Report on the development of GSI/WRF 4DVAR capability

Xin Zhang   Xiang-Yu Huang   Ricardo Todling

NCAR Earth System Laboratory

ACAPS Project Report

NCAR is sponsored by the National Science Foundation

Current Status

- This presentation reports to the status of the development of GSI/WRF 4DVAR as implemented in Boulder's version of January 2011

Current Status

- This presentation reports to the status of the development of GSI/WRF 4DVAR as implemented in Boulder's version of January 2011
- The WRF tangent linear and adjoint codes (hereafter, WRFPLUS) have been updated to be consistent with the latest WRF repository codes

Current Status

- This presentation reports to the status of the development of GSI/WRF 4DVAR as implemented in Boulder's version of January 2011
- The WRF tangent linear and adjoint codes (hereafter, WRFPLUS) have been updated to be consistent with the latest WRF repository codes
- The Major development in GSI had finished, GSI codes had been coupled with the latest WRFPLUS

Current Status

- This presentation reports to the status of the development of GSI/WRF 4DVAR as implemented in Boulder's version of January 2011
- The WRF tangent linear and adjoint codes (hereafter, WRFPLUS) have been updated to be consistent with the latest WRF repository codes
- The Major development in GSI had finished, GSI codes had been coupled with the latest WRFPLUS
- Because the parallelization of the latest WRFPLUS is still on going, only 1 processor parallel run can be done at this moment

Major Improvements of WRFPLUS

- New WRF adjoint and tangent linear codes based on the latest WRF repository codes.

Major Improvements of WRFPLUS

- New WRF adjoint and tangent linear codes based on the latest WRF repository codes.
- Testing the code on various platforms and compilers (IBM, Linux, Mac : xlf, g95, pgi, intel).

Major Improvements of WRFPLUS

- New WRF adjoint and tangent linear codes based on the latest WRF repository codes.
- Testing the code on various platforms and compilers (IBM, Linux, Mac : xlf, g95, pgi, intel).
- Add capability to do tangent linear check and adjoint test over any length of time window.

Major Improvements of WRFPLUS

- New WRF adjoint and tangent linear codes based on the latest WRF repository codes.
- Testing the code on various platforms and compilers (IBM, Linux, Mac : xlf, g95, pgi, intel).
- Add capability to do tangent linear check and adjoint test over any length of time window.
- Add option to control if all inputs and outputs were happen in disk or memory, so WRFPLUS can be used as a standalone tool or as a component in 4DVAR system.

Sample Tangent Linear and Adjoint Check

Tangent linear check

```
...
tl_check: alpha=.1000E-04  coef=0.10000447262220E+01
tl_check: alpha=.1000E-05  coef=0.99999981575068E+00
tl_check: alpha=.1000E-06  coef=0.99999998152933E+00
tl_check: alpha=.1000E-07  coef=0.99999990980017E+00
tl_check: alpha=.1000E-08  coef=0.99999956711797E+00
...
```

Adjoint check

```
ad_check: VAL_TL:     0.42476489986911E+11
ad_check: VAL_AD:     0.42476489986912E+11
```

Modification of GSI

GSI Boulder repository revision 572, 2011-01-14

```
M       src/main/wrf_binary_interface.F90
M       src/main/read_wrf_mass_files.f90
M       src/main/control2model.f90
M       src/main/update_guess.f90
M       src/main/model_tl.F90
M       src/main/control2state.f90
M       src/main/model_ad.F90
M       src/main/stub_pertmod.F90
M       src/main/fill_mass_grid2.f90
M       src/main/pcgsoi.f90
M       src/main/adjtest.f90
M       src/main/read_prepbufr.f90
M       src/main/gsi_4dvar.f90
A       src/main/wrf_pertmod.F90
M       src/main/wrwrfmassa.F90
M       src/main/wrf_netcdf_interface.F90
M       src/main/gsimod.F90
M       src/main/model2control.f90
M       src/main/state2control.f90
M       src/main/unfill_mass_grid2.f90
M       src/main/read_wrf_mass_guess.F90
M       src/main/evaljgrad.f90
M       src/main/Makefile.dependency
M       src/main/obsmod.F90
```

The New Module wrf_pertmod

The coupler and utilities used to couple GSI and WRFPLUS.

```
module wrf_pertmod
    subroutine model_nl_wrf            ! Subroutine to call WRF nonlinear model
    ...
    end subroutine model_nl_wrf
    subroutine model_tl_wrf             ! Subroutine to call WRF tangent linear model
    ...
    end subroutine model_tl_wrf
    subroutine model_ad_wrf            ! Subroutine to call WRF adjoint model
    ...
    end subroutine model_ad_wrf
    subroutine gsi2wrf_tl                   ! Transfer GSI perturbation to WRF perturbation
    ...
    end subroutine gsi2wrf_tl
    subroutine gsi2wrf_ad                ! Adjoint of gsi2wrf_tl
    ...
    end subroutine gsi2wrf_ad
    subroutine wrf2gsi_tl                  ! Transfer WRF perturbation to GSI perturbation
    ...
    end subroutine wrf2gsi_tl
    subroutine wrf2gsi_ad                ! Adjoint of wrf2gsi_tl
    ...
    end subroutine wrf2gsi_ad
end module wrf_pertmod
```

Single observation exp.

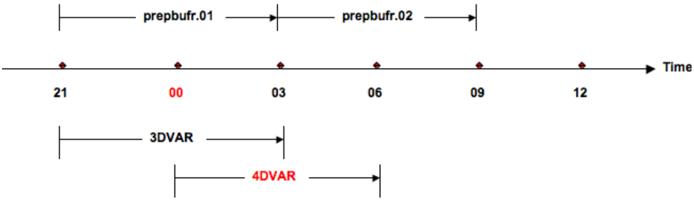
- Initial time: $2000\_01\_25\_00:00:00$
- Ending time: $2000\_01\_25\_06:00:00$
- Observation: 500 mb Temperature at ending time
  $O - B = -2.7K$
- To investigate the difference at ending time between the forecast from analysis and from background.

(Loading gsiwrf4dvar.mpeg)

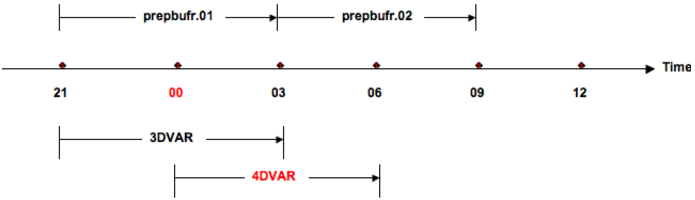
Forecasted 500mb T difference
(DA forecast - reference forecast)

- ⋆ is the location of obs. at the ending time (6h).
- Initial perturbation is on the upstream of the obs.
- Evolved perturbation at 6h hit the obs. location
- Very obviously flow dependent characteristics

Tutorial case – Observation Usage



Tutorial case – Observation Usage



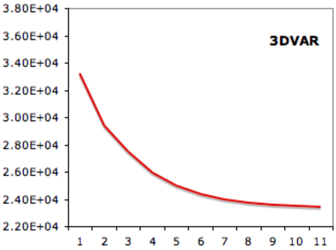
3DVAR

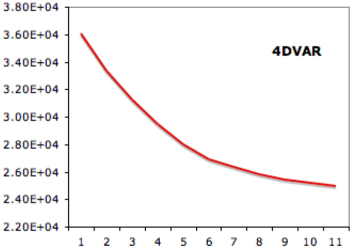
```
0:OBS_PARA: ps     13842
0:OBS_PARA: t      20114
0:OBS_PARA: q      18743
0:OBS_PARA: uv     30894
0:OBS_PARA: spd       48
0:OBS_PARA: sst      503
0:OBS_PARA: pw       880
```

4DVAR

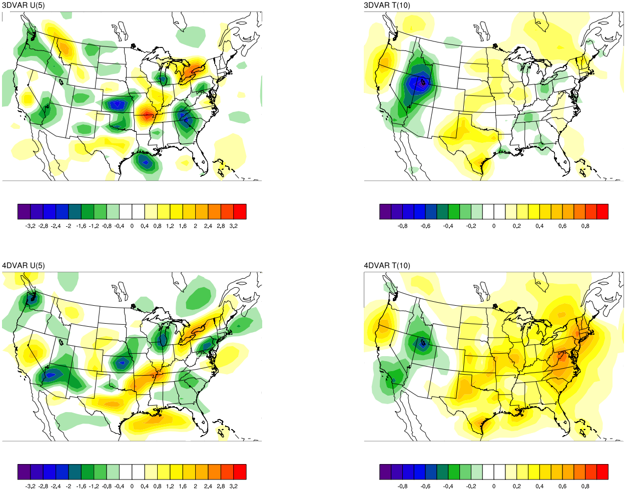
```
0:OBS_PARA: ps     13585
0:OBS_PARA: t      20639
0:OBS_PARA: q      19180
0:OBS_PARA: uv     28802
0:OBS_PARA: spd       80
0:OBS_PARA: sst      494
0:OBS_PARA: pw       766
------------------------------
0:OBS_PARA: ps        10
0:OBS_PARA: t        552
0:OBS_PARA: q        490
0:OBS_PARA: uv       568
```

Cost function

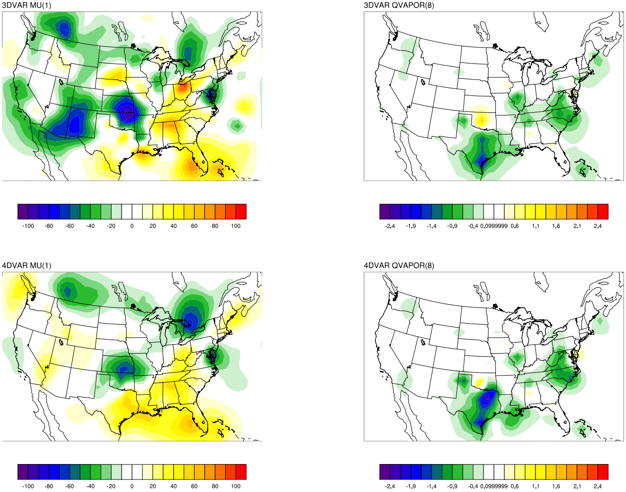




Sample increments comparison – U, T



Sample increments comparison – MU, QVAPOR



Quick Start

Install WRFPLUS and GSI

- WRFPLUS : WRF adjoint and tangent linear codes

```
> configure [-d] wrfplus
> compile em_real
```

- Set the the *WRF_DIR* environmental variable

```
> setenv WRF_DIR full_path_of_wrfplus
```

- GSI

```
> configure
> compile
```

Summary

- The GSI/WRF 4DVAR system was developed with minimum codes intervention.
- The single observation exp. preliminarily confirm that the system is valid and is able to produce flow dependent increments.
- The increments produced by 4DVAR run with tutorial case are comparable with the 3DVAR run.

Under development

- Add simplified physics packages into WRFPLUS: surface drag, large scale condensation, a simplified cumulus scheme, as well as a radiation scheme.
- Parallelization of WRF adjoint codes.
- Polishing the boundary condition treatment during minimization.
- Finalize the adjoint check and gradient check for GSI/WRF 4DVAR.
- Conduct real data experiment to confirm the performance.

Thank You

The NESL Mission is:
To advance understanding of weather, climate, atmospheric composition and processes;
To provide facility support to the wider community; and,
To apply the results to benefit society.

NCAR is sponsored by the National Science Foundation