MetReader: Documentation and User's Guide

Hans F. Schwaiger

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1 Introduction

MetReader is a library written in Fortran 90 that provides an interface to numerical weather prediction (NWP) data, or other forms of meteorological data, such as radiosonde or other 1-D data.

This library was originally written as a component of the USGS volcanic ash transport and dispersion model, Ash3d. However, since it is useful for programs in addition to Ash3d, this interface to NWP files is provided as a separate repository that can either be compiled as a library or simply compiled directly with other source code.

NWP data are generally made available by agencies (NCEP, NOAA, NASA, ECMWF, etc.) in a variety of formats (NetCDF, GRIB, ASCII); each product having its own data structure, naming convention, units, etc. This library isolates the calling program from the peculiarities of interfacing with a particular NWP product. Data can be returned to the calling program on the native grid of the NWP product, or on any grid needed by the calling program. Projection and interpolation of NWP data to the required grid, along with any rotation of velocity vectors to grid-relative, is calculated internally by MetReader.

2 Installation

This library requires two additional libraries made available on GitHub and USGS GitLab:

- HoursSince
  This is a library that takes a date and time, and calculates the number of hours since January 1, 1900 (or any arbitrary base year).
  `https://github.com/DOI-USGS/volcano-ash3d-hourssince`
  `https://code.usgs.gov/vsc/ash3d/volcano-ash3d-hourssince`

- projection
  This is a library that calculates commonly-used projected coordinates.
  `https://github.com/DOI-USGS/volcano-ash3d-projection`
  `https://code.usgs.gov/vsc/ash3d/volcano-ash3d-projection`

These libraries are installed by default into `/opt/USGS`. If they are installed elsewhere, then you will need to edit the `makefile` to point to your installation. Additionally, the default makefile will build MetReader with both NetCDF and GRIB interfaces enabled. If either of these libraries are unavailable on your system, you will need to deactivate those options by setting the corresponding flags to F in the makefile. On a Redhat systems (Fedora, RHEL, CentOS, Rocky), you can install the data format libraries by typing

```
sudo yum install netcdf netcdf-devel netcdf-fortran netcdf-fortran-devel
sudo yum install eccodes eccodes-devel
```

or for Ubuntu

```
sudo apt-get install libnetcdf-c++4 libnetcdf-dev libnetcdff-dev
sudo apt-get install libeccodes0 libeccodes-dev
```

To compile MetReader as a library, simply type:

```
make lib
```

This will build the requested components of the library. If GRIB is enabled, this will also build the GRIB indexer, gen_GRIB_index. This is a tool that generates an index file of the GRIB records which speeds access time to individual records substantially. Several other tools can be build via the command:

```
make tools
```

These tools include the following (described in Sec. 6).

- MetRegrid : This program reads a variable from a NWP file and regrids the data to a user-specified grid; then write out regridded point, line, sheet, or volume data.
- MetSonde : This tool takes command-line arguments specifying date, time, location and writes a file with temperature vs height from GFS or NCEP data.
- MetCheck : This program tests the windfiles to make sure all variable values are within the expected ranges.
- gen_GRIB_index : This tool builds a grib index to facilitate reading of grib files.
- MetProbe : This is a more general version of MetSonde controled by an input file that can handle more NWP data types.
- MR_ASCII_check : This tool takes two ESRI ASCII input files and compares them, returning an error if the files differ by more than a threshold value.
- MetTraj_F : This tool will generate foreward trajectories based on the time-series NWP data.
- MetTraj_B : This tool will generate backward trajectories based on the time-series NWP data.
- makegfsncml : This tool is used to strip out unused variable when converting grib to NetCDF using the download scripts.

To test the build, type:

```
make check
```

This will run four tests using the radiosonde data (found in `examples/UpperAirSoundings`), followed by four tests using the NCEP 50-year reanalysis data. The four tests for each wind data type are: `MetProbe`, `MetTraj_F`, `MetRegrid` (vertical slice) and `MetRegrid` (map view). Output data file are compared with saved datafiles in `tests/output[Sonde,NCEP][1-4]`. If `bc` and `awk` are installed on the system, the values in the output files are compared within a tolerance. Otherwise the files are compared using the unix `cmp` command, in which case small differences can be present in output files depending on if `OPT` or `DEBUG` was used when building the tools.

To install the library, module files and tools, edit the `INSTALLDIR` variable of the makefile (the default is `/opt/USGS`) and type:

```
make all
make check
sudo make install
```

This will also install scripts that can be used to download the 0.5° GFS forecast files and the NCEP 2.5° Reanalysis files.

You will need to have write permission in `INSTALLDIR` or install as root. Assuming the libraries `projection` and `hourssince` are installed in the default location, installation will result in the following directory structure:

```
/opt/USGS
|-- bin
|   |-- autorun_scripts
|   |   |-- autorun_gfs0.5deg.sh
|   |   |-- autorun_NCEP_50YearReanalysis.sh
|   |   |-- convert_gfs0.5deg.sh
|   |   |-- get_gfs0.5deg.sh
|   |   |-- get_NCEP_50YearReanalysis.sh
|   |   `-- grib2nc.sh
|   |-- gen_GRIB_index
|   |-- HoursSince1900
|   |-- MetCheck
|   |-- MetRegrid
|   |-- MetSonde
|   |-- MetTraj_B
|   |-- MetTraj_F
|   |-- MetProbe
|   |-- MR_ASCII_check
|   |-- project_for
|   |-- project_inv
|   `-- yyyymmddhh_since_1900
```

```
|-- include
|   |-- metreader.mod
|   `-- projection.mod
`-- lib
    |-- libhourssince.a
    |-- libMetReader.a
    `-- libprojection.a
```

The `makefile` included the following variables that can be changed, depending on your system.

- `SYSTEM` : `gfortran`, `ifort`, or `aocc`
  Fortran compiler.

- `RUN` : `DEBUG`, `PROF` or `OPT`
  Sets class of compiler flags for debugging, profiling, of optimization:

- `INSTALLDIR` : `/opt/USGS`
  Install location.

- `USENETCDF` : `T` or `F`
  Logical flag to build NetCDF interface.

- `USEGRIB` : `T` or `F`
  Logical flag to build GRIB2 interface.

- `USEPOINTERS` : `T` or `F`
  Logical flag to define public work arrays as pointer or allocatable space. There is no real proformance impact for either choice. Older `gfortran` compilers required allocatable arrays, but pointers facilitate access from `C` programs.

  Once installed, the download scripts will copy NWP data to the default location: `WINDROOT=/data/WindFiles`. If you would like to have data copied to another location, please ensure that the environment variable `WINDROOT` is set via your `.bash_profile` or `.bashrc` files.

3 Usage

MetReader can read a variety of input data formats (1-D, 3-D, ASCII, NetCDF, GRIB) and provide access to the meteorological data on either the native grid of the NWP data, or interpolated onto a finer regular grid. Before the meteorological data can be accessible, several preliminary steps must first be completed.

3.1 Preliminary meta-data

The calling program needs to prepare several parameters that define the type of meteorological data to be read.

- `MR_iwind` :: windfile class
  - 1 : 1-D wind sounding
  - 2 : 3-D grid is read from a ASCII file
  - 3 : single, multistep 3-D datafile
  - 4 : multiple 3-D datafiles
  - 5 : special case for products with one variable per file
    - NCEP 50-year reanalysis
    - JRA-55
    - NOAA-CIRES 20th Century Reanalysis
    - ERA-5
    - ERA 20th Century Reanalysis
- `MR_iwindformat` :: windfile format number (linked to specific product in Table 8.2 of Appendix 8.2)
- `MR_iGridCode` :: NCEP Grid ID
- `MR_idataFormat` :: Data file format code (ASCII, NetCDF, GRIB, etc)
  - 1 : ASCII
  - 2 : NetCDF
  - 3 : GRIB Edition 1 or 2
- `MR_iwindfiles` :: number of windfiles to be read
- `SimStartHour` :: The starting time needed given as hours since 1900-01-01 00:00Z
  This can alternatively be given as hours since a different base year as described below.
- `SimDuration` :: duration needed in hours

Additionally, there are several other parameters that could be set, if needed.

- MR_BaseYear :: The default value for this is 1900, but must be reassigned by the calling program if the NWP files to be read contain data prior to 1900.
- MR_useLeap :: The default is .true. but can be set to .false. if the NWP files use a calendar without leap years (e.g. some paleoclimate CAM files)
- MR_iHeightHandler :: This code defines how MetReader behaves when values at altitudes above those available in the NWP files are requested. Default value is 2.
  - 1 : Stop the program
  - 2 : Return wind values equal to the value at the highest available node; temperature values are filled by the U.S. Standard Atmosphere.
- MR_iwf_template :: This is the file name of the template for the custom NetCDF files described in section 5. This is only required to be set if MR_iwind=0. Currently, the custom windfile specification is only implemented for MR_idataFormat=2 (NetCDF).
- call MR_Reset_Memory :: If MetReader had been initialized and used for one set of NWP files, but later during the execution of the calling program, a subsequent set of NWP files is needed, this subroutine can be called to free all allocated memory.

Step 1: The space needed for storing the NWP file meta-data must be allocated.

```
call MR_Allocate_FullMetFileList(iw,iwf,igrid,idf,iwfiles)
```

This allocates the variable MR_windfiles(1:MR_iwindfiles).

Step 2: The calling program must now fill the list of file names MR_windfiles() with each name not exceeding 130 characters in length. For the special cases of one-variable files (MR_iwind=5), MetReader expects a specific structure to the directory holding the NWP files. For these reanalysis products, the list of files is only one string (MR_iwindfiles=1) with the 'file' given as the root directory to the NWP files. The following reanalysis products are implemented:

NCEP/NCAR Reanalysis 1: MR_iwindformat=25
http://www.esrl.noaa.gov/psd/thredds/fileServer/Datasets/ncep.reanalysis/pressure

```
MR_iwindfiles = 1
MR_windfiles(1) = '/data/WindFiles/NCEP'
```

Data are stored with each file containing a full year of values with a file structure as follows:

```
/data/WindFiles/NCEP
|-- 2016
|    |-- air.2016.nc
|    |-- hgt.2016.nc
|    |-- omega.2016.nc
```

```
|   |-- uwnd.2016.nc
|   `-- vwnd.2016.nc
|-- 2017
    |-- air.2017.nc
    |-- hgt.2017.nc
    |-- omega.2017.nc
    |-- uwnd.2017.nc
    `-- vwnd.2017.nc
```

JRA-55 reanalysis: `MR_iwindformat=26`
https://rda.ucar.edu/datasets/ds628.0
Data from this site is provided in GRIB1 format and must be converted to NetCDF with the NCAR Command Language (`ncl`) tool `ncl_convert2nc -L`.

```
MR_iwindfiles = 1
MR_windfiles(1) = '/data/WindFiles/JRA55'
```

Data are stored with each file containing one month of values with a file structure as follows:

```
/data/WindFiles/JRA55
|-- 2018
    |-- anl_p125.007_hgt.2018060100_2018063018.nc
    |-- anl_p125.011_tmp.2018060100_2018063018.nc
    |-- anl_p125.033_ugrd.2018060100_2018063018.nc
    |-- anl_p125.034_vgrd.2018060100_2018063018.nc
    `-- anl_p125.039_vvel.2018060100_2018063018.nc
```

NOAA-CIRES 20th Century Reanalysis: `MR_iwindformat=27`
https://rda.ucar.edu/datasets/ds131.3

```
MR_iwindfiles = 1
MR_windfiles(1) = '/data/WindFiles/NOAA'
```

Data are stored with each file containing full year of values with a file structure as follows:

```
/data/WindFiles/NOAA
|-- 2008
|   |-- anl_mean_2008_HGT_pres.nc
|   |-- anl_mean_2008_TMP_pres.nc
|   |-- anl_mean_2008_UGRD_pres.nc
|   |-- anl_mean_2008_VGRD_pres.nc
|   `-- anl_mean_2008_VVEL_pres.nc
|-- 2009
    | -- ...
```

Older versions of this product are available from https://rda.ucar.edu (e.g. ds131.2), but have a different name (pgrbanl_mean instead of anl_mean). These version 2 files are also only provided in GRIB format from this site and must be converted via ncl_convert2nc -L. If older versions are used, please set the variable MR_iversion to the correct version number. The default value of MR_iversion is the most recent version.

ECMWF ERA5 Reanalysis: MR_iwindformat=29
https://rda.ucar.edu/datasets/ds633.0

```
MR_iwindfiles = 1
MR_windfiles(1) = '/data/WindFiles/ERA5'
```

Data are stored with each file containing 24 hours of values with a file structure as follows:

```
/data/WindFiles/ERA5
|-- 2018
|   |-- e5.oper.an.pl.128_129_z.ll025sc.2018062000_2018062023.nc
|   |-- e5.oper.an.pl.128_130_t.ll025sc.2018062000_2018062023.nc
|   |-- e5.oper.an.pl.128_131_u.ll025uv.2018062000_2018062023.nc
|   |-- e5.oper.an.pl.128_132_v.ll025uv.2018062000_2018062023.nc
|   `-- e5.oper.an.pl.128_135_w.ll025sc.2018062000_2018062023.nc
|-- 2019
    | -- ...
```

Data from this site is provided in GRIB1 format and must be converted to NetCDF with the NCAR Command Language (ncl) tool ncl_convert2nc -L.

ECMWF ERA 20th Century Reanalysis: MR_iwindformat=30
https://rda.ucar.edu/datasets/ds626.0

```
MR_iwindfiles = 1
MR_windfiles(1) = '/data/WindFiles/ERA20C'
```

Data are stored with each file containing one month of values with a file structure as follows:

```
/data/WindFiles/ERA20C
|-- 1912
|   |-- e20c.oper.an.pl.3hr.128_129_z.regn80sc.1912060100_1912063021.nc
|   |-- e20c.oper.an.pl.3hr.128_130_t.regn80sc.1912060100_1912063021.nc
|   |-- e20c.oper.an.pl.3hr.128_131_u.regn80uv.1912060100_1912063021.nc
|   |-- e20c.oper.an.pl.3hr.128_132_v.regn80uv.1912060100_1912063021.nc
|   `-- e20c.oper.an.pl.3hr.128_135_w.regn80sc.1912060100_1912063021.nc
|-- 1913
    | -- ...
```

Data from this site is provided in GRIB1 format and must be converted to NetCDF with the NCAR Command Language (`ncl`) tool `ncl_convert2nc -L`.

Products generated by ECMWF are also available from https://cds.climate.copernicus.eu. When downloaded from this site, subsets of the data can be specified for the variables, pressure levels, time, and sub-region. Requests can be for data in either GRIB or NetCDF format. Data in NetCDF are stored as short integers with a scaling factor and offset, which allows for small files with a slight loss of precision. Alternatively, GRIB files can be downloaded, but must be converted to NetCDF to be read by MetReader, either by `ncl_convert2nc -L` or netcdf-java via the provided script `autorun_scripts/grib2nc.sh`. Data from this site are provided with all requested variables in the same file (`MR_iwind=`3 or 4) and do not require the specific filename structure outlined above. Since these NetCDF files can be from so many souce sites and/or conversion tools, MetReader assumes variable and dimension names, but checks against all known names if the default names are not present in the file. If MetReader is still unable to determine the variable and dimension names, you will need to convert the NetCDF files, renaming the variables, or use the custom NetCDF reader with a template file described in section 5 below.

Step 3: Once the names of the NWP files are specified, the files must be queried to determine the scope of the available data.

```
call MR_Read_Met_DimVars([iyear])
```

The `iyear` argument is optional, but is expected for `iwf`=25 or 27 since MetReader needs to know whether to allocate space for 365 or 366 days. Once the subroutine is called, each of the NWP files is checked for existence, then the following public variables are set:

- All the projection parameters for the NWP grid.
- `Met_dim_names()` :: The names of the dimensions in the file in the order of: time, pressure1, y, x, pressure2 (for Vz), pressure3 (for RH)
- `Met_var_names()` :: The names of the variables in the file according to the Table 8.1 of Appendix 8.1:
- `Met_var_conversion_factor()` :: For each of the variables, if the units are not as listed, then the corresponding factor is set that converts them to the expected units. For example, if precipitation rate is given in mm/hr, then the conversion factor to the expected units (kg/m^{2}s) is 1/3600 or 2.778×10^{-4}.
- `Met_var_IsAvailable()` :: set to `.true.` if the NWP file provides this variable.
- `nx_fullmet,ny_fullmet,np_fullmet` :: lengths of grid for x (lon), y (lat) and p
- `x_fullmet_sp,y_fullmet_sp,p_fullmet_sp` :: values of the grid in km (degrees) and hPa
- `IsLatLon_MetGrid` :: `.true.` if the grid is specified in longitude and latitude

- `IsGlobal_MetGrid` :: `.true.` if the grid is periodic in longitude. (Note: mapping across the poles is not yet implemented).
- `IsRegular_MetGrid` :: `.true.` if dx, dy $(dlon, dlat)$ is constant

Step 4: Next, the calling program needs to define the type of grid onto which MetReader will interpolate values. Namely, whether or not the computational grid is projected, and if so, which projection and associated values. This grid used by the calling program can be independent of the grid used by the NWP files. The parameters in the list for the subroutine below are the values needed by the `libprojection.a` library. Below is an example call from Ash3d.

```
call MR_Set_CompProjection(IsLatLon,A3d_iprojflag,A3d_lam0,            &
                                    A3d_phi0,A3d_phi1,A3d_phi2,        &
                                    A3d_k0_scale,A3d_radius_earth)
```

If `IsLatLon=.true.` then all other projection parameters are ignored. Similarly, some of the parameters are required and others not, depending on the projection used. Currently, `libprojection.a` has implemented: non-geographic (`iprojflag=0`), Polar stereographic (`iprojflag=1`), Albers Equal Area (`iprojflag=2`), UTM (`iprojflag=3`), Lambert conformal conic (`iprojflag=4`), and Mercator (`iprojflag=5`).

Step 5: The final preparatory step is to evaluate the windfiles provided with the spatial and temporal requirements of the calling program.

```
call MR_Initialize_Met_Grids(nxmax,nymax,nzmax,                &
                             x(1:nxmax),y(1:nymax),z(1:nzmax), &
                             IsPeriodic)
```

`nxmax,nymax,nzmax` are the sizes of the computational grid. `x,y,z` are the single-precision grid values in km (or degrees). `IsPeriodic` indicates whether or not the computational grid is periodic in x. This subroutine also determines the size of the sub-grid of the full NWP data that is needed by the calling program.

```
call MR_Set_Met_Times(SimStartHour, SimDuration)
```

Here `SimStartHour` and `SimDuration` give the initial time (in hours since 1900 (or other base year)) and the length of time needed in hours. This subroutine opens all the files listed in `MR_windfiles()` and verifies that the files provided cover the requested time span. Then a list is prepared of all the time steps and files needed to fully cover the requested time with the step index (`istep=1`) corresponding to the step at or just prior to `SimStartHour`. The hours between time steps is saved in `MR_MetStep_Interval()` and does not need to be constant.

3.2 Reading meteorological data

When handling data from the NWP files, there are four grids that MetReader uses:

- `metP` :: the native grid of the NWP file clipped to span the computational needs (possible re-ordered)
- `metH` :: the horizontal grid of the NWP file, but with the vertical coordinate mapped from the pressure grid of the NWP file to the altitude grid of the computational grid.
- `compP` :: the horizontal grid of the computational grid on the pressure nodes of the NWP grid.
- `compH` :: the full x,y,z of the computational grid.

For all of these grids, the x (or longitude) and y (or latitude) coordinates are from lowest to highest. Some NWP files store the longitude coordinate from north to south, but for `metP`, `metH`, `compP` and `compH`, longitude will be reordered from south to north. Similarly, some NWP products store the vertical coordinate, `p`, from lowest to highest. The MetReader grids all use a vertical coordinate (either `p` or `H`) from the ground surface to altitude. Once the computational grid is specified and the sub-grid of the NWP is determined in step 5 above, the following public work spaces are allocated.

```
MR_dum2d_met_int(nx_submet,ny_submet)           :: integer
MR_dum2d_met(nx_submet,ny_submet)               :: float
MR_dum3d_metP(nx_submet,ny_submet,np_fullmet)   :: float
MR_dum3d2_metP(nx_submet,ny_submet,np_fullmet)  :: float
MR_dum3d_metH(nx_submet,ny_submet,nz_comp)      :: float
MR_dum2d_comp_int(nx_comp,ny_comp)              :: integer
MR_dum2d_comp(nx_comp,ny_comp)                  :: float
MR_dum3d_compP(nx_comp,ny_comp,np_fullmet)      :: float
MR_dum3d_compH(nx_comp,ny_comp,nz_comp)         :: float
```

`nx_comp`, `ny_comp`, `np_comp` are the number of nodes in the computational grid and `nx_submet`, `ny_submet`, `np_submet` are the number of nodes of the NWP grid that is needed to span the required computational grid.

To read data from the meteorological files, the fundamental subroutine is

```
call MR_Read_3d_MetP_Variable(ivar,istep)
```

where `ivar` is the code for the variable of interests (see Table 8.1) and `istep` is the index of the sequence of time steps set up based on `SimStartHour` and `SimDuration` in Step 5 above. This subroutine provides a common interface regardless of the data format (ASCII, NetCDF, GRIB, etc.), data structure (latitude might be top-to-bottom or bottom-to-top, pressure might be surface-to-top or top-down, grid might be staggered, longitude might be $-180 \rightarrow 180$ or $0 \rightarrow 360$). In all cases for 3-D variables, what is returned is the public work array `MR_dum3d_metP`. This array is consistently ordered such that `x` and `y` (or `lon` and `lat`) increase with index (North to South NWP grids are flipped) and with `p` ordered from the surface to top (pressure is high to low).

If 3-D data is needed on the `metH` grid,

```
call MR_Read_3d_MetH_Variable(ivar,istep)
```

can be used which first populates MR_dum3d_metP, then interpolates onto MR_dum3d_metH.

For simply reading meteorological data onto the computational grid, use

```
call MR_Read_3d_Met_Variable_to_CompH(ivar,istep,[IsNext])
```

This subroutine reads the variable ivar from the NWP file into MR_dum3d_metP, then interpolates these values onto MR_dum3d_metH, finally interpolating onto MR_dum3d_compH. The optional argument IsNext is used when velocities are used at different points in the program and need to be saved. IsNext indicates that the velocity values MR_v[x,y]_metP_next should be copied to MR_v[x,y]_metP_last.

To interpolate 3-D data onto the altitude levels of the computational grid, first the geopotential height data must be read. This could be achieved by the subroutine MR_Read_3d_MetP_Variable described above, but as a simulation advances, we typically need to have the geopotential height data for the previous and the next time steps so that values can be interpolated between steps. The subroutine

```
call MR_Read_HGT_arrays(istep,[reset_first_time])
```

is a specialized reader for ivar=1. The first time this is called, both istep and istep+1 are called, populating the two public variables MR_geoH_metP_last and MR_geoH_metP_next. Subsequent calls copy MR_geoH_metP_next to MR_geoH_metP_last and reads the next values from istep+1. If the optional argument reset_first_time is given, both istep and istep+1 are directly read.

Similar read subroutines are available for 2-D variables.

```
call MR_Read_2d_Met_Variable(ivar,istep)
```

Given a 2-D variable identified with ivar, this populates the public work array MR_dum2d_met, where again, 1:nx_submet,1:ny_submet corresponds to the subset of nodes of the NWP file that is needed to span the computational grid.

```
call MR_Read_2d_Met_Variable_to_CompGrid(ivar,istep)
```

can be called similar to MR_Read_2d_Met_Variable which directly reads the variable needed and returns the values interpolated onto the public work space MR_dum2d_comp.

3.2.1 Regridding meteorological data

Internal to MetReader are a variety of regridding subroutines to interpolate from the metP grid onto metH, compP or compH. In some circumstances, data are initially needed just on the native NWP grid, but then derived values might be required on the full computational grid. For example, if air viscosity is needed for a particle fall model, temperature and pressure values on the NWP grid can be read. Then viscosities can be calculated for each of the corresponding nodes of the NWP grid. To interpolate these values from the metP grid to the compH grid, the subroutine

```
call MR_Regrid_MetP_to_CompH(istep)
```

can be used. This takes the variable MR_dum3d_metP and interpolates it onto MR_dum3d_compH. Similarly,

```
call MR_Regrid_MetP_to_MetH(istep)
```

interpolates MR_dum3d_metP to MR_dum3d_metH and

```
call MR_Regrid_Met2d_to_Comp2d
```

interpolates MR_dum2d_met to MR_dum2d_comp.

3.2.2 Wind velocity vectors

In some cases, the wind velocity vectors need to be mapped from the coordinate system of the NWP files to the computational grid. Velocity components on the computational grid are always provided as grid-relative. For some NWP files, such as the North American Regional Reanalysis (NARR), the NWP grid is projected, yet the wind components are provided as Earth-relative. In other cases, if the NWP data are provided on a projected grid, but the computational grid is either lon/lat or on a different projection, the grid-relative, projected velocity components must be converted to that needed for the computational grid.

If the wind data are provided as grid-relative on a projected grid and something else is needed, the subroutine

```
call MR_Rotate_UV_GR2ER_Met(MR_iMetStep_Now)
```

will read both U and V components and decompose the vector into earth-relative Easterly and Northerly wind components with values at the metP grid nodes. These components are put in the variables MR_u_ER_metP and MR_v_ER_metP. Once we have Earth-relative velocity components (either from direct read of lon/lat data, from the subroutine MR_Rotate_UV_GR2ER_Met or from direct read of NARR data), if the computational grid is not Earth-relative, then these Earth-relative components can be subsequently decomposed into grid-relative components on the computational grid with

```
call MR_Rotate_UV_ER2GR_Comp(MR_iMetStep_Now)
```

This subroutine returns the U and V components on the compH grid through the two dummy work space variables MR_dum3d_compH and MR_dum3d_compH_2

3.3 Additional Functions

Horizontal derivatives MetReader has subroutines for calculating horizontal derivatives of variables on the metP grid. This is used for calculating velocity gradients for diffusivity calculations, but could be applied to any variable. The two subroutines are MR_DelMetP_Dx and MR_DelMetP_Dy. Both read the values from MR_dum3d_metP and return derivative values on MR_dum3d2_metP.

U.S. Standard Atmosphere MetReader also has several functions for calculating values from the U.S. Standard Atmosphere.

- `MR_Temp_US_StdAtm(zin)` :: Returns a temperature in K given a height in km.
- `MR_Z_US_StdAtm(pin)` :: Returns a height in km given a pressure in hPa.
- `MR_Pres_US_StdAtm(zin)` :: Returns a pressure in hPa given a height in km.

4 Supported types of meteorological data

MetReader can read meteorological data in a variety of different formats, including a simple ASCII profile of wind velocity with height, Radiosonde data (in various formats), numerous forecast numerical weather prediction and reanalysis products, as well as output files from common NWP and atmospheric specification programs (WRF, CAM, AVO-G2S).

4.1 1-D ASCII data

The simplest format for meteorological data is just a 1-D wind profile in ASCII format. To read this type, set `MR_iwind = 1`. The particular format of the 1-D data can be specified by the `MR_iwindformat`, where 1 indicates a user-specified column of values and 2 indicates that the files are from the global radiosonde data available from https://ruc.noaa.gov/raobs or from http://weather.uwyo.edu. In both these cases, there is no NCEP grid ID associated with the sonde points so `MR_iGridCode` is interpreted as the number of profile points. Each point at each time must have its own file containing the profile data. `MR_idataFormat` is not needed (ASCII is assumed from `MR_iwind = 1`). Profiles at multiple times can be included by repeating the sequence of profile locations at the later times. All points must have profiles for all times and files for subsequent time steps must be given in the same order. Also, all profile files must be in the same format (projection, columns of data). For example:

```
MR_iwind       = 1
MR_iwindformat = 2
MR_iGridCode   = 3
MR_iwindfiles  = 6    # This must be an even multiple of MR_iGridCode
PADQ_2018060100.dat   # 00Z radiosonde at Kodiak, AK
PAKN_2018060100.dat   # 00Z radiosonde at King Salmon, AK
PANC_2018060100.dat   # 00Z radiosonde at Anchorage, AK
PADQ_2018060112.dat   # 12Z radiosonde at Kodiak, AK
PAKN_2018060112.dat   # 12Z radiosonde at King Salmon, AK
PANC_2018060112.dat   # 12Z radiosonde at Anchorage,
```

4.1.1 User-specified profiles

User-specified profiles describe minimally, the horizontal velocity as a function of height at a point (or points) in the domain. Beyond this constraint, the format is fairly general. The format is as follows.

```
L01 string header line
L02 time(hr) nlev [ncol] [ivar(ncol)]
L03 x/lon y/lat [LLflag] [projection parameters]
L04 data
     :
Ln  EOF
```

Line 1 is a header line that is ignored

Line 2 contains at least the time of the profiles and the number of lines of data to read. Optionally, the number of columns of data can be specified followed by a sequence of integers specifying the variable ID's (see Table 8.1) for the corresponding columns. If neither of these optional arguments `ncol ivar(ncol)` are given, then MetReader tests for the number of columns present. If there are 3, then the data are read in as altitude (in m), wind speed (in m/s), and wind direction (in degrees E of N, with the convention of where the wind is coming from). If 5 columns are present, the fourth and fifth columns correspond to pressure (in hPa) and temperature (in °C), respectively. If the optional parameters on line 2 are given with the number of columns of data and corresponding variables, then the variables can be read in any order, but must include some measure of height and some measure of the wind vector. Height can include either altitude (in m), or pressure (in hPa), or both. If only one of these two is given, the other is filled according the the U.S. Standard Atmosphere. The measure of the wind vector can be given either in U and V, or speed and direction. If temperature is not provided, it is calculated from the pressure or altitude using the U.S. Standard atmosphere.

Line 3 contains the coordinate of the 1-D profile. If two values are given, the coordinate system is assumed to be that of the computational grid (either in projected or lon/lat grids). If more that two parameters are given, then the parameters beyond 2 are interpreted to be the list of parameters required by `libprojection.a`. If the `LLflag` is given as a third parameter with a value of 1, then the coordinate is interpreted to be in longitude and latitude. If the value is 0, then the coordinate system is projected with specification defined by subsequent values on line 3.

Line 4 contains the start of `nlev` rows of data

Here is an example of the 3-column format where the columns correspond to altitude (m), wind speed (m/s) and wind direction (E of N).

```
Hanford
2    5                               # wind time, number of levels
-120.0   46.20                       # Longitude, latitude
0        10.000   90.00              # altitude, wind speed, wind direction
5000     10.000   90.00
10000    10.000   90.00
15000    10.000   90.00
20000    10.000   90.00
```

Below is an example of a user-specified number of columns with data on a projected grid. In this case, there are 5 variables: altitude (m), U (m/s), V (m/s), pressure (hPa), and temperature (C).

```
Hanford
0    5   5  1 2 3 0 5  #wind time, number of levels, nvar ivars(1:nvar)
```

```
-2062.26 2606.69 0 4 265.0 25.0 25.0 25.0 6371.229 # (-120.0   46.20) in LCC grid 212 coords
0       -10.000   0.00 1000.0  10.0    # Z, U, V, p, T
5000    -10.000   0.00  560.0 -5.5
10000   -10.000   0.00  262.0 -47.3
15000   -10.000   0.00  126.0 -58.1
20000   -10.000   0.00   58.0 -54.9
```

4.1.2 1-D radiosonde profiles (single or multiple times)

Instead of user-specified profiles, MetReader can also read radiosonde data. Both the global archive as well as the 00Z and 12Z radiosonde data are available from the NOAA Earth System Research Laboratory Rapid Update Cycle Radiosonde Database (https://ruc.noaa.gov/raobs). These data are also archived at the University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html). To use data in this format, set `MR_iwind = 1` and `MR_iwindformat = 2`. From both these sites, radiosonde data are available in a variety of formats. The default format for the University of Wyoming site is "Text: List"

```
72694 SLE Salem Observations at 00Z 20 Jun 2018

-----------------------------------------------------------------------------
   PRES   HGHT   TEMP   DWPT   RELH   MIXR   DRCT   SKNT   THTA   THTE   THTV
    hPa     m      C      C      %    g/kg    deg   knot     K      K      K
-----------------------------------------------------------------------------
 1007.0     61   30.6    8.6     25   7.01    345      7  303.1  324.5  304.4
 1002.0    110   29.4    9.4     29   7.44    349      8  302.4  324.9  303.7
 1000.0    129   29.2    9.2     29   7.35    350      8  302.4  324.6  303.7
  980.2    305   27.5    8.5     30   7.17    355      9  302.4  324.1  303.7
  946.7    610   24.6    7.4     33   6.85      0      7  302.4  323.2  303.7
  925.0    814   22.6    6.6     36   6.65    350      6  302.4  322.6  303.6
  914.4    914   21.7    5.7     35   6.33    345      7  302.5  321.8  303.7
  908.0    975   21.2    5.2     35   6.14    352      7  302.6  321.3  303.7
    :
    :
    :
   13.3  29602  -39.7  -76.7      1   0.08     66     18  802.1  803.1  802.2
   11.7  30480  -39.0  -76.4      1   0.10     90     30  834.6  835.8  834.6
   10.2  31394  -38.2  -76.2      1   0.12     80     19  869.7  871.2  869.8
   10.0  31557  -38.1  -76.1      1   0.12                876.2  877.8  876.2

Station information and sounding indices

                         Station identifier: SLE
                             Station number: 72694
                           Observation time: 180620/0000
                           Station latitude: 44.91
                          Station longitude: -123.00
                          Station elevation: 61.0
                            Showalter index: 6.44
    :
```

```
:
:
```

This file contains many pressure levels, but the radiosonde standard include a limited set of "required" pressure levels (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, and 100 mbar; and supplementally 70, 50, 30, 20, 10 if the probe reaches those heights.). When MetReader reads a file of this format, only these mandatory pressure levels are read. Only the pressure, height, temperature, wind direction and wind speed are read. After the columnar data are read, the `Station number` is read. From this number (72694 in the above example), the station longitude, latitude and elevation are automatically populated from internally stored station metadata available from https://ruc.noaa.gov/raobs/General_Information.html. The station list is truncated to just what is currently operational and to just current coordinates (some stations have been moved or deactivated). Next the `Observation time` is read.

An alternative format is the FAA604 WMO/GTS format from https://ruc.noaa.gov/raobs or the nearly identical "Text:Raw" format from the University of Wyoming.

```
 TTAA 70001 72694 99007 30672 34507 00129 29270 35008 92814 22666 35006 85542
17466 03511 70163 04859 09008 50582 10178 20015 40750 22974 23023 30953 39945
24033 25075 49164 24541 20220 52974 25050 15405 55180 26035 10660 60376 23011
88188 54573 25052 77999 31313 58208 82346 51515 10164 00006 10194 00508 09506
 TTBB 70008 72694 00007 30672 11002 29470 22908 21266 33890 20469 44814 15067
55762 10261 66693 04259 77655 00456 88615 02757 99592 05350 11580 05756 22573
05764 33566 06368 44551 07765 55547 07762 66536 08563 77526 08166 88518 08766
99509 09378 11494 10782 22468 14374 33440 16981 44381 25773 55346 31962 66330
34346 77323 35738 88302 39743 99278 44357 11261 47757 22245 49568 33240 49977
44231 49578 55220 51375 66194 53373 77188 54573 88175 54774 99172 53376 11170
52777 22160 54379 33153 54180 44143 56979 55134 56379 66129 57578 77120 57778
88110 60177 99106 59977 11104 60976 22102 59977 31313 58208 82346 41414 12761
 PPBB 70008 72694 90012 34507 35509 36007 90346 34507 02009 03008 90789 07002
16003 12508 91246 12505 12011 20008 9179/ 19506 19015 92025 21516 23018 23523
93046 23537 24524 25049 940// 25053 950// 26022
 TTCC 70002 72694 70883 60377 11004 50095 57778 11020 30421 52181 07020 20686
45783 08022 88999 77999 31313 58208 82346
```

This format contains nearly the same information as the previous example, but requires a bit of translation. Appendix F of the Federal Meteorological Handbook No. 3 (https://www.icams-portal.gov/resources/ofcm/fmh/FMH3/00-entire-FMH3.pdf) gives the full specification. If the string "TTAA" is found in the ASCII file, this format is attempted first, otherwise the "Text:List" is assumed. This WMO/GTS format is intended for the Rapid Update Cycle data and does not contain the year or month (only the day-of-month and hour) of the data. If this format is detected, the year and month of `SimStartHour` is assumed unless otherwise specified by the calling program.

4.2 Network of 1-D radiosonde profiles

In most of the world, the radiosonde launch sites are too disperse to form a meaningful network across which we can interpolate values. The radiosonde data is most useful for the regions of interest proximal to launch sites. If multiple radiosonde locations are in the computational domain, then data are interpolated onto the computational grid using an inverse distance algorithm. The value at a point j in the computational grid is calculated by a weighted average of all ($i = 1 \rightarrow n_s$) the sonde locations:

$$V_j = \sum_{i=1}^{n_s} v_i w_{ij}$$

where v_i are the values at sonde location i and the normalized weights of sonde i with respect to grid node j (w_{ij}) are calculated via

$$w_{ij} = \frac{d_{ij}^{-p}}{\sum_{i=1}^{n_s} d_{ij}^{-p}}$$

where d_{ij} is the distance between sonde i and interpolation point j and where p controls the decay in the radius of influence (default is $p = 4$). Currently, only the closest 4 stations are considered in the interpolation, but this (and the decay exponent) can be adjusted via the variables `MR_nstat` and `MR_pexp`. Setting `MR_nstat` to 1, for example, implements the nearest neighbor algorithm.

4.3 3-D forecast or reanalysis data

MetReader's preferred format for 3-D forecast and reanalysis files is NetCDF. Many products are available directly in NetCDF. format such as NCEP/NCAR Reanalysis 1 or NASA GEOS-5. These products generally require NetCDF version 4. Most of the NCEP forecast products are provided in GRIB format. To convert these forecast products to NetCDF format, MetReader relies on the NetCDF java package (https://www.unidata.ucar.edu/software/netcdf-java). The conversion script in the `autorun_scripts` folder are linked to `netcdfAll-5.4` however any recent version should work. Older versions create NetCDF files with different variable names. GRIB files can also be converted to NetCDF using the NCAR Command Language tools (`ncl`), available from https://www.ncl.ucar.edu. The command `ncl_convert2nc -L` will convert GRIB to NetCDF, but will produce files with different variable and dimension names, which may be incompatable.

Many of the forecast and reanalysis products are built in to MetReader where the grid geometry, variable list, and pressure levels are preset. These include all the `MR_iwindformat` numbers listed in section 3.1. If the products change such that the pressure levels differ or if variable names change, then the source code will need to be modified to account for the changes. Alternatively, a template file could be used as described in section 5 below.

MetReader can also read GRIB files directly for certain forecast products, including the NAM 196 grid over HI (`MR_iwindformat=11`), the NAM 91 grid over AK (`MR_iwindformat=13`) and the GFS 0.25° and 0.5° products (`MR_iwindformat=20,21,22`). To read these GRIB files, an index file containing the locations of all the records must be created. This index file can be created by the utility `gen_GRIB_index`, or if the file does not exist at run-time, can be generated through the subroutine call `MR_Set_Gen_Index_GRIB(filename)`. In practice, if windfiles will be used more than a few times, it is generally worthwhile to convert them to NetCDF prior to usage by MetReader. The current implementation of the GRIB reader will read each of the required GRIB records into memory, decompress the full gridded data, then extract the needed sub-grid; whereas the NetCDF interface allows a more natural direct access to sub-grids. For high resolution, global grids where only a small sub-grid is needed, the impact of reading and uncompressing full grids will be noticeable.

5 Custom meteorological file specification

As an alternative to using a particular forecast or reanalysis product with hard-coded file structure, a template file can be used the allows a custom specification of a NetCDF file. The custom template is indicated by `MR_iwindformat=0` and setting `MR_iwf_template` to the name of the template file. The template file has the following format.

Line 1: The line of projection parameters as expected by `libprojection.a`. e.g.

Polar-stereographic	Grid 91	`0 1 -150.0 90.0 0.933 6371.229`
Polar-stereographic	Grid 216	`0 1 -135.0 90.0 0.933 6371.229`
Mercator	Grid 196	`0 5 198.475 20.0 0.933 6371.229`
Lambert Conformal	Grid 212	`0 4 265.0 25.0 25.0 25.0 6371.229`
Lambert Conformal	Grid 221	`0 4 -107.0 50.0 50.0 50.0 6371.229`

Line 2: `StepInterval   [T/F]` :: time interval in hours, and flag indicating whether or not to use leap years (Assumed `T` if not provided)

Line 3: `ndims nvars` :: number of dimensions and variable that will be listed

Line 4+: list of dimensions where each row specifies the information about the dimension. Dimension lines are read using the format `(a1,i9,f9.2,a30)` so care must be taken to ensure that each term is in the correct position and with spaces in-between (no tabs). For example:

```
d      1  1.6667e-2 time                                 hours since
d      2      100.0 lev                                  Pa
```

In this example, the `d` signifies that the row describes a dimension, `1` is the dimension number, `1.6667e-2` is a scaling factor, and `time` is the name of the dimension. The dimensions should be listed in the following order: time, pressure used for primary state variables (geopotential height, velocity, temperature), y (or longitude), x (or latitude), pressure used for vertical velocities, and pressure used for moisture variables. Additional dimensions can be listed to support other specific variables. The scaling factor is the factor needed to convert the dimension from the units provided to the units required. In this example, the time values are supplied in minutes, and must be multiplied by `1.6667e-2` to be in the expected units of hours. Similarly, pressure is supplied in hPa but is expected in Pa.

Line 4+`ndims`- : list of variables where each row specifies the information about the variable. As in the formatted read of the dimension information, the variables are read using the format `(a1,i3,i3,i3,f9.2,a7,a71)`.

```
v 4  2 1        1.0    HGT   H
v 4  2 2        1.0   UGRD   U
v 4  2 3        1.0   VGRD   V
v 4  5 4        1.0   VVEL   OMEGA
v 4  2 5        1.0    TMP   T
```

```
v 4   6 30        1.0      RH   RH
v 4   6 31        1.0    SPFH   SH
```

In this example, the first character, `v`, signifies that the row describes a variable. The next integer is the dimensionality of the variable (`3` or `4`). It is assumed that the variable is a function of x, y, and t, but if also a function of pressure, the vertical dimension needs to be specified. The next integer indicated which of the vertical dimensions listed earlier in the file are used for this variable. The fourth item on the line (third integer) is the variable ID according to Table 8.1. Next is the scaling factor to convert the provided values to the units expected for the variable. The next two fields are the WMO variable name and the variable name given in the NetCDF file.

There are several limitations of the template for the custom NWP reader. Firstly, only the NetCDF reader is currently implemented. Secondly, currently all variables are assumed to be transient; so land-use or topography cannot be read with this scheme. Variables that cannot be simply scaled to the expected units cannot be described in this template. For example, WRF files (`MR_iwindformat=50`) uses a staggered grid with pressure and geopotential given both as a base value plus a perturbation. Lastly, to determine the start time of the data, a reference time must be read. First the time variable is checked for the `GRIB_orgReferenceTime` attribute. If this is not found, then the variable `reftime` is checked, if it exists.

Several examples of these template files used with NAM and GFS forecast products are shown in Appendix 8.3 and given in the `doc` folder of this repository.

6 Additional tools/Examples

In the `tools` folder, several programs are included the illustrate the use of the library.

6.1 `MetCheck`

This utility is used for checking the validity of the NWP files. In some cases, the downloading of files might be interrupted or the files on the NCEP server might be incomplete or corrupt. This utility opens each of the files and reads the full grid for the variables: geopotential height, Vx, Vy, Vz, and temperature. If any values are outside of expected ranges, then the program stops returning a non-zero stop-code (`stop 1`). Usage:

```
MetCheck MR_iwindformat MR_idataFormat filename [year]
```

This utility will write a log file, `MetCheck_log.txt` containing four columns: filename, step in file, year, day of year.

6.2 `MetRegrid`

This is a stand-alone program that uses the MetReader interface to calculate regridded atmospheric data. A control file is provided which defines the computational grid specifications, output time, output variable, output grid (could be `compH`, `compP`, `metH`, or `metP`), and the output dimension. The output dimension could be 0 for point data, 1 for line data, 2 for slices of the computational grid, or 3 for volume data. An example control file (`Regrid_NCEP.ctr`) for the NCEP 50-year Reanalysis is given in the `examples` directory.

```
1 1 -135.0 90.0 0.933 6371.229  ! Proj flags and params of computational grid
-125.0  38.0   0.0               ! x,y,z of bottom LL corner of grid (km, or deg. if latlongflag=1)
15.0    15.0  25.0               ! grid x-width, y-width, depth (km, or deg. if latlonflag=1)
0.1     0.1    0.5               ! DX, DY, Dz of grid cells  (km, or deg.)
1                                ! iHeightHandler
1980 5 18 15.5                   ! YYYY MM DD HH.H
1                                ! Output grid (1,2,3,4 for compH,compP,metH,metP)
5                                ! Output Var (1=H,2=Vx,3=Vy,4=Vz,5=T)
2 1                              ! Output Dimension (0,1,2,or 3), ASCII type: 0=full dump, 1=ESRI
0 0 15                           ! i,j,k of output grid with zeros for unused dims.
5 25 2 2                         ! MR_iwind MR_iwindformat MR_iGridCode MR_idataFormat
1                                ! MR_iwindfiles: number of windfiles
NCEP
```

Line 1 specifies the projection of the computational grid, in this case, the `LatLonFlag=1` indicating a latitude-longitude grid (subsequent parameters on this first line are ignored). Line 2 give the x, y, z coordinate of the bottom lower-left corner of the compuataional grid. Line 3 gives the total width in the three coordinate directions. Line 4 gives the grid spacing in each dimension. For lines 2-4, the x and y (or lat and lon) are given in either km or degrees, whereas all z values are in km. If a pressure-based grid is requested (`compP` or `metP`), the pressure levels of the NWP file are used and the z specifications are ignored. Line 5 is the iHeightHandler flag which determines if the program should stop if the computational grid requires data above that provided by the NWP file (`iHeightHandler=2`) or if those nodes should be populated using the top-most data of the NWP file (`iHeightHandler=1`). Line 6 specifies the year, month, day and hour of the output. Line 7 contains an integer flag specifing the output grid type (`compH`, `compP`, `metH`, `metP`). Line 8 contains the integer specifying the variable to regrid and export (see Table 8.1). Line 9 specifies the output dimension (0, 1, 2, or 3) and optionally a flag to indicate ASCII should be in ESRI format. This only applies to 2-d mapview regridding. Line 10 contains 3 integers specifying the nodes used in the output. 0 should be given for indexes of unused dimensions. In the example above, the output dimension is 2 indicating a slice of the grid will be exported. We need to specify only one index to indicate the location of the cutting plane. The $i = 0$ and $j = 0$ indicate that the plane is an $x - y$ sheet at $k = 15$. This is interpreted as either the 15th node along the height axis of the computational grid or the 15th pressure node of the NWP pressure coordinate, depending on the requested grid from line 8. Line 11 specifies the windfile format (`MR_iwind MR_iwindformat MR_iGridCode MR_idataFormat`). Line 12 gives the number of windfiles to be read. Line 13 → `EOF` are the names of the windfiles to be read.

An example control file for a network of radiosonde data is also given in `examples/Regrid_Sonde.ctr`. In this case lines 11, 12, and the file listing are given as follows:

```
1 2 6 1                          ! MR_iwind MR_iwindformat MR_iGridCode MR_idataFormat
48                               ! MR_iwindfiles: number of windfiles
UpperAirSoundings/BOI_1980051700_raw.dat
UpperAirSoundings/GGW_1980051700_raw.dat
UpperAirSoundings/GJT_1980051700_raw.dat
UpperAirSoundings/MFR_1980051700_raw.dat
UpperAirSoundings/SLC_1980051700_raw.dat
UpperAirSoundings/SLE_1980051700_raw.dat
UpperAirSoundings/BOI_1980051712_raw.dat
```

```
UpperAirSoundings/GGW_1980051712_raw.dat
UpperAirSoundings/GJT_1980051712_raw.dat
UpperAirSoundings/MFR_1980051712_raw.dat
UpperAirSoundings/SLC_1980051712_raw.dat
UpperAirSoundings/SLE_1980051712_raw.dat
.....
```

The `MR_iGridCode=6` indicates that there are 6 sonde locations provided. Each set of 6 must be repeated in the same order for the subsequent 12-hour times. Plots of V_x for both these control files using the same computational grid are shown below.

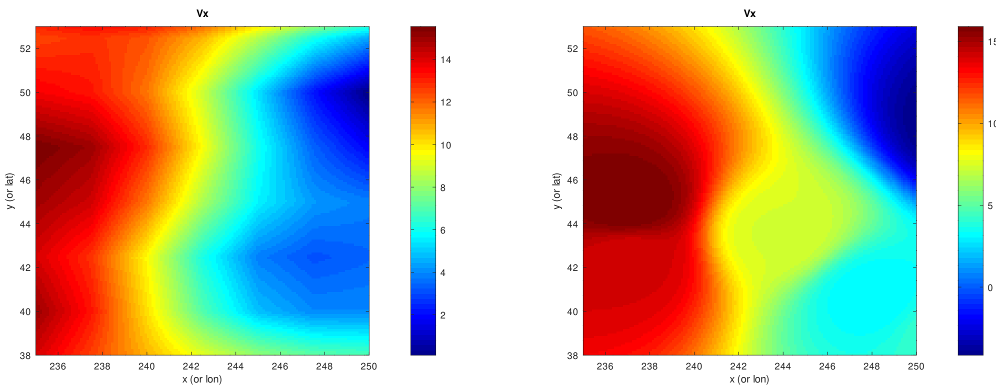

Figure 1: Example regridded output of V_x of the NCEP reanalysis (`MR_iwindformat=25`) and 6-point radiosonde data (left and right, respectively) using `RegridMet` with control files from the `examples` folder.

6.3 `MetSonde`

This utility is used for probing the either GFS or NCEP 50-uear reanalysis files and returning the temperature as a function of height. Usage:

`MetSonde lon lat YYYY MM DD HH [WIND_ROOT]`

The program assumes that the GFS and NCEP files are placed in the default directory, or at least in default subdirectories off of `WIND_ROOT`. Values are interpolated onto the requested point and time and are written to a file (`GFS_prof.dat`) in the current working directory. This 3-column file contains the height (in km), pressure (in Pa) and temperature (in °C).

6.4 `MetProbe`

This program is a more general version of `MetSonde`, requiring 15 or more command-line arguments. The command-line arguments are as follows.

filename	string	name of input file
timestep	integer	time step in file
llflag	integer	0 for using windfile grid; 1 for forcing Lat/Lon
lon/x	real	longitude (or x) of sonde point
lat/y	real	latitude (or y) of sonde point
trunc flag	character	truncation flag (T or F)
nvars	integer	number of pressure variables to export
varID(nvars)	integers	variable ID's to read and export (Tab 8.1)
MR_iwind	integer	windfile class code (3,4,5)
MR_iwindformat	integer	windfile product code
MR_idataFormat	integer	1 for ASCII, 2 for nc, 3 for grib
year	integer	only needed for MR_iwind = 5 files
month	integer	only needed for MR_iwind = 5 files
day	integer	only needed for MR_iwind = 5 files
hour	real	only needed for MR_iwind = 5 files

For example, the following command will probe a GFS file and write out GPH, U, V, and T.

```
MetProbe 2020061000_5.f006.nc 1 0 190.055 52.8222 T 4 1 2 3 5 4 20 2
```

This will write output data to the file `NWP_prof.dat`. If the truncation flag is set to `T`, then data are not interpolated onto the requested point, but instead the data corresponding to the node of the NWP grid on the lower-left of the cell containing the point will be writen to the output file.

6.5 `MetTraj`

This utility takes a similar argument list as `MetSonde`, but instead of probing a single point and time, this utility calculates trajectories within the NWP files. This utility must be compiled with either a `-DFORWARD` or `-DBACKWARD` preprocessor flag to generate separate executables for forward or backward trajectories. This utility can be run with a limited set of command-line arguments if GFS or NCEP reanalysis data are to be used, or using a control file which can be used to specify a more exhaustive set of options.

For the command-line options, `MetTraj_[F,B]` requires at least the longitude, latitude, year, month, day and hour. Optionally, the simulation time (in hours) can be provided (default is 24). Additionally, the trajectory levels can be provided, first with the number of levels, followed by the level altitudes in km. To specify 6 hours integrations at 3 levels (5, 10, and 15 km), use:

```
MetTraj_[F,B] -169.9468 52.8217 2022 8 29 5.5 6.0 3 5.0 10.0 15.0
```

If levels are not provided, then 6 levels are assumed at heights of 1.52, 3.05, 6.10, 9.14, 12.19, 15.24 km; corresponding to 5000, 10000, 20000, 30000, 40000, and 50000 ft.

The location of the windfiles is assumed to be the default for GFS and NCEP. To test for the optimal windfiles to use, `MetTraj_[F,B]` uses three parameters that describe the GFS windfiles. `FC_freq` (default = 12 hours) is the frequency that the GFS forecast packages are downloaded. `GFS_Archive_Days` (default = 14 days) is the number of days the GFS forecast packages are stored on the system. `GFS_FC_TotHours` (default = 198 hours) is the number of forecast hours downloaded for each forecast package. For forward trajectories, forecast package beginning most closely prior to the requested start time is used unless the start time is earlier than two weeks from present. If so, the NCEP files are used. For the backward trajectories, the forecast package chosen is that which can accommodate the default 24-hours of backward integration.

For each of the trajectory calculations, files are written to the current working directory with the longitude and latitude of the trajectory in 1-hour increments at various elevations. The default elevations are 5000, 10000, 20000, 30000, 40000, and 50000 ft. Files for forward trajectories are named `ftraj[1-6].dat` while the backward trajectories are `btraj[1-6].dat`.

Optionally, the length of time to integrate and a user-specified list of output elevations can be given. Elevations are given on the command line must be in km.

Usage:

```
MetTraj_F lon lat YYYY MM DD HH [FC_hours nlev lev1 lev2 ...]
```

If a single string command-line argument if given, it is interpreted to be a control file. The control file has the following format.

```
-122.18 46.20                        ! lon lat
1980 5 18 15.5                       ! YYYY MM DD HH.H
24.0                                 ! simtime
1                                    ! streamflag (0 for streak, 1 for streamlines)
60                                   ! output time step (minutes)
6                                    ! ntraj (<10)
1.524 3.048 6.096 9.144 12.192 15.240 ! level values in km
1 4 -107.0 50.0 50.0 50.0 6367.470   ! Output projection
5 25 2 2                             ! MR_iwind MR_iwindformat MR_iGridCode MR_idataFormat
0 12 14                              ! autoflag (0 for auto, 1 for specified) FC_freq GFS_Archive_Days
1                                    ! MR_iwindfiles: number of windfiles
NCEP
```

The first two lines specify the start point in space and time. Line 3 gives the length of time in hours for the trajectory forecast. Note that GPH values at the start point are used throughout the simulation so longer simulation times will lead to greater errors in assumed GPH values. Line 4 is an integer flag specifying streamlines (1) where the winds evolve in time along the trajectory, or streakline (0) where a static initial wind field is used. Line 5 allows users to specify the output interval in minutes (default is 60). Line 6 is the number of output trajectory levels (up to 10). In line 7, the altitudes of these trajectories is specified. Line 8 specifies the coordinate system of the output grid. Line 9 gives the windfile descriptions (`MR_iwind MR_iwindformat MR_iGridCode MR_idataFormat`). Line 10 allows windfiles to be spelected automatically, similar to when this utility is run with command-line options only. Alternatively, line 11 will specify the number of windfiles to read, followed by the windfile names in lines 12+. Examples of several command files are given in the folder, `examples` with some select output shown in Figure 2

6.6 `makegfsncml`

This utility takes two arguments (`infile` and `outfile`) and generates a `ncml` file that can be used when converting GRIB files to NetCDF. The `ncml` provides the conversion tool a

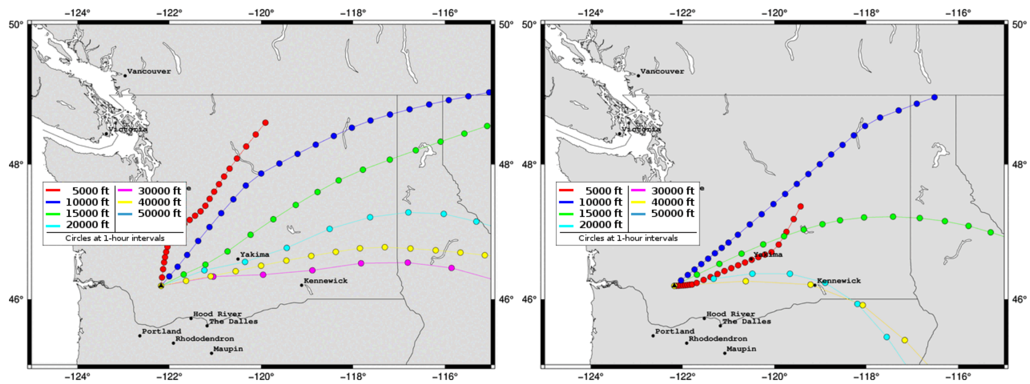

Figure 2: Example of foreward trajectory output using NCEP reanalysis (`MR_iwindformat=25`) and 6-point radiosonde data (left and right, respectively) using `RegridMet` with control files from the `examples` folder. The start time for both these trajectory simulations is May 18, 1980, 15:30 UTC. Because `MR_iHeightHandler=2` by default, the trajectories for 30,000 and 40,000 ft for the radiosonde data are equivalent.

template for identifying which variables to exclued when writing the netcdf file.

6.7 `MR_ASCII_check`

This utility takes two ESRI ASCII files are input arguments and calculates the L2 norm of the difference (they must be on the same grid). If the L2 norm exceeds the tolerance of 0.001, `MR_ASCII_check` will report a failure. Optionally, a different tolerance can be provided as a third command-line argument.

7 Windfile management scripts

Scripts used to manage GFS and NCEP Reanalysis files are provided in the folder `autorun_scripts`. The script `autorun_gfs0.5deg_00` (and the dependent scripts `get_gfs0.5deg.sh` and `convert_gfs0.5deg.sh`) is used for downloading and converting the 0.5° GFS files from NCEP. This script is intended to be run from a cron job and take as a parameter, the hour of the forecast package. For example `autorun_gfs0.5deg.sh 0` will download for 00Z for the current date. These scripts use a default root download directory of `/data/WindFiles`, but this can be modified within the scripts. The GFS files will be downloaded to `/data/WindFiles/gfs/gfs.YYYYMMDDHH` where `HH` is the forecast hour (00, 06, 12, or 18). The forecast files from hours 0-99 are downloaded then converted using netcdf-java 4.5. The path this package is set to `/ncj/netcdfAll-4.5.jar` but can be modified in `convert_gfs0.5deg.sh`.

Similarly, the script `get_NCEP_50YearReanalysis.sh` manages the downloading of the NCEP reanalysis files. These are placed in `/data/WindFiles/NCEP/YYYY/`

These scripts are intended to be run as cron jobs. The following line can be added to the crontab to download the files once they are available.

```
01 22 * *  * /opt/USGS/bin/autorun_scripts/autorun_gfs.sh 0p50 0            > gfs00_log       2>&1
```

```
01 11 * *  * /opt/USGS/bin/autorun_scripts/autorun_gfs.sh 0p50 12           > gfs12_log       2>&1
01 01 * 06 * /opt/USGS/bin/autorun_scripts/autorun_NCEP_50YearReanalysis.sh > NCEP_50yr_log   2>&1
30 03 * *  * /opt/USGS/bin/autorun_scripts/prune_windfiles.sh               > prune.log       2>&1
```

Also included in `autorun_scripts` is a simple stand-alone script (`grib2nc.sh`) for converting GRIB files to NetCDF using `netcdf-java`.

8 Appendix

8.1 Variable codes

Table 1: Variable codes

Variable type	ID	Name	dimensions
3-D Mechanical	1	Geopotential Height	gmp or m^2/s^2
	2	Vx	m/s
	3	Vy	m/s
	4	Vz	Pa/s
	5	Temperature	K
	6	Wind speed	m/s
	7	Wind direction	deg East of North
Surface	10	Planetary Boundary Layer Height	m
	11	U @ 10m	m/s
	12	V @ 10m	m/s
	13	Friction velocity	m/s
	14	Displacement Height	m
	15	Snow depth	%
	16	Soil moisture	kg/m2
	17	Surface Roughness	m
	18	Wind gust speed	m/s
	19	surface temperature	K
Atmospheric Structure	20	pressure at lower cloud base	Pa
	21	pressure at lower cloud top	Pa
	22	temperature at lower cloud top	K
	23	Total Cloud cover	%
	24	Cloud cover (low)	%
	25	Cloud cover (convective)	%
Moisture	30	Rel. Hum	%
	31	QV (specific humidity)	kg/kg
	32	QL (liquid)	kg/kg
	33	QI (ice)	kg/kg
Precipitation	40	Categorical rain	0 or 1
	41	Categorical snow	0 or 1
	42	Categorical frozen rain	0 or 1
	43	Categorical ice	0 or 1
	44	Precipitation rate large-scale (liquid)	kg/m^2s
	45	Precipitation rate convective (liquid)	kg/m^2s
	46	Precipitation rate large-scale (ice)	kg/m^2s
	47	Precipitation rate convective (ice)	kg/m^2s

8.2 NWP product ID (MR_iwindformat)

Several NWP product (both reanalysis and forecast) are recognized and do not need template files. These are listed in the table below by the format code. `MR_iwindformat=1,2` are ASCII files. `MR_iwindformat=3-19` are reserved for products with projected grids. `MR_iwindformat=20-49` are reserved for global (lon/lat) grids. `MR_iwindformat=50` is for NetCDF output from Weather Research and Forecasting (WRF) simulations.

Table 2: NWP product ID

MR_iwind	MR_iwindformat	Product	NCEP Grid	resolution
3/4	0	Custom format based on template		
1	1	ASCII profile		
1	2	Radiosonde data		
4	3	North American Regional Reanalysis NARR	221	32 km
4	4	NAM Regional North America	221	32 km
4	5	NAM Regional Alaska	216	45 km
4	6	NAM N. Hemisphere	104	90 km
4	7	NAM Regional CONUS	212	40 km
4	8	NAM Regional CONUS	218	12 km
4	9	NAM Regional CONUS	227	5.08 km
4	10	NAM Regional Alaska	242	11.25 km
4	11	NAM Regional Hawaii	196	2.5 km
4	12	NAM Regional Alaska	198	5.953 km
4	13	NAM Regional Alaska	91	2.976 km
4	14	NAM Regional CONUS	None	3.0 km
4	20	GFS	4	0.5°
4	21	GFS	3	1.0°
4	22	GFS	193	0.25°
4	23	NCEP-DOE Reanalysis 2	2	2.5°
4	24	NASA-MERRA-2 Reanalysis	None	$0.625 \times 0.5^\circ$
4/5	25	NCEP/NCAR Reanalysis 1	2	2.5°
5	26	JRA-55	45	1.25°
5	27	NOAA-CIRES 20th Century Reanalysis	2	2.5°
4	28	ECMWF ERA-Interim Reanalysis	170 (gg)	$\sim 0.7^\circ$
4/5	29	ECMWF ERA5 Reanalysis	None	0.281
5	30	ECMWF ERA-20C Reanalysis	None (gg)	$1.125\times \sim 1.121^\circ$
4	32	Air Force Weather Agency subcenter = 0	None	0.25°
4	33	CCSM3.0 Community Atmosphere Model	None	$3.75 \times 3.7^\circ$
4	40	NASA GEOS-5 Cp	None	$0.625 \times 0.5^\circ$
4	41	NASA GEOS-5 Np	None	$0.3125 \times 0.25^\circ$
4	50	WRF - output	None	

8.3 Example Template files

Figure 3: Outlines of North America Mesoscale (NAM) and Global Forecast System (GFS) models from NCEP that are compatible with MetReader template files.

8.4 NAM 221 Regional N.America (32.5 km)

`nam.t00z.awip3200.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

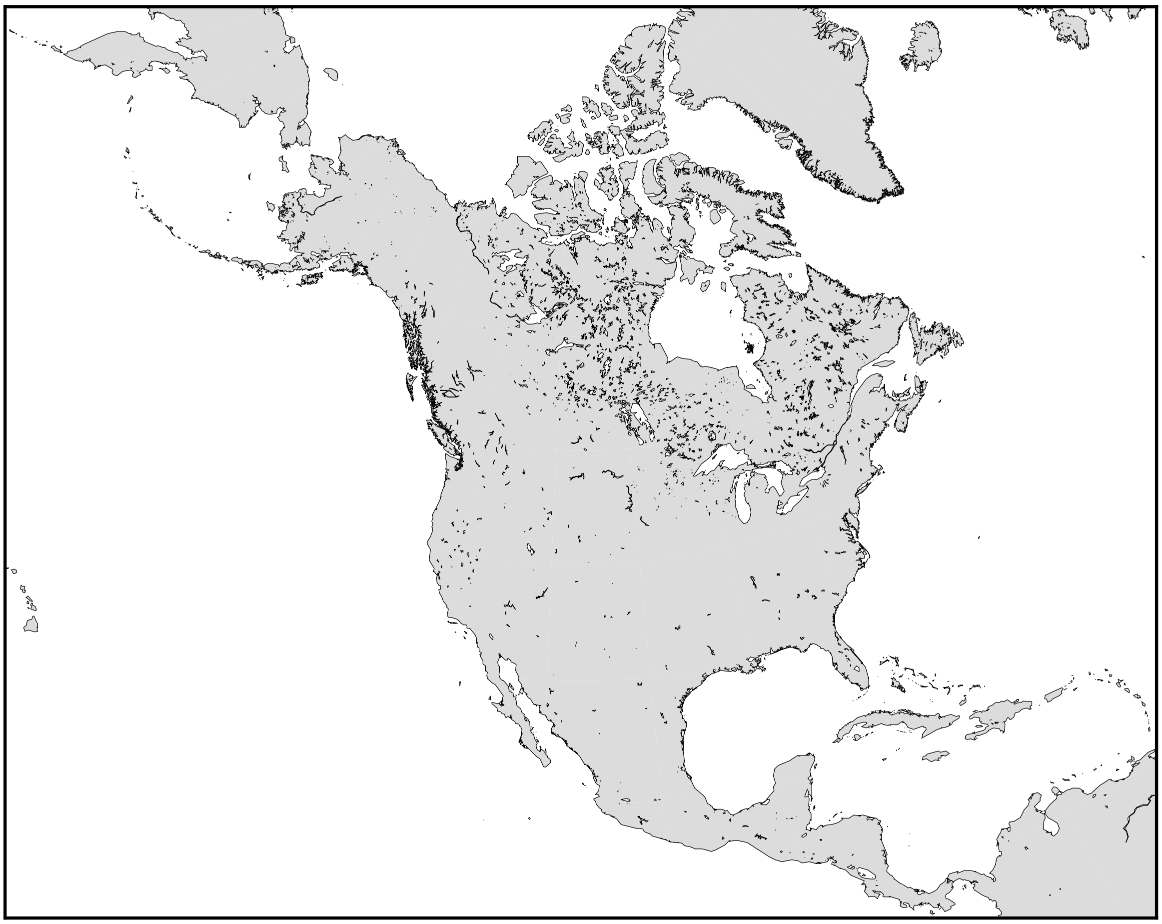

Figure 4: NAM 221, Regional N. America 32.5 km Lambert Conformal Conical

n221_template.txt

```
0 4 -107.0 50.0 50.0 50.0 6371.229                                             Projection params line
3.0                                                                            Time interval
9 29                                                                           ndims, nvars
d      1       1.0 time                                                        hours since
d      2       1.0 isobaric1                                                   Pa
d      3       1.0 y                                                           km or deg
d      4       1.0 x                                                           km or deg
d      5       1.0 isobaric1                                                   Pa
d      6       1.0 isobaric1                                                   Pa
d      7       1.0 height_above_ground3                                        m
d      8       1.0 depth_below_surface_layer                                   m
d      9       1.0 isobaric4                                                   Pa
v 4  2 1       1.0    HGT   Geopotential_height_isobaric                       gpm
v 4  2 2       1.0   UGRD   u-component_of_wind_isobaric                       m/s
v 4  2 3       1.0   VGRD   v-component_of_wind_isobaric                       m/s
v 4  5 4       1.0   VVEL   Vertical_velocity_pressure_isobaric                Pa/s
v 4  2 5       1.0    TMP   Temperature_isobaric                               K
v 3  0 10      1.0   HPBL   Planetary_Boundary_Layer_Height_surface            m
v 4  7 11      1.0   UGRD   u-component_of_wind_height_above_ground            m/s
v 4  7 12      1.0   VGRD   v-component_of_wind_height_above_ground            m/s
v 3  0 13      1.0  FRICV   Frictional_Velocity_surface                        m.s-1
v 3  0 15      1.0   SNOD   Snow_depth_surface                                 m
v 4  2 16      1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer   Fraction
v 3  0 17      1.0   SFCR   Surface_roughness_surface                          m
v 3  0 18      1.0   GUST   Wind_speed_gust_surface                            m/s
v 3  0 20      1.0   PRES   Pressure_cloud_base                                Pa
v 3  0 21      1.0   PRES   Pressure_cloud_tops                                Pa
v 3  0 23      1.0   TCDC   Total_cloud_cover_entire_atmosphere                %
v 4  6 30      1.0     RH   Relative_humidity_isobaric                         %
v 4  6 31      1.0   SPFH   Specific_humidity_isobaric                         kg/kg
v 4  9 32      1.0  CLWMR   Cloud_mixing_ratio_isobaric                        kg/kg
v 4  9 33      1.0   SNMR   Snow_mixing_ratio_isobaric                         kg/kg
v 3  0 40      1.0  CRAIN   Categorical_Rain_surface                           0 or 1
v 3  0 41      1.0  CSNOW   Categorical_Snow_surface                           0 or 1
v 3  0 42      1.0  CFRZR   Categorical_Freezing_Rain_surface                  0 or 1
v 3  0 43      1.0  CICEP   Categorical_Ice_Pellets_surface                    0 or 1
v 3  0 44      1.0  PRATE   Precipitation_rate_surface                         kg.m-2.s-1
v 3  0 45      1.0  CPRAT   Convective_Precipitation_Rate_surface              kg.m-2.s-1
v 3  0 45      1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation    kg.m-2
v 3  0 46      1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation   kg.m-2
v 3  0 47      1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation   kg.m-2
```

8.5 NAM 216 AK (45.0 km); NAM 242 AK (11.25 km)

`nam.t00z.awipak00.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`
`http://motherlode.ucar.edu/native/conduit/data/nccf/com/nam/prod/nam.YYYYMMDD/`

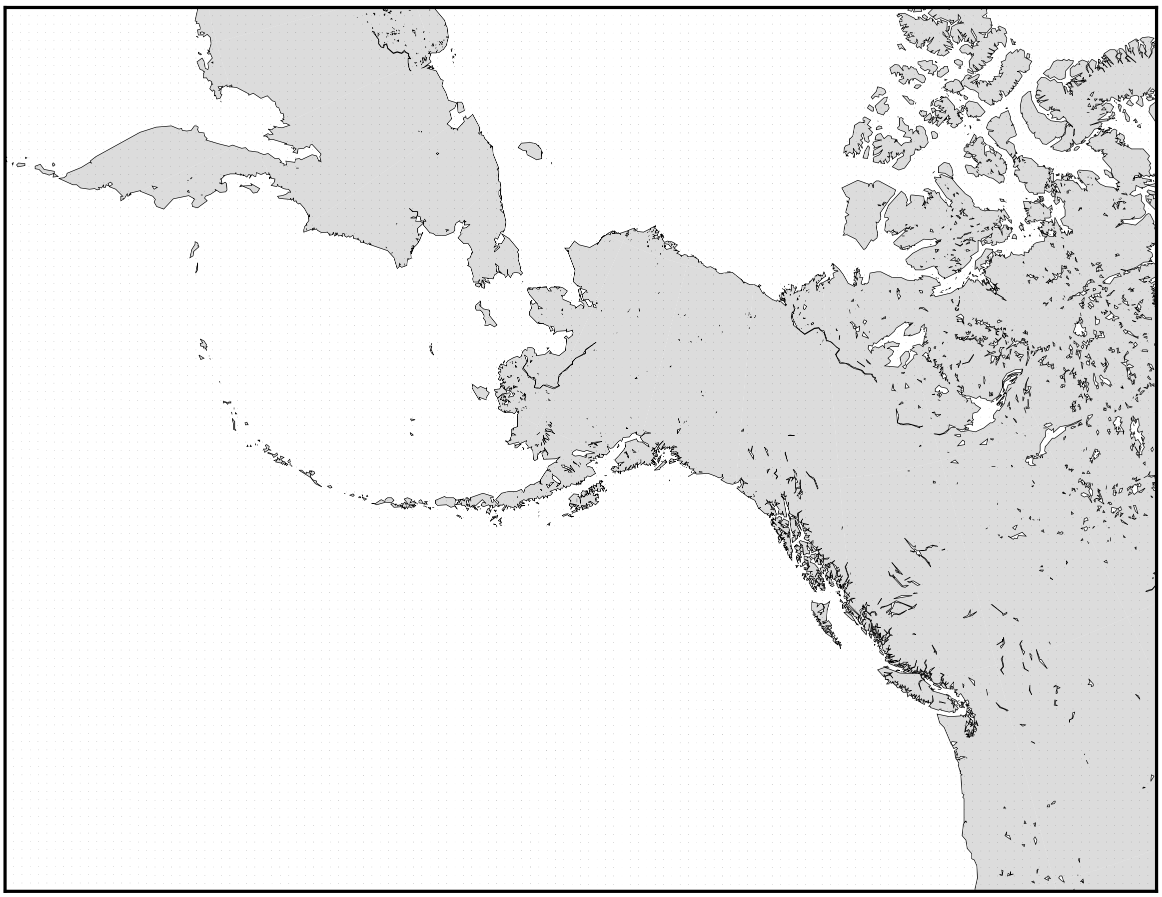

Figure 5: NAM 216, AK 45.0 km Polar Stereographic

n216_template.txt

```
0 1 -135.0 90.0 0.933 6371.229                                                                        Projection params line
3.0                                                                                                   Time interval
9 27                                                                                                  ndims, nvars
d      1       1.0 time                                                                               hours since
d      2       1.0 isobaric1                                                                          Pa
d      3       1.0 y                                                                                  km or deg
d      4       1.0 x                                                                                  km or deg
d      5       1.0 isobaric1                                                                           Pa
d      6       1.0 isobaric1                                                                          Pa
d      7       1.0 height_above_ground3                                                               m
d      8       1.0 depth_below_surface_layer                                                          m
d      9       1.0 isobaric4                                                                          Pa
v 4  2 1       1.0    HGT   Geopotential_height_isobaric                                              gpm
v 4  2 2       1.0   UGRD   u-component_of_wind_isobaric                                              m/s
v 4  2 3       1.0   VGRD   v-component_of_wind_isobaric                                              m/s
v 4  5 4       1.0   VVEL   Vertical_velocity_pressure_isobaric                                       Pa/s
v 4  2 5       1.0    TMP   Temperature_isobaric                                                      K
v 3  0 10      1.0   HPBL   Planetary_Boundary_Layer_Height_surface                                   m
v 4  7 11      1.0   UGRD   u-component_of_wind_height_above_ground                                   m/s
v 4  7 12      1.0   VGRD   v-component_of_wind_height_above_ground                                   m/s
v 3  0 13      1.0  FRICV   Frictional_Velocity_surface                                               m.s-1
v 3  0 15      1.0   SNOD   Snow_depth_surface                                                        m
v 4  2 16      1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer                Fraction
v 3  0 17      1.0   SFCR   Surface_roughness_surface                                                 m
v 3  0 18      1.0   GUST   Wind_speed_gust_surface                                                   m/s
v 3  0 20      1.0   PRES   Pressure_cloud_base                                                       Pa
v 3  0 21      1.0   PRES   Pressure_cloud_tops                                                       Pa
v 3  0 23      1.0   TCDC   Total_cloud_cover_entire_atmosphere                                       %
v 4  6 30      1.0     RH   Relative_humidity_isobaric                                                %
v 4  9 32      1.0  CLWMR   Cloud_mixing_ratio_isobaric                                               kg/kg
v 3  0 40      1.0  CRAIN   Categorical_Rain_surface                                                  0 or 1
v 3  0 41      1.0  CSNOW   Categorical_Snow_surface                                                  0 or 1
v 3  0 42      1.0  CFRZR   Categorical_Freezing_Rain_surface                                         0 or 1
v 3  0 43      1.0  CICEP   Categorical_Ice_Pellets_surface                                           0 or 1
v 3  0 44      1.0  PRATE   Precipitation_rate_surface                                                kg.m-2.s-1
v 3  0 45      1.0  CPRAT   Convective_Precipitation_Rate_surface                                     kg.m-2.s-1
v 3  0 45      1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                           kg.m-2
v 3  0 46      1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation                      kg.m-2
v 3  0 47      1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation      kg.m-2
```

Grid 242 uses the same projection and domain as Grid 216, but with 11.25 km grid spacing.

`nam.t00z.awak3d00.grb2.tm00`

Available from:

`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`
`n242_template.txt`

```
0 1 -135.0 90.0 0.933 6371.229                                                                   Projection params line
3.0                                                                                              Time interval
9 27                                                                                             ndims, nvars
d      1       1.0 time                                                                          hours since
d      2       1.0 isobaric2                                                                     Pa
d      3       1.0 y                                                                             km or deg
d      4       1.0 x                                                                             km or deg
d      5       1.0 isobaric                                                                      Pa
d      6       1.0 isobaric2                                                                     Pa
d      7       1.0 height_above_ground3                                                          m
d      8       1.0 depth_below_surface_layer                                                     m
d      9       1.0 isobaric6                                                                     Pa
v 4  2 1       1.0    HGT   Geopotential_height_isobaric                                         gpm
v 4  2 2       1.0   UGRD   u-component_of_wind_isobaric                                         m/s
v 4  2 3       1.0   VGRD   v-component_of_wind_isobaric                                         m/s
v 4  5 4       1.0   VVEL   Vertical_velocity_pressure_isobaric                                  Pa/s
v 4  2 5       1.0    TMP   Temperature_isobaric                                                 K
v 3  0 10      1.0   HPBL   Planetary_Boundary_Layer_Height_surface                              m
v 4  7 11      1.0   UGRD   u-component_of_wind_height_above_ground                              m/s
v 4  7 12      1.0   VGRD   v-component_of_wind_height_above_ground                              m/s
v 3  0 13      1.0  FRICV   Frictional_Velocity_surface                                          m.s-1
v 3  0 15      1.0   SNOD   Snow_depth_surface                                                   m
v 4  2 16      1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer           Fraction
v 3  0 17      1.0   SFCR   Surface_roughness_surface                                            m
v 3  0 18      1.0   GUST   Wind_speed_gust_surface                                              m/s
v 3  0 20      1.0   PRES   Pressure_cloud_base                                                  Pa
v 3  0 21      1.0   PRES   Pressure_cloud_tops                                                  Pa
v 3  0 23      1.0   TCDC   Total_cloud_cover_entire_atmosphere                                  %
v 4  6 30      1.0     RH   Relative_humidity_isobaric                                           %
v 4  9 32      1.0  CLWMR   Cloud_mixing_ratio_isobaric                                          kg/kg
v 3  0 40      1.0  CRAIN   Categorical_Rain_surface                                             0 or 1
v 3  0 41      1.0  CSNOW   Categorical_Snow_surface                                             0 or 1
v 3  0 42      1.0  CFRZR   Categorical_Freezing_Rain_surface                                    0 or 1
v 3  0 43      1.0  CICEP   Categorical_Ice_Pellets_surface                                      0 or 1
v 3  0 44      1.0  PRATE   Precipitation_rate_surface                                           kg.m-2.s-1
v 3  0 45      1.0  CPRAT   Convective_Precipitation_Rate_surface                                kg.m-2.s-1
v 3  0 45      1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                      kg.m-2
v 3  0 46      1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation                 kg.m-2
v 3  0 47      1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation kg.m-2
```

8.6 NAM 91 AK (2.95 km); NAM 198 AK (5.9 km)

`nam.t00z.alaskanest.hiresf00.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

Figure 6: NAM 91, AK 2.95 km Polar Stereographic (previously NAM 198, AK 5.9 km)

n091_template.txt

```
0 1 -150.0 90.0 0.933 6371.229                                                                               Projection params line
1.0                                                                                                          Time interval
9 29                                                                                                         ndims, nvars
d      1        1.0 time                                                                                     hours since
d      2        1.0 isobaric2                                                                                Pa
d      3        1.0 y                                                                                        km or deg
d      4        1.0 x                                                                                        km or deg
d      5        1.0 isobaric2                                                                                Pa
d      6        1.0 isobaric2                                                                                Pa
d      7        1.0 height_above_ground3                                                                     m
d      8        1.0 depth_below_surface_layer                                                                m
d      9        1.0 isobaric3                                                                                Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                                    gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                                    m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                                    m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                             Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                                            K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                                         m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                                         m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                                         m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                                     m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                              m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer                      Fraction
v 3  0 17       1.0   SFCR   Surface_roughness_surface                                                       m
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                                         m/s
v 3  0 20       1.0   PRES   Pressure_cloud_base                                                             Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                                             Pa
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                                             %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                                      %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                                                      kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                                     kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                                                      kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                                        0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                                        0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                               0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                                 0 or 1
v 3  0 44       1.0  PRATE   Precipitation_rate_surface                                                      kg.m-2.s-1
v 3  0 45       1.0  CPRAT   Convective_Precipitation_Rate_surface                                           kg.m-2.s-1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                                 kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation                            kg.m-2
v 3  0 47       1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation            kg.m-2
```

8.7 NAM 243 Eastern N. Pac./HI (0.40°)

`nam.t00z.awiphi00.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

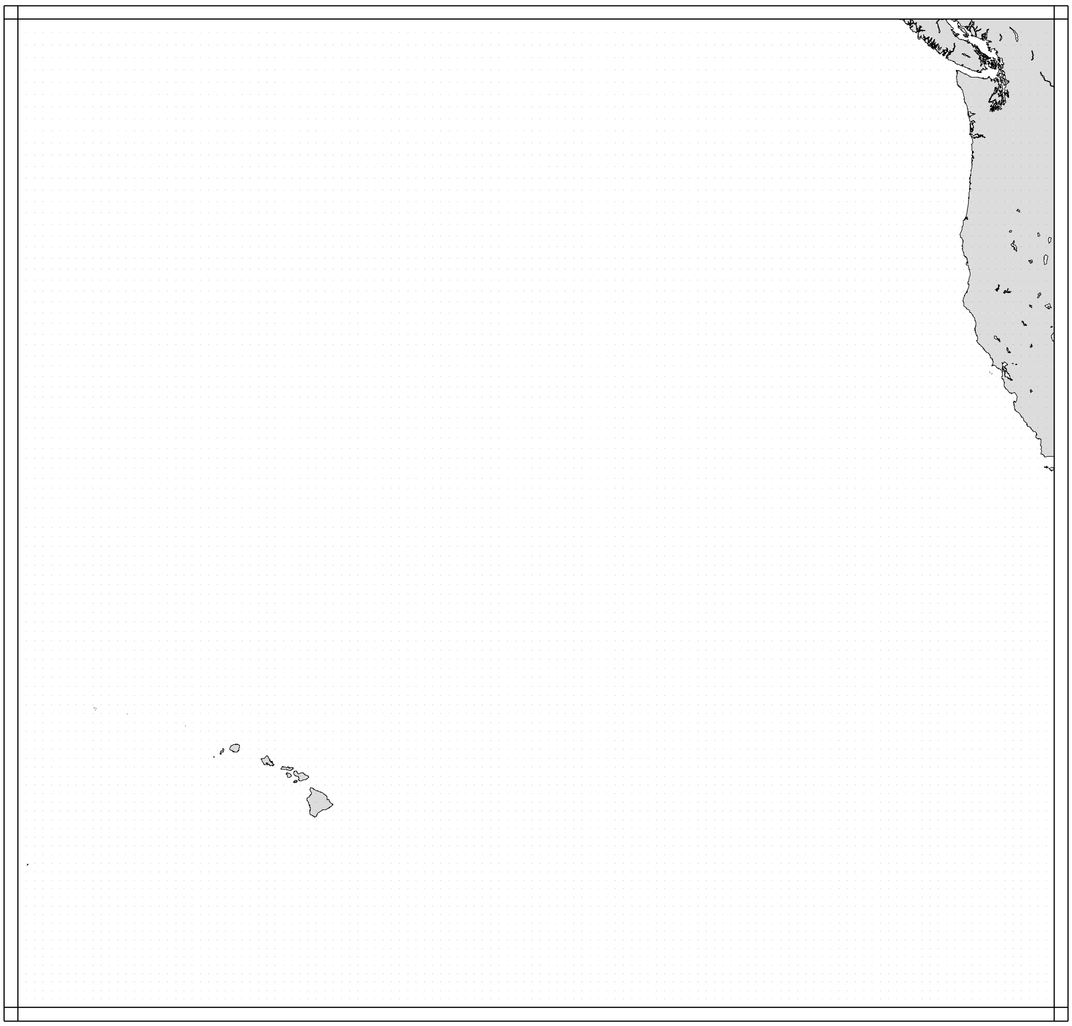

Figure 7: NAM 243, Eastern N. Pac./HI 0.4°

n243_template.txt

```
1 1 -150.0 90.0 0.933 6371.229                                                    Projection params line
3.0                                                                               Time interval
9 24                                                                              ndims, nvars
d      1        1.0 time                                                          hours since
d      2        1.0 isobaric2                                                     Pa
d      3        1.0 lat                                                           km or deg
d      4        1.0 lon                                                           km or deg
d      5        1.0 isobaric1                                                     Pa
d      6        1.0 isobaric2                                                     Pa
d      7        1.0 height_above_ground                                          m
d      8        1.0 depth_below_surface_layer                                     m
d      9        1.0 isobaric4                                                     Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                         gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                         m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                         m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                  Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                 K
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground              m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground              m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                          m.s-1
v 3  0 17       1.0   SFCR   Surface_roughness_surface                            m
v 3  0 20       1.0   PRES   Pressure_cloud_base                                  Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                  Pa
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                  %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                           %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                           kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                          kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                           kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                             0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                             0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                    0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                      0 or 1
v 3  0 44       1.0  PRATE   Precipitation_rate_surface                           kg.m-2.s-1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation      kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation kg.m-2
v 3  0 47       1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation   kg.m-2
```

8.8 NAM 182 HI ($0.108\,^\circ$)

`nam.t00z.afwahi00.grb2.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

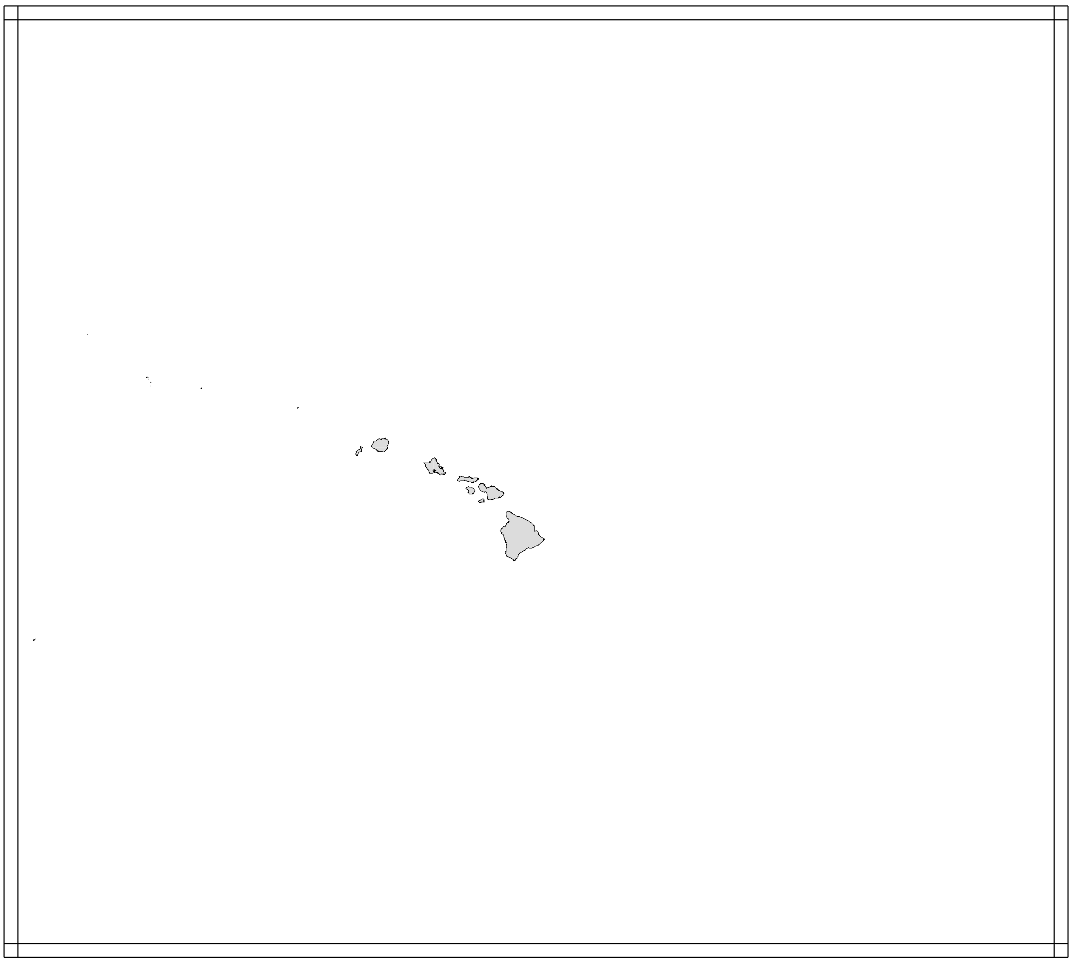

Figure 8: NAM 182, HI 0.108 °

n182_template.txt

```
1 1 -150.0 90.0 0.933 6371.229                                                                        Projection params line
3.0                                                                                                   Time interval
8 22                                                                                                  ndims, nvars
d       1        1.0 time1                                                                            hours since
d       2        1.0 isobaric                                                                         Pa
d       3        1.0 lat                                                                              km or deg
d       4        1.0 lon                                                                              km or deg
d       5        1.0 isobaric                                                                         Pa
d       6        1.0 isobaric                                                                         Pa
d       7        1.0 height_above_ground2                                                             m
d       8        1.0 depth_below_surface_layer                                                        m
v 4  2 1         1.0     HGT   Geopotential_height_isobaric                                           gpm
v 4  2 2         1.0    UGRD   u-component_of_wind_isobaric                                           m/s
v 4  2 3         1.0    VGRD   v-component_of_wind_isobaric                                           m/s
v 4  5 4         1.0    VVEL   Vertical_velocity_pressure_isobaric                                    Pa/s
v 4  2 5         1.0     TMP   Temperature_isobaric                                                   K
v 3  0 10        1.0    HPBL   Planetary_Boundary_Layer_Height_surface                                m
v 4  7 11        1.0    UGRD   u-component_of_wind_height_above_ground                                m/s
v 4  7 12        1.0    VGRD   v-component_of_wind_height_above_ground                                m/s
v 3  0 13        1.0   FRICV   Frictional_Velocity_surface                                            m.s-1
v 3  0 15        1.0    SNOD   Snow_depth_surface                                                     m
v 4  2 16        1.0   SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer             Fraction
v 3  0 23        1.0    TCDC   Total_cloud_cover_entire_atmosphere                                    %
v 4  6 30        1.0      RH   Relative_humidity_isobaric                                             %
v 4  6 31        1.0    SPFH   Specific_humidity_isobaric                                             kg/kg
v 4  9 32        1.0   CLWMR   Cloud_mixing_ratio_isobaric                                            kg/kg
v 4  9 33        1.0    SNMR   Snow_mixing_ratio_isobaric                                             kg/kg
v 3  0 40        1.0   CRAIN   Categorical_Rain_surface                                               0 or 1
v 3  0 41        1.0   CSNOW   Categorical_Snow_surface                                               0 or 1
v 3  0 42        1.0   CFRZR   Categorical_Freezing_Rain_surface                                      0 or 1
v 3  0 43        1.0   CICEP   Categorical_Ice_Pellets_surface                                        0 or 1
v 3  0 45        1.0    APCP   Total_precipitation_surface_0_Hour_Accumulation                        kg.m-2
v 3  0 46        1.0   ACPCP   Convective_precipitation_surface_0_Hour_Accumulation                   kg.m-2
```

8.9 NAM 196 HI (2.5 km)

`nam.t00z.hawaiinest.hiresf00.tm0`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

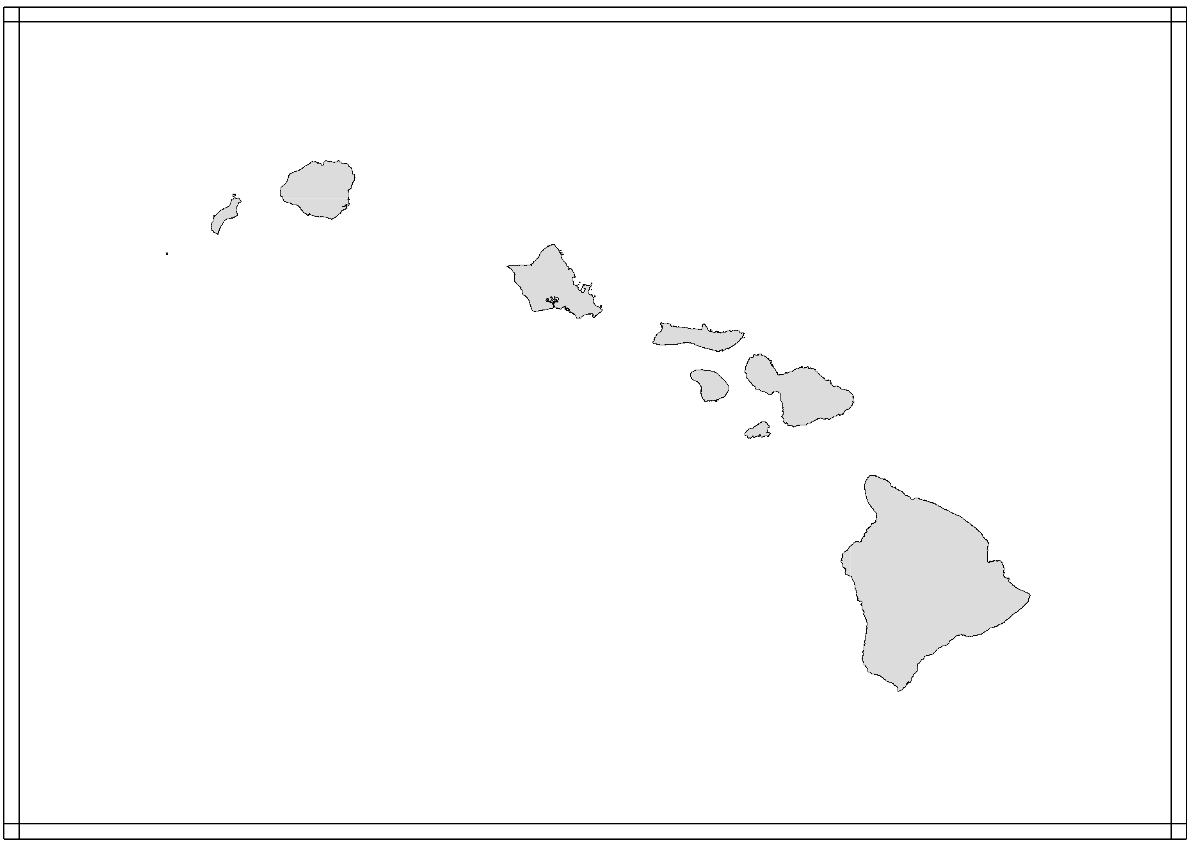

Figure 9: NAM 196, AK 2.5 km Mercator

n196_template.txt

```
0 5 198.475 20.0 6371.229                                                                        Projection params line
1.0                                                                                              Time interval
9 27                                                                                             ndims, nvars
d      1        1.0 time                                                                         hours since
d      2        1.0 isobaric2                                                                    Pa
d      3        1.0 y                                                                            km or deg
d      4        1.0 x                                                                            km or deg
d      5        1.0 isobaric2                                                                    Pa
d      6        1.0 isobaric2                                                                    Pa
d      7        1.0 height_above_ground3                                                         m
d      8        1.0 depth_below_surface_layer                                                    m
d      9        1.0 isobaric4                                                                    Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                        gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                        m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                        m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                 Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                                K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                             m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                             m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                             m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                         m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                  m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer          Fraction
v 3  0 17       1.0   SFCR   Surface_roughness_surface                                           m
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                             m/s
v 3  0 20       1.0   PRES   Pressure_cloud_base                                                 Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                                 Pa
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                                 %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                          %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                                          kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                         kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                                          kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                            0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                            0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                   0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                     0 or 1
v 3  0 44       1.0  PRATE   Precipitation_rate_surface                                          kg.m-2.s-1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                     kg.m-2
v 3  0 47       1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation kg.m-2
```

8.10 NAM 211/212/218/227 CONUS

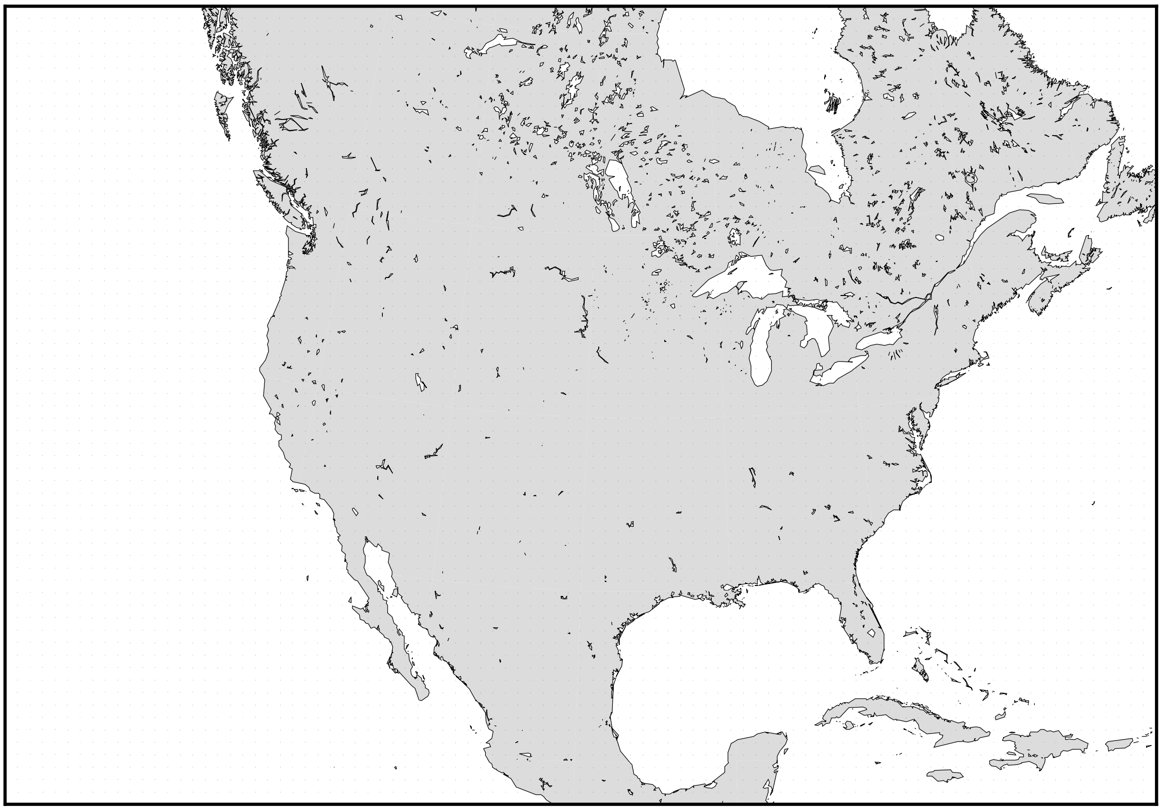

Figure 10: NAM 211/212/218/227 CONUS Lambert Conformal Conical (dots correspond to the 81.3 km 211 grid)

Available from:

`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

NAM 211 CONUS (81.3 km) :: `nam.t00z.awp21100.tm00`

`n211_template.txt`

```
0 4 265.0 25.0 25.0 25.0 6371.229                                                              Projection params line
6.0                                                                                            Time interval
9 18                                                                                           ndims, nvars
d      1        1.0 time                                                                       hours since
d      2        1.0 isobaric                                                                   Pa
d      3        1.0 y                                                                          km or deg
d      4        1.0 x                                                                          km or deg
d      5        1.0 isobaric                                                                   Pa
d      6        1.0 isobaric                                                                   Pa
d      7        1.0 height_above_ground1                                                       m
d      8        1.0 depth_below_surface_layer                                                  m
d      9        1.0 isobaric                                                                   Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                      gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                      m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                      m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                               Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                              K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                           m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                           m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                           m/s
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                           m/s
v 3  0 20       1.0   PRES   Pressure_cloud_base                                               Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                               Pa
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                        %
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                          0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                          0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                 0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                   0 or 1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                   kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation              kg.m-2
```

NAM 212 CONUS (40.6 km) :: `nam.t00z.awip3d00.tm00`

`n212_template.txt`

```
0 4 265.0 25.0 25.0 25.0 6371.229                                                                 Projection params line
3.0                                                                                            Time interval
9 29                                                                                           ndims, nvars
d      1        1.0 time                                                                       hours since
d      2        1.0 isobaric3                                                                  Pa
d      3        1.0 y                                                                          km or deg
d      4        1.0 x                                                                          km or deg
d      5        1.0 isobaric3                                                                  Pa
d      6        1.0 isobaric3                                                                  Pa
d      7        1.0 height_above_ground2                                                       m
d      8        1.0 depth_below_surface_layer                                                  m
d      9        1.0 isobaric3                                                                  Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                      gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                      m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                      m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                               Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                              K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                           m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                           m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                           m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                       m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer        Fraction
v 3  0 17       1.0   SFCR   Surface_roughness_surface                                         m
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                           m/s
v 3  0 20       1.0   PRES   Pressure_cloud_base                                               Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                               Pa
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                               %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                        %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                                        kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                       kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                                        kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                          0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                          0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                 0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                   0 or 1
v 3  0 44       1.0  PRATE   Precipitation_rate_surface                                        kg.m-2.s-1
v 3  0 45       1.0  CPRAT   Convective_Precipitation_Rate_surface                             kg.m-2.s-1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                   kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation              kg.m-2
v 3  0 47       1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation   kg.m-2
```

NAM 218 CONUS (12.2 km) :: `nam.t00z.awphys00.grb2.tm00`
`n218_template.txt`

```
0 4 265.0 25.0 25.0 25.0 6371.229                                                               Projection params line
1.0                                                                                             Time interval
9 21                                                                                            ndims, nvars
d      1        1.0 time                                                                        hours since
d      2        1.0 isobaric1                                                                   Pa
d      3        1.0 y                                                                           km or deg
d      4        1.0 x                                                                           km or deg
d      5        1.0 isobaric1                                                                   Pa
d      6        1.0 isobaric                                                                    Pa
d      7        1.0 height_above_ground4                                                        m
d      8        1.0 depth_below_surface_layer                                                   m
d      9        1.0 isobaric4                                                                   Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                       gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                       m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                       m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                               K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                            m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                            m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                            m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                        m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                 m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer         Fraction
v 3  0 17       1.0   SFCR   Surface_roughness_surface                                          m
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                            m/s
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                                %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                         %
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                           0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                           0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                  0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                    0 or 1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                    kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation               kg.m-2
```

NAM 227 CONUS (5.1 km) :: `nam.t00z.conusnest.hiresf00.tm00`
`n227_template.txt`

```
0 4 265.0 25.0 25.0 25.0 6371.229                                                               Projection params line
1.0                                                                                             Time interval
9 27                                                                                            ndims, nvars
d      1        1.0 time                                                                        hours since
d      2        1.0 isobaric2                                                                   Pa
d      3        1.0 y                                                                           km or deg
d      4        1.0 x                                                                           km or deg
d      5        1.0 isobaric2                                                                   Pa
d      6        1.0 isobaric2                                                                   Pa
d      7        1.0 height_above_ground3                                                        m
d      8        1.0 depth_below_surface_layer                                                   m
d      9        1.0 isobaric4                                                                   Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                       gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                       m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                       m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                               K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                            m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                            m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                            m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                        m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                 m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer         Fraction
v 3  0 17       1.0   SFCR   Surface_roughness_surface                                          m
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                            m/s
v 3  0 20       1.0   PRES   Pressure_cloud_base                                                Pa
v 3  0 21       1.0   PRES   Pressure_cloud_tops                                                Pa
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                                %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                         %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                                         kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                        kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                                         kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                           0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                           0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                  0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                    0 or 1
v 3  0 44       1.0  PRATE   Precipitation_rate_surface                                         kg.m-2.s-1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                    kg.m-2
v 3  0 47       1.0  NCPCP   Large-scale_precipitation_non-convective_surface_0_Hour_Accumulation kg.m-2
```

8.11 NAM 181 Caribbean (0.108°)

`nam.t00z.afwaca00.grb2.tm00`
Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/nam/prod/nam.YYYYMDD/`

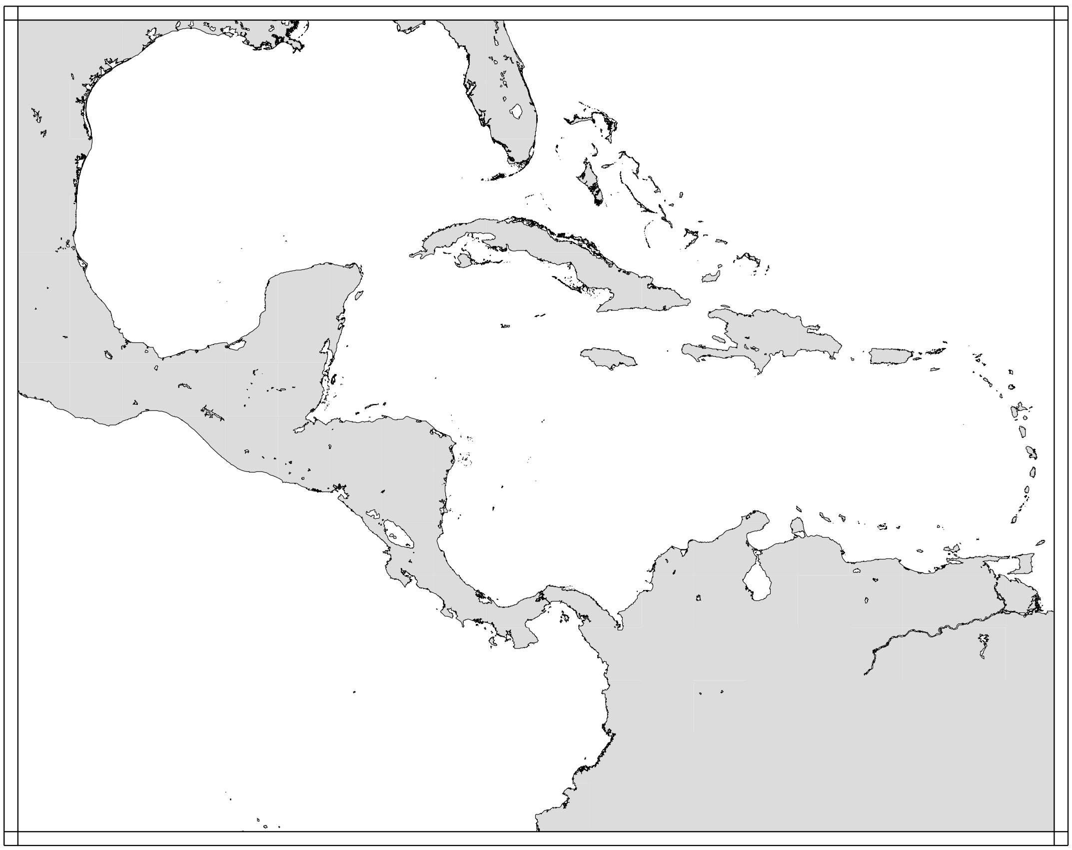

Figure 11: NAM 181, Caribbean 0.108°

n181_template.txt

```
1 1 -150.0 90.0 0.933 6371.229                                                                   Projection params line
3.0                                                                                              Time interval
8 22                                                                                             ndims, nvars
d      1        1.0 time1                                                                        hours since
d      2        1.0 isobaric                                                                     Pa
d      3        1.0 lat                                                                          km or deg
d      4        1.0 lon                                                                          km or deg
d      5        1.0 isobaric                                                                     Pa
d      6        1.0 isobaric                                                                     Pa
d      7        1.0 height_above_ground2                                                         m
d      8        1.0 depth_below_surface_layer                                                    m
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                        gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                        m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                        m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                 Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                                K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                             m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                             m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                             m/s
v 3  0 13       1.0  FRICV   Frictional_Velocity_surface                                         m.s-1
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                  m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer          Fraction
v 3  0 23       1.0   TCDC   Total_cloud_cover_entire_atmosphere                                 %
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                          %
v 4  6 31       1.0   SPFH   Specific_humidity_isobaric                                          kg/kg
v 4  9 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                         kg/kg
v 4  9 33       1.0   SNMR   Snow_mixing_ratio_isobaric                                          kg/kg
v 3  0 40       1.0  CRAIN   Categorical_Rain_surface                                            0 or 1
v 3  0 41       1.0  CSNOW   Categorical_Snow_surface                                            0 or 1
v 3  0 42       1.0  CFRZR   Categorical_Freezing_Rain_surface                                   0 or 1
v 3  0 43       1.0  CICEP   Categorical_Ice_Pellets_surface                                     0 or 1
v 3  0 45       1.0   APCP   Total_precipitation_surface_0_Hour_Accumulation                     kg.m-2
v 3  0 46       1.0  ACPCP   Convective_precipitation_surface_0_Hour_Accumulation                kg.m-2
```

8.12 GFS 3/4/193

Figure 12: GFS 3,4,193, (dots correspond to the 1.0° NAM 3 grid)

Available from:
`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/gfs.YYYYMDD/`
GFS NCEP Grid 3 (1.0 °) :: `gfs.t00z.pgrb2.1p00.f000.nc` `n003_template.txt`

GFS NCEP grid 4 (0.5 °) :: `n004_template.txt`

```
1 1 -150.0 90.0 0.933 6371.229                                                                      Projection params line
3.0                                                                                                 Time interval
9 13                                                                                                ndims, nvars
d      1        1.0 time                                                                            hours since
d      2        1.0 isobaric3                                                                       Pa
d      3        1.0 lat                                                                             km or deg
d      4        1.0 lon                                                                             km or deg
d      5        1.0 isobaric2                                                                       Pa
d      6        1.0 isobaric3                                                                       Pa
d      7        1.0 height_above_ground3                                                            m
d      8        1.0 depth_below_surface_layer                                                       m
d      9        1.0 isobaric4                                                                       Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                           gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                           m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                           m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                    Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                                   K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                                m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                                m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                                m/s
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                     m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer             Fraction
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                                m/s
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                             %
v 4  5 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                            kg/kg
```

GFS NCEP grid 193 (0.25 °) :: `n193_template.txt`

```
1 1 -150.0 90.0 0.933 6371.229                                                                      Projection params line
3.0                                                                                                 Time interval
9 13                                                                                                ndims, nvars
d      1        1.0 time                                                                            hours since
d      2        1.0 isobaric3                                                                       Pa
d      3        1.0 lat                                                                             km or deg
d      4        1.0 lon                                                                             km or deg
d      5        1.0 isobaric2                                                                       Pa
d      6        1.0 isobaric3                                                                       Pa
d      7        1.0 height_above_ground3                                                            m
d      8        1.0 depth_below_surface_layer                                                       m
d      9        1.0 isobaric4                                                                       Pa
v 4  2 1        1.0    HGT   Geopotential_height_isobaric                                           gpm
v 4  2 2        1.0   UGRD   u-component_of_wind_isobaric                                           m/s
v 4  2 3        1.0   VGRD   v-component_of_wind_isobaric                                           m/s
v 4  5 4        1.0   VVEL   Vertical_velocity_pressure_isobaric                                    Pa/s
v 4  2 5        1.0    TMP   Temperature_isobaric                                                   K
v 3  0 10       1.0   HPBL   Planetary_Boundary_Layer_Height_surface                                m
v 4  7 11       1.0   UGRD   u-component_of_wind_height_above_ground                                m/s
v 4  7 12       1.0   VGRD   v-component_of_wind_height_above_ground                                m/s
v 3  0 15       1.0   SNOD   Snow_depth_surface                                                     m
v 4  2 16       1.0  SOILW   Volumetric_Soil_Moisture_Content_depth_below_surface_layer             Fraction
v 3  0 18       1.0   GUST   Wind_speed_gust_surface                                                m/s
v 4  6 30       1.0     RH   Relative_humidity_isobaric                                             %
v 4  5 32       1.0  CLWMR   Cloud_mixing_ratio_isobaric                                            kg/kg
```

8.13 NASA GEOS-5

Figure 13: NASA GEOS-5, 0.625/0.5°

Available from:

`ftp://gmao_ops@ftp.nccs.nasa.gov/fp/forecast//`

NASA GEOS-5 Cp (0.625/0.5°) ::
`GEOS.fp.fcst.inst3_3d_asm_Cp.YYYYMMDD_00+YYYYMMDD_mmmm.V01.nc4`
`nGCp_template.txt`

```
1 1 -150.0 90.0 0.933 6371.229                                                                          Projection params line
3.0                                                                                                     Time interval
6 7                                                                                                     ndims, nvars
d      1  1.6667e-2 time                                                                                hours since
d      2      100.0 lev                                                                                 Pa
d      3        1.0 lat                                                                                 km or deg
d      4        1.0 lon                                                                                 km or deg
d      5      100.0 lev                                                                                 Pa
d      6      100.0 lev                                                                                 Pa
v 4  2 1        1.0    HGT   H                                                                          gpm
v 4  2 2        1.0   UGRD   U                                                                          m/s
v 4  2 3        1.0   VGRD   V                                                                          m/s
v 4  5 4        1.0   VVEL   OMEGA                                                                      Pa/s
v 4  2 5        1.0    TMP   T                                                                          K
v 4  6 30       1.0     RH   RH                                                                         %
v 4  6 31       1.0   SPFH   SH                                                                         kg/kg
```

NASA GEOS-5 Np (0.25/0.3125°) ::
`GEOS.fp.fcst.inst3_3d_asm_Np.YYYYMMDD_00+YYYYMMDD_mmmm.V01.nc4`
`nGNp_template.txt`

```
1 1 -150.0 90.0 0.933 6371.229                                                                          Projection params line
3.0                                                                                                     Time interval
6 7                                                                                                     ndims, nvars
d      1  1.6667e-2 time                                                                                hours since
d      2      100.0 lev                                                                                 Pa
d      3        1.0 lat                                                                                 km or deg
d      4        1.0 lon                                                                                 km or deg
d      5      100.0 lev                                                                                 Pa
d      6      100.0 lev                                                                                 Pa
v 4  2 1        1.0    HGT   H                                                                          gpm
v 4  2 2        1.0   UGRD   U                                                                          m/s
v 4  2 3        1.0   VGRD   V                                                                          m/s
v 4  5 4        1.0   VVEL   OMEGA                                                                      Pa/s
v 4  2 5        1.0    TMP   T                                                                          K
v 4  6 30       1.0     RH   RH                                                                         %
v 4  6 31       1.0   SPFH   SH                                                                         kg/kg
```