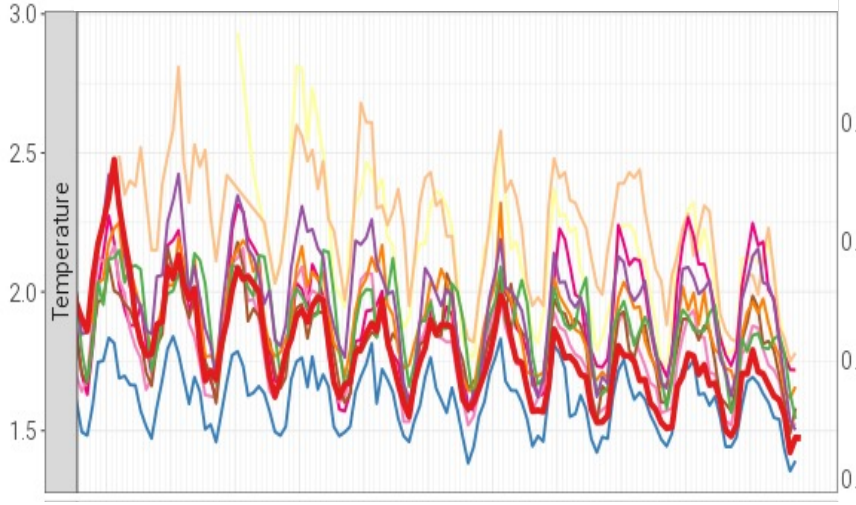
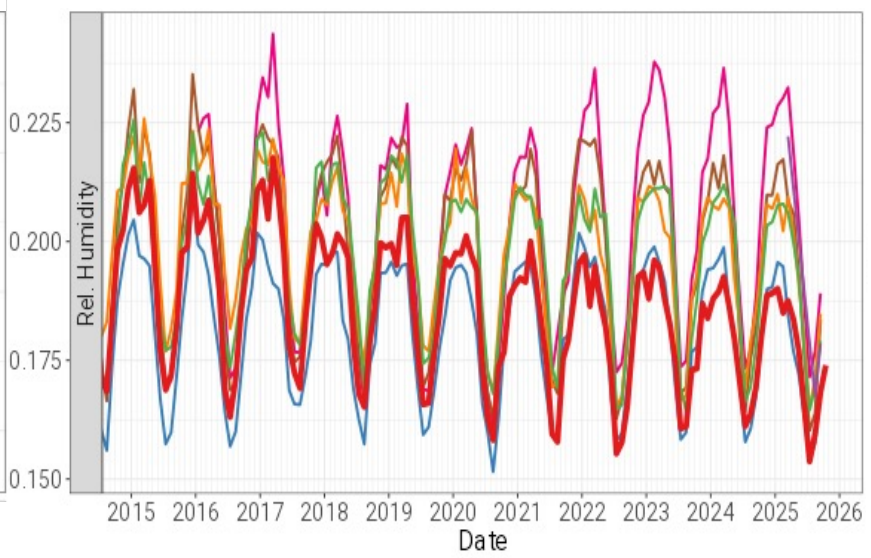
WMO scores

WMO Scores: NH, 72h, deterministic

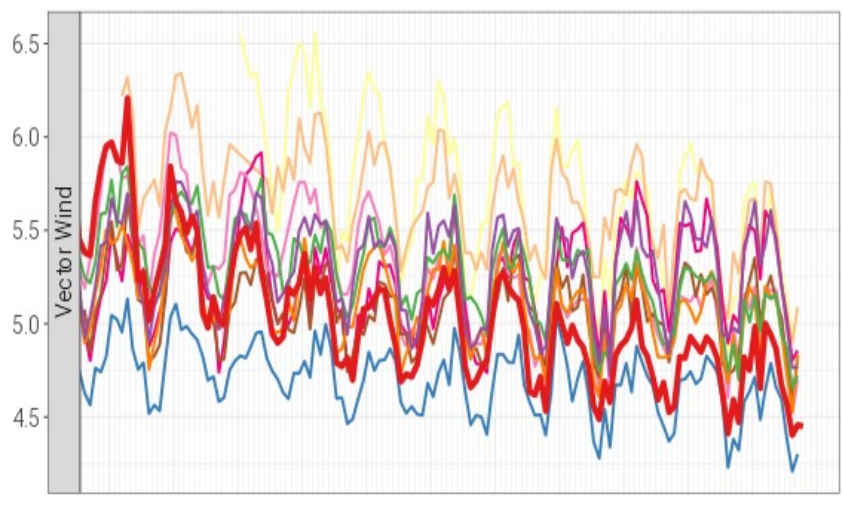
Temperature 850hPa



Relative Humidity 850hPa



Vector Wind. 850hPa



CHINA
RUSSIA
S-KOREA
CANADA
U-KINGDOM
JAPAN
FRANCE
AUSTRALIA
ECMWF
GERMANY

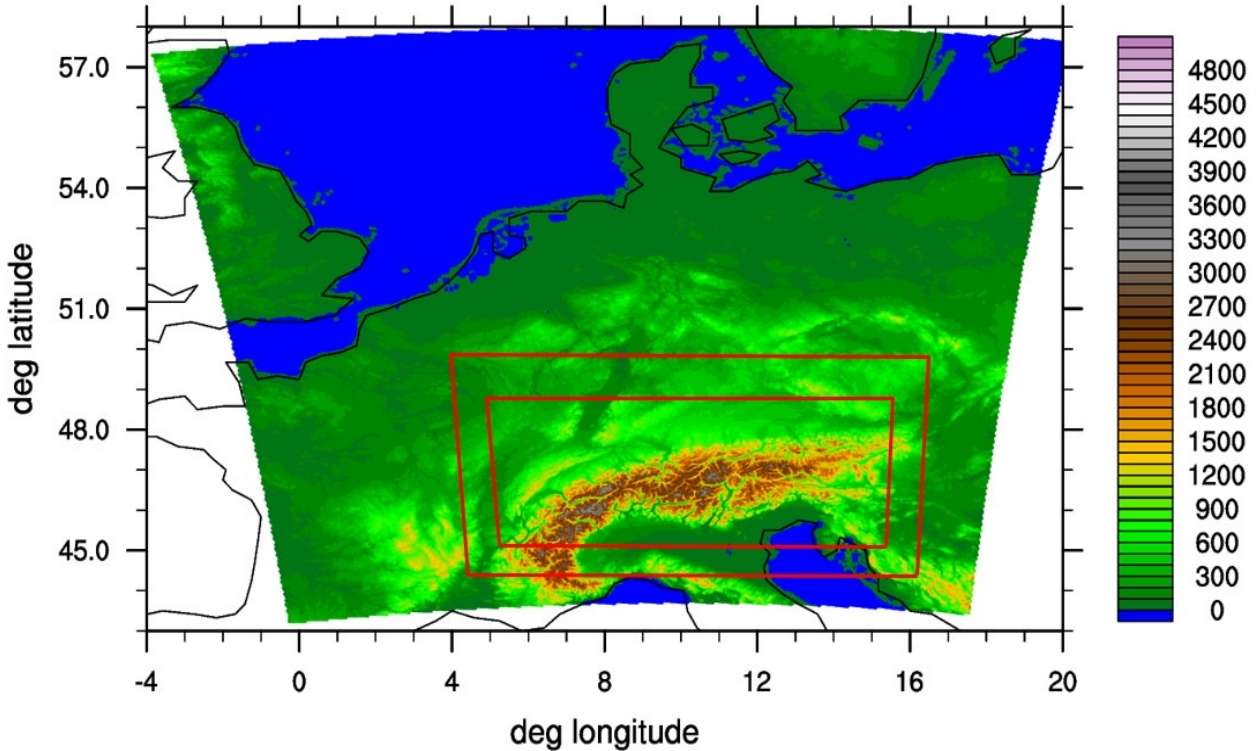
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

500m Germany
27 February 2025

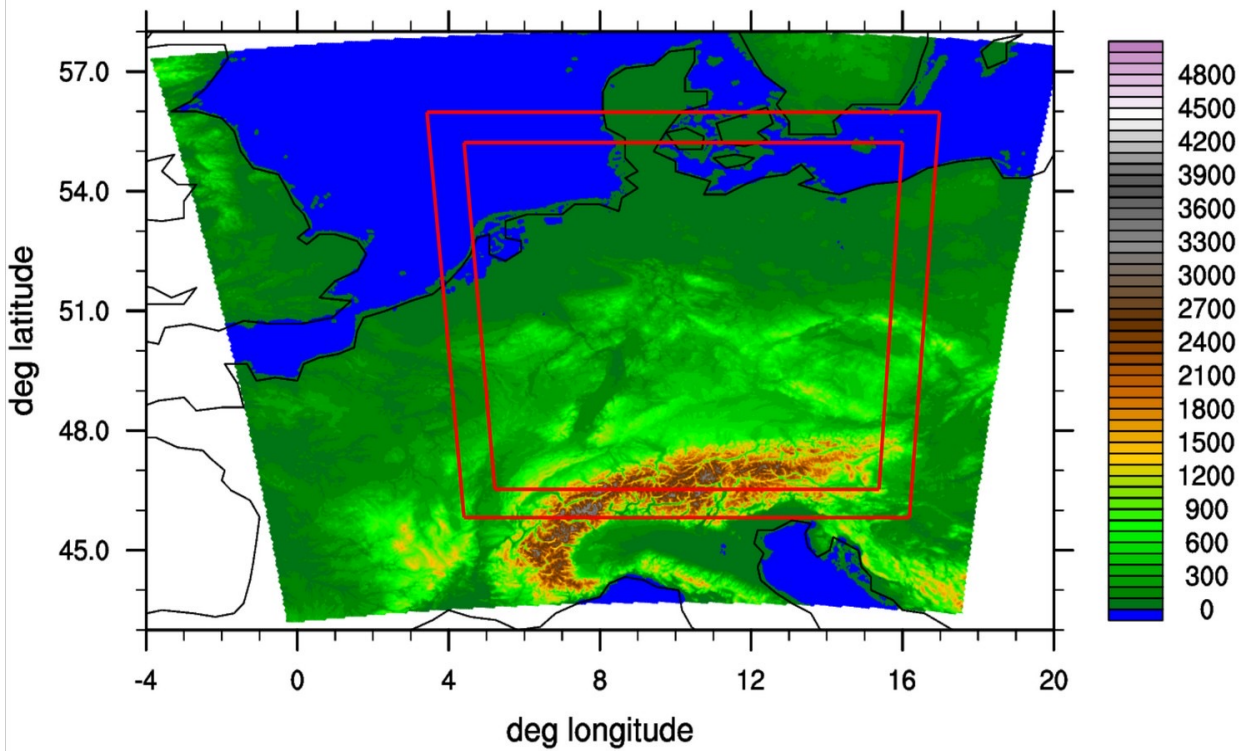
Technical configuration

- Two-step nesting into operational ICON-D2; except for size and location of the nested domains, ICON-D05 and ICON-A05 are identical
- Start from operational deterministic ICON-D2 analysis; nested domains are initiated successively after the end of the LHN phase (+40 min / +50 min)
- This avoids the need of a separate ensemble DA, for which our compute resources would not be sufficient

ICON-A05 incl. intermediate 1-km domain



ICON-D05 incl. intermediate 1-km domain



Model development work done for 500 m configurations

Model improvements developed specifically for 500 m configurations

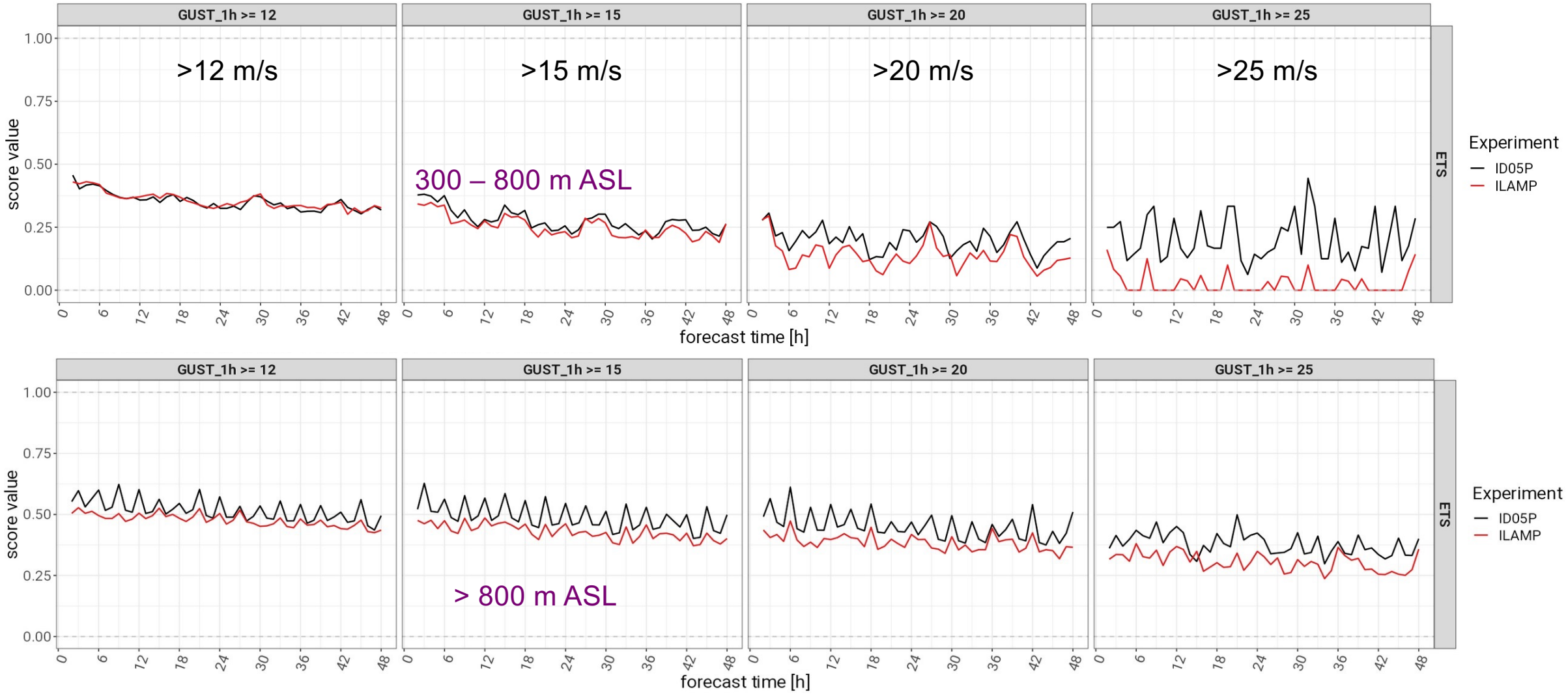
- Reduced parameterized **turbulent mixing over sloping terrain**, combined with reduced transfer resistance for surface fluxes
- **Reduced SSO** source term for TKE
- Revision of resolution-dependence of tuning parameters in convection scheme (**shallow convection** is still active at 500 m, but not grayzone deep convection)
- Modified **gust** parameterization based upon 10-min averaged 10-m winds with additional PBL limitation for gust excess speed

Other **configuration differences** using previously implemented options

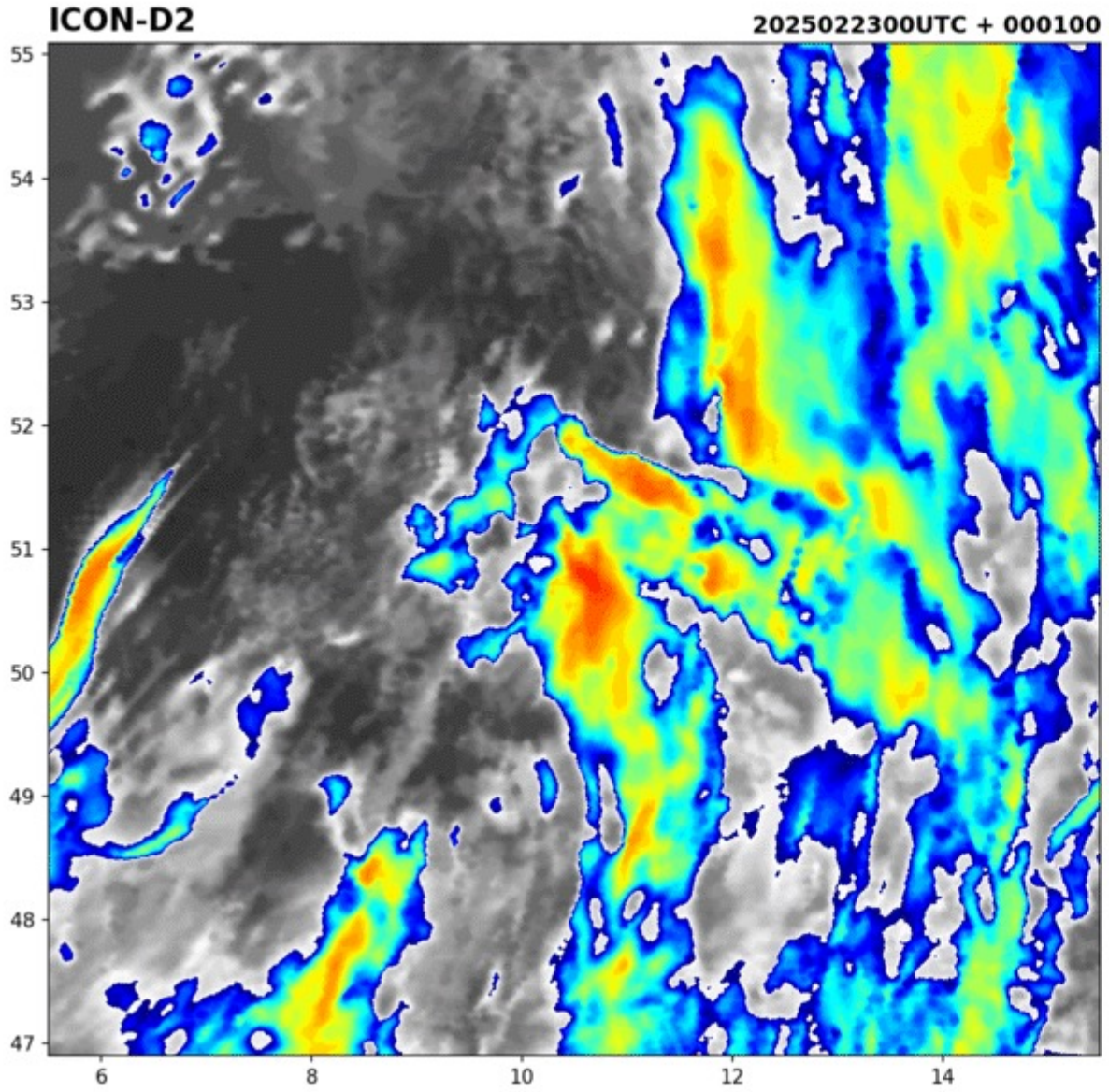
- Slightly increased **orography filtering**
- Turn off **sub-grid-scale condensation** heating at 500 m
- 3D **Smagorinsky** closure for numerical diffusion of V and T, plus Smagorinsky diffusion for W
- **Slope-dependent solar radiation** including shading

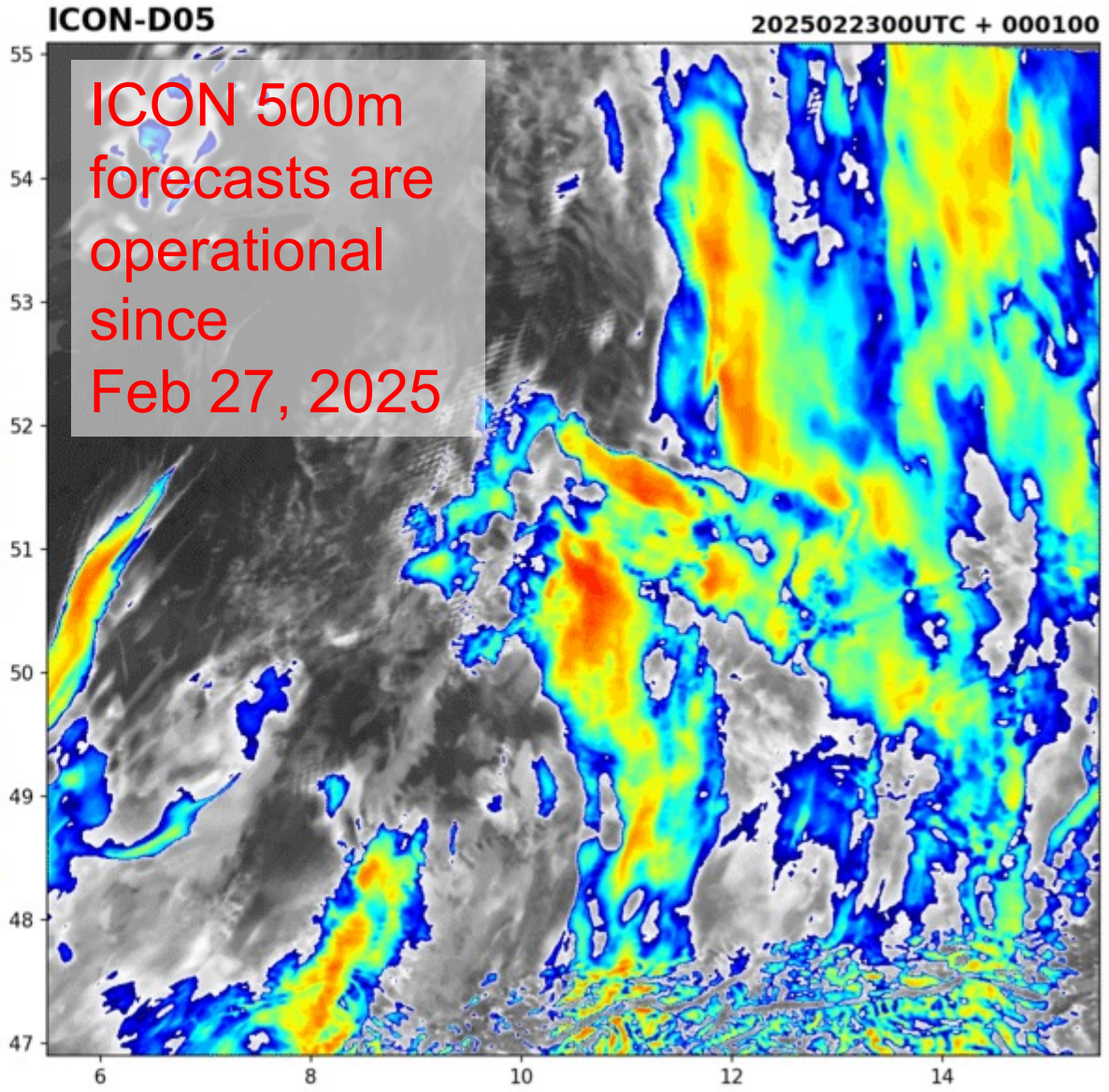
Benefits of the enhanced resolution: wind gusts

wind gusts: Equitable Threat Score (ETS) for ICON-D05, January 2025



500m ICON Operations





ICON 500m forecasts are operational since Feb 27, 2025

Rime deposition and Stratus

DWD updates last year

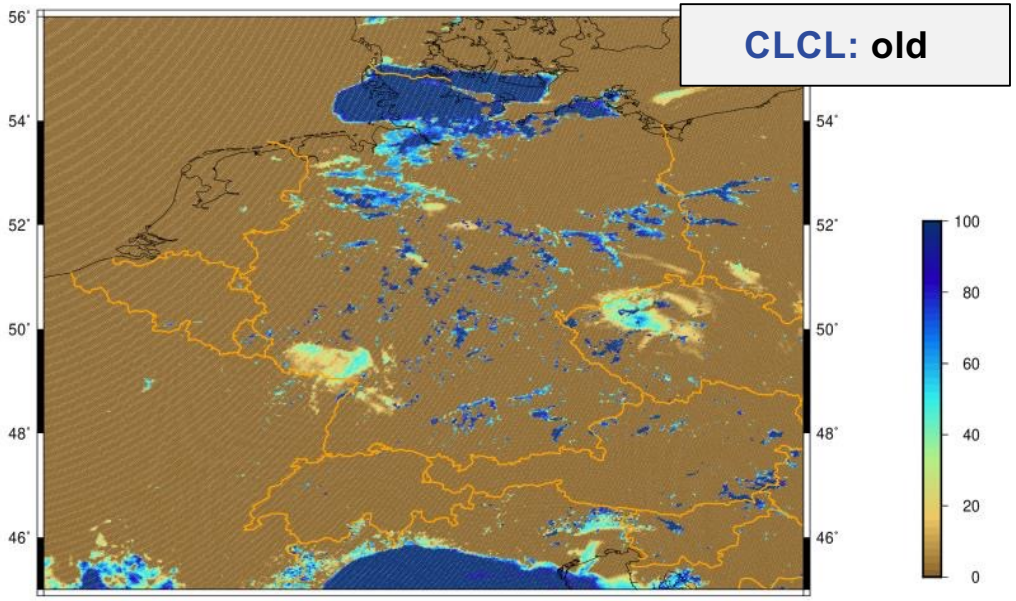
Martin Köhler, DWD

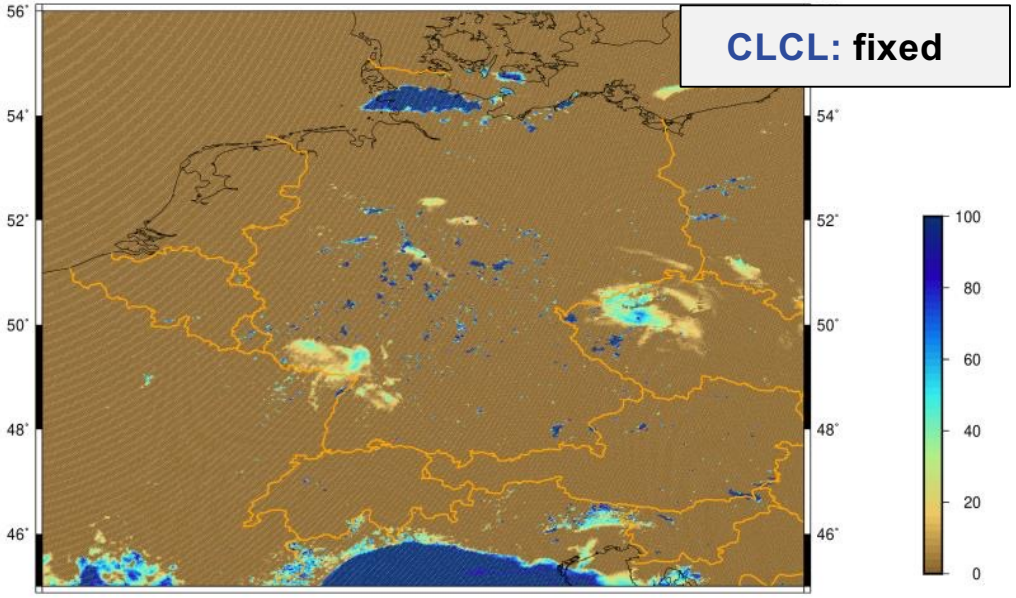
Material: Günther Zängl, Daniel Rieger, Roland Potthast

ICON-NWP Updates: Part II

Correction of rime deposition

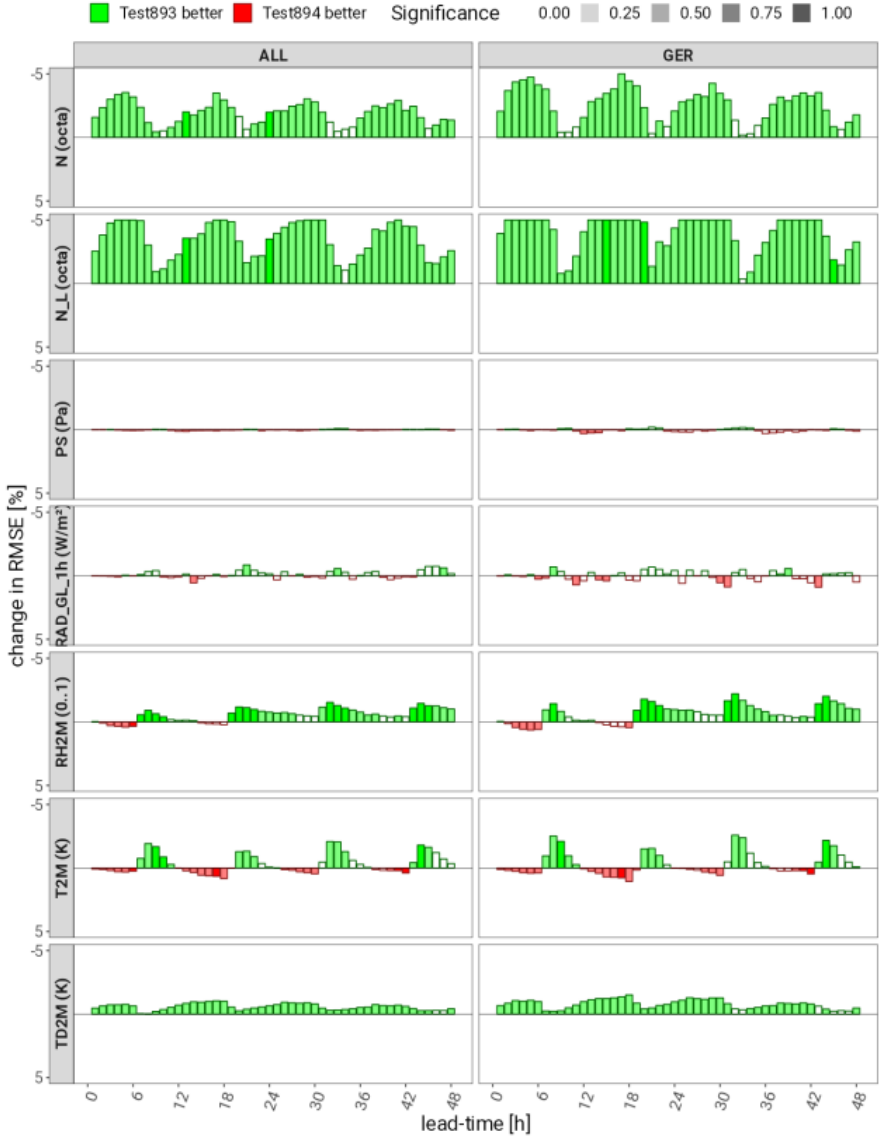
- **Background: ground fog overestimation**
  ICON-D2, several dates in March 2025
- **Bug in TERRA**
  Basically, no rime deposition on snow free surfaces
- **Correction worsened the results under certain conditions**
  Thus: Retuning of interception storage evaporation
- **Retuning (global, EU, D2)**
  `cwimax_ml = 7.5e-4` *(so far* `5.e-4` *)*
  `tune_eiscrit = 5` *(so far* `7`*)*



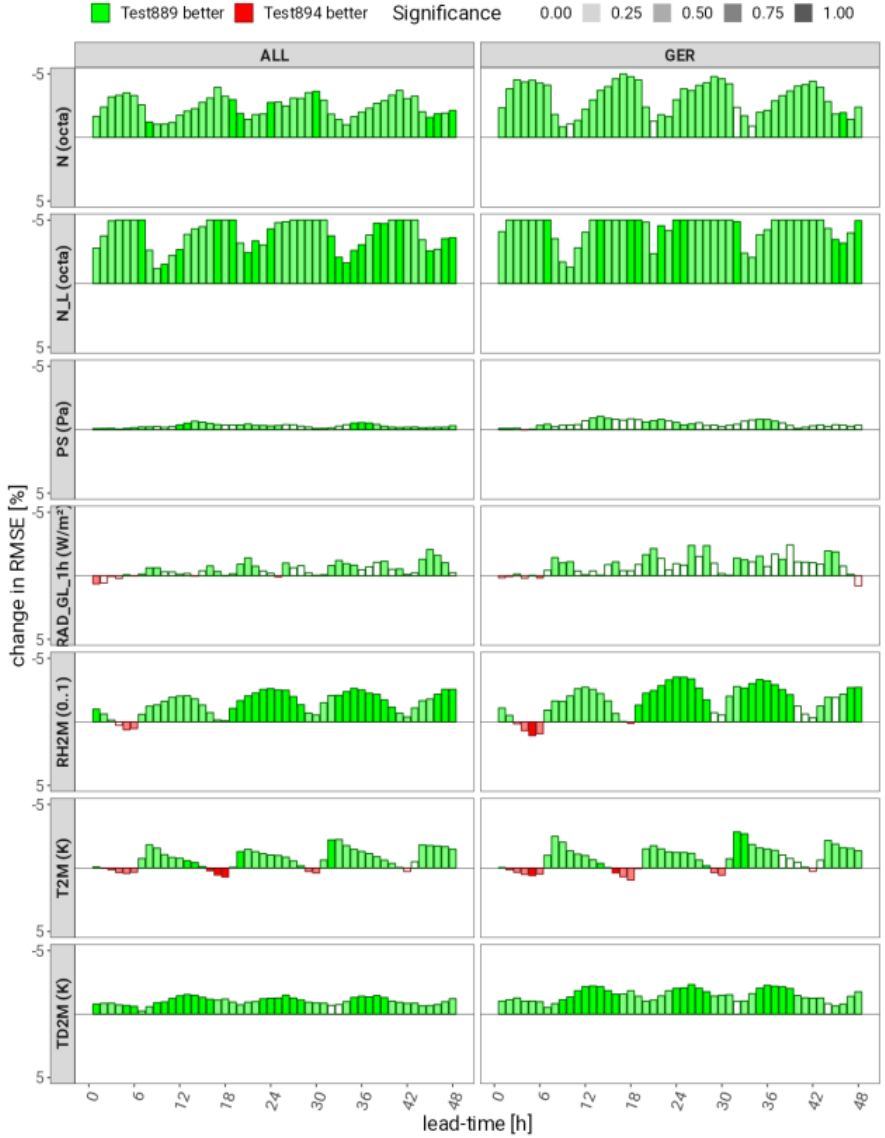


ICON-D2, March 2025

only Bugfix



with Retuning



warm-layer and cold skin

Zeng and Beljaars (2005)

- Cool skin
- Warm layer

t_g SST

$$T_{sk} = T_{-d} + (T_{-\delta} - T_{-d}) + (T_{sk} - T_{-\delta})$$

ΔT_{warm} ΔT_{cold}

OSTIA foundation SST from UK Met Office

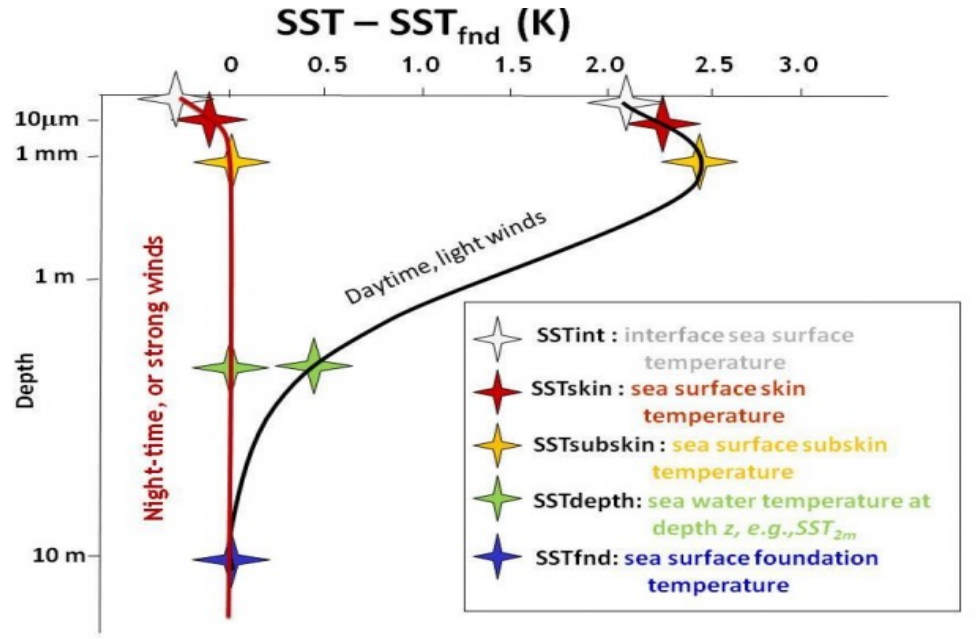
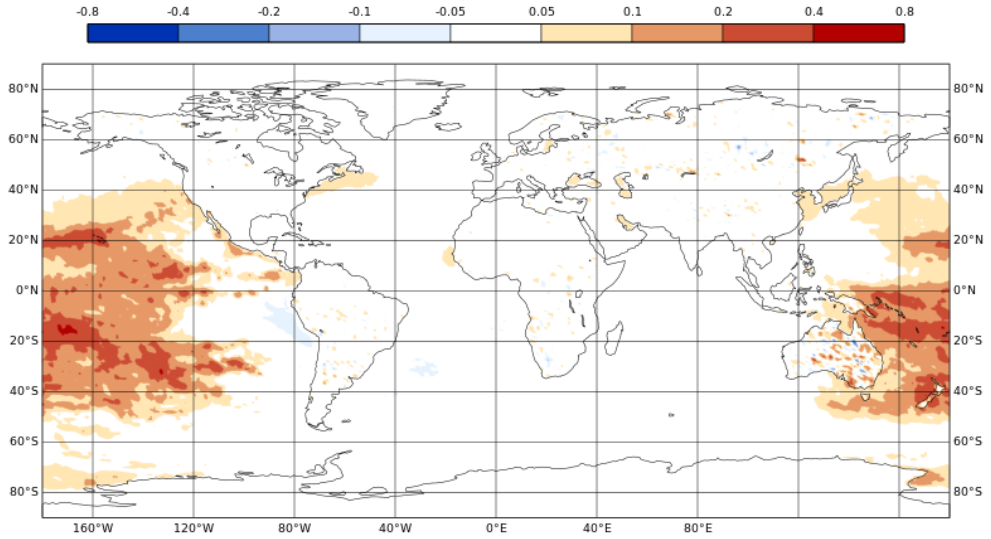


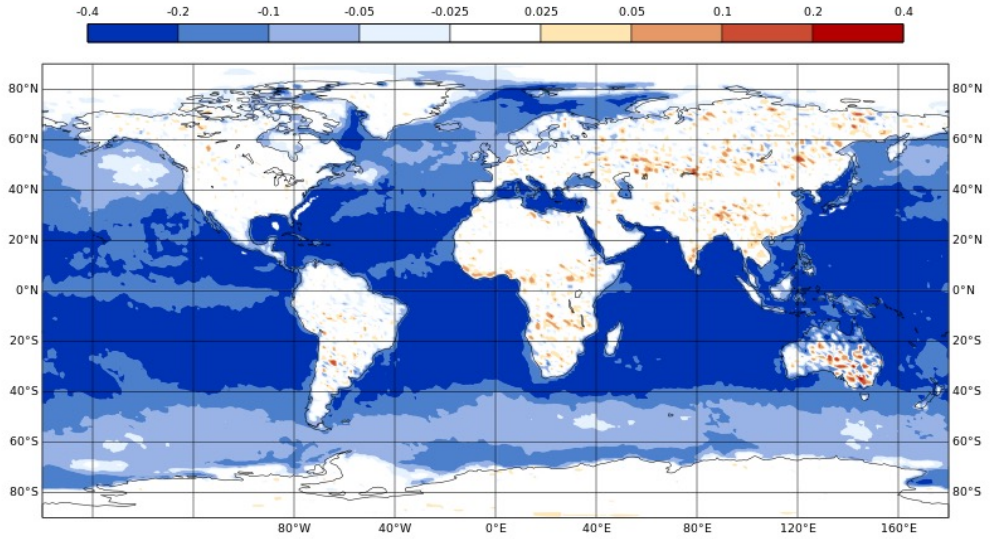
Figure 1. Cartoon of near-surface temperature gradients. The numbers on the axes are for guidance only and to not represent rigorously derived scales. Variability exists in both the temperature and depth scales.

Warm-layer and cold-skin in ICON: skin temperature

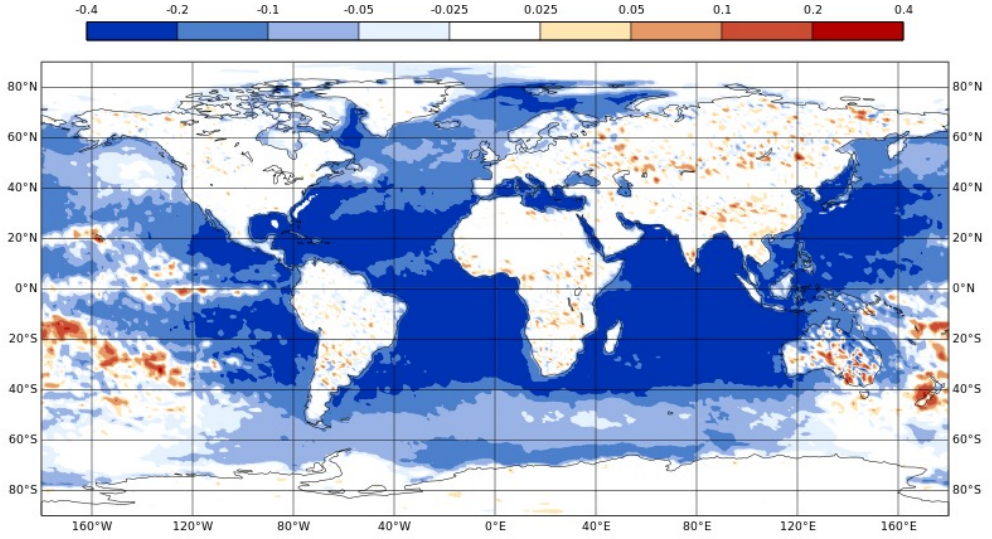
warm-layer only



cold-skin only



warm-layer and cold-skin

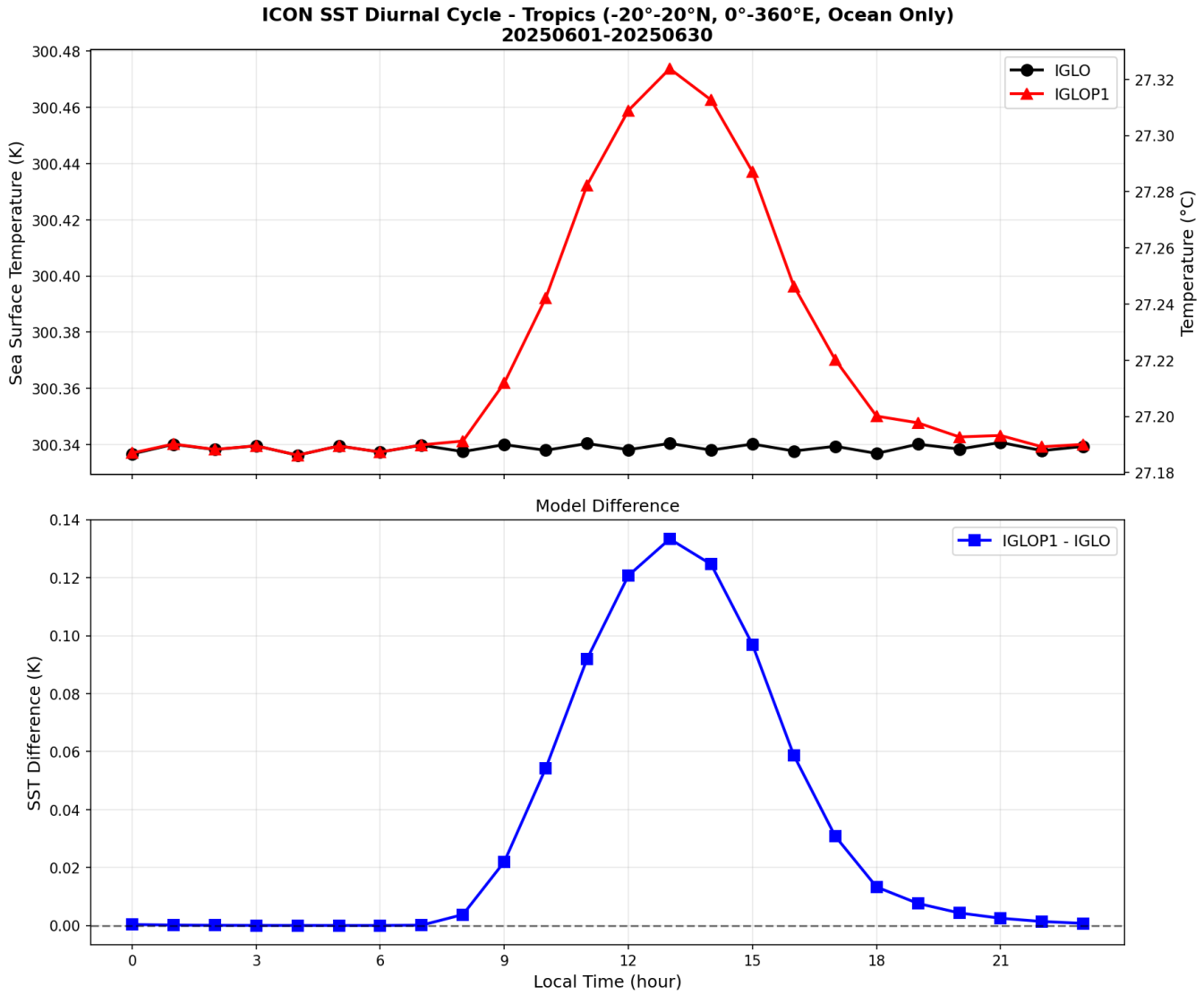


ICON R2B6 (40km)

- 24h forecasts of for January 2022
- mean at 00UTC

Zeng and Beljaars (2005), Takaya et al (2010), implemented by Martin Köhler and Julia Mengjuan Liu

Operational Introduction: Warm-Layer



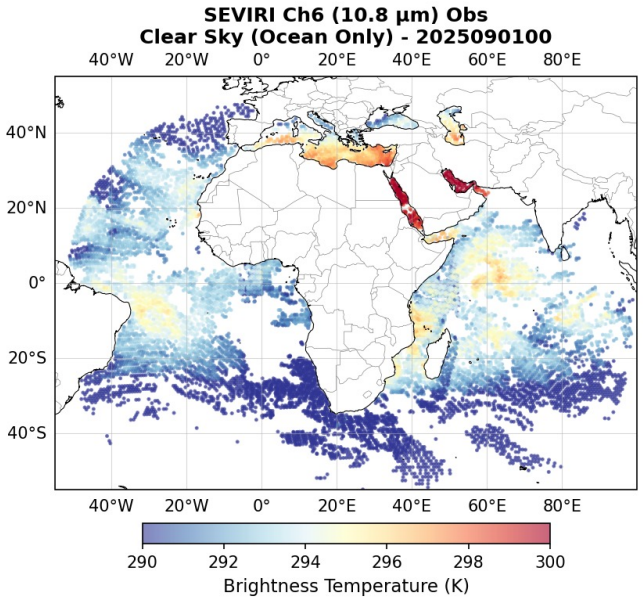
warm-layer
oper

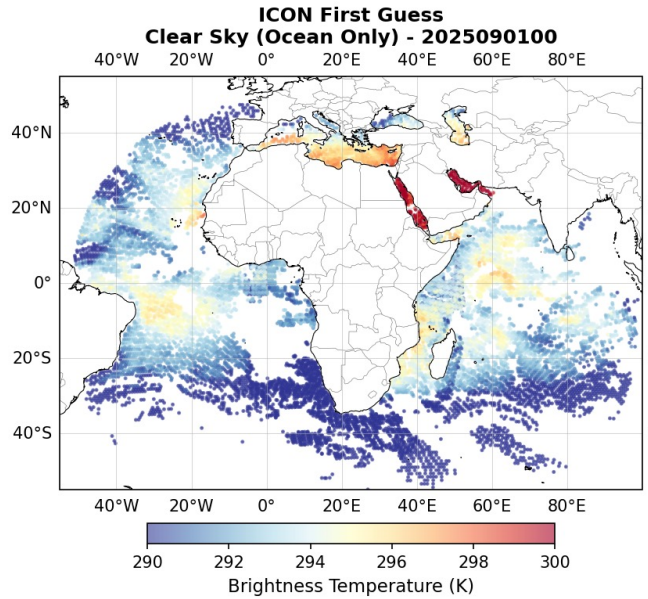
$\Delta T_{g,max}$ = 0.13K

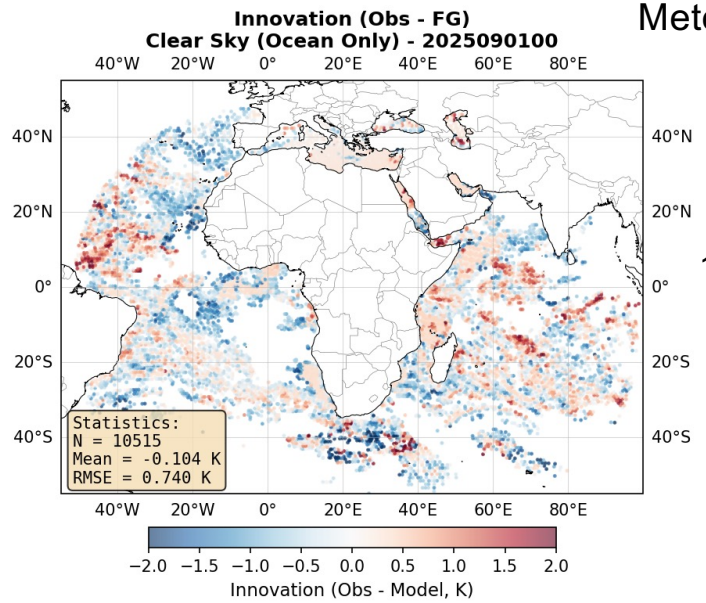
Tropical Oceans: 20S – 20N
Time: June 2025

ESM-W NRT (warm-layer) ICON FG *vs* SEVIRI 10.8μm

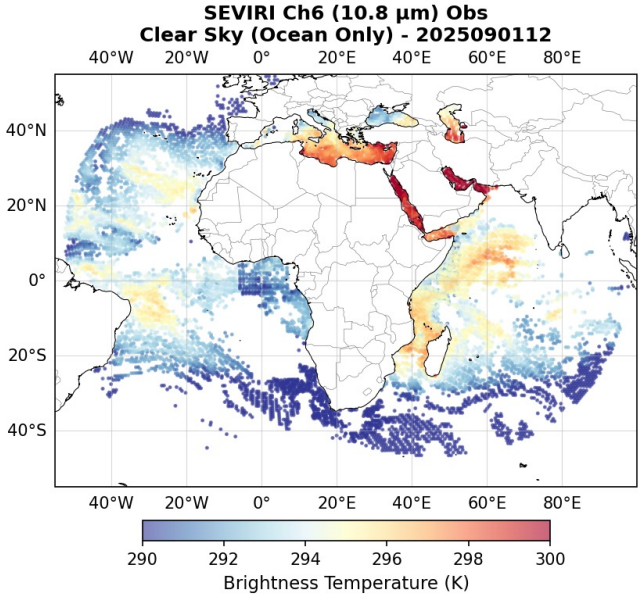
Meteosat 9/10

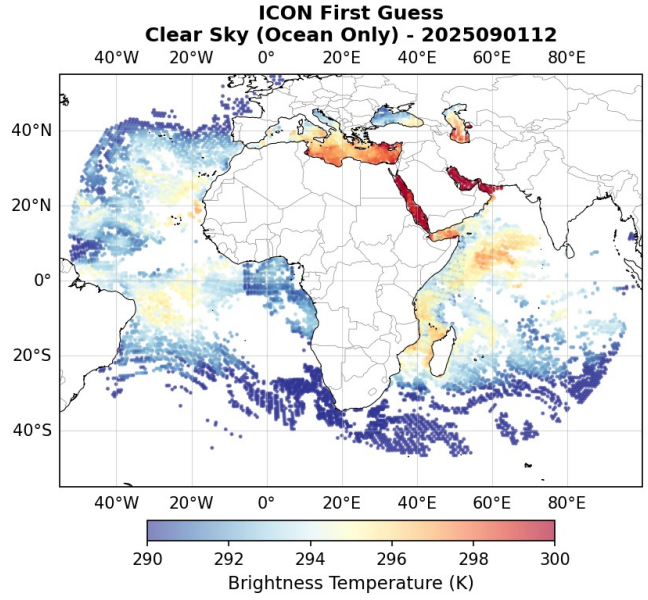


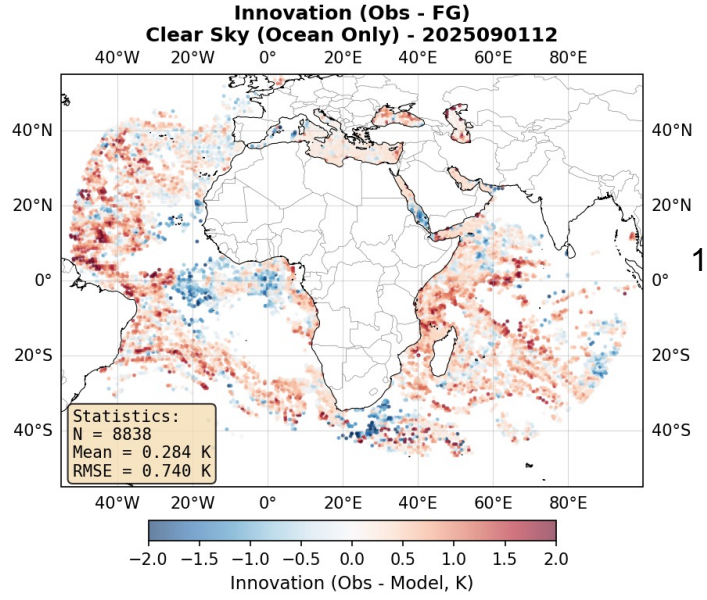




1. Sept. 2025
00UTC

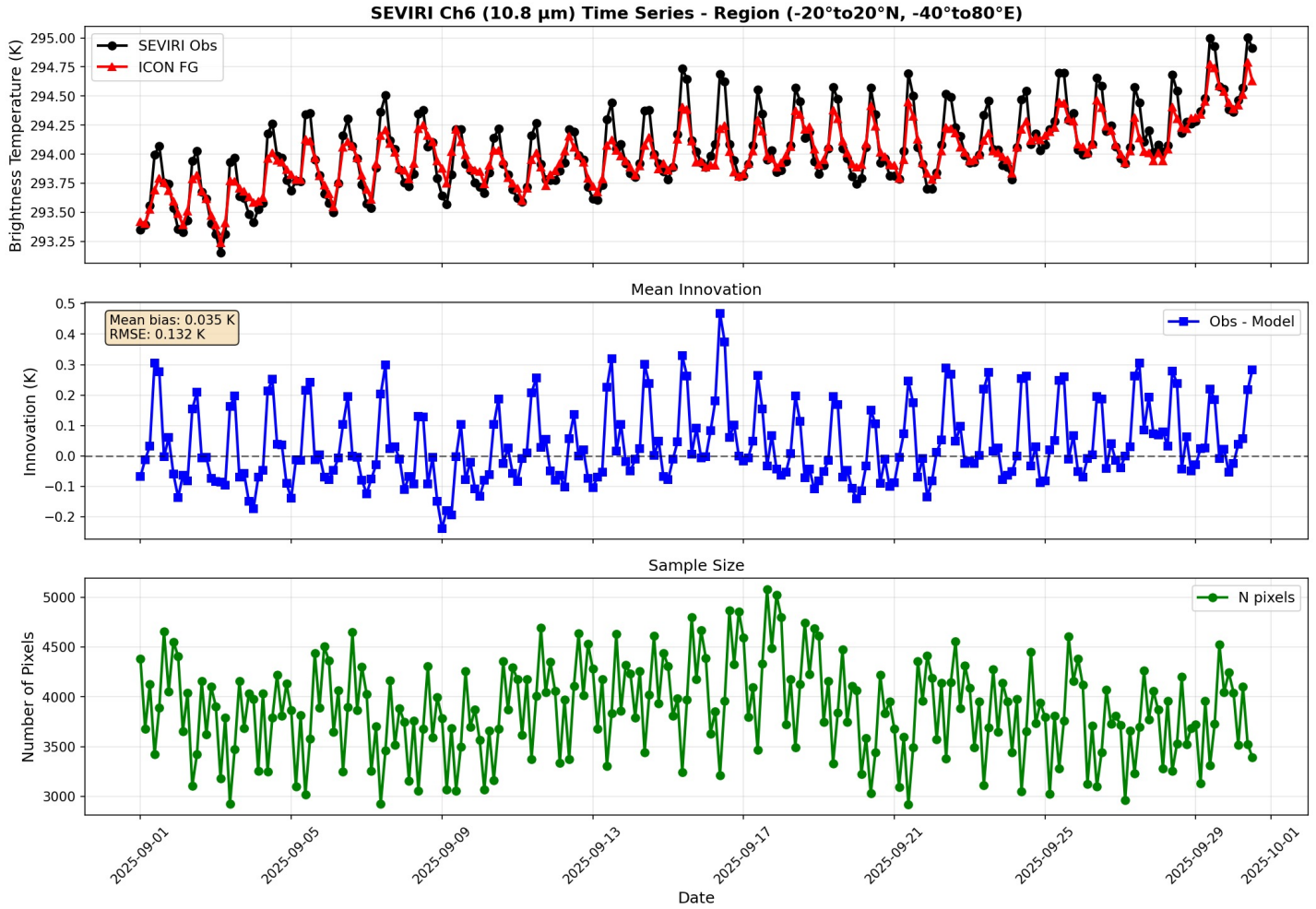




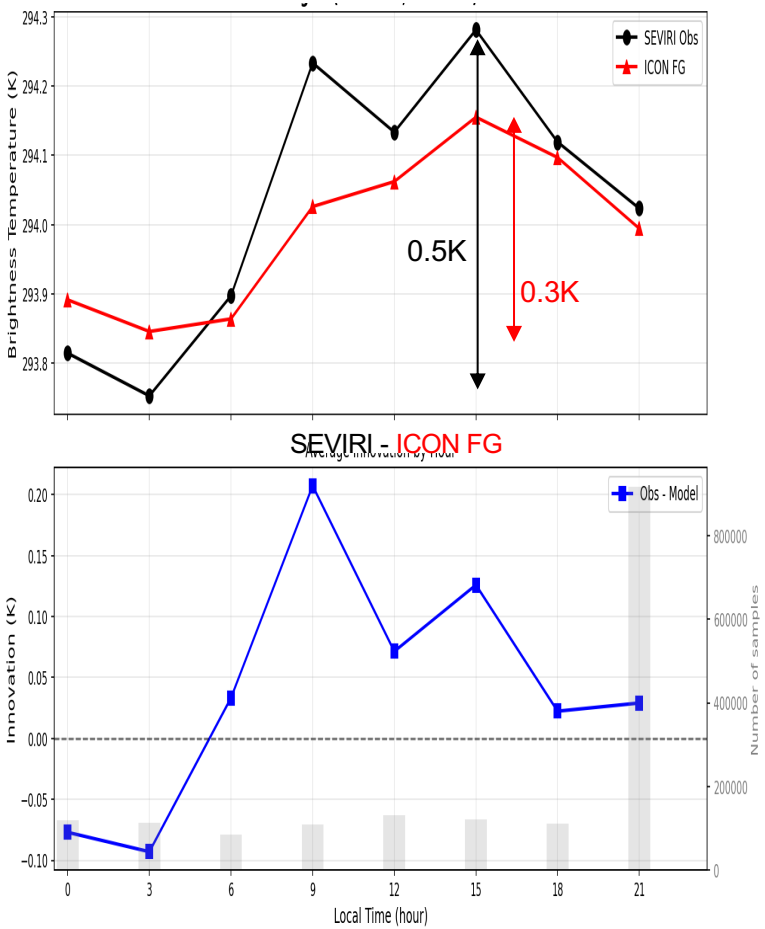


1. Sept. 2025
12UTC

ESM-W NRT ICON FG vs SEVIRI 10.8μm



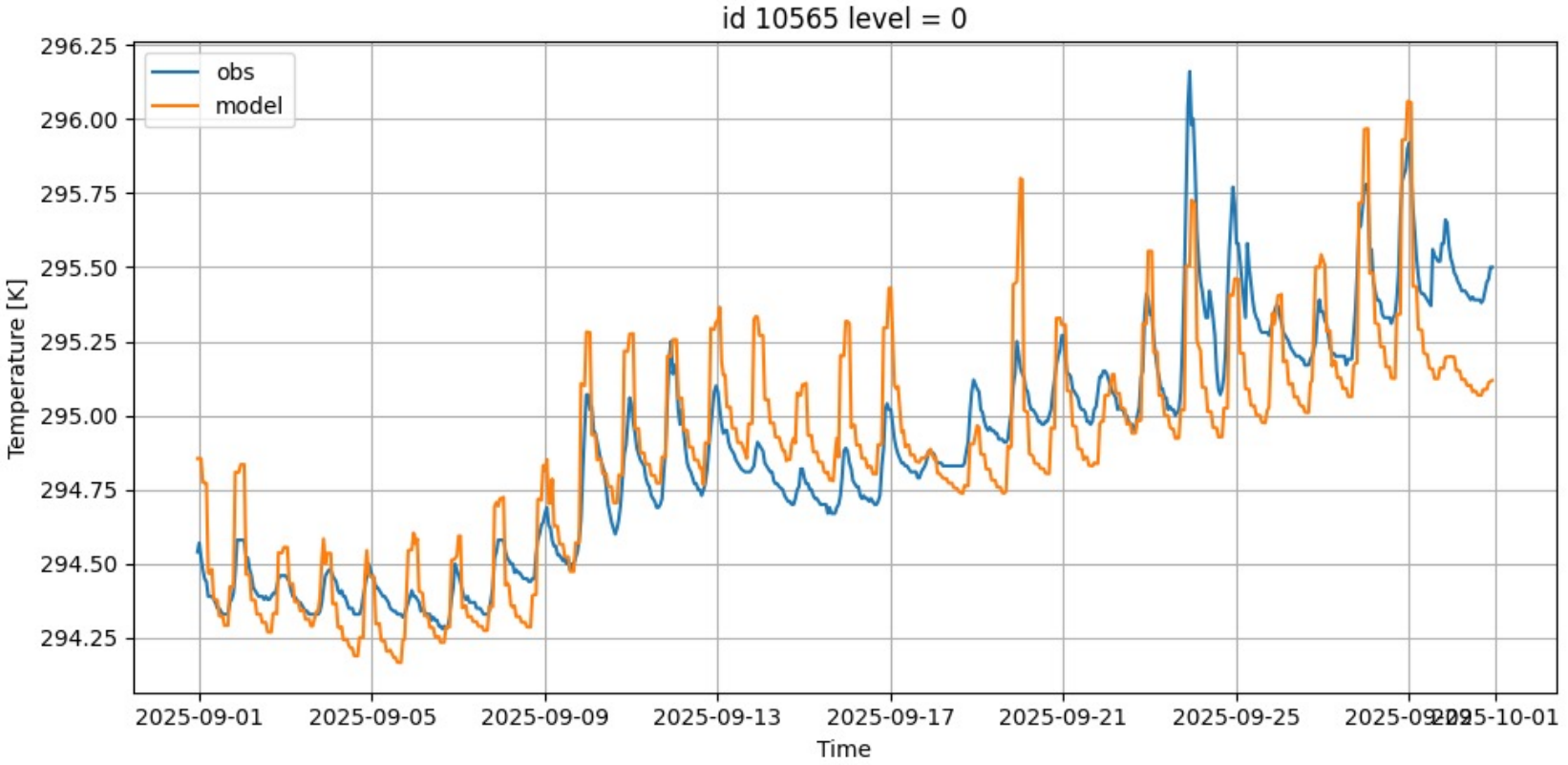
Average Diurnal Cycle **SEVIRI**, **ICON FG**

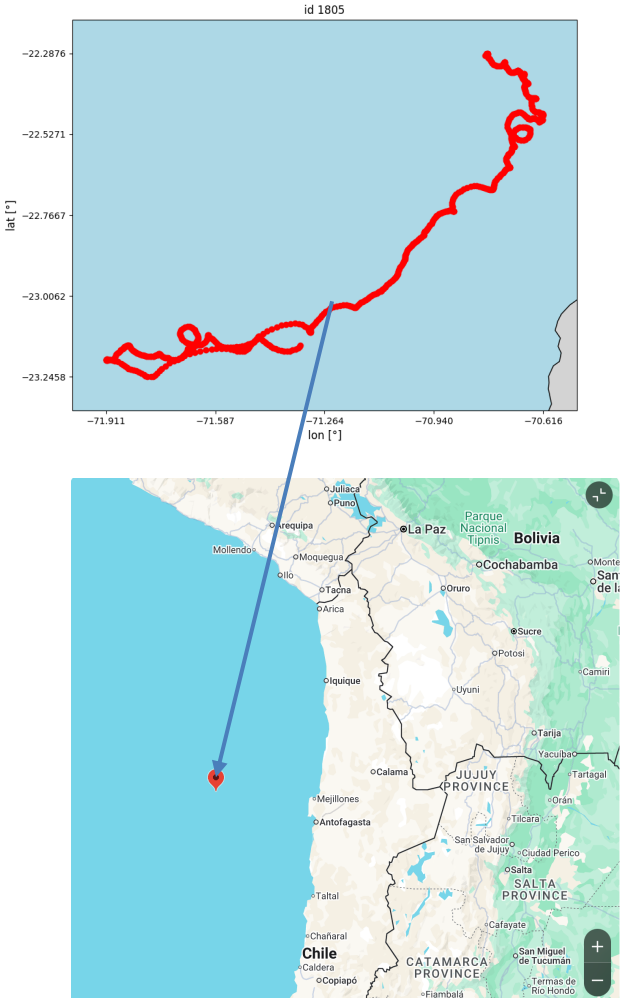


Sept. 2025 3-hourly
Tropics (20ºS - 20ºN, 40ºW - 80ºE)
Meteosat 9 & 10

cloud-free (flag=7)
ocean-only
state: 0,1,3,5 (good)

drift buoys





Sept. 2025 3-24h forecasts
ca. 50-100cm below surface (NOT SKIN)

Thomas Hüther

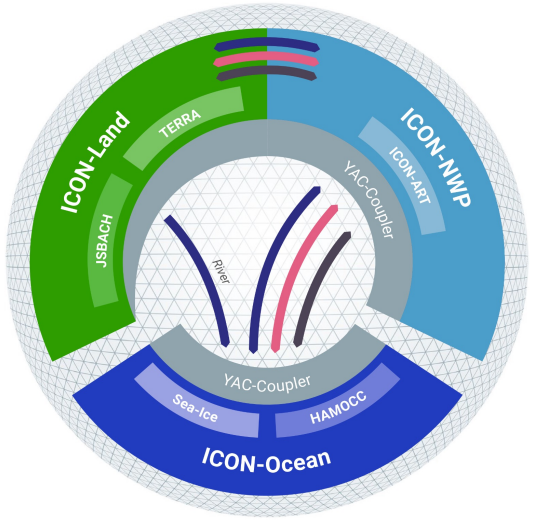
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

ICON as ESM
2025/10 version for CMIP7

ICON-Seamless
Coupled Forecasts for NWP, Climate and Paleo

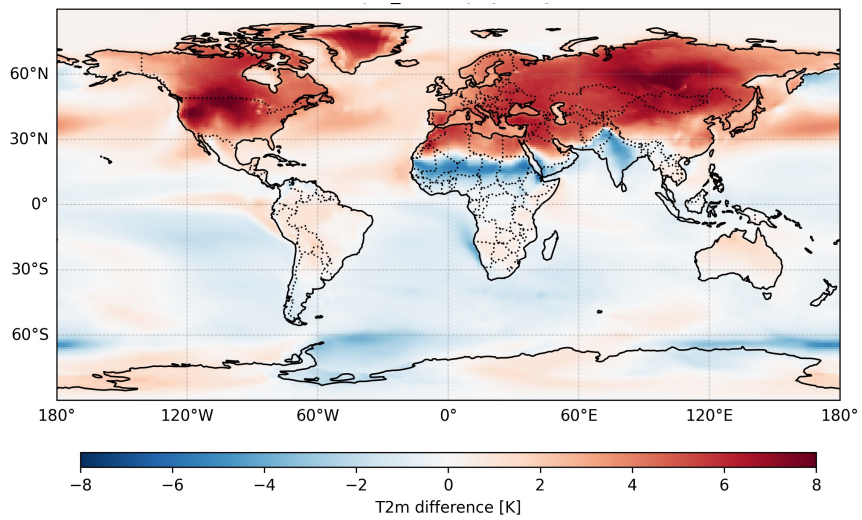
Martin Köhler, Nora Schenk, Trang Van Pham (DWD), Julia Brugger, Kira Rehfeld (U. Tübingen)

ICON-everything



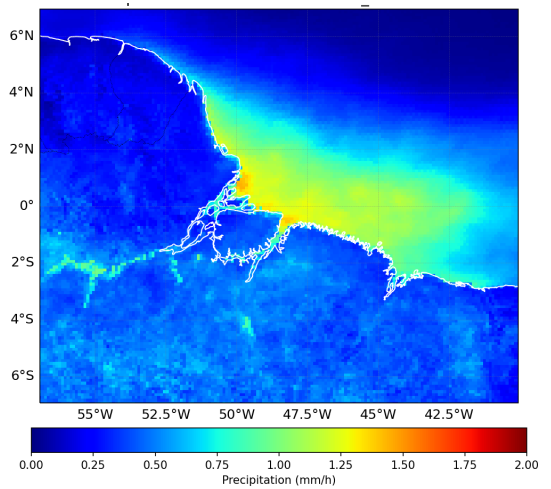
ICON-Paleo

LIG – PI-control July 100y mean

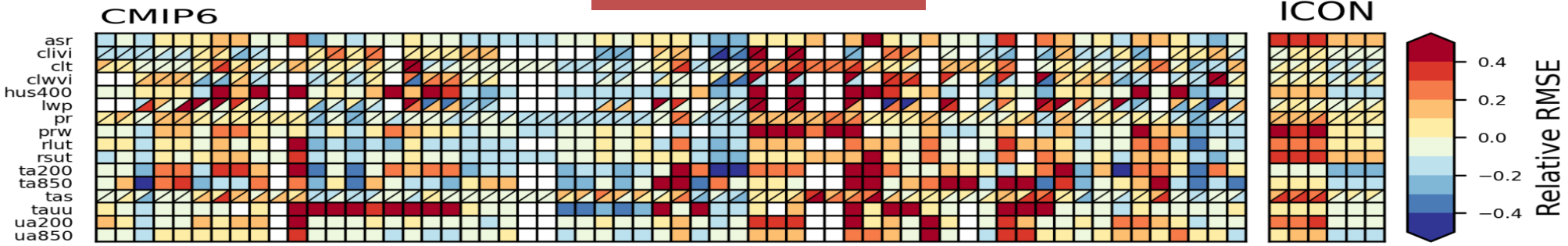


ICON-NWP

Amazon Precipitation ICON



ICON-Climate

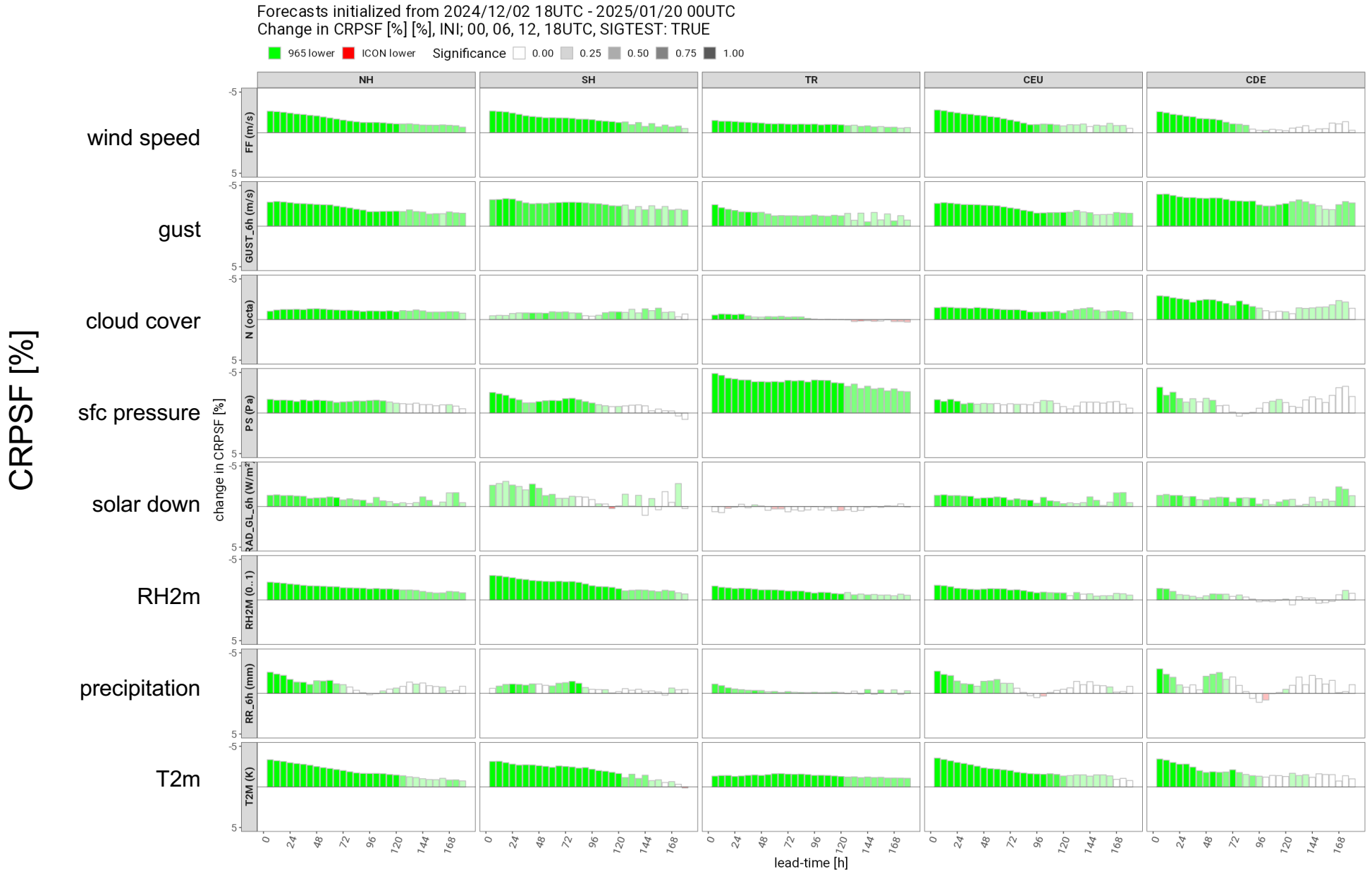


EPS resolution 26km > 20km

Resolution enhancement in global EPS

- **Resolution sensitivity experiments consistently indicate direct benefit of increased resolution on the global forecast quality terminates at mesh sizes of about 10 km.**
- **Significant benefit from increasing the EPS resolution from 26 to 20 km, but very little benefit when going from 13 to 10 km in the deterministic forecast.**
- **Verification scores indicate a significant improvement of forecast quality at the surface and, to a lesser extent, in the lower troposphere**

EPS SYNOP verification



Dec/Jan 2024/25

other changes

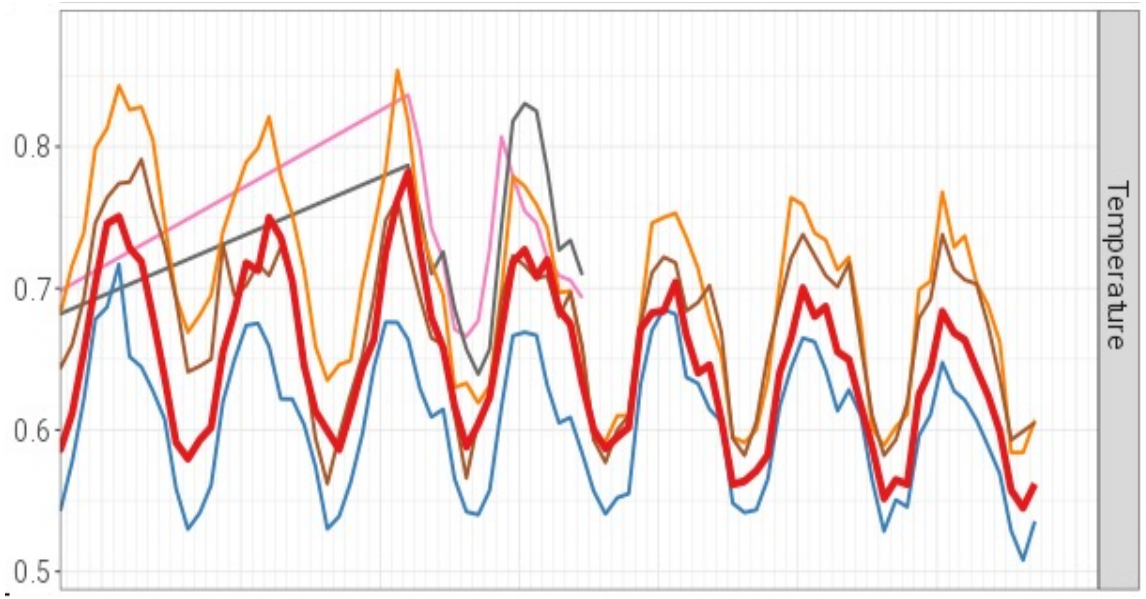
Other work 2025

- development of **coupled atmosphere – waves – ocean** NWP system including data assimilation
  - near-realtime A-O system is already running (13/20km), ICON-O-LAM version further
- updates to **adaptive parater tuning**
- **glacier** evaporation fix
- revision of **ozone-tropopause** coupling
- **urban** parameterization TERRA-URB in ICON-D2 / ICON-D05
- **dissipative heating** for momentum dissipation by turbulence scheme
- IFS coefficients for **saturation vapor pressure** (more accurate) in ICON, DA and verification; needed for better prediction of ice supersaturation by two-moment cloud ice scheme (new)
- **convection** scheme:
  - entrainment and detrainment profiles
  - downdrafts land/ocean to improve tropical land precipitation
- **open source** + documentation: towards open development (*https://docs.icon-model.org*)

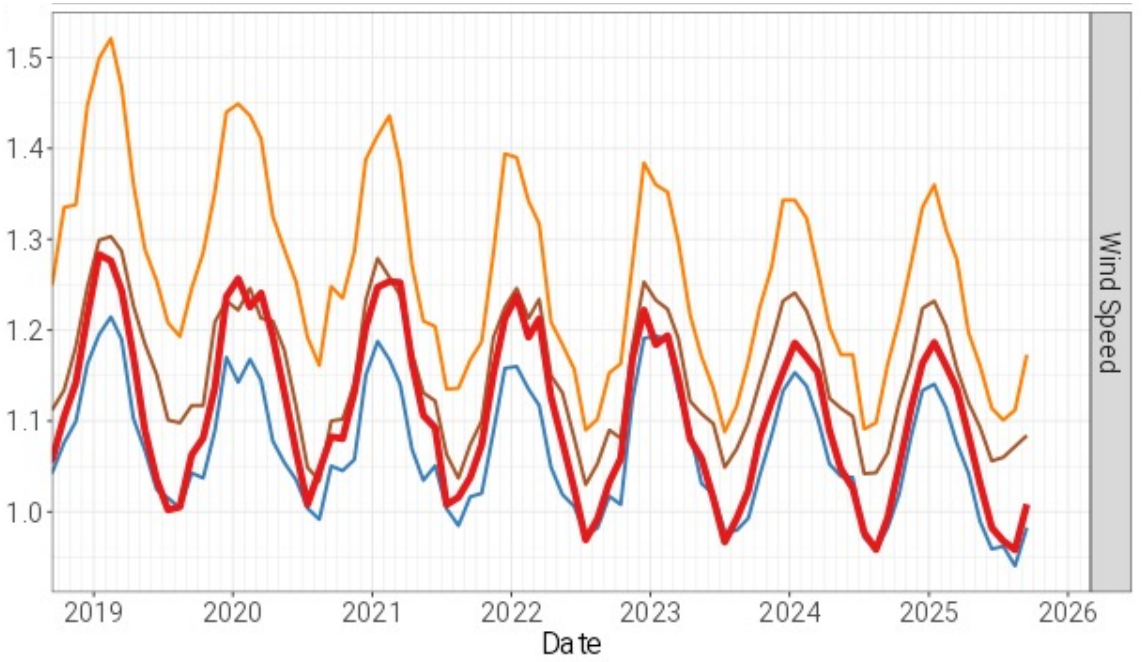
extra slides

WMO Scores: NH, 72h, ensemble

Temperature 850hPa



Wind Speed 850hPa



CMC
NCEP
JMA
UKMO
ECMWF
DWD

ICON-NWP Updates: Summary ICCARUS

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

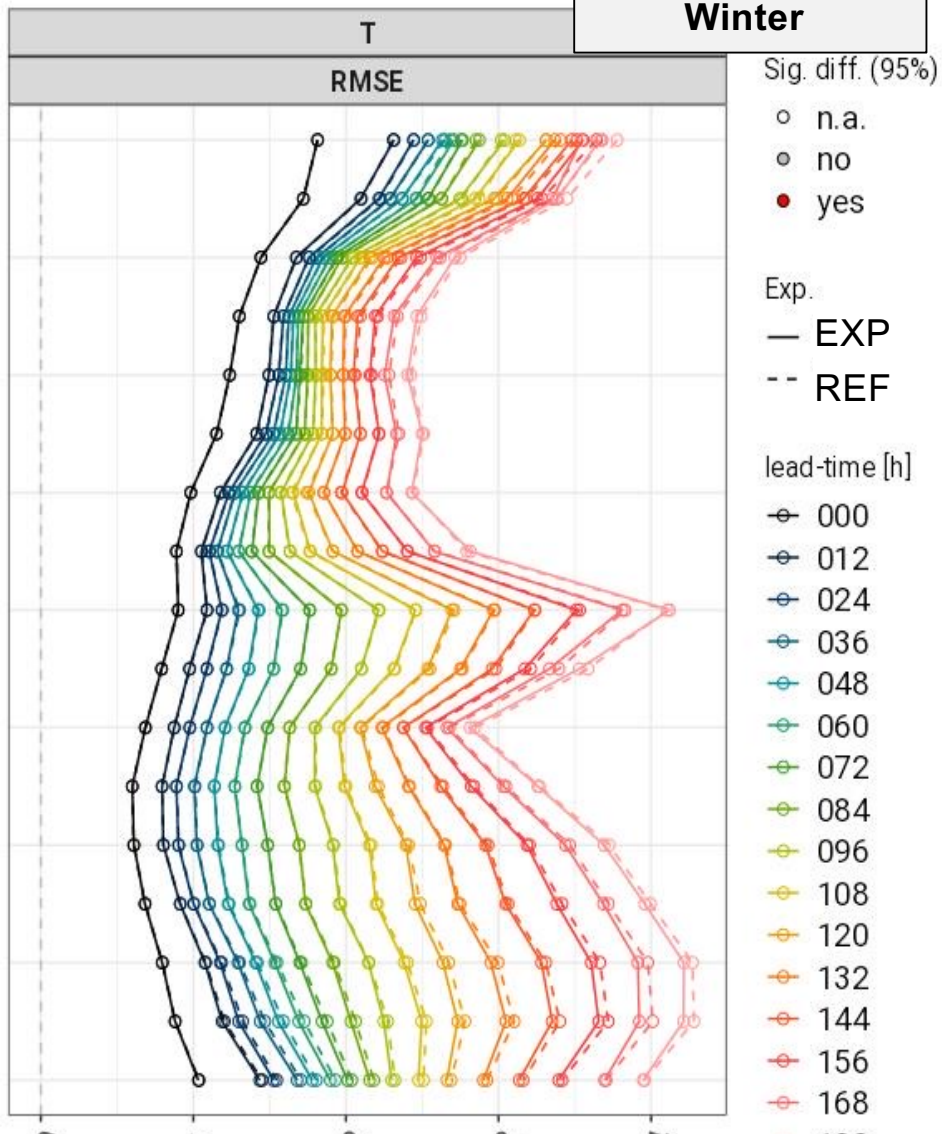
- **ICON-D05 and ICON-A05**
  ICON-D05: (Technical) operationalization (500 m over Germany)
  ICON-A05: quasi-operational 500-m forecasts for TEAMx
  Including corresponding model development
- **Further steps in adaptive parameter tuning (APT)**
  Several extensions, also after ICCARUS
- **Revision of ensemble perturbations in global EPS**
  revised EPS perturbations in convection scheme
  combined with reducing the SST perturbations by 25%
- **Upgrades in ICON-D2(-RUC)**
  Several changes to microphysics and convection
  TERRA-URB
  Revised gust parameterization
- **Preparation of resolution enhancement in global EPS**
  Significant improvement at the surface and, to a lesser extent, in the lower troposphere
  No time planning yet (cause: storage hardware)

ICON-NWP Updates: Part I

Update package

- **SST warm-layer-scheme**
  account for diurnal cycle
- **Consider momentum dissipation heat**
  with eq. from momentum dissipation
- **Using `tkhmin` for TKE**
  Improved consistency
- **Modifications to ozone**
  tropopause coupling, reduction of stratospheric tuning
- **Tuning systematic bias differences**
  between ENS mean and DET
- **Land-tile averaging in DA**
  already used for verification
- **Sub-grid-scale glaciers**
  Fix bug in evaporation, ad-hoc fix for wrong land-use data

NH RMSE in Winter



ICON-NWP Updates: Part III

Update cloud cover diagnostic below PBL inversion

- **Used in ICON-Global since 2023**
  Reduce neg. cloud cover bias in Sc regions (tropical oceans)
- **Inversion diagnostic**
  Increase cloud cover in RH transition zone
- **Applicable also for St clouds!**
  Minimal inversion height from 400m to 100m
- **In addition**
  Bugfix in inversion diagnostic
  Change temperature gradient calculation
- **Namelist changes**
  `tune_sc_invmin = 100.` *(global + D2)*
  `tune_sc_eis = 7` *(only D2; was already effective for global)*
  `c_diff = 0.1` *(before:* `0.2` *)*
  `tkhmin = 0.4` *(only D2, before:* `0.5` *)*
- **Highest impact on high pressure systems late autumn and winter**

Further improvements / developments

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

- Simple prognostic scheme for ocean skin layer (Martin K.)
- Dissipative heating for momentum dissipation by turbulence scheme
- Urban parameterization TERRA-URB in ICON-D2 / ICON-D05 (Jan-Peter)
- IFS coefficients for saturation vapor pressure (more accurate) in ICON, DA and verification; one important preparatory step for two-moment cloud ice scheme needed for a better prediction of ice supersaturation (Axel)
- Retuning of entrainment and detrainment profiles in convection scheme
- Revision of ozone-tropopause coupling
- (ICON-D2) Allow for supersaturation in strong updrafts, plus microphysics tuning, to reduce overprediction of high precipitation intensities (Axel, Alberto)

Further improvements / developments

- Extension of adaptive parameter tuning (see Zängl, 2023 https://doi.org/10.1002/qj.4535 for details on the basic implementation)
  - Additional predictor fields for daytime T2M and RH2M bias calculated from data assimilation increments, and retuning of some filtering time scales
  - Additional model fields / parameters included in adaptive tuning
    - Hydraulic diffusivity of the soil
    - Laminar surface transfer resistance
    - Land albedo
    - Diagnosis of snow-cover fraction
    - More sophisticated adaptive tuning of bare-soil evaporation resistance
- Bug fix for temperature variable used for bare-soil evaporation (soil-top temperature instead of skin temperature)

Überblick

- Warm-layer Parameterisierung für SST mit kompensierender Anpassung von rat_sea und alpha1
- Parameterisierung für Dissipationswärme aus turbulenter Impulsdissipation
- Rückführung der minimalen Diffusionskoeffizienten im turbdiff auf die TKE
- Modifizierte Ozon-Tropopause-Kopplung und leichte Reduktion des stratosphärischen Ozontunings
- Tuning zur Reduktion der systematischen Biasdifferenzen zwischen DET und EPS-Mittel
- Land-tile averaging für T2M und RH2M in der Datenassimilation, verbunden mit Reduktion des Landanteil-Schwellwerts für T2M von 50% auf 25%
- Anpassungen in Extpar und Schneeanalyse für subskalige Landpunkte / Gletscherpunkte (bereits am 18.03. vorgestellt)

SST warm layer

- Nicht nur die Landoberflächentemperatur hat einen Tagesgang, sondern auch die SST
- Unsere SST-Analysen enthalten die sog. „foundation temperature“, d.i. die um den Tagesgang bereinigte Temperatur, die für ein paar Meter unter der Oberfläche repräsentativ ist
- Die Differenz wird über das warm-layer Schema parameterisiert

- Schalter: `itype_oskin_warm=1` in lnd_nml
- Kompensierendes Tuning: `alpha1=0.4, rat_sea=0.825` (turbdiff_nml)
- Zusätzliche Variablen im FG-I/O:
  - `sst_warm_layer (DSST_WARM_LAYER)`
  - `t_seasfc (T_SEA)` – bislang nur für Analysen verwendet, nicht im FG-I/O
  - Empfehlung: Eintrag in check_fg nach erfolgtem Kaltstart

Dissipationswärme

- Momentan nutzen wir eine simple Parameterisierung der Dissipationswärme für die Impulstendenzen des SSO- und GWD-Schemas, d.h. *dT/dt = (-u·du/dt)/cv*
- Tests mit der im turbdiff verfügbaren Parameterisierung der TKE-Dissipationswärme (`ltmpcor = T`) zeigten eine deutliche Reduktion des cold bias im Winter (v.a. entlang der Antarktisküste)
- Allerdings hat diese Option numerische Stabilitätsprobleme, die vermutlich mit einer positiven Rückkopplung zwischen dem Auftriebsproduktionsterm und der dissipativen Heizrate zu tun haben
- Daher wird als vorläufige Lösung die o.g. simple Parameterisierung auf die turbulente Impulstendenz ausgedehnt

- Schalter: `itype_dissip_heat=2` in nwp_phy_nml
- Leichtes SSO-Retuning: `gkdrag_enh=0.125,0.14` im DET, `0.11,0.125` im EPS

tkhmin → TKE

- Motivation: Verbesserung der Konsistenz zwischen TKE und der parameterisierten Vertikaldiffusion in stabil geschichteten Regionen, in denen die regulären TKE-Quellterme nichts liefern
- Matthias‘ ursprüngliche Implementierung wirkt zu stark, aber die Tuningvariante `imode_tkemini=3` führt v.a. bei der Bewölkung zu leichten Verbesserungen
- Außerdem leistet diese Option einen kleinen Beitrag zur Reduktion des cold bias entlang der Antarktisküste
- Da die Bewölkung insgesamt leicht zunimmt, ist zur Beibehaltung der bisherigen Strahlungsbiaswerte eine Reduktion von `tune_box_liq_asy` von 3.25 auf 3.1 nötig.

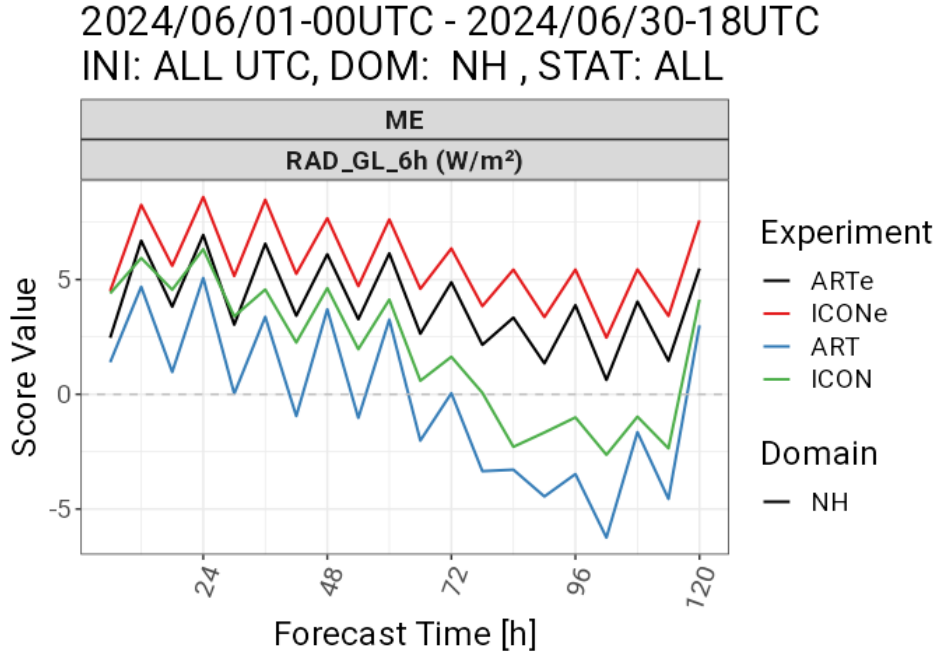
Ozon

- Die bisherige Version der Ozon-Tropopause-Kopplung wirkt bei tiefen Tropopausen (v.a. Antarktis im Sommer) zu stark
- In der neuen Version wird die Modifikation des Ozonprofils bzgl. der Klimatologie auf 125 hPa beschränkt; dies ist konsistent mit typischen vertikalen Skalen zyklonaler und antizyklonaler Anomalien im TP-Bereich
- Außerdem wurde die Tuning-Modifikation der Ozonklimatologie zur Reduktion des Temperaturbias in der Stratosphäre etwas abgeschwächt (mit Ausnahme der Antarktis)

- Schalter: `icpl_o3_tp=2` in nwp_phy_nml, `itune_o3=3` in tuning_nml

Reduktion der EPS-DET Biasdifferenzen

- Die SST-Störungen des EPS führen wegen der Nichtlinearität des Sättigungsdampfdrucks und nichtlinearer Wechselwirkungen zwischen SST-Störungen und Transferkoeffizienten im EPS-Mittel zu höheren Wärmeflüssen (fühlbar+latent)
- Für erstere gibt es bereits eine Kompensation; für letztere wird nun eine Anhebung von rat_sea vorgeschlagen
- Außerdem zeigen unsere Verifikationsergebnisse im EPS-Mittel höhere Globalstrahlungswerte als für DET. Diese sind nicht auf die EPS-Physikstörungen und auch nicht auf den Auflösungsunterschied zurückzuführen; den Grund kenne ich aber nicht
- Kompensation über cloudcover-Tuning
- Schalter (in ensemble_pert_nml)
  - `shift_boxliq_asy=0.15`
  - `shift_ratsea=0.05`



Land-tile averaging

- Nutzung des LTA für die Verifikation von T2M und TD2M/RH2M derzeit in den Parallelroutinen
- Nächster Schritt: Nutzung in der DA, kombiniert mit einer Reduktion des mindest-Landanteils für die T2M-Assimilation von 50% auf 25%

- Schalter (DACE): `version=5` in synop_obs, `fr_sea=0.75` in RULES für SYNOP T2M
- ... und Einträge für t2m_land, td2m_land, rh2m_land in diversen Variablenlisten in DACE und FG-Output (vv=90min) von ICON

Synopverifkation EPS Januar-März 2025