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Future changes in water balance components across irrigated lands of Central Asia as projected by a high-resolution modeling system

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High resolution probabilistic climate projections for the Arctic, Russia and Central Asia (grid step 25 km)

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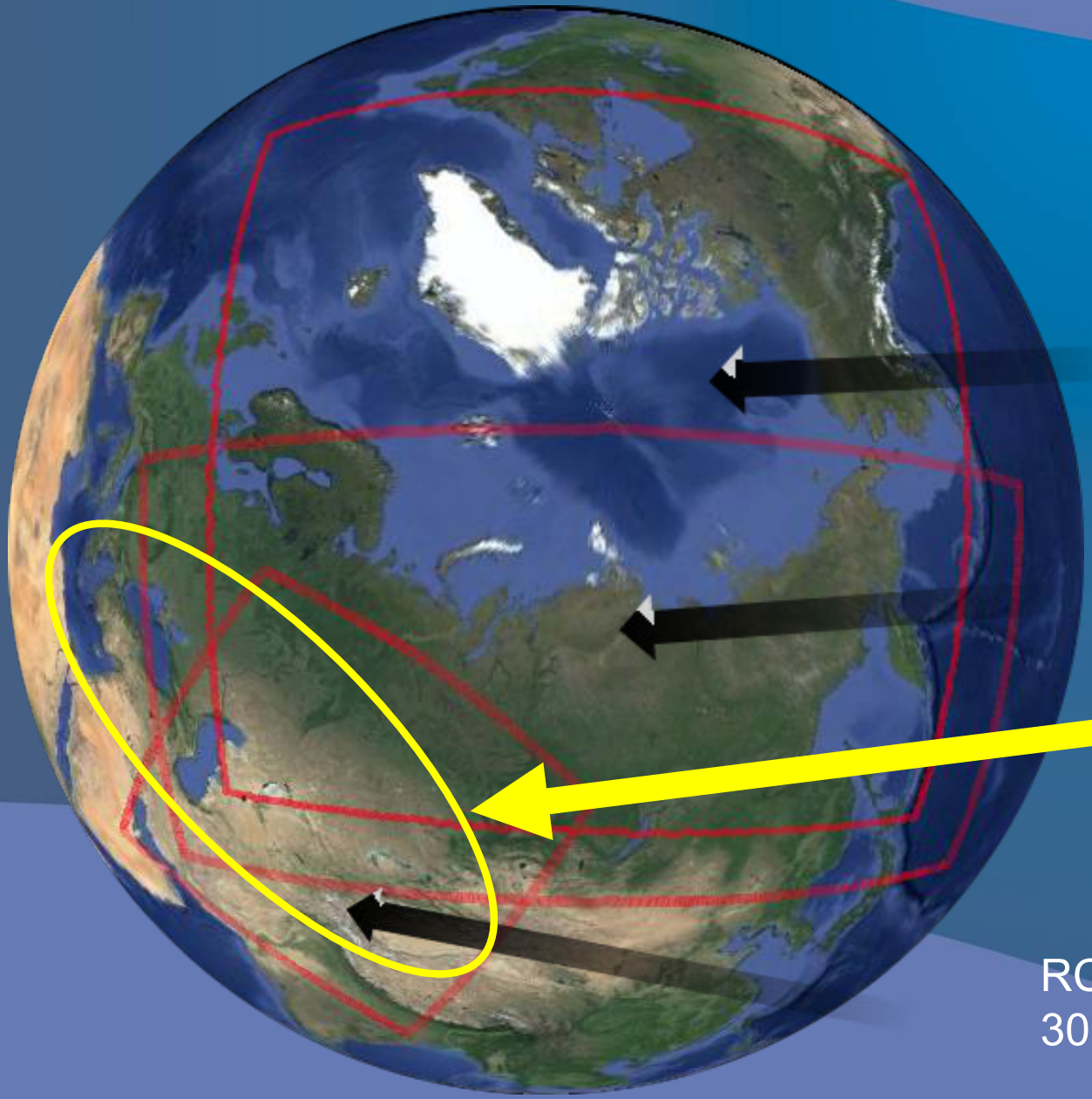

Pan-Arctic RCM
(CORDEX)

RCM for Russia
50 ensemble members

A drier climate is projected
in southwestern Russia
and Central Asia

RCM for Central Asia
30 ensemble members

Shkolnik et al 1998-2019

RCM for Russia
50 member ensemble projection + crop model

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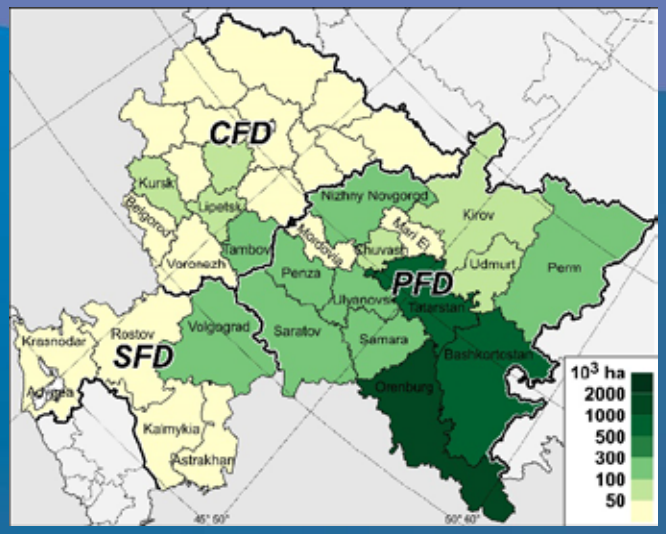
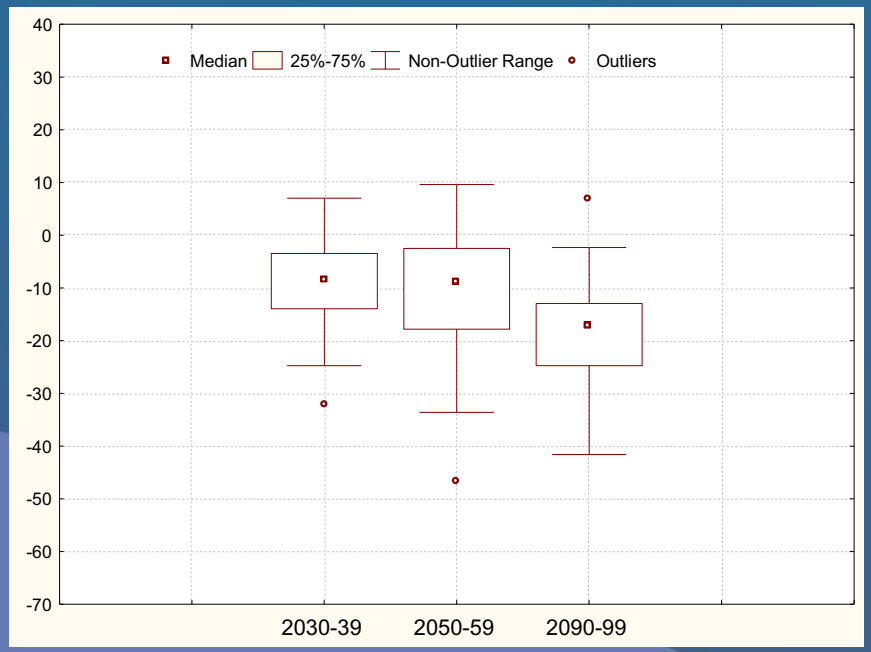
Arable land area



There projected the drop in yield of wheat



Pavlova et al 2019

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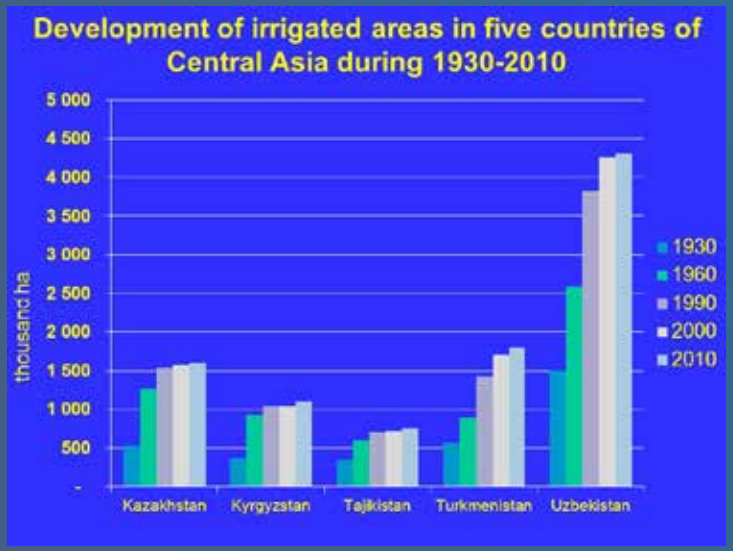
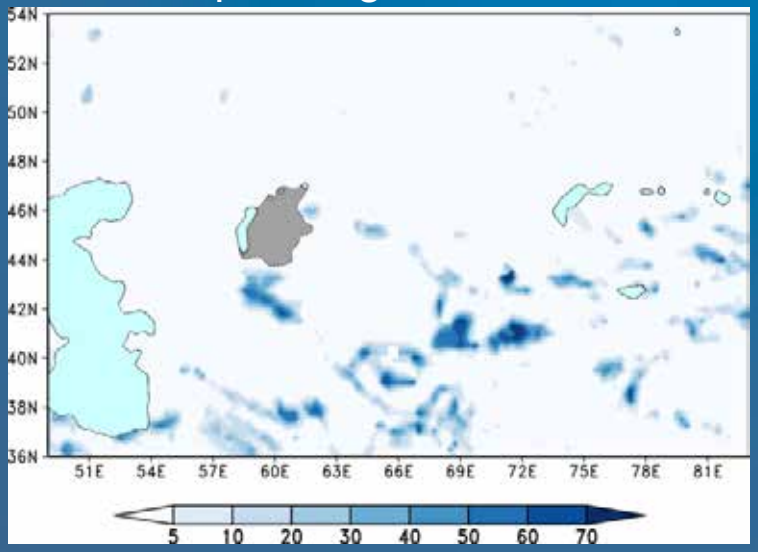
Irrigation in Central Asia is critical to sustain productivity of major crops

Area of irrigated lands in Central Asia



Nurbekov 2017

Map of Irrigation Areas



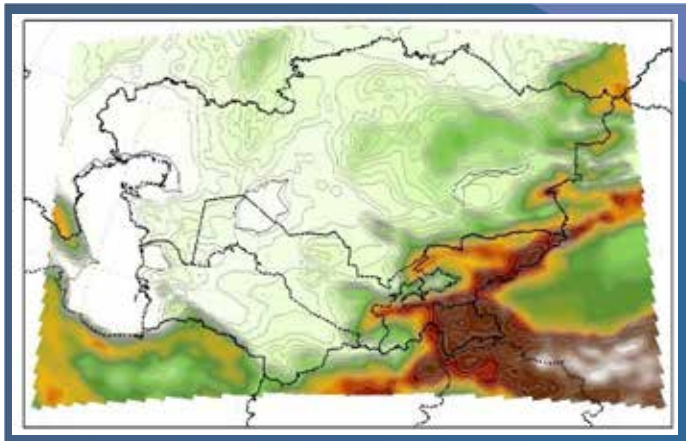
Siebert et al 2013

Major plants

cotton

wheat

Large number of small plots of land are not resolved explicitly at 25 km resolution



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Experiments

97×181 grid points in the horizontal and 25 unequally spaced levels in the vertical

30 simulations spanning 10yr slices in the past (1990-1999) and future (2050-2059) with perturbed initial conditions in the atmosphere and land surface, driven by MGO AGCM T42L25

prescribed SST/SIC evolution derived from the three CMIP5 models:
ACCESS1-0
CESM1-CAM5
MPI-ESM-MR

300 yrs of simulated climate variability (3 bc × 10 simulations × 10 yrs) for each temporal window

IPCC RCP8.5 scenario

Downscaling RCM projection using an atmospheric boundary layer model in order to describe future changes in water demand across irrigated lands during crop season (May-September)

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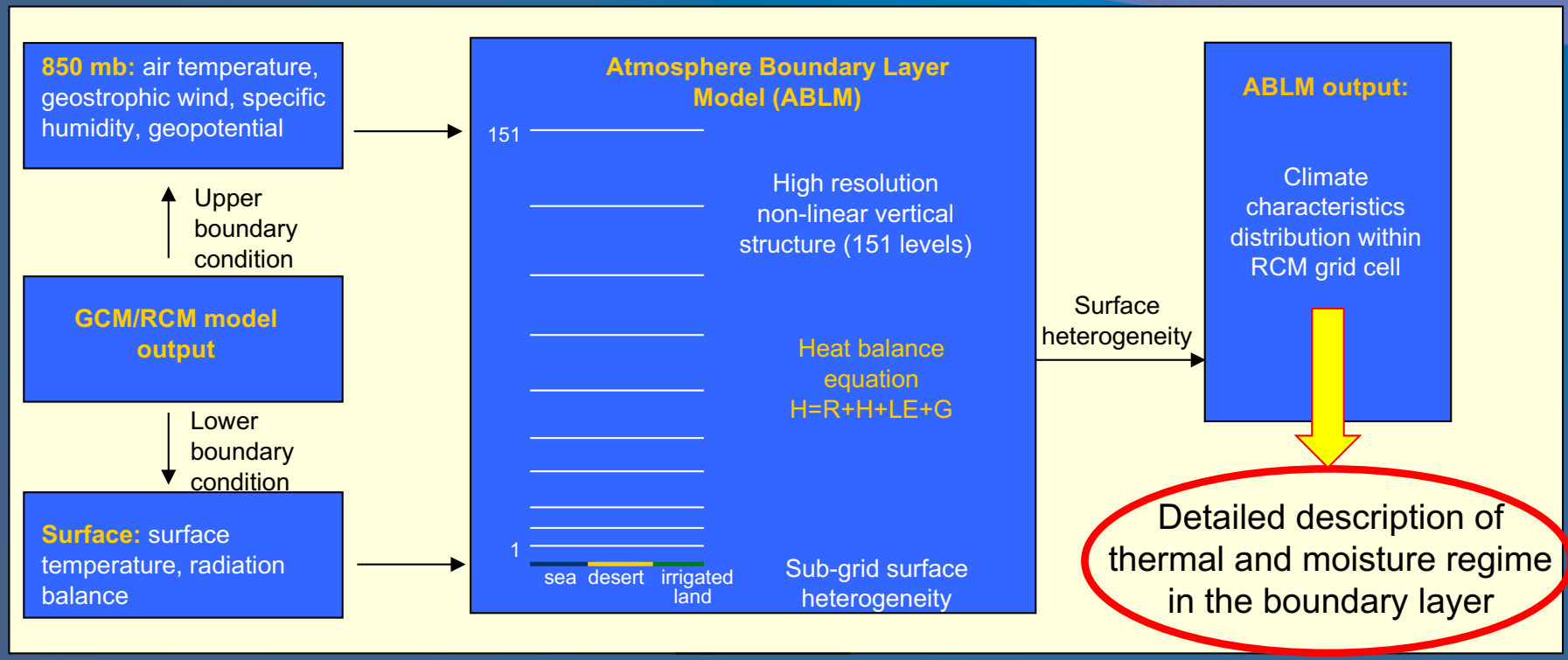
Atmosphere Boundary Layer Model (ABLM) driven by RCM



- High resolution vertical structure (151 levels)
- Two-equation turbulence model (k-ξ) is used as a closure for the Navier–Stokes equations
- Subgrid surface heterogeneity is considered
- Detailed description of the temperature and moisture distributions on scales not resolved explicitly by the RCM grid

Nadyozhina and Shklyarevich, 1994

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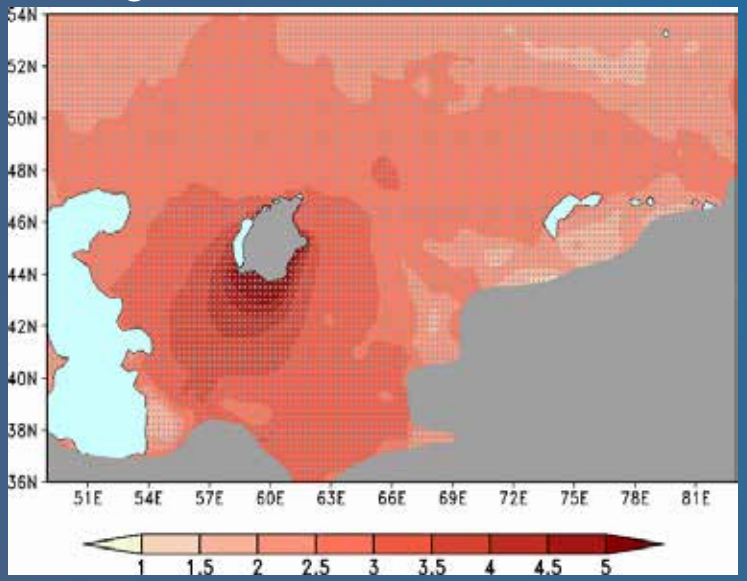
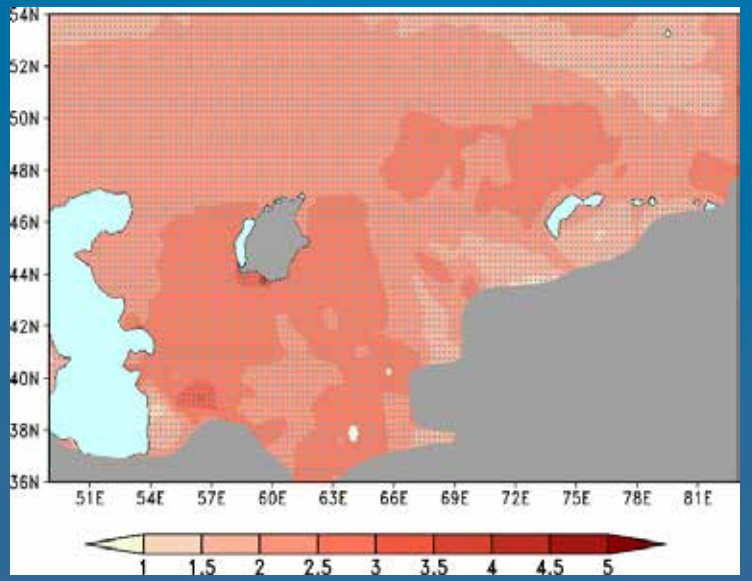
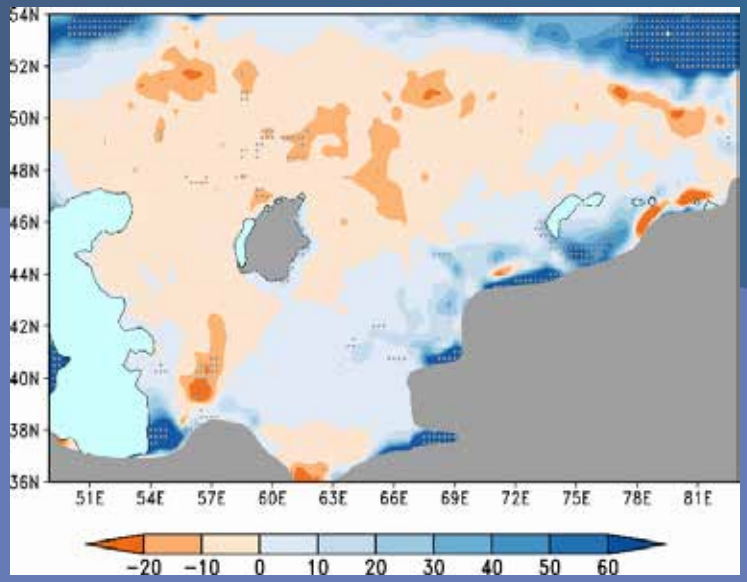
Projected changes in surface temperature and precipitation by 2050-59 relative to 1990-1999, MJJAS

T, degC, standalone RCM



T, degC, RCM+ABLM for irrigated area





P, %, standalone RCM

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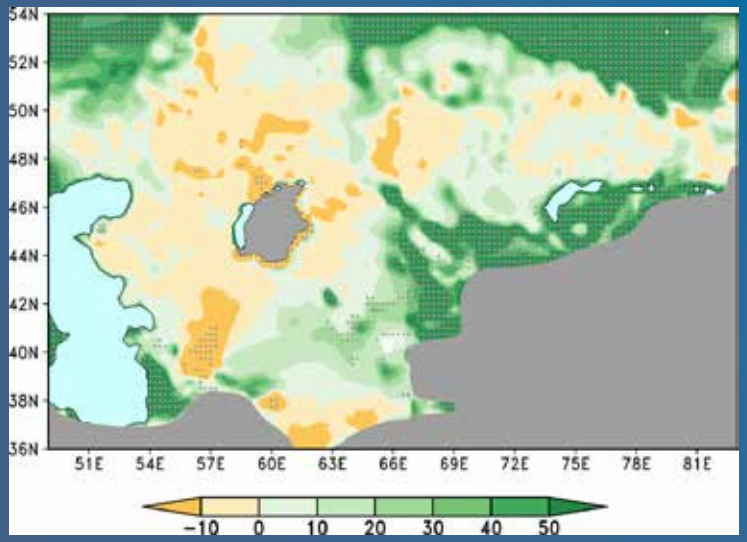
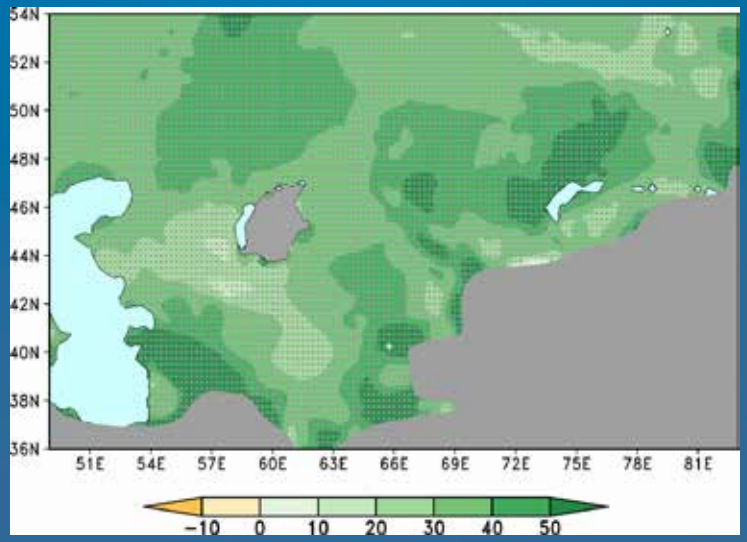
Projected changes in evapotranspiration ET and water deficit D (mm/season) by 2050-59 relative to 1990-1999, MJJAS

RCM

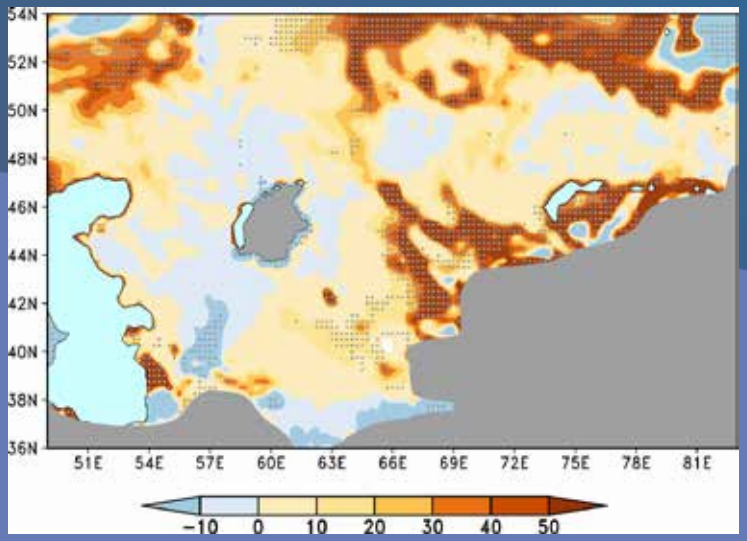
RCM+ABLM for irrigated area

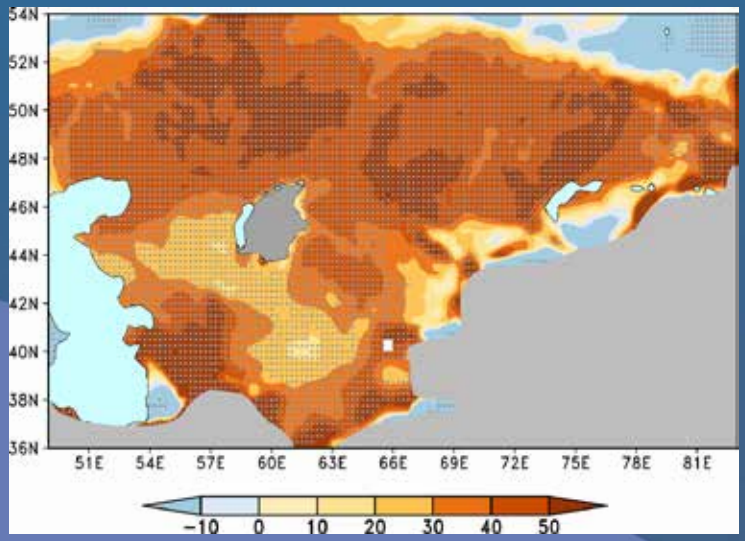
ET





D





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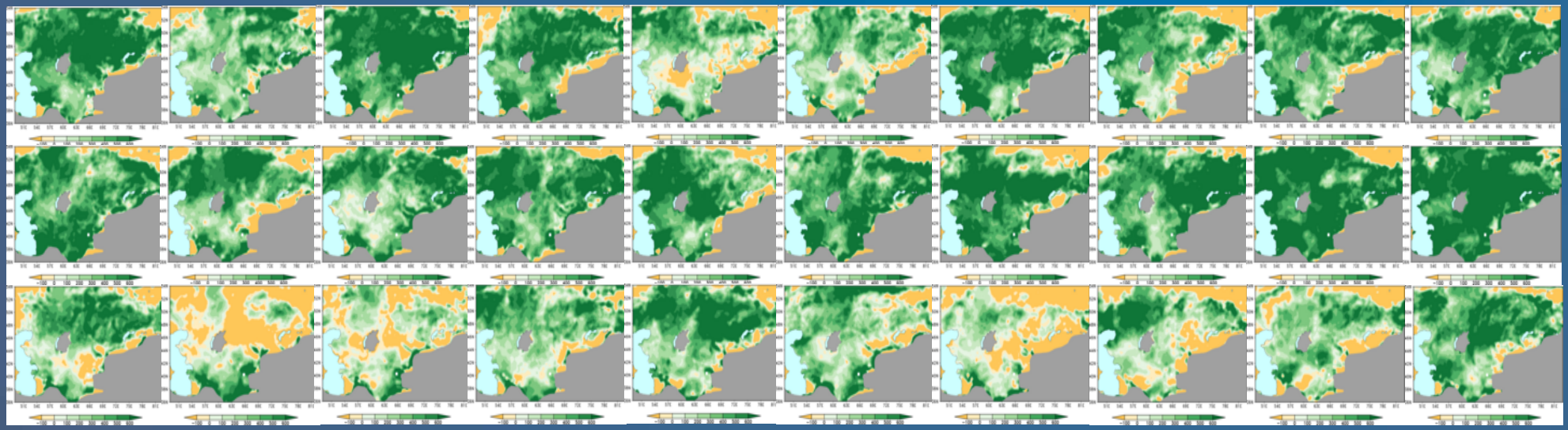
Projected changes in irrigation rate (m^3/ha) as simulated by individual ensemble members, MJJAS



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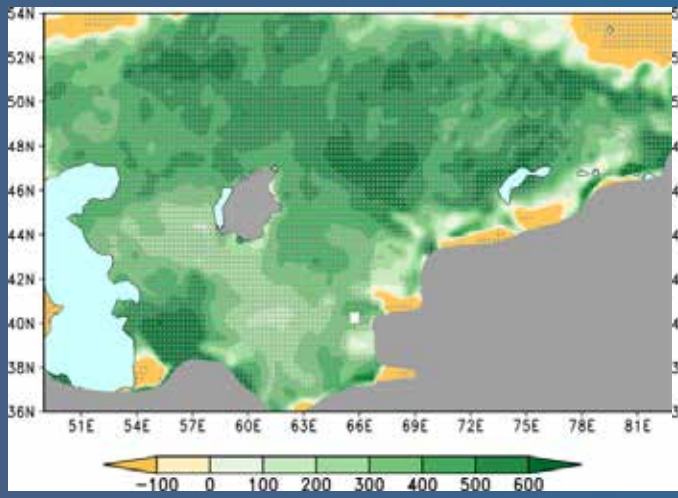
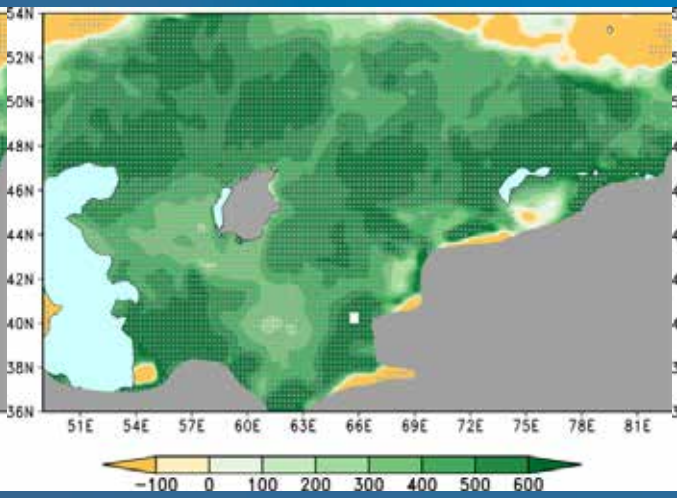
Projected changes in irrigation rate (m^3/ha) averaged for different SST/SIC projections (10 members each), MJJAS

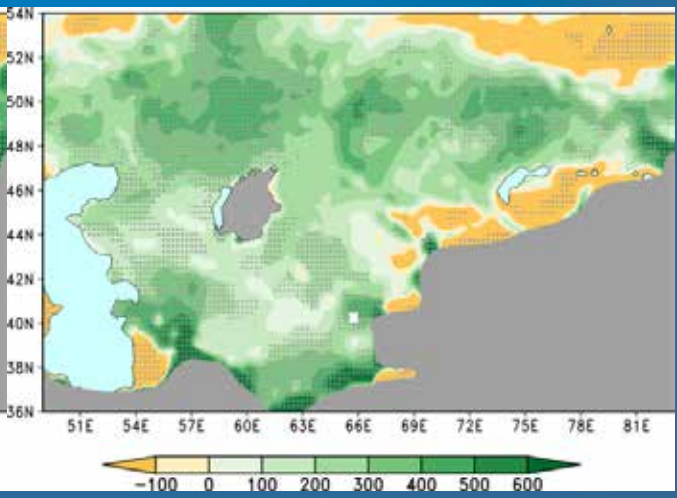
ACCESS-1.0

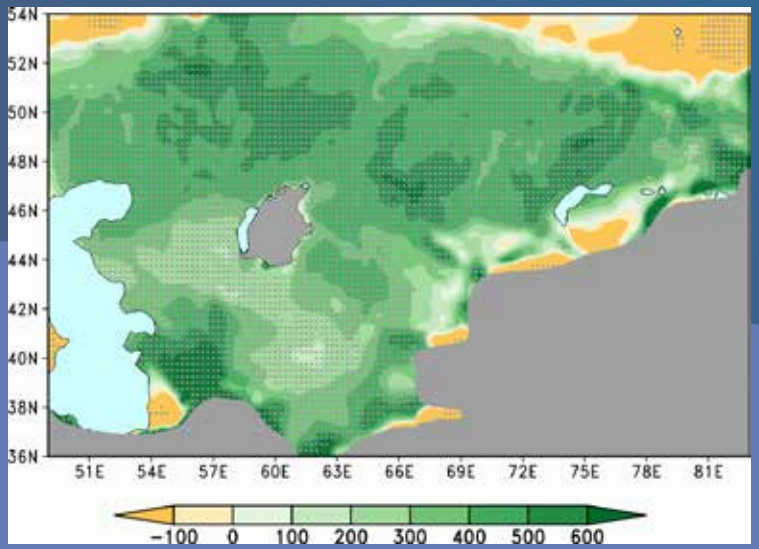


CESM1-CAM5



MPI-ESM-MR





30-member ensemble mean

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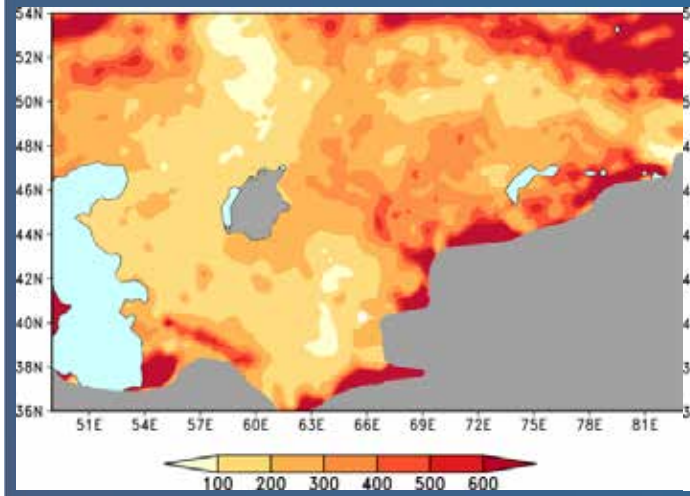
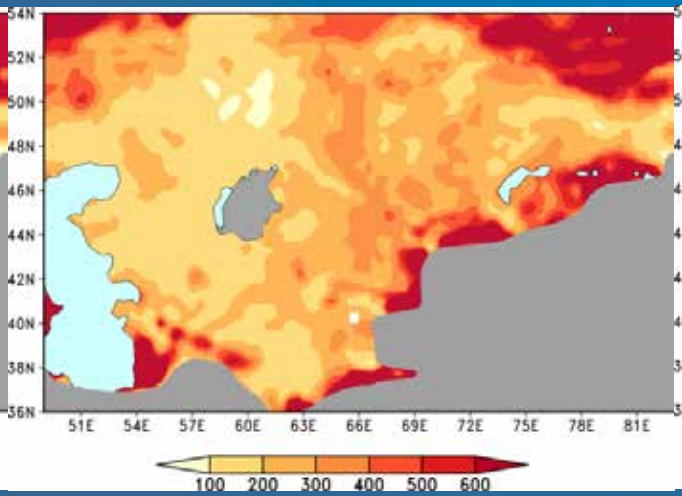
Intraensemble standard deviation of the projected changes in irrigation rate for different SST/SIC projections, m^3/ha

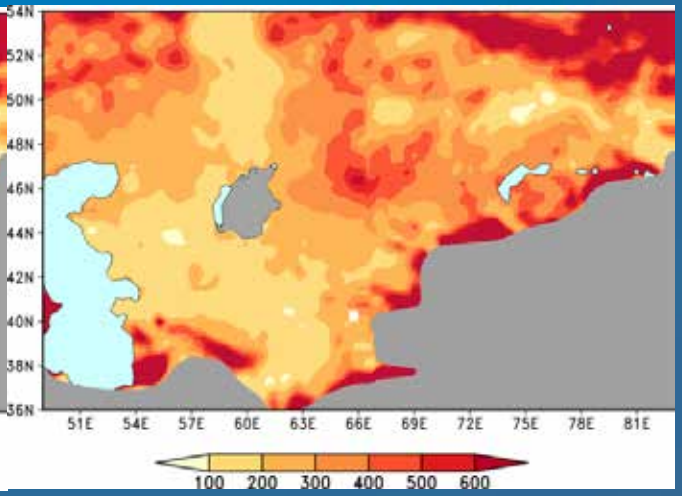
ACCESS-1.0

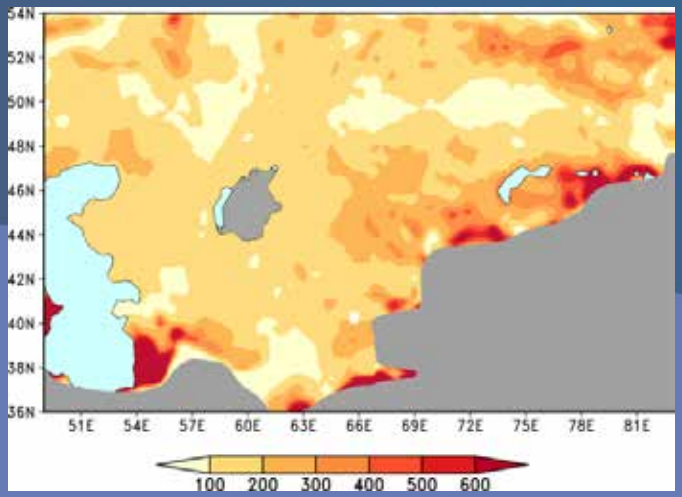


CESM1-CAM5



MPI-ESM-MR





Intraensemble standard deviation due to differences in the three SST/SIC projections, m^3/ha

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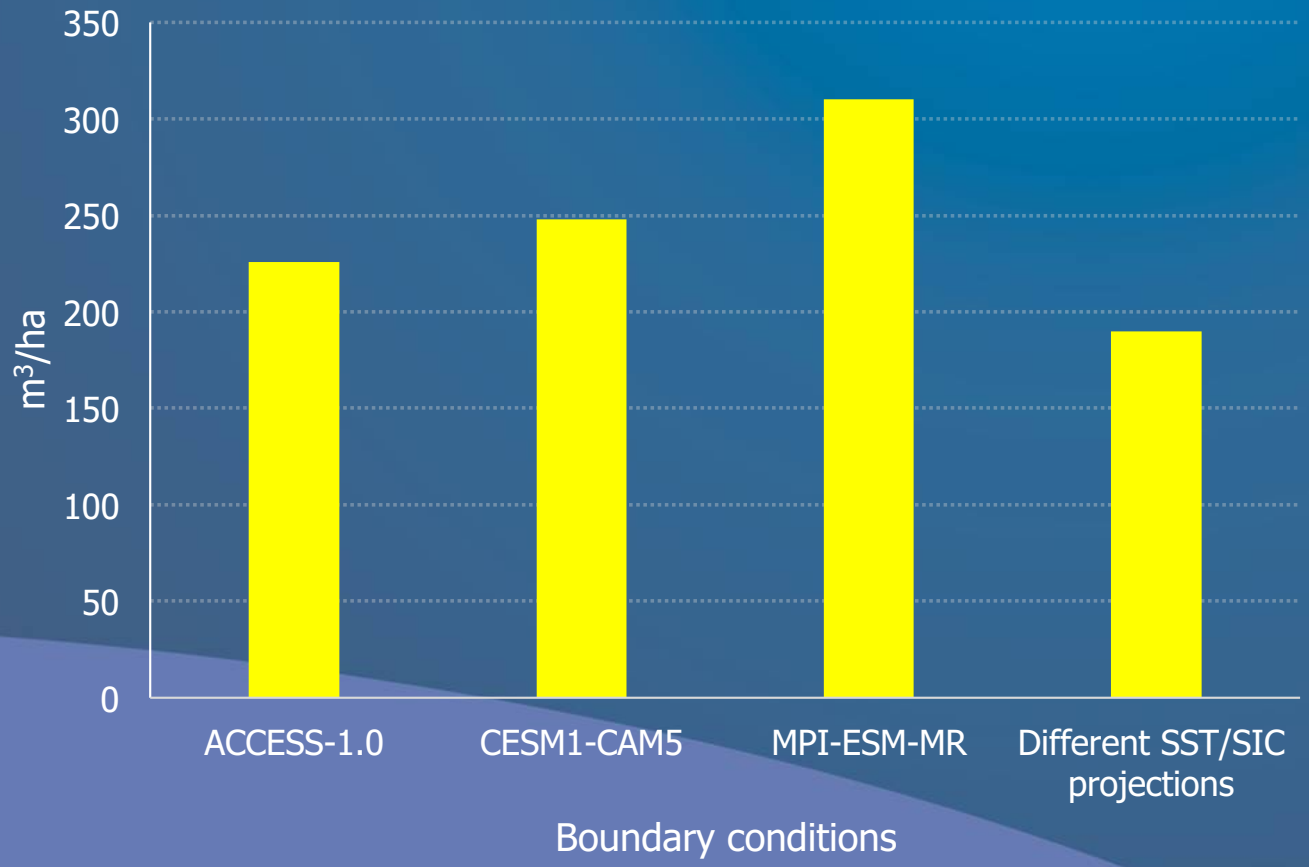
Averaged over irrigated lands intraensemble standard deviation of the projected changes in irrigation rate, m^3/ha, MJJAS



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Summary

Development of modeling chains from global and regional models to sub-models and impact models is an important step in developing effective mechanisms for providing climate information to end users;

Here, downscaling the RCM projection allows one to approach a quantitative assessment of future water demand for irrigated cropping regions, where it turns out to be critical to justifying regional development strategies; in this study, the projected increase in future irrigation water consumption by the mid 21st century falls in the range 5-10% relative to its current estimate;

In the Central Asia, there is a pressing need to apply multiscale downscaling methodologies, including very high resolution systems, to describe the effects of climate change on agriculture in the regions with complex topography;

Further assessments should include building larger ensembles accounting for a wider range of forcings and models – a good opportunity for CORDEX-CA community.

Acknowledgement: The study is supported by the Russian Science Foundation (Grant 16-17-00063)