Impact of data assimilation on WRF model prediction: satellite data, surface and upper air observations

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Abstract:

A number of studies has shown improvement of weather predictions assimilating data from different available sources. The impact of high-resolution data assimilation on short-term mesoscale numerical weather prediction using the Weather Research and Forecasting model (WRF) and its data assimilation module (WRFDA) was investigated. Remote sensing data acquired from satellite instruments and complementary surface and upper air observations were exploited. Four case scenarios of data assimilation were compared: 1) only satellite data; 2) only surface and upper air observations; 3) combination of both scenarios 1 and 2; and 4) without assimilation of any data. The objective of the study is to assess the most precise configuration for short-term high-resolution data assimilation to ensure the local forecast with improved analysis of atmospheric conditions - with sufficient details and accuracy.

ARW-WRF v.3.8.1 model setup for the Sofia region

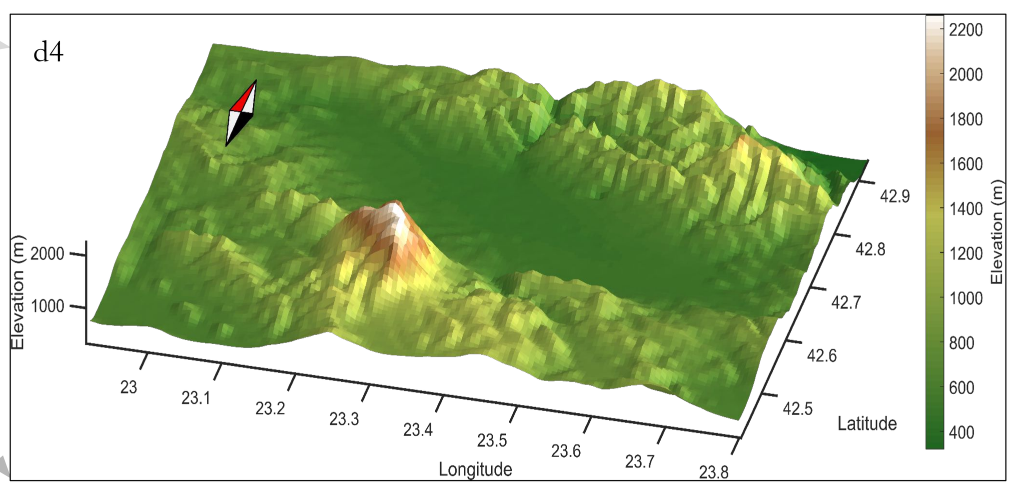
Configuration:

- Lambert projection (23.4°E, 42.68°N)
- 4 nested domains with grid sizes of 32, 8, 2 and 0.5 kms
- Resolution of the inner domain: 157x129x51
- High terrain resolution 1 arcsec: https://lta.cr.usgs.gov/SRTM1Arc
- High land-use resolution 3 arcsec: Corine adopted to USGS classes: http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012
- Input data: NCEP Final Analysis 0.25 deg: http://rda.ucar.edu/datasets/ds083.2;

NCEP GDAS Satellite Data: https://rda.ucar.edu/datasets/ds735.0;

NCEP ADP Global Upper Air and Surface Weather Observations: https://rda.ucar.edu/datasets/ds337.0

Model parametrization:
Radiation: RRTM and Dudhia schemes
Moisture: Lin et al. scheme
PBL: Yonsei University scheme
Land surface: Noah Land Surface Model



Case study

27.11.2015 (Synoptic analysis)

The 500 hPa fields analysis show relatively low pressure, cyclonic wind shear and a front passing through the north-western part of Bulgaria. The surface analysis indicate a Mediterranean cyclone has been formed over South Italy and continue moving in east direction. The cyclone got strengthen over the next few days and slowly changed direction of his path to north-east, passing through Bulgaria. The precipitation started as rain and occasional thunderstorms were observed over Bulgaria region, and with decrease of temperatures the rain turned into snow.

The reference values from the sounding are shown in the table at level 850hPa

PRES	HGHT	TEMP	DWPT	RELH	MIXR	DRCT	SKNT	THTA	THTE	THTV	WIND
hPa	m	C	C	%	g/kg	deg	knot	K	K	K	m/s
850	1400	0.4	0.4	100	4.66	115	27	286.6	300	287.4	13.9

3D-Var Data Assimilation:

The WRFDA module, version 3.8.1, was used for 3-D variational analysis. Configuration for 3-D Var case: the standard VARBC.in and cv=3 option for background errors with be.dat file and CRTM as a radiative transfer model were exploited.

- First guess - GFS 03 hours forecast
- ± 1h time window
- Satellite data and surface and upper air observation assimilated in all 4 domains
- Quality control was applied and bias correction

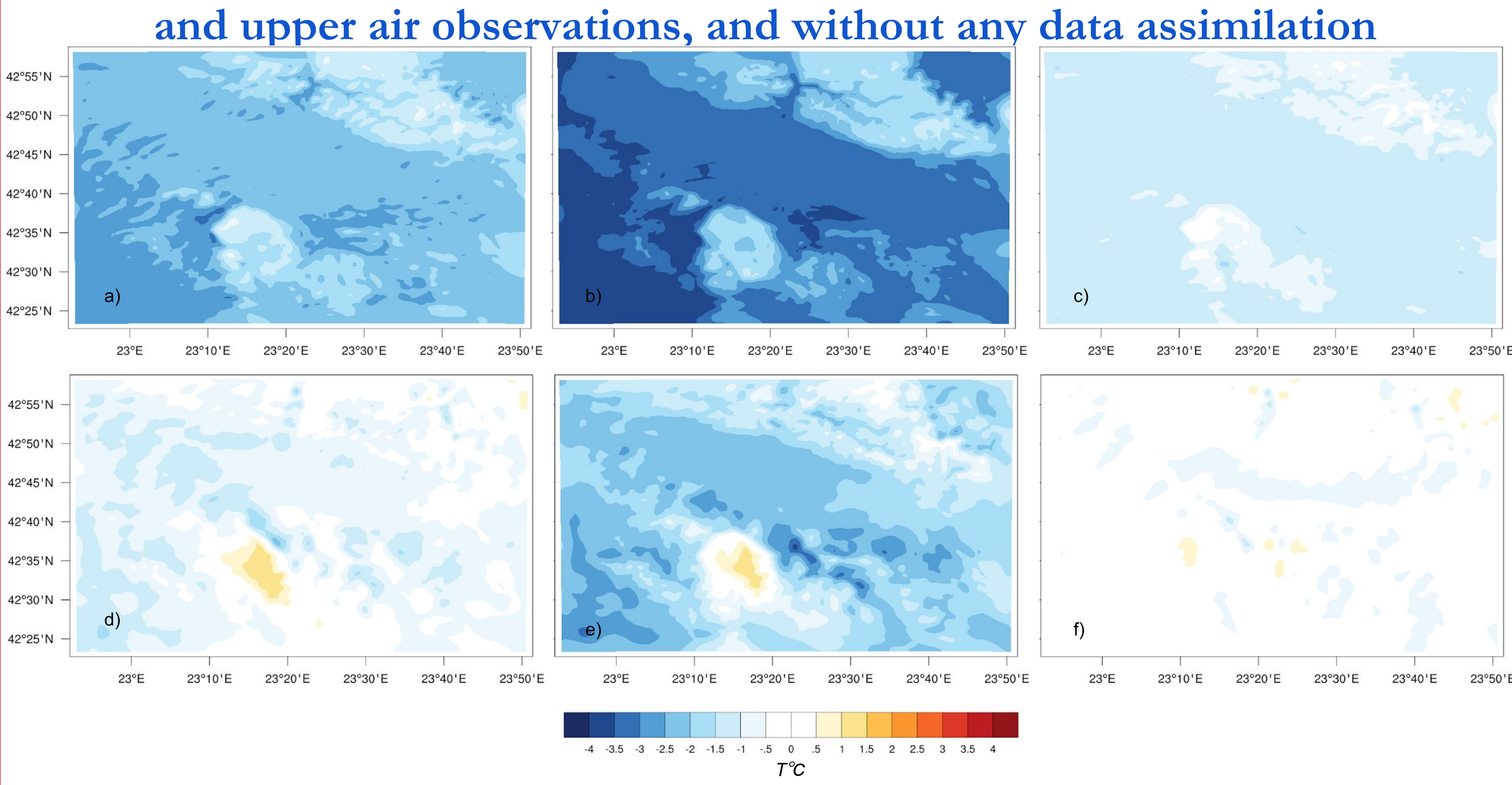
Description of the observations assimilated in the study case

Different number of observations from various sources can be used, depending on the time interval chosen for data assimilation. Data from sounding and sun-synchronous orbiting satellites were available at noon (12:00 pm) and assimilated for this particular case.

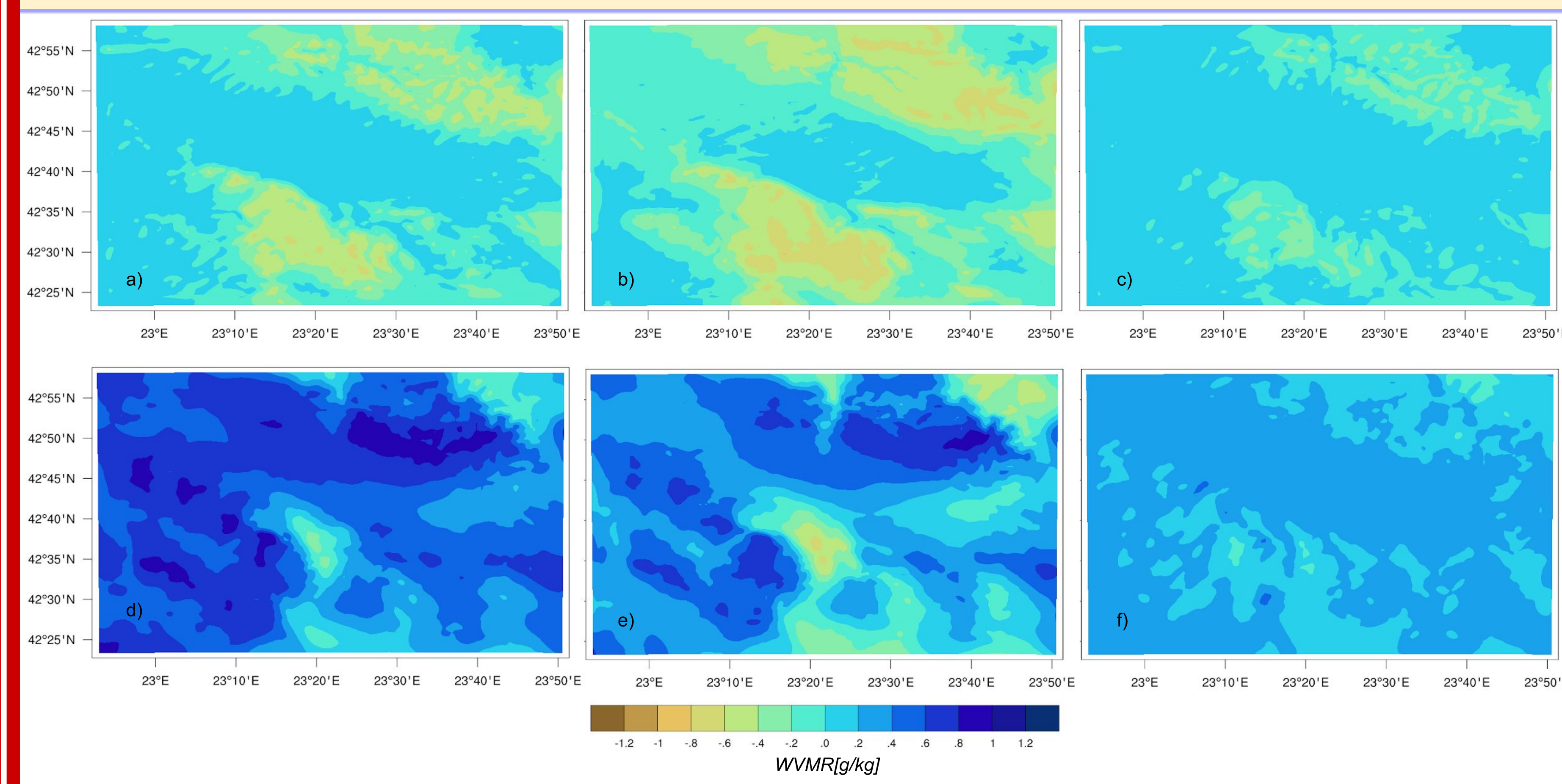
Upper air and surface observations assimilated	d01	d02	d03	d04
sound	9	2	1	1
synop	359	58	4	2
geoamv	480	90	3	-
gpsrf	300	-	-	-
metar	99	15	1	1
ships	7	-	-	-
sonde_sfc	9	2	1	1

	d01	d02	d03	d04
Satellite instrument assimilated	noaa19-amsua	noaa19-amsua	noaa19-amsua	noaa19-amsua
	eos2-airs	eos2-airs	eos2-amsua	eos2-amsua
	eos2-amsua	eos2-amsua	jpss0-atms	jpss0-atms
	jpss0-atms	jpss0-atms	noaa19-mhs	
	noaa19-mhs			

Differences between model output with combination of satellite, surface and upper air observations, and without any data assimilation

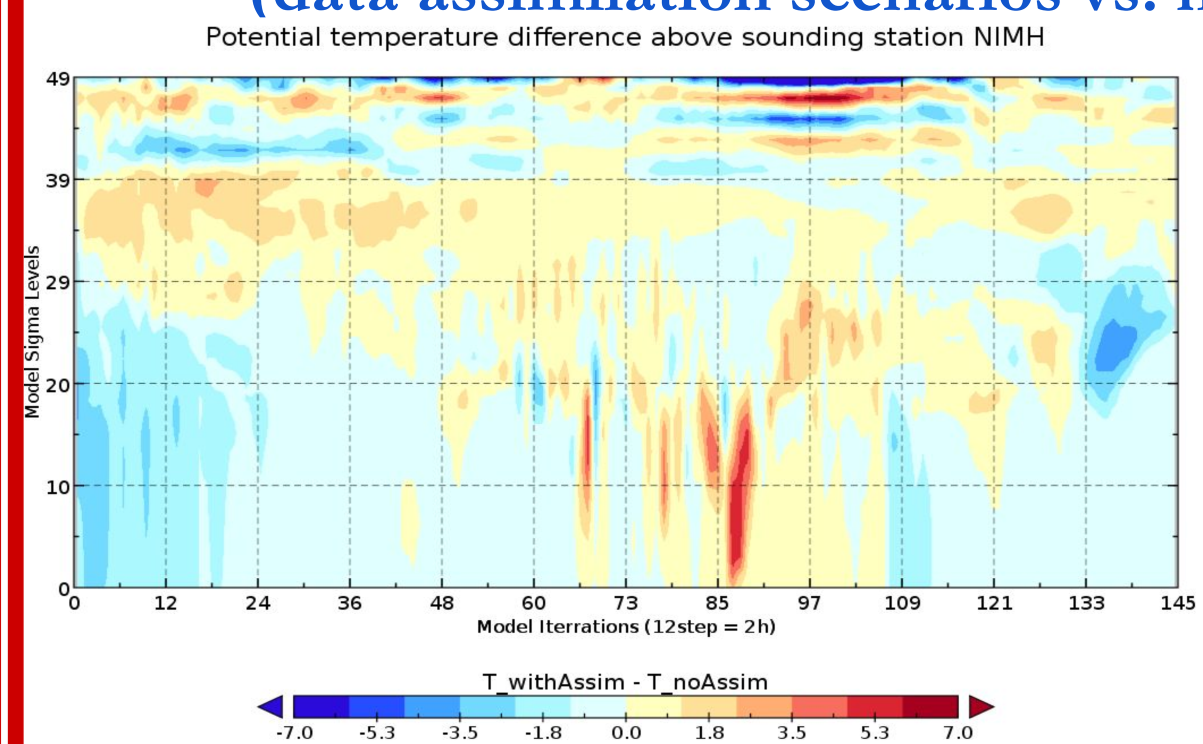


Temperature (T) field differences at first sigma model level (around 10m) - a), b), c); and at the 30-th sigma model level (around 1500m) - d), e), f). a) and d) T field difference between assimilated satellite and surface and upper air observations and the field without assimilated data; b) and e) T differences between assimilated satellite observations and the field without assimilated data; c) and f) T differences between assimilated surface and upper air observations and the field without assimilated data.

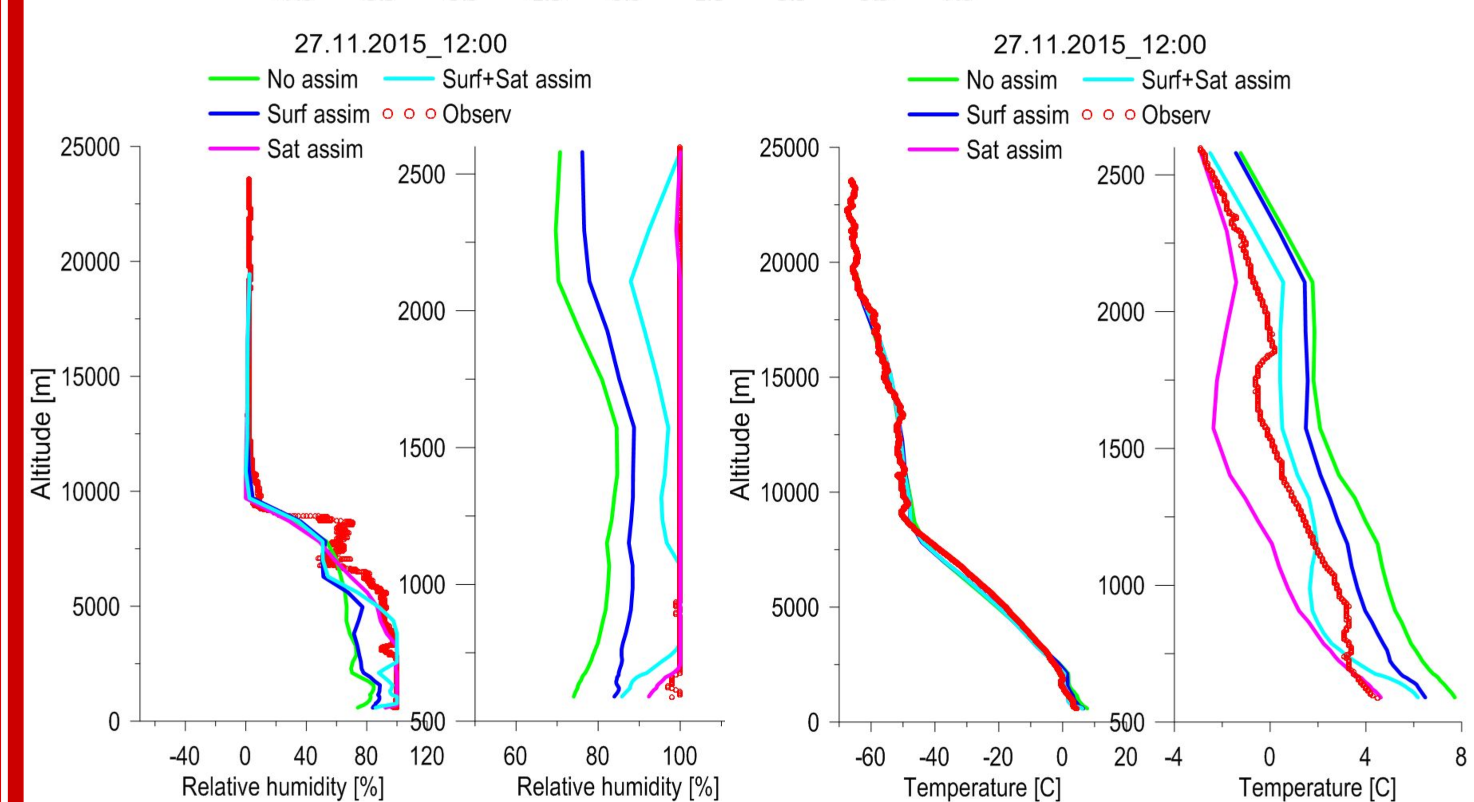


Water vapour mixing ratio(WVMR) field differences at first sigma model level (around 10m) - a), b), c); and at the 30-th sigma model level (around 1500m) - d), e), f). a) and d) WVMR field difference between assimilated satellite and surface and upper air observations and the field without assimilated data; b) and e) WVMR differences between assimilated satellite observations and the field without assimilated data; c) and f) WVMR differences between assimilated surface and upper air observations and the field without assimilated data.

Vertical temperature and relative humidity profile difference (data assimilation scenarios vs. no assimilation)



Data assimilation provide lower temperatures from the first (~940hPa) to around 25-th (~850hPa) model sigma level in the beginning. At the lower levels surface observations are dominant, but above 25-th level satellite observations have greater impact.



Comparison of vertical profiles for different data assimilation scenarios against observations for temperature and relative humidity at 12:00 UTC.

Due to the background error field for the satellite observations they have less impact on near surface temperature and on surface relative humidity also.

Conclusions

Data assimilation has significant effect on short time weather prediction of temperature and relative humidity for Sofia region and the satellite data have significant impact, due to the limited number of available surface observation. The method can be successfully applied for real-time predictions, but some restriction related to the satellite data availability have to be taken into account of which the most prominent are the spatial and time ones.

Acknowledgements

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Pineda, N., Jorba, O., Jorge, J., Baldasano, J.M., 2004. Using NOAA AVHRR and SPOT VGT data to estimate surface parameters: application to a mesocale meteorological model. Int. J. Remote Sens. 25 (1), 129–143.