Arctic Clouds - Evaluating modelled cloud with field observations

Ian Brooks

Jutta Vüllers, Gillian Young, Peggy Achtert, Ryan Neely, Barbara Brooks, Michael Tjernström, John Prytherch, Jonny Day, Ewan O’Connor, Rebecca Atkinson, Joseph Sedlar, Thorsten Mauritsen, Matthew Shupe, Ola Persson, Cathryn Birch,…
Arctic BL & Cloud Development

Melting sea ice: $T_s \sim 0^\circ C$

Zone of enhanced surface warming

Upstream dew-point temperature

Upstream temperature

Wind

Final state

Gradual transformation

Immediate response

Land surface: $T_s \sim 25^\circ C$

Dissipation rate, \( \varepsilon \)

Aug 28, 2008 (doy = 241)

Well-mixed BL

Cloud-mixed layer (CML)

Surface mixed layer (SML)

IR

T_s

turbulence
Global models do a poor job of representing Arctic stratus.

- BL too deep & too well mixed
- Cloud too thin & too low
- Cloud water content too low

→ radiative properties wrong
→ surface energy budget wrong
→ BL structure wrong – feedback on cloud

Birch et al. 2012, **12**, 3419–3435, doi: 10.5194/acp-12-3419-2012
Modelled longwave radiation is wrong → results in serious bias in net surface radiation budget: warming instead of cooling
Observed vs modelled cloud
Global models (still) do a poor job of representing Arctic stratus.

- IFS Cy40 (new cloud scheme) improves cloud representation, but...
- Little improvement in surface radiation
- Fails to represent clearing & cloud-free conditions (aerosol/CCN issue?)
- Fails to reproduce frequent decoupling of cloud from surface (BL mixing scheme issue)
- Fails to reproduce coincident temperature & humidity inversions

Cloud Forced Mixing

Cloud radar backscatter (dB) & radiosonde profiles for:

TOP: cloud capped by temperature inversion

BOTTOM: cloud extending into inversion

Both cases from ASCOS

Cloud Forced Mixing

Cloud Forced Mixing

Inversion base
Cloud limits

Cloud Forced Mixing

Cloud top

\[ \frac{Z}{Z_p} \]

\[ \text{LW}_{\text{heat}} \text{ [K day}^{-1}] \]

\[ \text{Max } W'W'' \text{ [m}^2\text{s}^{-2}] \]

\[ \text{Hr} \]
Observations in central Arctic Ocean

ASCOS – Aug 2 – Sep 9 2008
ACSE – Jul 5 – Oct 5 2014
AO2018 – Jul 20 – Sept 21
AO2018 Remote Sensing Cloud Measurements

HALO Doppler lidar
HATPRO Microwave radiometer
Metek Ka-band Cloud radar
Cloudnet retrieval scheme

Illingworth et al., Bams, 2007
Cloud radar & lidar

18 Aug 2018

Radar reflectivity factor

Attenuated backscatter coefficient
Cloudnet target classification

Aug 2018

Sept 2018

Target classification

Day of the month

Height (km)

Target classification

Height (km)

Target classification

Day of the month

Height (km)

Target classification

Day of the month

Height (km)
AO2018 Observed Cloud Statistics

Summer (melt)  
Autumn (freeze up)
AO2018 : IFS Model vs. Observations

measured cloud fraction by volume

model cloud fraction including snow
AO2018: IFS Model vs. Observations

Measured
Model
Model inc. snow

total (Day of Year: 226-256)
AO2018 : IFS Model vs. Observations

summer (Day of Year: 226-242)

- Measured
- Model
- Model inc. snow

Low cloud over-estimated
AO2018: IFS Model vs. Observations

autumn (Day of Year: 243-256)

Measured
Model
Model inc. snow
Ongoing Work

• Evaluate modelled cloud statistics from (IFS, MetUM, ERA5) for 2014 & 2018 campaigns
  – Bulk properties
  – LWP, IWP
  – Impact of aerosols on cloud properties (AO2018 partner measurements)
  – INP / cloud-ice relationships

• BL-cloud interactions
  – Thermodynamic & turbulent structure

• Cloud parameterisation (MetUM CASIM) evaluation and development
Thank You...