CONTRAST:

Convective Transport of Active Species in the Tropics

Co-PIs: Elliot Atlas (U.Miami); Ross Salawitch (U.Md.); Laura Pan (NCAR)

Location: Guam

Dates: January – February 2014

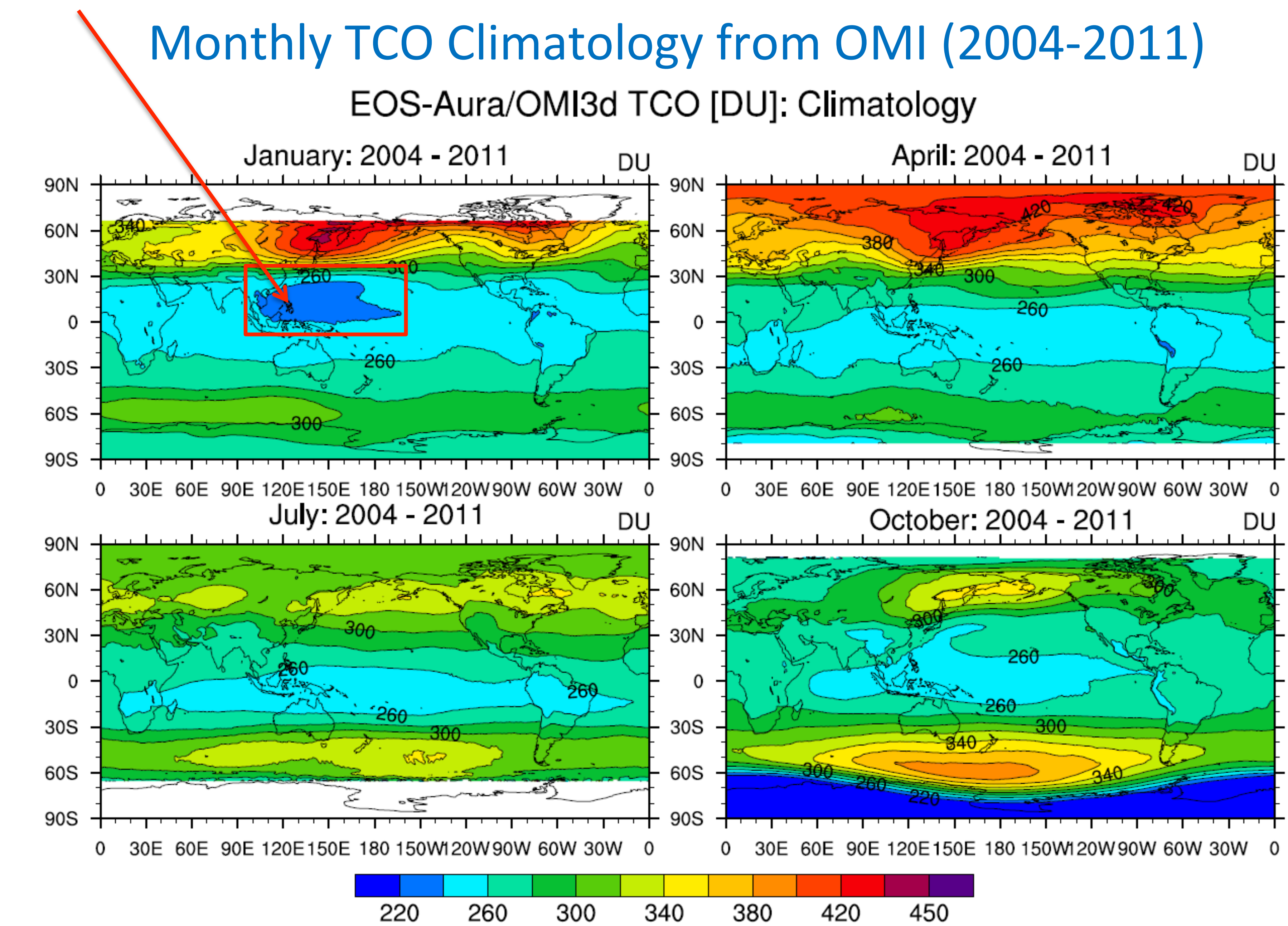
Status: Pending final approval from NSF

CONTRAST

- **Motivations**
  - Role of deep convection in TTL chemistry -> chemistry-climate interactions
  - Western Pacific – most convective region in NH winter -a unique and not well characterized chemical environment
- **Scientific Concept – hypothesis and goals**
  - Deep convection – zero ozone environment – possibly an OH hole – extended lifetime for short-lived species -impact on TTL and stratospheric chemistry
- **Experiment Design**
  - NSF GV – Guam, Jan-Feb 2014
  - Coordinated GV flights w. GH (ATTREX) and BAe146 (CAST) to investigate MBL to LS

Western Pacific in NH winter – an extremely low ozone environment

Monthly TCO Climatology from OMI (2004-2011)



Observations of Near-Zero Ozone Concentrations Over the Convective Pacific: Effects on Air Chemistry

Kley et al., 1996

D. Kley,* P. J. Crutzen, H. G. J. Smit, H. Vömel, S. J. Oltmans, H. Grassl, V. Ramanathan

A series of measurements over the equatorial Pacific in March 1993 showed that the volume mixing ratios of ozone were frequently well below 10 nanomoles per mole both in the marine boundary layer (MBL) and between 10 kilometers and the tropopause. These latter unexpected results emphasize the enormous variability of tropical tropospheric ozone and hydroxyl concentrations, which determine the oxidizing efficiency of the troposphere. They also imply a convective short circuit of marine gaseous emissions, such as dimethyl sulfide, between the MBL and the uppermost troposphere, leading, for instance, to sulfate particle formation.

Because of the reactions

$$O_3 + h\nu(\lambda < 320\,\mathrm{nm}) \rightarrow O(^1D) + O_2 \quad (R1)$$

$$O(^1D) + H_2O \rightarrow 2OH \quad (R2)$$

where h is Planck's constant, ν is frequency, and λ is wavelength, ozone (O_3) is the precursor molecule for hydroxyl (OH) radicals (*1*), the atmosphere's main oxidizing agent. The small fraction of atmospheric O_3 that is located in the troposphere thus plays a large role in the chemical composition of the atmosphere. In the stratosphere, photolysis of molecular oxygen (O_2) forms O_3, of which a fraction is transported mostly to the extratropical troposphere (*2*).

In the troposphere, reactions R1 + R2, and, in addition, reactions

$$CO + OH \rightarrow H + CO_2 \quad (R3)$$

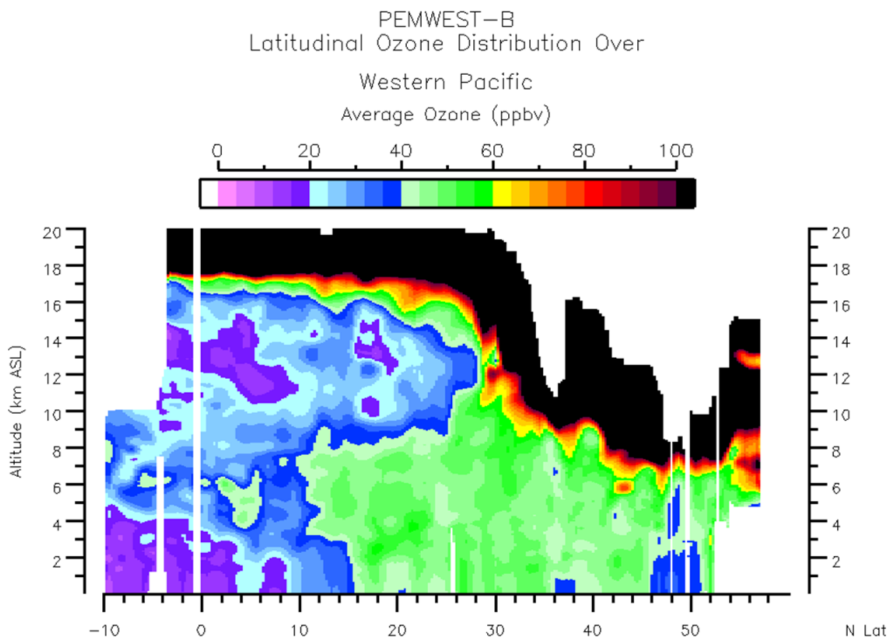
$$H + O_2 + M \rightarrow HO_2 + M \quad (R4)$$

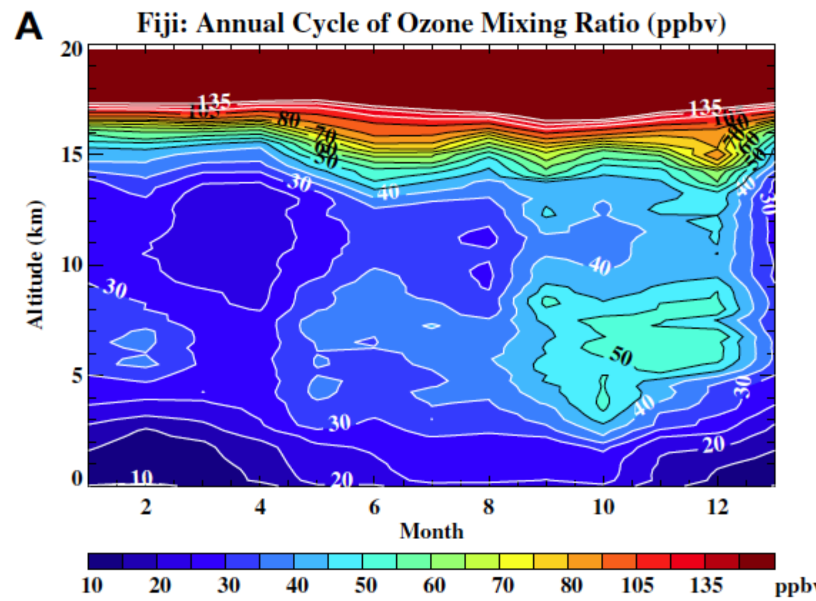
$$HO_2 + O_3 \rightarrow OH + 2O_2 \quad (R5)$$

$$\text{net: } O_3 + CO \rightarrow CO_2 + O_2$$

are responsible for O_3 destruction (*3*). In the oceanic atmosphere, emissions of nitric oxide (NO) from the surface and lightning are small. With measured NO volume mix-

Low ozone conditions observed by airborne LIDAR and ozonesondes





Lidar O_3 observations from PEM WEST-B

Feb 1994, along ~ 140 E

Crawford et al., 1997, Newell et al., 1997

O_3 seasonal cycle 1998-2008 SHADOZ/Fiji

Thompson et al., 2011

A Tropical West Pacific "OH hole" and Implications for Stratospheric Composition

Markus Rex[1], Theo Ridder[2], Ingo Wohltmann[1], Ralph Lehmann[1], Debra Weisenstein[3], Justus Notholt[2], Franz Immler[4] , Kirstin Krüger[5], Viktoria Mohr[5], Susann Tegtmeier[5]

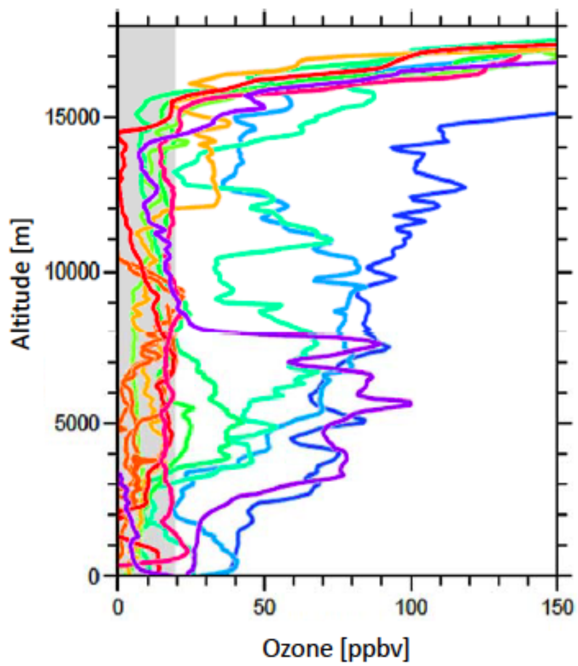
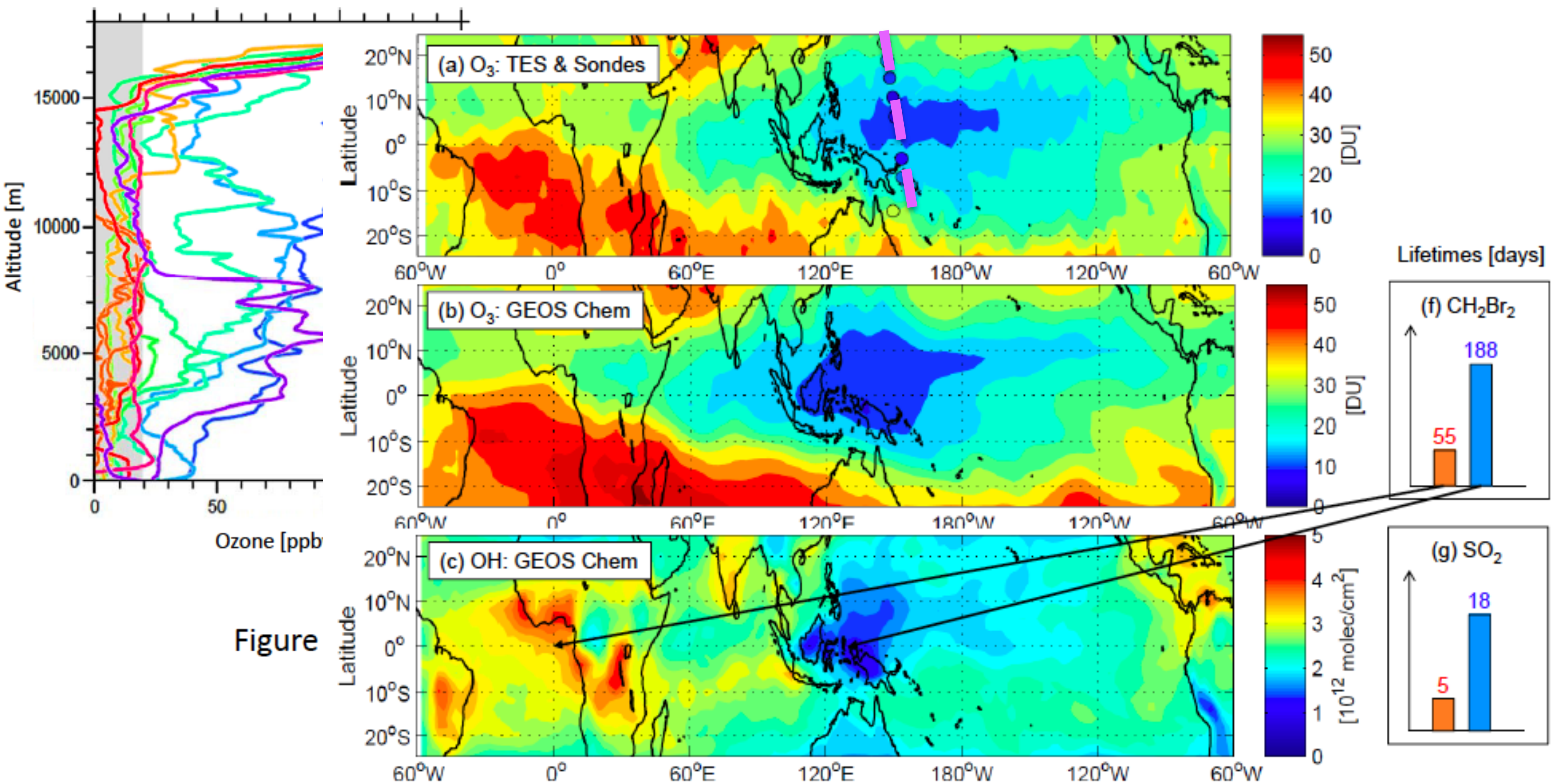


Figure 1

A Tropical West Pacific “OH hole” and Implications for Stratospheric Composition

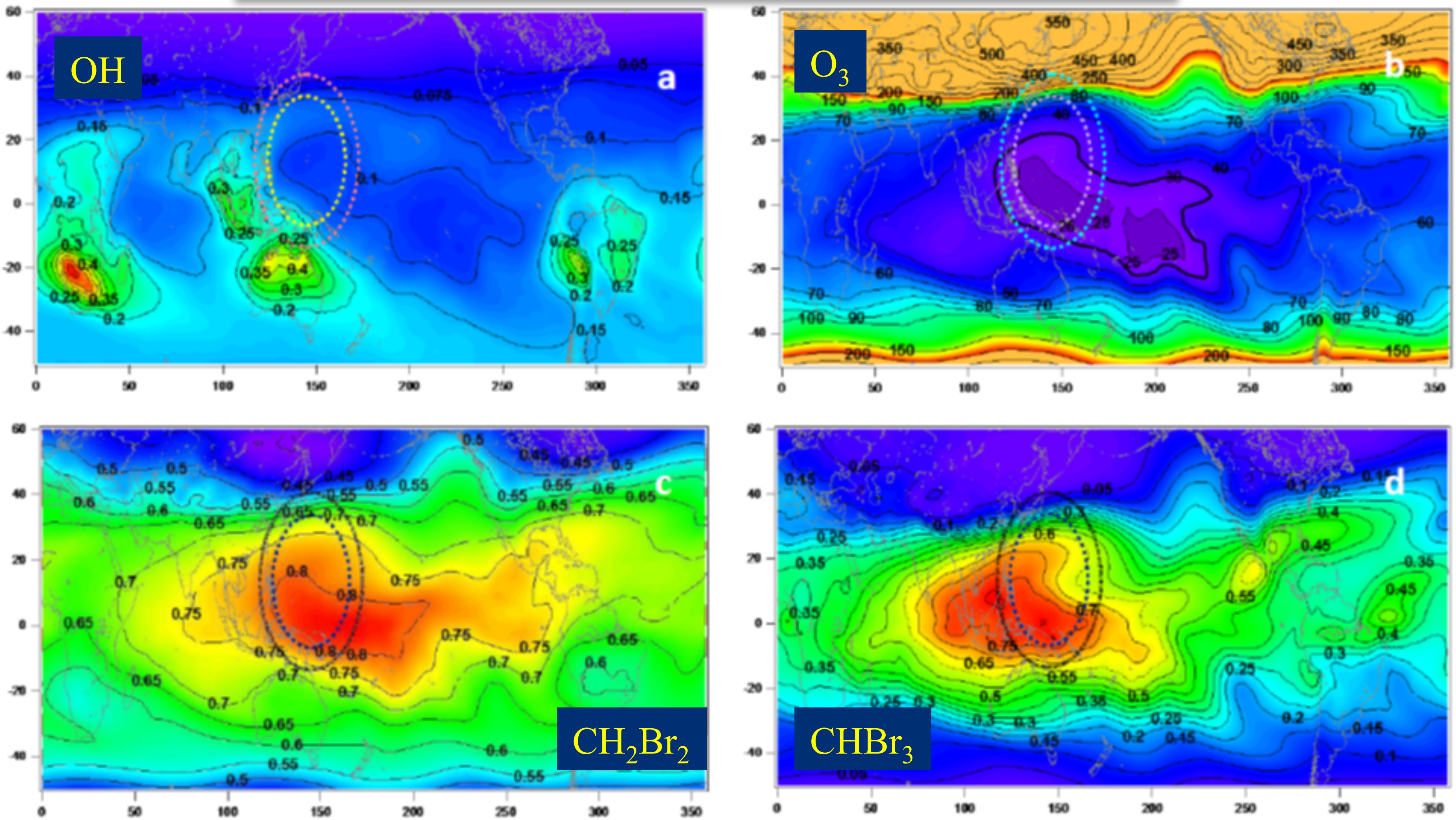
Markus Rex[1], Theo Ridder[2], Ingo Wohltmann[1], Ralph Lehmann[1], Debra Weisenstein[3], Justus Notholt[2], Franz Immler[4] , Kirstin Krüger[5], Viktoria Mohr[5], Susann Tegtmeier[5]



Figure

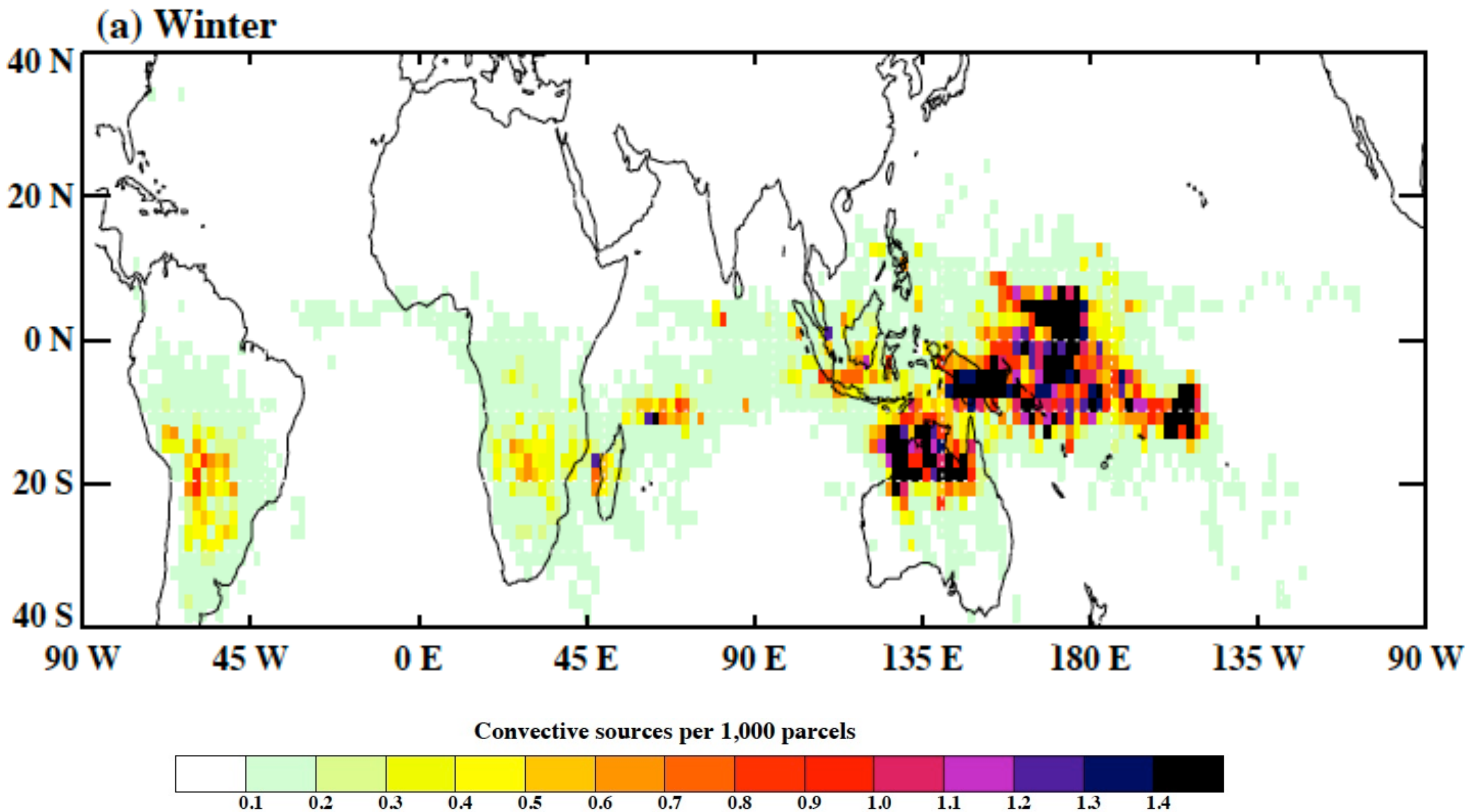
Models predict high levels of reactive halogens, low ozone and OH, with significant loss of O_3 due to halogen cycles. CONTRAST will test these model predictions.

Model predictions from CAM-CHEM

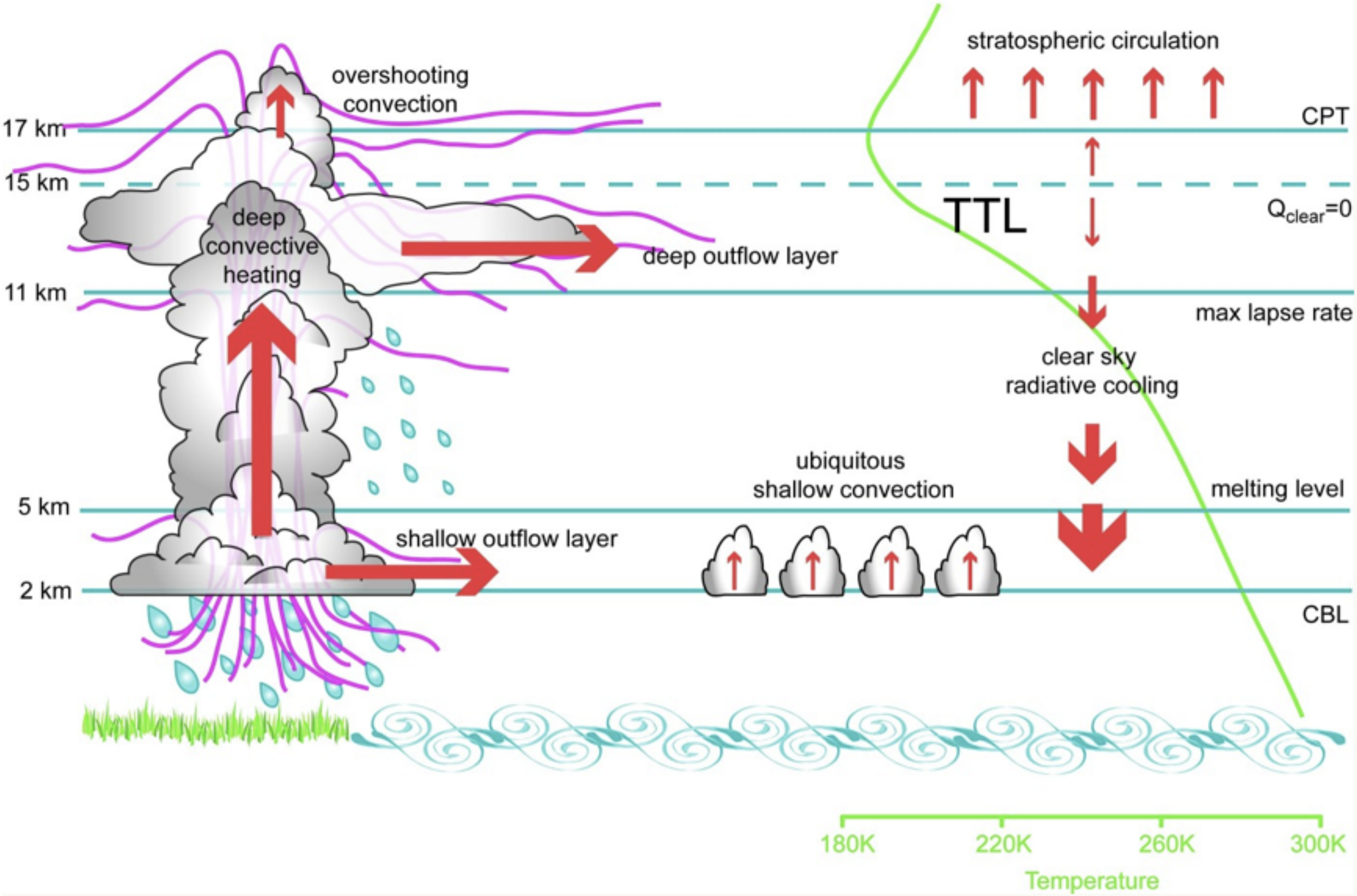


Bergman et al., 2011

Convective detrainment for air reaching 380 K



Tropical Tropopause Layer and Deep Convection



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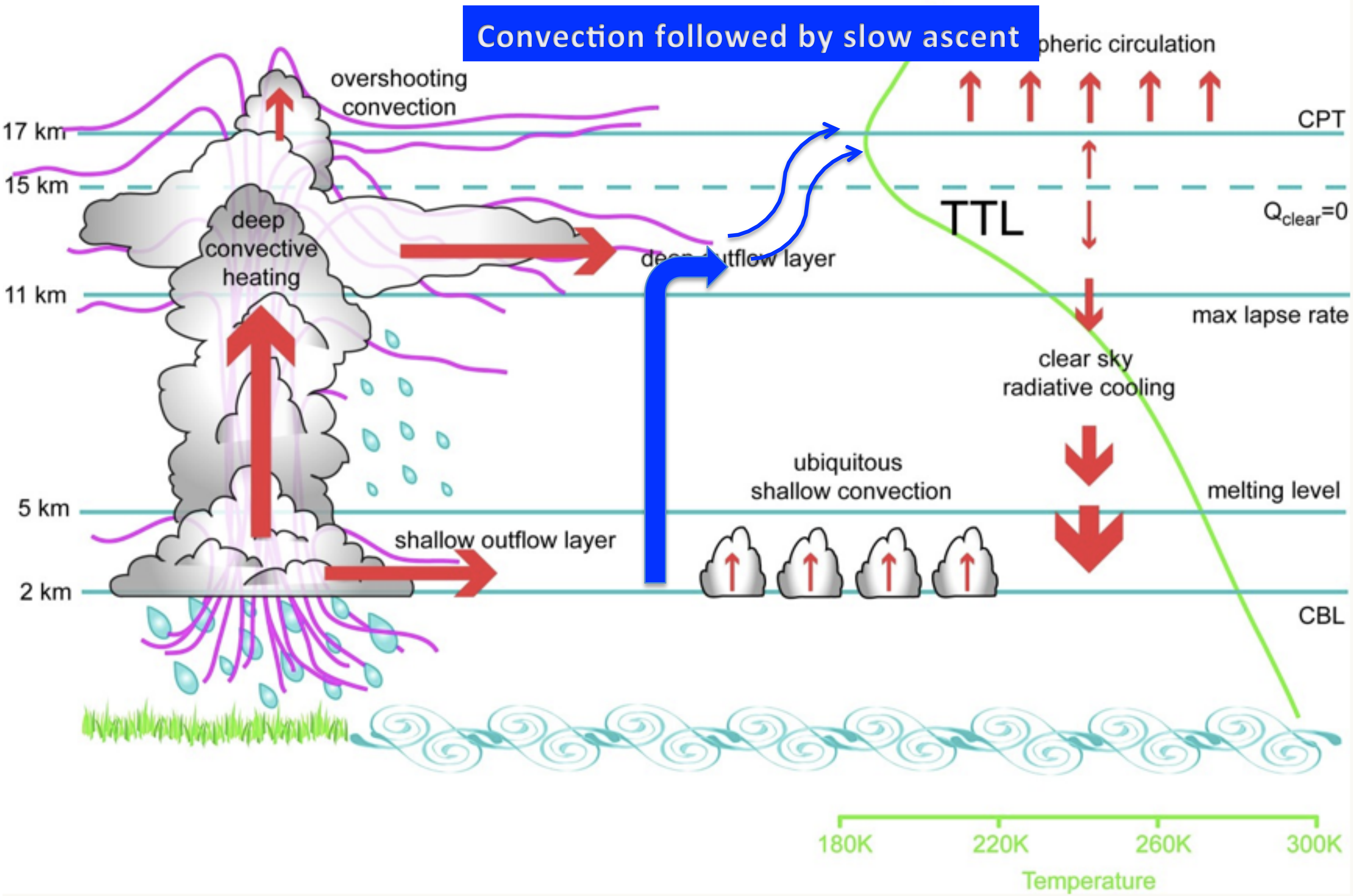

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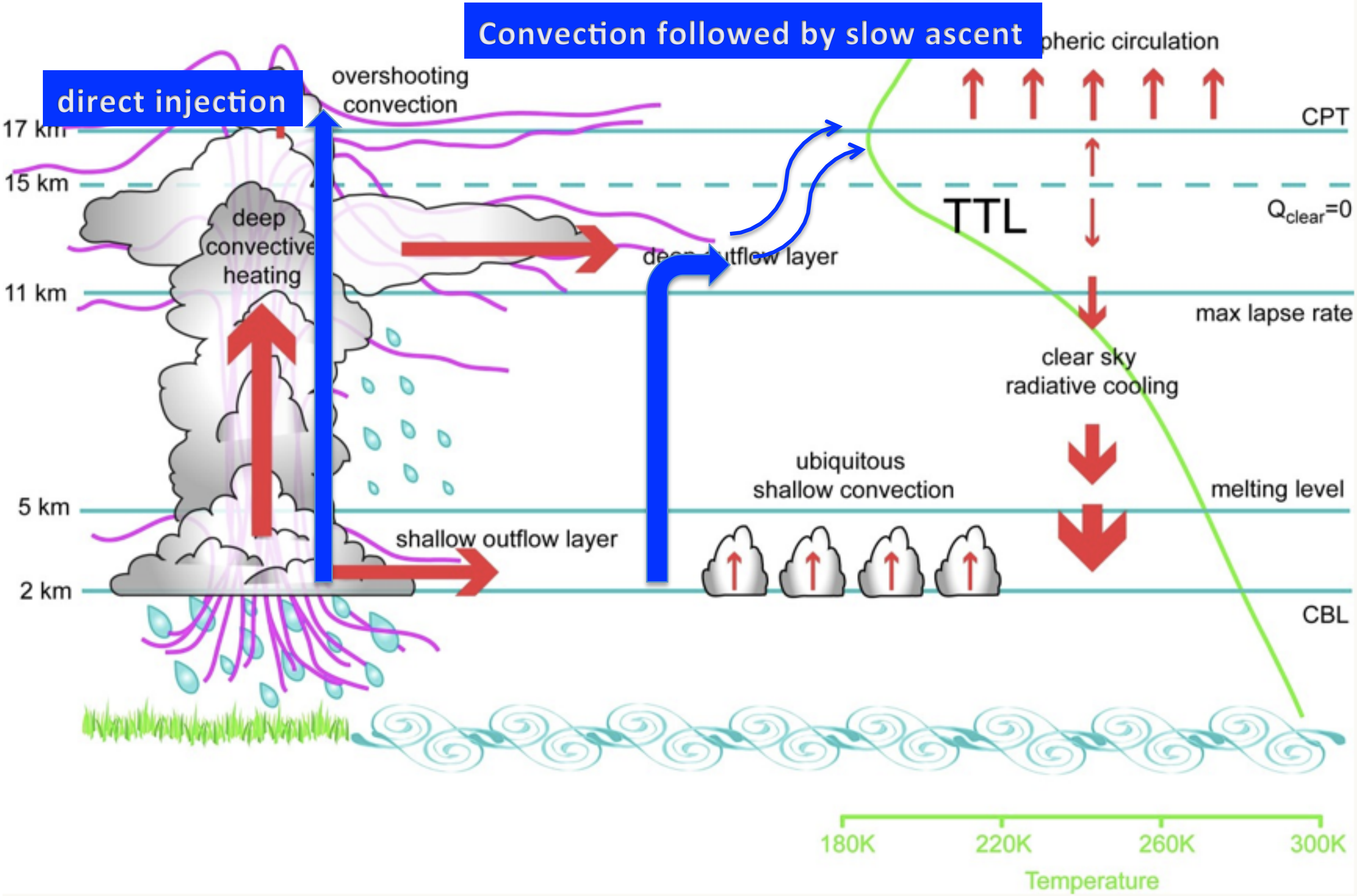

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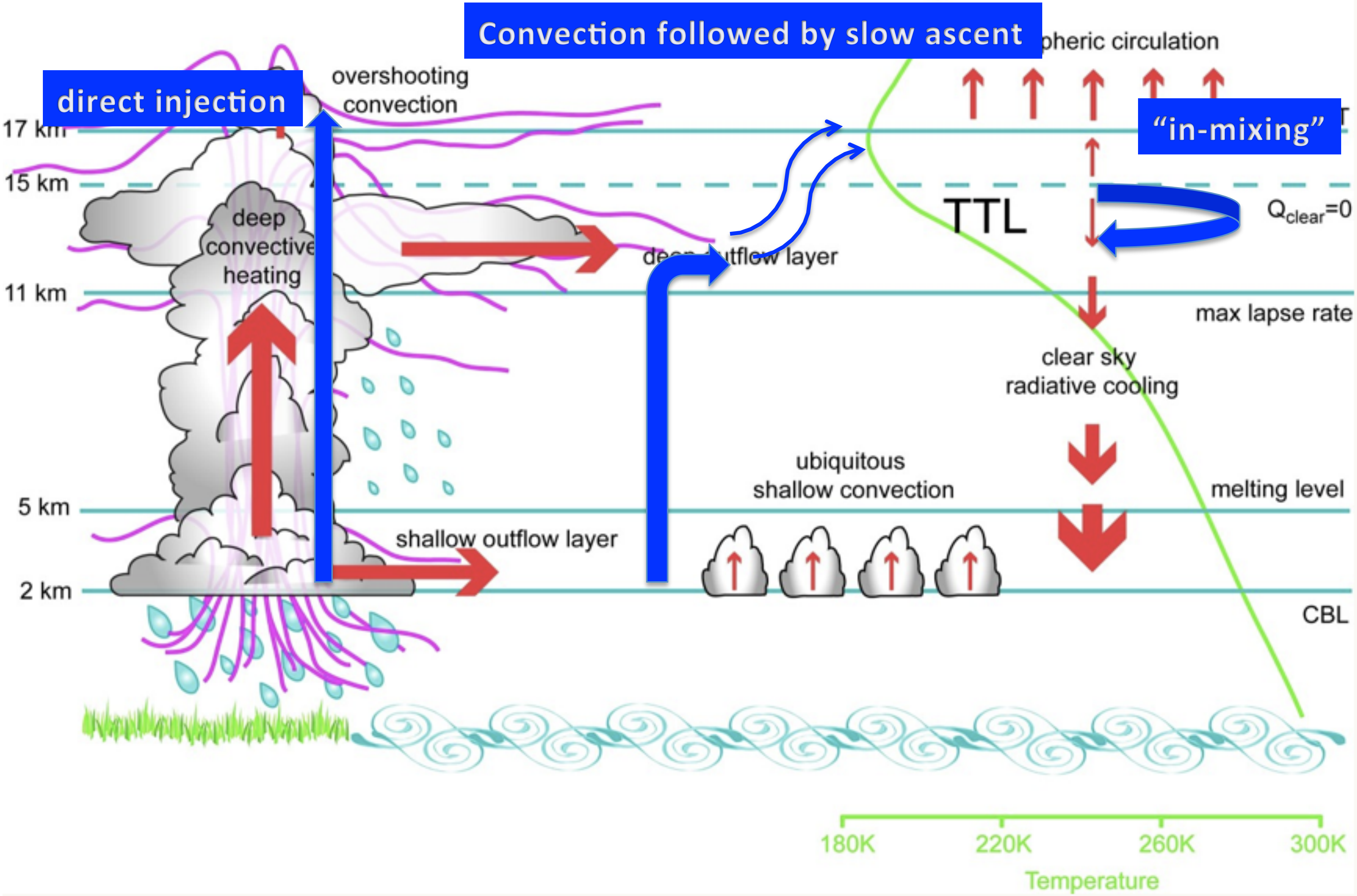


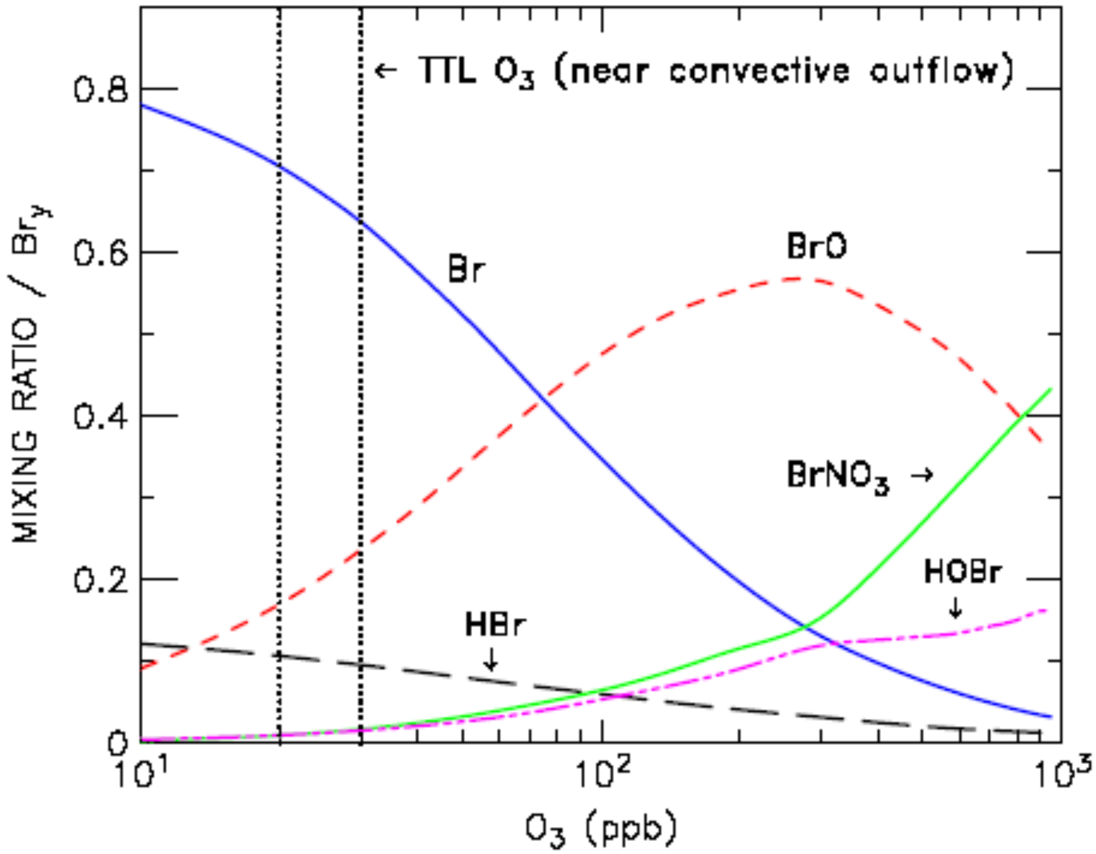


Figure 2. Calculated abundance of inorganic Br_y species, local noon, as a function of ozone mixing ratio. Results are normalized to the total abundance of Br_y. The model was run for the following inputs: Lat=10°N, Solar Decl=20° (summer), T=200 K, p=130 hPa, H_2O=12.5 ppm, CH_4=1.8 ppm, CO=60 ppb, Br_y=4 ppt; NO_y=400 ppt for O_3 < 100 ppb & $NO_y=0.00175\times O_3$ for O_3 > 230 ppb. Inputs for SA, Cl_y, and γHOBr+HBr are for Run 1a conditions (see Table 1). The abundances are from diurnal photochemical steady state simulations.

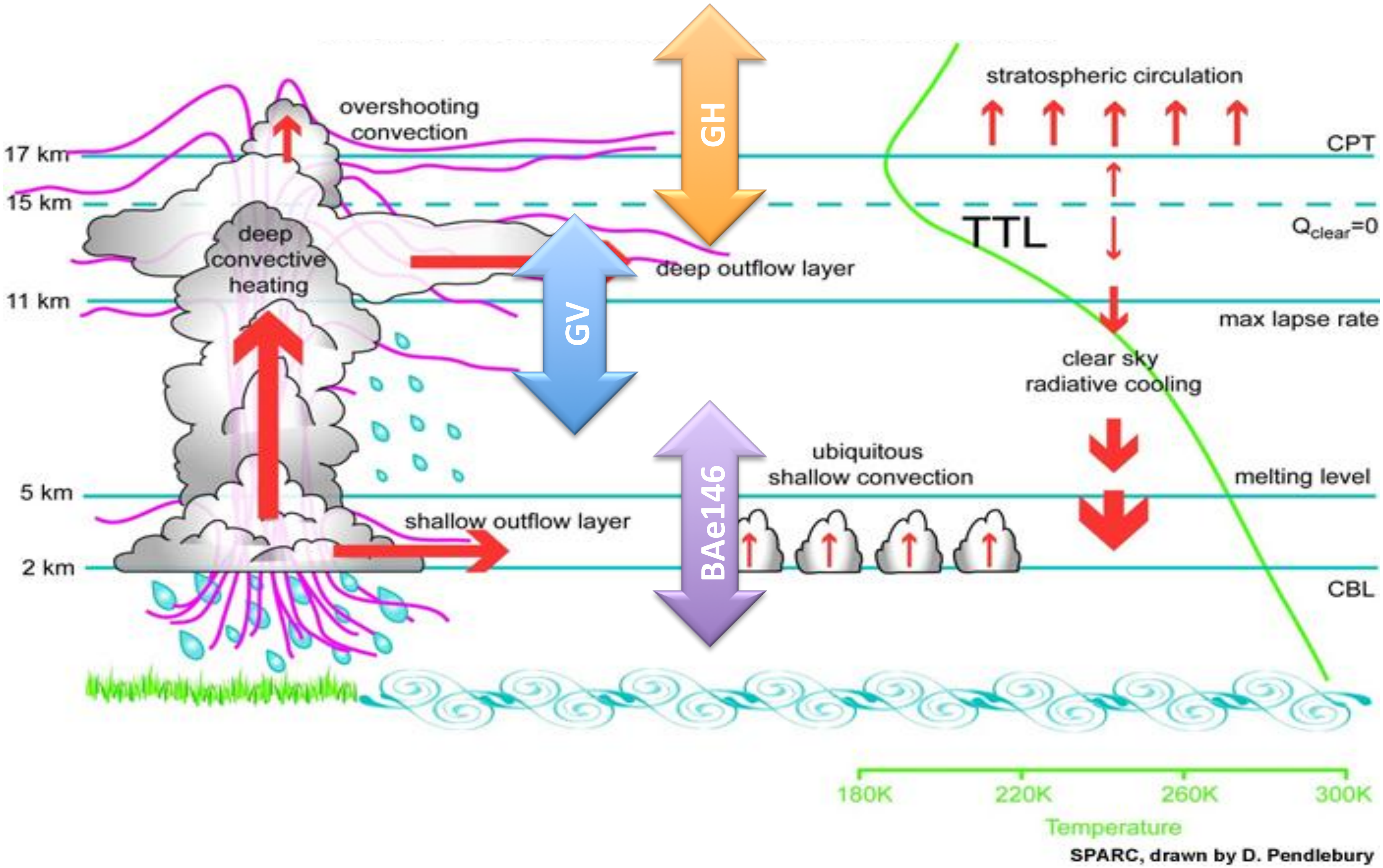
CONTRAST: Scientific Objectives

- **Characterize the chemical composition and ozone photochemical budget at the level of convective outflow over the Western Pacific during the deep convective season**

- **Evaluate the budget of organic and inorganic bromine and iodine in the TTL**

- **Investigate transport pathways from the oceanic surface to the tropopause using the GV coordinated flights with BAe-146 and Global Hawk**

TTL and Convective Transport



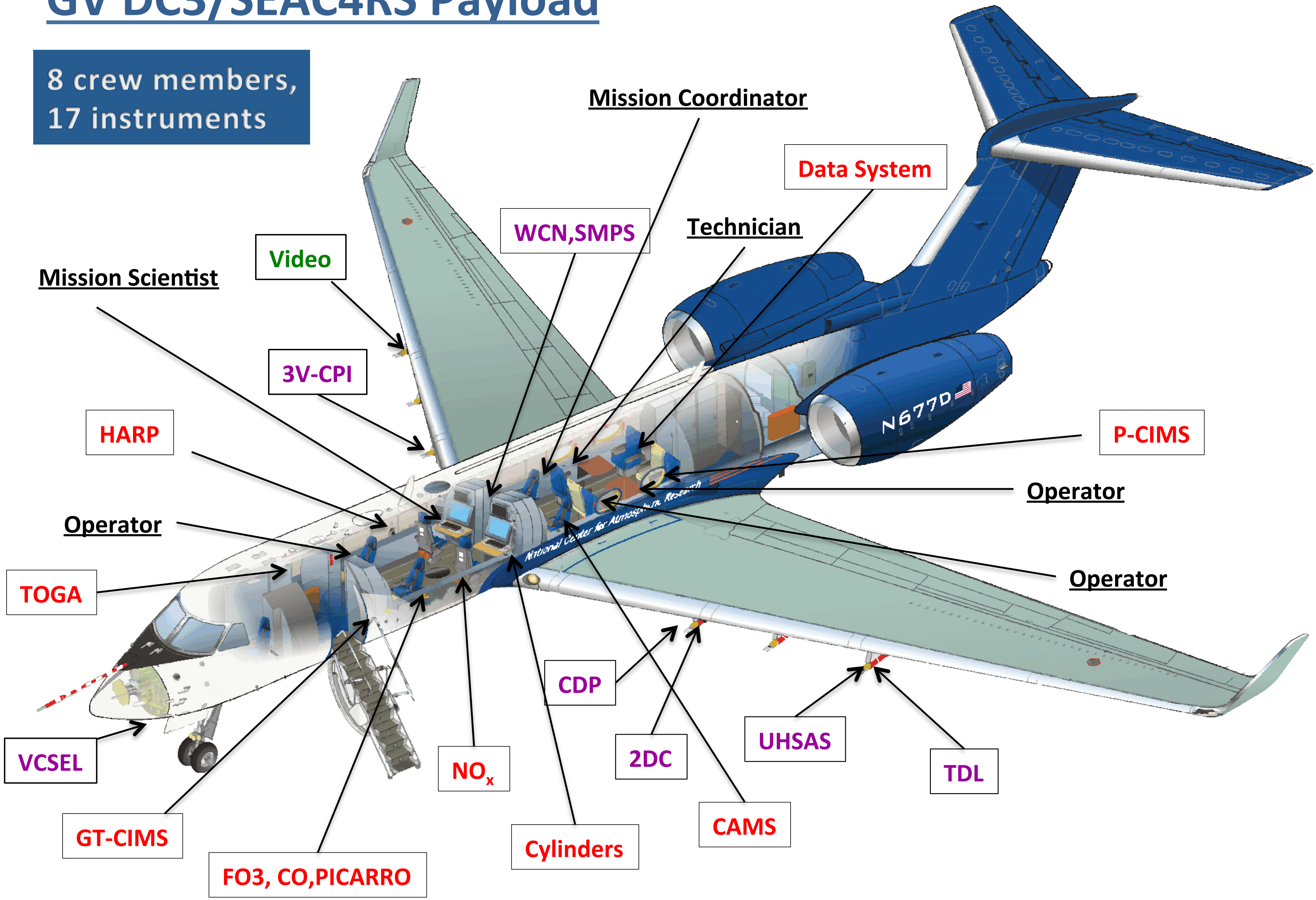

NSF
NCAR
NSF/NCAR Gulfstream V (GV)
National Center for Atmospheric Research
N677F

Observational Requirements and relationship to scientific objectives: 1=chemical characterization, O3 budget; 2=halogen budget; 3= transport and mixing. Comparable instruments on Global Hawk and BAe aircraft noted

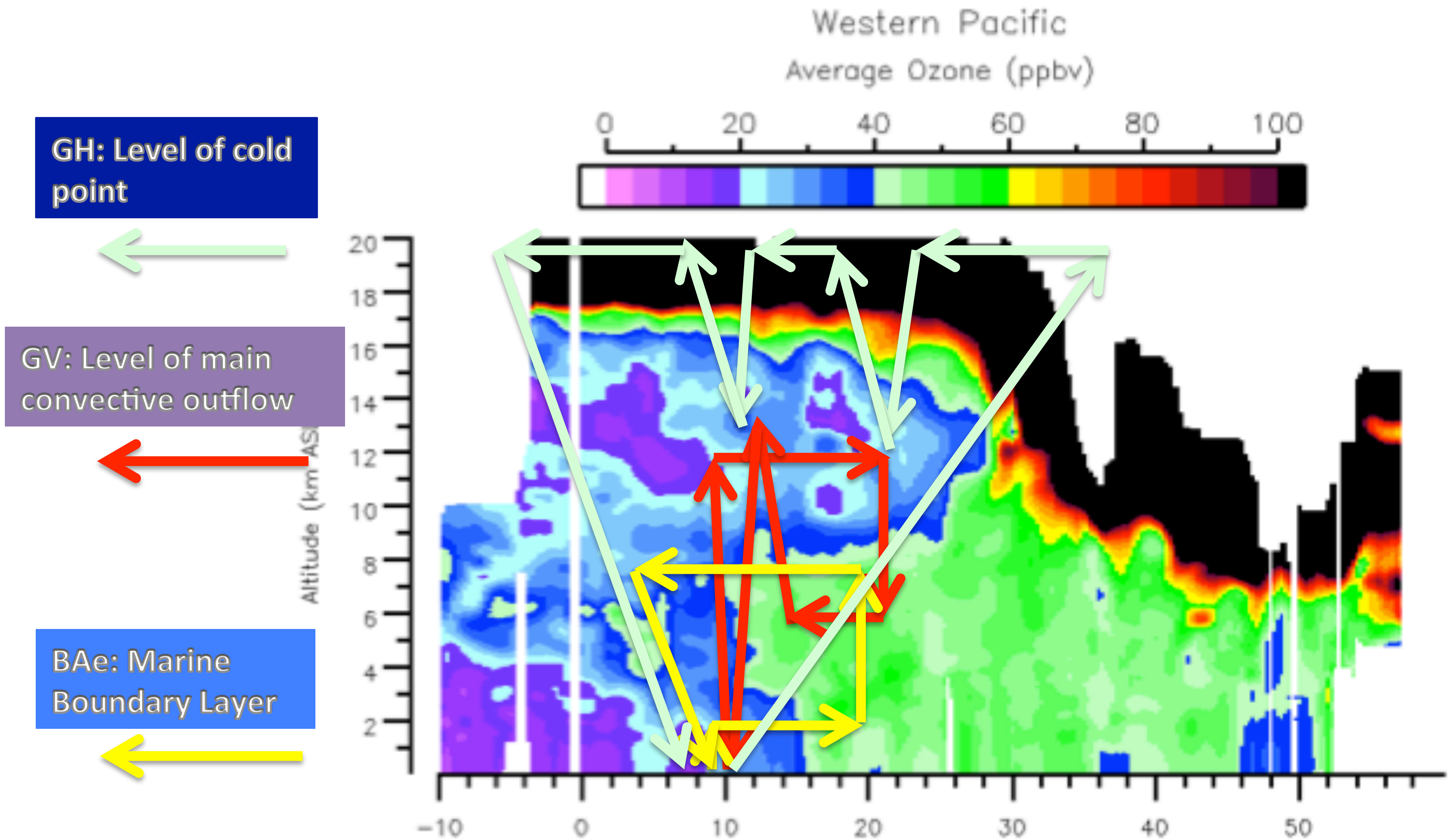
Observation	Requirement	Instrument Source & Status	Objective	GH	BAe
O3	1 ppbv; 10 s	Facility (Fast O3)	1,2,3	Yes	Yes
H2O Vapor	1 – 1000 ppmv; 1 s	Facility (VCSEL)	1,2	Yes	Yes
CO	5%; 10 s	ACD (VUV)	1,3	Yes	Yes
CH4	5 ppbv; 10 s	ACD (Picarro)	1,3	Yes	Yes
CO2	0.3 ppmv; 10 s	ACD (Picarro)	1,3	Yes	Yes
H2CO	25 pptv; 30 s	CU (Laser DFG)	1,2,3	No	No
NO, NO2	5 pptv; 10 s	ACD (Chemiluminescence)	1,2	No	Yes
BrO, HOBr, Br2 (in situ)	2 pptv; 10 s	Facility (CIMS)	1,2	No	Yes
BrO, IO, H2CO (remote)	2/1/100 pptv; 10 s	CU-AMAX (DOAS)	1,2	Yes	No
Br, I	2 pptv; <1 min	CIAC (Spain) (ROFLEX)	2	No	No
NMHC, including short lived tracers, HCFCs, halocarbons	Various	Facility (AWAS)	1,3	Yes	Yes
Oxygenated VOC, VOC	Various ; 2-4 min.	Facility (TOGA)	1,3	No	No
Aerosol (number, size, distribution)	Various	Facility (USHAS)	1,2	No	No
Cloud detection		Facility (CDP, 2D-C)	1,2	Remote	No
Microwave Temperature Profiler	2 K 6 km above / below aircraft	Facility (MTP)	3	Yes	No
Radiation (UV/VIS)		Facility (HARP)	1,2	Yes	Yes

GV DC3/SEAC4RS Payload

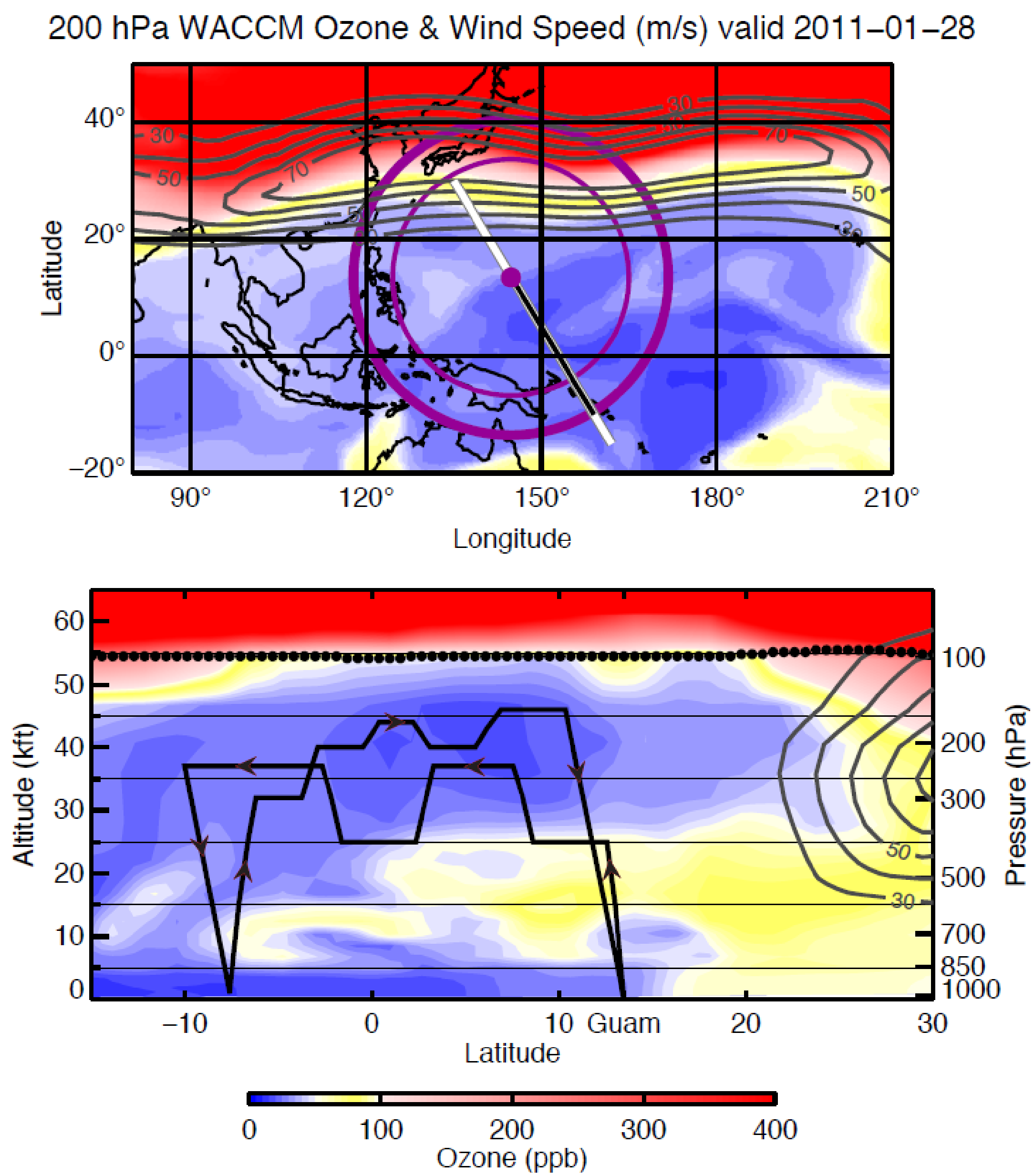
8 crew members,
17 instruments



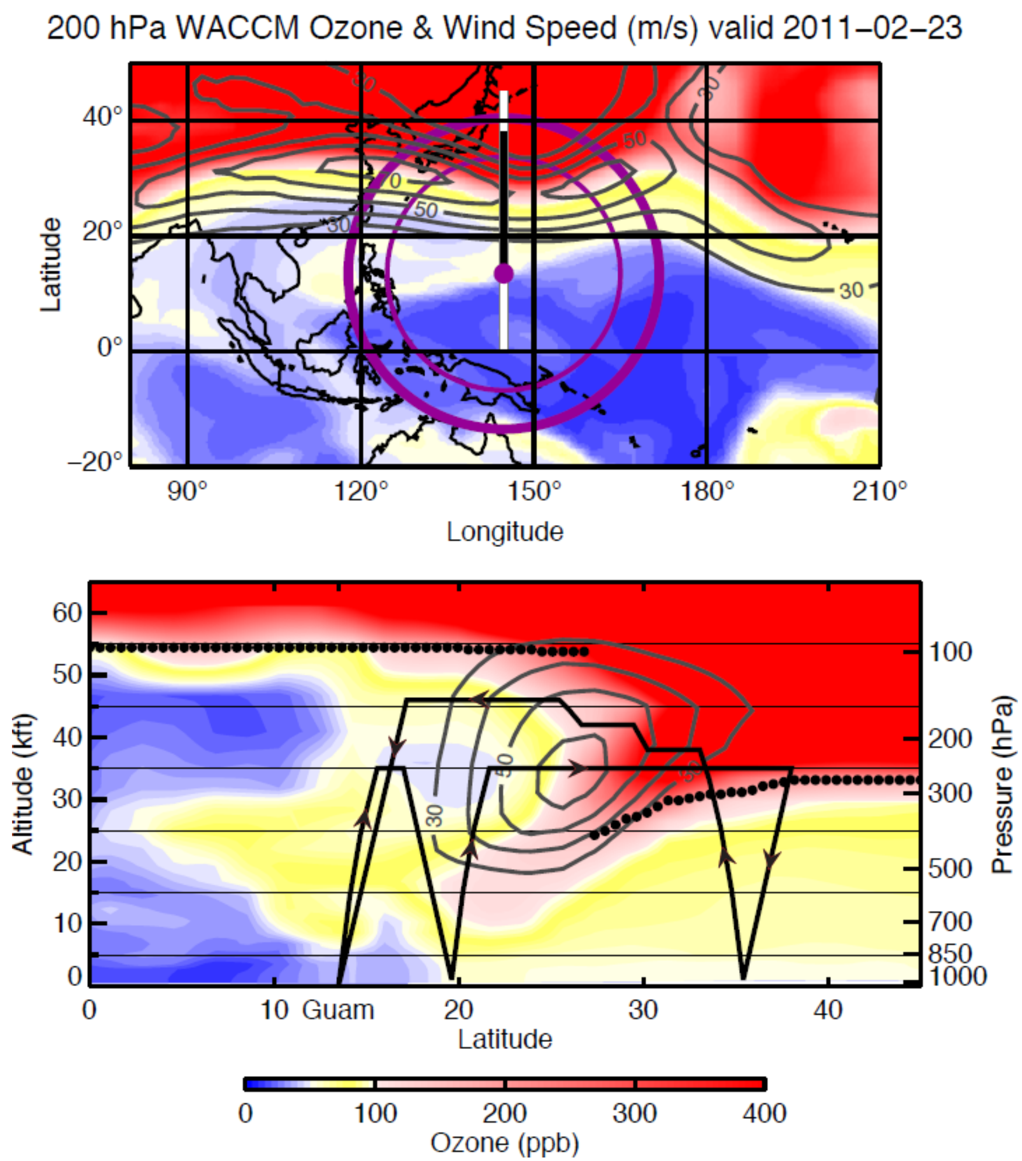
Flight coordination concept:



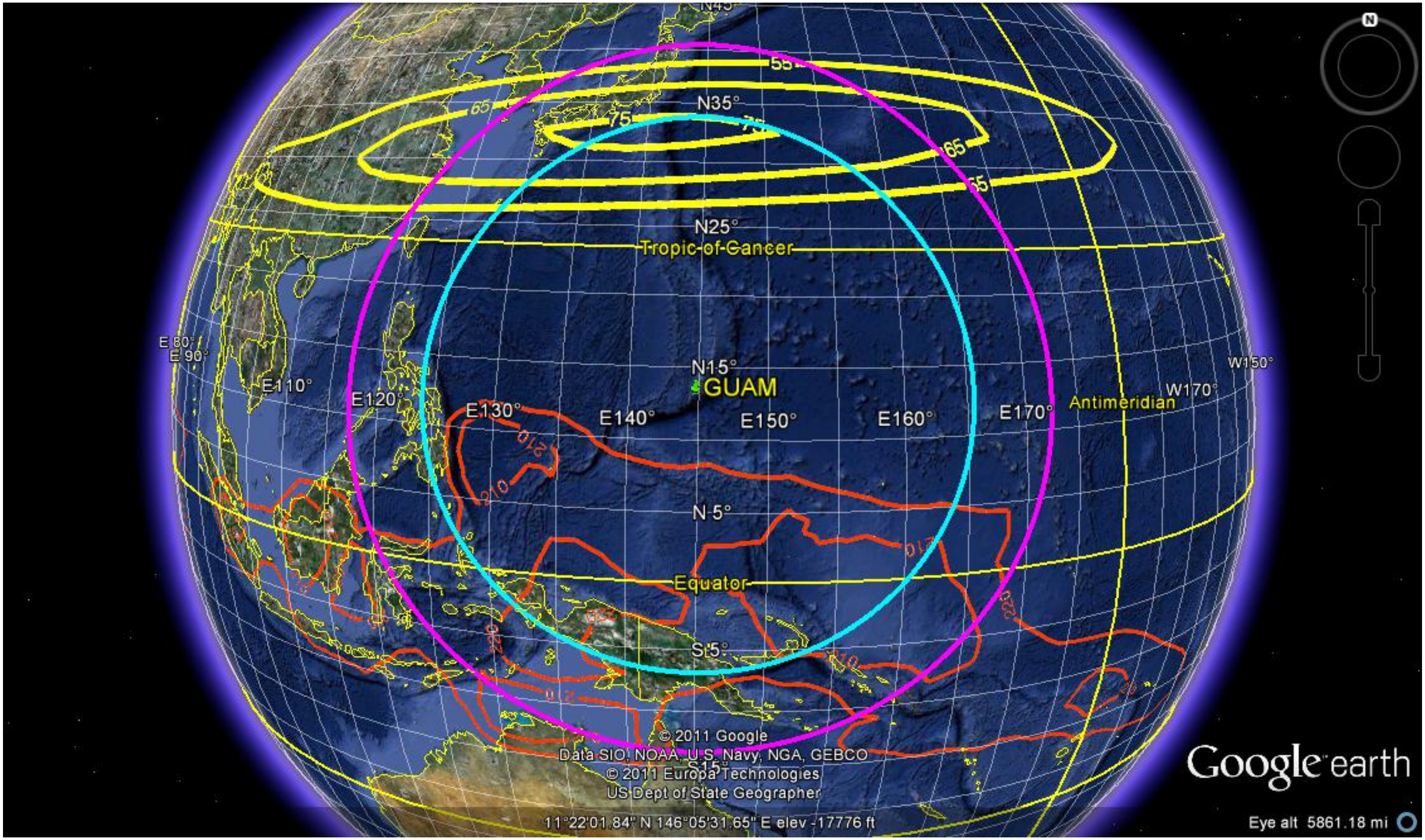
Conceptual GV flight patterns: Convective Outflow



Conceptual GV flight patterns: Jet crossing

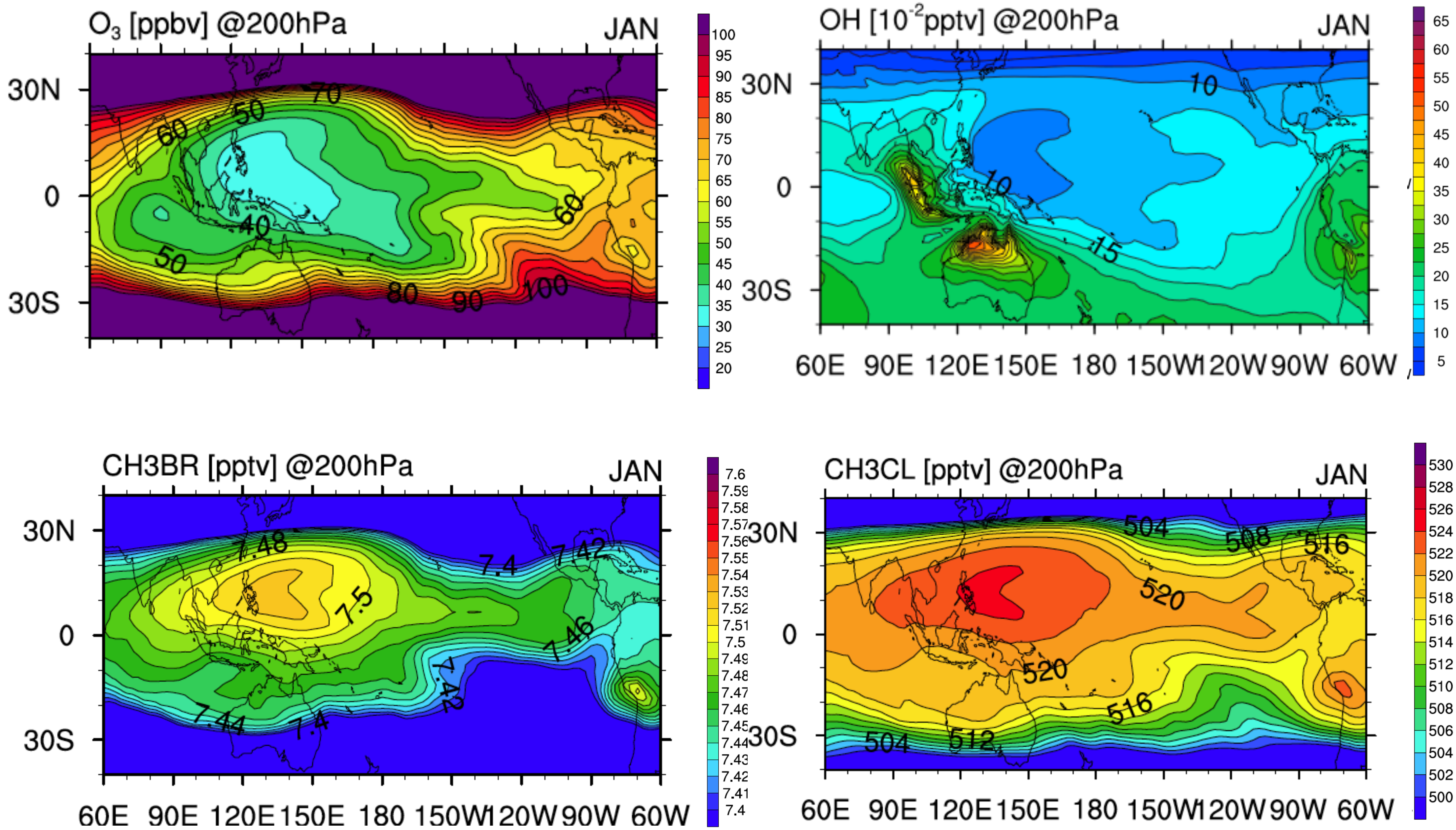


Map of Operations




Thank You !
RF18, June 27, 2008
3/4/08

Multi-year climatology from WACCM-SD



GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L23813, doi:10.1029/2005GL024323, 2005

On the distribution and variability of ozone in the tropical upper troposphere: Implications for tropical deep convection and chemical-dynamical coupling

S. Solomon,[1] D. W. J. Thompson,[2] R. W. Portmann,[1] S. J. Oltmans,[3] and A. M. Thompson[4]

Received 5 August 2005; revised 14 September 2005; accepted 20 October 2005; published 8 December 2005.

[1] Tropical ozonesonde measurements display events of substantially reduced or near-zero ozone in the upper troposphere that can be coherent over broad spatial scales. Available observations indicate that these events occur most frequently between about 300 and 100 mbar in the tropical southwest Pacific region. The spatial structure of the events suggests linkages to deep convection as the primary cause, with the potential for long-range transport from the southwest Pacific to other locations. Observations are sparse in time as well as space, but suggest possible long-term changes in tropical ozone transport and the frequency of deep convection there since the 1980s. **Citation:** Solomon, S., D. W. J. Thompson, R. W. Portmann, S. J. Oltmans, and A. M. Thompson (2005), On the distribution and variability of ozone in the tropical upper troposphere: Implications for tropical deep convection and chemical-dynamical coupling, *Geophys. Res. Lett.*, *32*, L23813, doi:10.1029/2005GL024323.