Comparing and Verifying WRF Simulations of Water Vapor for TC Ingrid (September 2013)

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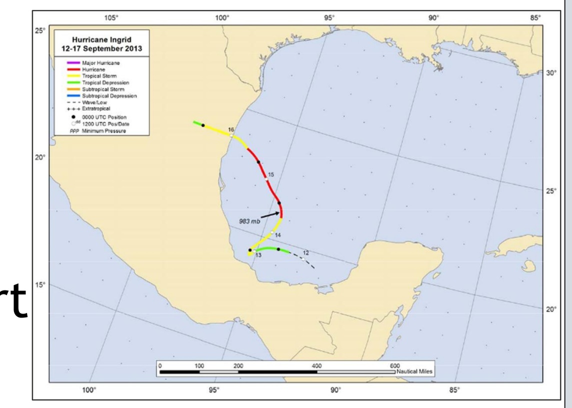
Introduction

- Water vapor is a potent greenhouse gas with important climate impacts in the upper troposphere and lower stratosphere (UTLS). (4)
- **Goal: Simulate the water vapor budget and transport of Hurricane Ingrid (September 2013) using the WRF model.**
- Research Objectives:

1. Which mechanisms of water vapor transport in the tropical cyclone (TC) can we quantify?
2. Is the TC a major source of water vapor to the UTLS?
3. How much water vapor is injected into the UTLS by the eye wall vs. outer rain bands?
4. How do the simulations verify against in situ data from the NASA SEAC4RS mission during September 2013?

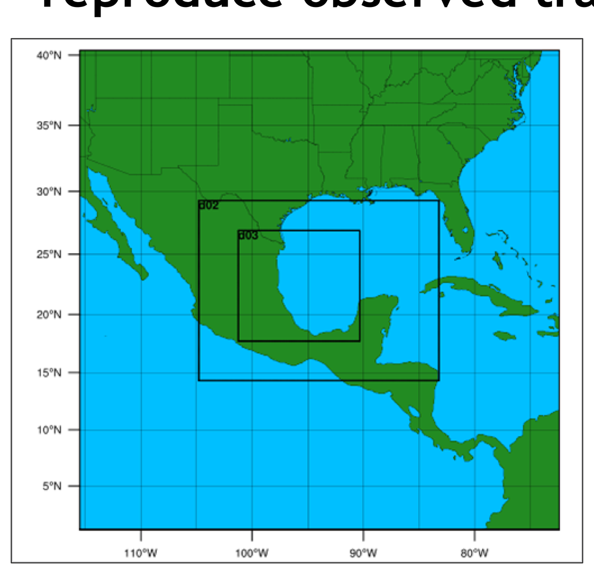


Ingrid track and intensity

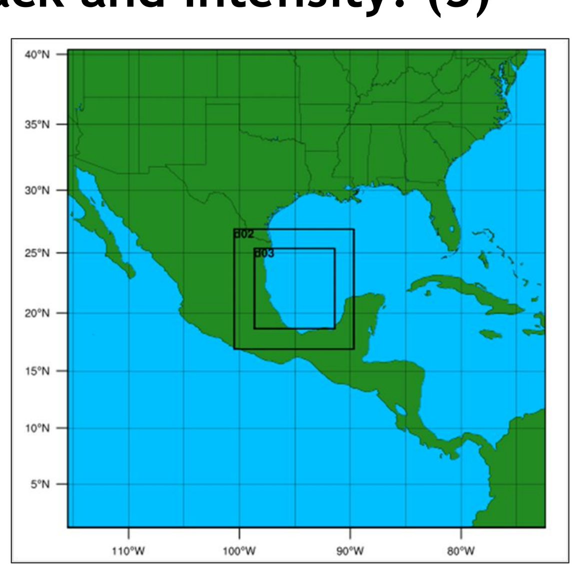
Model Overview

The simulations of Ingrid are created using the Weather Research and Forecasting (WRF) Model (1). The options used in running WRF are:

- WRF-ARW V3.6
- Initial data: NCEP FNL 1° x 1° Analyses
- 5 day runs (September 11-16)
- Nesting of 12, 4, 1.33 km grid spacing
- 1-D ocean mixed layer (OML); PBL: YSU scheme
- Cumulus (CU): New SAS (12-km only)
- Microphysics (MP): WDM 6-class
- 75 vertical levels; 66-h grid nudging
- **Smaller nested domains very beneficial to reproduce observed track and intensity! (3)**



Nested WRF configuration (larger nests)

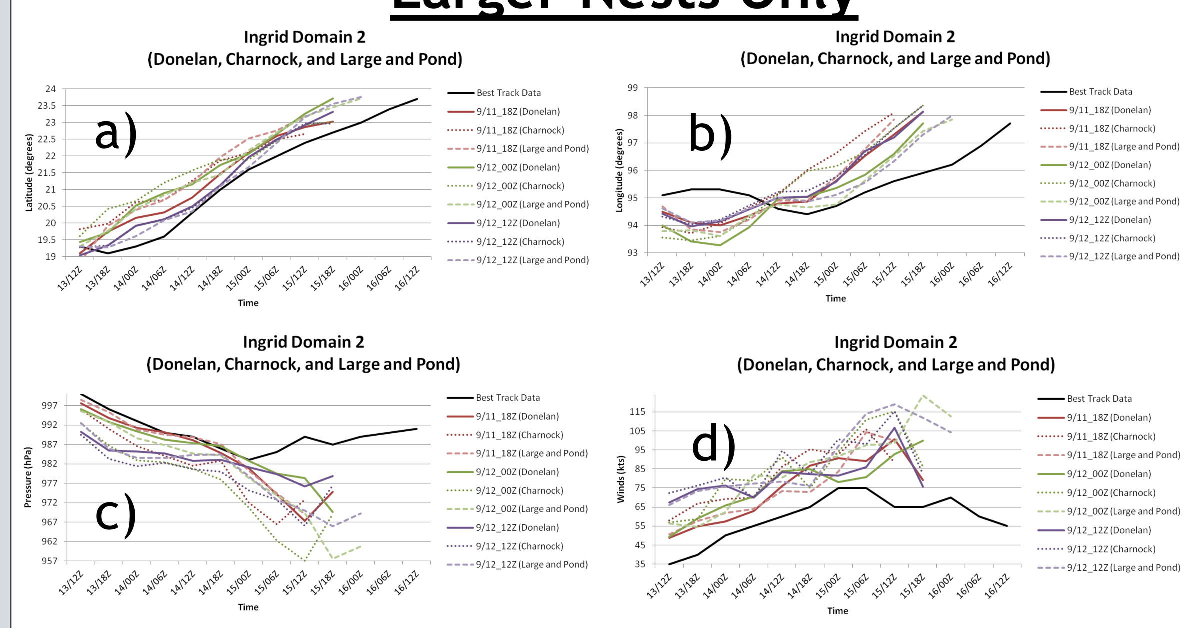


Final nested WRF configuration (smaller nests)

Sensitivity Testing of Various WRF Parameters

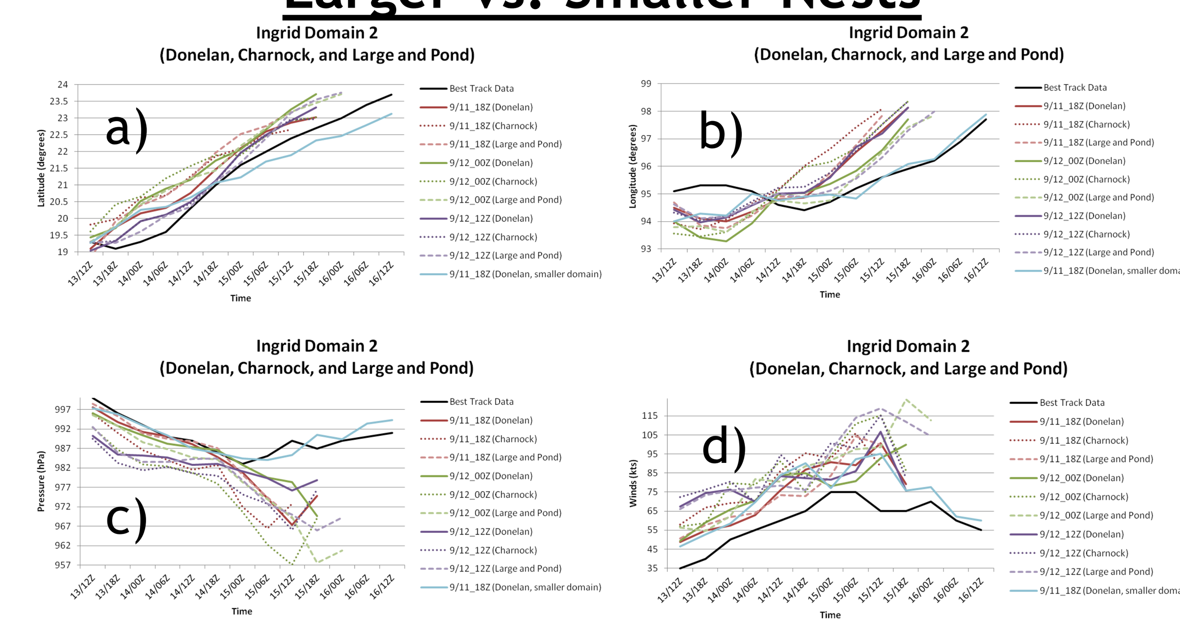
Varying Model Initialization Times and Surface Exchange Coefficients

Larger Nests Only



a) Latitude, b) Longitude, c) Pressure, d) Winds for a variety of model initialization times

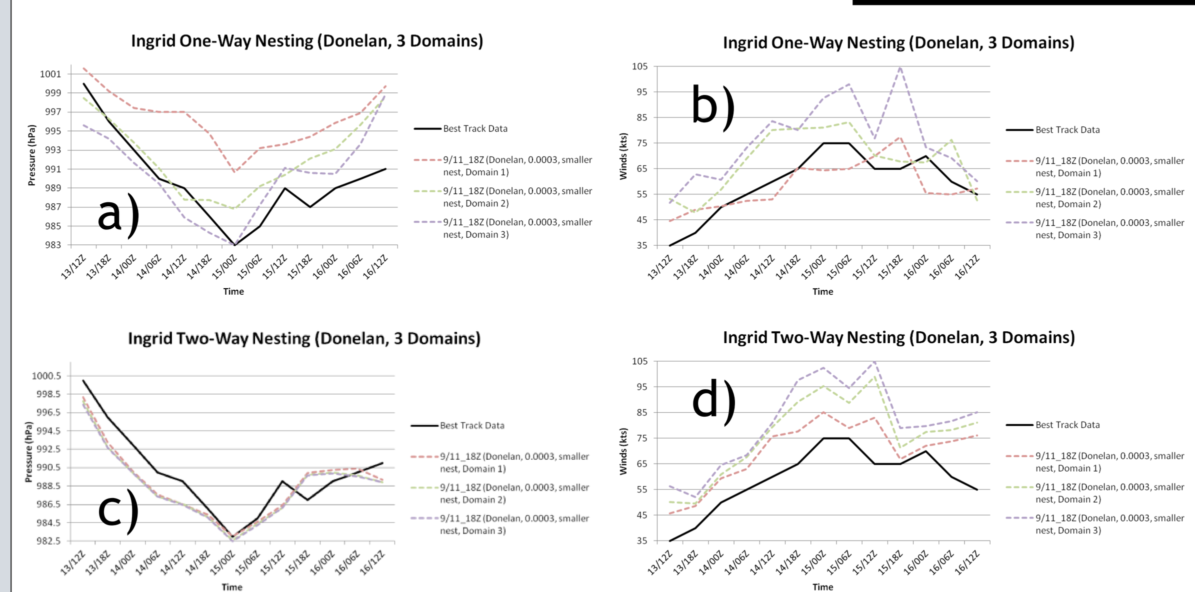
Larger vs. Smaller Nests



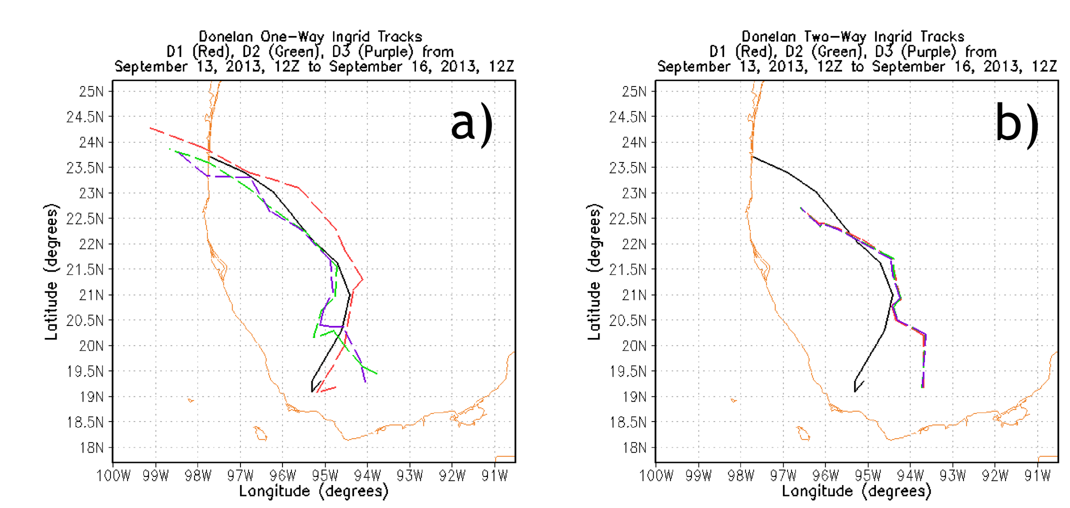
a) Latitude, b) Longitude, c) Pressure, d) Winds for a variety of model initialization times, with additional smaller nest results

Right figures: With much smaller nests, more reasonable results in WRF! (3)

One-way vs. Two-way Nesting



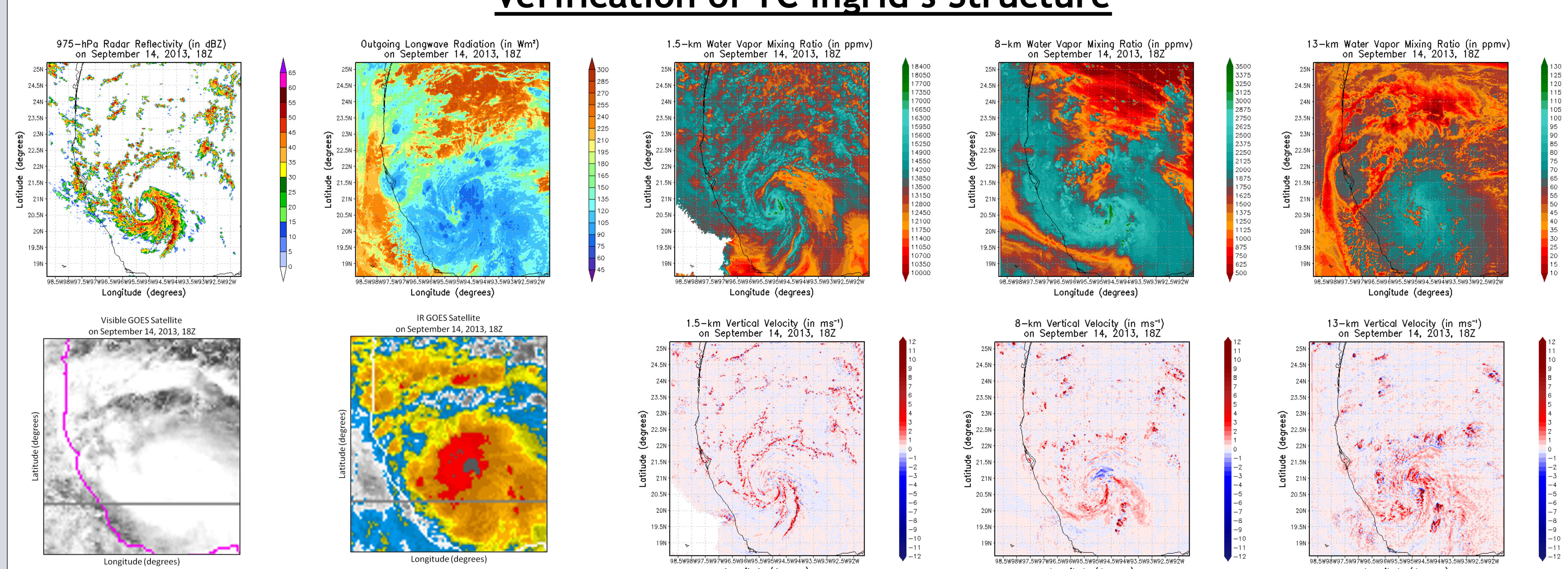
Pressure and winds using a) and b) one-way nesting vs. c) and d) two-way nesting



Track using a) one-way nesting vs. b) two-way nesting

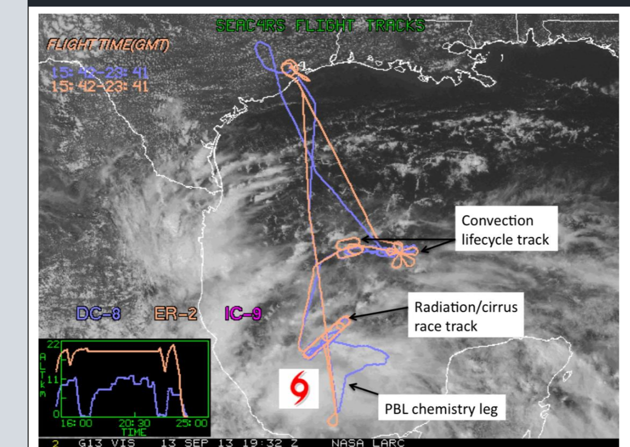
Track and intensity using one-way nesting are superior to two-way nesting.

Verification of TC Ingrid's Structure



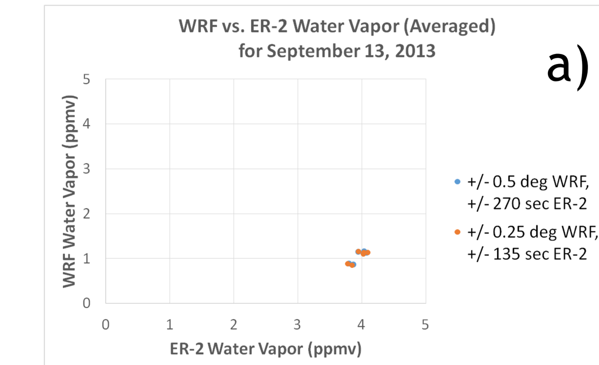
The WRF simulations closely agree with GOES imagery and expected TC structure.

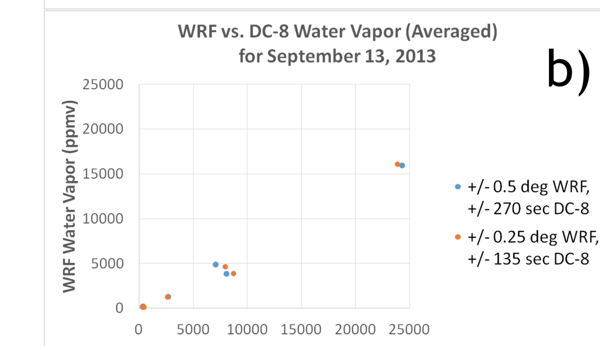
Verification of WRF to In Situ Data



- Use in situ water vapor data from the ER-2 and DC-8 aircraft from 13 September 2013 during the NASA SEAC4RS mission.

- The WRF model is **drier up to a factor of 4** compared to the a) ER-2 and b) DC-8.
- Better agreement between model and observations at lower levels than upper levels.





Conclusions

- WRF is sensitive to a variety of settings. The final chosen parameters produced a **good** simulation of TC Ingrid.
- WRF options used for Ingrid could be different for other TCs.
- Smaller nested domains significantly improve TC track and intensity for TC Ingrid.

Ongoing Research

- With the simulations completed, the mechanisms of water vapor transport, and how much water vapor is injected into the upper atmosphere will be investigated.
- High-resolution WRF nested runs (4 and 1.33 km) will be conducted to show TC structure, vertical motion, and water vapor transport. These simulations will be verified with in situ high altitude aircraft water vapor data.
- Water vapor in the UTLS has been shown to have a potent impact on climate change (4). This research will show if TCs are a major source of water vapor transport to the UTLS.

References

1: http://www.wrf-model.org/index.php

2: Davis, C., W.Wang, S. S. Chen, Y. Chen, K. Corbosiero, M. DeMaria, J. Dudhia, G. Holland, J. Klemp, J. Michalakes, H. Reeves, R. Rotunno, C. Snyder, and Q. Xiao, 2008: Prediction of Landfalling Hurricanes with the Advanced Hurricane WRF Model. *Mon. Wea. Rev.*, **136**, 1990–2005. doi: http://dx.doi.org/10.1175/2007MWR2085.1

3: Kumar, A., J. Done, J. Dudhia, and D. Niyogi, 2011: Simulations of Cyclone Sidr in the Bay of Bengal with a high-resolution model: Sensitivity to large-scale boundary forcing. *Meteor. Atmos. Phys.*, **114**, 123–137, doi:10.1007/s00703-011-0161-9.

4: Ravishankara, A. R., 2012: Water vapor in the lower stratosphere. *Science*, 337, 809-810.