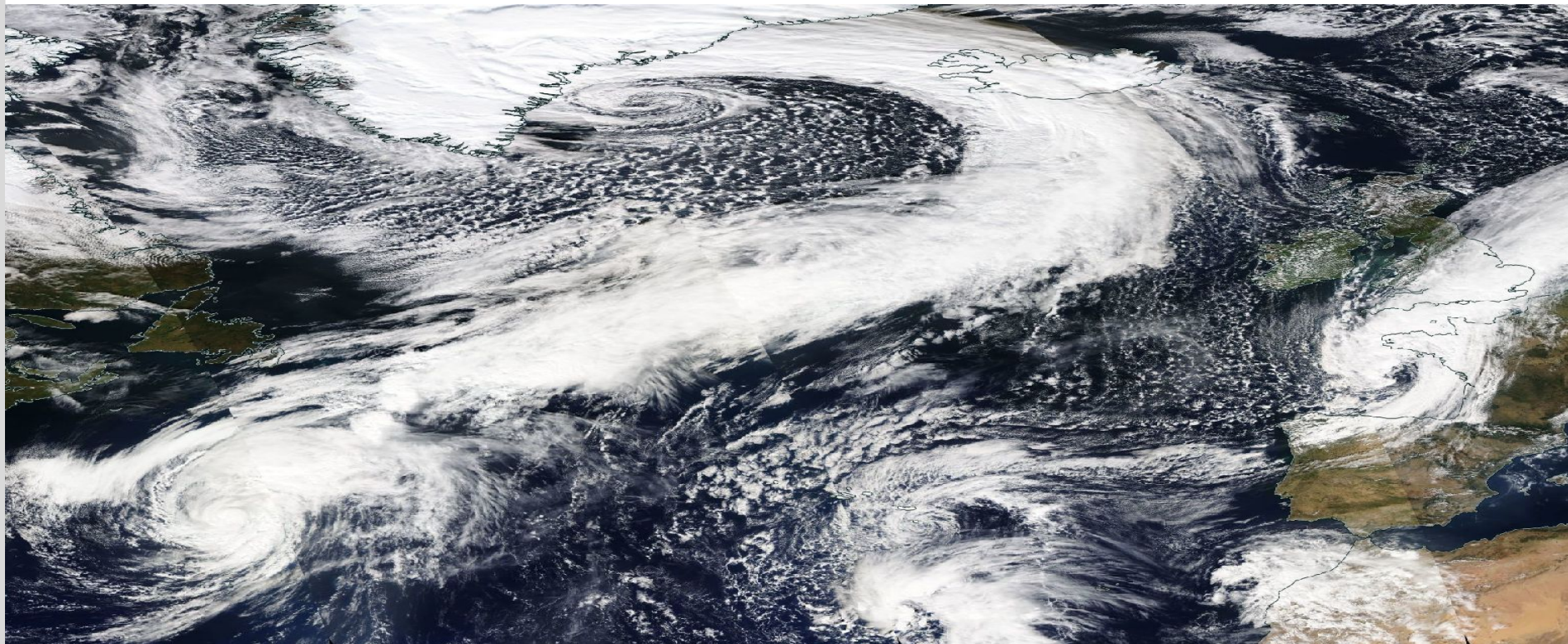# Observed cloud anomalies associated with the North Atlantic Oscillation and their radiative feedback
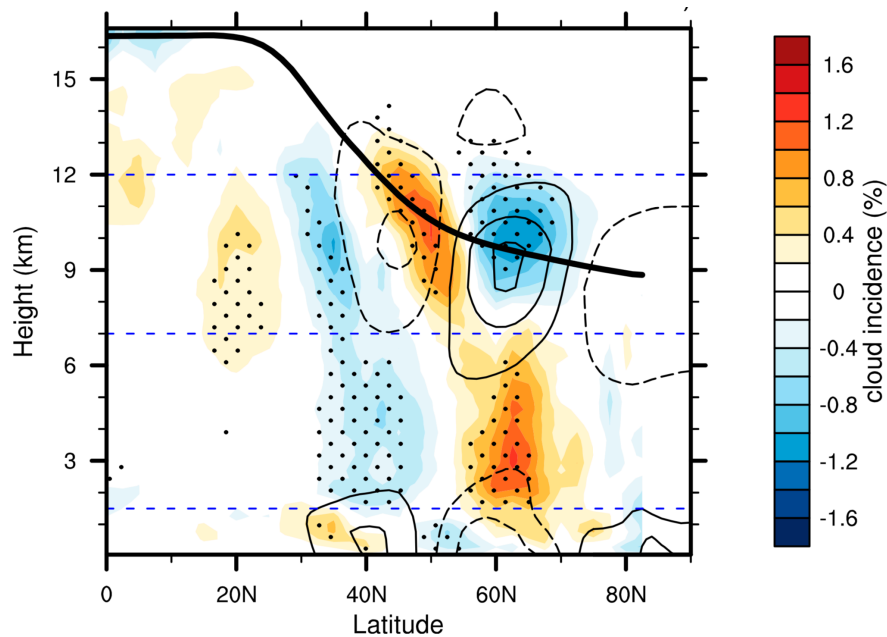
Georgios Papavasileiou[1], Aiko Voigt[1,2], Peter Knippertz[1]

[1]Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Karlsruhe, Germany
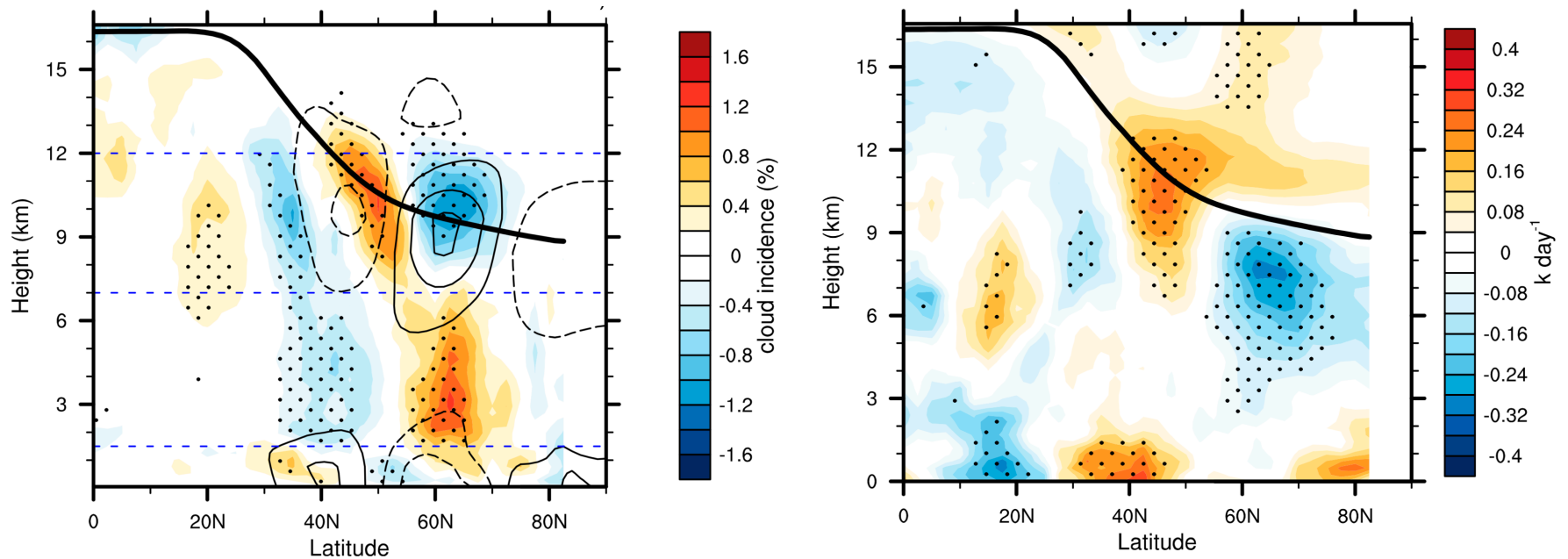[2]Lamont-Doherty Earth Observatory, Columbia University, New York, USA

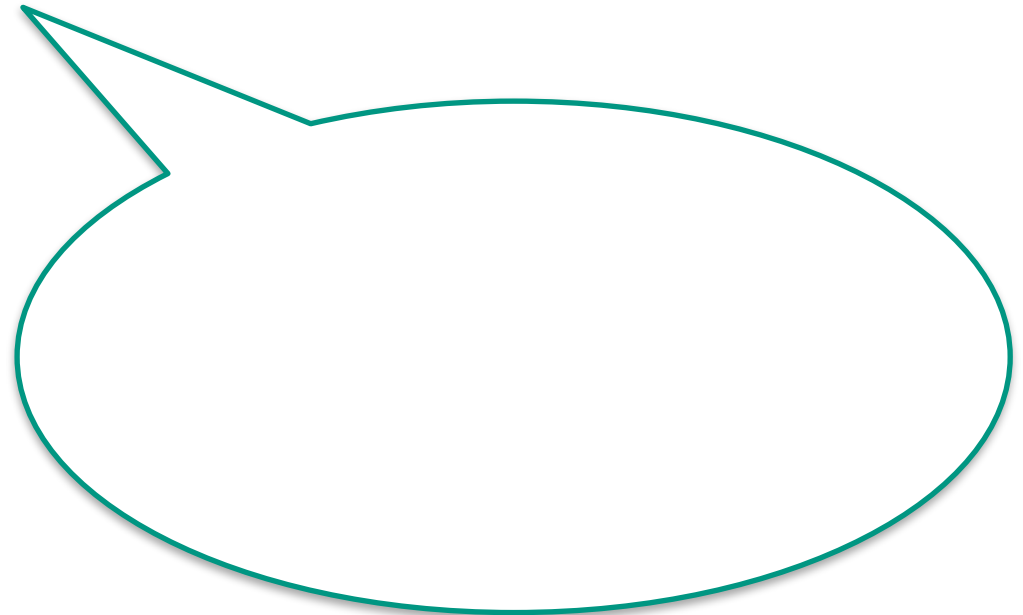# Anomalous cloud-radiative effects damp the NAO

Li et al., 2016
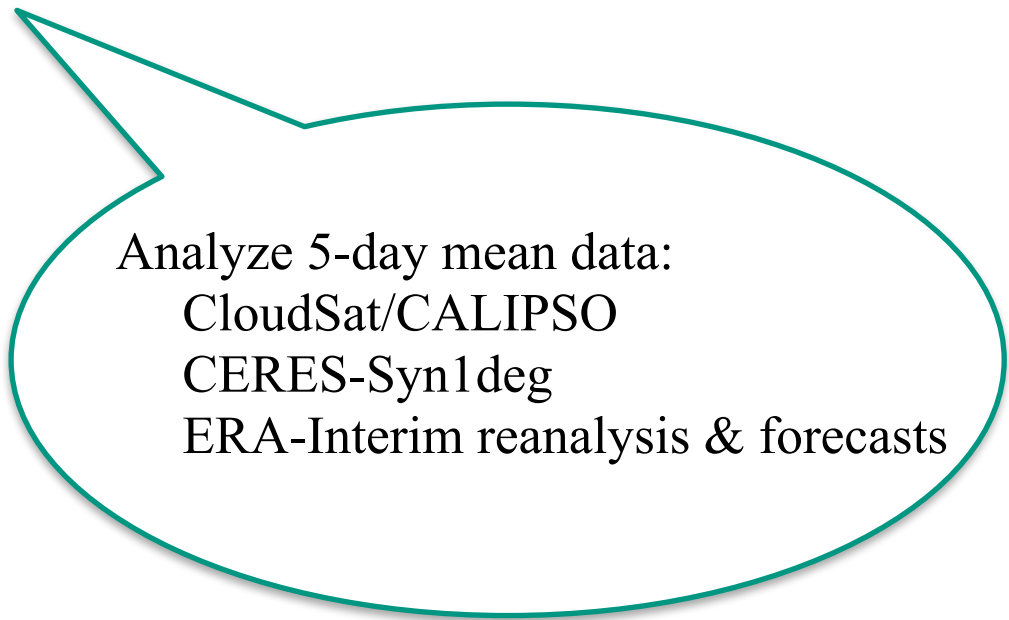
# Anomalous cloud-radiative effects damp the NAO

Li et al., 2016

Georgios Papavasileiou

What is the impact of the cloud-radiative effects on the NAO ?

What is the impact of the cloud-radiative effects on the NAO ?

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What is the impact of the cloud-radiative effects on the NAO ?

Analyze 5-day mean data:
    CloudSat/CALIPSO
    CERES-Syn1deg
    ERA-Interim reanalysis & forecasts
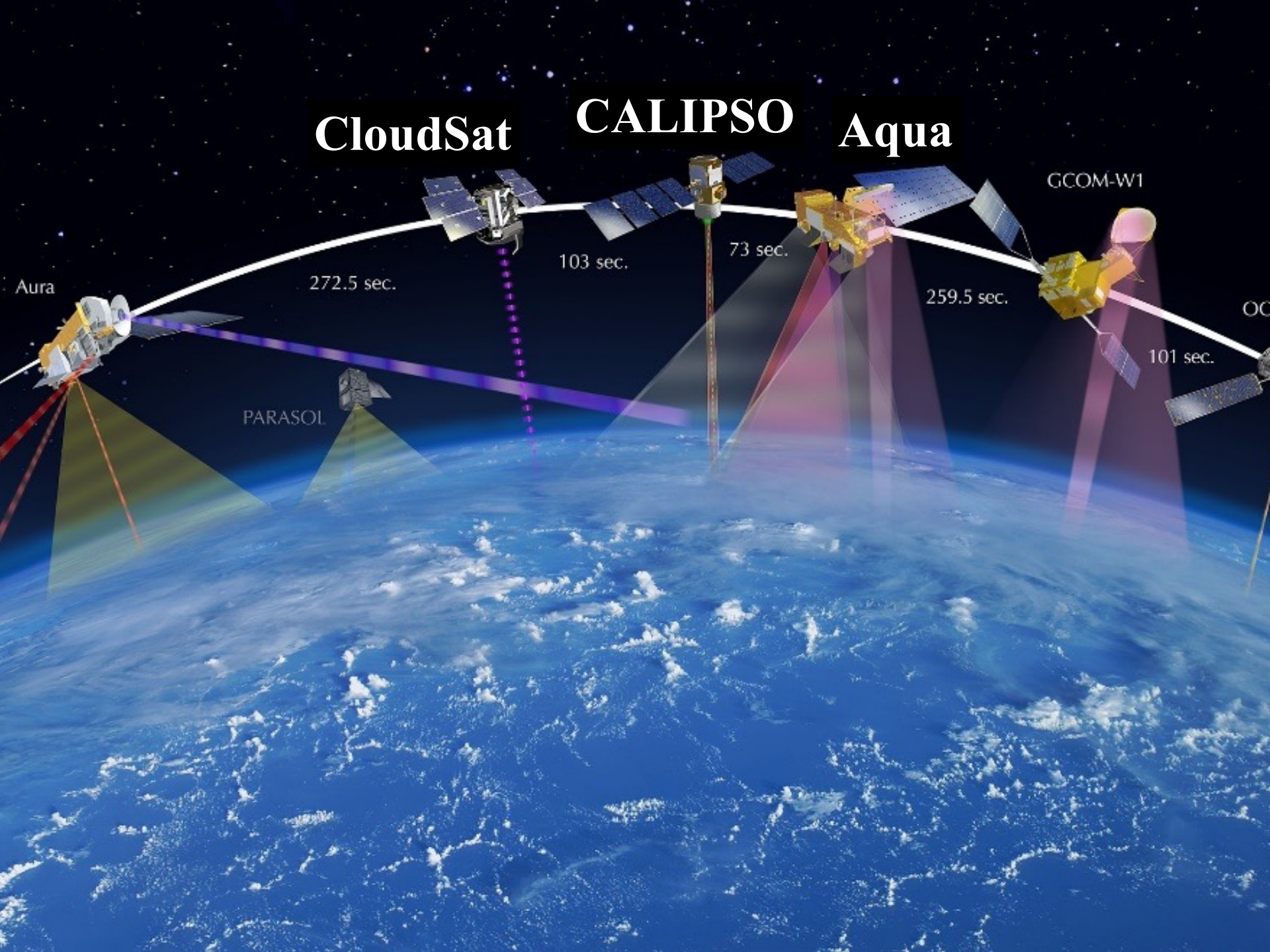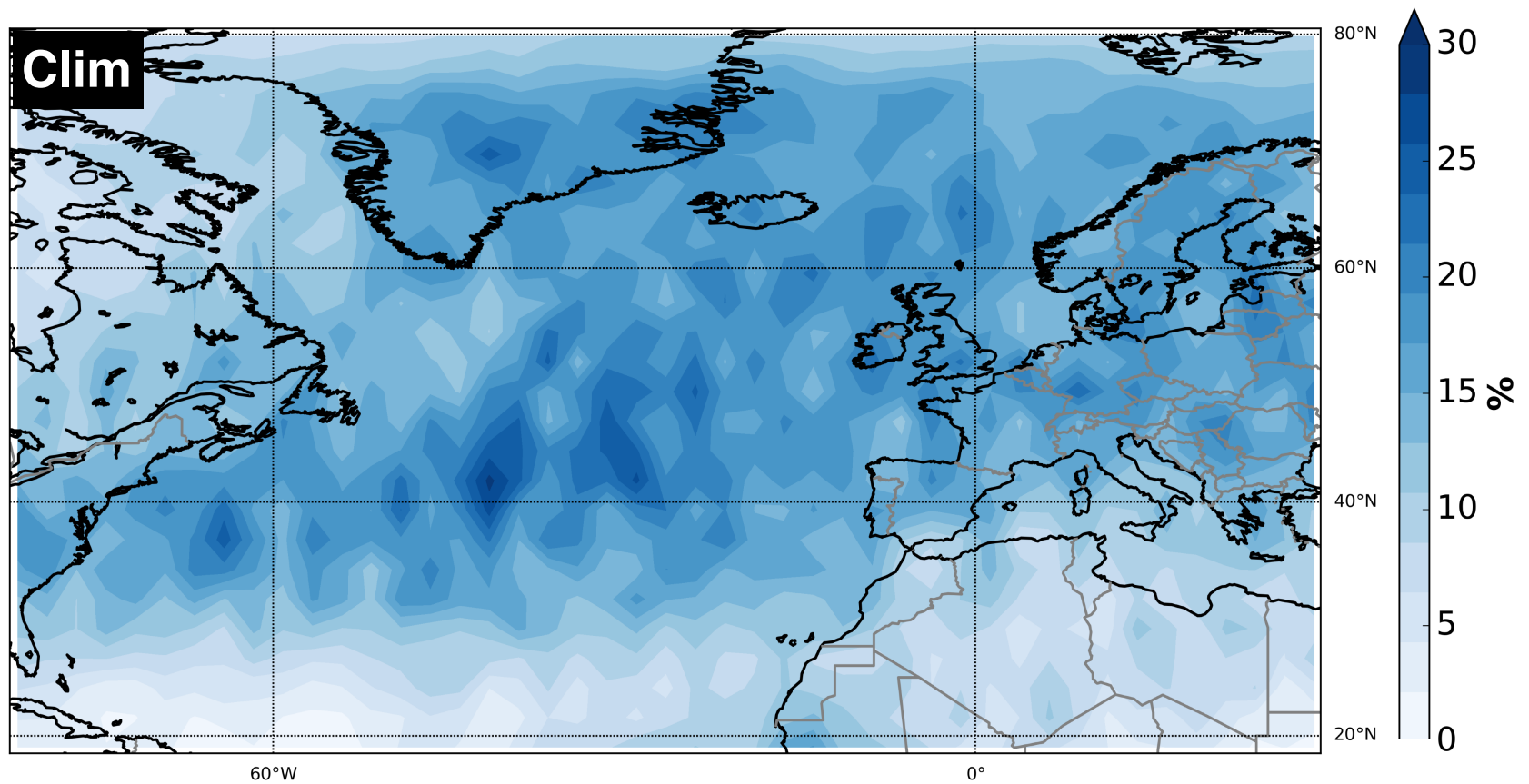
CloudSat CALIPSO Aqua

GCOM-W1
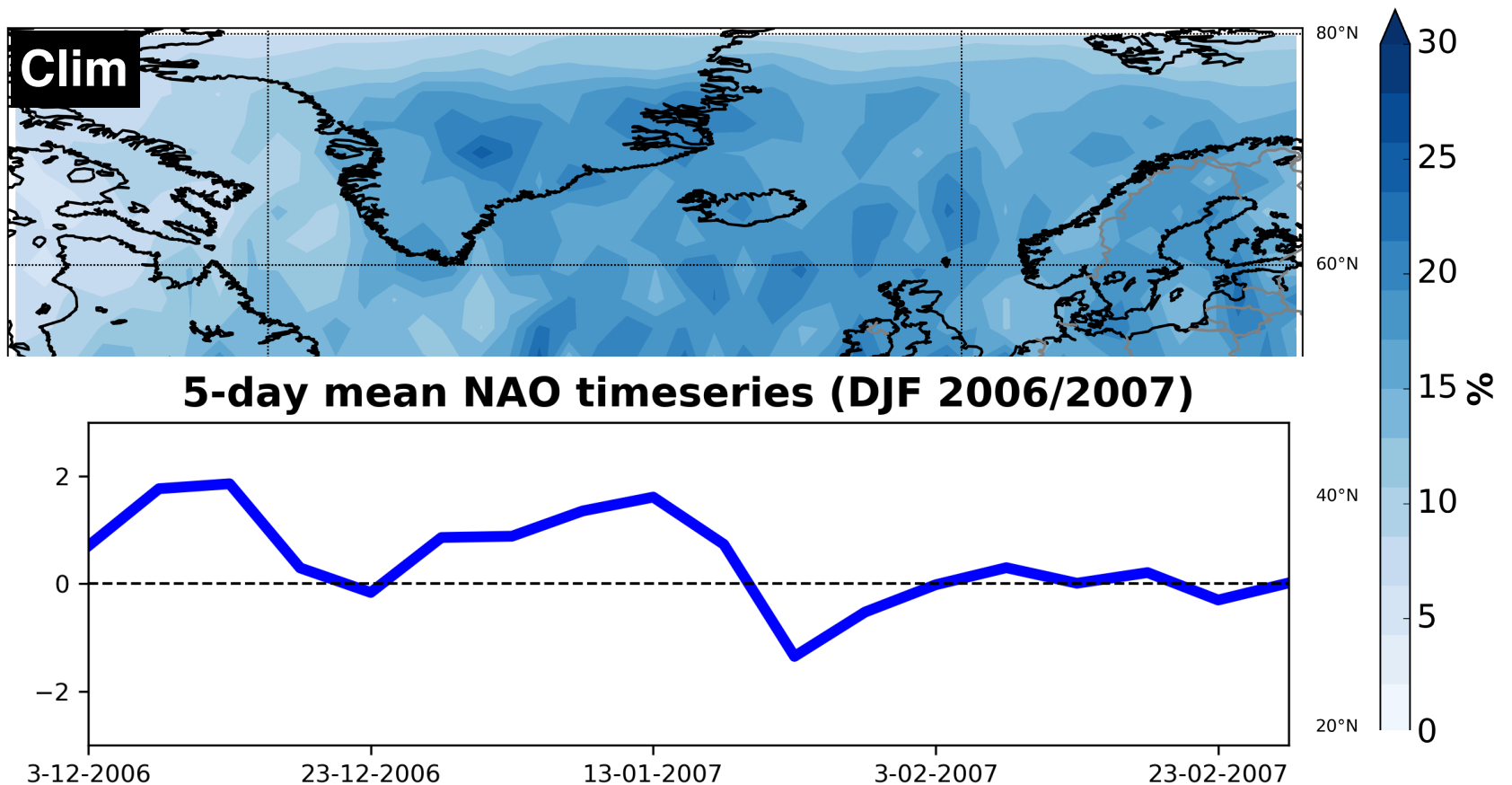
Aura

272.5 sec. 103 sec. 73 sec. 259.5 sec.

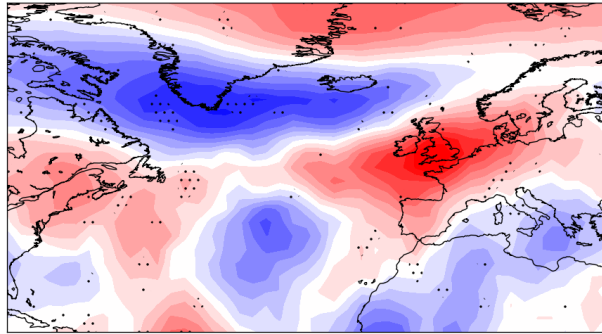101 sec.

PARASOL

OC

High-level cloud incidence climatology

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High-level cloud incidence climatology

5-day mean NAO timeseries (DJF 2006/2007)

Georgios Papavasileiou

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Cloud anomalies associated with positive NAO+

*Stippling shows non-statistically significant grid points

Georgios Papavasileiou   IMK-TRO

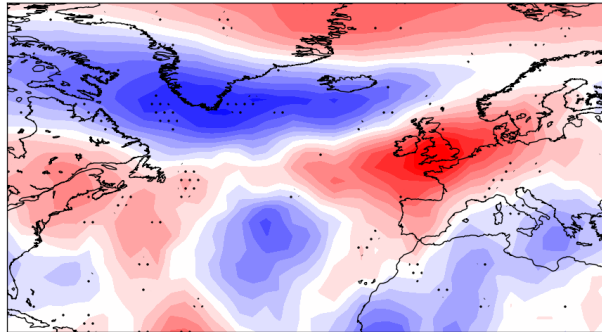# Cloud anomalies associated with positive NAO+

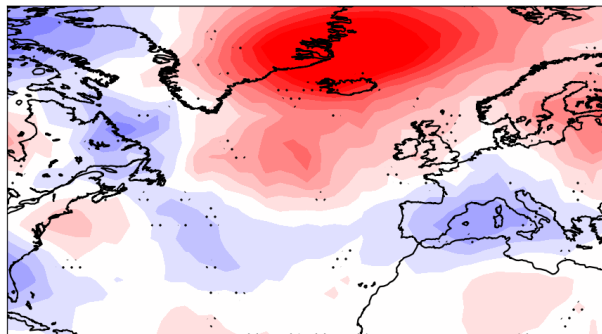

High-level cloud incidence

*Stippling shows non-statistically significant grid points

Cloud anomalies associated with positive NAO+
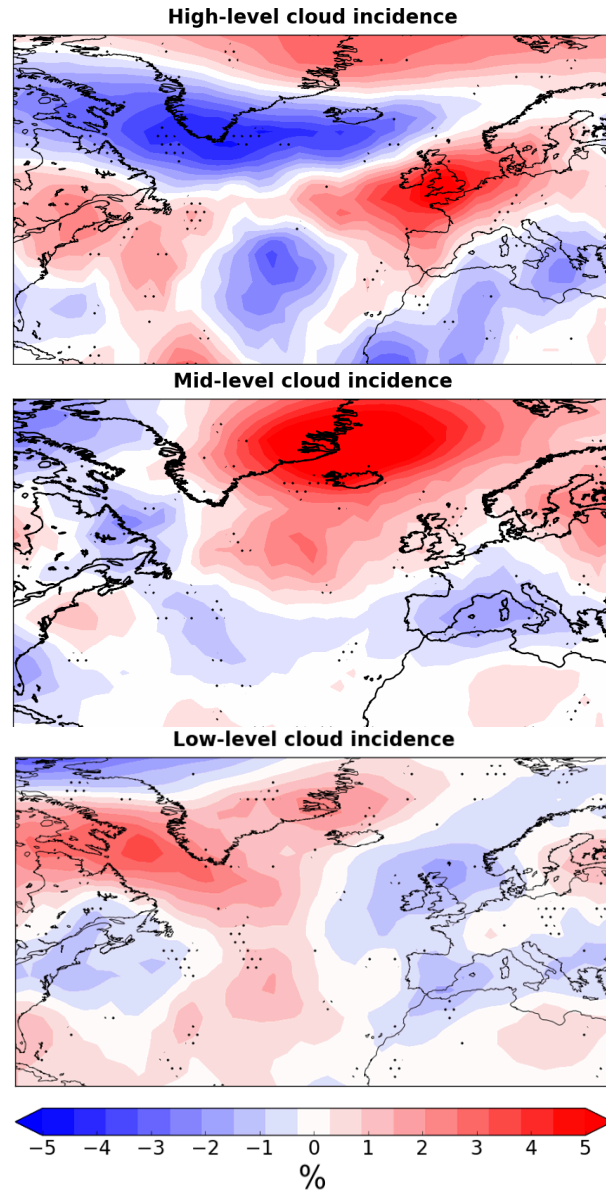

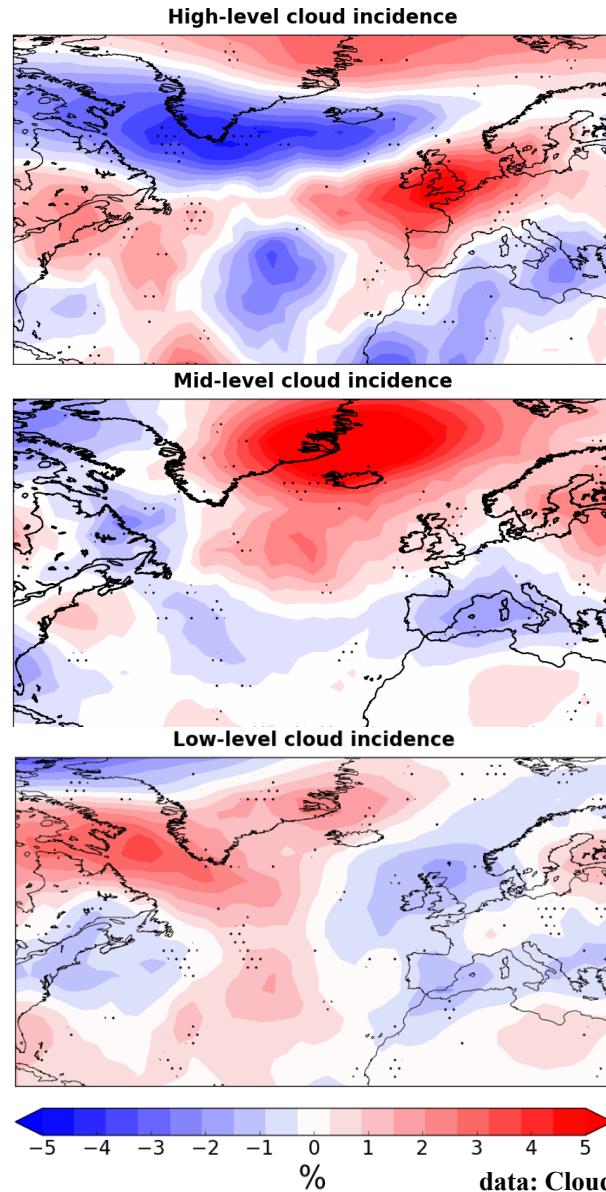High-level cloud incidence

Mid-level cloud incidence

*Stippling shows non-statistically significant grid points

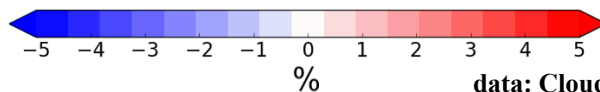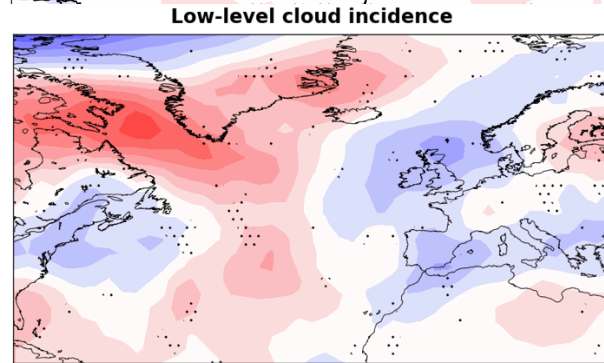# Cloud anomalies associated with positive NAO+

High-level cloud incidence

Mid-level cloud incidence
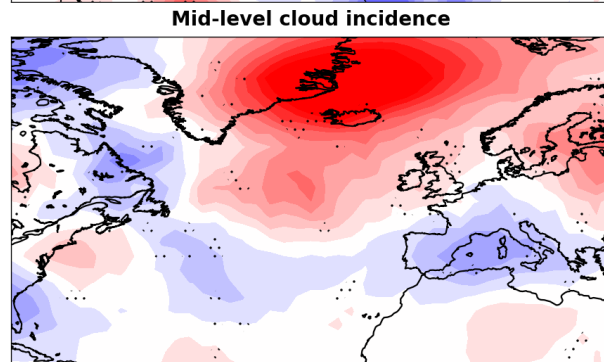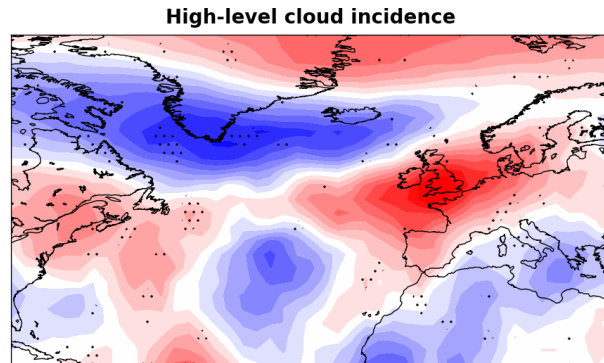
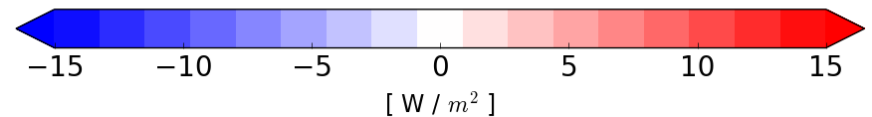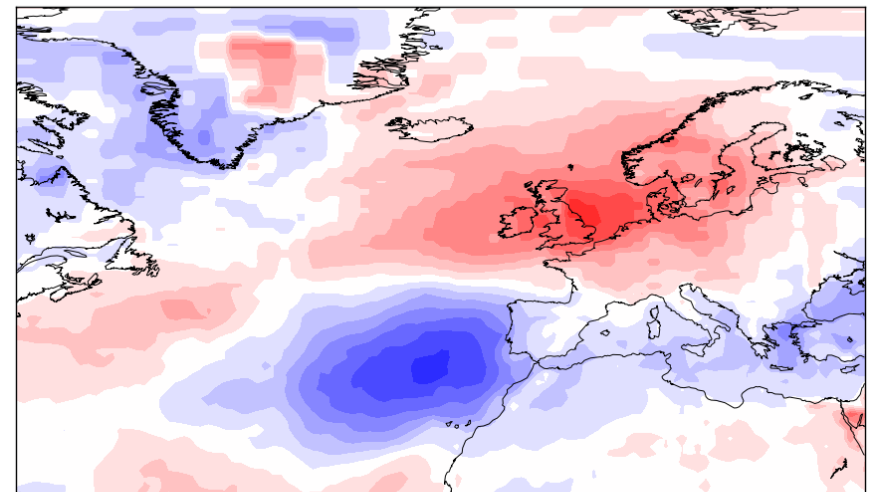Low-level cloud incidence

*Stippling shows non-statistically significant grid points

Cloud anomalies associated with positive NAO+

High-level cloud incidence

Mid-level cloud incidence

Low-level cloud incidence

−5 −4 −3 −2 −1 0 1 2 3 4 5
%

data: CloudSat/CALIPSO

*Stippling shows non-statistically significant grid points

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Cloud anomalies associated with positive NAO+

*Stippling shows non-statistically significant grid points
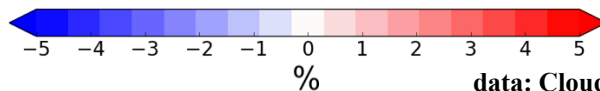
Cloud anomalies associated with positive NAO+

High-level cloud incidence

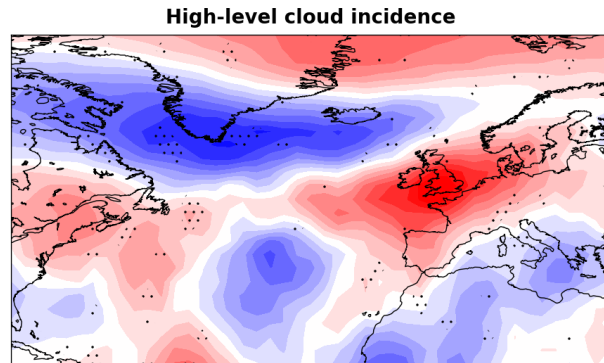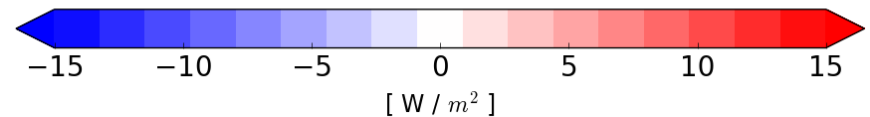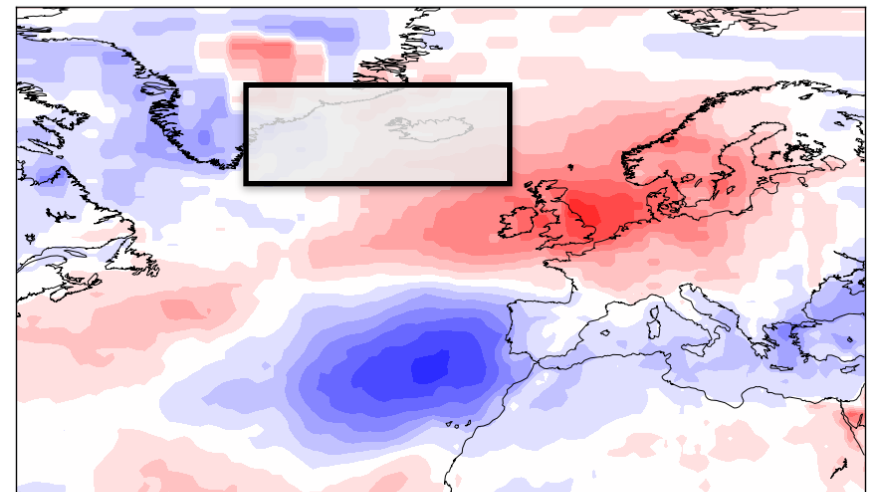Mid-level cloud incidence

Low-level cloud incidence

Atmospheric Cloud Radiative Effects

[W / m^2]

%

data: CloudSat/CALIPSO

*Stippling shows non-statistically significant grid points

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Cloud anomalies associated with positive NAO+

High-level cloud incidence

Mid-level cloud incidence

Low-level cloud incidence

Atmospheric Cloud Radiative Effects

ICELAND

[W / m^2]

%

data: CloudSat/CALIPSO

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Cloud anomalies associated with positive NAO+

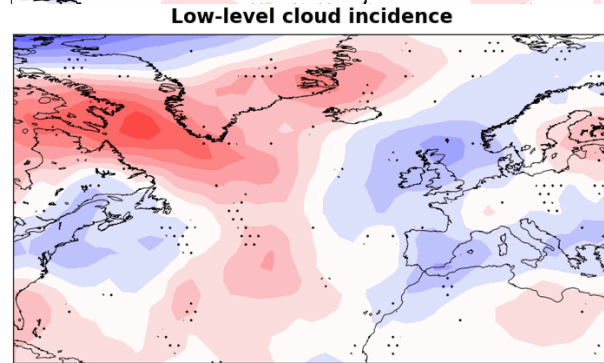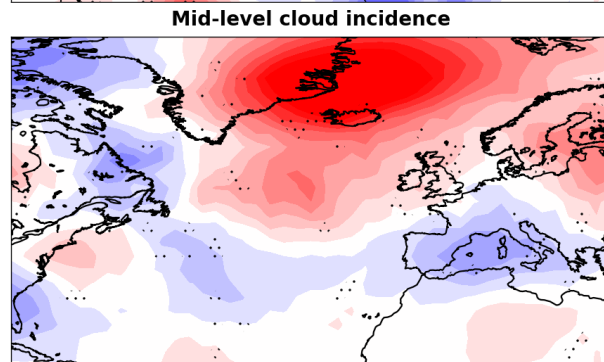High-level cloud incidence

Mid-level cloud incidence

Low-level cloud incidence

%

data: CloudSat/CALIPSO

Atmospheric Cloud Radiative Effects

ICELAND

[W / m^2]

*Stippling shows non-statistically significant grid points
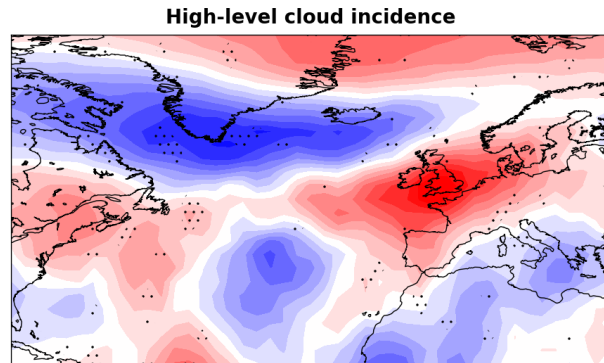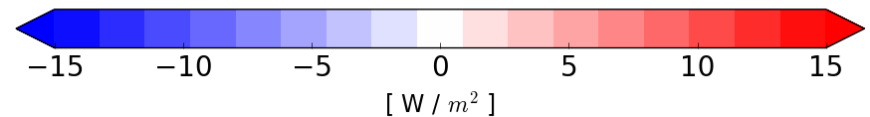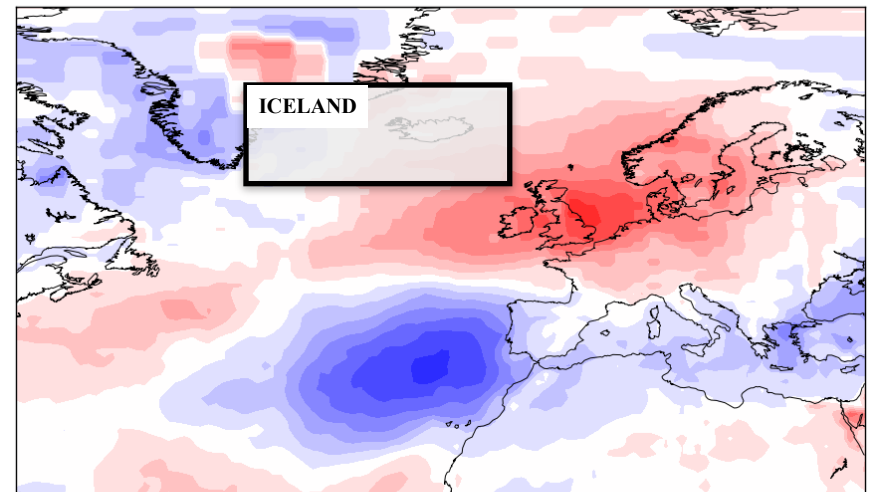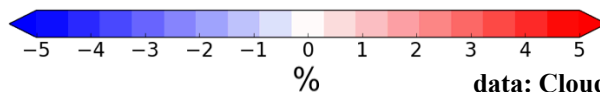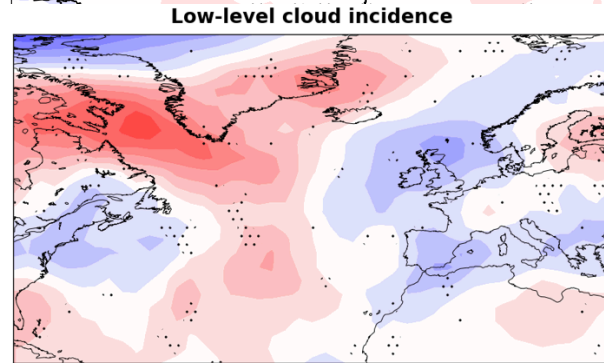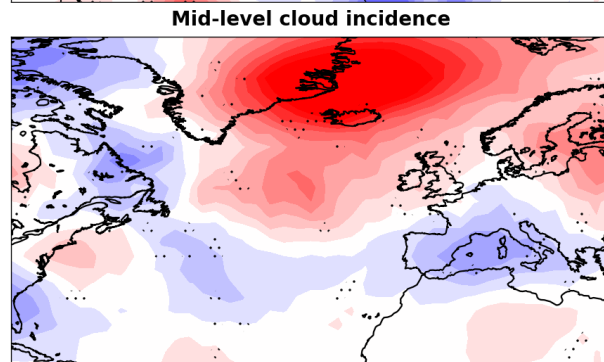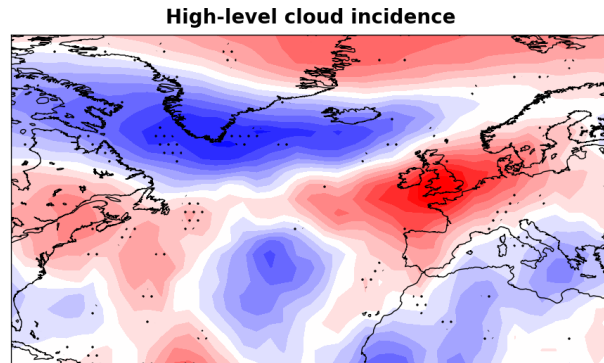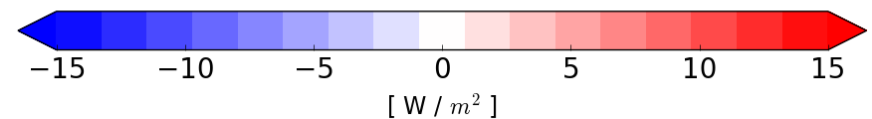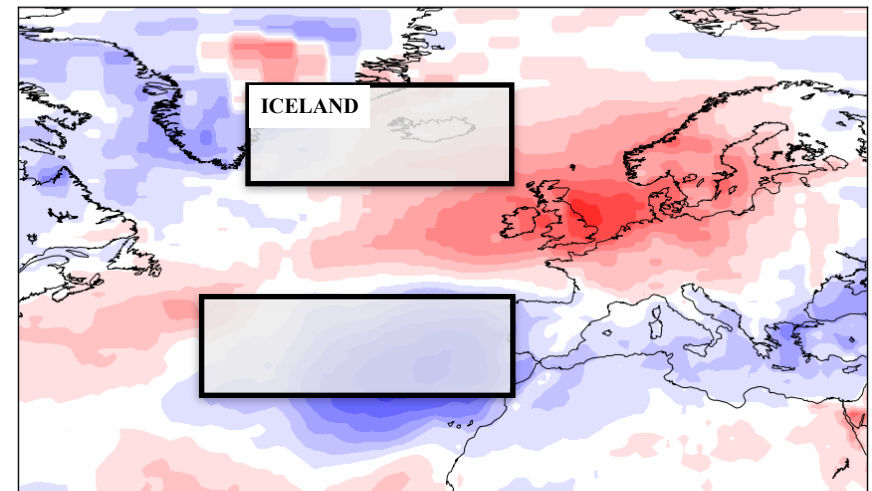
Cloud anomalies associated with positive NAO+

High-level cloud incidence

Mid-level cloud incidence

Low-level cloud incidence

Atmospheric Cloud Radiative Effects

ICELAND

AZORES

[W / m^2]

%

data: CloudSat/CALIPSO

*Stippling shows non-statistically significant grid points

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Cloud anomalies associated with positive NAO+

High-level cloud incidence

Mid-level cloud incidence

Low-level cloud incidence

%
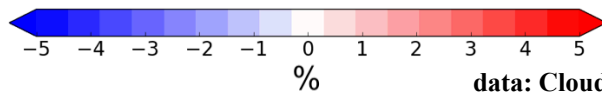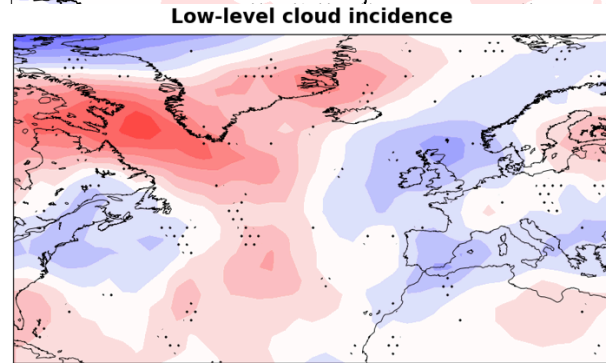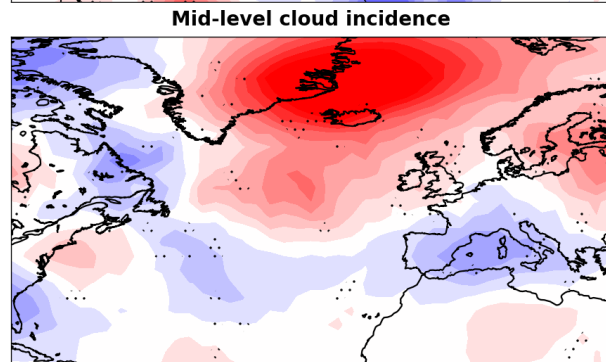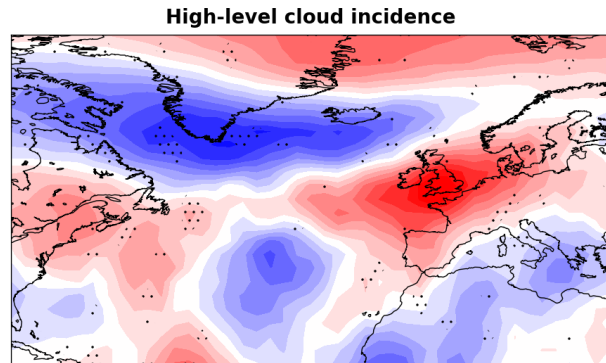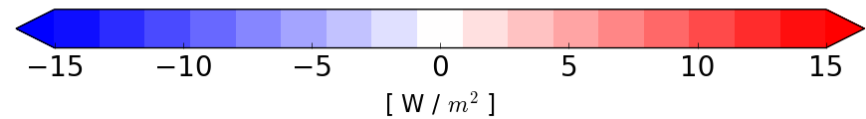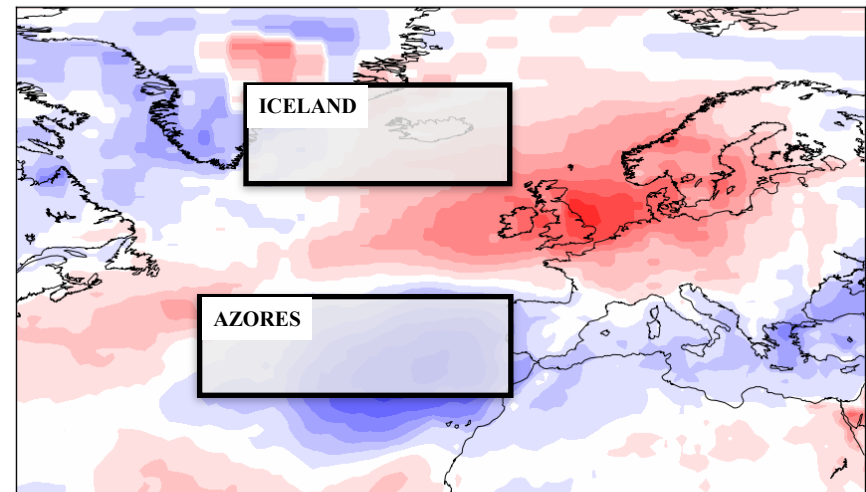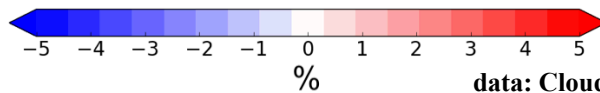
data: CloudSat/CALIPSO

Atmospheric Cloud Radiative Effects

ICELAND

AZORES

[W / m^2]

data: CERES-SYN1deg

*Stippling shows non-statistically significant grid points

Vertical profiles of the anomalies associated with NAO

Data: CloudSat/CALIPSO

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Vertical profiles of the anomalies associated with NAO

Data: CloudSat/CALIPSO

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Vertical profiles of the anomalies associated with NAO

Data: CloudSat/CALIPSO

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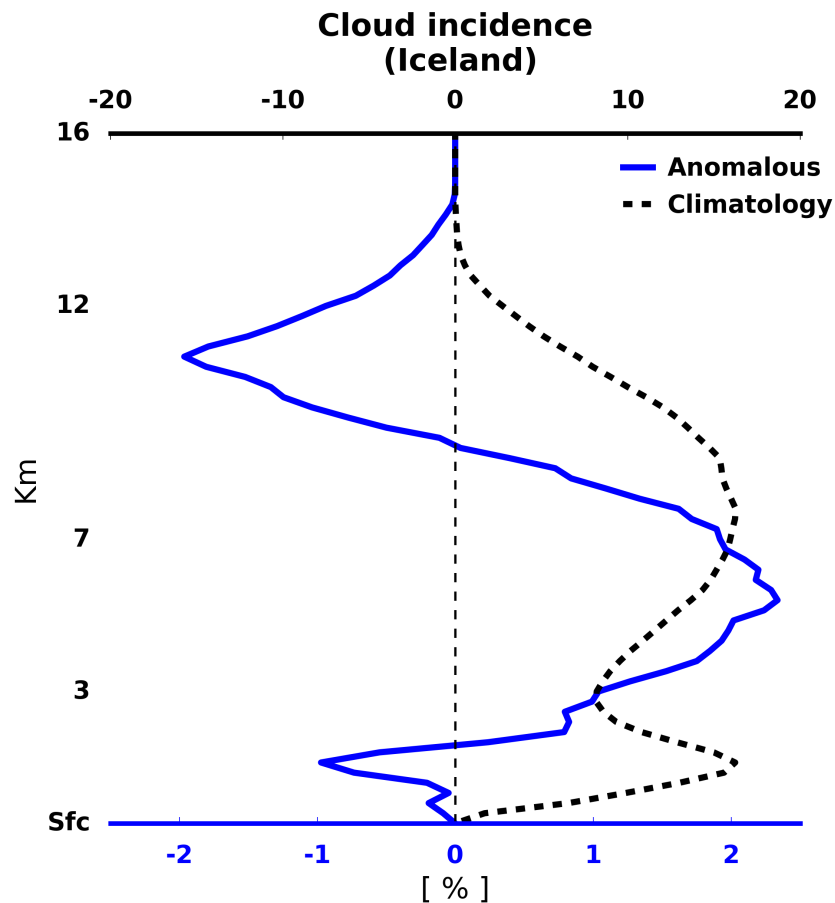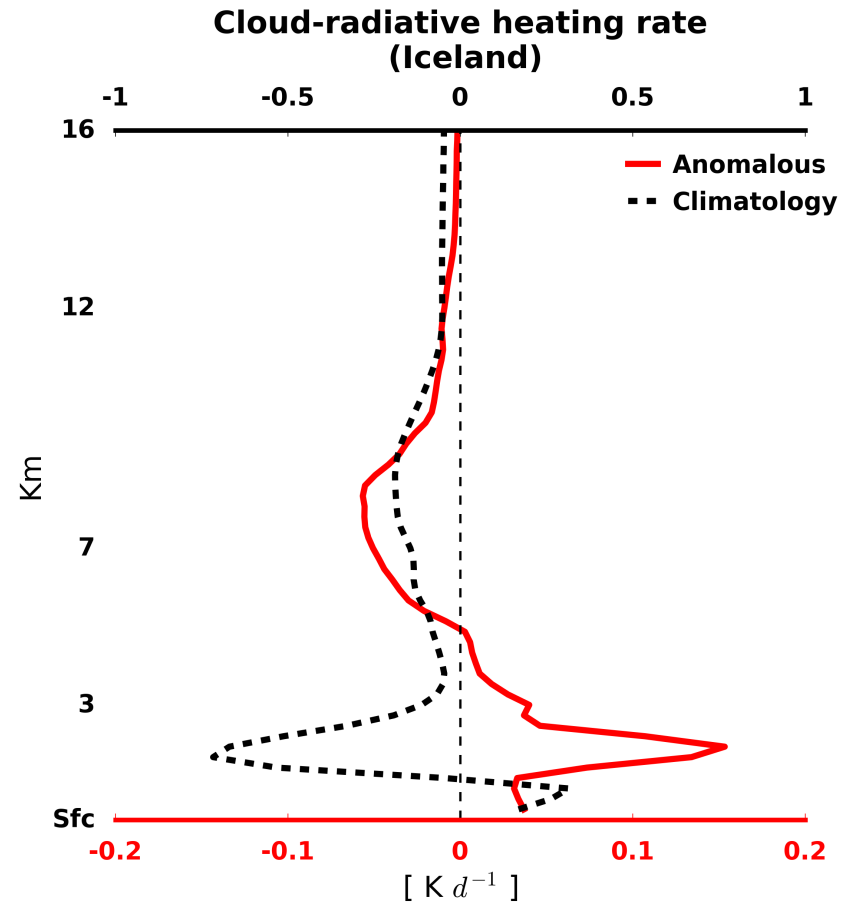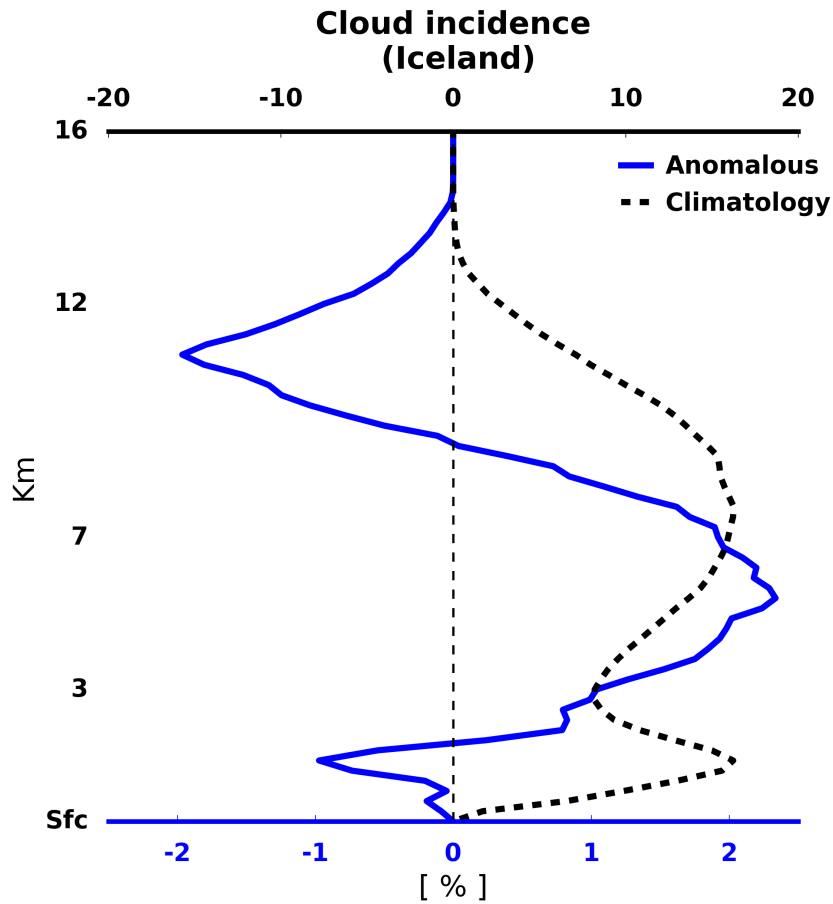
Vertical profiles of the anomalies associated with NAO
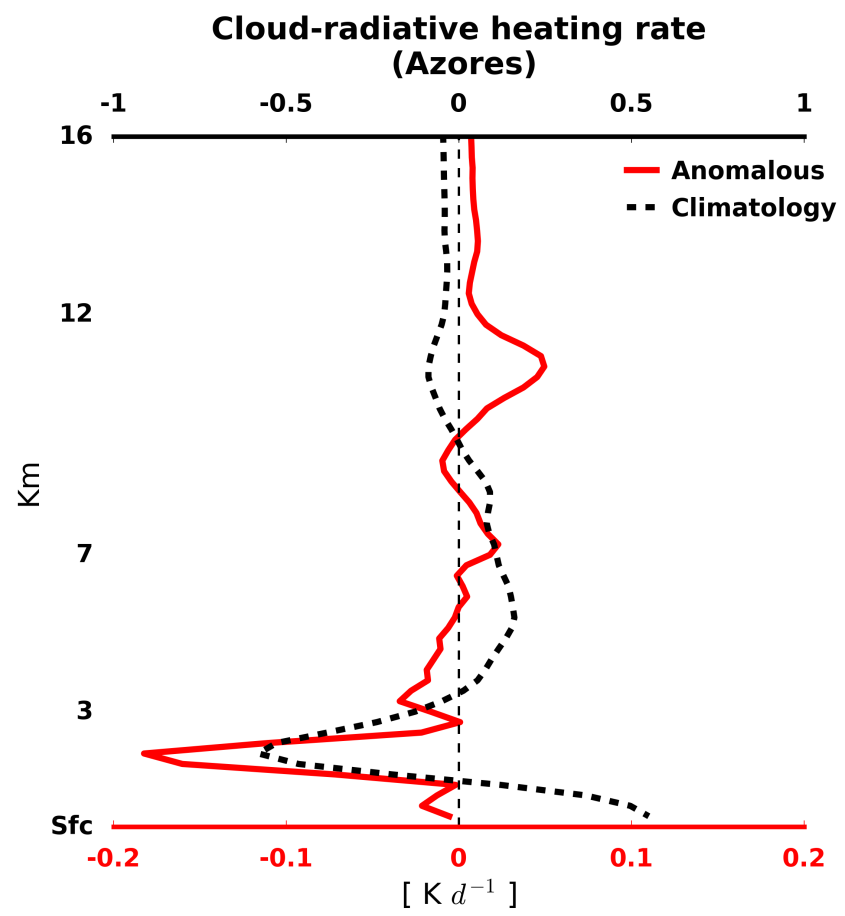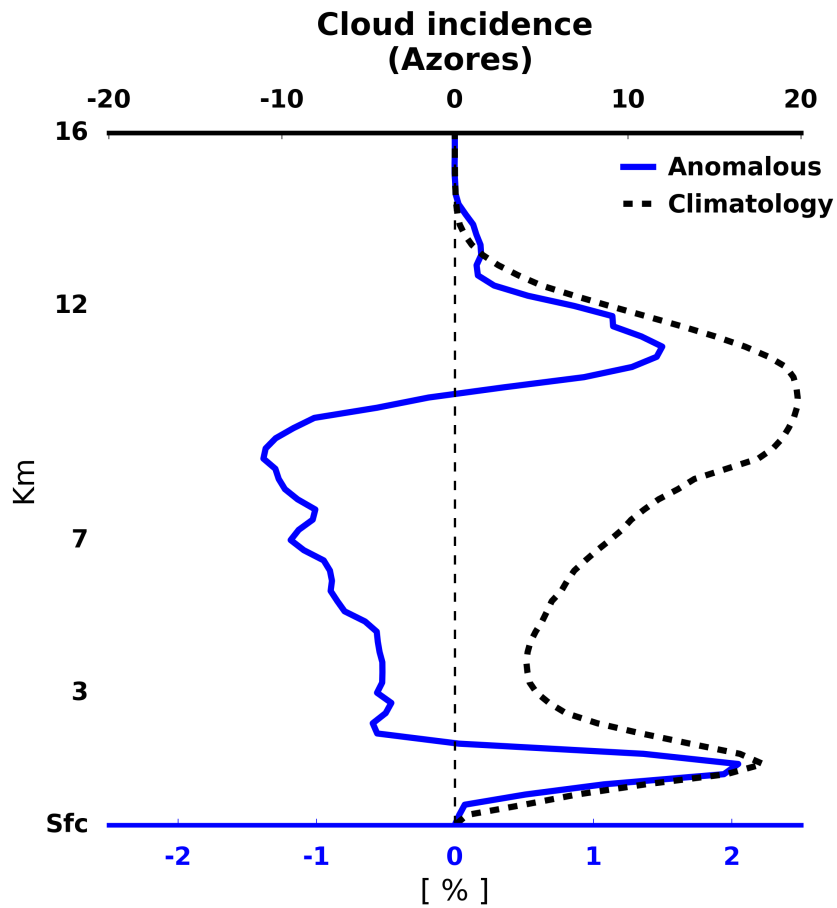
CRE anomalies are robust across different datasets
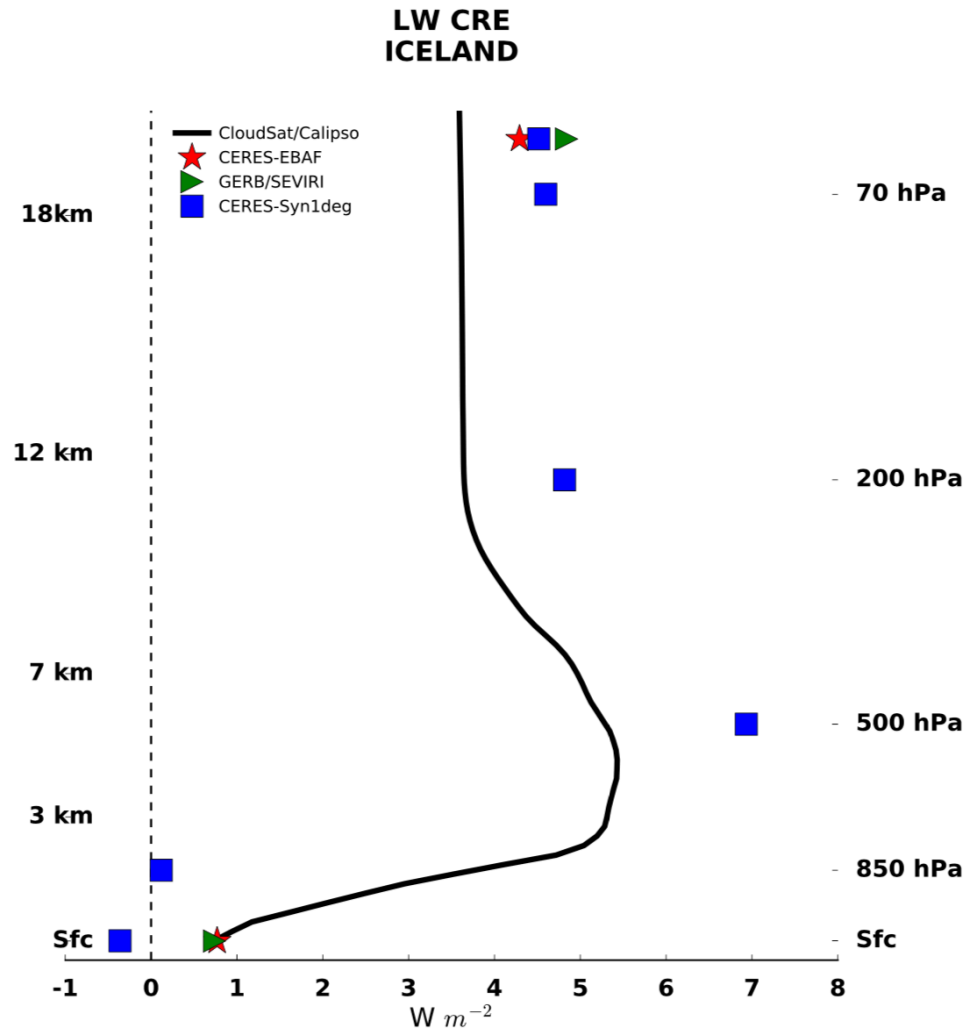
Surface Pressure Tendency perspective

Knippertz & Fink, 2008
Fink et al., 2012

Surface Pressure Tendency perspective

$$\underbrace{\frac{\partial p_{sfc}}{\partial t}}_{Dp} = \underbrace{\rho_{sfc}\frac{\partial \phi_{p_2}}{\partial t}}_{D\phi} + \underbrace{\rho_{sfc}R_d\int_{sfc}^{p_2}\frac{\partial T_v}{\partial t}d\ln p}_{ITT} + \underbrace{g(E-P)}_{EP} + RES_{PTE}$$

Knippertz & Fink, 2008

Fink et al., 2012

Surface Pressure Tendency perspective

$$\frac{\partial p_{sfc}}{\partial t} = \underbrace{\rho_{sfc} R_d \int_{sfc}^{p_2} \frac{\partial T_v}{\partial t} d\ln p}_{ITT} + \underbrace{g(E - P)}_{EP} + RES_{PTE}$$

Dp

Knippertz & Fink, 2008
Fink et al., 2012

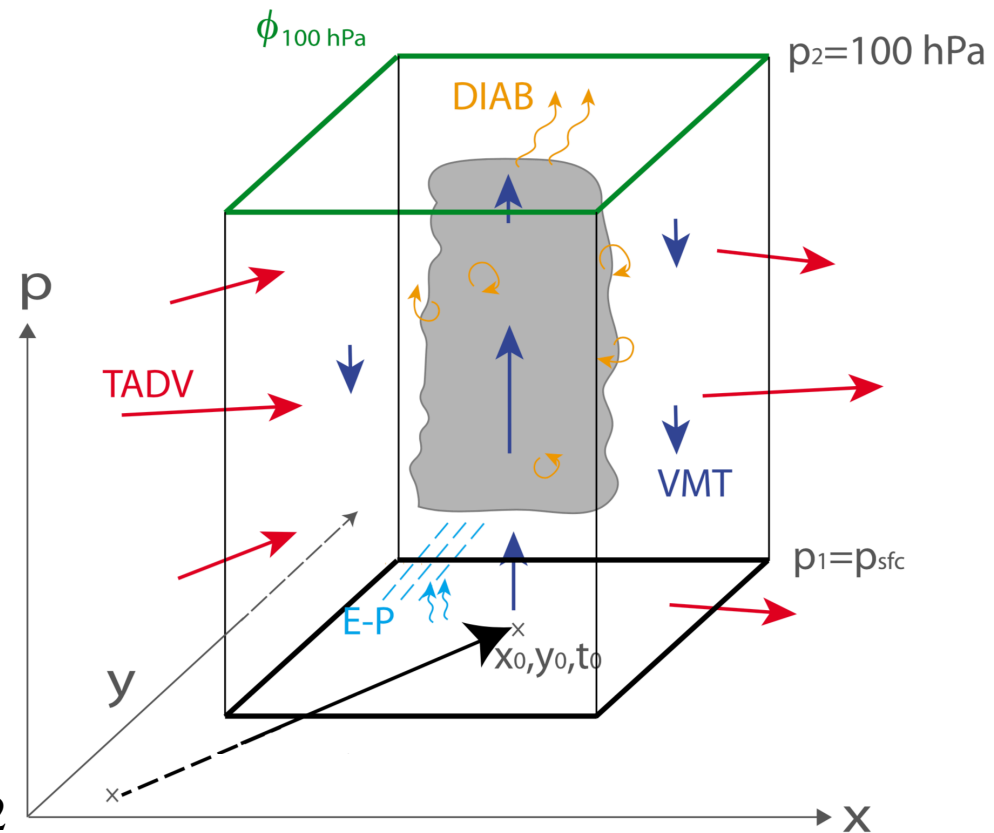# Surface Pressure Tendency perspective

$$\frac{\partial p_{sfc}}{\partial t} =$$

$$Dp$$

$$\rho_{sfc} R_d \int_{sfc}^{p_2} \frac{\partial T_v}{\partial t} d\ln p$$

$$ITT$$

Knippertz & Fink, 2008

Fink et al., 2012
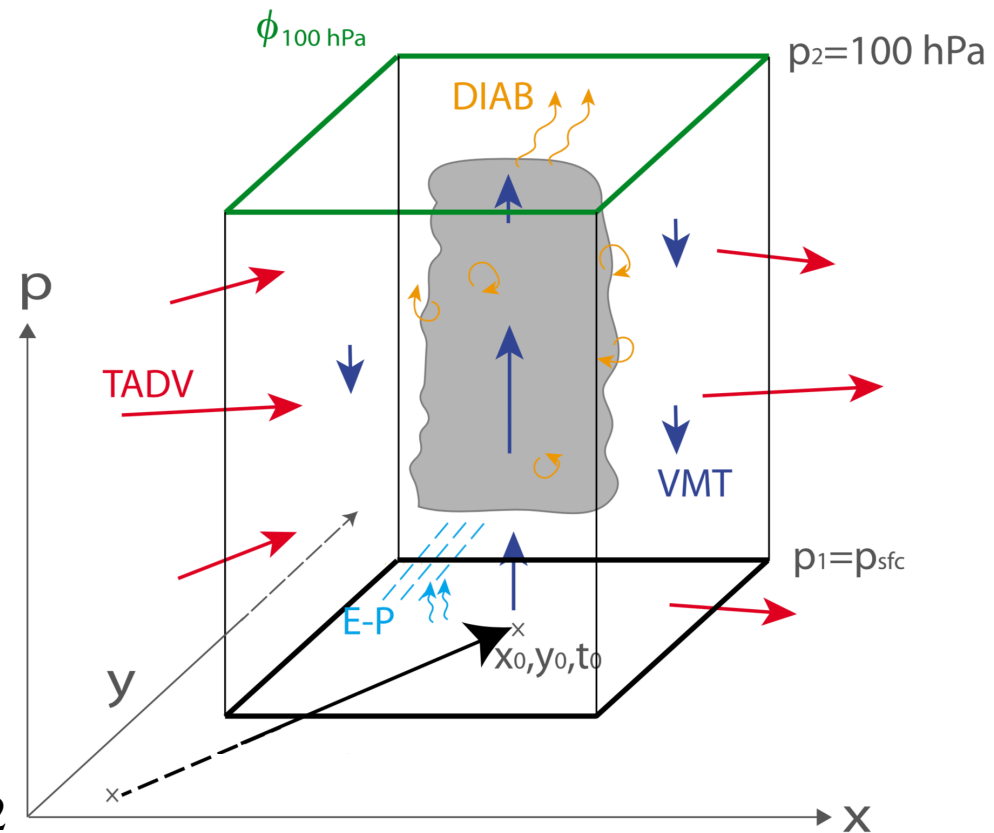
Schematic illustration of the PTE

$ITT =$

Fink et al., 2012

Schematic illustration of the PTE

$$ITT = + \rho_{sfc} R_d \int_{sfc}^{p_2} - \vec{v} \cdot \vec{\nabla}_p T_v d\ln p$$

Temperature Advection

Fink et al., 2012

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Schematic illustration of the PTE

$$ITT = + \rho_{sfc} R_d \int_{sfc}^{p_2} - \vec{v} \cdot \vec{\nabla}_p T_v d\ln p$$

Temperature Advection

$$+ \rho_{sfc} R_d \int_{sfc}^{p_2} \left(\frac{R_d T_v}{c_p p} - \frac{\partial T_v}{\partial p} \right) \omega d\ln p$$

Vertical Motions

Fink et al., 2012

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Schematic illustration of the PTE

$$ITT = + \rho_{sfc} R_d \int_{sfc}^{p_2} - \vec{v} \cdot \vec{\nabla}_p T_v \, d\ln p$$
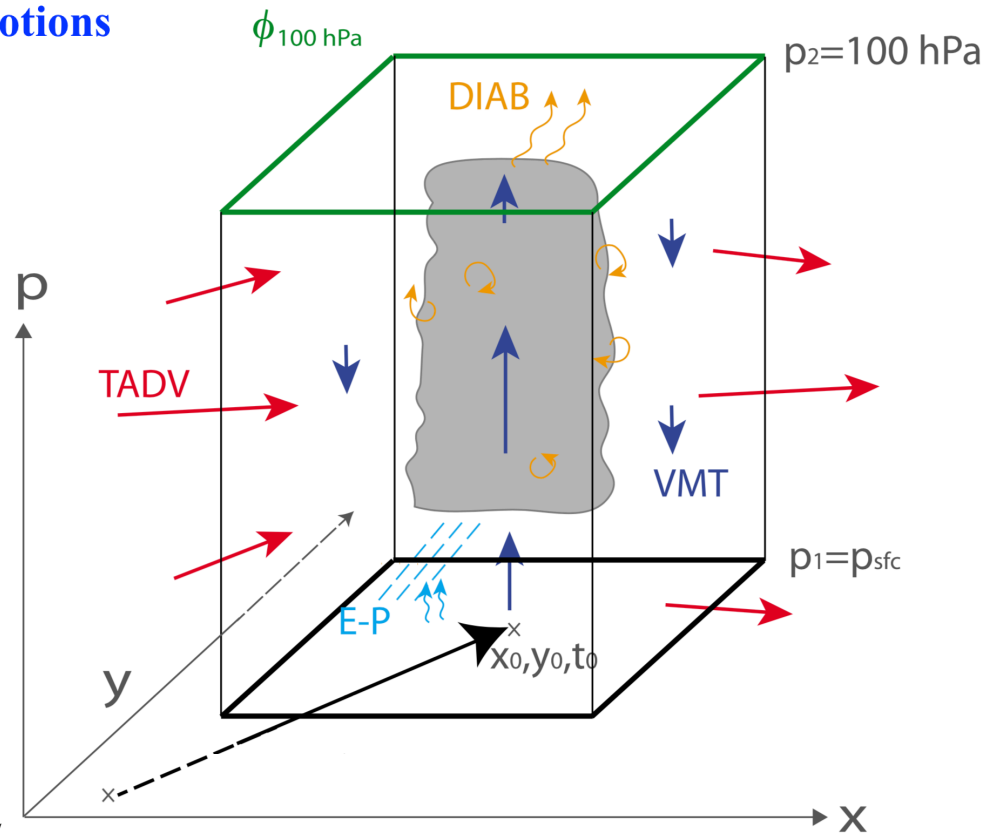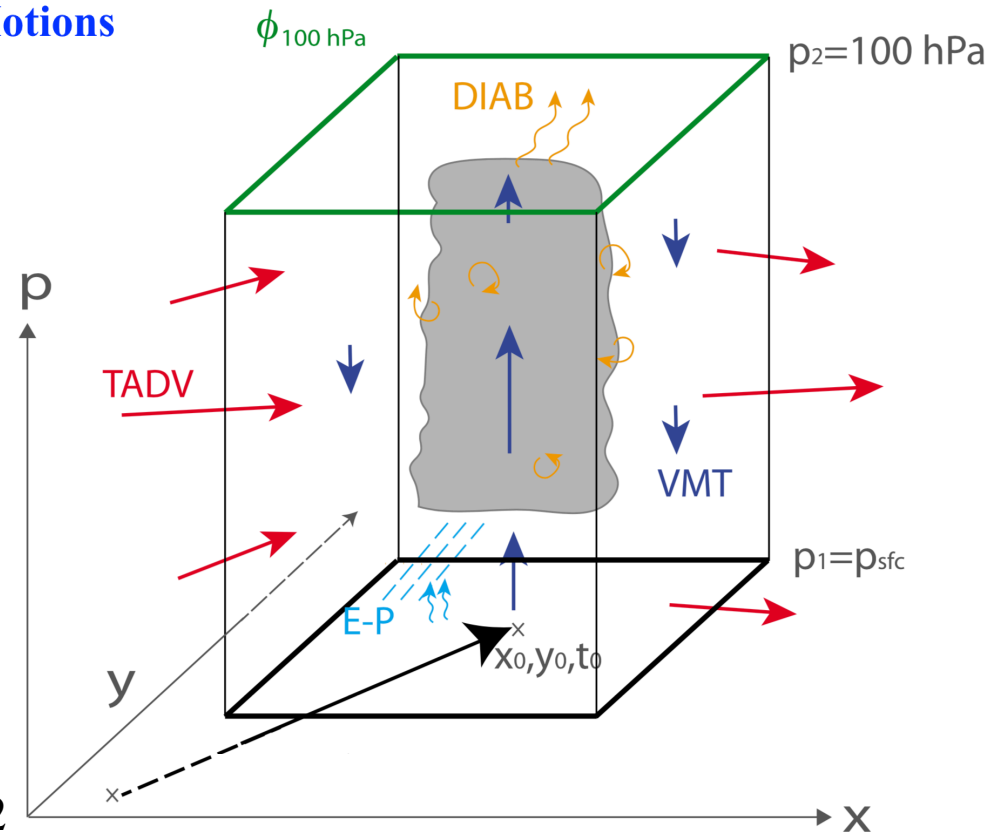
Temperature Advection

$$+ \rho_{sfc} R_d \int_{sfc}^{p_2} \left(\frac{R_d T_v}{c_p p} - \frac{\partial T_v}{\partial p} \right) \omega \, d\ln p$$

Vertical Motions

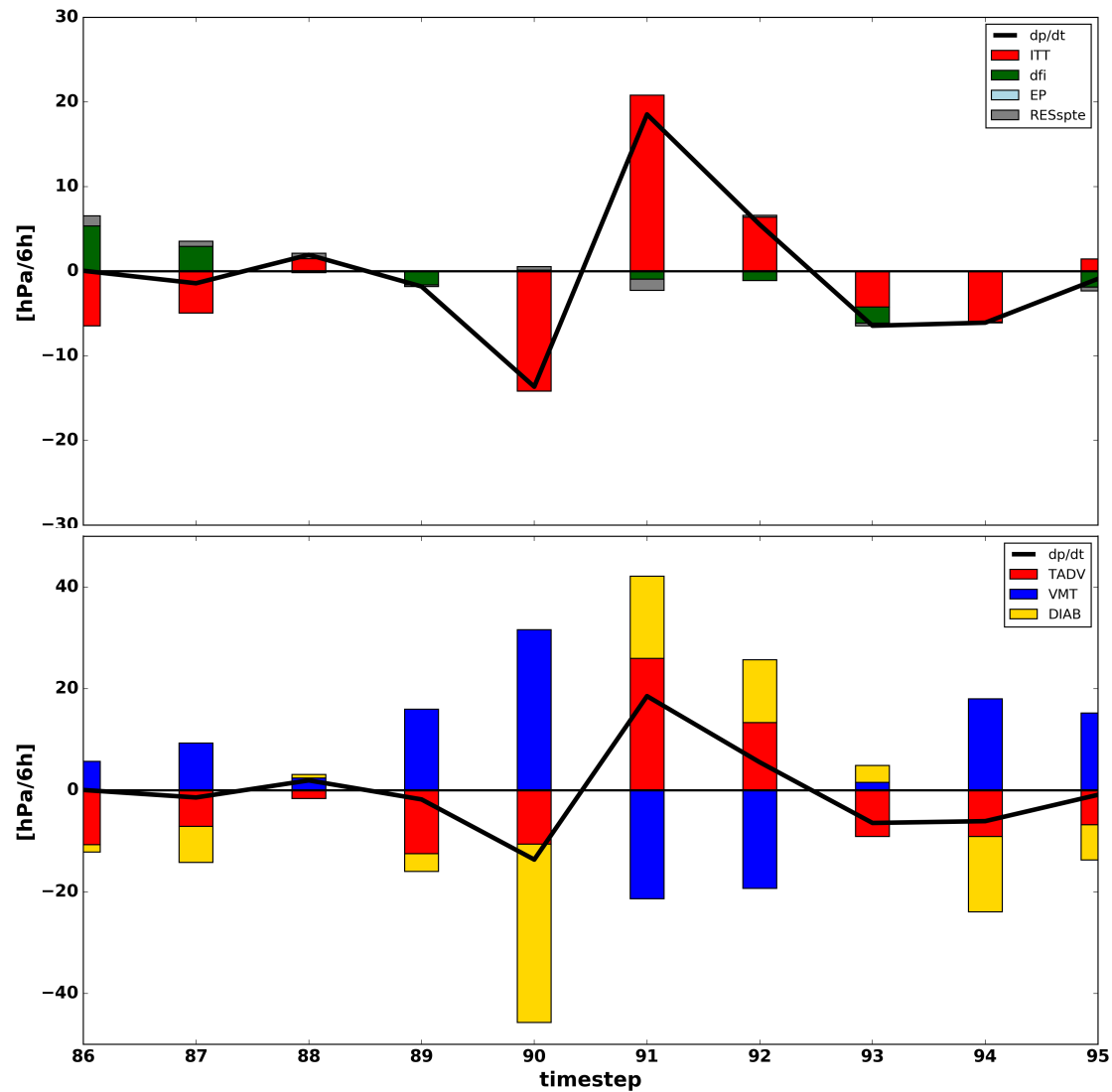$$+ \rho_{sfc} R_d \int_{sfc}^{p_2} \frac{T_v Q}{c_p T} \, d\ln p$$

Diabatics

$$+ RES_{ITT},$$

Fink et al., 2012

Surface Pressure Tendency analysis

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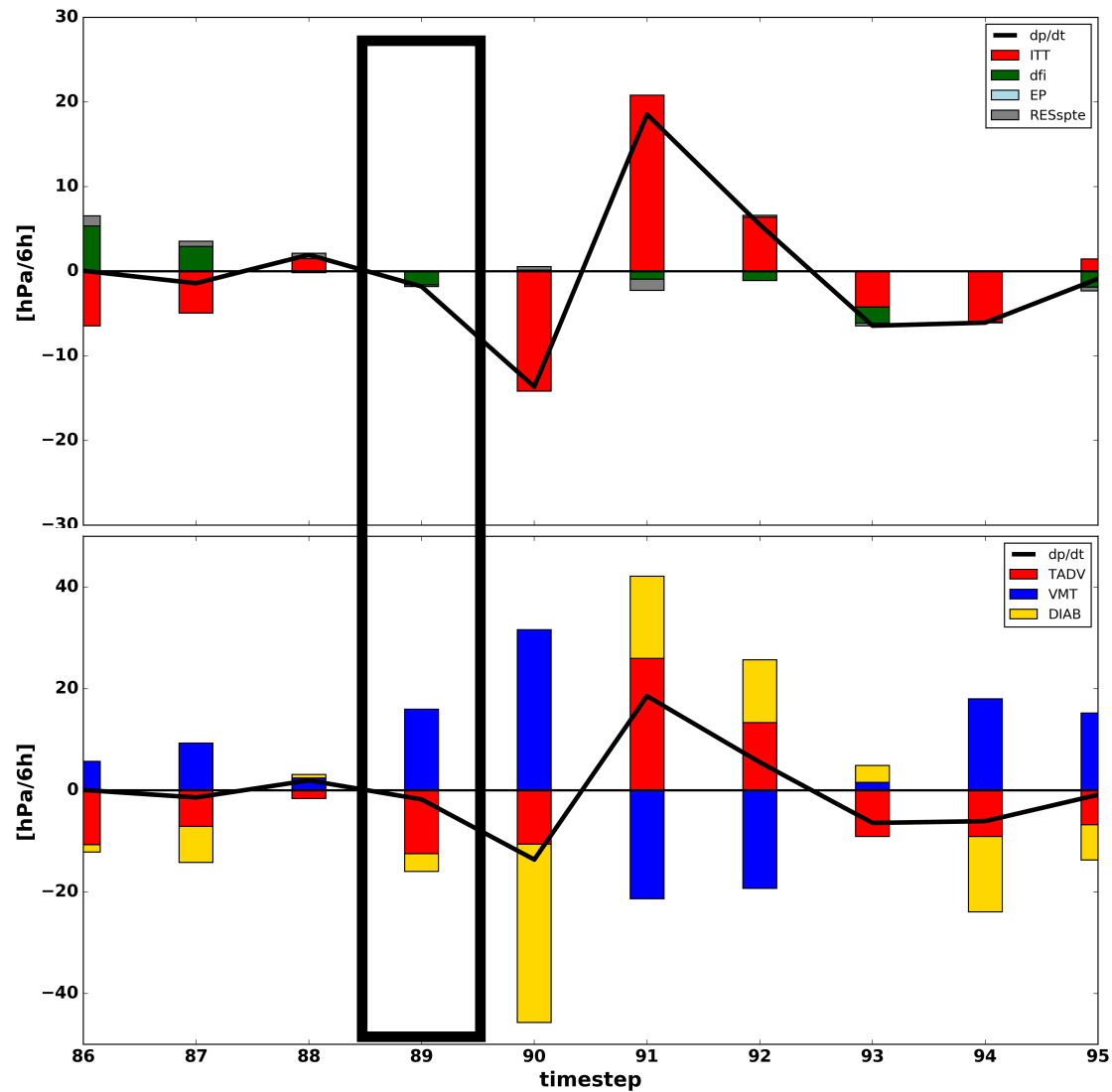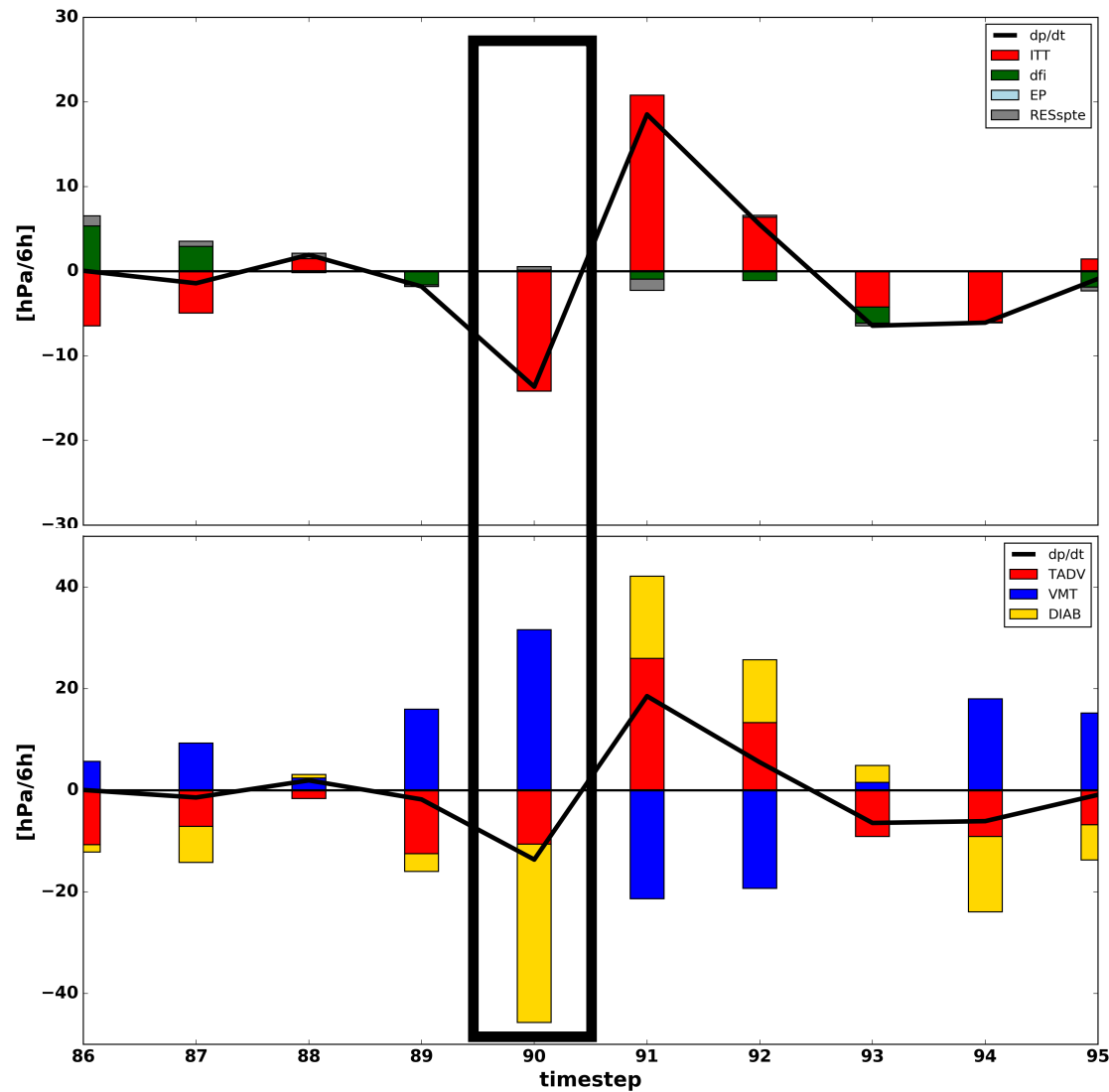
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Surface Pressure Tendency analysis

Surface Pressure Tendency analysis

Surface Pressure Tendency analysis

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Cloud-radiative effects damp the NAO+

Data: ERA-Interim

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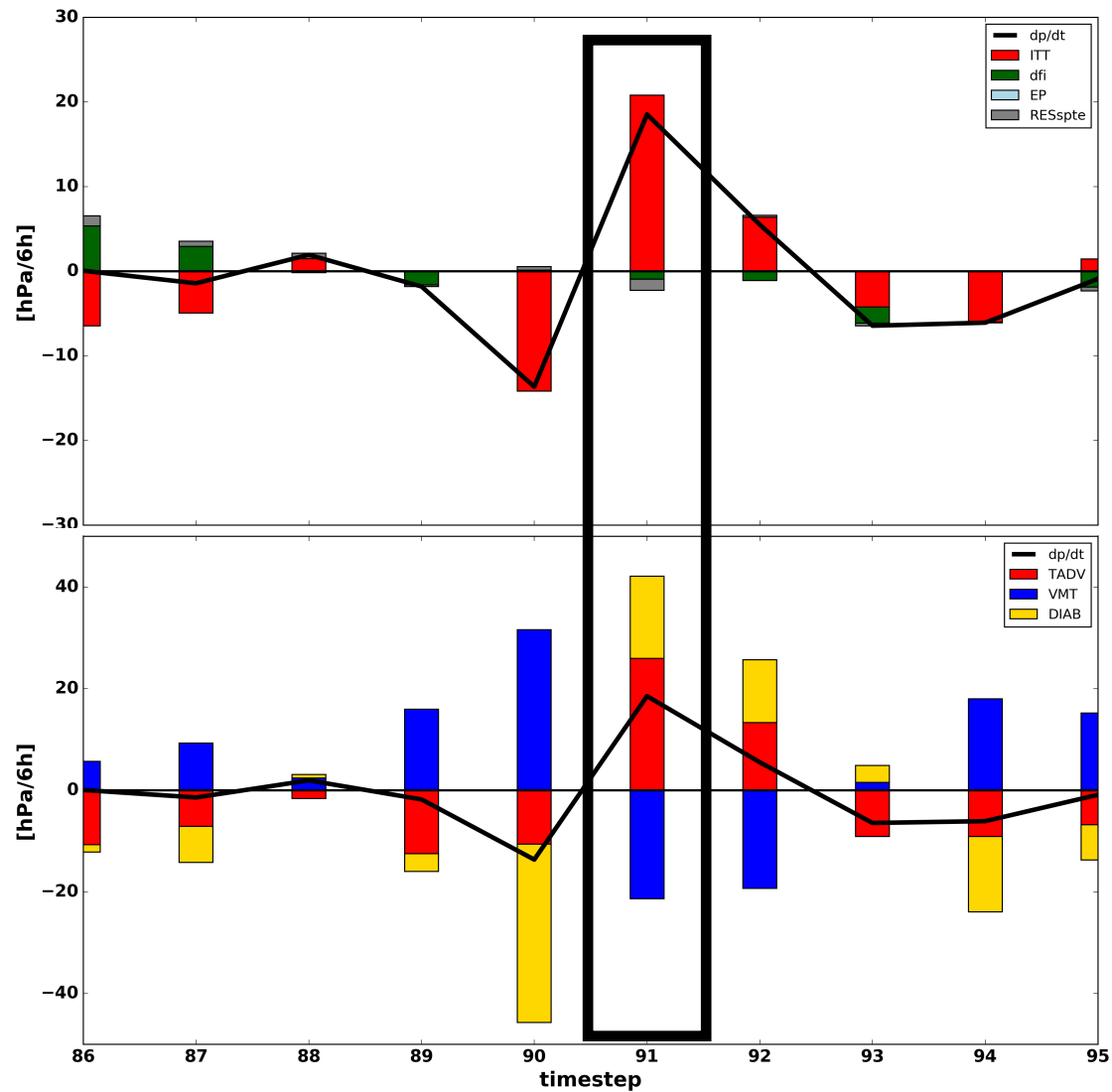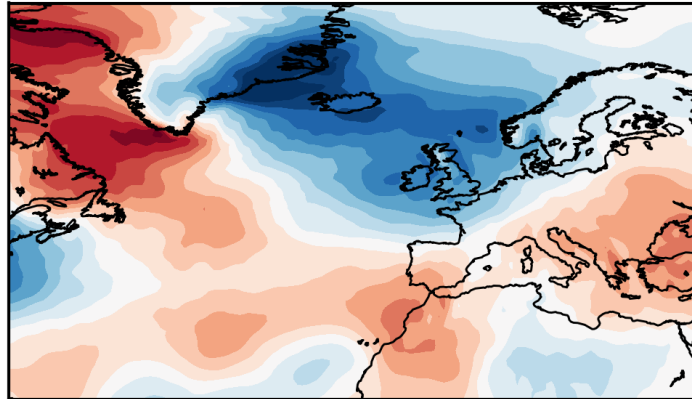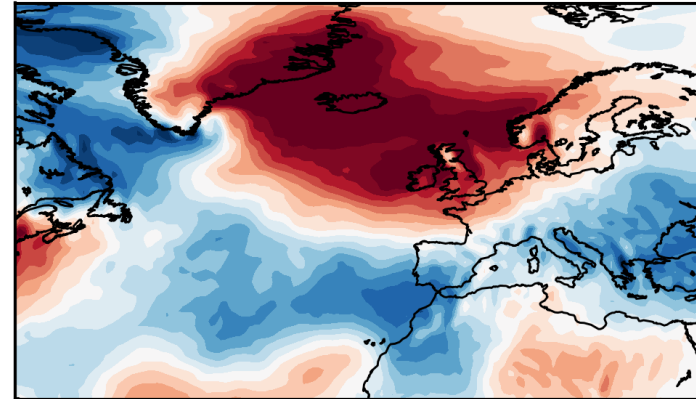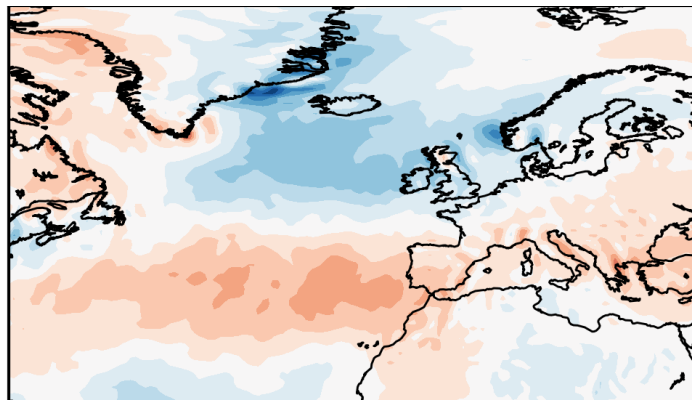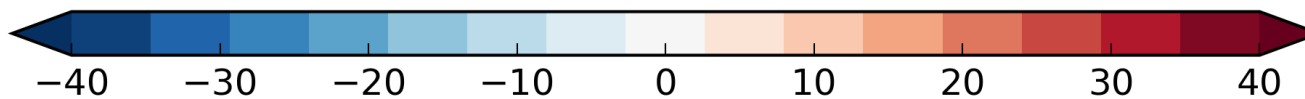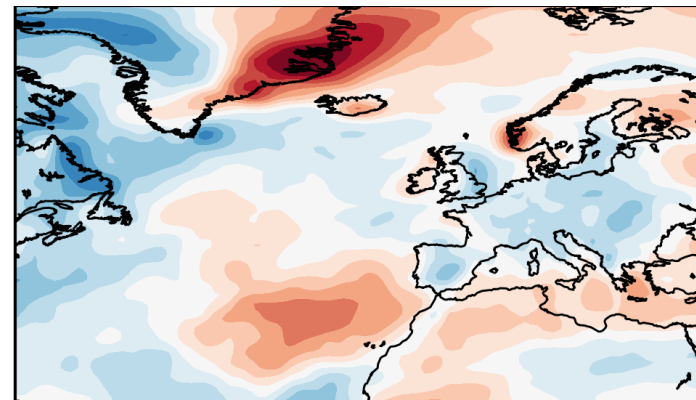
Summary

- The changes in clouds associated with the NAO lead to substantial changes in cloud-radiative effects which leads to a heating dipole in the N. Atlantic region.

- The heating dipole suggests that the anomalous CRE associated with the NAO have a negative feedback on the NAO timescale from the perspective of the surface pressure tendency equation.