WRF urban module: Specific module for output of urban variables

Contribution from the CORDEX FPS URB RCC

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  1. Classification of building categories at the grid point
  2. `URB_PARAM`: Characteristics of buildings

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  1. 11 different building categories LCZ (*Local Climate Zones*)
  2. Since WRF v4.5 direct use of data provided at the `geogrid.exe`
  3. Previously use w2w tro interpolate `.tiff` maps

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  1. 132 values at each grid cell
  2. Incorporated at `geogrid.exe` via variable `URB_PARAM`, data from NUDAPT (only USA)
  3. When `wrf.exe` simulates, zero grid-values of `URB_PARAM` are replaced by `URBPARM_LCZ.TBL` values for each LCZ

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- Characteristics of buildings: height, street direction, albdedo, heat capacity, heat transfer, ...
- `URB_PARAM` (shared drive document), dimensions (nxm,132,nym), however only a few of them are used:
  - `URB_PARAM`(i,91,j)=TOWN*BUILDING (grid point average)
  - `URB_PARAM`(i,94,j)=BUILDING_HEIGHT (averaged `BUILDING` > 0 & > 5 m)
  - `URB_PARAM`(i,95,j)=(WALL_O_HOR+BUILDING)*TOWN (grid point averagee)
  - `URB_PARAM`(i,117:132,j) building height distributions, example:
    - `URB_PARAM`(i,117,j) fraction of buildings 5m height
    - `URB_PARAM`(i,118,j) fraction of buildings 10m height

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A mess of dimensions

- base dimensions

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dim name	dim name wrf.exe	description	default value
udr		urban wind directions	4
urb		urban parameters	132
nurbmax		Maximum number of urban classes	11
ndm	num_urban_ndm	Maximum number of street directions	2
nz_um	num_urban_nz	Maximum number of vertical levels in the urban grid	18
ng_u	num_urban_ng	Number of grid levels in the ground	10
ngr_u	num_urban_ngr	Number of grid levels in green roof	10
nwr_u	num_urban_nwr	Number of grid levels in the walls or roofs	10
nf_u	num_urban_nf	Number of grid levels in the floors (BEM)	10
ngb_u	num_urban_ngb	Number of grid levels in the ground below building (BEM)	10
nbui_max	num_urban_nbui	maximum number of types of buildings in an urban class	15

source: `Registry/registry.dimspec`, `Registry/Registry.EM_COMMON`, `phys/module_sf_bep_bem.F`

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var. dim.	dimension	combination value	value
uamp0	num_urban_ndm	num_urban_ndm	2
umap1	urban_map_zrd	num_urban_ndm*num_urban_nwr*num_urban_nz	360
umap2	urban_map_zwd	num_urban_ndm*num_urban_nwr*num_urban_nz* num_urban_nbui	5400
umap3	urban_map_gd	num_urban_ndm*num_urban_ng	20
umap4	urban_map_zd	num_urban_ndm*num_urban_nz*num_urban_nbui	540
umap5	urban_map_zdf	num_urban_ndm*num_urban_nz	36
umap6	urban_map_bd	num_urban_nz*num_urban_nbui	270
umap7	urban_map_wd	num_urban_ndm*num_urban_nz*num_urban_nbui	540
umap8	urban_map_gbd	num_urban_ndm*num_urban_ngb*num_urban_nbui	300
umap9	urban_map_fbd	num_urban_ndm*(num_urban_nz - 1)*num_urban_nf* num_urban_nbui	5100
umap10	urban_map_zgrd	num_urban_ndm*num_urban_ngr*num_urban_nz	360

source: share/nomdule_check_a_mundo.F

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap0` = 2 (street direction)

name	dims	description	nuits
SFG_URB3D	i{umap0}j	SENSIBLE HEAT FLUX FROM URBAN SFC	W m-2
DG_URB3D	i{umap0}j	ROOF LAYER DEPTH WATER RETENTION	mm
LFG_URB3D	i{umap0}j	LATENT HEAT FLUX FROM URBAN SFC	W m-2

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap1` = 360 (street direction, levels in the walls/roofs, max lev urban)

name	dims	description	nuits
TRB_URB4D	i{umap1}j	ROOF LAYER TEMPERATURE	K

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap2` = 5400 (street direction, levels in the walls/roofs, max lev urban, max type bldgs urban class)

name	dims	description	nuits
TW1_URB4D	i{umap2}j	WALL LAYER TEMPERATURE	K
TW2_URB4D	i{umap2}j	WALL LAYER TEMPERATURE	K

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap3` = 20 (street direction, ground levels)

name	dims	description	nuits
TGB_URB4D	i{umap3}j	ROAD LAYER TEMPERATURE	K

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap4` = 540 (street direction, max lev urban, max type bldgs urban class)

name	dims	description	nuits
SFW1_URB3D	i{umap4}j	SENSIBLE HEAT FLUX FROM URBAN SFC	W m-2
SFW2_URB3D	i{umap4}j	SENSIBLE HEAT FLUX FROM URBAN SFC	W m-2

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap5` = 36 (street direction, max lev urban)

name	dims	description	nuits
SFR_URB3D	i{umap5}j	SENSIBLE HEAT FLUX FROM URBAN SFC	W m-2
T_PV_URB3D	i{umap5}j	PHOTOVOLTAIC PANELS TEMPERATURE	K
DRAIN_URB4D	i{umap5}j	GREEN ROOF DRAINAGE	mm
SFRV_URB3D	i{umap5}j	SENSIBLE HEAT FLUX FROM GREEN ROOF	W m-2
LFRV_URB3D	i{umap5}j	LATENT HEAT FLUX FROM GREEN ROOF	W m-2
DGR_URB3D	i{umap5}j	ROOF LAYER DEPTH WATER RETENTION	mm
LFR_URB3D	i{umap5}j	LATENT HEAT FLUX FROM URBAN SFC	W m-2

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap6` = 270 (street direction, max type bldgs urban class)

name	**dims**	**description**	**nuits**
TLEV_URB3D	i{umap6}j	INDOOR TEMPERATURE	K
QLEV_URB3D	i{umap6}j	SPECIFIC HUMIDITY	dimensionless

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap7` = 540 (street direction, max lev urban, max type bldgs urban class)

name	dims	description	nuits
TW1LEV_URB3D	i{umap7}j	WINDOW TEMPERATURE	K
TW2LEV_URB3D	i{umap7}j	WINDOW TEMPERATURE	K
SFWIN1_URB3D	i{umap7}j	SENSIBLE HEAT FLUX FROM URBAN SFC WINDOW	W m-2
SFWIN2_URB3D	i{umap7}j	SENSIBLE HEAT FLUX FROM URBAN SFC WINDOW	W m-2

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap8` = 300 (street direction, ground levels below building, max type bldgs urban class)

name	dims	description	nuits
TGLEV_URB3D	i{umap8}j	GROUND TEMPERATURE BELOW A BUILDING	K

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap9` = 5100 (street direction, max lev urban-1, floors levels, max type bldgs urban class)

name	dims	description	nuits
TFLEV_URB3D	i{umap9}j	FLOOR TEMPERATURE	K

A mess of dimensions

- base dimensions
- Combination of dimensions
- `umap10` = 360 (street direction, green roof levels, max lev urban)

name	dims	description	nuits
TRV_URB4D	i{umap10}j	GREEN ROOF LAYER TEMPERATURE	K
QR_URB4D	i{umap10}j	GREEN ROOF LAYER MOISTURE	dimensionless

What is needed to be output

- Requested variables

name	units	description
taspav	K	Near-surface temperature pavements
tasroof	K	Near-surface temperature roof
tasgree	K	Near-surface temperature green spaces
tasblue	K	Near-surface temperature blue spaces
anthroheat	W/m2 (?)	Anthropogenic heat flux
tsskin	K	Skin temperature
tspav	K	Surface temperature pavements
tsroof	K	Surface temperature roof
tsgree	K	Surface temperature green spaces
tsblue	K	Surface temperature blue spaces
ta50m	K	air-temperature at 50 m
ua50m	ms-1	air eastward wind speed at 50 m
va50m	ms-1	air northward wind speed at 50 m
qv50m	kgkg-1	air water vapour mixing ratio at 50 m

What is needed to be output

- Generic procedure, for a variable $\chi(i,j)$ as function $\mathcal{F}$ of $v_{urb}(i,j,dim_{urb}), atmos_1(i,j), ..., atmos_m(i,j)$

$$\chi(i,j) = \begin{cases} \sum_{\ell=1}^{dim_{urb}} \mathcal{F}\left(v_{urb}(i,j,\ell), atmos_k(i,j)\right) & \textit{average value each urb} \\ \mathcal{F}\left(\sum_{\ell=1}^{dim_{urb}} v_{urb}(i,j,\ell), atmos_k(i,j)\right) & \textit{value from urb average} \end{cases}$$

What is needed to be output

- Near surface temperatures (2-m ?)
  - can be used different standard extrapolation Monin-Obukov, TKE, ... methodologies (already implemented in WRF from each PBL)
  - or generic ones like from CORDEX-WRF, *[Fita et al., 2019, GMD, doi: 10.5194/gmd-12-1029-2019]*

What is needed to be output

- Example **tasroof**: Near-surface temperature roof
  - WRF variable: TRB_URB4D
  - dimensions: i{umap1}j
  - umap1 = 360 (street direction, levels in the walls/roofs, max lev urban)
  - Averaging individual tasroof:

$$tasroof(i,j) = \sum_{\ell=1}^{360} \mathcal{F}\left(TRB\_URB4D(i,j,\ell), atmos_k(i,j)\right)$$

  - tasroof from urban average

$$tasroof(i,j) = \mathcal{F}\left(\sum_{\ell=1}^{360} TRB\_URB4D(i,j,\ell), atmos_k(i,j)\right)$$

What is needed to be output

- Reduction of urban morphological data: (suggestion by A. Martilli)
  1. reduce the value of `nbui_max` in `module_sf_bep_bem.F` to 2 (default 15)
  2. estimate the maximum building height over all the grid points
  3. then put `nz_um=(max_build_height)/5+4`, where `max_build_height` is the numerical value of the maximum building height estimated (smaller than default value, 18)
  4. in `dyn_em/module_initialize_real.F` limit the loop to the numerical value of `nz_um`, instead of 15 (this is hardcoded):

```
DO k = 1, 15
  grid%HI_URB2D(i,k,j) = grid%URB_PARAM(i,k+117,j)
END DO
```