Volcanic and ENSO Effects on Climate in China in the last millennium

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Summary

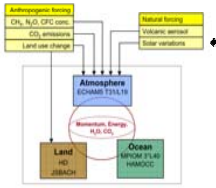
The effects of volcanic eruptions in two ensemble (8 simulations) by the COSMOS ASOB earth system model are analyzed. Following results are found:

■ Volcanic eruptions with neutral SOI cool Asia, dry NE China and Tibetan Plateau, and cause an El Niño like warming in the tropical Pacific. The global time scale of temperature decay is assessed by an exponential function fitting.

■ The favor of El Niño events following eruptions in previous studies is not found. ENSO overcome volcanoes with disturbed patterns of T2M and SPI.

■ A case study of Tambora in 1815 is compared with reconstructions.

Model and Method



Model components & forcings

E1: Ensemble 1 with weak variability of solar irradiance, 5 members
E2: Ensemble 2 with strong variability of solar irradiance, 3members

ENSO: PC1 of EOFs of the Tropical Pacific Sea Surface Temperature (SST) variability in the following winter (DJF).
El Niño: PC1>1.0
La Niña : PC1<-1.0

21 volcanic eruptions with at least -2.0 W/m² decrease in net top solar irradiation

No.	Year	Name	VEI*
1	842	Unknown	*Newhall C. G.
2	854	Unknown	S. Steve (1982)
3	897	Unknown	
4	971	Unknown	
5	1193	Unknown	
6	1228	Unknown	
7	1258	Unknown	
8	1286	Unknown	
9	1442	Unknown	
10	1456	Kuwae/ Vanuatu?	6
11	1600	Huaynaputina	6
12	1641	Parker	6
13	1673	Capelo	
14	1694	Serua	
15	1809	St Helen?	
16	1815	Tambora	7
17	1832	Babuyan Claro	4?
18	1835	Cosiguina	
19	1884		6
20	1903	Grimsvotn	4
21	1992	Pinatubo	6

Temperature Decay

The decay of the temperature anomaly is fitted by an exponential function:

$$\Delta T = \Delta T1 * \exp(-(t-1)/\tau)$$

2 fitting parameters:
$\Delta T1$ temperature anomaly at year 1
τ time scale
($1 \le t \le 10$, time after event, years)

(1) Volcanoes El Niño La Niña Vol/El Niño Vol/La Niña

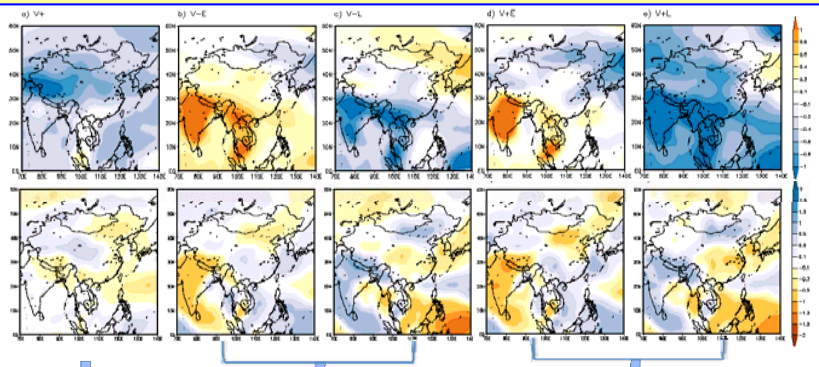


Fig 1 Temperature at 2 meters (T2M) anomaly

Fig 2 Standardized Precipitation Index (SPI, JJA)

at year one relative to event year

◆ T2M: Volcanoes (Fig1a) cool Asia with West China up to 1℃.

◆ SPI: Drought (Fig2b) in China: NE, south, east coast, and Tibetan Plateau. Wetness in Central and West China.

◆ T2M: El Niño (Fig1b) warms Asia except NE China. La Niña (Fig1c) effect antisymmetric.

◆ SPI: dipole pattern (Fig2b), NE China moderate drought, India severe drought and SE China wet. La Niña (Fig2c) effect antisymmetric.

◆ T2M: Cooling weakened/intensified by El Niño/La Niña (Fig1d/Fig1e) descending from SW to NE. Similar to ENSO effects (Fig1b & c).

◆ SPI: ENSO effects overcome volcanoes by disturbed pattern of drought/wetness in North China Plain (Fig2d/Fig2e). El Niño effects after eruptions slightly stronger than El Niño (Fig2b).

Table 1: T2M and precipitation anomaly at year one relative to event year

Variable	Ensemble	Volcanoes only	Volcanoes+ El Niño	Volcanoes+ La Niña
T2M /C	E1	-0.54	-0.12	-0.73
	E2	-0.38	-0.31	-0.68
Precipitation /mm	E1	-56	-64	29
	E2	-43	-68	29

◆ Simultaneous chances of volcanic eruptions and ENSO is 44 % (38%) in E1 (E2). No favor to El Niño following volcanic eruptions (half and half for El Niño and La Niña).

◆ Dynamic causes: The Monsoon Hadley Circulation index (MHI) and East Asia Monsoon Index (EAMI) no significant changes by V+, by V+E, significant phase-locking of MHI at year one & significant enhancement at year two, by V+L, the enhancement comes at year one.

(2) Global temperature decay

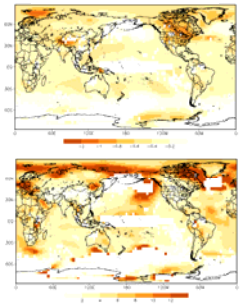


Fig 3 a) Temperature anomaly ΔT_1,

Fig 3 b) Decay time scale τ

◆ Big ΔT_1 (Fig3a) and big time scale τ (Fig3b) in NH.

◆ Small ΔT_1 in SH (Fig3a) with small τ or no-finite-positive values (Fig3b blank) through fitting due to the small values of temperature decrease of ocean to the volcanic eruptions, or even positive values. Same regions have intense long term memory found by Fraedrich and Blender (2003).

◆ Similar pattern between fitting ΔT_1 and simulated T2M at year 1 (not shown) with an El Niño like warming up at tropical Pacific).

(3) Tambora in 1815: a case study

◆ Cooling: -1.2 for E1, -1.3℃ for E 2, in reconstructions /historic documents (Fig4a). Droughts only in SE China in reconstructions but not in all 8 simulations, too strong ENSO signal.

◆ ENSO effects: Ocean conditions differ strongly in 8 simulations, 4 typical cases (Fig4b colored-dots, El Niño, La Niña, Neutral and best-guess which matches reconstructed ENSO by Quinn et al.,1998) are selected for T2M and SPI (Fig5).

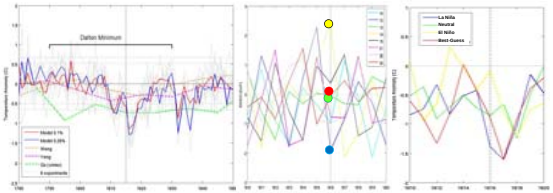


Fig 4: a) Simulated and reconstructed T2M b) ENSO c) Selected T2M

◆ T2M: La Niña enhances temperature reduction while El Niño compensates it at year one (Fig4c) with difference of 1.5 ℃.

◆ SPI: Droughts with neutral SOI (Fig5b, right); La Niña case is not 'standard' due to strong El Niño signal in1815 (Fig5a & Fig4b). El Niño has less 'power' in North China Plain (section 1, hint: ENSO at year 0 needs to be considered as well).

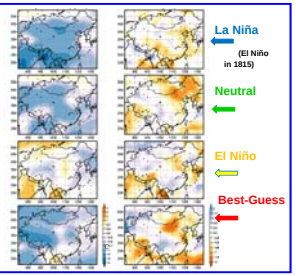


Fig 5: simulated T2M (left) and SPI (JJA, right) in 1816

Selected references:
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Zheng J.Y., W. C. Wang, Q.S. Ge, Z.M. Man, P. Y. Zhang, 2006: Precipitation variability and extreme events in eastern China during the past 1500 years. *Terrestrial Atmospheric and Oceanic Sciences* 17: 579-592.