# Observations Lecture 1: Conventional observations and Observation Pre-processing for WRFDA (OBSPROC)

Michael J. Kavulich, Jr.

Special thanks to Jamie Bresch

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National Center for Atmospheric Research
Boulder, CO

# Overview

- Observations in WRFDA
  - Types
  - Formats
- LITTLE_R format and OBSPROC
  - LITTLE_R format
  - OBSPROC
  - Other notes on observations
- Converting observations
  - Converting to LITTLE_R format
  - Converting to other formats
- Plotting observations

# Overview

- Observations in WRFDA
  - Types
  - Formats
    - BUFR and PREPBUFR format
    - AMSR-2 radiance in HDF5 format
    - Radar and precipitation data in ASCII format
- LITTLE_R format and OBSPROC
  - LITTLE_R format
  - OBSPROC
  - Other notes on observations
- Converting observations
  - Converting to LITTLE_R format
  - Converting to other formats
- Plotting observations

# Observations in WRFDA

- In Jake's earlier talk, he gave the basic definition of data assimilation: statistically combining a **model state** with **observations**, along with the **error** characteristics of both, in order to arrive at a "best guess" of the state of the atmosphere.
- This is done by minimizing a cost function:

## What is data assimilation?

- A statistical method to obtain the best estimate of state variables
- In the atmospheric sciences, DA involves combining model forecast (prior) and observations, along with their respective errors characterization, to produce an *analysis (Posterior)* that can initialize a numerical weather prediction model (e.g., WRF)



$$J(x) = \frac{1}{2}(x - x^b)^T \mathbf{B}^{-1}(x - x^b) + \frac{1}{2}[\mathbf{H}x - y]^T \mathbf{R}^{-1}[\mathbf{H}x - y]$$

- $J(x)$: Cost function
- $x$: Analysis
- $x^b$: Background
- **B**: Background error
- **H**: Observation operator
- $y$: observations
- **R**: Observation error

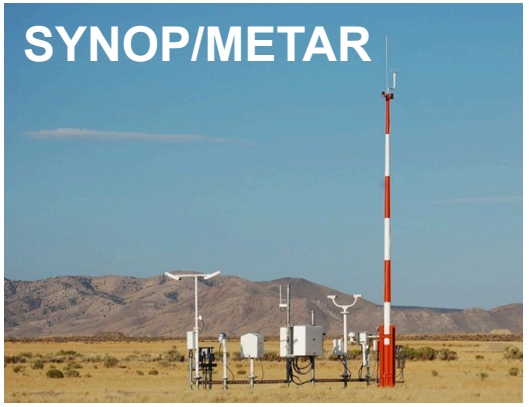
# Observation types in WRFDA

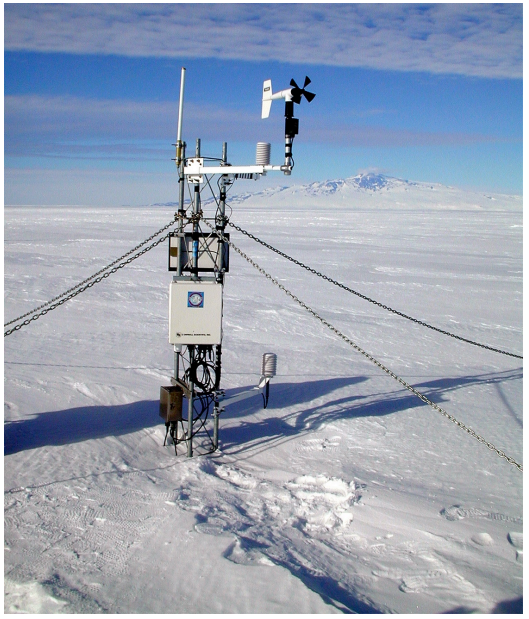
- **In-Situ observations**:
  - Surface (SYNOP, METAR, SHIP, BUOY)
  - Upper air (TEMP, PIBAL, AIREP, ACARS, AMDAR, TAMDAR)
- **Remotely sensed/derived observations**:
  - Atmospheric Motion Vectors (geo/polar) (SATOB)
  - SATEM thickness
  - Ground-based GPS Total Precipitable Water/Zenith Total Delay (GPSPW/GPSZD)
  - SSM/I oceanic surface wind speed and TPW
  - Scatterometer oceanic surface winds (QSCAT, ASCAT)
  - Wind profiler (PROFL)
  - Radar radial velocities and reflectivity
  - Satellite temperature/humidity/thickness profiles (AIRSR)
  - GPS refractivity (GPSRF)
  - Stage IV precipitation data/rain rate (only in 4DVAR mode)
- **Radiances (using RTTOV or CRTM):**
  - HIRS-3/4 (NOAA-16–19, METOP-A–B)
  - AMSU-A (NOAA-15–16, NOAA-18–19, EOS-Aqua, METOP-A–B)
  - AMSU-B (NOAA-15–17)
  - MHS (NOAA-18–19, METOP-A–B)
  - AIRS (EOS-Aqua)
  - SSMIS (DMSP-16–18)
  - IASI (METOP-A–B)
  - ATMS (Suomi-NPP)
  - MWTS (FY-3)
  - MWHS (FY-3)
  - SEVIRI (METEOSAT-8–10)
  - AMSR-2 (GCOM-W1)

# Observation types in WRFDA

## In-Situ surface observations:

- SYNOP: Surface station "**synop**tic" report
- METAR: Surface station "**met**eorological **a**viation **r**outine weather report
  - These are two commonly used report formats for surface observations, such as those
- SHIP: Surface report from a ship
- BUOY: Surface report from a buoy



# Observation types in WRFDA

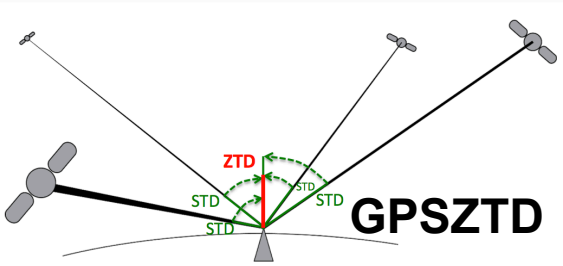
## In-Situ upper-air observations:

- TEMP: Vertical profile of temperature, wind, and/or humidity; typically a sounding balloon
- AIREP: **Air**craft **rep**ort of temperature and wind
- AMDAR: **A**ircraft **M**eteorological **Da**ta **R**elay
- TAMDAR: **T**ropospheric **AMDAR**


# Observation types in WRFDA

## Remotely sensed/derived observations:

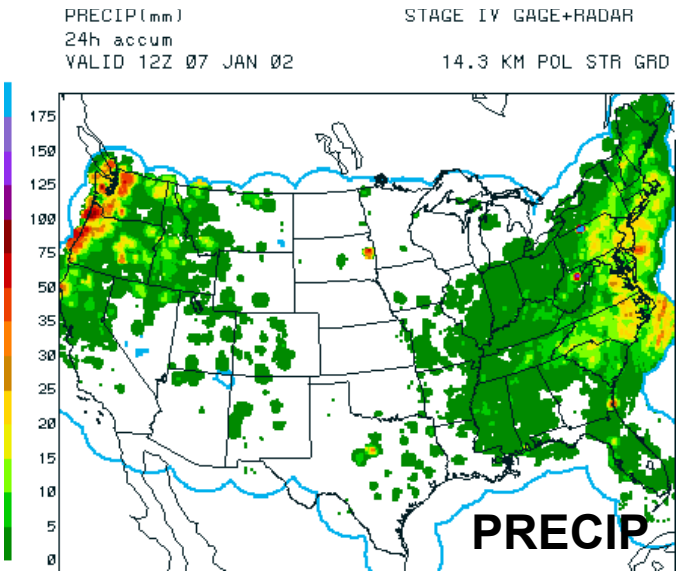
- SATOB: Atmospheric Motion Vectors; wind estimates from satellite images
- SATEM: Atmospheric thickness observation derived from satellite radiances
- GPSPW/ZTD: GPS Total Precipitable Water/Zenith Total Delay
- GPS refractivity (GPSRF)
- SSM/I: Oceanic surface wind speed and TPW from satellite: Special Sensor Microwave Imager
- QSCAT: Scatterometer oceanic surface winds (QuikSCAT, ASCAT, OSCAT)
- PROFL: Vertical wind profile, usually from radar instrument
- AIRSR: Temperature/humidity/thickness profiles retrieved from AIRS satellite




# Observation types in WRFDA

## Remotely sensed/derived observations:

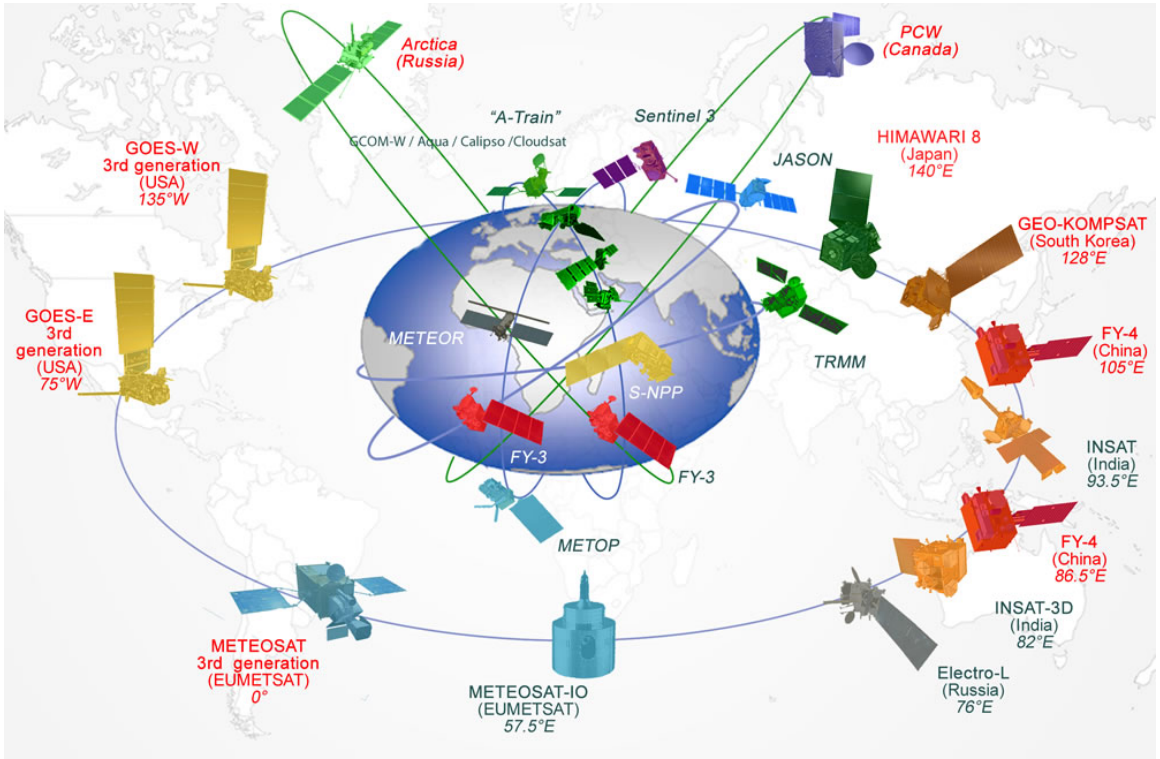
- Radar: radial velocity and reflectivity observations
- Stage IV precipitation: data set of accumulated precipitation derived from rain gauge and radar observations

# Observation types in WRFDA

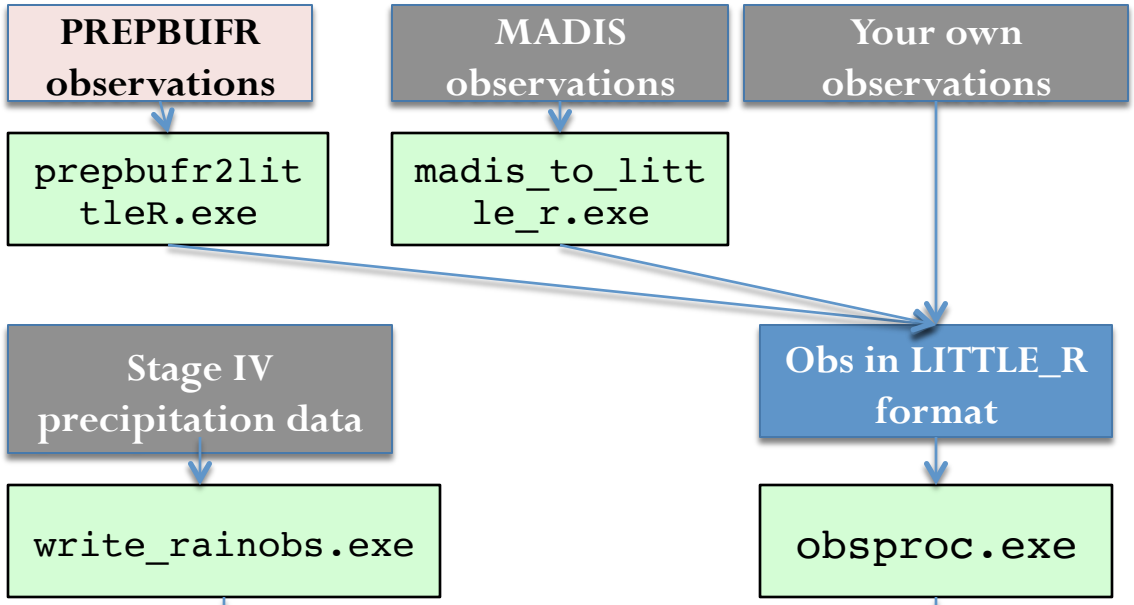
## Satellite radiances:

- Observations of brightness temperature at various wavelengths from dozens of instruments across 20+ satellites
- Too much to cover here; **radiance observations will get their own separate talk**

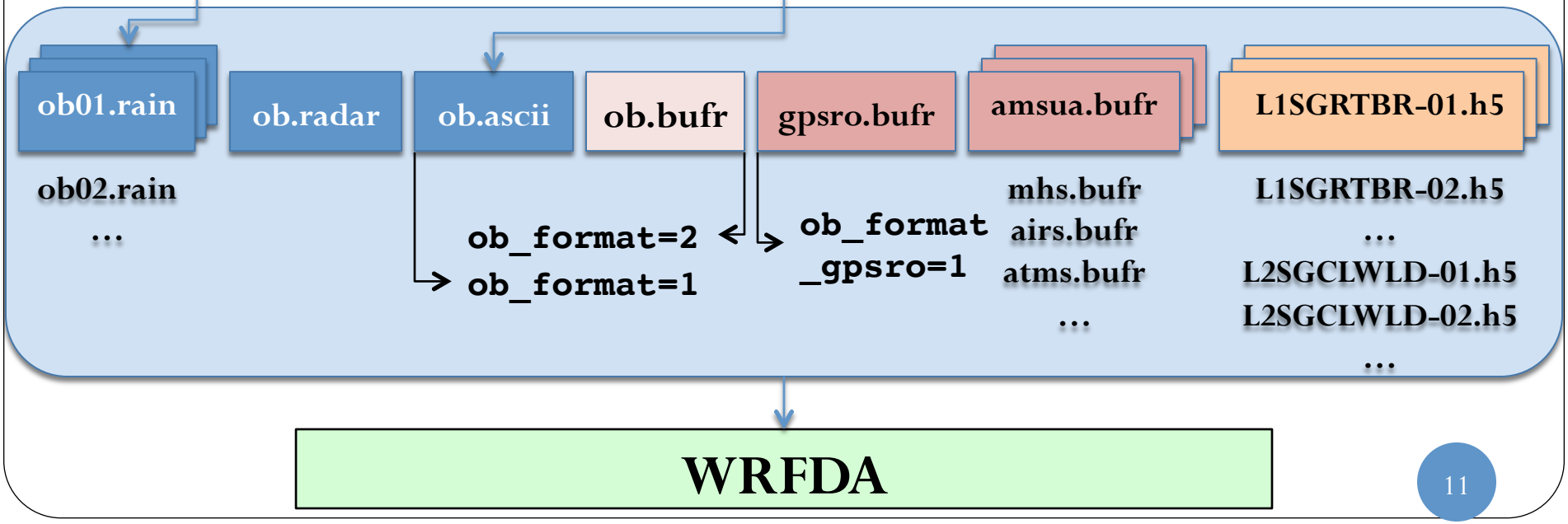



**Check out this page for the status of current and future satellites**
**http://www.wmo.int/pages/prog/sat/satellitestatus.php**

# Observation formats in WRFDA




- *ob.ascii*, *ob.radar*, *ob.rain* are in ASCII format
- *ob.bufr* is in NCEP PREPBUFR format
- *gpsro.bufr*, radiance bufr files are in NCEP BUFR format
- AMSR-2 radiance files are in HDF5 format
- Other formats should be converted before use



# BUFR and PREPBUFR format

**NCEP operational observation files in BUFR and PREPBUFR format can be directly used in WRFDA without any preprocessing**

- NCEP real-time data
  - http://www.ftp.ncep.noaa.gov/data/nccf/com/gfs/prod
- NOAA National Operational Model Archive and Distribution System (NOMADS) archive
  - http://nomads.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/
  - http://nomads.ncdc.noaa.gov/data/gdas
- NCAR CISL archive
  - http://rda.ucar.edu/datasets/ds337.0 – for conventional data
  - http://rda.ucar.edu/datasets/ds735.0 – for radiance data
  - http://rda.ucar.edu/datasets/ds099.0 – data used in NCEP Climate Forecast System Reanalysis
- NCAR HPSS personal archive (requires NCAR HPC account)
  - hsi:/LIUZ/GDAS/yyyymm/yyyymmddhh

# BUFR and PREPBUFR format

**Files to look for**

**gdas1.thhz.prepbufr.nr** → **ob.bufr**

**gdas1.thhz.gpsro.tm00.bufr_d** → **gpsro.bufr**

**gdas1.thhz.1bamua.tm00.bufr_d**
**gdas1.thhz.1bhrs4.tm00.bufr_d**
**gdas1.thhz.1bmhs.tm00.bufr_d**
**gdas1.thhz.airsev.tm00.bufr_d**
**gdas1.thhz.atms.tm00.bufr_d**
**gdas1.thhz.mtiasi.tm00.bufr_d**
**gdas1.thhz.sevcsr.tm00.bufr_d**

→ **amsua.bufr**

**mhs.bufr**
**airs.bufr**
**atms.bufr**
**iasi.bufr**
**hirs4.bufr**
**seviri.bufr**

***hh* is the analysis time: *00/06/12/18***

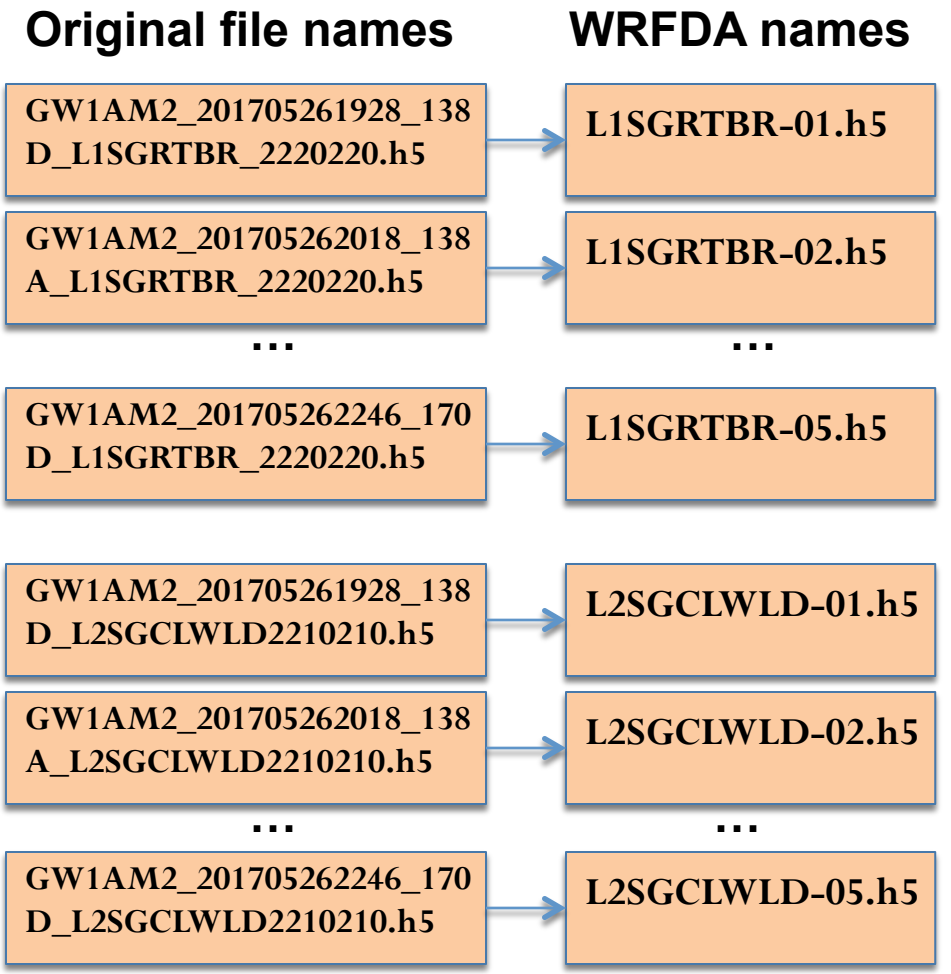
**NOTE:**
There will be a separate talk on assimilation of satellite radiance data tomorrow

- About NCEP BUFR format
  - http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB
  - http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/toc/prepbufr
- About NCEP PREPBUFR (prepared BUFR, **quality controlled**) data processing
  - http://www.emc.ncep.noaa.gov/mmb/data_processing/prepbufr.doc/document.htm
- Notes on using PREPBUFR in WRFDA
  - https://wiki.ucar.edu/display/~hclin/prepbufr2wrfvar

# AMSR-2 radiance in HDF5 format

**AMSR-2 radiance observations in HDF5 format can also be used directly in WRFDA**

- Download directly from JAXA website: http://gcom-w1.jaxa.jp/searchsat.html
- WRFDA looks for two sets of files:
  - Level 1R Brightness Temperature data (L1SGRTBR)
  - Level 2 Integrated Cloud Liquid Water (L2SGCLWLD) for quality control purposes (optional)




The file naming rules for AMSR2 data are described in http://suzaku.eorc.jaxa.jp/GCOM_W/data/doc/amsr2_data_user_guide.pdf

# Radar and precip data in ASCII format

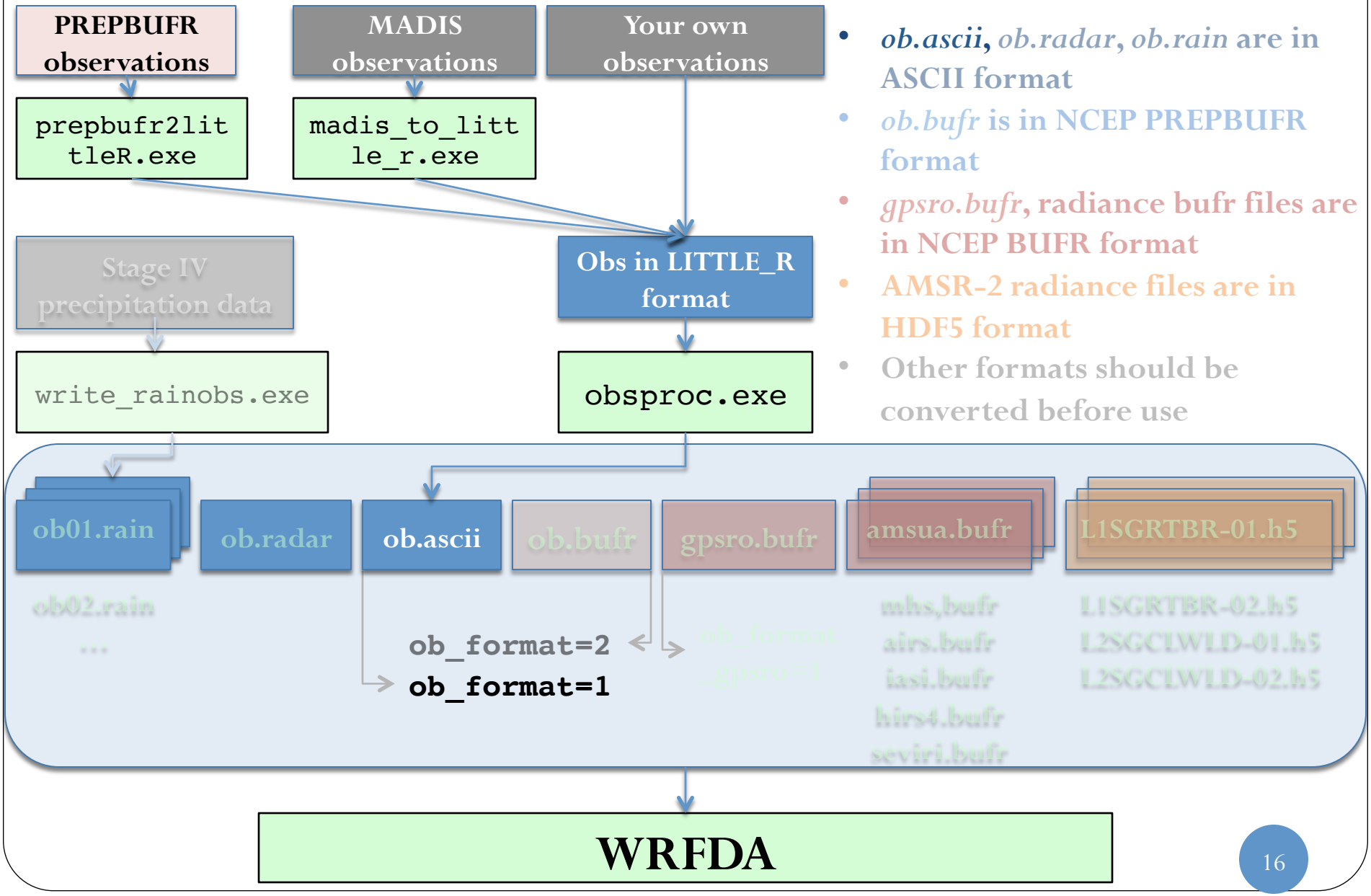
## NCEP Stage IV precipitation data

- Hourly and 6-hourly accumulated precipitation for the contiguous United States (plus Alaska and Puerto Rico starting April 2017)
  - Near-realtime: http://nomads.ncep.noaa.gov/pub/data/nccf/com/hourly/prod/
  - Archived data: http://data.eol.ucar.edu/dataset/21.093
- Data is in GRIB format, must be converted prior to use
  - Program provided for to convert this data: http://www2.mmm.ucar.edu/wrf/users/wrfda/download/precip_converter.tar.gz
  - Converts GRIB data to text-based format readable by WRFDA

## Radar data

- ASCII format (different from LITTLE_R or OBSPROC format)
- Should be quality controlled prior to use (user's responsibility)
- **There will be a separate talk on radar data assimilation tomorrow**

# Observation formats in WRFDA

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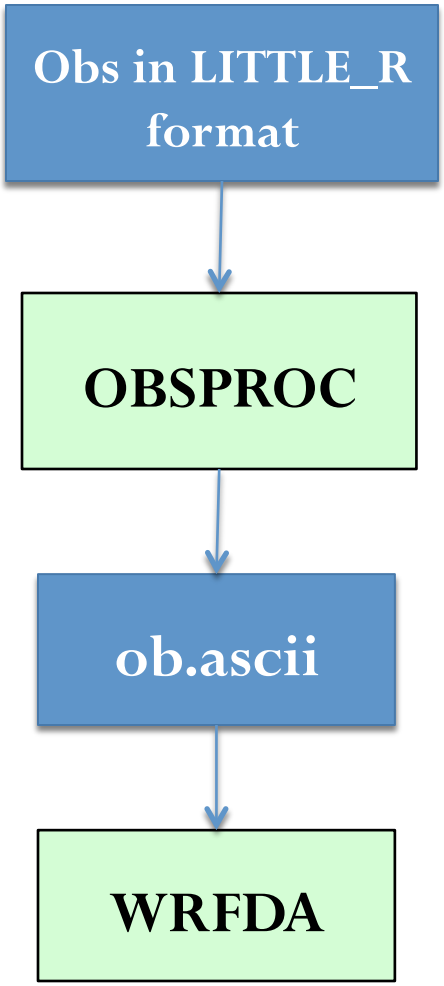
- Observations in WRFDA
  - Observation types in WRFDA
  - Observation formats in WRFDA
- LITTLE_R format and OBSPROC
  - LITTLE_R format
    - Header record, Data records, Ending record, and Tail integers
    - FM Codes
    - Special cases
  - OBSPROC
    - Observation errors
    - OBSPROC namelist
    - Running OBSPROC
    - Output from OBSPROC
    - ob.ascii (WRFDA ob format)
  - Other notes on observations
    - Quality control of observations
- Converting observations
- Plotting observations

# LITTLE_R format and OBSPROC



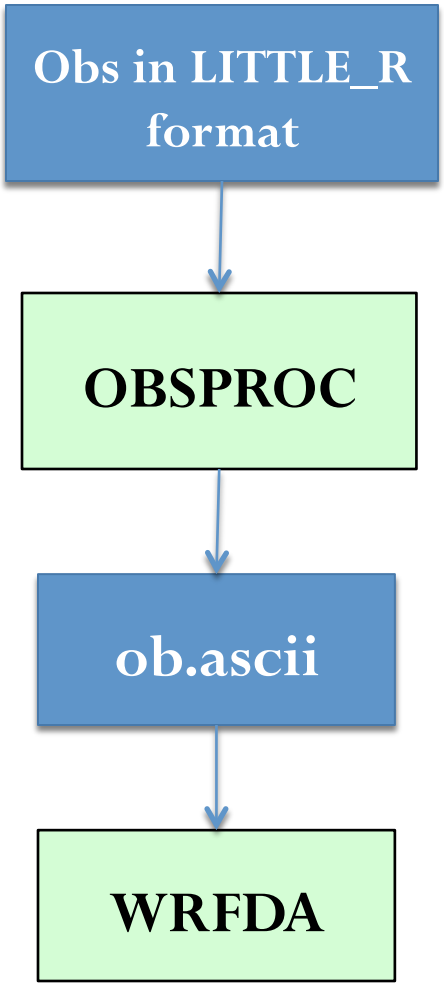

## What is LITTLE_R format?

- report-based ASCII file
- Designed to be easily concatenated (cat) together with other LITTLE_R files
- Originally used by MM5/Little_r objective analysis program, it is now Meant to be an intermediate format for converting other observations to be read by OBSPROC
- also used by WRF/OBSGRID objective analysis program

## What does OBSPROC do?

- Ingest multiple types of observations that are converted to little_r format and concatenated to one file, process the observation data and output the ASCII file(s) suitable for WRFDA needs – 3DVAR, FGAT (First Guess at Appropriate Time), 4DVAR

# LITTLE_R format

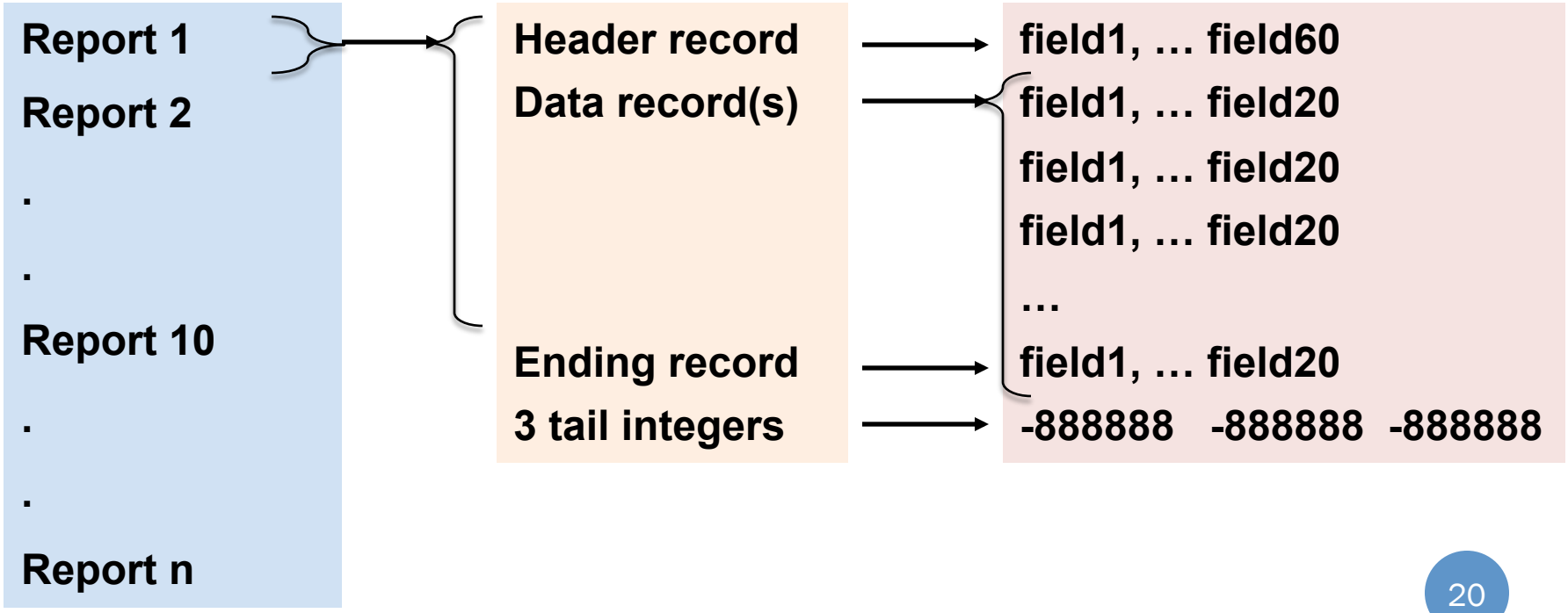



**Conventional observations in LITTLE_R format can be downloaded from a few sources:**

- Archived upper-air observations from the NCAR CISL Research Data Archive (RDA)
  - http://rda.ucar.edu/datasets/ds351.0/?hash=!access (1999 October to present)
  - Radiosondes, pilot balloons, and aircraft reports from the Global Telecommunications System (GTS)
  - Satellite Atmospheric motion vectors (AMVs) from the National Environmental Satellite Data and Information Service (NESDIS)
- Near-real-time and archived surface, upper-air, and remote observations from NCAR MMM on HPSS (requires NCAR HPC account)
  - hsi:/BRESCH/RT/DATA/yyyymm/obs.yyyymmddhh.gz (2003 April to present)
  - Radiosondes (TTAA, TTBB, PPBB, etc.), aircraft (PIREPS, AIREPS, AMDAR, ACARS), wind profilers, and Hurricane Hunter obs and dropsondes
  - Surface obs: SYNOPS, METARS, AWS, ships, buoys, CMAN
  - Satellite AMVs: GOES, METSAT, MODIS, AVHRR
  - Satem thickness
  - Quikscat (through November 2009
  - Ground-based GPS PW
  - GPS refractivity (COSMIC only)

# LITTLE_R format

- A little_r format observation file is composed of **reports**
- A **report** is composed of **records** (header, data, and ending) and 3 tail integers
- A **record** is composed of **fields**
  - fields in the header record
  - fields in the data record
  - fields in the ending record



# LITTLE_R format

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  - fields in the data record
  - fields in the ending record

```
          13.48000           2.1600061052                                NIAMEY-AERO / NIGER                  FM-35 TEMP
GTS (ROHK) USNR01 DRRN 051100 RRA                227.00000        1   -888888   -888888       299   -888888        T        F        F   -888888
-888888      20080205110000-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000
0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0
  98600.00000  0    227.00000  0 300.75000  0    293.75000  0      4.11556  0    240.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  92500.00000  0    788.00000  0 299.94998  0    290.94998  0      6.68778  0    255.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  85000.00000  0   1530.00000  0 295.94998  0    284.94998  0      1.54333  0    225.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  70000.00000  0   3187.00000  0 283.35001  0    278.75000  0      7.71667  0     75.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  50000.00000  0   5900.00000  0 267.04999  0    256.04999  0     12.86111  0     85.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  40000.00000  0   7610.00000  0 256.64999  0    240.64999  0      6.68778  0     75.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  30000.00000  0   9720.00000  0 242.64999  0    239.04999  0      6.68778  0    165.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  25000.00000  0  10990.00000  0 232.64999  0-888888.00000  0      6.17333  0    145.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
  20000.00000  0  12470.00000  0 220.25000  0-888888.00000  0      3.60111  0    135.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
-777777.00000  0-777777.00000  0  13.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
      62      0      0
 -71.86300         -125.59700-7777                                Platform Id >>> 71656                  FM-18 BUOY                                GTS (ROHK)
SSVX07 LFVW 051100                        0.00000        6   -888888   -888888       564   -888888        F        F        F   -888888   -888888
20080205110000  97940.00000      0-888888.00000      0-888888.00000      0-888888.00000      0  97940.00000      0-888888.00000      0-888888.00000
0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0
  97940.00000  0      0.00000  0 272.04999  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
-777777.00000  0-777777.00000  0   1.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
       6      0      0
```

**Example of a sounding report and a buoy report in a little_r file (some spaces removed for clarity)**

# LITTLE_R format: Header record

| No | Field | No | Field | No | Field |
|---|---|---|---|---|---|
| 1 | Latitude (f20.5) | 2 | Longitude (f20.5) | 3 | ID (a40) |
| 4 | Name (a40) | 5 | Platform (a40) | 6 | Source (a40) |
| 7 | Elevation (f20.5) | 8 | Num_vld_fld (i10) | 9 | Num_error (i10) |
| 10 | Num_warning (i10) | 11 | Seq_num (i10) | 12 | Num_dupd (i10) |
| 13 | Is_sound (L10) | 14 | Bogus (L10) | 15 | Discard (L10) |
| 16 | Unix time (i10) | 17 | Julian Day (i10) | 18 | Valid_time%date_char(a20) |
| 19 | Slp%data (f13.5) | 20 | Slp%qc (i7) | 21 | Ref_pres%data (f13.5) |
| 22 | Ref_pres%qc (i7) | 23 | Ground_t%data (f13.5) | 24 | Ground_t%qc (i7) |
| 25 | SST%data (f13.5) | 26 | SST%qc (i7) | 27 | Psfc%data (f13.5) |
| 28 | Psfc%qc (i7) | 29 | Precip%data (f13.5) | 30 | Precip%qc (i7) |
| 31 | T_max%data (f13.5) | 32 | T_max%qc (i7) | 33 | T_min%data (f13.5) |
| 34 | T_min%qc (i7) | 35 | T_min_night%data (f13.5) | 36 | T_min_night%qc (i7) |
| 37 | P_tend03%data (f13.5) | 38 | P_tend03%qc (i7) | 39 | P_tend24%data (f13.5) |
| 40 | P_tend24%qc (i7) | 41 | Cloud_cvr%data (f13.5) | 42 | Cloud_cvr%qc (i7) |
| 43 | Celling%data (f13.5) | 44 | Celling%qc (i7) | 45 | Pw%data (f13.5) |
| 46 | Pw%qc (i7) | | | | |

| Legend |
|---|
| Mandatory |
| Optional |
| Unused |
| Can be omitted |

**NOTE:**
Optional and unused fields must be filled with "missing data" flag values (-888888.00000 for example); they can not be omitted except for the final "PW" fields

```
          13.48000           2.1600061052                                NIAMEY-AERO / NIGER                 FM-35 TEMP
GTS (ROHK) USNR01 DRRN 051100 RRA                227.00000        1   -888888   -888888      299   -888888        T        F        F   -888888
-888888      20080205110000-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000
0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0-888888.00000      0
```

# LITTLE_R format: Header record

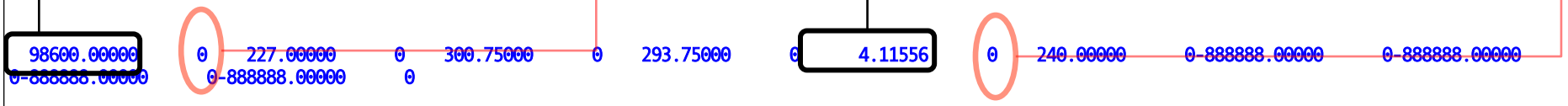
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13.48000 | | 2.16000 | | 61052 | | | | | |
| NIAMEY-AERO / NIGER | | | | FM-35 TEMP | | | | | |
| GTS (ROHK) USNR01 DRRN 051100 RRA | | | | | | 227.00000 | | 1 | -888888 |
| -888888 | 299 | -888888 | T | F | F | -888888 | -888888 | | |
| 20080205110000 | -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | |
| -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | | |
| -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | -888888.00000 | 0 | | |
| -888888.00000 | 0 | -888888.00000 | 0 | | | | | | |

| No | Field | No | Field | No | Field |
|---|---|---|---|---|---|
| 1 | Latitude (f20.5) | 2 | Longitude (f20.5) | 3 | ID (a40) |
| 4 | Name (a40) | 5 | Platform (a40) | 6 | Source (a40) |
| 7 | Elevation (f20.5) | 8 | Num_vld_fld (i10) | 9 | Num_error (i10) |
| 10 | Num_warning (i10) | 11 | Seq_num (i10) | 12 | Num_dupd (i10) |
| 13 | Is_sound (L10) | 14 | Bogus (L10) | 15 | Discard (L10) |
| 16 | Unix time (i10) | 17 | Julian Day (i10) | 18 | Valid_time%date_char(a20) |
| 19 | Slp%data (f13.5) | 20 | Slp%qc (i7) | 21 | Ref_pres%data (f13.5) |
| 22 | Ref_pres%qc (i7) | 23 | Ground_t%data (f13.5) | 24 | Ground_t%qc (i7) |
| 25 | SST%data (f13.5) | 26 | SST%qc (i7) | 27 | Psfc%data (f13.5) |
| 28 | Psfc%qc (i7) | 29 | Precip%data (f13.5) | … | … |

**Another note:** There are no separating characters between fields, so they can be confusing to read

# LITTLE_R format: Data record

| no | Field | no | Field |
|---|---|---|---|
| 1 | Pressure%data (f13.5) | 2 | Pressure%qc (i7) |
| 3 | Height%data (f13.5) | 4 | Height%qc (i7) |
| 5 | Temperature%data (f13.5) | 6 | Temperature%qc (i7) |
| 7 | Dew_point%data (f13.5) | 8 | Dew_point%qc (i7) |
| 9 | Speed%data (f13.5) | 10 | Speed%qc (i7) |
| 11 | Direction%data (f13.5) | 12 | Direction%qc (i7) |
| 13 | U%data (f13.5) | 14 | U%qc (i7) |
| 15 | V%data (f13.5) | 16 | V%qc (i7) |
| 17 | RH%data (f13.5) | 18 | RH%qc (i7) |
| 19 | Thickness%data (f13.5) | 20 | Thickness%qc (i7) |




- The "qc" integers after each piece of data are quality control identifiers. The only codes that OBSPROC will read are 0 (good data) and -88 (missing data)

# LITTLE_R format: Ending record

| no | field | no | field | no | field | no | field |
|---|---|---|---|---|---|---|---|
| 1 | -777777.00000 | 2 | 0 | 3 | -777777.00000 | 4 | 0 |
| 5 | -888888.00000 | 6 | 0 | 7 | -888888.00000 | 8 | 0 |
| 9 | -888888.00000 | 10 | 0 | 11 | -888888.00000 | 12 | 0 |
| 13 | -888888.00000 | 14 | 0 | 15 | -888888.00000 | 16 | 0 |
| 17 | -888888.00000 | 18 | 0 | 19 | -888888.00000 | 20 | 0 |

The ending record is a signal to OBSPROC that the observation report is ending. The only important field is field number 1, which should contain the "end record" flag value -777777.00000; the rest of the fields can be filled with any value

```
-777777.00000  0-777777.00000  0  13.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
```

# LITTLE_R format: Tail integers

The tail integers are legacy fields; they are not used by OBSPROC or WRFDA. **They must be included for back-compatibility, but have no meaning.**

Previously these values were used to store the number of valid fields, number of errors (from the decoding program), and number of warnings (from the decoding program), respectively. But you can use any valid I7 integers.

```
   62       0       0
```

# LITTLE_R format: FM Codes

- The World Meteorological Organization (WMO) defines a set of observation codes, or FM-Codes, which numerically identify different observation types
- Described in this document: http://www.wmo.int/pages/prog/www/**WMOCodes**/WMO306_vI1/Publications/2014update/Sel2.pdf
- These codes stop short of covering all observation types, so WRFDA has extended this list of codes to cover all observation types that can be read by OBSPROC
- These codes should be contained in the fifth header field: Platform (a40) and determine how OBSPROC and WRFDA will treat that observation

# LITTLE_R format: FM Codes

| Name | WMO FM code/ Platform ID | WMO code name |
|---|---|---|
| SYNOP | 12, 14 | SYNOP, SYNOP MOBIL |
| SHIP | 13, 17 | SHIP |
| BUOY | 18 | BUOY |
| METAR | 15, 16 | METAR, SPECI |
| PILOT | 32, 33, 34 | PILOT, PILOT SHIP, PILOT MOBIL |
| TEMP (SOUNDING) | 35, 36, 37, 38 | TEMP, TEMP SHIP, TEMP DROP, TEMP MOBIL |
| AMDAR | 42 | AMDAR |
| SATEM | 86 | SATEM |
| SATOB | 88 | SATOB |
| AIREP | 96, 97 | AIREP |
| TAMDAR | 101 | TAMDAR |
| GPSPW | 111 | GPSPW (Ground-based GPS precipitable water) |
| GPSZD | 114 | GPSZD (Ground-based GPS Zenith Total Delay) |
| GPSRF | 116 | GPSRF (Space-based GPS Refractivity) |
| PROFL | 132 | WIND PROFILER |
| AIRSR | 133 | AIRSRET |
| BOGUS | 135 | TCBOU (Typhoon bogus), BOGUS (other bogus) |
| QSCAT | 281 | Quik SCAT level-2B SeaWind |

***These numbers specific to WRFDA***

**Notes:**

- WRFDA treats AIREP and AMDAR observations the same: OBSPROC combines the two categories
- WRFDA treats SATOB (AMV) observations differently depending on if they are from a geostationary satellite (GEOAMV) or polar orbiting satellite (POLARAMV). An observation is assumed to be POLARAMV if its "ID" header field contains "AVHRR", or its "Name" header field contains "MODIS"

# LITTLE_R format: Special cases

- Because LITTLE_R is a legacy format that was developed decades ago, it was developed before many observation types became available. As a work-around for this, several observation types deviate from the formats described in the previous slides

## TCBOGUS (Tropical Cyclone "BOGUS" observations)

- For TCBOGUS observations, the observation error is specified in the observation file, rather than in the obserr.txt file. The error values are stored as shown:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| pressure | geopotential height | temperature | dew point | wind speed | wind direction | u | v | relative humidity | geopotential thickness |
| | | temperature | temperature error | wind speed | wind direction | wind speed obs error | | relative humidity | relative humidity error |

## GPS Refractivity

- For GPSREF observations, a format was chosen that allows the observation to keep retrieved temperature and pressure observations in the proper fields, and assigns the rest of the relevant observations to other fields. While there are several assigned fields for parameters such as azimuth angle, bending angle, etc., only pressure, height, temperature, and refractivity are ultimately read by WRFDA

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| pressure | geopotential height | temperature | dew point | wind speed | wind direction | u | v | relative humidity | geopotential thickness |
| pressure | height (m) | temperature | refractivity (N) | Impact parameter (x1.e-3) | azimuth angle (degree) | latitude | longitude | Bending angle (radx1.e7) | Optical bending |

# LITTLE_R format: Special cases

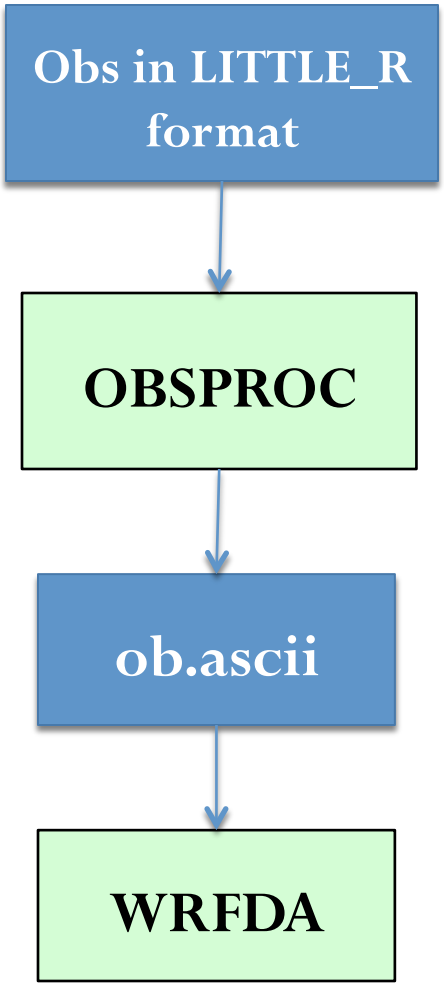
## GPS Precipitable Water (GPSPW) and Zenith Total Delay (GPSZTD)

- GPSPW and GPSZTD observations are unique in that the observation values are stored in the **header record** rather than the **data record**.
- Pw%data for GPSPW (FM-111) or GPSZD (FM-114) is in **units of cm**
- Pw%qc is used to store the observation error in units of **0.1 mm**
- If pw%qc is missing or zero, the default value of 20 (2.0 mm, 0.2 cm) is used

| No | Field | No | Field | No | Field |
|---|---|---|---|---|---|
| 1 | Latitude (f20.5) | 2 | Longitude (f20.5) | 3 | ID (a40) |
| 4 | Name (a40) | 5 | Platform (a40) | 6 | Source (a40) |
| 7 | Elevation (f20.5) | 8 | Num_vld_fld (i10) | 9 | Num_error (i10) |
| 10 | Num_warning (i10) | 11 | Seq_num (i10) | 12 | Num_dupd (i10) |
| 13 | Is_sound (L10) | 14 | Bogus (L10) | 15 | Discard (L10) |
| 16 | Unix time (i10) | 17 | Julian Day (i10) | 18 | Valid_time%date_char(a20) |
| 19 | Slp%data (f13.5) | 20 | Slp%qc (i7) | 21 | Ref_pres%data (f13.5) |
| 22 | Ref_pres%qc (i7) | … | … | … | … |
| … | … | 44 | Celling%qc (i7) | 45 | **Pw%data (f13.5)** |
| 46 | **Pw%qc (i7)** | | | | |

| Legend |
|---|
| Mandatory |
| Optional |
| Unused |

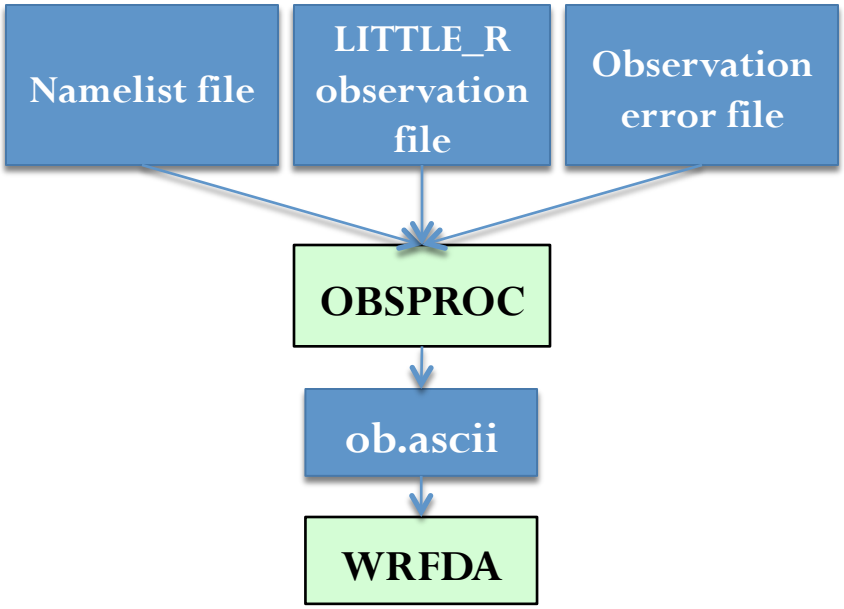
# Observation Preprocessor (OBSPROC)




## What is OBSPROC?

- OBSPROC is a program included with the WRFDA package
- OBSPROC prepares observations in LITTLE_R format for use in WRFDA
  - Reads in LITTLE_R data
  - Discards observations outside your specified domain and time window
  - Merges and/or discards duplicate observations
    - For 3DVAR and FGAT, observation closest to the analysis time is kept
    - For 4DVAR, observation closest to the center of each time window is kept
  - Assigns observation errors
  - Performs gross quality control checks
  - Corrects superadiabatic conditions and other inconsistencies if possible
  - Sorts observations by time
  - Writes observations into WRFDA ASCII format
    - Single file (ob.ascii) for 3DVAR
    - Multiple files (ob01.ascii, ob02.ascii, etc.) for FGAT or 4DVAR.

# Observation Preprocessor (OBSPROC)




- obsproc.exe takes 3 input files
  - LITTLE_R observation file
  - Observation error file (obserr.txt)
    - Contains standard error values for most observation types
    - Provided in WRFDA package
    - Can be modified by user to use your own error values
  - Namelist file (namelist.obsproc)
    - Contains runtime options

```
>ls WRFDA/var/obsproc/
 Makefile
 README.namelist
 msfc.tbl
 namelist.obsproc.3dvar.wrfvar-tut
 namelist.obsproc.4dvar.wrfvar-tut
 obserr.txt
 obsproc.exe
 src/
```

# Observation errors

## Observation errors come from one of two sources:

- obserr.txt
  - Standard table of observation error values used by the US Air Force Weather Agency (AFWA)
  - Contains error values broken down by observed variable, observation type, and pressure level
- For some observation types (GPSPW, GPSZTD), observation error information is contained in the observation file itself

```
0.5   0.5   0.5   0.5   0.5       BOGUS       TEMP SENSOR ERRORS
0.5   0.5   0.5   0.5   0.5         :
0.5   0.5   0.5   0.5   0.5         :
0.0   0.0   0.0   0.0   0.0        NU
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0        NU
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0        NU
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0         :
1.0   1.0   1.0   1.0   1.0       RAOBS
1.0   1.0   1.0   1.0   1.0         :
1.0   1.0   1.0   1.0   1.0         :
1.0   1.0   1.0   1.0   1.0       PIBALS
1.0   1.0   1.0   1.0   1.0         :
1.0   1.0   1.0   1.0   1.0         :
0.0   0.0   0.0   0.0   0.0        NU
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0        NU
0.0   0.0   0.0   0.0   0.0         :
0.0   0.0   0.0   0.0   0.0         :
1.0   1.0   1.0   1.0   1.0       AIREPS
1.0   1.0   1.0   1.0   1.0         :
1.0   1.0   1.0   1.0   1.0         :
```

# OBSPROC namelist

## OBSPROC namelist

- A namelist is a text file read by a Fortran program that is used to change its runtime behavior
- For OBSPROC, the namelist file is namelist.obsproc
- It is broken down into sections: &record1 through &record10
- Two example namelists can be found in the source code under WRFDA/var/obsproc
- Detailed descriptions can also be found in the users guide, or in the text file WRFDA/var/obsproc/README.namelist

```
>cat namelist.obsproc

&record1
 obs_gts_filename = 'obs.2008020512',
 obs_err_filename = 'obserr.txt',
/
&record2
 time_window_min  = '2008-02-05_11:00:00',
 time_analysis    = '2008-02-05_12:00:00',
 time_window_max  = '2008-02-05_13:00:00',
/
&record3
 max_number_of_obs        = 400000,
 fatal_if_exceed_max_obs  = .TRUE.,
/
&record4
 qc_test_vert_consistency = .TRUE.,
 qc_test_convective_adj   = .TRUE.,

...
```

# OBSPROC namelist

**&record1** **(Defines the input file names)**

| | |
|---|---|
| obs_gts_filename = 'obs.2008020512', | Little_r file name |
| obs_err_filename = 'obserr.txt', | Observation error file name |
| fg_format = 'WRF' | Mapping in WRF convention |
| gts_from_mmm_archive = .false. | Set to .true. if little_r files are from hsi:/BRESCH/RT/DATA |

/

**&record2** **(Defines the analysis time and time window)**

| | |
|---|---|
| time_window_min = '2008-02-05_11:00:00', | Beginning of time window |
| time_analysis = '2008-02-05_12:00:00', | Analysis time |
| time_window_max = '2008-02-05_13:00:00', | End of time window |

/

**&record3** **(Defines the maximum number of observations allowed)**

| | |
|---|---|
| max_number_of_obs = 400000, | Max number of observations to be read |
| fatal_if_exceed_max_obs = .true., | Exit with error if above number is exceeded |

/

# OBSPROC namelist

**&record4** **(Quality control checks)**

| | |
|---|---|
| qc_test_vert_consistency = .true. | Perform a vertical consistency check on sounding |
| domain_check_h = .true., | Discard the observations outside the domain |
| remove_above_lid = .false. | Discard observations above model top (false recommended) |
| thining_satob = .true. | |
| thining_qscat = .true. | |
| calc_psfc_from_QNH = .false. | set to .true. to calculate Psfc from METAR QNH reports for gts_from_mmm_archive=.true. only |

…

/

**&record5** **(Print a series of diagnostic file)**

| | |
|---|---|
| print_gts_read = .true., | Writes obs_gts_read.diag: lists files read and which were outside domain or time window |
| print_recoverp = .true., | Writes obs_recover_pressure.diag: lists observations where pressure was recovered from height |
| print_qc_conv = .true., | Writes obs_qc1.diag: lists observations that failed superadiabatic checks |
| print_recoverp = .true., | Writes obs_recover_height.diag: lists observations where height was recovered from pressure |

…

/

# OBSPROC namelist

```
&record6   (Defines the reference state for QC checks)
 ptop =  1000.0,                  reference pressure at model top
 base_temp  = 290.0,              mean sea level temperature
 base_lapse = 50.0,               temperature lapse rate
 base_pres = 100000.0,            reference sea level pressure
 base_strat_temp = 215.0,         isothermal temperature above tropopause
 base_tropo_pres = 20000.0,       tropopause pressure
/
&record7   (Defines geographical parameters)
 IPROJ = 1,                       0 = Cylindrical Equidistance, 1 = Lambert Conformal,
                                  2 = Polar stereographic, 3 = Mercator
 PHIC  = 40.0,                    central latitude of the domain
 XLONC = -95.0,                   central longitude of the domain
 TRUELAT1= 30.0,
 TRUELAT2= 60.0,
 MOAD_CEN_LAT = 40.0,             central latitude for the Mother Of All Domains
 STANDARD_LON = -95.0,            standard longitude
/
```

- Use command `ncdump -h wrfinput_d01` on your WRF file to find the above information.

# OBSPROC namelist

**&record8** **(Defines the domain settings)**

```
 IDD    =   1,          when XLONC /= STANDARD_LON, set IDD=2, otherwise set to 1
 MAXNES =  1,           set to 1
 NESTIX =  60,          I (north-south direction) dimension of the domain
 NESTJX =  90,          J (east-west direction) dimension of the domain
 DIS    =  60,          grid size of the domain
 NUMC = 1,              set to 1
 NESTI = 1,             set to 1
 NESTJ = 1,             set to 1
/
```

- ✓ OBSPROC was developed in the MM5 era when I referred to Y direction and J referred to X direction

**&record9** **(Defines the output assimilation type, and observation time windows)**

```
 use_for   = '3DVAR',          3DVAR, FGAT, or 4DVAR
 num_slots_past   = 3,         number of time slots before analysis time (FGAT and 4DVAR only)
 num_slots_ahead  = 3,         number of time slots after analysis time (FGAT and 4DVAR only)
/
```

**&record10** **(Wind speed-direction assimilation settings)**

```
 wind_sd = .false.,    Set to .true. if you will be using wind speed/direction assimilation (see users
                       guide:
                       http://www2.mmm.ucar.edu/wrf/users/wrfda/Docs/user_guide_V3.9/
                       users_guide_chap6.htm#_Wind_speed/direction_assimilation
/
```

# Running OBSPROC

- After successful compilation of WRFDA, OBSPROC executable can be found:
  - WRFDA/var/obsproc/src/obsproc.exe
- To run OBSPROC
  - Create a working directory (recommended)
  - Copy in obsproc.exe, obserr.txt (from WRFDA/var/obsproc), and your LITTLE_R observation file
  - Create or copy your namelist.obsproc file, and edit the options as desired
  - Run the executable! It should not take long, typically less than a minute
    - `./obsproc.exe >& obsproc.log`

**Redirects log messages into a file named "obsproc.log"**

# Output from OBSPROC

- Observation file(s)

  obs_gts_2017-07-24_12:00:00.3DVAR

  *or*

  obs_gts_2017-07-24_09:00:00.FGAT
  obs_gts_2017-07-24_10:00:00.FGAT
  …
  obs_gts_2017-07-24_15:00:00.FGAT

  *or*

  obs_gts_2017-07-24_09:00:00.4DVAR
  obs_gts_2017-07-24_10:00:00.4DVAR
  …
  obs_gts_2017-07-24_15:00:00.4DVAR

**For 3DVAR, all obs are written to a single file**

**For FGAT or 4DVAR, observations will be split according to your namelist-specified time windows**

- Log file (if you created one)

  obsproc.log

- A list of diagnostic files (according to your namelist settings):

  obs_check_height.diag
  obs_check_pressure.diag
  obs_gts_read.diag
  obs_qc1.diag
  …

# Output from OBSPROC

- Other output: observation error values
  - For convenience, the error values read in from obserr.txt will be output into text files broken down by variable (DIR.txt, HEIGHT.txt, PRES.txt, etc.)
  - These files are often easier to read and more convenient than the original obserr.txt, so you may find them useful.

**TEMP.txt**

TEMP SENSOR ERRORS

| level | synop | ship | buoy | metar | pilot | profl | sound | satem | satob | airep | tamdar | ssmt1 | ssmt2 | tovs | ssmi | airsr | other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.6 | 1.6 | 1.0 | 1.0 | 1.8 | 1.8 | 1.8 | 1.8 | 1.0 | 1.6 |
| 20. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.9 | 1.9 | 1.0 | 1.0 | 1.6 | 1.6 | 1.6 | 1.6 | 1.0 | 1.9 |
| 30. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.8 | 1.8 | 1.0 | 1.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.0 | 1.8 |
| 50. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.6 | 1.6 | 1.0 | 1.0 | 1.7 | 1.7 | 1.7 | 1.7 | 1.0 | 1.6 |
| 70. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.8 | 1.8 | 1.0 | 1.0 | 1.6 | 1.6 | 1.6 | 1.6 | 1.0 | 1.8 |
| 100. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.6 | 1.6 | 1.0 | 1.0 | 2.4 | 2.4 | 2.4 | 2.4 | 1.0 | 1.6 |
| 150. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.9 | 1.9 | 1.0 | 1.0 | 2.7 | 2.7 | 2.7 | 2.7 | 1.0 | 1.6 |
| 200. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.2 | 2.2 | 1.0 | 1.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.0 | 2.1 |
| 250. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.2 | 2.2 | 1.0 | 1.0 | 3.1 | 3.1 | 3.1 | 3.1 | 1.0 | 2.2 |
| 300. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.4 | 2.4 | 1.0 | 1.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.0 | 2.5 |
| 400. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.3 | 2.3 | 1.0 | 1.0 | 3.1 | 3.1 | 3.1 | 3.1 | 1.0 | 2.4 |
| 500. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.6 | 2.6 | 1.0 | 1.0 | 3.2 | 3.2 | 3.2 | 3.2 | 1.0 | 2.6 |
| 700. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.7 | 2.7 | 1.0 | 1.0 | 3.6 | 3.6 | 3.6 | 3.6 | 1.0 | 2.9 |
| 850. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 3.5 | 3.5 | 1.0 | 1.0 | 3.9 | 3.9 | 3.9 | 3.9 | 1.0 | 3.7 |
| 1000. | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 3.7 | 3.7 | 1.0 | 1.0 | 3.8 | 3.8 | 3.8 | 3.8 | 1.0 | 3.8 |

# Output from OBSPROC

**The observation files output from OBSPROC are a text format read by WRFDA**

- Observation file contains a human-readable header (with observation summary information)
- Each observation has an "info" record followed by data records (one for surface information, others for each vertical level)

**INFO Record format**

| A12, 1X | A19, 1X | A40, 1X | I6 | F12.3,11X | F12.3,11X | F12.3,17X | A40 |
|---|---|---|---|---|---|---|---|
| FM Code | Date string | Name | Vertical levels | Latitude | Longitude | Elevation | ID |

**SURFACE Record format**

| F12.3,I4,F7.2 | F12.3,I4,F7.2 |
|---|---|
| Surface pressure, QC, error | Precipitable water, QC, error |

**LEVEL Record format**

| F12.3,I4, F7.2 | F12.3,I4, F7.2 | F12.3,I4,F7.2 | 11x | F12.3,I4,F7.2 | F12.3,I4,F7.2 | F12.3,I4,F7.2 | 11X | F12.3,I4,F7.2 |
|---|---|---|---|---|---|---|---|---|
| Pressure, QC, error | Wind speed, QC, error | Wind direction, QC, error | | Height, QC, error | Temperature, QC, error | Dew Point, QC, error | | Humidity, QC, error |

# OBSPROC output name
# obs_gts_yyyy-mm-dd_hh:00:00.3DVAR

# WRFDA input name
# (ob.ascii)

```
TOTAL =  29596, MISS. =-888888.,
SYNOP =    463, METAR =    156, SHIP  =     25, BUOY  =     54, BOGUS =      0, TEMP  =     31,
AMDAR =    501, AIREP =     78, TAMDAR=      0, PILOT =     31, SATEM =      0, SATOB =   9318,
GPSPW =      0, GPSZD =      0, GPSRF =     49, GPSEP =      0, SSMT1 =      0, SSMT2 =      0,
TOVS  =      0, QSCAT =  18890, PROFL =      0, AIRSR =      0, OTHER =      0,
PHIC  = -87.40, XLONC = 180.00, TRUE1 = -71.00, TRUE2 = -91.00, XIM11 =   1.00, XJM11 =   1.00,
base_temp= 268.00, base_lapse=  50.00, PTOP  =  1000., base_pres=100000., base_tropo_pres= 20000., base_strat_temp=   215.,
IXC   =    217, JXC   =    165, IPROJ =      2, IDD   =      1, MAXNES=      1,
NESTIX=    217,
NESTJX=    165,
NUMC  =      1,
DIS   =  60.00,
NESTI =      1,
NESTJ =      1,
INFO  = PLATFORM, DATE, NAME, LEVELS, LATITUDE, LONGITUDE, ELEVATION, ID.
SRFC  = SLP, PW (DATA,QC,ERROR).
EACH  = PRES, SPEED, DIR, HEIGHT, TEMP, DEW PT, HUMID (DATA,QC,ERROR)*LEVELS.
INFO_FMT = (A12,1X,A19,1X,A40,1X,I6,3(F12.3,11X),6X,A40)
SRFC_FMT = (F12.3,I4,F7.2,F12.3,I4,F7.3)
EACH_FMT = (3(F12.3,I4,F7.2),11X,3(F12.3,I4,F7.2),11X,3(F12.3,I4,F7.2))
#-------------------------------------------------------------------------------#
FM-18 BUOY    2008-10-31_21:00:00 Platform Id >>> 55956                    1     -41.973              -166.164                0.000                  55956
  101090.000   0 200.00 -888888.000 -88  0.200
  101090.000   0 100.00 -888888.000 -88   1.40 -888888.000 -88   5.00          0.000   0   6.00 -888888.000 -88   2.00 -888888.000 -88   2.00          -888888.000 -88  10.00
FM-35 TEMP    2008-10-31_21:00:00 CHATHAM ISLAND / NEW ZEALAND              19     -43.950              -176.560               48.000                  93986
 -888888.000 -88 200.00 -888888.000 -88  0.200
  100400.000   0 100.00       7.202   0   1.40     330.000   0   5.00         48.000   0   7.00    284.348   1   1.80    279.848   1   1.80             73.609   1  10.00
  100000.000   0 100.00 -888888.000 -88   1.40 -888888.000 -88   5.00         83.000   0   7.00    284.024 -10   1.80    279.024 -10   1.80             71.046 -10  10.00
   99800.000   0  99.82 -888888.000 -88   1.41 -888888.000 -88   5.00        100.000   3   7.01    283.861   1   1.80    277.861   1   1.80             66.222   1  10.00
   92700.000   0  93.36 -888888.000 -88   1.64 -888888.000 -88   5.00        707.000   3   7.21    277.935   1   1.69    275.935   1   1.69             86.823   1  10.00
   92500.000   0  93.18 -888888.000 -88   1.65 -888888.000 -88   5.00        724.000   0   7.22    277.763   1   1.69    275.563   1   1.69             85.579   1  10.00
   91400.000   0  92.17 -888888.000 -88   1.69 -888888.000 -88   5.00        822.000   3   7.25    277.150   0   1.67    272.250   0   1.67             70.338   0  10.00
   90300.000   0  91.17 -888888.000 -88   1.72 -888888.000 -88   5.00        920.000   3   7.29    277.750   0   1.66    258.750   0   1.66             23.873   0  10.00
   85000.000   0  86.35 -888888.000 -88   1.90 -888888.000 -88   5.00       1410.000   0   7.46    275.750   0   1.57    263.750   0   1.57             40.903   0  10.00
   84600.000   0  85.99 -888888.000 -88   1.91 -888888.000 -88   5.00       1449.000   3   7.47    275.350   0   1.57    263.350   0   1.57             40.794   0  10.00
   78300.000   0  80.25 -888888.000 -88   2.12 -888888.000 -88   5.00       2072.000   3   7.69    273.550   0   1.46    249.550   0   1.46             14.884   0  10.00
   70000.000   0  72.70 -888888.000 -88   2.40 -888888.000 -88   5.00       2964.000   0   8.00    270.050   0   1.30    256.050   0   1.30             33.387   0  10.00
   69000.000   0  71.79 -888888.000 -88   2.42 -888888.000 -88   5.00       3078.000   3   8.03    269.450   0   1.30    256.450   0   1.30             36.084   0  10.00
   65700.000   0  68.79 -888888.000 -88   2.49 -888888.000 -88   5.00       3463.000   3   8.11    267.250   0   1.30    247.250   0   1.30             19.399   0  10.00
   64000.000   0  67.24 -888888.000 -88   2.52 -888888.000 -88   5.00       3669.000   3   8.16    267.450   0   1.30    228.450   0   1.30              3.148   0  10.00
   57700.000   0  61.51 -888888.000 -88   2.65 -888888.000 -88   5.00       4471.000   3   8.34    261.850   0   1.30    247.850   0   1.30             31.074   0  10.00
   56400.000   0  60.32 -888888.000 -88   2.67 -888888.000 -88   5.00       4646.000   3   8.39    262.050   0   1.30    239.050   0   1.30             13.679   0  10.00
   50100.000   0  54.59 -888888.000 -88   2.80 -888888.000 -88   5.00       5545.000   3   8.60    256.650   0   1.30    241.650   0   1.30             26.971   0  10.00
   50000.000   0  54.50 -888888.000 -88   2.80 -888888.000 -88   5.00       5560.000   0   8.60    256.650   0   1.30 -888888.000 -11   1.30          -888888.000 -11  10.00
   49700.000   0  54.23 -888888.000 -88   2.81 -888888.000 -88   5.00       5606.000   3   8.72    256.650   0   1.31 -888888.000 -11   1.31          -888888.000 -11  10.00
```

ob numbers

domain information

Data format

**Header**

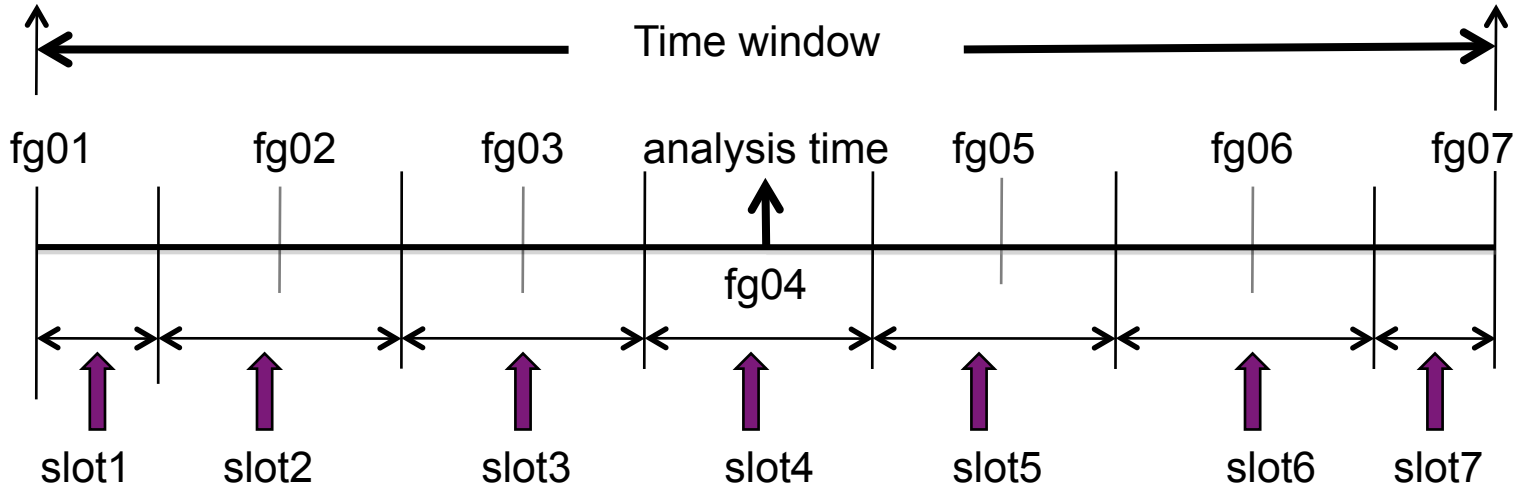
content not used in WRFDA: for human readability only

observation errors

# Notes about assimilation types

- 3DVAR
  - all observations within the time window are considered valid at the analysis time
  - when multiple reports from a fixed station are available within the time window, only one report that is closest to the analysis time will be kept
- FGAT (First Guess at Appropriate Time)
  - multiple time slots (model first guesses) within the time window
  - observations are binned in different time slots
  - when multiple reports from a fixed station are available within the time window, only one report that is closest to the analysis time will be kept
- 4DVAR
  - multiple time slots (model first guesses) within the time window
  - observations are binned in different time slots
  - time duplicate observations not allowed within each time slot

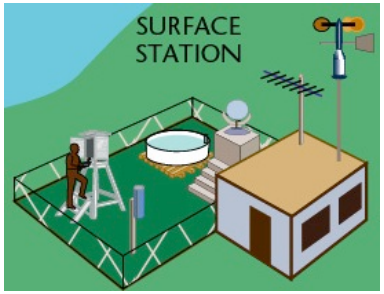
**More details on these algorithms will be included in future talks**



# Notes about assimilation types

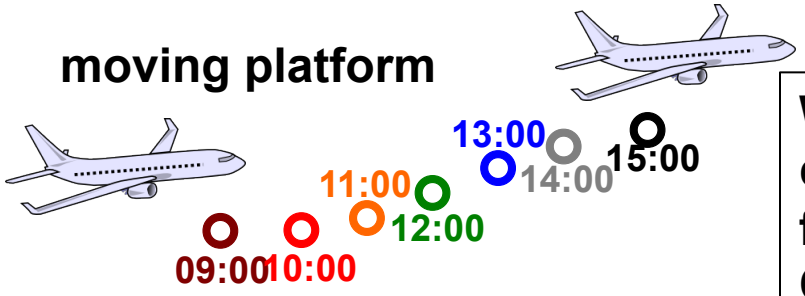
**For analysis time at 12:00 with ± 3 hour time window**

**fixed platform**




09:00
10:00
11:00
12:00
13:00
14:00
15:00

**moving platform**




**For calculating the departure of model background from observations, what observations should be considered?**

**3DVAR:**

**FGAT:**

| | |
|---|---|
| bin 01 | |
| bin 02 | |
| bin 03 | |
| bin 04 | |
| bin 05 | |
| bin 06 | |
| bin 07 | |

**4DVAR:**

| | |
|---|---|
| bin 01 | |
| bin 02 | |
| bin 03 | |
| bin 04 | |
| bin 05 | |
| bin 06 | |
| bin 07 | |

**WRFDA keeps only one observation closest to the analysis time from a fixed station in non-4DVAR mode. Other DA system may use multiple observations by giving time-dependent weights.**

# Quality control of observations

## Quality control checks are also done by WRFDA

- quality checks of radiances and GPS refractivity are done in WRFDA
- Quality control checks done by OBSPROC are honored by WRFDA; QC flag values less than 0 (see next slide) are rejected
- WRFDA honors quality flags embedded in ob.bufr (NCEP's prepared, quality controlled PREPBUFR file)
- WRFDA does an "innovation check"
  - If the difference between the observation and the background (innovation) is too large, the observation is rejected
  - This is controlled by WRFDA namelist options
  - More details in future talk

# Quality control of observations

```
missing_data             = -88,   ! Data is missing with the value of missing_r
outside_of_domain        = -77,   ! Outside horizontal domain or time window, data set to missing_r
wrong_direction          = -15,   ! Wind vector direction <0 or >360; set to missing_r
negative_spd             = -14,   ! Wind vector norm is negative => norm set to missing_r
zero_spd                 = -13,   ! Wind vector norm is zero => norm set to missing_r
wrong_wind_data          = -12,   ! Spike in wind profile =>direction and norm set to missing_r
zero_t_td                = -11,   ! t or td = 0 => t or td, rh and qv are set to missing_r
t_fail_supa_inver        = -10,   ! super-adiabatic temperature
wrong_t_sign             = - 9,   ! Spike in Temperature profile
above_model_lid          = - 8,   ! height above model lid => no action
far_below_model_surface  = - 7,   ! height far below model surface => no action
below_model_surface      = - 6,   ! height below model surface => no action
standard_atmosphere      = - 5,   ! Missing h, p or t =>Datum interpolated from standard atmosphere
from_background          = - 4,   ! Missing h, p or t =>Datum interpolated from model
fails_error_max          = - 3,   ! Datum Fails error max check => no action
fails_buddy_check        = - 2,   ! Datum Fails buddy check => no action
no_buddies               = - 1,   ! Datum has no buddies => no action
good_quality             =   0,   ! OBS datum has good quality
convective_adjustment    =   1,   ! convective adjustment check => apply correction on t,
                                  ! td, rh and qv
surface_correction       =   2,   ! Surface datum => apply correction on datum
hydrostatic_recover      =   3,   ! Height from hydrostatic assumption with the OBS data calibration
reference_OBS_recover    =   4,   ! Height from reference state with OBS data calibration
other_check              =  88,   ! passed other quality check
```

OBSPROC performs many quality control checks, and assigns them the above QC flags when creating the ob.ascii file. WRFDA will reject observations with a QC code <=0

# Other notes about observations

- Model meteorological fields are NOT used in OBSPROC
  - The domain variables entered in &record6 and &record7 are only used for discarding variables that are outside your domain
  - This is optional (controlled by namelist variable domain_check_h = .true., under &record4) but recommended to keep the observation file at a manageable size
- The observed variables are, by and large, different than the "state variables" used in WRF and WRFDA, which are also different from the "control variables" used in WRFDA

<u>variables in ob.ascii</u>

- wind speed *or* U (east-west wind)
- wind direction *or* V (north-south wind)
- sea level pressure
- pressure
- height
- temperature
- dew point temperature
- relative humidity
- total precipitable water
- **GPS refractivity**
- **SATEM thickness**

*converted to* →

<u>state variables in WRFDA</u>

- x-component wind u (relative to **model** grid)
- y-component wind v (relative to **model** grid)
- temperature
- specific humidity
- surface pressure
- pressure

*converted to* →

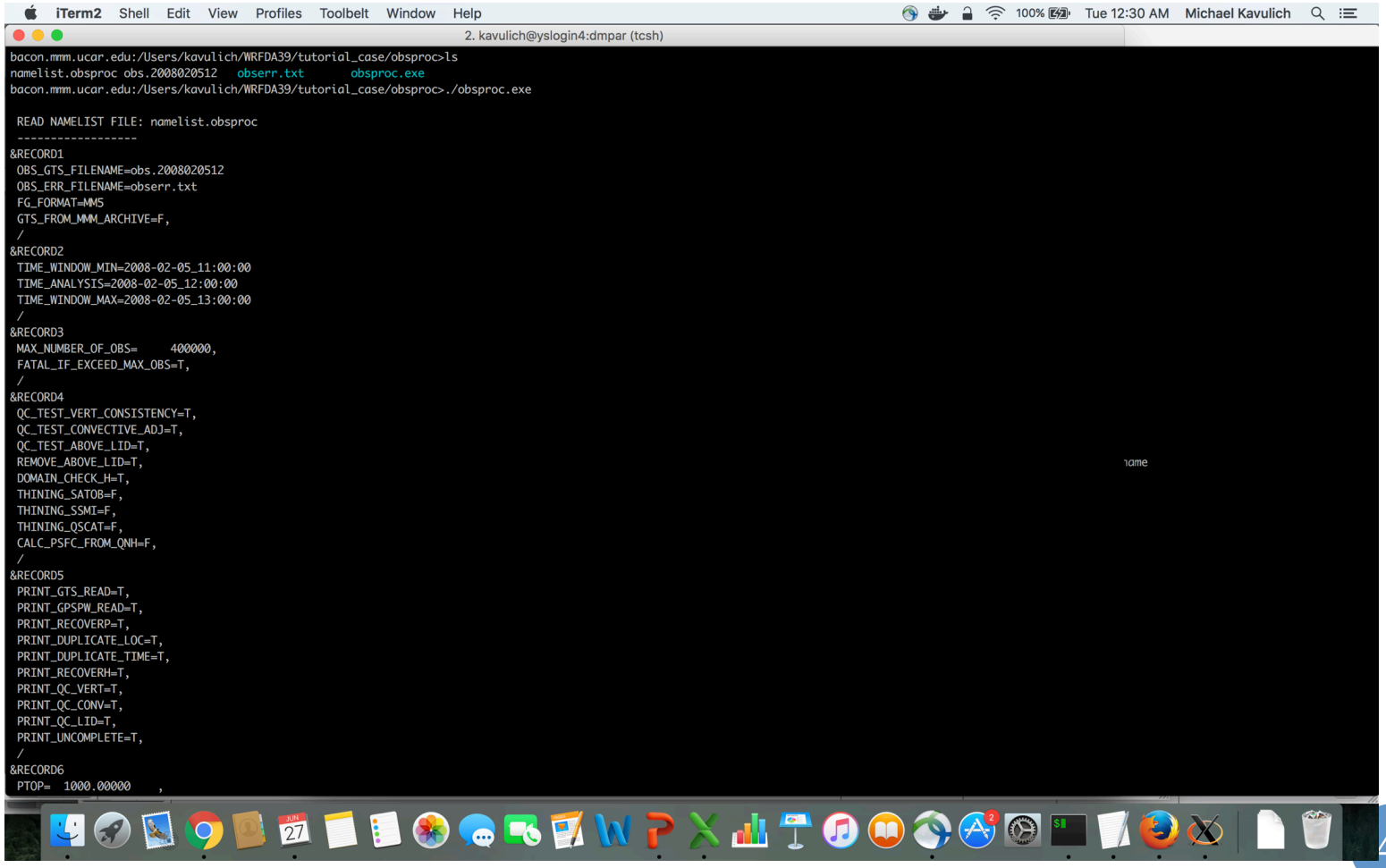
<u>control variables in WRFDA</u>

- **$\psi$ or u**
- **$\chi_u$ or v**
- **$T_u$ or T**
- **$P_{sfc,u}$ or $P_{sfc}$**
- **q or $RH_{s,u}$ or $RH_s$**

**More about control variables in the BE talk**

# Observation Preprocessor (OBSPROC)

## Live demonstration!



# Overview

- Observations in WRFDA
  - Observation types in WRFDA
  - Observation formats in WRFDA
- LITTLE_R format and OBSPROC
  - LITTLE_R format
  - OBSPROC
  - Other notes on observations
- Converting observations
  - Converting to LITTLE_R format
  - Converting to other formats
- Plotting observations

# Converting observations to LITTLE_R

## Things to consider when converting your observations to LITTLE_R format

- Not all variables are read in for each observation type
  - The FM-code determines which variables will be read by OBSPROC and WRFDA

| | | | |
|---|---|---|---|
| FM-12 SYNOP u, v, t, p, q | FM-32 PILOT: u, v | FM-88 SATOB (amv): u, v | FM-116 GPSREF: ref |
| FM-13 SHIP u, v, t, p, q | FM-35 SOUND u, v, t, q, psfc | FM-101 TAMDAR: u, v, t | FM-132 PROFL: u, v |
| FM-15 METAR u, v, t, p, q | FM-42/96 AMDAR/AIREP u, v, t | FM-111 GPSPW: tpw | FM-133 AIRSRET: t, q |
| FM-18 BUOY u, v, t, p, q | FM-86 SATEM: thickness | FM-114 GPSZTD: ztd | FM-281 QSCAT: u, v |

  - More information available here: http://www2.mmm.ucar.edu/wrf/users/wrfda/OnlineTutorial/Help/littler.html
- Some converters are available; you may be able to adapt the code for your own file format

# Converting observations to LITTLE_R

## MADIS2LITTLER converter

- Converts MADIS netCDF-format data into LITTLE_R format
  - MADIS is a data collection and distribution service that contains data from a large number of surface and upper air stations world-wide
  - Data available from http://madis.noaa.gov/
- http://www2.mmm.ucar.edu/wrf/users/wrfda/download/madis.html

## PREPBUFR2LITTLER converter

- Converts PREPBUFR format data into LITTLE_R format
- Useful if you have a mix of PREPBUFR and LITTLE_R data
- http://www2.mmm.ucar.edu/wrf/users/wrfda/download/prepbufr_littler.html

# Converting observations to LITTLE_R

## A sample of FORTRAN code for writing *surface* data in LITTLE_R format

```
 CHARACTER ( LEN = 120 ) , PARAMETER :: rpt_format =  &
                         ' (2F20.5, 4A40, 1F20.5, 5I10, 3L10, 2A40, ' &
                         // ' 1F20.5, 5I10, 3L10, 2I10, A20, 13(F13.5, I7)'

 CHARACTER ( LEN = 120 ) , PARAMETER :: meas_format = ' ( 10( F13.5, I7 ) ) '

 CHARACTER ( LEN = 120 ) , PARAMETER :: end_format = ' ( 3 ( I7 ) ) '

! header record:
 WRITE ( UNIT = iunit , FMT = rpt_format )                              &
      lat, lon, ID_string, Name_string, FM_string, Source_string,       &
      elev, 0, 0, 0, seq_num, 0, .false., is_bogus, discard, 0, 0,      &
      date_char, slp, slp_qc, ref_pres, ref_pres_qc, -888888., 0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0

! data record:
 WRITE ( UNIT = iunit , FMT = meas_format )                             &
      p, 0, z,0, t,0, td,0, spd,0, dir,0,                               &
      -888888.,0, -888888.,0,rh,0, -888888.,0

! ending record:
 WRITE ( UNIT = iunit , FMT = meas_format )                             &
      -777777.,0, -777777.,0, -888888.,0, -888888.,0, -888888.,0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0

! tail integers:
 WRITE ( UNIT = iunit , FMT = end_format )  1, 0, 0
```

# Converting observations to LITTLE_R

## A sample of FORTRAN code for writing *sounding* data in LITTLE_R format

```
! header record:
 WRITE ( UNIT = iunit , FMT = rpt_format )                              &
      lat, lon, ID_string, Name_string, FM_string, Source_string,       &
      elev, 0, 0, 0, seq_num, 0, .false., is_bogus, discard, 0, 0,      &
      date_char, slp, slp_qc, ref_pres, ref_pres_qc, -888888., 0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0

! data record(s):
 DO k = 1 , kx
    WRITE ( UNIT = iunit , FMT = meas_format )                          &
         p(k), 0, z(k),0, t(k),0, td(k),0, spd(k),0, dir(k),0,          &
         -888888.,0, -888888.,0,rh(k),0, -888888.,0
 END DO

! ending record :
 WRITE ( UNIT = iunit , FMT = meas_format )                             &
      -777777.,0, -777777.,0, -888888.,0, -888888.,0, -888888.,0,       &
      -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0

! tail integers:
   WRITE ( UNIT = iunit , FMT = end_format )  kx, 0, 0
```

# Other data sources

**These other data sources do not have converters, so will require some conversion work on your end. Some of these observations are already included in other data sets previously mentioned**

- GPS Refractivity
  - http://cdaac-www.cosmic.ucar.edu/cdaac/products.html
- AIRS Retrievals
  - https://disc.sci.gsfc.nasa.gov/uui/datasets/AIRX2RET_V006/summary?keywords=%22AIRS%22
- Scatterometer data
  - http://www.knmi.nl/scatterometer

# Converting observations to other formats

Code for reading the different observations can be found in the following WRFDA subroutines

- **ob.ascii**
  `var/da/da_obs_io/da_scan_obs_ascii.inc`
  `var/da/da_obs_io/da_read_obs_ascii.inc`

- **ob.bufr**
  `var/da/da_obs_io/da_read_obs_bufr.inc`

- **gpsro.bufr**
  `var/da/da_obs_io/da_read_obs_bufrgpsro.inc`

- **ob.rain**
  `var/da/da_obs_io/da_read_obs_rain.inc`

- **ob.radar**
  `var/da/da_obs_io/da_read_obs_radar.inc`

- **radiances**
  `var/da/da_radiance/da_read_obs_*.inc`

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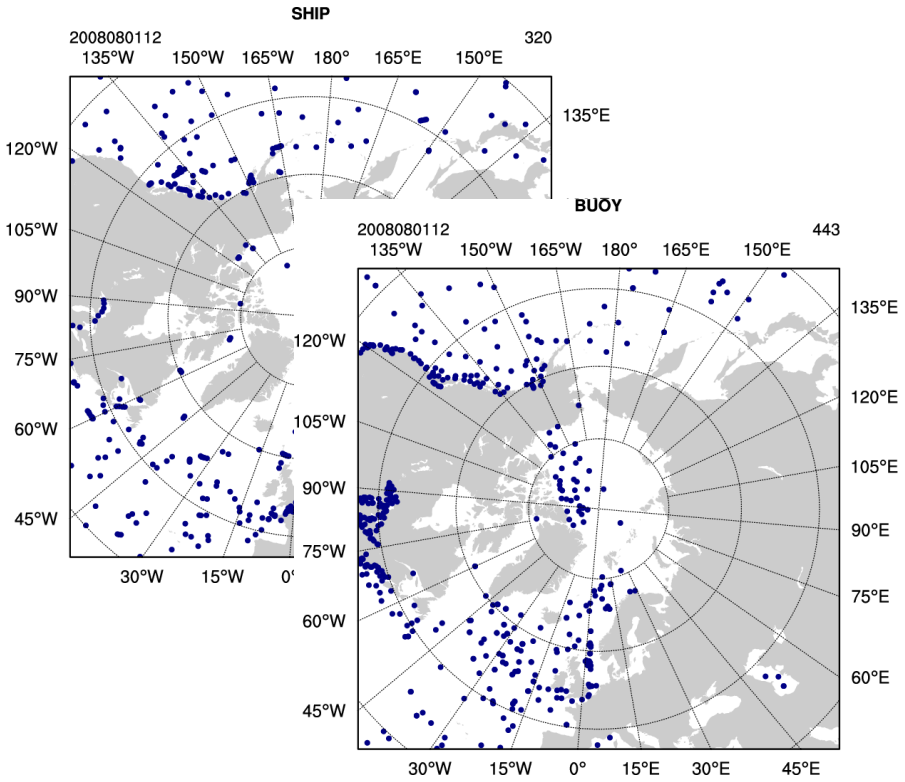
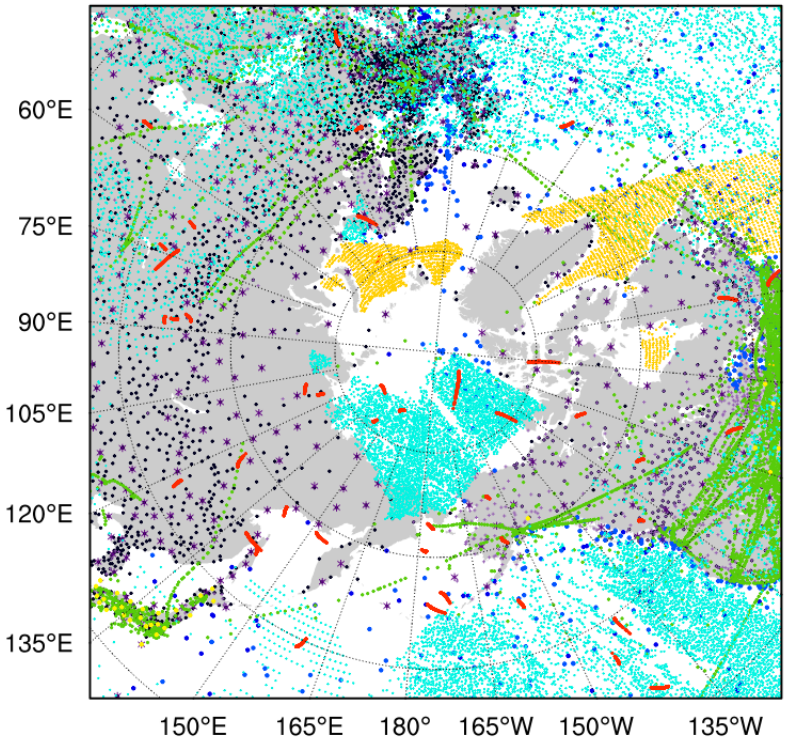
# Plotting observation locations



http://www2.mmm.ucar.edu/wrf/users/wrfda/download/tools.html

var/graphics/ncl/plot_ob_ascii_loc.ncl
– a sample NCL script to plot observation locations

Refer to http://www.ncl.ucar.edu/Applications/station.shtml for more station plotting examples

# To learn more

- Users guide: http://www2.mmm.ucar.edu/wrf/users/wrfda/Docs/user_guide_V3.9/users_guide_chap6.htm#_Running_Observation_Preprocessor_2
- LITTLE_R help page: http://www2.mmm.ucar.edu/wrf/users/wrfda/OnlineTutorial/Help/littler.html

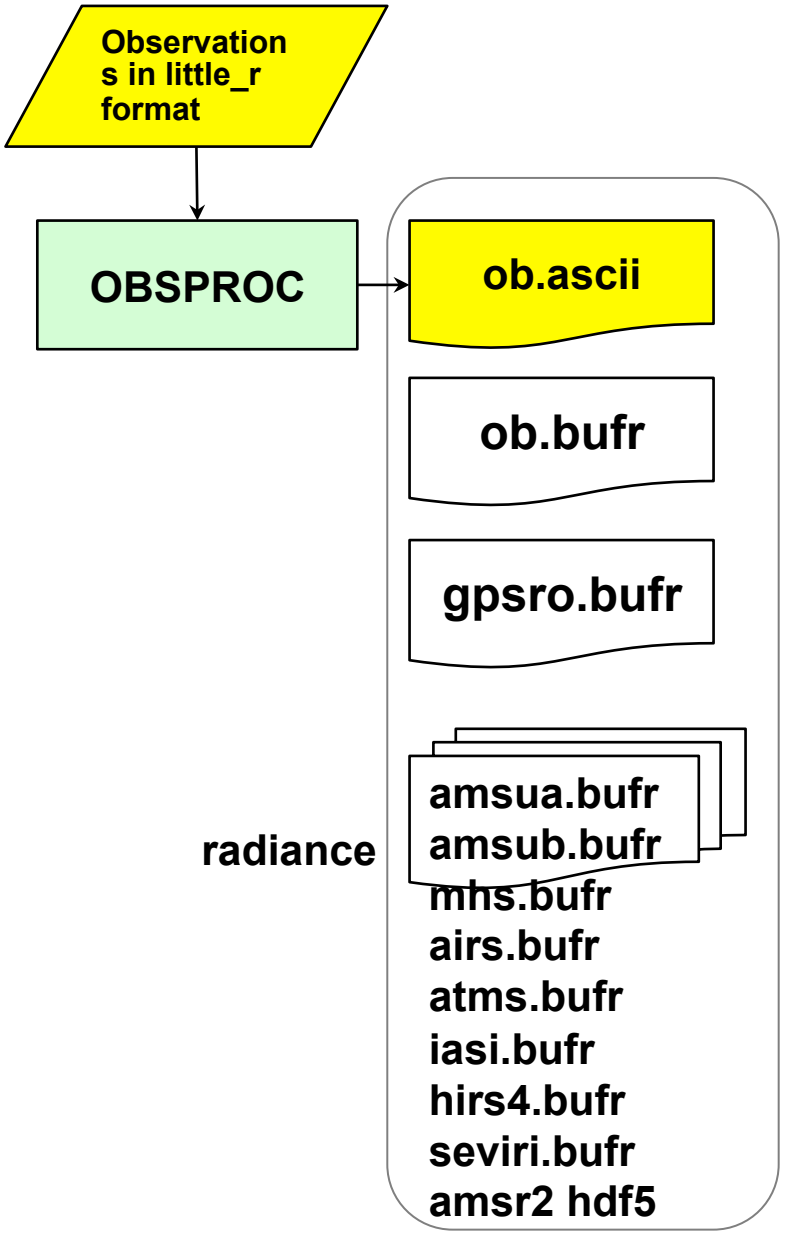
**Upcoming talks:**

- Radiance data assimilation (Craig Schwartz): Tuesday 9 am
- Radar data assimilation (Jenny Sun): Tuesday 2:20 pm

**Any questions?**

# Extra slides

# observation binning for WRFDA




**WRFDA**

**For conventional data:**

- **With ob_format=2, observation binning is done in OBSPROC**
- **With ob_format=1, binning is done inside WRFDA**

**For radiance data: binning is done inside WRFDA**