Evaluation of convective and turbulent scale processes using CSET and its role in seamless NWP

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Introduction to CSET

CSET is a flexible and configurable community toolkit for evaluation and verification of convective and turbulent scale weather and climate models. It addresses the needs of the full Research to Operations spectrum, from development of parametrisations and novel diagnostics to quasi-operational assessment of model upgrades.

CSET will refresh the Momentum® capability for evaluation of regional models, consolidating existing diagnostics and metrics in a toolkit built with useability, flexibility and portability in mind; using modern software and best development practices. It changes the evaluation focus to understanding the physical processes leading to model errors, thus achieving better alignment between model evaluation and parametrization development activities. CSET is open source and follows a community approach to diagnostics development.

Diagnostics contributed to CSET are made available to the community and carefully long-term curated in a git repository with extensive testing and expert peer review, enhancing the visibility and potential for uptake.

To learn more and contribute, visit the git repository on https://github.com/MetOffice/CSET, the documentation pages on https://metoffice.github.io/CSET/ or scan the QR code.

Technical	Science
Built on modern software • Python 3 • Cylc 8 • GitHub • Builds on Iris and METplus **Easy to use and contribute** • Clear documentation • Reproduceable • Portable • Open access **QA and best practice** • Automation for testing and docs • Scientific peer review	• Align parametrisation, diagnostics development and evaluation research linked to Regional Atmosphere Land (RAL) suites • Process based understanding, evaluation, and verification • Aligned with operational verification to support parallel suite and RAL3-LFRic testing • Ensembles supported by default
Community	
• Central and documented resource • Common working practices • Community-oriented development • Open-source (Apache 2.0) code • Provides a legacy for diagnostics and research observations	

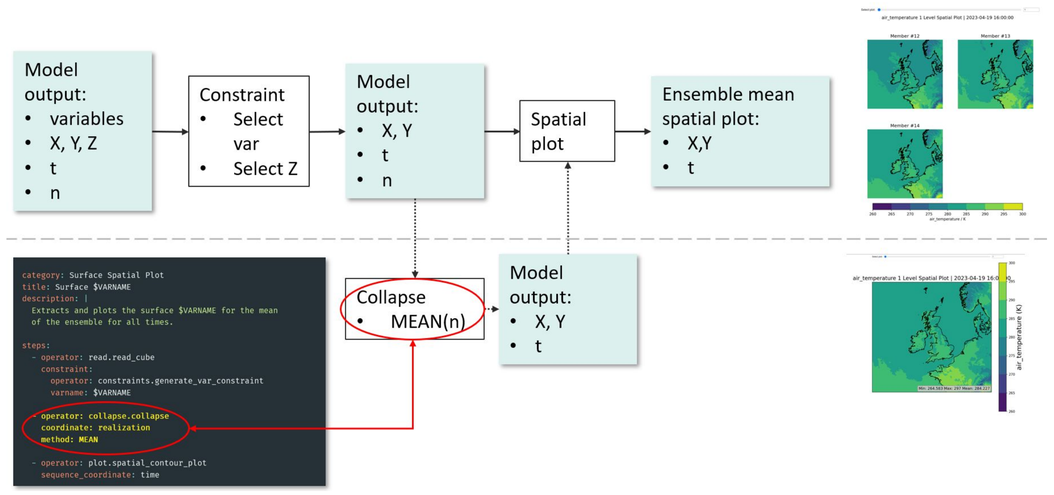
Principles underpinning CSET design

Description of CSET

CSET allows users to interrogate data and evaluate models in a flexible way. Therefore, CSET is based on the concept of **'operators'.** Operators form the smallest CSET unit and act on iris cubes. They execute a transformation of data and/or coordinates of model fields. '**Recipes'** (yaml files) chain operators together to produce a **diagnostic** that is visualised. CSET provides a python library of operators and the utility code to interpret the recipes, exposing to the user a collection of building blocks to be assembled with steps detailed in a configuration file; this approach allows the rapid creation and upscaling of complex diagnostics by sequentially listing the operators and their parameters as shown in the diagram on the right.

CSET can be launched using a command line interface (CLI), but its typical use pattern is in conjunction with the cylc workflow manager to generate a vast number of predefined diagnostics when assessing model upgrades. CSET has a cylc8 workflow definition and apps to launch recipes in parallel and cycle through case studies or trial cycles; it also has apps that run METPlus wrappers to produce objective verification results.

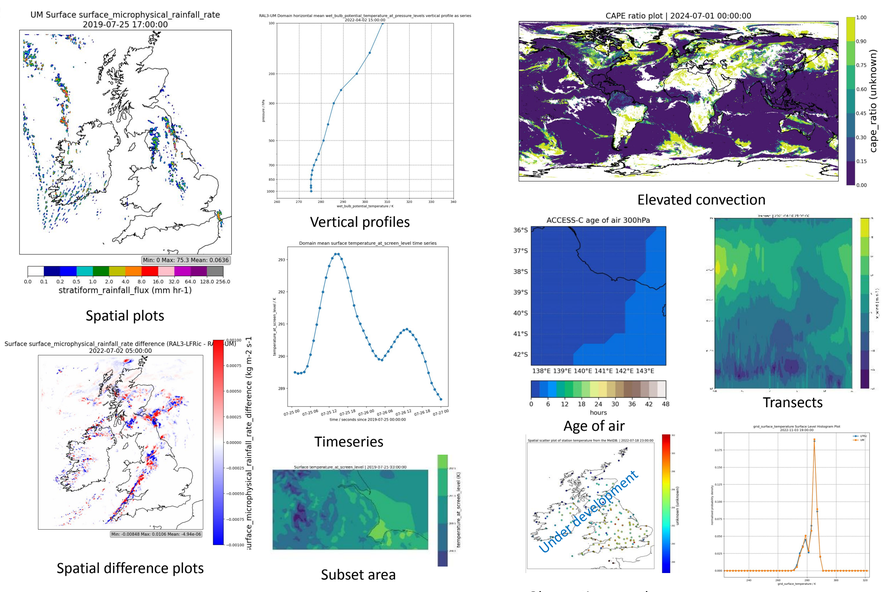
The workflow publishes an interactive website page to visualise the results, allowing easy navigation and selection of the multitude of plots and supports side-by-side view for easy comparison of different experiments. CSET will support both physical, data-driven models, and observations at convective scales.

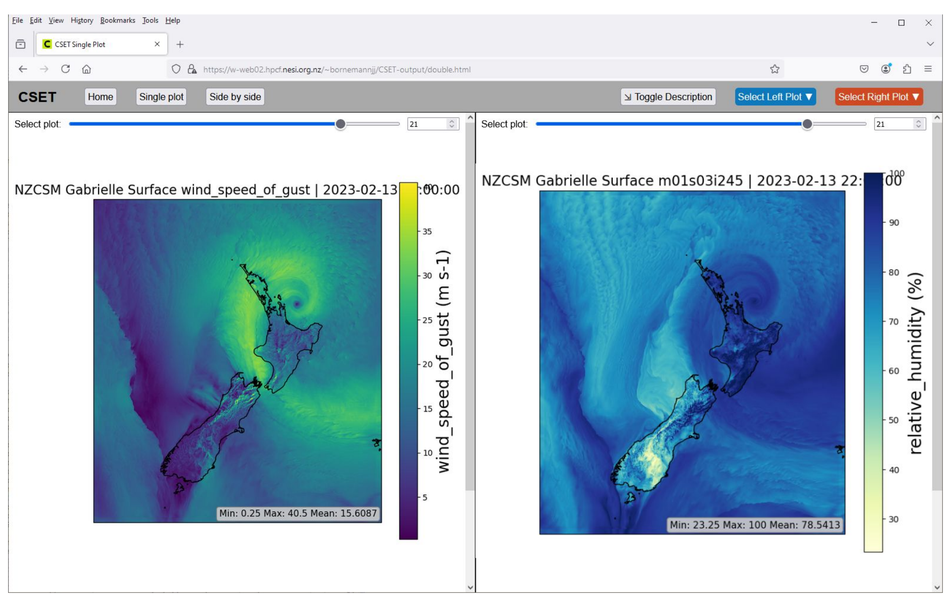


Example of flexibility: 3 extra lines in the configuration file add a 'collapse' operator and transform a postage stamp plot into an ensemble mean plot. Dashed arrows indicate modification to the recipe resulting in a different diagnostic.

The CSET library has currently 52 recipes, examples are listed below and shown on the right:

- CAPE_ratio_plot
- basic_qq_plot
- time_series (domain mean, selected point, etc)
- histogram_series (different time aggregations across case studies i.e. hour of day, validity time, lead time)
- spatial_plots as scrollable time sequence
- vertical profiles (domain mean, percentile, point)
- inflow_layer_properties
- transects
- Gaussian_Spatial_Perturbation
- Uniform_Spatial_Perturbation
- age_of_air
- DKE
- simple_mask
- spatial_plot_of_mask
- spatial_difference
- Multi-model in line plots
- Ensemble processing capability





CSET output webpage, showing side-by-side spatial plots of different variables.

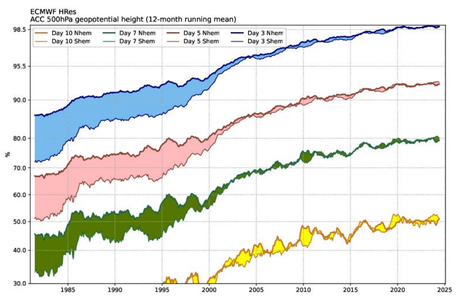
Role of CSET in seamless evaluation

The initial focus of CSET development has been on diagnostics for short-range, limited-area, high-resolution models to support the Regional Atmosphere Land (RAL) model development cycle; these diagnostics will become more relevant to global models as they reach higher resolutions whilst at the same time more will be added. Below are the key developments that will allow CSET to be used in a seamless framework.

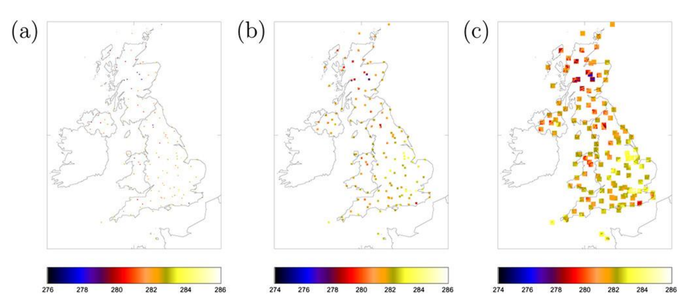
Across timescales: The research in convection-permitting regional climate models over the last decade has led to the development of diagnostics tailored to understand their characteristics. The addition of these diagnostics to CSET will provide the capability to evaluate the impact of changes into the model's climatology.

Across resolutions: We will explore the synergies with global models evaluation toolkits like ESMValTools

Apply to global models: CSET will be stress tested to deal with large data volumes when applied to Met Office's K-Scale model and possibly to the trailblazer 5km global data.



Long time series of Anomaly Correlation of 500hPa geopotential height.
Source: European Centre for Medium Range Weather Forecasting



HiRA neighbourhood sizes around each UK observing site [nb=1 (a), nb=3 (b), nb=5 (c). Source: Mittermaier (2014), Weather and Forecasting 29, 2.

Traditional objective verification scores of global models have experienced continuous improvement. However, the rate of improvement is steadily declining (above left); this is in part due to the increased difficulty to identify further sources of potential gains, and in part due to those scores not being suitable to show the benefits of higher resolutions, which manifest mostly on near surface variables with much larger spatial variability. Furthermore, as resolution increases, point-comparison approach to objective verification starts suffering from double penalty and representativity problems, which require neighbourhood methods (above right) to overcome.

With access through MET to the traditional verification scores and to the neighbourhood HiRA framework, CSET will be able to produce a comprehensive set of metrics.

Acknowledgments

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