Precipitation enhancement and redistribution by cloud seeding in the eastern Mediterranean

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Universität Karlsruhe (TH) Research University · founded 1825

Precipitation enhancement

Background:

- shortage of freshwater is an issue in many regions of this world
- precipitation especially important for agriculture → shortage may have fatal consequences for food supply
  - ➔ Since centuries people have tried to influence the weather in order to get more rain.
- today this is done mainly by emitting many small hygroscopic or galciogenig particles (cloud seeding)
- operational cloud seeding actvities in more than 24 countries although their efficacy is not proved (yet)
- in all the programs the aim is to *accelerate* precipitation formation

Situation in the eastern Mediterranean

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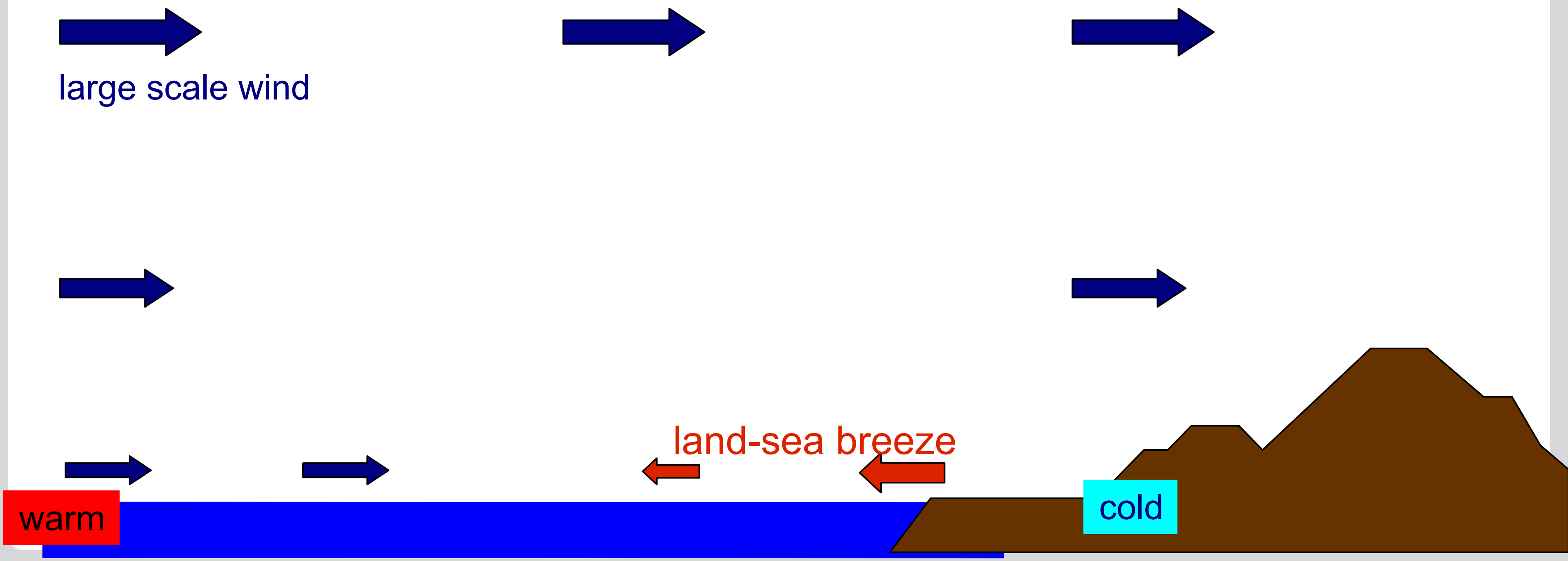
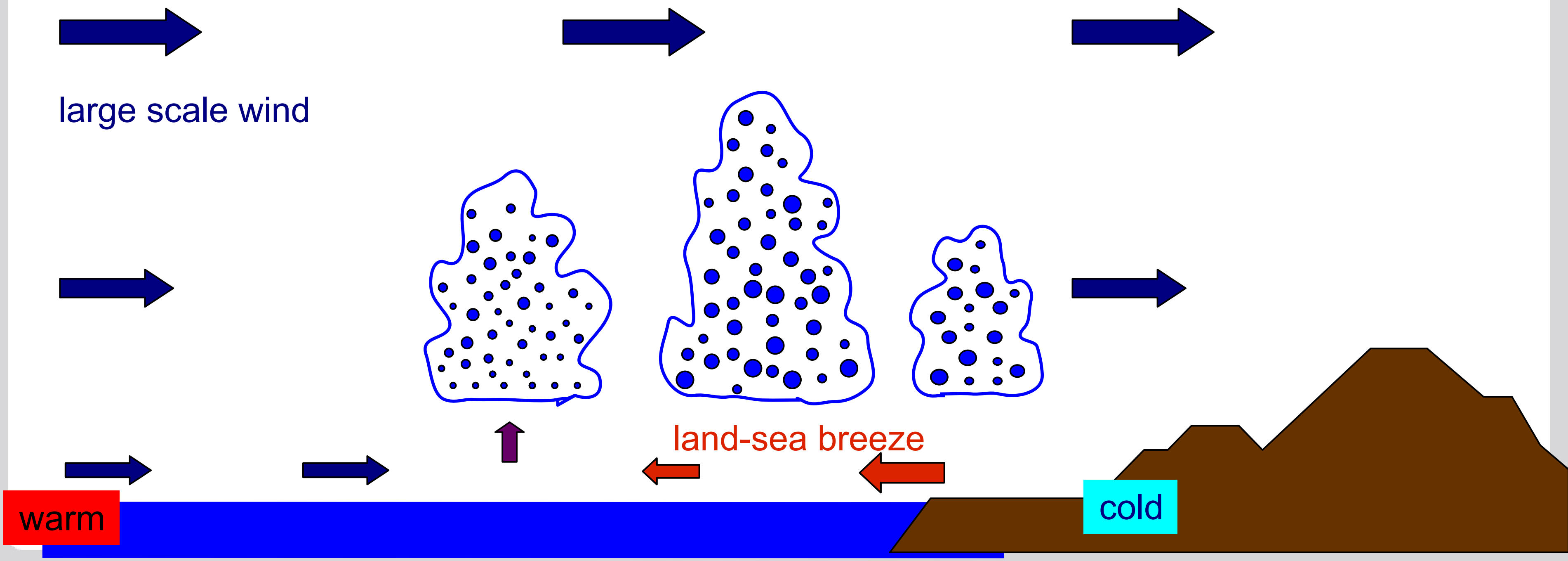
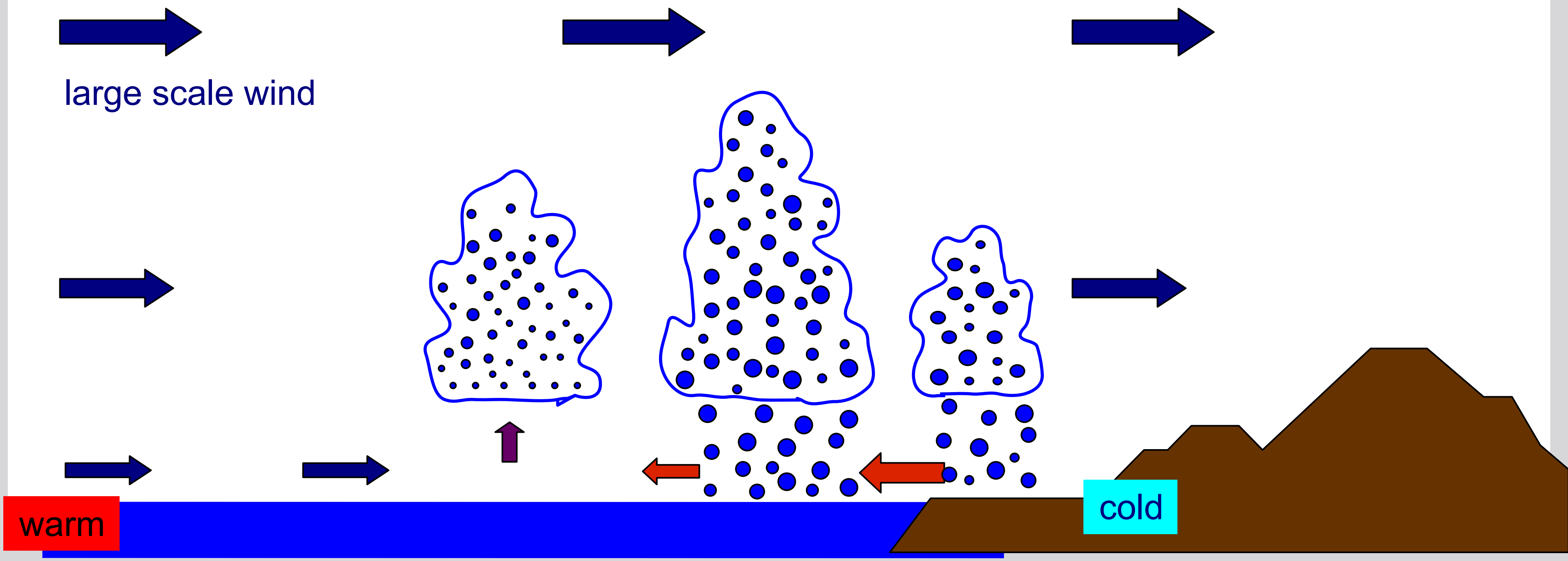


Situation in the eastern Mediterranean

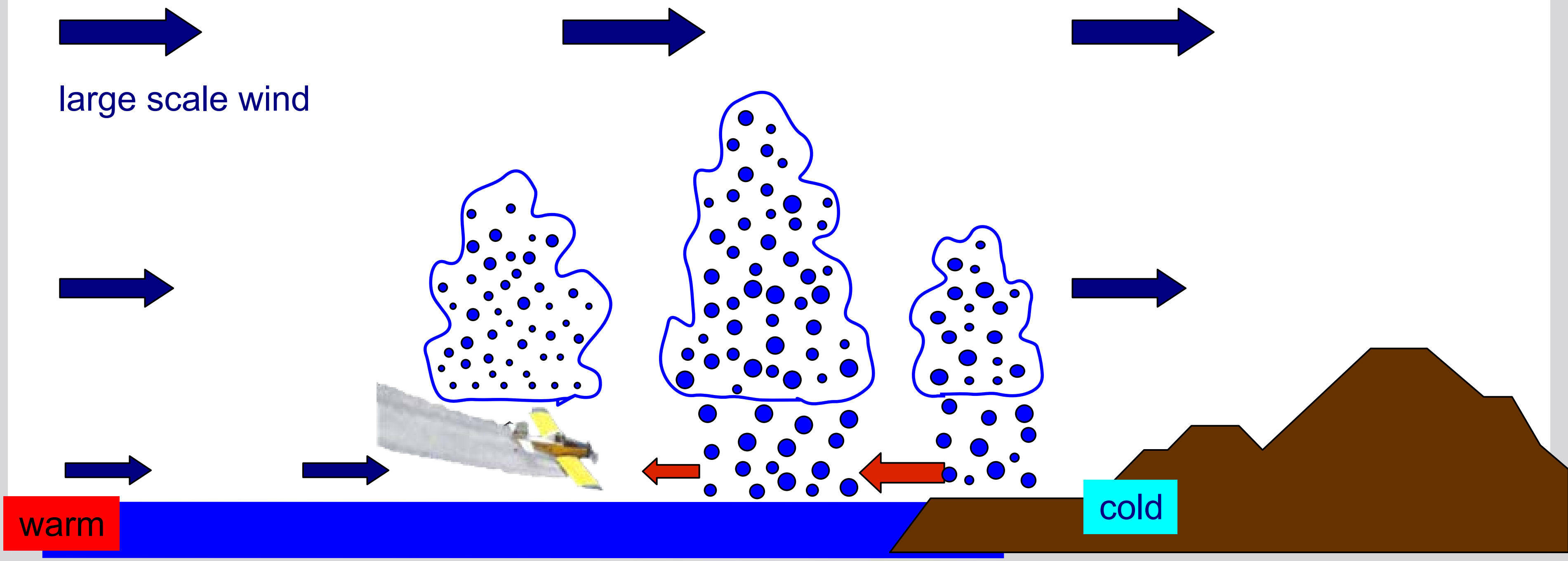


Situation in the eastern Mediterranean



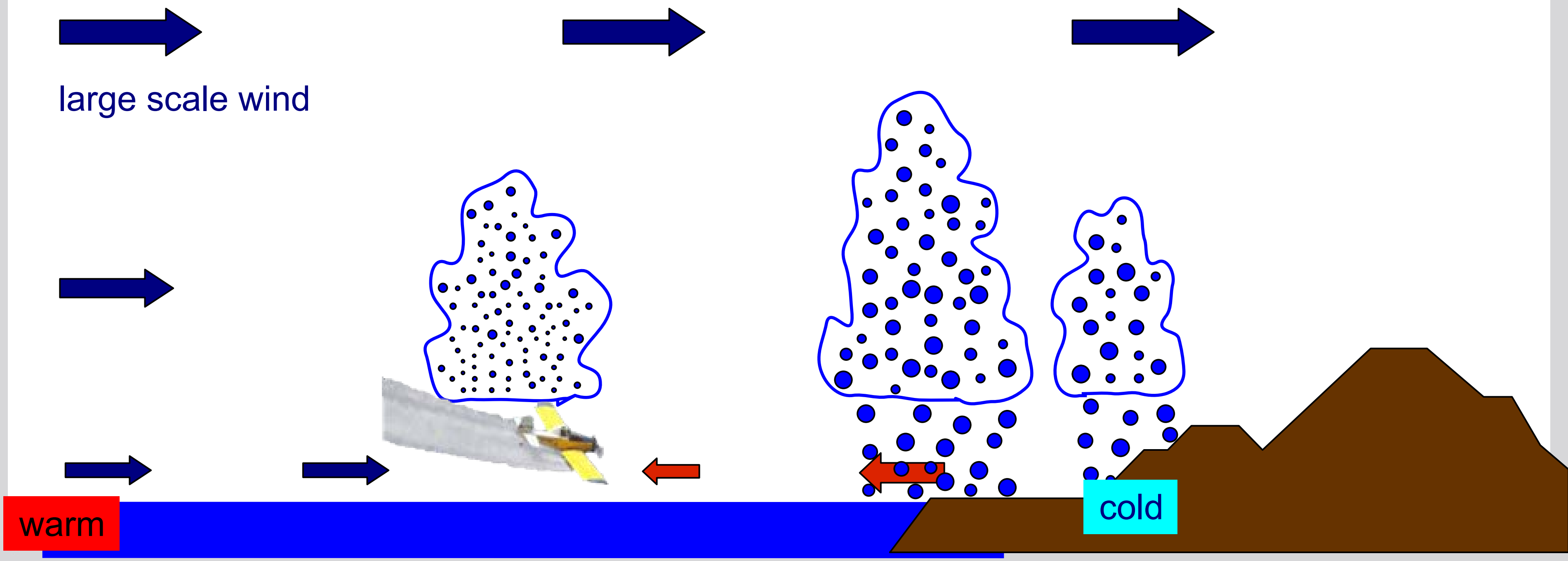
Situation in the eastern Mediterranean

Slow down precipitation formation!



Situation in the eastern Mediterranean

Slow down precipitation formation!



Slowing down precipitation formation

Two stages of cloud droplet growth

1. Condensational growth (dr/dt ~ 1/r)

- Slowed down when many droplets compete for the available water vapor

➔ **Action:** increase cloud droplet number by *seeding the cloud with many small hygroscopic particles (CCN)*

2. The collision-coalescence process

- slowed down when
  - starting from small droplets and
  - when collisions are less likely, i.e. all droplets have about the same size and therefore a similar terminal velocity

  ➔ **Action:** narrow the cloud droplet size distribution by *seeding the cloud with many (small) CCN of the same size*

3D-simulations with COSMO

Model version and setup

- COSMO 3.19
- horizontal resolution ≈ 2 km (0.018°) , $\Delta t = 10$ s
- Model domain: 201 x 201 x 60 gridpoints
- 3rd order Runge-Kutta scheme for time integration
- only shallow convection parameterized
- real orography
- idealized initial and boundary conditions

  (modified radio sounding with temperature deviation of 5 K over the sea)

3D-simulations with COSMO

Model version and setup

- enhanced 2-moment bulk scheme by Seifert & Beheng for cloud microphysics:

  ➔ prediction of mass (*q*) and number density (*n*) of cloud droplets, rain drops, cloud ice, snow, graupel, and hail

  ➔ for the size distribution of all particle classes a generalized gamma-distribution is assumed

$$f(x) = A\, x^{\nu} \exp(-\lambda x^{\mu})$$

  A and *λ* are determined by the predicted values of *q* and *n* , *ν* and *μ* have to be fixed ore diagnosed

3D-simulations with COSMO

Model version and setup

Three different types of background aerosol:

- low CCN ($n_c \approx 100\ cm^{-3}$)
- intermediate CCN ($n_c \approx 300\ cm^{-3}$)
- high CCN ($n_c \approx 1000\ cm^{-3}$)

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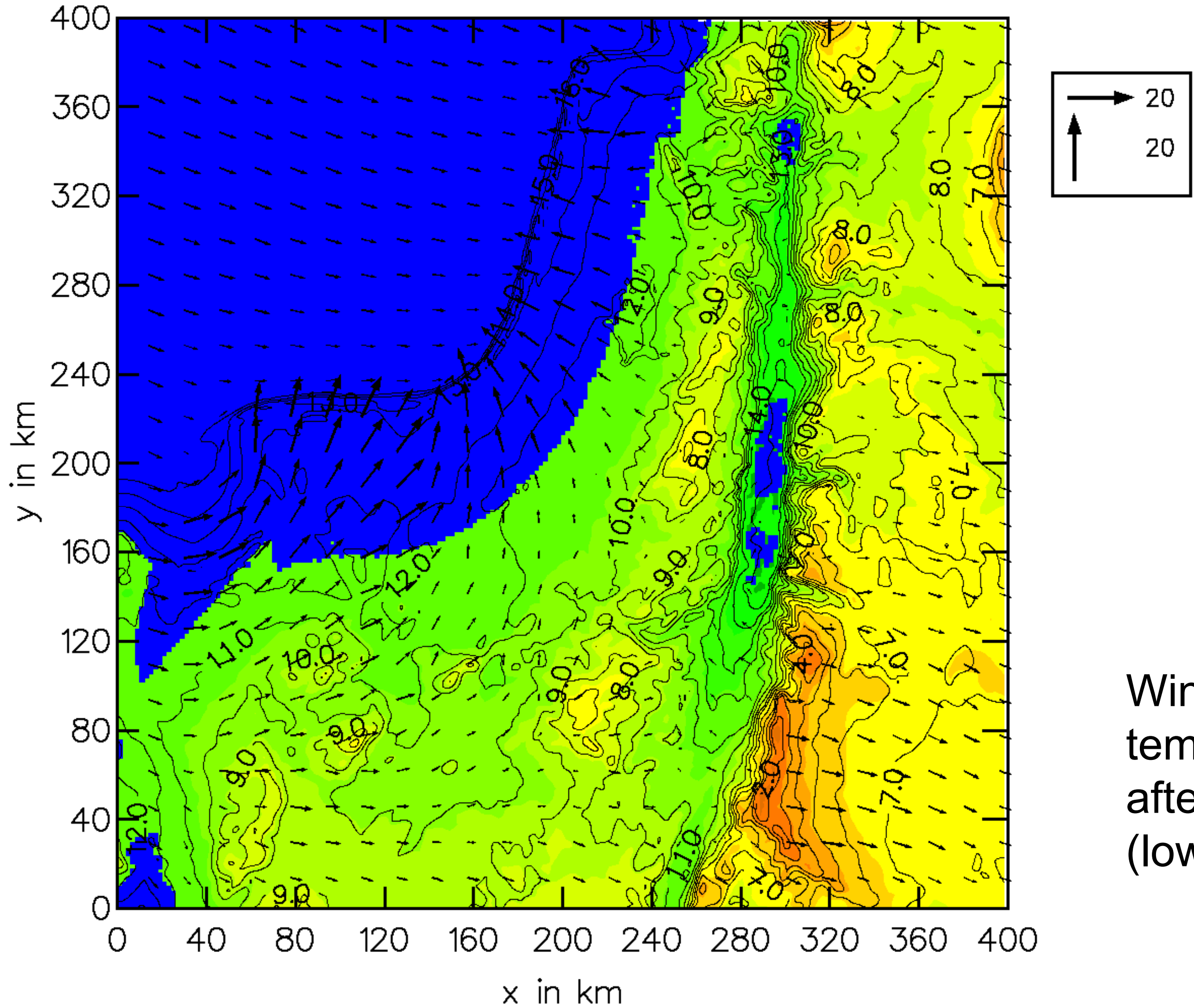
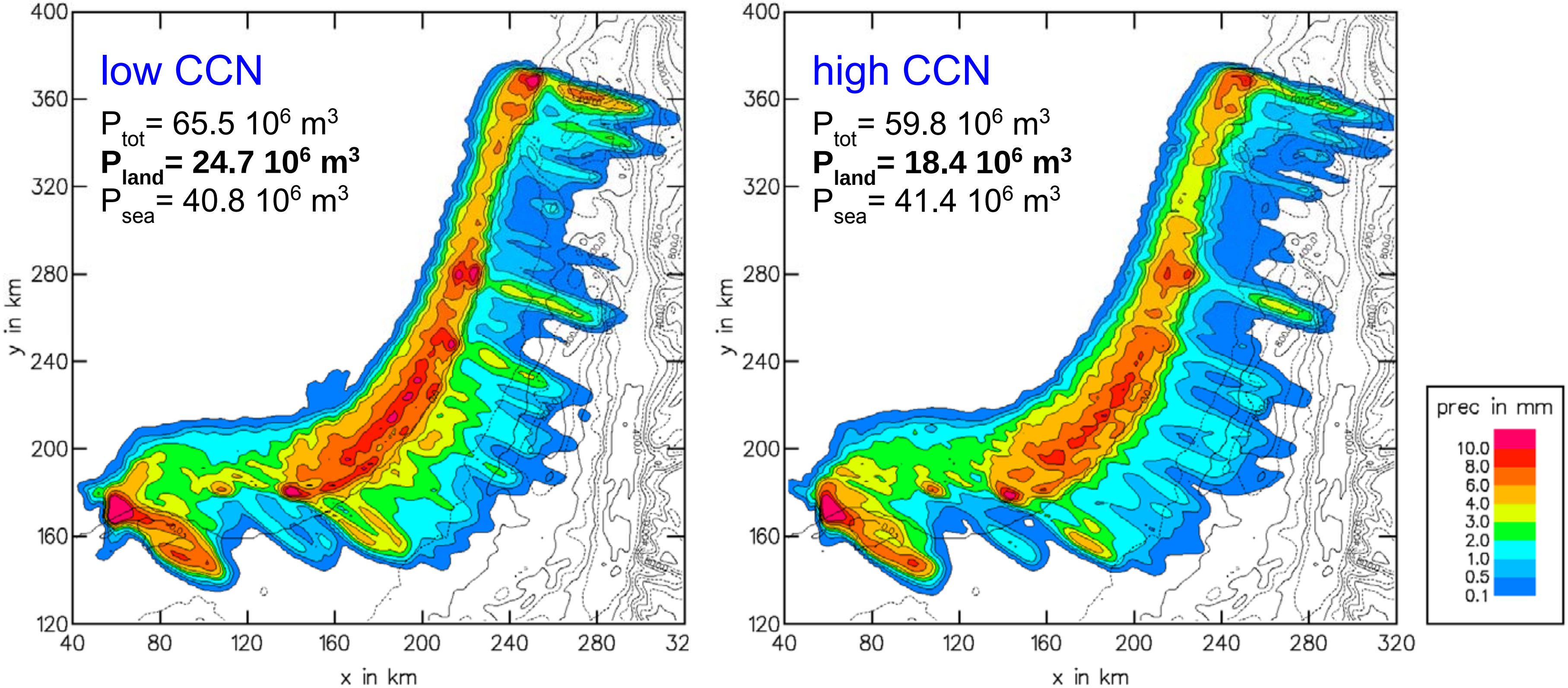
"Unseeded" model runs



Wind at 10 m agl and temperature at 2 m agl after 2 h simulation time (low CCN concentration)

“Unseeded” model runs

Accumulated precipitation after 2 h simulation time



“Seeded” model runs

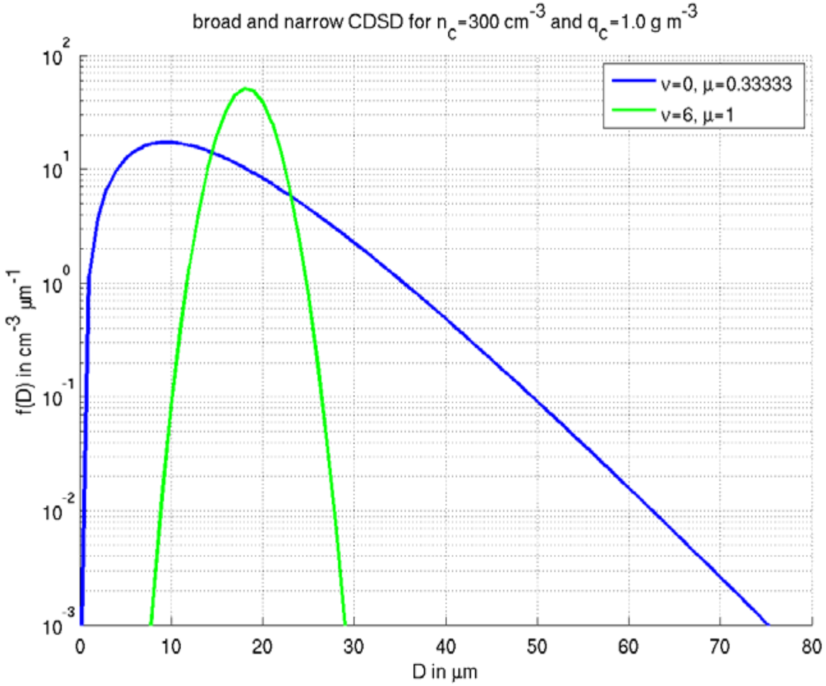
“Simulation” of cloud seeding

1. increase in the cloud droplet concentration

- CCN concentration is increased by 300 cm^{-3} between 0.5 km to 3 km amsl.

2. narrowing the cloud droplet size (

- Intstead of the broad background C CDSD with v=6 , μ=1 is assumed



“Seeded” model runs

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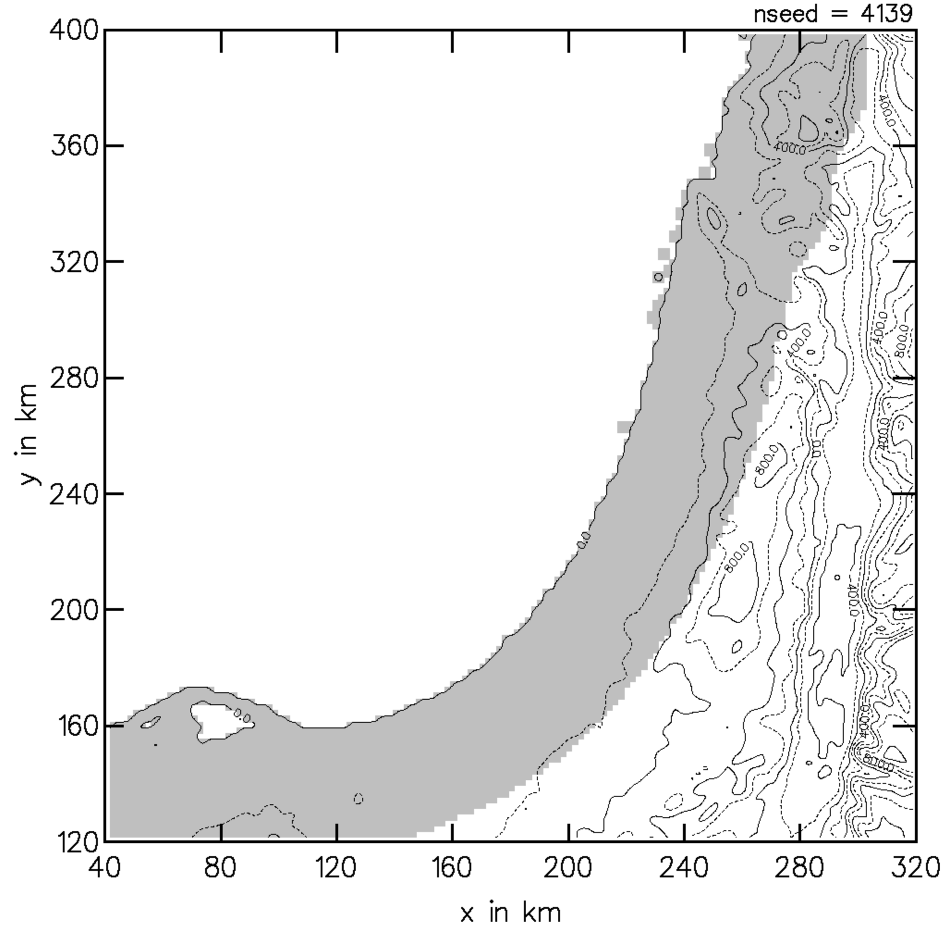
“Simulation” of cloud seeding

Seeding is applied in stripes of the coast located either over

- the sea
- the coast
- the land



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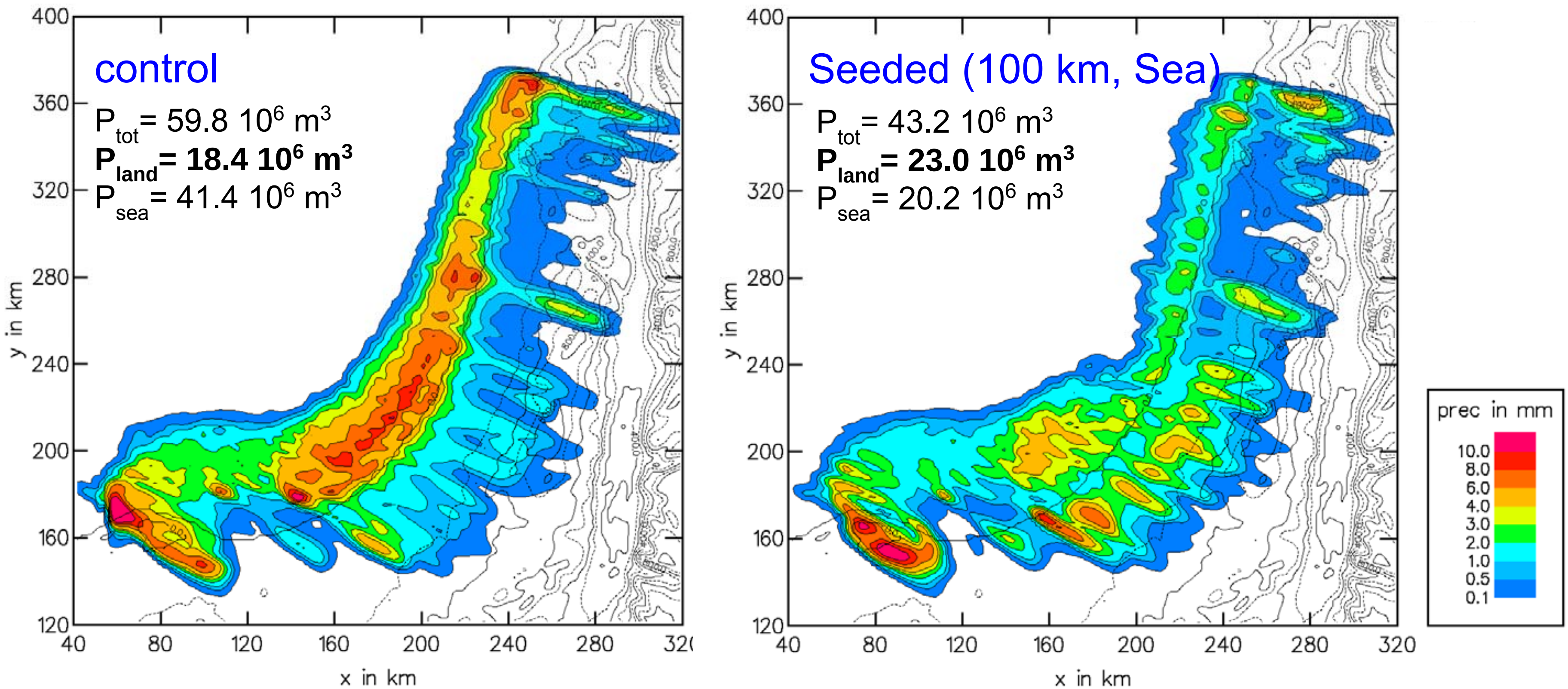
“Seeded” model runs

Results

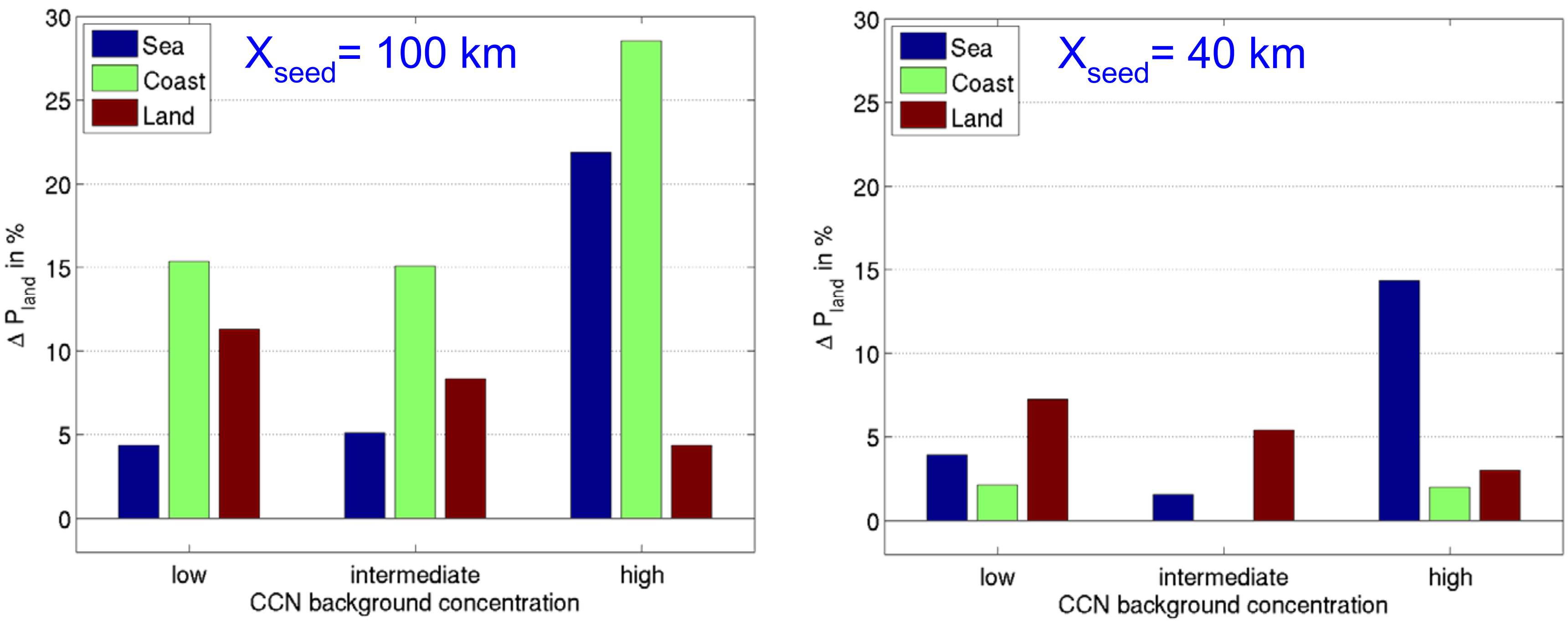
accumulated precipitation after 2 h for the high CCN case



“Seeded” model runs

Results

Change in precipitation over land by cloud seeding (after 3 h)

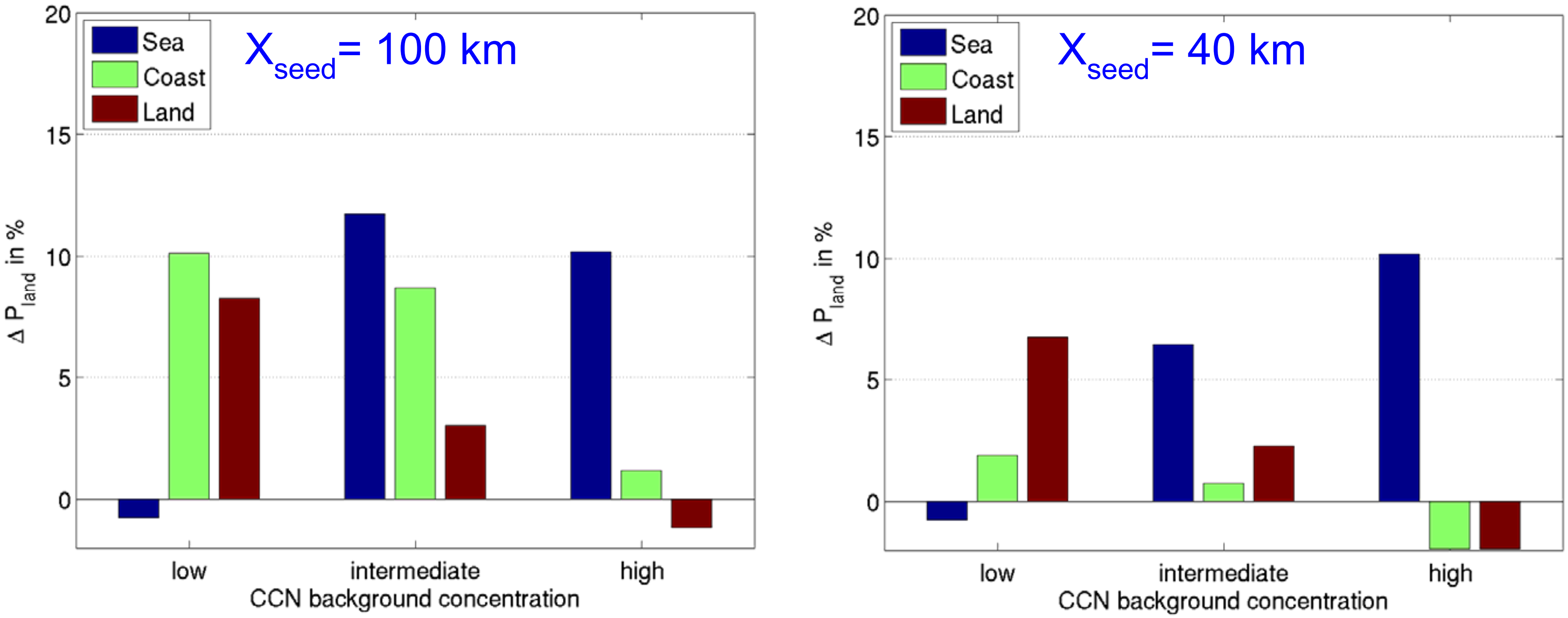


“Seeded” model runs

Results

Change in precipitation over land by cloud seeding (after 3 h)

for slightly different meteorological initial conditions



Summary and Conclusions

- COSMO with a 2-moment bulk microphysics was used to simulate a land-sea breeze situation typical for the eastern Mediterranean in wintertime
- The possibility to shift precipitation from sea to land by hygroscopic cloud seeding was studied, where cloud seeding was "simulated" in a quite simple way by
  - increasing the CCN number concentration
  - narrowing the CDSD

  in stripes along the coast
- Simulations for different CCN background concentrations, seeding strategies and initial conditions were performed
- Maximum increase in precipitation over land: **28 %**

Summary and Conclusions

- main positive effect by narrowing the CDSD
  - ➔ size of the seeding particles is important
- Which seeding strategy is best depends on the background aerosol and the meteorological situation
  - ➔ Seeding strategy has to be adjusted to the present aerosol and meteorological conditions

In general:

➔ The new approach to enhance precipitation over land by shifting precipitation from sea to land is very promising. Further numerical and experimental studies should be performed.

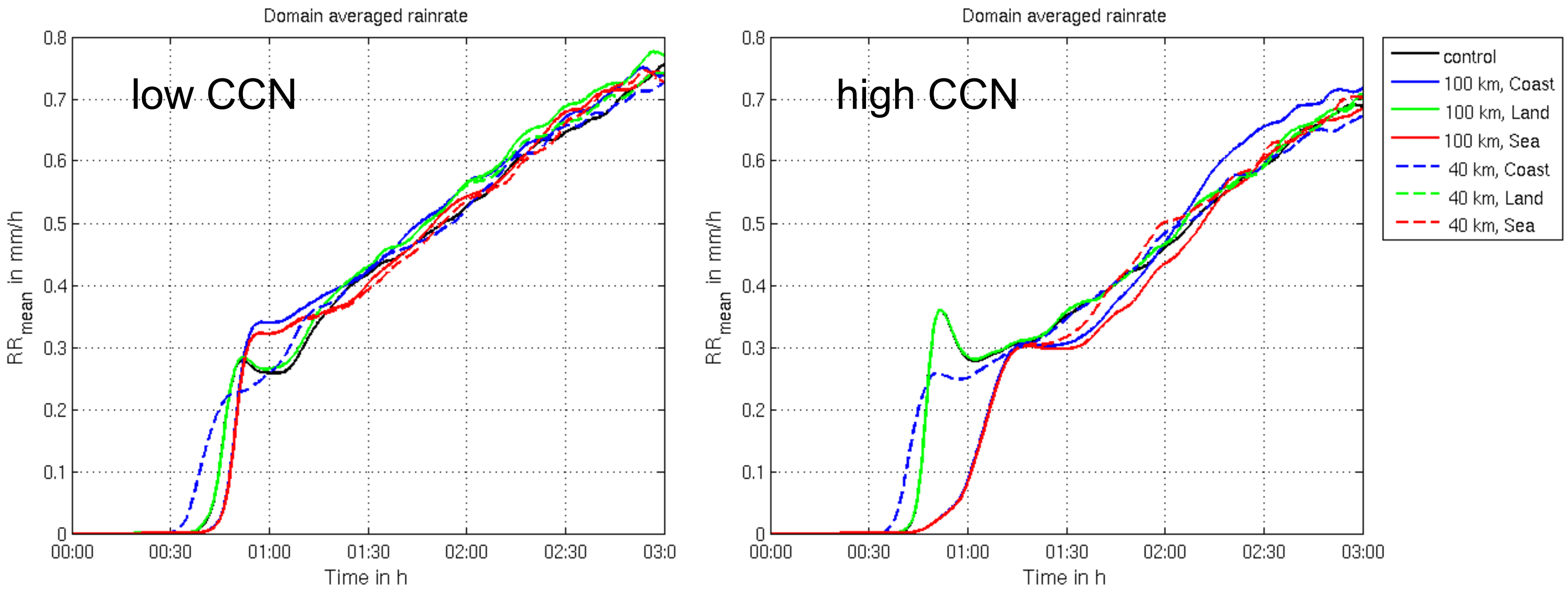
➔ The assumptions made in your mircophysics scheme concerning the number concentration and size distribution of cloud droplets may have a significant impact on how much and where rain falls!


Thanks for your attention

“Seeded” model runs

Results

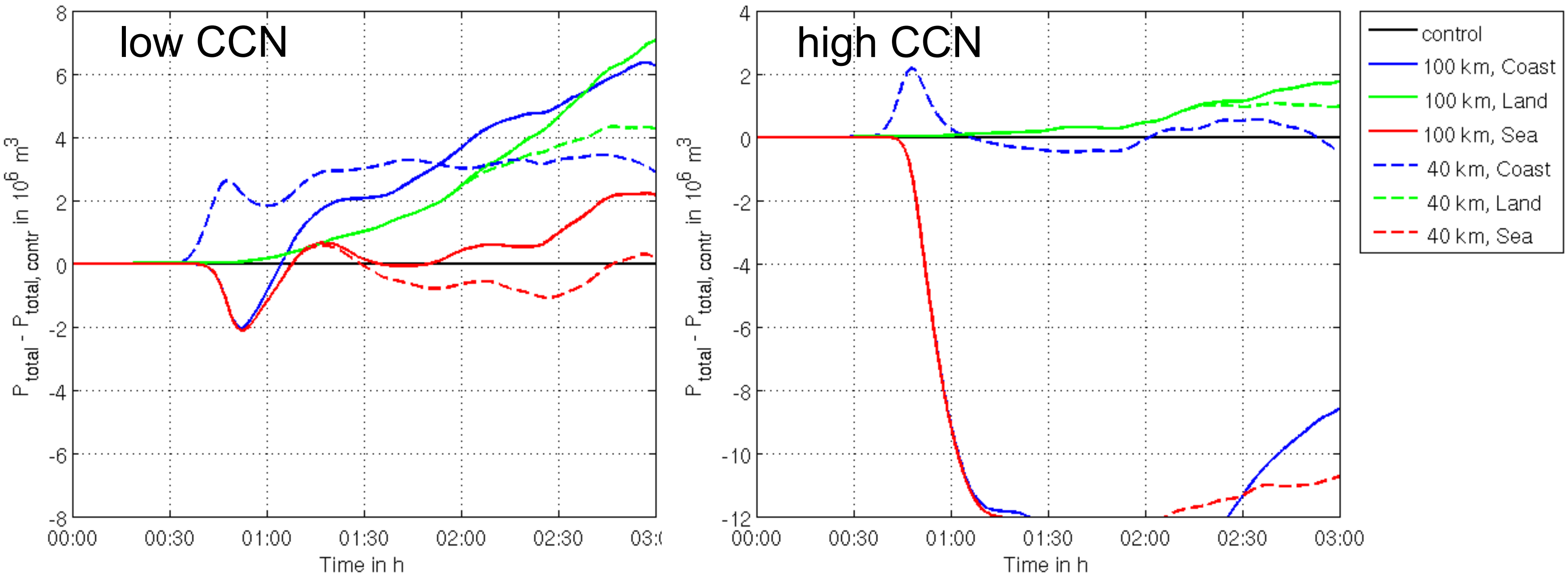
Change in domain averaged precipitation rate



“Seeded” model runs

Results

Change in total accumulated precipitation



"Seeded" model runs

Results

Change in total accumulated precipitation