Towards seamless predictions of water fluxes across scales

– advantages for drought and flood monitoring & forecasting –

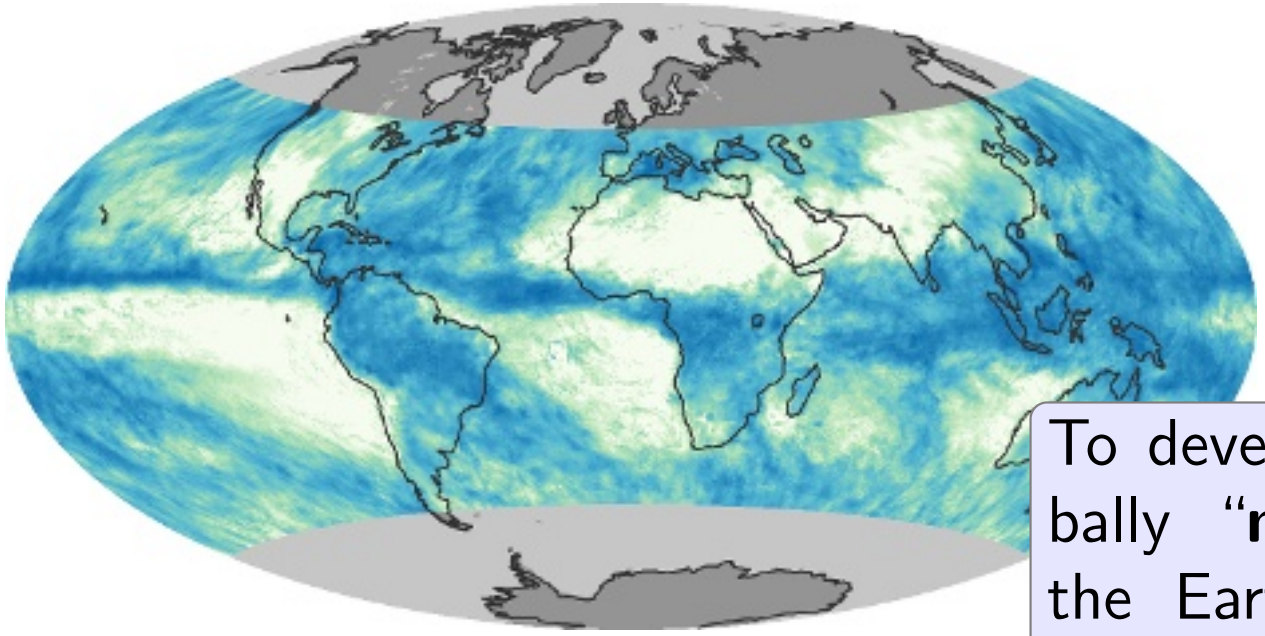
Luis Samaniego

Conference
Water and Climate Change

Leipzig, 16 November 2015

HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ

The "Grand Challenge" in hydro-meteorology



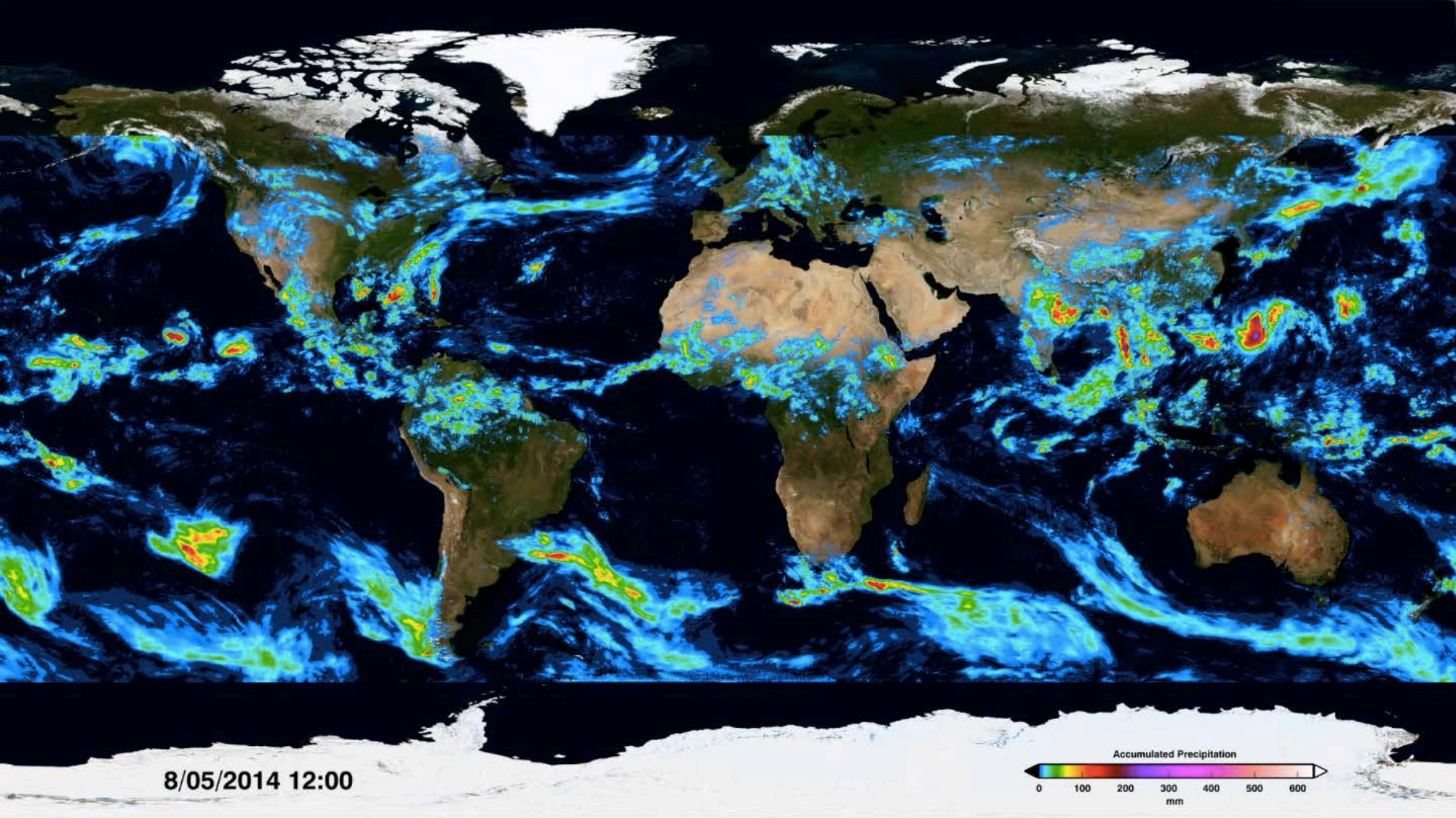
Global IMERG precipitation dataset, NASA

To develop the ability to globally "**monitor** and **predict** the Earth's terrestrial water, energy, and biogeochemical cycles" at resolutions of 1 km, or finer ...

Wood et al. WRR 2011

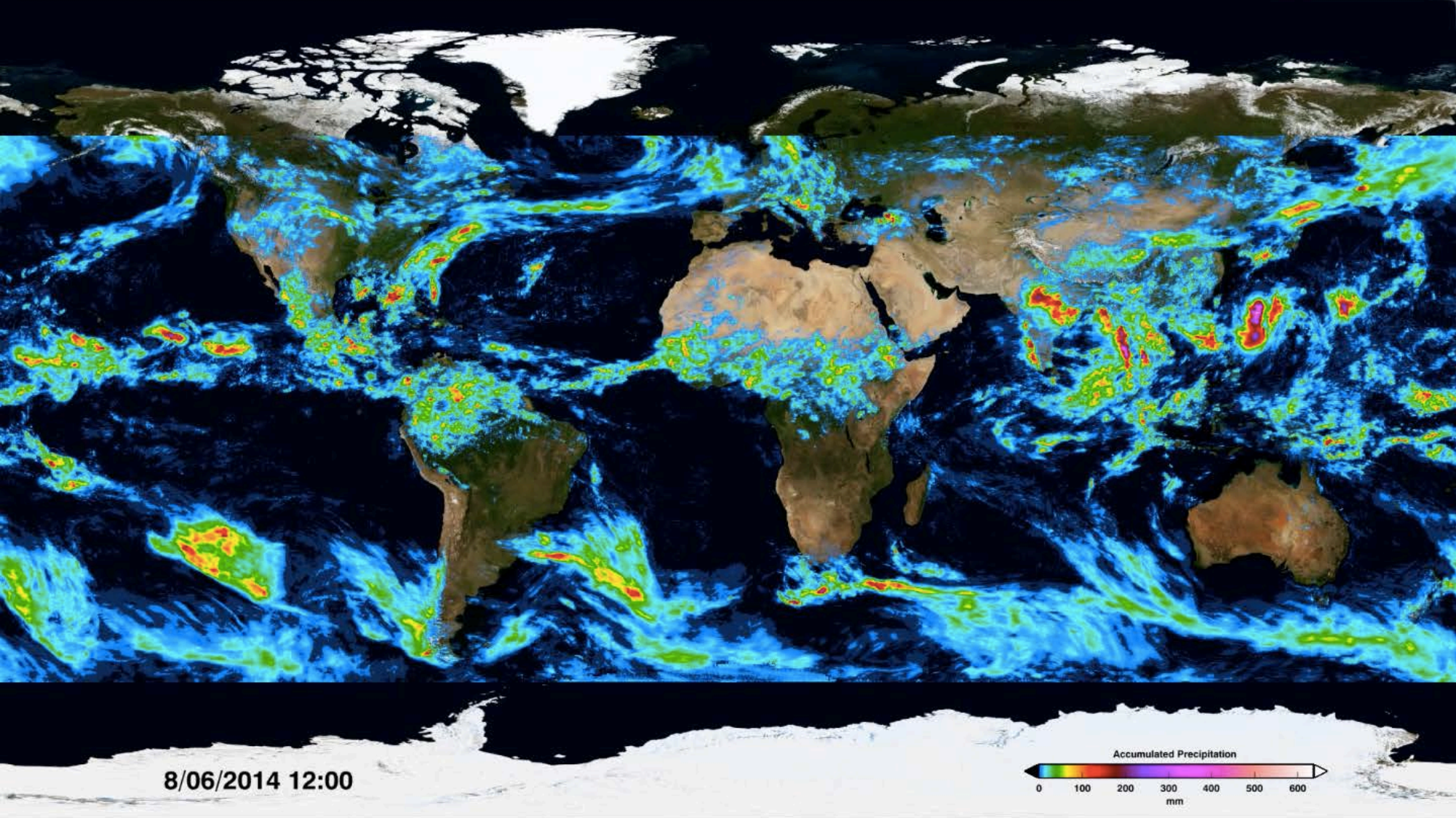
"Everywhere and locally relevant"

Bierkens et al. HP 2014



Integrated Multi-satellitE Retrievals for GPM (IMERG), NASA GES DISC

Δt 30 min



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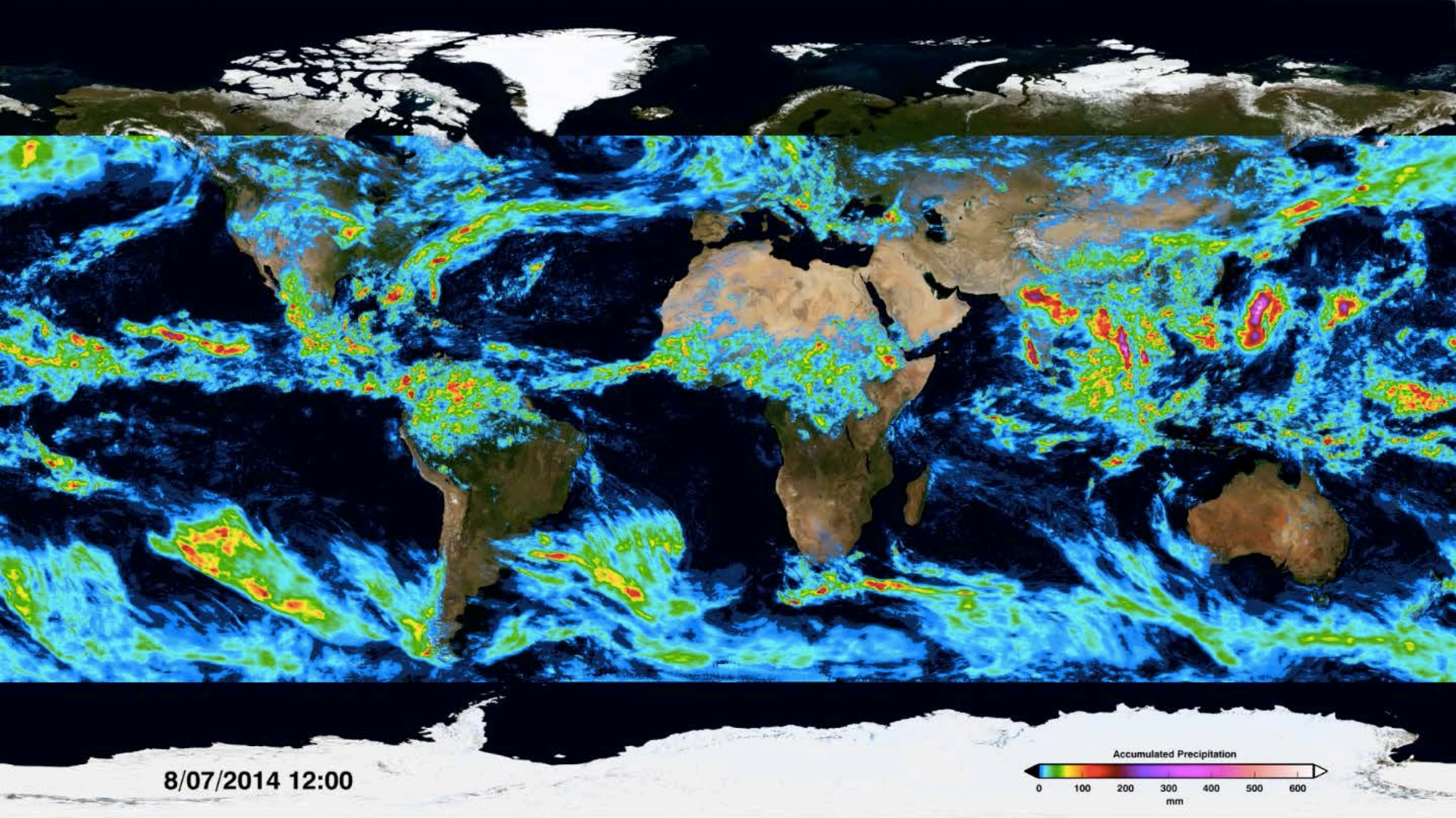

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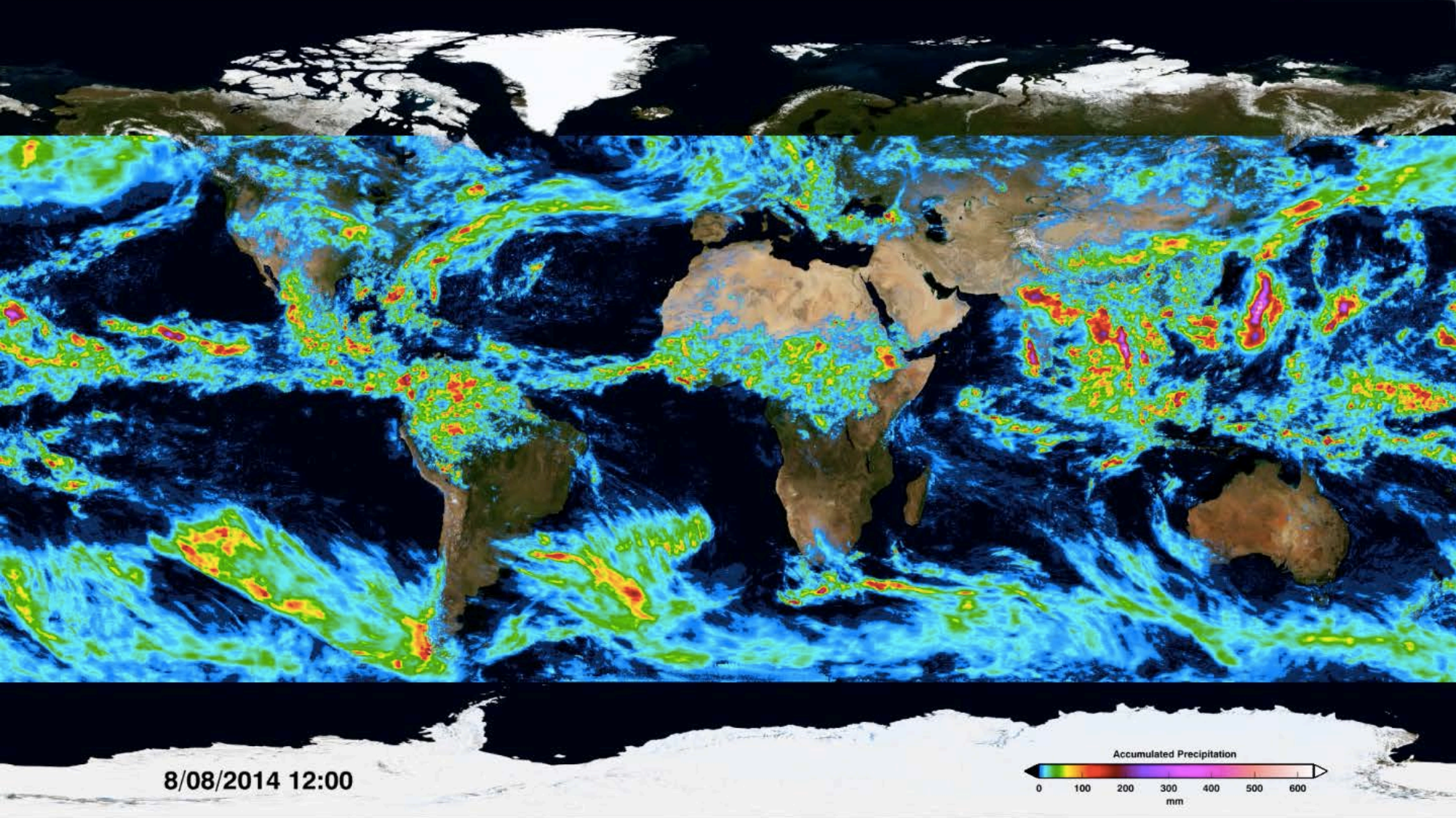

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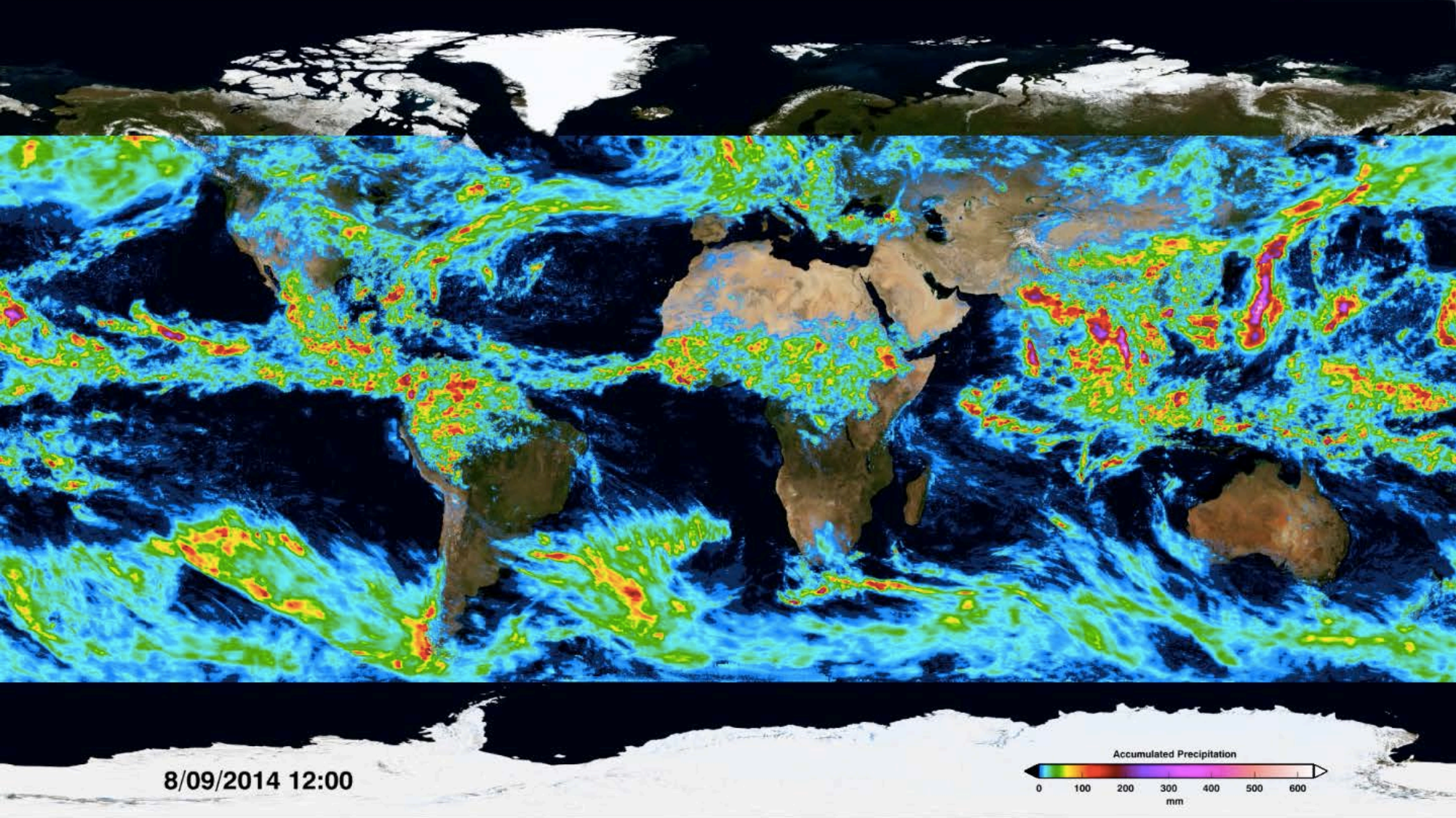
Δt 30 min



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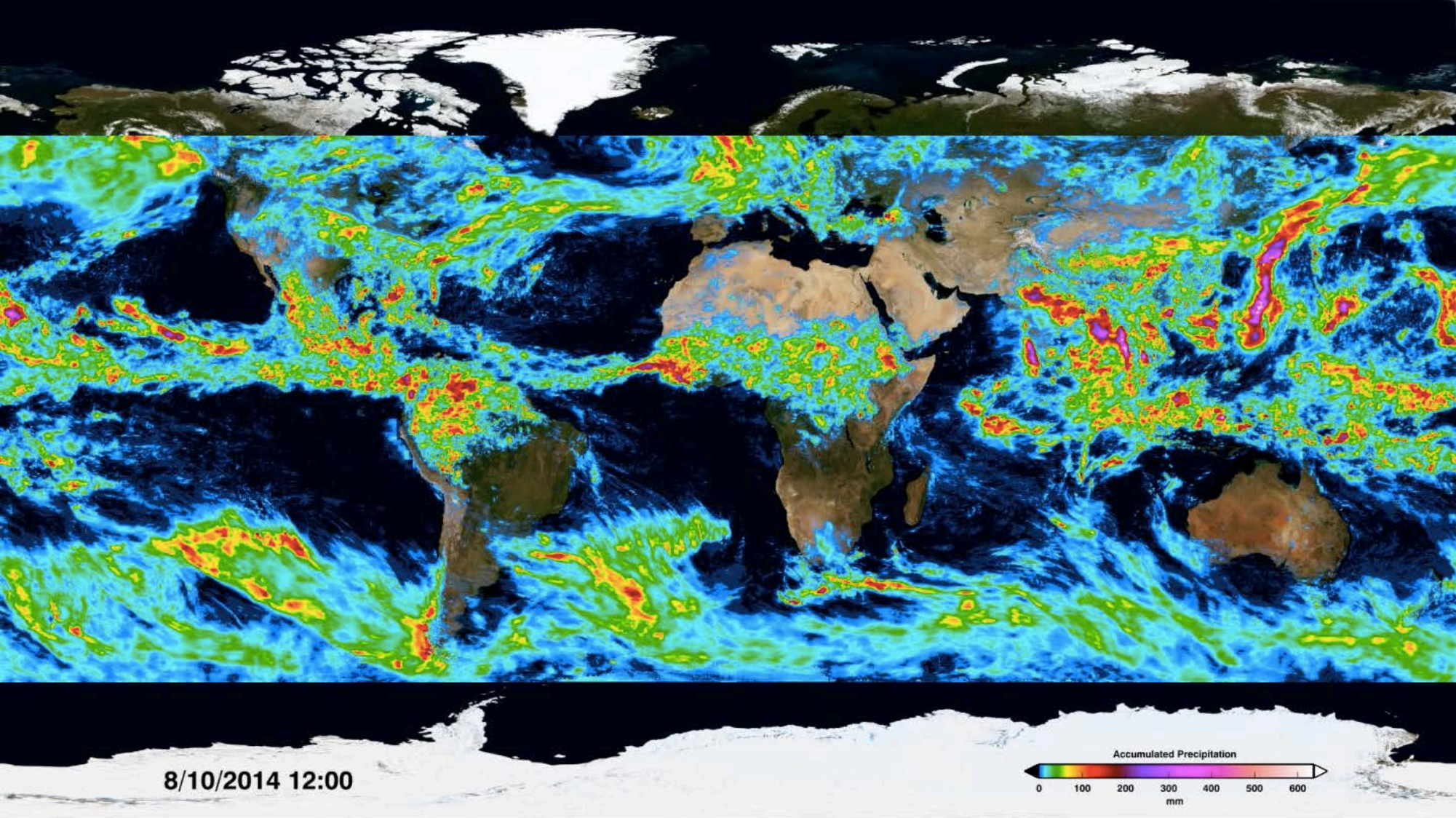
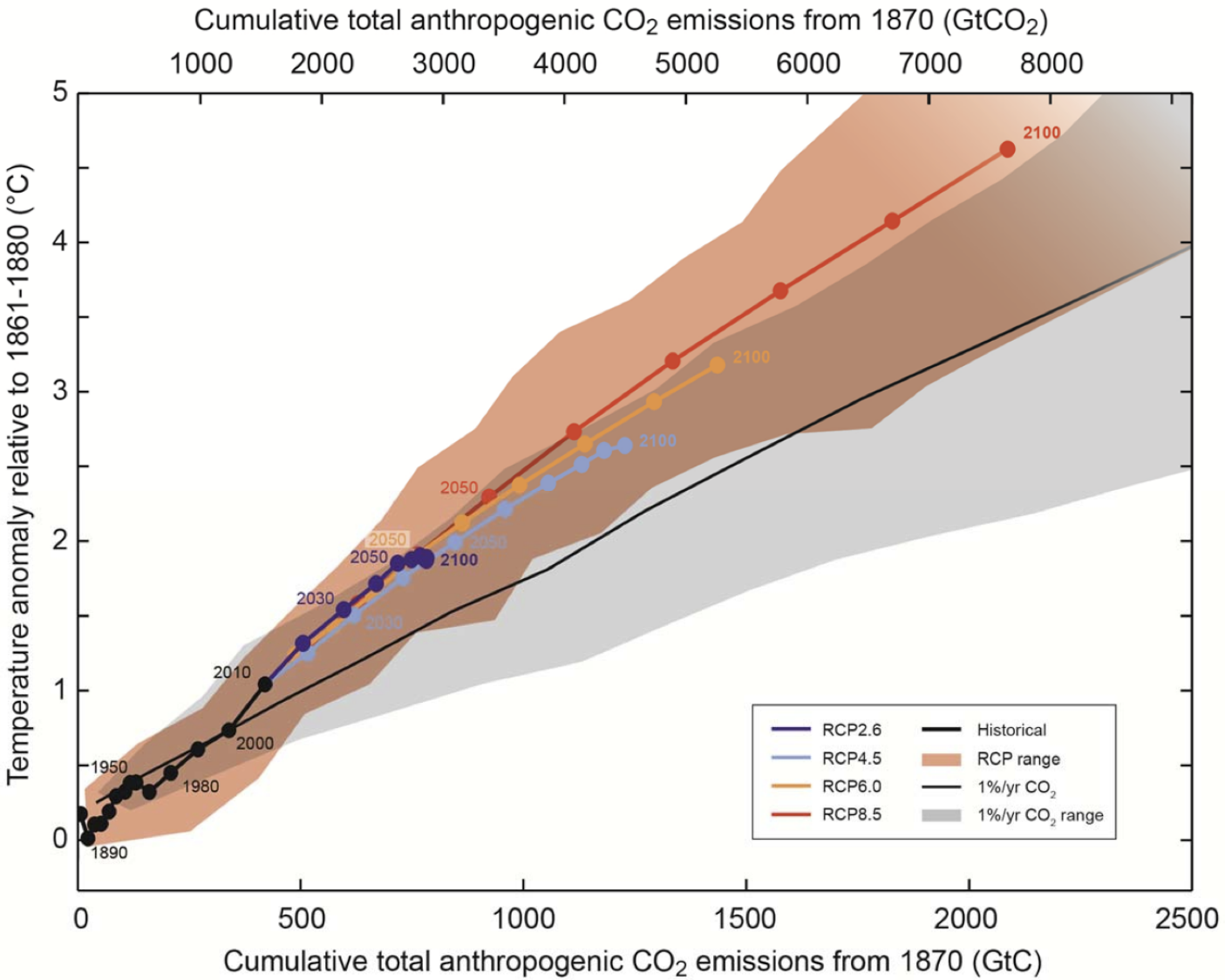
Δt 30 min



Integrated Multi-satellitE Retrievals for GPM (IMERG), NASA GES DISC

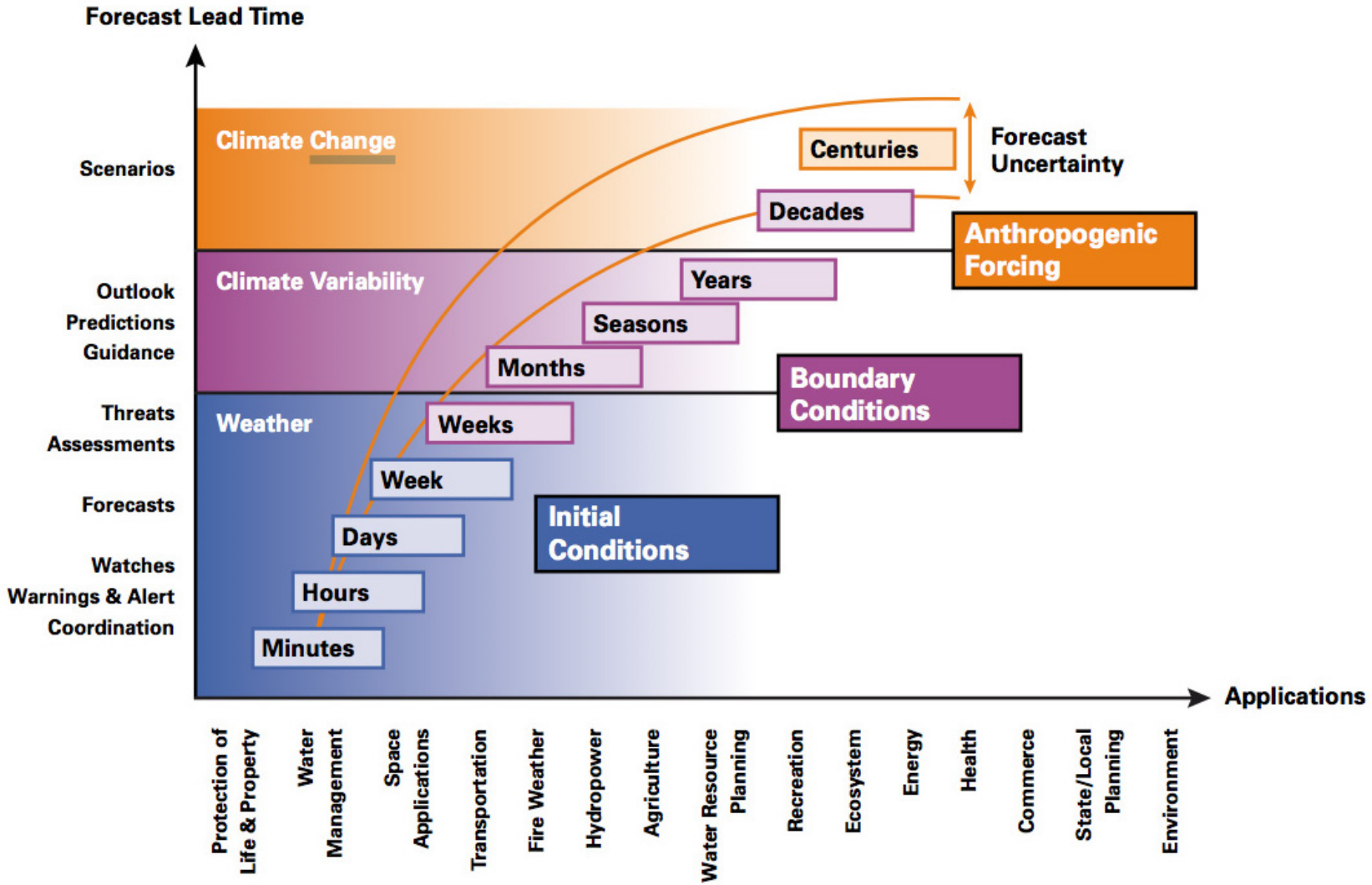
Δt 30 min

Great Expectations



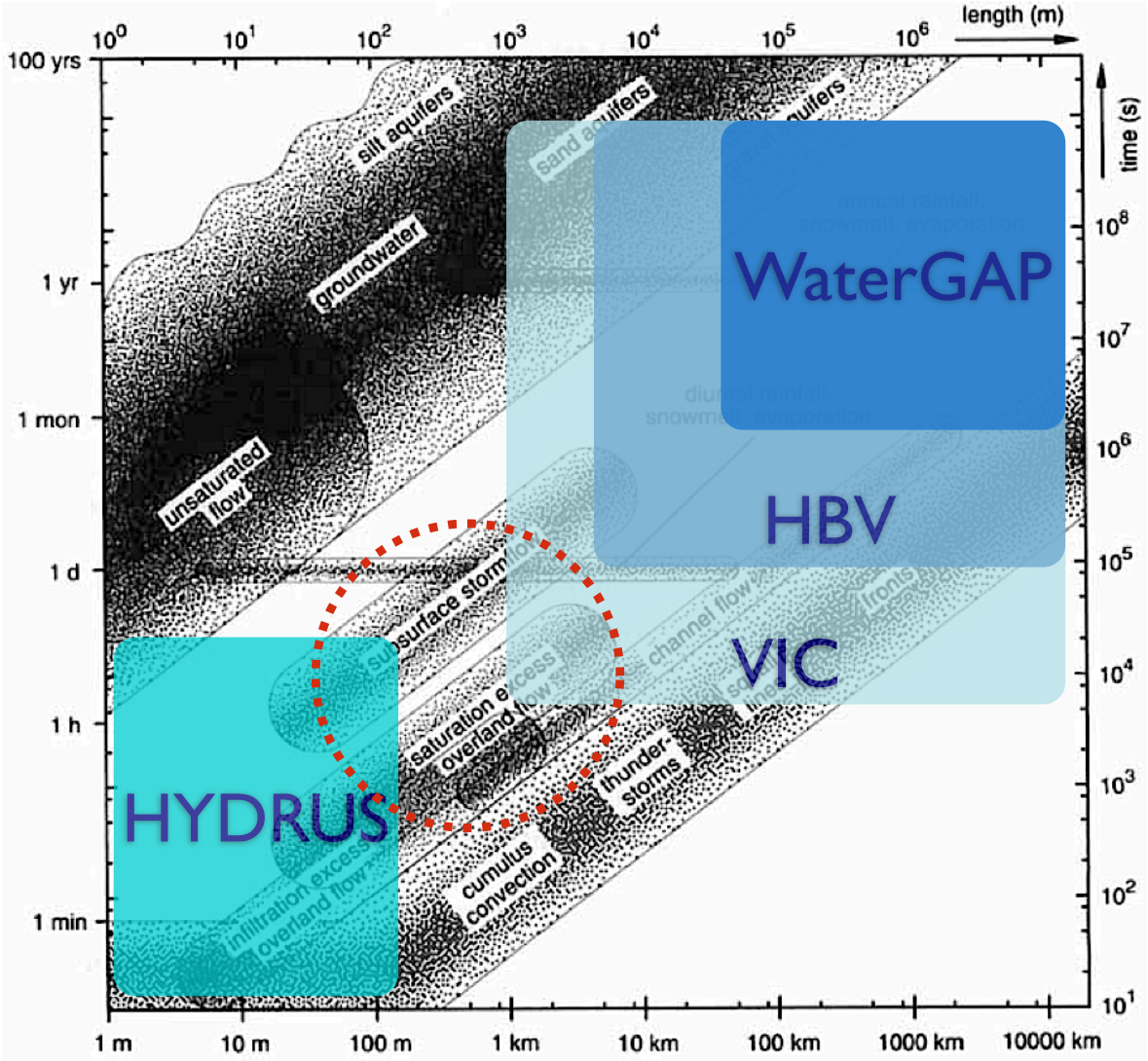
IPCC AR5-SPM10

Seamless prediction of weather and climate



www.wmo.int

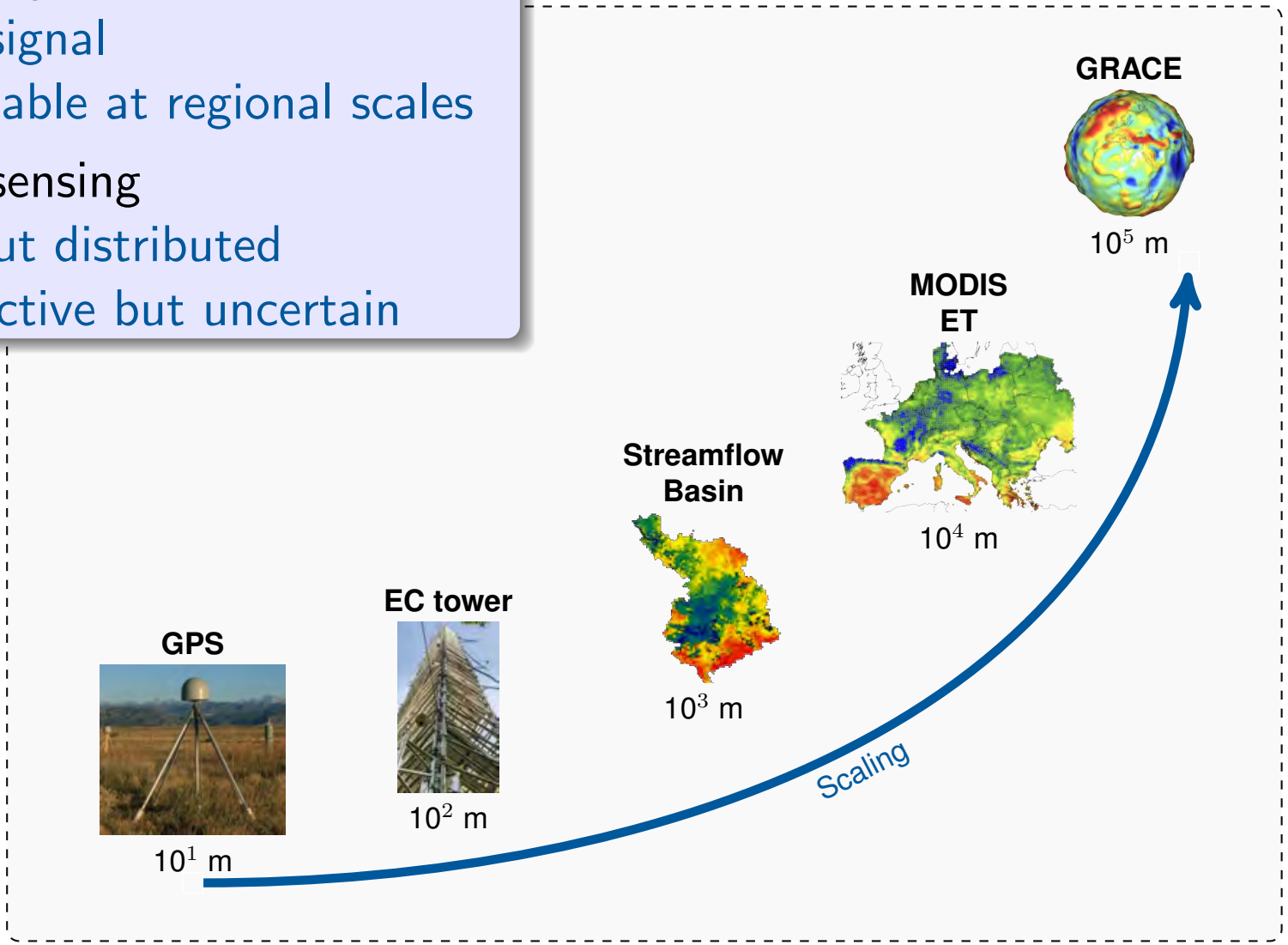
Key issues: 1) not scalable models



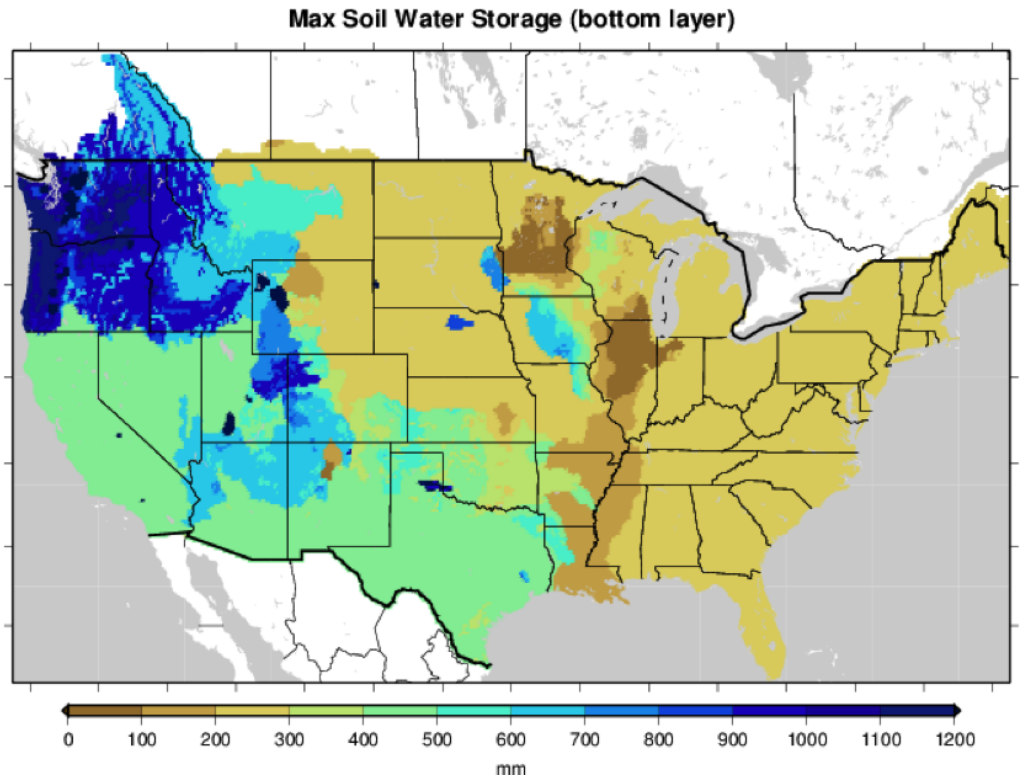
Based on Blöschl & Sivapalan HP 1995

Key issues: 2) Scale discrepancy of observations

- In-situ observations
  Small footprint
  Integral signal
  Not available at regional scales
- Remote sensing
  Coarse but distributed
  Cost-effective but uncertain



Key issues: 3) Biased parameter estimation



VIC-NLDAS simulation, Water Security Assessments NCAR
Mizukami & Clark et al.

AGU Fall Meeting, 2014

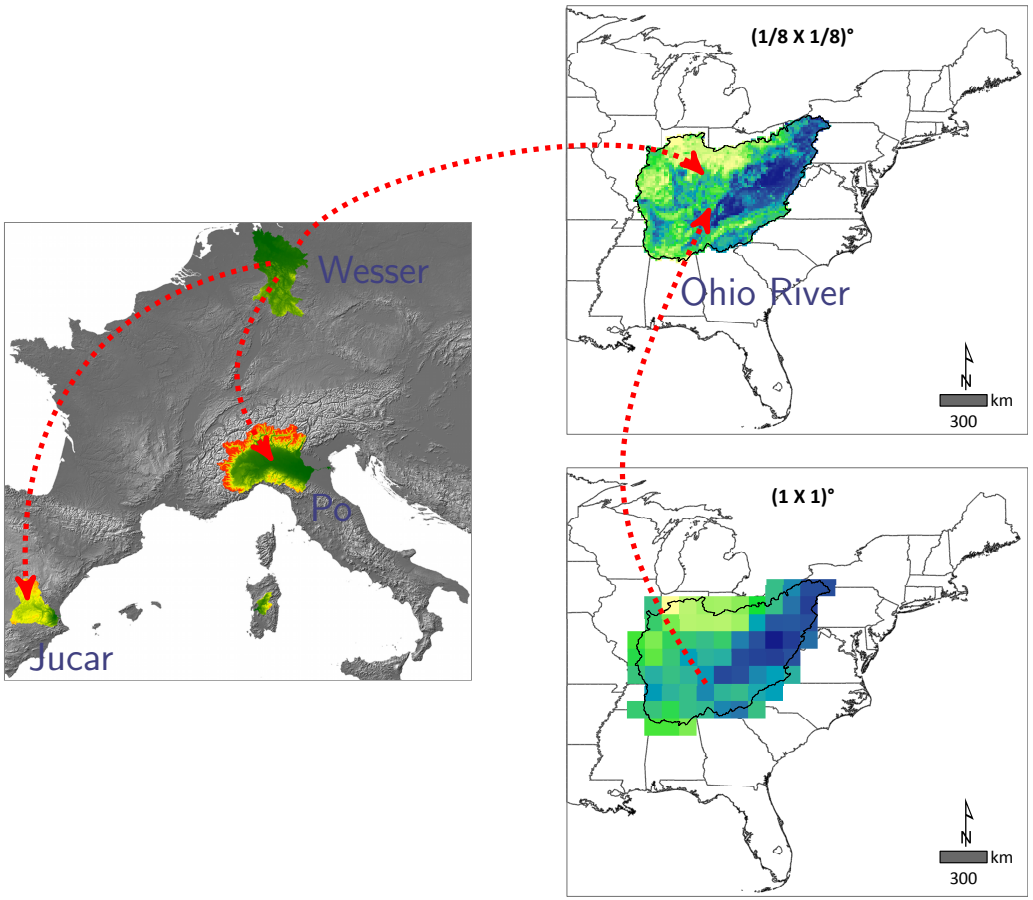
Scale/Basin-wise parameter estimation induces artifacts and bias

$\Rightarrow$ Less transferability

Our answer to these issues...

mHM + MPR

The main goal: Transferability



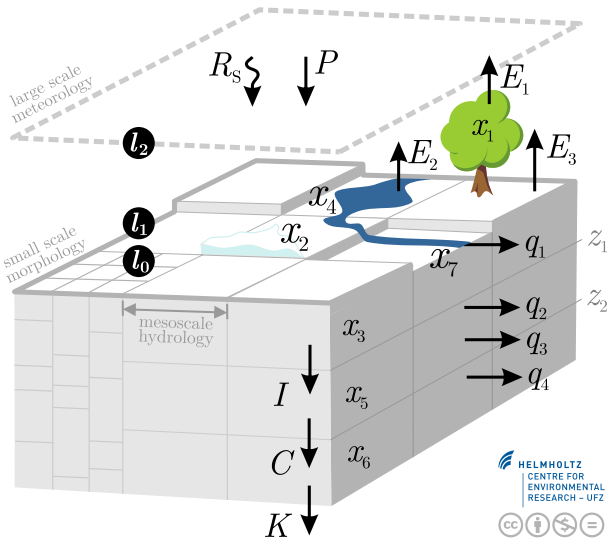
- Parameter identifiability and transferability
  Samaniego, HEPEX 2015
  Rakovec, et al. JHM 2015
- Computation efficiency
  Kumar et al. WRR 2013b

Parameterization of a hydrologic model

State equations

$$\frac{d}{dt}\mathbf{x}_{it} = \mathbf{g}(\mathbf{x}_{it}, \mathbf{u}_{it}, \beta_{it}) + \eta_{it}$$

$$\mathbf{y}_{it} = \mathbf{f}(\mathbf{x}_{it}, \mathbf{u}_{it}, \beta_{it}) + \epsilon_{it}$$



Cell i, time t

$\mathbf{x}$	model states, fluxes
$\mathbf{y}$	observations
$\hat{\mathbf{y}}$	model outputs
$\mathbf{u}$	scaled input data
$\mathbf{g}(\bullet)$	dominant processes
$\mathbf{f}(\bullet)$	transformation functions
η	structural error
ϵ	observation error
β	effective parameters ?

Parameterization of a hydrologic model

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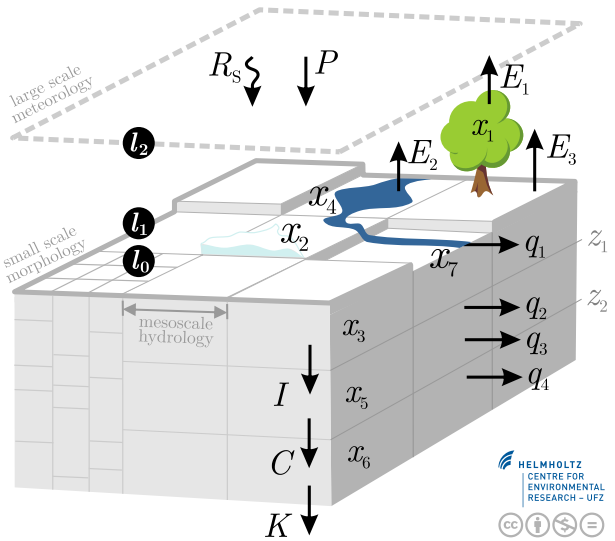
$$\min_{\hat{\beta}} = \|\mathbf{y} - \hat{\mathbf{y}}\|$$



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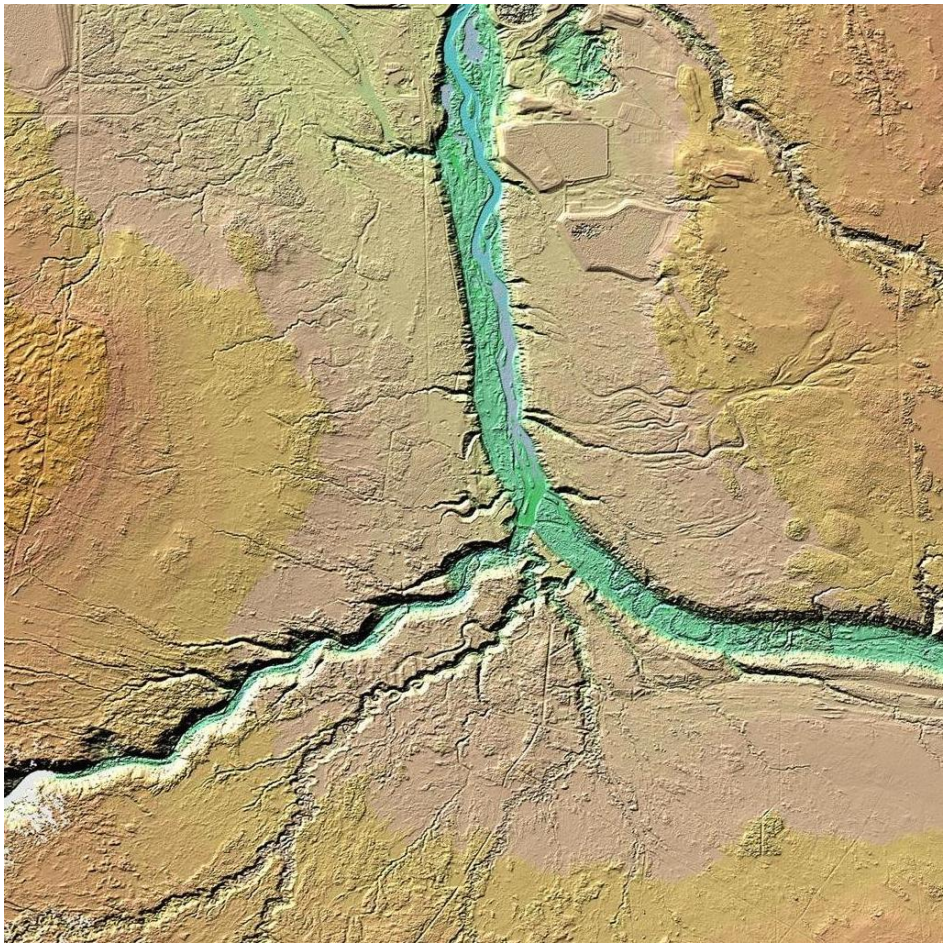
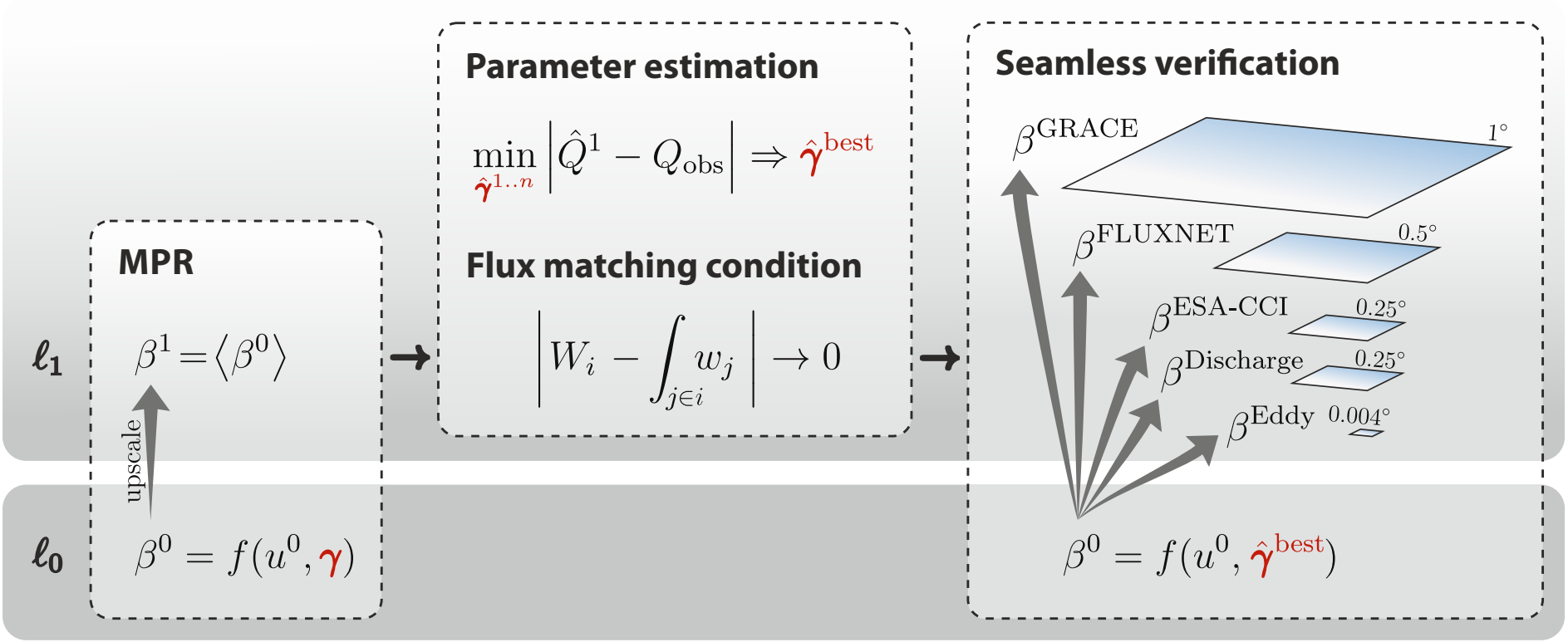


www.dlr.de/hr/

$\Delta X = 12$ m

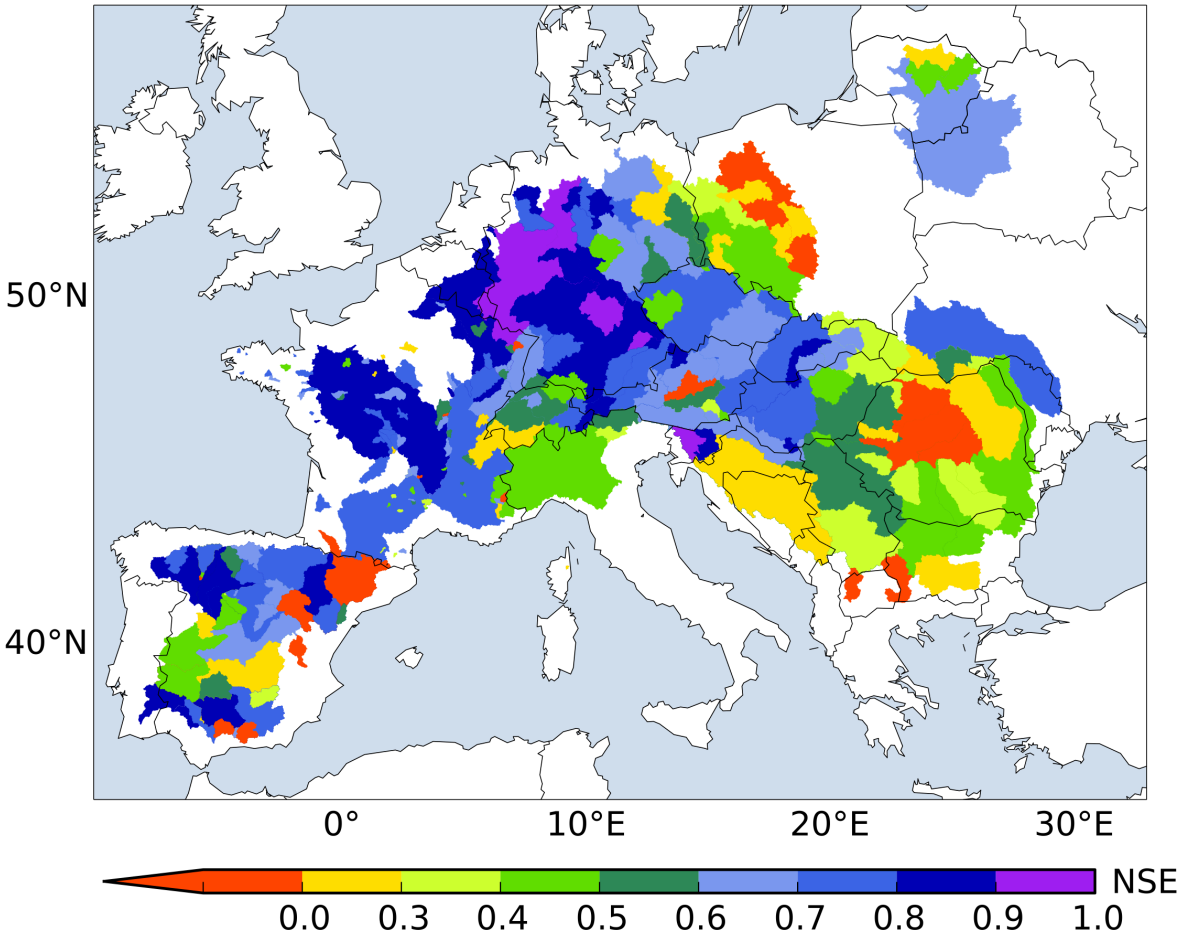
How to take into account the subgrid variability of $\mathbf{u}^0$ and β^0?

Multiscale Parameter Regionalization[1]



[1] Samaniego et al. WRR 2010 ... Rakovec et al. JHM 2015

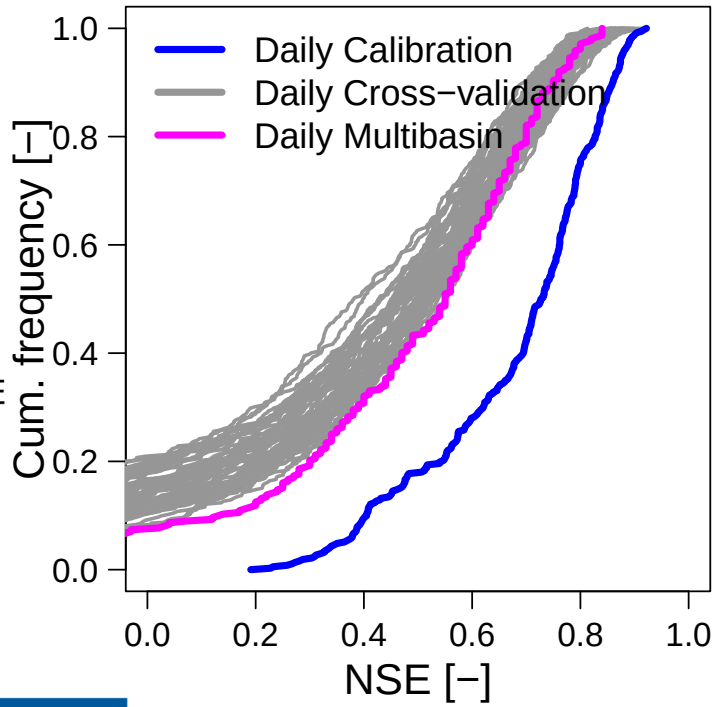
Multi-basin PE (streamflow)



Cross-validation

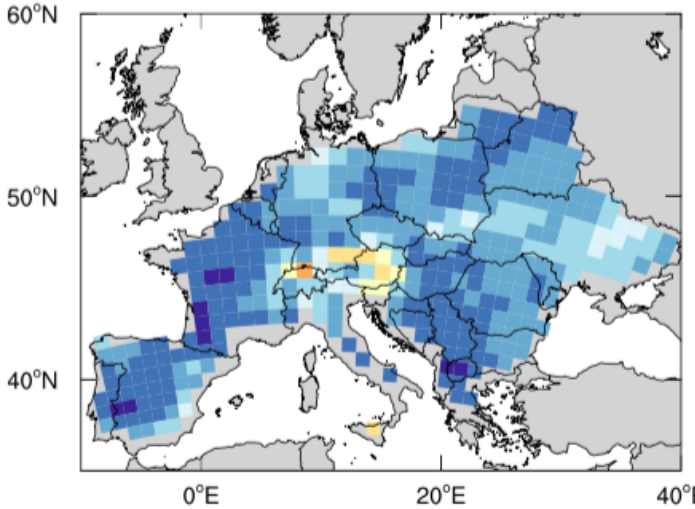
$n = 319$

Daily discharge

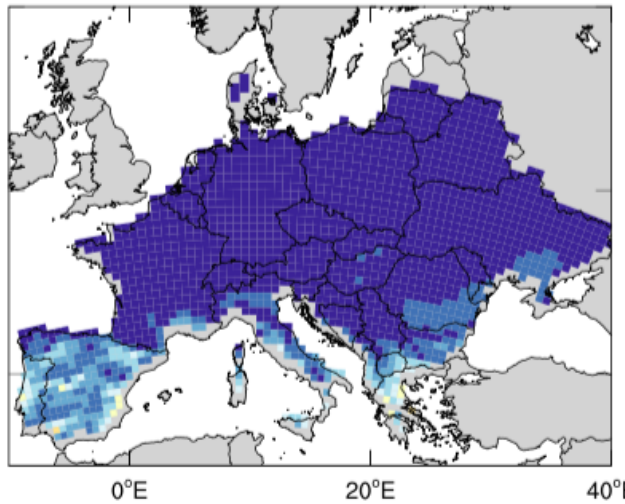


Multiscale data verification[2]

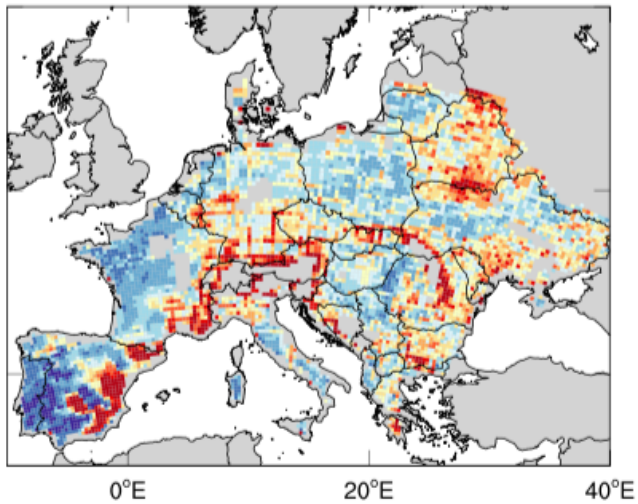
GRACE TWS anomaly

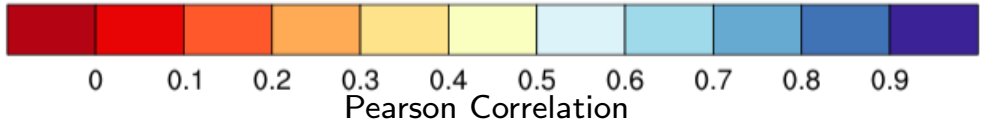


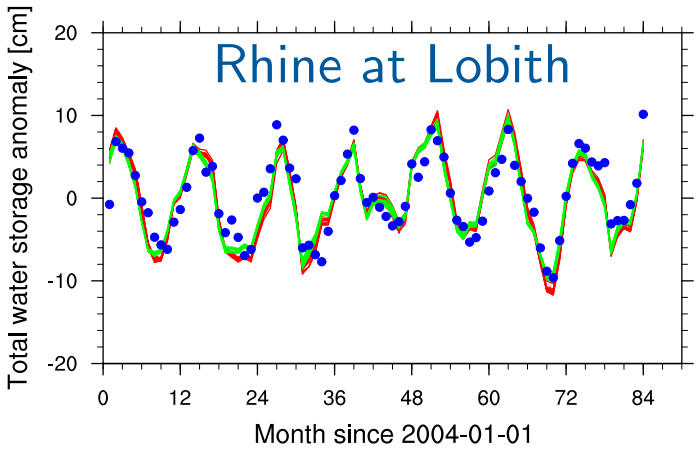
FLUXNET ET



Soil moisture ESA-CCI



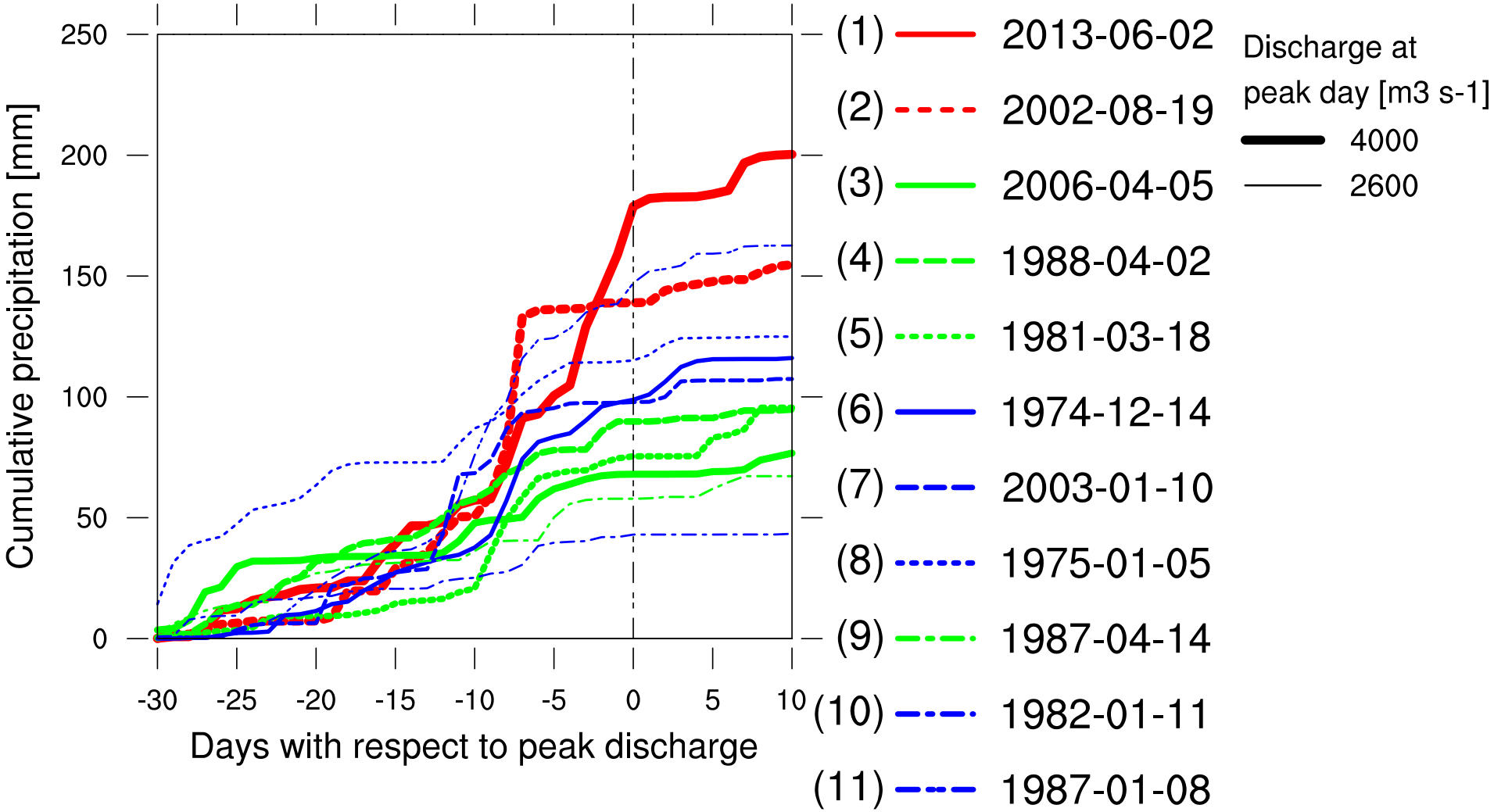




[2] Rakovec et al. JHM 2015

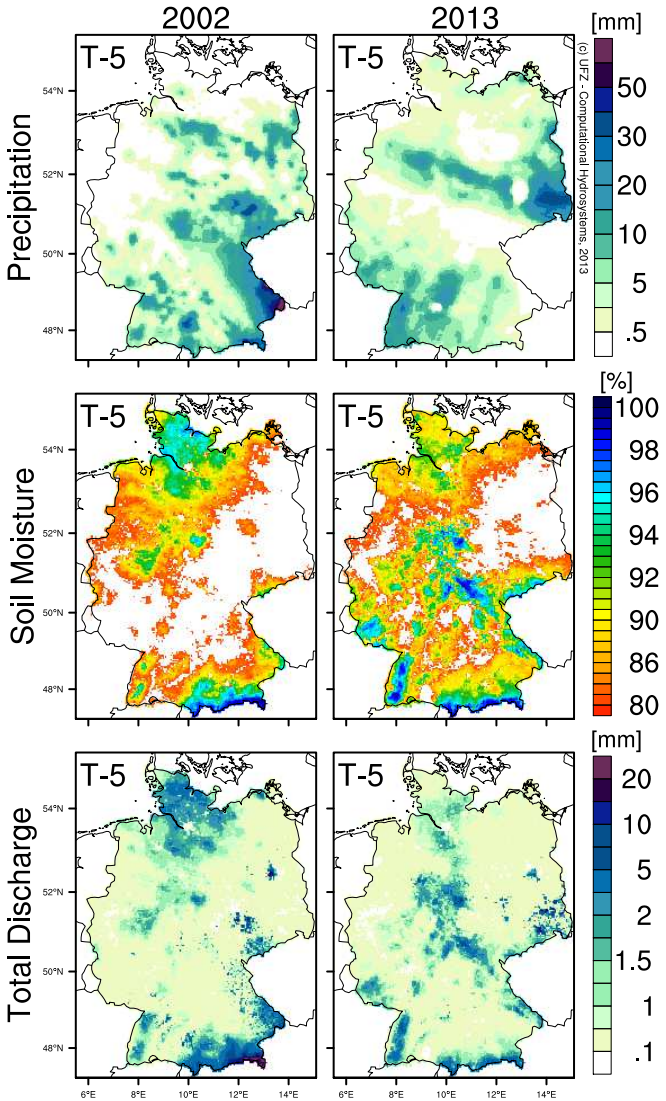
Flood Prediction

Top eleven Elbe flood events since 1950

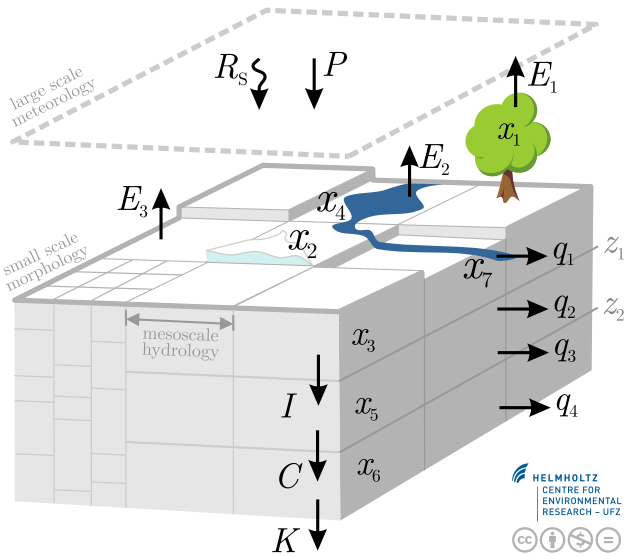


- Summer events - Spring events - Winter events

The 2002 and the 2013 floods in Germany



mHM simulations



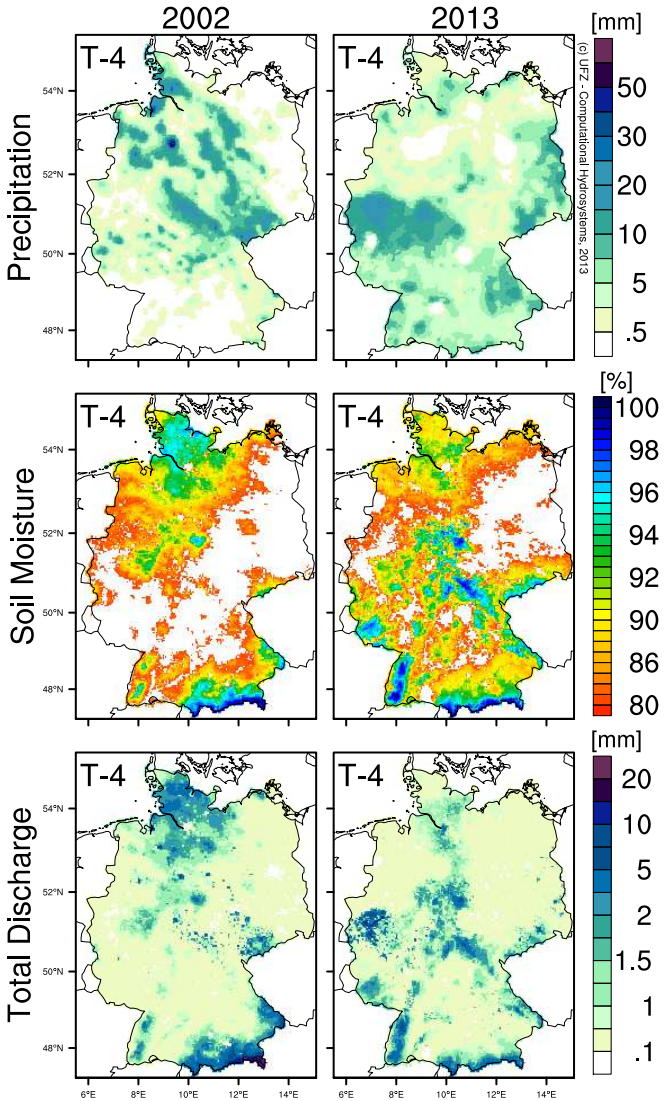
$\Delta t = 1$ h

$\Delta x = 4$ km

5 years spin-up

Forced with DWD data

The 2002 and the 2013 floods in Germany

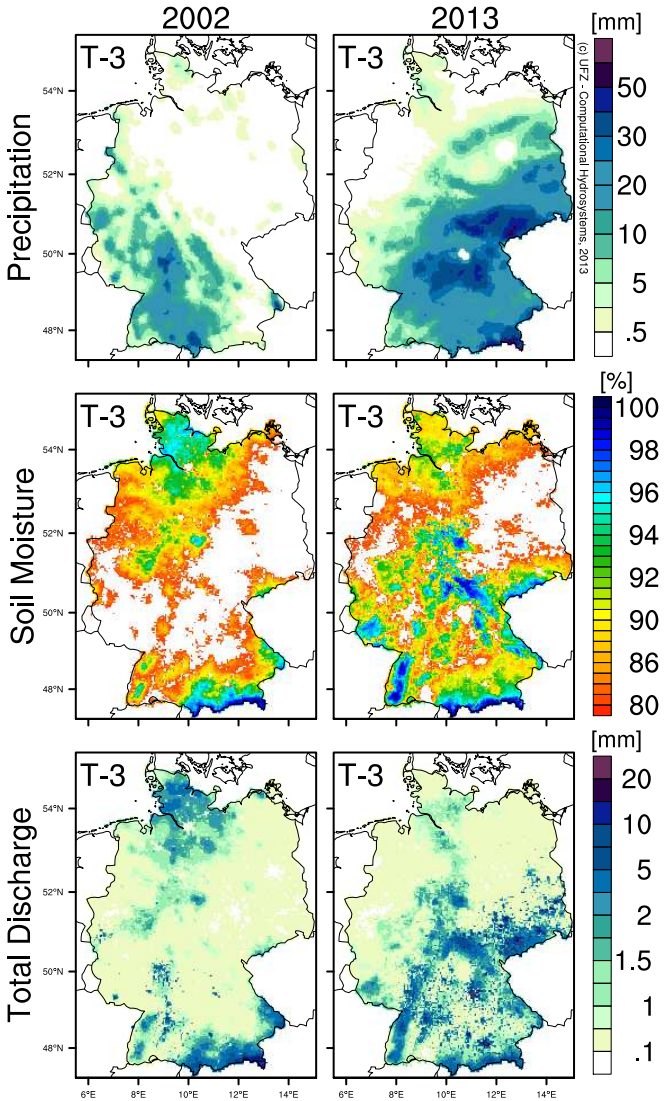


- Wreaked havoc in the Danube and Elbe river basins
- Estimated losses ≈ 12 billion Euros

  Filch Rating, GDV, Munich Re

Fischerdorf 05.06.2013

The 2002 and the 2013 floods in Germany



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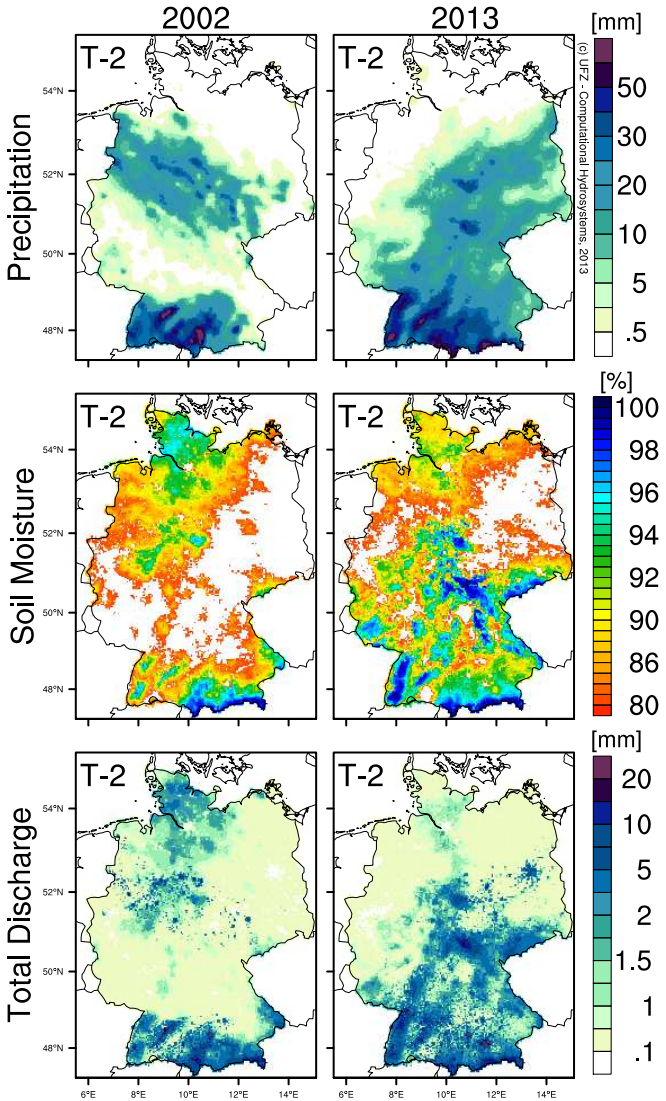

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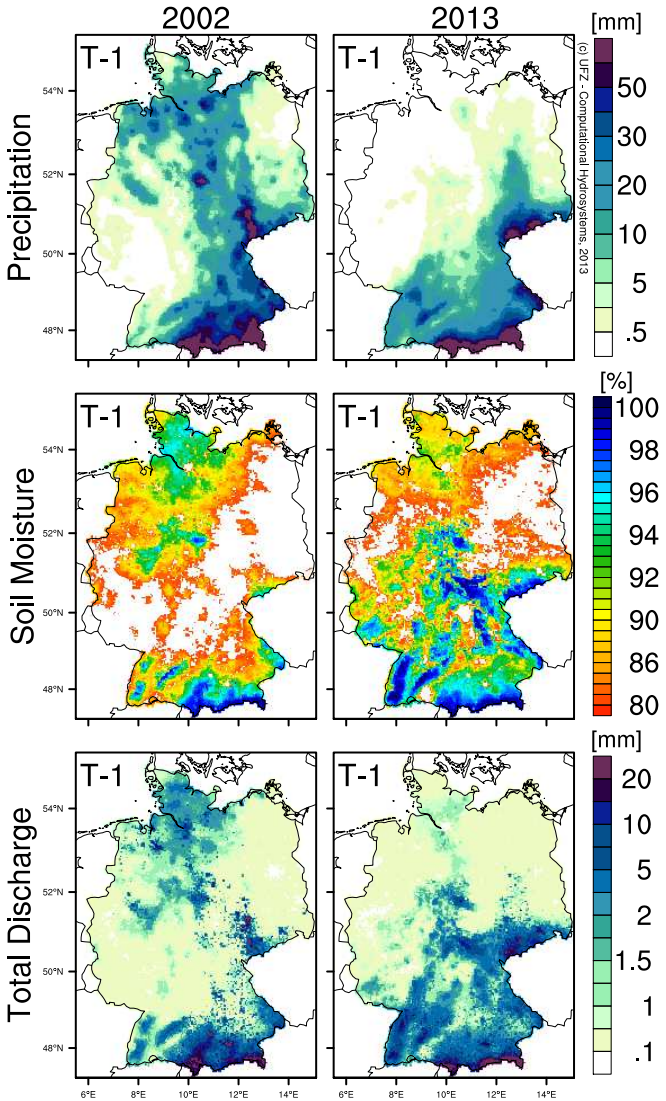

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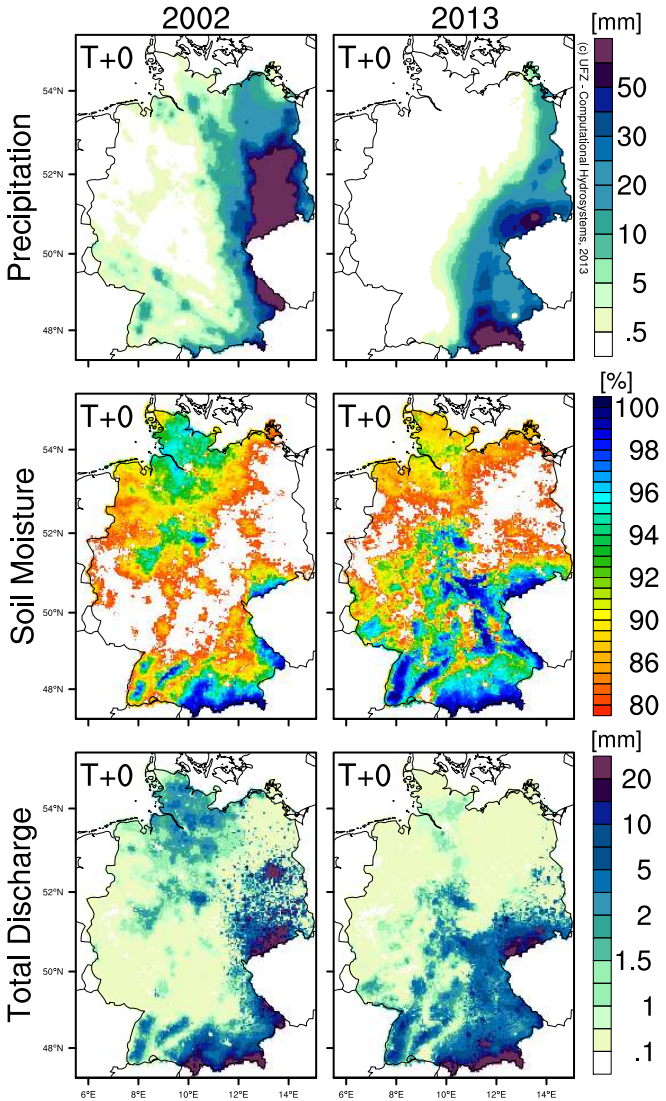

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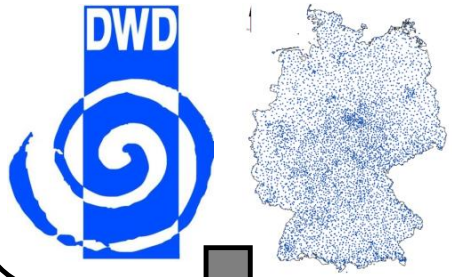
Fischerdorf 05.06.2013

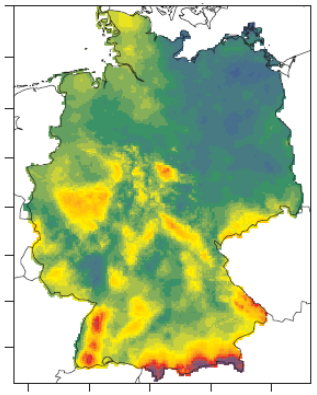
Drought Monitoring
&
Forecasting

High resolution drought monitoring framework

Daily download of weather data

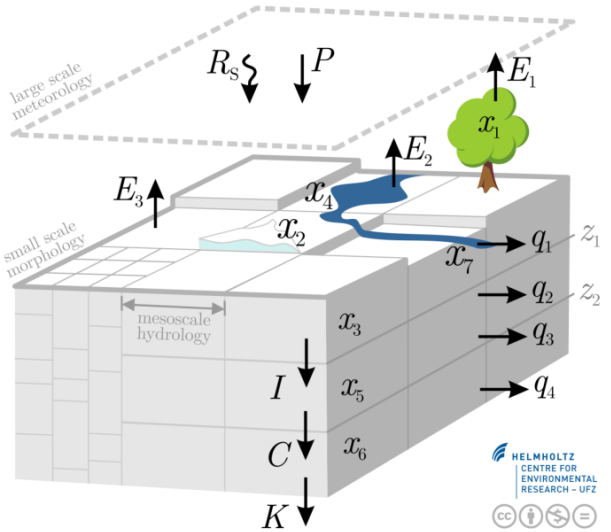


Interpolation



Hydrologic Model

mHM 5.0



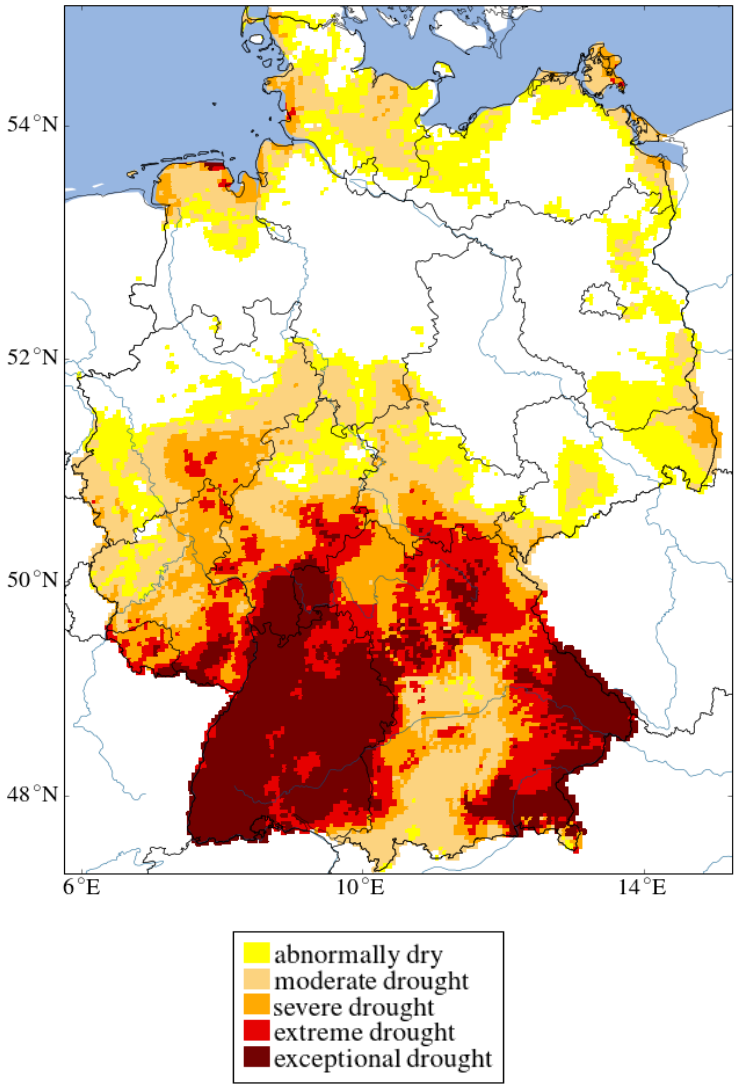
www.ufz.de/mhm

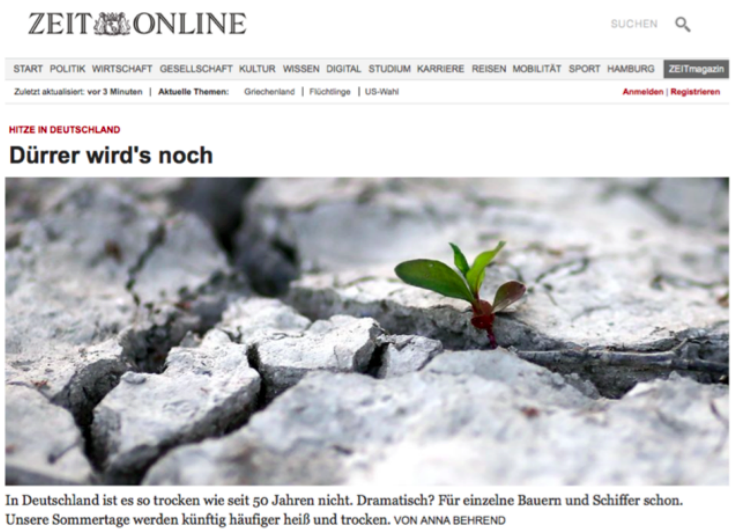
up-to-date SMI

Current SMI for Germany[3]

MITTELDEUTSCHES Klimabüro

Nov. 2015 Top 25 cm




ZEIT ONLINE

START POLITIK WIRTSCHAFT GESELLSCHAFT KULTUR WISSEN DIGITAL STUDIUM KARRIERE REISEN MOBILITÄT SPORT HAMBURG ZEITmagazin

Zuletzt aktualisiert: vor 3 Minuten | Aktuelle Themen: Griechenland | Flüchtlinge | US-Wahl

Anmelden | Registrieren

HITZE IN DEUTSCHLAND

Dürrer wird's noch

In Deutschland ist es so trocken wie seit 50 Jahren nicht. Dramatisch? Für einzelne Bauern und Schiffer schon. Unsere Sommertage werden künftig häufiger heiß und trocken. VON ANNA BEHREND

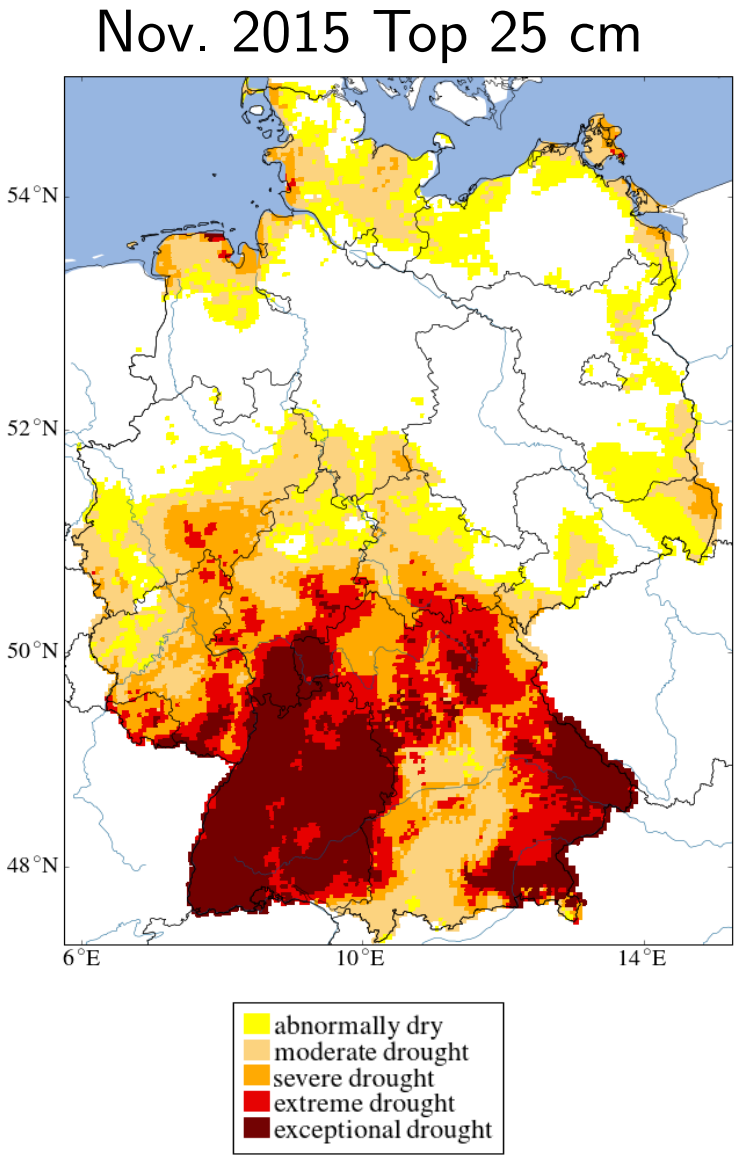
Die Zeit Online 2012-08-12

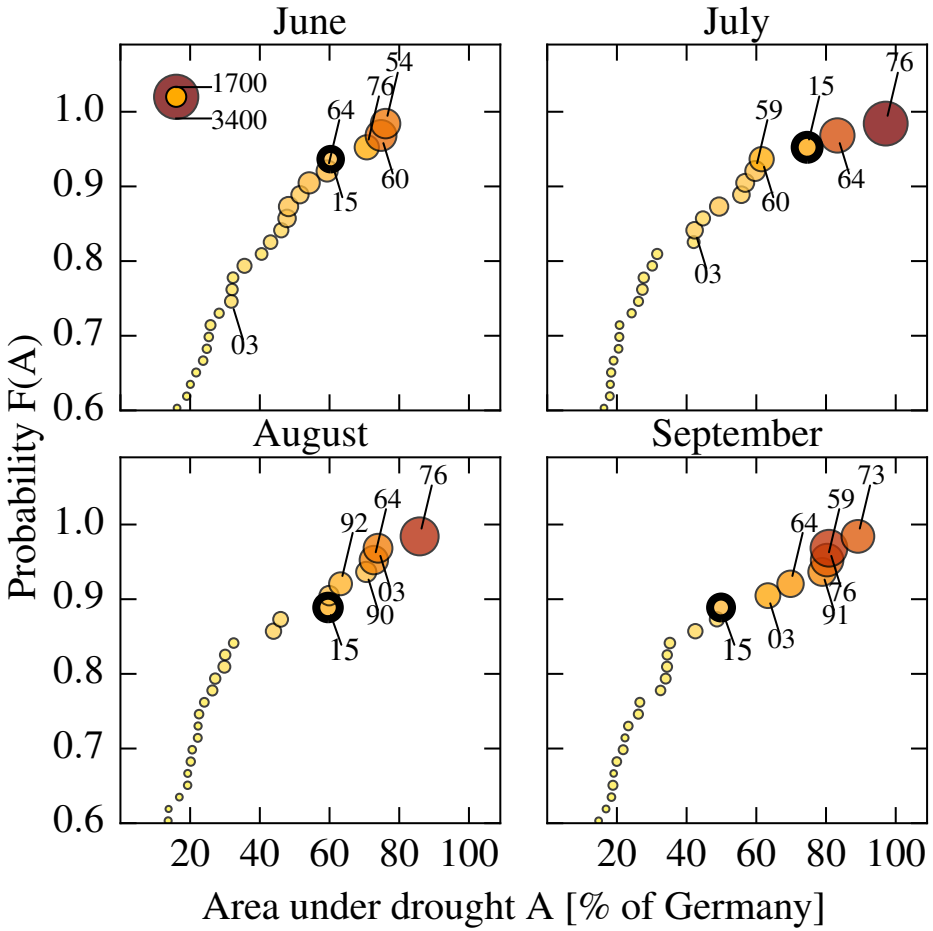
Bavaria 2015-08

[3] www.ufz.de/droughtmonitor, Zink et al.,

Current SMI for Germany[3]

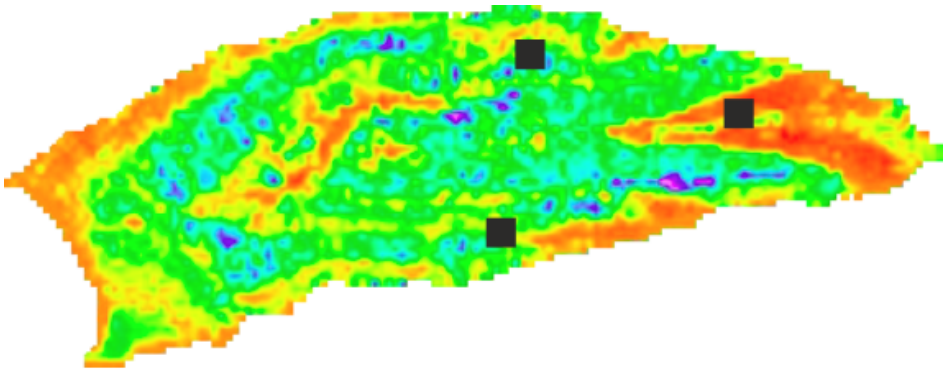
MITTELDEUTSCHES Klimabüro

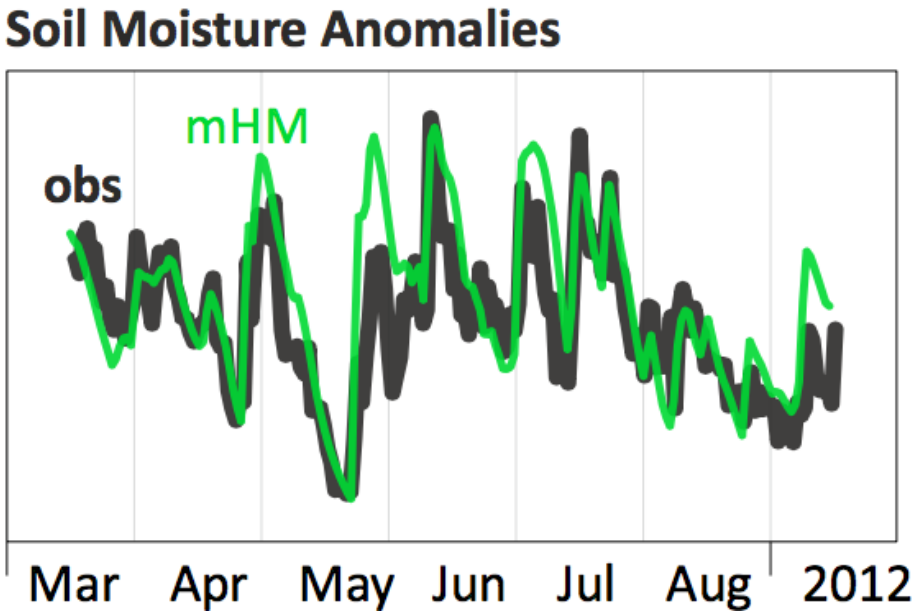




[3] www.ufz.de/droughtmonitor, Zink et al.,

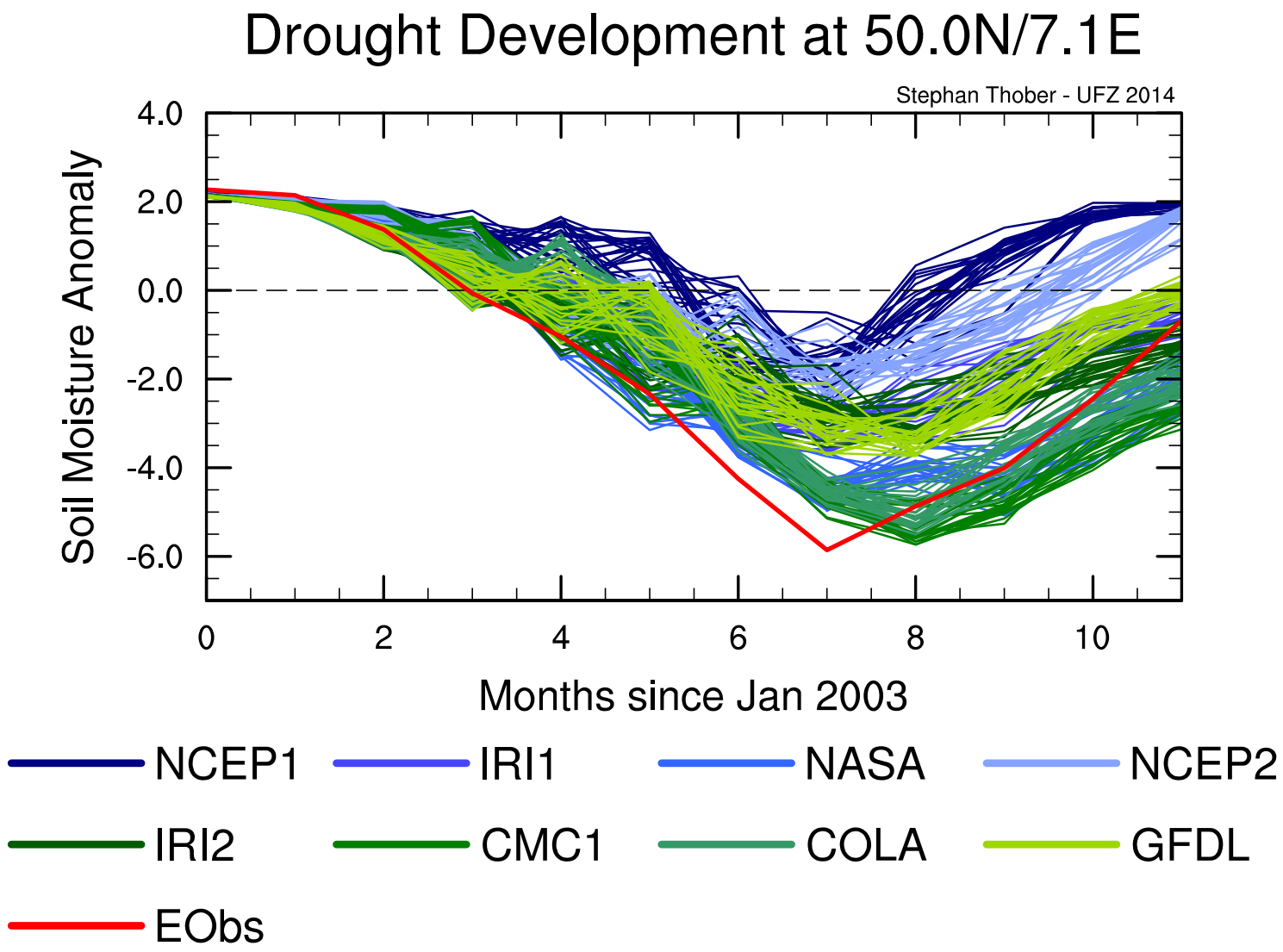
CNRS Soil moisture verification[4]





[4] Schön, et al., TERENO site

2003 Drought hindcast experiment (MME)[5]



[5] Thober et al. 2015 JHM

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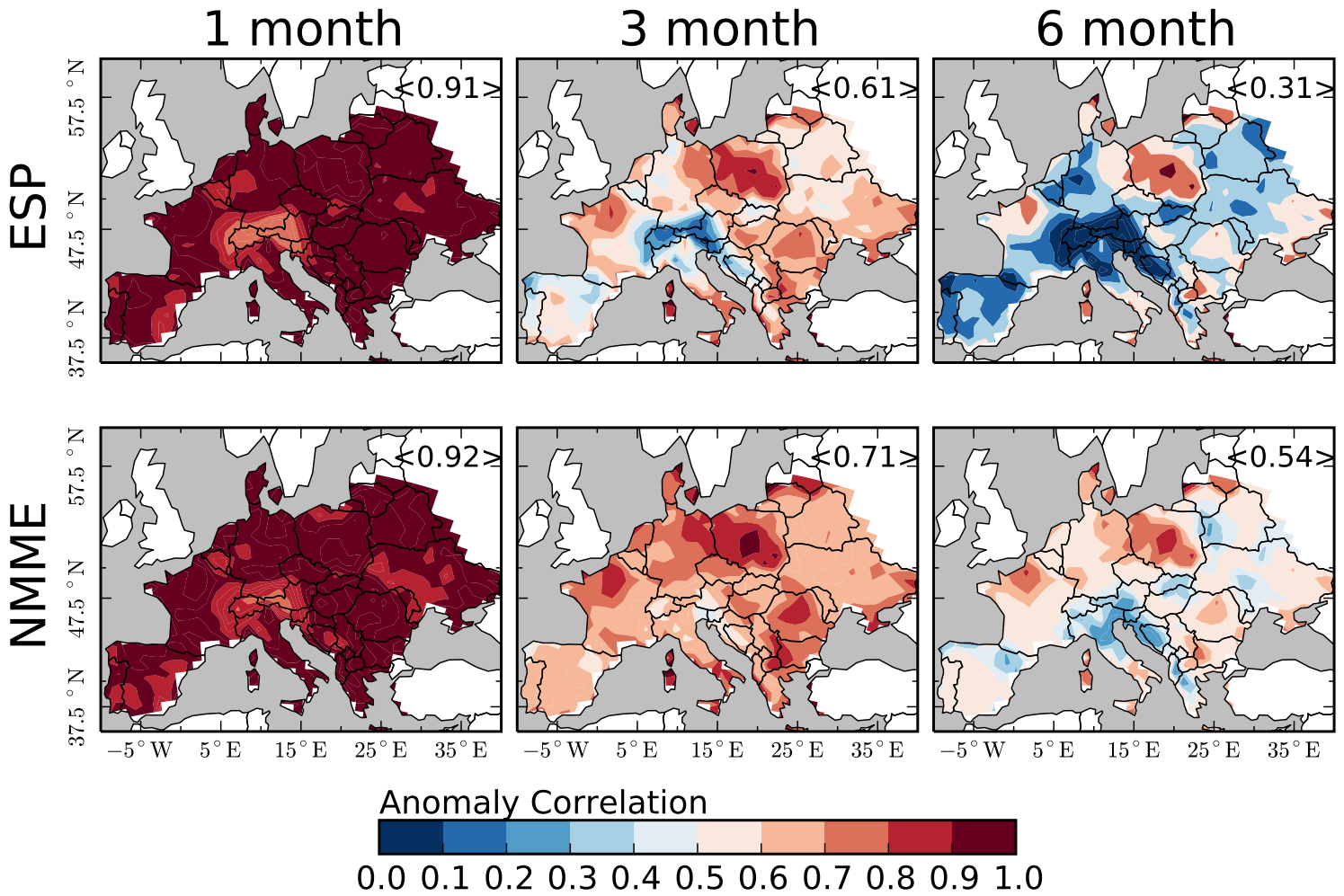

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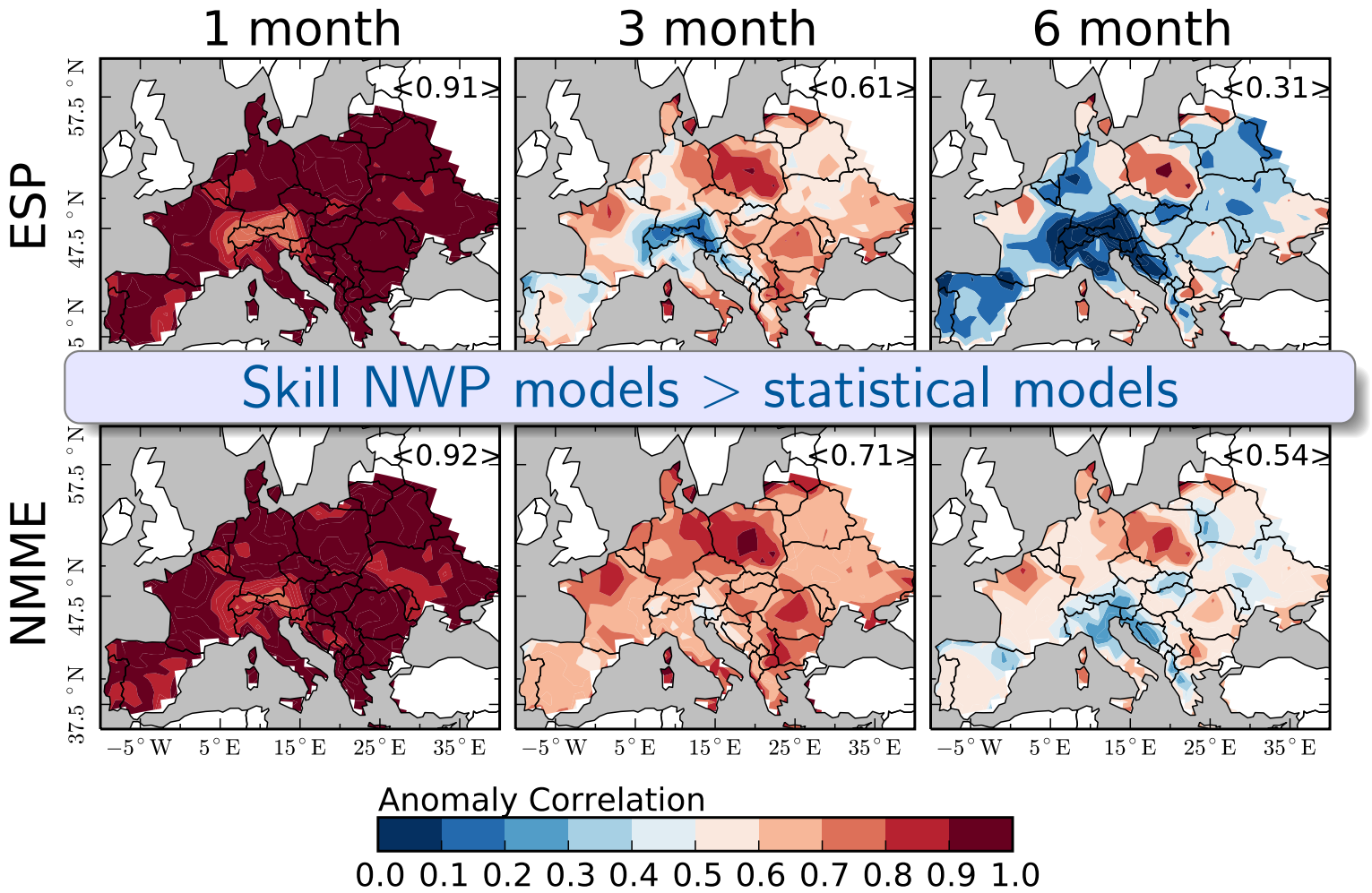
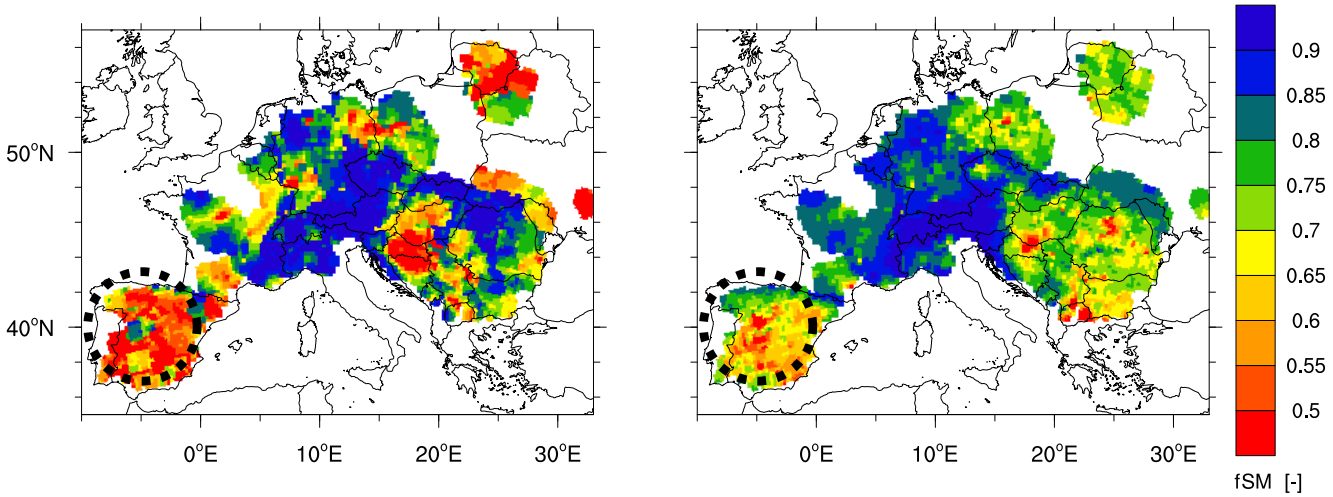


[5] Thober et al. 2015 JHM

Conclusions

- mHM with MPR $\rightarrow$ seamless predictions
  $\rightarrow$ Transferability across locations and scales (80% of the Pan-EU basins)
  $\rightarrow$ No artifacts in parameter fields, fluxes and states
- Multiple-scale verification & assimilation (native scales) $\rightarrow$ scale invariant parameterizations
  $\rightarrow$ Key for "locally relevant" prediction of floods and droughts



Acknowledgments

In collaboration with

R. Kumar, A. Marx, O. Rakovec, M. Schön, S. Thober, M. Zink

Sources

ECA&D
EOBS precipitation and temperature

FLUXNET
Latent heat

ESA
Soil moisture

EEA
Corine land cover

EWA
Basins characteristics and location

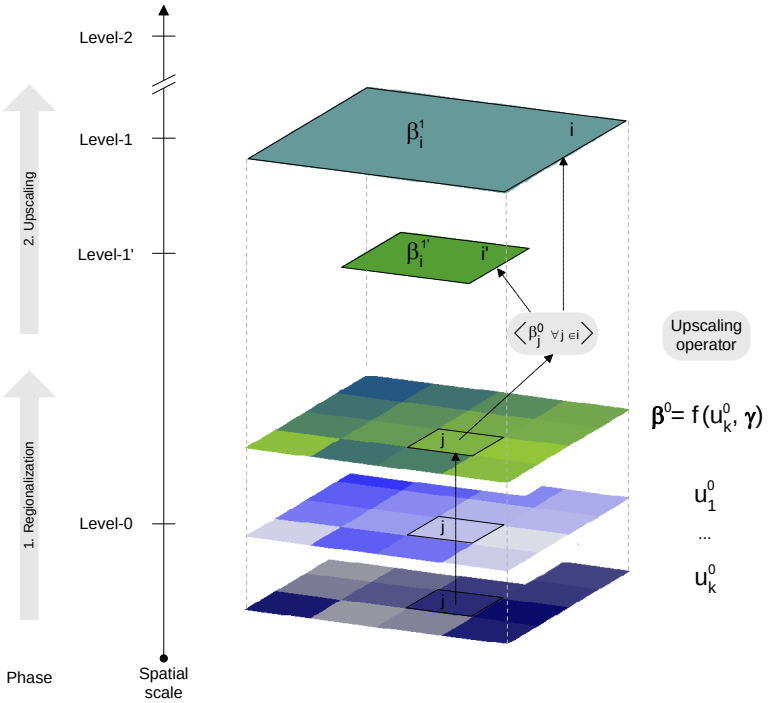
GRDC
Discharge data

NASA
SRTM DEM and LAI

FAO/IIASA/ISRIC/ISSCAS/JRC
Harmonized World Soil Database

Appendix

Multiscale Parameter Regionalisation [6]



$$\beta_j(t) = f\left(\boldsymbol{u}_j(t), \boldsymbol{\gamma}\right)$$

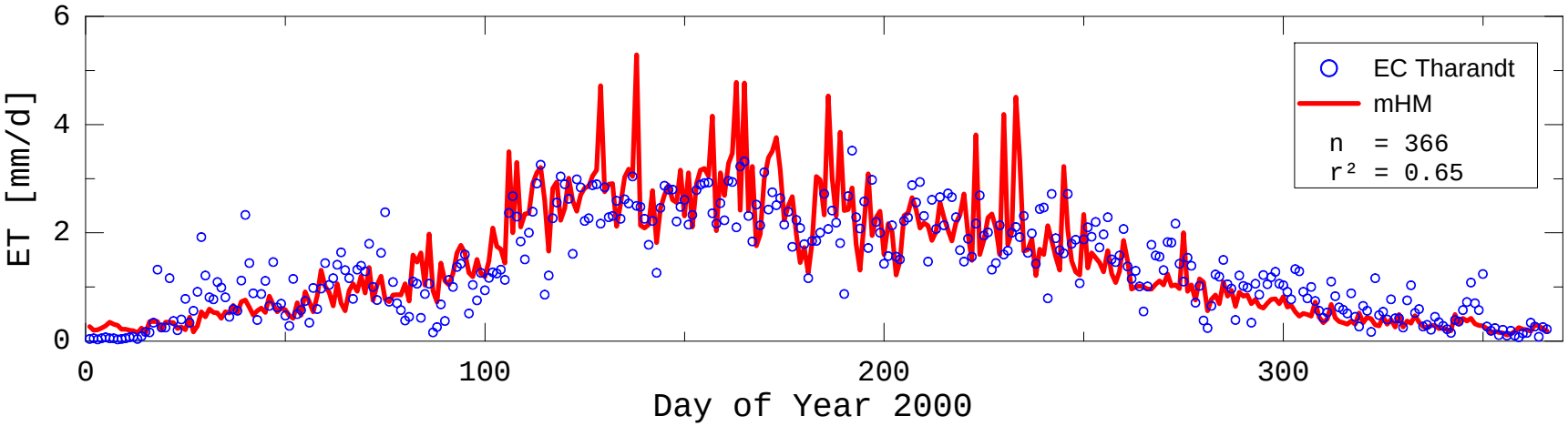
Regionalisation

$$\beta_i(t) = \mathrm{O}\left\langle \beta_{kj}(t) \quad \forall j \in i \right\rangle_i$$

Nonlinear upscaling operator

[6] Samaniego et al. WRR, 2010a, 2010b, Kumar et al. WRR, 2013a, 2013b

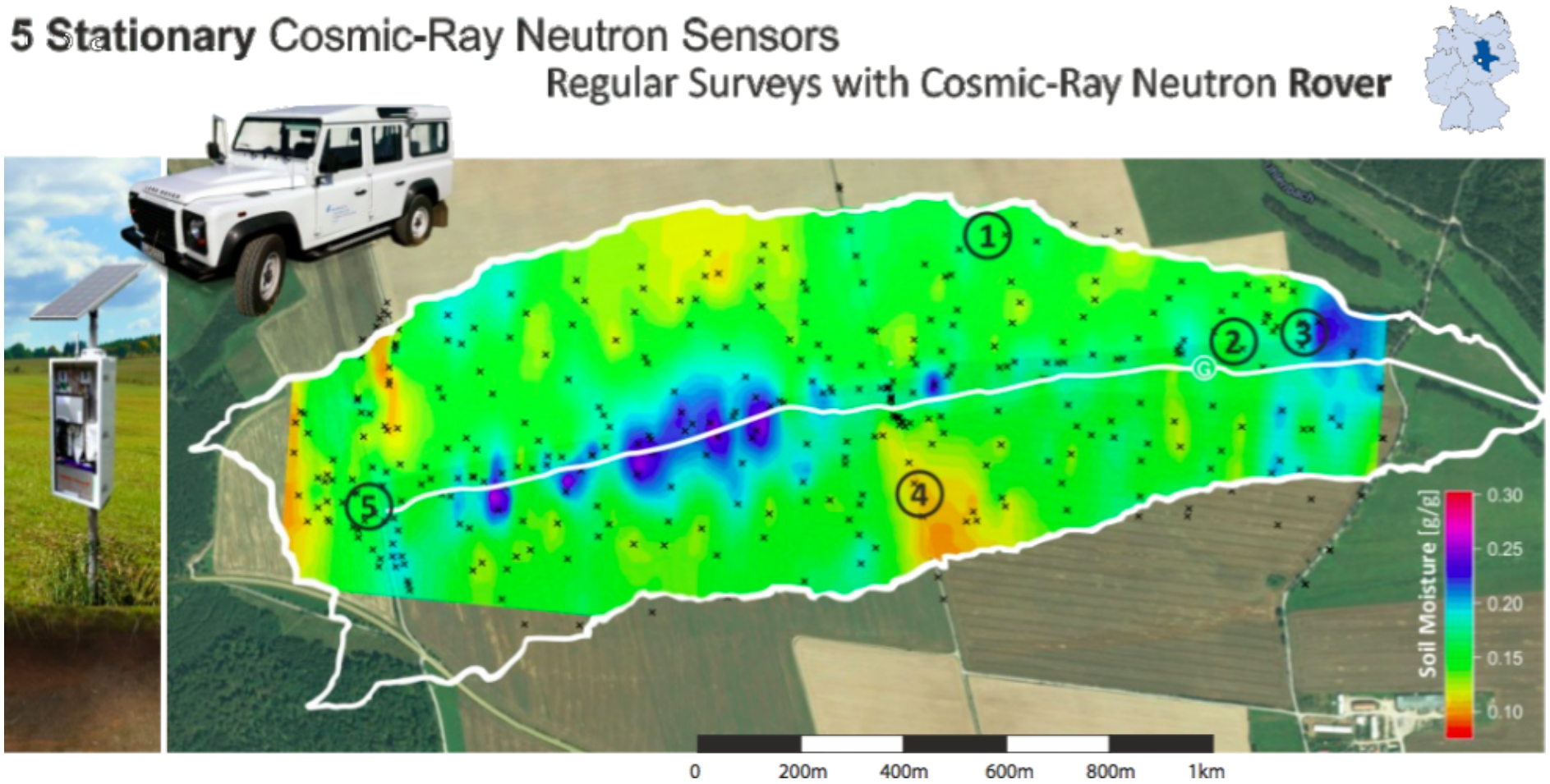
Verification at TERENO observatories



UFZ EC-Tower forest

UFZ EC-Tower grassland

Mobile soil moisture verification[7]



[7] Schön, et al., TERENO site