Reprocessed GNSS tropospheric products for regional climate model validation in Southeast Europe

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Introduction

The current study shows some results of a short-term scientific mission (STSM) done at Sofia University, Bulgaria in May 2014 under the COST Action of "Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate". The STSM aimed to start facilitating the use of reprocessed GNSS tropospheric products and comparing them with regional climate model (RCM) results on a longer time-scale. The used GNSS station is Sofia from IGS-repro1, while the RCM was ALADIN-Climate for the common period of 2000–2007. The STSM is a first step in application of GNSS data for long term studies is Southeast Europe and will likely benefit both climate and GNSS communities.

Data

At the Hungarian Meteorological Service (OMSZ), ALADIN-Climate RCM version 5.2 is used and for the current study the results of its 50 km resolution run were applied [1] (the integration domain is shown in *Figure 1*). Using ERA-Interim reanalysis fields [2] as lateral boundary conditions (LBCs) makes possible that climate model can also capture main weather patterns in Europe allowing to investigate shorter climate periods than the 30 years after World Meteorological Organisation reference.

In 2008, the International GNSS Service (IGS) initiated global GNSS data reprocessing campaign, namely IGS-repro1 *[3][4]*, in a fully consistent way using latest methodology. IGS-repro1 tropospheric products for Sofia station are available for 2000–2007. Zenith total delay (ZTD) and gradients are processed with JPL GIPSY/OASIS software. The station is located in the Plana mountain and equipped with an AR25 Leica antenna (*Figure 2*). Surface pressure and surface temperature were derived from the meteorological observation of Sofia at the altitude of 588 m to the GPS Sofia station location and altitude.

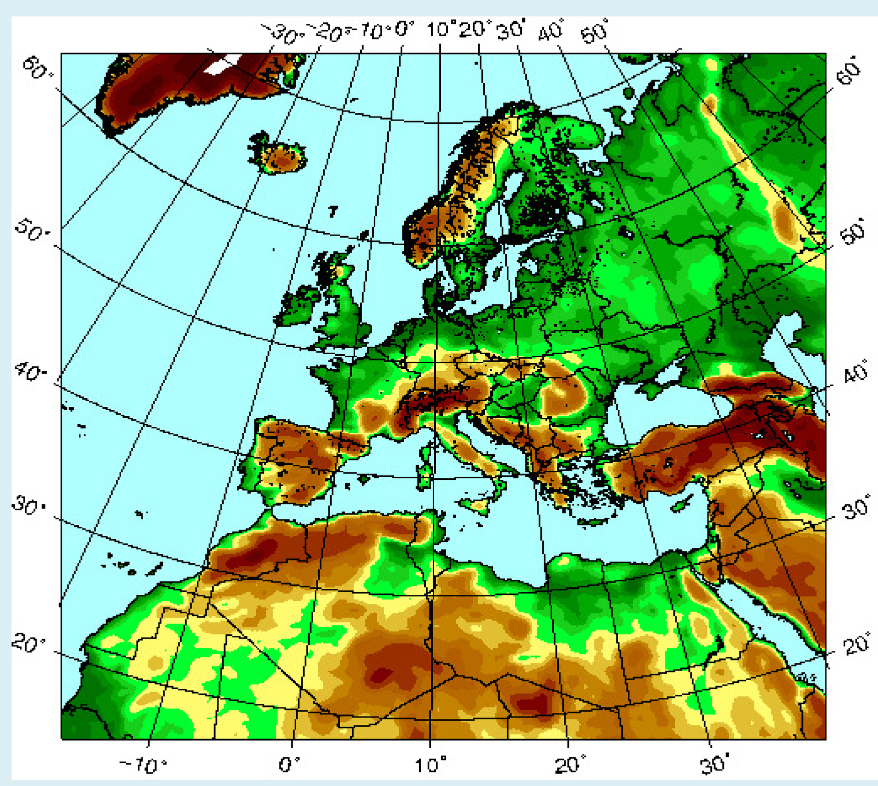

Figure 1. Integration area of ALADIN-Climate 5.2 run at the HMS with the resolution of 50 km.

Figure 2. GNSS antenna at Sofia station.

	latitude	longitude	altitude
G1 model	42.75N	23.25E	877 m
G2 model	42.25N	23.25E	1130 m
GNSS observation	42.56N	23.39E	1120 m

Table 1. Coordinates and height of the investigated model grid points and observation.

Methodology

Two RCM grid points were the closest ones to the GPS site (*Table 1*). Even though G2 is horizontally slightly further from the observation than G1, it is closer to the altitude of 1120 m (the main factor determining ZTD is pressure). 6 hour temporal resolution of the model and observation for the period from 4 January 2000 00UTC to 31 December 2007 18UTC was used. Gaps were identified in the GNSS data and some obvious errors from pressure and temperature were omitted. Our variables of interest were ZTD and integrated water vapour (IWV). ZTD is used directly during data assimilation of numerical weather prediction models, but for validation of climate models IWV is meaningful. The calculation is following Bevis et al. *[5]*.

ZTD
$T_{surface}$
$P_{surface}$
height
latitude

→

$ZHD=2.2768*p_s/F$
$ZWD=ZTD-ZHD$
ZHD-zenith hydrostatic delay
ZWD-zenith wet delay
F-gravitational acceleration variation

→ IWV

Results

- Surface pressure is too high at G1, likewise ZTD is overestimated at G1 by 70 mm, while at G2 by 3 mm which is relatively small to the magnitude of 2000 mm.
- Surface temperature is overestimated at G1 (G2 is better). This virtually does not affect ZTD values, and causes small biases in IWV values. We could recalculate pressure, temperature at G1 into the altitude of 1120 m.

Diurnal cycle

- Annual overestimation of IWV at G1 by 0.36 mm, at G2 underestimation by 1 mm.
- Relatively well simulated diurnal IWV cycle (*Figure 3*). Simulated IWV minimum is simulated at 00UTC, while observed at 06UTC.
- Higher magnitude of the diurnal cycle in the observation than in the model results.
- Means and variances at G1 are slightly closer to the observation than at G2.

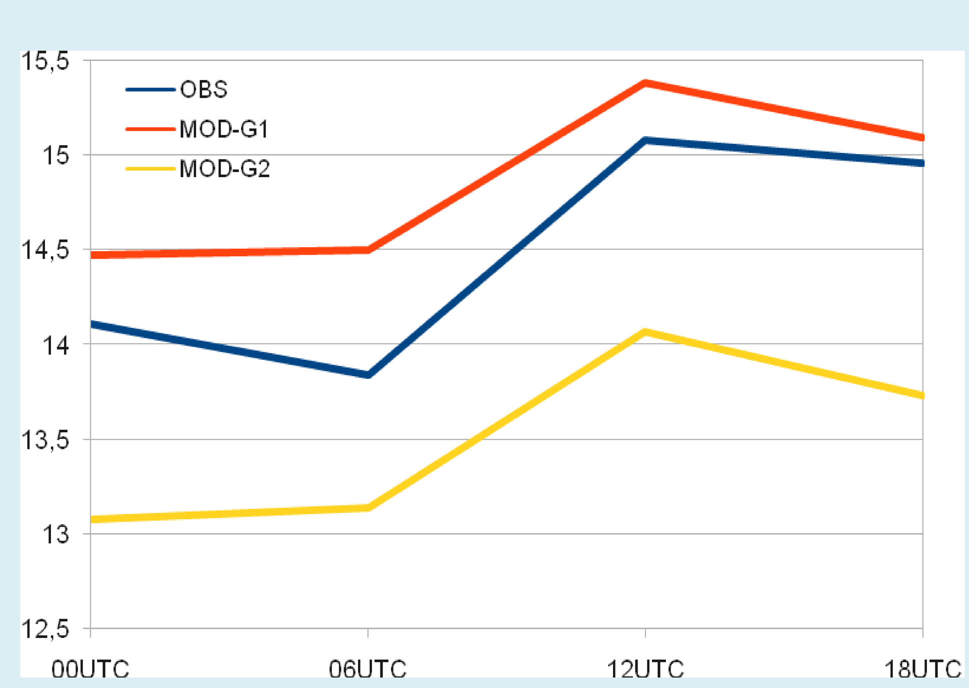

Figure 3. Diurnal cycle of IWV (mm) in GNSS observation (OBS) and model grid points (G1 and G2).

Correlation

- Very high temperature correlation with observation in both model grid points, with no significant difference between them (*Figure 4*).
- Correlation values of simulated ZTD and IWV with observation are lower (0.67-0.75, better values at G2), and they are best at 12UTC.
- Pressure values correlate better at G1 with observation.

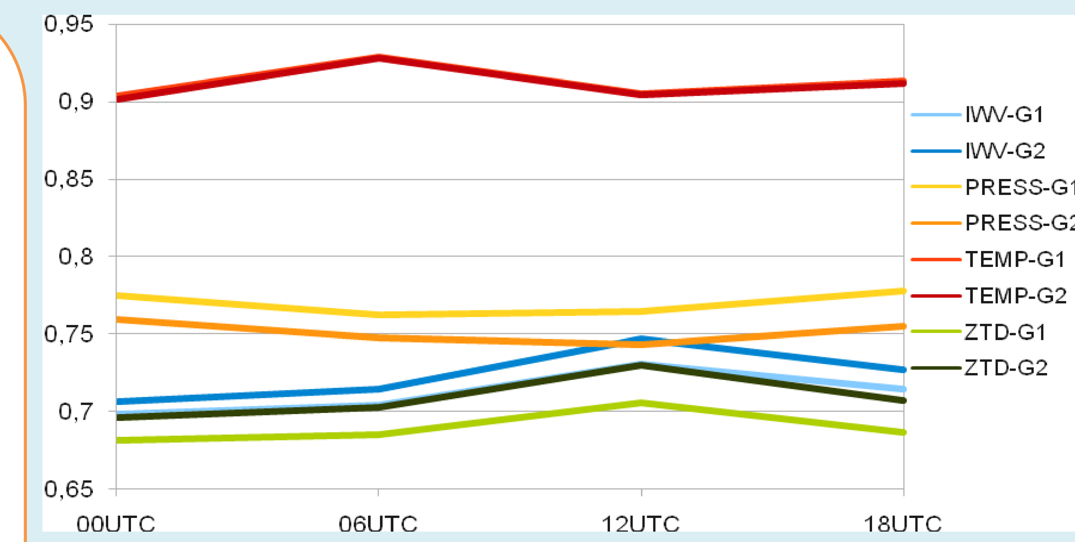

Figure 4. Correlation of observation and model results for integrated water vapour (IWV), surface pressure (PRESS), surface temperature (TEMP) and zenith total delay (ZTD).

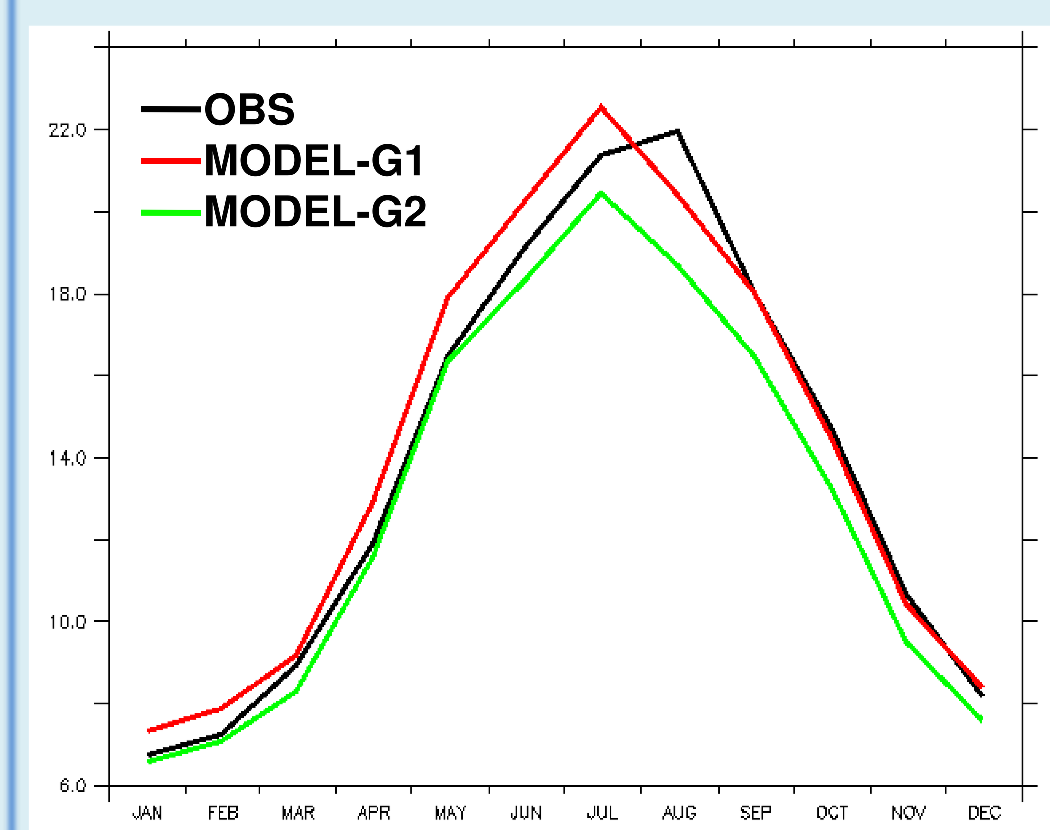

Figure 5. Annual cycle of IWV (mm) in observation and model results.

Annual cycle

- Fairly captured annual IWV cycle is in the model (*Figure 5*).
- Simulated IWV peaks in July, while the observed one in August.
- Larger biases from May to August and from July to November at G1 and G2, respectively.
- IWV at G1 is always 1-3 mm higher than at G2 (G1 is 250 m below G2). In the second half of the year, above the altitude of the observation the atmosphere is not wet enough in the model (IWV at G2 is underestimated and observed values are close to G1).

Event capture

- Simulated IWV follows observation smoothly with some high values at G1, especially during summer. Zooming in, bigger differences on some days can appear (*Figure 6*).
- During the heatwave of July 2007 modelled IWV happen to overestimate by 10 mm the observed ones (on the average of 45 days 20.3 mm in OBS, 22.8 mm at G1, 21.0 mm at G2).
- RCMs with reanalyses LBCs cannot capture all weather events at all points and times, but they supposed to capture these synoptic-scale events better. Systematic investigation is needed.

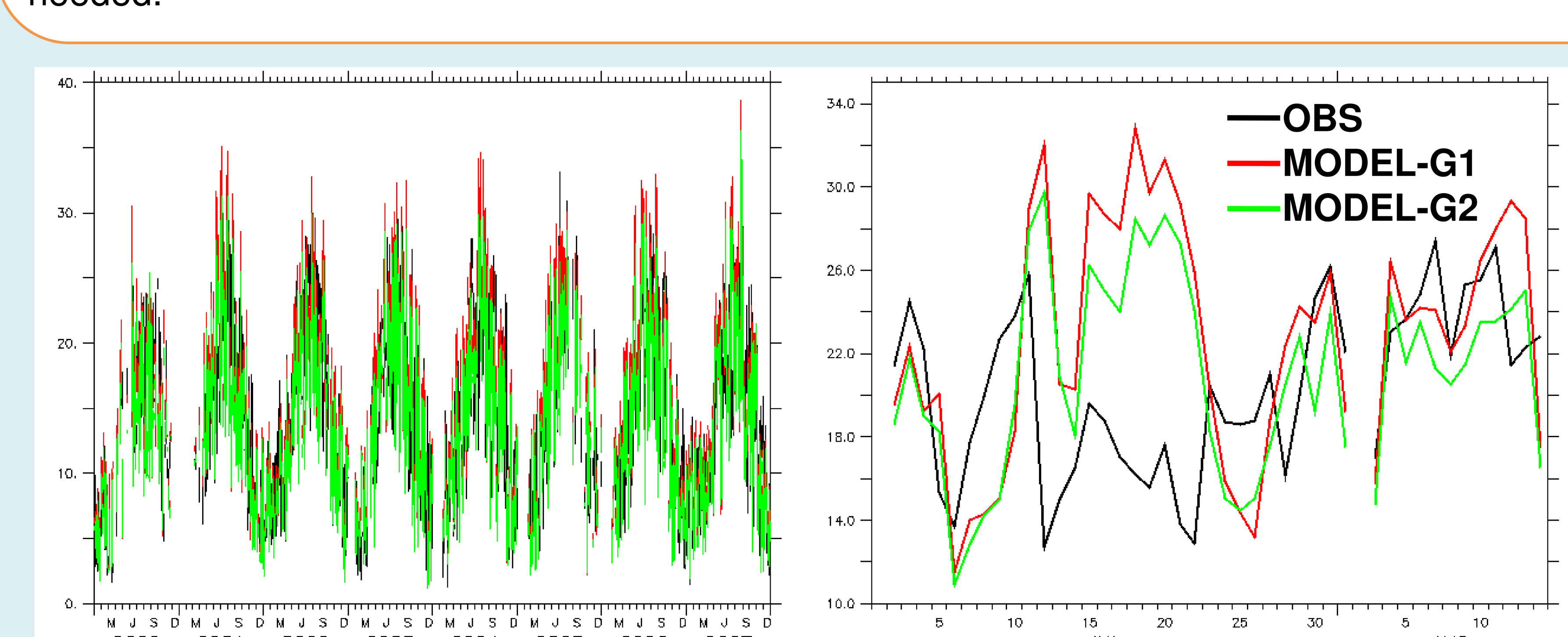

Figure 6. Daily averaged IWV (mm) for observation and model results for 2000–2007 (left) and July-August 2007 (right).

	Observation	Model-G1	Model-G2
35 mm <	0.0	0.26	0.02
25 mm <	7	9	5
15 mm <	45	46	39
5 mm <	93	94	92

Table 2. Percentage of different thresholds of the probability distribution function of IWV.

Thresholds

- No IWV values above 35 mm were observed in Sofia (*Table 2*). At G1 the probability of very high values is 0.26%, while at G2 it is virtually zero.
- Except the threshold of 15 mm, G2 captures better the values for the selected 4 thresholds than G1. Further study on the whole PDF is needed.

Future plans

- To calculate IWV after using surface pressure and temperature from the model and ZTD from the GPS, since G2 is almost at the same altitude as the GPS and pressure and temperature are not formulated, but they are physically consistent variables.
- To investigate lateral boundary conditions (ERA-Interim).
- To analyze more GNSS sites with available meteorological variables, including a more homogeneous period (1995–2007) and stations with different climate in order to test ALADIN-Climate around Europe. The following sites are options: Bucharest (RO), Dubrovnik (HR), Matera or Medicina (IT), Ondrejov (CZ), Onsala (SWE), Potsdam (D), Zimmerwald (CH).

References

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