

# How to setup the CORDEX diagnostics.

## 1 Overview

For the CORDEX experiment a set of new diagnostics was developed in WRF. These diagnostics are distributed at the CCRC as a modified version of WRF version 3.3. The new diagnostics are:

- A “statistics diagnostic” calculating the daily min/max, time of the min/max, mean and standard deviation of the temperature at 2 m, the water vapour mixing ratio at 2 m, the wind speed at 10 m, the U and V components of the maximum wind speed at 10 m, the skin temperature and the convective and non-convective precipitations.
- A “precipitation diagnostic” calculating the daily precipitation total starting at a time independent of the other diagnostics. For example, you can have the daily precipitation total from 8 am to 8 am while having all other diagnostics saved at midnight.
- A “running average diagnostic” calculating the maximums for precipitation rates and wind speeds over a 24 hours period. These diagnostics are calculated by doing running averages of the wind speeds and precipitation and taking the maximum over 24 hours. The lengths of the windows used for the running average are to choose among: 5 min, 10 min, 20 min, 30 min, 60 min. Each length of the averaging window gives a different output every 24 hours. Any combination of the averaging periods can be chosen by the user. Averaging windows can be chosen differently for rain and winds.
- A “sunshine diagnostic” calculating the sunshine duration over a 24 hours period. This diagnostic is contained in the same file as the maximums for precipitation rates and wind speed over a 24 hours period.

Following are some important specifications of the diagnostics:

1. Running average windows start at each time step. When the averaging length is not a multiple of the time step length, we interpolate the precipitation and wind speeds of the last time step in the averaging window.
2. For the running average diagnostics, average values count on the day their averaging window finishes. So the values for averaging windows that straddle the output time are counted in the next day.
3. These diagnostics will only be calculated if the code is compiled with specific C preprocessor options. A `configure.wrf` file created by the `configure` program will not contain these options by default. The `configure.wrf.nci` and `configure.wrf.crc` files distributed with the modified WRF code have been updated to use these options.

## 2 Namelist.input options to setup

These diagnostics add a lot of options in the `namelist.input` to control their output. The main option, `clwrf_variables`, switches the diagnostics on and off. There are also options to control which of the running average maximums for precipitation and wind are to be calculated. All these options were added in a new section of the `namelist.input` called `&diagnostics`. Other options that already existed in WRF are also used to manage the output file names and frequencies.

### &diagnostics section

<i>Namelist variable</i>	<i>Type</i>	<i>Number of entries</i>	<i>Description</i>
clwrf_variables	Integer	max_domains	1: Turn on the diagnostics 0 (default): Turn off the diagnostics.
max_window	Integer	1	Number of time-steps needed to calculate the running average diagnostics. See more details in the text. A test is done at the end of the first time-steps to ensure max_window is big enough. If not, the correct size is given.
max_rain_5m	Integer	max_domains	1: to output the max. 5 min. precipitation rate. 0 (default): turn diagnostic off
max_rain_10m	Integer	max_domains	1: to output the max. 10 min. precipitation rate. 0 (default): turn diagnostic off
max_rain_20m	Integer	max_domains	1: to output the max. 20 min. precipitation rate. 0 (default): turn diagnostic off
max_rain_30m	Integer	max_domains	1: to output the max. 30 min. precipitation rate. 0 (default): turn diagnostic off
max_rain_60m	Integer	max_domains	1: to output the max. 1 h precipitation rate. 0 (default): turn diagnostic off
max_wind_5m	Integer	max_domains	1: to output the max. 5 min. 10 m wind speed. 0 (default): turn diagnostic off
max_wind_10m	Integer	max_domains	1: to output the max. 10 min. 10 m wind speed. 0 (default): turn diagnostic off
max_wind_20m	Integer	max_domains	1: to output the max. 20 min. 10 m wind speed. 0 (default): turn diagnostic off
max_wind_30m	Integer	max_domains	1: to output the max. 30 min. 10 m wind speed 0 (default): turn diagnostic off
max_wind_60m	Integer	max_domains	1: to output the max. 1 h 10 m wind speed 0 (default): turn diagnostic off

### &time\_control section

<i>Namelist variable</i>	<i>Type</i>	<i>Number of entries</i>	<i>Description</i>
auxhist5_outname	String	1	Name of the output file for the maximum rain and wind speeds diagnostic and the total sunshine time.

io_form_auxhist5	Integer	1	To specify the format of the output file (2=netCDF)
auxhist5_interval	Integer	max_domains	Output frequency in minutes
auxhist5_begin_h	Integer	max_domains	To write the first output at the given number of hours after the start of the run (in hours)
frames_per_auxhist5	Integer	max_domains	Number of records for each variable in each output file.
auxhist4_outname	String	1	Name of the output file for the precipitation diagnostic.
io_form_auxhist4	Integer	1	To specify the format of the output file (2=netCDF)
auxhist4_interval	Integer	max_domains	Output frequency in minutes
auxhist4_begin_h	Integer	max_domains	To write the first output at the given number of hours after the start of the run (in hours)
frames_per_auxhist4	Integer	max_domains	Number of records for each variable in each output file
auxhist3_outname	String	1	Name of the output file for the statistics diagnostic.
io_form_auxhist3	Integer	1	To specify the format of the output file (2=netCDF)
auxhist3_interval	Integer	max_domains	Output frequency in minutes
auxhist3_begin_h	Integer	max_domains	To write the first output at the given number of hours after the start of the run (in hours)
frames_per_auxhist3	Integer	max_domains	Number of time steps in each output file

The variables in blue are default namelist variables in WRF, the other ones were added for these diagnostics.

Here is an example of a namelist.input file (excerpt) for these diagnostics:

```
&time_control
start_year           = 1989, 1989,
start_month          = 11, 11,
start_day             = 1, 1,
start_hour            = 00, 00, 12,
start_minute          = 00, 00, 00,
start_second          = 00, 00, 00,
end_year              = 1989, 1989,
end_month             = 11, 11,
end_day               = 4, 4,
end_hour              = 00, 00, 00,
end_minute            = 00, 00, 00,
end_second            = 00, 00, 00,
auxhist3_outname     = 'wrfxtrm_d<domain>_<date>'
io_form_auxhist3     = 2
auxhist3_interval    = 1440,1440
frames_per_auxhist3 = 7,7
```

```

auxhist4_outname      = 'wrfain_d<domain>_<date>'
io_form_auxhist4     = 2
auxhist4_interval    = 1440,1440
frames_per_auxhist4  = 7,7
auxhist4_begin_h     = 7,7
auxhist5_outname     = 'wrfc24h_d<domain>_<date>'
io_form_auxhist5     = 2
auxhist5_interval    = 1440,1440
frames_per_auxhist5  = 7,7
/

&diagnostics
clwrf_variables      = 1, 1
max_window           = 25
max_rain_5m          = 1, 1
/

```

With these options, you will get the statistic diagnostics outputs in the file named wrfxtrm\_d01\_1989-11-01\_00:00:00 with 4 outputs calculated from midnight to midnight for each of the 3 days of the run and the initial values (same for an inner nest if any exist). You will get the precipitation diagnostic in the file named wrfain\_d01\_1989-11-01\_07:00:00 (same for an inner nest if any exist). The file contains 2 outputs calculated from 7am to 7am on 1<sup>st</sup> November and 2<sup>nd</sup> November (because auxhist4\_begin\_h = 7 and the run starts at midnight). The data for 3<sup>rd</sup> November is not output since the calculation is not complete. The run would have to finish on 4<sup>th</sup> November at 7am to have a complete calculation of the 3<sup>rd</sup> output. Then you will have the running average and sunshine diagnostics in the file named wrfc24h\_d01\_1989-11-01\_00:00:00 (same for an inner nest if any exist). There will be 4 outputs per variable in this file with each output being calculated between midnight and midnight on each day of run and the initial values.

### 3 Statistics diagnostic

For this diagnostic, it is only possible to set the name of the file, the output file format, the number of records per output file, the output frequency and the starting time for the diagnostic. All these characteristics are set by the namelist options that manage the auxiliary history file 3. These namelist options are part of the standard WRF model and a description of these options can be found in the WRF manual.

This diagnostic was originally developed to record daily statistics but the output frequency can be freely set by the user (via auxhist3\_interval). Also, if you want to defer the calculation of the diagnostics, you can follow the same method as described in part 6 for the auxiliary history file 5, by simply changing the namelist option from auxhist5\_begin\_h to auxhist3\_begin\_h. This is particularly useful if your simulation has to start during the day (e.g. for a restart) but you want outputs every 24 hours from midnight to midnight.

### 4 Precipitation diagnostic

For this diagnostic, it is only possible to set the name of the file, the output file format, the number of records per output file, the output frequency and the starting time for the diagnostic. All these characteristics are set by the namelist options that manage the auxiliary history file 3. These namelist options are part of the standard WRF model and a description of these options can be found in the WRF manual.

Again, this diagnostic was originally developed to record daily precipitations but the output

frequency can be freely set by the user. Also, this diagnostic was developed to have a 24 hour total precipitation output starting at a different time than the starting time of the simulation. For example, if you want the 24 hour precipitation every day starting at 7am but your simulation starts at midnight. To do this, you will need to use `auxhist4_begin_h`. The use of `auxhist5_begin_h` is described in part 6. `auxhist4_begin_h` is used in exactly the same way as `auxhist5_begin_h`.

## 5 Running Average diagnostic

### 5.1 Set `max_window`

To calculate a running average, one needs to keep track of values for a given number of time steps in order to average them at the end of the window. This number of time steps varies depending on the length of the averaging window. For the running average diagnostic this number of time steps has to be specified by the user in `namelist.input`: `max_window`.

To calculate it, you have to divide the maximum length of the running average periods in the simulation by the time-step. Then you round the result up to the nearest integer. E.g. you want to output the 5 min maximum precipitation rate, the 10 min maximum wind speed and the 30 min maximum wind speed and you have a 8 min time-step. The longest averaging period is 30 min. So you get:  $30/8=3.75$ . You need `max_window=4`.

The correct value needed for `max_window` is calculated at the first time-step of the simulation. If the value given in the `namelist.input` file is too small, the code stops and gives the correct value to set. If the value given is too big, the code continues, it simply wastes some memory space.

### 5.2 Case of nests

A WRF domain can be quite complicated with telescopic nests and different nests at the same level (see figure).

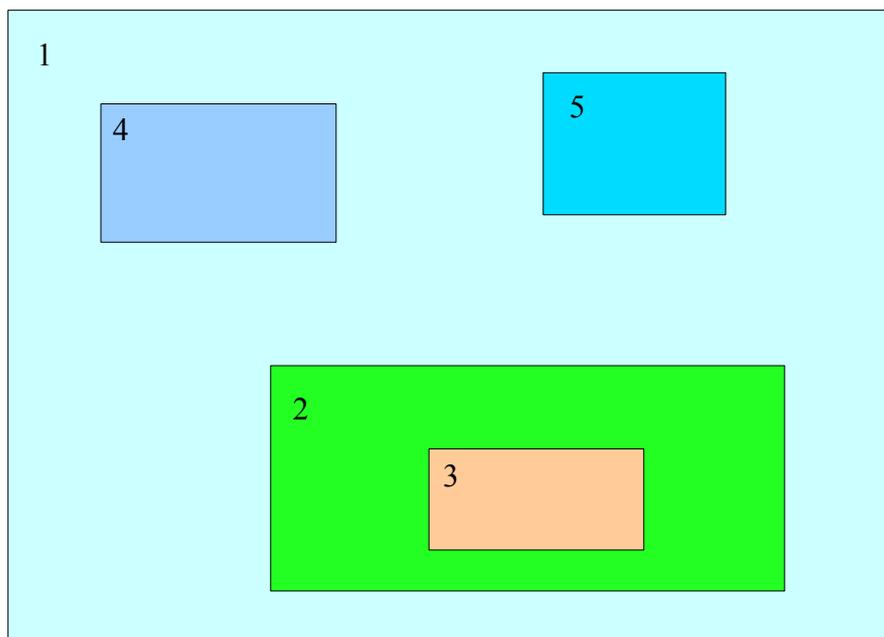


Figure: Representation of a WRF domain (1) with several nests. Nests 2, 4 and 5 are at the same level (they all have domain 1 as parent). Nest 3 has the domain 2 as parent. Domain 1, 2 and 3 are telescopic nests.

In case of using nests, `max_window` must correspond to the highest value needed. This means it must be calculated for the nest with the highest resolution since the time step on this nest will be the smallest used in the simulation. Usually the smallest time step will be for the most inner nest of telescopic nests but not always (see examples).

### 5.2.1 Example 1

For example, let's say you want the 10 min maximum wind speed for all the 5 domains of the figure with these specifications in the `namelist.input`:

```
&domains
time_step = 300
max_dom = 5
grid_id = 1, 2, 3, 4, 5
parent_id = 1, 1, 2, 1, 1
parent_time_step_ratio = 1, 2, 2, 3, 5
:
:
/
```

The `time_step` option gives the `time_step` used for the mother domain (domain 1). The other time steps are calculated using `parent_id` and `parent_time_step_ratio`. In this examples the time steps would be:

```
time_step(1) = 300           for domain 1
time_step(2) = 300/2       for domain 2 (since parent_time_step_ratio(2) = 2 and parent_id(2) = 1)
time_step(3) = (300/2)/2=300/4 for domain 3 (since it is the time step for domain 2 divided by 2)
time_step(4) = 300/3       for domain 4
time_step(5) = 300/5       for domain 5
```

So in this case the smallest time step is on the domain 5 ( $300/5 = 60$  seconds), and  $\text{max\_window} = (10*60)/60 = 10$ .

Now if you decide you don't need the running average diagnostic on the domain 5, the smallest time step is then on domain 3 ( $300/4 = 75$  seconds), and  $\text{max\_window} = (10*60)/75 = 8$ .

### 5.2.2 Example 2

Now let's say you have the same domains as defined in the example 1, but you want different diagnostics for each domain:

```
&diagnostics
clwrf_variables = 1, 1, 1, 1, 1
max_wind_10m = 1, 0, 1, 1, 1
max_wind_30m = 0, 0, 1, 0, 0
max_wind_60m = 1, 1, 0, 0, 0
/
```

The safest way to set `max_window` is to calculate its value for each domain and take the maximum (note the different values of the numerator because different diagnostics are asked on different nests):

```
max_window(1) = (60*60) / 300 = 12
max_window(2) = (60*60) / (300/2) = max_window(1)*2 = 24
max_window(3) = (30*60) / (300/2/2) = 24
max_window(4) = (10*60) / (300/3) = 6
max_window(5) = (10*60) / (300/5) = 10
```

In this example, you then need to set `max_window = 24` in the `namelist.input` file.

## 6 Get outputs at a given time

### 6.1 To defer outputs of less than 24 hours

In `namelist.input`, the output is defined by the output frequency rather than the output time. Sometimes the simulations have to start in the middle of an output period (e.g. when restarting a simulation). It can then be necessary to use `auxhist5_begin_h` (in hours), `auxhist5_begin_m` (in minutes), `auxhist5_begin_s` (in seconds) or `auxhist5_begin` (in minutes). These options allow you to specify the length of time after the starting time when to write the first output. Their use is best explained with an example. Note that the outputs on each domain can be defer by different amounts of time, independently of each other. Since the principles are the same for each domains, the examples here are only given for one nest for simplicity.

Let's say you want to output the diagnostics every day at 0 UTC, but your simulation starts at 15:00 UTC. Then the frequency of output is `auxhist5_interval = 1440`. But, the first output needs to be 9 hours (=24-15) after the starting time (not 24 hours), so you need to specify: `auxhist5_begin_h = 9`. Then the first output corresponds to the maximums computed from the 9 first hours of the run if not using a restart file, the following outputs are computed using 24 hours of run. If you are using a restart file, the computation of the diagnostic resumes for the 9 first hours of the run, and the first output correspond to the result for the preceding 24 hours.

It is important to note that the option `auxhist5_begin` is only considered if `auxhist5_begin_m` is not set in the `namelist` file. The different options, `auxhist5_begin_h`, `auxhist5_begin_m` or `auxhist5_begin` and `auxhist5_begin_s`, are summed up together to define the starting time. So if you want to skip 1h 30min, you can use *either* of the options:

```
auxhist5_begin_h = 1.5
```

or

```
auxhist5_begin_m = 90
```

or

```
auxhist5_begin_s = 5400
```

or

```
auxhist5_begin   = 90
```

or

```
auxhist5_begin_h = 1
```

```
auxhist5_begin_m = 30
```

or

```
auxhist5_begin_h = 1
```

```
auxhist5_begin   = 30
```

or

```
auxhist5_begin_h = 1
```

```
auxhist5_begin_s = 1800
```

or any other combination of `auxhist5_begin_h`, `auxhist5_begin_m`, `auxhist5_begin` and `auxhist5_begin_s`.

### 6.2 To defer output of more than 24 hours.

WRF also provides the options: `auxhist5_begin_d` (in days) and `auxhist5_begin_y` (in years). Preferably, these options should not be used because the diagnostics are still calculated during the time span by `auxhist5_begin_d` and `auxhist5_begin_y` options, although not written to file. So if you want to skip a long period, it is preferable to run your simulation in two parts: first part with the

diagnostics off (clwrf\_variables option to 0), then to restart the run at the chosen date for the start of the diagnostics.

If you still want to defer the output of more than 24 hours, it is better to use auxhist5\_begin\_h. With this option, the calculation of the running average diagnostic only begins after auxhist5\_begin\_h – auxhist5\_interval/60 hours into the simulation. If auxhist5\_begin\_h – auxhist5\_interval/60 is negative then the calculation of the diagnostic starts from the first time step, but the first output is not complete unless you are using a restart file with the diagnostics calculated in the previous run.

## 7 Examples

### 7.1 Example 1

You want to have the 10 min precipitation rate and 10 m wind speed maximums for every day of the simulation and for every morning (in UTC), and your simulation is starting at 15:00 UTC. Your time step is 3 min. Without a restart file, you need to setup the following options:

```
&time_control
:
:
:
auxhist5_interval = 720
auxhist5_begin_h = 21
/

&diagnostics
clwrf_variables = 1
max_window = 4
max_rain_10m = 1
max_wind_10m = 1
/
```

This will give you the morning and afternoon maximums, taking the maximums of the 2 values of each day will give you the 24h maximum. Also note auxhist5\_begin\_h value. The first output you are interested in is at 12 UTC of day 2, i.e. 21 hours after the start of the simulation. With the given values of auxhist5\_interval and auxhist5\_begin\_h, the calculation of the diagnostic will start after 21-12=9 hours of simulation. You also need to setup auxhist5\_outname, io\_form\_auxhist5 and frames\_per\_auxhist5 to your liking.

With a restart file, you have the values for the diagnostic from 12 UTC of day 1 to 15 UTC of day 1, so you need to setup auxhist5\_begin\_h=9. The calculation of the afternoon maximum will resume using the values in the restart file and output the maximum over the afternoon at 0 UTC, day 2.

### 7.2 Example 2

If using the same example but you now start the simulation at 9:00 UTC, without a restart file. Then you want to set auxhist5\_begin\_h = 27, so that the first output is at 12 UTC, day 2 (and the maximums were calculated over the 12 preceding hours). Then all outputs are of interest.

## 8 List of output variables

In addition of the diagnostic variables, each file contains the variables Times, XLAT and XLONG which contains the writing times, the 2D latitudes and 2D longitudes respectively.

**STATISTICS diagnostic  
in auxiliary history file 3**

<i>Variable name in netCDF files</i>	<i>Description</i>
T2MIN	Minimum 2m temperature
T2MAX	Maximum 2m temperature
TT2MIN	Time of the minimum 2m temperature
TT2MAX	Time of the maximum 2m temperature
T2MEAN	Mean 2m temperature
T2STD	Standard deviation of the 2m temperature
Q2MIN	Minimum 2m water vapour mixing ratio
Q2MAX	Maximum 2m water vapour mixing ratio
TQ2MIN	Time of the minimum 2m water vapour mixing ratio
TQ2MAX	Time of the maximum 2m water vapour mixing ratio
Q2MEAN	Mean of the 2m water vapour mixing ratio
Q2STD	Standard deviation of the 2m water vapour mixing ratio
SKINTEMPMIN	Minimum skin temperature
SKINTEMPMAX	Maximum skin temperature
TSKINTEMPMIN	Time of the minimum skin temperature
TSKINTEMPMAX	Time of the maximum skin temperature
SKINTEMPMEAN	Mean of the skin temperature.
SKINTEMPSTD	Standard deviation of the skin temperature.
SPDUV10MIN	Minimum 10m wind speed.
U10MIN	The U-component of the minimum 10m wind speed
V10MIN	The V-component of the minimum 10m wind speed
SPDUV10MAX	Maximum 10m wind speed.
U10MAX	The U-component of the maximum 10m wind speed
V10MAX	The V-component of the maximum 10m wind speed
TSPDUV10MIN	Time of the minimum of the 10m wind speed
TSPDUV10MAX	Time of the maximum of the 10m wind speed
SPDUV10MEAN	Mean of the 10m wind speed.
U10MEAN	Mean of the U-component of the 10m wind.
V10MEAN	Mean of the V-component of the 10m wind.

SPDUV10STD	Standard deviation of the 10m wind speed.
U10STD	Standard deviation of the U-component of the 10m wind speed.
V10STD	Standard deviation of the V-component of the 10m wind speed.
RAINCVMAX	Maximum convective precipitation
TRAINCVMAX	Time of the maximum convective precipitation
RAINCVMEAN	Mean of the convective precipitation
RAINCVSTD	Standard deviation of the convective precipitation
RAINNCVMAX	Maximum of the grid scale precipitation
TRAINNCVMAX	Time of the maximum of the grid scale precipitation
RAINNCVMEAN	Mean of the grid scale precipitation
RAINNCVSTD	Standard deviation of the grid scale precipitation

**PRECIPITATION diagnostic  
in auxiliary history file 4**

<i>Variable name in netCDF files</i>	<i>Description</i>
RAINC	Accumulated convective precipitation
RAINNC	Accumulated grid scale precipitation

**RUNNING AVERAGE diagnostic  
in auxiliary history file 5**

<i>Variable name in netCDF files</i>	<i>Description</i>
PRMAX5	Maximum 5 min precipitation rate
TPRMAX5	Time of the maximum 5 min precipitation rate (end of averaging window)
PRMAX10	Maximum 10 min precipitation rate
TPRMAX10	Time of the maximum 10 min precipitation rate (end of averaging window)
PRMAX20	Maximum 20 min precipitation rate
TPRMAX20	Time of the maximum 20 min precipitation rate (end of averaging window)
PRMAX30	Maximum 30 min precipitation rate
TPRMAX30	Time of the maximum 30 min precipitation rate (end of averaging window)

PRMAX1H	Maximum 1 hour precipitation rate
TPRMAX1H	Time of the maximum 1 hour precipitation rate (end of averaging window)
UVMAX5	Maximum 5 min wind speed
TUVMAX5	Time of the maximum 5 min wind speed (end of averaging window)
UVMAX10	Maximum 10 min wind speed
TUVMAX10	Time of the maximum 10 min wind speed (end of averaging window)
UVMAX20	Maximum 20 min wind speed
TUVMAX20	Time of the maximum 20 min wind speed (end of averaging window)
UVMAX30	Maximum 30 min wind speed
TUVMAX30	Time of the maximum 30 min wind speed (end of averaging window)
UVMAX1H	Maximum 1 hour wind speed
TUVMAX1H	Time of the maximum 1 hour wind speed (end of averaging window)

**SUNSHINE diagnostic  
in auxiliary history file 5**

<i>Variable name in netCDF files</i>	<i>Description</i>
SUNSHINE	Sunshine duration
TSUNSHINE	Start time of sunshine