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Water Vapor and Temperature Comparisons Between AIRS/AMSU-A and In Situ Aircraft Observations From 87°N to 67°S and Sensitivities to Spatial and Temporal Differences

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HIPPO Global Team; START08 Science Team

RAF Technical and Ground Crews

Southwest Sciences, Inc.

Photo by Minghui Diao

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Outline

- **Motivation and challenges**
  - Importance of the validation
  - Two major challenges for the *in situ* observation comparisons
- **Instrument and dataset**
  - NSF HIAPER Pole-to-Pole Observations (HIPPO) Global campaign (2009-2011)
  - NSF START08 Campaign (The Stratosphere Troposphere Analyses of Regional Transport campaign) (2008)
- **Validations with AIRS/AMSU-A water vapor and temperature**
  - Comparisons with previous validations
- **Sensitivity study to spatial and temporal comparison windows**
  - H2O and T comparisons results at different windows
- **Conclusion**

Photo by Minghui Diao

Motivations and Challenges

Importance of validating AIRS/AMSU-A water vapor and temperature distributions

- 1. Validating climate and weather models (Chahine *et al.,* 2006; Goldberg *et al.,* 2003; Pagano *et al.,* 2004)
- 2. Understanding global relative humidity distributions (Gettelman *et al.*, 2006; Lamquin *et al.*, 2012)
- 3. Understanding ice supersaturation and ice cloud formation (Gettelman *et al.*, 2006)

Difficulties

1. **Lack of validations with *in situ* observations (radiosonde, dropsonde, aircraft) at certain locations**
2. **Different spatial/temporal resolutions**
   1. **Difficult to intercompare** between different validation schemes
   2. **Unclear sensitivity** to comparison windows in space and time

Previous validation work

Lack of in situ observation validations for:

1. Southern Hemisphere
2. Ocean vs. land for Version 5 data
3. Limitations of radiosonde water vapor measurement in the UT/LS
   (e.g., RS80A radiosonde: Miloshevich *et al.,* 2001; Verver *et al.,* 2006)
4. Vertical profile validations by aircraft

Various comparison window scales

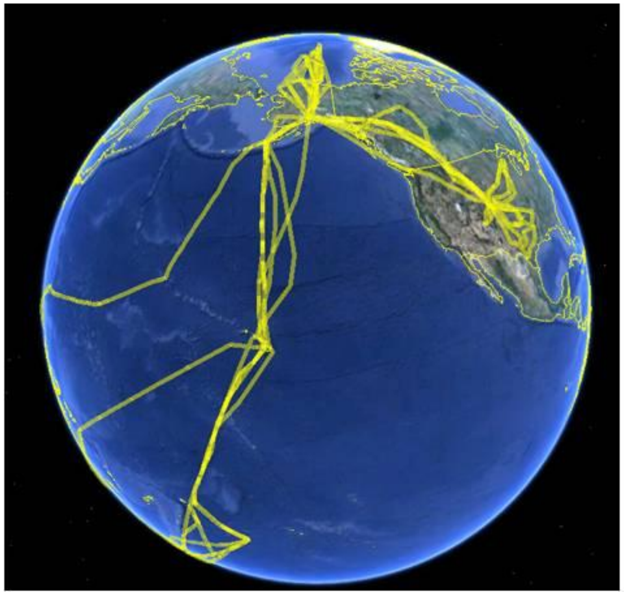
Reference	Data type	Spatial coverage	AIRS /AMSU-A version	AIRS distance window	AIRS time window
Gettelman *et al.*, 2004	Aircraft (PreAVE)	5°S-40°N Houston, Texas and San Jose, Costa Rica	V3	0.5° * 0.5° box	Same calendar day
Divakarla *et al.*, 2006	Radiosonde	Global point measurement	V4	100 km radius	≤ 3 hrs
Wu, 2009	Dropsonde	16-34°W, 10-22°N	V5	0.5° * 0.5° box	≤ 4.5 hrs
Lamquin *et al.*, 2012	Aircraft (MOZAIC)	120°W-150°E, 30°S-90°N	V5	Within AMSU footprint ~ 22.5km radius	≤ 30 min

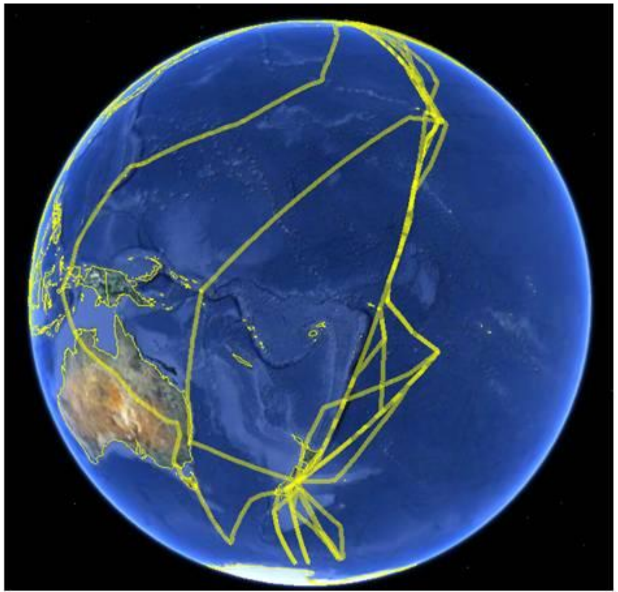
Data coverage in this study

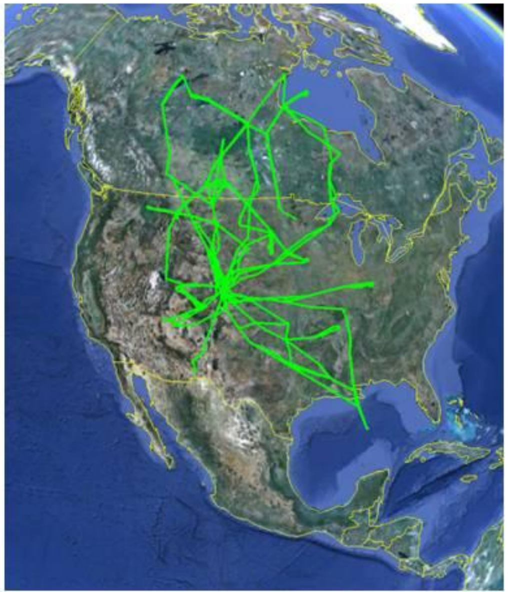
Reference	Data type	Spatial coverage	AIRS distance window	AIRS time window	AIRS /AMSU-A version
Current work	Aircraft (START08 and HIPPO Global #1-5 deployments)	87°N–67°S, 84°W–180°W–128°E North America, central Pacific Ocean	Compare various spatial windows	Compare various temporal windows	V5

NSF Hiaper Pole-to-Pole Observations (HIPPO) Global flight campaign #1-5 (2009-2011) (Wofsy et al., 2011)
~400 flight hour, ~600 vertical transects

NSF START08 Campaign (The Stratosphere Troposphere Analyses of Regional Transport campaign) (2008) (Pan et al., 2010)
~120 flight hour, ~90 vertical transects

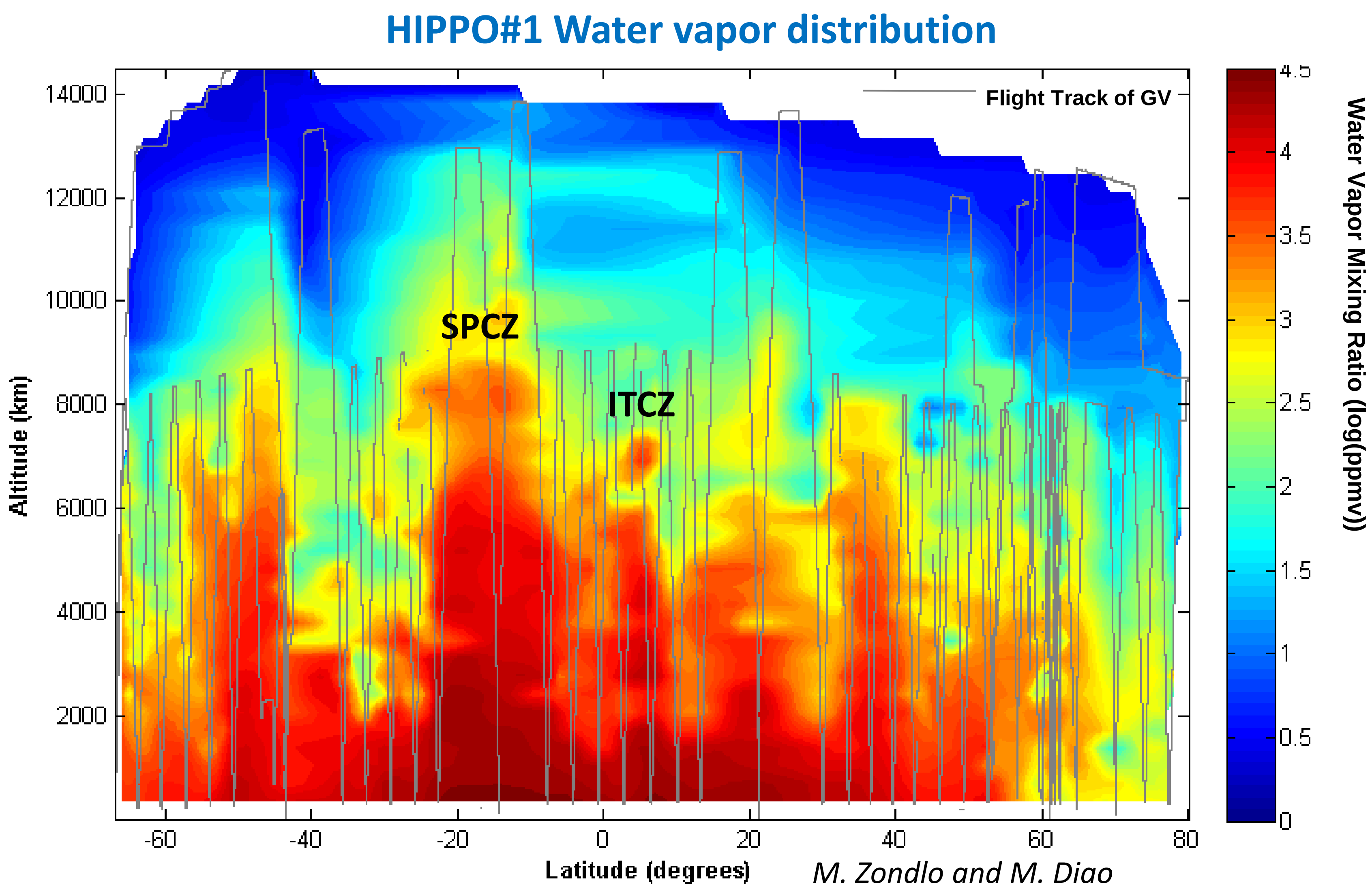






Current work data coverage

Vertical profile of HIPPO data: surface to the UT/LS



VCSEL hygrometer

- **Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer**
  - Near infrared; 25 Hz; Use 1 Hz (Aircraft true air speed ~ 230 m/s)
  - Accuracy ≤ 6 %; Precision ≤ 1-3 % (Zondlo *et al.*, 2010)

Challenges	Solutions of VCSEL hygrometer
Broad Dynamic Range from 1 to 40,000 ppmv	1854.03 nm (strong absorption line) 1853.37 nm (weak absorption line)
High affinity to surfaces	Open Path

VCSEL Hygrometer

NSF G-V research plane in HIPPO Global Campaigns

Method

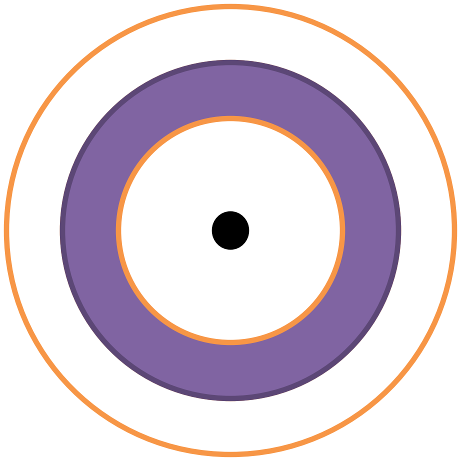
1. **Average aircraft data by 100 s**

   ~ **23 km horizontal** and **≤ 1 km vertical**

2. **Define distance and time comparison windows**
3. **Vertical interpolations**

   H_2O: log scale; T: linear scale

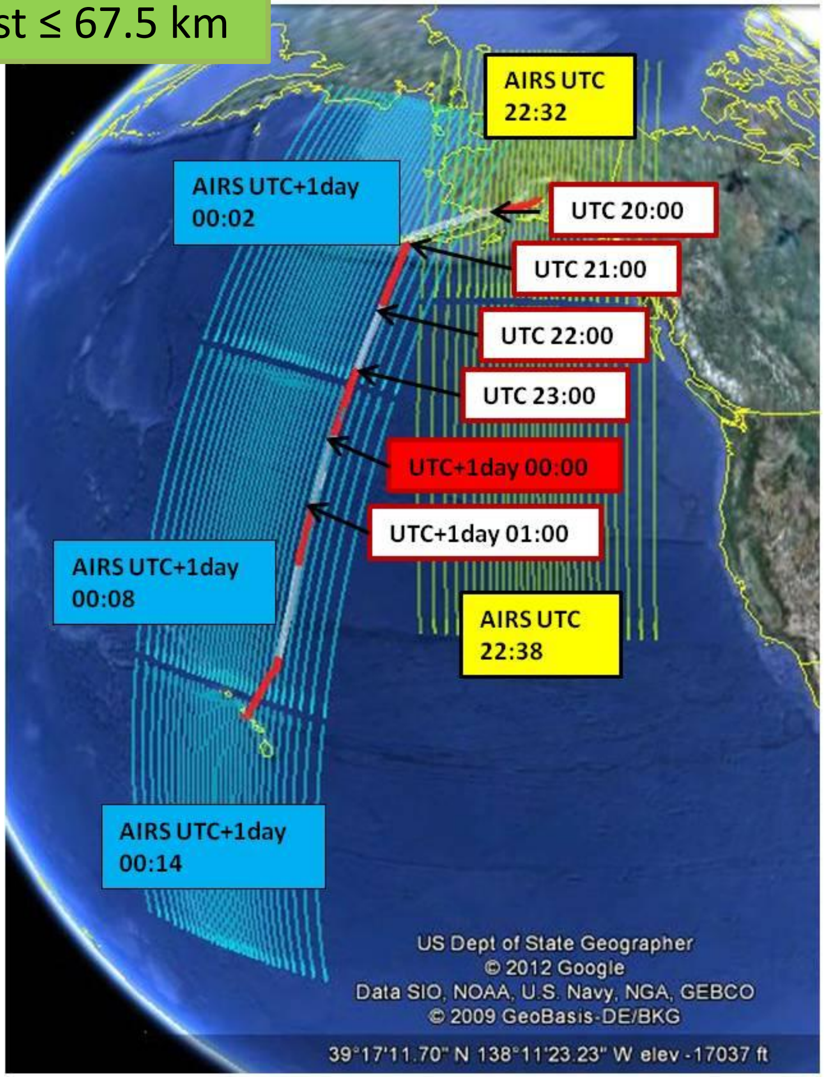
3. **Quality control**

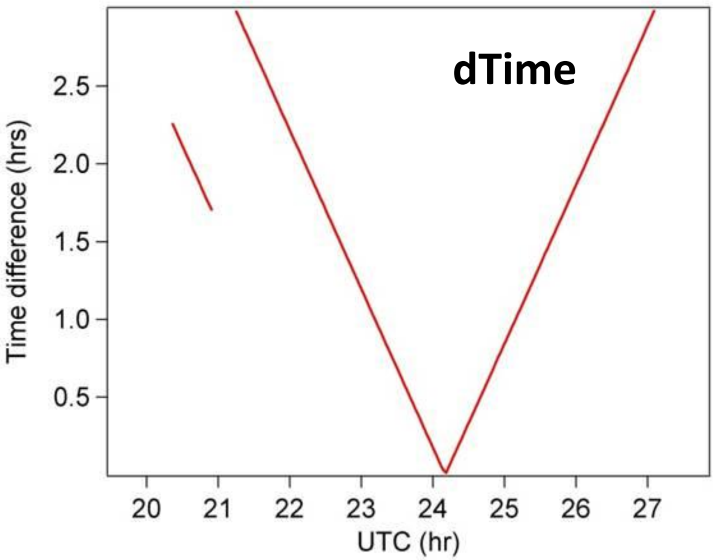


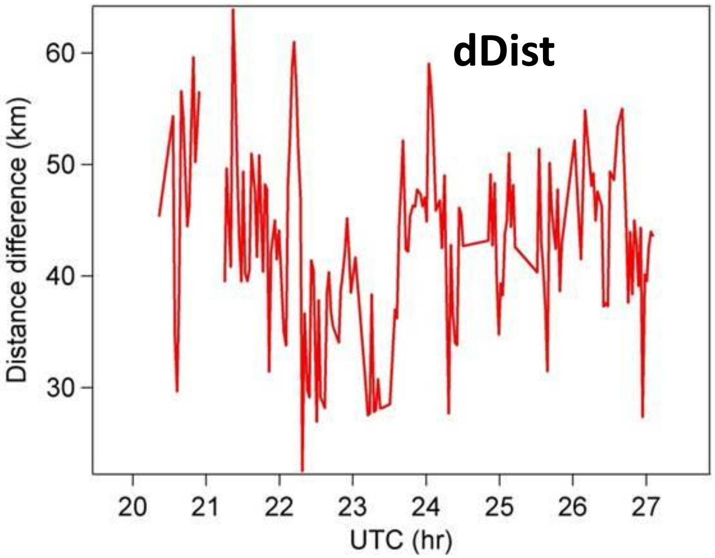
Temperature	Pressure > PGood is deleted (Susskind, 2007)
Water vapor	1. Qual_H2O = 2 is deleted 2. H2OMMRStdErr > 0.5*H2OMMRStd is deleted (Olsen et al., 2007) 3. Pressure > PBest is deleted

Time series comparison of HIPPO#1 RF04 (Anchorage, Alaska – Honolulu, Hawaii)

dTime ≤ 3 hr,
dDist ≤ 67.5 km



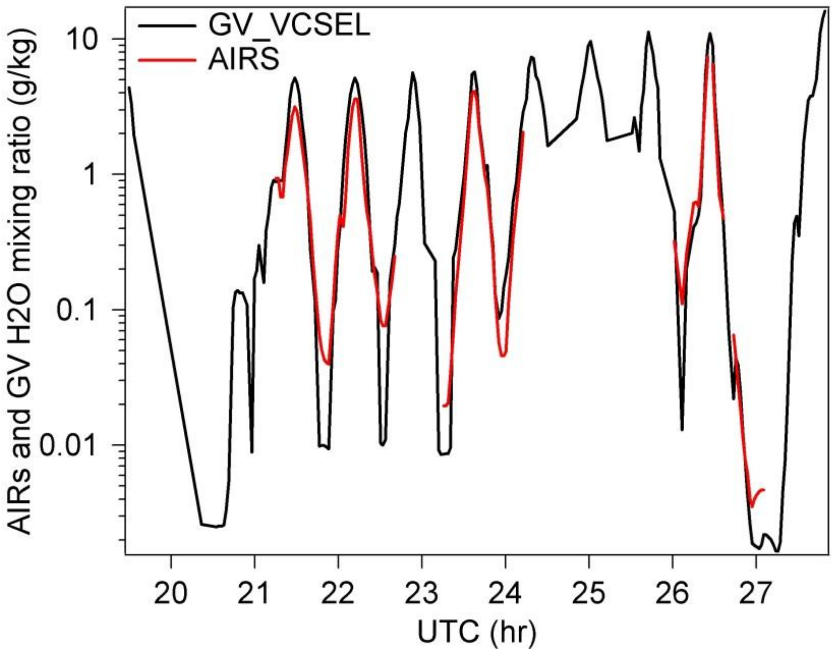




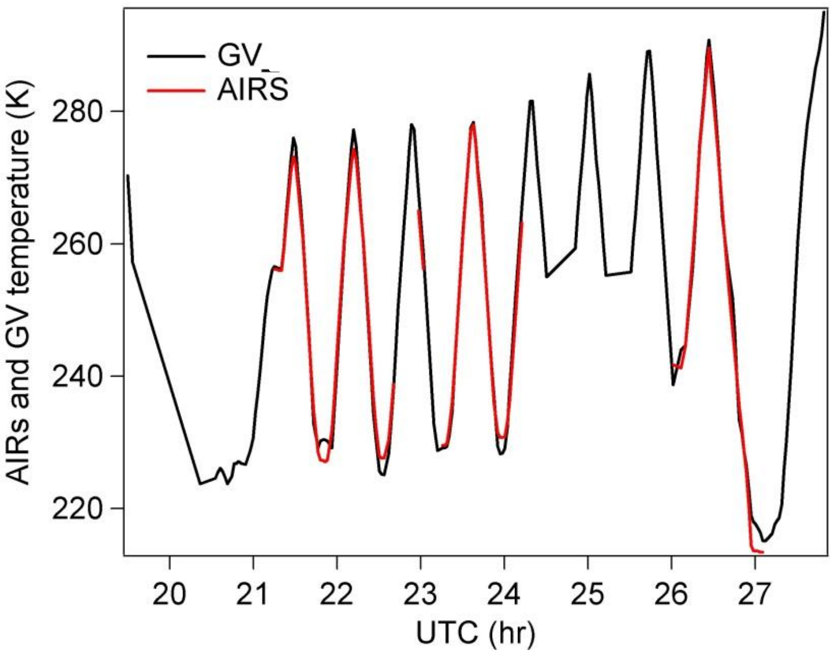
dTime ≤ 3 hr,
dDist ≤ 67.5 km

Example of HIPPO#1 RF04

H_2O time series



T time series



Black: GV

Red: AIRS

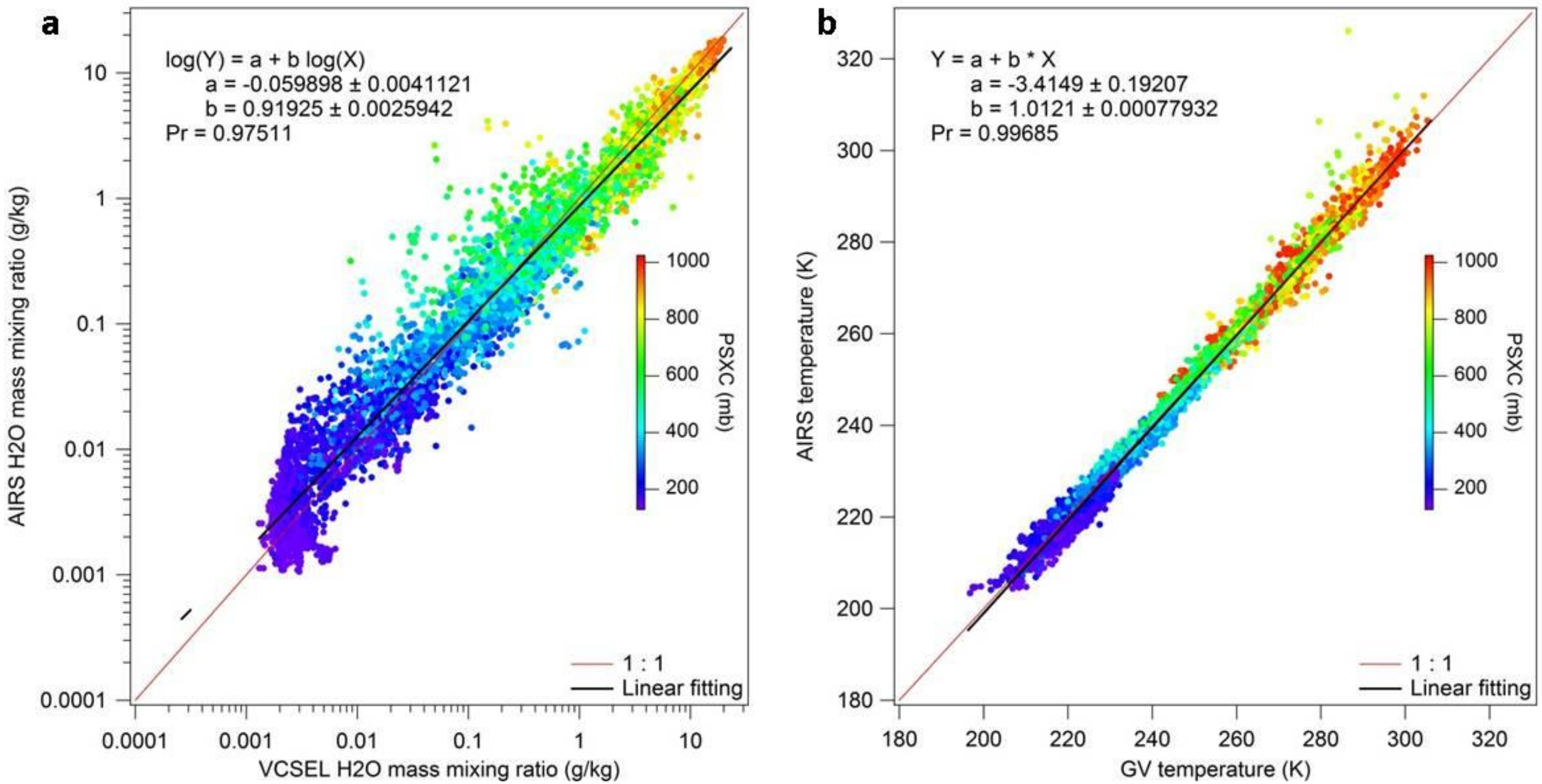
dTime ≤ 3 hr,
dDist ≤ 67.5 km

All data (HIPPO#1-5 & START08)

Compare with previous work (Gettelman *et al.* 2004)

Pearson-R value	H2O	T
Gettelman *et al.* 2004	0.91	0.98
Current work	0.975	0.997

Linear fitting	$\log_{10}(H_2O)$	T
Slope	0.92 ± 0.003	1.0 ± 0.001
Intercept	-0.060 ± 0.004	-3.4 ± 0.2

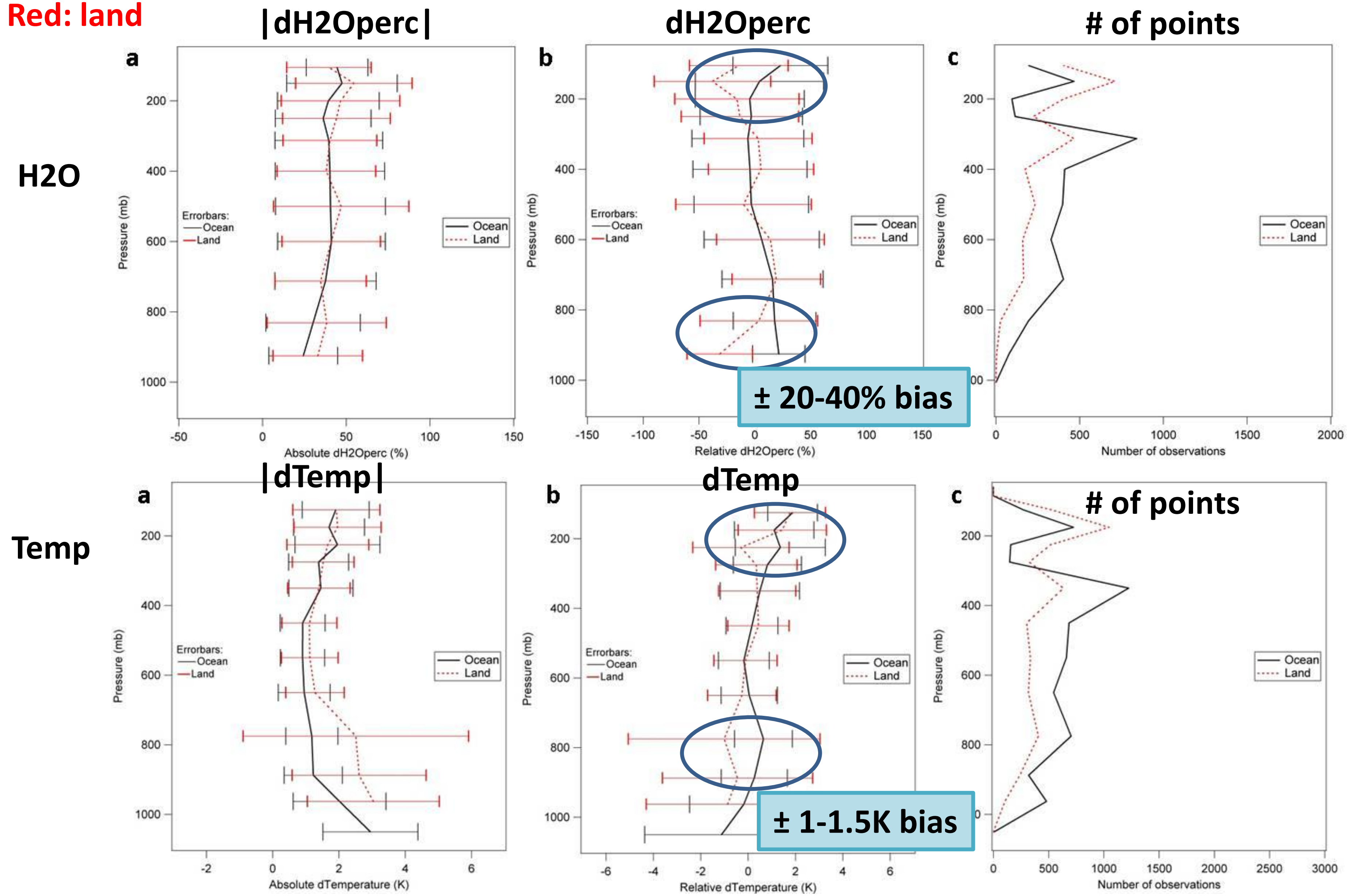


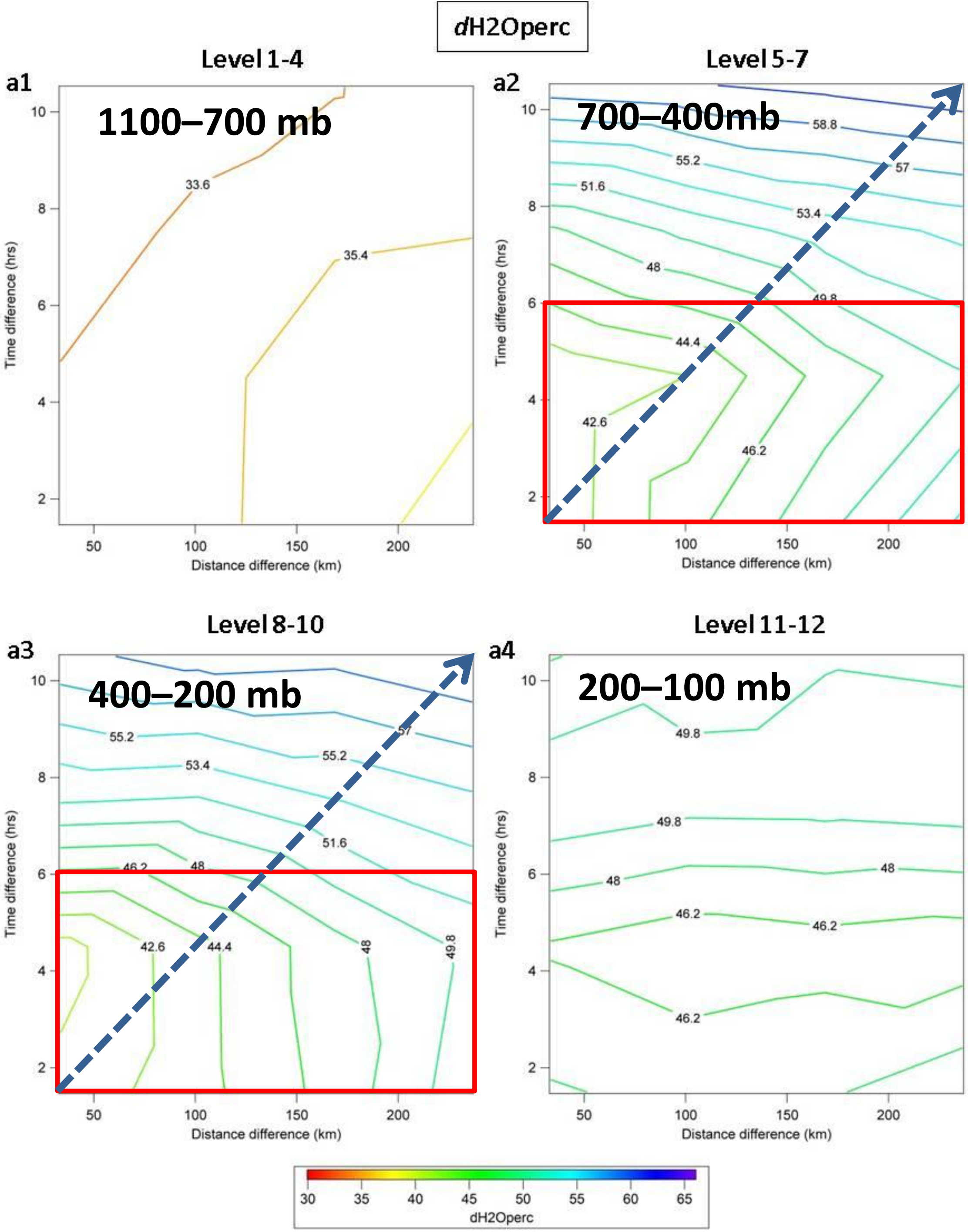
dTime ≤ 3 hr,
dDist ≤ 67.5 km

Land versus ocean

Biases in the UT/LS and near surface, Ocean (+) Land (-)

Black: ocean
Red: land





dDist = 0-270 km
dTime = 0-12 hr

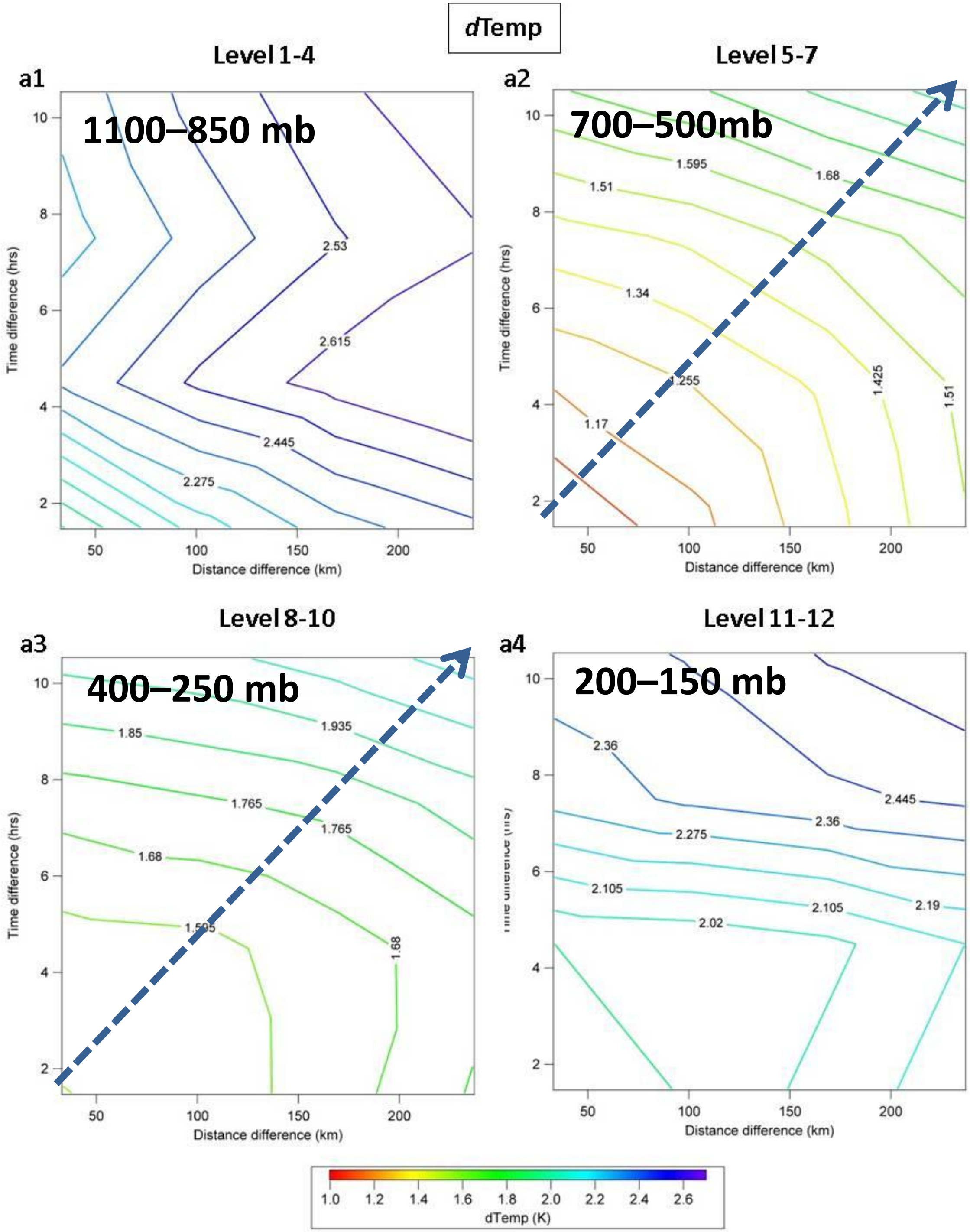
22.5 km versus 1 hr: **~6 m/s typical** horizontal wind speed

Sensitivity of |dH2Operc| at 700-200 mb:

1. ≤ 6 hr more sensitive to **dDist** than dTime

2. ≥ 6 hr more sensitive to **dTime** than dDist

3. Suggestion: use ≤ 6 hr time window; ~1.5 % dH2Operc increase per 22.5 km



dDist = 0-270 km
dTime = 0-12 hr

Sensitivity of |dTemp| at 250-700 mb:

1. 0-12 hr: similar sensitivity to dTime and dDist

2. Suggestion: ~0.1 K per 22.5 km or per 1 hr

Conclusion

1. A new, comprehensive dataset of HIPPO#1-5 and START08

– Scatter plots show ***improvements*** in comparison results using Level 2 ***Version 5*** data than ***Version 3*** *(*Gettelman *et al.,* 2004*)*

2. Water vapor and temperature vertical profiles

– Improvements over land at 700-200 mb than Version 4 (Divakarla *et al.,* 2006)

– **At the surface and UT/LS**

  – ***Negative biases over land 20-40% for dH2Operc, 1-1.5K for dTemp***

  – ***Positive biases over land 20-40% for dH2Operc, 1-1.5K for dTemp***

3. Sensitivity to temporal and spatial comparisons windows

200-700 mb: within 6 hr, H_2O comparisons have ***stronger sensitivity to spatial windows*** (22.5 km) than temporal (1 hr) windows

250-700 mb: Temperature has similar sensitivity to spatial and temporal windows

Future work

Compare relative humidity profiles

Acknowledgement

RAF Technical and Ground Crews
HIPPO Science Team; START08 Science Team

Thanks!

Questions?

Thanks to the NESSF fellowship for my PhD work:

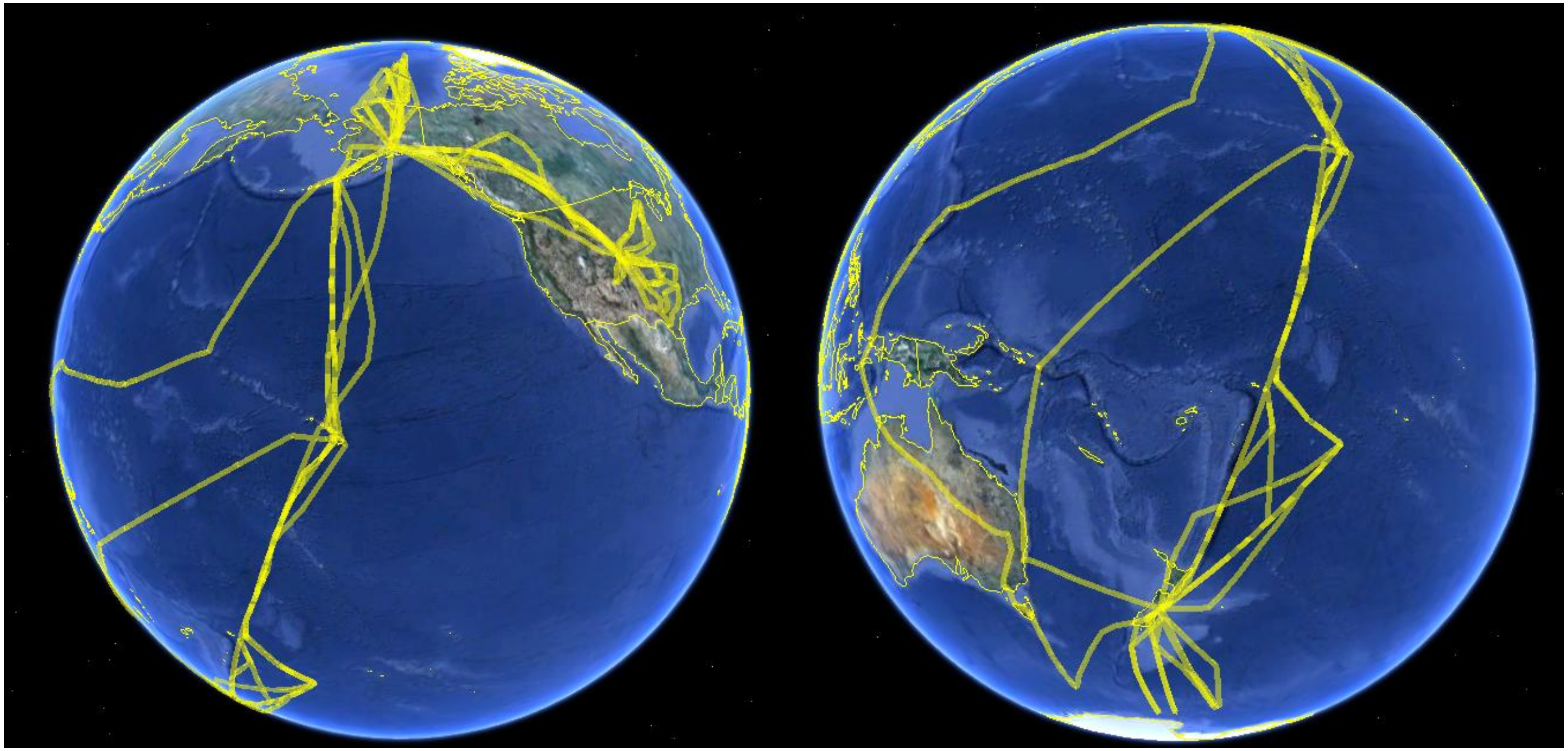
Diao, M., L. Jumbam, J. Sheffield, E. Wood and M.A. Zondlo. "Water vapor and temperature comparisons between AIRS/AMSU-A and in situ aircraft observations from 80°N to 67°S and sensitivities to spatial and temporal differences", *in preparation to Journal of Geophysical Research Atmosphere.*

Diao, M., M.A. Zondlo, A.J. Heymsfield, L.M. Avallone, M.E. Paige, S.P. Beaton, T. Campos. "Patchiness of ice supersaturated regions controlled by water vapor heterogeneities", *Nature Geoscience, in review*, NGS-2012-09-01474-T.

Fellowship and award	
2012	Walbridge Fund Graduate Award
2008-2012	Princeton Francis Upton Fellowship
2009-2012	NASA Earth and Space Science Fellowship
2011	Princeton Environment and Climate Scholars Travel Grant
2010	Outstanding student paper award for AGU Fall Meeting, San Francisco
2009	Outstanding student paper award for AGU Spring Assembly, Toronto
2009	Travel Award to attend Water Vapor and the Climate System (WAVACS) summer school, France

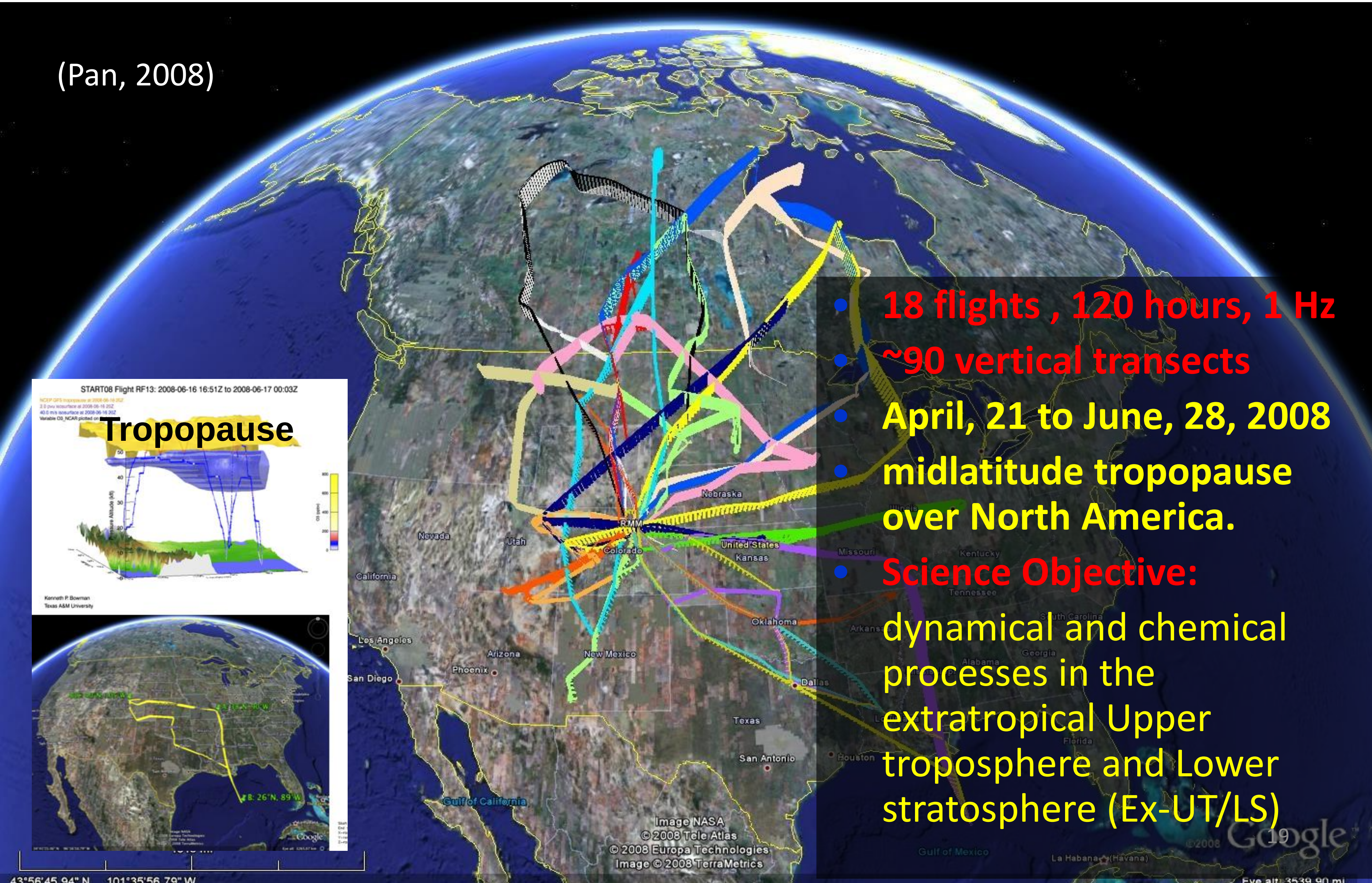
NSF Hiaper Pole-to-Pole Observations (HIPPO) Global flight campaign #1-5 (2009-2011)

- 87°N to 67°S, four seasons, ~400 hr flight time, 1 Hz data
- ~600 vertical transects from the surface to the tropical UT or the extratropical UT/LS (Wofsy et al., 2011)



NSF START08 Campaign (The Stratosphere Troposphere Analyses of Regional Transport campaign) (2008)

(Pan, 2008)



- 18 flights , 120 hours, 1 Hz
- ~90 vertical transects
- April, 21 to June, 28, 2008
- midlatitude tropopause over North America.
- Science Objective:

  dynamical and chemical processes in the extratropical Upper troposphere and Lower stratosphere (Ex-UT/LS)