CONSORTIUM FOR SMALL SCALE MODELING
COSMO

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

COSMO WG7 and PROPHECY PP activities

Chiara Marsigli

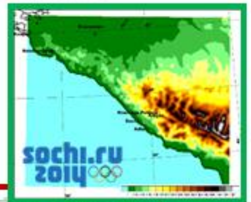
Deutscher Wetterdienst

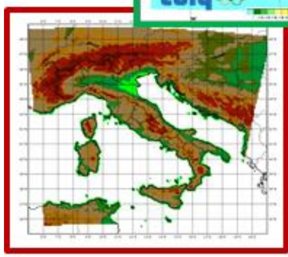
Outline

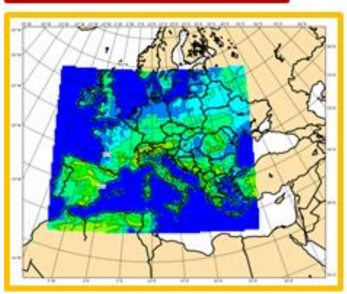
- The COSMO ensembles
- Recent developments in PROPHECY PP:
  - Sensitivity of ICON to physics parameters
  - Combination of SPPT and PP and in COSMO
  - More stochastic physics!
- Use of ensembles
- Final remarks

The COSMO ensembles

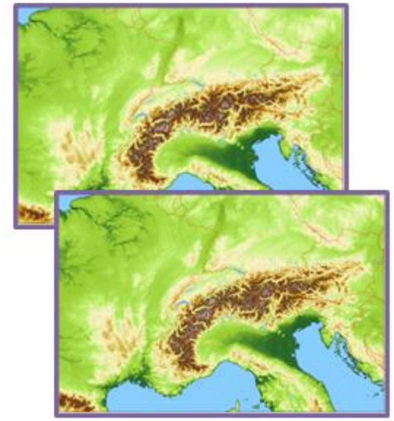
Ensemble systems

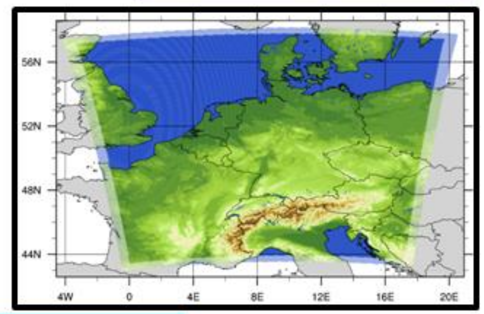


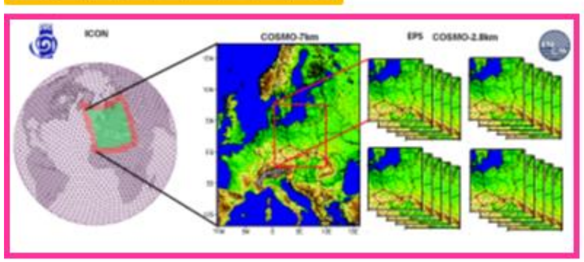


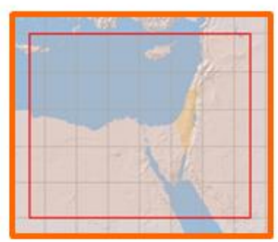


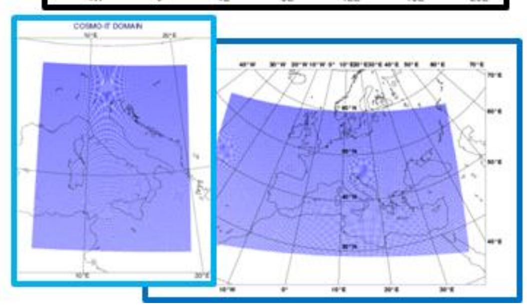
- ICON-D2-EPS
- COSMO-2E
  COSMO-1E
- TLE-MVE
- COSMO-2I-EPS
- COSMO-IT-EPS
- COSMO-Ru2-EPS
- COSMO-IL-ENS
- COSMO-LEPS
- COSMO-ME-EPS











http://www.cosmo-model.org/content/tasks/workGroups/wg7

Model perturbation

- Methods currently operational:
  - SPPT COSMO-2E, COSMO-1E, COSMO-IT-EPS, COSMO-ME-EPS
  - PP COSMO-LEPS, COSMO-I2-EPS, TLE-MVE
- Methods currently under development:
  - SMME – Stochastic Model for the Model Error (DWD)
  - AMPT – Additive Model-error perturbations scaled by Physical Tendencies (RHM) NEXT TALK!
- New developments outside WG7 but under test (DWD):
  - SSC - Stochastic shallow convection
  - PSP2 - Physically based stochastic perturbations for boundary layer turbulence

Parameter list for ICON

- A list of ICON parameters for tuning and model perturbation has been provided by L. Schlemmer et al.
- A dedicated webpage has been prepared by T. Andreadis: http://www.cosmo-model.org/content/support/icon/tuning/default.htm, with the description of the parameters, their range of variability and comments from the developers
- It aims at including also the experience matured in the COSMO Consortium on the usage of the parameters

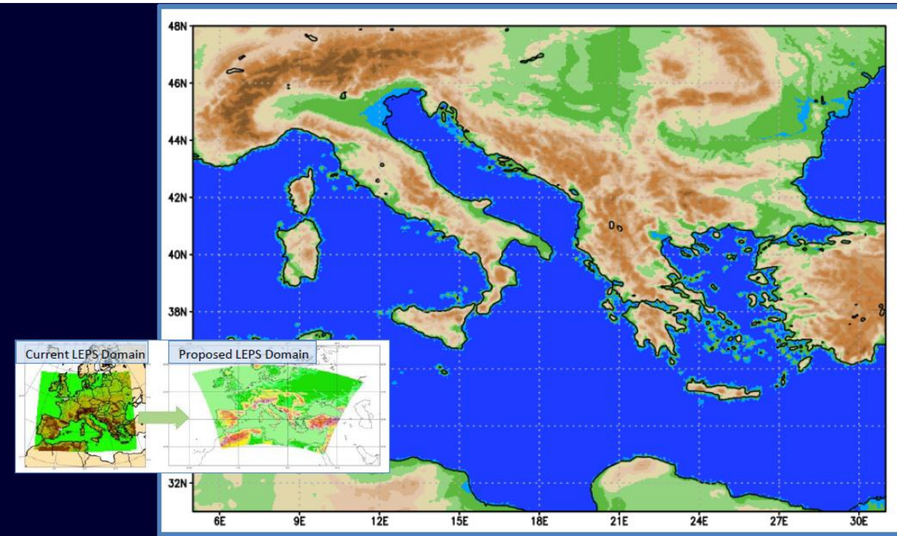
parameter	description	meaningful range	comment from the developers	model tuning	EPS perturbation	EPS perturbation in production
SSO tuning						
gkwake	low level wake drag constant Cd for blocking	1.5 ±0.5	Very strong dependency on raw data resolution: for ICON-D2 with ASTER data, we use 0.25	∄	∄	∄
turbulence						
q_crit	critical value for normalised super-saturation	1.6-4.0	∄	identified as "sensitive" for COSMO in [1]	∄	ICON-D2-EPS

Status of the experiments on parameter perturbations towards ICON-LEPS

Euripides N. Avgoustoglou
Hellenic National Meteorological Service

- Goal: study the sensitivity of the ICON model to a large set of parameters over a Mediterranean area, in view of the implementation of the Parameter Perturbation in ICON-LEPS (transition of COSMO-LEPS)
- Starting point: the list of ICON parameters provided by Schlemmer, Zängl and Reinert, with their range of variation
- Sensitivity runs performed at ECMWF, using Billing Units provided by HNMS; the set-up of the ICON model suite at ECMWF is provided by IMS colleagues (thanks!)

E. Augoustoglou, HNMS



24 parameters were considerd.

⊗

3 values/parameter including default.

⊗

The evaluation period consisted of 62 days from year 2020 i.e.: January 1-31, July1-31

3000 runs based on ICON-IMS (Gratis IMS):

- Horizontal grid size: R3B08 (~6.5km).
- 417x273 grid points (wider area of Greece and Italy), 65 levels.
- Integration time-step: 60 secs.
- Integration period: 132 hs.
- Boundary conditions : 3hr IFS Forecast.
- Computational Cost ~ $5x10^6$ b.u. on Cray X C40 of ECMWF (Gratis HNMS).

E. Augoustoglou, HNMS

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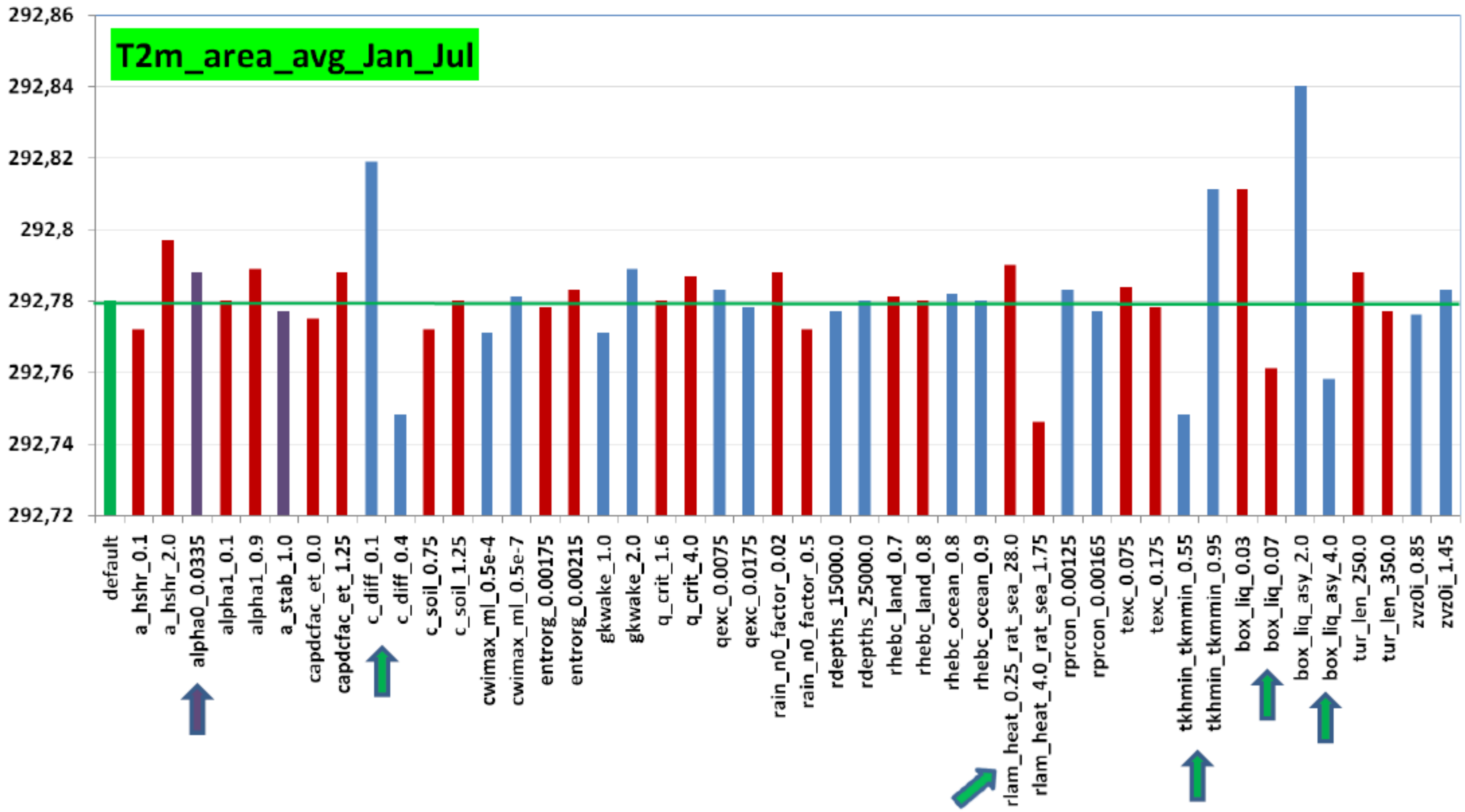
ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ
HELLENIC NATIONAL METEOROLOGICAL SERVICE

Areal <2m temperature> [K] (132nd hr)



Euripides Avgoustoglou, Hellenic National Meteotological Service, 23rd COSMO GM , September 13th 2021 07

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ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ
HELLENIC NATIONAL METEOROLOGICAL SERVICE

Dominating parameters table for the considered meteorological fields

				
T2m	2 m Temperature [K]	box_liq_asy	c_diff	tkhmin_tkmmin
Tmax2m	2 m max Temperature [K]	box_liq_asy	c_diff	tkhmin_tkmmin
Tmin2m	2 m min Temperature [K]	tkhmin_tkmmin	rlam_heat_0.25_rat_sea_28.0	c_diff
Td2m	2 m max dew point Temperature [K]	c_diff	box_liq	alpha1
tot_prec	accumulatedPrecipitation [kg/m^2]	box_liq_asy	rain_n0_factor	rprcon
pmsl	mean sea level Presure [Pa]	box_liq	gkwake	c_diff
u10m	10 m wind speed u component [m/s]	box_liq	box_liq_asy	tur_len
v10m	10 m wind speed v component [m/s]	gkwake	tkhmin_tkmmin	box_liq_asy
gust10m	wind gust 10 m above ground [m/s]	gkwake	box_liq	a_hshr
clcl	low cloud cover [1-100]	box_liq_asy	box_liq	alpha0
clcm	medium cloud cover [1-100]	box_liq	box_liq_asy	rdepths
clch	high cloud cover [1-100]	zvz0i	entrorg	rprcon
clct	total cloud cover [1-100]	box_liq_asy	box_liq	zvz0i
tqv	column integrated water vapour [kg/m2]	alpha1	a_stab	box_liq
tqi	total column integrated cloud ice [kg/m2]	zvz0i	rprcon	box_liq_asy
tqc	total column integrated cloud water [kg/m2]	rdepths	tur_len	q_crit

Euripides Avgoustoglou, Hellenic National Meteotological Service, 23rd COSMO GM , September 13th 2021 23

E. Augoustoglou, HNMS

COSMO-IL-ENS

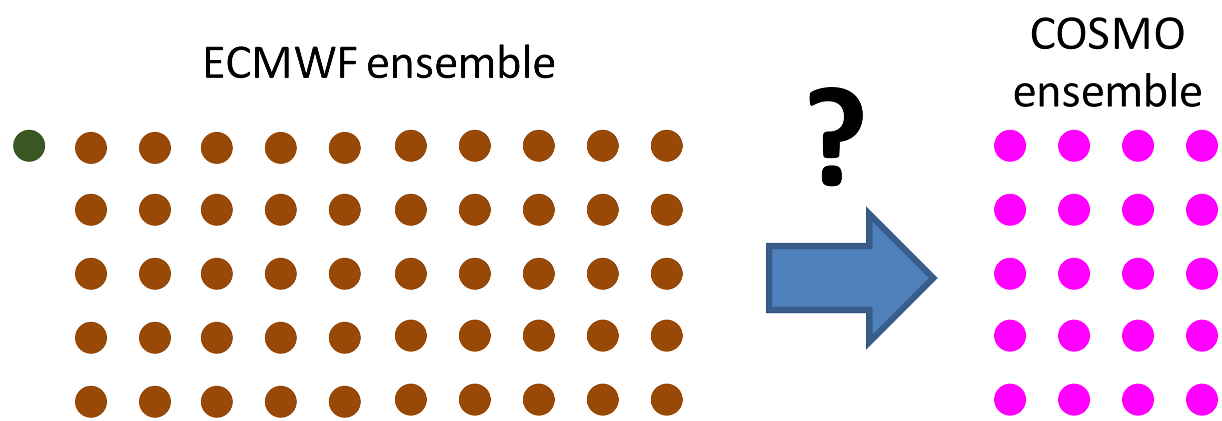
Sources of forecast uncertainty:

- V Uncertainty in boundary conditions → use of driving ensemble (**EC-ENS**)
- V Uncertainty in model physics → Stoch. Pert. of Param. Tendencies (**SPPT**), parameter perturbations (**PP**)
- Uncertainty in initial conditions → **KENDA** analysis perturbations.

Questions?

1. Which 20 EC-ENS members to choose?

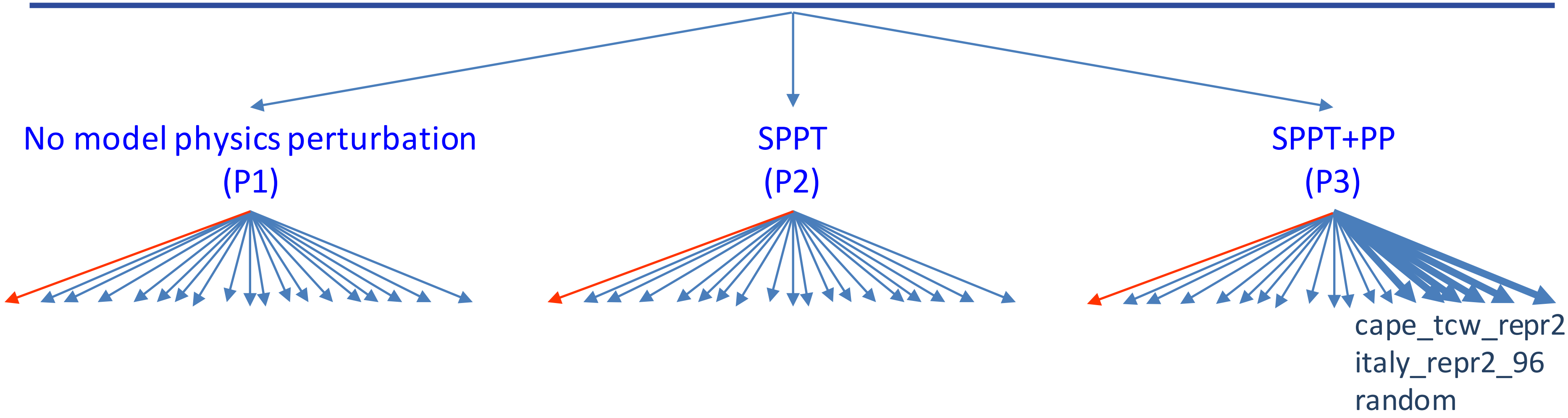
2. Do model physics perturbations benefit?



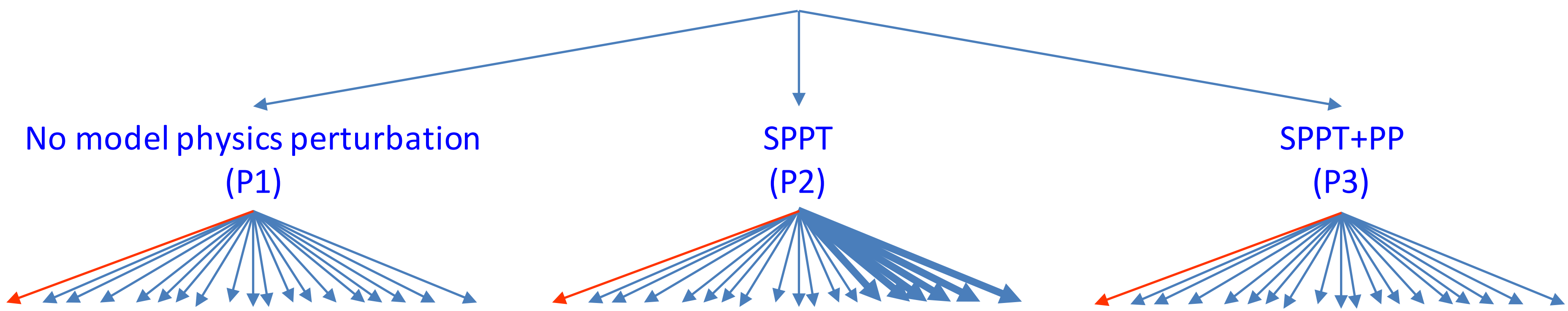
Please ask the authors for more information!

Khain et al., IMS

Which option of ensemble
structure is better
for near surface variables?



Which option of ensemble
structure is better
for precipitation?



Any method which
keeps member
weights identical

Khain et al., IMS

Schemes for model perturbation in ICON

- DWD, MeteoSwiss, RHM are implementing different schemes for model perturbation (SPPT / iSPPT, SPG and AMPT, SMME) in ICON
- The implementation is made in a consistent way and possibly using a unified interface.
- E-mail exchange and dedicated meeting have been organized as part of the PROPHECY coordination with Daniel Rieger and Günther Zängl. An implementation concept has been prepared by the three teams.
- More meetings followed …

- It is a very good testbed for the organization of the inclusion of COSMO contributions in the ICON code

Stochastic Model of the Model Error (SMME)

- SMME aims at modeling the model error by integrating a stochastic partial differential equation at different heights levels for u, v, and T.
- The solution of the SPDE has spatial and temporal correlations corresponding to the model error in the training data set.
- These solutions of the SPDE (different in each member of the ensemble) are added to the tendencies in the slow physics scheme

$$\frac{\partial\psi}{\partial t} = \left[\frac{\partial\psi}{\partial t}\right]_{\mathrm{det}} + \eta(t) \qquad \frac{\partial\eta}{\partial t} = -\gamma\eta + \gamma\nabla\cdot(\lambda^2\nabla\eta) + \sigma\xi(t)$$

ψ : perturbed variables (T, U, V)

$\eta(t)$: noise field / model error, correlated in time and space

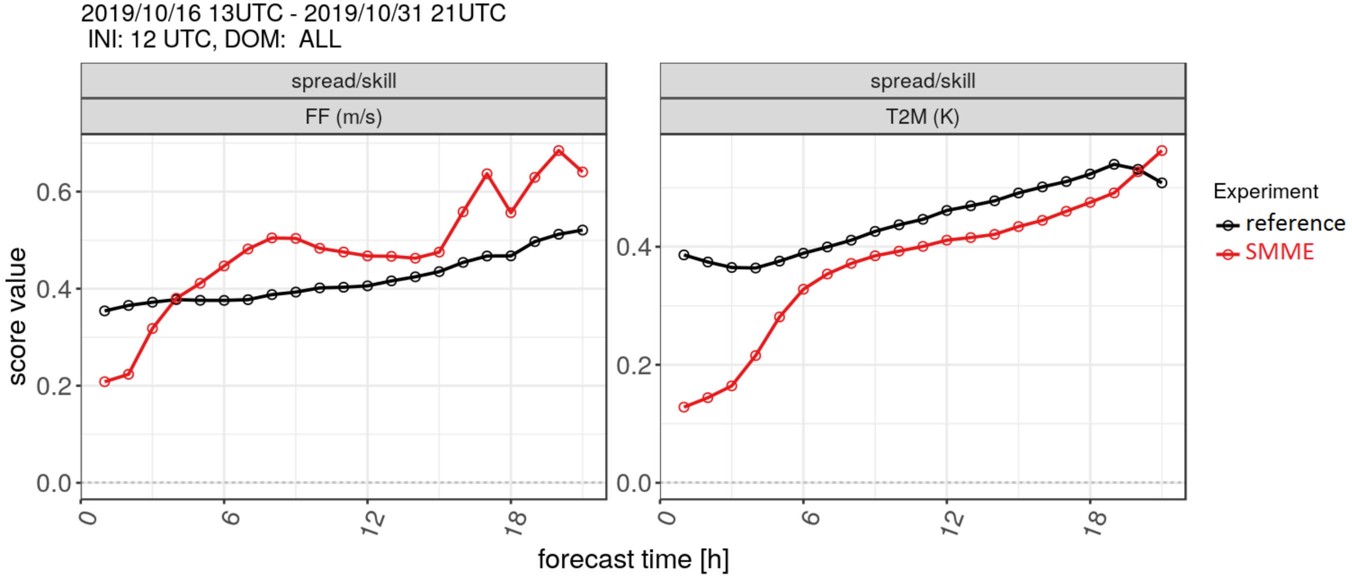
$\xi(t)$: Gaussian noise

γ, λ and σ are weather-dependent parameters and are derived from past data

M. Sprengel, DWD

Stochastic Model of the Model Error (SMME)

- First experiments with COSMO-D2-EPS looked promising
- Currently porting the SMME to ICON-D2-EPS
  - Parameter estimation for ICON-D2-EPS is completed
  - First runs with ICON-D2-EPS show mixed results (SMME exp; reference)



  - spread/skill improvement for wind speed but not for T2m
    → further work needed

M. Sprengel, DWD

Stochastic Workshop

- 2nd and 3rd of March 2021
- Purpose: to make the point about the activities on-going in the COSMO Consortium and in the other European Consortia in the field of "stochastic physics", in particular intrinsically stochastic parametrisations, in view of their usage in ensembles
- 40-50 participants, from COSMO members, LMU (University of Munich), ECMWF, Meteo France, Met Office, Met Eireann, KNMI, SMHI, Met No, Met Hu, AEMET, NCAR, KIT
- Presentations and minutes (of a very interesting discussion) are online at: http://www.cosmo-model.org/content/tasks/workGroups/wg7/default.htm

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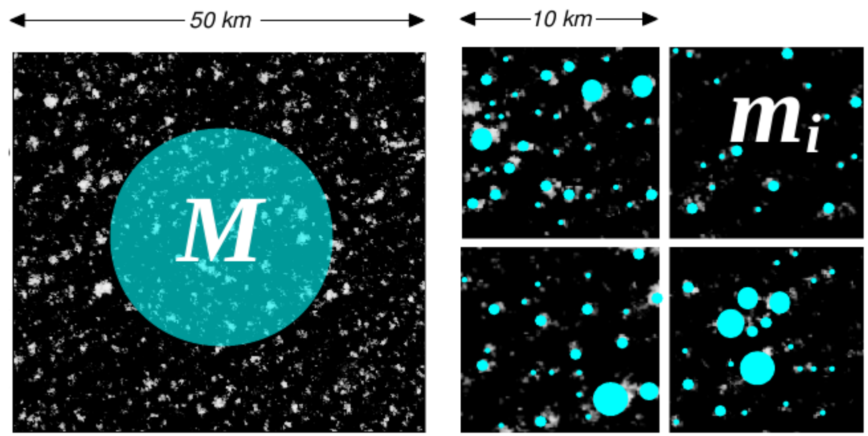
Stochastic shallow convection (SSC)

→ We will never be able to predict individual clouds with accuracy – but we can predict their distribution statistics!

- Grid box area **too small** to contain a complete ensemble of convective clouds



M: mass flux of the ensemble *mi: mass flux of an individual cloud*

→ Convection is **not** in equilibrium with the large-scale state (closure)

→ The resolved atmospheric state no longer predicts a **unique** (deterministic) convective state – there are many possible realisations!

- Parametrise effect of unresolved shallow convection (at km scale)
- A scheme that is resolution-independent and adapts automatically into the gray zone

M. Ahlgrimm, DWD

Stochastic shallow convection (SSC)

- first experiments run for 1 month in August/September 2020, only 00 UTC runs
- neutral results

- tests in ensemble mode (ICON-D2-EPS) on-going
  - stochastic shallow convection only
  - parameter perturbation only
  - stochastic shallow convection + parameter perturbation
- evaluation of diagnostic variables:
  - mf_b: "bulk" mass flux - used by the default convection scheme to measure convective activity
  - mf_p: stochastically "perturbed" mass flux - used in the stochastic scheme
  - ddt_qv_conv: convective tendency for qv
  - ddt_qc_conv: convective tendency for qc (liquid) condensate
  - ddt_temp_pconv: convective tendency for temperature

C. Gebhardt, C. Marsigli, DWD

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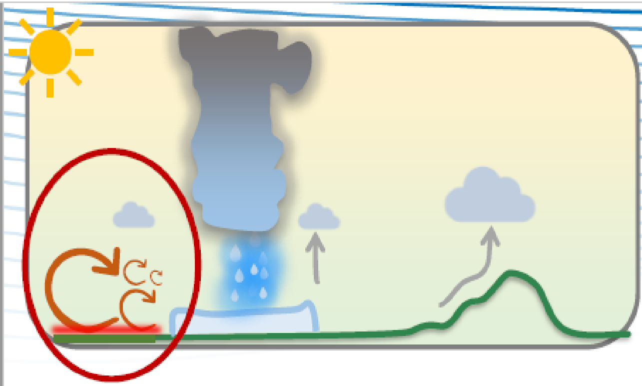


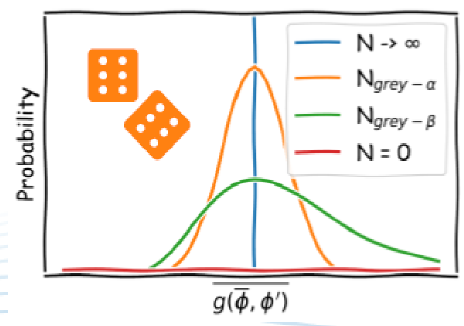
WAVES TO WEATHER

Hirt et al., 2021

PSP/PSP2 in ICON: Convective initiation by **Boundary layer turbulence**

M. Hirt

F. Jakub, I. Chen, C. Keil, G. Craig



Publications:

- Kober, K. and Craig, G. C. (2016) Physically based stochastic perturbations (**PSP**) in the boundary layer to represent uncertainty in convective initiation. Journal of the Atmospheric Sciences, 73, 2893–2911.
- Hirt, M., Rasp, S., Blahak, U. and Craig, G. (2019) Stochastic parameterization of processes leading to convection initiation in kilometre-scale models. Monthly Weather Review

Physically based stochastic perturbations for boundary layer turbulence : PSP (Kober and Craig, 2016)

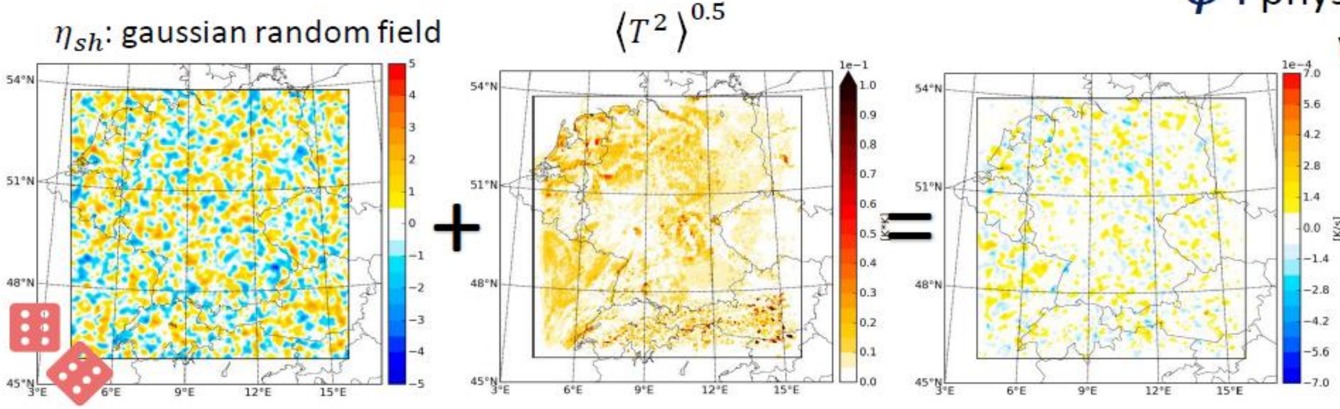
$$\left(\frac{\partial\phi}{\partial t}\right)_{all} = \frac{\partial\phi}{\partial t} + \underbrace{\alpha \cdot \boxed{\eta} \cdot \sqrt{\overline{\phi'^2}}}_{\text{Stochastic perturbations}}$$

ϕ ={T, q, w}

$\boldsymbol{\eta(t,\sigma)}$: Random field , regenerated every 10 min with spatial correlation σ

$\boldsymbol{\alpha}$: perturbation ampl., scaling factors

$\boldsymbol{\phi'}$: physical scaling/subgrid-scale variance of variable ϕ



(Kober and Craig, 2016)

2

It reintroduces the influence of the lost small-scale variability by adding perturbations to the tendencies of T, q_v, w on the smallest effectively resolved scale (5Δx)

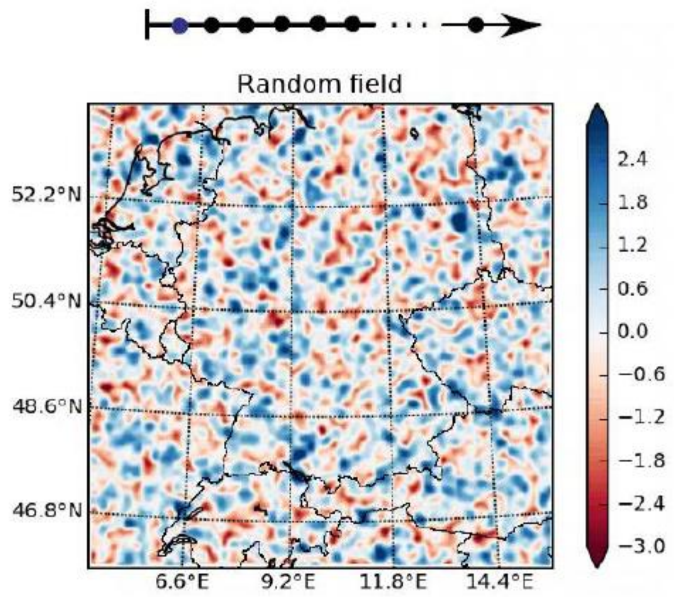
Modifications for improved physical consistency → PSP2

(Hirt et al., 2019, MWR)

- **Autoregressive Process**: Continously modifying η at every time step, but temporally correlated:

$$\eta_t = \sigma_t \cdot \eta_{t-1} + \epsilon_t$$

- Constraining the perturbations to the boundary layer (HPBLcut)
  → Reduce impact of perturbations at night
  →Scheme developed for buoyant turbulence, not shear (vertically correlated perturbations)



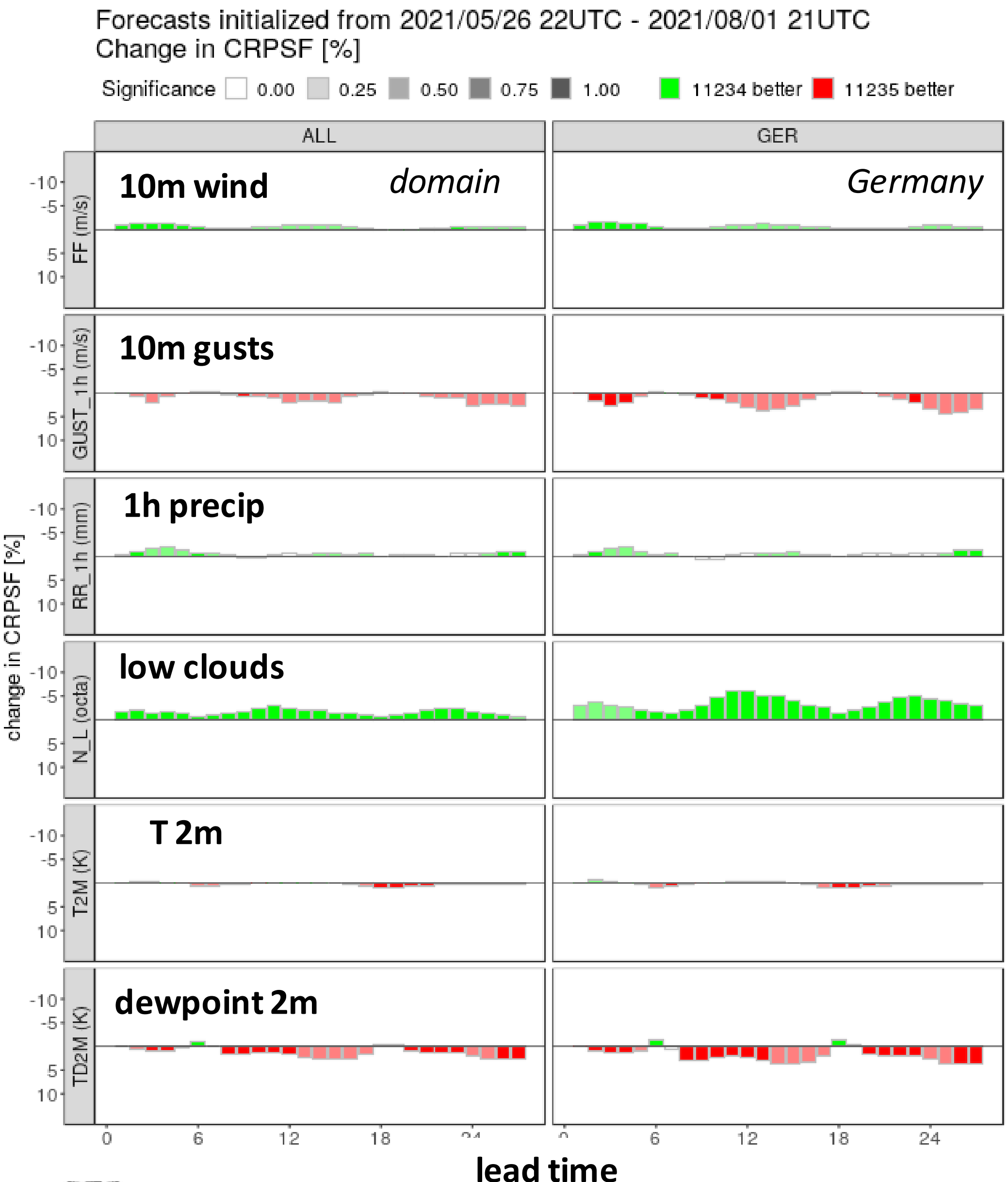
WAVES TO WEATHER

Physically based stochastic perturbations for boundary layer turbulence (PSP2)

- cooperation with Ludwigs-Maximilian-Universität in Munich (LMU)
- first promising tests at LMU
- PSP2 implemented in ICON by LMU based on the "current" version of the branch "icon-nwp/icon-nwp-dev" (including cp/cv bugfix & ecRad)
- first tests for a short period in August 2020 with ICON-D2-EPS
- test run from May 26th to August 1st 2021 at DWD

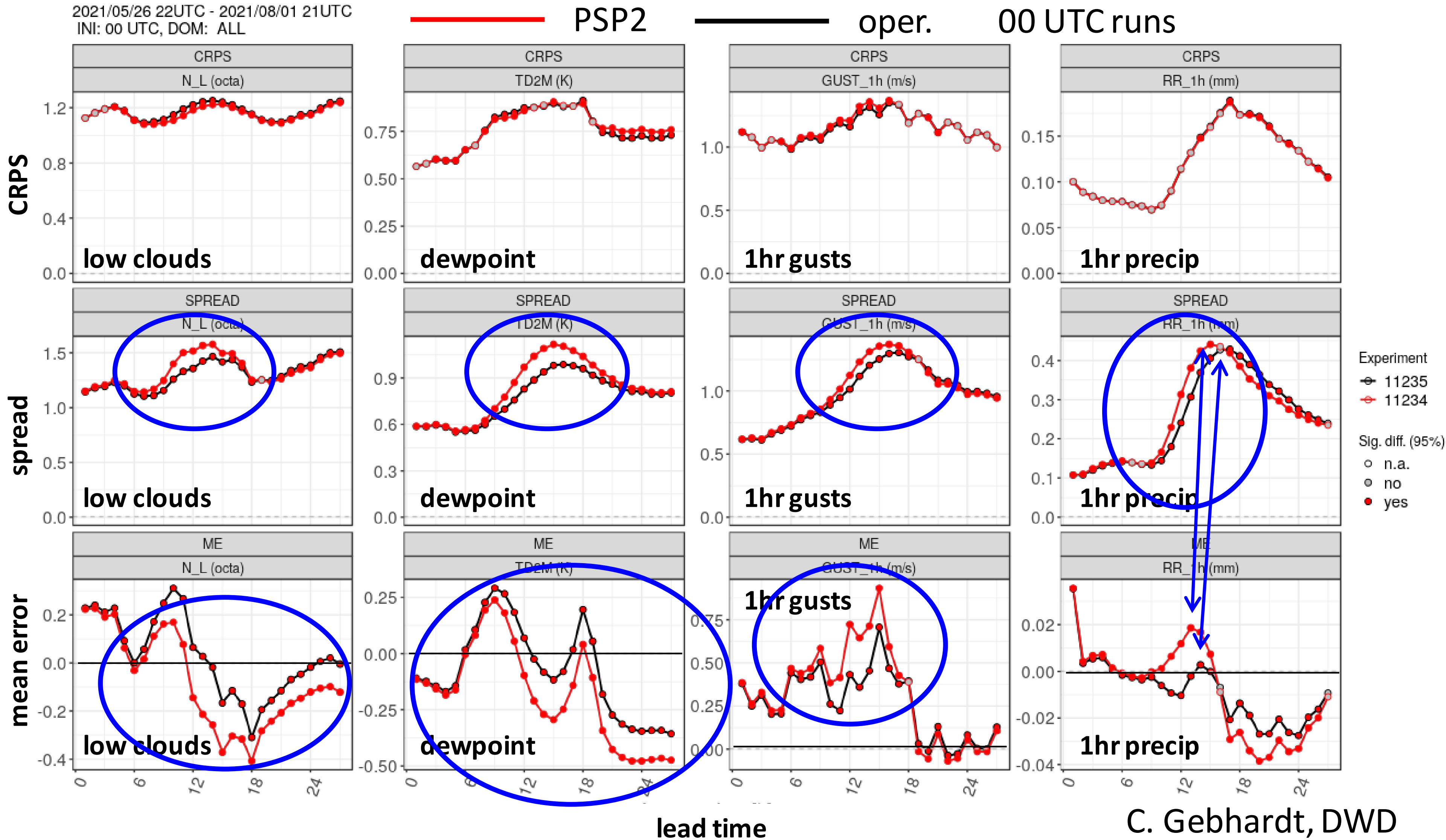
WAVES TO WEATHER

C. Gebhardt, C. Marsigli, DWD



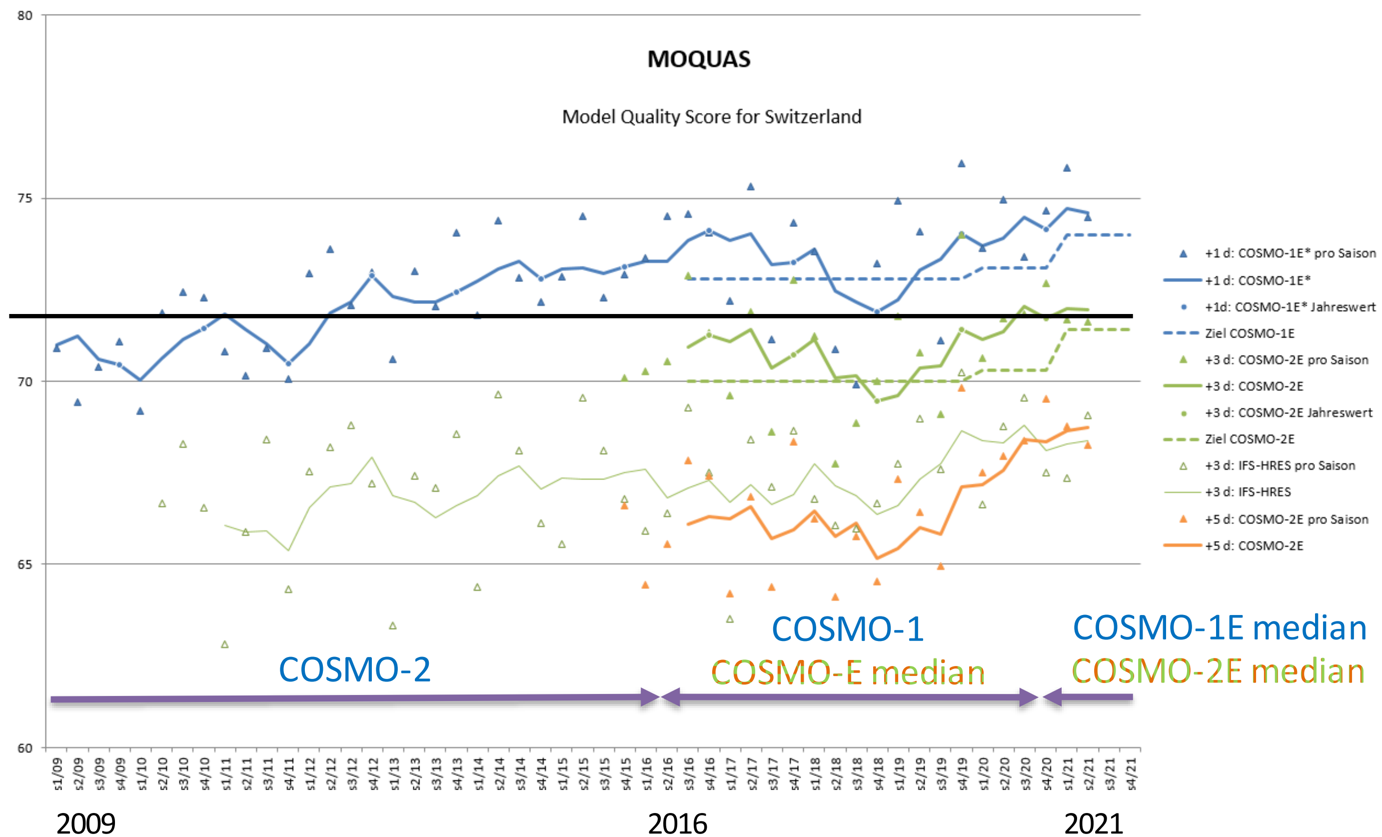
- ICON-D2-EPS with PSP2 vs. operational set up
- Change of CRPS
- green: PSP2 better
  red: PSP2 worse
- 26th May – 1st Aug 2021
  00 and 12 UTC runs
- SYNOP observations

C. Gebhardt, DWD



C. Gebhardt, DWD

MeteoSwiss model performance scores

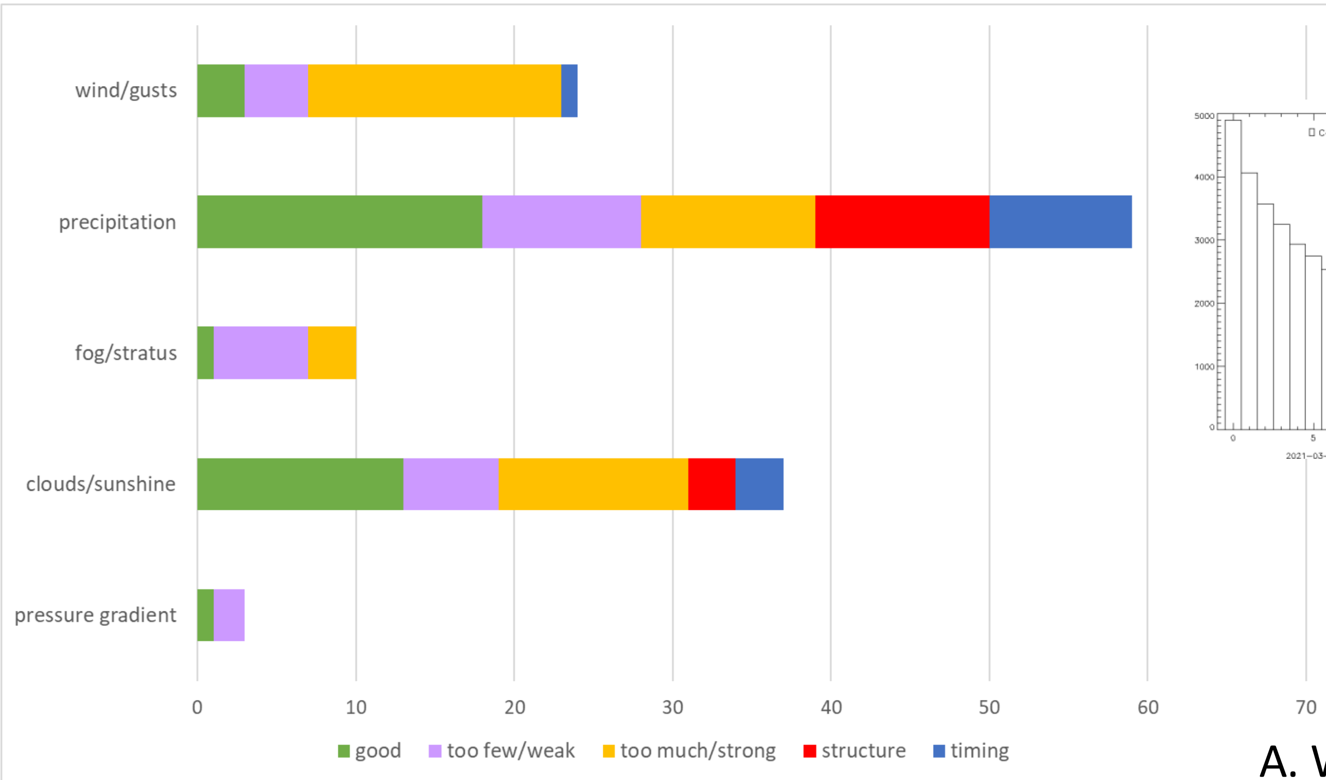


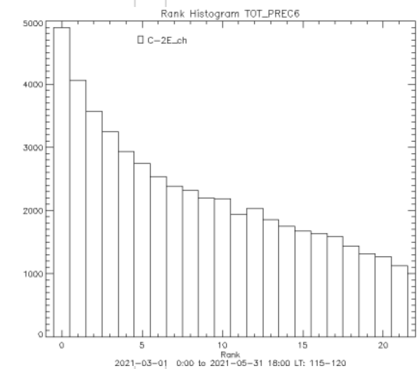
original figure:
Pirmin Kaufmann

A. Walser, MCH

Forecaster feedbacks 2021

- model feedbacks from forecaster on duty every day (scheduled, up to 15 min)
- increased use of ensemble information also in the short range
- probabilities are translated to keywords in forecast bulletins (possible, likely, ...)
- …but control run still get (too) much attention

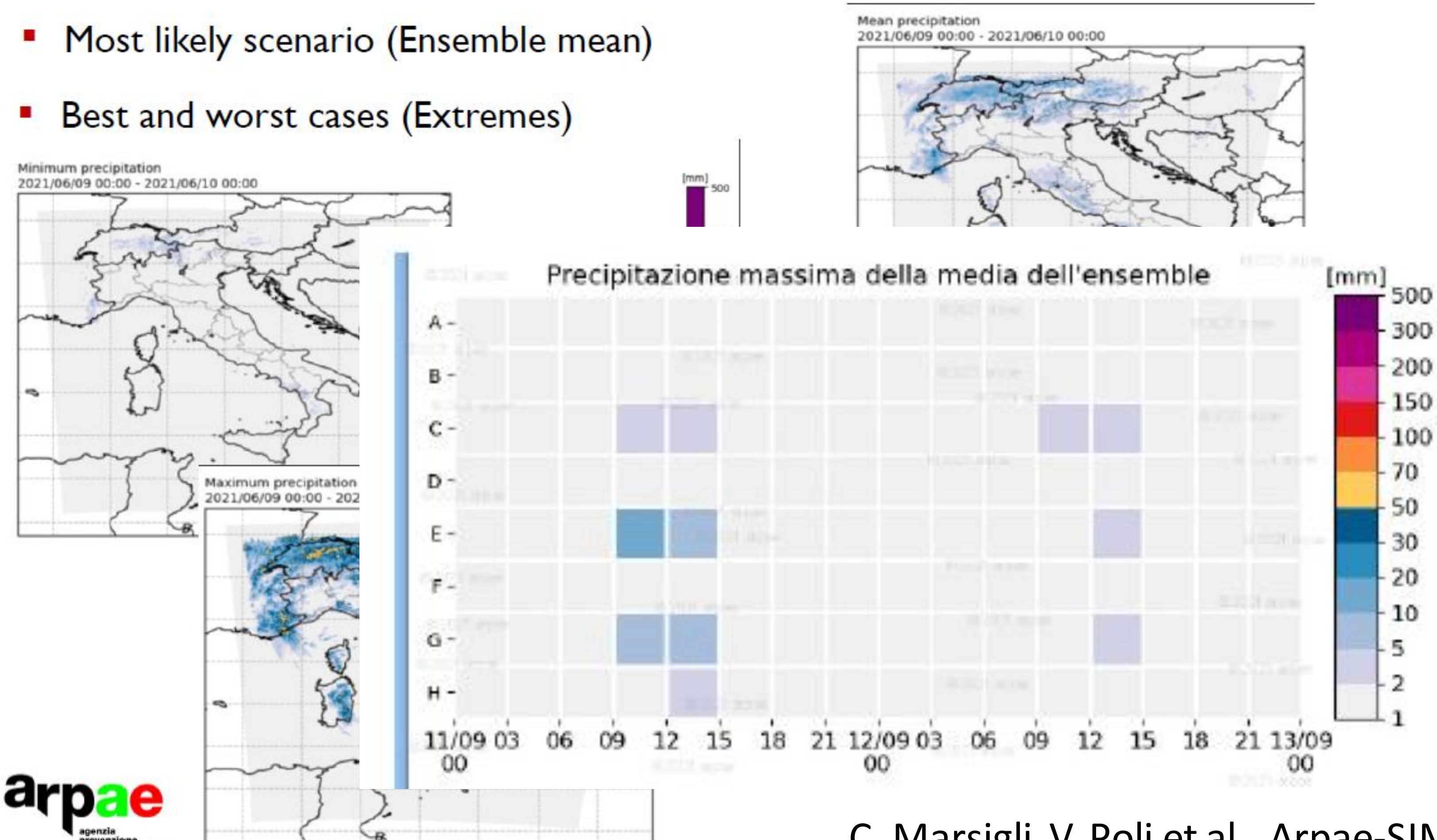




A. Walser, MCH

COSMO-2I-EPS

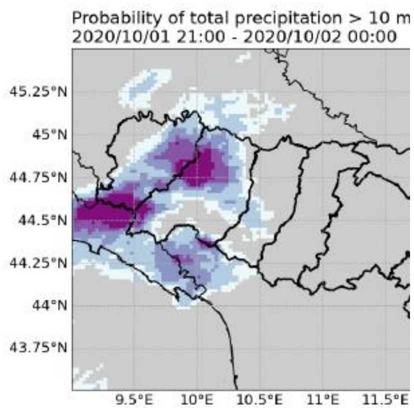
- Most likely scenario (Ensemble mean)
- Best and worst cases (Extremes)

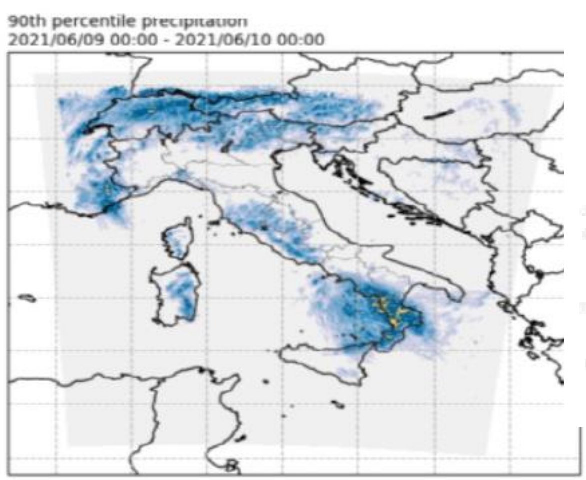


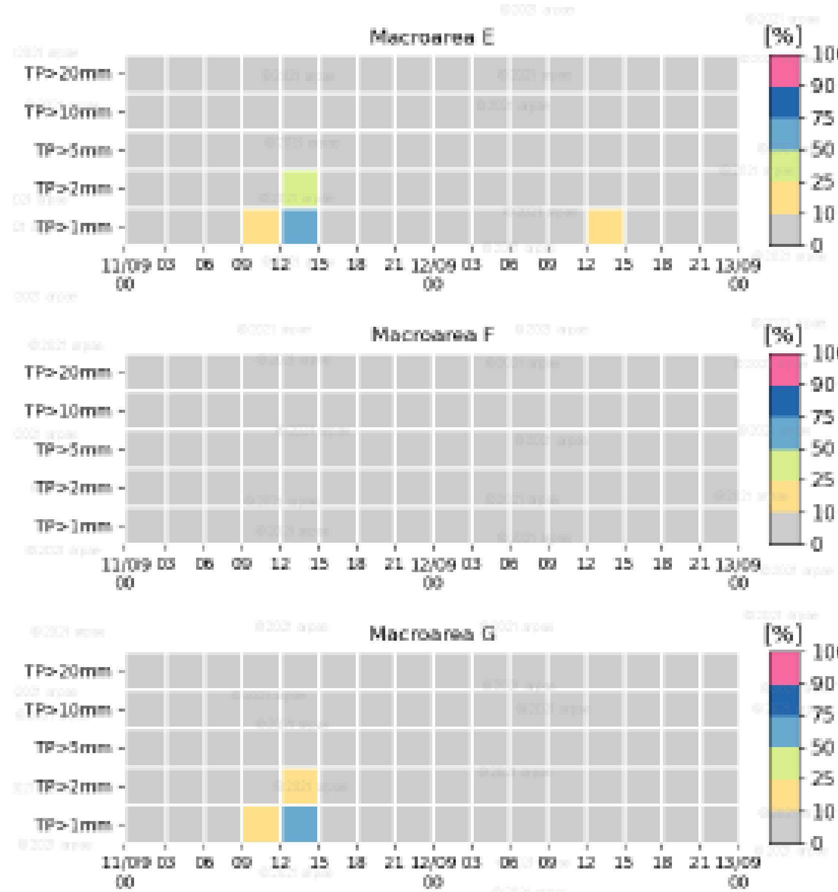
C. Marsigli, V. Poli et al., Arpae-SIMC

COSMO-2I-EPS

- Probability maps
- percentiles







C. Marsigli, V. Poli et al., Arpae-SIMC

Final remarks

- The transition of the ensembles to ICON is on-going
- Model perturbation schemes are further studied / developed /tested
- The ensemble development is becoming more and more part of the numerical modelling development
- It would be needed to invest more in ensemble interpretation and usage
  - ➢ we are all used to take decisions in condition of uncertainty!

Thank you for your attention!