School of Earth and Environment
INSTITUTE FOR CLIMATE & ATMOSPHERIC SCIENCE

Met Office
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Do externally forced North Atlantic circulation trends resemble modes of internal variability?

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Motivation

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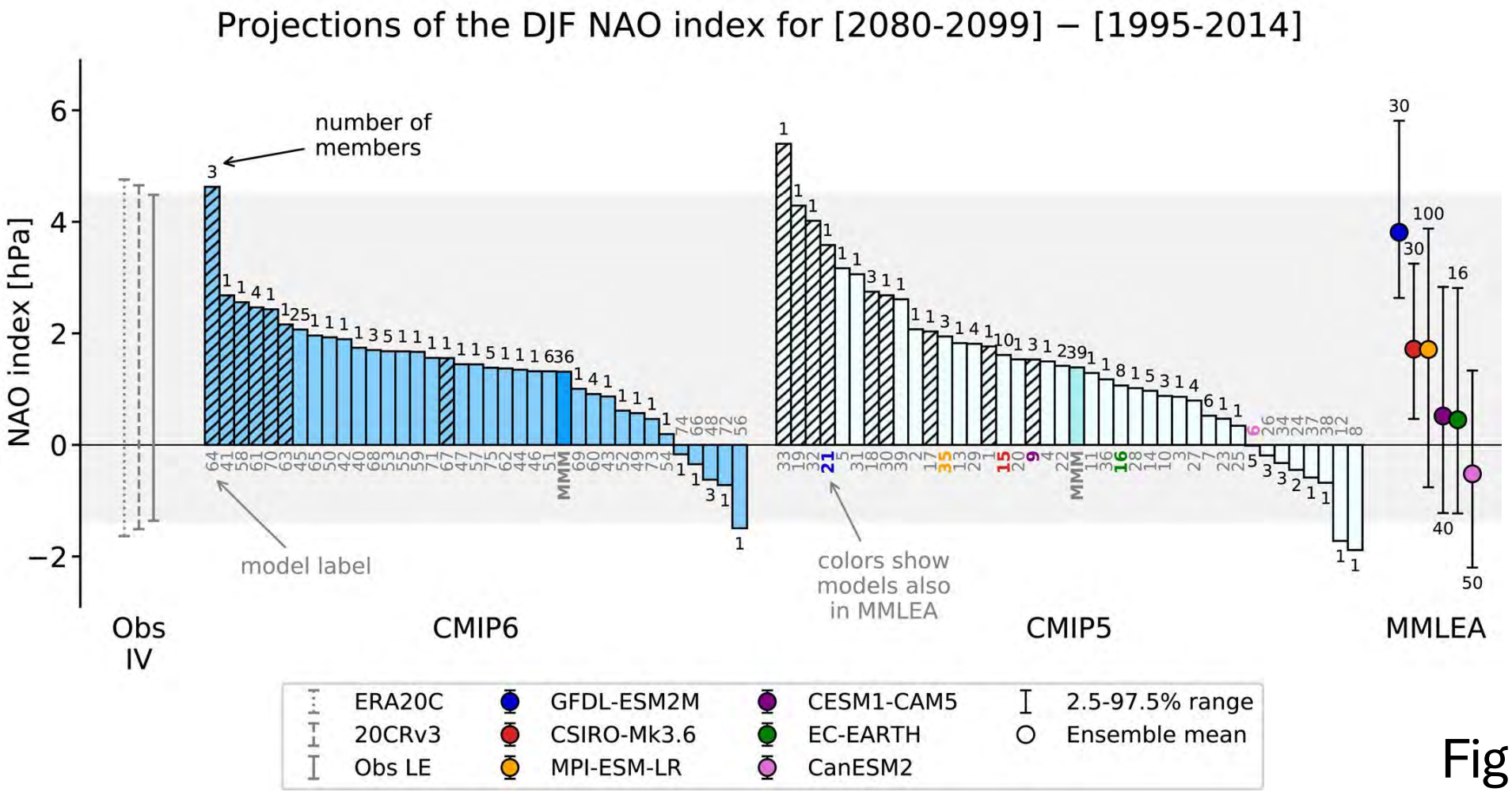

Fig 1, McKenna & Maycock (2021).

Motivation

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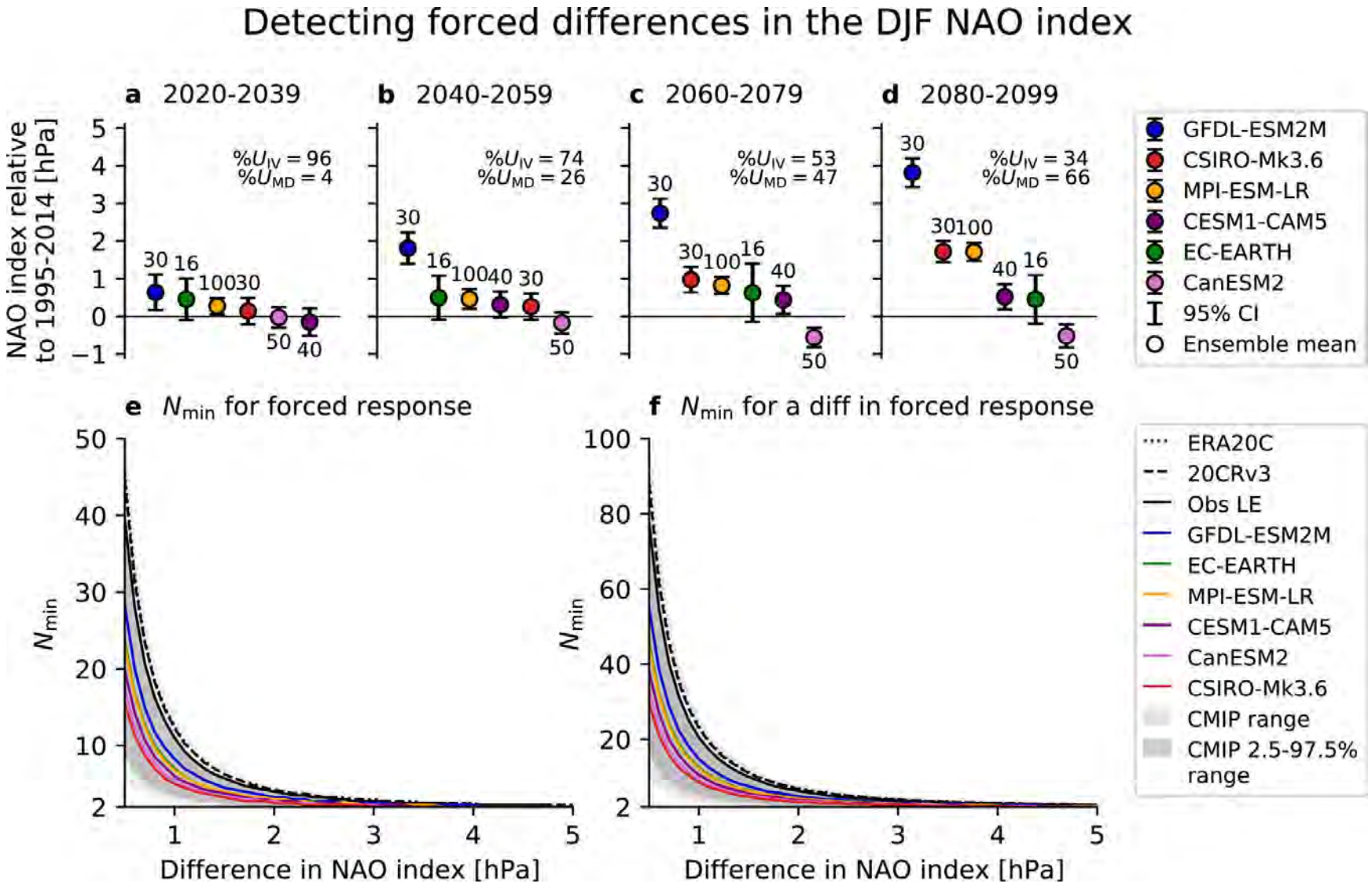

Fig 3, McKenna & Maycock (2021).

Motivation

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- Blackport & Fyfe *2022:* positive trend in the NAO index (1951-2020) in **tails of model distribution**.

- Smith et al. *2025:* multidecadal NAO variability **forced** by natural forcings (volcanic) and models **underestimate** the amplitude.

- Circulation trends are important for regional climate – **unclear** how much the forced responses **resemble** modes of internal variability.

Do externally forced North Atlantic circulation trends resemble modes of internal variability?

Methodology

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1. Take the ensemble mean and find the **forced response** (linear trend) across all the experiments (1850-2014).

2. Find **spatial patterns** for the internal modes of variability in the historical experiment by regressing pressure anomalies onto the leading EOFs (EOF1 - NAO and EOF2 – East Atlantic pattern).

3. **Project** the forced response onto the historical regression patterns and quantify the residuals.

Spatial patterns of modes

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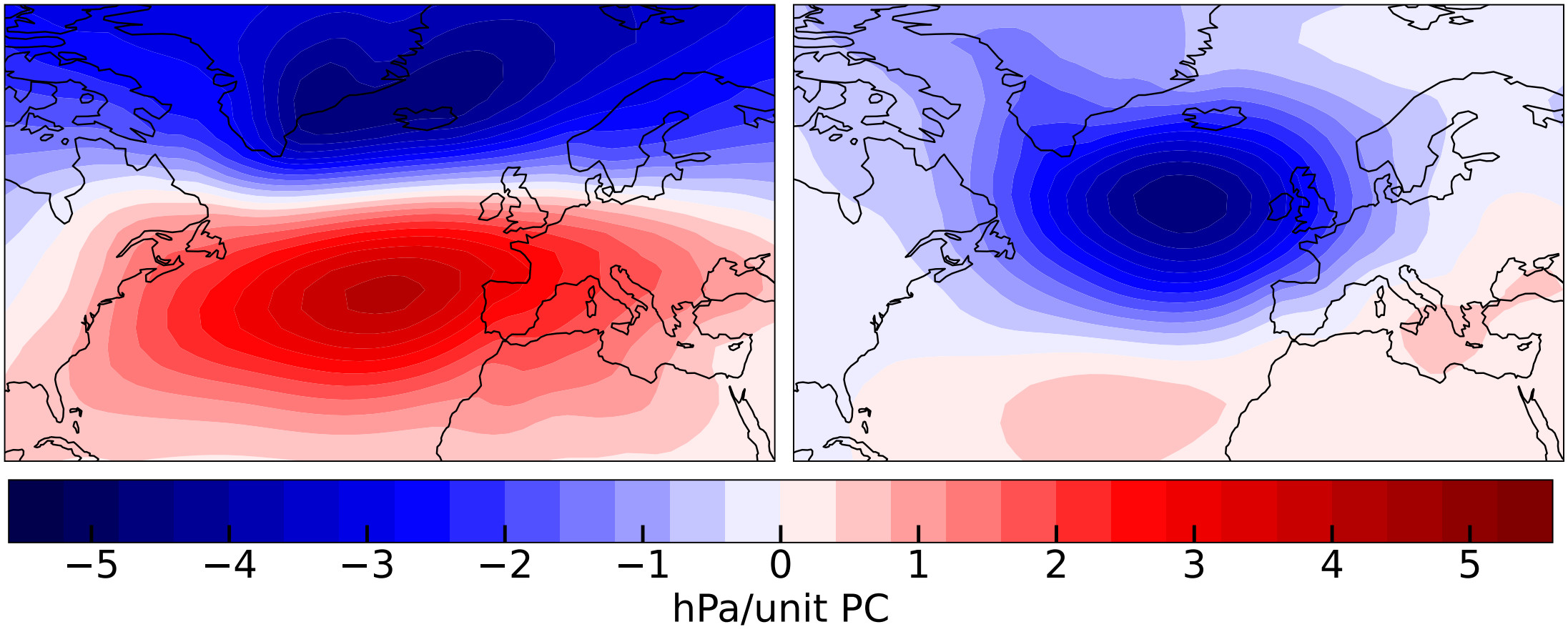
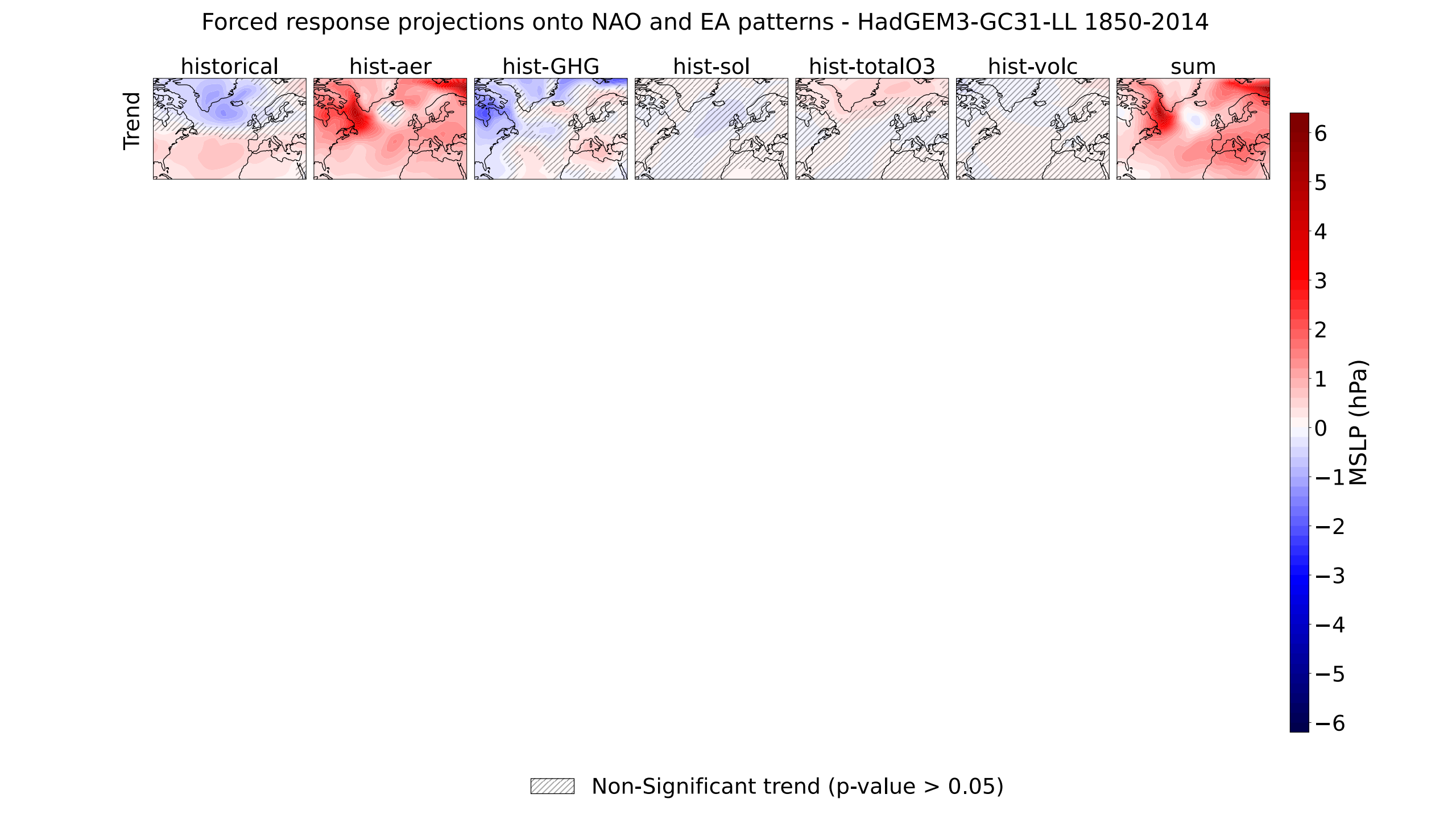
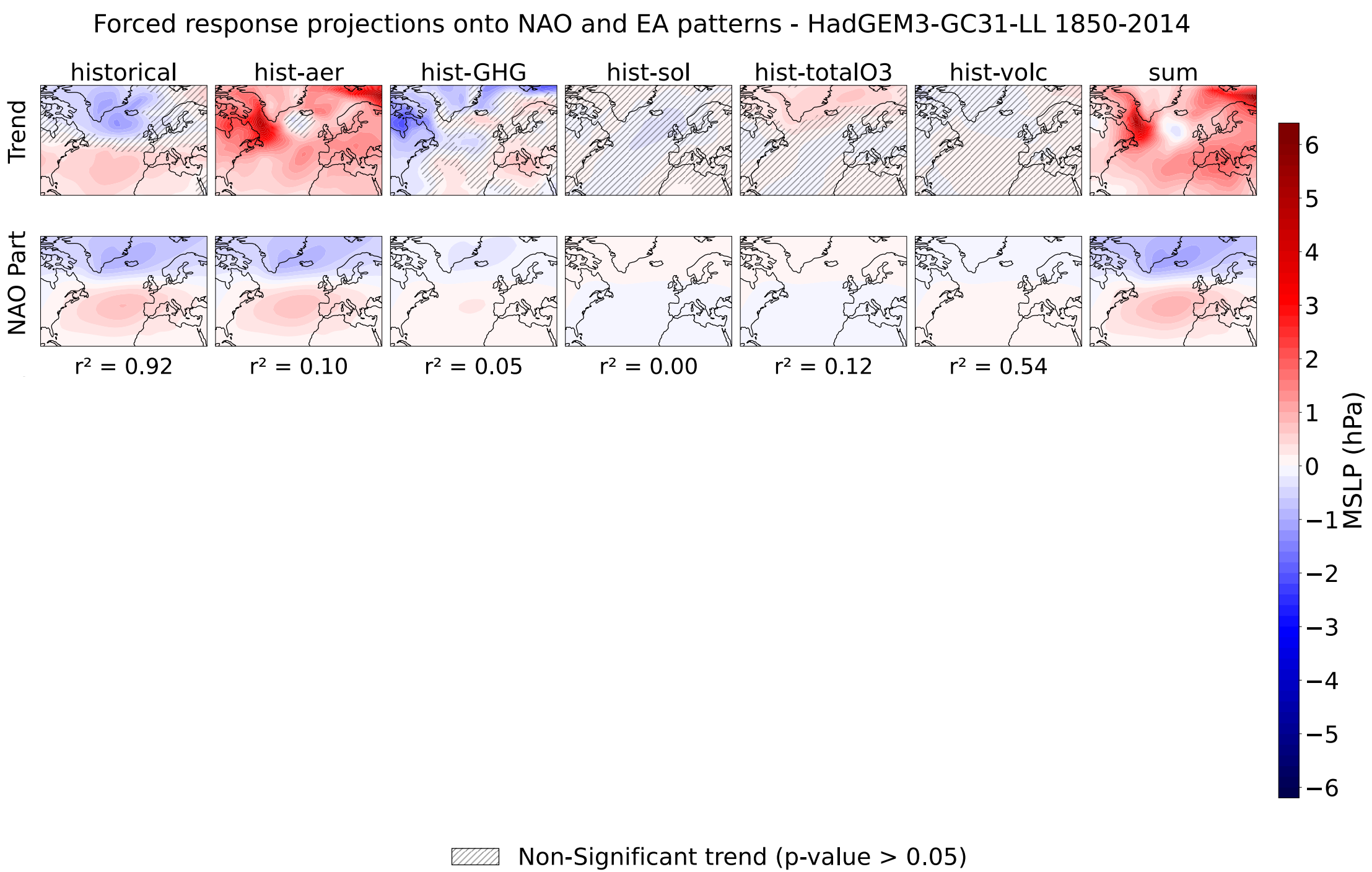
HadGEM3-GC31-LL's historical regression pattern (1850-2014)

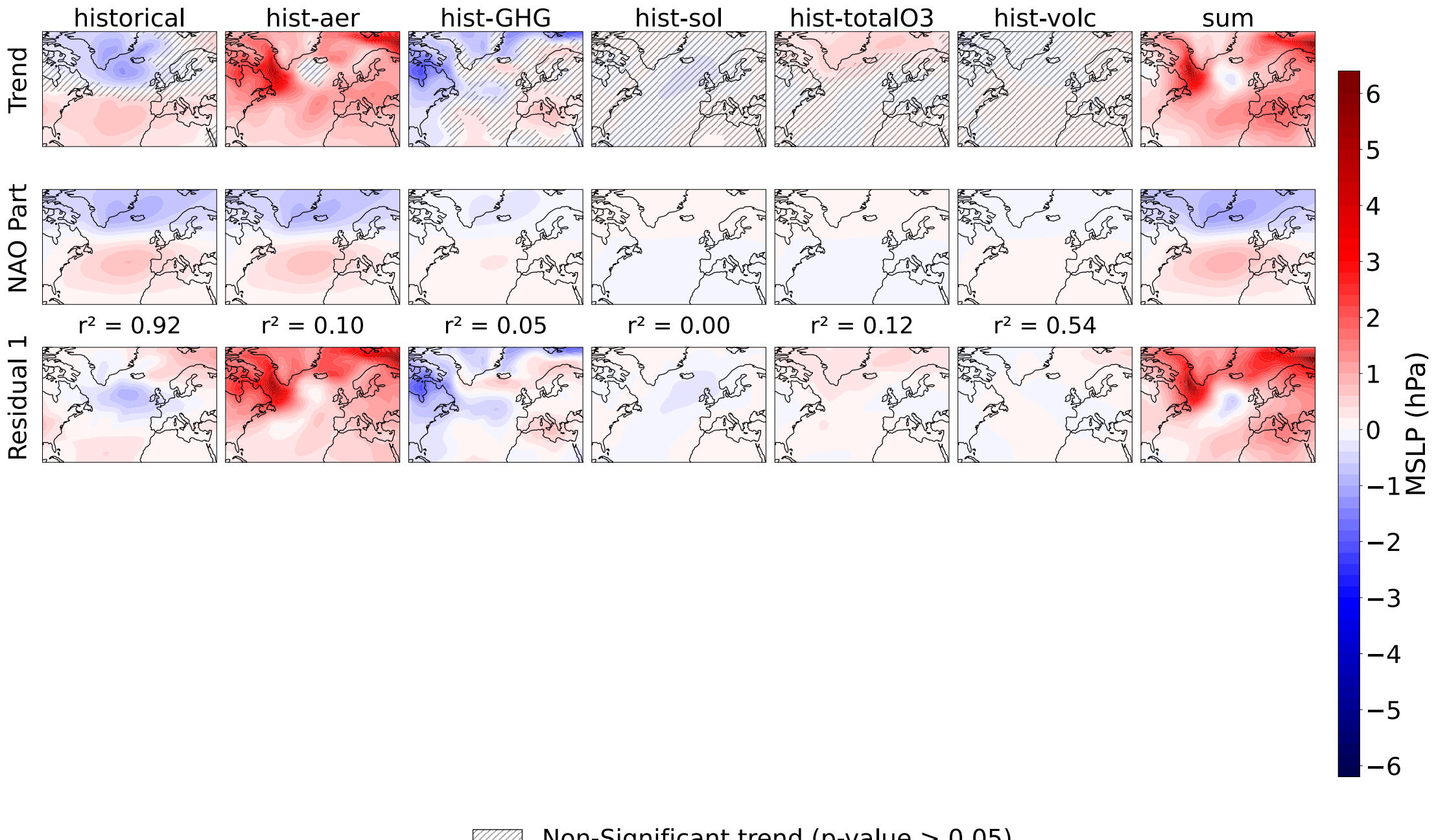
North Atlantic Oscillation

East Atlantic Pattern




Forced response projections onto NAO and EA patterns - HadGEM3-GC31-LL 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
Trend
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
MSLP (hPa)
Non-Significant trend (p-value > 0.05)


Forced response projections onto NAO and EA patterns - HadGEM3-GC31-LL 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
Trend
NAO Part
r² = 0.92
r² = 0.10
r² = 0.05
r² = 0.00
r² = 0.12
r² = 0.54
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
MSLP (hPa)
Non-Significant trend (p-value > 0.05)


Forced response projections onto NAO and EA patterns - HadGEM3-GC31-LL 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
Trend
NAO Part
Residual 1
r² = 0.92
r² = 0.10
r² = 0.05
r² = 0.00
r² = 0.12
r² = 0.54
6
5
4
3
2
1
0
−1
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−4
−5
−6
MSLP (hPa)
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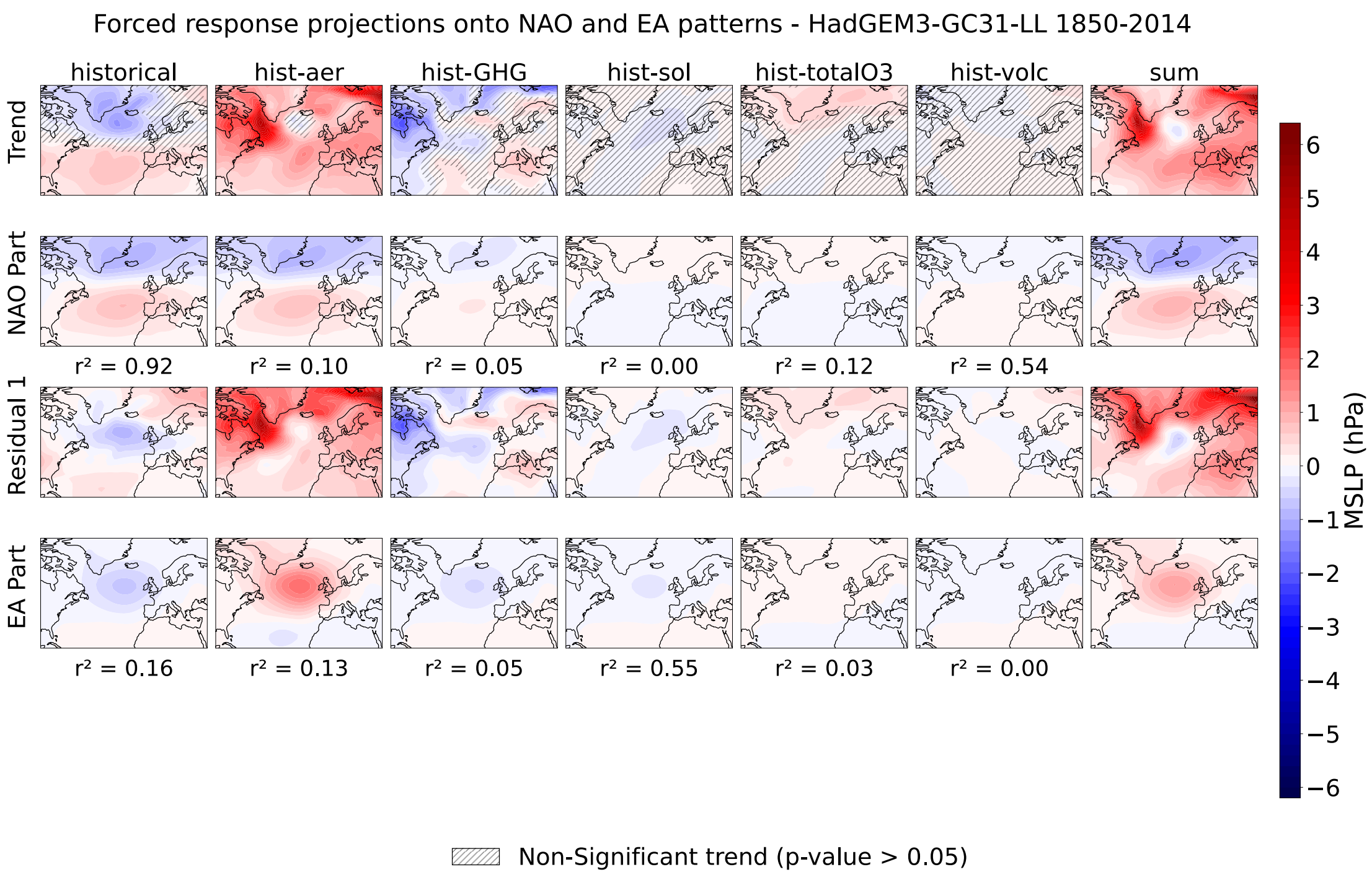
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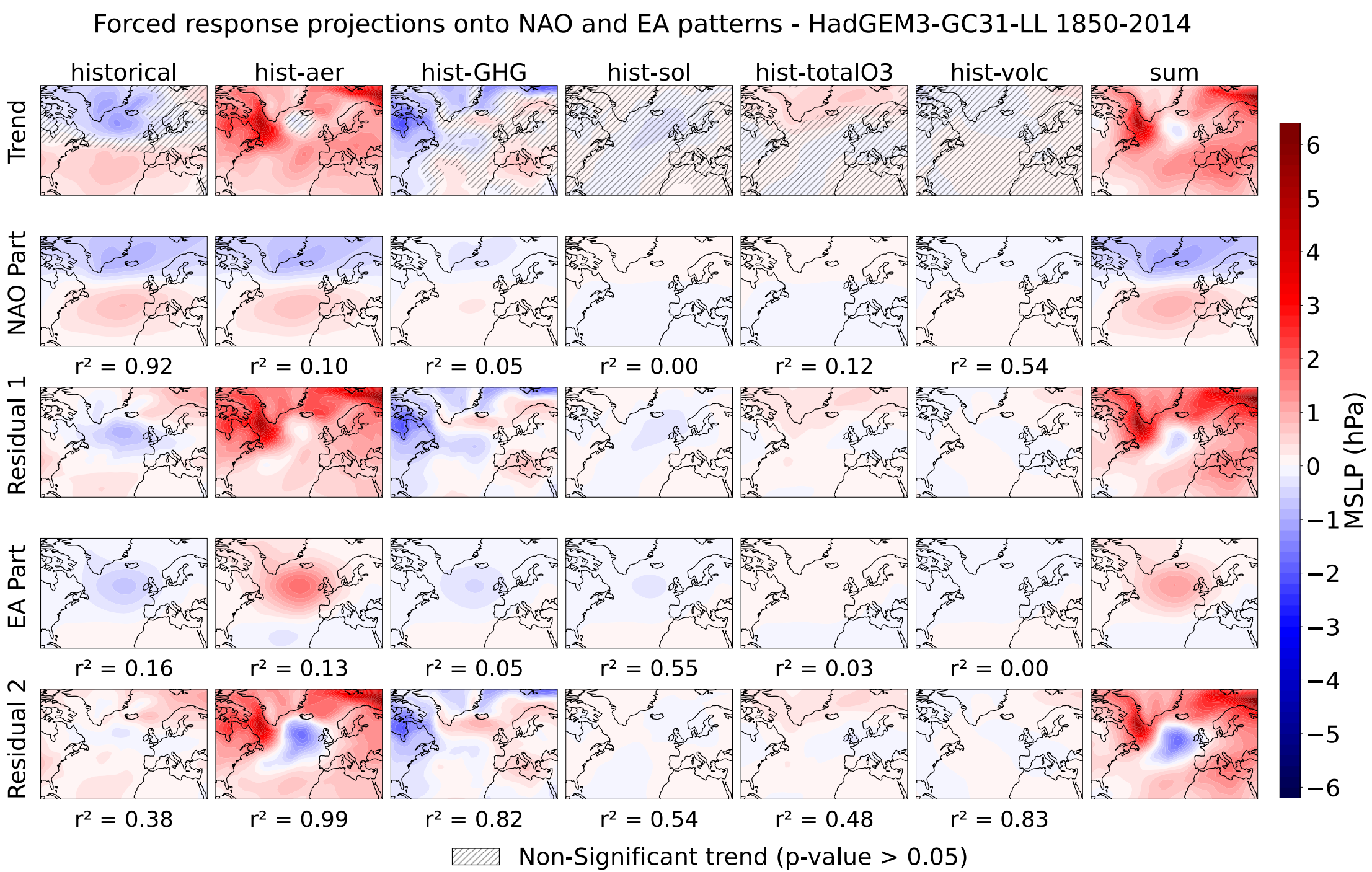
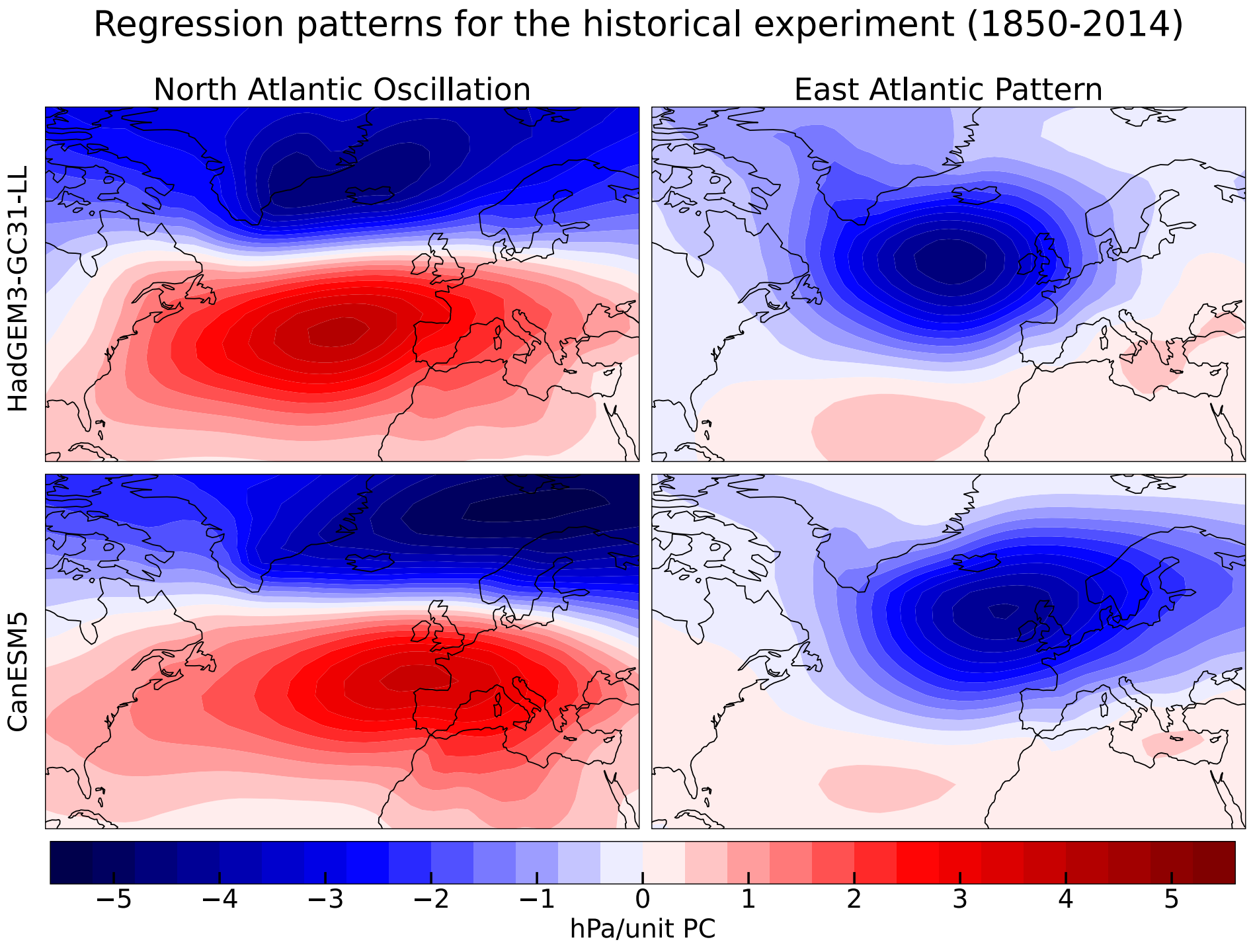
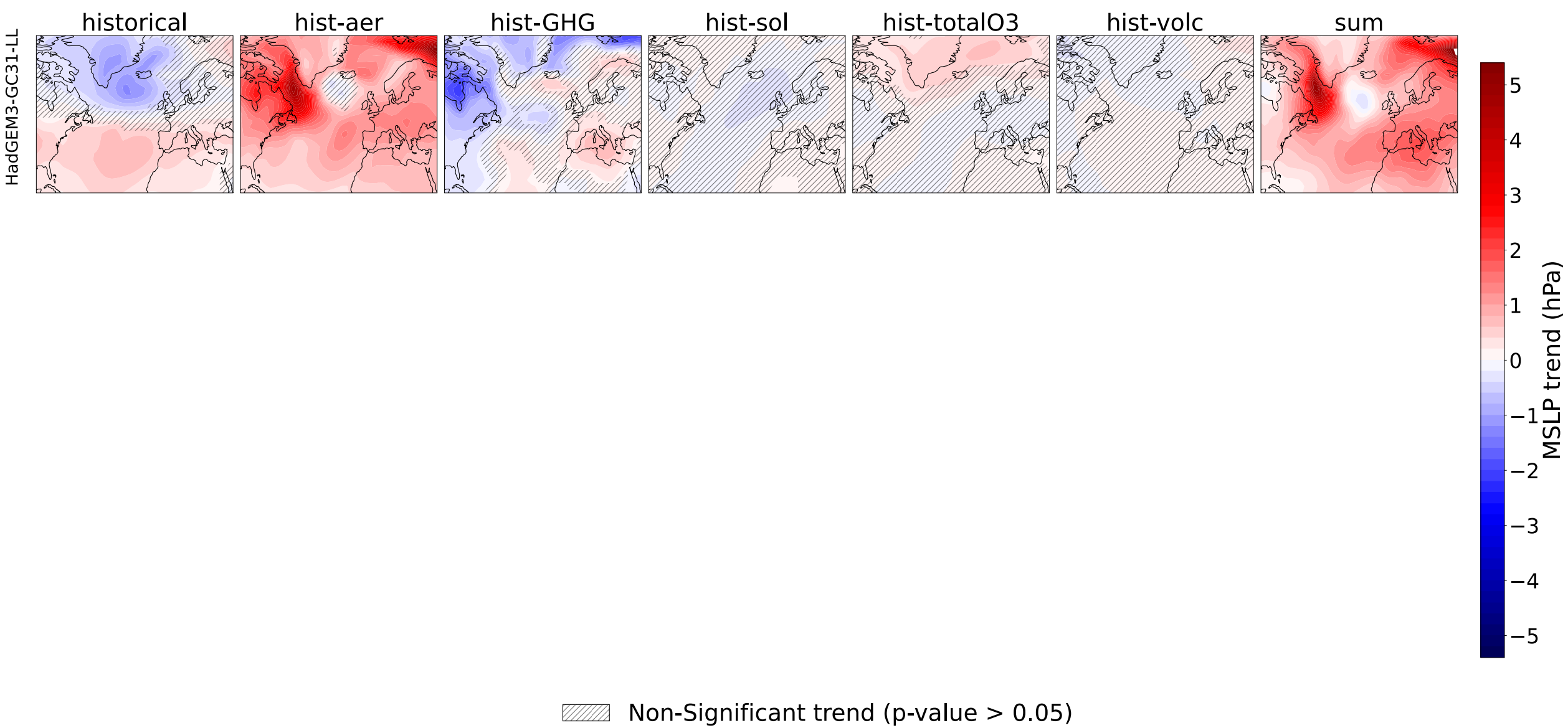
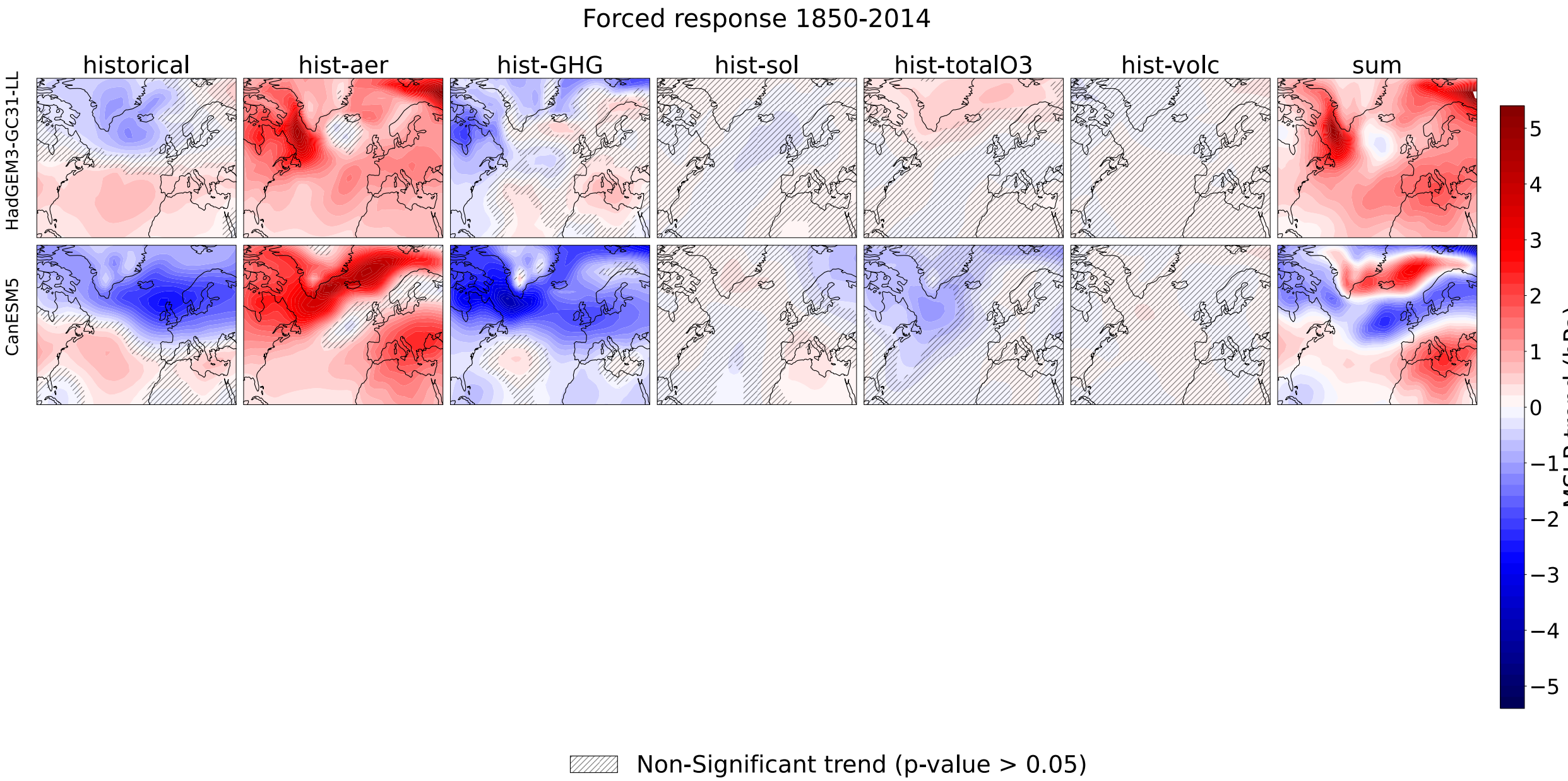
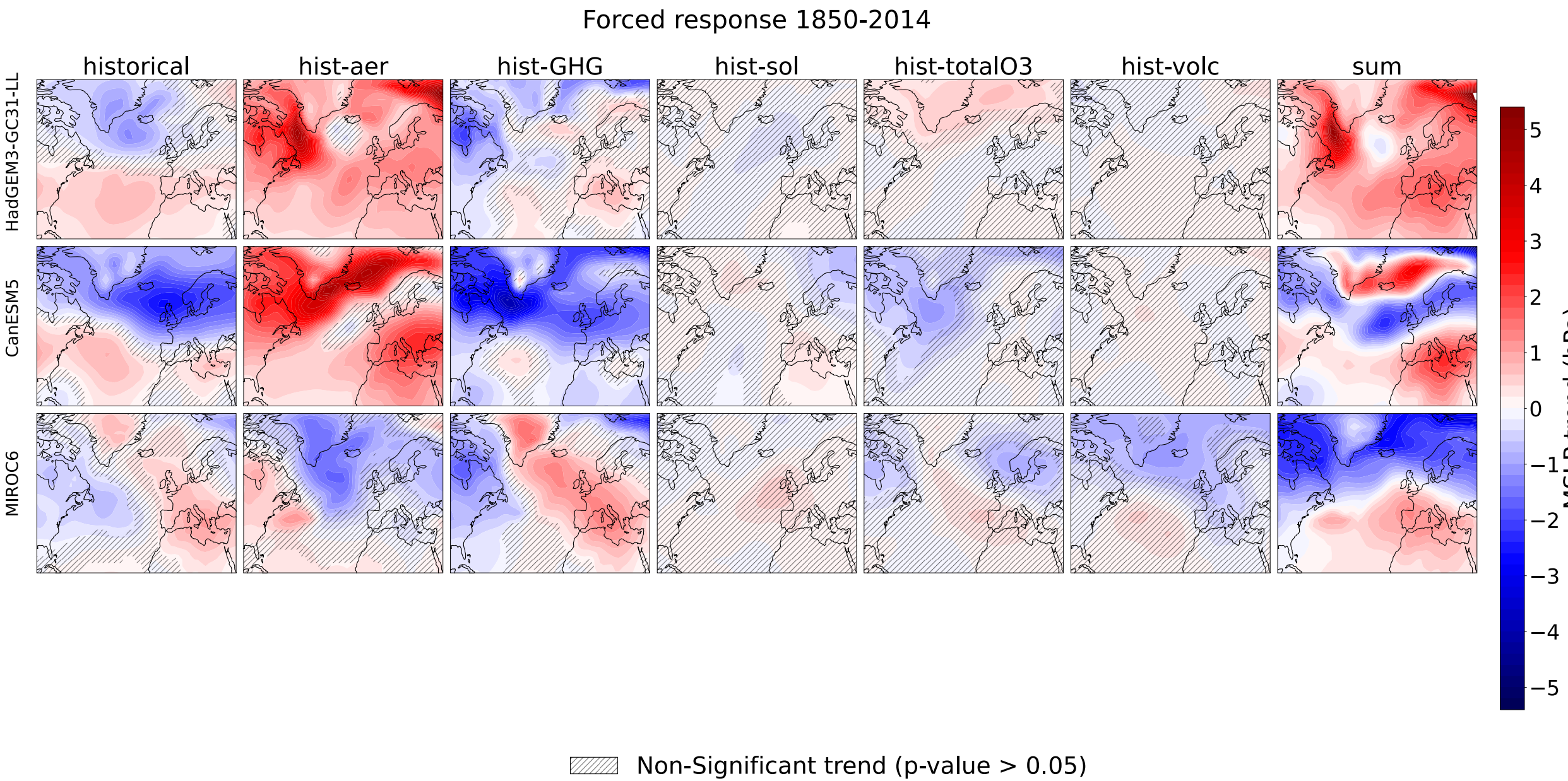
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
Trend
NAO Part
Residual 1
EA Part
r² = 0.92
r² = 0.10
r² = 0.05
r² = 0.00
r² = 0.12
r² = 0.54
r² = 0.16
r² = 0.13
r² = 0.05
r² = 0.55
r² = 0.03
r² = 0.00
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
MSLP (hPa)
Non-Significant trend (p-value > 0.05)

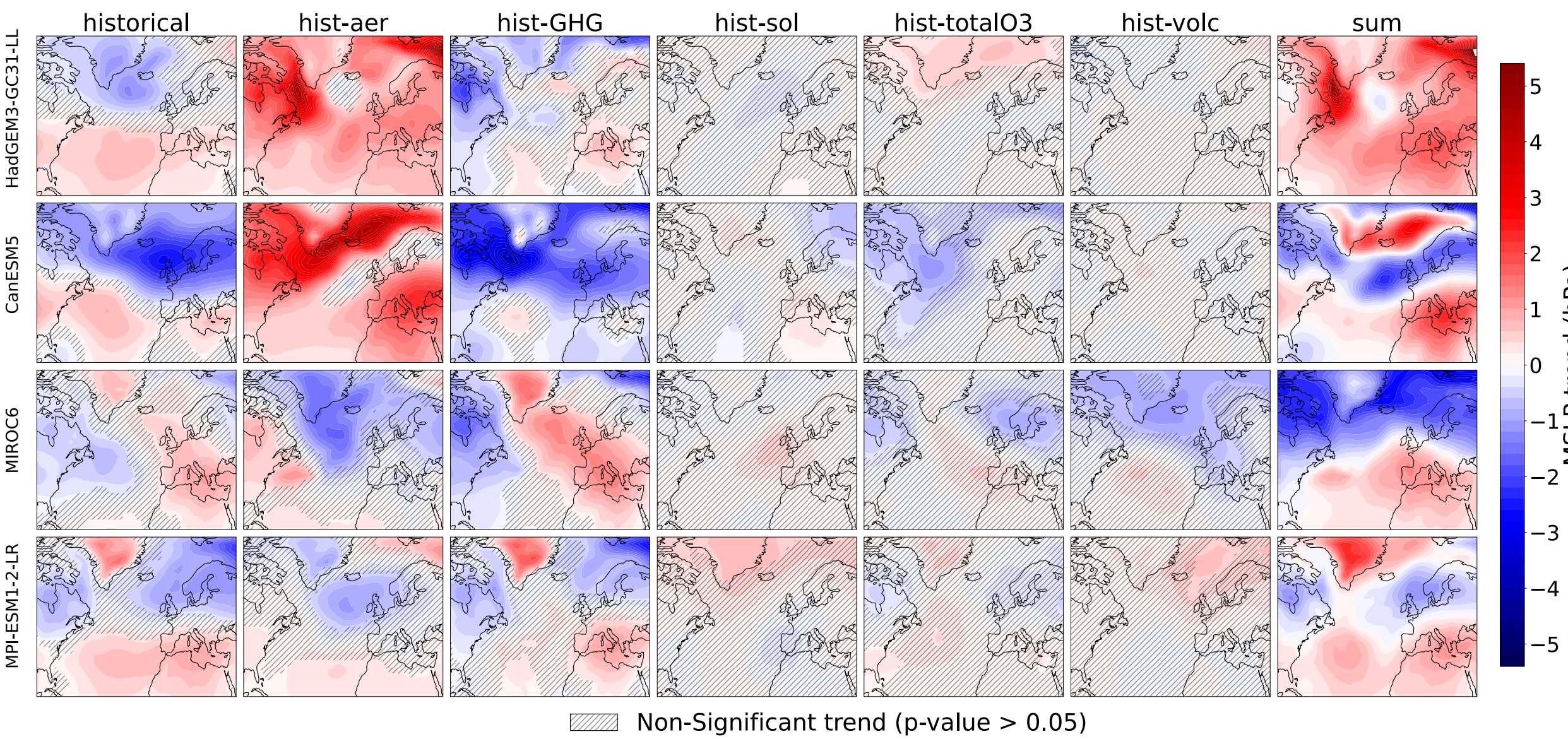

Forced response projections onto NAO and EA patterns - HadGEM3-GC31-LL 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
Trend
NAO Part
r² = 0.92
r² = 0.10
r² = 0.05
r² = 0.00
r² = 0.12
r² = 0.54
Residual 1
EA Part
r² = 0.16
r² = 0.13
r² = 0.05
r² = 0.55
r² = 0.03
r² = 0.00
Residual 2
r² = 0.38
r² = 0.99
r² = 0.82
r² = 0.54
r² = 0.48
r² = 0.83
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
MSLP (hPa)
Non-Significant trend (p-value > 0.05)


Regression patterns for the historical experiment (1850-2014)
North Atlantic Oscillation
East Atlantic Pattern
HadGEM3-GC31-LL
CanESM5
−5
−4
−3
−2
−1
0
1
2
3
4
5
hPa/unit PC


Forced response 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
HadGEM3-GC31-LL
MSLP trend (hPa)
5
4
3
2
1
0
−1
−2
−3
−4
−5
Non-Significant trend (p-value > 0.05)


Forced response 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
HadGEM3-GC31-LL
CanESM5
MSLP trend (hPa)
5
4
3
2
1
0
−1
−2
−3
−4
−5
Non-Significant trend (p-value > 0.05)


Forced response 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
HadGEM3-GC31-LL
CanESM5
MIROC6
MSLP trend (hPa)
5
4
3
2
1
0
−1
−2
−3
−4
−5
Non-Significant trend (p-value > 0.05)


Forced response 1850-2014
historical
hist-aer
hist-GHG
hist-sol
hist-totalO3
hist-volc
sum
HadGEM3-GC31-LL
CanESM5
MIROC6
MPI-ESM1-2-LR
MSLP trend (hPa)
5
4
3
2
1
0
−1
−2
−3
−4
−5
Non-Significant trend (p-value > 0.05)

Summary of projections across models

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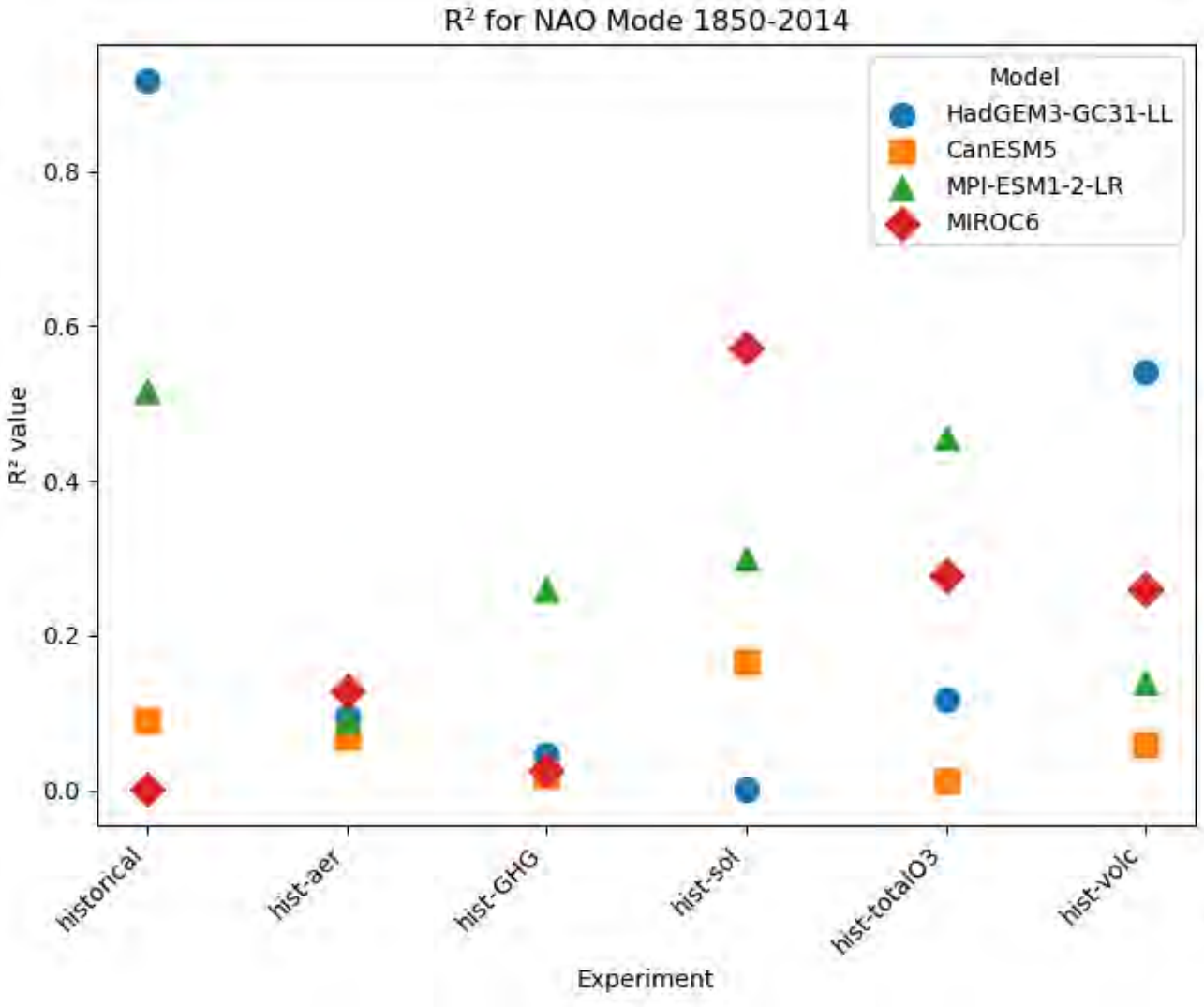

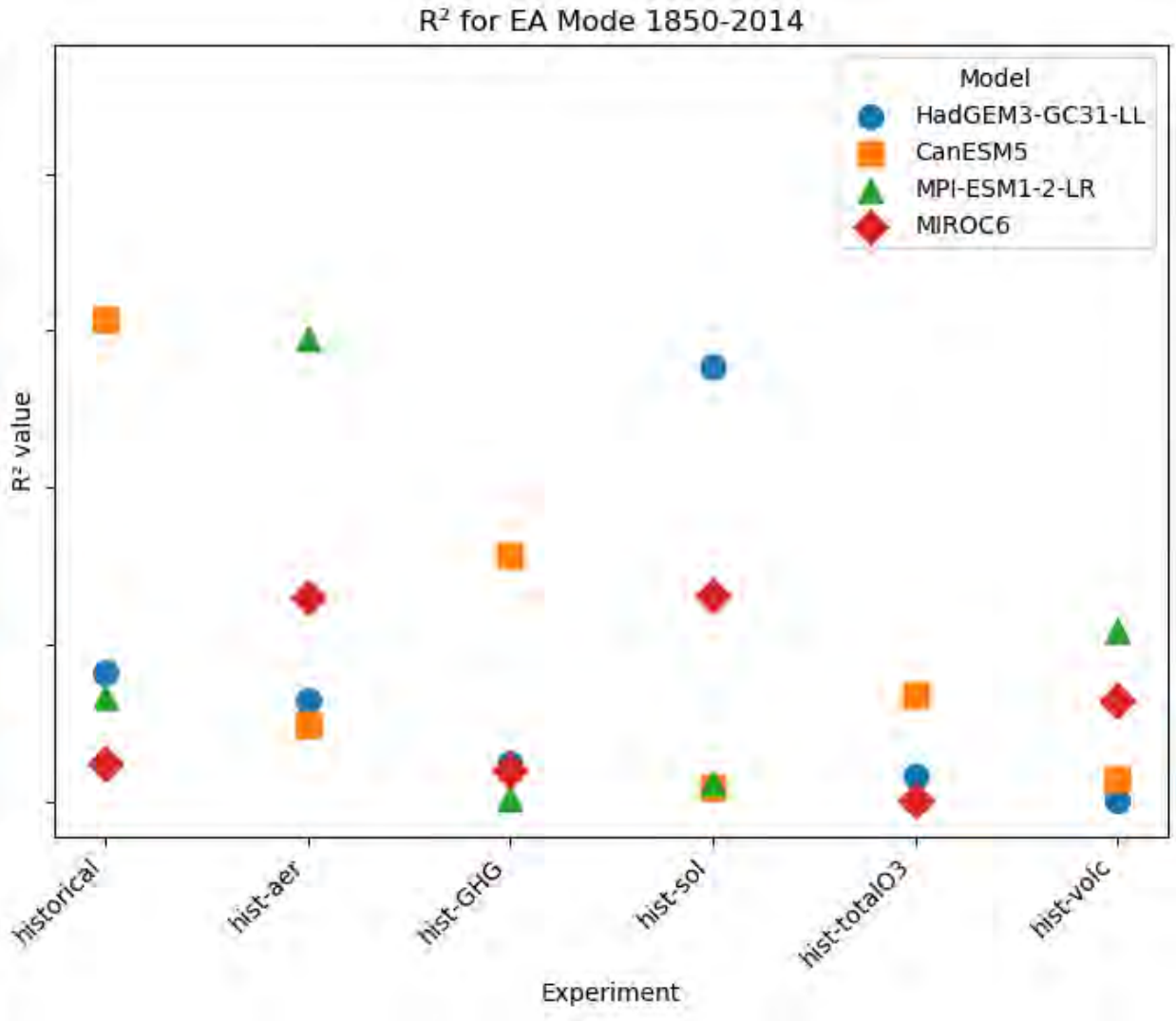

Future Work

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- Expand to other:
  - Models.
  - Seasons.
  - Modes of variability in different regions.

- Investigate the **differences** between the models.

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