Mean age of stratospheric air since 1985: large disagreements between five modern reanalyses?

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S-RIP Workshop, 23 October 2017
ECMWF, Reading, U.K.

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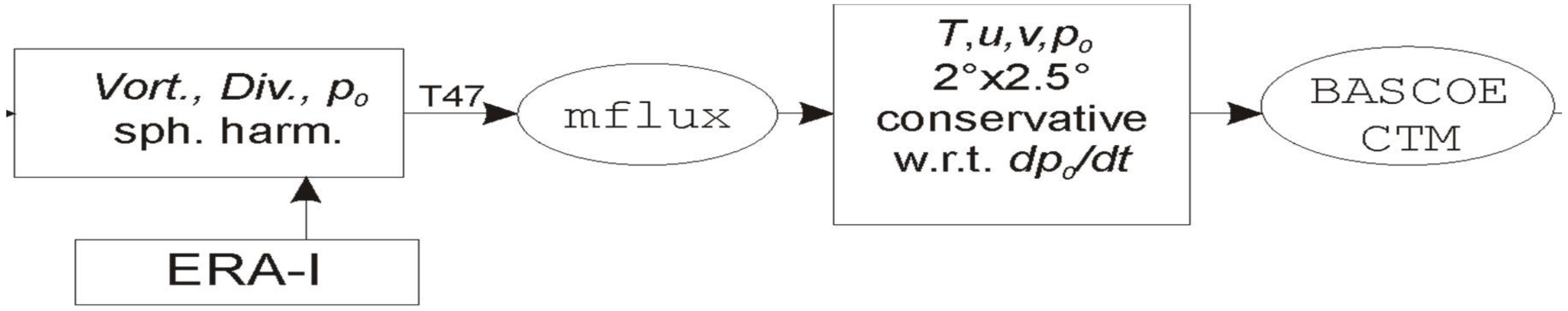
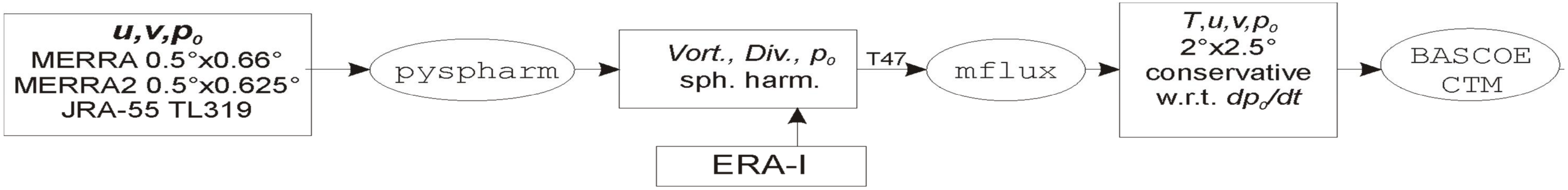
Pre-processing of ERA-I (i.e. spectral models)



BASCOE usually driven by ECMWF analyses (operational or **ERA-I**) :

- Start from *VO, D,* p_0 in spherical harmonics
- Keep native vertical grid (ERA-I: 60 levels)
- Choose coarse horiz grid: 2°x2.5°
  (Rotman et al., JGR, 2001)
- Truncate for FFSL on 2°x2.5° grid: T47
- Correct horiz winds for dp_0/dt and eval *u, v, p0* on 2°x2.5° grid (Segers et al., 2002)

Pre-processing of other (gridded) reanalyses



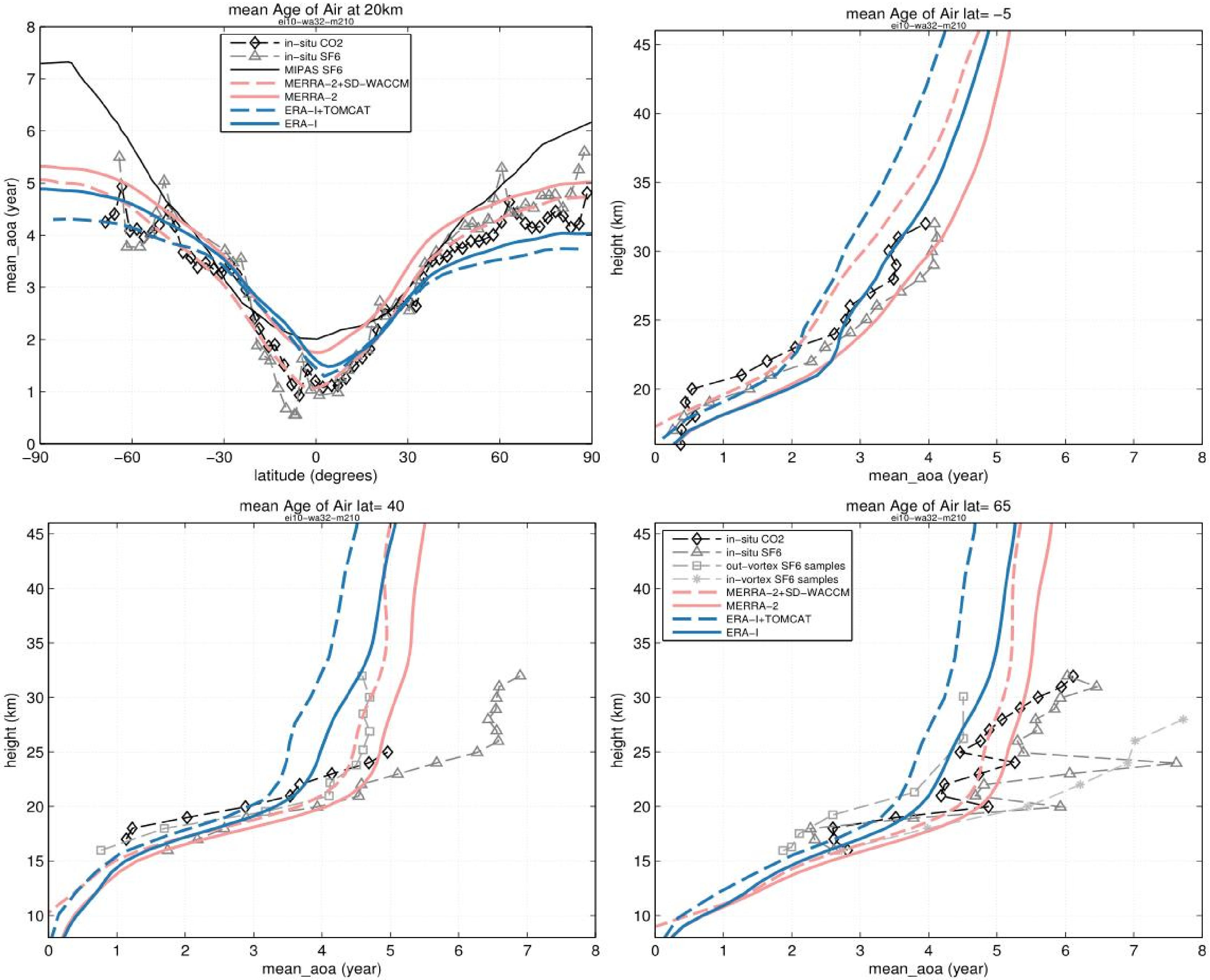
All other reanalyses (**MERRA**, **MERRA-2 ASM**, **JRA-55**, **CFSR/CFSv2**) provide *p0, u,v* on hi-res horiz grid

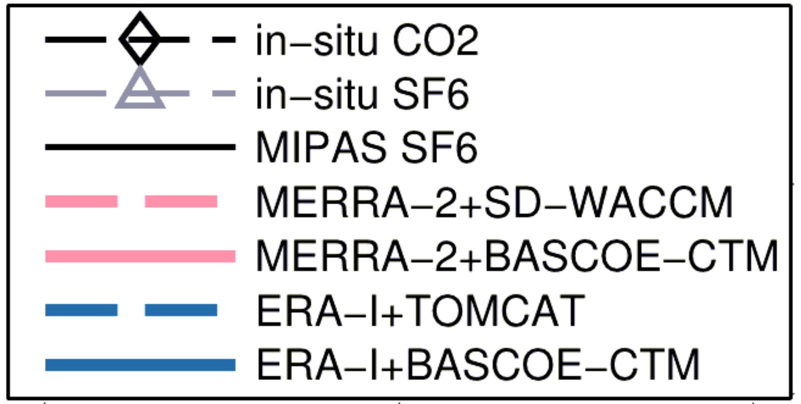
→ evaluate *VO, D,* p_0 in spherical harmonics and keep same pre-processing as for ERA-I

→ All reanalyses are truncated to T47

→ each reanalysis is run on its original vertical grid

Model verification: fixed-year 2000

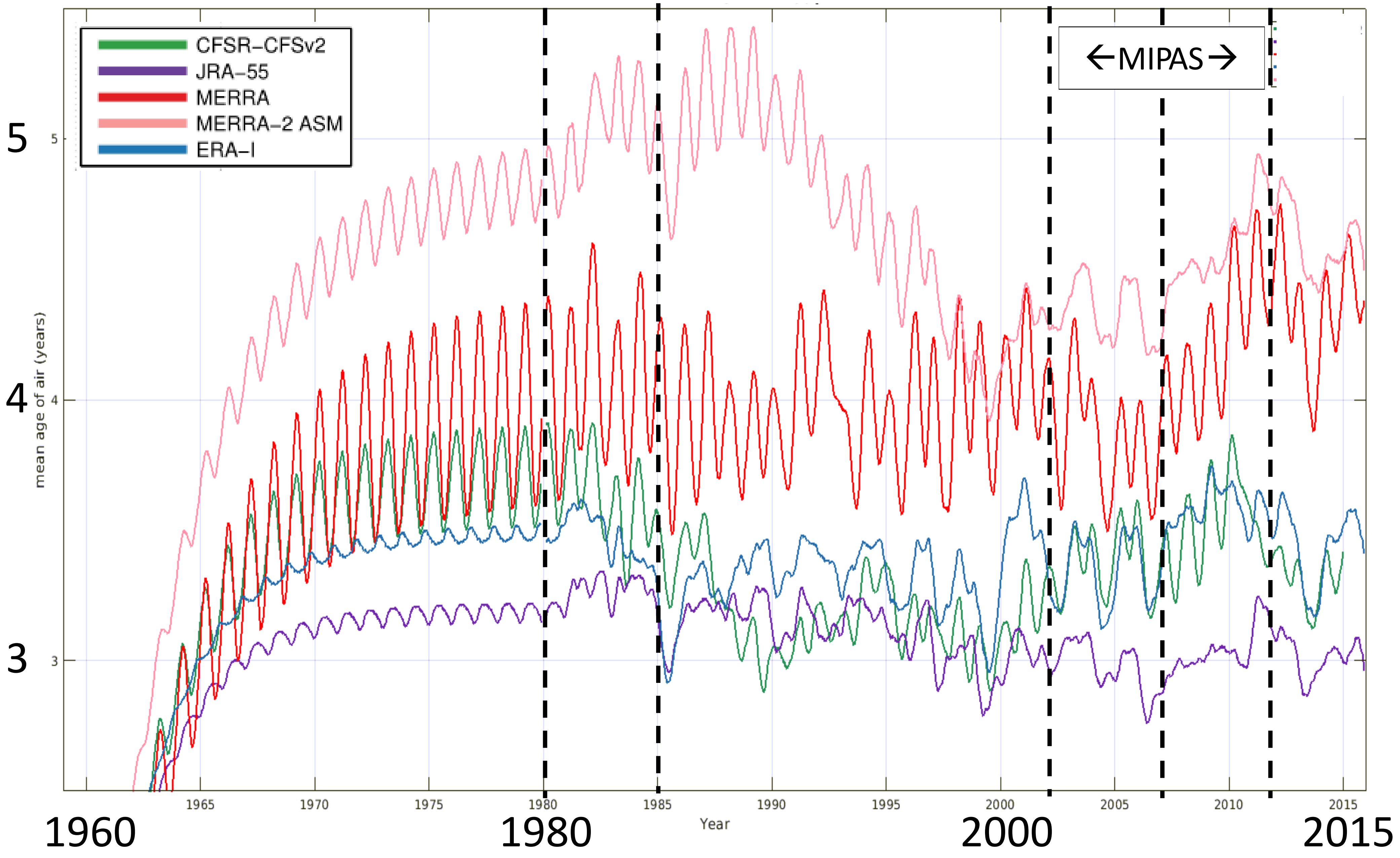




ÅRef region: surface (not TTL)
ÅNo param for convection
ÅTropical lower strato:
AoA slightly older than with TOMCAT or SD-WACCM
ÅThis overestimation propagates to other latitudes and higher levels
ÅImpacts all reanalyses in the same manner → intercomparison OK

Setting up the intercomparison

40°N-50°N ; p = 50 hPa (~20km)

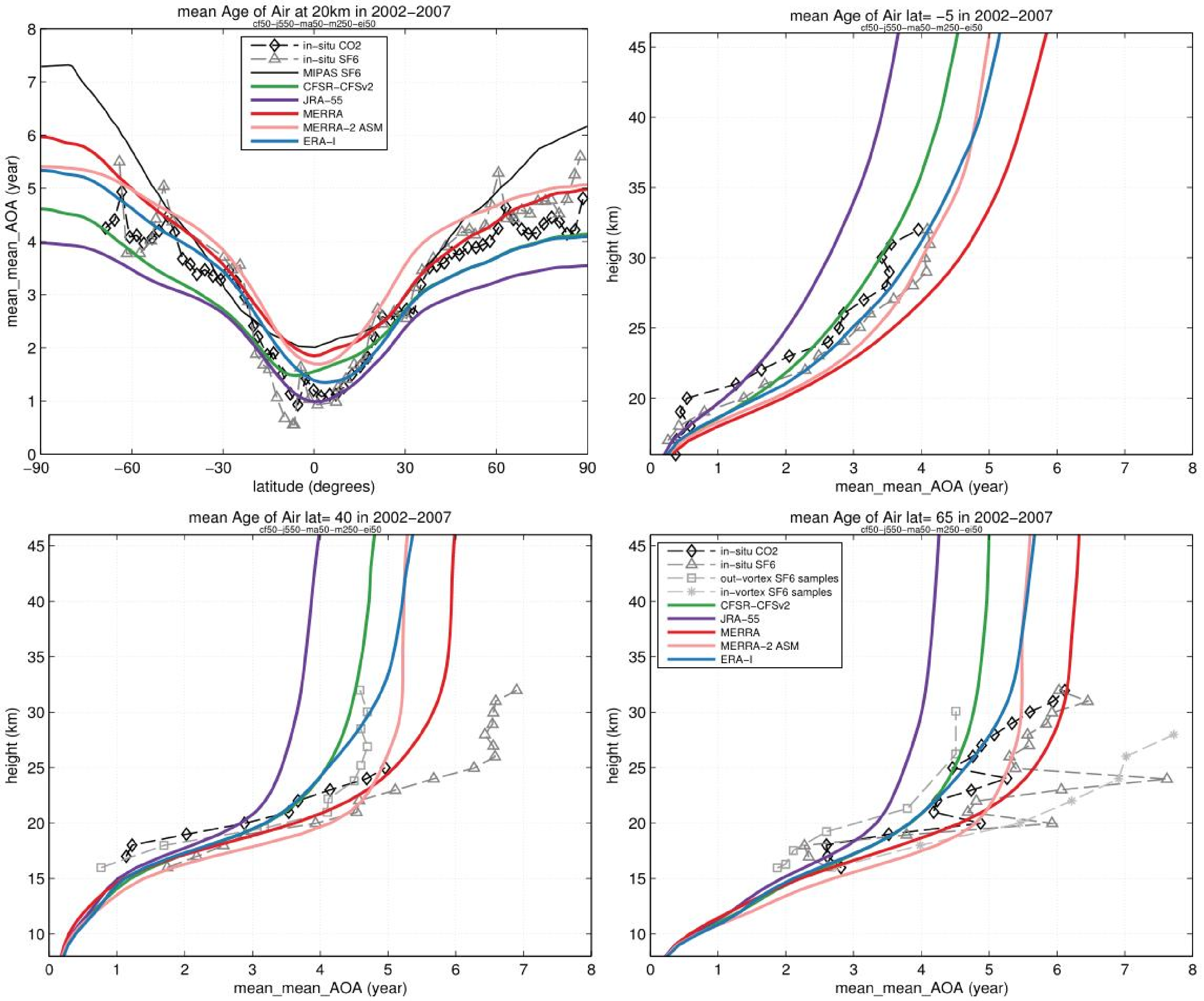


- Synthetic tracer increasing linearly at surface
- Let each simulation start from its own reanalysis

→ **20 years of fixed-year 1980**

- Drop first 5 years (~AoA=time for interannual vars to reach ROI)
- **Large differences between reanalyses:** abs. vals; ampl. season. and QBO cycles; trends
- ATOVS hiatus around 2000: mainly for MERRA-2 (seasonal ampl; trend)

Absolute values: 2002-2007 mean



Å **At 20km**: **JRA-55** youngest,
MERRA and **MERRA-2** the oldest

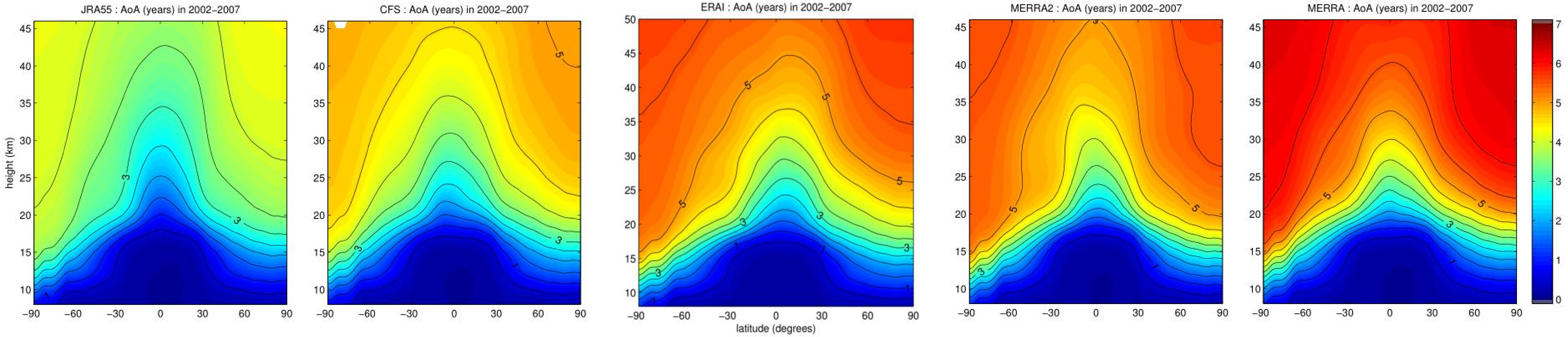
Å Equator-to-pole gradient:
weakest by **CFSR/CFSv2**
strongest by **MERRA-2**

Å **Vertical profiles**: **JRA-55** youngest,
MERRA oldest – at all latitudes

Å **MERRA-2** stands out:
vertical gradients larger in lower strato
but much smaller in upper strato

Å **ERA-I** intermediate and used in previous
CTM studies → chosen as reference

Absolute values: 2002-2007 mean

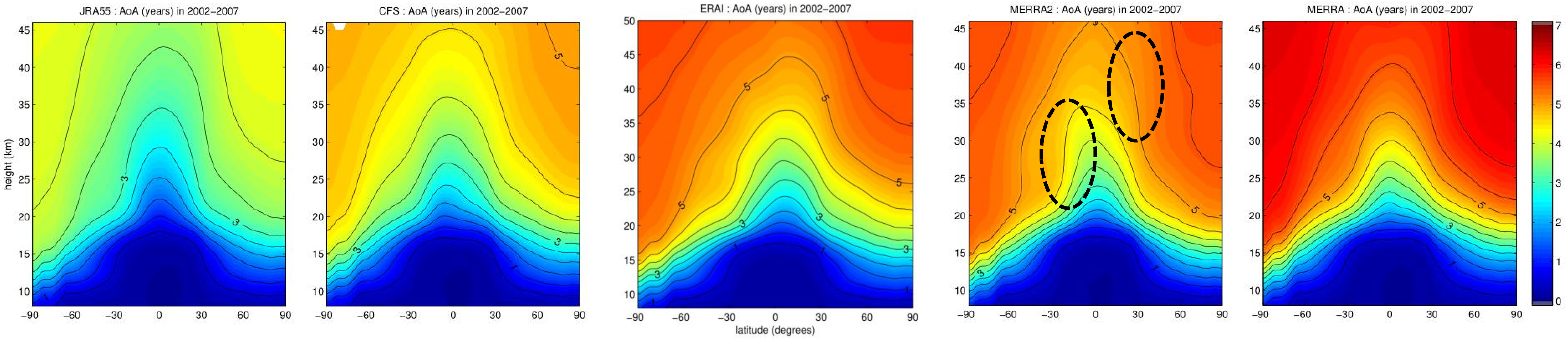


JRA-55 CFSR/CFSv2 ERA-I MERRA-2 MERRA

youngest: max(AoA) < 4.5 yr

oldest: max(AoA) >= 6 yr

Absolute values: 2002-2007 mean



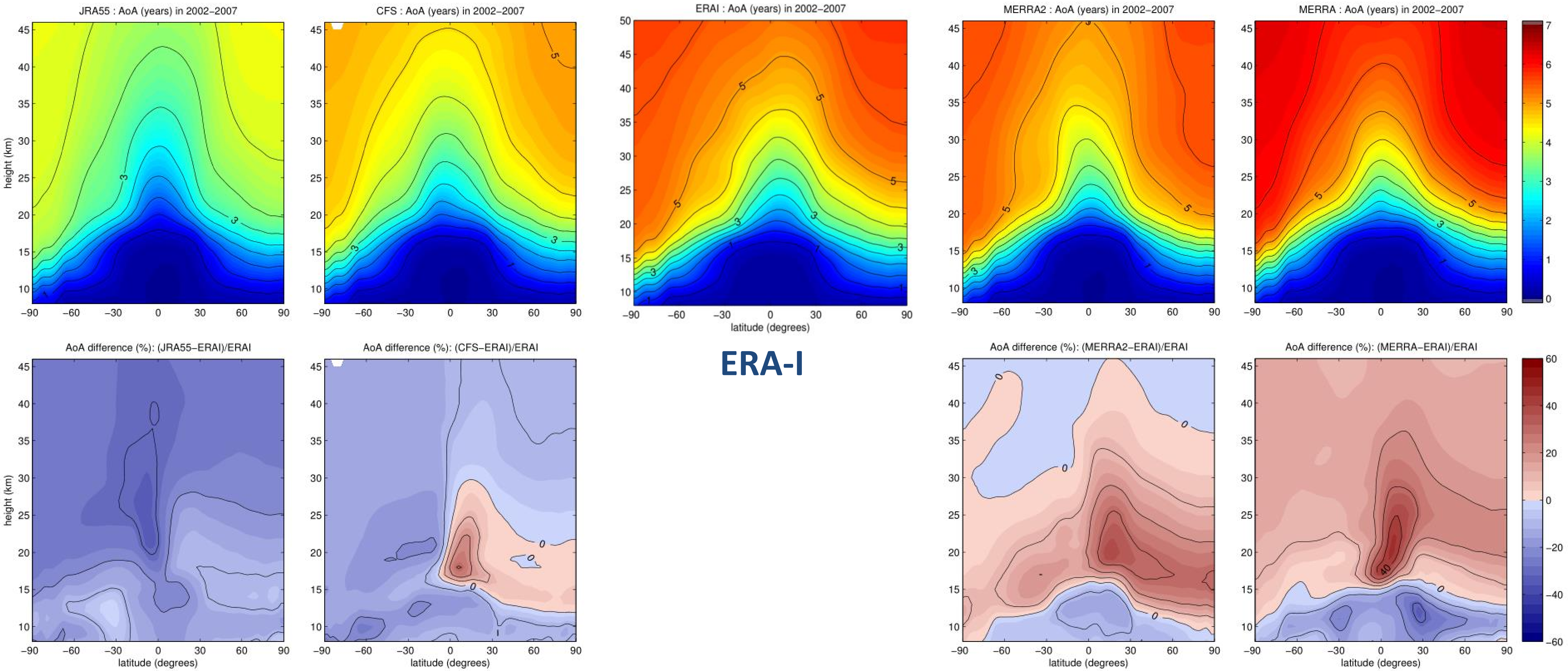
JRA-55 **CFSR/CFSv2** **ERA-I** **MERRA-2** **MERRA**

youngest: max(AoA) < 4.5 yr

oldest: max(AoA) >= 6 yr

Vertical isolines
not in MIPAS obs

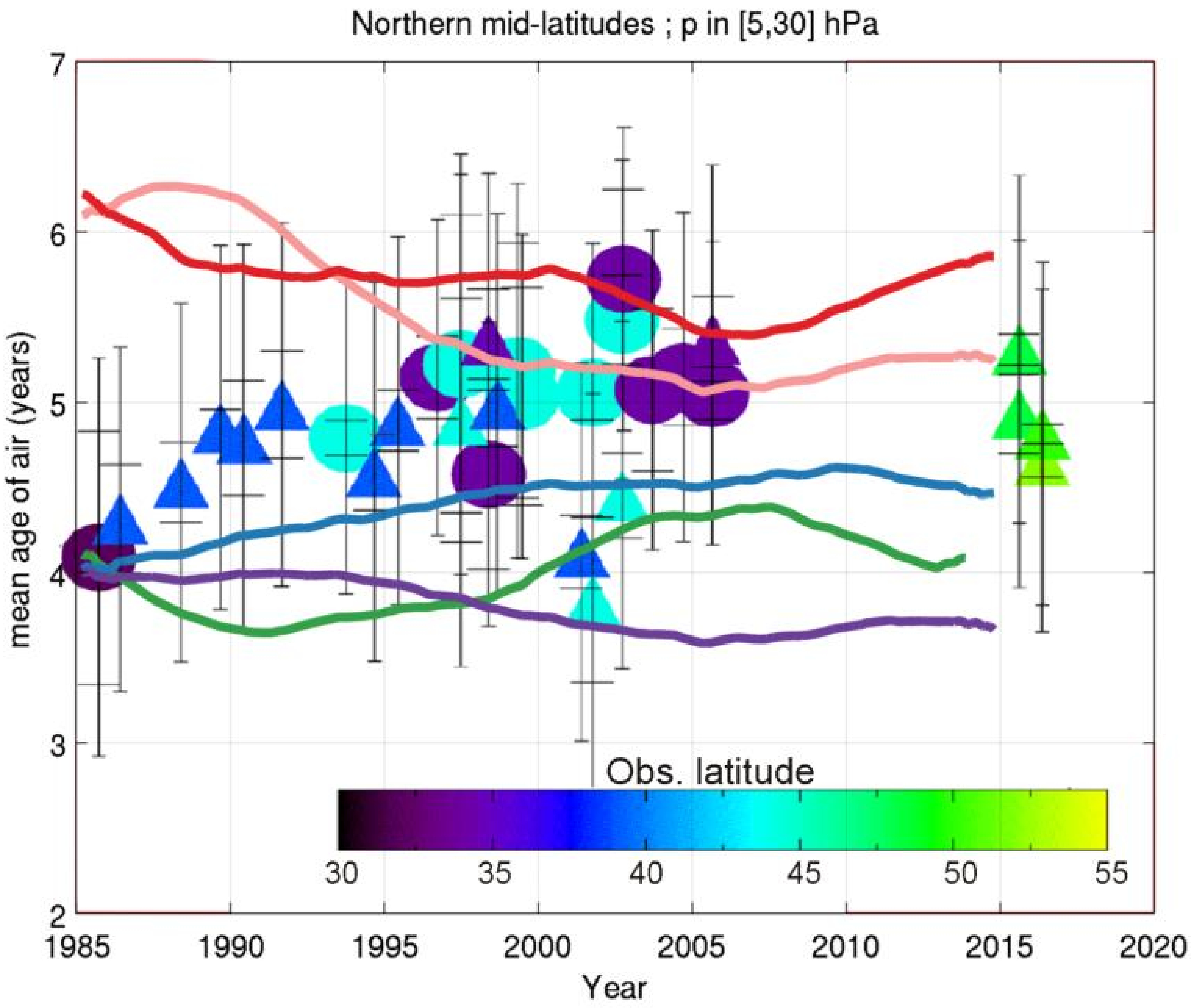
2002-2007 mean: relative diff. w.r.t. ERA -I



JRA-55 **CFSR/CFSv2** **MERRA-2** **MERRA**

Largest relative differences are in **tropical lower strato**

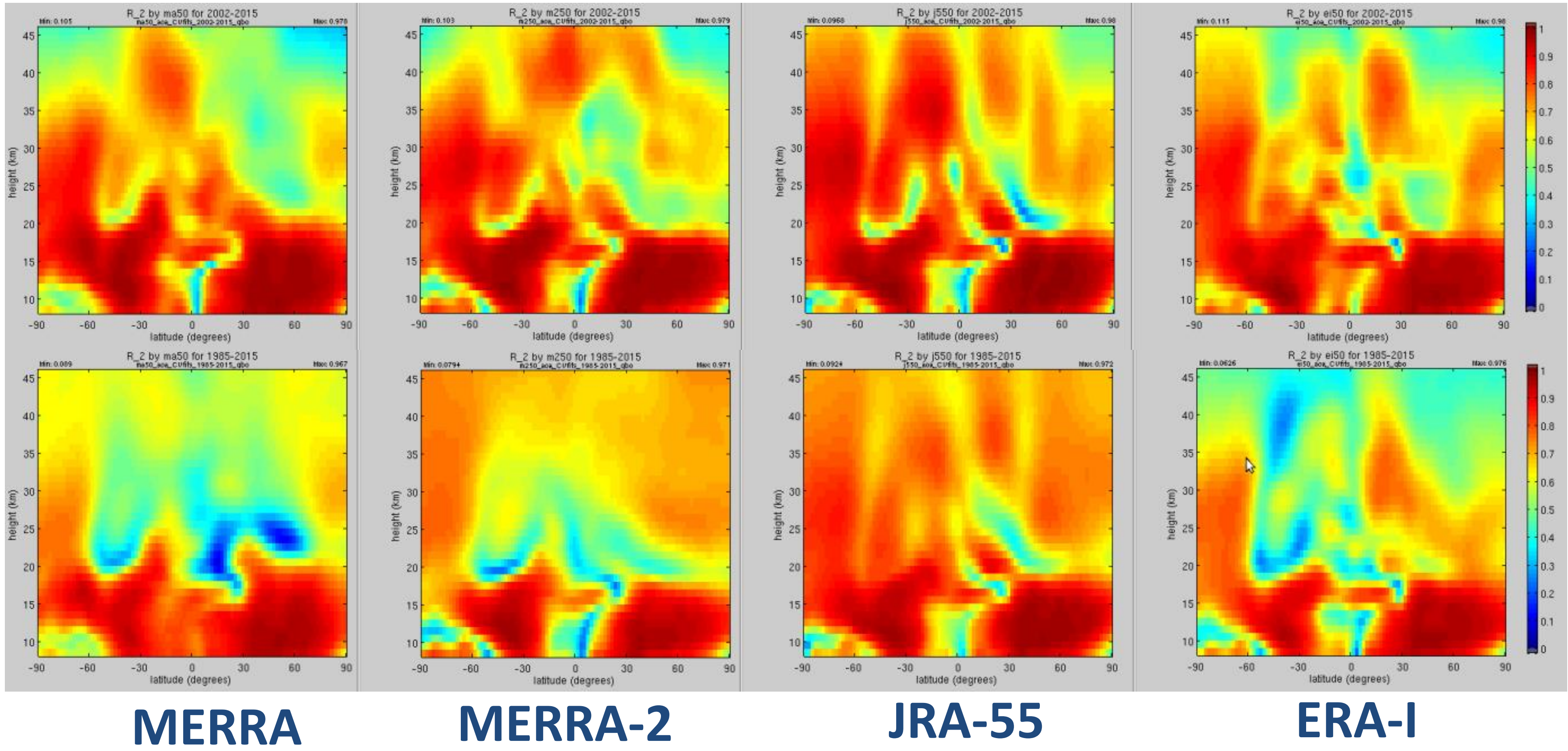
Time evolution in mid-strato N.Lat. versus ballon obs (Engels et al., 2017)



- Balloon obs are sparse
  → outer error bars include representativeness uncertainties
- **MERRA**, **MERRA-2** higher during 1980's
- **CFSR/CFSv2** lower during 1990's
  JRA-55 lower during early 2000's
- **ERA-I** : weakly positive trend over 1985-2015 seems to agree with obs but obs trend is not significant
- **ERA-I** : not overall trend after 2000, unless one arbitrarily ends in 2010
- Clear disagreements between trends by 5 reanalyses. Over 1985-2015: no change > 0.5 yr (except for MERRA-2…)
- Reminder: results obtained with one specific CTM !

Fitting with linear regression model

- Derive $A(t)$: monthly means of AoA as a function of latitude and *height* (interpolated to a 1 km grid)
- Fit: $A(t) = A_0 + A_1.t + S(t) + Q(t) + \varepsilon(t)$
- $Q(t)$ combines usual QBO index (u at Singapore, 10 and 30 hPa) with seasonal modulations
- Tried also ENSO and volcanic signals but found insignificant
- Considered periods 1985-2001, 2002-2015, 1985-2015



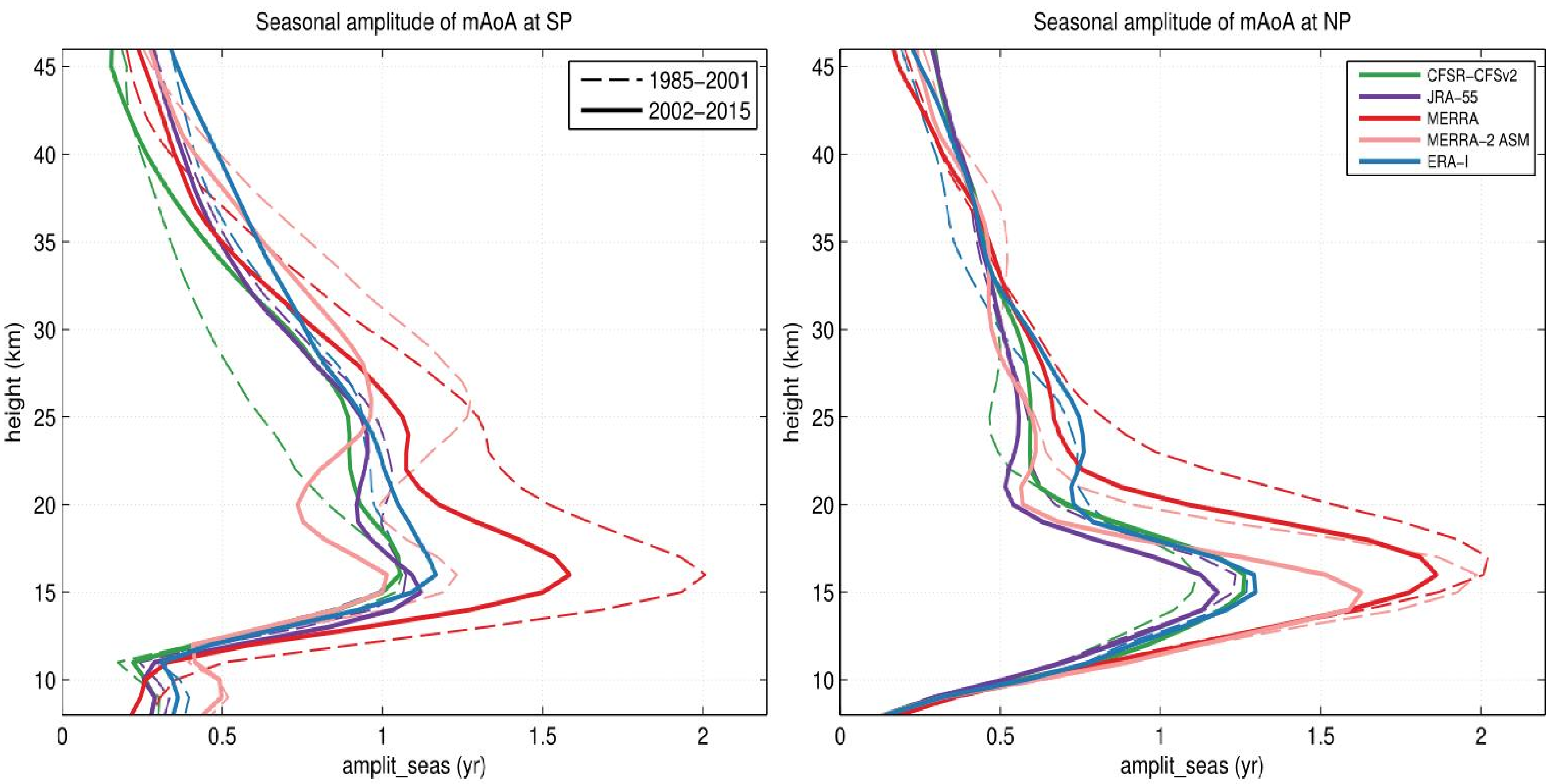
Correlation coefficients R_2

2002-2015

1985-2015

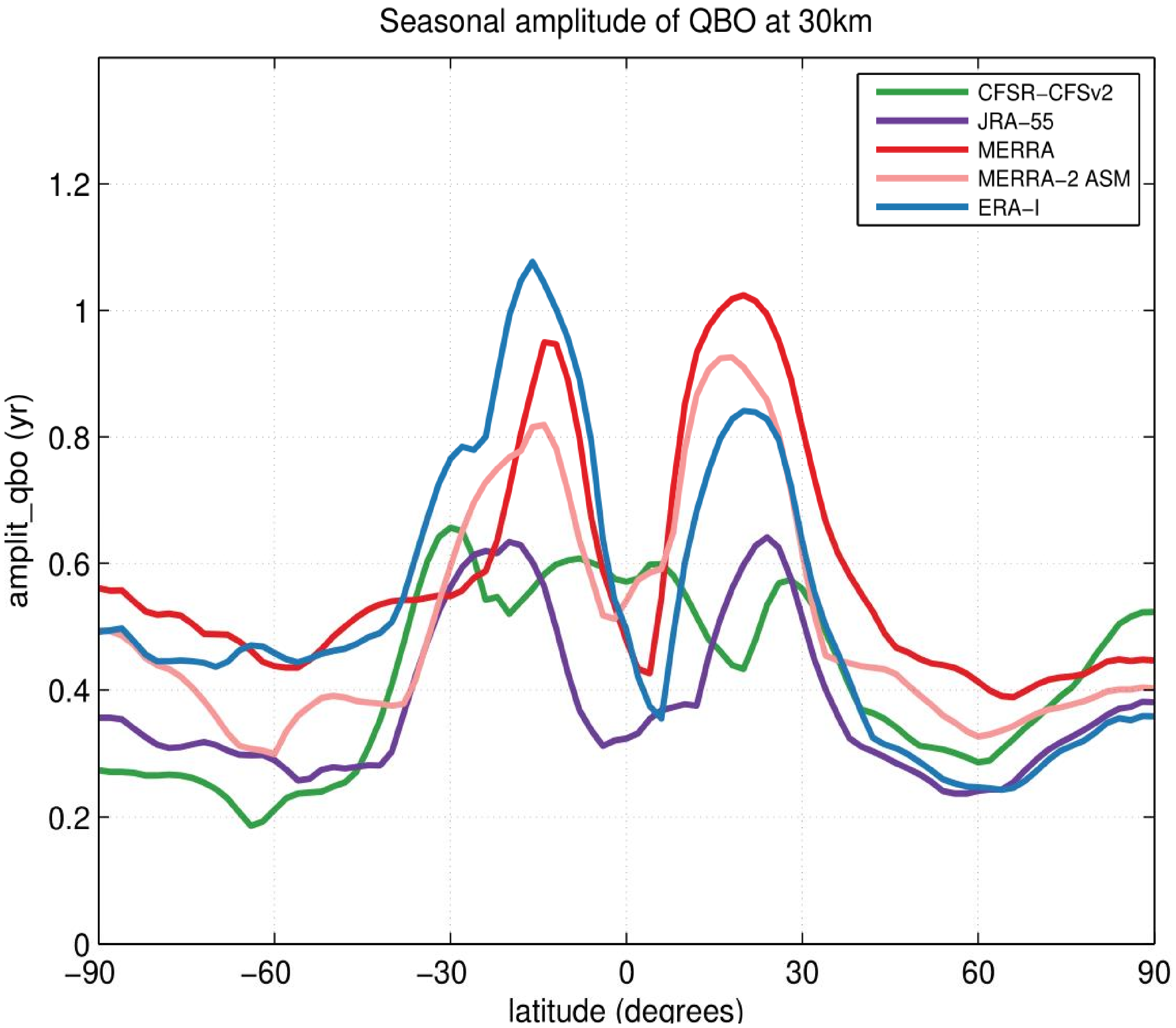
Amplitude of seasonal variations at poles

ÅERA-I : amplitude reaches ~1yr at poles, 16 km → agrees with Diallo et al. (2012)
ÅVertical structure ~same for 5 reanalyses



- ÅMid-strato: ERA-I smooth; others have secondary max
- ÅMERRA amplitudes twice larger than others
- ÅMERRA-2 larger at N.P. but not at S.P.
- ÅAmplitudes in MERRA, MERRA-2 larger during early period (1985-2001)
- ÅOpposite for CFSR/CFSv2 above S.P.
- ÅAmplitudes in JRA-55 and ERA-I do not depend on considered period

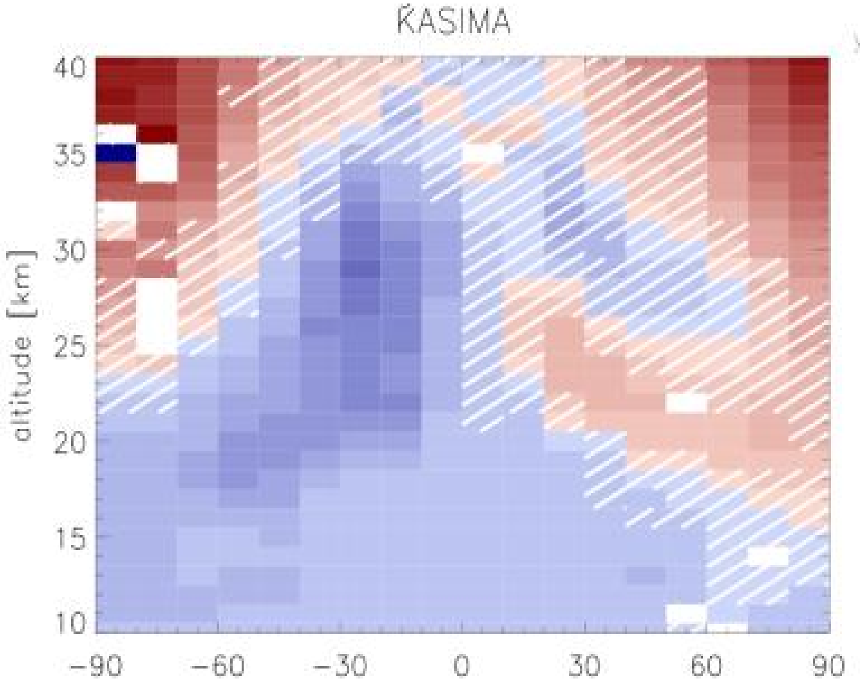
Amplitude of QBO at 30 km



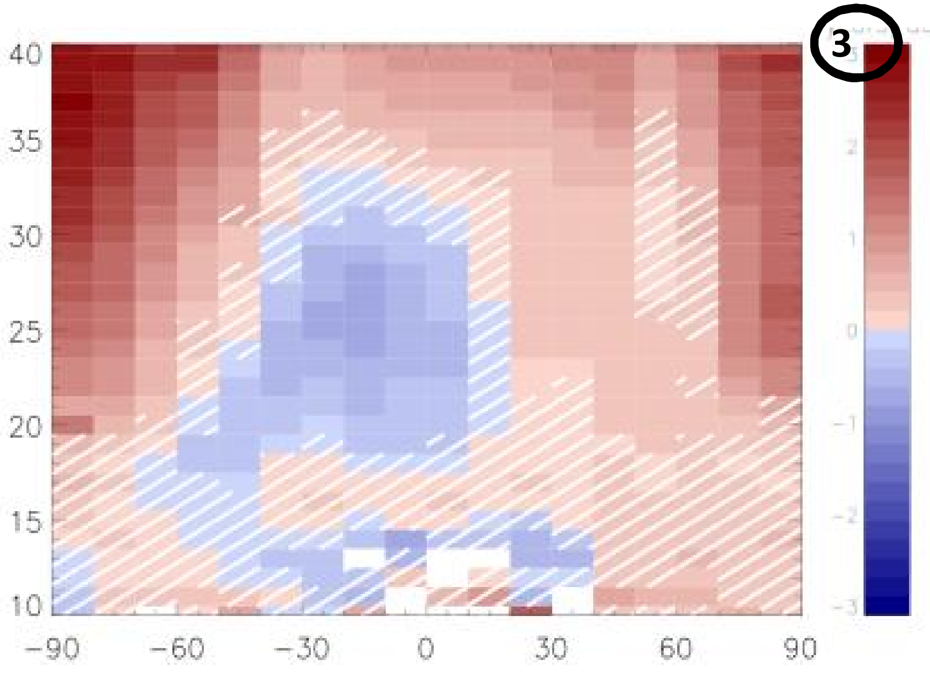
- Max at ~15°N and 15°S and min at equator - except in **CFSR/CFSv2**.
- QBO amplitudes by **ERA-I**, **MERRA** and **MERRA-2** twice larger than by **CFSR/CFSv2** and **JRA-55**

Trends of mean Age of Air (yr/dec): 2002-2012

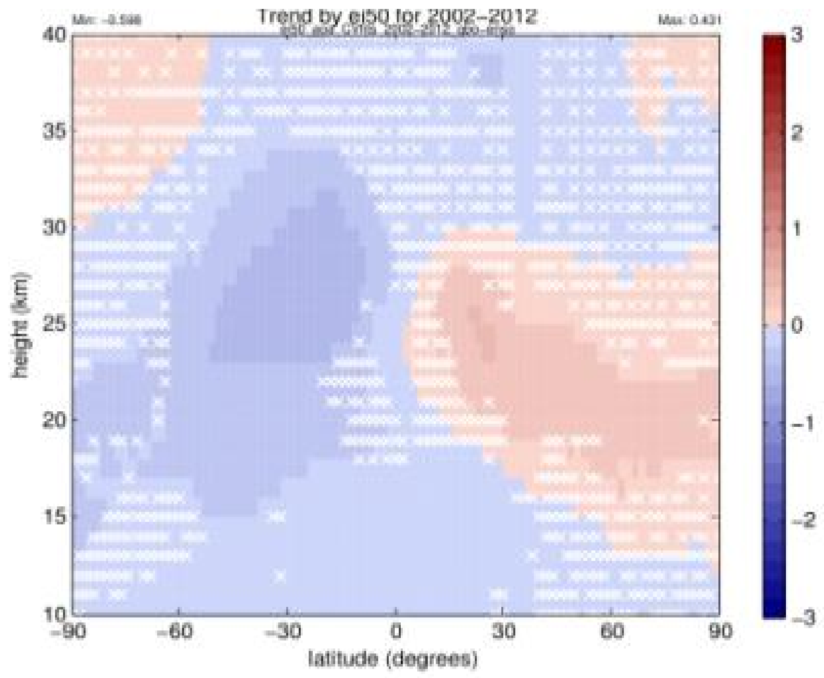
ERA-I + GCCM KASIMA



MIPAS SF_6



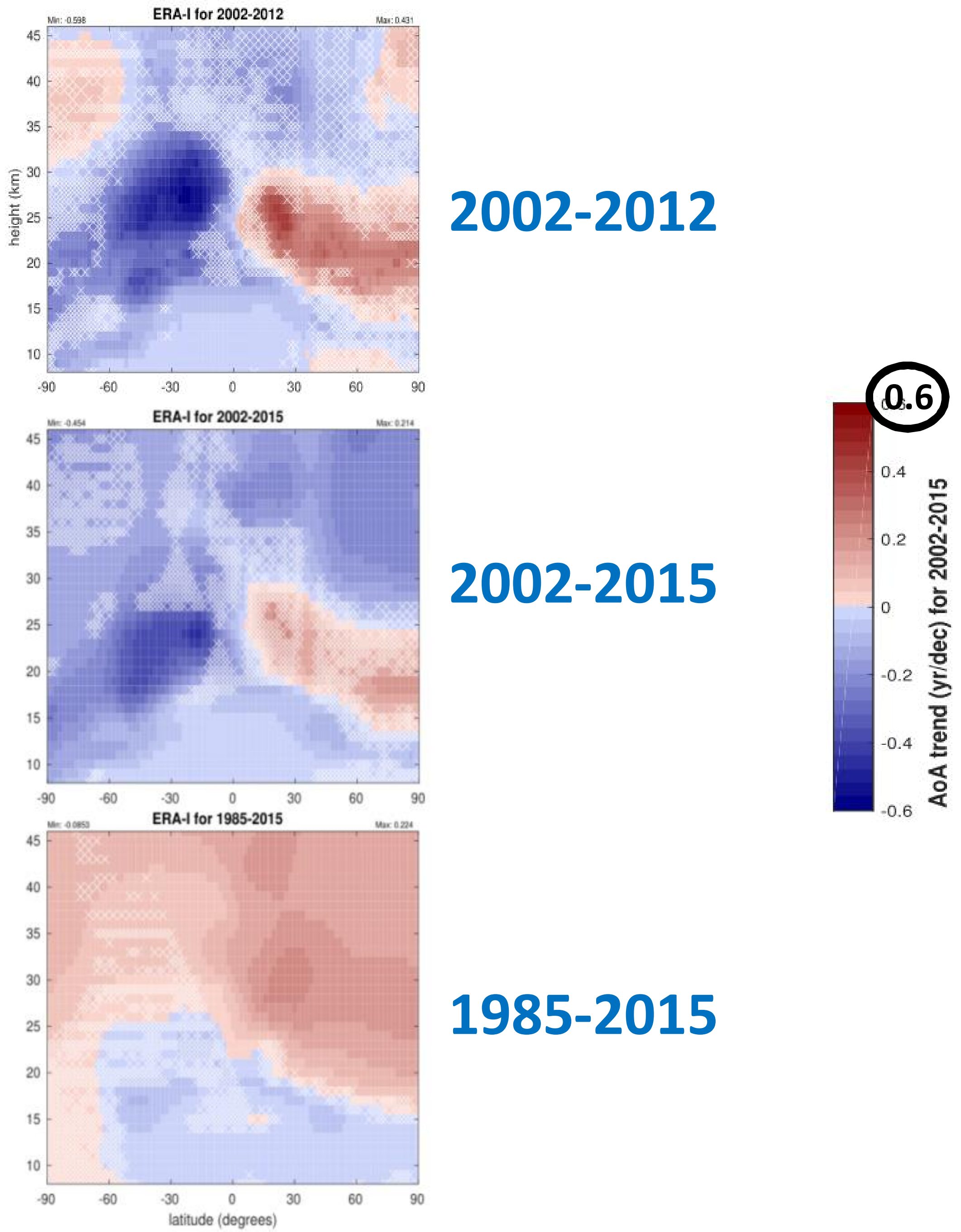
ERA-I + BASCOE CTM



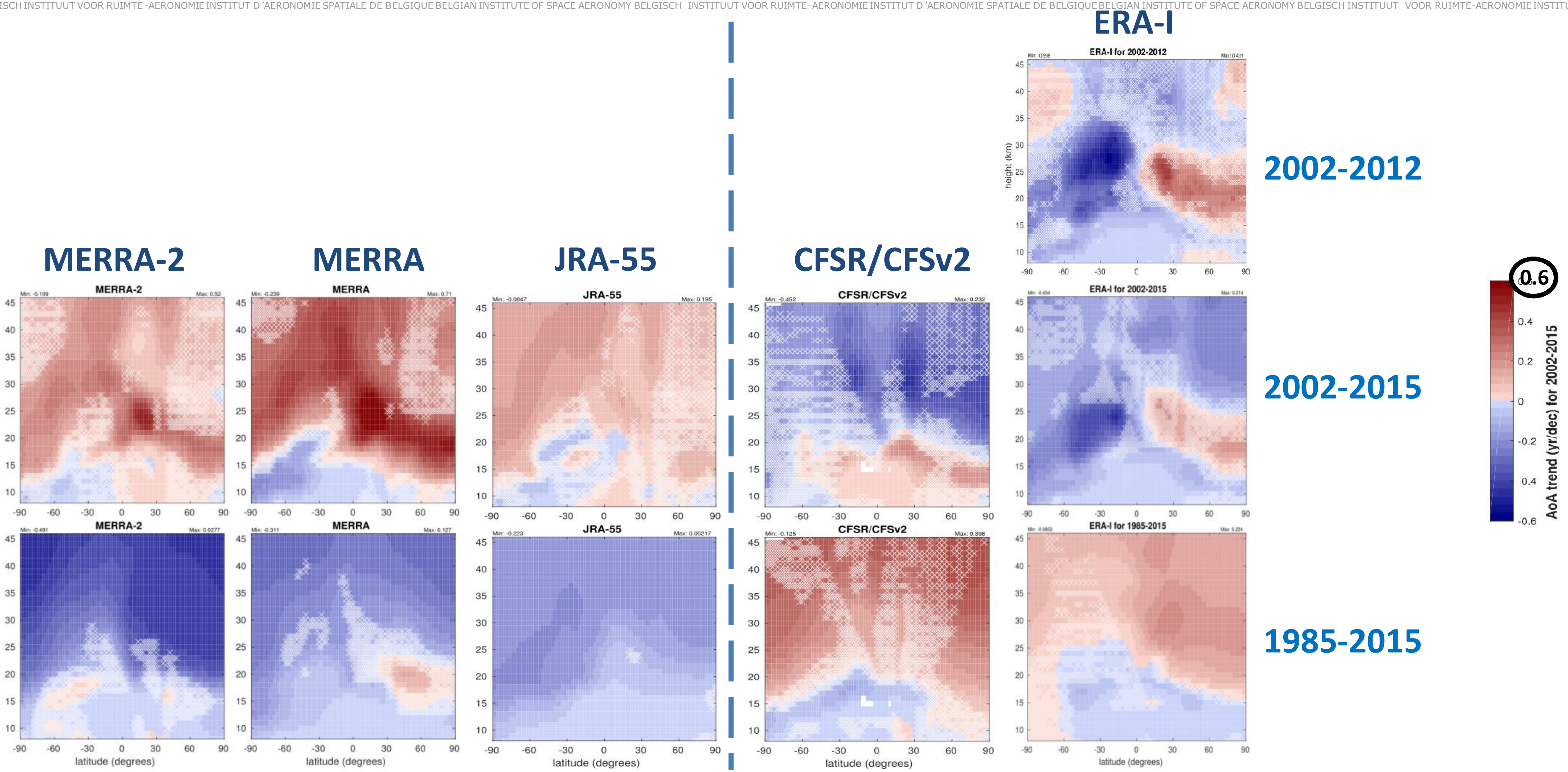
Haenel, Stiller, et al., ACP, 2015

Trends of mean Age of Air in ERA-I: denepnds on considered period

ERA-I



S-RIP Trends of mean Age of Air (yr/dec)



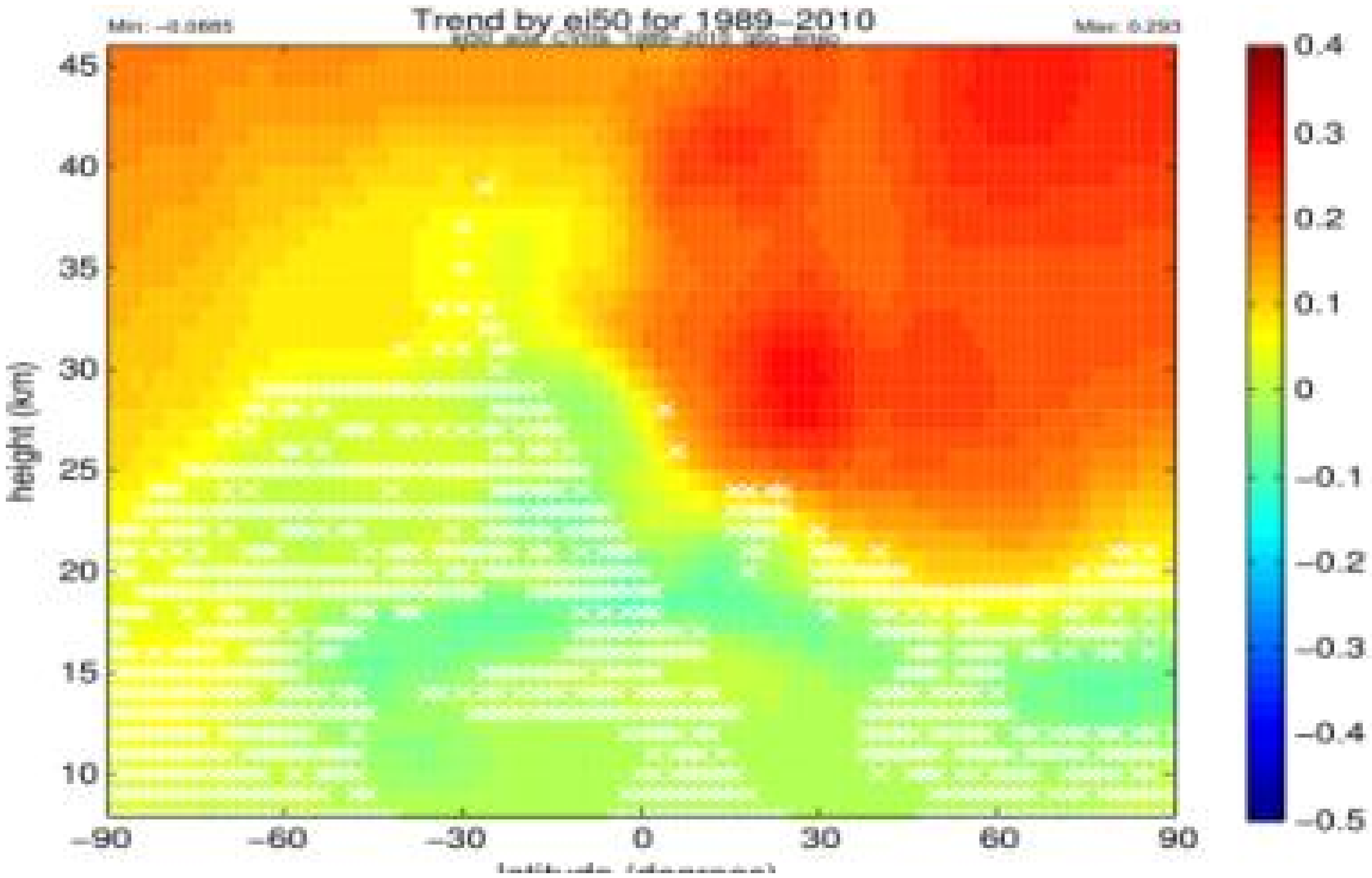
Outlook

- Intercomparison of reanalyses using different types of transport models: diabatic approach ; nudged GCCMs
- Comparisons with MIPAS and balloon observations - including interpolation of model output to obs locations!
- Comparisons with GCCMs

- 4 quick-and-dirty exemples (caution! For illustrative purposes only…)

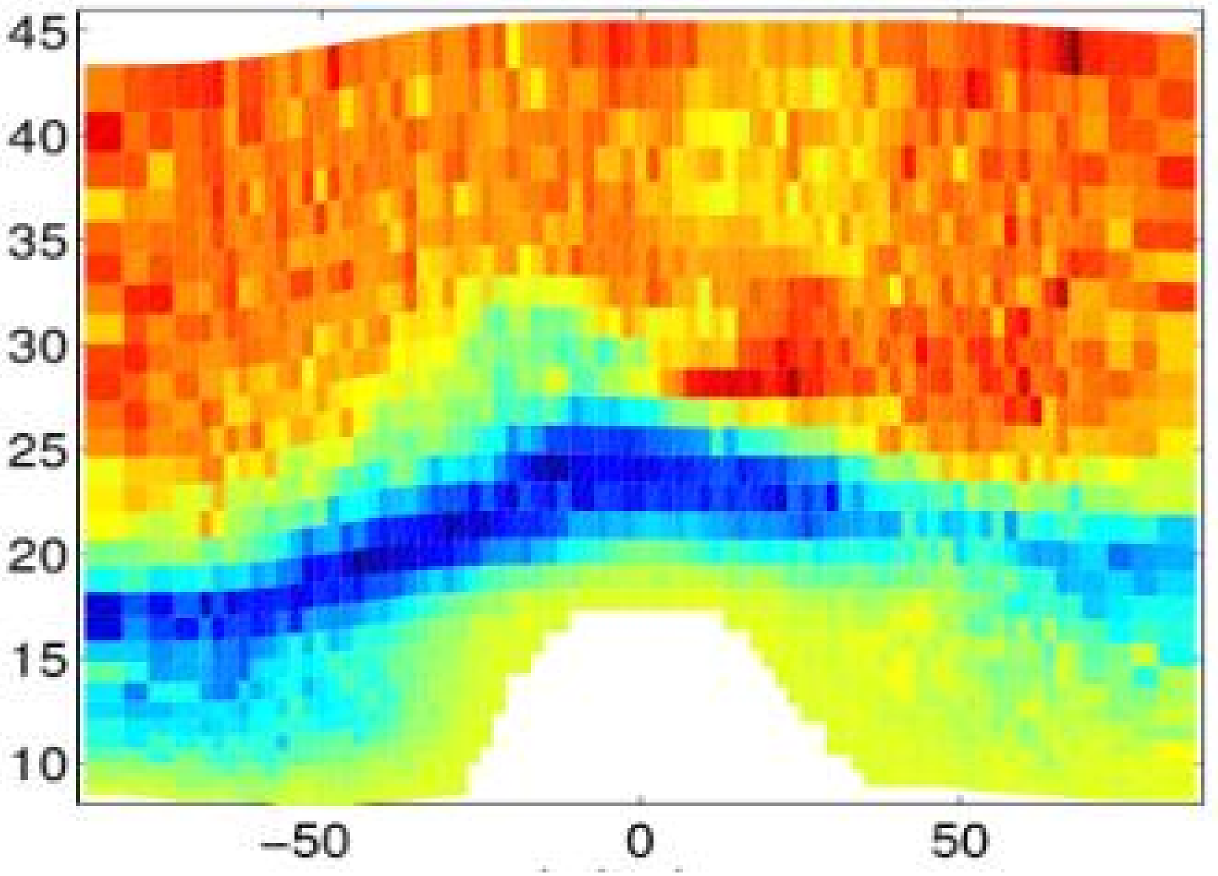
Outlook: use other types of transport models

AoA trends in ERA-I over 1989-2010



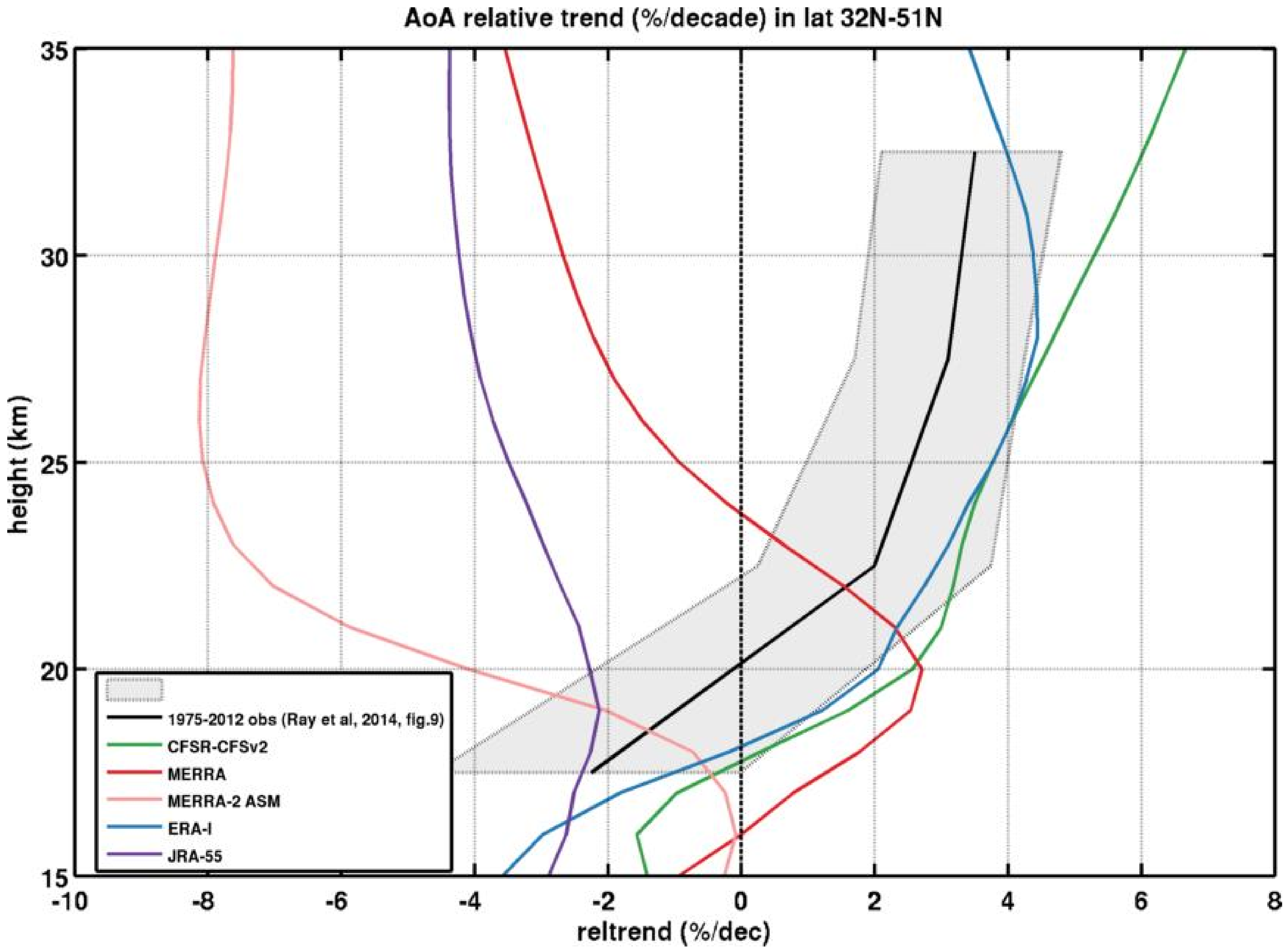
BASCOE CTM
(this work)

ERA-I (Diallo et al., 2012)



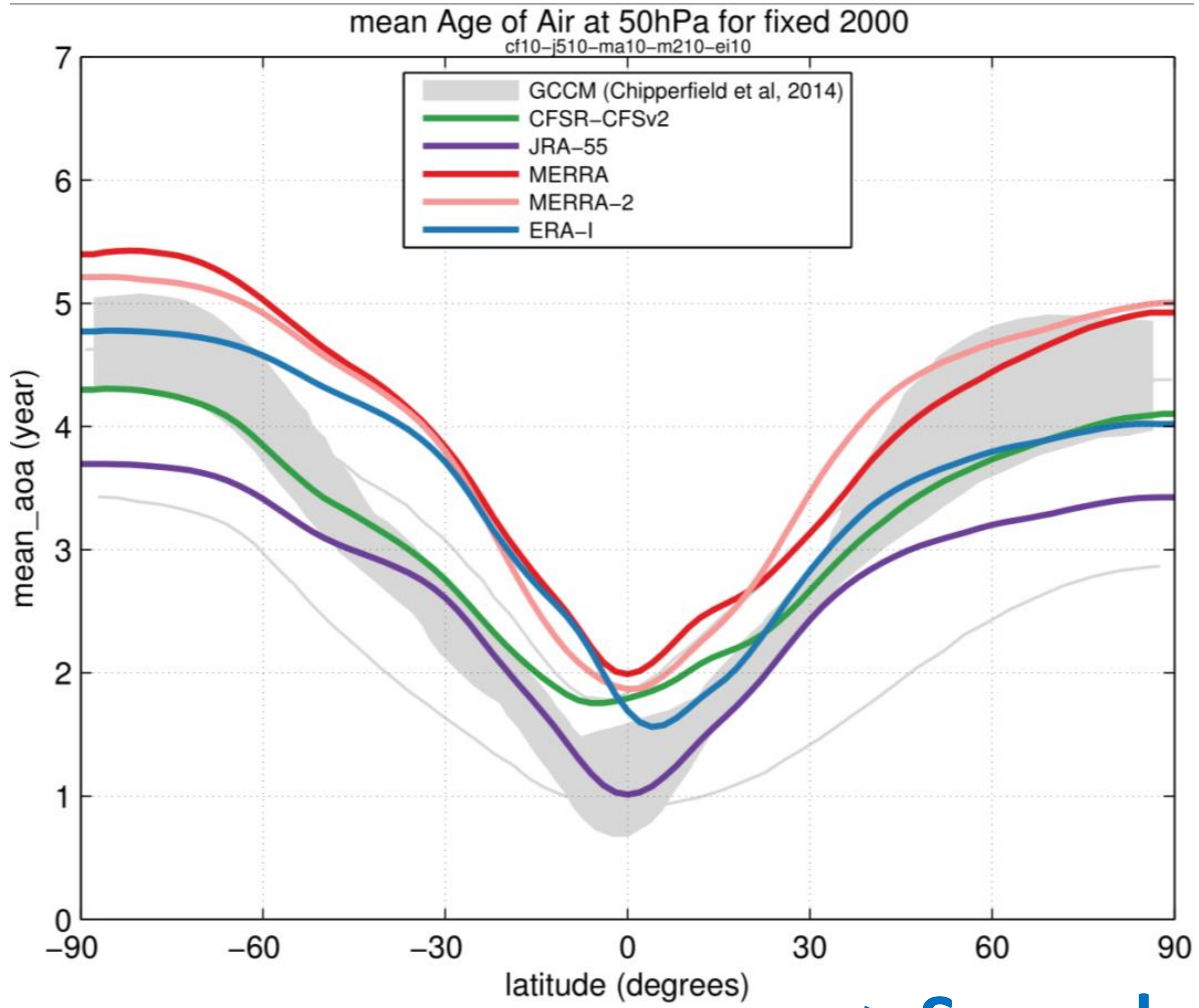
TracZilla
(Diallo et al., 2012)

Outlook: compare trends with balloon obs



Relative trends at MLNH:
reanalyses
1985-2015
versus balloon obs
1975-2012
(Ray et al., 2014)

Outlook: compare abs values with GCCMs

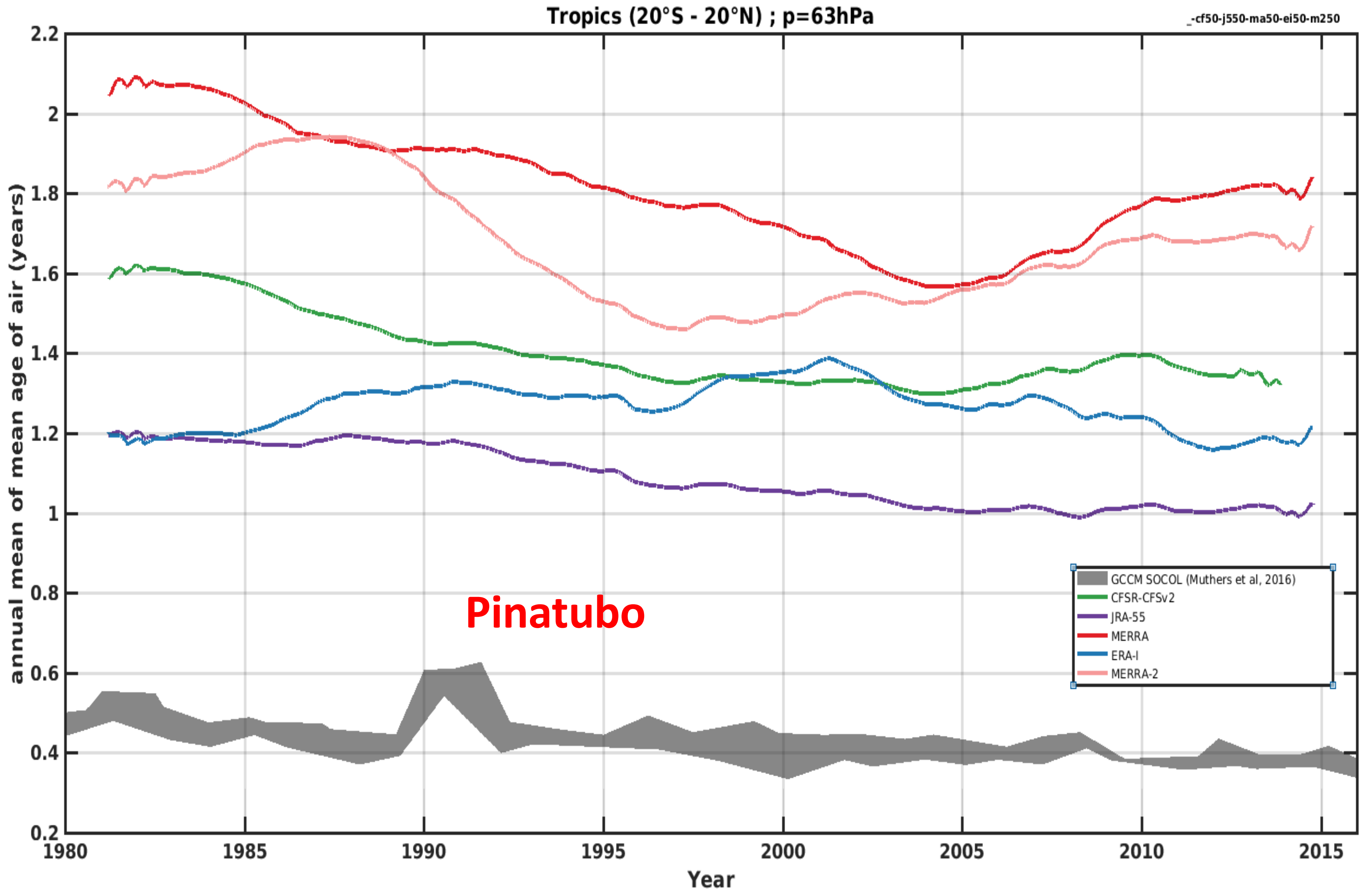


Grey: GCCM intercomparison (Chipperfield et al., 2014)

- Envelope: 5 GCCM
- 2 lines: outlying GCCM with coarse vert. resol. (L39)

=> Spread of reanalyses > spread of GCCMs!?

Outlook: compare timeseries with GCCMs



Comparison with GCCM SOCOL: Tropics, 63hPa

Muther et al.: Stratospheric age of air variations between 1600 and 2100 (GRL, 2016)

Summary and conclusions

I. The 5 modern reanalyses are compared with a Eulerian transport on native vertical grids and common (coarse) horiz grid thanks to a dedicated pre-processor based on spherical harmonics of Vort. and Div.

II. Large differences are found:
JRA-55, CFRS/CFSv2 quite young;
MERRA, MERRA-2 quite old;
ERA-I in between and seems to agree best with (sparse!) dataset of balloon obs

III. In MERRA and MERRA-2 , the amplitudes of seasonal variations depend on considered period (assim artifact?)

IV. Linear trends of ERA-I AoA for 2002-2012 has same dipole structure as found in MIPAS SF_6 (as in earlier modelling studies) but for 2002-2015 this dipole in ERA-I is weaker and not found with any other reanalysis

V. For 20002-2015, ERA-I and CFSR yield *negative* trends in middle strato but MERRA, MERRA-2, JRA-55 yield *positive* trends; for 1985-2015 it is exactly the opposite…

VI. Results should be confirmed with other types of transport models (diabatic; nudged GCCMs)

VII. Paper to submit shortly to ACP after last-minute improvements (work on cst-p grid; period of interest to start later, in 1989)

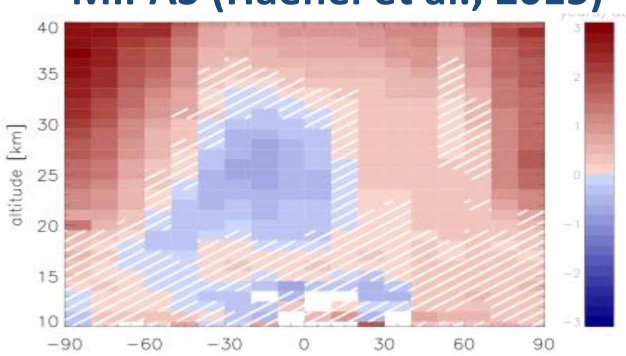
VIII. Next steps: quantitative comparisons with obs ; comparisons with GCCMs

Merci !

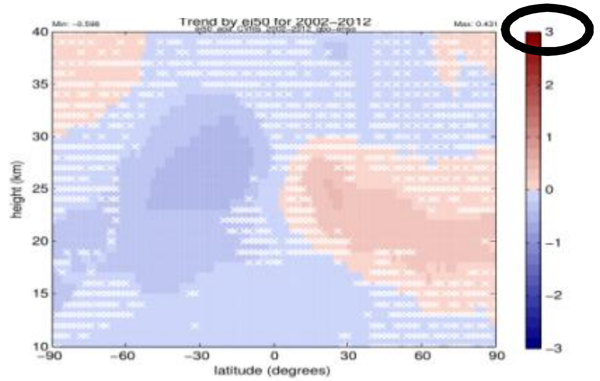
Trends of mean Age of Air (yr/dec): a compilation

2002-2012

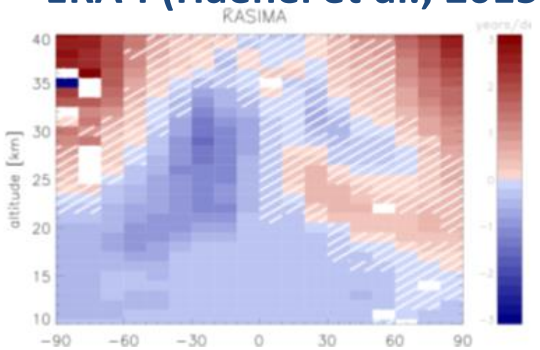
MIPAS (Haenel et al., 2015)



ERA-I
Chabrillat et al., 2017

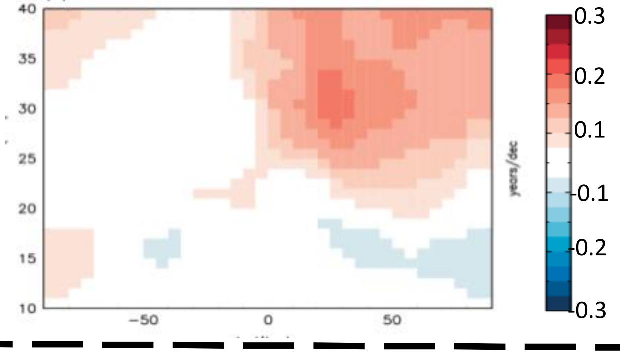


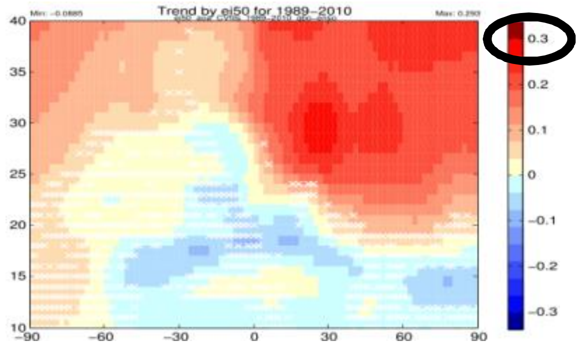
ERA-I (Haenel et al., 2015)

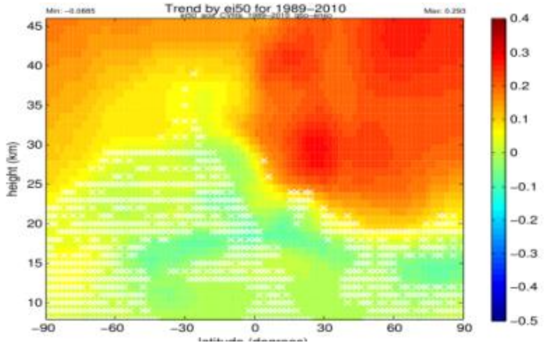


1989-2010

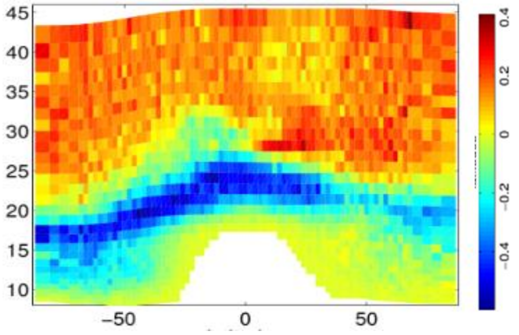
ERA-I (Monge-Sanz et al., 2012)





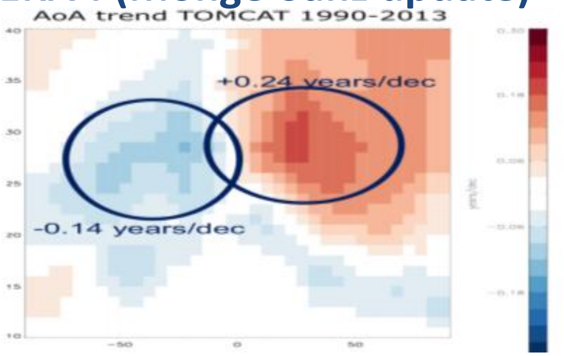


ERA-I (Diallo et al., 2012)

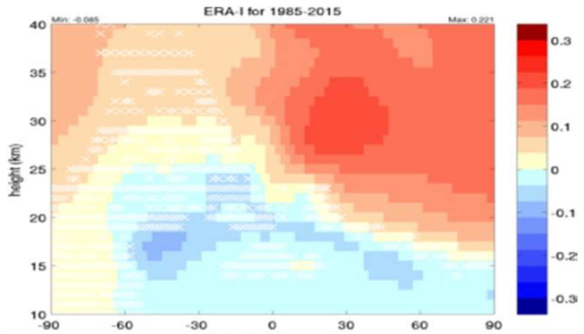


1990-2013

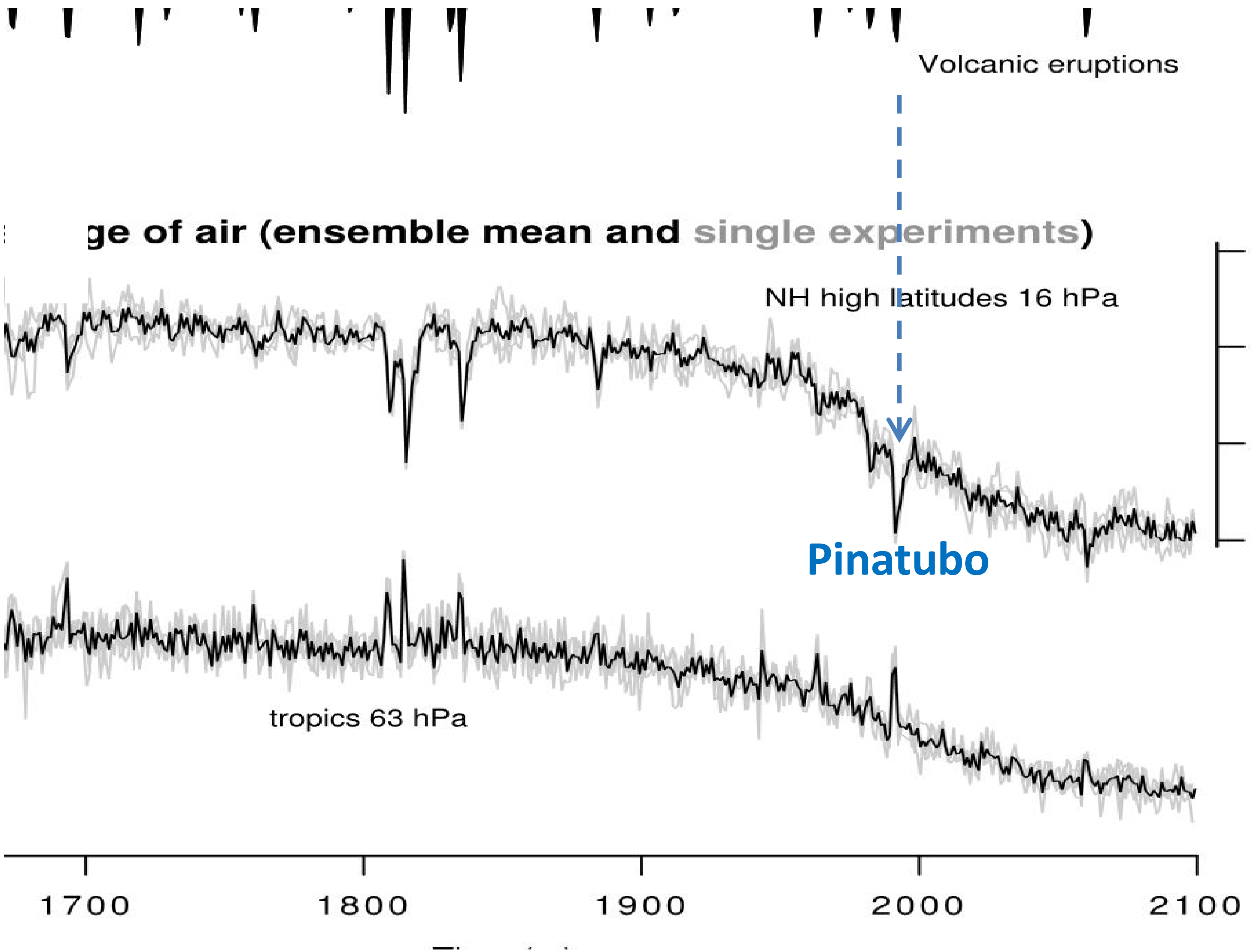
ERA-I (Monge-Sanz update)



1985-2015



Stratospheric age of air variations between 1600 and 2100 (Muther et al., GRL, 2016)

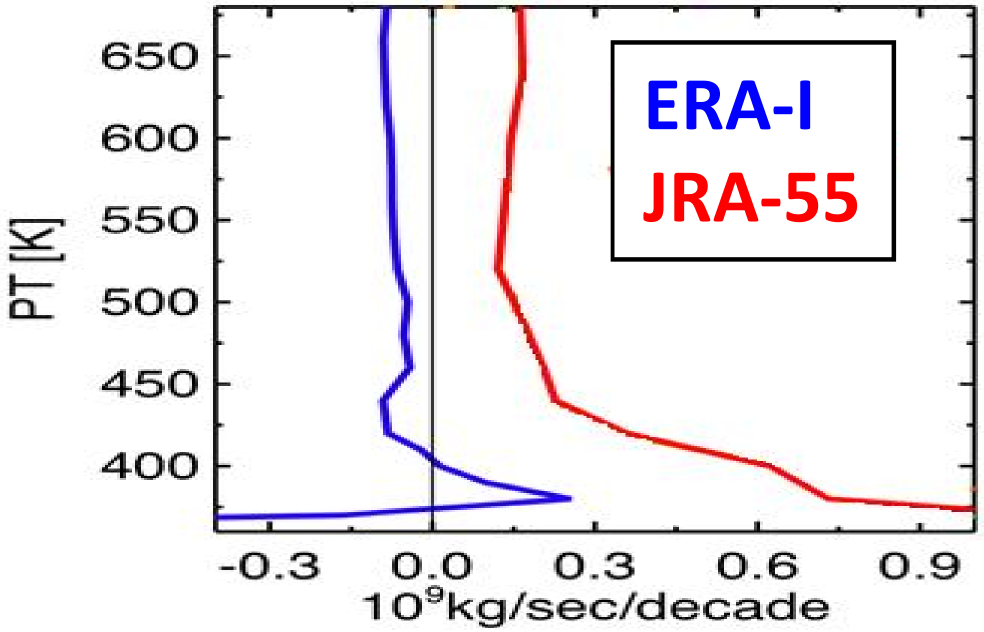


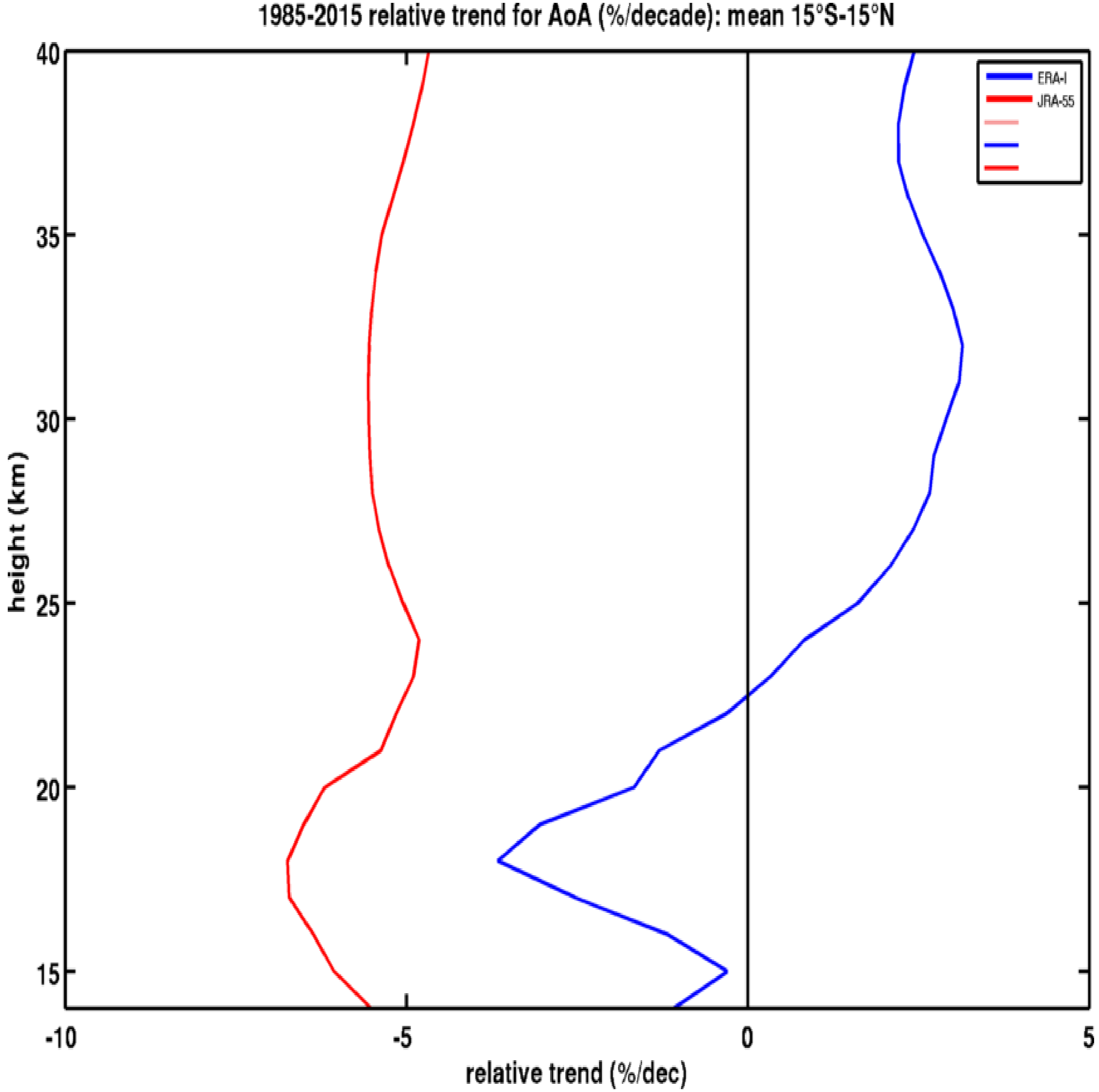
GCCM (SOCOL) simulations show expected impact of large volcanic eruptions (e.g. pinatubo) on AoA but no such impact visible in any reanalysis!?

Trend of AoA in Tropics versus trend of tropical upward mass flux

Flux increases
→ AoA should decrease: OK!

Miyazaki et al. (ACP, 2016): 1979-2012 trend of Tropical upward flux (DJF)





Tropical z=[14,17,26] km at θ=[370,400,675] K