

Data  
Assimilation  
Research  
Testbed



## DART Tutorial Section 19: Making DART-Compliant Models



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# DART Compliant Models

This section has not yet been updated for the Manhattan release. An update version should be available in June 2017.

# DART Compliant Models

DART uses identical assimilation code for menagerie of models.

Same namelists you've been using in low-order models still apply.

To work with DART, models must supply a subset of 16 interfaces.

Normally done by creating a `model_mod` that either 'wraps' the model (so the model itself is embedded in filter), or a `model_mod` that interfaces to the model (where it runs outside of filter).

More on interfaces follows.

# Large Models Compliant with DART

Many models available, from simple to highly complex.

Low order models, often for DA research

Geophysical models: Atmosphere, Ocean, Land, Solar, Space Weather,  
Upper Atmosphere, Hydrology, CICE (coming soon)

Non-geophysical applications: Economics, Target-tracking

# DART Compliant Global Atmosphere Models

CAM	Community Atmosphere Model (all 3 dynamical cores)	NCAR
CAM/CHEM	CAM with Chemistry	NCAR
WACCM	Whole Atmosphere Community Climate Model	NCAR
AM2	Atmosphere Model 2	NOAA/GFDL
ECHAM4,6	European Centre Hamburg Model	Hamburg
Planet WRF	Global version of WRF	JPL
MPAS	Model for Prediction Across Scales	NCAR/DOE
LMDZ5	Laboratoire de Météorologie Dynamique	Indian Inst. of Technology, Delhi

# DART Compliant Regional Atmosphere Models

WRF/ARW

Weather Research and Forecast  
Model

NCAR

WRF/CHEM

WRF with Chemistry

NCAR

NCOMMAS

Collaborative Model for Multiscale  
Atmospheric Simulation

NOAA/NSSL

COAMPS

Coupled Ocean/Atmosphere  
Mesoscale Prediction System

US Navy

CMAQ \*

Community Multi-scale Air Quality  
(\* interface not available)

EPA

COSMO

Consortium for Small-Scale Modeling

DWD

# DART Compliant Ocean Models

POP

Parallel Ocean Program

DOE/NCAR

MIT OGCM

Ocean General Circulation Model

MIT

ROMS

Regional Ocean Modeling System

Rutgers

MPAS

Model for Prediction  
Across Scales  
(Under development)

DOE/LANL

# DART Compliant Upper Atm / Space Weather

ROSE

NCAR

TIEGCM

Thermosphere Ionosphere  
Electrodynamic GCM

NCAR/HAO

GITM

Global Ionosphere  
Thermosphere Model

Michigan

Solar Dynamo

Dynamo/Sunspot Model

NCAR/HAO



# DART Compliant Land / Hydrology Models

CLM

Community Land Model

NCAR

NOAH

Relatively simple land model

Community

CABLE

Community Atmosphere  
Biosphere Land Exchange

CAWCR  
(Australia)

WRF Hydro

Hydrologic Model

NCAAR

# Creating a DART Compliant Model

Total of 16 interfaces for full compliance.

Can have partial compliance with subset of these.

See:

[http://www.image.ucar.edu/DAReS/DART/DART\\_Documentation.php#adding\\_a\\_model](http://www.image.ucar.edu/DAReS/DART/DART_Documentation.php#adding_a_model)

See *models/template/model\_mod.f90* for stripped interfaces.

The minimal interface includes:

1. *function get\_model\_size*: how big is the model?
2. *function get\_state\_meta\_data*: returns location and kind of each state variable element (DART sees one long vector for state).
3. *subroutine static\_init\_model*: does any initialization required by model, for instance allocating storage, reading namelist...

An initial ensemble of state vectors; can be generated offline.

With this implementation, can assimilate identity obs at a single time.

# Increasing Functionality

- 4. *function get\_model\_time\_step*: what is  $\delta t$  for model?
- 5. Stub for *subroutine adv\_1step* (just say  $\delta t$  is 0).

Can now test repeated assimilations of identity observations.

- 6. Allowing non-identity observation operators:
  - Implement *subroutine model\_interpolate*:
    - Given a location (and kind), return interpolated state value.

Can test repeated assimilations of non-identity observations.

# Increasing Functionality (cont)

7. Some way to advance the model in time.

This can be done by implementing *subroutine adv\_1step*  
Given state vector, what is state vector after  $\delta t$ ?

OR

By implementing a shell script that advances the model.  
Reads a state vector from a file, writes updated vector.

Can do arbitrary OSSEs.

Can do experiments for models that have real observations.

# Additional interfaces

8. *subroutine init\_conditions*: returns a state to start from. May not be appropriate for large models and can error out in this case.
9. *subroutine init\_time*: returns an initial time to start from. Again, may not be appropriate for large models and can error out.
10. *subroutine pert\_model\_state*: Generate an ensemble member by perturbing a control state. Optional. (filter will perturb if model\_mod has no special needs.)
11. *subroutines nc\_write\_model\_atts & nc\_write\_model\_vars*: format netCDF diagnostic output for your model. Can be a single 1D vector for initial implementation.
12. *subroutine end\_model*: cleans up when done. E.g. deallocate space allocated in the static\_init\_model subroutine.

# Additional interfaces (cont)

13-15. *get\_close\_maxdist\_init*, *get\_close\_obs\_init*, *get\_close\_obs*:  
Routines that are normally provided by *location\_mod*. Can start by including a *use* statement from *location\_mod* and a *public* declaration as seen in the *template/model\_mod*. These allow more control on efficiency, vertical transformations, etc. for close searches if needed.

16. *ens\_mean\_for\_model*: not usually required for low-order models. Some large models need the model ensemble mean to do consistent computations independent of any single ensemble member. For example, computing consistent distances between locations that depend on pressure. Can be a stub that simply returns.

# Approaches, Tools

Copy the DART models/template directory to a new location.

Add routines in the order suggested here so you can test as you go.

Decide how DART and your model will interact:

1. Subroutine-callable model inside filter
2. Serial, easily-advanced model driven from script called by filter
3. Parallel, complex-scripting model advanced separately from filter

Use *models/template/model\_mod\_check.f90* for testing specific routines as you implement them.

Start with single observation, no model advance, before getting more complicated.

# Assimilating Observations in Your Model

To assimilate observation types in your model, you need code in your `model_mod.f90 :: model_interpolate()` subroutine for all generic kinds needed by the forward operators.

1. Could be a simple interpolation if that observation kind is also present in the model state.
2. Could require a vertical transformation based on kinds present in the model state. e.g. temperature, moisture, pressure.
3. Could require forward operator code in an `obs_def_xxx_mod.f90` if the observation kind cannot be directly interpolated by the model. In this case you need to be able to interpolate any kinds required by the forward operator code in the `obs_def` file.



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