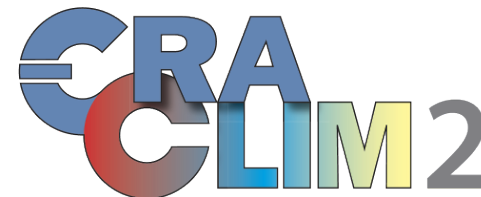
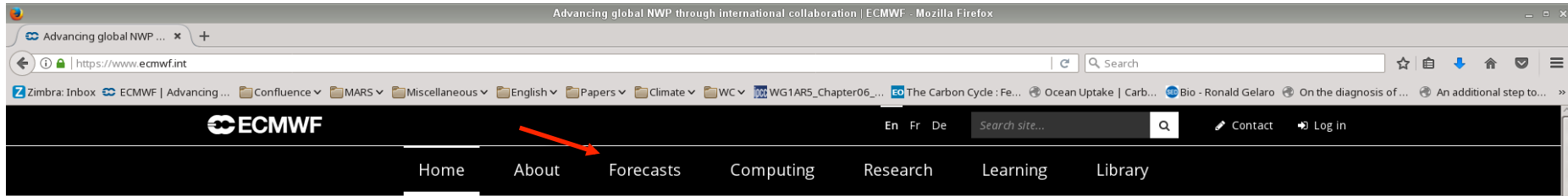


Overview WP1 (reanalysis production) and WP5 (service developments)

Patrick Laloyaux & Manuel Fuentes

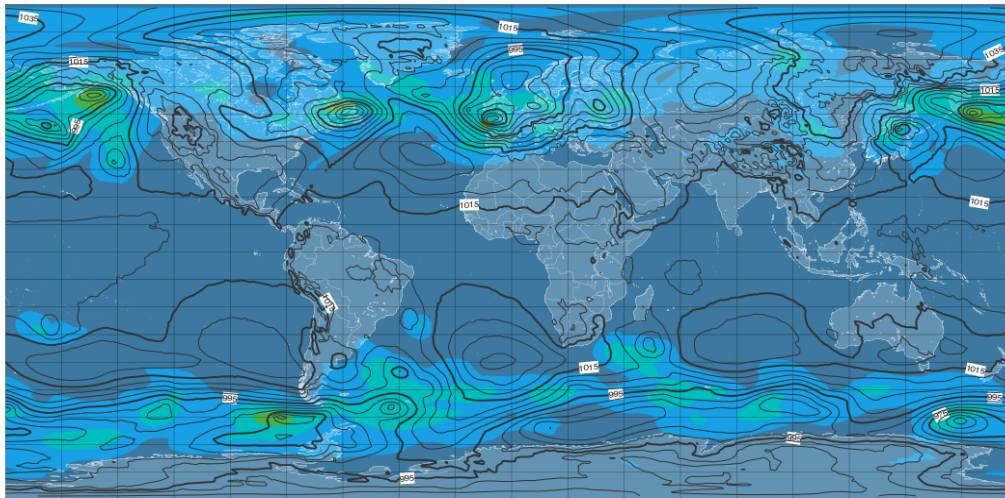


Overview from the user experience point of view



Forecasts menu to access datasets

Advancing global NWP through international collaboration



High resolution mean sea level pressure and ensemble spread

Thursday 07 December, 00 UTC T+96 Valid:
Monday 11 December, 00 UTC

Ensemble forecasts explained

One 'ensemble forecast' consists of 51 separate forecasts made by the same computer model, all activated from the same starting time. The starting conditions for each member of the ensemble are slightly different, and physical parameter values used also differ slightly. The differences between these ensemble members tend to grow as the forecasts progress, that is as the forecast lead time increases.

[View all charts >](#)



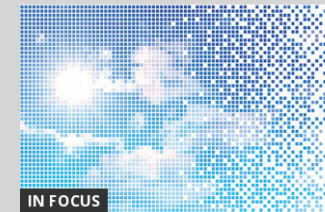
SCIENCE BLOG



NEWS



NEWS



IN FOCUS

Overview from the user experience point of view

The screenshot shows the ECMWF Datasets website in a Mozilla Firefox browser. The page layout includes a top navigation bar with the ECMWF logo, language options (En, Fr, De), a search bar, and contact/log in links. Below this is a main navigation menu with links for Home, About, Forecasts, Computing, Research, Learning, and Library. A secondary menu below the main navigation includes Charts, **Datasets** (highlighted with a red arrow), Quality of our forecasts, Documentation and support, and Accessing forecasts. The main content area is titled "Datasets" and contains a descriptive paragraph, three maps, and three columns of content: Operational, Climate reanalysis, and Atmospheric composition. A red arrow points to the "Browse reanalysis datasets" link in the Climate reanalysis section. On the right, there is a "Related topics" section with links to MARS catalogue, Search all datasets, and Catalogue of charts. The Windows taskbar at the bottom shows the system tray with the date 2017-12-07 and time 16:06, and the user name Patrick Laloyaux.

ECMWF

Home About Forecasts Computing Research Learning Library

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

Datasets

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.

Reanalysis datasets

Archive catalogue

Real-time catalogue

Public, WMO & ACMAD

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

Fire activity (CFR)

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

Browse reanalysis datasets

Reanalysis datasets

	Dataset	Archive	Time period	Atmosphere	Atmospheric composition	Ocean waves	Ocean sub-surface	Land surface	Sea Ice	Observation Feedback Archive
ERA5	ERA5	Download guide	2010-2016	✓		✓		✓		
ERA-Interim	ERA-Interim	Download	1979-present	✓		✓		✓		Expected soon...
ERA-Interim/Land	ERA-Interim/Land	Download	1979-2010					✓		
ERA-20C	CERA-SAT	Download	2008-2016	✓		✓	✓	✓	✓	✓
ERA-20CM	CERA-20C	Download	1901-2010	✓		✓	✓	✓	✓	✓
CERA-20C	ERA-20CM	Download	1900-2010	✓		✓		✓		
CERA-SAT	ERA-20C	Download	1900-2010	✓		✓		✓		✓
Archive catalogue	ERA-20CL	Expected soon...	1900-2010					✓		
Real-time catalogue	ERA-40	Download	1957-2002	✓		✓		✓		
Public, WMO & ACMAD	ERA-15	Download	1979-1993	✓				✓		
	ORAS4	Download	1958-2015				✓			
	ORAP5	Download	1979-2013				✓		✓	
	ORASS	Expected	1975-present				✓		✓	

D1.1 → CERA-SAT

D1.3 → CERA-20C

List of all the research and operational reanalyses produced at ECMWF

Overview from the user experience point of view

A comprehensive documentation of the dataset

A single access point for user support

Links towards carbon reanalyses (D1.2)

- CERA-20C/Ocean Carbon
- CERA-20C/Land Carbon

The screenshot shows the ECMWF website interface. The main navigation bar includes Home, About, Forecasts, Computing, Research, Learning, and Library. The 'Forecasts' section is active, showing sub-links for Charts, Datasets, Quality of our forecasts, Documentation and support, and Accessing forecasts. The 'Datasets' section is expanded, listing various reanalysis datasets: ERA5, ERA-Interim, ERA-Interim/Land, ERA-20C, ERA-20CM, CERA-20C, and CERA-SAT. The 'CERA-20C' dataset is selected, displaying its description: 'CERA-20C is the ECMWF 10-member ensemble of coupled climate reanalyses of the 20th century, from 1901-2010. It is based on the CERA assimilation system, which assimilates only surface pressure and marine wind observations as well as ocean temperature and salinity profiles. It is an outcome of the ERA-CLIM2 project.' Below the description, there are sections for 'Product description', 'Spatial and temporal resolution', 'Forecast steps', and 'Monthly means'. The 'Associated carbon reanalyses' section is expanded, providing links to 'CERA-20C/Ocean Carbon' and 'CERA-20C/Land Carbon'. The page also includes a search bar, contact information, and a log in link.

Overview from the user experience point of view

A comprehensive documentation of the dataset →

A single access point for user support →

Links towards carbon reanalyses (D1.4)

- CERA-SAT/Land Carbon

The screenshot shows the ECMWF website interface. The main content area is titled 'CERA-SAT' and includes a description: 'CERA-SAT is a reanalysis dataset spanning 8 years between 2008 and 2016. It has been produced within the scope of the ERA-CLIM2 project as a proof-of-concept for a coupled reanalysis with the full observing system available in the modern satellite age. CERA-SAT has been created using the CERA assimilation system and comprises an ensemble of 10 individual members. The ensemble accounts for model- and observational errors and can be used to infer information on the uncertainty of the analysed fields.' Below the description, there are several links: 'Product description', 'Spatial and temporal resolution', 'Forecast steps', 'Monthly means', 'Missing data', and 'Associated carbon reanalysis'. The sidebar on the left lists 'Reanalysis datasets' including ERA5, ERA-Interim, ERA-Interim/Land, ERA-20C, ERA-20CM, CERA-20C, and CERA-SAT. The 'Associated carbon reanalysis' link is highlighted with a red arrow pointing to the text 'Links towards carbon reanalyses (D1.4)'. Another red arrow points to the text 'A single access point for user support' which points to the 'Expand all' and 'Collapse all' buttons. A third red arrow points to the text 'A comprehensive documentation of the dataset' which points to the 'CERA-SAT' title.

Overview from the user experience point of view

The screenshot shows the ECMWF website's 'Browse reanalysis datasets' page. The page features a navigation menu with 'Home', 'About', 'Forecasts', 'Computing', 'Research', 'Learning', and 'Library'. Below the menu, there are links for 'Charts', 'Datasets', 'Quality of our forecasts', 'Documentation and support', and 'Accessing forecasts'. The main content area is titled 'Browse reanalysis datasets' and contains a table of datasets. On the left side, there are three categories: 'Reanalysis datasets', 'Archive catalogue', and 'Real-time catalogue'. The 'Reanalysis datasets' category is expanded, showing a list of datasets. Two red arrows point to 'CERA-SAT' and 'CERA-20C' in the table, with labels 'D1.1' and 'D1.3' respectively. The table has columns for Dataset, Archive, Time period, Atmosphere, Atmospheric composition, Ocean waves, Ocean sub-surface, Land surface, Sea Ice, and Observation Feedback Archive. The 'Time period' column for CERA-SAT and CERA-20C has the text '1900-2010' crossed out with a red line.

Dataset	Archive	Time period	Atmosphere	Atmospheric composition	Ocean waves	Ocean sub-surface	Land surface	Sea Ice	Observation Feedback Archive
ERA5	Download guide	2010-2016	✓		✓		✓		
ERA-Interim	Download	1979-present	✓		✓		✓		Expected soon...
ERA-Interim/Land	Download	1979-2010					✓		
CERA-SAT	Download	1900-2010	✓		✓	✓	✓	✓	✓
CERA-20C	Download	1900-2010	✓		✓	✓	✓	✓	✓
ERA-20CM	Download	1900-2010	✓		✓		✓		
ERA-20C	Download	1900-2010	✓		✓		✓		✓
ERA-20CL	Expected soon...	1900-2010					✓		
ERA-40	Download	1957-2002	✓		✓		✓		
ERA-15	Download	1979-1993	✓				✓		
ORAS4	Download	1958-2015				✓			
ORAP5	Download	1979-2013				✓		✓	
ORASS	Expected	1975-present				✓		✓	

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

CERA-20C, Synoptic Monthly Means - Mozilla Firefox

apps.ecmwf.int/datasets/data/cera20c/levtype=sfc/type=an/

ECMWF Home Chart dashboard Contact Search ECMWF Log in

About Forecasts Computing Research Learning

Type of level

- Model levels
- Potential temperature
- Potential vorticity
- Pressure levels
- Surface

Type

- Analysis
- Forecast

CERA-20C sets

- Daily
- Synoptic Monthly Means
- Monthly Means of Daily Means
- Invariant
- Ocean Wave Daily
- Ocean Wave Invariant
- Ocean Wave Synoptic Monthly Means
- Ocean Wave Monthly Means of Daily Means

About

- Conditions of use
- Documentation

Navigation

- Home
- Public Datasets
- Web-API Activity
- Job list

See also...

- Access Public Datasets
- General FAQ
- Web-API FAQ
- Accessing forecasts
- GRIB decoder

CERA-20C, Synoptic Monthly Means

Please [login](#) before retrieving data from this dataset server.

Select a year

1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911

1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922

1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933

1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944

1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955

1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966

1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977

1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988

1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

Select time

00:00:00 03:00:00 06:00:00 09:00:00 12:00:00 15:00:00 18:00:00 21:00:00

[Select All](#) or [Clear](#)

Select number

0 1 2 3 4 5 6 7 8 9

[Select All](#) or [Clear](#)

Select parameter

2 metre dewpoint temperature 2 metre temperature

10 metre U wind component 10 metre V wind component

10 metre wind speed 100 metre U wind component

100 metre V wind component Albedo

Boundary layer height Chamock

Convective available potential energy Forecast albedo

Forecast logarithm of surface roughness for heat Forecast surface roughness

High cloud cover Ice temperature layer 1

Ice temperature layer 2 Ice temperature layer 3

Ice temperature layer 4 Instantaneous eastward turbulent surface stress

Instantaneous moisture flux Instantaneous northward turbulent surface stress

Instantaneous surface sensible heat flux Lake bottom temperature

Lake cover Lake depth

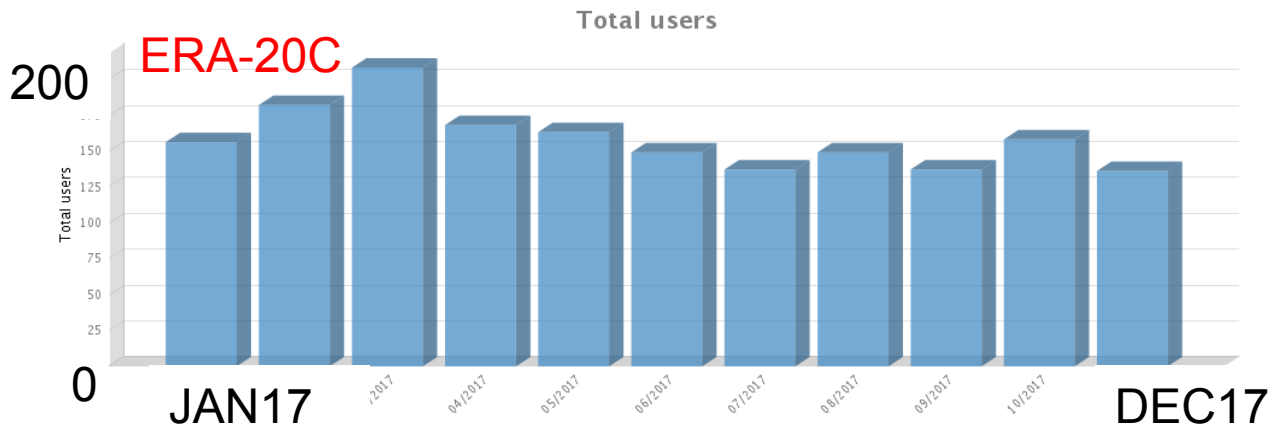
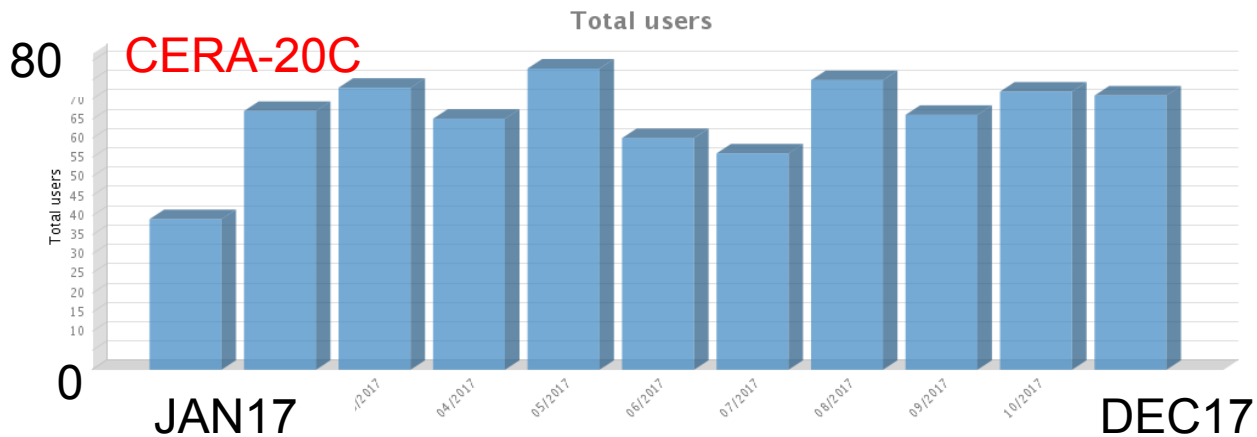
Lake ice depth Lake ice temperature

Lake mix-layer depth Lake mix-layer temperature

WINDOWS STANDARD CERA-20C, Synoptic Mont... [erpl - File Manager] 2017-12-07 16:08 Patrick Laloyaux

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

Outer loop coupling in the CERA system

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

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

for $k=0,1,\dots$ do

 Compute observation departures

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

 Compute increments

$$\delta \mathbf{x}^k = (\mathbf{x}^b - \mathbf{x}^k) + \mathbf{B}\mathbf{H}^T (\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} \delta \mathbf{y}^k$$

$$\delta \mathbf{x}^k = (\mathbf{x}^b - \mathbf{x}^k) + \mathbf{B}\mathbf{H}^T (\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} \delta \mathbf{y}^k$$

 Update initial condition

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

end

Outer loop coupling in the CERA system

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

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

for $k=0,1,\dots$ do

 Compute increments

$$\delta \mathbf{x}^k = (\mathbf{x}^b - \mathbf{x}^k) + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} (\mathbf{y} - \mathcal{H}\mathcal{M}(\mathbf{x}^k, \mathbf{x}^k))$$

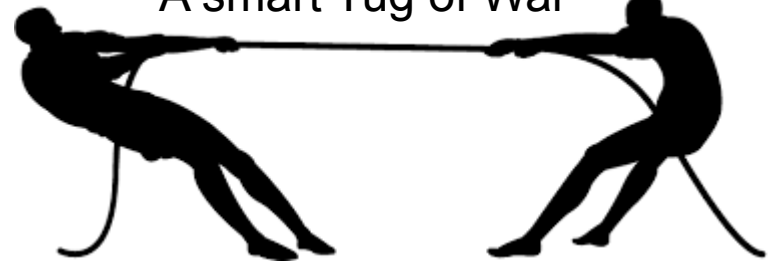
$$\delta \mathbf{x}^k = (\mathbf{x}^b - \mathbf{x}^k) + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} (\mathbf{y} - \mathcal{H}\mathcal{M}(\mathbf{x}^k, \mathbf{x}^k))$$

 Update initial condition

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

end

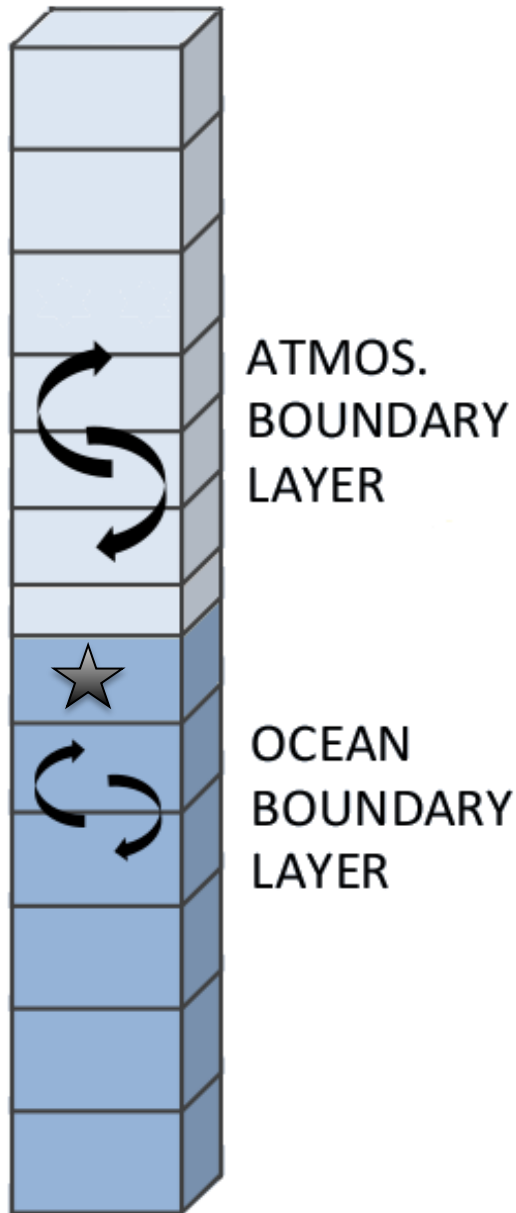
A smart Tug of War



Atmospheric increment depends on the **current ocean state**

Ocean increment depends on the **current atmospheric state**

Single observation experiments



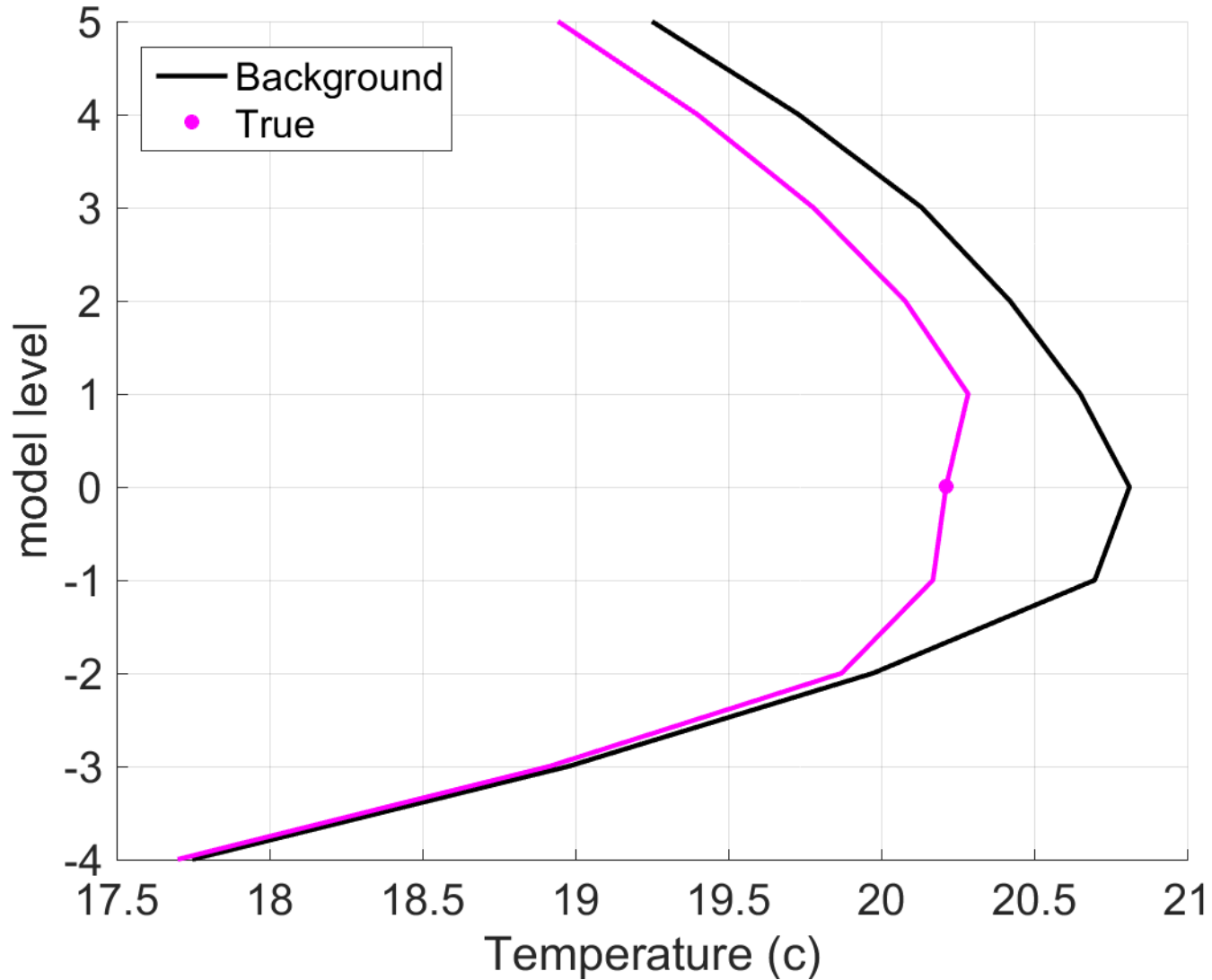
Compare the implicit cross-correlations from CERA with explicit cross-correlation from an ensemble

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

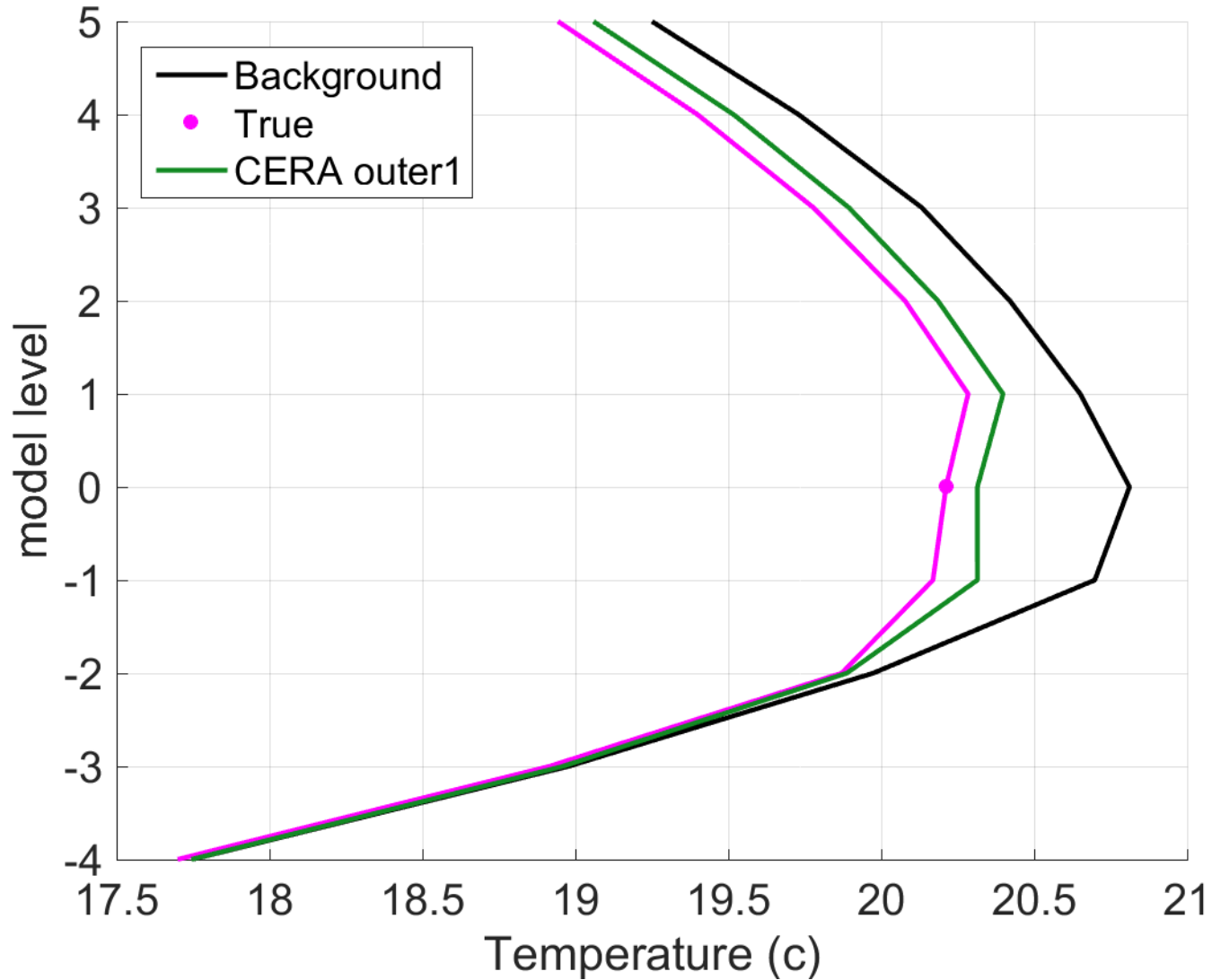
How CERA transfers information in space

Coupled state estimate after 10 hours



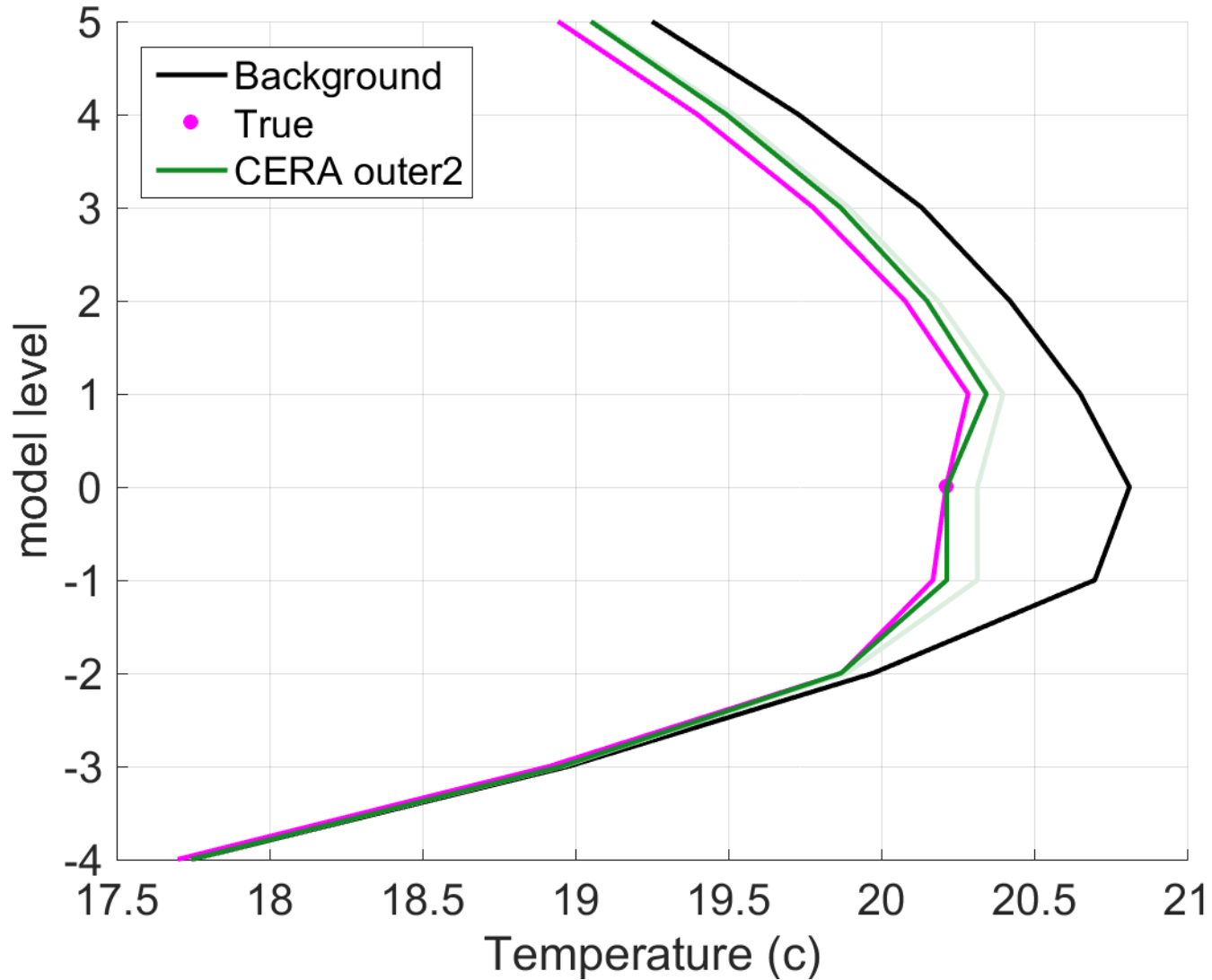
How CERA transfers information in space

Coupled state estimate after 10 hours



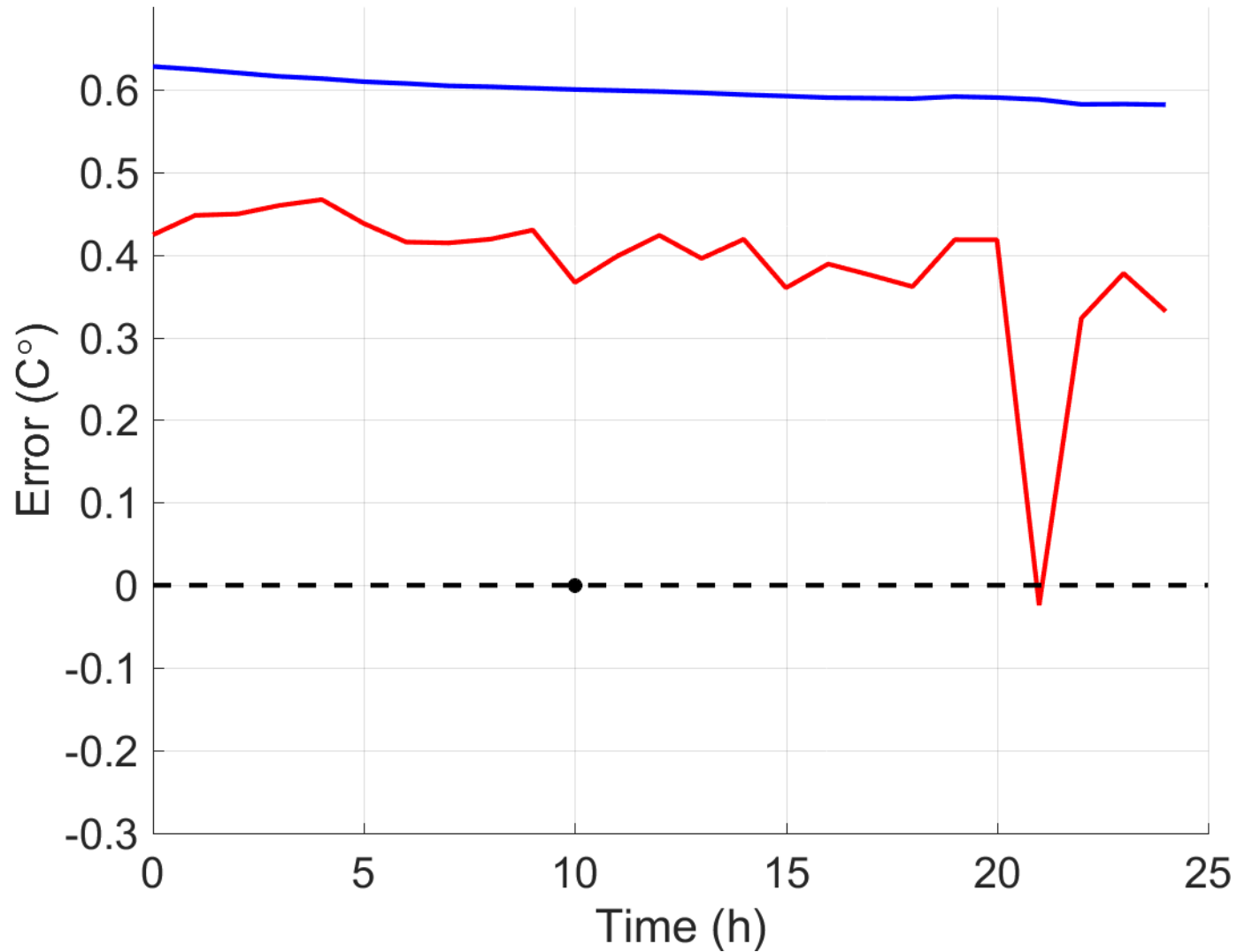
How CERA transfers information in space

Coupled state estimate after 10 hours



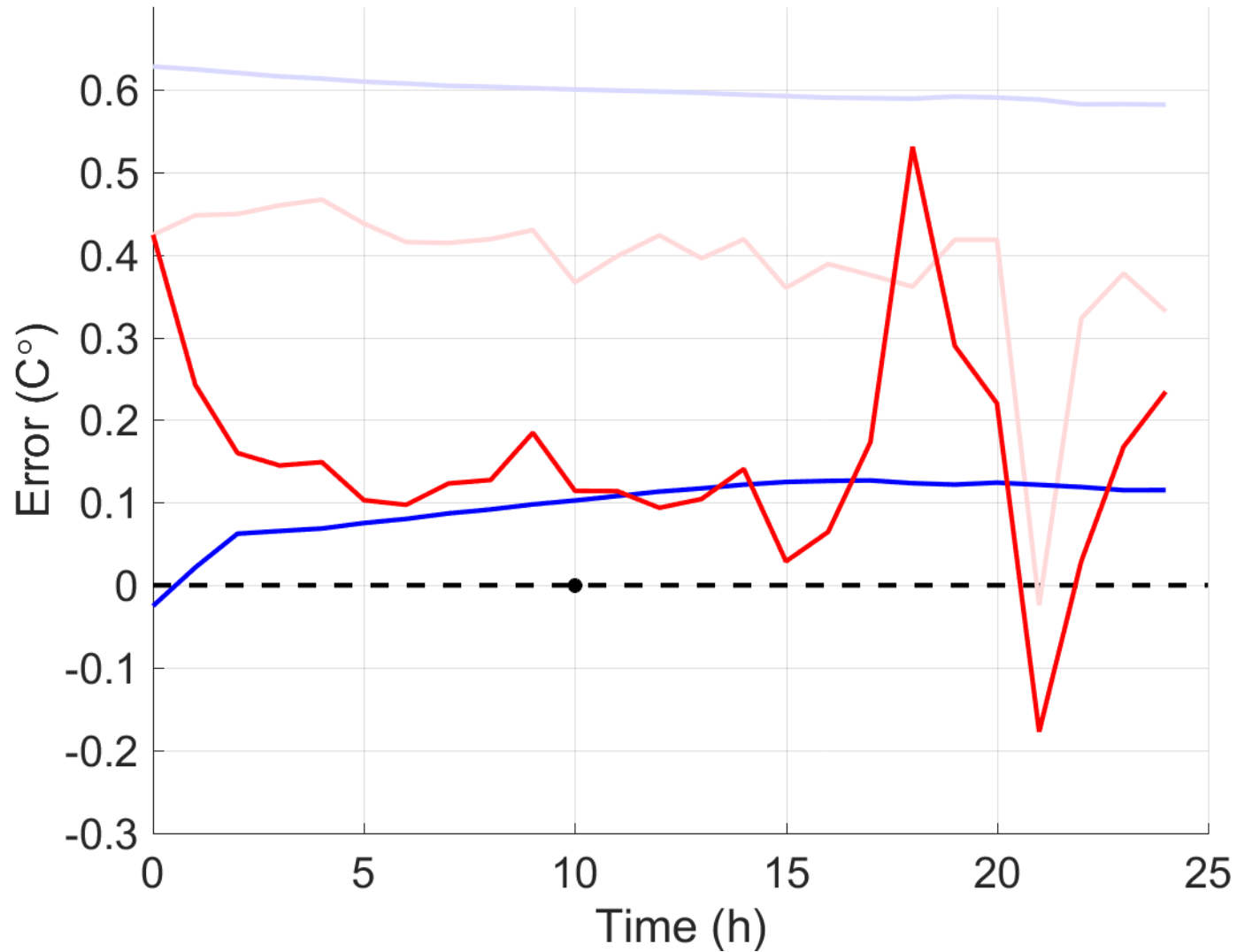
How CERA transfers information in time

Ocean and atmospheric trajectories during the CERA minimisation



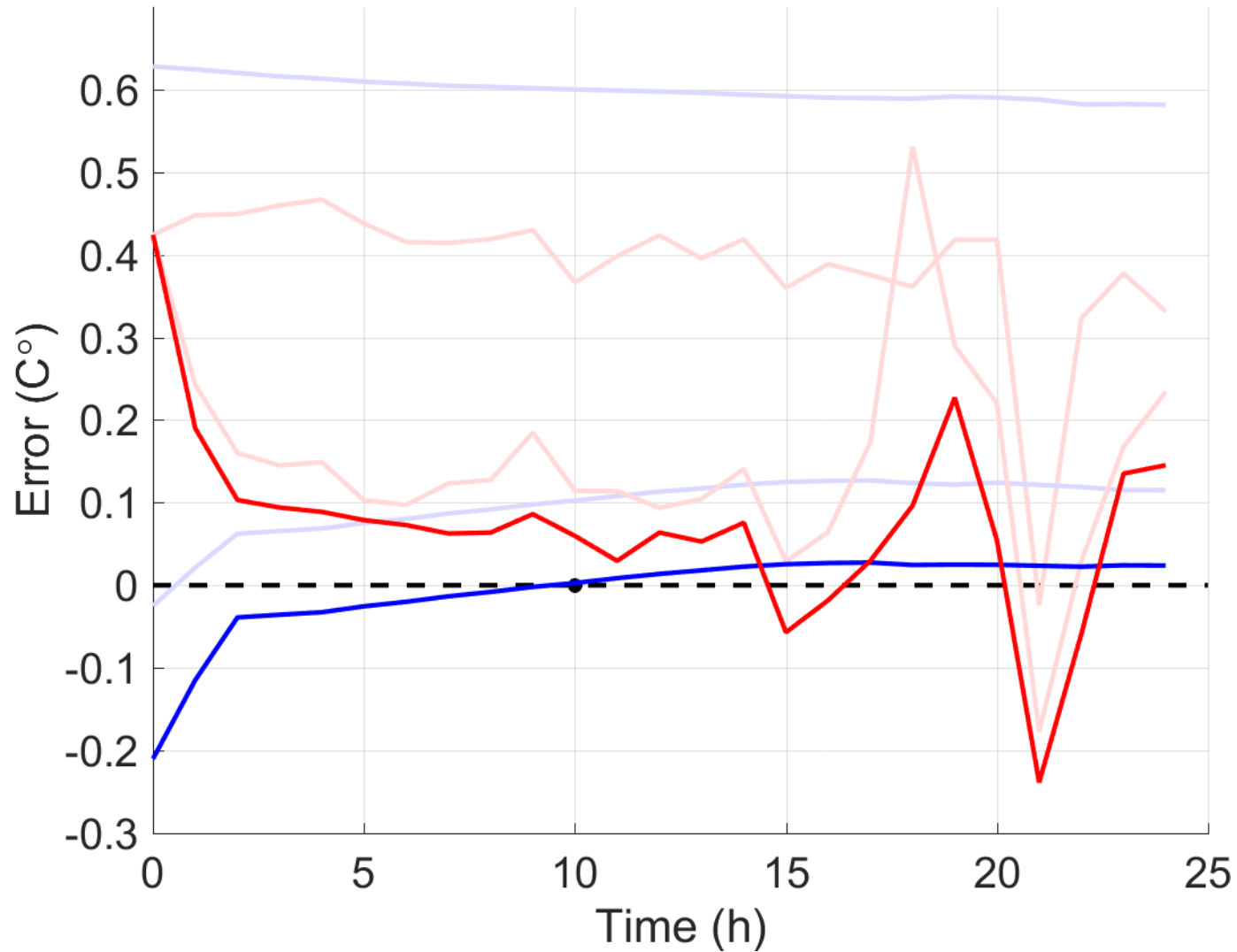
How CERA transfers information in time

Ocean and atmospheric trajectories during the CERA minimisation



How CERA transfers information in time

Ocean and atmospheric trajectories during the CERA minimisation



Explicit cross-correlations from an ensemble

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

Compute observation departures

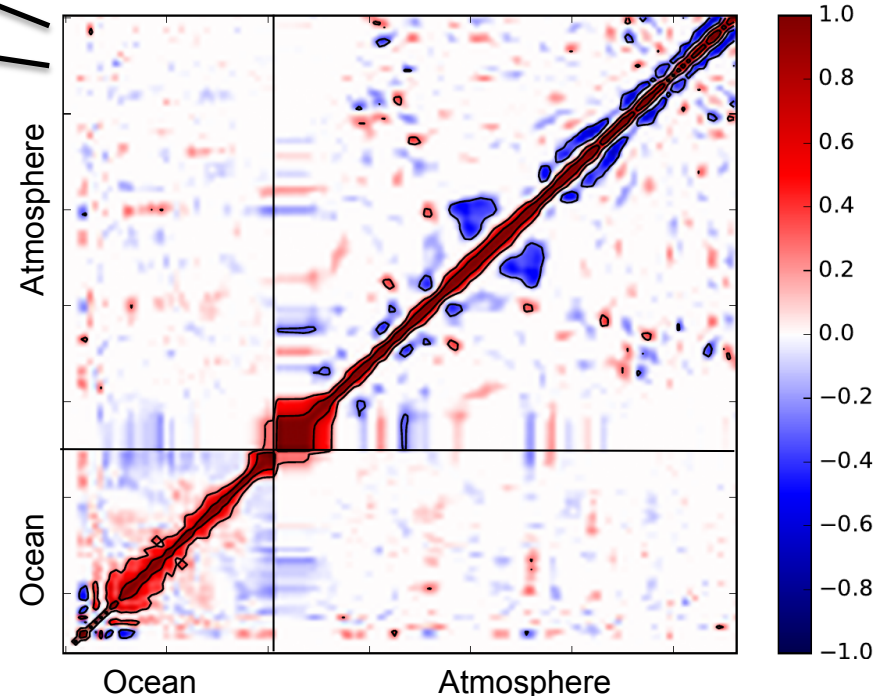
$$\begin{bmatrix} \delta \mathbf{y} \\ \delta \mathbf{y} \end{bmatrix} = \begin{bmatrix} \mathbf{y} \\ \mathbf{y} \end{bmatrix} - \begin{bmatrix} \mathcal{H} \\ \mathcal{H} \end{bmatrix} \mathcal{M}(\mathbf{x}^k, \mathbf{x}^k)$$

Compute analysis

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

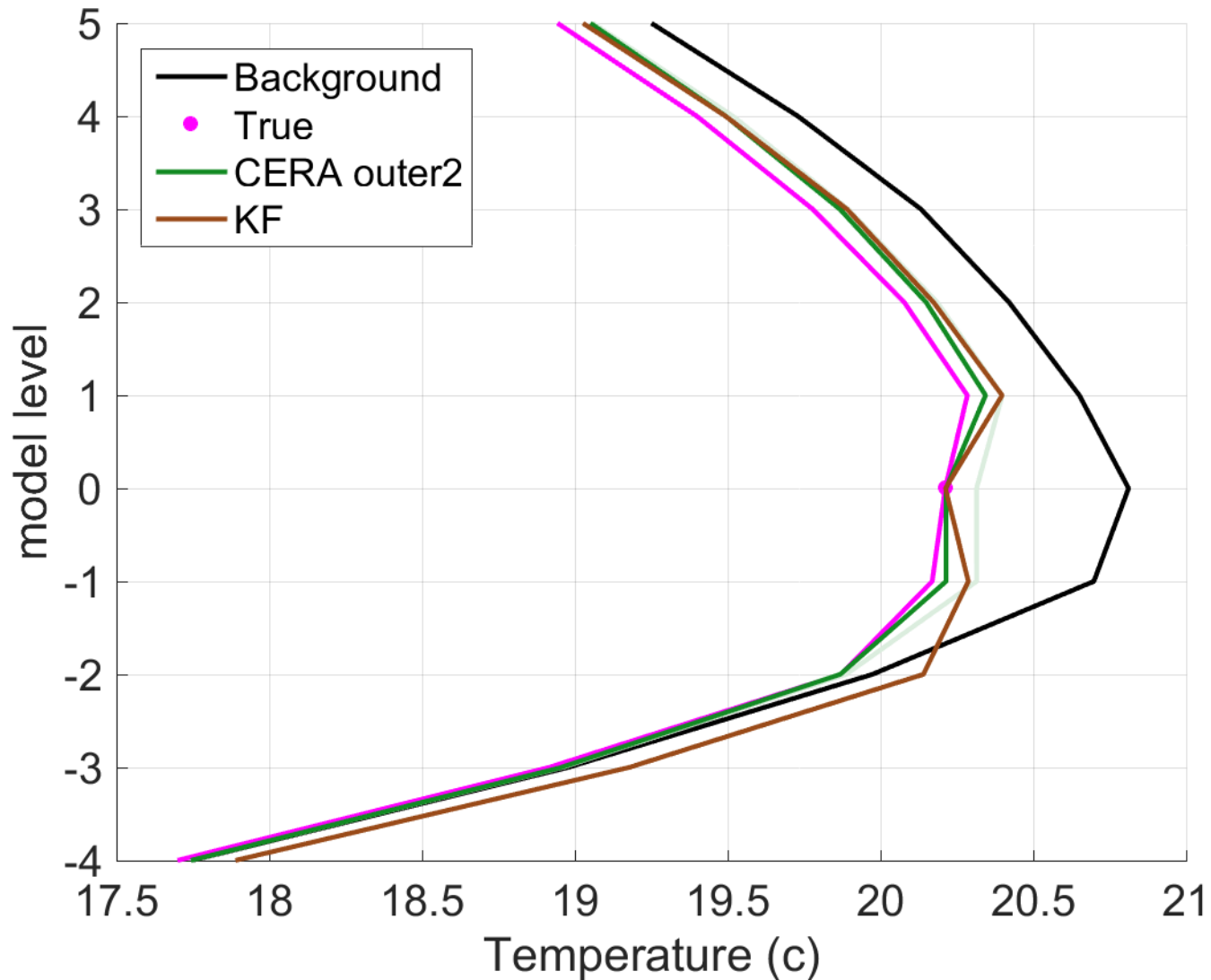
Explicit coupled background error, computed from an ensemble of 25 coupled forecasts.

Used to update the background state following the Kalman filter equation



Explicit cross-correlations from an ensemble

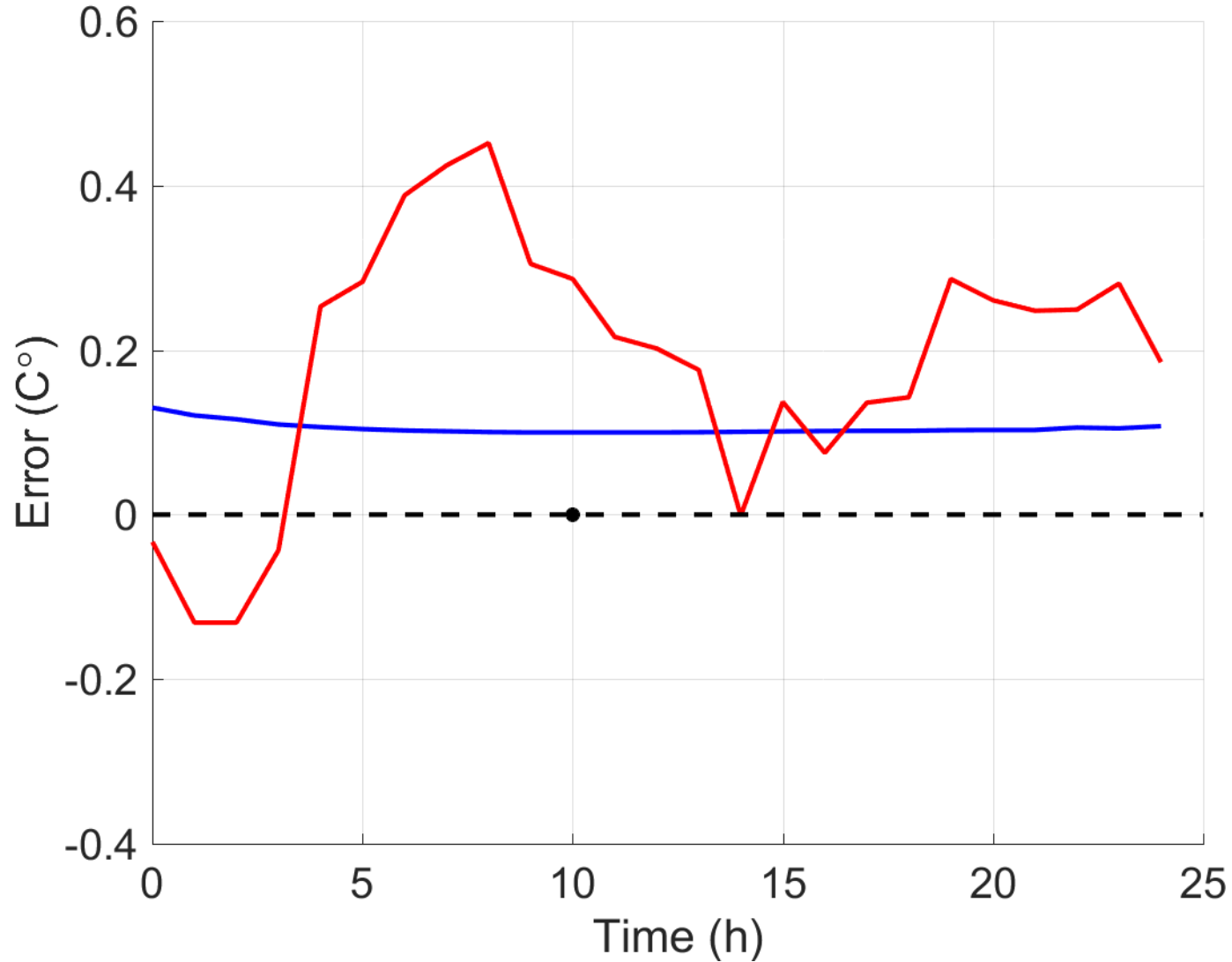
Coupled state estimate after 10 hours



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

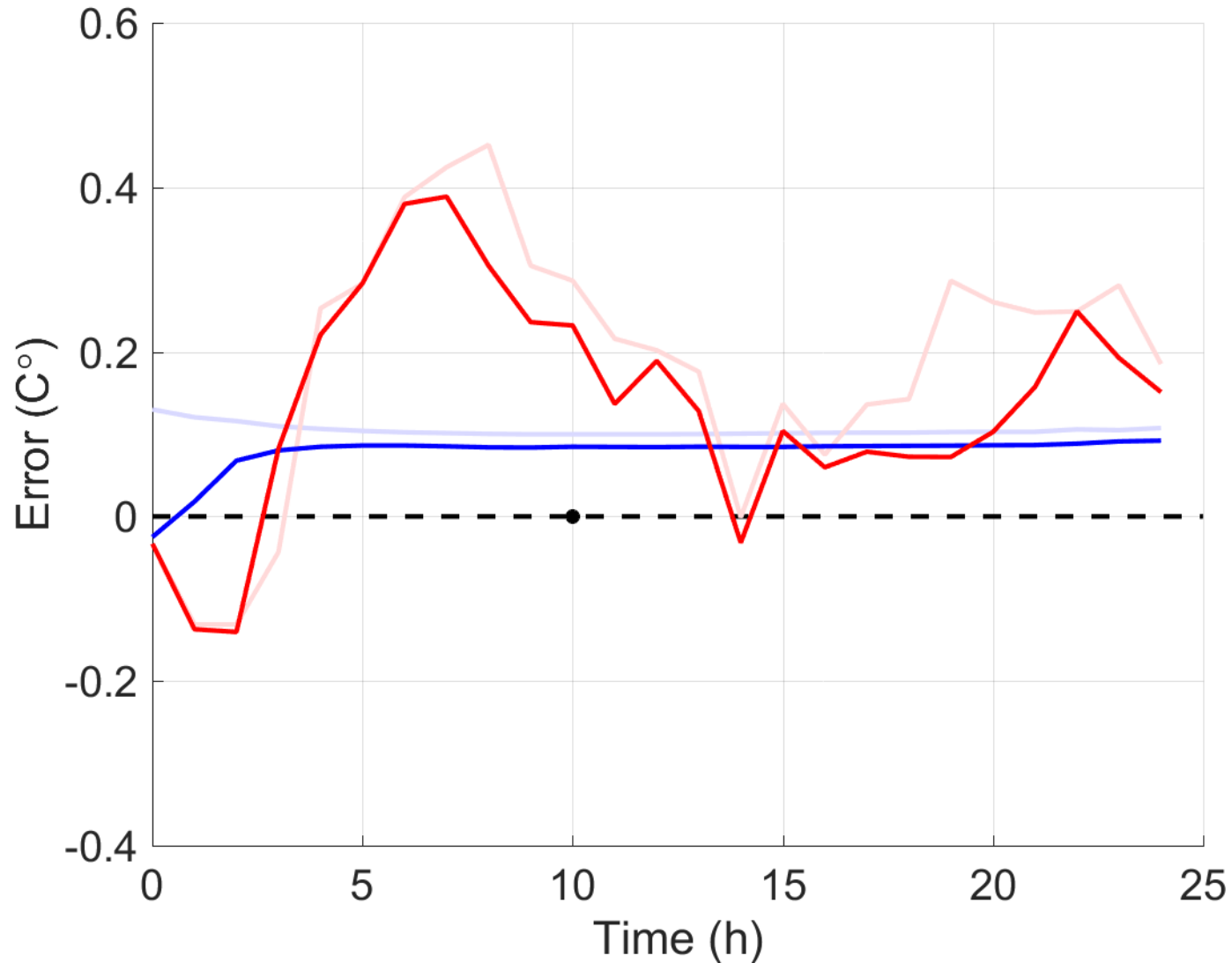
What's happening when the mixed layer is deep?

Ocean and atmospheric trajectories during the CERA minimisation



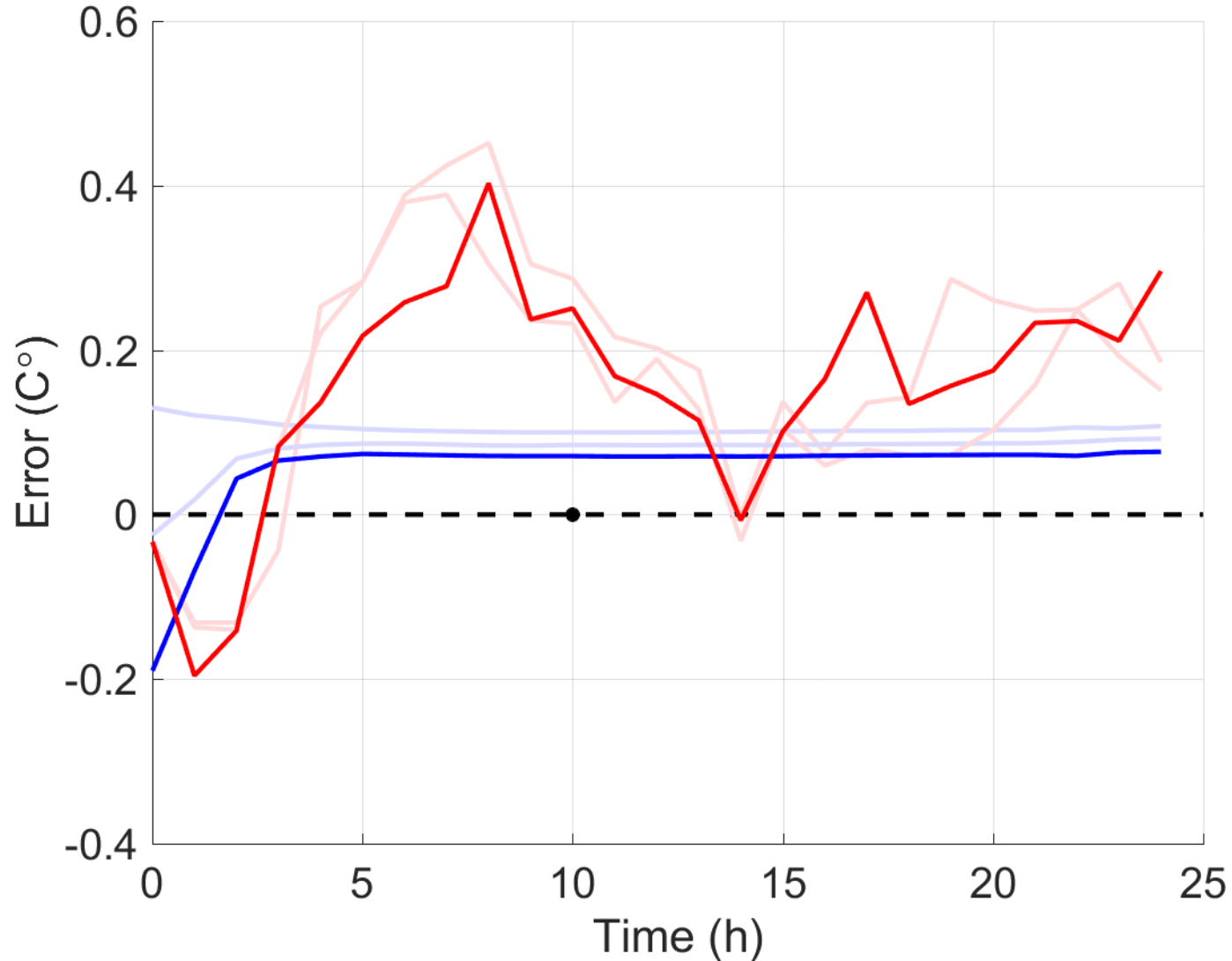
What's happening when the mixed layer is deep?

Ocean and atmospheric trajectories during the CERA minimisation



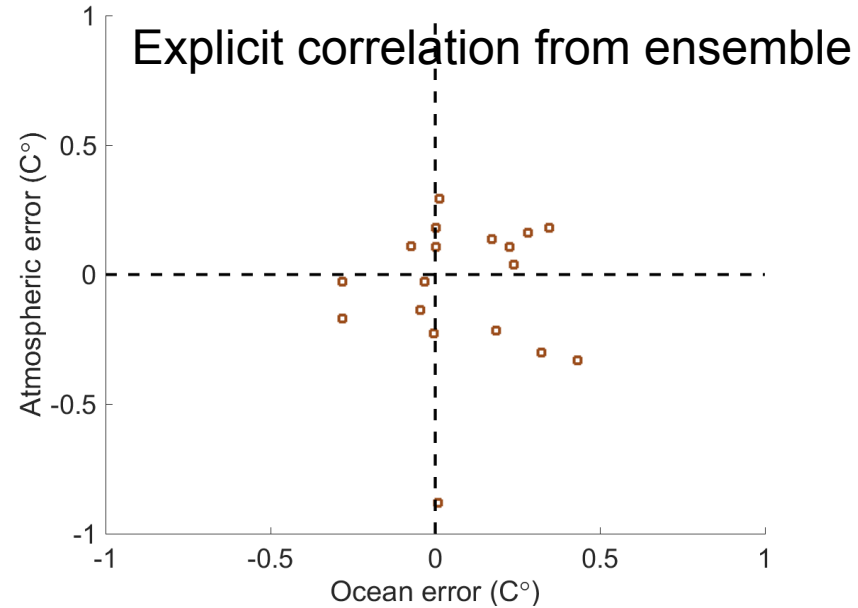
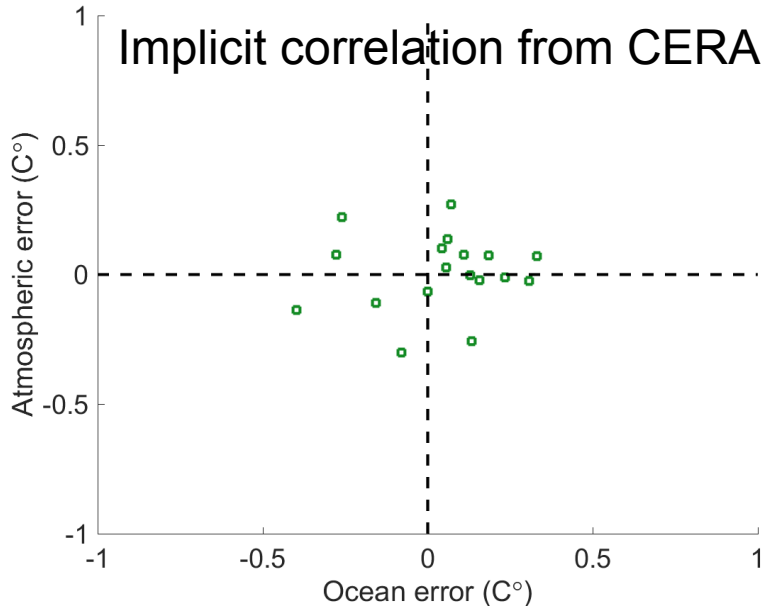
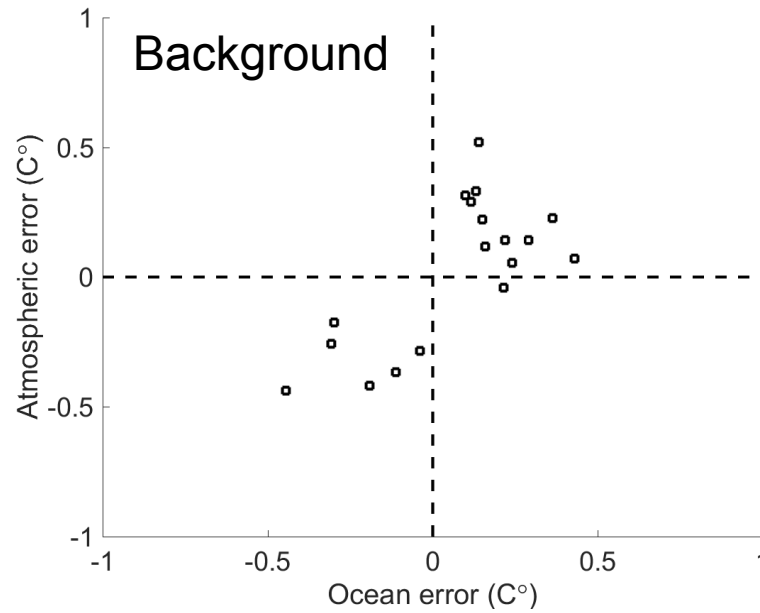
What's happening when the mixed layer is deep?

Ocean and atmospheric trajectories during the CERA minimisation



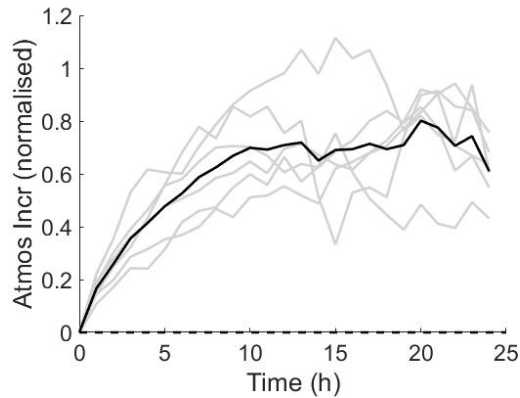
Why does the 0.3 ocean temperature increment disappear after 2 hours?

Summary plot of the 18 single observation experiments



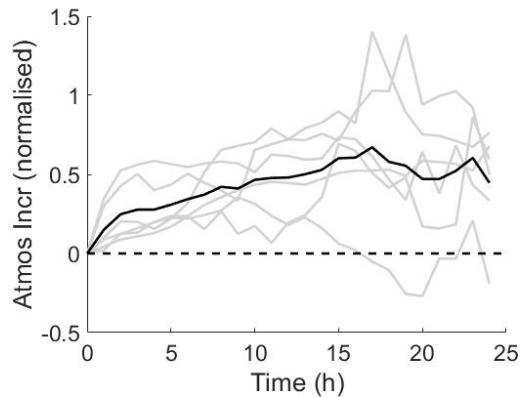
Summary plot of the 18 single observation experiments

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



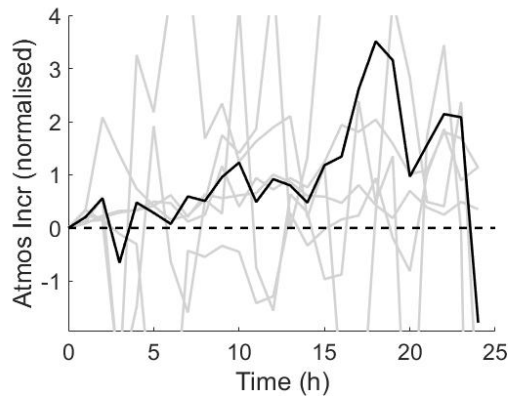
Tropics

→ 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