Radiative Effects of Cloud Systems over the North Atlantic

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HD(CP)² High definition clouds and precipitation for advancing climate prediction

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Introduction

Research Questions

- What are the contributions of different **cloud types** to the total **cloud-radiative effect** over the North Atlantic?
- How does the current ICON-NWP framework simulate fractional coverage and cloud-radiative effects for different cloud types depending on:
  - grid spacing?
  - explicit vs. parameterized convection?
  - 1-moment vs. 2-moment microphysics?

Summary

Findings

- **cloud coverage (CC)**
  - simulated CC has a bias of -10% compared to retrieved CC → CC is a problematic quantity!
  - a pronounced resolution dependence of very-low and fractional clouds is found
  - two-moment scheme reduces CC bias of high -thin clouds, increases CC of high opaque clouds
- **cloud-radiative effect (CRE)**
  - nearly all cloud types cool the considered region, but cooling magnitude is underestimated in most simulations
  - increasing resolution or using explicit convection or 2-Moment scheme: average CREs become more realistic

Data and Methods

Observations and Simulations

- **Clouds from Meteosat**
  - infrared SEVIRI brightness temperatures
  - GERB-like TOA radiation fluxes
  - 1 hourly data, 3 x 6 km² pixel size

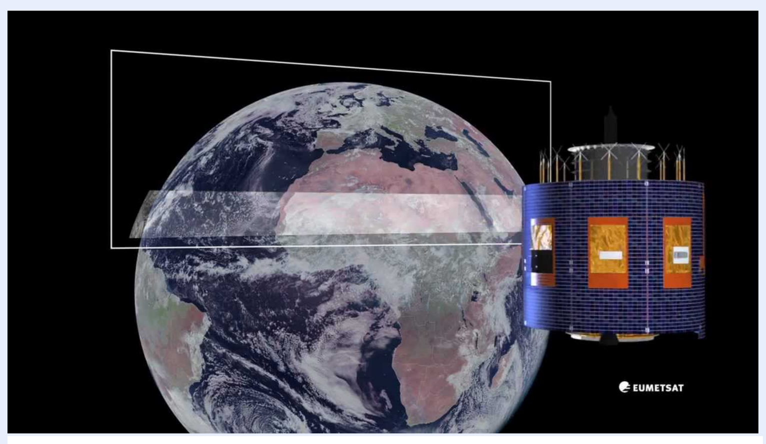

Fig. 1: The imaging radiometer Meteosat SEVIRI scans our Earth.

- **Numerical Experiments with ICON-NWP**
  - 4 sets of 4-day forecasts (last 3 analyzed)
  - grid spacing: 2.5 km, 5 km, 10 km, 20 km, 40 km and 80 km
  - explicit vs. parameterized convection
  - 1-Moment vs. 2-Moment microphysics

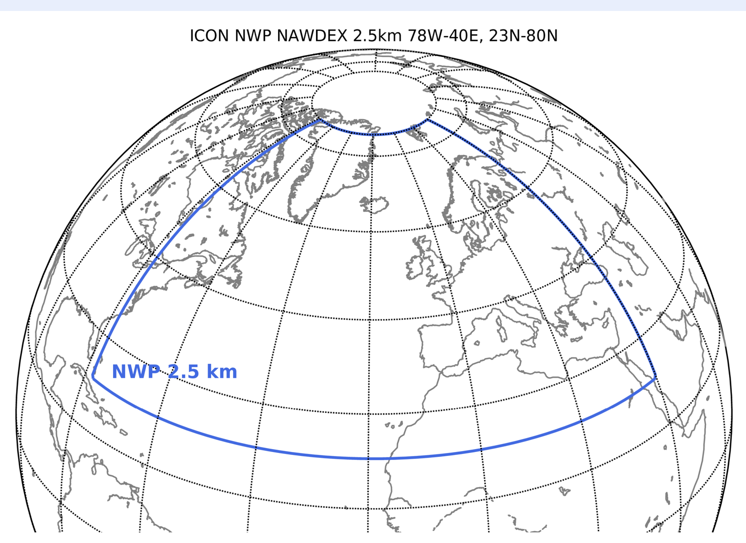

Fig. 2: ICON_NWP model domain.

RTTOV and Synthetic Radiances

- very fast radiative transfer model
- simulates infrared radiances of MSG-SEVIRI
- ice and snow added and McFarquhar et al. (2003) for ice crystal diameters

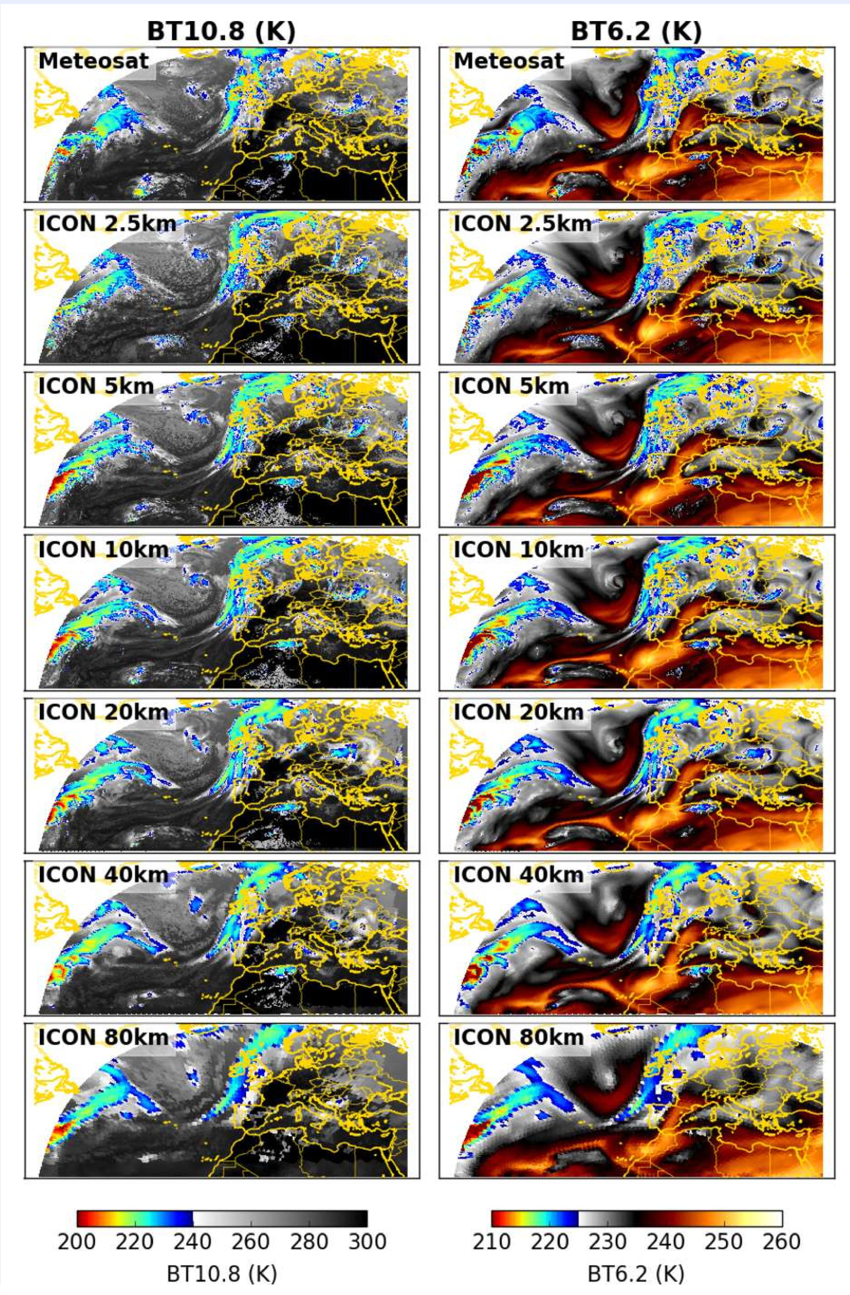

Fig. 3: A sequence of observed and synthetic BTs from Meteosat (top) and ICON-NWP with increasing grid spacing (other rows) for IR radiation from window channel (left) and water vapor channel (right).

NWC-SAF

- EUMETSAT Nowcasting-SAF provides software for nowcasting
- cloud properties include cloud mask (CMa), cloud type (CT) and cloud top altitude (CTH)

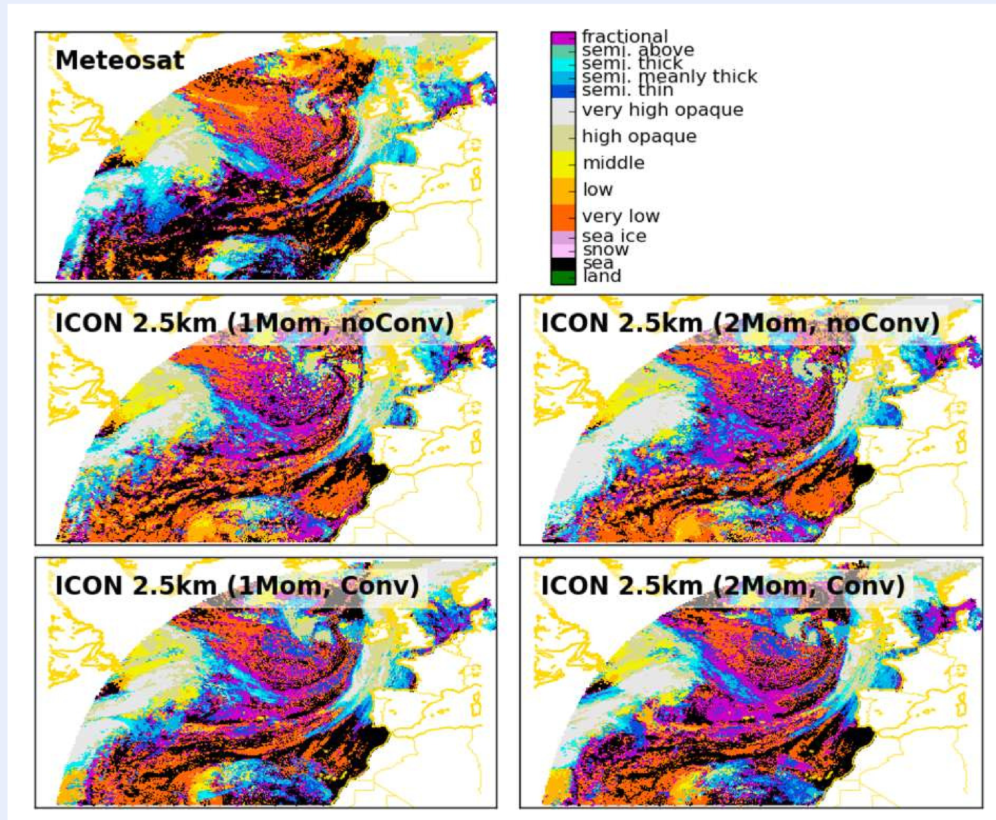

Fig. 4: Cloud Typing derived with the NWCSAF v2013 product suite. Only North Atlantic is considered and permanent night-mode is applied. Observation (upper left) is compared to ICON-NWP simulations (2nd and 3rd row) with different parameterization settings:

- 1-Moment microphysics scheme (left column) vs. 2-Moment microphysics scheme (right column)
- explicit convection (2nd row) vs. parameterized convection (3rd row)

Estimating Clear-Sky Fluxes

- clear-sky fluxes are not available for cloudy observations
- due to high regional cloud coverage, temporal estimation of clear-sky fluxes is not feasible

simulation bias: ocean too bright!

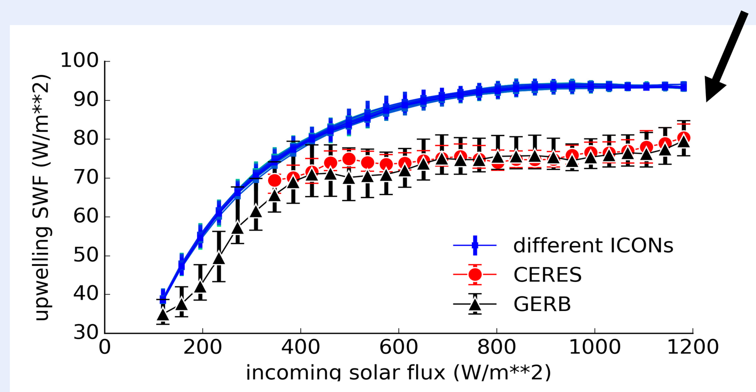

Fig. 5: Upwelling clear-sky shortwave fluxes for different observations (CERES, GERB) and ICON simulations.

→ use simulated clear-sky and apply bias correction factor 0.85

Comparison of Cloud Cover and Cloud-Radiative Effects

Cloud Cover

- cloud cover is notoriously hard to quantify
- for fair comparison: observed and synthetic cloud masks are compared

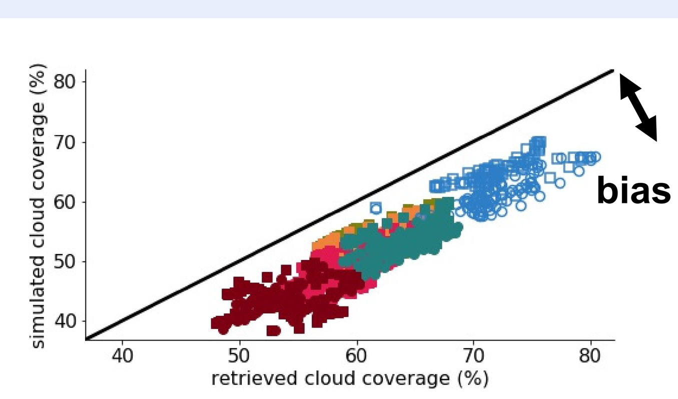

Fig. 6: Simulated vs retrieved CC. Simulation Output vs. synthetic NWCSAF Cloud mask.

▸ CC from sim. output -10% too low

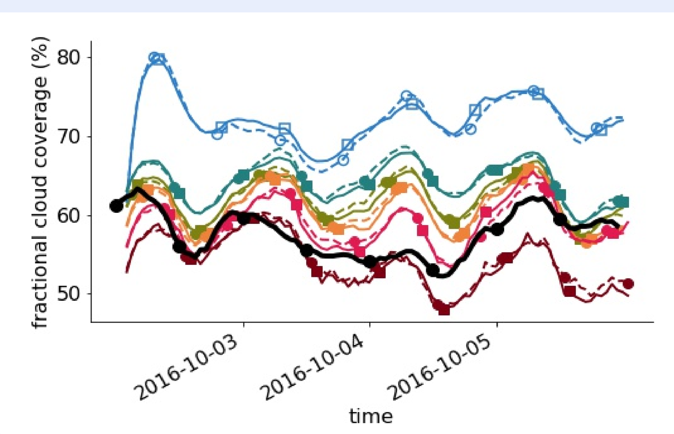

Fig. 7: Time series of CC for observation (black) and ICON-NWP simulation with different grids (rainbow).

▸ simulated CC increases with resolution

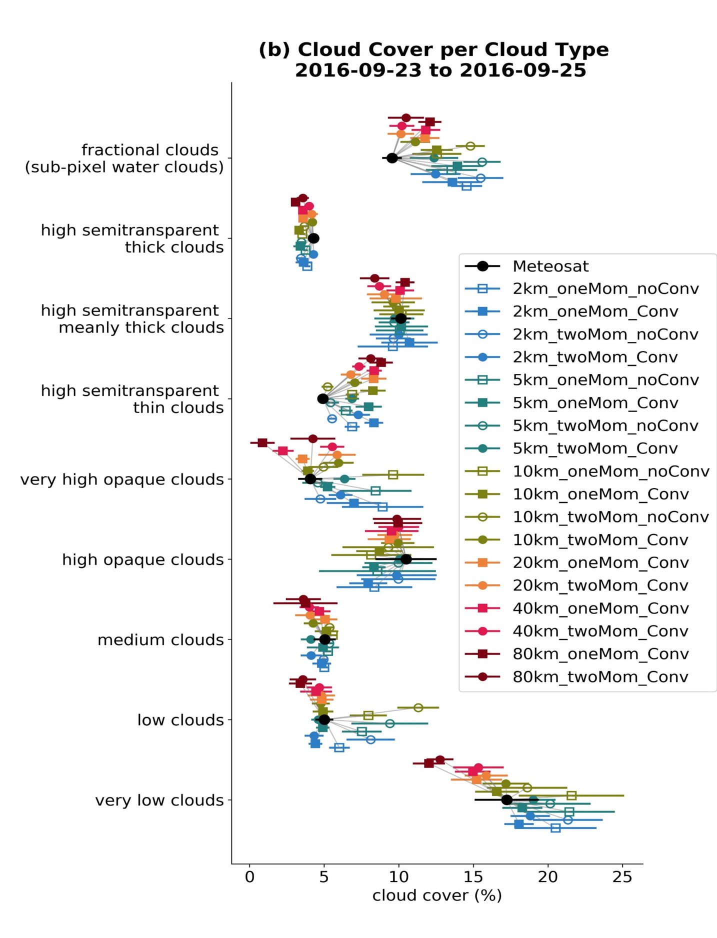

Fig. 8: Average simulated and observed CC for different cloud types derived from NWCSAF software.

- **resolution dependence for very low clouds**
- **explicit convection increases very low / low cloud coverage**
- **microphysics impacts cirrus**

Cloud-Radiative Effects

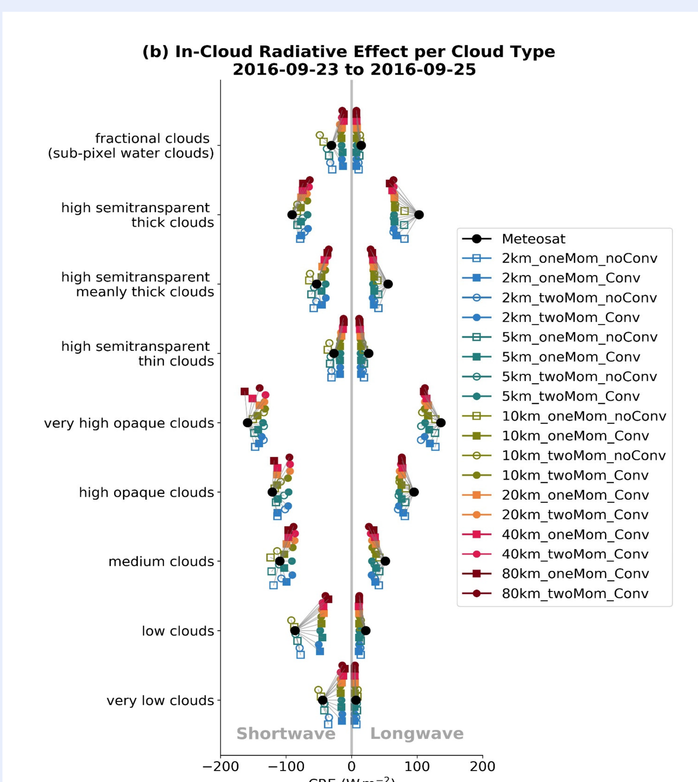

Fig. 9: Shortwave and longwave relative cloud-radiative effects per cloud type (vertical axis) for observation (black) and different ICON simulations (rainbow colors).

$$\langle F_{tot} \rangle = \langle F_{clear} \rangle + \sum \langle f_i \Delta F_{cloud,i} \rangle$$

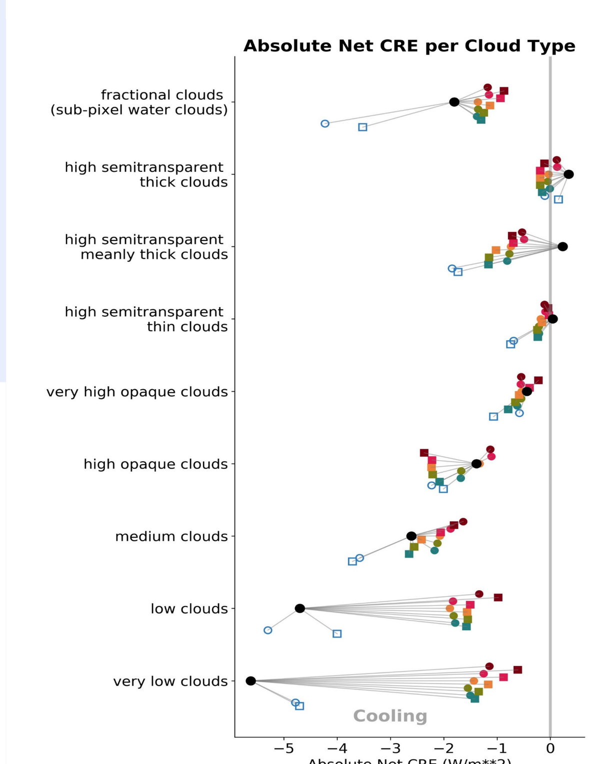

Fig. 10: Net absolute cloud-radiative effects per cloud type (vertical axis) for observation (black) and different ICON simulations (rainbow colors). The absolute CRE is weighted by cloud fraction and gives the absolute radiation flux contribution per cloud type.

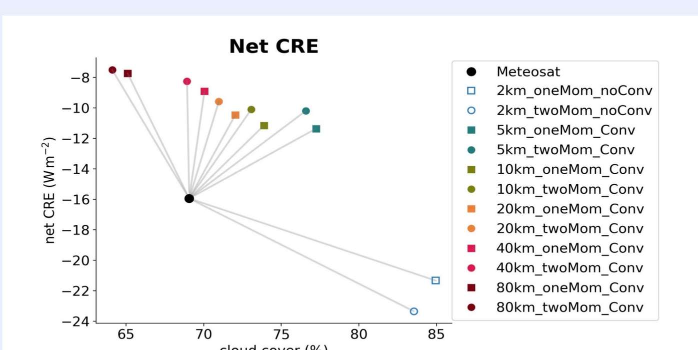

Fig. 11: Net cloud-radiative effect vs. cloud cover.

- **nearly all clouds cool**
- **explicit convection strongly improves CRE of very low / low clouds**
- **2-Moment microphysics improves CRE of cirrus clouds**
- **increasing resolution generally leads to more negative CREs**