WRF 3D-VAR

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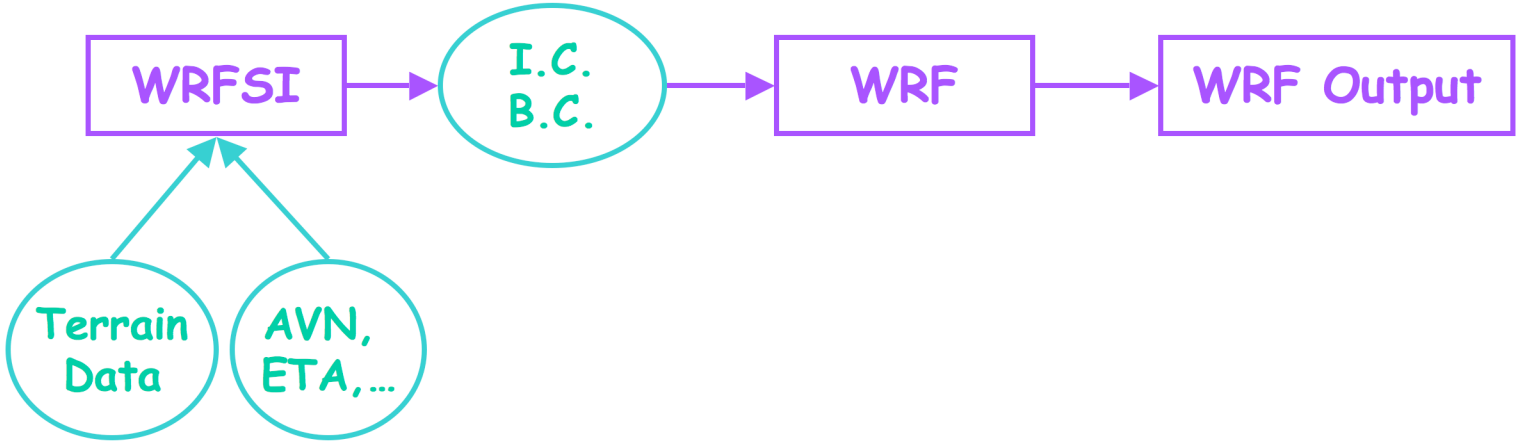
[2] NCAR/MMM

http://www.mmm.ucar.edu/wrf/WG4

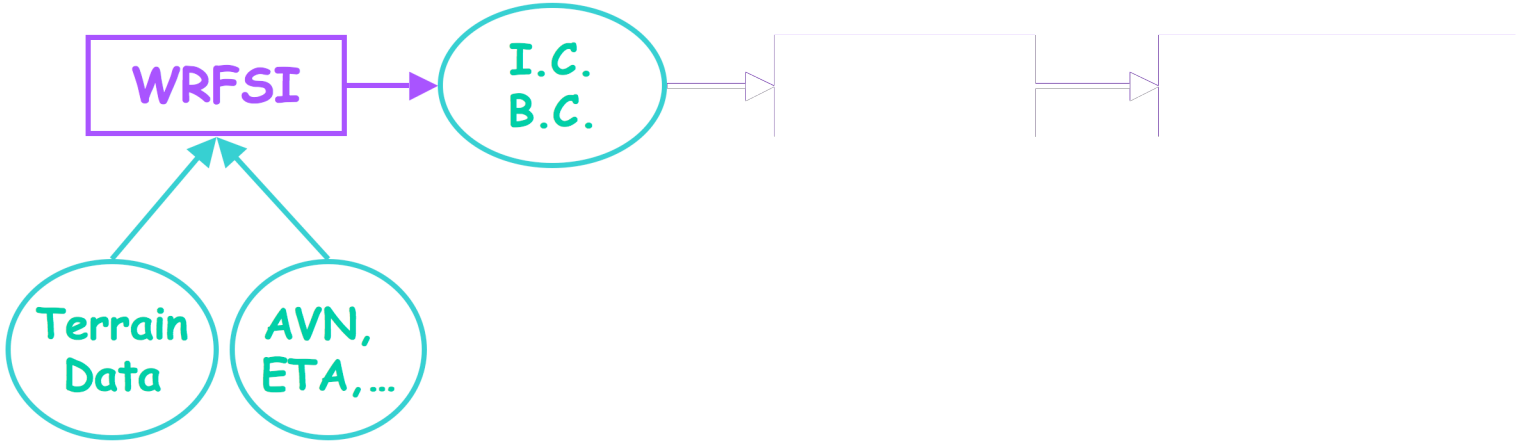
Special Thanks to

Y.-R. Guo & S.-Y. Chen

Run Regional WRF Model Flow Chart



Run Regional WRF Model Flow Chart

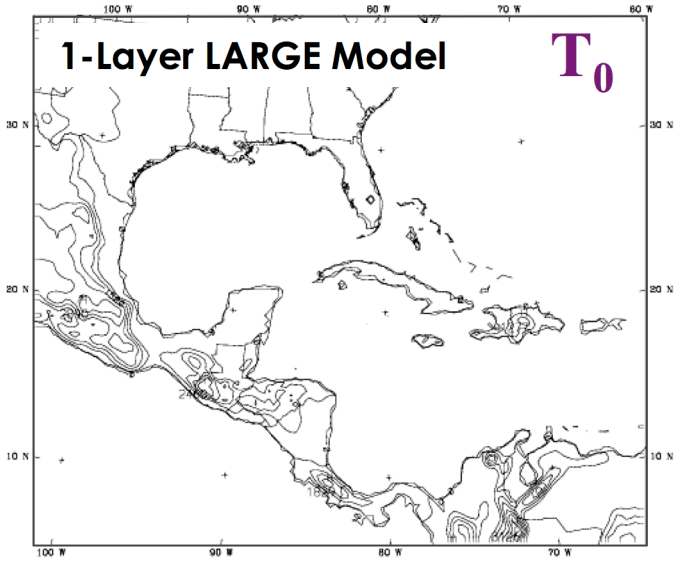


I.C. & B.C.

Example, a 1-Layer SMALL Model (1LSM)

I.C. & B.C.

Example, a 1-Layer SMALL Model (1LSM)



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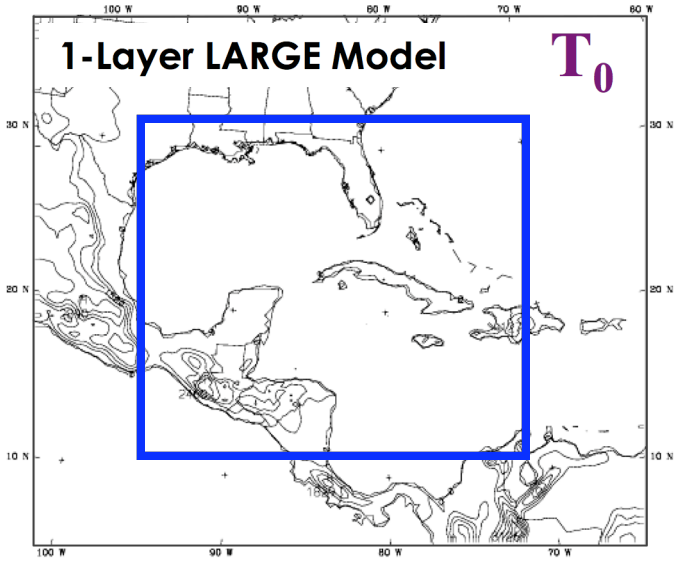

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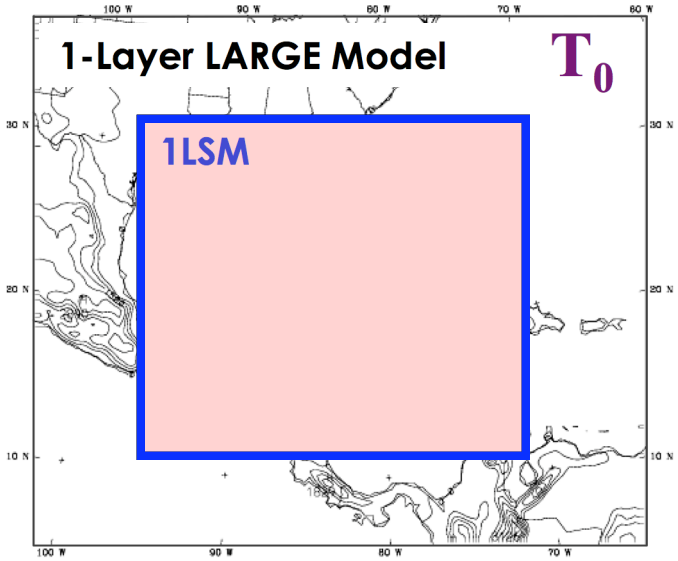

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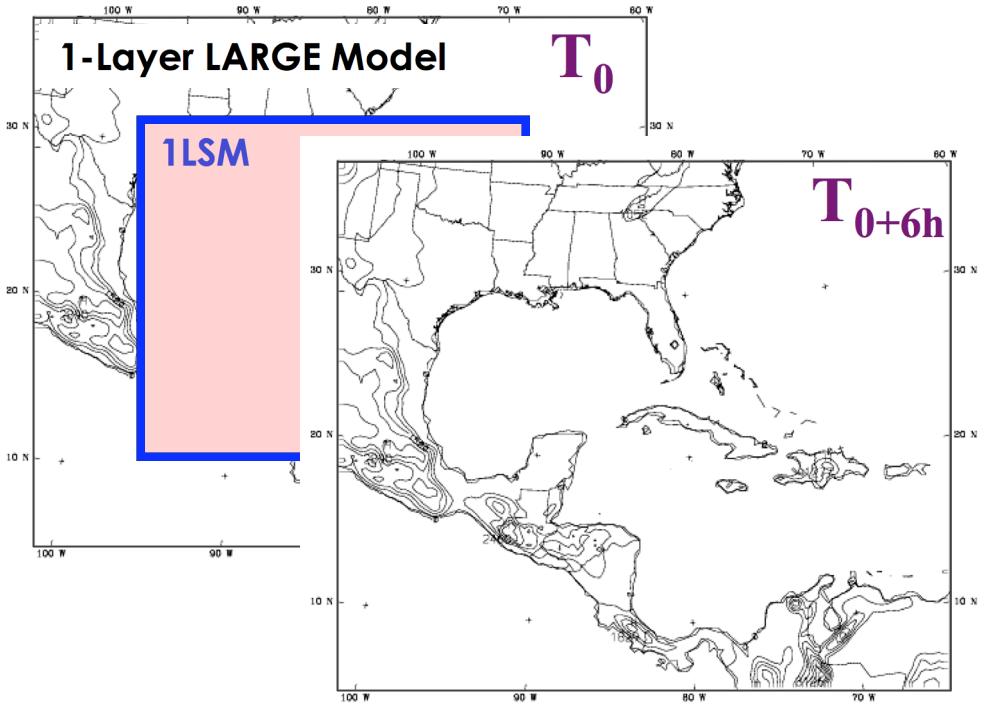

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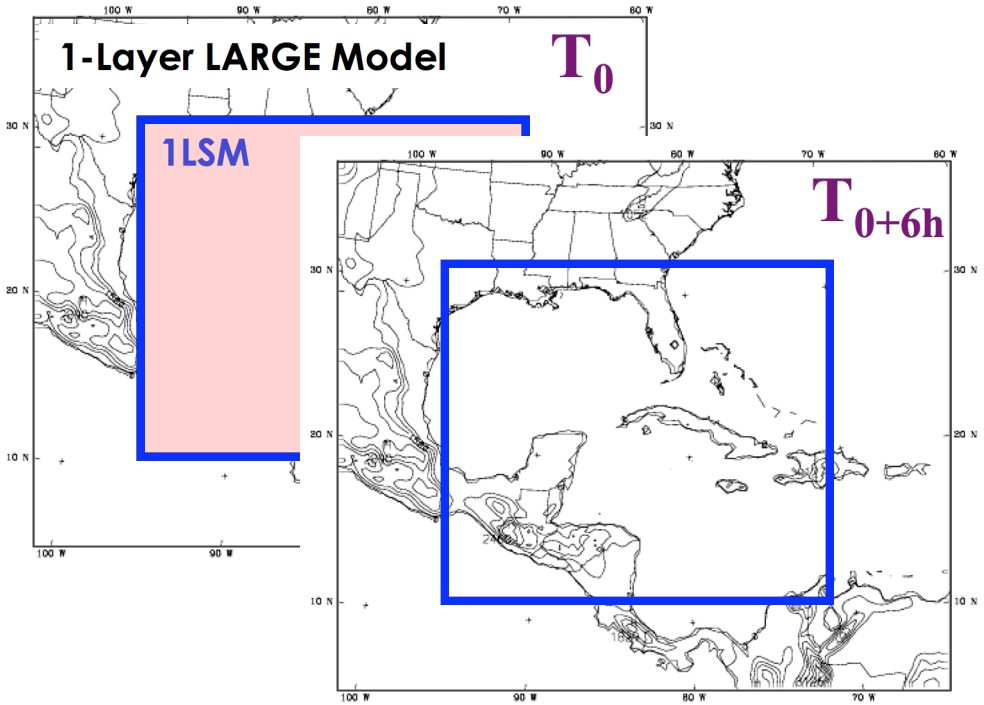

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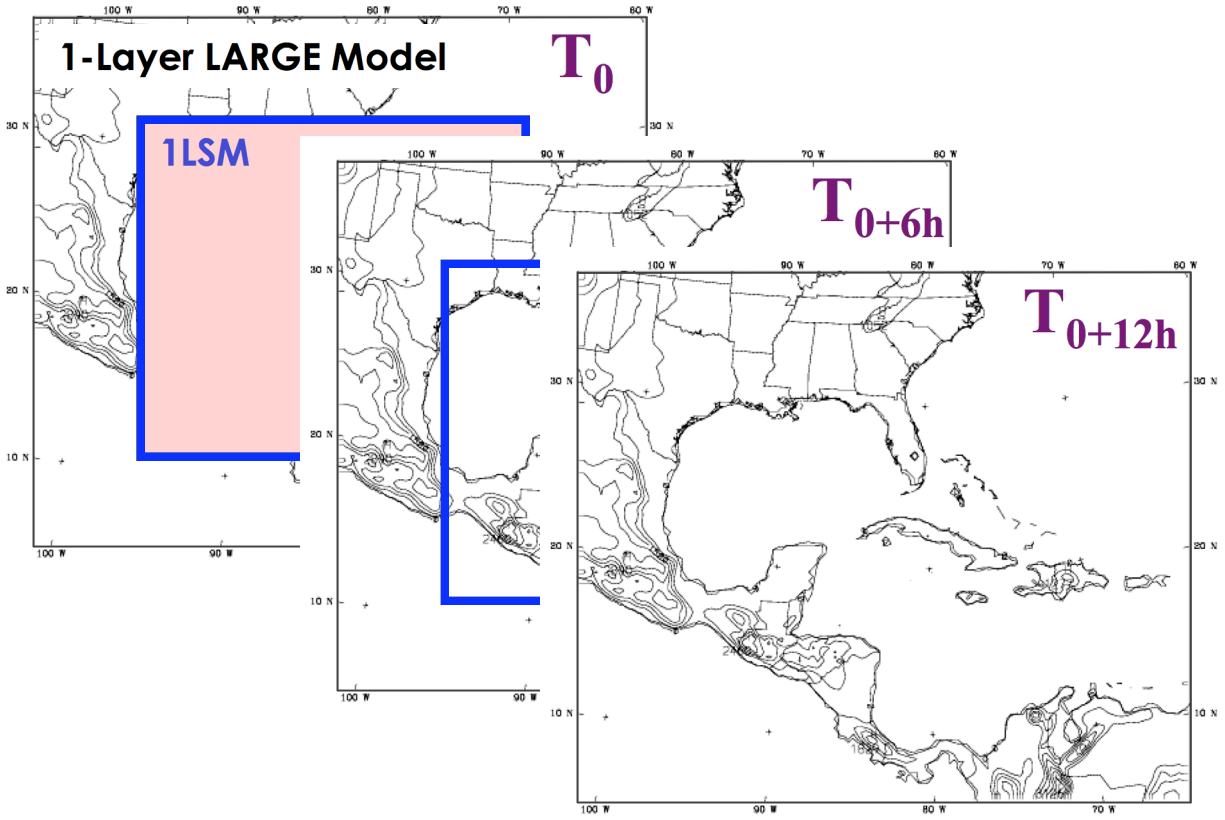

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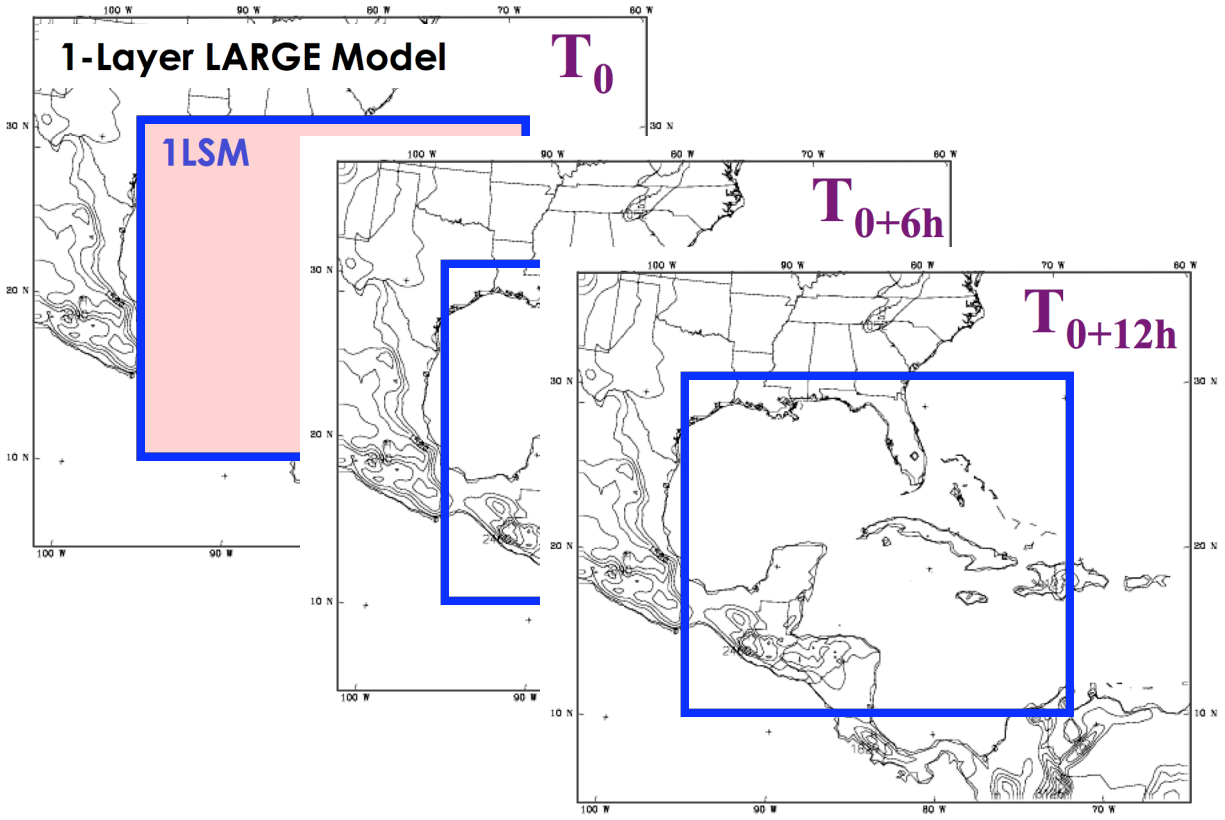

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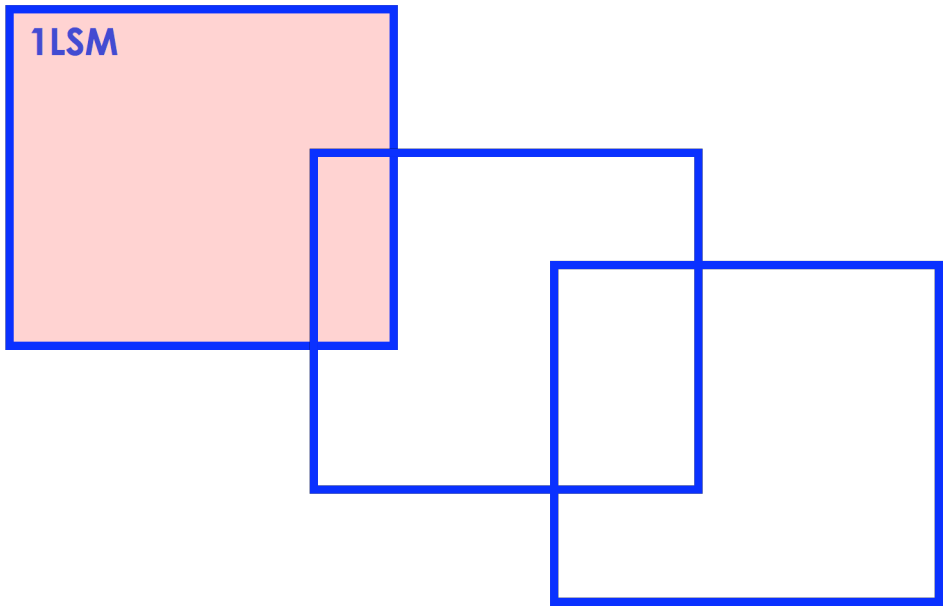

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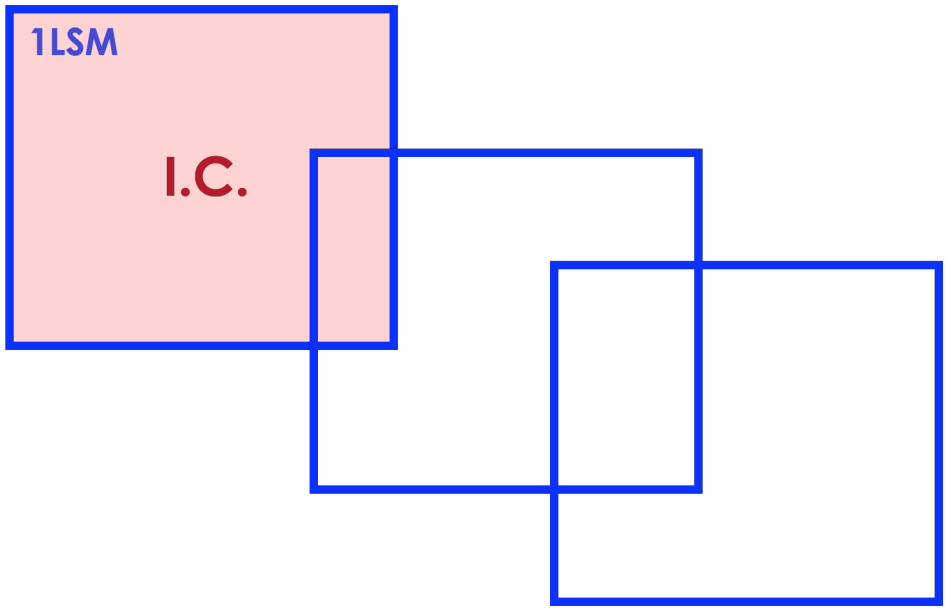

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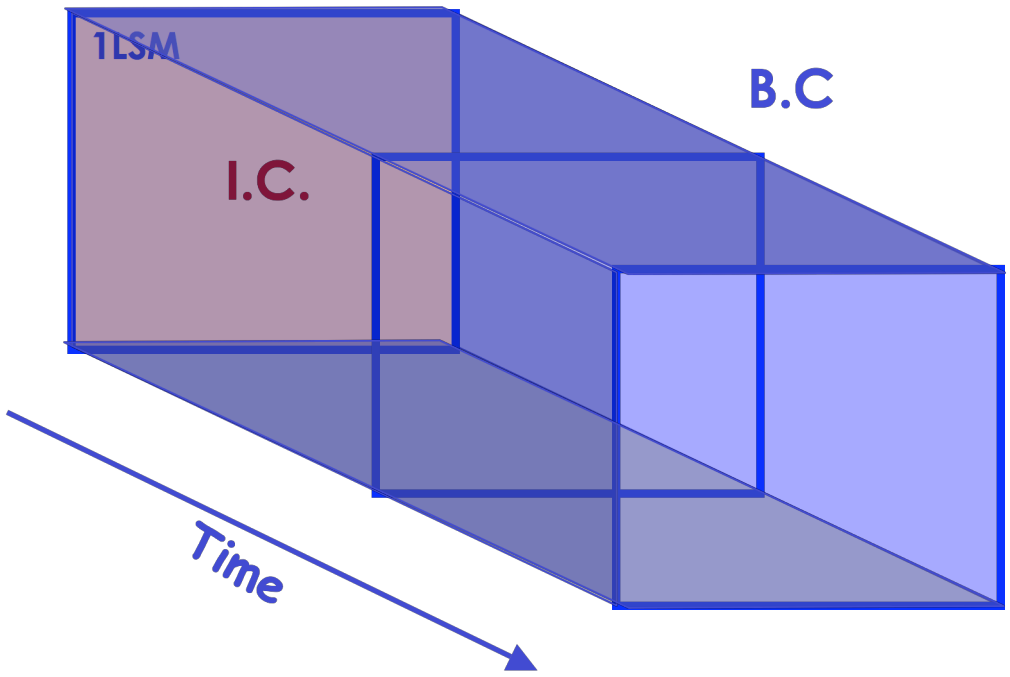

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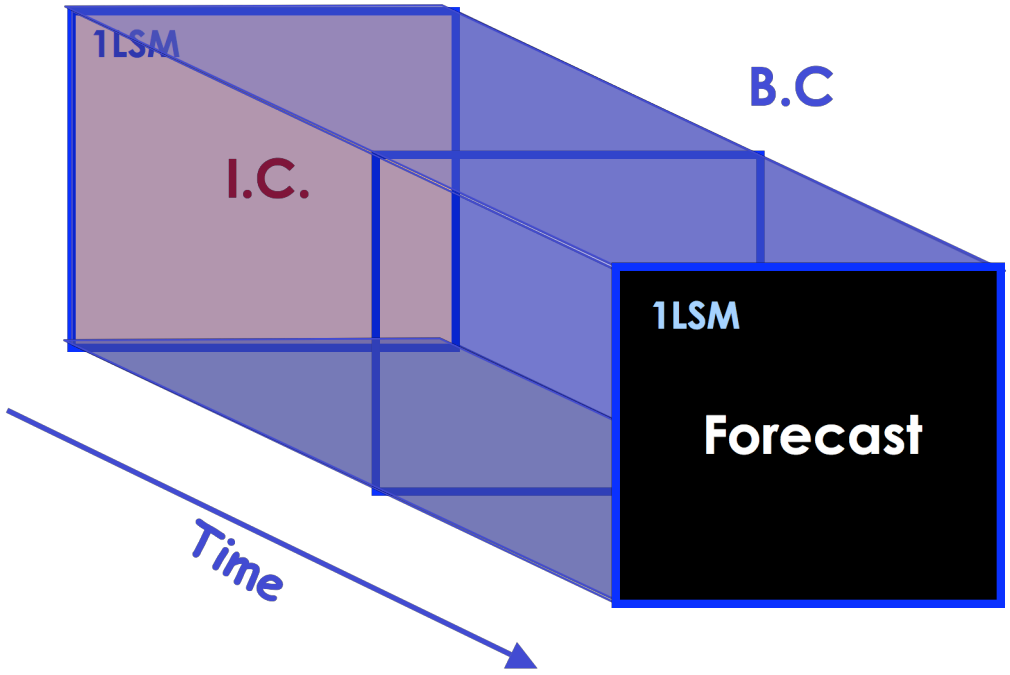

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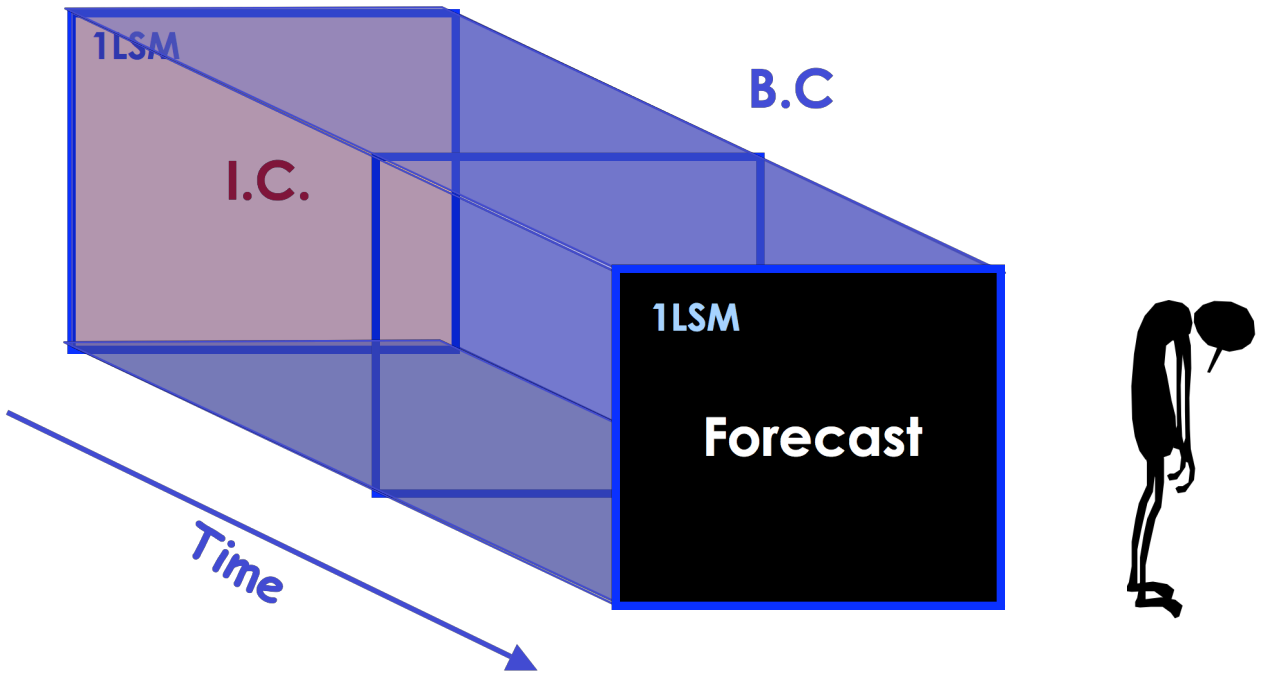
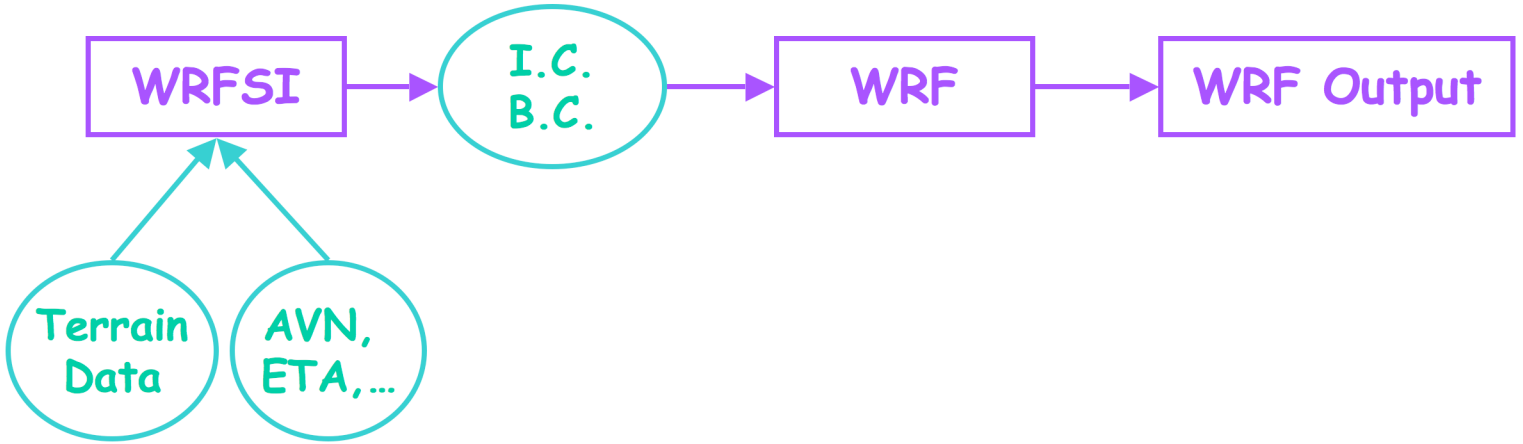
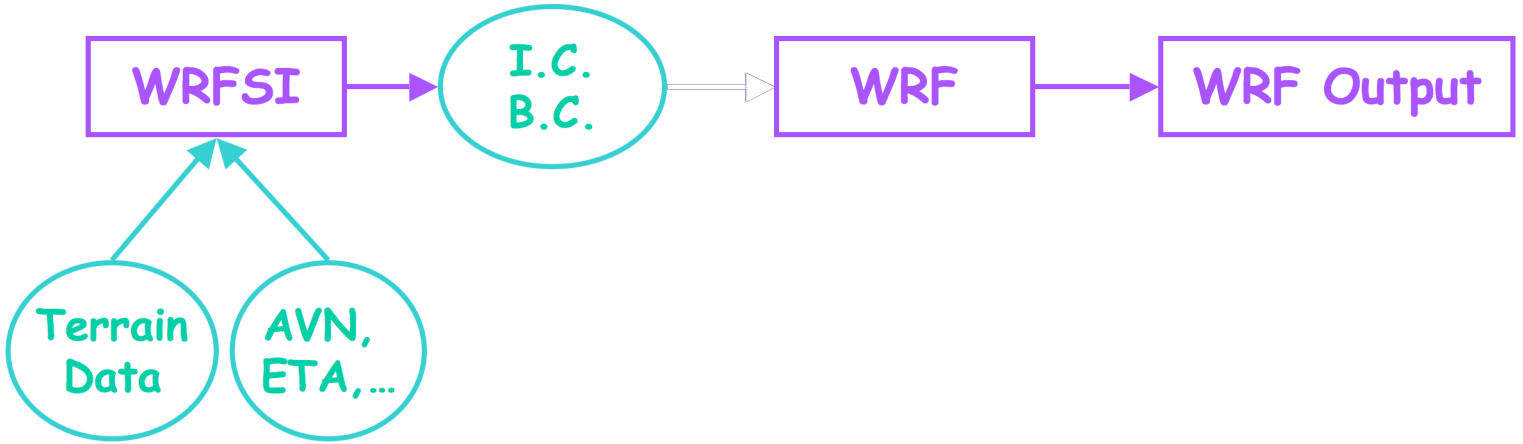


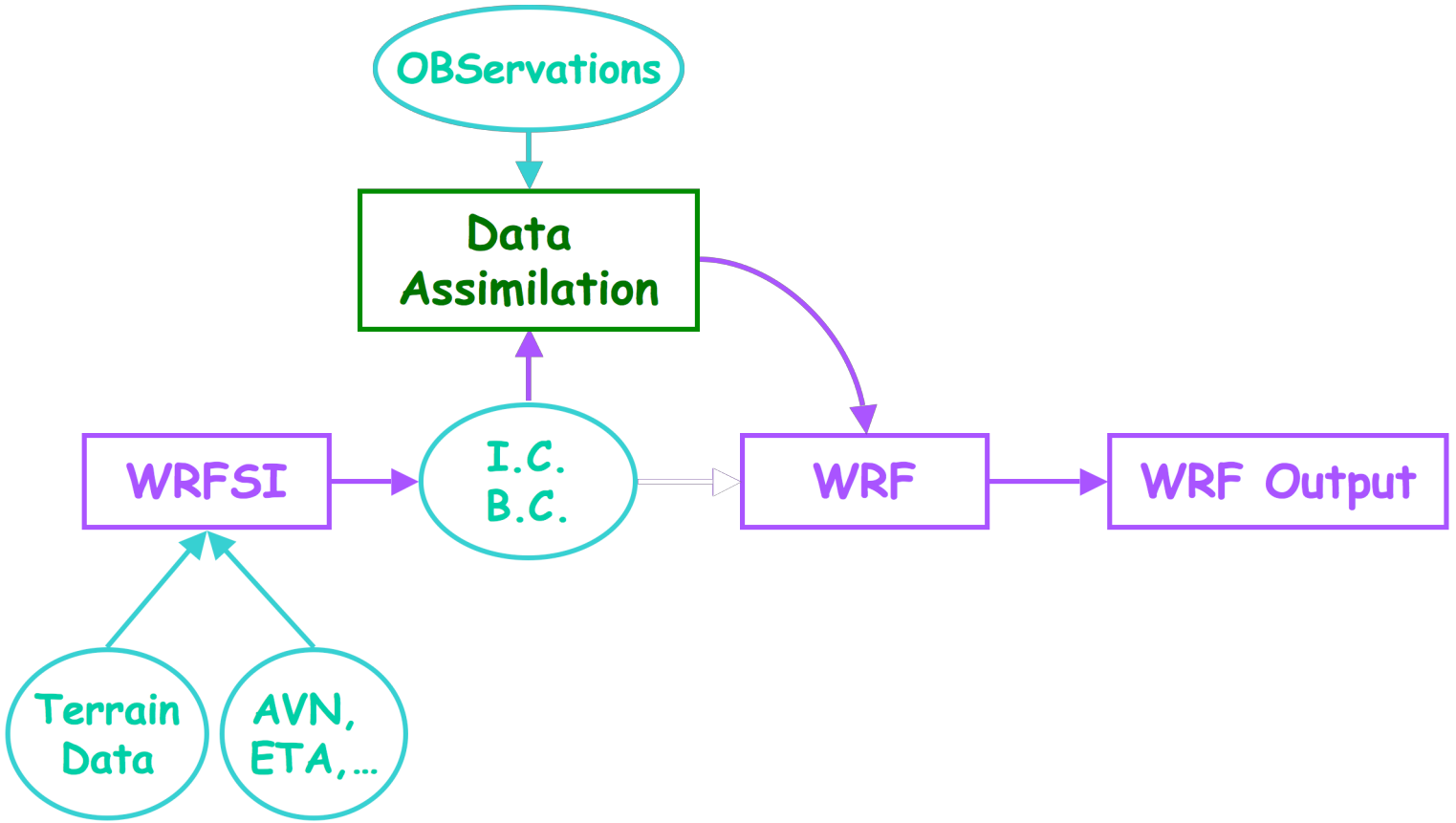
WRF Model Flow Chart



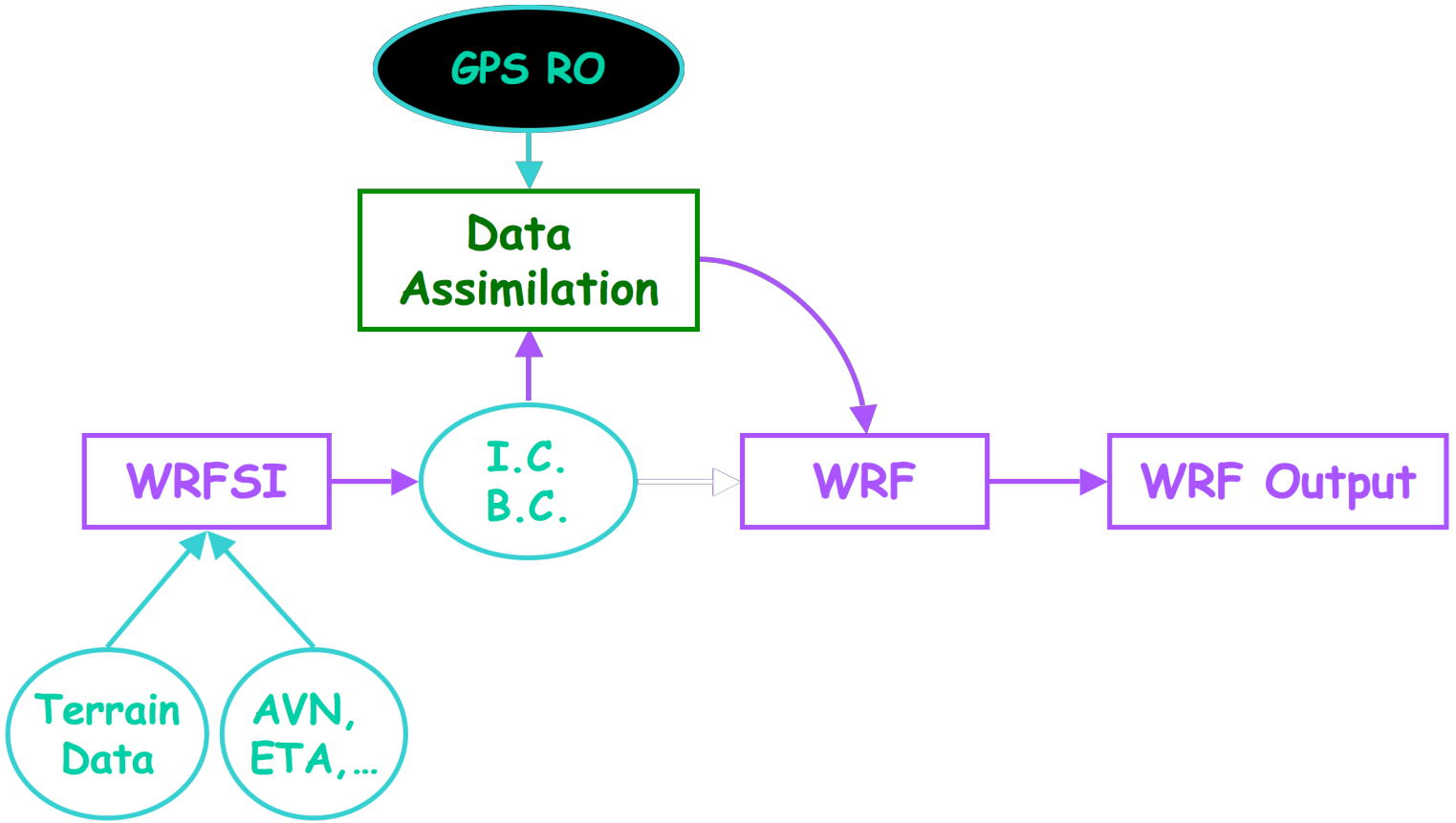
WRF Model Flow Chart



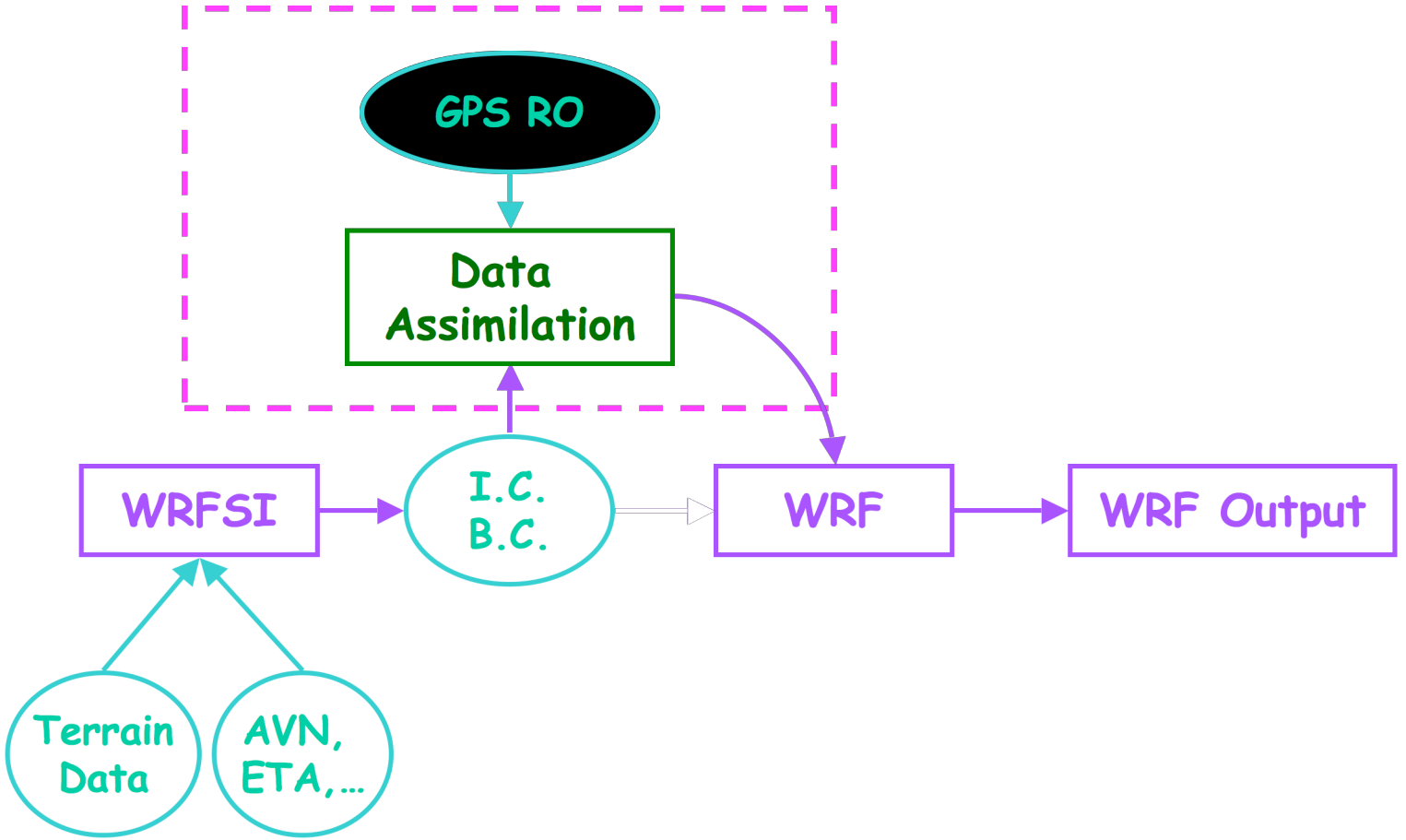
WRF Model Flow Chart



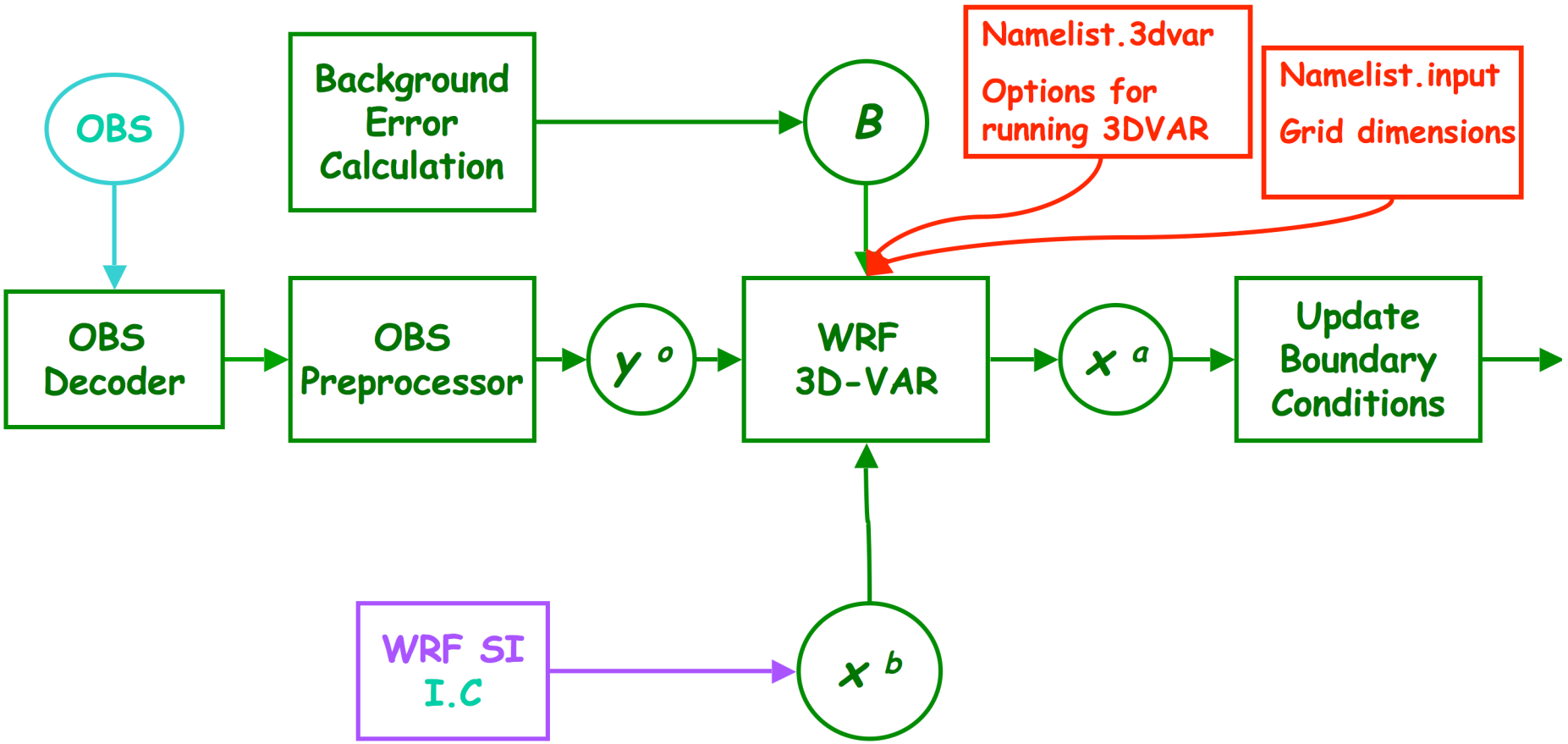
WRF Model Flow Chart



WRF Model Flow Chart



WRF 3D-VAR Flow Chart



Main Features of WRF 3D-VAR System (V2.0)

- Assimilation of 19 types of observations;
- Two choices of the control variables and the corresponding background error statistics (cv_options=2 and 3);
- Two minimization algorithms: Quasi-Newton and Conjugate Gradient;
- Outer-loop implementation for the incremental approach;
- Capable of applying to both MM5 and WRF models;
- Code parallelized in WRF framework with high computing efficiency, and running on multiple platforms.

OBS Can be Assimilated (May 2004)

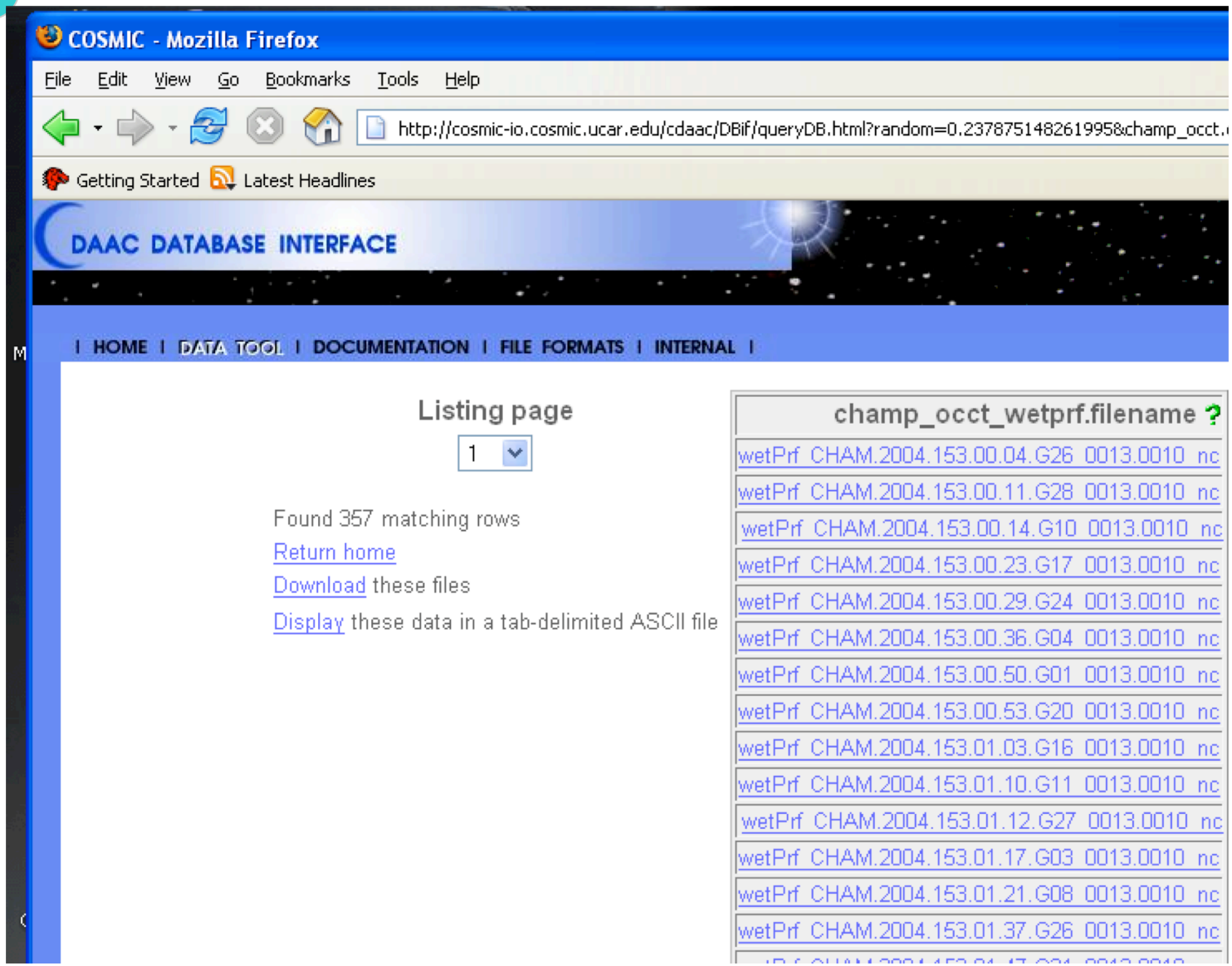
- Conventional:
  - Surface (SYNOP, METAR, SHIP, BUOY).
  - Upper air (TEMP, PIBAL, AIREP, ACARS).

- Remotely sensed retrievals:
  - Cloud-track winds (SATOBS).
  - ATOVS thicknesses (SATEMs).
  - Ground-based GPS TPW.
  - SSM/I oceanic surface wind speed and TPW.
  - SSM/T1 temperature retrievals.
  - SSM/T2 relative humidity retrievals.
  - Scatterometer (Quikscat) oceanic surface winds.
  - Radar radial velocity.
  - Wind Profiler.
  - GPS refractivity (2005)

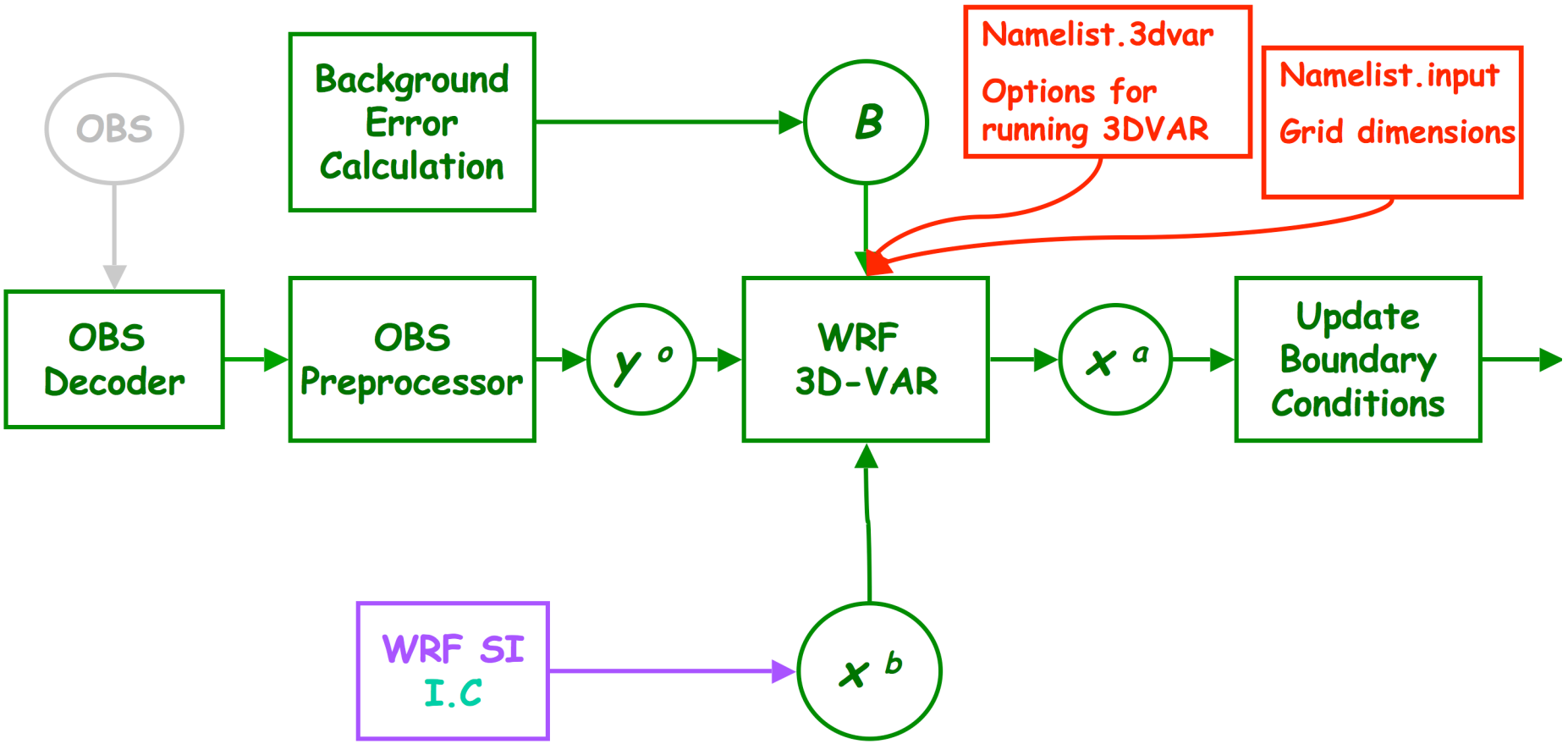
- Radiances:
  - SSM/I brightness temperatures.

GPS Radio Occultation Data

GPS Radio Occultation Data



WRF 3D-VAR Flow Chart



Decoder

champ_decoder.tar

- Read CHAMP and SAC-C L2 amtprf and wetprf RO Data from the CDDAC web site

Decoder

champ_decoder.tar

> tar xvf champ_decoder.tar
> make
(Produce two executable files:
atmprf_decoder and wetprf_decoder)

> wetprf_decoder -i data_nc
(Produce data_rip and data_decoded)

> Catenate xxx_decoded files
(say, example_decoded)

OBS Preprocessor

3DVAR_OBSPROC.tar

> tar xvf 3DVAR_OBSPROC.tar

> 3dvar_obs.csh

In 3dvar_obs.csh, there is a link to a namelist file (say, namelist.3dvar_obs.xxx)

OBS Preprocessor

In namelist.3dvar_obs.xxx

```
&record1
 obs_gts_filename = 'example_decoded ',
 fg_format        = 'WRF',
 obs_err_filename = 'obserr.txt',
/

&record2
 time_window_min  = '2004-06-01_15:00:00',
 time_analysis    = '2004-06-01_18:00:00',
 time_window_max  = '2004-06-01_21:00:00',
/
```

OBS Preprocessor

In namelist.3dvar_obs.xxx (cont.)

```
&record7
 IPROJ              =  1,
 PHIC               = 33.,
 XLONC              = -90.,
 TRUELAT1           =  20.,
 TRUELAT2           =  40.,
 MOAD_CEN_LAT       =  33.,
 STANDARD_LON       = -90.,
/
```

OBS Preprocessor

In namelist.3dvar_obs (cont.)

```
&record8
 IDD      =  1,
 MAXNES =  2,
 NESTIX = 120, 341,
 NESTJX = 120, 281,
 DIS      =  20.,   4.,
 NUMC    =    1,   2,
 NESTI   =    1,  30,
 NESTJ   =    1,  36,
 /
```

> 3dvar_obs.csh

Output – obs_gts.3dvar

OBS Preprocessor

In obs_gts.3dvar

```
TOTAL =      4, MISS. =-888888.,
SYNOP =      0, METAR =      0, SHIP  =      0, BUOY  =      0, TEMP  =      0, AMDAR =      0,
AIREP =      0, PILOT =      0, SATEM =      0, SATOB =      0, GPSPW =      0, GPSZD =      0,
GPSRF =      4, SSMT1 =      0, SSMT2 =      0, TOVS  =      0, QSCAT =      0, PROFL =      0,
OTHER =      0,
PHIC  =  33.00, XLONC = -90.00, TRUE1 =  20.00, TRUE2 =  40.00, XIM11 =   1.00, XJM11 =   1.00,
TS0   = 300.00, TLP   =  50.00, PTOP  =  5000., PS0   =100000.,
IXC   =   120, JXC   =   120, IPROJ =     1, IDD   =     1, MAXNES=     2,
NESTIX=   120,  341,
NESTJX=   120,  281,
NUMC  =     1,    2,
DIS   =    20.,   4,
NESTI =     1,   30,
NESTJ =     1,   36,
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,A5)
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,1(F12.3,I4,F7.2)))
#-------------------------------------------------------------------------------#
FM-116 GPSRF 2004-06-01_10:50:33 wetPrf_CHAM.2004.153.10.50.G10
```

3DVAR

wrf3dvar.tar

> tar xvf wrf3dvar.tar

> compile 3dvar

> cd run

(Modify DA_Run_3DVAR.csh)

> DA_Run_3DVAR.csh

3DVAR

In DA_Run_3DVAR.csh

```
#Specify job details here:

set DA_FG_FORMAT  = 1          # First Guess format: 1=WRF, 2=MM5
set DA_OB_FORMAT  = 2          # Observation format: 1=BUFR, 2=ASCII "little_r"
set DA_CV_OPTIONS = 2          # Background error statistics: 2=NCAR, 3=NCEP.
```

3DVAR

In DA_Run_3DVAR.csh (cont.)

```
# Tuning the BES:

if ( $DA_CV_OPTIONS == 3 ) then
    set DA_as1 = "0.25 , 1.0 , 1.5"
    set DA_as2 = "0.25 , 1.0 , 1.5"
    set DA_as3 = "0.35 , 1.0 , 1.5"
    set DA_as4 = "0.10 , 1.75, 1.5"
    set DA_as5 = "0.35 , 1.0 , 1.5"

else if ( $DA_CV_OPTIONS == 2 ) then
    set DA_RF_PASSES = 4
    set DA_VAR_SCALING1 = 1.35
    set DA_VAR_SCALING2 = 1.35
    set DA_VAR_SCALING3 = 1.35
    set DA_VAR_SCALING4 = 1.00
    set DA_VAR_SCALING5 = 0.9

    set DA_LEN_SCALING1 = 0.20
    set DA_LEN_SCALING2 = 0.20
    set DA_LEN_SCALING3 = 0.20
    set DA_LEN_SCALING4 = 1.0
    set DA_LEN_SCALING5 = 1.0
endif
```

3DVAR

In DA_Run_3DVAR.csh (cont.)

```
setenv DA_ANALYSIS_DATE       2004-06-01_18:00:00.0000  # Specify date in this format.
setenv WEST_EAST_GRID_NUMBER     120                     # Number of gridpoints in x(i) dim.
setenv SOUTH_NORTH_GRID_NUMBER 120                       # Number of gridpoints in y(j) dim.
setenv VERTICAL_GRID_NUMBER       31                     # Number of vertical levels.
setenv GRID_DISTANCE           20000                     # Grid resolution (m).
```

3DVAR

In DA_Run_3DVAR.csh (cont.)

```
#Specify directories/files here:

 setenv WRF_DIR /data5/wrf3dvar
setenv DAT_DIR  /data5/wrf3dvar/data
setenv RUN_DIR  /data5/wrf3dvar/run

setenv DA_FIRST_GUESS  ${DAT_DIR}/wrfinput_d01                    # wrf3dvar "first guess" input.
setenv DA_BACK_ERRORS  ${DAT_DIR}/be.cv_${DA_CV_OPTIONS}   # wrf3dvar background errors.
setenv DA_SSMI             ${DAT_DIR}/ssmi.dat              # SSM/I radiances (ignore if not using).
setenv DA_RADAR            ${DAT_DIR}/radar.dat             # Radar data (ignore if not using).

if(${DA_OB_FORMAT} == 1) then
   set DA_OBSERVATIONS = ${DAT_DIR}/ob.bufr.${endian_form} # Input BUFR observation file.
else if(${DA_OB_FORMAT} == 2) then
   set DA_OBSERVATIONS = ${DAT_DIR}/obs_gts.3dvar             # Input "little_r" format obs
else
   echo "DA_OB_FORMAT error: Do not know how to handle DA_OB_FORMAT = ${DA_OB_FORMAT}"
   exit 1
endif
```

3DVAR

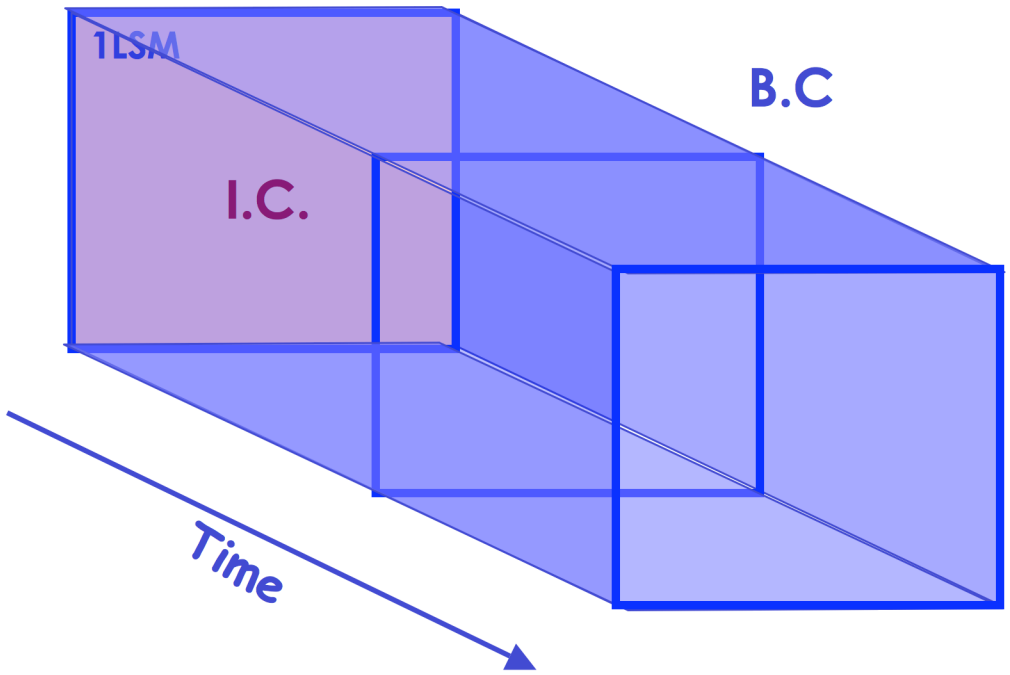
In DA_Run_3DVAR.csh (cont.)

```
if ( ! $?DA_USE_SYNOPOBS ) set DA_USE_SYNOPOBS = .FALSE.
if ( ! $?DA_USE_SHIPSOBS ) set DA_USE_SHIPSOBS = . FALSE.
if ( ! $?DA_USE_METAROBS ) set DA_USE_METAROBS = . FALSE.
if ( ! $?DA_USE_PILOTOBS ) set DA_USE_PILOTOBS = . FALSE.
if ( ! $?DA_USE_SOUNDOBS ) set DA_USE_SOUNDOBS = . FALSE.
if ( ! $?DA_USE_SATEMOBS ) set DA_USE_SATEMOBS = . FALSE.
if ( ! $?DA_USE_SATOBOBS ) set DA_USE_SATOBOBS = . FALSE.
if ( ! $?DA_USE_AIREPOBS ) set DA_USE_AIREPOBS = . FALSE.
if ( ! $?DA_USE_GPSPWOBS ) set DA_USE_GPSPWOBS = . FALSE.
if ( ! $?DA_USE_RADAROBS ) set DA_USE_RadarObs = .FALSE.
if ( ! $?DA_Use_Radar_rv ) set DA_Use_Radar_rv = .FALSE.
if ( ! $?DA_Use_Radar_rf ) set DA_Use_Radar_rf = .FALSE.
if ( ! $?DA_USE_GPSREFOBS ) set DA_USE_GPSREFOBS = .TRUE.
if ( ! $?DA_USE_PROFILEROBS ) set DA_USE_PROFILEROBS = . FALSE.
…
```

Output - wrf_3dvar_output -> wrfinput_d01
Update B.C.

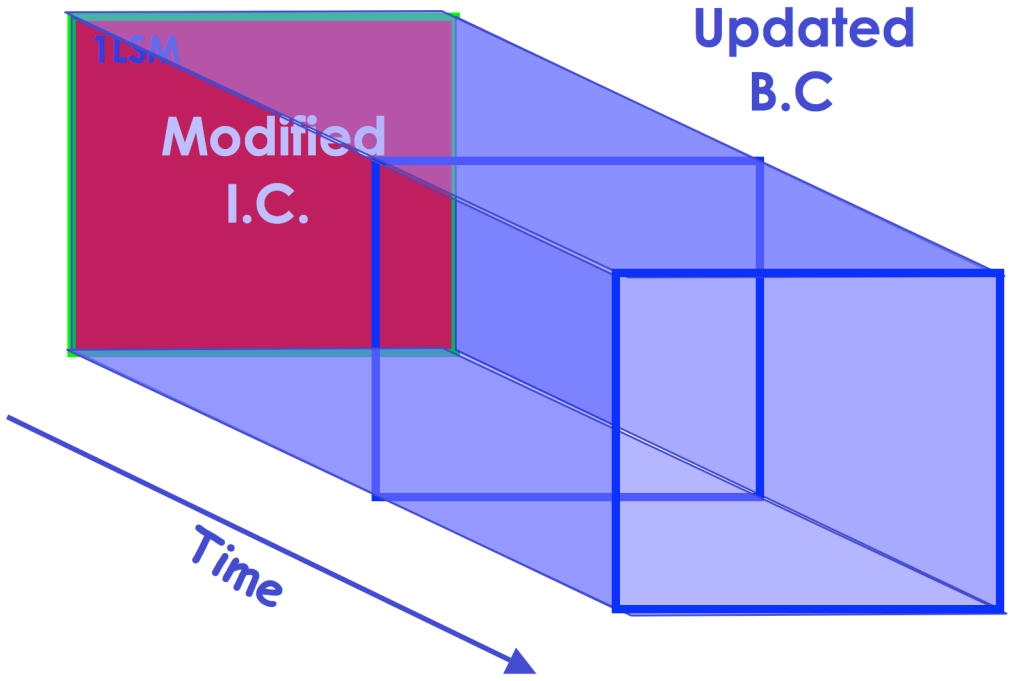
I.C. & B.C.

Example, a 1-Layer SMALL Model (1LSM)

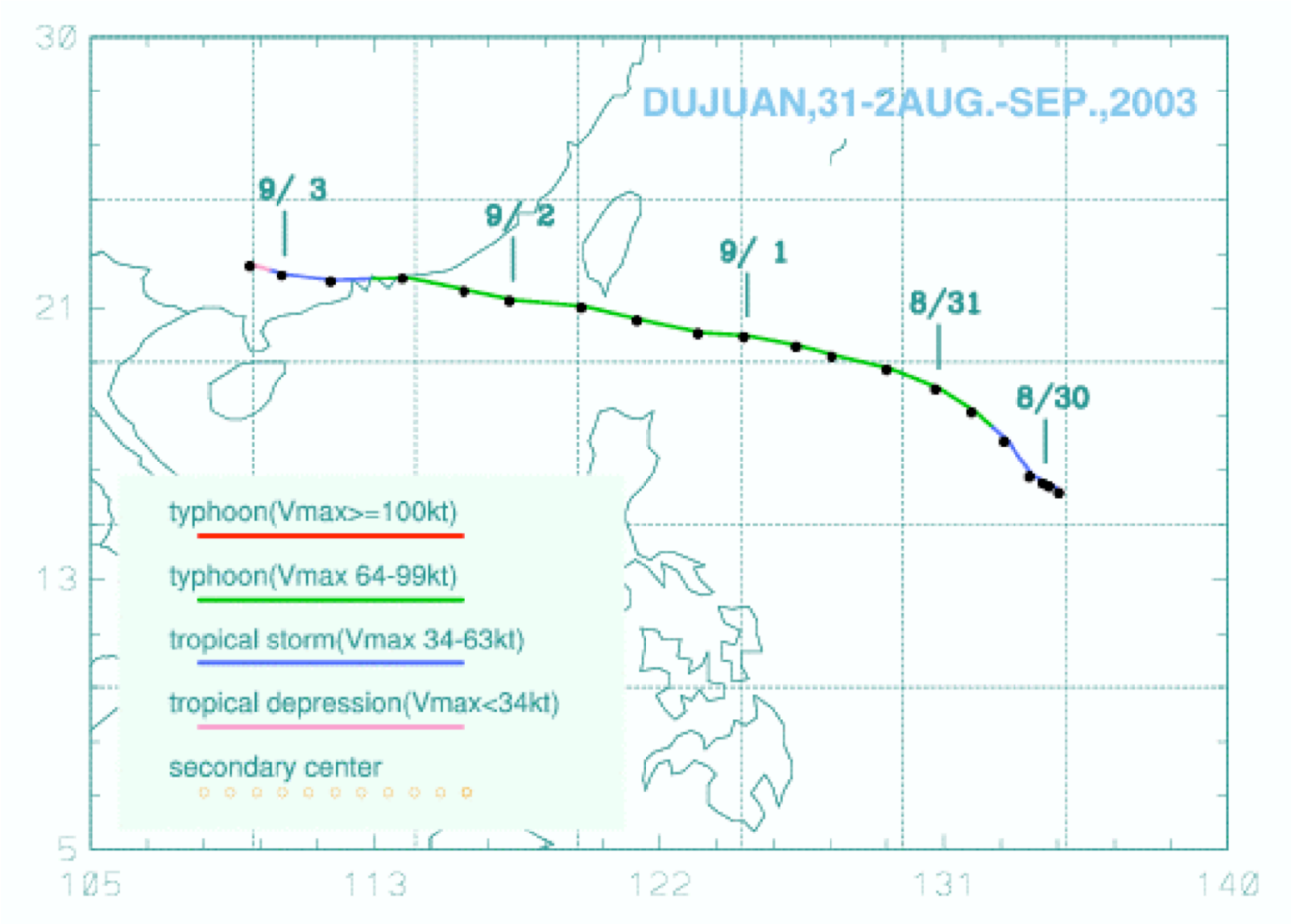


Modified I.C. & Updated B.C.

Example, a 1-Layer SMALL Model (1LSM)
With the assimilation of OBS

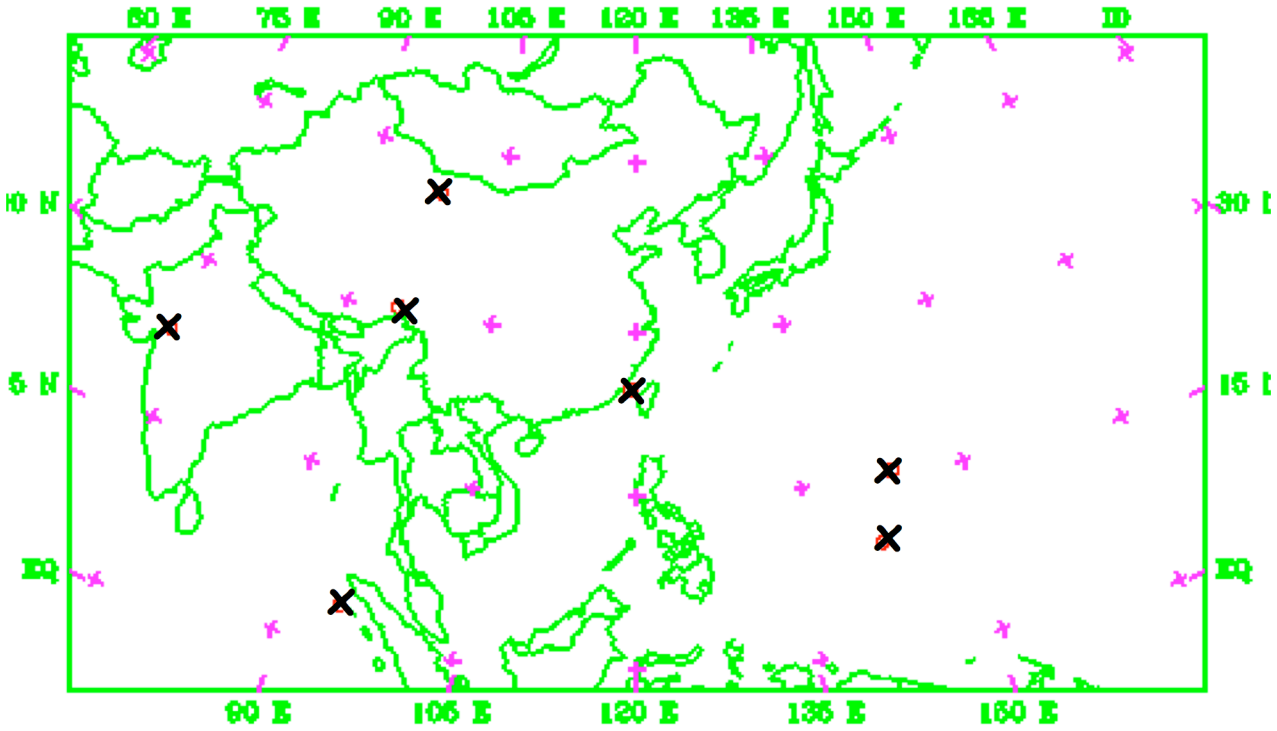


Typhoon Dujuan 2003



Best Track Position

Typhoon Dujuan
(12 UTC Aug 30 2003)



2003083009Z to 2003083015Z

Background Error Statistics (BES) tuning

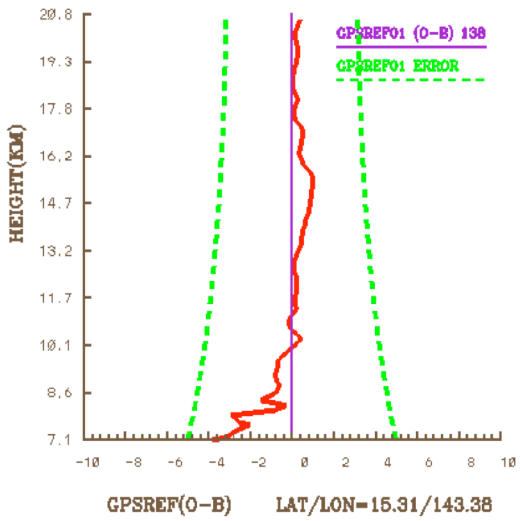
CV_OPTION = 3				CV_OPTION = 2		
Control	**Variance** Default / Tuned	**H-length** Default / Tuned	**V-length** Default / Tuned	**Control**	**Variance** Default / Tuned	**H-length** Default / Tuned
ψ	0.25 / 0.25	0.75 / 1.0	1.5 / 1.5	ψ	1.0 / 1.35	1.0 / 0.2
χ_u	0.25 / 0.25	0.75 / 1.0	1.5 / 1.5	χ	1.0 / 1.35	1.0 / 0.2
T_u	0.25 / 0.35	0.75 / 1.0	1.5 / 1.5	p_u	1.0 / 1.35	1.0 / 0.2
q_p	0.25 / 0.10	0.75 / 1.75	1.5 / 1.5	q	1.0 / 1.00	1.0 / 1.0
$Psfc_u$	0.25 / 0.35	0.75 / 1.0	1.5 / 1.5			

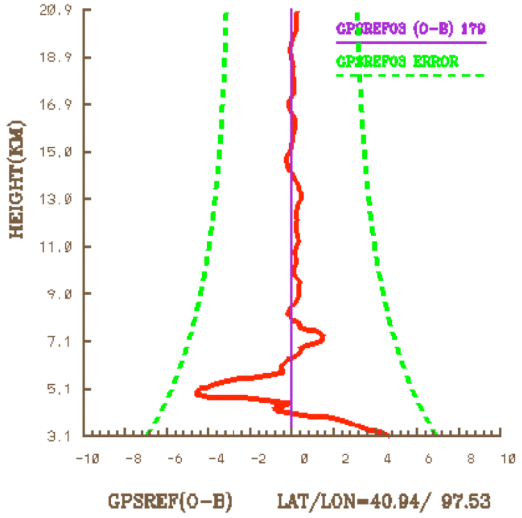
1, Tuning the BES subjectively (when collected enough (O-B) data, tuning the parameters is possible);

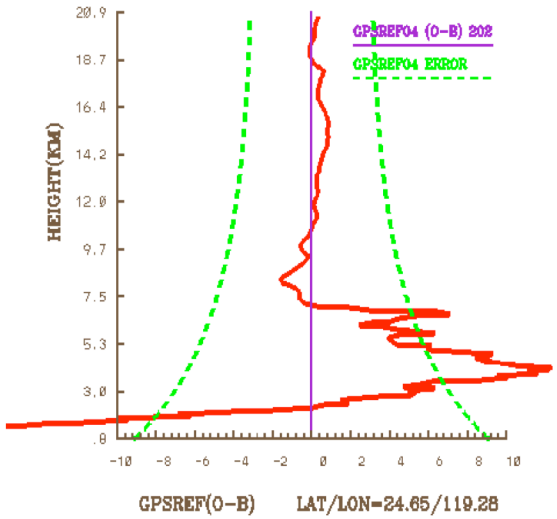
2, Increasing the variances of BES will reduce the (O-A) or increase the magnitudes of the increments;

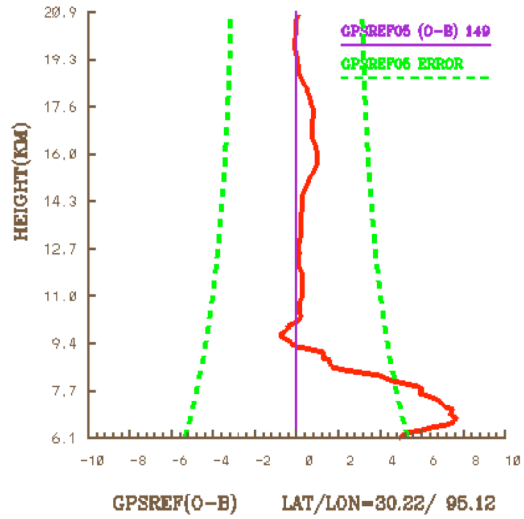
3, Reducing the scale-length will reduce the influence range of the observations.

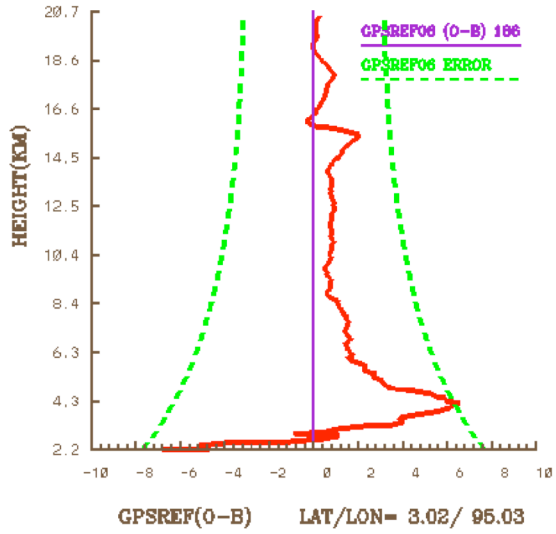
Innovation (O-B) of GPS Refractivity from NCEP Analysis and the Obs Errors

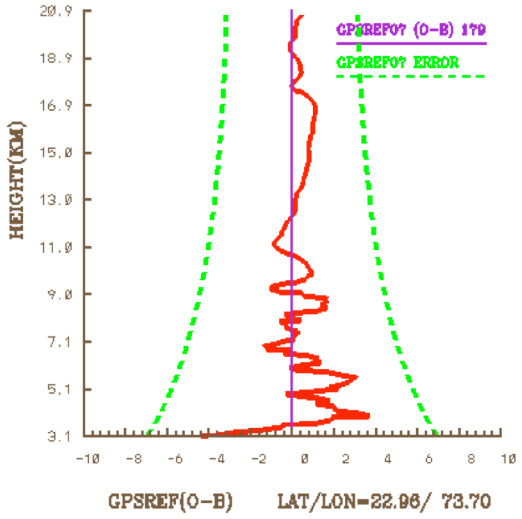




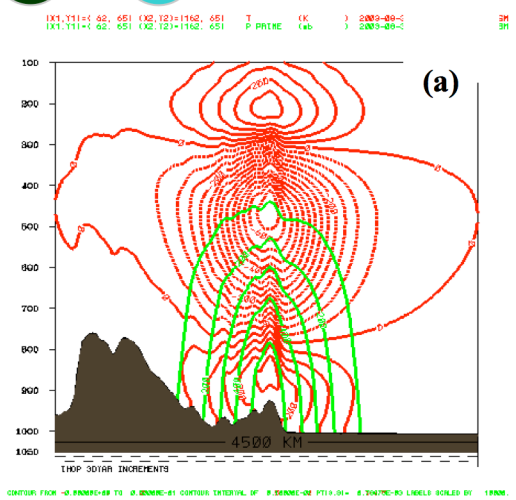


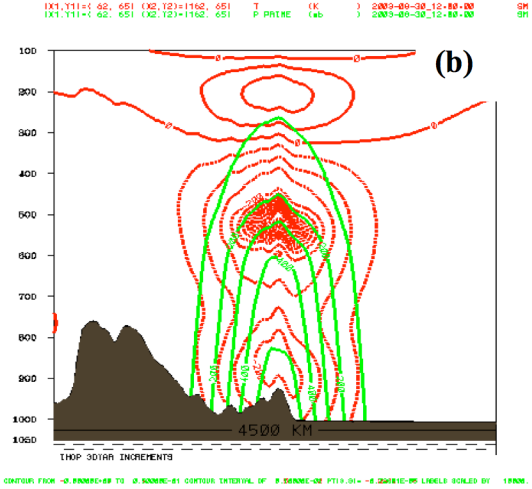


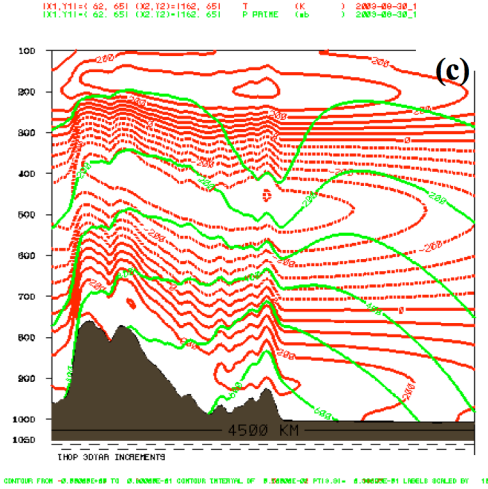


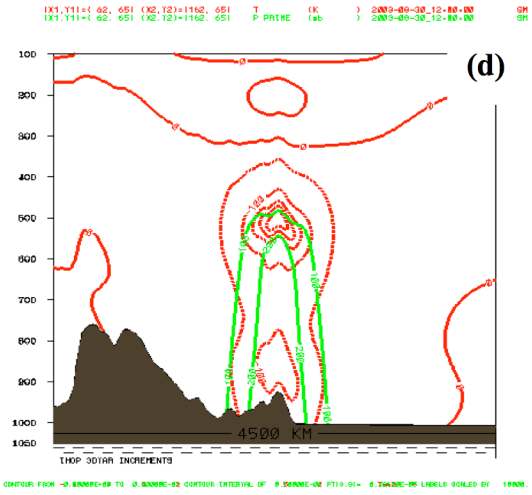


Single Obs test for GPS refractivity





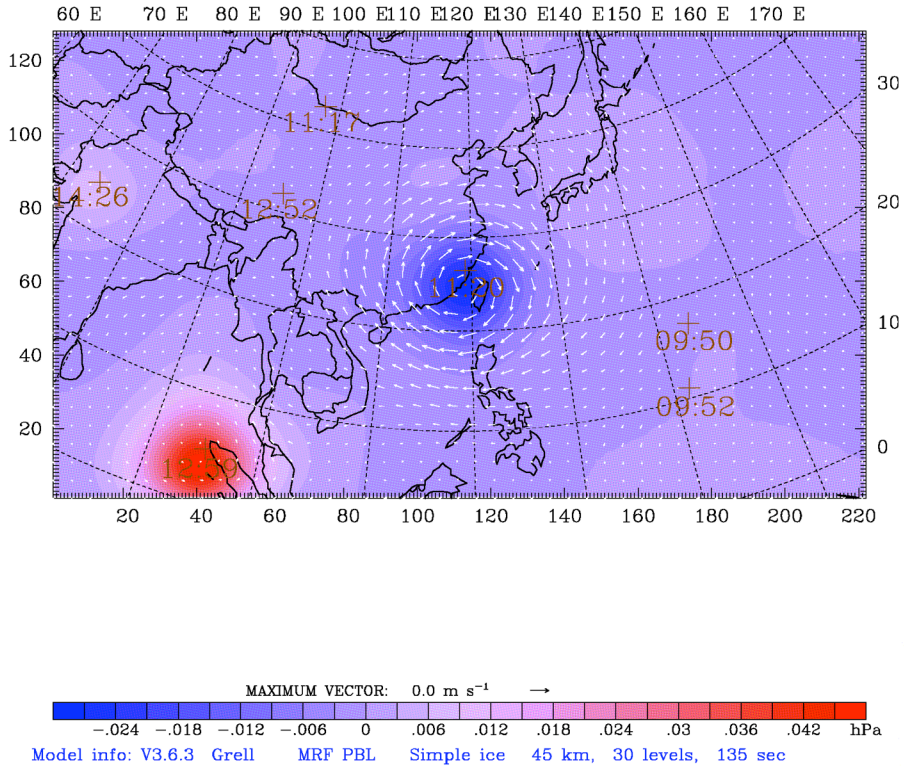




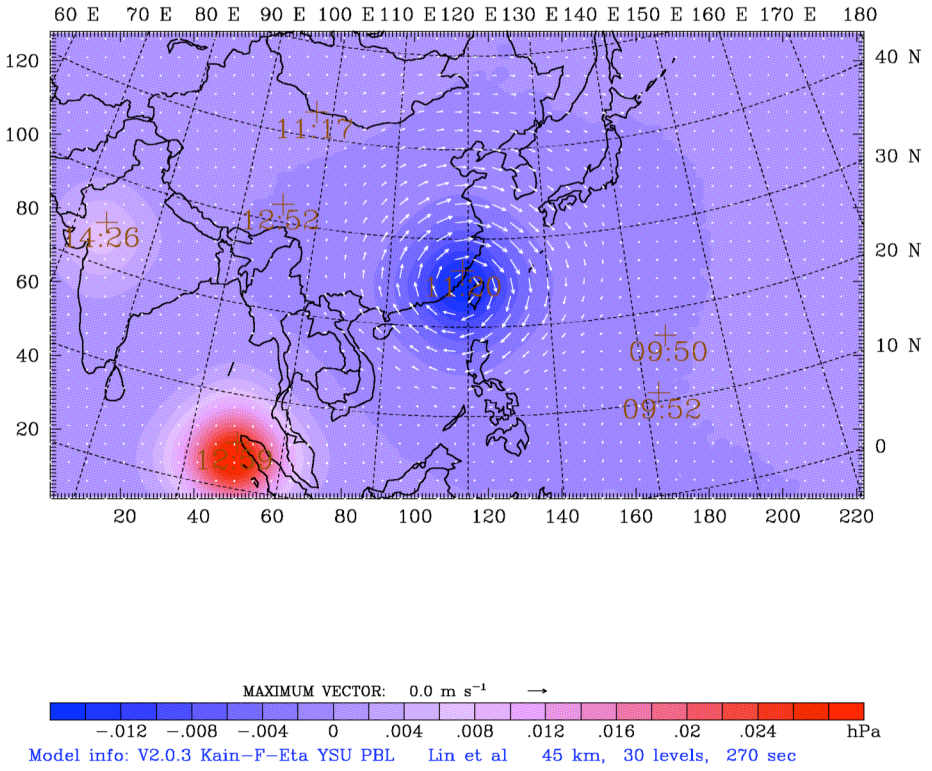
The T/P increments cross-section (West-East about 4,500 km) for Single GPS Ref OBS tests for Typhoon Dujuan case in CWB domain (a) cv_options=2 with the tuning factors: 1.35, 1.35, 1.35, 1.00 for VAR and 0.2, 0.2, 0.2, and 1.0 for LEN; (b) cv_options=3 with the tuning factors: as1=(0.25, 1.0, 1.5), as2=(0.25, 1.0, 1.5), as3=(0.35, 1.0, 1.5), as4=(0.10, 1.75, 1.5), and as5=(0.35, 1.0); (c) cv_options=2 default; (d) cv_options=3 default. The OBS value and error of the Ref. Is 1.0 located at x=112, y= 65, z=15. The CWB domain is 222x128x30 with 45-km grid distance.

Surface Pressure and Wind (GTS&GPS – GPS)

MM5 (V.3.6)

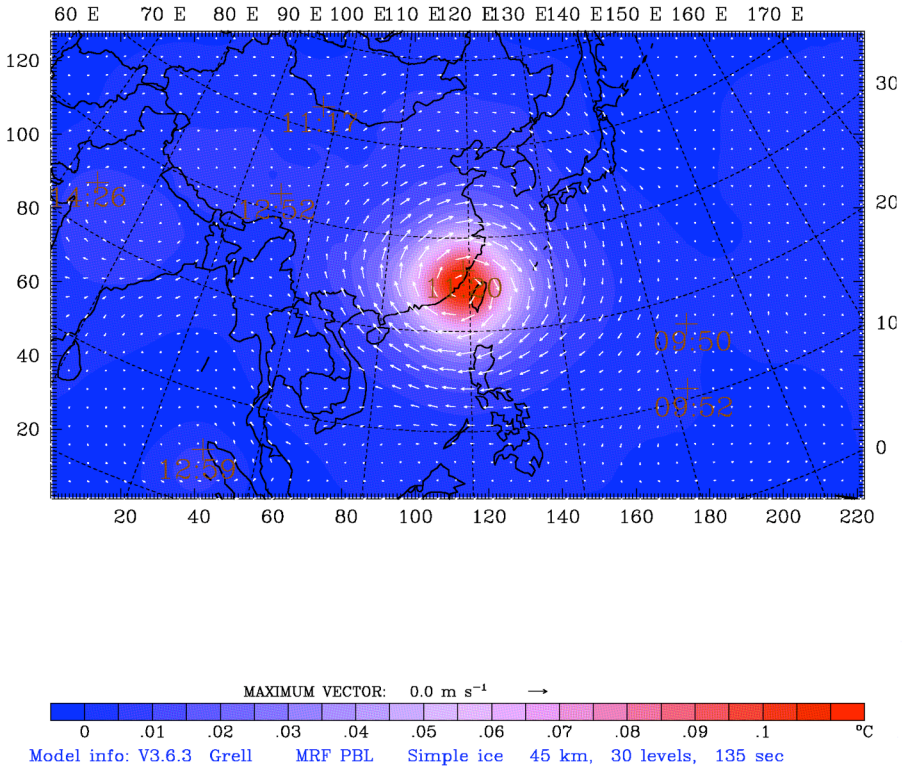


WRF (V.2.0.3.1)

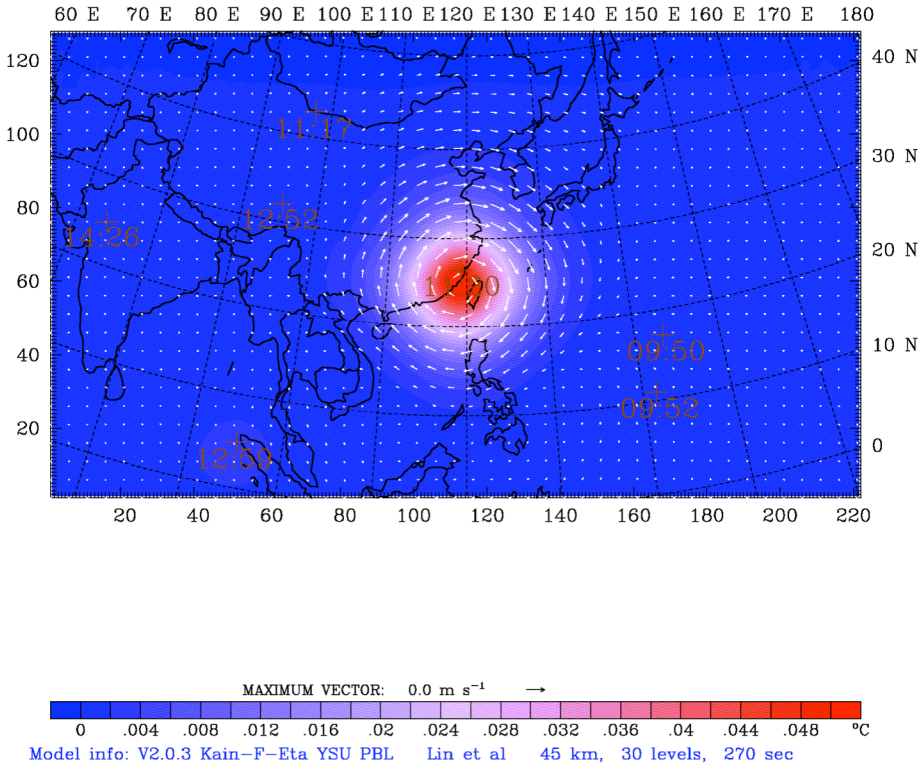


Surface Temperature and Wind (GTS&GPS – GPS)

MM5

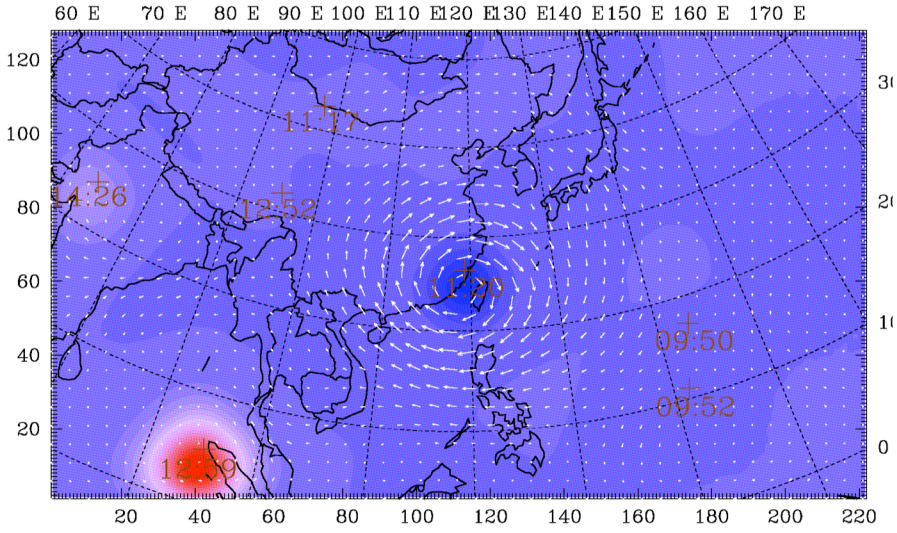


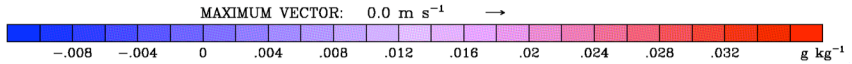
WRF



Surface Water Vapor Mixing Ratio and Wind (GTS&GPS – GPS)

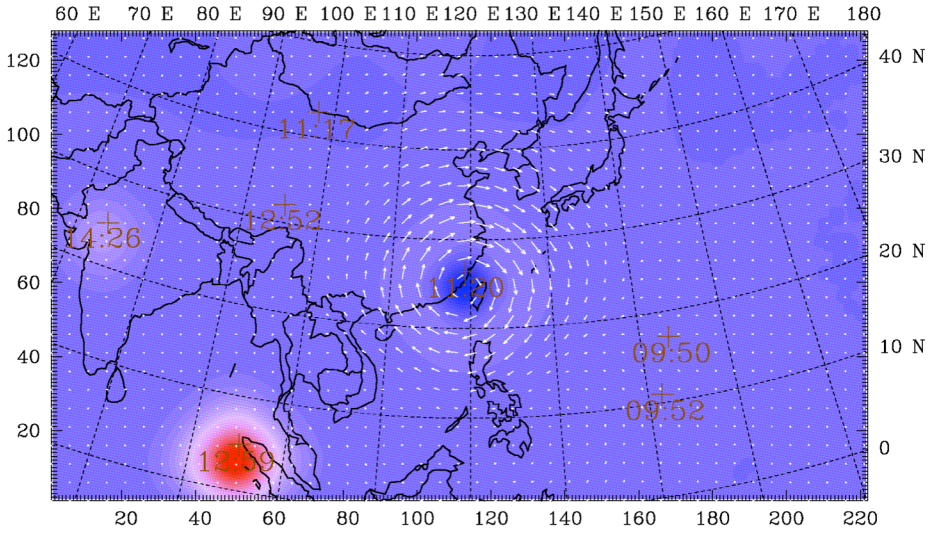
MM5

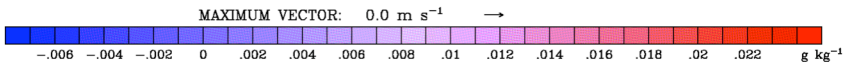




Model info: V3.6.3 Grell MRF PBL Simple ice 45 km, 30 levels, 135 sec

WRF

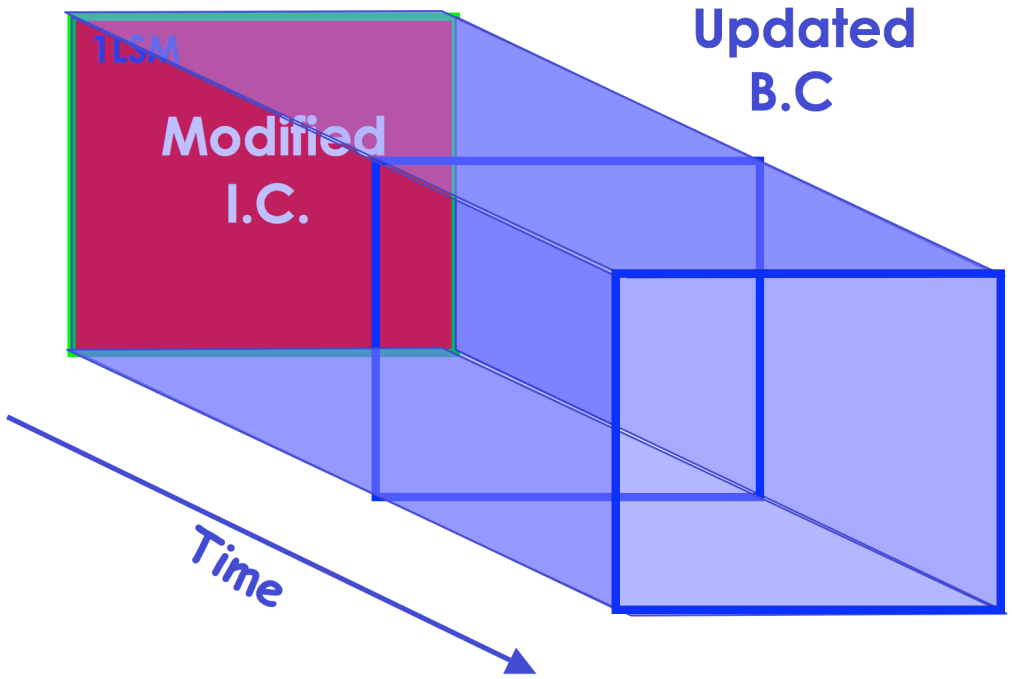




Model info: V2.0.3 Kain−F−Eta YSU PBL Lin et al 45 km, 30 levels, 270 sec

I.C. & B.C.

Example, a 1-Layer SMALL Model (1LSM)
With the assimilation of OBS



I.C. & B.C.

Example, a 1-Layer SMALL Model (1LSM)
With the assimilation of OBS