KENDAscope: KENDA from Surface to Cloud Observations Progressive Extension

(Sept. 2020 – Aug. 2025)

- Task 1: algorithmic developments

  1.1 refinements of reference KENDA (currently LETKF)

  1.2 Variational DA (EnVar , CEnVar, 4D-EnVar)

  1.3 Particle Filter

- Task 2: observations (from surface to clouds)

  2.1 Radar (Z + Vr)

  2.2 ground-based GNSS ZTD + STD

  2.3 all-sky IR + VIS radiances

  2.4 MTG IRS

  2.5 screen-level obs (T2M, RH2M)

  2.6 PBL profiling obs (wind lidar, MW radiometer, Raman lidar, drones, towers)

- Task 3: soil / surface (satellite soil moisture, SST, …)

DWD   *(Hendrik Reich, Christoph Schraff, Klaus Stephan, et al.)*

operational changes in ICON-D2:

- 19 Jan. 2022: Major revision of latent heat nudging (LHN)

  $\rightarrow$ *talk by Klaus Stephan*

to be introduced operationally on 23 March:

- new high-density Mode-S aircraft data $\rightarrow$ *talk by Christoph Schraff*

MeteoSwiss $\rightarrow$ *talk by Daniel Leuenberger*

(on status + plans of KENDA-1)

EnVar for ILAM   *(Mareike Burba, Hendrik Reich, Elisabeth Bauernschubert, Sven Ulbrich, Steffi Hollborn, Christoph Schraff et al.)*

- **EnVar**:   runs technically in a preliminary version (for conventional obs with DACE obs operators that are used operationally in global DA)

  - 'unified DACE operators' := DACE operators adapted for convective scale (based on contents of COSMO operators)
    - → little / no effort to derive TL + adjoint
    - → implementation finished for aircraft obs   → *talk by Hendrik Reich*
    - → next: radiosondes, Synop, wind profilers,…   (not likely finished by end of 2022)

  - careful EnVar tests / comparison to (3D-)LETKF ongoing
    - ○ for AIREP only: similar scores (slightly better RMSE, slightly larger bias) if similar settings for QC, interpolation, etc.
      → *poster by Mareike Burba @ICCARUS*
    - ○ next: introduce radiosondes (w. DACE op.)

- Hybrid EnVar: aim to develop **regional** climatological B-matrix: required very well-trained resources currently not available (due to other high-priority work, e.g. 4D-EnVar)

EnVar for ILAM

- **CEnVar**:   *(Sven Ulbrich et al.)*

  – runs technically in a preliminary version

    (with ensemble-B from ICON-EU or ICON-global from their complete model fields;
     it also runs for fields cropped with ICON-remap, but not yet with ICON-sub)

  – plan by mid 2022:

    o   implement full technical C-EnVar capabilities
          (incl. B-matrix from cropped ICON-EU and ICON-global fields)

    o   *preliminary* performance testing (comparison to EnVar, LETKF)

  – full performance tests should be done by any other institutes
     that want to apply CEnVar on their own model domain

Particle Filter for ICON-LAM *(Nora Schenk, Anne Walter, Roland Potthast)*
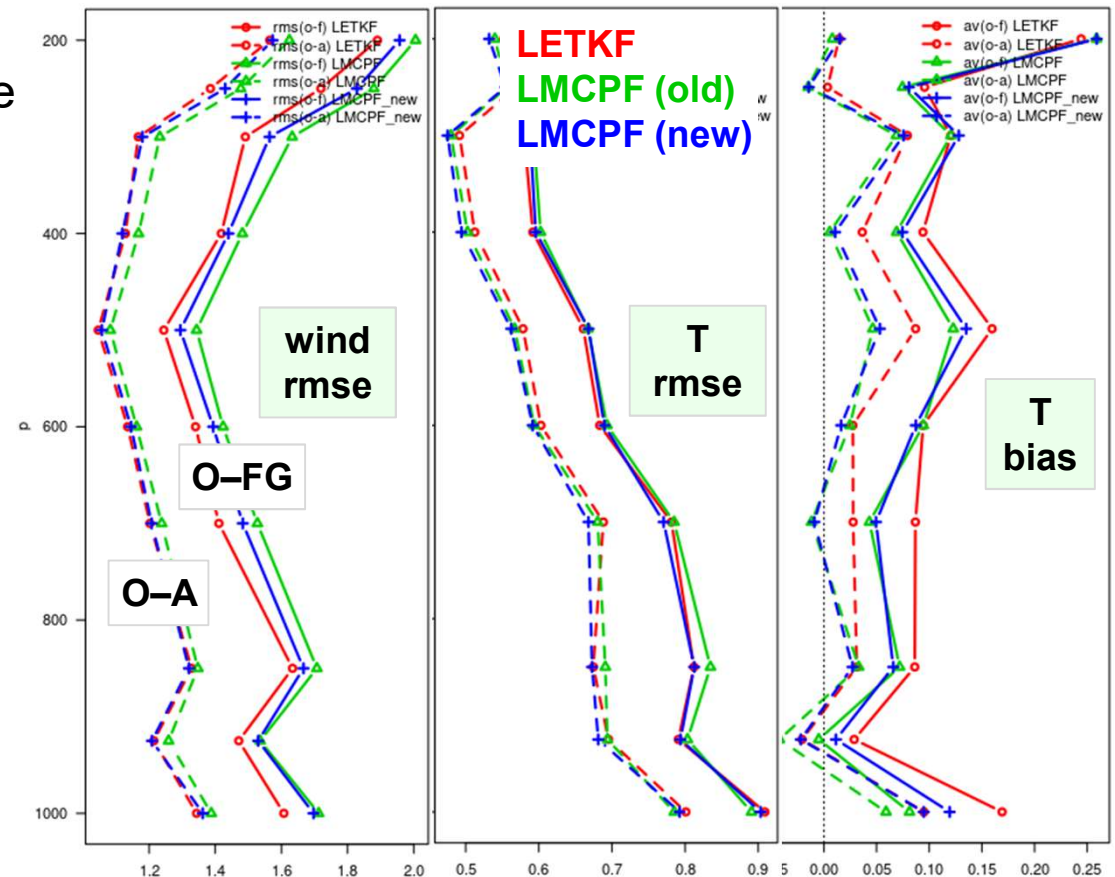
- revised new particle weights in LMCPF (Localised Mixture Coefficients PF)

  → larger ensemble spread
  to which PF is very sensitive

- 36-hour test with ICON-LAM
  (incl. use radar, T2M, RH2M obs):

  – new weights better

  – LMCPF vs. LETKF:
  better T bias,
  worse RMSE

- next: further tuning
  + quality assessment
  with ICON-LAM

Task 2: Observations (surface to clouds)

Task 2.1: 3-D radar

- radial wind: $\rightarrow$ ARPAE: *talk by Thomas Gastaldo*

- reflectivity: testing / adjustment to 2-moment microphysics (also model tuning!)
  sensitivity tests rel. to obs errors (dep. on height / obs increments)
  ($\rightarrow$ talk by *Kobra Khosravian* at ICCARUS)

  testing targeted covariance inflation:
  in areas with missing (insufficient) precip / spread *(Klaus Vobig)*

- prepare for processing / use foreign radars (BUFR $\rightarrow$ ODIM HDF5 ($\rightarrow$ 23 March))

- WG1: DA of radar-derived objects / lightning / nowcast **cell features / textures** (FSS, ongoing)
  ($\rightarrow$ talk by *Lisa Neef* at ICCARUS)

- WG1: assimilation of dual-polarization moments (direct / hydrometeor mixing ratio retrieval)
  ($\rightarrow$ talk by *Jana Mendrok* at ICCARUS)

Overview on KENDAscope developments
KENDA Meeting, Telco, 10 March 2022
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Deutscher Wetterdienst

Task 2.2:   ground-based GNSS Zenith / Slant Total Delay *(M. Bender)*

- plan: DA experiments with ICON-D2 by Q3/22
  still requires some technical work (selective DB retrieval, BUFR reader,..))

- later on also needed: improved bias correction + obs error specification

Task 2.3: all-sky (cloudy) IR + VIS radiances *(Annika Schomburg, Lilo Bach, Thomas Deppisch a.o.)*

- **IR WV** (water vapour) channels: info on WV + clouds in mid- to upper troposphere
  - still considerable technical work needed for operationalisation (e.g. process. w/in ICON)

- **VIS** channels: info on all clouds, incl. low clouds (but not on cloud top height) at daytime
  - technically very nearly ready for operations   (e.g. obs operators applied w/in ICON)
  - optional novel bias correction (adjustment of reflectance histogram bias), to be optimized
  - (→ talk by *Lilo Bach* at ICCARUS)

- latest main results (after many exp. w. different LHN + ILAM versions, obs error settings, bias corr.,…)
  - impact: positive for cloud + upper-level humidity (wet bias reduced)
                     & in TEMP + Synop verif. (incl. global radiation)

    negative for precip ('dry' bias increased)   ←   biased model, fdbk w. modellers

- Aim: **simultaneous DA of WV + VIS** channels (further technical work needed for op.)
              (may also help improving 'height assignment' problem with VIS data)

  - first experiment worse (RH in FG) than DA of WV alone

Task 2.4:   MTG IRS   (Meteosat Third Gen. hyperspectral IR Sounder*)*

(Mahdiyeh Mousavi, Christina Köpken-Watts, a.o. DWD)

- simulated ‚obs' (with RadSim)   →
  (output as feedback file)

- ICON-global,   EnVar:
  technical test with DA
  of simulated obs done

- ILAM: (call of RadSim in BACY implemented)

  LETKF code being extended for use of
  non-diagonal obs error covariance matrix R
  with interchannel correlations
  (DACE experts required!   → *Steffi Hollborn + Hendrik Reich*)

simulated IRS obs – channel 59
(20200802, 1UTC)
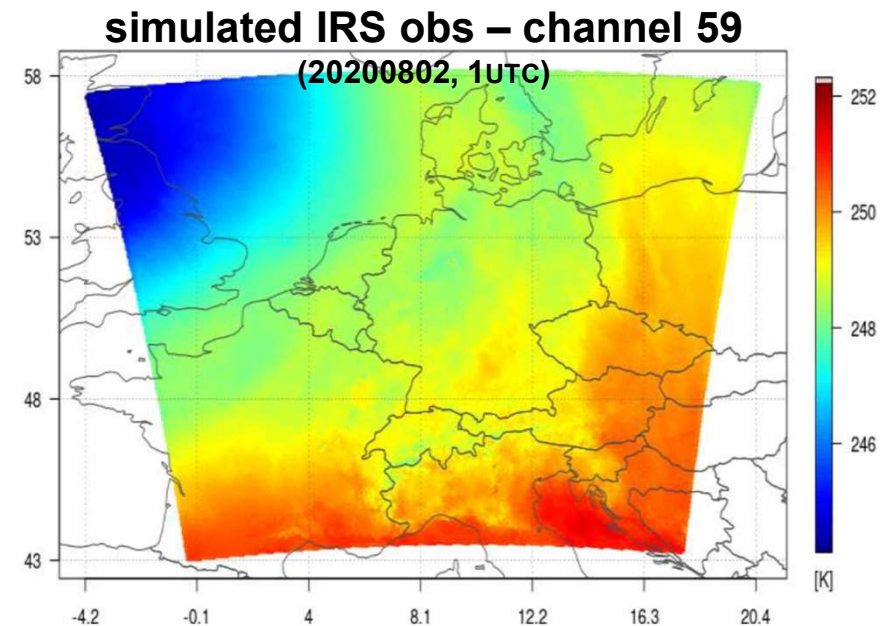
- important aspects: slant radiative transfer, 4D-EnVar (for indirect wind info),
  horiz. obs error correlations (for use of obs at high resolution)

Deutscher Wetterdienst

Task 2.5:   **2-m Temperature + Humidity**

- **operational** for ICON (DWD, COMET) and COSMO (MeteoSwiss)
  without bias correction due to **strong positive impact**

- no further work on bias correction (at least) until Elisabeth is back to work (~2023)

Task 2:   Observations (surface to clouds)

Task 2.6:   **ground-based PBL profile obs**   → posters by MCH and by DWD

- **MW radiometer** radiances   → talks by *Claire Merker (MCH)* and *by Jasmin Vural (DWD)*

  – DA: clearly positive impact on brightness temperatures (i.e. observed variable)
  impact in physical (model) space (T, humidity): at best 'mixed' (MCH)

  – DWD: better to assimilate only 1 T channel + 1 humidity channel   (out of 7 + 7)

    → need account for interchannel obs error correlations in LETKF (→ DACE experts!)

- **Doppler wind lidar**   → talk by *Daniel Regenass (MCH)*

  – MCH: assimilation tests with positive impact (several hours)

  – MCH: operational introduction end of Feb. 2022 (3 lidars); investigating 4th lidar (Basel)

  – DWD: first assimilation tests with 1 lidar

- **Raman lidar** (temperature + mixing ratio profiles) → talk by *Bas Crezee (MCH)*

  – observation operator for T and Mixing Ratio implemented dace_code

  – DA: slight positive impact (on humidity bias, cloud, precip) in convective period; ongoing

- (no new work on meteo-drones or towers)

Task 3.1: Soil moisture analysis using **satellite soil moisture data**
(Valerio Cardinali, Francesca Marcucci, COMET)

- DACE code being adapted to apply to ICON

- experimental runs with soil moisture assimilation in COSMO-IT: no impact so far

Task 3.3: **Sea Surface Temperature** (SST) analysis
(Thomas Hüther, Gernot Geppert, Martin Lange, DWD)

- "**omniVAR**":   flexible (at present 2-D)-variational analysis in DACE:

  - core of code developed, for plain 2D-Var

  - currently adapted to T2M analysis (e.g. height correction)
    (T2M analysis used e.g. for soil moisture analysis)

  - then adapted to SST analysis (needs to account for land/sea mask)

New 'Referatsleiter' (section leaders) at DWD

• FE11: Data Assimilation and Predictability: Jan Keller

• FE12: Observation Operators and Verification: Stefanie Hollborn
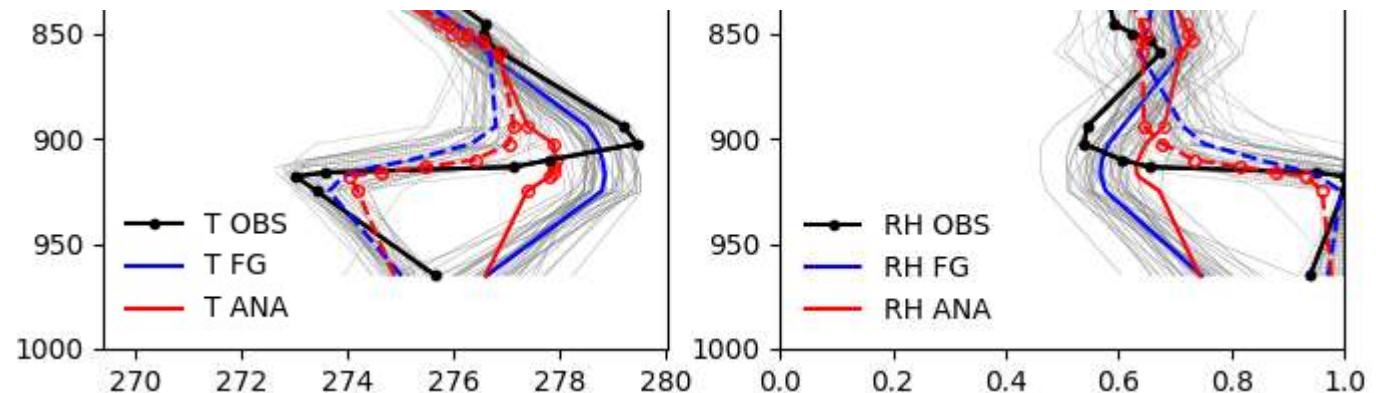
🇨🇭 **MeteoSwiss** *(Daniel Leuenberger, Daniel Regenass, Claire Merker, Bas Crezee)*

- PBL profiling obs: MWR, wind lidar, Raman lidar: see later Task 2

- **fog / low stratus** (strong inversions): "a serious issue at MeteoSwiss" (one year ago)

  (large, systematic FG errors + small spread → small analysis increments + poor analyses)

→ assimilation of 2-m temperature + humidity in COSMO model (w/o bias corr.)

  – large positive impact, particularly in the fog season 2020

  – introduced operationally on 27 Sept. 2021

  – e-suites for spring + summer periods have confirmed the positive impact

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