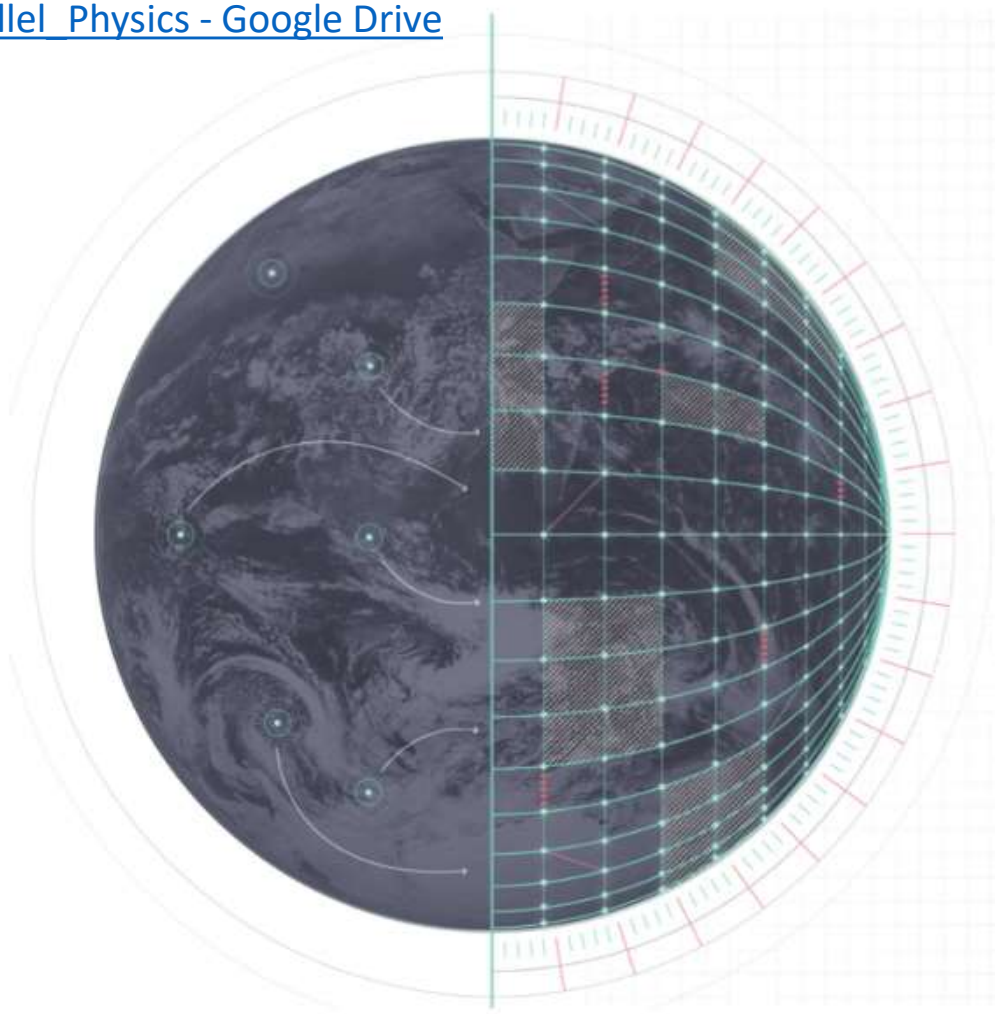
Summary of parallel physics session

Mike Bush, Kristian Pagh Nielsen, Matthias Raschendorfer

Parallel_Physics - Google Drive



DESTINATION EARTH

Forecasting PV power production

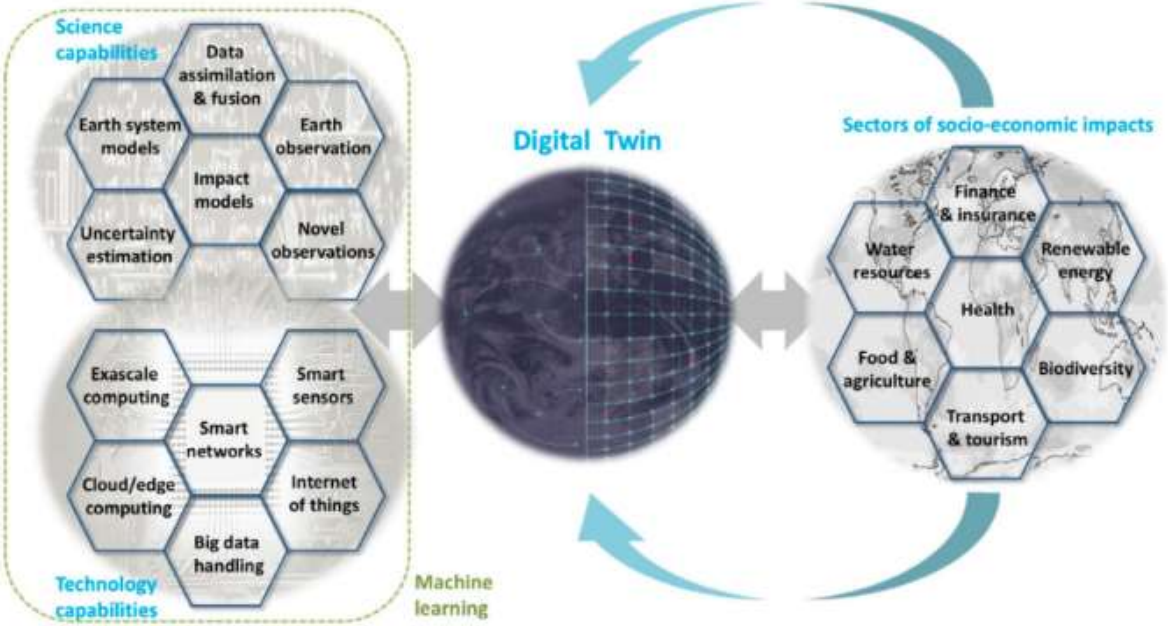
Kristian Pagh Nielsen, DMI

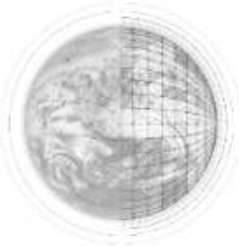
45th EWGLAM and 30th SRNWP Meeting, Reykjavik, 2023-09-27

Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT

DESTINATION EARTH

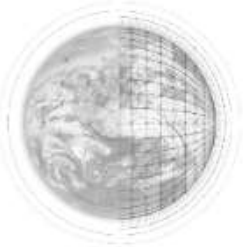
Digital Twin





- Digital Twin for Weather induced and geophysical extremes consists of two main components:
  - Global continuous digital twin component (ECMWF)
  - On-demand extremes digital twin (DE_330_MF project consortium led by Météo-France)

Impact: PV production



- Photovoltaic (PV) production is given in kWh
- NWP models produce SW↓ (at the surface)

Image from
iea.pvps.org

Data

- PV production data from Energinet.dk – the Danish TSO
- … from 2017 onwards
- 15 minute resolution
- 98 Danish municipalities (GDPR)

- Corresponding we have hourly SW↓ (or GHI) observations from 26 stations, and from the operational model

Summary

- Through **Empirical Parameterizations**, established model parameters P are **substituted** by functions of the
  - **model state** ϕ : $P_{\pi}(\phi)$ <-> "hyper-parameterization" **or**
  - **model error** $\Delta\phi$: $P_{\tilde{\pi}}(\Delta\phi) = f^{P}_{\tilde{\pi}}(\Delta\phi) \cdot P^{0}$ <-> "**Adaptive Parameter Tuning**"

Estimated from **DA** increments

Establishes parameter value

Equal "1" at vanishing DA increments => adapts "qualitatively" (but not "quantitatively") to running model improvement

- This is done, if **optimal values** of the original parameters P appear still to be dependent on some circumstances (that means the **grid scale model state**)
- This indicates that the **original parameterization function** $F_P(\phi)$ is so far **incomplete!**
- The **missing dependency** on ϕ can be introduced by **empirical information** taken from **verification** or **DA**
- The **empirical amendment-functions** are so far derived by **expert tuning**, introducing some **new parameters** π or $\tilde{\pi}$
  - ➢ Should be substituted by **automatic AI/ML methods** in order to be fully **adaptive** to running development of physics **!?**

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Process-Based Climate Model Development Harnessing Machine Learning: I. A Calibration Tool for Parameterization Improvement

Fleur Couvreux, Frédéric Hourdin, Daniel Williamson, Rom
Najda Villefranque, Catherine Rio, Olivier Audouin, James Salt

First published: 07 December 2020 | https://doi.org/10.102

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First published: 04 December 2020 | https://doi.org/10.1029/2020MS002225 | Citations: 12

This article is a companion to Couvreux et al. (2020), https://doi.org/10.1029/2020MS002217.

Discussion

- During the discussion the concern was raised that empirical parameterizations could cause some over-tuning of parameters in terms of an intractable network of error-compensation.
- Matthias stressed the point that the empirical amendment functions are intended to introduce additional knowledge (gained by verification) in a COMPLEMENTARY sense.
- ADP is already designed accordingly, as its impact vanishes at vanishing DA-increments.

COSMO Science Plan 2015-2020 about

Empirical extensions of physical parameterizations:

6. Physics

Author: Matthias Raschendorfer (DWD)

General aspects

Future challenges

For the scope of this science plan we are aware of the following general challenges:

ix. **Improving model diagnostics** and developing methods of an **objective determination of optimal parameter values**. In the long run we're thinking also about a kind of **statistical hyper-PM**, in order to remove the **remaining dependency of model parameters on the model state**, what always is a characteristic **of incomplete physical PM schemes** (see chapter 11.2 about "**Processing verification feedback on model development**").

11.2 Processing verification feedback on model development: WG 1, 3a, 3b, 4, 5, 7

Authors: Matthias Raschendorfer (DWD), Flora Gofa (HNMS), Christoph Schraff (DWD)

Basic scientific background, motivation and strategy

Evidently, Physical Parameterisations (PMs) can't be developed solely by **analytical derivation**. Rather they must be based on various **assumptions** and related **effective parameters** in order to close the system of **discretised model equations**. As a consequence, … **measurements** used for **data assimilation** and **model verification** are the best available estimate of atmospheric observables and thus should be used for the purpose of model development as well. This issue may be called "**verification with feedback**" and requires the implementation of **specific procedures**.

Consequently, **3D component testing** needs to be **integrated into data assimilation runs**. In such an approach, the **error estimate** for the model (component) should be based on **assimilation increments**.

[Usually], … optimal values for the "**internal parameters**" are not constant in space and time or "external parameters" are not only dependent on external conditions. Rather these parameters are likely to **depend on the model state itself**. In this case, it might be a further strategy to express each **physical parameter** by a **regression function** of some model variables dependent on a few **regression parameters** substituting the prior **physical parameter**. This could be called "**automatic parameterisation**" or "**statistical hyper-parameterisation**" and is a kind of natural consequence of most likely always incomplete physical parameterisations.

Empirical Extensions of Physical Parameterizations:

non-confident model parameters:
- treated as a constants
- turn out to be functions of the model state (including gradients)

any derived variable of a specific SGS process

estimated model errors

$$\psi = F_{P_\pi(\phi)}(\phi) = \tilde{F}_{\pi}(\phi) = F_{P_{\tilde{\pi}}(\Delta\phi)}(\phi)$$

new parameters of a statistical **hyper-parameterization**

new parameters of an **Adaptive Parameter Tuning**

Current incomplete parameterization function

Desired **complete** parameterization function

❖ **Expectations** related to $P_{\tilde{\pi}}(\Delta\phi)$:

- It is dependent only on a **few sensitive components** of full $\Delta\phi$!

➢ It is easier to find than $P_{\pi}(\phi)$!

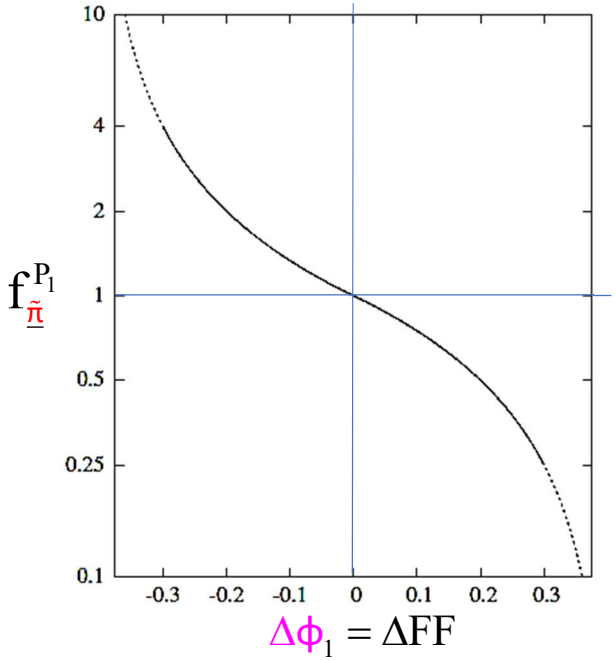
Adaptive Parameter Tuning (ADP) by Günther Zängl:

- **Time-filtered DA-increments** $\Delta\phi_i$ of $\phi_i \in$

i =	1	2	3		4
	FF	T	RH	and	$T \cdot \cos\left(2\pi \frac{t_{local}}{\Delta t_{day}}\right)$
	FF10M	T2M	RH2M		
	FF	T	RH	and	T -amplitude

at the **lowermost model level**

  - **Dominated** by **measurements** of
  - **Proxies** for **local systematic error** of **adapting to weather condition**
  - **Used** as **predictors** for **multiplicative** **empirical correction-factors** $f_{\underline{\tilde{\pi}}}^{P_j}\left(\Delta\phi_{1,\ldots 4}\right)$ **for uncertain parameters** P_j **:**



P_1 : **Land-use roughness** and **SSO blocking tendency** $\Delta\phi_1$

P_2 : **Minimal evaporation resistances of bare soil** and **plant stomata** $\Delta\phi_{2,3,4}$

P_3 : **Heat-conductivity** and **-capacity** $\Delta\phi_4$

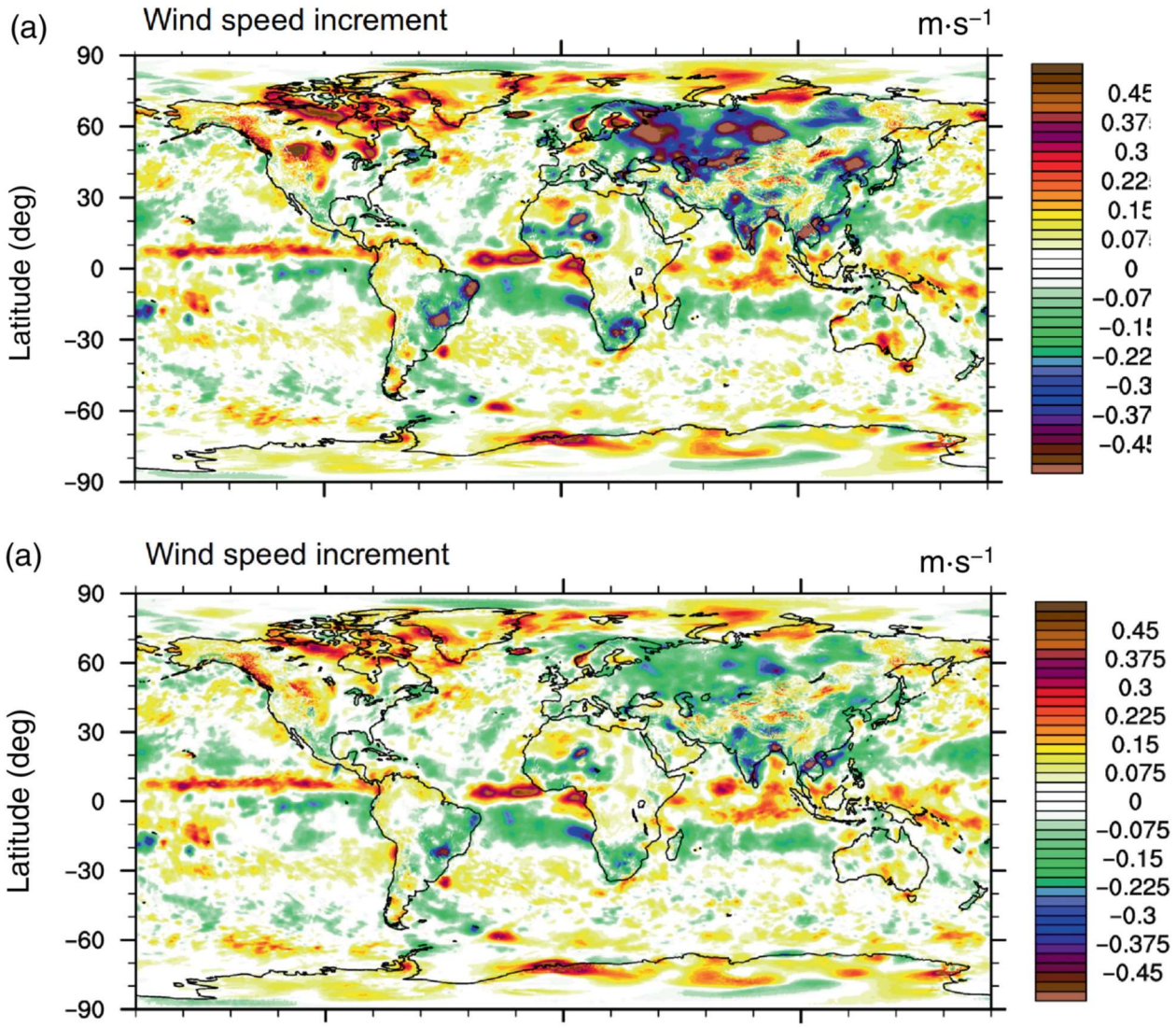
P_4 : **Snow-albedo** $\Delta\phi_2$

P_5 : **Minimal diffusion coefficient** $\Delta\phi_{2,4}$

$$P_j = f_{\underline{\tilde{\pi}}}^{P_j}\left(\Delta\phi_{1,\ldots 4}\right) \cdot P_j^0$$

default value of **(internal global** or **external local) parameter**

https://rmets.onlinelibrary.wiley.com/doi/10.1002/qj.4535



Reference:

Filtered assimilation increment
without APT

for ICON (13km, 90 level)
at lowest level
averaged over each day of November 2020

New routine:

Filtered assimilation increment
including APT

provided by Günther Zängl

A general problem that may be tackled by AI/ML:

- **Non-adaptive empirical measures** partly **counteract ConSAT** development
  - Particular **over-tuning** of some **direct parameters** $\underline{P}$
  - **Static** empirical **hyper-parameterizations** with **fixed** internal parameters $\underline{\pi}$

  always **adapted to present model errors** (**partial error-compensation**)!

- **APT automatically adapts** to improvement by **classical parameterization qualitatively**
  - **Retuning** of APT **scaling-functions** $f^{P_1}_{\underline{\tilde{\pi}}}$ required for **quantitative optimization**

➢ **Automatic optimization** of remaining parameters $\underline{P}$, $\underline{\pi}$ or $\underline{\tilde{\pi}}$ should b e a matter for **ML/AI !!**