Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Reducing systematic errors in DWD's ICON model

WGNE meeting, Offenbach, 26 Sep. 2019

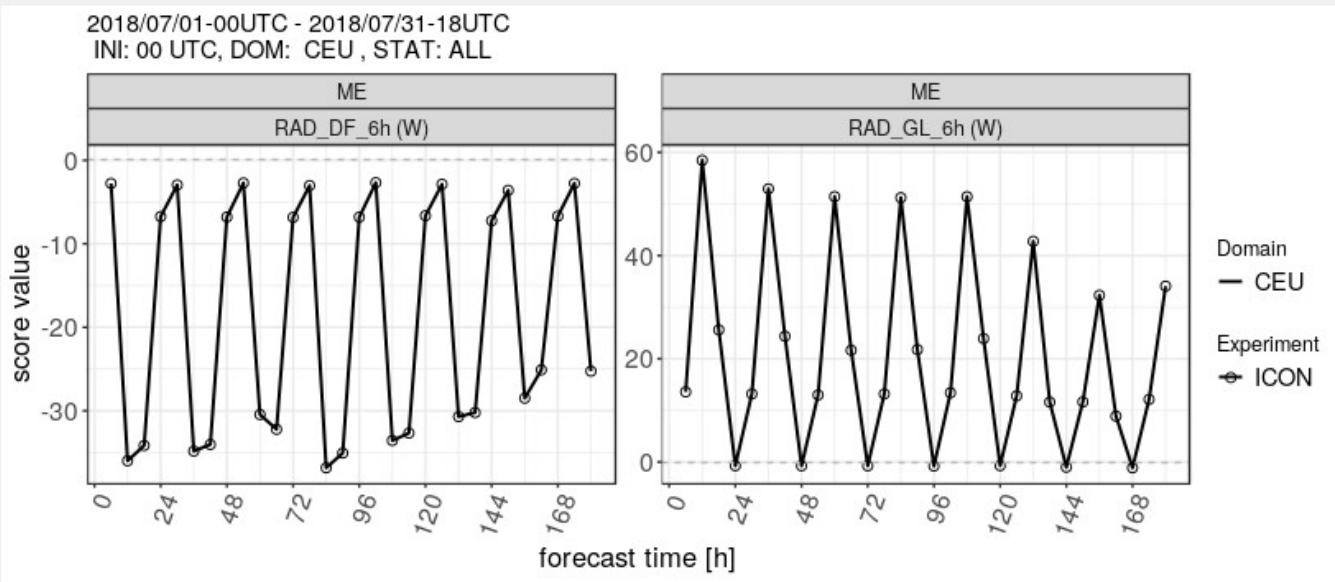
Günther Zängl

Overview

- (Selection of) open bias issues as of summer 2018
- Steps towards reducing the biases in ICON
- Ongoing projects

Open bias issues

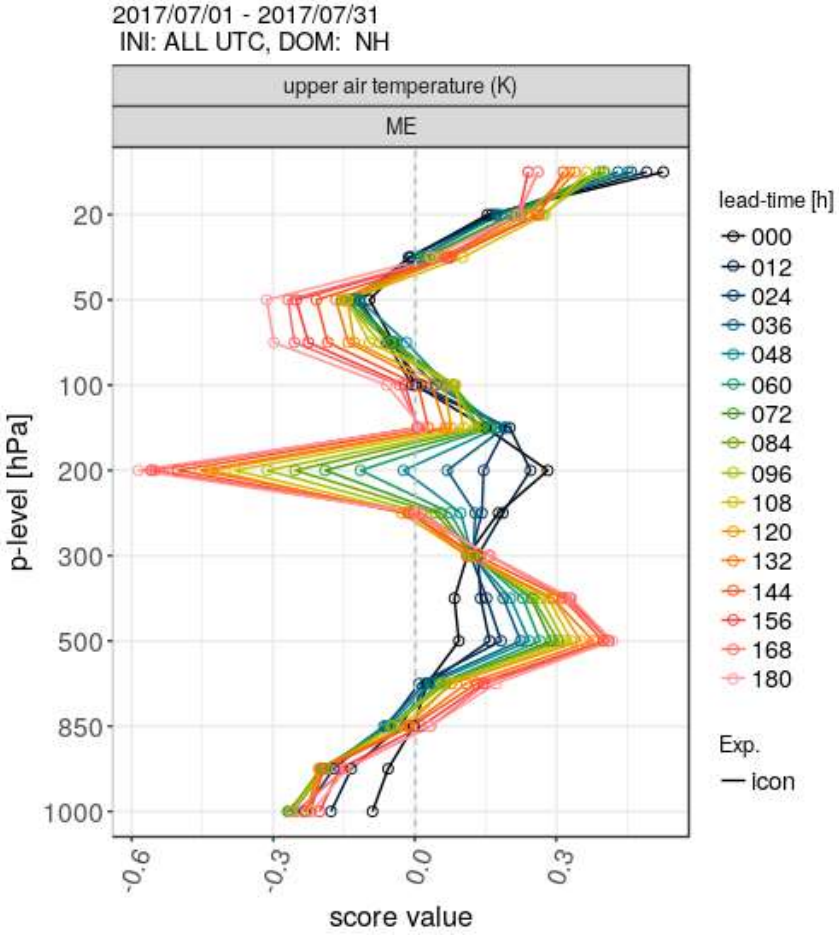
- Overestimation of global radiation over land, going along with too little diffuse radiation (example for July 2018, Europe)



- Conditional verification indicates that the bias is largest under partly cloudy conditions, but elevated regions used to receive too much solar radiation all the time

Open bias issues

- Cold bias in 200 hPa in NH summer
- Annually recurring in July/August, in some years already occurring in early summer
- Sometimes extends to 150 hPa

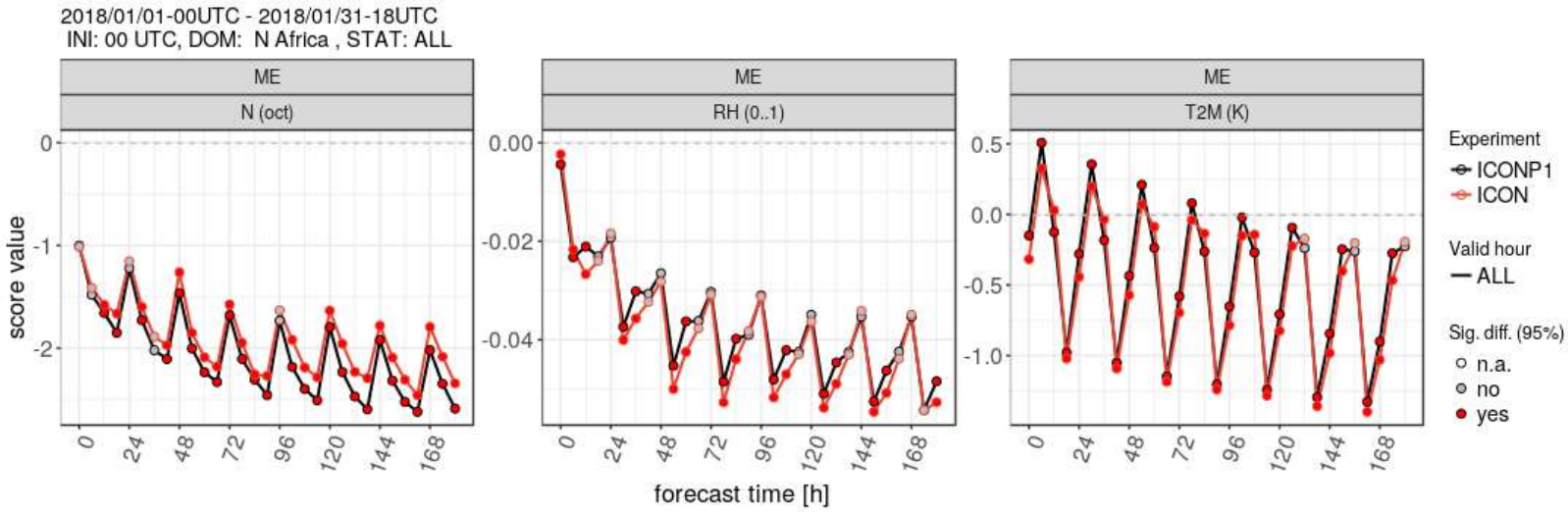


Possible causes

- Too high tropopause?
- Too weak tropopause inversion?
- Too deep convection?
- Too high moisture above tropopause?

Open bias issues

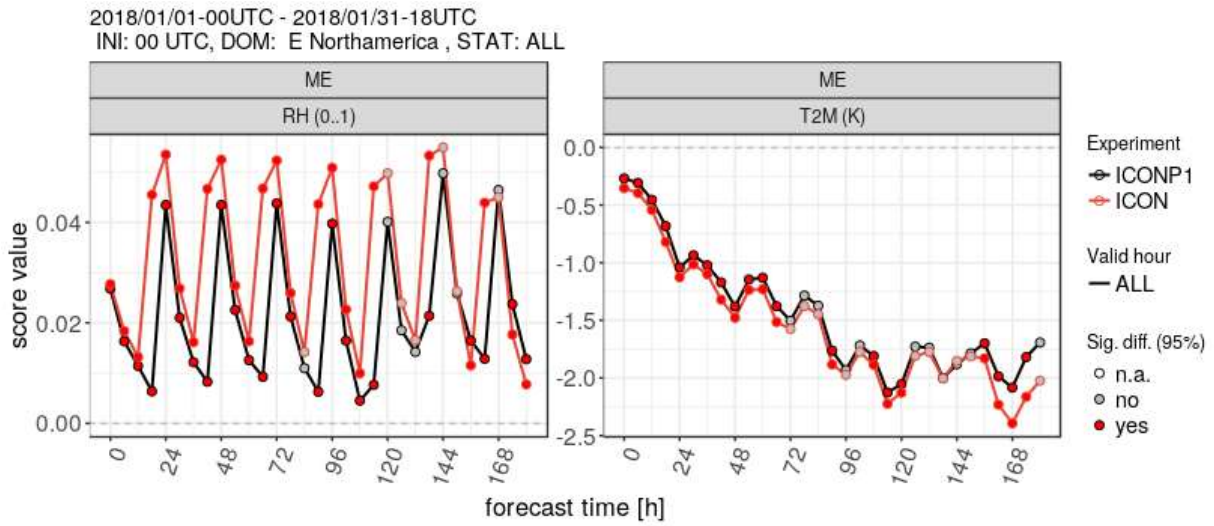
- **North African bias: too little cloud cover, too dry and too cold …**



- **… despite tuning measures like reduced albedo over the Saharan desert, increased LW absorption of mineral dust and tuned heat conductivity of sand**
- **This is clearly opposite to what we expect in a region with a positive radiation balance**

Open bias issues

- North American bias: much too cold in winter



- Bias growth is more rapid during daytime than at night, indicating too low surface heat fluxes
- Maybe the surface flux intercomparison project will help shedding some light on this issue…

Steps towards reducing the biases

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a) Radiation

- Bug fix in vertical distribution of aerosols taken from AOD climatology (solved systematic loss of AOD in elevated regions)
- Coupling of distribution width of subgrid-scale cloud cover to standard deviation of saturation deficit (calculated in the turbulence scheme): improves diurnal cycle of boundary-layer clouds
- Correction for underestimation of thin moist/cloud layers at coarse vertical resolution: reduces underestimation of mid-level clouds
- Activation of Forbes (2012) parameterization for supercooled cloud water on top of Arctic stratus clouds (needed to be retuned in order to avoid warm bias in Siberian winter)
- Simple parameterization for diffuse radiation generated by reflection of solar radiation at cumulus clouds (radiation scheme accounts only for direct scattering effect)

Improvement of cloud cover

(central Europe, April – July 2019)

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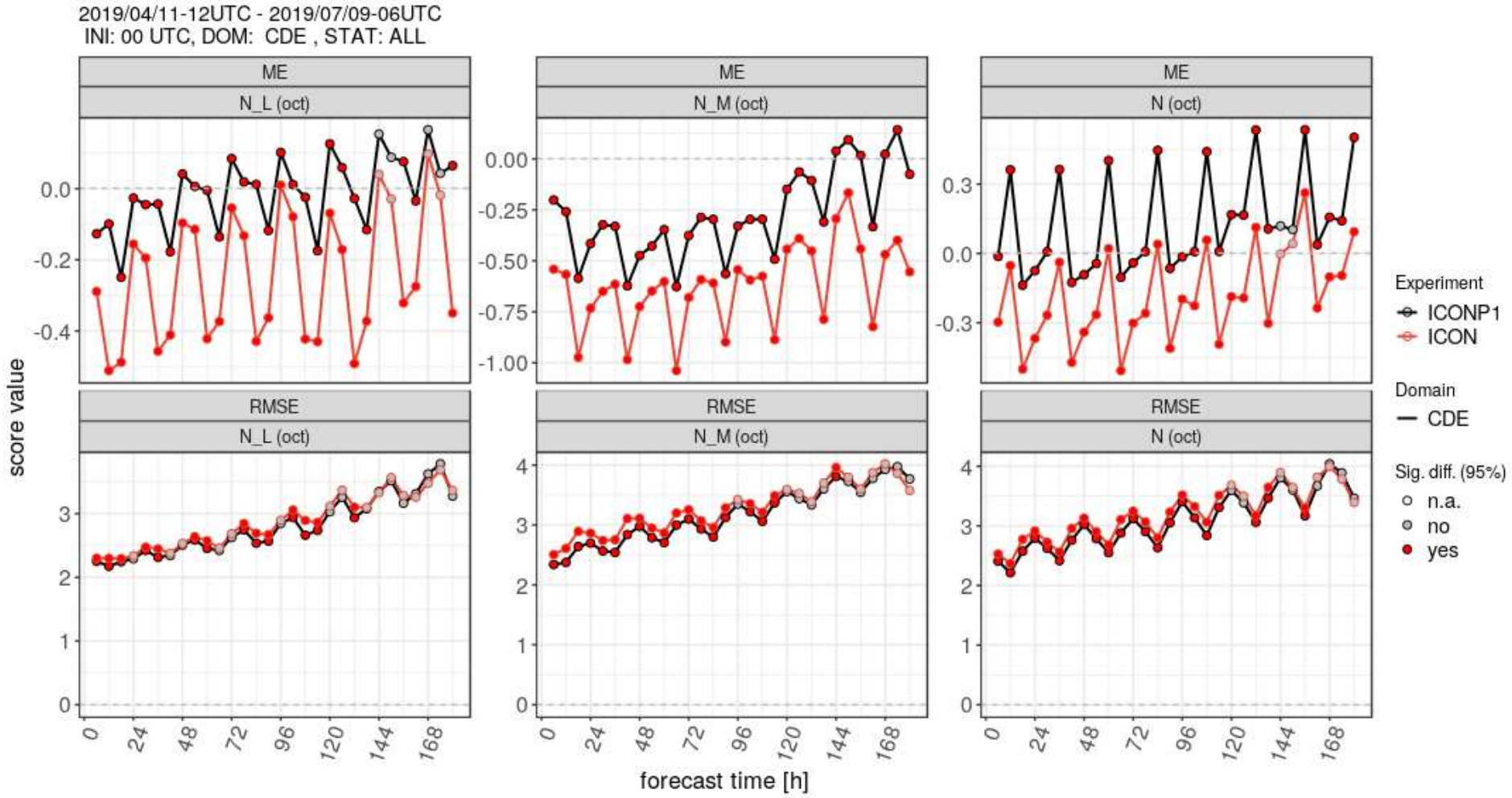

low cloud cover | mid-level cloud cover | total cloud cover

Improvement of radiation

(central Europe, April – July 2019)

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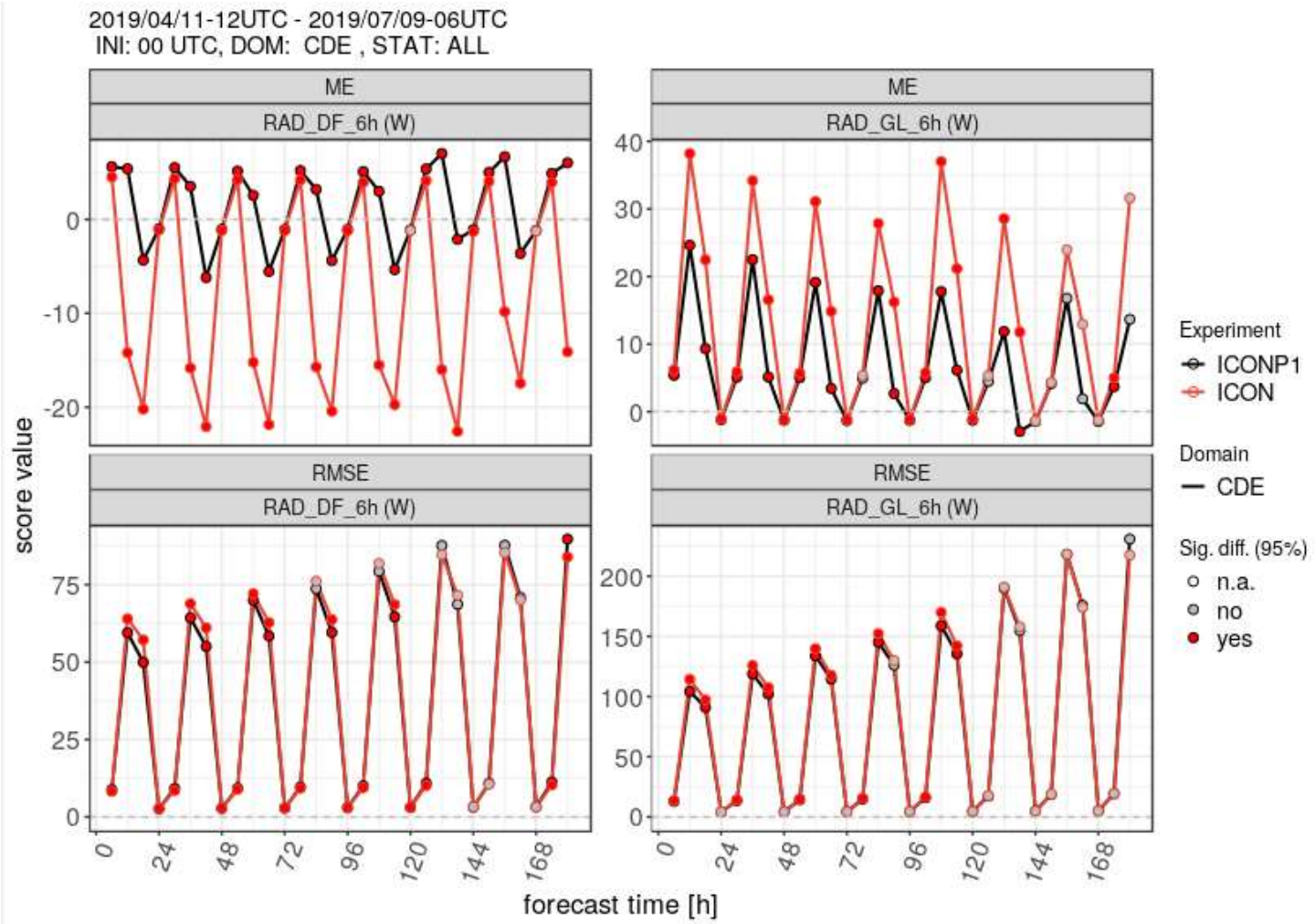

diffuse radiation

global radiation

Steps towards reducing the biases

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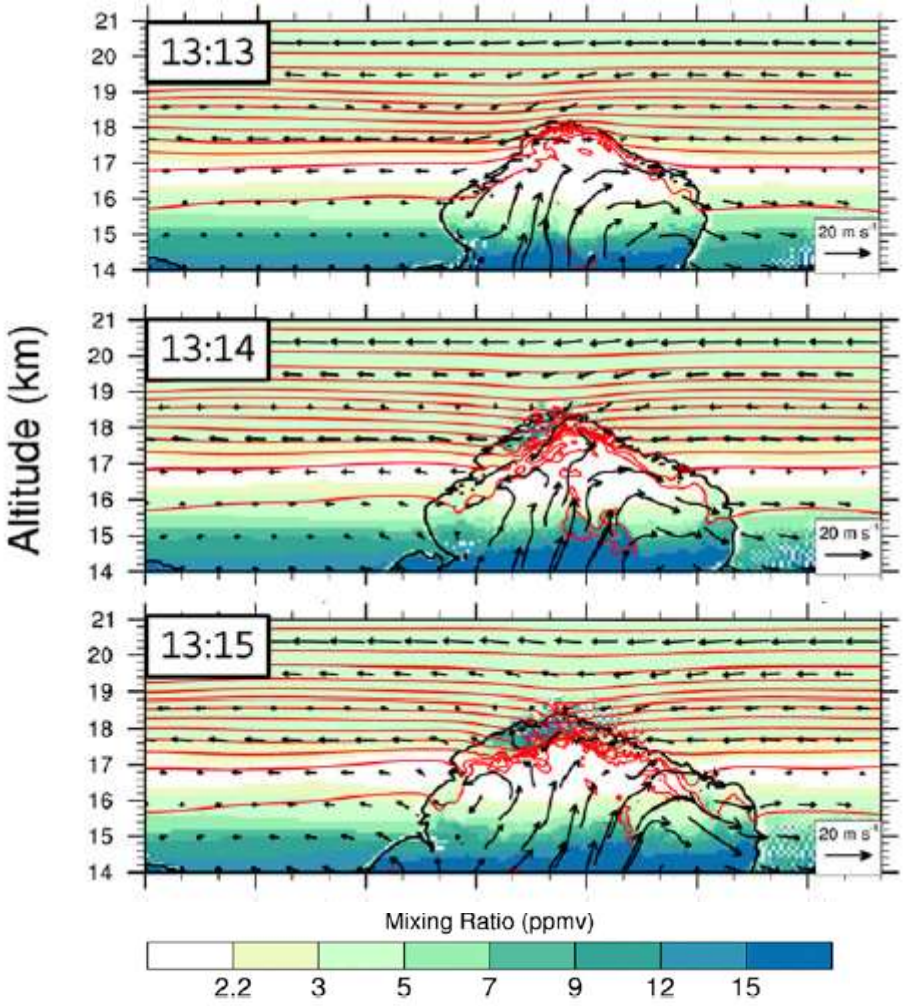
b) Cold bias above tropopause

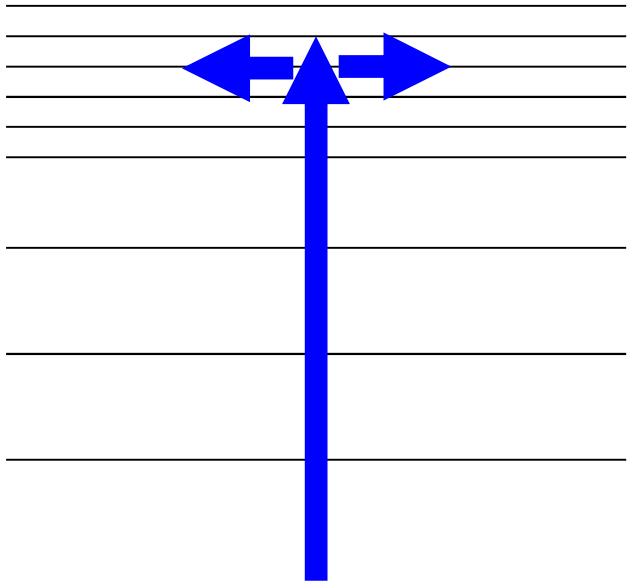
- Verification against radiosondes indicates too high moisture above extratropical tropopause
- Initially, diffusivity of model numerics (moisture transport) was thought to be the main reason, but an improved implementation of the (vertical) flux limiter had only a minor impact
- Later on, the convection scheme was identified as an important source of the moist bias because overshooting convection is not (cannot be?) adequately represented
- An artificial limiter for overshooting in stable environments (stratosphere) brought a substantial improvement

- Also successfully tested in IFS

Overshooting convection



Nature as represented by LES
(Dauhut and Chaboureau 2018, JAS)



Overshoots in parameterized convection: moisture detrainment takes place too high above the tropopause

Radiosonde verification for rel. humidity, NH, April/May 2019

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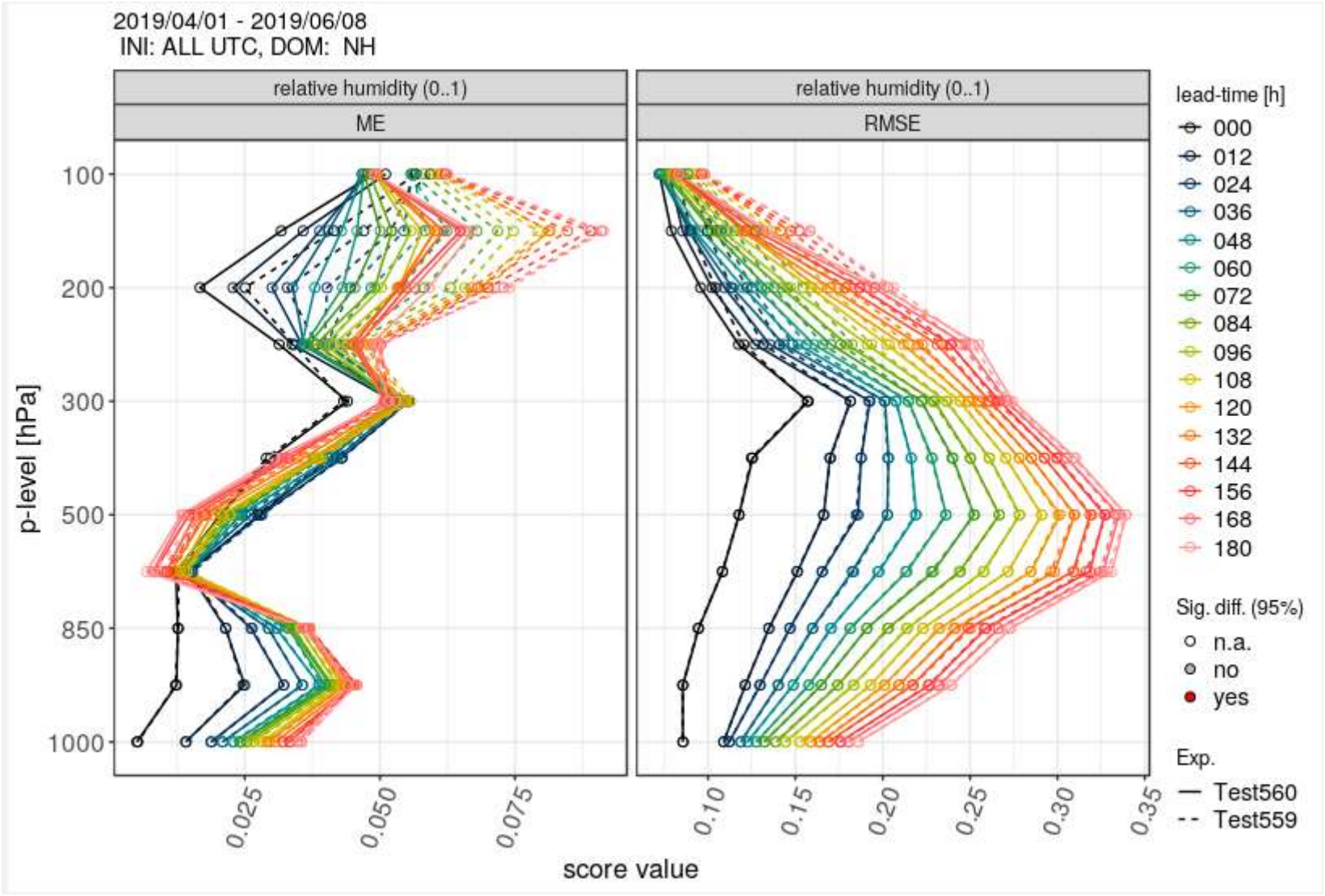

Radiosonde verification for temperature, NH, April/May 2019

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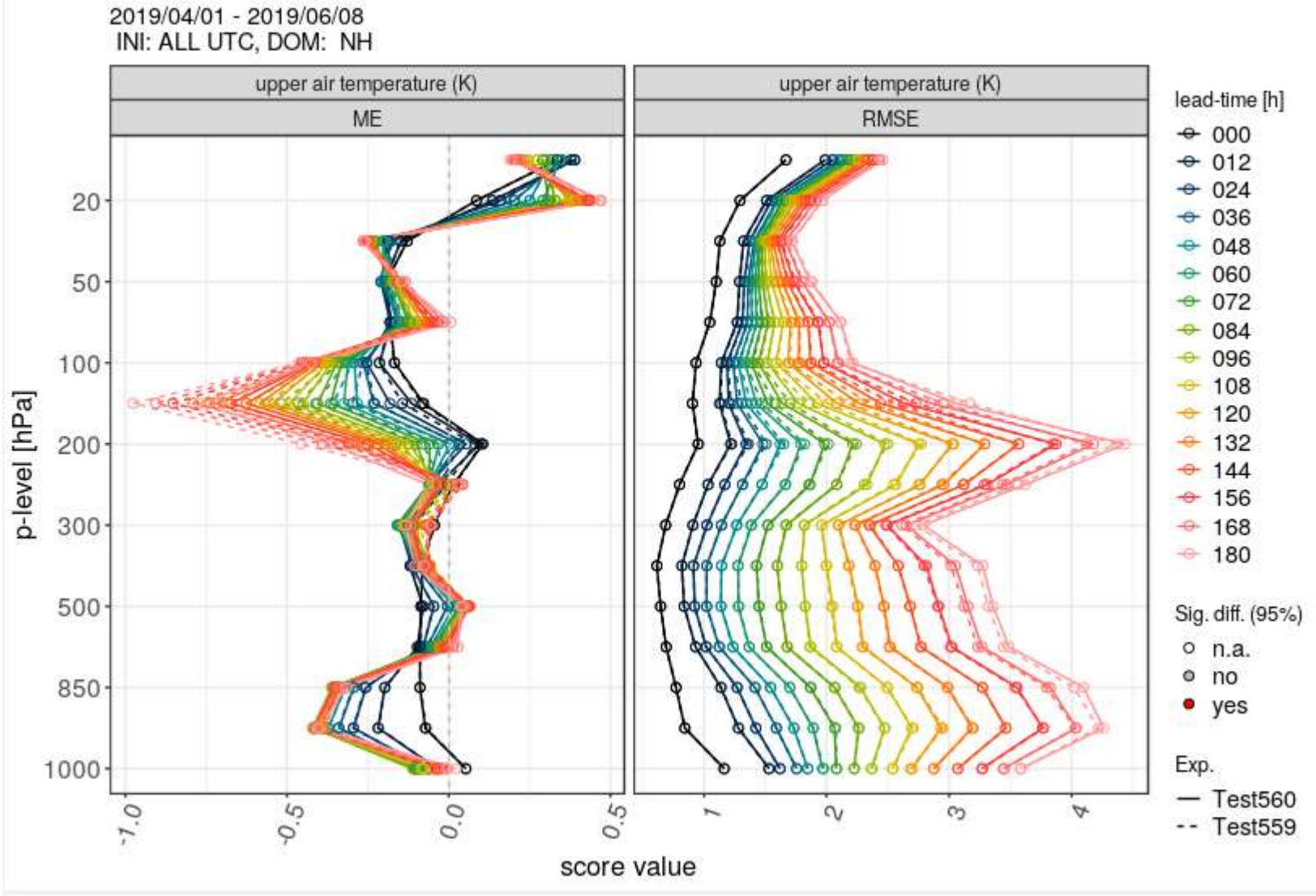

Steps towards reducing the biases

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c) Cold bias in Saharan region (ongoing work)

- Improved specification of longwave emissivity based on satellite retrievals
- Use of more recent (and hopefully more accurate) aerosol climatology, or simple prognostic aerosol scheme

- Results are not yet conclusive…

Further ongoing projects

- Participation in MOSAiC campaign: dedicated operational forecast products during campaign; use MOSAiC data sets to identify and improve model deficits afterwards (see subsequent slides)

- Implementation of mixed-layer scheme for ocean
- Coupling with wave model (WAM; currently operated offline)

- Change from RRTM to ECRad radiation scheme

- Use of more modern and higher-resolved external parameter data sets, e.g. for soil and vegetation properties
- Implementation of canopy-layer scheme for land-surface model
- Implementation of TOFD scheme (orographic form drag)

Weather forecast by DWD Product examples

Flight weather report

Bordwetterwarte FS Polarstern

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Reise: PS117	Position: 67.7° S 46.4° E , Station 58
Flugbericht	25.01.2019, 09 UTC, gültig bis: 12 UTC
Nr.: 15	Schiffskurs / vor. Position zum Ende der PAF-Gültigkeit: Stationär
	SA: 05:11 Bordzeit SU: 01:25 Bordzeit

1. Wetterlage:
Ein Tief zieht von den South Shetland Inseln ostwärts. Dessen Frontensystem hat den Nordteil des Einsatzgebietes erreicht. Der Süden befindet sich unter leichtem Zwischenhocheinfluss.

2. Fluggebietsvorhersage:
Südlich von 66.5 °S überwiegend geschlossene SC-Bewölkung mit Untergrenzen um 2000 Fuss, vereinzelt leichte Schneeschauer mit Untergrenzen bei 1000 Fuss, davon abgesehen gute Sicht. Im Norden zeitweise Schneefall aus tiefen Untergrenzen und schlechte Sicht.

3. Landeplatzwetter:
METAR = Meteorological Aerodrome Routine Report
PAF = Polarstern Airfield Forecast

METAR DBLK 250850Z 10018KT 9999 NSW FEW008 BKN019 M02/M06 Q979

PAF DBLK 250845Z 250900/251200 11022KT 9999 NSW FEW010 BKN020
PROB30 TEMPO -SNSH BKN 1000

4. Aerologie um 06 UTC:

```
DBLK  25.01.19 06 UTC FS Polarstern 067 53 W045 41
Höhe  Druck   Wind       Temp Spread  Schicht   VWS   T-ADV Grad-T
FL/ft  hPa  DDD/FFFkt     °C   T-Td    FL/kft  dv/dz  dT/dt  dT/dx
FL390  200  120/  4kt   -47.6  35.7   350/390   2.5    0.8    2.4
FL350  250  170/ 13kt   -50.9  28.7   300/350   6.8    4.4    6.2
FL300  300  260/ 29kt   -51.7   9.0   240/300   1.8   -2.1    1.9
FL240  400  250/ 38kt   -37.4  14.3   180/240   1.4    0.6    1.5
FL180  500  250/ 30kt   -23.6  11.4   140/180   6.3   -3.4    6.9
FL140  600  200/  9kt   -19.8  21.0   100/140   3.3   -0.8    3.8
FL100  700   75/  6kt   -17.0   9.0    70/100   3.4    0.5    4.6
FL 70  780   90/ 14kt   -11.3   6.6    50/ 70   2.5   -0.2    3.0
FL 50  850   80/ 17kt    -8.3   5.4   3.0/5.0   1.2    1.3    1.3
 3000    -   85/ 18kt   -10.0   0.0   2.0/3.0   3.0   -0.0    3.4
 2000    -   85/ 21kt    -7.7   0.0   1.5/2.0   2.9   -3.1    3.4
 1500    -   80/ 20kt    -6.3   0.9   SFC/1.5   4.1    0.0    4.8
  SFC  981   75/ 15kt    -2.2   3.8                kt/kft K/6hr K/100nm
```

5. Hazards und ergänzende Parameter

Nullgradgrenze	keine
Vereisung	leicht, dicht unterhalb SC
Turbulenz	keine
Sichtkontrast	gut, Richtung Westen moderat
Horizont	gut
Wassertemperatur	-1.9 °C
Windchill-Temperatur (bei T, < 0°C)	-15 °C
Wellenhöhe (bei Flügen über Wasser)	1.5 m

Maritime weather report

Meteorological Office
RV Polarstern

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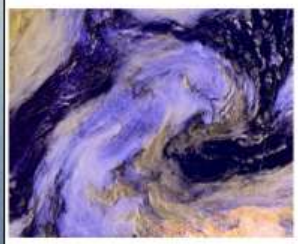
Expedition: PS117	**Position: 66.0° South - 12.2° West**
Report No. 45	**2019-01-07, 08:30 Ships time**

Weather situation of 00 UTC :
The research area is located in an area of low pressure with embedded low centers. A low center close east of the RV "Polarstern" is nearly stationary. In further course this center is moving to east. A new center is approaching and wind is shifting to northeast, later southeast.

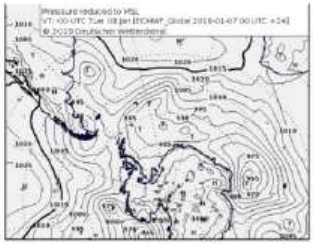
Forecast until Monday evening:
south to southwest 4 Bft, decreasing at times, outside of snow mainly good visibility, sea with swell about 1.5 m, swell from northwest

Outlook until Tuesday morning:
south to southwest 3 to 4 Bft, backing northeast to east increasing slowly 4 to 5 Bft, snow, otherwise mainly good visibility, sea with swell outside of ice about 1.5 m, swell from northwest to north, later north to northeast

Trend until Wednesday evenening:
east to northeast about 5 Bft, later east to southeast about 4 Bft, snow, otherwise mainly good visibility, sea with swell outside of ice about 1.5 m, swell from north to northeast



Satellite picture
NOAA RGB 07.01.2019 07:32 UTC



Surface forecast valid for midnight

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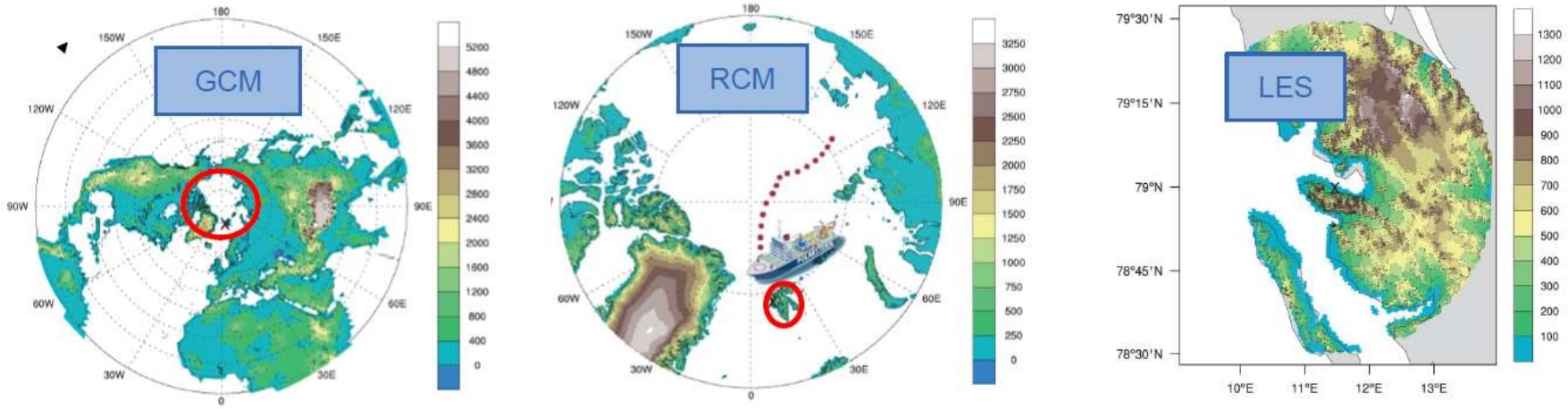
MOSAiC International Arctic Drift Expedition

ICON strategy for upscaling
Improved sub-gridscale parameterisations and data assimilation

AWI

Large-and meso-scale forcing as function of model complexity



Process understanding, sub-grid scale parameterisation development for different synoptical conditions

Illustration of the ICON model family used within (AC)3 representing the model strategy and the coverage from global to local scales. Global modelling includes **ICON**: Icosahedral non–hydrostatic atmospheric general circulation model, **ICON–HAM**: Coupled climate–aerosol model, **ICON–SWIFT**: Coupled climate–ozone model, and **ICON–O**: Icosahedral global ocean model. Regional modelling applies ICON as a nested Limited Area Model (LAM), while on the process level simulations with the ICON-LEM (Large-Eddy Model) will be performed. These ICON family members will be for the irst time extensively tested and utilised in the Arctic region.

(Dethloff, 2019)