Lecture 20: Atmospheric Modeling

Working with Real Atmospheric Models

NWP Basics

Agenda

- Review Exam 2
- A little on NWP
- Taring files for our activities on Monday

Exam Problem 1

Exam Problem 3

- CFL Criteria

Exam Problem 4

Exam Problem 2
Contributions

- http://meted.comet.ucar.edu
- Numerical Weather Prediction
  - Model Fundamentals
  - 10 Common NWP Misconceptions

What we want

- Operational Meteorology
  - “Save Lives. Protect Property”
  - Numerical Weather Prediction
    - Global/Synoptic/Mesoscale
- Climate Research
  - Long Term Climate Impacts
  - General Circulation Models (GCM)
  - Regional Climate Models

You might remember these

- ATM Models are a collection of deterministic equations placed in a numerical solution framework
  - $F=ma$
  - $\frac{du}{dt} + \frac{\partial}{\partial x} \left( u \frac{du}{dx} \right) = -\frac{\partial}{\partial x} \left( \frac{y}{\beta} \frac{du}{dx} \right)$
  - $\frac{dq}{dt} + \frac{\partial}{\partial x} \left( q \frac{dq}{dx} \right) = \frac{\partial}{\partial x} \left( \frac{e+u}{\beta} \right)$
  - Cons. of mass
    - $\frac{\partial u}{\partial t} + \frac{\partial}{\partial x} \left( u \frac{\partial u}{\partial x} \right) = 0$

Model Components

- The Atmospheric Modeling Process, though clearly discipline-specific, has many components important in other disciplines
  - (If only as an example of key common modeling issues)

Data

- Data are collected to define the initial state of the atmosphere & boundaries. Sources include surface stations, satellite data, profilers, aircraft, soundings, radar and even GPS information.
- A major endeavor in ATM NWP
- GIGO!
Data and Initialization

- We have a discretized grid of one resolution
- ... And Processes and Observational Data covering a spectrum of resolutions!

Computer Resources

- The capacity and speed of computing resources available to run a Fx model govern the amount and complexity of the data and model components used. Thus, the computer resources can be a significant limitation in NWP
  - Data storage and access (networking/archiving)
  - Forward-in-Time Speed (Speed)
  - Memory (capacity and domain size & detail)
  - Multi-processing (speed & tasking)

The Model

- And we finally get to the actual model!
  - The Fx model contains all of the components needed to compute the current state and 3-D evolution of basic Wx variables. The components include the numerics, assimilation system, explicit dynamics and implicit physical processes

Numerics

- Model numerics refers to the characteristics such as the mathematical formulations used to solve the Fx equations (shown earlier).
  - How data is represented
  - Model resolutions
  - Computational domain
  - Coordinate system
- These all affect the handling of dynamics and how consistently the initial conditions and physical processes are represented

QC & Objective Analysis

- Through a series of checks and test data are quality controlled to ensure the viability of info input into the model. This helps ensure that inaccurate data are adjusted or removed before proceeding to the analysis.
- Data must be ingested into the model so that the fields represent the best mean value for that grid cell for the resolution and dynamics of the model.

Some Key Numerics Issues

- Stability
- Finite Grids vs Elements vs Spectral
- Aliasing and Resolution Issues
- Predictability
  - Enter Chaos
Assimilation

- An assimilation system is a complex system by which observed meteorological parameters are converted to forecast variables and blended with previous short-range forecasts from earlier runs to create the initial conditions to start a new forecast.
- The system tries to find initial fields that will optimize the accuracy of the forecast based on the available data and first guess fields.

Assimilation

- Assimilation is part of the initialization process.
- Rather than starting with a "cold" start with the previous output + current conditions, we can...
  - Use the previous forecast as an initial WAG™
  - Add obs to these 1st guess field
  - Start the model "before" our forecast period (e.g., 12 hr before)
  - Inject observations during the forecast period (Nudging)
Variational Assimilation
- $J$: Cost Function $\rightarrow \ln(P(x))$
- $x$ = the gridded forecast/analysis
- $\hat{x}$ = current analysis against forecasted analysis
- $y$ = observations and grid-interpolated observation points
- $\hat{y}$ = Real ob vs analysis point

$$J(x) = \frac{1}{2} (\tilde{\mathbf{x}} - \hat{\mathbf{x}})^T B^{-1} (\tilde{\mathbf{x}} - \hat{\mathbf{x}}) + \frac{1}{2} (\tilde{\mathbf{y}} - \hat{\mathbf{y}}^o)^T (O + F)^{-1} (\tilde{\mathbf{y}} - \hat{\mathbf{y}}^o)$$

Nudging
- (or Newtonian Relaxation)
- Observed values of $a$ are delivered into the model as it runs

$$\frac{d\alpha}{dt} = \text{Forcings} + N(\alpha, t) \alpha [\alpha - \alpha]$$

Dynamics
- In NWP, dynamic processes often refer to the ATM process best derived from "first principles" and are explicitly represented. These include grid scale advection, pressure gradient forces, adiabatic heating and cooling. These processes are described by a set of basic equations (shown earlier)
- These are also often called "explicit" processes

Physics
- In NWP, physical processes often refer to 3 types of processes:
  - Those operating at scales below that of the model resolution
  - Those involving exchanges of energy and momentum between the atmosphere and external sources (e.g., radiation and land/sea surface processes)
  - Cloud and precip microphysics

"Parameterizations!"
Physics

- In other words, these are what we cannot model explicitly and must approximate based on those values and processes that we can predict explicitly.
- “Parameterizations!”

Parameterizations

- The slide here “cartoons-out” (appropriately enough!) examples of many implicit processes in NWP.

Post Processing

- OK.. The model’s done
- Here we begin the most important part of the forecast process.
- We begin to use the results of the model.

Numerical Guidance Sites

- http://www.wxmaps.org
- http://weather.unisys.com

Numerical Guidance

- Products taken from the model output and placed in a form used by forecasters.

Statistical Guidance

- Model Gridded Fields can be interpreted statistically by regressing key model output variables to past events of temperature, precip etc.
- “Model Output Statistics” (Can be said to works during the normal spectrum of weather)
Now the Lab Activity

Ensemble NWP runs based on Physics Options
Today

Access the WRF-ARW Model
Learn about Tarballs

Monday

Run WRF for various physics options
We’ll distributed the tasks Monday

Wednesday

Look at the Output Together in IDV

De Tarball

- Tar files
  - Like Zip files without the Zip
  - To make a tar file
    - tar –cvf tarfilename.tar [files or directory]
  - To extract “untar” a file
    - tar –xvf tarfilename.tar

Shrink that file (or files)

- gzip and gunzip
  - “gzipped” files are marked with a .gz
  - Make me tiny
    - gzip –r [files or directory]
  - Make me really tiny
    - gzip –9r [files or directory]
  - Unzip me
    - gunzip –r [files.gz or directory w/ zips]
  - Unzip and untar at once – LINUX
    - tar –zxvf tarball.tar.gz