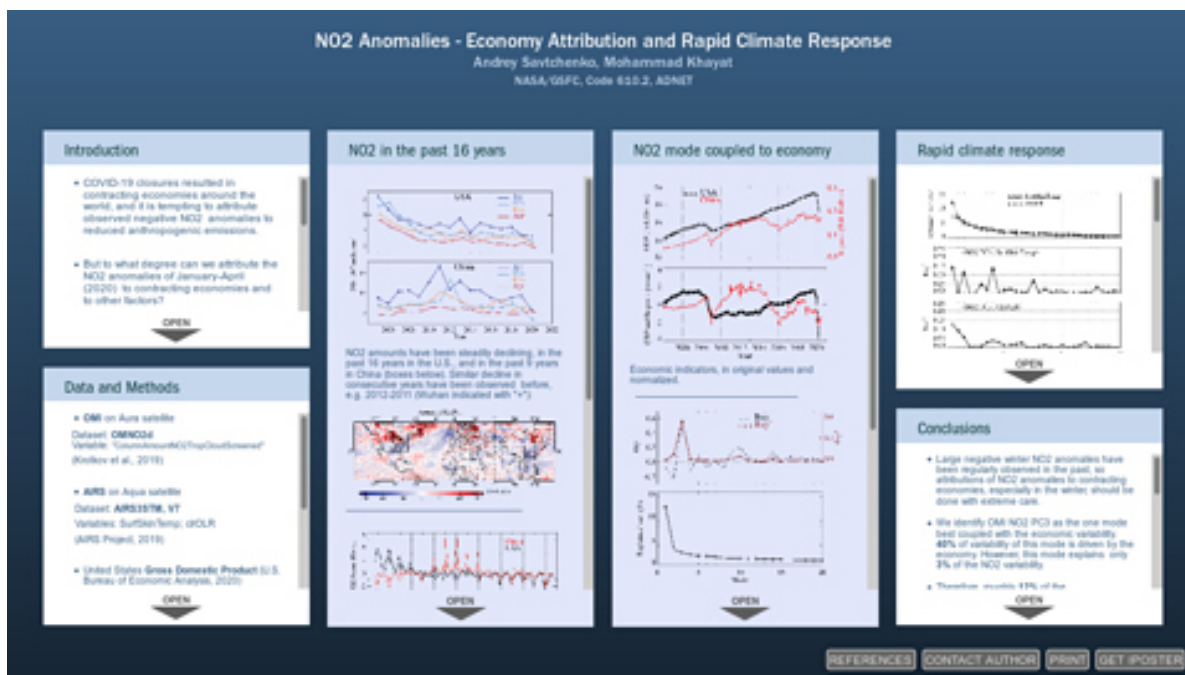


N₂O Anomalies - Economy Attribution and Rapid Climate Response



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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

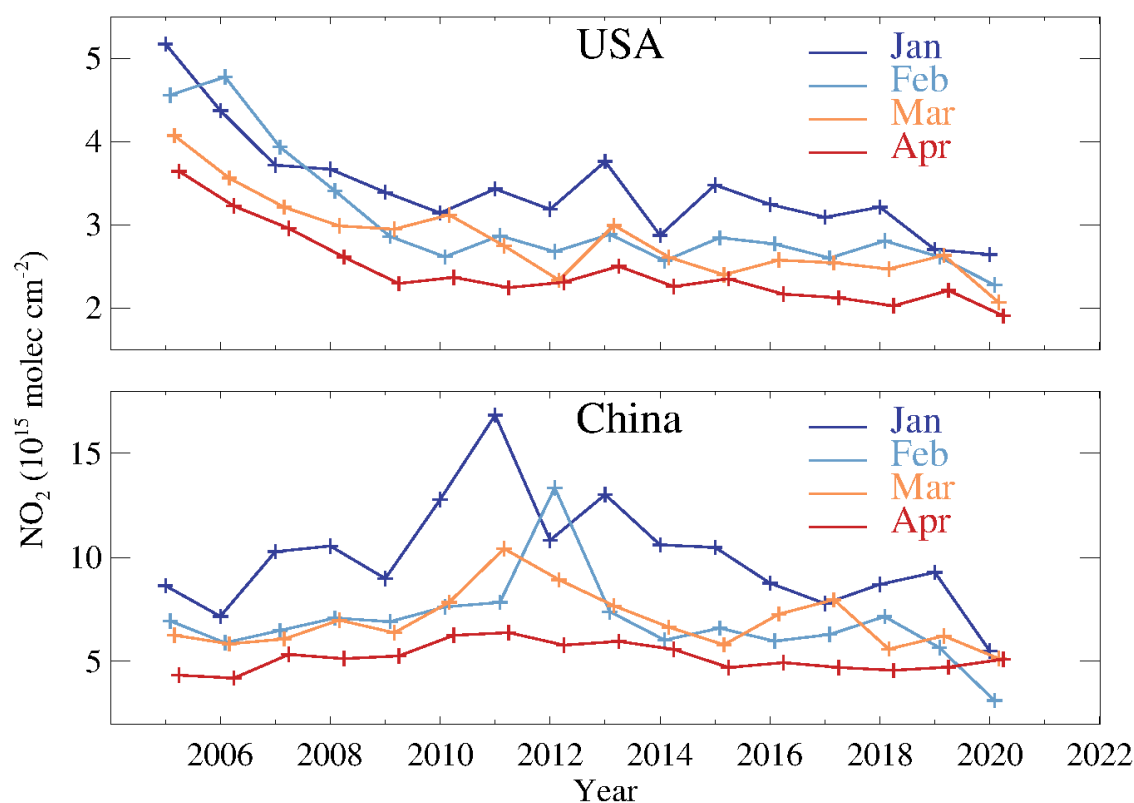
Dataset: **AIRS3STM, V7**

Variables: SurfSkinTemp; clrOLR

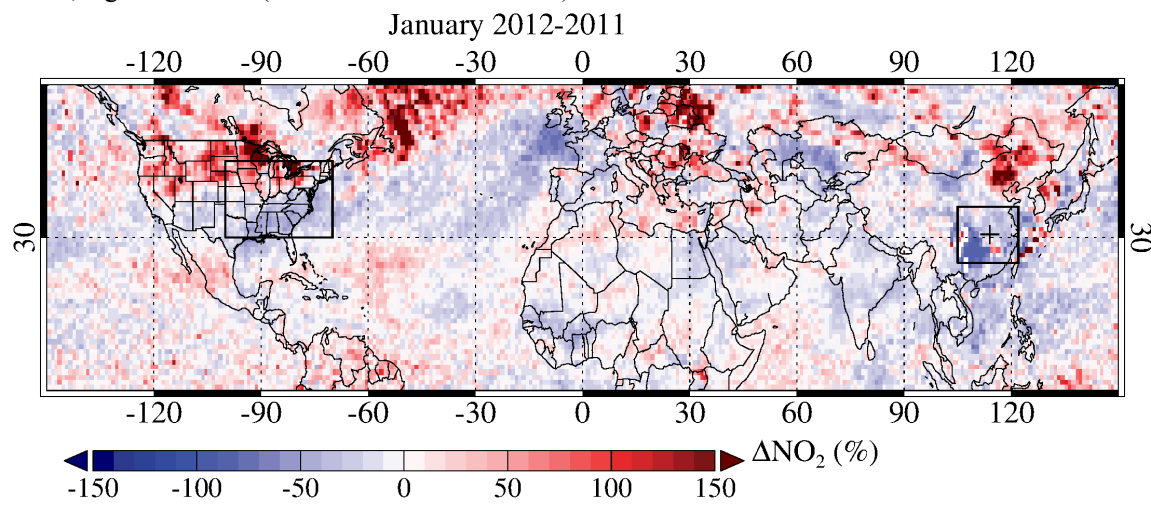
(AIRS Project, 2019)

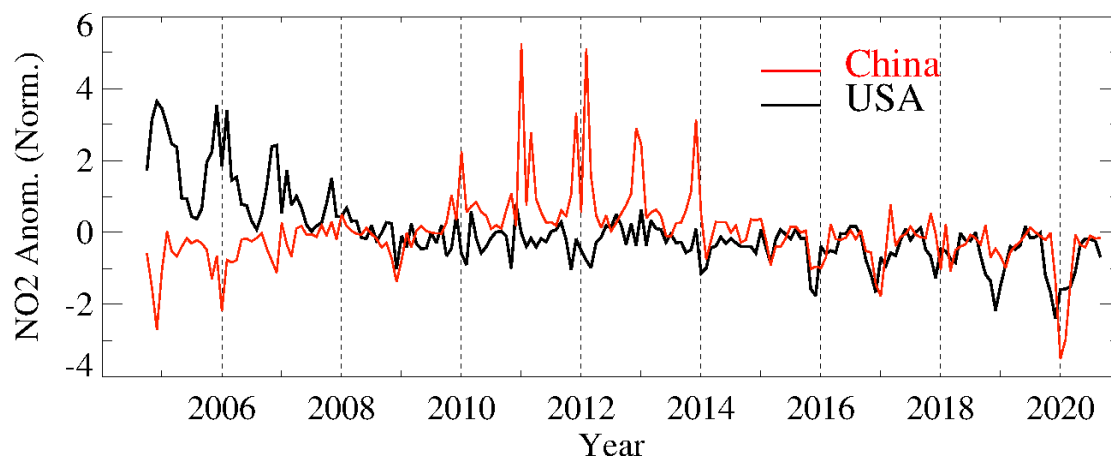
- United States **Gross Domestic Product** (U.S. Bureau of Economic Analysis, 2020)
- **Monthly Imports Indicator** for China (Organization for Economic Co-operation and Development, Imports, 2020)
- **Principal Component Analysis** is applied to deseasonalized monthly series of OMI and AIRS. Northern Hemisphere only.

NO₂ IN THE PAST 16 YEARS

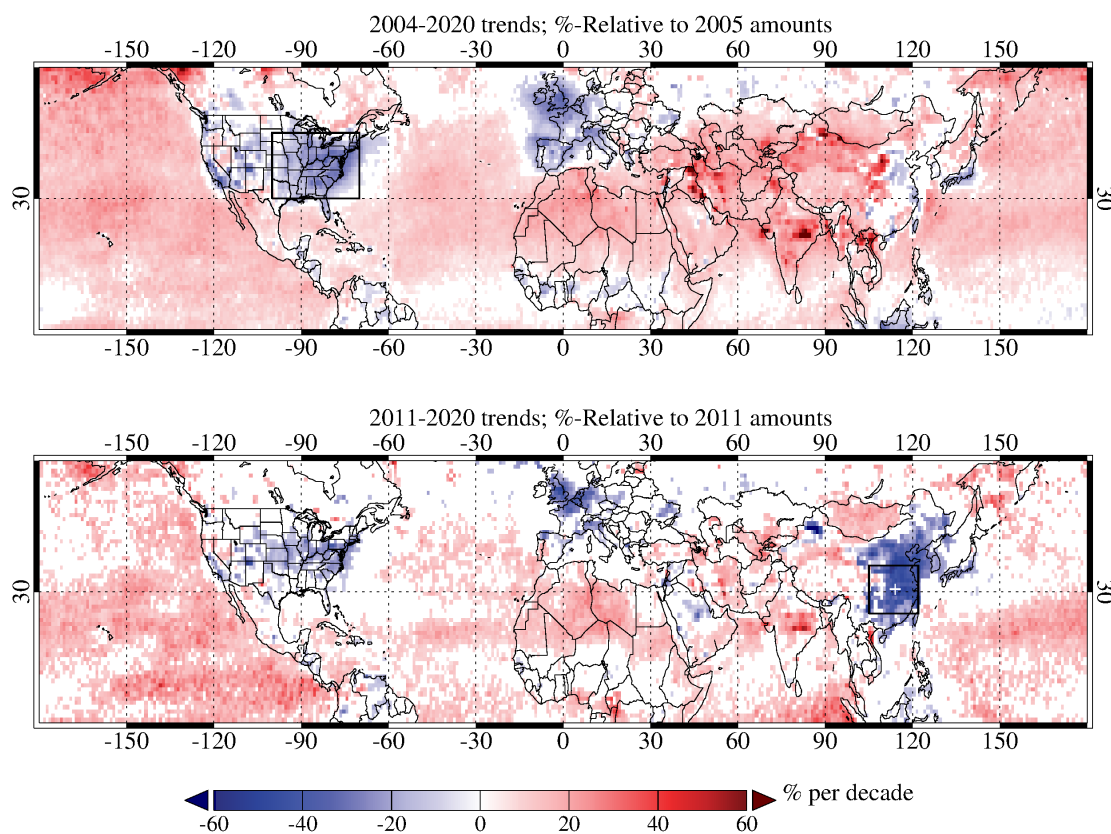


NO₂ amounts have been steadily declining, in the past 16 years in the U.S., and in the past 9 years in China (area average in the boxes, below). Similar decline in consecutive years have been observed before, e.g. 2012-2011 (Wuhan indicated with "+"):



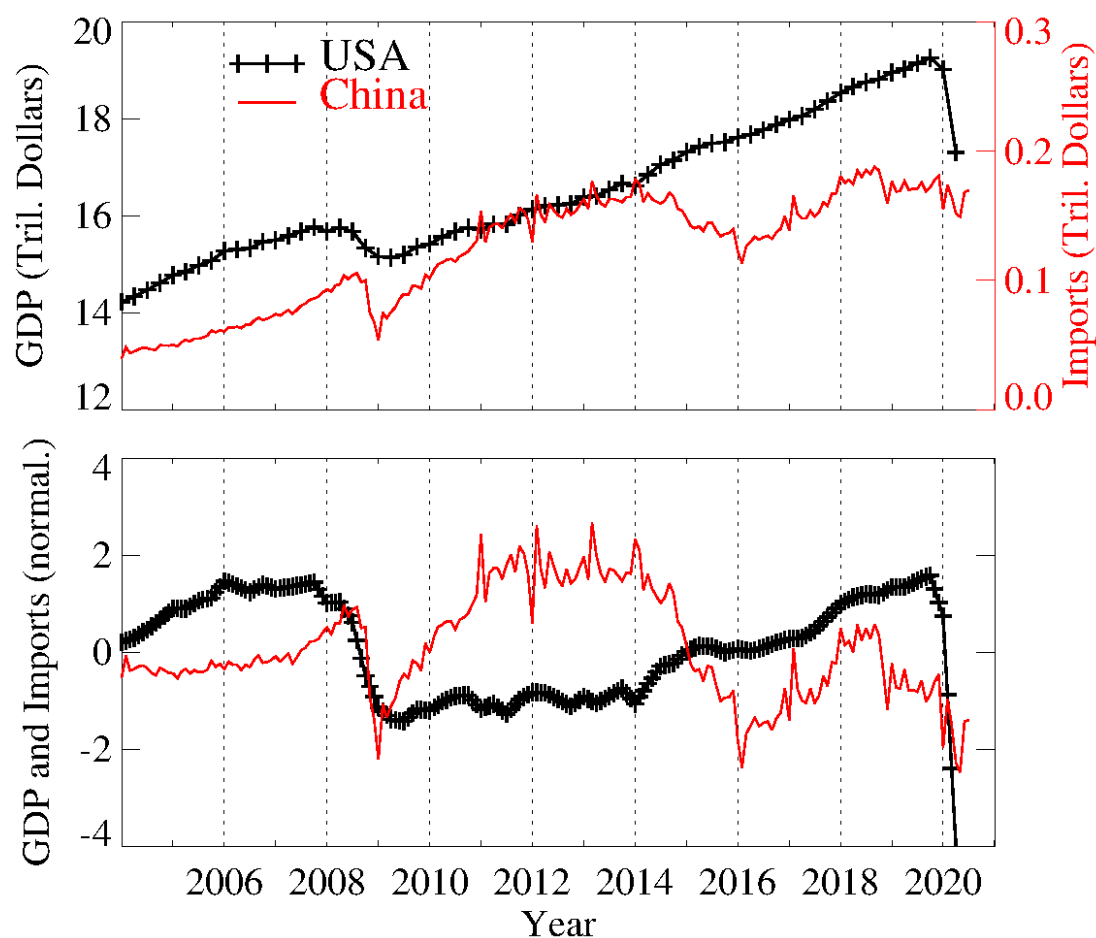


Area averages from the boxes above, land only. Strong negative NO2 anomalies have been observed before, always in the winter.

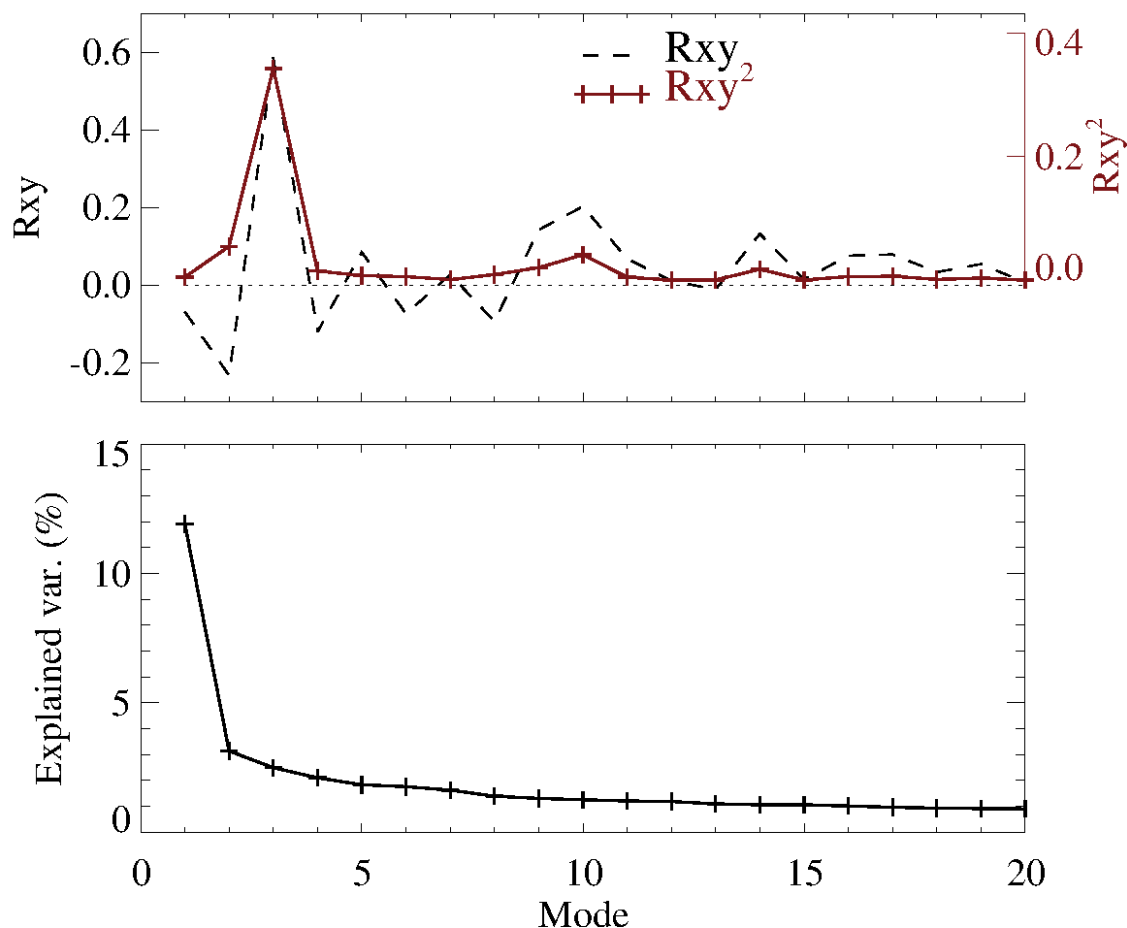


Declining tendencies of NO2 amounts are seen at 95% confidence over the U.S. and China.

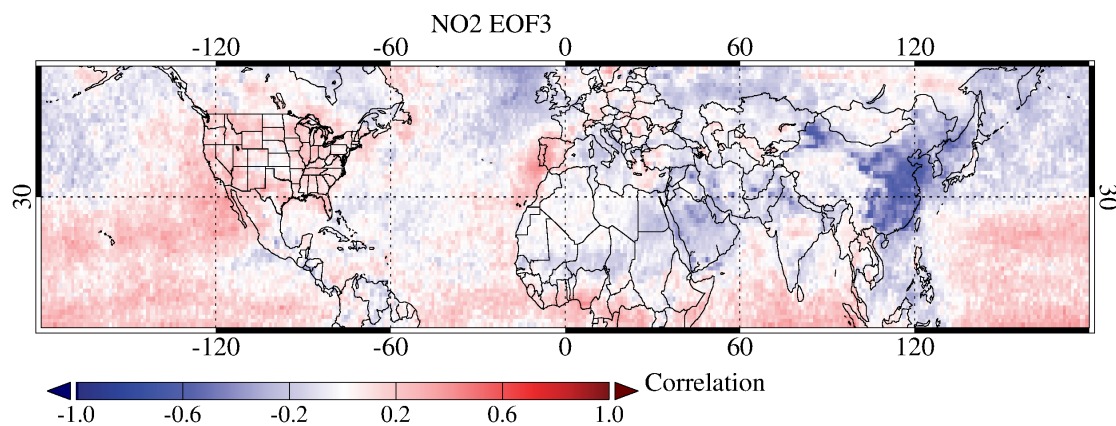
NO2 MODE COUPLED TO ECONOMY



Economic indicators, in original values and normalized.

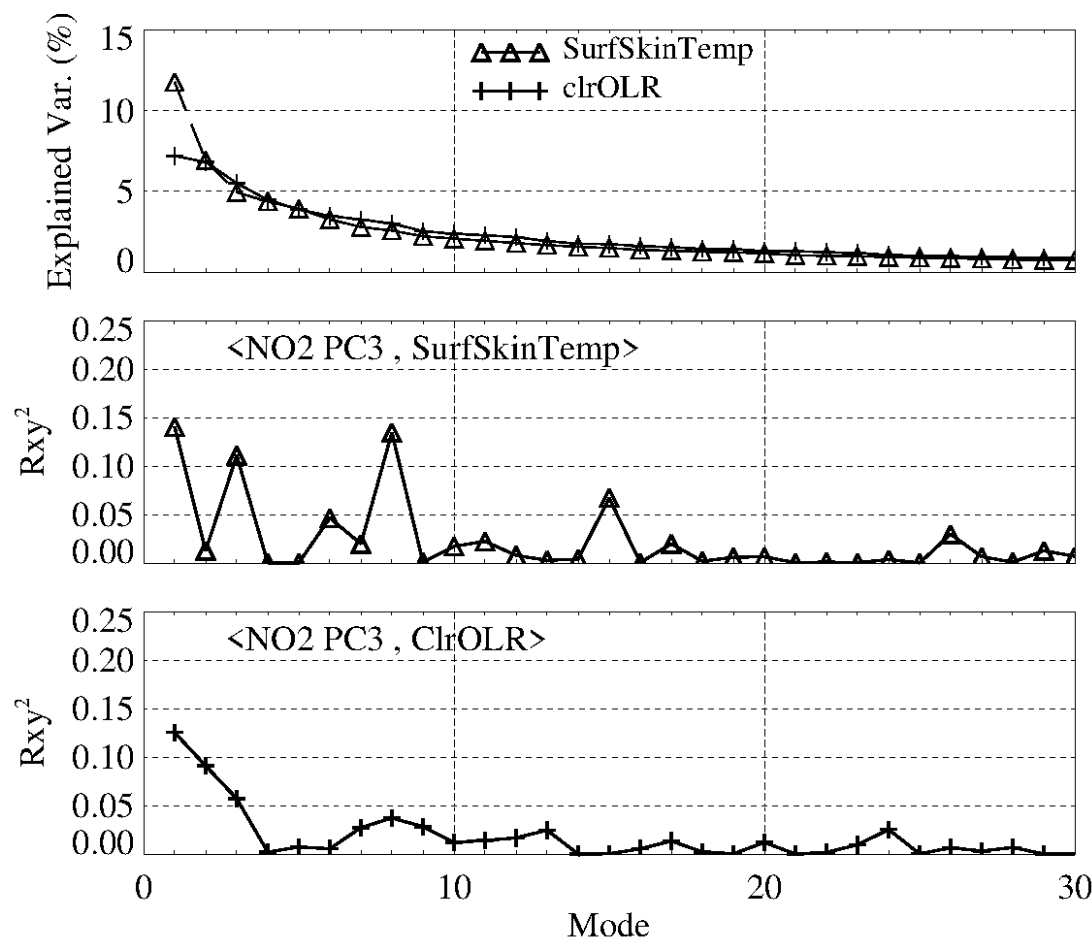


- Indicators regressed to NO2 Principal Components show that NO2 **PC3** is the one coupled and positively correlated with economy.
- 40% of variability in **PC3** can be explained by the economy.
- However, **PC3** explains only 3% of NO2 variability.

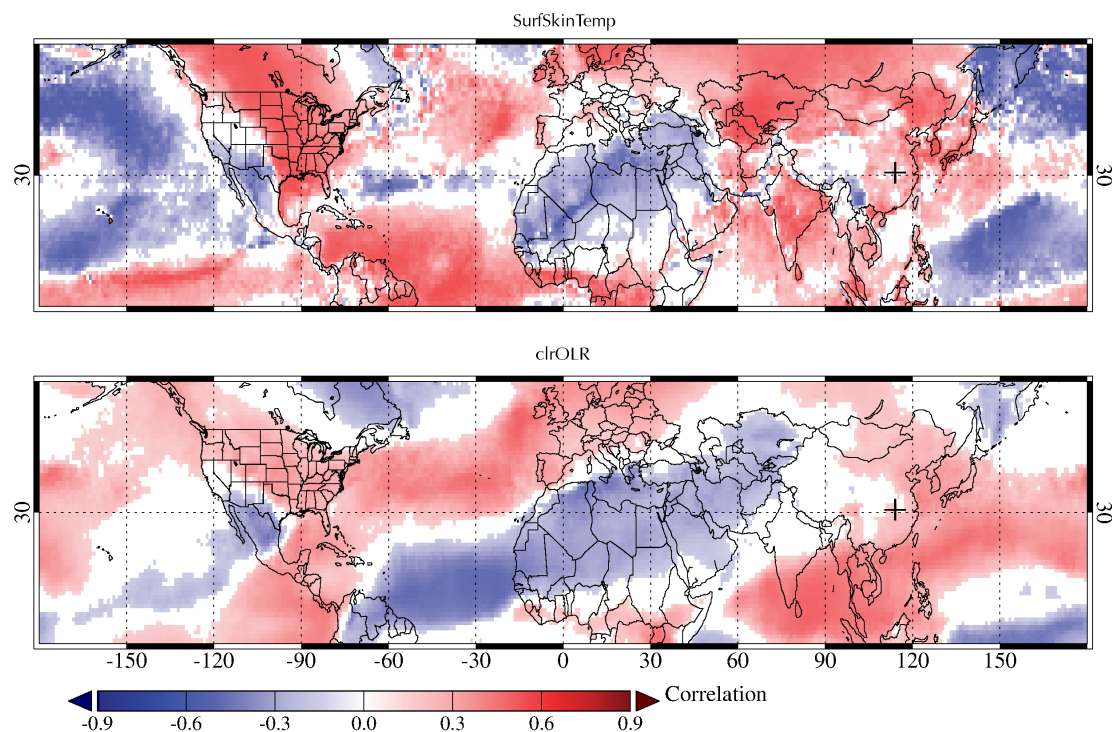


EOF3 shows the spatial pattern of the most likely impacts of economy on NO2.

RAPID CLIMATE RESPONSE



- (Top) Explained **SurfSkinTemp** and **clrOLR** 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 **clrOLR** 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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