Status of Results from CCMI WACCM

D. Kinnison, D. Marsh, R. Garcia, A. Smith, H. Lee, S. Tilmes, J-F. Lamarque, R. Neely, A. Conley, C. Bardeen, T. Wegner, and M. Brakebusch.

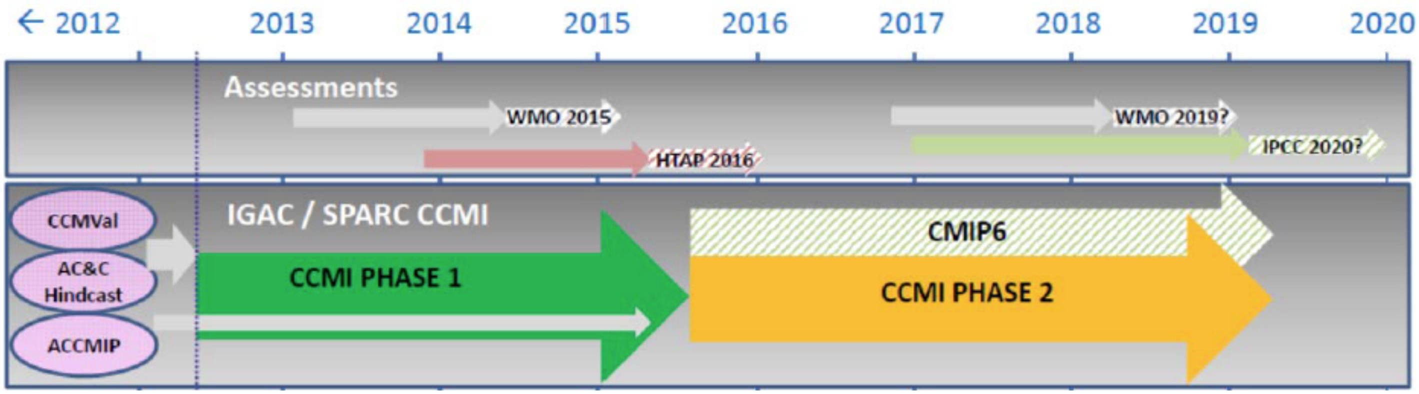
National Center for Atmospheric Research, Boulder, USA

18 June 2013, Breckenridge Co, CESM Meeting

Outline

- Show Chemistry Climate Model Initiative (CCMI) timeline.
- Discuss scenarios and WACCM commitment to CCMI and WMO-2015.
- Review updates to CESM1 (WACCM) since CMIP5 and CCMVal2 assessments.
- Highlight a few preliminary results for the polar stratosphere.
- Discuss polar stratosphere temperature bias.

Chemistry Climate Modeling Initiative (CCMI)



- First meeting was in May 2012 (Davos, Switzerland).
- Second meeting was in May 2013 (Boulder, NCAR, USA).
- Phase I of CCMI will be to support the WMO 2015 O_3 Assessment.
- Model simulation will need to be finished no later than 1 Jan 2014.
- Model simulation (for the first time) will include "nudged" approaches for CCMI.
- Next meeting will May 2014 (Lancaster, UK).

CCMI Scenarios

Standard Simulation

Sim	Period	GHGs	ODS	SSTs/ SICs	Sulfate Aerosol	SV	QBO	VSLs	Trop. Emissions	Members
REFC1	1960-2010	OBS	OBS	OBS	OBS	LEAN	OBS	YES	YES	3x
REFC1 SD	1979-2010	OBS	OBS	OBS	OBS	LEAN	OBS	YES	YES	1x
REFC2	1960-2100	OBS / RCP6.0	OBS / A1	Coupled Ocean	OBS / Volc Clean	LEAN	Internal	YES	YES	3x

Additional Simulations:

- REF-C1SD with updated chemistry based on SPaRC lifetime assessment.
- REF-C2 with additional RCP.

Storage:

- For the simulations mentioned here, the total storage will be approximately 150Tb.

Updates to CESM1 (WACCM)

- Updated chemical rate constants to JPL-2010.

- Additional tropospheric chemistry (Total of 164 Species and 450 reactions)
    - Includes BAM aerosols (*Lamarque et al*., 2012).

- Deposition.
    - Wet Deposition based on Neu (*Lamarque et al.,* 2012)
    - Dry Deposition based on CESM Land model.

- New recommendation on future organic halogen evolution (WMO 2010).
    - Several species have latitudinal gradients based on HIPPO aircraft observations (*Park et al*., 2013).

- Additional organic halogens (no surrogates) were included – 18 total.
    - The lifetime of these species has been evaluated in the SPaRC Lifetime assessment.

- Include representation of very short lived (VSL) organic bromine ($CHBr_3$, CH_2Br_2)
    - Added ~ 6.5 pptv additional BrO_Y (total BrO_Y is ~ 22.5pptv).

Updates to CESM1 (WACCM)

- Included representation of Fluorine chemistry (F, HF, COF_2, COFCl).
  - HF is long-lived and useful transport tracer and measured by satellite instruments.

- Updated Heterogeneous Chemistry Module (*Wegner et al.,* 2013a,b)
  - Better representation of PSCs (i.e., STS, NAT, and ICE SAD).
  - Inclusion of HCl solubility in STS.
  - ICE formation now starts at 100% saturation (not 80%).

- New Sulfate Surface Area Density (SAD) Time series (1960-2010).
  - Created by the CCMI working group.
  - Includes time evolution of H_2SO_4 mass and radius.

- Improved representation of volcanic heating (R. Neely and A. Conley).
  - Now using observed H_2SO_4 mass and radius for input into CAMRT.
  - Preliminary results show less volcanic heating.

- Satellite output for SD simulations (courtesy of M. Brakebusch).
  - Approximately 35 instruments (1979-2012).

Polar Ozone and Temperature

- The next few slides will focus on polar total column ozone and temperature at Halley (75S, 26W). This station has the longest total column ozone record (1950s). Temperature comparisons will be made to the MERRA data product.

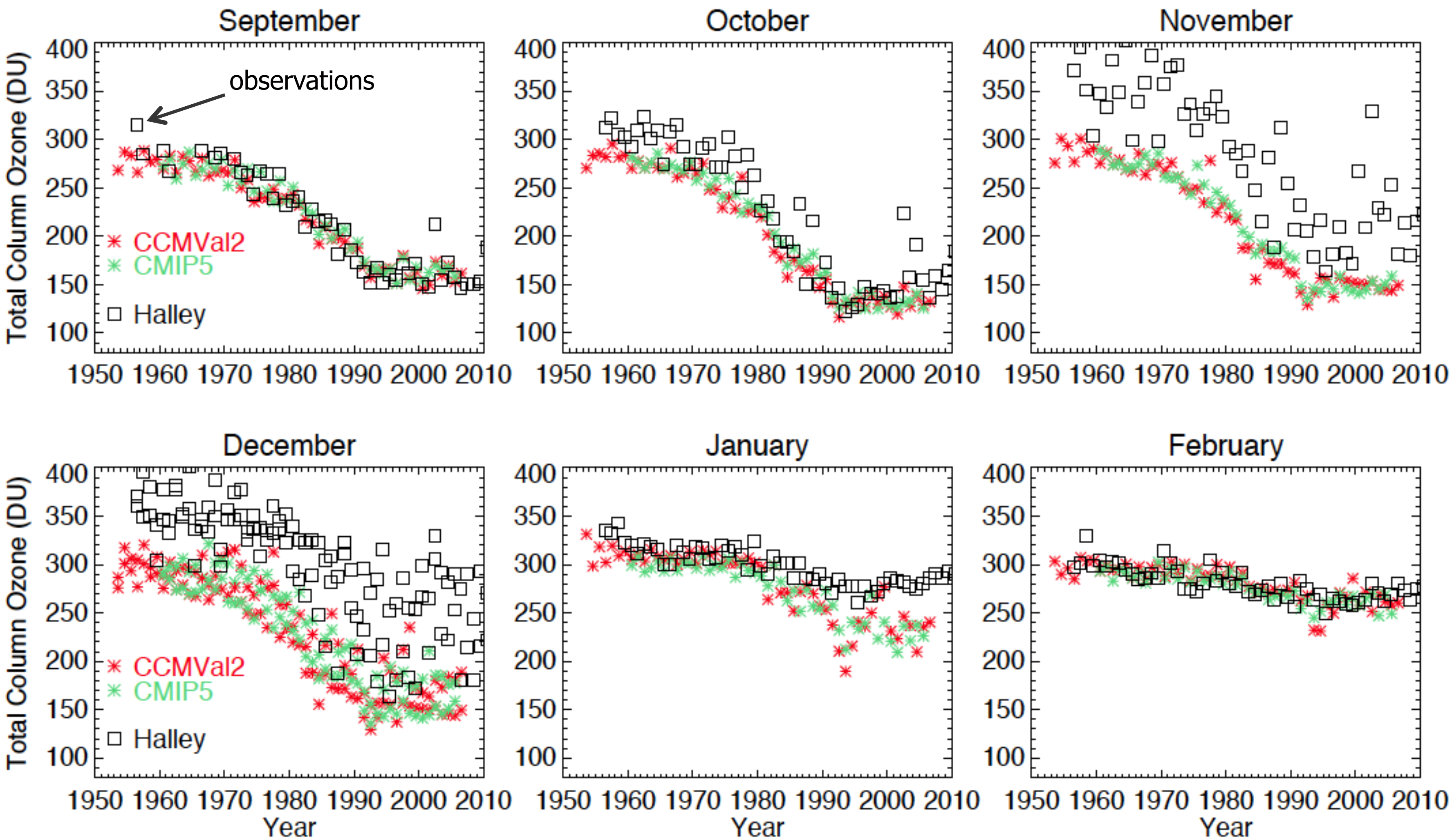
- Simulations from CMIP5 and CCMVal2 will be shown first. These simulations used an older, less scientifically accurate representation of polar heterogeneous processes.

- We then will show results from the FR- and SD-WACCM simulations defined by CCMI.

- The FR-WACCM polar temperature cold bias will be discussed.

- A new CCMI FR-WACCM simulation (to address this bias) including inertial-gravity waves will be shown.

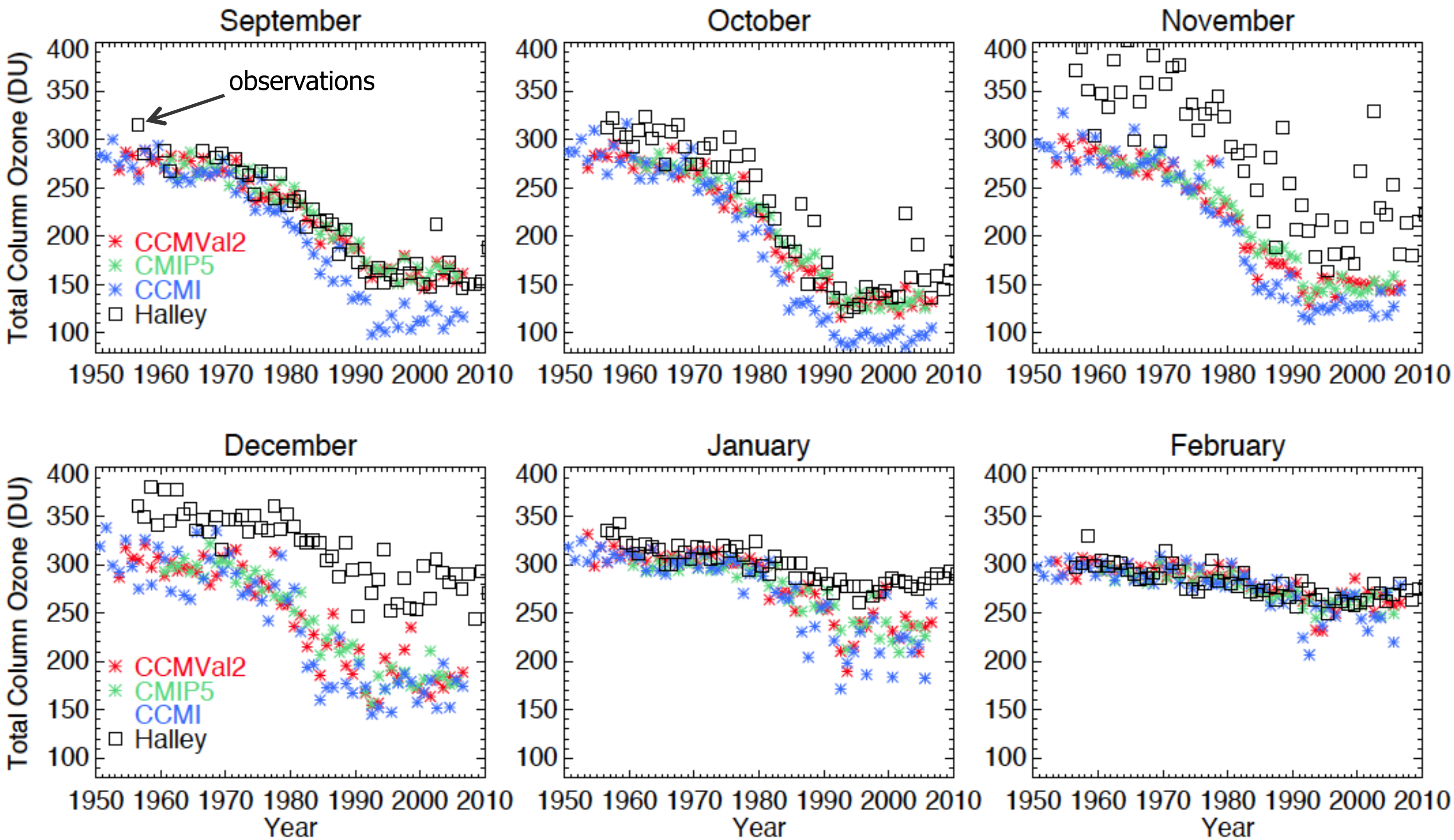
Total Ozone (DU) *** Halley (75S, 26W)



FR-WACCM does a good job of representing the Sept and October period at Halley.
The vortex breaks up late for November through January.

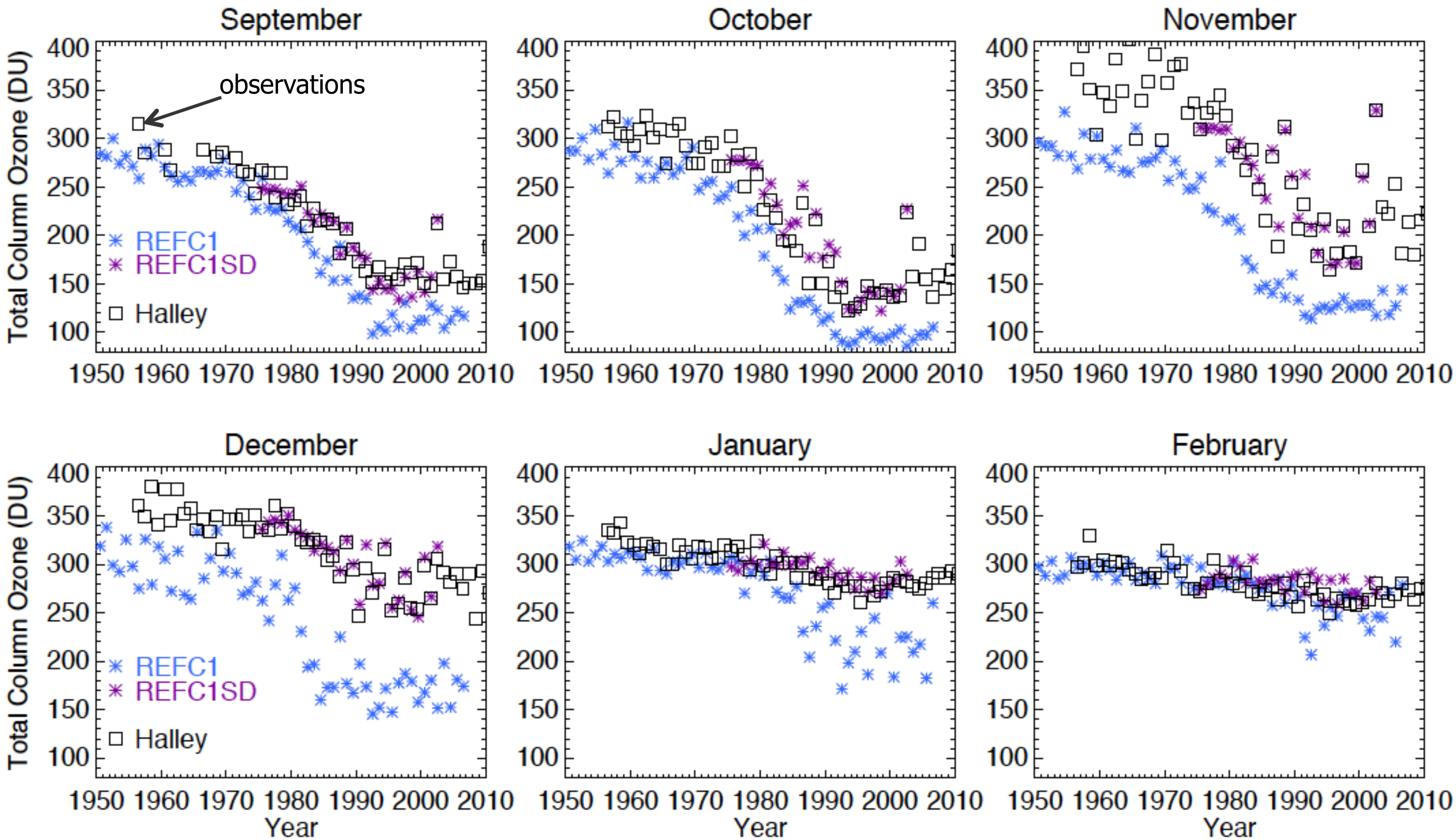
Figure updated from *Marsh et al.*, 2013

CCMI *** Total Ozone (DU) *** Halley (75S, 26W)



CCMI FR-WACCM derives too much column ozone depletion relative to observations and previous assessments.

CCMI *** Total Ozone (DU) *** Halley (75S, 26W)



In SD-WACCM, driven with accurate temperatures, total column ozone is in good agreement with observations.

Polar Temperatures *** Inertial-Gravity Waves

Background …

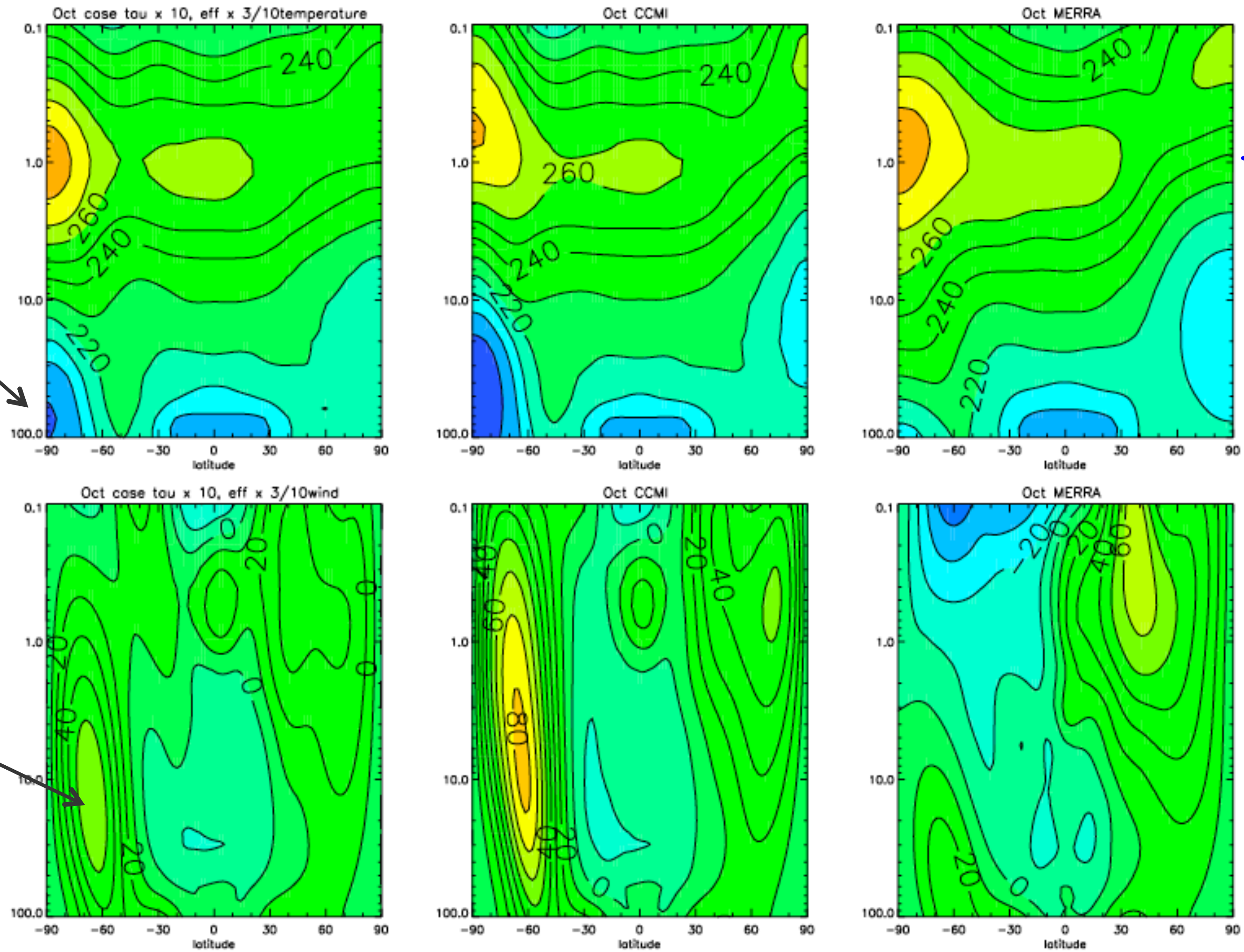
- Internally Generated QBO (*Xue et al.*, JGR, 2012):
  - ⇒ By extending the gravity wave parameterization to include a spectrum of "inertial-gravity" waves, with typical horizontal wavelength 1000 km.
  - ⇒ In contrast to the mesoscale gravity wave spectrum in the standard parameterization, which have wavelength 100 km, the inertial-gravity waves break in the stratosphere and can drive a QBO there.

IGW Simulation…

- Polar Stratospheric Temperature bias (*Tan and Liu*, in prep, 2013):
  - ⇒ If the spectrum of inertial-gravity waves is allowed to operate outside the Tropics, it can also influence the momentum budget of the SH polar stratosphere, reducing the zonal-mean zonal wind and increasing temperatures in the lower stratosphere.

Bias Correction Result for T and U *** October

IGW simulation | CCMI simulation | MERRA



Polar LS Warmed

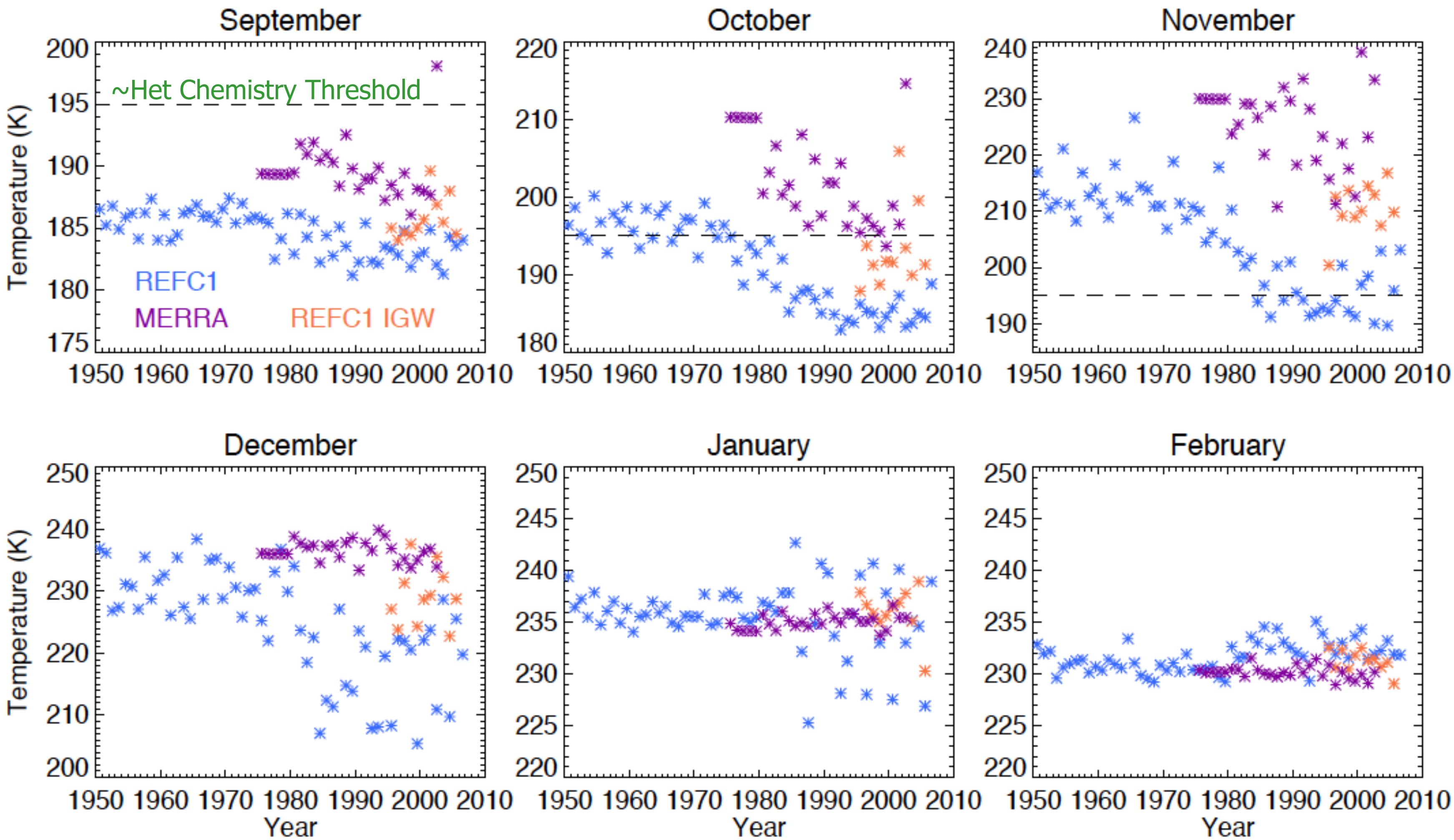
<= Temperature

Zonal winds reduced

<= Zonal Winds

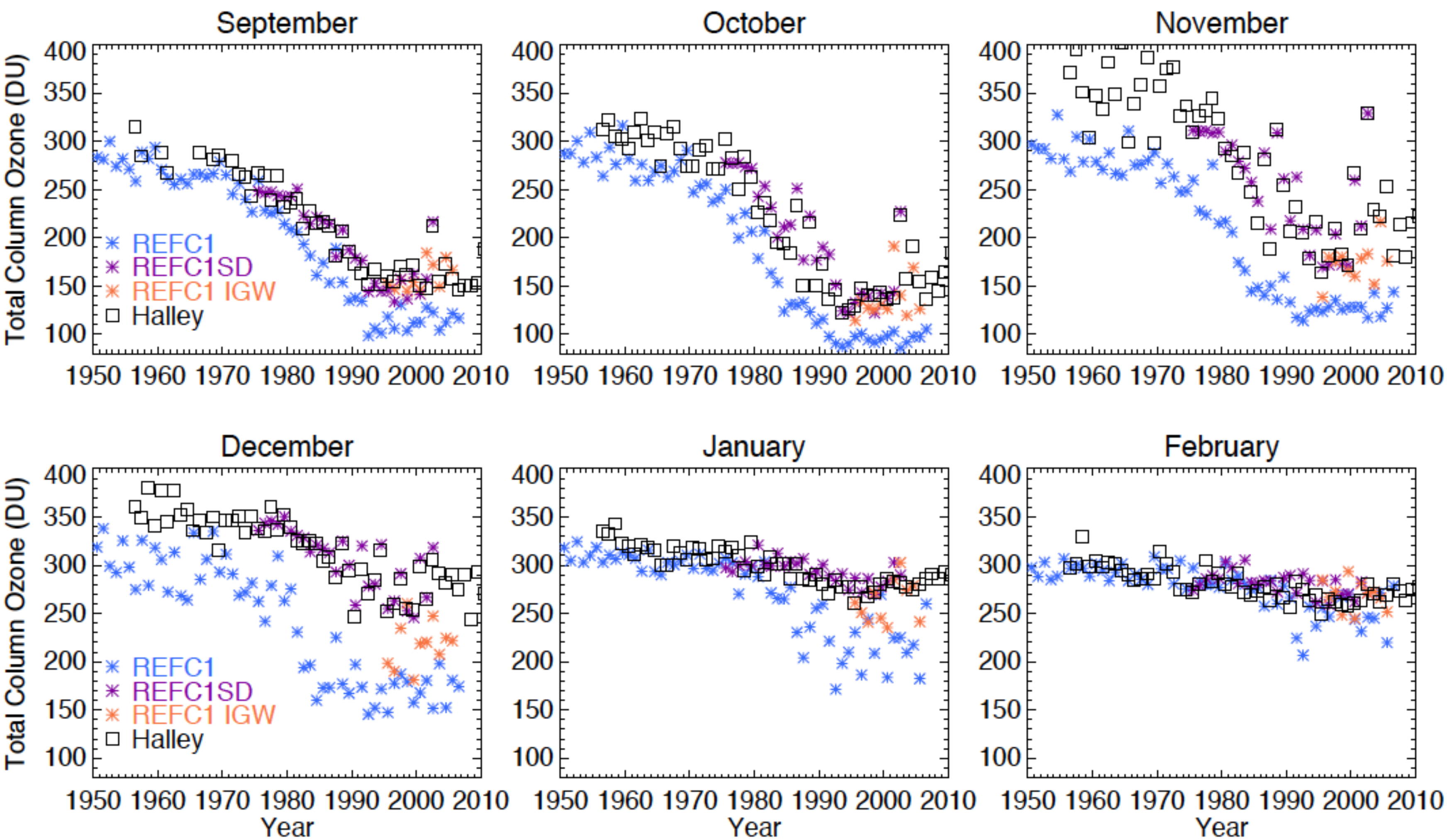
Figure Courtesy of A. Smith, NCAR

With IGW *** Temperature (K) *** Halley, 43hPa



The IGW approach warms the the polar stratosphere significantly in September through December.

IGW *** Total Ozone (DU) *** Halley (75S, 26W)



Adding the IGW approach to FR-WACCM improves the total column ozone results.

Summary and Future Work

- The CCMI simulations (FR and SD) are the most completed representation of chemical processes ever attempted in a hindcast WACCM simulation.

- Updates to the model heterogeneous chemistry has improved chemical processes and gives good results in the Specified Dynamics version of WACCM.

- However, in FR-WACCM, due to a lower stratosphere polar temperature bias (-5 to -10K), these updates have also increased the sensitivity to polar ozone depletion.

- Ongoing efforts are underway to reduce the FR-WACCM polar temperature bias (e.g., IGW simulation).