Transient aerosols with ICON-CLM

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Helmholtz-Zentrum hereon

Introduction

more and more projects aim to utilize the ICON model as working horse:

- joint project ‚RegiKlim': user-specific high-resolution information about climate change for the development of adaptation strategies with respect to different so-called „model regions"

WAKOS WASSER AN DEN KÜSTEN OSTFRIESLANDS

Klima Konform

NUKLEUS Nutzbare lokale Klimainformationen für Deutschland

- NUKLEUS: Long-term hindcasts, historical simulations and projections for COSMO-CLM and ICON-CLM in parallel

Are there systematic differences between both models?
Is the quality of the ICON-CLM simulations comparable to COSMO-CLM?

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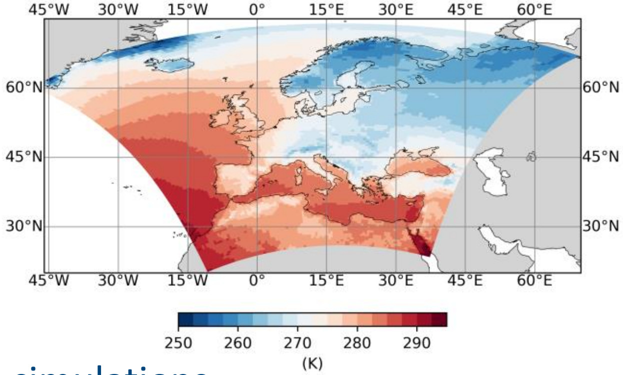
The NUKLEUS simulation setups

2m-temperature field, EURO-CORDEX domain

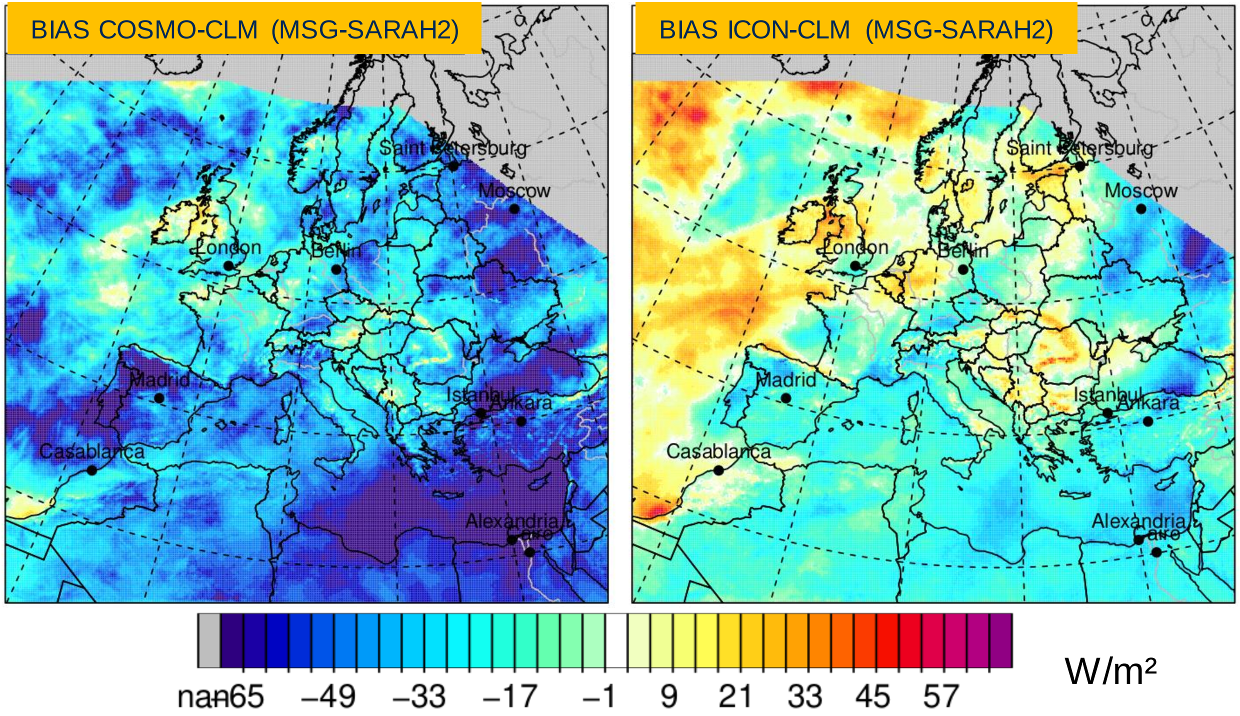


evaluation simulations on EURO-CORDEX (CORDEX) and Central Europe (CEU)

Models:	ICON: 2.6.4 with several extensions for climate simulations
	COSMO: 6.0 (CEU) / 5.10 (CORDEX)
Period:	CORDEX: January 1979 – December 2020
	CEU: January 2005 – December 2015
Forcing:	ERA5 with updates every 3 hours
Resolution:	CORDEX: 12 km resolution (COSMO: 0.11°, ICON: R13B05)
	CEU: 2.8 km resolution (COSMO: 0.0275°, ICON: R13B07)
Aerosols :	**ICON: Tegen**
	COSMO: TanRe
Radiation scheme:	ICON: ecRad
	COSMO: Ritter-Geleyn

Incoming shortwave radiation – „Bright ages“

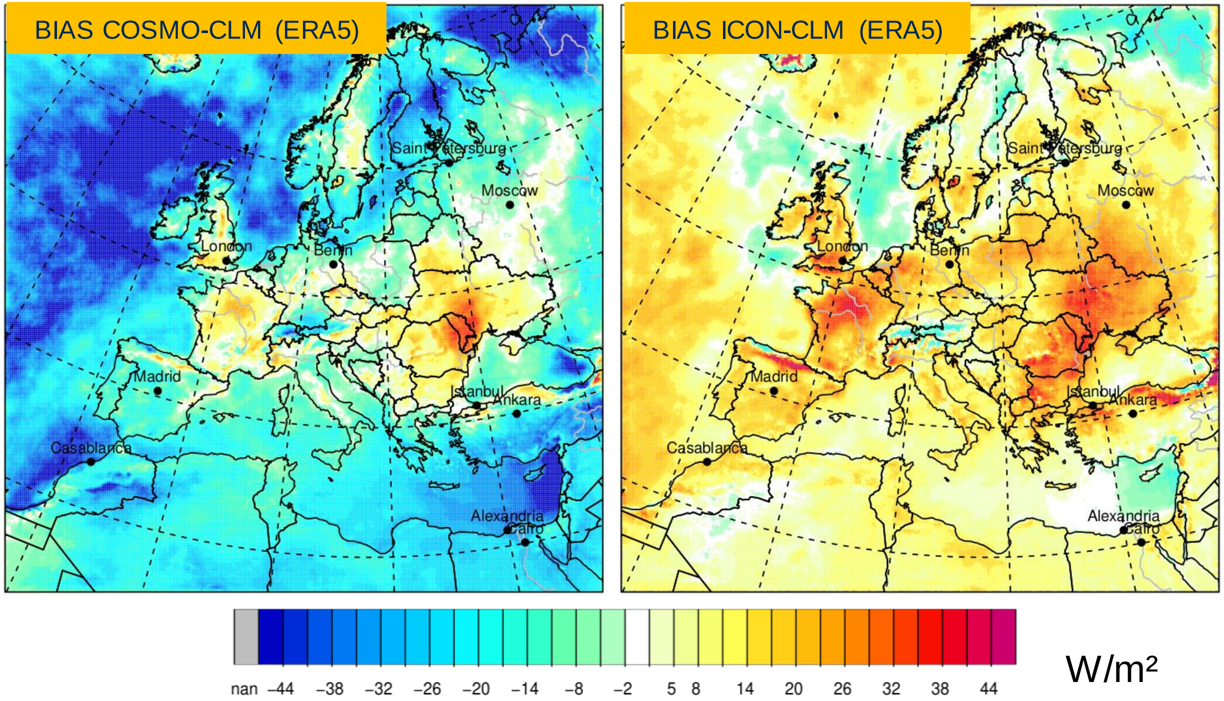
Analysis for the summer period in 2002-2008

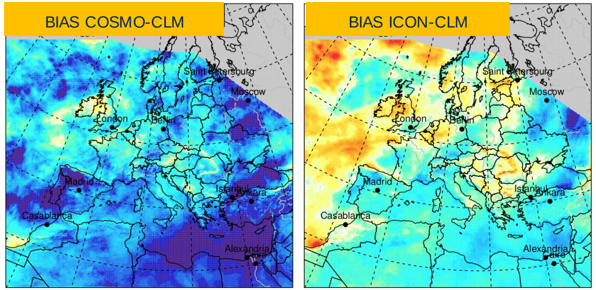


2000s: ICON-CLM outperforms COSMO-CLM in particular southern regions (thanks to more reliable Tegen climatology)

Incoming shortwave radiation – „dark ages“

Analysis for the summer period in 1981-1986

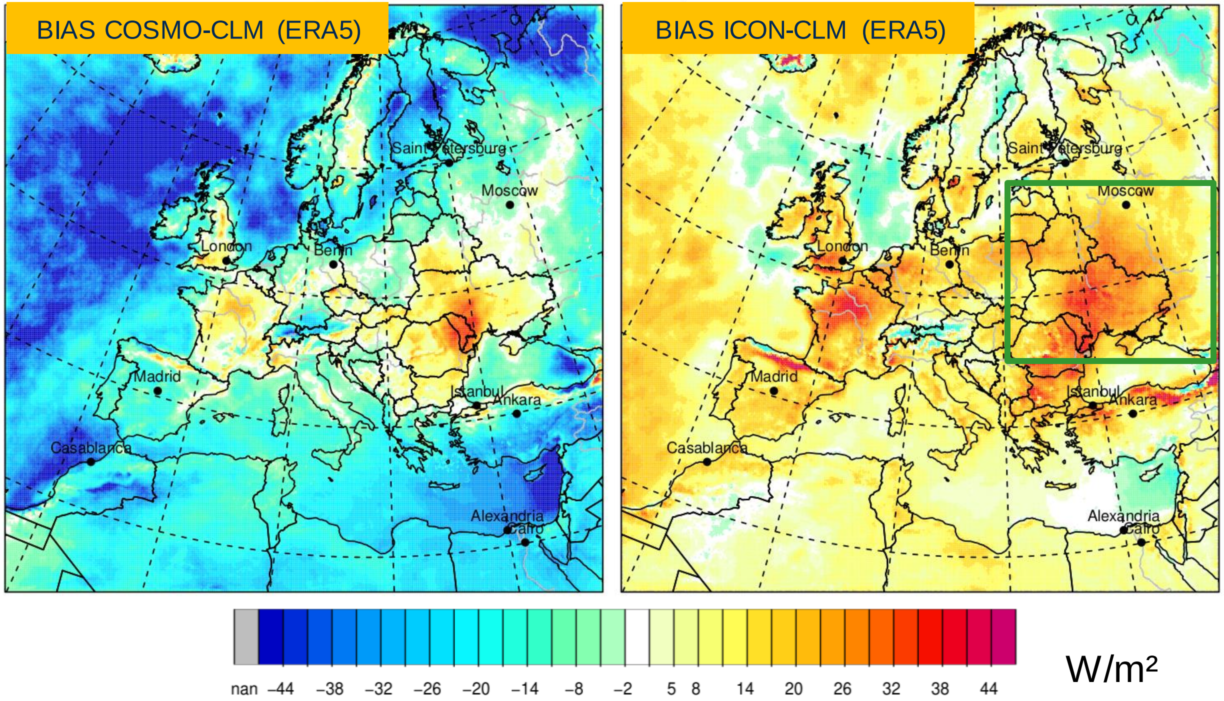


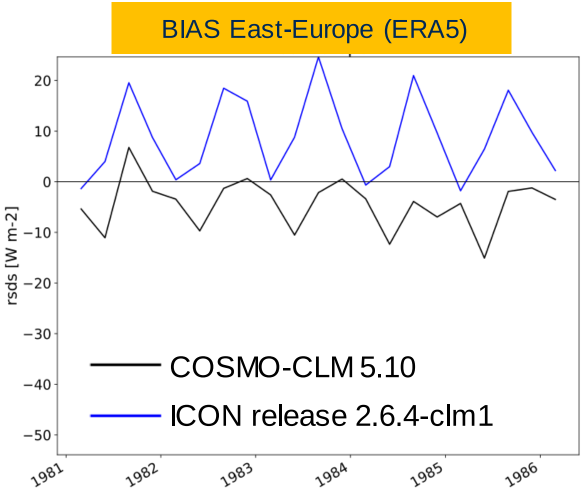


1980s: COSMO-CLM outperforms ICON-CLM in particular in the midlatitudes (thanks to the old TanRe climatology)

Incoming shortwave radiation – „dark ages“

Analysis for the summer period in 1981-1986

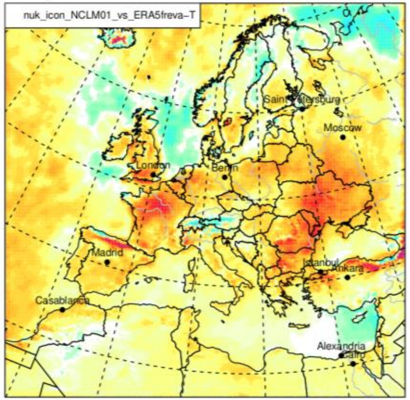




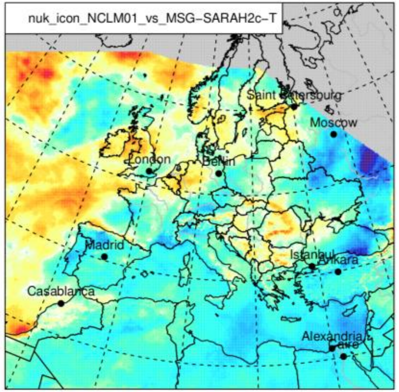
1980s: COSMO-CLM outperforms ICON-CLM in particular in the midlatitudes (thanks to the old TanRe climatology)

Setting the scene

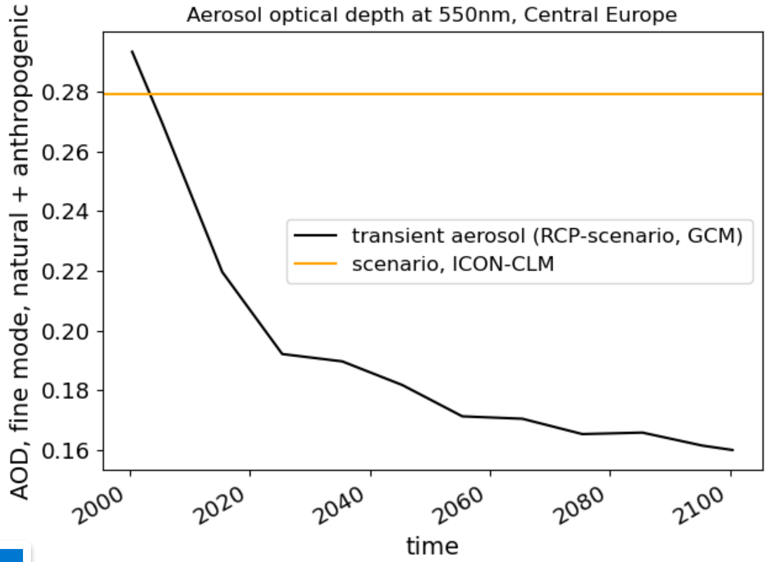
1980s (ERA5)



2000s (MSG-S2)



Future / projections



Need for a transient aerosol climatology due to historical changes in aerosol load **AND** future reduction of aerosol load given by AMIP scenarios

Characteristics of MACv2 transient aerosols

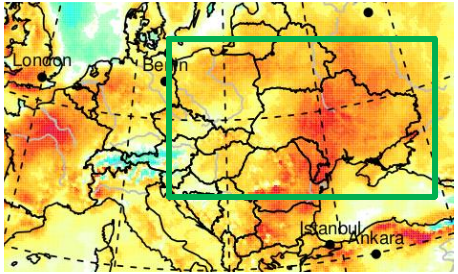
MACv2 (Kinne, 2019) subdivided into different types of aerosols:

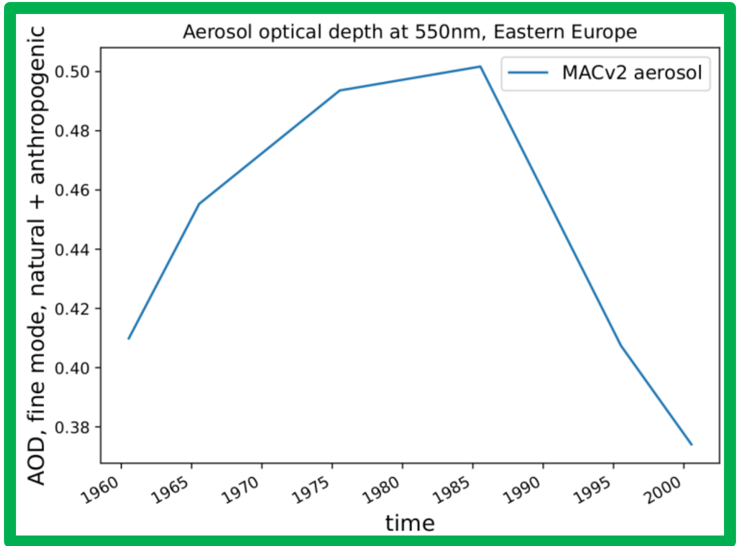
1. Fine mode background (natural) aerosol – preindustrial (1850)

2. Coarse mode background (natural) aerosol – preindustral (1850)

3. deviations from 1 and 2: fine mode anthropogenic concentrations – temporally varying for historical and future scenarios

Volcanic aerosol following Stenchikov – temporally varying





ICON-CLM experiment with transient Kinne Aerosol

Models: ICON 2.6.5 (release from July 2022 with fix)
Period: January 1979 – December 2010
Forcing: ERAinterim
Resolution: R3B13 over CORDEX domain
Radiation scheme: ICON: ecRad
Aerosols: **ICON standard: Tegen**
ICON transient: MACv2
Aerosol data: aerosol optical depth, single scattering albedo and symmetry factor with respect to ICONs spectral bands: 14 shortwave and 16 longwave (Kinne und Rast, MPI)
Namelist config: radiation_nml → irad_aero = 15 (Trang Pham, DWD)

?

Impact of dimming and brightning over Europe on simulated solar radiation

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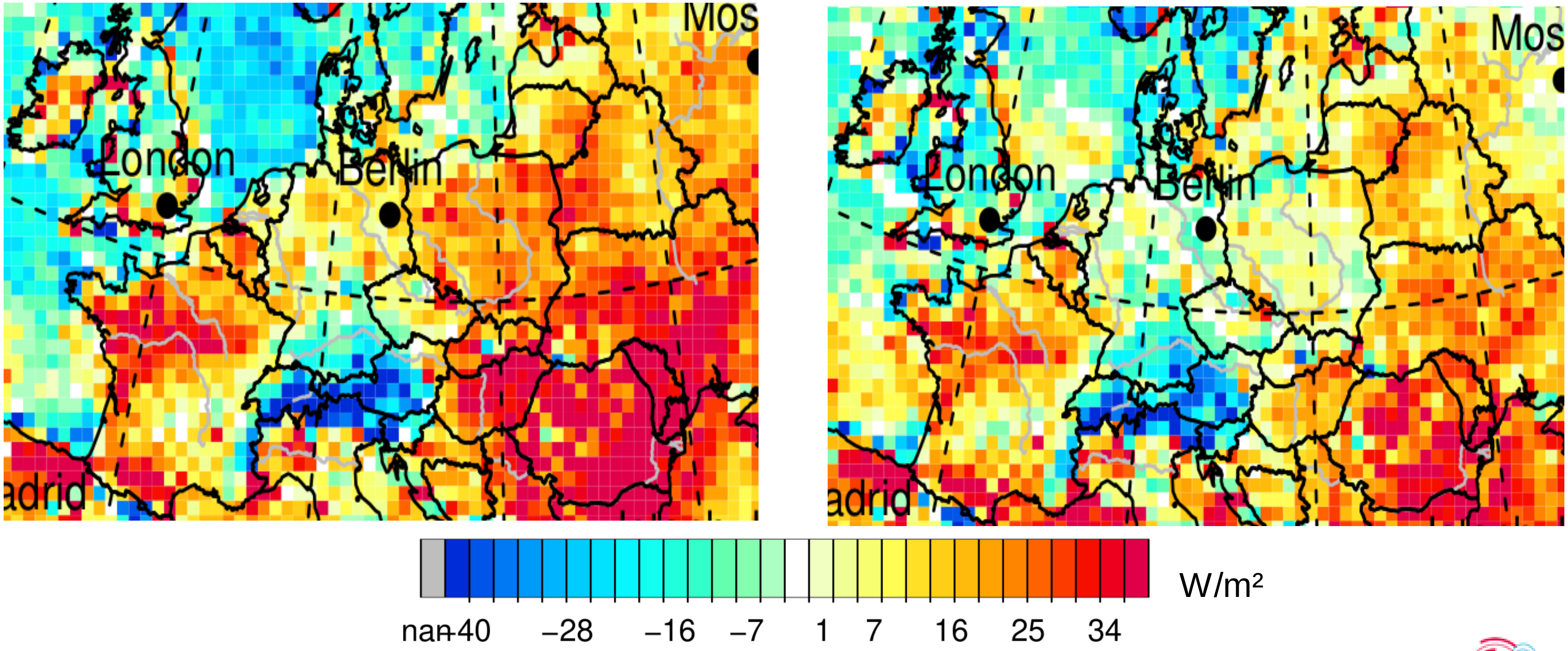
Impact of transient aerosols – the time of dimming I

Analysis for the summer period in 1981-1986

BIAS 1981 - 1986 (ICON 2.6.5 standard Tegen vs. ERA5)

BIAS 1981 - 1986 (ICON 2.6.5 Kinne transient vs. ERA5)



- **Eastern Europe brighter in TEGEN climatology compared to Kinne**

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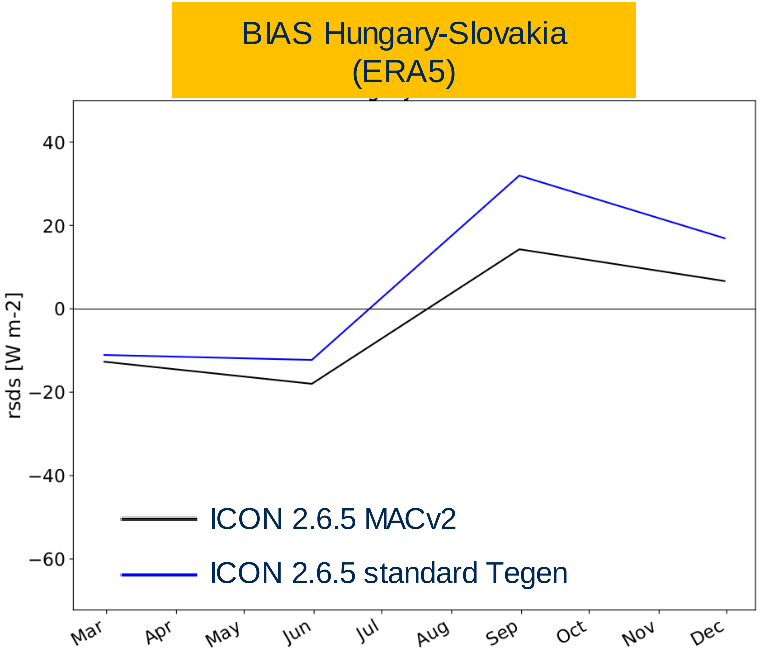
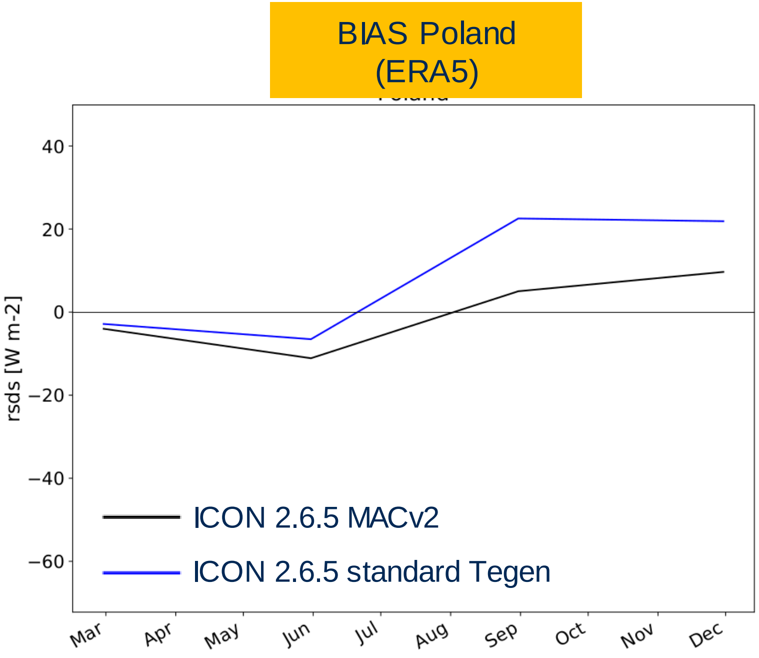
Impact of transient aerosols – the time of dimming II

Analysis for the summer period in 1981-1986



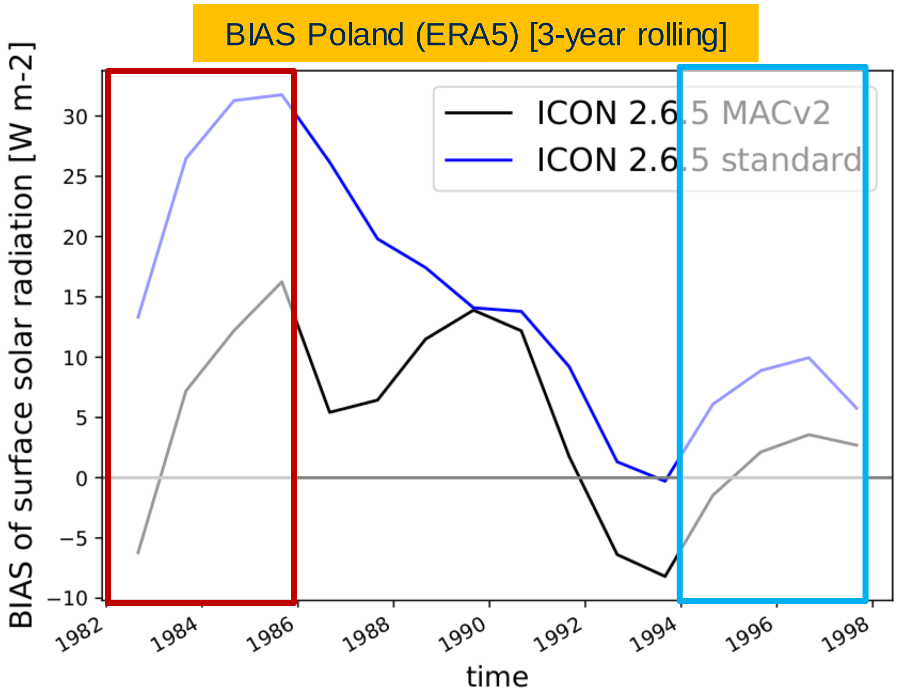


- **Eastern Europe brighter in TEGEN climatology compared to Kinne**

Transition from dimming to lightning

Analysis for the summer period in 1981-1999

BIAS Tegen, W m-2	1981-1986	1994-1999
Poland	25	10
HungarySlovakia	35	18
Romania	42	20
Ukrain	30	18



- **better transition in MACv2 compared to TEGEN**
- **Transient aerosol more consistent to reanalysis, but also to observations?**

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Conclusions

- dimming and ligthning over Eastern Europe better captured by ICON-CLM with transient aerosol data set (assuming ERA5 to be reliable)
- Redistribution between diffusive solar radiation and direct solar radiation in MACv2 climatology
- Discrepancy between reanalysis (ERA5) and MACv2 over Mediterranean Sea in the 80s

<u>What to do next?</u>

- Higher model resolution aiming to improve cloud-radiation feedbacks
- Analysis of radiation fluxes and budgets for recent day climate using data from ground stations and the satellite area
- Investigation of TOA radiation budget in future climate using transient and constant aerosol climatology

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Thank you for your attention

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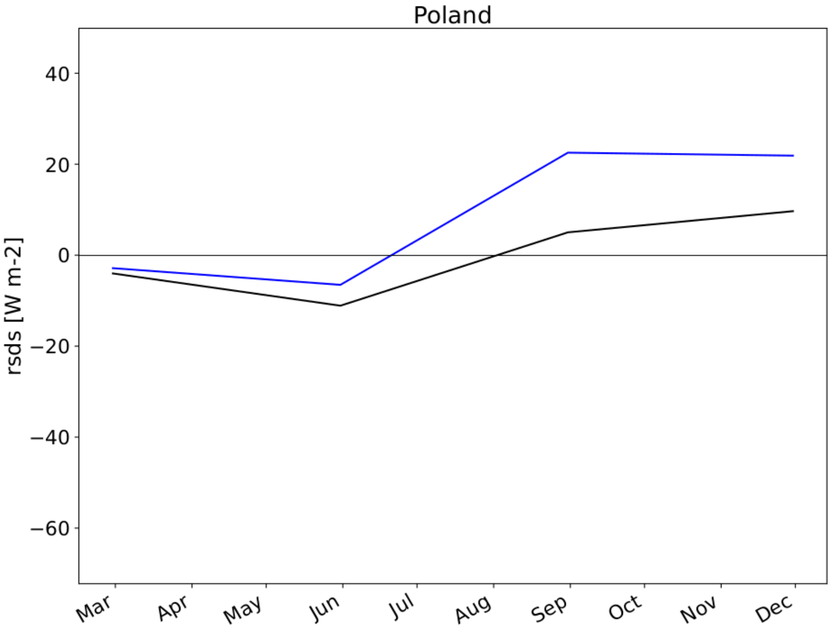
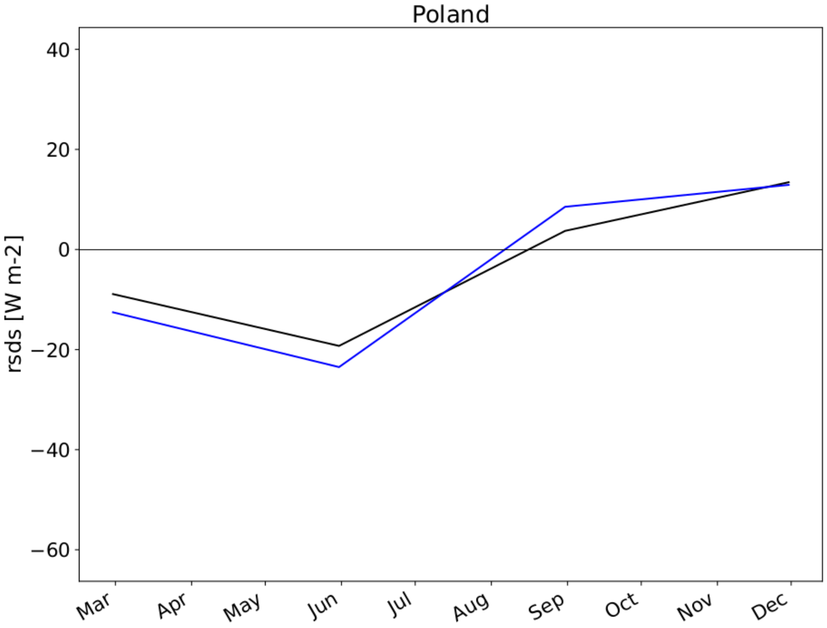
1981 to 1986

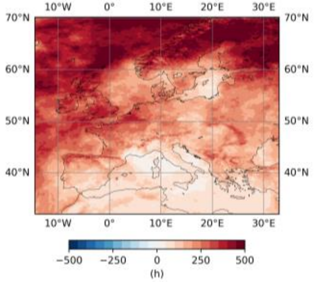


1994 to 1999

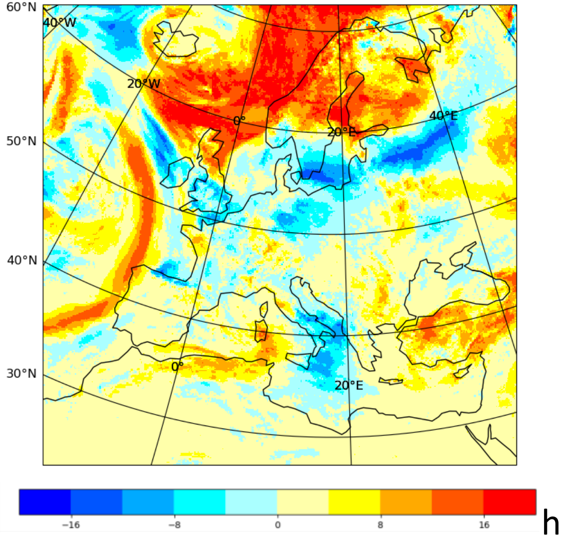


A) Solar forcing – Duration of sunshine

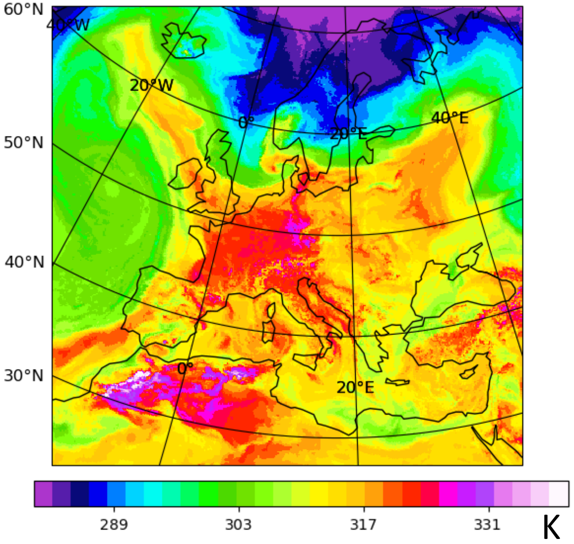
Event based verification (6.6.1982)



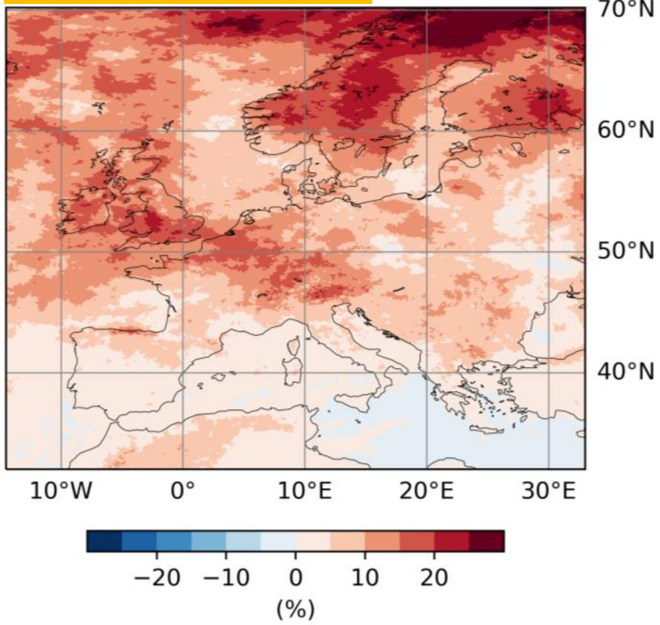
DURSUN, ICON – COSMO



ICON, θ_{ae} 925hPa



DURSUN of SGS,
Koehler – COSMO



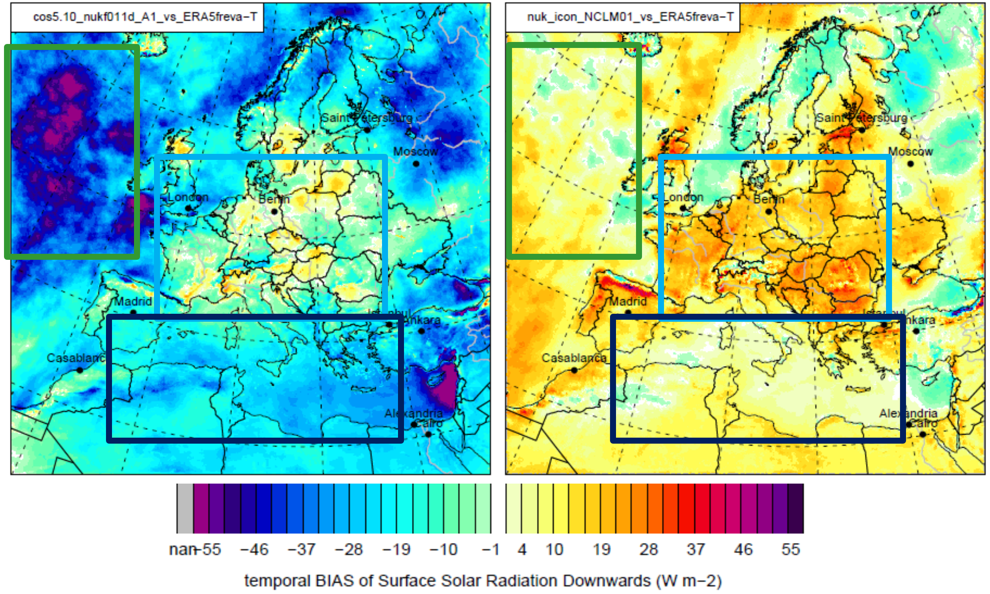
- strongly increased DURSUN in ICON-CLM under same forcing conditions → impact of subgrid cloud cover scheme (SGS)
- DURSUN differences also caused by radiation code and aerosols

A) Solar forcing – amount of solar irradiance

Analysis for the summer period in 1982 (representative for all summer seasons)

BIAS ASOD_S, COSMO (ERA 5)

BIAS ASOD_S, ICON (ERA 5)

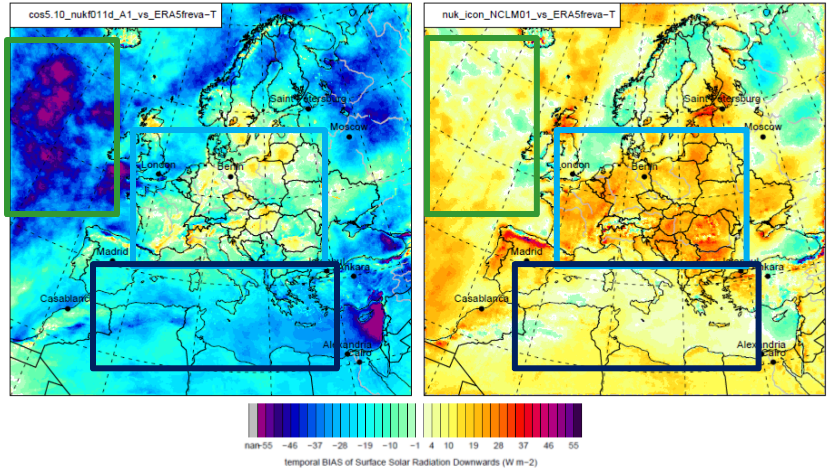


- Regional dependency → different ‚error' characteristics
- Input for radiation transfer scheme? (Cloud water path, sub-grid cloud cover, aerosols, …)

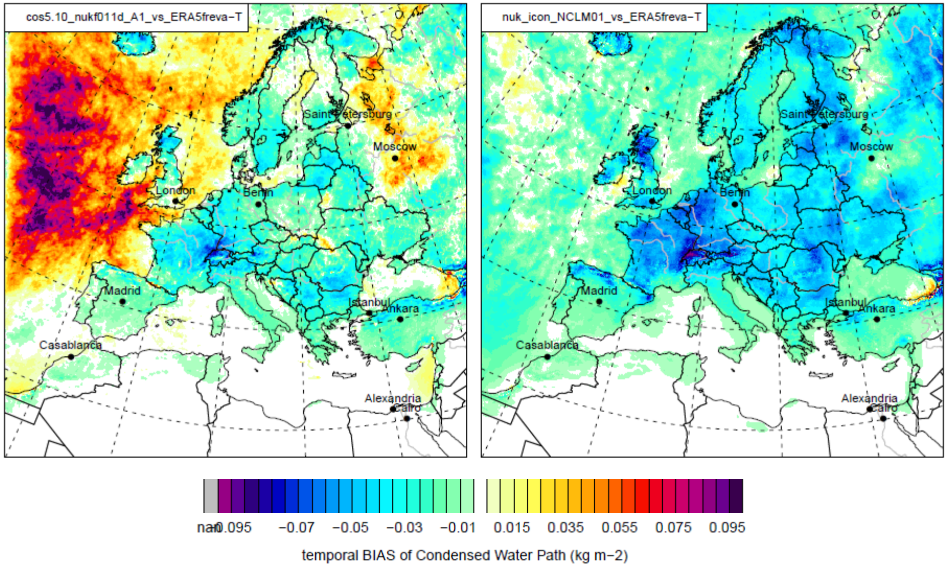
A) Solar forcing – amount of solar irradiance (Cloud Water Path)

Analysis for the summer period in 1982 (representative for all summer seasons)

BIAS ASOD_S, COSMO (ERA 5) | BIAS ASOD_S, ICON (ERA 5)



BIAS CWP, COSMO (ERA 5) | BIAS CWP, ICON (ERA 5)



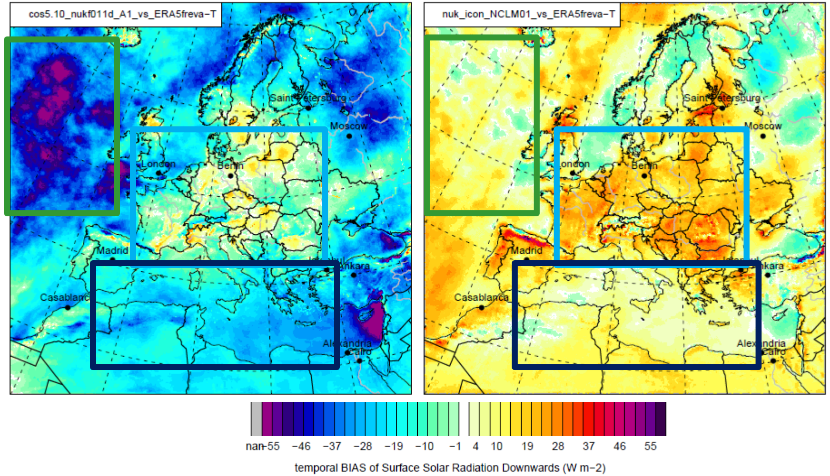
- Cloud water path: deficits for ICON over land and for COSMO over East Atlantic
- Physically plausible relationship between CWP and solar irradiance

A) Solar forcing – amount of solar irradiance (sub-grid cloud cover)

Analysis for the summer period in 1982 (representative for all summer seasons)

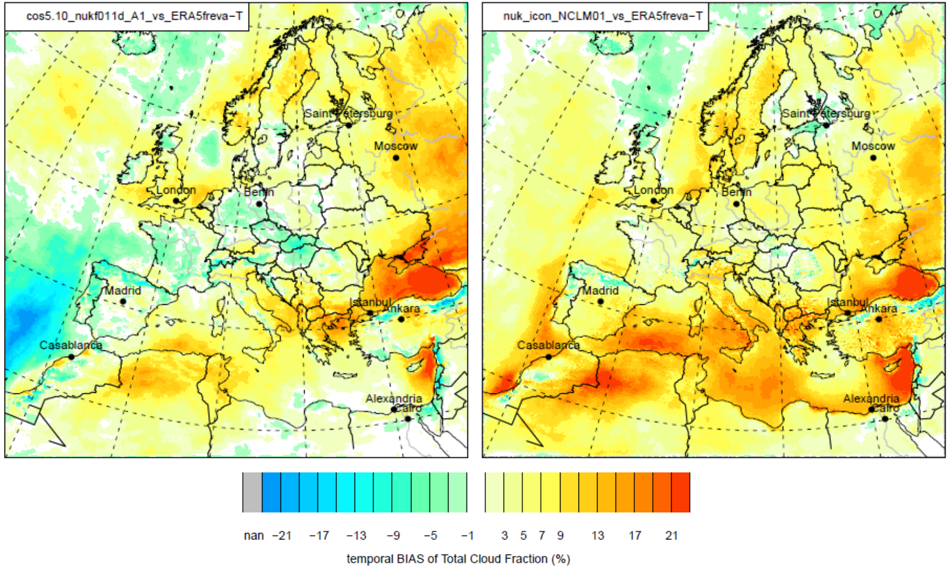
BIAS ASOD_S, COSMO (ERA 5)

BIAS ASOD_S, ICON (ERA 5)



BIAS CLCT, COSMO (ERA 5)

BIAS CLCT, ICON (ERA 5)



- Total Cloud cover: slightly positive BIAS over land and much more over Mediterranean (dependent on SGS scheme)
- questionable relationship between CLCT and solar irradiance / cloud water path / sunshine duration **??**

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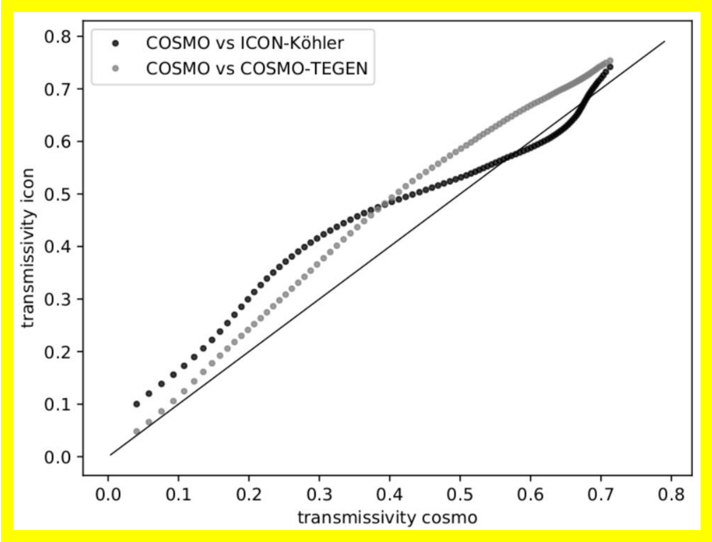
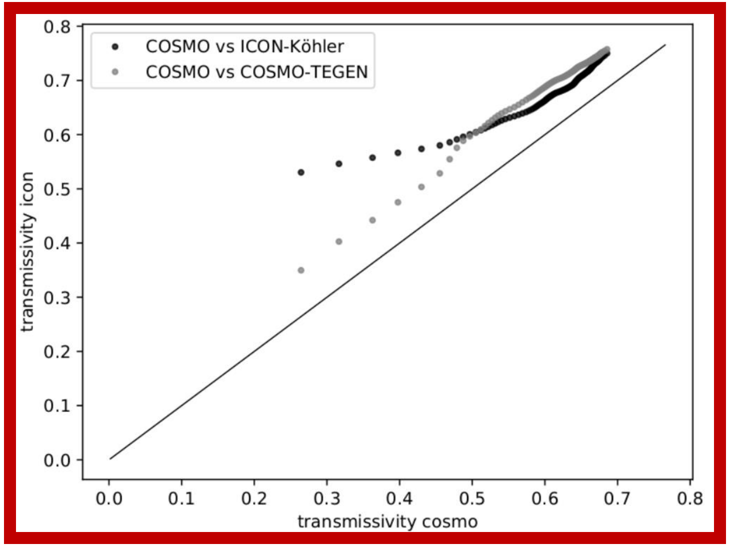
A) Solar forcing – amount of solar irradiance (transmissivity)

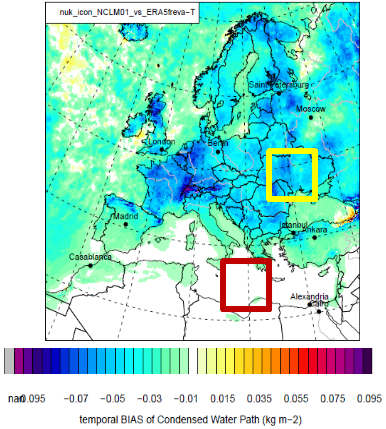
Quantile analysis for summer 1982 (surface radiation vs TOA radiation)

Percentiles 7-15 UTC, COSMO vs ICON, Ukraine



Percentiles 7-15 UTC, COSMO vs ICON, MED

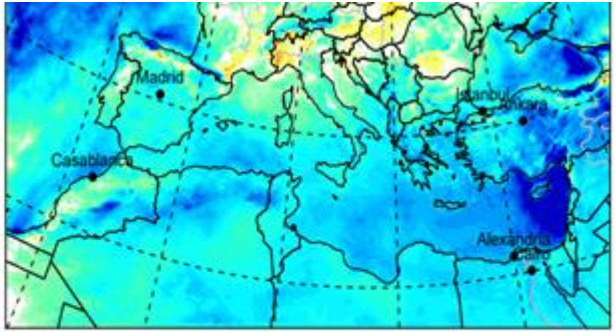




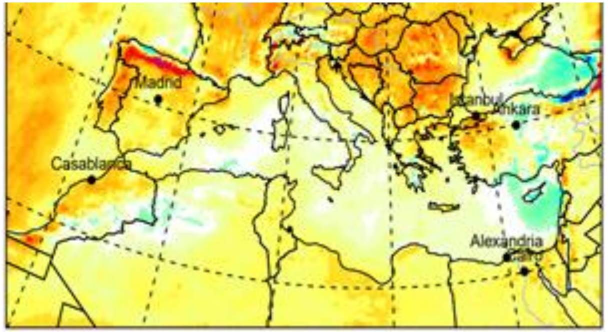
- ICON allows for more transmissivity / ‚brighter' atmosphere because of (i) radiation scheme, (ii) missing cloud water, (iii) aerosols
- May explain increased sunshine duration in the high latitudes

A) Solar forcing – amount of solar irradiance (aerosol impact)

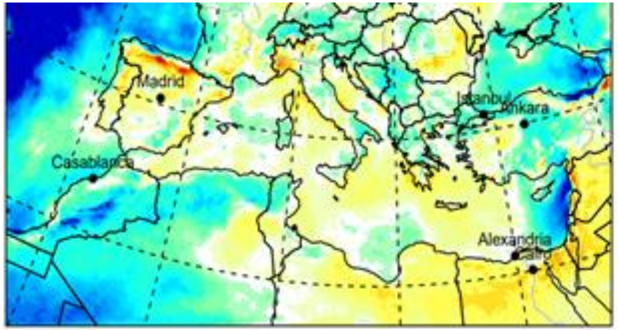
BIAS ASOD_S, COSMO-TanRe (ERA 5)

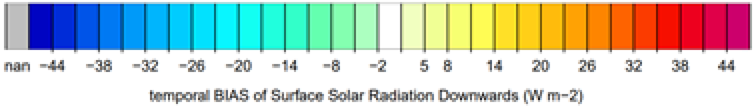


BIAS ASOD_S, ICON-Tegen (ERA 5)

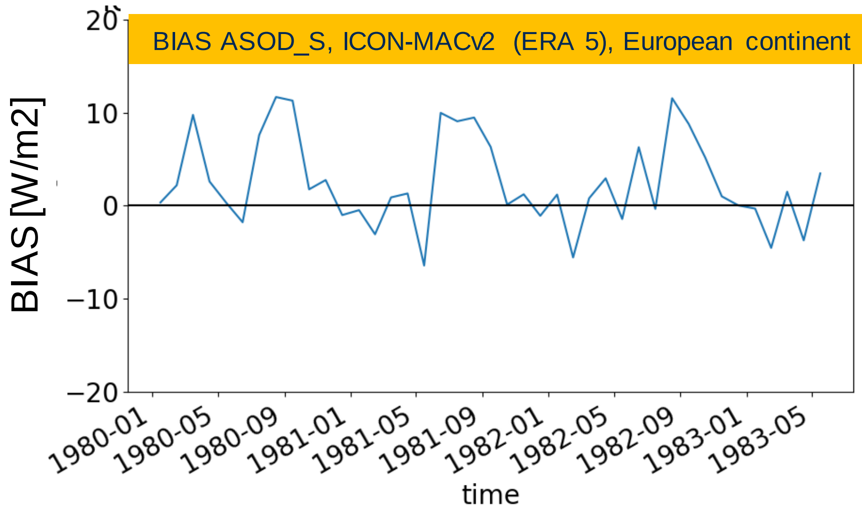


BIAS ASOD_S, COSMO-MAC (ERA 5)





BIAS ASOD_S, ICON-MACv2 (ERA 5), European continent



Transient aerosols (MACv2 + volcanoes) implemented in ICON

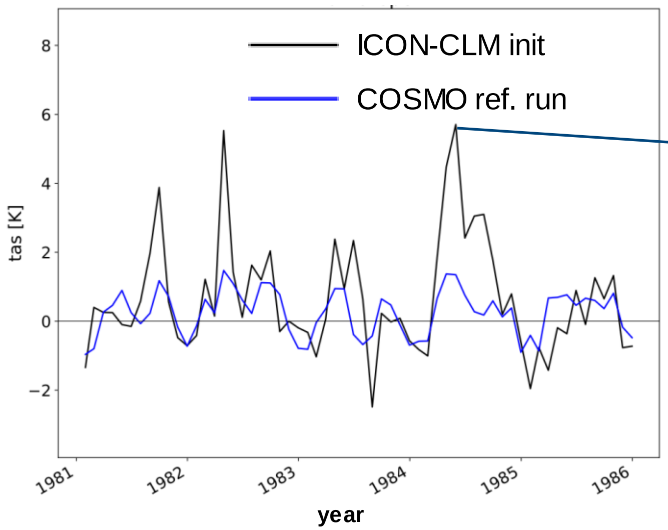
Part B) Atmospheric transport – evaluation of initial ICON-CLM runs

Score board with Eobs_v21, model: nuk_icon_nosnow,refmod: cos5.10_nuk_A1, region: Mid-Europe

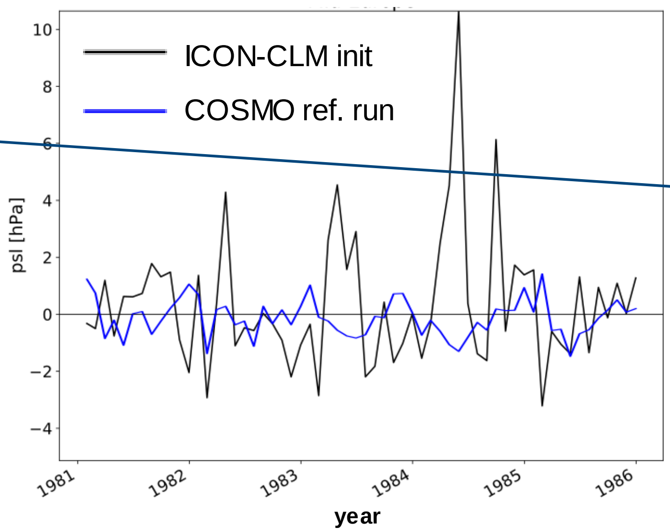
season	Summer			Winter			Spring			Autumn		
metric	BIASsk	AMSESSsk	TiCorsk	BIASsk	AMSESSsk	TiCorsk	BIASsk	AMSESSsk	TiCorsk	BIASsk	AMSESSsk	TiCorsk
psl		▼	▼	▲		▼	▼	▼	▼	▲	▽	▼
rsds		▼	▼				▼	▼	▼	▼		
tas	▲	▼	▼				▼	▼	▼	▽	▼	▼
tasmin		▼	▼					▼	▼	△		▽
tasmax	▲	▼	▼					▼	▼	▲	▼	▼
pr_amount				△					▼			

Evaluation for the period 1981-1986 (monthly means)

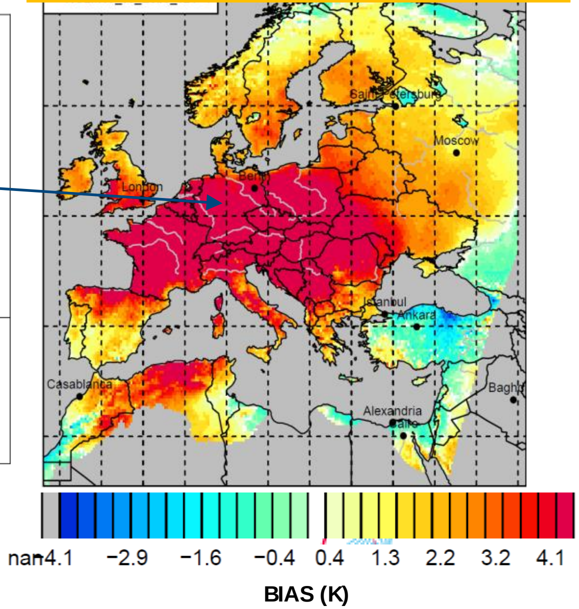
BIAS T2M, MidEurope (EObsv21)



BIAS PMSL, MidEurope (EObsv21)



BIAS ICON-CLM, April 1984 (EObsv21)



- occasionally the large-scale atmospheric state is diverging in the model

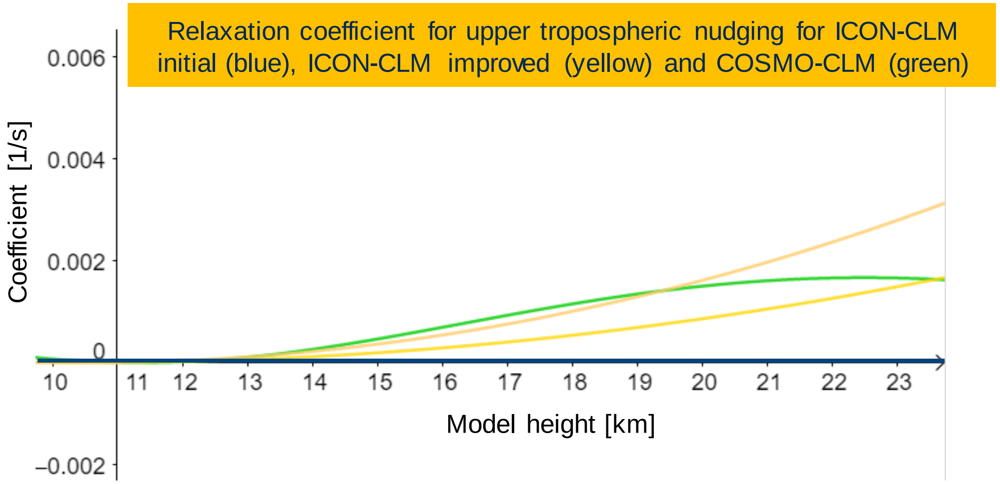
Part B) Atmospheric transport – overcome deficits in synoptic patterns

Nudging of the upper boundary to the solution of the forcing model

$$\left(\frac{\partial \psi}{\partial t}\right) = -\mu_b \left(\psi - \psi_b\right)$$

- **Harmonizing relaxation coefficients between COSMO-CLM and ICON-CLM**
- **Choosing sufficient vertical extend**
- **impact of relaxation on troposphere expected to be high for increased tropospheric height**

ICON-CLM initial → ICON-CLM new (improved setup)

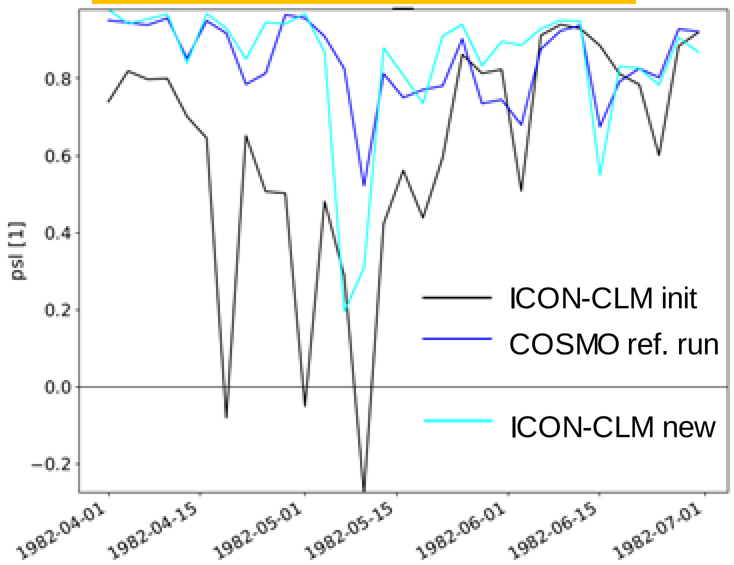


Part B) Atmospheric transport – overcome deficits in synoptic patterns

Nudging of the upper boundary to the solution of the forcing model

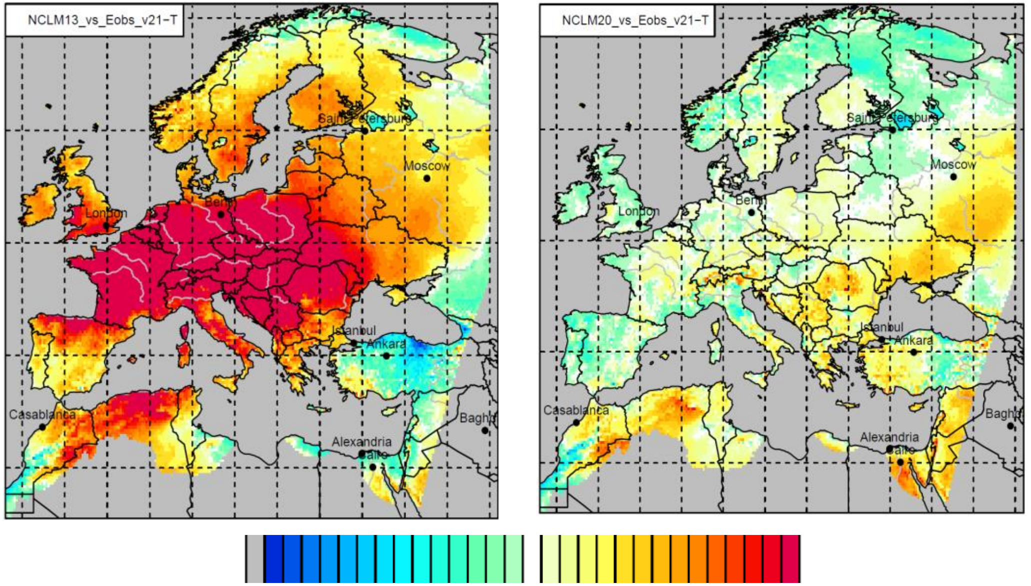
$$\left(\frac{\partial \psi}{\partial t}\right) = -\mu_b\left(\psi - \psi_b\right)$$

Correlation pattern, MidEurope (EObsv21)



BIAS T2M, April 1984, ICON-CLM init

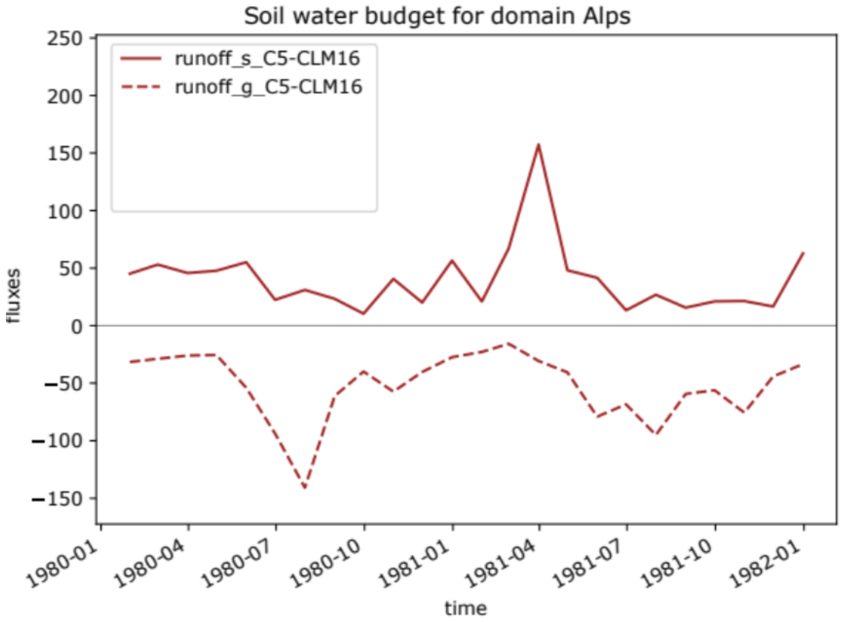
BIAS T2M, April 1984, ICON-CLM new



ICON-CLM new: improved model performance

Part C) Transport along the rivers – runoff simulation with ICON-CLM

First tests with ICON-CLM (release 2.6.2) offered some strange results for discharge simulations
→ Investigate the runoff simulation of COSMO and ICON



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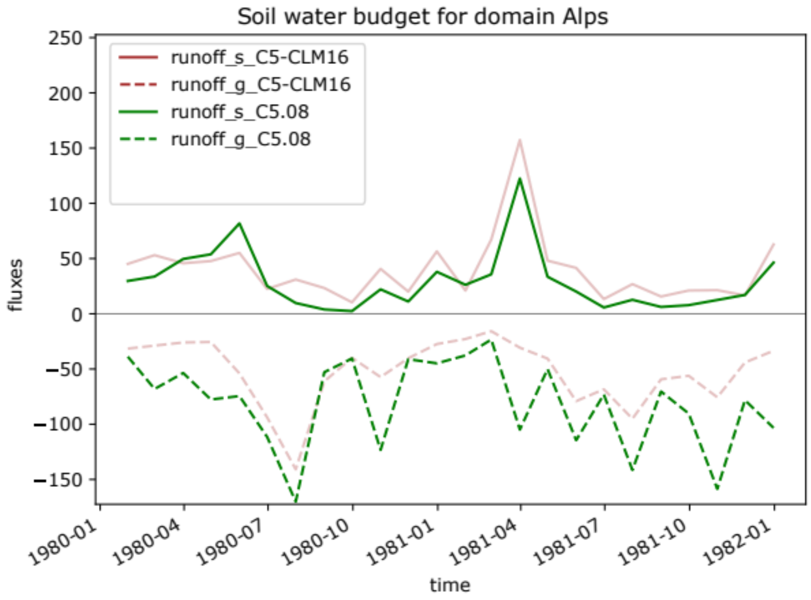

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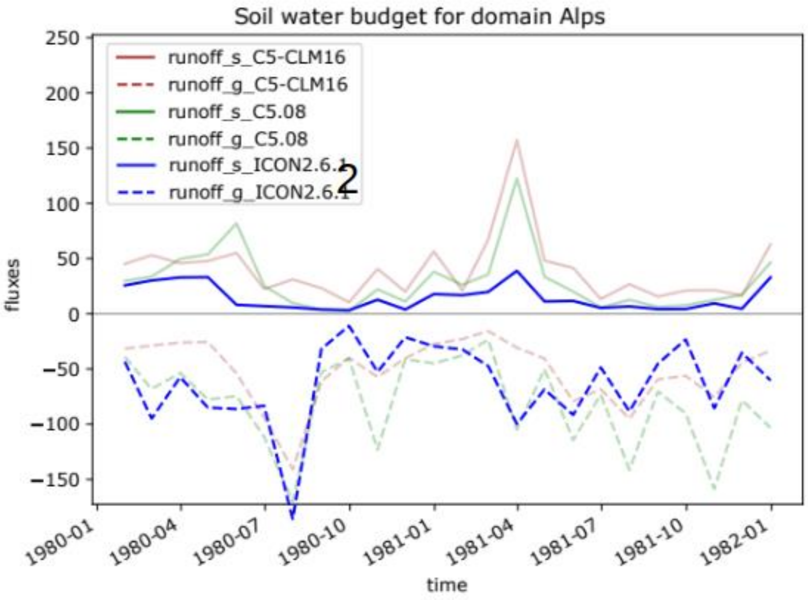


What is the characteristics of all fluxes and source terms related to the mass content of water in soil? Are there artificial sources and sinks?

Part C) Transport along the rivers – budget of soil water content

$$BSW = d_t P_r + d_t P_s - d_t R_g - d_t R_s + d_t E_{grd} + d_t E_{snw} - d_t S_{snow} - d_t S_{icep}$$

$$RC = \frac{\partial q_{sw}}{\partial t} + \frac{\partial q_{si}}{\partial t}$$

P_r / P_s: Sedimentation flux of liquid / frozen hydrometeors

R_g / R_s: Surface / subsurface runoff flux

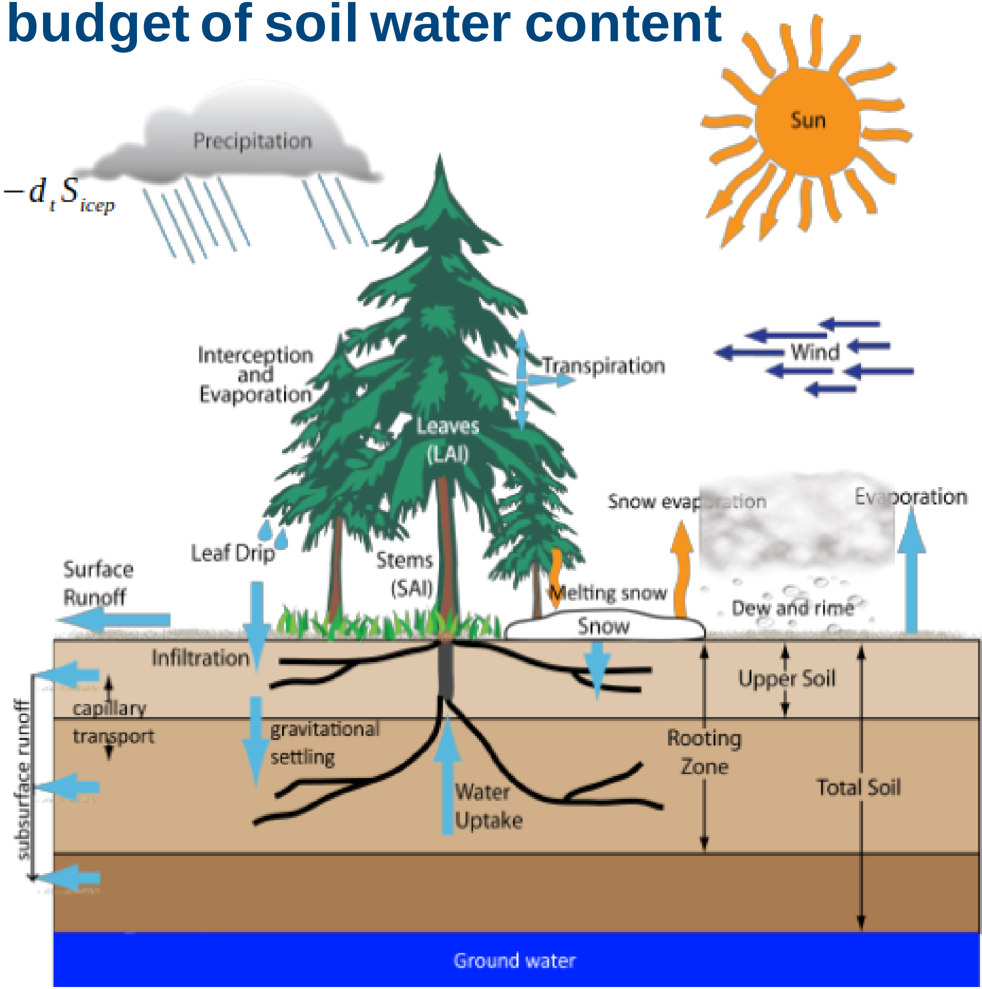
E_{grd} / E_{snw}: Evaporation flux over ground / snow

S_{snow}: Snow storage (accu./melt.)

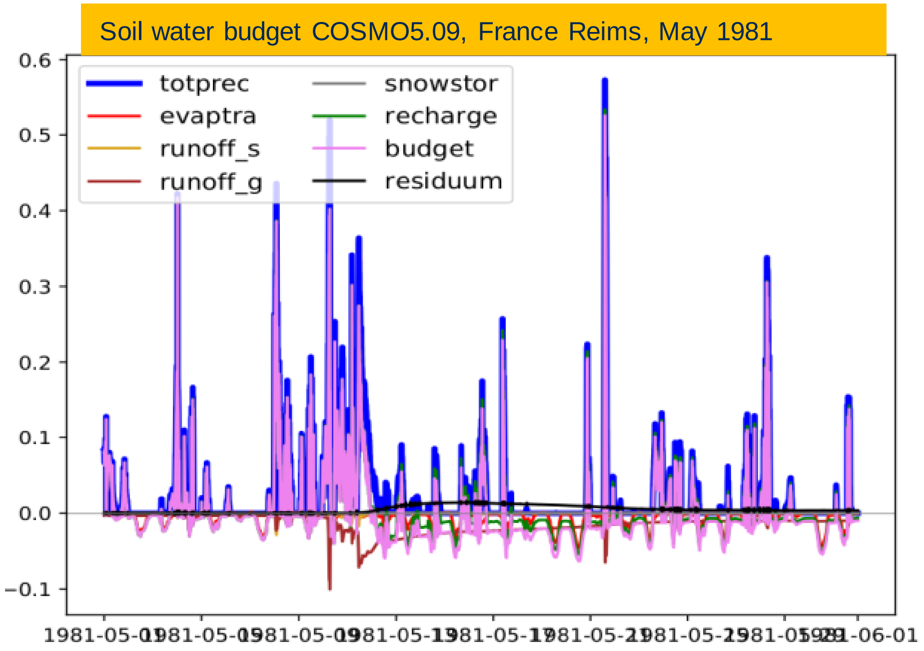
S_{icep}: Interception water storage

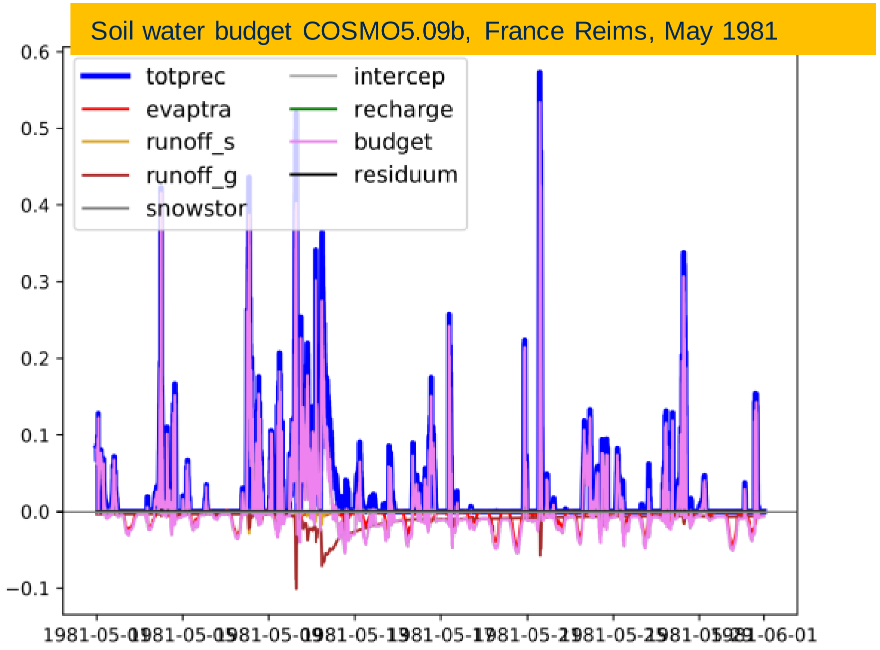
q_{sw}, q_{si}: Liquid / frozen Soil water content

$RC - BSW = R$: Residuum of soil water budget (recharge - budget_soil_water)



Part C) Transport along the rivers – closed soil water budget





Runoff re-calculation: hydrologically active layers only + lower boundary dispersive to gravitational settling

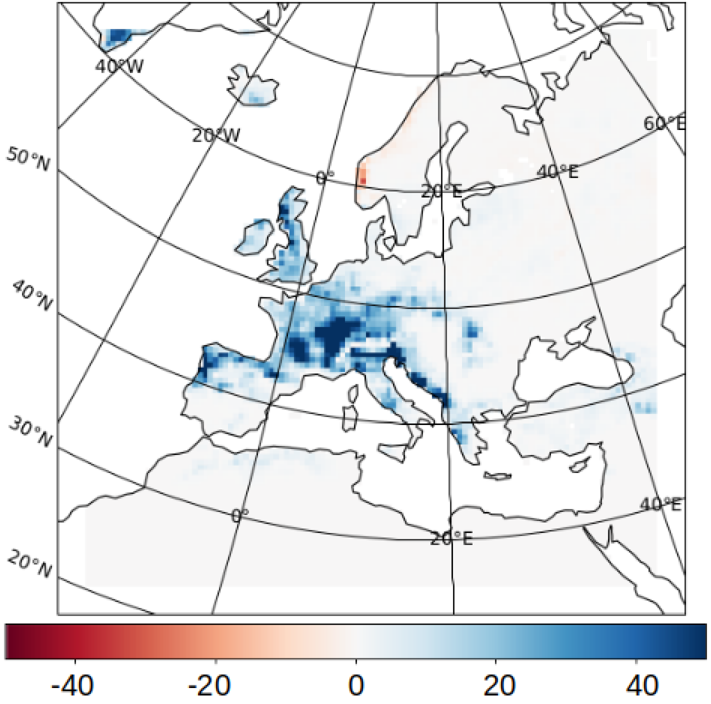
ICON 2.6.4
+
COSMO 5.09b

Part C) Transport along the rivers – closed soil water budget

Consolidated runoff calculation + consolidated aggregation of weighted aggregations over tiles

ICON 2.6.4
+
COSMO 5.09b

Soil water budget ICON-release 2.6.3, March 1979



Soil water budget ICON-release 2.6.4, March 1979