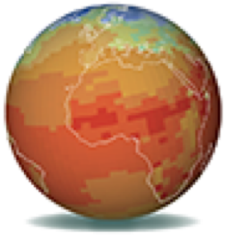

climateprediction.net

the world's largest climate modelling experiment for the 21st century

Expanding the climateprediction.net project: the creation of a multi model distributed computing infrastructure for climate science

Department of Engineering Science, Oxford, UK

Andy Bowery · Sarah Sparrow · David Wallom

ECMWF, Reading, UK

Glenn Carver · Marcus Köhler

Department of Atmospheric Physics, Oxford, UK

Antje Weisheimer

University of Canterbury, Christchurch, New Zealand

Dongqin Lin · Marwan Katurji

NIWA, New Zealand

Suzanne Rosier

ECMWF

Oxford Physics

Oxford e-Research Centre

DEPARTMENT OF ENGINEERING SCIENCE

UNIVERSITY OF OXFORD

Computational challenge of weather and climate science

climate*prediction*.net (C*P*DN)
Climate Modeling with Volunteer Distributed Computing

- **CPDN** has been running for **15 years**
- CPDN is a **citizen science project** that uses **BOINC**
- Enables the computation of **very large ensembles of climate simulations** using **spare computing cycles** of volunteers
- **Low cost**, free computation, only pay for infrastructure
- Allows **unlimited ensemble size of climate simulations**
- **Disadvantages:**
  - Limited diagnostics and resolution
  - All mistakes are in public

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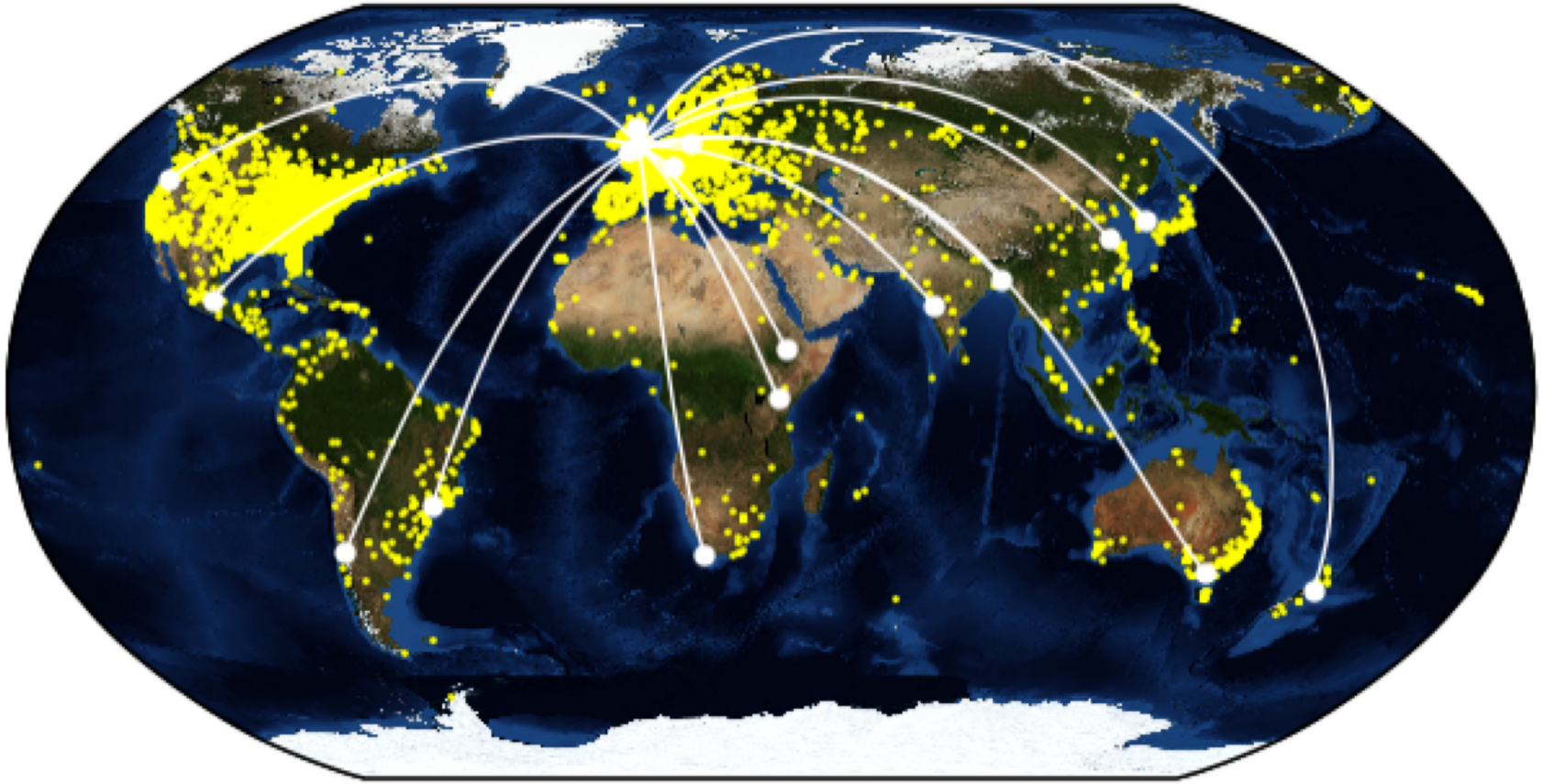
CPDN Volunteer Network



15 years, >30 sub projects, >650,000 volunteers, >200M model-years

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Berkeley Open Infrastructure for Network Computing (BOINC)

- **Volunteer distributed computing** framework

- Used by a **variety of academic projects**, across a variety of scientific disciplines

- Maintained by an **open source** community

- **L-GPL** 3.0 licensed

- Allows the use of volunteer computational resources, **computational cycles** that would have gone to waste

- Allows multiple applications in the same BOINC project, this allows CPDN to **run multiple models concurrently**

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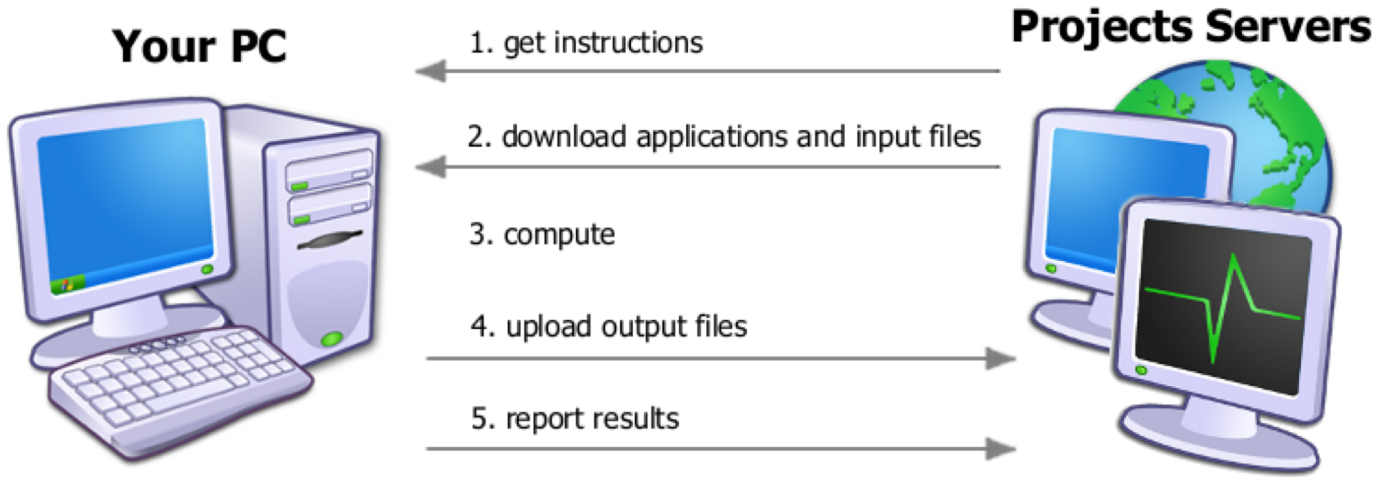
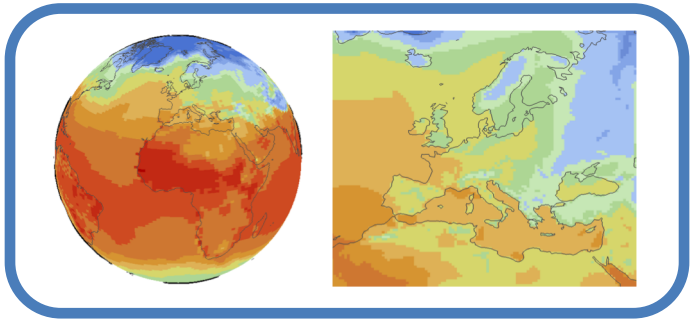
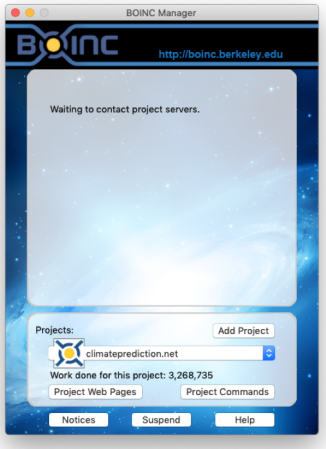
Berkeley Open Infrastructure for Network Computing (BOINC)







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Models

HadCM3

- Previous generation MetOffice Forecast model
- Resolution: N48 L19 atmosphere, 1.25x1.25 L20 ocean.

HadAM4

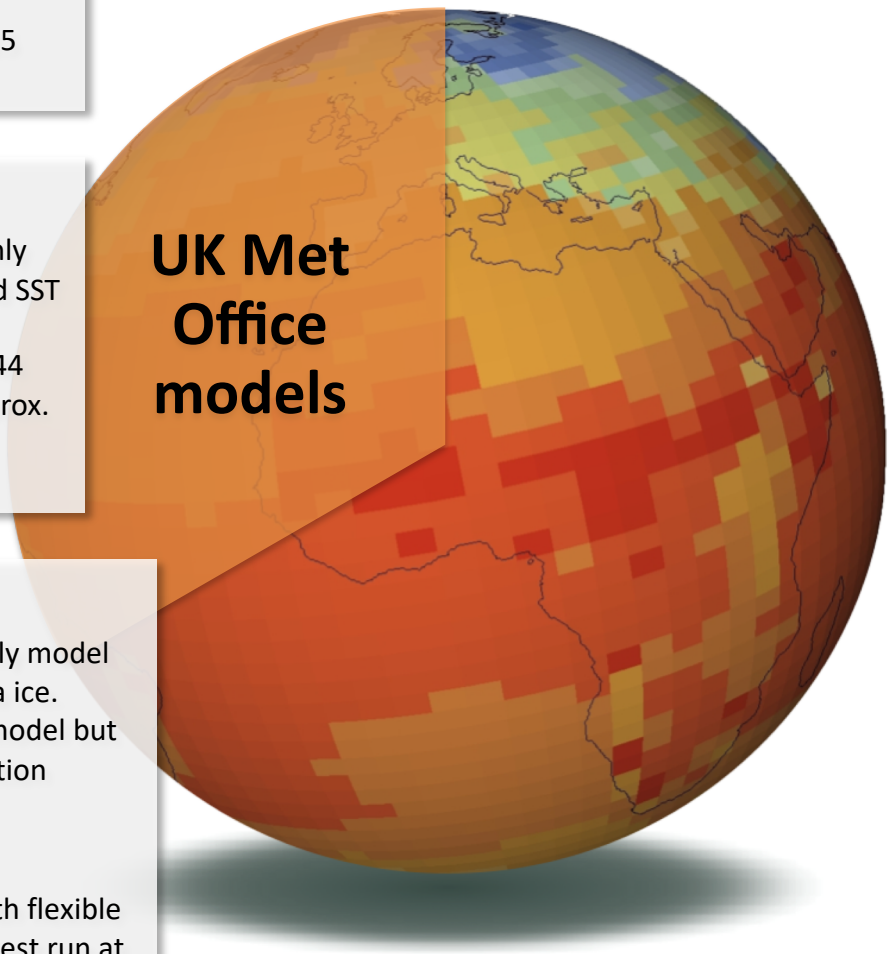
- Global atmosphere only model with prescribed SST and sea ice.
- Resolution: Either N144 L38 or N216 L38 (approx. 90km or 60km respectively)

HadAM3P

- N96 Global Atmosphere only model with prescribed SST and sea ice.
- Used as driver of regional model but capable of individual operation

HadRM3P

- Regional Climate Model with flexible user defined region of interest run at either 25 km or 50 km.



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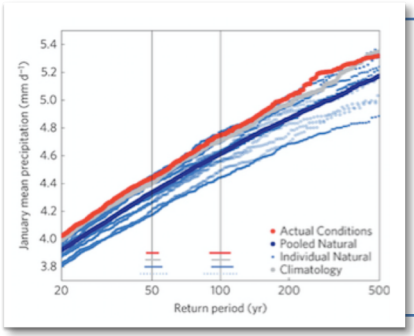
Current CPDN Experiment Types

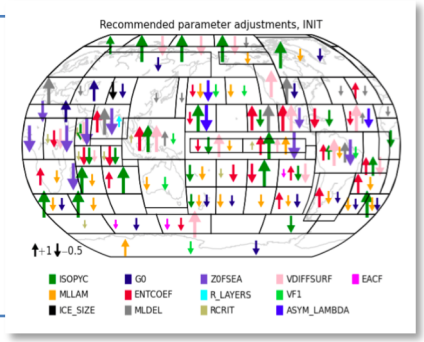


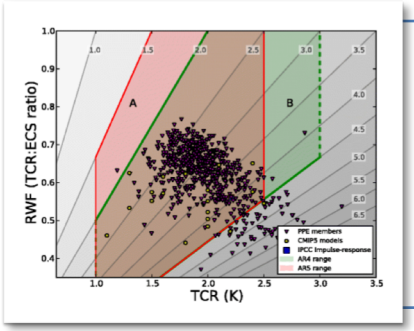
Extreme weather event attribution:

Quantitative assessments are made of the change in likelihood of extreme weather events occurring between past, present and possible future climates.

Bias reduction methods:

Improved skill for initialised climate model forecasts, through bias reduction from global and regional process adjustment in perturbed parameter sensitivity studies.





Climate sensitivity studies:

Mapping plausible ranges of climate sensitivity through large perturbed parameter ensembles.

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Missing from CPDN

- *However* with the UK Met Office models in CPDN:
  - We are not able to do **seasonal forecasts** of the weather
  - We are not able to do **fine-scale** climate modeling

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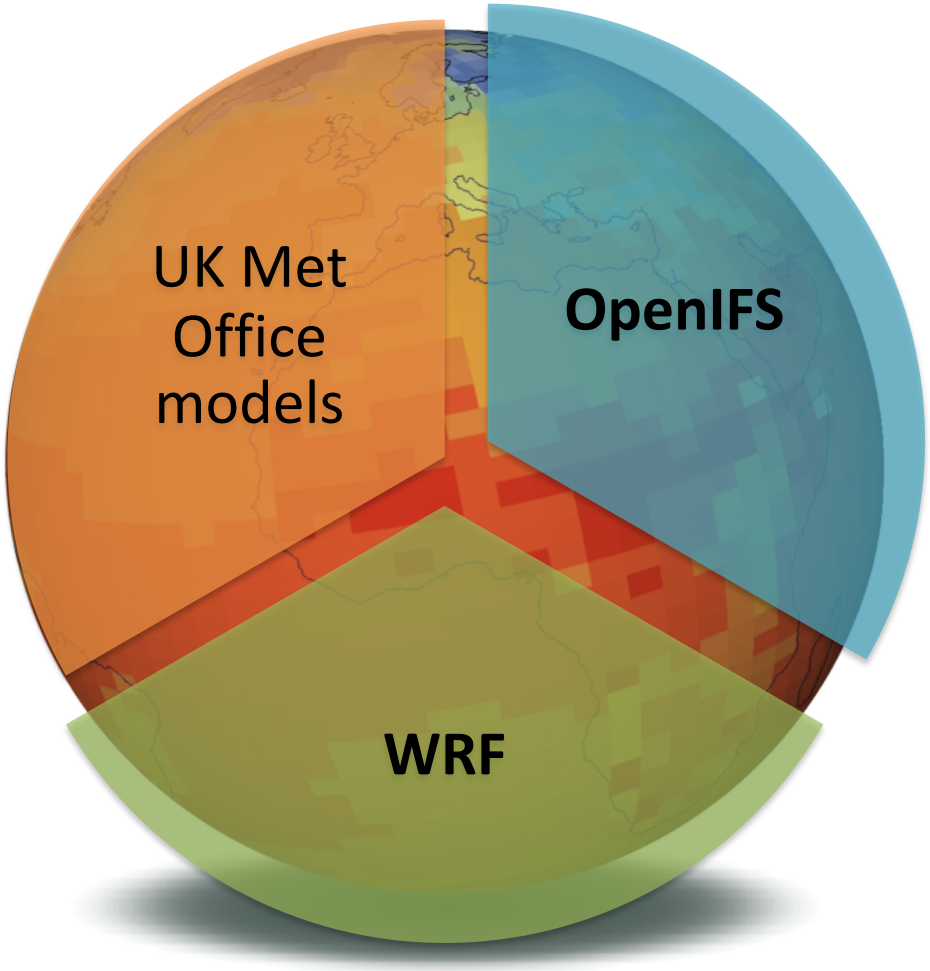
Adding new models to CPDN



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Considerations for adding new models to CPDN

- **Scientific user considerations:**
  - **Large user community** of scientists
  - Model needs to be able to run on a single machine at sufficient simulation **resolution** and produce **timely results** that are still **scientifically useful**

- **Technical considerations:**
  - Available for one or more of the supported platforms: **Linux**, **Mac**, or **Windows**
  - Model is **portable** to run on a volunteer's machine without the installation of further executables
  - Does not excessively use **network bandwidth** of volunteer

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OpenIFS suitability for CPDN

- **Scientific user suitability:**
  - **Large user community** of atmospheric scientists

- **Technical suitability:**
  - **Open source**, **portable** version of the **ECMWF (European Centre for Medium Range Weather Forecast) IFS** numerical weather forecast model for universities and research institutes, it has the same forecast capability as IFS but no data assimilation
  - Designed to work **efficiently** across a range of computing systems, from massively parallel high-performance computing systems to a desktop
  - Produces the standard **GRIB format** (WMO) files that are optimized for low data transmission rates

Introducing OpenIFS@home

- Added OpenIFS into CPDN as '**OpenIFS@home**'
  - enables large ensemble initialized probabilistic *weather forecasts* to be run by CPDN public volunteers
  - provide a novel and new platform for scientific experiments with OpenIFS
- **Model configuration:**
  - 125km or 60km approx. resolution (T159 and T255) with 60 or 91 vertical levels

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Adaptations made to OpenIFS model for OpenIFS@home

- Parallel execution is not needed so the **MPI** parallel library was **removed** this reduced memory footprint and size of executables

- Addition of model **restarting capability**, to ensure stop-start is handled on volunteer's machines

- Custom change to the output files to allow **larger ensembles** beyond 255 members

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New experiments enabled with OpenIFS@home

Large ensembles to study the **predictability** of weather forecasts especially for high impact extreme weather

Explore interesting past weather and climate events will be explored by **testing sensitivities to physical parameter choices** in the model

Study of probabilistic forecasts in a chaotic atmospheric flow and reduce uncertainties due to nonlinear interactions

Current OpenIFS experiments can be run in OpenIFS@home

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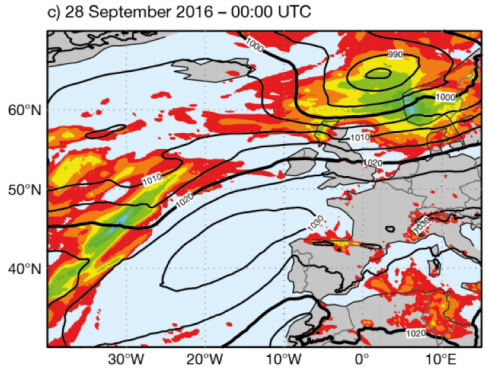
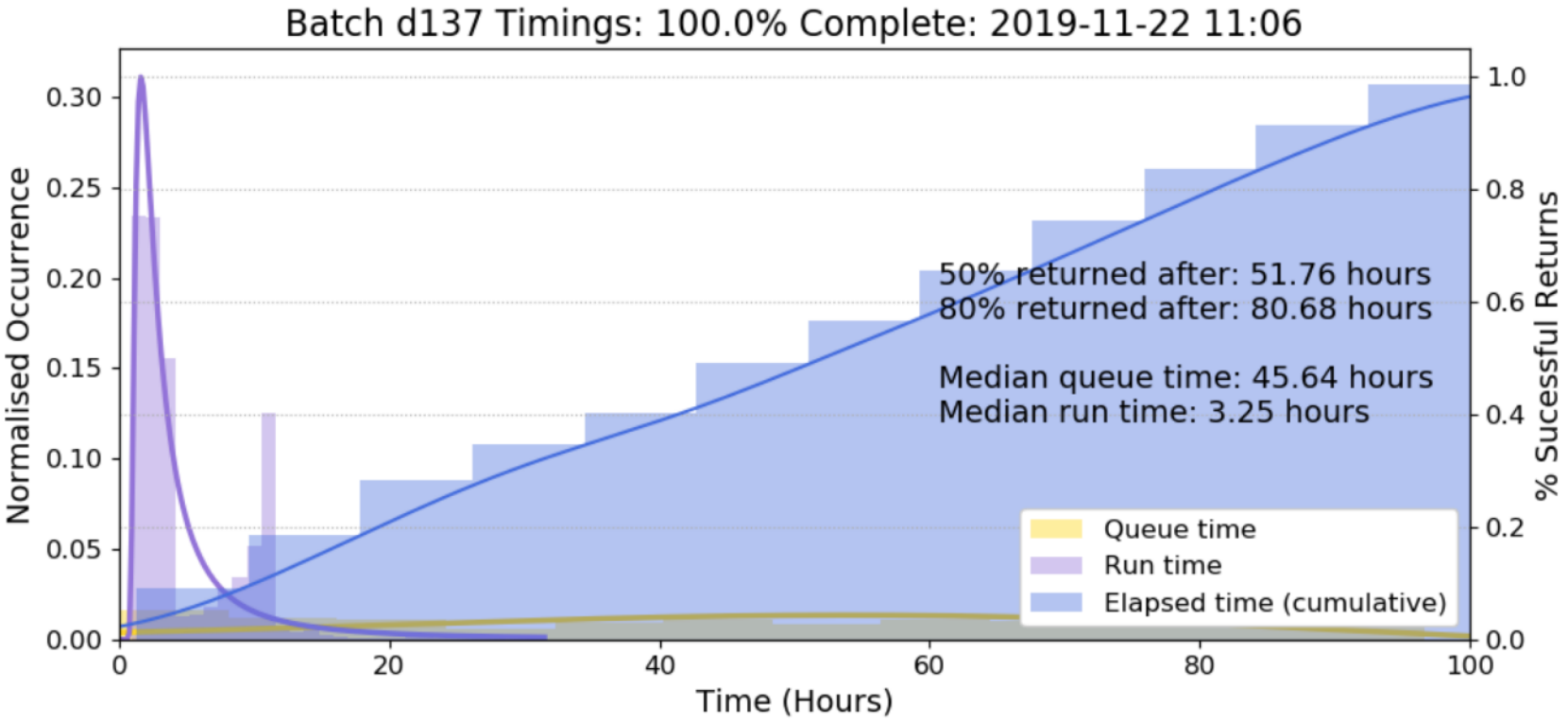
OpenIFS@home Validation using Storm Karl Ensemble



Sept 2016



- Forecasts with **2000 ensemble members** were generated for 8 days ahead and computed by volunteers in CPDN in **4 days**, a **scientifically useful timeframe**

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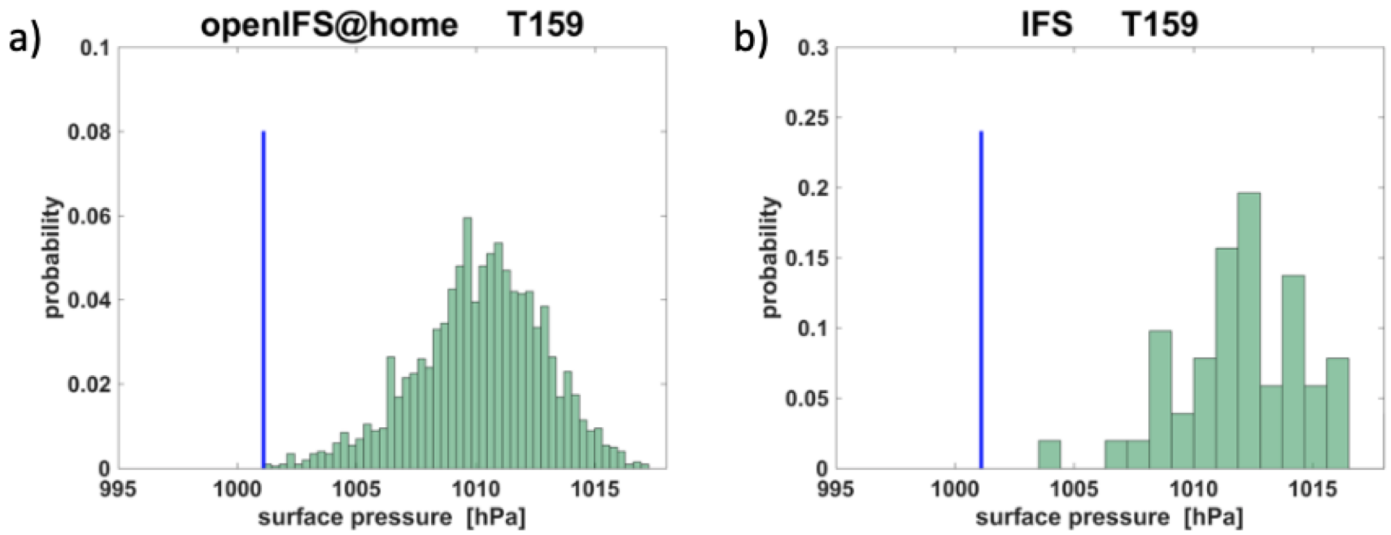
OpenIFS@home Validation Results



- OpenIFS@home provides the **same results** as the smaller ensemble of IFS runs produced on ECMWF HPC
- Large number of runs in OpenIFS@home provide **greater detail** than IFS

Publication: *Sparrow, S., Bowery, A., Carver, G.D., Köhler, M.O., Ollinaho, P., Pappenberger, F., Wallom, D., Antje Weisheimer, A.*: **OpenIFS@home version 1: a citizen science project for ensemble weather and climate forecasting.** Geoscientific Model Development (2021).

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Weather Research and Forecasting (WRF) model

- WRF is produced through a collaboration led by National Center for Atmospheric Research (**NCAR)**
- It is a next-generation regional **numerical weather prediction** (NWP) system designed for both **atmospheric research** and **operational forecasting**
- **Open source** and available in the **public domain**
- Serves a **wide range of scales** of meteorological applications from tens of meters to thousands of kilometres
- Can be used for **simulations using actual data** or ideal conditions, **or operational forecasting**

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WRF suitability for CPDN

- **Scientific user suitability:**
  - **Large worldwide community** of scientific users (a cumulative total of over **48,000** in over **160** countries)

- **Technical suitability:**
  - Executables are **portable** and can be run on **single core Linux** systems

  - Can distribute to volunteers' computers the self-contained WRF program for real-data (**real.exe**) (performs the work of vertically interpolating meteorological fields) and the numerical integration program (**wrf.exe**)

  - It is a **Fortran** application available for a number of **OS's** and **compilers,** on a variety of **hardware**, including:
    - **OS**: Linux, AIX, Darwin
    - **Compilers**: Intel, PGI, gfortran, PathScale
    - **Hardware**: Cray, IBM, SGI, Mac, Fujitsu

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New functionality enabled by WRF in CPDN

- WRF in CPDN enables new experiments:
  - Enables **finer scale simulations** than currently can be performed with the UK Met Office models
  - Enables problems to be examining where large ensembles would be useful, currently the WRF community cannot **explore WRF model uncertainties**

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Control code for OpenIFS@home and WRF in CPDN

- Control code is a **key** component, time needs to be spent for it work properly
- Handles the **communication with BOINC client** software on the volunteers' computer
- Controls the operation of the model on the volunteers' computer, including all parameters, and simulation file structure
- Handles all states of the volunteer's machine, including **paused**, **shutdown** and **aborted**
- Provides regular uploads and deleting data uploaded to prevent the build up of data on the volunteers' computer
- Code is **open source** and available online

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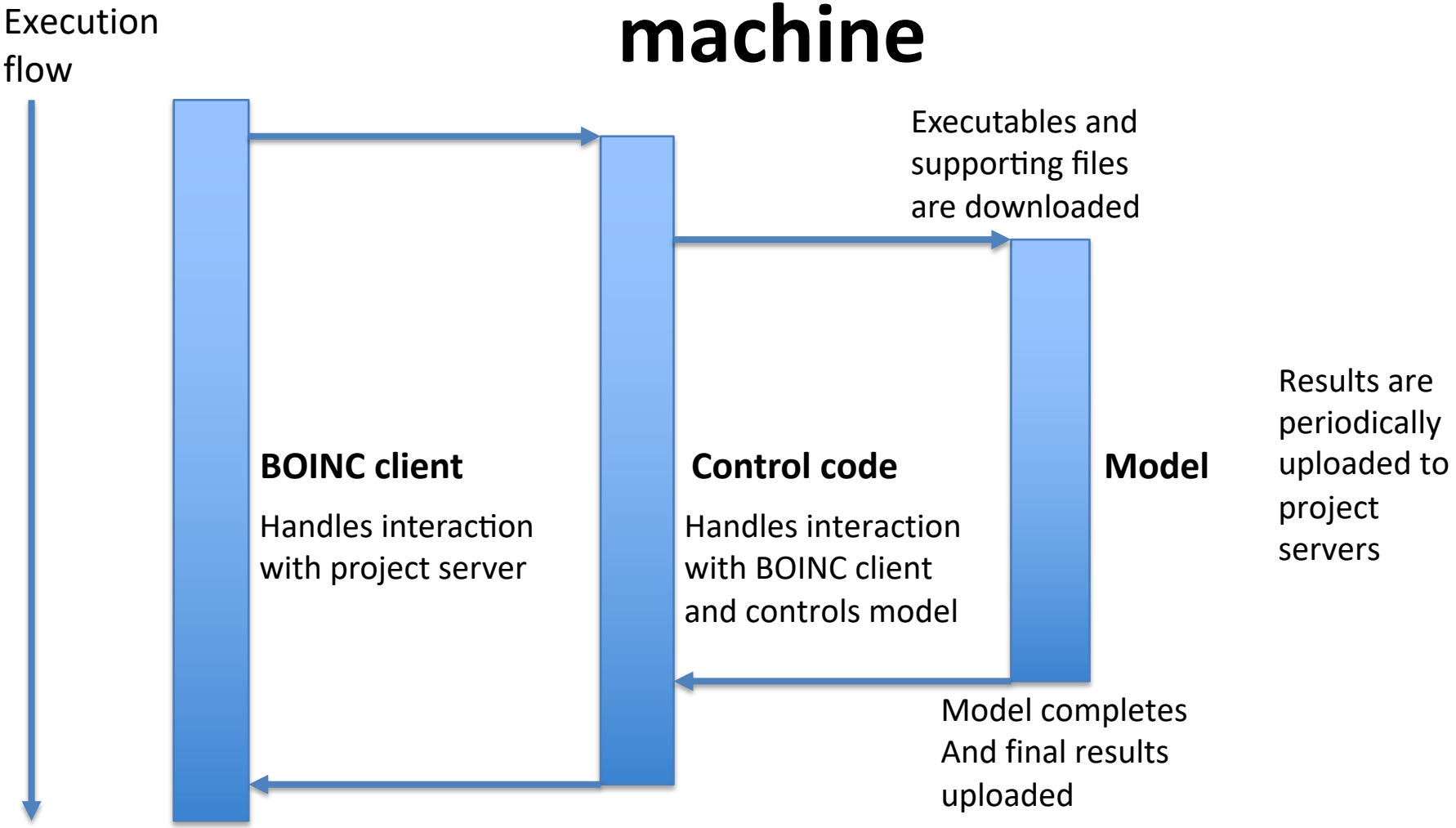
Control Code Flow on a Volunteer's machine



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Future development of WRF and OpenIFS@home in CPDN

- **Validation experiment** of the **WRF** model
- Include the **OpenIFS 43r3** version into **OpenIFS@home**
- Explore the possible **combination** of the two models linearly, so that **OpenIFS@home** results feed into **WRF**
- Port **OpenIFS@home** and **WRF** in **CPDN** to other operating systems:

	UK Met Office models	OpenIFS	WRF
Linux	✓	✓	✓
MacOS	✓	✓	
Windows	✓		

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Conclusion

- Successfully **incorporated OpenIFS** and **WRF** into **CPDN**
- Performed validation of **OpenIFS@home** using the example of Storm Karl
- Results are produced in a **scientifically useful timeframe**
- Enables a range of **new capabilities** for scientists
  - **OpenIFS@home** enables **very large ensemble weather forecasts** supporting types of studies previously too computationally expensive to attempt using **OpenIFS**
  - **WRF** in **CPDN** enables **fine scale resolution models**

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Finally, thank you to all our volunteers!

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