National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITY OF CAMBRIDGE | Yusuf Hamied Department of Chemistry

VISION: towards seamless integration of Model, Satellite and In-Situ Observation data

The VISION team

University of Reading

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

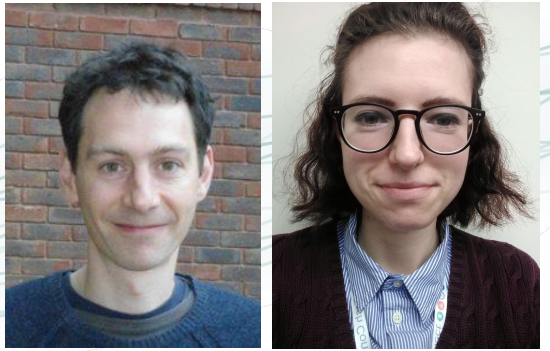
FAAM

UNIVERSITY OF LEEDS

Introducing the VISION team

NCAS Cambridge

NCAS Leeds



NCAS Reading

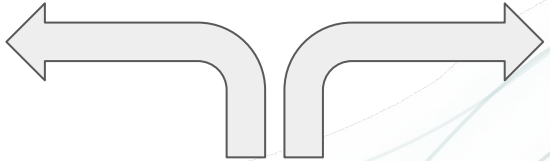
NCEO RAL STFC

FAAM (project partner)

How this project came about:

Develop satellite_simulator to output model data on satellite swaths (Brian Kerridge, RAL)

Using flight_simulator with data input from WRF model (Leeds)



flight_simulator

Improve flight_simulator's portability and interoperability (Sadie and David, Reading)

Discussion with FAAM on joint science opportunities. (Alan Woolley and FAAM staff)

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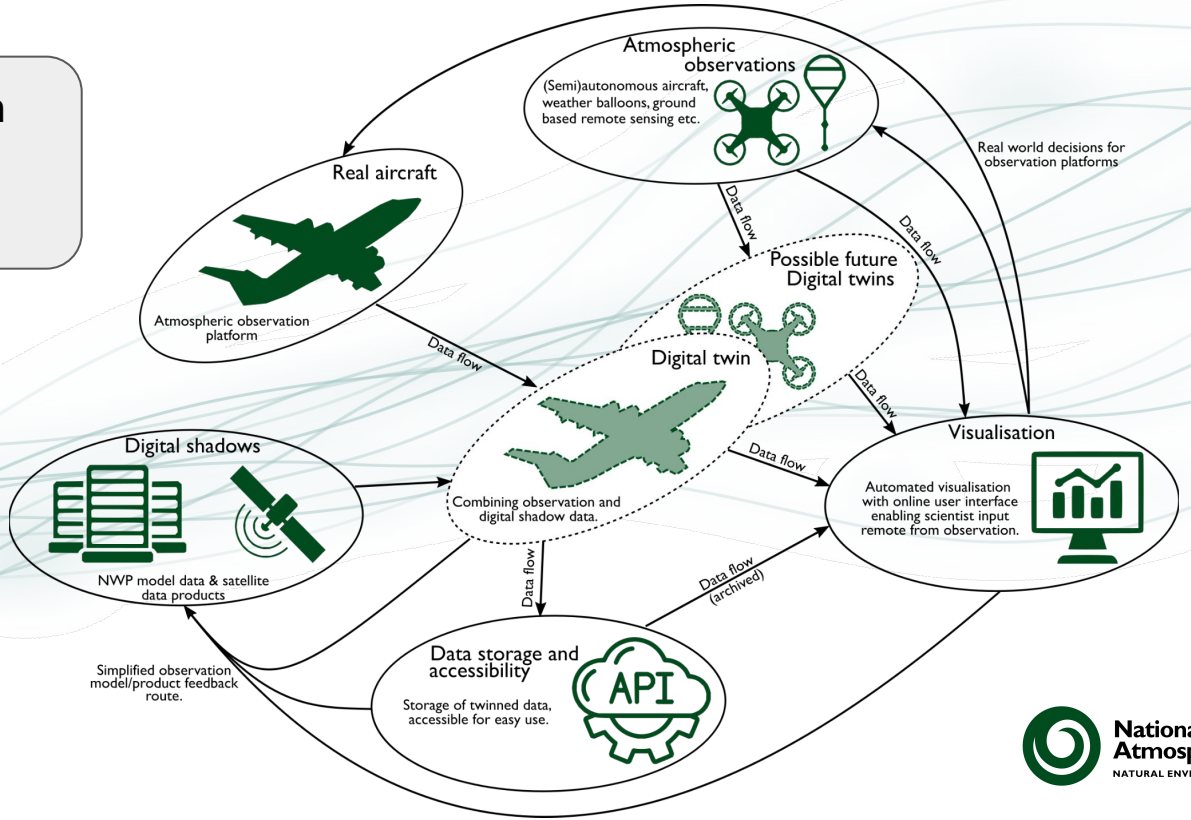
NERC-TWINE programme: Digital Twins for Environmental Science

VISION (Virtual **I**ntegration of **S**atellite and **I**n-Situ **O**bservation **N**etworks)

Started on 1st of Jan
15 months
622K



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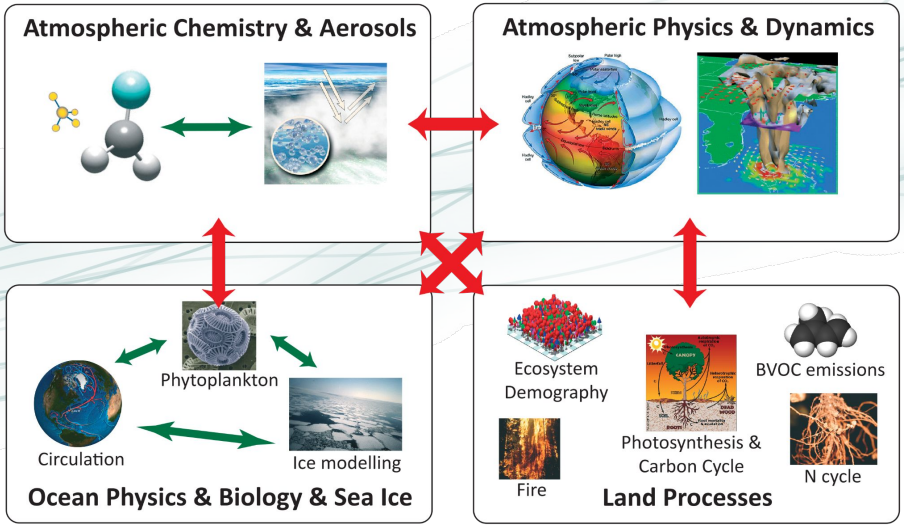
VISION AIMS

1. Reduce NERC carbon emissions by optimising impact and outcomes from the FAAM Airborne Laboratory.

2. Improve policy decision making for climate mitigation by providing tools for integrating right-time observational data into Earth System Models.



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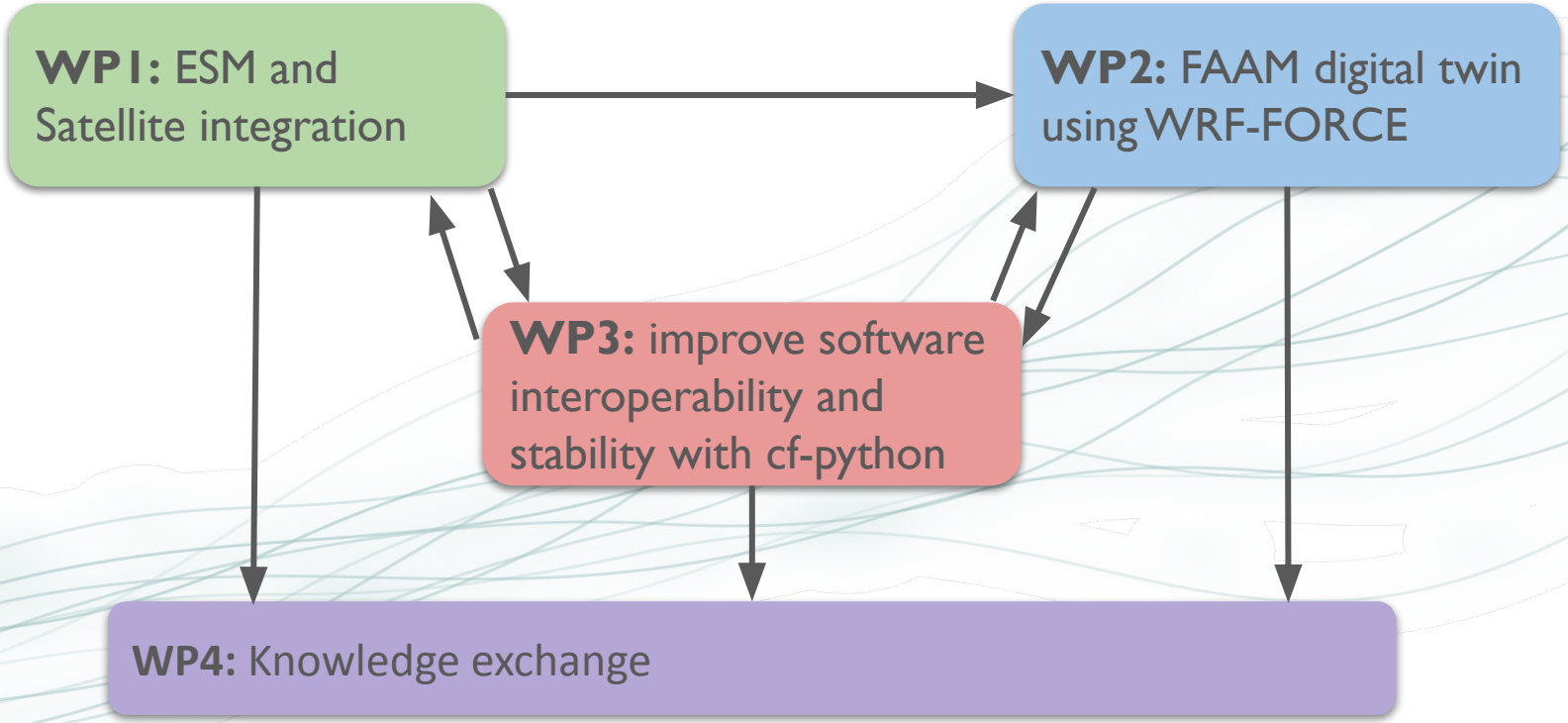
VISION Work Packages



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WP1

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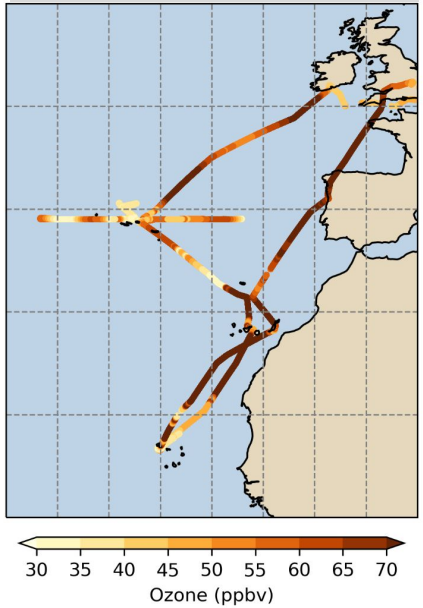
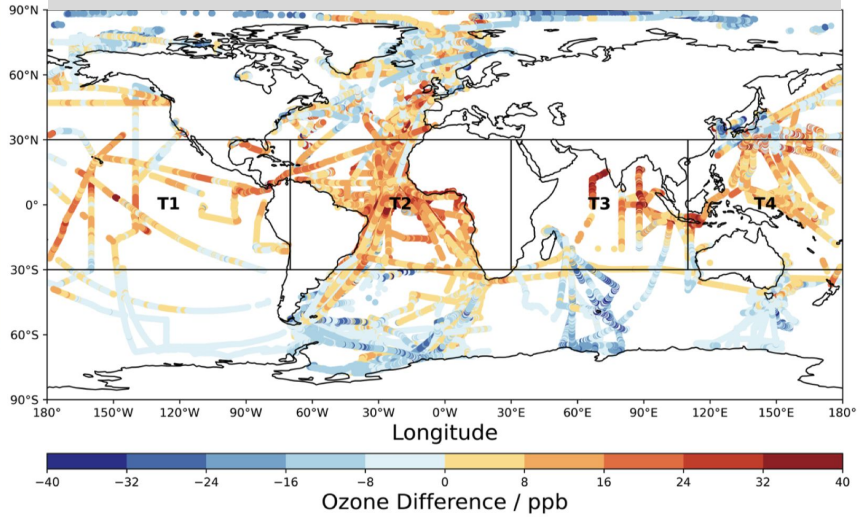
From flight_simulator to ISO_simulator:

"Virtual Integration of Satellite and In-situ Observation Networks (VISION) v1.0: In-Situ Observations Simulator"
Russo et al., GMDD (**2024**)

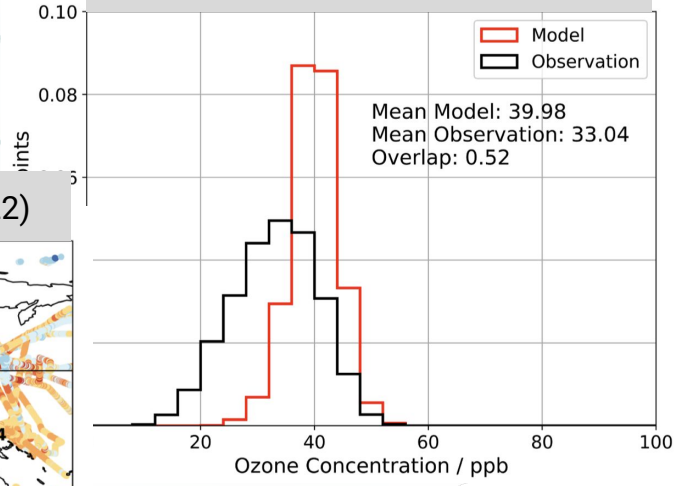
FAAM Research aircraft



TOAR ozone dataset from ships-buoys (1986-2022)



Cape Verde Atmospheric Observatory



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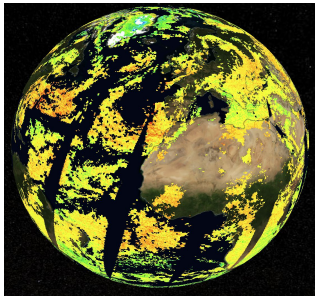
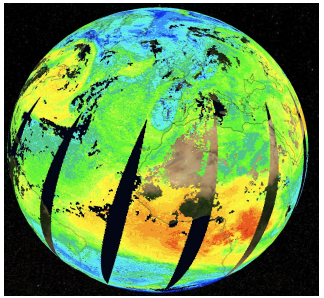
Developing Satellite Simulator:

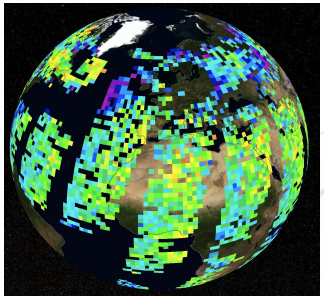
Methane



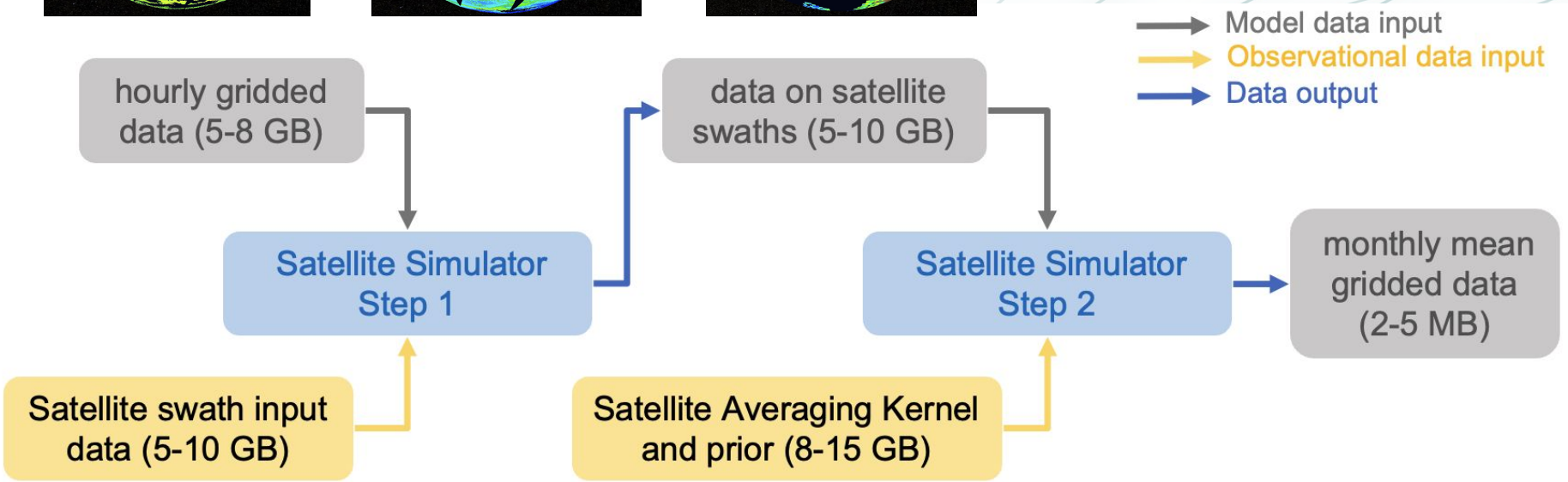
CO



Ozone



Remote Sensing Group Data Viewer:
https://gws-access.jasmin.ac.uk/public/rsg_share/webpages/rsg_data_viewer/



WP2

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WP2: developing a digital Twin of the FAAM aircraft

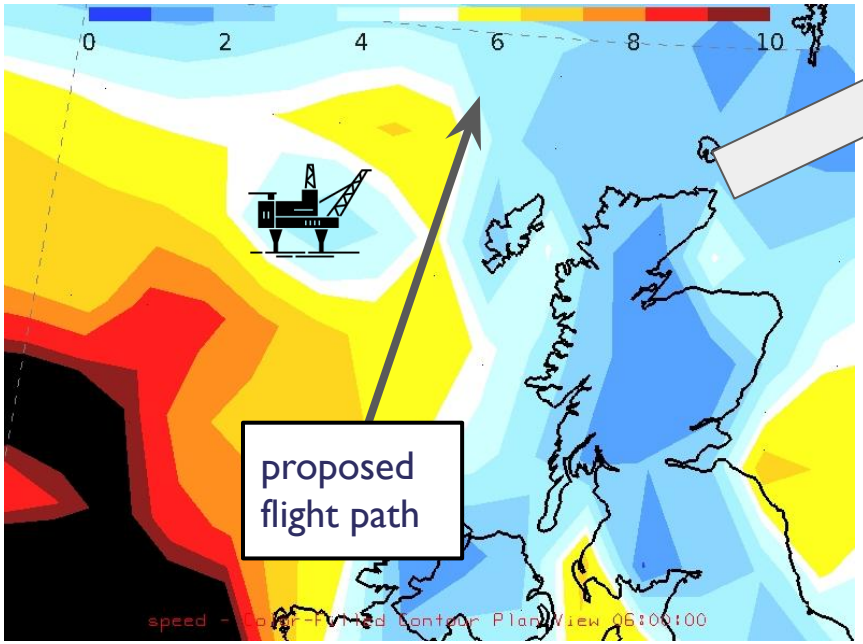
WP2.1 Construction of a ready-to-use model-flight-simulator infrastructure to optimise FAAM flying and improve the hit-rate

WP2.2 Coupling the Satellite Simulator

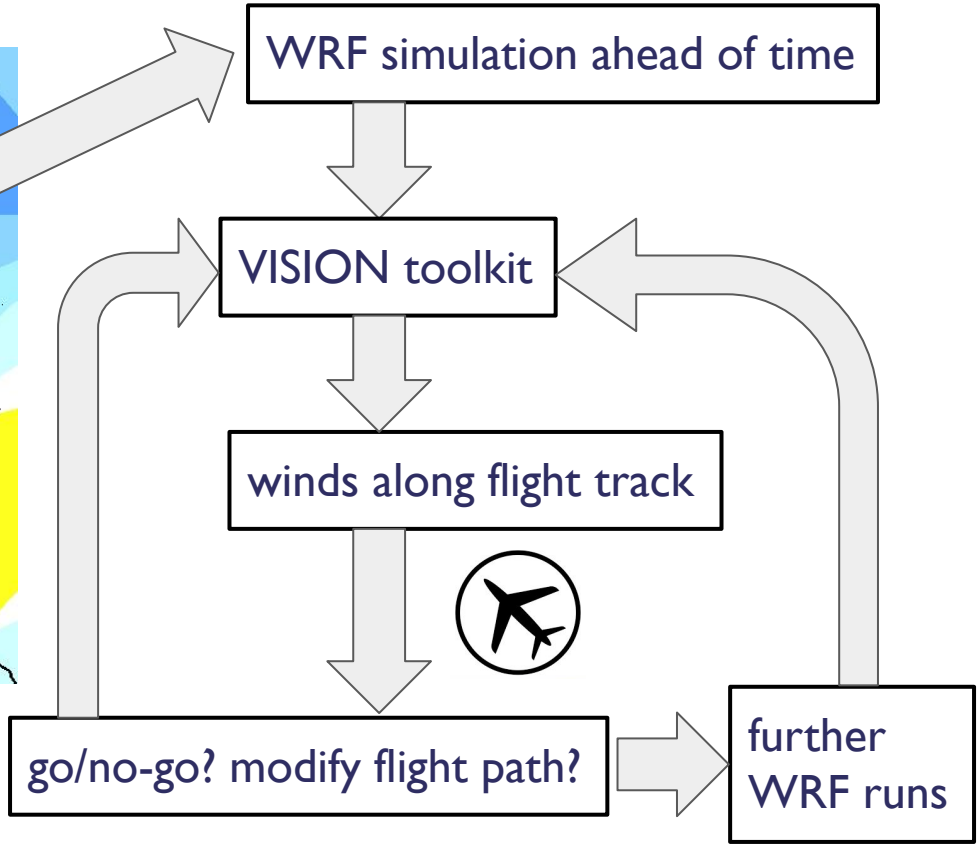
WP2.3 Provision of tools to visualise the simulator/WRF/FAAM data

WP2.4 Case study/campaign planning. Demonstration of the new capability using real examples/case studies.

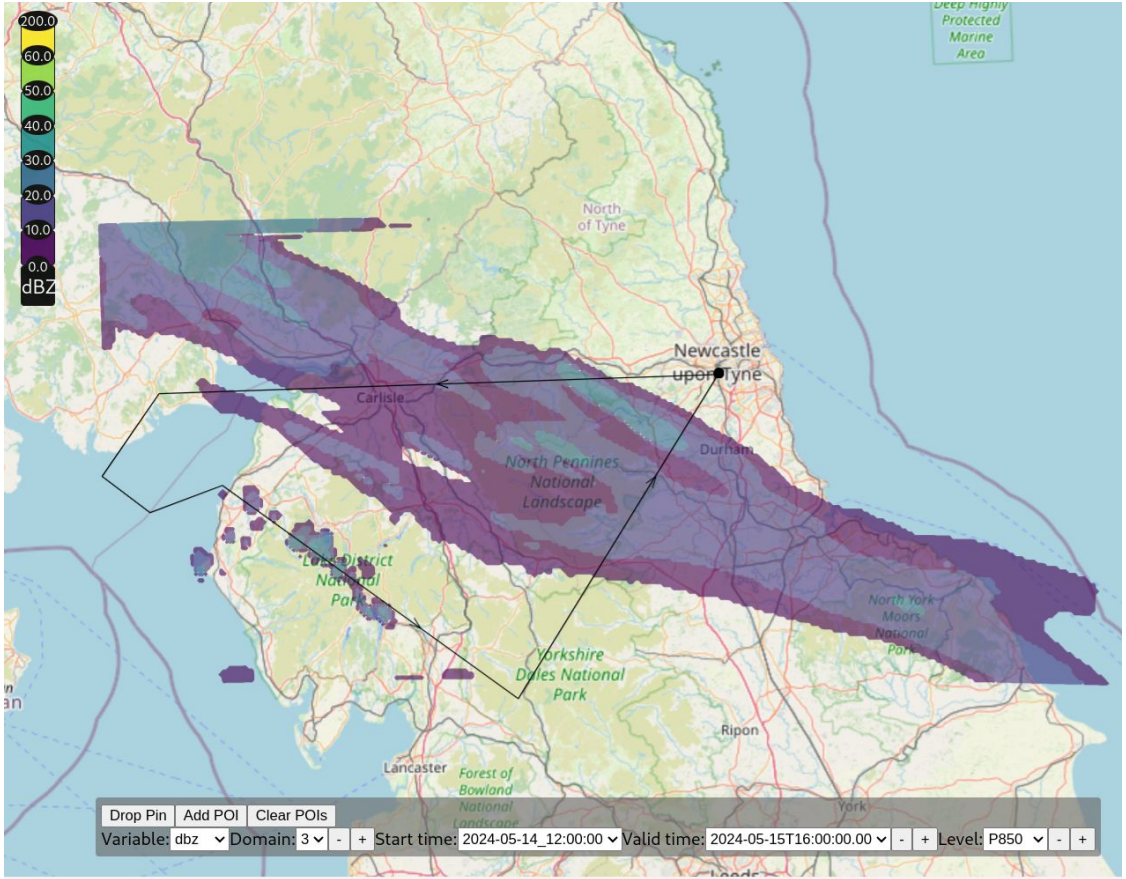
Context: example: detecting plumes from oil and gas platforms - *wind speeds above 4-5 m/s are needed*



GFS forecast winds valid at flight time:
marginal case



Developing User Interface and Tools



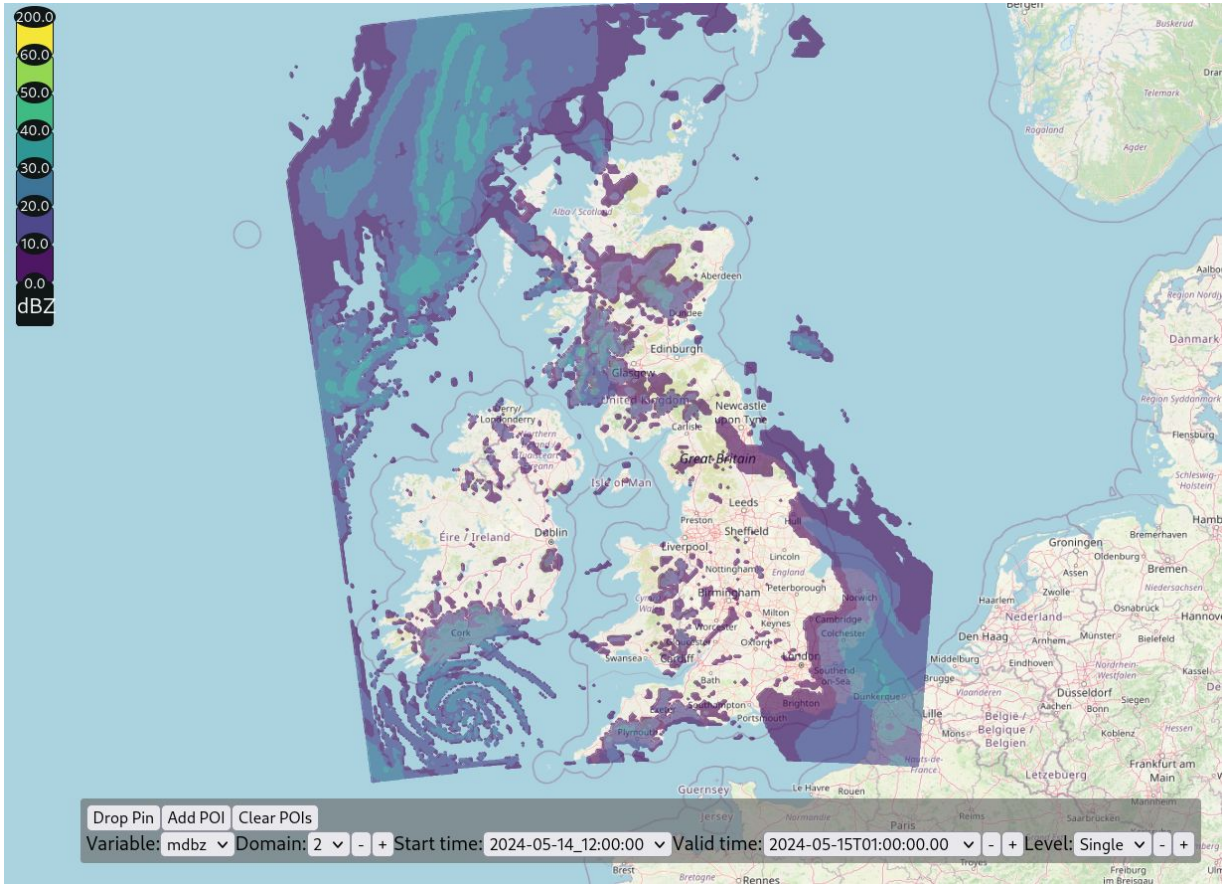
Interactive map with model data overlayed

Points of interest in three dimensional space and time can be captured alongside metadata.

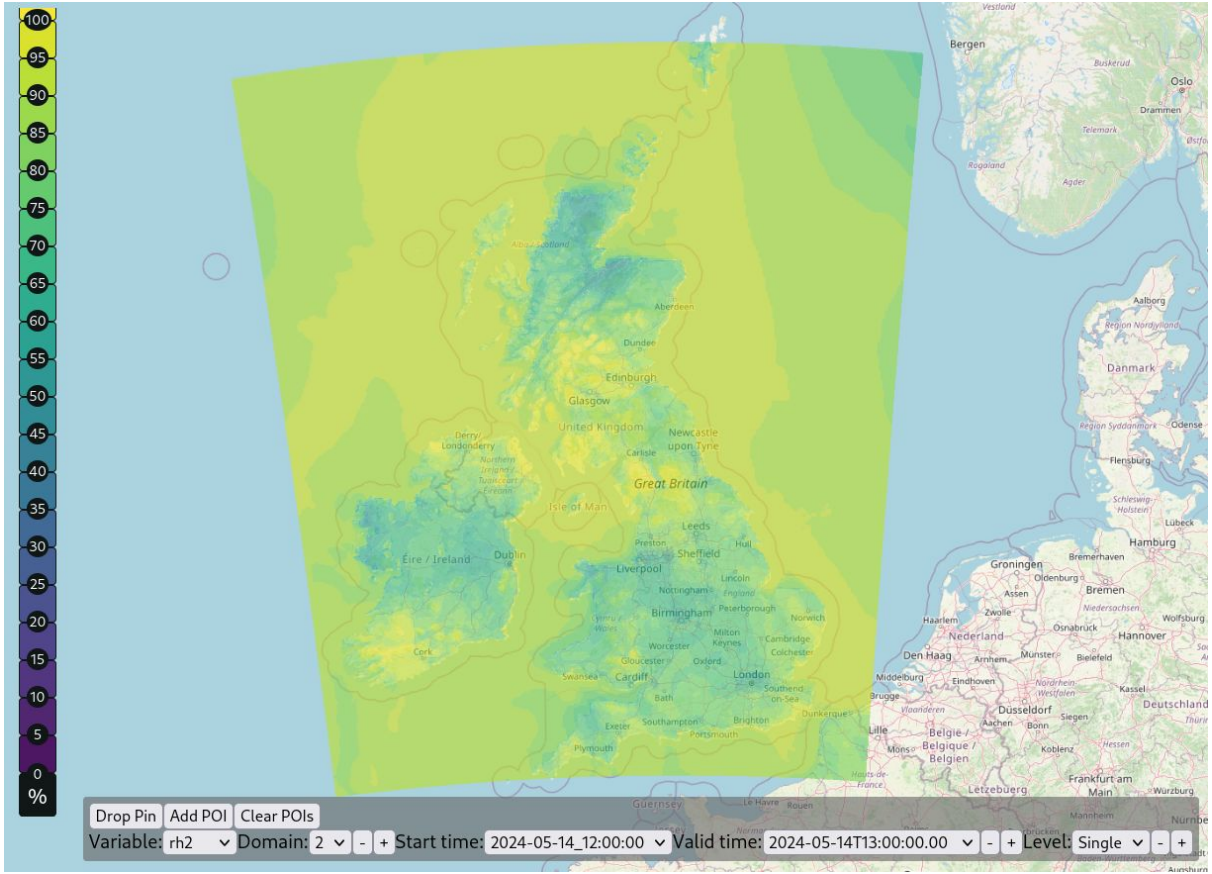
Potential flight tracks drawn using insight from model overlays; then passed to VISION for fine grained analysis of forecast observations along trajectory.

Image shows radar reflectivity diagnostic from WRF at 850 hPa with exemplar flight track overlayed. Data is 800m resolution produced in support of the AMMSS course in the Lake District, May 2024.

Radar Reflectivity



Relative Humidity



WP3

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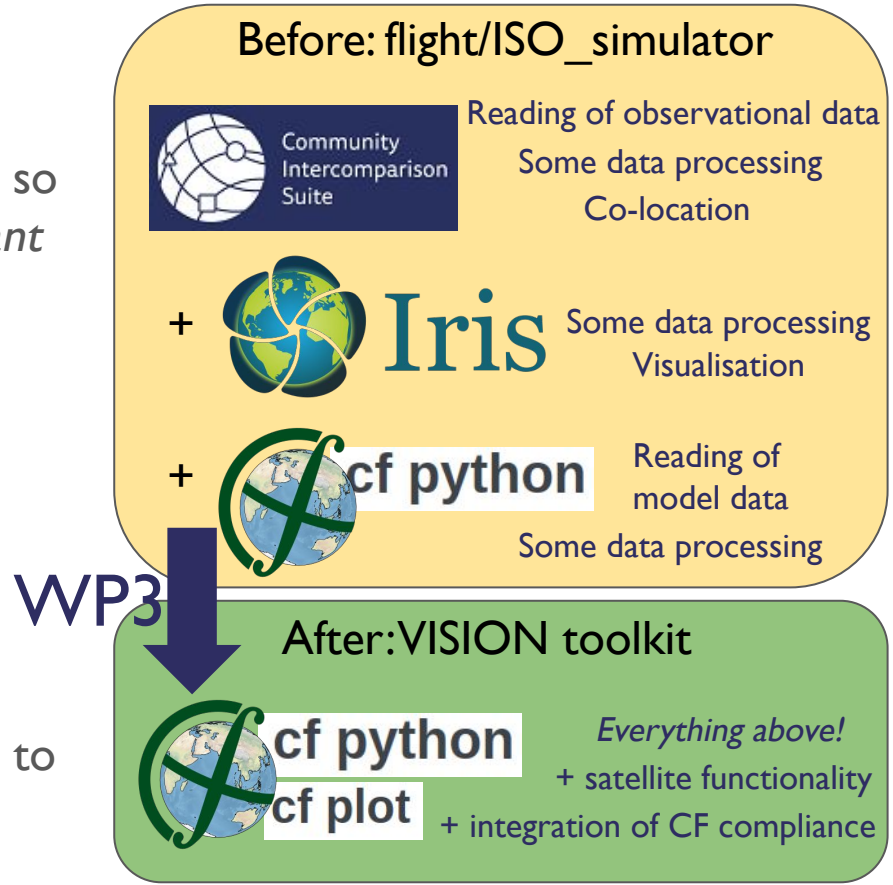
WP3: Improving software interoperability and stability

- Recast existing and future VISION software into a **more accessible** package that is **easier and faster to use**, and is **portable** so can be used by anyone, with *any CF-compliant* model and observational dataset.
- This will use **cf-python** and **cf-plot**, data analysis and visualisation libraries developed and maintained within NCAS.
- An important aspect of portability will be that the software will rely on standardised CF-compliant data from/for the models. We will develop **CF-netCDF usage guidance** to define what this entails.



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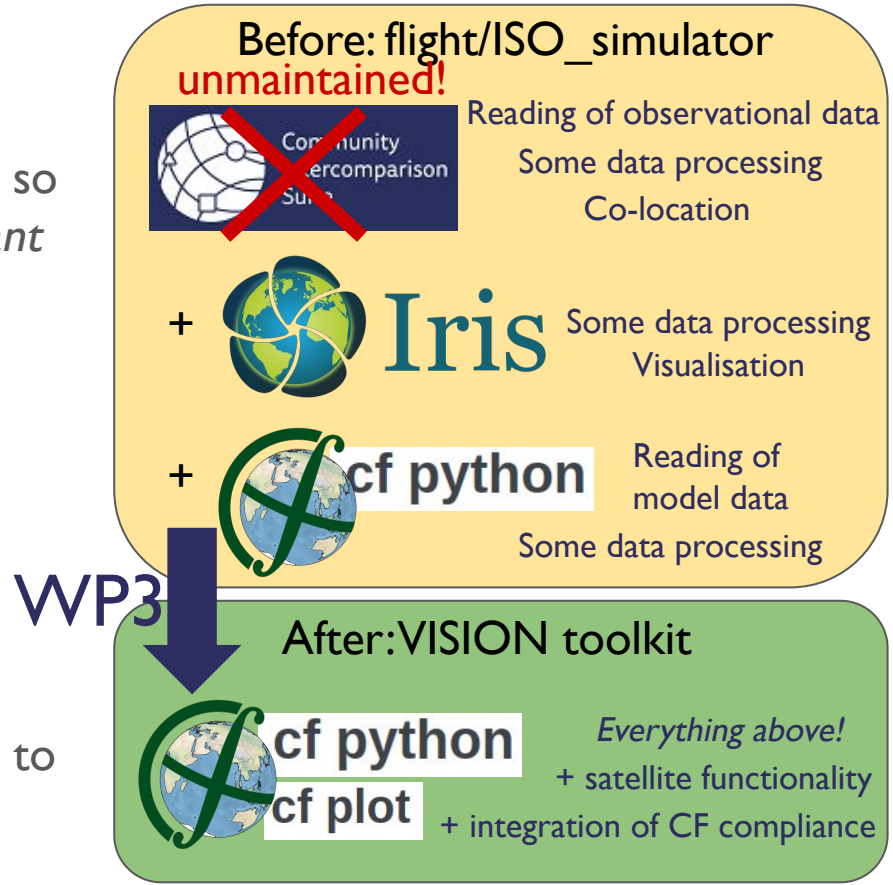

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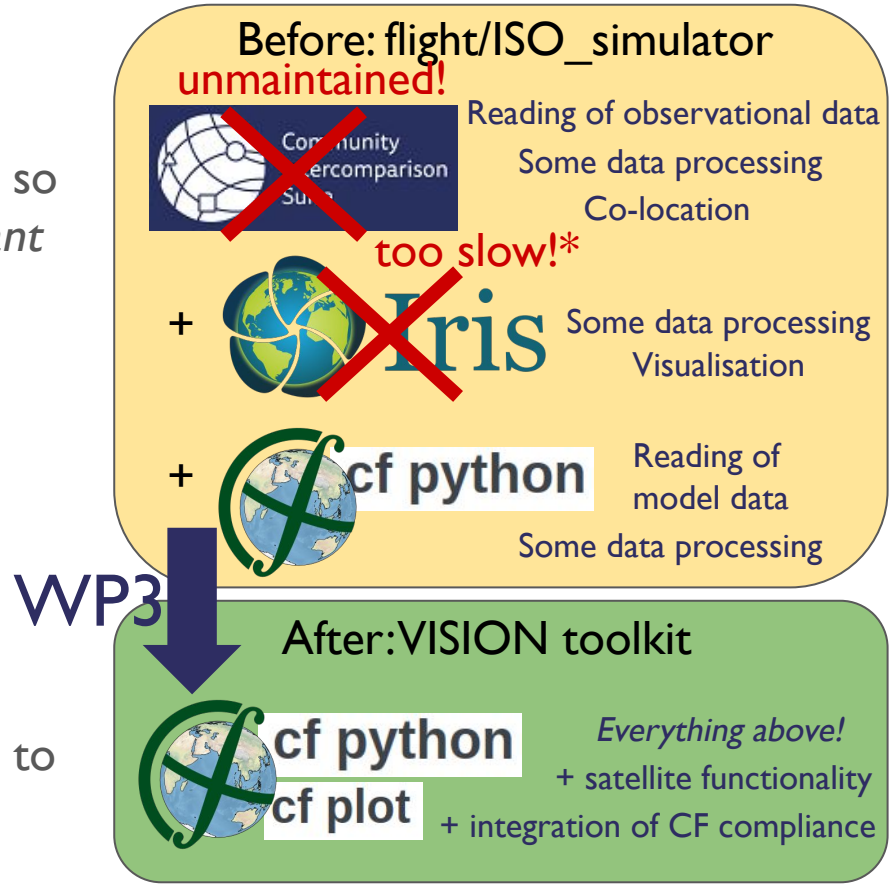
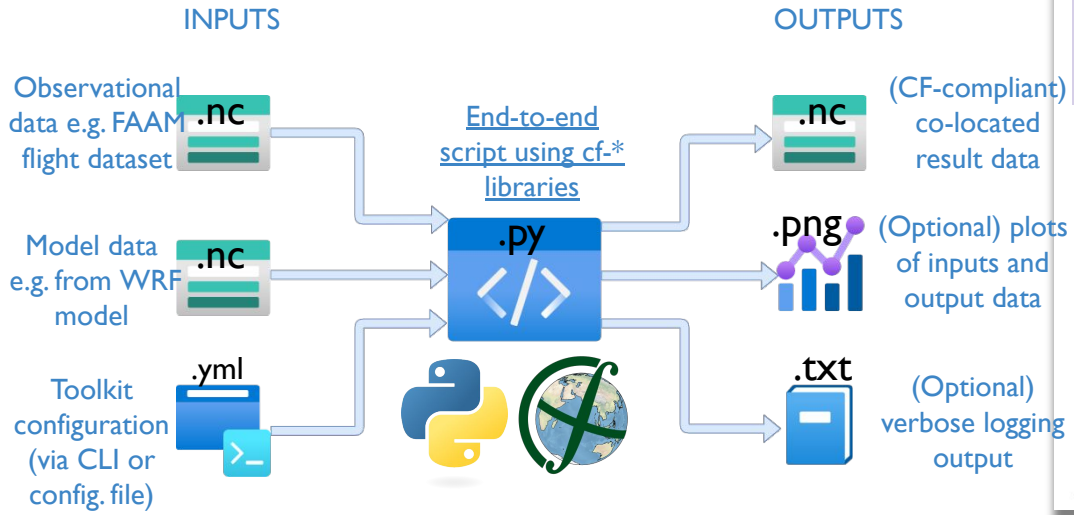


*Russo et al., GMDD (2024)

WP3: Progress so far

- Have a **working end-to-end script** replicating ISO_simulator functionality using only 'cf' tools, being incrementally improved and extended
- **Reciprocal benefits**: in developing for VISION, the NCAS 'cf' libraries have improved (new features, bugs noticed and fixed, etc.)



Changelog for the latest cf-python release:

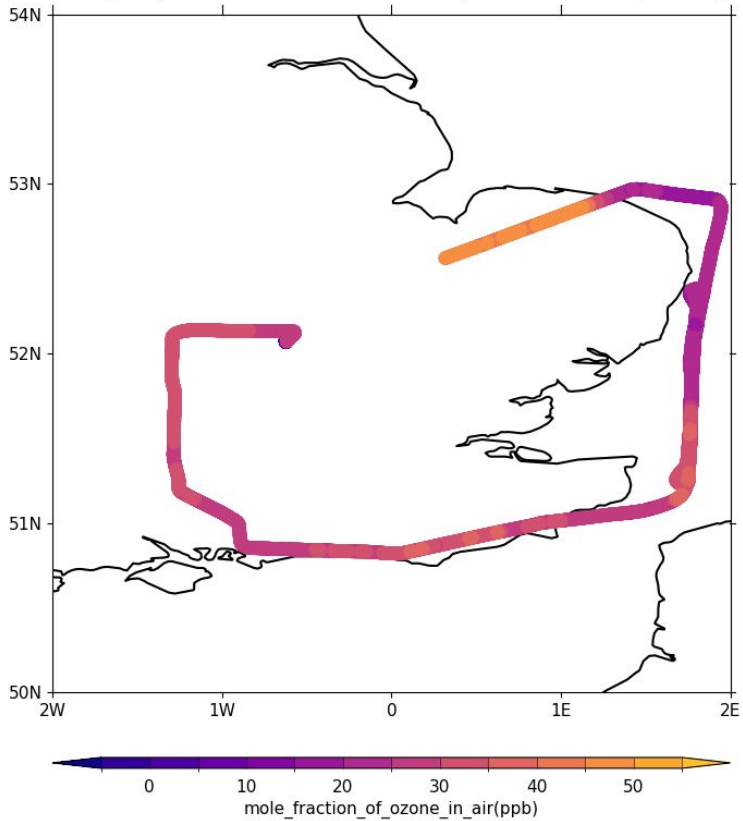
version 3.16.2

2024-04-26 *Key: Resulting (direct or indirect) from VISION work*

- Improve the performance of reading and accessing the data of PP and UM fields files (https://github.com/NCAS-CMS/cf-python/issues/746)
- Improve `cf.Field.collapse` performance by lazily computing reduced axis coordinates (https://github.com/NCAS-CMS/cf-python/issues/741)
- Improve `cf.Field.__getitem__` performance by not re-calculating axis cyclicity (https://github.com/NCAS-CMS/cf-python/issues/744)
- Reduce output CFA netCDF file size by setting the HDF5 chunksizes of CFA variables to be no larger than required (https://github.com/NCAS-CMS/cf-python/issues/739)
- Allow a halo to be added by `cf.Field.indices` and `cf.Field.subspace` (https://github.com/NCAS-CMS/cf-python/issues/759)
- Added spherical regridding to discrete sampling geometry destination grids (https://github.com/NCAS-CMS/cf-python/issues/716)
- Added 3-d spherical regridding to `cf.Field.regrids`, and the option to regrid the vertical axis in logarithmic coordinates to `cf.Field.regrids` and `cf.Field.regridc` (https://github.com/NCAS-CMS/cf-python/issues/715)
- New keyword parameter to `cf.Field.regrids` and `cf.Field.regridc`: `return_esmpy_regrid_operator` (https://github.com/NCAS-CMS/cf-python/issues/766)
- New keyword parameters to `cf.wi`: `open_lower` and `open_upper` (https://github.com/NCAS-CMS/cf-python/issues/740)
- Fix misleading error message when it is not possible to create area weights requested from `cf.Field.collapse` (https://github.com/NCAS-CMS/cf-python/issues/731)
- Fix bug in `cf.read` when reading UM files that caused LBPROC value 131072 (Mean over an ensemble of parallel runs) to be ignored (https://github.com/NCAS-CMS/cf-python/issues/737)
- Fix bug in `cf.aggregate` that sometimes put a null transpose operation into the Dask graph when one was not needed (https://github.com/NCAS-CMS/cf-python/issues/754)
- Fix bug in `cf.aggregate` that caused a failure when property values were `numpy` arrays with two or more elements (https://github.com/NCAS-CMS/cf-python/issues/764)
- Fix bug in `cf.aggregate` that didn't correctly handle the "actual_range" CF attribute (https://github.com/NCAS-CMS/cf-python/issues/764)
- Fix bug whereby `Field.cyclic` is not updated after a `Field.del_construct` operation (https://github.com/NCAS-CMS/cf-python/issues/758)
- Fix bug that meant `cyclic()` always returned an empty set for domains produced by `cf.Field.domain` (https://github.com/NCAS-CMS/cf-python/issues/762)
- Changed dependency: `cfunits>=3.3.7`
- Changed dependency: `netCDF4>=1.6.5`

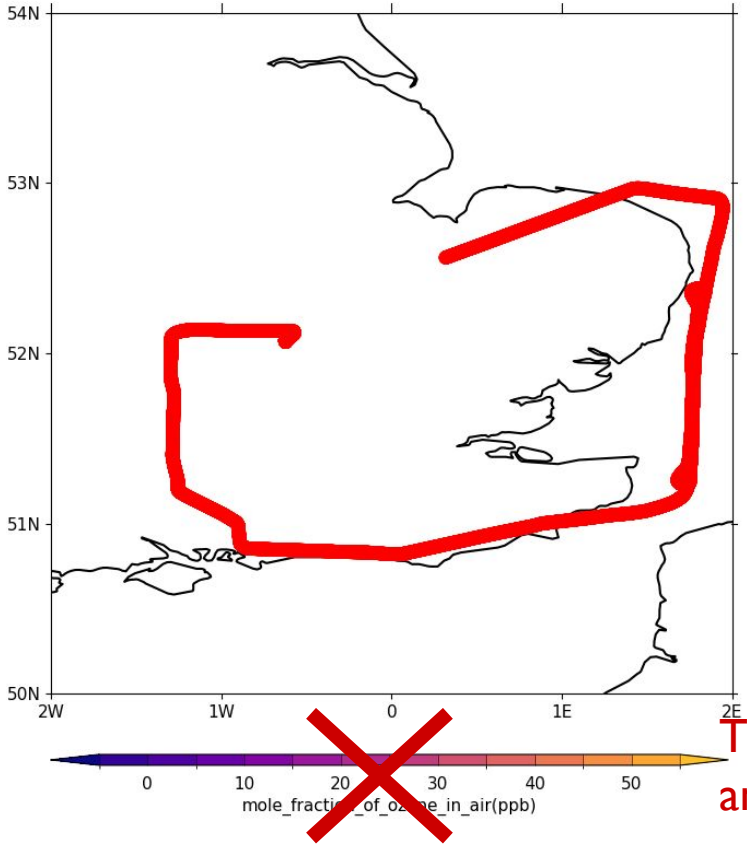
Example: end-to-end script plots

Observational input (shown left): flight from a FAAM STANCO campaign (2017)

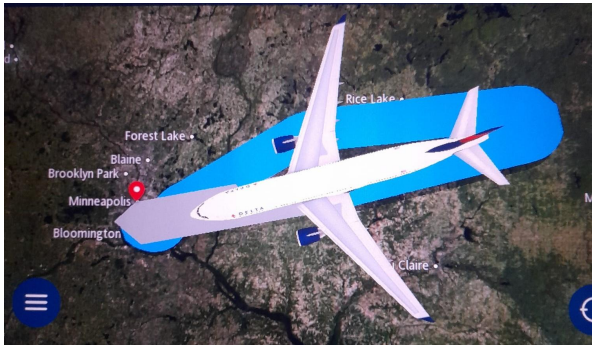


Example: end-to-end script plots

Observational input (*track only* shown left): flight from a FAAM STANCO campaign (2017)



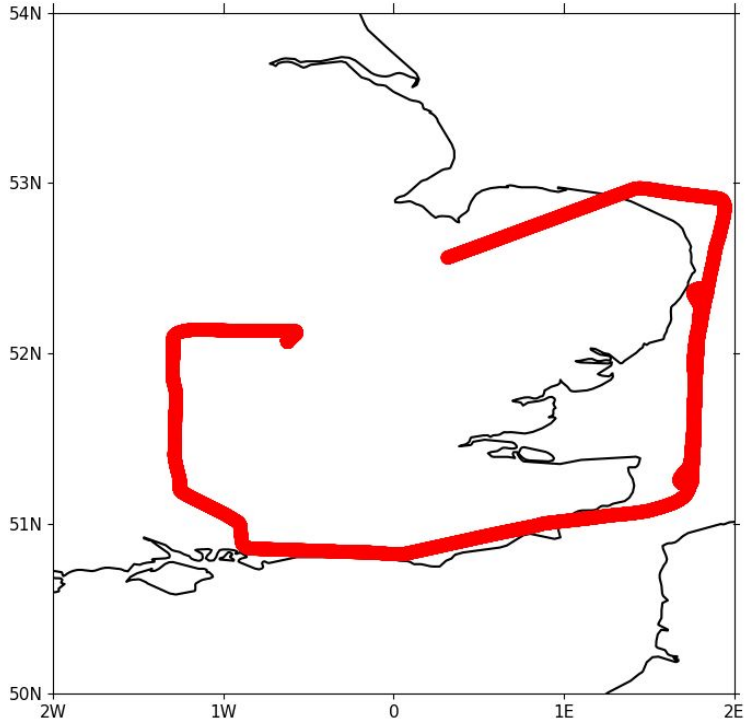
The lat-lon (x-y) plane track



This data is irrelevant! Only the spatial trajectory and temporal sampling are of concern.

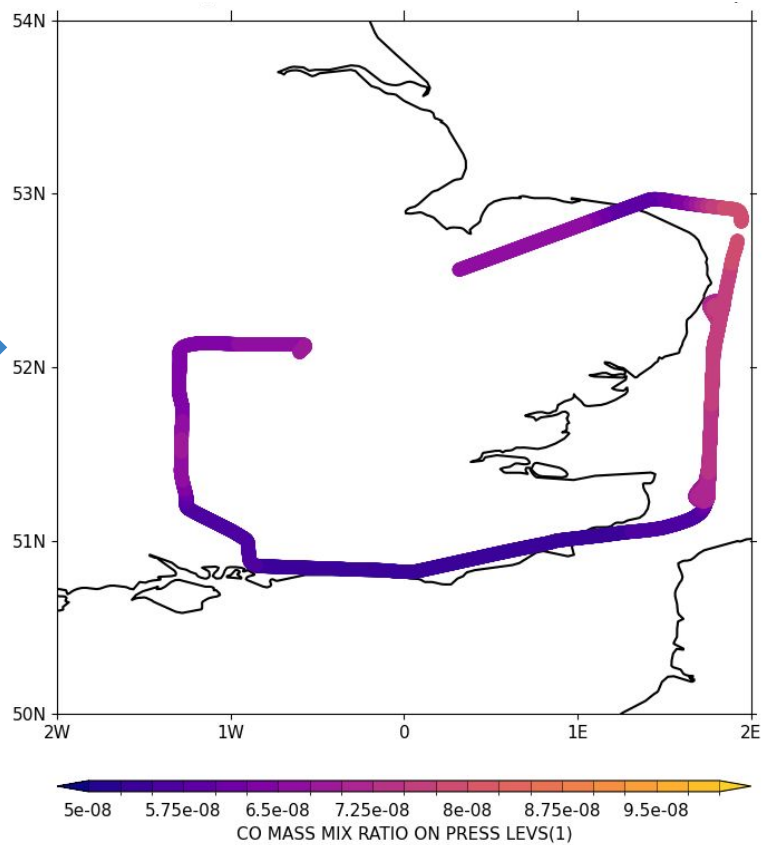
Example: end-to-end script plots

Observational input (*track only*): flight from a FAAM STANCO campaign (2017)



End-to-end script using cf-python and cf-plot libraries

UM model input co-located onto the flight track of the observational input



Conclusions:

- Successfully bringing together scientists from different parts of NCAS!

- ISO_simulator description paper in discussion for GMD (Russo et al., 2024)

- Get involved: find out how VISION can best help you with your model evaluation, campaign planning or to make your observational product more easily available to the VISION community