Numerical Weather Prediction
Eta Model - Introduction

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What is a Model?

- Take the equations of fluid mechanics and thermodynamics that describe atmospheric processes.
- Convert them to a form where they can be programmed into a large computer.
- Solve them so that this software representation of the atmosphere evolves within the computer.
- This is called a “model” of the atmosphere

Basic equations

- Apply to many different types of atmospheric models
  - operational weather prediction models
  - global climate models
  - building-scale urban (CFD) models
  - research atmospheric models
  - models of flow over an airfoil

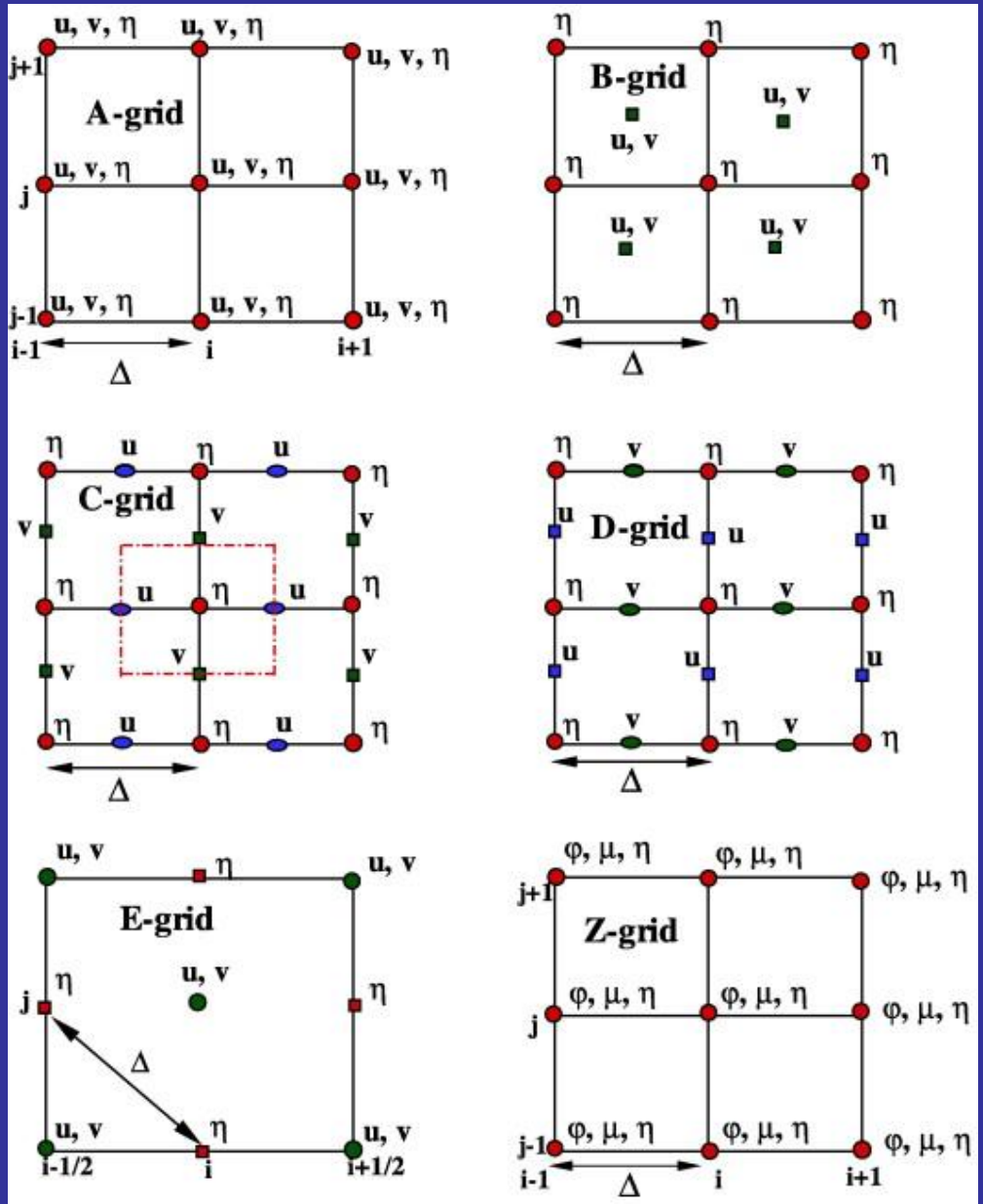
- In all cases, they are the equations of fluid dynamics applied to the atmosphere

Eta model

- Design of the Eta ancestor code started in Belgrade, first code written beginning of 1973
- It became officially operational at NCEP on 8 June 1993
- In its various versions, the model has been and/or is widely used in numerous countries

- Regional grid point model
- Semi staggered Arakawa E grid
- Transformed area

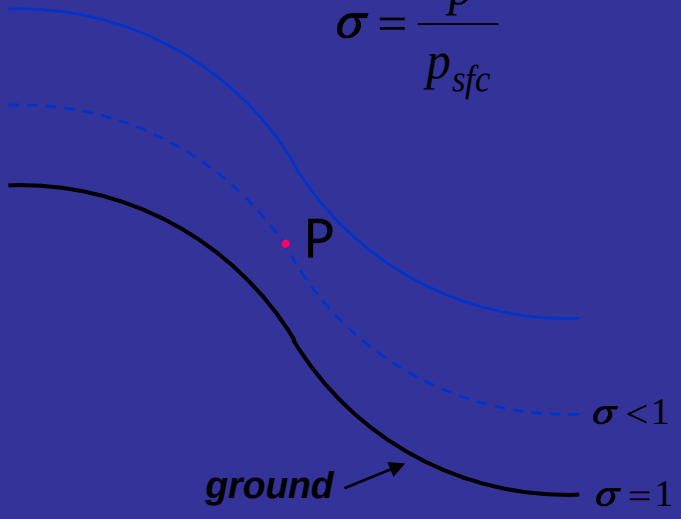
Horizontal grid structures



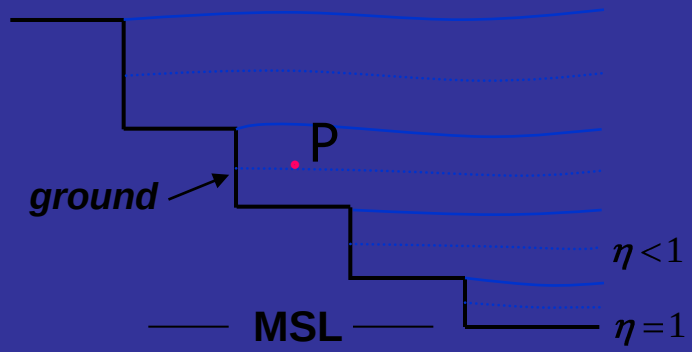
Sigma and Eta Coordinates

$$PGF = -\alpha \nabla p - g \nabla z$$

$$\sigma = \frac{p}{p_{sfc}}$$



$$\eta = \sigma \times \frac{p_{ref} - p_{sfc}}{p_{ref}}$$



At point P: $\nabla_\sigma p >> 0$

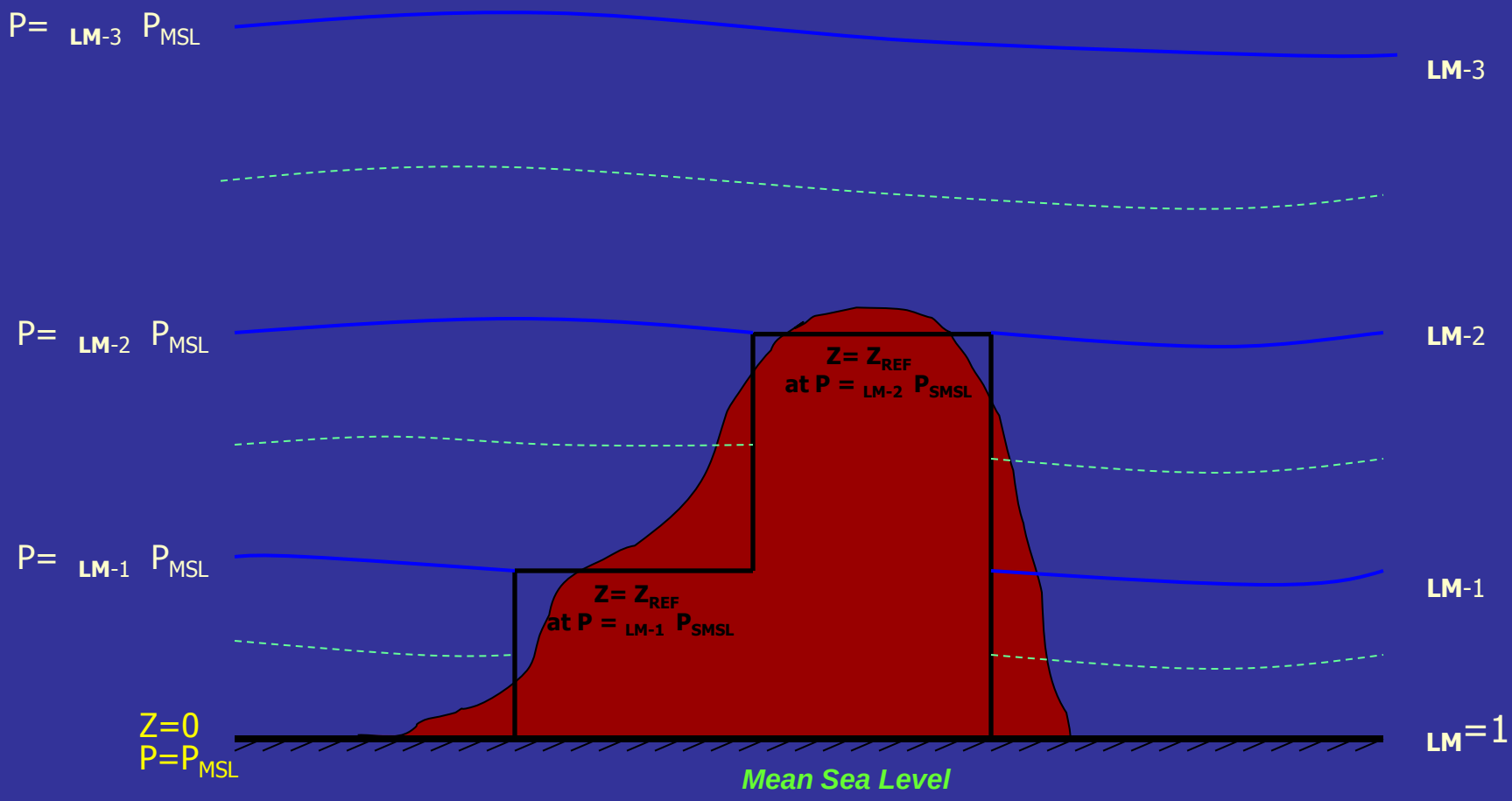
$\nabla_\sigma z << 0$

At point P: $\nabla_\eta p$ is small

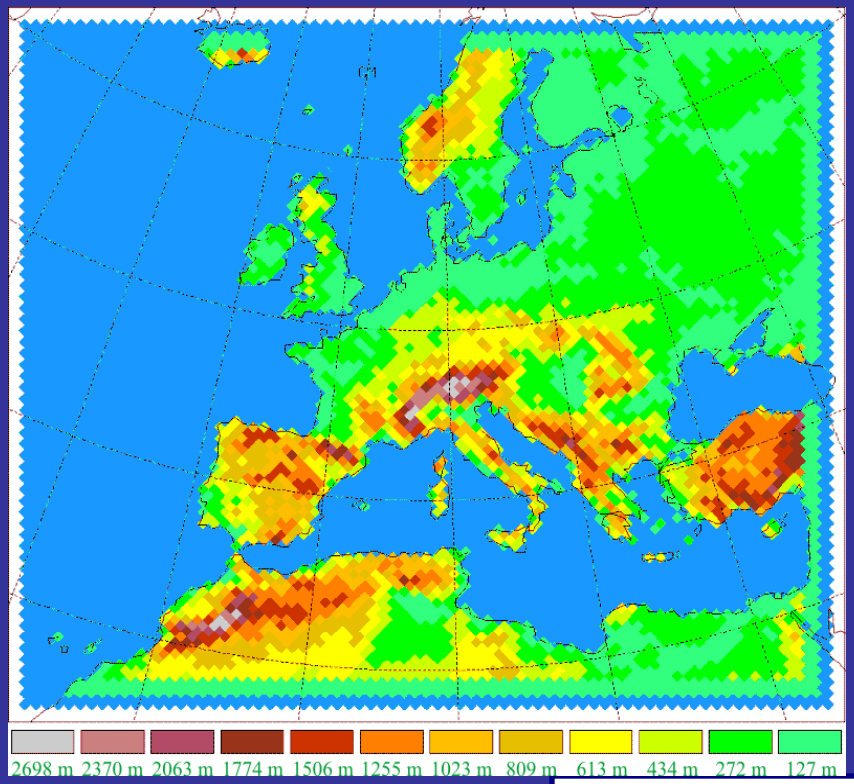
$\nabla_\eta z$ is small

Eta Coordinate

Reference heights and temperatures taken from the standard atmosphere



Eta model Orography

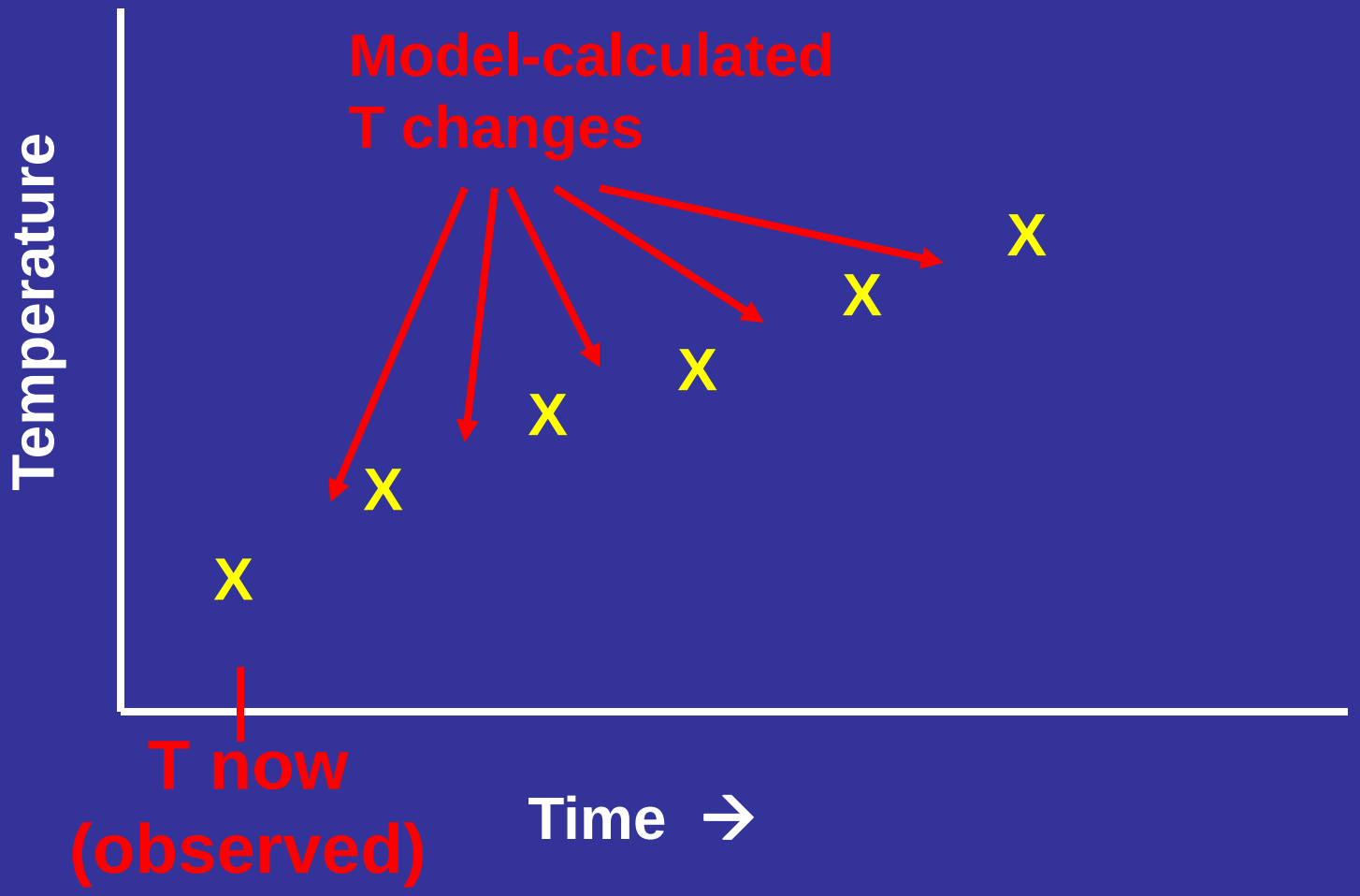


From Boybeyi et al. (2001)

Parameterizations

- Parameterizations approximate the bulk effects of physical processes that are too small, too complex, or too poorly understood to be explicitly represented

How the Model Forecasts



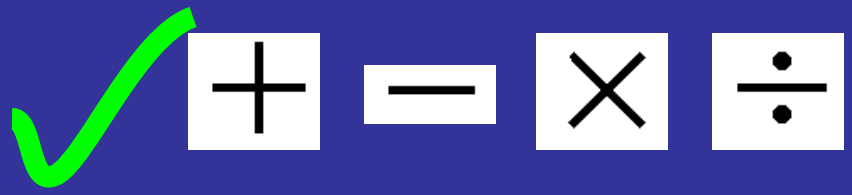
Governing equations

- An example of one momentum equation: 1-d wind accelerated by only the pressure gradient force

$$\frac{Du}{Dt} = -\frac{1}{\rho}\frac{\partial p}{\partial x}$$

Computers cannot analytically solve even this very simple equation!

- The problem: computers can perform arithmetic but not calculus



$$\frac{d(f)}{dx} \qquad \int (f)dx$$

- The solution: numerical methods

Integration of the equations

Nonlinear advection

$$\frac{\partial U}{\partial t} = U\left(\frac{\partial U}{\partial x}\right)$$

$$\frac{U_i^{k+1} - U_i^k}{\Delta t} = U_i^k\left(\frac{U_{i+1}^k - U_{i-1}^k}{2\Delta x}\right)$$

Time step

$$\Delta t < \frac{\Delta x}{U_i^k}$$

Choose time step based on expected wind speeds and grid spacing