Platform for **A**dvanced **S**cientific **C**omputing (**PASC**) Conference 2023
Davos, Switzerland
26.6 - 28.6.2023

DWD
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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

M. Zacharuk, C. A. Welzbacher, N. Rathmann, I. Schnoor,

C. Eser, F. Prill, U. Blahak, SINFONY-Team

At Deutscher Wetterdienst (DWD), 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.

Container-Image

A container is based on a Container-Image, which is build in advance on a build environment. Since we are restricted to user permissions we can not build this image on the NWC- or on the NWP-Infrastructure. Due to that we build the image in GitLab using the KANIKO tool.

To set up the Container-Image an installation package of the NWC-tools is used. This package is generated with Jenkins and versioned using perforce in a Continuous Integration Continuous Deployment (CICD) procedure.

Within this project the CI procedure is expanded by coupling GitLab with Jenkins. The CD procedure is closed by establishing an evaluation procedure of newly created Container-Images on the NWP-Infrastructure.

With these two extensions of the CICD procedure we minimize effort for frequent updates of the Container Image which will pay off during the long term perspective of SINFONY.

Container-runtime

To execute a Container based on a Container-Image a runtime environment is necessary. On the HPC at DWD we use singularity (sylabs), which allows to execute containers almost in the same way as regular executables. Singularity is particularly developed for HPC container applications and, among other benefits, allows container executions with user permissions.

Singularity separately converts the beforehand constructed Docker-Container-Image into a singularity-Container-Image. This conversion is included in the above mentioned CICD procedure with GitLab, which allows us to archive the singularity-Container-Image with Jenkins.

The containers data access on the host file system is restricted, so that write permissions of all containers are limited to one prespecified output folder. To control NWC-tools inside the containers the same commands are used as for native execution on the NWC-Infrastructure, which allows direct support of NWC developers.

In applications we observed 20% faster runtime of Konrad3D executed inside the Container on the NWP-Infrastructure compared to executing Konrad3D on the NWC-Infrastructure. Even though this speed up can be explained by hardware differences of both infrastructures and/or the applied resources, it proves that containers are the proper tool for SINFONY to port NWC tools.
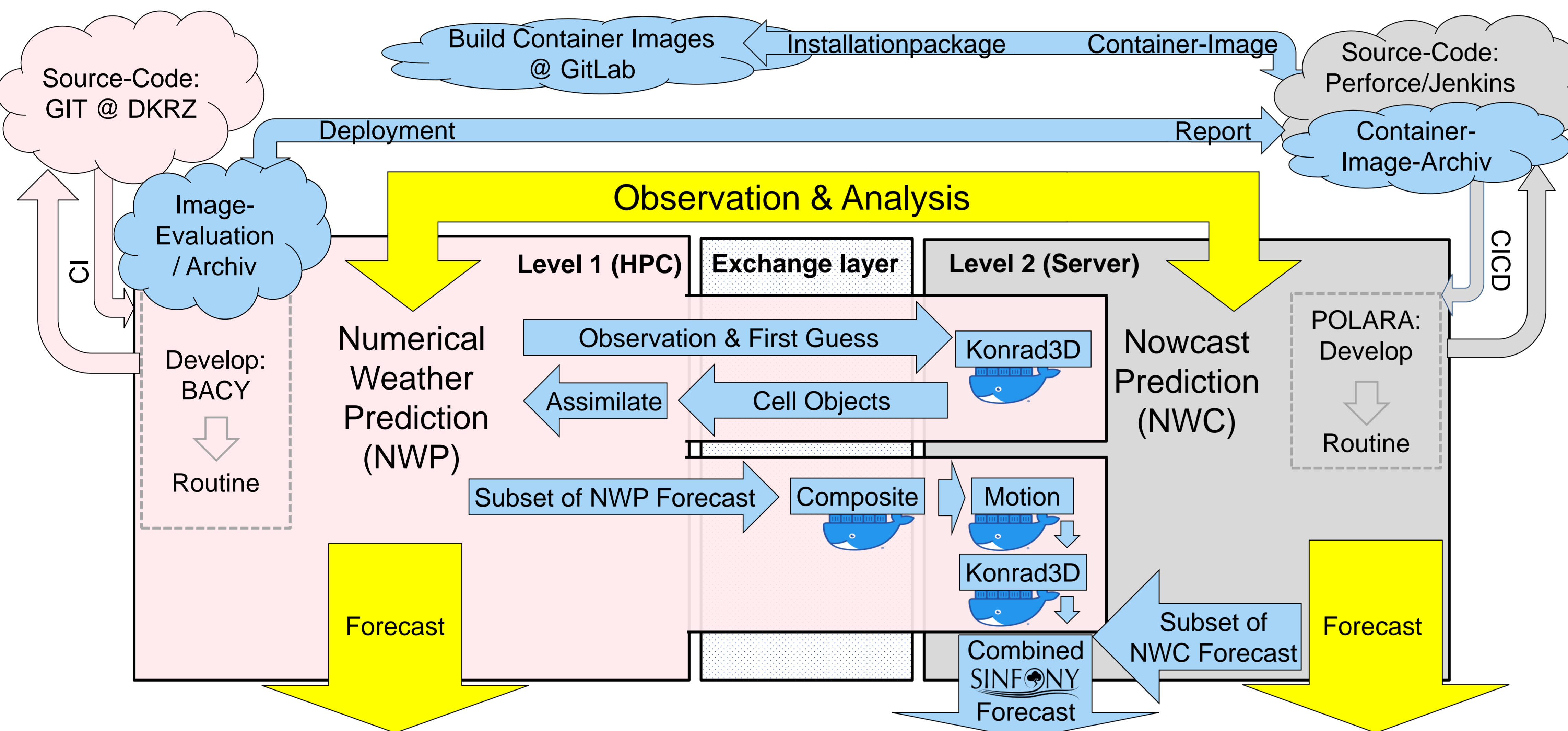

Fig. 1: The SINFONY-System: The general procedure of DWD's Forecast-System containing NWP, NWC and SINFONY. Red, grey and dotted boxes indicate DWD's infrastructure. Yellow arrows indicate NWP & NWC data-streams (in & out). Clouds indicate DWD's source-code infrastructure and red/grey arrows it's connection with the NWP and NWC Forecast-System. All blue elements represent newly introduced SINFONY components located at the respective infrastructure. Blue blocks are SINFONY elements introduced to the DWD's Forecast-System. Blue clouds represent container-CICD elements and Blue arrows show SINFONY data-streams and dependencies. Processes carried by the docker wale (🐳) are migrated from level 2 to level 1 using Docker-Container.

DWD's Forecasting Procedure

At Deutscher Wetterdienst (DWD) the weather forecasting system 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.

In a comparison of both procedures the NWC outperforms the NWP on short forecasting ranges up to about two hours, whereas for longer ranges the NWP is clearly superior.

SINFONY

In DWD's Seamless Integrated ForecastiNg sYstem (SINFONY) we introduce various further developments to both NWC and NWP. Among other developments the combination of both is one of the major tasks of SINFONY. We elaborate this combination at two steps in the forecasting system:

- One step is the **assimilation** cycle of the NWP. Here the NWC's cell detection routine konrad3d is introduced, which is used to detect cell properties of observations and NWP first guess fields.
- At the other step the NWP forecast is analyzed with NWC techniques. Here we use a (radar) composite generator to create simulated radar fields, a motion vector calculator, which estimates associated velocities, and the cell detection routine konrad3d. In the subsequent combination with NWC forecasts the seamless **Combined SINFONY Forecast** is generated, which so far shows better forecast scores than NWP and NWC individually.

IT Infrastructure of NWC & NWP

Technically challenging for SINFONY is the separation of NWC and NWP on two different IT-Infrastructure levels. 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 with a daily repeating sequence of forecast routines and by this with a rather predictable work load.

In case, that both procedures remain on their initial infrastructure levels SINFONY is faced with two challenges:

- Data transfer (potentially slow)
- Complex and by that fragile solution

Docker-Container @ SINFONY

Both challenges do not come into play, if the NWC components are executed on the same IT-Infrastructure as the NWP. For this we use Docker-Container, which are efficient stand alone executables of NWC components including all dependencies. These containers facilitate the application of NWC components on any IT-Infrastructure and by that it is the proper tool to port NWC tools from the NWC-Infrastructure to the NWP-Infrastructure.

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
Kaniko: https://github.com/GoogleContainerTools/kaniko
Konrad3D: https://www.dwd.de/DE/forschung/wettervorhersage/met_fachverfahren/nowcasting/konrad_node.html
Singularity: https://sylabs.io/singularity