Recent Developments in Computer Software Related to GCM and Mesoscale Rainfall Simulation

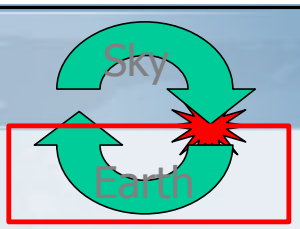
Re-linking the cycle...

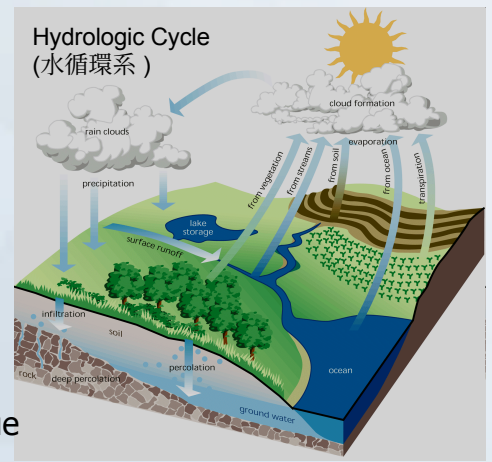
Assela Pathirana

UNITED NATIONS UNIVERSITY

Why Atmosphere?

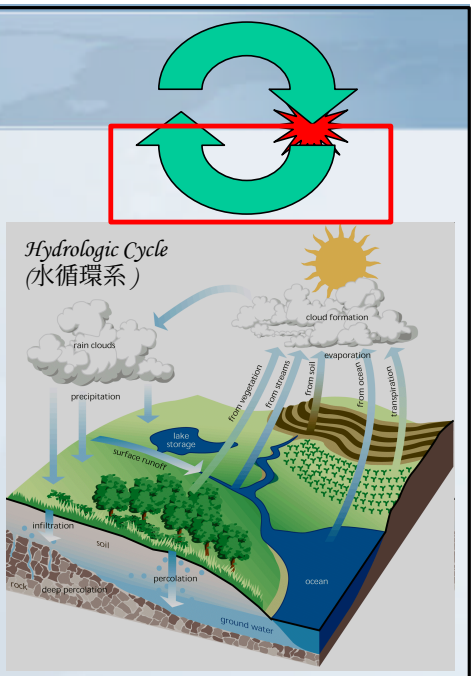
- 'Forcing' for surface hydrology
  - Rainfall
  - Radiation
  - Winds,
  - Moisture forcing on evapotranspiration
- Traditionally surface, point scale
  - Rain gauges, Weather stations
  - **Scaling up** was an issue
    e.g. Theissan polygons





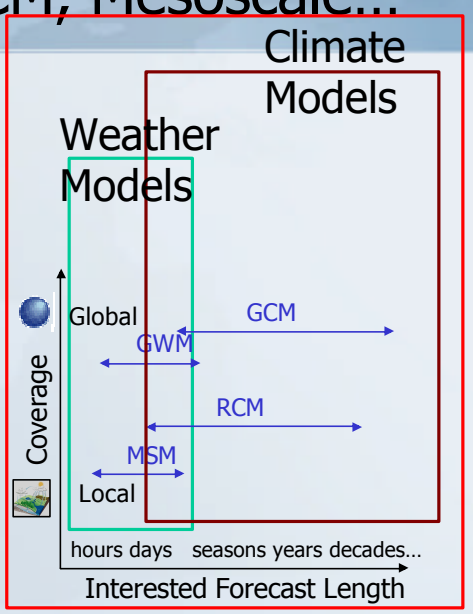
Why Atmosphere?

- Increasing use of Satellite Remote sensing, Radar, **atmospheric modeling**.
  - More comprehensive treatment in **space-time**.
  - Possibilities of **forecasting**. Weather, medium-term, and long-term.



GCM, GWM, RCM, Mesoscale…

- 3-D physical equations.
- **GCM – long-term** trends – climate (global)
  - Validation – statistical
- **NWPM – short-term** – weather (global/regional/smaller)
- Global models
  - **really forecast**.
- Regional/mesoscale models
  - need **boundary conditions**

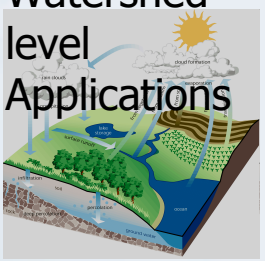


The Scale-Gap

Global Models

?

Watershed level Applications



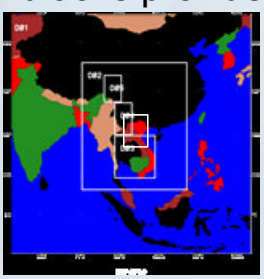
~ 100km
~ days

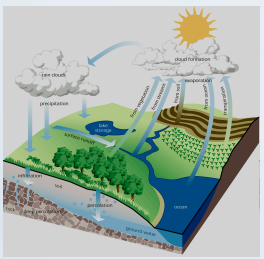
< 1km
~ hours, min

Need for 'Downscaling'

Downscaling

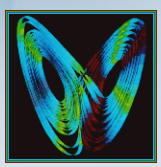
- Stochastic methods (e.g. Multifractal Scaling Methods)
- **Physical Methods**
  - Using a LAM (Mesoscale model)
  - Boundary conditions provided by Global model.





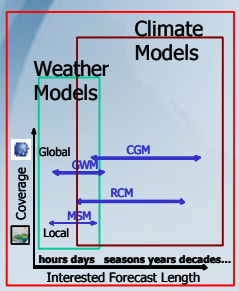
Predictability: Chaos in Atmosphere

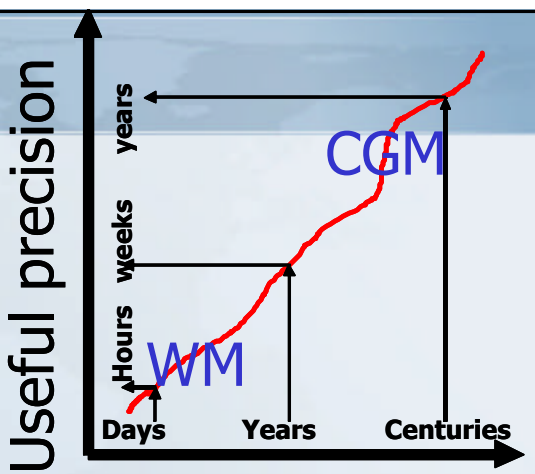
Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?
–Edward Lorenz



- Complex system – atmosphere
  - Sensitive dependence on initial condition.
- Weather forecasts depend on atmospheric initialization
  - rarely demonstrate skill beyond a week.
- However, **statistical forecasting** is possible (Climatological predictions) even centuries.

What is Predictable?





Interested forecast length

A few selected examples

- Real-time downscaling of GWM results – automation
- How the Mesoscale models behave at high resolutions (that hydrologists need)
- Non-standard uses – aerosol radiative forcing example.

Global Weather Models

- Very specialized applications needing large amounts of , dedicated computing power.
- Number of institutions regularly run their models.
  - Output made available.
- e.g.: ECMWF (Europe), JMA (Japan), AVN & GFS (US).

Case GFS System* (NCEP)

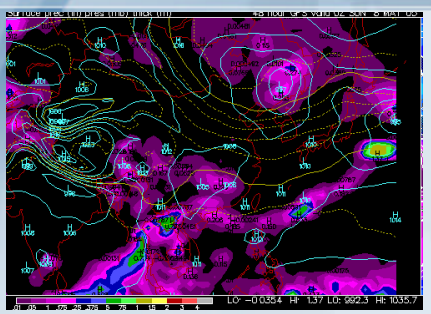


Image © UniSYS Weather

* Formerly known as **AVN**

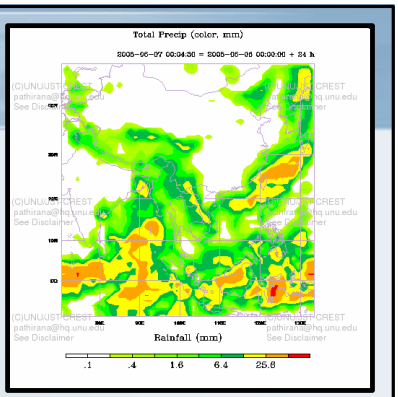
** RS/6000 SP (Class VIII)

- Resolution
  - → ~ 0.5^0X0.5^0
  - ↑ 64 layers
    (surface to 0.27hPa)
- 12 min/day
  IBM supercomputer**
- Runs daily
  Forecasts for 16 days.
- Model output
  First 7 days at 6h.
  Public access ~ 3h of 00:00GMT

Using GFS results

for local scale hydrology

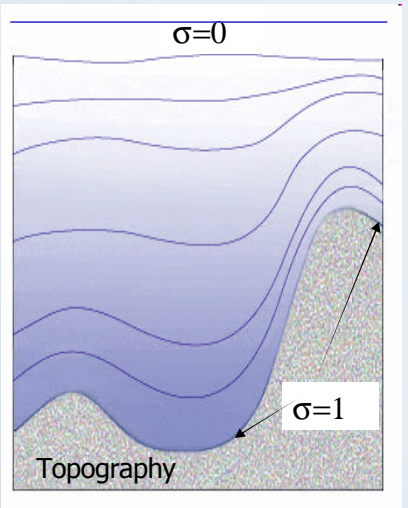
- Downscale in 'real-time' with a LAM.
- Example: WRF* runs over Mekong watershed.



*Weather Research and Forecast Model, NCAR, USA.

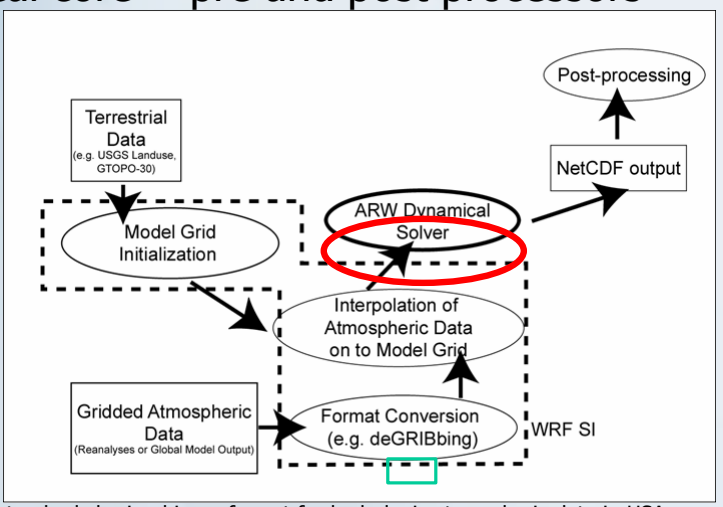
WRF (Weather Research and Forecast) Model (NCAR, USA)

- A relatively new Limited Area Model
  - Replaces popular MM5 model
- Solves a full set of
  - Non-hydrostatic equations
  - In 3-dimension with X, Y and s coordinates.



WRF Modelling System

- Numerical core + pre and post processors



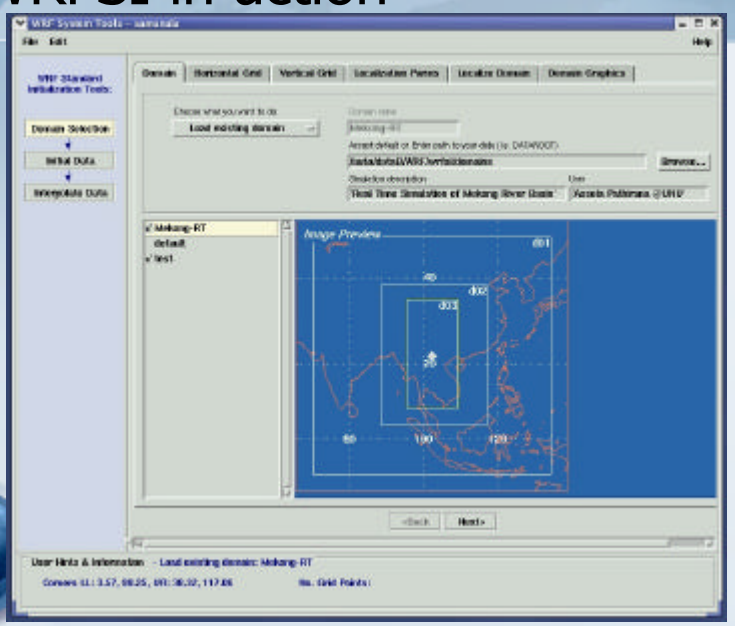
GRIB– standard sharing binary format for hydrologic-atmospheric data in USA.

Features of Model Software

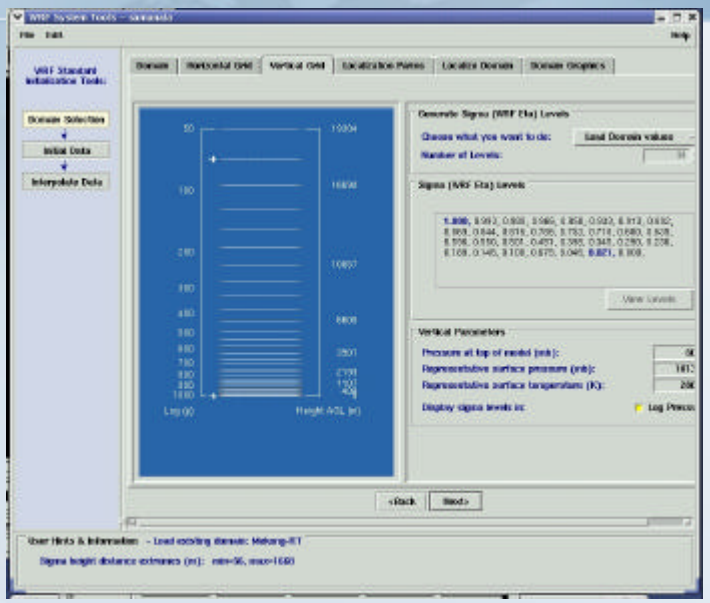
- Model source **open and free**.
- Free support by NCAR.
- Community support.
- Model setup
  by
  a graphical interface – **WRFSI**

  (Convenience and efficiency compared to previous models.
  e.g. MM5,RAMS, RegCM3)

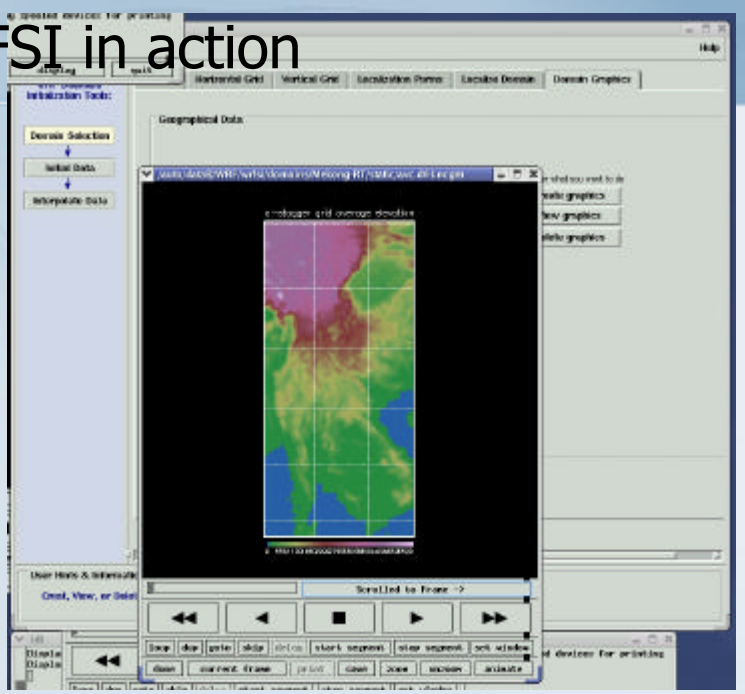
WRFSI in action



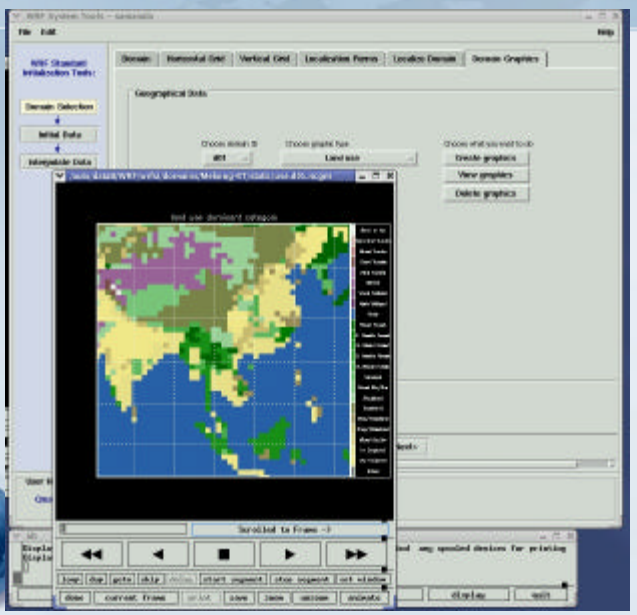
WRFSI in action



WRFSI in action

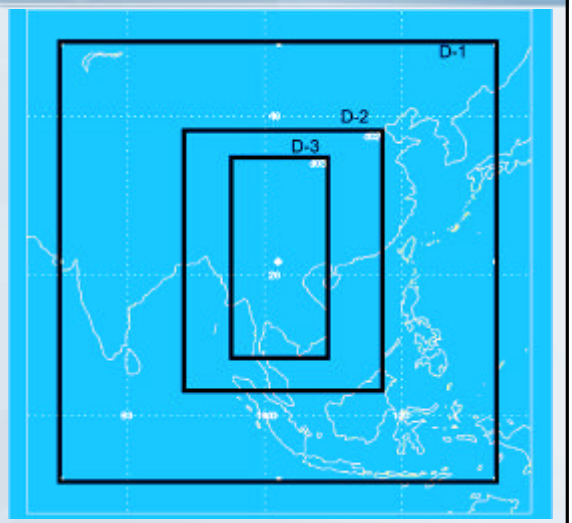


WRFSI in action



WRF forecast for Mekong at UNU

- Three nested domains
  - 135, 45, 15 km
- Model run everyday at UNU with GFS forcing data.



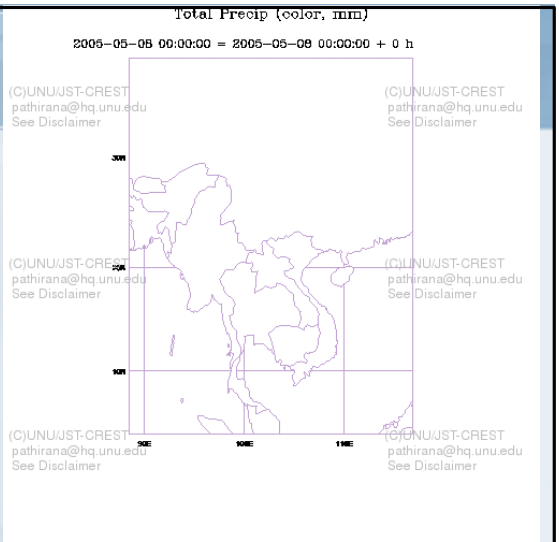
Interface (for results)

- Results posted on WWW.
- The modeling system, post-processing and web-posting of results **completely automated**.

For Science…

and

… for capacity building.



A. Pathirana, S. Herath, T. Yamada, and D. Swain, "Hydrometeorological input for improving Flood forecasting in the Mekong: Development of a real-time rainfall forecasting system.," in Proceedings of the International Workshop Role of Water Sciences in Transboundary River Management, United Nations University, 2005.

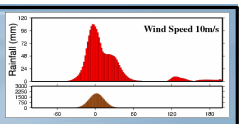
LAMs at high resolution

- Can mesoscale models at high resolution represent the known features of rainfall variability?

  E.g. orographic effects.

- MM5 model modified to feed idealized initial/boundary conditions used to investigate.

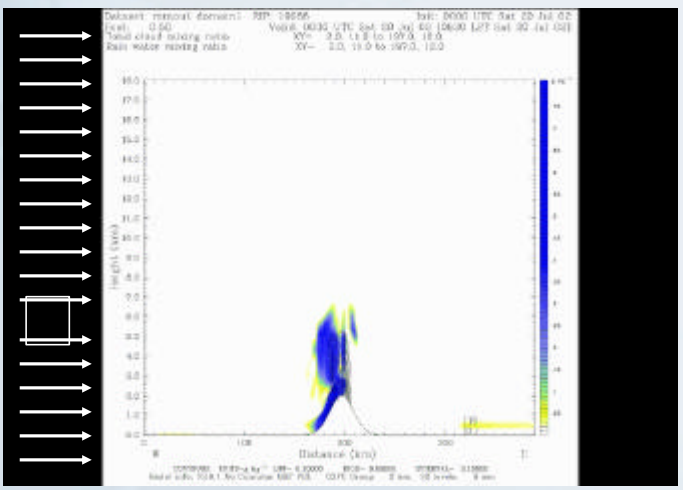
Example: Wind-Mountain interaction.



- Height 2km Wind 10m/s (uniform)

Color: Cloud Water Mixing Ratio

Contours: Rain Water Mixing Ratio



Elevation (km)

Distance (km)

Findings

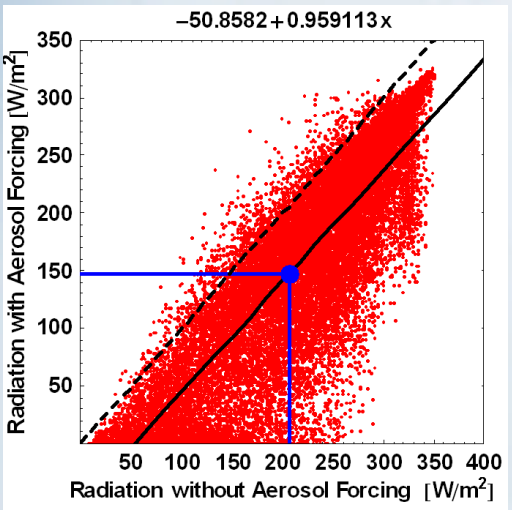
- LAMs can indeed represent atmospheric phenomena and **precipitation variability** at high spatial resolutions.
- Most of the 'classical' **rainfall patterns** associated with wind-topographic interactions could be reproduced by the simulations.

A. Pathirana, S. Herath and T. Yamada, Simulating orographic rainfall with a limited-area, non-hydrostatic atmospheric model under idealized forcing, Atmos. Chem. Phys., 5, 215-226, 2005

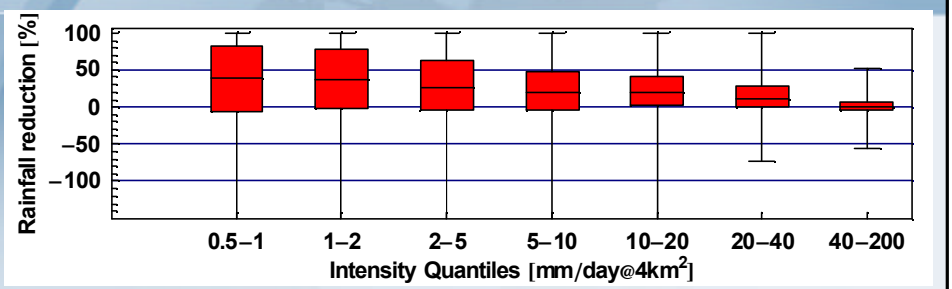
Scenario Studies Example

- Investigating atmospheric systems response for various **scenarios** (e.g. Future situations).
- Example: Possible effects of **increase of high-absorbing carbonaceous aerosols** in the south Asian skies on the rainfall yields.
  - Aerosols dramatically change the atmospheric radiative balance.
  - Possibility of 'slowing down' of the hydrological cycle.
  - Few studies at watershed level.
- A **modified MM5 model** was used clarify the aerosol radiative forcing impacts on rainfall process.

Surface radiation reduction



Rainfall Change



- For large rainfalls the % effect is small (e.g. for 100mm/day rainfall about 4%)
- For small rainfalls % effect is large (e.g. for many 1-2mm/day rainfalls almost 60-70%!!)

Findings

- For rain dependant industries like agriculture, dramatic reduction of small rainstorms can be very detrimental. e.g. delaying of start of cultivation.
- Presently we are conducting multi-disciplinary research on the possible impacts and policy implications.

A. Pathirana and S. Herath, "Assessment of atmospheric brown cloud impacts on local climate with a modified mesoscale atmospheric model," in Proceedings of the International Conference of Sustainable Water Management in the Changing Environment of the Monsoon Region, pp. 34-42, United Nations University, 2004.

Summery

- **Global weather models** are still beyond the reach of PC level computing power.
- **Results** of GWMs are available for public, near real-time.
- **LAM**s are very much within the capabilities of today's **PC** systems.
  - We run our real-time system and did all other simulations on normal PCs running Linux operating system.
- In addition to stochastic methods, **superior downscaling** based on LAMs is a very real possibility.
- Freely available **model-code (open source)** makes it possible to modify models for non-standard applications.
- It also results a accurate and robust code as a result of **peer verification**.

Recent Developments in Computer Software Related to GCM and Mesoscale Rainfall Simulation

. . . *where heavens meet the earth!*

Thank you !

Acknowledgements:
Prof. T. Yamada,
Dr. S. Herath

Assela Pathirana
pathirana@hq.unu.edu