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IMPACT OF SATELLITE-DERIVED CLOUD COVER ON ROAD WEATHER FORECAST IN THE CZECH REPUBLIC

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Summary

The goal of the contribution is to assess an impact of extrapolated cloud cover derived from satellite observations on forecasts of road surface temperature (RST) and road surface condition (RSC) performed by the road weather model FORTE. By default, the model uses prognostic cloud cover data derived from the ALADIN NWP model and, in cases where these prognoses significantly differ from observations, the FORTE model may produce erroneous RST and/or RSC. This is supported by preliminary results, which show that the inclusion of satellite-derived cloud cover leads to more realistic RST forecasts for several selected case studies.

Introduction

Forecast of road surface temperature and conditions is crucial information for traffic safety in winter conditions. Majority of forecasting methods is based on the application of mathematical models consisting of the heat conduction equation and the energy balance equation [1][2]. The initial model conditions are usually derived from meteorological, surface and subsurface data measured at road weather stations (RWS). Prognostic data derived from a numerical weather prediction (NWP) model form boundary conditions, and they are used to forecast road surface temperatures (RST) and road surface conditions (RSC).

It should be emphasized that cloud cover is a meteorological variable that has the strongest impact on the resulting radiation fluxes into the road surface, and therefore its prediction is crucial for the correct forecast of RST and RSC. In this contribution, the effect of satellite-derived cloud cover on road weather forecasts will be assessed and compared to the standard model setup that use NWP model data only.

Model description

The Institute of Atmospheric Physics (IAP) CAS and the Czech Hydrometeorological Institute (CHMI) have developed and currently run FORTE model for a linearly continuous forecast of RST and RSC on Czech highways. The model stems from the METRo model [1] and differs mainly in detailed check of input data, and radiation fluxes, which are calculated taking into account shadowing of direct sun radiation by obstacles and the impact of sky-view factor [3]. The model uses measured data at RWS, and forecasts of the ALADIN NWP model as inputs to prepare initial and boundary conditions [2][4]. The model utilizes detailed topography (parameters of buildings, woods, orography etc.), which can influence the radiation fluxes. Calculation procedures of the FORTE model using standard (ALADIN NWP model data only) and new (ALADIN NWP model data + extrapolated Cloud Mask) schemes is shown in Fig. 1.

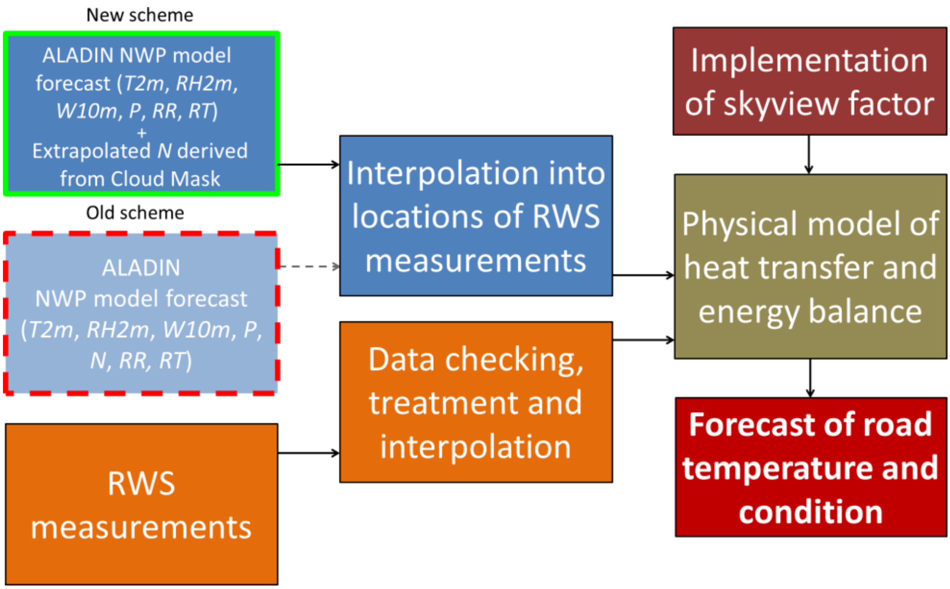

Fig. 1. Calculation scheme of road weather model FORTE. The old scheme using only NWP model forecasts is highlighted by dotted red line. The new scheme combining prognostic variables derived from ALADIN NWP model and extrapolated cloud cover (N) derived from the Cloud Mask algorithm is highlighted by full green line. T2m, RH2m, W10m, P, RR and RT stand for air temperature at 2 m, relative humidity at 2 m, wind speed at 10 m, model pressure at the model orography, accumulated precipitation and type (rain/snow), respectively.

Satellite data and extrapolation

Satellite data measured by the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) aboard the geostationary meteorological satellite Meteosat-11 of Meteosat Second Generation (MSG) is used as a source data for the estimation of cloud cover. MSG data are available every 15 minutes in 12 spectral channels ranging from visible to infrared part of the electromagnetic spectrum and its horizontal resolution is about 4 x 6 km over the Czech Republic. The assessment of whether a given grid box is cloudy or cloud-free is made using the Cloud Mask (CMa) algorithm, which is part of the NWC SAF (Satellite Application Facility on Support to Nowcasting & Very Short Range Forecasting) software provided by EUMETSAT in cooperation with national meteorological services and scientific institutions

[5]. The CMa cloud detection is performed by a multi-spectral threshold method using both operational satellite and NWP model data. The observed values in individual spectral channels and their differences are compared with thresholds, which delimit brightness temperatures/reflectance of cloud-free pixels from those that contain clouds. The total cloud cover *N* over a given grid box will be obtained as a mean value of a number of cloudy pixels from the square of a given size (square of 10 x 10 grid box centred over a considered pixel).

The estimate of cloud cover for the next minutes and hours is then calculated using the Extrapolated Imagery (EXIM) algorithm [6], which extrapolates the CMa (or other selected product) based on atmospheric motion vectors with a defined period of lead time. The prerequisite for a correct estimate is to maintain the wind speed and its direction. The prognostic variable *N* derived from the ALADIN NWP model is replaced by

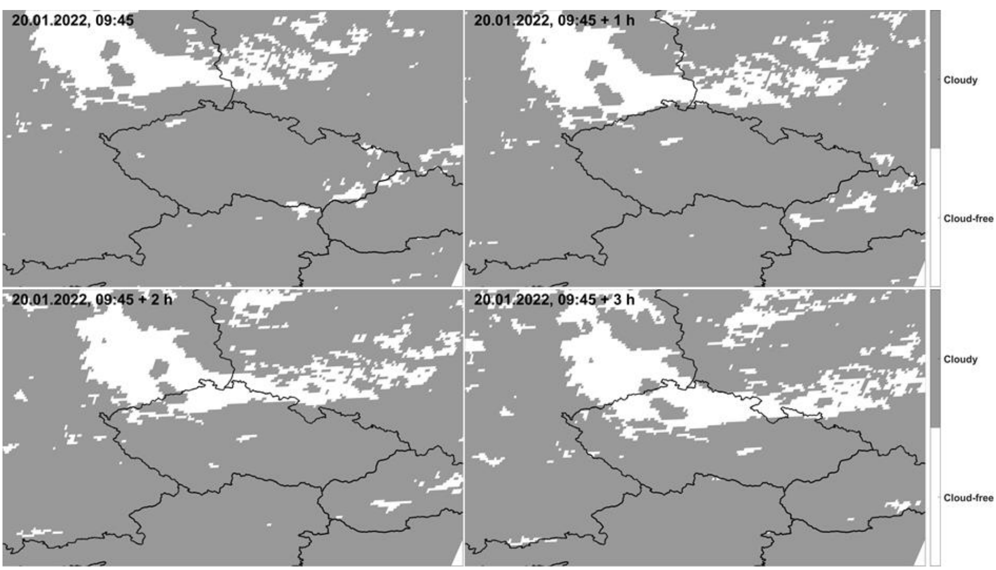

Fig. 2. Example of Cloud Mask (CMa) output for January 20, 2022, 0945 UTC (top left panel) and its extrapolation (EXIM) for the 1st (top right panel), 2nd (bottom left panel) and 3rd hour (bottom right panel). Grey and white colours display cloudy and cloud-free pixels, respectively.

extrapolated CMa at RWS locations every hour with a lead time of 3 hours (Fig. 1). For the longer lead times (3 – 6 hours), the blending with ALADIN NWP model data is applied. In this case, as the lead time increases, more weight is given to the model cloud cover forecast. An example of the CMa and EXIM outputs is shown in Fig. 2.

Verification of results

The model run with the application of extrapolated cloud cover is compared with the original run using only NWP model data. The performance of both runs is evaluated in respect to RWS measurements using statistical verification scores, such as Mean Error, Mean Absolute Error, Root Mean Square Error and/or bias. The evaluation is done for the whole winter season (i.e., from 1st November to 31st March) 2021/2022 and, in addition, selected

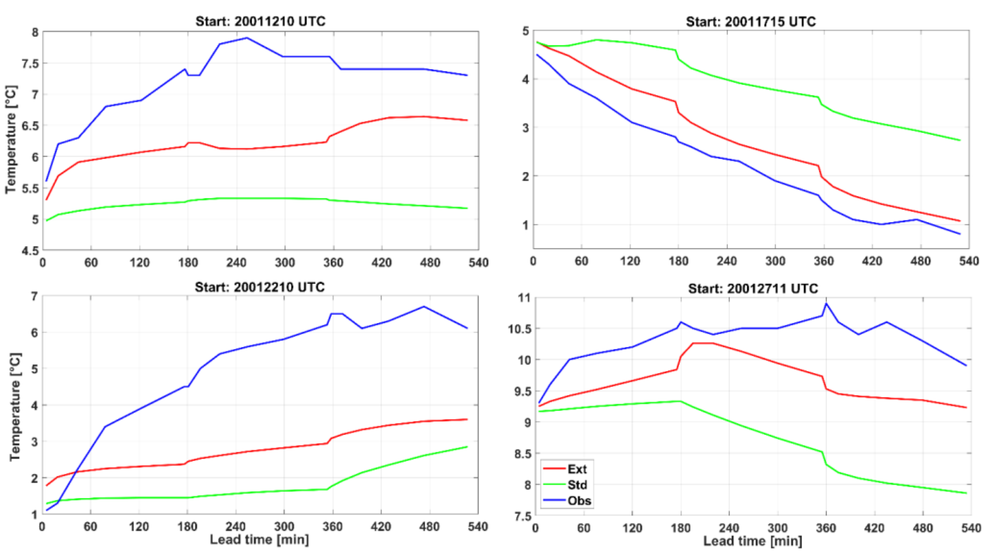

Fig. 3. Road surface temperature forecasted by FORTE model using a standard setup (Std; green line) and extrapolated Cloud Mask (Ext; red line) and measured by RWS A009 located in southern Prague. The start of the model run for the four selected case studies is given above each panel in the YYMMDDhh format and is expressed in UTC.

case studies are analysed and discussed in more detail. Example of RST forecasts for both model runs in comparison with measurements at station A009 (located on the D0 motorway south of Prague, Czech Republic) is shown in Fig. 3. Four selected case studies from January 12, 17, 22 and 27, 2020 show that inclusion of extrapolated CMa can generate RST closer to the observation for the next tens of minutes. However, such improvement is not observed in all forecasts. Possible effects, such as large differences of radiation fluxes coming from both datasets under specific weather conditions, will be discussed in the presented contribution.

Acknowledgements

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