Convection-Resolving Simulations of Subtropical Marine Stratocumulus Clouds

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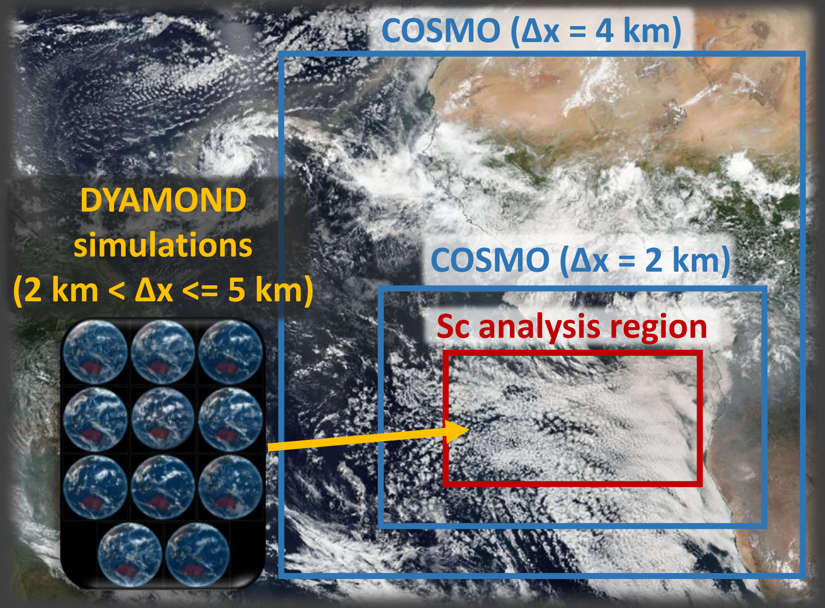
Experimental Setup:

Analysis of 40-day long limited-area COSMO(1) simulations and global DYAMOND(2) simulations to see how convection-resolving models simulate subtropical marine Stratocumulus (Sc) clouds over the South East Atlantic.

17th August 2016, VIIRS on Suomi NPP



(1) Baldauf et al. 2011, (2) Stevens et al. 2019

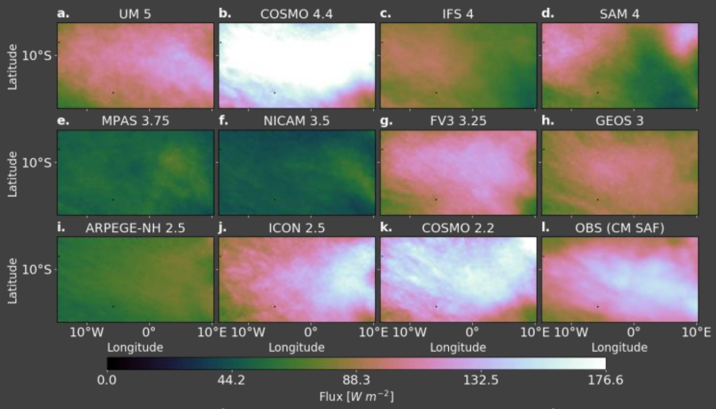
Key Findings:

- Most models simulated realistic Sc cloud decks. (slide 2)
- Substantial inter-model spread in the simulated reflected shortwave flux. (slide 3)
- Overall overestimation of outgoing longwave flux. (slide 3)
- Models with higher inversions tend to simulate higher cloud cover. (slide 4)

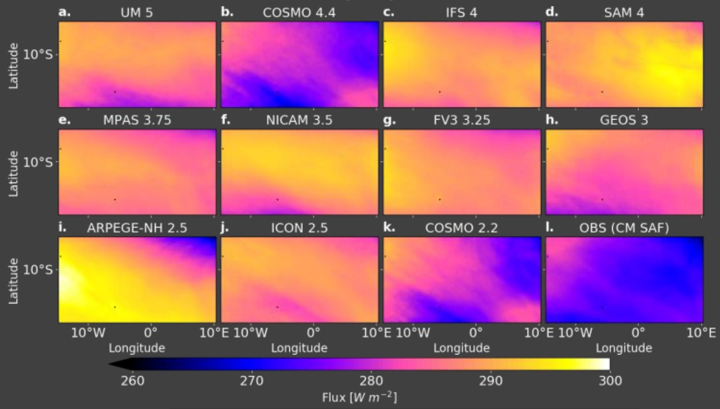
Conclusion:

- Even at convection-resolving resolution (Δx <= 5km), inter-model differences in the simulation of Sc clouds are substantial – perhaps more important than model resolution.

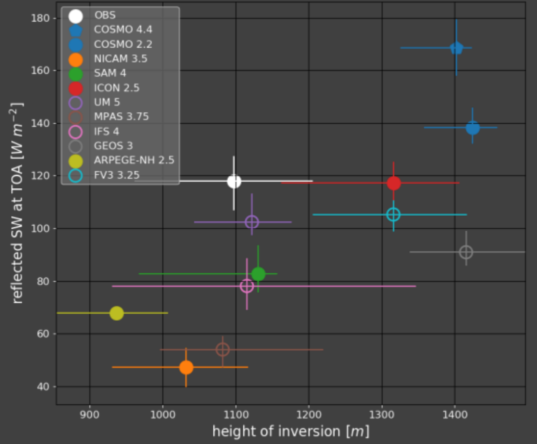
Slide 3
reflected shortwave



Slide 3
outgoing longwave

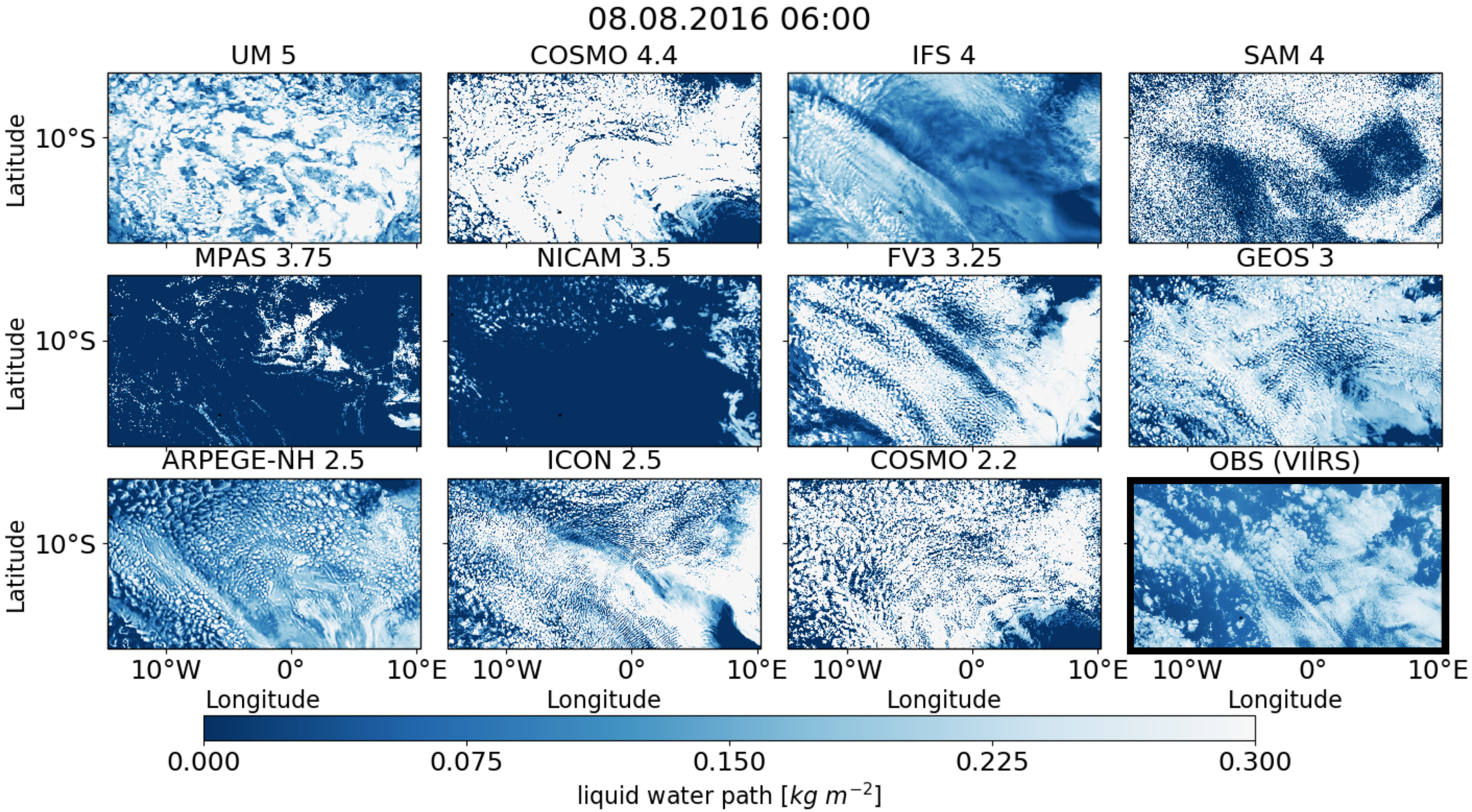


Slide 4
reflected shortwave vs. mean inversion height



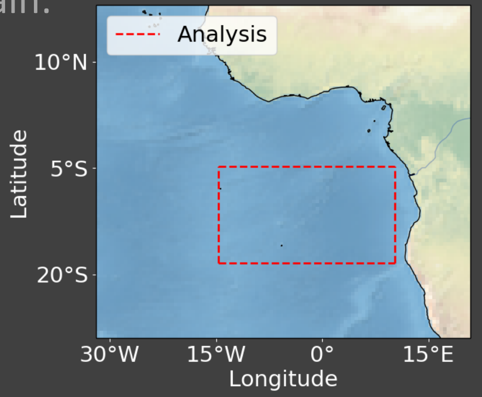
Cloud field

- Compared to observations, most models simulate a cloud field that appears realistic in terms of:
  - spatial coverage
  - cloud structuring and aggregation



Note: A direct comparison between the simulated cloud field and the satellite picture (lower right corner) is not possible because the global DYAMOND simulations run without lateral forcing whereas the limited area COSMO simulations are laterally driven by reanalysis data.

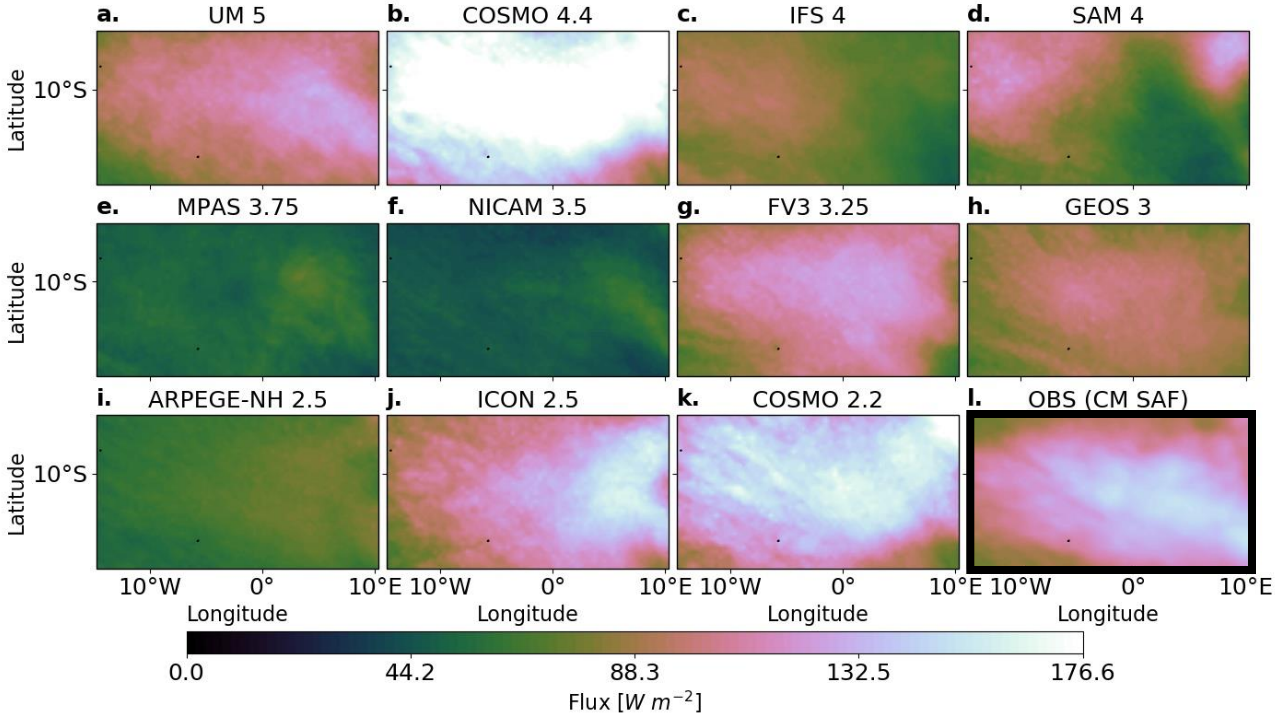
- snapshot of liquid water path on 08.08.2016 at 06:00
- VIIRS (Suomi NPP) satellite picture shown in lower right corner.
- domain:



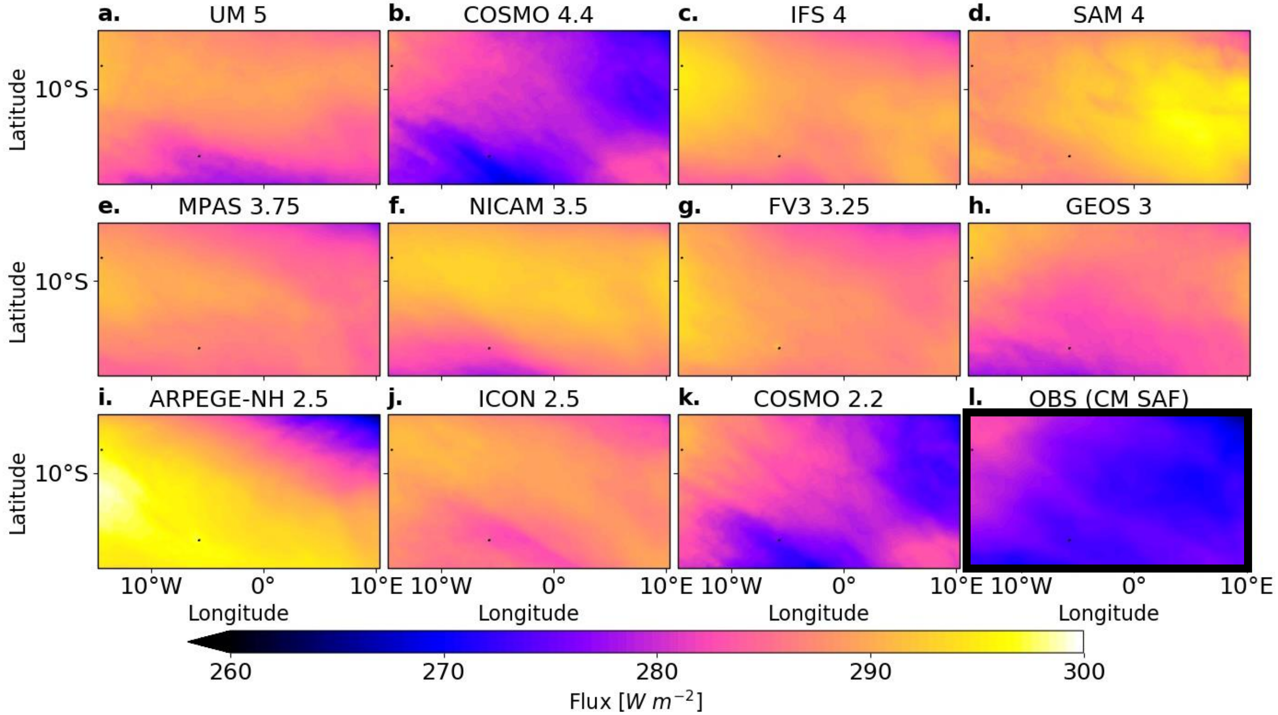
Radiative fluxes

- high variability between models
- Most models underestimate reflected shortwave representing a lower than observed low-level cloud cover fraction.
- All models overestimate outgoing longwave radiation by ~ 20 W/m^2.

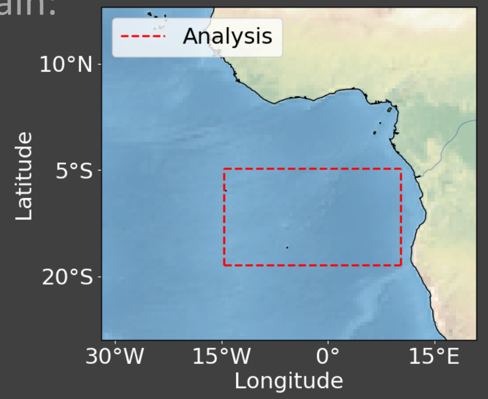
reflected shortwave at TOA [W m^{-2}]



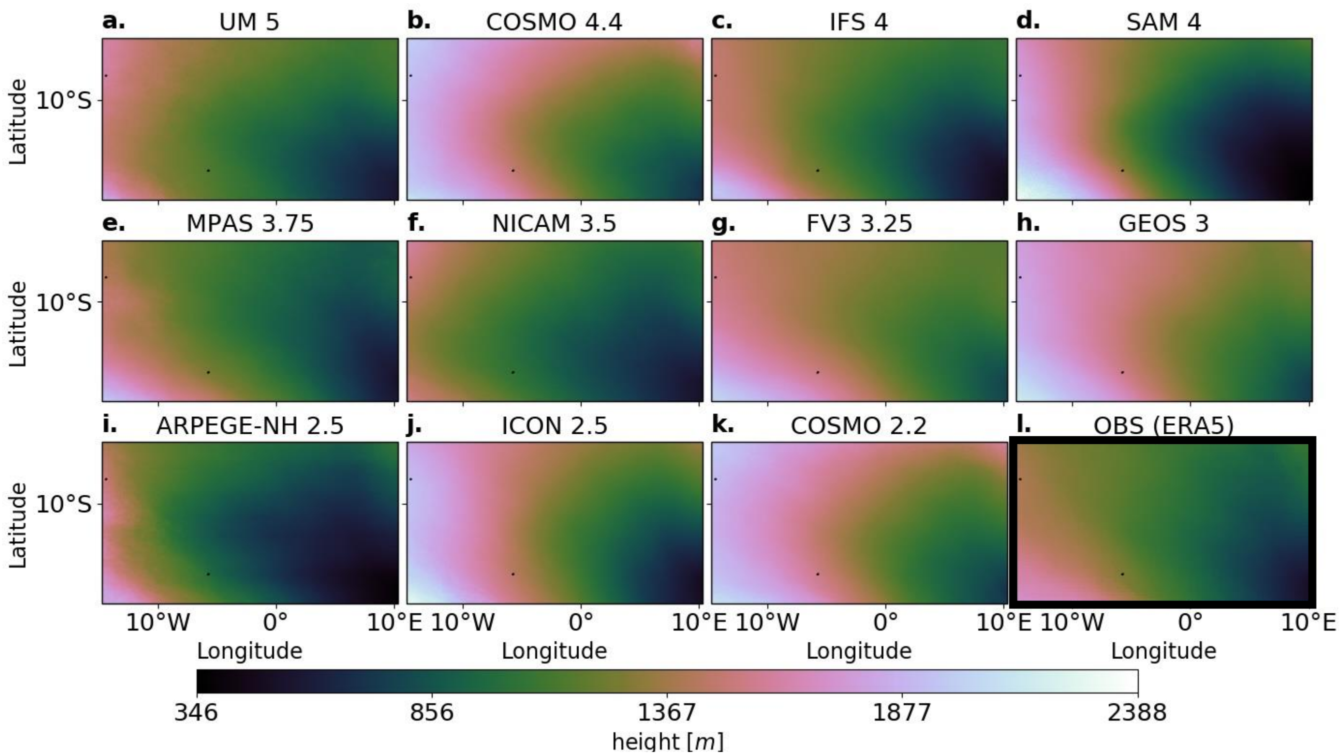
outgoing longwave at TOA [W m^{-2}]



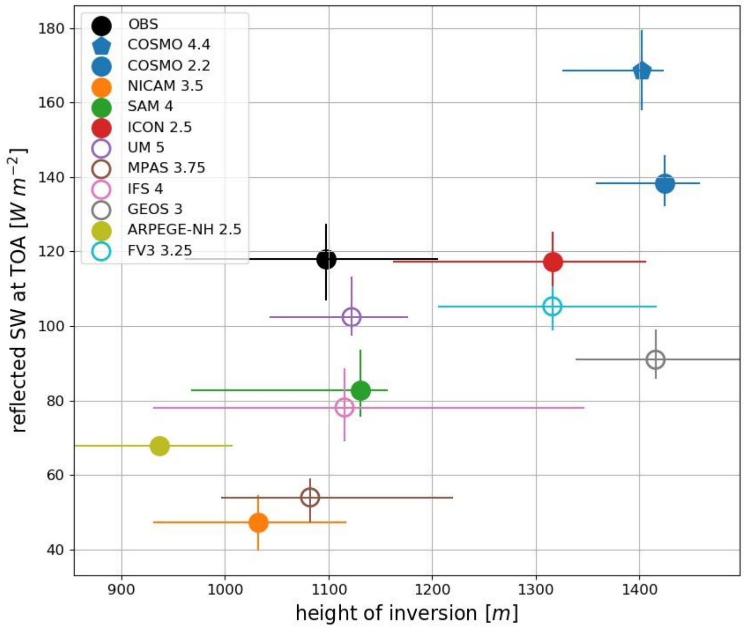
- mean between 06.08.2016 – 09.09.2016
- CM SAF observation is shown in panel **l**.
- domain:



inversion height [m]



domain-average reflected shortwave radiation vs. inversion height



Inversion height

- On average, models with higher inversions tend to have a higher cloud-cover fraction (more reflected shortwave).

Inversion height (above):

- mean between 06.08.2016 – 09.09.2016
- ERA5 reanalysis in panel **l**

Reflected SW vs inversion height (below):

- comparison of spatial (analysis domain) and temporal (06.08.2016 – 09.09.2016) mean reflected shortwave radiative flux at TOA vs. inversion height
- Bars indicate interquartile range of daily mean values.
- Simulations with an empty circle deploy a shallow convection scheme whereas those with a full circle do not.
- Observation (black) is based on ERA5 (inversion height) and CM SAF (reflected shortwave).

Simulation Setup

- 1 limited area convection-resolving model:
  - **COSMO** (Baldauf et al. 2011)
- 9 global convection-resolving simulations from DYAMOND project: (Stevens et al. 2019)
  - **NICAM**
  - **ICON**
  - **IFS**
  - **MPAS**
  - **UM**
  - **SAM**
  - **FV3**
  - **GEOS**
  - **ARPEGE-NH**

COSMO simulations

time period:

- 40 days of SH winter (1.8.2016 – 9.9.2016)

lateral boundaries:

- ERA5[1] → COSMO@4km → COSMO@2km (one-way nesting)

lower boundary:

- prescribed SST (ERA5)
- soil moisture initialized with 17-year long COSMO@24km simulation

Hentgen 2019; Schär et al. 2019

DYAMOND simulations

time period:

- 40 days of SH winter (1.8.2016 – 9.9.2016)

lower boundary:

- prescribed SST (ERA-Interim[2])
- soil moisture initialized individually for each model

(1) Copernicus Climate Change Service (C3S) 2017, (2) Dee et al. 2011

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