Overview WP1 (reanalysis production) and WP5 (service developments)

Patrick Laloyaux & Manuel Fuentes

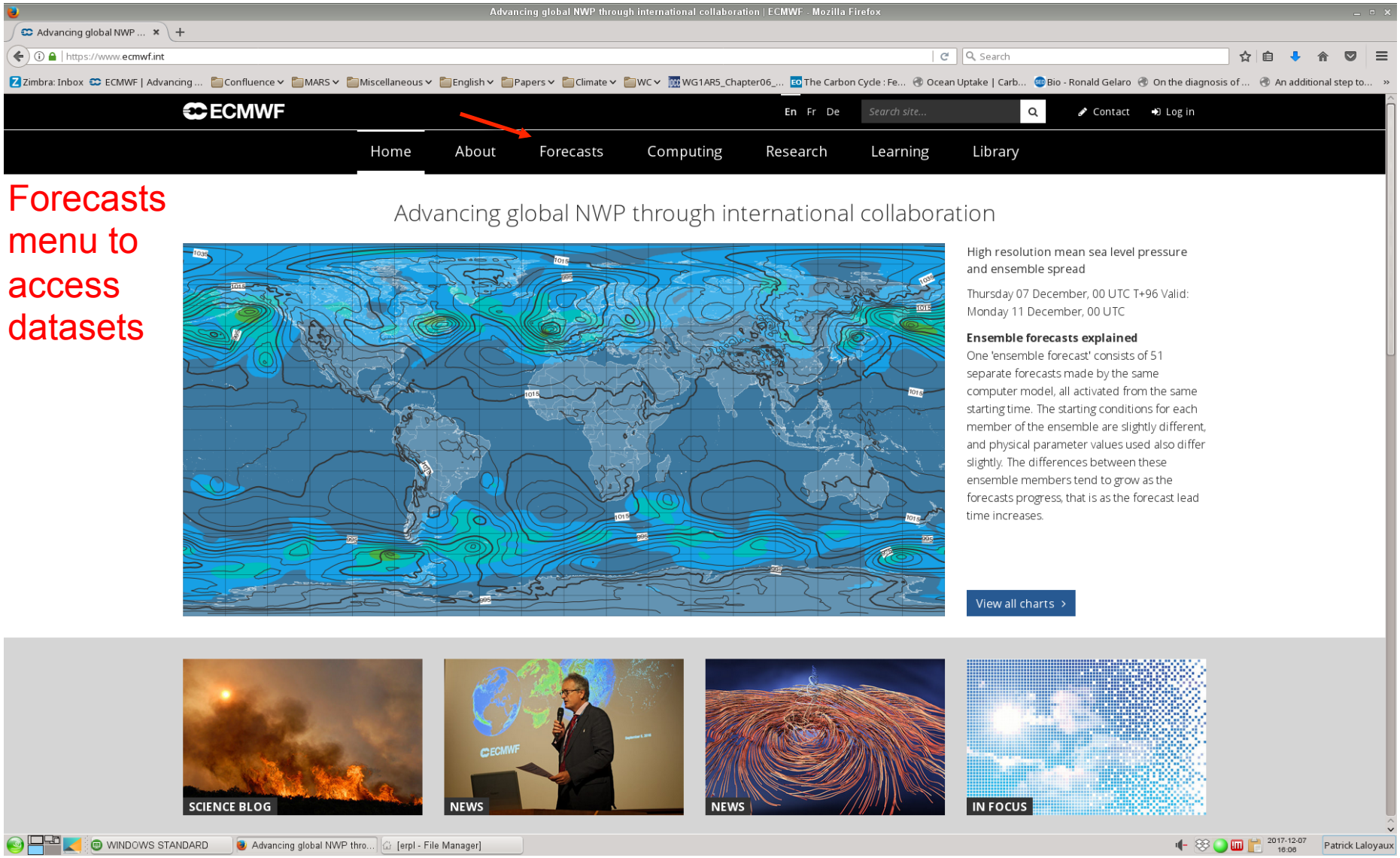
ECMWF
EUROPEAN CENTRE FOR MEDIUM RANGE WEATHER FORECASTS

ERA CLIM 2

SEVENTH FRAMEWORK PROGRAMME

Overview from the user experience point of view

Forecasts menu to access datasets



Overview from the user experience point of view

Datasets | ECMWF - Mozilla Firefox

https://www.ecmwf.int/en/forecasts/datasets

ECMWF

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Charts | **Datasets** | Quality of our forecasts | Documentation and support | Accessing forecasts

Datasets

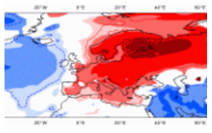
Reanalysis datasets

Archive catalogue

Real-time catalogue

Public, WMO & ACMAD

Forecasts, analyses, climate re-analyses, reforecasts and multi-model data are available from our archive (MARS) or via dedicated data servers or via point-to-point dissemination.



Operational

Operational datasets are the forecasts output by our current model.

- Medium range
- Extended Range
- Long Range

Real-time data

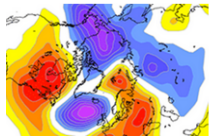
Atmospheric HRES 10-day

Ocean Wave 10-day

Atmospheric ENS 15-day

Ocean Wave ENS-WAM 15-day

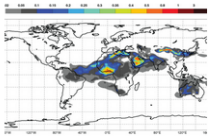
Atmospheric ENS ext 46-day



Climate reanalysis

ECMWF uses its forecast models and data assimilation systems to 'reanalyse' archived observations, creating global data sets describing the recent history of the atmosphere, land surface, and oceans.

Browse reanalysis datasets



Atmospheric composition

Datasets for atmospheric composition from the Copernicus Atmosphere Monitoring Service (CAMS) combine atmospheric modelling with Earth observation data to provide information covering European air quality, global atmospheric composition, climate forcing, the ozone layer, UV and solar energy, and emissions and surface fluxes.

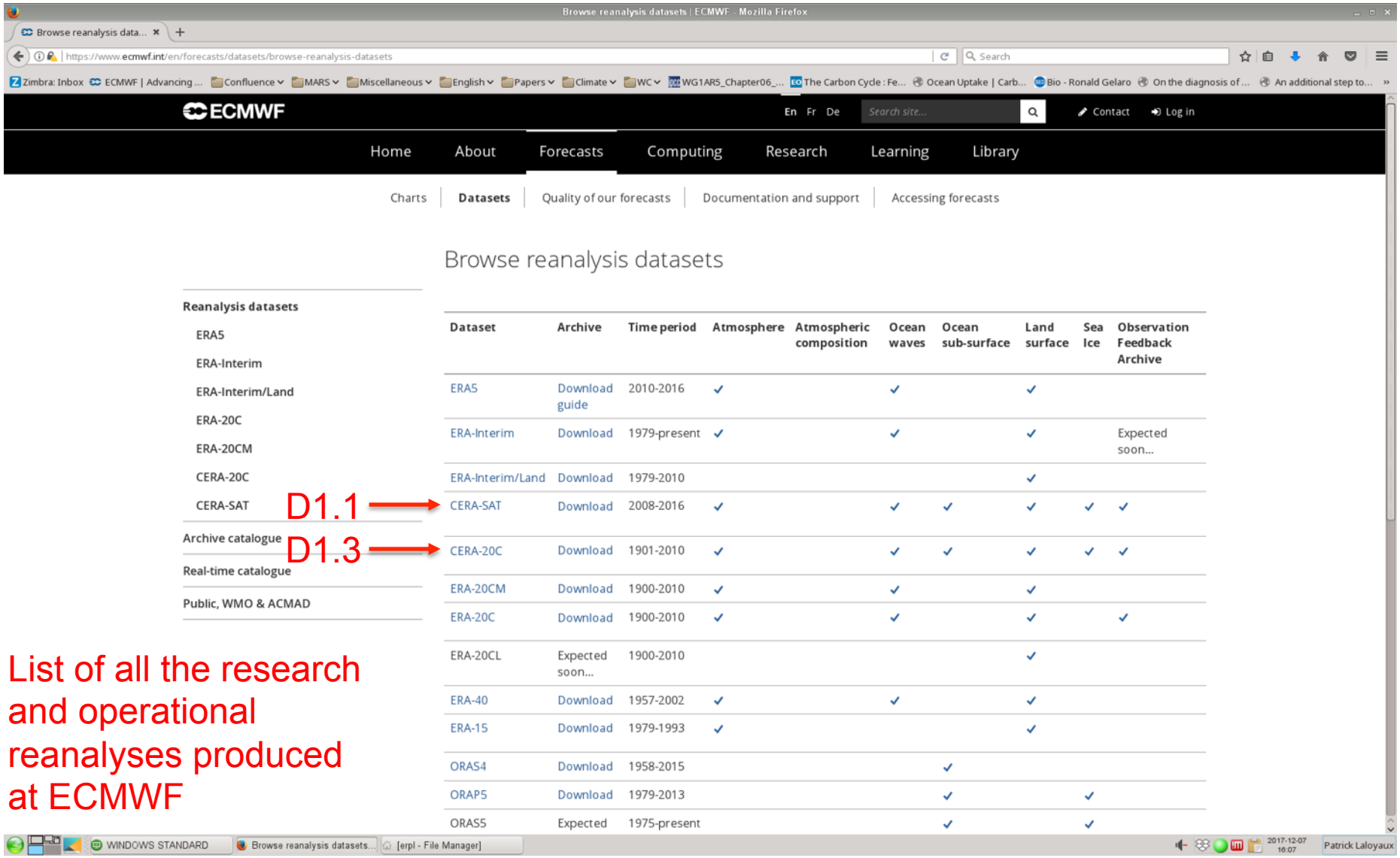
CAMS forecasts

Related topics

- MARS catalogue
- Search all datasets
- Catalogue of charts

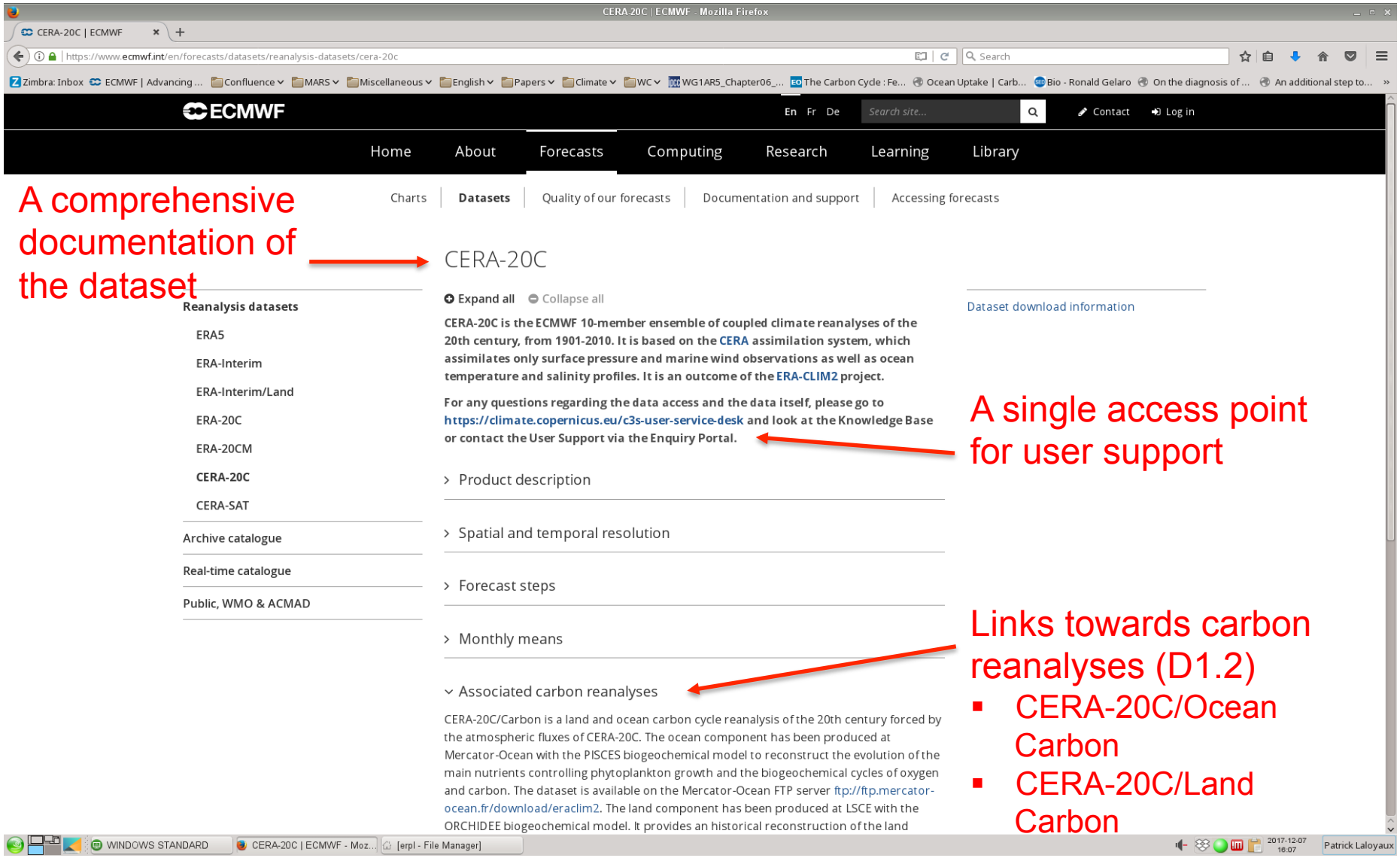
One access point for the reanalysis datasets

Overview from the user experience point of view



List of all the research and operational reanalyses produced at ECMWF

Overview from the user experience point of view



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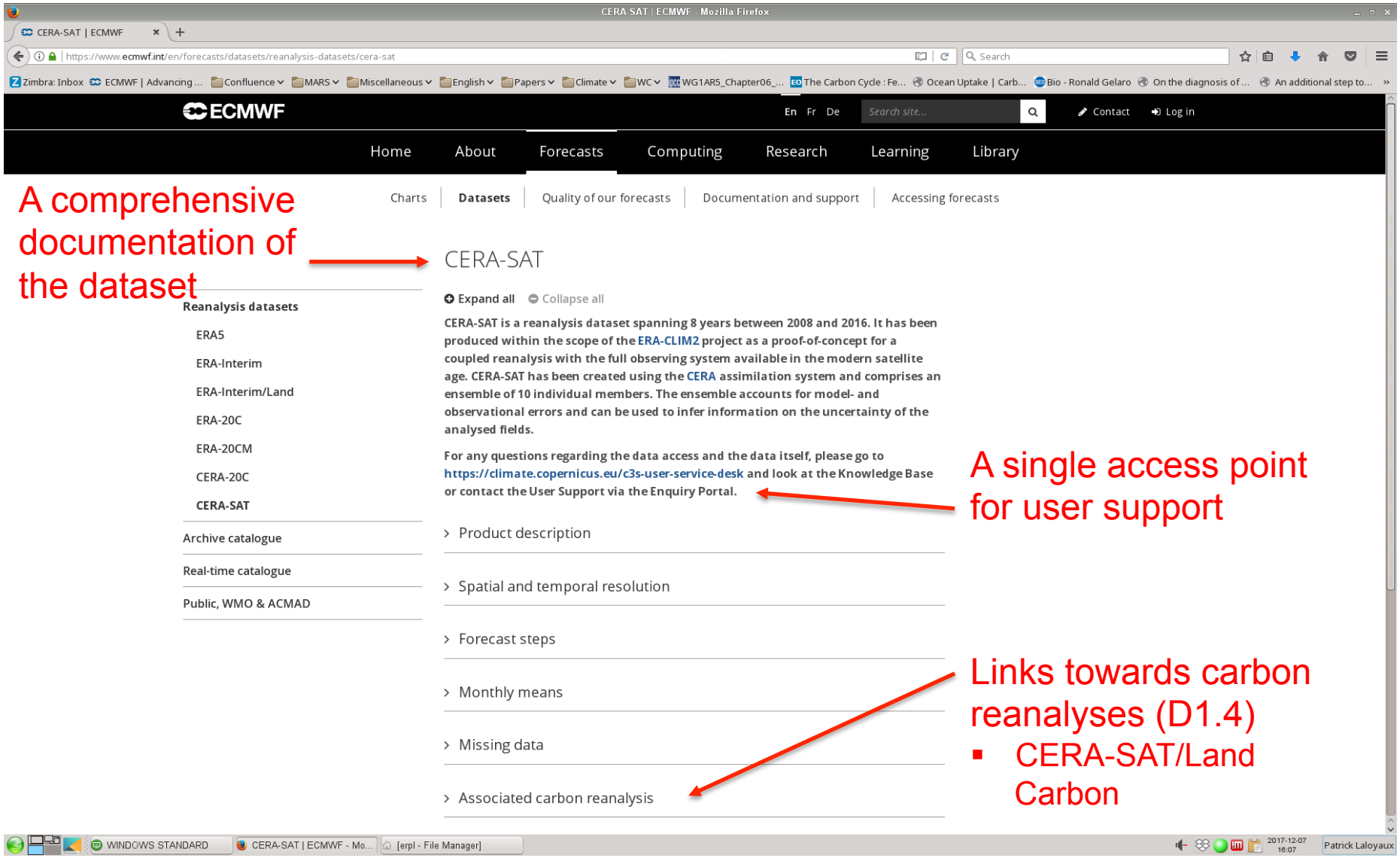

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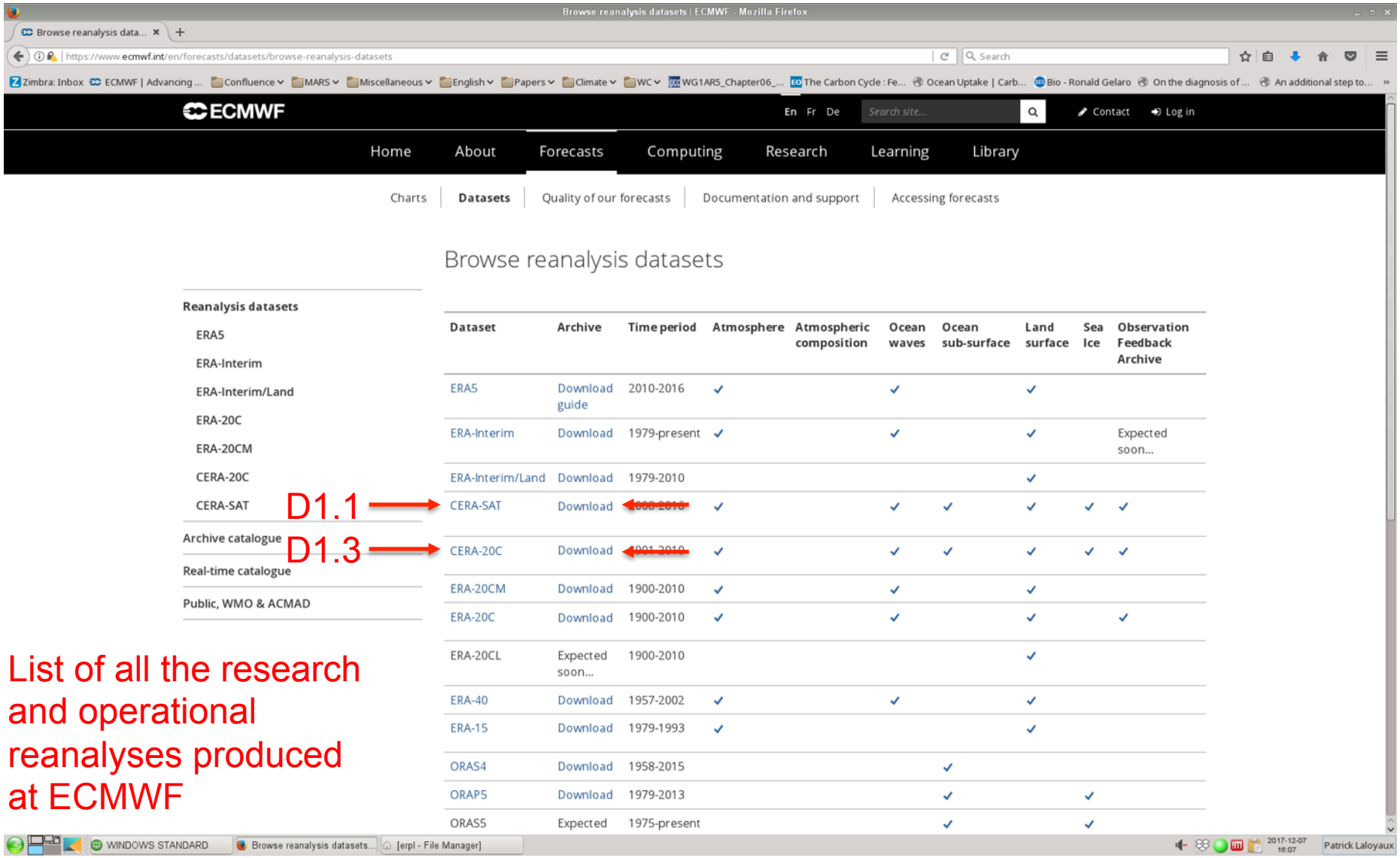


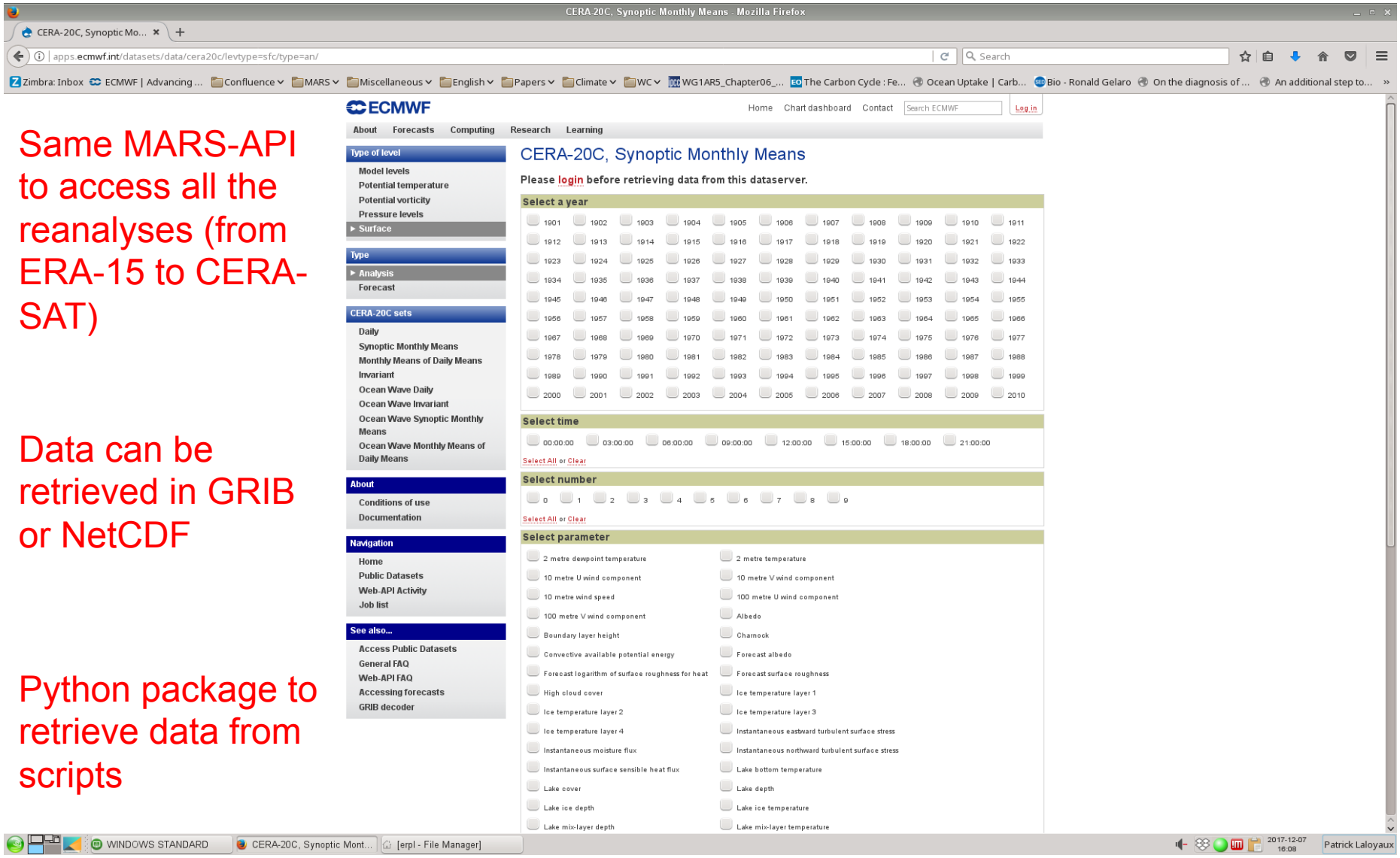
List of all the research and operational reanalyses produced at ECMWF

Overview from the user experience point of view

Same MARS-API to access all the reanalyses (from ERA-15 to CERA-SAT)

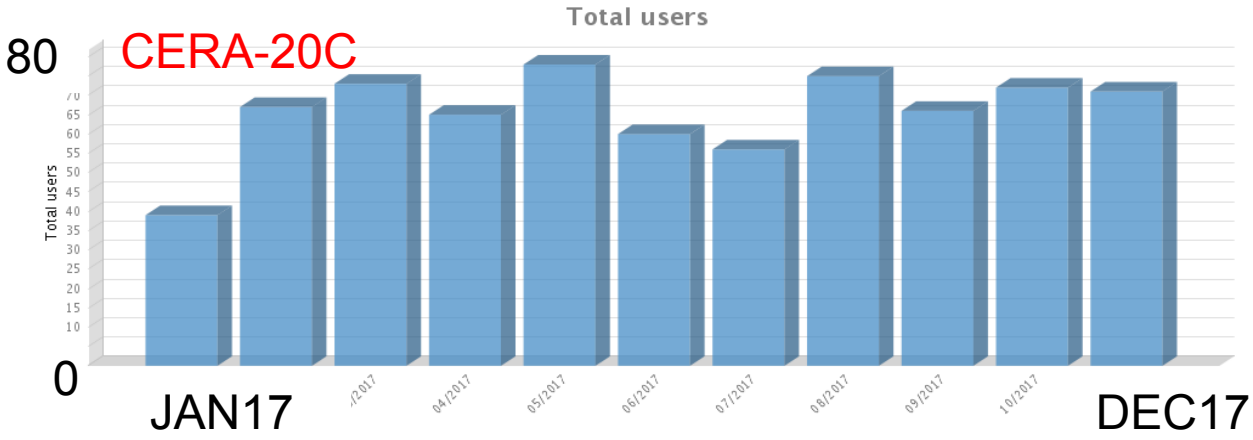
Data can be retrieved in GRIB or NetCDF

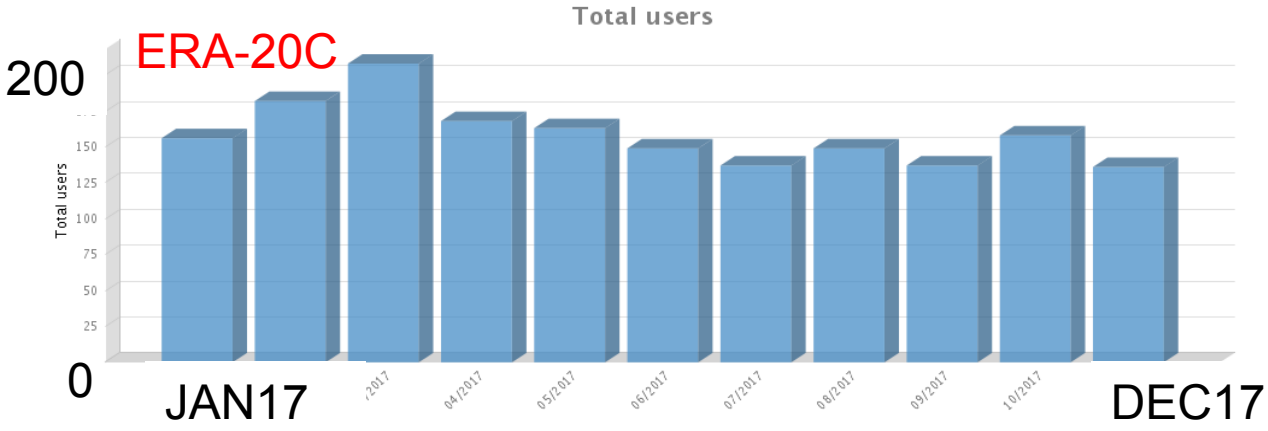
Python package to retrieve data from scripts



User statistics for CERA-20C

- Advertised on the main reanalysis websites
- E-mail sent to all the ERA-20C users
- ECMWF newsletter published
- Datasets presented in many conferences





How much coupling in the CERA system?

Patrick Laloyaux, Sergey Frolov (NRL) and Massimo Bonavita

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CERA CLIM2

SEVENTH FRAMEWORK PROGRAMME

Outer loop coupling in the CERA system

Iterative process where the ocean and the atmosphere converge towards a consistent coupled state

$$\begin{bmatrix} \mathrm{x}^0 \\ \mathrm{x}^0 \end{bmatrix} = \begin{bmatrix} \mathrm{x}^\mathrm{b} \\ \mathrm{x}^\mathrm{b} \end{bmatrix}$$

for k=0,1,... do

Compute observation departures

$$\begin{bmatrix} \delta\mathrm{y}^\mathrm{k} \\ \delta\mathrm{y}^\mathrm{k} \end{bmatrix} = \begin{bmatrix} \mathrm{y} \\ \mathrm{y} \end{bmatrix} - \begin{bmatrix} \mathcal{H} \\ \mathcal{H} \end{bmatrix} \mathcal{M}(\mathrm{x}^\mathrm{k}, \mathrm{x}^\mathrm{k})$$

Compute increments

$$\delta\mathrm{x}^\mathrm{k} = (\mathrm{x}^\mathrm{b} - \mathrm{x}^\mathrm{k}) + \mathrm{BH}^\mathrm{T}(\mathrm{HBH}^\mathrm{T} + \mathrm{R})^{-1}\delta\mathrm{y}^\mathrm{k}$$

$$\delta\mathrm{x}^\mathrm{k} = (\mathrm{x}^\mathrm{b} - \mathrm{x}^\mathrm{k}) + \mathrm{BH}^\mathrm{T}(\mathrm{HBH}^\mathrm{T} + \mathrm{R})^{-1}\delta\mathrm{y}^\mathrm{k}$$

Update initial condition

$$\begin{bmatrix} \mathrm{x}^{\mathrm{k}+1} \\ \mathrm{x}^{\mathrm{k}+1} \end{bmatrix} = \begin{bmatrix} \mathrm{x}^\mathrm{k} \\ \mathrm{x}^\mathrm{k} \end{bmatrix} + \begin{bmatrix} \delta\mathrm{x}^\mathrm{k} \\ \delta\mathrm{x}^\mathrm{k} \end{bmatrix}$$

end

Outer loop coupling in the CERA system

Iterative process where the ocean and the atmosphere converge towards a consistent coupled state

$$\begin{bmatrix} \mathrm{x}^0 \\ \mathrm{x}^0 \end{bmatrix} = \begin{bmatrix} \mathrm{x}^\mathrm{b} \\ \mathrm{x}^\mathrm{b} \end{bmatrix}$$

for k=0,1,... do

Compute increments

$$\delta\mathrm{x}^\mathrm{k} = (\mathrm{x}^\mathrm{b} - \mathrm{x}^\mathrm{k}) + \mathrm{BH}^\mathrm{T}(\mathrm{HBH}^\mathrm{T} + \mathrm{R})^{-1}\left(\mathrm{y} - \mathcal{H}\mathcal{M}(\mathrm{x}^\mathrm{k}, \mathrm{x}^\mathrm{k})\right)$$

$$\delta\mathrm{x}^\mathrm{k} = (\mathrm{x}^\mathrm{b} - \mathrm{x}^\mathrm{k}) + \mathrm{BH}^\mathrm{T}(\mathrm{HBH}^\mathrm{T} + \mathrm{R})^{-1}\left(\mathrm{y} - \mathcal{H}\mathcal{M}(\mathrm{x}^\mathrm{k}, \mathrm{x}^\mathrm{k})\right)$$

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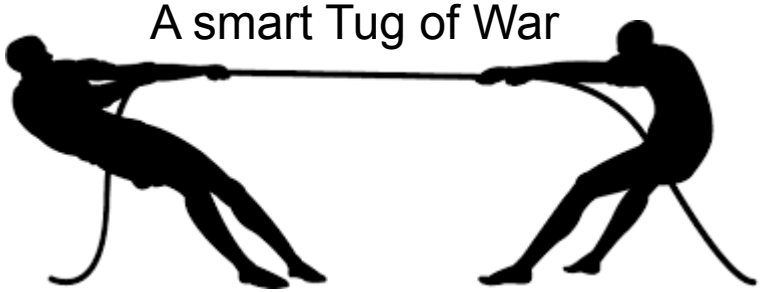
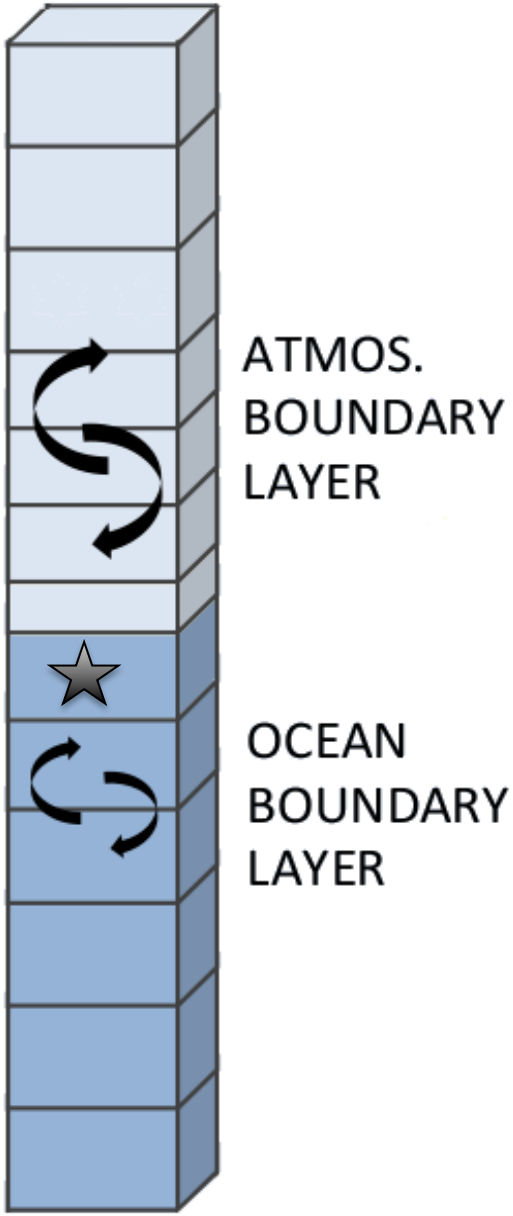
end

A smart Tug of War



Atmospheric increment depends on the current ocean state
Ocean increment depends on the current atmospheric state

Single observation experiments



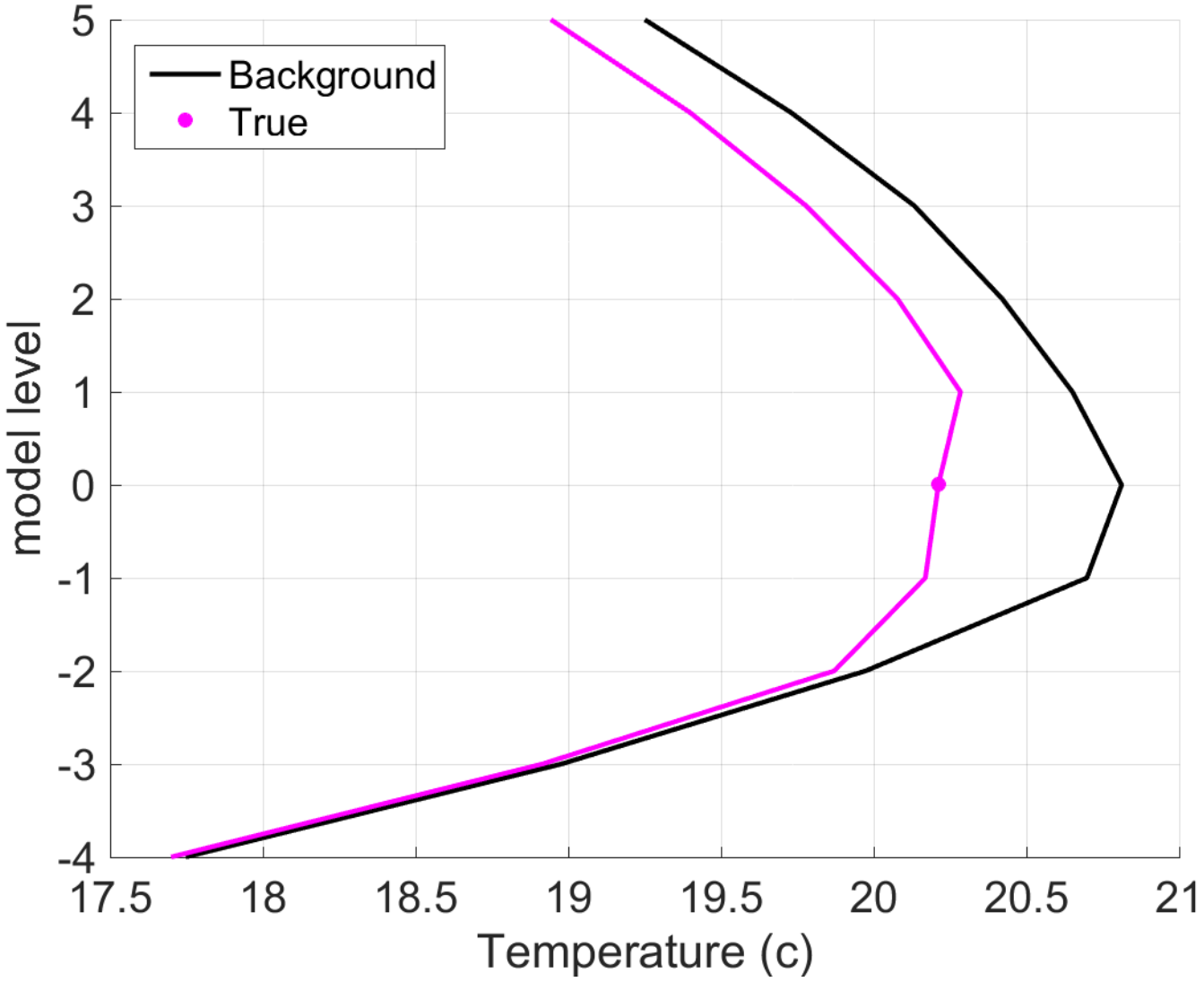
Compare the implicit cross-correlations from CERA with explicit cross-correlation from an ensemble

Single observation experiments

- the true state is known
- one accurate and unbiased observation (T, first level in the ocean, valid after 10 hours)
- background from another run with a larger error

How CERA transfers information in space

Coupled state estimate after 10 hours



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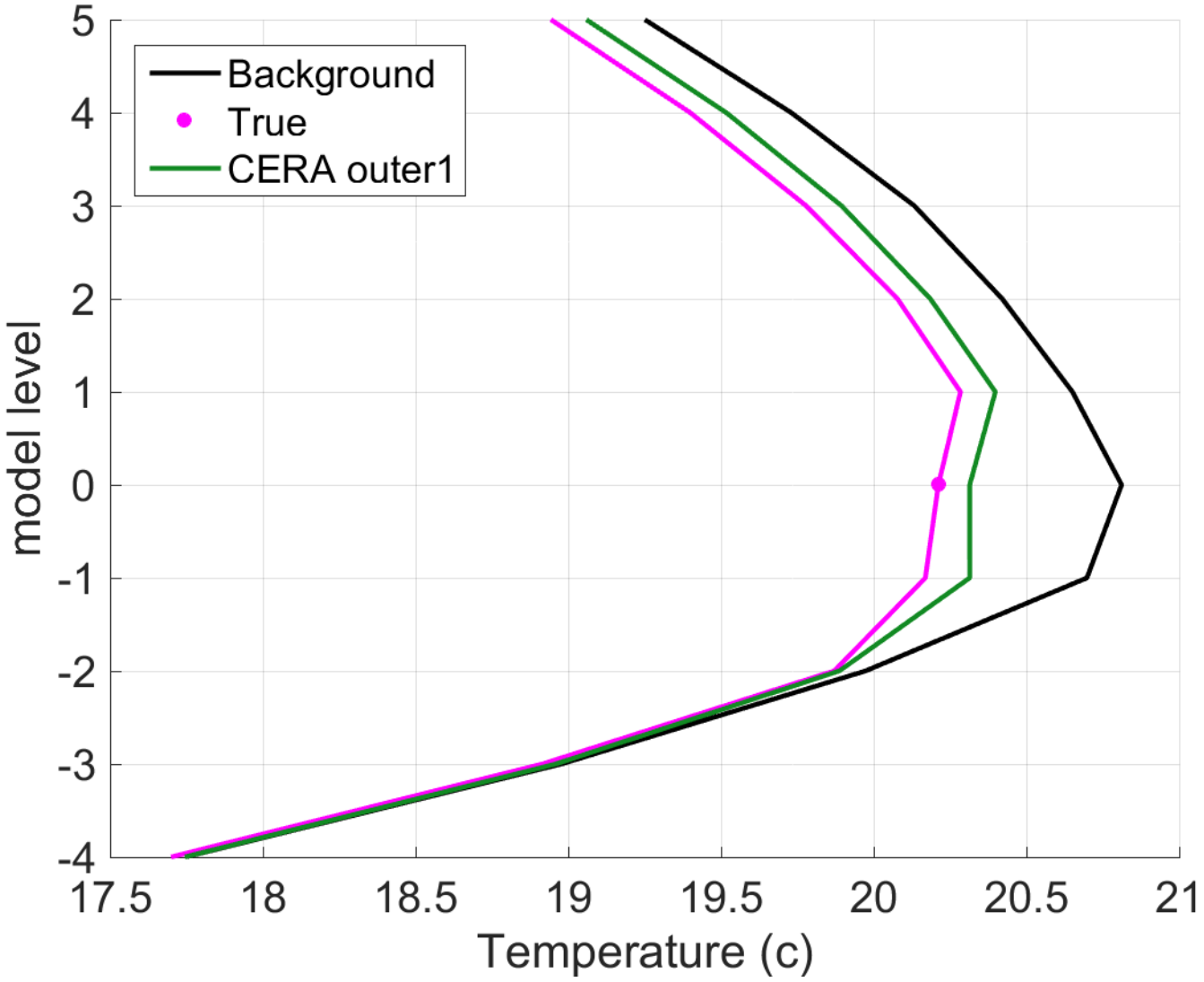
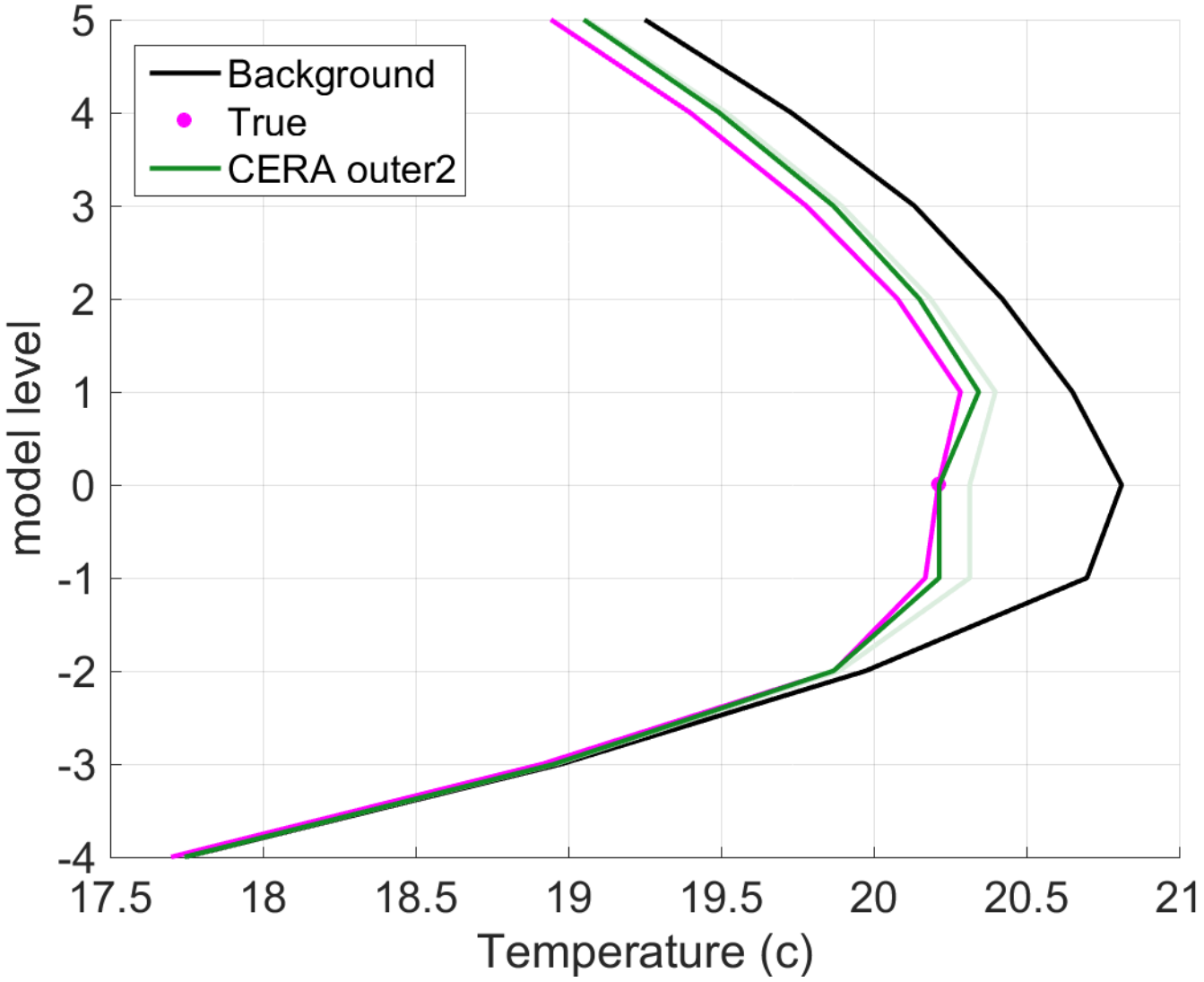
Coupled state estimate after 10 hours



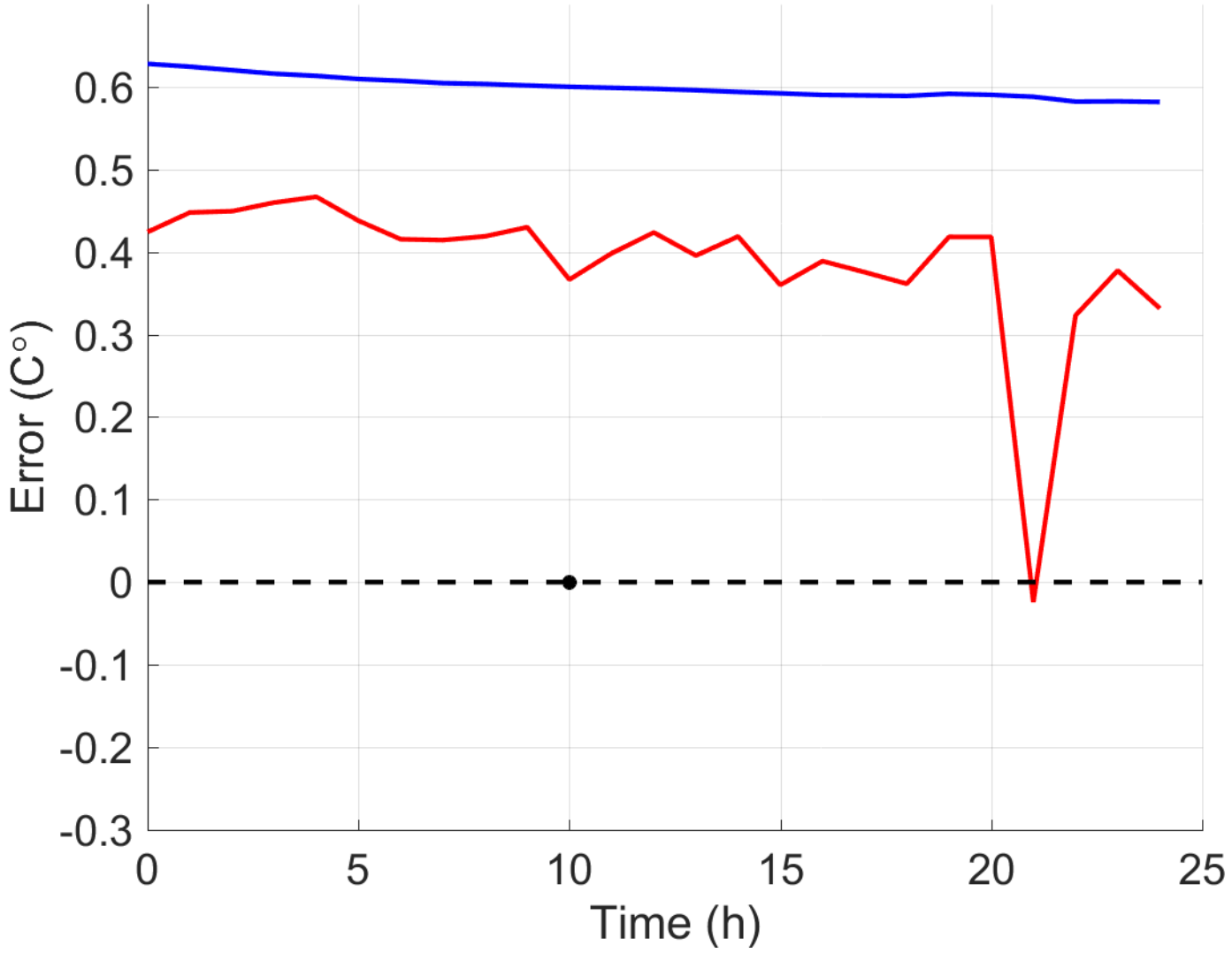
How CERA transfers information in space

Coupled state estimate after 10 hours



How CERA transfers information in time

Ocean and atmospheric trajectories during the CERA minimisation



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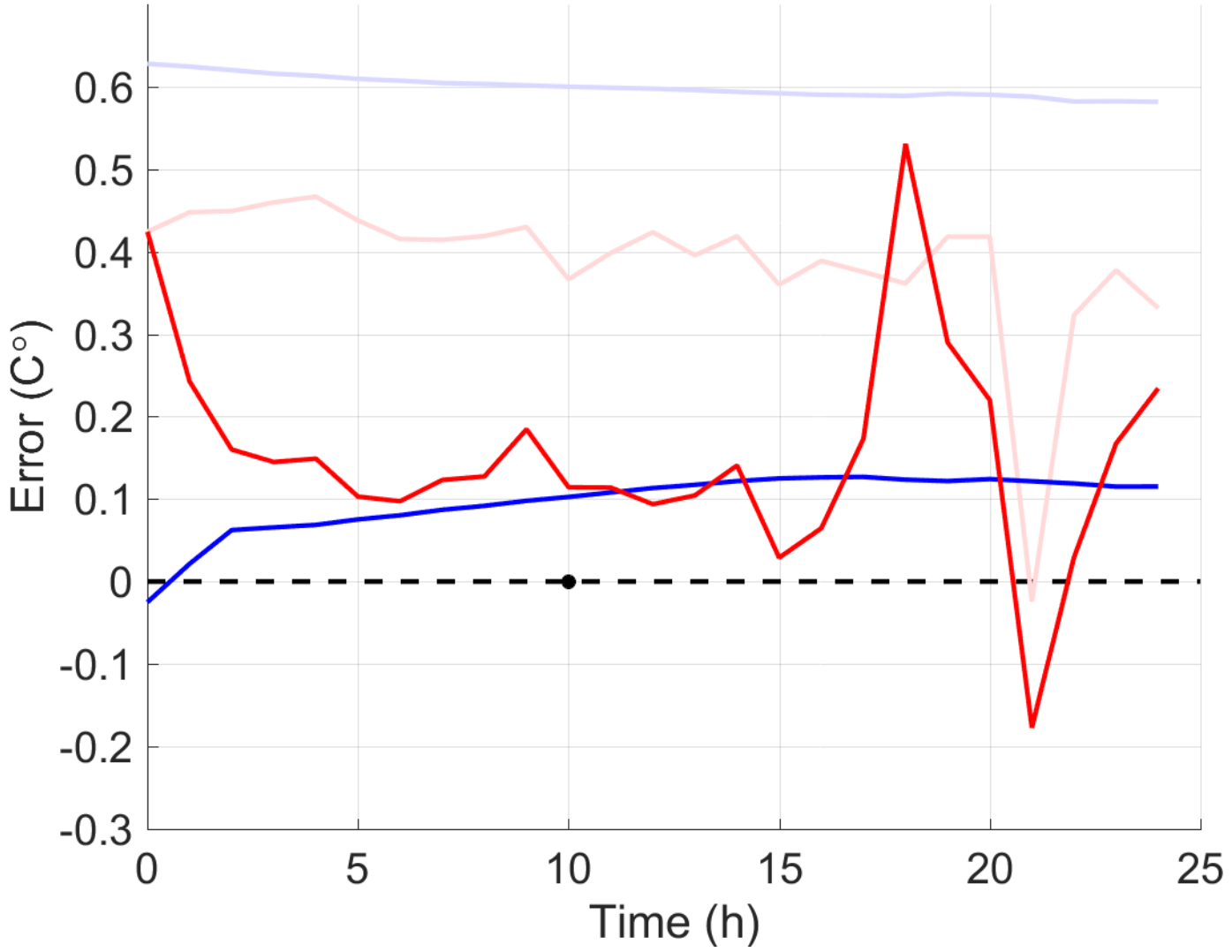

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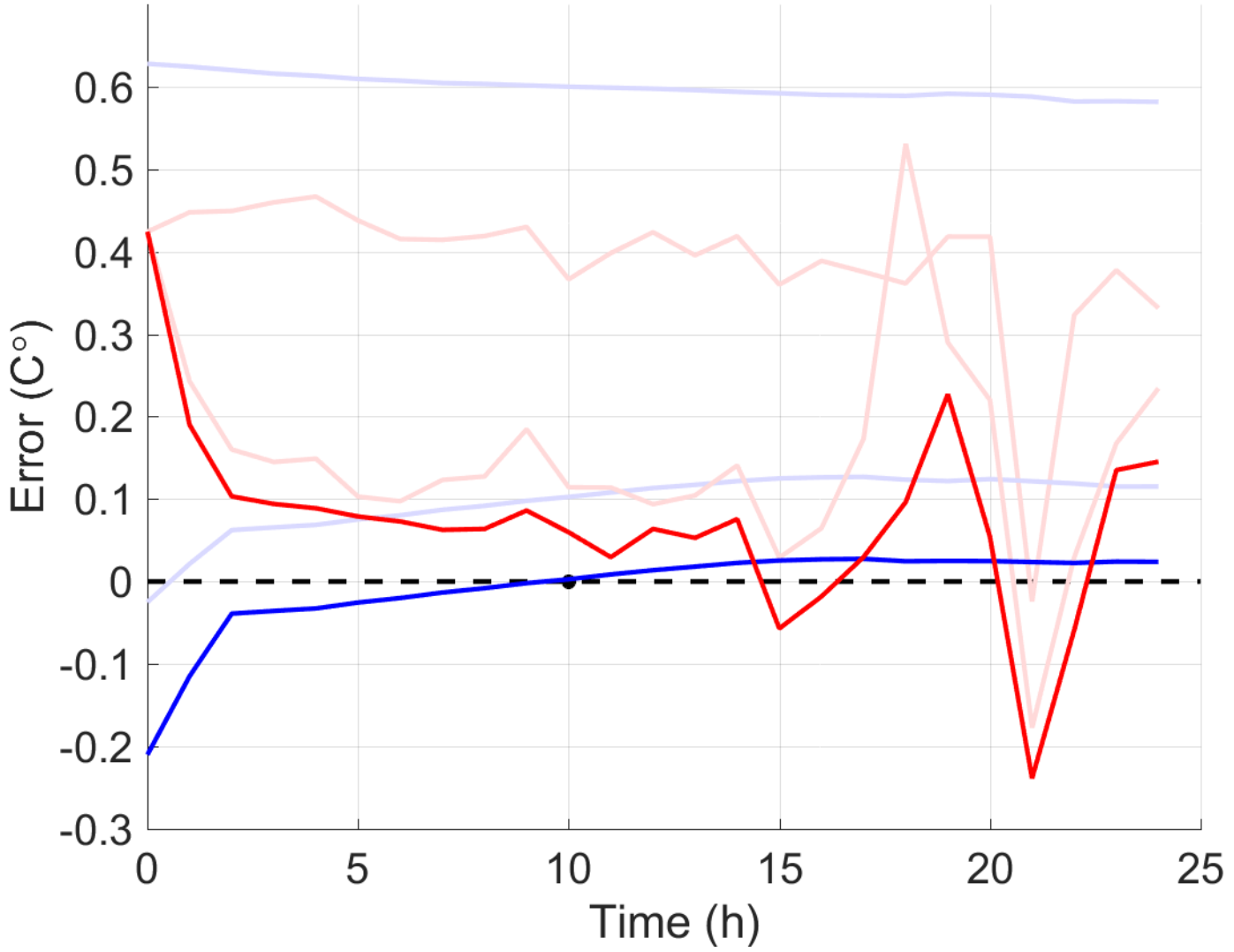


Explicit cross-correlations from an ensemble

$$\begin{bmatrix} \mathrm{x}^{\mathrm{f}} \\ \mathrm{x}^{\mathrm{f}} \end{bmatrix} = \begin{bmatrix} \mathrm{x}^{\mathrm{b}} \\ \mathrm{x}^{\mathrm{b}} \end{bmatrix}$$

Compute observation departures

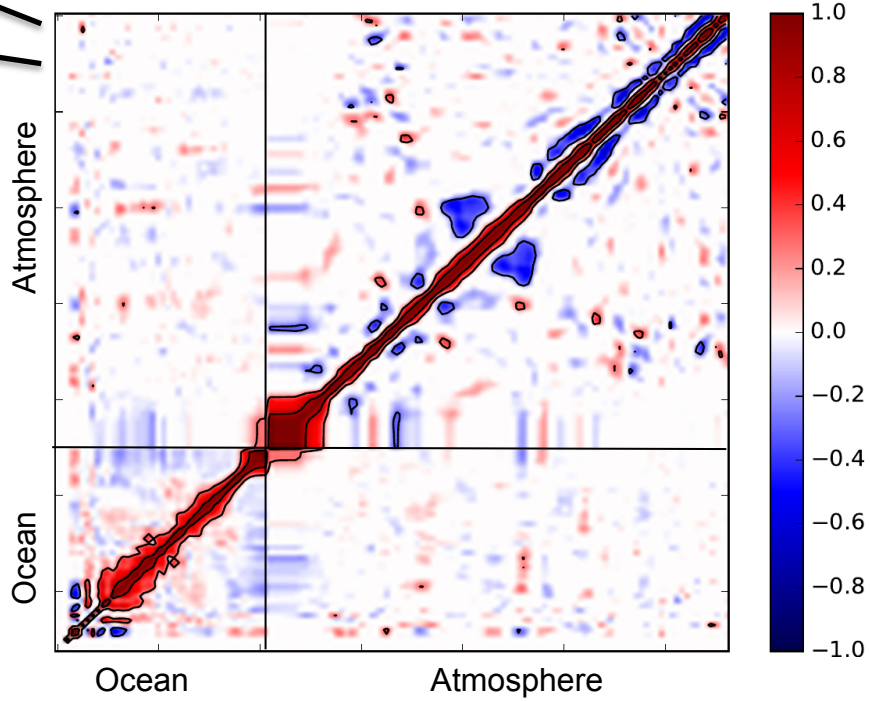
$$\begin{bmatrix} \delta\mathrm{y} \\ \delta\mathrm{y} \end{bmatrix} = \begin{bmatrix} \mathrm{y} \\ \mathrm{y} \end{bmatrix} - \begin{bmatrix} \mathcal{H} \\ \mathcal{H} \end{bmatrix} \mathcal{M}(\mathrm{x}^{\mathrm{k}}, \mathrm{x}^{\mathrm{k}})$$

Compute analysis

$$\begin{bmatrix} \mathrm{x}^{\mathrm{a}} \\ \mathrm{x}^{\mathrm{a}} \end{bmatrix} = \begin{bmatrix} \mathrm{x}^{\mathrm{f}} \\ \mathrm{x}^{\mathrm{f}} \end{bmatrix} + \begin{bmatrix} \mathrm{B} & \mathrm{B} \\ \mathrm{B} & \mathrm{B} \end{bmatrix} [\mathrm{H}\ \mathrm{H}] \left(\begin{bmatrix} \mathrm{H} \\ \mathrm{H} \end{bmatrix} \begin{bmatrix} \mathrm{B} & \mathrm{B} \\ \mathrm{B} & \mathrm{B} \end{bmatrix} [\mathrm{H}\ \mathrm{H}] \right)^{-1} \begin{bmatrix} \delta\mathrm{y} \\ \delta\mathrm{y} \end{bmatrix}$$

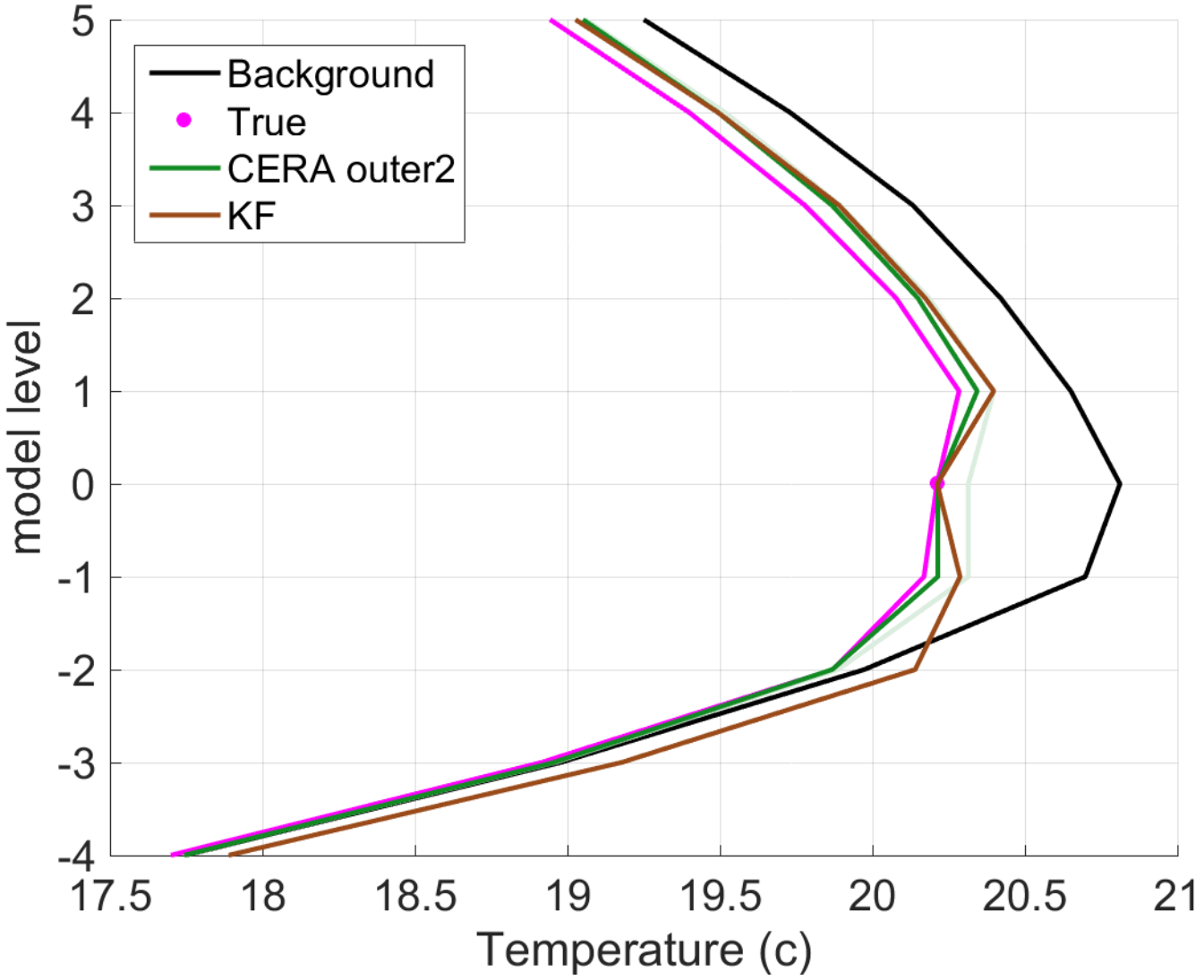
Explicit coupled background error, computed from an ensemble of 25 coupled forecasts.

Used to update the background state following the Kalman filter equation



Explicit cross-correlations from an ensemble

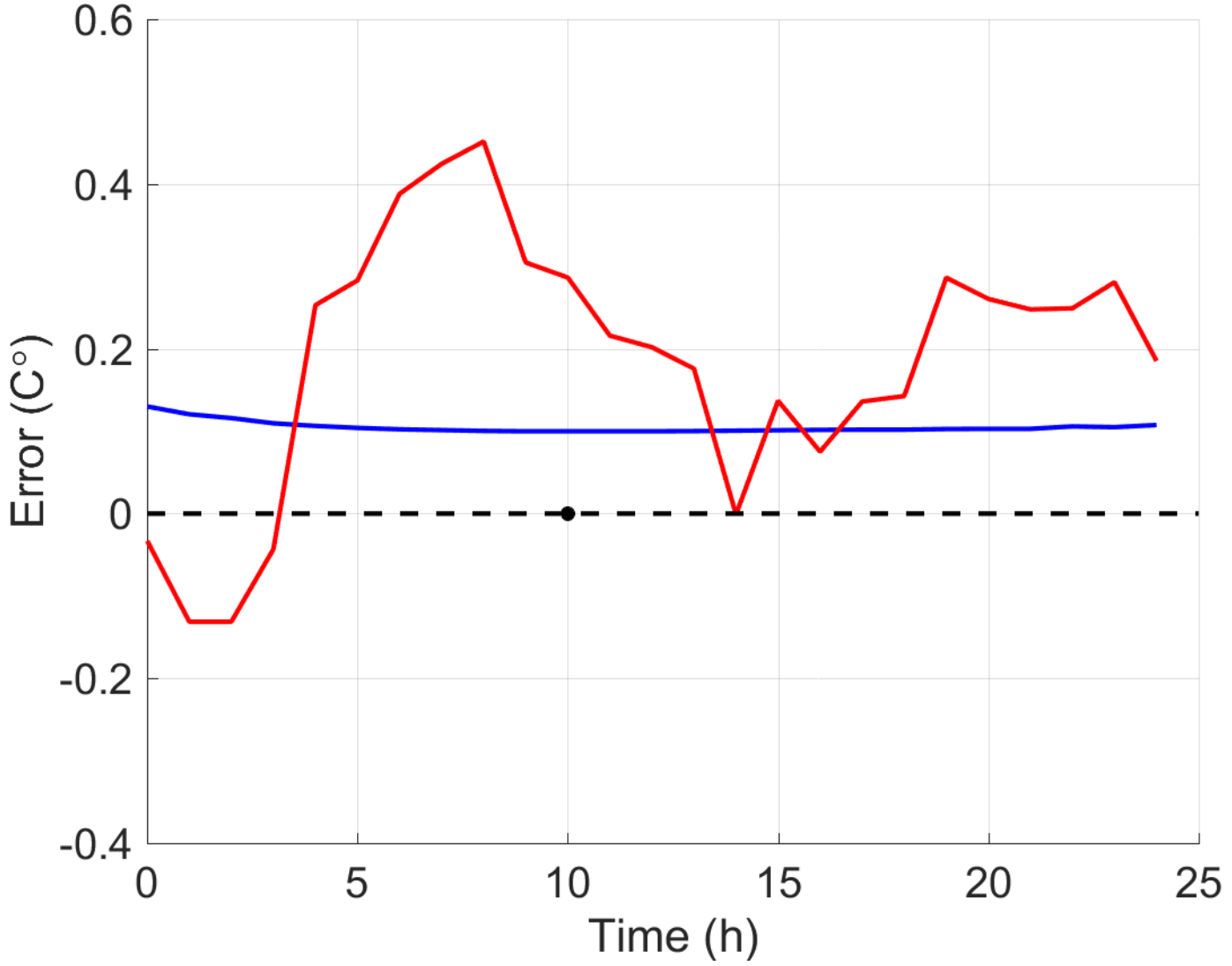
Coupled state estimate after 10 hours



Implicit cross-correlation from CERA and explicit cross-correlation from an ensemble correct the coupled state in a similar way

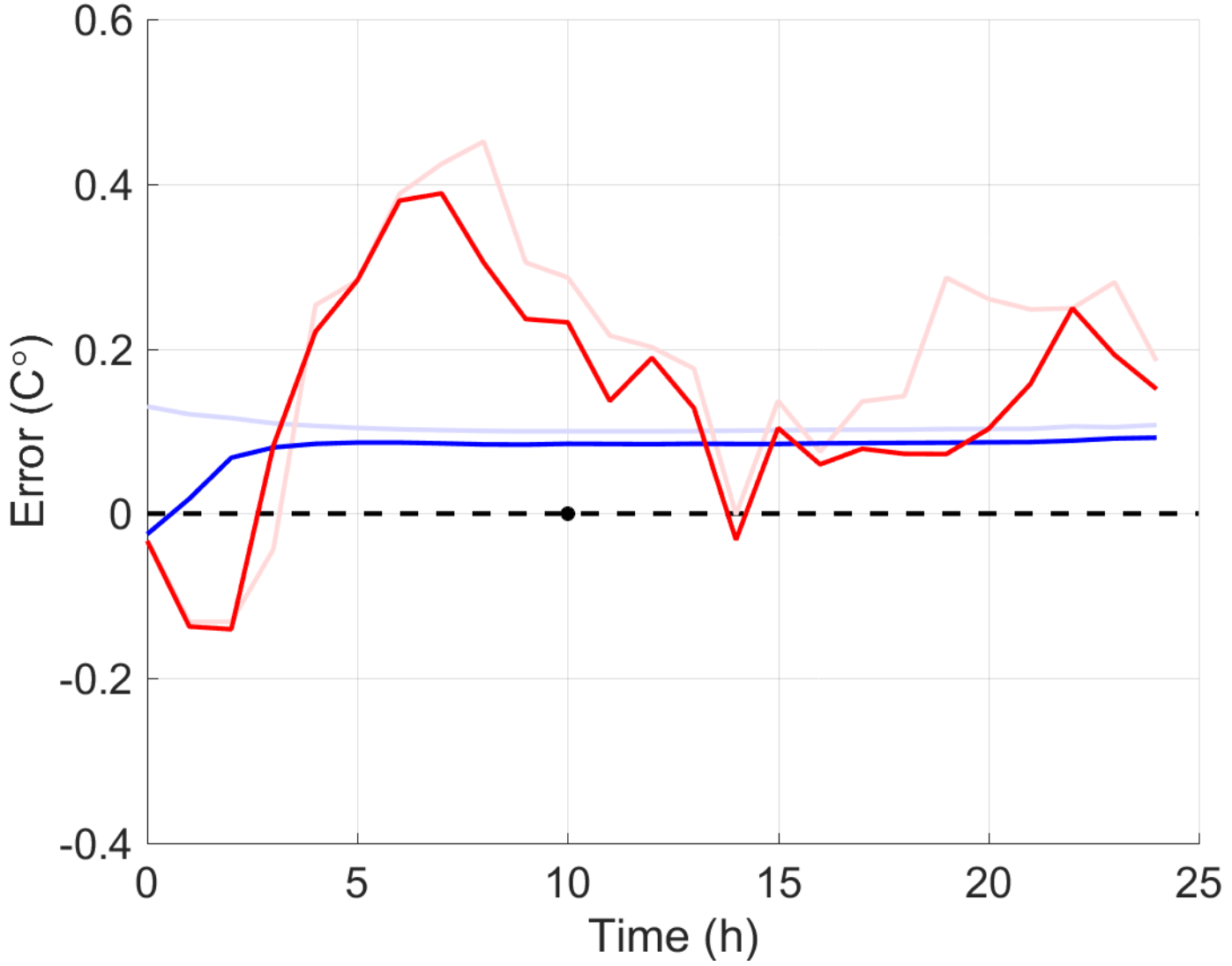
What's happening when the mixed layer is deep?

Ocean and atmospheric trajectories during the CERA minimisation



What's happening when the mixed layer is deep?

Ocean and atmospheric trajectories during the CERA minimisation



What's happening when the mixed layer is deep?

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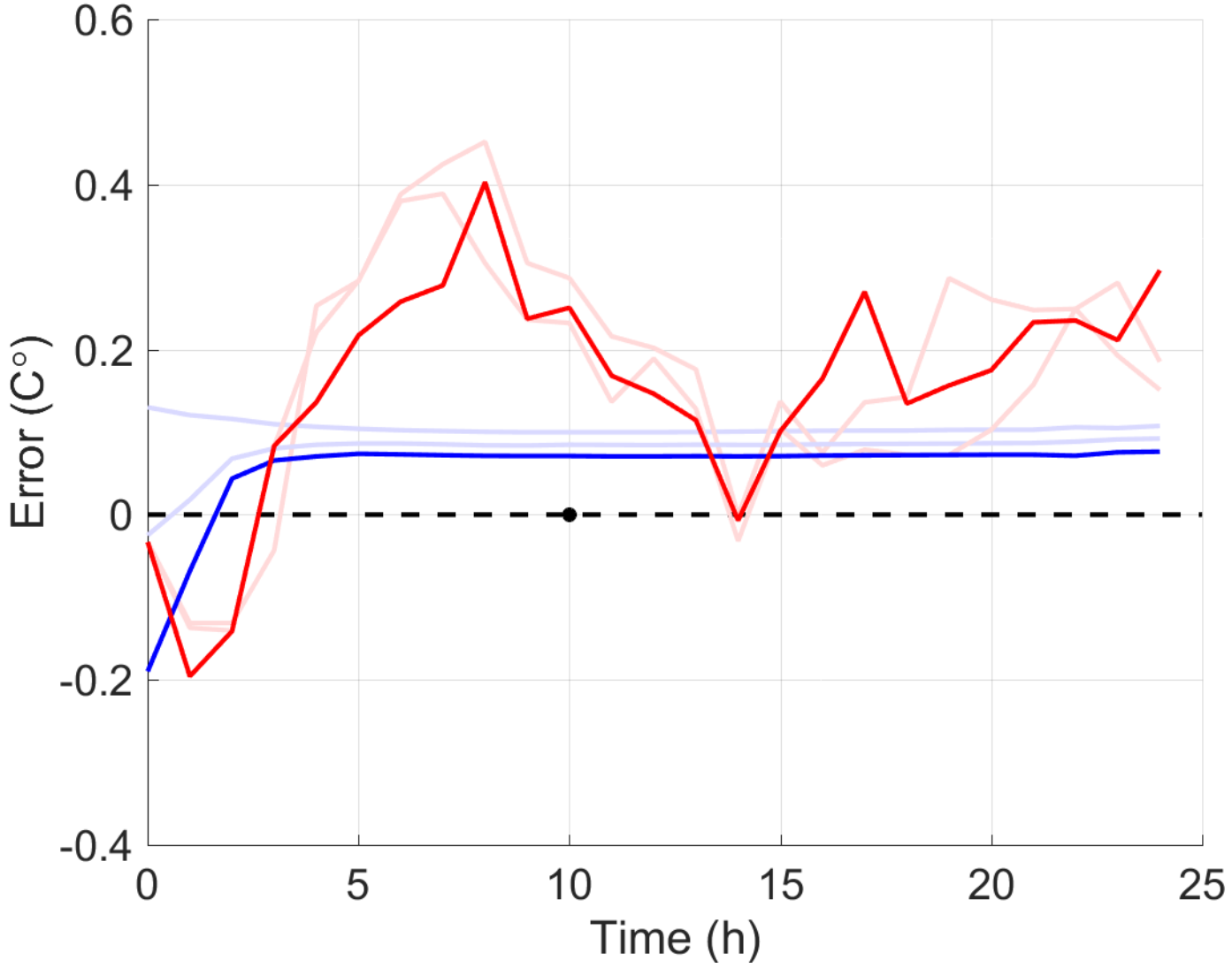
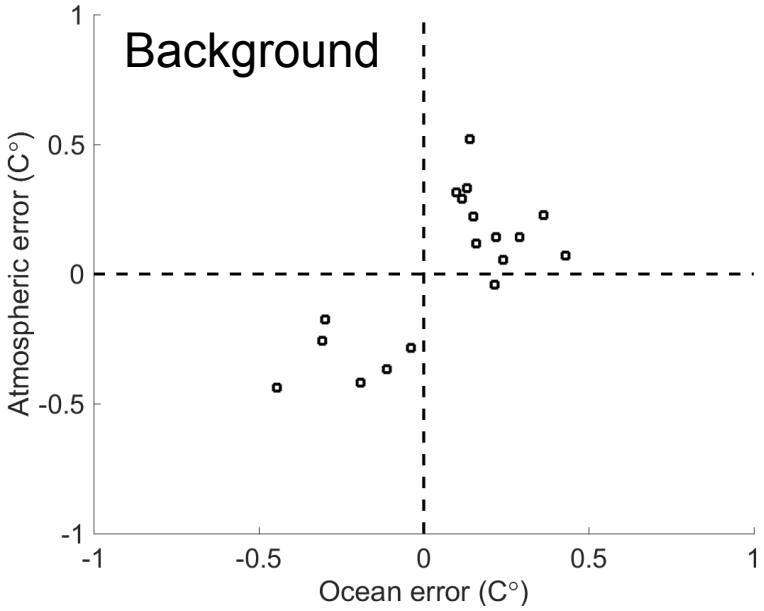
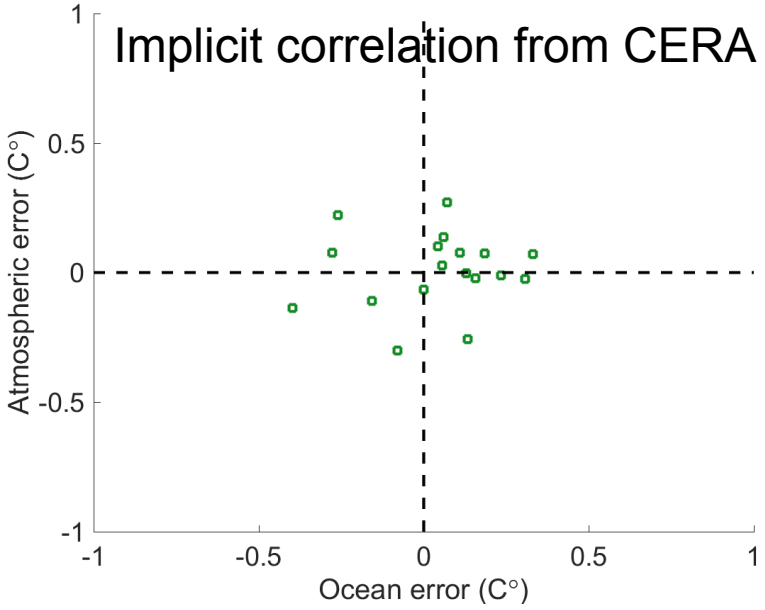
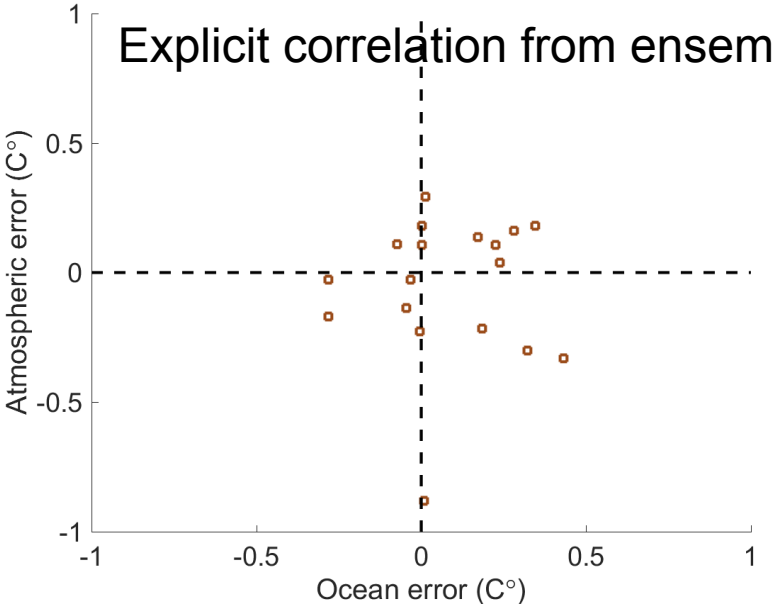


Why does the 0.3 ocean temperature increment disappear after 2 hours?

Summary plot of the 18 single observation experiments

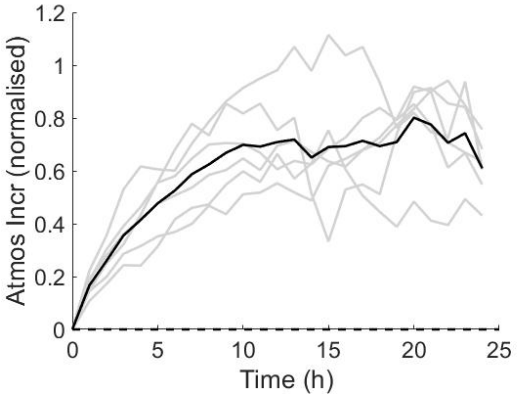




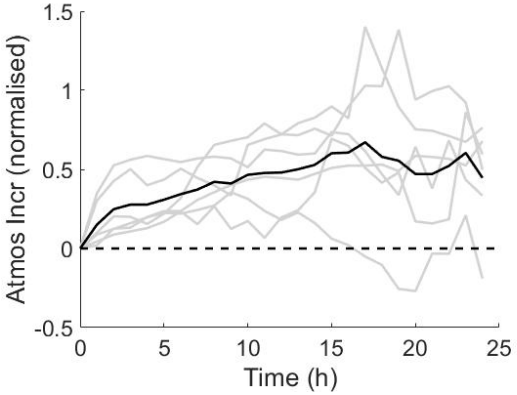


Summary plot of the 18 single observation experiments

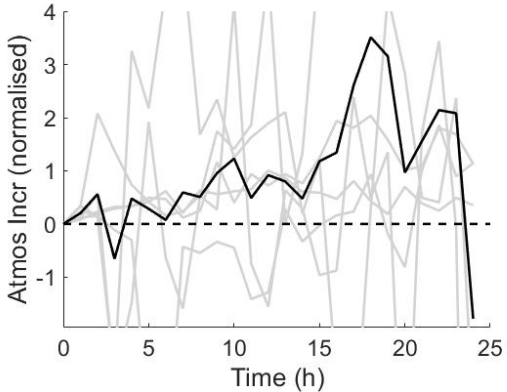
Evolution of the atmospheric increment (normalised by the ocean increment)



Tropics
→ Most of the ocean increment is transferred to the atmosphere within 10 hours



Extra-tropics (shallow mixed layer)
→ Most of the ocean increment is transferred to the atmosphere within 10 hours



Extra-tropics (deep mixed layer)
→ Atmospheric response is extremely noisy