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User's Manual for the Navy Coupled Ocean Data Assimilation 3D Variational Analysis (NCODA 3DVar) System, Version 3.0

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1.0 INTRODUCTION

Ocean data assimilation is a mathematically rigorous process that merges ocean observations with ocean models to extract the most pertinent information from often sparse and incomplete observations of time-varying ocean circulation. A data assimilation system has three parts: an observation data set, a dynamical model, and an assimilation, or melding, scheme. The melding of dynamics and data is a powerful tool for producing efficient, accurate and realistic estimations which might not otherwise be feasible. Its primary functions are to initialize ocean models using all available observations through sequential forecasting methods and to marry observations with ocean models to obtain dynamically consistent estimates of changing ocean state.

The Navy Coastal Ocean Data Assimilation (NCODA) system v3.0 differs substantially from the current operational NCODA analysis system, version 2.3. NCODA v2.3 is based on Multivariate Optimum Interpolation (MVOI), and NCODA v3.0 employs the three-dimensional variational analysis (3DVar) scheme, which is an oceanographic implementation of the Navy Atmospheric Variational Data Assimilation System (NAVDAS) (Daley and Barker, 2001). In addition to the assimilation solver, NCODA v3.0 has many upgrades to its pre- and post-processing tools.

The primary difference between NCODA v2.3 and NCODA v3.0 is the algorithm used to solve the analysis problem in observation space. NCODA v2.3 uses a direct solution while NCODA v3.0 employs an iterative, variational solution. While a direct solution is limited by the size of the observation error covariance matrix that can be stored in memory, the variational solution is not, and a true global analysis can be obtained. A global solution occurs when all observations influence all model grid points. In practice, a global solution is not strictly necessary since observations widely separated in space from model grid points are likely to be uncorrelated and do not impact the final solution.

NCODA v3.0 can operate as a stand-alone ocean data analysis program or as an ocean data assimilation system. It is used in conjunction with an ocean forecast model through a sequential incremental update cycle. NCODA v3.0 may be executed in either 2D or 3D mode. In two-dimensional mode, NCODA v3.0 performs a series of univariate sea surface temperature (SST), sea surface height (SSH), significant wave height (SWH), and sea ice concentration analyses separately or in combination. For example, SST and sea ice may be analyzed concurrently for use as lower boundary conditions in Navy atmospheric models such as the Navy Global Atmospheric Prediction System (NOGAPS, Hogan and Rosmond, 1991) and the Coupled Ocean Atmospheric Mesoscale Prediction System (COAMPS, Smith et al., 2010). Significant wave height and sea ice are analyzed for use in wave model data assimilation in either the Shallow Water Analysis Forecast System (SWAFS, Horton et al., 1997) or the WaveWatch III (WW3, Tolman, 2009) model. Sea surface temperature and SSH may be analyzed and assimilated with the Navy Coastal Ocean Model (NCOM, Martin et al., 2008a, 2008b) and Hybrid Coordinate Ocean Model (HYCOM, Metzger et al., 2009).

NCODA v3.0 also can be run in a fully multivariate three-dimensional mode, generating analyses or model updates of ocean SSH, sea ice concentration, temperature (T), salinity (S), and vector currents. It provides updated initial conditions for the next model forecast. Corrections to the ocean model forecast are based on all observations that have become available since the last analysis. These include satellites surface observations including altimeter SSH anomalies, SST, sea ice concentration, *in situ* SSTs from ships and buoys, and T and S profile data from XBTs, CTDs and Argo floats. All observations are quality controlled through the NCODA_QC quality control scheme. By combining these various observational data types via data assimilation and using the dynamical interpolation skill of the model, the 3D ocean environment can be more accurately nowcast and forecast.

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1.1 Document Overview

The purpose of this User's Manual is to provide instruction for executing the three dimensional variational analysis version of the NCODA system. NCODA is in operational use at the two Navy oceanographic production centers: Naval Oceanographic Office (NAVOCEANO) and Fleet Numerical Meteorology and Oceanography Center (FNMOC). Specifics on NCODA implementation at each of the centers requires detailed knowledge of the computer systems and other considerations that are not included in the document. This User's Manual provides detailed directions for manipulating the namelist user interface to the system, which is aimed at users who access the NCODA v3.0 software programmatically. It also describes other interfaces and implementation details behind the setup and execution of the NCODA system. The new capabilities of the NCODA v3.0 system and changes made to the user interface also will be explained in this document. It is assumed that the user is familiar with the existing operational NCODA v2.3 system as described in Cummings and Carroll, 2006.

2.0 APPLICATION

2.1 Description of NCODA v3.0 Components

An NCODA v3.0 ocean analysis is produced using three primary executables: NCODA_PREP, NCODA, and NCODA_POST. Figure 1 illustrates the flow of execution for each of the executables.

- NCODA_PREP is used to set up the ocean grid (horizontal and vertical), bathymetry, and covariances (horizontal and vertical), in addition to processing the ocean observations for the follow-on NCODA analysis. NCODA_PREP computes and prepares the innovation vector. Innovations are defined as the differences between the observations and the model forecast (or previous analysis) at the observation location and/or the observation sampling time.
- NCODA v3.0 reads the innovation and covariance output of NCODA_PREP and performs the 2D and/or 3D variational analysis solutions. NCODA v3.0 outputs increment fields for all of the analysis variables. Increment fields are defined as the observation and model differences at the analysis grid points, taking into account observational and forecast errors of the model background field at the analysis update cycle interval.
- NCODA_POST computes full valued fields from the analyzed increments, updates prediction errors with the increment fields for use in the next analysis cycle, and computes observing system validation and verification statistics for routine monitoring of the NCODA performance.
- NCODA_ET takes the assimilation control run as input and computes multivariate perturbed initial conditions for each of the ensemble members consistent with the analysis error covariances used in the assimilation.
- NCODA_ERR provides an estimate of the analysis error variance in the form of a normalized forecast error reduction ranging from 1 (0% reduction) to 0 (100% reduction) for each analysis variable at all model grid points.
- NCODA_CONVRT converts a model restart file to a set of NCODA v3.0 first guess fields or alternatively updates a model restart file with a set of NCODA v3.0 analyzed increment fields.
- NCODA_GRAPH is a National Center for Atmospheric Research (NCAR) graphics package that includes options for plotting observation and grid node analysis volumes, analysis volume interactions in the solver, and horizontal maps or vertical cross sections of the new 3D vertical correlations, among others.

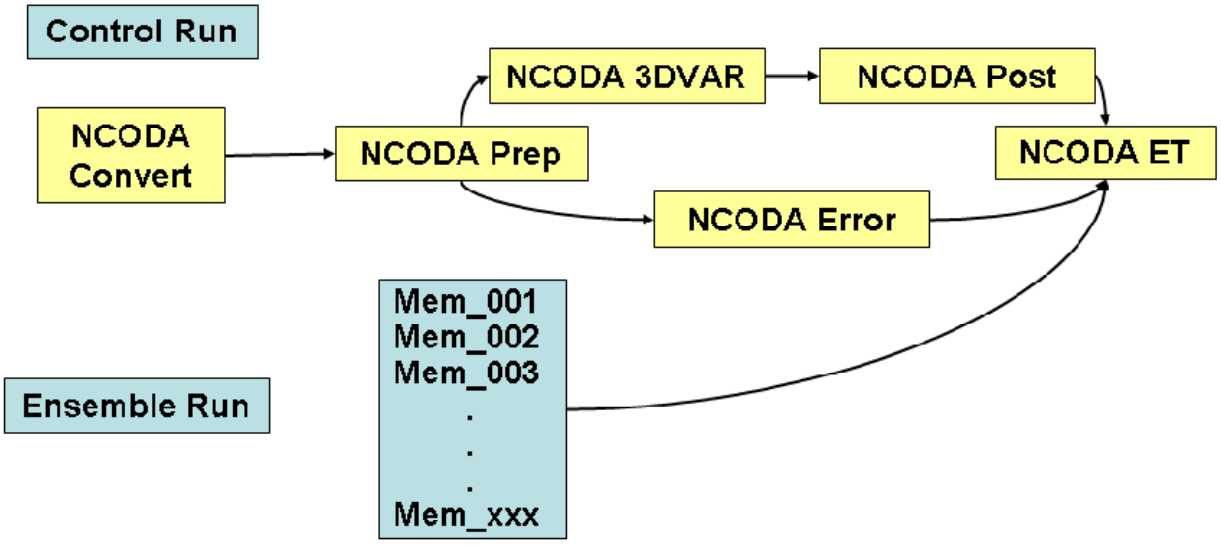

Figure 1: Schematic showing execution of the NCODA v3.0 variational analysis in the Navy coupled ensemble forecasting system.

2.2 NCODA v3.0 Directory Structure

The model code directory (*ncoda_var*) contains all the files needed to generate the NCODA v3.0 executable. The typical structure of this directory is:

ncoda_var/

- Makefile- Top-level makefile for NCODA v3.0.
- config.os- Operating system configuration file included in the top and intermediate level makefiles.
- config.user- Configuration file included in makefiles and contains Fortran options and general commands used in the makefiles.
- bin/- Directory for NCODA v3.0 executable(s).
  - ncoda- Primary model executable.
  - ncoda_convrt- Model conversion executable.
  - ncoda_et- Ensemble transfer executable.
  - ncoda_post- Post processing executable.
  - ncoda_prep- NCODA v3.0 setup and innovation vector prep.
- include/- NCODA v3.0 include files.
  - coda_parms.h- Defines grid nests, grid levels, # of iterations, etc.
  - coda_types.h- Observational data types.
  - dsetnl.h- Directory path include file.
  - ensbnl.h- Ocean ensemble transform namelist file.

gridnl.h- Grid namelist include file.
oanl.h- Analysis namelist include file.

lib/- Directory of NCOM compiled libraries.

libncoda.a - Compiled library of all NCODA v3.0 subroutines.
libconvrt.a - Compiled library of all NCODA converter subroutines.
libet.a- Library of all ocean ensemble transform routines.
libfnoc.a- Library of all FNMOC routines.
libmodas.a- Library of MODAS routines.
libpost.a- Library of all post-processing routines.
libprep.a- Library of NCODA v3.0 setup routines.
libshare.a- Library of shared routines.
libutil.a- Library of utility routines.

libsrc/- Directory of all NCODA v3.0 Fortran subroutine files.

Makefile- Makefile to build libraries used by the CODA analysis system.
coda/- Ocean analysis subroutines.
Makefile- Makefile to compile CODA routines.
convrt/- Converter subroutine library.
Makefile- Makefile to compile local source code.
et/- Directory of ocean ensemble subroutines.
Makefile- Makefile to compile local source code.
fnoc/- Directory of main FNMOC routines.
Makefile- Makefile to compile local source code.
modas/- MODAS synthetic BT library.
Makefile- Makefile to compile local source code.
post/- Post-processing subroutine library.
Makefile- Makefile to compile local source code.
prep/- Innovation prep subroutine library.
Makefile- Makefile to compile local source code.
share/- Shared subroutine library.
Makefile - Makefile to compile local source code.
util/- Utility subroutine library.
Makefile - Makefile to compile local source code.
xfer/- Directory of Fortran modules that compute synthetic temperature and salinity profile observations from altimeter data.

src/-

Makefile-
ncoda/-

ncoda.f- Main program to provide 2D lateral boundary conditions (LBCs) for NOGAPS and COAMPS or 3D analyses for NCOM or HYCOM.

ncoda_convrt/- Directory for NCODA converter program.

Makefile - Makefile to build NCODA converter.

ncoda_et/-

Makefile- Makefile to build program ***ncoda_et.F***.

ncoda_et.f – Main program for the ensemble transform function.

ncoda_post/- Directory of NCODA v3.0 post-processing programs.

Makefile- Makefile to build program ***ncoda_post.F***.

ncoda_post.f- Main program for post processing of NCODA v3.0 analyses.

ncoda_prep/-

Makefile- Makefile to build program ***ncoda_prep.F***.

ncoda_prep.f- Main setup program for NCODA v3.0.

2.3 Memory and Processor Allocation

The computer resources required for an NCODA v3.0 ocean analysis vary by the size of the area, grid resolution, selected analysis options, and density of the observations in the analysis domain. The number of processors used to execute NCODA v3.0 can be as few as one or as many as the maximum number of observation or grid node volumes. As in NAVDAS, memory utilization for the conjugate gradient solver in NCODA v3.0 is reduced as the number of processors is increased. This feature allows NCODA v3.0 to scale very well across many processors on large machines and run efficiently on small platforms with limited memory.

2.4 Code Modifications

2.4.1 Changes from NCODA Version 2.3 to NCODA Version 3.0

Several new capabilities have been incorporated into the NCODA v3.0 analysis. These capabilities are described here in no particular order.

- *Profile Data Preparation*- Profile and glider observations are layer-averaged using the vertical grid defined at the nearest grid point in NCODA v3.0.
- *Land distance correlations*- A new tensor was developed to force correlation structures to be maximized along, not across, land-sea boundaries.
- *A vertical grid*- Three options are available to define the vertical grid in the 3DVar analysis system.
- *Non-separable vertical correlations*- Vertical correlation length scales can now vary with area in the 3DVar.
- *Altimeter SSH Assimilation*- Altimeter SSH observations may now be assimilated along-track or by sampling an analyzed SSH anomaly increment field.

- *Ensemble Transformation*- A new ensemble transformation (ET) program (NCODA_ET) has been added to NCODA v3.0.
- *Cold Starts*- There are now two options to facilitate a cold start of NCODA v3.0 in 3D mode.
- *Analysis Error*- A new analysis error program, NCODA_ERR, gives estimates of the analysis error variance.
- *Background Errors*- a model-data error component is included in the calculation of background error variance updates in the post-processing step.
- *Graphics*- An NCAR-based graphics package has been developed for the NCODA 3DVar code, referred to as NCODA_GRAPH.

2.4.2 Future Upgrades

Development is continuing on the following components of the NCODA v3.2 system. These developments are in varying stages of completion.

- *Analysis Quality Control* - Currently, the NCODA 3DVar data prep program flags observations as suspect based on a background tolerance check that only considers observations in isolation. However, the iterative solution of the variational analysis can be used to evaluate these suspect observations for consistency across all other observations in the analysis by checking the fit of the analysis to the suspect data during one or more of the solver iterations. In this way, an observation considered suspect in isolation may be validated after some number of iterations because the interim solution using other near-by data has found the otherwise suspect observation to be consistent. The advantage of doing data quality control in the analysis is that it takes into account the full error covariance used in the assimilation. The cost to the analysis when the quality control is turned on is a few more iterations of the conjugate gradient solver.
- *Radiance Assimilation* - Direct assimilation of infrared and microwave satellite SST radiances is being added to the NCODA 3DVar. Radiance assimilation will require the addition of the Community Radiative Transfer Model (CRTM) as an observation operator in NCODA v3.0. The use of CRTM will allow NCODA v3.0 to produce a true skin-SST analysis for use in the NOGAPS and COAMPS weather models and in the coupled COAMPS/NCOM model.
- *Assimilation Adjoint* - Development of the adjoint of the NCODA 3DVar variational assimilation system is complete. The adjoint of the assimilation will be used in conjunction with the adjoint of HYCOM to determine observational data's impact on the reduction of some aspect of the model forecast error. Work is continuing on adapting the assimilation adjoint to process multiple forecast error cost functions for assessing the impact of different ocean observing systems.
- *Model State T/S Bias Corrections* - Direct assimilation of satellite altimeter observations does not explicitly correct for model error. Model error is usually seen as a departure of model temperature-salinity (T/S) relationships from the relatively tight T/S relationships that exist at depth in the world ocean. A T/S bias correction has been added to the NCODA 3DVar data preparation step (NCODA_PREP). At the present time, it uses T/S relationships derived from the Global Digital Elevation Model (GDEM) v4.0

climatology and computes bias corrections to the model state when satellite altimeter data are assimilated using the direct method. Eventually, direct assimilation of altimeter SSH, and the corresponding T/S bias correction, will be implemented as observation operators in the 3DVar program. This change will remove the need to generate synthetic profiles in order to assimilate altimeter SSH observations. In addition, the 3DVar will be enhanced to include an option for performing one or more outer loops of the assimilation to improve the altimeter SSH assimilation using the direct method.

- *Conjugate Gradient Solver* – The current form of the conjugate gradient (CG) solver is not ideal because the number of iterations required for a convergent solution can be large. More importantly, extra iterations are often required to overcome rounding errors. A new flexible conjugate gradient (FCG) solver is being implemented in the 3DVar. It has greater give in handling different types of pre-conditioning. The FCG solver differs from the standard CG solver in that an explicit re-orthogonalization of the search direction vector is performed at each iteration. The extra computational cost to form the scalar dot products required in the re-orthogonalization step is relatively small compared to the cost of calculating additional matrix-vector products when performing additional iterations. The current form of the CG solver and the new FCG method obtain identical results in exact arithmetic. However, in finite-precision arithmetic, the FCG method gives an improved solution for the re-orthogonalization step.
- *State Space Solver* – Development is currently underway to implement a capability to perform the assimilation problem in the state space using correlations modeled with the implicit solution of the diffusion equation. The advantages of using this option are: 1) it will be computationally more efficient when assimilation volumes have a moderate-to-large data density; and 2) it will provide a more flexible framework for implementing different methods to calculate the background error covariances (such as ensemble and hybrid schemes). The primary disadvantage of this option is that it may not be compatible with some of NCODA's current capabilities.

3.0 SETTING UP A SIMULATION

3.1 Customizing Namelist Input Variables

Control of the NCODA v3.0 executable is through the **oanl** namelist parameters. The NCODA v3.0 **oanl** control file namelist parameters are listed in Table 1. The **gridnl** grid namelist parameter is listed in Table 2, and the **dsetnl** directory path namelist parameters are listed in Table 3.

The NCODA_PREP, NCODA, and NCODA_POST programs use several namelists to define run-time variables. The entries are in the format <variable name> = <value>, with the namelist name as the first entry preceded by the character '$' in column two. Following all of the entries, the input is terminated by a '$end' (beginning in column two) or a backslash, depending on the computer system. For example, those variables not provided in the input record for the namelist will use the default value defined within the program. Values may be entered in any order separated by commas. Array variables are entered in word order separated by commas or indexed directly using array elements. Blank space or blank lines may be used for clarity. The variable name and declared type in the user defined namelist must match the namelist declarations in the programs or the namelist read will fail.

The variables for the **oanl.h, dsetnl.h,** and **gridnl.h** namelists are listed in the sections below with the variable name, type (integer, real, logical, or character), description, and default value for each input namelist. For array input variables, each default value is separated by commas for the array size. The maximum input length of character strings is given in characters such as 'char*80'.

3.1.1 NCODA v3.0 ocean analysis namelist (*oanl*)

The **oanl** namelist file contains the parameters that control the behavior of the NCODA v3.0 analysis software. Because of the importance of these namelist parameters to the overall performance of the system, each parameter is described in detail below, including their default values. The reference to MVOI in the **oanl** parameter description refers to the NCODA multivariate analysis variables: temperature, salinity, geopotential and the u, v vector velocities.

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)

Name	Type	Description	Default Values

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
adj_run	logical	(true) Indicates that there is a corresponding adjoint sensitivity run of both the forecast model and the assimilation to determine observational data impacts on forecast error reduction. It saves innovation, solution, and synthetic residual vectors needed by the assimilation adjoint.	default=false
amsr_bias	logical	(true) Applies bias correction of Advanced Microwave Scanning Radiometer (AMSR) microwave SST. These are potentially biased cold due to high wind speed and land contamination of the signal. The bias correction is based on *in situ* buoy match-ups.	default=false
amsr_dw	logical	(true) Removes diurnal warming signal (due to low wind speed and high solar radiation) and returns foundation SST.	default=false
argo_bias	logical	(true) Performs bias correction (drift adjustment) of Argo float salinities, which can drift over time due to bio-fouling, changes in calibration, etc. It is based on the GDEM salinity climatology.	default=false
atsr_bias	logical	(true) Performs bias correction of Along Track Scanning Radiometer (ATSR) SST.	default=false
atsr_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default=false
blist	char	Black-listed call signs, such as those that pass the QC checks but are still considered erroneous. Only for use with obs that are reported with unique call signs.	default= 300
bv_chk	real	Brunt-Vaisala frequency threshold (cph).	default= -1
cluster (5)	real	Increases grid mesh used in super-ob data thinning. For satellite data, a value of 1 sets the data thinning to the ratio of the grid mesh and the correlation length scale. Values less (greater) than one result in decreased (increased) data thinning. It is analysis variable dependent: (1) ice, (2) SST, (3) SSH, (4) profiles, (5) SWH.	default= 1 (for all)

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
cluster_eq(5)	real	Additional multiple of grid meshes to use in the data thinning for observations within eight degrees latitude from the equator. Similar to the *cluster* namelist parameter, the value of *cluster_eq* is added to the value of *cluster* for a given analysis variable.	default= 1 (for all)
conflict	logical	(true) Grid node reduction. Analyzes every other grid note (2:1 grid node reduction), resulting in an analysis run time 2-3 times faster with minimal loss of information (if analysis performed on *z*-levels). There is some information loss that occurs with sigma/*z* grids, which is not recommended when *z_opt* = 'hycom' and *vc_mdl* = 'isop'.	default = false
corr_mdl (2)	integer	Correlation model functional options: 1= Second-order Auto-Regressive (SOAR) function, or 2 = Gaussian function. The functional form may be defined independently for horizontal *corr_mdl(1)* or vertical *corr_mdl(2)* length scales.	default = 1, 2
dbv_opt	char	Controls how the various bathymetry databases are used by NCODA v3.0 to compute analysis bottom depths for the analysis grid. Source bathymetry database: 'DOD' = DBDBV from NAVOCEANO, 'SAS' = Smith and Sandwell, and 'all' = all sources (DBDBV plus Smith and Sandwell).	default = 'DOD'
dbv_res	real	Minimum resolution of bathymetry to retrieve from a variable resolution database (minutes). Use caution when using bathy values not homogenous in the analysis domain.	default = 5 (min)

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
debug	logical	(true) Generates formatted output files to diagnose problems or monitor results from the analysis: 1) Argo salt bias correction, pooling of profile moorings and profile rejections (fort.32); 2) profile inflexion point, standard level data and vertical extension results using background fields, tropical mooring insertion (fort.33) (fort.39); 3) geopotential profile observations (fort.34); 4) observation and prediction errors (fort.35); 5) listing of MVOI observations (fort.36); 6) synthetics (direct and MODAS) for MODAS that includes rejections and editing results (fort.37); 7) layer pressure observations (fort.38); 8) produces diagnostics from 3DVar analysis such as processor assignment, volume interaction scales, etc.; 9) produces diagnostics about ensemble transformation file Input/Output (I/O; stdout) in the NCODA_ET program; or 10) retains temporary volume solution files generated in the analysis step when the *himem* option is set true after post processing by the NCODA_POST program.	default = false (for all)
deny	integer	Entire observing systems can be denied in the analysis by listing the observing system (defined in **coda_types.h**) in the *deny* namelist parameter.	default = 0 (for all)

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
dh_scl	real	The covariances computed by NCODA v3.0 can be made flow-dependent by maximizing correlations *along* geopotential contours and minimizing correlations *across* geopotential contours. The model forecast SSH field provides the flow contours. The smaller (larger) the value of *dh_scl* (defined in meters), the stronger (weaker) the flow dependence. Analysis variable dependent with different units: (1) Ice (%) (2) SST (deg C) (3) SSH (dynamic m) (4) Multivariate (dynamic m) (5) SWH (m).	default = -1, 0.7, 0.2, 0.2, -1.
direct	logical	(true) Altimeter SSH anomaly data are assimilated by the CH method if *direct* is set true. The CH method is preferred if NCODA v3.0 is cycling with a forecast model that is skillful. The method cannot explicitly correct for model errors and so should not be used when the analysis is cycling on itself or the forecast model has systematic errors or biases.	default = false
diurnal	logical	(true) Daytime satellite SST retrievals are biased warm when the insolation is high and wind speeds are low. The NCODA_QC system flags satellite SST retrievals in diurnal warming events. Set *diurnal* to true to use these flagged observations in the NCODA v3.0 analysis.	default = false
ds_scl (5)	real	Land distance correlation scale (km). It is analysis variable dependent with different units: (1) Ice (%) (2) SST (deg C) (3) SSH (dynamic m) (4) Multivariate (dynamic m) (5) SWH (m).	default = -1 (for all)
dv_dz	real	Vertical gradient length scale (units are dependent upon *vc_mdl* selection). Smaller values equal shorter vertical length scales.	default = 0.8

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
fcst	logical	(true) Uses forecast model backgrounds on input. It is analysis variable dependent: 1) ICE, 2) SST, 3) SSH, 4) multivariate, 5) SWH.	default = false
fcst_off	integer	Number of hours to offset the analysis date-time group (DTG) for the start of the forecast. It is used in HYCOM to correct for the 6 hr incremental analysis update (IAU) that is used.	default = 0
fgat	integer	First guess appropriate time update interval (hrs) for: (1) Ice (%) (2) SST (deg C) (3) SSH (dynamic m) (4) Multivariate (dynamic m) (5) SWH (m).	default = -1 (for all)
gldr_slct	real	Glider selection criteria options: (1) acceptable level probability gross error (2) minimum number of sampling levels (3) minimum ratio of last sampling depth and bottom depth (4) minimum sampling depth (if glider has not sampled water column) (5) maximum acceptable distance between adjacent levels (6) maximum acceptable temperature difference between adjacent levels (7) maximum acceptable depth difference at level of maximum temperature difference (8) maximum acceptable temperature difference at level of maximum level difference (9) maximum depth of the first sample (10) maximum surface extrapolation depth.	default = .99, 5, 0.5, 300, 300, 5, 100, 2.5, 50, 10.
global	logical	(true) Global cyclic grid.	default = false
goes_bias	logical	(true) Performs bias correction of GOES SST data.	default = false
goes_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default = false

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
hc_mdl	char	Controls how the horizontal correlation length scales are defined in NCODA v3.0. If *hc_mdl* is set to 'locl' then NCODA v3.0 will attempt to read a 2D array of correlation length scales from a local file. It is anticipated that 'locl' will be used when the horizontal correlations are computed from an ensemble run of the analysis/forecast system. Horizontal correlation model options: 'rsby' = Rossby radius deformation, 'homo' = homogeneous scales, and 'locl' = user defined scales for the analysis variables: (1) Ice (%) (2) SST (deg C) (3) SSH (dynamic m) (4) Multivariate (dynamic m) (5) SWH (m).	default = 'rsby '(for all)
himem	logical	(true) Executes analysis using I/O of analysis volumes rather than *mpi_reduce.*	default = false
ice_asm	logical	(true) Assimilates sea ice observations.	default = false
ice_time	char	Ice observation processing option: 'obst' = select obs based on obs time 'synt' = select obs that are synoptic for analysis update interval.	default ='obst'
lac_bias	logical	(true) Performs bias correction of Advanced Very High Resolution Radiometer (AVHRR) Local Area Coverage (LAC) SST data.	default = false
lac_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default = false

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
lndz	real	Minimum bottom depth (m) used to define land points in the analysis grid. The NCODA v3.0 analysis grid can be masked for grid points over land or under the bottom. Masked grid points are not used in the analysis, which results in a considerable savings in computational time. All grid nodes shallower than the *lndz* parameter can be set as mask points. This parameter is often used in combination with ocean forecast model definitions of a minimum depth at the coast (see also the *mask_opt* namelist parameter).	default = 0.5 M
lvl_nmo	real	Level of no motion for geopotential calculations. The level of no motion varies with the ocean basins. It is shallower in the Pacific and deeper in the Atlantic.	default = 2000 m
mask_opt	char	Grid mask option (‘0D’ ‘2D’ or ‘3D’): ‘0D’= water only, ‘2D’ = extends water points into land and below bottom, and ‘3D’ = land and below bottom points eliminated.	default = ‘0D’
mcsst_bias	logical	(true) Performs bias correction of AVHRR Global Area Coverage (GAC) SST data.	default = false
mcsst_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default = false
mds_edit	logical	(true) Edits MODAS synthetic temperature profiles that are often computed with spurious mixed layer structures and inversions at depth. Setting *mds_edit* to true will force the MODAS profiles through an automated editor that attempts to correct the deficiencies in the MODAS algorithm and supporting databases.	default = true
mds_rej_sal	logical	(true) Does not assimilate MODAS derived salinity observations (but does assimilate MODAS temperatures).	default = false
mds_xtnd	logical	(true) Extends MODAS synthetics with Levitus climatology.	default = true
metop_bias	logical	(true) Performs bias correction of Polar Orbiting Meteorological Satellite (METOP) AVHRR GAC and LAC SST data.	default = false
metop_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default = false

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
mld_src	char	Source file for 3D density field to compute mixed layer depths. 'modl': forecast model T and S fields, 'clim': GDEM climate T and S fields, or 'none': no MLD field used.	default = 'modl'
modas	logical	(true) Performs assimilation of altimeter SSHA using MODAS synthetic profiles. Salinity is computed from the synthetic temperatures using historical TS relationships that are also stored in the MODAS database.	default = false
model	char	Forecast (NCOM, HYCOM) or wave model (WaveWatch III) region name.	no default settings
msg_bias	logical	(true) Performs bias correction of Meteosat Second Generation (MSG) SST data.	default = false
msg_dw	logical	(true) Removes diurnal warming signal and returns foundation SST.	default = false
mx_dst	real	Maximum land distance (km). Beyond this maximum, land distance gradients are set to zero, effectively cancelling the effect of the land distance tensor on horizontal correlation structures.	default = 20
mx_lyr_prs	real	Maximum acceptable layer pressure innovation (a negative value disables the test).	default = -1
n_cold_anl	integer	Number of update cycles to execute the analysis in cold start mode.	default=-1
n_hst	integer	Number days into the past to use in forming prediction errors from analyzed increments for ice, SST, SSH, multivariate and SWH analysis variables.	default = 10, 20, 30, 30, 20
n_it	integer	Number of conjugate gradient solver iterations.	default = 30
n_pass	integer	Number of 3x3 smoother passes on full valued analysis output fields.	default = 2

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
offset	real	(i, j) offsets from the gird boundary to restrict data selection for the assimilation (only for nest 1): from north (grid top), from south (grid bottom), from east (grid right), or from west (grid left). When NCODA v3.0 is cycled with a forecast model that has open boundaries, the forecast fields in the boundary zones often reflect the LBCs more than the forecast. Accordingly, innovations computed from observations in these boundary zones are likely to be very inaccurate and may adversely affect the forecast away from the boundaries depending on the covariances used to spread the innovations to the surrounding grid points.	default = 0 (for all)
ohc	logical	(true) Output ocean heat content on this grid nest.	default = false
ohc_mld	real	Temperature difference from surface for definition of heat content mixed layer (°C).	default = 1
prf_hrs	integer	Number of hours of profile observations.	default = 24
prf_slct	real	Profile selection criteria options for : 1) acceptable level probability gross error, 2) minimum number of sampling levels, 3) minimum ratio of last sampling depth and bottom depth, 4) minimum sampling depth (if profile has not sampled the water column), 5) maximum acceptable depth distance between adjacent levels, 6) maximum acceptable temperature difference between adjacent levels, 7) maximum acceptable depth difference at level of maximum temperature difference, (8) maximum acceptable temperature difference at level of maximum level difference, (9) maximum depth first sample, (10) maximum surface extrapolation depth.	default = 0.99, 5, 0.5, 300, 300, 5, 100, 2.5, 50, 10

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
prf_time	char	Profile time sampling options: 'cycl' = select profiles based on the number of *prf_hrs* specified, 'obst' = select profiles based on the time profile was observed, 'rcpt' = select profiles based on time profile was received at the center, and 'synt' = select obs that are synoptic for the analysis update interval. For real-time analyses, the 'rcpt' option is useful to ensure that profiles received late are still selected. For delayed-mode analyses, the 'obst' option is useful to ensure that only profiles observed in the period of the analysis time window are selected. For these two *prf_time* options, the look-back period for profile observations is a floating DTG determined by the youngest observation assimilated in the previous analysis. Profile data selection can also be forced to coincide with the analysis time window by setting *prf_time* to 'synt'.	default = 'obst'
pt_anl	logical	(true) Potential temperature analysis. Observations are reported as *in situ* temperatures, while ocean forecast models use potential temperature. If *pt_anl* is set true, NCODA v3.0 converts all *in situ* temperatures from observations and climate databases to potential temperature. The analyzed temperature increments become potential temperature increments and can be used directly to correct the model forecast temperatures in a sequential incremental update cycle.	default = false

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
qc_err	real	Maximum acceptable probability random error for: 1) Defense Meteorological Satellites Program (DMSP) sea ice, 2) AVHRR satellite GAC SST, 3) Geostationary Operational Environmental Satellites (GOES) SST, 4) *in situ* SST, 5) profile temperatures (integrated over levels), 6) profile salinities (integrated over levels), 7) altimeter sea surface height anomaly (SSHA), 8) altimeter/buoy SWH, 9) LAC satellite SST, 10) AMSR satellite SST, 11) ATSR satellite SST, 12) MSG satellite SST, 13) METOP GAC satellite SST, and 14) METOP LAC satellite SST.	default = 0.99, 0.99, 0.99, 0.99, 0.95, 0.95, 1, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99
redu	integer	Grid node analysis volume reduction factor for ice, SST, SSH, MVOI, and SWH.	default=2, 2, 2, 3, 2
rscl	real	Horizontal correlation length scales based on the Rossby radius of deformation can be adjusted by multiplying with a scalar value defined in *rscl* for a given analysis variable. The adjustment can be made to increase or decrease the length scales interpolated from the 1° resolution Rossby radius database to the analysis grid. The Rossby radius scaling factor is for ice, SST, SSH, MVOI, and SWH analysis variables.	default = 2 (for all)
sal_asm	logical	(true) Assimilates real salinity observations.	default = true
sal_std	real	Salinity is computed from MODAS synthetic temperatures using climatological TS relationships stored in the MODAS database. The derived salinity is checked for consistency with climate salinity estimates by forcing the derived salinity to be within some number of standard deviations from the climate mean. *Sal_std* is the max number of std deviations to scale MODAS salinity from climatology.	default = 3

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
spval	real	A special value used to indicate missing values in all grids, observations, and validation and verification output. NCODA v3.0 requires that the special (missing) value must be a large negative number less than -99.	default = -999
ssh_asm	logical	(true) Performs altimeter SSH assimilation.	default = false
ssh_grd	logical	(true) Performs 2D SSH analysis.	default = false
ssh_hrs	integer	Number of hours of altimeter SSH obs. This option is useful when a complete repeat cycle of a satellite altimeter is assimilated.	default = 24
ssh_mean	char	When altimeter SSHA data are assimilated via synthetic profiles generated by the CH algorithm (namelist parameter *direct* is set true), NCODA v3.0 requires a SSH mean field. SSH mean field options: 'modl' = model mean field 'data' = data derived mean field.	default = 'data'
ssh_std	real	Max number of standard deviations to scale altimeter SSH from climatology. If an altimeter SSHA observation exceeds *ssh_std*, then the altimeter observation is scaled to fall within *ssh_std* + 1 standard deviations of the dynamic height variability that has been computed from 50 years of historical profile data and stored in the MODAS database.	default = 1
ssh_time	char	Altimeter SSH processing option: 'cntr' = select obs in data window centered around analysis time, 'cycl' = select obs based on full TOPEX repeat cycle (10 days), 'obst' = select obs based on time SSHA was observed, 'rcpt' = select obs based on time SSHA was received at center, or 'synt' = select obs that are synoptic for analysis update interval.	default = 'obst'

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
sst_asm	logical	(true) Performs SST assimilation. Turning off the assimilation of SST data (*sst_asm* set false) may be useful in large domains when there are millions of SST observations. If *sst_asm* is set false, then the forecast model is typically relaxed to the SST corrections computed in the NCODA v3.0 2D analysis.	default = false
sst_time	char	SST obs processing option: 'obst' = select obs based on obs time, or 'synt' = select obs that are synoptic for analysis update interval. For real-time analyses, 'rcpt' ensures that SST data received late are still selected. For delayed-mode analyses, 'obst' ensures that only SST data observed in the analysis time period are selected. For these two *sst_time* options, the look-back period for SST observations is a floating DTG determined by the youngest observation assimilated in the previous analysis. SST data selection can also be forced to coincide with the analysis time window by setting *sst_time* to 'synt'.	default = 'obst'
swh_asm	logical	(true) Assimilates SWH observations.	default = false
swh_da	char	SWH assimilation option: 'bmrc' = Australian Bureau of Meteorology Research Centre (BMRC) method, or 'ncep' = National Centers for Environmental Prediction (NCEP) method.	default = 'ncep'

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
swh_time	char	SWH observation processing option: 'obst' = select obs based on time SWH observed, 'rcpt' = select obs based on time SWH received at center, or 'synt' = select obs that are synoptic for analysis update interval. For real-time analyses, 'rcpt' ensures that altimeter SWH data received late are still selected. For delayed-mode analyses, 'obst' ensures that only SWH data observed in the analysis time period are selected. For these two *swh_time* options, the look-back period for SWH observations is a floating DTG, determined by the observations. Finally, altimeter SWH data selection can be forced to coincide with the analysis time window by setting *swh_time* to 'synt'.	default = 'obst'
tmp_std	real	Max number of standard deviations to scale MODAS temperature from climatology.	default = 4
tol_fctr	real	Innovation error check tolerance factor for 1) ice, 2) SST, 3) SSH, 4) temperature, 5) salinity, 6) geopotential, 7) velocity, 8) SWH and 9) layer pressure. The normalized innovation vector over many realizations is a normal distribution with a standard deviation (STD) = 1. Tolerance limits are defined to remove unacceptable observations and are equivalent to the number of acceptable standard deviations of the innovation from the analysis background. Since the background error covariances are never perfectly known, it is best to use a higher rather than lower tolerance value in this procedure.	default = -1 (for all)
topo_mn	real	Minimum depth for SSH observations (m). Altimeter SSHA observations are prone to error in shallow water areas because of uncertainties in the tides, the geoid, and the actual altimeter measurements near land. Accordingly, altimeter SSHA data are scaled to zero at locations where the bottom depth is less than the depth specified in the *topo_mn* namelist parameter.	default = 150

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
topo_mx	real	Maximum depth for unscaled SSH observations (m). SSH data are scaled from full value at *topo_mx* to zero at *topo_mn* depending on the bottom topography value.	default = 400
topo_src	char	Source of topography for scaling SSH: 'modas' = MODAS smoothed topography, 'model' = forecast model topography, and 'ncoda' = turns off scaling of SSHA. The bottom depth field used in the topography test can be the analysis bathymetry file or a global depth that has been smoothed with shallow areas extended into deep ocean areas in the vicinity of isolated, open ocean islands.	default = 'modas'
upd_cyc	integer	Analysis update cycle (hours). Background fields from a previous analysis or a model forecast must be available in the restart directory at the prescribed update cycle interval. Changing *upd_cyc* during a cycling analysis run may force NCODA v3.0 to cold start if restart files at the update cycle are missing.	default = 24
vc_mdl	char	Vertical correlation model options: 'mixl' = mixed layer, 'dens' = correlation length scales defined by first guess vertical density gradients, 'temp' = temperature stratification, 'mono' = monotonic, 'cons' = constant, 'isop' = vertical correlations defined along isopycnal surfaces, or 'none' = no vertical correlation.	default = 'dens'
vc_src	char	Source file for computing vertical correlations: 'clim' = GDEM climatology (updated monthly) 'modl' = forecast model valid at analysis time.	default = 'clim'
vhalo	real	Size of halo region to extract observations for estimation of analysis error. It is defined in terms of multiples of analysis grid volume *x*, *y* dimensions.	default = 2

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
vscl	real	Number of horizontal correlation length scales within an observation analysis volume. Analysis variable dependent: 1) ICE, 2) SST, 3) SSH, 4) multivariate, 5) SWH.	default = 4, 3, 3, 3, 5
warm_ice	logical	(true) Positive sea ice concentration retrievals from the DMSP series of satellites can occur in high rain and wind events. SST is collocated with the sea ice retrievals in NCODA_QC, and the retrievals are flagged as impossible ice if the SST exceeds a threshold value. These flagged retrievals can still be used in a subsequent sea ice analysis by setting *warm_ice* true. The *warm_ice* retrievals are converted to zero ice concentration prior to being used in the analysis.	default = false
wlist	char	Observations that have been rejected by NCODA_QC with probabilities of random or gross errors that exceed the *qc_err* namelist parameter setting can be forced into the analysis via the whitelist (*wlist*) namelist parameter. Valid observations are often rejected by NCODA_QC because of erroneous background or forecast error fields. By forcing an observation into the analysis the background is corrected, the forecast errors are adjusted, and any subsequent observations in the vicinity of the white-listed observation should pass the NCODA_QC procedures and be accepted into the analysis. Only observations that are reported with unique call signs can be placed on the white list.	default = 300
z_lvl	real	Pressure levels or sigma/z levels if *z_opt* is set to 'ncom'.	default = 0, 5, 10, 15, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750, 2000, 2500, 3000, 70*0

Table 1: NCODA v3.0 Ocean Analysis Namelist (*oanl*)			
Name	**Type**	**Description**	**Default Values**
z_opt	char	Vertical grid options: pressure: *z_opt* = 'none' sigma/*z*: ='ncom' hybrid: = 'hycom'.	default = none

3.1.2 NCODA v3.0 grid namelist (*gridnl*)

Gridnl is an include file containing namelist parameters and parameters that define the analysis grid (Table 2). The analysis grid latitudes and longitudes are computed internally by NCODA v3.0 if the projection number is greater than zero. Analytical solutions exist for computing the index of an observation grid location for projection numbers greater than zero. NCODA v3.0 works best if the analysis grid is defined as a Mercator, Lambert Conformal, or Polar Stereographic projection. Spherical projections should be avoided if at all possible. If the projection number is less than zero, then NCODA v3.0 reads the analysis grid positions from a local file. In this case, NCODA v3.0 assumes the grid is irregular and cannot be defined by one of the standard projections. The computation of indices of randomly located observations on an irregular analysis grid is done by a search routine. The search routine is much less efficient than the analytical solution.

Table 2: NCODA v3.0 grid namelist (*gridnl*)			
Name	**Type**	**Description**	**Default Values**
alnnt	real	Standard longitude of grid.	default = 240
delx	real	Grid spacing in x-direction.	default = 81000
dely	real	Grid spacing in y-direction.	default = 81000
ii	integer	Coarser mesh x grid point.	default = 1 (for all grids)
iref	integer	i-coordinate of reference point.	default = 1 (for all grids)
jj	integer	Coarser mesh y grid point.	default = 1 (for all grids)
jref	integer	j-coordinate of reference point.	default = 1 (for all grids)
kka	integer	Number of atmospheric vertical levels (layers).	default = 30
kko	integer	Number of ocean analysis levels.	default = 1
kkom	integer	Number of ocean model mass levels.	default = 1
kkosm	integer	Number of sigma/z ocean model sigma levels.	default = 0
lnmove	logical	(true) Moving nest indicator.	default = false (for all grids)

Table 2: NCODA v3.0 grid namelist (*gridnl*)			
Name	**Type**	**Description**	**Default Values**
m	integer	Number of x grid positions.	default = 61
n	integer	Number of y grid positions.	default = 61
nnest	integer	Number of nested grids.	default = 1
npgrid	integer	Parent grid number.	default = 1,1,2,3,4,5,6
nproj	integer	Grid projection number: <0 = irregular (grid defined externally by user) 1 = Mercator 2 = Lambert Conformal 3 = Polar Stereographic 4 = Cartesian 5 = Spherical >10 = Gaussian (defines number of grid longitudes).	default = 2
phnt1	real	1st standard latitude of grid.	default = 60
phnt2	real	2nd standard latitude of grid.	default = 30
rlat	real	Grid reference latitude.	default = 42.5
rlon	real	Grid reference longitude.	default = 16.5

3.1.3 NCODA v3.0 directory path namelist (*dsetnl*)

The *dsetnl* namelist stores the file system paths to databases, datasets, and working directories. Default path values depend on the center and computer system where NCODA v3.0 is being executed (Table 3). NCODA_PREP automatically searches four directory paths when gathering observations. The observation data directory paths are defined in the *dsetnl* namelist on the basis of the classification of the observations contained in the directory. However, the *dsoudat, dsordat, dsocdat, dsosdat* directories can point to any directory regardless of the classification level of the observations in the directory. This option is useful when new observing systems are being evaluated in NCODA v3.0. For example, the operational data can be defined by the *dsoudat* namelist parameter and the new, unclassified, observing system data available in test mode can be defined by the *dsordat* namelist parameter.

Table 3: NCODA v3.0 directory path namelist (*dsetnl*)			
Name	**Type**	**Description**	**Default Values**
dsnrff	char	COAMPS flat file directory path.	(none)
dsoclim	char	Ocean climate file directory path.	(none)
dsoensm	char	Ensemble file directory path.	(none)

Table 3: NCODA v3.0 directory path namelist (*dsetnl*)			
Name	**Type**	**Description**	**Default Values**
dsogdem	char	GDEM climate directory path.	(none)
dsomdas	char	MODAS database file directory path.	(none)
dsomrff	char	Ocean model restart directory path.	(none)
dsorff	char	Ocean restart file directory path.	(none)
dsostat	char	Ocean model static directory path.	(none)
dsoudat	char	Unclassified ocean data directory.	(none)
dsordat	char	Restricted ocean data directory.	(none)
dsocdat	char	Confidential ocean data directory.	(none)
dsosdat	char	Secret ocean data directory.	(none)
dsowork	char	Analysis work file directory path.	current working directory.

3.1.4 NCODA v3.0 ocean ensemble transform (ET) namelist (*ensbnl*)

The ensbnl namelist contains the parameters, directories and file names that are required to run NCODA_ET (Table 4). NCODA_ET is used when an ensemble of forward model runs is being created. This program provides the initial conditions for each of the *n_mem* forward model ensembles by perturbing the initial conditions of the control run based on the statistics of the updated forecast error covariance.

Table 4: NCODA v3.0 ocean ensemble transform (ET) namelist (*ensbnl*)			
Name	**Type**	**Description**	**Default Values**
ensm_pfx	char	Ensemble directory prefix.	(none)
err_scl	real	Scalar conversion of forecast error to analysis error (if analysis error is not available).	default = 0.5
n_mem	integer	Number of ensemble members.	default = 0
rst_name	char	Ensemble member restart file name.	(none)
var_src	char	Source of analysis variance estimate comes from either: 1) 'fcst' – NCODA forecast error variance 2) 'ensm' – ensemble member error variance	Default = 'fcst'

3.2 Include Files

NCODA v3.0 uses two include files, **coda_parms.h** and **coda_types.h** to define analysis grid parameters and observing systems supported by the analysis. These include files are defined in the include subdirectory under the NCODA v3.0 main source code directory. Variable settings in these include files are not accessible through namelist input at runtime. Rather, the include files must be edited and saved, and the NCODA v3.0 programs recompiled before any changes are incorporated into the analysis system. The NCODA v3.0 makefiles contain the appropriate dependencies that automate this process when an include file is updated.

3.2.1 NCODA v3.0 Parameter Include File (*coda_parms*)

The include file **coda_parms** defines the maximum number of grid nests, number of grid nest levels and maximum number of time iterations. The *max_it* parameter is used within the COAMPS forecast model and is included here in the **coda_parms** namelist only for compatibility purposes. It is expected that users should never have to change any of the **coda_parms** namelist parameter settings (see Table 5).

Table 5: NCODA v3.0 parameter include file (*coda_parms*)

Name	Type	Description	Default Values
mx_depths	integer	Maximum number of profile depths.	default = 2048
mx_grids	integer	Maximum number of grid nests.	default = 7
mx_nlvls	integer	Maximum number of grid nest levels.	default = 7
max_it	integer	Maximum number of time iterations.	default = 5000

3.2.2 NCODA v3.0 Data Types Include File (*coda_types*)

Observation data types in the NCODA v3.0 system are defined in the **coda_types** include file. The observation data type definition includes the observing system name, the expected measurement error of the observing system, and an observing system sampling scale value (Tables 6). For *in situ* data types the sampling scale is set to a default value of 1 km. For satellite data the sampling scale is set to the resolution of the satellite footprint, which varies considerably among the different satellite systems. The sampling scale is used to assign a representation error to satellite retrievals in high gradient areas relative to the resolution of the analysis grid. Users will need to update the **coda_types** include file when new ocean data types are added to the system (see Table 7). At the present time, the maximum number of ocean data types permitted in a NCODA v3.0 analysis is set to 200, but this number can easily be increased as new observing systems become available. Type 0 (zero) is a diagnostic data type used to describe the combination of data types in the NCODA_POST validation and verification processing.

Table 6: NCODA v3.0 observation data types include file (*coda_types)*			
Name	**Type**	**Description**	**Default Values**
mx_types	integer	Maximum number of data types.	default = 136
data_lbl	char	Data type labels.	none
inst_err	real	Obs instrumentation error	none
rerr_scl	real	Obs representative scale (km)	none

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
No.	**Description (*data_lbl*)**	**Instrumentation Error (*inst_err*)**	**Representative Scale (*rerr_scl*)**
0	All Data Combined	1.0	1
1	Bathy Temperatures (°C)	0.12	1
2	NOAA14 Day GAC SST (°C)	0.31	8
3	Ship Engine Room Intake (°C)	1.30	3
4	Fixed Buoy Temperature (°C)	0.05	1
5	Drifting Buoy (°C)	0.12	1
6	NOAA14 Night GAC SST (°C)	0.26	8
7	NOAA14 Relaxed Day GAC SST (°C)	0.49	8
8	SSM/I F11 Ice (%)	10.0	10
9	SSM/I F13 Ice (%)	10.0	10
10	SSM/I F14 Ice (%)	10.0	10
11	Supplemental Ice (%)	50.0	25
12	TOPEX (M)	0.03	7
13	ERS2 (M)	0.08	7
14	Geosat Follow On (GFO) (M)	0.10	7
15	MODAS Temperature (°C)	1.0	14
16	GDEM 3D Climatology (°C)	1.0	27

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
17	GOES8 Day SST (°C)	0.49	12
18	GOES8 Night SST (°C)	0.31	12
19	Direct Method Temperature (°C)	1.0	1
20	TESAC Temperature (°C)	0.01	1
21	SHIP Bucket (°C)	1.21	1
22	SHIP Hull Sensor (°C)	0.64	1
23	CMAN SST (°C)	1.10	1
24	NOAA15 Day GAC SST (°C)	0.31	8
25	NOAA15 Night GAC SST (°C)	0.26	8
26	NOAA15 Relaxed Day GAC SST (°C)	0.49	8
27	Mechanical BT (°C)	0.55	1
28	Hydrocast BT (°C)	0.31	1
29	SSM/I F15 Ice (%)	10	10
30	*In Situ* Sea Surface Height Anomaly (M)	0.01	1
31	SSM/I Ice Shelf	50	50
32	TESAC Salinity (PSU)	0.01	1
33	MODAS Salinity (PSU)	1.0	14
34	TRACK OB Temperature (°C)	0.30	1
35	TRACK OB Salinity (PSU)	1.0	1
36	Argo Float Temperature (°C)	0.02	1
37	Argo Float Salinity (PSU)	0.01	1
38	Supplemental MODAS Temperature (°C)	1.0	14
39	Supplemental MODAS Salinity (PSU)	1.0	14
40	Supplemental SSHA(M)	1.0	7
41	Supplemental Sea Ice SST (°C)	50	25

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
42	SST Super Ob (°C)	0.30	12
43	NOAA16 Day GAC SST (°C)	0.31	8
44	NOAA16 Night GAC SST (°C)	0.26	8
45	NOAA16 Relaxed Day GAC SST (°C)	0.49	8
46	SST Derived Surface Salinity (PSU)	2.5	2
47	GOES10 Day SST (°C)	0.49	12
48	GOES10 Night SST (°C)	0.31	12
49	Direct Method Salinity (PSU)	1.0	1
50	Extended Temperatures (°C)	0.5	12
51	Extended Salinity (PSU)	1.0	12
52	Fixed Buoy Salinity (PSU)	0.01	1
53	Jason-1 SSH (M)	0.03	7
54	Drifting Buoy Salinity (PSU)	0.02	1
55	ENVISAT SSH (M)	0.08	7
56	NOAA17 Day GAC SST (°C)	0.31	8
57	NOAA17 Night GAC SST (°C)	0.26	8
58	NOAA17 Relaxed Day GAC SST (°C)	0.49	8
59	NOAA16 Day LAC SST (°C)	0.31	2
60	NOAA16 Night LAC SST (°C)	0.26	2
61	NOAA17 Day LAC SST (°C)	0.49	2
62	NOAA17 Night LAC SST (°C)	0.31	2
63	ERS2 SWH (M)	0.50	7
64	TOPEX SWH (M)	0.50	7
65	GFO SWH (M)	0.50	7
66	Jason-1 SWH (M)	0.50	7

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
67	Envisat SWH (M)	0.50	7
68	Fixed Buoy SWH (M)	0.20	1
69	AMSRE Day Microwave SST (°C)	0.71	25
70	GOES12 Day SST (°C)	0.49	12
71	GOES12 Night SST (°C)	0.31	12
72	AMSRE Night Microwave SST (°C)	0.71	25
73	TRMM Microwave SST (°C)	0.71	50
74	AATSR (ENVISAT) Day SST (°C)	0.5	12
75	AATSR (ENVISAT) Night SST (°C)	0.3	12
76	TOPEX Interleaved SSH (M)	0.03	7
77	TOPEX Interleaved SWH (M)	0.50	7
78	SSM/I Sea Ice Super Observations	10.0	10
79	SST Super Obs.	1.00	1
80	SSMIS F17 Ice (%)	10.0	10
81	Altimeter SSH Super Observations	0.03	7
82	Altimeter SWH Super Observations	0.5	7
83	Near Shore Ice (%)	20.0	25
84	Aircraft SST (°C)	0.30	1
85	Not Used	1.00	1
86	Not Used	1.00	1
87	Not Used	1.00	1
88	Not Used	1.00	1
89	Not Used	1.00	1
90	SSMIS F18 Ice (%)	10.0	10
91	Jason-2 SSH (M)	0.03	7

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
92	Not Used	1.00	1
93	Not Used	1.00	1
94	NOAA18 Day GAC SST (°C)	0.31	8
95	NOAA18 Night GAC SST (°C)	0.26	8
96	NOAA18 Relaxed Day GAC SST (°C)	0.49	8
97	NOAA18 Day LAC SST (°C)	0.31	2
98	NOAA18 Night LAC SST (°C)	0.26	2
99	MSG Day SST (°C)	0.31	12
100	MSG Night SST (°C)	0.31	12
101	MSG Day/Night SST (°C)	0.31	12
102	Glider Temperature Profiles (°C)	0.05	1
103	Glider Salinity Profiles (PSU)	0.01	1
104	Not Used	1.00	1
105	Not Used	1.00	1
106	HYCOM Layer Pressure (db)	5	1
107	GOES11 Day SST (°C)	0.49	12
108	GOES11 Night SST (°C)	0.31	12
109	SSMIS F16 Ice (%)	10.0	1.
110	METOP-A Day GAC SST (°C)	0.31	8
111	METOP-A Night GAC SST (°C)	0.26	8
112	METOP-A Relaxed Day GAC SST (°C)	0.49	8
113	METOP-A Day LAC SST (°C)	0.31	2
114	METOP-A Night LAC SST (°C)	0.26	2
115	METOP-B Day GAC SST (°C)	0.31	8
116	METOP-B Night GAC SST (°C)	0.26	8

Table 7: NCODA v3.0 Observation Data Types Include File (coda_types.h)			
117	METOP-B Relaxed Day GAC SST (°C)	0.49	8
118	METOP-B Day LAC SST (°C)	0.31	2
119	METOP-B Night LAC SST (°C)	0.26	2
120	METOP-C Day GAC SST (°C)	0.31	8
121	METOP-C Night GAC SST (°C)	0.26	8
122	METOP-C Relaxed Day GAC SST (°C)	0.49	8
123	METOP-C Day LAC SST (°C)	0.31	2
124	METOP-C Night LAC SST (°C)	0.26	2
125	Jason-2 SWH (M)	0.50	7
126	Jason-1 Interleaved SWH (M)	0.50	7
127	Jason-1 Interleaved SSH (M)	0.03	7
128	NOAA19 Day GAC SST (°C)	0.31	8
129	NOAA19 Night GAC SST (°C)	0.26	8
130	NOAA19 Relaxed Day GAC SST (°C)	0.49	8
131	NOAA19 Day LAC SST (°C)	0.31	2
132	NOAA19 Night LAC SST (°C)	0.26	2
133	Marine Mammal Temperature (°C)	0.04	1
134	Marine Mammal Salinity (PSU)	0.02	1
135	GOES13 Day SST (C)	0.49	12
136	GOES13 Night SST (C)	0.31	12

3.3 Grid Domain Decomposition

NCODA 3DVar is run by grouping observations and grid nodes into separately defined analysis volumes. Observation volume size is defined using the **oanl** namelist parameter *vscl*, which can be defined separately for each analysis volume. The maximum horizontal correlation length scale in the analysis domain is multiplied by the value of *vscl* after converting from distance to grid mesh units. Grid node volumes are defined using a 2:1 or 3:1 sub-setting of observation volumes depending upon whether the user is running a 2D or 3D

analysis, although the settings may be overridden through the *redu* namelist parameter. Experimentation is needed to determine optimum settings for *vscl* in an analysis domain and for a given analysis variable. Typically, *vscl* is set to values that result, on average, in a thousand observations or less in an observation volume. It is important to note that partitioning observations and grid nodes into analysis volumes has no effect on the final result. At the end of the minimization, correlations between all relevant observations and grid nodes are included in the solution.

3.4 Setting up Bathymetry

The **ocn_depth.f** software modules found in the '/libsrc/share/' sub-directory access the variable resolution bathymetry databases used by the NCODA_PREP program. As new bathymetry data are digitized, there may be a need for creating corrections to existing database files or new ocean bottom depth databases for selected areas in resolutions not currently available.

3.5 Setting up a vertical grid

Three options are available to define the vertical grid in the 3DVar analysis system using the *z_opt* **oanl** namelist parameter (Table 1). The vertical grid options include pressure levels (default), hybrid coordinates (z/isopycnal/sigma levels), or sigma/z levels. Sigma/z levels are primarily used with NCOM. The hybrid coordinates are used with HYCOM. Vertical grids using sigma/z and hybrid coordinates necessarily vary with location.

3.6 Defining Non-Separable Vertical Length Scales

Two options exist for defining non-separable vertical length scales. The first, *vc_mdl* in the **oanl** namelist, has vertical correlation length scales that can differ along the horizontal axes using length scales computed from either model background vertical density gradients, where the vertical separation between grid points and observations is based on pressure differences (*dens*) or from changes in isopycnal separation after transforming the vertical grid coordinate from pressure to density (*isop*). The second option for defining vertical length scales is *vc_src*, which uses a source file, either GDEM climatology (updated monthly) or the forecast model solution (updated at every analysis time), to compute vertical correlations.

3.7 Assimilating Altimeter Sea Surface Height

Altimeter SSH observations may now be assimilated along-track or by sampling an analyzed SSH anomaly increment field. In either situation, the altimeter SSH data are converted to synthetic T and S profiles either through MODAS or directly, using the Cooper Haines method. The user must be careful not to inundate the analysis with synthetic profiles. Using the *cluster(3)* namelist parameter (Table 1), the along-track altimeter data may be thinned in conjunction with the specified horizontal correlation length scales. Altimeter data also can be assimilated by mapping the along-track data to the model grid (the **oanl** namelist parameter

ssh_grd must = .true.) and then sampling the analyzed increment field to create synthetic profiles at an interval based on the **oanl** namelist parameter *smpl*. The synthetic profile sampling interval is modulated by the background error correlation structure similar to the way the *cluster* namelist parameter works on satellite data. Execution of the synthetic profile sampling option requires that a NCODA v3.0 SSH analysis is run in 2D before NCODA v3.0 is run in 3D mode.

3.8 Profile and Glider Data Preparation

Profile and glider observations are layer-averaged using the vertical grid defined at the nearest grid point in NCODA v3.0. Multiple profile observations within a layer are employed to estimate layer variability and profile representation error. This preprocessing relaxes the somewhat stringent profile data selection criteria that are imposed when profiles are interpolated to the analysis levels before assimilation into NCODA. Experimentation with the various data selection options provided in the **oanl** namelist parameters *prf_slct* and *gldr_slct* is encouraged. The results may be monitored via the profile reject list created when the **oanl** variable *debug(1)* is set to true.

3.9 Adjusting the Land Distance Tensor

A new tensor was developed for NCODA v3.0 to force correlation structures to be maximized *along*, not *across*, land-sea boundaries. The tensor uses a new 1/25° resolution land distance database created for use in the ocean data quality control system. The user controls the options to influence relaxation of the tensor as distance from land increases (*ds_scl*, Table 1).

3.10 Thinning the Data

The **oanl** namelist parameter *cluster* is used to thin data based on the ratio of horizontal correlation length scales and horizontal grid resolution. This ratio is automatically adjusted within one-degree latitude bands to account for changes in correlation length scale that vary by an order of magnitude from the equator to the pole, when based on the Rossby radius of deformation. *Cluster* is specified separately for each satellite observation data type (ice, SST, SSH, or SWH). Data thinning is achieved by averaging multiple observations within the spatially varying length scale bins, taking into account observation error and water mass of origin in the averaging process. The amount of data thinning can be increased by setting *cluster* to a value greater than one, and similarly decreased by setting *cluster* to a value less than one. Increasing the data density will require more conjugate gradient solver iterations. It may not noticeably alter the results, given the smoothing operation of the post-multiplication analysis step. Some experimentation is usually required to determine optimum settings for *cluster* in a given analysis domain.

Profile observations are thinned by determining duplicates based on position only. The value of *cluster*(4) is used for profile observations and must be set ≥1. It is defined as the multiple of the analysis grid resolution in latitude/longitude space for identifying near-identical positions. Once a set of profile duplicates has been identified, the profile with the most complete vertical

sampling is retained in the analysis. Profiles from fixed moorings that report with high frequency are handled differently in the analysis. Here, multiple mooring profiles selected for the analysis are averaged within reporting depth levels to form a single profile. This process uses a table look-up of World Meteorological Organization (WMO) call signs that must be updated periodically when new moorings are deployed.

4.0 RUNNING NCODA v3.0

4.1 NCODA v3.0 Execution and Processing

NCODA v3.0 can be executed in 2D mode or 3D mode. In 2D mode the analysis variables are sea ice, SST, SSH, or SWH. The 2D analysis variable(s) must be explicitly specified in the **oanl** namelist (Table 1) in order for an analysis of that variable to occur. The user does not need to precede execution of NCODA v3.0 in 3D mode with a 2D analysis, as was done in NCODA v2.3. However, NCODA v3.0 may still be run in 2D mode prior to a 3D analysis when mapping and sampling altimeter observations on the model grid rather than directly assimilating along-track altimeter data. For details on this mode of execution see Section 3.7.

A variety of 2D analysis options are available. A series of univariate sea ice, SST, SSH, or SWH analyses may be executed separately or in combination. For example, SST and sea ice may be analyzed simultaneously for use as LBCs in numerical weather prediction (NWP) models, SWH and sea ice analyzed for use in wave model data assimilation, or SST and SSH analyzed for ocean circulation model assimilation. In 3D mode, the analysis is fully multivariate with analysis variables of temperature, salinity and the u, v vector velocity components. Control of the NCODA v3.0 executable is through the **oanl** namelist parameters. A complete description of the **oanl** namelist parameters is provided in Table 1. Figure 2 illustrates the flow of execution for each of the NCODA v3.0 components.

Figure 2: Flow of information from the observations to the quality control, analysis and forecast model.

The NCODA v3.0 ocean analysis programs can be easily set up and run using the following steps. It is assumed that all operational program binaries, static input files and directory structures are in place, and that the user has an understanding of the use of text editors and UNIX commands.

1. Modify the *gridnl* namelist to specify the region desired and edit the input namelist parameters using the definitions provided in Section 3.1.2.
2. Define the valid time of the analysis in the form of a date-time-group (YYYYMMDDHH). Set the *crdate* environmental variable, if necessary.
3. Modify file directory paths as needed for input and output files. Static input files and program binaries should point to their locations in operational directories.
4. On the IBM mainframes at the NAVOCEANO DoD Supercomputing Resource Center (DSRC), batch in the script using the IBM LOADLEVELER `llsubmit` command. On the SGI mainframes at FNMOC, batch in the script using the SGI IRIX `bsub` command.
5. Check output file for errors, warnings and data summaries. Evaluate the analysis results using graphical output from NCODA_GRAPH.

To execute NCODA v3.0 in 2D (or 3D) mode use the following set of binaries and command line arguments − mode option (2D or 3D), grid namelist (local file name), and analysis date time group (YYYYMMDDHH − year, month, day, hour):

```
ncoda_prep      2D (or 3D) ogridnl $ddtg
ncoda           2D (or 3D) ogridnl $ddtg
ncoda_post      2D (or 3D) ogridnl $ddtg
```

4.1.1 NCODA_PREP Execution

The NCODA_PREP command for execution is:

```
ncoda_prep [opt] [gridnl] {dtg},
```

where `[opt]` is a required command line argument. Valid options include:

`2D` - performs sea ice and SST analysis preps, or
`3D` - performs a full 3D multivariate analysis prep.

`[gridnl]` is a required command line argument that specifies the local file name of the model grid namelist file.

`[dtg]` is an optional command line argument that specifies the valid time of the analysis. The NCODA_PREP and the NCODA analysis programs are executed sequentially in the script. For example,

```
2D analysis   ncoda_prep          2D gridnl dtg
              ncoda_analysis      2D gridnl dtg
              ncoda_post          2D gridnl dtg
3D analysis   ncoda_prep          3D gridnl dtg
              ncoda_analysis      3D gridnl dtg
              ncoda_post          3D gridnl dtg
```

Control of NCODA_PREP is through the "**oanl**", "**odsetnl**" and "**gridnl**" namelists.

4.1.2 NCODA v3.0 Execution

Control of the NCODA v3.0 executable is through the **oanl** namelist parameters. A complete description of the **oanl** namelist parameters, including default settings, is provided in the Table 1. The NCODA v3.0 command for execution is:

```
ncoda [opt] [gridnl] [dtg]
```

where `[opt]` is a required command line argument. Valid options include:

`2D` - performs sea ice, SSH and SST analysis, or
`3D` - performs a full 3D multivariate analysis (T, S, H, U, V).

`[gridnl]` is a required command line argument that specifies the local file name of the model grid namelist file.

`[dtg]` is a required command line argument that specifies the valid time of the analysis.

Execution of NCODA must be preceded by execution of NCODA_PREP and following by execution of NCODA_POST. It is not necessary to precede execution of NCODA in 3D mode with execution of NCODA in 2D mode, although there are several analysis options where this is necessary (Section 4.1). The order of execution is the same as for NCODA_PREP. Control of NCODA v3.0 is through the "**oanl**", "**odsetnl**", and "**gridnl**" namelists.

4.1.3 NCODA_POST Execution

The NCODA_POST execution command is:

```
ncoda_post [opt] [gridnl] {dtg}.
```

The NCODA analysis and NCODA_POST programs are executed sequentially in the script. For example,

```
2D analysis  ncoda_prep     2D gridnl dtg
             ncoda_analysis 2D gridnl dtg
             ncoda_post     2D gridnl dtg
3D analysis  ncoda_prep     3D gridnl dtg
             ncoda_analysis 3D gridnl dtg
             ncoda_post     3D gridnl dtg
```

Control of NCODA_POST is through the "**oanl**", "**odsetnl**" and "**gridnl**" namelists.

4.1.4 NCODA_CONVRT Execution

When cycling with the NCOM, HYCOM, or WaveWatch III forecast models, the variational analysis is bracketed by execution of the NCODA_CONVRT program using the following set of binaries and command line arguments:

```
ncoda_convrt   ncom(or wave)  ncoda          ogridnl $ddtg
ncoda_prep     2D(or 3D)      ogridnl        $ddtg
ncoda          2D(or 3D)      ogridnl        $ddtg
ncoda_post     2D(or 3D)      ogridnl        $ddtg
ncoda_convrt   ncoda          ncom(or wave)  ogridnl $ddtg
```

On the front end, the NCODA_CONVRT program changes model specific restart files to the file naming convention and format used by the analysis. On the back end, NCODA_CONVRT updates the model specific restart files with the analysis increments (corrections) for the next run of the forecast model. Alternatively, NCODA_CONVRT can output increment fields on the model grid, which then may be used to update the model in an Incremental Analysis Update

(IAU) procedure. Note that the NCODA and NCODA_POST programs require MPI (execution via the *mpirun* command or its equivalent). The NCODA_PREP and NCODA_CONVRT programs are parallelized using OpenMP commands at the loop level specified in the code itself.

The NCODA conversion program execution is through the following command:

```
ncoda_convrt [from] [to] [gridnl] [dtg] {opt},
```

where `[from]` is a required command line argument specifying the direction for input files into the program. Valid options are "`ncom`", "`hycom`", "`ncoda`", or "`wave`".

The `[to]` argument is a required command line argument. It specifies the direction for output files from the program. Valid options are "`ncom`", "`hycom`", "`ncoda`", or "`wave`".

`[gridnl]` is a required command line argument that specifies the local file name of the model grid namelist file.

`[dtg]` is a required command line argument is optional. It specifies the valid time of the analysis.

`{opt}` is an optional command line argument. It specifies one of two model update options:

`'update'` - correct model restart file (default), or

`'relax'` - output analysis variable increment fields on the model sigma/*z* or hybrid grid using COAMPS field naming conventions.

The program assumes the analysis and model have been executed on the same horizontal grid. The primary function of NCODA_CONVRT is the labeling of forecast fields in the NCODA naming convention, conversion from *z* to sigma/*z* vertical coordinates (and vice versa) in the case of NCOM, and conversion from *z* to hybrid vertical coordinates (and vice versa) in the case of HYCOM. These conversions are not necessary when the analysis vertical grid is identical to the model vertical grid (the **oanl** namelist parameter *z_opt*=`'ncom'` or *z_opt*=`'hycom'`). NOCDA_CONVRT brackets the normal order of NCODA v3.0 executables. For a 2D wave model analysis or a 3D NCOM or HYCOM ocean model analysis, the sequence of NCODA v3.0 executables is as follows:

1. wave analysis -

```
ncoda_convrt wave ncoda gridnl dtg {opt}
ncoda_prep     2D gridnl dtg
ncoda          2D gridnl dtg
ncoda_post     2D gridnl dtg
ncoda_convrt ncoda wave gridnl dtg {opt}
```

2. NCOM analysis -

```
ncoda_convrt ncom ncoda gridnl dtg {opt}
ncoda_prep     3D gridnl dtg
ncoda          3D gridnl dtg
ncoda_post     3D gridnl dtg
```

```
                    ncoda_convrt ncoda ncom gridnl dtg {opt}

3. HYCOM analysis - ncoda_convrt hycom ncoda gridnl dtg {opt}
                    ncoda_prep     3D gridnl dtg
                    ncoda          3D gridnl dtg
                    ncoda_post     3D gridnl dtg
                    ncoda_convrt ncoda hycom gridnl dtg {opt}
```

Control of NCODA_CONVRT is through the "**oanl**", "**odsetnl**" and "**gridnl**" namelists (same as the analysis itself).

4.1.5 NCODA v3.0 Ensemble Transform (ET) Execution

The ensemble transformation (ET) program (NCODA_ET) takes the assimilation control run as input and computes multivariate perturbed initial conditions for each of the ensemble members consistent with the analysis error covariances used in the assimilation. The entire forecast state vector (T, S, U, and V) is used simultaneously in NCODA_ET when cycling with NCOM. This approach gives balanced increments when updating the ensemble member forecasts.

The ET takes as input the assimilation control run and computes multivariate perturbed initial conditions for each of the ensemble members consistent with the analysis error covariances used in the assimilation. The execution command is:

```
ncoda_et [opt] [gridnl] [dtg]
```

`[opt]` is a required command line argument. Valid options include: `'wave'` or `'ncom'`.
`[gridnl]` is a required command line argument. It specifies the local file name of the model grid namelist file.
`[dtg]` is a required command line argument. It specifies the analysis date time group.

Control of NCODA_ET is through the "**oanl**", "**odsetnl**", "**gridnl**", and "**ensbnl**" namelists.

4.2 Doing a Cold Start of NCODA v3.0

Two options facilitate a cold start of NCODA v3.0 in 3D mode. The first option uses the **oanl** parameter *mds_grd* to generate MODAS synthetic temperature and salinity fields from a prior 2D analysis of SST and SSH. This option should only be used when the analysis is cycling on itself (no forecast model input). Background errors are specified as the difference between the MODAS synthetics and the GDEM v4.0 climatology. The second cold start option uses the **oanl** namelist parameter *n_cold_anl* (Table 1) to specify a number of cold-start mode analysis update cycles. With this option, the 3DVar model only assimilates satellite altimeter SSH and profile observations. The high density surface-only SST observations are excluded and some namelist parameters are set to degraded values. The idea behind this option is to assimilate climatology when climate is used as the first guess, to incorporate a reduced set of observations for a week or so, or to correct long-term free running model errors. The analysis spin-up period

is useful to bootstrap the background error variances to be consistent with model forecast variability and innovation time history using the approach outlined in Section 4.3 below.

4.3 Background Error Variances

Calculation of background error variance updates in the post-processing step includes a model-data error component derived from a time history of the analysis increment fields and a model variability component resulting from a time history of model forecast differences. Correlation time scales used to form these time mean estimates are computed from the ratio of spatially varying horizontal length scales and forecast velocity fields. In this approach, model-data errors tend to dominate background error variance estimates in low-flow environments, while model variability tends to dominate in high-flow environments.

4.4 Computing Analysis Error

NCODA_ERR, the analysis error program gives estimates of the analysis error variance in the form of a normalized reduction of the forecast error. The range is from 1 (0% reduction) to 0 (100% reduction) for each analysis variable at all model grid points. NCODA_ERR uses the same data inputs created by NCODA_PREP for the analysis. This approach allows for simultaneous runs of both the analysis and analysis error programs (on separate processors) to reduce NCODA v3.0 run time. The main application of the analysis error program is in the NCODA_ET. NCODA_ERR is parallelized using MPI (via the `mpirun` command)**.**

4.5 Determining Convergence

NCODA v3.0 convergence is determined by the norm of the gradient of the cost function estimated at each iteration step. This gradient is a vector the size of the number of observations and the norm is the square root of the sum of the elements, which are the residuals of the analysis fit to the innovations. In practice, convergence is reached when the gradient norm is reduced by 1.5 orders of magnitude, typically 8-15 iterations. This is considered to be sufficient because an increase in the number of iterations only fits smaller and smaller spatial scales. This may seem beneficial, but the post-multiplication step is a spatially smoothing operation when the background error correlations are applied. Thus, the extra iterations in the solver required to resolve smaller spatial scales in the observations have little effect on the final analyzed increment field due to the smoothing effect of the post-multiplier.

4.6 Parallel Processing

Parallelization is done in three different places in NCODA v3.0. The first parallelization is performed over observation volumes in the pre-conditioner, the second over observation volumes in the conjugate gradient solver, and the third is done over grid node volumes in the post-multiplication step (mapping from observation space to grid node space). The number of processors used to execute NCODA v3.0 can be as few as one or as many as the maximum

number of observation or grid node volumes. Memory utilization for the conjugate gradient solver in NCODA v3.0 is reduced as the number of processors is increased. This feature allows NCODA v3.0 to scale very well across many processors on large machines, and run efficiently on small platforms with limited memory.

4.7 Output File Naming Conventions

The output products of a NCODA v3.0 run are two- and three-dimensional fields of various parameters that may then be used to correct an ocean model forecast in a model initialization program or used as a final product. All NCODA v3.0 analysis output files are written to the directory defined by the *dsorff* variable in the **dsetnl** namelist. The fields are written as 32-bit IEEE binary files using a direct access format. Within the software modules, the files are written using specific naming conventions to allow for easy identification, archival and retrieval. A sample file name is given below:

seatmp_pre_000000_003000_1o0151x0149_2010060500_00000000_analfld

A description of the components of the sample file name is given in Table 8. Each item in a NCODA v3.0 output file name is separated by an underscore ('_') to enhance readability. For example, the sample field name indicates that the file is a three-dimensional ocean temperature analysis field, over a depth range from 0 m to 3000 m, valid at 00Z on 5 June 2010, on an analysis grid with 151 x-grid points and 149 y-grid points.

Table 8: NCODA v3.0 File Naming Convention

Component	Example	Description
Field Prefix	seatmp	Specifies analysis variable or analysis parameter (see Table 9 for definitions).
Level Type	pre	'pre' indicates a 3D pressure field, and 'sfc' indicates a 2D surface field.
Depth Range	000000_003000	First vertical depth level to bottom vertical depth level in analysis vertical grid.
Grid Nest Number	1	Nest number of this grid.
Model Type	o	'o' = oceanographic field 'w' = wave model field.
Geometry	0151x0149	Number of x-grid and y-grid positions in the analysis grid.
Analysis Time	2010060500	Valid time of the analysis in date time group form YYYYMMDDHH.
Forecast Period	00000000	Hour, minute, second of forecast field in the form HHHHMMSS.
File Type Suffix	analfld	Specifies the type of analysis field (see

Table 8: NCODA v3.0 File Naming Convention		
Component	**Example**	**Description**
		definitions in Table 10).

NCODA v3.0 uses many field prefix or parameter names to indicate the differing contents of an analysis output file. A complete list of the six-character field parameter prefixes found at the beginning of all NCODA v3.0 output files is provided in Table 9. A definition of the prefix is provided, as well as a description of the purpose of that output file type in the NCODA v3.0 system.

Table 9: Output File Field Prefix Names		
Parameter	**Definition**	**Usage**
chisqr	chi square diagnostics	This diagnostic provides information on the specifications of the observation and background errors in the analysis. The diagnostic is used to tune the error statistics in the analysis. The *chisqr* file contains a time-history of these diagnostics for 240 update cycles stratified by the observing system.
codaoi	analysis control records	NCODA computes and saves the youngest data found in an analysis time window in the *codaoi* file. The date time groups are saved by the observing system and used as the look back time for observations in the next analysis, depending on the *ice_time*, *prf_time*, *ssh_time*, and *sst_time* namelist parameters in **oanl**.
cvstat	verification statistics	NCODA v3.0 routinely computes RMSE and mean error statistics at the end of each analysis. A time series of these statistics is saved for 240 update cycles in the **cvstat** file for all observing systems and analysis variables.
datahd	data header	The **gridnl** namelist parameters are saved in the **datahd** file, along with the vertical grid levels and grid information such as latitude/longitude of the analysis grid corners and the level of no motion.
depths	bottom depth	The bathymetry of the analysis grid locations is saved in the **depths** file. Units are in meters.
geoptl	geopotential	Geopotential analysis variable output fields are saved with the *geoptl* file prefix. Units are dynamic meters over a depth range from the surface to the level defined by the *lvl_nmo* variable in the **oanl** namelist.

Table 9: Output File Field Prefix Names		
Parameter	**Definition**	**Usage**
grdage	age of the data	Age of the data is an analysis variable computed from innovations of observation time and the valid time of the analysis. The **grdage** file is the age of the data on the grid in a 3D variable analysis, and the ages pertain to all of the multivariate analysis variables. Units are hours and negative values are possible (age of the data is younger than the analysis time).
grdlat	grid latitudes	The analysis grid latitudes are saved in the **grdlat** file.
grdlon	grid longitudes	The analysis grid longitudes are saved in the **grdlon** file.
grdlvl	grid levels	The analysis grid levels are saved in the **grdlvl** file.
grdscl	correlation length scales	Unmodified correlation length scales are saved in the **grdscl** file. These scales can be modified internally within NCODA v3.0 by flow dependence calculations and grid nesting ratios. Units are km.
maskls	mask field	The NCODA v3.0 *maskls* field is defined as the number of vertical grid levels above bottom at the grid locations. A value of zero would indicate a land point and a value less than the vertical level number would indicate bottom masking at that grid location.
salint	salinity	Salinity analysis variable output fields are saved with the *salint* file prefix. Units are PSU.
seahgt	sea surface height	Altimeter sea surface height analysis variable output fields are saved with the *seahgt* file prefix. Units are meters.
seaice	sea ice concentration	Sea ice concentration analysis variable output fields are saved with the *seaice* file prefix. Units are per cent.
seatmp	sea temperature	Sea temperature analysis variable output fields are saved with the *seatmp* file prefix. Units are degrees Celsius.
uucurr	u vector velocity	U-vector velocity analysis variable output fields are saved with the *uucurr* file prefix. Units are meters per second.
vvcurr	v vector velocity	V-vector velocity analysis variable output fields are saved with the *vvcurr* file prefix. Units are meters per second.

Each of the NCODA v3.0 output file prefixes can have one or more file suffixes at the end of a file name. The contents of an NCODA v3.0 output file depend on the setting of both the file prefix and the file suffix. Table 10 below lists all of the seven-character file type suffixes used in NCODA v3.0. A definition of the file suffix is provided, as well as how files with that suffix are used in the NCODA v3.0 system.

Table 10: Output File Field Suffix Names

File Type	Definition	Usage
analerr	analysis error	Analysis error is a measure of the forecast error reduction from the assimilation of observations in the current analysis update cycle.
analfld	analysis field	Analysis fields are full valued analysis variables after the first guess field has been updated by the analysis increment field.
analinc	analysis increment	Analysis increment fields are raw output and represent the model-data differences (innovations) spread from the observation locations to the analysis grid locations.
climerr	climatology error	Variability estimates from the GDEM climate database are used for T and S climate error. Climate error for geopotential and the u, v vector velocity variables is computed from the difference between the analysis and climate fields of the analysis variable computed from the GDEM T and S climatology at each update cycle.
climfld	climatology field	GDEM T and S climate fields are used both directly for the T and S analysis variables and in the computation of geopotential and the u, v vector velocity climate fields.
dataerr	data errors	Contains running sums of squares of a time history of the analyzed increment fields that is used to compute the background errors of the appropriate analysis variable.
datafld	data field	Generic suffix used to indicate a data field. Used for *grdlat*, *grdlon*, *grdlvl*, and other NCODA v3.0 fields.
infofld	information field	Used with the data header file to indicate grid definition information.
fcsterr	forecast error	NCODA v3.0 computes forecast error fields at the update cycle interval from a time history of the analyzed increment fields.
fcstfld	forecast field	Indicates a forecast model first guess field.
modlerr	model error	When cycling with a forecast model, an

Table 10: Output File Field Suffix Names		
File Type	**Definition**	**Usage**
		appropriate measure of model error may be computed from the variability of a model running with no data assimilation.
obsdata	innovation vector	NCODA v3.0 saves information about the observations assimilated in an innovation vector file. The information saved is at the observation locations and includes observation and background errors, the first guess background value, and the analyzed field value after applying the corrections from the analyzed increment field.
timeinc	age of the data analysis increment	Contains the analyzed increments of the observation ages from the assimilation of the observations in the current update cycle.
timefld	age of the data analysis field	Age of the data on the grid is a measure of how long it has been since a grid node has been influenced by an observation.

4.8 Generating Graphical Output

NCODA_GRAPH is based on a graphics package originally developed by NCAR. It has been customized for NCODA by NRL-Monterey. It contains options for displaying observation and grid node analysis volumes, analysis volume interactions in the solver, and horizontal maps or vertical cross sections of the new 3D vertical correlations, among others functions. All plotting options may be seen by executing the `ncoda_map` or `ncoda_crs` commands without any command line arguments.

NCODA_MAP command line arguments:

```
ncoda_map {anl_dtg} {tau}
{anl_dtg} = analysis date time group (yyyymmddhh)
{tau}     = forecast period (hours).
```

NOTES: 1. `{anl_dtg}` is required.
2. `{tau}` is optional and the default is 0 (analysis).

NCODA_MAP environmental variables:

OCEAN_OUTPUT_DIR = directory path to restart files

There are several plotting options available in NCODA_GRAPH. The plotting options may be chosen through editing the values of the **omapnl** namelist file. Table 11 lists the **omapnl** namelist parameters and default values.

Table 11: NCODA_ GRAPH plotting namelist parameters (*omapnl*)			
Name	**Type**	**Description**	**Default Values**
btm_max	integer	Maximum bottom depth to plot	.true.
do_btm	logical	Plots grid bathymetry and open sea nodes	.true.
do_dist	logical	Plots land distance field	.true.
do_ensm	logical	Plots ensemble increment fields	.false.
do_flow	logical	Plots flow dependence fields	.true.
do_gpt	logical	Plots geopotential	.true.
do_grdnt	logical	Plots gradient field for selected variables	.true.
do_ice	logical	Plots sea ice	.true.
do_ice_err	logical	Plots sea ice prediction error	.true.
do_lyp	logical	Plots layer pressure increments	.true.
do_lyp_err	logical	Plots layer pressure prediction error	.true.
do_ohc	logical	Plots ocean heat content fields	.true.
do_sal	logical	Plots salinity	.true
do_sal_err	logical	Plots salinity prediction error	.true
do_scl	logical	Plots length scales	.false
do_ssh	logical	Plots SSH	.true
do_ssh_err	logical	Plots SSH prediction error	.true
do_sst	logical	Plots SST	.true
do_sst_err	logical	Plots SST prediction error	.true
do_swh	logical	Plots SWH	.true.
do_swh_err	logical	Plots SWH prediction error	.true.
do_tmp	logical	Plots 3D temperature	.true.
do_tmp_err	logical	Plots 3D temperature prediction error	.true.
do_vel	logical	Plots velocity	.true
do_vel_err	logical	Plots velocity prediction error	.true
do_vfy	logical	Plots verification scatter plots	.true
do_vol	logical	Plots analysis volume definitions	.true.
n_plot	integer	Number of levels to plot	1
sal_cnt	integer	Salinity contour interval	

Table 11: NCODA_ GRAPH plotting namelist parameters (*omapnl*)			
Name	**Type**	**Description**	**Default Values**
sal_del	integer	Salinity color slicing interval	.025, .025, .025, .025, .01, .01, .01, .01
sal_grd	integer	Maximum salinity gradient	
sal_min	integer	Minimum salinity for color slicing	34.1, 34.1, 34.4, 34.7, 34.5, 33.9, 34.0, 34.3
sst_cnt	integer	SST contour interval	0
sst_del	integer	SST color slicing interval	0.25
sst_min	integer	Minimum SST for color slicing	22
tmp_cnt	integer	Temperature contour interval	0
tmp_del	integer	Temperature color slicing interval	.1, .1, .1, .2, .2, 0.5, 0.5
tmp_grd	integer	Maximum temperature gradient	
tmp_min	integer	Minimum temperature for color slicing	15., 15., 15., 15., 15., 9., 5., 3.5
vel_max	integer	Velocity maximum at each level	
vel_thn	integer	Skips every (i, j) vector in velocity overlay	
z_plot	integer	Indices of vertical levels to plot	1
zoom	integer	i, j, start, stop indices for subsetting grid, input as left, right, bottom, top	

It is important to note that in order to suppress drawing contour lines, set contour intervals to zero or a negative value. Suppressing vector overlays requires that *set vel_thn* be set to a negative value. Any of the "do_*" parameter default values are false, therefore the NCODA_MAP program will do nothing by default. The user also must consider the fact that there are 60 color choices when setting the **_del* and **_min* namelist parameters.

4.9 Backing up the Data

The output files produced by the NCODA v3.0 programs and described in Section 4.7 are written to temporary or scratch disk directories and are defined by the operating system only for the life of the job. Users are required to ensure that adequate backup procedures are in place in case of a system crash. An archive function must exist to maintain a history of analysis fields for monitoring the skill and performance of the analysis system as well as to evaluate changes to namelist parameters in the process of tuning the variational analysis parameters.

4.10 Error and Malfunction Recovery

Error returns from the NCODA v3.0 modules are produced using plain language messages that define the error captured and the routine name in which the error occurred. Recovery procedures should be initiated based on the error message created in the NCODA v3.0 modules. NCODA v3.0 contains an extensive reporting functionality that writes a detailed report to standard out as it executes. An interruption in the standard out report is also an indication of where the error occurred, although this can be very misleading since output is buffered by the operating system. The end of the NCODA v3.0 standard-out report may be far removed from where the actual error occurred that caused a system crash.

4.11 Messages

Messages written to standard out for either successful or unsuccessful runs of any of the NCODA v3.0 programs are generated by many of the software modules. These messages, varying in complexity and purpose, include warnings, input argument lists, input errors, input summaries, intermediate values, and error messages. Additional output includes file paths, file access lists, output summaries, and observation summaries. These messages and reports should be saved for reference. A common message format allows the use of UNIX commands such as `grep`, `sed` and `awk` for string searches within these message files to aid in troubleshooting.

5.0 FUNCTIONAL DESCRIPTION

Please refer to the NCODA v3.0 Software Design Description (Cummings et al., 2010), for a comprehensive description of the basic equations, theory, and code of the NCODA v3.0 model. For RELO_NCOM documentation, see Rowley et al., 2010, Martin et al., (2008), and for HYCOM documentation, Metzger et al., (2009).

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7.0 NOTES

7.1 Acronyms and Abbreviations

Acronym	Description
3DVar	Three Dimensional Variational data assimilation
AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BMRC	Australian Bureau of Meteorology Research Centre
BT	Bathythermograph
CG	Conjugant Gradient
CH	Cooper-Haines technique
C-MAN	Coastal-Marine Automated Network
COAMPS	Coupled Ocean Atmosphere Mesoscale Prediction System
CRTM	Community Radiative Transfer Model
CTD	Conductivity, Temperature, and Depth
DBDBV	Digital Bathymetric Database, Variable Resolution
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DSRC	DoD Supercomputing Resource Center
DTG	Date Time Group
ENVISAT	Environmental Satellite
ERS-2	European Remote Sensing satellite 2
ET	Ensemble Transform
FCG	Flexible Conjugant Gradient
FNMOC	Fleet Numerical Meteorology and Oceanography Center
GAC	Global Area Coverage
GDEM	Global Digital Elevation Model
GFO	Geosat Follow-On
GOES	Geostationary Operational Environmental Satellites
HYCOM	HYbrid Coordinate Ocean Model
I/O	Input/Output
IAU	Incremental Analysis Update
LAC	Local Area Coverage
LBC	Lateral Boundary Condition
MCSST	Multi-Channel Sea Surface Temperature
METOP	Polar Orbiting Meteorological Satellite
MLD	Mixed layer depth
MODAS	Modular Ocean Data Assimilation System
MP	Multi-Processor

Acronym	Description
MPI	Message Passing Interface
MSG	Meteosat Second Generation
MVOI	Multivariate Optimum Interpolation
NAVDAS	NRL Atmospheric Variational Data Assimilation System
NAVOCEANO	Naval Oceanographic Office
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCODA	Navy Coupled Ocean Data Assimilation
NCOM	Navy Coastal Ocean Model
NOAA	National Oceanographic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction
NRL	Naval Research Laboratory
NWP	Numerical Weather Prediction
OpenMP	Open Multi-Processing
PSU	Practical Salinity Units
QC	Quality Control
RMS	Root-mean-square
S	Salinity
SAS	Smith and Sandwell
SDD	Software Design Description
SOAR	Second-order Auto-Regressive function
SSH	Sea Surface Height
SSHA	Sea Surface Height Anomaly
SSM/I	Special Sensor Microwave/Imager
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
STD	Standard Deviation
SWAFS	Shallow Water Analysis and Forecast System
SWH	Significant Wave Height
T	Temperature
TESAC	Temperature, Salinity and Current report
TRMM	Tropical Rainfall Measuring Mission
WHOI	Woods Hole Oceanographic Institute
WMO	World Meteorological Organization
WW3	WaveWatch III
XBT	Expendable Bathythermograph

8.0 APPENDIX A Argument Variables

8.1 Primary NCODA Variables

Variable	Type	Usage	Description
adj_run	logical	input	(true) Adjoint sensitivity run
amsr_bias	logical	input	(true) AMSR bias correction
amsr_dw	logical	input	(true) Removes diurnal SST
anl_time	real	input	Analysis time (hours)
anm	real	input	Innovations
argo_bias	logical	input	(true) ARGO salt bias fix
atsr_bias	logical	input	(true) ATSR SST bias correction
atsr_dtg	char	input	Oldest/newest ATSR observations
atsr_dw	logical	input	(true) Removes diurnal SST or dw signal from ATSR between observations.
bias	logical	input	(true) AMSR bias correction
blist	char	input	Black listed call signs
btm	real	input	Observation bottom depth
bv_chk	real	input	Brunt-Vaisala frequency threshold
bv_frq	real	output	Buoyancy frequency
clim_coef	real	input/ output	MODAS synthetic coefficients/ synthetic BT model coefficients
clim_dir	char	input	Climate file directory path
clim_lat	real	output	Climate grid latitudes
clim_lon	real	output	Climate grid longitudes
clim_lvl	real	output	MODAS climatology levels
clim_mld	real	input	MODAS mixed layer depth coeff.
clm_dir	char	input	Climate file directory path
cluster	real	input	Data (glider, profile) thinning factor or grid mesh scalar for super-obs
cn, cm	real	input	Cosine transformation of angle between observations
cob	real	input	Observation solution vector
coef	real	output	Interpolated coefficients
conf	logical	input	(true) Grid reduction option
corr	real	output	Correlation matrix
corr_mdl	integer	input	Correlation models
cos_bm, cos_bn,	real	output	Cosine transformation of angle between observations
data_dir	char	input	Data directory paths

Variable	Type	Usage	Description
dbv_opt	char	input	Source bathymetry database: 'dod' - DBDBV from NAVOCEANO 'sas' - Smith and Sandwell 'all' - all sources (DBDBV plus Smith and Sandwell)
dbv_res	real	input	Minimum resolution of bathymetry to retrieve from variable resolution database (minutes)
debug	logical	input	(true) Generates diagnostics
delx	real	input	Grid spacing in x-direction
dely	real	input	Grid spacing in y-direction
deny	integer	input	Data types to deny analysis
depth	real	in/out	Bathymetry at grid nodes (m)
dh	real	input	Inverse flow dependent scale
dh_scl	real	input	Flow dependent length scale ((1) ice (2) SST 3) SSH)
direct	logical	input	(true) Direct assimilation SSH/A
diurnal	logical	input	(true) Use diurnal SSTs
do_invc	logical	input	(true) Innovation error check
do_vol	logical	input	Volume interaction matrix
ds	real	input	Inverse distance land length scale
ds_scl	real	input	Distance land length scale
dtg	char	input	Analysis DTG
dv_dz	real	input	Isopycnal length scale
ens_dir	char	input	Ensemble directory path
err_plus	real	input	Covariance tuning parameter
erro	integer	input	Level of print diagnostics, Bits 0-4 set output switches, i.e., ERRO = B"01001" for 4 and 1.
f	real	input	Coriolis force at point (*i*,*j*)
fail	logical	output	(true) MODAS profile rejected
fcst	logical	input	(true) Forecast guess fields
fgat	integer	input	First guess appropriate time
file_dtg	char	input	Background DTG
file_obs	integer	input	Max number of obs / file
fld	real	input	Analysis field
flip	logical	input	(true) Grid crosses 360°
gldr_slct	real	input	Glider selection criteria: (1) level probability gross error (2) number of sampling levels

Variable	Type	Usage	Description
			(3) ratio sample to bottom depth (4) minimum sampling depth (5) distance between levels (6) temperature between levels (7) depth difference at max *delt* (8) temp difference at max *delz* (9) depth of first sample (10) surface extrapolation depth
global	logical	input	(true) Global grid
goes_bias	logical	input	(true) GOES SST bias correction
goes_dw	logical	input	(true) Removes diurnal SST
grd_btm	real	input	Grid bathymetry
grd_cx	real	input	Grid "x" volume center
grd_cy	real	input	Grid "y" volume center
grd_dst	real	input	Grid land distance field
grd_gpt	real	input	Grid flow dependence field
grd_hcv	real	input	Grid scale at volume center
grd_hsc	real	input	Grid horizontal length scales
grd_lat	real	input	Grid node latitudes
grd_lon	real	input	Grid node longitudes
grd_lvl	real	input	Grid levels
grd_msk	integer	input	Grid mask
grd_scl	real	input	Horizontal length scales
grd_xmu	real	input	Grid geostrophic coupling horizontal length scales
himem	logical	input	(true) High memory option
ht_mean	real	output	Mean observed SSH on climate grid
ht_mn	real	output	Min observed SSH on climate grid
ht_mx	real	output	Max observed SSH on climate grid
ht_std	real	output	SSH variability on climate grid
hx	real	output	Map factor in x-direction
hy	real	output	Map factor in y-direction
ice_asm	logical	in/out	(true) Assimilates sea ice
ice_time	char	input	Sea ice obs sampling time 'obst' = time ice observed 'synt' = synoptic time
igrid	integer	input	Type of grid projection: 1. Mercator projection 2. Lambert Conformal projection 3. Polar stereographic projection

Variable	Type	Usage	Description
			4. Cartesian coordinates 5. Spherical projection
igrid	integer	input	Grid projection number
iref	integer	input	I-coordinate of reference point
jb	integer	input	Obs start off-diagonal block
jref	integer	input	J-coordinate of reference point
kb	integer	input	Obs start in diagonal block
lac_bias	logical	input	(true) LAC SST bias correction
lac_dw	logical	input	(true) Removes diurnal SST
lat1	real	input	Southern-most latitude
lat2	real	input	Northern-most latitude
lda_nb	integer	input	Block diagonal array indices
len_w	integer	output	Block diagonal work size
lev	integer	input	Grid level labels
lndz	real	input	Bottom depth for defining land
lon1	real	input	Western-most longitude
lon2	real	input	Eastern-most longitude
lvl	real	input	Obs grid levels
m	integer	input	Number of x grid positions
mask_opt	char	input	Mask options ("0D", "2D", "3D")
master	logical	input	(true) Master processor
mcsst_bias	logical	input	(true) GAC SST bias correction
mcsst_dw	logical	input	(true) Remove dw from MCSST
mdl	integer	input	Correlation model 1 = horizontal 2 = vertical
mdl_grd	real	input	Model grid definition
mdl_lvl	real	output	Returned 3D depths
mds_edit	logical	input	(true) Edit MODAS synthetics
mds_rej	logical	input	(true) Reject MODAS salinities
mds_xtnd	logical	input	(true) Extend MODAS with Levitus
message	char * (*)	input	User supplied error message
metop_bias	logical	input	(true) METOP SST bias correction
metop_dw	logical	input	(true) Remove diurnal SST
MODAS_dir	char	input	MODAS file directory path
model	char	input	Forecast model name
msg_bias	logical	input	(true) MSG SST bias correction
msg_dw	logical	input	(true) Removes diurnal SST
mx_iwrk	integer	input	Integer work array dimension

Variable	Type	Usage	Description
mx_nodes	integer	input	Max number of grid nodes
mx_scl_grd	real	input	Grid volume length scales
mx_scl_obs	real	input	Number of obs volume scales
mx_wrk	integer	input	Real work array dimension
mz	integer	output	Max level above bottom
n	integer	input	Number of y grid positions
n_3d	integer	input	Number of 3D analyses to date
n_anl	integer	input	Number of analyses
n_blst	integer	input	Number of black listed call signs
n_bts	integer	in/out	Number of profile obs on grid
n_data	integer	input	Number of observations
n_deny	integer	input	Number of denied data types
n_depth	integer	input	Number of data type denials
n_dir	integer	input	Number of data directories
n_files	integer	input	Number of data files to process
n_ice	integer	output	Number of ice super-obs
n_it	integer	input	Number of CG iterations
n_lat	integer	input	Number of grid latitudes
n_lon	integer	input	Number of grid longitudes
n_lvl	integer	input	Number of grid or analysis levels
n_mdl	integer	input	Number of model sigma/z positions
n_nodes	integer	input	Number of grid nodes this volume
n_nodes_vol	integer	input	Number of nodes per volume
n_obs	integer	input	Number of observations
n_obs_vol	integer	input	Number of obs per volume
n_prf	integer	input	Max number of profile observations
n_prof	integer	output	Number of profile observations
n_sgm	integer	input	Number of model sigma levels
n_ssh_obs	integer	input	Number of SSH observations
n_sst	integer	input	Number of SST observations
n_strt	integer	input	Starting index number
n_syn	integer	output	Number of synthetic observations
n_tang	integer	input	Number of triangles in MODAS region
n_tmp	integer	input	Number of temperature observations
n_var	integer	input	Number of analysis variables
n_vol	integer	input	Number of analysis volumes
n_vol_grd	integer	input	Number of grid volumes
n_vol_obs	integer	input	Number of obs volumes
n_wlst	integer	input	Number of white listed signs

Variable	Type	Usage	Description
ncz	integer	output	Number of climate levels
ndx	integer	input	Obs volume sorted list
ndx_grd	integer	input	Grid node volume index
ndx_obs	integer	input	Obs volume index
ndx_vol	integer	input	Work sorted volume index
nest	integer	input	Grid nest number
new_dtg	char	input	Newest obs DTG
new_gldr	char	output	Newest glider obs DTG
new_xbt	character	input	Newest XBT DTG
nj	integer	input	Number of obs off-diagonal block
nk	integer	input	Number of obs in diagonal block
no	integer	input	Obs start in analysis volume
nodes	integer	input	Array grid node indices
nsea	integer	input	Number of sea points
nth	integer	input	Number of directional bins
nx	integer	input	Number of x grid positions
ny	integer	input	Number of y grid positions
nz	integer	output	Max climate model level
obs_age	real	output	Obs age relative to analysis
obs_anm	real	input	Obs innovations
obs_btm	real	input	Observation bathymetry
obs_cx	real	input	Obs "x" volume center
obs_cy	real	input	Obs "y" volume center
obs_dst	real	input	Obs distance land
obs_err	real	input	Obs error variance
obs_gpt	real	input	Obs surface height
obs_hcv	real	input	Obs scale at volume center
obs_hsc	real	input	Obs correlation scales
obs_lat	real	input	Observational data latitudes
obs_lon	real	input	Observational data longitudes
obs_lvl	real	input	Observation levels
obs_nd	integer	in/out	Last or total number of observed levels
obs_pos	real	input	Transformed obs positions
obs_sal	real	output	Obs salinity
obs_sal_err	real	output	Salinity err at observation locations
obs_sal_typ	integer	output	Salinity data type
obs_tmp	real	output	Observed synthetic temperature
obs_tmp_err	real	output	Observed temperature error
obs_tmp_typ	integer	output	Temp data type

Variable	Type	Usage	Description
obs_typ	integer	input	Observation data types
obs_val	real	input	Observed value
obs_var	integer	input	Observation variable type code
obs_vsc	real	input	Obs vertical scales
obs_xi	real	input	Obs "x" grid index
obs_xmu	real	input	Obs geostrophic coupling
obs_yj	real	input	Obs "y" grid index
obs_zk	real	input	Obs *z* grid position
offset	real	input	(i,j) grid offsets for data
old_dtg	char	input	Oldest observation DTG
old_gldr	char	input	Oldest glider obs DTG
old_xbt	char	input	Oldest XBT profile obs DTG
opt	char	input	Processing option: '2D' - SST and sea ice '3D' - multivariate
opt	integer	input	Correlation option
opt	char	input	Assimilation option
out_dir	char	input	Output file directory path
parm	character	input	Analysis parameter
prf_hrs	integer	input	Number of hours of profile data
prf_slct	real	input	Profile selection criteria (1) level gross error (2) number of sampling levels (3) ratio sample/bottom depth (4) minimum sampling depth (5) distance between levels (6) temperature between levels (7) depth difference at max *delt* (8) temp difference at max *delz* (9) depth first sample (10) surface extrapolation depth
prf_time	char	input	Profile sampling time: 'obst' = time profile observed 'rcpt' = time profile received 'cycl' = number of *prf_hours* data 'cntr' = centered time window
pt_anl	logical	input	(true) Potential temp analysis
qc_prb	real	input	Max probability gross error
qc_prob	real	input	Minimum gross error probability
qc_sprb	real	input	Minimum salinity gross error

Variable	Type	Usage	Description
qc_tprb	real	input	Minimum temperature gross
reflat	real	input	Grid reference latitude
reflon	real	input	Grid reference longitude
restart	logical	input	(true) Climate cold start
routine	char	input	Name of routine
s	real	output	Volume distance normalized by correlation length scales
s_nm	real	output	Great circle distance (km)
sal	real	output	Interpolated salinity
sal_asm	logical	input	(true) Assimilates salinity data
sal_err	real	input	Salinity error field
sal_grd	real	input	Salinity background field
sal_std	real	input	Max number of salinity std deviations
sample	integer	input	Profile sampling array
scl_obs	real	output	Observation volume length scale
sfg	real	output	Levitus 94 deep salinity
sgm_lvl	real	output	Sigma/z vertical levels
slatm, slatn	real	input	Sine transformation latitudes
slonm, slonn	real	input	Sine transformation longitudes
source	character	input	Data desired (Navy/DOD only or any): = 'dod', use Navy files only = 'Navy', use Navy files only = ' ', use any dictionary file
spval	real	input	Special value
ssh	real	in/out	Analyzed SSH
ssh_asm	logical	in/out	(true) Assimilates SSH
ssh_grd	logical	input	(true) Performs 2D SSH analysis
ssh_hrs	integer	input	Number of hours altimeter SSH data
ssh_opt	character	input	SSH mean field options: 'modl' - model mean field 'data' - data mean field
ssh_std	real	input	Max number of SSH standard deviation
ssh_time	char	input	Altimeter SSH sampling time
sss_grd	real	input	Forecast surface salinities
sst	logical	input	(true) Retrieve SST observations
sst_asm	logical	input	(true) Assimilate SSTs.
sst_time	char	input	SST obs sampling time ‘obst’ = time SST observed ‘synt’ = synoptic time

Variable	Type	Usage	Description
std_var	real	input	Variable standard deviations
stdlon	real	input	Standard longitude of grid (points to the north)
stdlt1	real	input	1st standard latitude of grid
stdlt2	real	input	Second standard latitude of grid (required for Lambert Conformal)
swh_asm	logical	in/out	(true) Assimilates SWH
swh_grd	real	input	SWH forecast
swh_msk	integer	input	SWH grid mask
swh_time	char	input	SWH obs sampling time 'obst' = time SWH 'synt' = synoptic time 'rcpt' = time SWH received
tau	integer	input	Forecast update period
tfct	real	input	Innovation tolerance factors
tfg	real	output	Levitus 94 deep temperature
tmp	real	input	Temperature profile
tmp_err	real	input	Temperature error field
tmp_grd	real	input	Temperature background field
tmp_std	real	input	Max number of temperature std
topo_mn, mx	real	input	SSH data topography range (m)
topo_src	character	input	Source of topography file: 'MODAS' - smoothed topography 'model' - actual depth file 'ncoda' - turns off scaling
typ	integer	input	Observational data variable types
unit_xbt	integer	input	XBT or glider obs output unit number
unit1, unit2	integer	input	Climate file unit numbers
upd	integer	input	Analysis update cycle (hrs)
upd_cycle	integer	input	Analysis update cycle (hours)
vc_mdl	char	input	Vertical correlation model: 'mixl' - mixed layer 'dens' - density stratification 'isop' - isopycnal 'mono' - monotonic increasing 'cons' - constant scales
vol_nb	integer	input	Observation start in volume
vrsn_dtg	char	input	Date file format changed
vsc	integer	input	Grid vertical length scales
w	real	input	Blocks diagonal arrays or covariances
warm	logical	input	(true) Uses warm SST sea ice

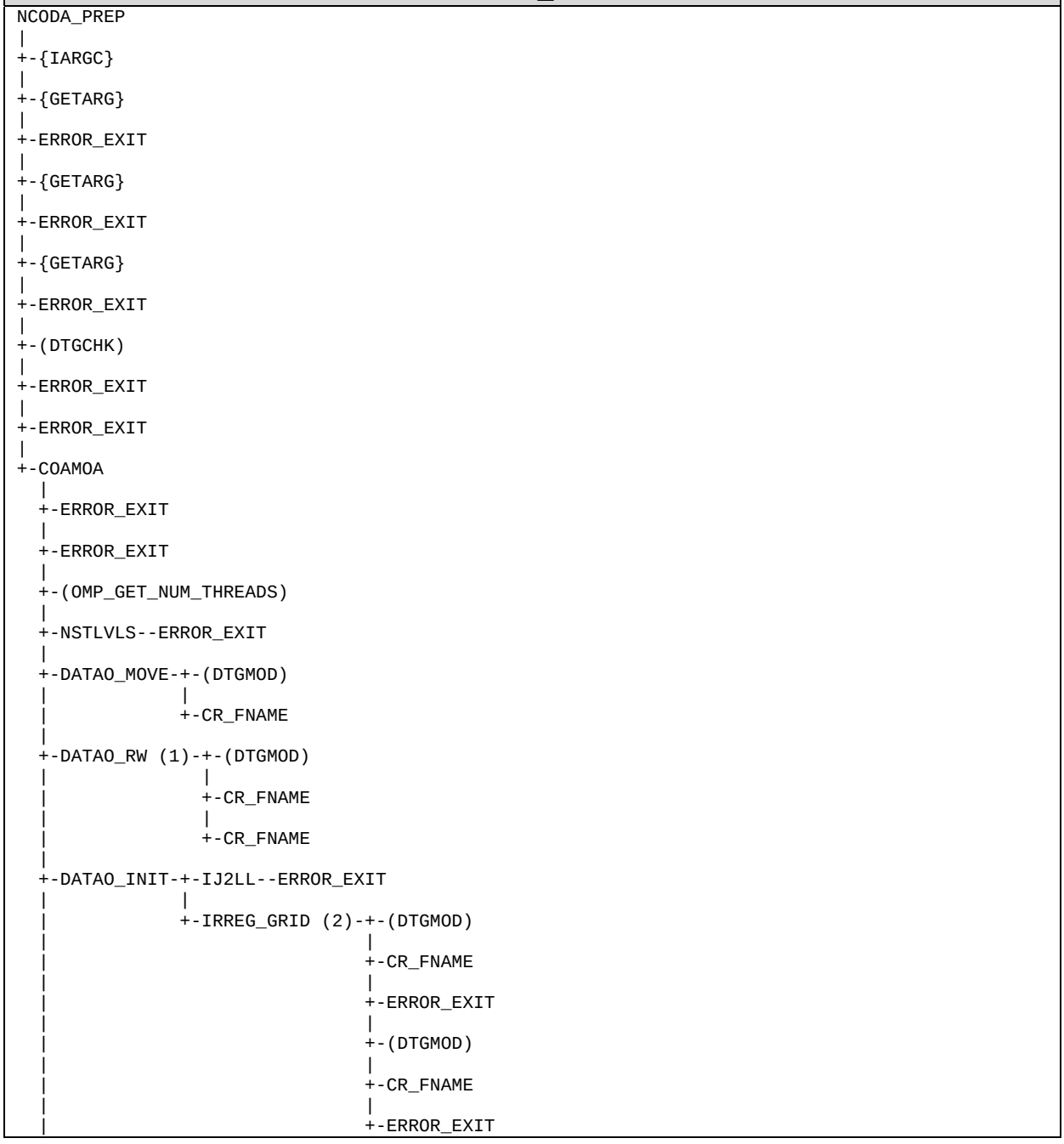
Variable	Type	Usage	Description
wlist	char	input	White listed call signs
wrk_dir	character	input	Work file directory path
xi, yj	real	input	Observation x, y, z, coordinates
xpos	real	output	X-position in meters from line extending from pole through standard longitude (*reflat*)
z_lvl	real	input	Vertical pressure levels
z_opt	char	input	Vertical grid option

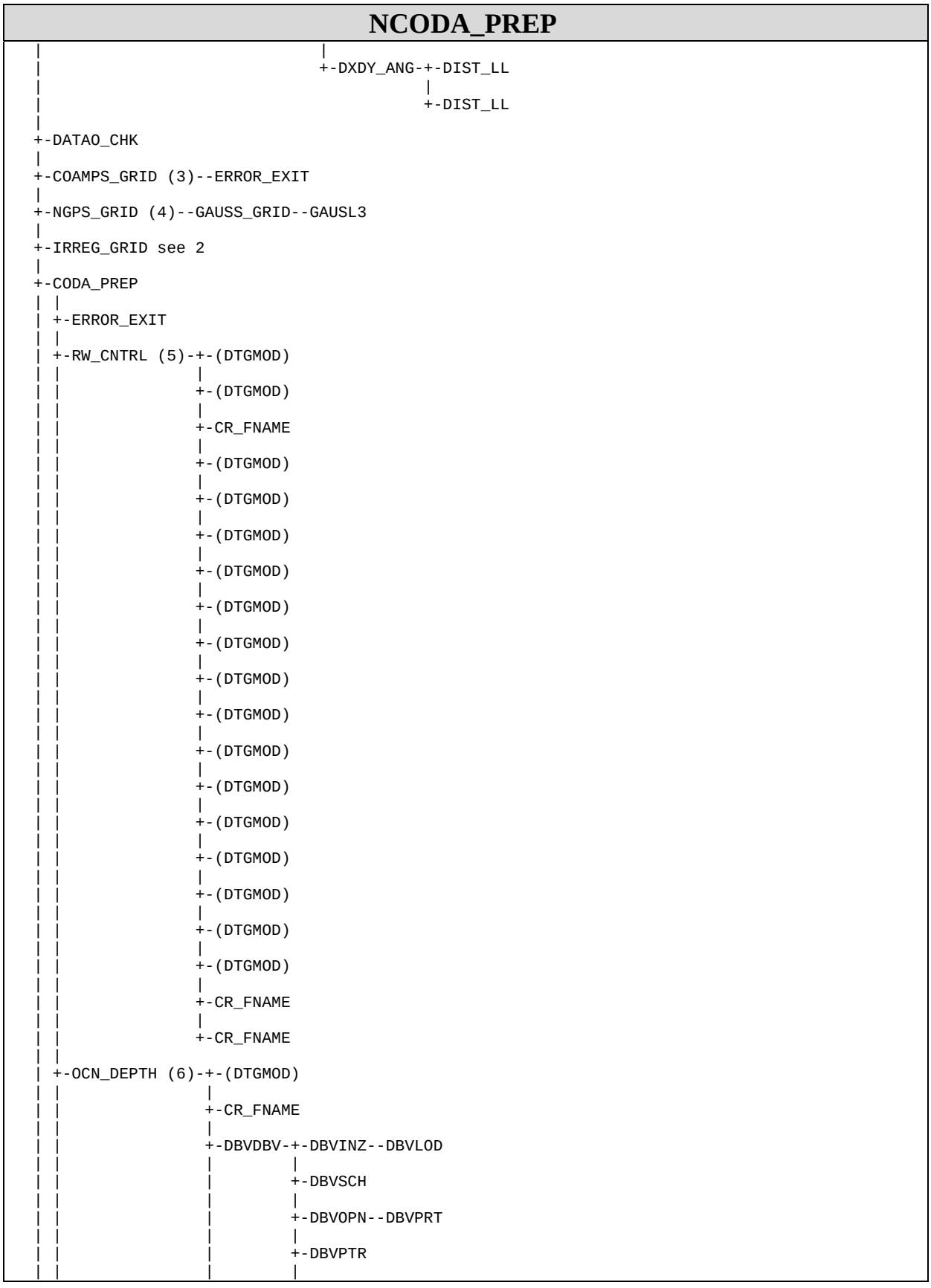
9.0 APPENDIX B NCODA Call Trees

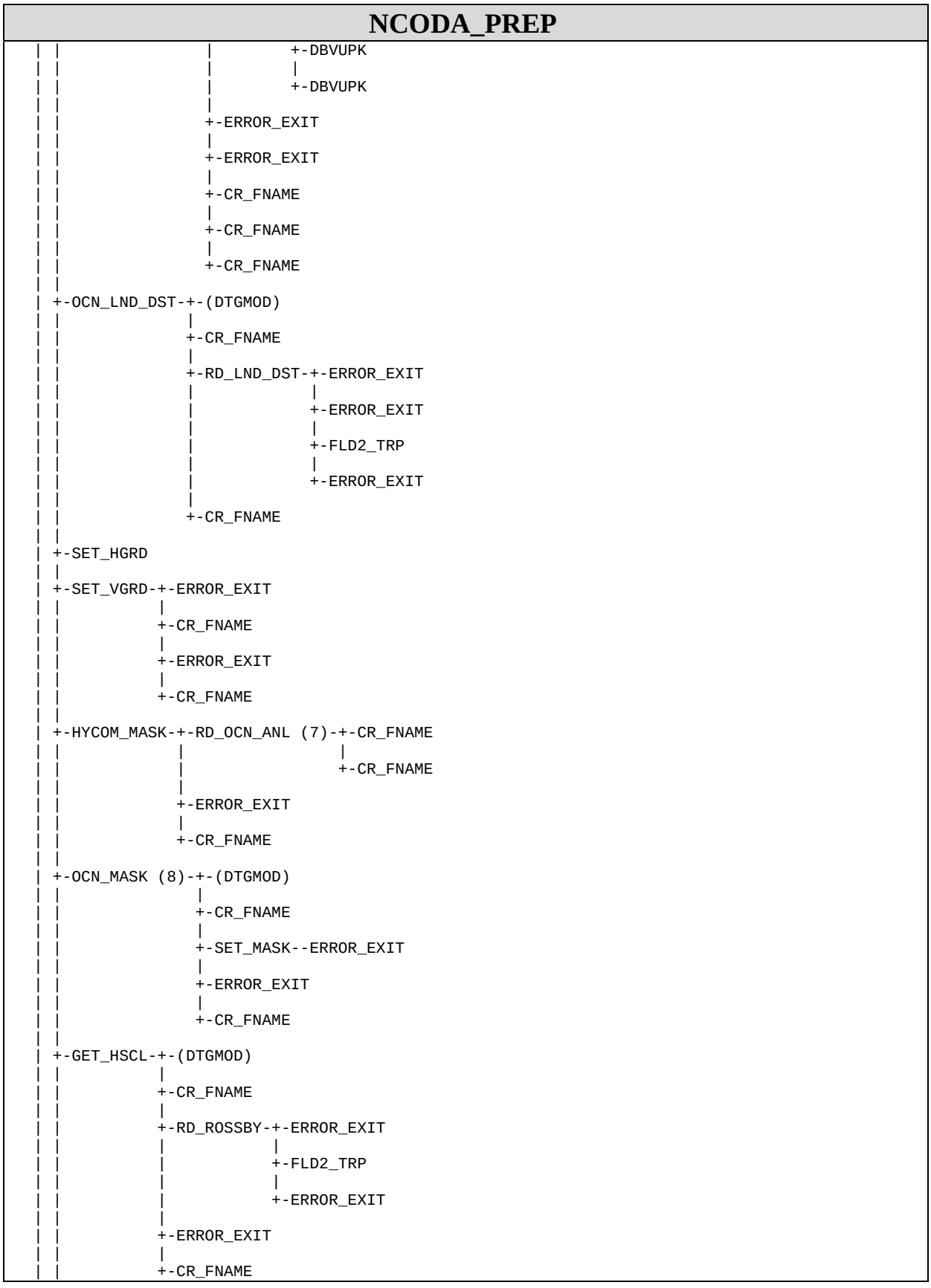
Calling trees are shown below for the NCODA v3.0 main driver programs '**ncoda_prep.f**', '**ncoda.f**', and '**ncoda_post.f**'. A numbering system within the call tree labels subroutines recurring throughout the program. For example, *datao_rw* is labeled with a one (1), and each time it reappears in the tree, *datao_rw* will have a "(see 1)" designation beside it, referring the user back to its original tree location to view the subsequent routines called by it.

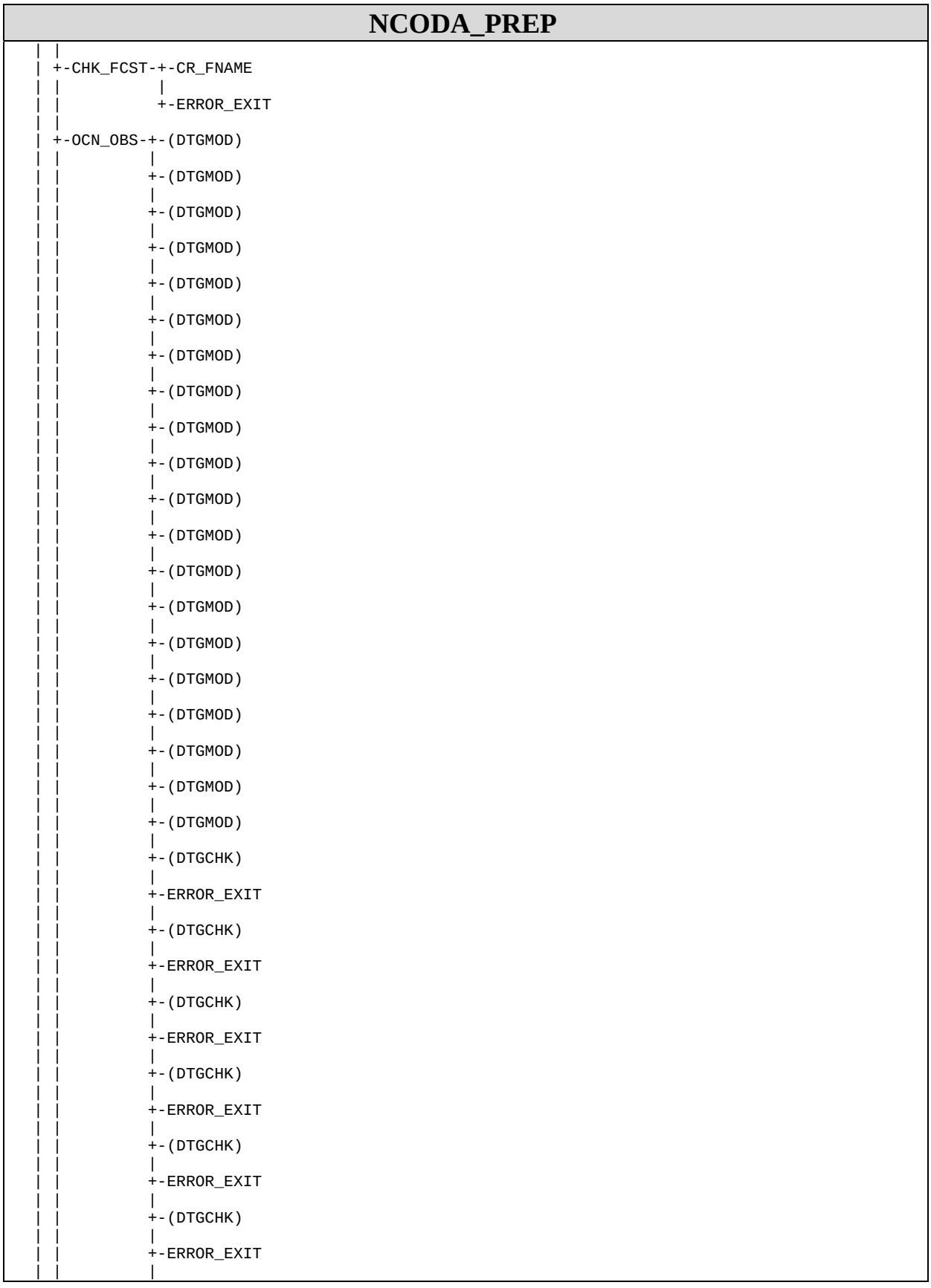
9.1 NCODA_PREP Call Tree

NCODA_PREP




NCODA_PREP
+-DXDY_ANG-+-DIST_LL
+-DIST_LL
+-DATAO_CHK
+-COAMPS_GRID (3)--ERROR_EXIT
+-NGPS_GRID (4)--GAUSS_GRID--GAUSL3
+-IRREG_GRID see 2
+-CODA_PREP
+-ERROR_EXIT
+-RW_CNTRL (5)-+-(DTGMOD)
+-(DTGMOD)
+-CR_FNAME
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-CR_FNAME
+-CR_FNAME
+-OCN_DEPTH (6)-+-(DTGMOD)
+-CR_FNAME
+-DBVDBV-+-DBVINZ--DBVLOD
+-DBVSCH
+-DBVOPN--DBVPRT
+-DBVPTR


NCODA_PREP
+-DBVUPK
+-DBVUPK
+-ERROR_EXIT
+-ERROR_EXIT
+-CR_FNAME
+-CR_FNAME
+-CR_FNAME
+-OCN_LND_DST-+-(DTGMOD)
+-CR_FNAME
+-RD_LND_DST-+-ERROR_EXIT
+-ERROR_EXIT
+-FLD2_TRP
+-ERROR_EXIT
+-CR_FNAME
+-SET_HGRD
+-SET_VGRD-+-ERROR_EXIT
+-CR_FNAME
+-ERROR_EXIT
+-CR_FNAME
+-HYCOM_MASK-+-RD_OCN_ANL (7)-+-CR_FNAME
+-ERROR_EXIT
+-CR_FNAME
+-OCN_MASK (8)-+-(DTGMOD)
+-CR_FNAME
+-SET_MASK--ERROR_EXIT
+-ERROR_EXIT
+-CR_FNAME
+-GET_HSCL-+-(DTGMOD)
+-CR_FNAME
+-RD_ROSSBY-+-ERROR_EXIT
+-FLD2_TRP
+-ERROR_EXIT
+-ERROR_EXIT
+-CR_FNAME


NCODA_PREP
| |
| +-CHK_FCST-+-CR_FNAME
| | |
| | +-ERROR_EXIT
| |
| +-OCN_OBS-+-(DTGMOD)
| | |
| | +-(DTGMOD)
| | |
| | +-(DTGMOD)
| | |
| | +-(DTGMOD)
| | |
| | +-(DTGMOD)
| | |
| | +-(DTGMOD)
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| | +-(DTGMOD)
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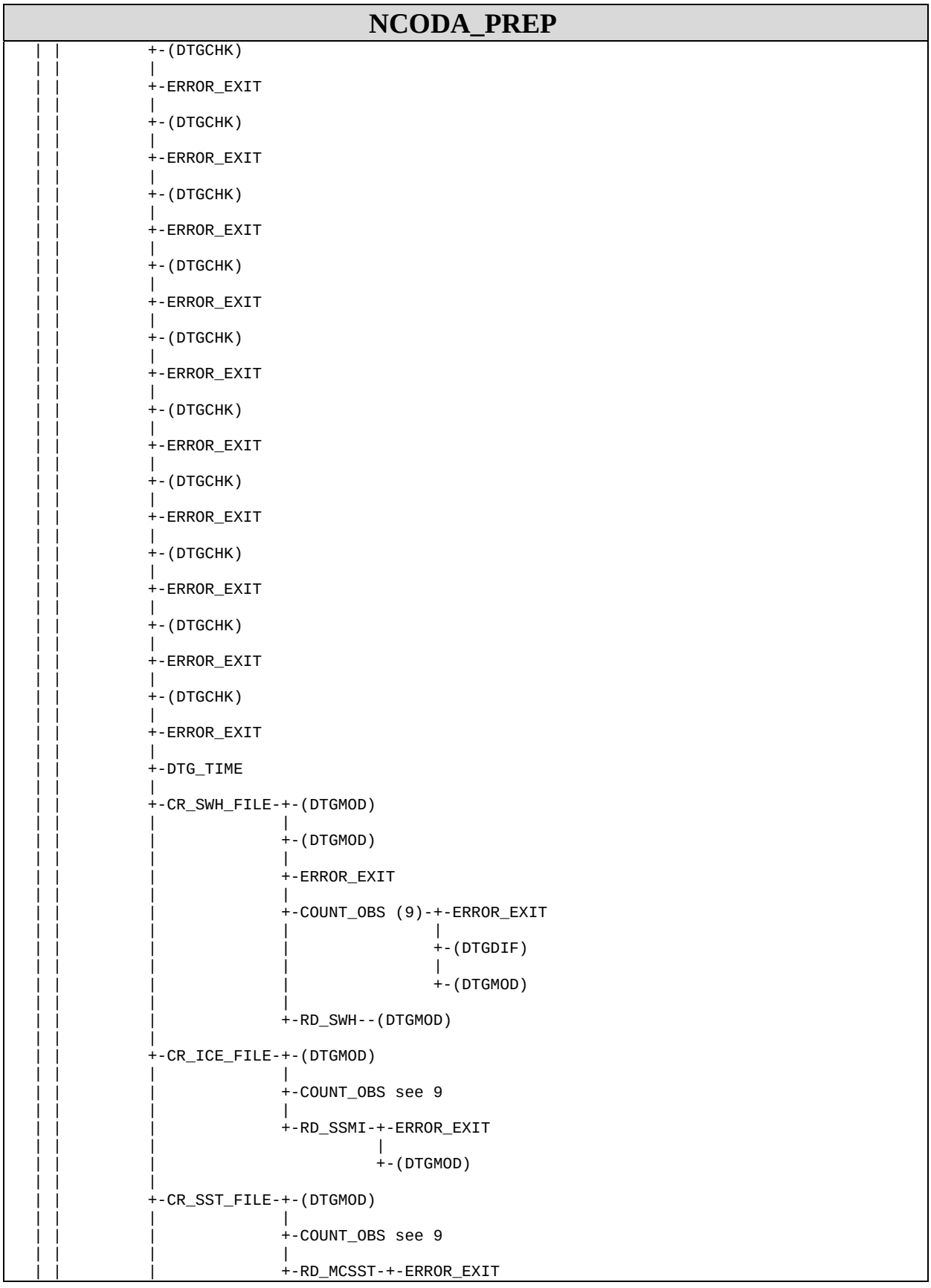
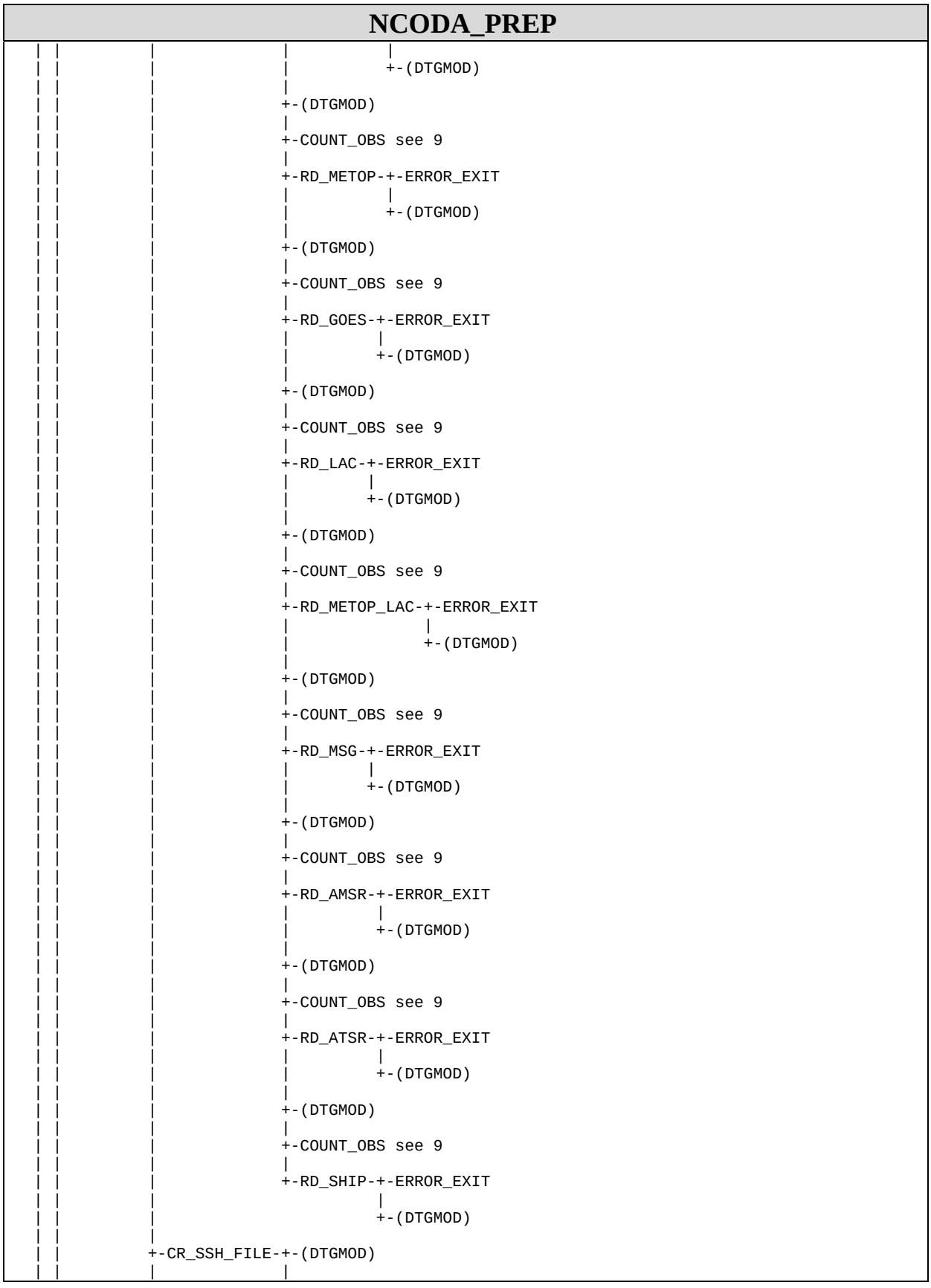
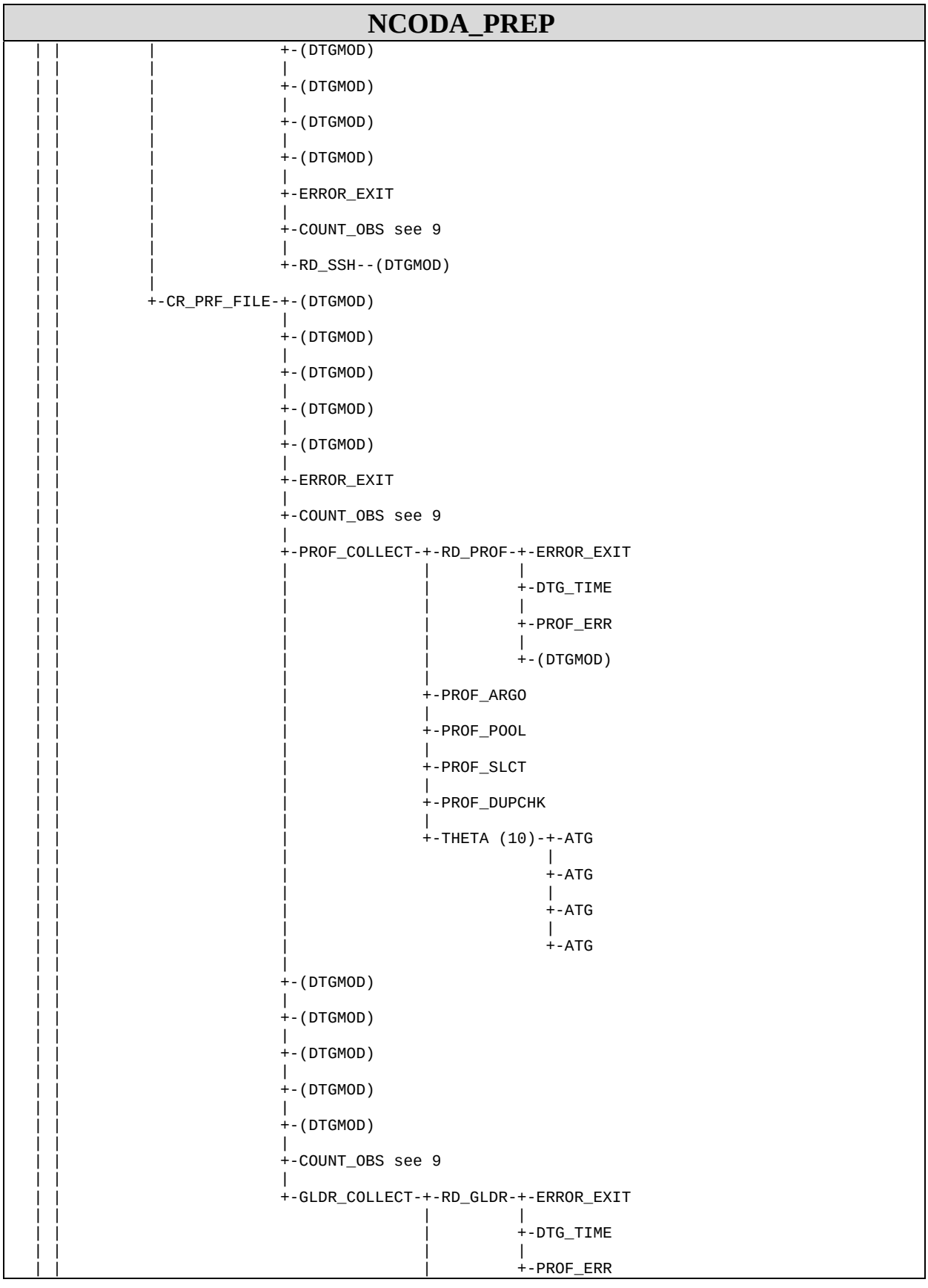
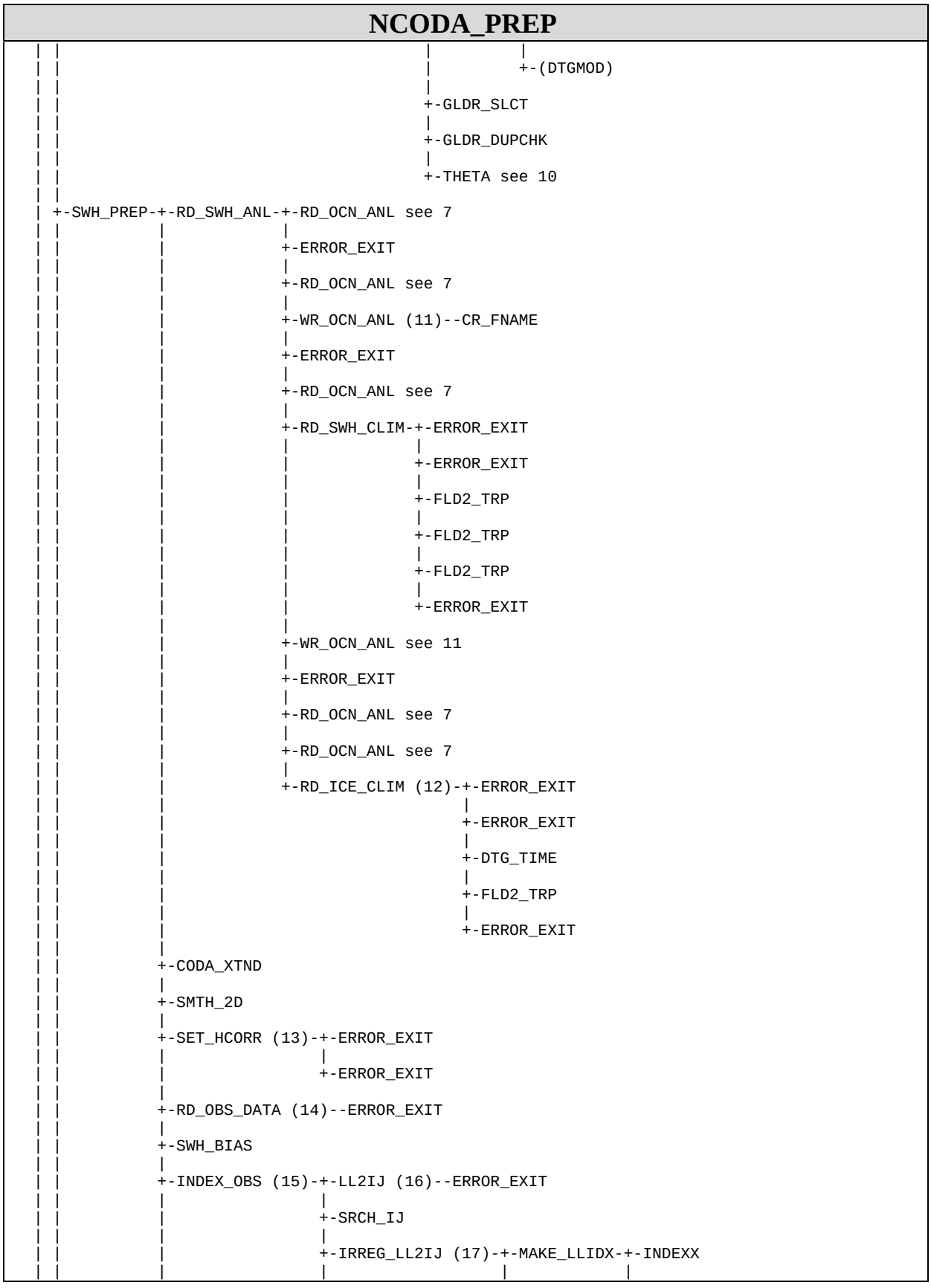
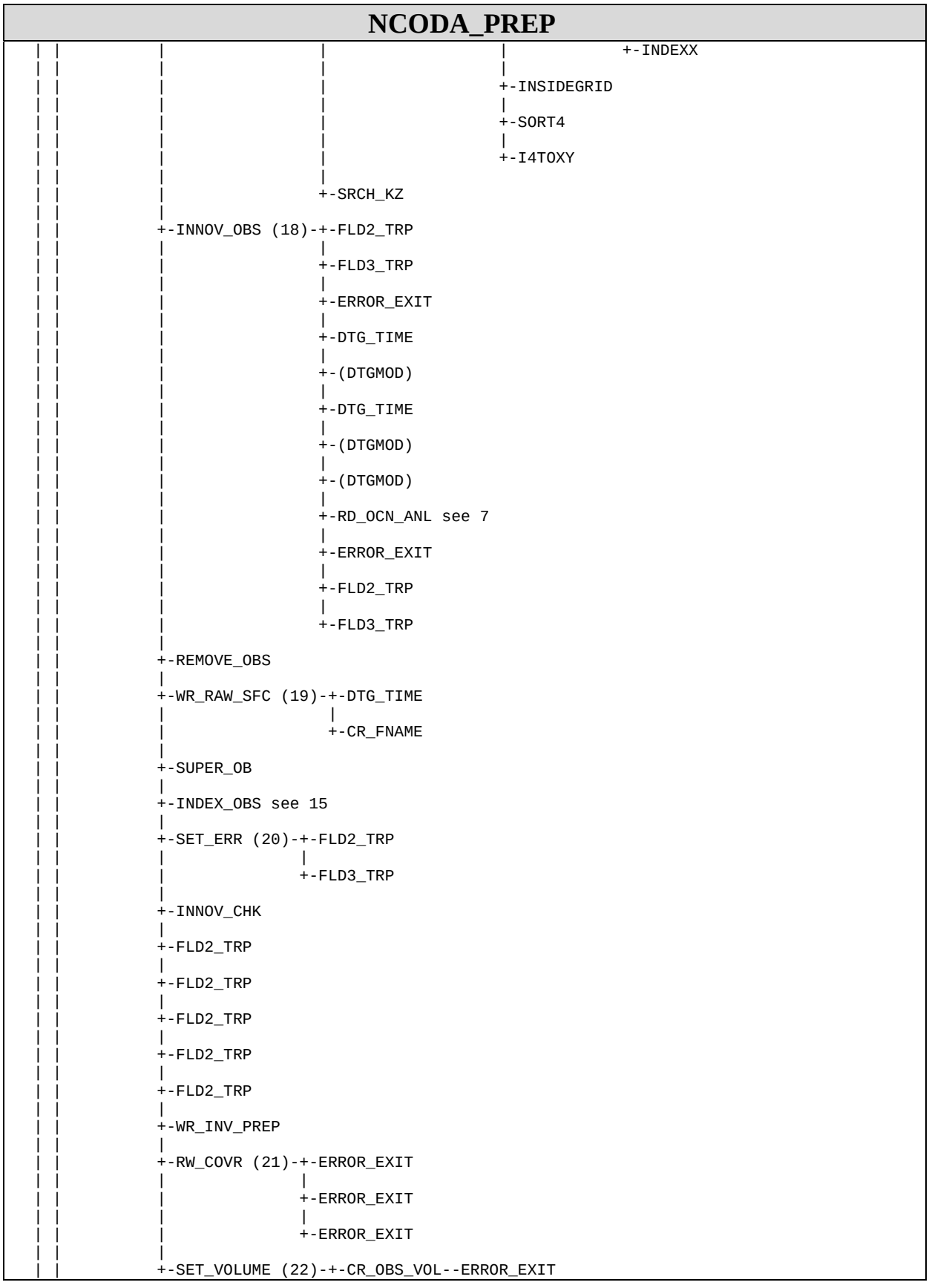
| | +-(DTGMOD)
| | |
| | +-(DTGMOD)
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |
| | +-(DTGCHK)
| | |
| | +-ERROR_EXIT
| | |

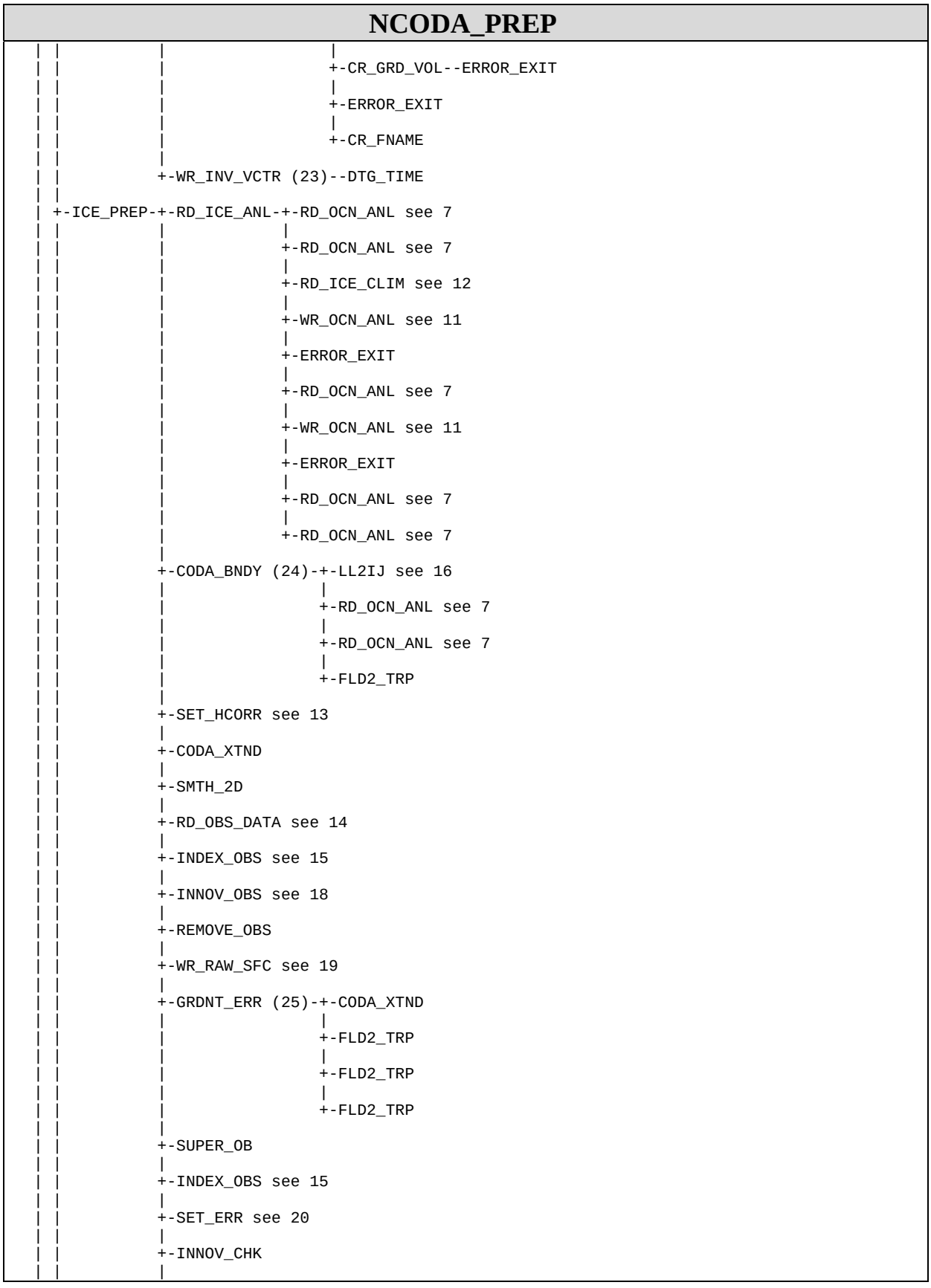

NCODA_PREP
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-(DTGCHK)
+-ERROR_EXIT
+-DTG_TIME
+-CR_SWH_FILE-+-(DTGMOD)
+-(DTGMOD)
+-ERROR_EXIT
+-COUNT_OBS (9)-+-ERROR_EXIT
+-(DTGDIF)
+-(DTGMOD)
+-RD_SWH--(DTGMOD)
+-CR_ICE_FILE-+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_SSMI-+-ERROR_EXIT
+-(DTGMOD)
+-CR_SST_FILE-+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_MCSST-+-ERROR_EXIT

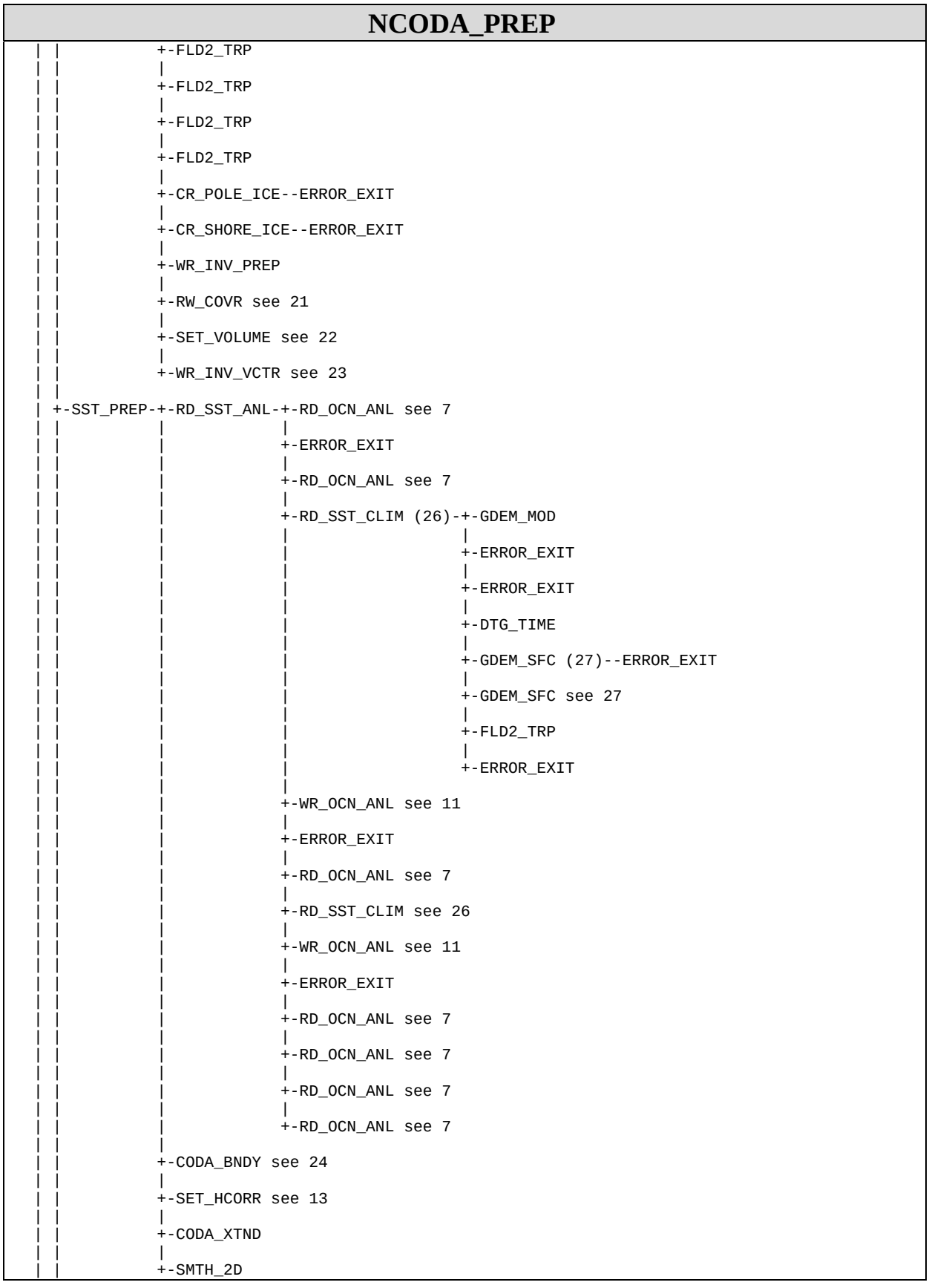

NCODA_PREP
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_METOP-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_GOES-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_LAC-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_METOP_LAC-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_MSG-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_AMSR-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_ATSR-+-ERROR_EXIT
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-RD_SHIP-+-ERROR_EXIT
+-(DTGMOD)
+-CR_SSH_FILE-+-(DTGMOD)


NCODA_PREP
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-ERROR_EXIT
+-COUNT_OBS see 9
+-RD_SSH--(DTGMOD)
+-CR_PRF_FILE-+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-ERROR_EXIT
+-COUNT_OBS see 9
+-PROF_COLLECT-+-RD_PROF-+-ERROR_EXIT
+-DTG_TIME
+-PROF_ERR
+-(DTGMOD)
+-PROF_ARGO
+-PROF_POOL
+-PROF_SLCT
+-PROF_DUPCHK
+-THETA (10)-+-ATG
+-ATG
+-ATG
+-ATG
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-(DTGMOD)
+-COUNT_OBS see 9
+-GLDR_COLLECT-+-RD_GLDR-+-ERROR_EXIT
+-DTG_TIME
+-PROF_ERR

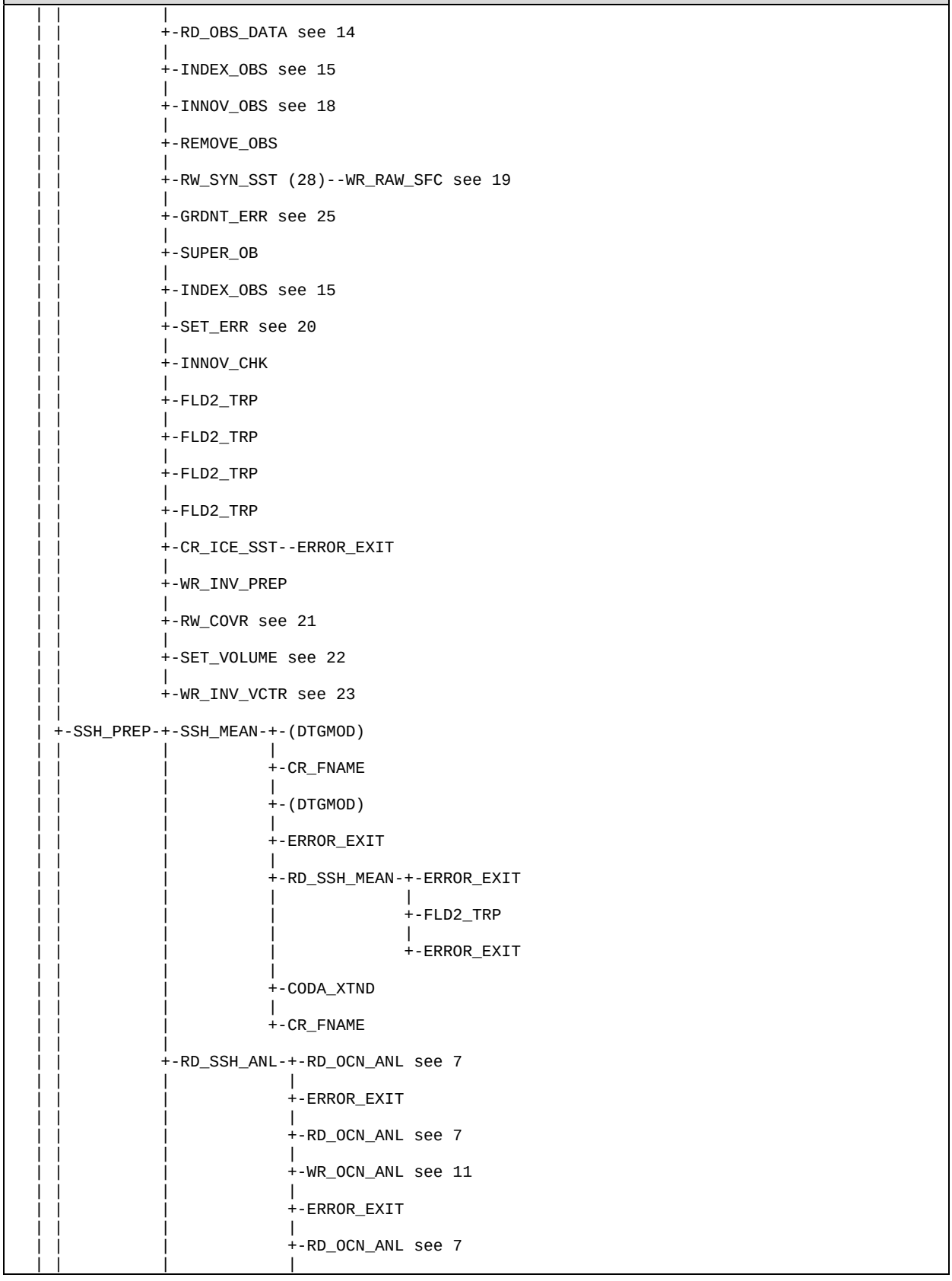

NCODA_PREP
+-(DTGMOD)
+-GLDR_SLCT
+-GLDR_DUPCHK
+-THETA see 10
+-SWH_PREP-+-RD_SWH_ANL-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-WR_OCN_ANL (11)--CR_FNAME
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_SWH_CLIM-+-ERROR_EXIT
+-ERROR_EXIT
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-ERROR_EXIT
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-RD_ICE_CLIM (12)-+-ERROR_EXIT
+-ERROR_EXIT
+-DTG_TIME
+-FLD2_TRP
+-ERROR_EXIT
+-CODA_XTND
+-SMTH_2D
+-SET_HCORR (13)-+-ERROR_EXIT
+-ERROR_EXIT
+-RD_OBS_DATA (14)--ERROR_EXIT
+-SWH_BIAS
+-INDEX_OBS (15)-+-LL2IJ (16)--ERROR_EXIT
+-SRCH_IJ
+-IRREG_LL2IJ (17)-+-MAKE_LLIDX-+-INDEXX


NCODA_PREP
+-INDEXX
+-INSIDEGRID
+-SORT4
+-I4TOXY
+-SRCH_KZ
+-INNOV_OBS (18)-+-FLD2_TRP
+-FLD3_TRP
+-ERROR_EXIT
+-DTG_TIME
+-(DTGMOD)
+-DTG_TIME
+-(DTGMOD)
+-(DTGMOD)
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD2_TRP
+-FLD3_TRP
+-REMOVE_OBS
+-WR_RAW_SFC (19)-+-DTG_TIME
+-CR_FNAME
+-SUPER_OB
+-INDEX_OBS see 15
+-SET_ERR (20)-+-FLD2_TRP
+-FLD3_TRP
+-INNOV_CHK
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-WR_INV_PREP
+-RW_COVR (21)-+-ERROR_EXIT
+-ERROR_EXIT
+-ERROR_EXIT
+-SET_VOLUME (22)-+-CR_OBS_VOL--ERROR_EXIT

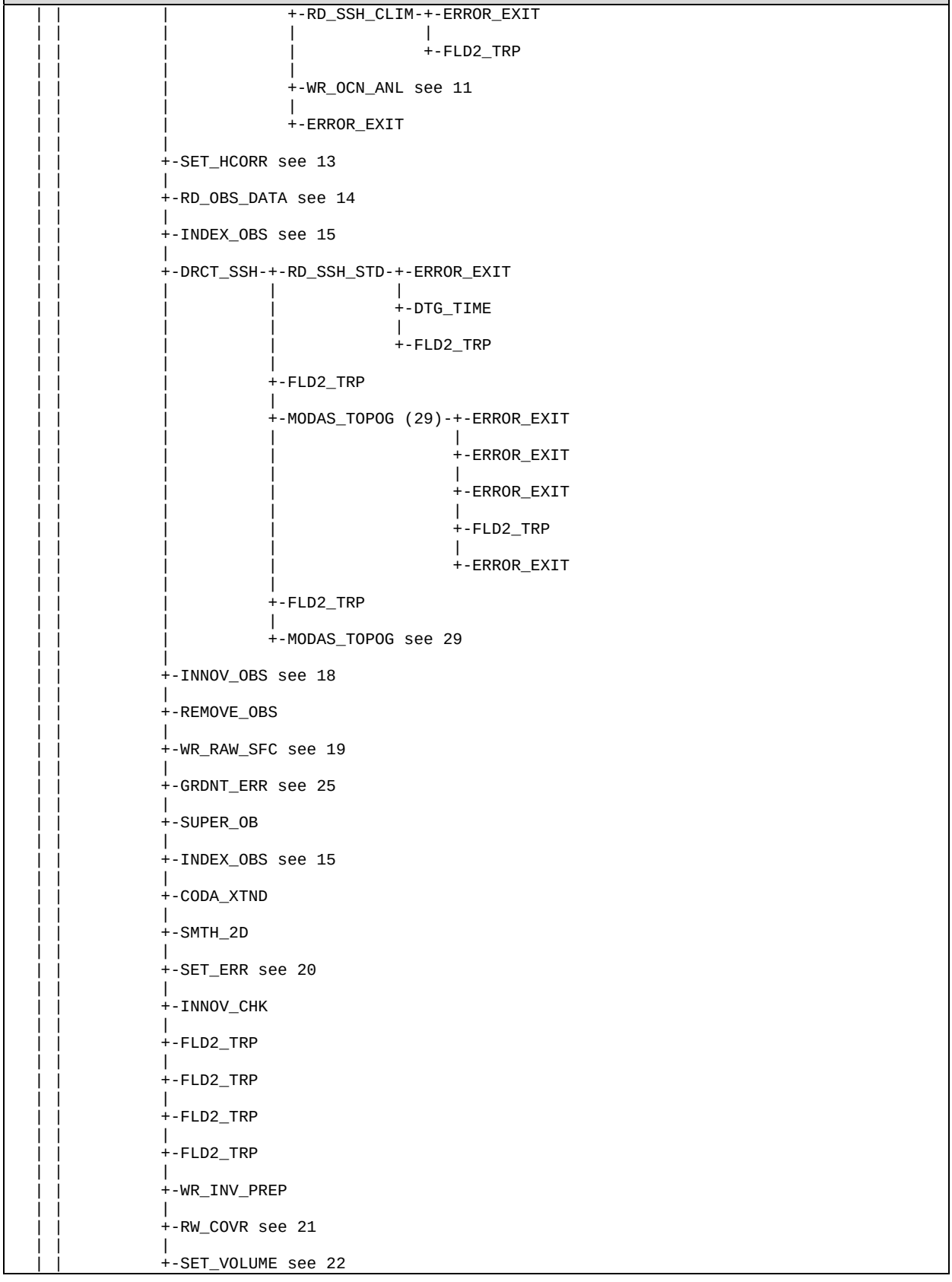

NCODA_PREP
+-CR_GRD_VOL--ERROR_EXIT
+-ERROR_EXIT
+-CR_FNAME
+-WR_INV_VCTR (23)--DTG_TIME
+-ICE_PREP-+-RD_ICE_ANL-+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-RD_ICE_CLIM see 12
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-CODA_BNDY (24)-+-LL2IJ see 16
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-FLD2_TRP
+-SET_HCORR see 13
+-CODA_XTND
+-SMTH_2D
+-RD_OBS_DATA see 14
+-INDEX_OBS see 15
+-INNOV_OBS see 18
+-REMOVE_OBS
+-WR_RAW_SFC see 19
+-GRDNT_ERR (25)-+-CODA_XTND
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-SUPER_OB
+-INDEX_OBS see 15
+-SET_ERR see 20
+-INNOV_CHK

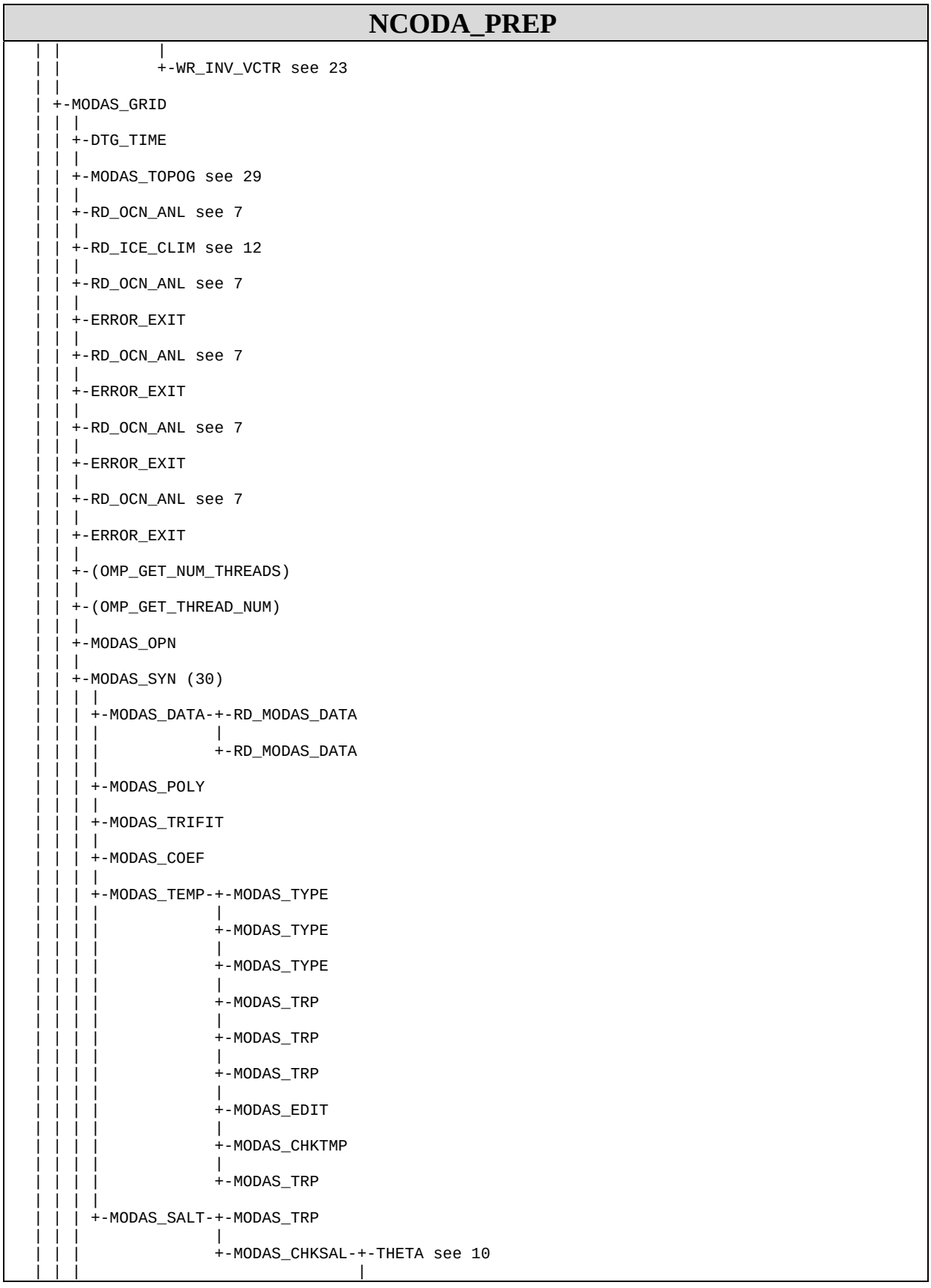

NCODA_PREP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-CR_POLE_ICE--ERROR_EXIT
+-CR_SHORE_ICE--ERROR_EXIT
+-WR_INV_PREP
+-RW_COVR see 21
+-SET_VOLUME see 22
+-WR_INV_VCTR see 23
+-SST_PREP-+-RD_SST_ANL-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_SST_CLIM (26)-+-GDEM_MOD
+-ERROR_EXIT
+-ERROR_EXIT
+-DTG_TIME
+-GDEM_SFC (27)--ERROR_EXIT
+-GDEM_SFC see 27
+-FLD2_TRP
+-ERROR_EXIT
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_SST_CLIM see 26
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-CODA_BNDY see 24
+-SET_HCORR see 13
+-CODA_XTND
+-SMTH_2D

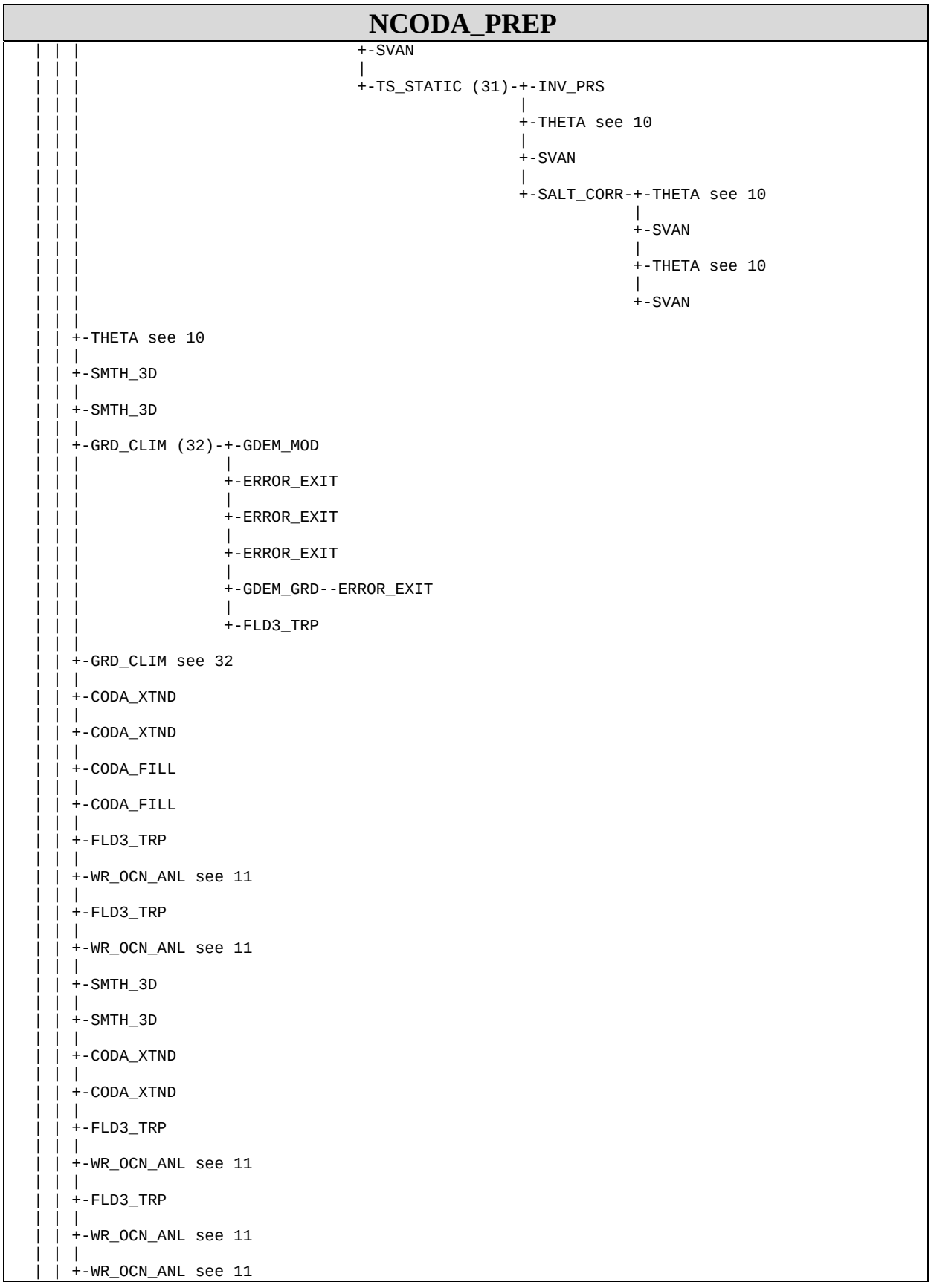
NCODA_PREP


+-RD_OBS_DATA see 14
+-INDEX_OBS see 15
+-INNOV_OBS see 18
+-REMOVE_OBS
+-RW_SYN_SST (28)--WR_RAW_SFC see 19
+-GRDNT_ERR see 25
+-SUPER_OB
+-INDEX_OBS see 15
+-SET_ERR see 20
+-INNOV_CHK
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-CR_ICE_SST--ERROR_EXIT
+-WR_INV_PREP
+-RW_COVR see 21
+-SET_VOLUME see 22
+-WR_INV_VCTR see 23
+-SSH_PREP-+-SSH_MEAN-+-(DTGMOD)
+-CR_FNAME
+-(DTGMOD)
+-ERROR_EXIT
+-RD_SSH_MEAN-+-ERROR_EXIT
+-FLD2_TRP
+-ERROR_EXIT
+-CODA_XTND
+-CR_FNAME
+-RD_SSH_ANL-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-RD_OCN_ANL see 7

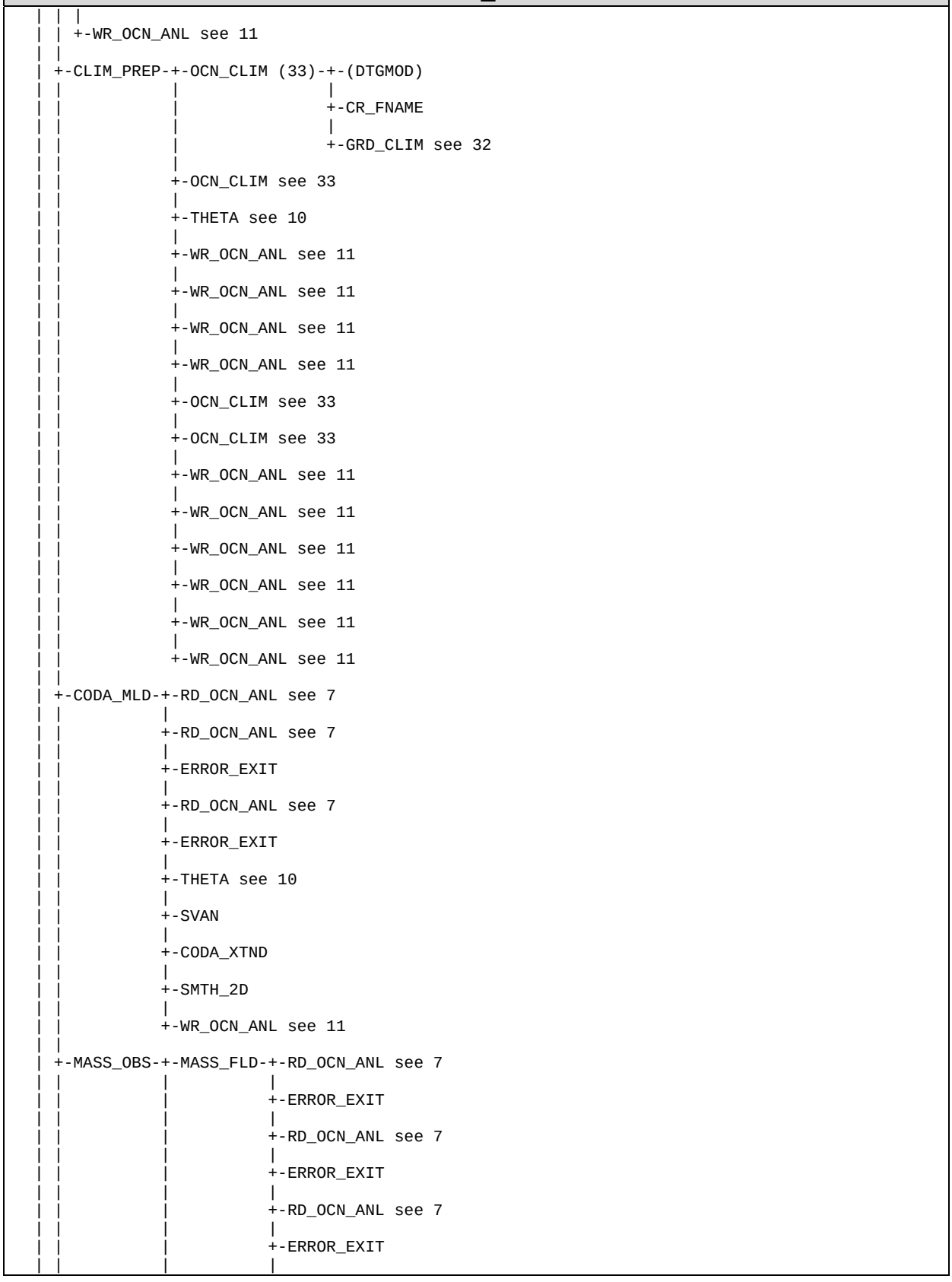
NCODA_PREP


+-RD_SSH_CLIM-+-ERROR_EXIT
+-FLD2_TRP
+-WR_OCN_ANL see 11
+-ERROR_EXIT
+-SET_HCORR see 13
+-RD_OBS_DATA see 14
+-INDEX_OBS see 15
+-DRCT_SSH-+-RD_SSH_STD-+-ERROR_EXIT
+-DTG_TIME
+-FLD2_TRP
+-FLD2_TRP
+-MODAS_TOPOG (29)-+-ERROR_EXIT
+-ERROR_EXIT
+-ERROR_EXIT
+-FLD2_TRP
+-ERROR_EXIT
+-FLD2_TRP
+-MODAS_TOPOG see 29
+-INNOV_OBS see 18
+-REMOVE_OBS
+-WR_RAW_SFC see 19
+-GRDNT_ERR see 25
+-SUPER_OB
+-INDEX_OBS see 15
+-CODA_XTND
+-SMTH_2D
+-SET_ERR see 20
+-INNOV_CHK
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-FLD2_TRP
+-WR_INV_PREP
+-RW_COVR see 21
+-SET_VOLUME see 22

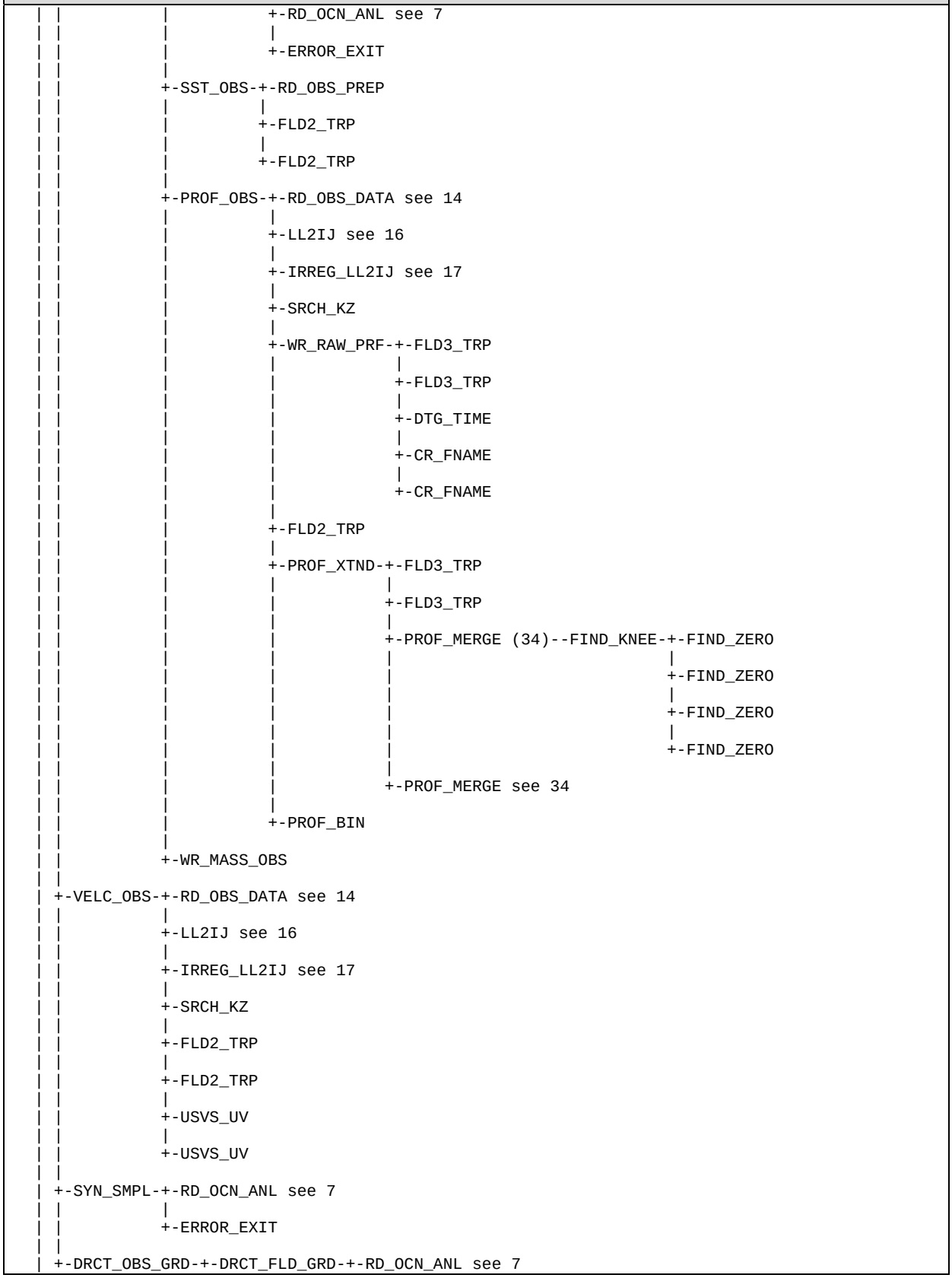

NCODA_PREP
| | |
| | +-WR_INV_VCTR see 23
| |
| +-MODAS_GRID
| | |
| | +-DTG_TIME
| | |
| | +-MODAS_TOPOG see 29
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-RD_ICE_CLIM see 12
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-(OMP_GET_NUM_THREADS)
| | |
| | +-(OMP_GET_THREAD_NUM)
| | |
| | +-MODAS_OPN
| | |
| | +-MODAS_SYN (30)
| | | |
| | | +-MODAS_DATA-+-RD_MODAS_DATA
| | | | |
| | | | +-RD_MODAS_DATA
| | | |
| | | +-MODAS_POLY
| | | |
| | | +-MODAS_TRIFIT
| | | |
| | | +-MODAS_COEF
| | | |
| | | +-MODAS_TEMP-+-MODAS_TYPE
| | | | |
| | | | +-MODAS_TYPE
| | | | |
| | | | +-MODAS_TYPE
| | | | |
| | | | +-MODAS_TRP
| | | | |
| | | | +-MODAS_TRP
| | | | |
| | | | +-MODAS_TRP
| | | | |
| | | | +-MODAS_EDIT
| | | | |
| | | | +-MODAS_CHKTMP
| | | | |
| | | | +-MODAS_TRP
| | | |
| | | +-MODAS_SALT-+-MODAS_TRP
| | | |
| | | +-MODAS_CHKSAL-+-THETA see 10
| | | |

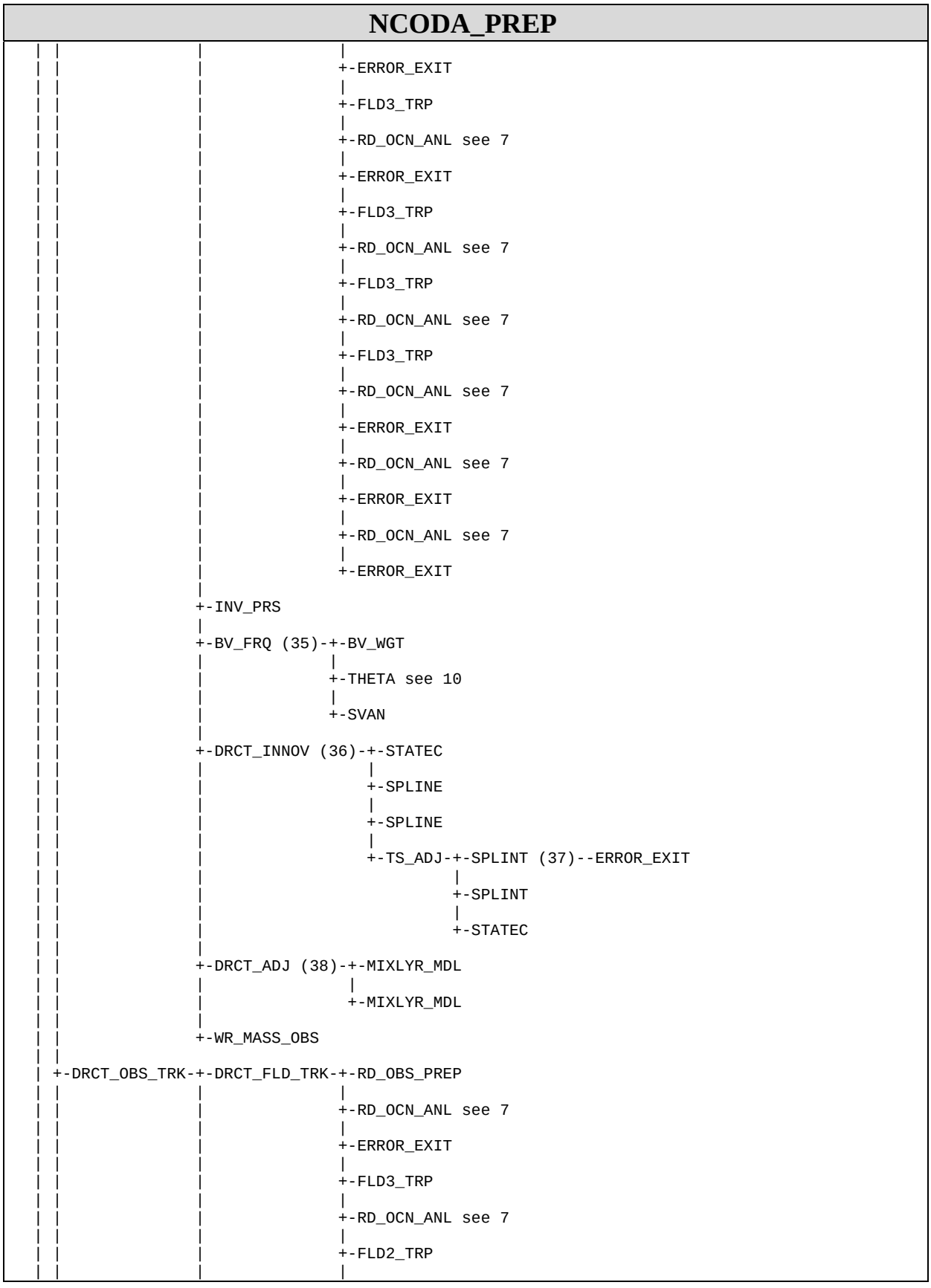

NCODA_PREP
+-SVAN
+-TS_STATIC (31)-+-INV_PRS
+-THETA see 10
+-SVAN
+-SALT_CORR-+-THETA see 10
+-SVAN
+-THETA see 10
+-SVAN
+-THETA see 10
+-SMTH_3D
+-SMTH_3D
+-GRD_CLIM (32)-+-GDEM_MOD
+-ERROR_EXIT
+-ERROR_EXIT
+-ERROR_EXIT
+-GDEM_GRD--ERROR_EXIT
+-FLD3_TRP
+-GRD_CLIM see 32
+-CODA_XTND
+-CODA_XTND
+-CODA_FILL
+-CODA_FILL
+-FLD3_TRP
+-WR_OCN_ANL see 11
+-FLD3_TRP
+-WR_OCN_ANL see 11
+-SMTH_3D
+-SMTH_3D
+-CODA_XTND
+-CODA_XTND
+-FLD3_TRP
+-WR_OCN_ANL see 11
+-FLD3_TRP
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11

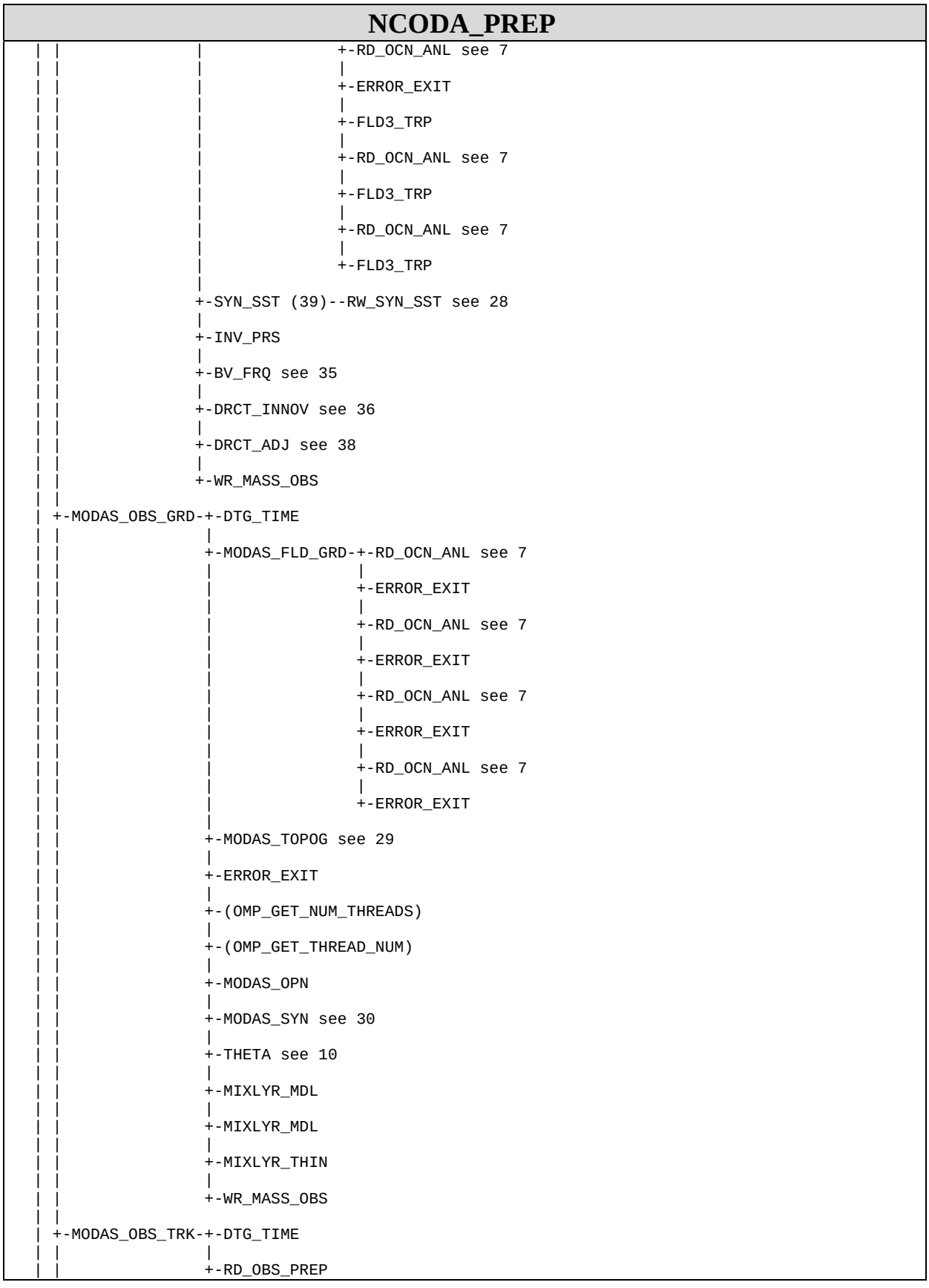
NCODA_PREP

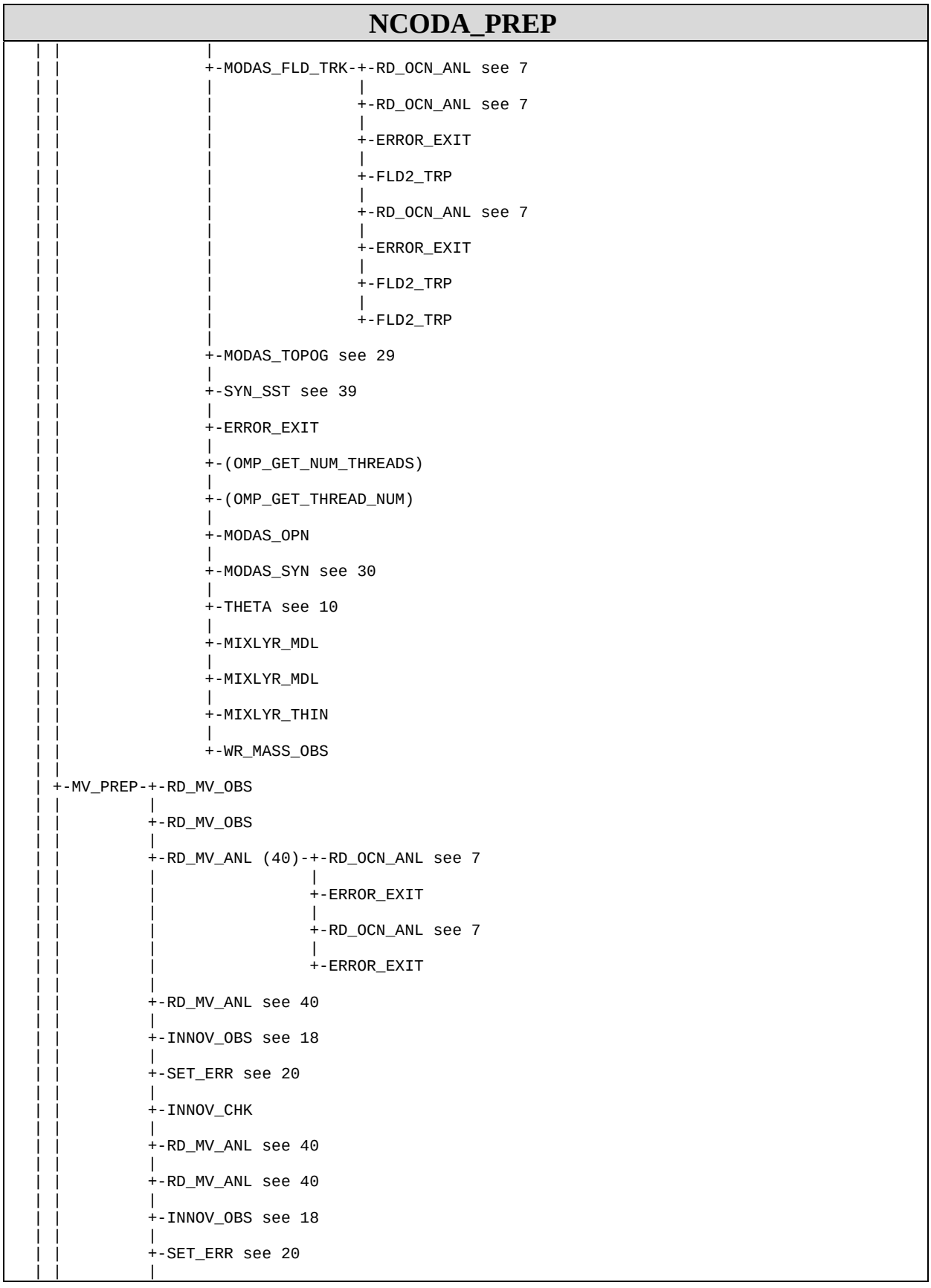

| | |
| | +-WR_OCN_ANL see 11
| |
| +-CLIM_PREP-+-OCN_CLIM (33)-+-(DTGMOD)
| | | |
| | | +-CR_FNAME
| | | |
| | | +-GRD_CLIM see 32
| | |
| | +-OCN_CLIM see 33
| | |
| | +-THETA see 10
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-OCN_CLIM see 33
| | |
| | +-OCN_CLIM see 33
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| | |
| | +-WR_OCN_ANL see 11
| |
| +-CODA_MLD-+-RD_OCN_ANL see 7
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-RD_OCN_ANL see 7
| | |
| | +-ERROR_EXIT
| | |
| | +-THETA see 10
| | |
| | +-SVAN
| | |
| | +-CODA_XTND
| | |
| | +-SMTH_2D
| | |
| | +-WR_OCN_ANL see 11
| |
| +-MASS_OBS-+-MASS_FLD-+-RD_OCN_ANL see 7
| | | |
| | | +-ERROR_EXIT
| | | |
| | | +-RD_OCN_ANL see 7
| | | |
| | | +-ERROR_EXIT
| | | |
| | | +-RD_OCN_ANL see 7
| | | |
| | | +-ERROR_EXIT
| | | |

NCODA_PREP

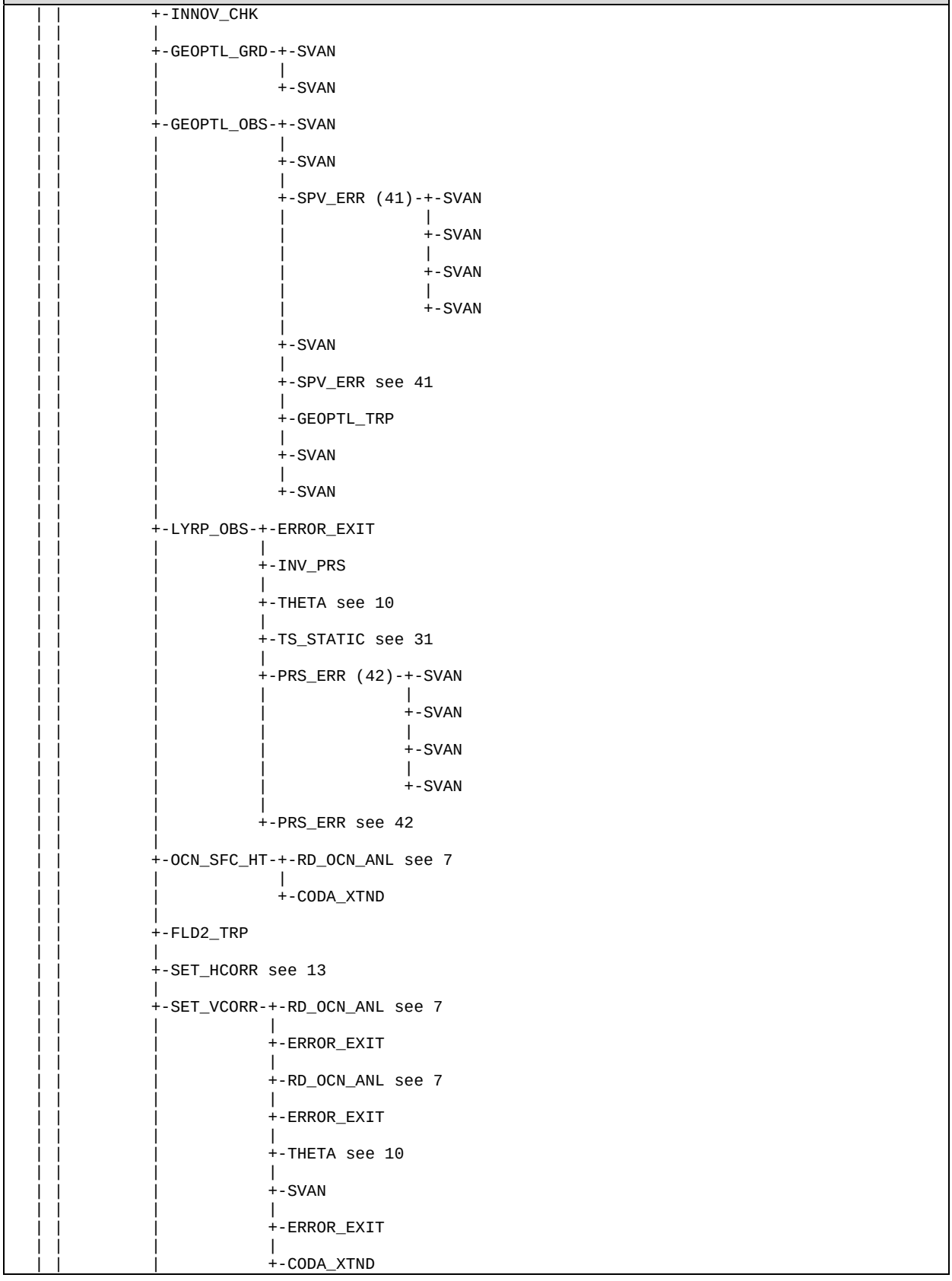

+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-SST_OBS-+-RD_OBS_PREP
+-FLD2_TRP
+-FLD2_TRP
+-PROF_OBS-+-RD_OBS_DATA see 14
+-LL2IJ see 16
+-IRREG_LL2IJ see 17
+-SRCH_KZ
+-WR_RAW_PRF-+-FLD3_TRP
+-FLD3_TRP
+-DTG_TIME
+-CR_FNAME
+-CR_FNAME
+-FLD2_TRP
+-PROF_XTND-+-FLD3_TRP
+-FLD3_TRP
+-PROF_MERGE (34)--FIND_KNEE-+-FIND_ZERO
+-FIND_ZERO
+-FIND_ZERO
+-FIND_ZERO
+-PROF_MERGE see 34
+-PROF_BIN
+-WR_MASS_OBS
+-VELC_OBS-+-RD_OBS_DATA see 14
+-LL2IJ see 16
+-IRREG_LL2IJ see 17
+-SRCH_KZ
+-FLD2_TRP
+-FLD2_TRP
+-USVS_UV
+-USVS_UV
+-SYN_SMPL-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-DRCT_OBS_GRD-+-DRCT_FLD_GRD-+-RD_OCN_ANL see 7


NCODA_PREP
+-ERROR_EXIT
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-INV_PRS
+-BV_FRQ (35)-+-BV_WGT
+-THETA see 10
+-SVAN
+-DRCT_INNOV (36)-+-STATEC
+-SPLINE
+-SPLINE
+-TS_ADJ-+-SPLINT (37)--ERROR_EXIT
+-SPLINT
+-STATEC
+-DRCT_ADJ (38)-+-MIXLYR_MDL
+-MIXLYR_MDL
+-WR_MASS_OBS
+-DRCT_OBS_TRK-+-DRCT_FLD_TRK-+-RD_OBS_PREP
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-FLD2_TRP


NCODA_PREP
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-SYN_SST (39)--RW_SYN_SST see 28
+-INV_PRS
+-BV_FRQ see 35
+-DRCT_INNOV see 36
+-DRCT_ADJ see 38
+-WR_MASS_OBS
+-MODAS_OBS_GRD-+-DTG_TIME
+-MODAS_FLD_GRD-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-MODAS_TOPOG see 29
+-ERROR_EXIT
+-(OMP_GET_NUM_THREADS)
+-(OMP_GET_THREAD_NUM)
+-MODAS_OPN
+-MODAS_SYN see 30
+-THETA see 10
+-MIXLYR_MDL
+-MIXLYR_MDL
+-MIXLYR_THIN
+-WR_MASS_OBS
+-MODAS_OBS_TRK-+-DTG_TIME
+-RD_OBS_PREP


NCODA_PREP
+-MODAS_FLD_TRK-+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD2_TRP
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-FLD2_TRP
+-FLD2_TRP
+-MODAS_TOPOG see 29
+-SYN_SST see 39
+-ERROR_EXIT
+-(OMP_GET_NUM_THREADS)
+-(OMP_GET_THREAD_NUM)
+-MODAS_OPN
+-MODAS_SYN see 30
+-THETA see 10
+-MIXLYR_MDL
+-MIXLYR_MDL
+-MIXLYR_THIN
+-WR_MASS_OBS
+-MV_PREP-+-RD_MV_OBS
+-RD_MV_OBS
+-RD_MV_ANL (40)-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_MV_ANL see 40
+-INNOV_OBS see 18
+-SET_ERR see 20
+-INNOV_CHK
+-RD_MV_ANL see 40
+-RD_MV_ANL see 40
+-INNOV_OBS see 18
+-SET_ERR see 20

NCODA_PREP


+-INNOV_CHK
+-GEOPTL_GRD-+-SVAN
+-SVAN
+-GEOPTL_OBS-+-SVAN
+-SVAN
+-SPV_ERR (41)-+-SVAN
+-SVAN
+-SVAN
+-SVAN
+-SVAN
+-SPV_ERR see 41
+-GEOPTL_TRP
+-SVAN
+-SVAN
+-LYRP_OBS-+-ERROR_EXIT
+-INV_PRS
+-THETA see 10
+-TS_STATIC see 31
+-PRS_ERR (42)-+-SVAN
+-SVAN
+-SVAN
+-SVAN
+-PRS_ERR see 42
+-OCN_SFC_HT-+-RD_OCN_ANL see 7
+-CODA_XTND
+-FLD2_TRP
+-SET_HCORR see 13
+-SET_VCORR-+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-RD_OCN_ANL see 7
+-ERROR_EXIT
+-THETA see 10
+-SVAN
+-ERROR_EXIT
+-CODA_XTND

NCODA_PREP

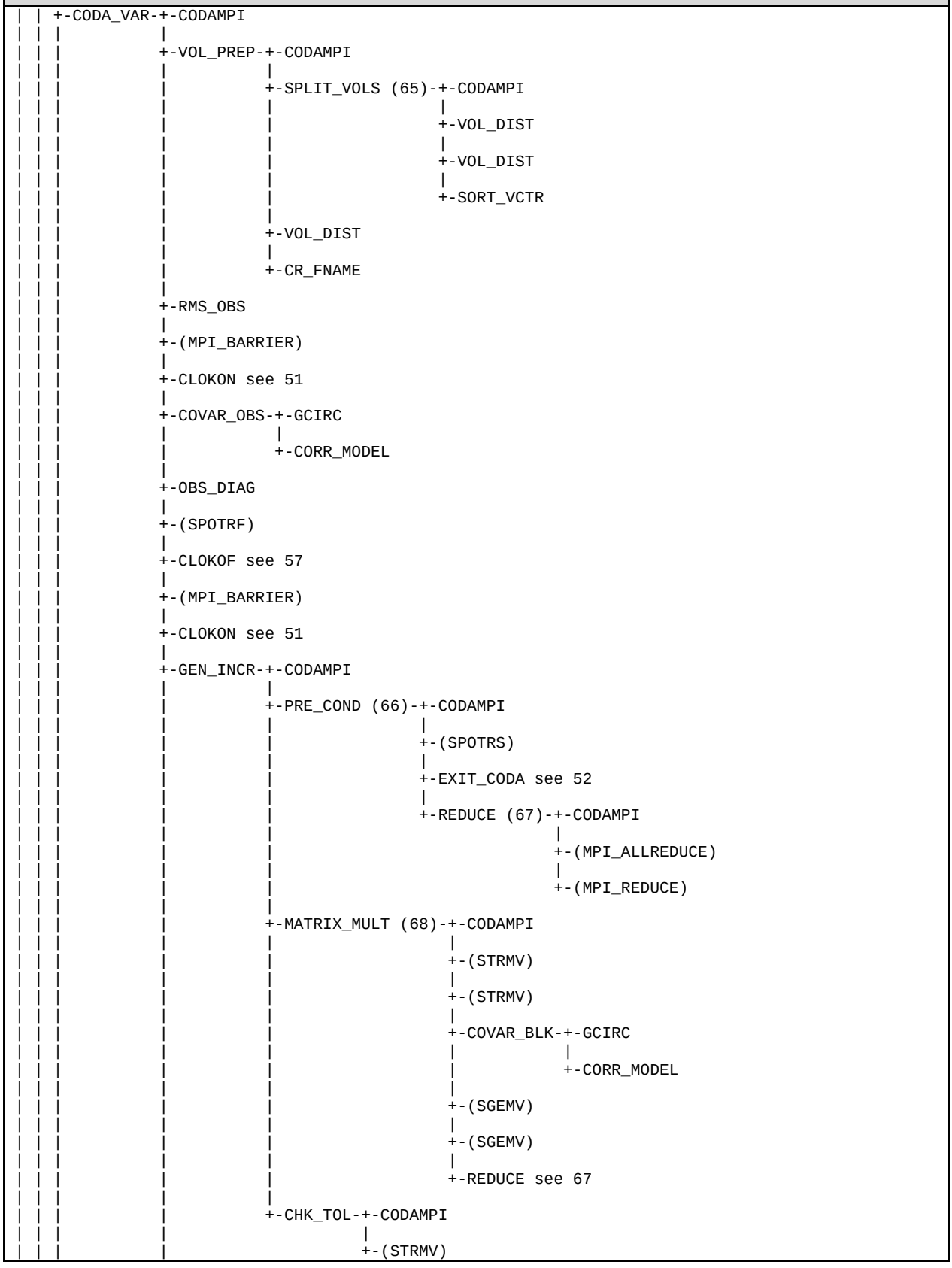
```
| |          |           |
| |          |           +-SMTH_3D
| |          |           |
| |          |           +-WR_OCN_ANL see 11
| |          |
| |         +-FLD2_TRP
| |          |
| |         +-FLD2_TRP
| |          |
| |         +-FLD2_TRP
| |          |
| |         +-SVAN
| |          |
| |         +-SVAN
| |          |
| |         +-FLD3_TRP
| |          |
| |         +-RD_MV_OBS
| |          |
| |         +-RD_MV_ANL see 40
| |          |
| |         +-RD_MV_ANL see 40
| |          |
| |         +-INNOV_OBS see 18
| |          |
| |         +-SET_ERR see 20
| |          |
| |         +-INNOV_CHK
| |          |
| |         +-RD_MV_ANL see 40
| |          |
| |         +-RD_MV_ANL see 40
| |          |
| |         +-INNOV_OBS see 18
| |          |
| |         +-SET_ERR see 20
| |          |
| |         +-INNOV_CHK
| |          |
| |         +-WR_INV_PREP
| |          |
| |         +-WR_INV_VCTR see 23
| |          |
| |         +-WR_INV_VCTR see 23
| |          |
| |         +-WR_INV_VCTR see 23
| |          |
| |         +-WR_INV_VCTR see 23
| |          |
| |         +-WR_INV_VCTR see 23
| |          |
| |         +-SET_VOLUME see 22
| |          |
| |         +-RW_COVR see 21
| |          |
| |         +-WR_GRD_VOL--ERROR_EXIT
| |
| +-RW_PREP_HDR
| |
| +-RW_CNTRL see 5
|
+-DATAO_RW see 1
```

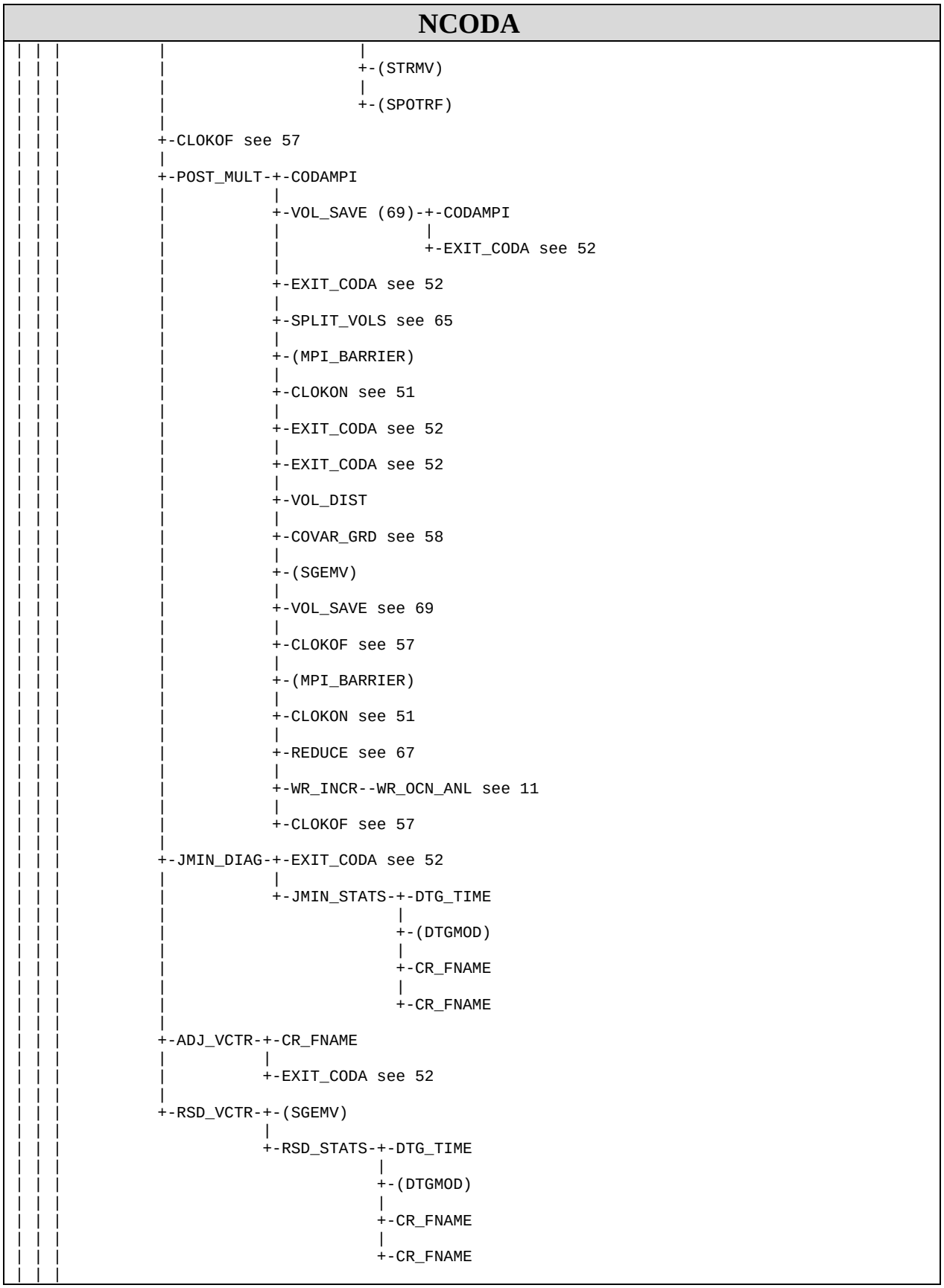
9.2 NCODA Call Tree

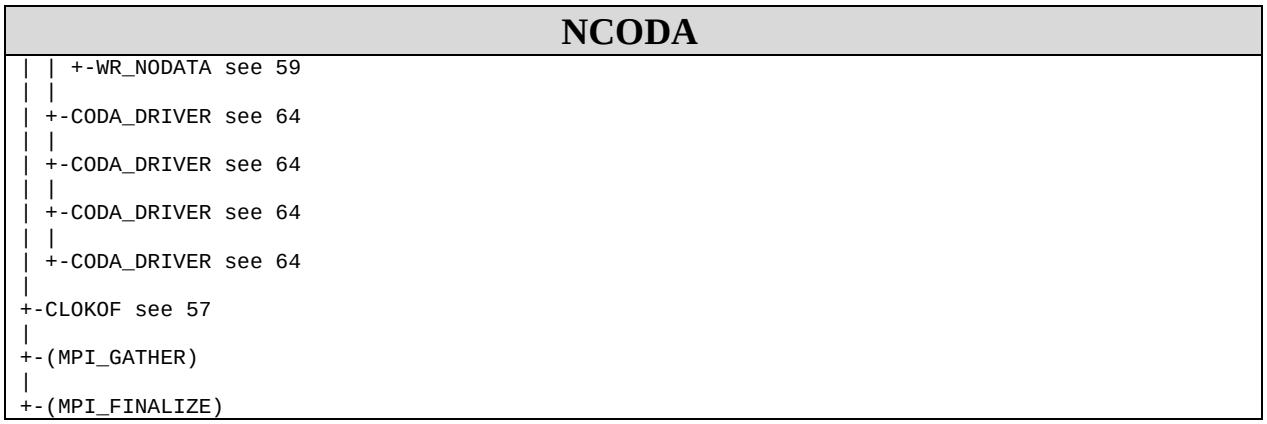
NCODA

```
NCODA
|
+-CODAMPI
|
+-(MPI_INIT)
|
+-(MPI_COMM_RANK)
|
+-(MPI_COMM_SIZE)
|
+-CLOKON see 51
|
+-{IARGC}
|
+-{GETARG}
|
+-EXIT_CODA see 52
|
+-{GETARG}
|
+-EXIT_CODA see 52
|
+-{IARGC}
|
+-{GETARG}
|
+-EXIT_CODA see 52
|
+-(DTGCHK)
|
+-EXIT_CODA see 52
|
+-EXIT_CODA see 52
|
+-EXIT_CODA see 52
|
+-RW_PREP_HDR
|
+-EXIT_CODA see 52
|
+-CODA
| |
| +-CODAMPI
| |
| +-EXIT_CODA see 52
| |
| +-COAMPS_GRID see 3
| |
| +-NGPS_GRID see 4
| |
| +-IRREG_GRID see 2
| |
| +-SET_HGRD
| |
| +-CODA_DRIVER (64)
| | |
| | +-RD_INV_PREP see 54
| | |
| | +-RW_COVR see 21
| | |
| | +-RD_VOL_DEF see 55
| | |
| | +-VOL_DEF
| | |
| | +-VOL_RPT
| | |
```

NCODA

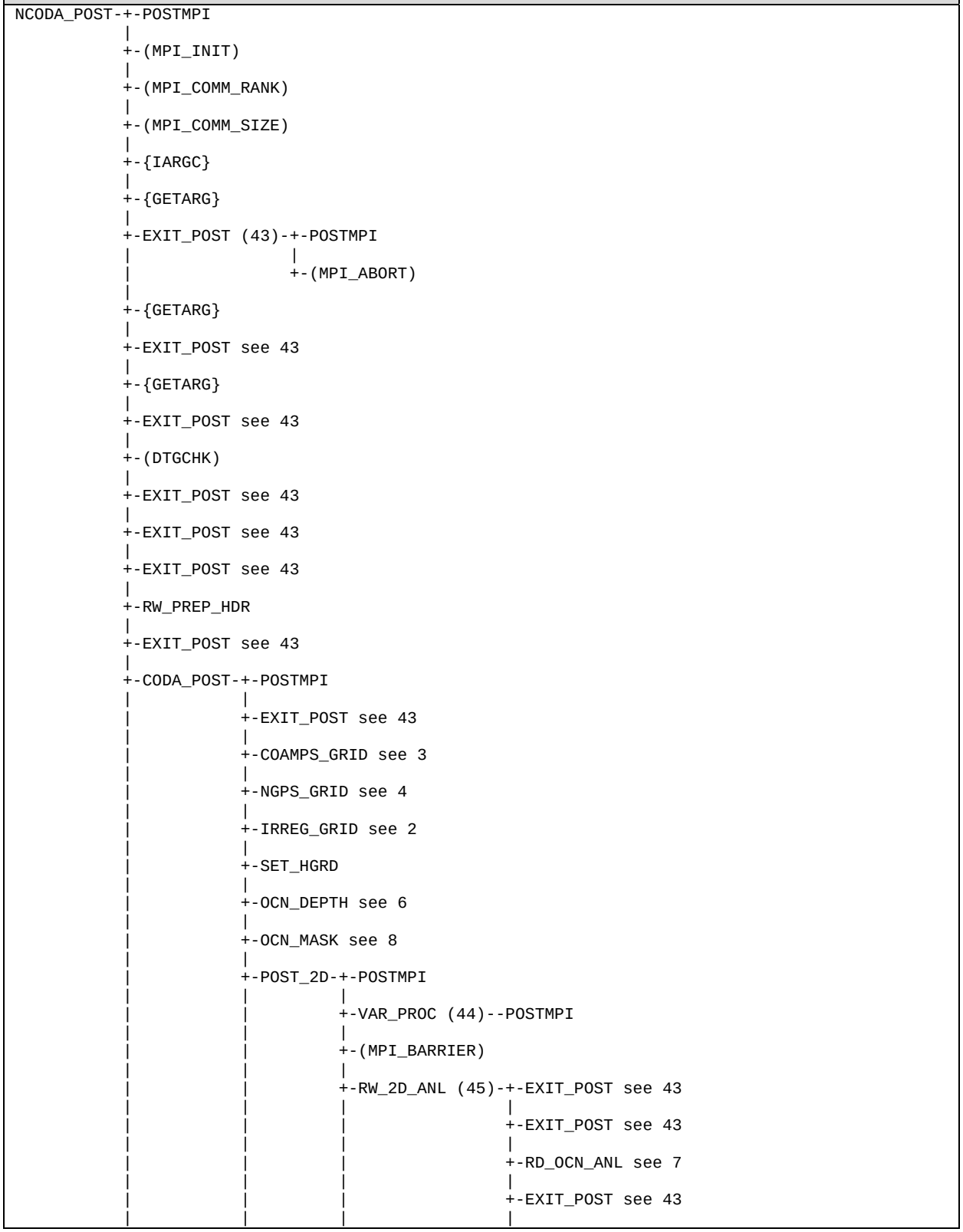

+-CODA_VAR-+-CODAMPI
+-VOL_PREP-+-CODAMPI
+-SPLIT_VOLS (65)-+-CODAMPI
+-VOL_DIST
+-VOL_DIST
+-SORT_VCTR
+-VOL_DIST
+-CR_FNAME
+-RMS_OBS
+-(MPI_BARRIER)
+-CLOKON see 51
+-COVAR_OBS-+-GCIRC
+-CORR_MODEL
+-OBS_DIAG
+-(SPOTRF)
+-CLOKOF see 57
+-(MPI_BARRIER)
+-CLOKON see 51
+-GEN_INCR-+-CODAMPI
+-PRE_COND (66)-+-CODAMPI
+-(SPOTRS)
+-EXIT_CODA see 52
+-REDUCE (67)-+-CODAMPI
+-(MPI_ALLREDUCE)
+-(MPI_REDUCE)
+-MATRIX_MULT (68)-+-CODAMPI
+-(STRMV)
+-(STRMV)
+-COVAR_BLK-+-GCIRC
+-CORR_MODEL
+-(SGEMV)
+-(SGEMV)
+-REDUCE see 67
+-CHK_TOL-+-CODAMPI
+-(STRMV)


NCODA
|
+-(STRMV)
|
+-(SPOTRF)
+-CLOKOF see 57
+-POST_MULT-+-CODAMPI
+-VOL_SAVE (69)-+-CODAMPI
+-EXIT_CODA see 52
+-EXIT_CODA see 52
+-SPLIT_VOLS see 65
+-(MPI_BARRIER)
+-CLOKON see 51
+-EXIT_CODA see 52
+-EXIT_CODA see 52
+-VOL_DIST
+-COVAR_GRD see 58
+-(SGEMV)
+-VOL_SAVE see 69
+-CLOKOF see 57
+-(MPI_BARRIER)
+-CLOKON see 51
+-REDUCE see 67
+-WR_INCR--WR_OCN_ANL see 11
+-CLOKOF see 57
+-JMIN_DIAG-+-EXIT_CODA see 52
+-JMIN_STATS-+-DTG_TIME
+-(DTGMOD)
+-CR_FNAME
+-CR_FNAME
+-ADJ_VCTR-+-CR_FNAME
+-EXIT_CODA see 52
+-RSD_VCTR-+-(SGEMV)
+-RSD_STATS-+-DTG_TIME
+-(DTGMOD)
+-CR_FNAME
+-CR_FNAME

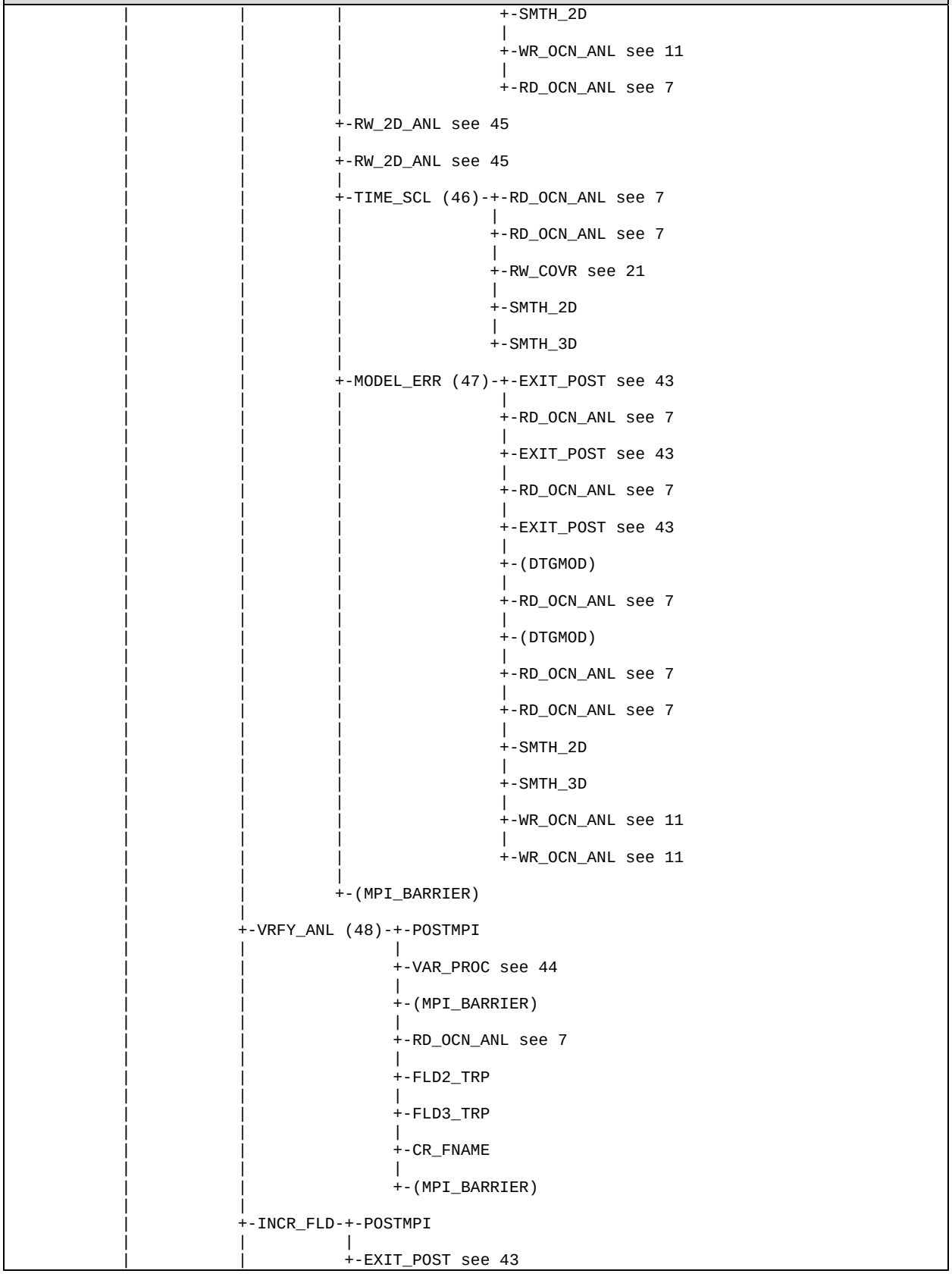

NCODA
| | +-WR_NODATA see 59
| |
| +-CODA_DRIVER see 64
| |
| +-CODA_DRIVER see 64
| |
| +-CODA_DRIVER see 64
| |
| +-CODA_DRIVER see 64
|
+-CLOKOF see 57
|
+-(MPI_GATHER)
|
+-(MPI_FINALIZE)

9.3 NCODA_POST Call Tree

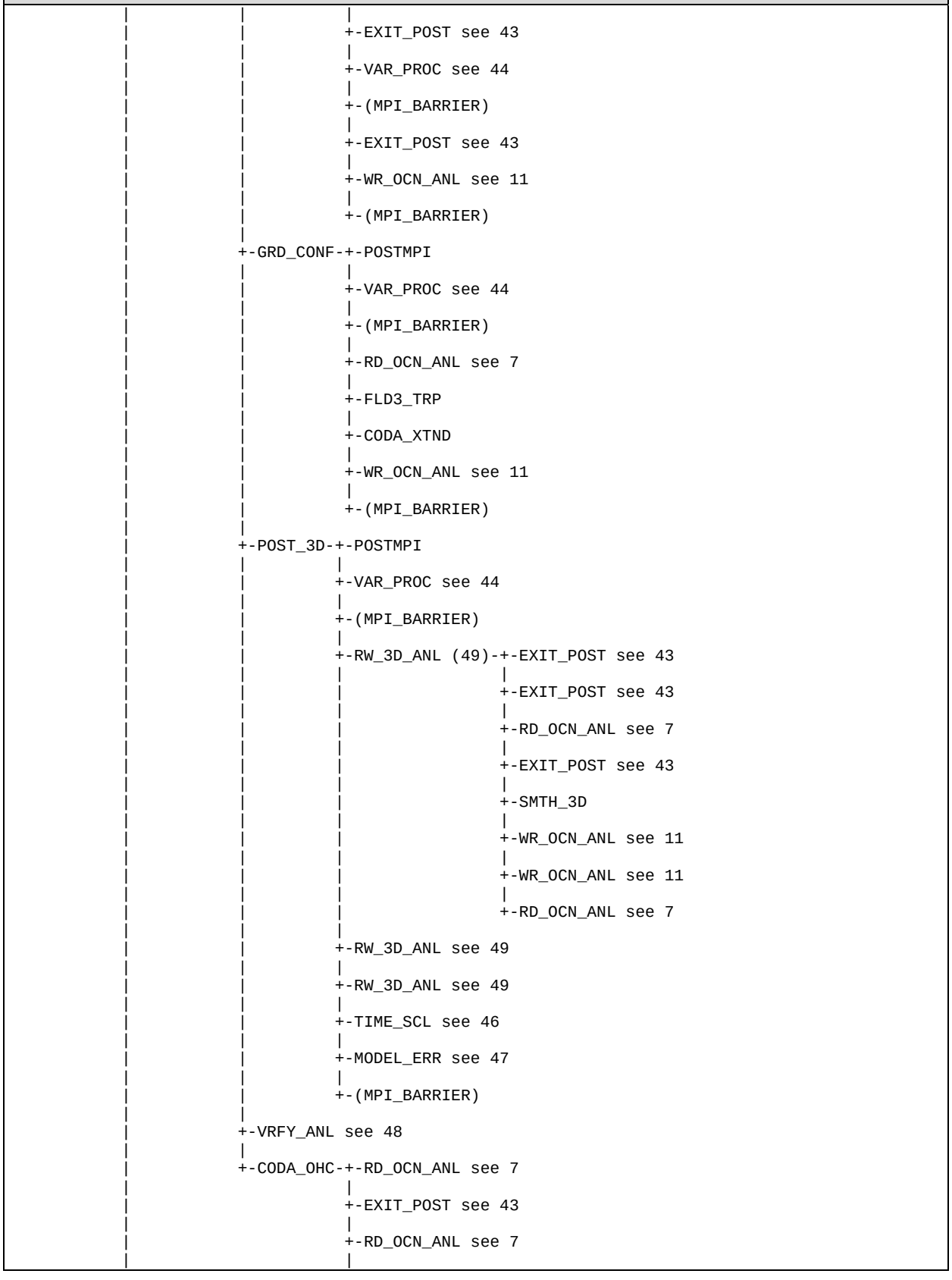
NCODA_POST

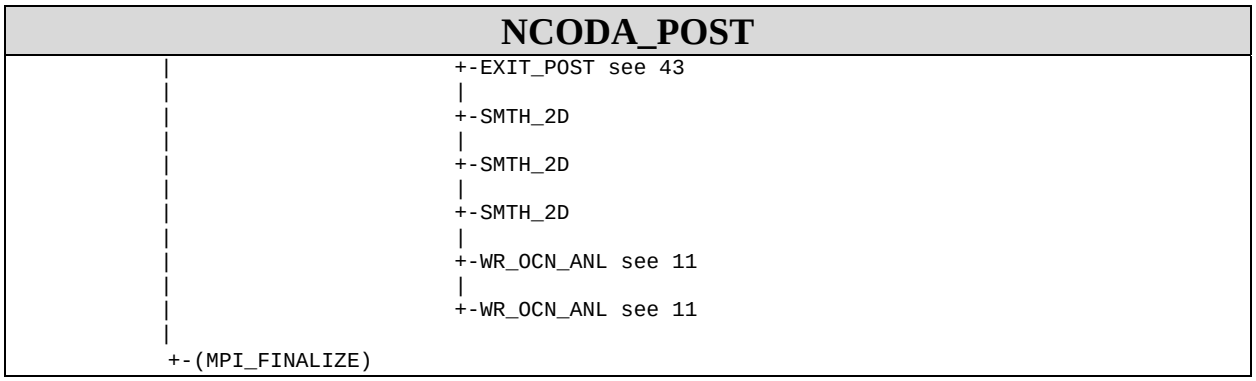


NCODA_POST


+-SMTH_2D
+-WR_OCN_ANL see 11
+-RD_OCN_ANL see 7
+-RW_2D_ANL see 45
+-RW_2D_ANL see 45
+-TIME_SCL (46)-+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-RW_COVR see 21
+-SMTH_2D
+-SMTH_3D
+-MODEL_ERR (47)-+-EXIT_POST see 43
+-RD_OCN_ANL see 7
+-EXIT_POST see 43
+-RD_OCN_ANL see 7
+-EXIT_POST see 43
+-(DTGMOD)
+-RD_OCN_ANL see 7
+-(DTGMOD)
+-RD_OCN_ANL see 7
+-RD_OCN_ANL see 7
+-SMTH_2D
+-SMTH_3D
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-VRFY_ANL (48)-+-POSTMPI
+-VAR_PROC see 44
+-(MPI_BARRIER)
+-RD_OCN_ANL see 7
+-FLD2_TRP
+-FLD3_TRP
+-CR_FNAME
+-(MPI_BARRIER)
+-INCR_FLD-+-POSTMPI
+-EXIT_POST see 43

NCODA_POST


+-EXIT_POST see 43
+-VAR_PROC see 44
+-(MPI_BARRIER)
+-EXIT_POST see 43
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-GRD_CONF-+-POSTMPI
+-VAR_PROC see 44
+-(MPI_BARRIER)
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-CODA_XTND
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-POST_3D-+-POSTMPI
+-VAR_PROC see 44
+-(MPI_BARRIER)
+-RW_3D_ANL (49)-+-EXIT_POST see 43
+-EXIT_POST see 43
+-RD_OCN_ANL see 7
+-EXIT_POST see 43
+-SMTH_3D
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-RD_OCN_ANL see 7
+-RW_3D_ANL see 49
+-RW_3D_ANL see 49
+-TIME_SCL see 46
+-MODEL_ERR see 47
+-(MPI_BARRIER)
+-VRFY_ANL see 48
+-CODA_OHC-+-RD_OCN_ANL see 7
+-EXIT_POST see 43
+-RD_OCN_ANL see 7

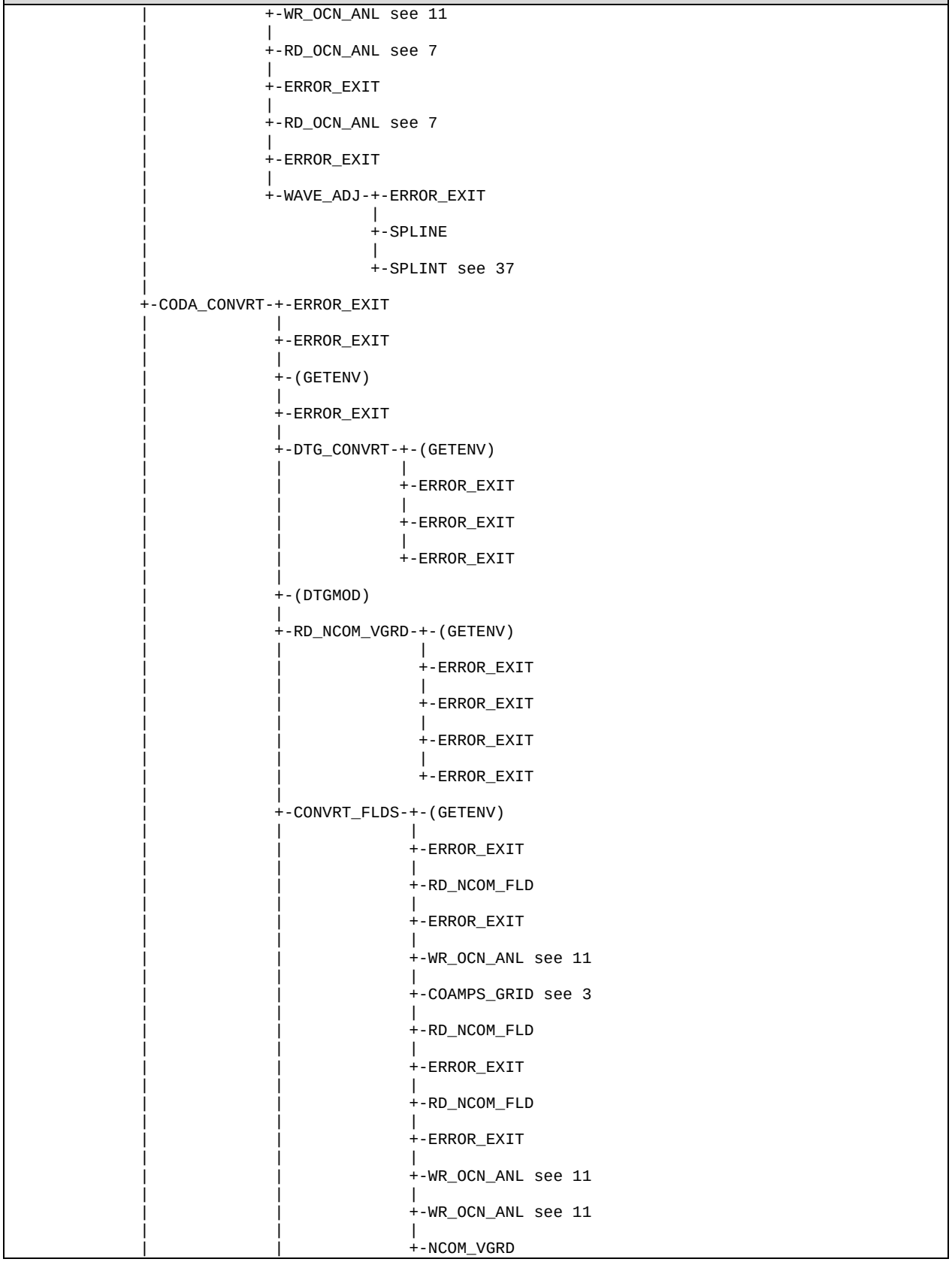

NCODA_POST
+-EXIT_POST see 43
+-SMTH_2D
+-SMTH_2D
+-SMTH_2D
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-(MPI_FINALIZE)

9.4 NCODA_CONVRT Call Tree

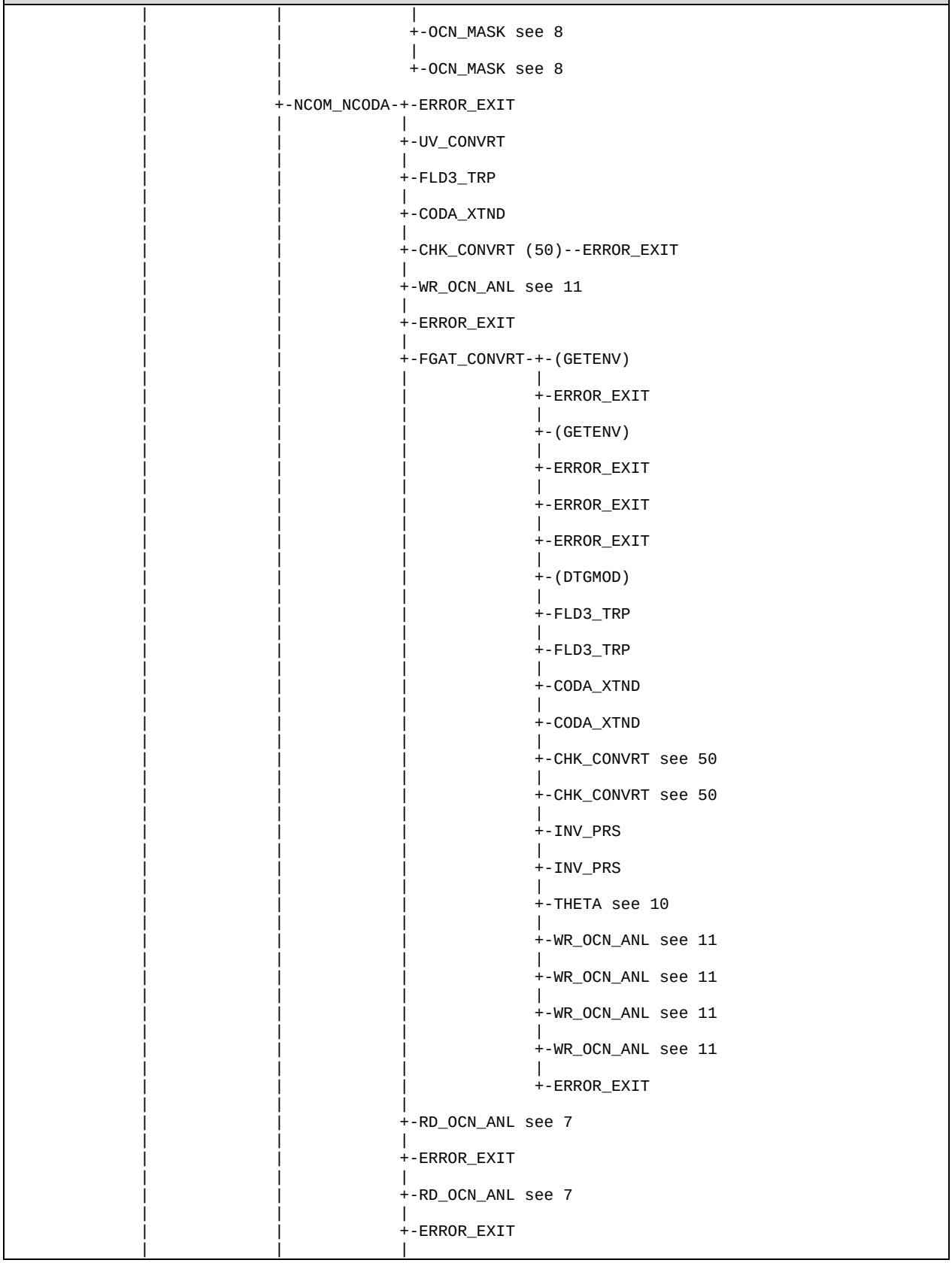
NCODA_CONVRT

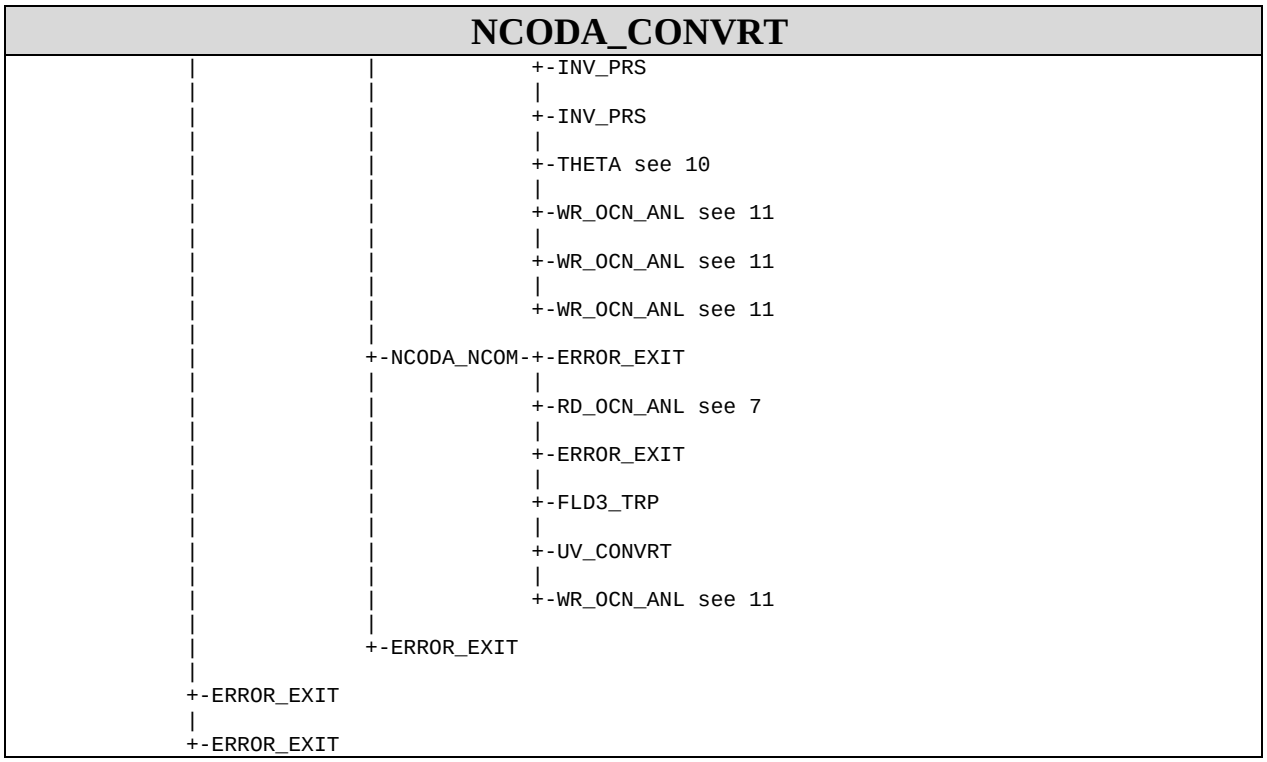
```
NCODA_CONVRT-+-{IARGC}
             |
             +-{GETARG}
             |
             +-ERROR_EXIT
             |
             +-{GETARG}
             |
             +-ERROR_EXIT
             |
             +-{GETARG}
             |
             +-ERROR_EXIT
             |
             +-{GETARG}
             |
             +-ERROR_EXIT
             |
             +-(DTGCHK)
             |
             +-ERROR_EXIT
             |
             +-{GETARG}
             |
             +-ERROR_EXIT
             |
             +-WAVE_NCODA-+-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-(DTGMOD)
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-(DTGDIF)
             |            |
             |            +-WR_OCN_ANL see 11
             |            |
             |            +-WR_OCN_ANL see 11
             |
             +-NCODA_WAVE-+-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-(DTGMOD)
             |            |
             |            +-RD_OCN_ANL see 7
             |            |
             |            +-ERROR_EXIT
             |            |
             |            +-RD_OCN_ANL see 7
             |            |
             |            +-ERROR_EXIT
             |            |
```

NCODA_CONVRT



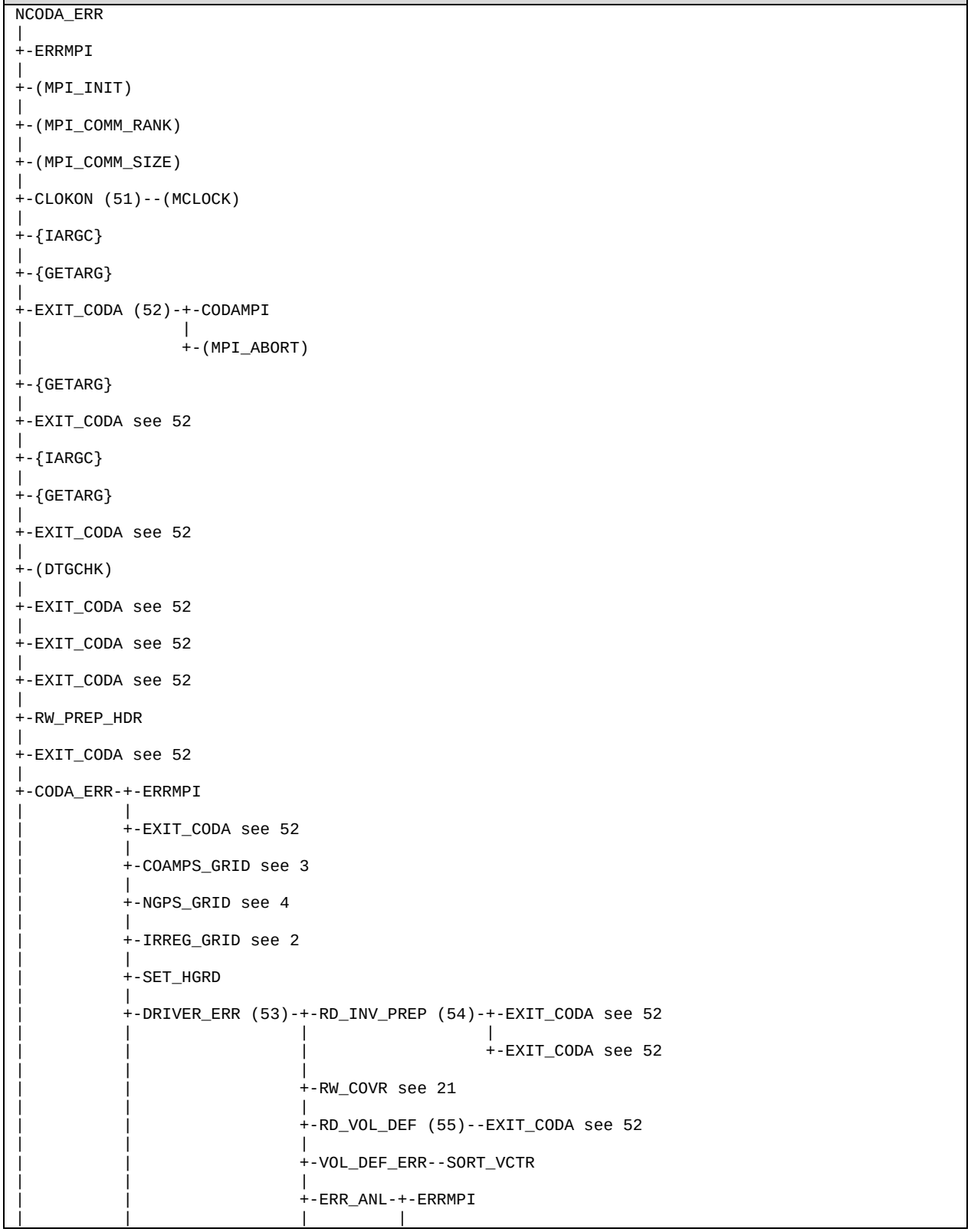
NCODA_CONVRT

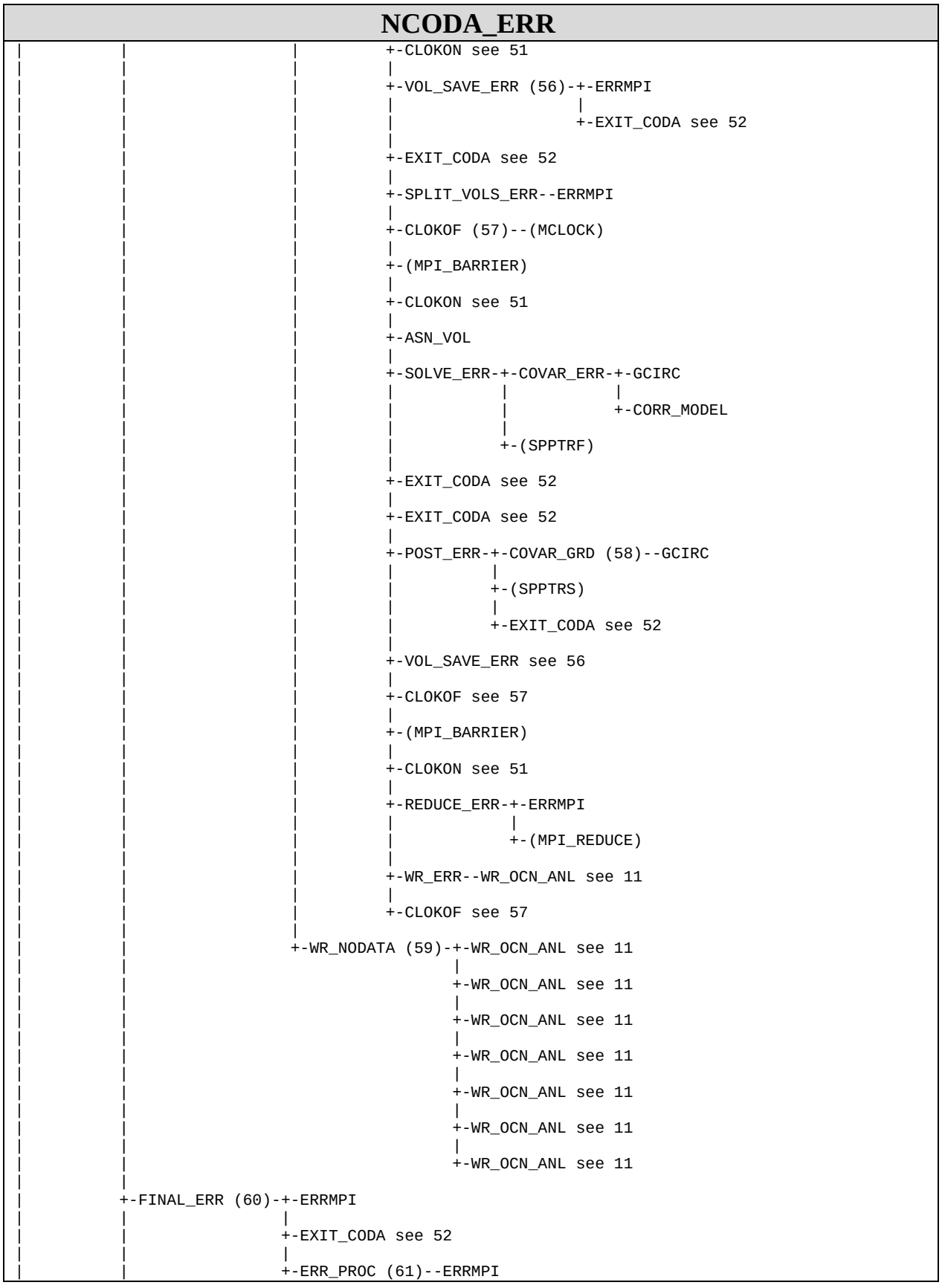


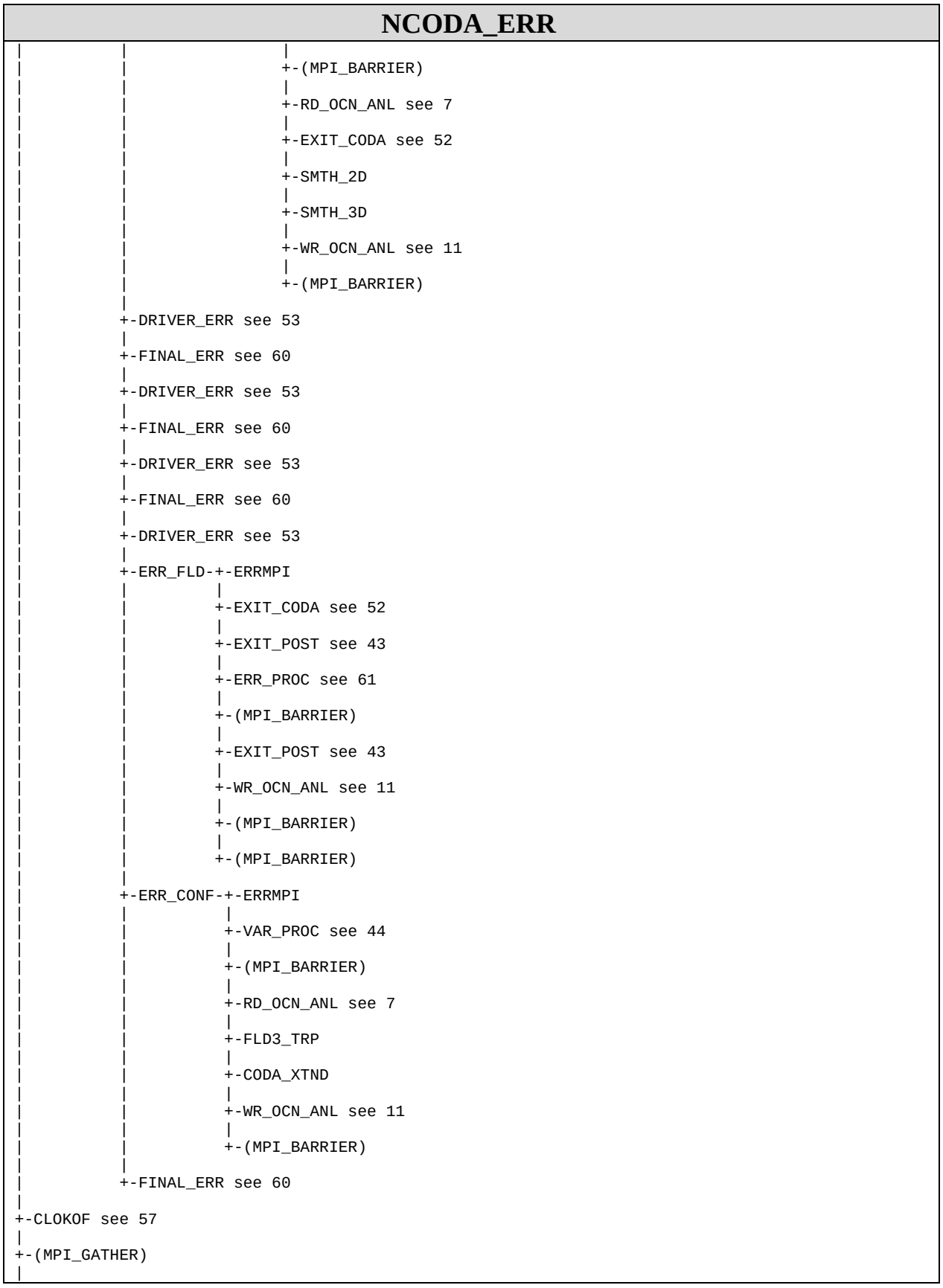

NCODA_CONVRT
|
|
|

9.5 NCODA_ERR Call Tree

NCODA_ERR




NCODA_ERR
+-CLOKON see 51
+-VOL_SAVE_ERR (56)-+-ERRMPI
+-EXIT_CODA see 52
+-EXIT_CODA see 52
+-SPLIT_VOLS_ERR--ERRMPI
+-CLOKOF (57)--(MCLOCK)
+-(MPI_BARRIER)
+-CLOKON see 51
+-ASN_VOL
+-SOLVE_ERR-+-COVAR_ERR-+-GCIRC
+-CORR_MODEL
+-(SPPTRF)
+-EXIT_CODA see 52
+-EXIT_CODA see 52
+-POST_ERR-+-COVAR_GRD (58)--GCIRC
+-(SPPTRS)
+-EXIT_CODA see 52
+-VOL_SAVE_ERR see 56
+-CLOKOF see 57
+-(MPI_BARRIER)
+-CLOKON see 51
+-REDUCE_ERR-+-ERRMPI
+-(MPI_REDUCE)
+-WR_ERR--WR_OCN_ANL see 11
+-CLOKOF see 57
+-WR_NODATA (59)-+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-WR_OCN_ANL see 11
+-FINAL_ERR (60)-+-ERRMPI
+-EXIT_CODA see 52
+-ERR_PROC (61)--ERRMPI


NCODA_ERR
+-(MPI_BARRIER)
+-RD_OCN_ANL see 7
+-EXIT_CODA see 52
+-SMTH_2D
+-SMTH_3D
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-DRIVER_ERR see 53
+-FINAL_ERR see 60
+-DRIVER_ERR see 53
+-FINAL_ERR see 60
+-DRIVER_ERR see 53
+-FINAL_ERR see 60
+-DRIVER_ERR see 53
+-ERR_FLD-+-ERRMPI
+-EXIT_CODA see 52
+-EXIT_POST see 43
+-ERR_PROC see 61
+-(MPI_BARRIER)
+-EXIT_POST see 43
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-(MPI_BARRIER)
+-ERR_CONF-+-ERRMPI
+-VAR_PROC see 44
+-(MPI_BARRIER)
+-RD_OCN_ANL see 7
+-FLD3_TRP
+-CODA_XTND
+-WR_OCN_ANL see 11
+-(MPI_BARRIER)
+-FINAL_ERR see 60
+-CLOKOF see 57
+-(MPI_GATHER)

NCODA_ERR

+-(MPI_FINALIZE)

9.6 NCODA_ET Call Tree

NCODA_ET

```
NCODA_ET-+-{IARGC}
         |
         +-{GETARG}
         |
         +-ERROR_EXIT
         |
         +-{GETARG}
         |
         +-ERROR_EXIT
         |
         +-{GETARG}
         |
         +-ERROR_EXIT
         |
         +-(DTGCHK)
         |
         +-ERROR_EXIT
         |
         +-ERROR_EXIT
         |
         +-ERROR_EXIT
         |
         +-ERROR_EXIT
         |
         +-ERROR_EXIT
         |
         +-ERROR_EXIT
         |
         +-DATAO_RW see 1
         |
         +-ERROR_EXIT
         |
         +-OCN_MASK see 8
         |
         +-NCOM_ET-+-RD_OCN_ANL see 7
         |         |
         |         +-ERROR_EXIT
         |         |
         |         +-NCOM_VGRD_ET (62)-+-ERROR_EXIT
         |         |                   |
         |         |                   +-ERROR_EXIT
         |         |
         |         +-NCOM_SIGMA
         |         |
         |         +-ERROR_EXIT
         |         |
         |         +-UV_ET
         |         |
         |         +-FLD3_TRP
         |         |
         |         +-CODA_XTND
         |         |
         |         +-RW_ENS_MEM (63)--ERROR_EXIT
         |
         +-WAVE_ET-+-ERROR_EXIT
         |         |
         |         +-(DTGMOD)
         |         |
         |         +-ERROR_EXIT
         |         |
         |         +-(DTGDIF)
         |         |
         |         +-RW_ENS_MEM see 63
         |
         +-WAVE_SETUP-+-RD_OCN_ANL see 7
         |            |
```

NCODA_ET

```
          |            +-RD_OCN_ANL see 7
          |            |
          |            +-ERROR_EXIT
          |            |
          |            +-WR_OCN_ANL see 11
          |            |
          |            +-RD_OCN_ANL see 7
          |            |
          |            +-ERROR_EXIT
          |            |
          |            +-WR_OCN_ANL see 11
          |
         +-ERROR_EXIT
          |
         +-ENSB_ET-+-RW_ENS_MEM see 63
          |        |
          |        +-ENSB_VAR--WR_OCN_ANL see 11
          |        |
          |        +-RD_OCN_ANL see 7
          |        |
          |        +-ERROR_EXIT
          |        |
          |        +-RD_OCN_ANL see 7
          |        |
          |        +-ET-+-(DSYEV)
          |        |    |
          |        |    +-ERROR_EXIT
          |        |
          |        +-RD_OCN_ANL see 7
          |        |
          |        +-ERROR_EXIT
          |        |
          |        +-RW_ENS_MEM see 63
          |
         +-ET_NCOM-+-RD_OCN_ANL see 7
          |        |
          |        +-ERROR_EXIT
          |        |
          |        +-NCOM_VGRD_ET see 62
          |        |
          |        +-NCOM_SIGMA
          |        |
          |        +-ERROR_EXIT
          |        |
          |        +-RW_ENS_MEM see 63
          |        |
          |        +-FLD3_TRP
          |        |
          |        +-UV_ET
          |
         +-ET_WAVE-+-ERROR_EXIT
          |        |
          |        +-RW_ENS_MEM see 63
          |        |
          |        +-RW_ENS_MEM see 63
          |        |
          |        +-RW_ENS_MEM see 63
          |        |
          |        +-WAVE_ADJ_ET-+-ERROR_EXIT
          |                      |
          |                      +-SPLINE
          |                      |
          |                      +-SPLINT see 37
          |
         +-ERROR_EXIT
```