Review of Tropical Dry Intrusions During CONTRAST

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What are these dry layers?

- They were not extensively investigated until the TOGA COARE experiment in 1992-1993.
- They received a lot of attention by the tropical convection crowd following TOGA COARE (well over two dozen papers).
- They are called ‘dry intrusions’ since the dry air originates aloft at higher latitudes and subsides into the tropics in long filaments several hundred km in width.

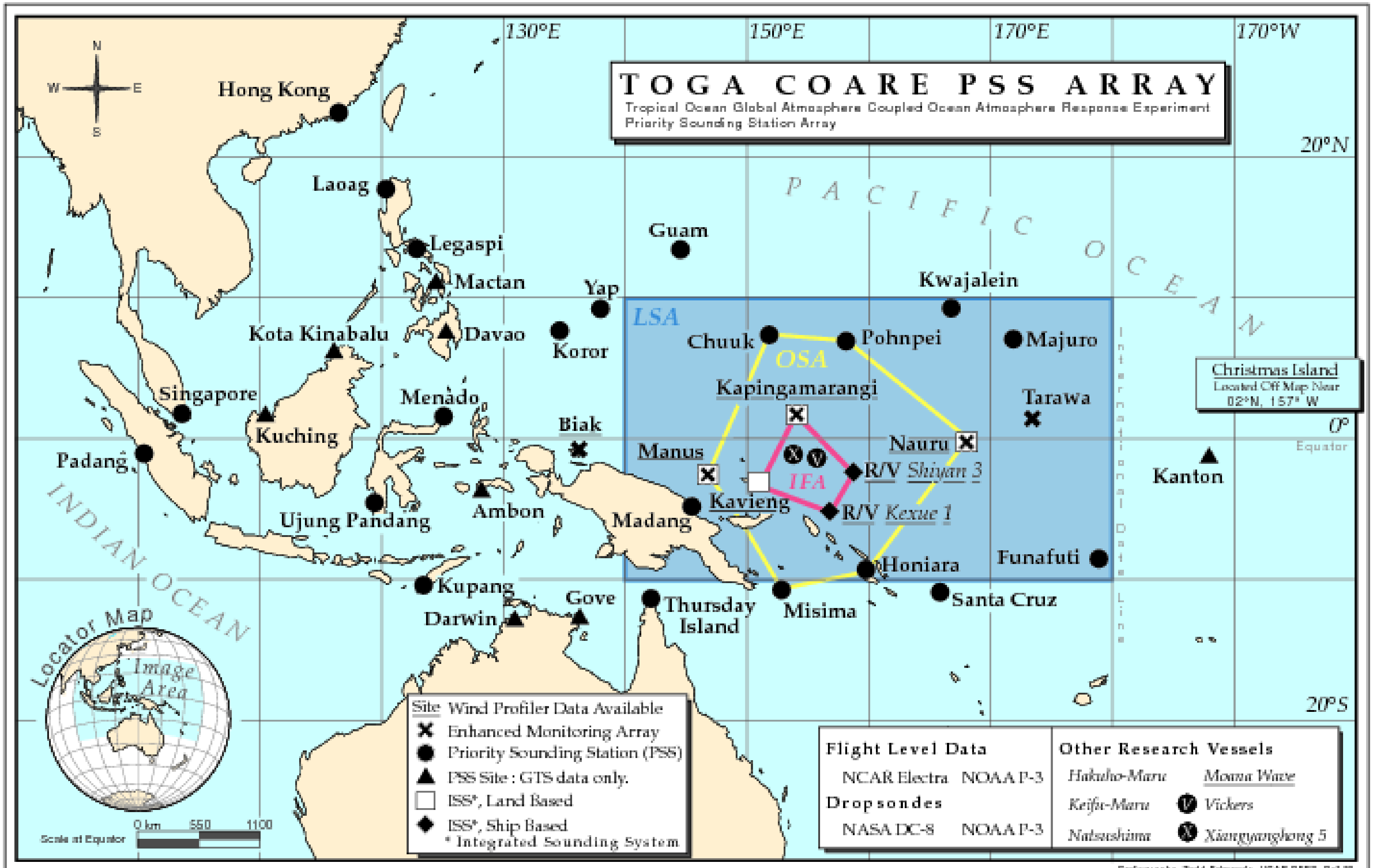
Redelsperger et al. (2002)

What are these dry layers?

- It takes about 10 to 20 days for the atmosphere to recover following a dry intrusion.
- Dry intrusions are important for the tropospheric moisture budget and modulate the convection.

Parsons et al. (2000)

- Hayashi et al (2008) related the dry layers to elevated O3 levels.



TOGA COARE PSS ARRAY
Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment
Priority Sounding Station Array
130°E
150°E
170°E
170°W
20°N
0°
Equator
20°S
N
S
W
E
PACIFIC OCEAN
INDIAN OCEAN
LSA
OSA
IFA
Hong Kong
Laoag
Legaspi
Mactan
Davao
Kota Kinabalu
Singapore
Kuching
Padang
Menado
Ujung Pandang
Ambon
Biak
Yap
Koror
Guam
Chuuk
Pohnpei
Kwajalein
Majuro
Kapingamarangi
Tarawa
Nauru
Manus
Kavieng
Madang
R/V Shiyan 3
R/V Kexue 1
Honiara
Funafuti
Kanton
Kupang
Darwin
Gove
Thursday Island
Misima
Santa Cruz
Christmas Island
Located Off Map Near
02°N, 157° W
International Date Line
Locator Map
Image Area
0 km
550
1100
Scale at Equator
Site Wind Profiler Data Available
Enhanced Monitoring Array
Priority Sounding Station (PSS)
PSS Site : GTS data only.
ISS*, Land Based
ISS*, Ship Based
* Integrated Sounding System
Flight Level Data
NCAR Electra
NOAA P-3
Dropsondes
NASA DC-8
NOAA P-3
Other Research Vessels
Hakuho-Maru
Moana Wave
Keifu-Maru
Vickers
Natsushima
Xiangyanghong 5

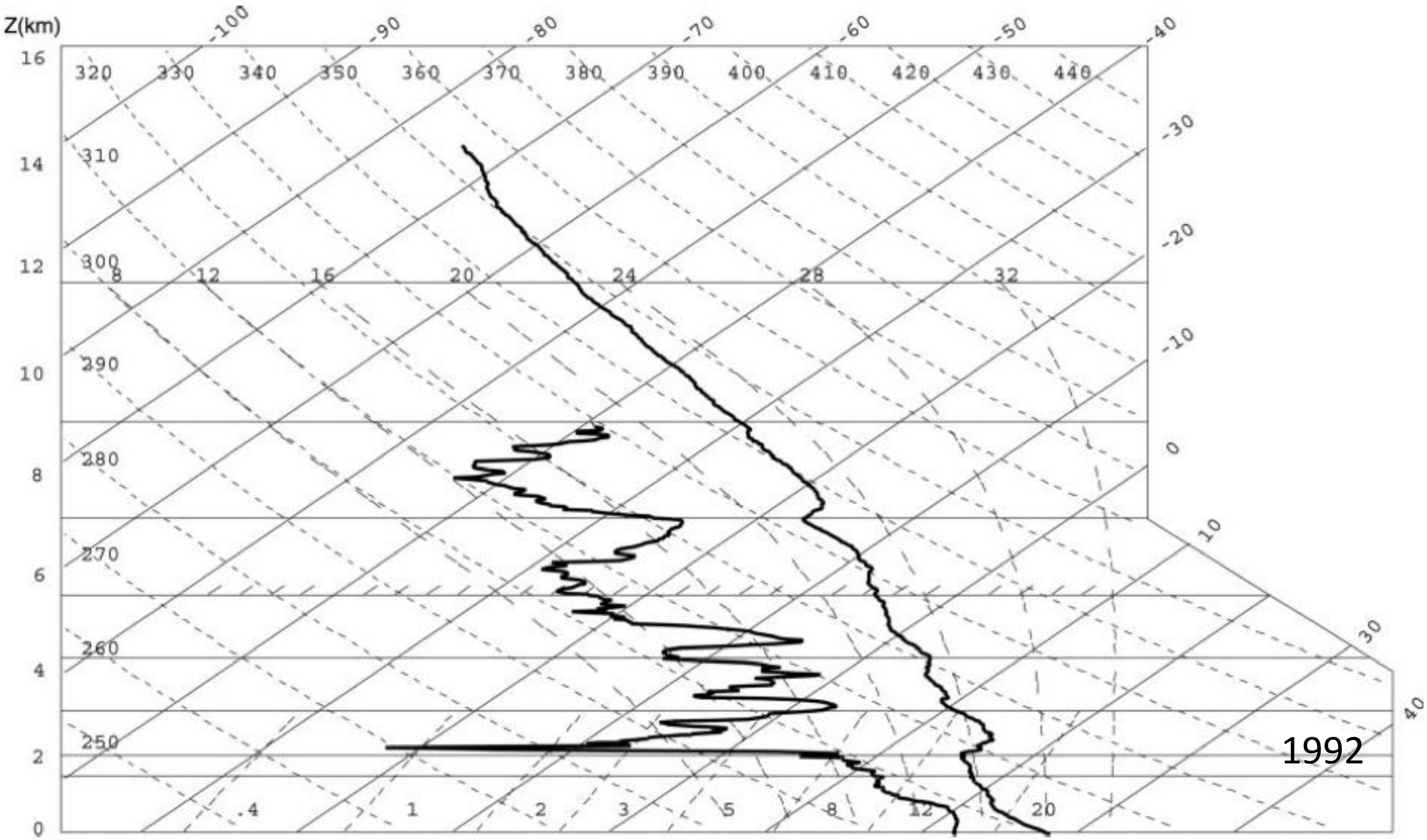
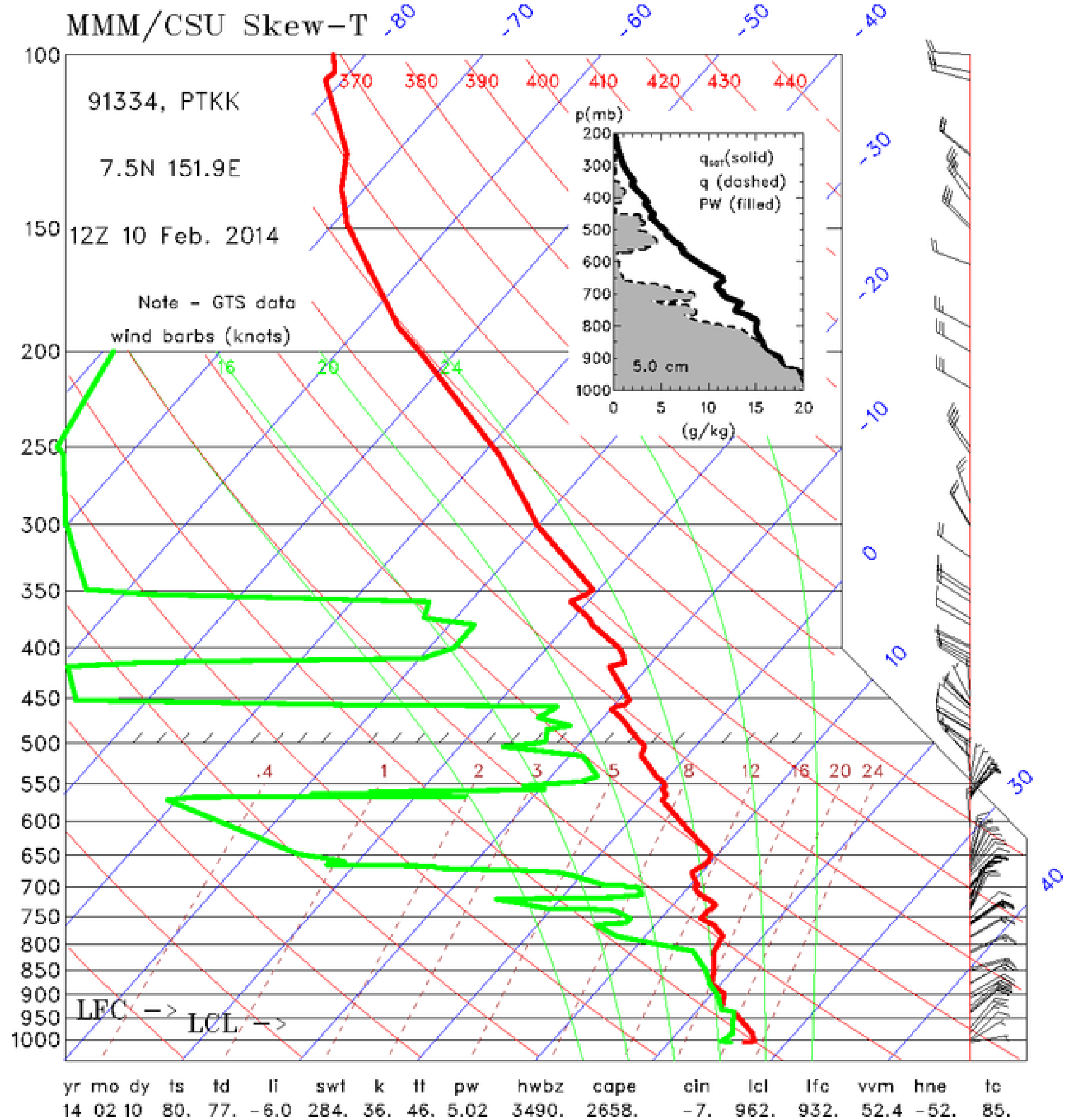


FIG. 18. Sounding from R/V *Moana Wave* at 2300 LST 15 Nov.

From RPG

Note that the base of the dry layer is usually accompanied by a temperature inversion as explained in detail by Mapes and Zuidema (1996).



Chuuk sounding, 10 February 2014

4-month

Several dry intrusions occurred during the TOGA-COARE period, but some of them were constrained to the upper troposphere.

Blue: dry
Red: moist

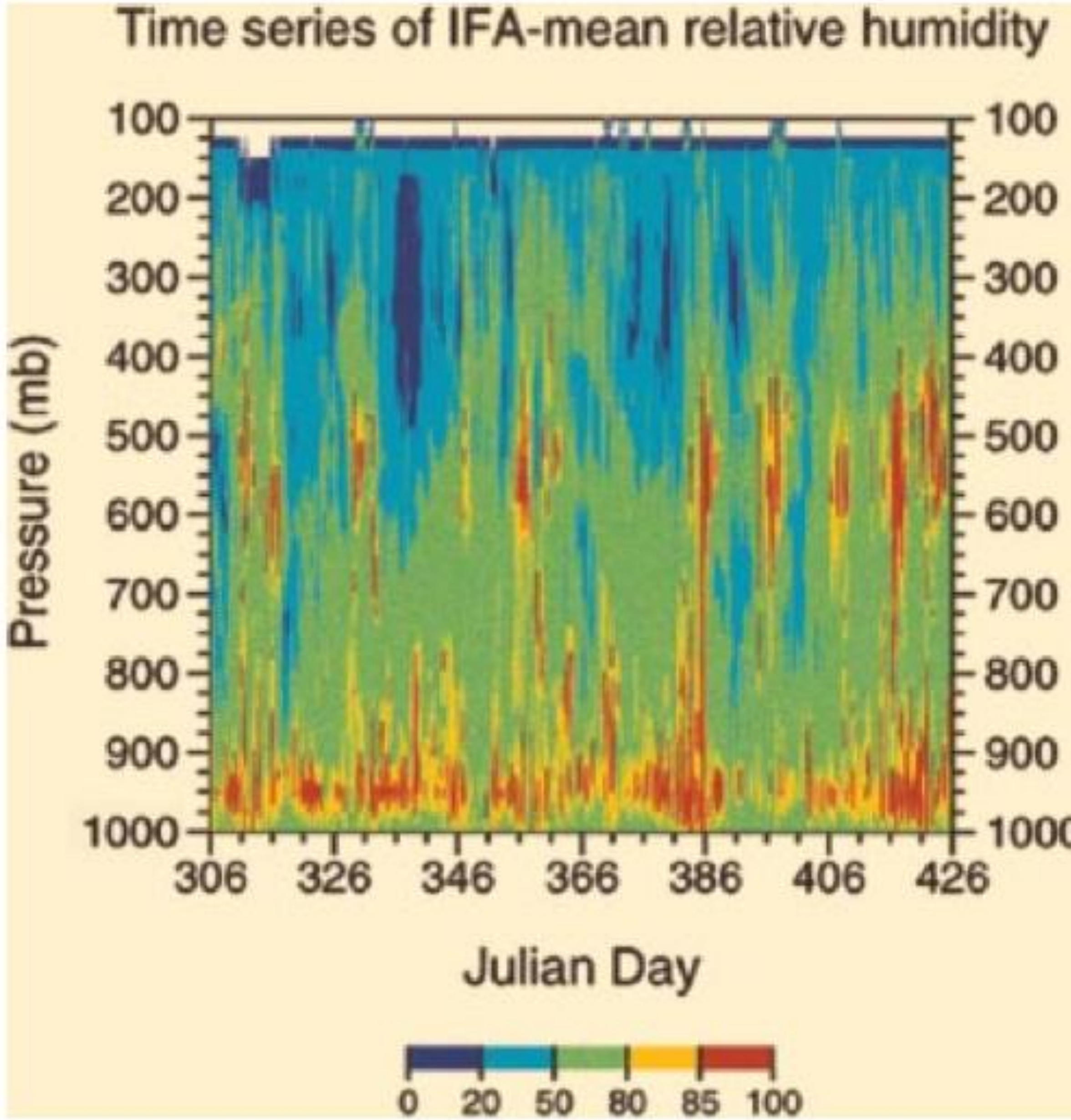
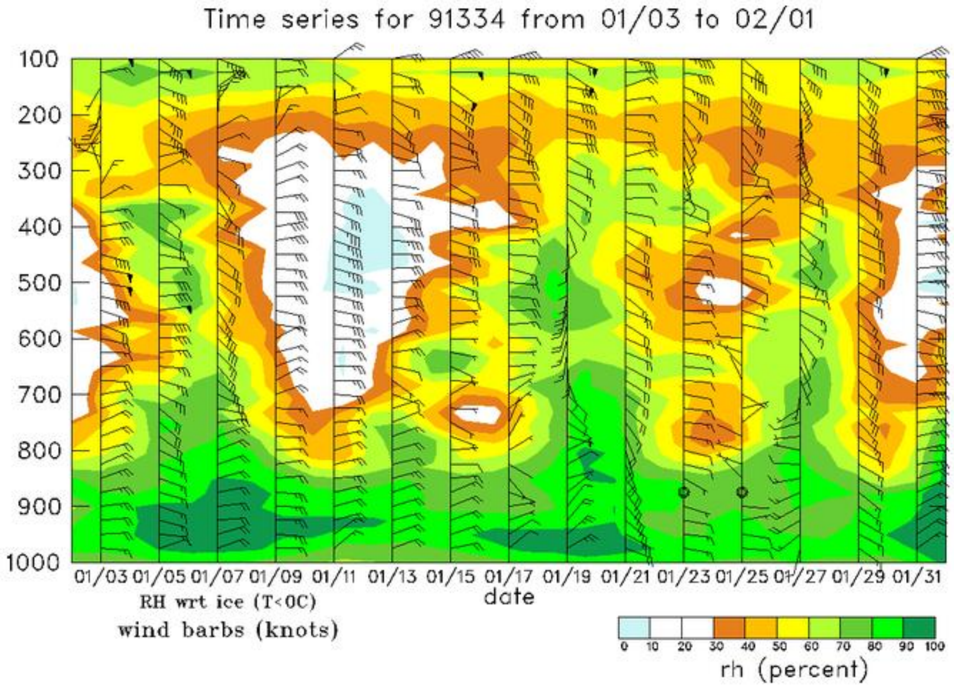


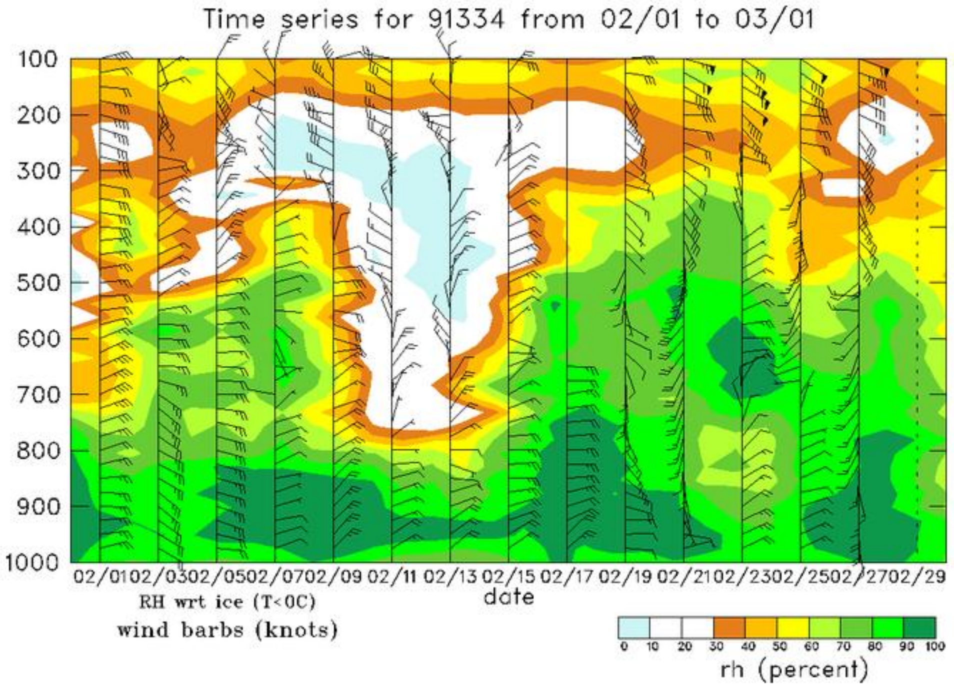
FIG. 7. Time–height cross section of tropospheric relative humidity during COARE IOP. Temporal resolution is every 6 h.

DeMott and Rutledge 1998

Chuuk RH (7.5N, 151.9E)



January



February

CONTRAST time series exhibit periodic dry intrusions as occurred during TOGA-COARE

Yoneyama and Parsons (1999) noted that dry events are very common and can be classified into two types:

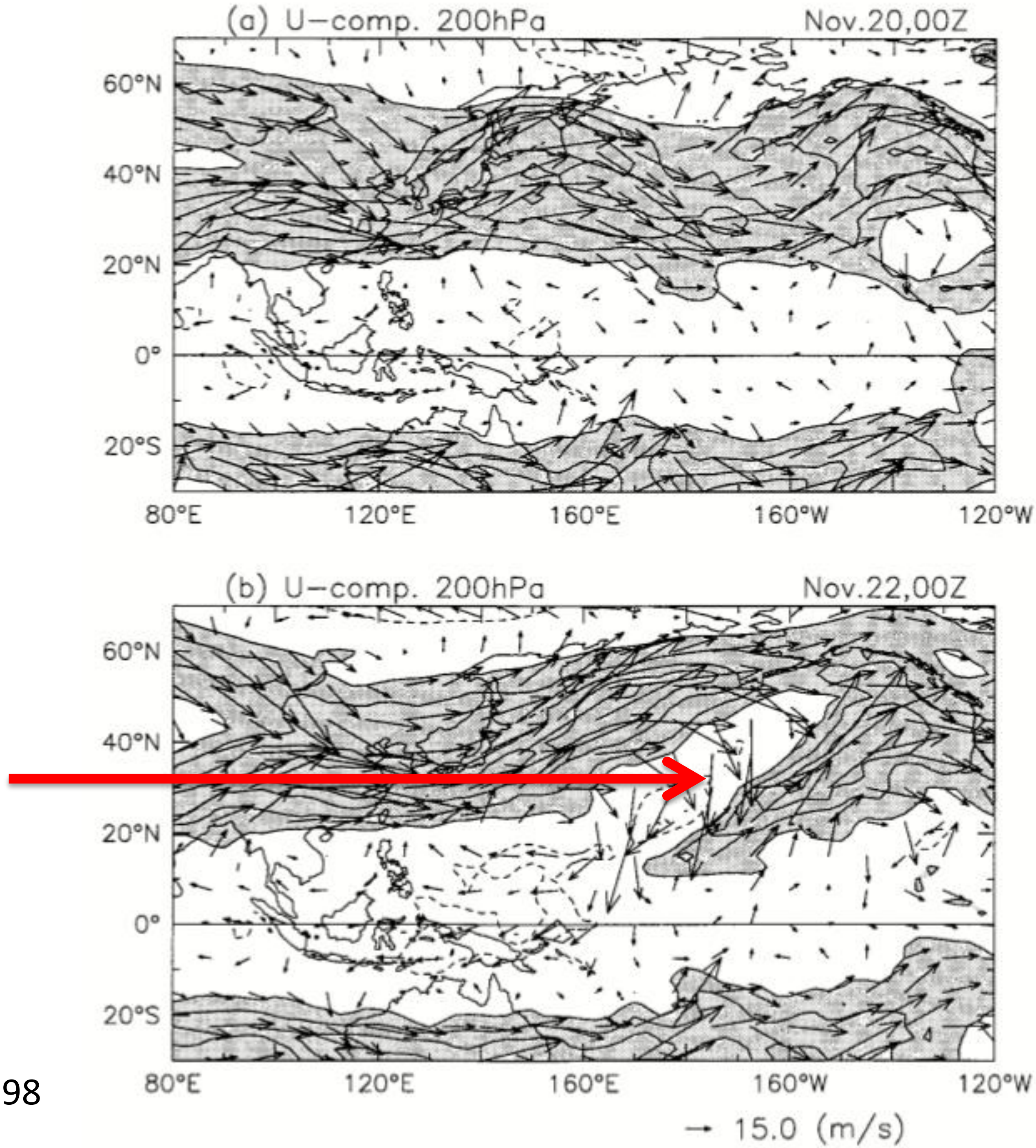
1) Low-level event (below 500 hPa), that is extremely dry and arrives suddenly. It lasts 3 to 7 days.

2) Upper-level event (above 550 hPa) that is not as dry, but can last longer (more than 7 days).

“Many studies have reported that these extensive dry air layers cannot be explained by vertical adiabatic displacements. Instead, the horizontal advection of air from the subtropics has been shown to account for the origins of these air masses”.

“A single mechanism (baroclinic waves) is responsible for advection of dry air into the Tropics, once in the Tropics dry air is advected by different type of disturbances”.

Example of Rossby wave-breaking during the November 1992 event.



Yoneyama and Parsons, 1998

Mapes and Zuidema (1996):

"[the extremely dry layer] has undergone something like 20 days of radiative cooling since it was last in contact with a low-latitude sea-surface."

"Clearly, horizontal advection is the proximate cause of the main dry layer…"

November 1992 TOGA COARE events using ERA-40 data.

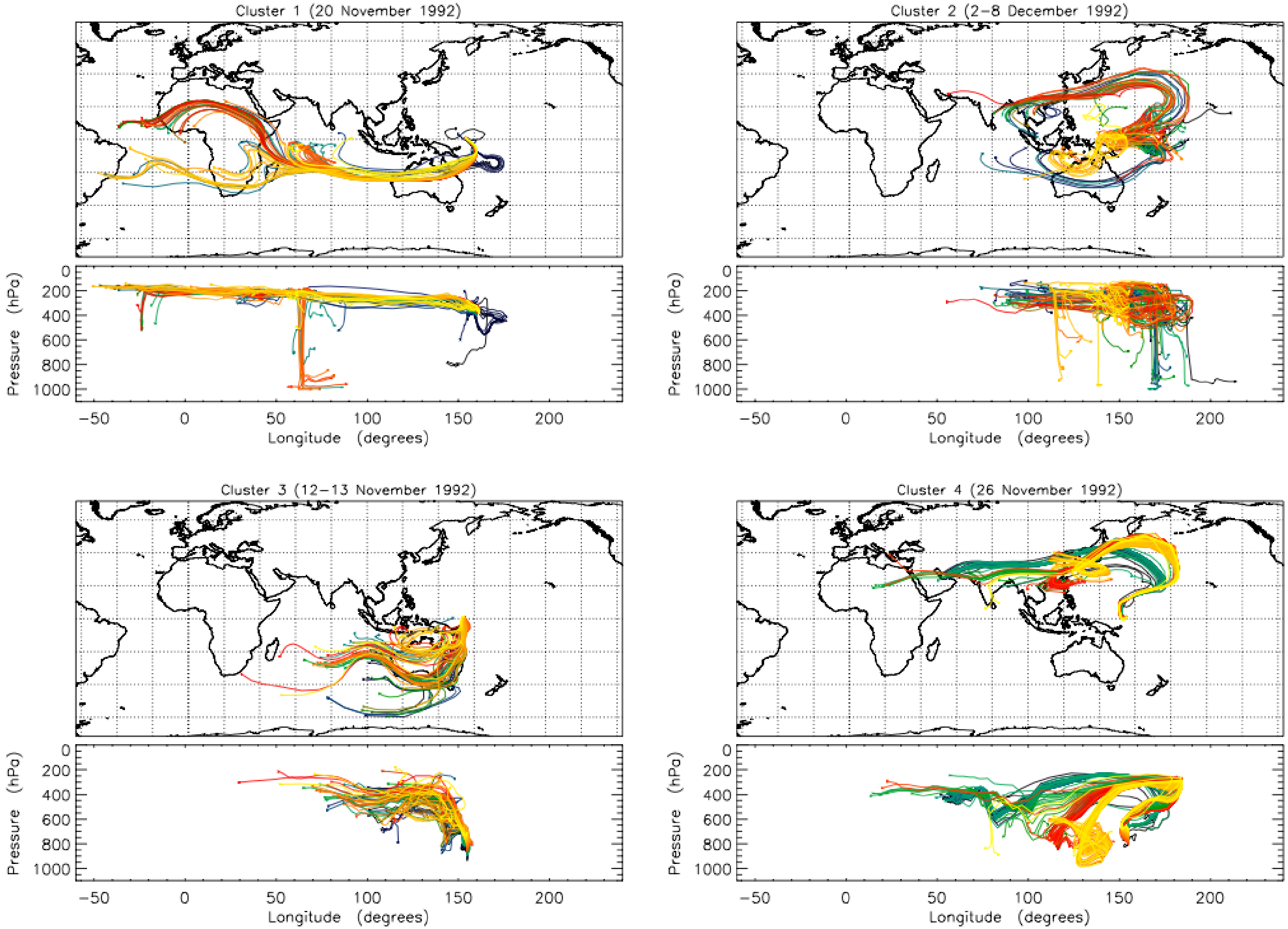


Figure 14. Twelve-day back trajectories for four dry events at Kapingamarangi (154°E, 01°N). With reference to Figure 11 they correspond to the dry events (black) in the upper troposphere on 20 November 1992 (cluster 1 - sonde 61), the first decad of December (cluster 2, around sonde 100), in the lower troposphere on 12–13 November (cluster 3, around sonde 40), and 26 November (cluster 4, around sonde 80). The trajectories shown are a regular sample of the many associated with the dry events. See text for an explanation of the coloring.

Cau et al., 2005

Cau et al 2007. "Origins of dry air in the tropics and subtropics". J. Climate.

Trajectory analysis using ERA-40 data from January 1993.

Dry air in the western Pacific mainly originates near the jet location east of Japan, over the Indian Ocean and Tibet.

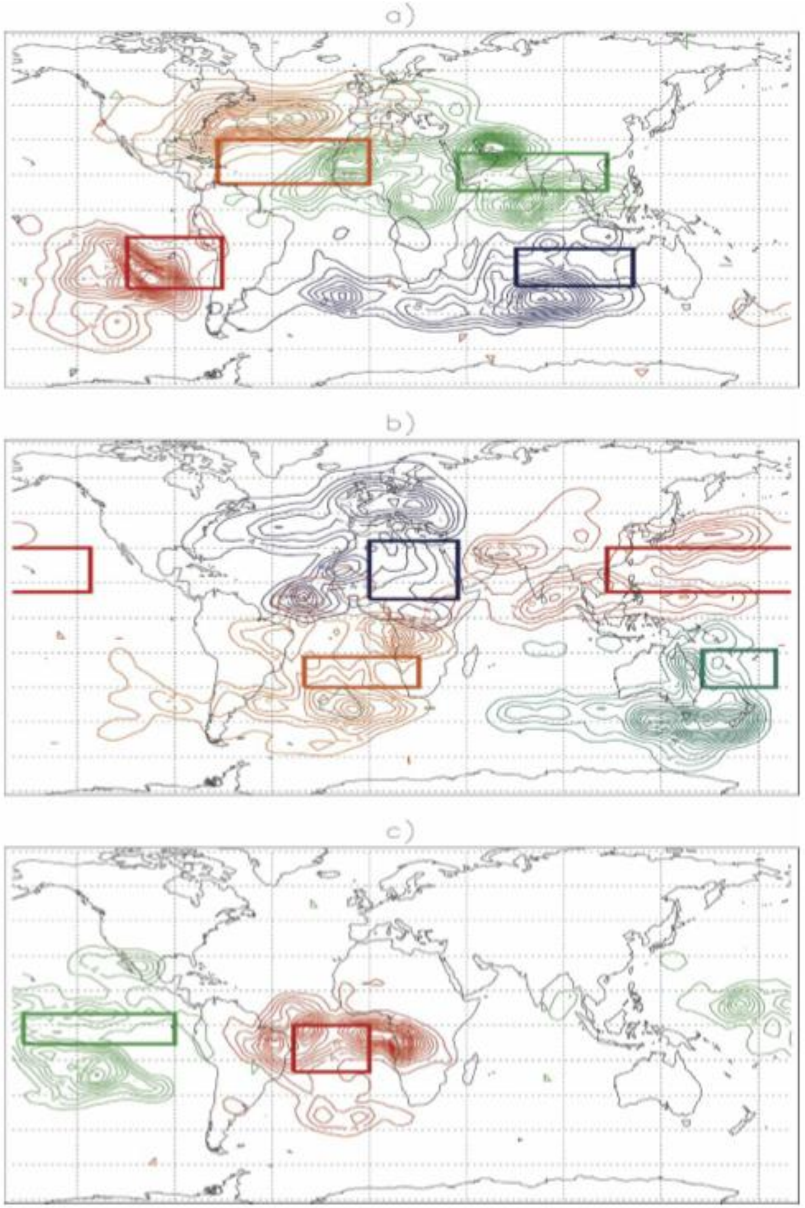


FIG. 7. Origin of air masses arriving in the boxed regions with RH < 20%. These boxes correspond to the regions with the most dry events (RH < 20%) in Fig. 6a and are listed in Table 2.

Cau et al 2007.

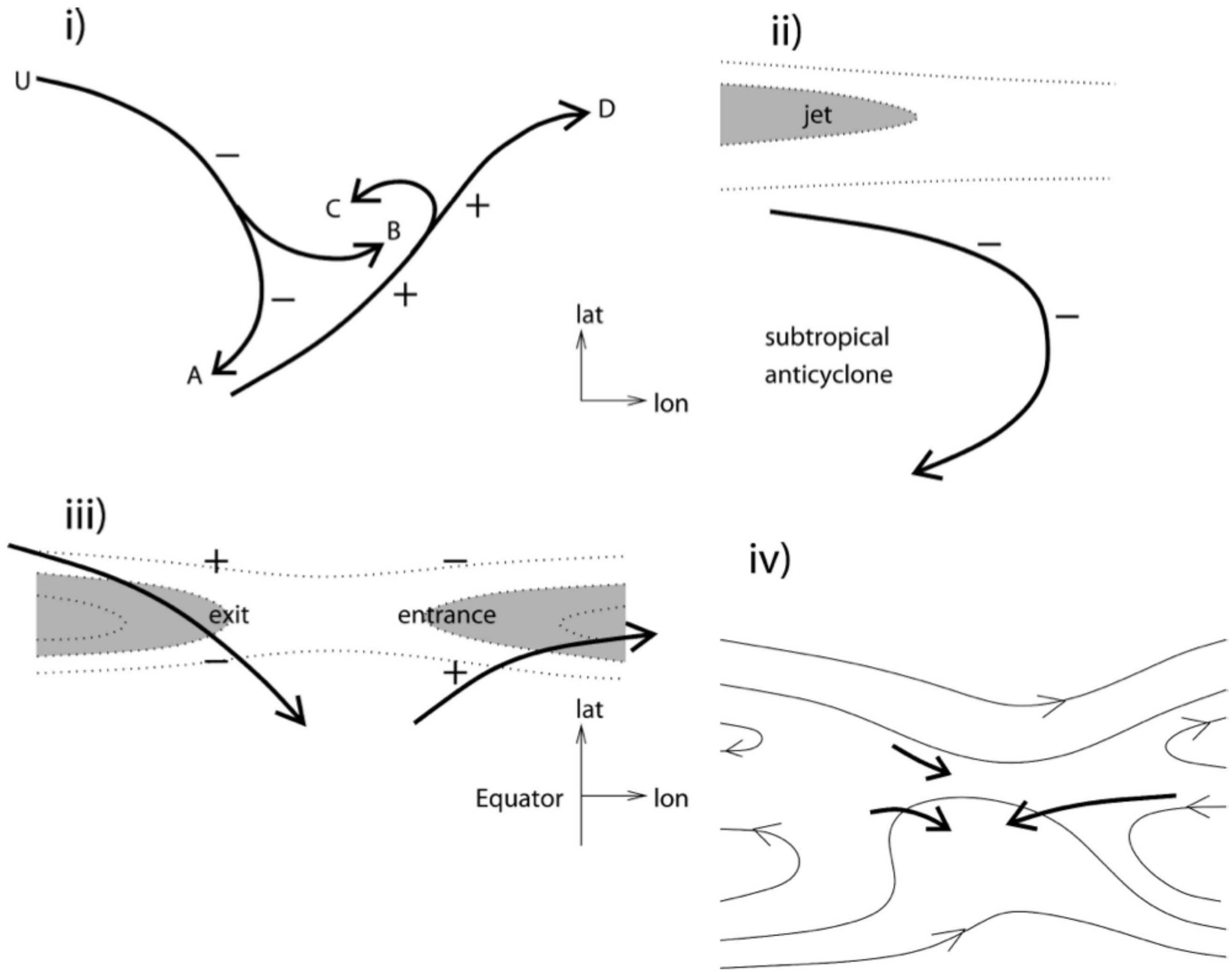
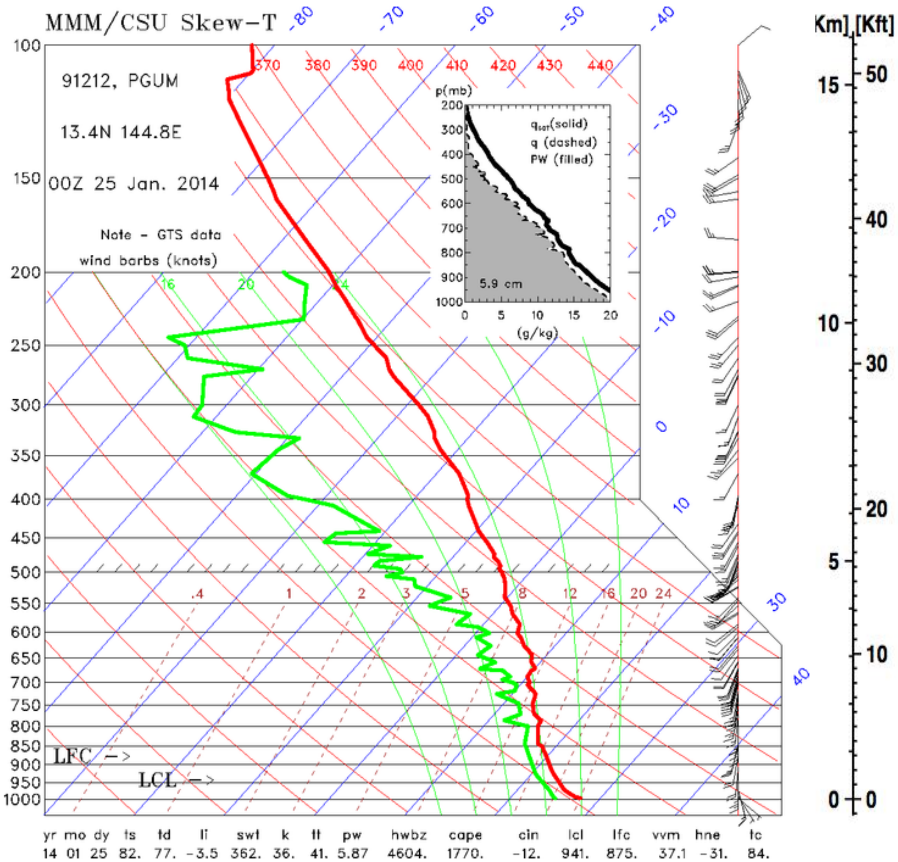


FIG. 9. Four transport processes linking dry air in the Tropics and subtropics to its origins. Arrows indicate typical trajectories. Dotted lines indicate isotachs of the time-average flow. Minus symbols mark descent and pluses mark ascent. (i) Extratropical baroclinic waves via their descending branch A; (ii) capture from the equatorial flank of the jet around subtropical anticyclones; and (iii) associated with a minimum in subtropical jet strength. Descent equatorward across the jet exit and ascent poleward into the jet entrance; and (iv) dry air converging near a stagnation region in the upper troposphere between regions of deep convection. Thin lines indicate the time-average streamfunction.

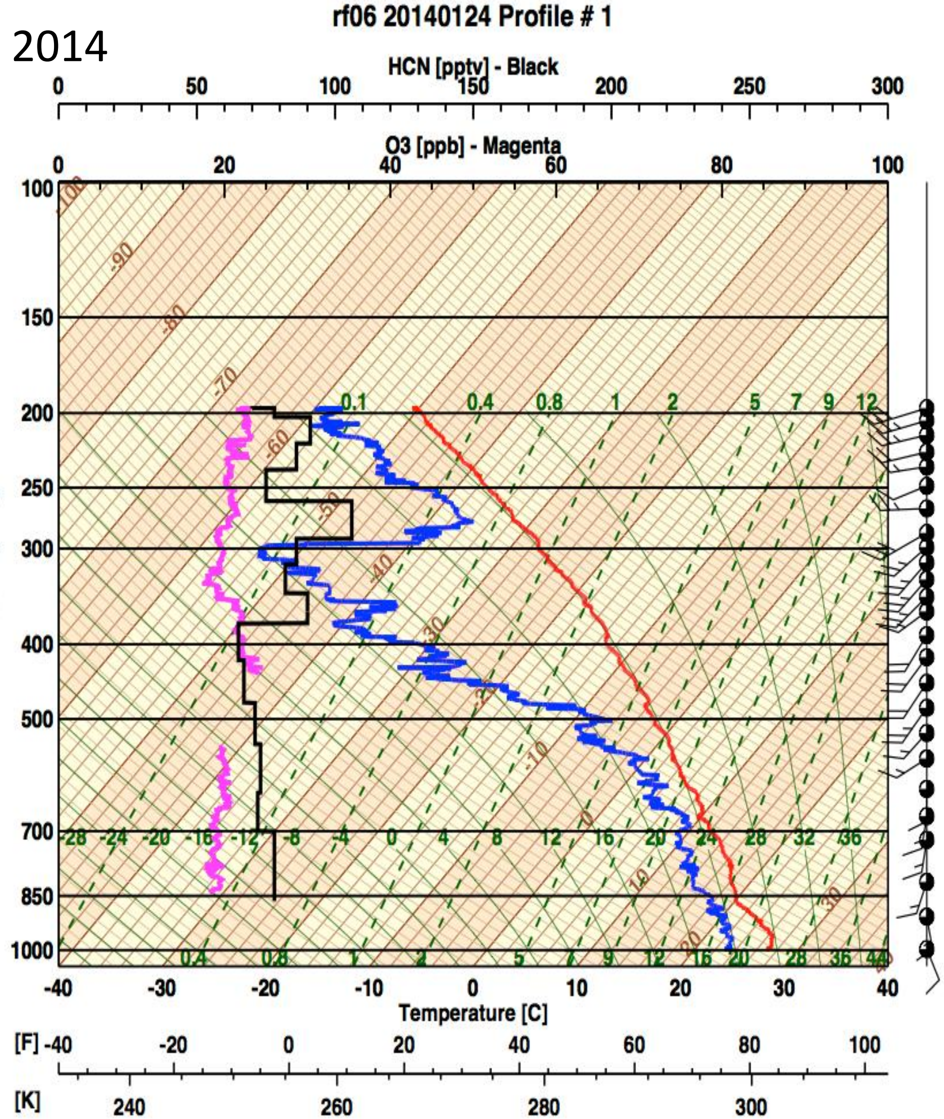
The accuracy of the NWS radiosonde replacement system has been questioned. Therefore, we wish to verify the reliability of the NWS soundings by comparing them with proximity soundings from the GV.

RF06 25 Jan 2014

00z = 10 A.M. local



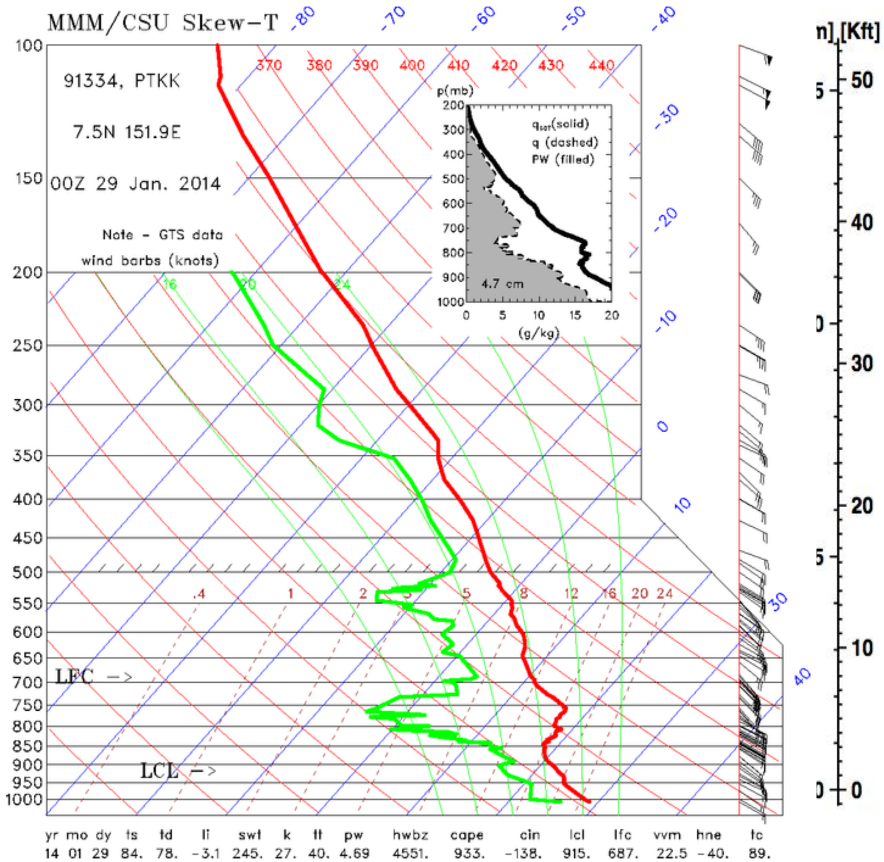
NWS Sounding



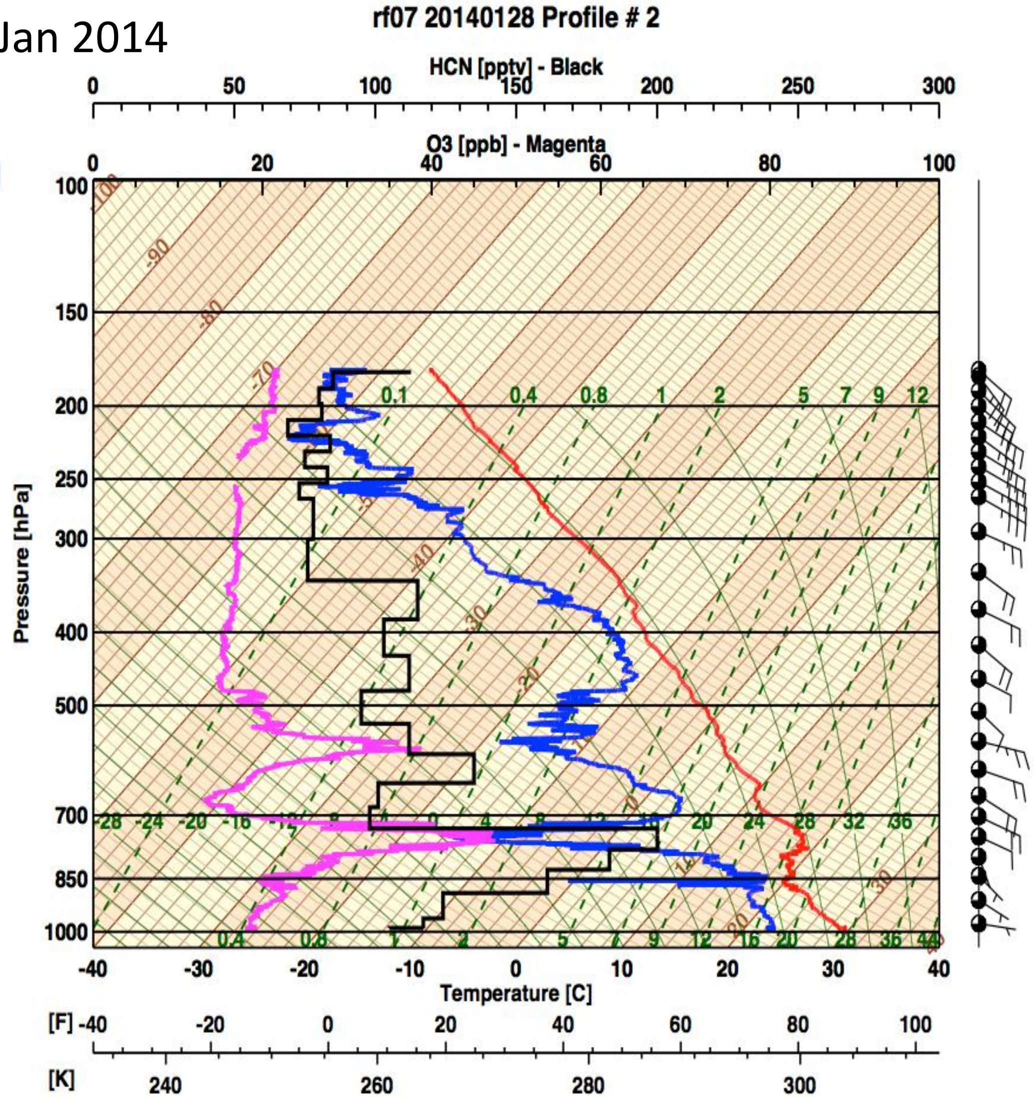
GV takeoff sounding

Courtesy Shawn Honomichl

RF07 29 Jan 2014

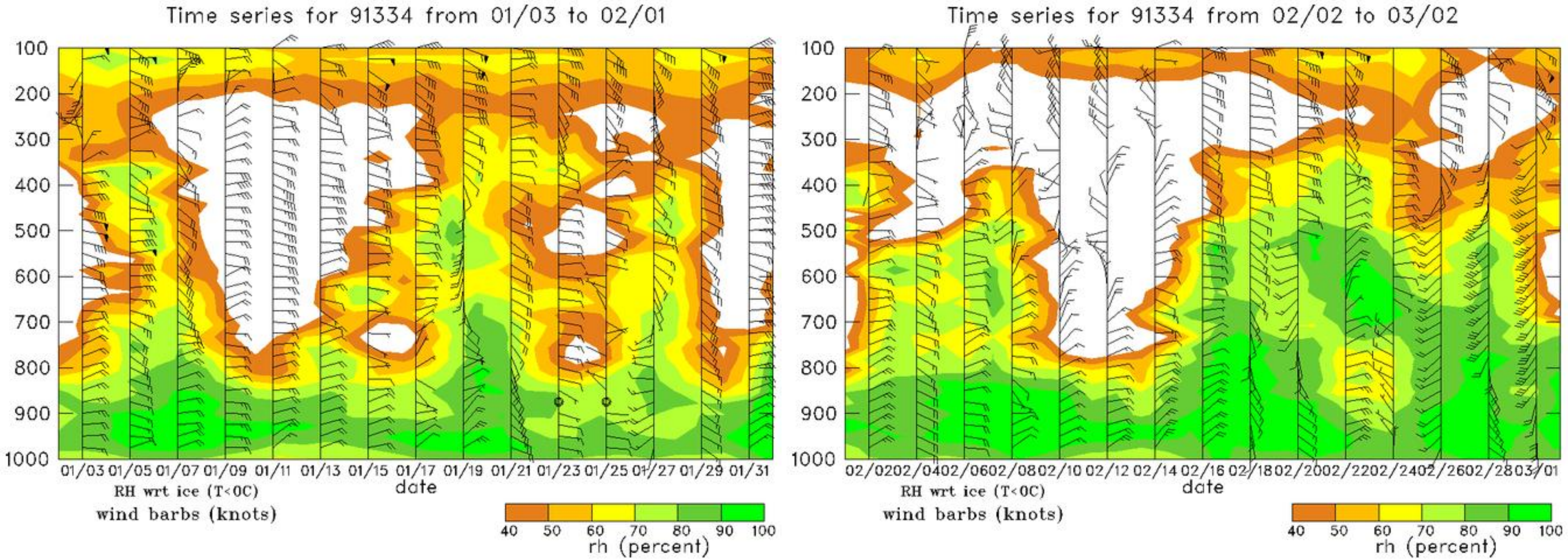


NWS Sounding



GV Chuuk sounding

Chuuk RH (7.5N, 151.9E)



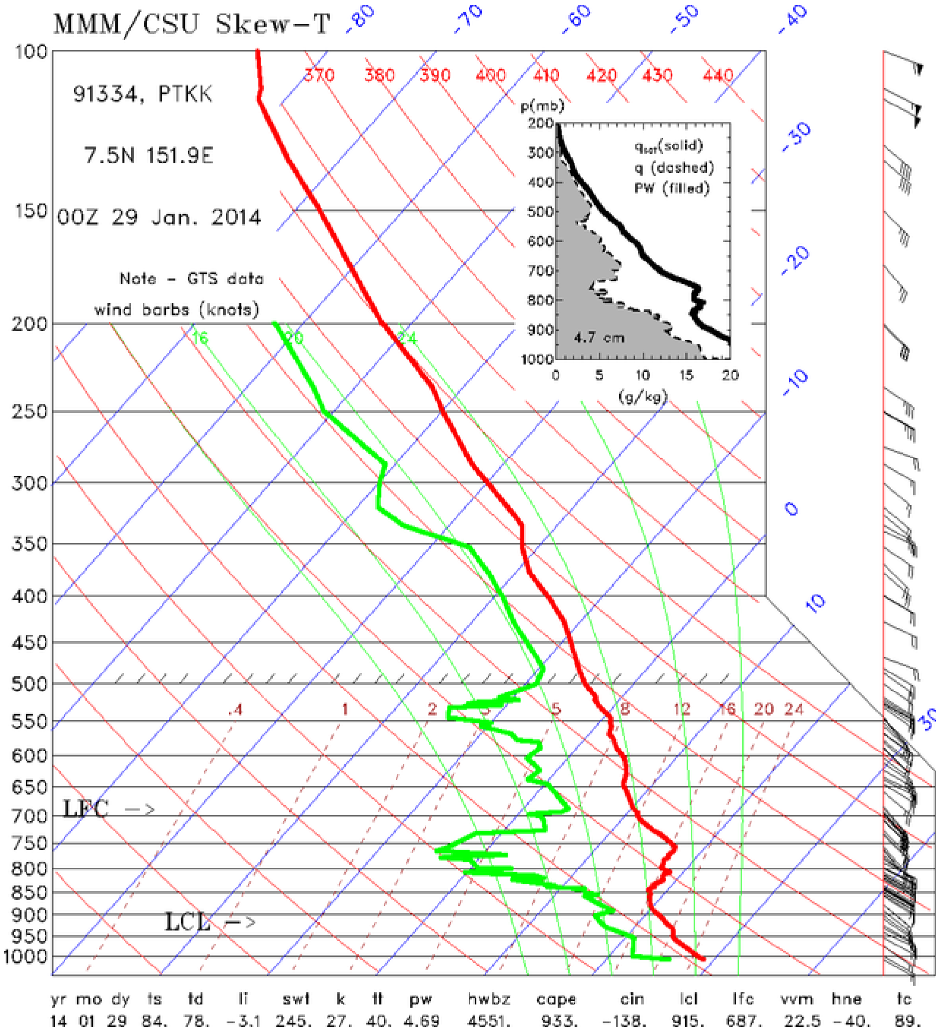
January

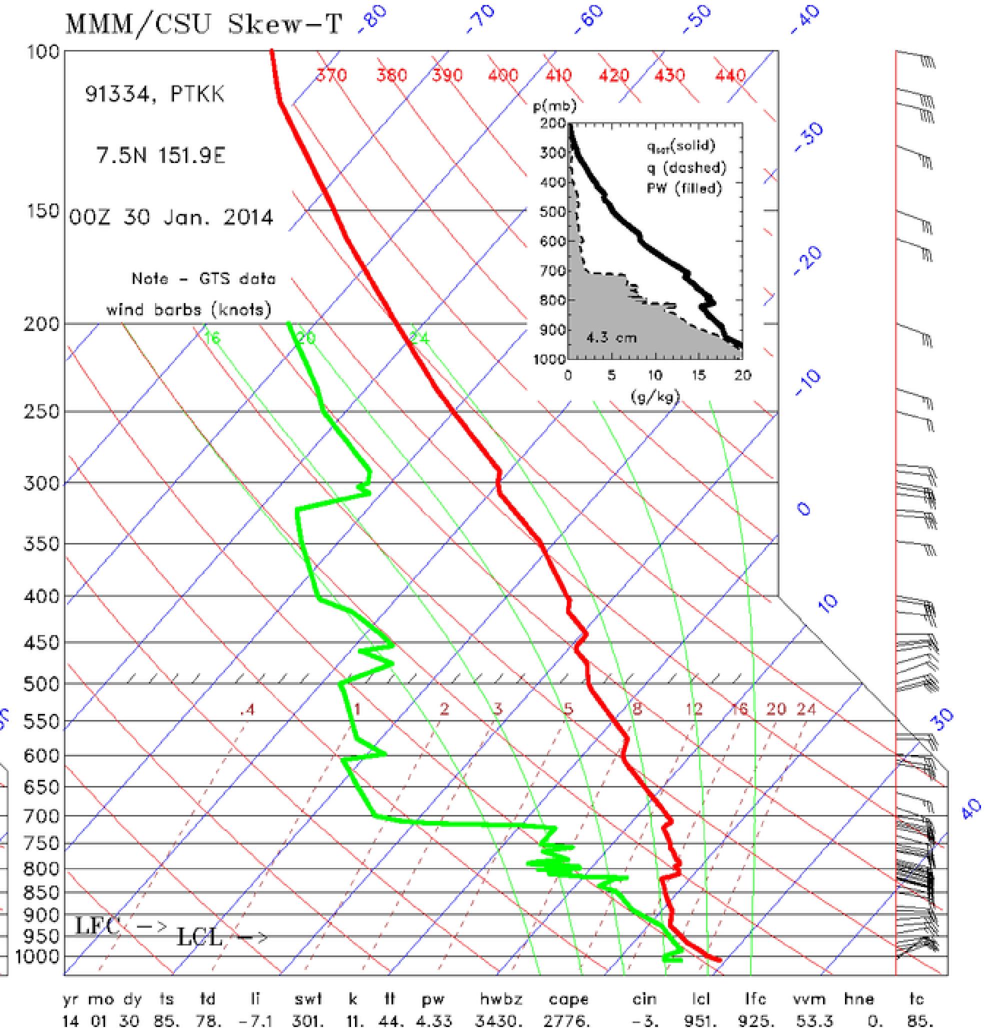
February

RF07

RF10

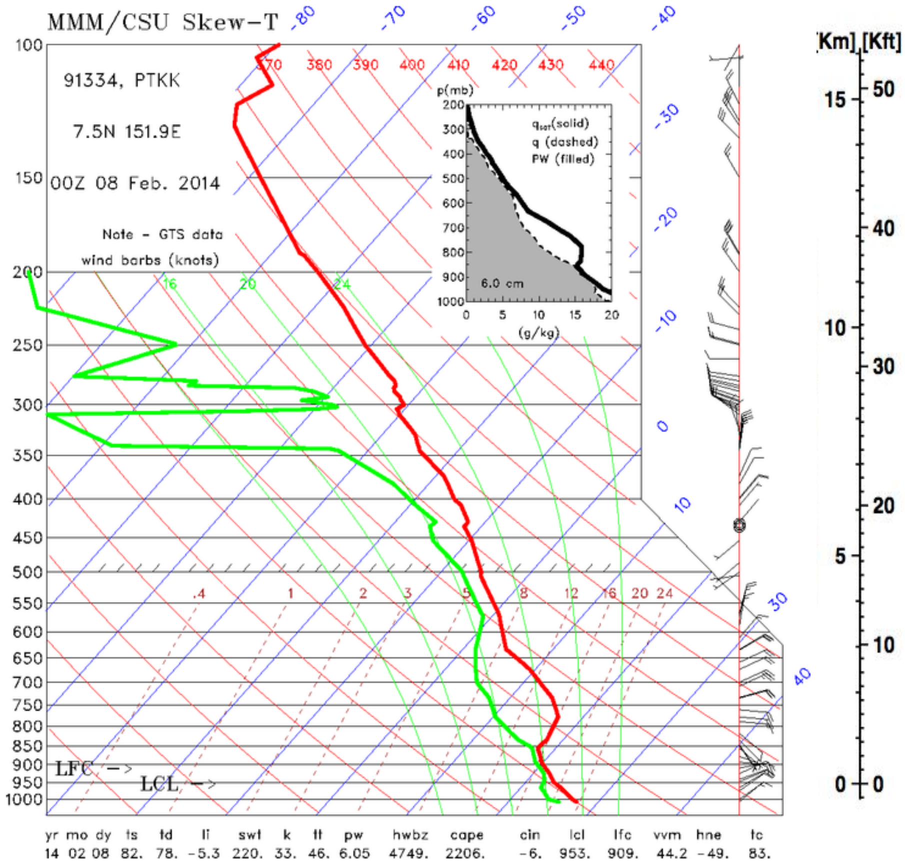
NWS Chuuk sounding

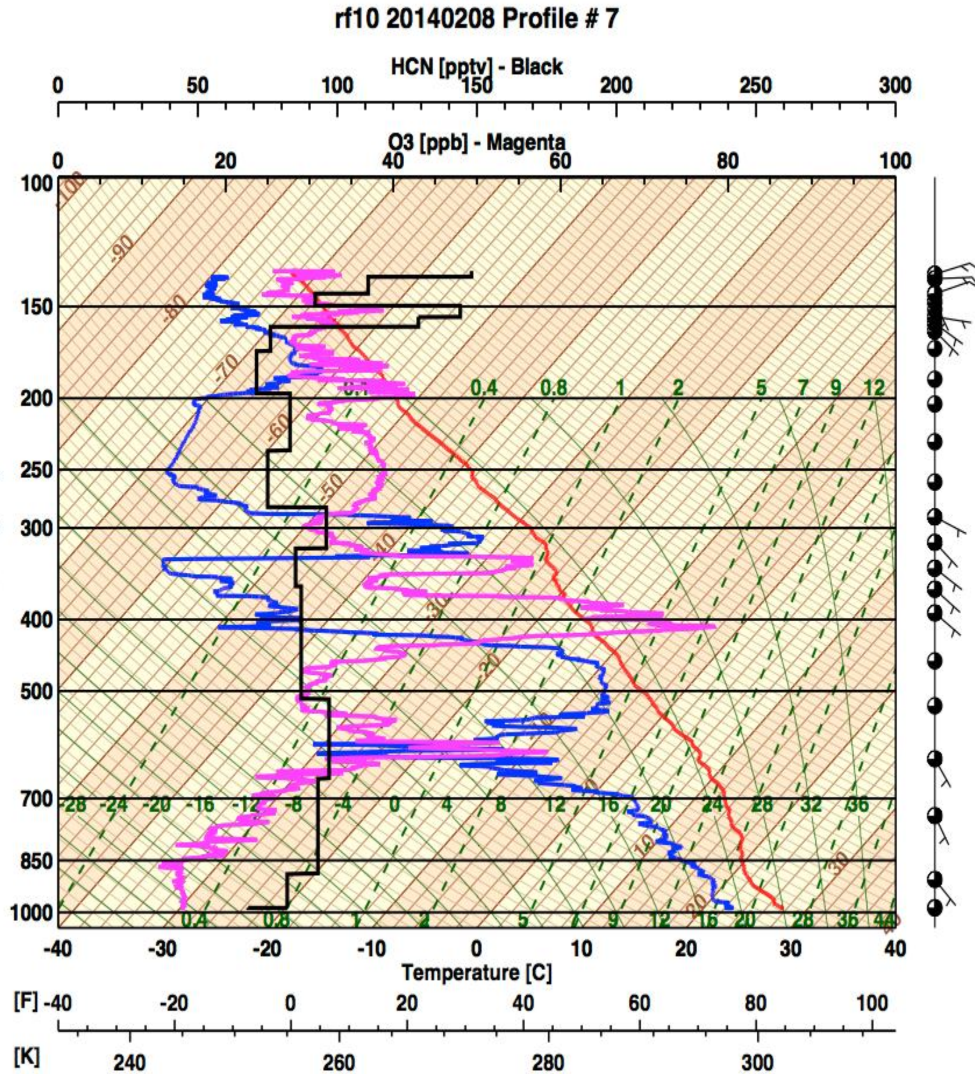




RF07 occurred just at the onset of a dry event at Chuuk

RF10 08 Feb 2014

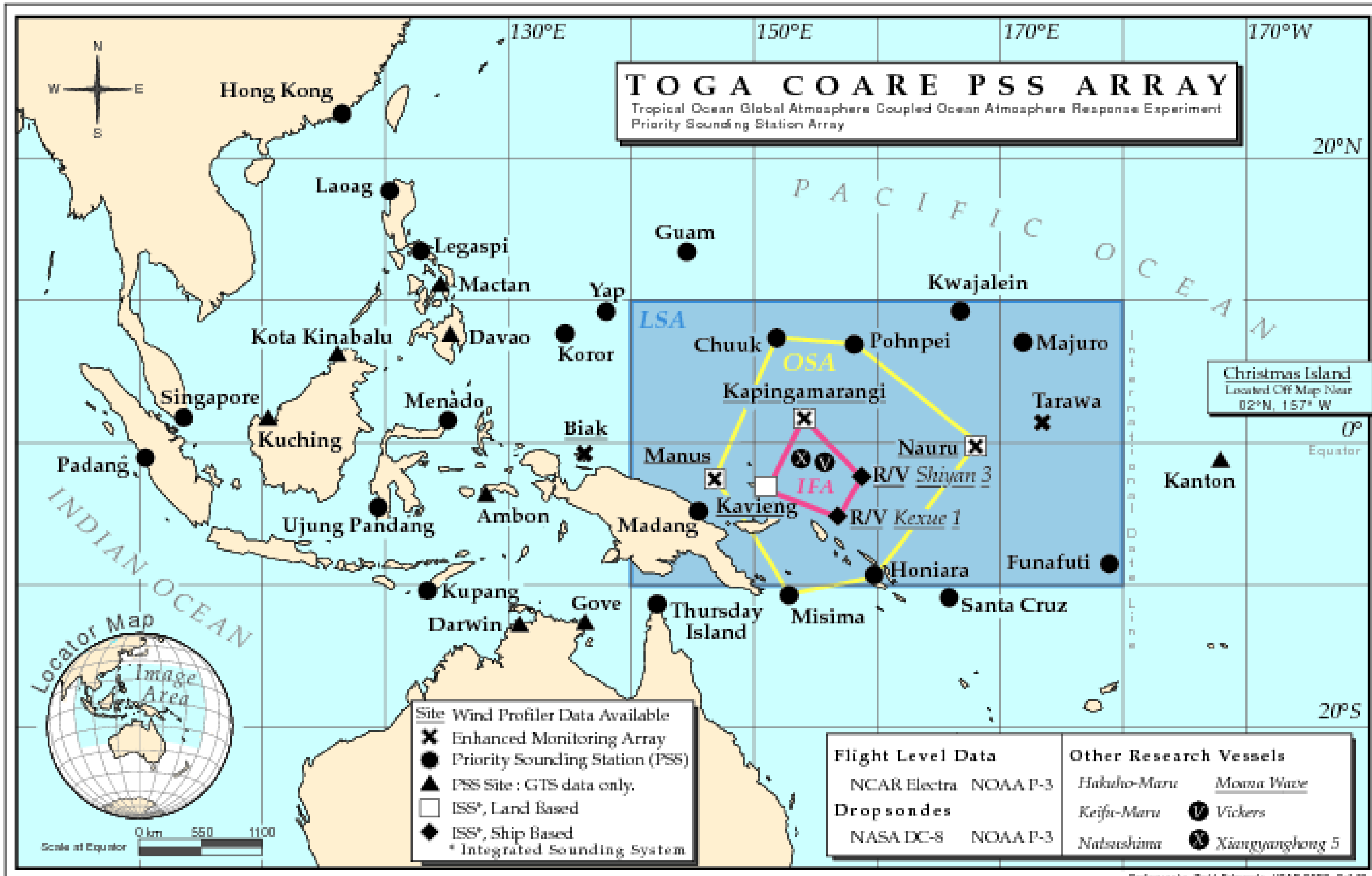




NWS Chuuk Sounding

GV sounding (about 7.5N, 148E)

400 km west of Chuuk



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20°N
0°
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PACIFIC OCEAN
INDIAN OCEAN
N
S
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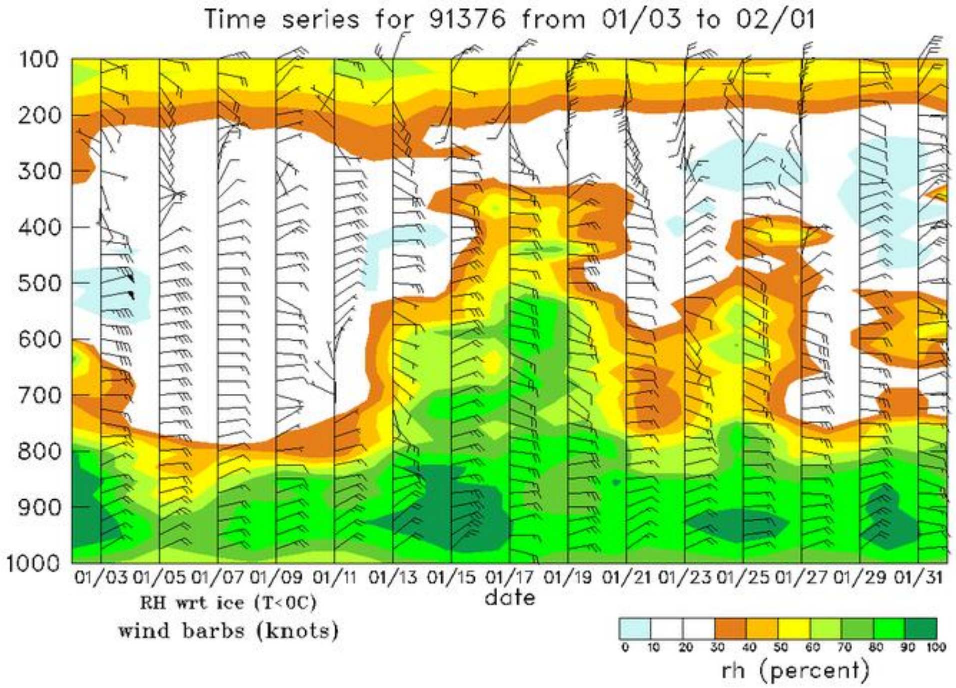
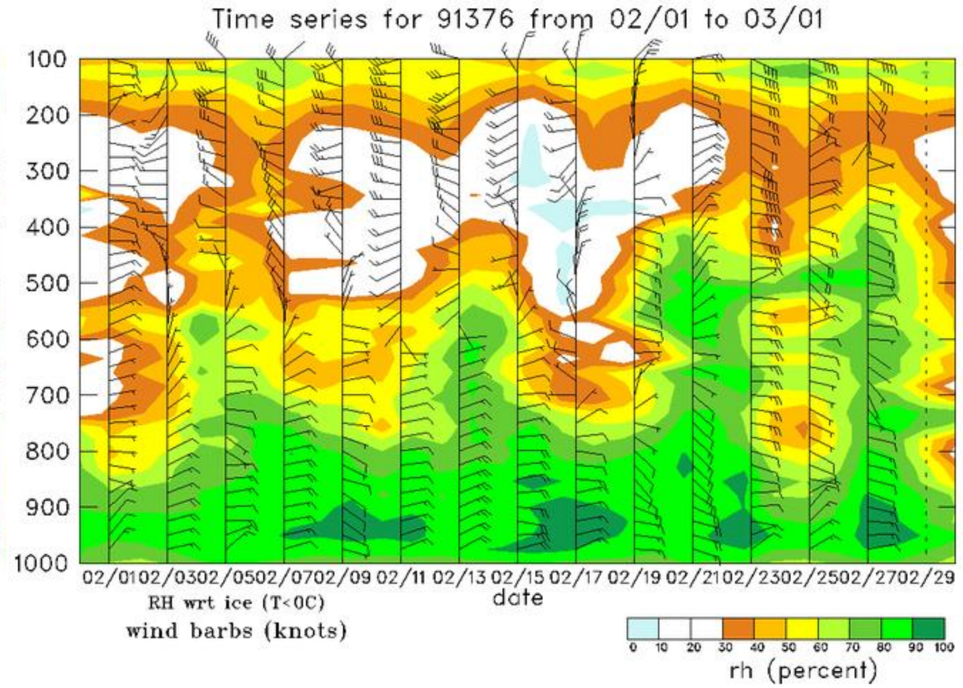
Hong Kong
Laoag
Legaspi
Mactan
Davao
Kota Kinabalu
Singapore
Kuching
Padang
Menado
Ujung Pandang
Ambon
Kupang
Darwin
Gove
Thursday Island
Yap
Koror
Guam
Biak
Manus
Kavieng
Madang
Misima
Honiara
Santa Cruz
Chuuk
Pohnpei
Kapingamarangi
Nauru
Kwajalein
Majuro
Tarawa
Funafuti
Kanton
LSA
OSA
IFA
R/V Shiyan 3
R/V Kexue 1
International Date Line
Christmas Island
Located Off Map Near
02°N, 157° W
Locator Map
Image Area
Scale at Equator
0 km
550
1100
Site Wind Profiler Data Available
Enhanced Monitoring Array
Priority Sounding Station (PSS)
PSS Site : GTS data only.
ISS*, Land Based
ISS*, Ship Based
* Integrated Sounding System
Flight Level Data
NCAR Electra
NOAA P-3
Dropsondes
NASA DC-8
NOAA P-3
Other Research Vessels
Hakuho-Maru
Moana Wave
Keifu-Maru
Vickers
Natsushima
Xiangyanghong 5

Majuro RH (7.1N, 171.4E)

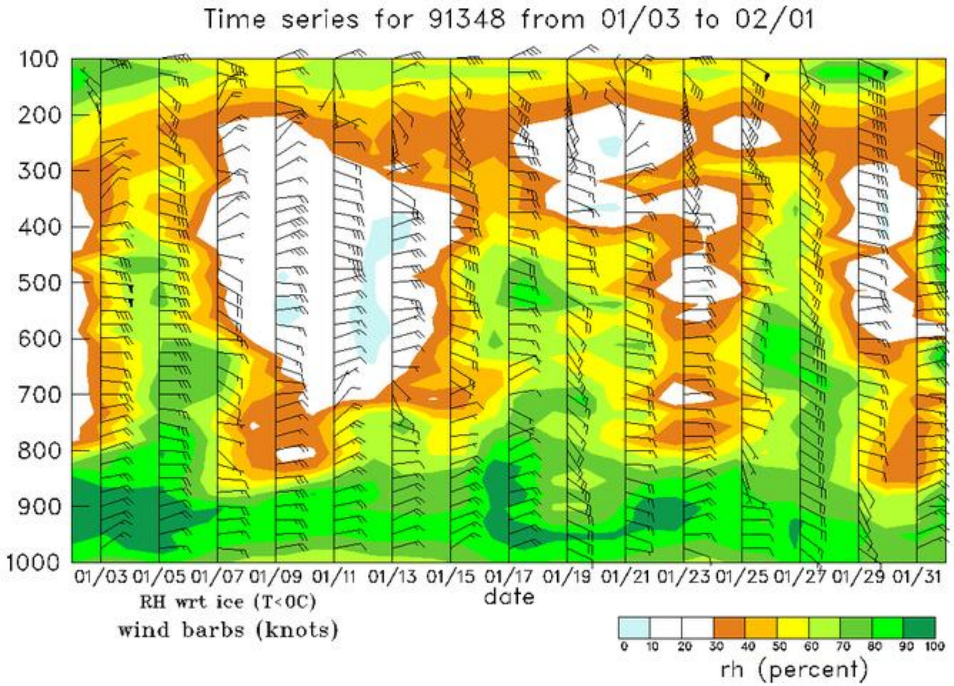


January

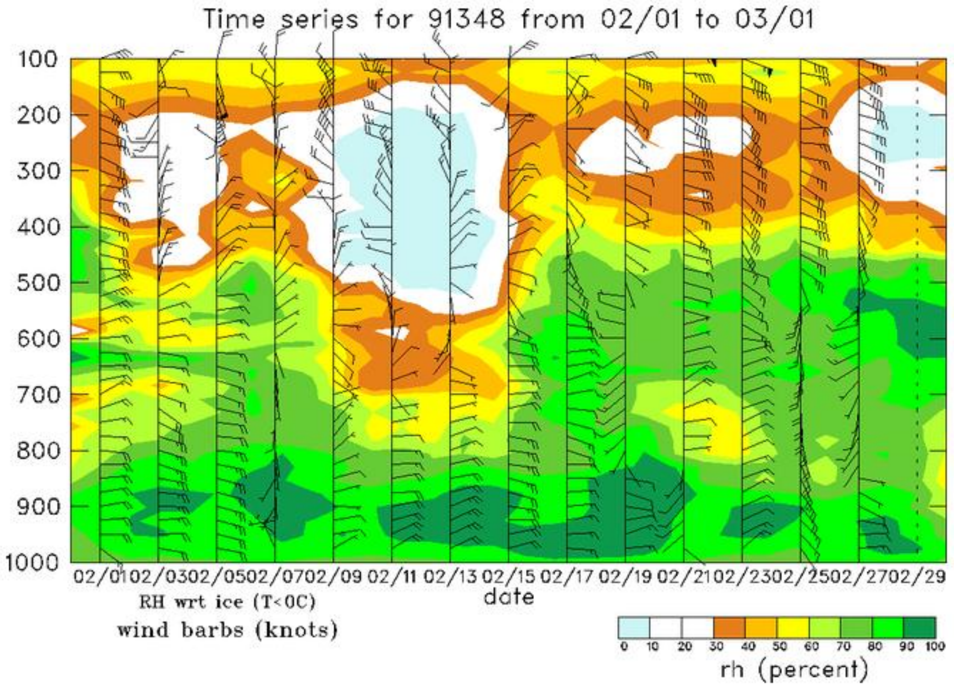


February

Pohnpei RH (7.0N, 158.2E)

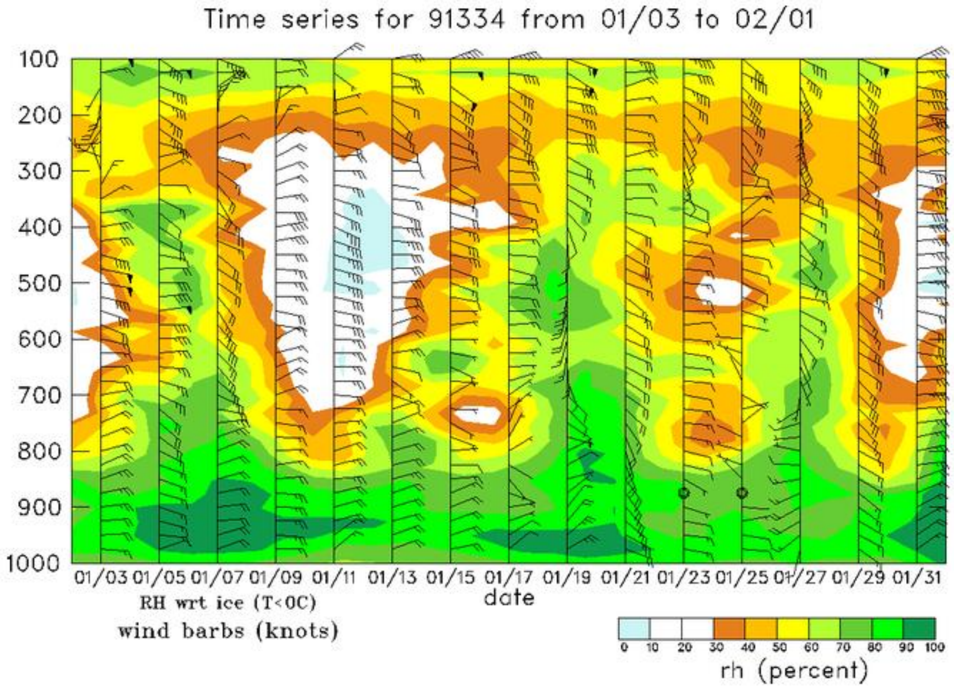


January

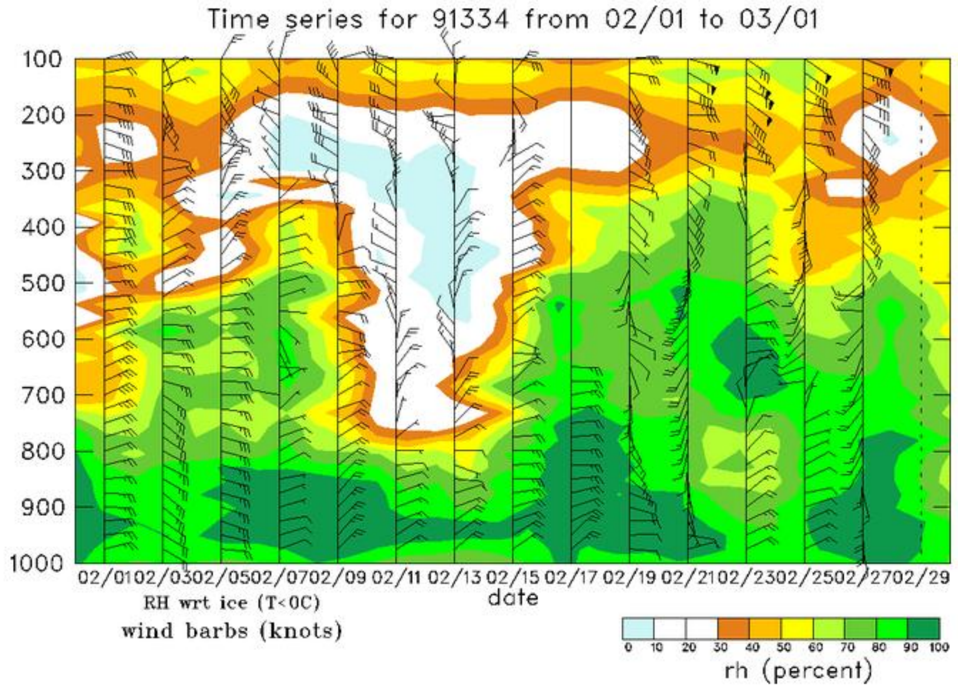


February

Chuuk RH (7.5N, 151.9E)

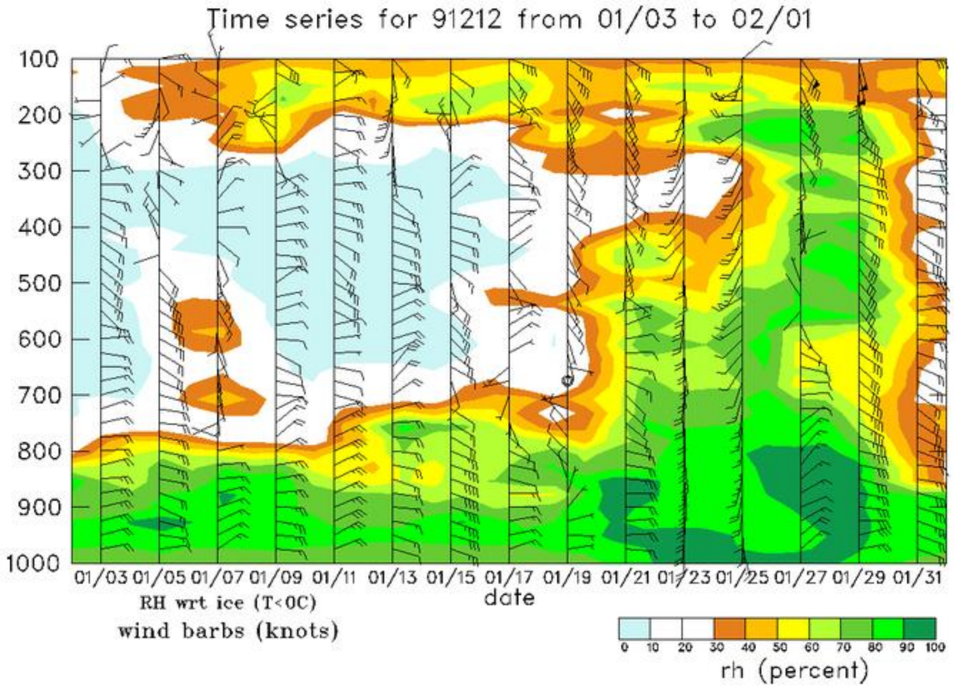


January

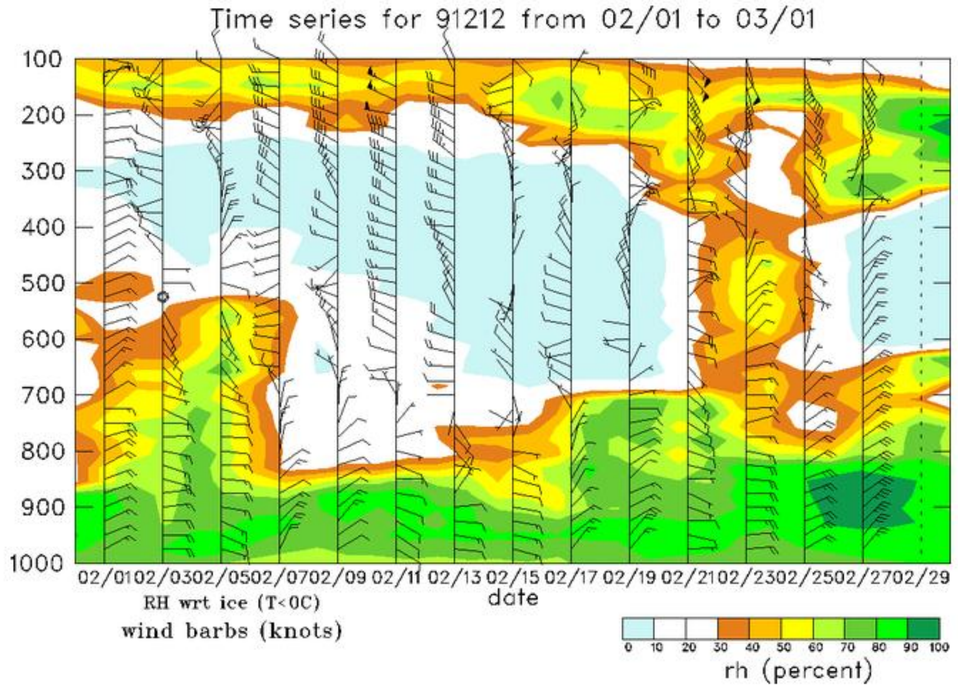


February

Guam RH (13.4N, 144.8E)

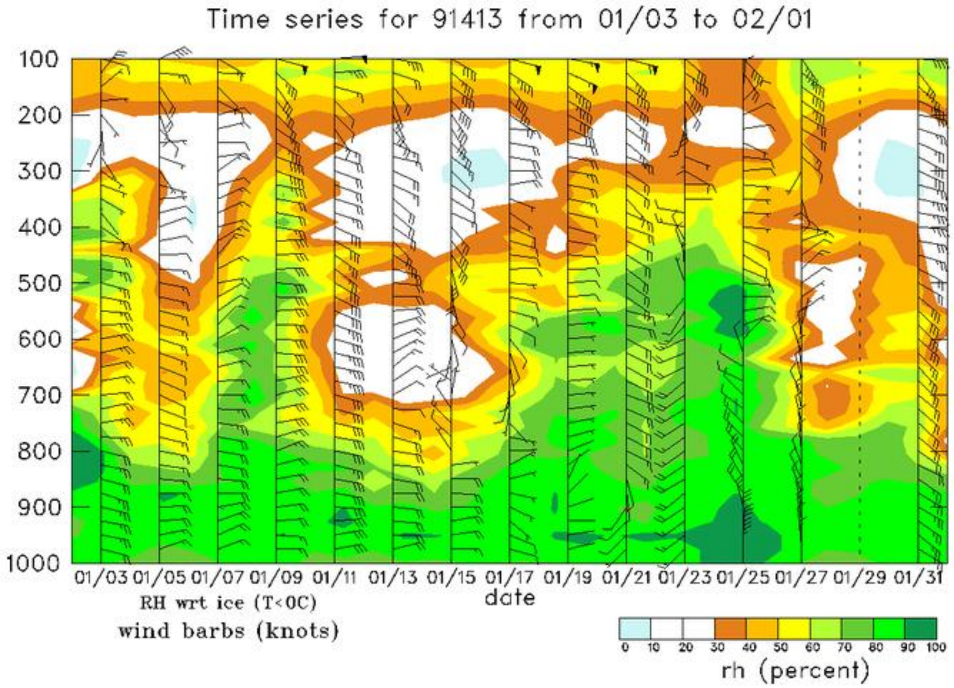


January

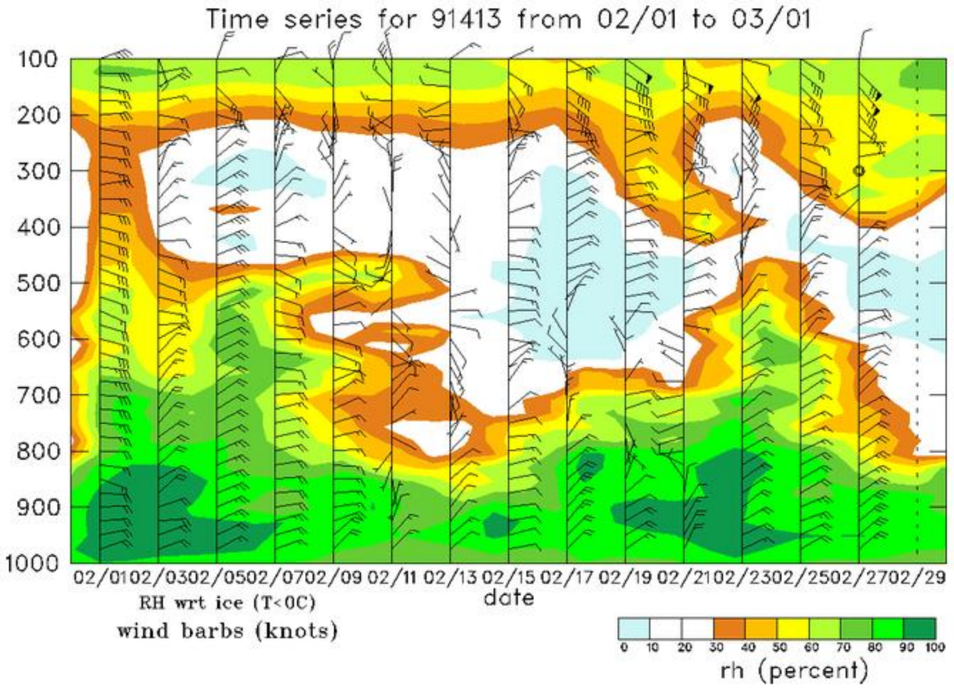


February

Yap RH (9.5N, 138.1E)

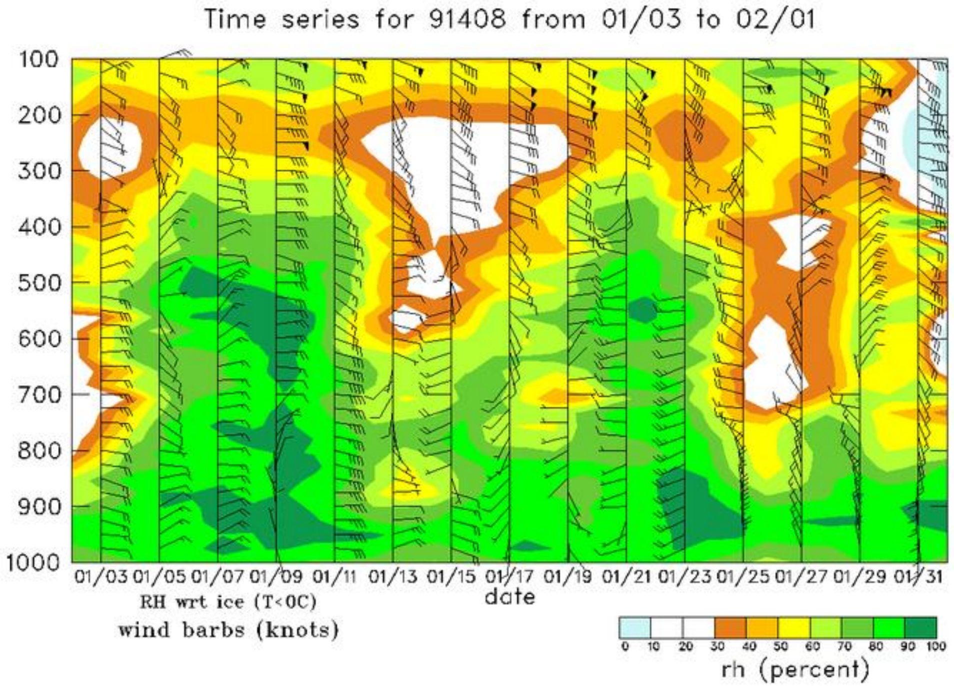


January

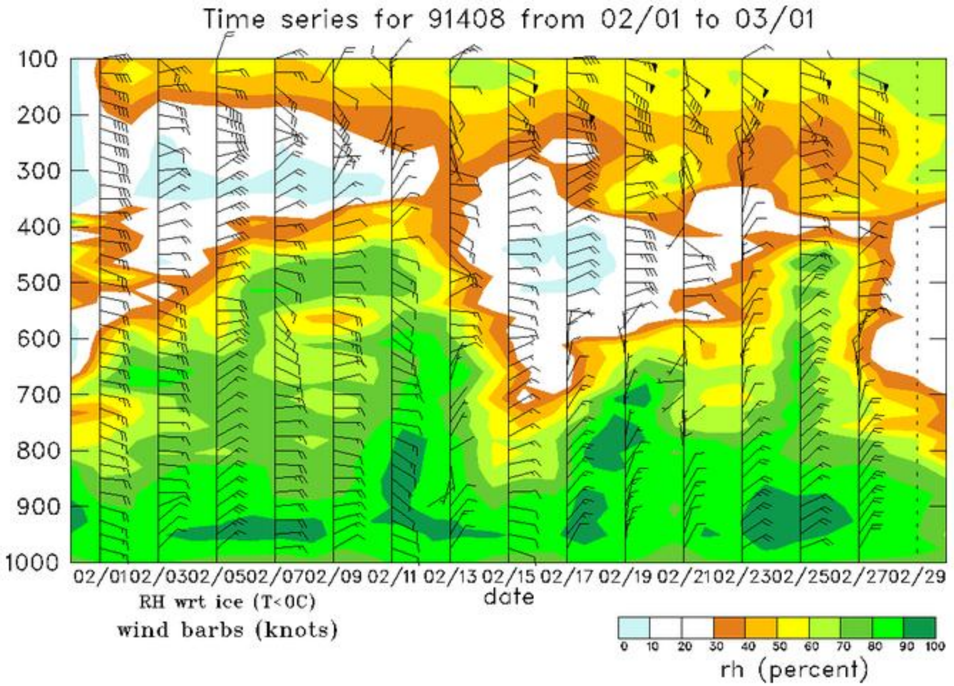


February

Koror RH (7.3N, 134.5E)

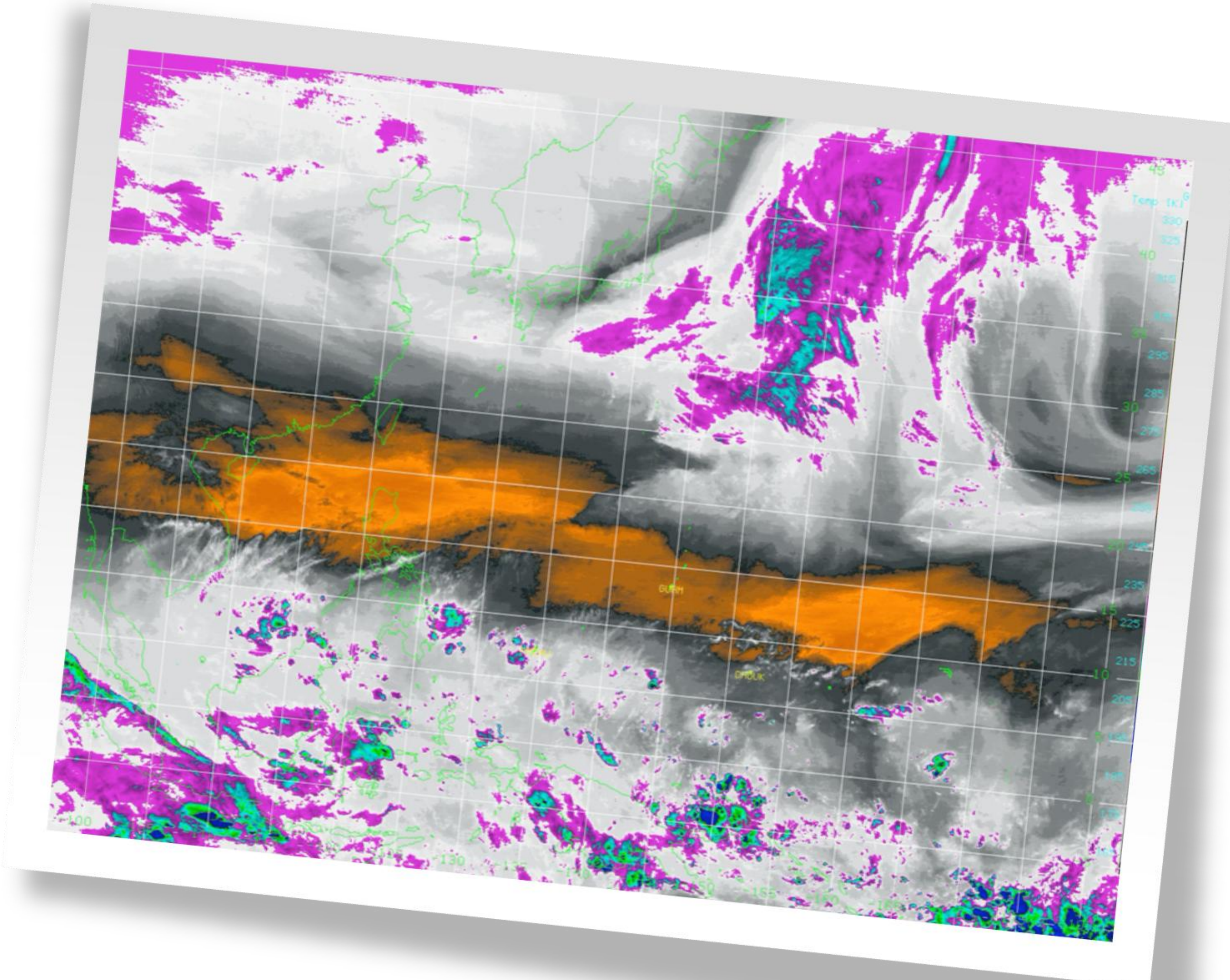


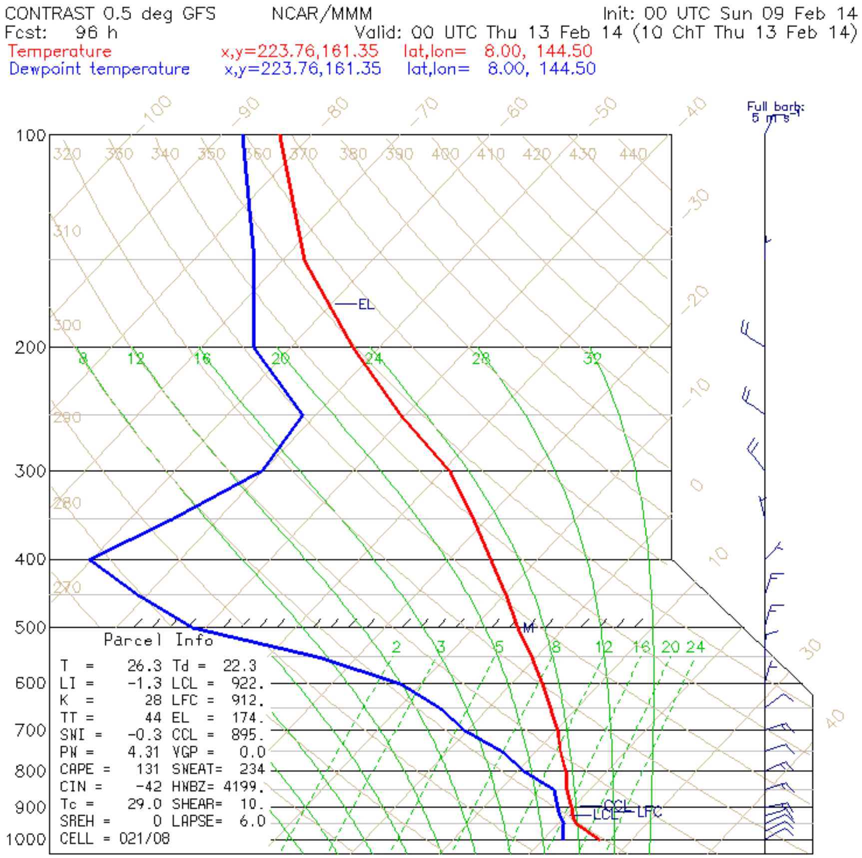
January



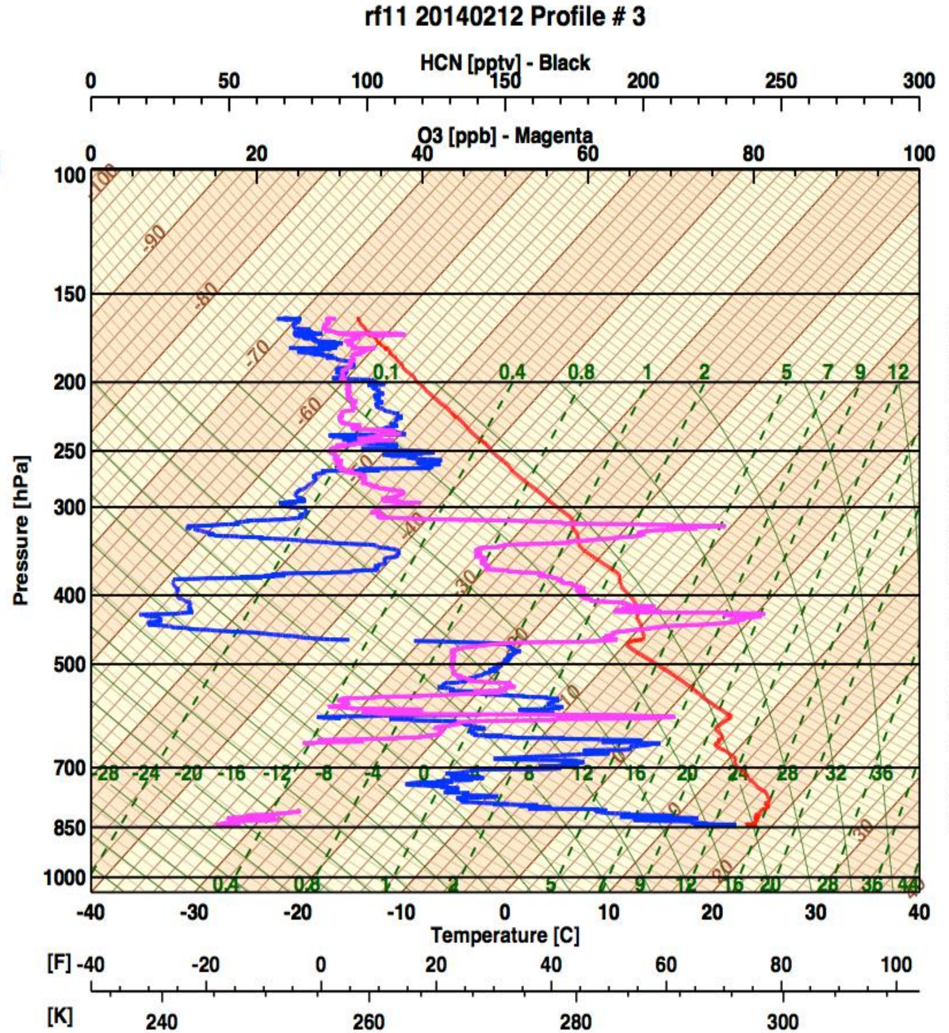
February

Water vapor loop from 9 Feb to 13 Feb





GFS analysis



The 27-pressure-level GFS (50-mb spacing) only captures the broad features of the moisture profile. It completely misses the thin layers and the shallow inversions. Perhaps the native resolution data captures these features.

Concluding thoughts

- Tropical dynamicists' consensus is that the low-latitude dry air comes from the subtropics.
- Convection preferentially detrains into stable layers such those associated with dry tongues (M&Z, Bretherton and Smolarkiewicz 1989).
- Perhaps the thin, dry layers are what remains of a thick dry layer that has had several day's worth of convection detraining into it.


Thank you!

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