# Comparison of observed lower stratospheric ozone changes with free-running chemistry climate models


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# Take home

- Observational data **imply**
  *ozone is still decreasing in the lower stratosphere*
  Ball et al., 2017; 2018; 2019

- Chemistry transport models **match**
  *and attribute changes to dynamics*
  Chipperfield et al., 2018; Wargen et al., 2018; Orbe et al., 2020

- Nudged and free running models
  ***do not agree** with observations at **mid-latitudes***
  WMO 2014, 2018; Ball et al., in review (ACPD); Orbe et al., 2020

- **Tropical decline** is robust
  *and upwelling acceleration may be responsible*
  Ball et al., 2019; in review (ACPD)

- **Mid-latitude differences**
  *may be related to QBO representation*
  See presentation by A. Stenke (EGU2020-16682)

# Observations: changes since 1998

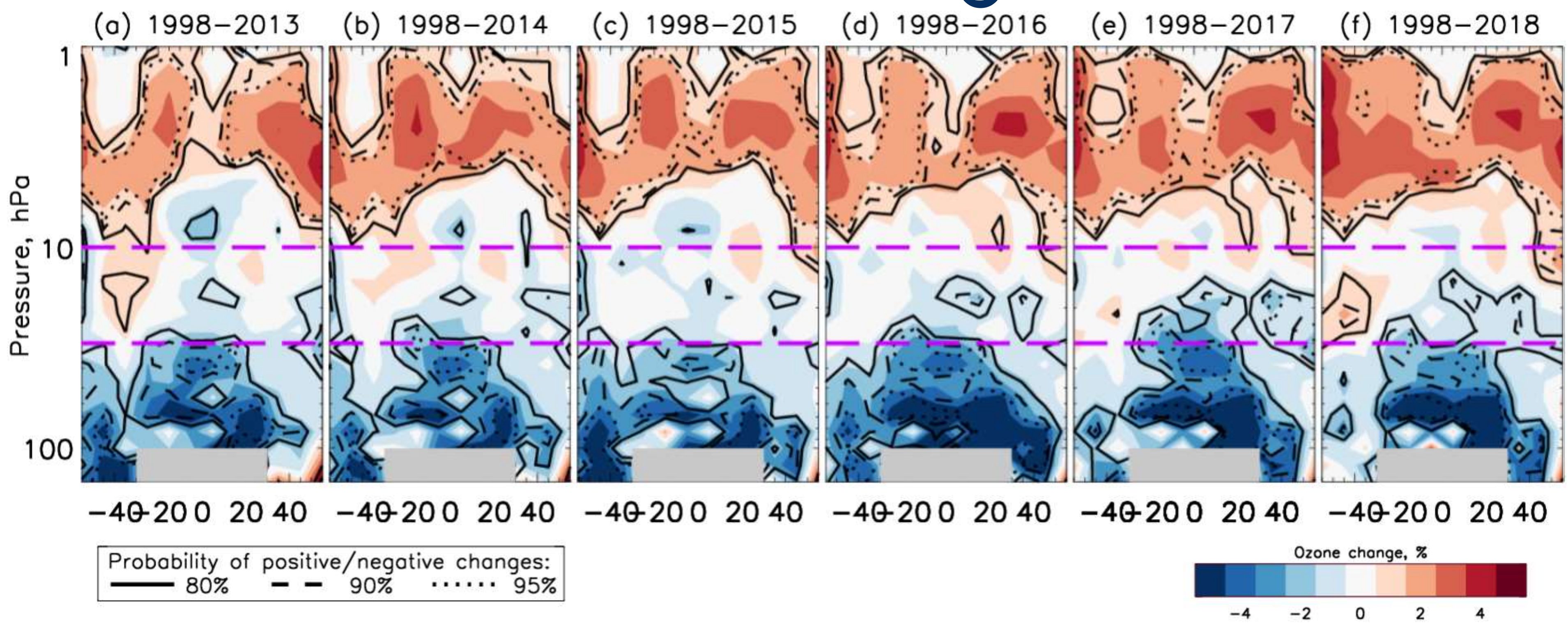
*End-point sensitivity*

❶ Stratospheric ozone changes over 1998-2013/…/2018: dynamical linear modelling applied to BASIC observational composite

❸ **Tropical lower stratosphere →** negative trend, robust to end year

❷ **Upper stratosphere** → over time, confidence and strength in recovery increase

❹ **Mid-lat. lower stratosphere →** oscillatory but not positive; dynamics, perhaps QBO related.




❺ Observational data **imply** *ozone is still decreasing in the lower stratosphere*

*Ball et al., 2019, ACP*

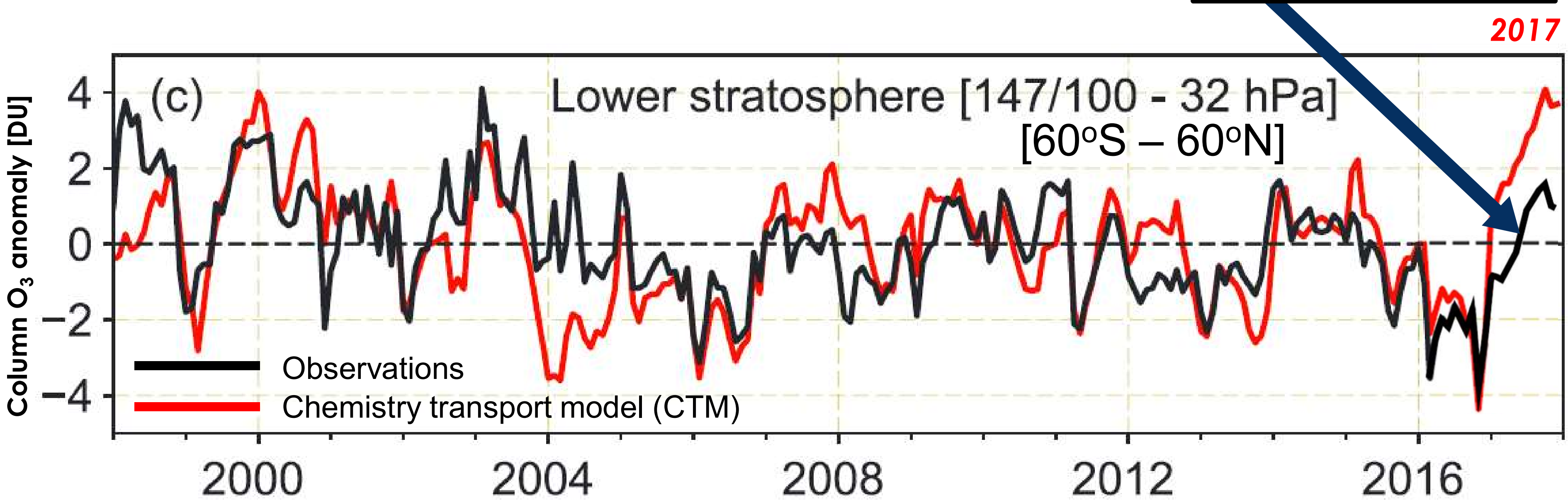
# Chemistry transport models
## reproduce general behaviour

❶ CTM using ERA-Interim (red) and observations (BASIC; black) for 1998-2017; results are integrated lower stratosphere (see Fig.)

❷ **CTM generally matches** the overall changes, and much of the short-term variability

❸ Chipperfield et al. conclusively **demonstrate** almost all **variability is dynamically driven**

❹ **Added 1 year to BASIC overlayed on figure from Chipperfield et al., 2018**: implication that CTM over estimates 2017 resurgence in ozone




❺ Chemistry transport models **match** *and attribute changes to dynamics*

*Chipperfield et al., GRL, 2018 (see also, Wargan et al., 2018; Orbe et al., 2020)*

# **Nudged models:** 1998+ ozone changes

Ball et al., 2018, ACP

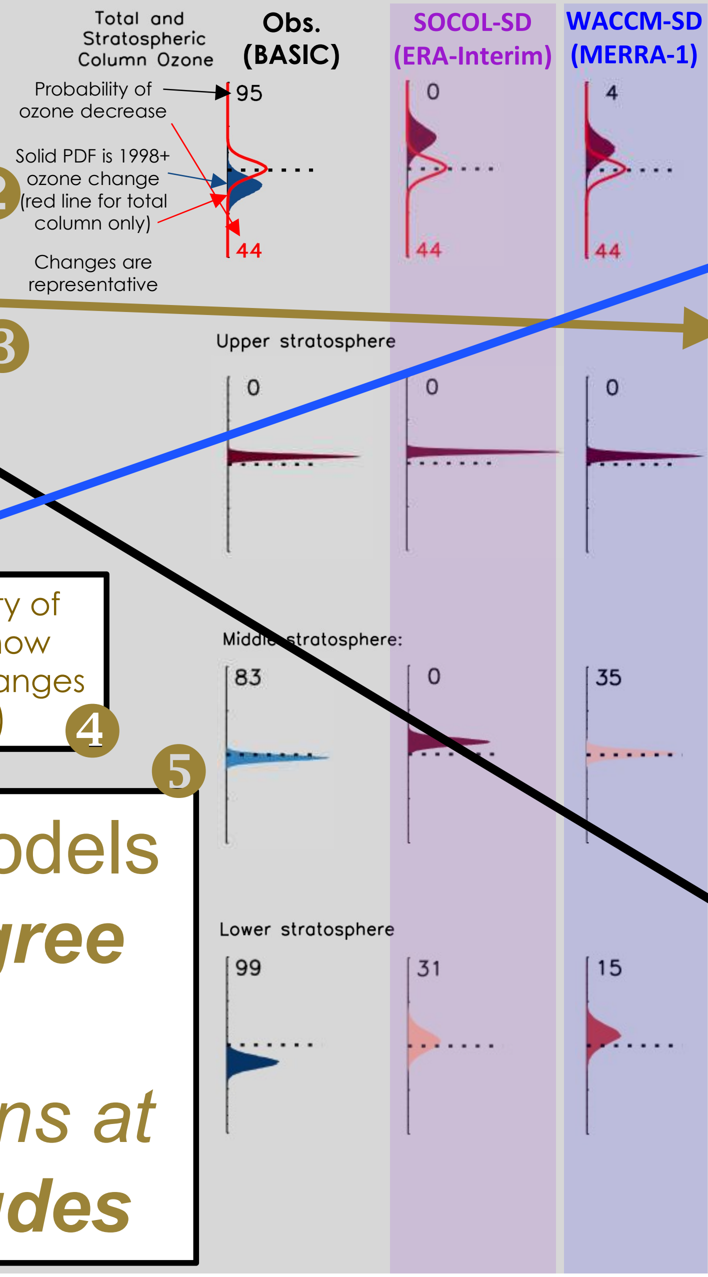
1 WACCM + SOCOL CCMs nudged with MERRA-1 and ERA Interim

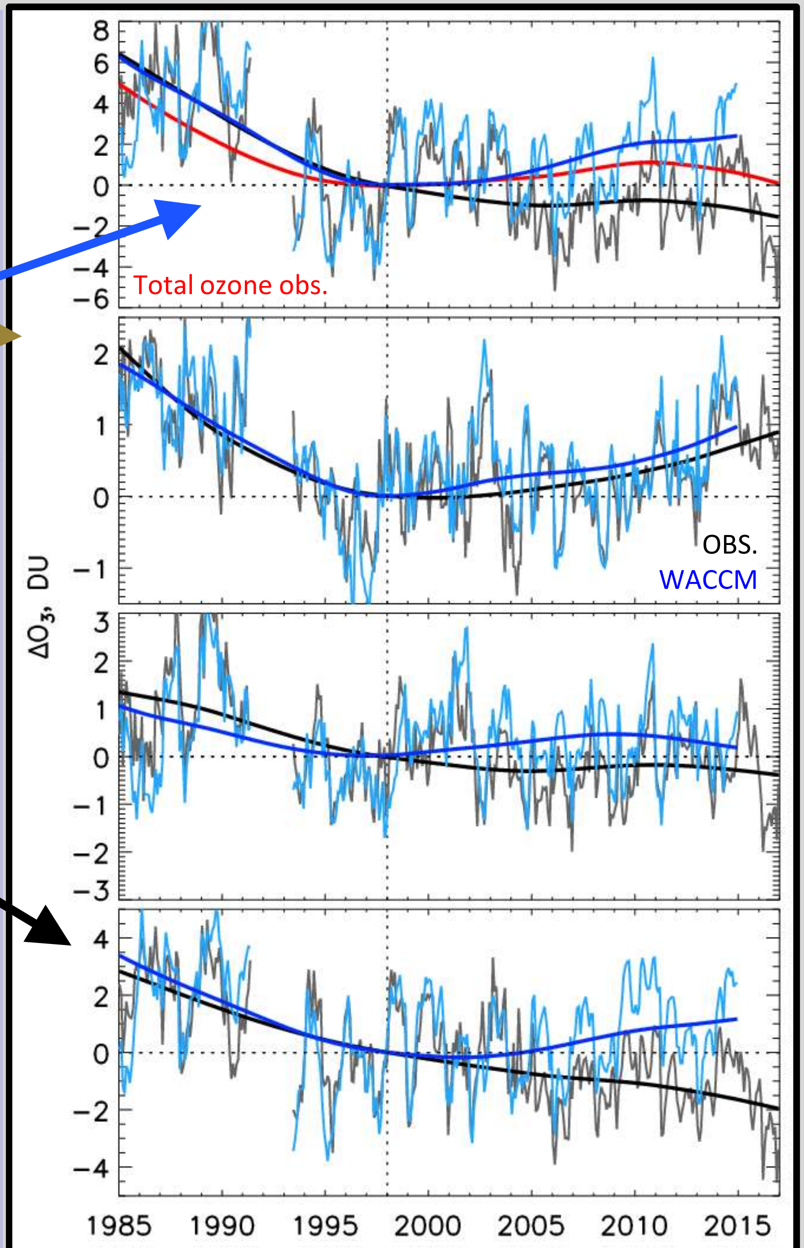
2 Short term variability in good (qualitative) agreement…

3 … but long-term changes diverge in **lower stratosphere**, driving **stratospheric column divergence**

4 PDFs provide probability of changes, timeseries show short- and long-term changes (SOCOL not shown)

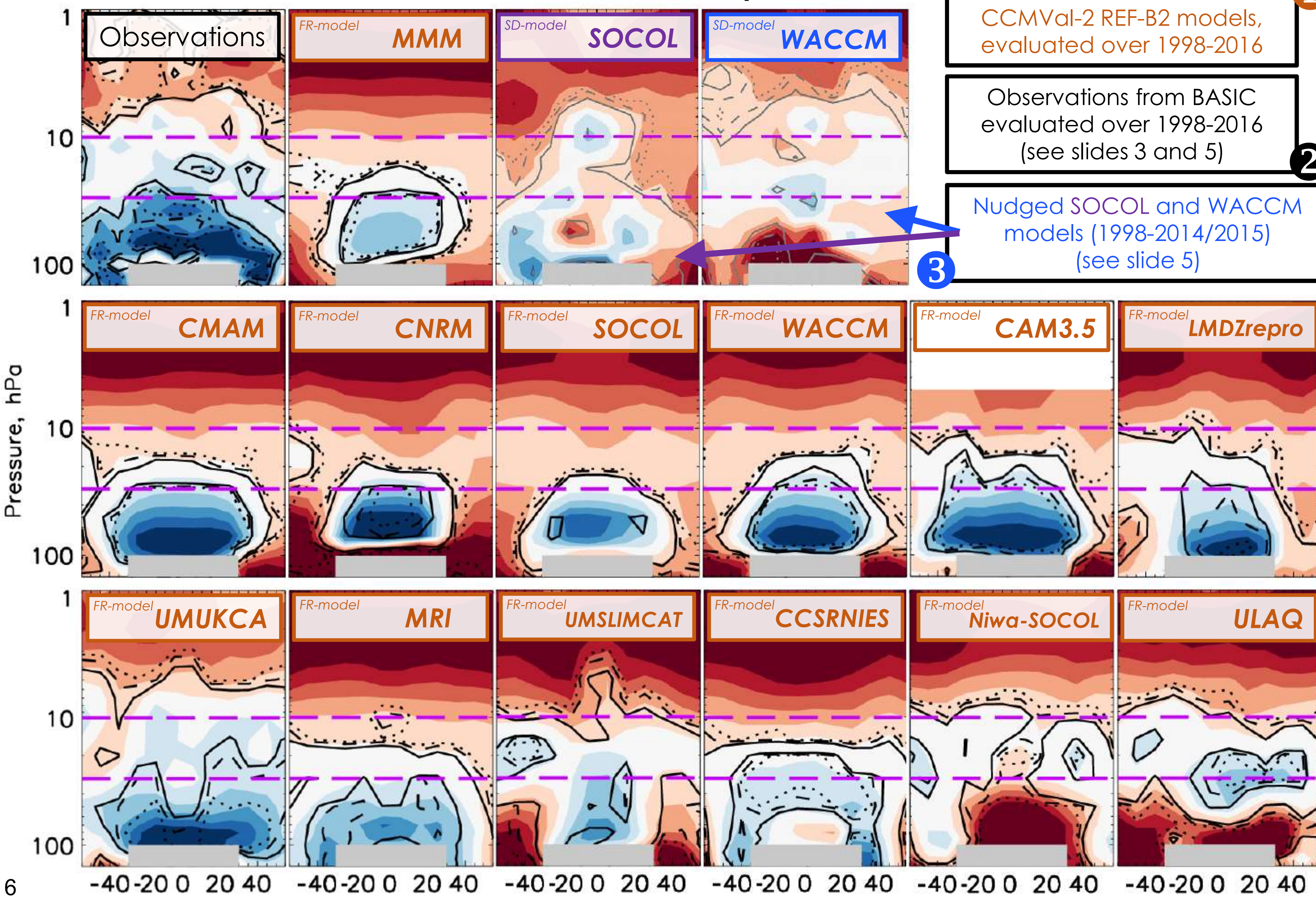
5 Nudged models ***do not agree*** *with* *observations at* ***mid-latitudes***



# Free running CCMVAL-2 models in comparison…

Ball et al., in review, ACPD




1 CCMVal-2 REF-B2 models, evaluated over 1998-2016

2 Observations from BASIC evaluated over 1998-2016 (see slides 3 and 5)

3 Nudged SOCOL and WACCM models (1998-2014/2015) (see slide 5)

Ball et al., in review, ACPD

# Free running CCMVAL-2 models

in comparison…

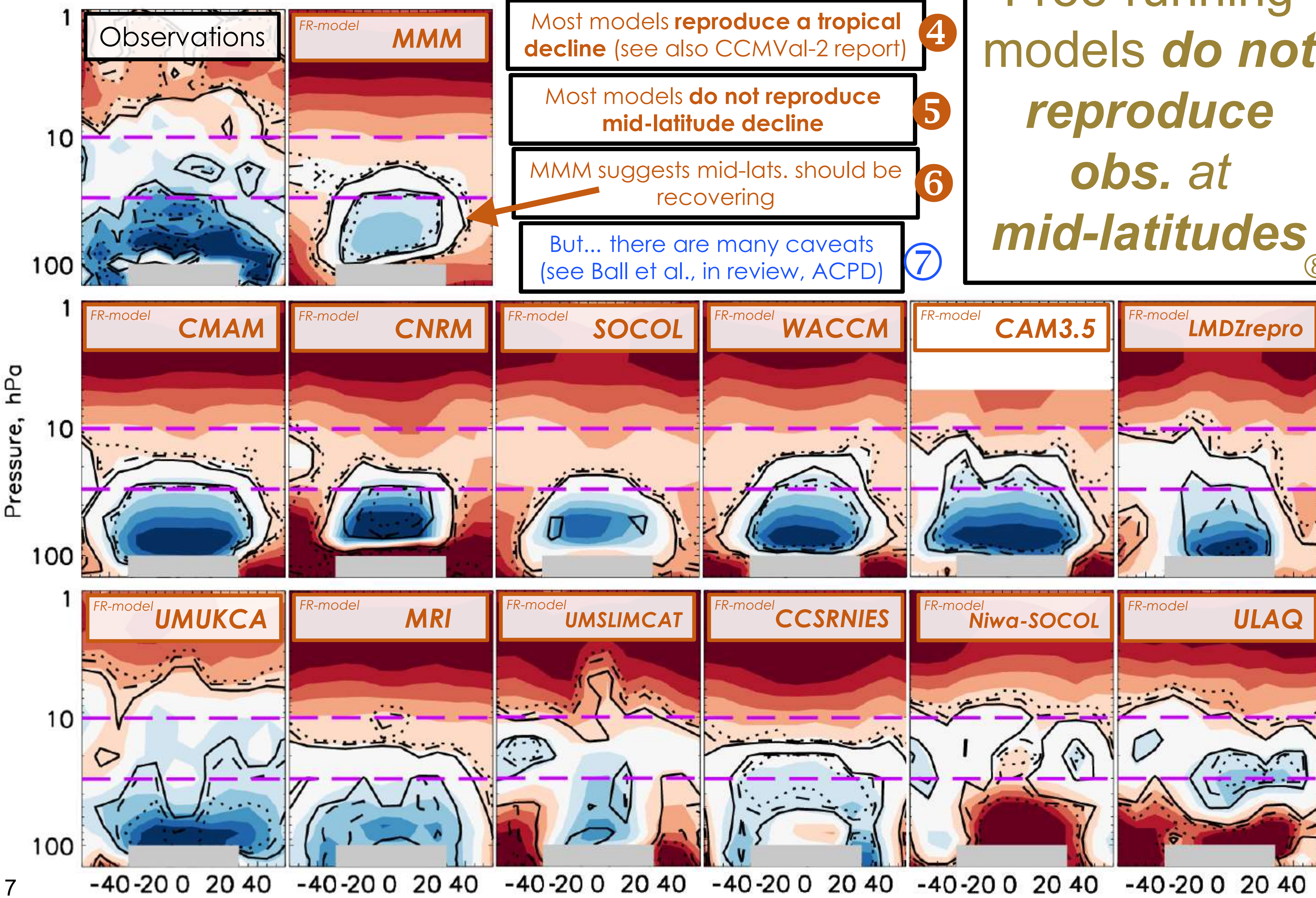
Most models **reproduce a tropical decline** (see also CCMVal-2 report) ④

Most models **do not reproduce mid-latitude decline** ⑤

MMM suggests mid-lats. should be recovering ⑥

But… there are many caveats (see Ball et al., in review, ACPD) ⑦

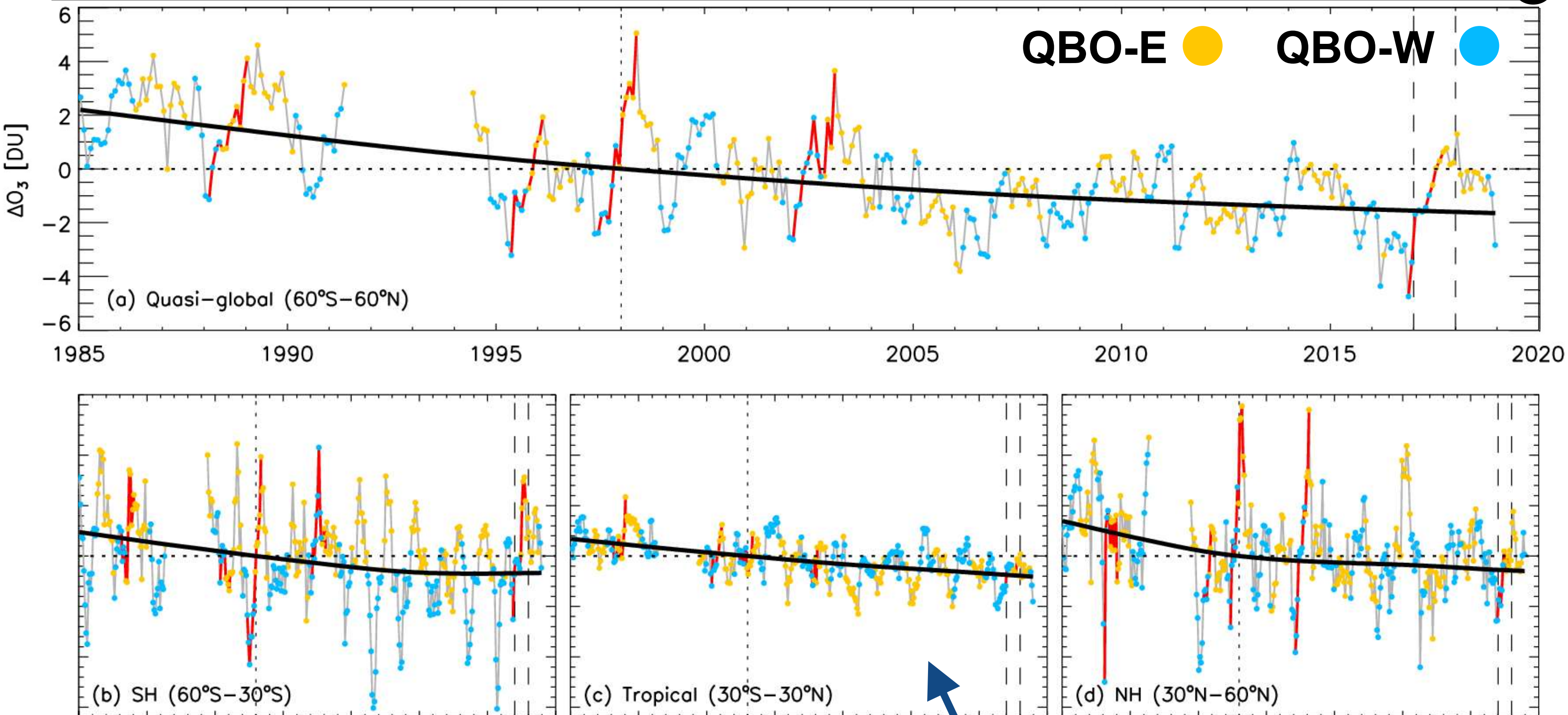
Free-running models ***do not reproduce obs.*** *at* ***mid-latitudes*** ⑧



# Observations: 1985-2018

*Ball et al., 2019*

Deseasonalised observations from BASIC composite (grey) with large upward surges identified, such as in 2017 (see slide 4); easterly or westerly QBO states at 30 hPa (yellow/blue dots); ozone data are integrated lower stratospheric ozone (a) globally, (b) southern hemisphere, (c) tropical, and (d) northern hemisphere. ❶



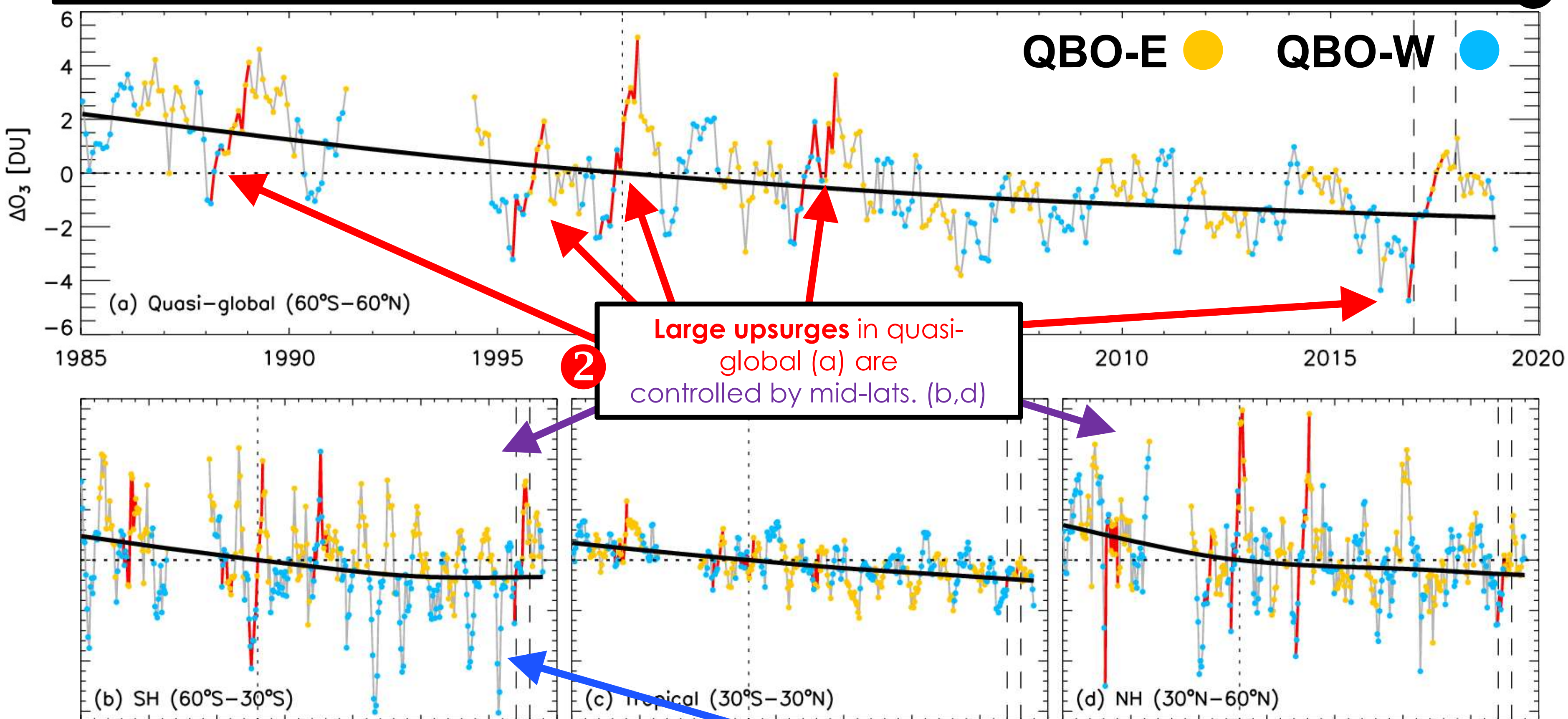

**Tropical lower stratospheric ozone:** variability much lower than mid-lats.; displays downward trend; robust with 95% probability by 2018 (see slide 3) ❷

**Tropical decline** is robust *and upwelling acceleration may be responsible* ❸

# Observations: 1985-2018

*Ball et al., 2019*

Deseasonalised observations from BASIC composite (grey) with large upward surges such as in 2017 (see slide 4); easterly or westerly QBO states at 30 hPa (yellow/blue dots); ozone data are integrated lower stratospheric ozone (a) globally, (b) southern hemisphere, (c) tropical, and (d) northern hemisphere. ❶




❷ The large changes appear to be dominated by a non-linear QBO-seasonal interaction, which is particularly clear in the southern hemisphere

❸ Models do not appear to reproduce this QBO-seasonal variability well (**see A. Stenke:** EGU2020-16682)

**Mid-latitude differences** *may be related to QBO representation* *(this is an open line of research)* ❹

# Conclusions

- Observational data **imply**
  *ozone is still decreasing in the lower stratosphere*
  Ball et al., 2017, 2018, 2019

- Chemistry transport models **agree**
  *and attribute changes to dynamics*
  Chipperfield et al., 2018; Wargen et al., 2018; Orbe et al., 2020

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**See also presentation by A. Stenke (EGU2020-16682)**