Control and influence of NH summer monsoons on stratospheric water vapor

Bill Randel, NCAR
Kai Zhang and Rong Fu, U. Texas, Austin
Tao Wang, JPL
Well-known seasonal cycle of water vapor in lower stratosphere

Aura MLS 100 hPa
Stratospheric H$_2$O is controlled by tropical cold point temperatures

Deseasonalized anomalies

- H$_2$O
- T$_{CP}$
- Temp (K)

r=0.80

near-global mean (60° N-S) water vapor at 82 hPa from combined HALOE-MLS data

cold-point tropical tropopause temperatures 10° N-S

black: radiosondes
red: GPS (after 2001)
weaker correlations during summer

what else is controlling $H_2O$ during summer?

Deseasonalized anomalies

$H_2O$

$T_{CP}$

$r=0.80$

Winter-spring

Summer-fall

$r=0.89$

$r=0.39$
100 hPa water vapor climatology from MLS

2 questions:
• What controls monsoon water vapor
• What is the monsoon influence on the globe?
What controls stratospheric water vapor in the NH summer monsoon regions? JGR 2015

William J. Randel¹, Kai Zhang², and Rong Fu²

9 years of MLS observations
deseasonalized anomalies

How is this variability related
to deep convection
and circulation/temperature?

(a) Asian monsoon (May-Sep)

(c) 100hPa H₂O anomalies after removing QBO & ENSO effect
Surprising result: less (more) convection

more (less) lower stratosphere H$_2$O
Aspects of the 40–50 Day Oscillation during the Northern Summer as Inferred from Outgoing Longwave Radiation

KA-MING LAU
Goddard Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

P. H. CHAN
Applied Research Corporation, Landover, MD 20785

1st EOF of OLR over monsoon region
H. Annamalai · J. M. Slingo

_active/break cycles: diagnosis of the intraseasonal variability of the Asian Summer Monsoon_

Principal Oscillation Patterns (POP)

(a) Real Part

40-day mode

(b) Imaginary Part

15-day mode

(a) Real Part

(b) Imaginary Part
Asian monsoon: links to temperatures at 100 hPa

Warm temps in low latitude stratosphere

Balanced dynamical response to change in convection

Temp anomalies near 90 E

Less convection
The influence of summertime convection over Southeast Asia on water vapor in the tropical stratosphere

J. S. Wright, R. Fu, S. Fueglistaler, Y. S. Liu, and Y. Zhang

Received 1 December 2010; revised 3 March 2011; accepted 28 March 2011; published 17 June 2011.

Subtropics: most important region for dehydration
time series over Asia during summer 2009

H₂O in monsoon

100 hPa temps, 10-30 N

30-40 day oscillations

less convection

more convection
North American monsoon

9 years of MLS observations
deseasonalized anomalies

(d) 100hPa H$_2$O anomalies after removing QBO & ENSO effect
Composites over N America wrt 100 hPa H₂O

Same result: less convection ~ wet lower stratosphere
temp anomalies for wet composites

Similar connection:
subtropical temps at 100 hPa
Key points:

- Surprising result: strong (weak) convection associated with dry (wet) lower stratosphere

- Monsoon $\text{H}_2\text{O}$ controlled by temperatures in the subtropical stratosphere

- Coherent links to oscillations of the 'tropospheric' monsoon

![Diagram showing dehydration on cold equatorward side with upward transport by overshooting convection and/or large-scale circulation.](image)
What is the influence of the monsoons on global stratospheric $\text{H}_2\text{O}$?

Schoeberl et al 2013
Domain-filling trajectory model

Large-scale circulation and temps; no parameterized convection
100 hPa anomalies in Asian monsoon water vapor

Overall, the trajectory model does a good job at large-scale variability.
Experiments

• **1. ASIA:** remove parcels that ever meet Asian monsoon region 370K-420K during JJA.

• **2. NA:** remove parcels that ever meet NA monsoon region 370K-420K during JJA.

• **3. ASIA&NA:** remove parcels that ever meet either Asian or NA monsoon region 370K-420K during JJA.
ASIA experiment

100 hPa differences

blue: monsoon moistens
red: monsoon dries
ASIA experiment

100 hPa differences

ERAi

MERRA
ASIA experiment

100 hPa differences

Blue = monsoon moistens

Red = monsoon dries
ASIA experiment

Communication between Asian and NA monsoons!

Traj_ERAi difference maps

moistening
drying

100 hPa

(a) JJA AS-ORIG (Traj_ERAi) 100 hPa

(b) SON AS-ORIG (Traj_ERAi) 100 hPa

(c) DJF AS-ORIG (Traj_ERAi) 100 hPa

(d) MAM AS-ORIG (Traj_ERAi) 100 hPa

ppmv

-0.2 0.12 0.04 0.04 0.12 0.2
ASIA experiment

Traj_ERAi
difference maps

100 hPa

82 hPa
ASIA experiment

Traj_MERRA
difference maps

100 hPa

82 hPa
Blue = monsoon moistens

Red = monsoon dries

100 hPa
NA experiment

100 hPa climatology

moistening

NA–ORIG (Traj ERAi)

H$_2$O (100 hPa) climatology

drying

NA–ORIG (Traj MERRA)

H$_2$O (100 hPa) climatology
NA experiment

100 hPa

Traj_ERAi difference maps

 SON

MAM

DJF

JJA

ppmv

-0.2
0.12
-0.04
0.04
0.12
0.2

(a) JJA

(b) SON

(c) DJF

(d) MAM

NA–ORIG (Traj_ERAi)
Notes:

- Work in progress and we don’t understand it very well yet.
- These are interesting results, but how should we interpret them?
- Do monsoons both moisten and dry lower stratosphere?
- Thanks for any suggestions.