Copernicus
Emergency Management Service (CEMS)

SMOS Soil Moisture: Potential within CEMS Flood Forecasting at ECMWF

Calum Baugh

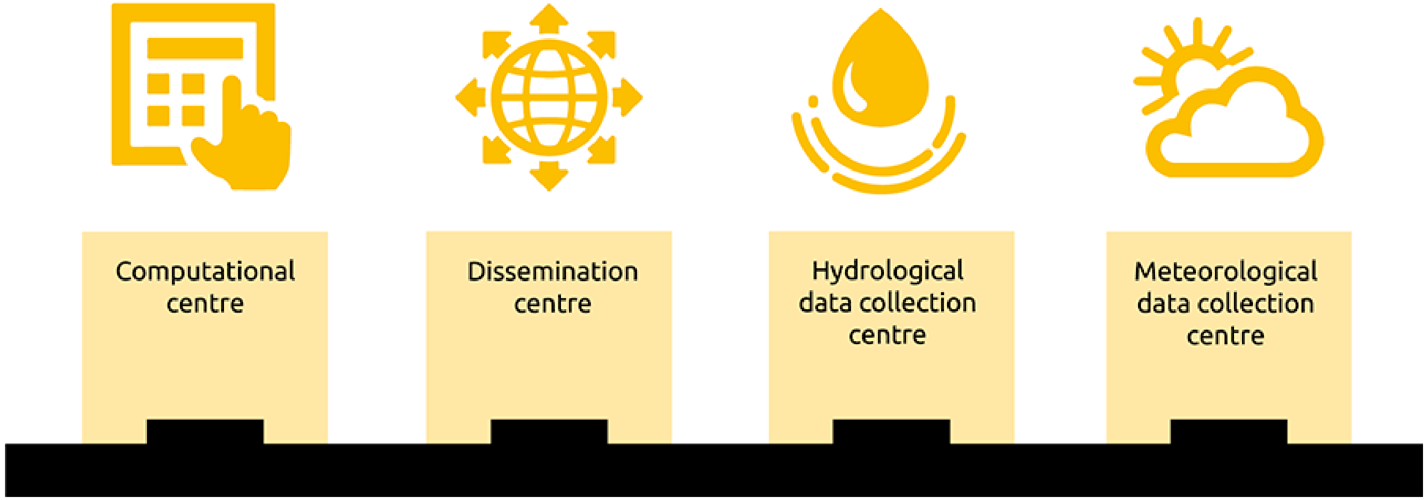
Toni Jurlina, Heather Lawrence, Christel Prudhomme, Patricia de Rosnay, Francesca di Giuseppe, Matthias Drusch

Copernicus Emergency Management Service - CEMS

- Provides information for emergency response to different natural, man-made &/or humanitarian disasters
- Composed of
  - on-demand mapping
  - early warning & monitoring systems for **floods (EFAS & GloFAS)**, droughts and forest fires

CEMS-Floods Consortium

- Operational CEMS-Floods is made of 4 centres executed by different consortia, overseen by JRC

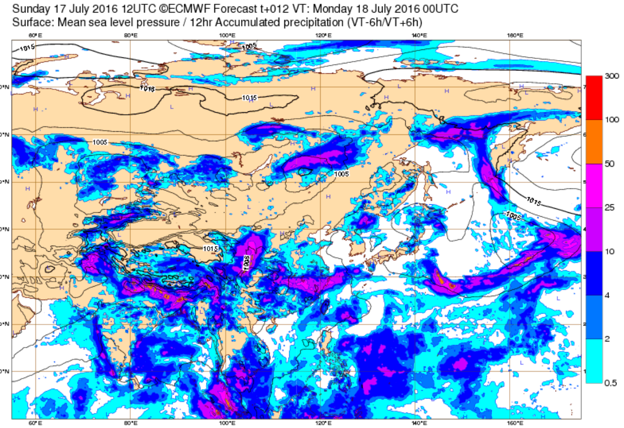


European & Global Flood Forecasts

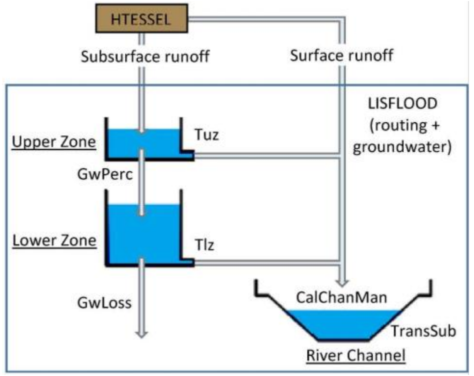
European Commission

General Modelling Framework

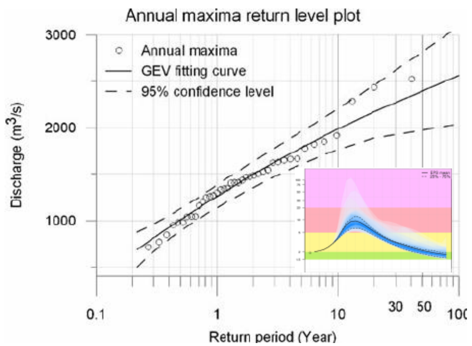
Ensemble NWP



Hydrological + River Modelling



Climate Thresholds



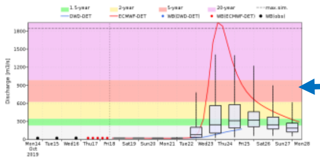
EFAS
European Flood Awareness System

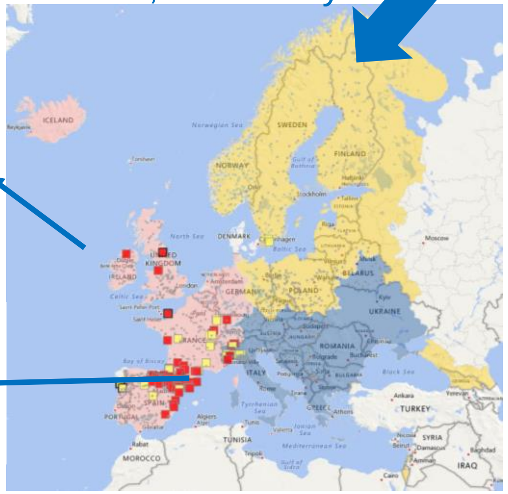
5 km, twice daily

EFAS Flood Notification - Type: Formal*

Country(ies): **Russia**
River(s): **Ponoy (Ponoy basin)**
Predicted start of event: **Saturday 12th of May 2018**
Earliest predicted peak: **Sunday 13th of May 2018**
Probability to exceed a 5-year return period magnitude: **100%**
Probability to exceed a 20-year return period magnitude: **0%**
Forecast date: **2018-05-10 00 UTC**
Comment: -

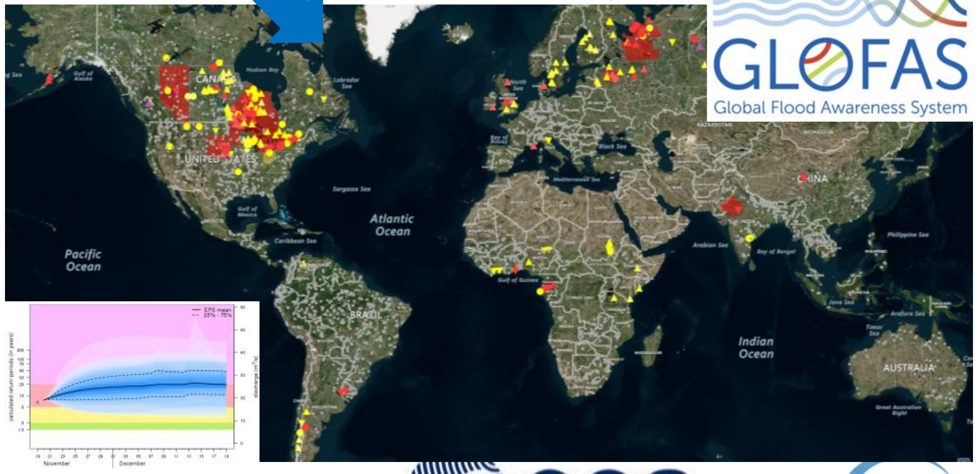
This is the only notification you will receive for this event! Please follow the evolution of the event on EFAS.





10 km, once daily

GLOFAS
Global Flood Awareness System

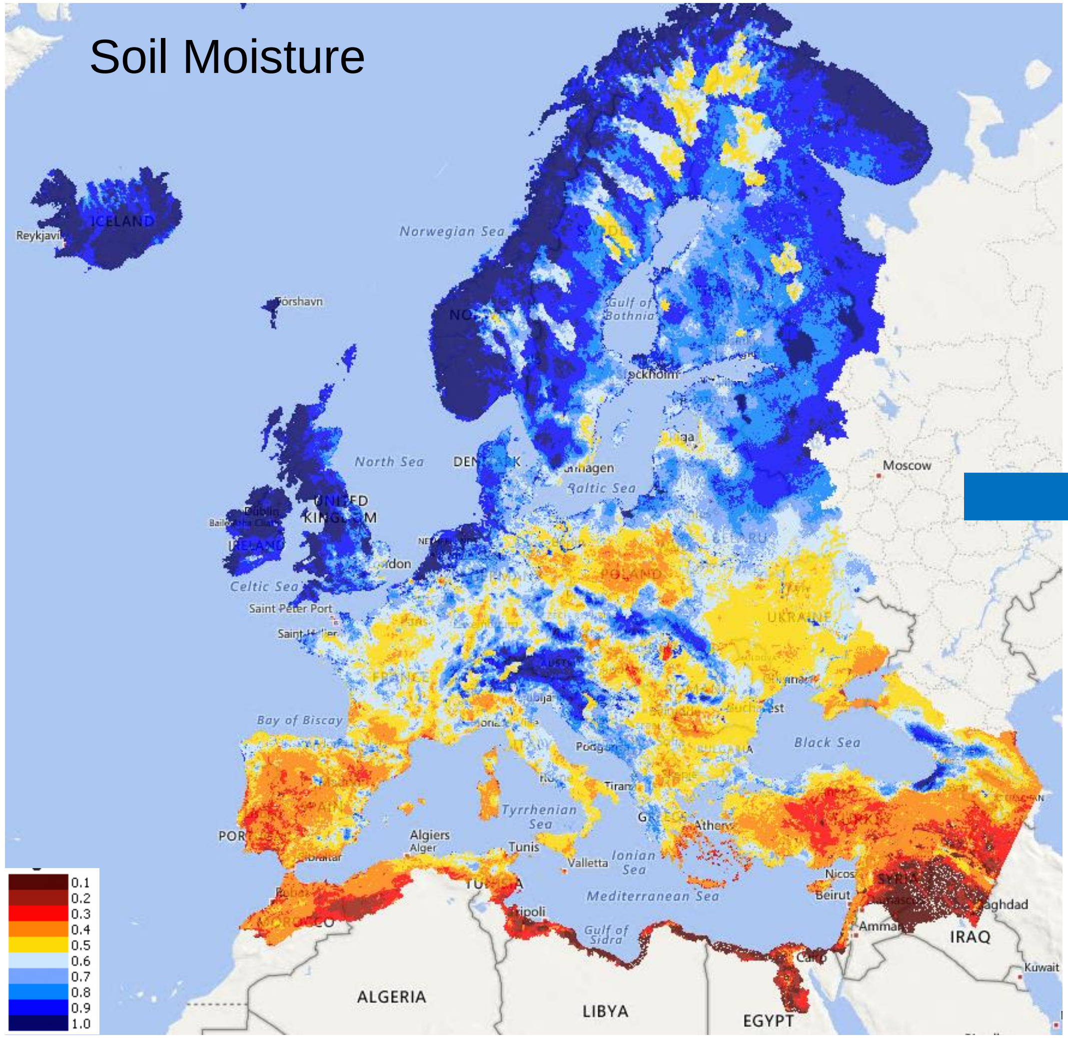


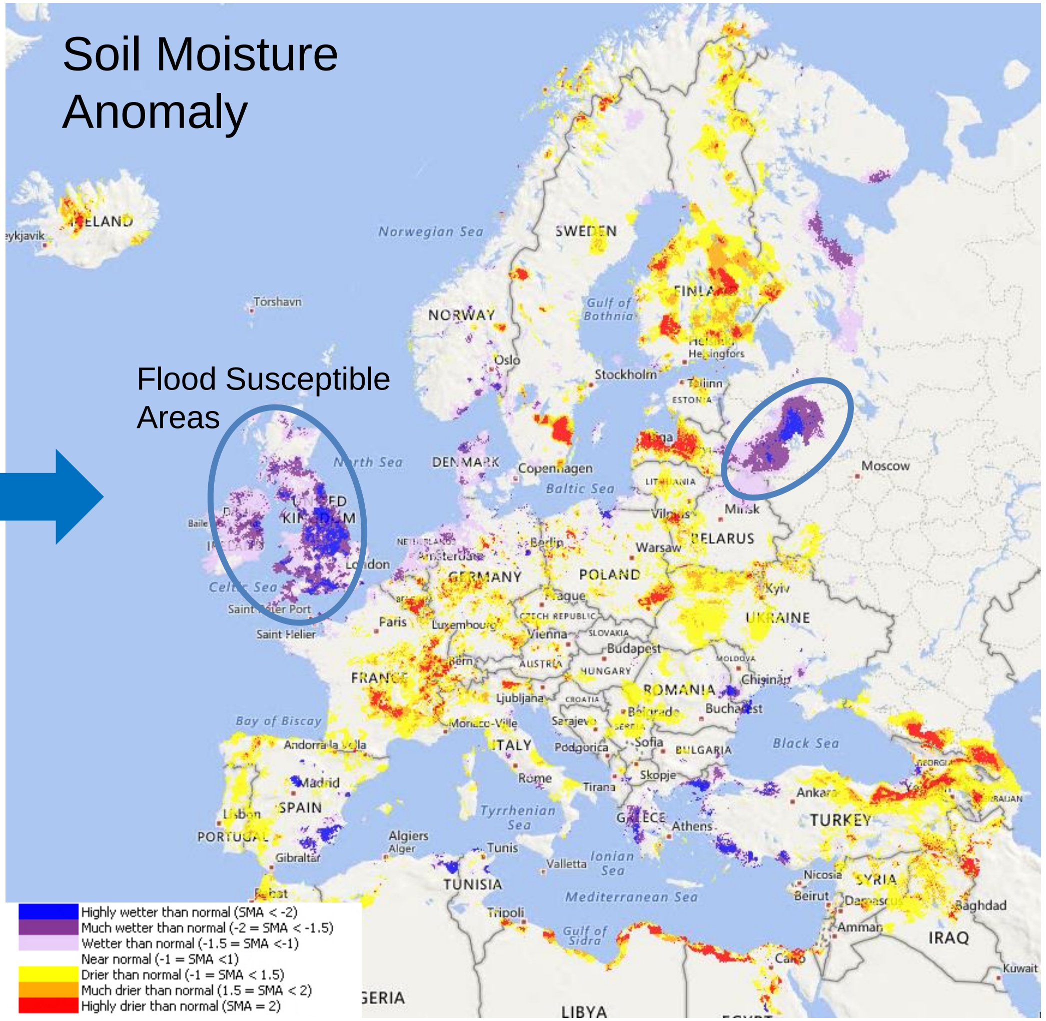
ECMWF
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

esa
copernicus
Europe's eyes on Earth

Soil Moisture for Initialisation

- Accurate estimates of antecedent soil moisture conditions are required





GloFAS Soil Moisture: Data Assimilation via H-TESSEL

European Commission

Ensemble Data Assimilation (EDA)

NWP Forecast Coupled Land-Atmosphere (H-TESSEL)

Forcings

Global Flood Awareness System

Soil moisture initial conditions

Jacobians

T2m, RH2m

& soil moisture

Background

Soil Analysis (SEKF)

SM1, SM2, SM3

$\sigma^{o}{}_{T2m} = 1K \qquad \sigma^{b} = 0.01\, m^3 m^{-3}$

$\sigma^{o}{}_{RH2m} = 4\% \qquad \sigma^{o}{}_{ASCAT} = 0.05\, m^3 m^{-3}$

Screen level analysis (2D-OI)

T_2m RH_2m

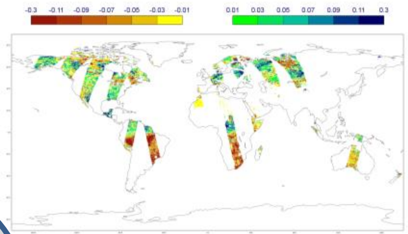
$\sigma^{o}{}_{T2m} = 2K \qquad \sigma^{o}{}_{RH2m} = 10\%$

Observations

T_2m
RH_2m

ASCAT SM
SMOS SM
SMOS TB

Observations



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SMOS Level 2 Soil Moisture Neural Network Product

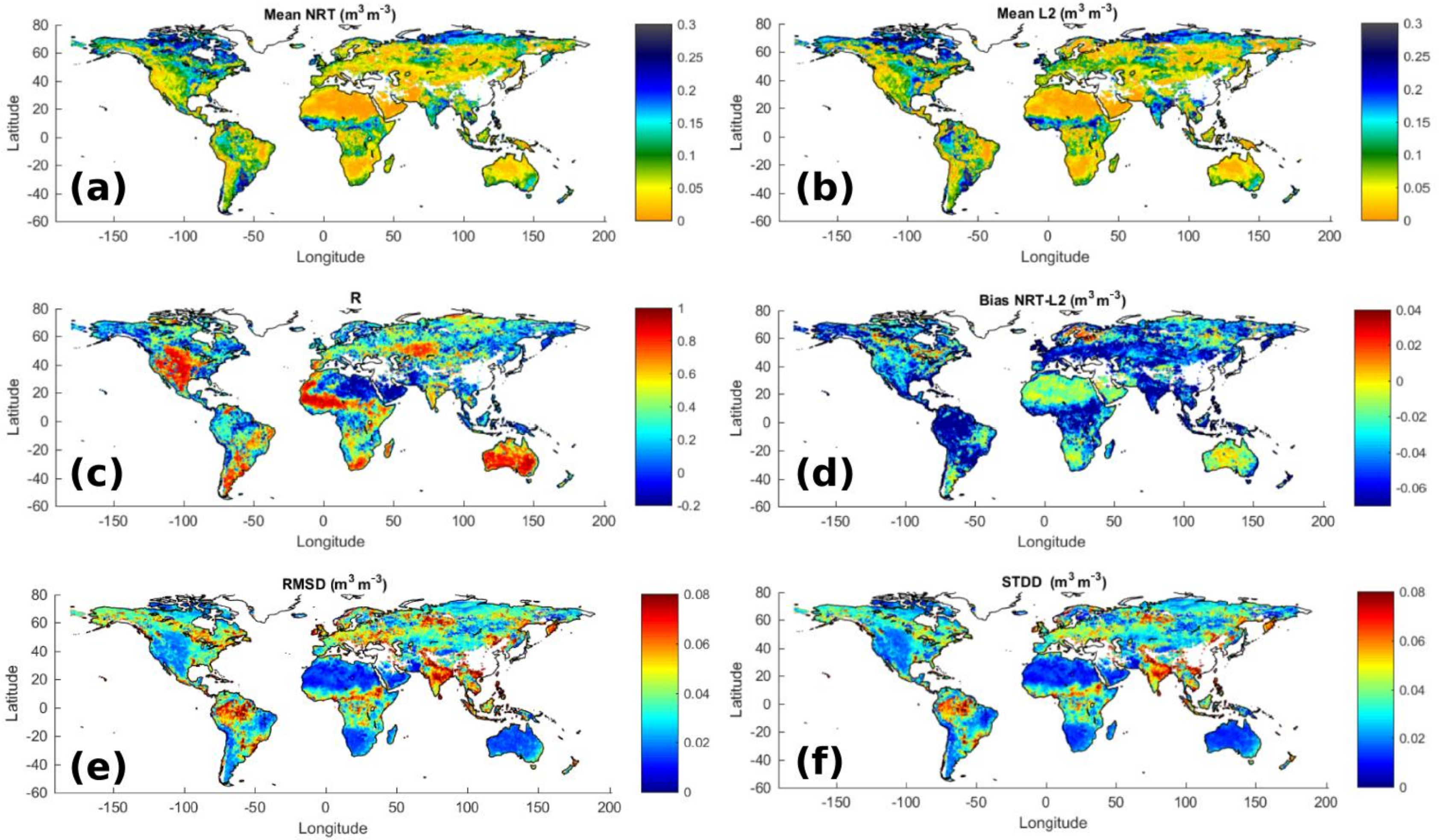
European Commission

- SMOS soil moisture Level 2 not available in NRT

- Created a Level 2 NRT soil moisture from Neural Network processor of Level 1 T_b and ECMWF soil temperature against SMOS SM L2

- Pearson Correlation >0.7 in most of world

- Standard deviation of differences <0.05 m^3 m^{-3}



Rodriguez-Fernandez *et al.*, 2017

ECMWF
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

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Assessing SMOS DA Impact on GloFAS

- SMOS soil moisture L2 NN (ECMWF trained) product assimilated into IFS since 46r1 (12th June 2019)
- What impact has this had upon GloFAS streamflow forecasts?

Experiment Design:

- IFS Analysis Data Denial Experiment
  - Cycle 45r1, TCo 399 grid, 0.25° x 0.25° horizontal resolution, climate v015
  - 1st March 2017 – 21st May 2018
  - 1) LDAS without SMOS assimilation, 2) LDAS with SMOS assimilation
- Outputs used to force GloFAS at 24h timestep
- Assess GloFAS streamflow predictions vs:
  - In-situ in USA & Australia
  - GloFAS ERA-5

Impact upon Streamflow: USA

- 283 locations with daily streamflow

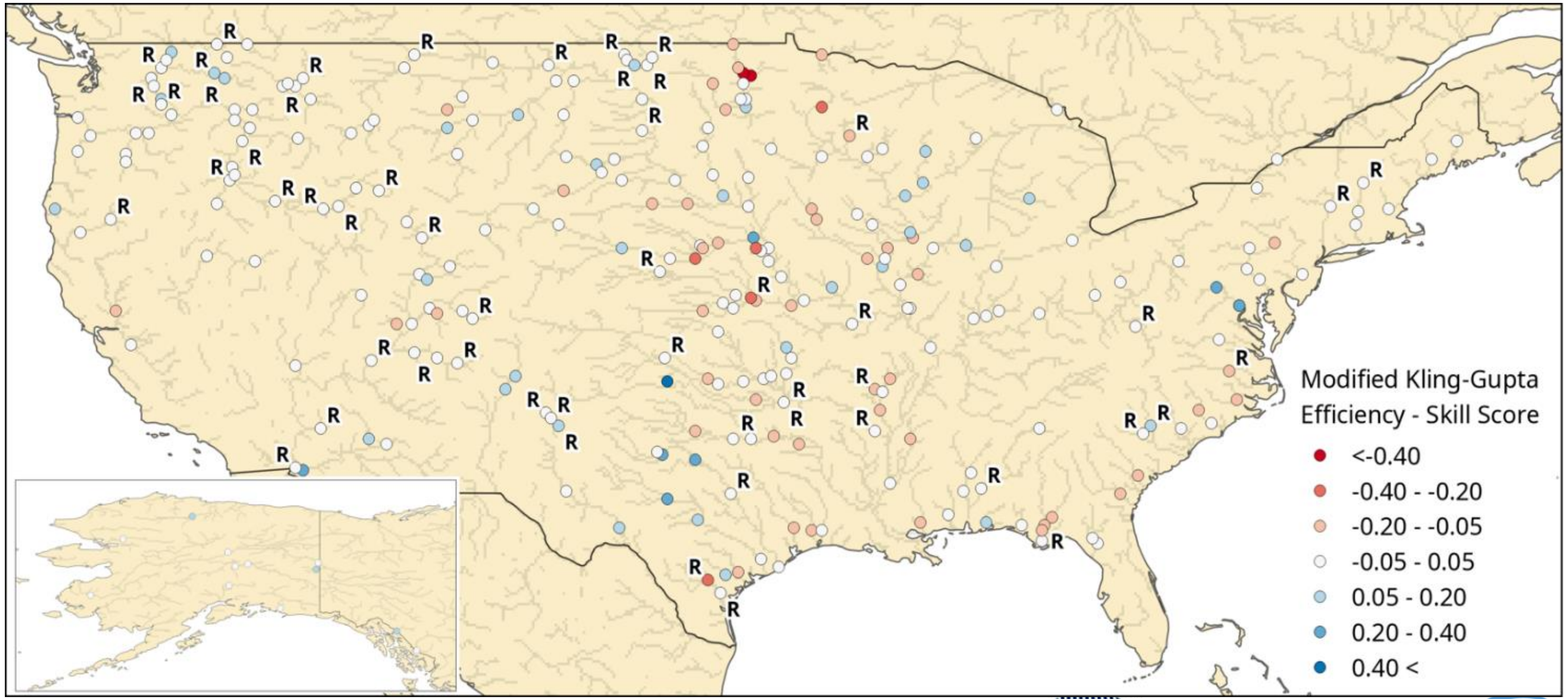
	R	Bias	KGE_{mod}
Without SMOS DA	0.428	0.840	-0.504
With SMOS DA	0.420	0.812	-0.472

$$KGE_{mod} = 1 - \sqrt{(r-1)^2 + (\beta-1)^2 + (\gamma-1)^2}$$

$$r = \frac{cov_{s,o}}{\sigma_s \cdot \sigma_o}, \quad \beta = \frac{\mu_s}{\mu_o}, \quad \gamma = \frac{\sigma_s/\mu_s}{\sigma_o/\mu_o}$$

$$KGE_{mod} Skill\ Score = \frac{KGE_{mod}[w\ SMOS] - KGE_{mod}[w/out\ SMOS]}{KGE_{mod} Perf - KGE_{mod}[w/out\ SMOS]}$$

- 40 locations where KGE_{mod} Skill Score > 0.05
  - Many such locations have low KGE_{mod} values
- River regulation affects streamflow skill
  - But no correlation with impact of SMOS



Impact upon Streamflow: Australia

- 32 locations with daily streamflow

- North shows decline in KGE_{mod} Skill Score with SMOS
  - 9 locations show an improvement

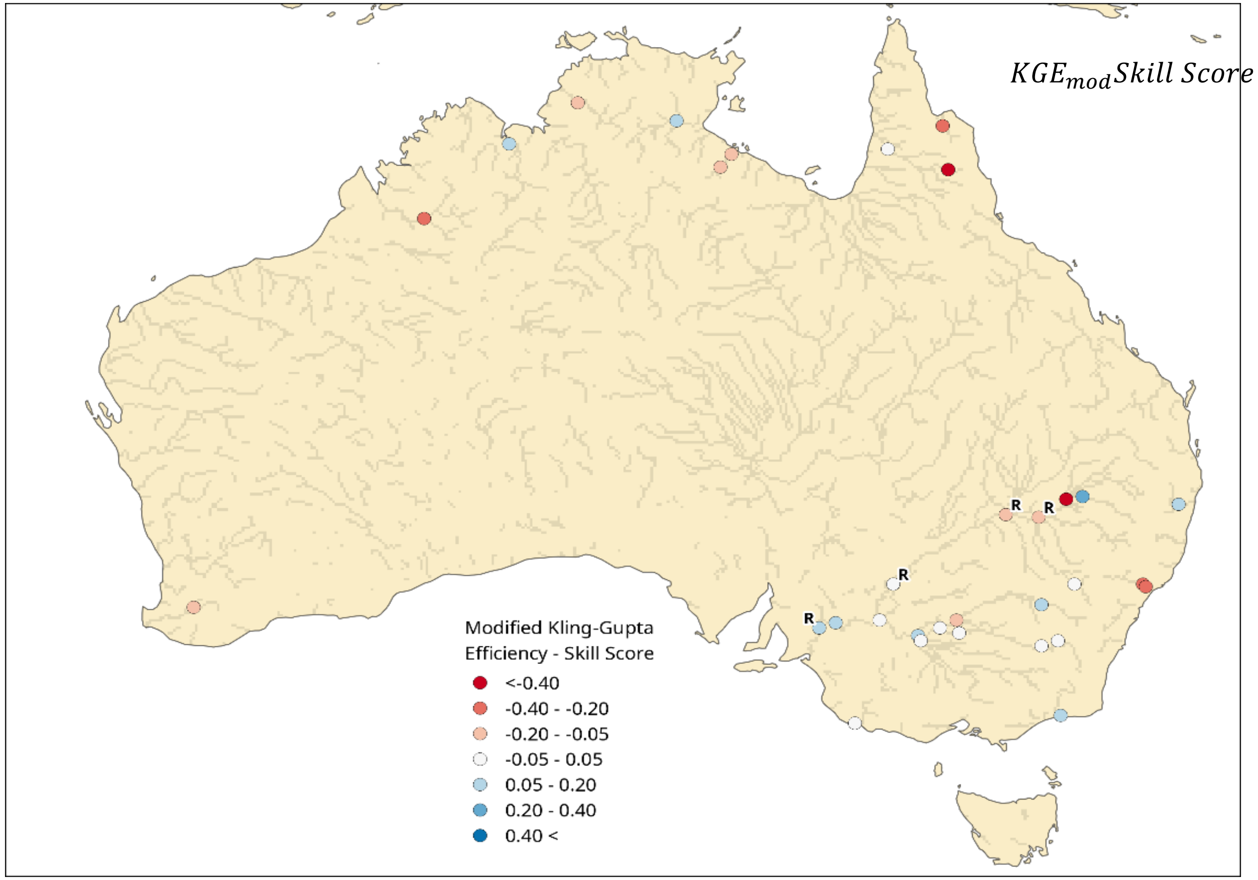
- Neutral results in Murray-Darling

	R	Bias	KGE_{mod}
Without SMOS DA	0.410	2.466	-1.248
With SMOS DA	0.356	2.558	-1.340

$$KGE_{mod} = 1 - \sqrt{(r-1)^2 + (\beta - 1)^2 + (\gamma - 1)^2}$$

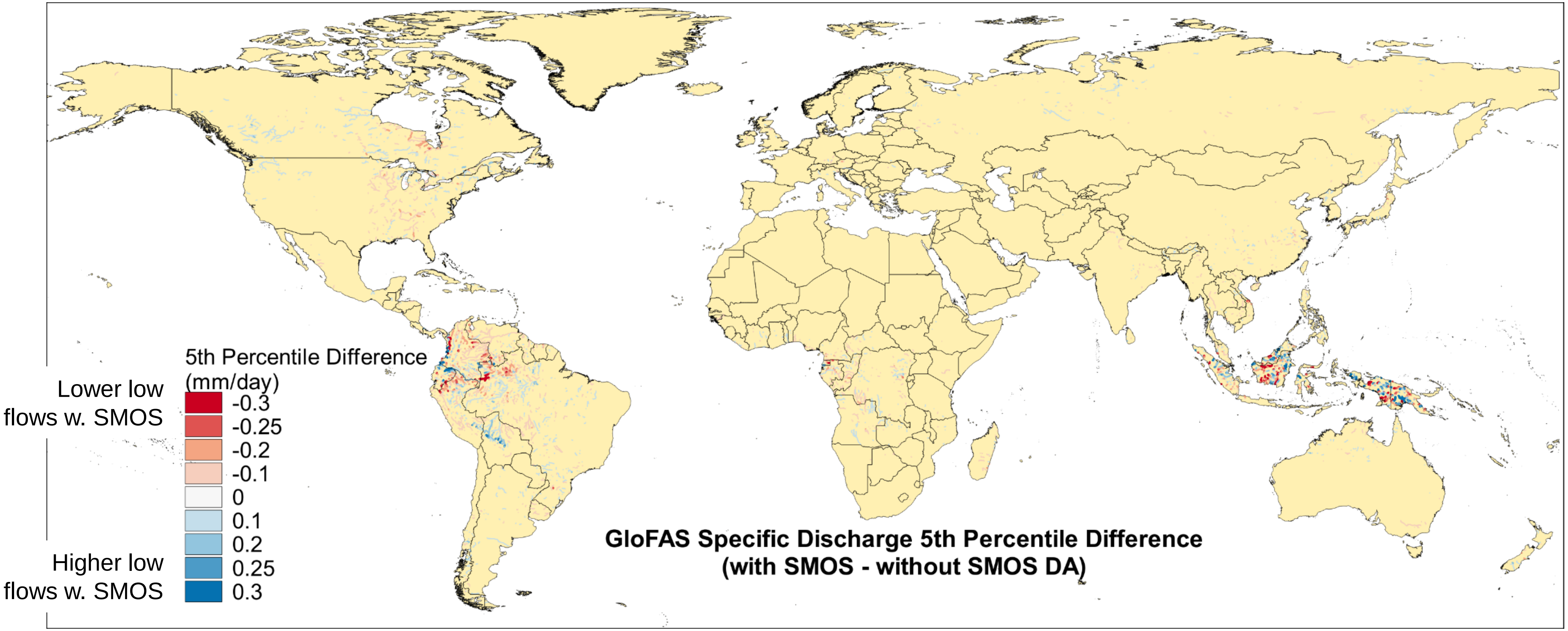
$$r = \frac{cov_{s,o}}{\sigma_s \cdot \sigma_o}, \quad \beta = \frac{\mu_s}{\mu_o}, \quad \gamma = \frac{\sigma_s/\mu_s}{\sigma_o/\mu_o}$$

$$KGE_{mod}Skill\ Score = \frac{KGE_{mod}[w\ SMOS] - KGE_{mod}[w/out\ SMOS]}{KGE_{mod}Perf - KGE_{mod}[w/out\ SMOS]}$$



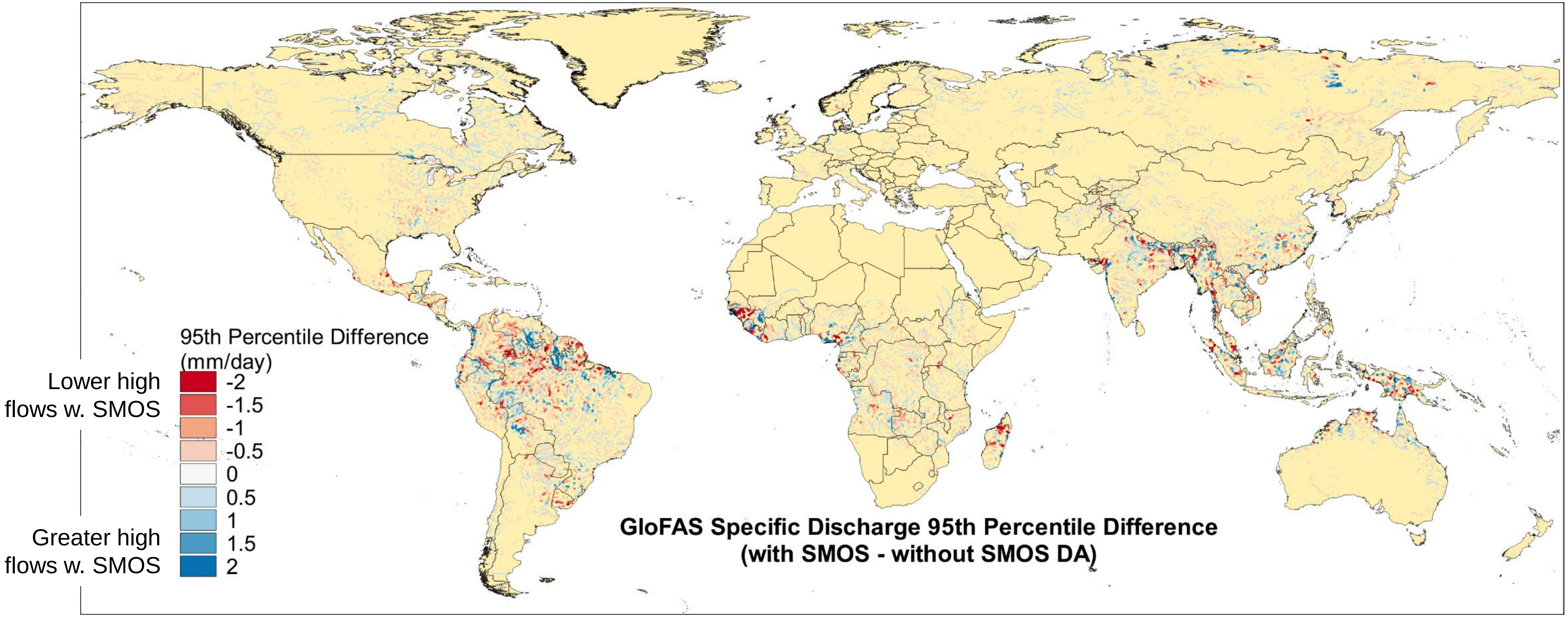
Global Differences: Low Flows

- Small impact upon low flows
  - Greatest differences in upper Amazon and Indonesian archipelago



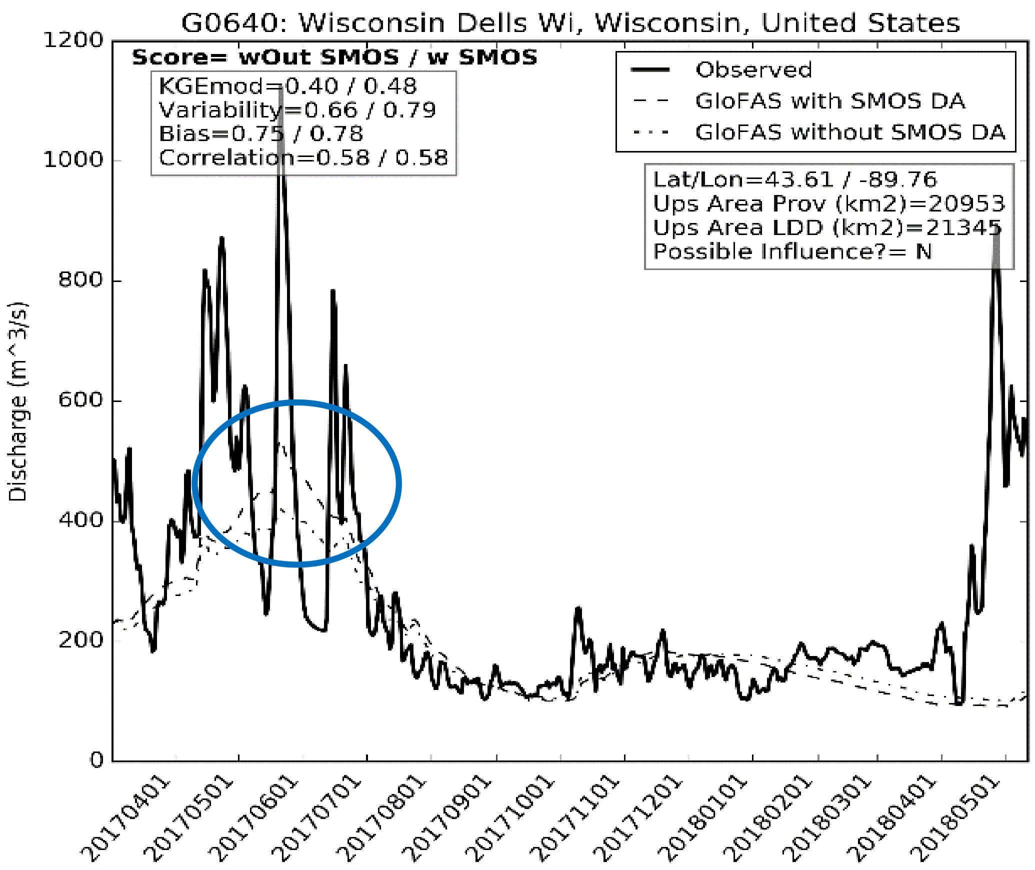
Global Differences: High Flows

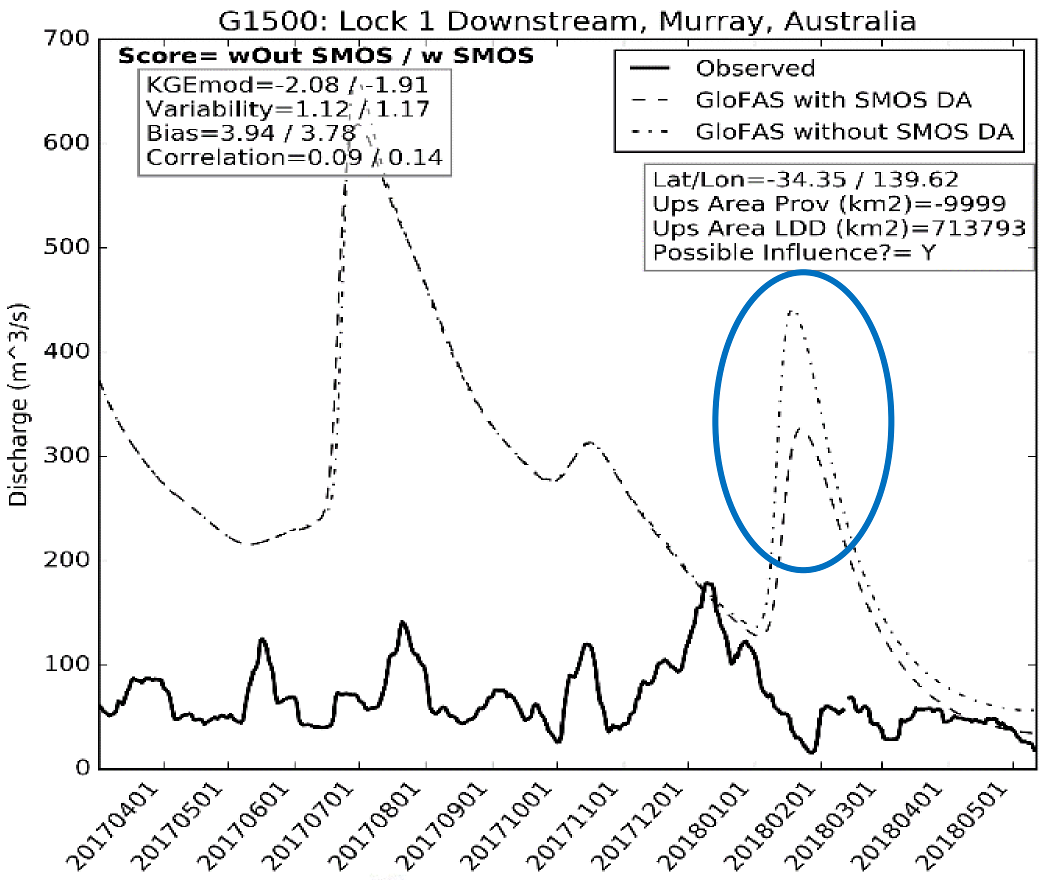
- Impact of SMOS assimilation on high flows more pronounced
- Broader latitude band of difference
- Still no clear spatial trend



Impact upon Simulated Hydrographs

- Differences most pronounced at high flows
- Direction of difference has no clear trend





Conclusions

- SMOS already being used automatically in CEMS Floods GloFAS through ECMWF LDAS

- GloFAS experiments show that SMOS data assimilation has a small impact upon streamflow predictions

- Most pronounced impact at high flows
  - Future analyses to look at high flows / flood event case studies

- Future work looking at impact upon EFAS
  - Fully calibrated hydrological model in Europe
  - Independent from LDAS
  - SMOS soil wetness to possibly inform flood susceptible areas