EGI Conference 2024
Lecce, Italy
30.9.2024 – 4.10.2024

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Docker container in DWD's Seamless INtegrated FOrecastiNg sYstem (SINFONY)

M. Zacharuk, S. Ulbrich, L. Josipovic, C. A. Welzbacher, U. Blahak, SINFONY-Team

*At German Meteorological Service the SINFONY project has been set up to develop a seamless ensemble prediction system for convective-scale forecasting with forecast ranges of up to 12 hours. It combines Nowcasting (**NWC**) techniques with numerical weather prediction (**NWP**) in a seamless way. So far NWC and NWP run on two different IT-Infrastructure levels. Due to the data transfer between both infrastructures, this separation slows down the SINFONY, makes it complex and prone to disturbances. These disadvantages are solved by applying the interconnected part of the SINFONY on a single architecture using Docker Container.*

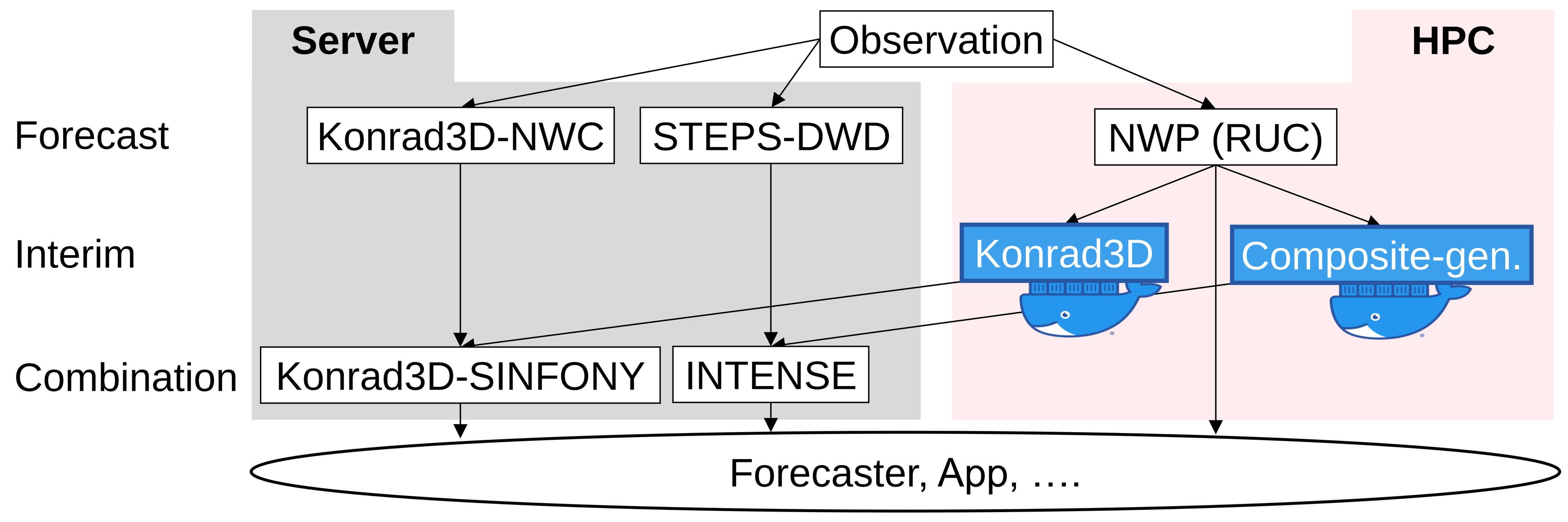

*Fig. 1: Schematic view of the **(runtime) SINFONY-System** for the combined forecasts. It contains two NWC procedures STEPS-DWD (based on composites) and Konrad3D-NWC (based on cell objects) both executed on the Level 2 (Server) infrastructure (grey region) and the NWP (RUC) procedure executed on the Level 1 (HPC) infrastructure (red region). The RUC-forecast itself is published. Besides that it is used for the combination with the NWC forecasts and for that further processed in the Interim step. Here cell objects of the RUC forecast are generated using Konrad3D and composites are generated using Composite-generation. Both Procedures are containerized indicated by the Docker wale ( ). The RUC-cell-objects are then combined with the Konrad3D-NWC-cell-objects (Konrad3D-SINFONY) and the RUC-composites are combined with STEPS-DWD-composites (INTENSE).*

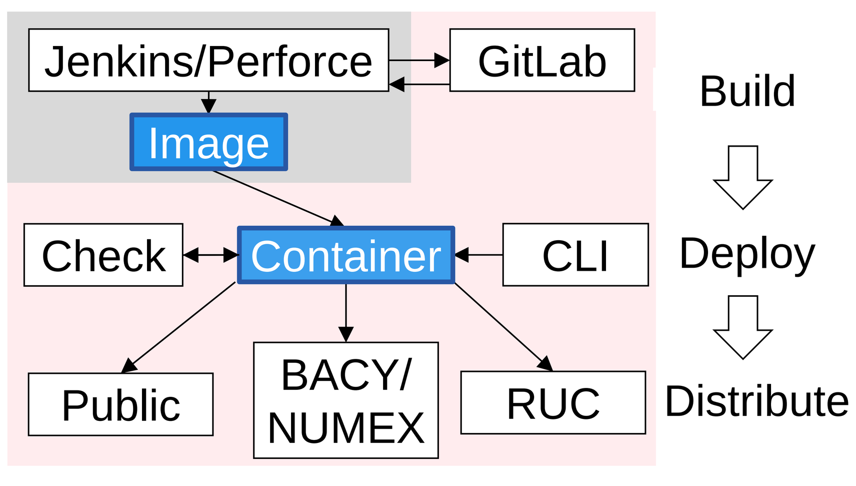

*Fig. 2: **CICD-workflow** to update container. Infrastructures are indicated as in Fig. 1 (red & grey region). During build stage the installation package is created with Jenkins/Perforce. The Image is build using GitLab and archived with Perforce. During the Deploy stage the container corresponding the new image is executed using the CLI and checked using reference data. If the new container is accepted it is then distributed to users at DWD directly and implemented to DWD's test environments BACY and NUMEX and RUC.*

DWD's Forecasting Procedure

The weather forecasting system at Deutscher Wetterdienst (**DWD**) is divided into two so far independent prediction procedures.

There is one procedure for a short forecasting range up to 2 hours and rather small spatial scales, the Nowcasting (**NWC**). The NWC focuses on extreme weather events like convective cells with special interest in precipitation forecasts.

There is another forecasting procedure for longer ranges up to 14 days on a global scale, the classical numerical weather prediction (**NWP**). Here the focus is on predicting variables like surface pressure, wind, temperature and humidity. Currently ICON is the global model of DWD with a nest over Europe and a limited area domain covering Germany. This is at the same time the model domain of SINFONY.

SINFONY

In DWD's **S**eamless **IN**tegrated **FO**recasti**N**g s**Y**stem (**SINFONY**) we introduce various further developments to both NWC and NWP. For NWP a major piece is the rapid update cycle (**RUC**), an hourly refreshing NWP procedure, which is technically operationalized already.

Among this and other developments the combination of RUC with NWC is one of the major tasks of SINFONY. We elaborate this combination at three steps in the forecasting system:

- One step is introducing **composites** (simulated radar fields) and cell objects into the data assimilation cycle. Whereby the composites are created using NWC's Composite-generator and the **cell objects** are created using NWC's Konrad3D.

This procedure is still developed in **BACY** (DWD`s test environment) and far from operationalization. By that we focus on the following two steps. These steps are subsequent to the RUC with the aim to produce **combined forecasts** of RUC and NWC (*Fig.1*):

- One procedure (**Konrad3D-SINFONY**) combines cell objects of the RUC forecast with cell objects of the Konrad3D-NWC forecast.
- The other procedure (**INTENSE**) combines RUC composites with NWC forecast composites created with STEPS-DWD.

So far both combined forecasts outperform the individual NWP and NWC forecasts.

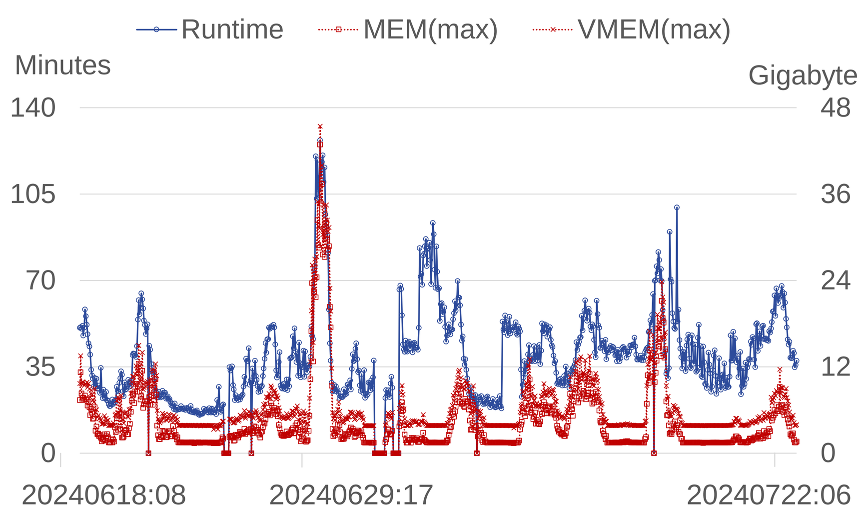

*Fig. 4: Analysis of **procession** of hourly **RUC** forecast using **Konrad3D.** Shown is the procession time (blue, left axis), maximum memory consumption (MEM(max), right axis) and maximum virtual memory consumption (VMEM(max), right axis).*

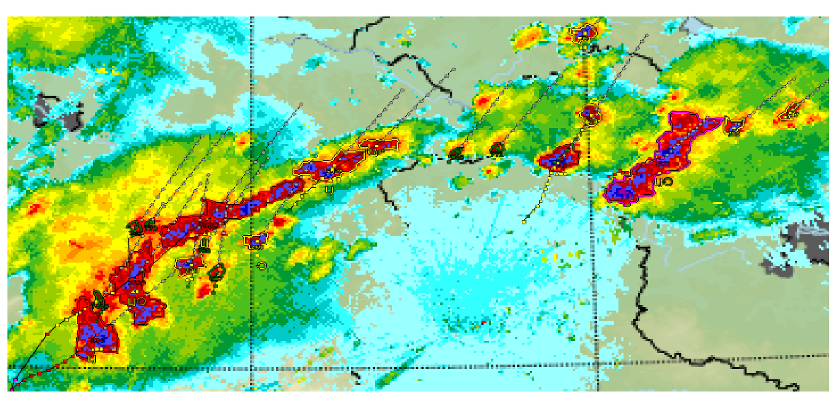

*Fig. 5: **Observed** single elevation radar **composites** (colored region) and konrad3d cell objects (bordered regions) with cell propagation (connected dots) of **2024-06-29:2215 UTC***

IT Infrastructure of NWC & NWP

Technically challenging for SINFONY is the separation of NWC and NWP on two different IT-Infrastructures. NWC is executed on a cluster of independent high performance (virtual) **servers** with an on demand oriented relatively volatile work load. NWP is executed on a classical batch high performance cluster (**HPC**) with a daily repeating sequence of forecast routines and by this with a rather predictable work load.

Container @ SINFONY

To reduce the complexity of SINFONY Konrad3D and Composite-generator are both ported the HPC. For this we use (Docker-/Apptainer-) **Container**, which are efficient stand alone executables of the NWC components including all dependencies.

A container is based on a corresponding **Image**. The Image is build with GitLab using KANIKO based on an installation package generated with Jenkins/Perforce. New Images are evaluated on the HPC. All these steps are integrated in an automatized **CICD** (Continuous Integration Continuous Deployment) procedure, see *Fig.2*.

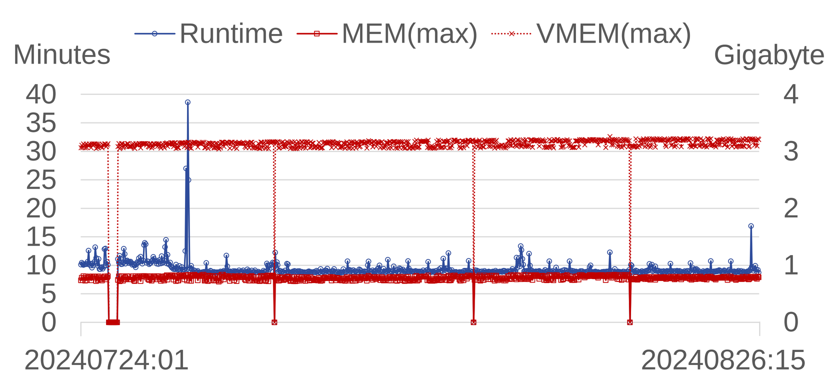

*Fig. 6: Same as Fig. 4, but for **composite generation**.*

Container-runtime

To execute the Container based on the Container-Image we use the **Apptainer** runtime environment, which is particularly developed for HPC container applications. Executing apptainer is controlled by the Command line user Interface (**CLI**), which translates NWC native commands to (Apptainer-) container commands. In consequence, users do not even notice a difference between native and containerized execution, see *Fig. 3*.

```
# Activate Container@DWD
PATH=$PATH:/hpc/uhome/for0exp/…..
# Available NWC Tools
composite_generation --{options}=…
motion_vector_calculator --{options}=…
Konrad3d  --{options}=…
```

*Fig. 3: **Example commands** demonstrate how to access and use container on Level1 (HPC).*

Technical Evaluation

For both combined forecasting procedures the containers are technically evaluated in a pre-operational procedure. Here the hourly produced RUC-forecasts are loaded as soon as they are available and both the cell objects and the composites are generated in two individual jobs.

Runtime and (virtual-) memory consumption for the object generation is shown in *Fig. 4,* where both show a dynamic behavior, since Konrad3D depends on the weather situation. A visualization of one observed section (single elevation composite) of the most expensive calculation (20240629:17 UTC init) is shown in *Fig. 5*. The calculation is way too slow, since it clearly exceeds 1 hour and it is currently computationally too expensive. These two issues have to be addressed in the next steps.

A similar plot as *Fig. 4* for calculating the composites is shown in *Fig. 6*, however this experiment is executed with the numerical experimental System of DWD (**NUMEX**). The composition is independent of the weather situation, computationally cheap and sufficiently fast. Runtime scales 1:1 with the used parallel resources, so a further speed-up is accessible and will be used depending on the project requirements. As the next step the generated composites will be integrated to INTENSE.

Apptainer : https://apptainer.org
Docker: https://www.docker.com/
ICON: Zängl, G. et al. (2015). The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core. *Q. J. R. Meteorol. Soc.* 141, 563–579
INTENSE: D. Nerini at al. (2019). "A Reduced-Space Ensemble Kalman Filter Approach for Flow-Dependent Integration of Radar Extrapolation Nowcasts and NWP Precipitation Ensembles". M. W. R., V. 147, I. 3
Kaniko: https://github.com/GoogleContainerTools/kaniko
Konrad3D:https://www.dwd.de/DE/forschung/wettervorhersage/met_fachverfahren/nowcasting/konrad_node.html
STEPSDWD: R. Reinoso-Rondinel (2022), "Nationwide Radar-Based Precipitation Nowcasting—A Localization Filtering Approach and its Application for Germany". IEEE, V. 15
SINFONY:https://www.dwd.de/DE/forschung/forschungsprogramme/sinfony_iafe/sinfony_node.html

Research and Development, Division 13 (Numerical Models)
Email: Matthias.Zacharuk@dwd.de