Asian Monsoon and Elevated Heat Pump mechanism in the CMCC coupled aerosol-climate model simulations

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OBJECTIVES:

A coupled aerosol-atmosphere-ocean-seaice model is used to analyze the relationship between aerosol and the Asian summer monsoon.

In this analysis the elevated heat pump (**EHP**) hypothesis and the **solar dimming** effect associated with aerosol loading are verified and are found to be consistent with our simulations.

As these results reproduce a reasonably realistic pattern, it is possible to consider **absorbing aerosols** as a possible source of **seasonal predictability** of the Asian summer monsoon over the Indian subcontinent.

BACKGROUND

Observational evidences of the aerosols-Asian monsoon relationship are presented by [1] and these are consistent with the EHP mechanism which posits that accumulation of dust and black carbon [2] over the Indo-Gangetic Plain during the pre-monsoon season, may induce to increased warming in the upper troposphere during the late spring and early summer and lead enhanced monsoon rainfall over northern India in June-July [3].

METHODOLOGY:

We have realized a control simulation representing the present climate.

The simulation is 80-yrs long after spin up.

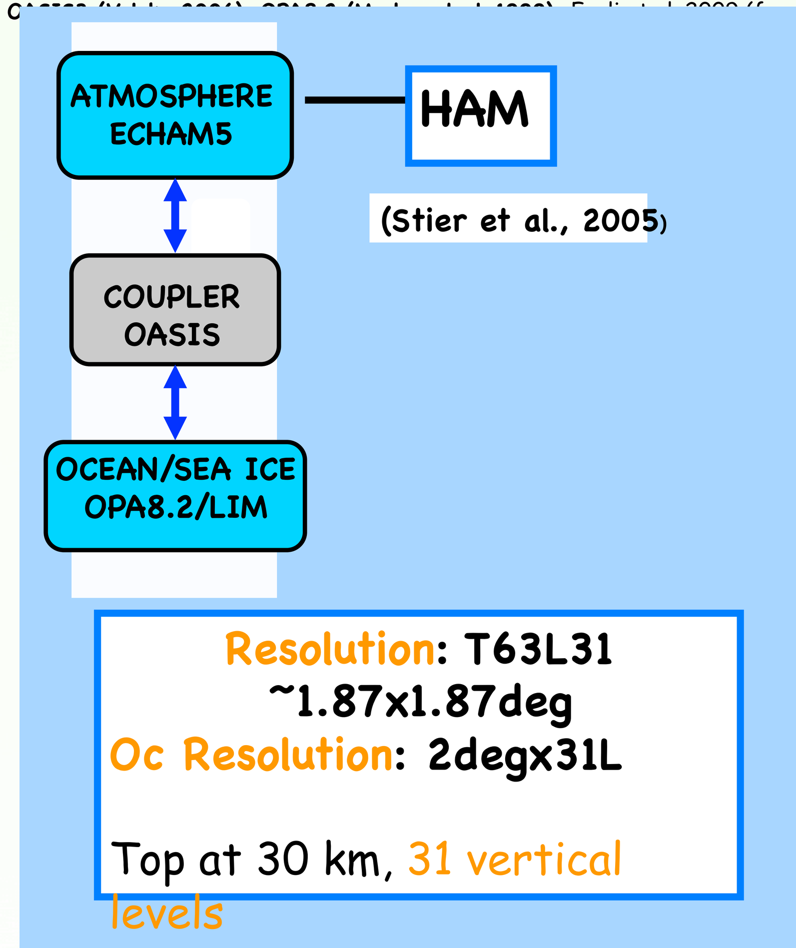
Estimated conditions at 2000 determine the external forcings of the Control experiment and follow the CMIP5 protocol for the forcing data.

External forcings are prescribed constant in time for well-mixed green house gases, including CO_2, CH_4, N_2O, and incoming solar irradiance; the seasonally varying ozone distribution is repeated every year.

MODEL

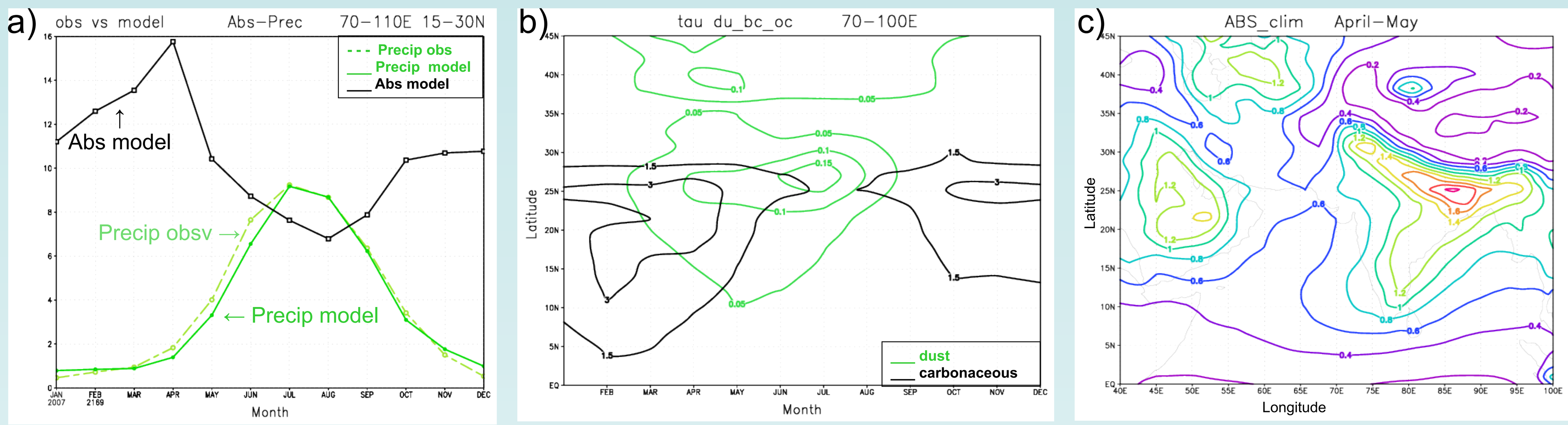
CMCC-HAM Climate Model with the Aerosol Component

ECHAM5 (Roeckner et al. 2003, 2006; SW radiation scheme [Cagnazzo et al., 2007];);



RESULTS

Figure 1 : The observations are from GPCP 1986-2007 and the simulations are over 80 years present climate 2000 iterated.



a) Annual cycle of absorbing aerosols (10^{-3})(black line) and total rainfall mm/day for the model (green solid line) and observations (green dashed line) over Region 70°-100°E, 15°-30°N;
b) time-latitude evolution of aerosol optical thickness (AOT) of carbonaceous (black carbon and organic carbon) in black line and soil dust (green line) aerosols averaged over the longitude sector from India to the Taklamakan desert (70°–100°E);
c) Climatological distribution of absorbing aerosols over the Indian subcontinent and adjacent areas for April–May.

Precipitation model in agreement with observations

A seasonal cycle of aerosols loading:

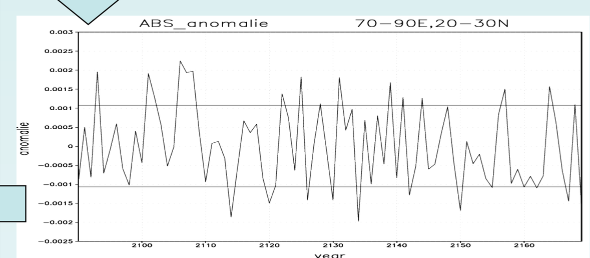
- The **maximum** pick in **April –May** due to the both contribution of dust and carbonaceous aerosols [2]
- The minimal pick in July-August due to wet deposition of rainfall season

Source of absorbing aerosols are:

- **carbonaceous** local emitted
- **dust** transported from desert

Impact on precipitation-temperature-wind in early monsoon and monsoon season

INDEX:



An aerosol index is developed as:

- absorbing aerosols averaged over 70°-90°E, 20-30°N [1] by considering the **anomaly** of April-May ABS time series with respect to the 80-year **April-May**.

From this index we select:

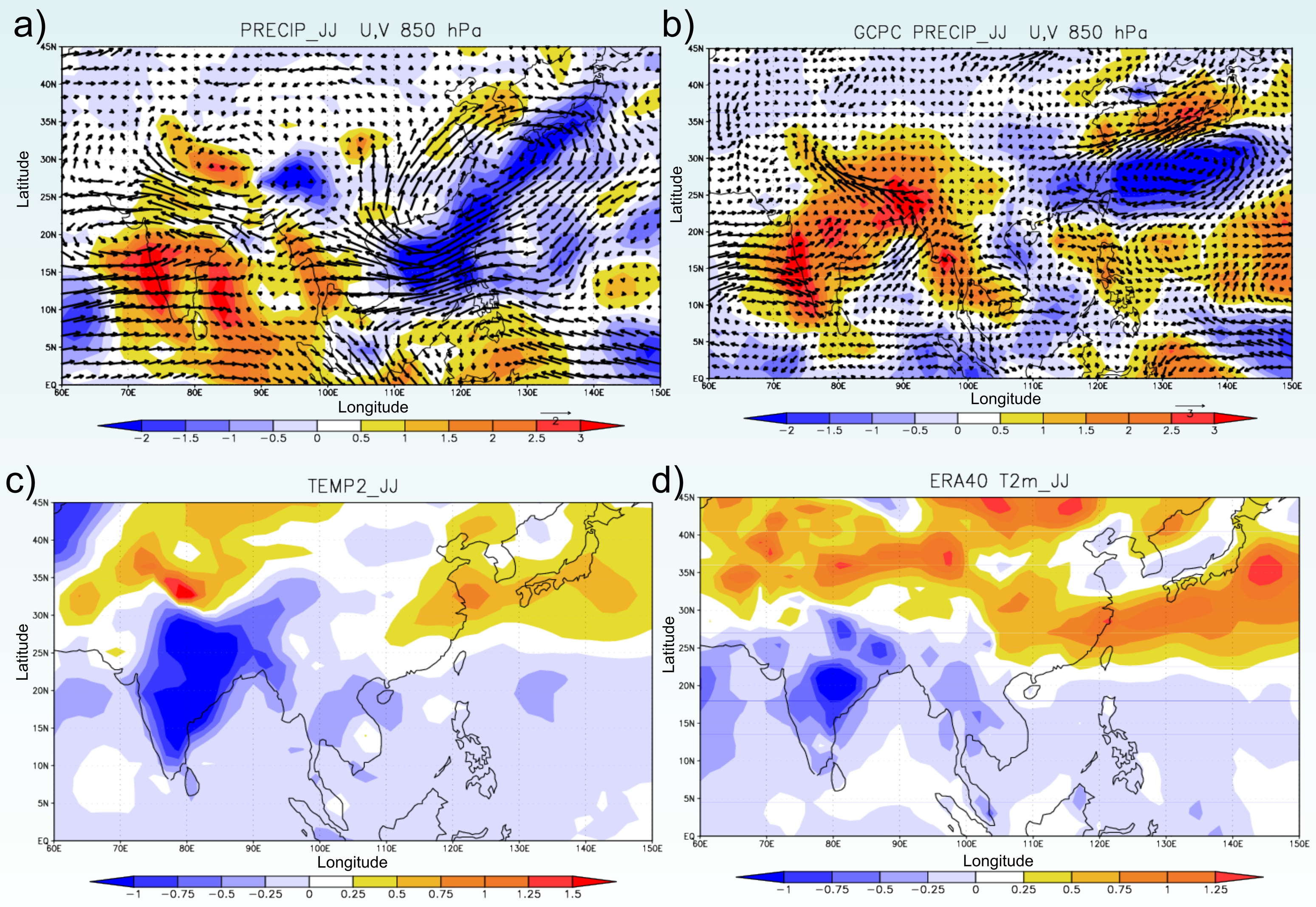
- **Strong** (**weak**) years of aerosol loading

corresponding to

- years with an amount of absorbing aerosols **larger (smaller)** than its 1-standard deviation.

Early monsoon

Figure 2:



anomalies = composites of **strong - weak** years

Concordant with GCPC and ERA40 data, fig2.b shows enhanced precipitation and wind at 850 hPa in June-July over the entire Indian subcontinent.

a) June-July composite of rainfall (mm/day) and 850 hPa wind pattern (m/sec) for the model and
b) the observed rainfall anomalies GCPC and 850hPa ERA40 winds;
c) 2-meter temperature (K) anomaly composite in June-July for the model and
d) the two metre temperature observed. For ERA40 and GCPC observations, weak years (1982,1983, 1990, 1992) and strong years (1980, 1985, 1988, 1991) were selected according with [1].

The anomalies of westerly monsoon winds:

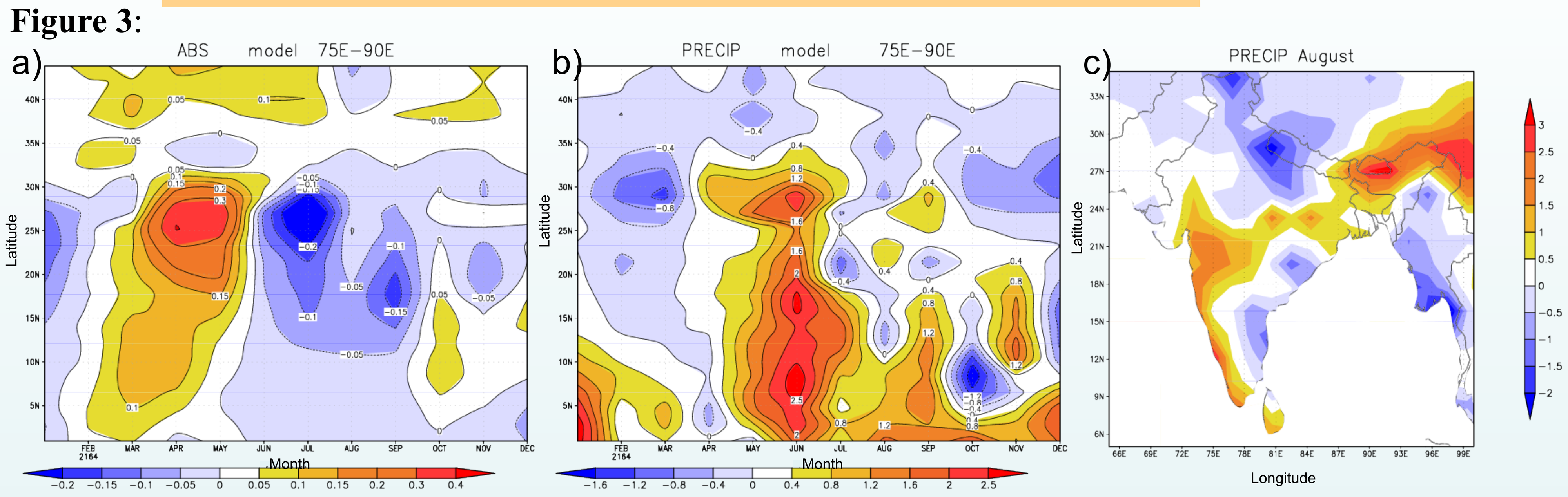
- bring more dust from the Middle East deserts toward the Indian subcontinent

this together with enhanced precipitation

- generates a surface cooling of about 1.5K over the Indian continent, (solar **dimming effect).**

The monsoon season

Figure 3:



Time-latitude cross-sections showing composite seasonal evolution during year of (a) the AI anomalies and (b) the rainfall anomalies (mm/day) over 75°-90°E sector; (c) composite of rainfall (mm/day) in August.

EHP mechanism

A larger presence of aerosols in **A-M** provides a heat source and a warming greater length in upper troposphere over the Tibetan Plateau and Northern India.

This produces ascending air that forces convection driving the meridional circulation in April-May,

amplifying the lower level increasing of moist air that produces a positive feedback.

At that time the northward migration of rainfall anomaly heading for land masses from Indian ocean leads

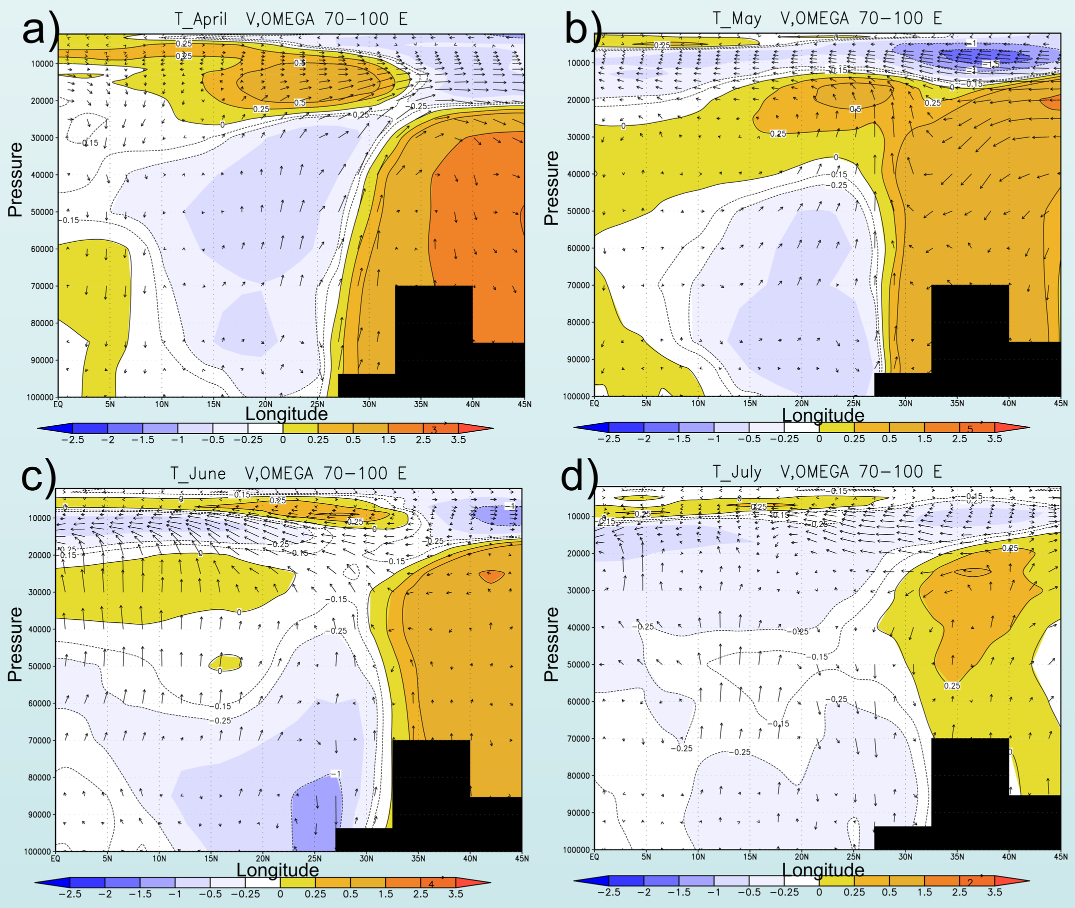
to an intensification of monsoon precipitation in **J-J** over the entire Indian subcontinent, strengthening the monsoon season:

In **August:**

The **global dimming effect** increases the atmospheric stability over west-central and south of India subcontinent which weakens the Asian monsoon (not shown) by reducing temperature gradient between land mass and Indian ocean [3].

- a diminution of precipitation is found over northwest and central-north-east of the sub-continent especially over west central and peninsular region.

Figure 4:



Height-latitude distributions temperature and meridional circulation anomalies due to aerosols over the longitude sector of 70–100 E for a) April, b) May, c) June and d) July. Units of pressure velocity and meridional wind are 10^{-4} hPa/sand m/s, respectively.

CONCLUSIONS

When **increased aerosol** loading is found on the Himalayas slopes in the **pre-monsoon** period (April-May), an **intensification** in **early monsoon rainfall** over India is obtained.

An increase in rainfall during the early monsoon has a **cooling effect** on the land **surface** produced also through the **solar dimming effect** by the presence of more dust from the deserts brought by an increased westerly flow in early monsoon season.

A subsequent reduction in monsoon rainfall over India is found, with a beginning of this decrease in northern India.

It can be deduced that the amount of **aerosol** loading before the monsoon onset is a **source of predictability of the seasonal mean climate** in the Indian subcontinent. It should therefore be estimated if a correct representation of the amount of absorbing aerosols in April-May could improve model prediction skills for the extended summer season.

REFERENCES

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