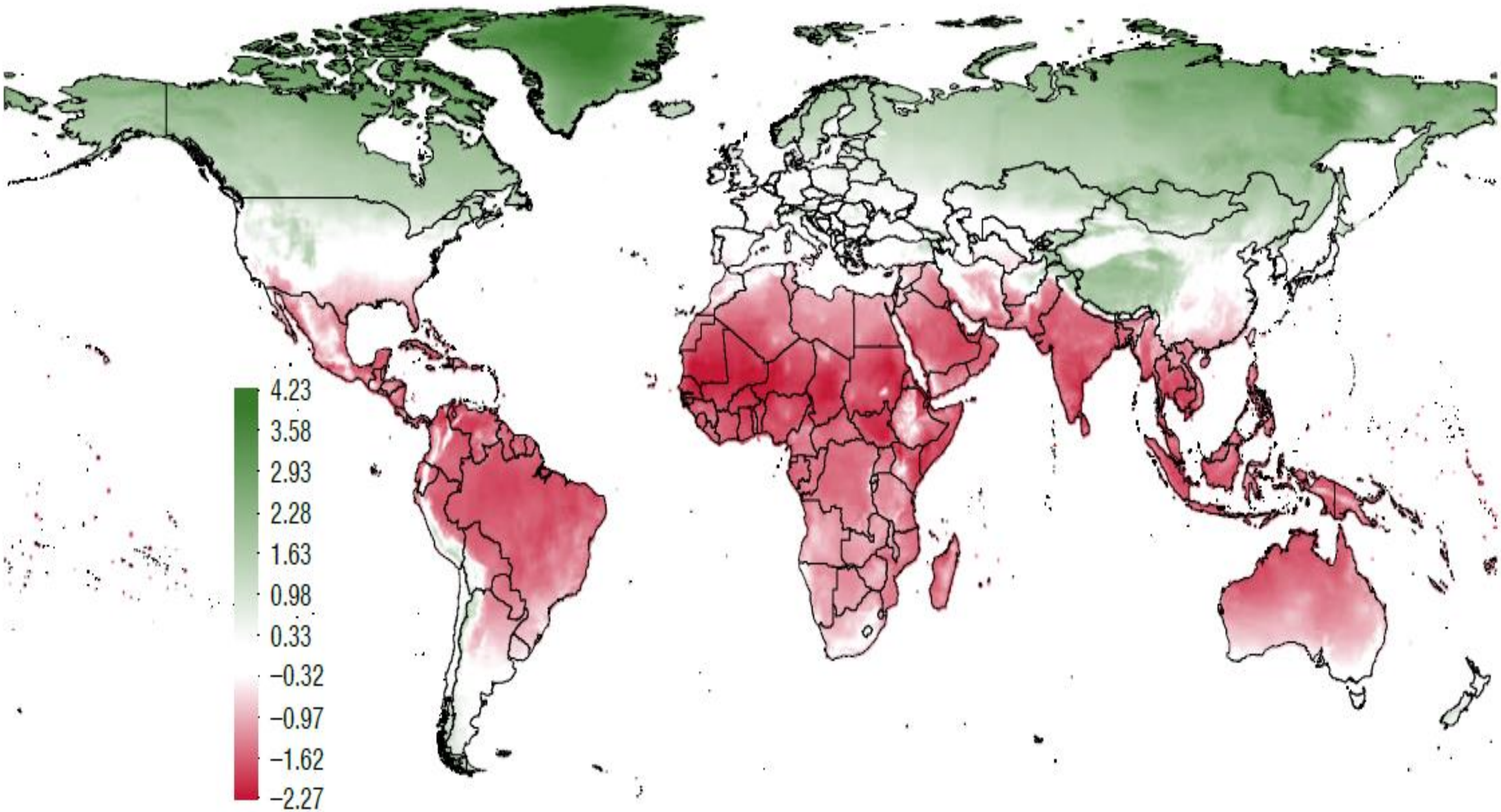
Climate model studies: Increase due to anthropogenic climate change (Willet et al., 2010, Environ. Res. Letter, 5; Santer et al., 2007, PNAS, 104)

Global precipitation 1986–2015 vs. 1901–1960



WMO OMM

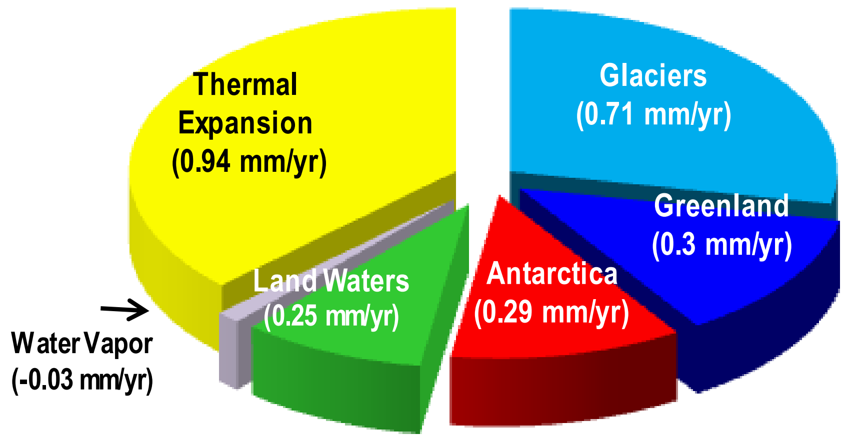
Effect of 1°C temperature increase on per capita output

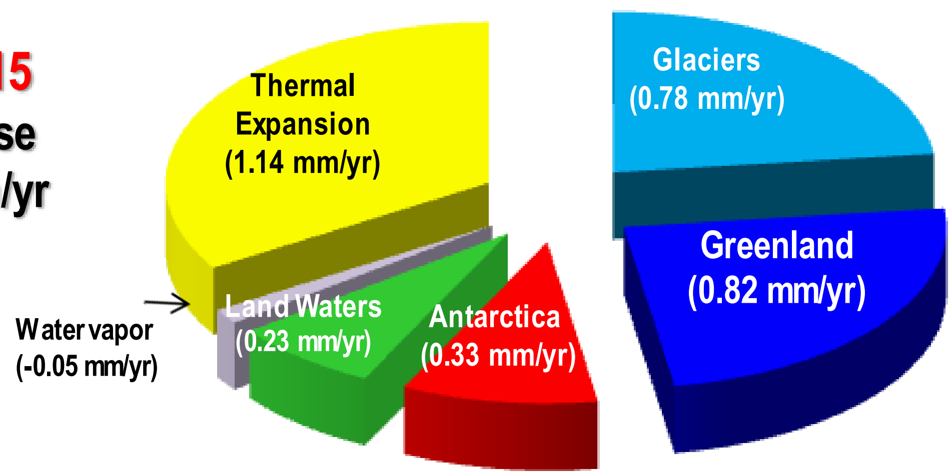


WMO OMM

Source: International Monetary Fund (IMF) World Economic Outlook

Contributions to global sea level rise



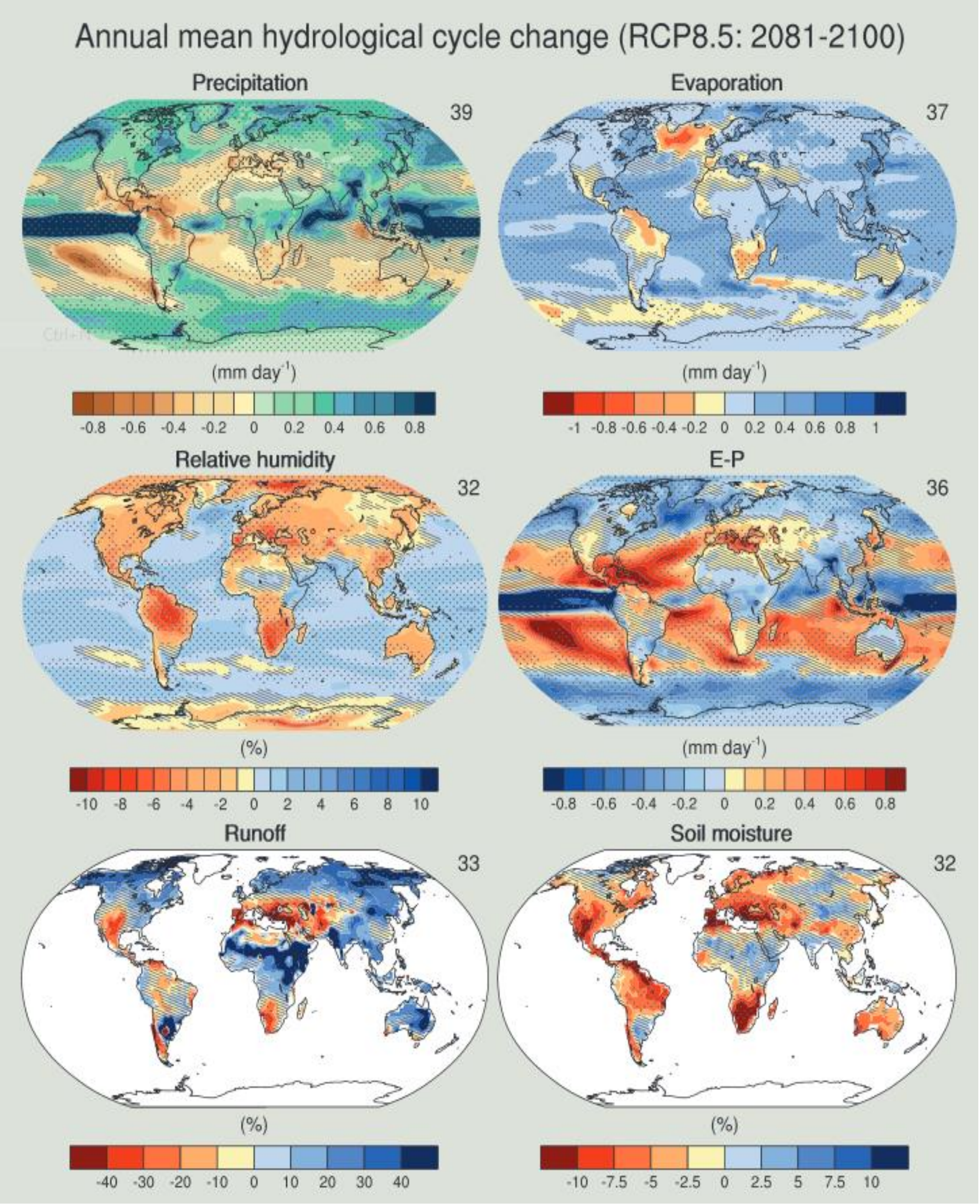


WMO OMM

Source: LEGOS

NO EMISSION CUTS

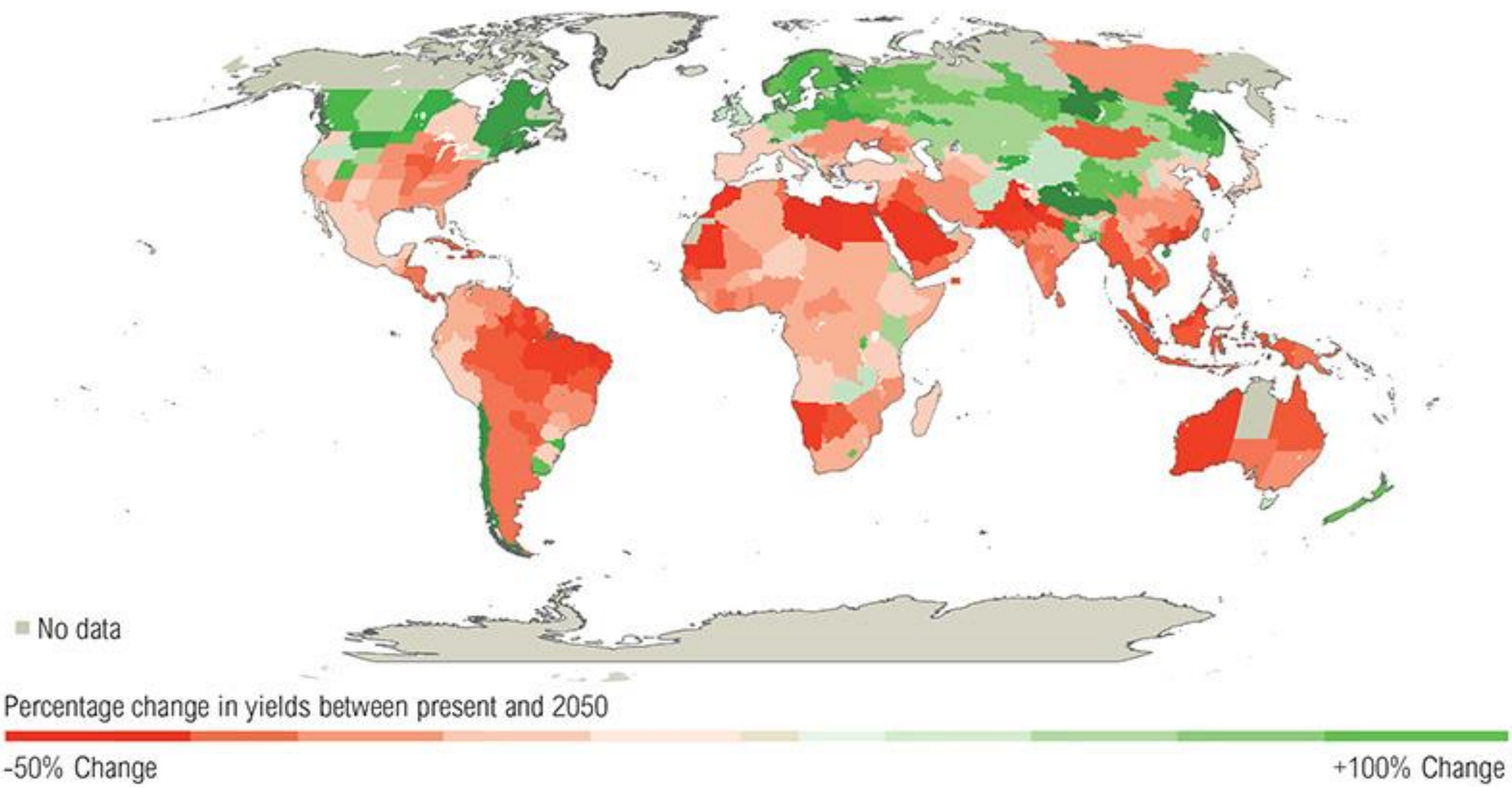
NOW => 2081-2100



WMO OMM

Impact of 3 C warming on crop yields

Most studies now project adverse impacts on crop yields due to climate change (3°C warmer world)



WORLD RESOURCES INSTITUTE

Sources: http://ow.ly/rpfMN

WMO OMM

WMO/ Water

1. Water one of the three focal areas
2. Promotion of national multi-hazard early warning systems: weather, hydrology, oceanography, seismology, volcanology, air quality, space weather
3. Earth System observation and IT infrastructures, WIGOS
4. Climate research and services
5. Better engagement of hydrological actors in WMO activities
6. One day of WMO Executive Council June 2018 dedicated to water
7. Investments in science, new Chief Scientist prof. Pavel Kabat/IIASA

WMO OMM

Expected impact of the conference

1. WMO is serving the interests of global water/hydrology community more effectively

2. Global hydrological infrastructures are improved and exchange of data enhanced

3. Co-operation between meteorological, climate and water communities is enhanced at global, regional and national levels

4. Additional development resources are dedicated to hydrometeorological infrastructure and service development

5. Water becomes more integral part of all WMO activities and hydrological community benefits from the expertise of meteorological community

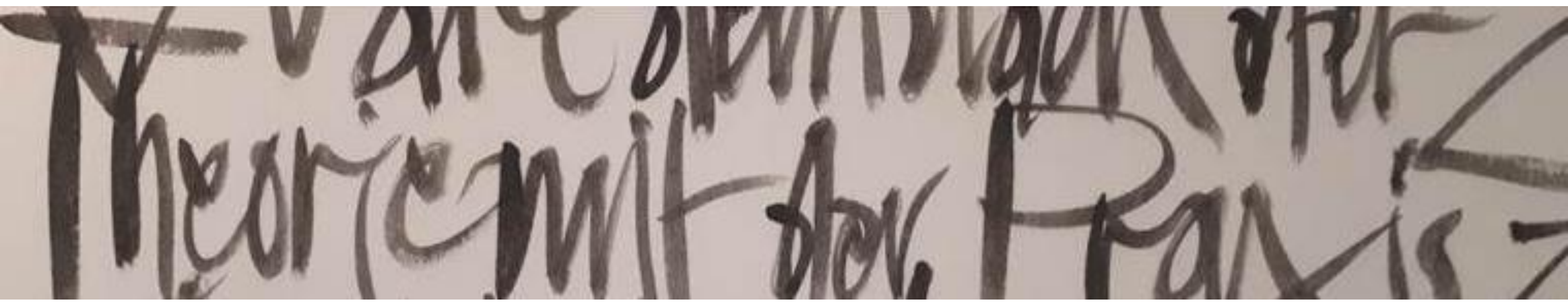
WMO OMM

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

The value of hydrological sciences for operational applications and services

Günter Blöschl, TU Wien



Leibniz (1646–1716)

7 May 2018, Geneva

The value of science for practice

"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast."

Da Vinci (1452–1519)

The value of $\underbrace{\text{of science}}$ ..

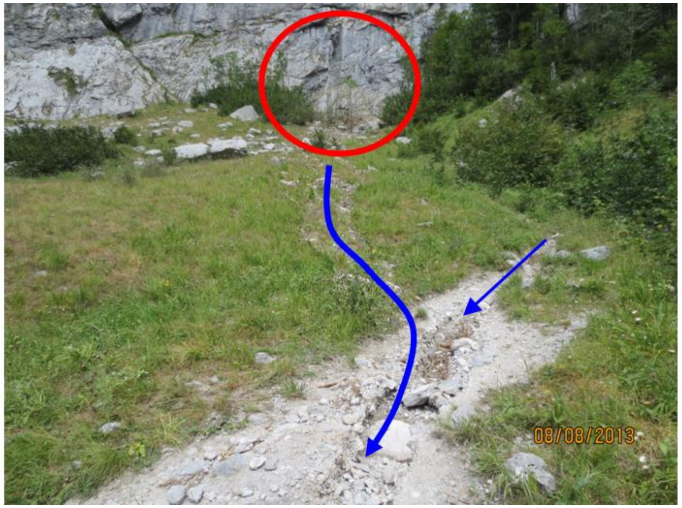
new

Four examples from my own research group

1st example

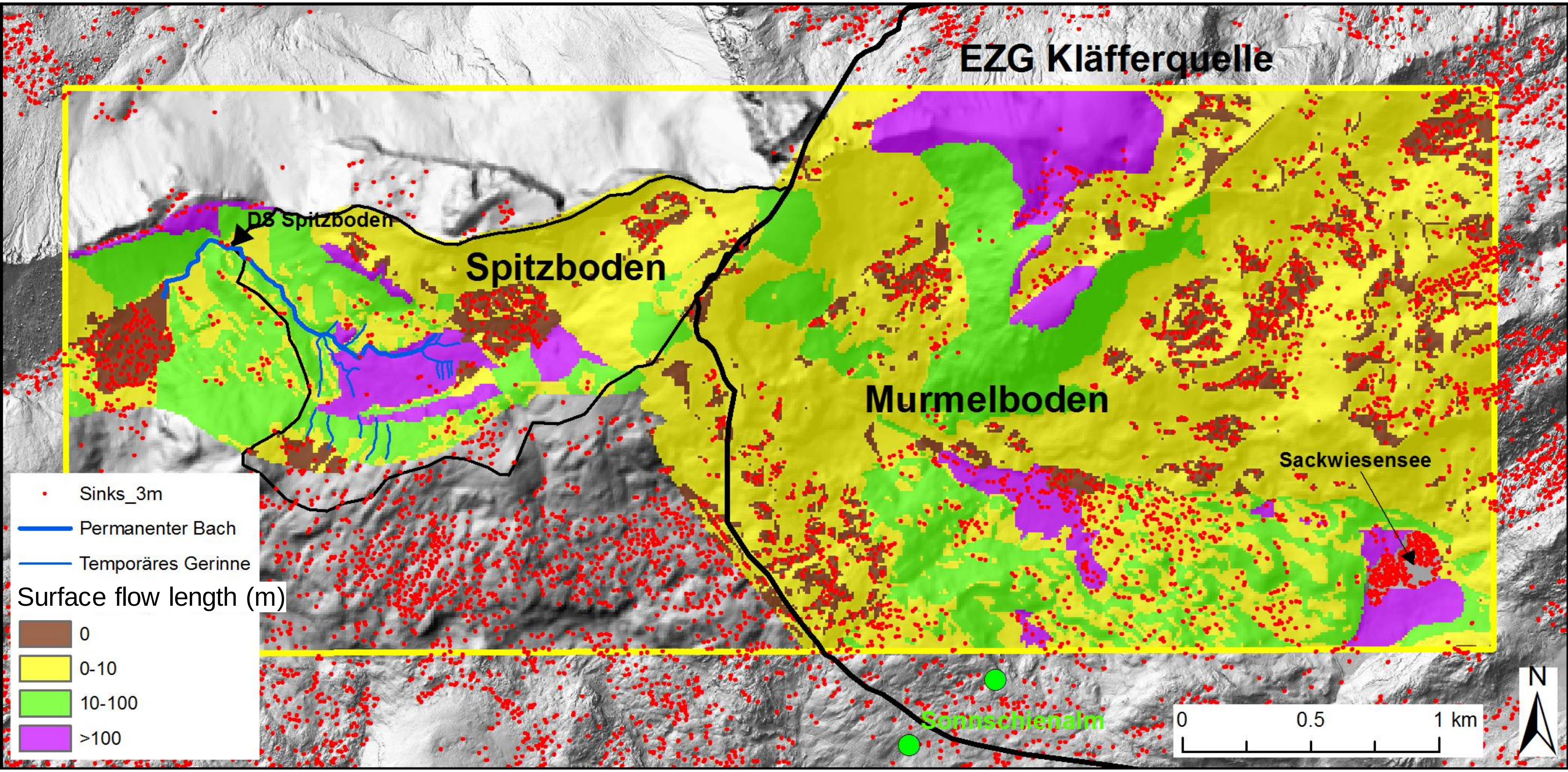
Science = Surface flow paths in karst areas

- New mapping method (large scale)
- Spatial information for distributed hydrol. models



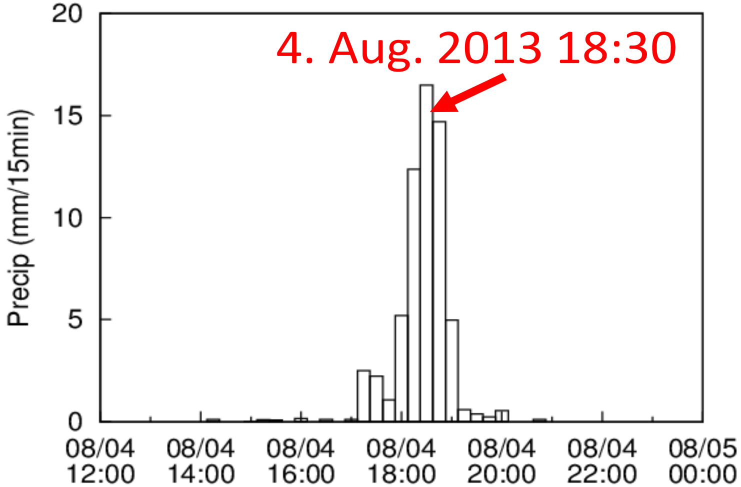
Reszler et al. (2018) HESS

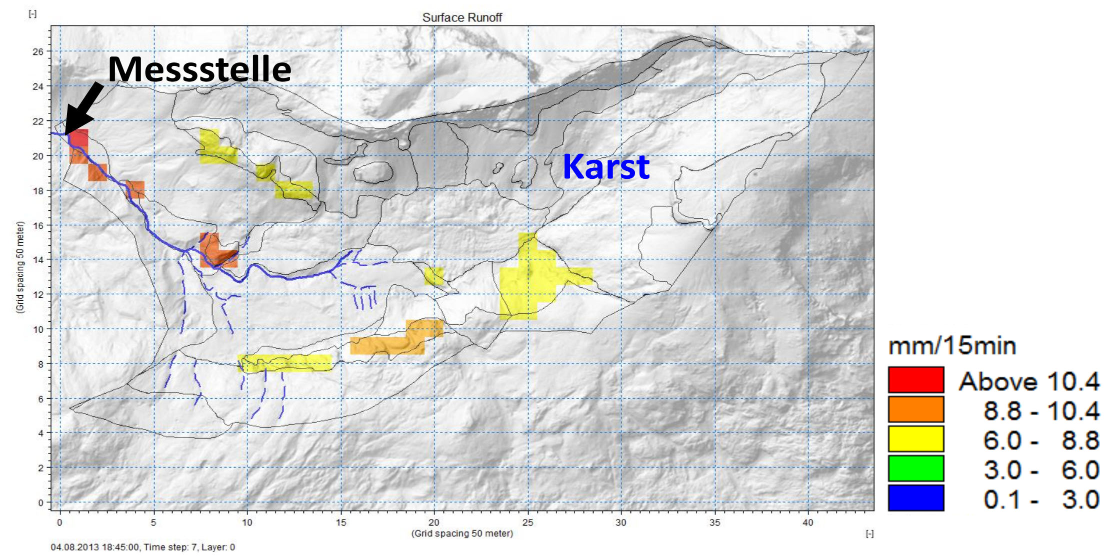
- Flow path lengths from new mapping method
- Testing against sink holes from Lidar

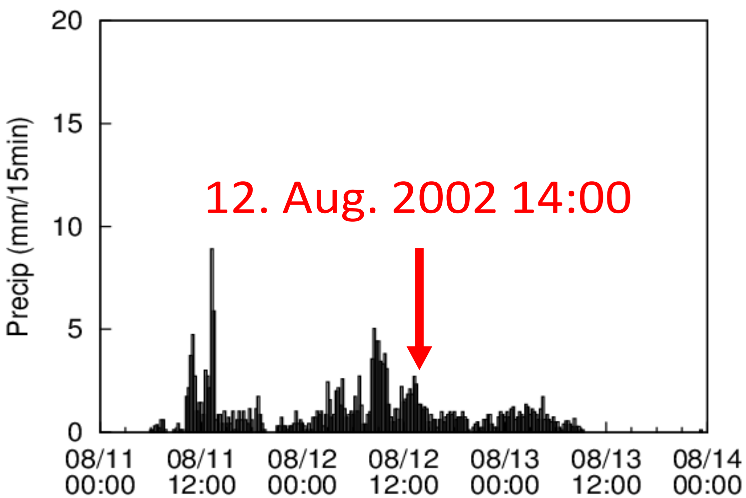


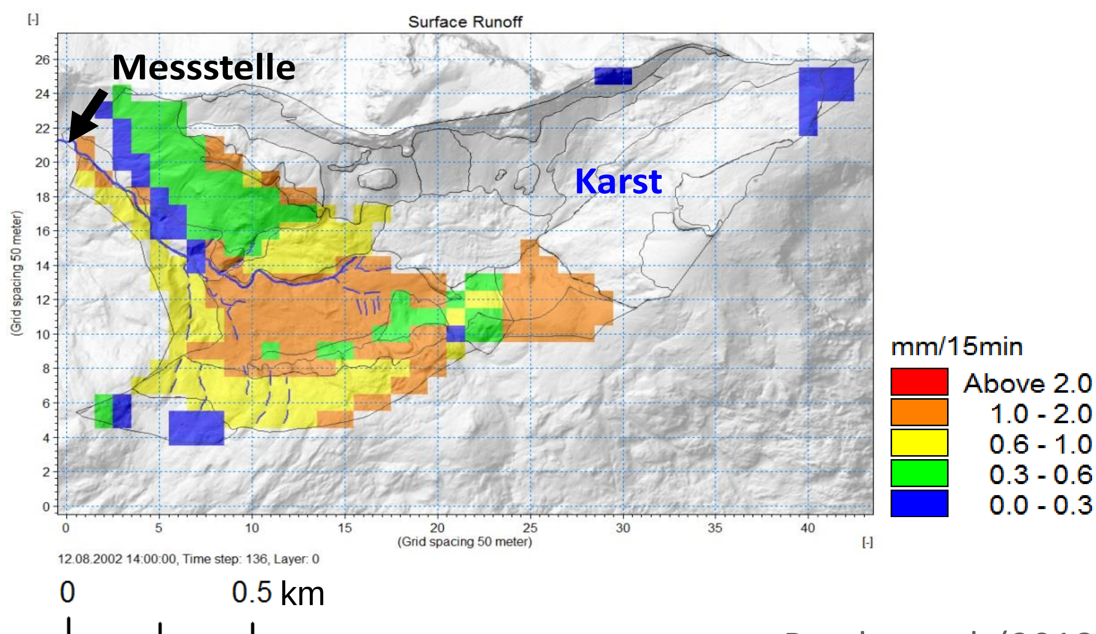
Reszler et al. (2018) HESS

Modelled spatial patterns of surface runoff based on flow paths









Reszler et al. (2018)

Application = Land management to protect karst springs (Vienna water supply)

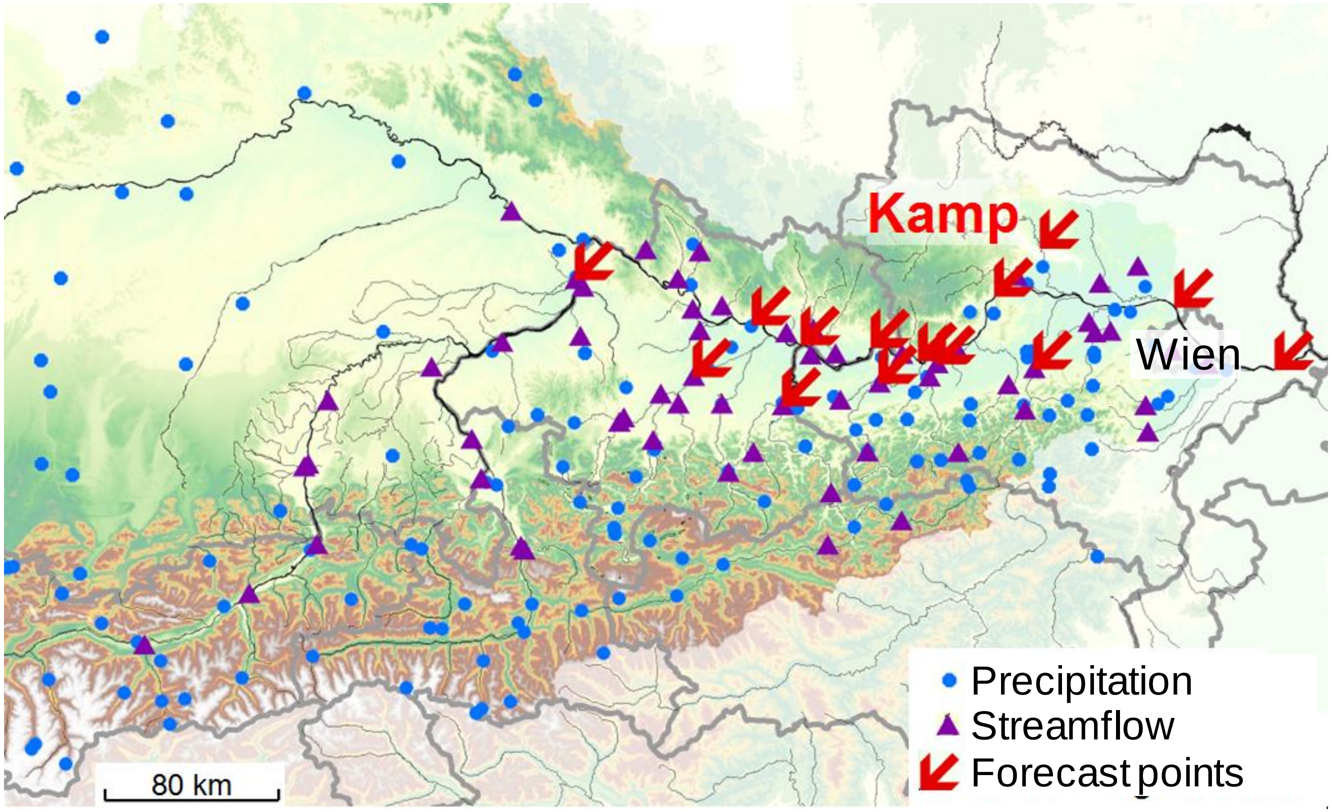
- Surface runoff may enhance pollution

Value = Prioritisation of protection zones, management options

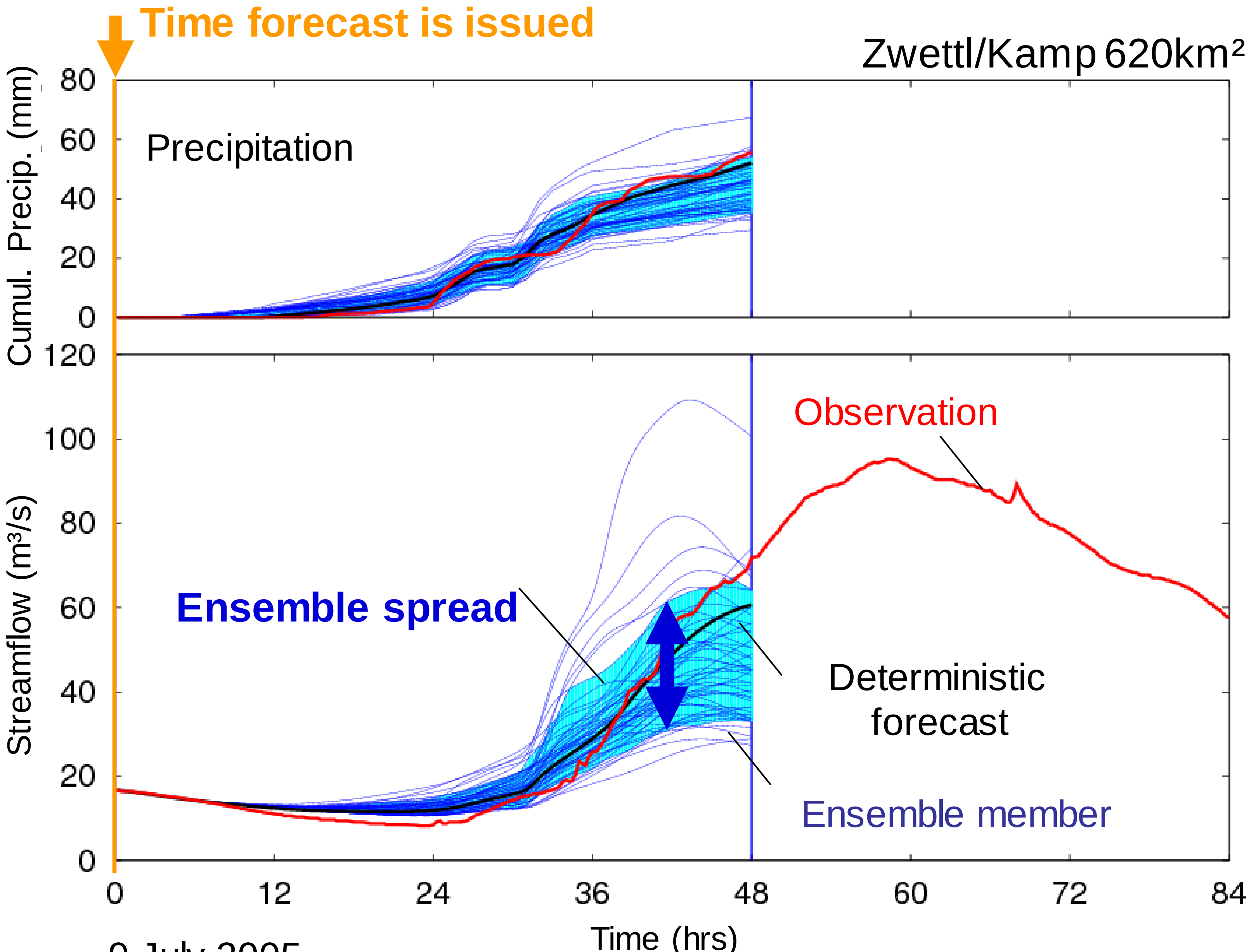
2nd example

Science = New methods of ensemble streamflow forecasts

- Soil moisture updating based on streamflow
- Ensemble spread consistent with forecasting uncertainty



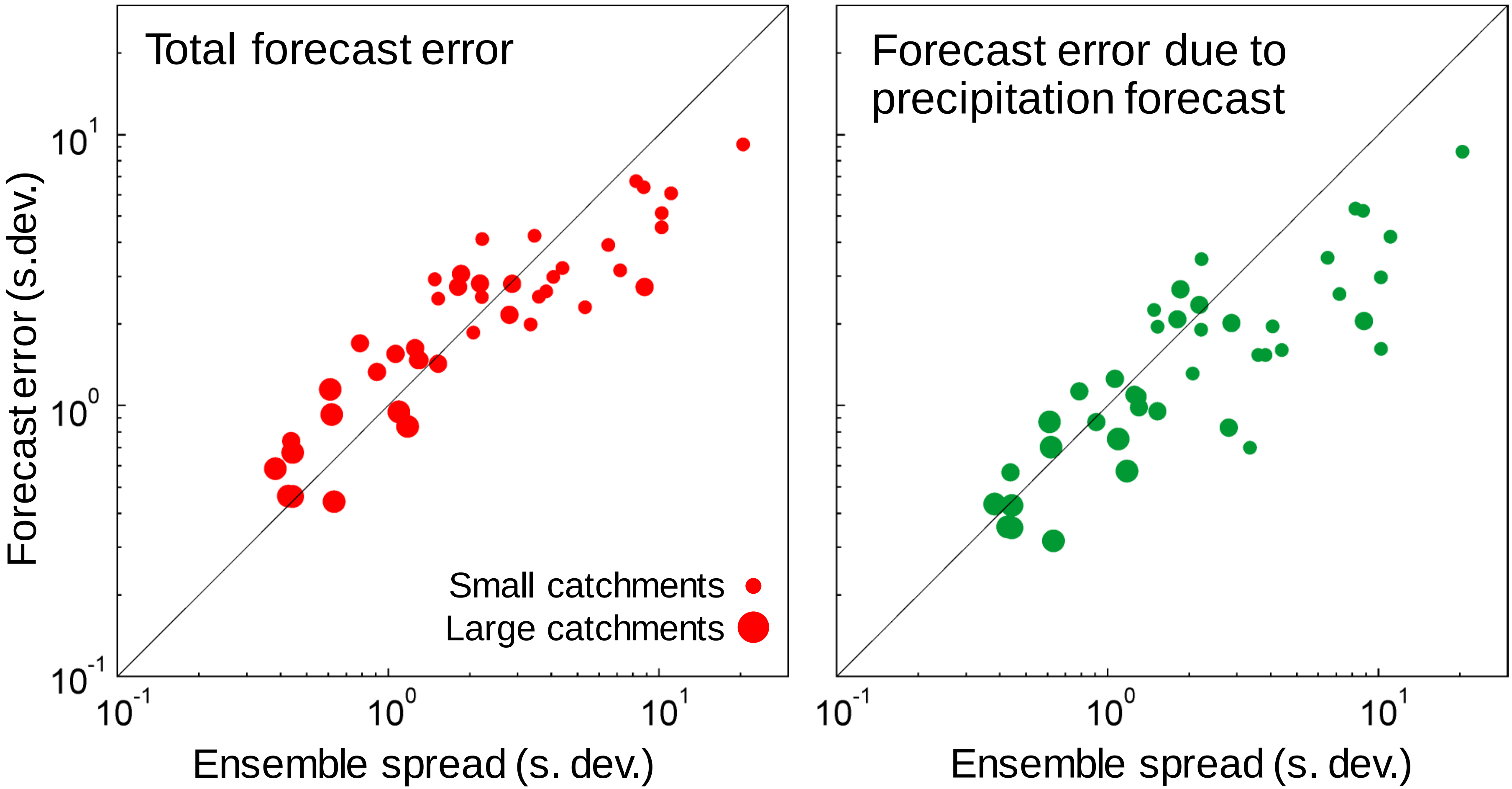
Ensemble forecasts



9 July 2005

Blöschl et al. (2005)

Ensuring consistency of ensemble spread with forecast uncertainty of streamflow

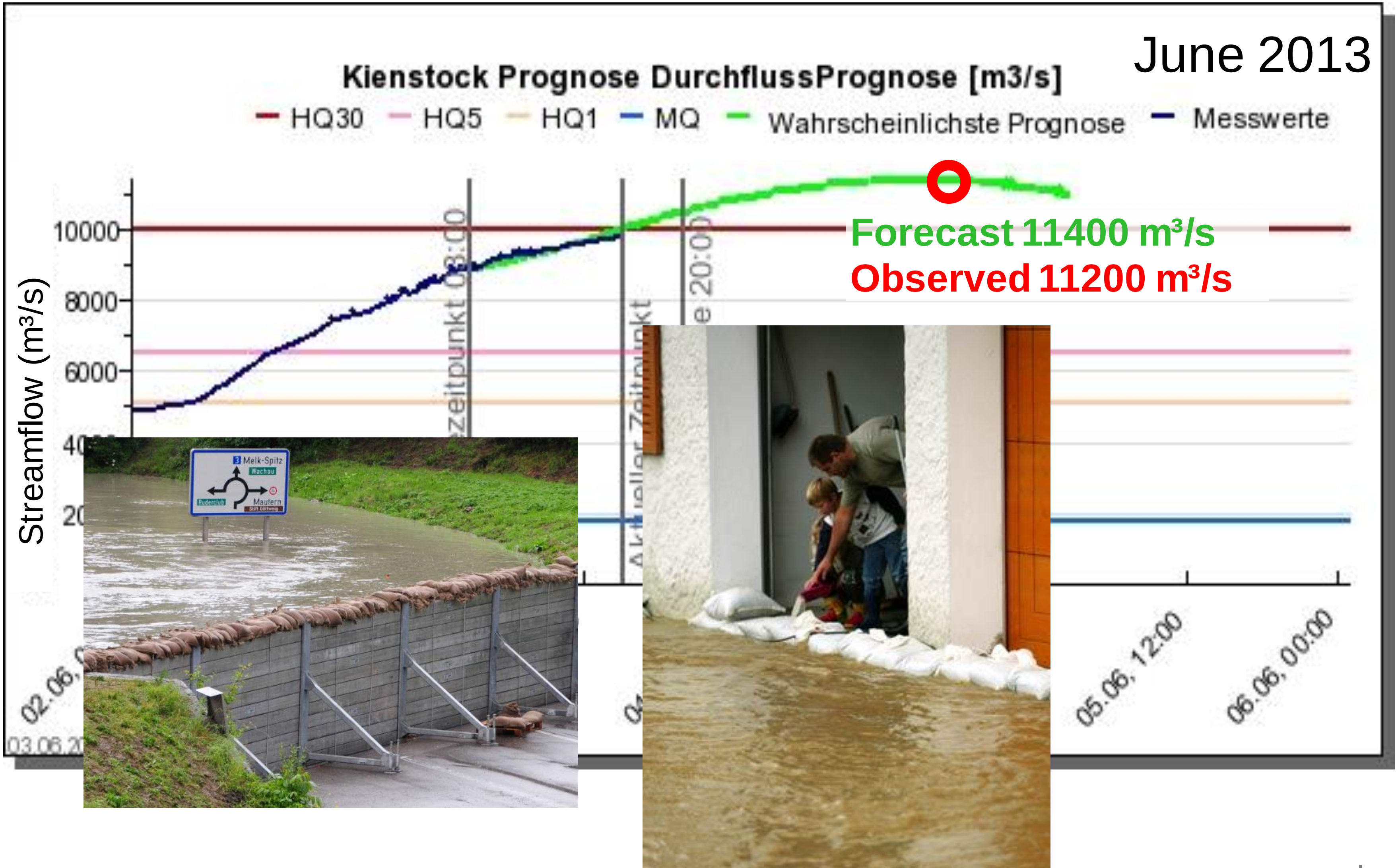


48 hr forecasts for tributaries to Danube
Errors and spread scaled by mean streamflow

Nester et al. (2011) WRR

Application = Flood warning at the Danube by governments; Cargo optimisation – low flows (Viadonau)

Value = More reliable assessment of uncertainties

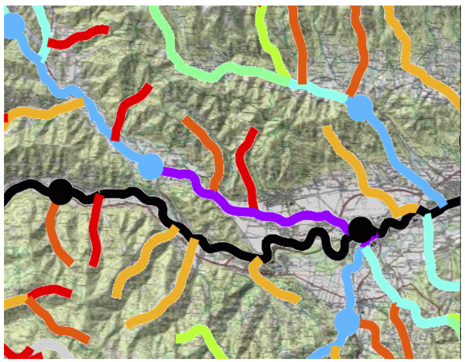


www.noel.gv.at

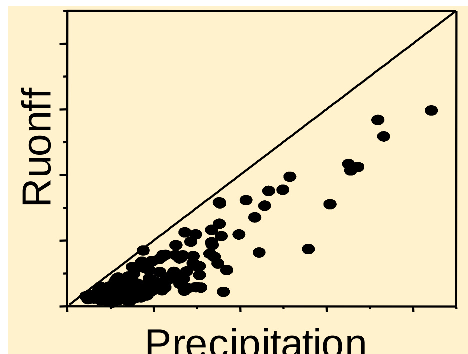
3rd Example

Science = flood frequency hydrology

Combining process understanding + statistics

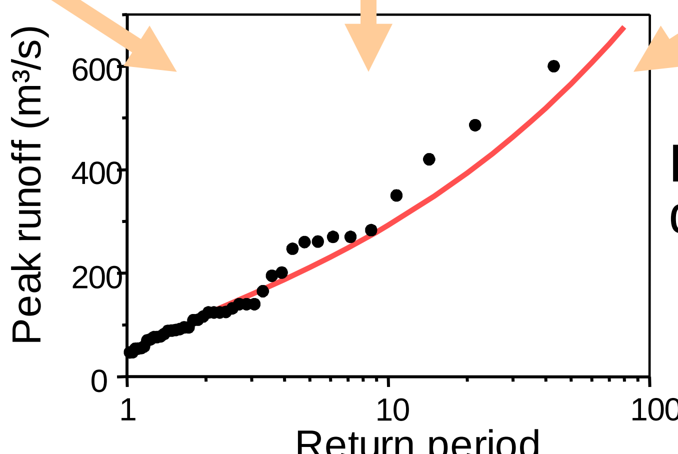


Spatial information



Causal information

Temporal information

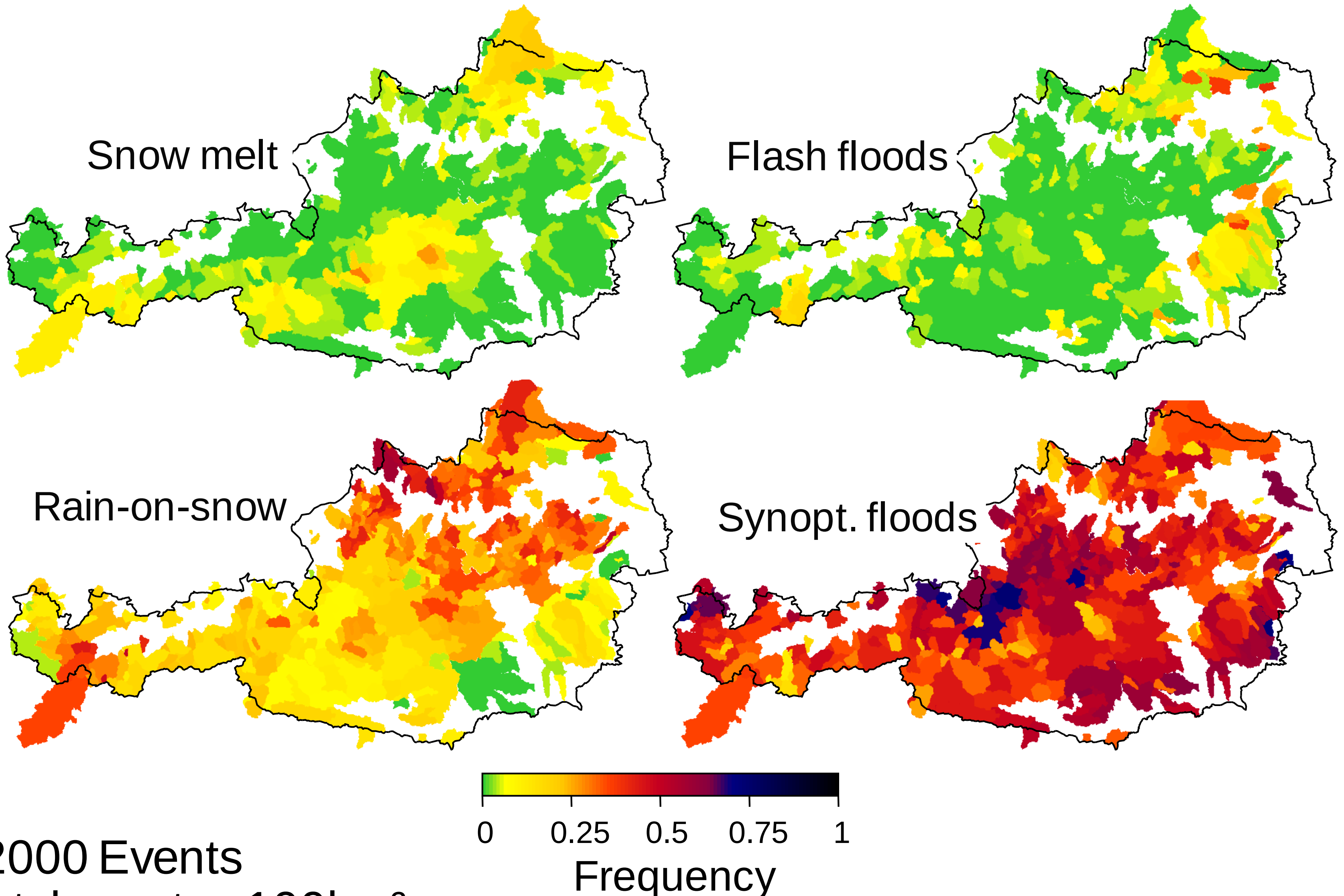


Flood data

Merz und Blöschl (2008) WRR

Causal expansion of information

e.g. Frequency of flood process types

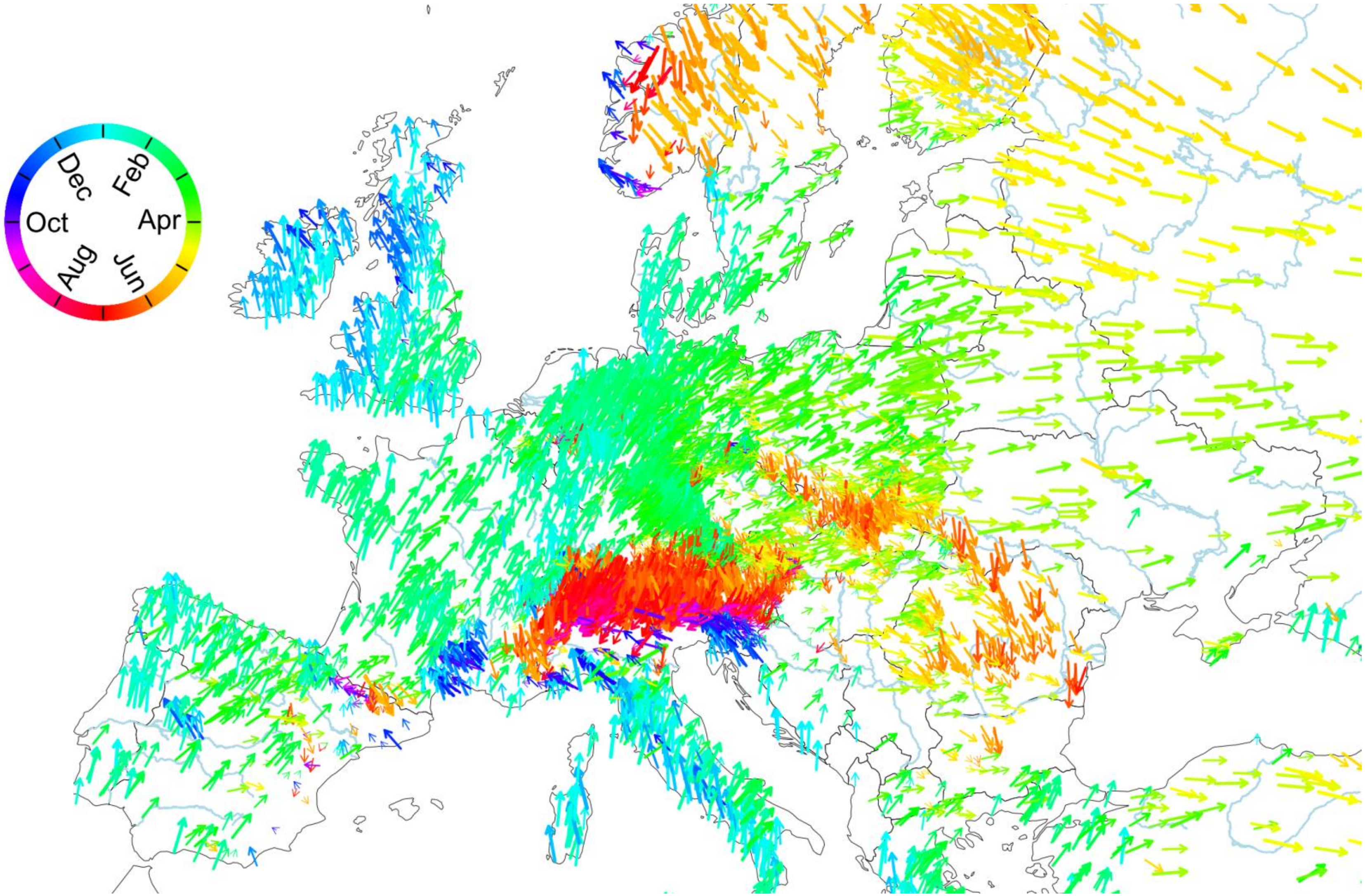


12000 Events
Catchments >100km²

Merz und Blöschl (2004) WRR

Causal expansion of information

Eg. timing of floods within the year to understand changes



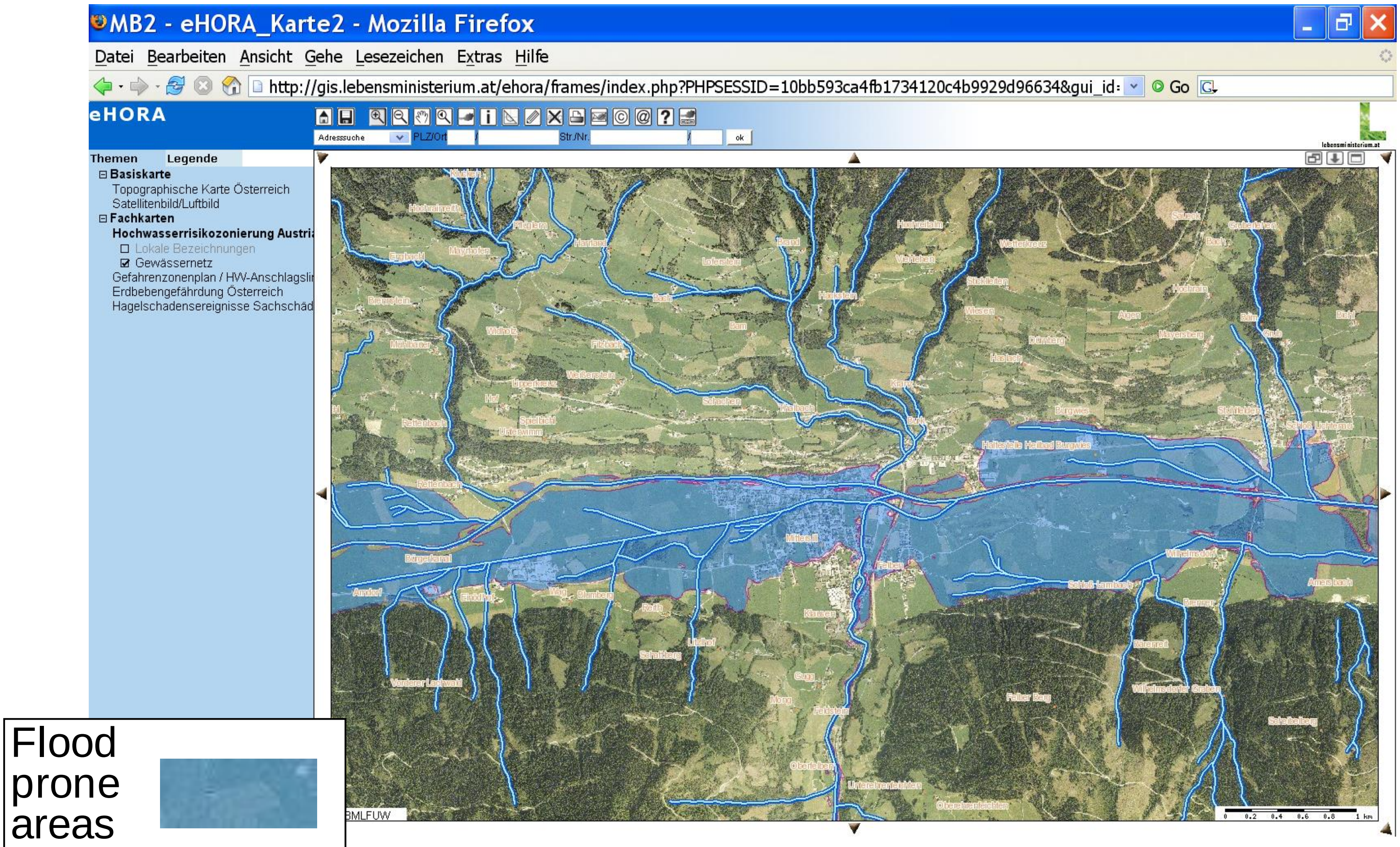
 5000 Stations, 1960-2010

Blöschl et al. (2017) *SCIENCE*

Application = Flood risk mapping Austria (HORA)

(Ministry, states, insurance industry, general public)

Value = More reliable risk estimates under change

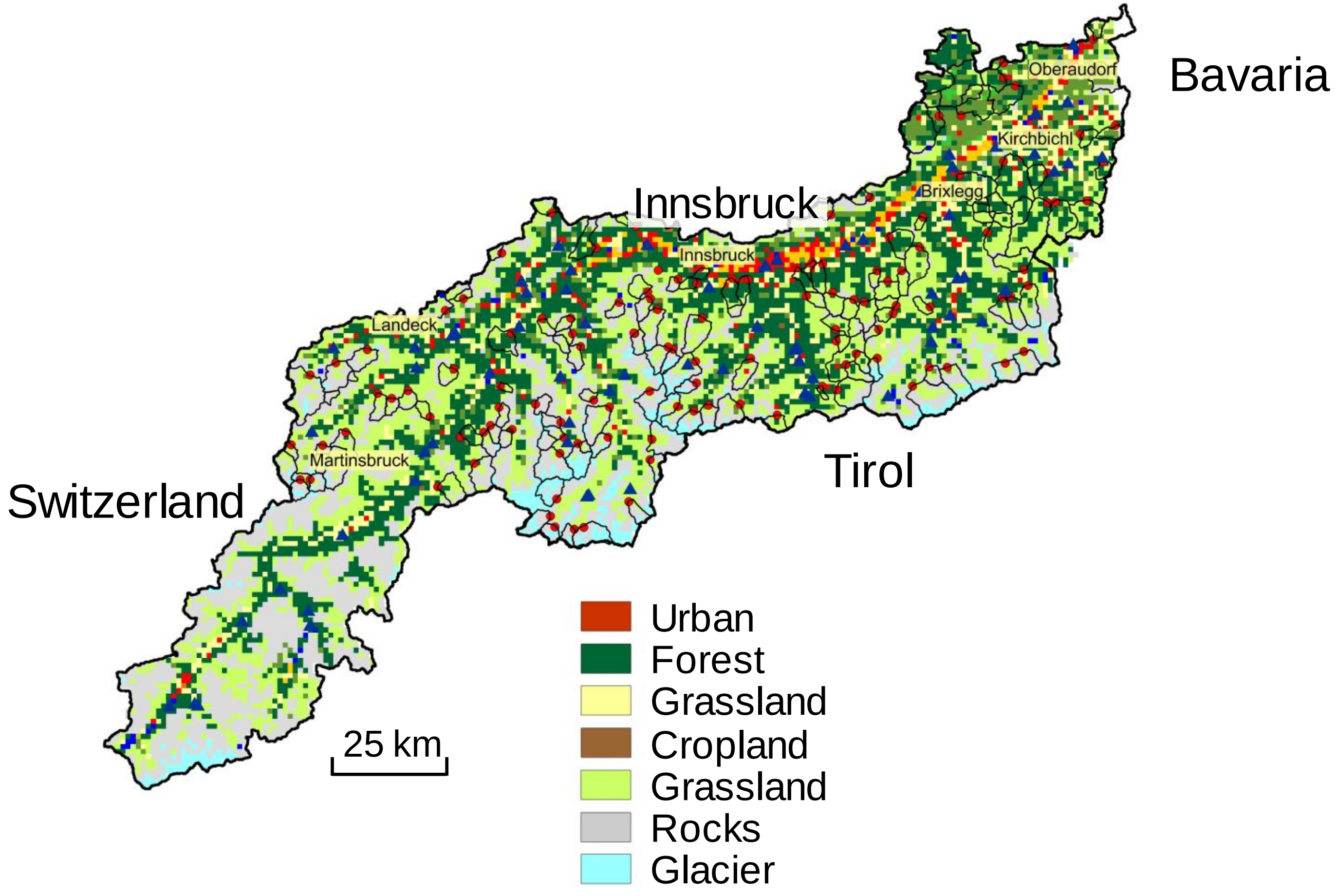


Projekt HORA - www.hochwasserrisiko.at

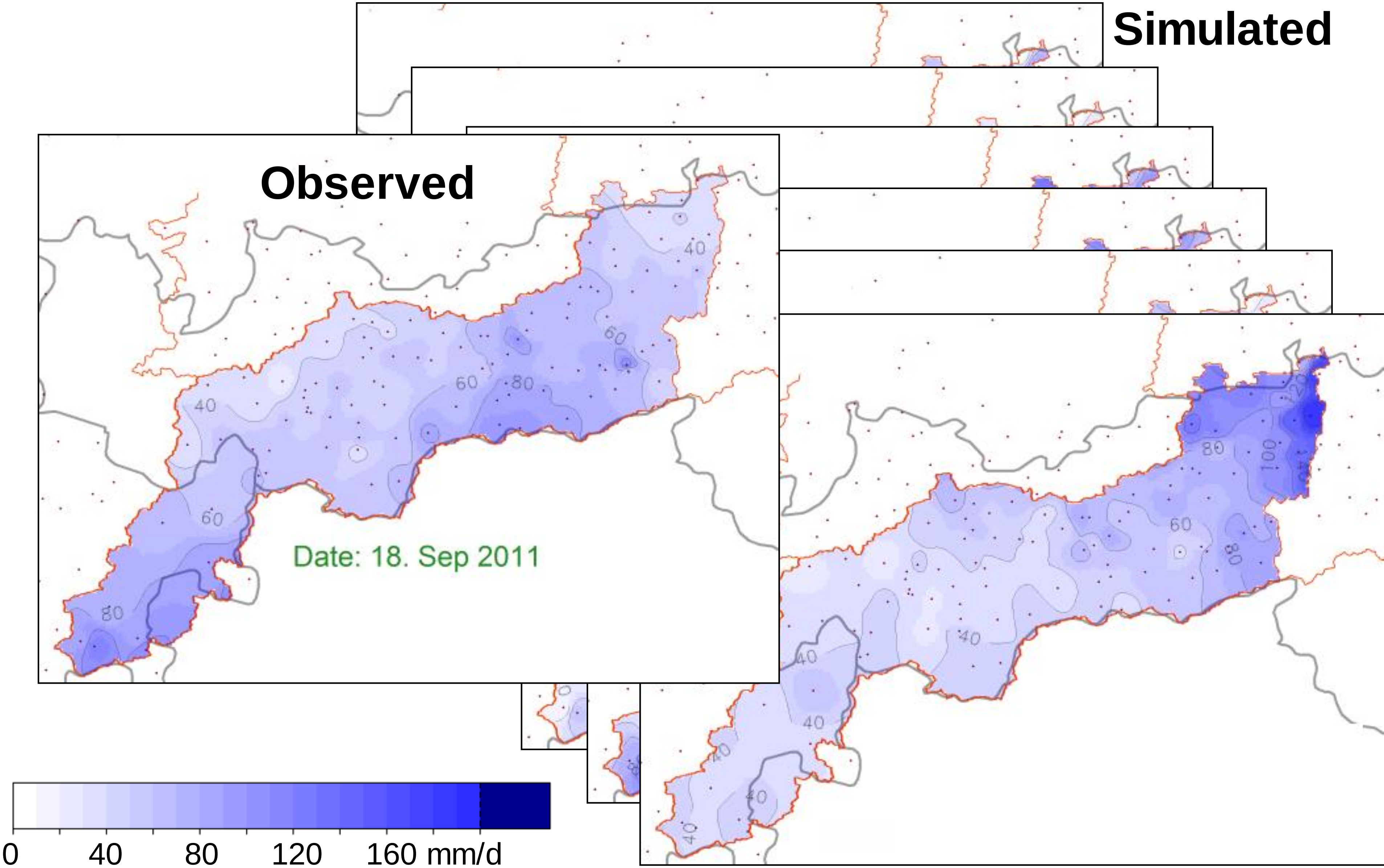
4th example

Science = propagation of flood probabilities through catchments

- Robust spatial stochastic precipitation modelling
- Regional Monte Carlo Simulations



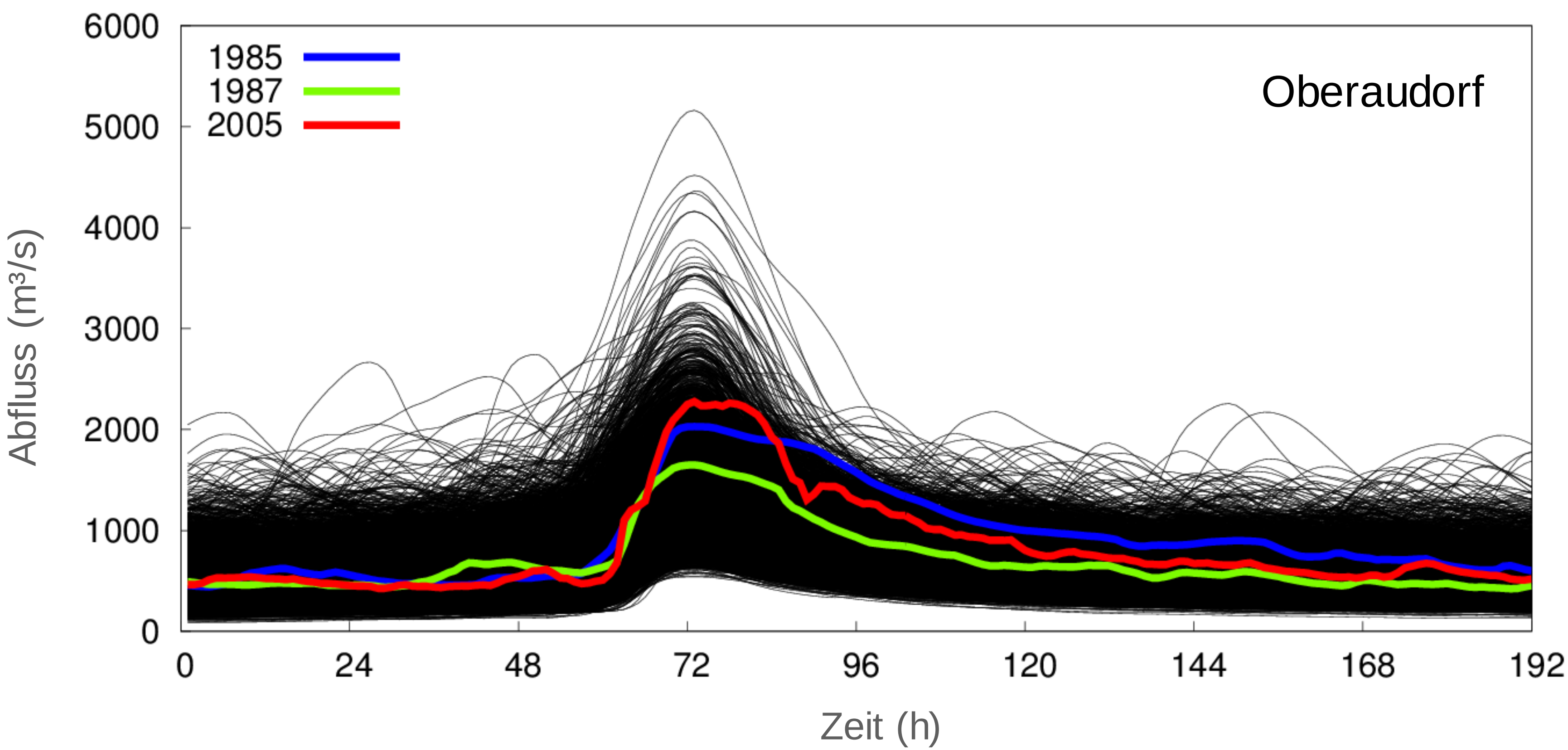
Stochastic precipitation model



Salinas et al. (2018)

Monte Carlo Simulations (spatially distributed rainfall-runoff)

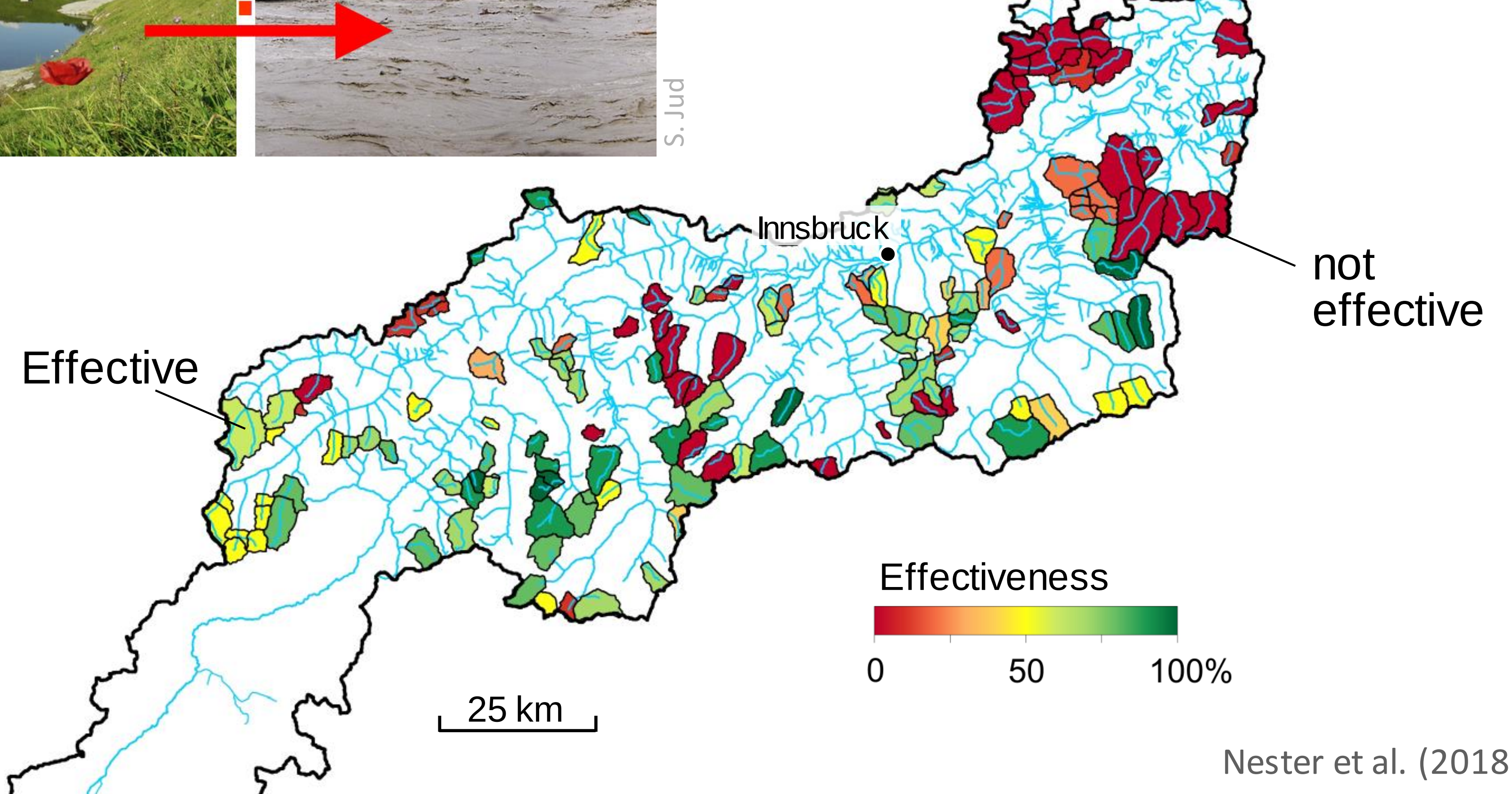
- Testing return periods of flood runoff spatially
- Confluence of floods – how do return periods combine?



Nester et al. (2018)

Application = Strategic flood risk management at the Inn (Tirol, Bavaria)

Value = Understanding effectiveness of retention reservoirs in headwater catchments for main stream



Nester et al. (2018)

Good science leads to better applications, which lead to better science

	Science .. published in recent literature	Applications and services .. direct societal value
1.	Surface flow paths in karst areas	Land management to protect karst springs (Vienna water supply)
2.	New methods of ensemble stream-flow forecasts	Flood warning at the Danube; Cargo optimisation (Viadonau)
3.	Flood frequency hydrology	Flood risk mapping (HORA), including change
4.	How do flood probabilities propagate through catchments?	Strategic flood risk management at the Inn (Tirol, Bavaria)

The economic benefit of integrating weather, hydrological and climate services

- A Nordic case study

Árni Snorrason

Director-General

The Icelandic Meteorological Office

Overview

Icelandic Met Office

Challenges

Nordic collaboration

Case study

Methodology

Results

Application – Implementation

Case study from the National Power Company in Iceland

Summary

Changes in volume and seasonality of runoff

Icelandic Met Office

Nordic Energy Research

Extremes!

Icelandic Met Office

2nd May 2008: Flood and mud-slide north of the centre of Otta in Oppland. Photo: Tom Østhuus

Nordic Energy Research

Dam safety

Icelandic Met Office

Nordic Energy Research

Extended chain of successful Nordic / Icelandic climate change projects and their impacts on renewable energy resources led by the Icelandic Met Office

Icelandic Met Office

Main objectives: To improve the **decision framework** of the energy sector in the face of imminent impacts of climate change on renewable resources and the energy system with special emphasis on the near future relevant to the energy sector

Partners:

All Nordic meteorological and hydrological institutes, energy companies, universities and research institutes

Nordic Project on Climate and Hydropower (CCEP) 1991-1993

Climate Water and Energy 2001-2002 (2MNOK)

Climate and Energy 2003-2006 (15MNOK)

Climate and Energy Systems 2007-2010 (18MNOK)

Funded by the energy sector and:

Nordic Energy Research

norden

Top-level Research Initiative

Main milestones and deliverables

Icelandic Met Office

Provide a coherent and consistent analysis of a new generation of regional climate scenarios and subsequent projections for renewable energy for the Nordic region, for use in energy systems analysis, risk assessments and adaptation strategies.

Provide risk assessment framework for use in climate change management within the energy sector.

Provide assistance to the energy sector in developing strategies for adaptation to climate change through an intensified stake-holder dialogue.

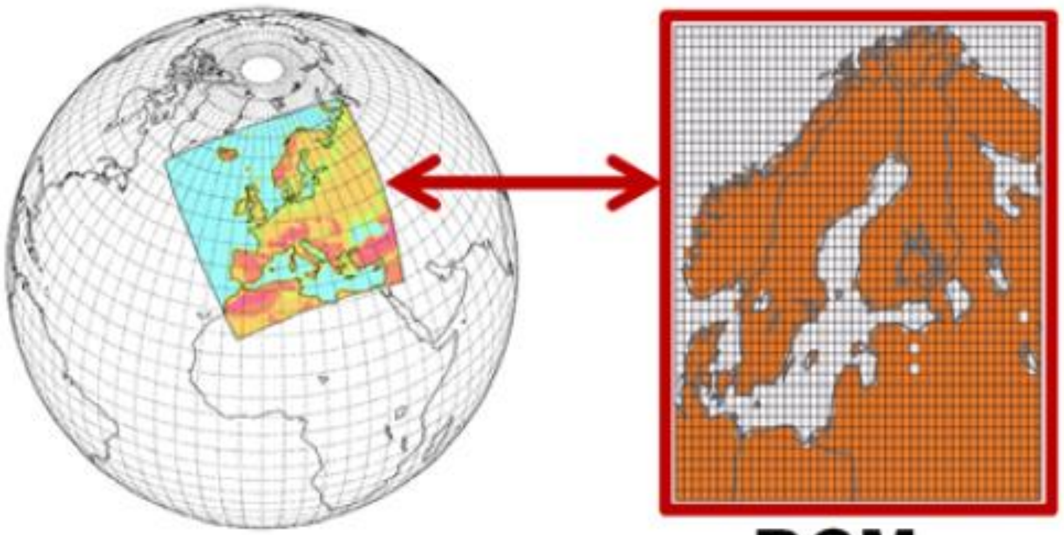
Report improved methodologies in general to the scientific community and stakeholders across borders.

Nordic Energy Research

Methodology

Icelandic Met Office

Downscale output from Global Climate Models to regional / local scale



AOGCM
Whole globe
Lower resolution

RCM
Smaller domain
Higher resolution
Lateral boundaries from AOGCM

Nordic Energy Research

Hydrological information

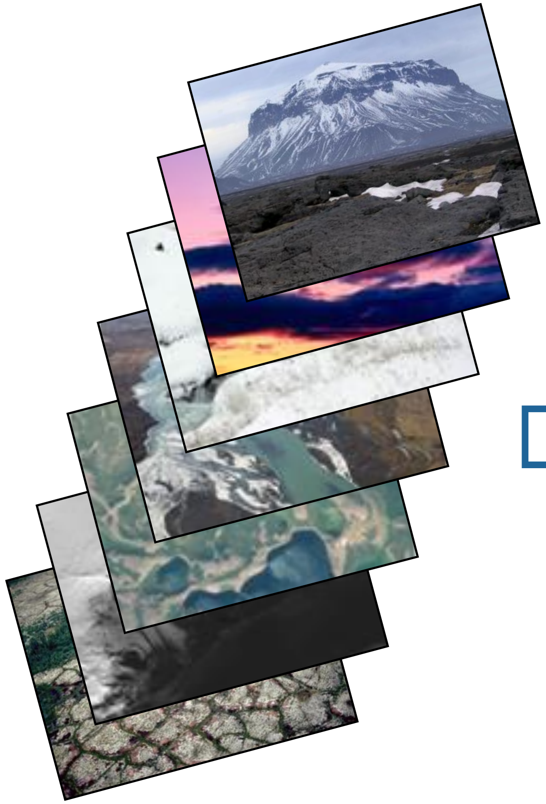
Icelandic Met Office

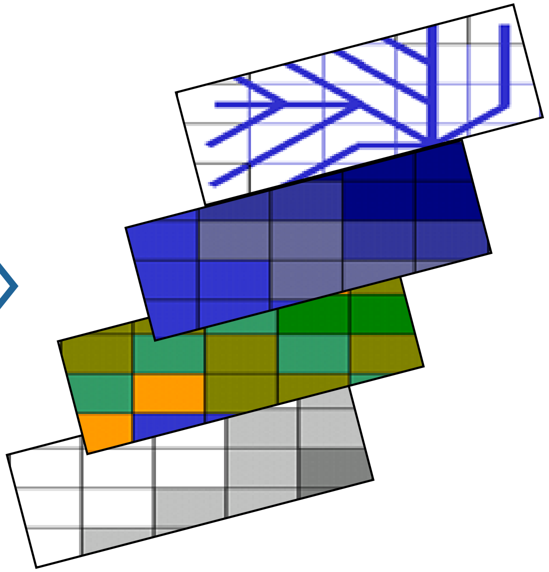
Arctic HYDRA

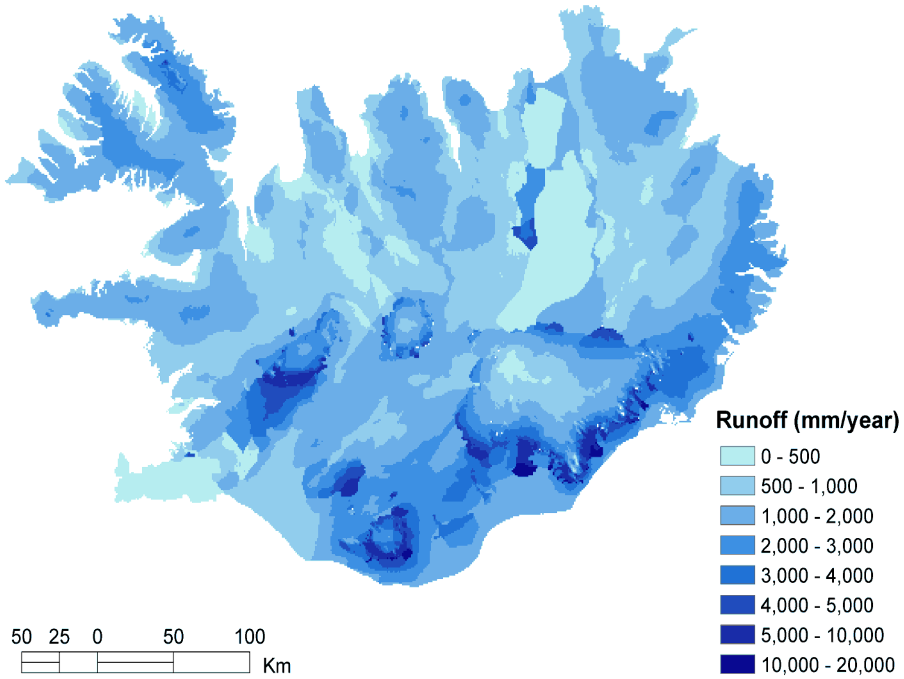
HYDROLOGICAL SERVICE

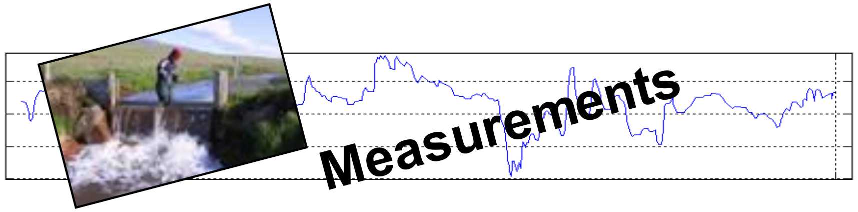
Integration

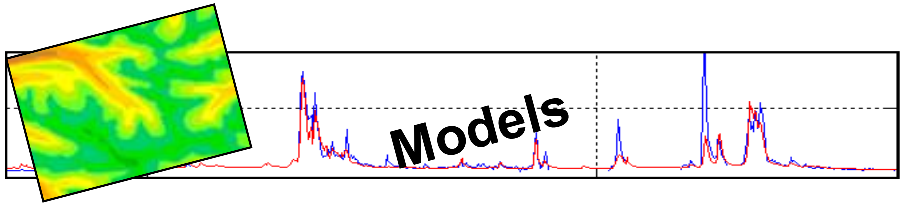
Icelandic Met Office





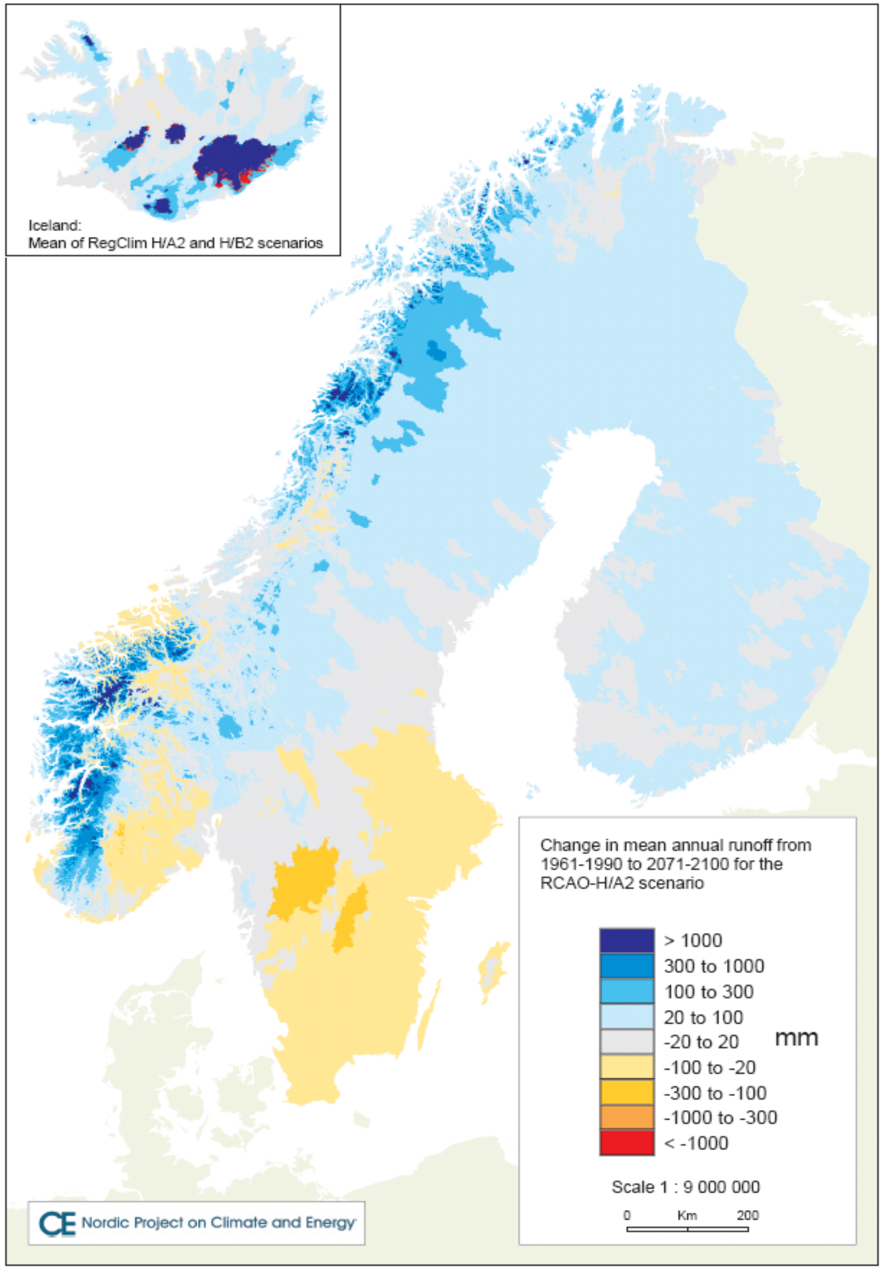






HYDROLOGICAL SERVICE

Changes in average annual runoff from the period 1961-1990 to 2071-2100 for the Hadley A2 scenario



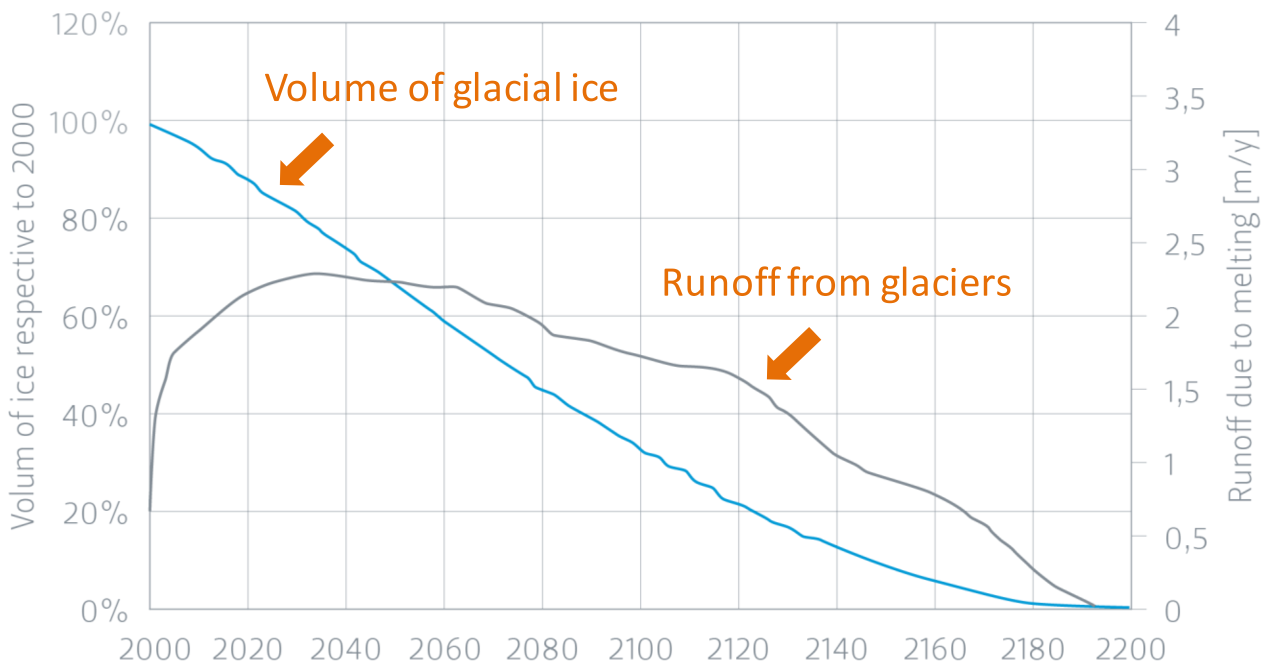
Annual runoff change (mm)

Hadley/A2

Melting of glaciers due to climate change

- Glacial river flow is forecasted to increase
- The runoff is expected to peek around 2050
- Flows are expected to stay high for more than a century
- In 2200 it is forecasted that almost no glaciers will be left in Iceland

  …unless we manage to control the changes

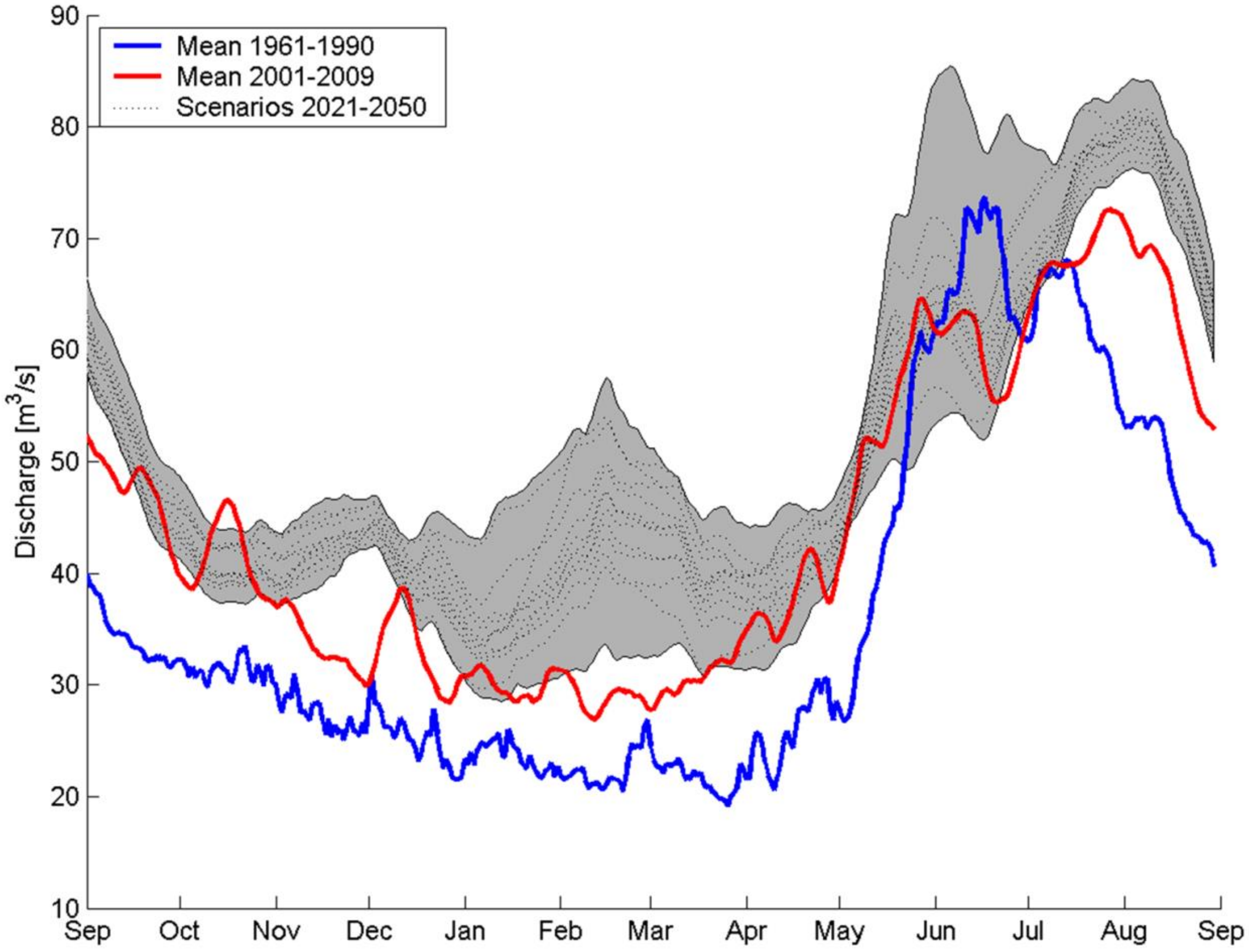


Changes in glacial river runoff

Icelandic Met Office

Mean discharge seasonality for a partly glacier covered watershed in northern Iceland

- The magnitude of spring floods is predicted to decrease and they will appear earlier in the year.
- Seasonal discharge becomes more evenly distributed with higher winter discharge.



The National Power Company of Iceland

Case study

Better utilization of present system

Redesign of existing powerplants

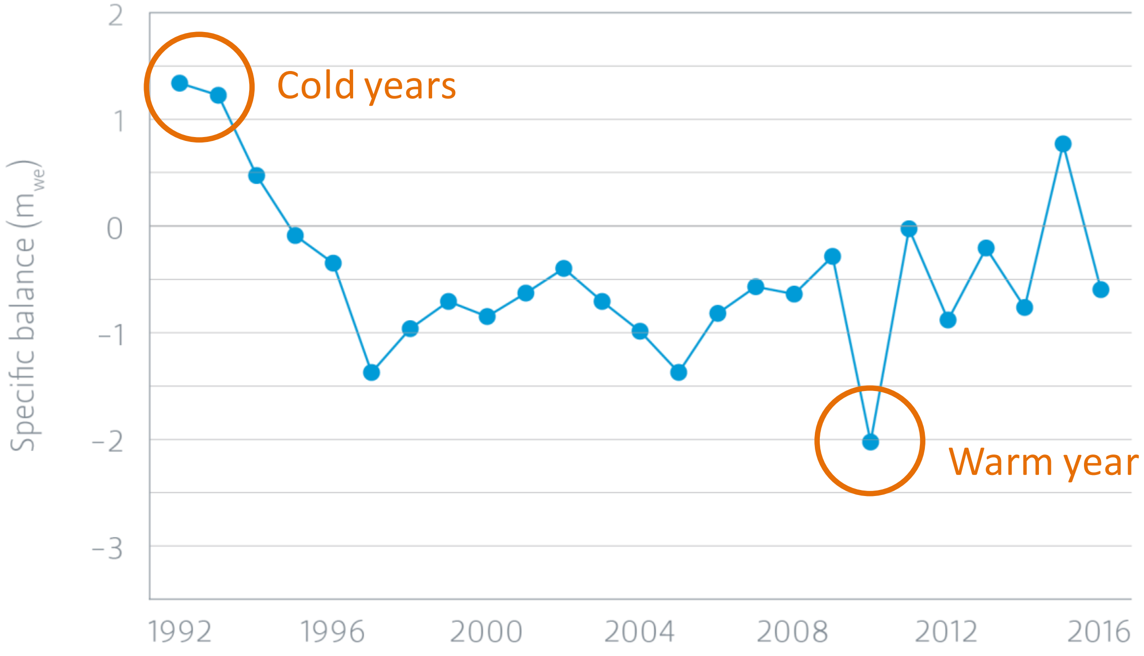
Operations based on scenarios

Landsvirkjun

National Power Company of Iceland

Not-so glacial response to temperature change

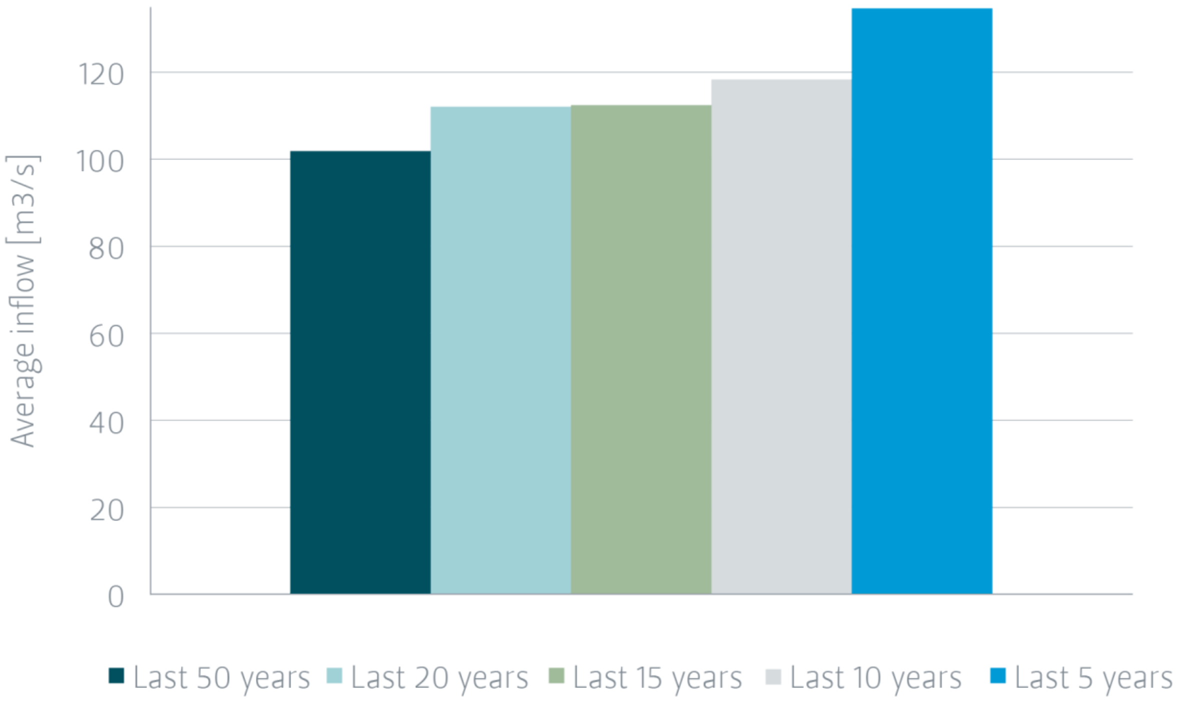
Annual change of Vatnajökull glacier total mass



Glacial river runoff - observations

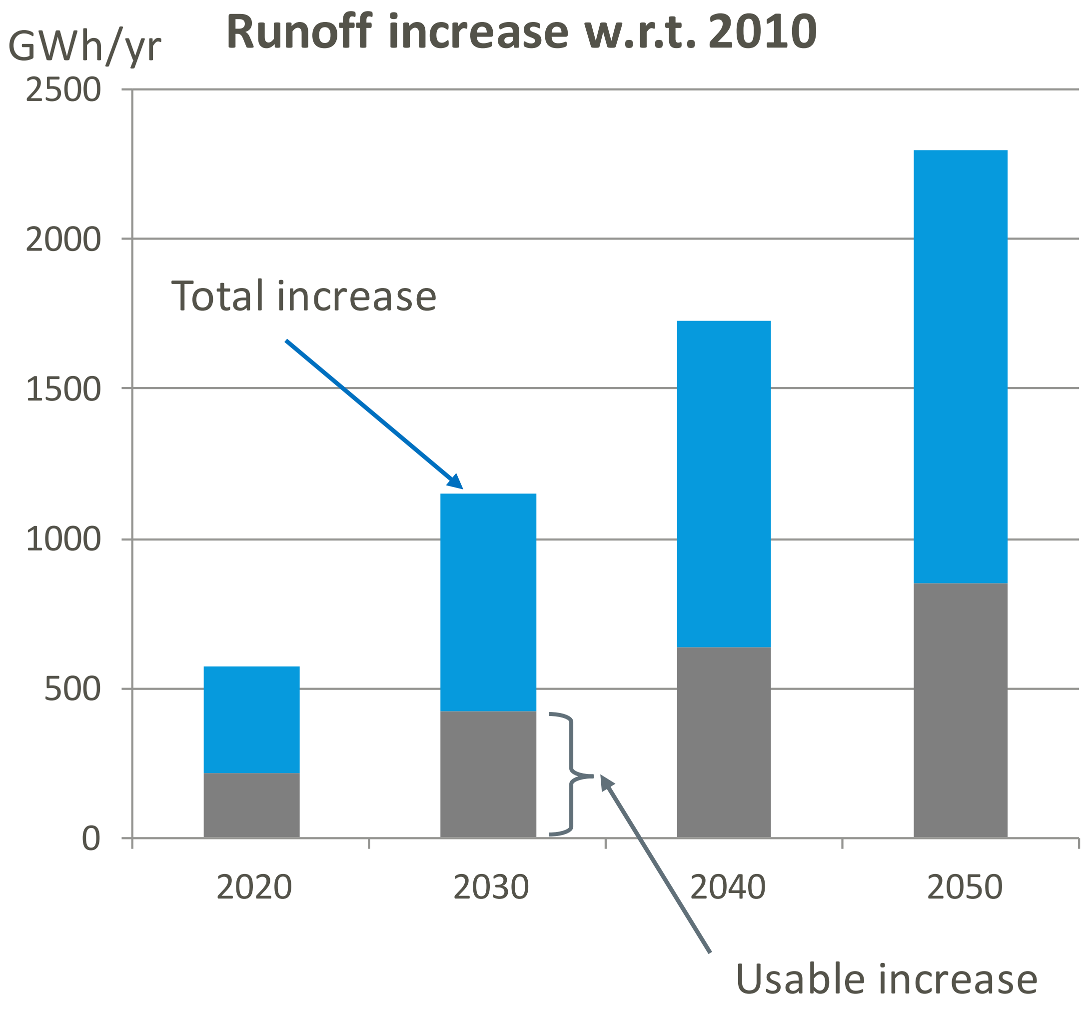
Landsvirkjun

Change in average inflow to Kárahnjúkar storage reservoir



Climate change projection

- Runoff has increased in the last 20 years
- Annual energy generation capacity had increased by 8% in 2010 due to warming
- Energy in inflow to Landsvirkjun's system is expected to increase further by 15% from 2010 to 2050
- Current system will only be able to utilize 30% of the increased runoff
- Capacity increase and storage increase is needed for further utilization of increased runoff

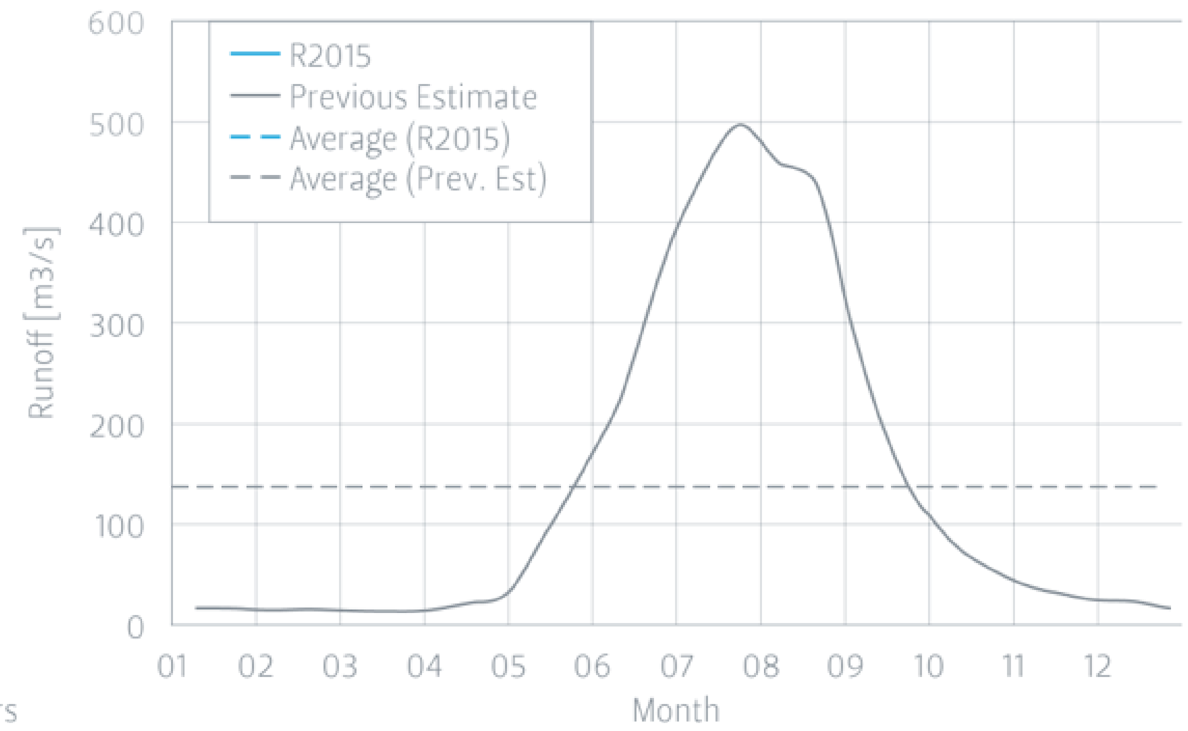


Source: Landsvirkjun

Changes in seasonal patterns

Landsvirkjun

Average total inflow to Fljótsdalur station



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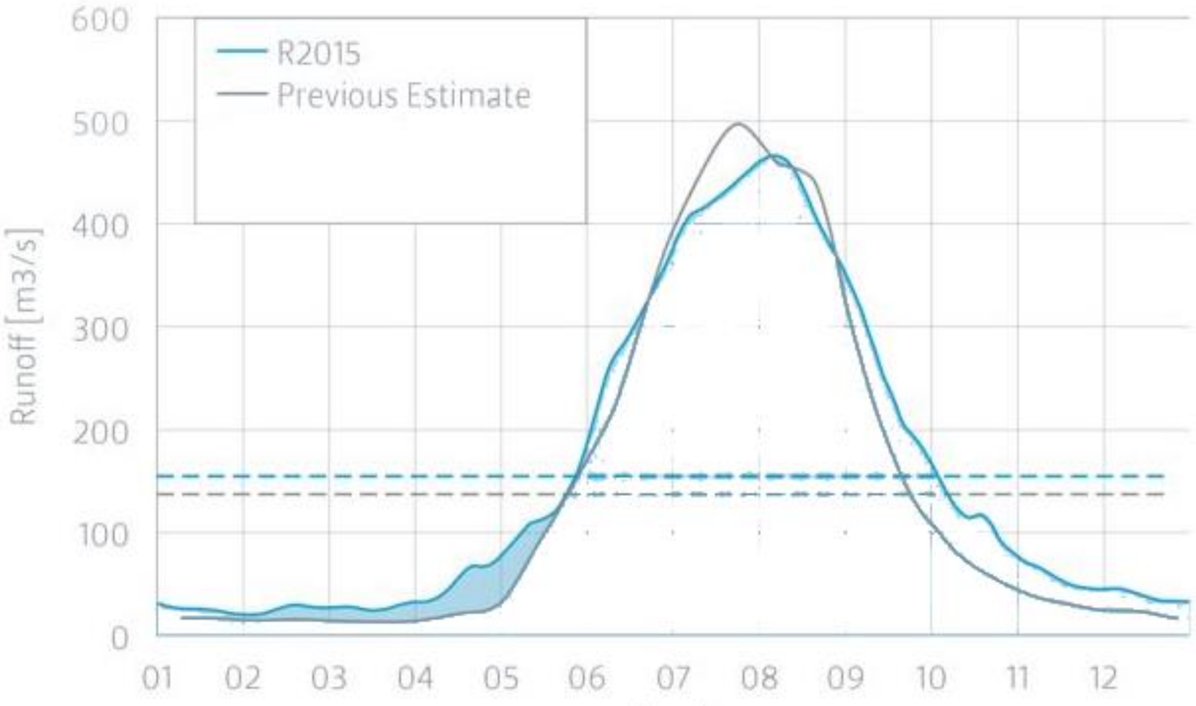
Changes in seasonal patterns

Landsvirkjun

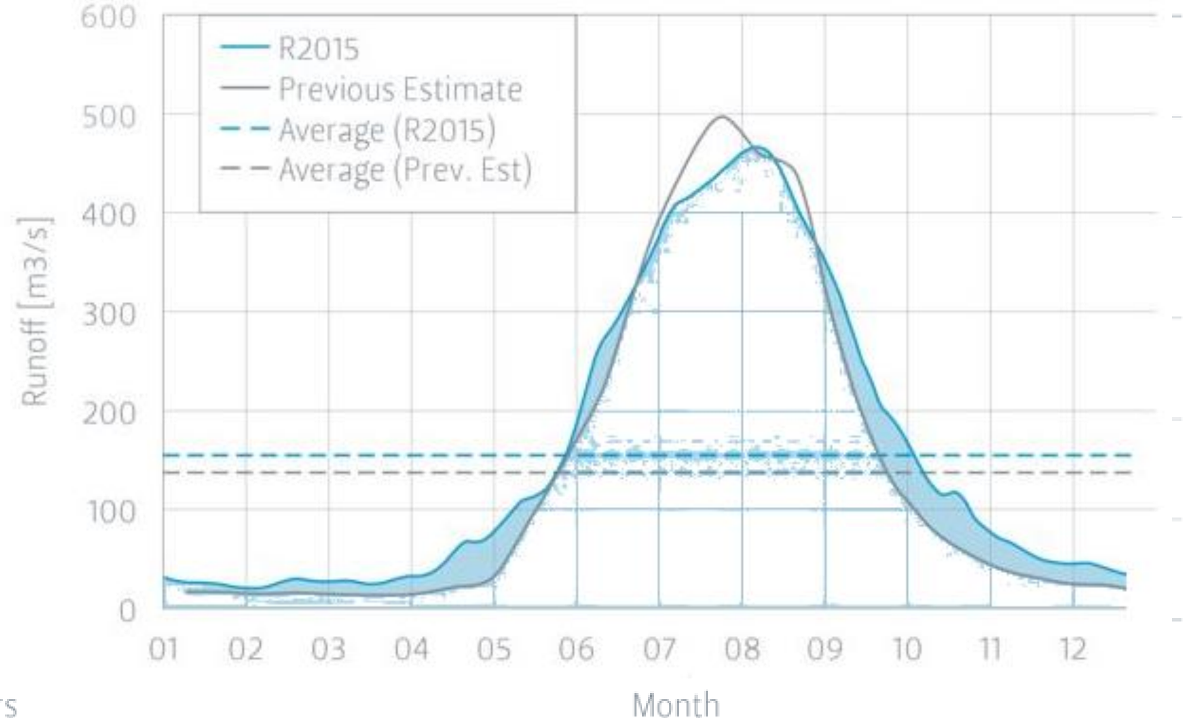
Average total inflow to Fljótsdalur station



Changes in seasonal patterns

Landsvirkjun

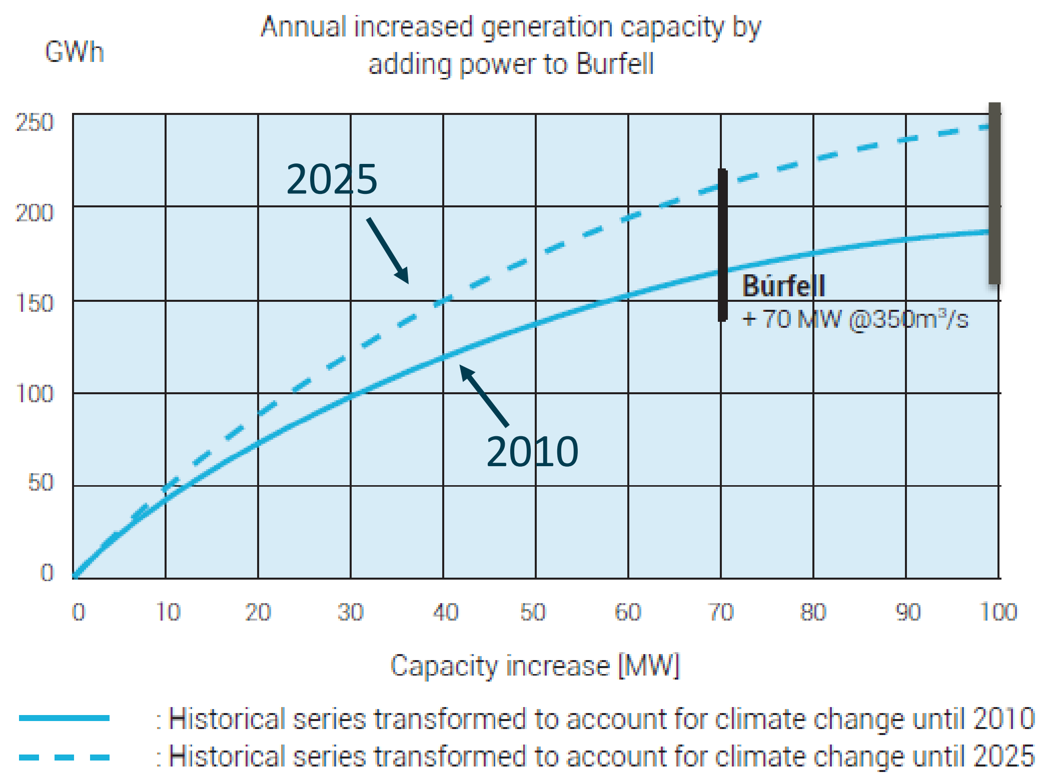
Average total inflow to Fljótsdalur station



rs

Capacity increase - responding to changing inflows

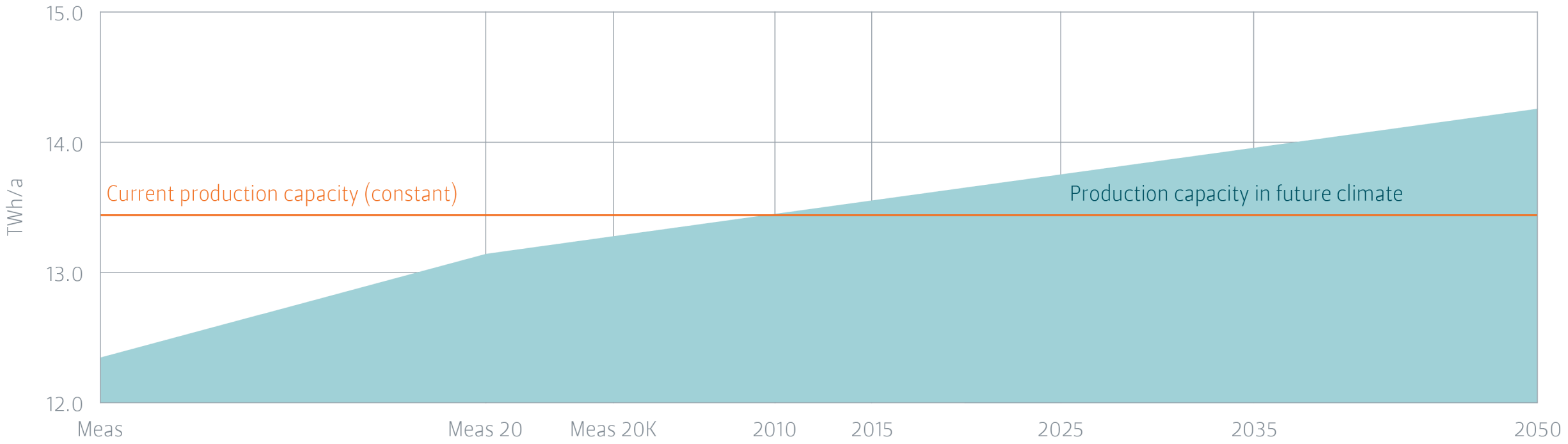
- Burfell is Landsvirkjun's oldest hydropower station utilizing a glacial river
- At Burfell spilling of water has increased in the last decades
- The station is now being expanded, a response to changing climate
- Taking into account the forecasted 2025 flows the capacity of the new turbine will be 100MW.



Taking small steps

Landsvirkjun

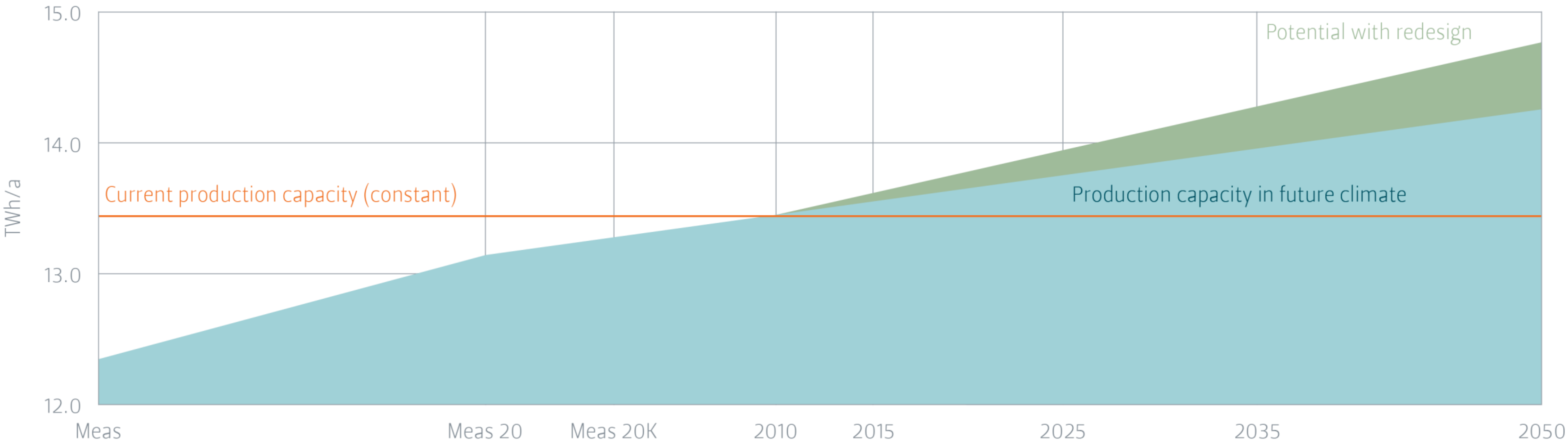
Increased production capacity of current generation system



Taking small steps

Landsvirkjun

Increased production capacity with redesign



Conclusions

Icelandic Met Office

- The overall conclusion is that the predictability of the response of the cryosphere to climate change is fundamental in achieving changes in the decision making framework of the energy sector
  - Hydropower production is expected to increase mostly due to changes in the glacial contribution
  - The annual rhythm in river flow will be more favorable due to changes in snow accumulation and melting
- Impact on extremes and dam safety is not self-evident and has to be analyzed carefully

Conclusions

- Successful changes in the decision framework in all of the Nordic hydropower sector

- The National Power Company of Iceland has implemented radical changes in their decision framework at all time scales based on stepwise adaptation of climate scenarios rather than the historical record. This is generating significant benefits from:
  - Selling additional firm energy from present system at the same risk with significant benefit at no additional cost
  - Re-designing and expanding capacity in powerplants already in operation at low marginal cost
  - Scheduling seasonal and interannual operations based on scenarios generating considerable additional benefits

The WMO HydroConference is co-organized with

with the support of

Key-Note by Dr. / Assoc. Prof. Berit Arheimer,

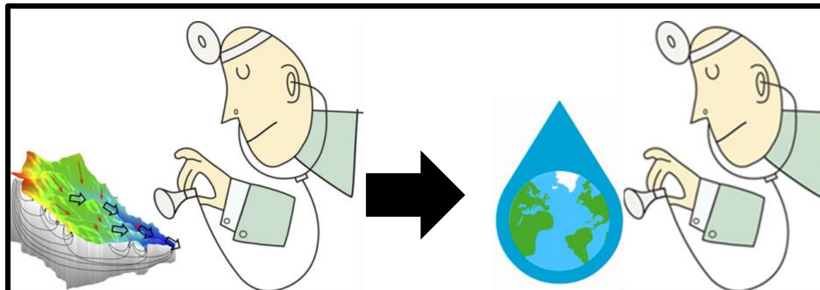
Head of Hydrological Research, Swedish Meteorological and Hydrological institute (SMHI)

Outline

- Current state & Challenges – personal experience
- Key-elements of addressed initiatives
- Reflections & Constructive messages

http://hydroconference.wmo.int/en/resources

Why do hydrologists need to share data NOW?


Blöshl et al. 2013

Traditionally:

Hydrology is local ***vs.*** Meteorology is global

Some societal drivers:

- Transboundary rivers and aquifers
- Climate change adaptation
- Globalisation and SDG

=> Predictions in un-gauged basins (transferring info from gauged sites).

Some technical drivers:

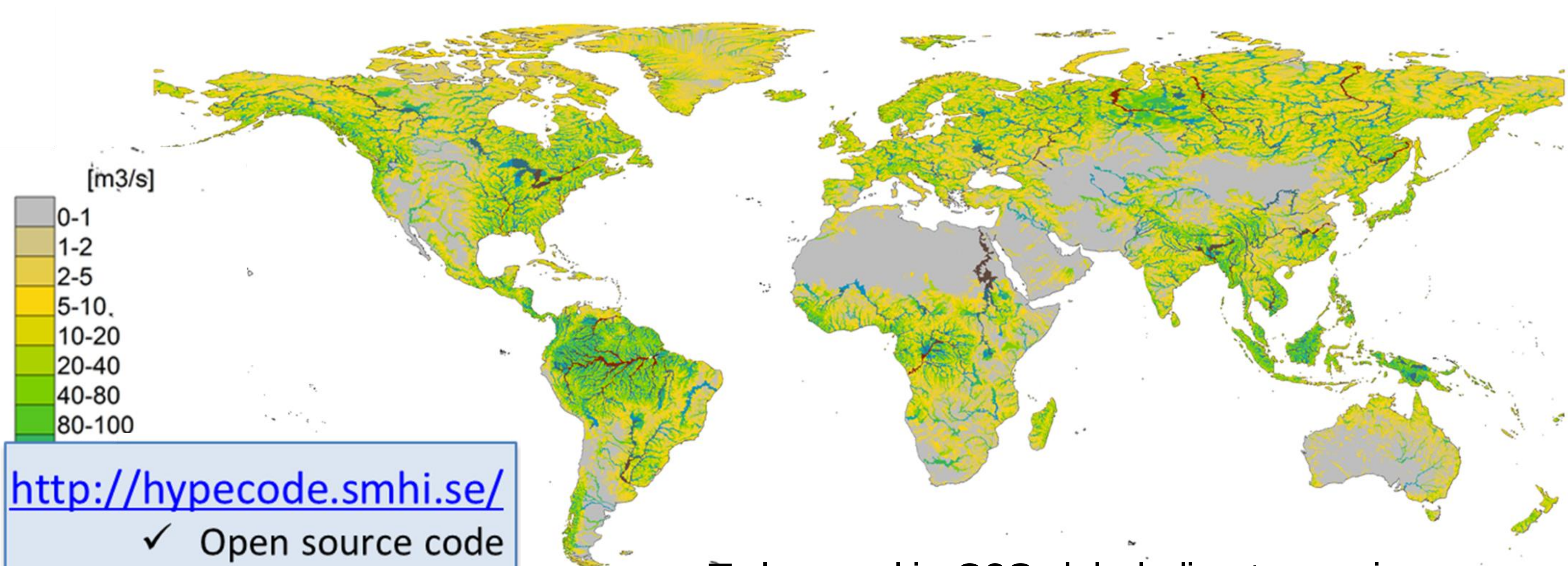
- Earth observations and global databases
- Better precipitation estimates from meteorological/climate models and re-analysis
- Regional and global model calibration techniques

Some scientific drivers:

- Transparency and reproducible research
- Comparative hydrology for better understanding of 'cause-effect' relationships.
- Critical mass is needed to advance scientific research

Example of going global with catchment modelling

River flow (m^3s^{-1}) using the World-Wide HYPE model version 1.3



http://hypecode.smhi.se/

- ✓ Open source code
- ✓ Annual open course
- ✓ Forum for user support

"Get a piece of a world!"

To be used in C3S global climate service:

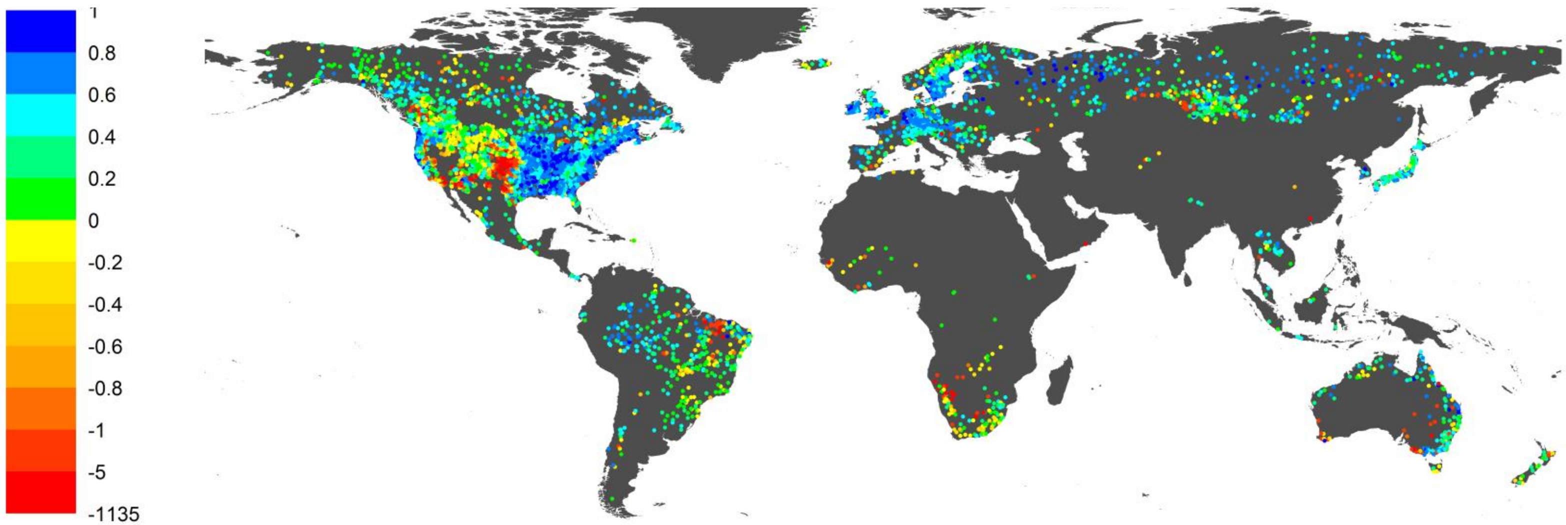
http://climateservice-global.eu/

Copernicus Europe's eyes on Earth
Climate Change Service

Data needed for evaluation and parameter estimation

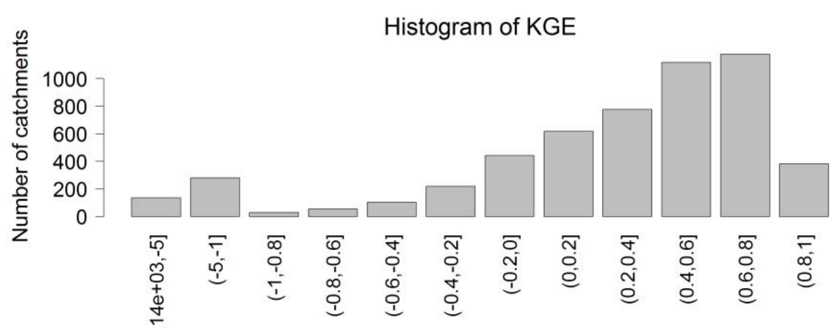
Min. of 10 years and max +/-10% catchment discrepancy vs metadata

KGE using some 11 500 stations (>1000 km^2)



Run info

start (cdate) : 1981-01-01
end (edate) : 2012-12-31
variable : Discharge (m3/s)
comparison : rout vs cout
obs vs sim
time step : monthly
exec.time : 3 h 7 min



KGE Statistics

Median : 0.402

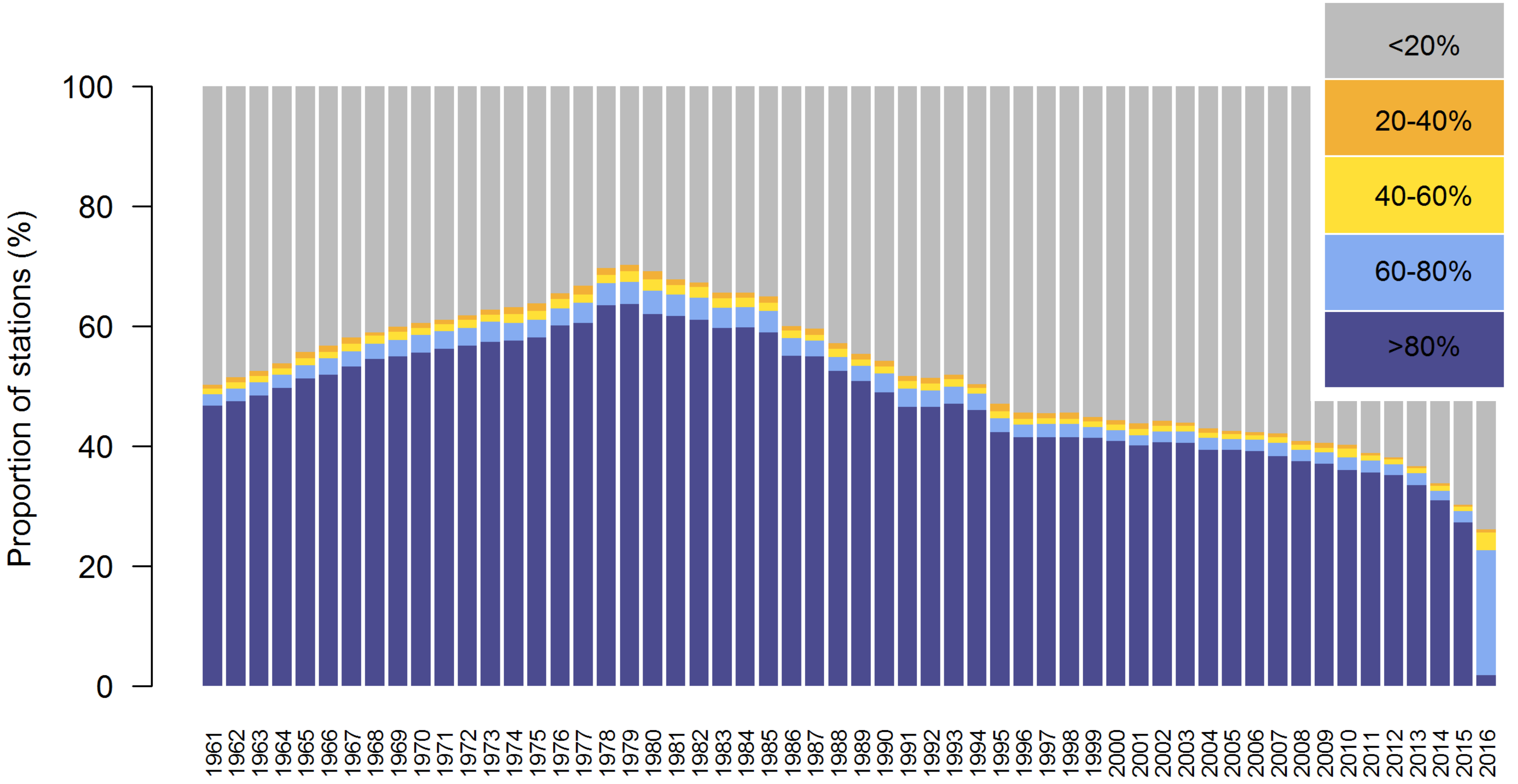
Max : 0.929
Q75 : 0.638
Q25 : 0.027
Min : -1.1e+03

Easily accessible open data of river flow

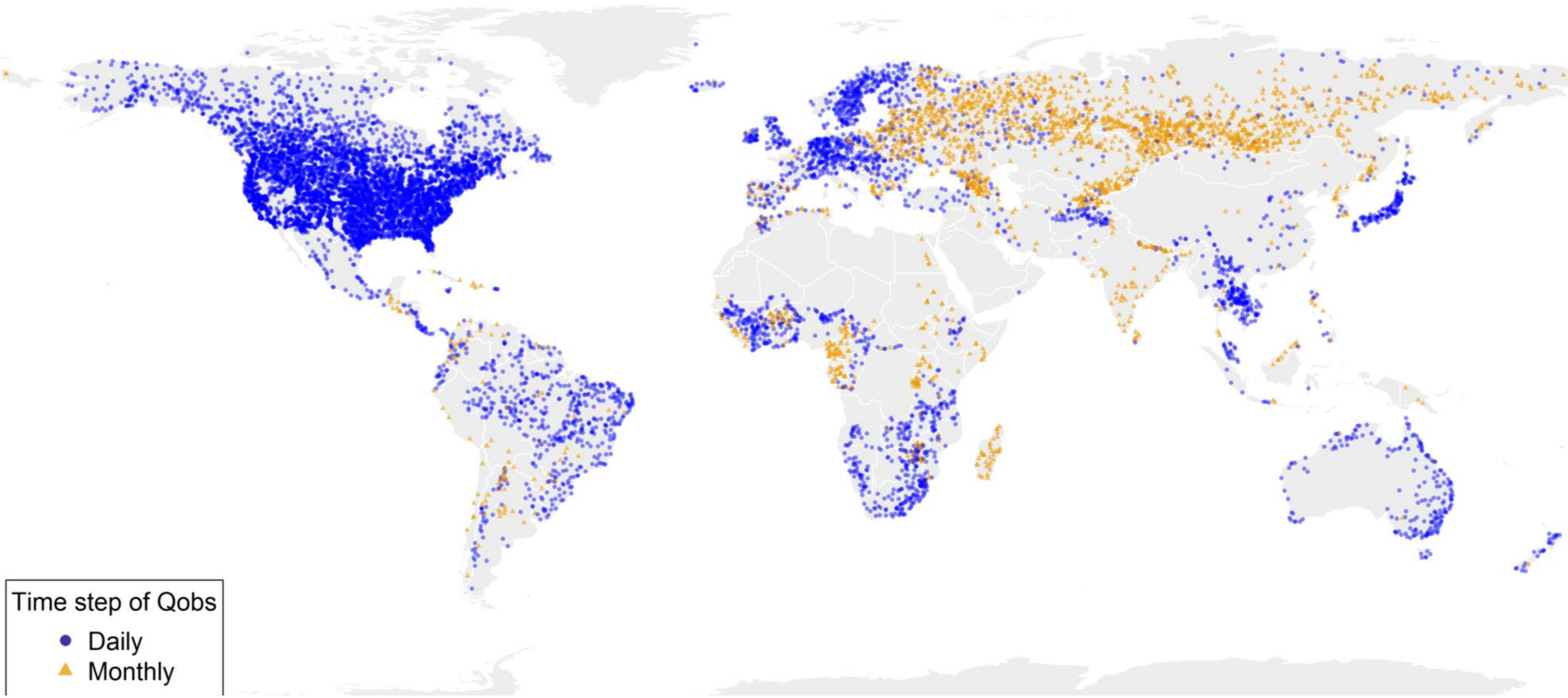
- Some 22 000 time-series from 11 data sources (half was disqualified for WWH)
- + some 30 sources with info on locations of gauges

Data set	Coverage	Provider/reference
GRDC	Global	GRDC
EWA	Europe	GRDC
ds553.2 Russian River data by Bodo	Former Soviet Union	Byron Bodo. 2000
R-ArcticNet v 4.0	Arctic region	UNH
RIVDIS v 1.1	Global	Vörösmarty et al., 1998
USGS	USA	U.S. Geological Survey
HYDAT	Canada	Water Survey of Canada (WSC)
Chinese Hydrology Data Project	China	Henck et al., 2011
National data	Spain	Spanish authorities
CICOS		
WISKI	Sweden	SMHI

Data availability per year 1961-2016



Distribution of daily and monthy time-series (1961-2016)



Other initiatives from the scientific community

NEW: The Global Streamflow Indices and Metadata Archive (GSIM)
Published in Earth Syst. Sci. Data, 2018

Indices from more than 35 000 daily streamflow time-series from 12 databases.

Hong Xuan Do et al., Part 1: The production of daily streamflow archive and metadata

Gudmundsson et al., Part 2: Quality control, time-series indices and homogeneity assessment

Earth Syst. Sci. Data, 10, 765–785, 2018
https://doi.org/10.5194/essd-10-765-2018

Open Access Earth System Science Data

The Global Streamflow Indices and Metadata Archive (GSIM) – Part 1: The production of a daily streamflow archive and metadata

Hong Xuan Do[1], Lukas Gudmundsson[2], Michael Leonard[1], and Seth Westra[1]
[1]School of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide, Australia
[2]ETH Zürich, Institute for Atmospheric and Climate Science, Zürich, Switzerland
Correspondence: Hong Xuan Do (hong.do@adelaide.edu.au)

Received: 7 September 2017 – Discussion started: 20 September 2017
Revised: 9 March 2018 – Accepted: 16 March 2018 – Published: 17 April 2018

Abstract. This is the first part of a two-paper series presenting the Global Streamflow Indices and Metadata archive (GSIM), a worldwide collection of metadata and indices derived from more than 35 000 daily streamflow time series. This paper focuses on the compilation of the daily streamflow time series based on 12 free-to-

Earth Syst. Sci. Data, 10, 787–804, 2018
https://doi.org/10.5194/essd-10-787-2018

Open Access Earth System Science Data

The Global Streamflow Indices and Metadata Archive (GSIM) – Part 2: Quality control, time-series indices and homogeneity assessment

Lukas Gudmundsson[1], Hong Xuan Do[2], Michael Leonard[2], and Seth Westra[2]
[1]Institute for Atmospheric and Climate Science, Department of Environmental Systems Science, ETH Zurich, Universitaetstrasse 16, Zurich 8092, Switzerland
[2]School of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide, Australia
Correspondence: Lukas Gudmundsson (lukas.gudmundsson@env.ethz.ch)

Received: 7 September 2017 – Discussion started: 20 September 2017
Revised: 9 March 2018 – Accepted: 16 March 2018 – Published: 17 April 2018

Abstract. This is Part 2 of a two-paper series presenting the Global Streamflow Indices and Metadata Archive (GSIM), which is a collection of daily streamflow observations at more than 30 000 stations around the world. While Part 1 (Do et al., 2018a) describes the data collection process as well as the generation of auxiliary

Basic Metadata available from sources in GSIM

NEW: The Global Streamflow Indices and Metadata Archive (GSIM)
Published in Earth Syst. Sci. Data, 2018

Database	Station ID	Station name	River name	Geographical coordinates	Station elevation	Drainage area	Catchment boundary
GRDB	X	X	X	X	X	X	X
EWA	X	X	X	X	X	X	X
CHDP	X	X	X	X	–	X	–
GAME	X	X	X	X	X	X	–
ARCTICNET	X	X	X	X	X	X	–
USGS	X	X	–	X	X	X	–
HYDAT	X	X	–	X	–	X	–
ANA	X	E	E	X	X	X	–
ADF	X	E	E	X	X	X	–
MLIT	X	E	E	X	–	–	–
BOM	X	X	–	X	–	–	–
WRIS	X	X	X	X	X	X	–

X: metadata available; –: metadata are unavailable; E: metadata are not available in English.

Other major data needed (and sources)

Topography and routing
- GWD-LR [3arcsec]: flow direction, upstream area, river width *(Yamazaki et al., 2014)*
- SRTM – Digital elevation database [3arcsec] *(USGS)*
- HYDRO-1K [30 arcsec] *(USGS)*
- GIMP [90 m] *(Howat et at., 2014)*

Land cover
- CCI Land Cover [300 m] (ESA)
- MIRCA2000 (Arendt et al., 2015)
- GMIA (Siebert et al., 2013)
- Randolph Glacier Inventory (RGI) (Arendt et al., 2015)
- Greenland Glacier Inventory (Rastner et al, 2012)

Waterbodies
- Global Lakes & Wetland Database, GLWD (Lehner & Döll, 2004)
- Global Reservoir and Dam Database (GRanD) (Lehner et al. 2011)
- CCI water bodies [150 m] (ESA)
- GWD-LR (Yamazaki et al., 2014)

Forcing data
- MSWEP (Bek et al., 2017; HESS) Princeton Uni., USA
- Hydro-GFD (Berg et al., 2018; HESS) SMHI, Sweden
- CRU, Uni East Anglia, UK

Current trends in shared data management

- Shared catalogues for data search (key-words, geogr. position) using Metadata and a spatial data/info platform for:
  - Quick visualisation and inspection
  - Distributed storage and maintenance (e.g. WMO-WIS; GEOSS)
- From Downloading to Processing at data site (e.g. HydroShare/CUASHI; ESA-TEP; Copernicus Services/C3S-ECMWF)
- From Databases to Data services – all data management systems needs user guidance, training, instructions and tutorials, e.g. Services.

hydrology tep

Community Platform

An open, collaborative and inclusive community where users can **SHARE** information, knowledge, algorithms, methods, tools, results, products, services.

Service Platform

A portal providing **LARGE SCALE EO SERVICES & PRODUCTS** customised for hydrology applications. Flood monitoring and small Water bodies mapping, Water quality and level, Hydrological models.

Enhancing Platform

A workspace based on the Cloud where users can discover, access, **PROCESS**, **UPLOAD**, visualise, manipulate and compare data.

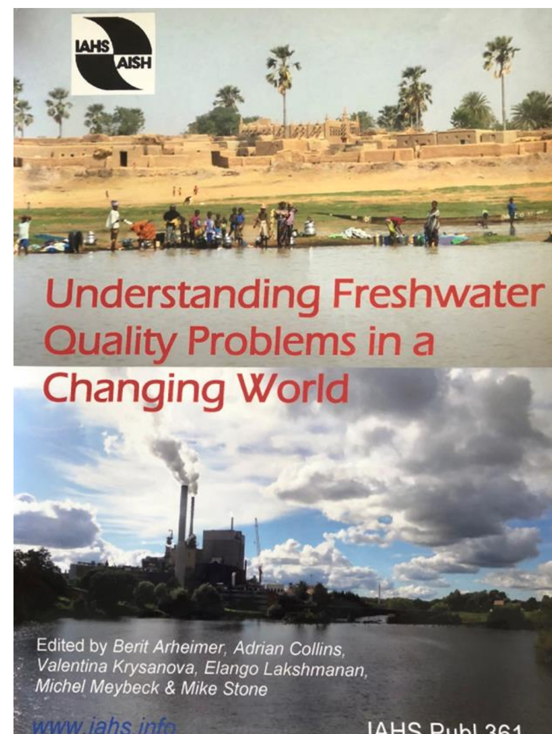
Potentials with data/info sharing?

- Earth system modelling – increased scientific knowledge of planet functioning
- (Local) Water management – hazards, floods & droughts, effective use, multiple use, etc.
- (Global) Economic growth and improved quality of life



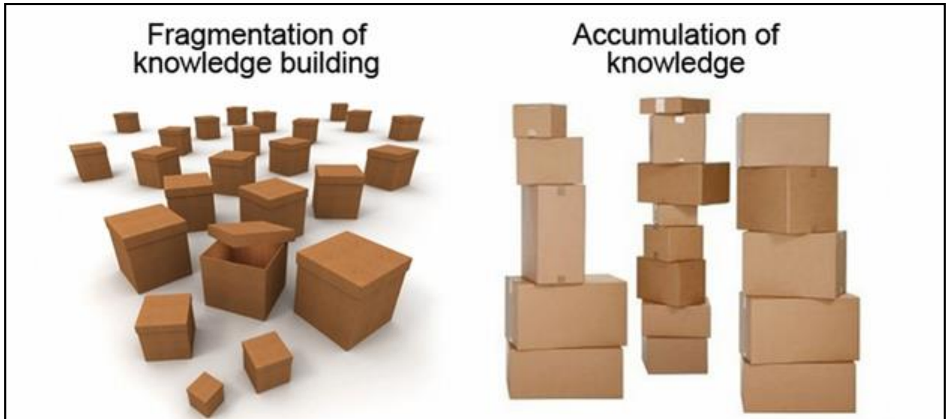






Challenges for the Hydro. community?

- Meta-data: standard attributes (formats?)
- Quality assurance and workflows (shared protocols)
- Immature community for big data – lack technical skills!



Blöshl et al. 2013

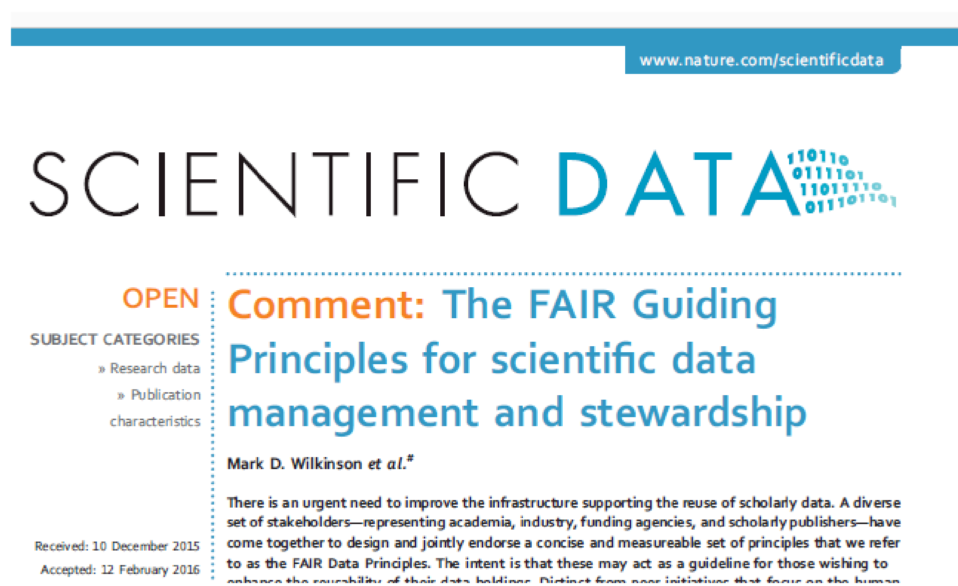

What do we need
to ensure data availability?
Logistical Infrastructure
Data Management
Networks
Dissemination
Data Collection
Quality Management
Capacity Building

We need FAIR data!

Wilkinson, M. D. et al. 2016; Nature Sci. Data

To be Findable:

F1. (meta)data are assigned a globally unique and persistent identifier
F2. data are described with rich metadata (defined by R1 below)
F3. metadata clearly and explicitly include the identifier of the data it describes
F4. (meta)data are registered or indexed in a searchable resource



www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson *et al.*#

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measureable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to

Received: 10 December 2015
Accepted: 12 February 2016

We need FAIR data!

Wilkinson, M. D. et al. 2016; Nature Sci. Data

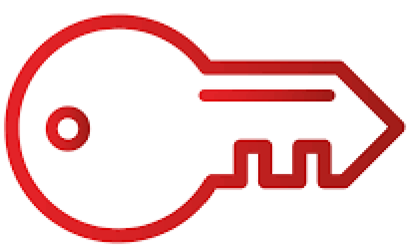
To be Accessible:

A1. (meta)data are retrievable by their identifier using a standardized communications protocol

A1.1 the protocol is open, free, and universally implementable

A1.2 the protocol allows for an authentication and authorization procedure, where necessary

A2. metadata are accessible, even when the data are no longer available



www.nature.com/scientificdata

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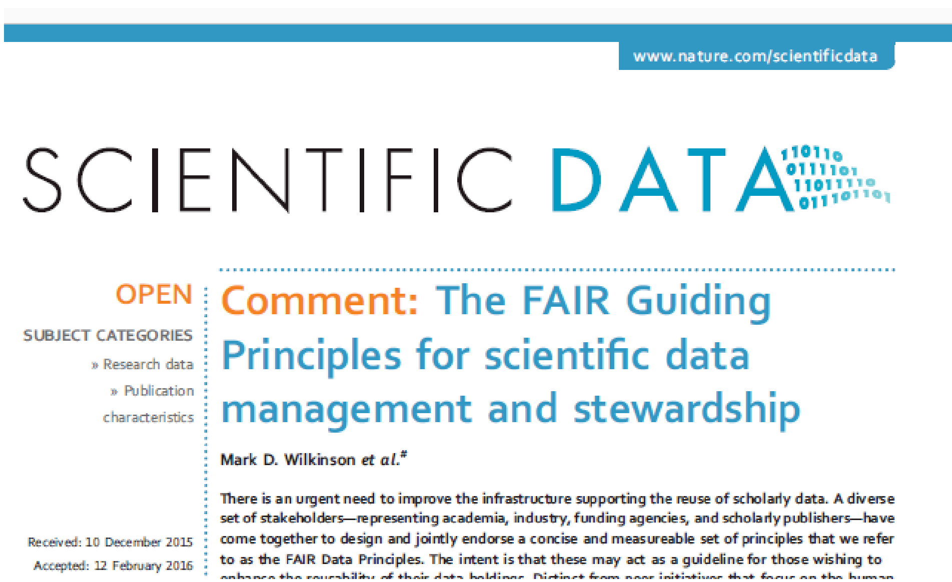
We need FAIR data!

Wilkinson, M. D. et al. 2016; Nature Sci. Data

To be Interoperable:

I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
I2. (meta)data use vocabularies that follow FAIR principles
I3. (meta)data include qualified references to other (meta)data



www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Received: 10 December 2015
Accepted: 12 February 2016

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson *et al.*#

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measureable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to

We need FAIR data!

Wilkinson, M. D. et al. 2016; Nature Sci. Data

To be Reusable:

R1. meta(data) are richly described with a plurality of accurate and relevant attributes

R1.1. (meta)data are released with a clear and accessible data usage license

R1.2. (meta)data are associated with detailed provenance

R1.3. (meta)data meet domain-relevant community standards

www.nature.com/scientificdata

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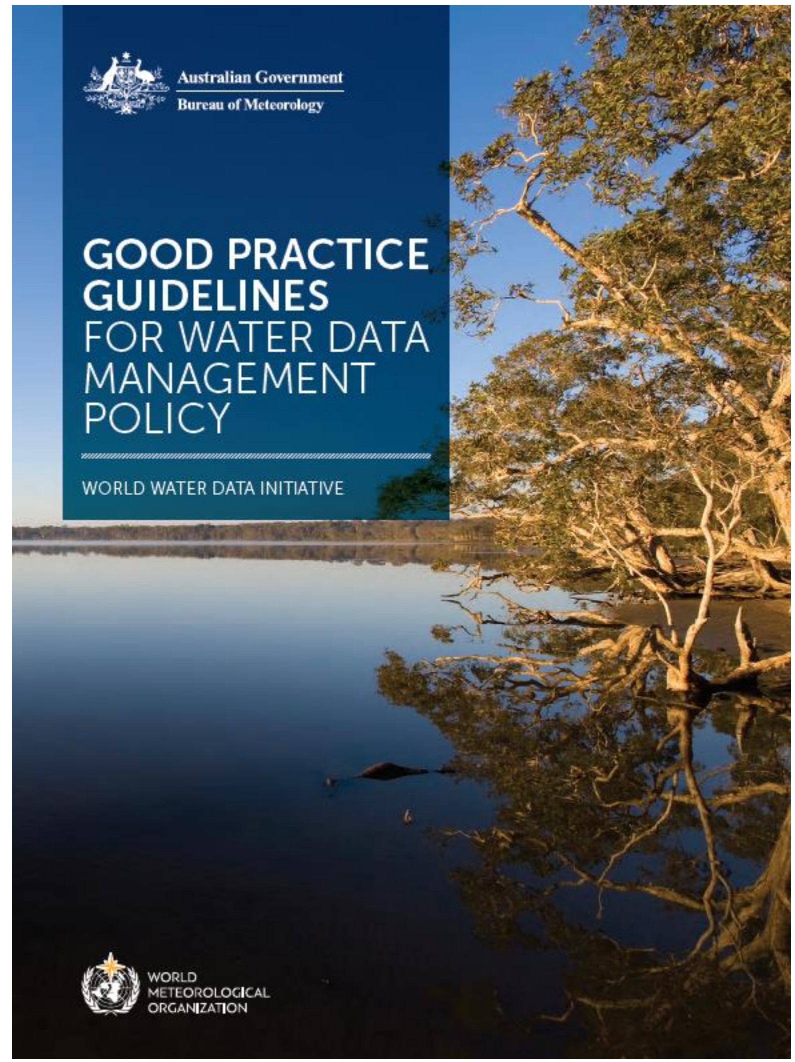
Received: 10 December 2015

We need a road map!

the **World Water Data Initiative**,
on behalf of the United Nations and World Bank High Level Panel on Water.

Bureau of Meteorology, 2017. (Australia)



We need Open Data!

Open data =
"*data that can be freely used, re-used and redistributed by anyone…*"

License: e.g. Creative Commons, Open Data Commons

Some of the many benefits:

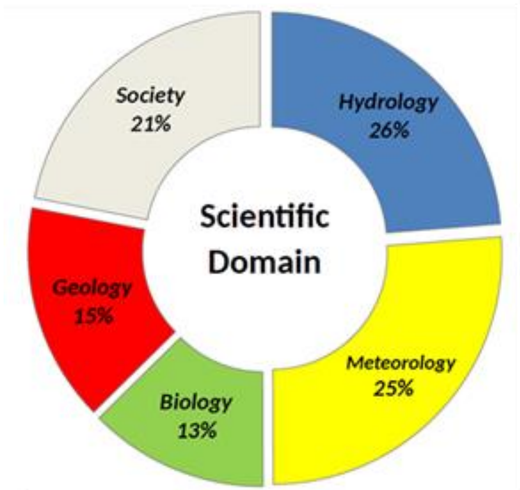
- Improving the efficiency of public services
- Improving data quality
- Developing innovative services
- Creating new business models
- Improving transparency and accountability
- Enhancing citizen participation

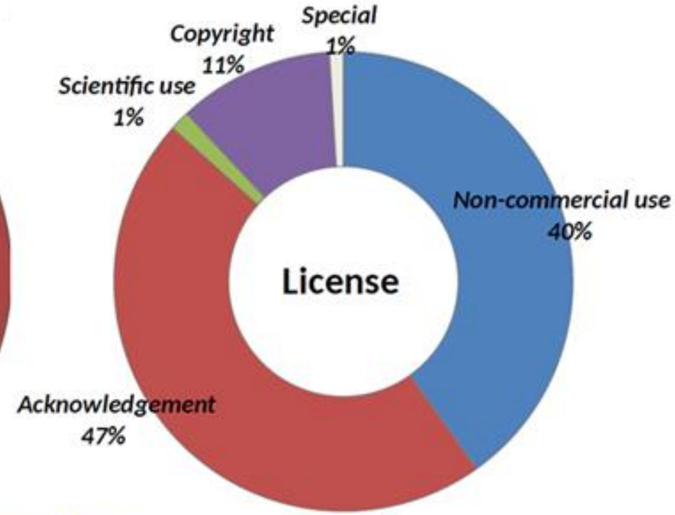
We need good examples!

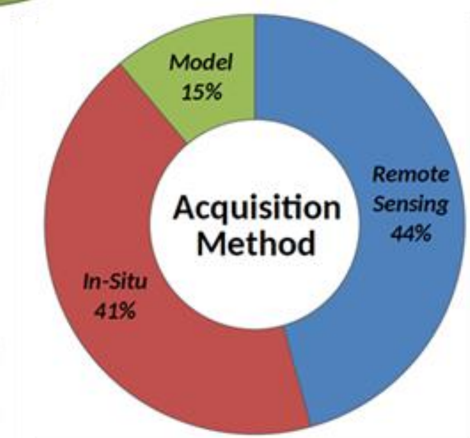
http://www.water-switch-on.eu/

The SWITCH-ON data portal
>800 water-related datasets

- 14 innovative commercial products
- Virtual water-science lab.







EU FP7 Collaborative project
(grant agreement No. 603587)

Do we need water data standards? WaterML

Bureau of Meteorology, 2017. (Australia)

Part	Description	Status @ November 2017
WaterML2.0 Part1: Time Series Encoding Standard	A standard information model for exchanging water observations data sets between users and information systems. Highly recommended for adoption.	Endorsed and published by OGC[49]
WaterML2.0 Part2: Ratings, Gaugings and Sections	A standard information model for exchanging rating tables, gauging observations, and river sections. Highly recommended for adoption.	Endorsed and published by OGC[50]
WaterML2.0 Part3: Surface Hydrology Features	A standard information model for defining fundamental relationships among major components of the hydrosphere such as hierarchies of catchments, river network topologies and water bodies. Further reference to this standard will be made in Chapter 10 of these guidelines. Highly recommended for adoption once approved.	Being considered by OGC for endorsement[51]
WaterML2.0 Part4: Groundwater	A standard information model for the exchange of groundwater data, also referred to as GroundWaterML2.0 (GWML2). Highly recommended for adoption.	Endorsed and published by OGC[52]
WaterML2.0 Part5: Water Quality	A standard information model for the exchange of water quality data. Still in early stages of development and consultation amongst the water data community.	Being considered by OGC for endorsement[53]

NetCDF

Title

1. General

1.1 Summary

summary

1.2 Units

units

1.3 Keywords

keywords

1.4 Contact

contact

2. Dataset coverage

2.1 Geographic area

Longitude: geospatial_lon_min – geospatial_lon_max

Latitude: geospatial_lat_min – geospatial_lat_max

2.2 Temporal resolution

Output_frequency

2.3 Time period

Reference period: reference_period

Time Coverage: time_coverage_start – time_coverage_end

2.4 Spatial resolution

Spatial_resolution

3. Usage

3.1 License conditions

licence

3.2 Acknowledgements and citations

acknowledgements

references

4. Lineage statement

4.1 Original data source

history

source

4.2 Tools used in production of indicators (post-processing)

production_tools

5. Data quality

data_quality

Attributes:

- title
- summary
- units
- keywords
- contact
- geospatial_lon_min
- geospatial_lon_max
- geospatial_lat_min
- geospatial_lat_max
- temporal_resolution
- output_frequency
- reference_period (neeeded for return periods?)
- time_coverage_start
- time_coverage_end
- spatial_resolution
- licence
- acknowledgement
- references
- history
- source
- production_tools
- data_quality


Do our initiatives cover
all critical areas?
WMO HydroHub
IHP-WINS
WORLD BANK GROUP
Global Assessment
of the State of
Hydrological Services
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WMO GLOBAL CONFERENCE: PROSPERITY THROUGH HYDROLOGICAL SERVICES

WMO Headquarters, Geneva, Switzerland, 7 to 9 May 2018

Data Management

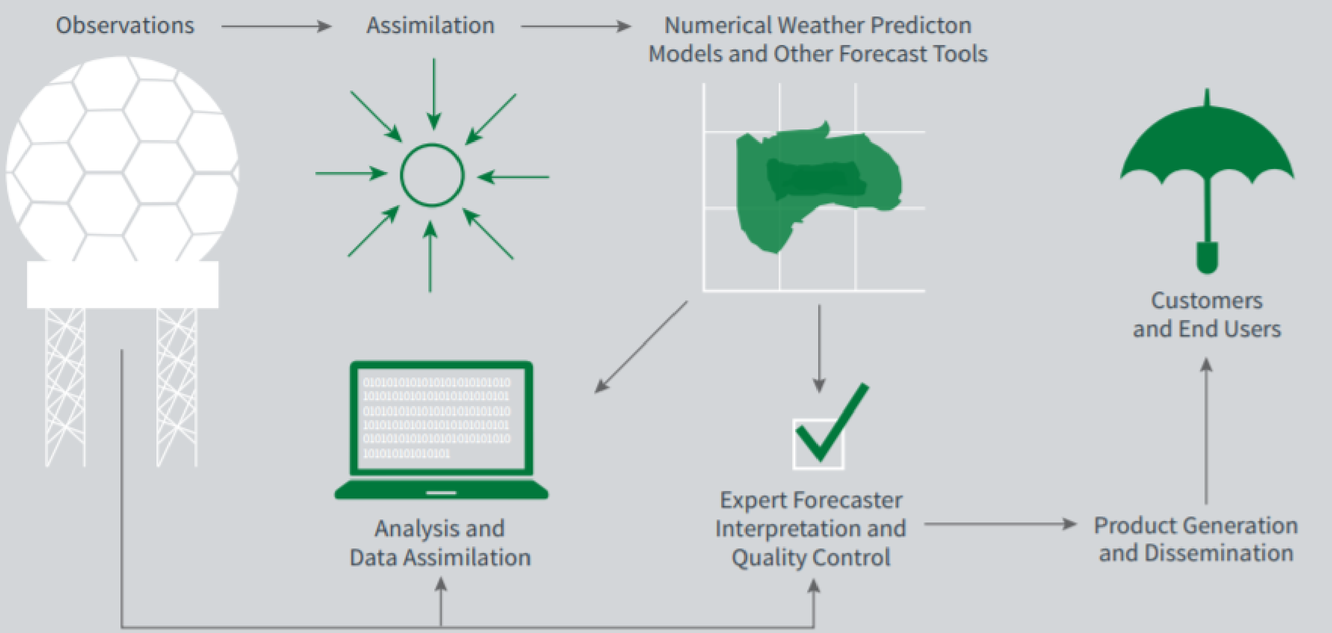
SMHI

GFDRR Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

Activities of a Typical National Meterological Service

Effective prediction of a hyrdromet event is critical in mitigating the effects. A good national meteoroligical service is designed with its end users in mind—including businesses, institutions, and community members.



Mission:

1. Upgrading Infrastructure
2. Training and Capacity Building
3. Coordination

WMO

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PROSPERITY THROUGH HYDROLOGICAL SERVICES
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GFDRR's Weather and Climate Resilience report, 2017

HYDROMET

Improving monitoring and prediction of meteorological and hydrological hazards

Improved hydro-meteorological forecasting and early warning could save at least:

$65 billion

$13 billion per year in asset losses

$22 billion per year in losses to well-being

$30 billion per year in increased productivity

$2.4 trillion in economic losses were caused by hazards between 1970 and 2012.

26 million people are forced into poverty every year by natural disaster

2 million people were killed by natural hazards between 1970 and 2012.

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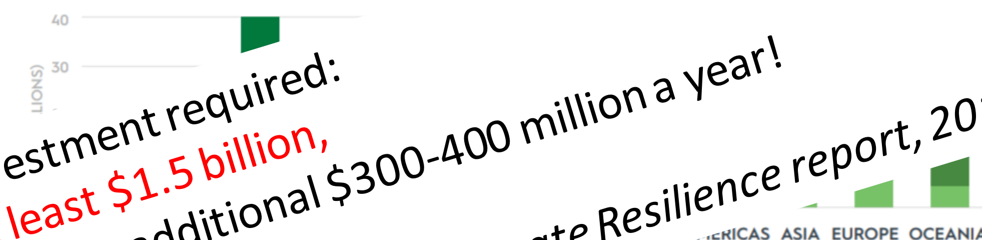
Modernization is needed in more than 100 countries, half of which are in Africa.

Geophysical | Hydrological | Meteorological | Climatological

Average annual damages caused by reported natural disas…

Average annual estimated damages per disaster group

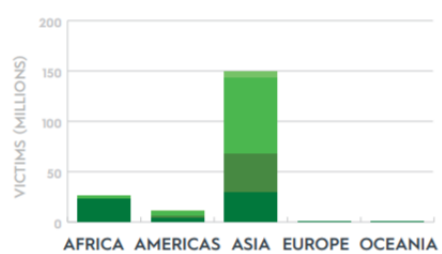


Investment required:
at least $1.5 billion,
with an additional $300-400 million a year!

(GFDRR's Weather and Climate Resilience report, 2017)

…ions) per disaster group, 2005–2015

	AFRICA	AMERICAS	ASIA	EUROPE	OCEANIA
Geophysical	22.94	4.10	29.29	0.12	0.19
Hydrological	0.25	1.62	38.58	0.15	0.06
Meteorological	3.02	4.33	74.81	0.37	0.08
Climatological	0.04	1.07	7.36	0.02	0.06



Measuring Impact

» GFDRR is currently supporting **OVER $600 MILLION** to improve hydromet agencies from partners such as WBG, Climate Investment Fund and Green Climate Fund.

» The program has trained **MORE THAN 300 SPECIALISTS** in the last three years.

» The initiative aims to support WBG in reaching an additional **100 MILLION PEOPLE** in developing countries with access to high-quality hydromet, and EWS data and services.


Do our initiatives cover
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IAHS AISH

IAHS « COMMISSIONS « WORKING GROUPS « MOXXI

MOXXI

MOXXI Measurements & Observations in the 21st Century

<u>MOXXI:</u> Measurements and observations in the XXI Century

<u>Task:</u>

"promote the advancement of novel observational techniques that leads to new sources of information to help better understand the hydrological cycle"

- 131 researchers signed up from more than 15 countries
- Dedicated sessions at EGU, AGU, and IAHS meetings
- Yearly topical conferences (hosted at ESA in 2016, jointly organized at WMO in 2017)

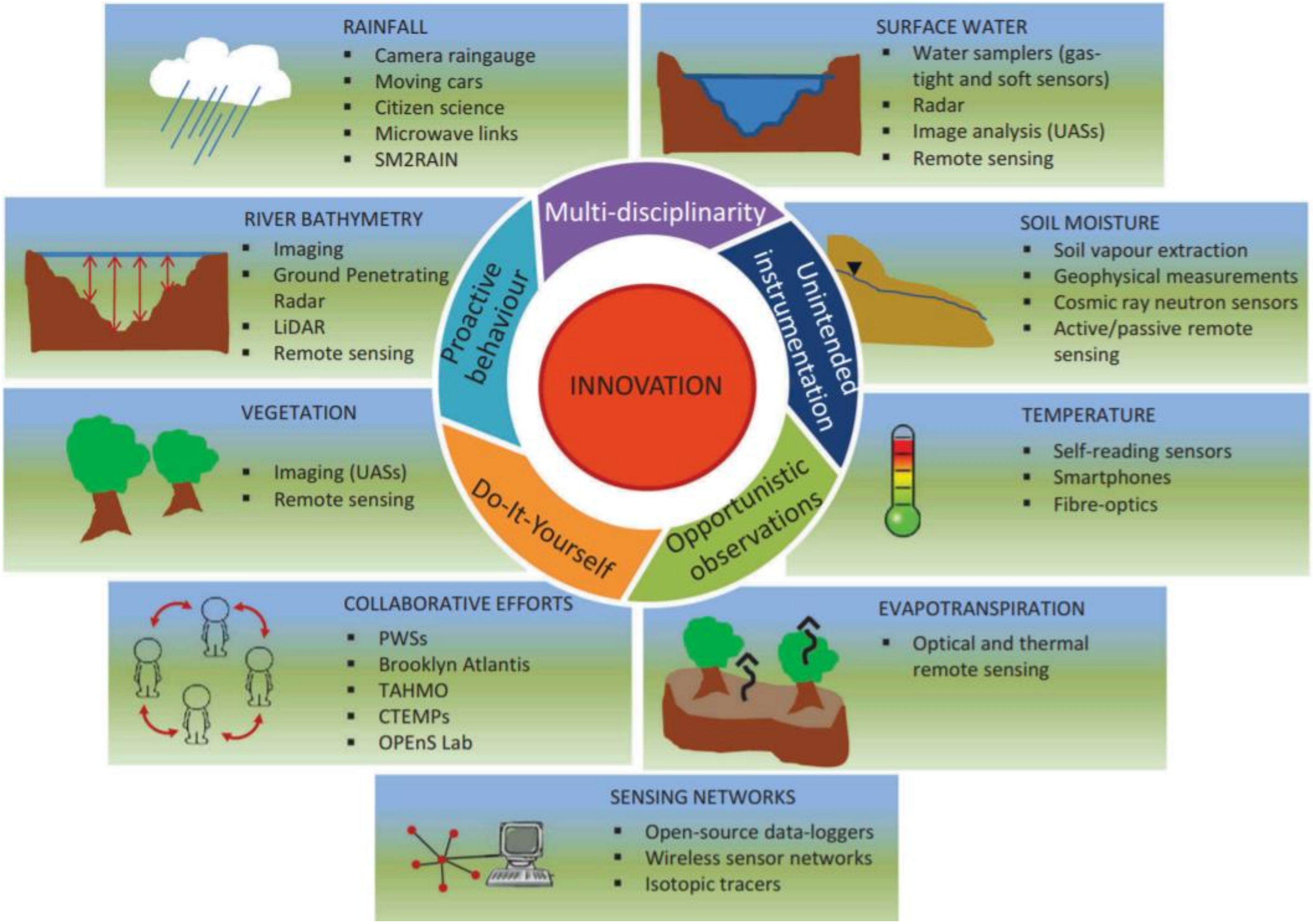
- Key research questions:
  - What are the key gaps in our understanding of hydrologic change?
  - How can we advance our monitoring and data analysis capabilities to predict and manage hydrologic change?

IAHS « COMMISSIONS « WORKING GROUPS « MOXXI

MOXXI

MOXXI Measurements & Observations in the 21st Century

MOXXI is a growing community of researchers from diverse fields



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MOXXI

MOXXI Measurements & Observations in the 21st Century

Dedicated website with contributions presented at MOXXI sessions/events

Major achievements:

- Recently published community paper in *Hydrological Sciences Journal*
- Participation in the EU COST Action HARMONIOUS: *Harmonization of UAS techniques for agricultural and natural ecosystems monitoring*

HYDROLOGICAL SCIENCES JOURNAL, 2018
https://doi.org/10.1080/02626667.2017.1420191

Taylor & Francis

Measurements and Observations in the XXI century (MOXXI): innovation and multi-disciplinarity to sense the hydrological cycle

Flavia Tauro[a], John Selker[b], Nick van de Giesen[c], Tommaso Abrate[d], Remko Uijlenhoet[e], Maurizio Porfiri[f], Salvatore Manfreda[g], Kelly Caylor[h], Tommaso Moramarco[i], Jerome Benveniste[j], Giuseppe Ciraolo[k], Lyndon Estes[l], Alessio Domeneghetti[m], Matthew T. Perks[n], Chiara Corbari[o], Ehsan Rabiei[p], Giovanni Ravazzani[o], Heye Bogena[q], Antoine Harfouche[a], Luca Brocca[i], Antonino Maltese[k], Andy Wickert[r], Angelica Tarpanelli[i], Stephen Good[b], Jose Manuel Lopez Alcala[s], Andrea Petroselli[t], Christophe Cudennec[u], Theresa Blume[v], Rolf Hut[c] and Salvatore Grimaldi[a,f]

[a]Department for Innovation in Biological, Agro-food and Forest Systems, University of Tuscia, Viterbo, Italy; [b]Department of Biological and Ecological Engineering, Oregon State University, Corvallis, Oregon, USA; [c]Department of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands; [d]Basic Systems in Hydrology Division, World Meteorological Organization, Geneva, Switzerland; [e]Department of Environmental Sciences, Wageningen University, Wageningen, The Netherlands; [f]Department of Mechanical and Aerospace Engineering, New York University Tandon School of Engineering, Brooklyn, New York, USA; [g]Dipartimento delle Culture Europee e del Mediterraneo, University of Basilicata, Potenza, Italy; [h]Earth Research Institute, University of California Santa Barbara, Santa Barbara,

Do our initiatives cover all critical areas?

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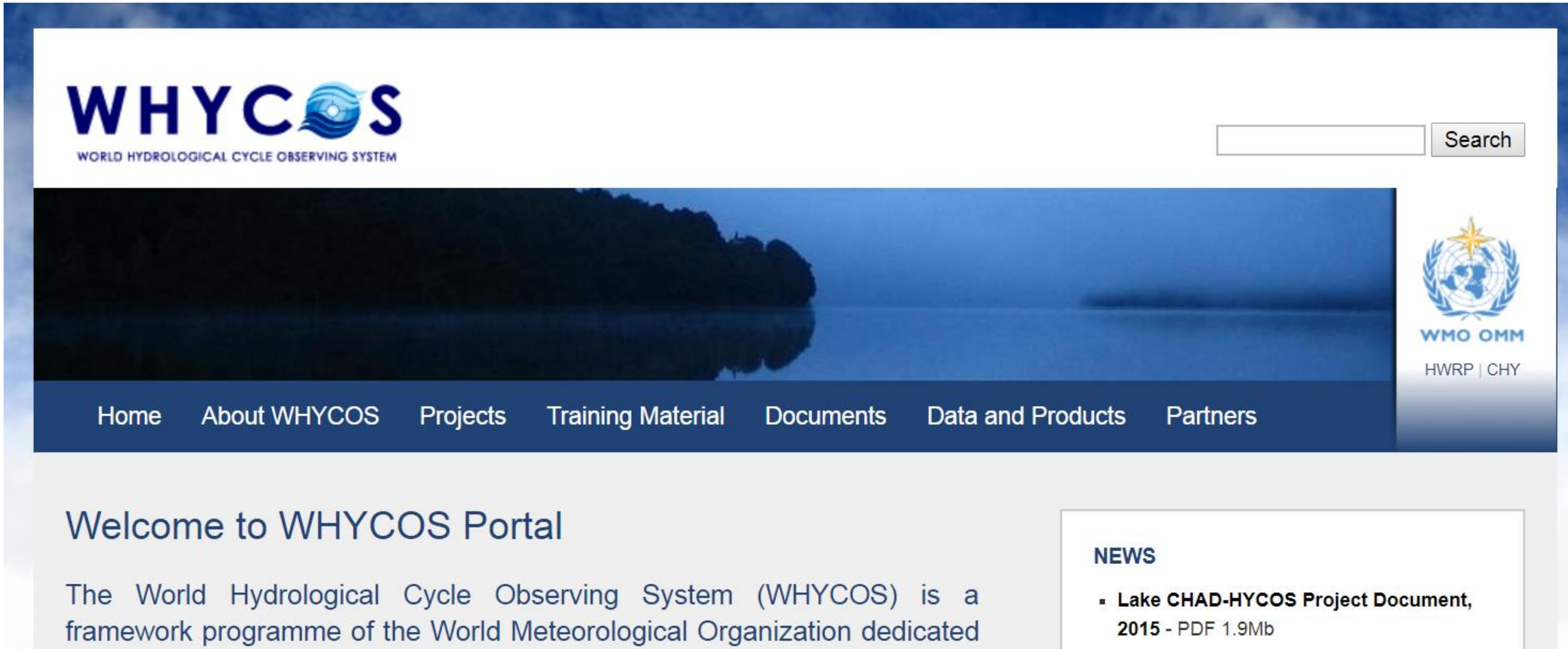

- Since 1997 – on-going
- Data sharing between National HydMet. inst. of a water body/catchment/aquifer
- Collaboration with GPCC, GRDC and GEMS-water

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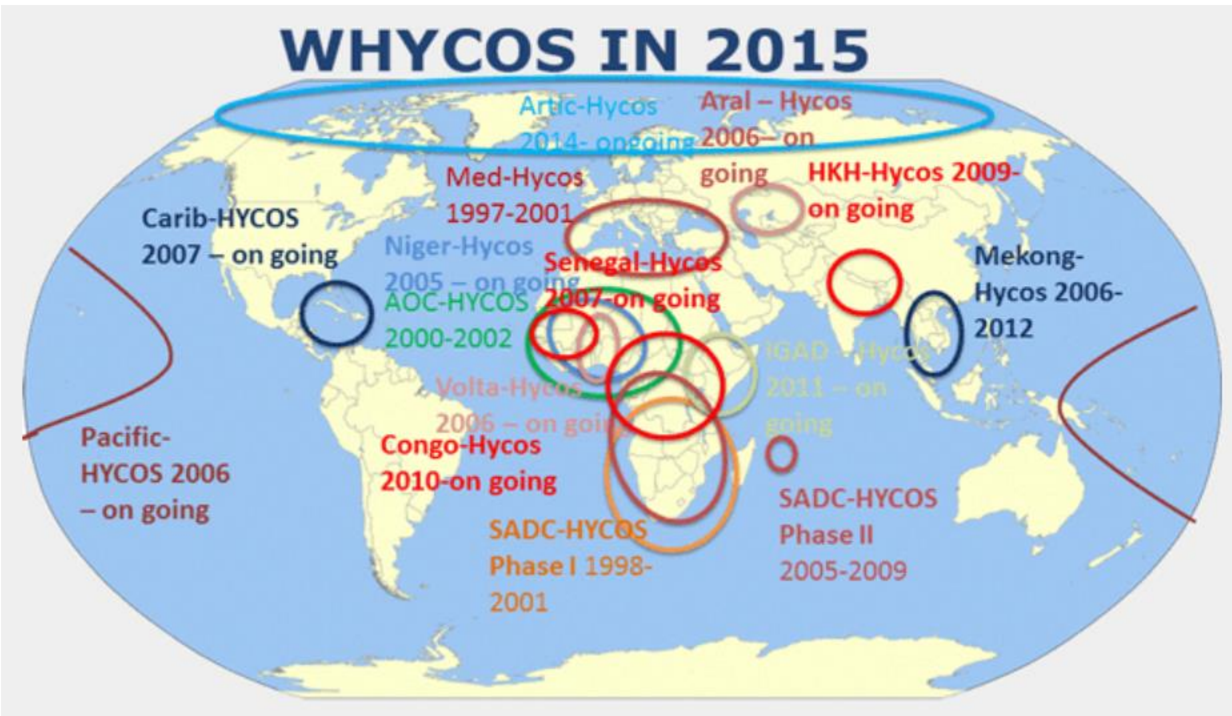
WHYCOS
WORLD HYDROLOGICAL CYCLE OBSERVING SYSTEM
WMO OMM



CONTENT

- 4 implemented projects
- 7 projects under implementation
- 6 project proposals in advanced preparation stage
- 1 project proposal in preparatory stage

Each project initiation, implementation and post-maintenance according to pre-conditions.

WHYCOS
WORLD HYDROLOGICAL CYCLE OBSERVING SYSTEM
WMO OMM

Drought and Floods in West Africa:
- Bulletin from Niger-HYCOS

AUTORITE DU BASSIN DU NIGER *Projet Niger-HYCOS* *Bulletin Mensuel janvier 2008*		NIGER BASIN AUTHORITY *Niger-HYCOS Project* *January 2008 Monthly Bulletin*

LA CRUE GUINEENE ATTEINT SA POINTE

La crue guinéenne a atteint sa pointe au niveau du Niger moyen à Niamey avec un débit maximum de 1830 m 3/s observé entre le 1er au 6 janvier 2008.

Le volume d'eau écoulé de juin à janvier 2008 est de l'ordre de : 29,15 milliards de m3 à Koulikoro, 26,76 milliards de m3 à Nantaka, 25,04 milliards de m3 à Niamey et 174,26 milliards de m3 à Lokoja comme montrent le tableau 1 et les fig 1 à

THE BLACK FLOOD ATTAINED ITS PEAK

The black flood flow attained its peak between 1st and 6th January 2008 at the Middle Niger in Niamey with a maximum flow of 1830 m3/s.

The total flow volume since the beginning of the last wet season in June 2007 to 31st January 2008 is as follows; Koulikoro about 29.15 billion m3; Nantaka about 26.76 billion m3; Niamey 25.04 billion m3 and Lokoja about 174.26 billion m3 as

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WHYCOS
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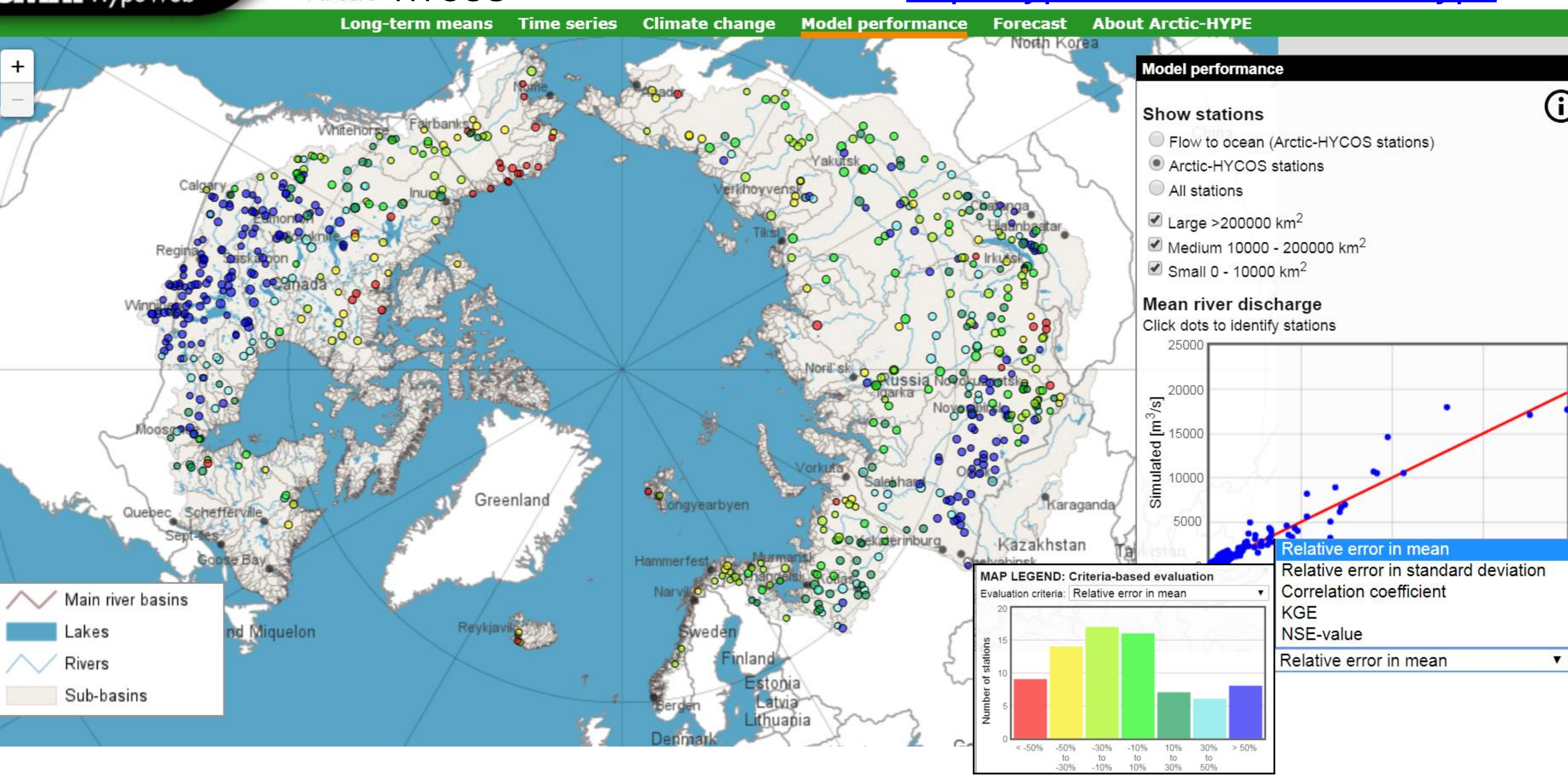
WMO OMM

Climate change in the Arctic:

- 79 Arctic-HYCOS flow-to-ocean stations
- 540 Arctic HYCOS upstream stations *(model evaluation period 1971-2010)*

http://hypeweb.smhi.se/arctichype

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http://ihp-wins.unesco.org/

- Geospatial Information Platform – for data search, visualisation and download
- Allows storing, combining from several sources, and sharing open data
- GIS-layers, maps, documents, people, groups, (time-series)
- Standard Metadata + DOI
- Creative Commons Attribution 4.0 license

United Nations Educational, Scientific and Cultural Organization · International Hydrological Programme

IHP WINS

Content (since Jan 2017):

- 153 layers (12 raster, 141 vector)
- 3 maps
- 42 documents
- 169 people, 10 with affiliation (and not Unesco)
- 61 groups with 1-5 members (Groundwater and Education = 9)

Search by text

- KEYWORDS
- EXTENT
- TYPE
- RESPONSIBLES
- DATE
- REGIONS

Explore Layers

CATEGORIES

Cross-cutting	23
Ecohydrology	26
Groundwater	22
SDGs	4
Water education	7
Water for settlements	42
Water quality	10
Water-related disasters	14
Water scarcity	5

http://ihp-wins.unesco.org/

Sharing in communities

Map and community portal

Data collection

New Data sources

Open data?
Processing facilities?
Metadata is key!

Million dollar questions:

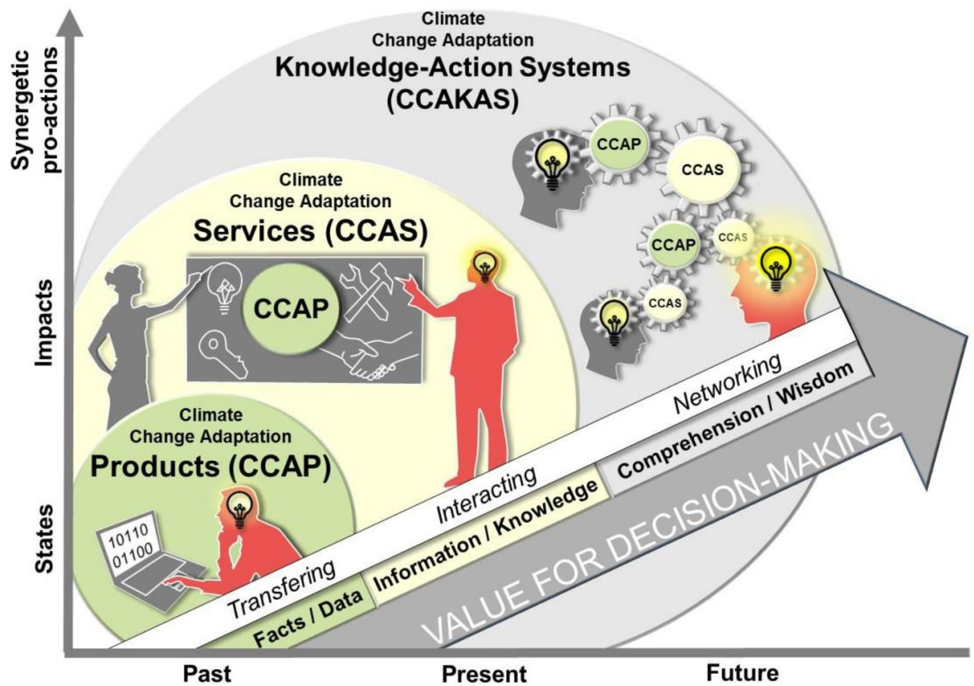
- There are many “donors” investing (competing?) – but which system is sustainable when “donor” is gone?
- There are many scientific publications – but how to make new data marketable for society?
- There are many DATA Portals and Platforms – where is the content and the users?
- It’s already complicated to share in closed communities – so how to foster open data policies?

Hydrological services value chain

Data Management → Products → Service/Product Delivery → Interactions between services

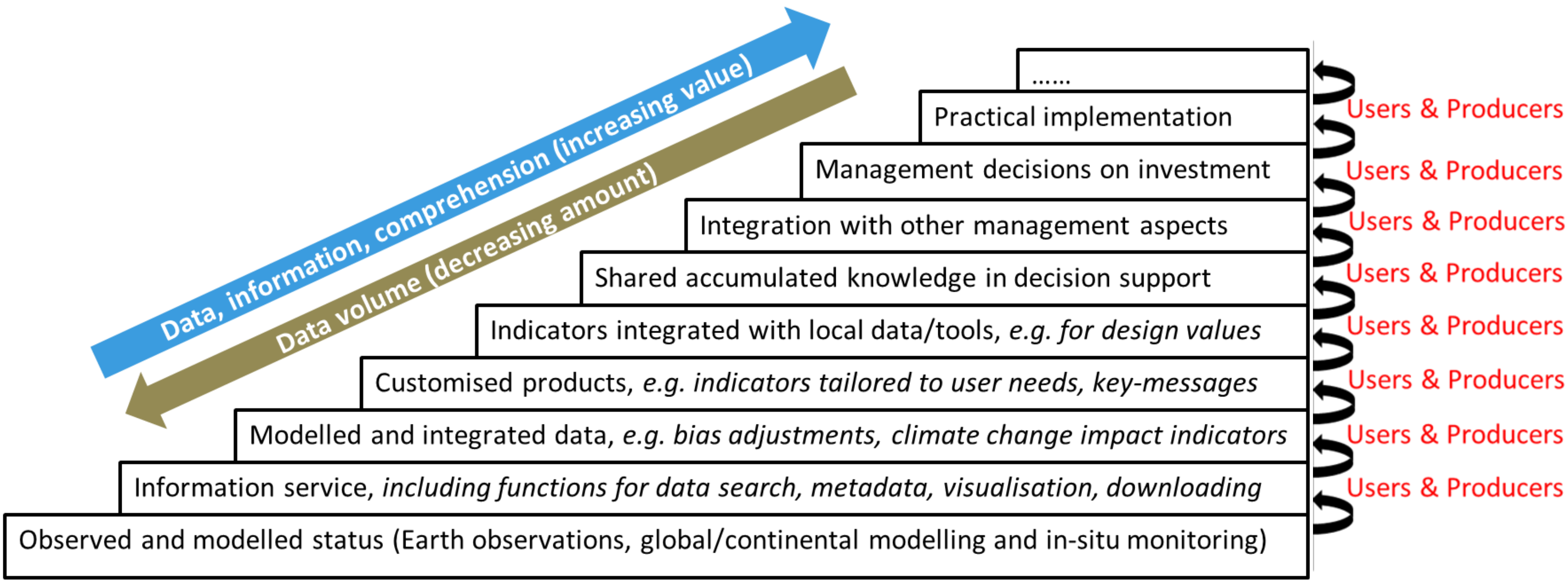
Fostering Collaboration!

Evolving climate services into knowledge-action systems



Weichselgartner and Arheimer, 2018:
In review for Nature Climate Change

Data management and product/services: Who is the target audience?



Weichselgartner and Arheimer, 2018:
In review for Nature Climate Change

To be continued....

Some key messages

- Fostering data management is needed for collaboration in hydrology.
- Global databases with open data from 20-40 thousands gauged time-series of river flow can ‘easily’ be compiled.
- Standards for metadata, quality assurance, format, etc is currently missing.
- There is a risk of data loss and reduced in-situ monitoring.
- We need FAIR data for sharing.
- We need Open Data.
- We need to recognise good examples from the scientific community.
- Hydrologists are immature and must learn from Big data communities.
- Current trend is to process data were the data is stored.
- Be user specific and evolve to interacting services.

Thank you for your attention!

Personal reflections

- Technology transfer:
  - Work agile with incremental development - starting small, then trial and error based on user requests and feedback.
  - Use new (but not newest) technology and thinking, but adapted to local setting.
  - Be specific and targeted – no “one size fits all”, instead Recycle pieces and build new!
  - Distributed systems, which communicates between eachother.

- Seconded experts:
  - Build institutions and leadership/management during collaboration.

- Financial support:
  - Work agile with incremental development - starting small, then trial and error based on user requests and feedback.
  - Long-term commitments.

- Partnership:
  - Alliances with complementary competences.
  - Build trust through endurance and engagement.
  - Openness and Ownership….