2013 Beijing GSI Tutorial
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Beijing, China

Introduction to 3DVAR, Gridpoint Statistical Interpolation System (GSI), and its Community Support

Ming Hu

Developmental Testbed Center
NCAR-NOAA/GSD

What is Data Assimilation

- Numerical Weather Prediction is an initial-boundary value problem
  - Given an estimate of the present state of the atmosphere (initial conditions), and appropriate surface and lateral boundary conditions, the model simulates (forecasts) the atmospheric evolution
  - The more accurate the estimate of the initial conditions, the better the quality of the forecasts
- Data Assimilation: The process of combining observations and short-range forecasts to obtain an initial condition for NWP
- The purpose of data assimilation is to determine as accurately as possible the state of the atmospheric flow by using all available information

Three-dimensional Variational Data Analysis (3Dvar)
Concepts and Methods

Basic equation and concepts

$$J(x) = (x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathrm{H}[x])^T \boldsymbol{R}^{-1}(y-\mathrm{H}[x])$$
$$= J_b + J_o$$

- J is called the *cost function* of the analysis (*penalty function*)
- J_b is the *background term*; J_o is the *observation term.*
- The dimension of the model state is n and the dimension of the observation vector is p.
  - x_t true model state (dimension n)
  - $\boldsymbol{x}_b$ background model state (dimension n)
  - $\boldsymbol{x}_a$ analysis model state (dimension n)
  - $\boldsymbol{y}$ vector of observations (dimension p)
  - H observation operator (from dimension n to p)
  - **B** covariance matrix of the background errors ($\boldsymbol{x}_b - \boldsymbol{x}_t$) (dimension $n \times n$)
  - **R** covariance matrix of observation errors ($\boldsymbol{y} - H[\boldsymbol{x}_t]$) (dimension $p \times p$)

Hypotheses assumed

- **Linearized observation operator**: the variations of the observation operator in the vicinity of the background state are linear:
  - for any $\boldsymbol{x}$ close enough to $\boldsymbol{x}_b$:
    $H(\boldsymbol{x}) - H(\boldsymbol{x}_b) = \boldsymbol{H}(\boldsymbol{x} - \boldsymbol{x}_b)$, where $\boldsymbol{H}$ is a linear operator.
- **Non-trivial errors**: **B** and **R** are positive definite matrices.
- **Unbiased errors**: the expectation of the background and observation errors is zero i.e. $< x_b - x_t > = < y - \mathrm{H}(x_t) > = 0$
- **Uncorrelated errors**: observation and background errors are mutually uncorrelated i.e. $< (x_b - x_t)(y - \mathrm{H}[x_t])^T > = 0$
- **Linear analysis**: we look for an analysis defined by corrections to the background which depend linearly on background observation departures.
- **Optimal analysis**: we look for an analysis state which is as close as possible to the true state in an r.m.s. sense
  - i.e. it is a minimum variance estimate.
  - it is closest in an r.m.s. sense to the true state $\boldsymbol{x}_t$.
  - If the background and observation error pdfs are Gaussian, then $\boldsymbol{x}_a$ is also the *maximum likelihood estimator* of $\boldsymbol{x}_t$

Background term

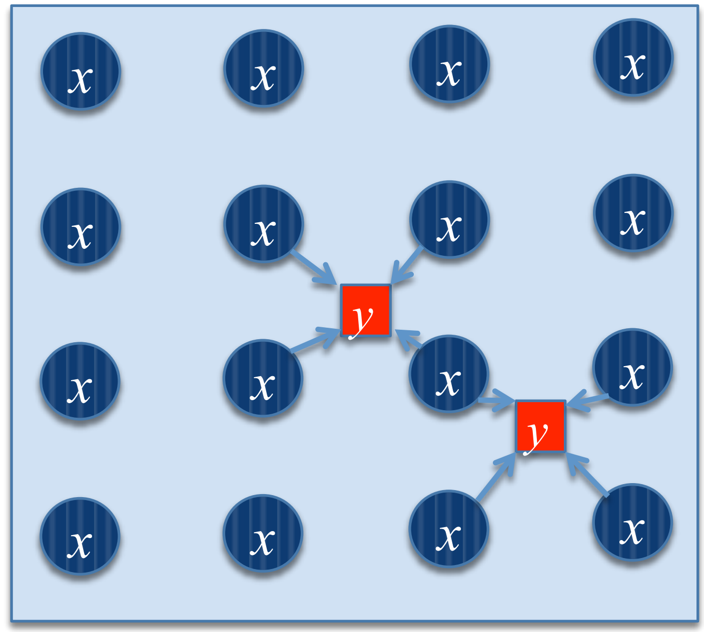
$$J(x) = (x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathrm{H}[x])^T \boldsymbol{R}^{-1}(y-\mathrm{H}[x])$$

- Background (forecast field): x_b
- Analysis: x
- Analysis increment: $x-x_b$
- Background error covariance: B
  - Variance
  - Correlation
    - Horizontal and vertical
    - balance

Observation term

$$J(x) = (x-x_b)^T \boldsymbol{B}^{-1}(x-x_b) + (y-\mathrm{H}[x])^T \boldsymbol{R}^{-1}(y-\mathrm{H}[x])$$

- Observation: y
- Observation operator: H[x]
  - Most: 3D interpolation
  - Some: Complex function
    - Radiance (CRTM) = $f(t,q)$
    - Radar Reflectivity = $f(q_r, q_s, q_h)$
- Observation innovation: y-H[x]
- Observation error variance: R
  - No correlation between two observations



Simplification: scalar t

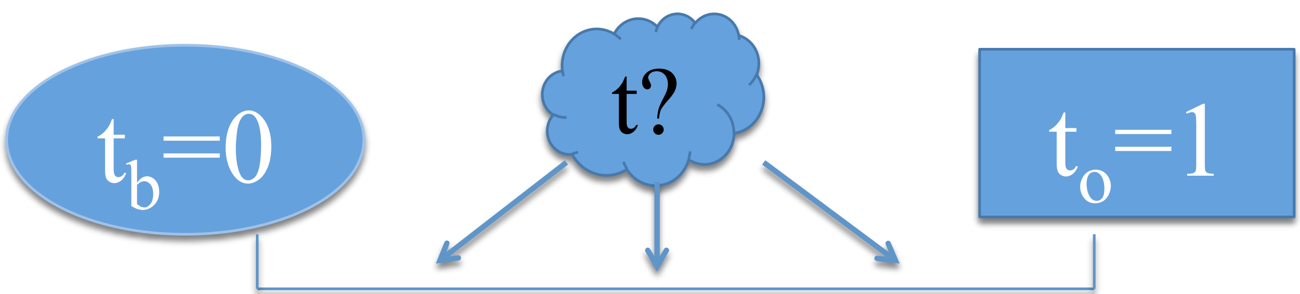
$$J(x) = (x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathrm{H}[x])^T \boldsymbol{R}^{-1}(y-\mathrm{H}[x])$$

Assume

x is scalar (t)

B, R, H, T

$$\mathrm{J(t)} = (\mathrm{t}-\mathrm{t_b})\sigma_{\mathrm{B}}^{-1}(\mathrm{t}-\mathrm{t_b}) + (\mathrm{t_o}-\mathrm{t})\sigma_{\mathrm{R}}^{-1}(\mathrm{t_o}-\mathrm{t})$$



The scalar case: solve

$$J(t) = (t-t_b)\sigma_B^{-1}(t-t_b) + (t_o-t)\sigma_R^{-1}(t_o-t)$$

$$J(t) = \frac{(t-t_B)^2}{\sigma_B} + \frac{(t_o-t)^2}{\sigma_B}$$

When $\frac{\partial J(t)}{\partial t}=0$, J(t) is minimum and t is the best guess to truth

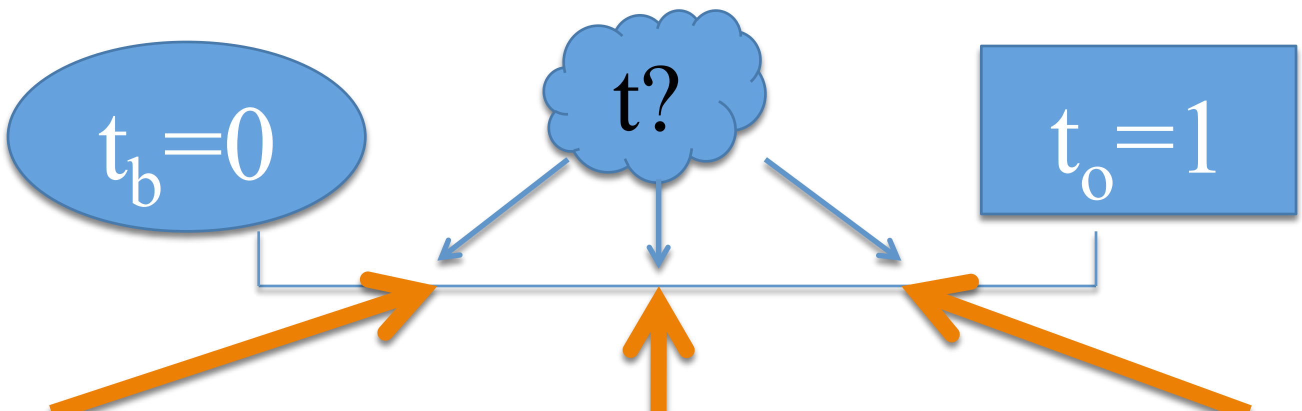
$$t = \frac{\sigma_R}{\sigma_R+\sigma_B}t_B + \frac{\sigma_B}{\sigma_R+\sigma_B}t_o$$

The scalar case: solution

$$J(t) = (t-t_b)\sigma_B^{-1}(t-t_b) + (t_o-t)\sigma_R^{-1}(t_o-t)$$

$$t = \frac{\sigma_R}{\sigma_R + \sigma_B} t_B + \frac{\sigma_B}{\sigma_R + \sigma_B} t_o$$

The analysis is decided by the ratio of background error and observation error



$0.25*\sigma_R=\sigma_B$ $t=0.8*t_b+0.2*t_o$ $t=0.2$	$\sigma_R=\sigma_B$ $t=0.5*t_b+0.5*t_o$ $t=0.5$	$\sigma_R=0.25*\sigma_B$ $t=0.2*t_b+0.8*t_o$ $t=0.8$

Background error covariance

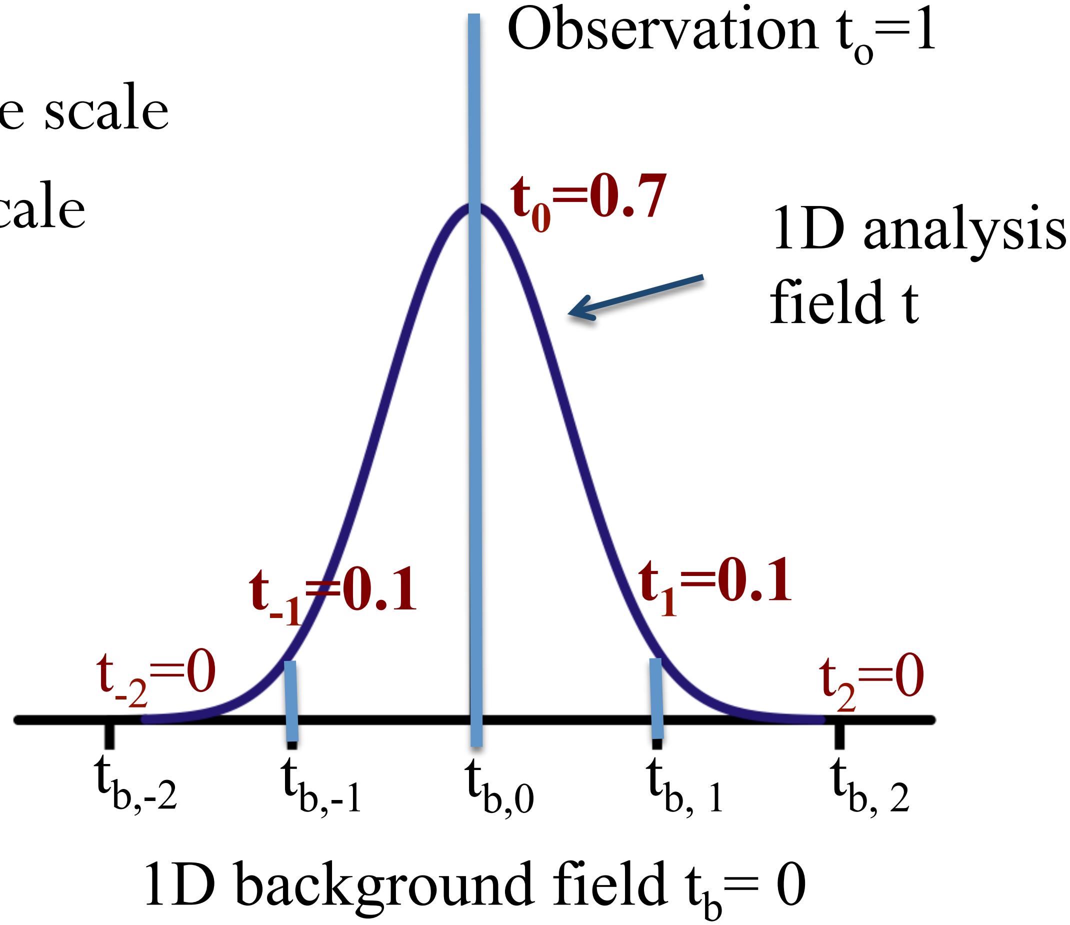
$$J(x) = (x - x_b)^T \mathbf{B}^{-1} (x - x_b) + (y - H[x])^T \mathbf{R}^{-1} (y - H[x])$$

- Background error covariance: B
  - Variance
    - Ratio to the observation variance to decide how much analysis results fit to the observations
  - Correlation
    - Horizontal and vertical
    - Balance

Background error covariance: scale

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

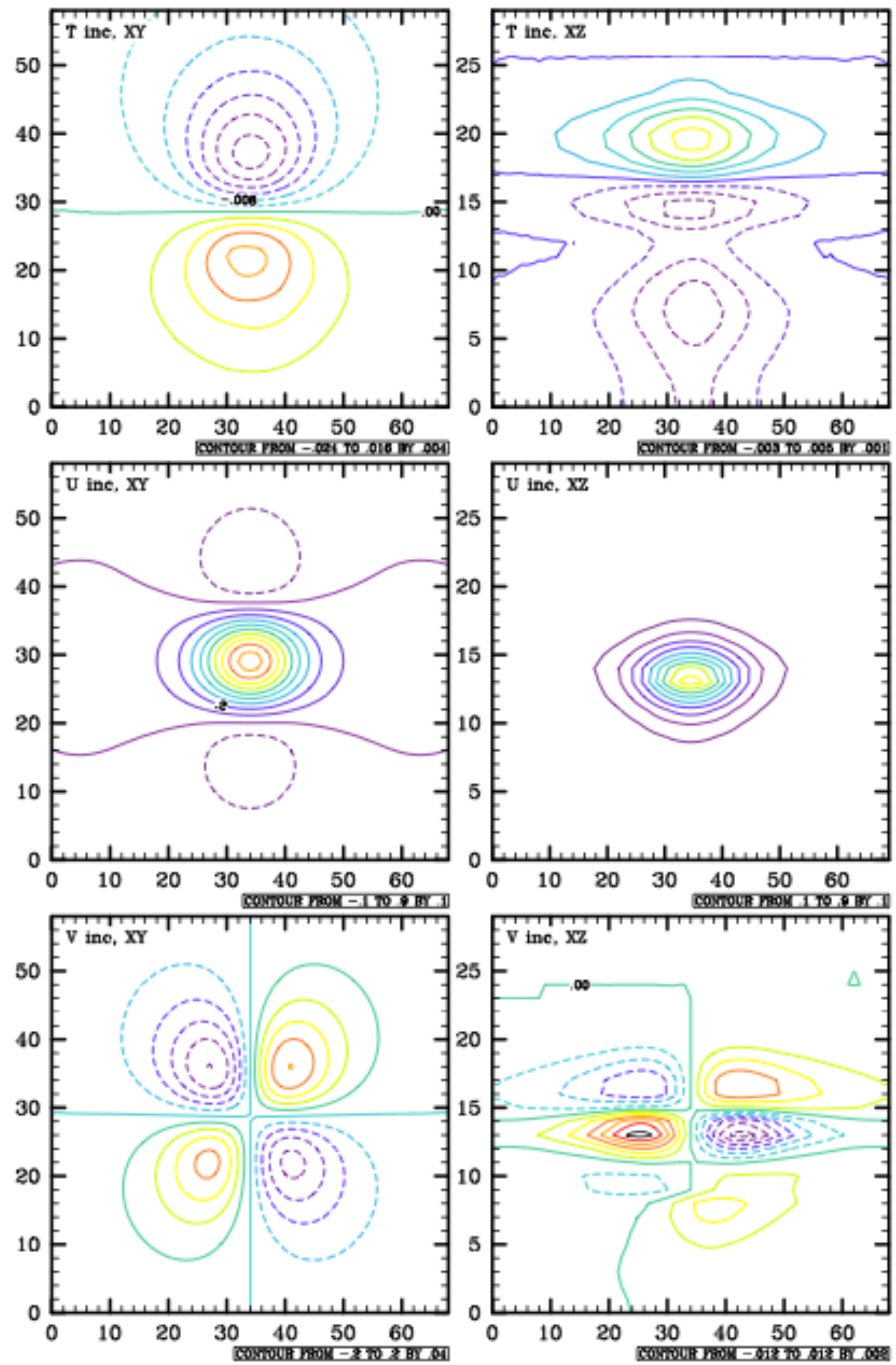
- Correlation:
  - Horizontal influence scale
  - Vertical influence scale
  - In Gaussian Shape



B: Balance

$$J(x) = (x-x_b)^T \mathbf{B}^{-1}(x-x_b)$$

- Correlation:
  - Balance among different fields, most important is balance between mass and wind fields



Developmental Testbed Center

Summary with GSI

Analysis results: wrf_inout

Background field: wrf_inout

Background covariance: berror

$$J(x) = (x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathrm{H}[x])^T \boldsymbol{R}^{-1}(y-\mathrm{H}[x])$$

Observations: prepbufr/bufr files

Code (setup*) and CRTM

Observation error: errtable

GSI
History and Current Status

Based on John Derber's talk

in 2012 summer GSI tutorial

History

- The Spectral Statistical Interpolation (SSI) analysis system was developed at NCEP in the late 1980's and early 1990's.
  - Originally called Spectral Optimal Interpolation(SOI) - references still in code
- Main advantages of this system over OI systems were:
  - All observations are used at once (much of the noise generated in OI analyses was generated by data selection)
  - Ability to use forward models to transform from analysis variable to observations
  - Analysis variables can be defined to simplify covariance matrix and are not tied to model variables (except need to be able to transform to model variable)
- The SSI system was the first operational
  - variational analysis system
  - system to directly use radiances

History

- While the SSI system was a great improvement over the prior OI system – it still had some basic short-comings
  - Since background error was defined in spectral space – not simple to use for regional systems
  - Diagonal spectral background error did not allow much spatial variation in the background error
  - Not particularly well written since developed as a prototype code and then implemented operationally

History

- The Gridpoint Statistical Interpolation (GSI) analysis system was developed as the next generation global/ regional analysis system
  - Wan-Shu Wu, R. James Purser, David Parrish
    - *Three-Dimensional Variational Analysis with spatially Inhomogeneous Covariances. Mon. Wea. Rev., 130, 2905-2916.*
  - Based on SSI analysis system
  - Replace spectral definition for background errors with grid point version based on recursive filters

History

- Used in NCEP operations for
  - Regional
  - Global
  - Hurricane
  - Real-Time Mesoscale Analysis
  - Rapid Refresh (ESRL/GSD)
- GMAO collaboration
- Preparation for AFWA implementation
- Modification to fit into WRF and NCEP infrastructure
- Evolution to NEMS

General Comments

- GSI analysis code is an evolving system.
  - Scientific advances
    - situation dependent background errors -- hybrid
    - new satellite data
    - new analysis variables
  - Improved coding
    - Bug fixes
    - Removal of unnecessary computations, arrays, etc.
    - More efficient algorithms (MPI, OpenMP)
    - Bundle structure
    - Generalizations of code
      - Different compute platforms
      - Different analysis variables
      - Different models
    - Improved documentation
  - Removal of legacy options
  - Fast evolution creates difficulties for slower evolving research projects

General Comments

- Code is intended to be used Operationally
  - Must satisfy coding requirements
  - Must fit into operational infrastructure
  - Must be kept as simple as possible
  - Must run fast enough and not use too many computer resources.
- External usage intended to:
  - Improve external testing
  - Transition research science into operations
  - Reduce transition time/effort to operations
  - Reduce duplication of effort

Simplification to operational 3-D for presentation

- For today's introduction, I will be talking about using the GSI for standard operational 3-D var. analysis. Many other options available or under development
  - 4d-var
  - hybrid assimilation
  - observation sensitivity
  - FOTO
  - Additional observation types
  - SST retrieval
  - NSST analysis
  - Detailed options

- Options make code more complex – difficult balance between options and simplicity

Analysis variables

- Background errors must be defined in terms of analysis variable
  - Streamfunction (Ψ)
  - Unbalanced Velocity Potential ($\chi_{unbalanced}$)
  - Unbalanced Temperature ($T_{unbalanced}$)
  - Unbalanced Surface Pressure ($Ps_{unbalanced}$)
  - Ozone – Clouds – etc.
  - Satellite bias correction coefficients

- Size of problem
  - NX x NY x NZ x NVAR
  - Global = ~130 million component control vector
  - Requires multi-tasking to fit on computers

Analysis variables

- $\chi = \chi_{unbalanced} + A\,\Psi$
- $T = T_{unbalanced} + B\,\Psi$
- $Ps = Ps_{unbalanced} + C\,\Psi$
- Streamfunction is a key variable defining a large percentage T and P_s (especially away from equator). Contribution to χ is small except near the surface and tropopause.

u,v

- Analysis variables are streamfunction and unbalanced velocity potential
- u,v needed for many routines (int,stp,balmod, etc.) on different domains
- u,v updated along with other variables by calculating derivatives of streamfunction and velocity potential components of search direction x and creating a dir x (u,v)

Background fields

- Current works for following systems
  - NCEP GFS – NEMS, GFSIO and spectral coefficients
  - NCEP NMM – binary and netcdf
  - NCEP RTMA
  - NCEP Hurricane
  - GMAO global
  - ARW – binary and netcdf
- FGAT (First Guess at Appropriate Time) enabled up to 100 time levels

Background Errors

- Three paths
  - Isotropic/homogeneous
    - Most common usage.
    - Function of latitude/height
    - Vertical and horizontal scales separable
    - Variances can be location dependent
    - See talk by Syed Rizvi
  - Anisotropic/inhomogeneous
    - Function of location /state
    - Can be full 3-D covariances
    - Still relatively immature
  - Hybrid
    - Dual resolution
    - Operational in global
    - See talk by J. Whitaker

Observations

- Observational data is expected to be in BUFR format (this is the international standard)
- See presentation by Ruifang Li
- Each observation type (e.g., u,v,radiance from NOAA-15 AMSU-A) is read in on a particular processor or group of processors (parallel read)
- Data thinning can occur in the reading step.
- Checks to see if data is in specified data time window and within analysis domain

Data processing

- Data used in GSI controlled 2 ways
  - Presence or lack of input file
  - Control files input (info files) into analysis
    - Allows data to be monitored rather than used
    - Each ob type different
    - Specify different time windows for each ob type
    - Intelligent thinning distance specification

Input data – Satellite currently used

- Regional
  - GOES-13 Sounder
    - Channels 1-15
    - Individual fields of view
    - 4 Detectors treated separately
    - Over ocean only
    - Thinned to 120km
  - AMSU-A
    - NOAA-15 Channels 1-10, 12-13, 15
    - NOAA-18 Channels 1-8, 10-13, 15
    - NOAA-19 Channels 1-7, 9-13, 15
    - METOP Channels1-6, 8-13, 15
    - Thinned to 60km
  - AMSU-B/MHS
    - NOAA-18 Channels 1-5
    - METOP Channels 1-5
    - Thinned to 60km
  - HIRS
    - NOAA-19 Channels 2-15
    - METOP Channels 2-15
    - Thinned to 120km
  - AIRS
    - AQUA 148 Channels
    - Thinned to 120km
  - IASI
    - METOP 165 Channels

- Global
  - **all thinned to 145km**
  - Geo Sounders/imagers
    - GOES-13 and 15 Sounders
      - Channels 1-15
      - Individual fields of view
      - 4 Detectors treated separately
      - Over ocean only
    - SEVIRI
      - Clear Sky Radiances
      - Channels 2-3
  - AMSU-A
    - NOAA-15 Channels 1-10, 12-13, 15
    - NOAA-18 Channels 1-8, 10-13, 15
    - NOAA-19 Channels 1-7, 9-13, 15
    - METOP Channels 1-6, 8-13, 15
    - AQUA Channels 6, 8-13
  - ATMS
    - NPP Channels 1-14, 16-22
  - AMSU-B/MHS
    - NOAA-19 Channels 1-5
    - NOAA-18 Channels 1-5
    - METOP Channels 1-5
  - HIRS
    - NOAA-19 Channels 2-15
    - METOP Channels 2-15
  - AIRS
    - AQUA 148 Channels
  - IASI
    - METOP 165 Channels

Input data – Conventional currently used

- Radiosondes
- Pibal winds
- Synthetic tropical cyclone winds
- wind profilers
- conventional aircraft reports
- ASDAR aircraft reports
- MDCARS aircraft reports
- dropsondes
- MODIS IR and water vapor winds
- GMS, JMA, METEOSAT and GOES cloud drift IR and visible winds
- GOES water vapor cloud top winds
- Surface land observations
- Surface ship and buoy observation
- SSM/I wind speeds
- QuikScat and ASCATwind speed and direction
- SSM/I and TRMM TMI precipitation estimates
- Doppler radial velocities
- VAD (NEXRAD) winds
- GPS precipitable water estimates
- GPS Radio occultation refractivity and bending angle profiles
- SBUV ozone profiles and OMI total ozone

Simulation of observations

- To use observation, must be able to simulate observation
  - Can be simple interpolation to ob location/time
  - Can be more complex (e.g., interpolation plus radiative transfer)
- For radiances we use CRTM
  - Vertical resolution and model top important

Quality control

- External platform specific QC
- Some gross checking in PREPBUFR file creation
- Analysis QC
  - Gross checks – specified in input data files
  - Variational quality control
  - Data usage specification (info files)
  - Outer iteration structure allows data rejected (or downweighted) initially to come back in
  - Ob error can be modified due to external QC marks
  - Radiance QC much more complicated. Andrew Collard!

Observation output

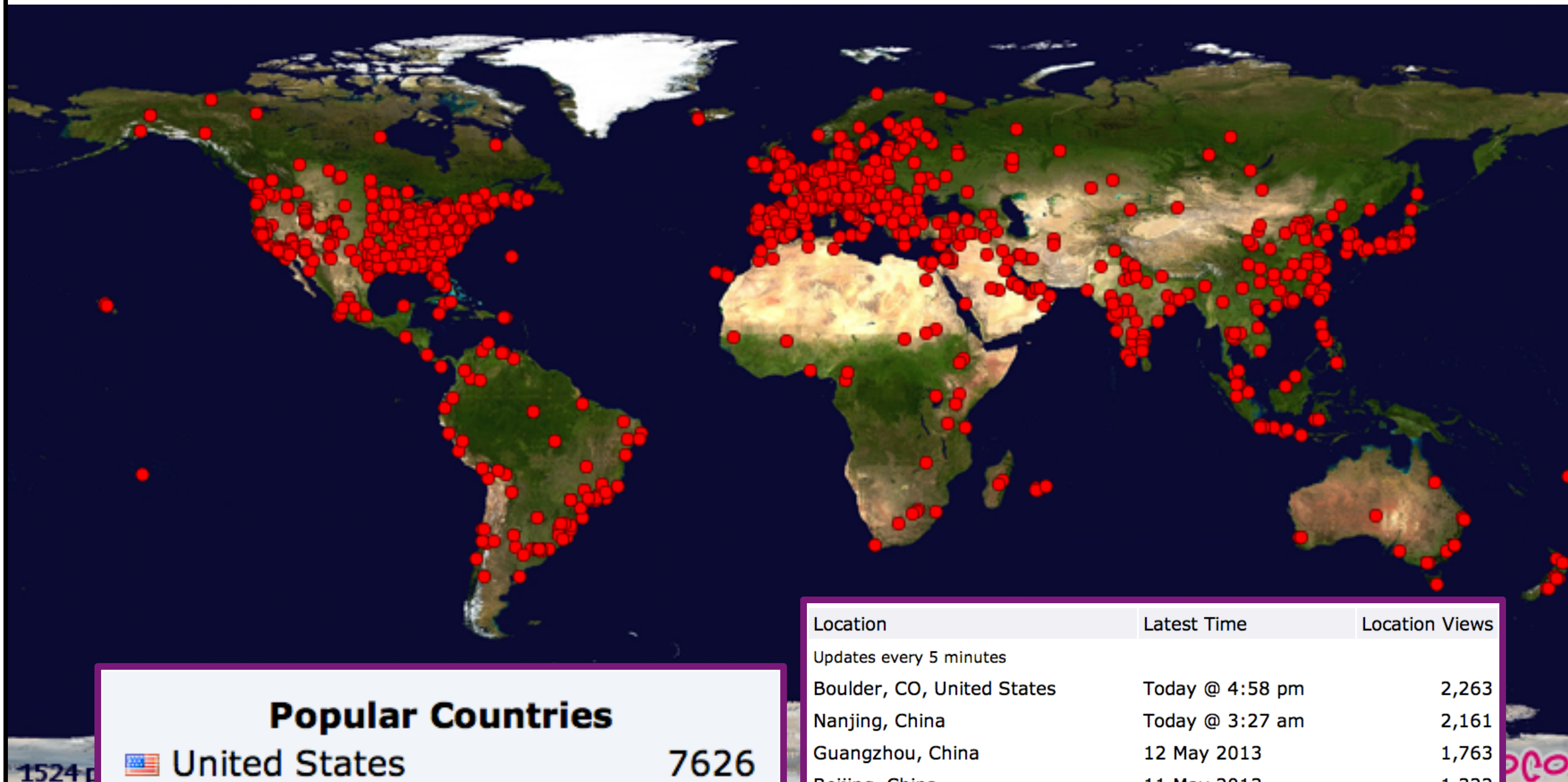
- Diagnostic files are produced for each data type for each outer iteration (controllable through namelist)
  - Used for data monitoring - essential
- Output from individual processors (sub-domains) and concatenated together outside GSI
- External routines for reading diagnostic files supported by DTC – general reader/writer under development

Community GSI

Community GSI

- Community GSI Goals:
  - Provide current operation GSI capability to research community (O2R) and a pathway for research community to contribute operation GSI (R2O)
  - Provide a framework to enhance the collaboration from distributed GSI developers
- GSI Community code includes:
  - Community GSI repository
  - User's webpage
  - Annual code release with user's guide
  - Annual residential tutorial
  - Help desk (over 700 registered users)

Community GSI Website Visitors



Popular Countries

United States	7626
China	7130
Korea, Republic of	923
Brazil	742
India	603

Location	Latest Time	Location Views
Updates every 5 minutes		
Boulder, CO, United States	Today @ 4:58 pm	2,263
Nanjing, China	Today @ 3:27 am	2,161
Guangzhou, China	12 May 2013	1,763
Beijing, China	11 May 2013	1,322
Seoul, Korea, Republic of	Today @ 2:22 am	803
Shanghai, China	11 May 2013	547
Hangzhou, China	17 Apr 2013	403
Madison, WI, United States	Yesterday @ 12:48 pm	400
Taipei, Taiwan	8 May 2013	380
Longmont, CO, United States	18 Apr 2013	275

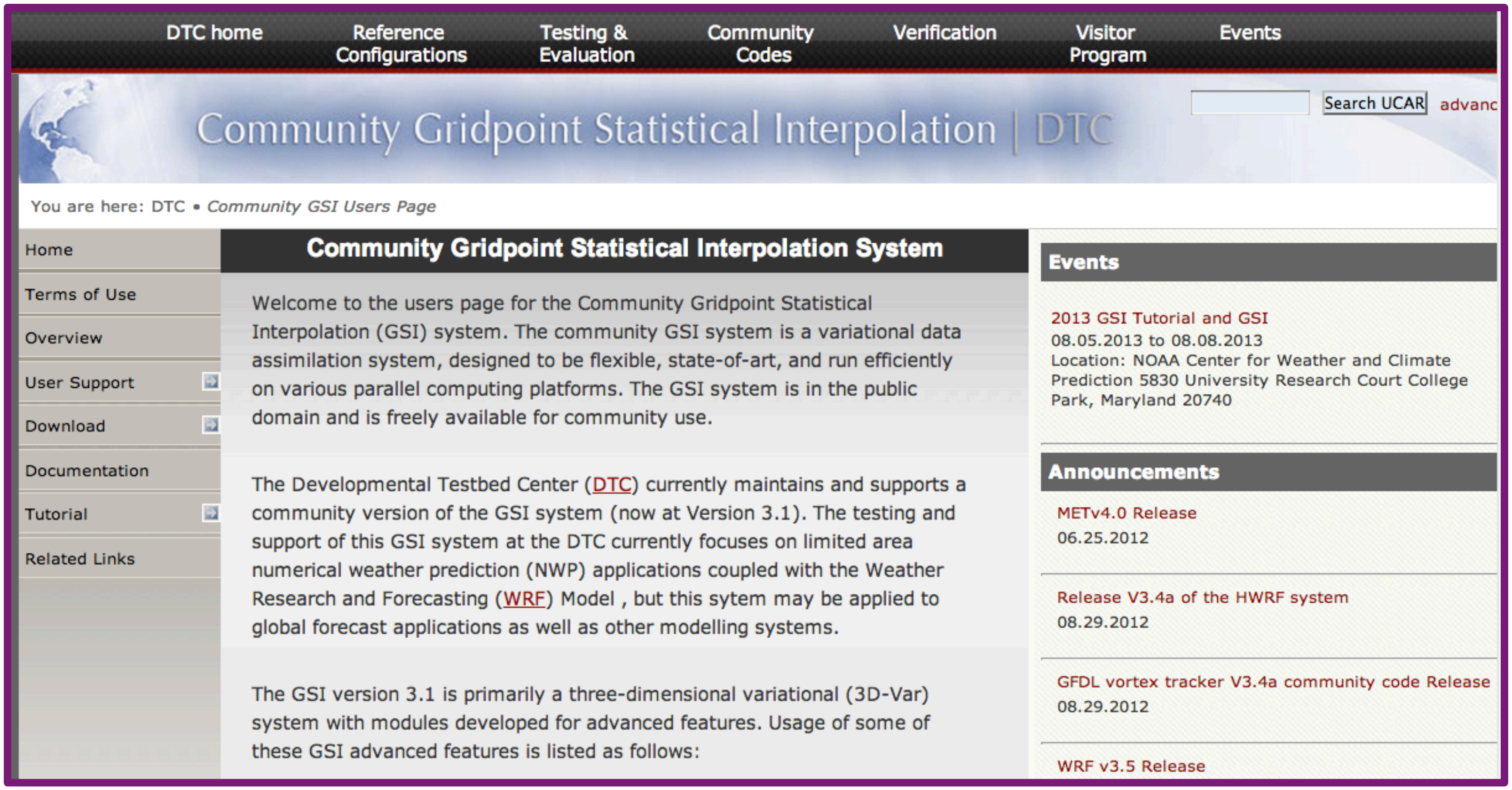
“History”

- June, 2006:North American Mesoscale (NAM) System, NCEP
- May, 2007: Global Forecast System (GFS), NCEP
- 2007: DTC started to document GSI.
- 2009:
  - Created GSI code repository over NCEP and DTC
  - First GSI release V1.0
  - Started user support
- 2010:
  - First Community GSI tutorial
  - Created GSI Review Committee
- 2011
  - First Community GSI workshop

Community GSI – User's Page

- Mainly support through User's Page and help desk:

  http://www.dtcenter.org/com-GSI/users/index.php



Community GSI Release

GSI Downloads

GSI System

You may download the following versions of the GSI system (GSI source codes, libraries, compiling system, fixed files, and run script) from this site.

- Community GSI system V3.1: Release on 07/20/2012
- Community GSI system V3.0: Release on 04/29/2011
- Community GSI system V2.5 Patch Release: 11/29/2010
- Community GSI system V2.0: Released on 04/27/2010
- Community GSI system V1.0: Released on 09/25/2009

Source code and fixed files were based on:
the GSI EMC trunk r19180 (May 10, 2012)
the community GSI trunk r826

Source code and fixed files were based on:
the GSI EMC trunk r12534 (Feb 25, 2011)
the community GSI trunk r593

Source code was based on the NCEP Global Implementation: Q1FY10

GSI Documents And Publications

GSI User's Guide

- **GSI version 3.1** comprehensive user
- **GSI version 3.0** comprehensive user
- **GSI version 2.0** comprehensive user
- **GSI version 1.0**

GSI Tutorials

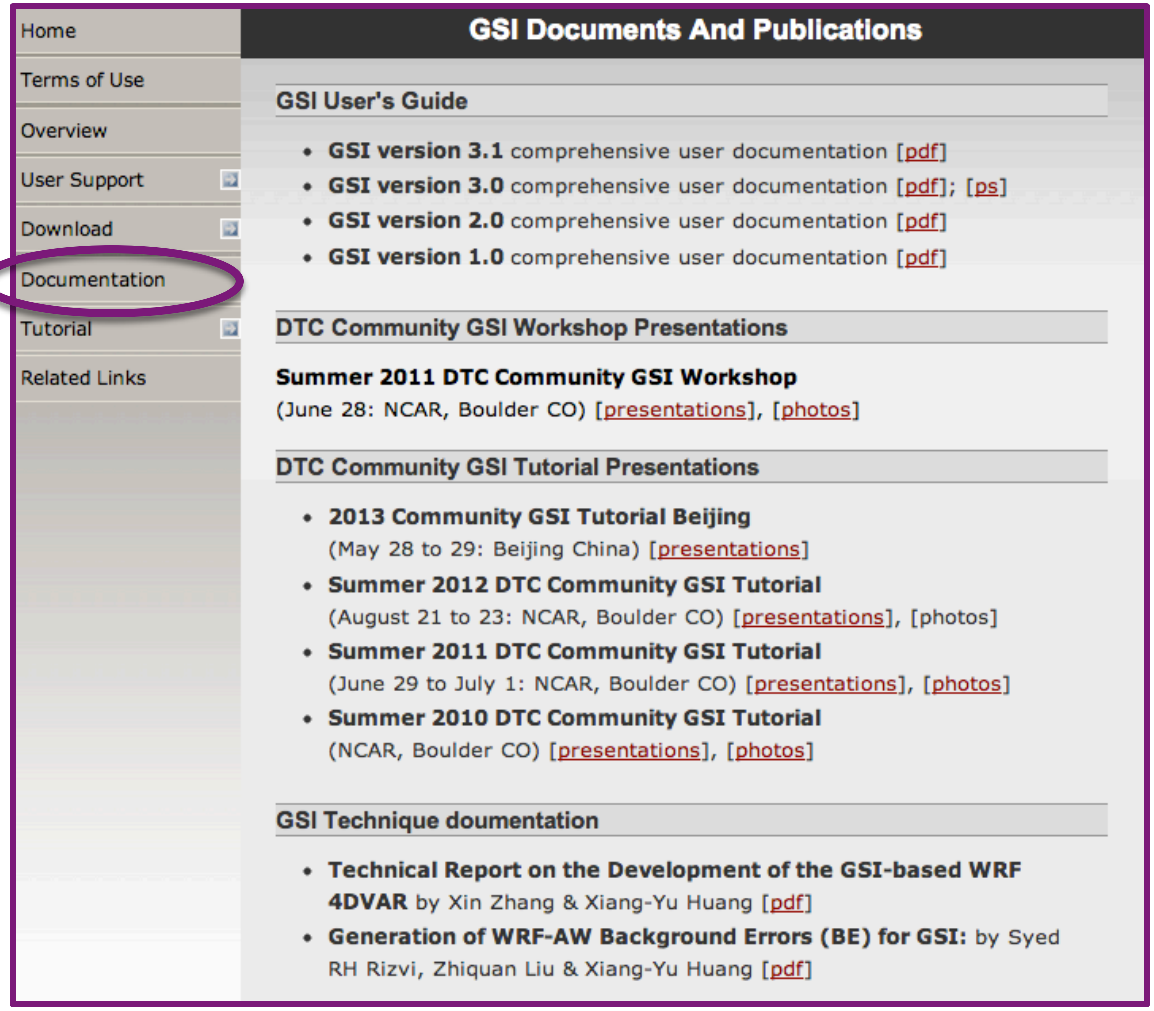
The GSI On-line Tutorial provides the basic steps to compile the GSI system, and test cases for the code to run.

- Tutorial for community GSI Version 3.1
- ...0
- ...er 2011 Practical

The GSI User's Guide and the on-line tutorial cases are updated with each official release.

Community GSI - Documents

- User's Guide
  - Match each official release
- Tutorial lectures
- Code browser
  - Calling tree
- Key publications



Community GSI - Practice

- On-line tutorial for each release
- Residential tutorial practice cases

Home
Terms of Use
Overview
User Support
Download
Documentation
Tutorial
Related Links

GSI Tutorials

The GSI On-line Tutorial provides the basic steps to compile the GSI system, and test cases for the code to run.

- Tutorial for community GSI Version 3.1
  - Further exercises from the Summer 2012 Practical
- Tutorial for community GSI Version 3.0
  - Further exercises from the Summer 2011 Practical
- Tutorial for community GSI Version 2.0
  - Further exercises from the Summer 2010 Practical
- Tutorial for community GSI Version 1.0

GSI Residental Tutorial classes for new users are generally offered once a year. These classes consist of lectures on the components of the GSI system, as well as practical sessions providing hands-on experience on using the software.

Basic Practical Cases

0). BUFR/PrepBUFR tools [practice]

To run any of the following practical cases, start with the basic **run_gsi.ksh**, found in the **comGSI_v3.1/run** directory, and m modifications to it. These changes are used by all the basic exe specific to using the COMET classroom. If you are running thes elsewhere, additional modifications will be necessary.

1). Single Observation Tests:

- [a]. ARW background with global BE
- [b]. ARW background with NAM BE
- [c]. NMM background with global BE
- [d]. NMM background with NAM BE

2). Test with conventional data (prepbufr):

- [a]. ARW background
- [b]. NMM background

3). Test with conventional and satellite radiance data:

- [a]. ARW background
- [b]. NMM background

4). Test with conventional and gpsro data:

- [a]. ARW background
- [b]. NMM background

5). Test with conventional data and radar radial wind:

- [a]. ARW background
- [b]. NMM background

Community GSI - tutorial

- 2010 summer tutorial (28-30 June, 2010)
  - 14 lectures and 8-h practice session
- 2011 summer tutorial (28-30 June, 2012)
  - Lectures + basic practice
  - Optional advanced practice (Full day on 30 June)
- The 1st GSI Workshop on 27 June, 2011
- 2012 summer tutorial (21-23 August, 2012)
- 2013 summer tutorial (5-7 August, 2013 at NCEP)
- The 2nd GSI workshop on 8 August, 2013 at NCEP
- 2013 Beijing tutorial: 1st oversea

Community GSI - Help desk

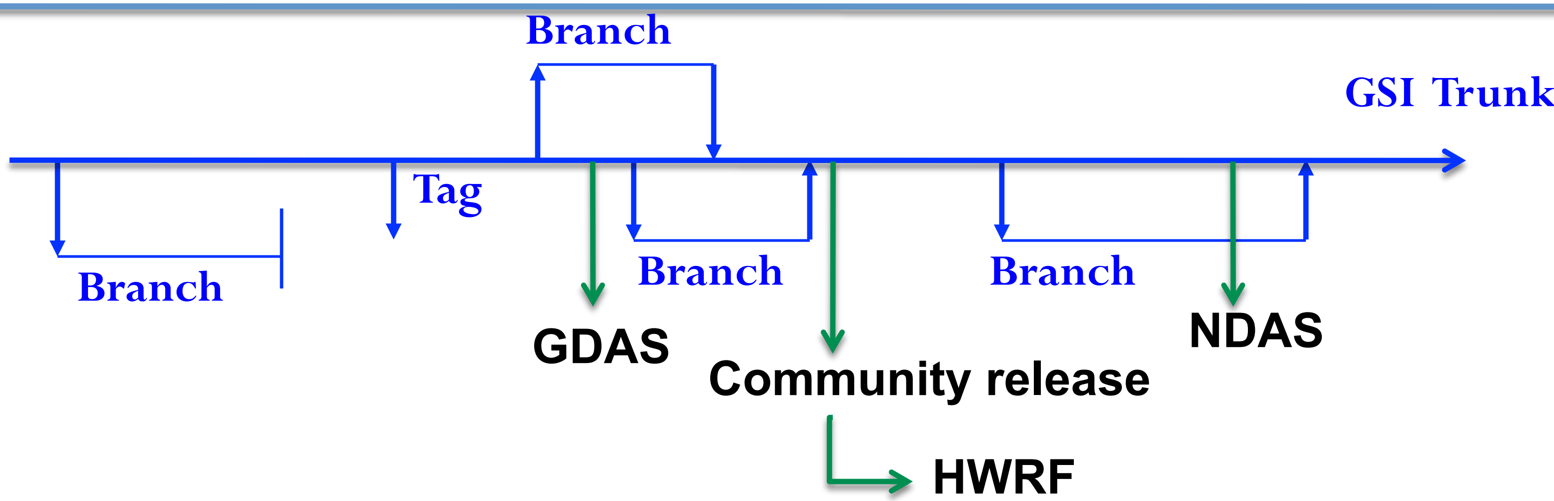
- gsi_help@ucar.edu
- Any GSI related questions
- Most of questions were answered by DTC staff
- Forward complex questions to NCEP colleague

Developmental Testbed Center

GSI Developers

- DTC supports GSI developers through:
  - Maintaining community GSI repository
  - Organizing GSI review committee
  - Testing and reviewing the new code
  - Organizing monthly community GSI developer's meeting
  - Help desk
- R2O: Developers need to:
  - Identify the work that will contribute to operation
  - Send development proposal to the committee early
  - Develop the new code based on GSI trunk

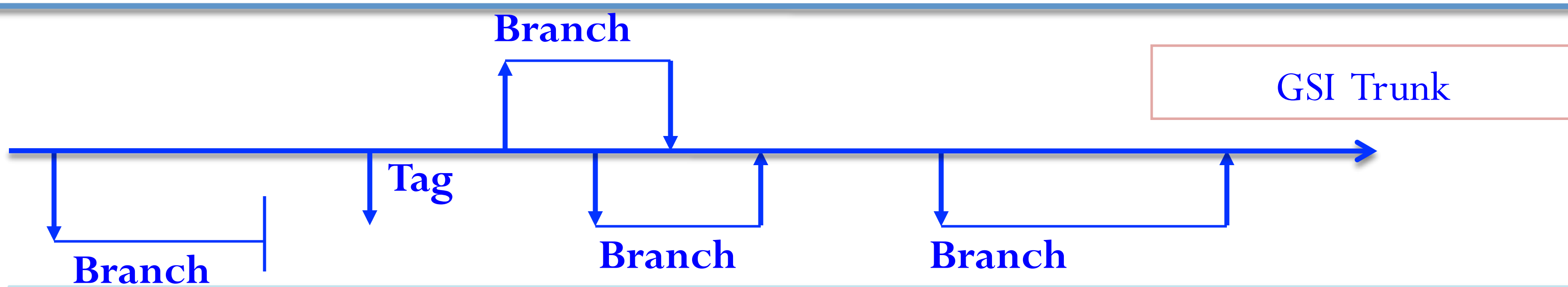
GSI Code Repository



- Use tags or branches for: Release, new development, bug fix …
- Applications may use different revisions in the trunk ("snapshot").

✓ Which GSI should I use ?
There is no "DTC GSI", "EMC GSI" or "global GSI". There is only one GSI! For a researcher, community release should be sufficient to use. If you are interested in getting new development back to the GSI trunk, contact GSI helpdesk (gsi_help@ucar.edu) get access to the developmental version of GSI.

GSI Review Committee



GSI Review Committee

DTC | NCEP/ EMC | NASA/ GMAO | NOAA/ ESRL | NESDIS | NCAR/ MMM | AFWA

- Represent research and operational community
- Coordinate distributed GSI development
- Conduct GSI Code Review

- DTC is working as the pathway between the research community and operational community.
- Provide visitor program for potential contributions to the operational code.
- Provide equivalent-operational tests of community contributions and provide rational basis for operational implementations.

Tutorial Agenda: Lectures and Practices

Overview and introductions (*Tuesday*)

Welcome, Background and Participants' Introduction
Fundamentals of Data Assimilation
Overview of GSI
Introduction to Practice Session

Group Picture: Tuesday Morning Break, 10:30 am, August 21, 2012

Community GSI fundamentals and tools (Tuesday-Wednesday)

GSI Fundamentals (1): Setup and Compilation: *Tuesday*
GSI Fundamentals (2): Run and Namelist: *Tuesday*
GSI Fundamentals (3): Diagnostics: *Wednesday*
GSI Fundamentals (4): Applications: *Wednesday*
Community Tools (1): PrepBUFR/BUFR tools: *Wednesday*
Community Tools (2): GEN_BE: *Wednesday*

Practice Session: COMET room (right behind the front desk at the main entrance)

Advanced topics (Wednesday-Thursday)

GPSRO Data Assimilation: Wednesday
Satellite Radiance Assimilation: Wednesday
GSI Infrastructures: Thursday
GSI Hybrid Data Assimilation: Thursday
Cloudy Radiance Data Assimilation: Thursday

Hand on Practices

Practice session: *Tuesday and Wednesday afternoon*
Optional Practice Session: *Thursday*

Tutorial Lecturers and Practical Session Instructors

NCEP/EMC	NASA/GMAO	NOAA/ESRL	NCAR/MMM	NCAR/RAL
John Derber Andrew Collard Lidia Cucurull** ** UCAR	Ricardo Todling	Jeff Whitaker Ming Hu*	Tom Augline Syed Rizvi Ruifang Li	Hui Shao* Don Stark* Kathryn Newman* Chunhua Zhou*

* Developmental Testbed Center (DTC)

Ming Hu, Hui Shao, Don Stark, Kathryn Newman, Chunhua Zhou

Pamela Johnson

Summary

- DTC works with NCEP/EMC to provide current operation GSI capability to research community (O2R)

- DTC also works with researchers to bring research community contributions back to the GSI operation repository (O2R)

- Send your questions to gsi_help@ucar.edu