Introduction to Weather Modeling

Numerical weather prediction (NWP) is a concept that relies heavily on computational mathematics. NWP uses numerical mathematics to predict future atmospheric conditions. These systems of differential equations, representing physical conditions, often cannot be solved analytically, so numerical methods are used. The difficulty is in balancing speed and accuracy when implementing these methods.

Leapfrog Method in NWP

The leapfrog integration scheme is a popular method in NWP with regards to time integration. NWP uses leapfrog because it provides second-order accuracy while only requiring the storage of one previous time step. Because NWP needs to evaluate massive numbers of points, memory storage and speed are important to take into consideration.

Filtering Techniques

Numerical methods, such as leapfrog, have various reasons that can cause them to go unstable. The most common way to determine the stability region is to look at the eigenvalues (λ) and time-step size (Δt). The product, λΔt, can be plotted using a root locus curve, which shows the boundaries of the area of stability for that technique (Figure c).

The leapfrog method’s stability region from the root locus curve is only the imaginary axis from [−1, i]. In practice, λΔt with values in R : [−1, 0], 3 : [−i, i] will be used. Filtering techniques perform additional calculations to expand the stability region to include more of these values of λΔt.

Leapfrog Filters in Use

- The Global Forecast System (GFS) Global Spectrum Model (GSM)
- Models used by the meteorological agencies of Japan, Australia, Germany, and Netherlands
- General atmospheric circulation models
- General ocean circulation models

Reference: