

NO₂ anomalies - economy attribution and rapid climate response

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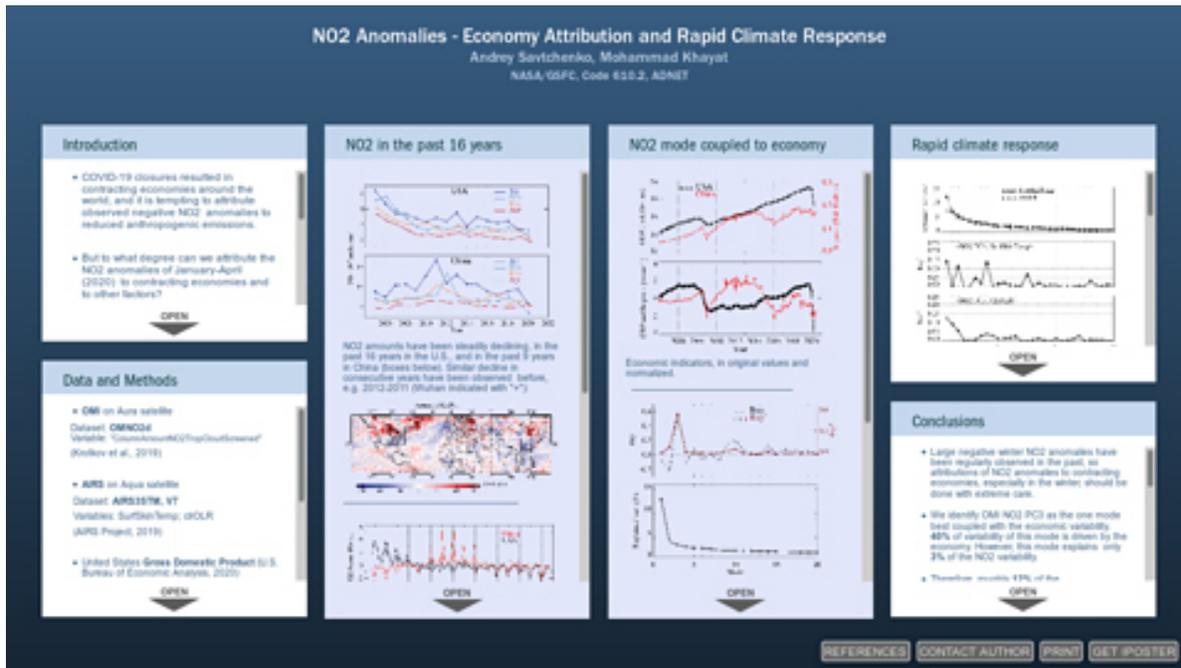
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Abstract

Using principal component (PC) analysis of 16 years of monthly series of nitrogen dioxide (NO₂) from the Ozone Monitoring Instrument on the Aura satellite, we show that it is the third PC (PC3) from the deseasonalized hierarchy of principal modes that is best coupled with the economic indicators. This coupling is positive, i.e. PC3 and economic indicators manifest positive covariance. However, the economic variability can explain only 40% of the information in PC3. Furthermore, this mode by itself explains only 3% of the total deseasonalized NO₂ variability. We thus conclude that, while having an unambiguous impact, the economy can be awarded at best third order of importance in the NO₂ departures from the seasonal averages. Once we identified PC3 as the NO₂ mode that is coupled with the economic variability, we use this mode as an indicator and look for rapid climate adjustments to that part of NO₂ variability that we are confident is coupled with the economic variability. We focus on observational data from the Atmospheric Infrared Sounder (AIRS) on board of NASA Aqua satellite, decompose series of surface skin temperature and clear-sky outgoing longwave radiances (OLR) into principal components, and identify potential impacts of NO₂ PC3 on these climate variables.

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NASA/GSFC, Code 610.2, ADNET



PRESENTED AT:



INTRODUCTION

- COVID-19 closures resulted in contracting economies around the world, and it is tempting to attribute observed negative NO₂ anomalies to reduced anthropogenic emissions.
- But to what degree can we attribute the NO₂ anomalies of January-April (2020) to contracting economies and to other factors?
- Considering this and past NO₂ anomalies, can we see any rapid adjustments of the climate system?
- The NO₂ cycle in the atmosphere is rather complex. Climate impacts are indirect, through formation of O₃, CH₄ and nitrate aerosols (Ciais, P., et al. , 2013).

DATA AND METHODS

- **OMI** on Aura satellite

Dataset: **OMNO2d**

Variable: "ColumnAmountNO2TropCloudScreened"

(Krotkov et al., 2019)

- **AIRS** on Aqua satellite

Dataset: **AIRS3STM, V7**

Variables: SurfSkinTemp; clrOLR

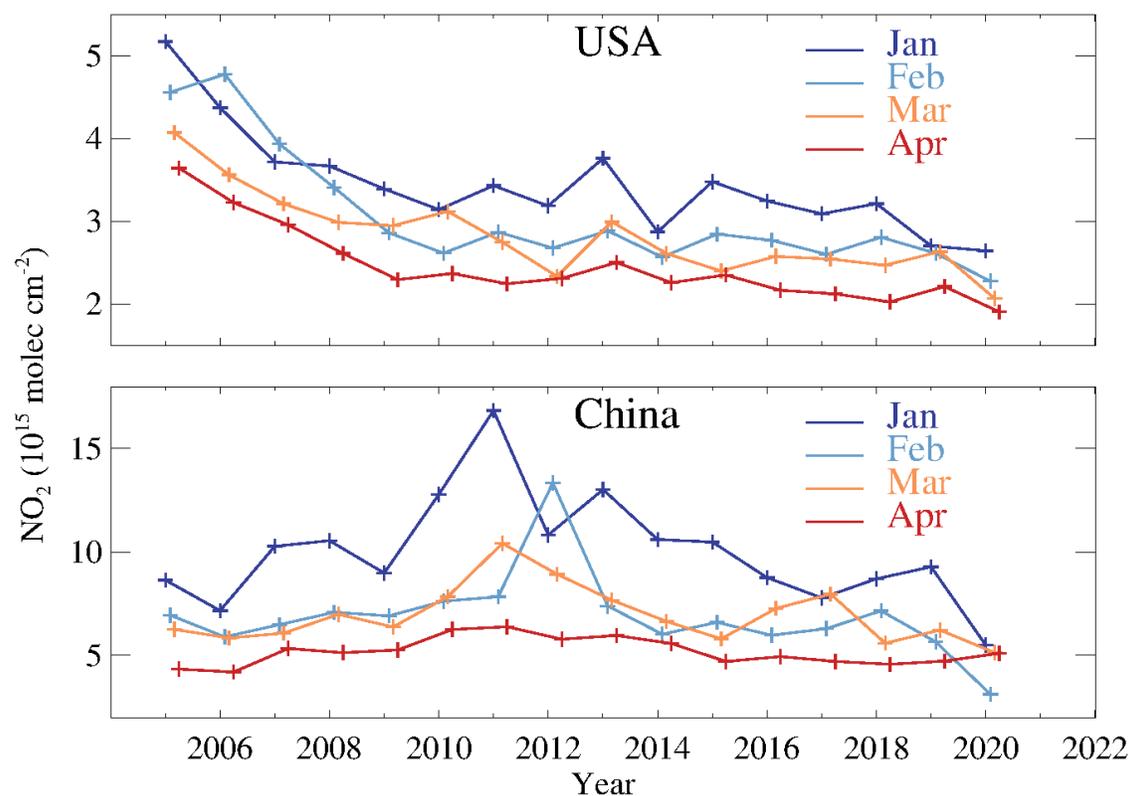
(AIRS Project, 2019)

- United States **Gross Domestic Product** (U.S. Bureau of Economic Analysis, 2020)

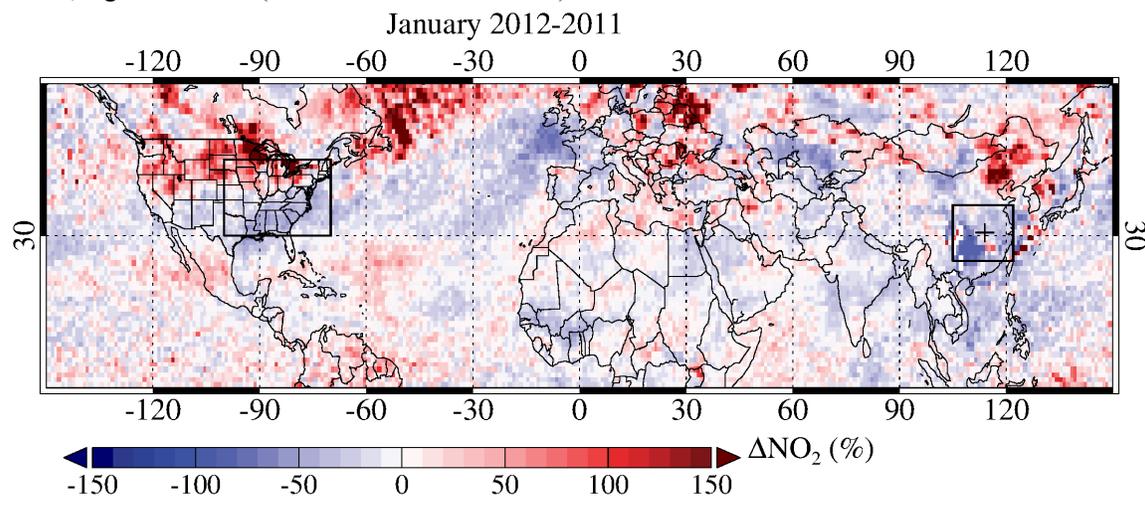
- **Monthly Imports Indicator** for China (Organization for Economic Co-operation and Development, Imports, 2020)

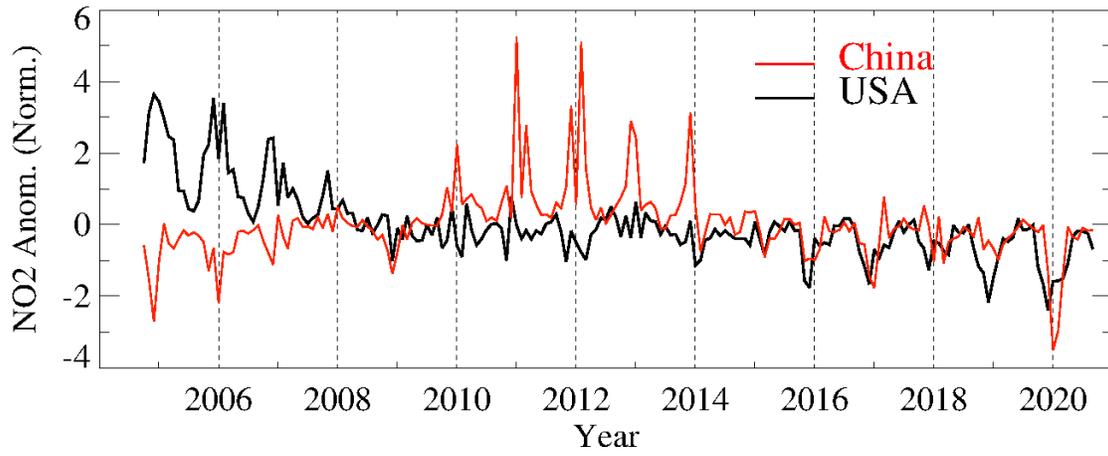
- **Principal Component Analysis** is applied to deseasonalized monthly series of OMI and AIRS. Northern Hemisphere only.

NO2 IN THE PAST 16 YEARS

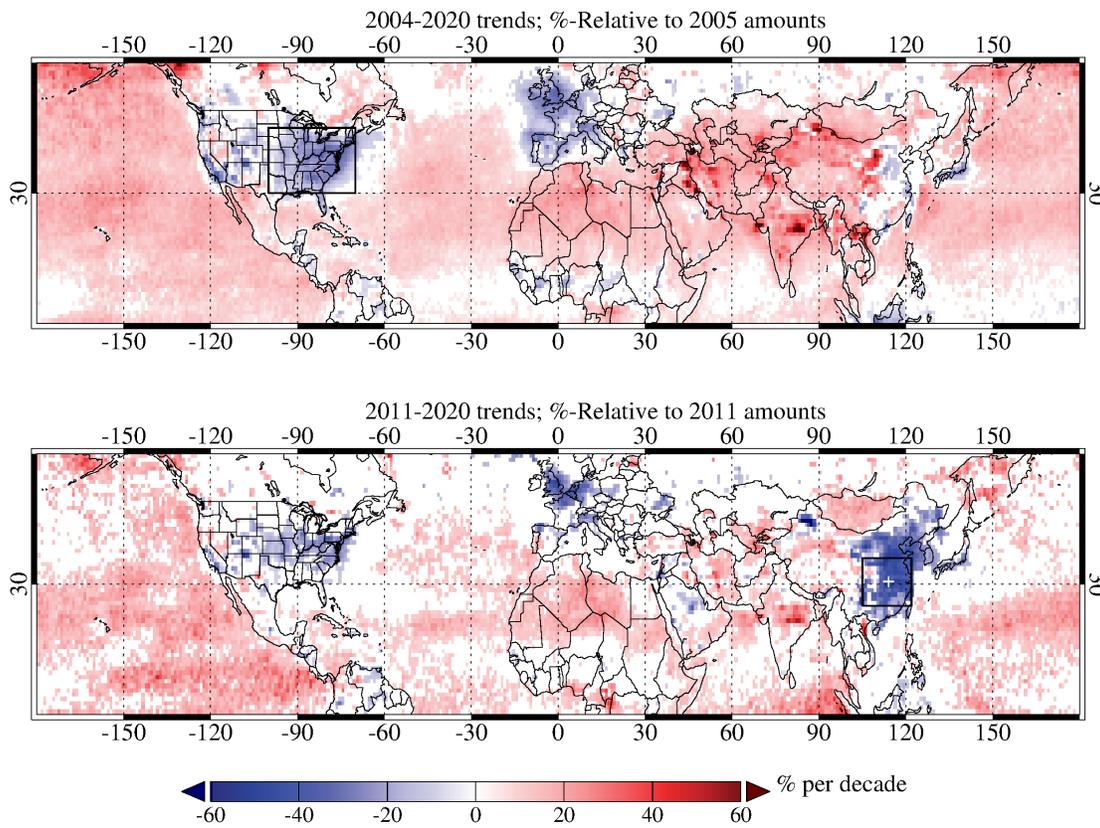


NO₂ amounts have been steadily declining, in the past 16 years in the U.S., and in the past 9 years in China (area average in the boxes, below). Similar decline in consecutive years have been observed before, e.g. 2012-2011 (Wuhan indicated with "+"):



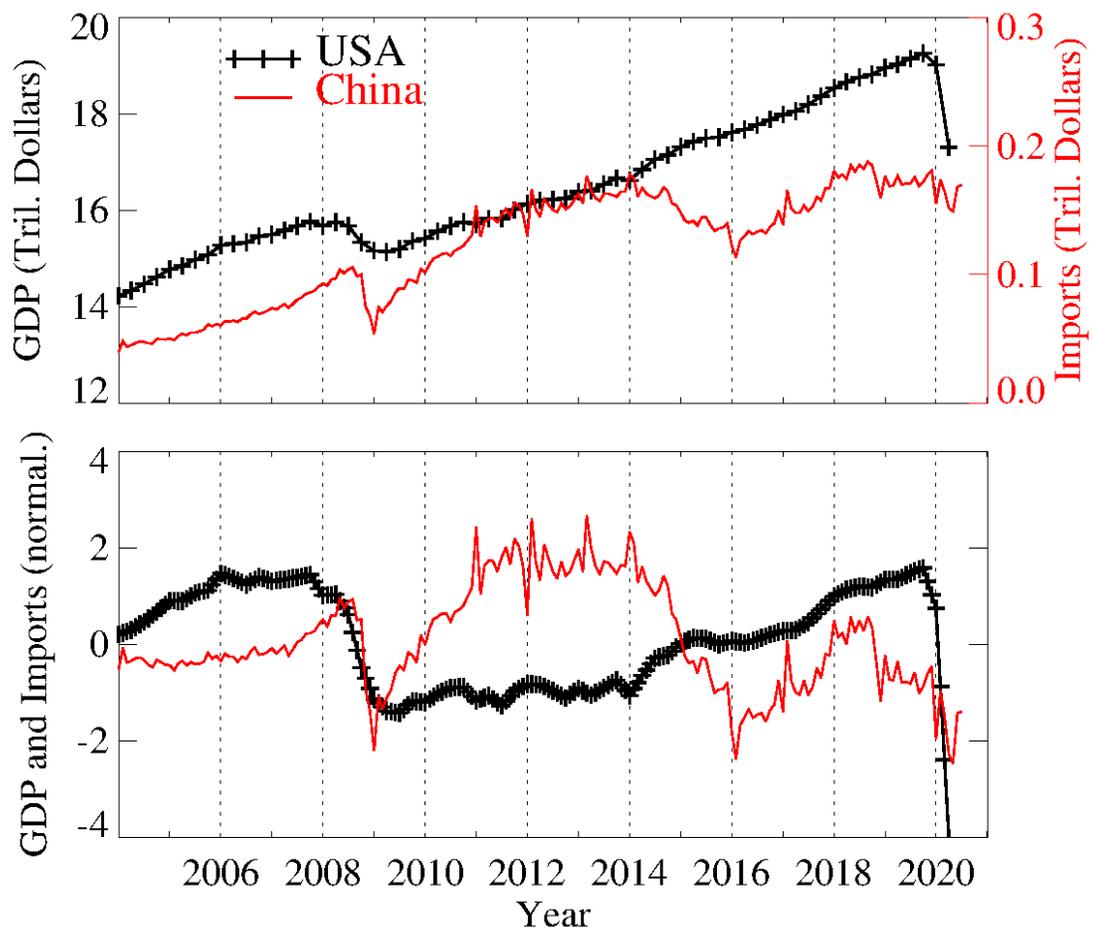


Area averages from the boxes above, land only. Strong negative NO2 anomalies have been observed before, always in the winter.

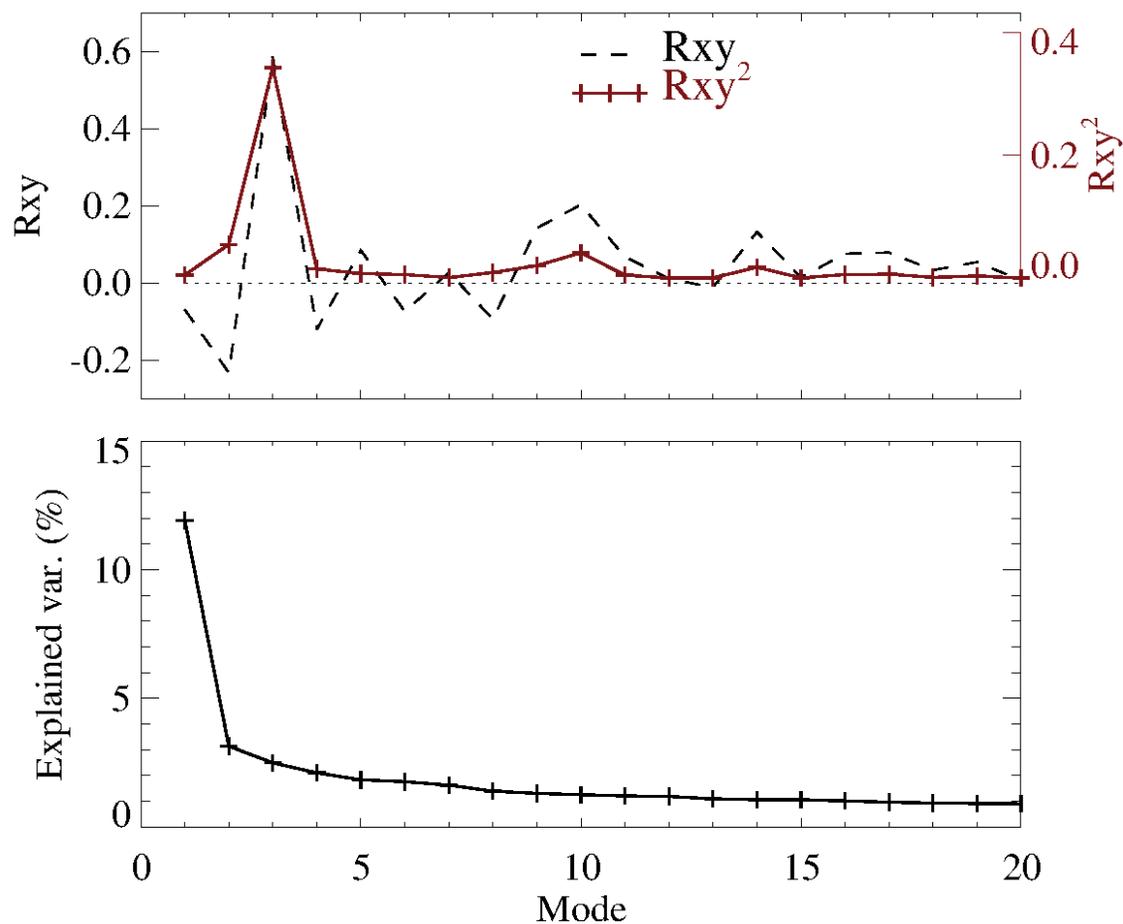


Declining tendencies of NO2 amounts are seen at 95% confidence over the U.S. and China.

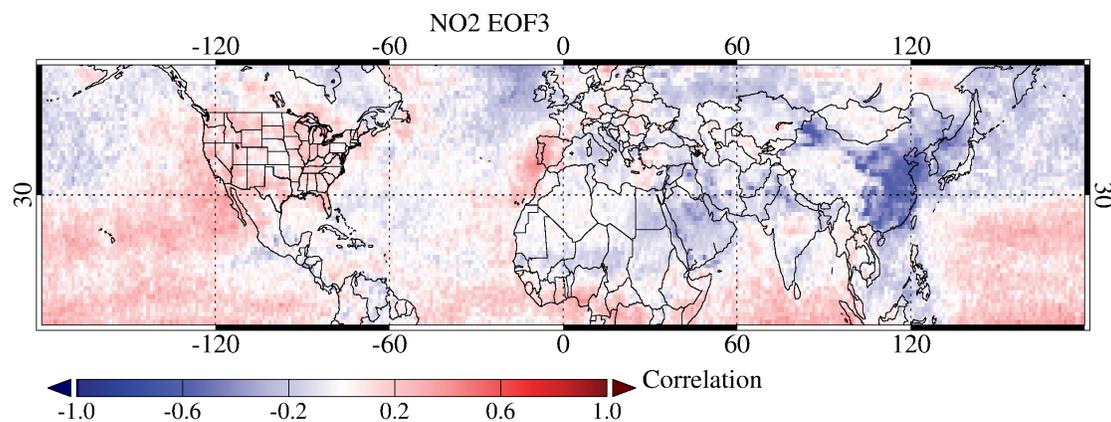
NO2 MODE COUPLED TO ECONOMY



Economic indicators, in original values and normalized.

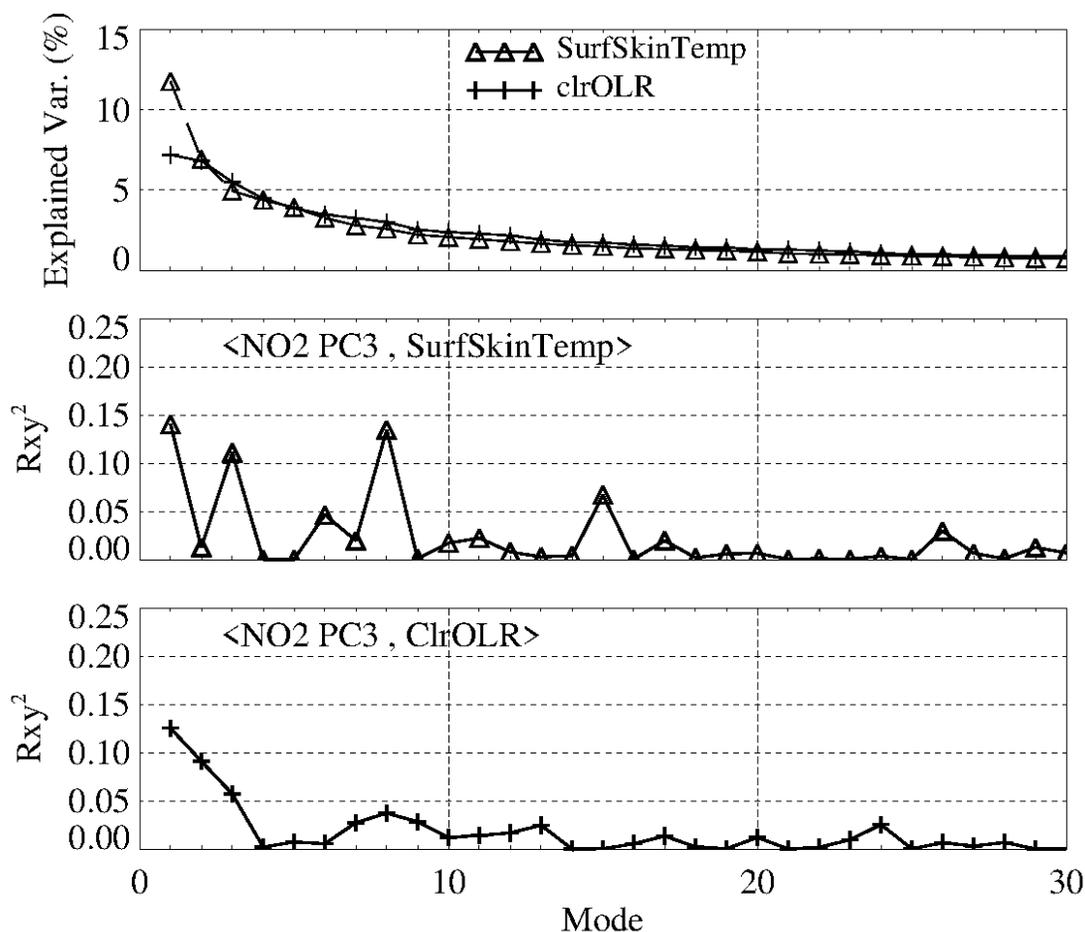


- Indicators regressed to NO2 Principal Components show that NO2 **PC3** is the one coupled and positively correlated with economy.
- 40% of variability in **PC3** can be explained by the economy.
- However, **PC3** explains only 3% of NO2 variability.

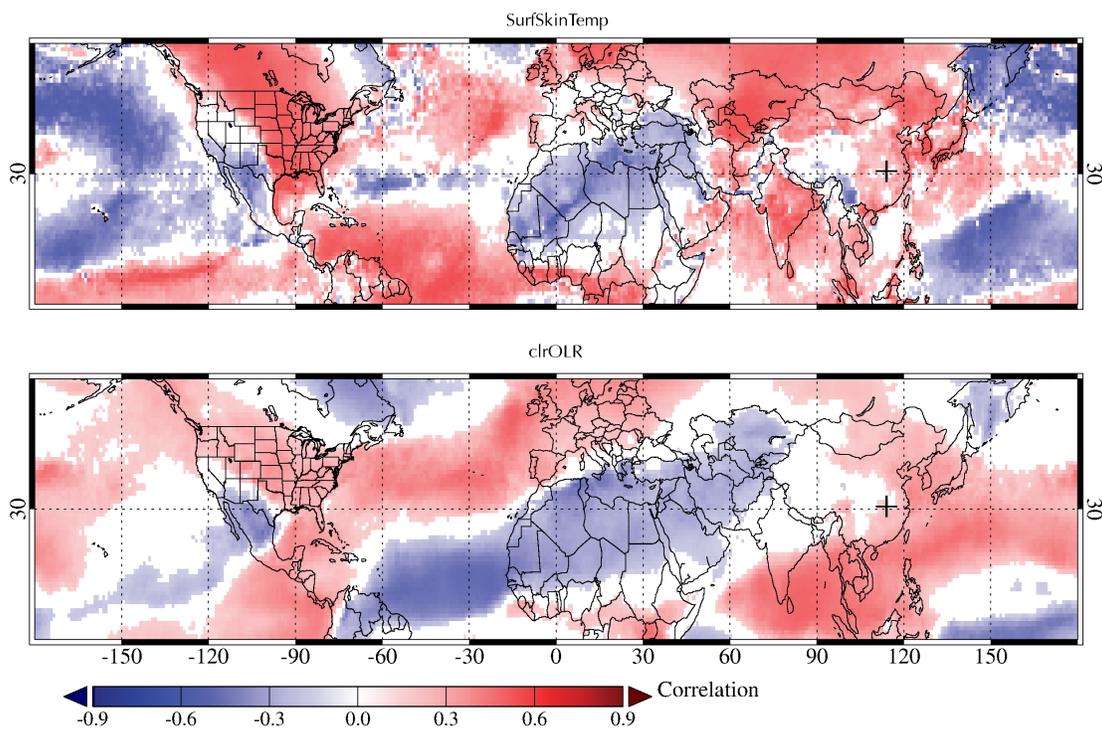


EOF3 shows the spatial pattern of the most likely impacts of economy on NO2.

RAPID CLIMATE RESPONSE



- (Top) Explained **SurfSkinTemp** and **clrORL** deseasonalized variability by each of the principal modes.
- OMI NO2 **PC3** impacts AIRS modes 2-8, but weakly - explains less than **30%** (R_{xy}^2).
- Furthermore, modes 2-8 explain less than **20%** of **SurfSkinTemp** and **clrORL** variability.



Using only impacted modes, we reconstruct series of **SurfSkinTemp** and **clrOLR**, and regress them with **NO2 PC3**. Shown are correlation coefficients that pass 95% confidence test. Wuhan region is indicated with a "+" symbol.

These are the patterns of the most likely climate impacts.

CONCLUSIONS

- Large negative winter NO₂ anomalies have been regularly observed in the past, so attributions of NO₂ anomalies to contracting economies, especially in the winter, should be done with extreme care.
- We identify OMI NO₂ PC3 as the one mode best coupled with the economic variability. **40%** of variability of this mode is driven by the economy. However, this mode explains only **3%** of the total deseasonalized NO₂ variability.
- Therefore, roughly **12%** of the deseasonalized NO₂ variability can be explained by the economy, but the rest is driven by other factors.
- We use NO₂ **PC3** as an indicator to assess climate adjustments to the economy-driven NO₂ variations.
- Rapid climate adjustments to these NO₂ anomalies, in terms of **clear-sky OLR**, and **surface skin temperatures**, are visible in a band of their principal components, but are weak. Most likely they cannot be felt directly, and should only be considered in the context of other impacts.
- Increase in the economy-driven NO₂ emissions have warming potential for large portions of the industrialized regions (Europe, USA, eastern China, south Asia). Conversely, NO₂ reductions should have cooling contribution in these regions.
- We note a different regime of NO₂ impacts over Northern Africa - cooling with increased NO₂ emissions - which is indicative of likely dominance of nitrate aerosols production.

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