CONCORDE Meteorological Analysis (CMA)

Data Guide

April 2018

Version 1.0

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1. Introduction

CONCORDE is the CONsortium for oil spill exposure pathways in COastal River-Dominated Ecosystems (CONCORDE), and is an interdisciplinary research program funded by the Gulf of Mexico Research Initiative (GoMRI) to conduct scientific studies of the impacts of oil, dispersed oil and dispersant on the Gulf's ecosystem (Greer et al. 2018). A CONCORDE goal is to implement a synthesis model containing circulation and biogeochemistry components of the Northern Gulf of Mexico shelf system which can ultimately aid in prediction of oil spill transport and impacts.

The CONCORDE Meteorological Analysis (CMA) is an hourly gridded NetCDF dataset which provides atmospheric forcing for the synthesis model. CMA includes a variety of parameters from multiple sources. The Real-Time Mesoscale Analysis (RTMA; De Pondeca et al. 2011) provides the surface momentum and the thermodynamic atmospheric data. The radiation parameters and total cloud cover percentage are from the North American Mesoscale (NAM) Forecast System fields. The hourly precipitation is extracted from the Next Generation Weather Radar (NEXRAD) Level-III. Gridded sea surface temperature fields (SST) are computed daily using a 10-day running mean of the Advanced Very High-Resolution Radiometer (AVHRR) SST product. The Coupled Ocean-Atmosphere Response Experiment flux (COARE) algorithm calculates sensible heat flux and surface momentum stresses (Fairall et al. 2003).

CMA's spatial domain's lowest west grid point is at 90.13°W, 29°N, and the highest east grid point is at 87.05°W, 30.94°N. The grid spacing is 0.01 degree, and the grid dimension is 309 by 195.

1.1. Contacts

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2. Installation

2.1. CMA Directory Structure

2.1.1. Main Directory

The main CONCORDE directory is "Concorde-final" here. It is represented by the variable "$CONCORDE_DIR" in the rest of the data guide.

The "AVHRR" directory contains data processing scripts for sea surface temperature.

The "COARE-3_Flux" directory contains the FORTRAN flux algorithm and the main CMA data processing scripts.

The "data" directory has CONCORDE domain grid information, gridded NetCDF NaN file and ASCII zero text file for NEXRAD initialization, and the NetCDF distance mask file for NEXRAD processing.

The "download" directory stores all downloaded and processed data files.

The "java" directory has NetCDF java archive (jar) and other java classes.

The "metForce" directory stores temporary files during data processing.

The "NAM" directory contains scripts to process NAM data.

The "NEXRAD" directory contains scripts to process NEXRAD Level III data.

The "RTMA" directory contains scripts to process "RTMA" data.

The "wct-3.7.9" directory has NOAA's Weather and Climate Toolkit to process NEXRAD radar data into gridded NetCDF data file.

2.1.2. Download Directory

The "download" directory has auto-generated monthly subdirectories ("YYYYMM"). Each monthly directory has daily subdirectories ("YYYYMMDD"). Each daily directory stores hourly files for the day.

The "AVHRR" directory contains downloaded SST NetCDF data files, and a script to break the data file with multiple days into daily SST NetCDF files.

The "NAM" and "RTMA" directories have a subdirectory named "NOAA-HDSS-HAS". It contains a script to download data from NOAA's HDSS Access System, and stores the downloaded data files.

The "NEXRAD-KLIX-DAA" and "NEXRAD-KMOB-DAA" directories have an "ucarThredds" subdirectory. It has scripts to download data as well as storing temporary and processed data for radar stations KLIX and KMOB respectively.

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2.2. Other Software Requirements

2.2.1. Climate Data Operators (CDO)

CDO can be downloaded from https://code.mpimet.mpg.de/projects/cdo. Version cdo-1.7.1 was used to generate the CMA data files. See the following version information at the development site.

```
cdo -V
Climate Data Operators version 1.7.1 (http://mpimet.mpg.de/cdo)
Compiled: by joey on Viking2.HPC.MsState.Edu (x86_64-unknown-linux-gnu) Jul
1 2016 08:35:52
Compiler: gcc -std=gnu99 -g -O2 -fopenmp
 version: gcc (GCC) 4.9.3
Features: DATA PTHREADS OpenMP4 HDF5 NC4/HDF5 OPeNDAP Z UDUNITS2 PROJ.4 SSE2
Libraries: HDF5/1.10.0 proj/4.8
Filetypes: srv ext ieg grb nc nc2 nc4 nc4c
     CDI library version : 1.7.1 of Jul  1 2016 08:35:06
 CGRIBEX library version : 1.7.4 of Feb 19 2016 11:03:41
  NetCDF library version : 4.4.1 of Jun 30 2016 08:52:50 $
    HDF5 library version : 1.10.0
 SERVICE library version : 1.4.0 of Jul  1 2016 08:34:53
   EXTRA library version : 1.4.0 of Jul  1 2016 08:34:48
     IEG library version : 1.4.0 of Jul  1 2016 08:34:51
    FILE library version : 1.8.2 of Jul  1 2016 08:34:49
```

2.2.2. curl

curl version 7.19.7 was used to download CMA data files.

2.2.3. FORTRAN Compiler

FORTRAN compiler pgf90 was used to compile the COARE algorithm. But, other FORTRAN compiler should work as well.

2.2.4. JAVA and netcdfAll-4.5.jar

Java version 1.7.0_65 was used to process the CMA data files. In addition, the java NetCDF archive "netcdfAll-4.5.jar" was used.

2.2.5. ncdump

ncdump is one of the NetCDF utilities. CMA used it to convert time information of the NetCDF files into ASCII text for processing.

2.2.6. NetCDF Operators (NCO)

NCO can be downloaded from http://nco.sourceforge.net/. Version nco-4.6.0 was used to generate the CMA data files.

2.2.7. PERL and Date:Calc Module

Perl version v5.10.1 was used to process the CMA data files. The Date:Calc module evaluated the dates needed for the SST running mean.

2.2.8. PERL Scripts "get_inv.pl" and "get_grib.pl"

The PERL scripts "get_inv.pl" and "get_grib.pl" allow fast downloading of grib files by doing partial http transfers. User acquires the grib file inventory first, and subsets the desired records in the grib file accordingly. These scripts are included in the "$CONCORDE_DIR/NAM" directory. Information about them can be found at http://www.cpc.ncep.noaa.gov/products/wesley/fast_downloading_grib.html.

2.2.9. Weather and Climate Toolkit (WCT)

NOAA's Weather and Climate Toolkit (WCT) is used for batch processing of NEXRAD Level III data to generate gridded precipitation values. Version wct-3.7.9 of the software is included in the "$CONCORDE_DIR" directory. Information about it can be found at https://www.ncdc.noaa.gov/wct/.

2.2.10. wget

GNU wget version 1.12 was used to download CMA data files.

2.2.11. wgrib2

wgrib2 information can be found at http://www.cpc.ncep.noaa.gov/products/wesley/wgrib2/index.html. Version v0.2.0.2 3/2015 was used to generate the CMA data files.

3. Real-Time Mesoscale Analysis (RTMA)

The Real-Time Mesoscale Analysis (RTMA) provides the surface momentum and the thermodynamic atmospheric data. These data include the surface pressure, 2-m temperature, 2-m dewpoint, 10-m wind speed, 10-m wind direction, 10-m u component of wind, and 10-m v component of wind. In addition, the relative humidity is calculated using the pressure, temperature, and dewpoint data.

RTMA (De Pondeca et al. 2011) is a 2.5-km 2DVAR product which uses the High Resolution Rapid Refresh (HRRR) model forecast (Benjamin et al. 2016) for the background field, adjusted with surface observations and a non-isotropic recursive filter (Purser et al. 2003). The RTMA data assimilation procedure matches observed surface data, captures mesoscale and diurnal patterns, and provides a coherent field that best matches the geographically-related features.

3.1. Automated Data Download and Processing

The archive for automated RTMA data download (https://nomads.ncdc.noaa.gov/data/ndgd/) stores data from September 2008 to the current month.

The directory "RTMA" ("$CONCORDE_DIR/RTMA") contains scripts to download and process the RTMA data. These scripts can download monthly data as well as daily data. The data files stored in the archive are in grib2 format. The scripts process the data files and output them in NetCDF format.

The script "prepareRTMA1MonthNetcdfFiles.sh" accepts 2 input arguments:
1. The year and month of the data in YYYYMM format
2. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "prepareRTMA24HrsNetcdfFiles.sh" to download and process the data one day at a time.

The script "prepareRTMA24HrsNetcdfFiles.sh" accepts 2 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally as well as the proper web link. Then, it loops to download and process the hourly data files. The processing steps for each hour are as follows:

Loop six times to process each RTMA variable individually from Step 1 to Step 4.
1. Download one archive file named "L?IA98_KWBR_YYYMMDDHH00" where IA is the Contiguous United States (Conus) 2.5km resolution grid, and ? is the variable N, P, R, T, U, or V.
   N = 10m wind speed in m/s and direction in degT from True North
   P = surface pressure in Pa
   R = 2m dew point in Kelvin
   T = 2m temperature in Kelvin
   U = u component of wind in m/s
   V = v component of wind in m/s
   This file is renamed to "rtma_YYYYMMDDHH_?.grb2" in the local directory.
2. Subset the grib2 data file to a smaller grid
3. Convert the grib2 data file into NetCDF format

4. Subset and interpolate the NetCDF data file into the CONCORDE domain using bilinear interpolation ("rtma_YYYYMMDDHH _?_MS.nc")
5. Combine the individual NetCDF data files into one data file
6. Calculate the relative humidity (rha) in percentage (0-100) using the formulas in CDO scripts "calc_e_es" and "calc_rha_rhp"
7. Merge relative humidity to the final data file ("rtma_YYYYMMDDHH_MS.nc")

Six RTMA variable files ("rtma_YYYYMMDDHH_?_MS.nc" where ? is N, P, R, T, U, V) should exist for each hour under directory "download/YYYYMM/YYYYMMDD". The user should check if all the files have been downloaded and processed successfully. If any file is missing, see section 3.2. for instruction on downloading missing files.

3.2. Alternate Archive Data Download and Processing

If the hourly RTMA data files for some variables (N, P, R, T, U, V) are missing in the web link mentioned in section 3.1., you may be able to recover them (2.5 km, L?I) or get a lower resolution version (5 km, L?M) of the same variables at NOAA's National Centers for Environmental Information (NCEI) Archive Information Request System (AIRS) with web link https://www.ncdc.noaa.gov/has/HAS.FileAppRouter?datasetname=9950_01&subqueryby=STATION&applname=&outdest=FILE. The 9950_01 datasetname code is not documented, but we speculate it represents the 0.995 sigma level for "near-surface" products.

However, there is no immediate download from this archive. The user must request the data with a valid email address, and wait for an email confirmation. Each data request is assigned a HDSS Access System (HAS) number. See the example below for downloading temperature (LTI):

1. Select WMO header, enter date range and email address. Click "Proceed With Order" button.

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2. Choose all or select specific tar files to download. Also, there is an option to order specific items within the tar files. Click "Proceed With Order" button.

■ National Digital Guidance Database (NDGD)

There are 2 files available for ordering (369,315,840 bytes of data).

Choose From Order Options

○ Order All Available Files

- OR -

◉ Order Specific Files Only (make selections below)

```
9950_NDGD_LTI_20180205.tar - 177274880
9950_NDGD_LTI_20180206.tar - 192040960
```

Would you like to order specific items within the tar files selected? Item selection will be provided on the next page.
YES○ / NO◉

Proceed With Order

3. If you selected "YES" to order specific items within the tar files, you will see the following page showing individual file names and their corresponding file sizes. Select the items you want, and click "Proceed With Order" Button.

■ National Digital Guidance Database (NDGD)

Choose From Order Options

○ Order All Available Files

- OR -

◉Order Specific Files Only (make selections below)

```
LTIA98_KWBR_201802050000 - 7384539
LTIA98_KWBR_201802050100 - 7384539
LTIA98_KWBR_201802050200 - 7384539
LTIA98_KWBR_201802050300 - 7384539
LTIA98_KWBR_201802050400 - 7384539
LTIA98_KWBR_201802050500 - 7384539
LTIA98_KWBR_201802050600 - 7384539
LTIA98_KWBR_201802050700 - 7384539
LTIA98_KWBR_201802050800 - 7384539
LTIA98_KWBR_201802050900 - 7384539
```

Proceed With Order

4. A HAS order number will be assigned to your order.

The processing directory for these RTMA data files from HAS is located at "$CONCORDE_DIR/download/RTMA/NOAA-HDSS-HAS". If downloading only one HAS number, you can download an exact copy of the data directory by using the following command

```
wget -erobots=off -nv -m -np -nH --cut-dirs=2 --reject "index.html*"
https://www1.ncdc.noaa.gov/pub/has/$HAS/
```

where $HAS is the actual HAS number assigned to your order.

If multiple HAS orders exist, you can create a file with all the HAS numbers in it. Then, you use the script "wgetOrderGroup.sh" with the file you just created to download all the HAS directories and data files.

If tar files are selected, then the ordered files come zipped up like "9950_NDGD_Lvarres_YYYYMMDD.tar" where $var is the variable N, P, R, T, U, V and $res is the grid resolution I or M. You should untar all of them. If specific files are selected, then one or more directories "00*" and data files "LvarresA98_KWBR_YYYYMMDDHH" along with its corresponding "fileList.txt" file would be downloaded.

Finally, you must process these files with the following scripts under "$CONCORDE_DIR/RTMA". The correct output directory should be "$CONCORDE_DIR/download/YYYYMM/YYYYMMDD". However, you can output to temporary directory "$CONCORDE_DIR/RTMA/processedMissingHrs", and then copy or move the files to the correct output directory using the scripts "copy.sh" or "move.sh".

    a. "prepareRTMAHourlyNetcdfFilesFromHAS.sh" - process one time stamp of all the variables (N, P, R, T, U, V)
This script accepts 4 input arguments:
      1. YYYYMMDDHH is the time stamp to be processed
      2. Resolution ID is IA (conus 2.5km) or MA (conus 5km)
      3. HAS directory storing the data files of all variables
      4. Output directory for the output files

    b. "prepareRTMAMissingHrsNetcdfFilesFromHAS.sh" - process a group of time stamps of a particular variable
This script accepts 5 input arguments:
      1. File name containing rows of missing time stamps in YYYYMMDDHH format
      2. Variable name, one of N, P, R, T, U, or V

3. Resolution ID is IA (conus 2.5km) or MA (conus 5km)
4. HAS directory storing all the data files
5. Output directory for the output files

c. "prepareRTMAHourlyNetcdfFilesFromHAS-1var.sh" - process one time stamp of a particular variable
This scripts accepts 5 input arguments:
1. YYYYMMDDHH is the time stamp to be processed
2. Variable name, one of N, P, R, T, U, or V
3. Resolution ID is IA (conus 2.5km) or MA (conus 5km)
4. HAS directory storing the data file
5. Output directory for the output file

For b and c above, you must run the script "prepareRTMA24HrsNetcdfFiles-mergeOnly.sh" afterwards.

d. "prepareRTMA24HrsNetcdfFiles-mergeOnly.sh" – loop to calculate the hourly relative humidity and combine all the hourly data files of the different variables together into one file named "rtma_YYYYMMDDHH_MS.nc"
This script accepts 2 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The main CONCORDE directory

4. North American Mesoscale (NAM) Forecast System

The North American Mesoscale (NAM) Forecast System provides the downward short-wave radiation flux (DSWRF) in W/m^2, the downward long-wave radiation flux (DLWRF) in W/m^2, and the total cloud cover percentage (TCDC) (0-100%). Except for the model initialization times, these are short-term forecast fields.

4.1. Automated Data Download and Processing

The archive for automated NAM data download (https://nomads.ncdc.noaa.gov/data/meso-eta-hi/) stores data for the last 11 months. NOAA's National Weather Service Climate Prediction Center provides 2 PERL scripts ("get_inv.pl" and "get_grib.pl") to perform fast downloading of GRIB files with partial http transfers at http://www.cpc.ncep.noaa.gov/products/wesley/fast_downloading_grib.html. CMA's NAM daily processing script utilizes these PERL scripts to subset variables and saves downloading time.

The directory "NAM" ("$CONCORDE_DIR/NAM") contains scripts to download and process the NAM data. These scripts can download monthly data as well as daily data. The data files stored in the archive are in grib2 format. The scripts process the data files and output them in NetCDF format.

The script "prepareNAM1MonthNetcdfFiles.sh" accepts 2 input arguments:
1. The year and month of the data in YYYYMM format
2. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "prepareNAM24HrsNetcdfFiles-partialGrb2.sh" to download and process the data one day at a time.

The script "prepareNAM24HrsNetcdfFiles-partialGrb2.sh" accepts 2 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally as well as the proper web link. Then, it loops to download and process the hourly data files. The processing steps for each hour are as follows:

1. Use "get_inv.pl" to get the inventory of the grib2 data file, and subset the correct variables using "get_grib.pl" into the hourly grib2 data file locally ("nam_218_YYYYMMDDHH.grb2")
   The NAM data files are in 6-hourly cycle hours. Hence,

Archive Filename	Local Filename
nam_218_YYYYMMDD_0000_000	nam_218_YYYYMMDD00.grb2
nam_218_YYYYMMDD_0000_001	nam_218_YYYYMMDD01.grb2
:	:
nam_218_YYYYMMDD_0000_005	nam_218_YYYYMMDD05.grb2
nam_218_YYYYMMDD_0600_000	nam_218_YYYYMMDD06.grb2
:	:
nam_218_YYYYMMDD_0600_005	nam_218_YYYYMMDD11.grb2
nam_218_YYYYMMDD_1200_000	nam_218_YYYYMMDD12.grb2
:	:
nam_218_YYYYMMDD_1200_005	nam_218_YYYYMMDD17.grb2
nam_218_YYYYMMDD_1800_000	nam_218_YYYYMMDD18.grb2
:	:
nam_218_YYYYMMDD_1800_005	nam_218_YYYYMMDD23.grb2

2. Convert the grib2 data file into NetCDF format
3. Rename variables in the NetCDF file to shorter names
4. Subset and interpolate the NetCDF data file into the CONCORDE domain using bilinear interpolation ("nam_218_YYYYMMDDHH_MS.nc")

However, the inventory files (*.inv) may be missing at times at the web site. If this happens, the above scripts would not be able to download any NAM data. CMA provides the script "prepareNAMHourlyNetcdfFilesFromMesoEtaHi.sh" to download and process individual time stamp when the grib2 data file exists, but the corresponding inventory file is missing. This script has to download the entire grib2 data file and subset the variables locally.

The script "prepareNAMHourlyNetcdfFilesFromMesoEtaHi.sh" accepts 2 input arguments:
1. The year, month, day, and hour of the data in YYYYMMDDHH format
2. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally as well as the proper web link. Then, it downloads and processes the hourly data file as follows:

1. Figure out the correct grib2 data file (cycle hour and forecast time) of the desired time stamp, and download it locally ("nam_218_YYYYMMDDHH.grb2")
2. Subset the variables
3. Convert the grib2 data file into NetCDF format
4. Rename variables in the NetCDF file to shorter names
5. Subset and interpolate the NetCDF data file into the CONCORDE domain using bilinear interpolation ("nam_218_YYYYMMDDHH_MS.nc")

Hourly NAM NetCDF file ("nam_218_YYYYMMDDHH_MS.nc") for each day should exist under directory "download/YYYYMM/YYYYMMDD". The user should check if all the hourly files have been downloaded and processed successfully. If any file is missing, see section 4.2. for instruction on downloading missing files.

4.2. Alternate Archive Data Download and Processing

If the hourly NAM data files are missing in the web link mentioned in section 4.1, you may be able to recover them at NOAA's National Centers for Environmental Information (NCEI) Archive Information Request System (AIRS) with this web link:
https://www.ncdc.noaa.gov/has/HAS.FileAppRouter?datasetname=NAM218&subqueryby=STATION&applname=&outdest=FILE.

However, there is no immediate download from this archive. The user must request the data with a valid email address, and wait for an email confirmation. Each data request is assigned a HDSS Access System (HAS) number. See the example below for downloading an entire NAM file:

1. Select cycle hours (see section 4.1. on page 10 for the description of the cycle hour and forecast hour corresponding to the hour of the day), enter date range and email address. Click "Proceed with Order" button.

■ North American Meso-scale model Grid 218

Select UTC Cycle (Hour)

```
00 (02/03/2005 - 03/14/2018)
03 (12/14/2007 - 12/14/2007)
06 (02/15/2005 - 03/14/2018)
09 (12/14/2007 - 12/14/2007)
```

Select Start Date (YYYY/MM/DD)
```
2018   /  02   /  05
```
Select End Date: (YYYY/MM/DD)
```
2018   /  02   /  06
```

Delivery Destination: FTP

Submit Batch (skip file selection)?: ○ Yes ◉ No

Email Address
```
lau@gri.msstate.edu
```

Important Notes:
-- If your data request will contain more than 2,000 files, you must select "Yes" for the Submit Batch option above.
  -- There is a data volume limit of 250 Gigabytes per request.

[Proceed With Order] [Reset Form]

2. Choose all or select specific tar files with data file sizes. Click "Proceed with order" button.

■ North American Meso-scale model Grid 218

There are 4 files available for ordering (12,194,713,600 bytes of data).

Choose From Order Options

○ Order All Available Files

- OR -

◉ Order Specific Files Only (make selections below)

```
nam_218_2018020500.g2.tar - 3074764800
nam_218_2018020600.g2.tar - 3031255040
nam_218_2018020506.g2.tar - 3060561920
nam_218_2018020606.g2.tar - 3028131840
```

[Proceed With Order]

3. A HAS order number will be assigned to your order.

Order Submitted

Your data request has been submitted.
An email with a link to the requested data will be sent when processing is complete.

ORDER INFORMATION		
Order Number:	HAS011079239	Check order status
Requested Data:	North American Meso-scale model Grid 218	
Email Address:	lau@gri.msstate.edu	
Date Submitted:	2018-03-15 03:13:53	

The processing directory for these NAM data files from HAS is located at "$CONCORDE_DIR/download/NAM/NOAA-HDSS-HAS". If downloading only one HAS number, you can download an exact copy of the data directory by using the following command
```
wget -erobots=off -nv -m -np -nH --cut-dirs=3 --reject "index.html*"
https://www1.ncdc.noaa.gov/pub/has/model/$HAS/
```
where $HAS is the actual HAS number assigned to your order.

If multiple HAS orders exist, you can create a file with all the HAS numbers in it. Then, you use the script "wgetOrderModelGroup.sh" with the file you just created to download all the HAS data files. The ordered files come zipped up like "nam_218_YYYYMMDDHH.g2.tar" where HH is the cycle hour of 00, 06, 12 or 18.

Once all the HAS tar files are downloaded, you can untar just the first 6 hours of each tar file using
```
tar -xvf $tarFile --wildcards "*_000.grb2" "*_001.grb2" "*_002.grb2"
"*_003.grb2" "*_004.grb2"
```

Finally, you must process these files with the following scripts under "$CONCORDE_DIR/NAM". The correct output directory should be "$CONCORDE_DIR/download/YYYYMM/YYYYMMDD". However, you can output to temporary directory "$CONCORDE_DIR/NAM/processedMissingHrs", and then copy or move the files to the correct output directory using the scripts "copy.sh" or "move.sh".

a. "prepareNAMMissingHrsNetcdfFiles.sh" - process a group of time stamps
   This script accepts 3 input arguments:
   1. File name containing rows of missing time stamps in YYYYMMDDHH format
   2. HAS directory storing all the data files
   3. Output directory for the output files

b. "prepareNAMHourlyNetcdfFilesFromHAS.sh" - process one missing time stamp
   This scripts accepts 3 input arguments:
   1. YYYYMMDDHH is the time stamp to be processed
   2. HAS directory storing the data file
   3. Output directory for the output file

5. Next Generation Weather Radar (NEXRAD) Level-III

The Next Generation Weather Radar Level-III provides the hourly precipitation totals on a 0.24-km by 1-deg grid (256 Level / 230 km) based on a dual polarization Quantitative Precipitation Estimate (QPE) algorithm. CMA utilized data from two National Doppler Radar Sites: KLIX in New Orleans, LA, and KMOB in Mobile, AL. The distances from each grid point of the CONCORDE domain to both KLIX and KMOB were calculated, then a reusable NetCDF mask file for the grid ("$CONCORDE_DIR/data/KLIX_KMOB_mask.nc") was created to identify the closest radar site to use for each grid point. Based on which site has closer proximity to the analysis grid point, the data is interpolated by nearest neighbor.

Depending on whether the radar is in clear air mode or precipitation mode, NEXRAD data files exist every 5-10 minutes. However, CMA uses only the data file closest in time to the top of each hour because the data represents hourly precipitation accumulation.

5.1. Automated Data Download and Processing

The most recent (last 30 days) NEXRAD Level III data can be obtained from UCAR THREDDS at https://thredds-jumbo.unidata.ucar.edu/thredds/catalog/nexrad/level3/DAA/catalog.html. Two convenient scripts under "$CONCORDE_DIR/download/NEXRAD-KLIX-DAA/ucarThredds/"and "$CONCORDE_DIR/download/NEXRAD-KMOB-DAA/ucarThredds/" can be used to download them.

The script "wgetMonthlyCatalogLevel3Data.sh" accepts 2 input arguments:
1. The year and month of the data in YYYYMM format
2. The radar site, either LIX or MOB

This script finds out the number of days for the month, and loops to call the script "wgetDailyCatalogLevel3Data.sh" to download and process the data one day at a time.

The script "wgetDailyCatalogLevel3Data.sh" accepts 2 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The radar site, either LIX or MOB

This script downloads the THREDDS catalog collection of the radar site for the entire date, and puts everything in a subdirectory with the same date name. Then, it creates a text file ("fileList.txt") with the actual archive file names in the file server. Finally, it loops to read each file name and download the data.

After the data files are downloaded from both radar sites, you can start processing them in the directory "$CONCORDE_DIR/NEXRAD".

The script "prepareNexradLvl3OneMonthDailyPrecip1HrFiles-ucarThredds.sh" accepts 3 input arguments:
1. The year and month of the data in YYYYMM format
2. The radar site, either LIX or MOB
3. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "prepareNexradLvl3DailyPrecip1HrFiles-wct-ucarThredds.sh" to process the data one day at a time.

The script "prepareNexradLvl3DailyPrecip1HrFiles-wct-ucarThredds.sh" accepts 6 input arguments:
1. The input data directory

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2. The full path to the "fileList.txt" file
3. The prefix (before the date) of the file names in "fileList.txt" ("Level3_[LIX|MOB]_DAA_")
4. The new prefix of the output file names, ("K[LIX|MOB]_SDUS84_DAA[LIX|MOB]_")
5. The year, month, day of the data in YYYYMMDD format
6. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally. It creates a file of file names with time stamps closest in time to the top of the hour of each hour of the day. Then, it loops to process each hourly file as follows:

1. Check file size to make sure it has some data in it
2. Use NOAA's Weather and Climate Toolkit (WCT) to export the NEXRAD data to a gridded NetCDF data file. The CONCORDE grid specification is inside "wctConcordeConfig.xml".
3. Change the precipitation values from "inch/hr" to "mm/hr"
4. Change the variable name of "daa" to "precip1Hr"
5. Add "long_name" for longitude, latitude, precip1Hr, and add unit of "mm/hr" to precip1Hr
6. Set and fill missing value to NaN
7. Subset and interpolate the NetCDF data files into the CONCORDE domain using near neighbor ("K[LIX|MOB]_SDUS84_DAA[LIX|MOB]_YYYYMMDDHH_MS.nc")

5.2. Alternate Archive Data Download and Processing

Older NEXRAD Level III DAA data can be obtained from archive by submitting data request at https://www.ncdc.noaa.gov/nexradinv/chooseday.jsp?id=klix and https://www.ncdc.noaa.gov/nexradinv/chooseday.jsp?id=kmob. Again, there is no immediate download from this archive. User must request the data with a valid email address, and wait for an email confirmation. Each data request is assigned a HAS number. See the example below.

1. Set the date and filter "DAA" product. Then click the "Create Graph" button as shown below.

NEXRAD Inventory: Choose Day and Product

KLIX - NEW ORLEANS, LA
(Site Metadata)

Period of Record:
Level-II: 05/16/1995 to 03/14/2018
Level-III: 01/03/1995 to 03/12/2018

Examine Inventory:
Choose Date: 03 ▾ 01 ▾ 2018 ▾ 🗓 (GMT)

Choose Product:
L3 [DAA] - One Hour Precipitation (Dual Pol.) (256 Level / 230 KM)

Product Filter: DAA   Clear

Create Graph

2. Enter your email address, and click the "Order Data" button as shown below.

NEXRAD Inventory: View Results and Order Data

KLIX - NEW ORLEANS, LA
(Site Metadata)

Period of Record:
Level-III: 01/03/1995 to 03/12/2018

02 / 28 / 2018   **03 / 01 / 2018**   03 / 02 / 2018

**LVL3 – ONE HOUR PRECIPITATION
(DUAL POL.) (256 LEVEL / 230 KM)**

00:00   02:00   04:00   06:00   08:00   10:00   12:00   14:00   16:00   18:00   20:00   22:00   00:00
KLIX   03/01/2018   Timezone: GMT

— Clear Air Mode — Precip Mode — Maintenance Mode — Unknown Mode

Enter Email Address: lau@gri.msstate.edu

Start Time: 00:00 GMT ▾   End Time: 24:00 GMT ▾

Order Data

3. Then, you will be given a HAS order number. Once the order is completed, you will receive an email to pick up your data.

NEXRAD Inventory - Order Submission Complete

Order Number: #011079071

You will receive an email within 5 - 25 minutes when your order is ready.
The data will be available on an NCEI FTP site and HTTP web server. Radar data is raw binary data and another program is needed to visualize the data. NCEI provides a free application to view Radar data, save images and export the data to other formats. For more information on this visualization software, please refer to the NOAA Weather and Climate Toolkit.

- Order another day of the same product?
- Order a different product from KLIX
- Select a different site? (From Map) - (From List)
- Track the status of this order.

The processing directory for these NEXRAD data files from HAS is located at "$CONCORDE_DIR/download/NEXRAD-KLIX-DAA" and "$CONCORDE_DIR/download/NEXRAD-KMOB-DAA". If downloading only ones HAS number, you can download an exact copy of the data directory by using the following command
```
wget -erobots=off -nv -m -np -nH --cut-dirs=2 --reject "index.html*"
https://www1.ncdc.noaa.gov/pub/has/$HAS/
```
where $HAS is the actual HAS number assigned to your order.

If multiple HAS orders exist, you can create a file with all the HAS numbers in it. Then, you use the script "wgetOrderGroup.sh" with the file you just created to download all the HAS directories and data files.

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Once all the HAS data files are downloaded, you must create a symbolic link of each HAS data directory to the date it represents using "linkDir.sh".
linkDir.sh HAS011079071 -- for one HAS order number
linkDir.sh HAS01107907   -- for a group of HAS order numbers with the same prefix

Finally, you are ready to process them in the directory "$CONCORDE_DIR/NEXRAD".

The script "prepareNexradLvl3OneMonthDailyPrecip1HrFiles.sh" accepts 3 input arguments:
1. The year and month of the data in YYYYMM format
2. The radar site, either LIX or MOB
3. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "prepareNexradLvl3DailyPrecip1HrFiles-wct.sh" to process the data one day at a time.

The script "prepareNexradLvl3DailyPrecip1HrFiles-wct.sh" accepts 5 input arguments:
1. The input data directory ("$CONCORDE_DIR/download/NEXRAD-K[LIX|MOB]-DAA/YYYYMMDD")
2. The full path to the "fileList.txt" file ("$CONCORDE_DIR/download/NEXRAD-K[LIX|MOB]-DAA/YYYYMMDD/fileList.txt")
3. The prefix of the data files ("K[LIX|MOB]_SDUS84_DAA[LIX|MOB]_")
4. The year, month, day of the data in YYYYMMDD format
5. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally. It creates a file of file names with time stamps closest in time to the top of the hour of each hour of the day. Then, it loops to process each hourly file as follows:
1. Check file size to make sure it has some data in it
2. Use NOAA's Weather and Climate Toolkit (WCT) to export the NEXRAD data to a gridded NetCDF data file. The CONCORDE grid specification is inside "wctConcordeConfig.xml".
3. Change the precipitation values from "inch/hr" to "mm/hr"
4. Change the variable name of "daa" to "precip1Hr"
5. Add "long_name" for longitude, latitude, precip1Hr, and add unit of "mm/hr" to precip1Hr
6. Set and fill missing value to NaN
7. Subset and interpolate the NetCDF data files into the CONCORDE domain using near neighbor ("K[LIX|MOB]_SDUS84_DAA[LIX|MOB]_YYYYMMDDHH_MS.nc")

6. Advanced Very High-Resolution Radiometer (AVHRR) SST

The Advanced Very High-Resolution Radiometer (AVHRR) is a broad-band, four or five channel (depending on the model) scanner, sensing in the visible, near-infrared, and thermal infrared portions of the electromagnetic spectrum. This sensor is carried on NOAA's Polar Orbiting Environmental Satellites (POES). Each pass of the satellite provides a 2399 km (1491 mi) wide swath. The satellite orbits the earth 14 times each day. The average instantaneous field-of-view yields a ground resolution of approximately 1.1 km at the satellite nadir from the nominal orbit altitude of 833 km. More information is at https://lta.cr.usgs.gov/1km/avhrr_sensor.

One AVHRR product provides high-resolution SST data based on empirically-derived algorithms. These schemes blend a regression procedure with a decision tree of quality assessment for cloud contamination, suspect retrievals, etc. (Kilpatrick et al. 2001). The NOAA AOML SST data will have missing data at grid points due to cloud cover, the intermittent polar-orbit satellites passes, and gaps between the satellite swaths. To minimize this problem, CMA computes daily SST values using a 10-day running mean instead (5 days before, the current date, and 4 days after).

6.1. Data Download and Processing

The AVHRR SST product can be downloaded from the archive at http://cwcgom.aoml.noaa.gov/thredds/ncss/grid/AVHRRSST/SST.nc/dataset.html as seen below.

Select "sst", enter the bounding box values, specify the starting and ending time range, check "Add Lat/Lon variables", and click the "Submit" button.

NetCDF Subset Service for Grids

Dataset: /thredds/ncss/grid/AVHRRSST/SST.nc

Base Time: 2018-01-01T00:00:00Z

Gridded Dataset Description
As Point Dataset

Select Variable(s): **Choose Spatial Subset:**

☑ sst

○ All
⦿ Bounding Box (decimal degrees):

North

`31`

West `-91`   `-87` East

`29`

South

Choose Time Subset:

○ All
⦿ Time Range:

Starting: `2018-01-01T00:00:00Z`
Ending: `2018-02-04T00:00:00Z`

Horizontal Stride:

`           `

Add Lat/Lon to file
☑ Add Lat/Lon variables

[Submit] [Reset]

Once submitted, a NetCDF SST data file (SST.nc) will be downloaded instantaneously. This data file contains all the available time stamps requested. So, it must be broken down into daily files. Under "$CONCORDE_DIR/download/AVHRR", you can run the "getDailyAvhrrNetcdf.sh" script to create the daily files "avhrrSST_YYYYMMDD_MS.nc" in directory "$CONCORDE_DIR/download/YYYYMM/YYYYMMDD/".

The script "getDailyAvhrrNetcdf.sh" accepts 3 input arguments:
1. The downloaded NetCDF SST data file
2. The prefix of the daily files, use "avhrrSST"
3. The main CONCORDE directory

6.2. Ten-Day Running Mean Processing

The daily 10-day running mean data files can be created using the scripts under "$CONCORDE_DIR/AVHRR".

The script "prepareAvhrrSST1MonthNetcdfFile-Avg10days.sh" accepts 2 input arguments:
1. The year and month of the data in YYYYMM format
2. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "prepareAvhrrSSTDailyNetcdfFile-AvgDays.sh" script to calculate the mean one day at a time.

The script "prepareAvhrrSSTDailyNetcdfFile-AvgDays.sh" accepts 3 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The main CONCORDE directory
3. The number of days to be included in the mean, use "10"

This script has several processing steps as follows:
1. Set up the correct subdirectory ("download/YYYYMM/YYYYMMDD") locally
2. Loop to create a string of file names of the ten days to be averaged (current date=the date in input argument 1, the 5 days before the current date, and the 4 days after the current date)
3. Calculate the mean
4. Subset and interpolate the data file into the CONCORDE domain using distance-weighted average remapping ("avhrrSST_10DayAvg_remapdis_YYYYMMDD_MS.nc")

7. The Coupled Ocean-Atmosphere Response Experiment flux (COARE) algorithm

The Coupled Ocean-Atmosphere Response Experiment flux (COARE) algorithm calculates sensible heat flux and surface momentum stresses for zonal and meridional directions (Fairall et al. 2003). CMA uses FORTRAN version 3.0a of the algorithm at https://coaps.fsu.edu/COARE/flux_algor/.

7.1. FORTRAN Program

The FORTRAN source code of the algorithm is under "$CONCORDE_DIR/COARE-3_Flux/fortran_3.0". The command to compile may be different depending on your operating system and compiler. In our development site, we use the following command to compile, and produce the COARE algorithm executable "cor3_0af_allInput".

```
pgf90 -o cor3_0af_allInput cor3_0af_allInput.for cor30a.F90 grv.F90
nrtype.f90 nrutil.f90 julday.f90 nr.f90 psit_30.F90 psiu_30.F90 qsat.F90
qsee.F90
```

In normal circumstances, the user does not call the COARE algorithm directly. Convenient scripts (as described in section 7.2.) manage the data processing and COARE execution. Here, the input and output of the "cor3_0af_allInput" executable are listed for your reference. It accepts 2 input arguments:

1. Full path of the input text file name. This file should have a header line followed by rows of data. The header line has 5 values in number of meters as follows:
   1) Height of the wind (10)
   2) Height of the air temperature (2)
   3) Height of the relative humidity (2)
   4) Height of the standard measurement (10)
   5) Depth of the sea surface temperature (0.05)

   Each data row has 14 columns as follows:
   1) Time stamp in YYYYMNDDhhmmss.ss
   2) Wind in m/s
   3) Sea surface temperature in degC
   4) Air temperature in degC
   5) Relative humidity in decimal (0.0 to 1.0)
   6) Downward short wave radiation flux in Watts/m^2
   7) Downward long wave radiation flux in Watts/m^2
   8) Rain rate in mm/hr
   9) Latitude
   10) Longitude
   11) Alternative 6m depth sea temperature in degC (use missing value -99999.000000)
   12) Surface Pressure in mb
   13) U-component of wind in m/s
   14) V-component of wind in m/s

2. Full path of the output text file name. Each data row has 17 columns as follows:
   1) Data row number
   2) Time stamp in YYYYMNDDhhmmss.ss
   3) Latitude
   4) Longitude

5) Sensible heat flux in Watt/m^2
6) Latent heat flux in Watt/m^2
7) Skin temperature in degC
8) Wind stress (turbulent part) in N/m^2
9) Webb mean vertical velocity in m/s
10) Heat flux due to rainfall in Watt/m^2
11) Cool skin temperature difference in degC
12) Total warm layer temperature difference in degC
13) Thickness of warm layer
14) Cool skin thickness in meter
15) Gustiness factor in m/s
16) Surface U momentum stress in N/m^2
17) Surface V momentum stress in N/m^2

CMA uses only columns 3, 4, 5, 16 and 17 of the COARE algorithm output file.

7.2. Data Processing

The directory "$CONCORDE_DIR/COARE-3-Flux" contains scripts to create CMA data files in NetCDF format. These scripts can create monthly data as well as daily data.

The script "run1MonthCOARE3Flux.sh" accepts 2 input arguments:
1. The year and month of the data in YYYYMM format
2. The main CONCORDE directory

This script finds out the number of days for the month, and loops to call the script "run24HrsCOARE3Flux-5DayBefore4DayAfter-remapdis-rtma1By1.sh" to process the daily data.

The script "run24HrsCOARE3Flux-5DayBefore4DayAfter-remapdis-rtma1By1.sh" accepts 2 input arguments:
1. The year, month, day of the data in YYYYMMDD format
2. The main CONCORDE directory

This script sets up the correct subdirectory ("download/YYYYMM/YYYYMMDD"). It checks for the previously prepared 10-day running mean daily AVHRR NetCDF data file, and converts it to ASCII text. Then, it loops to process the hourly data files. The processing steps for each hour are as follows:

1. Check existence of the hourly RTMA NetCDF file, and convert it to ASCII text. Then, extract the relevant columns (wind, relative humidity, surface pressure, air temperature, u component and v component of wind), and convert variable units appropriately (relative humidity from percentage to decimal, pressure from Pa to mb, and temperature from Kelvin to degC)
2. Check existence of the hourly NAM NetCDF file, and convert it to ASCII text. Then, extract the relevant columns (downward short wave radiation flux and long wave radiation flux)
3. Check existence of the hourly KLIX and KMOB NEXRAD NetCDF files. If both exists, get a merged file using the mask file (previously prepared using shortest distance from each grid point to the radar sites). If none exists, use prepared NaN file. Then, convert it to ASCII text, and extract the precipitation column
4. Combine the extracted AVHRR, RTMA, NAM and NEXRAD column files into one hourly file
5. Run the COARE algorithm with the file from step 4, and produce hourly COARE output text file

6. Extract surface heat flux, surface U momentum stress and surface V momentum stress from the COARE output file separately, and create 3 different NetCDF files
7. Set date, time, missing value, fill value, name, unit, etc. for the newly created NetCDF files
8. Combines relevant variables from RTMA, NAM, AVHRR, NEXRAD, and the newly created NetCDF files into one final hourly CMA NetCDF data file ("Metforcing_YYYYMMDDHH.nc")

After all 24 hours have been processed, this script merges them together to create a convenient daily file ("Metforcing_YYYYMMDD_24Hrs.nc").

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