Appearance of the persistently low tropopause temperature and ozone over the Asian monsoon region

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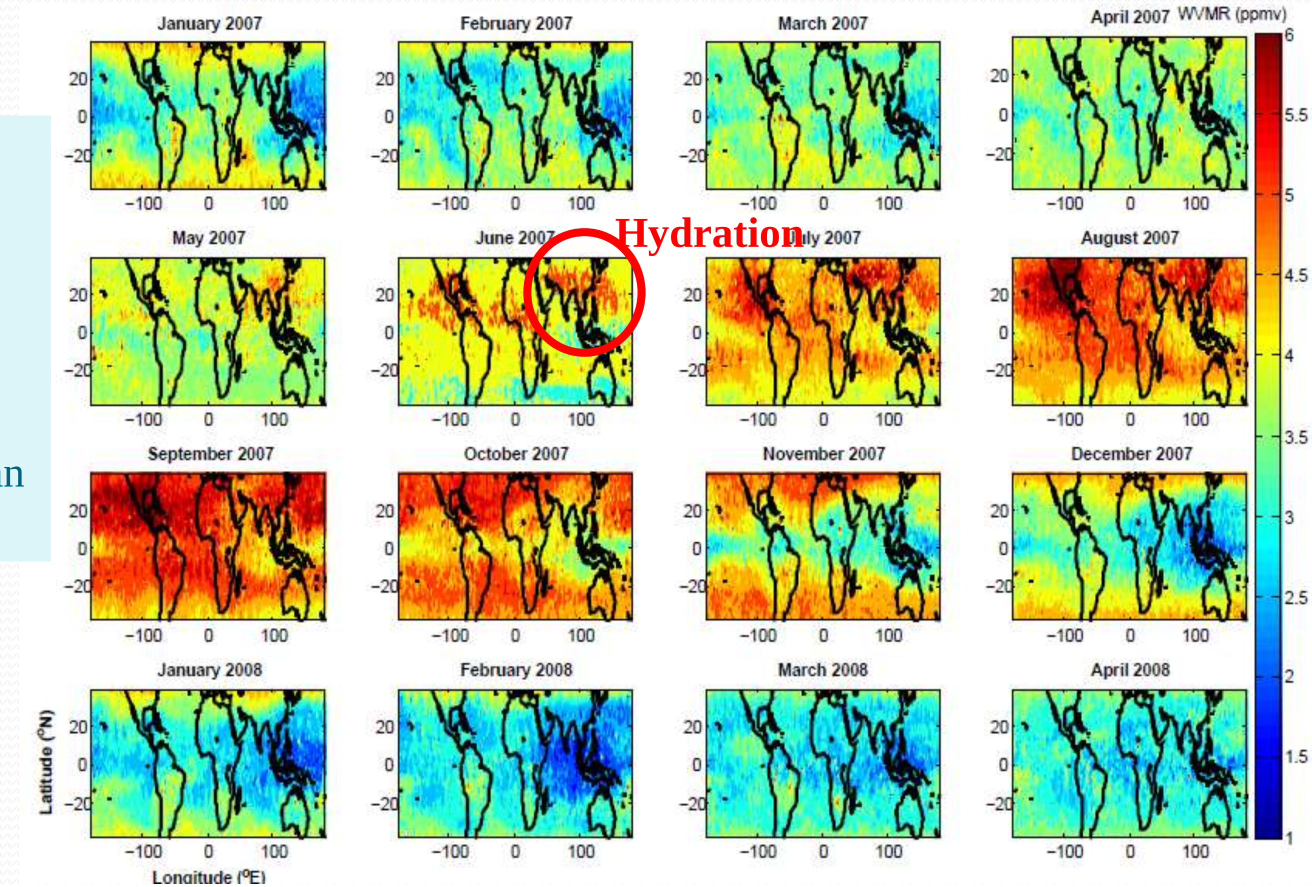
UTLS water vapour seasonal cycle consists of a hydrating and dehydrating phase

HYDRATION OF THE UTLS

Observed during NH summer monsoon

Location: Asian (AMR), American and African monsoon region



Monthly mean WVMR at 100 hPa level obtained from Aura MLS

Deepest convection over Asian monsoon region (AMR) for JJAS

OLR- proxy for convective activity

Low OLR + Deep penetrating convective clouds

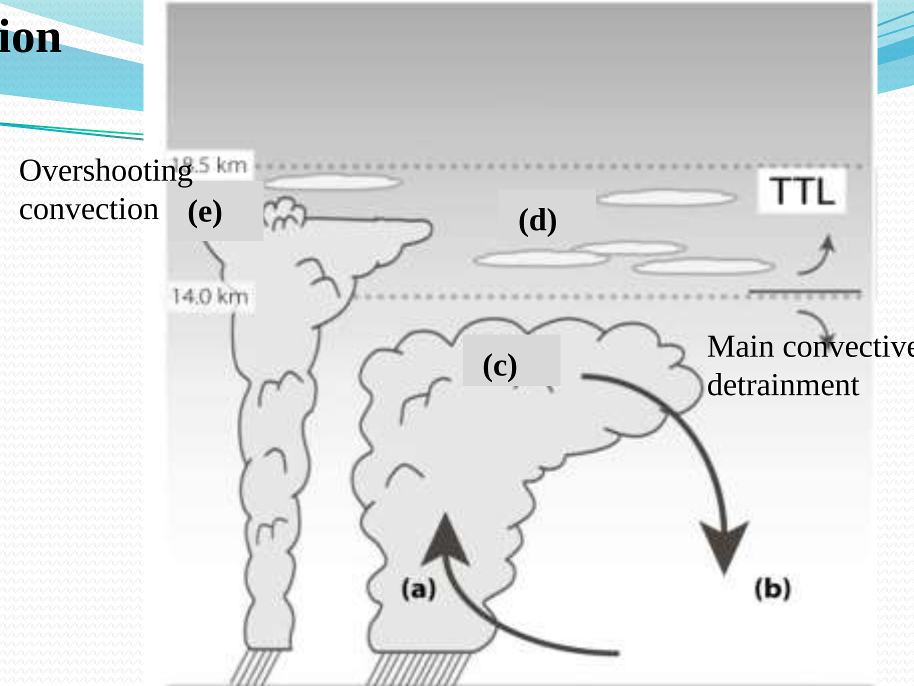
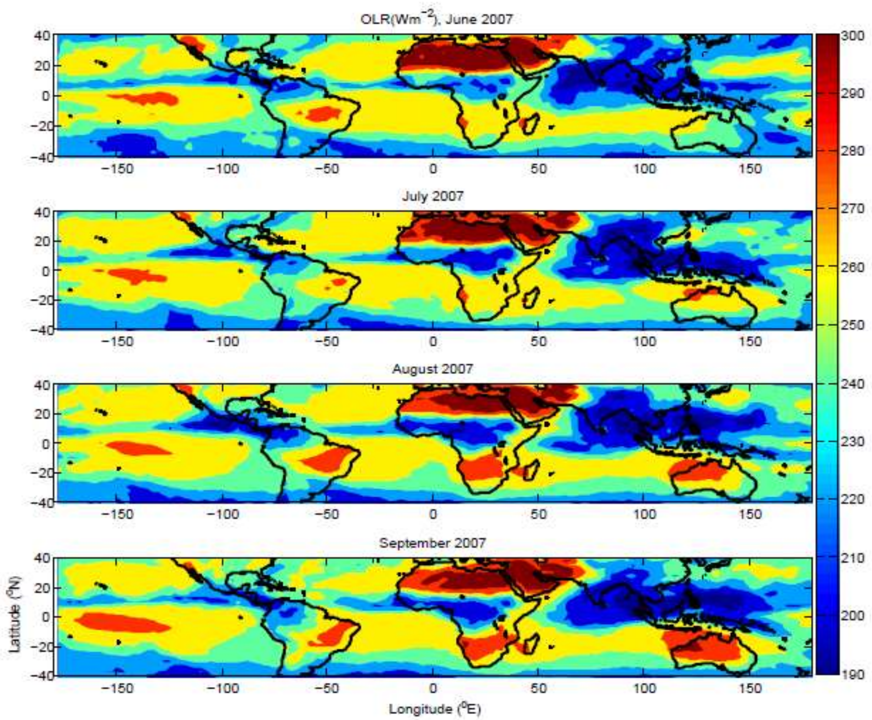
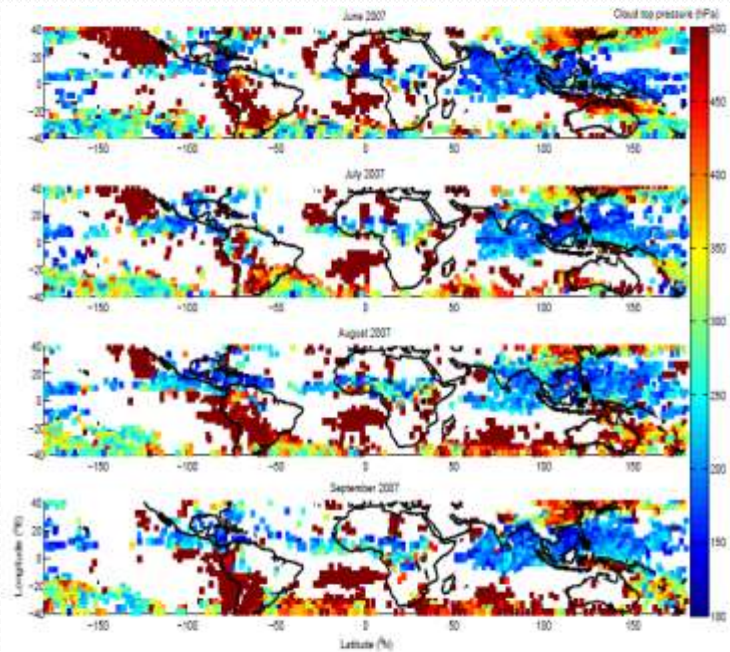


Image Source: Fueglistaler et al., 2009

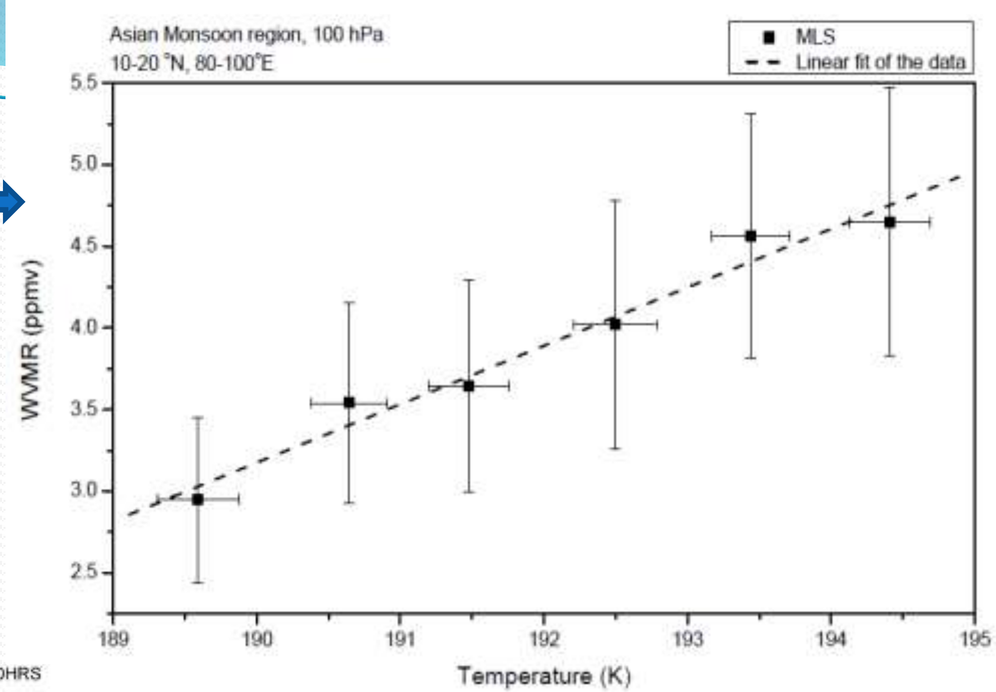


Interpolated OLR distribution from NOAA

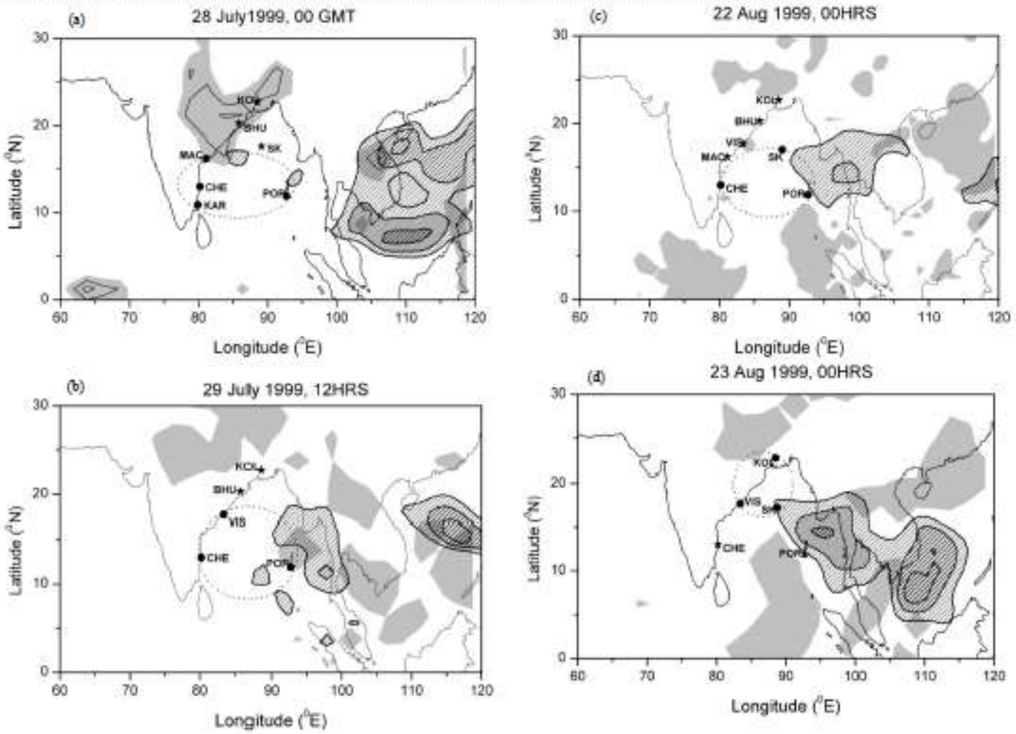


Convective cloud top pressure from ISCCP

T_{100} and $WVMR_{100}$ are observed to be closely related over Asian monsoon region (Jain et al., 2013).



Patches of extremely low temperatures near the tropopause level are also observed (Jain et al., 2006, 2010 and 2011).



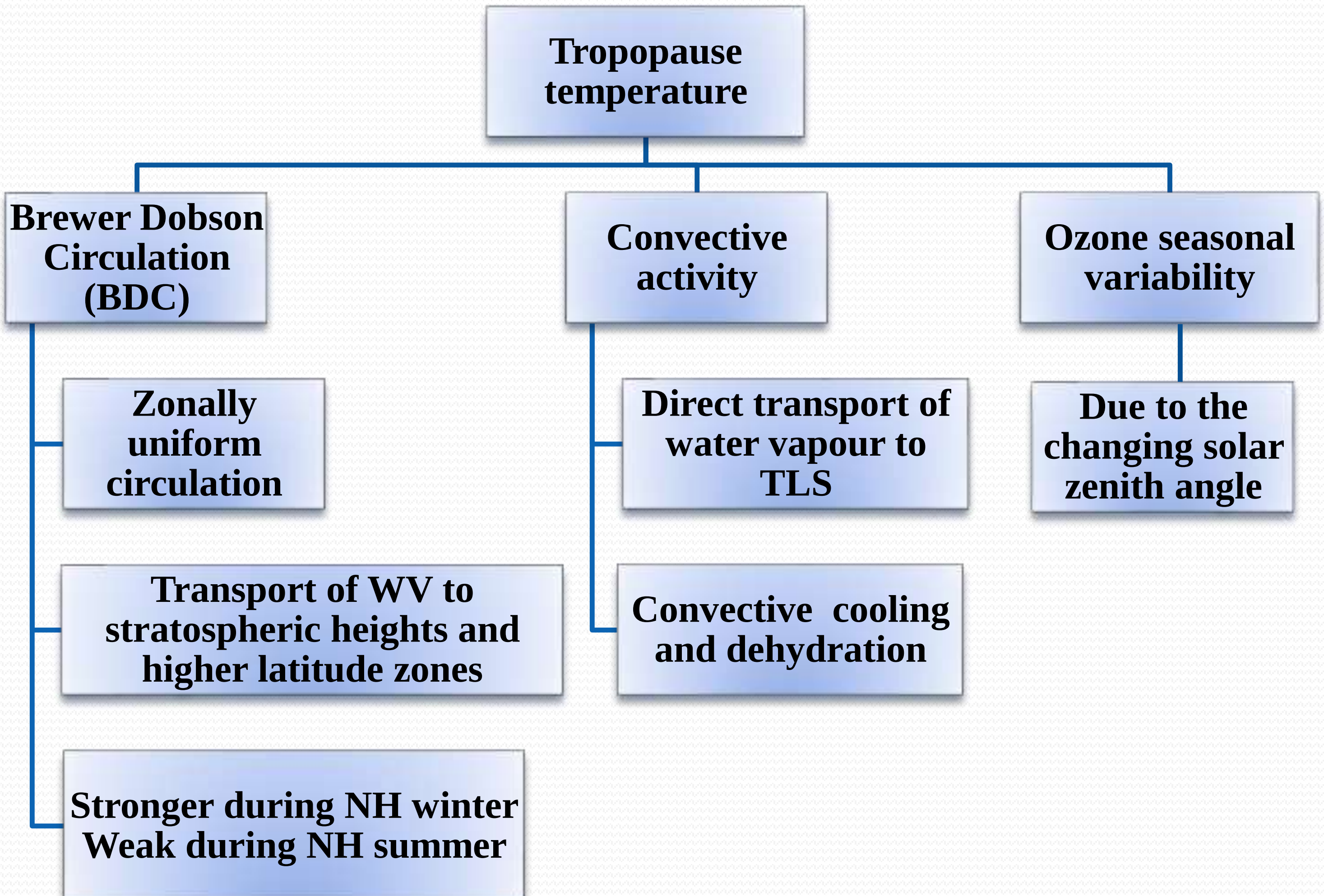
- **Tape recorder effect (Mote, 1995)**
- **Freeze drying mechanism (Brewer, 1949; Newell and Gould, 1981)**

It is important to understand that how the hydration of UTLS takes place in the the presence of patches of extremely low tropopause temperatures.

Factors affecting water vapour in UTLS

UTLS water vapour is closely associated with the tropopause temperatures

Therefore, to understand the water vapour distribution near tropopause, it is important to understand the processes which influence the tropical tropopause temperatures.

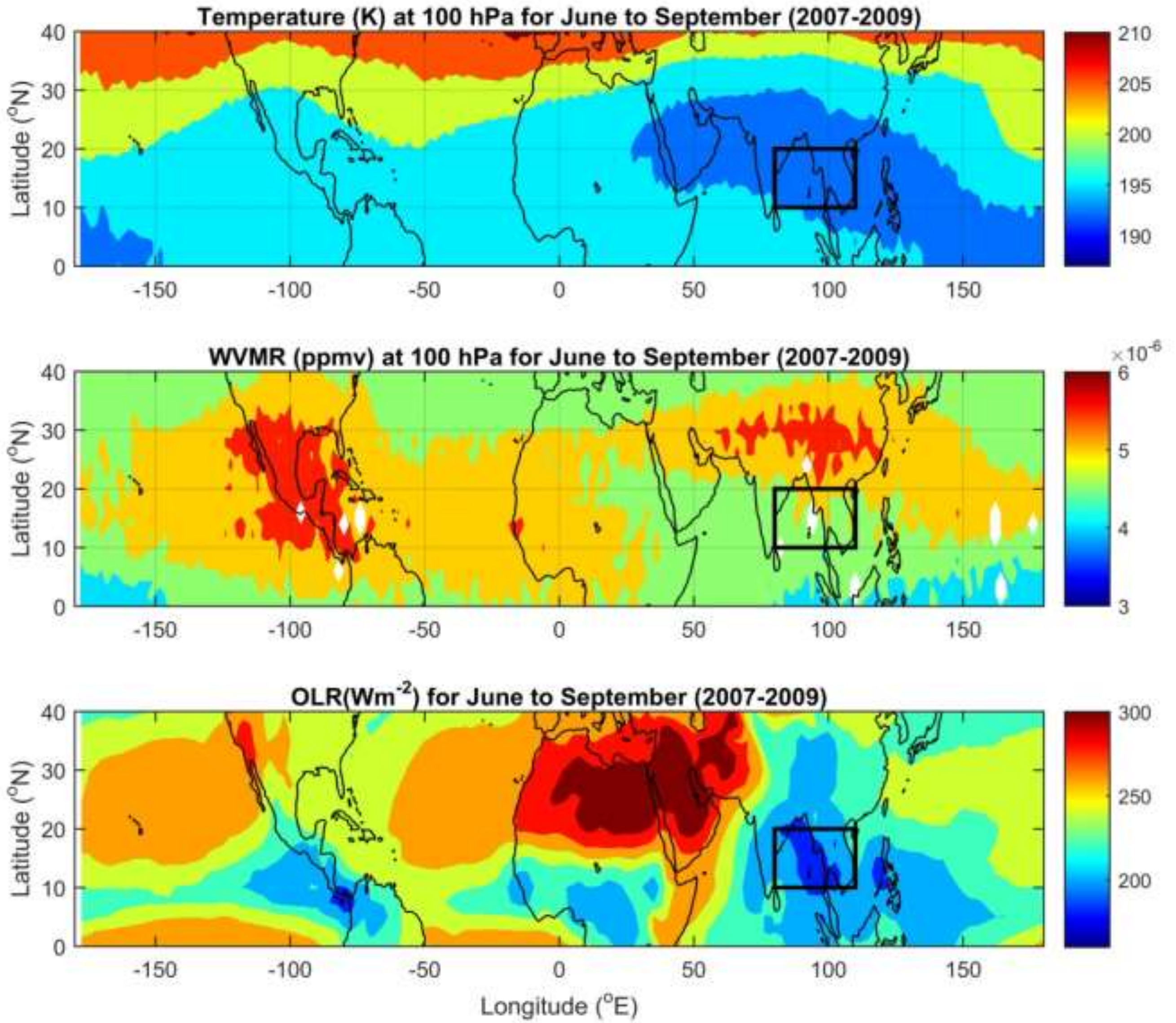


Spatial distribution of seasonal mean for JJAS 2007-2009

Low T_{100}

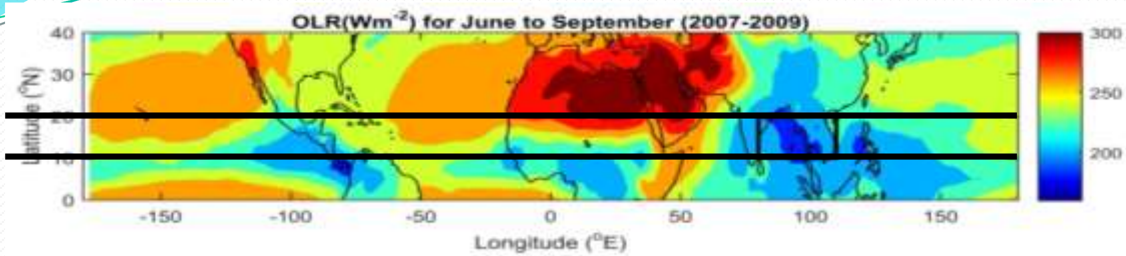
Low $WVMR_{100}$

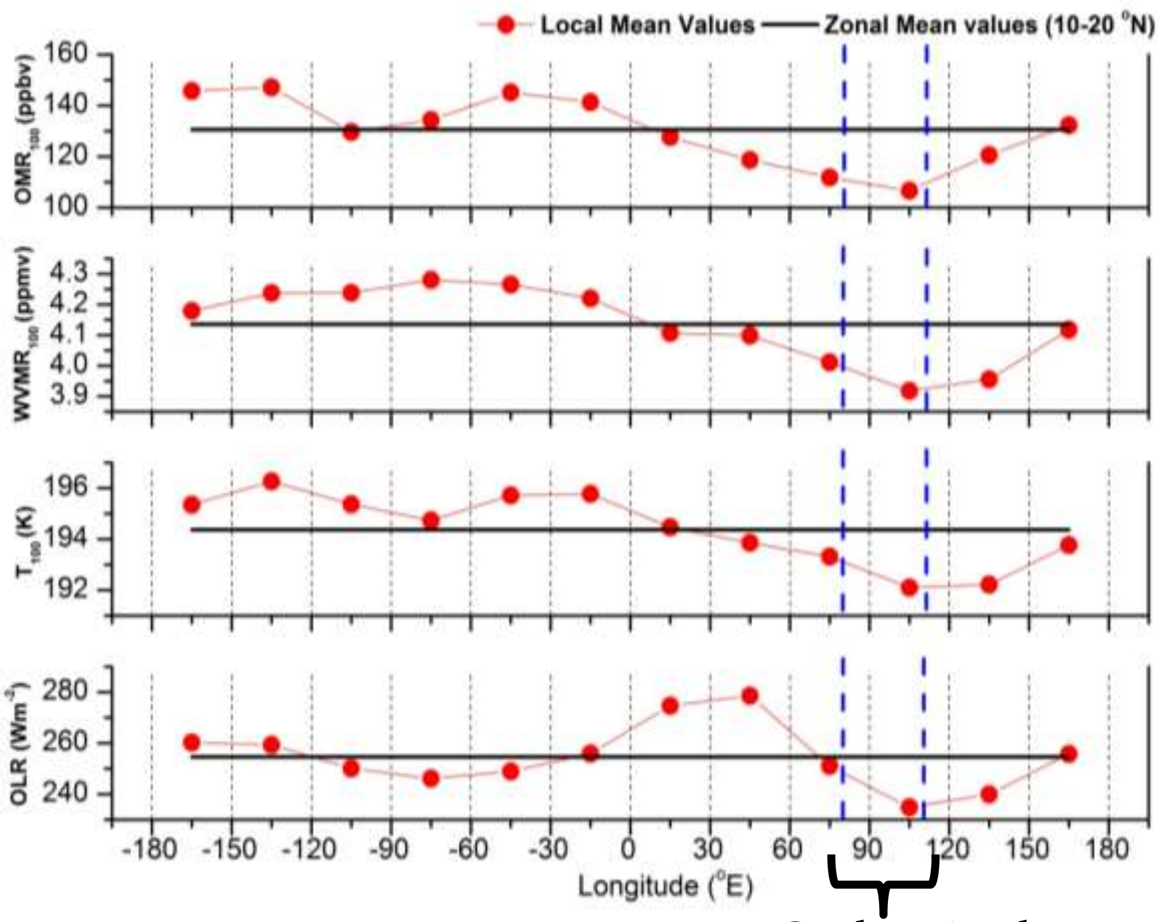
Low OLR



Deepest convection over Bay of Bengal but relatively low temperatures and WVMR during NH Summer -monsoon period

Longitude series of mean values (2006-2010) for 10-20 ºN for all seasons





BOB longitude sector

Quantification of the role of various processes is done by following methodology:

(a)BDC is a zonally uniform circulation and zonal mean temperatures are used to account the contribution of BDC to the low T_{100}

$$\Delta T_{100} = T_{100}\ (LOCAL) - T_{100}\ (ZONAL)\ \text{(in K)}$$

(b) Multiple linear regression analysis is carried out to explain the additional decrease or increase in tropopause temperatures over BOB due to convective activity and low ozone

$$\Delta T_{100} = a_0 + a_1 * (\Delta OLR) + a_2 * (\Delta OMR_{100})\ \text{(in K)}$$

Delta time series of OLR, T_{100} , $WVMR_{100}$ and OMR_{100} over the BOB

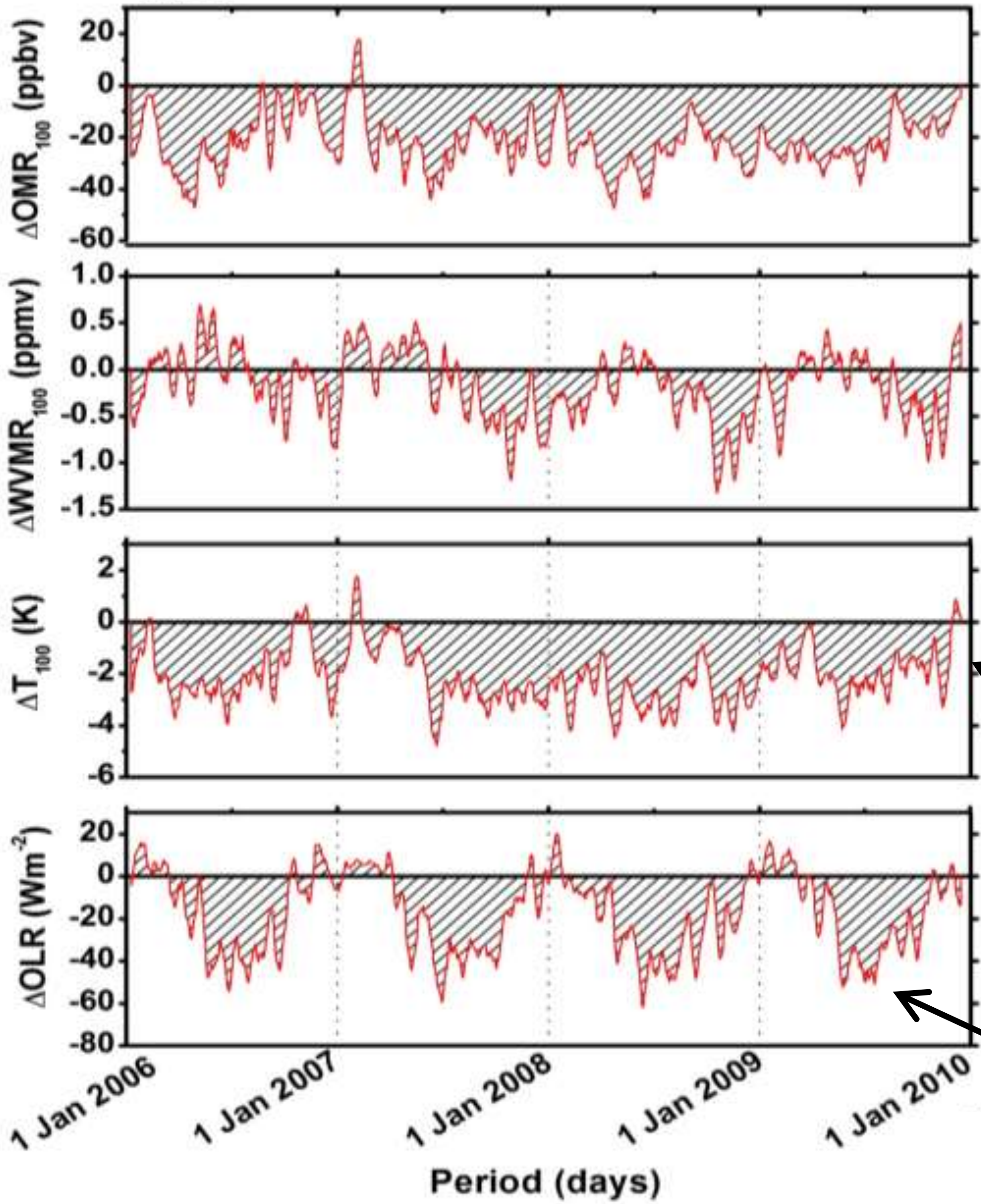
The long term mean value (i.e. January 2006 – December 2009) of the T_{100} over

BOB= 192.3 K
Zonal means = 194.5 K.

Long term mean temperature over the BOB is ~2.2 K lower than the corresponding zonal mean.

OLR and ΔOMR_{100} is lower than their long term zonal mean values over BOB

$\Delta OLR = -17.9\ Wm^{-2}$
$\Delta OMR_{100} = -22.5$ ppbv



Persistently low ozone over the BOB

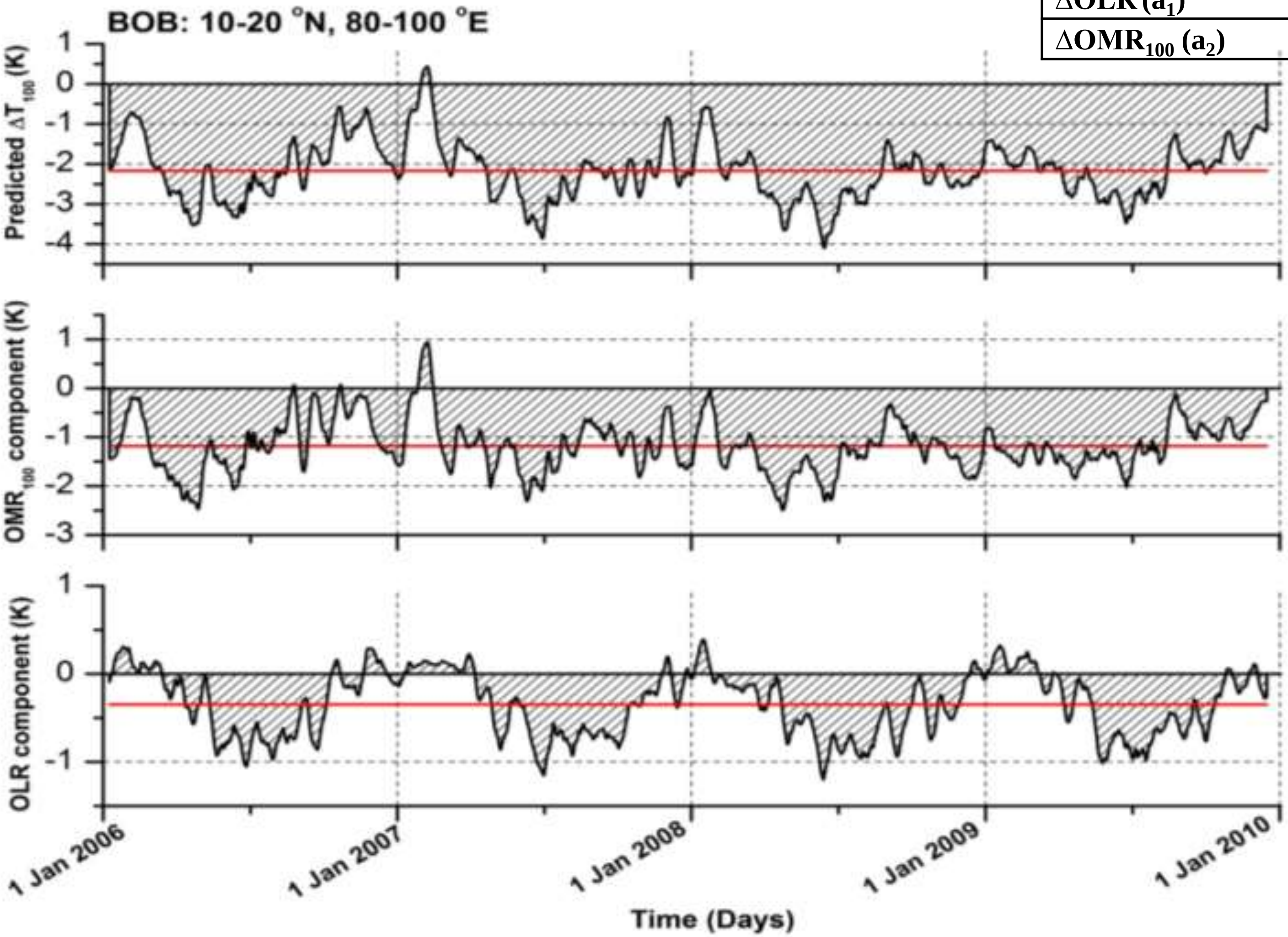
Temperatures are continually lower than the zonal mean values over this region

Intense convection over BOB

Values of coefficients obtained from regression analysis

$$\Delta T_{100} = a_0 + a_1 * (\Delta OLR) + a_2 * (\Delta OMR_{100}) \text{ (in K)}$$

	Regression statistics over the BOB region
Multiple R	0.67
R Square	0.45
Adjusted R Square	0.45
Standard Error	0.81
No. of observations	1437
Intercept (a_0)	-0.643 ± 0.051
ΔOLR (a_1)	0.019 ± 0.001
ΔOMR_{100} (a_2)	0.052 ± 0.002



Reconstructed time series

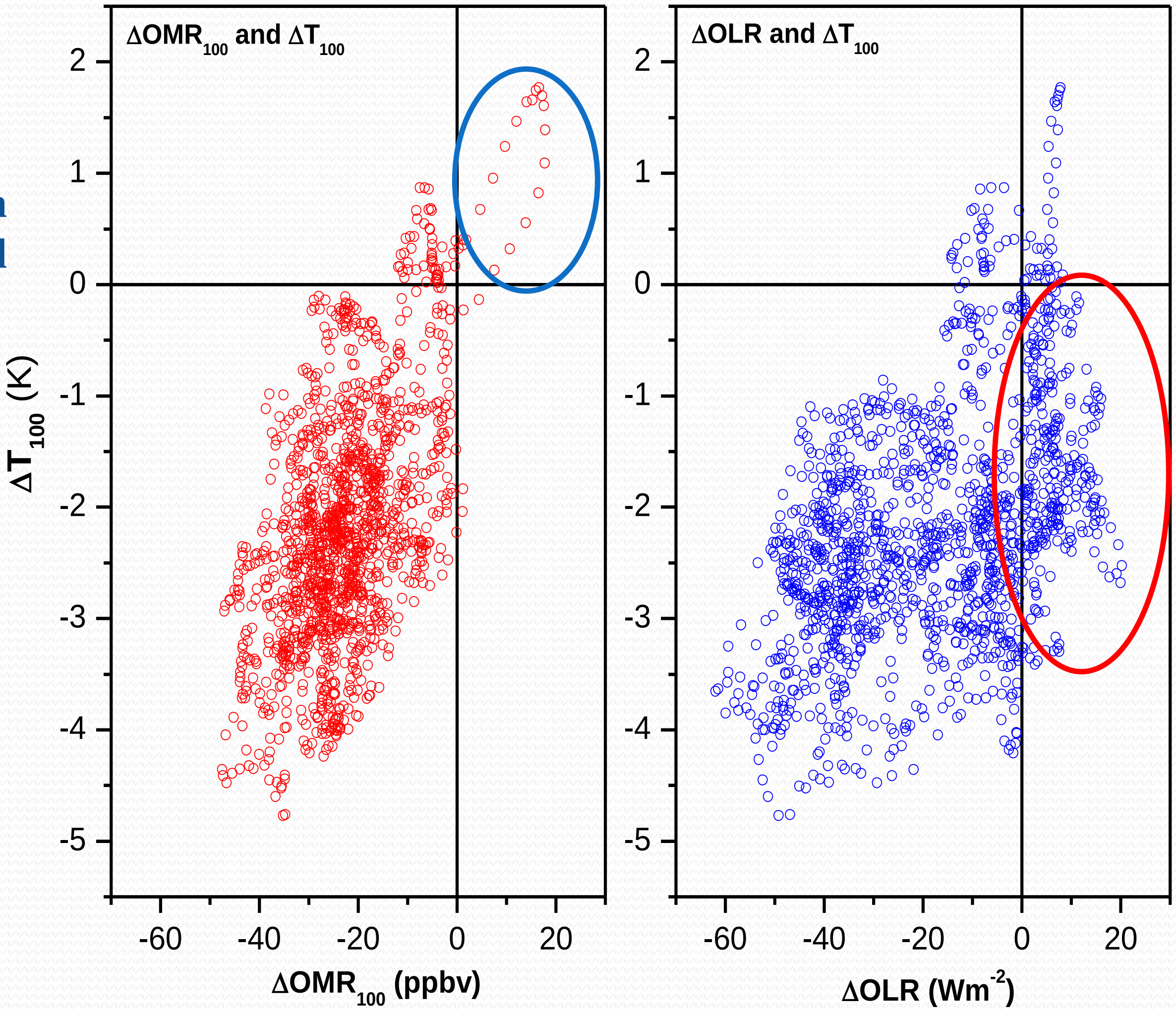
Quantitative contribution of various processes in giving rise to the persistently low T_{100} over the BOB

S. No.	Process	Mean Change in T_{100} over Asian region (K)
1.	**Contribution of OLR to low T_{100}**	-0.35 ± 0.03
2.	**Contribution of OMR to low T_{100}**	-1.18 ± 0.05
3.	**a_0**	-0.64 ± 0.05
	Predicted T_{100}	-2.17±0.18
	Observed (from MLS)	2.2

Scatter plot of ΔT_{100} vs ΔOMR_{100} and ΔT_{100} vs ΔOLR over Bay of Bengal

Better correlation between ΔT_{100} and ΔOMR_{100}.

The positive values of ΔOMR_{100} correspond to the positive values of ΔT_{100} only.



Significant number of cases when convection was absent but lower temperatures are there

ΔOLR is positive <u>only</u> during the NH winter period. For NH winter period, there are other processes which gives rise to the low temperatures near the tropopause.

CONCLUSIONS

Temperatures near the tropopause are observed to be persistently lower than the corresponding zonal mean values over the BOB.

Low ozone and deep convection contributes to the persistently low temperatures.

Contribution of ozone is more than convection.

Convection only contributes to the low T_{100} during NH summer monsoon period

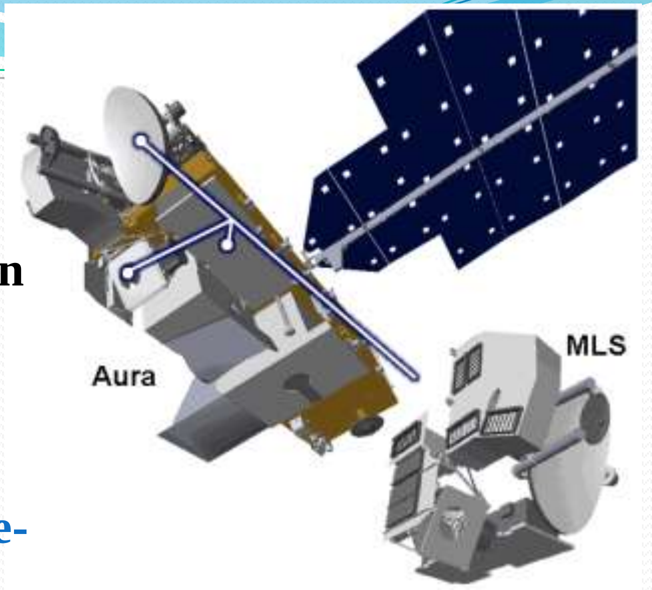
Around 0.7 K couldn't be explained by changes in convection or ozone. There are other processes which gives rise to low T_{100} for e.g. positive water vapour feedback process or persistent cloud cover over the BOB.

Low ozone can give rise to low temperatures in the UTLS region. The sources which can deplete ozone may give rise to the persistently low ozone mixing ratios and temperatures in the tropopause region (?)

Data Acknowledgements

Outgoing longwave radiation (OLR)- NCEP/NOAA

NASA's A-Train Constellation



WVMR and Temperature- Aura MLS

Image source: mls.jpl.nasa.gov

Ozone mixing ratio- Aura TES

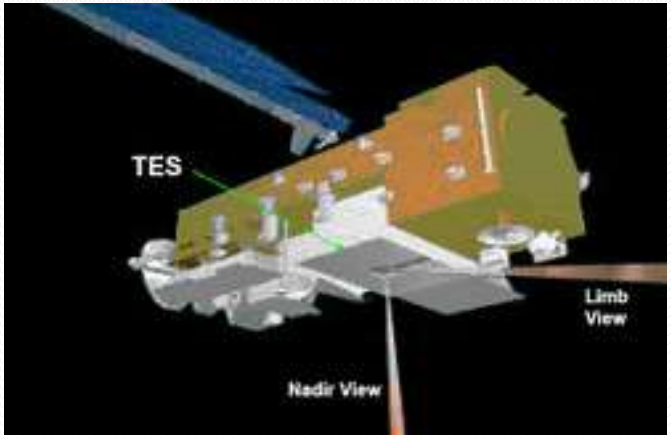


Image source: mynasadata.larc.nasa.gov

Convective cloud data- ISCCP D1

THANK YOU

SUGGESTIONS?

EXTRA SLIDES

Key points about hydration and dehydration from literature studies

HYDRATION

- Observed during NH summer monsoon
- Location: Asian (AMR), American and African monsoon region
- Convection plays a key role in carrying water vapor from surface level to the upper troposphere.
- Maximum convective events occur over South East Asia during the NH summer-monsoon period (June-September)
- Most of the stratospheric-tropospheric exchange occur through tropical tropopause layer
- Seasonal variation of water vapour in UTLS is closely linked to tropopause temperatures

DEHYDRATION

- Observed during NH winter-spring (SH summer)
- Location: Indonesian Australian western Pacific region (IAWPR)
- Low tropopause temperatures are observed over IAWPR
- It has been postulated that the air might have undergone through a 'freeze drying' process when temperature in the tropopause region is sufficiently low and air has stayed in this region for a sufficiently long time.
- Tropical upwelling, which leads to Brewer-Dobson circulation (BDC), is one of the known processes which gives rise to the low temperatures in the tropical upper troposphere and lower stratosphere

SUMMARY OF THE DATASET USED IN THIS STUDY

S.No	Parameter	Source	Spatial resolution	Temporal resolution	Period	Validation
1.	Water vapour mixing ratio (WVMR)	EOS Aura MLS Version 3.3 Standard atmospheric product	• Vertical resolution ~ 2.5km at 316-215 hPa ~ 3.0km at 100-1.0 hPa >3.4 km at > 1.0 hPa • Horizontal resolution is 2.8 km × 210 km	Daily data	January 2005 to December 2010	Livesey et al., 2011 Lambert et al., 2007
2.	Temperature (T)	EOS Aura MLS Version 3.3 Standard atmospheric product	• Vertical resolution ~ 5 km from 261 - 100 hPa ~ 4 km at 56.2 - 3.16 hPa ~ 7.2 km at 1 - 0.316 hPa ~10 km at 0.1 - 0.001 hPa • Horizontal resolution is 5 km × 165 km	Daily data	January 2005 to December 2010	Livesey et al., 2011 Schwartz et al., 2008
3.	Sea surface temperatures (SST)	Era Interim reanalysis	1.5×1.5°	Daily data	January 2005 to December 2010	Dee et al., 2011
4.	Outgoing longwave radiation (OLR)	NCEP/NOAA	2.5×2.5°	Daily data	January 2005 to December 2010	Liebmann and Smith (1996)
5.	Convective cloud top pressure (CTP)	ISCCP Stage D1	280 km × 280 km	Daily (at every 3 hr interval)	December 2007 to March 2008	Rossow et al., 1996 Rossow and Schiffer, 1999
6.	Ozone mixing ratio (OMR)	EOS Aura TES, Level 2, Version 5, Nadir	16 orbits Global survey Resolution 5.3 km (across track) × 8.5 km (along the spacecraft ground track)	Interpolated to daily	January 2006 to December 2009	Worden et al., 2007 Nassar et al., 2008 Herman et al., 2013