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NWM forecast monitoring with (near) real-time GNSS tropospheric products

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Abstract

During the last two decades, Global Navigation Satellite System (GNSS) has proved to be a highly efficient and weather-independent technique for monitoring the state of the troposphere. The GNSS-based tropospheric products estimated in near real-time (90min delay) within the E-GVAP project (egvap.dmi.dk) are today operationally assimilated into numerical weather forecasting systems at several meteorological institutions. Ultra-fast (sub-hourly) or even real-time GNSS tropospheric products are also available from several analysis centers now, see the Real-Time Demonstration campaign of the GNSS4SWEC project (gnss4swec.knmi.nl). However, (near) real-time ground-based GNSS tropospheric products can be also useful for the monitoring or long-term assessment of the quality of numerical weather predictions (NWP). We initiated a routine derivation of GNSS tropospheric parameters from the high-resolution NWP model, and we assess the quality of the prediction length with respect to the GNSS products. A potential of NWP-based tropospheric corrections for utilization in GNSS real-time applications, such as positioning, navigation and timing, is evaluated.

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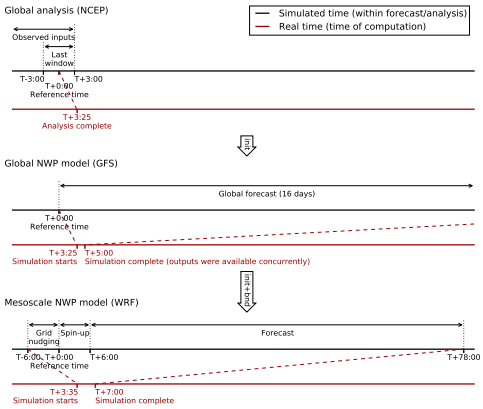
NWM forecasts, ICS WRF operational scheme

The Weather Research and Forecasting (WRF) model is a mesoscale numerical weather prediction system with two dynamical cores, ARW and NMM, a data assimilation system and a software architecture facilitating parallel computation and system extensibility.



ICS WRF characteristics:

- domains: D01/EU (9x9km), D02/CZ (3x3km),
- Lambert Conformal Conic grid,
- 38 vertical levels: top level at 50 hPa,
- four forecasts per day: 00, 06, 12, 18 UTC,
- 1-hour forecasts resolution up to 72 hours.

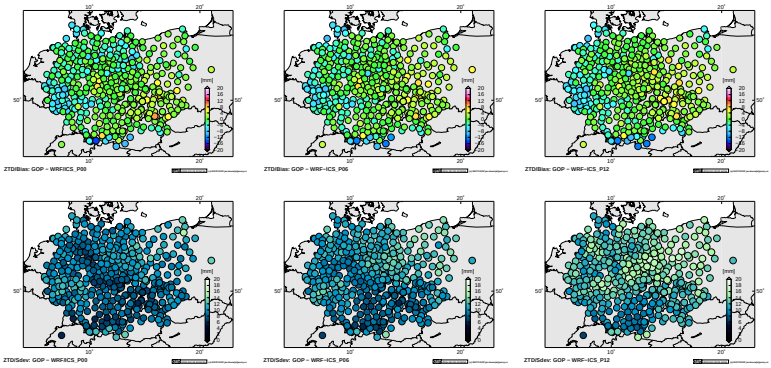
ICS WRF parameters feeding GNSS tropo-model:

- base+perturbation pressure at model levels,
- base+perturbation geopotential at model levels,
- water vapour mixing ratio at model levels,
- temperature at model levels,
- surface pressure,
- terrain height.

Upper part of the figure displays the GFS global model runs four times daily starting at times 00, 06, 12, 18 UTC (data are collected within a 6-hour around synoptic time T). The global model runs forecasts for increasing time horizons up to 14 days (middle part) and the results are successively uploaded until about T+5h. The mesoscale WRF model (bottom part) starts its simulation run at the synoptic time T using previous analysis (T-6h) and the time window from T-6h to T. The so called grid nudging is performed while the mesoscale model reaches a state in time T, being a downscaled analysis. The mesoscale simulation starts at approximately T+3h 35min real time and during the grid nudging and the subsequent spinup phases, the mesoscale model simulation catches up the real time, (T+4h 30min). At about T+7 real time the forecast horizon T+78h is produced.

NWM tropo-model dependence on the forecast length

To study the dependence of augmentation tropospheric correction model performance, we calculated hourly statistics over 14 days in 2013 (May/June) using different NWM predictions: 0-6h, 6-12h and 12-18h from the analysis. Figures show geographical plots of biases (top) and standard deviations (bottom) for all prediction windows (left to right).



G-Nut/Shu and NWM data processing

G-Nut/Shu software has been developed at GOP for generating tropospheric correction models using NWM data fields. The software is designed to support flexible functions (selection):

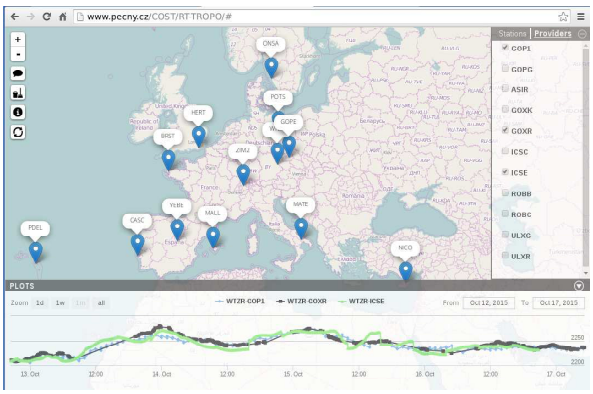
- handle NWM products: ERA, WRF, ALADIN, HARMONIE, GFS (GRIB/NETCDF), parameters, coordinate systems, etc.,
- calculate selected tropospheric and meteorological parameters for requested area (grid) or user location (GNSS stations),
- support variants of temporal and spatial interpolation methods (linear/bi-linear/spline, vert2hor/hor2ver/integration . . .)
- apply different approaches for vertical parameter fitting (power/logarithmic, height-/pressure-dependent, . . .),
- use various ZWD surface calculations (integration, Askne-Nordius, GOP-ZWD/GOP-AN model variants,. . .),
- exploit variants of ZWD vertical scaling (GOP, RTCA-MOPS, . . .)
- model height-pressure relation using fixed/linear/zero T lapse rates,
- refractivity coefficients (SW 1953, TH 1974, BV 1992, FO 1999, RU 2002),
- densify original profile with a multiplication factor,
- adjust surface parameters in vertical parameter approximations,
- estimate tropospheric linear horizontal gradients from ZWD/ZHD grids,
- estimate combination ratio between water vapour and ZWD decays.

Summary statistics and final remarks

The table summarize statistics of the WRF mesoscale model for the two domains in terms of zenith tropospheric delays (ZTD) suitable for providing external tropospheric corrections for e.g. GNSS real-time positioning. Statistics over 14 days and 400 stations of the GNSS4SWEC Benchmark campaign are based on ZTDs calculated from 0-6h, 6-12h and 12-18h forecasts. The summary shows a slow degradation of ZTD accuracy within up to 18h prediction: 9.5-13.5mm (ZTD accuracy degrades roughly at a rate of 1-2%/hour). Significant dependence of mean biases were however not observed. According to the scheme for WRF operational run given above, under standard condition ZTDs usable for real-time GNSS positioning will correspond to prediction of 6-12h.

NWM model	spatial domain	prediction [h]	bias [mm]	sdev [mm]	RMS [mm]
WRF/D01	Europe	0 - 6h	-1.50	9.93	10.42
WRF/D01	Europe	6 - 12h	-0.89	10.95	11.55
WRF/D01	Europe	12 - 18h	-0.51	12.91	13.48
WRF/D02	Czech Republic	0 - 6h	+2.05	9.14	9.84
WRF/D02	Czech Republic	6 - 12h	+2.46	10.33	11.90
WRF/D02	Czech Republic	12 - 18h	+3.20	12.83	13.50

NWM forecast monitoring within RT-Demo campaign



Within the COST ES1206 Action (other presentation) WG1 for Advanced GNSS Tropospheric Products, the demonstration campaign was organized in support of developing and assessing new real-time tropospheric products using ground-based GNSS observations that may be used in numerical or non-numerical nowcasting systems. Besides six GNSS solutions, GOP recently introduced also a contribution for ZTDs calculated from the ICS's NWM forecasts. The monitoring aims at comparing tropospheric parameters available in real time from various GNSS and NWM sources. The web interface in the figure can be found at http://www.pecny.cz/COST/RT-TROPO/.

References:

Dousa J, Elias M (2014) An improved model for calculating tropospheric wet delay, Geoph Res Lett, V41(12):4389–4397.

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