Simulating the variations of carbon dioxide in the global atmosphere on a hexagonal grid with the LMDZ - Dynamico model

03/10/2023

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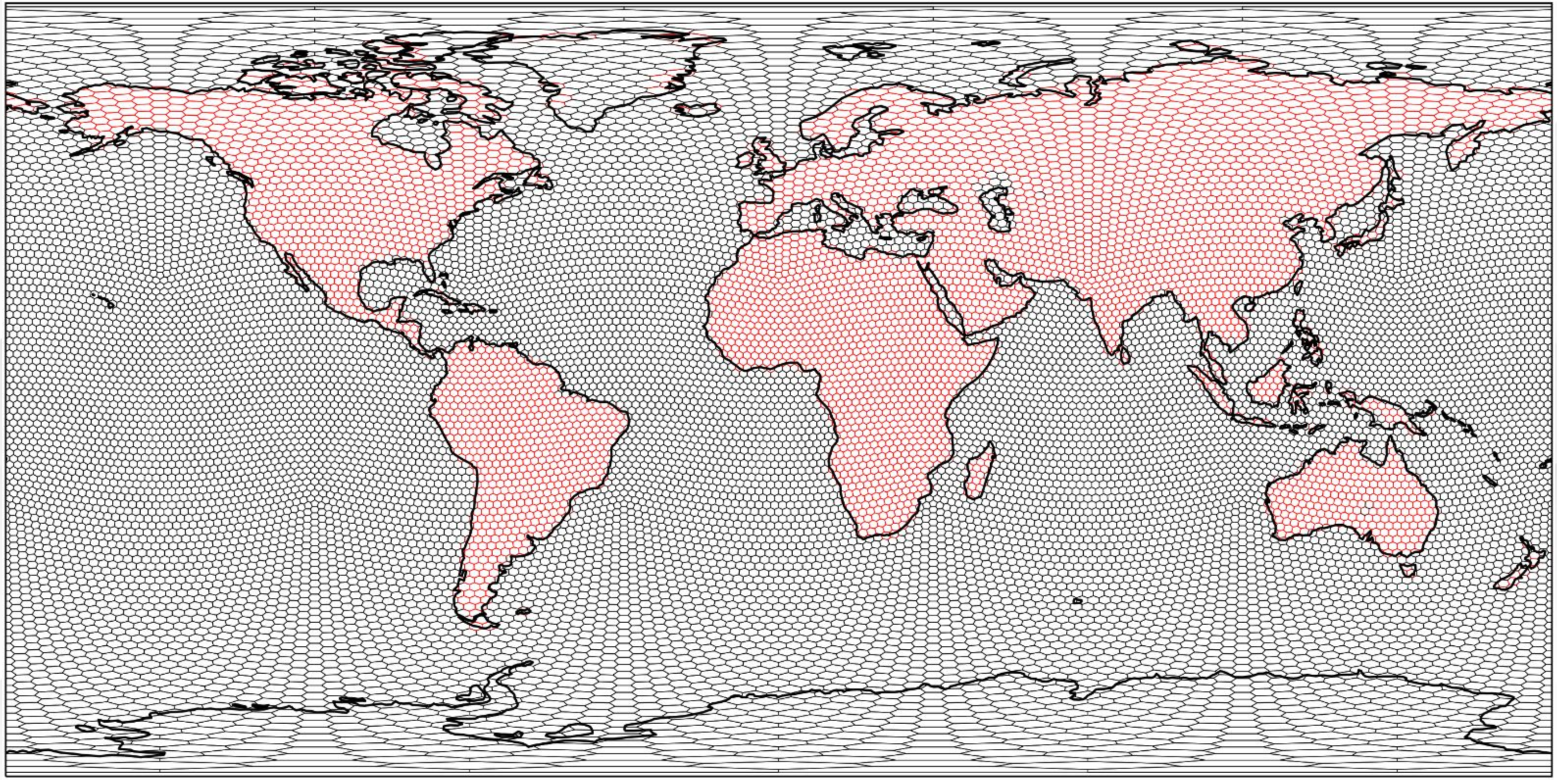
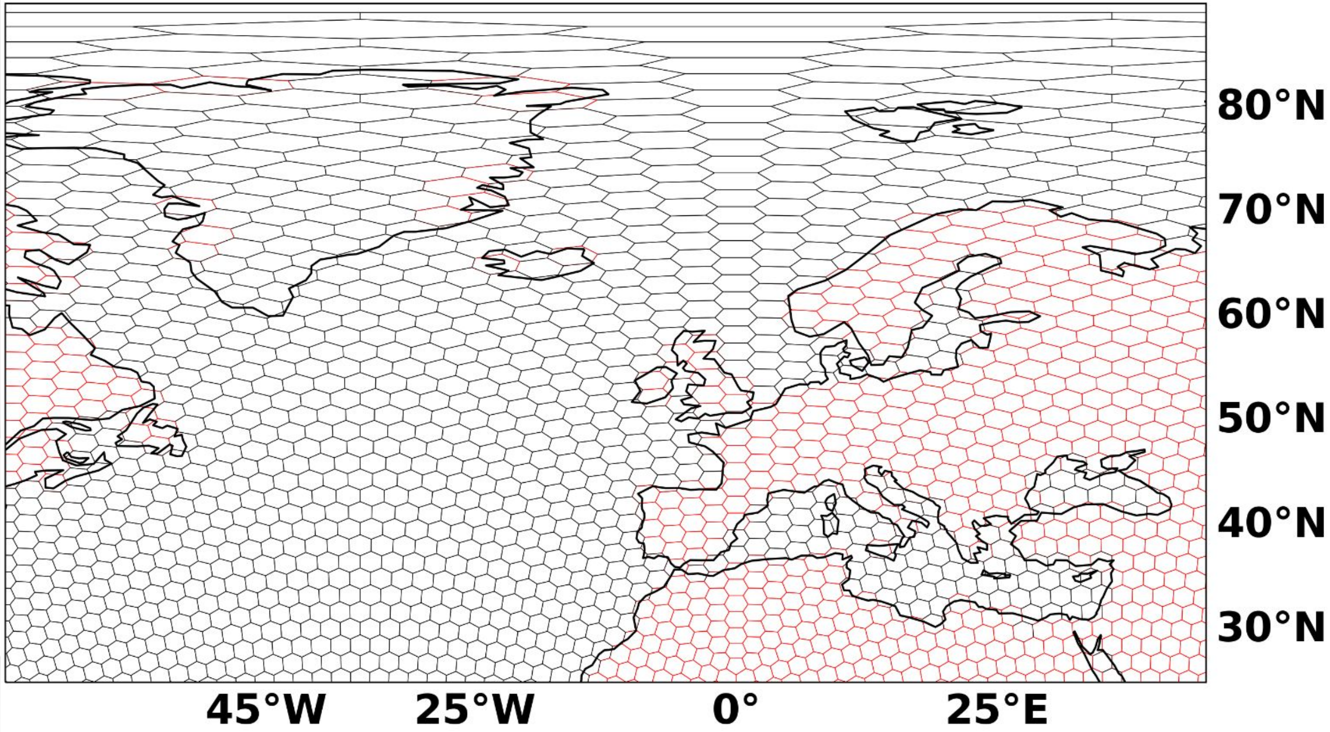
Dynamico grid



Zoom - Dynamico grid

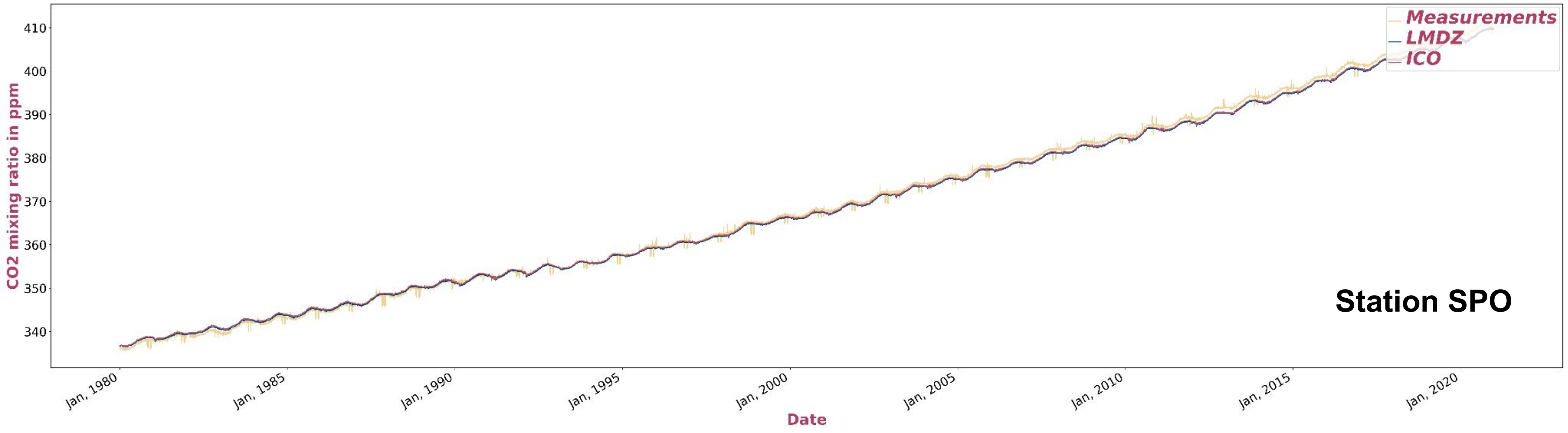
- Grid
  - Icosahedral cells
  - Hexagon surface
  - Constant resolution
- New dynamical core
  - Clean code
  - Same equations



Grid comparison

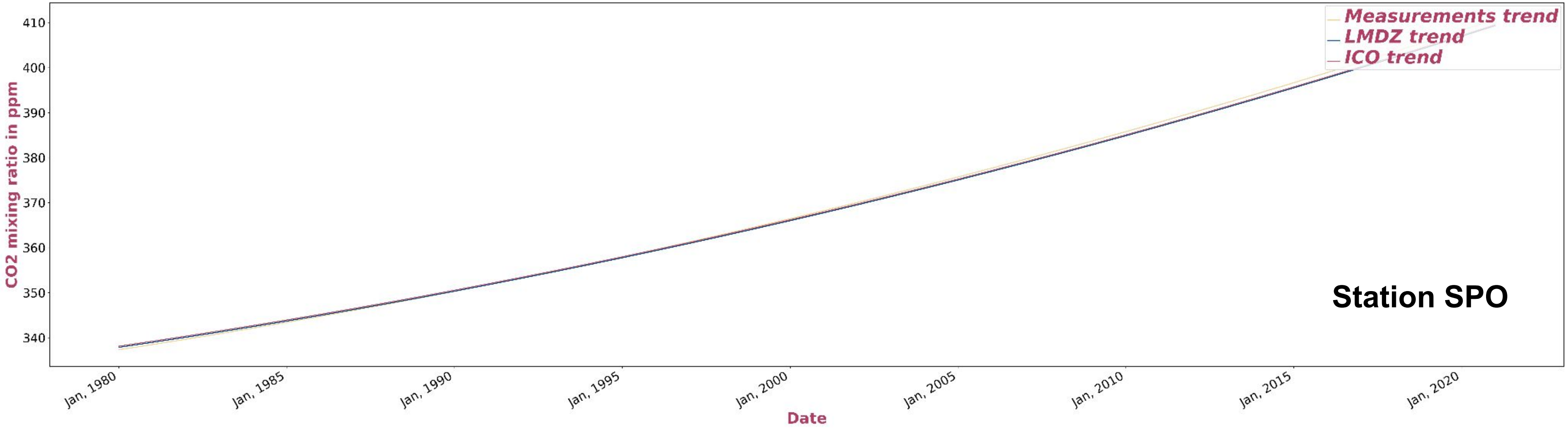
	LMDZ	Dynamico
Resolution	144x143x79	Nbp 40 - 79 levels
Number of cells per level	20592	16002 22% gain
Resolution in degrees	2.5° longitude by 1.27° latitude	2.5° longitude by 1.25° latitude
Cell size at equator	278 km by 140 km	Hexagon side 110 km
Poles	Singularity, resolution clustering	No singularity, no change in resolution
Speed per month (Coupled model)	820 seconds	660 seconds 20% gain

Comparison to surface station measurements



- Obspack (NOAA)
  - 107 surface stations
  - Global
- Seasonal decomposition: polynomial fit
  - Annual trend
  - Seasonal cycle
  - Residue (Synoptic variability)

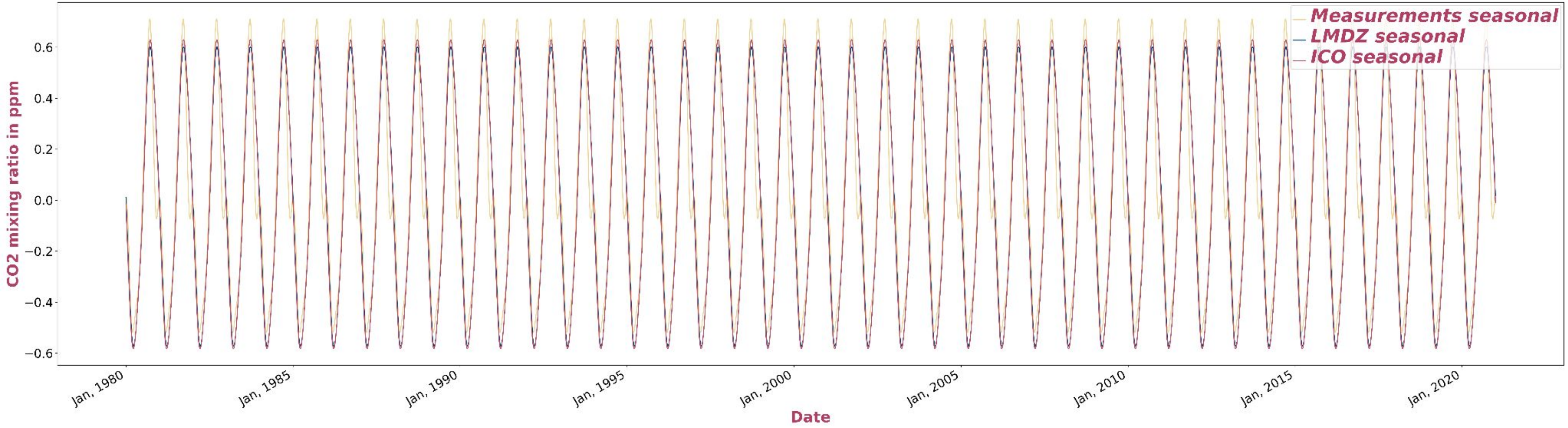
Comparison to surface station measurements



- **Annual Trend**
  - **Fit of whole time serie**
  - **Yearly average**

$$f(t) = \underbrace{p_0 + p_1 \cdot t + p_2 \cdot t^2}_{\text{Trend}} + \sum_{k=3}^{10} p_k \cdot sin(2\pi kt)$$

Comparison to surface station measurements

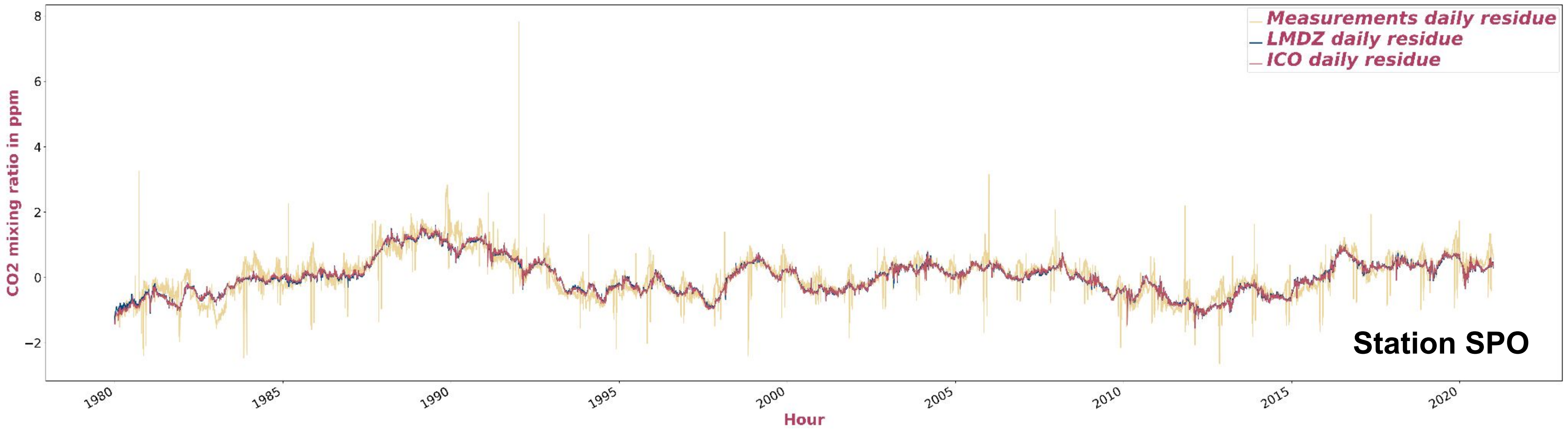


- Seasonal cycle
  - Fit of whole time serie
  - Yearly average

$$f(t) = p_0 + p_1 \cdot t + p_2 \cdot t^2 + \underbrace{\sum_{k=3}^{10} p_k \cdot sin(2\pi k t)}_{\text{Seasonal cycle}}$$

Seasonal cycle

Comparison to surface station measurements

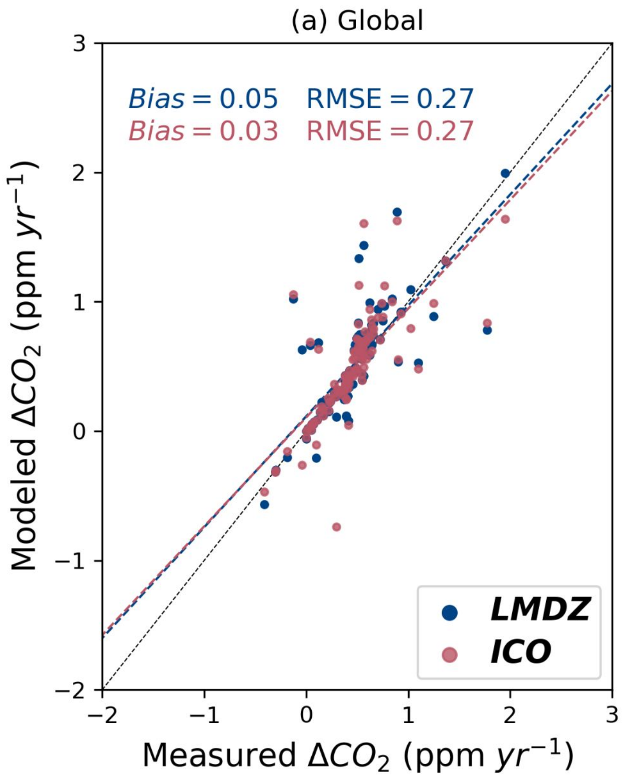


- **Remove the trend and seasonal cycle**
  - **High frequency variability**
  - **Then: average per day**

$$Residue(t) = Obs(t) - f(t)$$

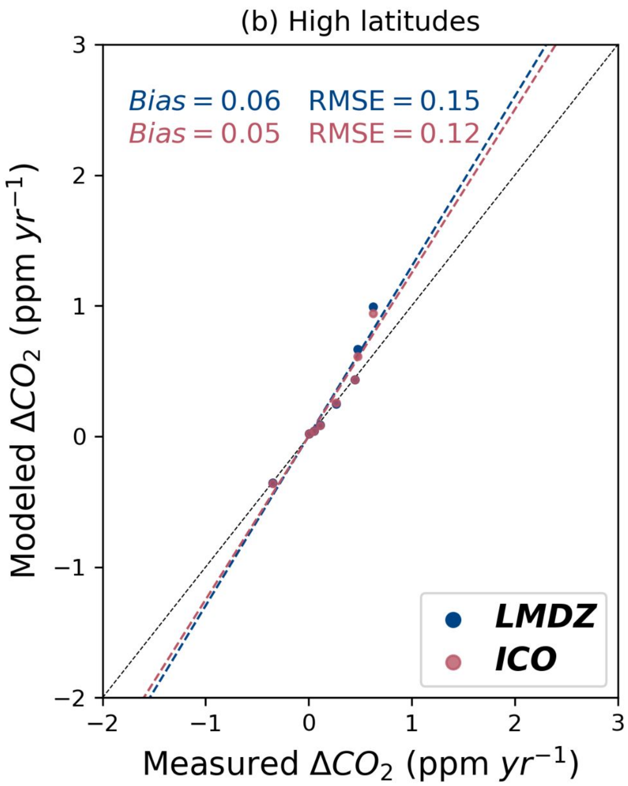
CO_2 annual gradient vs SPO

- Annual growth rate of CO_2 in relation to SPO
  - Each station compared to observations
  - Difference to SPO
- Both models are very similar
- Both models are accurate



CO_2 annual gradient in high latitudes

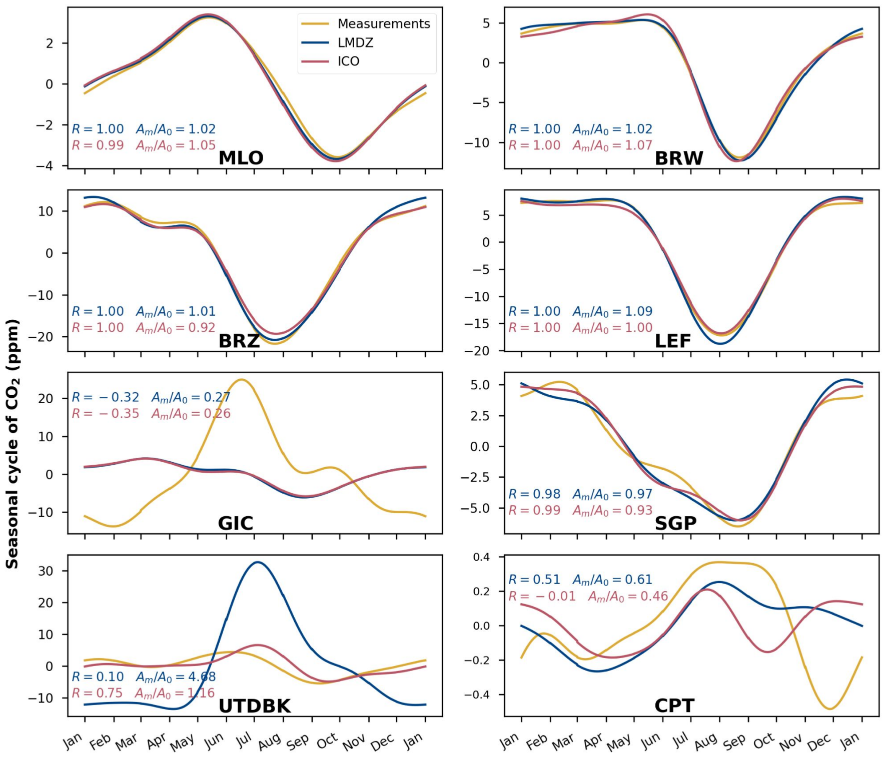
- Annual growth rate of CO_2 in relation to SPO
  - Each station compared to observations
  - Difference to SPO
- Both models are very similar
- Both models are accurate
- Only high latitudes ?
  - Biggest grid difference
  - Resolution ICO < LMDZ
- Almost identical
  - No degradation



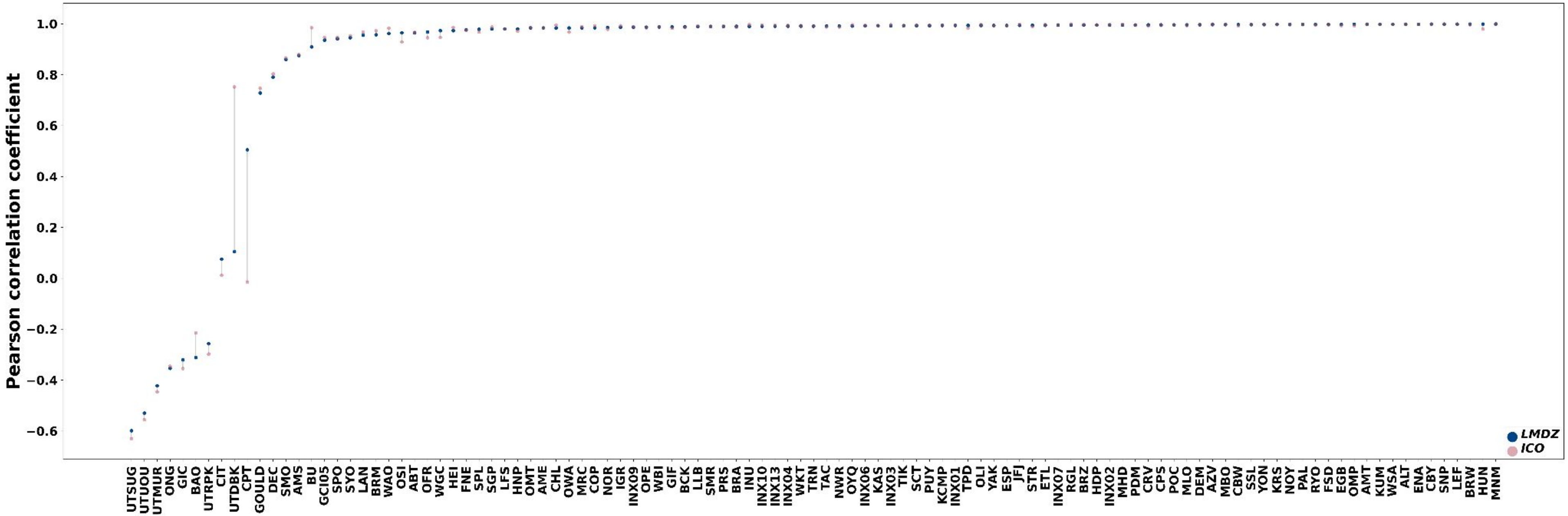
Modeling the average seasonal cycles at the surface

Sample of different stations

- Accuracy of seasonal cycle capture
  - Correlation coefficients
- Vast majority of stations identical
- Some stations not captured by either
- Rare station with only 1 good model

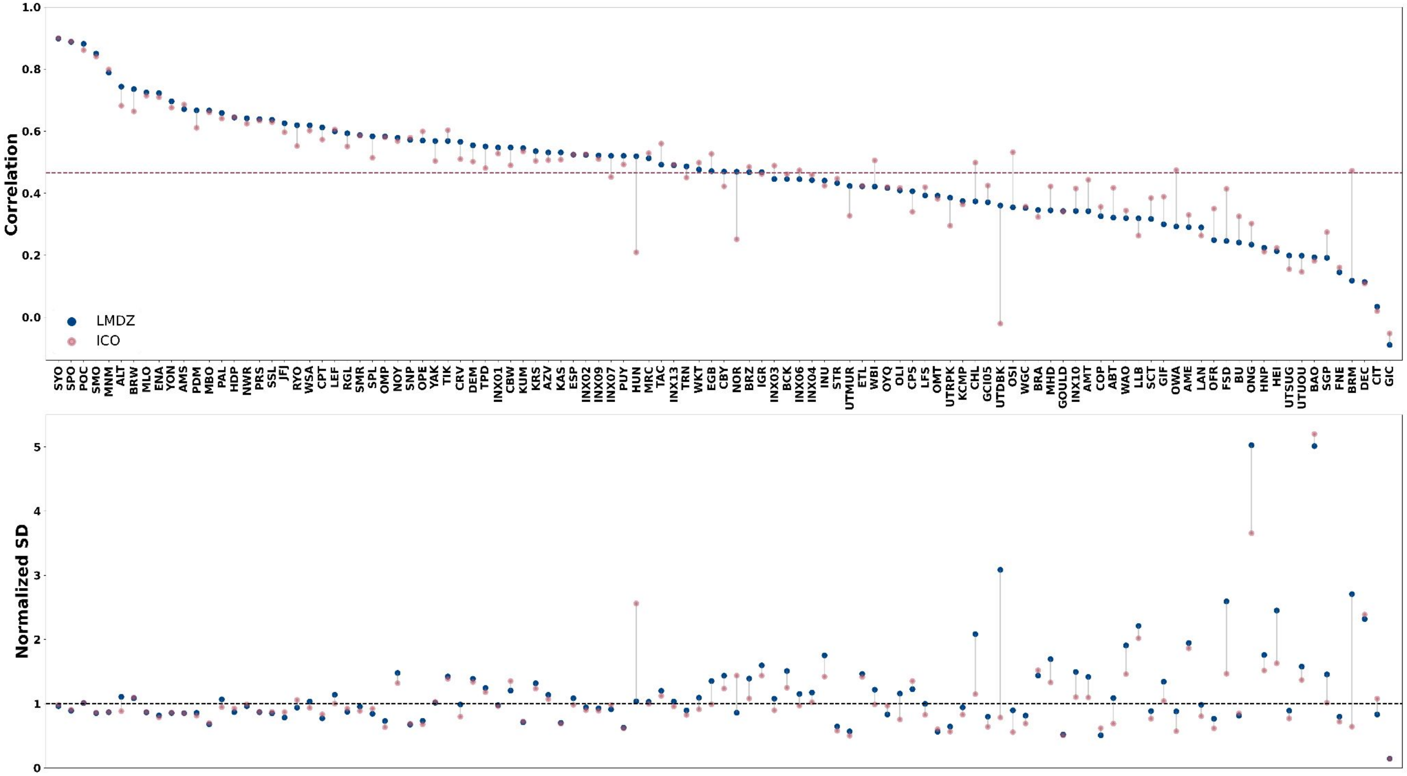


Correlation of modelled seasonal cycles



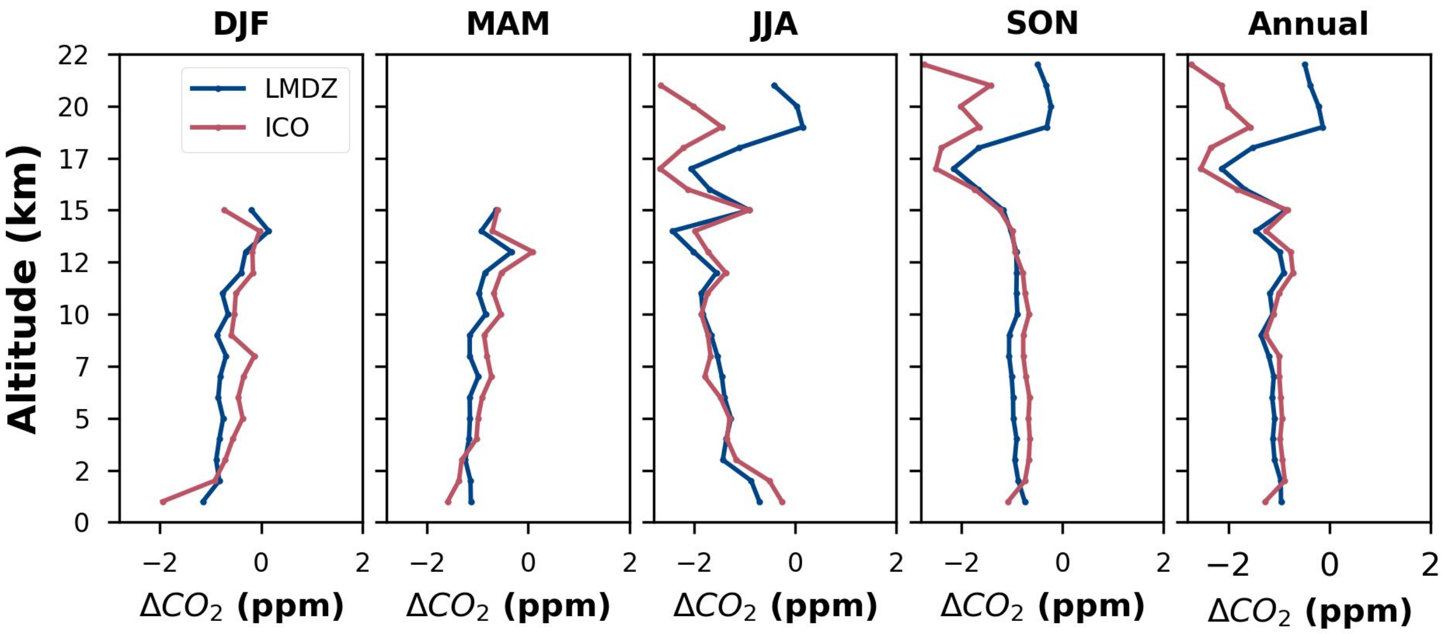
Correlation / Normalized Standard Deviation (NSD) of the modeled synoptic variability

- Worse than seasonal
- Expected at our resolution
- Average :
  - R_{both} = 0.47
  - NSD_{ICO} = 1.06
  - NSD_{LMDZ} = 1.20



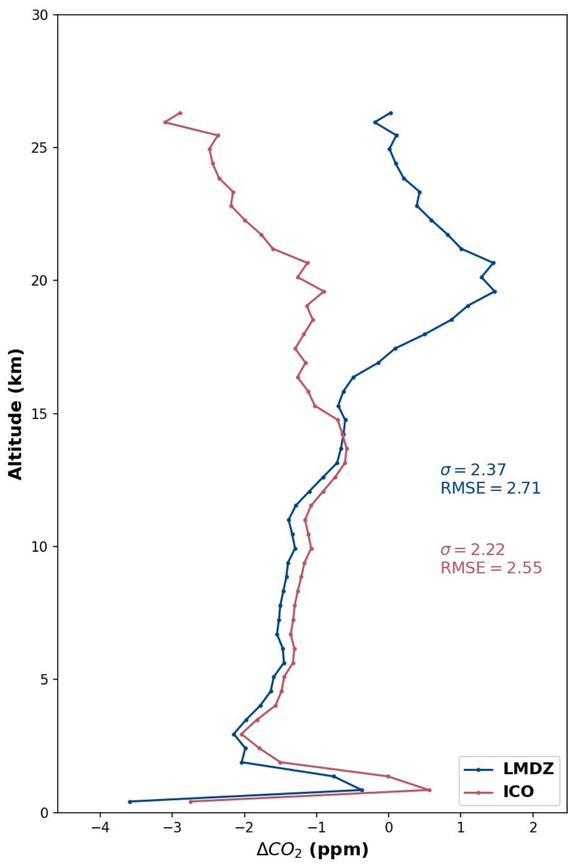
CO_2 vertical profiles compared to aircrafts

- **Both have general bias**
- **Diverge in high altitude**

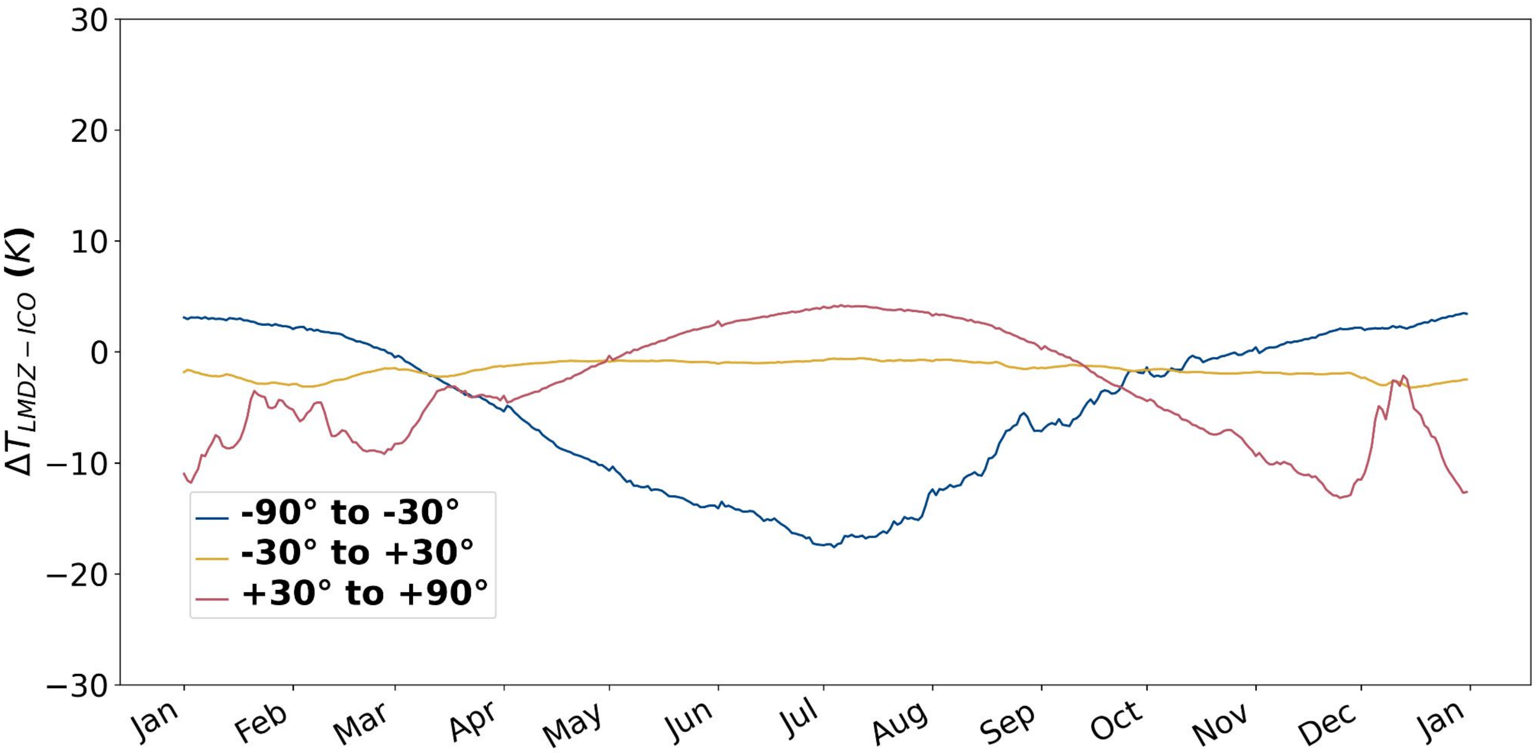


CO_2 vertical profiles compared to AirCore

- **Much larger difference at 20 km**
- **Different gradient at this altitude**
- **Still not properly explained**
- **Problem with AirCore data itself ?**
  - **But LMDZ has issues with CH_4 at this altitude too**
  - **But why is Dynamico different ?**



Temperature difference between models at the stratopause



Model's improvement

- Dynamico
  - Sponge layer
  - Fine tuning (ongoing work)
  - Integrating it into the inverse system
- Scaling LMDZ for inversion
  - 256x256
  - Powered by GPUs
  - Reaching computing limits…

Conclusion

- ICOLMDZORINCA operational for direct simulations
- Validated for CO_2 transport near the surface
- Work left to do for vertical
- Just needs more people experimenting with it !