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mGROWA-Slovenia

Rezultati modela vodne bilance za Slovenijo

Water balance simulation results for the whole country of Slovenia

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Kazalo

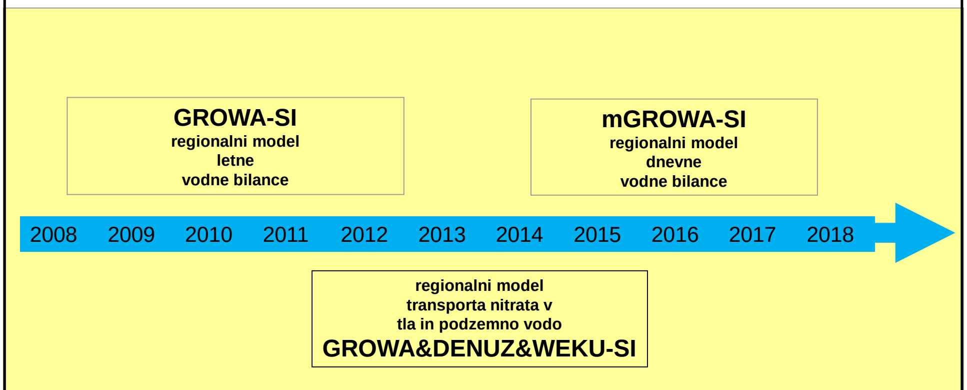
1. Uvod
2. mGROWA v Evropi
3. Modelski pristop mGROWA in razvojni pristop za Slovenijo
4. Rezultati mGROWA za obdobje 1981-2010
5. Projekcije možnega vpliva podnebnih sprememb na vodno bilanco v Sloveniji
6. Zaključek, sklepi in nadaljevanje…

mGROWA v Evropi

mGROWA applications in Europe

Frank Wendland

10 years collaboration
Agencija RS za okolje – Forschungzentrum JÜLICH



- Tetzlaff, B., Andjelov, M., Kuhr, P., Uhan, J. & Wendland, F. (2015): Model-based assessment of groundwater recharge in Slovenia.- **Environmental Earth Sciences** 74, 6177–6192
- Andelov, M., Kunkel, R., Uhan,J. & Wendland, F. (2014): Determination of nitrogen reduction levels necessary to reach groundwater quality targets in Slovenia.- **Journal of Environmental Sciences** 29-9, 1806-181

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Geographical overview of established mGROWA modelling activities since 2011

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Specific research priorities in different model areas (Germany)

Metropolitan area of Hamburg (BMBF, 2011-2015)**:**
- Crop-specific irrigation need
- Indicators for assessing climate change impact on sustainability of groundwater-supplied irrigation

Lower Saxony (LBEG, NLWKN, since 2011):
- Usable groundwater quantities
- Ensemble simulations for identifying mechanisms of climate-induced temporal shifts of the groundwater recharge period

North Rhine-Westphalia (LANUV, since 2011):
- Usable groundwater quantities
- Climate change impact on groundwater
- Implementation into the nutrient model chain RAUMIS – mGROWA – DENUZ – WEKU for implementation of EU-WFD and EU-NiD

Erftverband (regional water board, since 2011):
- Intercomparison of groundwater recharge (models)

Weser catchment (BMBF, since 2017):
- Assessing pathways for inputs of micro-plastics

Rhineland-Palatinate, Mecklenburg-West-Pomerania (MUEEF, LUNG, since 2017/18):
- Implementation into the nutrient model chain RAUMIS – mGROWA – DENUZ – WEKU for implementation of EU-WFD and EU-NiD

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Specific research priorities in different model areas (Europe, Mediterranean)

Thau lagoon catchment (EU-FP7, 2011-2015):
- Multi-model-ensemble for projecting climate change impacts on water resources and droughts
- Influence of different soil parameter sources (soil maps vs. remote sensing) on groundwater recharge

Izmit bay catchment (EU-FP7, 2011-2015):
- Multi-model-ensemble for projecting climate change impacts on water resources and droughts

Riu Mannu catchment (EU-FP7, 2011-2015):
- Influence of root zone characteristic in climate impact studies with relation to groundwater recharge

Pinios catchment (cooperation since 2012):
- Routing of in-situ groundwater recharge from recharge areas to managed aquifers
- Climate change impacts on groundwater recharge of overused aquifers
- Parameter assessment in groundwater recharge areas

Alento catchment (DAAD, planned):
- Parameter assessment in groundwater recharge areas

Ergene catchment and North-Western of Jordan (cooperation since 2014):
- Drought indices
- Quantification of water resources

Slovenia (ARSO, since 2015):
- Initial implementation of the mGROWA snow module
- Influence of snowpack on temporal and spatial patterns of groundwater recharge

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Peer reviewed mGROWA publications (since 2013)

Herrmann F, Hübsch L, Elbracht J, Engel N, Keller L, Kunkel R, Müller U, Röhm H, Vereecken H, Wendland F. Mögliche *Auswirkungen von Klimaänderungen auf die Grundwasserneubildung in Niedersachsen*. **Hydrologie und Wasserbewirtschaftung** 2017; 61: 245-261. DOI: 10.5675/HyWa_2017,4_3

Herrmann F, Baghdadi N, Blaschek M, Deidda R, Duttmann R, La Jeunesse I, Sellami H, Vereecken H, Wendland F. *Simulation of future groundwater recharge using a climate model ensemble and SAR-image based soil parameter distributions — A case study in an intensively-used Mediterranean catchment*. **Science of The Total Environment** 2016; 543: 889-905. DOI: 10.1016/j.scitotenv.2015.07.036

Ehlers L, Herrmann F, Blaschek M, Duttmann R, Wendland F. *Sensitivity of mGROWA-simulated groundwater recharge to changes in soil and land use parameters in a Mediterranean environment and conclusions in view of ensemble-based climate impact simulations.* **Science of The Total Environment** 2016; 543: 937-951. DOI: 10.1016/j.scitotenv.2015.04.122

Herrmann F, Kunkel R, Ostermann U, Vereecken H, Wendland F. *Projected impact of climate change on irrigation needs and groundwater resources in the metropolitan area of Hamburg (Germany).* **Environmental Earth Sciences** 2016; 75. DOI: 10.1007/s12665-016-5904-y

La Jeunesse I, Cirelli C, Aubin D, Larrue C, Sellami H, Afifi S, Bellin A, Benabdallah S, Bird DN, Deidda R, Dettori M, Engin G, Herrmann F, Ludwig R, Mabrouk B, Majone B, Paniconi C, Soddu *A. Is climate change a threat for water uses in the Mediterranean region? Results from a survey at local scale.* **Science of The Total Environment** 2016; 543: 981-996. DOI: 10.1016/j.scitotenv.2015.04.062

Panagopoulos A, Arampatzis G, Tziritis E, Pisinaras V, Herrmann F, Kunkel R, Wendland F. *Assessment of climate change impact in the hydrological regime of River Pinios Basin, central Greece.* **Desalination and Water Treatment** 2016; 57: 2256-2267. DOI: 10.1080/19443994.2014.984926

Herrmann F, Keller L, Kunkel R, Vereecken H, Wendland F. *Determination of spatially differentiated water balance components including groundwater recharge on the Federal State level – A case study using the mGROWA model in North Rhine-Westphalia (Germany).* **Journal of Hydrology: Regional Studies** 2015; 4: 294-312. DOI: 10.1016/j.ejrh.2015.06.018

Kreins P, Henseler M, Anter J, Herrmann F, Wendland F. *Quantification of Climate Change Impact on Regional Agricultural Irrigation and Groundwater Demand.* **Water Resources Management** 2015; 29: 3585-3600. DOI: 10.1007/s11269-015-1017-8

Herrmann F, Chen S, Heidt L, Elbracht J, Engel N, Kunkel R, Müller U, Röhm H, Vereecken H, Wendland F. *Zeitlich und räumlich hochaufgelöste flächendifferenzierte Simulation des Landschaftswasserhaushalts in Niedersachsen mit dem Model mGROWA.* **Hydrologie und Wasserbewirtschaftung** 2013; 57: 206-224. DOI: 10.5675/HyWa_2013,5_2

Herrmann et al. *Influence of snowpack on spatiotemporal patterns of groundwater recharge at the state level:* Submission to **Hydrology and Earth System Sciences** or **Water**

Frantar et al. *Regional patterns and water resources availability in Slovenia*. Submission to **Journal of Hydrology: Regional Studies** or **Water**

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mGROWA modelski pristop in razvoj za Slovenijo

mGROWA modelling approach and specific developments for the country of Slovenia

Frank Herrmann

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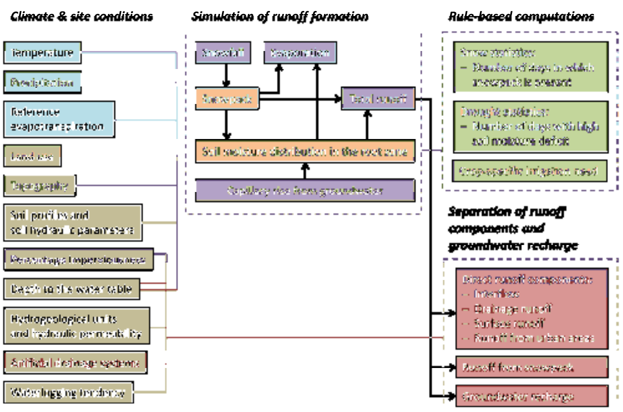
Data basis and general modelling scheme of the mGROWA model



mGROWA – Deterministic distributed model for balancing and projecting water availability on river basin or state level:

- To determine runoff components in high spatial and temporal resolution (i.e. days, 100 m grid)
- To predict the impact of climate variability and change on soil water balance, irrigation need and groundwater resources
- To identify the relevant pathways for nutrient input into groundwater and surface waters

Sources: ARSO - Slovenian Environment Agency, European Environment Agency (EEA), Biotechnical Faculty - University of Ljubljana, Surveying and Mapping Authority of the Republic of Slovenia (GURS), Geological Survey of Slovenia (GeoZS), Slovenian Ministry of Agriculture, Forestry and Food (MKGP) + various literature sources

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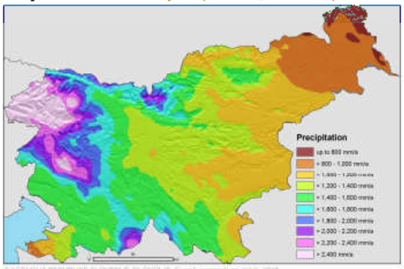
Data base: Climate data

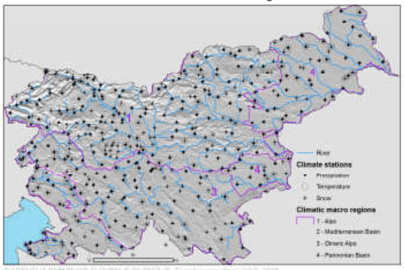
mGROWA climatic data base provided by ARSO:

- Raster based monthly sum of precipitation and reference evapotranspiration
- Station-based time series in daily time-steps:
  - Precipitation (210 stations)
  - Temperature (84 stations)
  - Reference evapotranspiration (84 stations)

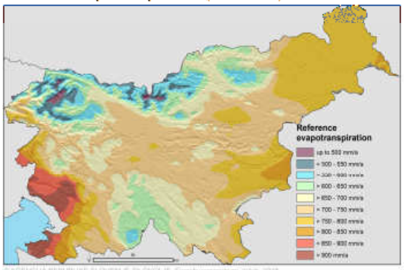
Long-term mean annual precipitation (1981-2010)



Climate stations and climatic macro regions



Long-term mean annual reference evapotranspiration (1981-2010)



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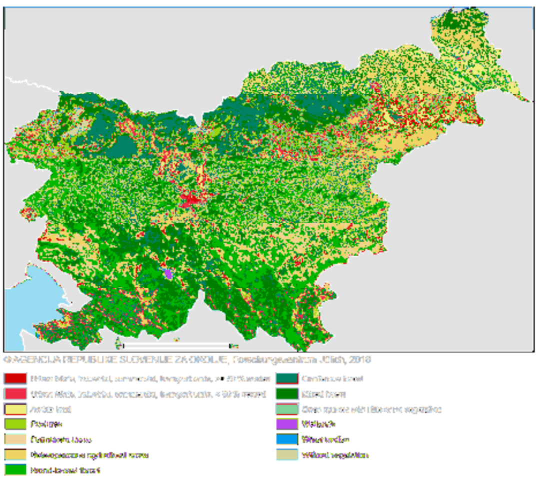
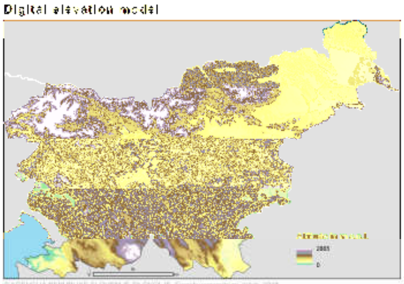
Data base: Land use and topography

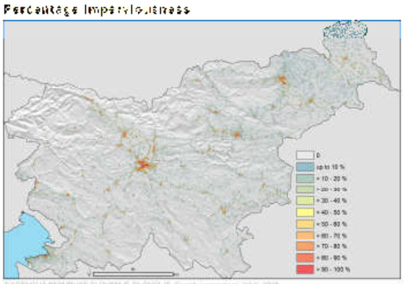
Corine Land Cover 2006



Digital elevation model



Percentage imperviousness



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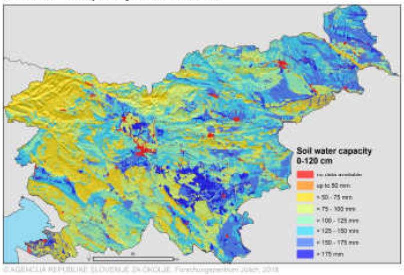
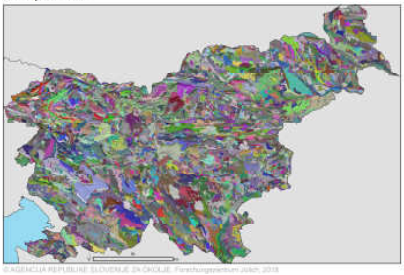
Data base: Soil map

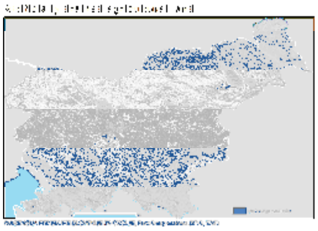
> 10,000 soil profile descriptions

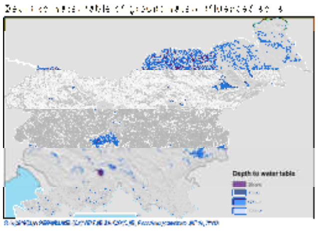
Soil water capacity in 0 - 120 cm

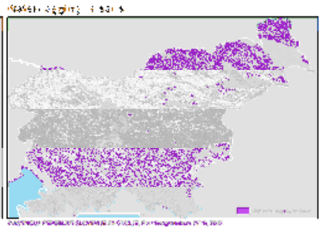


Soil profiles









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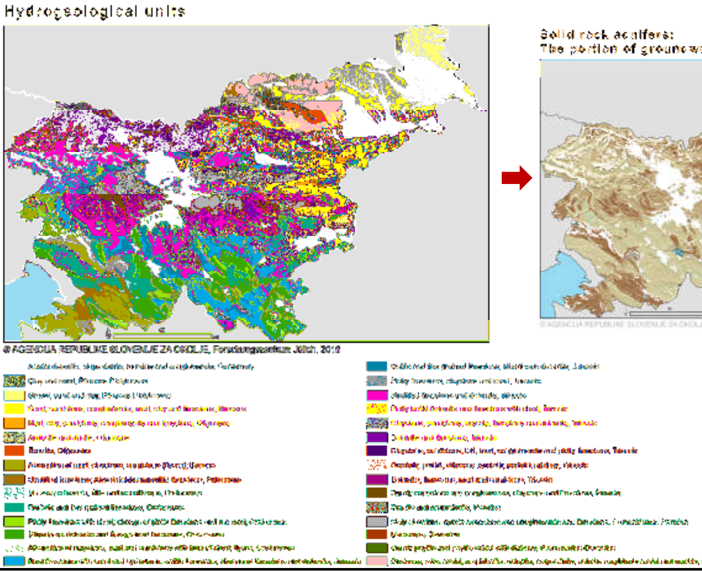
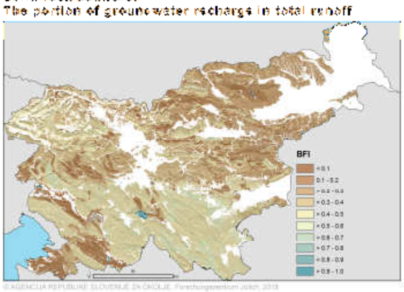
Data base: Hydrogeological map

Hydrogeological units



Solid rock aquifers:
The portion of groundwater recharge in total runoff



Tetzlaff, B., Andjelov, M., Kuhr, P., Uhan, J., Wendland, F., 2015. *Model-based assessment of groundwater recharge in Slovenia.* **Environmental Earth Sciences**, 74(7): 6177-6192. DOI: 10.1007/s12665-015-4639-5

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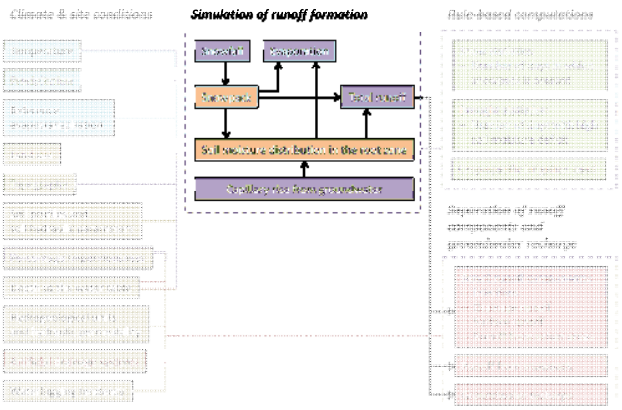
Data basis and general modelling scheme of the mGROWA model



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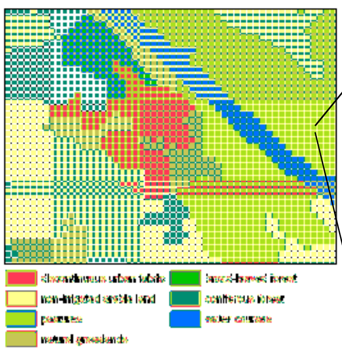
mGROWA – Basic water balance equations



Slovenia:
2,027,330 individual grid cells (100 m size)

Balancing the amount of water for every grid cell based on the water balance equation:

$$p + q_{in} = et_a + q_t + (s_2 - s_1)$$

Calculation of the actual evapotranspiration based on the Penman-Monteith-equation, **site-specific parameters and site-specific functions**:

$$et_a = et_0 \cdot k_{LN} \cdot f(\beta, \gamma) \cdot \boxed{f(s)}$$

BOWAB for sites with vegetation	impervious surface	… *expandable*

function $f(s)$ is defined differently for different sites

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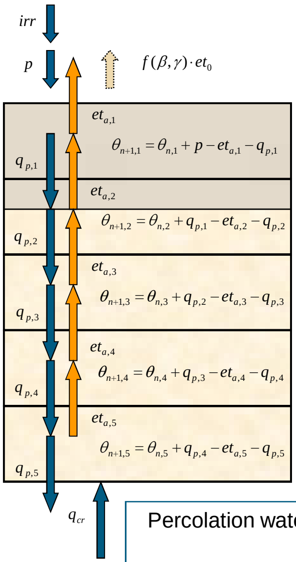
Soil water content simulation in daily time steps



$$et_{a,1}=\left(p-\left(p-et_{max}\right)\cdot S_1(\theta)\right)\cdot A_1$$
$$q_{p,1}=\begin{cases}0 & \text{für } \theta_1\le FK_1\\ \theta_1-FK_1 & \text{sonst}\end{cases}$$
$$et_{a,2}=et_{max}\cdot S_2(\theta)\cdot A_2$$
$$q_{p,2}=\begin{cases}0 & \text{für } \theta_2\le FK_2\\ \theta_2-FK_2 & \text{sonst}\end{cases}$$
$$et_{a,3}=et_{max}\cdot S_3(\theta)\cdot A_3$$
$$q_{p,3}=\begin{cases}0 & \text{für } \theta_3\le FK_3\\ \theta_3-FK_3 & \text{sonst}\end{cases}$$
$$et_{a,4}=et_{max}\cdot S_4(\theta)\cdot A_4$$
$$q_{p,4}=\begin{cases}0 & \text{für } \theta_4\le FK_4\\ \theta_4-FK_4 & \text{sonst}\end{cases}$$
$$et_{a,5}=et_{max}\cdot S_5(\theta)\cdot A_5$$
$$q_{p,5}=\begin{cases}0 & \text{für } \theta_5\le FK_5\\ \theta_5-FK_5 & \text{sonst}\end{cases}$$

Percolation water rate per cell and day
=
Total runoff per cell

- Automated structuring of grids displaying vegetation in variable soil layers (at present 5 layers, 3 dm thickness each).
- Automated Parameterization of model layers based on mapped soil profiles (determination of „effective field capacity, field capacity, etc.)

1. Determination of p and et_0
2. Determination of irrigation need depending on soil moister content in the root zone (optional)
3. Calculation of capillary rise rate depending on soil moisture tension
4. Calculation of actual evapotranspiration depending on soil moisture and rooting depth.
5. Calculation of the percolation water rates between the 5 individual layers and out of the root zone (simplified overflow model)
6. Re-calculation of water balance per layer

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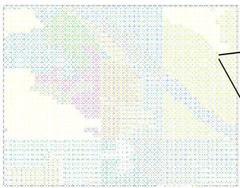
mGROWA – New implementation of snow storage

[Snow water equivalent]



Landscape with snow cover

Balancing the amount of water for every grid cell based on the water balance equation:

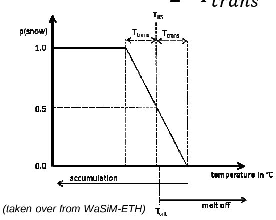
$$p+q_{in}=et_a+q_t+(s_2-s_1)$$

The storage term comprises:

- **Snow storage**
- Soil water storage

Snowfall

$$p(snow)=\frac{T_{RS}+T_{trans}-T}{2\cdot T_{trans}}$$



(taken over from WaSiM-ETH)

Evaposublimation

$$es_a=et_0\cdot c_t\cdot c_{snow}$$

Melting and refreezing

$$M_{pos}=DDF\cdot(T-T_{crit})$$

Solid and liquid water storage of the snowpack

$$Max_{liq}=c_1\cdot(SWC_{solid}+SWC_{liq})$$

Surplus melt water is running off q_{sp}

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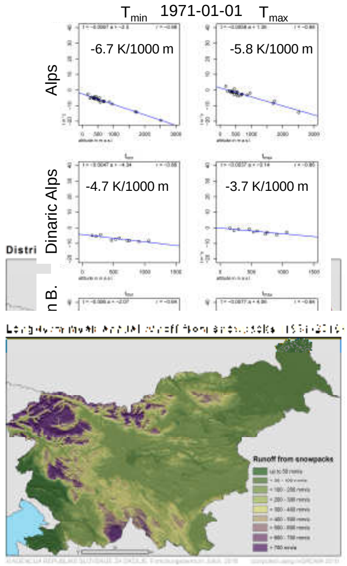
Snowpack simulation in daily time steps

- Zonal estimation of air temperature lapse rates (i.e. relation between temperature and ground elevation)
- Interpolation of temperature fields based on observed station-based temperature values and the estimated lapse rates
- Calculation of snowfall from precipitation and temperature fields, i.e. separation into rain and snow
- Calculation of evaposublimation from snowpack using distributed evaposublimation-factors
- Calculation of snow melting using the temperature-index approach and distributed degree-day factors
- Calculation of refreezing of liquid water (snowpack metamorphism)
- Recalculation of liquid and solid water content in the snowpack
- If liquid water content exceeds the liquid water storage capacity of the snowpack, then snowmelt runoff is calculated and separated into a surface and a subsurface part



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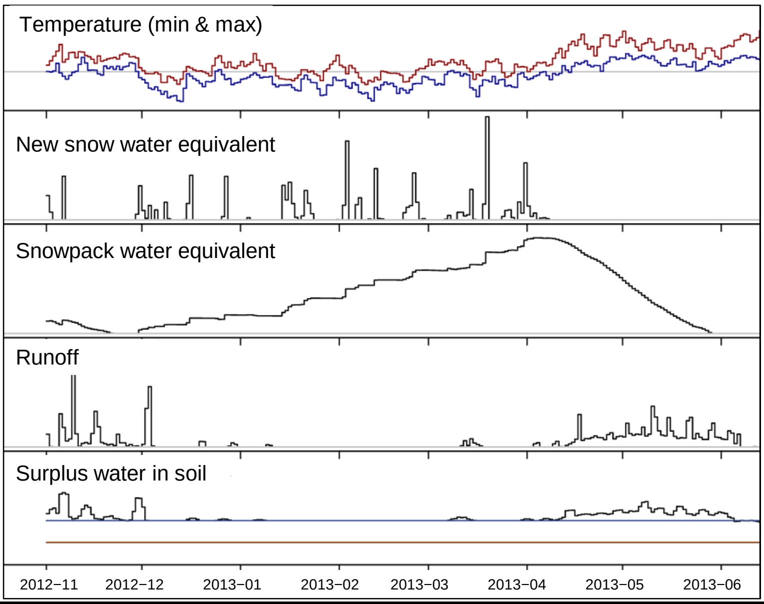
Example – Site in high altitudes of the Alps in 2013



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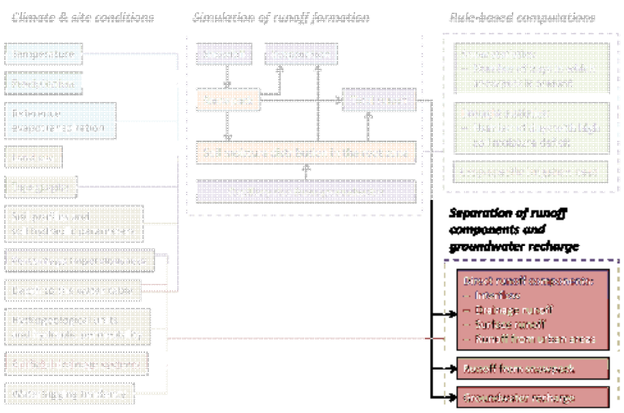
Data basis and general modelling scheme of the mGROWA model



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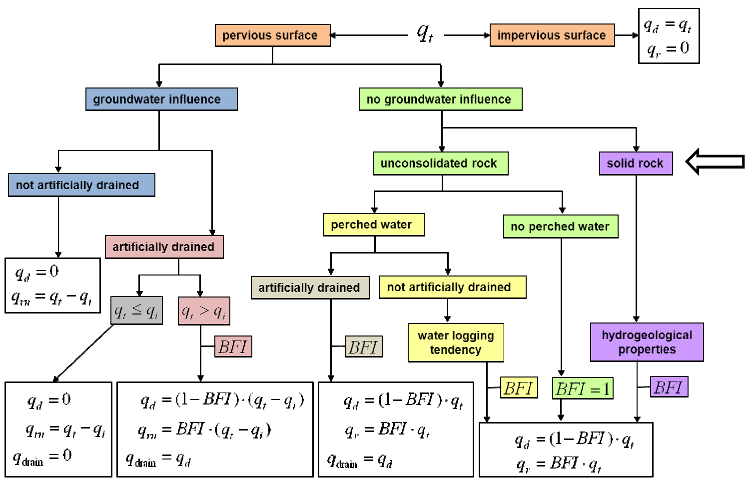
Site characteristics that determine groundwater recharge in mGROWA



Dominating site condition in Slovenia

q_t	total runoff	q_{rn}	net groundwater recharge	BFI	base flow index
q_d	direct runoff	q_{drain}	drainage runoff		
q_r	groundwater recharge	q_i	influx (e.g. capillary rise)		

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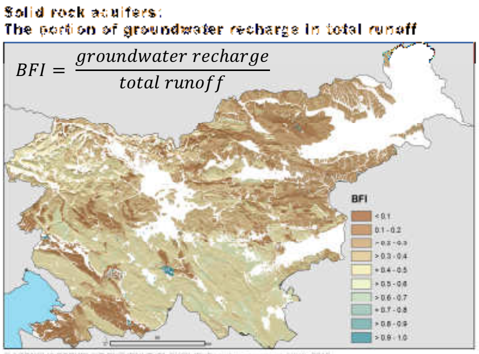
Distributed BFI values in Slovenia



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High BFI values >0.6:

- Mainly unconsolidated rock areas in the lowlands
- The groundwater path is the dominant runoff pathway
- High water storage capacity of aquifers

Moderate BFI values 0.6 .. 0.4:

- Mainly karstified rock areas
- Aquifers show spatially highly varying permeabilities
- The subsurface path is the dominant runoff pathway but composed of fast and slow portions (short and long residence times)
- Short-term storage capacity for fast sub-surface runoff is high and the long-term storage capacity for slow components is low

Low BFI values <0.4:

- Mainly fractured rock areas
- Direct runoff (overland flow, interflow) is the dominant runoff pathway
- Low water storage capacity of aquifers

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Rezultati mGROWA v obdobju 1981-2010

mGROWA results for the reference period 1981-2010

Peter Frantar, Gregor Gregorič

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mGROWA – Overview of grid output

Groups	Quantities	Temporal resolution	Symbol
General water balance	Total evaporation	Monthly & daily	eta
	Total runoff (formation)	Monthly & daily	q
	Inflow over system boundaries consisting of capillary rise from shallow groundwater and vaporised water from free water surfaces	Monthly	e
Snowpack	New snow water equivalent	Monthly & daily	nswe
	Evapo-sublimation from snow surface	Monthly	es
	Snowpack water equivalent	Daily	spwe
Storage statistics	Number of days in which snowpack is present	Month ... Decades	spd
	Number of days with soil water deficit above a threshold	Month ... Decades	ndswd
	Maximum number of consecutive days with soil water deficit above a threshold	Month … Decades	mdswd
Irrigation	Cumulated irrigation need according to crop-specific irrigation rules	Monthly	mi

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mGROWA – Overview of grid output

Groups	Quantities	Temporal resolution	Symbol
Runoff components & balances	Net total runoff (total runoff minus inflow over system boundaries)	Monthly	qn
	Climatic water balance	Monthly	cwb
	Runoff from snowpack (snowmelt)	Monthly & daily	qsp
	Runoff from impervious surfaces (e.g. paved areas in cities)	Monthly	qu
	Runoff from artificial drainage systems in agriculture	Monthly	qad
	Direct runoff (including surface runoff)	Monthly	qd
	Net groundwater recharge	**Monthly**	**qrn**
Identification of groundwater recharge	Proportion of groundwater recharge in total runoff	Monthly	bfi
	Site characteristic that determine groundwater recharge	Monthly	scc

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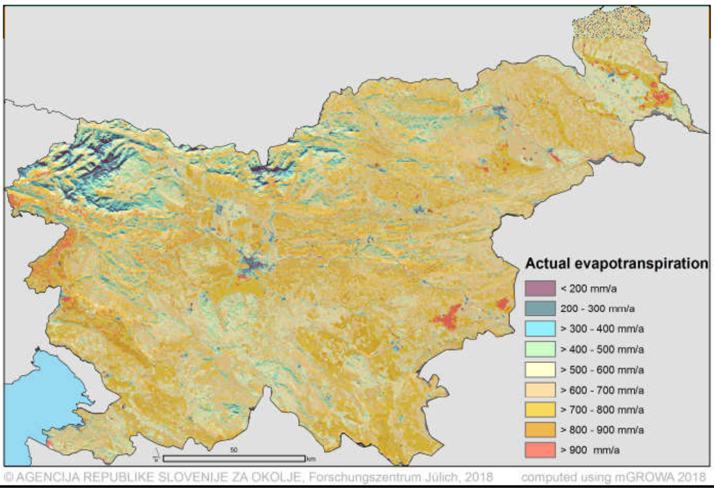
Long-term mean annual actual evapotranspiration (1981-2010)



Countrywide mean value: **620 mm/a**

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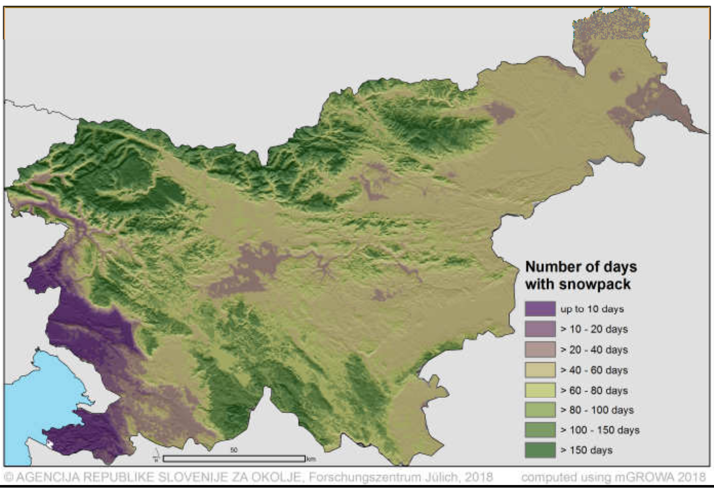
Long-term mean annual number of days in which snowpack is present (1981-2010)



Countrywide range: **1 - 360 days**

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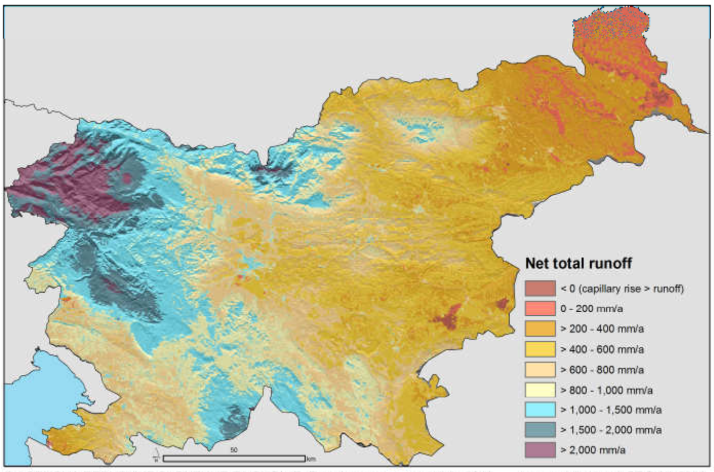
Long-term mean annual total runoff (1981-2010)



Countrywide mean value: **790 mm/a**

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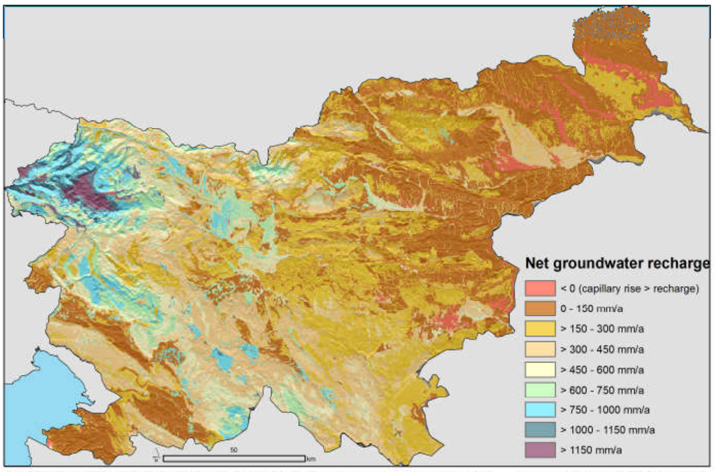
Long-term mean annual groundwater recharge (1981-2010)



Countrywide mean value: **305 mm/a**

Note:
Countrywide mean of groundwater recharge calculated with GROWA (1971-2000) was **304 mm/a**

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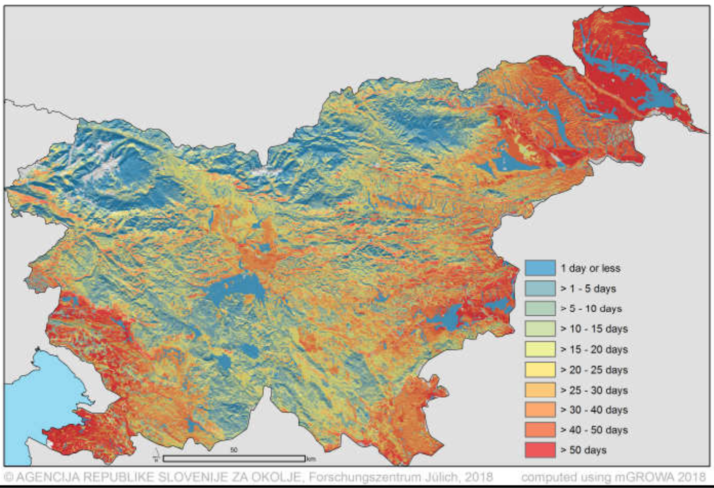
Long-term mean number of days with soil moisture deficit above 60 % during summer half-year (1981-2010)



Countrywide mean of arable land: **39 days**

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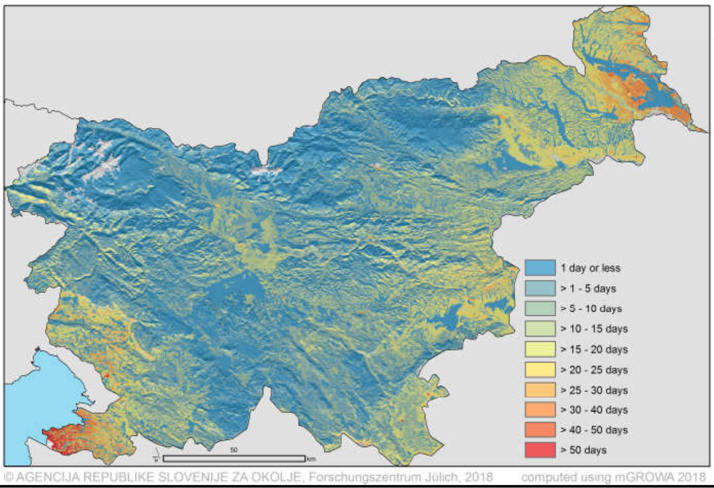
Long-term mean number of days with soil moisture deficit above 80 % during summer half-year (1981-2010)



Countrywide mean of arable land: **16 days**

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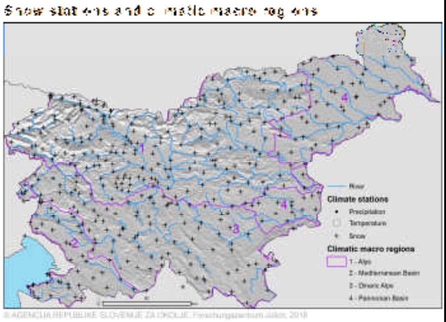
Evaluation of model performance on the country-level

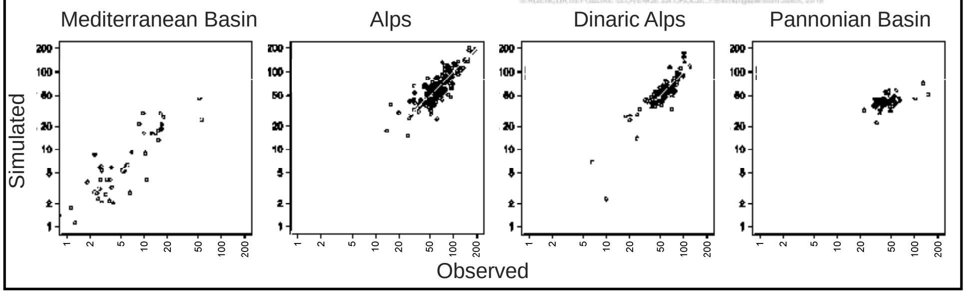
Long-term mean annual number of days with snowpack (1981-2010)

Evaluation data basis:

- 419 Stations in Slovenia with the information snowpack or no snowpack

No significant tendency to over- or underestimation in Alps, Dinaric Alps and Pannonian Basin





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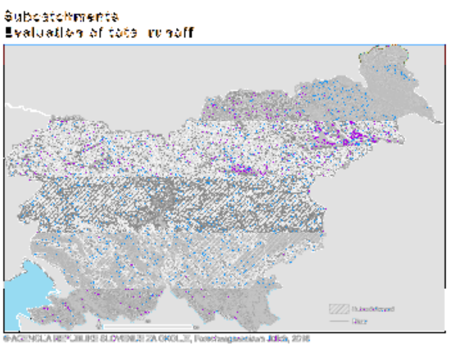
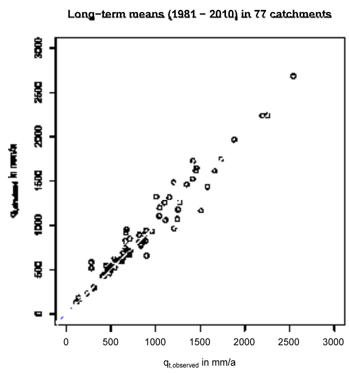
Evaluation of model performance on the country-level

Total runoff (1981-2010)

Evaluation data basis:

- 77 streamflow records
- Comparison of long-term mean annual values





- Very good match of observed and simulated total runoff on the country-level
- Very slight tendency to underestimation indicated by PBIAS = 3%

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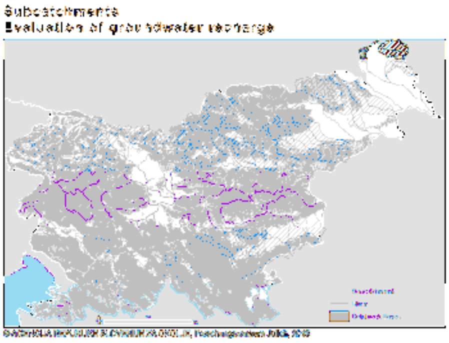
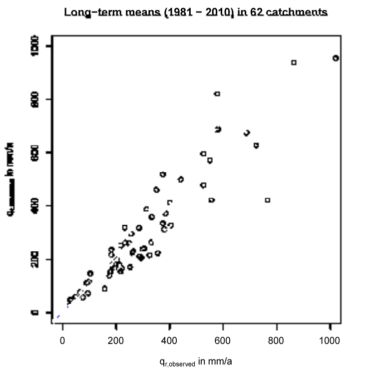
Evaluation of model performance on the country-level

Groundwater recharge (1981-2010)

Evaluation data basis:

- 62 streamflow records
- Calculation of “observed” base flow using the methods of Wundt (unconsolidated rock zones) and Demuth (soil rock zones)





- Good match of calculated base flow and simulated groundwater recharge on the country-level
- Slight tendency to underestimation indicated by PBIAS = 9 %

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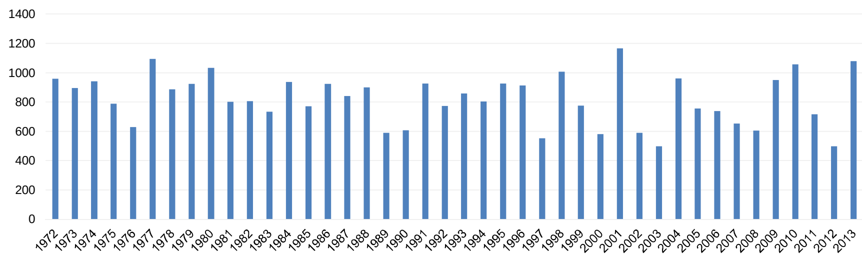
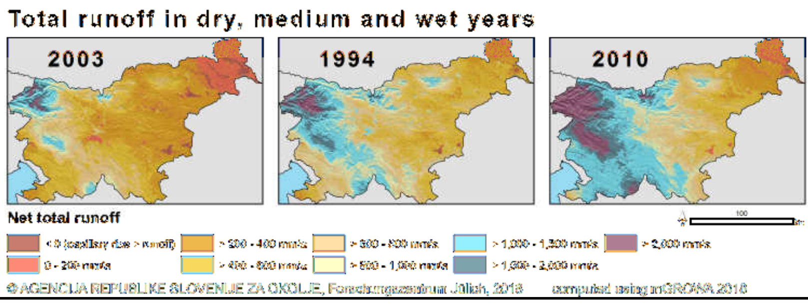
Interannual variability of total runoff

Total runoff / Skupni odtok – Slovenia [mm]





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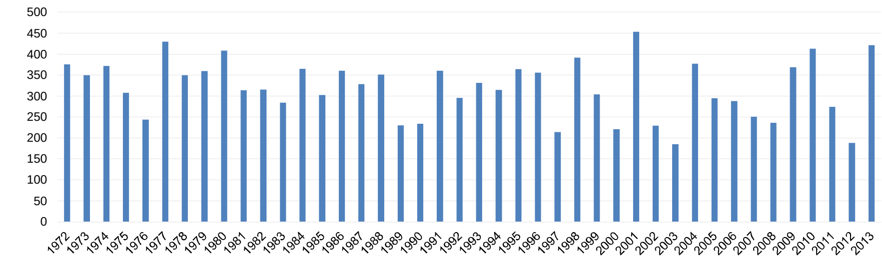
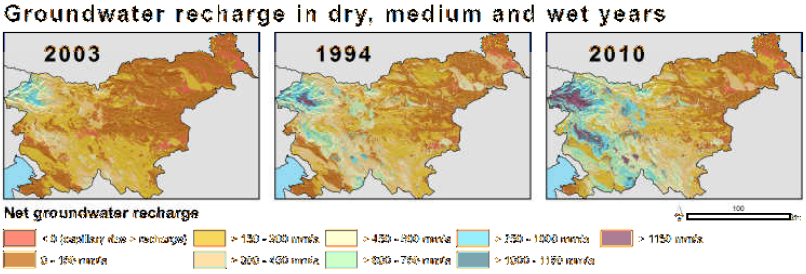
Interannual variability of groundwater recharge

Groundwater recharge / Napajanje podzemne vode – Slovenia [mm]



Groundwater recharge in dry, medium and wet years



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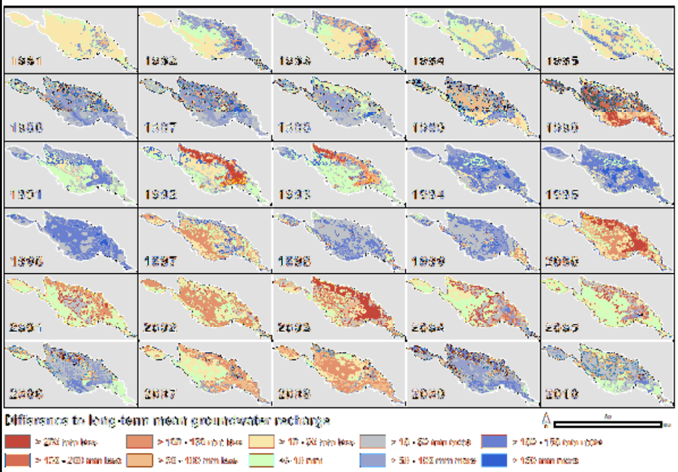
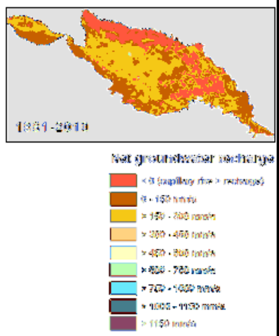
Interannual variability of groundwater recharge in the Murska kotlina groundwater body





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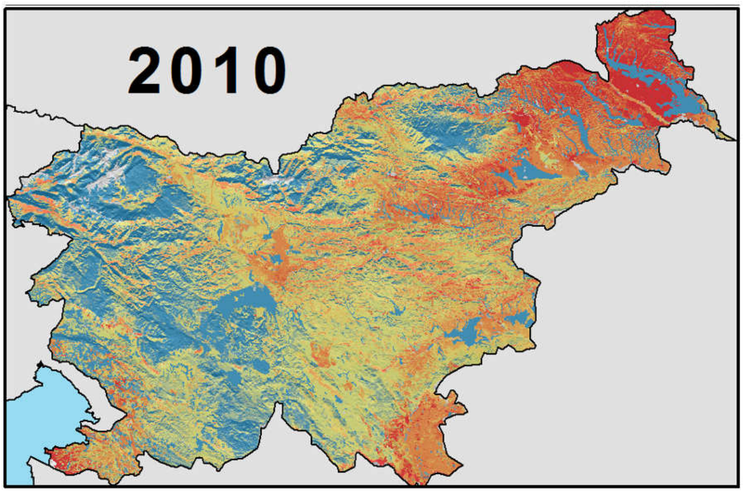
Interannual variability of number of days with soil moisture deficit above 60 % during summer half-year



1 day or less | > 5 - 10 days | > 15 - 20 days | > 25 - 30 days | > 40 - 50 days
> 1 - 5 days | > 10 - 15 days | > 20 - 25 days | > 30 - 40 days | > 50 days

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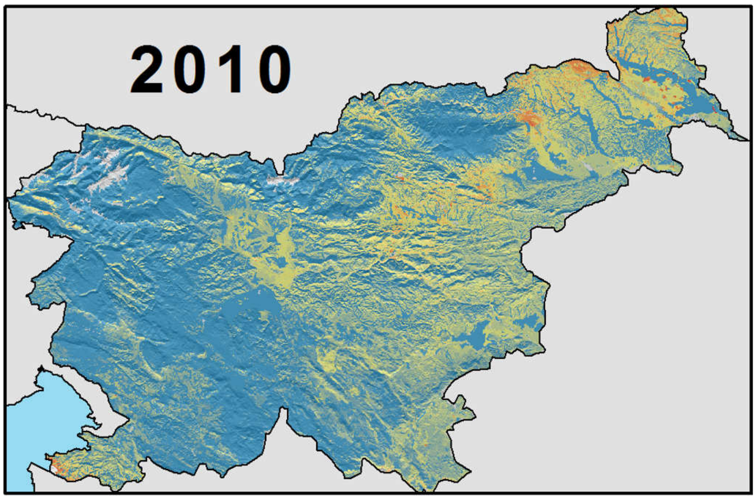
Interannual variability of number of days with soil moisture deficit above 80 % during summer half-year



1 day or less | > 5 - 10 days | > 15 - 20 days | > 25 - 30 days | > 40 - 50 days
> 1 - 5 days | > 10 - 15 days | > 20 - 25 days | > 30 - 40 days | > 50 days

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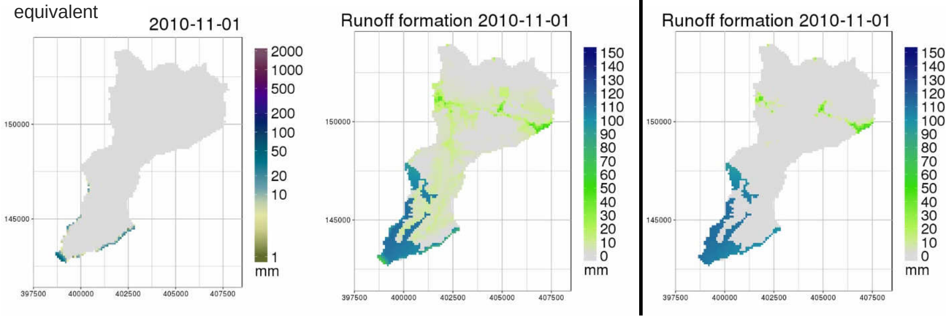
Influence of snowpack on runoff formation Sava Dolinka – Kranjska Gora

Snowpack water equivalent

Snow module activated | Snow module deactivated



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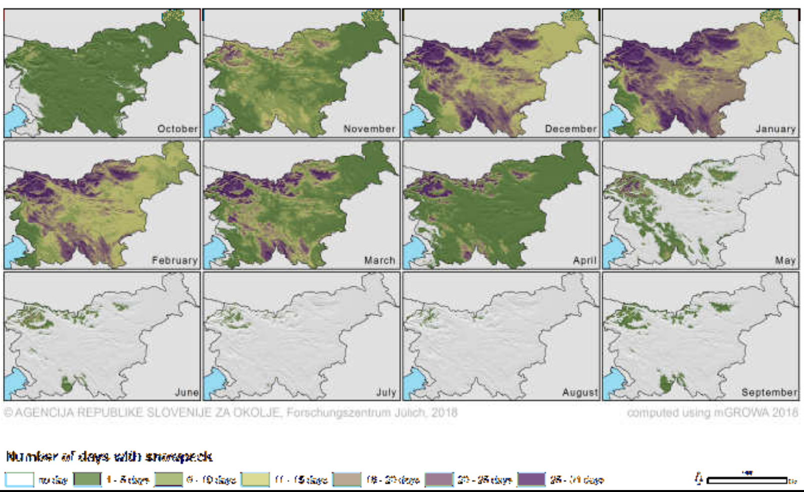
Annual cycle of snow cover:

Long-term mean monthly number of days in which snowpack is present (1981-2010)



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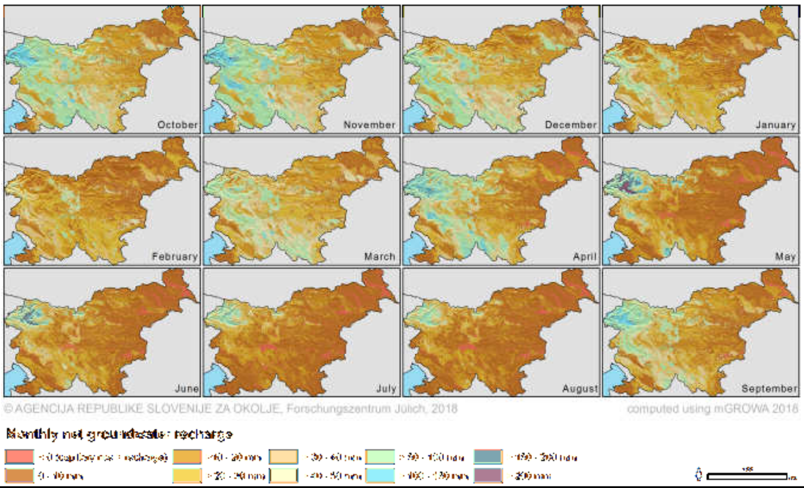
Annual cycle of Groundwater recharge:

Long-term mean monthly groundwater recharge (1981-2010)



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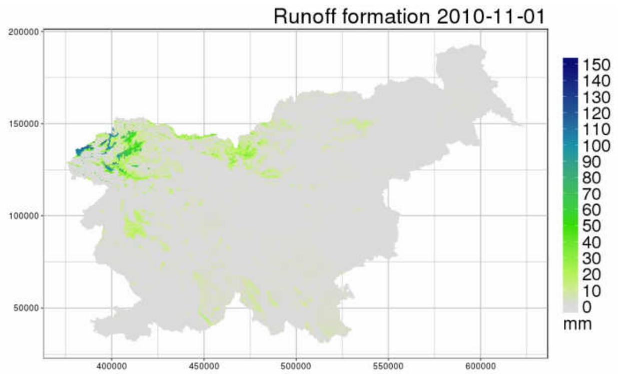
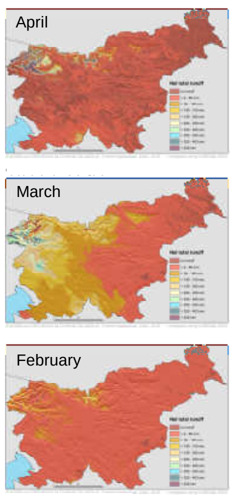
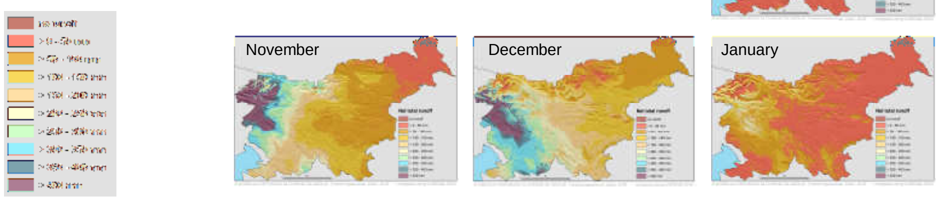
Runoff formation in winter 2010/2011







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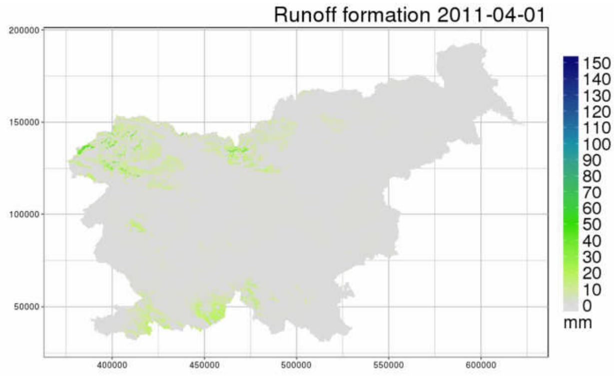
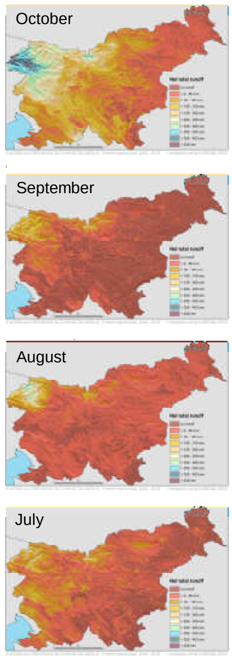
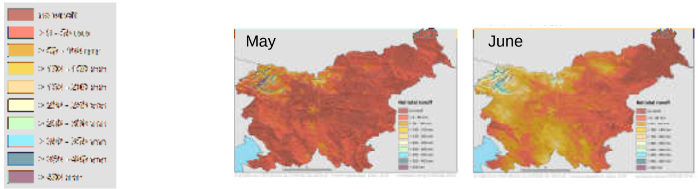
Runoff formation in summer 2011







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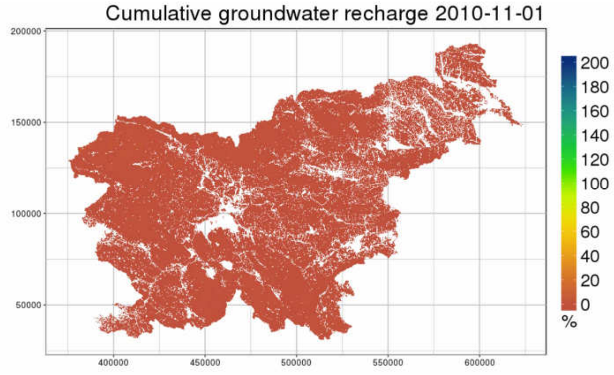
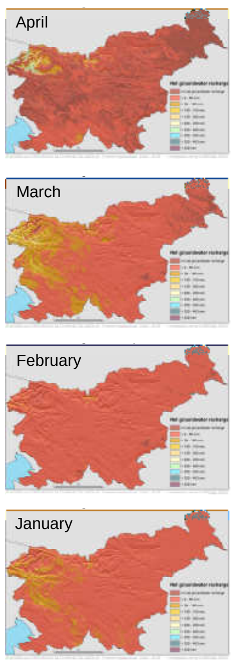
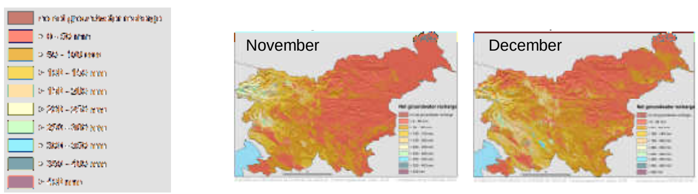
Groundwater recharge in winter 2010 in % of longterm mean 1981-2010







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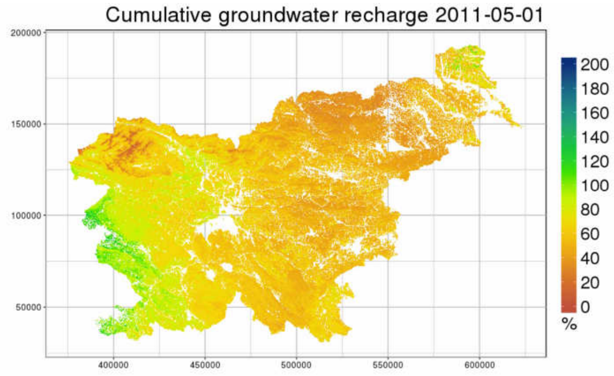
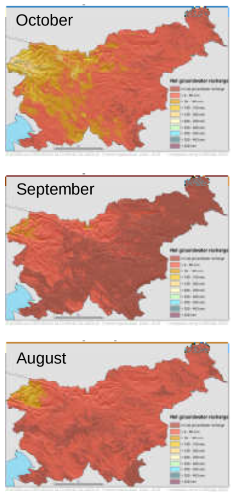
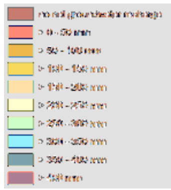
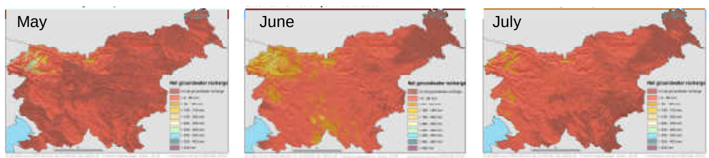
Groundwater recharge in summer 2011 in % of longterm mean 1981-2010









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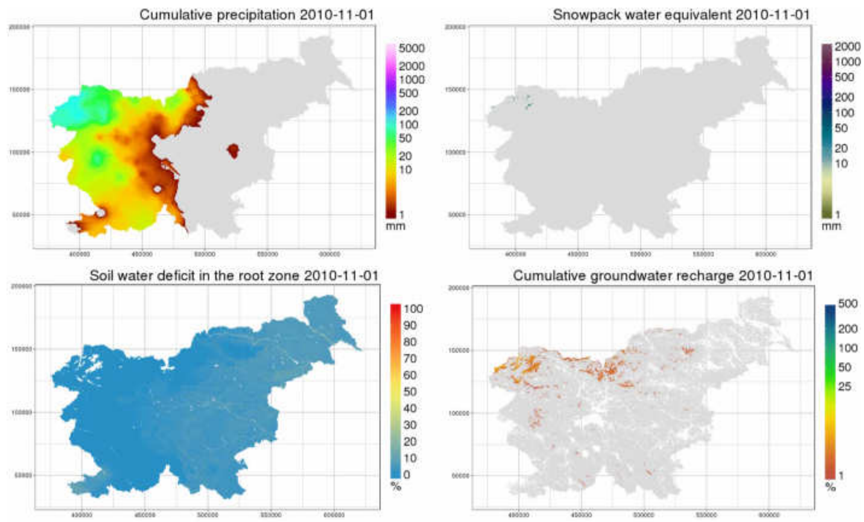
Progression of precipitation, snowpack, soil water deficit and groundwater recharge within the year 2011



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mGROWA – Overview of single cell output

File type	Content description	Variables & Parameters
cpDaySnow	Daily snow data	– Min & max temperature – Relevant temperature for snow melt – Altitude – Melt factor – Snowpack water equivalent – Runoff from snowpack – Dry and solid snow storage – …
cpDayValues	Water balance values in daily time steps (integrated over all layers)	– Precipitation – Reference evapotranspiration – Actual evapotranspiration – Min & max temperature – New Snow water equivalent – Plant available water content in the root zone – …
cpDayWaterContent	Layer-specific daily soil water storage status	– Water content – Consumption for actual evapotranspiration – Soil water pressure head – …

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mGROWA – Overview of single cell output

File type	Content description	Variables & Parameters
cpMonthParameter	Parameter on a monthly basis	– Land use ID – Soil profile ID – Percentage imperviousness – Topography factor – …
cpMonthValues	Water balance values in monthly time steps	– Precipitation – Reference evapotranspiration – Actual evapotranspiration – Total runoff formation – Runoff from impervious urban areas – Sum of capillary rise from groundwater – …

cpMonthValuesRunoff	Runoff component values in monthly time steps	– Net groundwater recharge
		– Direct runoff
		– …
		– Runoff relevant site conditions:
		    – Depth to water table
		    – BFI of hard rock unit
		    – …

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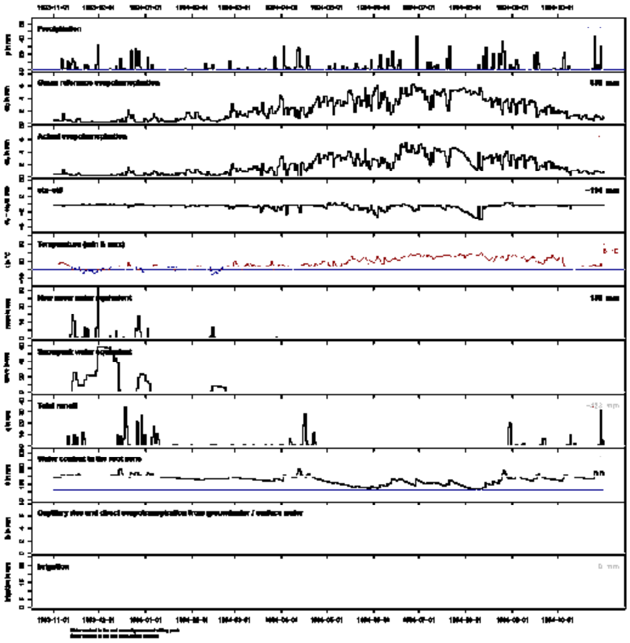
mGROWA example of single cell output

Agricultural site in the east of Slovenia

year 1994



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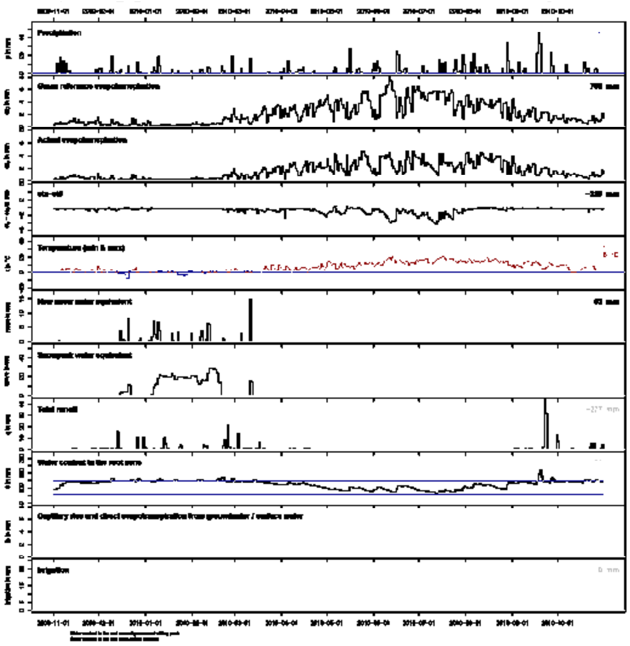
mGROWA example of single cell output

Agricultural site in the east of Slovenia

2010 (wet year)



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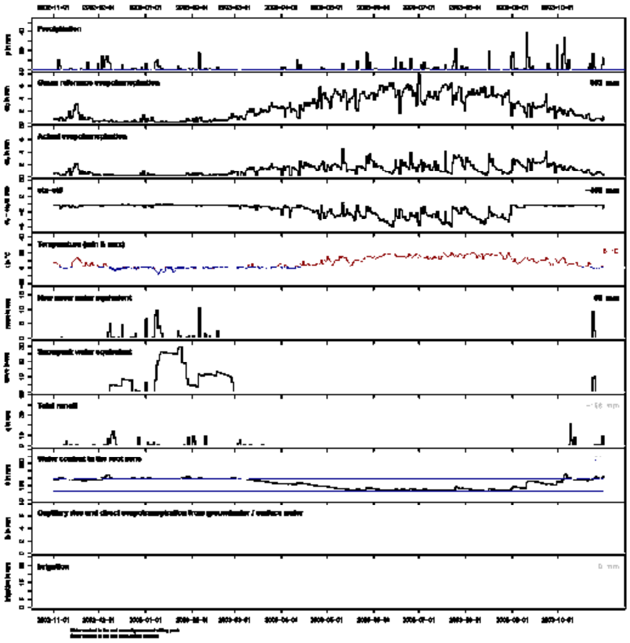
mGROWA example of single cell output



Agricultural site in the east of Slovenia

2003 (dry year)

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mGROWA single column model (SCM) setup

Motivation:

Agrometeorological applications are typically limited to single field setups of crop/soil combinations with near/on-field meteorological measurements.

Calibrated model is needed for drough aftermath studies as well as for irrigation optimization and forecasting

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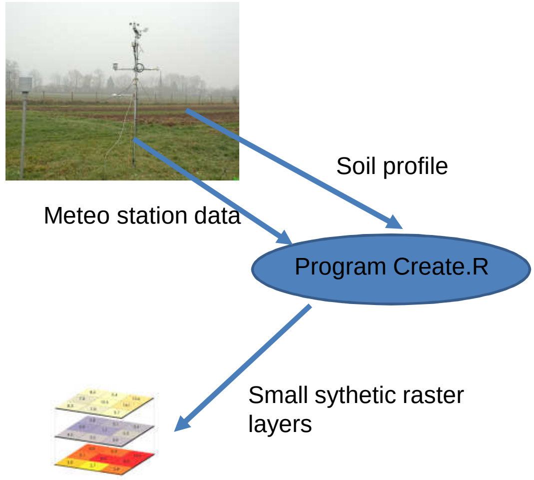
mGROWA single column model (SCM) setup

Solution:

A program was created to prepare small input rasters with one calculation point.

Input: single station data time series, single soil profile

Output: control point (cp) file



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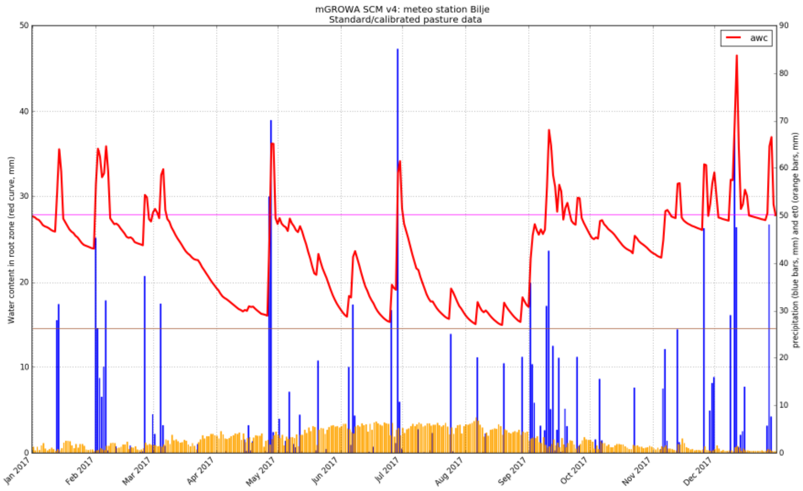
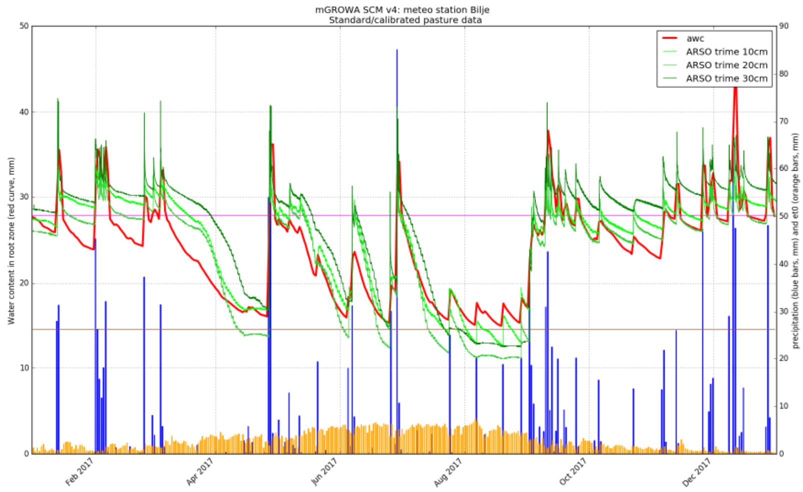
mGROWA SCM examples



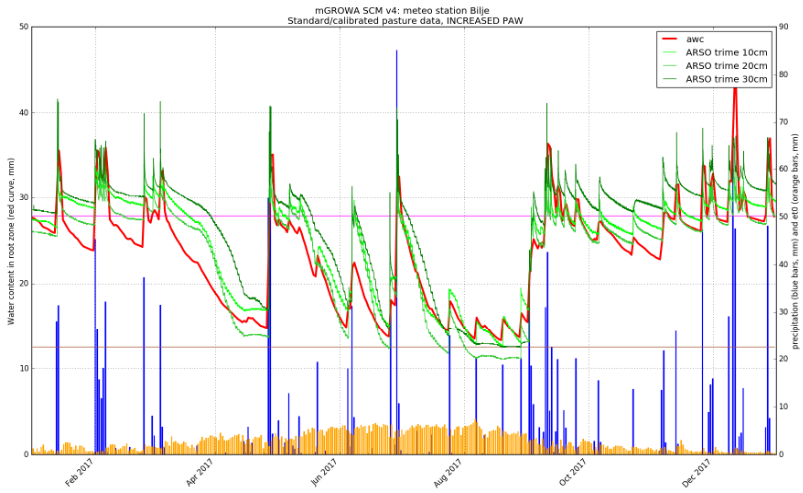
ax1.legend()

mGROWA SCM examples



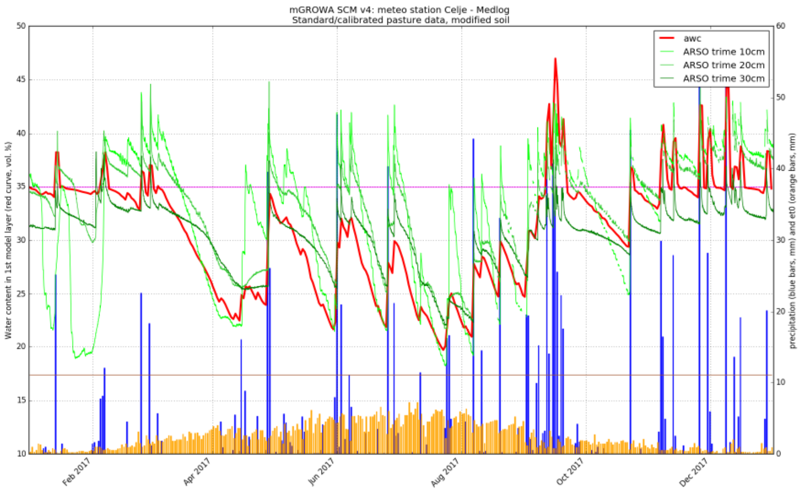
ax1.legend()

mGROWA SCM examples



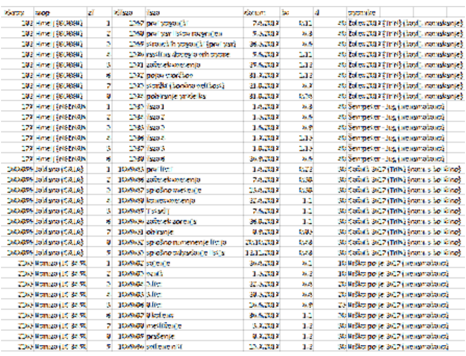
ax1.legend()

mGROWA SCM examples



ax1.legend()

mGROWA SCM future work:



Interface to agromet/phenological database

GROWA SCM daily update

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Scenariji vplivov podnebnih sprememb na vodno bilanco Slovenije

Projection of possible climate change impact on the water balance in Slovenia

Mojca Dolinar

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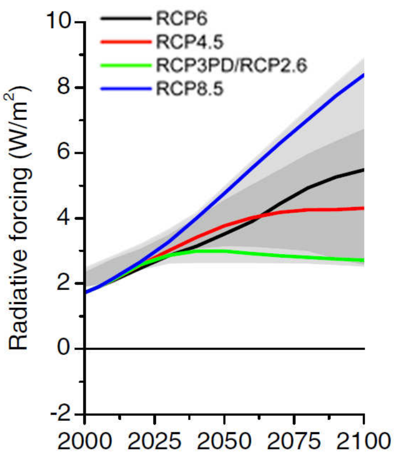
GHG scenarios

4 GHG scenarios (IPCC):
Representative Concentration Pathways – RCP



- Climate mitigation(Paris agreement)
- Population growth

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Scenarios for future water balance

- 6 regional Climate models, RCP4.5 in RCP8.5
- Spatial resolution: ~ 14 km
- Temporal resolution: day
- Input in mGROWA model:
  - Minimum, maximum and mean daily temperature
  - Precipitation
  - Reference evapotranspiration

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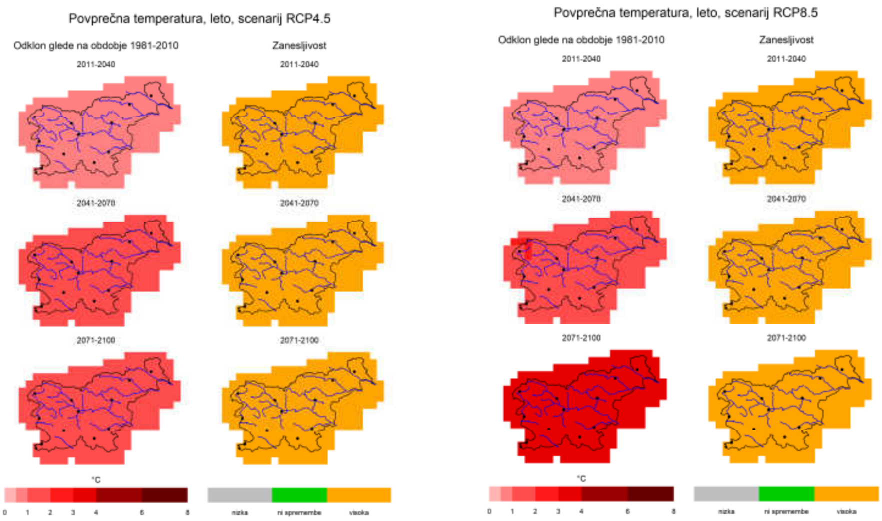
Future projections of mean temperature



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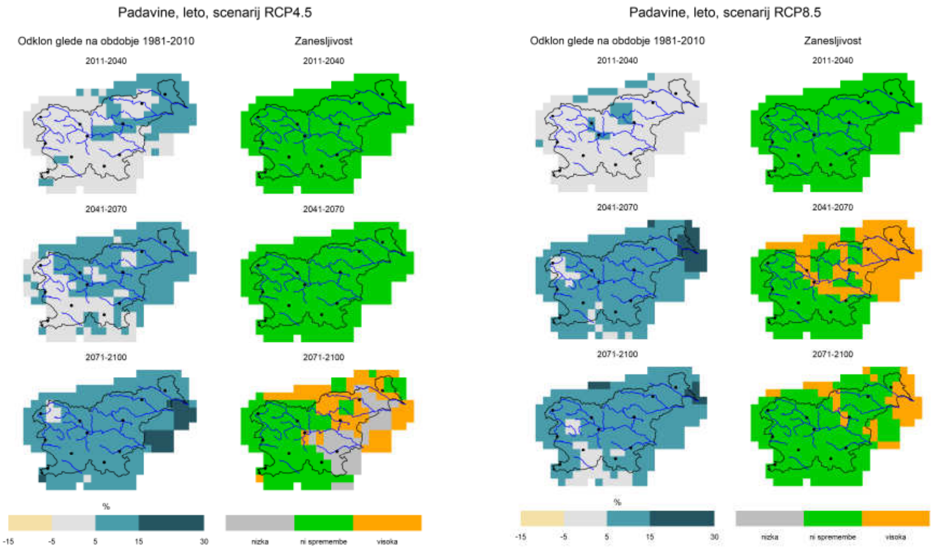
Future projections of precipitation



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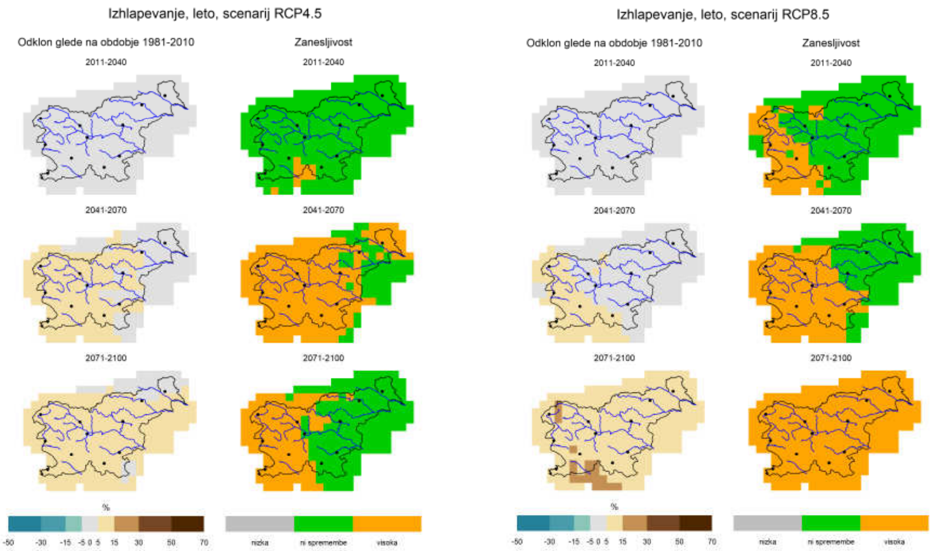
Future projections of reference evapotranspiration



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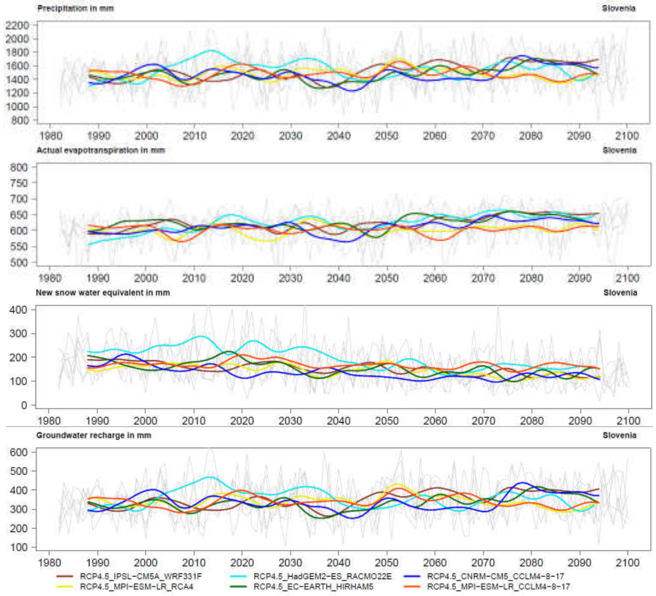
Annual time series for 6 RCM (RCP4.5)



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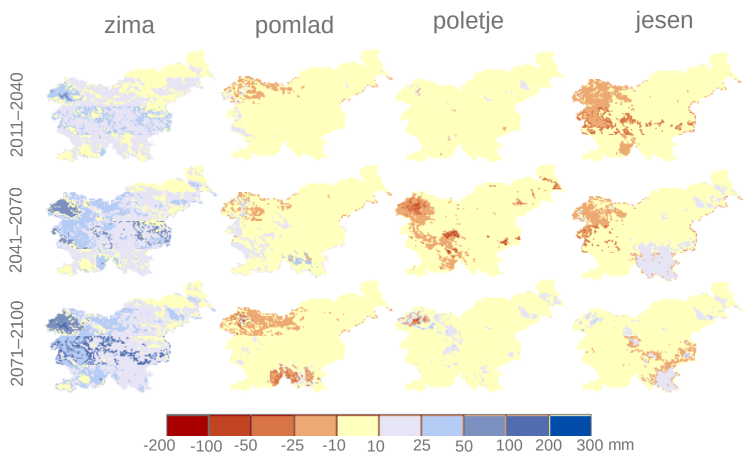
Groundwater recharge change (RCP4.5)



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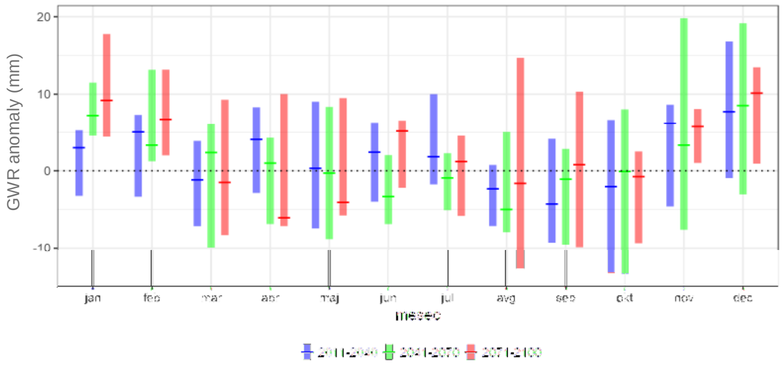
Groundwater recharge change (RCP4.5)

- 6 Regional Climate Models
- Spatial average for Slovenia



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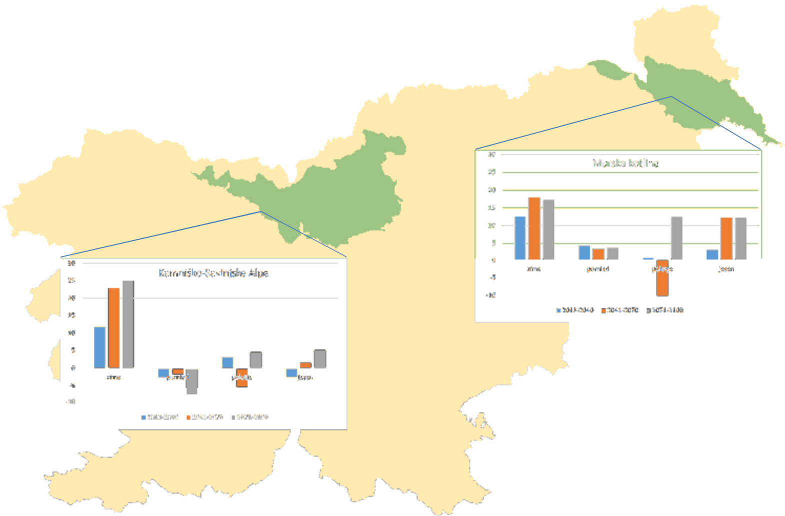
Groundwater recharge change (RCP4.5)



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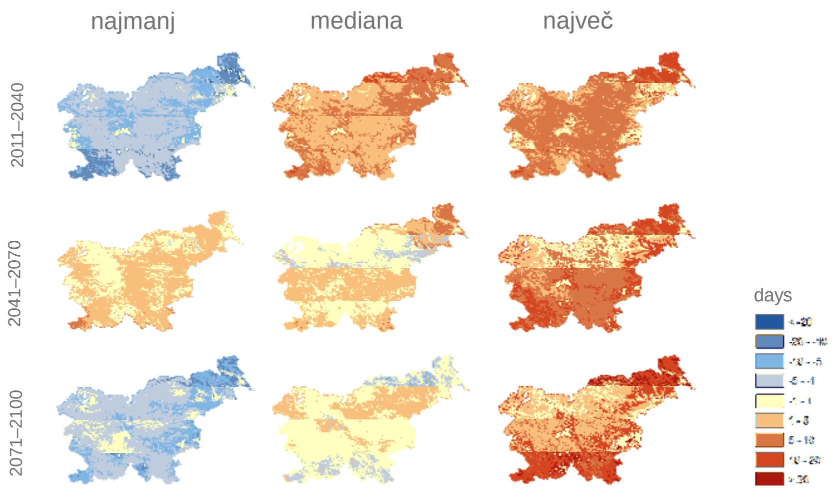
Change in number of days with soil water deficit (RCP4.5)



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Summary, conclusions & outlook

- successful continuation of research cooperation between ARSO and FZJ
- contribution from various ARSO sectors: meteo, hydro, environment,…
- improved representation of **countrywide** water balance on daily and monthly temporal scale
- newly developed and implemented snow module into mGROWA-SI
- climate change impact modelling
- implementation in ARSO at HPC

2018 & beyond

- operationalization of mGROWA-SI in ARSO
  - dissemination of results
  - exploitation of mGROWA-SI potential (enhanced drought stats,…)
- implementation into the matter flux models (nutrients, microplastics,…)
- application for joint projects (EU, …)

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Thanks for your attention !