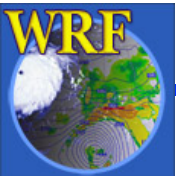
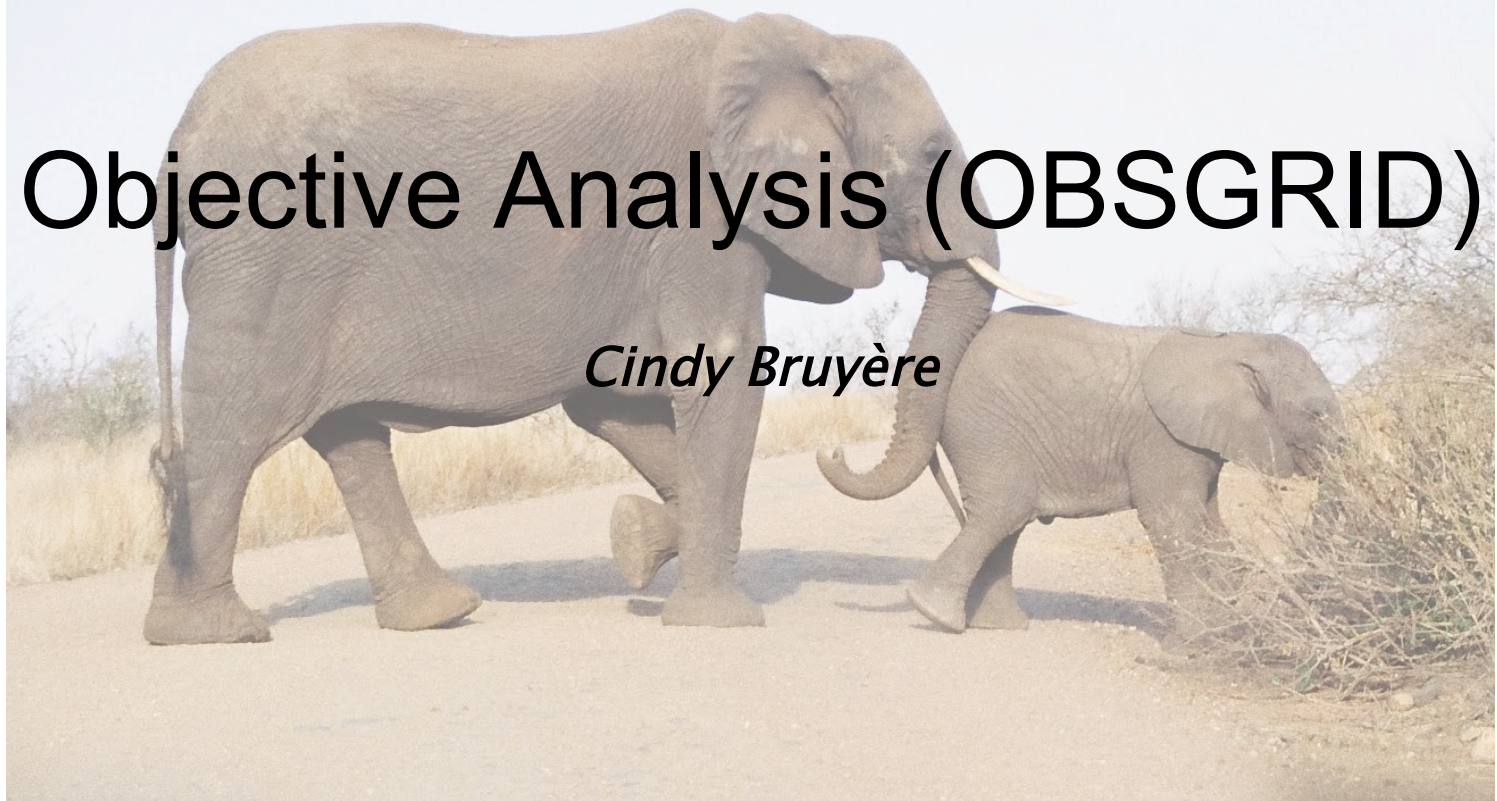


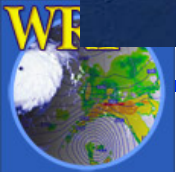
Four Dimensional Data Assimilation (FDDA) *WRF Nudging – Analysis Nudging*

Objective Analysis (OBSGRID)

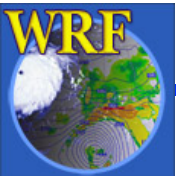
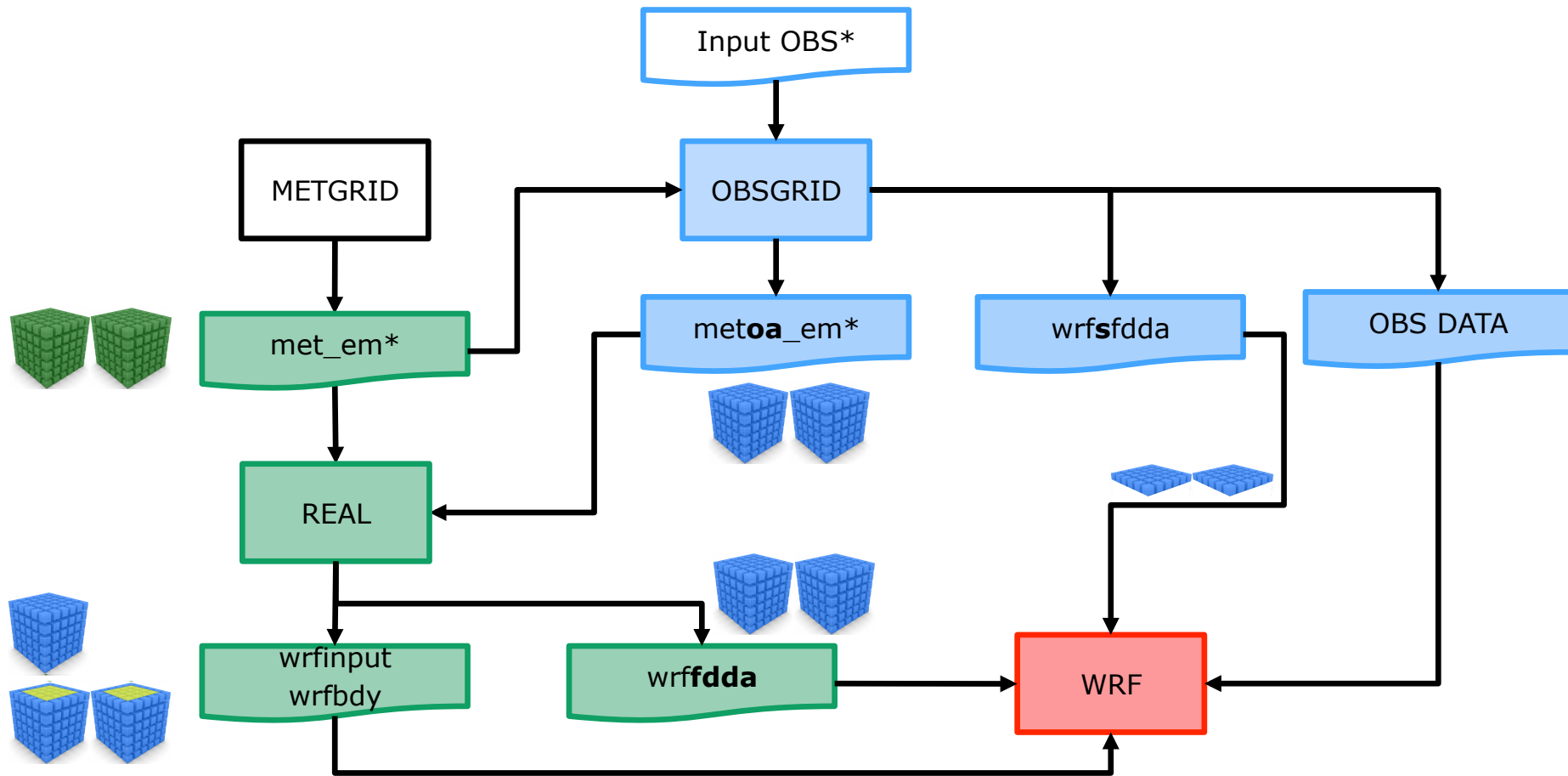
Cindy Bruyère



Concept of Nudging

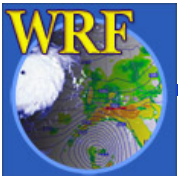


Program Flow

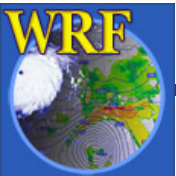
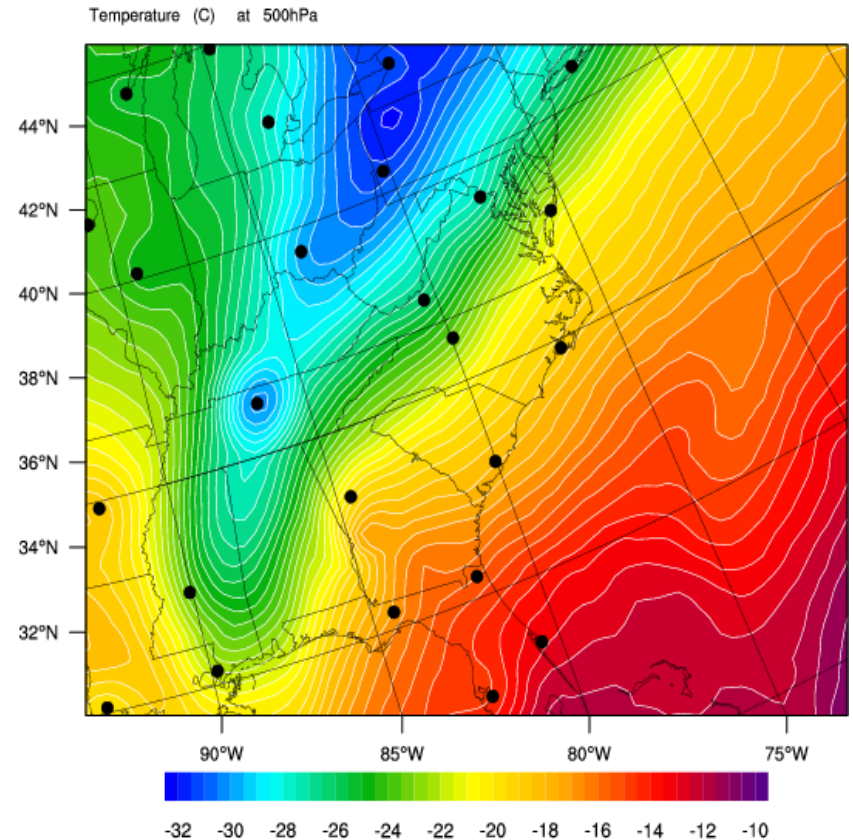
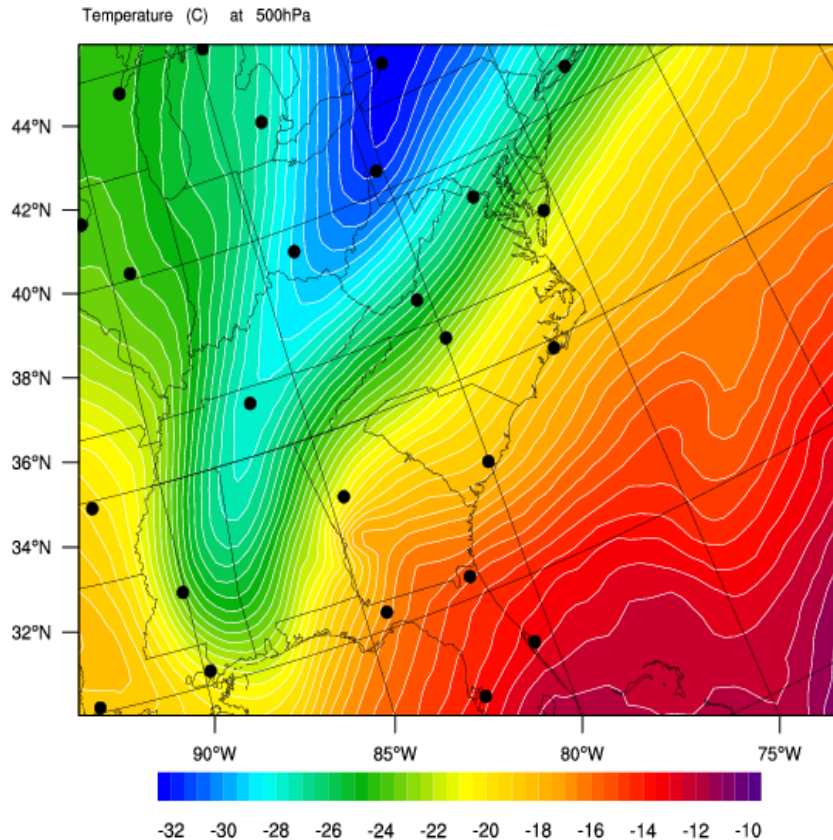


Objective Analysis

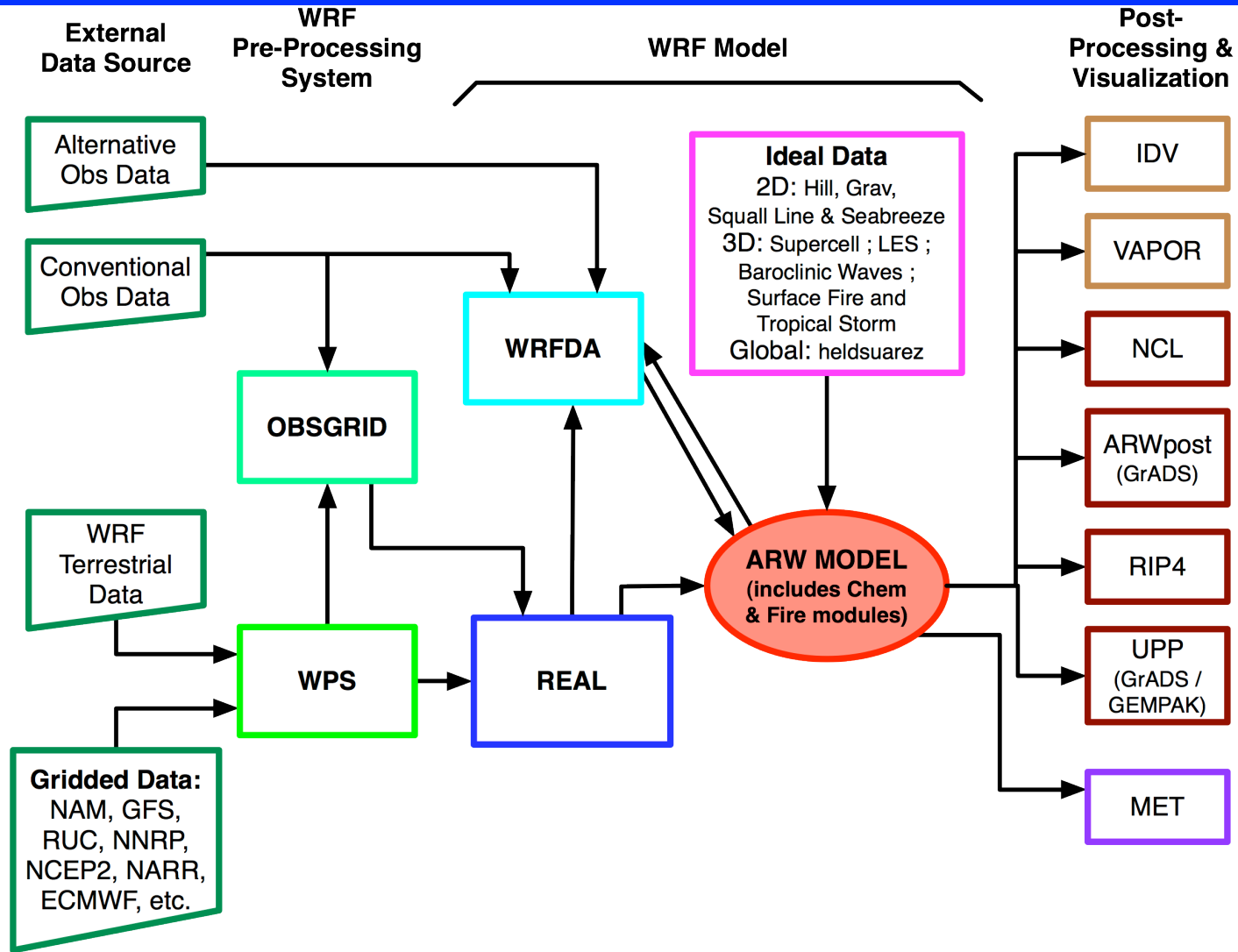
- To improve a *first-guess* gridded analysis by incorporating additional observational information
 - Traditionally, this first-guess analysis comes from low-resolution global analysis and forecast grids
 - These days, higher-resolution, regional scale analyses are more readily available
 - *These high-resolution analyses mean that in many cases, the objective analysis step is not essential when running WRF*
- Methods
 - Traditional methods
 - *Direct observations of T, U, V, RH at surface and on pressure levels (conventional observations)*
 - Variational Analysis
 - *Direct and indirect observations on model levels (conventional + alternative observations)*
 - *WRFDA*



Objective Analysis



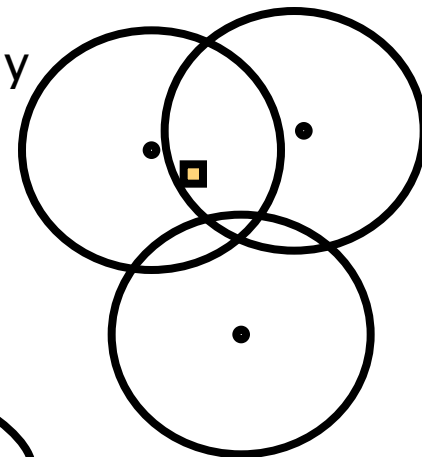
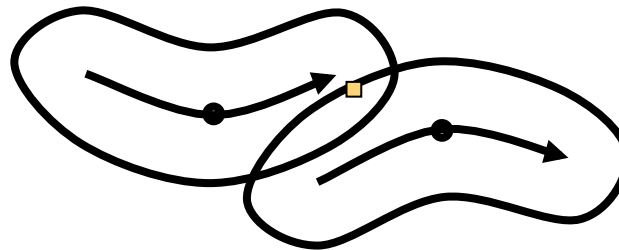
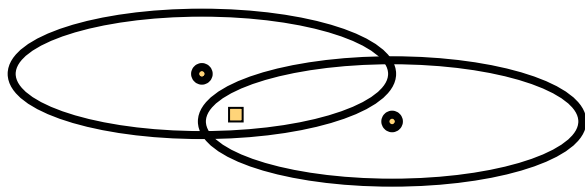
WRF Modeling System Flow Chart



OA Techniques in OBSGRID

- Cressman-based analysis

- Impact of observation within radius of influence only
- Multiple scans
- With ellipse and banana extensions

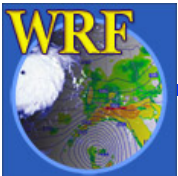
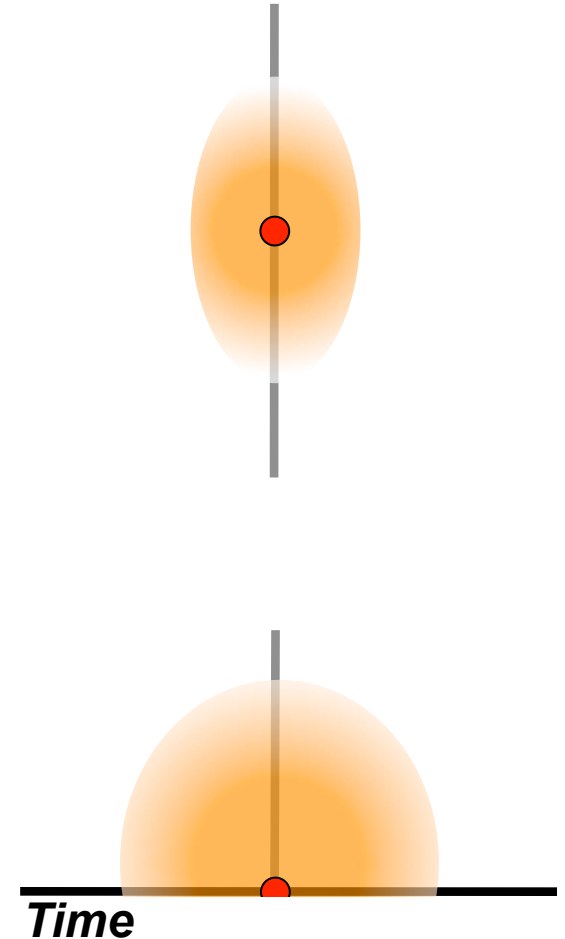
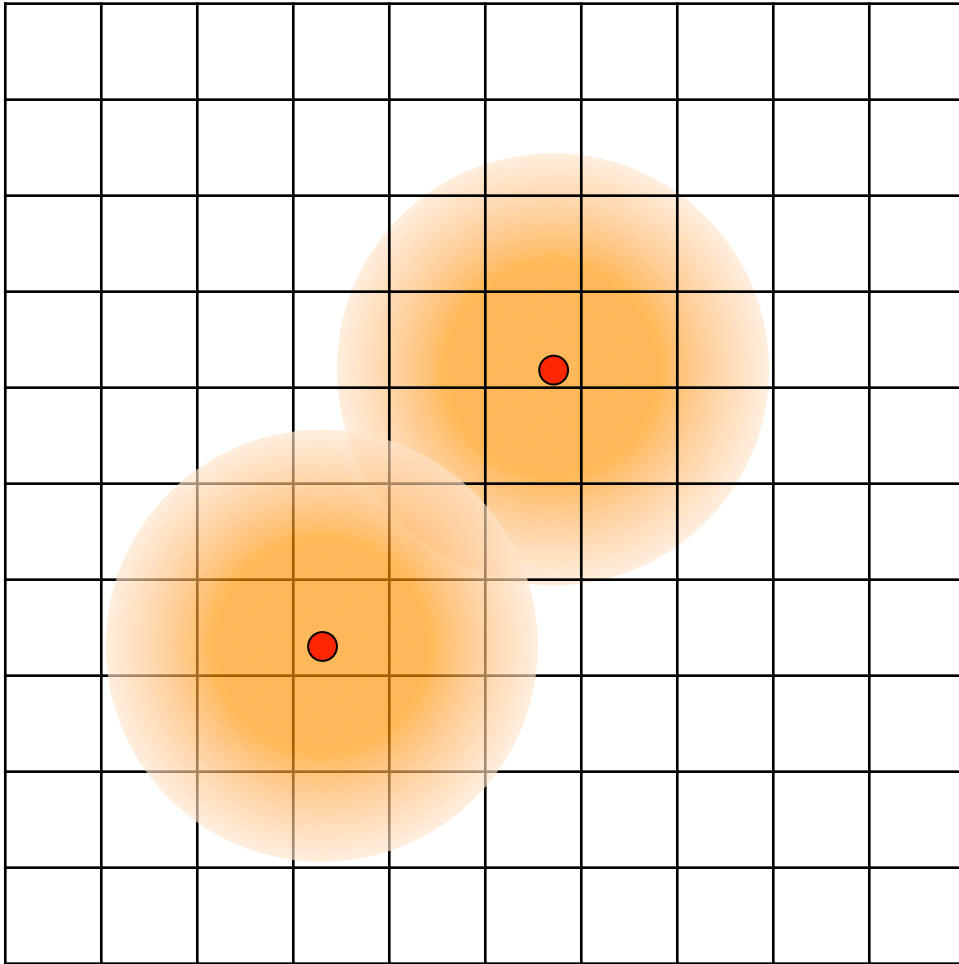


- Multi-Quadric analysis

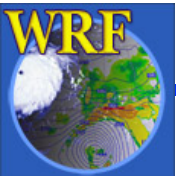
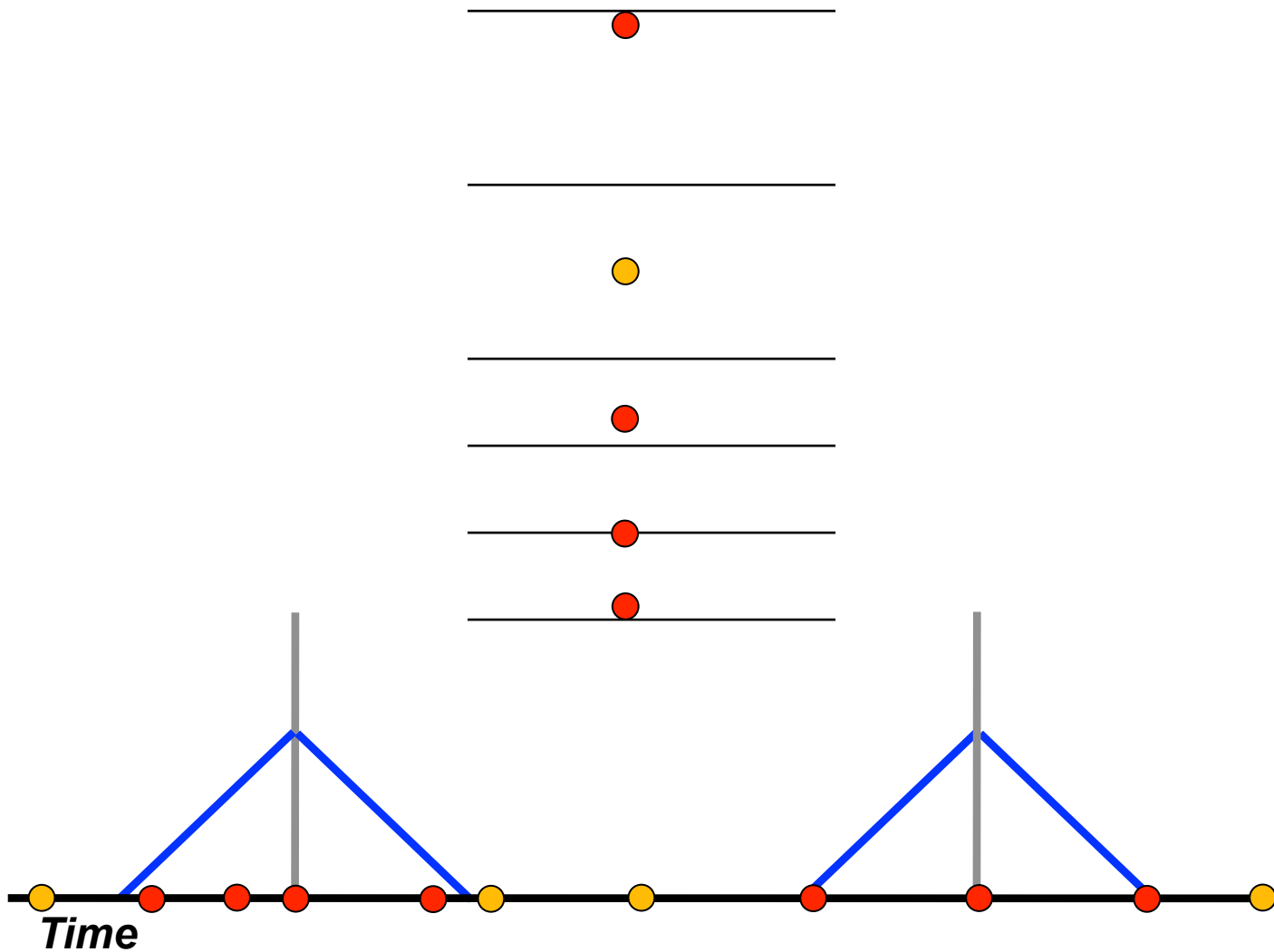
- Impact of observations are over the entire model domain
- Scheme is sensitive to the data density distribution
- Makes use of hyperboloid radial basis functions to interpolate observation corrections onto model grid



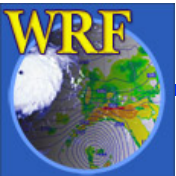
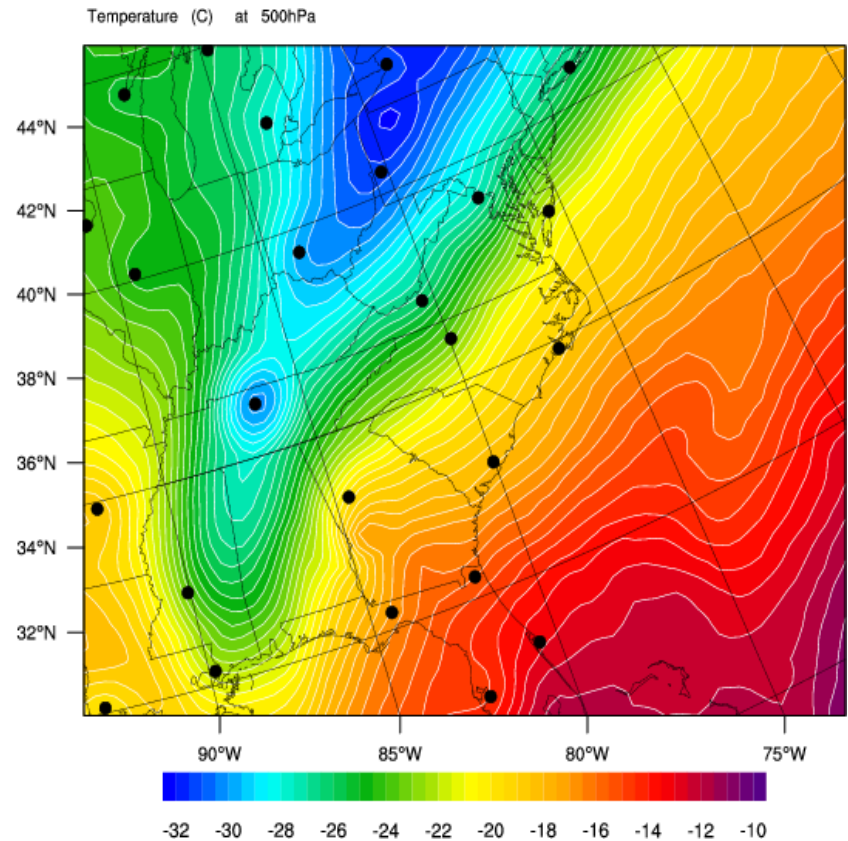
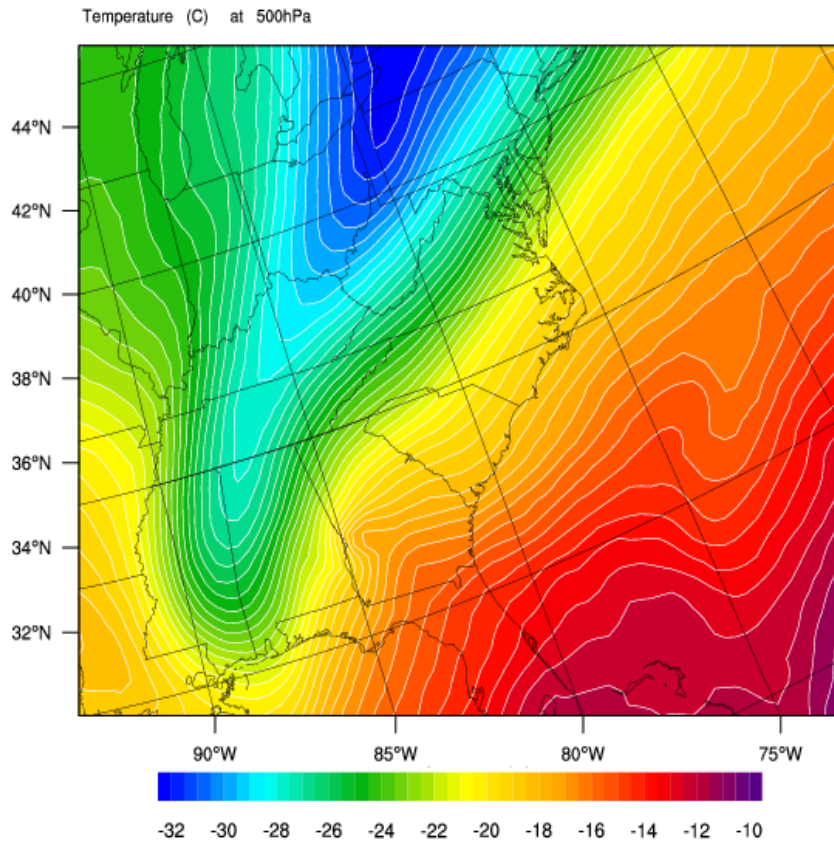
Observational Nudging



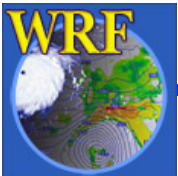
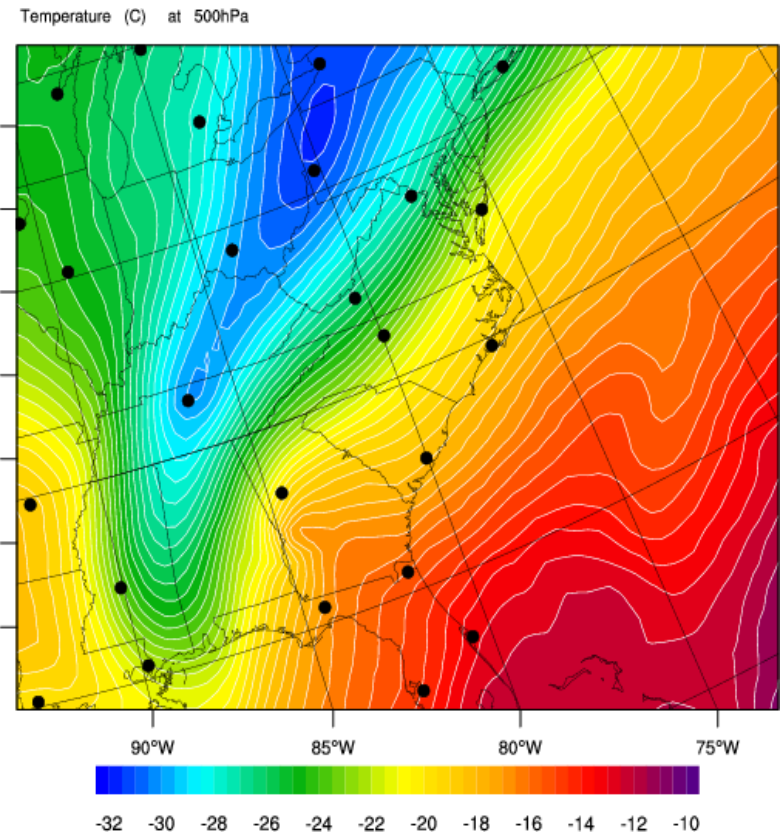
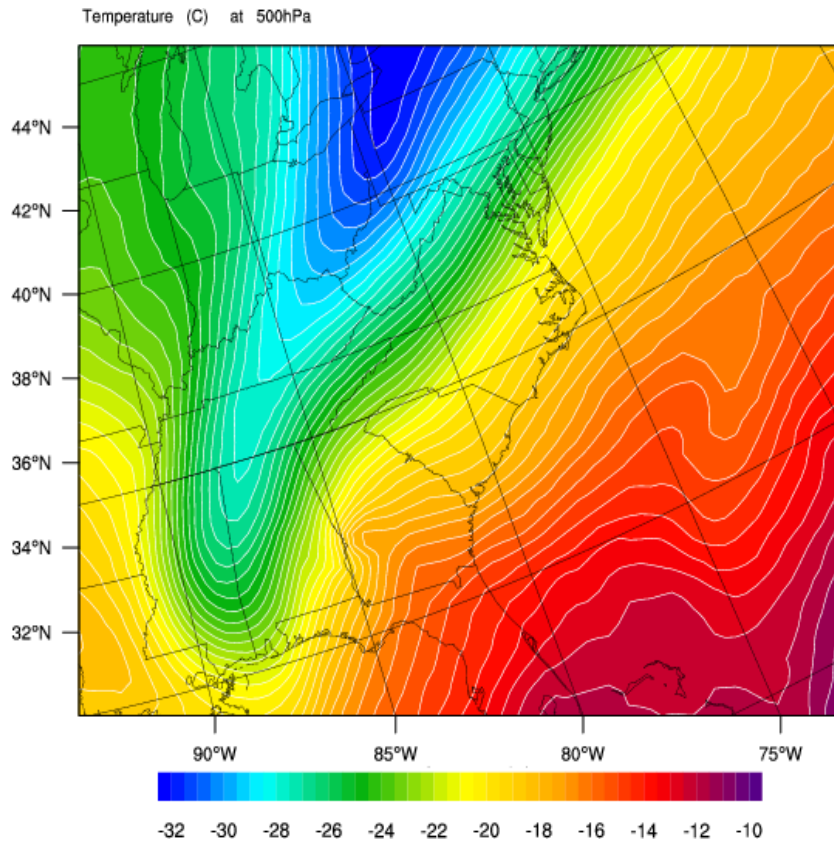
QC of Observations



Cressman Scheme

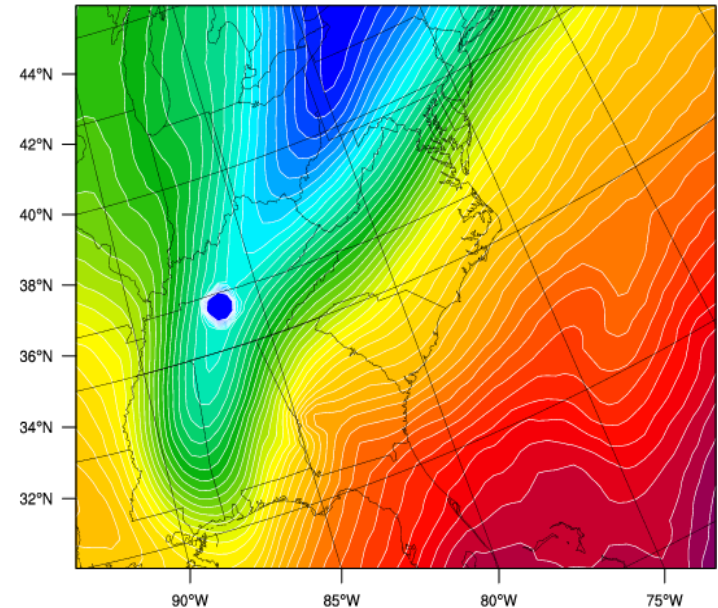


Multi-Quadric Scheme



Quality Control for Observations

- A critically important step
 - Bad observations = Bad objective analysis
- Even a single bad observation can ruin initial conditions
- Default namelist settings should in most cases prevent this from happening
- Tests performed in OBSGRID
 - Tests on individual reports
 - *Only gross checks, no comparisons to other soundings or to first-guess field*
 - ERRMAX test
 - Buddy test



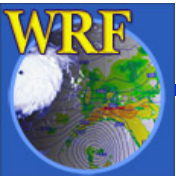
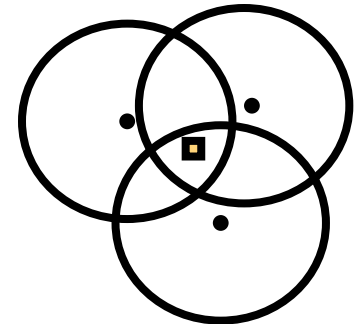
Tests performed in OBSGRID

- **ERRMAX test**

- Observations are compared to first-guess field
- If the difference between the observation and the first-guess exceeds a threshold, the observation is discarded
- Threshold varies depending on field, level, time of day
- Works well with good first-guess field

- **BUDDY test**

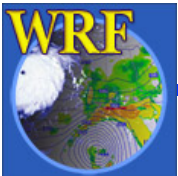
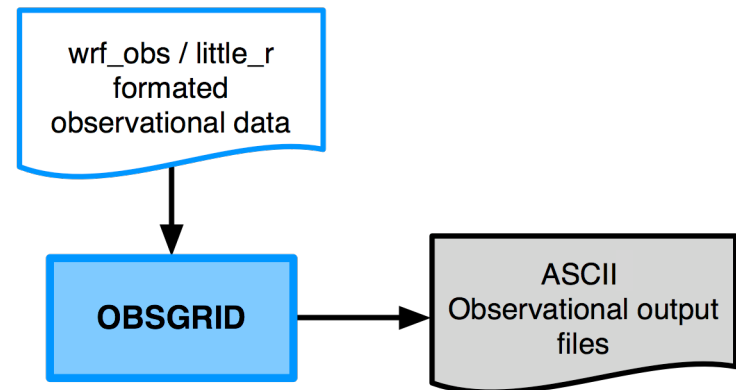
- Observations are compared to the first guess and to nearby observations
- If an observation deviates from the first guess in a manner inconsistent with the deviations of surrounding stations observation is discarded
- Works well in regions of good data density



Observations

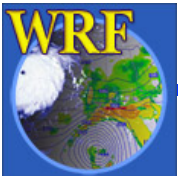
UG: 7-13

- ASCII text files (*wrf_obs / little_r format*)
 - One entry per observation (*sfc or upper-air*)
 - Header ; Data ; End
- Each time period is stored in a separate file
 - Naming convention: *obs_filename:<YYYY-MM-DD_HH>*
- OBSGRID combines reports, removes duplicates, interpolates to analysis levels



Observations Format

header {
station_latitude, station_longitude, station_id,
station_name, type_of_observation, observation_source,
station_elevation, num_valid_fields, num_errors,
num_warnings, report_number, number_of_report_duplicates,
is_this_a_sounding, is_this_a_bogus_observation,
discard_the_report, time_of_report, julian_day,
report_time, slp, slp_qc, ref_pres, rpres_qc, ground_t,
t_qc, sst, sst_qc, psfc, psfc_qc, precip, precip_qc,
t_max, t_max_qc, t_min, t_min_qc, t_min_night,
t_min_night_qc, p_tend03, tend03_qc, p_tend24, tend24_qc,
cloud_cvr, cloud_qc, ceiling, ceiling_qc
end data {
pressure, p_qc, height, z_qc, temperature, t_qc,
dew_point, td_qc, speed, spd_qc, direction, dir_qc, u,
u_qc, v, v_qc, rh, rh_qc, thickness, tn_qc
num_valid_fields, num_errors, num_warnings



Observations Format

44.08000 -103.2100072662 RAPID CITY WFO, SD. / UNITED STATES OF AFM-35 TEMP										GTS (ATEC)	
UEUS05 KWBC 190000	1029.00000	20	-888888	-888888	446	-888888	T	F	F	-888888	-888888
20080119000000-888888.00000	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	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	00000	0			
100000.00000	0	249.00000	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
92500.00000	0	852.00000	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
90400.00000	0	1029.00000	0	260.65000	0	255.65000	0	6.18557	0	335.00000	0-888888.00000
90300.00000	0-888888.00000	0	261.25000	0	252.25000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
89600.00000	0-888888.00000	0	261.05000	0	252.05000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
88900.00000	0-888888.00000	0	260.85000	0	247.85000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
85000.00000	0	1400.00000	0	257.65000	0	246.65000	0	15.46302	0	315.00000	0-888888.00000
79500.00000							0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
78000.00000							0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
73100.00000							0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
72100.00000							0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
70000.00000							0	330.00000	0-888888.00000	0-888888.00000	0
69400.00000	0-888888.00000	0	249.05000	0	243.05000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
62300.00000	0-888888.00000	0	243.65000	0	233.65000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
55700.00000	0-888888.00000	0	237.85000	0	226.85000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
50700.00000	0-888888.00000	0	232.05000	0	223.05000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
50300.00000	0-888888.00000	0	231.65000	0	222.65000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
50000.00000	0	5300.00000	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
46100.00000	0-888888.00000	0	227.85000	0	217.85000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
3100.00000	0-888888.00000	0	214.45000	0	213.65000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
-77777.00000	0-77777.00000	0	20.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0
20	0	0									

51.48000 -0.4500003772 ICAO EGLL London / Heathrow Airport Un tFM-15 METAR										GTS (ATEC)	
SAUK31 KWBC 190020 CCA	24.00000	10	-888888	-888888	525	-888888	F	F	-888888	-888888	
20080119002000-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0 101200.00000	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	24.00000	0	286.15000	0	284.15000	0	8.76289	0	230.00000	0-888888.00000
-77777.00000	0-77777.00000	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
10	0	0									



Quality-Control Flags

- Binary flags indicating which warning and error conditions have been met

Pressure interpolated from first-guess height	2**1	2
Temperature and dewpoint both 0	2**4	16
Wind speed and direction both 0	2**5	32
Wind speed negative	2**6	64
Wind direction < 0 or > 360	2**7	128
Level vertically interpolated	2**8	256
Value vertically extrapolated from a single level	2**9	512
Sign of temperature reversed	2**10	1012
Superadiabatic level detected	2**11	2048
Vertical spike in wind speed or direction	2**12	4096
Convective adjustment applied to temperature field	2**13	8192
No neighboring observations for buddy check	2**14	16384

data outside normal analysis time and not QC-ed	2**15	32768

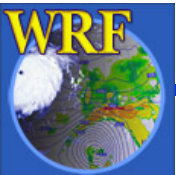
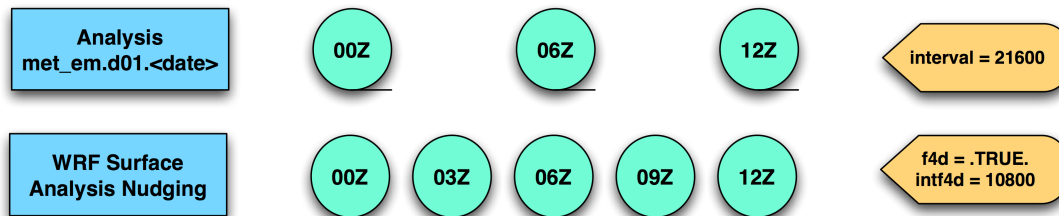
fails error maximum test	2**16	65536
fails buddy test	2**17	131072
observation outside of domain detected by QC	2**18	262144



Namelist

UG: 7-15

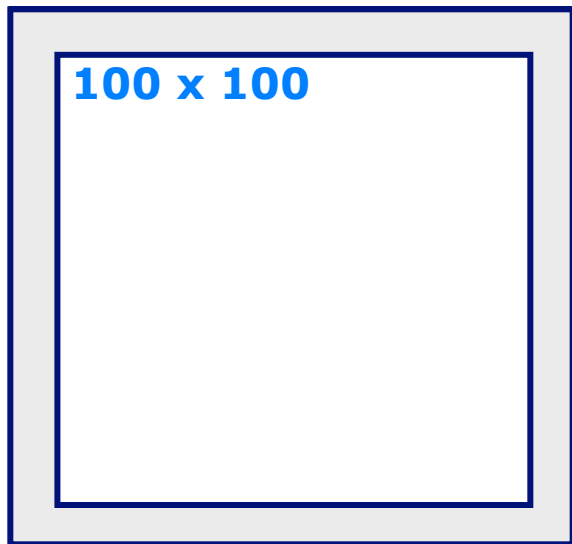
obs_filename	Root file name (<i>may include directory information</i>) of the observational files. All input files must have the format <code>obs_filename:<YYYY-MM-DD_HH></code> . One file per time period Also used when doing surface fdda (<i>F4D=.TRUE.</i>)
interval	Interval between analysis times (sec) <i>i.e., interval between met_em.d0x.<date> files</i>
f4d	Turn on / off the creation of the surface analysis file (<i>wrfsfdda_d0x</i>)
intf4d	Time interval (sec) for surface analyses (<i>typically smaller than interval between analysis</i>)



Namelist

<code>domain_id</code>	ID of domain to process
<code>trim_domain</code>	Set to <code>.TRUE.</code> if this domain must be cut down on output
<code>trim_value</code>	Value by which the domain will be cut down in each direction

110 x 110

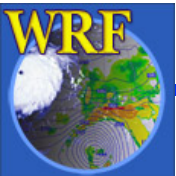


- **Why do this:**

This allows observations just outside the desired grid box of 100x100 grid points to be included in the OA

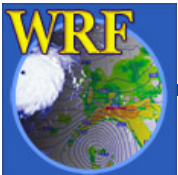
- ***geogrid* and *metgrid* run with a domain size of 110x110**

- **When running *obsgrid* set
`trim_domain = .TRUE.`
`trim_value = 5`**



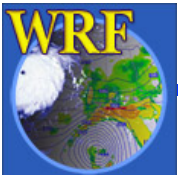
Namelist

<code>qc_test_error_max</code>	Turn on error-max test (T/F)
<code>max_error _t _uv _rh _p</code>	Max difference in T, uv, RH & SLP allowed for error-max test
<code>qc_test_buddy</code>	Turn on buddy test (T/F)
<code>max_buddy _t _uv _rh _p</code>	Threshold for T, uv, RH & SLP allowed for buddy test
<code>buddy_weight</code>	Scaling for buddy thresholds
<code>qc_test_vert_consistency</code>	Turn on vertical tests (T/F)
<code>remove_data_above_qc_flag</code>	Data with qc flags higher than this will not be output to OBS_DOMAINdxx (32768/65536)
<code>remove_unverified_data</code>	Unverified data will not be output to OBS_DOMAINdxx



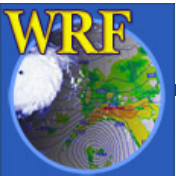
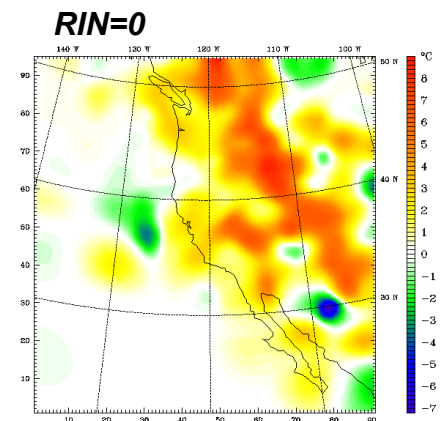
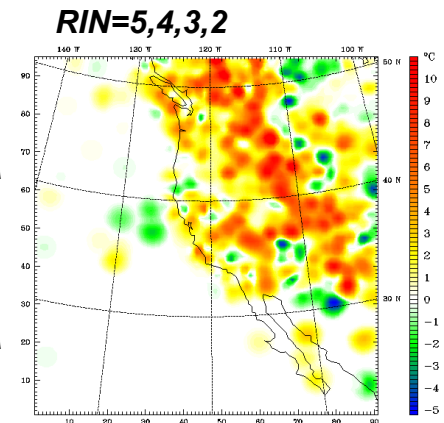
Namelist

OA_type	“MQD” or “Cressman”
radius_influence	Radius of influence for Cressman {0} ; {-5} ; {5,4,3,2}
OA_min_switch (T/F) MQD_minimum_num_obs	Switch to Cressman if too few obs for MQD Minimum number of obs for MQD to switch
OA_max_switch (T/F) MQD_maximum_num_obs	Switch to Cressman if too many obs for MQD Maximum number of obs for MQD to switch
OA_3D_type	“Cressman”
OA_3D_option	0 ; 1 ; 2



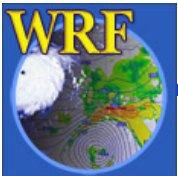
Namelist

- OA_type = “Cressman”
 - *All OA for surface and upper-air will be Cressman*
- radius_influence
 - **0**
*Code will automatically calculate number of grids to use of OA
Will use 4 scans*
 - **-5**
*Code will automatically calculate number of grids to use of OA
Will use set number of scans (5 in the example)*
 - **5, 4, 3, 2**
Use 4 scans with grid points as set



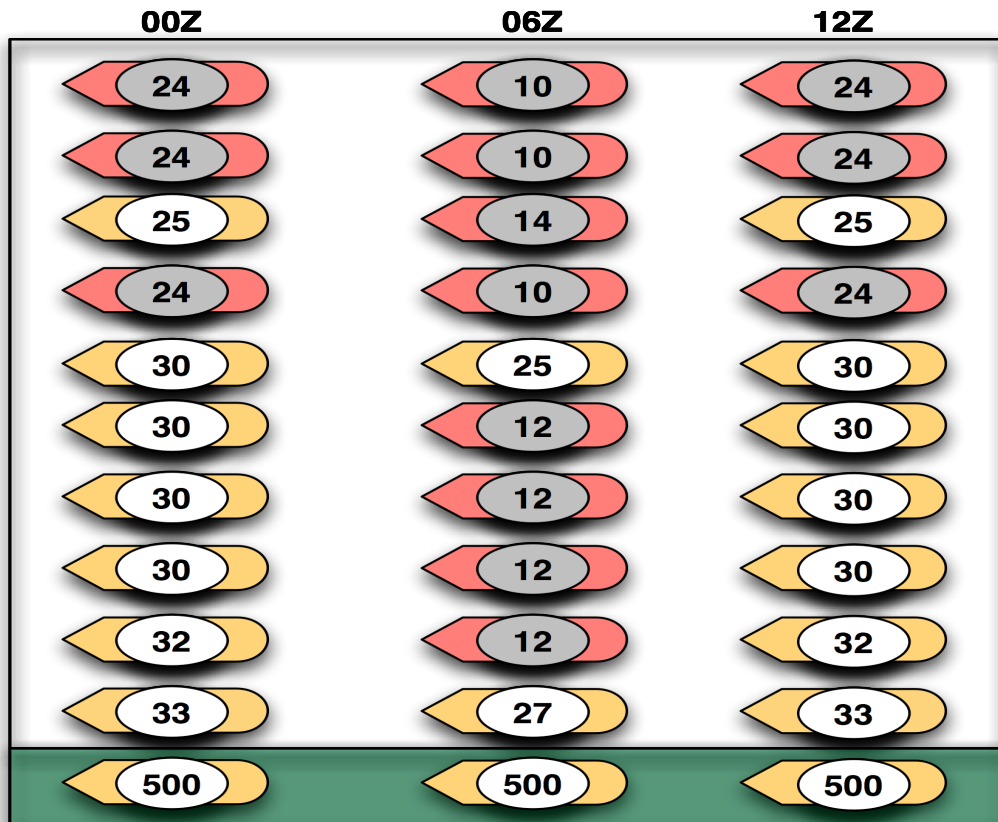
Namelist

- OA_type = “MQD”
 - *Will attempt to use MQD for all OA*
 - *Set radius_influence in case code has to switch to Cressman (recommend 0)*
- OA_max_switch (T/F) ; MQD_maximum_num_obs
 - *T ; Switch to Cressman if too many observations*
 - *F ; No OA if too many observations*
 - *Only needed if the code takes too long to execute due to large number of observations*
- OA_min_switch (T/F) ; MQD_minimum_num_obs
 - *T ; Switch to Cressman if too few observations*
 - *F ; No OA if too few observations*



Namelist

- OA_type = “MQD” ;
OA_min_switch = T ; MQD_minimum_num_obs = 25



Different schemes used in surface and upper-air is fine

Switch in upper-air between MQD and Cressman is undesired

Code will STOP
{OA_3D_option = 0}

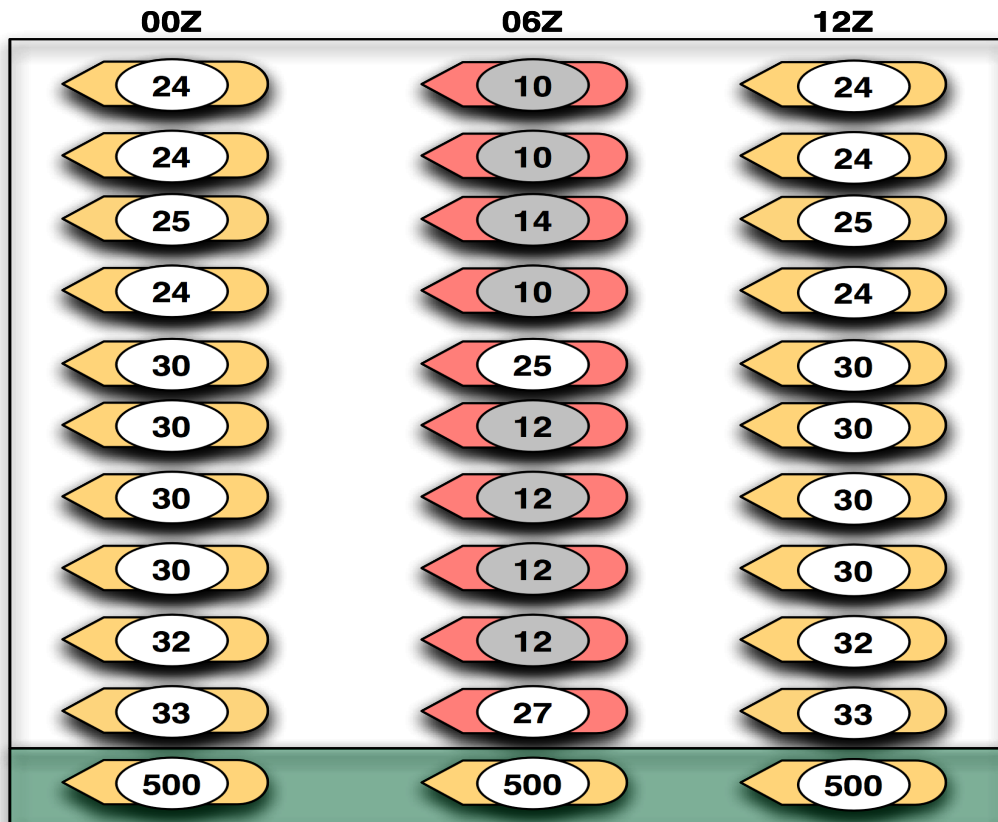
Can force this behavior
{OA_3D_option = 2}

MQD ; Cressman



Namelist

- OA_type = “MQD” ;
OA_min_switch = T ; MQD_minimum_num_obs = 24



MQD_minimum_num_obs = 24

Do not make this too low in order to force MQD (i.e., 9 in this case)

OA_3D_option = 1

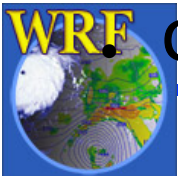
*All upper-air, at a given time
Especially good for f4d runs*

MQD ; Cressman



How to run OBSGRID

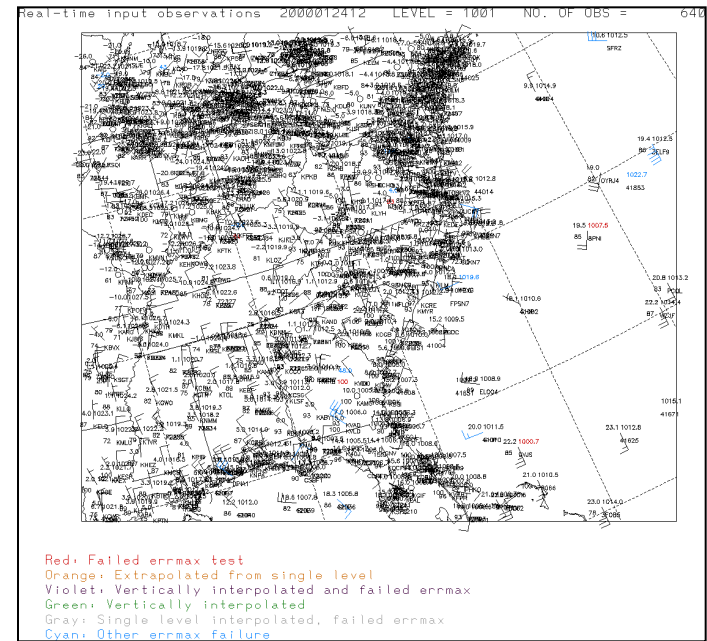
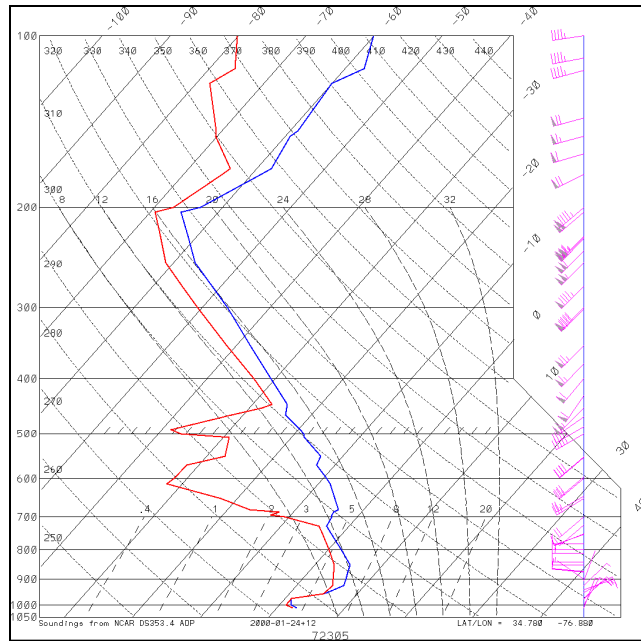
- Get the source code
- Compile (*./configure & ./compile*)
- Prepare observations files
 - Users need to generate this file (*some sample programs are available*)
- Edit the namelist
- Run the program



• Check your output

Utilities

- **plot_sound**
 - Plot sounding from the 'raw' or 'used' wrf_obs / little_r output files
 - Namelist control: &record1, &record2, &plot_sounding
- **plot_level**
 - Plot data used on all levels
 - Namelist control: &record1, &record2



Special NOTE for Classroom

From your WRFV3/test/em_real directory

```
cp /wrfhelp/SOURCE_CODE/wrf.exe .
```

