Contents

0.1 GNSS Extensions

Modifications to `chapter0604.tex`

Section 6.4 - Observation Input Files

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GPS (GNSS) zenith total delay and water vapour
...

GNSS zenith total delay

File name: 'cdfin_gnss_ztd'.

The GPS data described in the previous section can also be processed by the GNSS STD operator. In contrast to the GPS IWV operator the STD operator is not part of the nudging assimilation system. The output of the STD operator is written to a specific feedobs file `fof_gnssgb_*` but the model state is not modified.

In order to distinguish between both operators unique input file names are required even if the contents of the files is identical.

New file `chapter0605.tex`, Subsection 6.5 Geoid Undulation

0.2 Geoid Undulation

COSMO provides the surface height (field `HSURF`) and the heights of half levels (field `HHL`) as heights above mean sea level which are equivalent to heights above geoid. The geoid is related to the local gravity field of the Earth and only empirical estimates of the Earth's geoid are available. Consequently, there is no general transformation from the geographical coordinates provided by COSMO and other reference systems, e. g. used to define satellite data. It is necessary to translate the heights above geoid to heights above a reference ellipsoid. Such ellipsoidal coordinates can easily be transformed to global Cartesian coordinates and to any other reference system.

The geoid undulation describes the difference between the height above geoid and the height above ellipsoid. Several empirical data sets are available and are updated in regular intervals, either because of new gravity data or because the Earth's gravity field changed. One of the most recent and best resolved data sets is the `eigen-6c3stat` geoid which is used in COSMO.

The global `eigen-6c3stat` geoid with a resolution of 0.1° can be obtained from the web site `http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html`. The web server provides the 350 MB ASCII file `eigen-6c3stat-450553.gdf`. The format of the geoid data is described on the web site and in Förste et al. (2013). It is rather time consuming to read such a large ASCII file therefore a netCDF converter was written. The size of the netCDF file is 50 MB and it is possible to read only the geoid subarray required for the given model domain. The contents of the netCDF file is described below.

The geoid file is required only if the GNSS STD operator is running.

0.2.1 Geoid netCDF file

The geoid is provided on a regular latitude/longitude grid. The latitudes and longitudes are stored as 1-dim arrays the geoid is a 2-dim array with the corresponding dimensions:

```
dimensions:
        londim = 3601 ;
        latdim = 1801 ;
variables:
        double geoid(latdim, londim) ;
                geoid:standard_name = "geoid" ;
                geoid:units = " meter" ;
        float lon(londim) ;
                lon:standard_name = "longitude" ;
                lon:units = "degree" ;
        float lat(latdim) ;
                lat:standard_name = "latitude" ;
                lat:units = "degree" ;
```

The geoid file is read by the GNSS STD operator. Path and file name need to be provided in the parameter `GeoidFile` of the `STD_OBS` namelist. The netCDF geoid file can be obtained from the DWD.

Modifications to `chapter0709.tex`

Section 7.9 NUDGING

Name	Type	Definition / Purpose / Comments	Default
		observation type: reports inside the exclusion area are set passive if their type is set to `.FALSE.`	
`lsynop`	`LOG`	observation type SYNOP	`.TRUE.`
`laircf`	`LOG`	observation type AIREP (aircraft)	`.TRUE.`
`lsatob`	`LOG`	observation type SATOB	`.FALSE.`
`ldribu`	`LOG`	observation type DRIBU (drifting buoy)	`.TRUE.`
`ltemp`	`LOG`	observation type TEMP	`.TRUE.`
`lpilot`	`LOG`	observation type PILOT	`.TRUE.`
`lsatem`	`LOG`	observation type SATEM	`.FALSE.`
`lgps`	`LOG`	observation type GPS IWV	`.FALSE.`
`lgnssstd`	`LOG`	observation type GPS STD/ZTD	`.FALSE.`
`lscatt`	`LOG`	observation type SCATT (scatterometer)	`.TRUE.`

New file `chapter0715.tex`, Subsection 7.15 - Namelist STD Operator

0.3 STD_OBS — Parameter for the GNSS STD Operator

The namelist group `/STD_OBS/` contains parameters required by the GNSS STD operator for assimilating GNSS zenith total delays (ZTDs) and slant total delays (STDs). To run the STD operator the parameter `lgnssstd` of the `NUDGING` namelist needs to be `.TRUE.`.

GNSS STD and ZTD observations can be assimilated by the LETKF. Nudging of these observation types is not possible. However, there exists an option to nudge GNSS IWV observations (see Section **??** on page **??**).

Name	Type	Definition / Purpose / Comments	Default
`NStepVertMod`	`INT`	Number of supporting points used for vertical integration inside the model, should be ≥ the number of vertical grid nodes of the model. The number of supporting points on the signal path is scaled with the elevation.	60
`NStepVertTop`	`INT`	Number of supporting points used for vertical integration above the model top. `NStepVertTop` can usually be smaller than `NStepVertMod` as the contributions from the upper atmosphere is small and the information about the refractivity above the model top is limited. Like `NStepVertMod` this is scaled with the elevation.	20
`Hmax`	`REAL`	The STD is integrated from the GNSS station up to a maximum height `Hmax` in m. It is assumed that the neutral atmosphere reaches up to `Hmax`: 100000 ≤ Hmax ≤ 200000 (100 km ... 200 km)	150000

Name	Type	Definition / Purpose / Comments	Default
HScaleP	REAL	Scale hight in m of a hypothetical pressure profile. This profile is used to scale the density of supporting points with height. Smaller numbers lead to more points in the lower atmosphere. HScaleP is used for the signal path inside the model.	6500
HScaleP2	REAL	Like HScaleP but used for the region above the model top. HScaleP2 should be much larger than HScaleP in order to obtain a homogeneous distribution of supporting points along the whole signal path from the receiver up to Hmax. Both, HScaleP and HScaleP2, need to be adjusted to the specific model configuration. If HScaleP is too small as compared to the vertical extension of the model most supporting points are located in the lower grid levels and the upper levels are not regarded appropriately. If HScaleP is too large the distribution is almost equidistant and some of the lower levels might not be regarded.	25000
UseRaytracer	REAL	Maximum elevation in degrees for using the raytracer. The raytracer is called only if the elevation of the STD is below this angle. For larger elevations it is assumed that the signal path between the satellite and the receiver is a straight line. UseRaytracer = 90°: The raytracer is called for all ZTDs and STDs. UseRaytracer = 0°: The raytracer is never called and a straight line is assumed for all elevations.	50°
k_1	REAL	Refractivity coefficient k_1 [K hPa^{-1}] used in the Smith & Weintraub formula or the Thayer formular, default according to Bevis et al. (1994).	77.60
k_2	REAL	Refractivity coefficient k_2 [K hPa^{-1}], default according to Bevis et al. (1994).	70.40
k_3	REAL	Refractivity coefficient k_3 [K^2 hPa^{-1}], default according to Bevis et al. (1994).	$3.739 \cdot 10^5$
ZTDerror	REAL	Assumed ZTD observation error in m. For STDs ZTDerror is mapped to the given elevation using the Global Mapping Function (GME). The corresponding observation error is written to the feedback files.	0.012 m
GeoidFile	CHAR	Path and file name of the geoid file. The geoid file provides the geoid undulation required to transform heights above geoid into heights above ellipsoid and vice versa. So far only the eigen-6c3stat geoid is supported. The STD operator in COSMO does not work without a valid geoid and COSMO will be terminated if the STD operator is started without a GeoidFile.	' '
Href	REAL	Reference height in m above the GNSS station used by the LETKF. In the feedback files the parameters plevel, dlat, dlon give the position on the signal path where the height above the station is Href. For Href = 0 the station position and the pressure at the station are given.	0 m
MaxSTDobs	INT	Maximum number of STDs to read/process	100000
MaxZTDobs	INT	Maximum number of ZTDs to read/process The memory required to read and process the GNSS observations grows with the number of observations and may exceed the available memory. As the number of future observations is unpredictable an upper limit is set in order to guarantee stable operation.	50000

Name	Type	Definition / Purpose / Comments	Default
verbose	REAL	Verbosity level of program messages. At higher verbosity levels the output of all lower levels will also be provided. This parameter is used by the STD operator only. verbose = 0 (default) Output limited to some status messages. verbose = 1 Messages necessary to follow the program flow. verbose = 2 More messages and output of some important variables. verbose = 3 Debug mode, huge amount of output.	0
HORIFile	CHAR	Path and file name of the GNSS station list. The GNSS station list is required to process STD observations which are provided in a preliminary data format. As STD and ZTD data are processed in the same way the GNSS station list needs to be available even if only ZTDs are used. This parameter will become obsolete as soon as STD BUFR data are available.	' '

Modifications to `chapter08.tex`

Section 8.3 NetCDF Feedobs File

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8.3.1 Operator Specific Feedobs Files

In addition to the above mentioned standard feedobs file several operator specific feedobs files may exist. Observation operators which are not part of the nudging assimilation system, e.g. the radar operator or the STD operator, use their own feedobs files. These files can be used for verification purposes or by the LETKF.

The file name used by the STD operator is defined in a similar way as the standard feedobs file name but with an additional substring `gnssgb` for *GNSS ground based* observations:

```
'fof_gnssgb_' // yyyymmddhhttss // '.nc'
```

Modifications to `.../trunk/Literature/lit.bib` Additional References

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2 new references:
(Bevis, Businger, Chiswell, Herring, Anthes, Rocken, and Ware 1994)
(Förste, Bruinsma, Marty, Flechtner, Abrikosov, Dahle, Lemoine, Neumayer, Biancale, Barthelmes, and König 2013)

References

Bevis, M., S. Businger, S. Chiswell, T. A. Herring, R. A. Anthes, C. Rocken, and R. H. Ware, 1994. GPS Meteorology: Mapping Zenith Wet Delays onto Precipitable Water. *J. Appl. Meteor. 33*(3), 379–386.

Förste, C., S. Bruinsma, J.-C. Marty, F. Flechtner, O. Abrikosov, C. Dahle, J.-M. Lemoine, K. H. Neumayer, R. Biancale, F. Barthelmes, and R. König, 2013. EIGEN-6C3stat - the newest High Resolution Global Combined Gravity Field Model based on the 4th Release of the GOCE Direct Approach. Talk, Potsdam/Toulouse.