

Description of the SNOWE technology

PT SNOWE

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The technology SNOWE consists of several programs and files. The example of file structure used at Hydrometcenter of Russia needed for the technology is represented in fig.1 (the user could change it according to his discretion).

The main steps of the technology are shown in fig.2. SNOWE run is carried out by the control file OPER_SNOW.sh where namelist *smfe_data.nl* is formed every day. Example of *smfe_data.nl* you can see below. All the main settings for the technology are done here (parameters, paths...).

Output data from SNOWE technology contains snow water equivalent (SWE) and snow density (RHO) values for COSMO-model in laf-file.

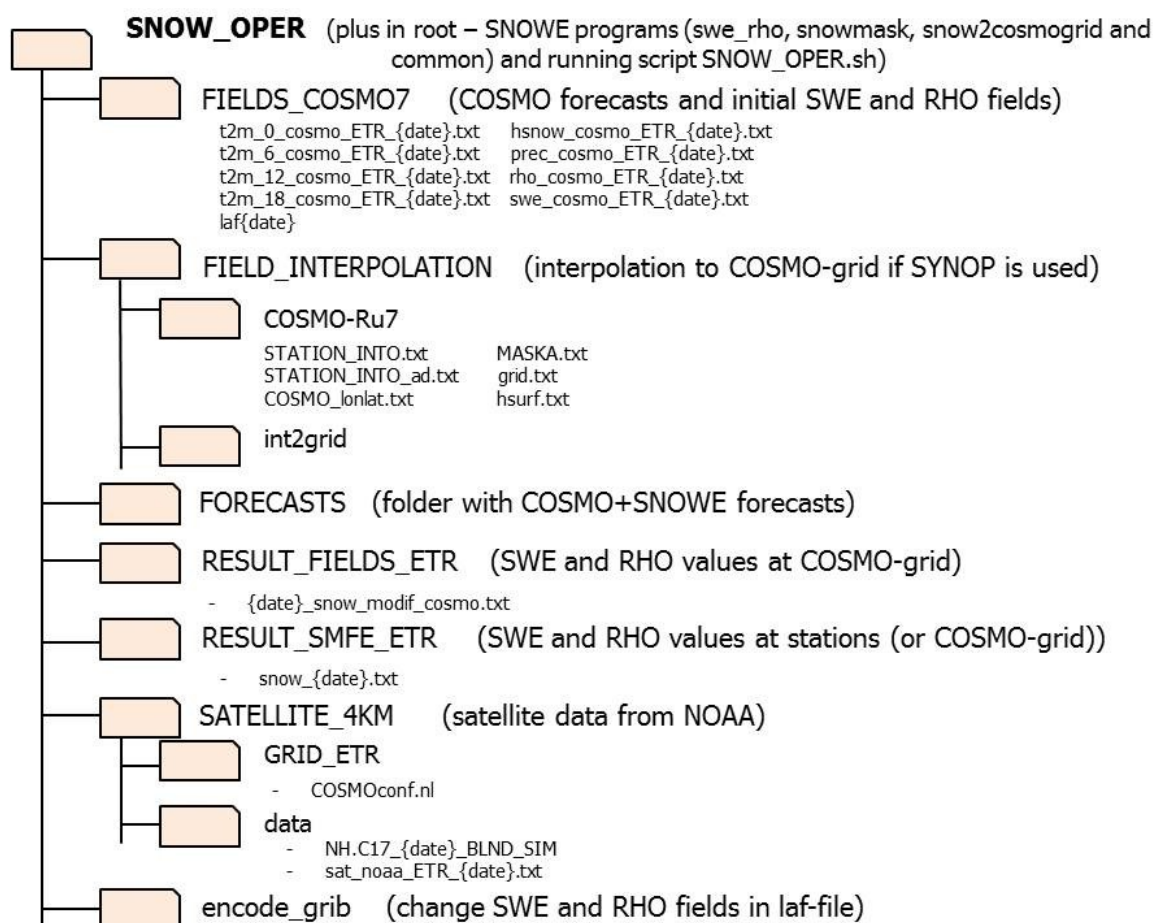


Fig.1. Parts of the SNOWE technology (file structure)

&smfe_data

srcDataType=0, ! 0 – COSMO past forecasts, 1 – SYNOP measurements

```

cosmoGridsCount=434000, !amount of COSMO grid points (700x620)
stationsCount=2163, !amount of SYNOP stations
satelliteGridsCount=434000, ! amount of satellite grid points (equal to COSMO)
sweRhoLayersCount=3, !amount of layers for snow output
region ='ETR', ! COSMO-region
yearSnowStart =2016, !year
monthSnowStart = 02, !month
daySnowStart = 16, !day
hourSnowStart = 0, !hour
dayNumber=46, ! day number, for NOAA satellite filename
interpolationMethod=3, !see STEP4
int2gridFactor = 30, !resolution for interpolation from SYNOP to COSMO-grid in int2grid
(km)
radius=8000, !radius for SYNOP data interpolation (example for COSMO-Ru7 (7km)) (m),
for int2grid
lonBottomPoint=-19.0, !longitude of left bottom corner of COSMO-grid, for int2grid
latBottomPoint=30.0, !latitude of left bottom corner of COSMO-grid, for int2grid
!Data Base parameters
dBHost = '192.168.97.72',
dBName = 'SHOT',
dBCode = 260601
!paths and filenames
filename_history = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/RESULT_SMFE_ETR /history.bin", !snow history for each point (COSMO grid or SYNOP)
!int2grid
filename_int2gridExe = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/int2grid/int2grid.ex",
filename_int2gridIn = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/synop_ex.txt",
filename_int2gridGrid = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/grid.txt",
filename_int2gridOut = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/result.txt",
!data characteristics
filename_COSMOLonLat = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/COSMO_lonlat.txt", !COSMO-grid longitude and
latitude
filename_stationsLonLat = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER /STATION_
%.r.txt", !list of SYNOP stations
filename_surfaceHeight = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/hsurf.txt", !COSMO surface height
!COSMO fields
filename_snowDepth = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/hsnow_cosmo_%.r_%.y%.m%.d.txt",

```

```

filename_p12Sum = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/prec_cosmo_%r_%y%m%d.txt",
filename_t2m0 = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/t2m_0_cosmo_%r_%y%m%d.txt",
filename_t2m6 = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/t2m_6_cosmo_%r_%y%m%d.txt",
filename_t2m12 = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/t2m_12_cosmo_%r_%y%m%d.txt",
filename_t2m18 = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/t2m_18_cosmo_%r_%y%m%d.txt",
filename_srcRho = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/rho_cosmo_%r_%y%m%d.txt",
filename_srcSwe = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELDS_COSMO7/swe_cosmo_%r_%y%m%d.txt",
!satellite
filename_satelliteRaw = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/SATELLITE_4KM/data/NH.C17_%y%n_BLND_SIM",
filename_satelliteData = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/SATELLITE_4KM/data/sat_noaa_%r_%y%m%d.txt",
filename_satConf = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/SATELLITE_4KM/GRID_%r/COSMOconf.nl", !COSMO-grid parameters
!result files
filename_resultSMFE = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/RESULT_SMFE_ETR_TEST/snow_%y_%m_%d.txt",
filename_result = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/RESULT_FIELDS_ETR/%y%m%d_snow_modif_cosmo.txt",
filename_resultLayers = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/RESULT_FIELDS_ETR/%y%m%d_snow_modif_layers.txt",
!files for interpolation in int2grid
filename_pointsIntoCOSMO = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/STATION_INTRO.txt", !stations that are completely in
COSMO area
filename_pointsOutCOSMO = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/STATION_INTRO_ad.txt", !other stations, outside
COSMO-grid (needed for correct interpolation)
filename_mask = "/RHM-GPFS/users/cosmo/ekazakova/SNOW_OPER
/FIELD_INTERPOLATION/COSMO-Ru7/MASKA.txt" !COSMO land/sea mask
/

```

Tags in filenames mean the following (for flexible changes, located in *mod_settings* in *common* folder):

"%y" – year

"%m" – month

"%d" – day

"%h" – hour

"%n" – day number

"%r" – region

SNOWE technology is focused on COSMO forecasts usage (see fig.3). Additionally user could work with SYNOP data and satellite data. At Hydrometcenter of Russia satellite data from NOAA server (<ftp://140.90.213.161/autosnow/4kmNH/>) is used. NOAA satellite data has a restricted covering area (see example picture http://satepsanone.nesdis.noaa.gov/northern_hemisphere_multisensor.html), so check if your COSMO-area is completely covered by this satellite information.

For that moment at Hydrometcenter of Russia calculations according to SNOWE technology are done once a day for 00 UTC in quasi-operational regime with the use of the previous day data. Let's view the steps separately (here we look at COSMO-Ru7 as an example) for the case when COSMO past forecasts (*srcDataType=0*) are used for SWE and RHO calculations for current day.

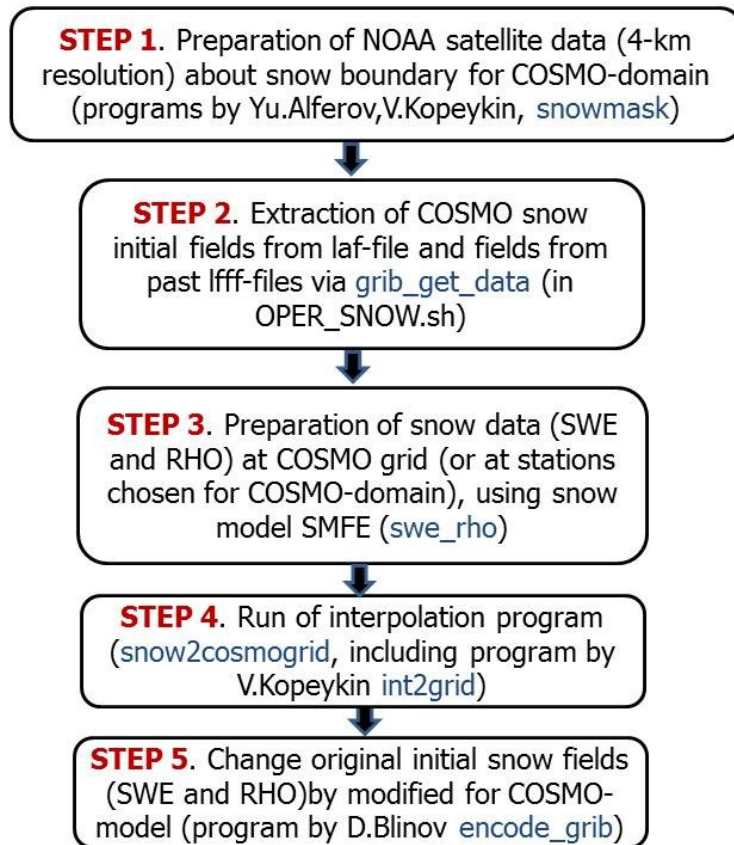


Fig.2. Steps of the SNOWE technology

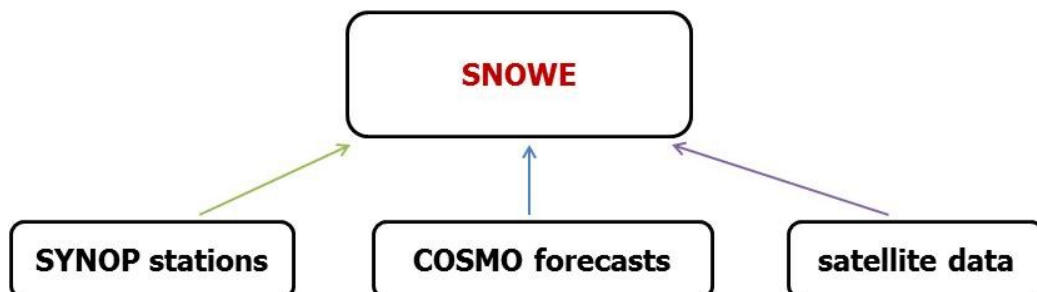


Fig.3. Possible data types used for SNOWE technology

STEP 1. In *snowmask* the file containing information about snow fractional cover is produced. In order to have it we should download satellite data (file NH.C17_{date}_BLND_SIM) for the

previous day (fig.4). At Hydrometcenter of Russia downloading is done by the use of function *curl*.

When calculating snow fractional cover you should determine the COSMO area for which you want to have this satellite product (file COSMOconf.nl). File COSMOconf.nl should be written in the way:

```
&CosmoGrid
NorthLat=35.0, NorthLong=215.0,
CosmoN=700, CosmoM=620,
LeftLong=-19.0, LowLat=-19.0,
LongStep=0.0625, LatStep=0.0625
/
```

where first line – geographical coordinates of the North pole for COSMO-model, second line – number of nodes for the COSMO area, third line – coordinates of the low left corner (in COSMO rotated coordinates), fourth line – COSMO grid step.

Note. *NorthLong* should not be written as a negative value.

STEP 1

Input	Output
<ul style="list-style-type: none">• COSMOconf.nl (COSMO grid)• 'NH.C17_{date}_BLND_SIM' (input satellite image)	<ul style="list-style-type: none">• sat_noaa_ETR_{date}.txt

Fig.4. Step1 of the SNOWE technology

You can use any satellite data as well but the final file should be written as *sat_noaa_ETR_{date}.txt*:

Longitude Latitude Value

STEP 2. We extract initial SWE and RHO fields which we want to change from COSMO lsf-file (via *grib_get_data* in file OPER_SNOW.sh). Forecasts of T2m, 10m wind speed and precipitation sums are also extracted if we want to make snow characteristics' calculation directly in COSMO-grid points (fig.5).

STEP 2

Input	Output
<ul style="list-style-type: none">• COSMO past forecasts on grid (lbff-files)• Initial fields for COSMO-model (SWE and RHO) (laf-file)	<ul style="list-style-type: none">• hsnow_cosmo_ETR_{date}.txt• prec_cosmo_ETR_{date}.txt• t2m_0_cosmo_ETR_{date}.txt• t2m_6_cosmo_ETR_{date}.txt• t2m_12_cosmo_ETR_{date}.txt• t2m_18_cosmo_ETR_{date}.txt• swe_cosmo_ETR_{date}.txt• rho_cosmo_ETR_{date}.txt

Fig.5. Step2 of the SNOWE technology

STEP 3. In *swe_rho* SWE and RHO values are prepared using snow model SMFE (fig.6).

If calculations of snow model SMFE are done directly at COSMO-grid points (*srcDataType=0*), then past COSMO forecasts should be available (e.g., if we want to prepare initial RHO and SWE fields for 5 March 00 UTC we need to take forecasts of T2m, 10m wind speed and precipitation sums for appropriate terms of 24, 30, 36, and 48 hours with start 00 UTC 4 March).

Note. Type of observations (*srcDataType*, SYNOP or COSMO past forecasts) shouldn't be changed for the whole snow season! In order to read/write snow history file and SWE and RHO values for needed points.

If the procedure is done for stations, then their list should be determined (STATION_ETR.txt, *srcDataType=1*) in the way:

WMO station number Latitude Longitude

Note. If station has west longitude, the longitude value should be written as a negative value (e.g., -8.7). The list must contain only those stations which have snow depth measurements and send SYNOP data at least 3 times a day (in order to have adequate averaged daily air temperature).

SYNOP station measurements should be downloaded from local Data Bases situated in a meteorological center.

STEP 3

Input	Output
<ul style="list-style-type: none">• COSMO_lonlat.txt (COSMO-grid) or STATION_ETR.txt (station list) (if we use SYNOP, <i>srcDataType=1</i>)• COSMO past forecasts on grid (STEP 2) or SYNOP measurements at stations (Data Bases, <i>srcDataType=1</i>)• satellite file (STEP 1) sat_noaa_ETR_{date}.txt	<ul style="list-style-type: none">• snow_{date}.txt

Fig.6. Step3 of the SNOWE technology

Output file contains SWE and snow density for each station (or at each grid cell, if directly COSMO past forecasts on grid are used).

```
i lat lon swe rho
```

If the option of printing layers of the snowpack is used, then output is written as:

```
i lat lon swe rho swe1 rho1 swe2 rho2
```

Note. If SWE and rho values are calculated by the snow model with option 'layers' (sweRhoLayersCount), file after interpolation {date}_snow_modif_cosmo.txt will also contain information about layers. The whole snow season this option shouldn't be changed in order to read files correctly.

STEP 4. In *snow2cosmogrid* SWE and RHO values are just rewriting (in case of direct calculation at COSMO-grid using COSMO past forecasts, *srcDataType*=0) or written for COSMO-grid using interpolation (in case of SYNOP stations, *srcDataType*=1) (fig.7).

Interpolation options that are available:

- interpolationMethod =1 (*srcDataType* =1, interpolation from SYNOP to COSMO grid (no first guess); only for small territories with dense SYNOP network). Here only program by V.Kopeykin (interpolation by Delaunay triangulation) is needed to make interpolation from SYNOP to COSMO grid.
- interpolationMethod =2 (*srcDataType* =1, calculation of relations between SYNOP and first guess,their interpolation and first guess changes)
- interpolationMethod =3 (use calculations of SMFE at each cell of COSMO-model grid (no interpolation, only change fields in laf-file, *srcDataType* =0)). Here we just rewrite values to the final file {date}_snow_modif_cosmo.txt.

STEP 4

Input	Output
<ul style="list-style-type: none"> • COSMO past forecasts on grid or SYNOP measurements at stations (STEP 2 and 3) • satellite file (STEP 1) • COSMO_lonlat.txt (COSMO grid) • hsurf.txt (COSMO surface height) • MASKA.txt (COSMO land/sea) • STATION_ETR.txt (station list, <i>srcDataType</i>=1) • STATION_INT0.txt (<i>srcDataType</i>=1) • STATION_INT0_ad.txt (<i>srcDataType</i>=1) • grid.txt (for int2grid program, <i>srcDataType</i>=1) 	<ul style="list-style-type: none"> • {date}_snow_modif_cosmo.txt

Fig.7. Step4 of the SNOWE technology

File COSMO_lonlat.txt contains information about COSMO-model grid (longitude and latitude) in 2 columns (without header):

```
lon lat .
```


File *hsurf.txt* contains data from the COSMO-model about surface height in a way (without header):

700 620 (number of grids in COSMO-model domain in vertical (longitude) and horizontal (latitude) direction), then
hsurf (variable value).

File *MASKA.txt* has values (from 0 to 1) about sea/land fraction in COSMO-model (longitude, latitude, value):

Lon lat val_si .

File *STATION_INT0.txt* contains information about stations which are completely inside the COSMO-model domain:

WMO station number Latitude Longitude

File *STATION_INT0_ad.txt* contains information about stations which are situated outside COSMO-model domain but needed for correct interpolation:

WMO station number Latitude Longitude

Note. If station has west longitude, the longitude value should be written as a negative value.

For program *int2grid* (by V. Kopeykin) in executable file *OPER_SNOW.sh* *synop_ex.txt*, *grid.txt* and *result.txt* are files with coordinates and values at needed stations, with COSMO-grid and file with result values of SWE and RHO (*synop_ex.txt* and *result.txt* are auxiliary). **Note:** don't change these names.

Note. File *grid.txt* should be made once in program *snow2COSMOgrid.f90* (comments are present) or anywhere.

Output files contain SWE and RHO values for COSMO-grid. Default RHO values for lakes/seas are from original COSMO *laf*-file. For case SWE=0 at land default value *rho_const_land_cosmo* is equal to 50 kg/m³ (can be changed in *snow2cosmogrid*).

Note. When changing files in *common* folder for projects *snowmask*, *swe_rho* and *snow2cosmogrid*, you should do 'make' again in order to have changes for all these projects!

It is suggested that if according to COSMO initial file the cell is free of snow, in the final file we also remove this snow (in order not to spoil T2m forecasts, especially near the snow boundary).

STEP 5. According to program *encode_grib* (by D.Blinov) we replace original SWE and RHO fields by modified (fig.8).

Here directories and some parameters should be determined:

indir – directory where original COSMO *laf*-file is present;

NX – 700, number of grids in COSMO-model domain in vertical (longitude) direction;

NY – 620, number of grids in COSMO-model domain in horizontal (latitude) direction;

region – COSMO-region;

iValFile – file which contains modified SWE and RHO values ({date}_snow_modif_cosmo.txt).

STEP 5

Input	Output
<ul style="list-style-type: none">• {date}_snow_modif_cosmo.txt (STEP 4)• original laf-file for COSMO-model	<ul style="list-style-type: none">• laf-file for COSMO-model with specified SWE and RHO fields

Fig8. Step5 of the SNOWE technology

The final file has the same name and size as the original laf-file for COSMO-model.

The whole SNOWE technology works several minutes on average depending on the amount of grid points (or SYNOP stations), interpolation step *int2gridFactor* (for SYNOP, *int2grid*) and computing resources.