Water Quality / Water Resources—Creative approaches to regional water resources…

Another Water Resource for Caribbean Countries: Water-from-Air

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Abstract

Regional droughts in the Caribbean are common. Water managers seeking solutions to water scarcity are often unfamiliar with the option of using water-from-air technology. Maps of the specific humidity composite mean for Junes and Decembers during the ten-year period 2004–2013 quantify the water-from-air resource demonstrating it is suitable for operation of water-from-air systems in Caribbean countries. Quantitative investigations by the author found droughts and long-term climate change do not appear to affect the magnitude of the Caribbean region's water-from-air resource. Case studies include one for a proposed water-from-air commercial greenhouse on Grand Turk. Another case is about the experience of commissioning a 2500 L/d water-from-air machine in Belize City. Lessons learned from the case studies are outlined.

Introduction

Caribbean countries have suffered droughts for decades. According to ECLAC (2007), regional droughts occurred in 1998, 2000, 2001, and 2005. Country-specific droughts mentioned by Trotman and others (2008) included: Grenada in 1984 and 1992, Trinidad in 1987, and Jamaica in 1996 through 2000. During 2010 a drought affected Antigua & Barbuda, Barbados, Dominica, Guyana, Saint Lucia, and Trinidad & Tobago (Antillean, 2010). ReliefWeb (2010) had a slightly different list, stating the 2010 drought affected Barbados, Grenada, Guyana, Saint Lucia, Saint Vincent & the Grenadines, and Trinidad & Tobago. The recent water stress ranking by country done by the World Resource Institute (Gassert and others, 2013) included seven Caribbean countries in the highest water risk category. These countries were: Antigua & Barbuda, Barbados, Dominica, Jamaica, Saint Lucia, Saint Vincent & the Grenadines, and Trinidad & Tobago.

Although each listing depends on different selections of criteria chosen by the various authors, it is clear that access to fresh water supplies is an ongoing problem for people living in the Caribbean region. Integrated water resources management (IWRM) plans are recommended for Caribbean countries by water managers (Trotman and others, 2008). Have all the available water resources in the region been considered? Water-from-air, obtained using mechanical dehumidification or desiccant technologies, is a water resource that remains unfamiliar to many water resources professionals. The purpose of this paper is to explore this resource in a scientific context by discussing:

- Research quantifying the water-from-air resource in the Caribbean region;
- Research quantifying the impact of droughts and climate change on the water-from-air resource available to Caribbean countries;
- Case studies from Turks & Caicos Islands and Belize; and
- Lessons learned about introducing water-from-air technology to these two Caribbean countries.

Caribbean water-from-air resource

The water-from-air resource for a site is quantified by its specific humidity [grams of water vapour per kg of moist air]. This is the resource that can be tapped by a *processor of atmospheric water vapour*. This term refers to machines (Figures 1 and 2) acting on the water vapour in the atmosphere to change (process) the water from its gas phase to its liquid phase. Although this is what a dehumidifier does, it is important to distinguish between conventional dehumidification with production of water regarded as waste and the purposeful production of clean treated water from water vapour, to be used usually for drinking water. Marketing terminology for the machines includes *water-from-air machines* and *atmospheric water generators*.

The maps (Figures 3 and 4) show the specific humidity in the Caribbean region for the Northern Hemisphere seasonal extremes of the summer solstice month (June; high sun) and the winter solstice month (December; low sun). The specific humidity field during June is characterized by a shallow regional gradient normal to the coastline of Central America. The field for December is different, with a steep gradient, normal to latitude, especially between northern Florida and Cuba. Specific humidity fields for other months are intermediate or transitional to the fields for June and December.

Figure 1: Residential water-from-air machine rated at 7 L/day (mechanical dehumidifier; prototype). Photo by author.

Figure 2: 2500 L/day water-from-air system (mechanical dehumidifier; commercial product) in Belize City. Photo by author.

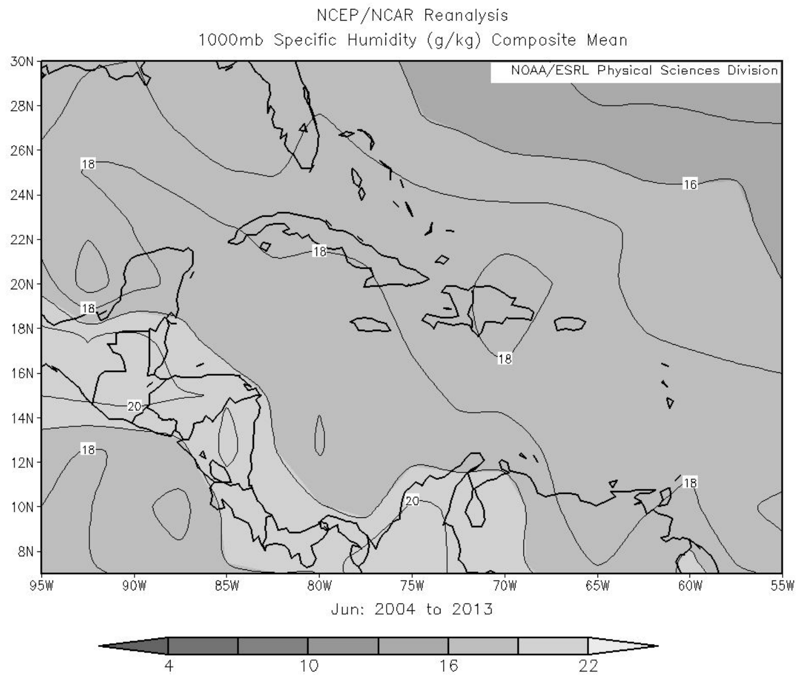


Figure 3: Caribbean water-from-air resource during June. The resource is represented by the composite mean specific humidity for the ten June months during 2004 to 2013. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

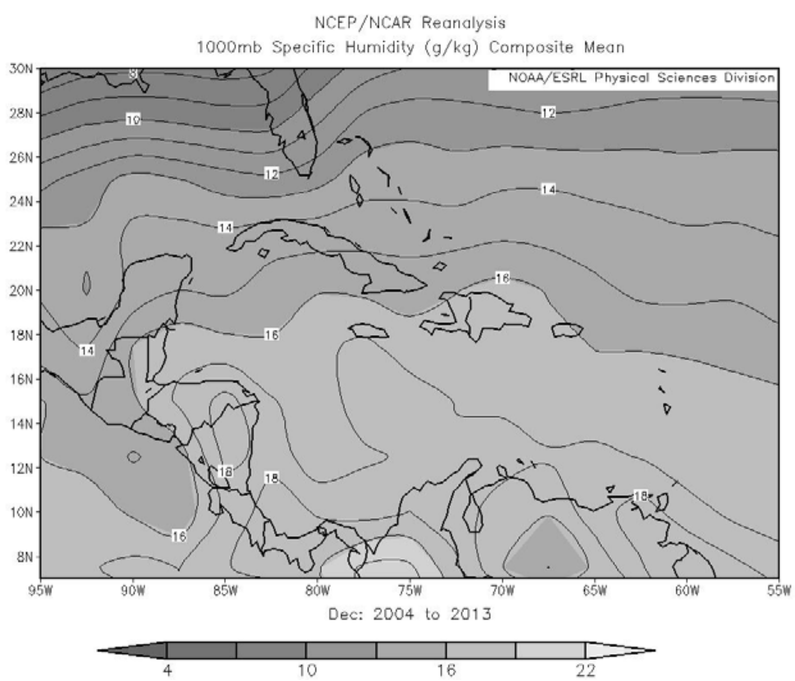


Figure 4: Caribbean water-from-air resource during December. The resource is represented by the composite mean specific humidity for the ten December months during 2004 to 2013. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

A widely accepted industry standard for rating the performance of dehumidification equipment (and water-from-air systems) is the volume of water produced when the entering air conditions are: 1013.241 mb pressure, 26.7°C temperature, and 60% relative humidity. At these conditions the specific humidity is approximately 13 g/kg.

Looking at the maps (Figures 3 and 4) of the specific humidity fields for June and December, values equal or exceed 13 g/kg everywhere in high sun and low sun seasons with the exception of the northern Bahamas in December. The practical result is water-from-air systems will produce water at their specified rate year-round in Caribbean countries. The water production rate is constrained by the refrigeration capacity of the equipment so operation at a site experiencing say, specific humidity of 18 g/kg, will not necessarily enable the machine to produce water at a rate much exceeding its rated output in an atmosphere with a water vapour concentration of 13 g/kg.

Some water-from-air system manufacturers rate their equipment for warmer and more humid conditions, for example, 29.4°C, 70% relative humidity. The corresponding water vapour concentration is a specific humidity of 17 g/kg. The specific humidity field maps would have to be interpreted accordingly when deciding to deploy machines to sites.

Drought and the water-from-air resource

Does drought affect the water-from-air resource? This possibility was investigated using the Monthly/Seasonal Climate Composites application provided by the U.S Department of Commerce National Oceanic and Atmospheric Administration at http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl. The drought years mentioned in the Introduction to this paper were checked by producing regional maps (Figures 5 and 6) for the 1000 mb specific humidity composite mean for June of the drought year. These maps showed the net result of subtracting the specific humidity composite mean for the climate normal time period (1981–2010). June represents the seasonal extreme of the summer solstice when drought is likely to be most pronounced.

The result for the 1984 drought (Figure 5) showed the water vapour resource decreased slightly with the diminishment ranging from 0 to -1.8 g/kg. The maximum decrease occurred in southern Florida where the June specific humidity composite mean in Figure 3 was 17 g/kg. The maximum decrease was about 11%. The 2000, 2001, and 2009 droughts (maps not shown here) showed a similar pattern. As noted earlier, many water-from-air systems have water production ratings based on the air having a specific humidity of 13 g/kg so this magnitude of drought-related decrease in the water-from-air resource is not of great concern.

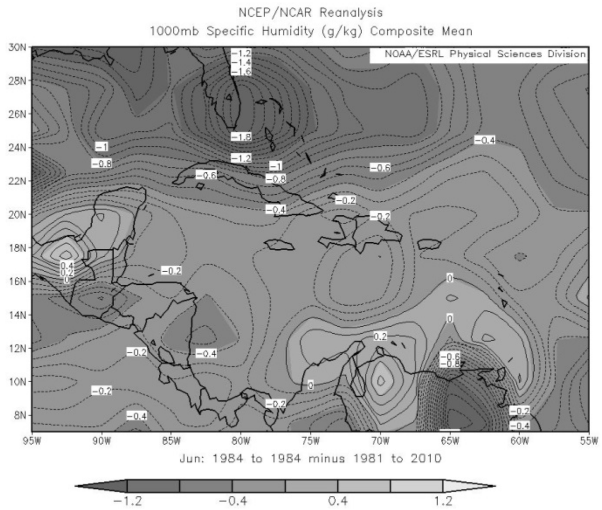


Figure 5: Net specific humidity when the climate normal mean was subtracted from the June 1984 drought month mean. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

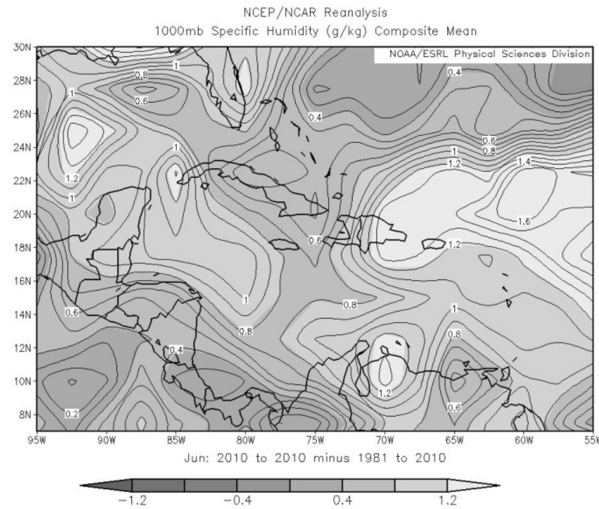


Figure 6: Net specific humidity when the climate normal mean was subtracted from the June 2010 drought month mean. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

The other drought years showed a regional slight increase of the water vapour resource ranging from 0.4 to +1.2 g/kg. In the air surrounding Haiti in June, the added moisture in the air would represent an increase of 1.2 g/kg to a mean value of 18 g/kg, or 7%. Most water-from-air systems, with their water production rating constrained by their designed refrigeration capacity would be unable to exploit this increase. June 2010 was typical of drought years showing an increase in the water-from-air resource (Figure 6).

It is reasonable to conclude that droughts are not affecting the viability of using the water-from-air resource as another water source for Caribbean countries.

<u>Climate change and the water-from-air resource</u>

The possibility that climate change affects the water-from-air resource was checked by comparing the specific humidity composite mean fields between the recent ten-year period 2004–2013 with the half-century ago ten year period 1948–1957. The results for June and December are in Figures 7 and 8 respectively.

The field for June shows an overall slight increase in water vapour concentration in the atmosphere as would be expected with the observed rise in mean temperatures in many regions in this era of global climate change.

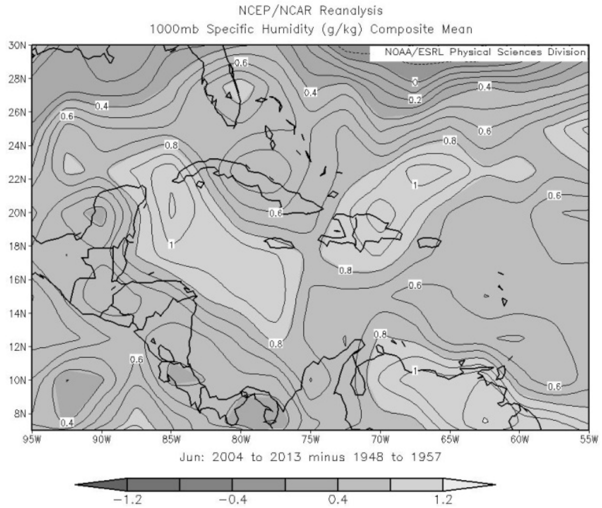


Figure 7: Net specific humidity composite mean field for June when the field for 1948–1957 was subtracted from the field for 2004–2013. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

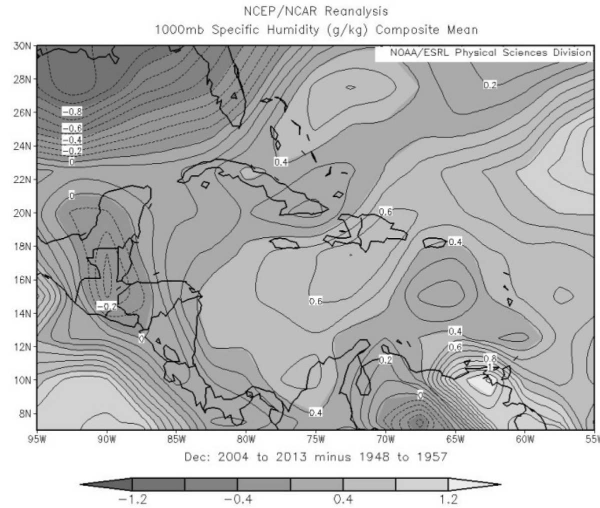


Figure 8: Net specific humidity composite mean field for December when the field for 1948–1957 was subtracted from the field for 2004–2013. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

December's net specific humidity composite mean field is a more complex mixture of slightly negative and positive values.

A reasonable conclusion is that climate change is not affecting to any great degree the availability of the water-from-air resource in Caribbean countries.

Case Study—Grand Turk, Turks and Caicos Islands

In 2003, the people living on the island of Grand Turk, TCI were importing 100% of their food and had inadequate, unreliable fresh water supplies (Wahlgren, 2003). Could water-from-air technology provide a solution?

I participated in answering this question during 2001–2003 when I was the scientific/technical consultant to a Canadian International Development Agency (CIDA)-supported project which confirmed through modeling the technical feasibility and financial and commercial viability of a water-from-air greenhouse (Figure 9) on the island.

A monthly model of the WaterProducer-Greenhouse™ system water production is shown in Figure 10. Although the first installation remains to be built, the modeling results for this chilled coil (deep saline groundwater coolant) are instructive.

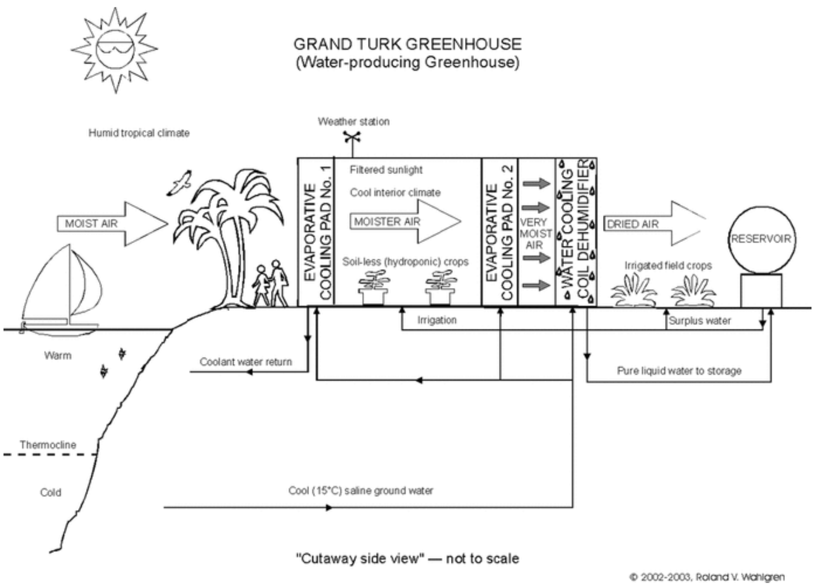


Figure 9: WaterProducer-Greenhouse™ conceptual drawing. Twenty-seven exhaust fans force outdoor air at 1.52 m/s (300 ft per minute) through a 3,500 m^2 (0.87 acre) greenhouse. There is one air change every minute. Small carbonate islands often have a reverse geothermal gradient. Cool (15°C; 59°F), salty (36 ‰) groundwater, from four wells 400–500 m (1,300–1,650 ft) deep, is pumped through 27 water-cooled coils. Total flow is 256 L/s (4,050 US gal per minute) The aluminum-finned copper-nickel coils (total face area 2,700 ft^2) are colder than dew-point. Airflow moisture (11–28 g/m^3) turns into pure fresh water droplets collected in a reservoir for crop irrigation and water bottling. The diagram is by the author.

Climate, Refrigeration Load, and Water Production Model—**WaterProducer-Greenhouse™ System**

Grand Turk, Turks and Caicos Islands

Elevation*: 2 metres above sea level; Lat: 21° 26' N

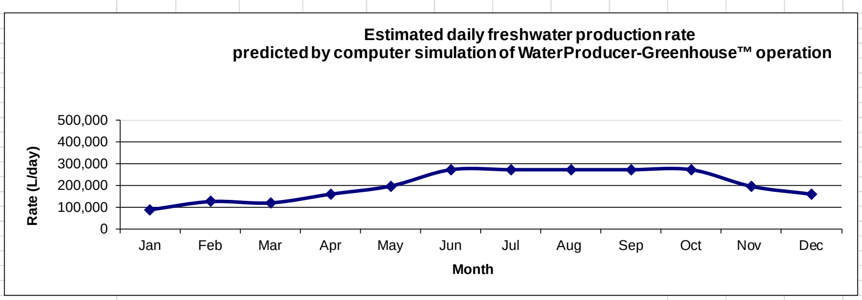
Standard atmosphere: 1.013 bar; Long: 71° 08' W

Delta T is adjusted to simulate natural coolant constant temperature
Delta T = air temperature - leaving air (coolant) temperature
Model Input value

MaximizeWater Production

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Calibration
Airflow, cfm	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000
Airflow, m^3/s	382	382	382	382	382	382	382	382	382	382	382	382	382
Temperature*, db, °C	24	24	25	25	27	28	28	28	28	28	26	25	27
Relative Humidity, RH, %	69%	74%	69%	74%	70%	74%	74%	74%	74%	74%	74%	74%	60%
Wet bulb, wb, °C	19.9	20.6	20.8	21.5	22.8	24.3	24.3	24.3	24.3	24.3	22.5	21.5	20.9
Air pressure, bar	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
Delta T (°C) - adjusted for leaving air (coolant) temp = 15°C	9.0	9.0	10.0	10.0	12.0	13.0	13.0	13.0	13.0	13.0	11.0	10.0	11.7
Leaving air (coolant) temp, db, °C	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Leaving RH, % - conservative setting	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dew-point*, t_4, °C, of entering air	18.0	19.1	18.9	20.0	21.1	22.9	22.9	22.9	22.9	22.9	21.0	20.0	18.3
Total cooling capacity, Tons	1,920	2,228	2,308	2,634	3,194	3,938	3,938	3,938	3,938	3,938	3,054	2,634	2,348
water vapor density, g/m^3	15.1	16.2	16.0	17.1	18.1	20.2	20.2	20.2	20.2	20.2	18.1	17.1	15.3
Estimated water production, Litres/day	**89,121**	**126,807**	**120,793**	**160,776**	**197,931**	**273,255**	**273,255**	**273,255**	**273,255**	**273,255**	**196,453**	**160,776**	**99,164**

* Climate data and altitude input to model (various sources, believed to be accurate)



Disclaimer: Operational factors beyond our control may cause actual water-from-air production to be different from model results.

Figure 10: Monthly model of freshwater production from the WaterProducer-Greenhouse™ for a proposed operation on Grand Turk. The average estimated water production was 201,578 L/day. The model is by the author.

At latitude 21°N, seasonal variations are apparent in the water vapour density (the water resource) and therefore daily water production. Production is highest during the high sun season and lowest during the low sun season. Reservoirs are needed to store water to, in effect, even out the flow for a steady consumption rate.

<u>Case Study—Belize City</u>

In January 2006 I commissioned two 2500 L/day water-from-air machines my client had shipped to a business in Belize City. The monthly model results are in Figure 11.

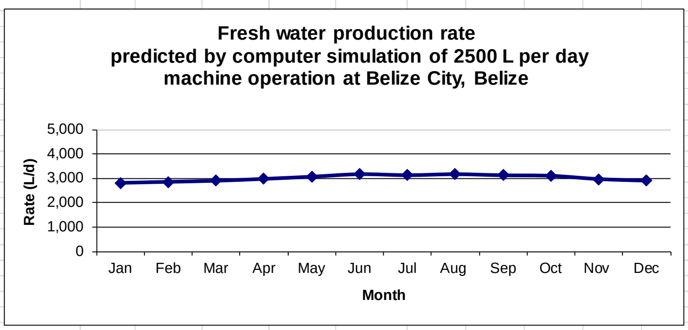
Climate, Refrigeration Load, and Water Production Model—2500 L per day machine

Belize City, Belize

Controller setpoint used to adjust Delta T.

Elevation...	4	metres above sea level	Lat:	17° 32' N	Model Input value
Standard atmosphere...........................	1.013	bar	Long:	88° 18' W	Climate data from *www.weatherbase.com*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Airflow, cfm	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Airflow, m^3/s	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Temperature*, db, °C	**23**	**24**	**26**	**27**	**28**	**28**	**28**	**28**	**27**	**26**	**25**	**24**
Relative Humidity, %	**84%**	**83%**	**81%**	**80%**	**80%**	**84%**	**84%**	**84%**	**86%**	**86%**	**85%**	**85%**
Wet bulb, wb, °C	21.0	21.8	23.4	24.2	25.2	25.8	25.7	25.8	25.0	24.2	23.1	22.1
Air pressure, bar	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
Delta T (°C) - adjusted for ≤ 40 Tons and leaving air temp ≥ 5°C	15.5	15.0	14.5	14.5	14.0	13.0	13.0	13.0	13.0	13.5	14.0	14.5
Leaving air temp, db, °C	7.5	9.0	11.5	12.5	14.0	15.0	15.0	15.0	14.0	12.5	11.0	9.5
Leaving RH, % - conservative setting	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Req'd Total capacity, Tons	39.9	39.6	39.2	39.8	39.9	39.6	39.3	39.6	39.3	39.8	39.3	39.4
Total capacity, kW	140	139	138	140	140	139	138	139	138	140	138	139
Sensible capacity, kW	60	58	56	56	54	50	50	50	50	52	54	56
Difference: Latent capacity, kW	80	81	82	84	87	90	88	90	88	88	84	82
Expected water prod'n, L/d	**2,813**	**2,855**	**2,900**	**2,976**	**3,066**	**3,168**	**3,128**	**3,168**	**3,124**	**3,103**	**2,969**	**2,901**
Efficiency of water recovery from air	58%	56%	52%	51%	49%	49%	48%	49%	50%	52%	53%	55%



Energy cost of water — **Average** **0.36 kWh/L** (based on operation all year)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Voltage (V), 3 phase	460	460	460	460	460	460	460	460	460	460	460	460
Average current (A)	70	70	70	70	70	70	70	70	70	70	70	70
Power (W)	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565
Time (hours)	24	24	24	24	24	24	24	24	24	24	24	24
Energy (kWh)	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
Energy cost of water (kWh/L)	**0.38**	**0.37**	**0.37**	**0.36**	**0.35**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.36**	**0.37**

Figure 11: Results of author’s computer simulation of 2500 L/day water-from-air operation in Belize City.

Belize City is 17 degrees latitude north of the equator. Seasonal influence on water production was not as pronounced as in Grand Turk because performance was constrained by refrigeration capacity. Energy cost of the produced water was about as good as it can be with mechanical dehumidification—0.34 to 0.38 kWh per litre. The model represents a machine that is perfectly designed and adjusted. The model does not reference details of cooling coil materials, dimensions, or coil arrangement.

It is interesting to look at the actual data-logged observations (Figure 12) from the commissioning of a 2500 L/day machine in Belize City. The machine responded continually to fluctuations of entering air pressure, temperature, and water vapour density. It is apparent the model results for January–February and observations during late January–early February have similar values for water production rate and the energy cost of the water. So, the model can be relied on for guidance in planning deployment of machines in a region.

s/n 0001

				Entering Air			Discharge		Leaving Air		Daily Equiv.	Energy
Record Number	Date	Time Start	Time End	Temp °C	RH %	Airflow CFM	Air Setting °F	Coil temp °C	Temp °C	RH %	Production L/d	Cost kWh/L
1	26-Jan-06	13:34:00	13:46:50	26.9	75	5085	41.0	not recorded	not recorded		2244	not recorded
2	26-Jan-06	14:38:30	14:50:45	27.4	77	5085	45.0	4.1	14.8	87	2351	not recorded
3	26-Jan-06	15:15:10	15:30:20	24.2	98	5085	50.0	8.9	12.3	99	1899	not recorded
4	27-Jan-06	10:46:00	10:58:35	26.0	81	7337	47.5	not recorded	not recorded	not recorded	2289	not recorded
5	27-Jan-06	11:04:00	11:15:18	26.2	81	7337	47.5	9.9	12.2	99	2549	not recorded
6	27-Jan-06	11:50:00	12:00:45	26.7	80	7337	47.5	10.0	12.7	99	2679	0.35
7	27-Jan-06	12:15:00	12:26:30	27.3	73	7337	47.5	10.7	13.1	99	2504	0.40
8	30-Jan-06	11:09:00	11:19:36	32.6	50	7337	47.5	12.6	13.4	99	2717	0.40
9	30-Jan-06	11:25:00	11:35:50	31.9	58	7337	47.5	12.0	13.1	99	2658	0.35
10	30-Jan-06	11:39:00	11:50:00	32.4	52	7337	47.5	12.6	13.5	99.0	2618	0.40
11	31-Jan-06	12:36:00	12:47:50	33.4	51	7337	47.5	11.9	12.5	99.0	2434	0.40
12	31-Jan-06	12:50:00	13:01:50	33.0	52	7337	47.5	11.8	12.4	99.0	2434	0.40
13	31-Jan-06	13:05:00	13:16:50	33.0	52	7337	47.5	11.8	12.6	99.0	2434	0.40
14	02-Feb-06	11:37:00	11:47:55	32.2	50	7337	47.5	11.4	12.3	99.0	2638	0.35
15	02-Feb-06	11:49:30	12:00:35	31.9	57	7638	47.5	11.6	12.4	99.0	2598	0.35
16	02-Feb-06	12:03:00	12:13:10	32.3	50	7638	47.5	11.4	12.4	99.0	2833	0.35
17	04-Feb-06	10:30:00	10:42:25	26.8	82	5286	45.0	6.8	7.6	99.0	2319	0.40
18	04-Feb-06	10:43:30	10:55:23	26.6	84	5286	45.0	7.0	7.3	99.0	2424	0.40
19	04-Feb-06	10:57:00	11:08:45	26.5	86	5286	45.0	6.9	7.3	99.0	2451	0.40

Figure 12: Water production observations for client's machine s/n 0001 operated in Belize City in 2006.

Lessons Learned

Grand Turk

The water-from-air resource and natural coolant (deep cold saline groundwater) resource were favorable for operation of the proposed water-from-air self-irrigating commercial greenhouse (Figure 9). The monthly model (Figure 10), discussed earlier in this paper, showed average daily water production should exceed 200,000 L/day. The technical feasibility study (Wahlgren, 2002) estimated energy cost of the water at 0.025 kWh/L. This study, coupled with the financial and commercial viability report (Crocker and Wahlgren, 2002) anticipated a positive outcome for the project.

Despite the promising technical and economic aspects of the project, obstacles remained for building the WaterProducer-Greenhouse™ in Grand Turk:

- No existing similar design installation as a precedent;
- Limited access to risk capital;
- Resistance from water managers to changing to an unfamiliar decentralized water distribution business model;
- Resistance from energy utility managers to allowing wind, solar, and other energy alternatives to be used for projects within their region of jurisdiction; and
- Importing food and water to Grand Turk remains relatively easy in the short-term.

Belize City

Energy metering during the commissioning period confirmed the energy cost of the produced water to be 0.4 kWh/L or less.

Year-round operation at the water-from-air machine's rated capacity was certainly practical in Belize City as seen in Figure 11. Why did the successfully commissioned machines rapidly fall into disuse? The reasons included:

- Relatively high energy costs of USD 0.215 per kWh (in 2006);
- Inadequate entrepreneurial vision and advance business planning; and
- Limited funds available to sustain demonstration site operation until a local market developed for the product water or the machines themselves for other sites in Belize and neighbouring countries.

Conclusion

As resident and tourist populations grow in Caribbean countries, water managers now know they have another reliable water source to tap: water-from-air.

References

Antillean (2010) Region in drought: the thirsty Caribbean [http://Antillean.org/region-in-drought-the-thirsty-caribbean/; accessed 2014-07-04]

Crocker, R. G. and R. V. Wahlgren (2002) *Financial & Commercial Viability Study—Grand Turk Solar Desalination Greenhouse for Water + Food*™ . Report delivered to Batavia Greenhouse Builders Ltd. by Site Specific Structures, Langley, BC, Canada and Atmoswater Research, North Vancouver, BC, Canada.

ECLAC (2007) Agriculture, Rural Development, Land, Drought and Desertification: Outcomes, Trends and Challenges for Sustainable Development of Latin America and the Caribbean. United Nations, Economic Commission for Latin America and the Caribbean (ECLAC). LC/L.2831 (23 November 2007).

Gassert, F., Reig, P., Luo, T, and Maddocks, A. (2013) Aqueduct country and river basin rankings: a weighted aggregation of spatially distinct hydrological indicators. Working paper. Washington, DC: World Resources Institute, November 2013. Available online at wri.org/publication/aqueduct-country-river-basin-rankings.

Kalnay, E. and Coauthors (1996) The NCEP/NCAR Reanalysis 40-year Project. *Bull. Amer. Meteor. Soc.*, 77, 437–471.

ReliefWeb (2010) Caribbean: Drought – Feb 2010 [http://reliefweb.int/disaster/dr-2010-000029-tto; accessed 2014-07-04]

Trotman, A., Pologne, L., Stoute, S., Mehdi, B., Senecal, C. and Gollamudi, A. (2008) A Proposed Approach to Monitoring and Assessing Drought in the Caribbean. The Second Turkey-Israel Workshop on Drought Monitoring and Mitigation, Turkey, June 16–29, 2008.

Wahlgren R. V. (2002) *Technical Feasibility Study—Grand Turk Solar Desalination Greenhouse for Water + Food™, 2nd ed. (revised September 2002)*. Report delivered to Batavia Greenhouse Builders Ltd. by Atmoswater Research, North Vancouver, BC, Canada.

Wahlgren R. V. (2003) *Final Activity Report*. *—Grand Turk Solar Desalination Greenhouse for Water + Food™.* Report delivered to Batavia Greenhouse Builders Ltd. by Atmoswater Research, North Vancouver, BC, Canada.