GARUDA at IIT Delhi

Co-ordination committee

Prof. S. K. Dash, CAS

Prof. B. N. Jain, CSE, DD(F)

Prof. Huzur Saran, CSE

Mr. N. C. Kalra, CSC

Dr. Pragya Jain, CSC

Applications

- Weather and Climate Modelling
- Distance Education
- Bio-sciences
- CFD
- Students grid projects

Weather and Climate Research using GARUDA

S. K. Dash

Why weather models are suitable for grid computing

- Very large number crunching
- Sufficient parallelism inherent in weather models
- Complex physical parameterisation schemes (load imbalance)
- Model integrations in ensemble mode
- Role of regional high resolution models
- Several physical processes not yet understood
  (Research at university level)

Basics of Numerical Weather Prediction

The horizontal momentum equation,

$$\frac{d\vec{V}}{dt} + f\hat{k}\times\vec{V} = -\nabla\phi + \frac{\sigma}{p_s}\frac{\partial\phi}{\partial\sigma}\nabla p_s + \vec{F}$$

Continuity equation,

$$\nabla_{.}(p_s\vec{V}) + \frac{\partial}{\partial\sigma}(p_s\dot{\sigma}) + \frac{\partial p_s}{\partial t} = 0$$

Thermodynamic energy equation,

$$\frac{1}{R}\frac{d}{dt}\left[\sigma\frac{\partial\phi}{\partial\sigma}\right] + \frac{RT}{C_p p}\left[p_s\dot{\sigma} + \sigma\dot{p}_s\right] = -Q$$

Hydrostatic equation,

$$\frac{\partial \phi}{\partial \sigma} = -\frac{RT}{\sigma}$$

Surface pressure tendency equation,

$$\frac{\partial p_s}{\partial t} = -\int_0^1 \nabla.\left[p_s \vec{V}\right] d\sigma$$

and the moisture equation,

$$\frac{\partial}{\partial t}\left[p_s\, q\right] + \nabla.\left[p_s\, q \vec{V}\right] + \frac{\partial}{\partial \sigma}\left[p_s\, q\, \dot{\sigma}\right] = p_s\, S$$

The above set of six equations can be solved in principle to get the values of six unknowns viz., horizontal wind velocity $\vec{V}$, surface pressure p_s, temperature T, moisture q, geopotential ϕ and sigma velocity $\dot{\sigma}$. The meteorological parameters $\vec{V}$, p_s, T and q are time dependent while $\dot{\sigma}$ and ϕ are called the diagnostic fields.

These equations constitute a closed system, which can be solved at all future times

- From a given initial state
- With the prescribed boundary conditions

The governing equations can be written as

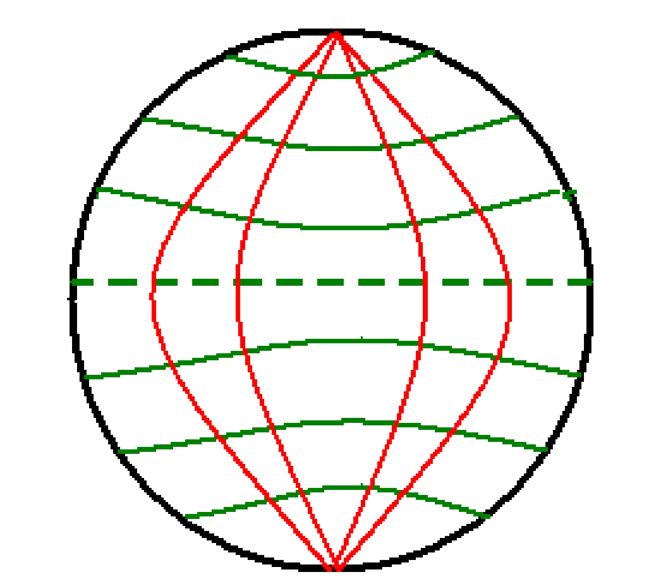
$$\frac{\partial X}{\partial t} = D(X) + P(X)$$

Here, X (x, y, z, t) : any model variable e.g. wind, Temperature, Humidity, Surface pressure etc.

D : Dynamics e.g. advection, pressure forces etc.

P : Physics e.g. evaporation and Condensation of water, solar heating, infra-red cooling, Frictional drag at the surface of the earth etc.

Number of Arithmetic Operations in a GCM



A : Integration Domain

Δs : Average horizontal grid size

K : Number of vertical levels

n : Number of variables per grid point

Total number of grid points = $K\,A/(\Delta s)^2$

Number of degrees of freedom in the model $n\,K\,A/(\Delta s)^2$

The maximum value of time step Δt depends on the integration scheme for computational stability.

(Courant – Friedrichs – Lewy Criterion)

1. ***For Explicit Time Integration Scheme***

$$\Delta t < \Delta s / \sqrt{2}\,(c + U_{max})$$

Here c ~300m/s; Speed of the fastest gravity wave

U_{max} : Maximum horizontal wind speed