Satellite Ozone needs for Climate Applications

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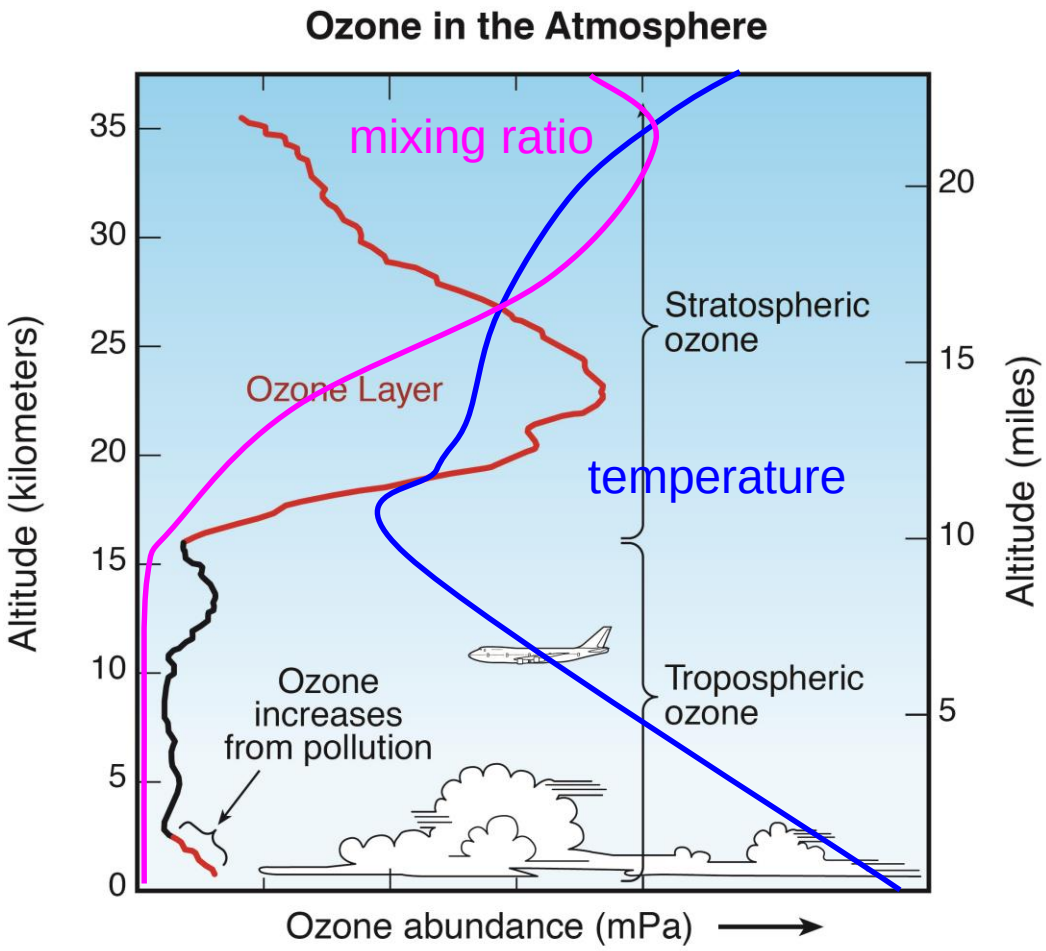
Thanks to many many colleagues!!

1.Feb 2016 Ulf Köhler

atmosphere = complex + beautiful
1 observation & 1 species are not going to do it

1.Feb 2016 Ulf Köhler

ozone & climate



- O_3 heats stratosphere
- “lid” on troposphere
- absorbs & blocks UV radiation

- CO_2 cools stratosphere
- O_3,CO_2 control temperature field and circulation

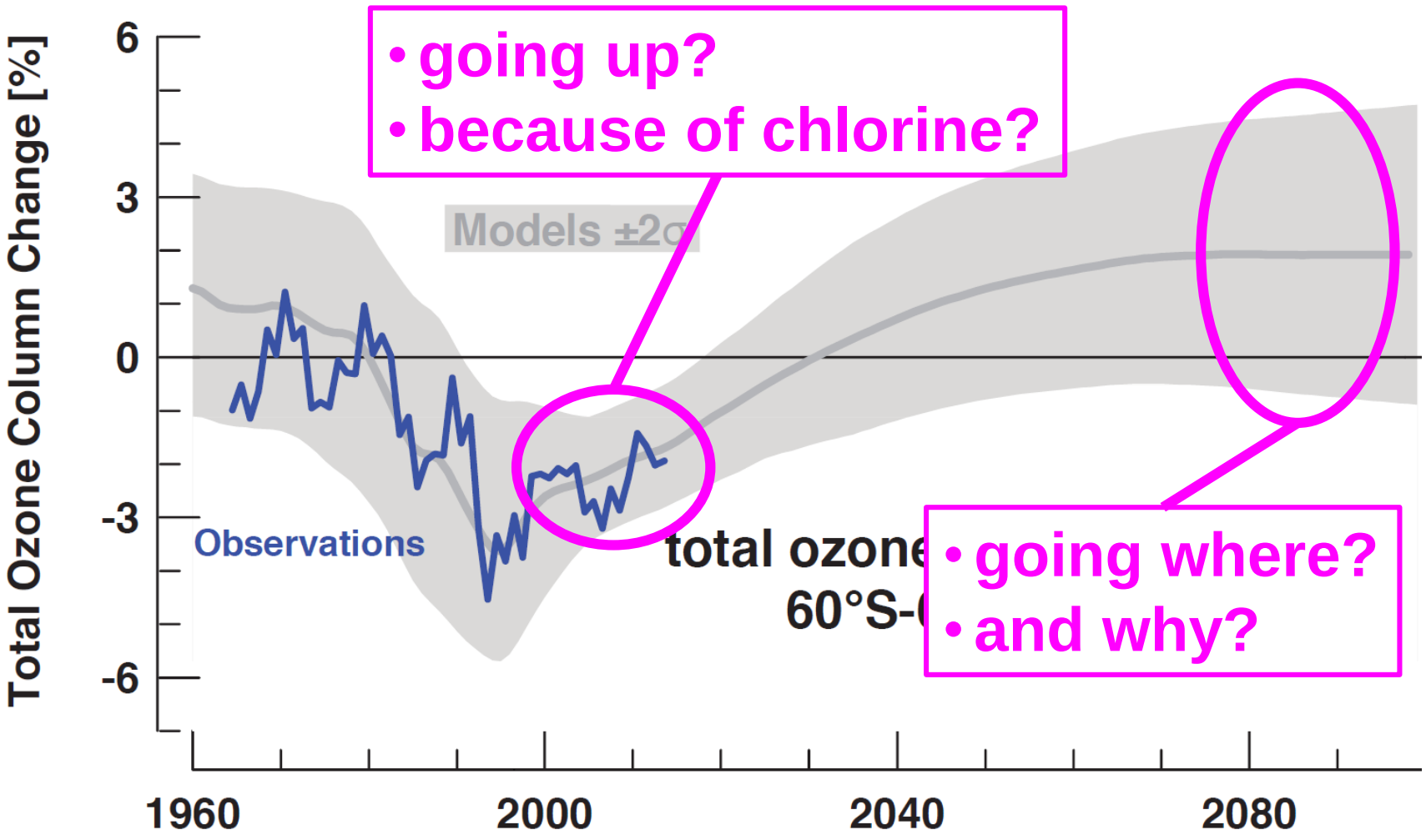
- O_3 key for air-quality

- relatively easy to measure

anthropogenic changes

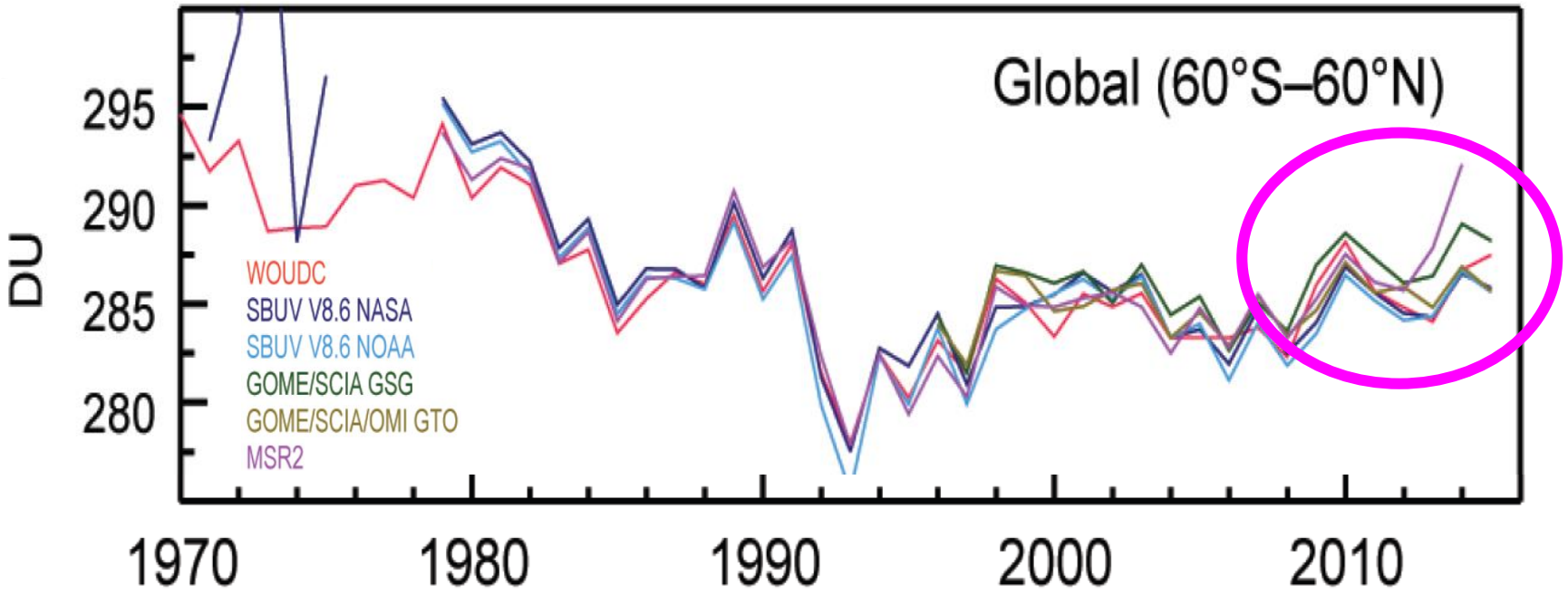
- CFCs, Halons, Cl & Br: fast increase until late 1990s, slow decrease after 2000; Vienna Convention (1985), Montreal Protocol (1987 …)
- O_3 declines until late 1990s, recovers since 2000?
- CO_2 and other greenhouse gases increase, Kyoto Protocol (1997, …, Paris 2015)
- N_2O, NO_x increase (fertilizers, traffic)
- CH_4 increases (food production)
- climate, H_2O change (CH_4 oxidation)

global ozone



WMO 2014

global ozone - measurements

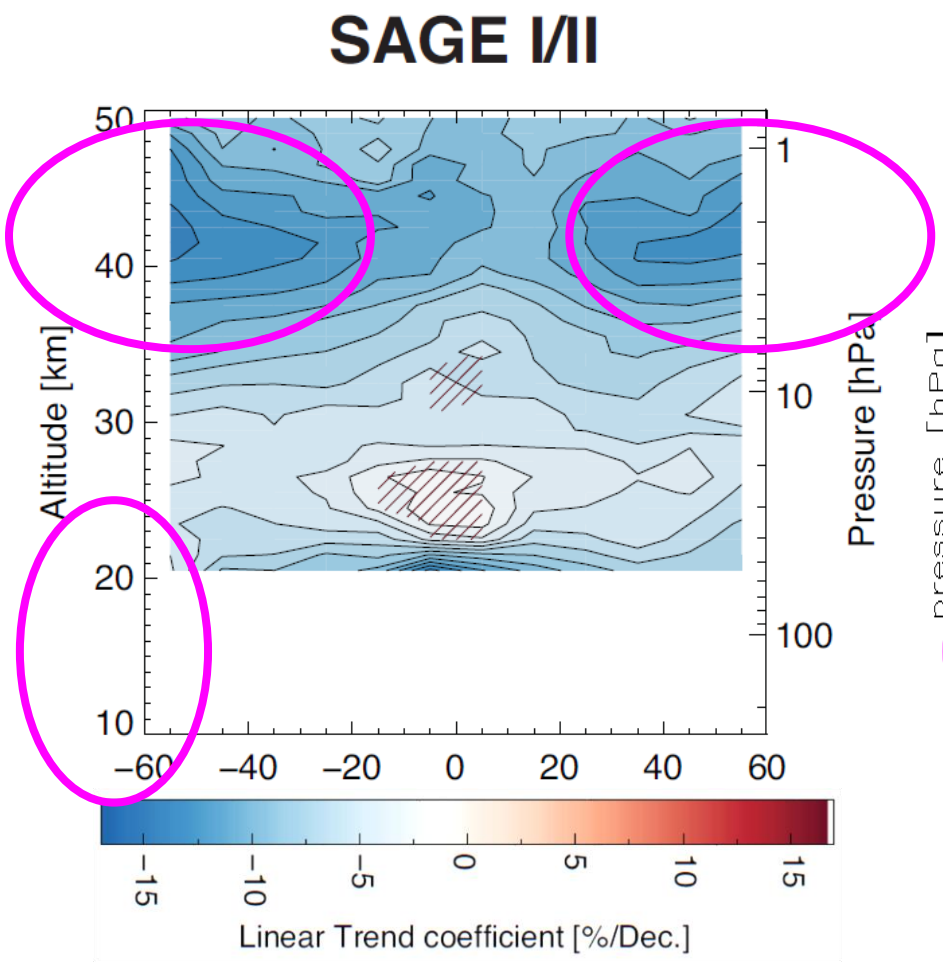


- **different answers for different data sets**
- **accuracy ≈2 to 5 DU**
- **need < 3 DU, > 20 years, < 1 DU / decade**
- **<1% + decades = challenging !!**

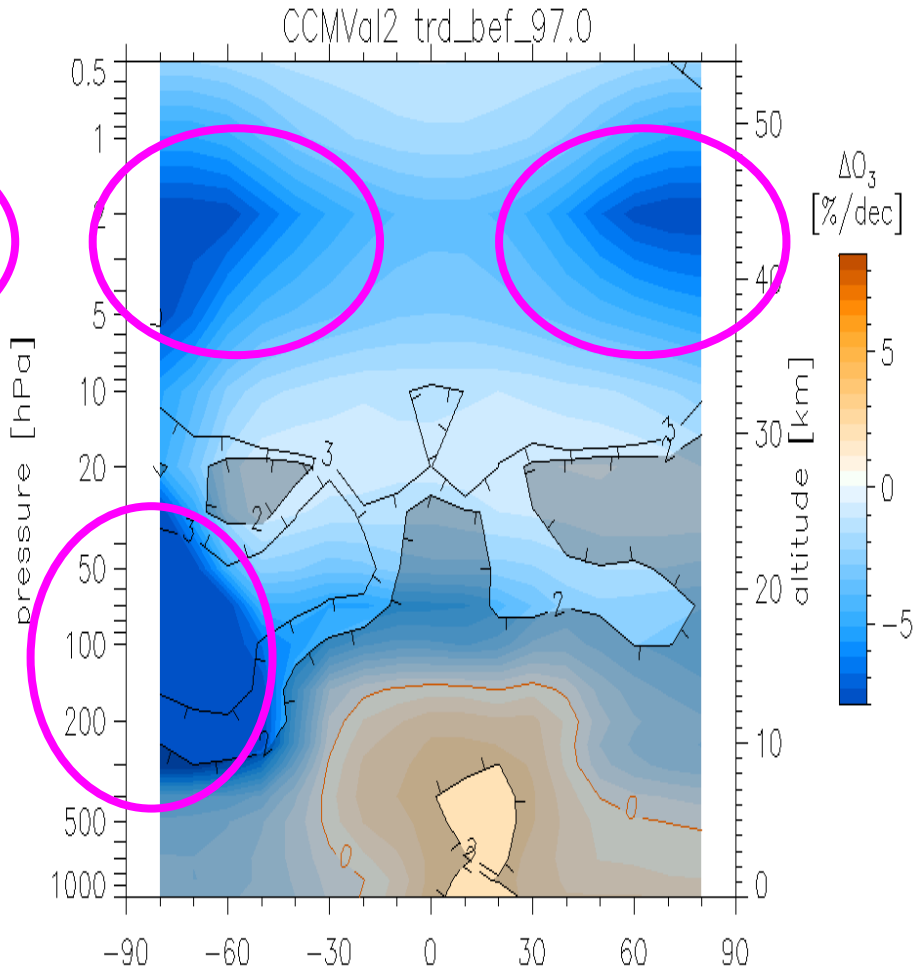
Weber et al., BAMS, 2016

fingerprint of ozone depletion

1979 to 1997, SI2N, Harris et al., 2015



model simulated, WMO 2014



fingerprint of ozone recovery

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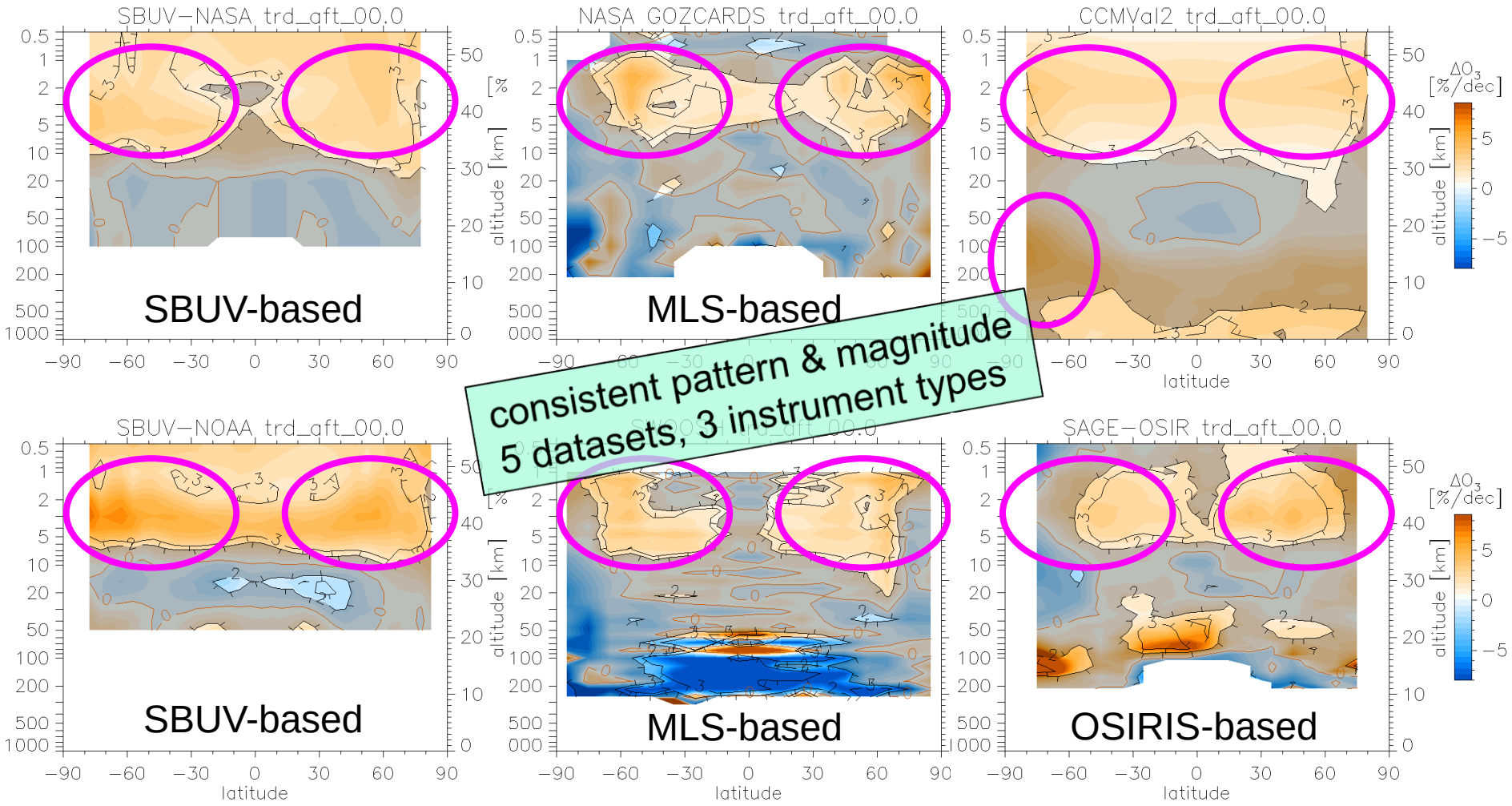
2000 to 2015/16, updated from WMO 2014

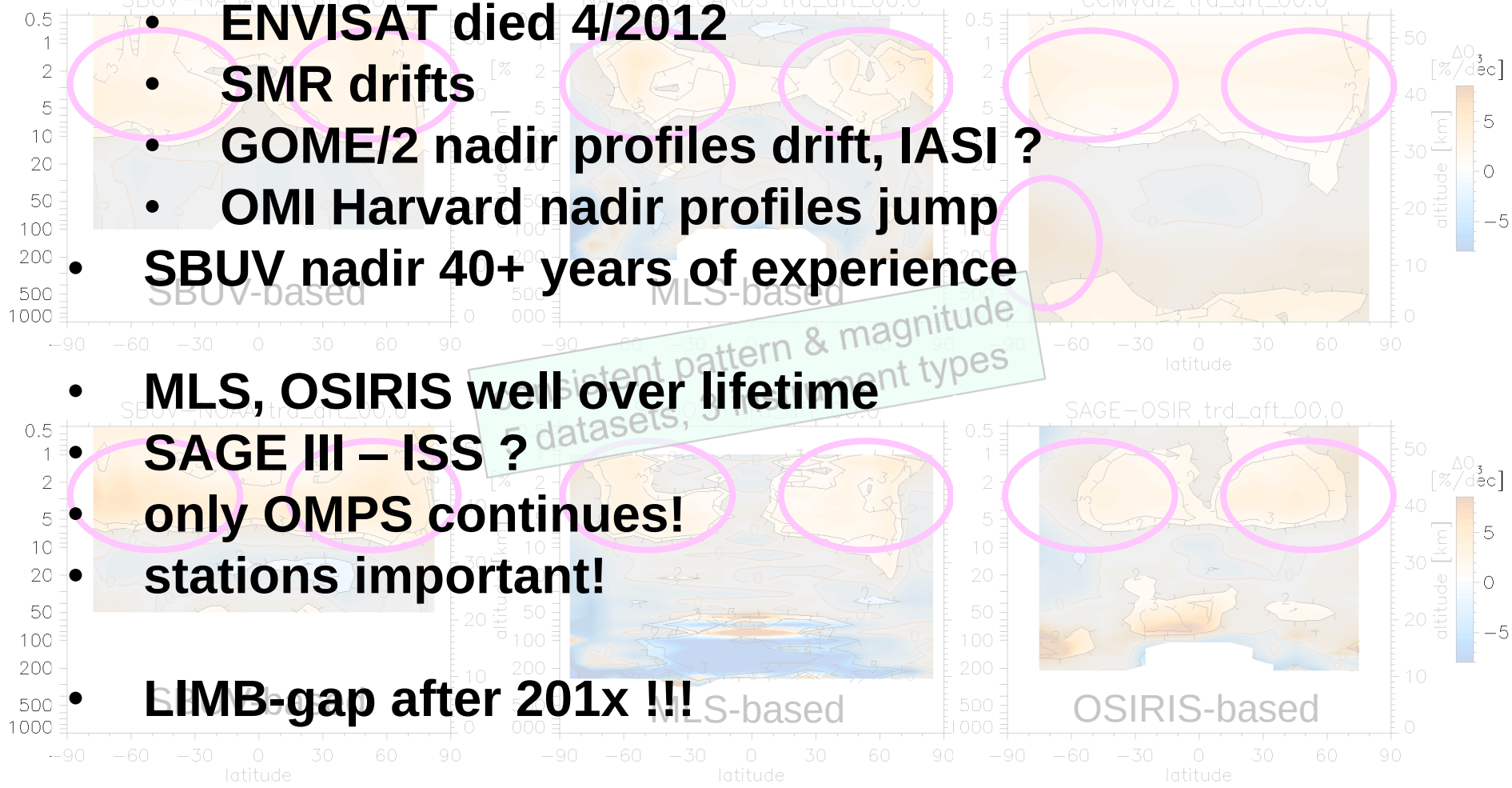
simulated



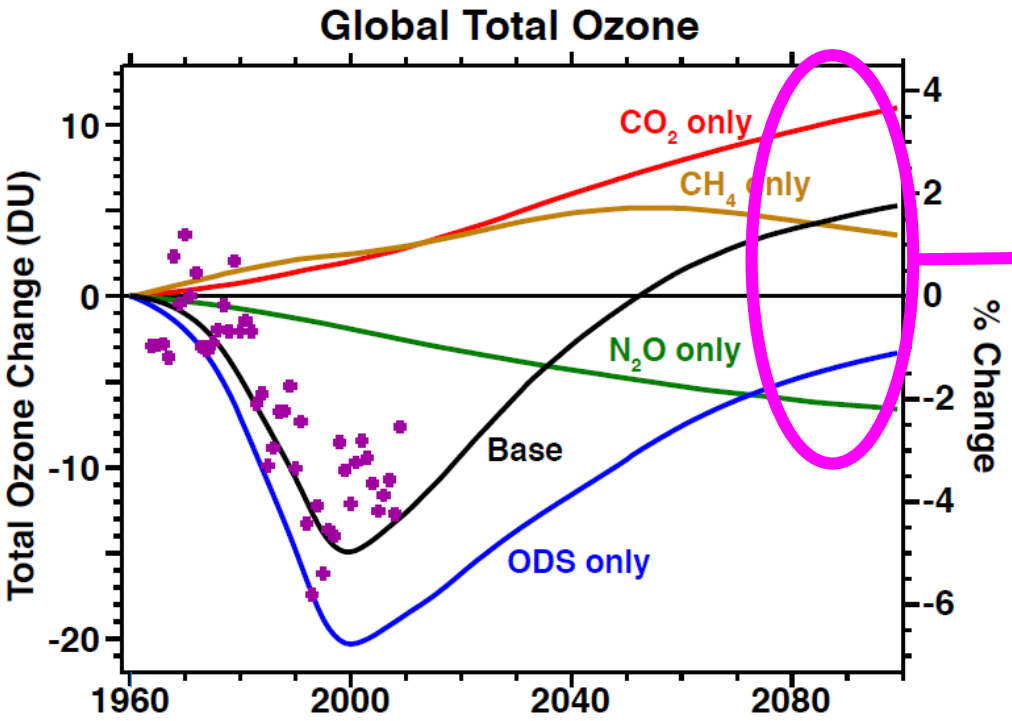
fingerprint of ozone recovery

- currently only 3 instrument sets + stations
  - ENVISAT died 4/2012
  - SMR drifts
  - GOME/2 nadir profiles drift, IASI ?
  - OMI Harvard nadir profiles jump
- SBUV nadir 40+ years of experience
- MLS, OSIRIS well over lifetime
- SAGE III – ISS ?
- only OMPS continues!
- stations important!

- LIMB-gap after 201x !!!



future ozone



- going where?
- and why?

observations !!

Past: ODS world

Future: CO_2, N_2O, CH_4, ODS

→ ODS deplete O_3

→ CO_2 cools, increases O_3

→ N_2O depletes O_3

→ CH_4 increases O_3

depending on altitude, latitude, season

Fleming ACP 2011, Portmann RoySoc 2012, WMO 2014

future ozone - dilemma

- complexity will increase
- strat. O_3 / UV danger will likely decrease
- observing capabilities decrease
  - less redundancy
  - fewer satellites & stations
  - LIMB gap
  - fewer ozone relevant trace gases
- lower accuracy
  - recovery / trends need <1% / decade
- blinder / less process understanding
  - Arctic ozone holes?
  - tropical UTLS?

summary = Vienna convention (1985)

Annex I: Research and systematic observations

job not done yet
patient still in hospital

1. … **major scientific issues** … modification …
   a. …**ozone layer** … change in … **UV-B** … mankind;
   b. …**vertical distribution of ozone** … **temperature structure** …**weather/climate**

2. … Parties … shall co-operate in … research and systematic observations …
   a. Research into the physics and chemistry of the atmosphere …
   b. Research into health, biological and photodegradation effects …
   c. Research on effects on climate …
   ***d. Systematic observations** on:*
      i. The status of the **ozone layer** (… **total column** content and **vertical distribution**) … integration of **satellite and ground-based** systems …
      ii. The tropospheric and stratospheric concentrations of source gases for the **HO_x, NO_x, ClO_x and carbon families**;
      iii. The **temperature** from the ground to the mesosphere, utilizing both **ground-based and satellite** systems;

summary = Vienna convention (1985)

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NECESSARY in 21st century as well

?

Thank you!!


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BACKUP SLIDES

Future ozone changes N_2O, CH_4

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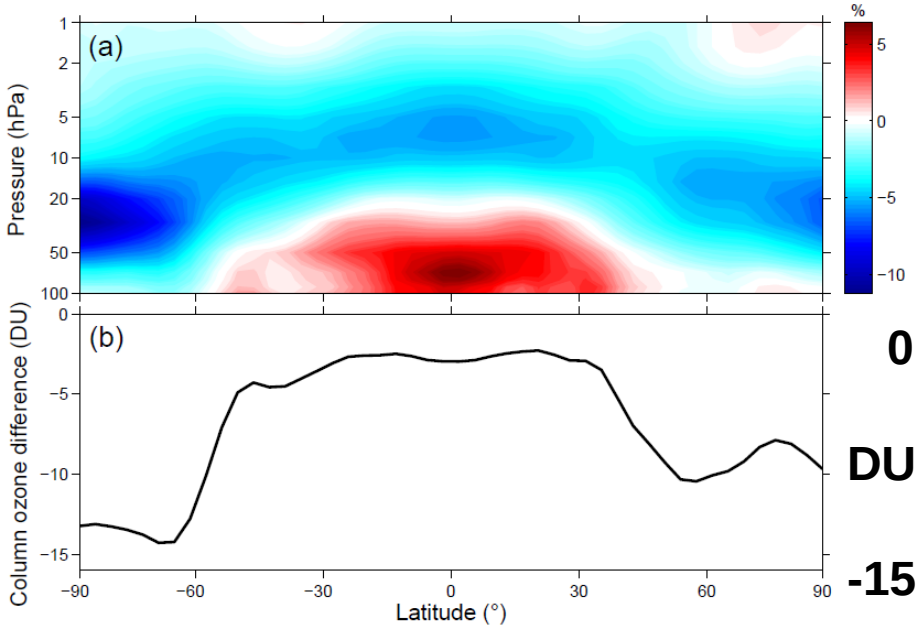
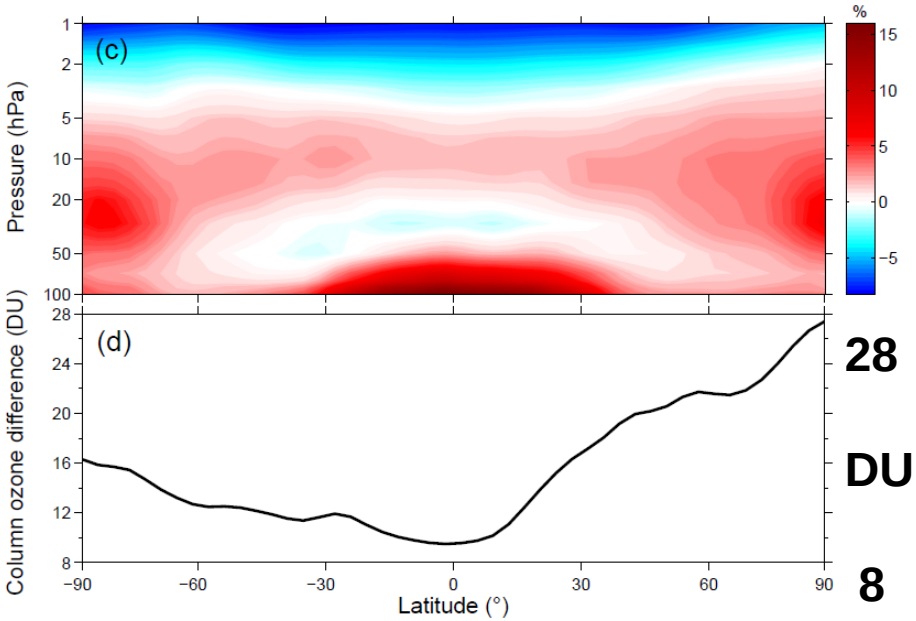
more N_2O → less ozone



more CH_4 → more ozone



$N_2O \rightarrow NO_x \rightarrow O_3 \downarrow$

$R\text{-}CH_3 + NO_x \rightarrow O_3 \uparrow$ (smog)

$CH_4 + NO_x \rightarrow O_3 \uparrow$ (smog)

$CH_4 \rightarrow H_2O \uparrow \rightarrow T \downarrow \rightarrow O_3 \uparrow$

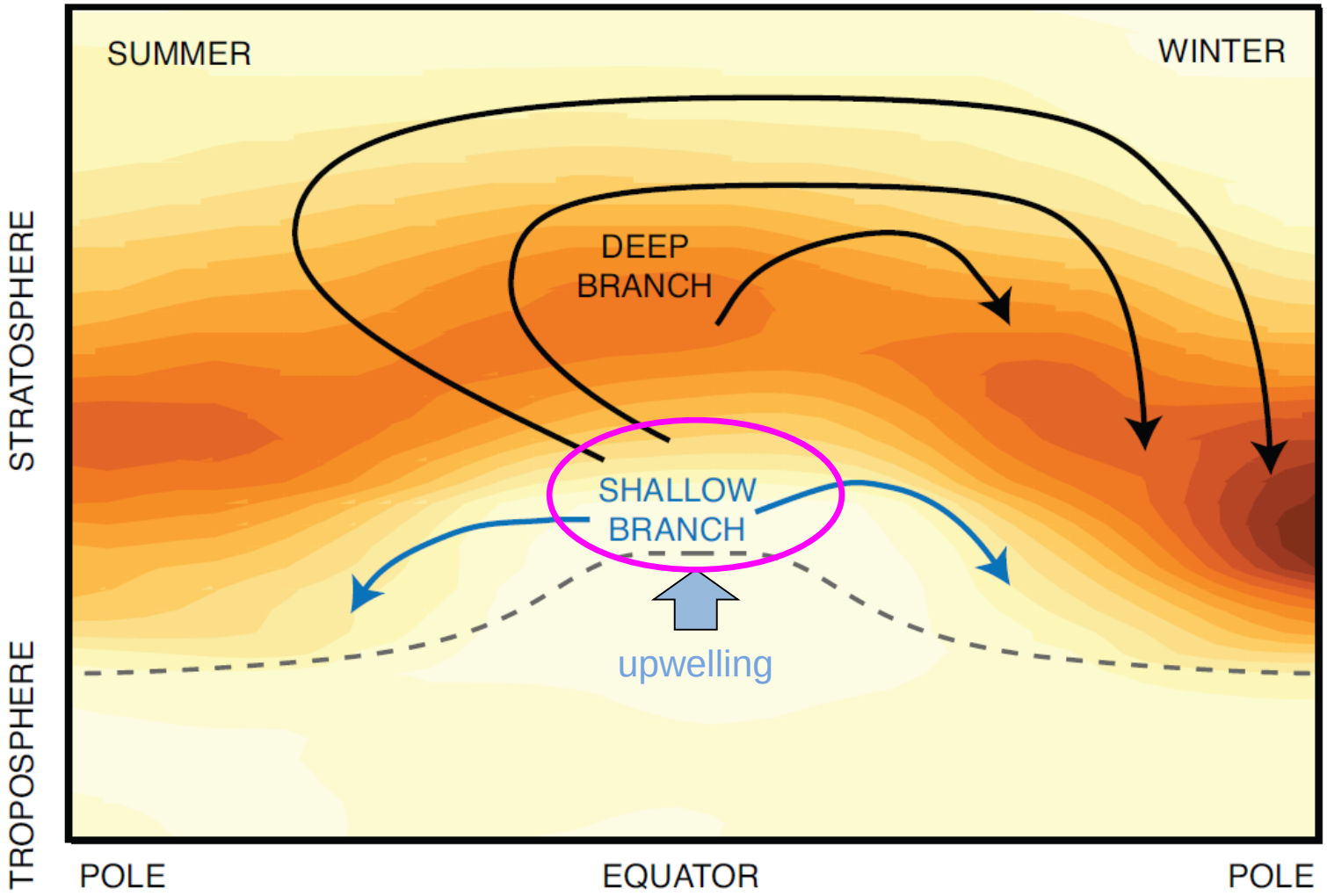
$CH_4 + Cl \rightarrow HCl \rightarrow O_3 \uparrow$

$CH_4 \rightarrow HO_x \rightarrow O_3 \downarrow$

N_2O, CH_4: RCP8.5 – RCP2.6 in 2090 **CO_2, other**: SRESA1B **ODS**: WMO 2007 *Revell et al., ACP, 2012*

Brewer Dobson Circulation

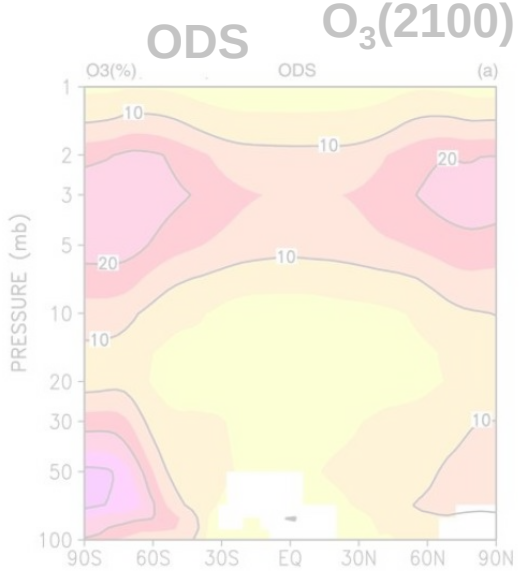
Models simulate increasing BDC on 50 to 100 year time-scale

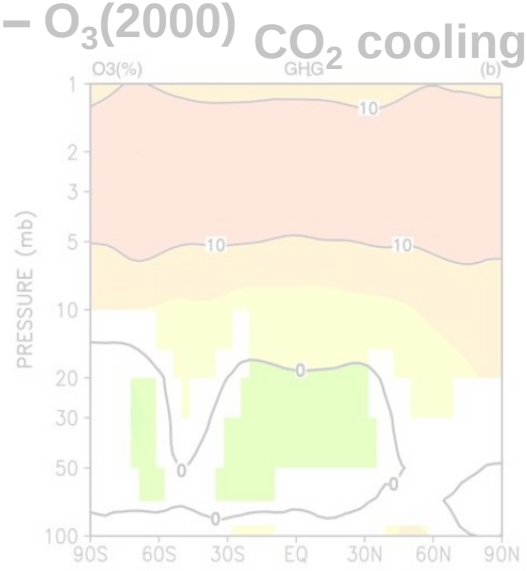


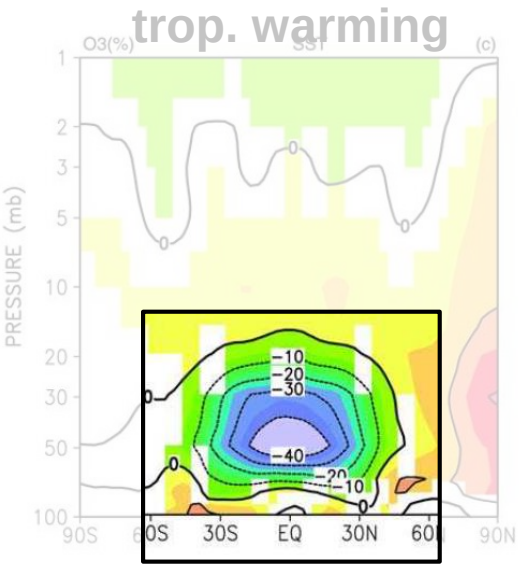
drivers of future ozone changes

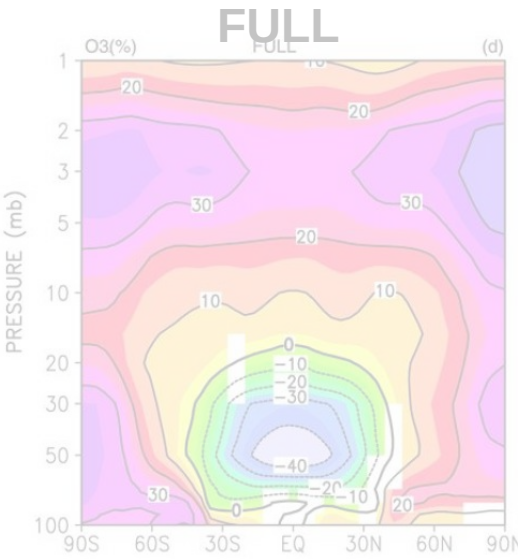
- Less ODS → more O_3
- more CO_2 → strat. cools → more O_3
- more GHG → troposphere warms → enhanced ascent in tropics → enhanced waves → enhanced BDC
- larger ozone columns at higher latitudes
- smaller ozone columns in tropics?

$O_3(2100) - O_3(2000)$









Zubov et al. 2012

Tropical ozone – no ODS, but climate

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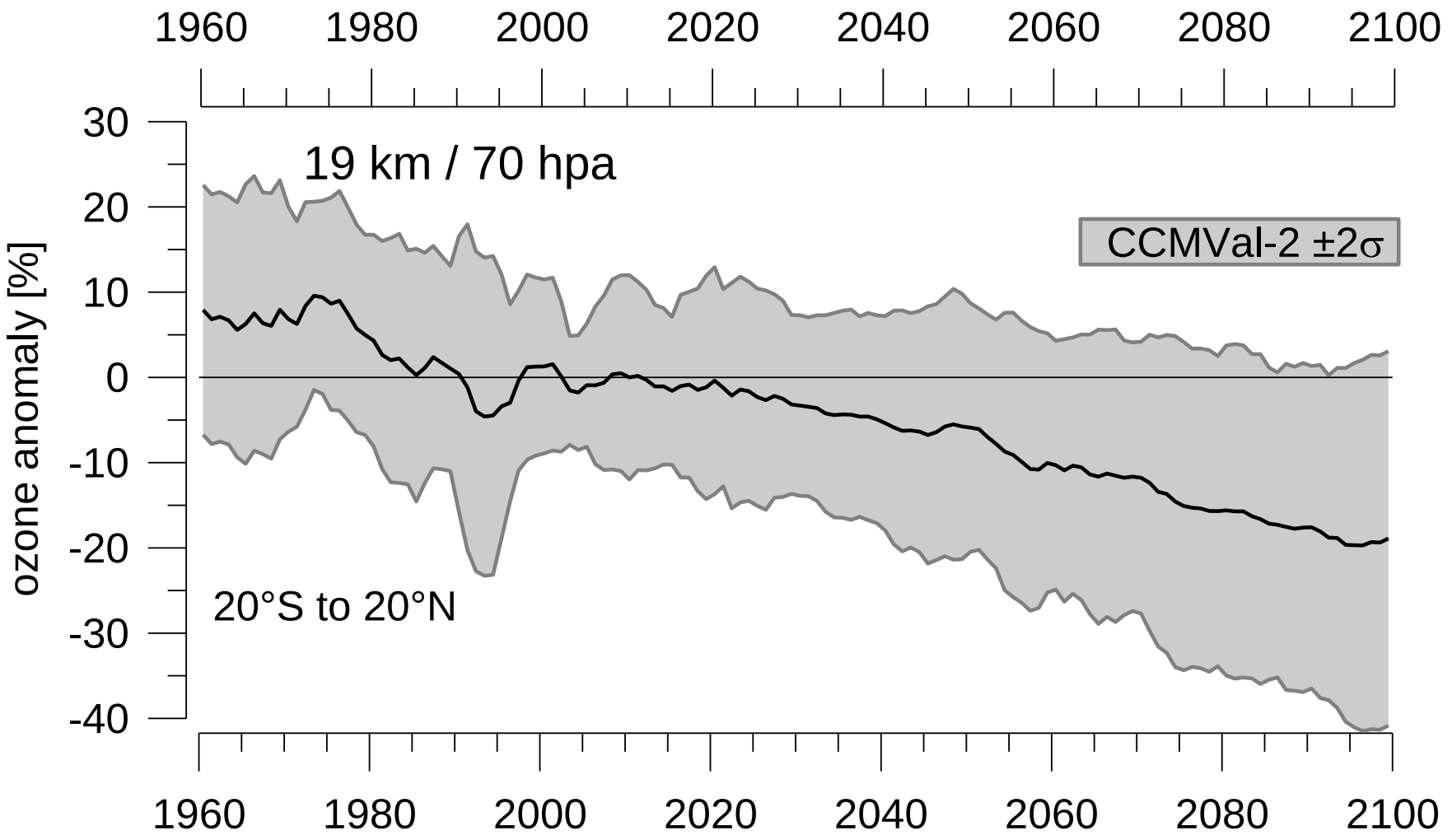
Models simulate increasing BDC – declining ozone in tropical LS



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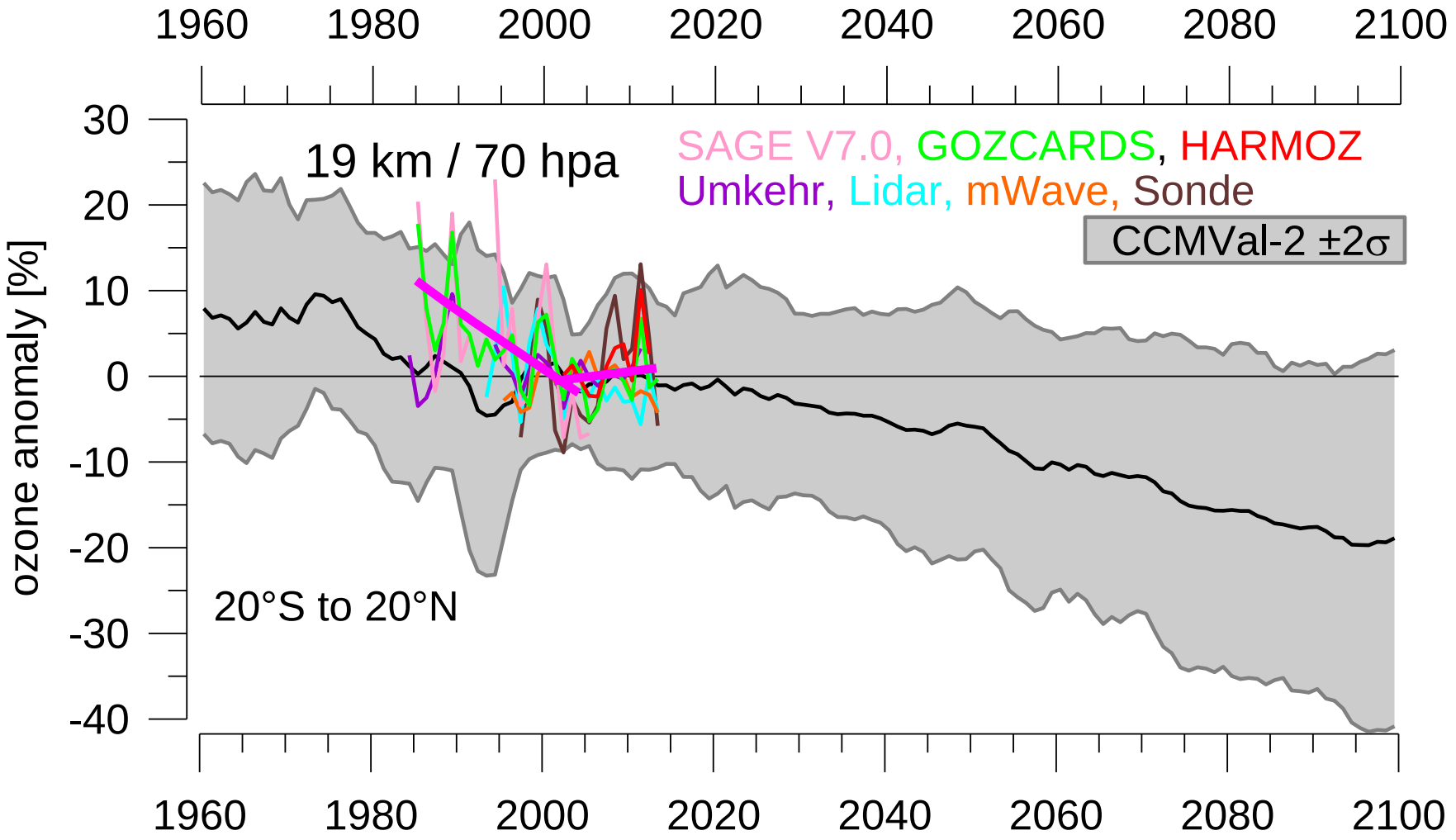
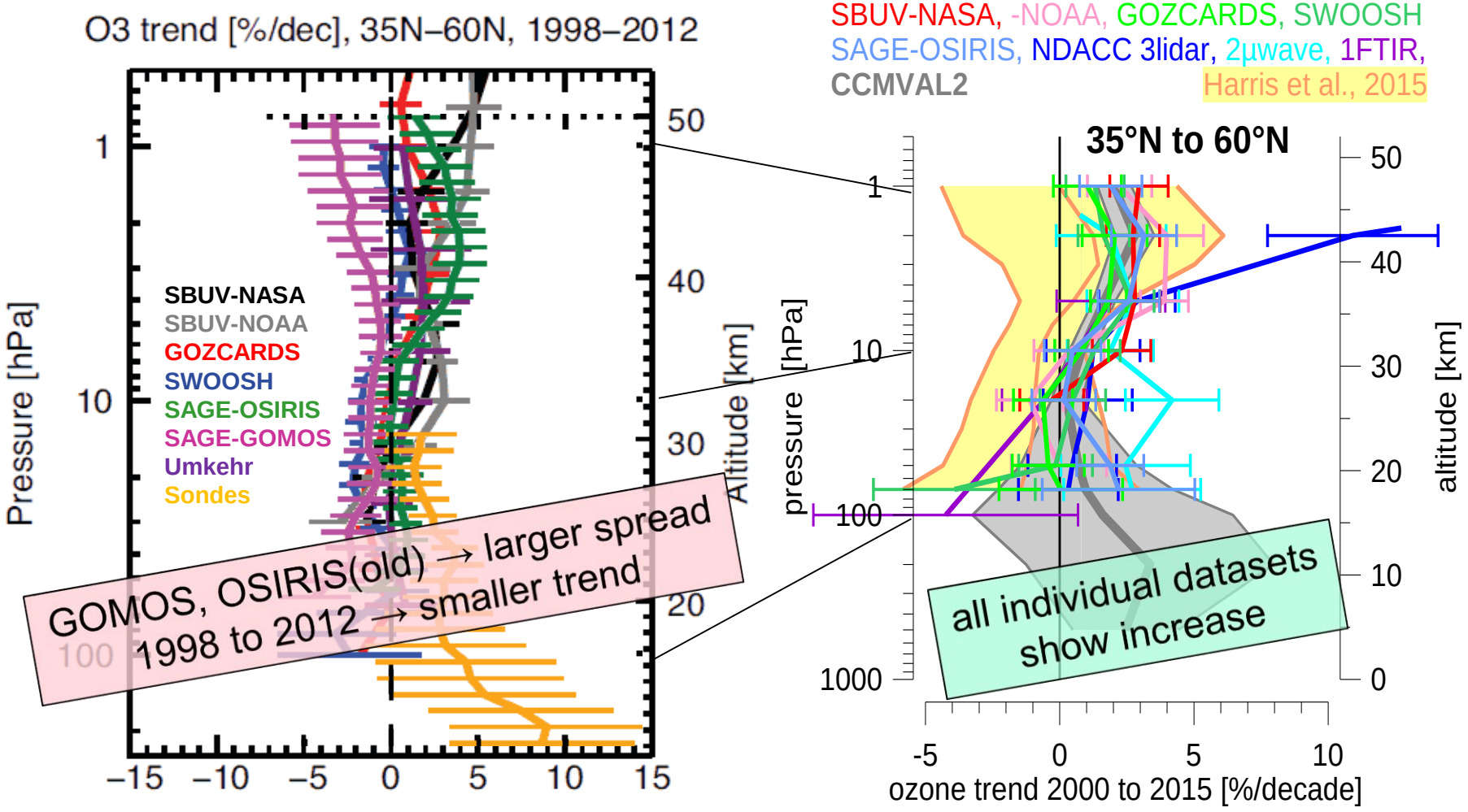


trend profile, Northern mid-latitudes

1998 to 2012, SI2N, Harris et al., 2015

2000 to 2015/6 updated from WMO 2014



changes in ozone profiles

observed & CCM simulated trends agree
simulations: ½ ODS decline + ½ cooling by increasing CO_2