Numerical Weather Prediction

Meteorology 3110

Closed Set of Equations

- Same number of equations as unknown variables.

- Equations
  - Momentum equations (3)
  - Thermodynamic energy equation
  - Continuity equation
  - Equation of state

- Variables: u, v, w, T, p, ρ

Nomenclature

- Dynamics: Atmospheric motions and their time evolution
  - Application of Newton’s second law.
- Kinematics: Properties that can be deduced without reference to Newton’s second law.

Solve Equations

- Approximate mathematical equations
  - Not enough data to compute continuous derivatives.
- Discretization needed.
  - Approximation needed in both time and space.
  - Centered difference and one-sided upstream scheme are both used.
- What about edges of domain or boundaries?
  - Model approximates conditions at the boundary, or
  - Model gets data from another model.
    - Regional models get boundary data from global models.

Method

- Collect observations of weather (data).
- Quality control data to remove spurious reports.
- Perform Objective Analysis to model grid points.
  - Observations don’t match the model grid.
  - They need to be “gridded” before they are useful to the model.
- Initialize the model insuring that balance occurs.
- Integrate the model forward in time to produce model forecast.
- Post-process results to produce nice looking graphs.
- Interpret the results.
  - Adjustment based on forecaster understanding and model biases.

Model Types

- Finite difference models
  - Gridded data
  - Use methods that you learned in class.
    - Centered-difference and One-sided upwind difference.
    - Taylor-series expansions about a point.
    - Accuracy and computational error depends on how many terms you keep.
  - Typically regional models.
- Spectral models
  - Fourier series to represent waves in the atmosphere.
  - Global models.
  - Resolution given by R (Rhomboidal truncation) or T numbers (Triangular truncation).
  - T159 ~ 126km, T511 ~ 39km, T1279 ~ 16km

Taylor Series

Taylor series: $f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \cdots + \frac{f^{(n)}(a)}{n!}(x-a)^n + \cdots$

Taylor polynomial: $f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \cdots + \frac{f^{(n)}(a)}{n!}(x-a)^n$

Remainder: $R_n(x) = \frac{f^{(n+1)}(a)}{(n+1)!}(x-a)^{n+1} + \frac{f^{(n+2)}(a)}{(n+2)!}(x-a)^{n+2} + \frac{f^{(n+3)}(a)}{(n+3)!}(x-a)^{n+3} + \cdots$

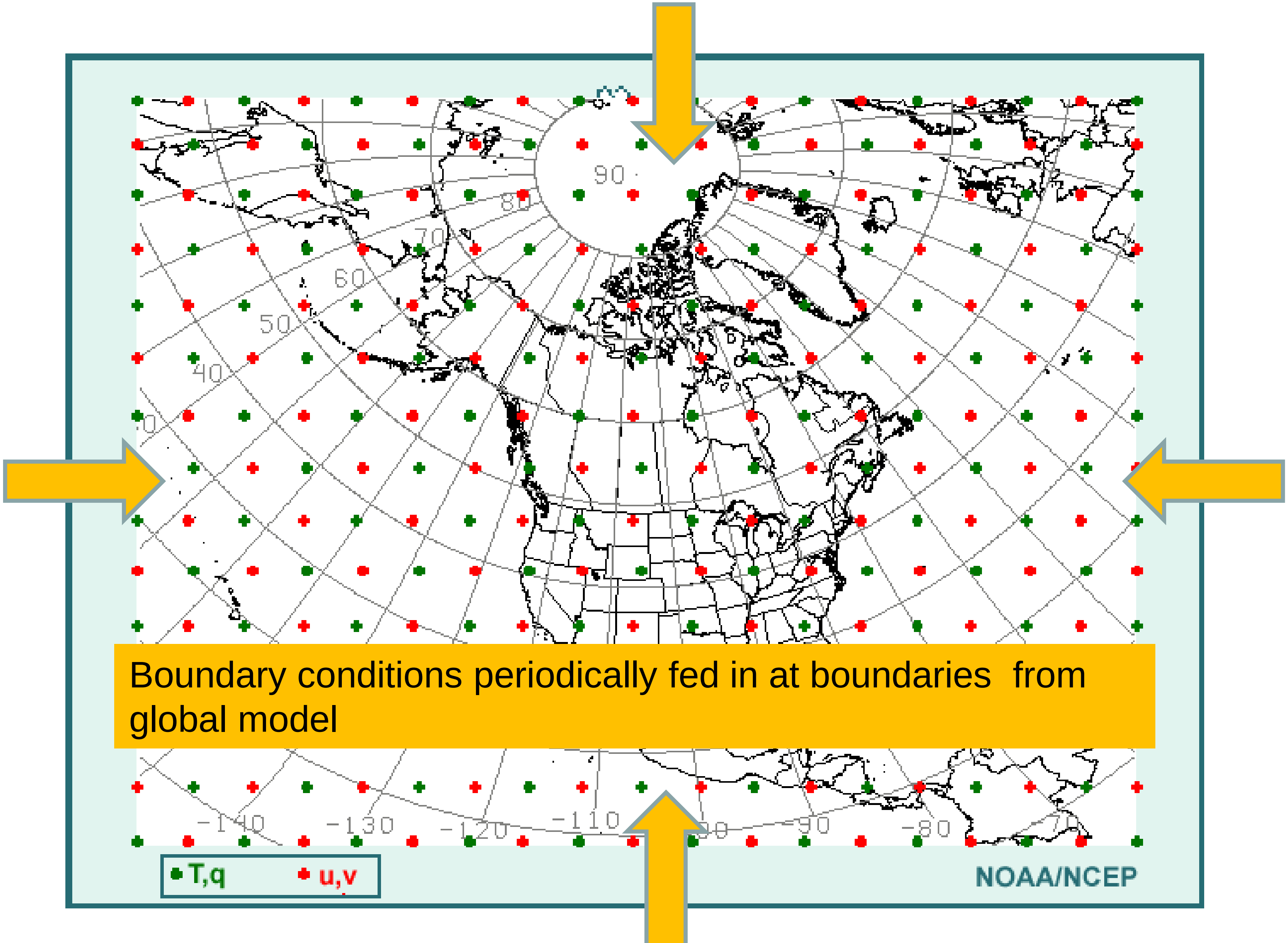
Derivative form of remainder: $R_n(x) = \frac{f^{(n+1)}(z)}{(n+1)!}(x-a)^{n+1}$ where z is a number between a and x.

Integral form of remainder: $R_n(x) = \frac{1}{n!}\int_a^x f^{(n+1)}(t)(x-t)^n \, dt$

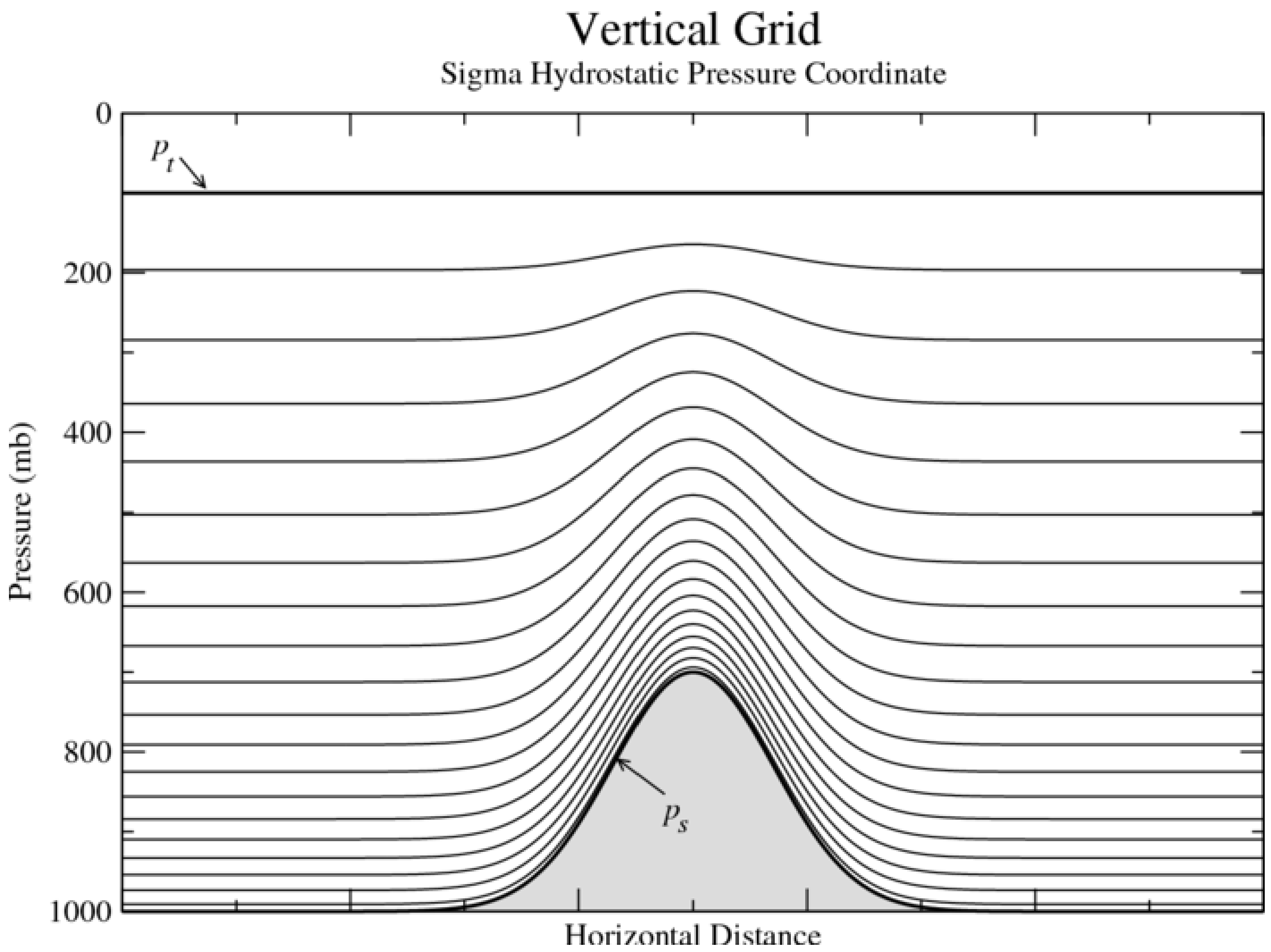
Important Features

- Horizontal resolution
  - “Effective” resolution is 4-5 times model grid spacing.
- Vertical coordinate
  - Sigma coordinate – terrain following coordinate.
- Vertical resolution
  - Spacing of vertical grid.
- Domain
  - Regional or Global.

Horizontal Resolution/Regional Model



Sigma Vertical Coordinate



NCEP Operational Models

- NAM (NMM)
  - North American Mesoscale
  - Currently NMM-B
  - WRF-ARW
  - ETA – Really old NAM
- GFS
  - Global Forecast System
- RAP/HRRR
  - Rapid Refresh – Replaced the RUC (Rapid Update Cycle in May 2012.
- RRFS-A – Rapid Refresh Forecast System
  - Scheduled for operation in 2024
  - Will likely replace the RAP and HRRR.

Non-NCEP models

- ECMWF
  - European Centre for Medium-Range Weather Forecast
- UKMET
  - British atmospheric model
- GEM
  - Global Environmental Multiscale
  - Canadian forecast model

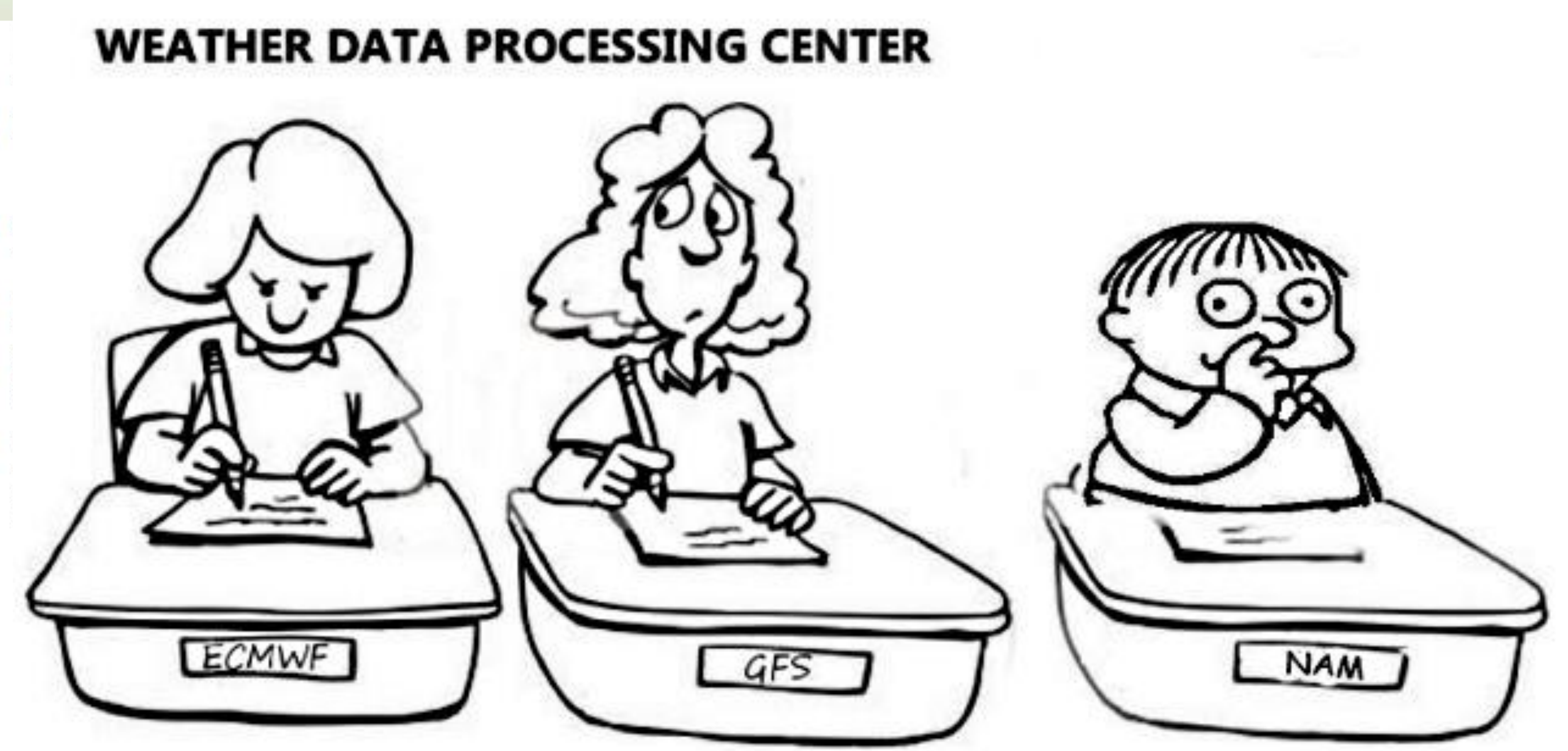
News

Is U.S. Global Weather Prediction Falling Behind?

By Jess Baker | Published: Feb 16, 2013, 8:02 AM EST | weather.com

17 FEBRUARY 2013

Seriously Behind: U.S. Near the Bottom In



A man scrapes snow off of his car on Wednesday in Virginia, not far from Washington, which was mostly spared the white stuff.

PHOTOGRAPH BY KAREN BLEIER, AFP/GETTY IMAGES

U.S. numerical weather prediction has fa

The information beyond this point applies to the old MOS and FOUS applications. This is no longer applicable past Fall 2024. We will now be working with NBM text bulletins. More information on these will be given in class.

MOS/FOUS

- MOS
  - Model Output Statistics.
  - Statistical equations used to calculate. meteorological variables.
  - Accounts for persistent model biases.
- FOUS
  - Forecast Output United States
  - Raw model data.
  - Data will contain model biases

MOS features

- Equations developed over time.
  - Types of events that occurred over the development time are well handled.
  - Rare events will not be well handled by MOS equations.
  - New models require time to develop robust MOS equations
- Different equations for different regions.
- Two sets of equations based on time of year.
  - Summer/Winter set of equations.
- Three slides: Advantages/Disadvantages/Poor MOS forecasts.

MOS Advantages

- Account for persistent model bias.
- Take advantage of model derived variables that are not observed.
  - Vorticity.
  - Upward vertical velocity.
- Emphasize reliability of forecast.

MOS Disadvantages

- Change in model requires the development of new MOS equations.

- Long development time for MOS equations (2 seasons of data).
  - 2 years, thousands of equations to develop.

- MOS forecasts tend to lack sharpness.

When will MOS produce a poor forecast?

- After a model change.
- If the current weather was not experienced during the development period of the MOS equations.
- If the circumstances from today's weather differ from the norm.
- If the forecast depends on mesoscale effects not accounted for in the MOS equations.