Three new papers in eight slides

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What is the solar influence on climate? Overview of activities during CAWSES-II

Annika Seppälä[1,2*], Katja Matthes[3], Cora E Randall[4] and Irina A Mironova[5]

Abstract

This paper presents an overview of the main advances in the Key Questions identified by the Task Group 'What is the Solar Influence on Climate' by the SCOSTEP CAWSES-II science program. We go through different aspects of solar forcing from solar irradiance, including total solar irradiance (TSI) and solar spectral irradiance (SSI), to energetic particle forcing, including energetic particle precipitation (EPP) and cosmic rays (CR). Besides discussing the main advances in the timeframe 2009 to 2013, we also illustrate the proposed mechanism for climate variability for the different solar variability sources listed above. The key questions are as follows: What is the importance of spectral variations to solar influences on climate? What is the effect of energetic particle forcing on the whole atmosphere and what are the implications for climate? How well do models reproduce and predict solar irradiance and energetic particle influences on the atmosphere and climate?

Keywords: Climate; Atmosphere; Solar irradiance; Total solar irradiance; TSI; Solar spectral irradiance; SSI; Energetic particles; EPP; Cosmic rays

Winter pole

Equator

Summer pole

EPP

NO_x

EPP

HO_x

EPP

O_3

T

NO_x

U

NO_x

O_3

T

EPP

HO_x

O_3

T

NO_x

O_3

Thermosphere

Mesosphere

Stratosphere

Troposphere

Ocean

Impact on wave propagation and winds - dynamical coupling feedback mechanism

Winter pole

Equator

Summer pole

Thermosphere

Mesosphere

Stratosphere

Troposphere

Ocean

CR

SEP

GCR

CR

GEC

SEP

GCR

CR ionization

GLE

frontiers in
PHYSICS

ORIGINAL RESEARCH ARTICLE
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Energetic particle forcing of the Northern Hemisphere winter stratosphere: comparison to solar irradiance forcing

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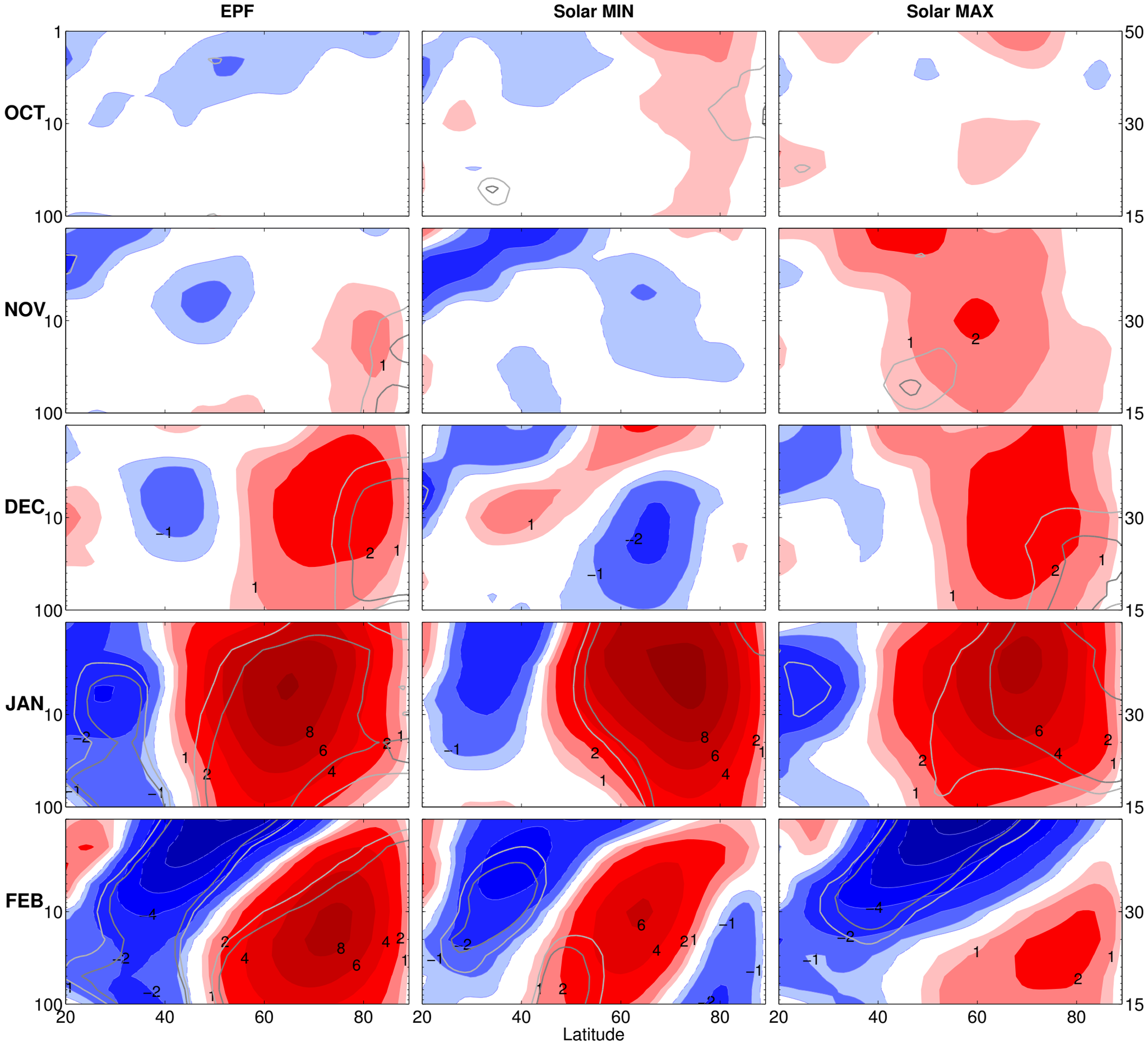
Variation in solar irradiance is considered an important factor in natural climate forcing. Variations in the solar UV in particular are now regarded as a major source of decadal variability in the stratosphere, influencing surface climate through stratosphere–troposphere coupling. However, by analyzing meteorological re-analysis data we find that the magnitude of the solar controlled energetic particle forcing signal in stratospheric zonal mean zonal winds and polar temperatures is equivalent to those arising from solar irradiance variations during the Northern Hemisphere polar winter months. We find that energetic particle forcing drives warmer polar upper stratospheric temperatures from early winter leading to an anomalously strong polar night jet via modulation of the vertical temperature gradient. By midwinter the stratosphere–troposphere coupling pathway becomes analogous to the solar UV impact at high latitudes. This not only highlights the importance of the energetic particle forcing contribution to stratospheric circulation, but enables us to understand the pathways responsible for the previously reported energetic particle forcing impacts on the troposphere in terms of the coupling of solar UV forcing to dynamics in the latter part of the winter.

Keywords: energetic particle precipitation, stratosphere, dynamics, stratosphere–troposphere connection, solar forcing, solar cycle, solar variability


EPF
Solar MIN
Solar MAX
OCT
NOV
DEC
JAN
FEB
1
10
100
50
30
15
20
40
60
80
Latitude

Zonal mean T anomaly (60N–90N)

High EPF

Solar MIN

Solar MAX

Pressure [hPa]

Alt [km]

1
10
100

50
30
15

OCT
NOV
DEC
JAN
FEB

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ARTICLE

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Missing driver in the Sun–Earth connection from energetic electron precipitation impacts mesospheric ozone

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Energetic electron precipitation (EEP) from the Earth's outer radiation belt continuously affects the chemical composition of the polar mesosphere. EEP can contribute to catalytic ozone loss in the mesosphere through ionization and enhanced production of odd hydrogen. However, the long-term mesospheric ozone variability caused by EEP has not been quantified or confirmed to date. Here we show, using observations from three different satellite instruments, that EEP events strongly affect ozone at 60–80 km, leading to extremely large (up to 90%) short-term ozone depletion. This impact is comparable to that of large, but much less frequent, solar proton events. On solar cycle timescales, we find that EEP causes ozone variations of up to 34% at 70–80 km. With such a magnitude, it is reasonable to suspect that EEP could be an important part of solar influence on the atmosphere and climate system.

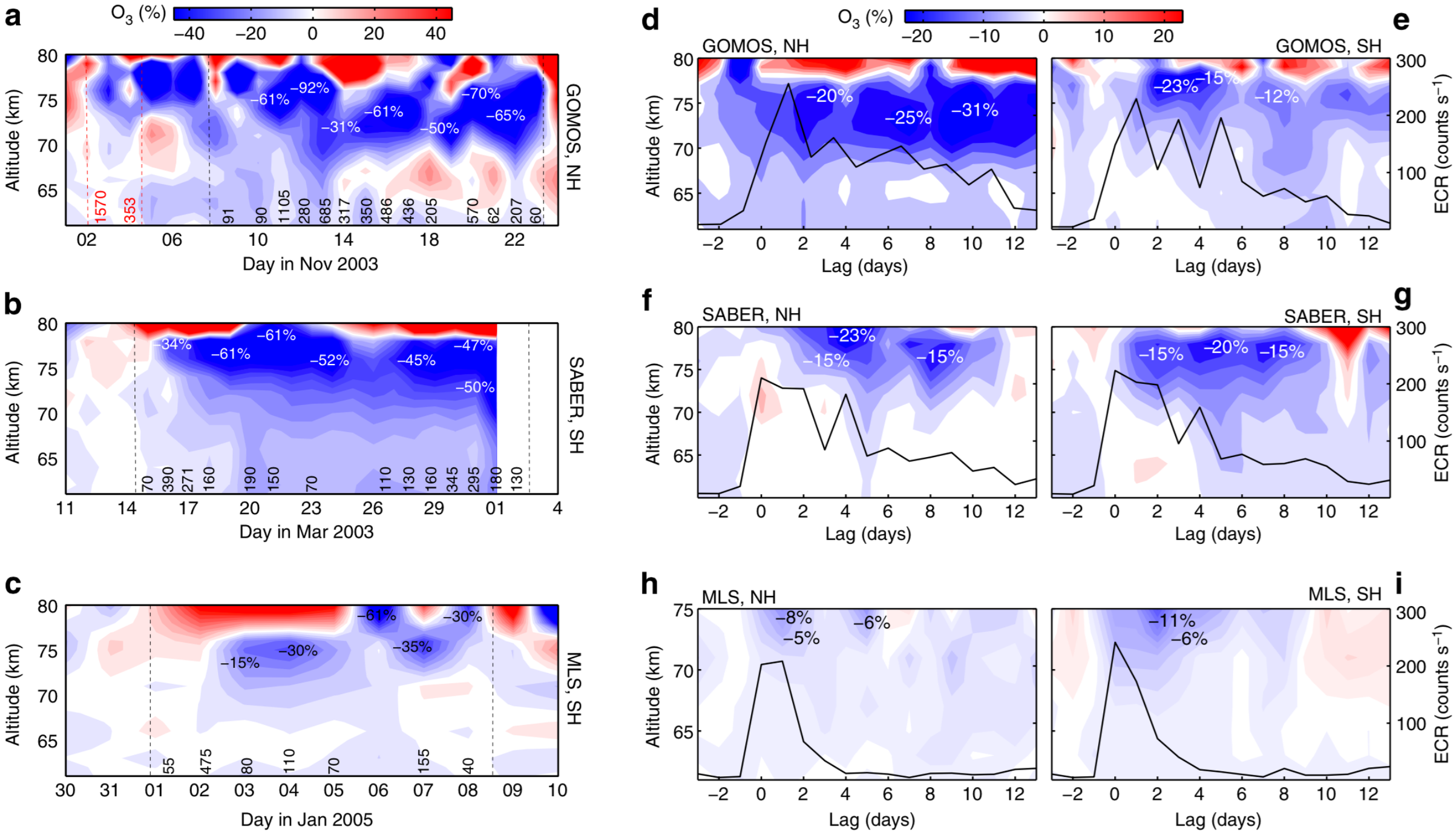

Figure 2 | Magnitude of the short-term EEP effects on mesospheric ozone. (**a**–**c**) O_3 anomalies (%) for selected EEP events in the Northern hemisphere and in the Southern hemisphere derived from GOMOS (**a**), SABER (**b**) and MLS (**c**) observations. Black dashed lines: EEP event start end end; red dashed lines: SPE event start end end; black numbers: daily mean ECRs; red numbers: >10 MeV pfu. (**d**–**i**) Superposed epoch analysis for EEP events with daily ECR >150 (counts s^{-1}) showing ozone anomalies (%) and ECR (black lines) in the Northern hemisphere (**d**,**f**,**h**) and in the Southern hemisphere (**e**,**g**,**i**). White numbers: O_3 loss at different altitudes.