GEWEX Water Availability Challenge for North America
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HYPER-RESOLUTION LAND SURFACE MODELING

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Hyperresolution global land surface modeling: Meeting a grand challenge for monitoring Earth's terrestrial water

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"Adequately addressing critical water cycle science questions and applications requires systems that are implemented globally at much higher resolutions, on the order of 1 km, resolutions referred to as hyperresolution in the context of global land surface models."

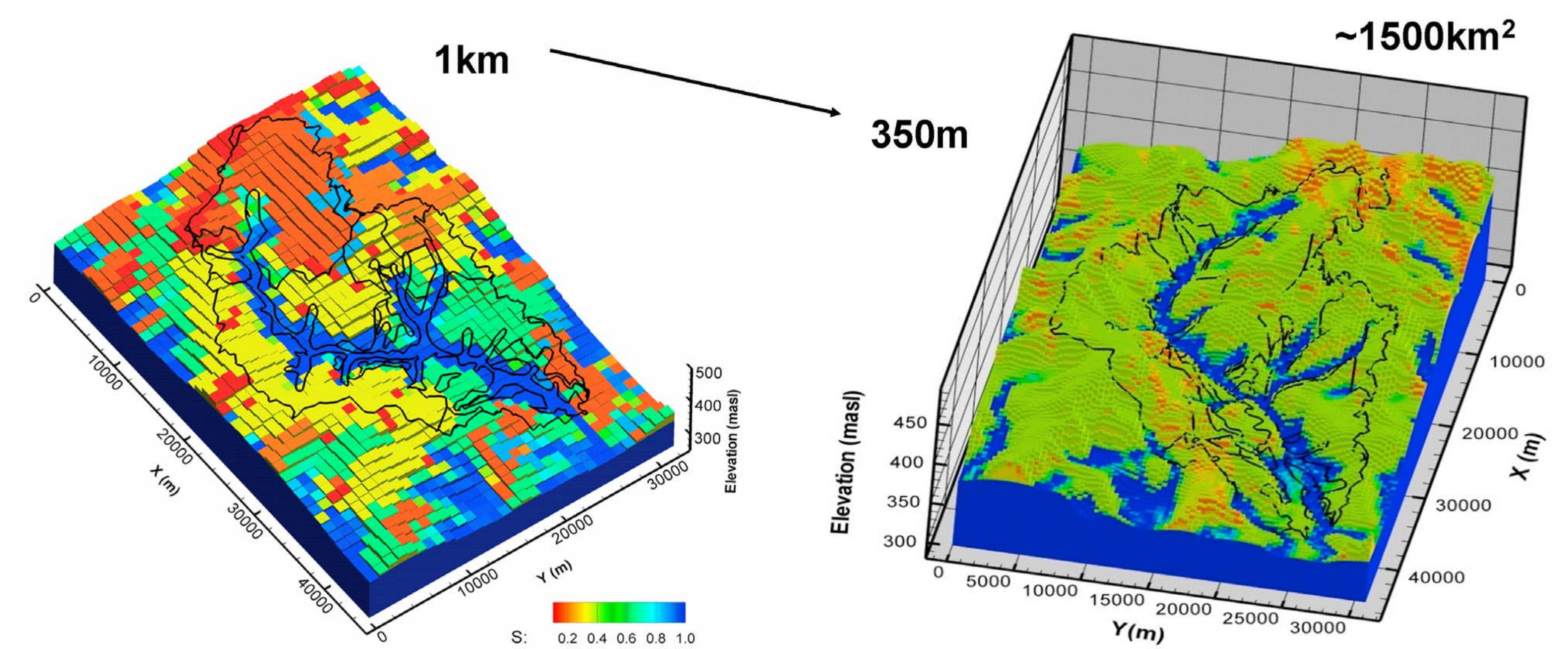
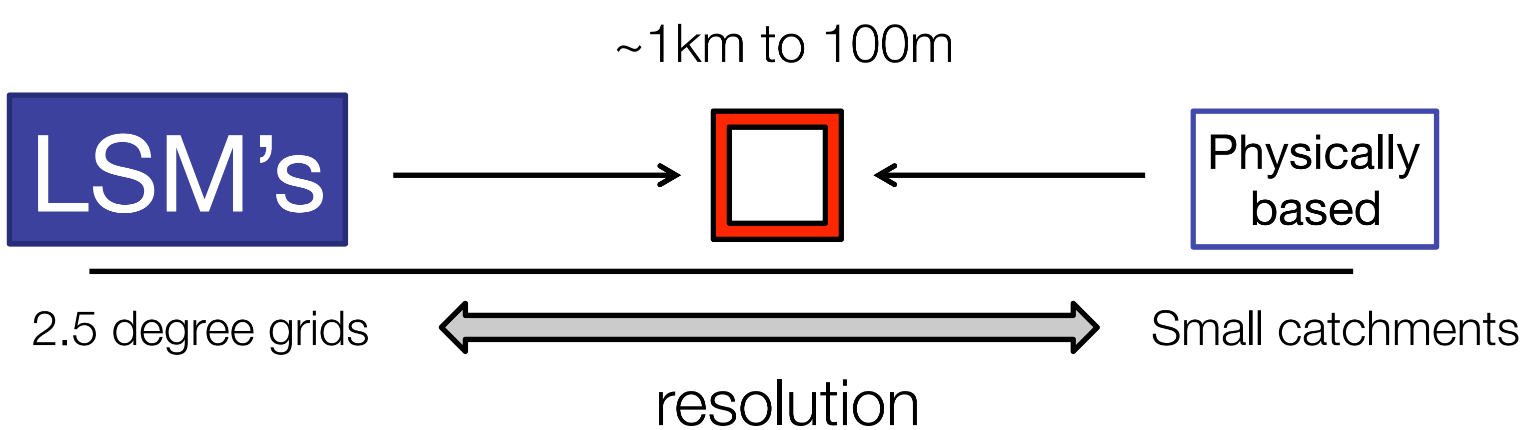


Figure 1. Higher-resolution modeling leads to better spatial representation of saturated and nonsaturated areas, with implications for runoff generation, biogeochemical cycling, and land-atmosphere interactions. Soil moisture simulations on the Little Washita showing the impact that the resolution has on its estimation [*Kollet and Maxwell*, 2008].

Several groups are already doing this

- WaterGAP (Döll et al., 2003) now runs at 5min globally (Flörke et al., 2013)
- PRC- GLOBWB (Van Beek et al., 2011): 5 min globally
- LISFLOOD (De Roo et al., 2000; Van Der Knijff et al., 2010) runs at 6 min globally
-
- NOAH-MP (Niu et al., 2011) is being coupled to Dynamic TOPMODEL (Beven and Freer, 2001) for 30-m continental simulations
- LIS: can support 1 km (Peters-Lidard et al., 2007).
- Physically based models scaling up (Kollet and Maxwell, 2006; Camporese et al., 2010; Brunner and Simmons, 2012; Maxwell, 2013).



HyperHydro group (http://www.hyperhydro.org/)

- open network of scientists
- aim of continental-scale simulations at high-spatial resolution
- comparing different large-scale hydrological models, at various spatial resolutions, from 50 km to 1 km
- Model results are evaluated to available observation data and compared across models and resolutions.

Three working groups:

1. WG1: Setting up a testbed for comparing different large-scale models at different resolutions.

2. WG2: computational challenges, including parallel computing and model component coupling.

3. WG3: parameter sets, model concepts and forcing.

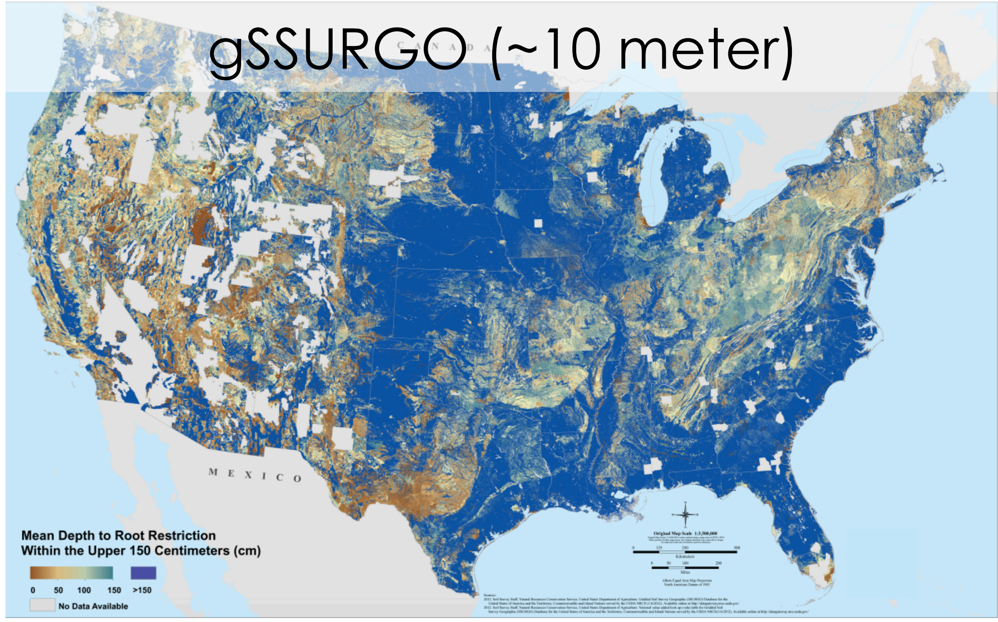
Current WG1 members and affiliations

Model	Groups
TOPLATS	Wood
CLM	Famiglietti
WRF-Hydro	Gochis
ParFlow	Maxwell, Kollet
WaterGAP	Doll, Florke
PRC-GLOBWB	Bierkens
mHM/MPR	Samaniego
HydroGeoSphere	Sudicky
eWaterCycle	Bierkens, Hut
Grid-to-Grid	Bell
GLOFRIS	Winsemius

- As the starting point, we use the Rhine and San Joaquin river basins as the test bed areas. In the near future, we have an ambition to extend our study areas to the CONUS (Contiguous-US) and EURO-CORDEX (Europe) domains.
- Models can be run at 4 spatial resolutions for inter-comparison:
  - 1/2-degree (30-min, ~50km)
  - 1/8-degree (12.5km) or 5-min (~10km)
  - 4 km
  - 1 km
- Modeled soil moisture, evaporation, latent heat flux, discharge, runoff, groundwater table level, snow water equivalent are compared among the models and with ground truth and/or remote sensing data.

Test case modeling protocol

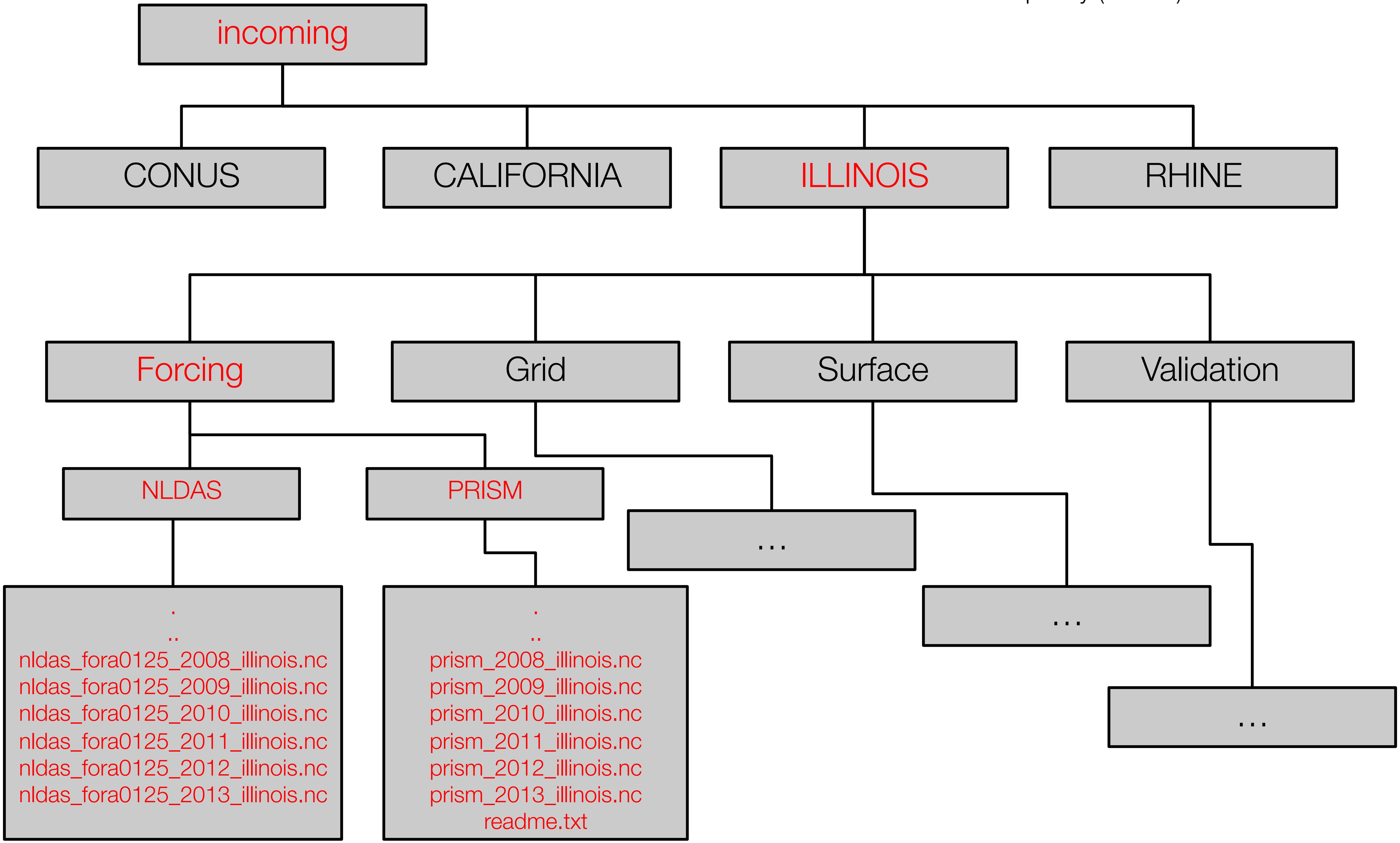
Location	Rhine river	San Joaquin
Simulation time (depends on data availability)	2008	2008
Resolutions	0.5 deg 0.125 deg, 4km, 1km	0.5 deg, 0.125 deg, 4 km, 1km
Model surface data	HydroSHEDS (3") FAO soil Gleeson permeability Landuse MODIS	USGS 1/3" DEM STATSGO @ 30" NLCD @ 1"
Model forcing	5km EFAS Cordex	4km NLDAS Princeton over CONUS
Observation data	TERENO/PALSAR soil moisture Discharge Groundwater head (MODIS) temp Eddy covariance fluxes (TR32)	Fluxnet sites DWR/USGS wells SNODAS 1km GRACE @ 1-deg USGS reservoirs & streamflow MODIS temp



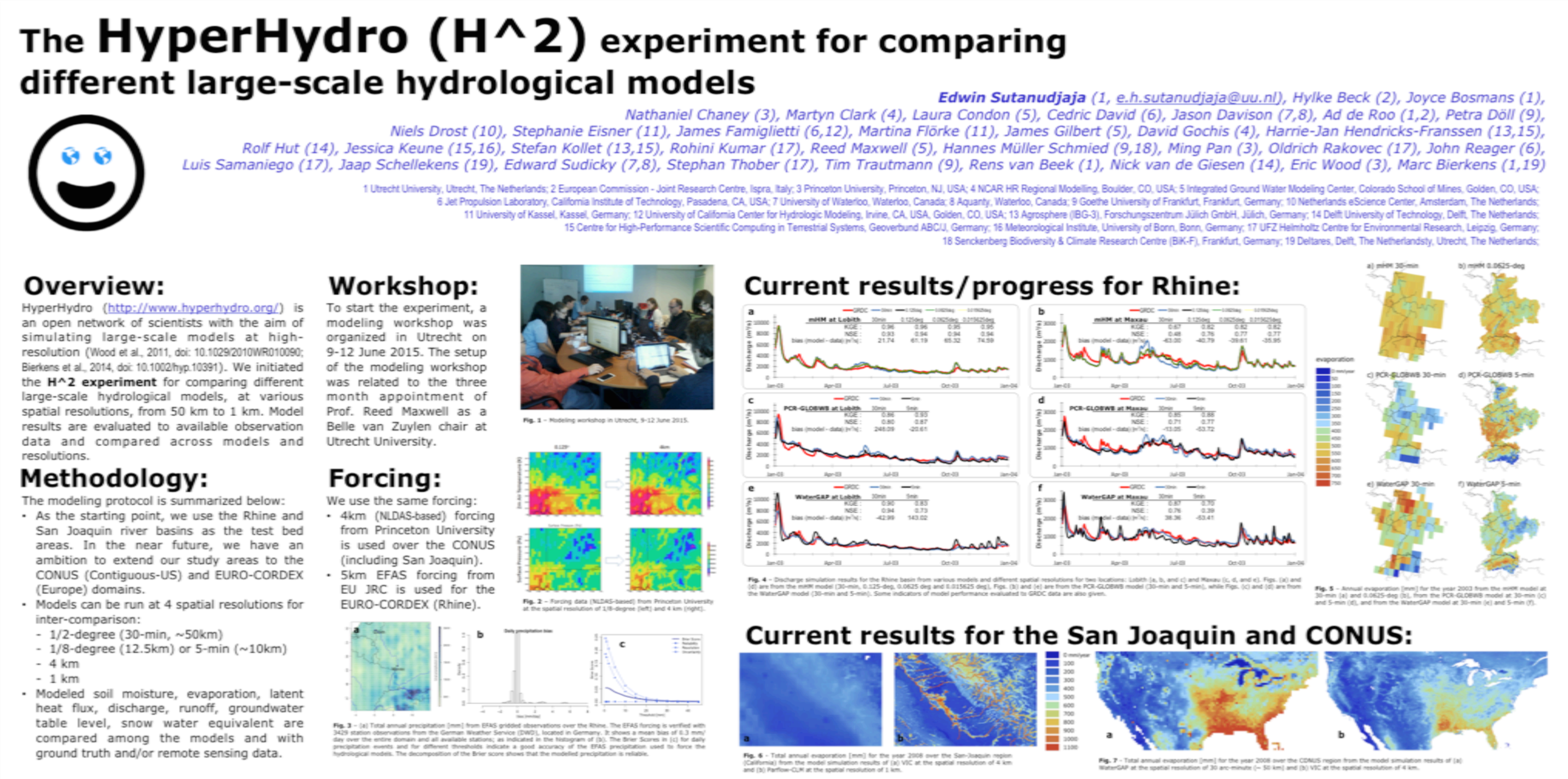
Hyper-hydro data server now

Login: hyper@data.ucchm.org
Password: hydro

**sftp only (no ssh)



Progress



The HyperHydro (H^2) experiment for comparing different large-scale hydrological models

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Overview:

HyperHydro (http://www.hyperhydro.org/) is an open network of scientists with the aim of simulating large-scale models at high-resolution (Wood et al., 2011, doi: 10.1029/2010WR010090; Bierkens et al., 2014, doi: 10.1002/hyp.10391). We initiated the **H^2 experiment** for comparing different large-scale hydrological models, at various spatial resolutions, from 50 km to 1 km. Model results are evaluated to available observation data and compared across models and resolutions.

Methodology:

The modeling protocol is summarized below:

- As the starting point, we use the Rhine and San Joaquin river basins as the test bed areas. In the near future, we have an ambition to extend our study areas to the CONUS (Contiguous-US) and EURO-CORDEX (Europe) domains.
- Models can be run at 4 spatial resolutions for inter-comparison:
  - 1/2-degree (30-min, ~50km)
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  - 4 km
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- Modeled soil moisture, evaporation, latent heat flux, discharge, runoff, groundwater table level, snow water equivalent are compared among the models and with ground truth and/or remote sensing data.

Workshop:

To start the experiment, a modeling workshop was organized in Utrecht on 9-12 June 2015. The setup of the modeling workshop was related to the three month appointment of Prof. Reed Maxwell as a Belle van Zuylen chair at Utrecht University.

Fig. 1 – Modeling workshop in Utrecht, 9-12 June 2015.

Forcing:

We use the same forcing:

- 4km (NLDAS-based) forcing from Princeton University is used over the CONUS (including San Joaquin).
- 5km EFAS forcing from EU JRC is used for the EURO-CORDEX (Rhine).

Fig. 2 – Forcing data (NLDAS-based) from Princeton University at the spatial resolution of 1/8-degree (left) and 4 km (right).

Fig. 3 – (a) Total annual precipitation [mm] from EFAS gridded observations over the Rhine. The EFAS forcing is verified with 3429 station observations from the German Weather Service (DWD), located in Germany. It shows a mean bias of 0.3 mm/day over the entire domain and all available stations; as indicated in the histogram of (b). The Brier Scores in (c) for daily precipitation events and for different thresholds indicate a good accuracy of the EFAS precipitation used to force the hydrological models. The decomposition of the Brier score shows that the modelled precipitation is reliable.

Current results/progress for Rhine:

Fig. 4 – Discharge simulation results for the Rhine basin from various models and different spatial resolutions for two locations: Lobith (a, b, and c) and Maxau (c, d, and e). Figs. (a) and (d) are from the mHM model (30-min, 0.125-deg, 0.0625 deg and 0.015625 deg), Figs. (b) and (e) are from the PCR-GLOBWB model (30-min and 5-min), while Figs. (c) and (d) are from the WaterGAP model (30-min and 5-min). Some indicators of model performance evaluated to GRDC data are also given.

Fig. 5 – Annual evaporation [mm] for the year 2003 from the mHM model at 30-min (a) and 0.0625-deg (b), from the PCR-GLOBWB model at 30-min (c) and 5-min (d), and from the WaterGAP model at 30-min (e) and 5-min (f).

Current results for the San Joaquin and CONUS:

Fig. 6 – Total annual evaporation [mm] for the year 2008 over the San-Joaquin region (California) from the model simulation results of (a) VIC at the spatial resolution of 4 km and (b) Parflow-CLM at the spatial resolution of 1 km.

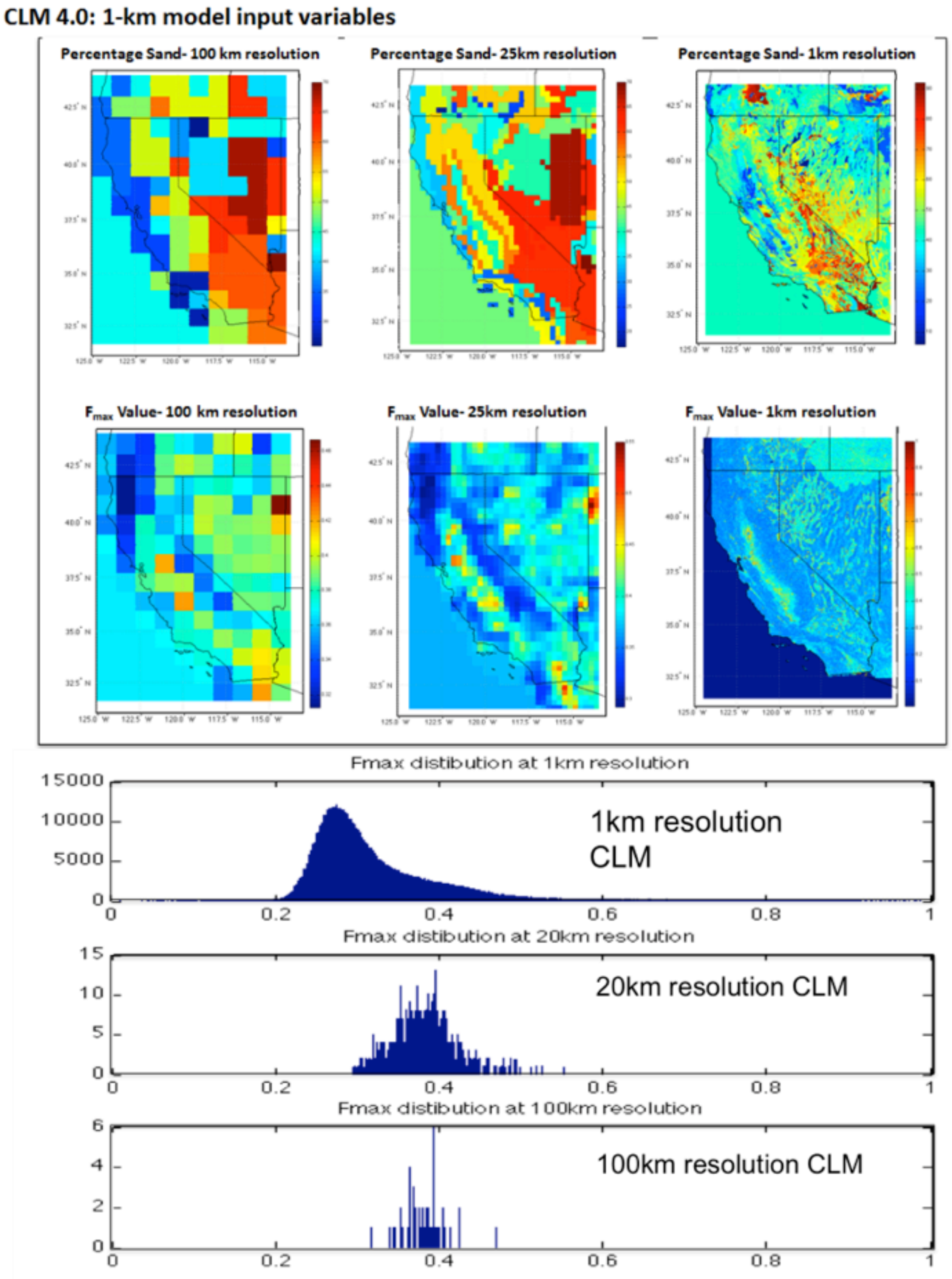
Fig. 7 – Total annual evaporation [mm] for the year 2008 over the CONUS region from the model simulation results of (a) WaterGAP at the spatial resolution of 30 arc-minute (~ 50 km) and (b) VIC at the spatial resolution of 4 km.

Biggest challenges

- Some models are not meant to run at 1-km resolution
- Subsurface physics are really important
- Subsurface data sets are really important (e.g. soil depth)
- Observations for validation are critical (e.g. SMAP, ASO, in-situ)
- Better forcing is key

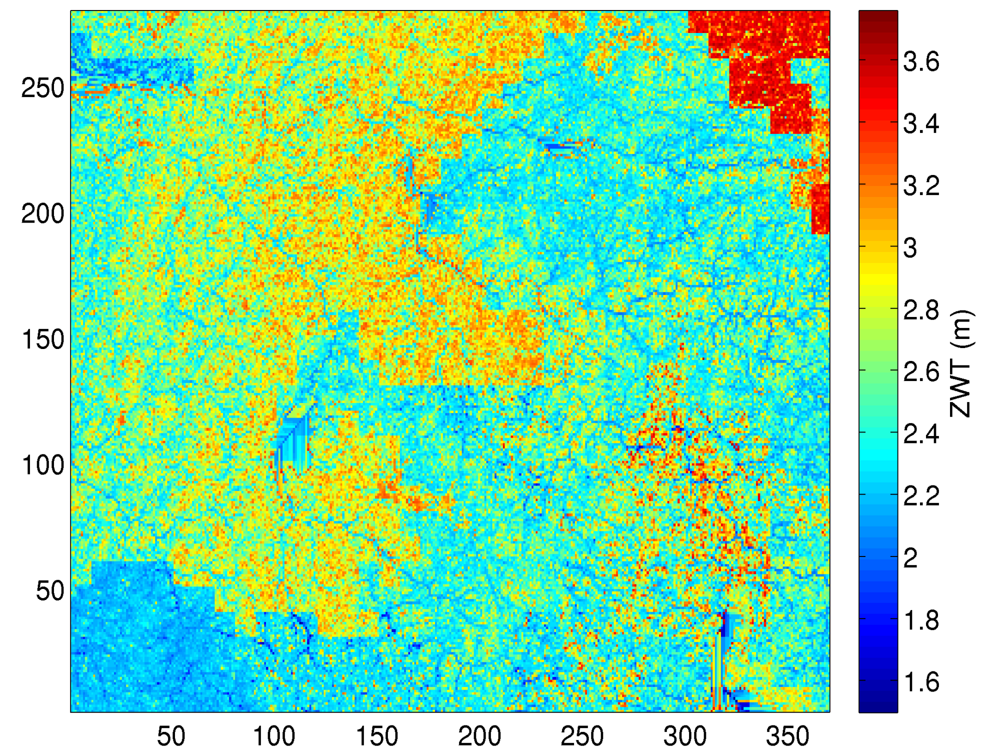
1-km CLM over California

"Current computational capabilities have outrun the theoretical underpinnings of land surface hydrological models." [Wood et al., 2011]

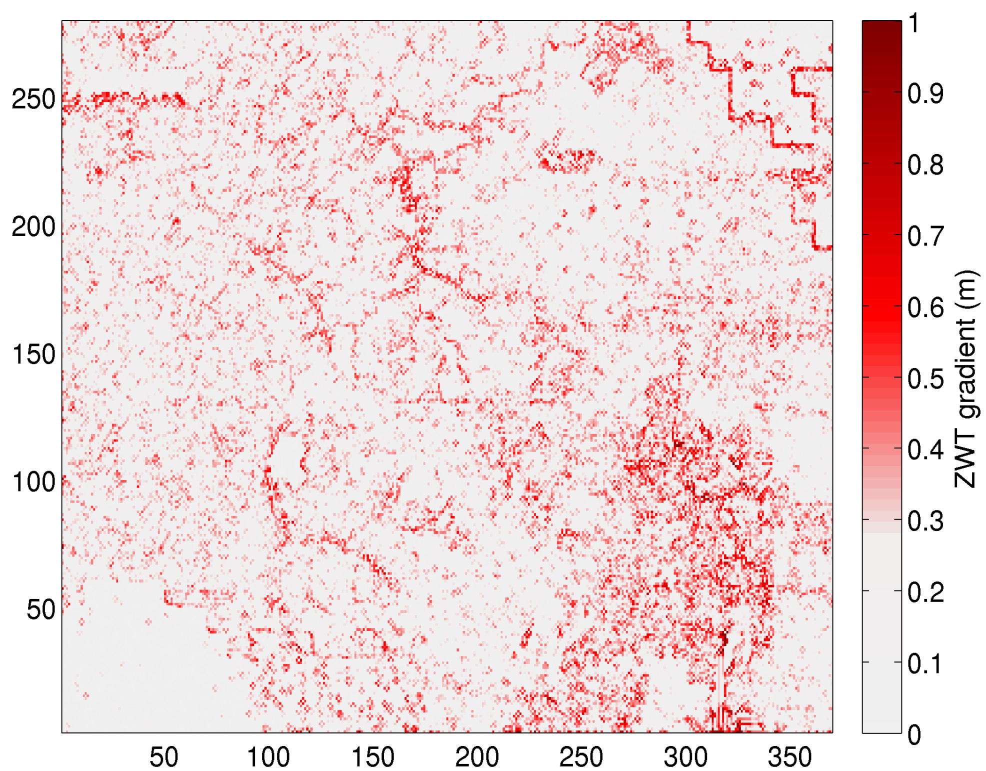


Singh, Reager, Miller, Famiglietti, 2015, WRR

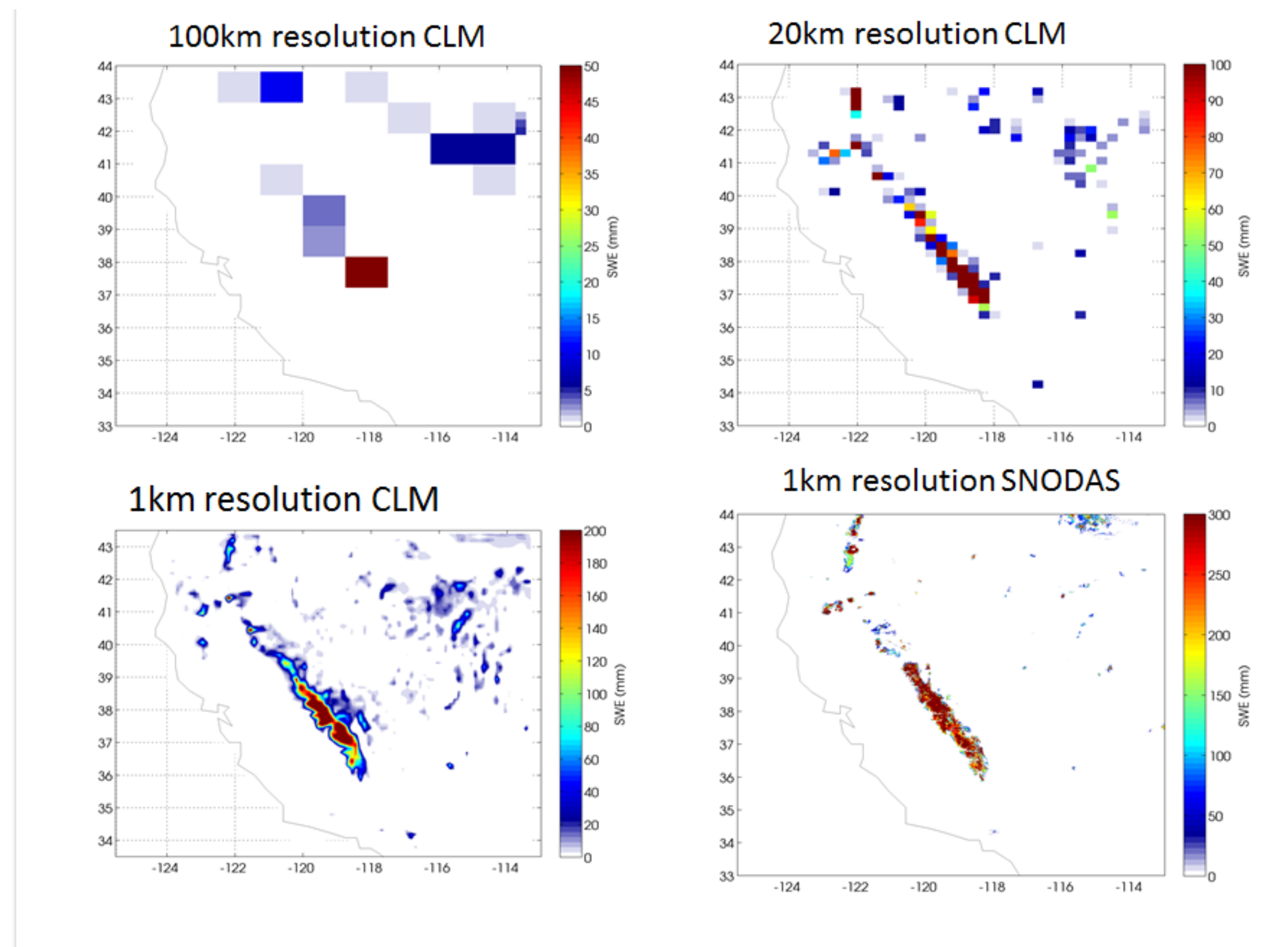
Water table depth (m)

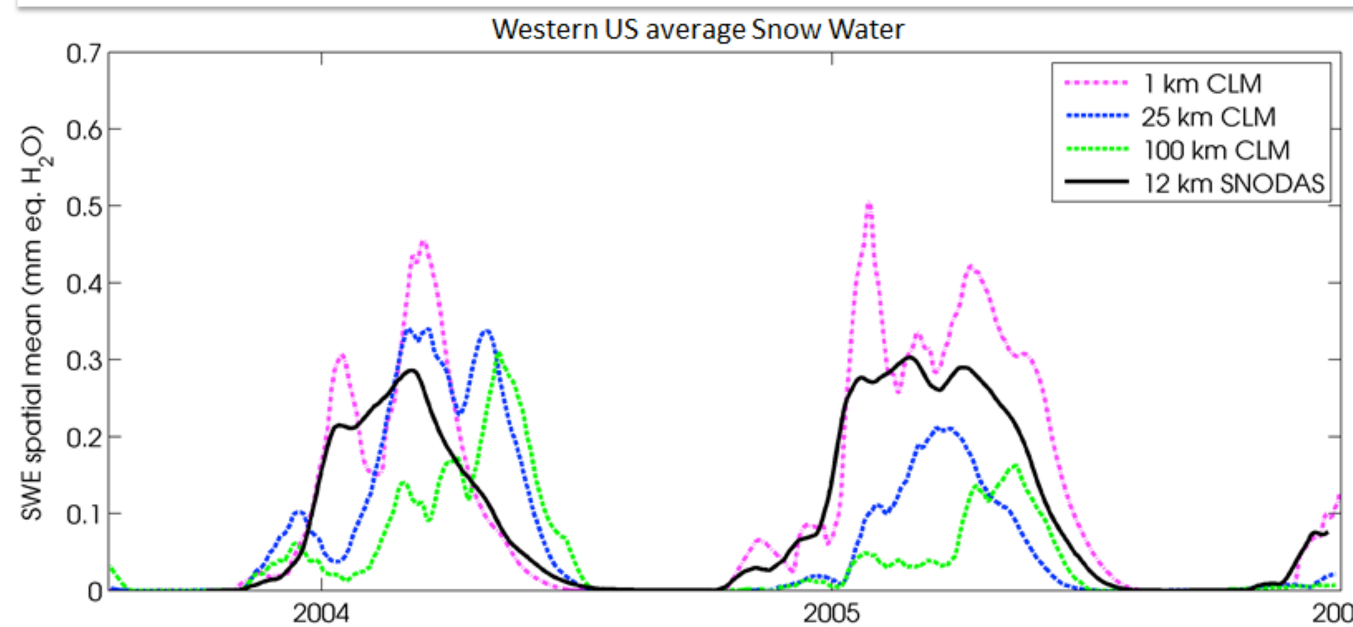


Water table depth gradient (m)



Results: comparison of the mean(2003-2005) snow water equivalents over the domain





Singh, Reager, Miller, Famiglietti, 2014, WRR