How robust are stratospheric age of air trends from different reanalyses?

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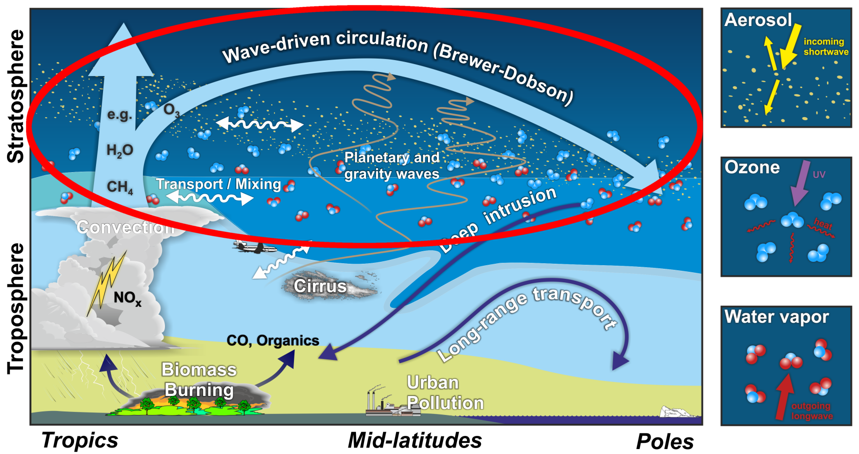
JÜLICH Forschungszentrum

Motivation

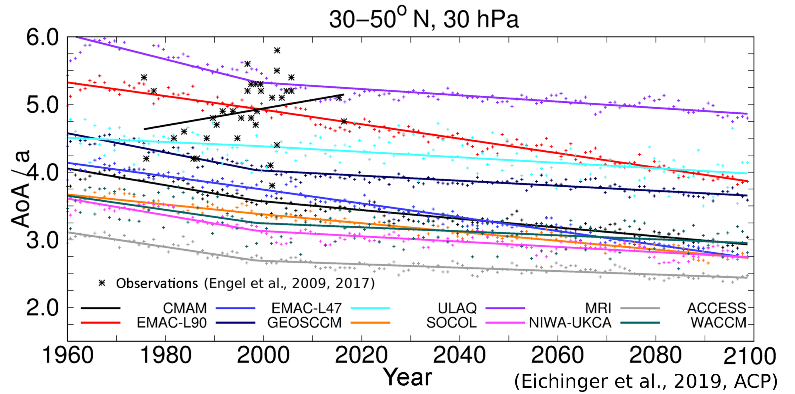


★ Stratospheric Brewer-Dobson (BD) circulation controls trace gas composition ⇒ relevant for climate

★ BD-circulation measured by **age of air**: transit time through stratosphere

Motivation

★ How does age of air (and BD circulation) changes with climate change?



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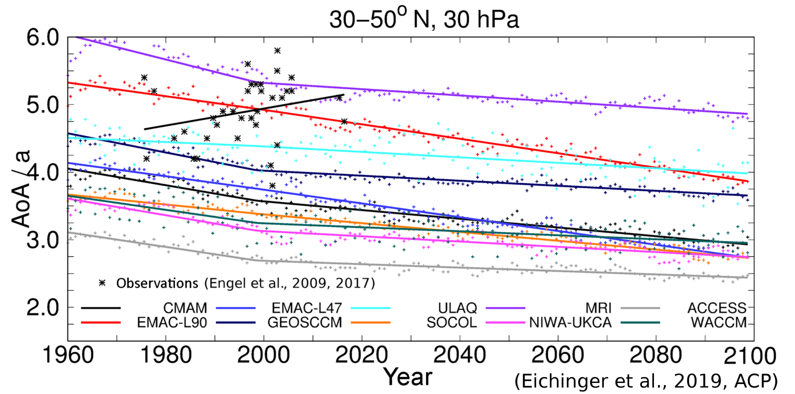


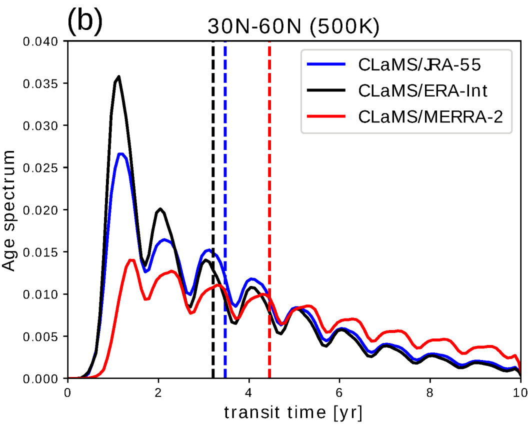
Brewer-Dobson circulation puzzle:

Climate models show decreasing age - observations not!

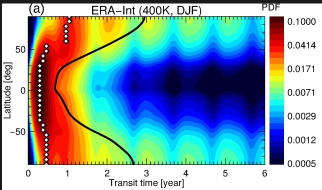
$\Rightarrow$ **What about current generation reanalyses?**

Method

- Lagrangian diabatic transport model CLaMS for 1989–2015
- Driven by different reanalyses: ERA–Interim, JRA–55, MERRA–2
- Age spectrum and mean age from inert pulse tracers (in CLaMS)



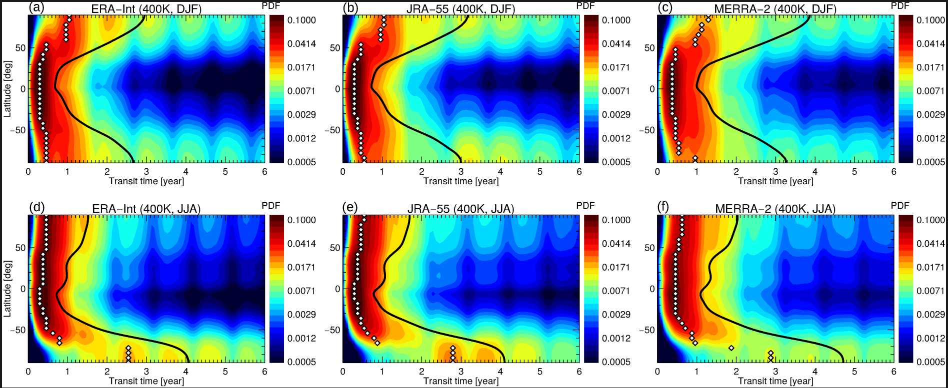
Seasonality in age of air



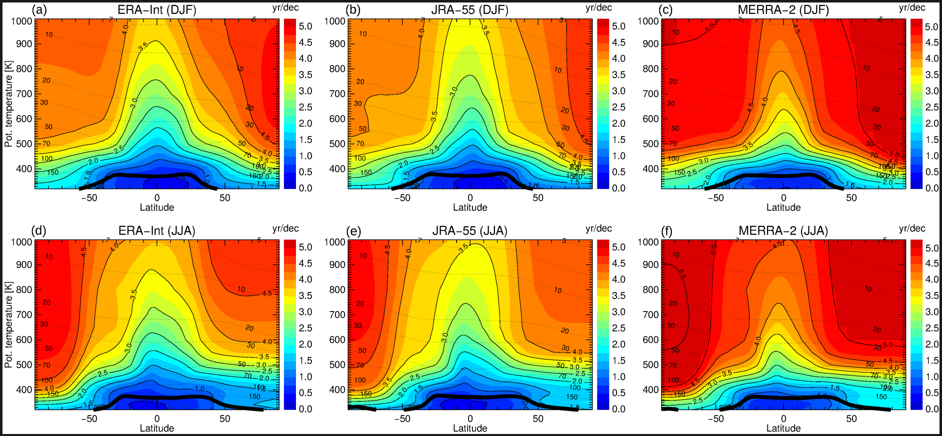
Age spectrum, 400K (Dec-Feb)

ERA-Interim

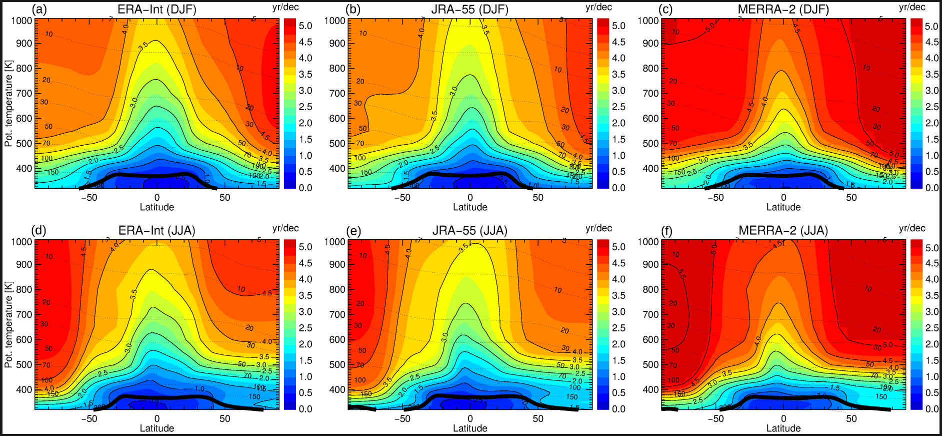
Seasonality in age of air



- ★ Annual spectrum peaks for all reanalyses ⇒ seasonality in stratospheric transport robust
- ★ Weaker tropics-extratropics gradient for MERRA–2 ⇒ stronger exchange (recirculation)



- ★ Robust features in reanalyses: tropical air youngest in NH winter
  oldest air in winter hemisphere
- ★ MERRA–2 shows substantially older air ⇒ result of stronger recirculation



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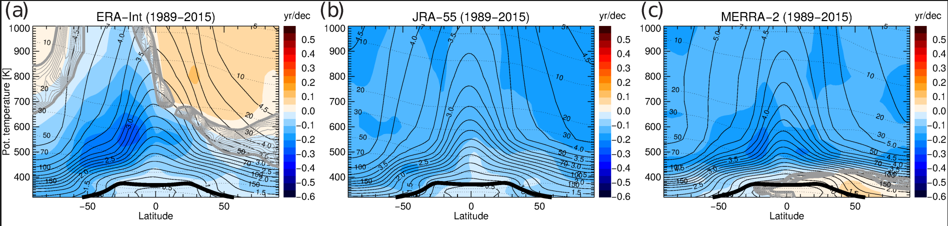
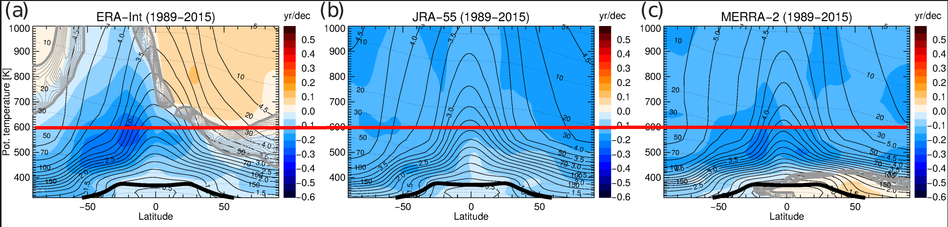
Seasonality in stratospheric transport

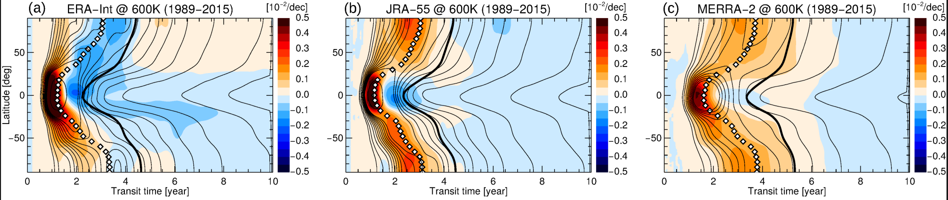
⇒ robustly represented in reanalyses

Trends in age of air (1989–2015)

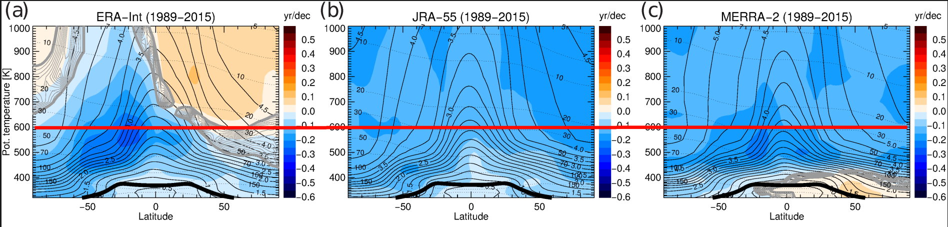


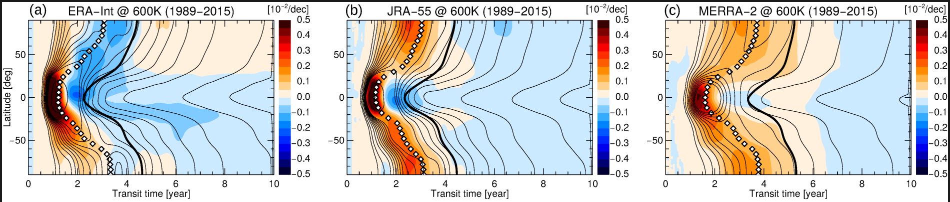
- ★ Decreasing mean age in stratosphere ⇒ accelerating BD-circulation
- ★ Differences in NH above 30 hPa (24 km): aging in ERA-Interim





- ★ Age spectrum trend at **600 K**: shift towards shorter transit times
- ★ Shift of peak (modal age) ⇒ accelerating residual circulation





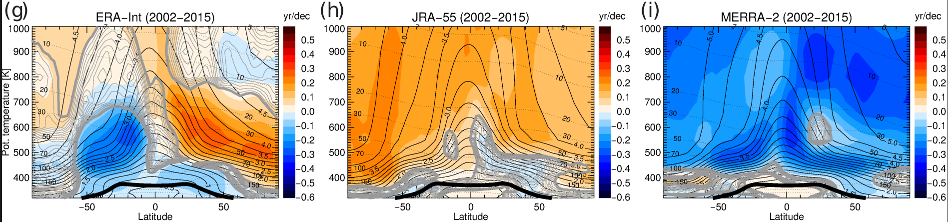
★ Age spectrum trend at **600 K**: shift towards shorter transit times

★ Shift of peak (modal age) ⇒ accelerating residual circulation

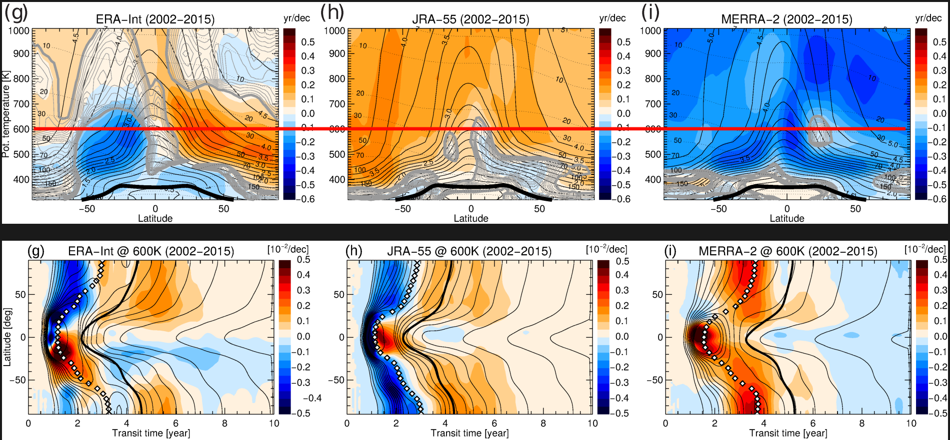
Age of air trend 1989–2015:

Robust acceleration of residual circulation

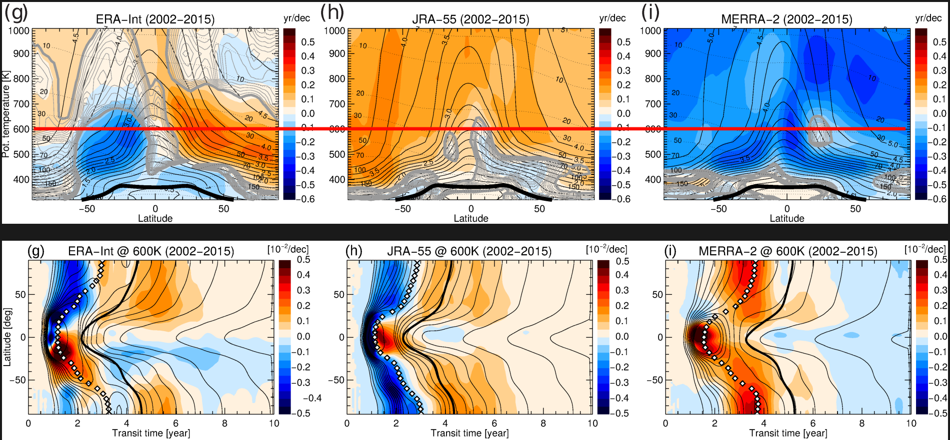
Decadal changes of age of air (2002–2015)



- ★ Mean age changes 2002–2015 very different
- ★ Opposite changes for JRA–55 and MERRA–2
- ★ Dipole pattern (NH–SH) only for ERA–Interim



- ★ Age spectrum change at **600 K**: very different
- ★ Shift towards lower/higher transit time for MERRA–2/JRA–55
- ★ Dipole pattern for ERA–Interim



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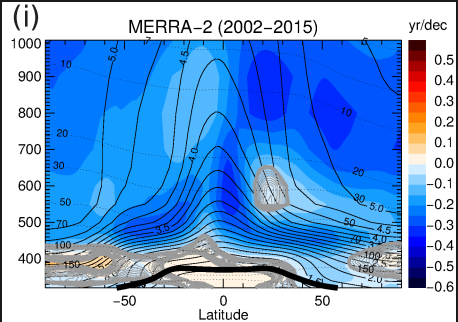
Decadal age of air change 2002–2015:

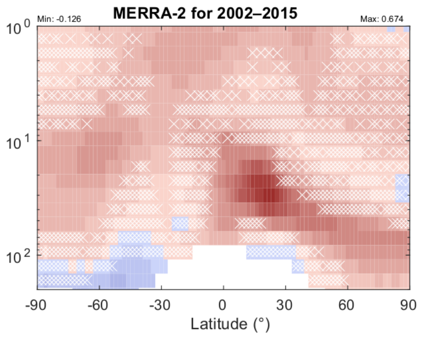
Very sensitive to reanalysis

Comparison to kinematic transport (Chabrillat et al., 2018)

CLaMS /diabatic
(Ploeger et al., 2019)

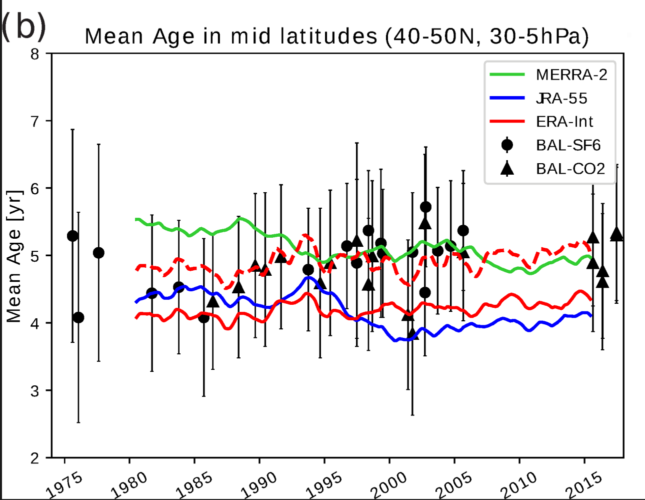


BASCOE / kinematic
(Chabrillat et al., 2018)



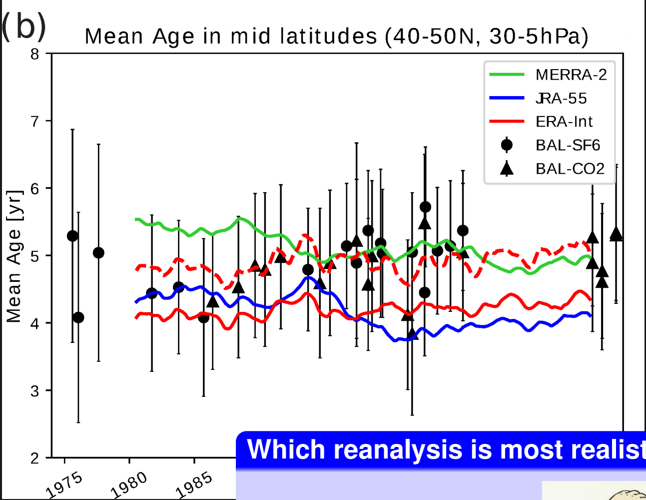
★ Decadal age of air changes sensitive to used model transport scheme

Comparison to observations



- ★ Reanalyses age trends cover observational uncertainty range
- ★ ERA–Interim shows positive trend - as observations

Comparison to observations



★ Reanalyses age trends co

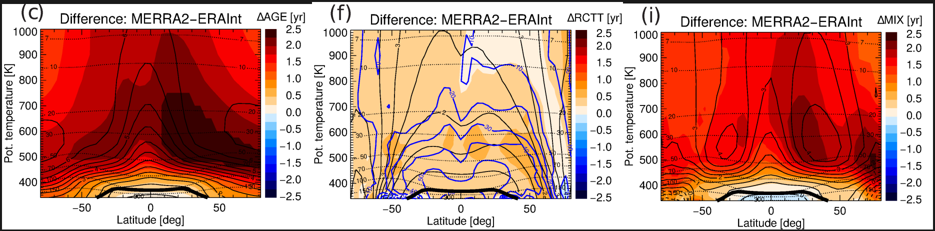
★ ERA–Interim shows positiv

Which reanalysis is most realistic?

No clear answer from existing observations...

Residual circulation and mixing

ΔAge = ΔCirculation + ΔMixing



- ★ Residual circulation differences alone do not explain higher age for MERRA–2
- ★ Mixing effect important ("aging by mixing", Garny et al., 2014)
- ★ Stronger mixing effect caused by slower upwelling...!?

Conclusions

- ★ Comparison of age of air in stratosphere in current generation reanalyses (ERA–Interim, JRA–55, MERRA–2)
- ★ Mean age climatological value sensitive to reanalysis
  $\Rightarrow$ MERRA–2 shows older stratosphere
- ★ Seasonality in age of air robustly represented: mean age
  age spectrum peaks
- ★ "Long-term" trends (1989–2015) robustly represented
  $\Rightarrow$ acceleration of Brewer-Dobson circulation
- ★ Decadal trends sensitive to chosen reanalysis
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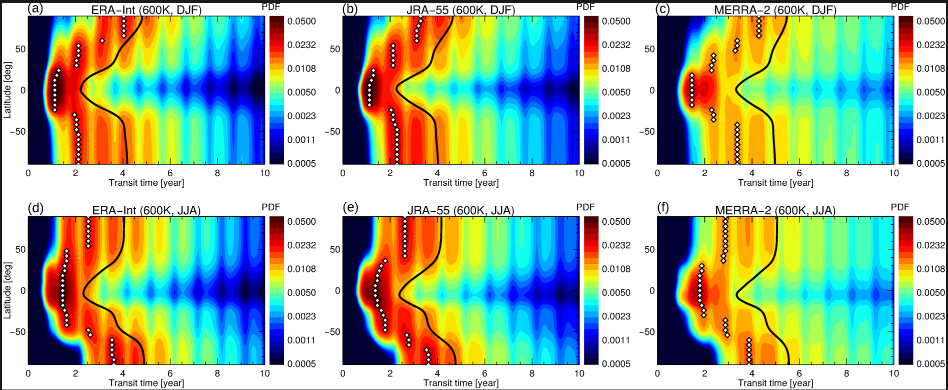
Appendix

Seasonality in age of air



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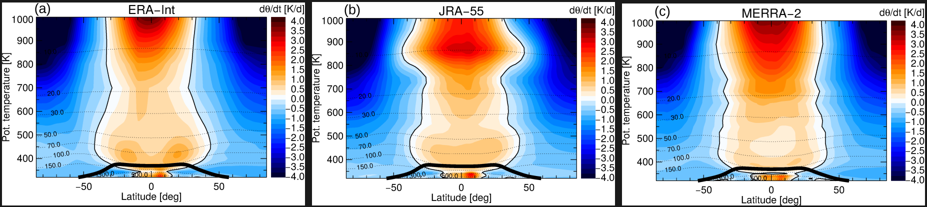
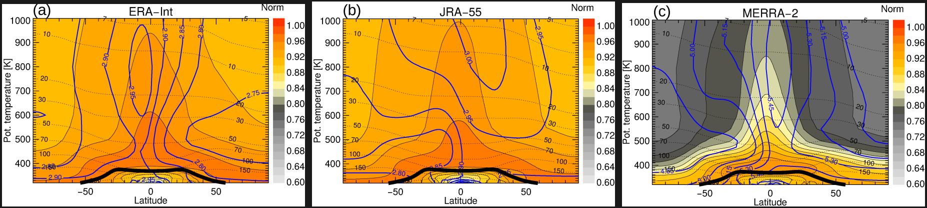
Diabatic heating rates in reanalyses



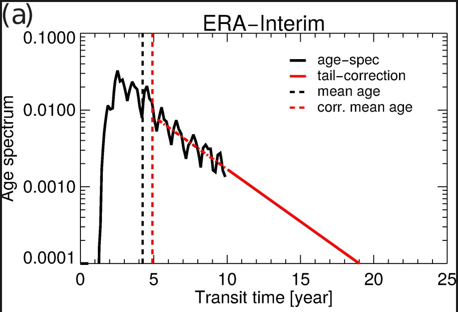
- ★ Weaker upwelling for MERRA–2 in lower stratosphere (“bottle-neck” around 350 K)

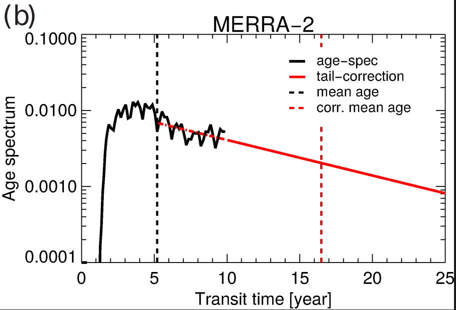
Age spectrum norm



★ Normalization of age spectra less stringent for MERRA–2 ⇒ larger amount of very old air

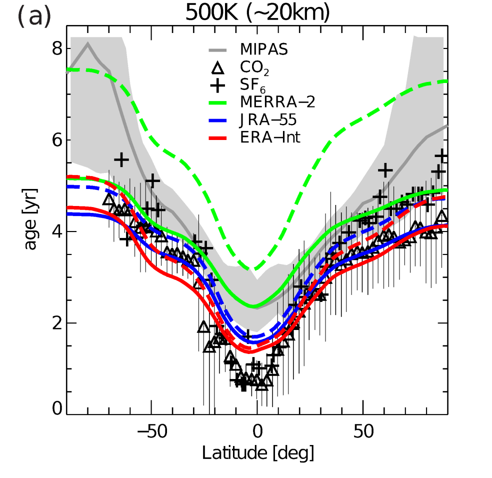
Tail decay of age spectra



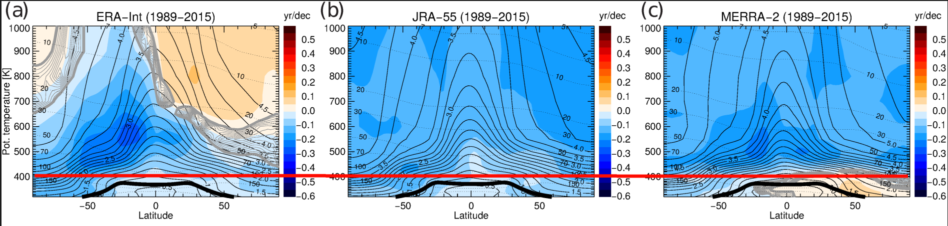


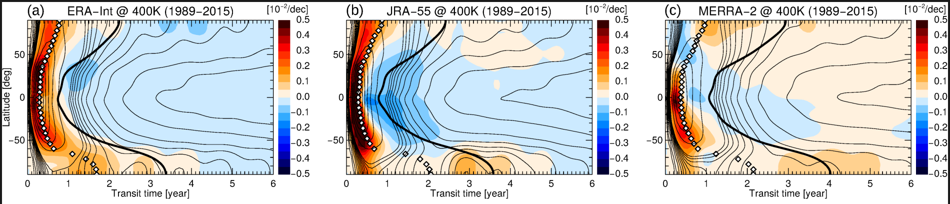
★ No clear exponential decay of age spectrum tail for MERRA–2

Comparison to observations



- ★ Mean age from different reanalysis in observational range
- ★ MERRA-2 shows older air in tropics





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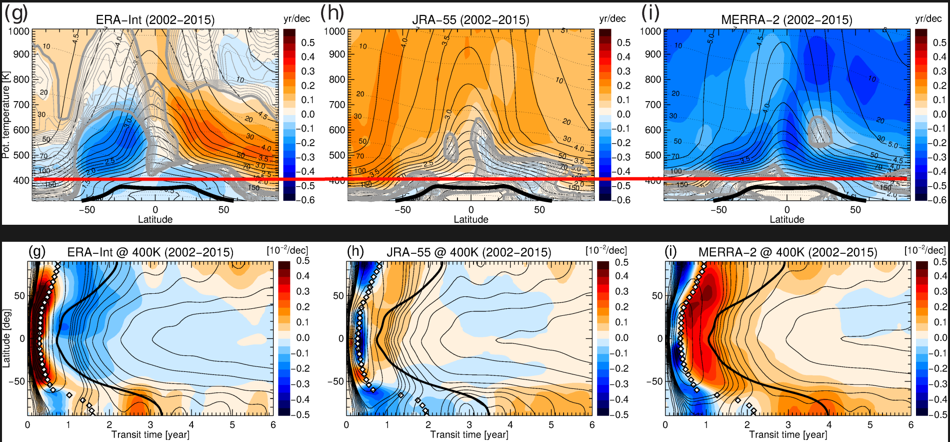

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