WRF4PALM: A Mesoscale Dynamical Driver for the Microscale PALM Model System 6.0

Dongqi Lin[1,2] (dongqi.lin@pg.canterbury.ac.nz), Basit Khan[3], Marwan Katurji[2], Laura E. Revell[1], Leroy Bird[4], and Ricardo Faria[5]

[1]*School of Physical and Chemical Sciences, University of Canterbury, Christchurch, New Zealand*
[2]*School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[3]*Institute of Meteorology and Climate Research - Atmospheric Environmental Research (IMK-IFU), Karlsruher Institut für Technologie (KIT), Garmisch-Partenkirchen, Germany*
[4]*Bodeker Scientific, Alexandra, New Zealand*
[5]*Oceanic Observatory of Madeira, Funchal, Madeira, Portugal*

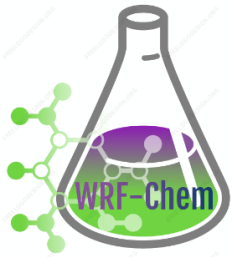
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

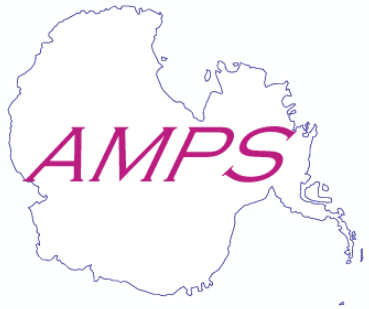
Karlsruher Institut für Technologie

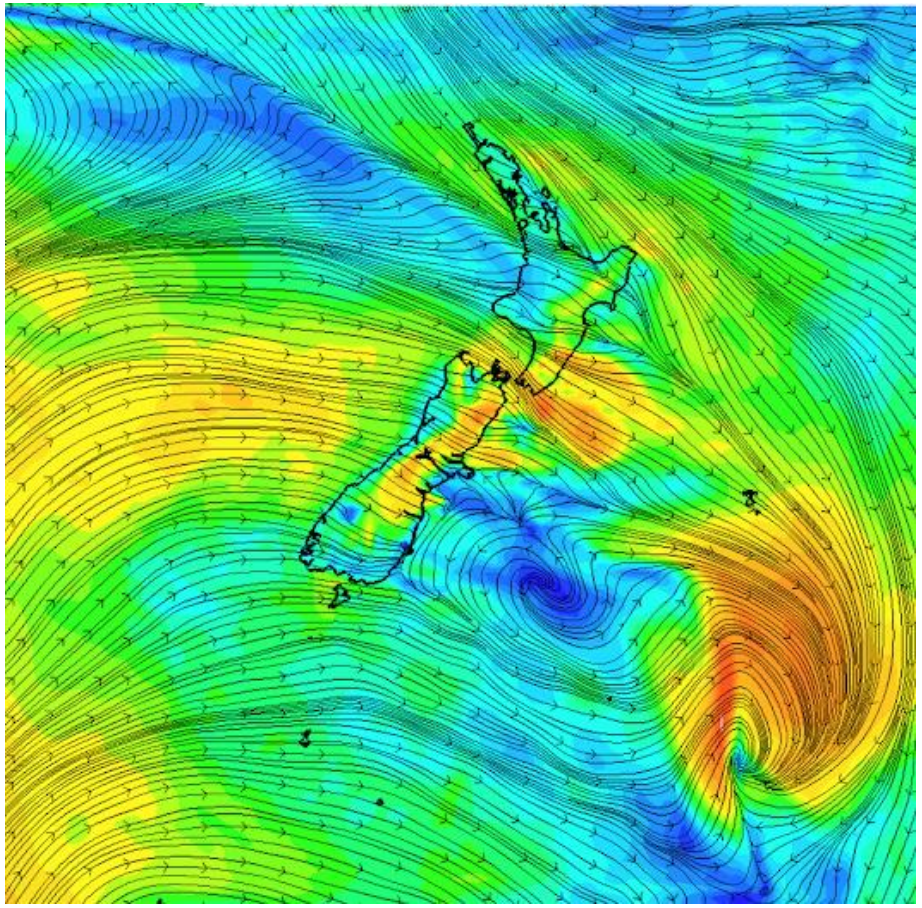
mapm mapping air pollution emissions

Bodeker Scientific

Introduction – WRF



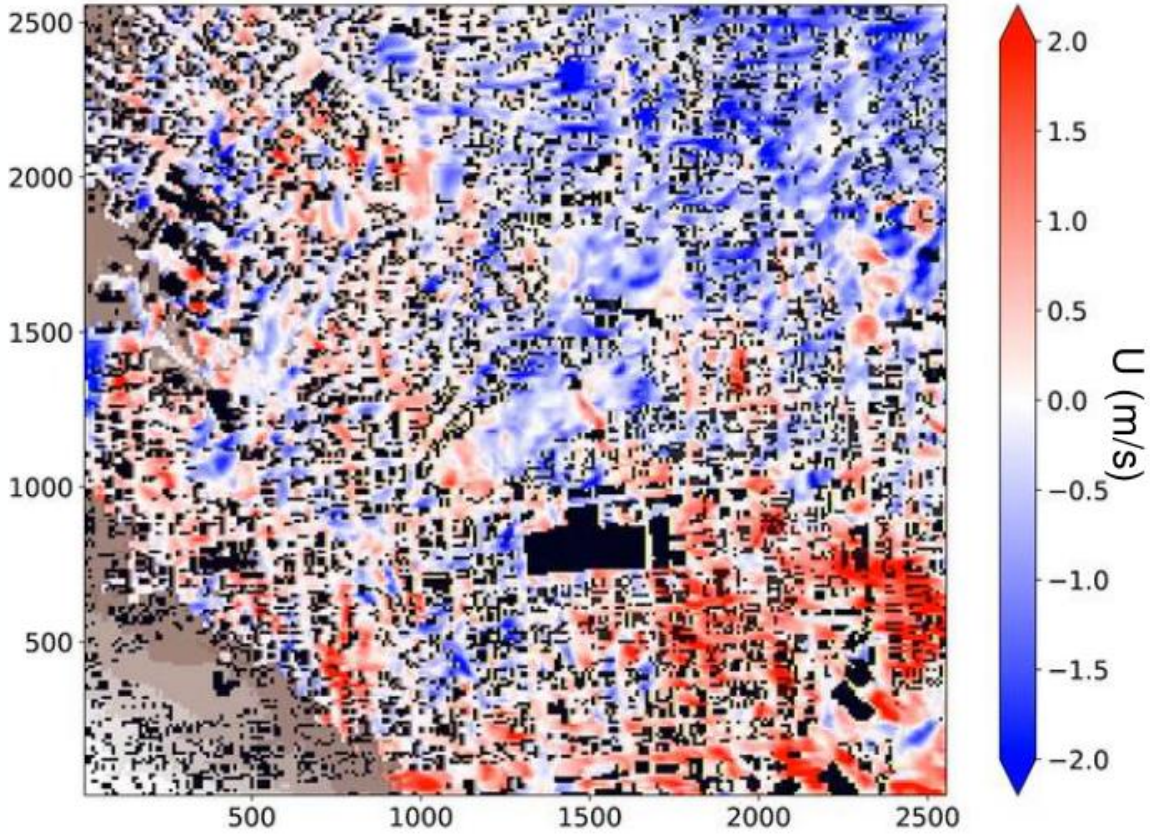




- The Weather Research and Forecasting (WRF) model
- Popular in the atmospheric research community
- Widely applicable across the world
- Free and open-source

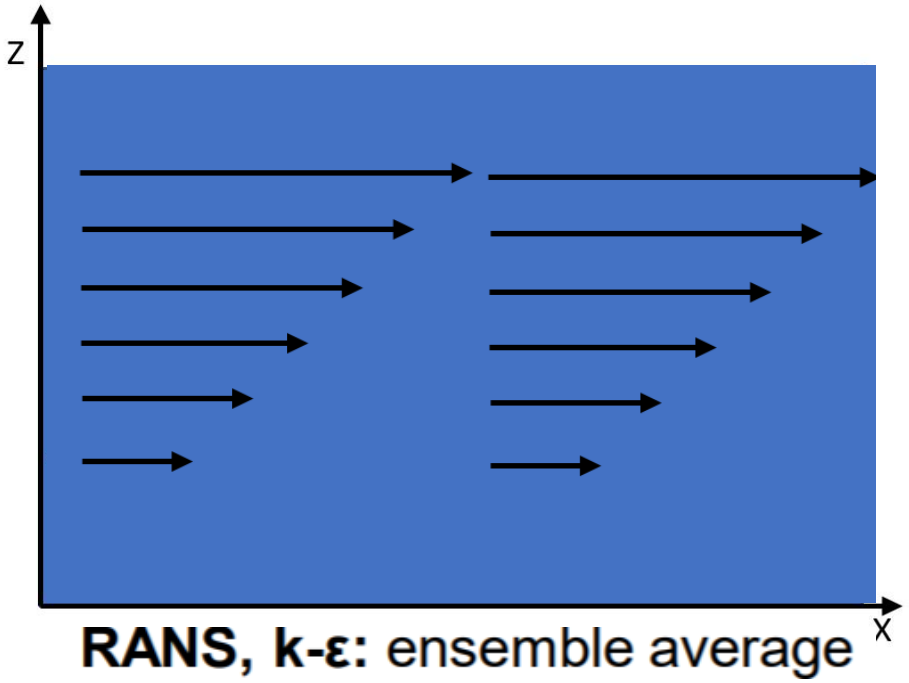
Introduction – PALM

- The Parallelised Large Eddy Simulation Model (PALM)
- Over 20 years of atmospheric and oceanic boundary layers study
- Turbulence and building resolving
- Simulate real-world environments in detail
- Free and open-source



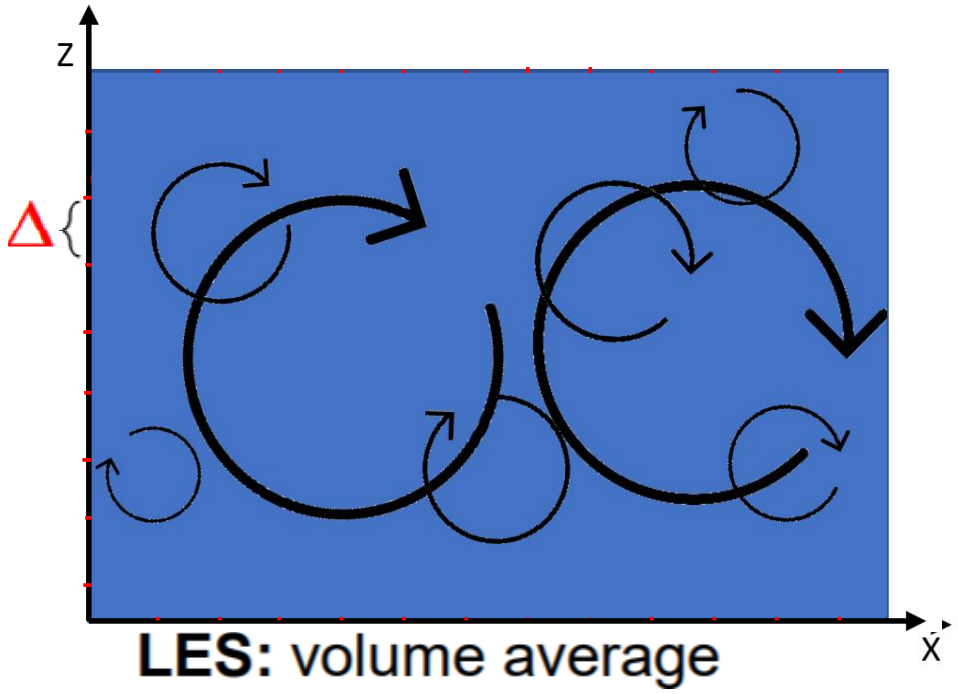
Mesoscale and Microscale

- **Reynolds Averaged (Navier-Stokes) Simulation (RANS)**
  - Parameterize turbulence over the whole eddy spectrum
  - Computationally inexpensive, fast
  - Applications that only require average statistics of the flow (i.e. the mean flow)
  - Turbulent fluctuations not explicitly captured



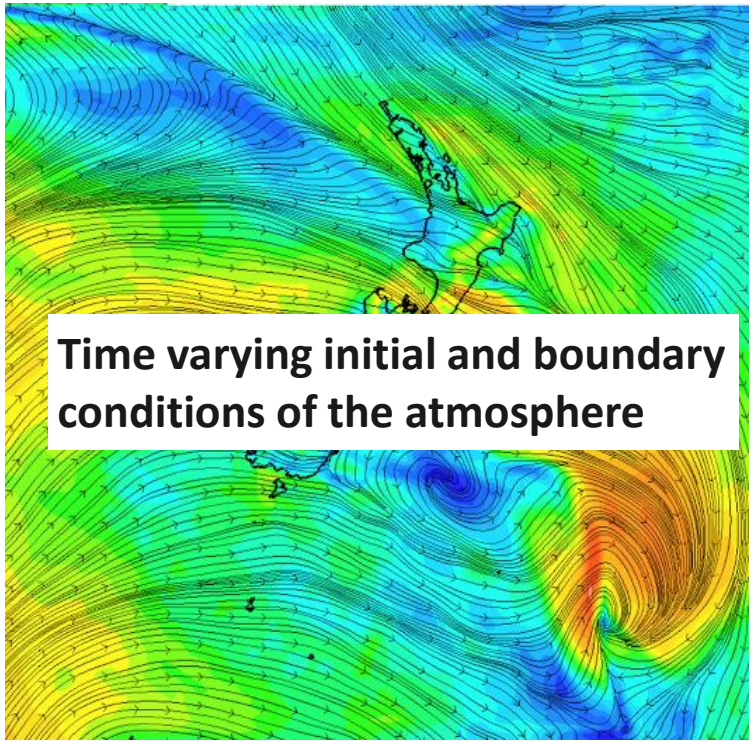
Usually for mesoscale (10^4 to 2×10^5 m)

- **Large Eddy Simulation (LES)**
  - Apply a local filter
  - Large eddies are explicitly resolved
  - The impact of small eddies on the large-scale flow is parameterized
  - Highly turbulent flows can be simulated

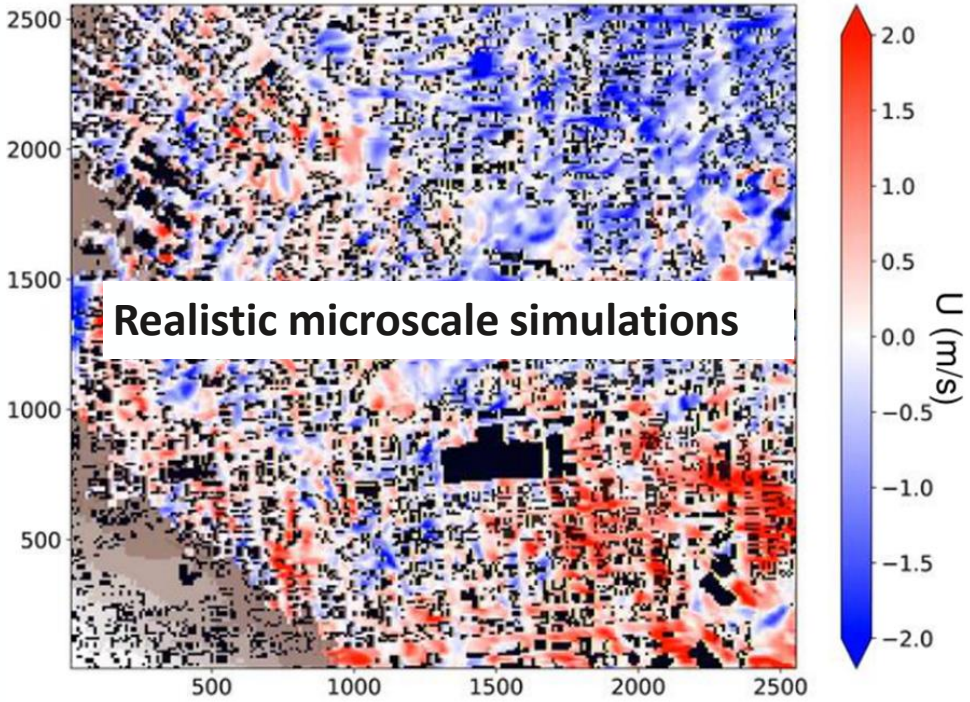


Usually for microscale (10^{-2} to 10^3 m)

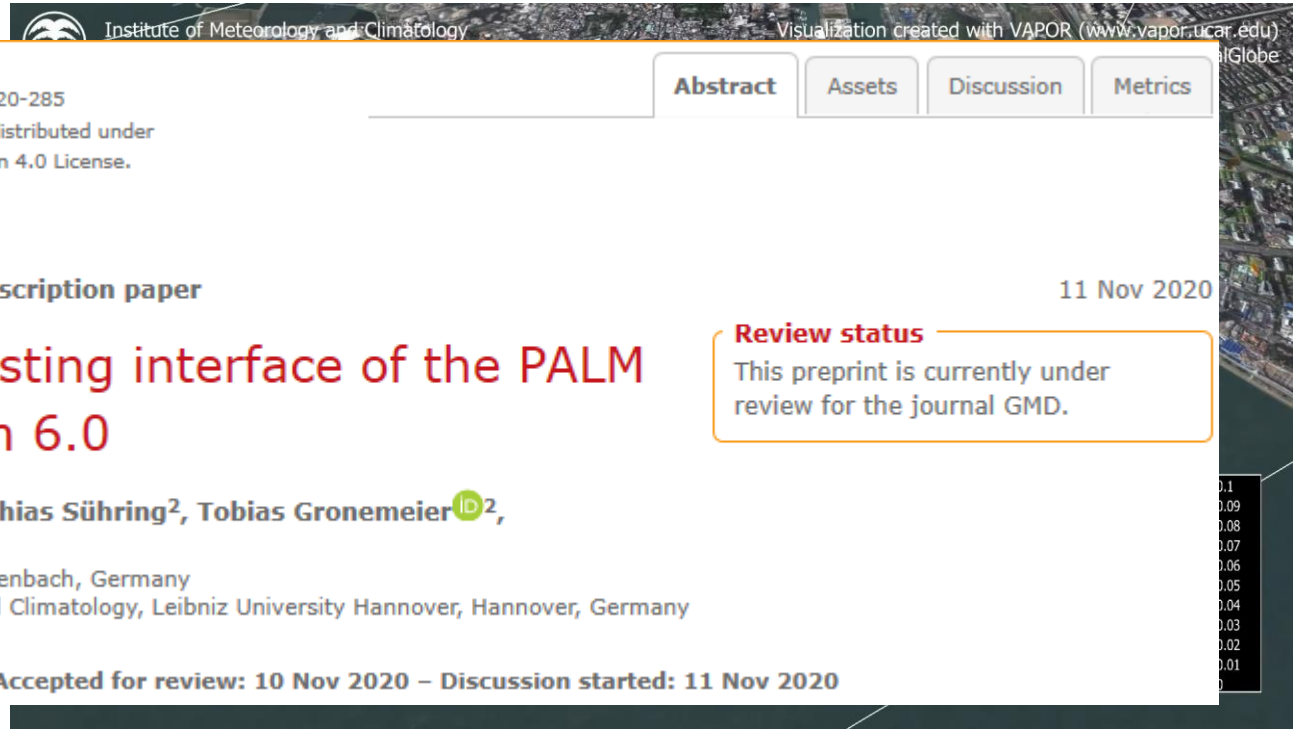
Mesoscale and Microscale



Important



Offline Nesting in PALM



Offline-nesting is realised as that:

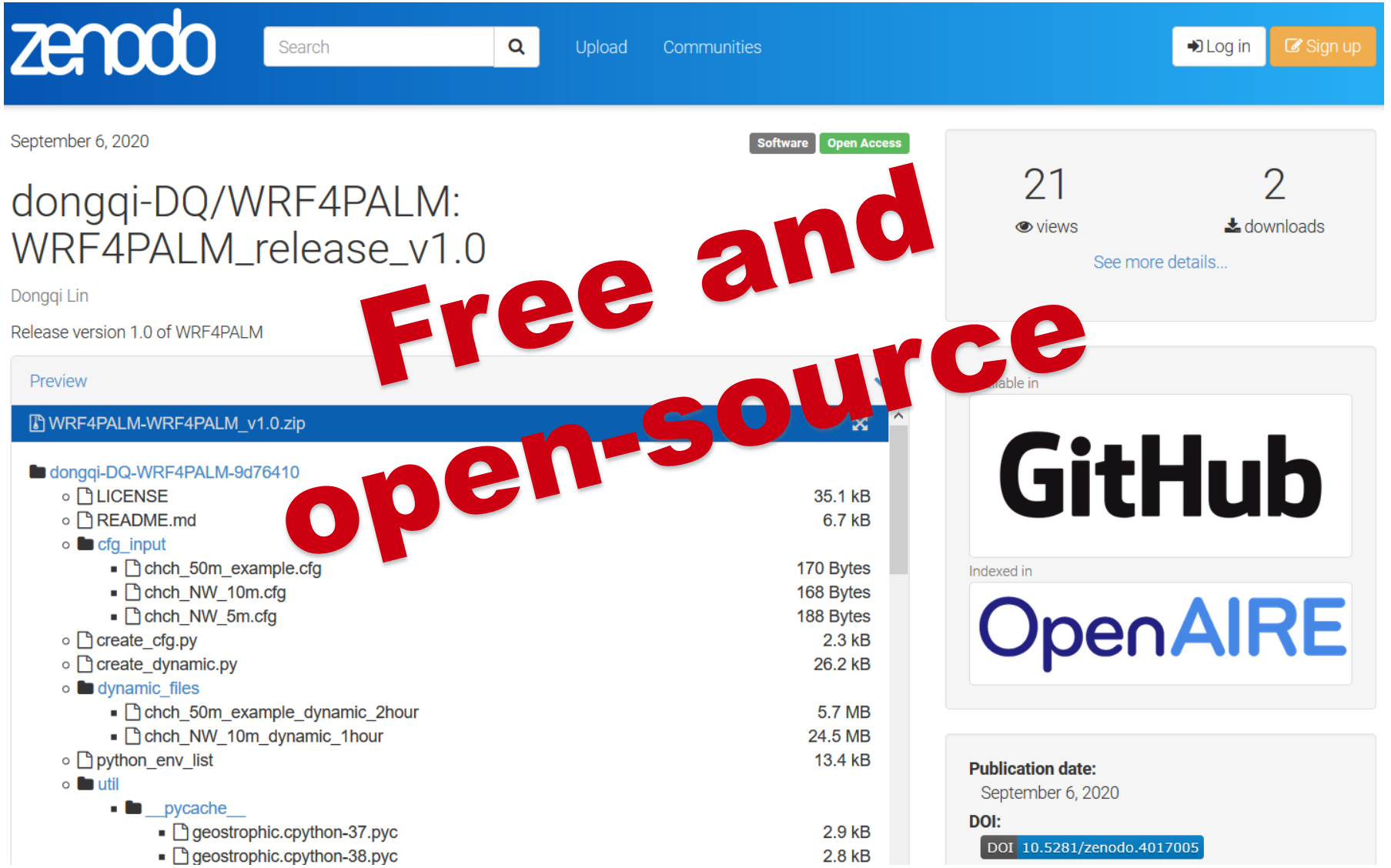
1. Mesoscale dynamical data are passed onto PALM after mesoscale simulations are finished
2. PALM does not have to run along with or provide any feedback to the mesoscale model

- PALM only implement tools to use COSMO (Consortium for Small Scale Modelling) data
- COSMO is free to use but **not** open-source
- Not currently available to many regions outside of Europe

WRF4PALM DOI 10.5281/zenodo.4017005

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha

Tools to create a dyanmic driver to enable WRF-PALM offline nesting

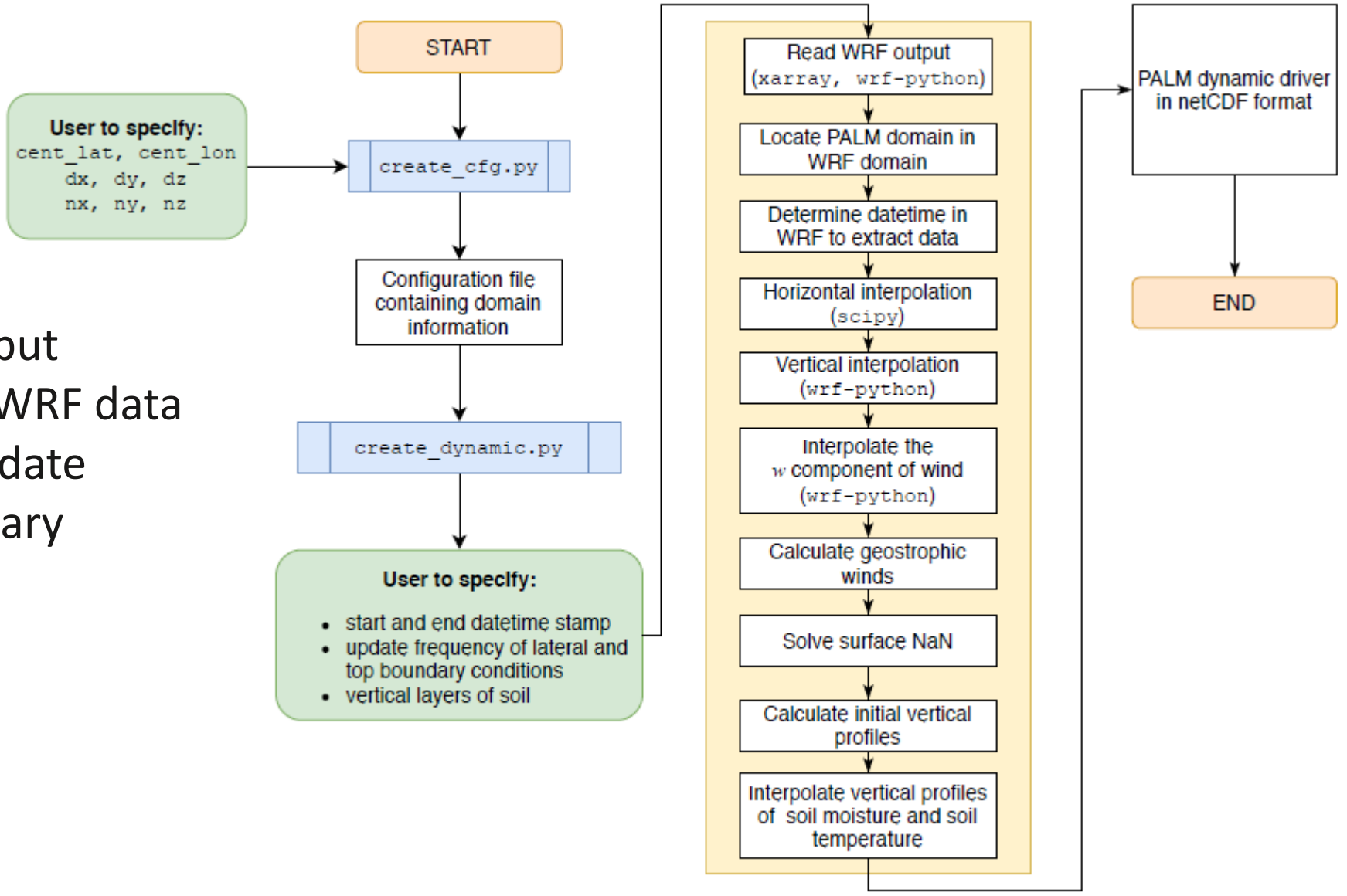


Free and open-source

WRF4PALM Framework

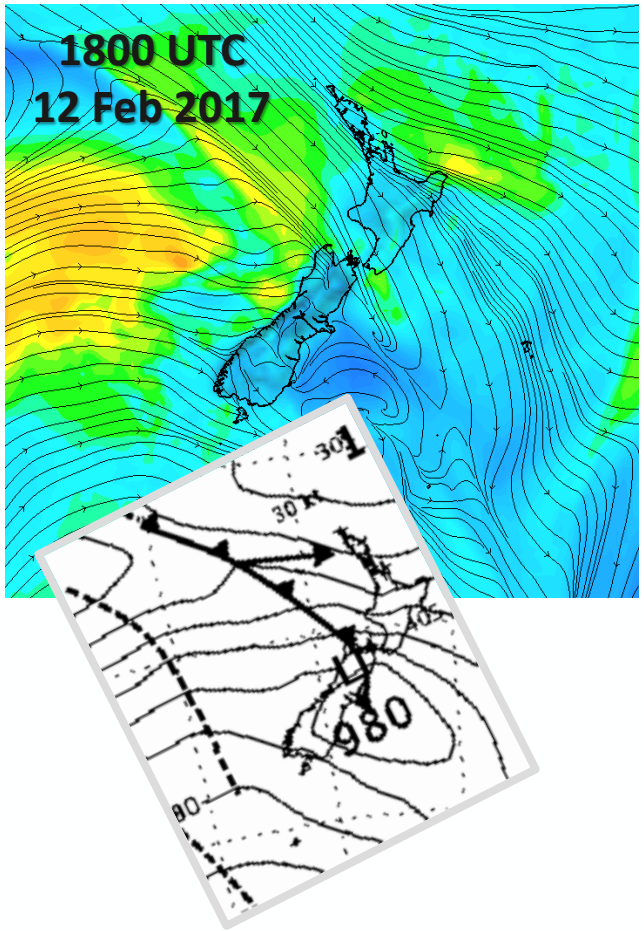
Input from users:

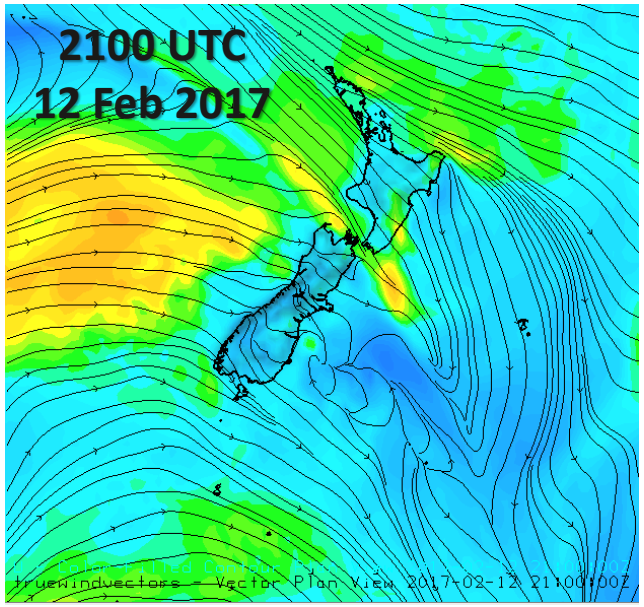
- Their own WRF output
- Location to extract WRF data
- Timestamps and update frequency of boundary conditions

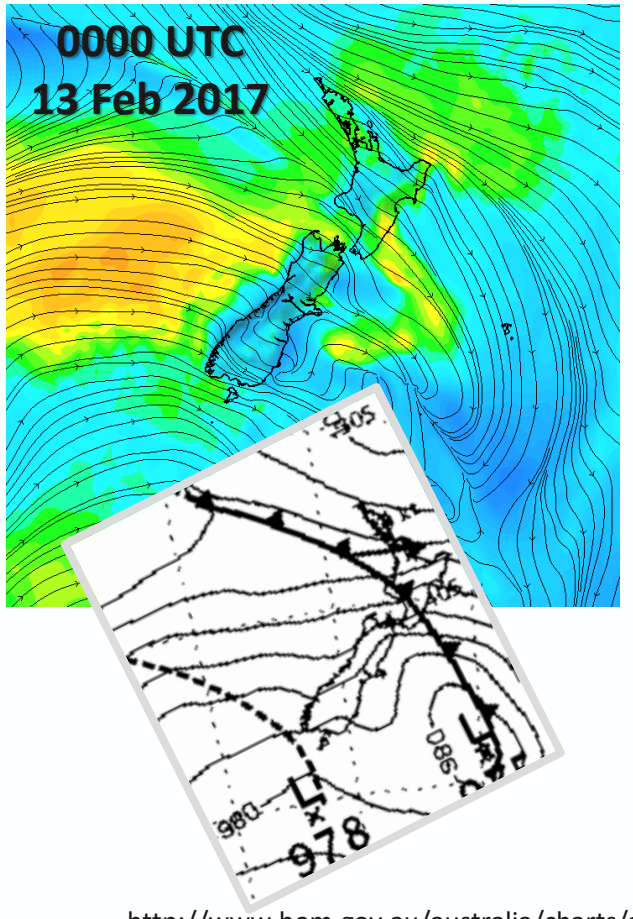


Case Study

- To verify the performance of WRF4PALM, several case studies have been carried out
- WRF is initialised with ERA5 data, the fifth generation of European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate

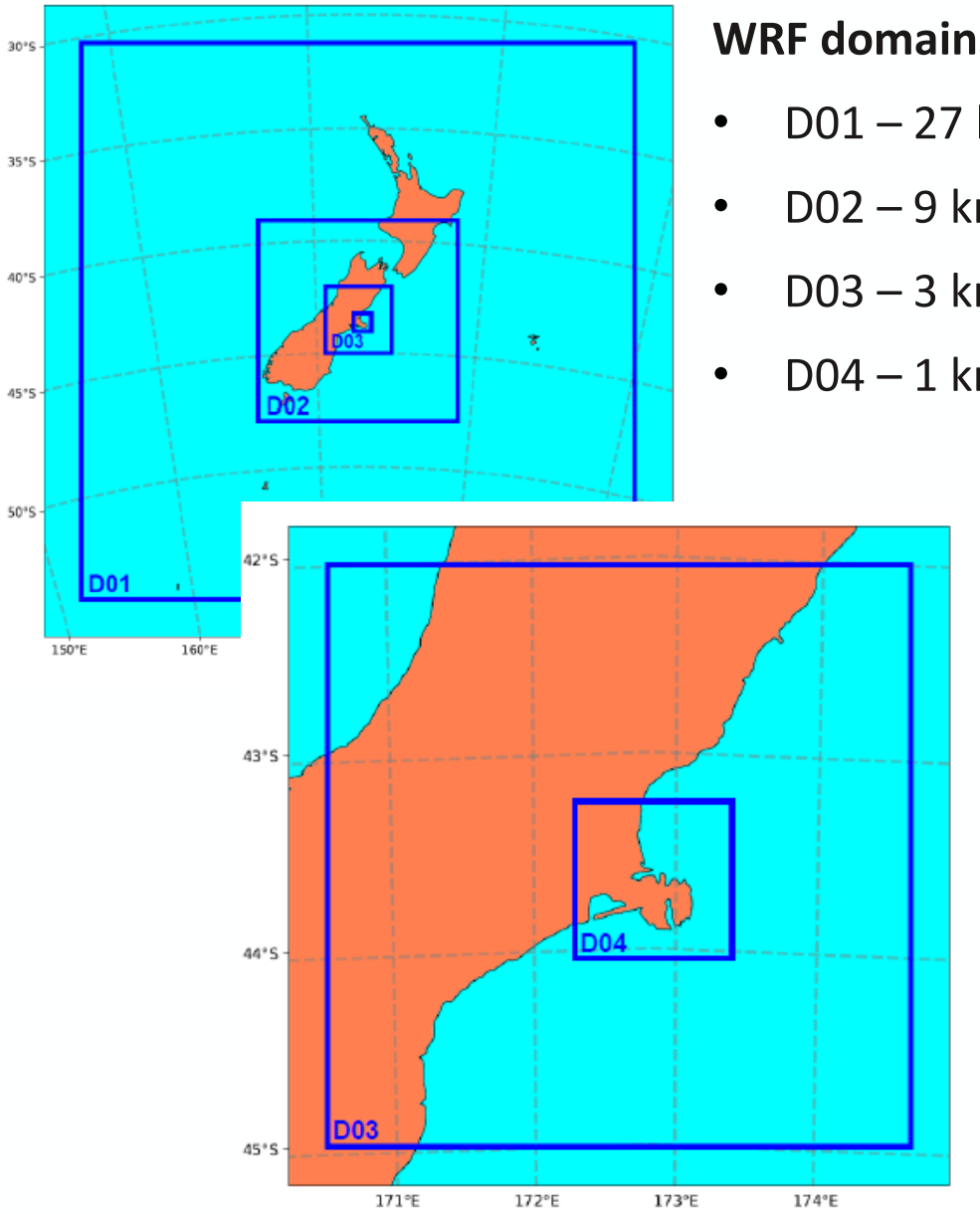






http://www.bom.gov.au/australia/charts/archive/index.shtml

Domain Configuration



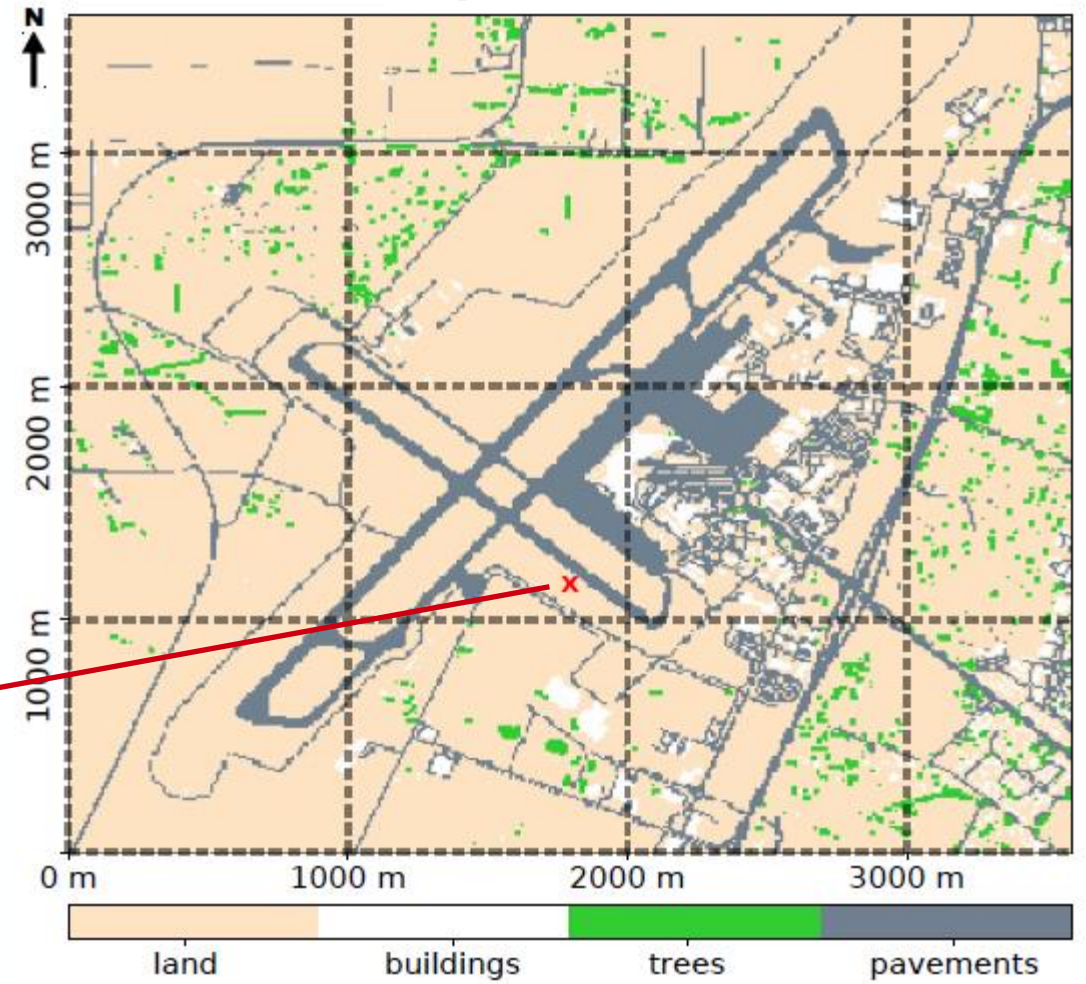
WRF domains:

- D01 – 27 km
- D02 – 9 km
- D03 – 3 km
- D04 – 1 km

PALM domain:

Directions	Total lengths	Grid points	Grid resolutions
X	3600 m	360	10 m
Y	3600 m	360	10 m
Z^+	2950 m	200	10 m

+: vertical grid resolution is trenched with a factor of 1.02 above z=1200 m with max vertical grid resolution of 30 m



AWS operated by MetService

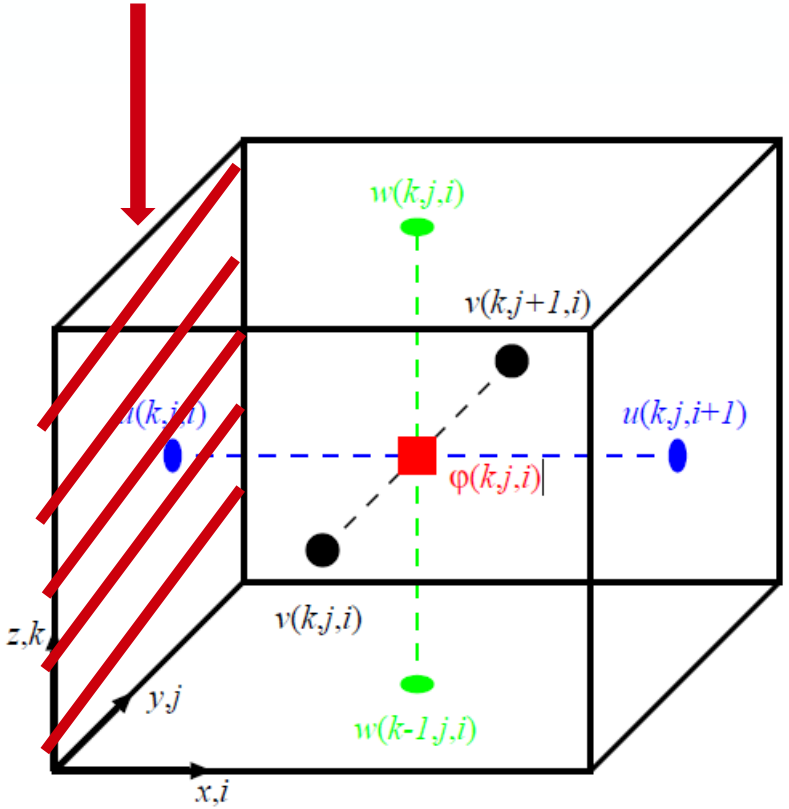
Initial and Boundary Conditions

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha

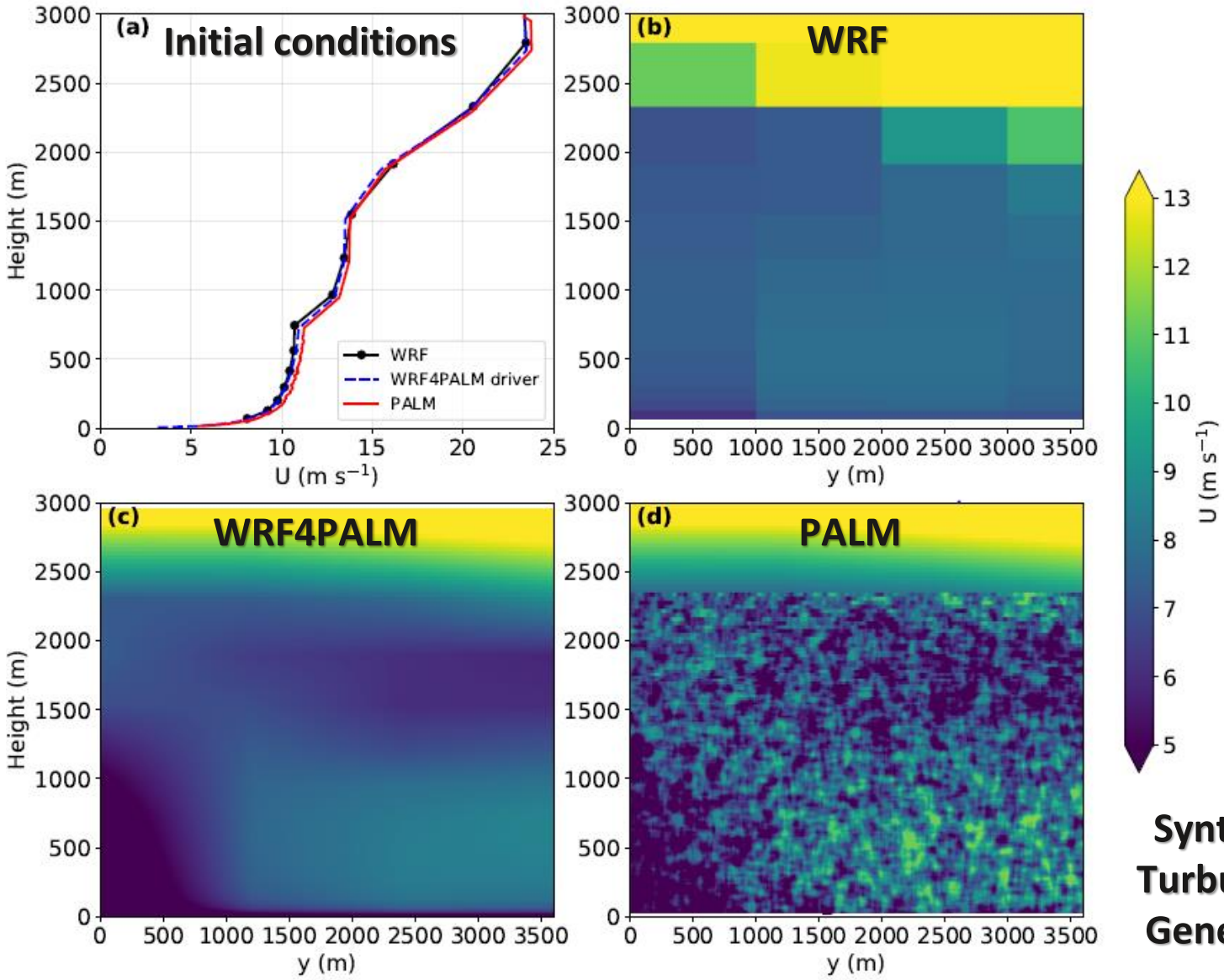
U-component of wind

1400 NZDT 13 February 2017

Left (west) boundary



Arakawa staggered C-grid



Synthetic Turbulence Generator

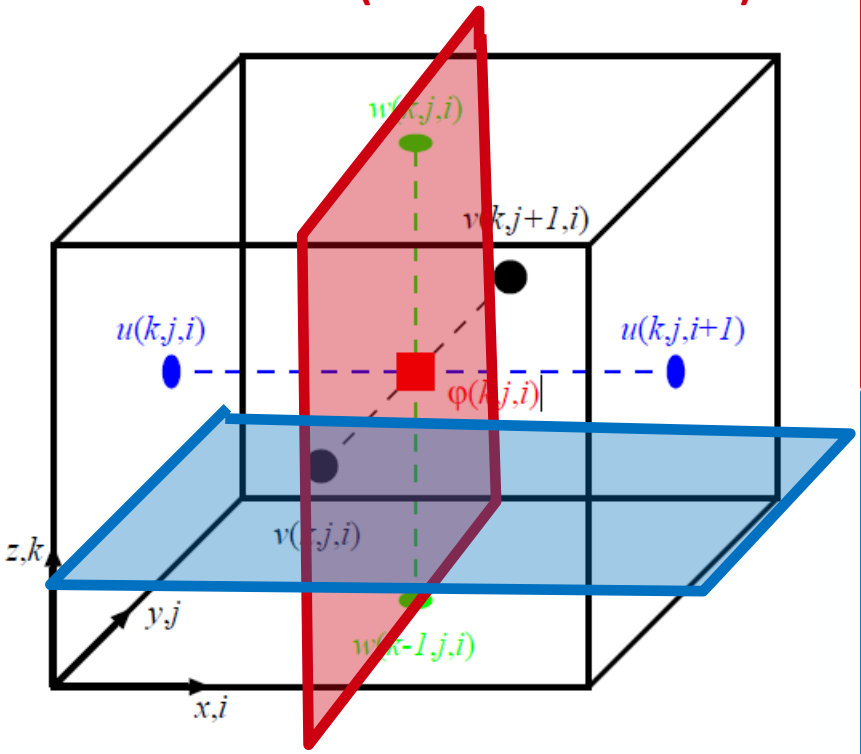
Cross-Sections in WRF and PALM

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha

U-component of wind

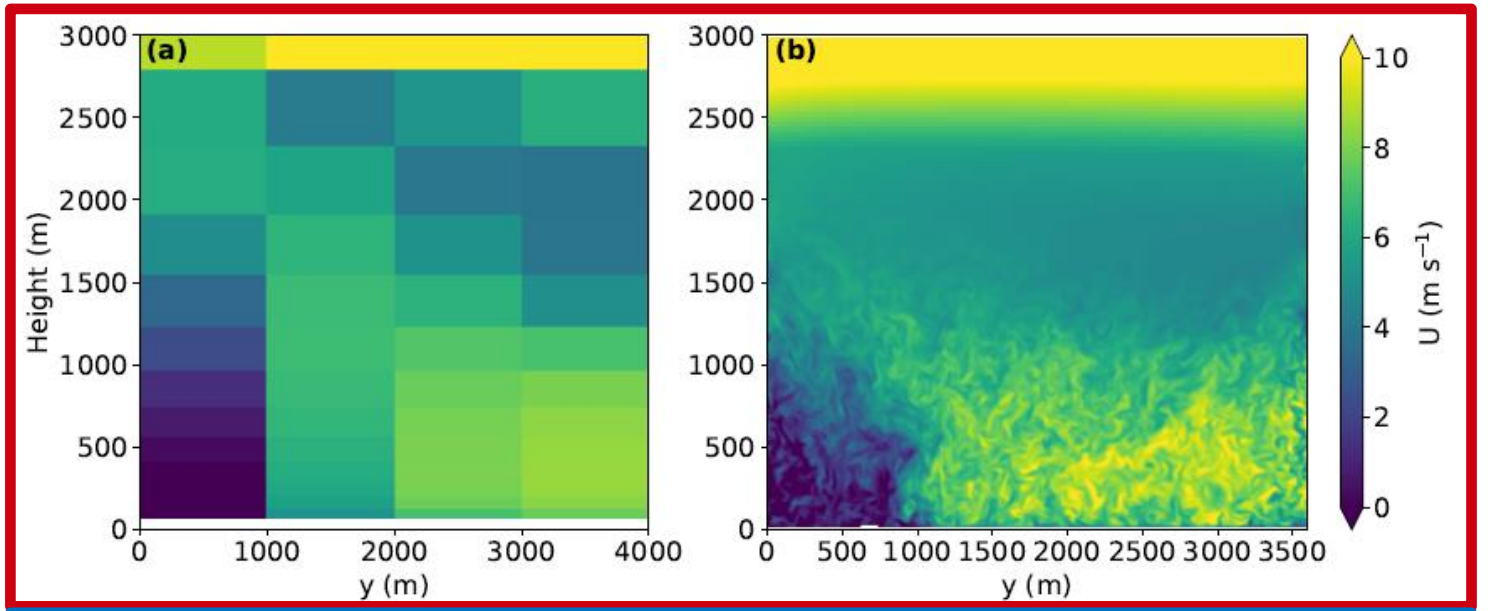
1400 NZDT 14 February 2017

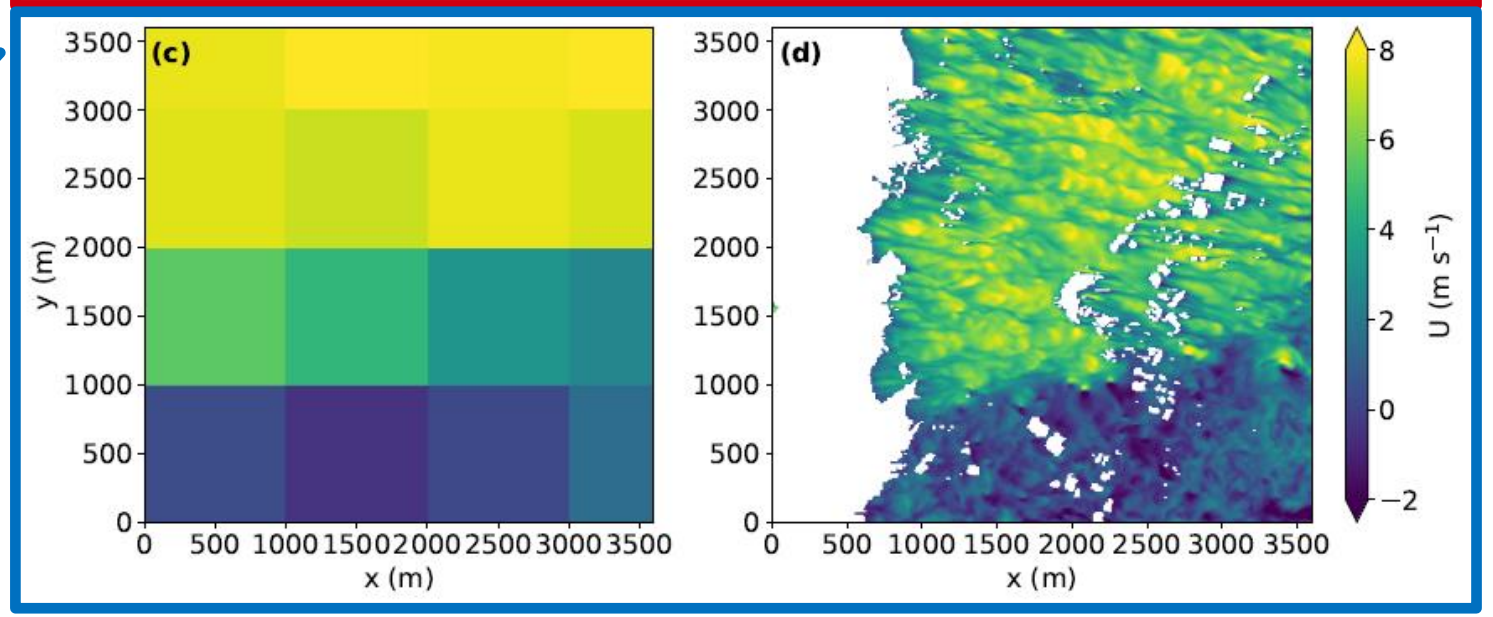
Vertical cross sections (near AWS location)



Horizontal cross sections (lowest available level)

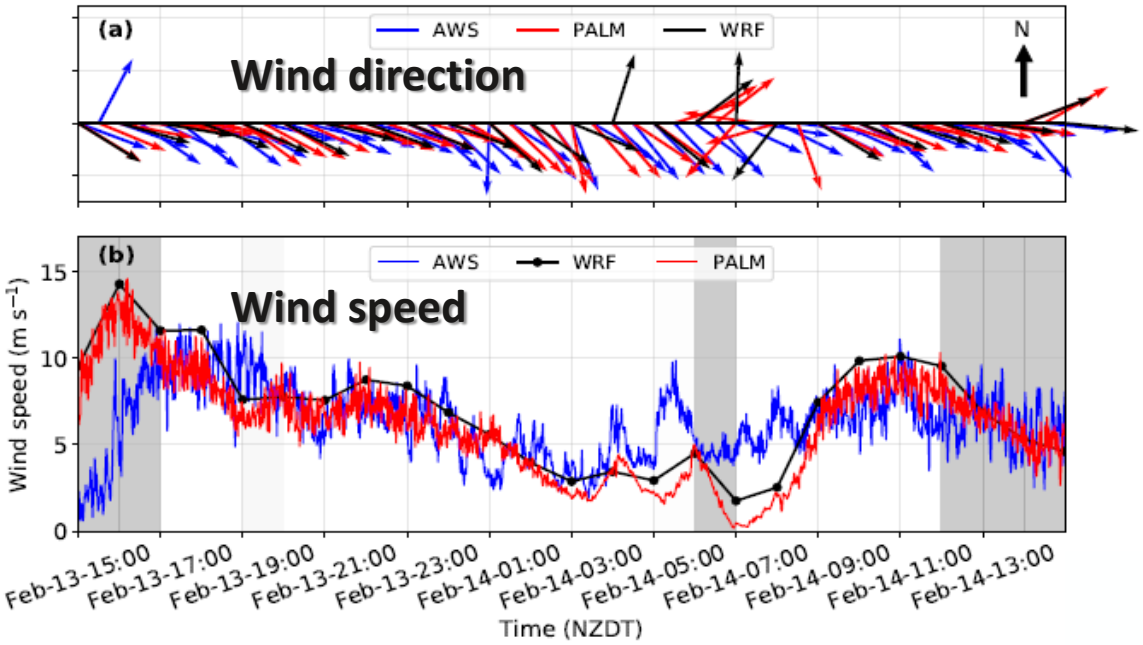
WRF **PALM**

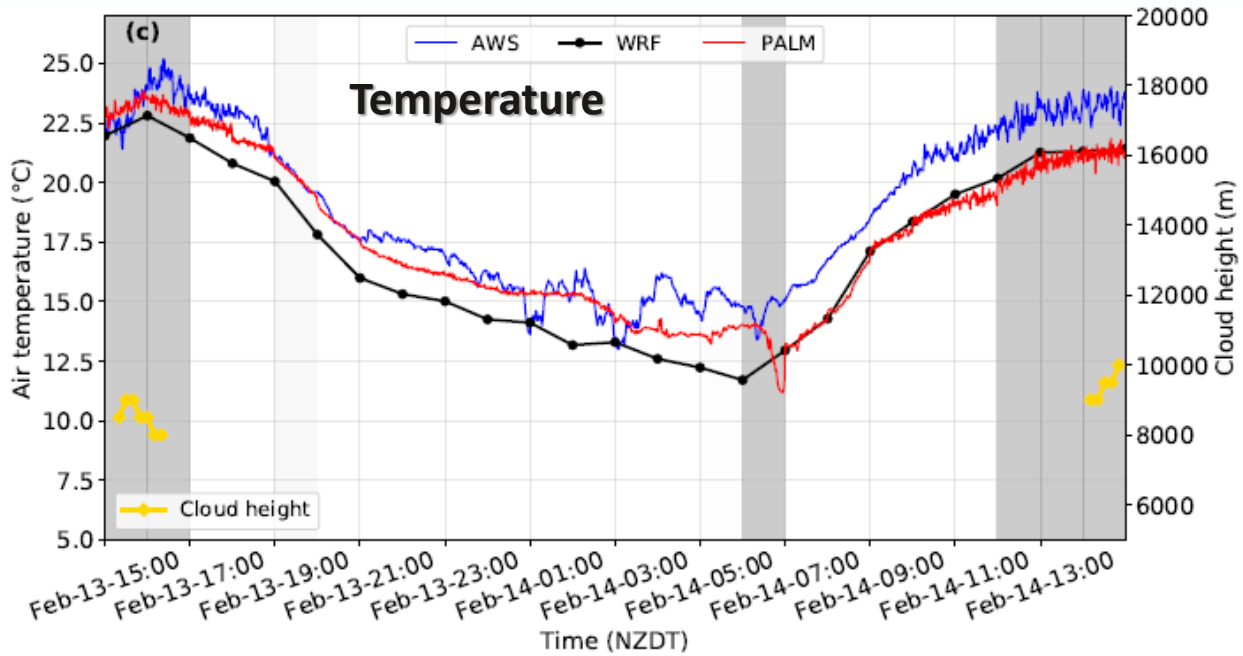




Time Series

- Comparing PALM and WRF modelled data with AWS observational data
- PALM has better Root Mean Square Error (RMSE) and Index of Agreement (IOA)





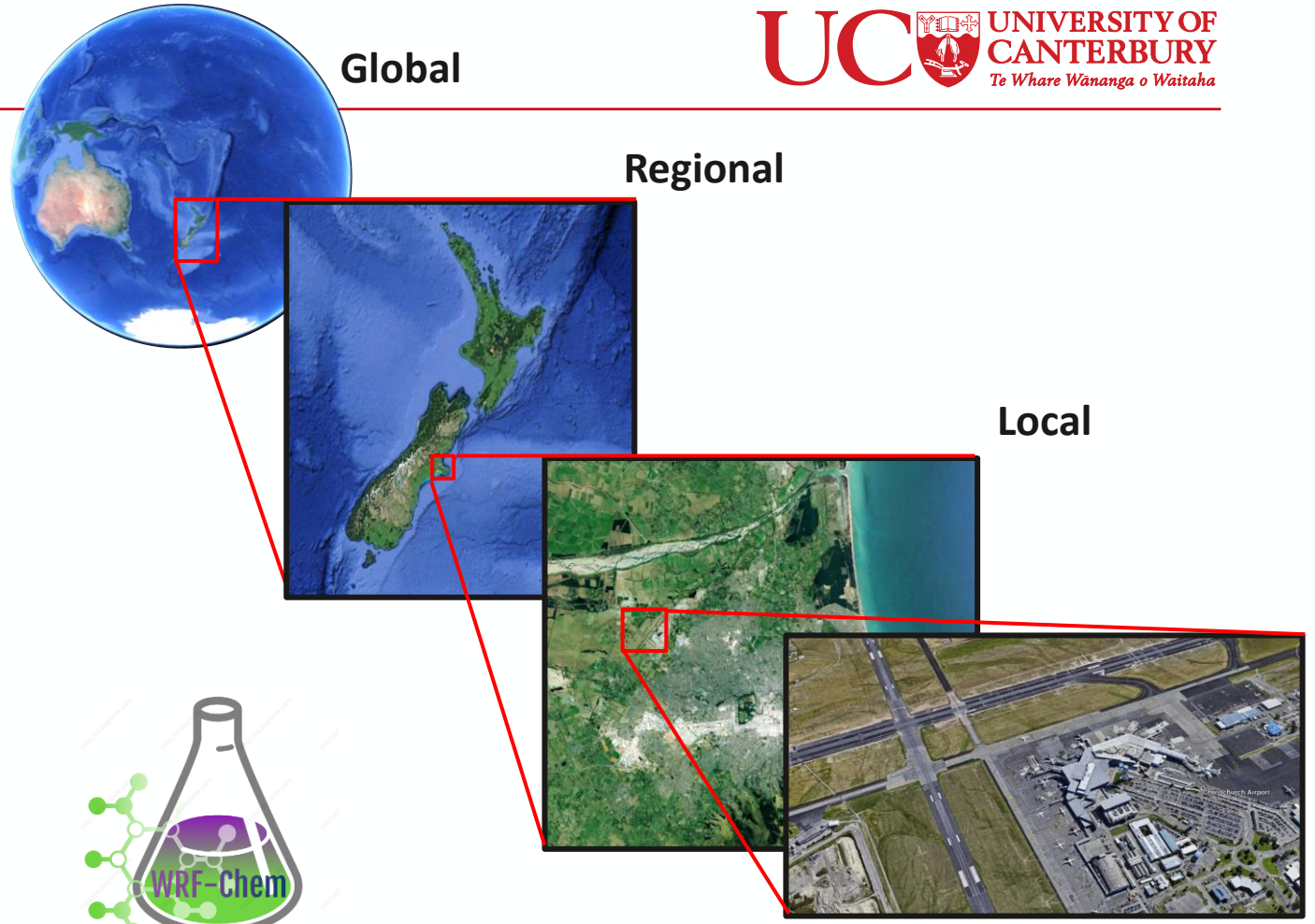
Counterparts	Temperature RMSE	Temperature IOA	Wind RMSE	Wind IOA
North-westerly Case				
AWS and WRF	2.02	0.72	2.70	0.50
AWS and PALM	1.44	0.81	2.42	0.56
WRF and PALM	0.91	0.87	1.54	0.75

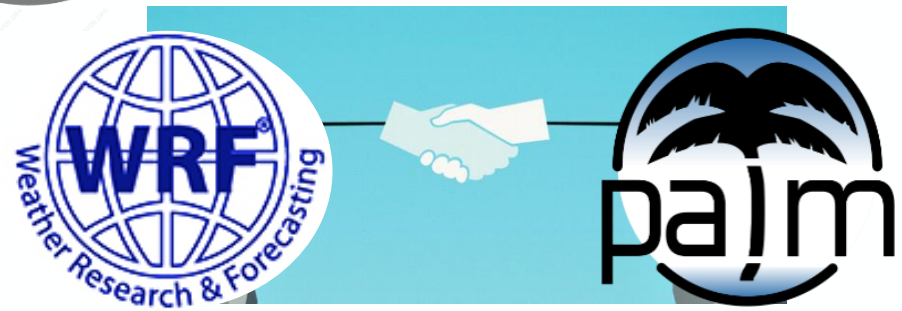
Conclusions

- Realistic mesoscale forcings are important for microscale LES
- A novel utility WRF4PALM is developed to link WRF to PALM
- Case study shows good performance of WRF4PALM
- WRF4PALM could be widely applicable for mesoscale and microscale studies

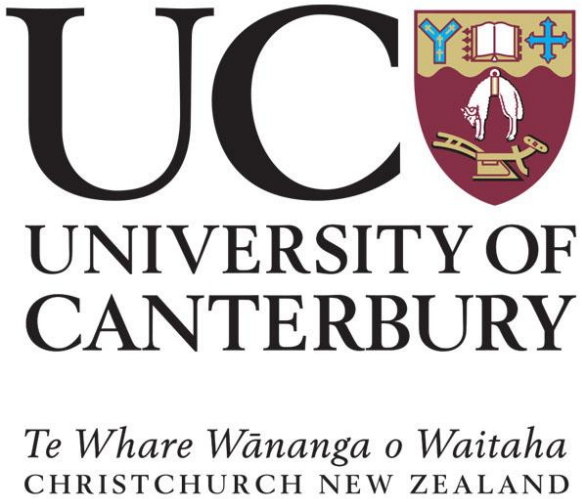
Outlook

- We will keep improving and developing WRF4PALM
- We welcome all users to optimise, modify and contribute to the code
- WRF4PALM can be used to link WRF-Chem to PALM in the future





Acknowledgments



Thank you

Lin, D., Khan, B., Katurji, M., Bird, L., Faria, R., and Revell, L. E.: WRF4PALM v1.0: A Mesoscale Dynamical Driver for the Microscale PALM Model System 6.0, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2020-306, in review, 2020.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND