Meteorology

Lecture 6

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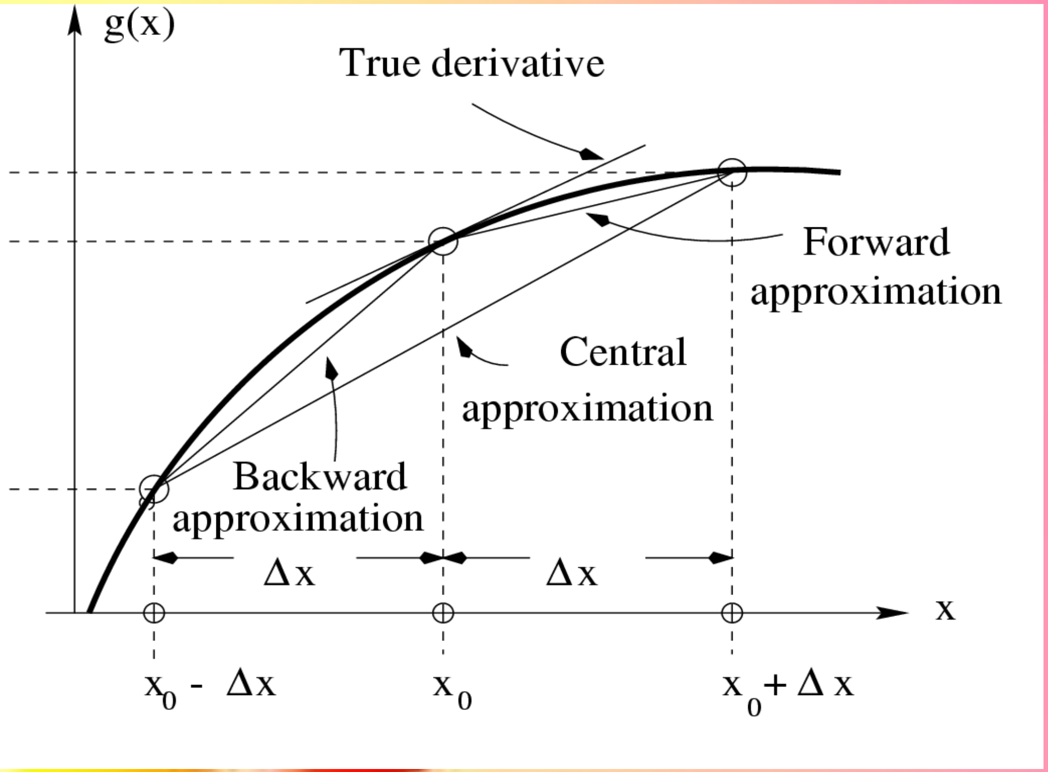
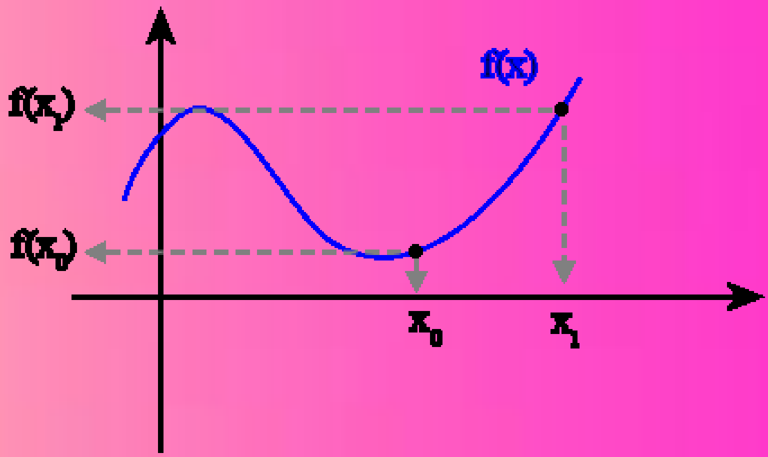
Finite difference approximation to derivatives





Consider a smooth function g(x). Taylor's theorem reads:

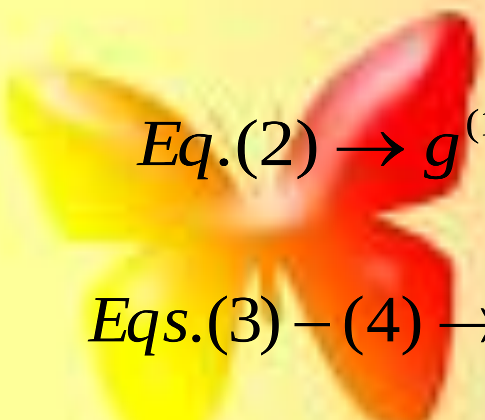
$$g(x_0+\Delta x)=g(x_0)+\sum_k \frac{\Delta x^k}{k!}g^{(k)}(x_0)$$

In particular:

$$g(x_0+\Delta x)=g(x_0)+\Delta x g^{(1)}(x_0)+O(\Delta x^2) \qquad (1)$$

$$g(x_0-\Delta x)=g(x_0)-\Delta x g^{(1)}(x_0)+O(\Delta x^2) \qquad (2)$$

$$Eq.(1)\rightarrow g^{(1)}(x_0)=\frac{g(x_0+\Delta x)-g(x_0)}{\Delta x}+O(\Delta x) \qquad (3)$$



$$Eq.(2)\rightarrow g^{(1)}(x_0)=\frac{g(x_0)-g(x_0-\Delta x)}{\Delta x}+O(\Delta x) \qquad (4)$$

$$Eqs.(3)-(4)\rightarrow g^{(1)}(x_0)=\frac{g(x_0+\Delta x)-g(x_0-\Delta x)}{2\Delta x}+O(\Delta x^2)$$

First Numerical Forecast

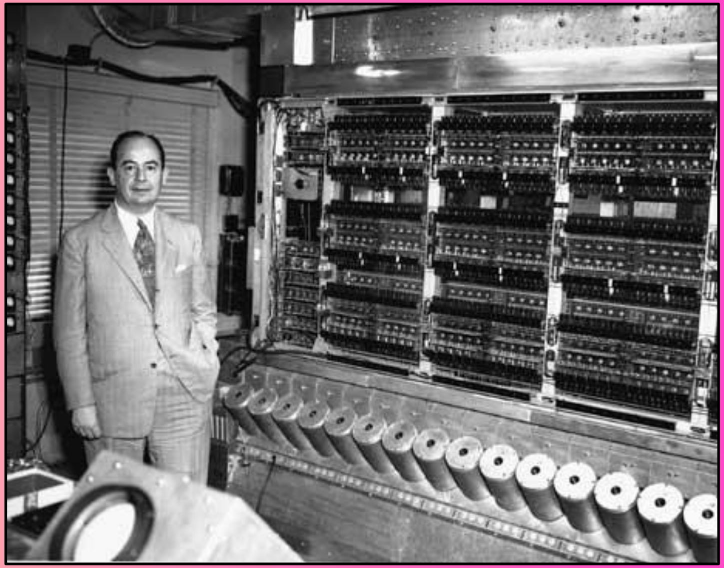
Charney and Neuman barotropic model run on ENIAC computer (1950)

Produced 500 mb height forecast

Bad forecast but looked realistic

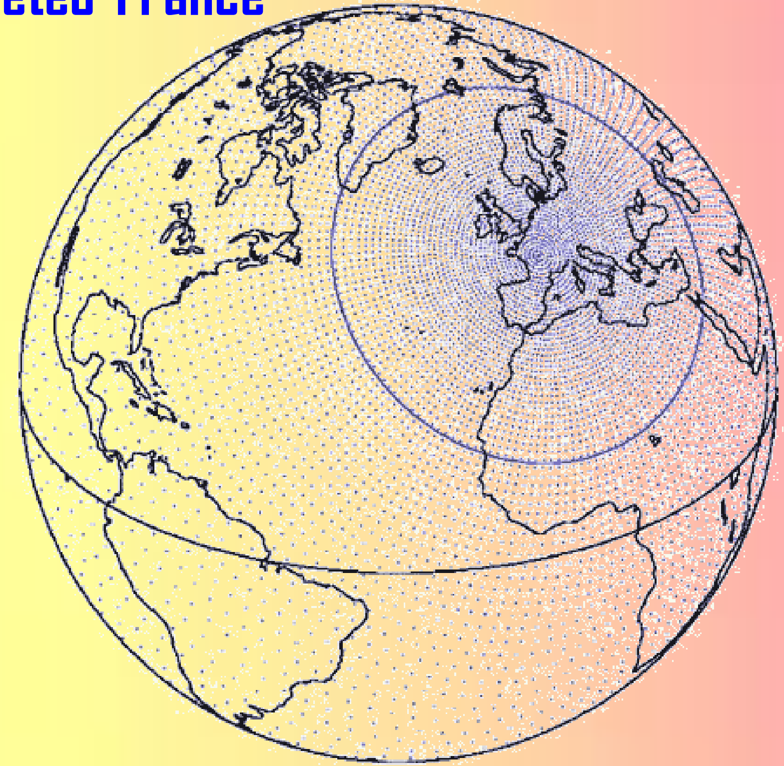
First successful forecast:

A 24-hour forecast took **33 days** to produce, working day and night.

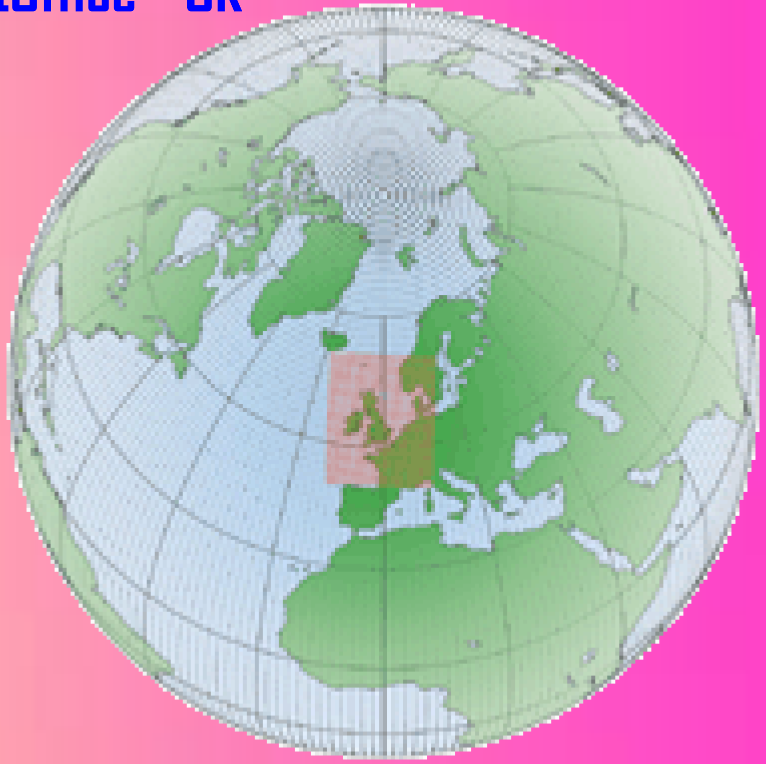


ENIAC Computer

Meteo-France



MetOffice - UK

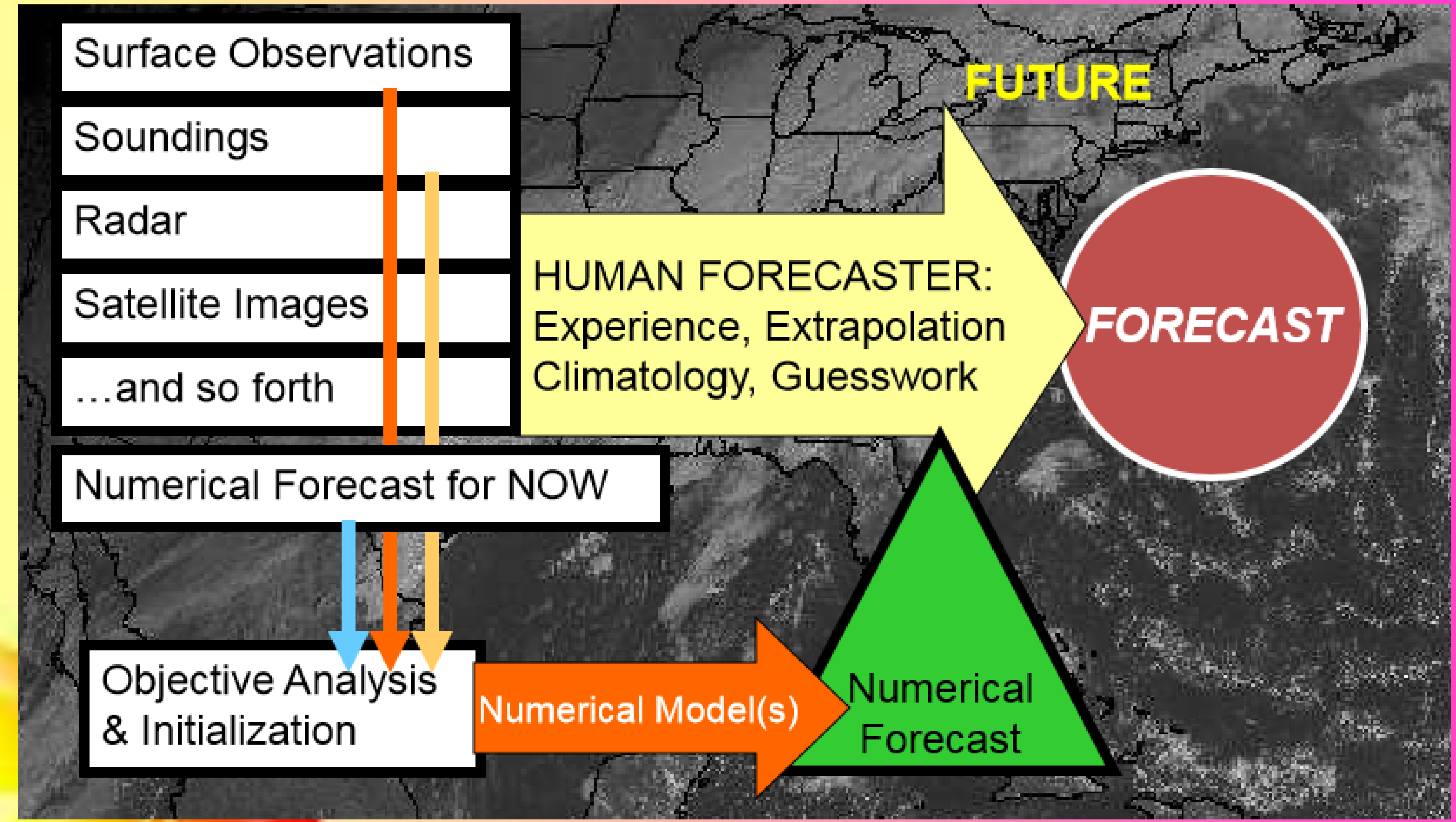


Modern forecast models include the whole globe at a horizontal resolution of up to ~1° (~111km).

Region of interest modelled at ~10km resolution.

Forecasts made every 12 or 24 hours for 0000 and 1200 GMT (sometimes 0600 and 1800) for up to 5 days ahead.

Forecast Process



NWP Process

Gather Observations

➘ Data Assimilation

➘ Numerical Weather Predictions

➘ Forecast Postprocessing

➘ Issue forecasts, Evaluate

Numerical Weather Prediction

A **numerical model** includes the primitive equations, physics parameterization, and a way to solve the equations (usually using finite differences on a grid)

Makes use of powerful computers

Keep in mind that a model with certain horizontal grid spacing is barely simulating phenomenon with a scale four times the grid spacing. So a 12-km model barely is getting 50 km scale features correct.

Model Integration: Numerical Weather Prediction

The initialization is used as the starting point for the atmospheric simulation.

Numerical models consist of the basic dynamical equations ("primitive equations") and physical parameterizations.

Physics Parameterizations

We need physics parameterizations to include key physical processes.

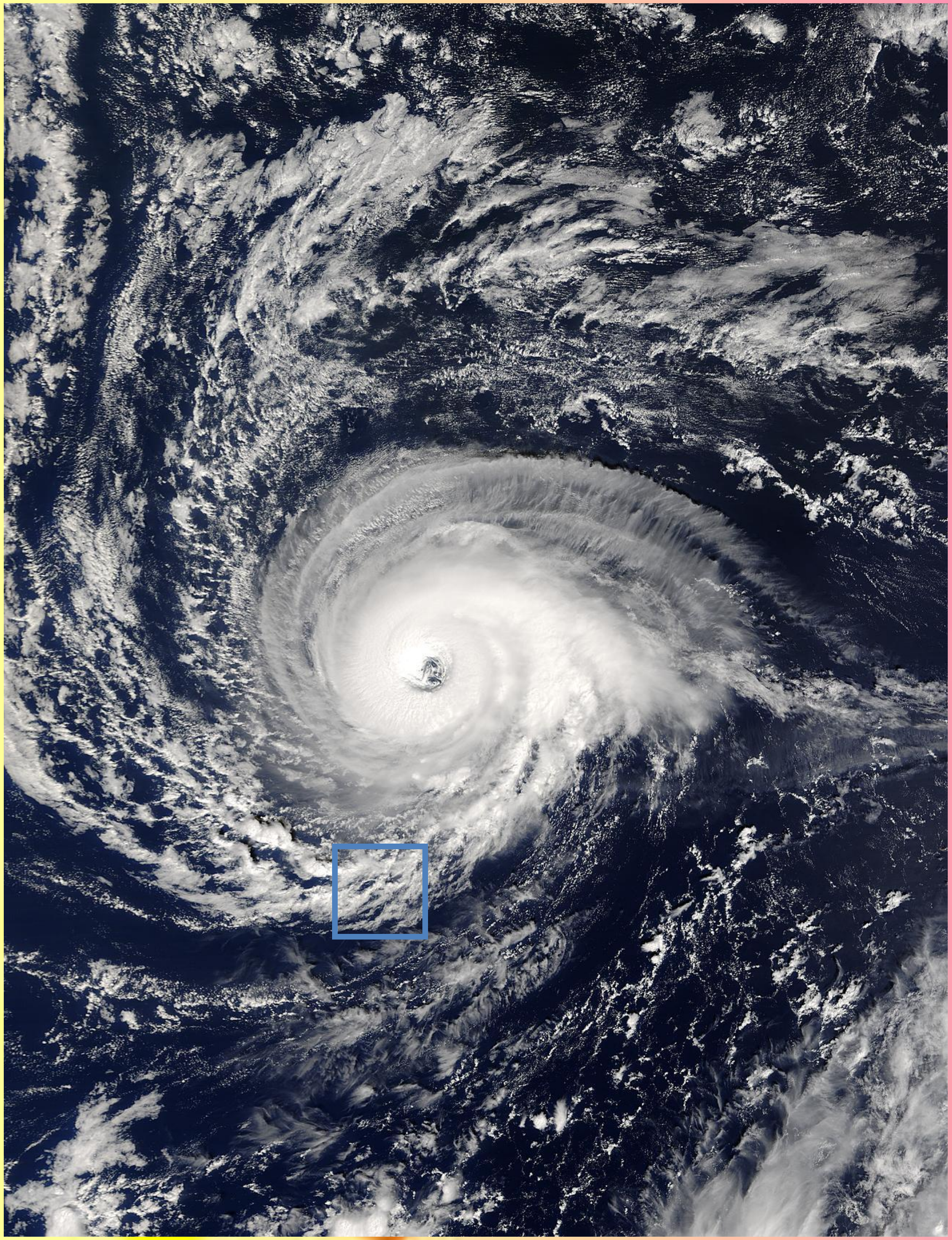
Examples include radiation, cumulus convection, cloud microphysics, boundary layer physics, etc.

Why?

Primitive equations lack the necessary physics

Lack sufficient resolution to resolve key processes.

Small scale physics has to be put in terms of larger scale variables



Source: MODIS

"Parameterizations"

Much of the weather occurs at scales smaller than those resolved by the weather forecast model.

Model must treat, or "parameterize" the effects of the sub-gridscale on the resolved scale.

Example: Cumulus Parameterization

Most numerical models (grid spacing of 12-km is the best available operationally) cannot resolve convection (scales of a few km or less).

In parameterization, represent the effects of sub-grid scale cumulus on the larger scales.

Types of Models

Short range models

These tend to be more suitable for more specific features such as fronts, temperatures, and convection. They are considered non-hydrostatic.

Forecasting for as little as the next 1 hour to as long as 3 ½ days.

Long range models

These are hemispheric or global models and are highly skilled at wave patterns within the jet stream.

However they also have skill at synoptic features and an outperform the short range models at times! These are usually hydrostatic or isentropic.

Forecasting out to as far as 15 days.

Numerical Weather Prediction

Most operational modeling systems are run four times a day (00, 06, 12, 18 UTC), although some run twice a day (00 and 12 UTC)

The main numerical modeling centers in the U.S. are:

Environmental Modeling Center (EMC) at the National Centers for Environmental Prediction (NCEP)--part of the NWS. Located near Washington, DC.

Fleet Numerical Meteorology and Oceanography Center (FNMOC)- Monterey, CA

Air Force Weather Agency (AFWA)-Offutt AFB, Nebraska

So many models!

RUC – Rapid Update Cycle

NAM – North American Mesoscale

WRF – The Weather Research and Forecasting
WRF-NMM, WRF-ARW and WRF-HRW

GFS – Global Forecast Systems

ECMWF – European Center for Medium Range Weather Forecasting

NGM – Nested Grid Model (being phased out.)

GEM – Global Environmental Multiscale (Canada)

UKMET – United Kingdom Meteorological Model

Major U.S. Models

Global Forecast System Model (GFS).

Uses spectral representation rather than grids in the horizontal. Global, resolution equivalent to 25 km grid model. Run out to 384 hr, four times per day.

Weather Research and Forecasting Model (WRF).

WRF is a mesoscale modeling system system that is used by the NWS and the university/research community.

Two versions (different ways of representing the dynamics): WRF-NMM and WRF-ARW.

Universities use WRF-ARW. The NWS runs WRF-NMM at 12-km grid spacing, four times a day to 84h. AFWA is also using WRF (ARW). Run here (36, 12, 4, 1.3 km)

Different Types of Atmospheric Models

Cloud-Resolving Models (CRMs)

Mesoscale Models

Numerical Weather Prediction (NWP) Models

Regional Climate Models (RCMs) • Global Circulation Models (GCMs)

Some common NWP models

U.S. National Centers for Environmental Prediction (NCEP)

- Global forecasting system
- Weather Research and Forecast model (WRF)

NCAR

- Mesoscale model - version 5 (MM5)
- Weather Research and Forecast model (WRF)
- EuLag CFD model
- (various climate models)

European Center for Medium Range Weather Forecasting (ECMWF) model

British Meteorological Office

U. S. Naval Research Lab. – COAMPS, NOGAPS

Air Force Weather Agency - WRF

http://www.wrf-model.org/index.php

www.wrf-model.org/index.php

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WRF ▸ THE WEATHER RESEARCH & FORECASTING MODEL

Home | Working Groups | User Resources | Events | Real-Time Forecasts

- Home
- WRF User Resources
- WRF ARW Users' Page
- WRF NMM Users' Page
- WRF Release Information
- WRF Administration
- Publications
- Presentations
- The DTC

The Weather Research & Forecasting Model

CLICK TO SEE WRF FORECAST

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It features two dynamical cores, a data assimilation system, and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. The effort to develop WRF began in the latter part of the 1990's and was a collaborative partnership principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the (then) Forecast Systems Laboratory (FSL)), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA).

WRF can generate atmospheric simulations using real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while providing recent advances in physics, numerics, and data assimilation contributed by developers across the very broad research community. WRF is currently in operational use at NCEP, AFWA, and other centers.

WRF has a large worldwide community of registered users (over 30,000 in over 150 countries), and workshops and

Upcoming Events

Information on events may be found at: Events.

There are no upcoming WRF events currently scheduled.

-model.org/plots/wrfrealtime.php

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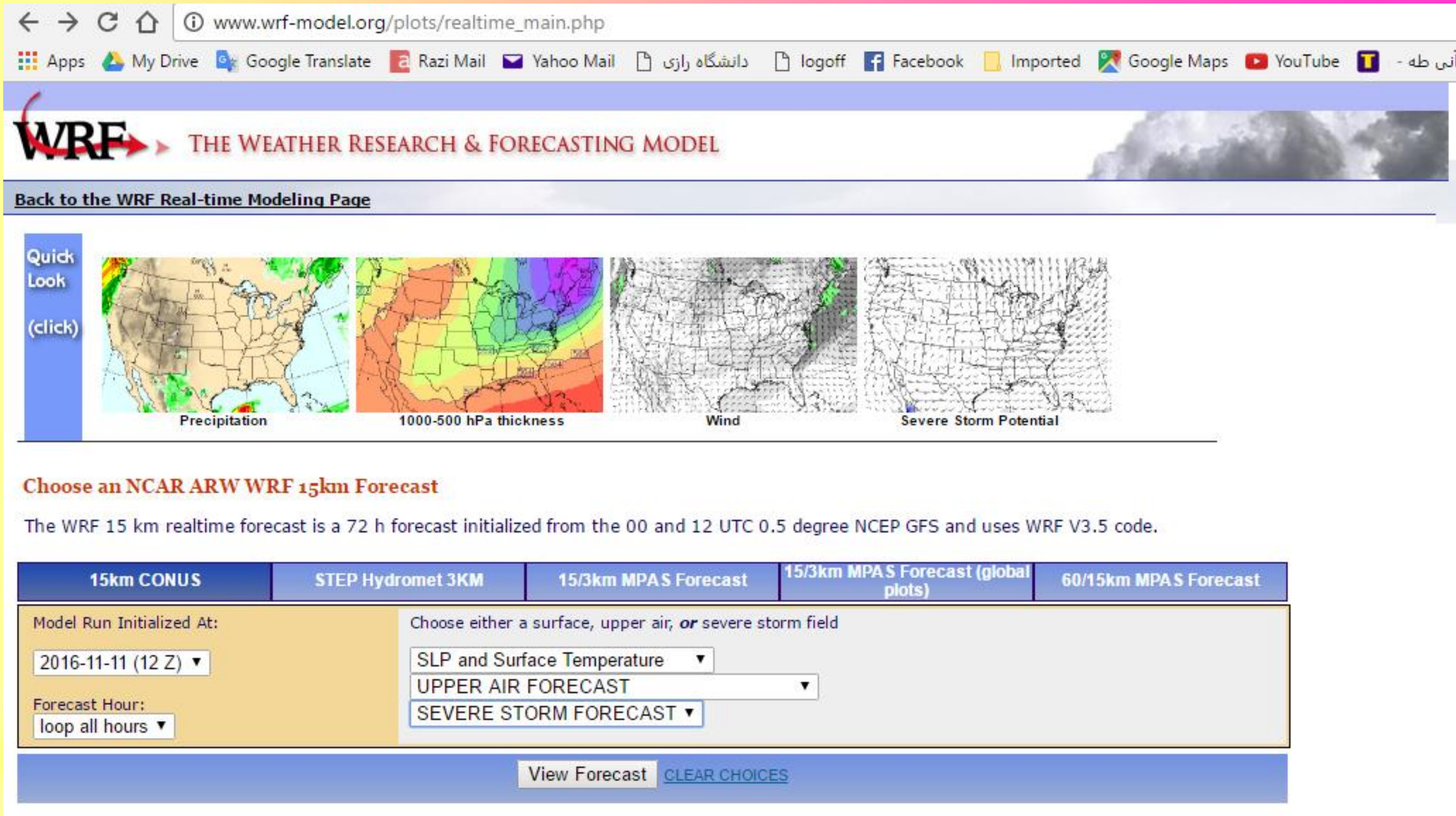
Home | Working Groups | User Resources | Events | Real-Time Forecasts

WRF Real-Time Forecasting

Real-Time WRF— Sample Links

The following list offers a sampling of real-time WRF operations simply to illustrate the breadth of this use of WRF and to provide examples of real-time WRF products. It is in no way a complete list of real-time WRF sites, and being on this list is not an endorsement of the operation. Real-time operations of WRF may be in flux, so some sites may no longer be active.

- NCAR— National Center for Atmospheric Research
- NCEP— National Centers for Environmental Prediction
- AFWA— Air Force Weather Agency
- NOAA/ESRL— Earth System Research Laboratory Rapid Refresh
- NOAA/NSSL— National Severe Storms Laboratory
- AMPS— Antarctic NWP
- University of Illinois
- Millersville University
- Institute of Atmospheric Sciences and Climate (ISAC) of the Italian National Research Council (CNR) (Italy)
- Uruguay Meteorological Institute (Uruguay)
- National Observatory of Athens (Greece)
- Weather-It-Is (Israel)
- Slovenian Meteorological Amateur Research Team (Slovenia)
- Consorzio LaMMA (Laboratory for Meteorology and Environmental Modeling of Tuscany) (Italy)
- Institute of Astronomy and Meteorology of the University of Guadalara (Mexico)
- CDAC— Centre for Development of Advanced Computing (India)
- University of Basel (Switzerland)
- Joint Center for High-Impact Weather and Climate Research of Seoul National University (Korea)
- CentroMeteo (Italy)


www.wrf-model.org/plots/realtime_main.php
Apps My Drive Google Translate Razi Mail Yahoo Mail دانشگاه رازی logoff Facebook Imported Google Maps YouTube
WRF
THE WEATHER RESEARCH & FORECASTING MODEL
Back to the WRF Real-time Modeling Page
Quick Look (click)
Precipitation
1000-500 hPa thickness
Wind
Severe Storm Potential
Choose an NCAR ARW WRF 15km Forecast
The WRF 15 km realtime forecast is a 72 h forecast initialized from the 00 and 12 UTC 0.5 degree NCEP GFS and uses WRF V3.5 code.
15km CONUS
STEP Hydromet 3KM
15/3km MPAS Forecast
15/3km MPAS Forecast (global plots)
60/15km MPAS Forecast
Model Run Initialized At:
2016-11-11 (12 Z)
Forecast Hour:
loop all hours
Choose either a surface, upper air, or severe storm field
SLP and Surface Temperature
UPPER AIR FORECAST
SEVERE STORM FORECAST
View Forecast
CLEAR CHOICES

Types of Numerical Models

Barotropic Model

Barotropic atmosphere (constant density/temperature on pressure surface, no vertical motion)

Absolute vorticity conserved

$$\frac{d\left(f+\zeta\right)}{dt}=0$$

Somewhat skillful at large-scale wave prediction

Integration of the equations

Nonlinear advection

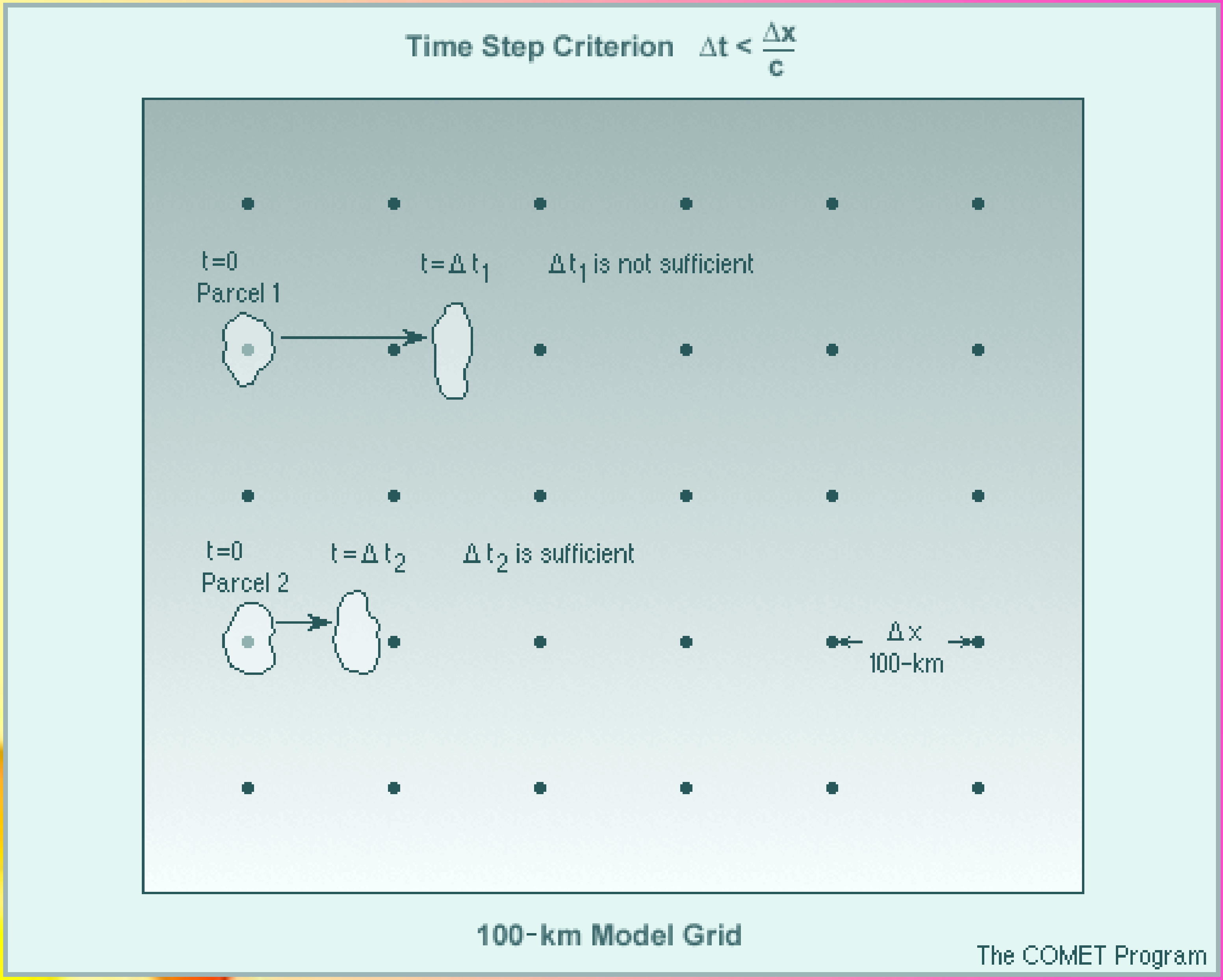
$$\frac{\partial U}{\partial t} = U\left(\frac{\partial U}{\partial x}\right)$$

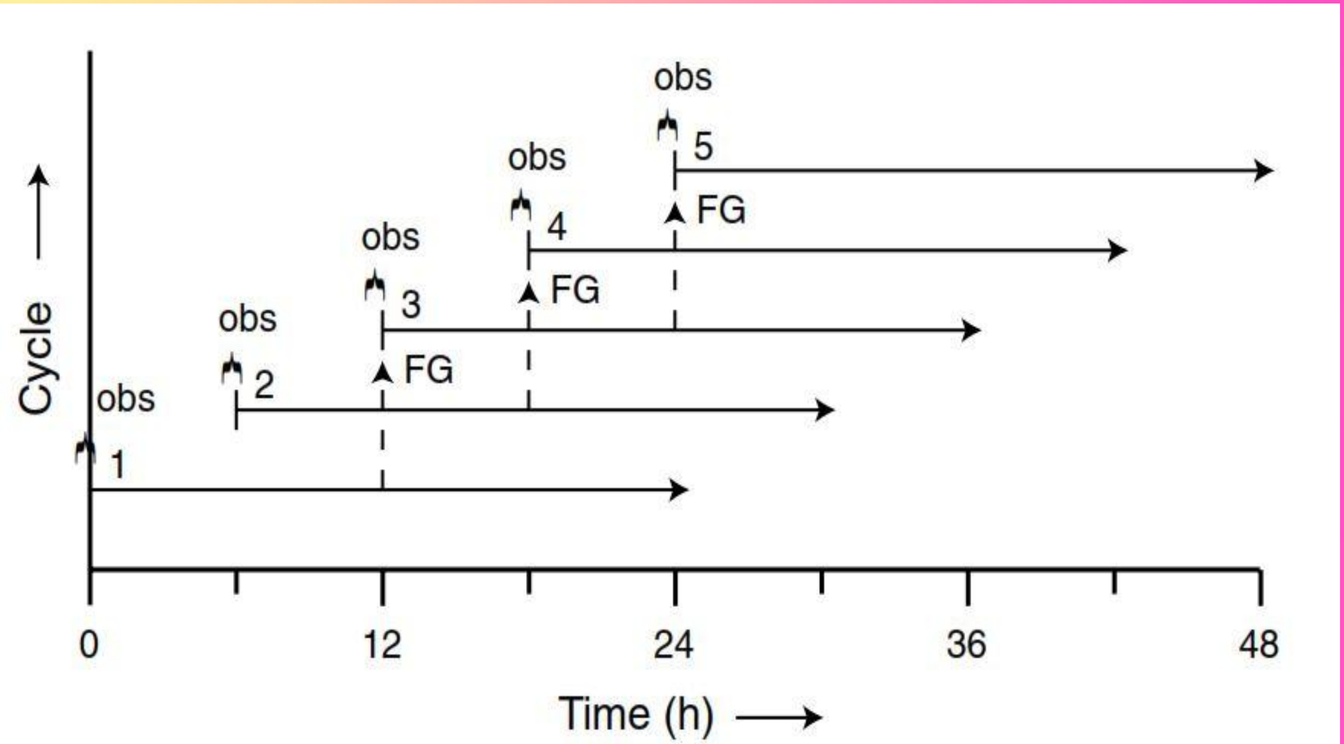
$$\frac{U_i^{k+1} - U_i^{k}}{\Delta t} = U_i^{k}\left(\frac{U_{i+1}^{k} - U_{i-1}^{k}}{2\Delta x}\right)$$

Time step

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

Choose time step based on expected wind speeds and grid spacing


Time Step Criterion $\Delta t < \frac{\Delta x}{c}$
t=0
Parcel 1
t=Δt1
Δt1 is not sufficient
t=0
Parcel 2
t=Δt2
Δt2 is sufficient
Δx
100-km
100-km Model Grid
The COMET Program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Cycle
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36
48
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