Running your own numerical weather forecast

Benjamin Held (Raziel)

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Previous talk: Basics of the numerical weather forecast

- Development of weather forecast
- Basic numerical ideas
- "Weather as a service"
  - German Weather Service (DWD, Offenbach)
  - National Oceanic and Atmospheric Administration (NOAA)
  - MetOffice: UK weather service
  - European Center for medium-range weather forecasts (ECMWF)
  - and many more ...

And now:

How to run a weather forecast model on your own hardware...

Global Forecast System (GFS) [5]

- Numerical model from the National Weather Service (NWS)
- Different horizontal resoultions for different time scales
- Different time output: every hour (0-120 h),
  every 3 h ($<$ 10 days), every 12 h (up to 16 days)
- NOAA publishes three output resolutions every 6 hours:
  1°, 0.5°and 0.25°uo to 384 h forecasts
- Can be used as starting and boundary data for the WRF model

Weather Research & Forecast Model (WRF) [1]

- Numerical weather prediction model
- Usable for atmospheric research and operational forecast
- Developed by the National Center of Atmospheric Research (NCAR) in Boulder
- Development started in the 2nd half of the 1990s
- Several numeric solvers for different use cases, here: ARW

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Hardware and operating system

- Virtual machine with 8 cores and 8 Gb ram
- 200 Gb hard drive
- ArchLinux minimal
  - Base system following the ArchLinux guide
  - alternatives:
    - Ubuntu usage (34C3 workshop)
    - Debian usage (script collection, github)

Installation process

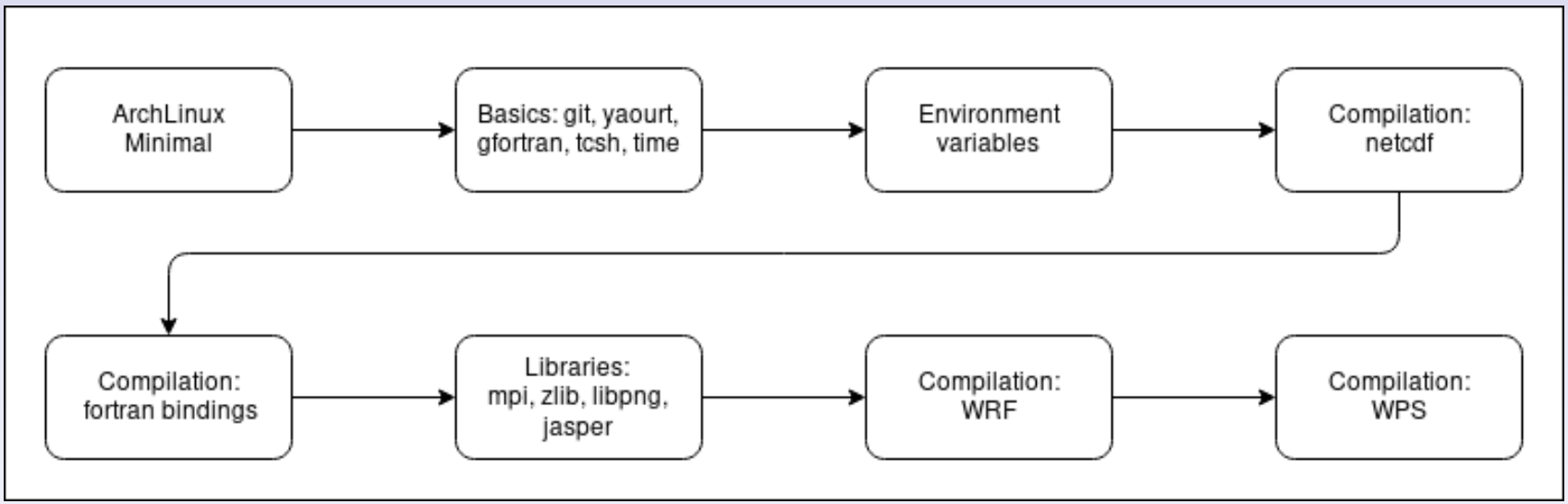

Figure: Installation proccess

Software packages [4]

- Fortran compiler (here gfortan) since the model is implemented in fortran
- Libraries for Network Commom Data Format (netCDF) for input and output data
- netCDF Fortran library
- Message Passing Interface (mpi) for parallel model runs
- Compression and Image libraries (libpng, zlib, jasper)

Software packages [4]

- WRF Preprocessing System (WPS)
  - geogrid, ungrib and real are preprocessing steps which work on the input and geographical data
- Weather Research and Forcast Model (WRF)
  - real: prepares the input data and boundaries
  - wrf: the numeric model

Software packages

- NCAR Command Language (NCL)
  - Fortran based script language
  - Can be used for postprocessing and result visualization
  - Different software components for postprocessing available

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Model pipeline

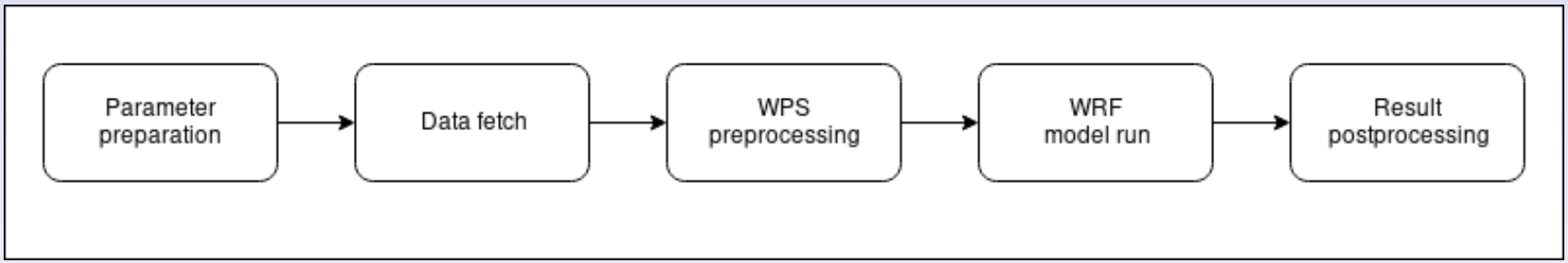


Figure: Model pipeline

Parameter preparation

- Horizontal resolution in m: dx, dy
- Grid points: e_we, e_sn, e_vert
- Start and end time: year, month, day, hour (each)
- Time step in seconds: dt
- most other parameters with fixed values for each model run

Data fetch

- Input data for start and boundary values

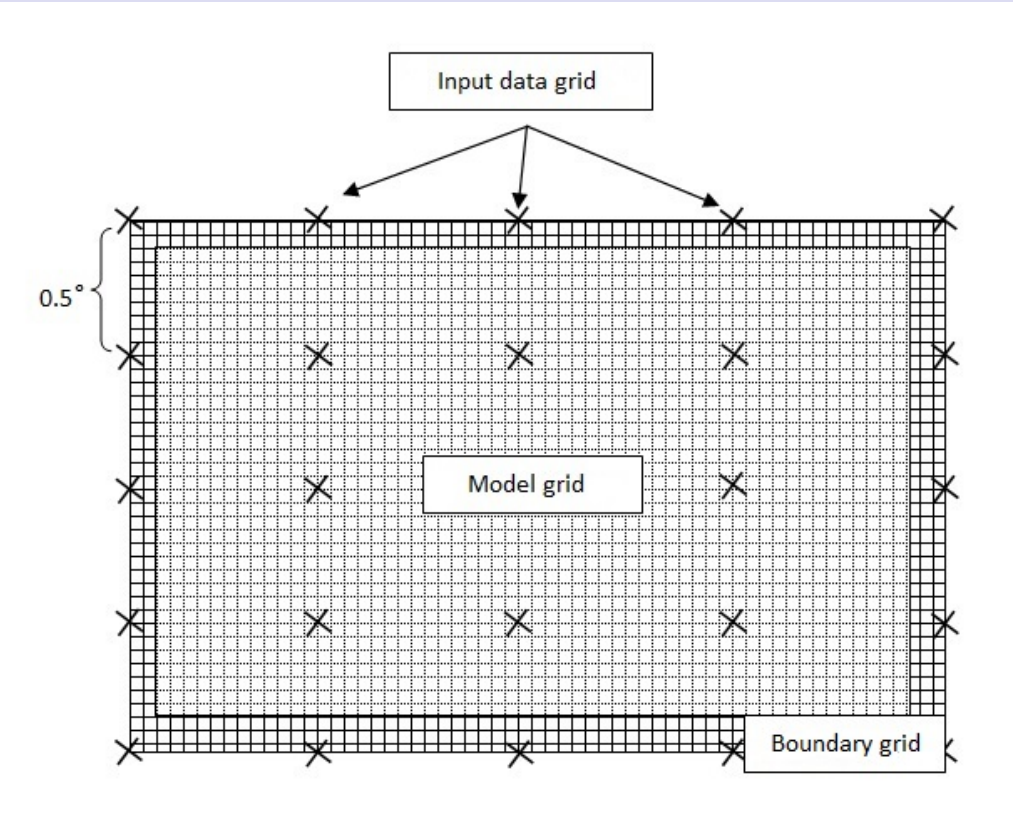
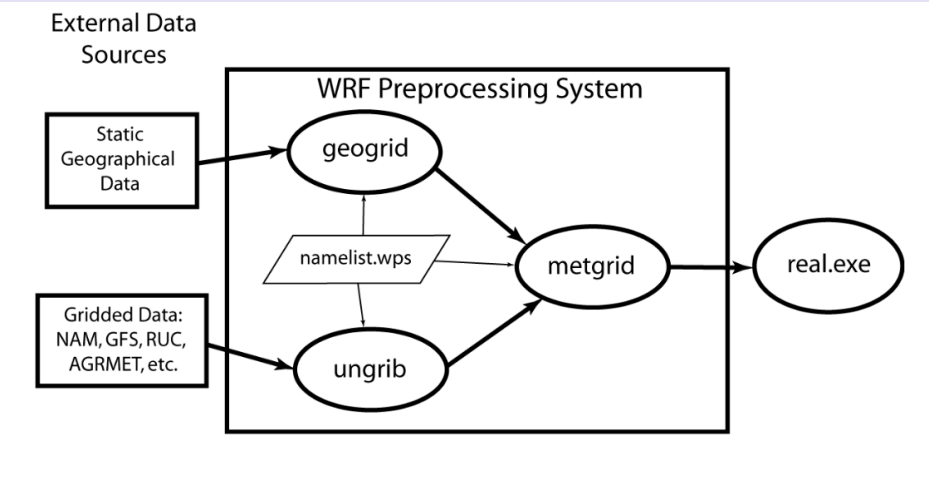


Figure: Grid overlay for input data and model area [3]

Preprocessing [2]

- geogrid: defines model domains and interpolates static geographical data to the grids
- ungrib: extracts meteorological fields from GRIB-formatted files
- metgrid: horizontally interpolates the extracted meteorological fields



Model run

- Solves numerical equations for given parameters
- Runtime on described hardware:
  - grid: 300 x 300, dt: 80 s, Period: 180 h needs 4.6 h; total: 6.5 h
  - grid: 300 x 300, dt: 80 s, Period: 84 h needs 2.3 h; total: 3.75 h
- 180 h forecast with 0.5° input data take

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Output Dimensions [6]

Timebased output

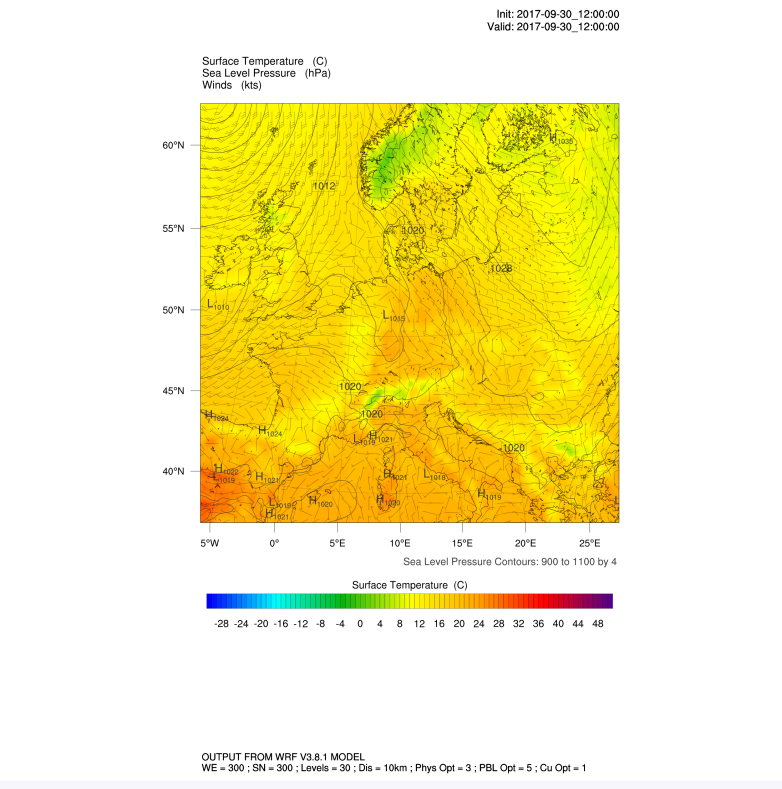
- Results for grid of forecast region
- Configurable output interval, e.g. every 3 h
- around 60 output parameter:
  - e.g. temperature, pressure, wind, precipitation, clouds, radiation

Output Dimensions

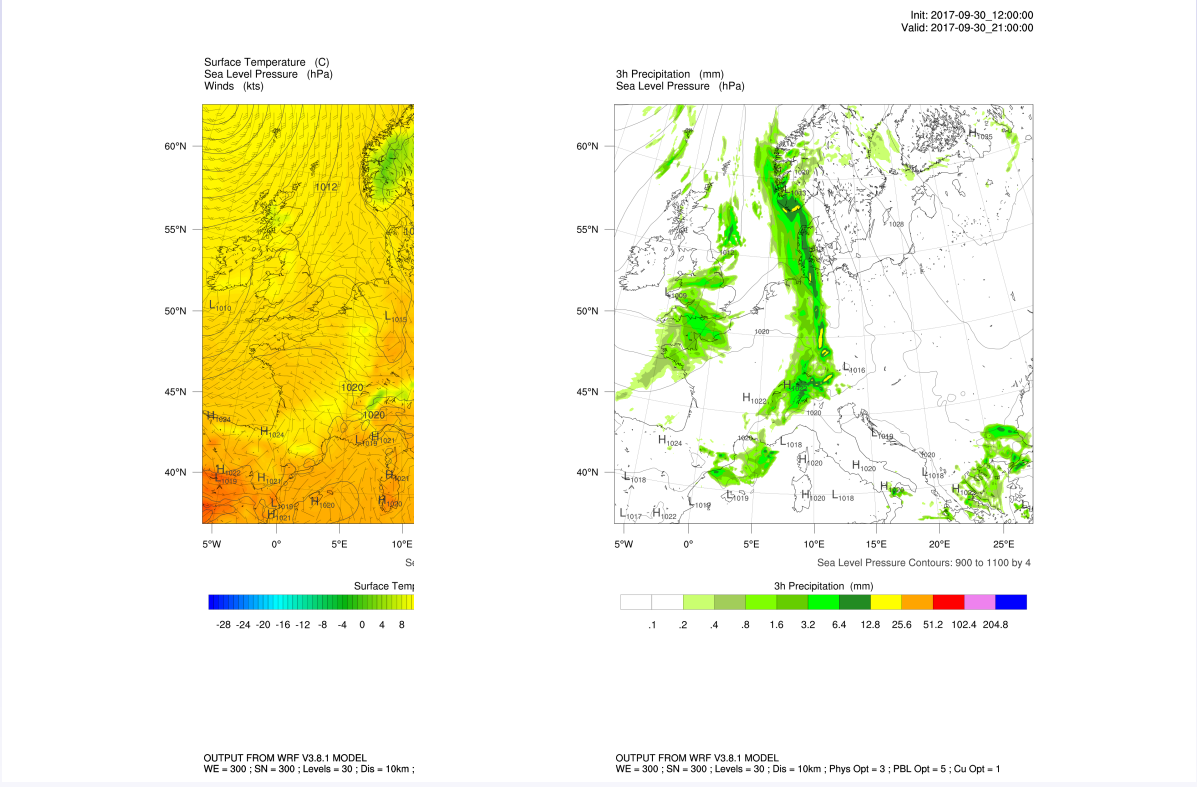
Locationbased output

- Configurable locations specified by (lat,lon) coordinates
- Time series of ground parameters:
  - temperature, wind, pressure, radiation, precipitation, water vapor
- Time series of vertical parameters:
  - wind, potential temperature and height, water vapor

Results


Init: 2017-09-30_12:00:00
Valid: 2017-09-30_12:00:00
Surface Temperature (C)
Sea Level Pressure (hPa)
Winds (kts)
60°N
55°N
50°N
45°N
40°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
Sea Level Pressure Contours: 900 to 1100 by 4
Surface Temperature (C)
-28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40 44 48
OUTPUT FROM WRF V3.8.1 MODEL
WE = 300 ; SN = 300 ; Levels = 30 ; Dis = 10km ; Phys Opt = 3 ; PBL Opt = 5 ; Cu Opt = 1

Results


Surface Temperature (C)
Sea Level Pressure (hPa)
Winds (kts)
60°N
55°N
50°N
45°N
40°N
5°W
0°
5°E
10°E
Surface Temp
-28 -24 -20 -16 -12 -8 -4 0 4 8
OUTPUT FROM WRF V3.8.1 MODEL
WE = 300 ; SN = 300 ; Levels = 30 ; Dis = 10km ;
Init: 2017-09-30_12:00:00
Valid: 2017-09-30_21:00:00
3h Precipitation (mm)
Sea Level Pressure (hPa)
60°N
55°N
50°N
45°N
40°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
Sea Level Pressure Contours: 900 to 1100 by 4
3h Precipitation (mm)
.1 .2 .4 .8 1.6 3.2 6.4 12.8 25.6 51.2 102.4 204.8
OUTPUT FROM WRF V3.8.1 MODEL
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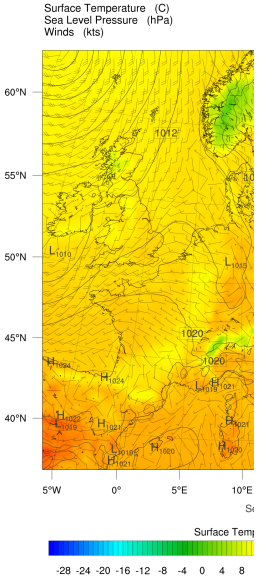
Results


Surface Temperature (C)
Sea Level Pressure (hPa)
Winds (kts)
60°N
55°N
50°N
45°N
40°N
5°W
0°
5°E
10°E
Surface Temp
-28 -24 -20 -16 -12 -8 -4 0 4 8
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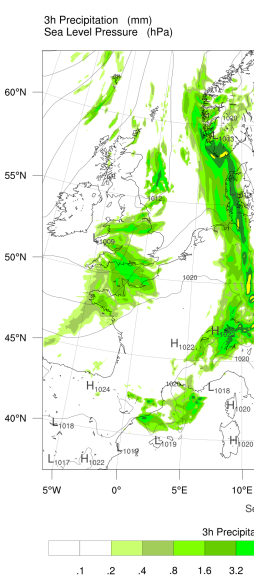
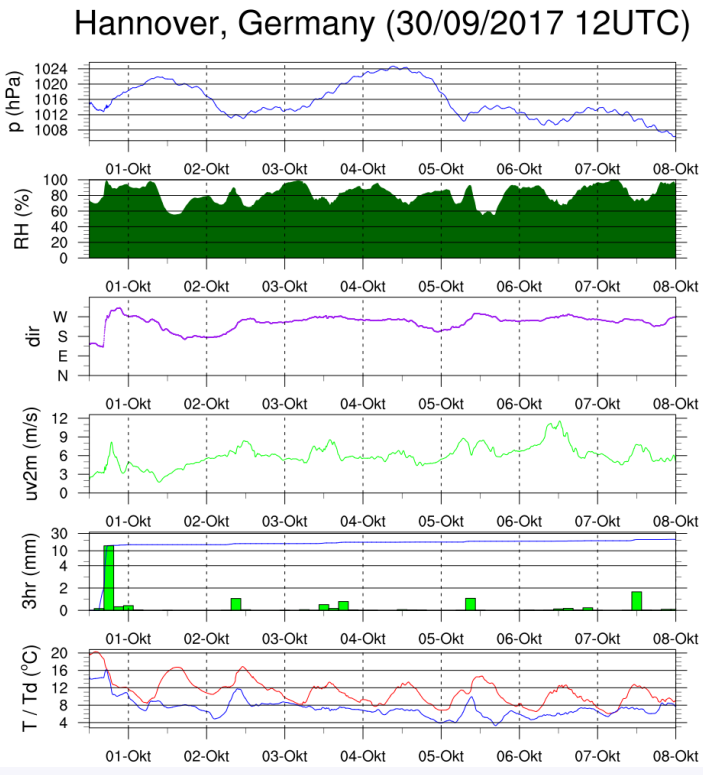

3h Precipitation (mm)
Sea Level Pressure (hPa)
60°N
55°N
50°N
45°N
40°N
5°W
0°
5°E
10°E
3h Precipita
.1 .2 .4 .8 1.6 3.2
OUTPUT FROM WRF V3.8.1 MODEL
WE = 300 ; SN = 300 ; Levels = 30 ; Dis = 10km ;


Hannover, Germany (30/09/2017 12UTC)
p (hPa)
1024
1020
1016
1012
1008
RH (%)
100
80
60
40
20
0
dir
W
S
E
N
uv2m (m/s)
12
9
6
3
0
3hr (mm)
30
10
4
2
0
T / Td °C)
20
16
12
8
4
01-Okt
02-Okt
03-Okt
04-Okt
05-Okt
06-Okt
07-Okt
08-Okt

And now?

- Handling numerical instabilities
- Optimizing model output
  - resolution
  - accuracy
- Extending forecast products

Questions?


Bill Kuo et al.
The Weather Research & Forecasting Model (WRF).
http://www.wrf-model.org/index.php, 09 2016.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ARWUserGuide V3.9.
University Corporation for Atmospheric Research, 2017.


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09 2016.


National Oceanic and Atmospheirc Administration.
Global Forecast System (GFS).
https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs, 09 2016.


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http://www.meteo.unican.es/wiki/cordexwrf/OutputVariables, 09 2017.