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First Results of Urban Microscale Air Quality Simulations for Berlin, Germany, Using PALM-4U

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OUTLINE

- Background
  - The MOSAIK Project
  - PALM, The LES Model
  - PALM-4U - Components
- Chemistry in PALM-4U
  - Interface between Chemistry and PALM-4U
  - Current Features
- A Case Study from Downtown Belin-Germany
  - Model Setup
  - Simulation Domain
  - Results
- Summary and Outlook

BACKGROUND

The MOSAIK Project

"Model-based city planning and application in climate change" (MOSAIK) to develop an urban climate model within the framework of Urban Climate Under Change ([UC]^2).

Main Aim

To develop a highly-efficient, state-of-the-art high-resolution microscale urban climate model that allows for building and turbulence-resolving simulations of large cities.

PALM, the core Model

PALM *(Raasch and Schröter, 2001; Maronga et al., 2015)* was selected as the core model for the new microscale urban climate model named as PALM-4U of large cities such as Berlin (Germany).

PALM, The LES Model.

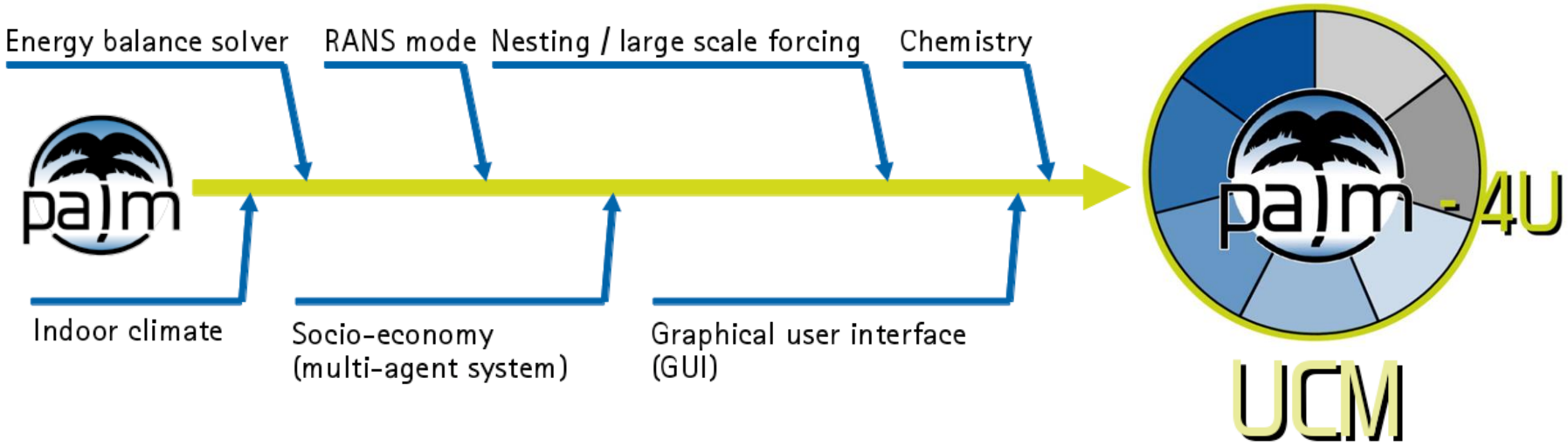
- The PALM is based on the non-hydrostatic, filtered, incompressible Navier-Stokes equations in Boussinesq-approximated form.

- The Model has 6 prognostic quantities (u, v, w, θ, q_v and an optional ‘s’ for passive tracer).

- An additional equation for subgrid scale TKE ‘e’ (default **LES** mode)
  OR
  the total TKE for **Reynolds Averaged Navier-Stokes (RANS)** mode.

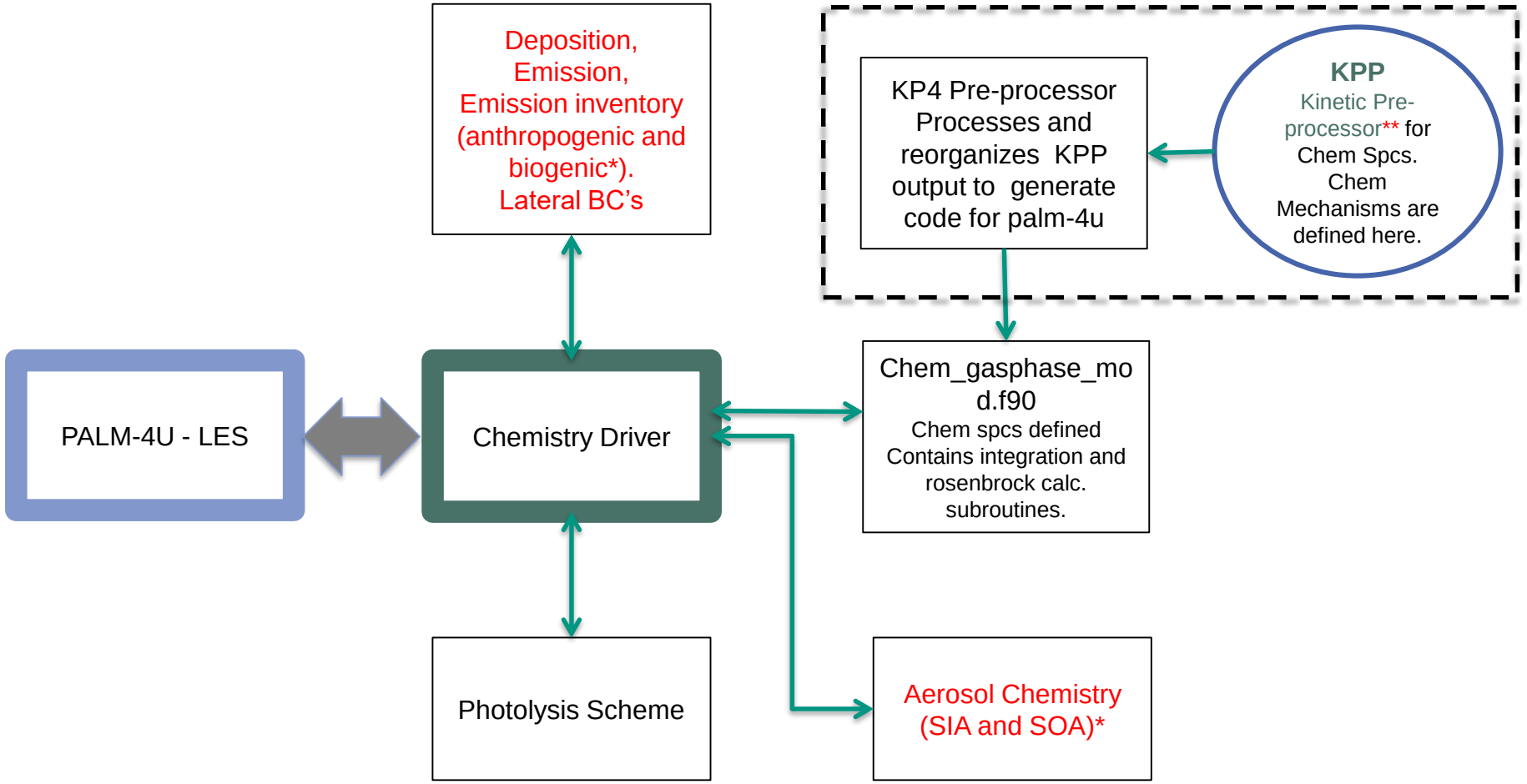
PALM-4U

- **PALM-4U = PALM + Urban Climatology + Air Chemistry**



CHEMISTRY IN PALM-4U

Interface b/w Chemistry and PALM-4U



* Not implemented as yet

** Damian et al 2002
http://people.cs.vt.edu/asandu/Software/Kpp

Current Features

Current Features of Chemistry Model in PALM-4U Modeling System:

- An ‘Online’ coupled chemistry in LES mode for Gas-phase chemistry
- Chemical reactions
- Advection and diffusion
- Photolysis
- Ability to take any user provided chemical mechanism
- Passive tracer
- Nesting
- Static emissions in time and space.

A Case Study from Downtown Berlin - Germany

Model Setup

- nX = nY = 96, nZ = 120; dX=dY=dZ =10 m; Ug = Vg = 1.0 m s^{-1}
- Day & Time: 21 July, 5:00 UTC; Simulation length = 16 hours.
- Modules: radiation, urban surface model, land surface model, canopy model, chemistry model, photolysis model
- Emissions related to OpenStreetmap street types:
  Enhancement factor for main roads = 1.667, Reduction factor for side roads = 0.334
- Emission: NO= 1.318 ppm s^{-1};NO_2= 0.368 ppm s^{-1}; RH=0.1804 ppm s^{-1}; PM10 = 0.75 ug m^2 s^{-1}.

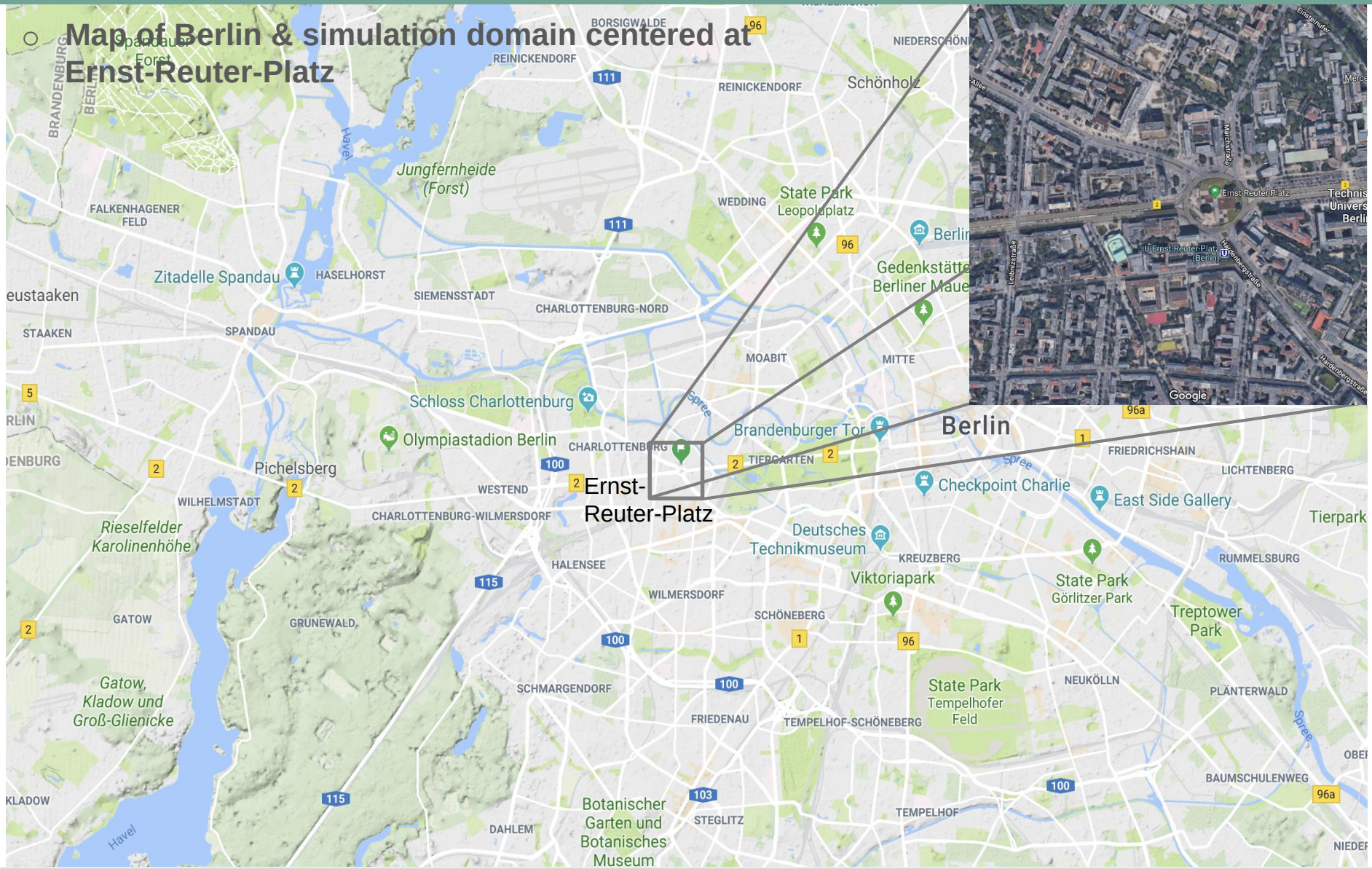
The mechanism has 11 gas-phase chemical species and one non-reactive aerosol(PM10).

```
{1.} NO2 + hv = NO + O3              : phot(j_no2)
{2.} O3 + hv = 2OH + O2              : phot(j_o31d)
{3.} NO + O3 = NO2                   : arr2( 1.8E-12_dp, 1370.0_dp, temp)
{4.} RH + OH = RO2 + H2O             : arr2(  2.E-11_dp,  500.0_dp, temp)
{5.} RO2 + NO = NO2 + RCHO + HO2: arr2( 4.2E-12_dp, -180.0_dp, temp)
{6.} HO2 + NO = NO2 + OH             : arr2( 3.7E-12_dp, -240.0_dp, temp)
{7.} NO2 + OH = HNO3                 : arr2(1.15E-11_dp,    0.0_dp, temp)
{8.} PM10 = PM10                     : 1.0_dp
```

Simulation Domain

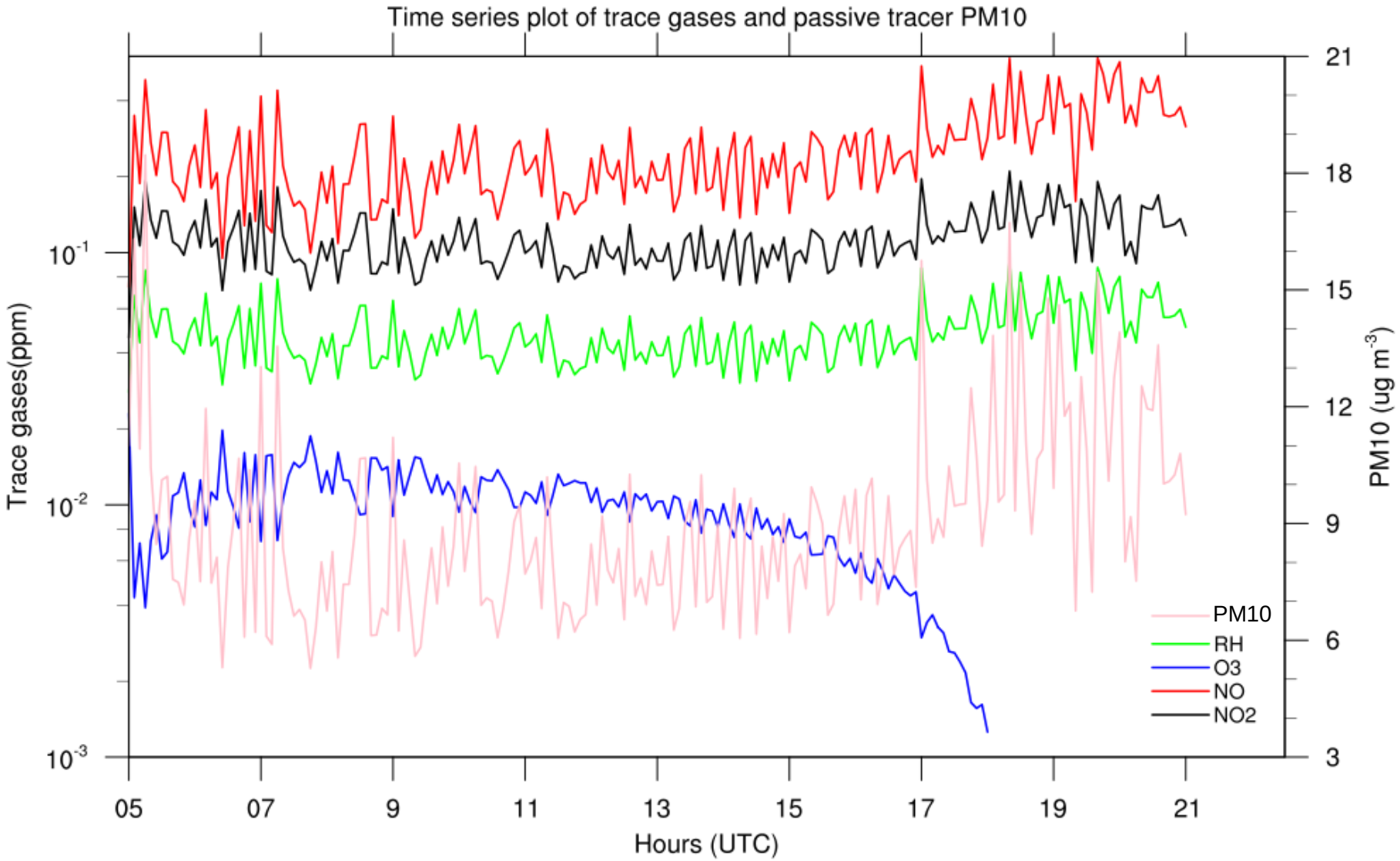
[A Case Study-Berlin]

- Map of Berlin & simulation domain centered at Ernst-Reuter-Platz



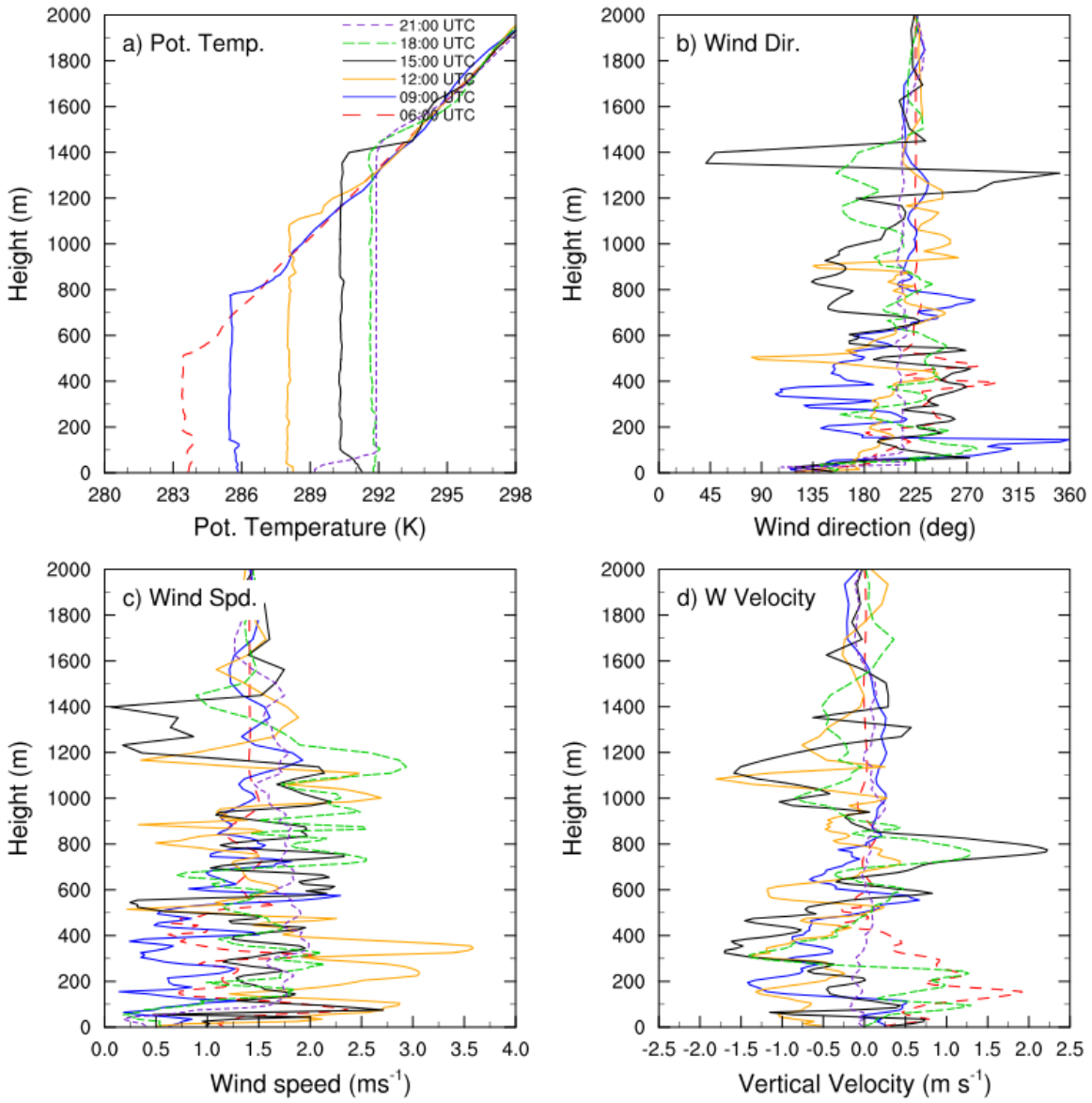
Results

[A Case Study-Berlin]



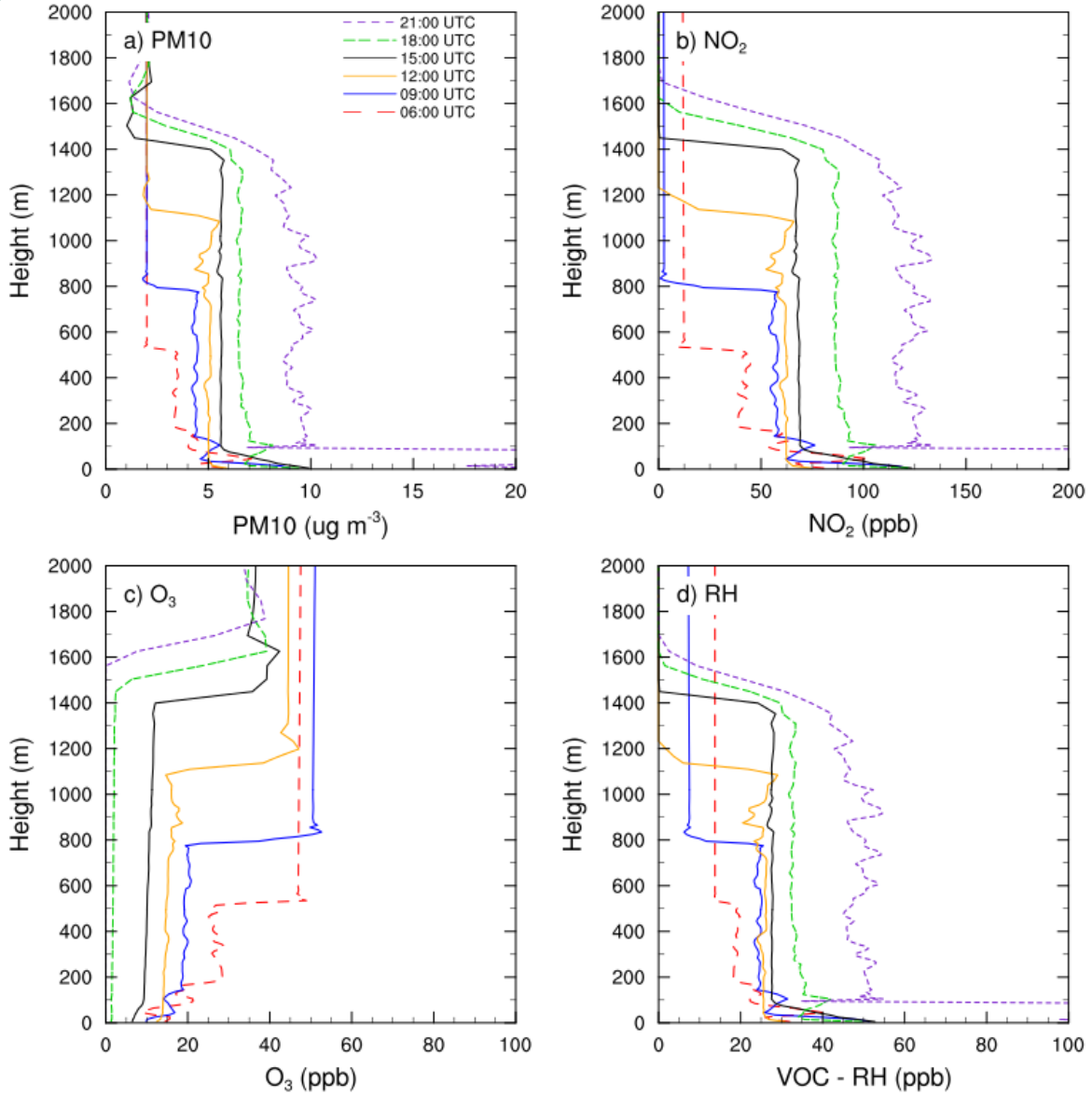
Results

[A Case Study-Berlin]



Results

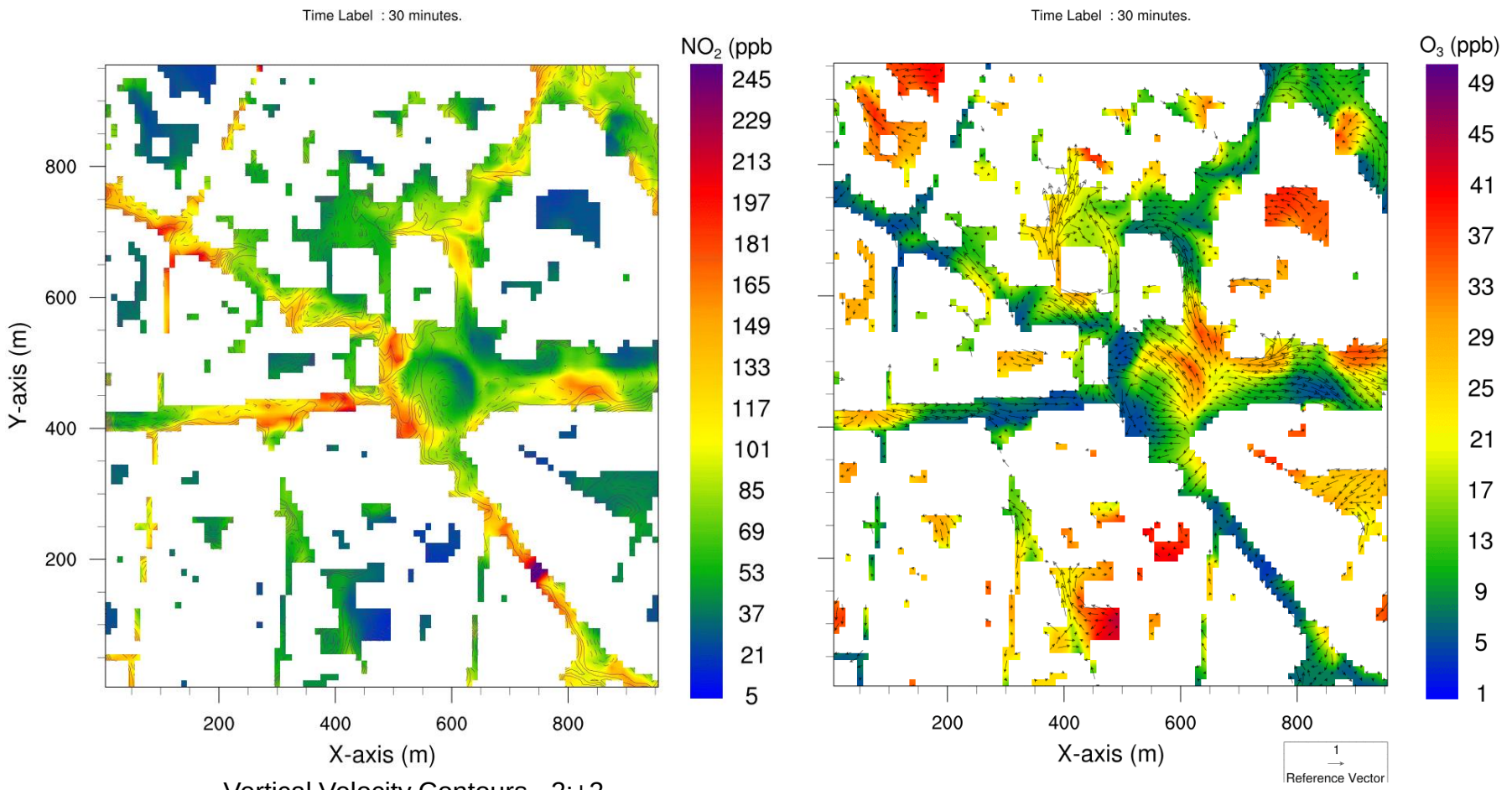
[A Case Study-Berlin]



Results

[A Case Study-Berlin]

Horizontal cross-sections; Level: 5 meter; Left Panel: NO_2 shaded, w-Contours, Right Panel: O_3 shadded and horizontal wind vectors.

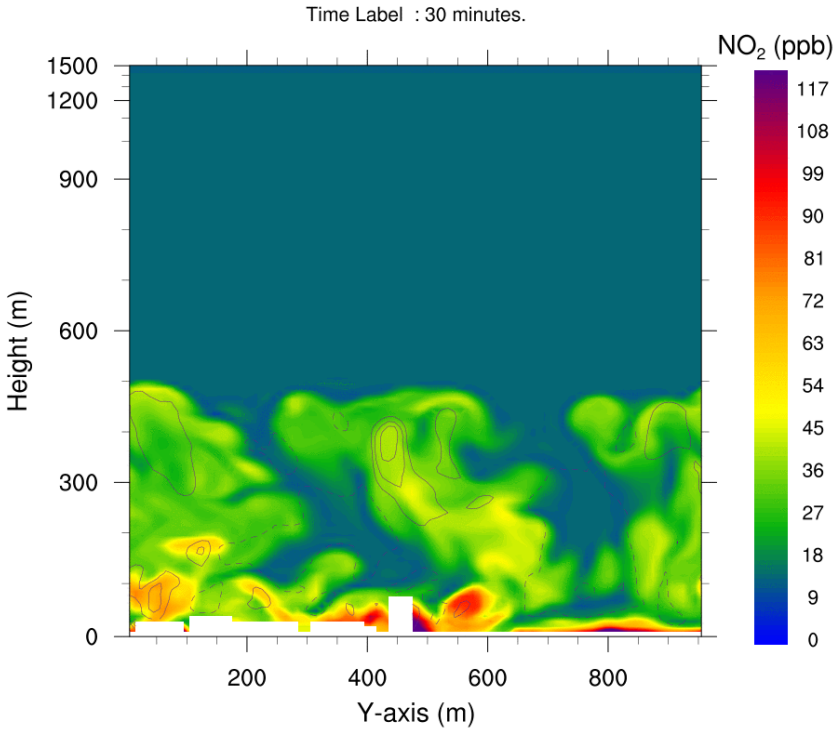


Vertical Velocity Contours -2:+2

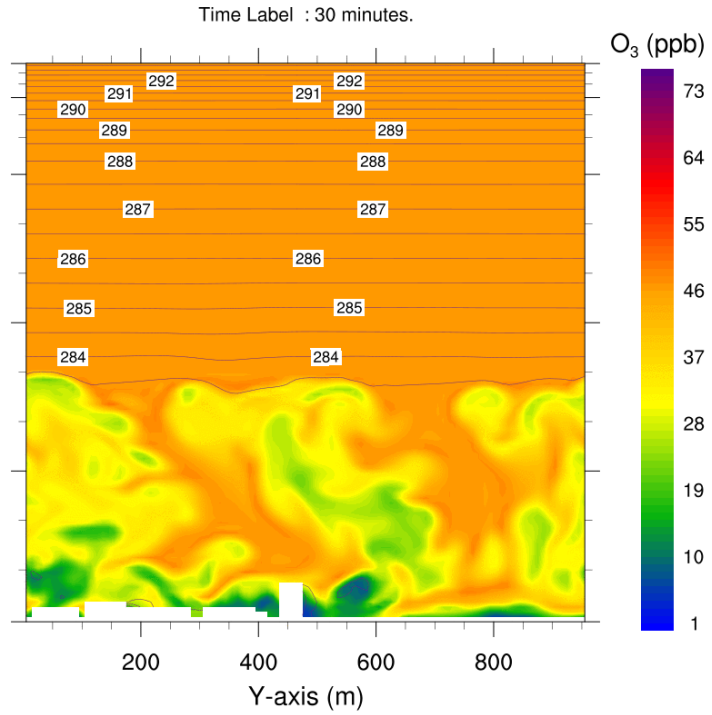
Results

[A Case Study-Berlin]

Vertical cross-sections; Left Panel: NO_2 shaded, W-Contours, Right Panel: O_3 shadded, potential temperature contours.



Vertical Velocity Contours -2:+2 m s^{-1}



Potential Temp Contours 282: 300 K

Summary and Outlook

Summary

- Turbulence and building resolving LES PALM-4U model allows accurate simulation of reaction, advection, and removal of atmospheric trace gases and aerosols at appropriate scales.
- PALM-4U has the potential to be the future state-of-the-art comprehensive urban climate modelling system that could be used for the assessment, prediction and investigation of urban climatology, air quality and city planning of large urban areas.

Coming soon …

- Chemistry forcing at the lateral boundaries of the parent domain
- Aerosol chemistry (SIA and SOA). SALSA sectional aerosol model (Kokkola et al., 2008) in the process to be incorporated in PALM-4U.
- Deposition module for chemical species and aerosols.
- Detailed anthropogenic emissions (temporal and spatial disaggregation, VOC split etc.).
- Reynolds Averaged Navier-Stokes (RANS) Mode for larger domain, longer simulations and complex mechanisms.

Wenn du Luft atmest, solltest Du Dich darum kümmern!

Danke für die Aufmerksamkeit!

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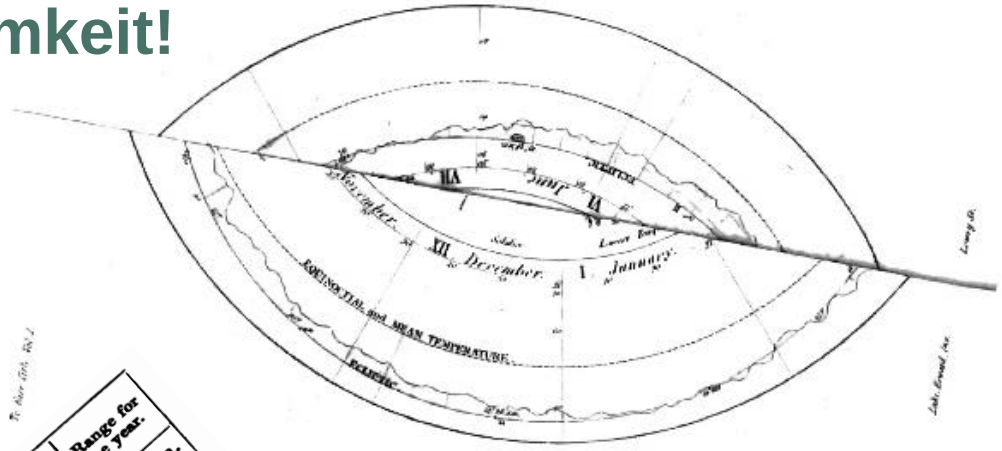

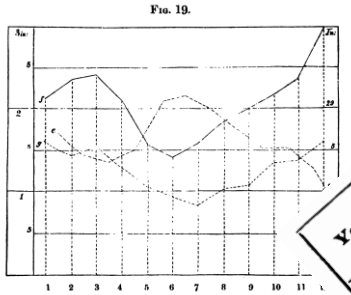

Year.	Mean of 12 greatest elevations.	Mean of 12 greatest depressions.	Medium of elevations & depress.	Highest observation in the year.	Lowest observation in the year.	Range for the year.
1807	30·310	29·167	29·738	30·60	28·68	1·92 in.
1808	30·338	29·263	29·800	30·71	28·72	1·99 in.
1806	30·295	29·088	29·691	30·49	28·25	2·24 in.
1810	30·323	29·327	29·825	30·51	28·50	2·01 in.
1811	30·302	29·195	29·748	30·61	28·65	1·96 in.
1812	30·266	29·279	29·772	30·51	28·53	1·98 in.
1813	30·314	29·214	29·764	30·50	28·64	1·86 in.
1814	30·266	29·190	29·728	30·42	28 22	2·20 in.
1815	30·309	29·136	29·722	30·58	28·85	1·73 in.
1816	30·327	29·023	29·675	30·62	28·53	2·09 in.
Averages	30·305	29·188	29·746	30·555	28·557	1·998 in.