7th Study Conference on BALTEX

# How a two-way online coupled model system impacts regional climate simulations

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# Motivation


➢ The regional climate model **CCLM** driven by 6-hourly **ERA-interim** reanalysis data (T159, ~80km) has **systematic wet precipitation biases** over Europe in general and over **Scandinavia** in particular, especially in **summer**.


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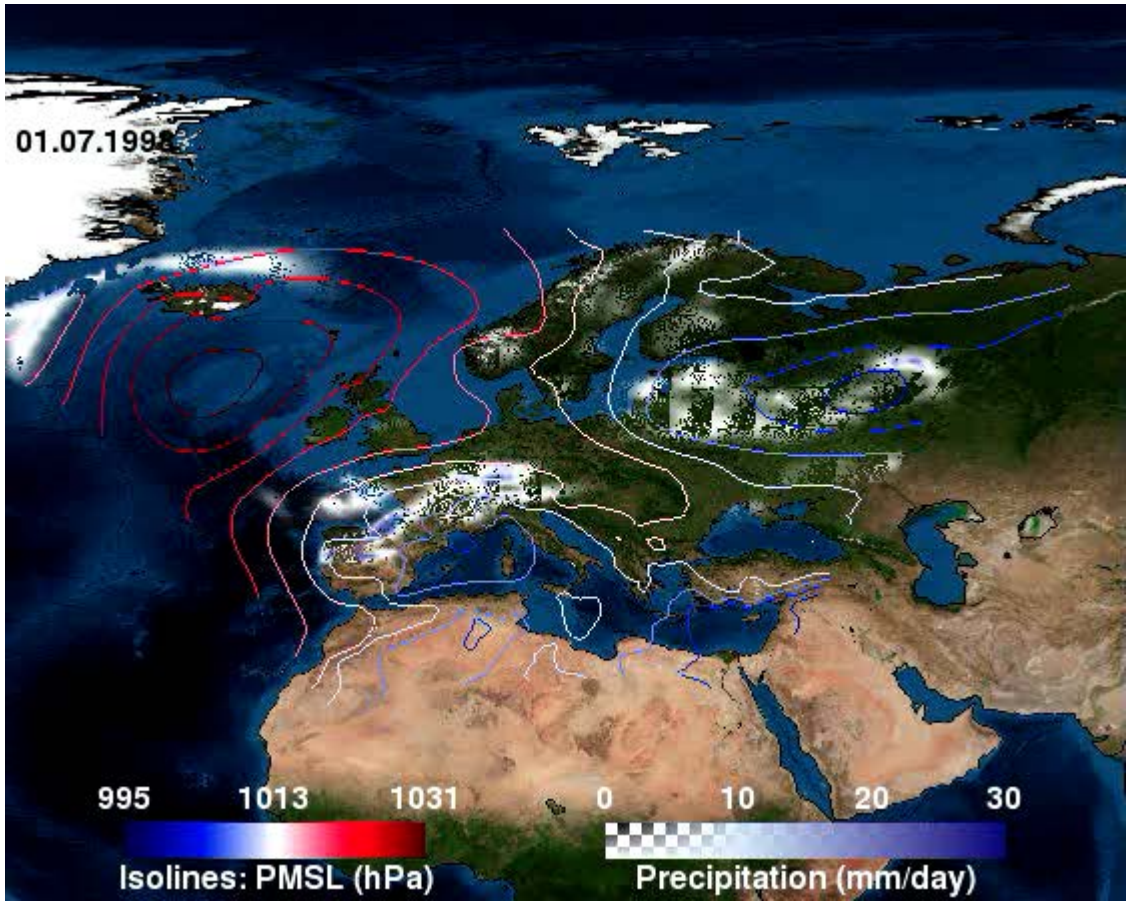
# Motivation

## Daily Precip. (shaded, grey), PMSL (contours)

*WATCH forcing data Precip. & ERA-interim PMSL*




*WATCH data: Daily time series of ECMWF reanalysis data where the monthly means are corrected with GPCC precipitation data and a gauge undercatch correction according to Weedon et al. (2011)*

➢ Precipitation of Scandinavia is strongly associated with the **North Atlantic Oscillation (NAO)**, in combination with **high orography** effects along the Norway **coastlines** and over Sweden.

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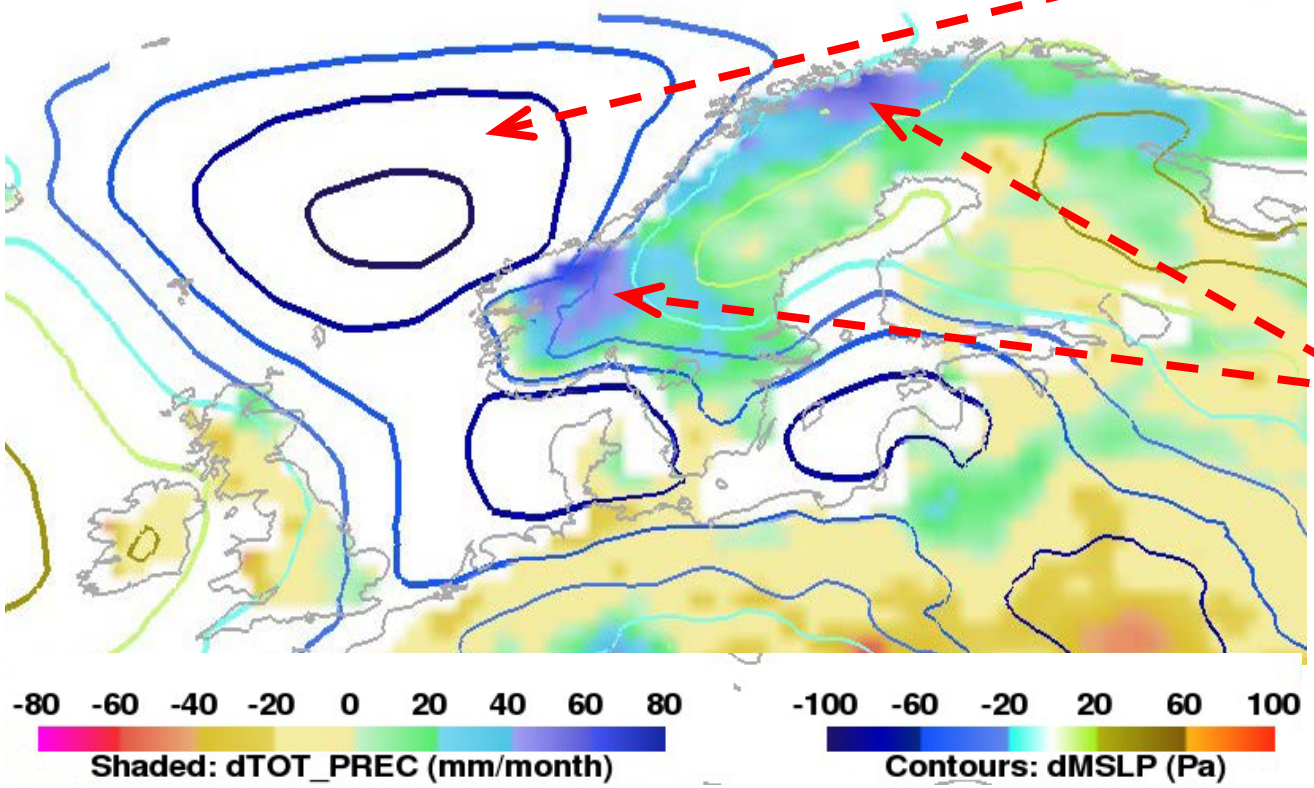
**Daily Precip. (shaded), PMSL (contours)**

*CCLM standalone – OBS, JJA 1998-2002*

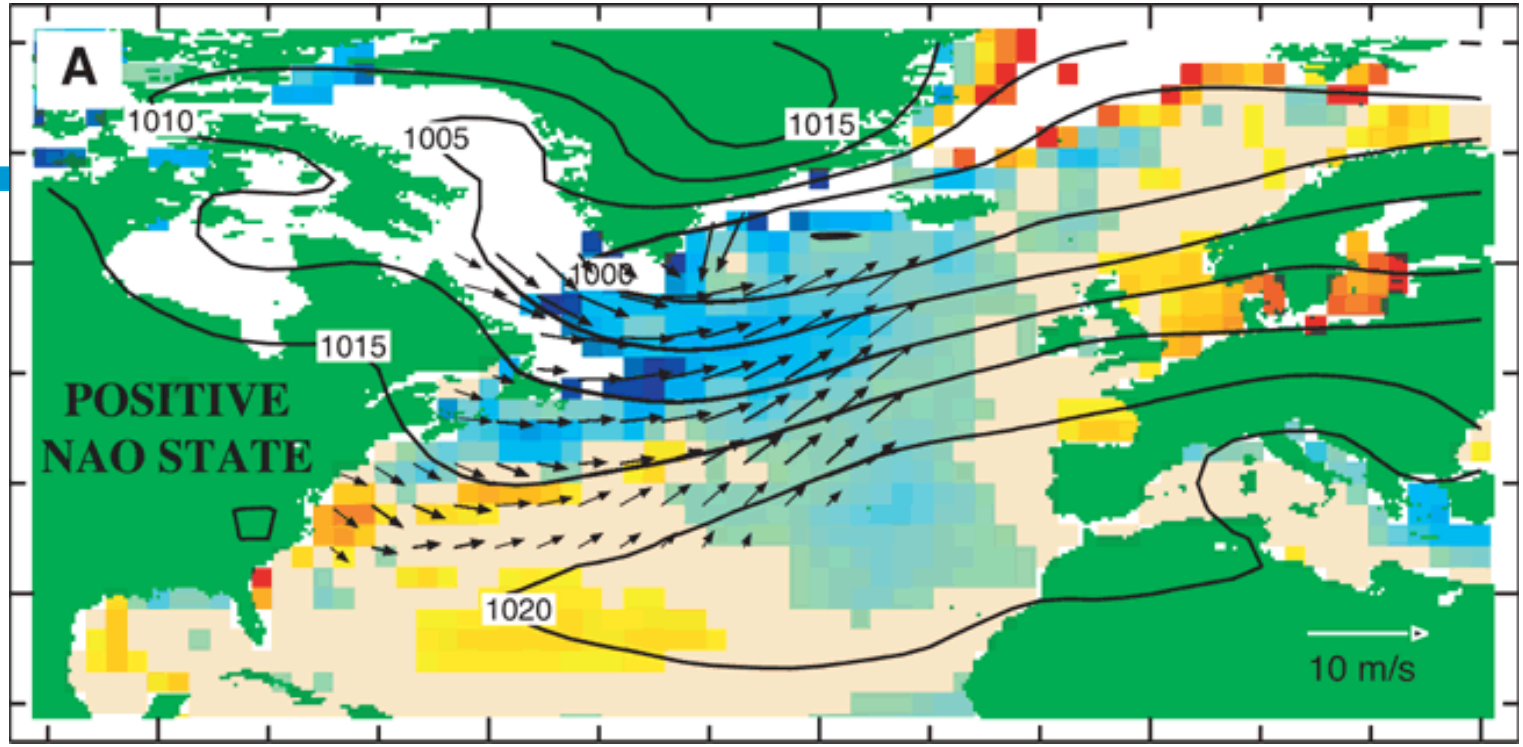



*Difference of CCLM precipitation from WATCH data (shaded)*
*Difference of CCLM MSLP from ERA-interim (contours).*

➢**MSLP** of CCLM is **lower** over the North Atlantic Ocean, the North- and Baltic Seas than ERA-interim.

➢ **Scandinavia precipitation** is correlated with **MSLP** over the oceans (correlation coefficients are up to **-0.65**, not shown): **negative bias of MSLP → wet bias of precip**.

# Motivation

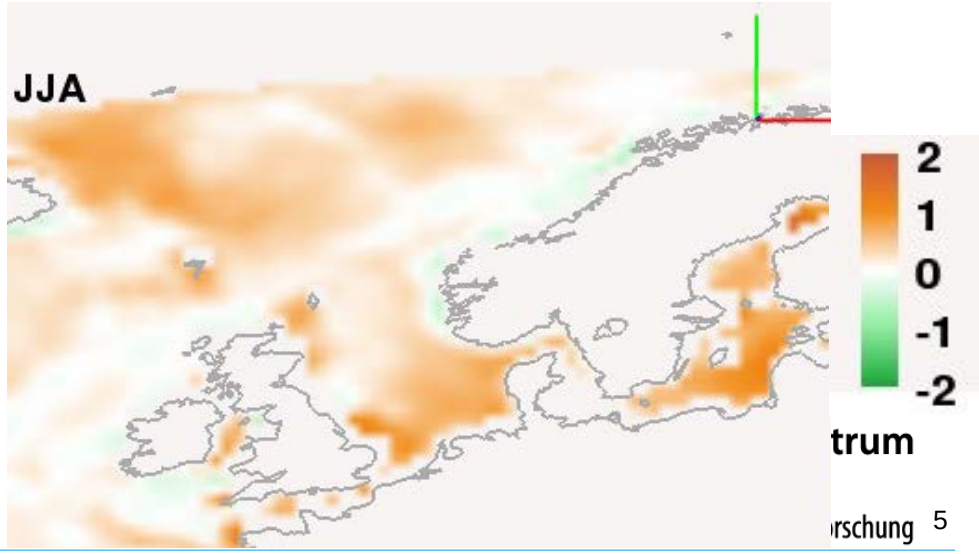



http://www.nefsc.noaa.gov/ecosys/ecology/Climate/

- **NAO** is strongly associated with **SST** of North Atlantic Ocean (*Hurrell et al., 2003, Visbeck et al., 2001, Greatbatch, 2000, …*).
- **ERA-interim SST mostly is warmer than observed** (e.g., compared to satellite & buoy NOAA OISST data, ¼° x ¼°), especially in **summer**.

**→ more adequate SST from a high resolution regional ocean model ?**

**Seasonal mean SST differences between ERA-interim and NOAA OISST 1997 – 2005**



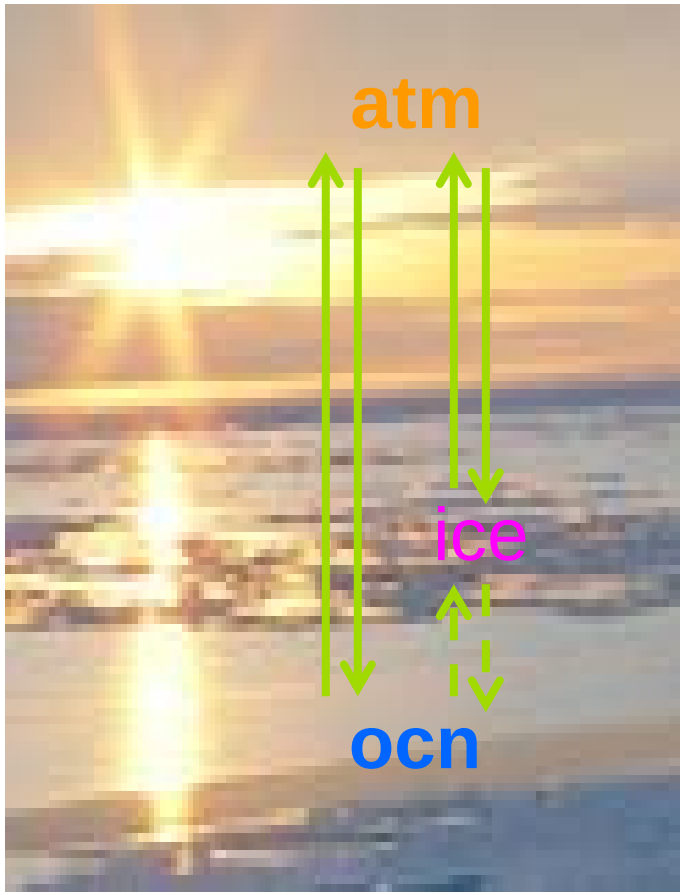
# Motivation

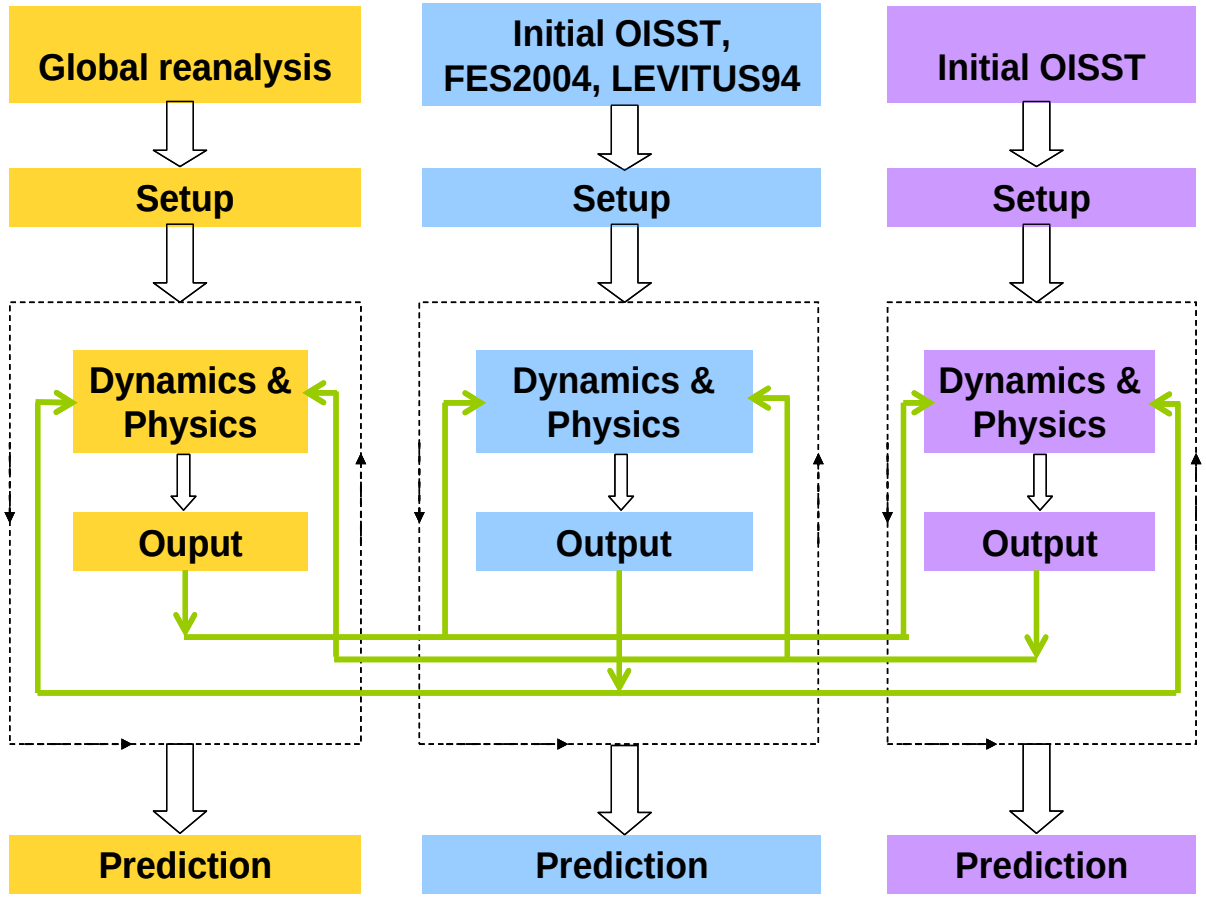
## Aims

→ To develop a coupled model system that reproduces atmosphere-ocean-sea ice interactions and feedback.

→ To analyse impacts of the coupled system on climate simulations.

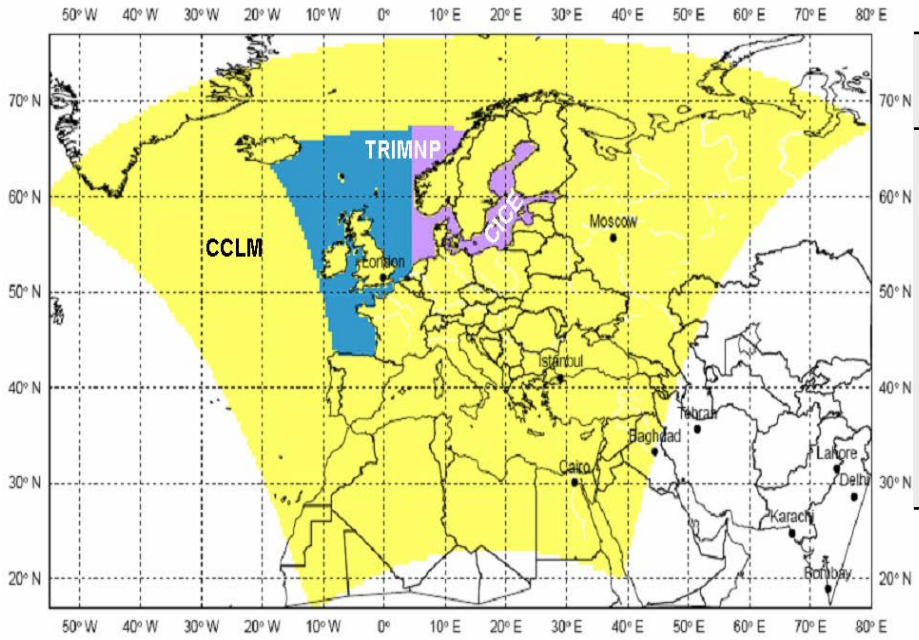
→ To improve simulations of regional climate of Baltic Sea and North Sea regions.




- **CCLM**: the non-hydrostatic regional climate model CCLM (**CO**nsortium for **S**mall scale **MO**delling model in **CL**imate **M**ode) developed by COSMO and the CLM-community.
- **TRIMNP**: the "**N**ested and **P**arallel" version of the non-hydrostatic regional ocean model developed at HZG on the basis of the **TRIM**3D (Tidal Residual and Intertidal Mudflat Simulations in 3-D) model (Italy).
- **CICE**: the Los Alamos sea ice model (USA).
- The coupler **OASIS3** (CERFACS, France).

| | CCLM | TRIMNP | CICE |
|---|---|---|---|
| Horizontal resolution | 50km | 12.8km | 12.8km |
| Vertical resolution | 32 layers | 50 layers | 5 ice-categories |
| Domain (grid points) | 101 x 111 | 200 x 230 | 120 x 120 |
| Initial & Lateral boundary conditions | 6-hourly ERA-interim | NOAA OISST, Levitus94, FES2004 | NOAA OISST |




| EXPS | Strategy | Time | Skin temperature |
|---|---|---|---|
| STERAi | Stand-alone | 1997-2002 | ERA-interim, 6-hourly updated |
| CPERAi “COSTRICE1.0” | Coupled | 1997-2002 | is the combination of SST of TRIMNP & sea ice skin temperature of CICE, 3-hourly exchanged |

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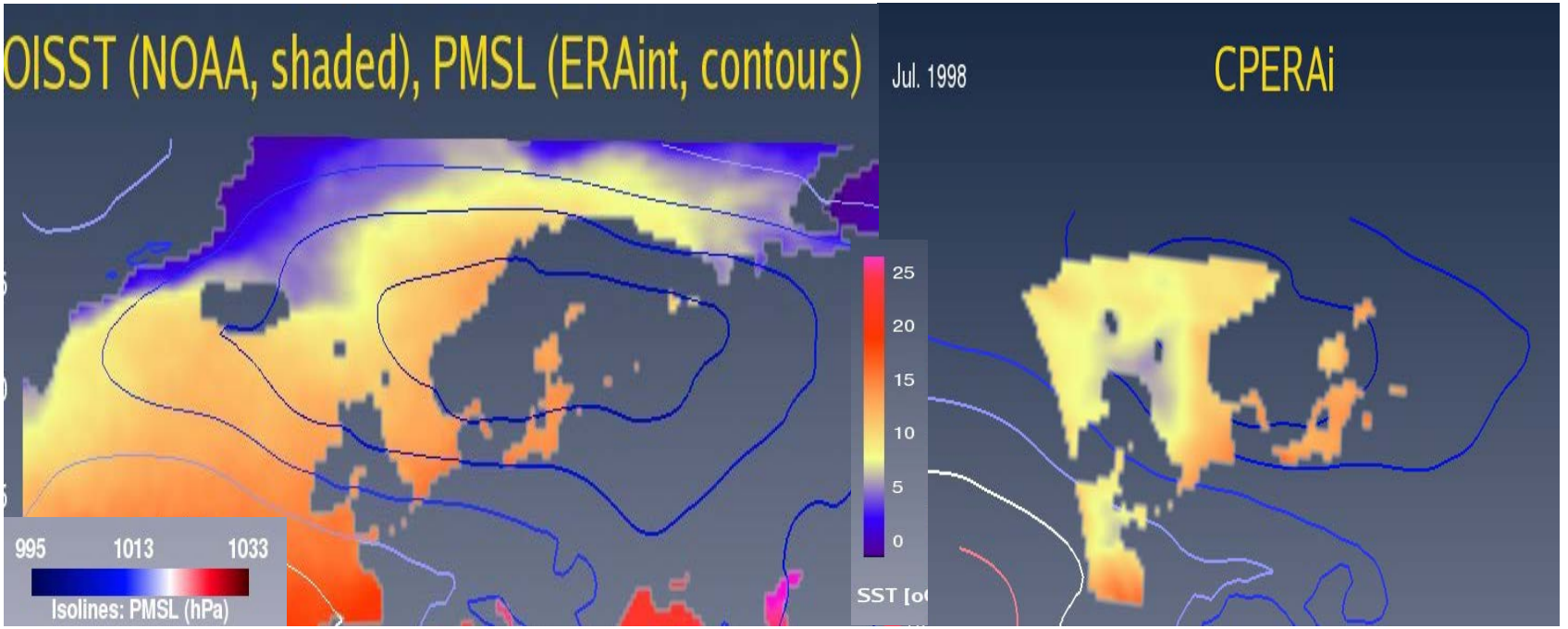
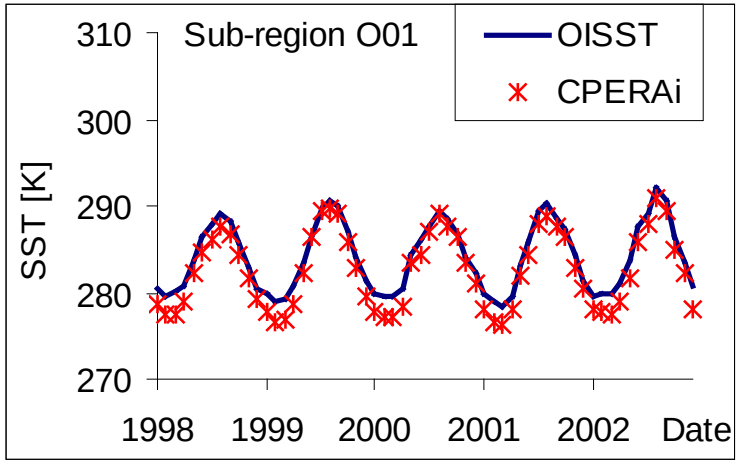
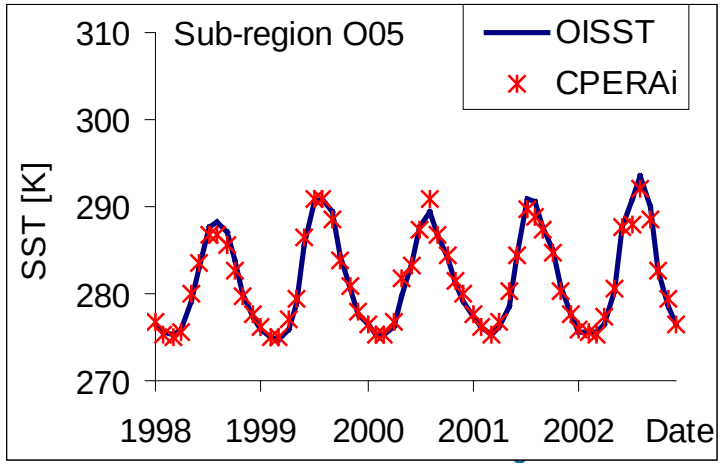
# SST &
# Mean sea level pressure

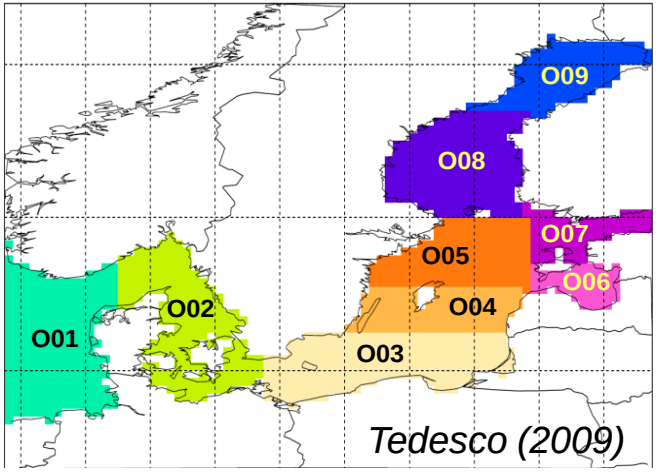



- Monthly mean SST (shaded) and mean sea level pressure PMSL (contours) are reproduced well by COSTRICE1.0.

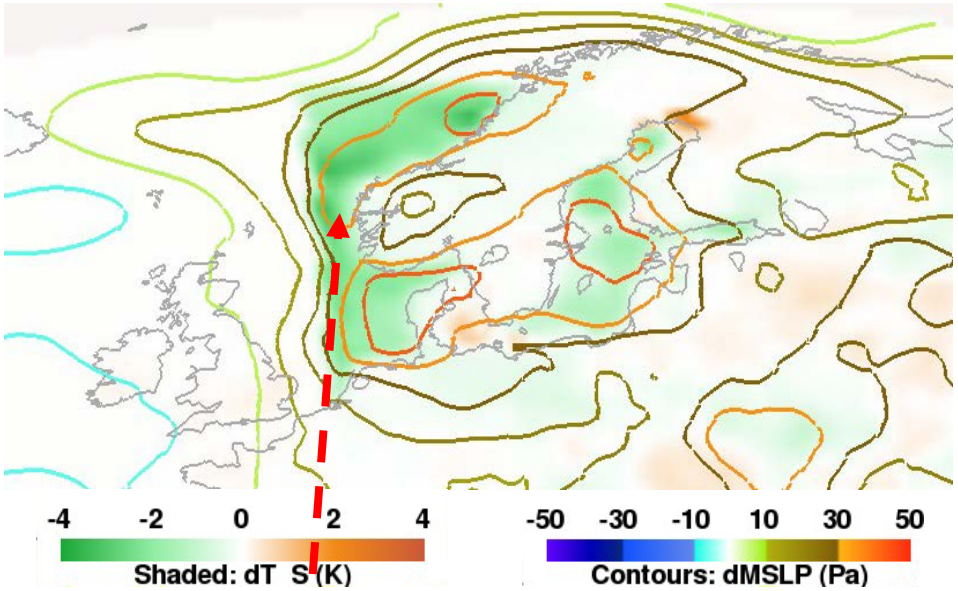
- Monthly area averaged SST (K) for 1998-2002 of sub-regions



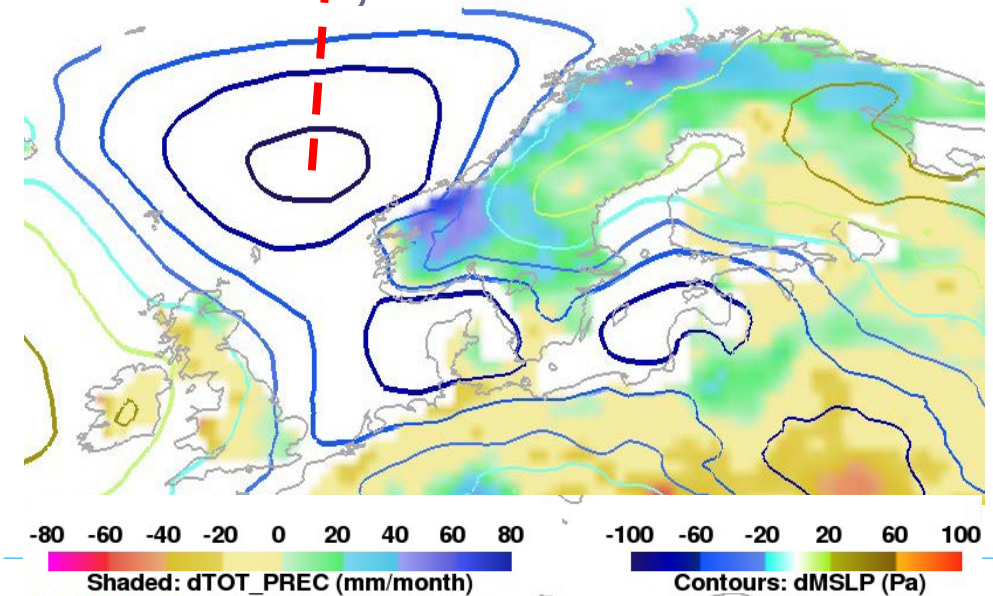



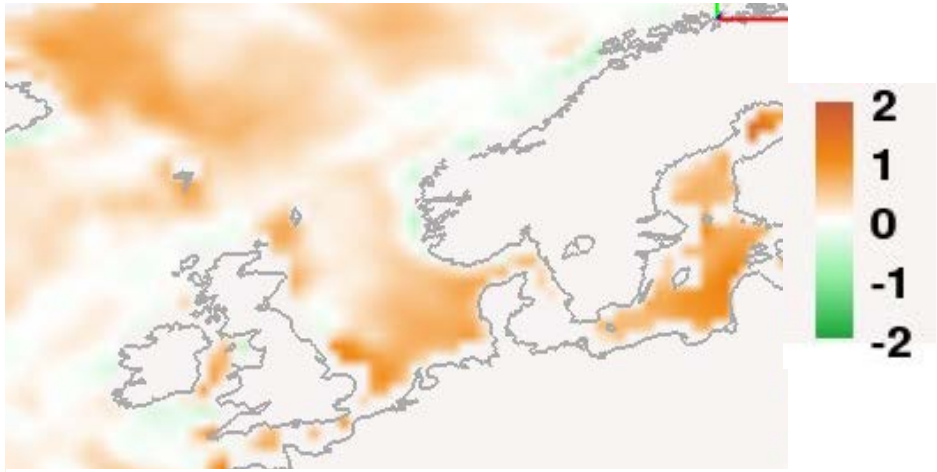
## CPERAi – ERAint




## PMSL, STERAi – ERAint




## STERAi - OISST

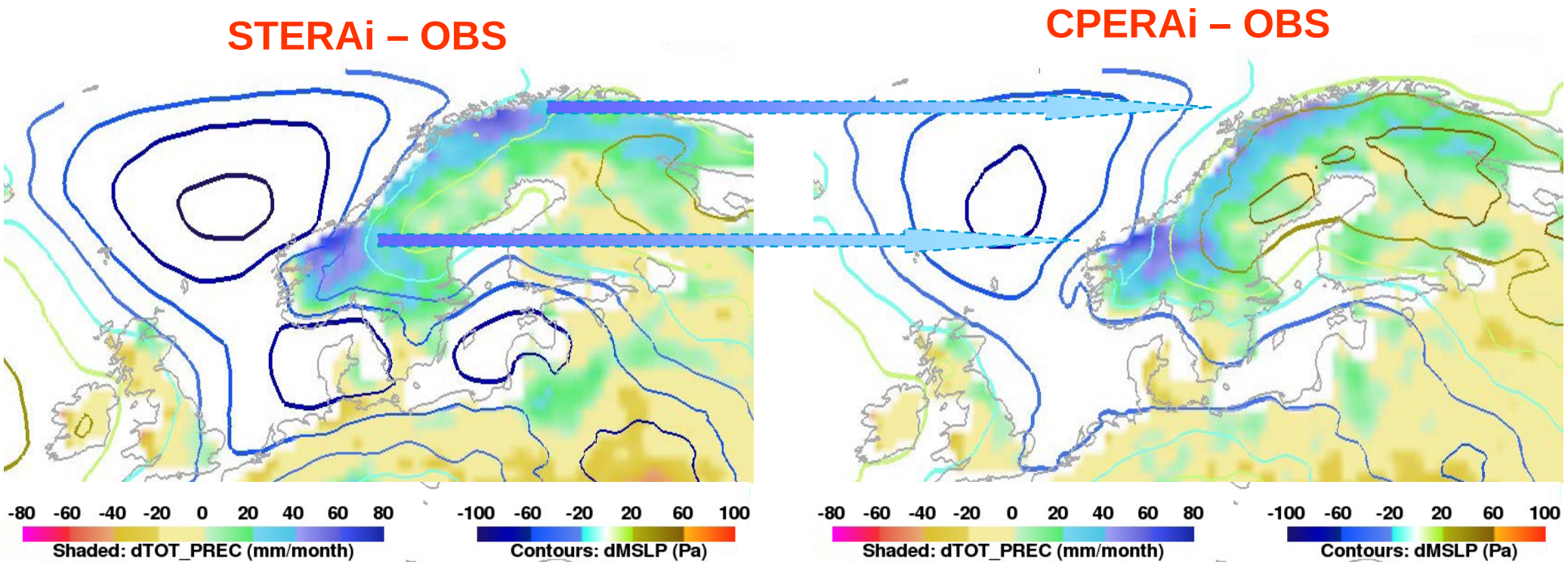



**SST (shaded), PMSL (contours)**

➢ COSTRICE reduces the **warm bias** of ERA-interim **SST** (compared to OISST), that is used to force STERAi.

➢ **MSLP** of COSTRICE over North Atlantic Ocean, the North- & Baltic Seas is slightly higher than the stand-alone CCLM → **the low** is more similar to ERA-interim.

# Precipitation



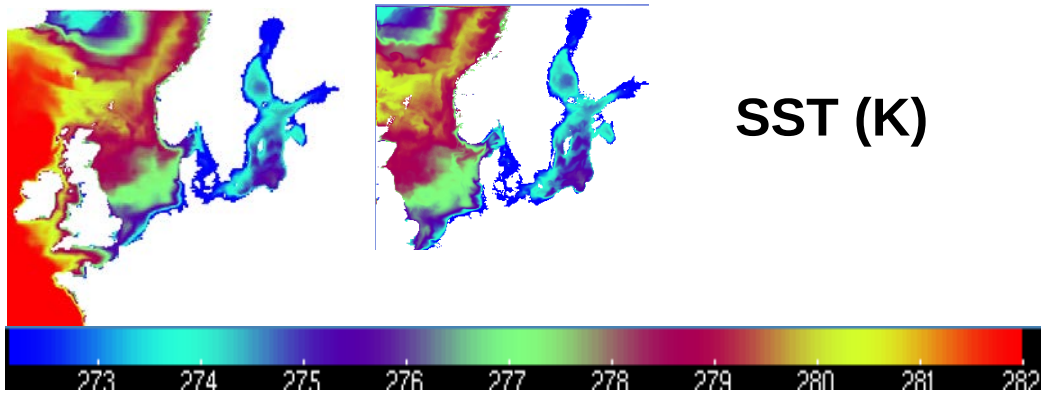

Difference of precipitation [mm/month] of STERAi (left)/CPERAi (right) from WATCH data (shaded)
Difference of MSLP [Pa] from ERA-interim (contours). Time: JJA 1998-2002.

- The **negative MSLP** bias over the oceans is **reduced** by COSTRICE1.0.
- Consequently, COSTRICE1.0 has **reduces precipitation biases** over Scandinavia, Lithuania, Latvia and Finland, north Germany, Poland, Ukraine.

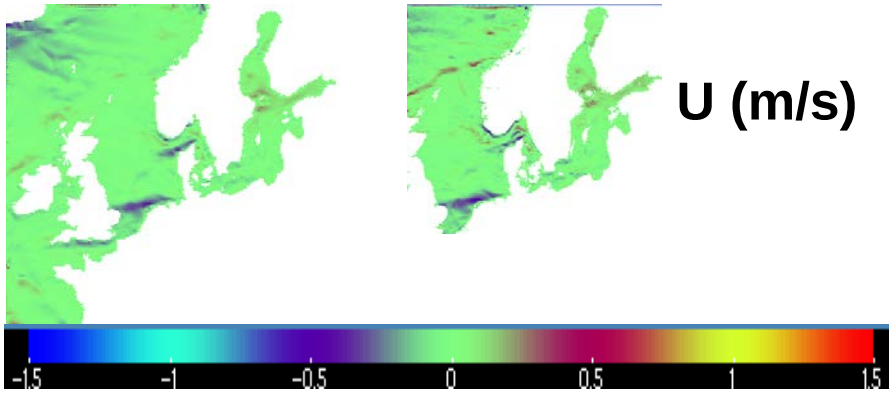
- COSTRICE1.0 has capability to reproduce SST and sea ice over the Baltic Sea and the North Sea.
- Include a sea ice model within the coupled system to improve the simulation of skin temperature over the ocean in winter.
- The NAO-like pattern (shown in MSLP) is captured well by COSTRICE1.0 compared to ERA-interim. The negative MSLP biases over North Atlantic Ocean, the North- & Baltic Seas of standalone CCLM are reduced by COSTRICE1.0 since the SSTs are better simulated. Consequently, precipitation biases are reduced over Baltic catchment and adjacent areas.
- Air-ocean-sea ice interactions and feedback were reproduced in the coupled system, which lead to some improvements in the climate simulations. However, a more robust conclusion will be made after the assessment of a long term simulation.

1. **Spin-up TRIMNP**: TRIMNP will be run for 1979 - 1995 forced by the monthly ECMWF operational Ocean Re-Analysis System 4 data (ORAS4).
2. **COSTRICE2.0**: Upgraded TRIMNP2.5, the latest version CCLM5.0, using the coupler OASIS3-MCT2.0.
3. **Coupled**: long-term run for 1995 – 2011 on higher resolutions (0.11 x 0.11 deg. CCLM, 3.2 km TRIMNP & CICE).

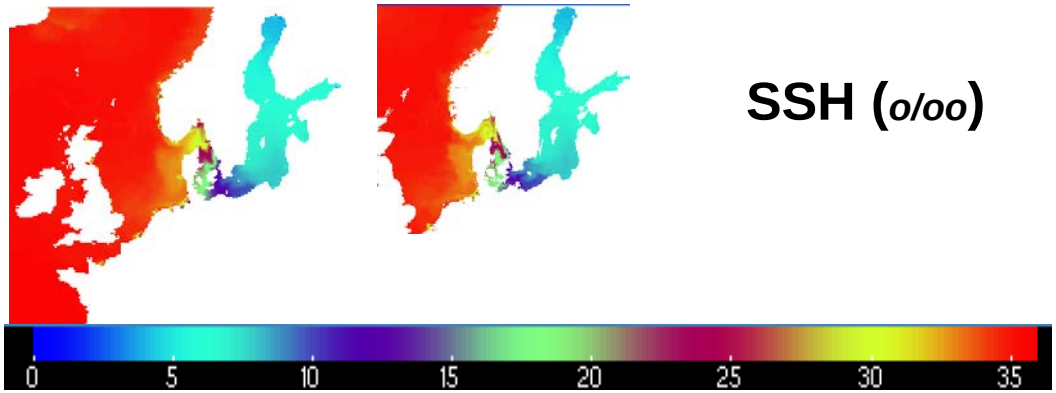
# Res. 12.8 km (left) vs Res. 3.2 km (right), TRIMNP



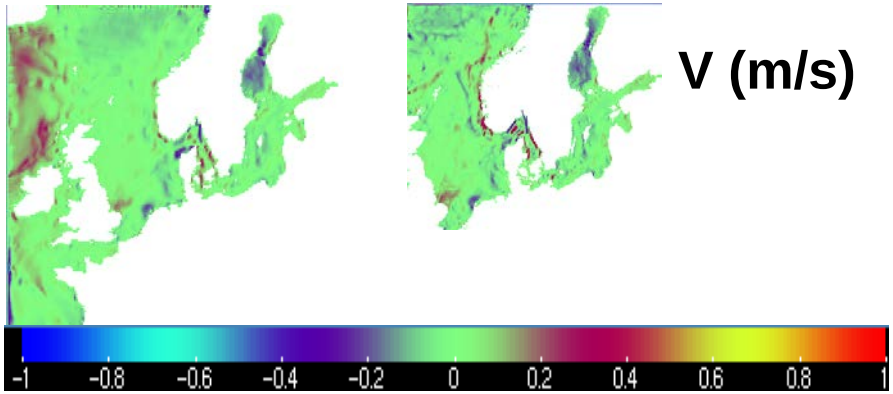

**SST (K)**



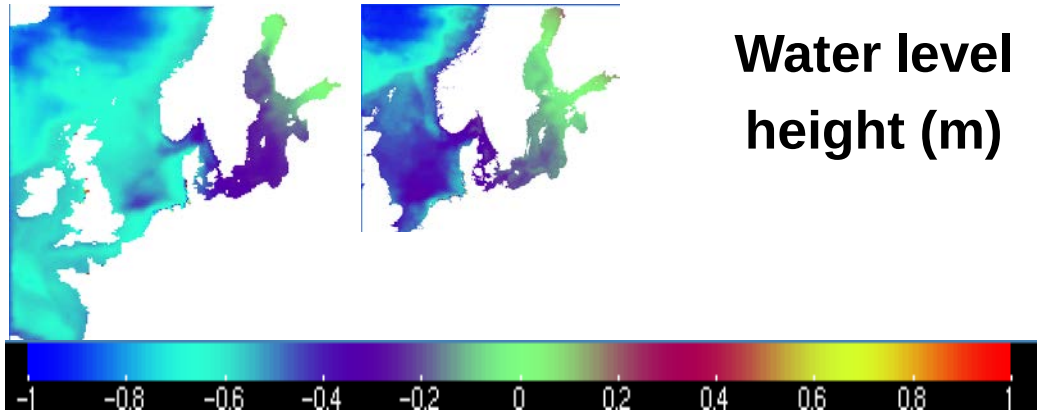

**U (m/s)**




**SSH (*o/oo*)**




**V (m/s)**




**Water level height (m)**

Higher resolution:

→ more details of SST, SSH;

→ stronger currents;

→ higher water level height.

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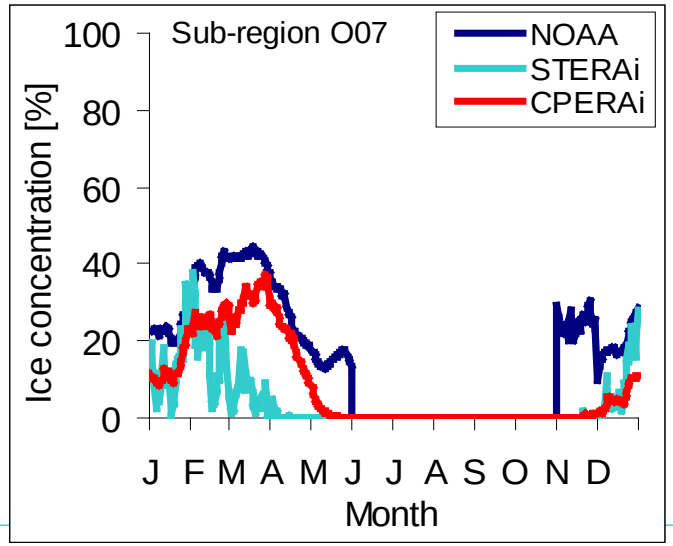
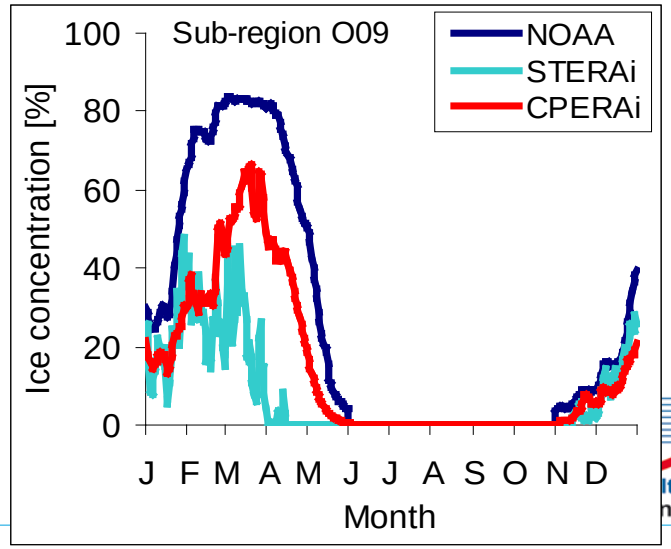
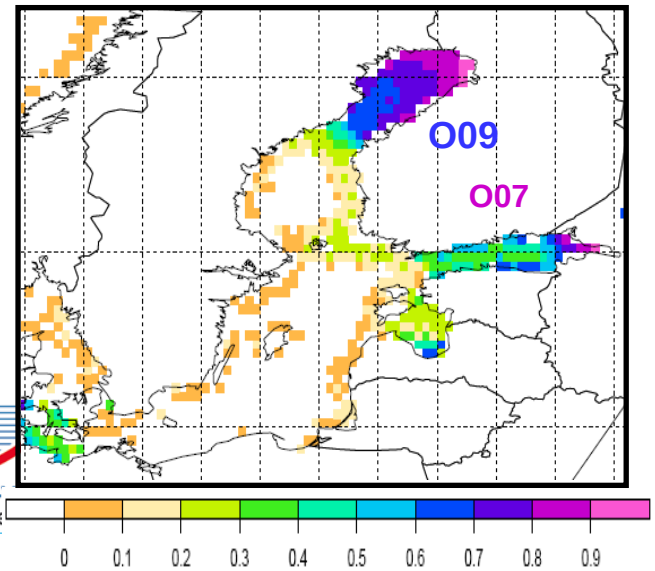
**Outlook:** coupling the hydrological discharge model HD of MPI-M to the COSTRICE. **Why?**

- COSTRICE1.0 has the better performance in reproducing **sea ice** than the ocean only run. However, COSTRICE1.0 still underestimates sea ice concentration compared to NOAA data.
- **The reason?**
  - ✓ Current simulations: Lacking of river discharge data, especially along Sweden.
  - ✓ Climate projections for future: Important role of runoff in the climate system.

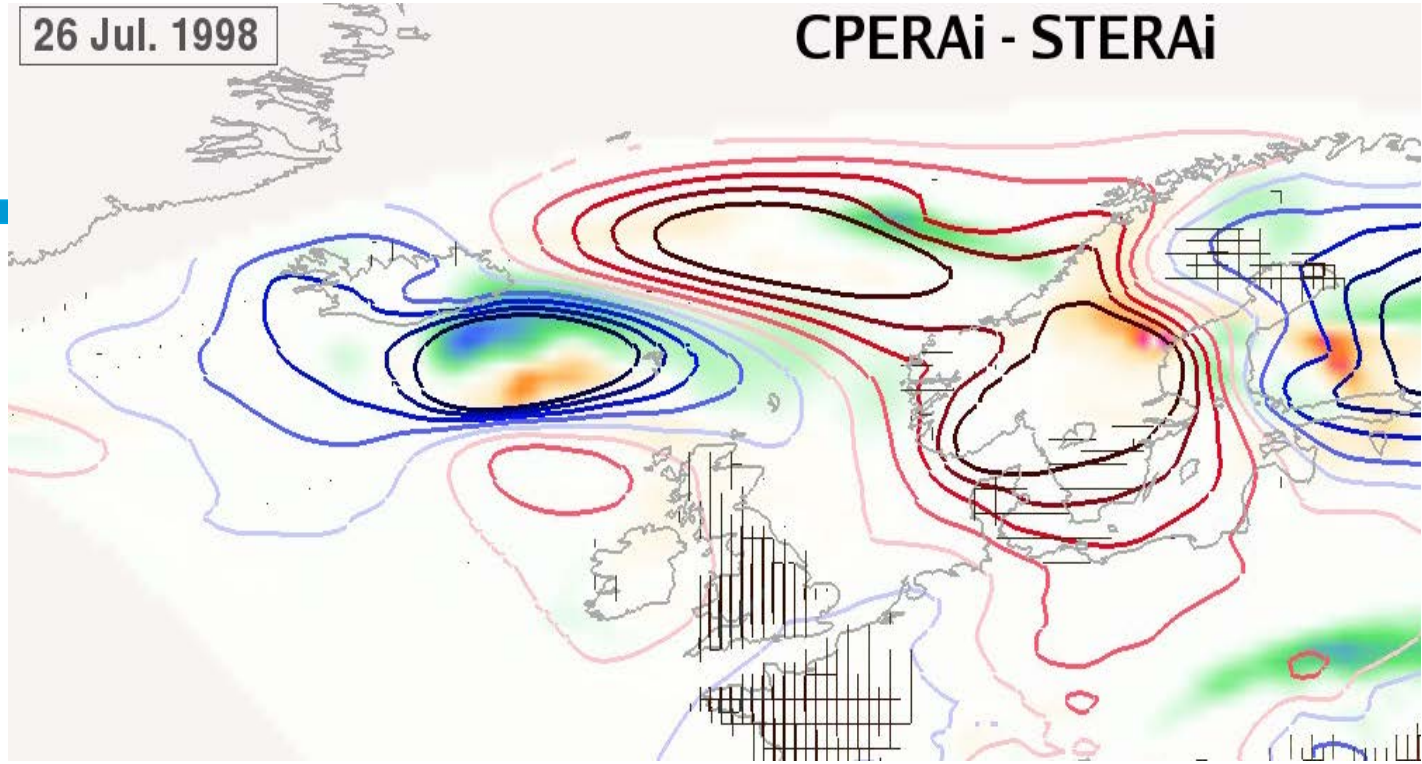
**Annually variation of area averaged ice concentration [%], 1998 - 2002**

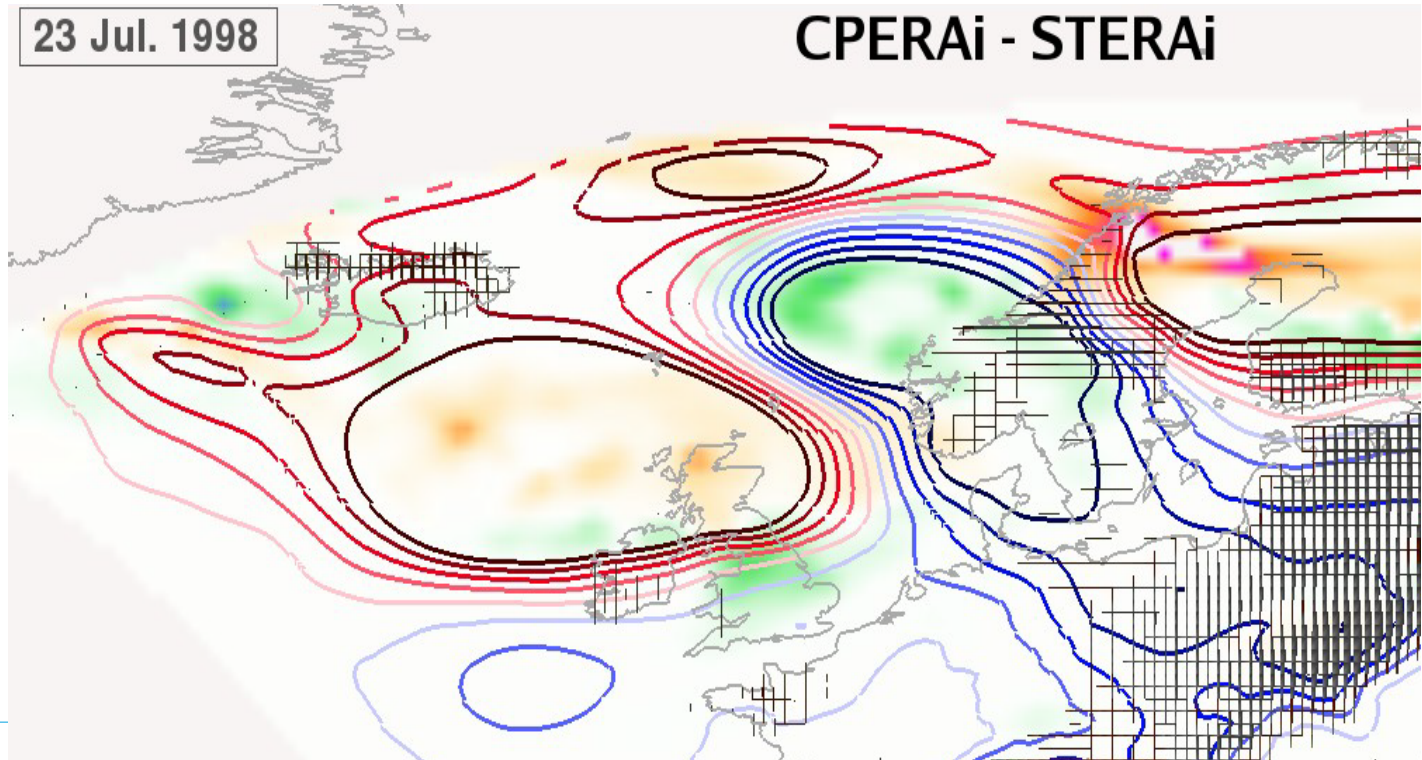


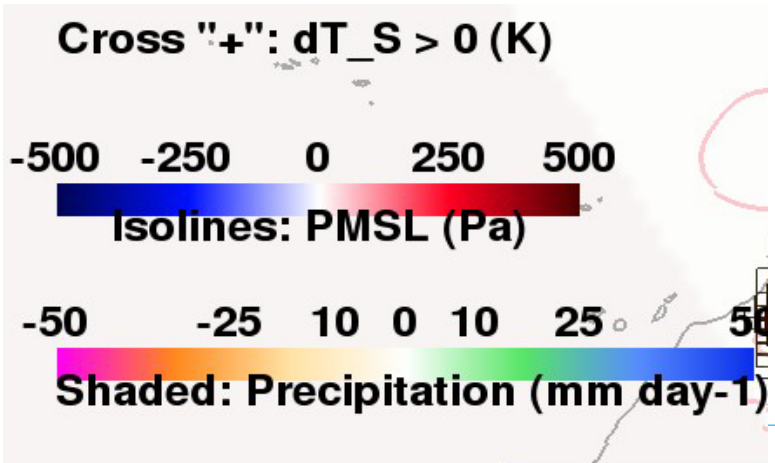



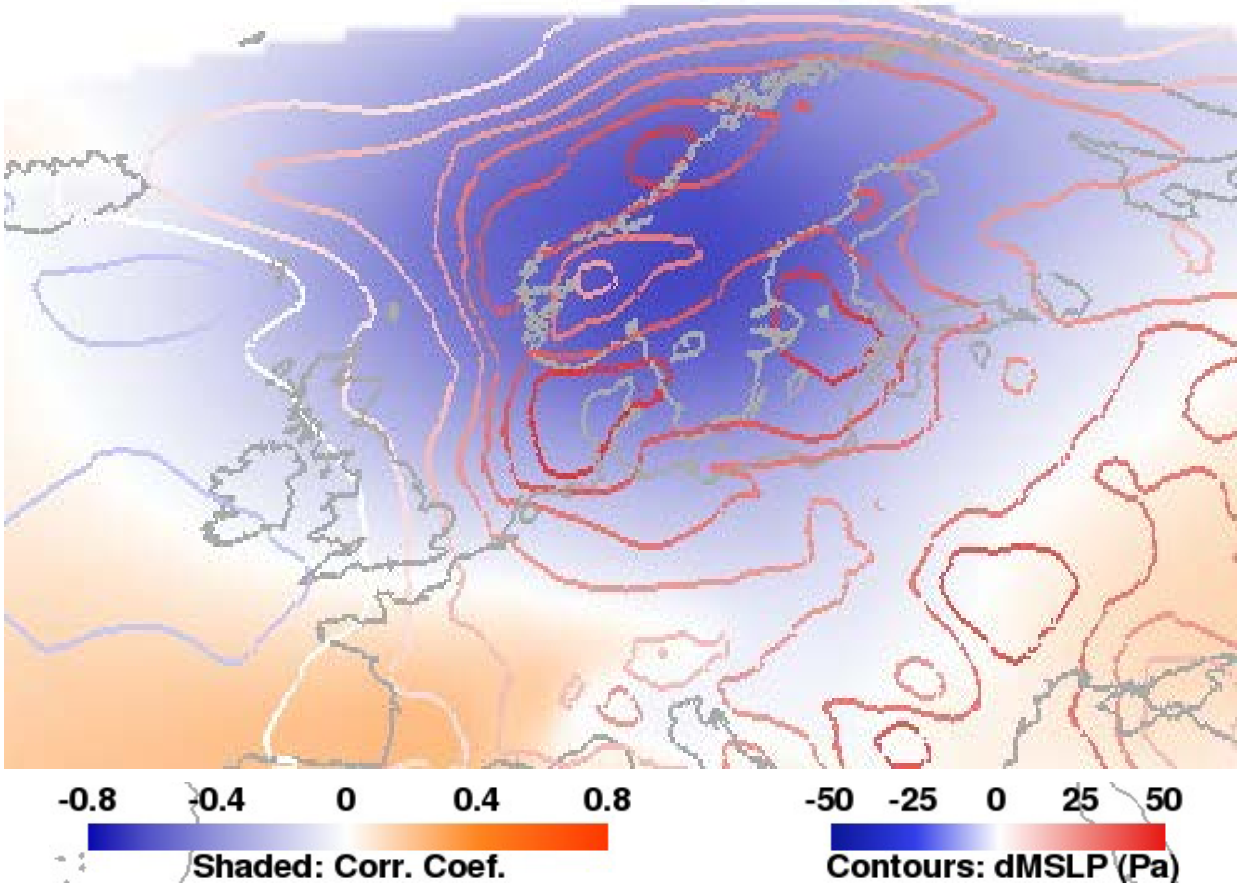
Difference of precipitation [mm/day], and difference of MSLP [Pa] (contours) between CPERAi & STERAi.



The **decrease of rainfall** of **Scandinavia** in COSTRICE is due to the **increase of mean sea level pressure** over the North Sea and Baltic Sea regions.

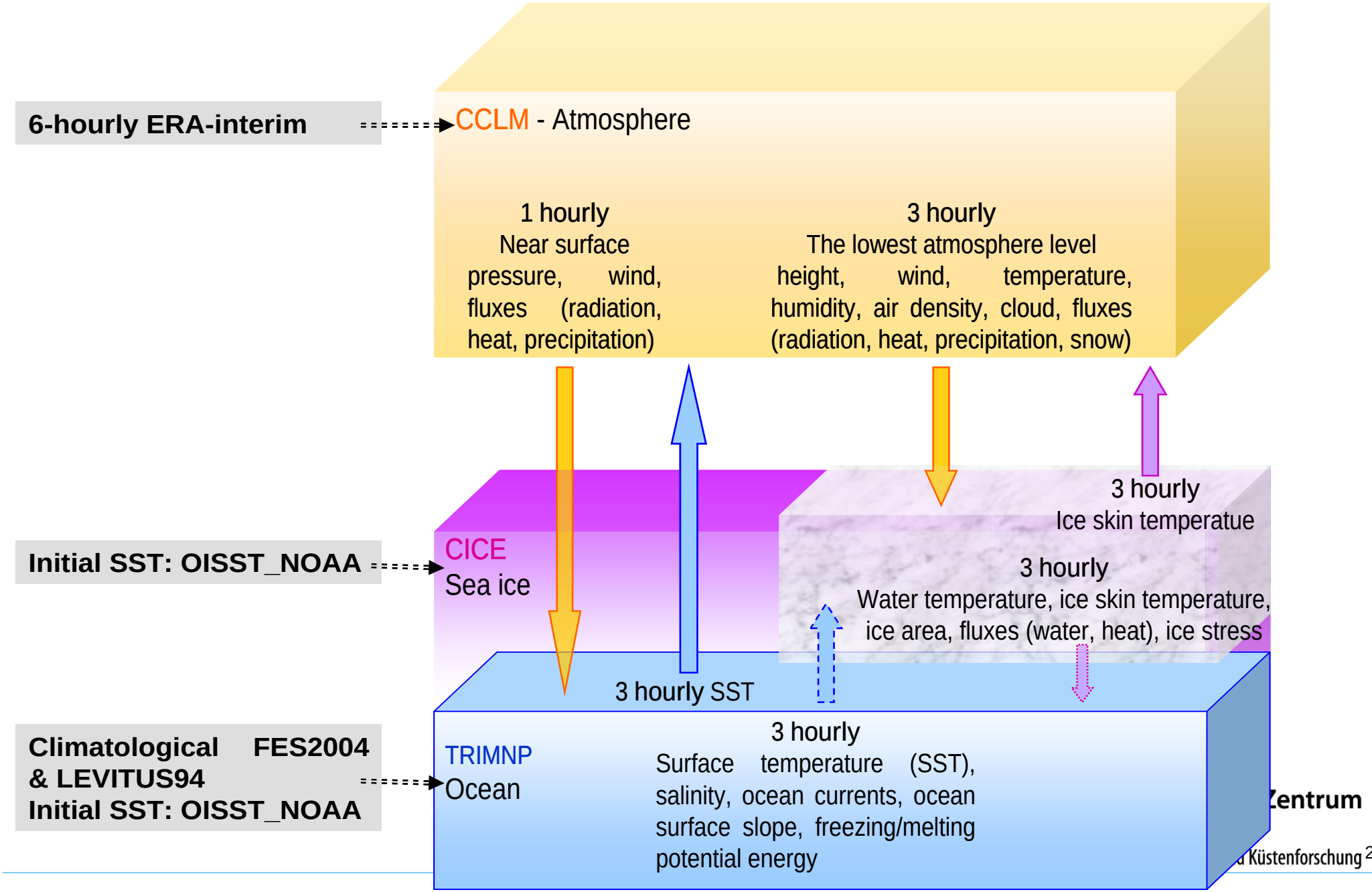



➔ **Shaded: Corr. Coef.** of (i) **difference** of **rainfall** (mm/month) between CPERAi and STERAi, averaged over **Scandinavia** and (ii) **difference** of **MSLP** (Pa) between CPERAi and STERAi, for JJA 1998-2002. Max. is up to **-0.6**: MSLP increases → rainfall decreases.

➔ **Contours: Difference of MSLP** [Pa] between CPERAi & STERAi for JJA 1998-2002.

# The COSTRICE system

- **Atmosphere model CCLM**: the non-hydrostatic regional climate model CCLM (**CO**nsortium for **S**mall scale **MO**delling model in **CL**imate **M**ode) version cosmo_4.8_clm11 developed by COSMO and the CLM-community.
- **Ocean model TRIMNP**: the "**N**ested and **P**arallel" version of the non-hydrostatic regional ocean model developed at HZG on the basis of the **TRIM**3D (Tidal Residual and Intertidal Mudflat Simulations in 3 Dimensions) model of University of Trento, Italy.
- **Sea ice model CICE**: the Los Alamos sea ice model version 4.1 from Los Alamos National Laboratory, US
- **The coupler OASIS**: the **O**cean **A**mosphere **S**ea **I**ce **S**oil model version 3 of CERFACS, France. OASIS3 exchanges data amongst component models via green arrows.


6-hourly ERA-interim
CCLM - Atmosphere
1 hourly
Near surface pressure, wind, fluxes (radiation, heat, precipitation)
3 hourly
The lowest atmosphere level height, wind, temperature, humidity, air density, cloud, fluxes (radiation, heat, precipitation, snow)
3 hourly
Ice skin temperatue
Initial SST: OISST_NOAA
CICE
Sea ice
3 hourly
Water temperature, ice skin temperature, ice area, fluxes (water, heat), ice stress
3 hourly SST
Climatological FES2004 & LEVITUS94
Initial SST: OISST_NOAA
TRIMNP
Ocean
3 hourly
Surface temperature (SST), salinity, ocean currents, ocean surface slope, freezing/melting potential energy

| EXPS | Strategy | Time | Skin temperature |
|---|---|---|---|
| STERAi | Stand-alone | 1997- 2002 | ERA-interim, 6-hourly updated |
| CPERAi | Coupled | 1997 – 2002 (Jan.1997 is a coupling "spin-up" time) | is the combination of SST of TRIM & sea ice skin temperature of CICE, 3-hourly exchanged |

$$TS = \sqrt[4]{\frac{HFL}{\varepsilon\sigma}}$$

$$HFL = \varepsilon\sigma TS^4$$

$$HFL = \varepsilon\sigma T_{Ice}^4 \times A_{Ice} + \varepsilon\sigma T_{Oce}^4 \times (1 - A_{Ice})$$

HFL: heat flux over a grid box

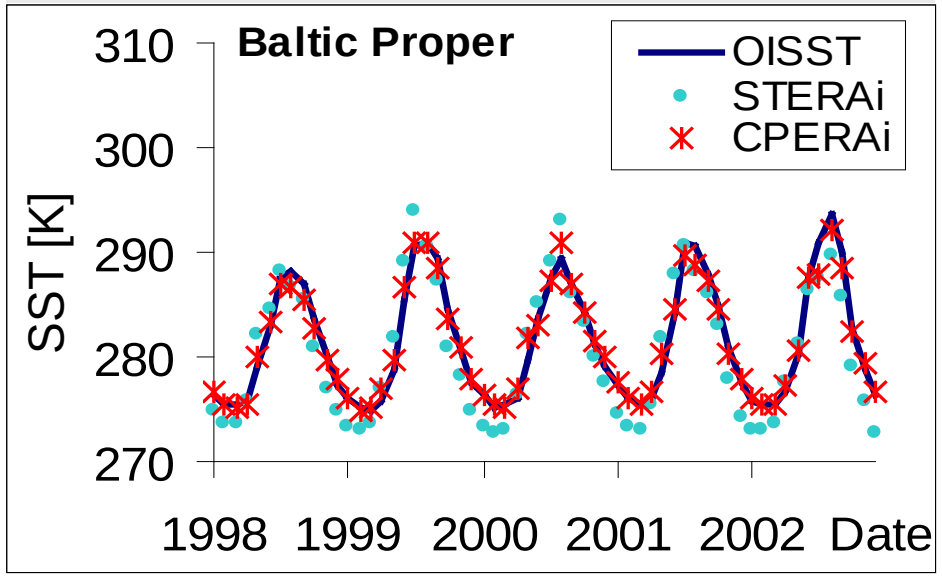
TS: surface skin temperature

$T_{Ice}$: sea ice skin temperature

$T_{Oce}$: water skin temperature

$A_{Ice}$: sea ice area

## Monthly SST [K], 1998 - 2002




➢ Compared with the ocean only run: COSTRICE1.0 has the better performance in reproducing **SST** (top) and **sea-ice** (bottom) over the North- and Baltic Sea regions (compared to NOAA data).

## Annually variation of area averaged ice concentration [%], 1998 - 2002