Beyond gauges : Using global resources for resolving watershed-scale rainfall

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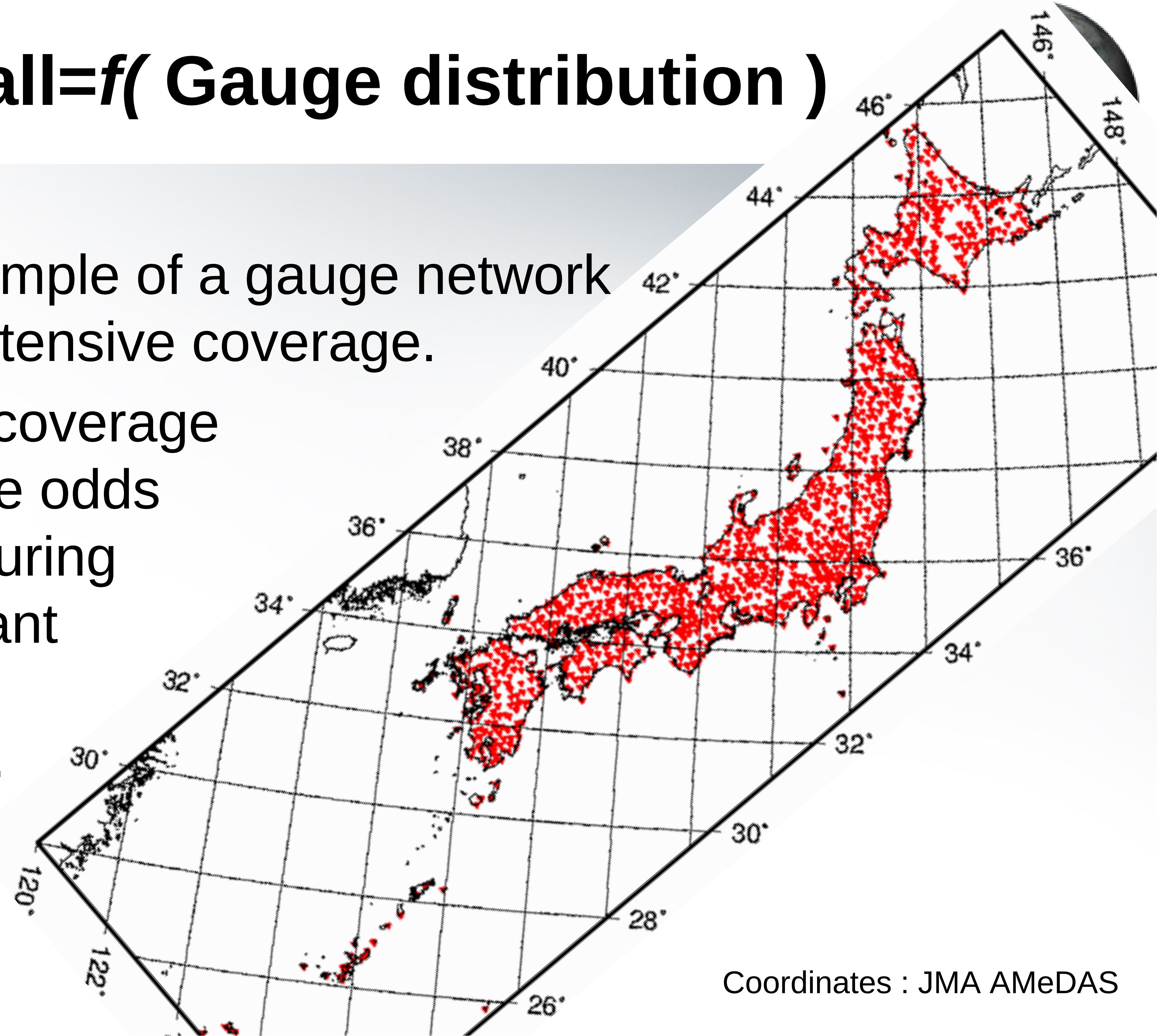
Rainfall=*f*(Gauge distribution)

- An example of a gauge network with extensive coverage.
- Better coverage improve odds of capturing important rain events.

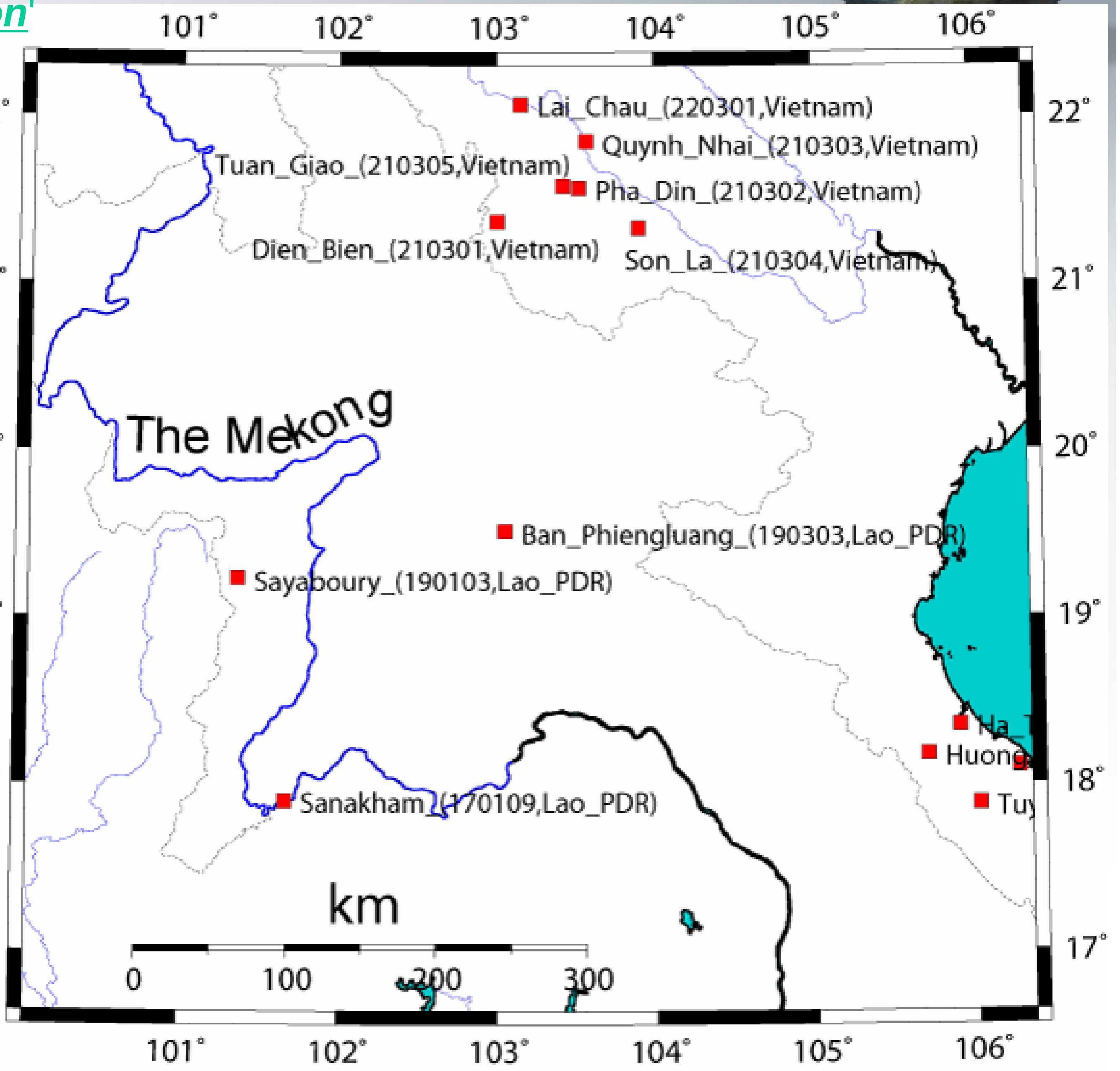


Coordinates : JMA AMeDAS

Rainfall – A function of ‘sensors’

‘Reality is ... created by mind,
*based solely on **sensory perception**’*
-- An Indian Philosopher
(6th C. B.C.)

- Mekong – very low Rainguage density.
- Example: A sub-region of lower Mekong around Lao-PDR.



Coordinates : Mekong River Commission.

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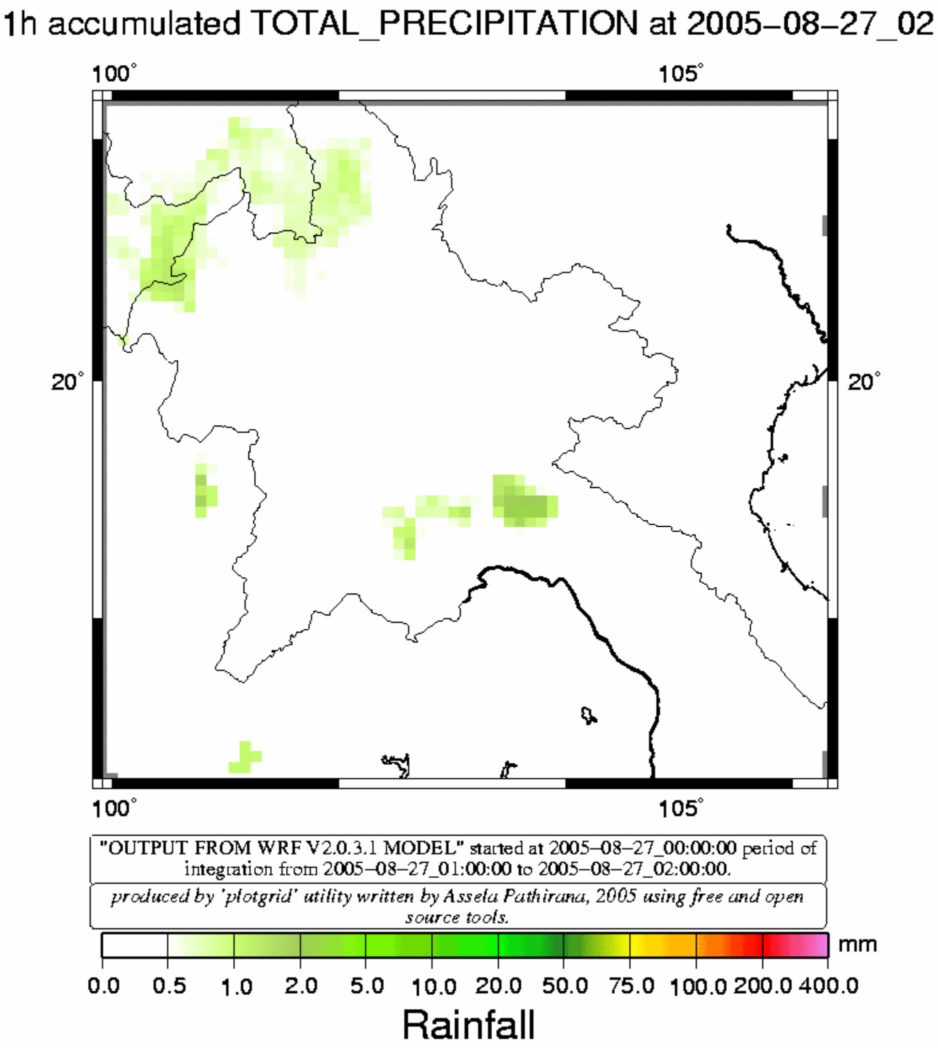
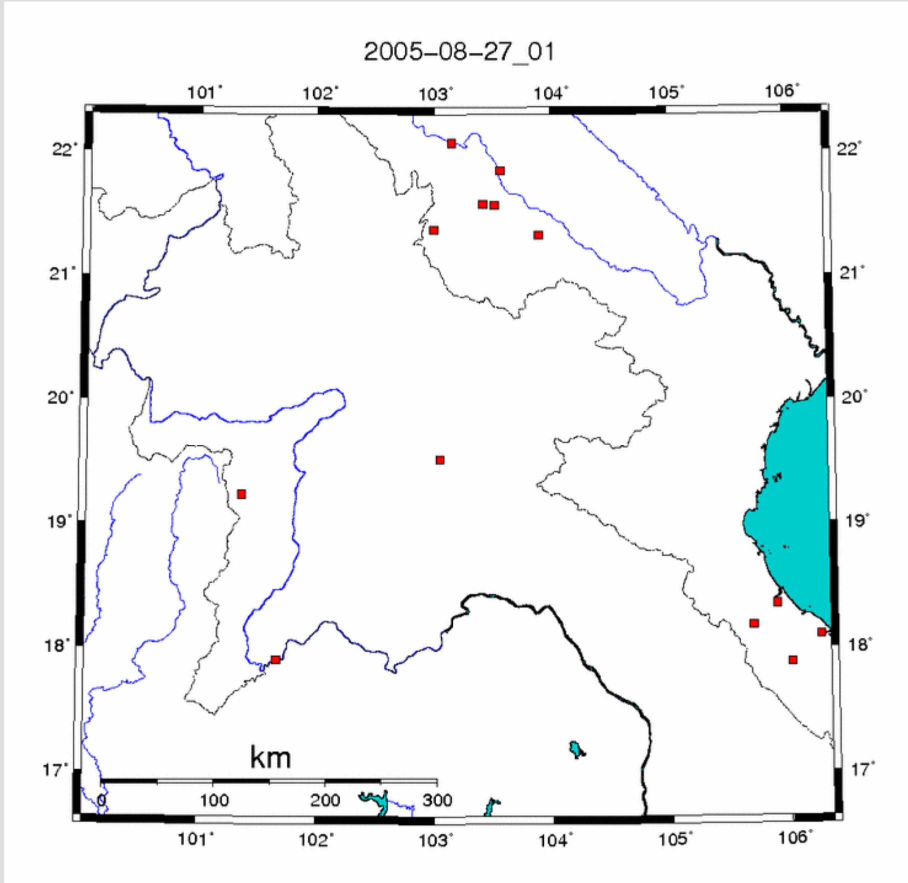




Feasibility of Improving the picture

*‘We have to define a **working hypothesis for reality** matching the problem at hand. One should not confuse a snake for a coil of rope, handling the problem of staying alive!'*
-- unknown origin

- Capturing the <u>**ultimate picture**</u> of rainfall is unfeasible*.
- ... Adequate accuracy <u>**for a purpose**</u>
- Ex. Problem: Distributed hydrological modeling (e.g. For flood forecasting).

*ref: scaling of rainfall in space and time.
e.g. Fractal modeling of rainfall, applications in hydrological modeling in space and time, Ph.D. thesis, Tokyo University, 2001.

Feasibility of Improving the picture

- Premise: Capturing the **<u>ultimate picture</u>** of rainfall is unfeasible*.
- ... Adequate accuracy **<u>for a purpose</u>**
- Ex. Problem**: Distributed hydrological modeling** (e.g. For flood forecasting).

One solution: Use of <u>alternative resources</u>, of various origins, including global ones. e.g. **Global data**

*ref: scaling of rainfall in space and time.

Challenge: Bridging the Scale-Gap

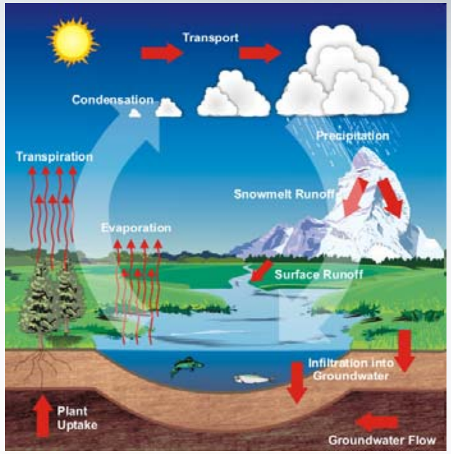
Global Resources

~ 100km

~ days

?

Watershed level



< 1km

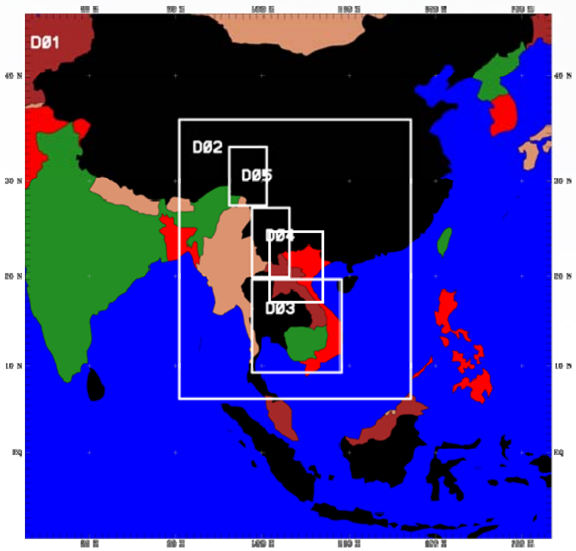
~ hours, min

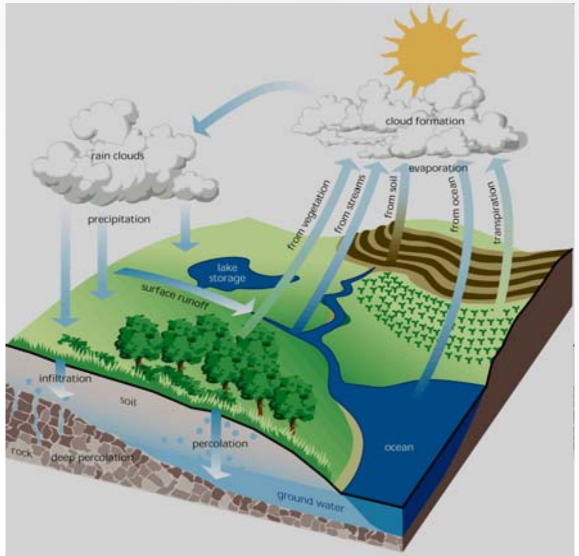
Need for

‘**Downscaling**’

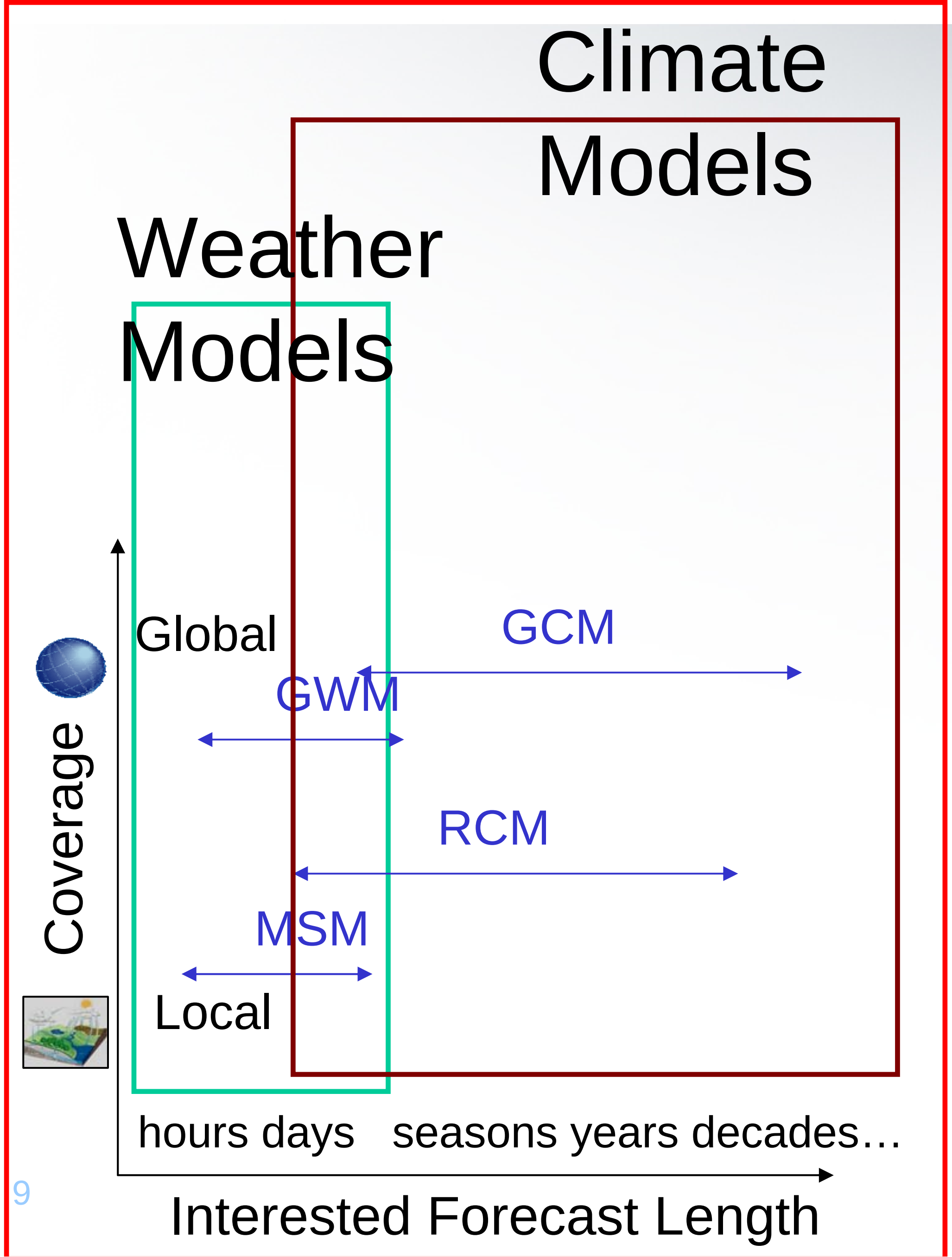
Limited-area models as ‘Brokers’ (Dynamical method)

- Use boundary conditions provided by Global Weather Models (GWMs) to ‘drive’ 3-D numerical model, solving physical governing equations.



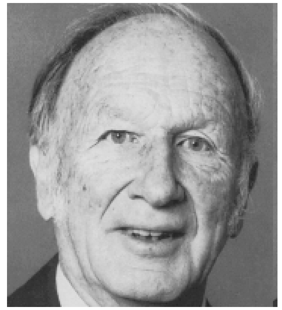


Atmospheric Models (galore!!): GCM, GWM, RCM, Mesoscale…



- 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**

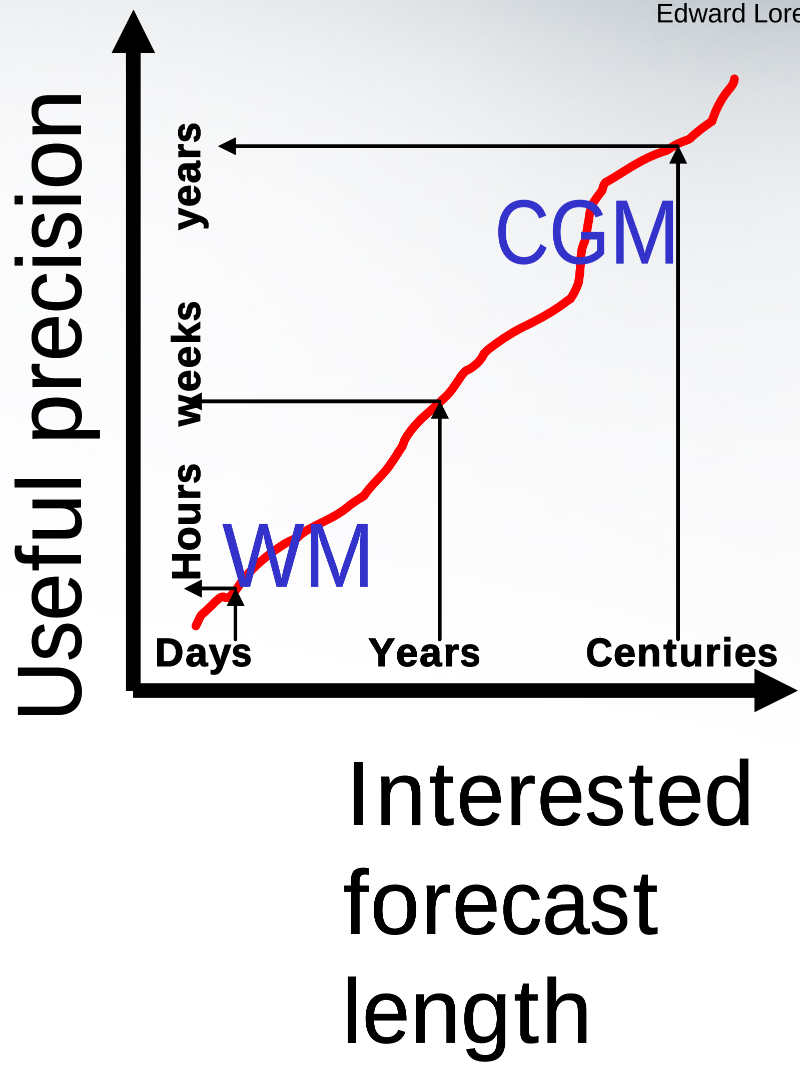
Predictability: (How the God Play dice)
Chaos in Atmosphere



Edward Lorenz (born 1917)

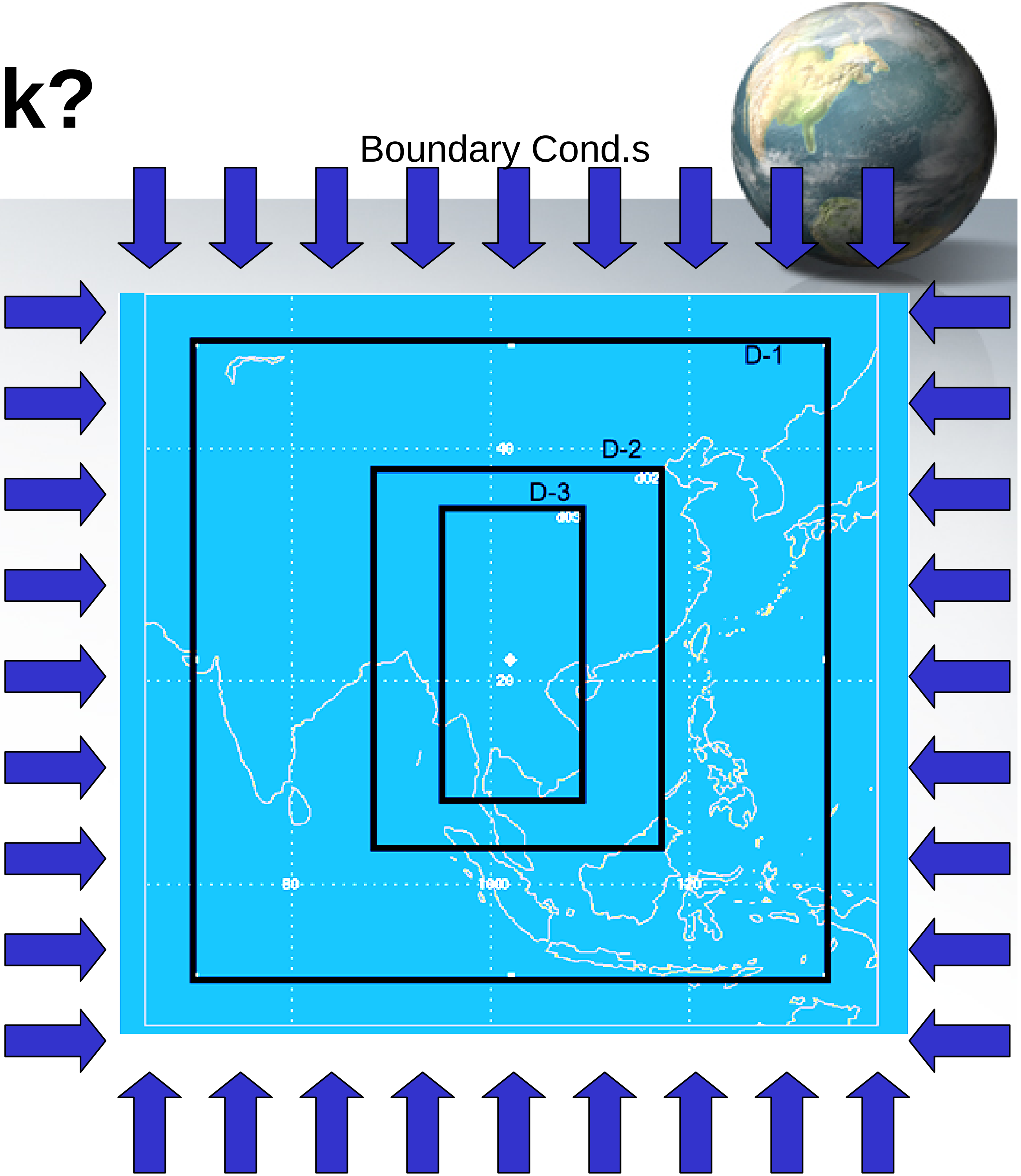
Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?
–Edward Lorenz

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



How LAMs work?

- Needs **boundary conditions**.
  - Usually global model output. (T, R.h., ***u***,***v***,***w***)
- **'Nested' domains**
  - At increasingly higher resolution
- Solves a numerical system, to **predict the future states** within the boundaries (e.g. rainfall)
- Works effectively for periods of several days.



Real-time Rainfall Forecasting Framework at UNU

Examining the feasibility of **using weather model output for driving watershed models**.

Extending water disaster* warnings using atmospheric input.
*e.g. Floods, Landslides

As a **framework for collaboration** and to invite the **experts in the fields of meteorology and hydrology** to share insights into improving the ‘Rainfall picture’.

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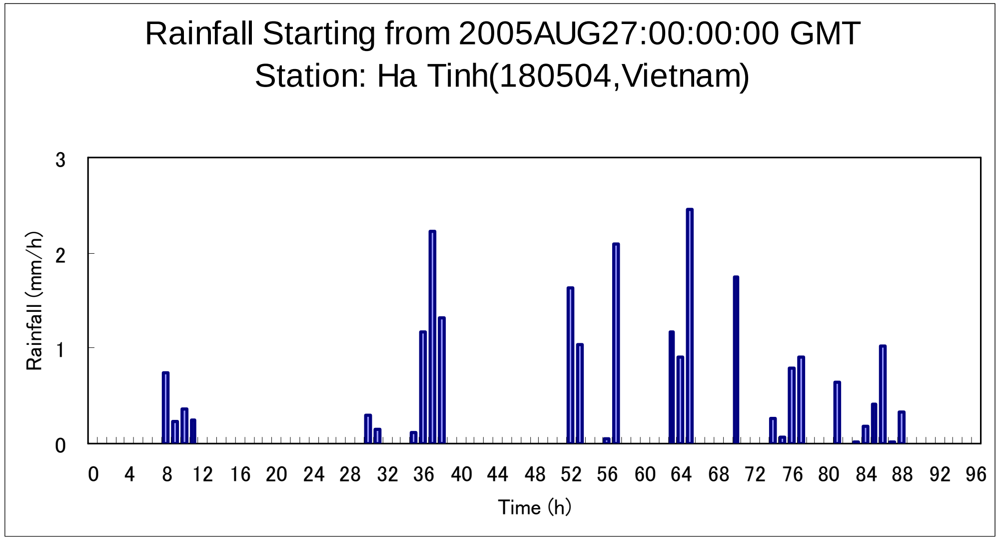
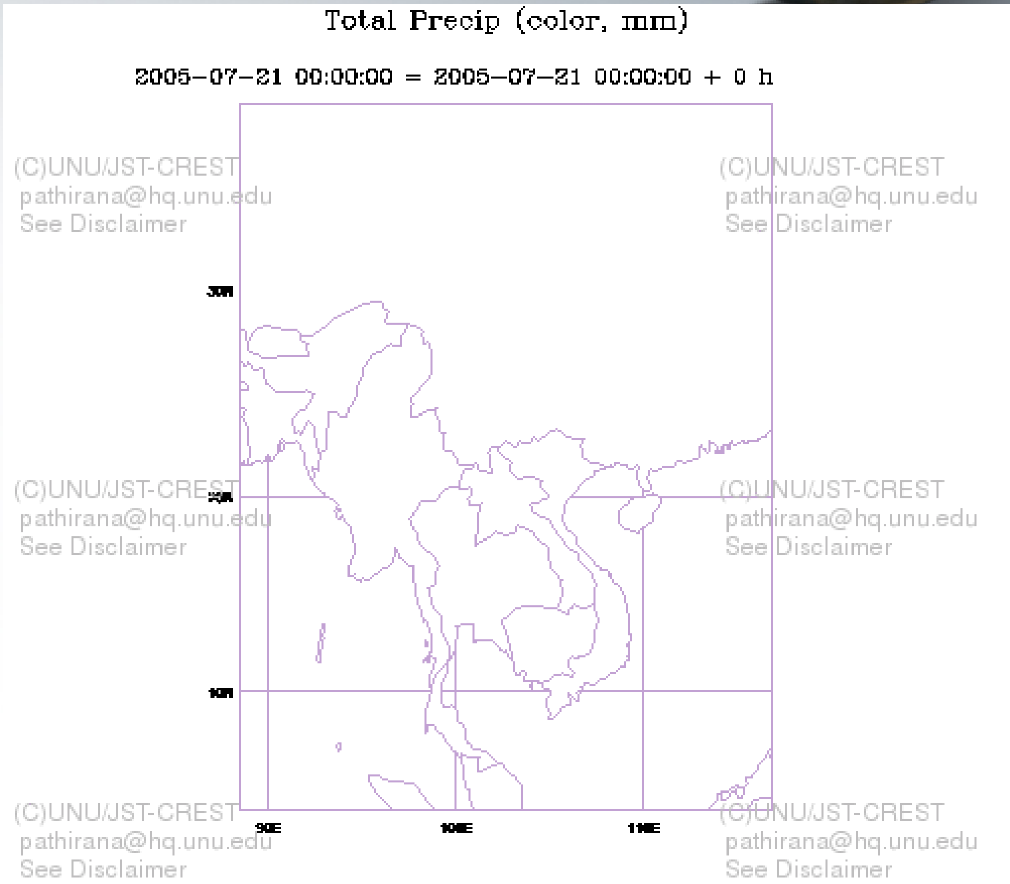
WRF forecast for Mekong at UNU

- Three nested domains
  - 135, 45, 15 km
- Model run everyday at UNU
- With Boundary conditions from GFS global weather model





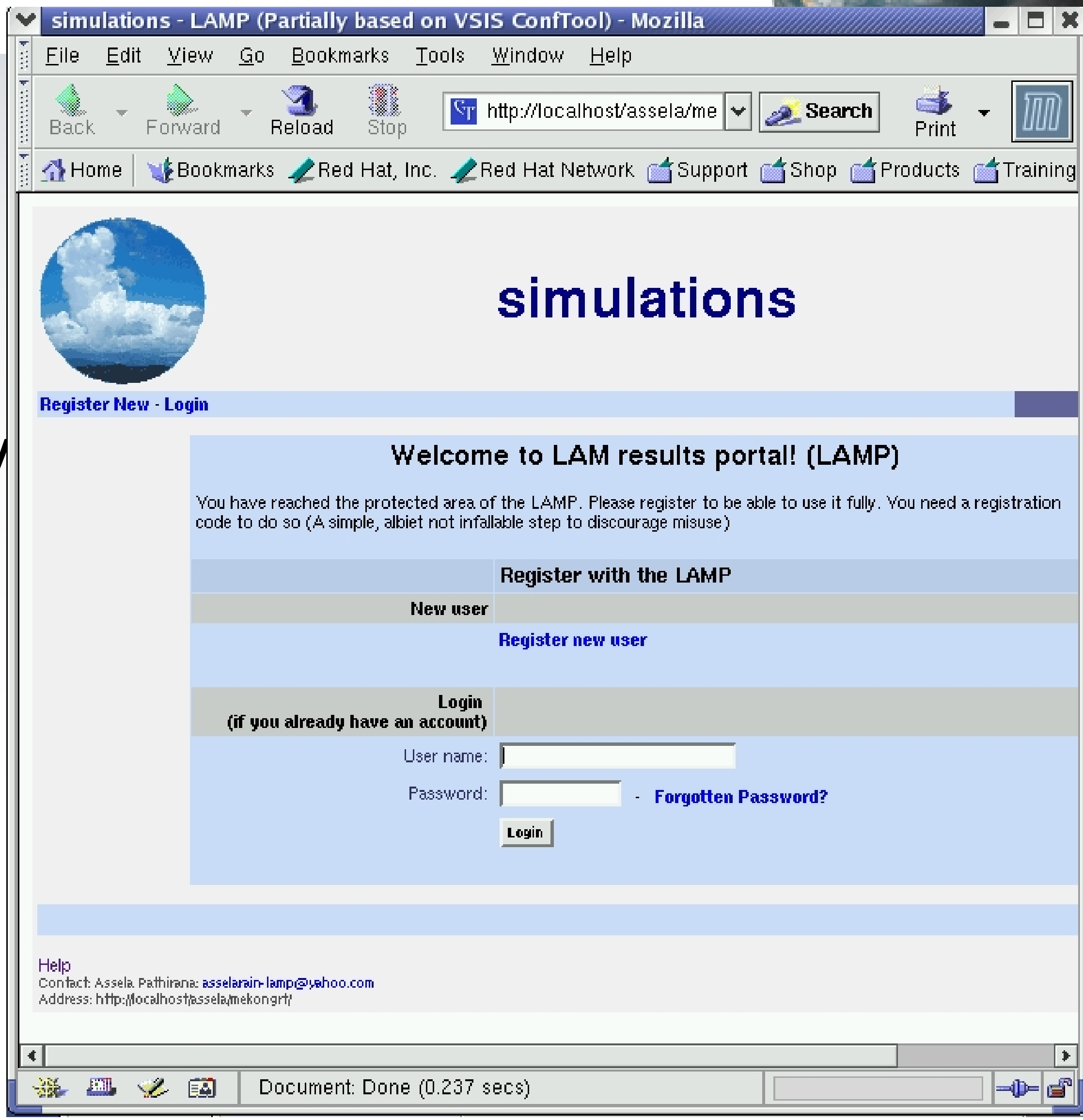
Rainfall accumulation in domain #2

An hourly rainfall series for point (MRC Ref: 180504, Vietnam) extracted from model output.

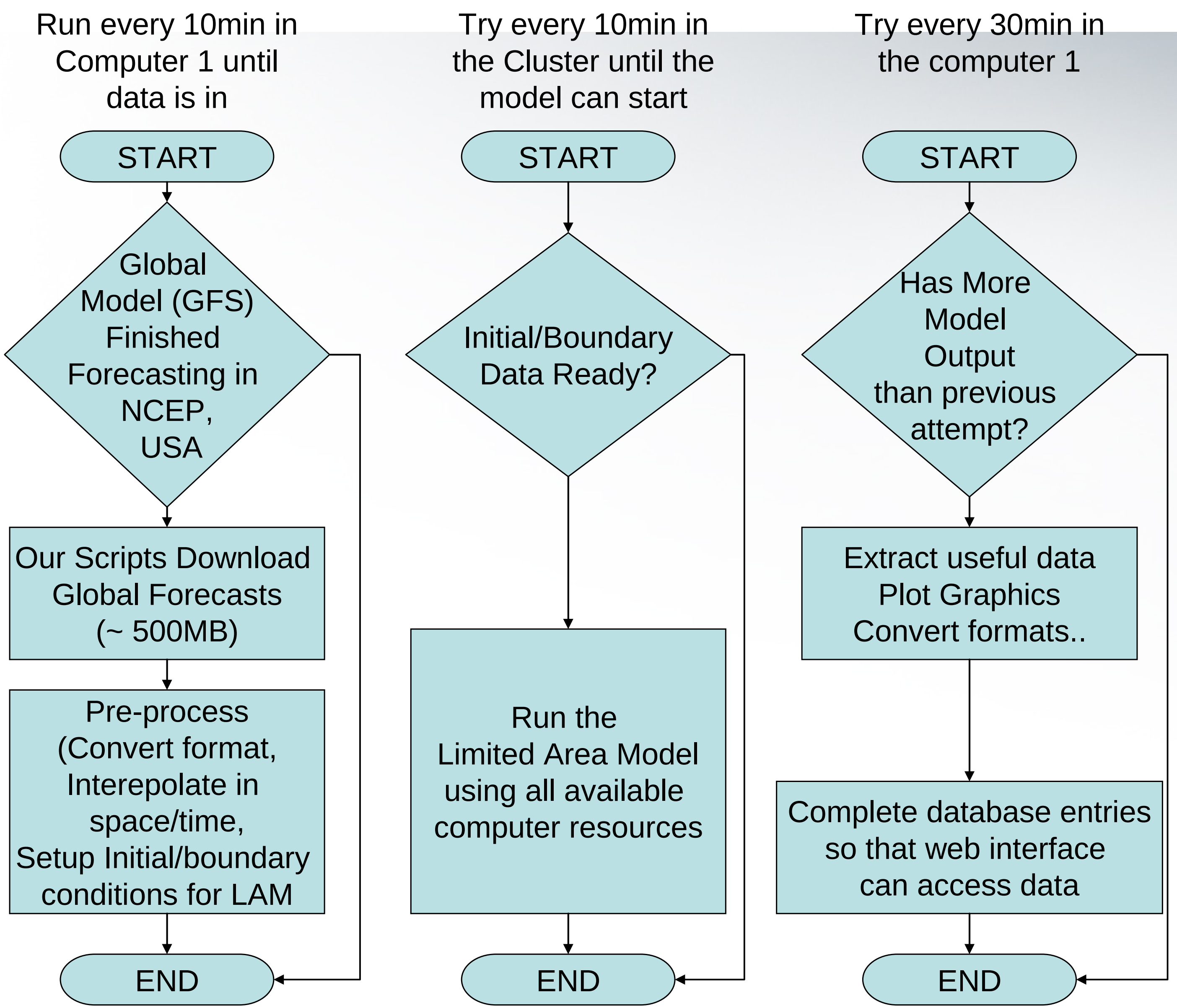
Daily operation of UNU simulation

- Fully automatic; forecasts 48h; results ready around 16:00H CST (10:00H UT)
- Results are automatically posted on the web, for near-real-time access.
- Model **output is archived** in an indexed database. Can be searched and retrieved.

(pathirana@hq.unu.edu)



How it works



Tools Used:

Model:
Weather Research and Forecasting (WRF) Model of NCAR, USA

Operating Systems:
Linux (Redhat, Fedora & Scientific)

Database:
MySQL with InnoDB engine

Web Interface:
PHP front end on Apache server.

Graphics:
NCAR Graphics and ncl

Distributed Computing:
Message Passing Interface (MPICH2)

Automation:
Bash scripts with Cron

Main Utilities:
ImageMagick, Ghostscript, wget, awk, sed, GIFsicle

Behind the scene

Cluster Workstations

Pre-post processing computer

High-powered workstation

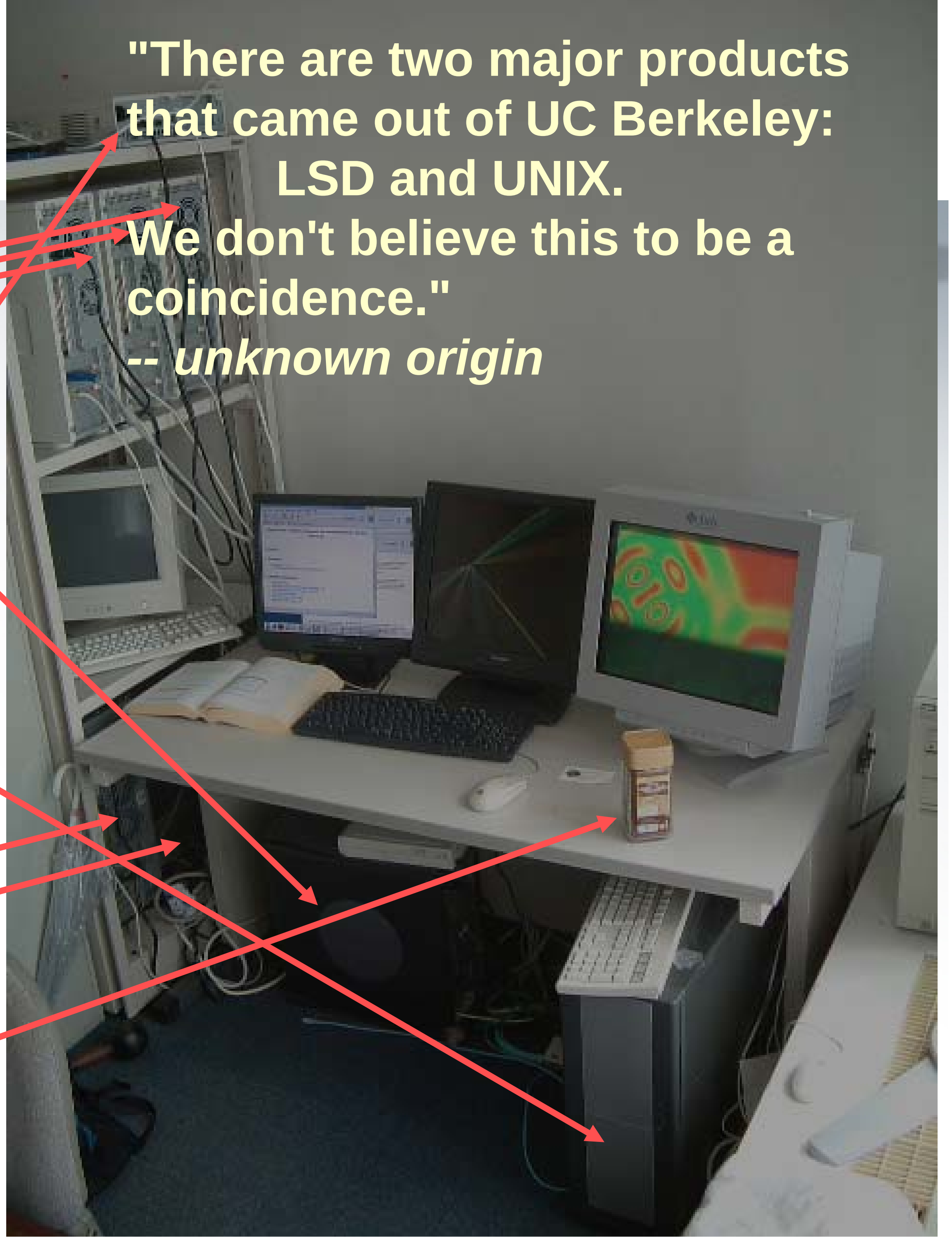
DNS server

Additional workstation

Server

Gateway/Router

Coffee



"There are two major products that came out of UC Berkeley: LSD and UNIX. We don't believe this to be a coincidence."

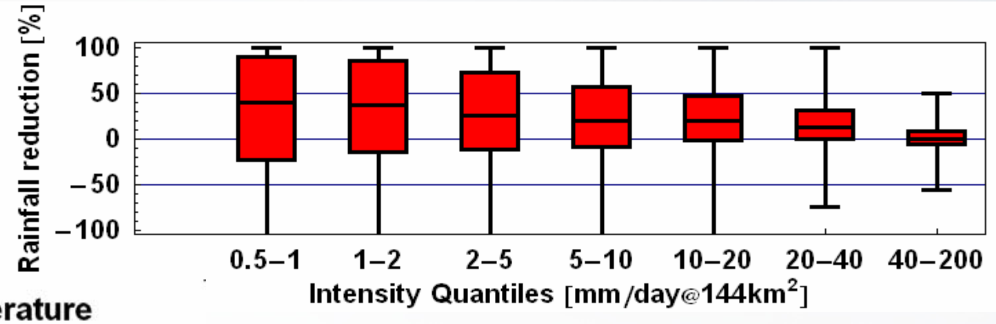
-- unknown origin

Features of the System

- Completely based on free, **open-source software**. No licensing issues.
- Based on a **flexible API**, that allows extension to include various localities (Sri Lanka, Bhutan, already done.)
- **100% automated**, quite fault-tolerant.
- Low-cost implementation.
- Simple to use.
  - **Replicable**
  - **Manageable**
  - **Economical**

New Possibilities

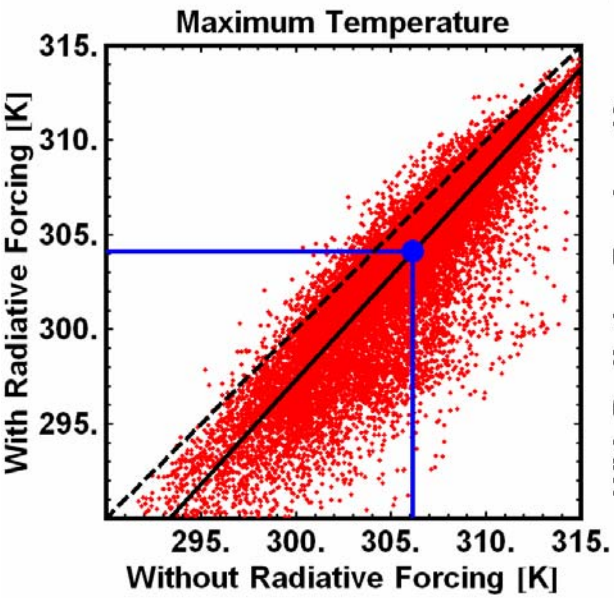
- **A host of useful output.**
  (Temperature, Moisture, Winds, etc...)
- **Scenario** studies, e.g. climatic change.
  - Example: Aerosol driven seasonal radiative change.

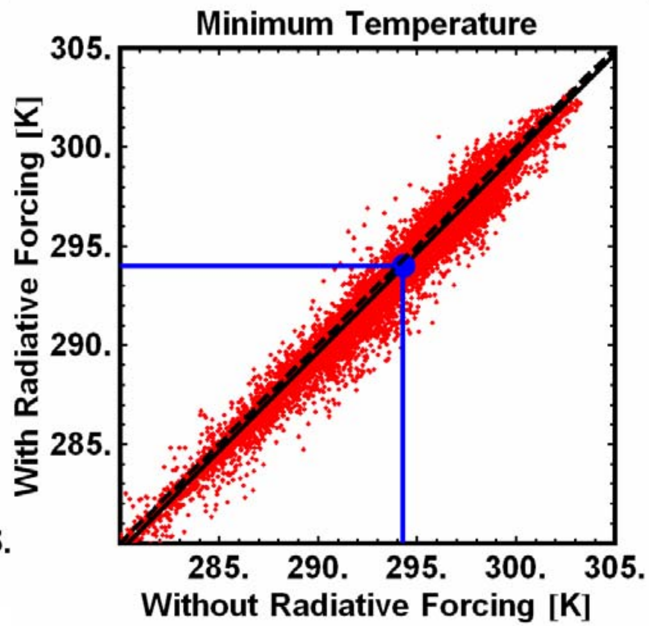


Reduction of Rainfall

Surface Temperature (Max/Min)

Results of a six months period simulation over southern part of Sri Lanka.





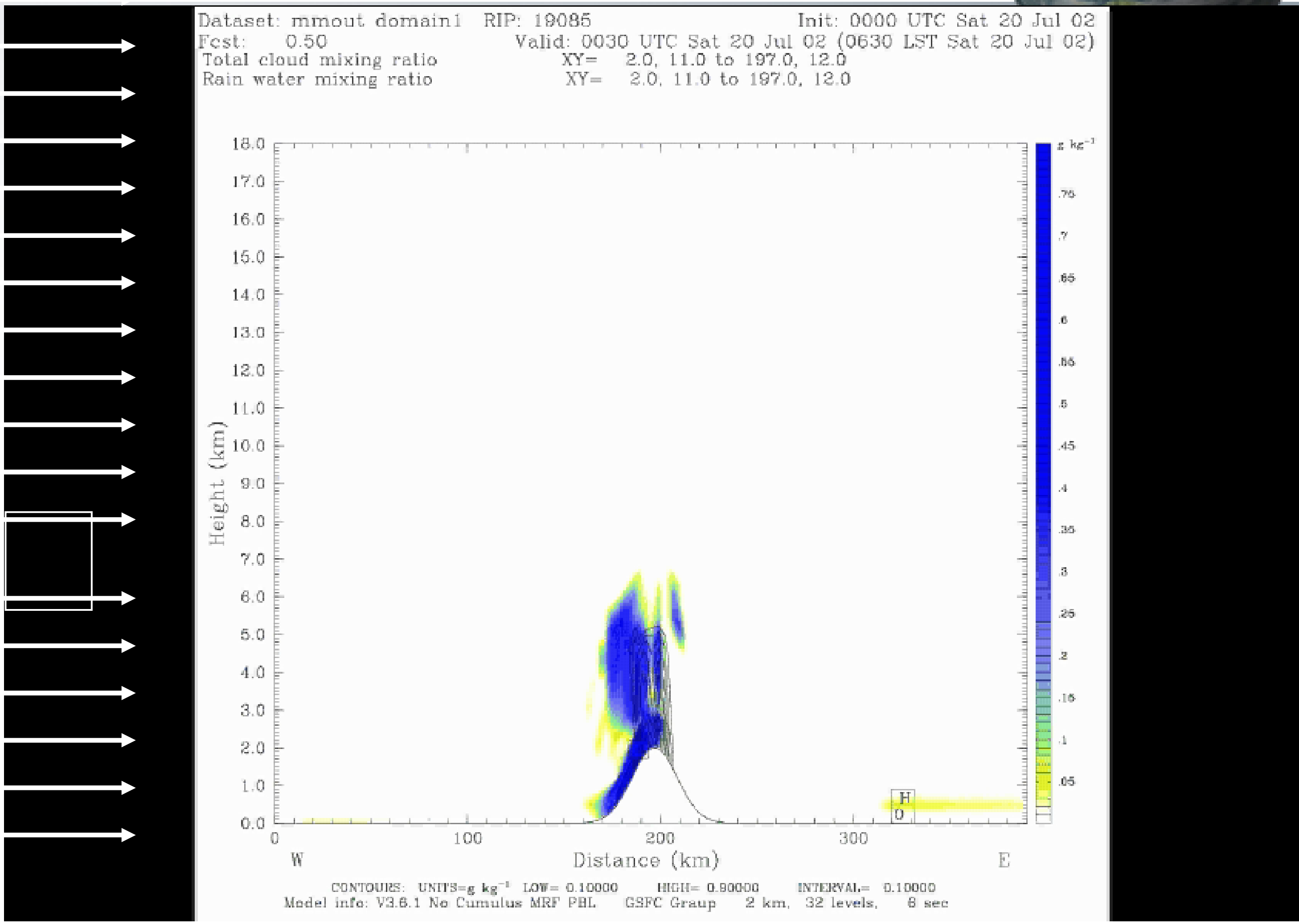
New possibilities: Understanding the rainfall process

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

Color: Cloud Water Mixing Ratio

Contours: Rain Water Mixing Ratio

Elevation (km)



Distance (km)

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

Issues to be addressed

- The scale effect on rainfall intensities
  - Rainfall shows ‘scaling’ properties in space – **intensity increases dramatically** with decreasing averaging area.
  - How to compare gauges and LAM output. (<1m^2 with > 1km^2 !!) – validating issues.
- Accuracy issues.
  - Spatial accuracy, but **less accuracy at point**.
  - May not be an issue for distributed hydrological modeling.

Minor-Issues

- Computing/ Network bandwidths
  - No supercomputers needed, though computationally intensive.

Synthesis

- **Large scale data sources** are useful as input for basin scale analyses (e.g. distributed models) as shown by the example of rainfall.
- LAMs today are **accessible tools** for downscaling GWM forcings.
- We have implemented a **easy-to-use and replicable** rainfall forecasting system for the Mekong, which can be used by the community.
  - Exclusive use of **open source tools** facilitate sharing of resources.
- We expect this framework will help in providing a forum for the experts in meteorology and hydrology to interact and contribute in improving rainfall products.
- A platform for **integrating** watershed models with LAMs.
- Rainfall forecasting does not involve much local-resources
  - Can easily cover **an international basin**.

However,

- Potential for improvement using better local datasets like **landuse**, **topography,...**
- Inherently **less point-scale accuracy**, needs careful validation and supplementation with local rainfall records, etc.

Modeling of Rainfall for Hydrological Applications

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Thank you !

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