Karlsruher Institut für Technologie

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

New Cloud Optical Properties in ICON

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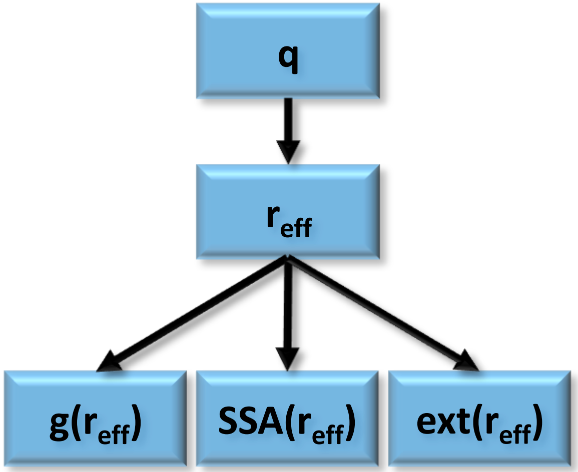
Optical Properties of Hydrometeors

- old
- lookup-tables of $r_{eff}(q)$
- cloud ice, cloud droplets



Optical Properties of Hydrometeors

- Fu, 1996; Fu et al., 1998; Fu, 2007
  - effective radius

$$r_e = \frac{\int V(L)n(L)dL}{\int \bar{A}(L)n(L)dL}$$

  - aspect ratio

$$AR = \frac{\int \frac{D}{L}\bar{A}(L)n(L)dL}{\int \bar{A}(L)n(L)dL}$$

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- optical properties of hydrometeors for RRTM (Fits by U. Blahak and H. Muskatel)
  - extinction coefficient

$$ext = \frac{\sum_i c_i {r_e}^i}{\sum_j c_j {r_e}^j}$$

  - single-scattering-albedo

$$SSA = \frac{\sum_i b_i {r_e}^i}{\sum_j b_j {r_e}^j}$$

  - asymmetry parameter

$$g = \frac{\sum_i a_i {r_e}^i}{\sum_j a_j {r_e}^j}$$

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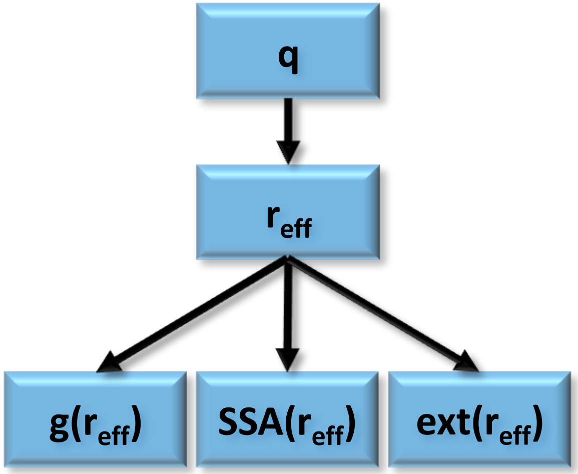
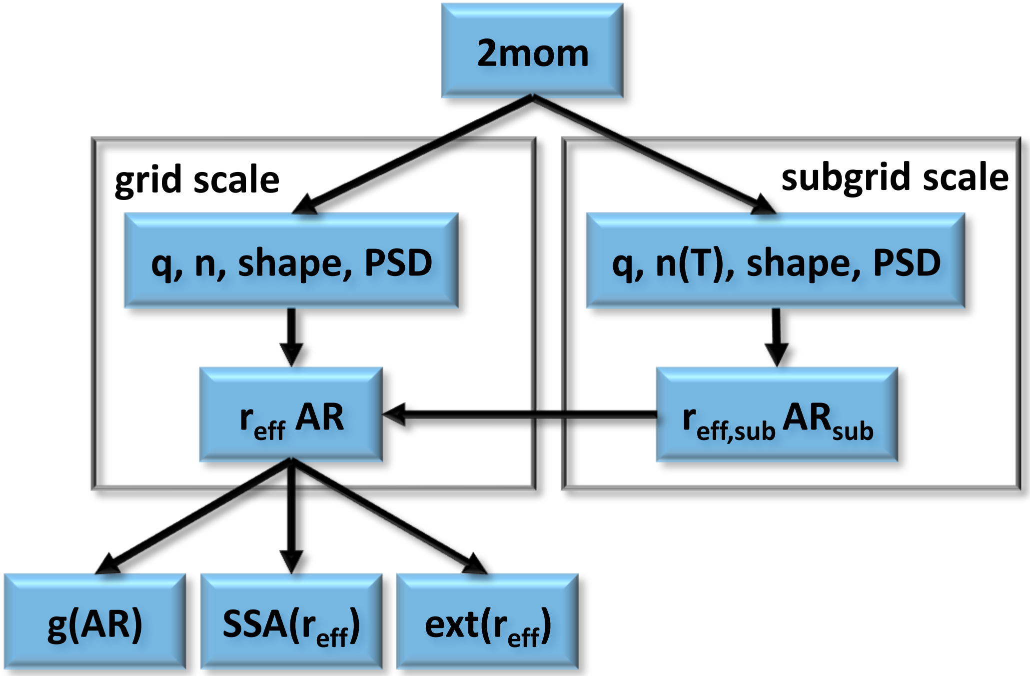
- new
- explicitly consider number conc.
- cloud ice, cloud droplets, rain, snow, graupel





Optical Properties of Hydrometeors

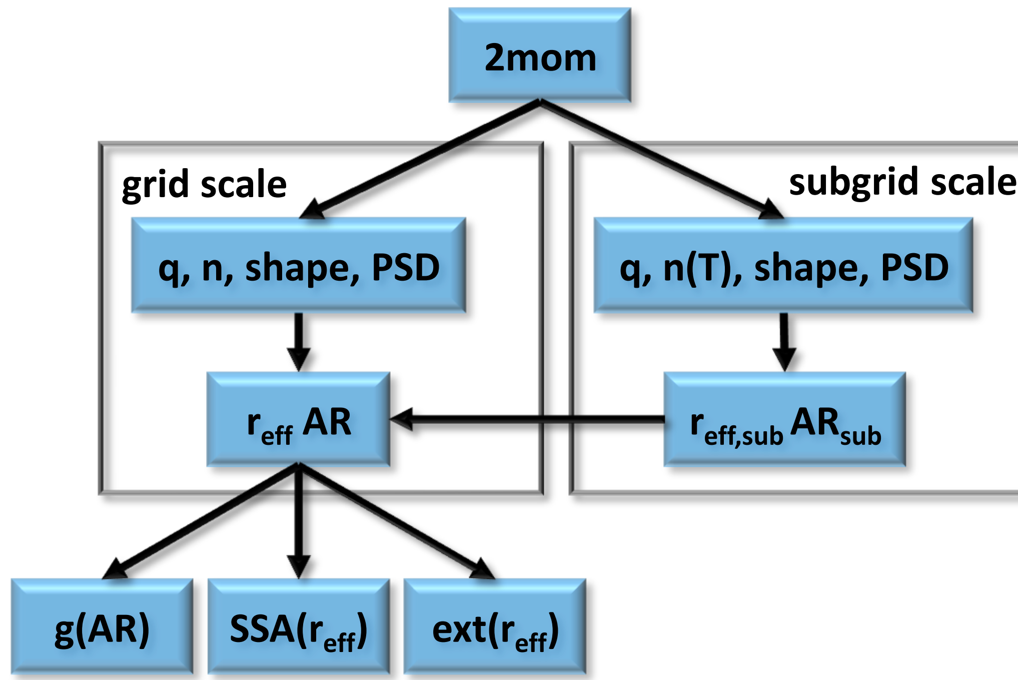
- new
- explicitly consider number conc.
- cloud ice, cloud droplets, rain, snow, graupel

$$x = \frac{q}{n}$$

$$L = ax^b$$

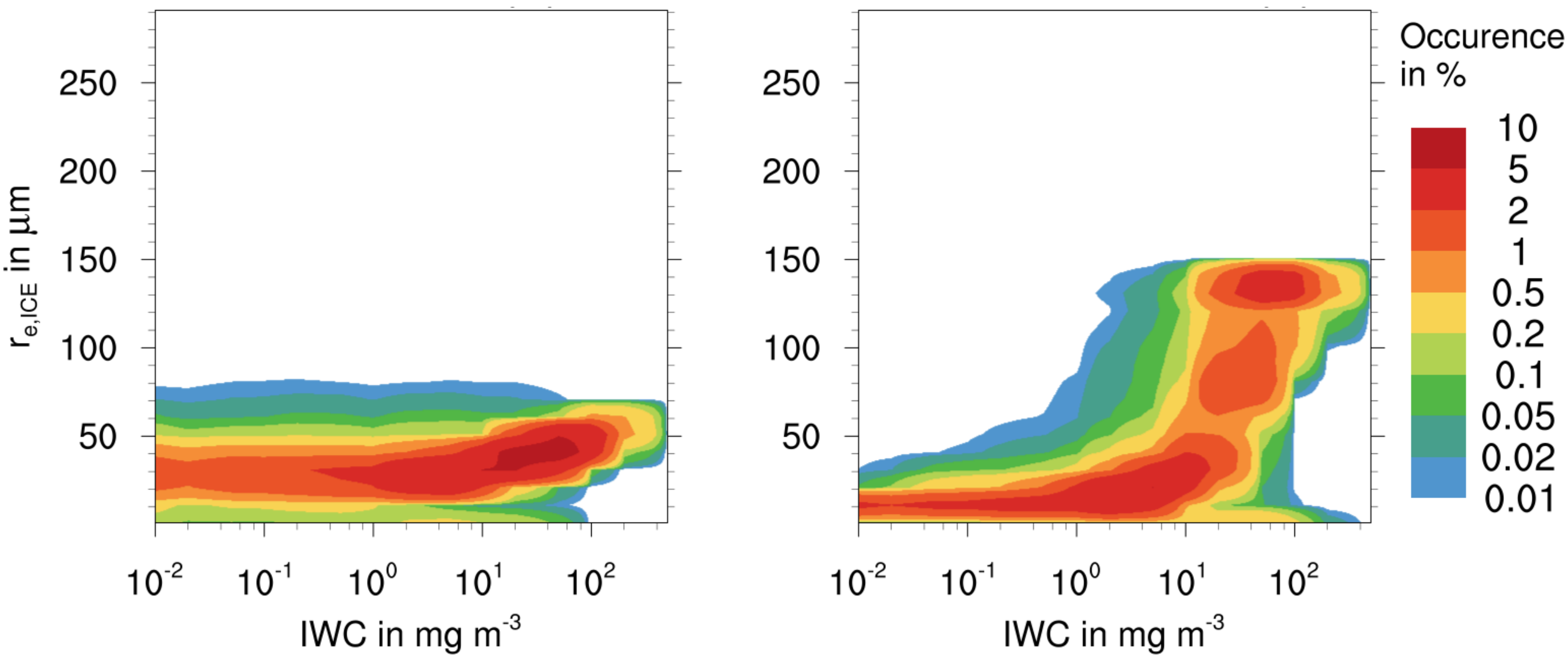
$$r_e = \frac{\int V(L) f(L) dL}{\int \bar{A}(L) f(L) dL}$$

$$r_e = \alpha x^\beta$$



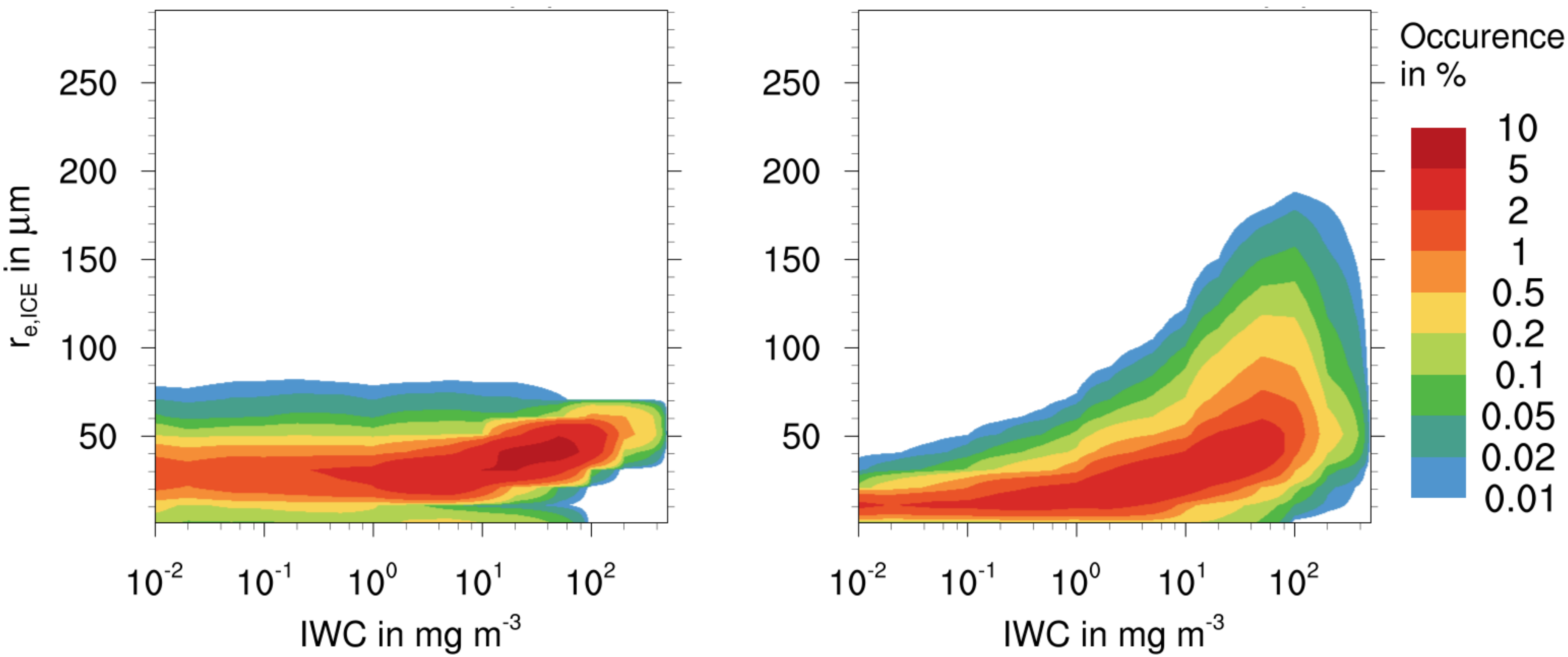
Optical Properties of Hydrometeors

- old
- new, 1mom



Optical Properties of Hydrometeors

- old
- new, 2mom



Optical Properties of Hydrometeors

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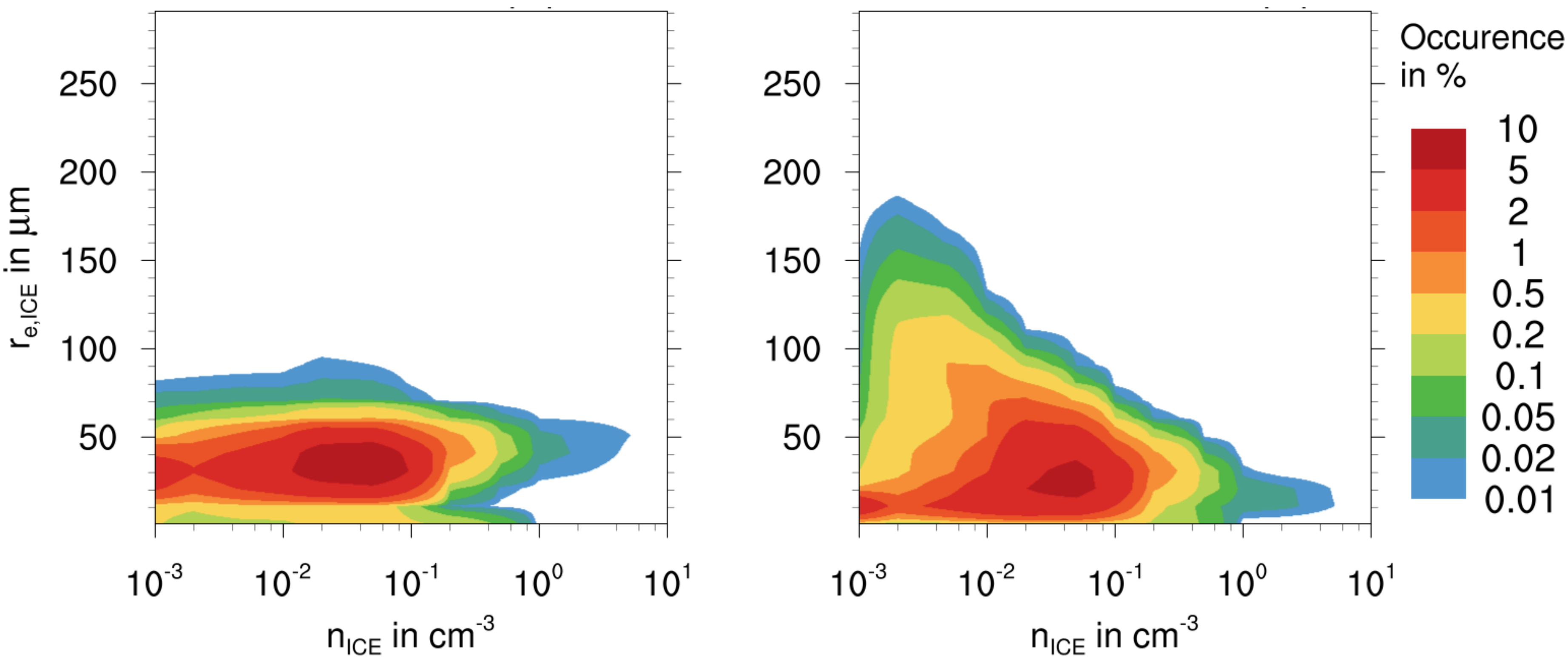
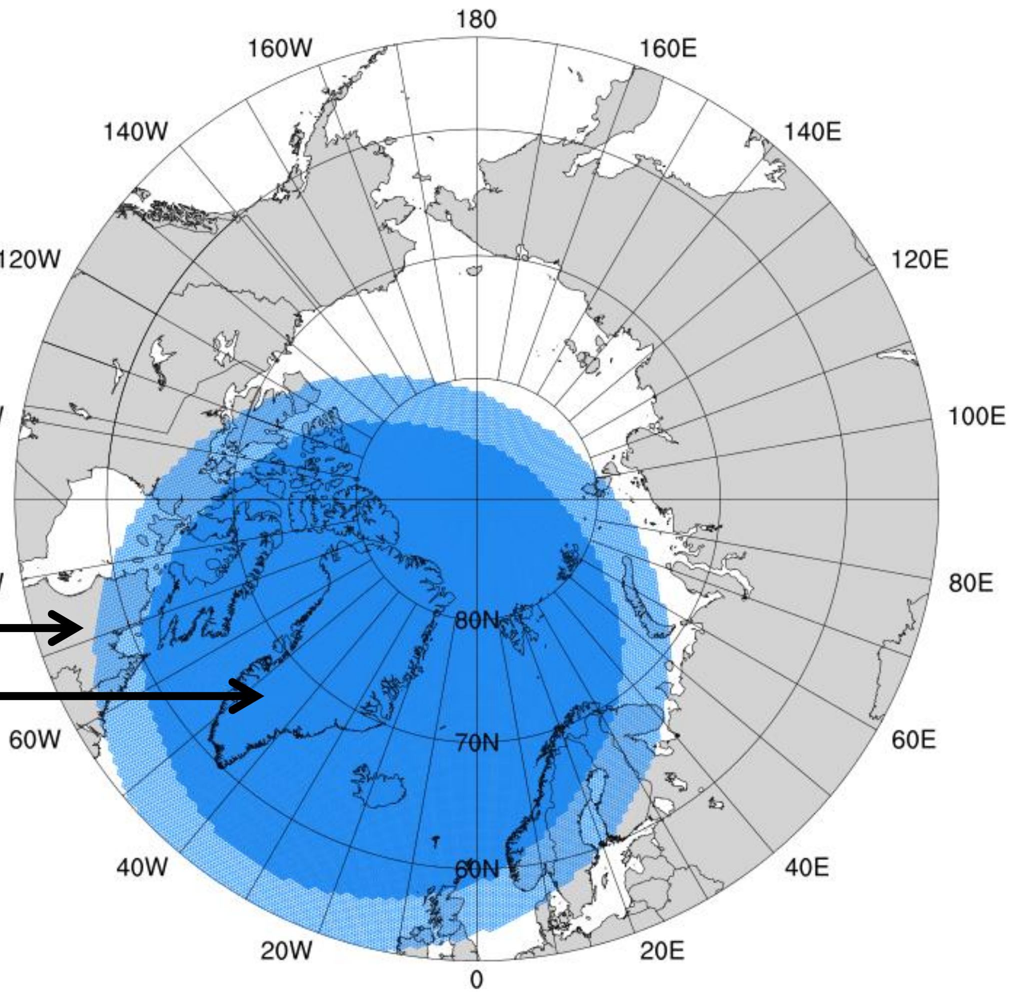


Case study I: Model Setup



DOM01: 40 km

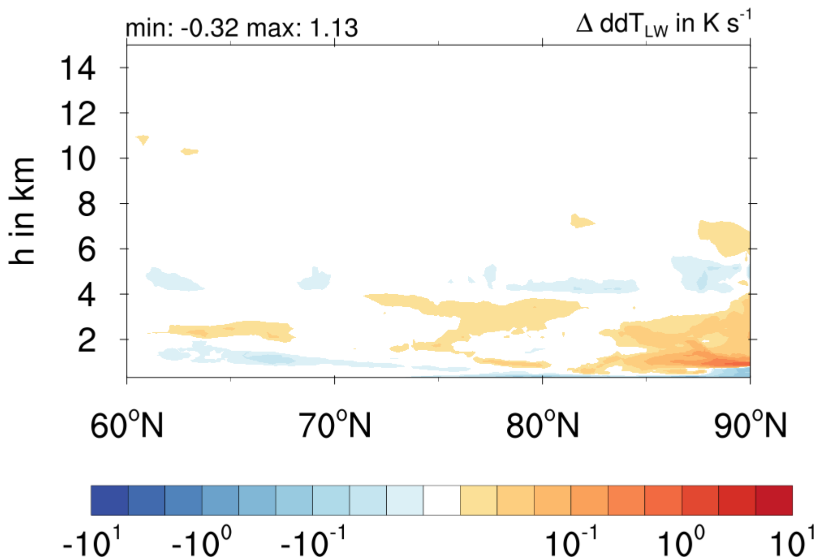
DOM04: 5 km

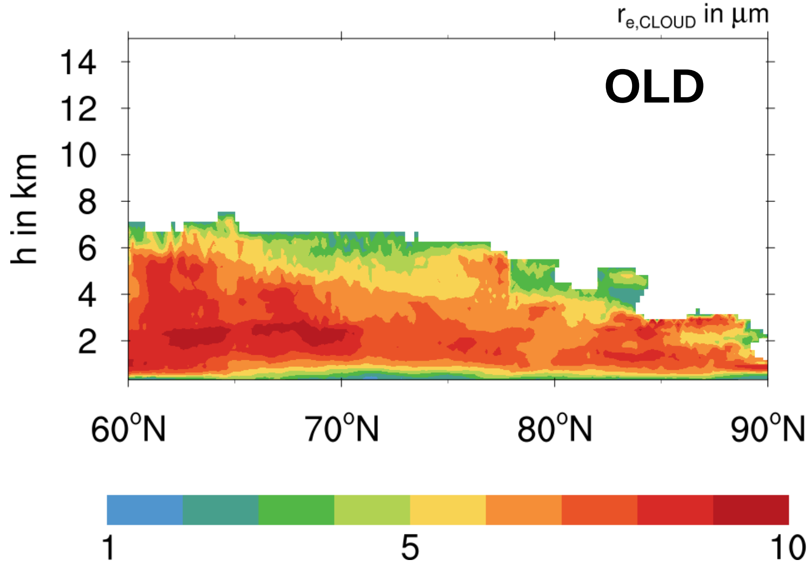
Case study I: Model Setup

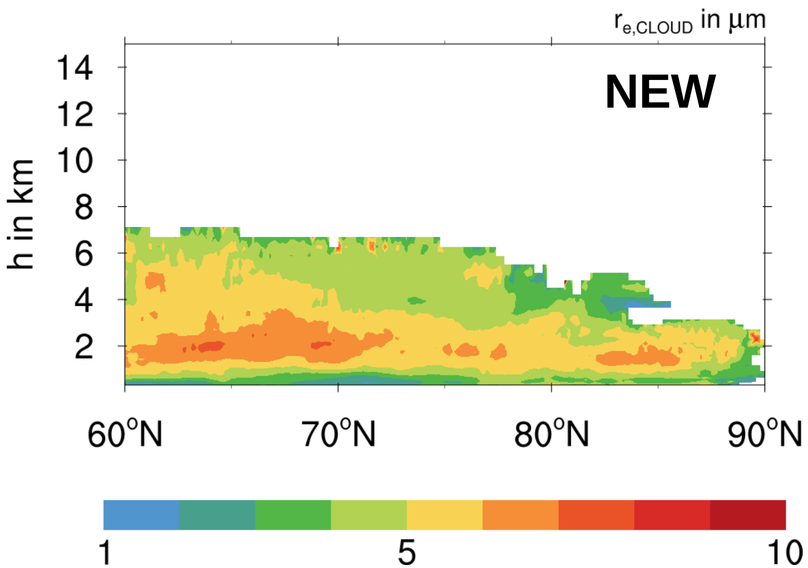
- Arctic winter 2015 / 2016
- two-moment bulk microphysics: Seifert and Beheng, 2006
- improved calculation of cloud optical properties: Fu, 1996; Fu et al., 1998; Fu, 2007
- cirrus nucleation: Barahona and Nenes, 2008
  heterogeneous nucleation: Philips et al., 2013
- activation of CCN: Barahona et al., 2009
- prognostic aerosol: mineral dust, sea salt

Radiative Temperature Tendency

- cloud droplets

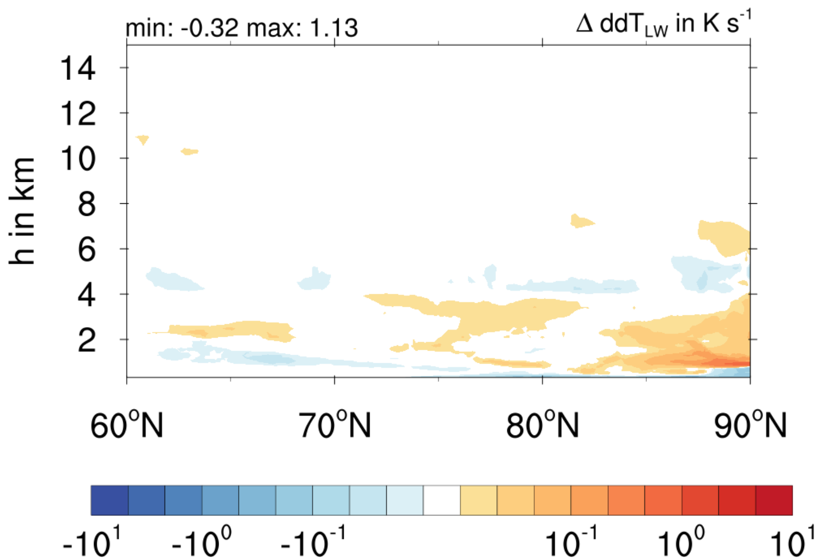


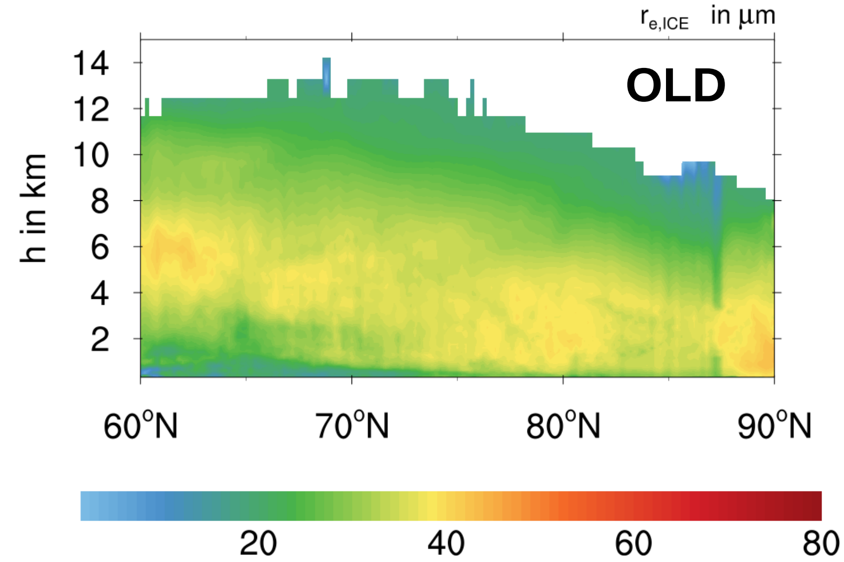


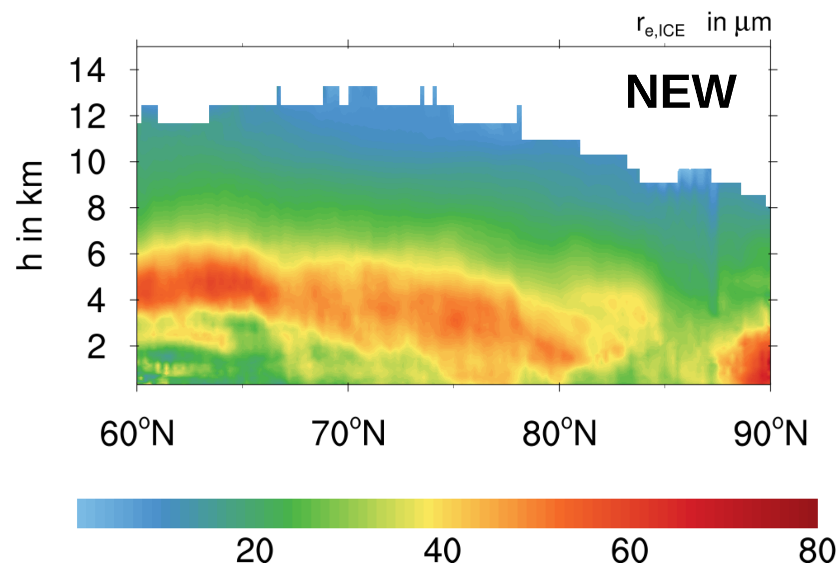


Radiative Temperature Tendency

- cloud ice

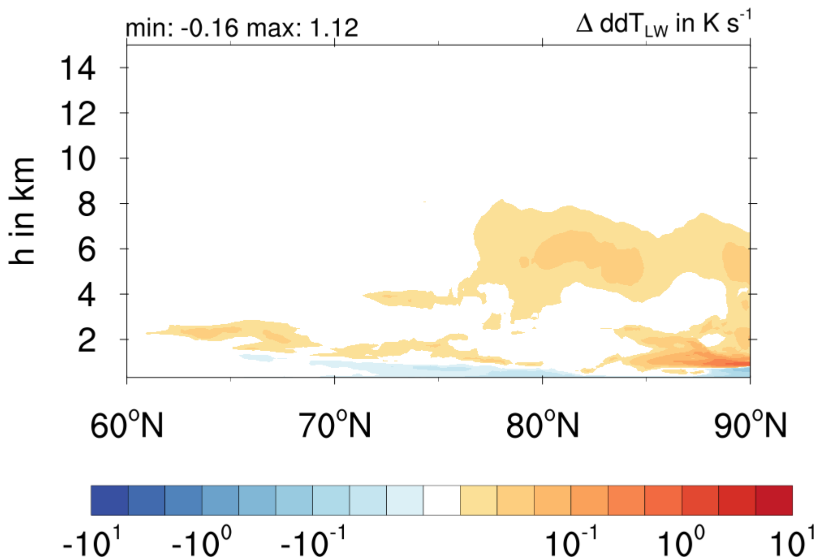


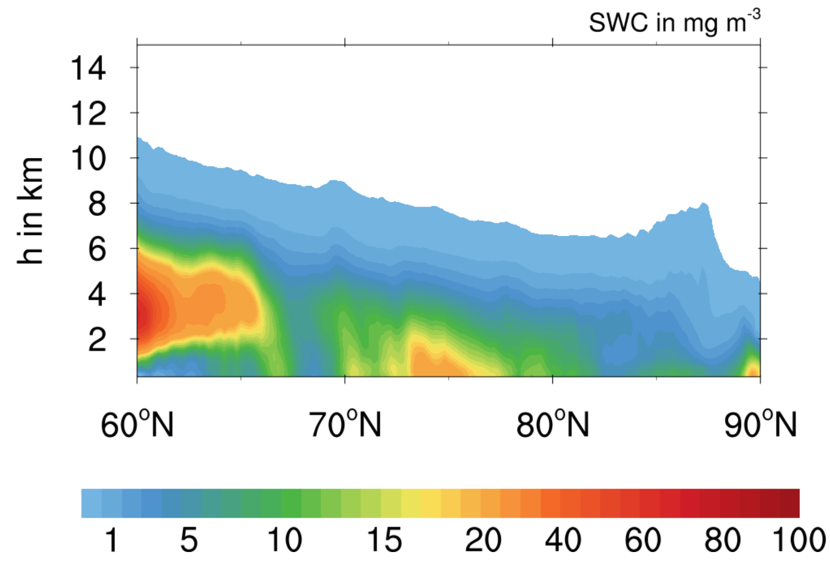


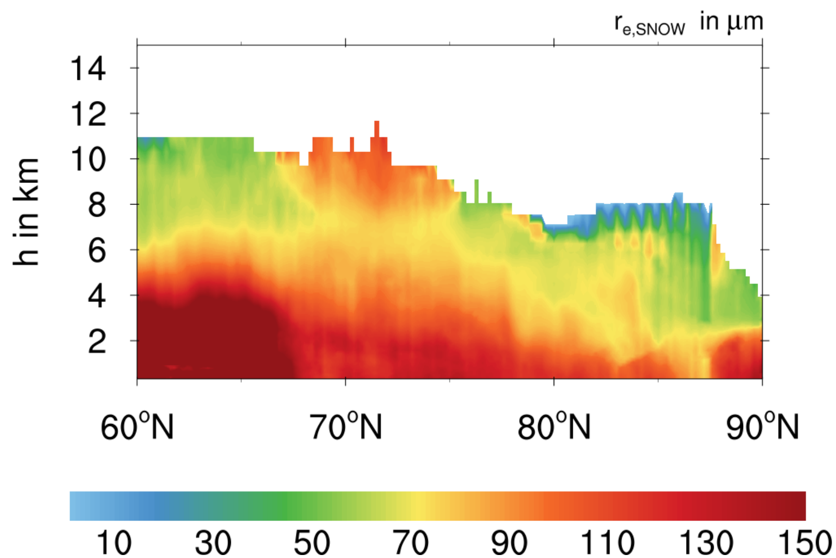


Radiative Temperature Tendency

- cloud droplets, ice crystals, **snow**







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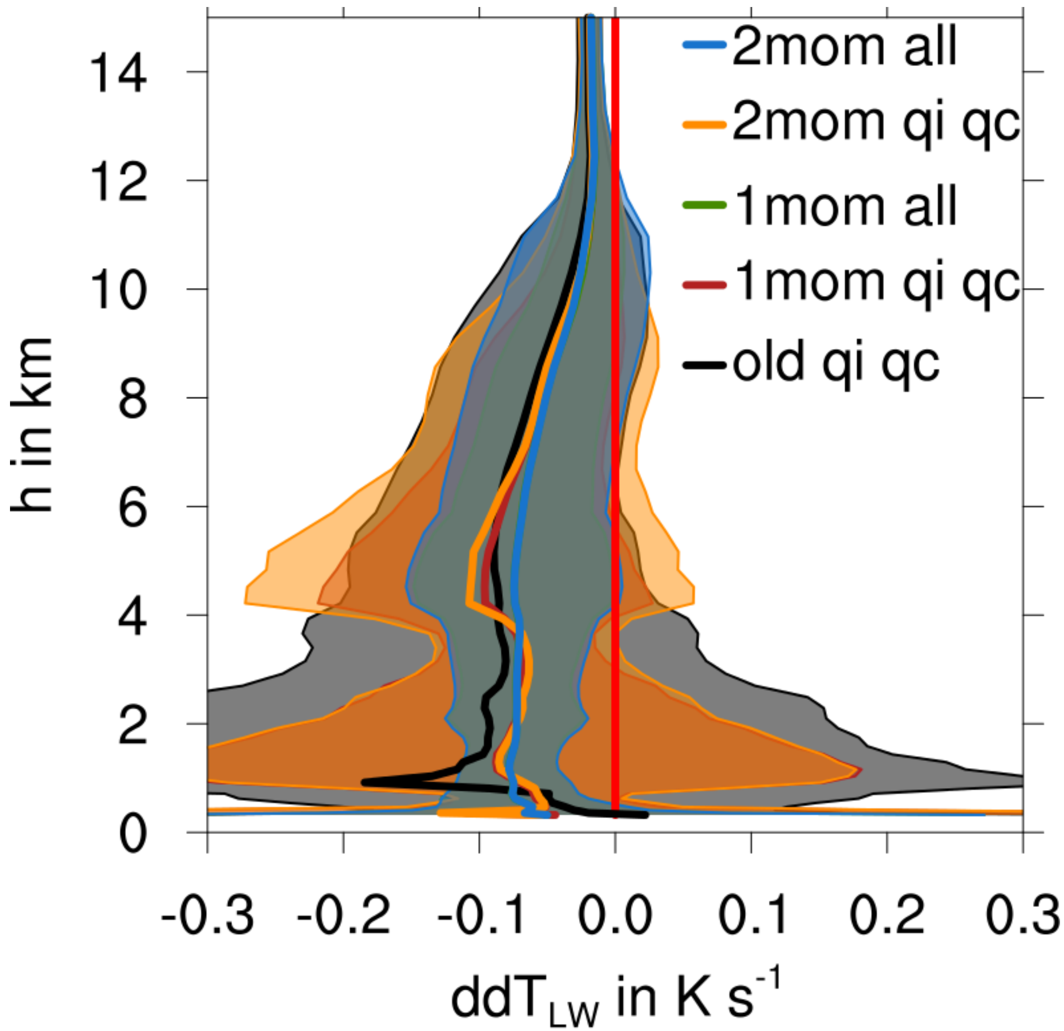
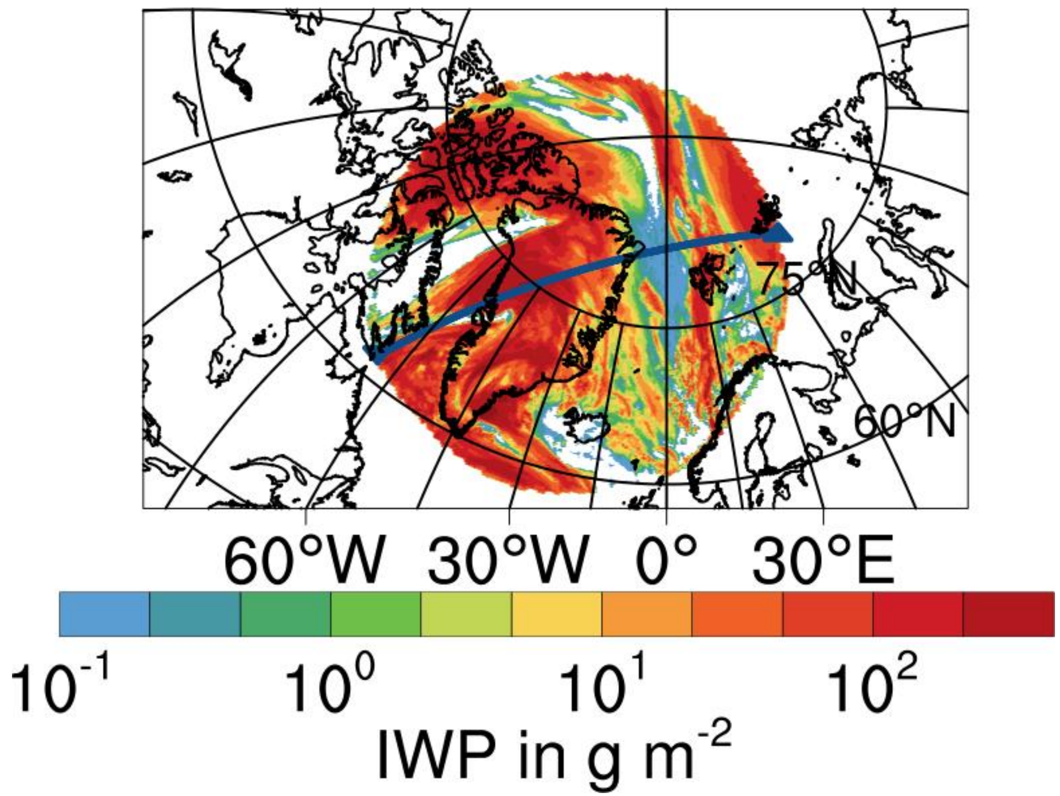
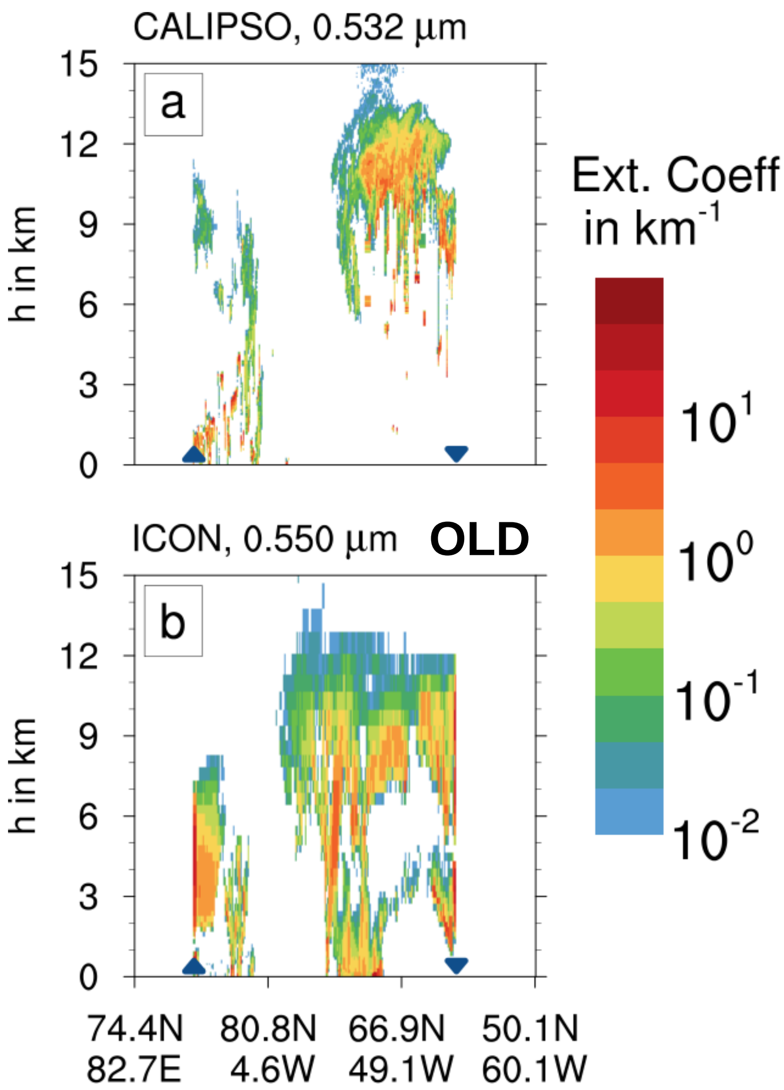


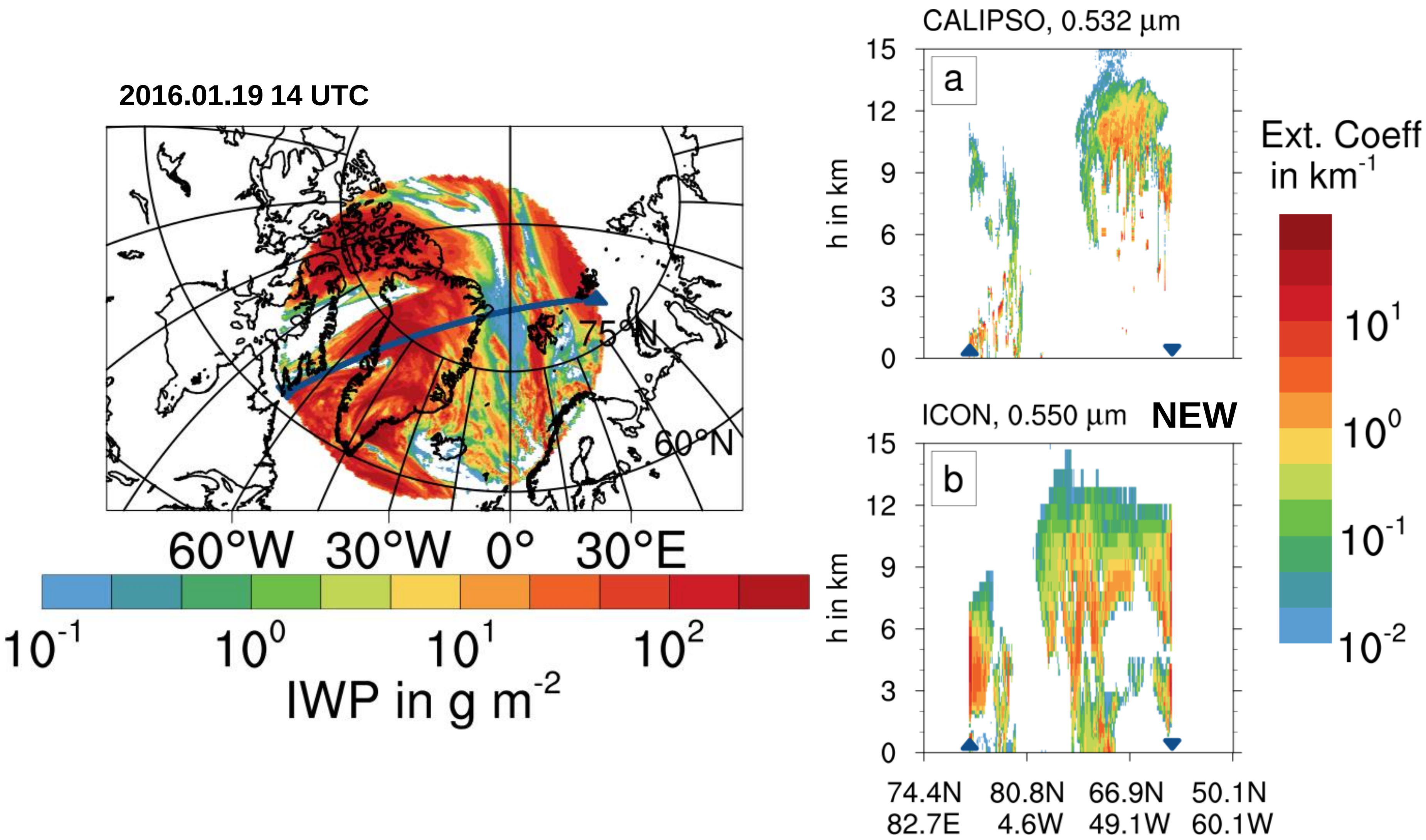
ICON vs Calipso

2016.01.19 14 UTC





ICON vs Calipso



Case study II: Model Setup

- two-moment bulk microphysics: Seifert and Beheng, 2006
  - sub-stepping for microphysics (150 s → 5 s)
- improved calculation of cloud optical properties: Fu, 1996; Fu et al., 1998; Fu, 2007
- cirrus nucleation: Barahona and Nenes, 2008

  heterogeneous nucleation: Philips et al., 2013
- activation of CCN: Barahona et al., 2009
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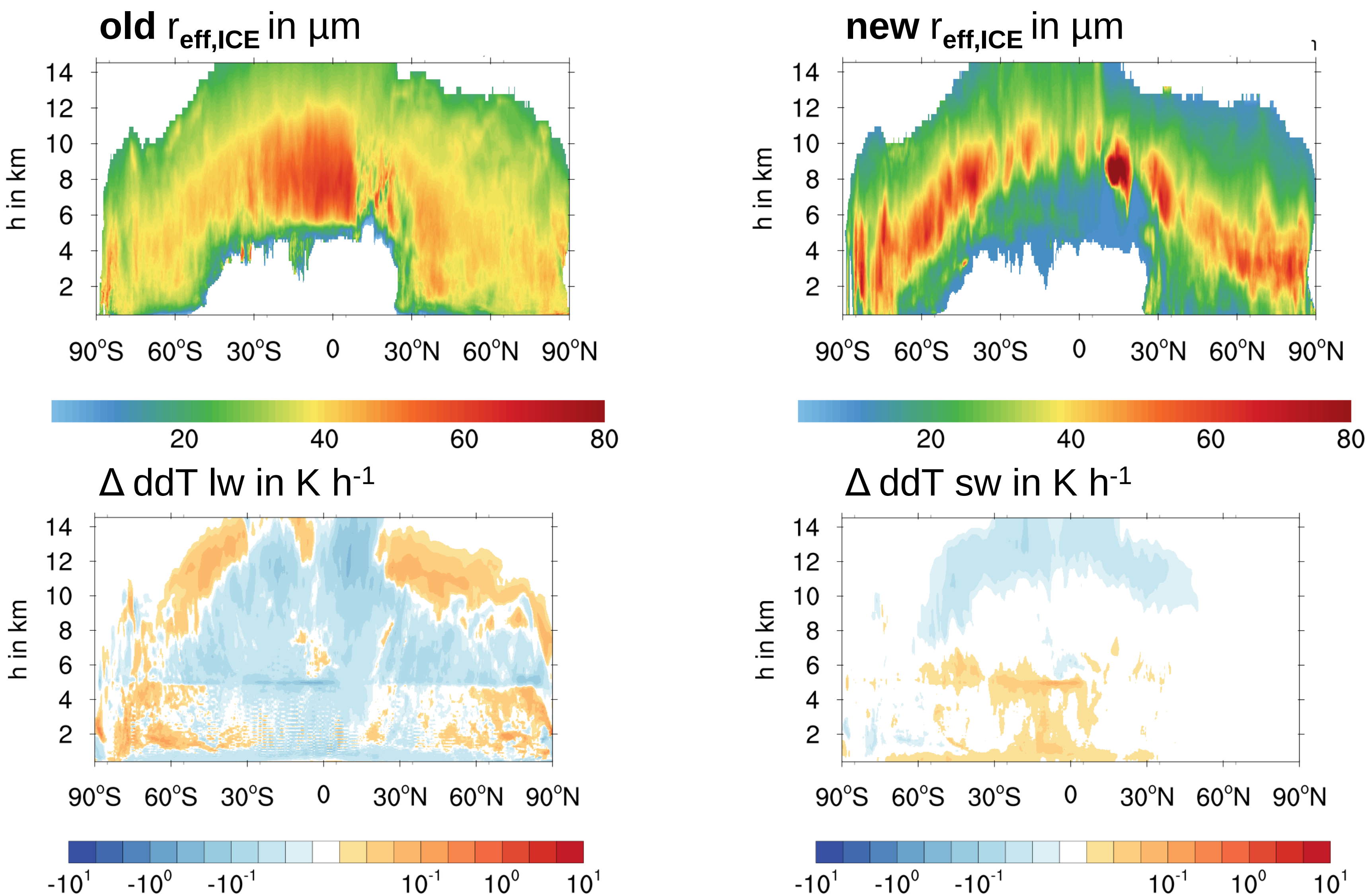
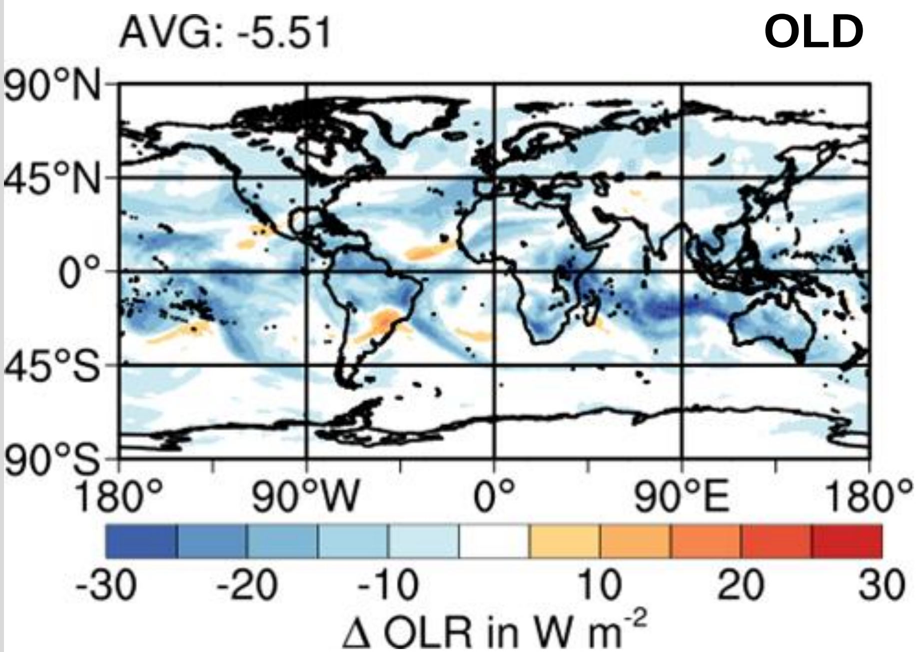
r_{eff} and ddT

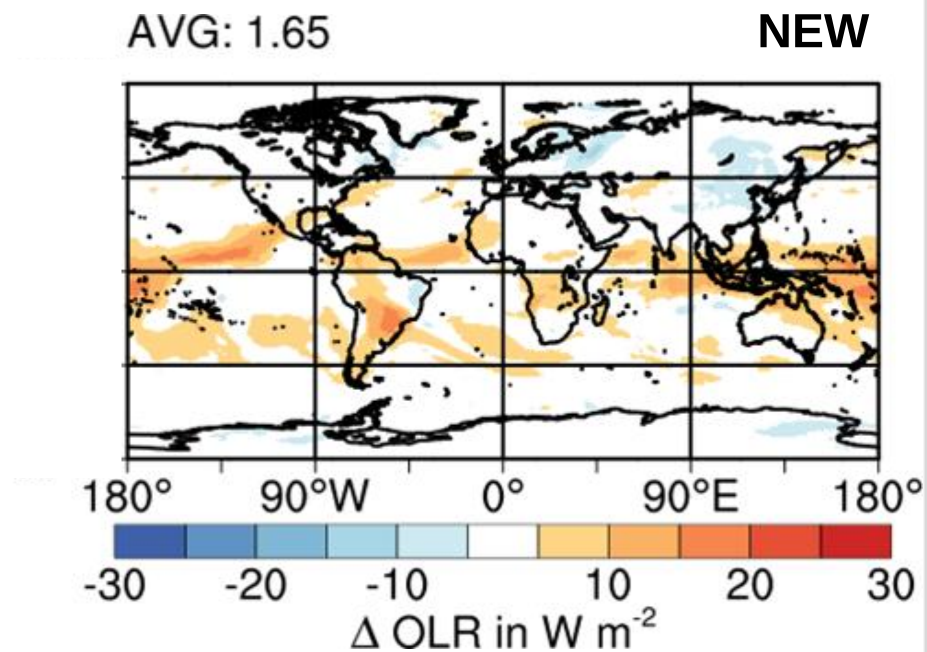


old $r_{eff,ICE}$ in µm
new $r_{eff,ICE}$ in µm
h in km
14 12 10 8 6 4 2
90°S 60°S 30°S 0 30°N 60°N 90°N
20 40 60 80
Δ ddT lw in K h^{-1}
Δ ddT sw in K h^{-1}
-10^1 -10^0 -10^{-1} 10^{-1} 10^0 10^1

ICON vs CERES, January 2016

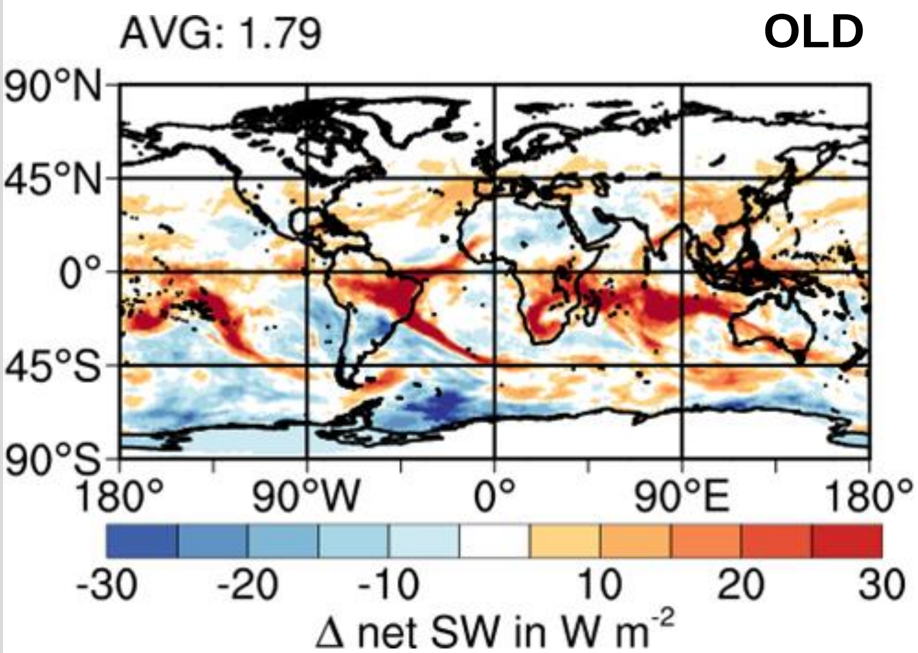
- **OLR**

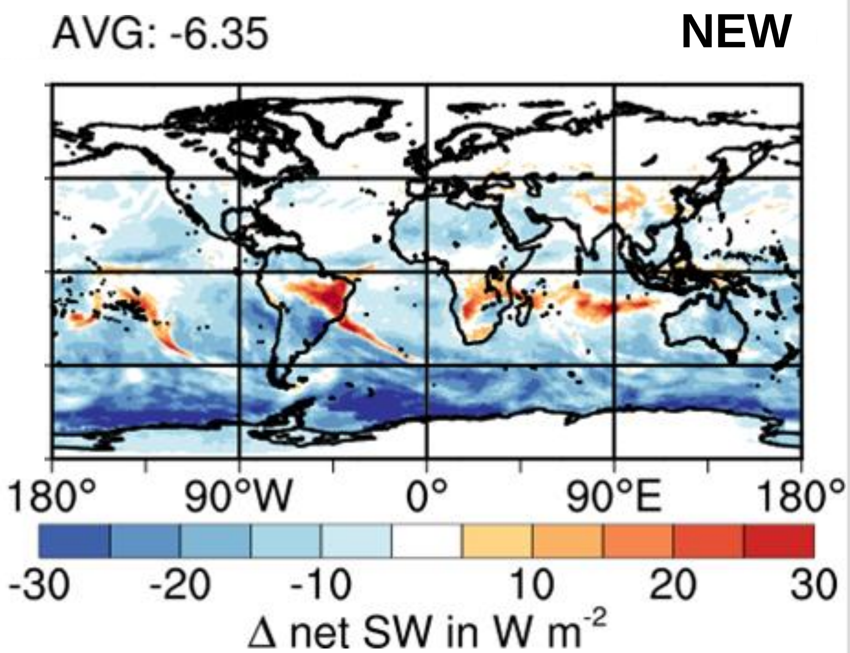




ICON vs CERES, January 2016

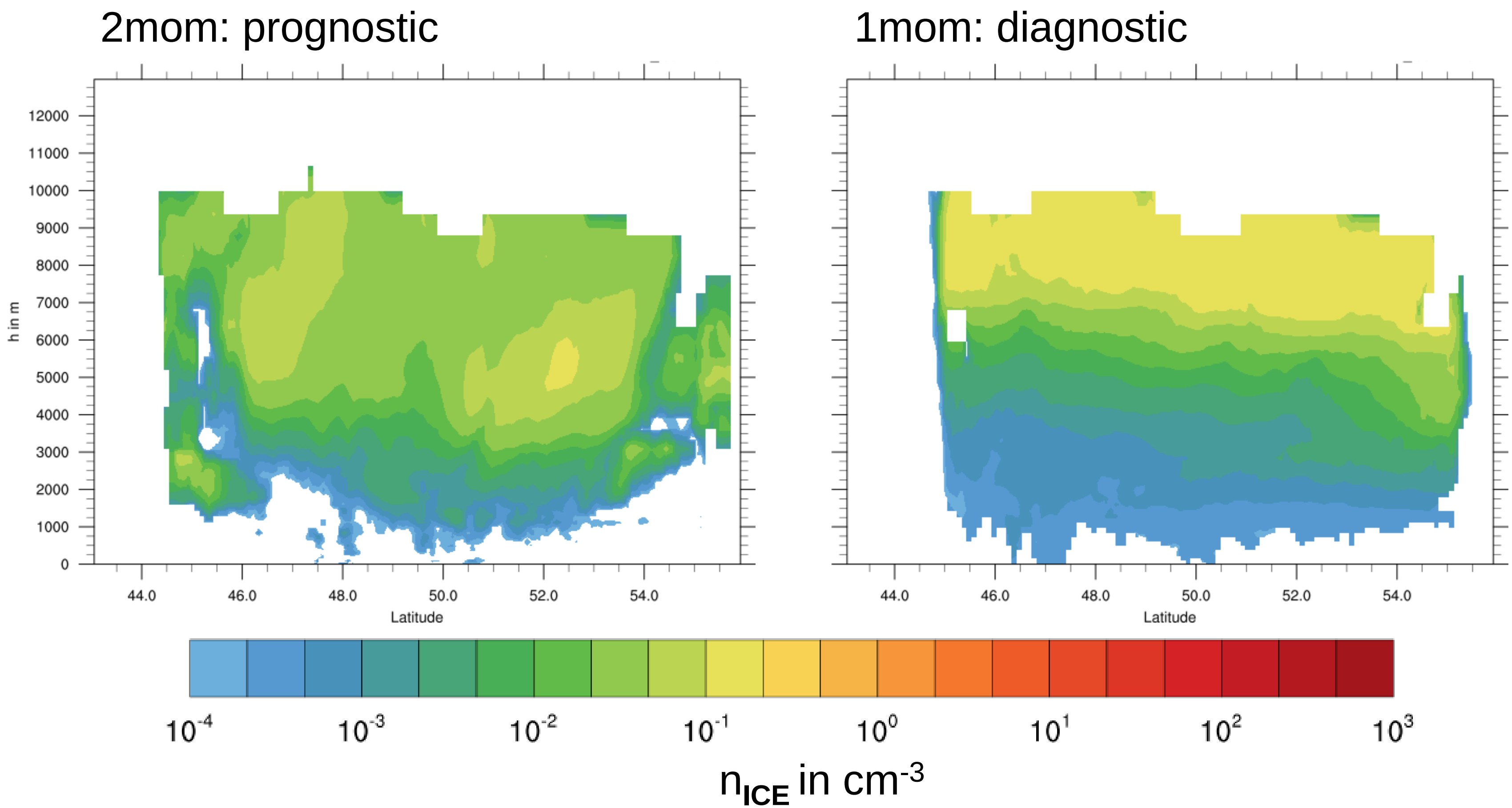
- **net SW**





Issue: Diagnostic n_{ICE}

- needed for calculation of $r_{eff,ICE}$
- $n_{ICE}(T)$: number of activated nuclei (Cooper, 1986)



Current Status

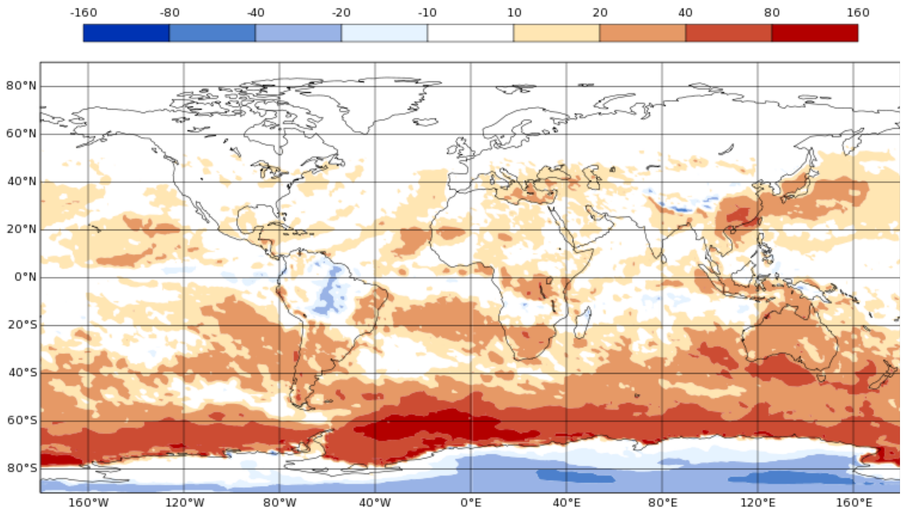
- calculation of r_{eff} / AR based on particle mean mass
- fits for RRTM bands
- used for cloud ice, cloud droplets, rain, snow, graupel
- case study I:
  - new optical properties agree better with Calipso
- case study II
  - change of sign in ICON radiation biases
  - optically thicker in for sw
  - more OLR
- used with 1mom $r_{eff,ICE}$ become very large

Next Steps

- sub-grid scale clouds / aerosol effect
- new $n_{\mathbf{ICE}}$(T) only for radiation?
- what about reduced grid / “repartitioned radiation”?

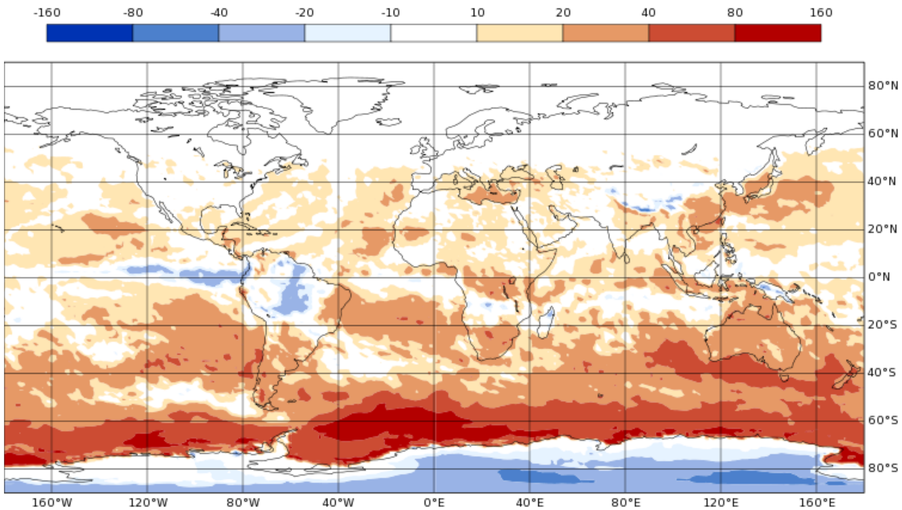
Net. Shortwave at TOA

New opt – CERES



bias: 14.0 W m^{-2}

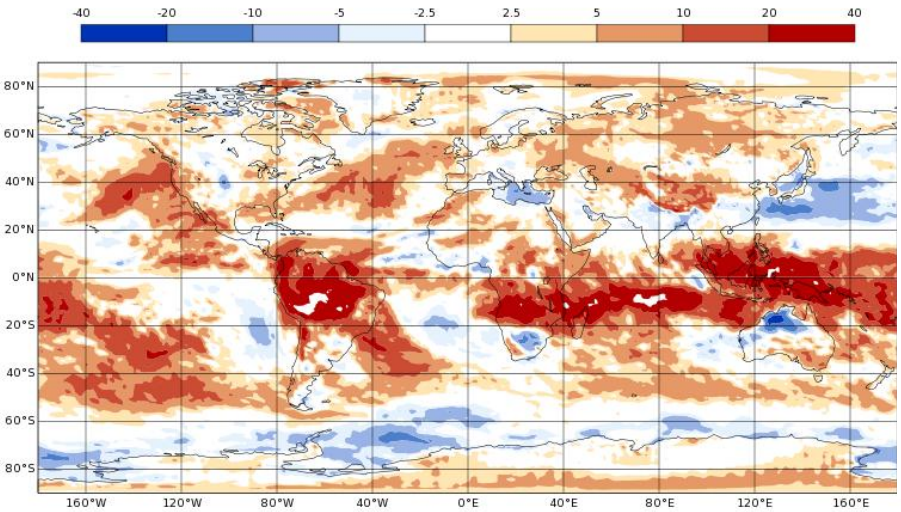
Old opt - CERES



bias: 16.2 W m^{-2}

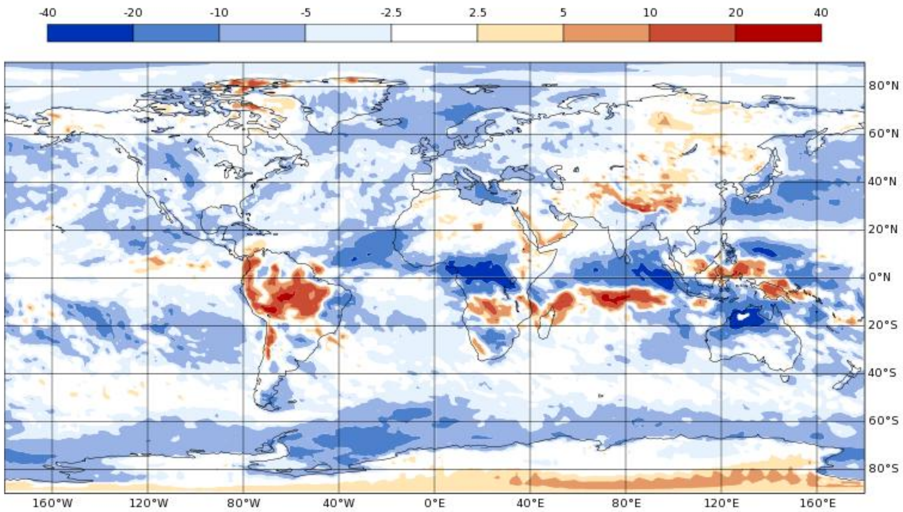
Outgoing Longwave Radiation at TOA

New opt – CERES



bias: 5.1 W m^{-2}

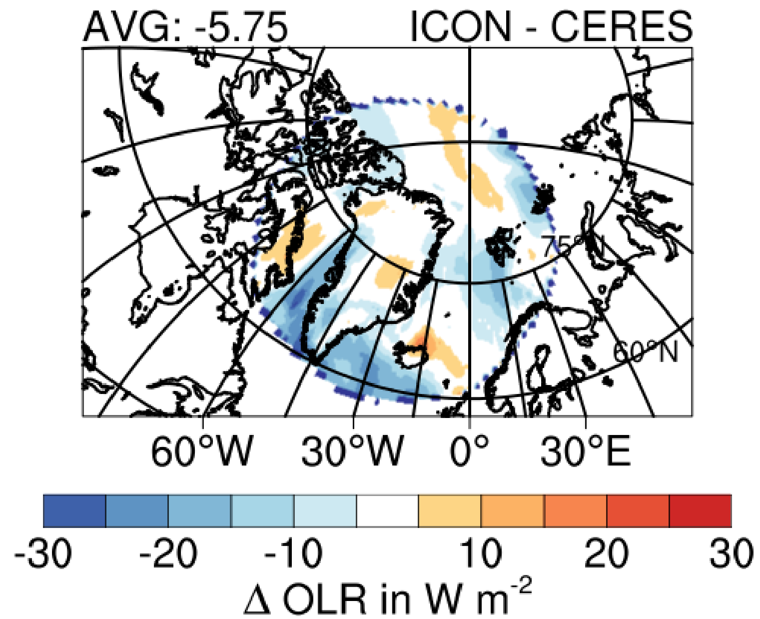
Old opt - CERES

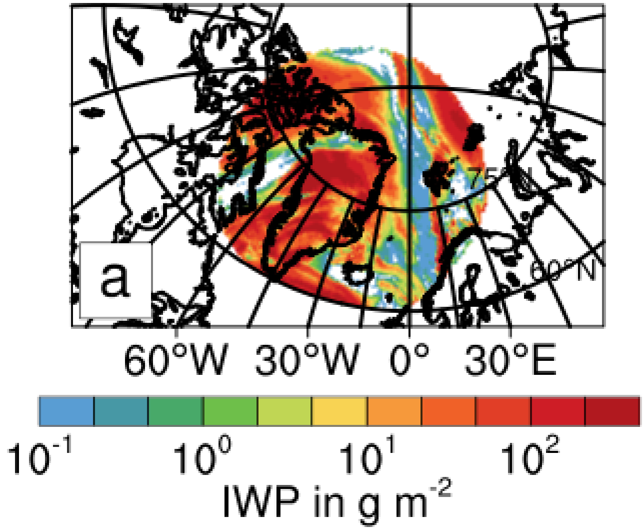


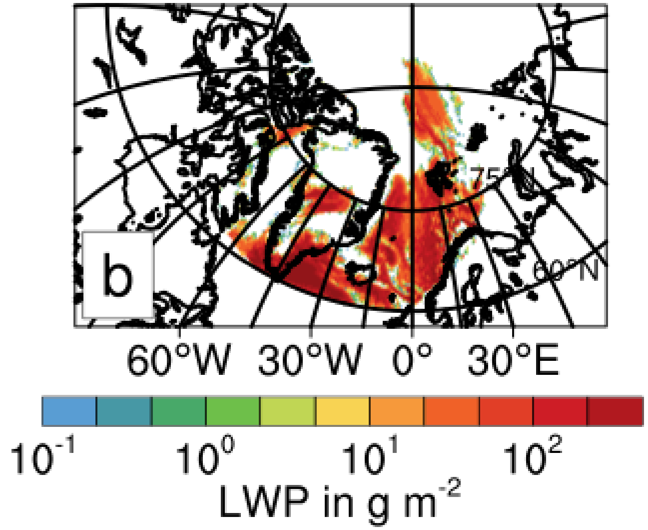
bias: -3.7 W m^{-2}

ICON vs CERES, January 2016

OLD

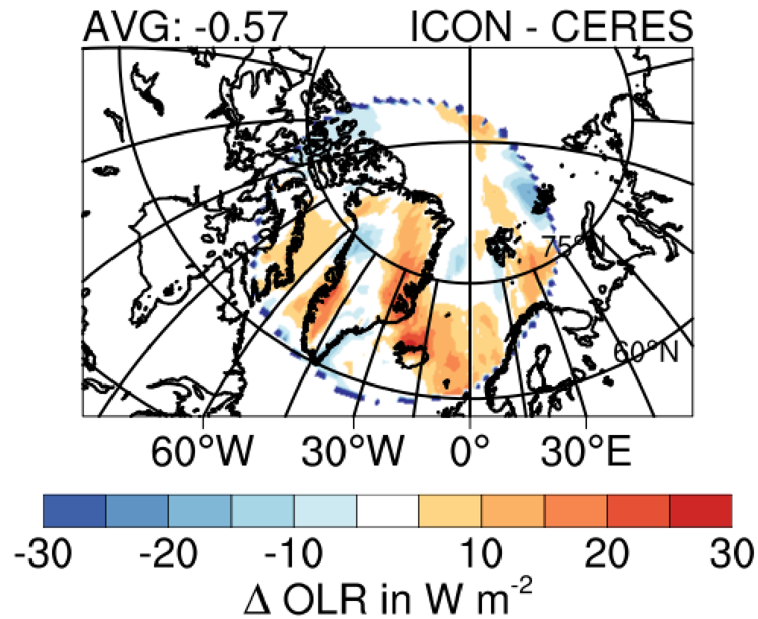


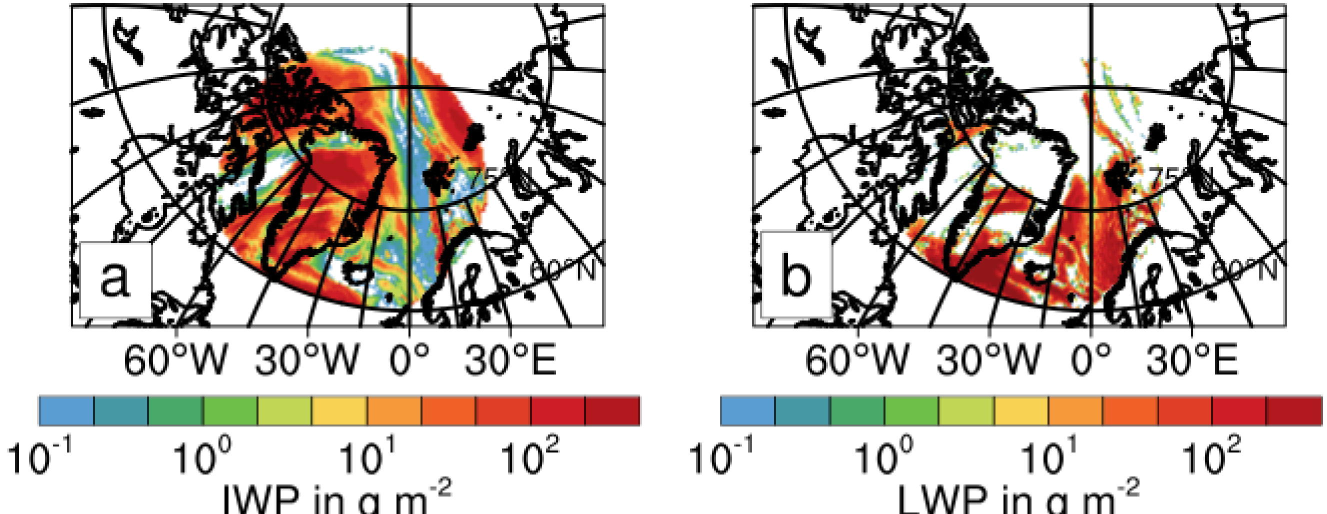




ICON vs CERES, January 2016

NEW





ICON vs CERES, January 2016

**NEW,
incl. snow**