# Modelling and Measurement of Marine fog, on Sable Island

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1) A modelling hypothesis and measurement strategy.
2) Some Sable Island data, WRF results and suggestions.

A modelling hypothesis.

a) Turbulence will make droplets (1-50 μm) strike the water surface. Inertia effects.

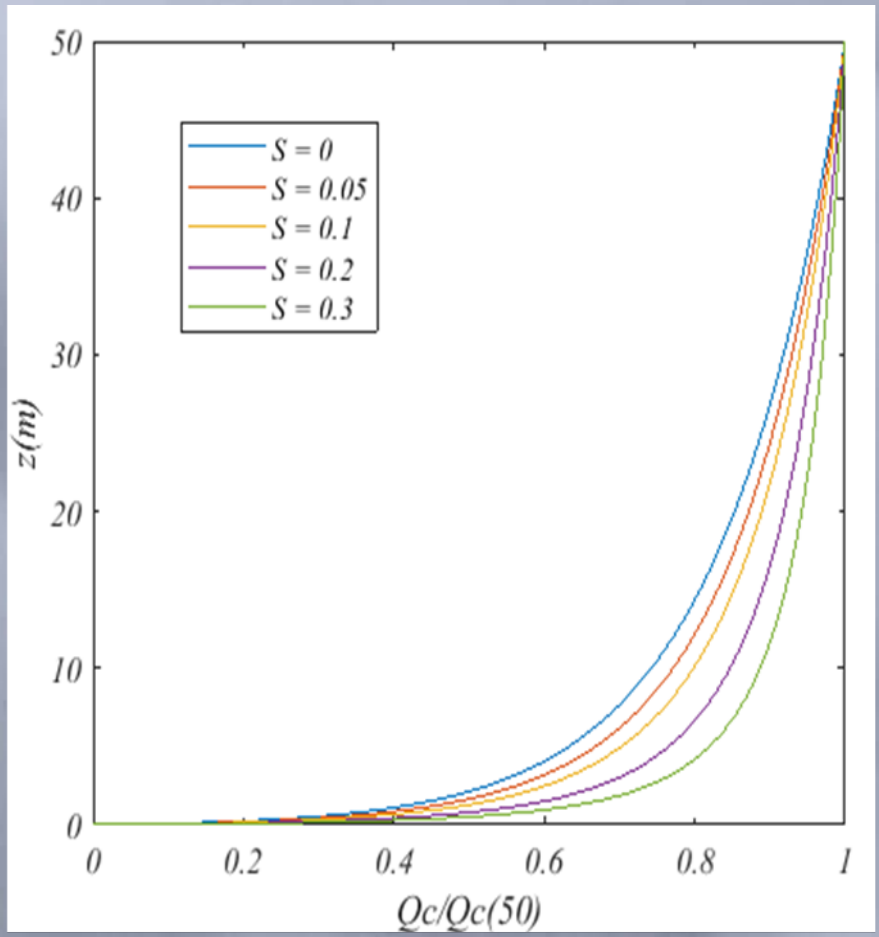
b) They will then collide and coalesce.

c) The water surface is a sink for fog droplets and Qc – liquid water.

These ideas are accepted and used for fog over vegetation and for aerosols over water but not by the marine fog community.

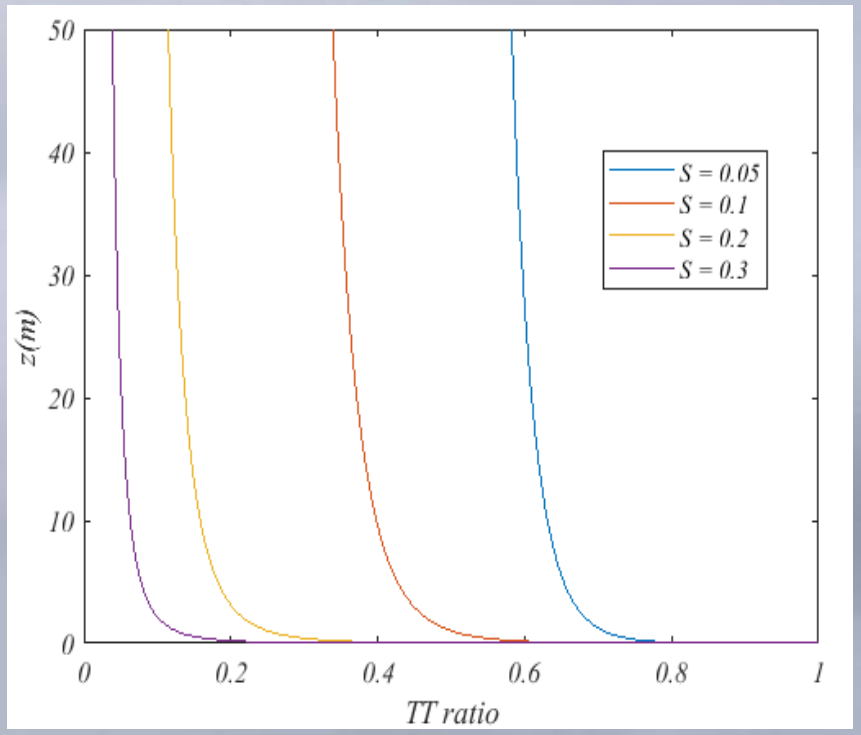
# A proposed measurement strategy.

Turbulent mixing and deposition can be represented via eddy diffusivity and roughness lengths, $z_{0c}$. **Must determine $z_{0c}$ from profile measurements**. Many complications including gravitational settling $w_s$. Use $S = w_s/(ku^*)$. Size distributions, surface waves




…… **For CFLGS and other papers see: https://www.yorku.ca/pat/fog/index.html**

a)




b)

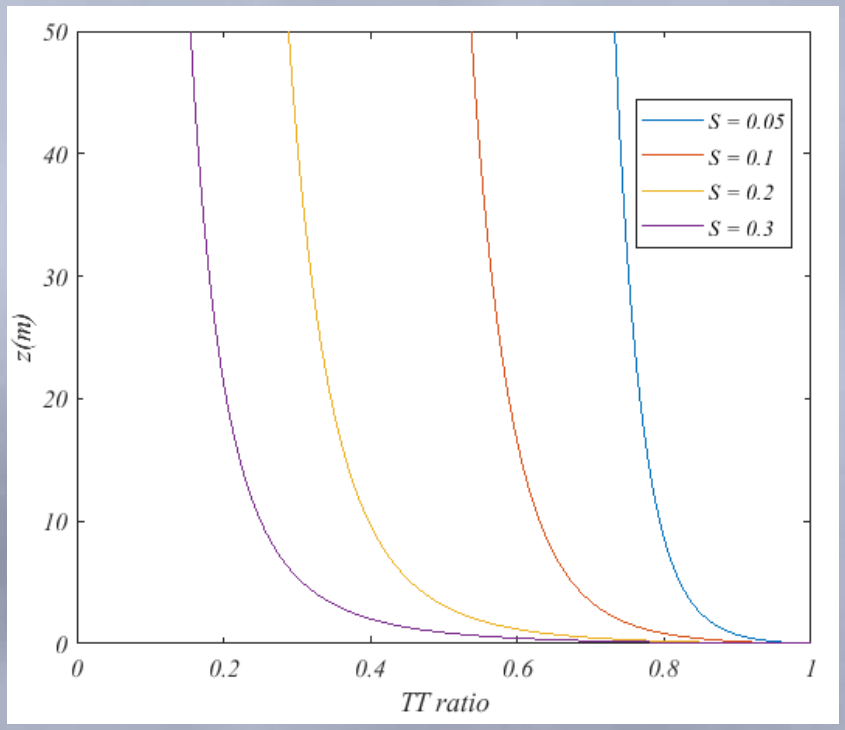



**Fig. 2** Variation of the Turbulent Transfer fraction of the total *Qc* flux and its variation with *z* and *S*. Note that these *z* values are based on a) $z_{0c}$ = 0.001 m and b) $z_{0c}$ = 0.1 m

Gravitational settling dominates at top (50m) while turbulent transfer is responsible for more flux as z approaches 0. $S = w_s/(ku^*)$.

**Fog over Sable Island and the surrounding ocean** – in preparation for CMOS Bulletin

Li Cheng, Zheqi Chen, Peter Taylor, Zoe Lucas, Yongsheng Chen and George Isaac

Photo (26 Sept 2020,
07:20 am EDT,
10.20 UTC
from Jason Surette, Parks Canada

Photo (31 May, 2021:
06: 45 EDT,
09:45 UTC)
from Zoe Lucas, Greenhorse Society

- Marine fog occurs frequently offshore from Atlantic Canada. It can cause problems for helicopter flights to oil rigs offshore from Newfoundland and any flights to the National Park on Sable Island, Nova Scotia as well as in many coastal communities along the East Coast.
- Fog is formally defined as visibility or Meteorological Optical Range, MOR) less than 1 km and mist is specified for MOR < 5 km.
- Summer statistics (Climate Normals) from Sable Island show fog reported in 200 (out of 720 or 744) hours in June and July, although individual Sable Island A weather reports often indicate fog with visibility > 1 km.
- Isaac et al (2020) report fog from a platform on the Grand Banks occurring approximately 40% of the time in June and July from 20 years of METAR reports.
- Accurately forecasting visibility conditions is a challenge.

- On land, even on the narrow (~ 1 km) strip of sand that is Sable Island, heating of the ground by solar radiation and cooling at night via long wave radiation lead to diurnal changes in land surface and near surface air temperatures which are far greater than they are over water, where mixing in the upper water column reduces water surface temperature variations.

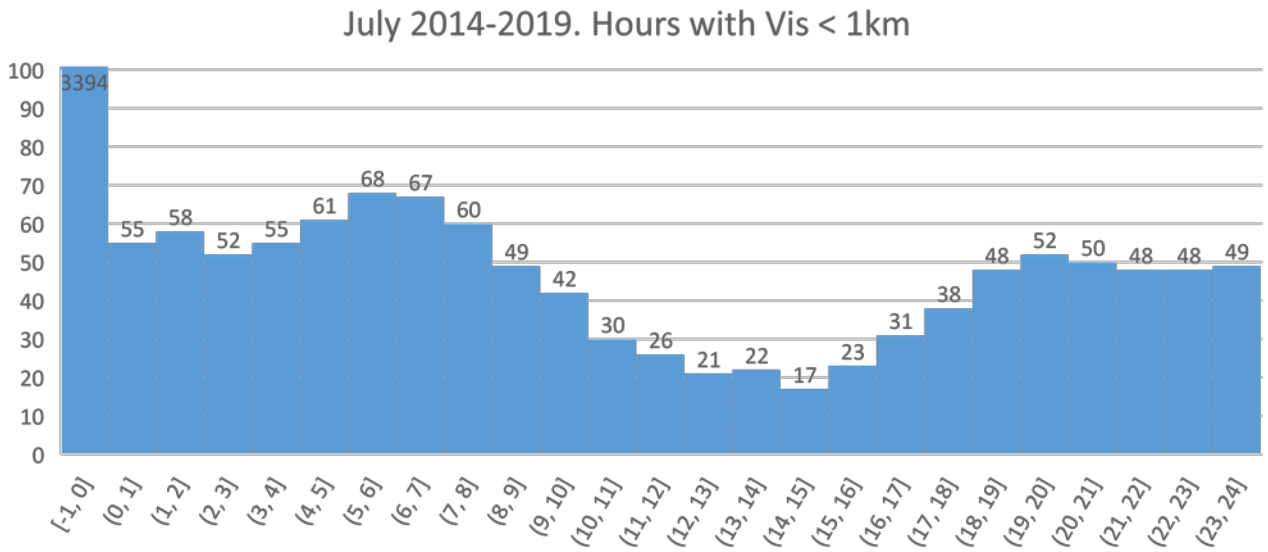
- With near-saturated air drifting in from the sea, and radiative cooling of the land surface, more water vapour can condense and a low level radiation fog can occur in light wind conditions.

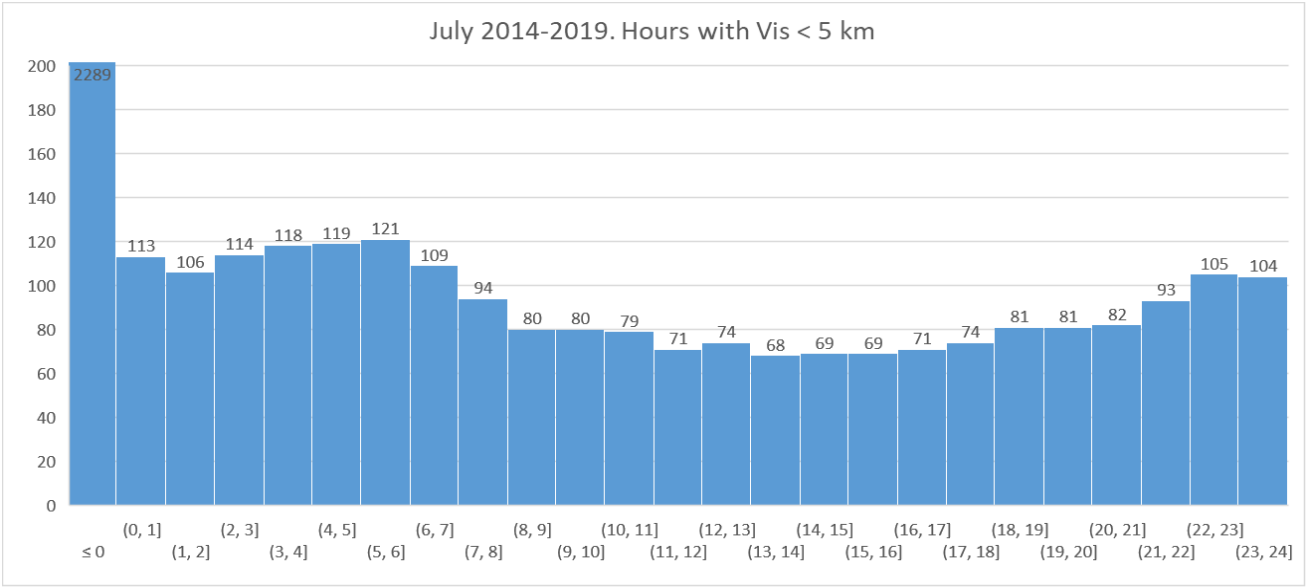
- With strong winds and marine fog over the water being advected over Sable Island, even a small afternoon warming of the near surface air in its 400 m path over the sand and bushes between the water and the YSA weather station could cause some evaporation of fog droplets and modify the visibility reported by the automatic weather station instrument relative to that over surrounding ocean.

- On one of the days shown in the two photos above (Sept 26, 2020) and from a study of weather reports for that day (below) it appears that winds were relatively light, fog formed at the weather station over night but skies cleared by noon. (https://climate.weather.gc.ca/index_e.html)

- On other occasions, such as May 31, 2021 shown above, fog or mist persists all day in the Sable Island A reports (below) although with increasing temperatures during the day, visibility there may be better than over the surrounding ocean.

- We can also use the Hourly Data Reports to investigate whether there is a diurnal cycle in the frequency of fog occurrence. The figures below shows the numbers of hours with visibility < 1 km and < 5 km for 6 years of July data (visibility data are not available in July 2020).




Over the ocean there is NO diunal cycle!

Sable Island weather station is a “coastal” site!

The ECCC web site states, “Please note that these observations might not always be representative of weather conditions over their associated marine area”. This needs to be taken seriously.

# WRF Modelling – and some recent results

- WRF comes with many options to represent boundary layer mixing, cloud physics and radiation processes and it is important to select the best options.
- The modules used for the results presented below were MYNN boundary layers and Thompson microphysics with the optional addition of additional turbulent deposition to the water surface using a liquid water roughness length $z_{0c}$ = 0.01m.
- Once cloud droplets, typically in the size range (1-50µm) have formed they will be subject to gravitational settling (typical velocities in the cm/sec range) and this is represented within WRF. What is not generally included for marine fog is the added deposition to the surface associated with turbulent impaction, collision and coalescence of water droplets with the surface.
- We have added an optional process in our modified treatment of the boundary layer and surface interactions through a roughness length ($z_{0c}$) concept in the turbulent mixing of fog liquid water and deposition to the surface. One consequence of this is that the underlying water surface then becomes a stronger sink for fog droplets and the liquid water concentration, and visibility, can then vary significantly with height.
- So far our modelling is limited because WRF only considers total liquid water content without a specified size distribution (all droplets are the same size) but it is a start on developing a more detailed fog prediction model.
- Some earlier results and more details at https://www.yorku.ca/pat/fog/

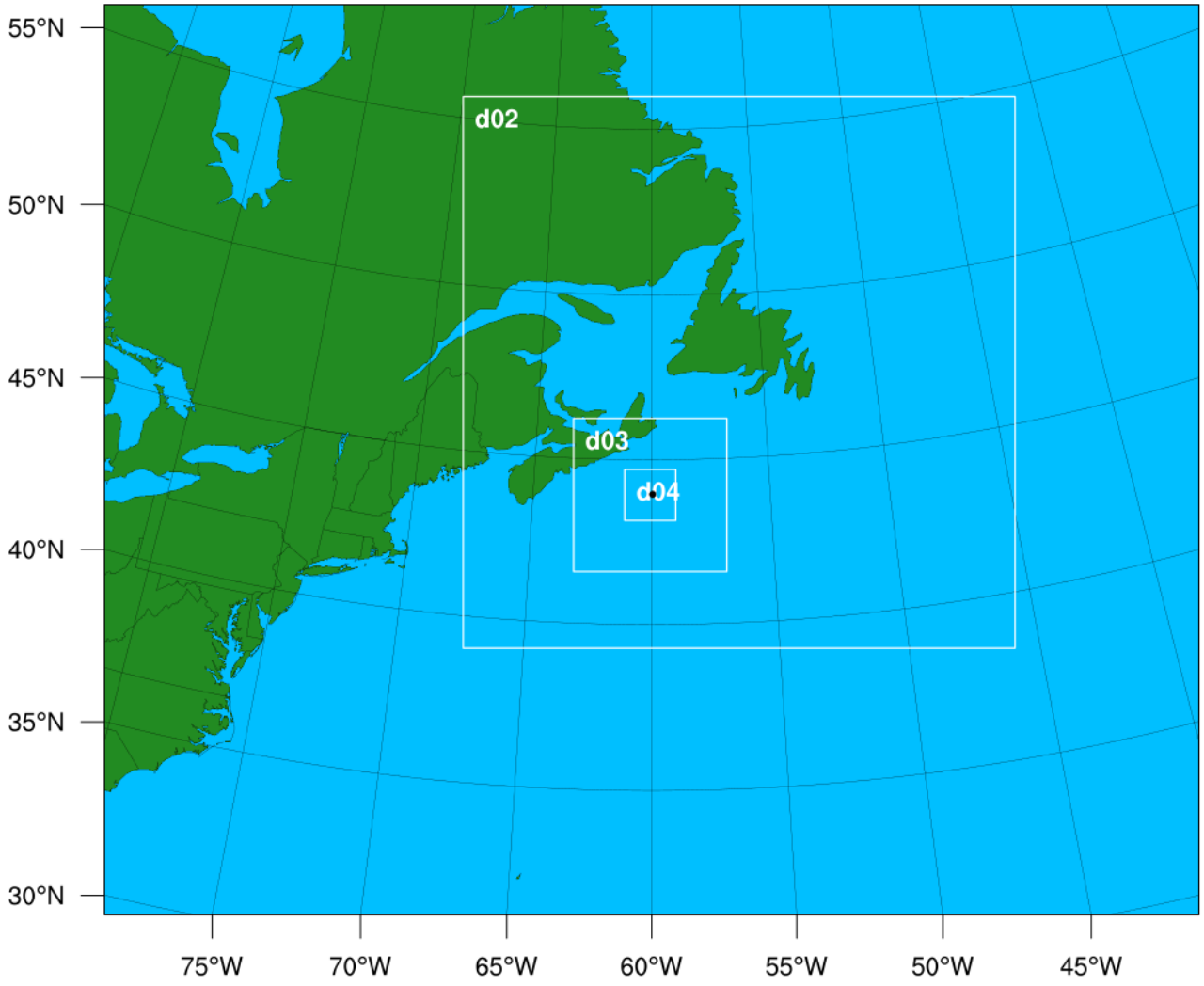
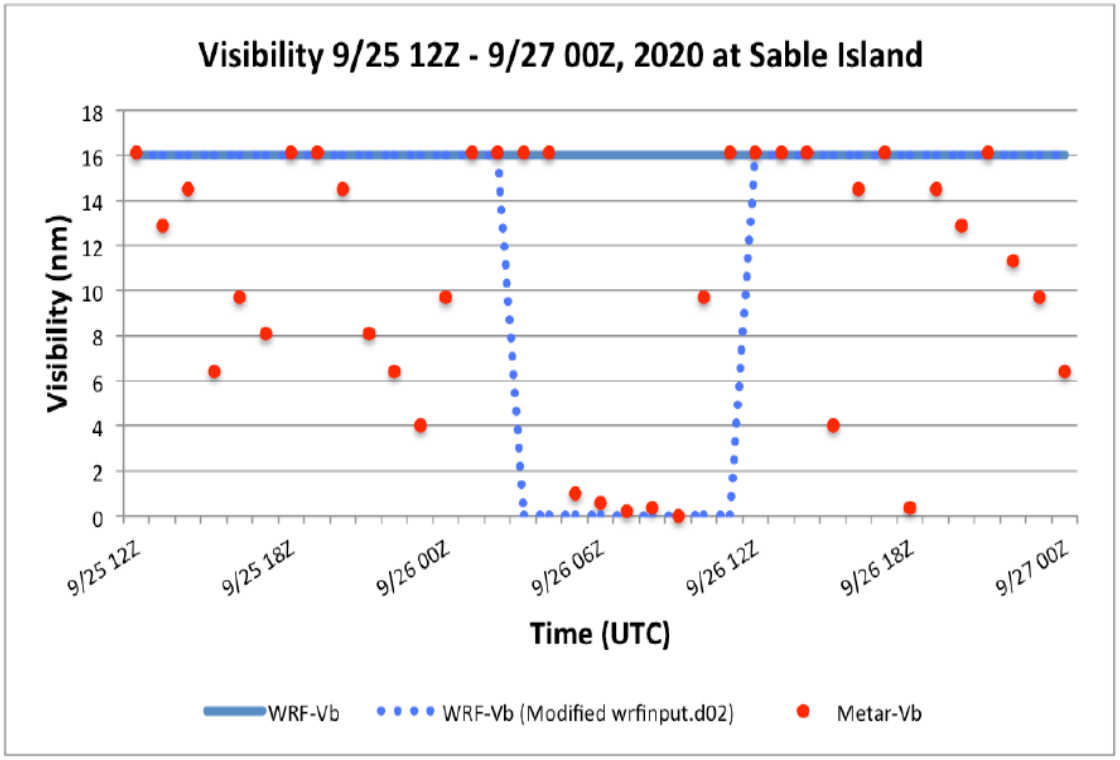



Figure 5. WRF domains used for Sable Island study. Grid resolutions (30 km, 10 km, 3.1km, 1.1km)

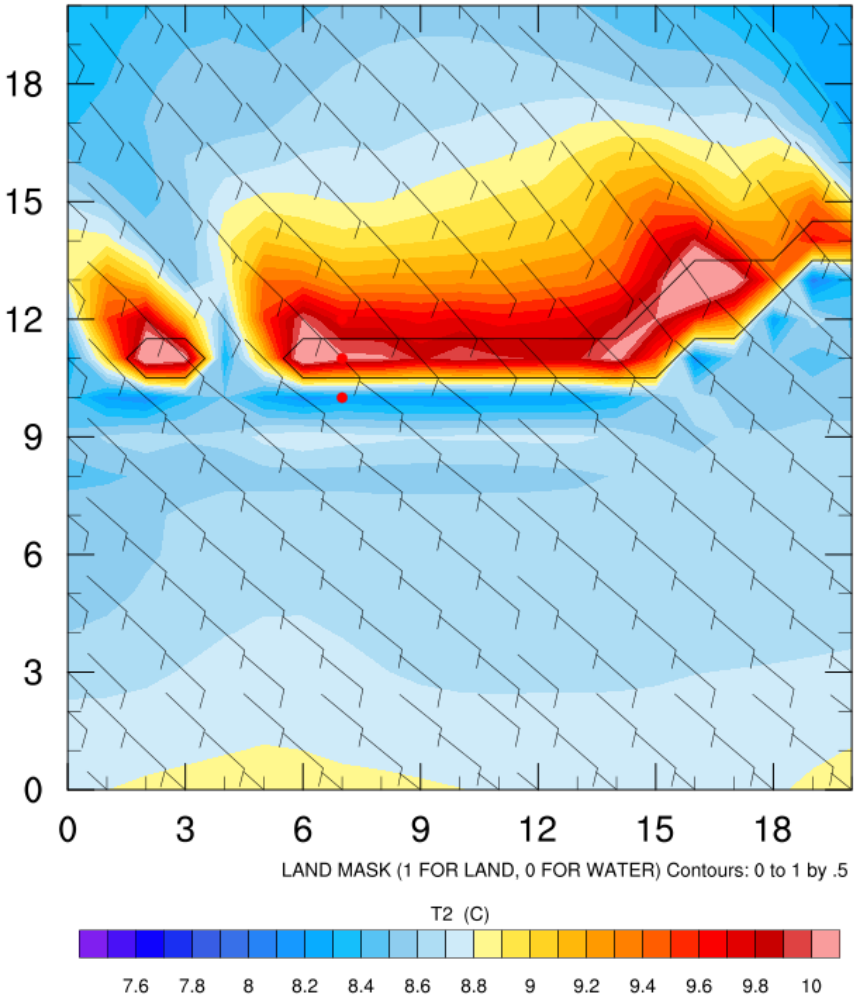


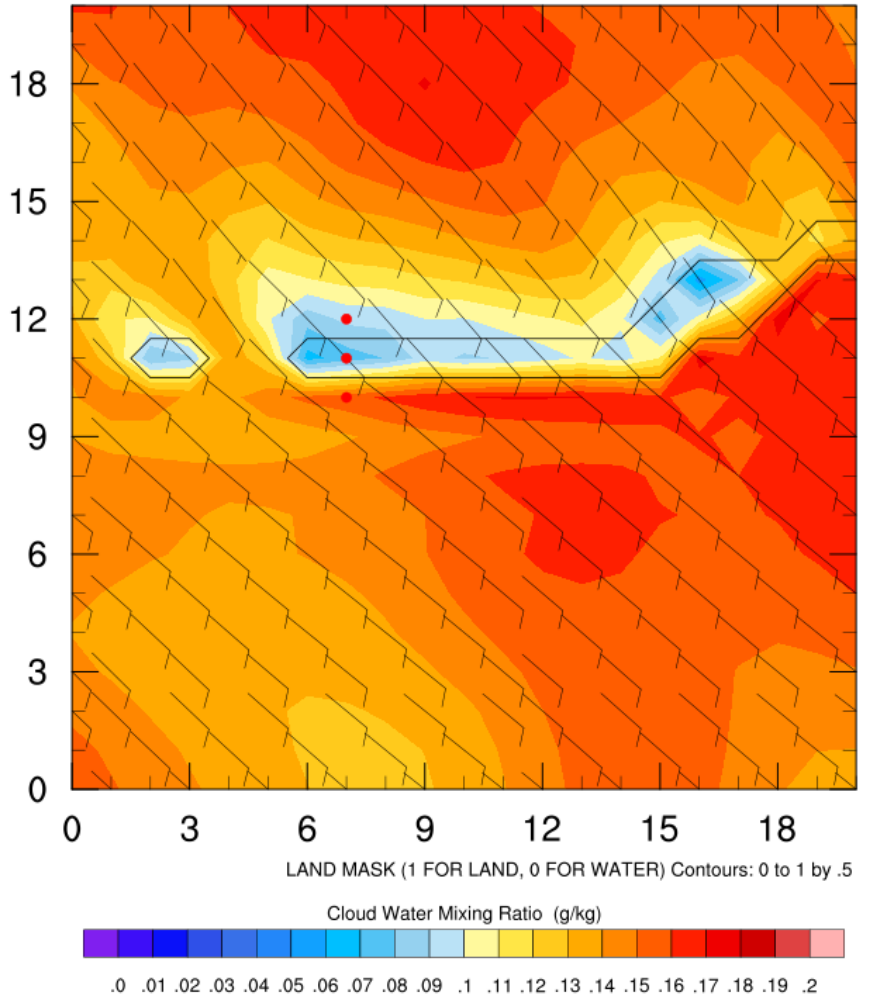

Hourly Data Report for September 26, 2020

| TIME LST | Temp °C | Dew Point °C | Rel Hum % | Precip. Amount mm | Wind Dir 10's deg | Wind Spd km/h | Visibility km | Stn Press kPa | Hmdx | Wind Chill | Weather |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00:00 | 13.6 | 12.9 | 95 | 0.2 | 31 | 11 | 16.1 | 102.17 | | | NA |
| 01:00 | 12.4 | 11.9 | 97 | 0.0 | 30 | 5 | 16.1 | 102.23 | | | NA |
| 02:00 | 9.7 | 9.6 | 99 | 0.0 | 24 | 5 | 1.0 | 102.23 | | | Fog |
| 03:00 | 8.3 | 8.2 | 99 | 0.0 | 30 | 5 | 0.6 | 102.24 | | | Fog |
| 04:00 | 7.5 | 7.5 | 100 | 0.0 | 26 | 5 | 0.2 | 102.29 | | | Fog |
| 05:00 | 5.6 | 5.6 | 100 | 0.0 | | 0 | 0.4 | 102.30 | | | Fog |
| 06:00 | 5.4 | 5.4 | 100 | 0.0 | 12 | 4 | 0.0 | 102.35 | | | Fog |
| 07:00 | 13.4 | 13.4 | 100 | 0.0 | 16 | 11 | 9.7 | 102.35 | | | Fog |
| 08:00 | 14.5 | 14.5 | 100 | 0.0 | 17 | 9 | 16.1 | 102.40 | | | NA |
| 09:00 | 15.4 | 14.8 | 96 | 0.0 | 15 | 8 | 16.1 | 102.47 | | | NA |
| 10:00 | 15.5 | 14.1 | 92 | 0.0 | 17 | 11 | 16.1 | 102.49 | | | NA |
| 11:00 | 16.6 | 14.0 | 85 | 0.0 | 18 | 13 | 16.1 | 102.48 | | | NA |
| 12:00 | 16.0 | 14.5 | 91 | 0.0 | 20 | 18 | 4.0 | 102.41 | | | Fog |
| 13:00 | 15.1 | 14.0 | 93 | 0.0 | 18 | 18 | 14.5 | 102.39 | | | NA |
| 14:00 | 16.3 | 14.3 | 88 | 0.0 | 19 | 18 | 16.1 | 102.35 | | | NA |
| 15:00 | 14.4 | 14.3 | 99 | 0.0 | 21 | 8 | 0.4 | 102.33 | | | Fog |
| 16:00 | 14.3 | 14.2 | 100 | 0.0 | M | 4 | 14.5 | 102.35 | | | NA |
| 17:00 | 14.3 | 13.8 | 97 | 0.0 | 19 | 5 | 12.9 | 102.37 | | | NA |

Fig 6. WRF 10 km grid simulations with and without a land point representing Sable Island. We used ERA5 reanalysis data to drive the simulations for Sept. 26, 2020. These results were with no additional turbulent deposition to the surface (i.e. no z0c).

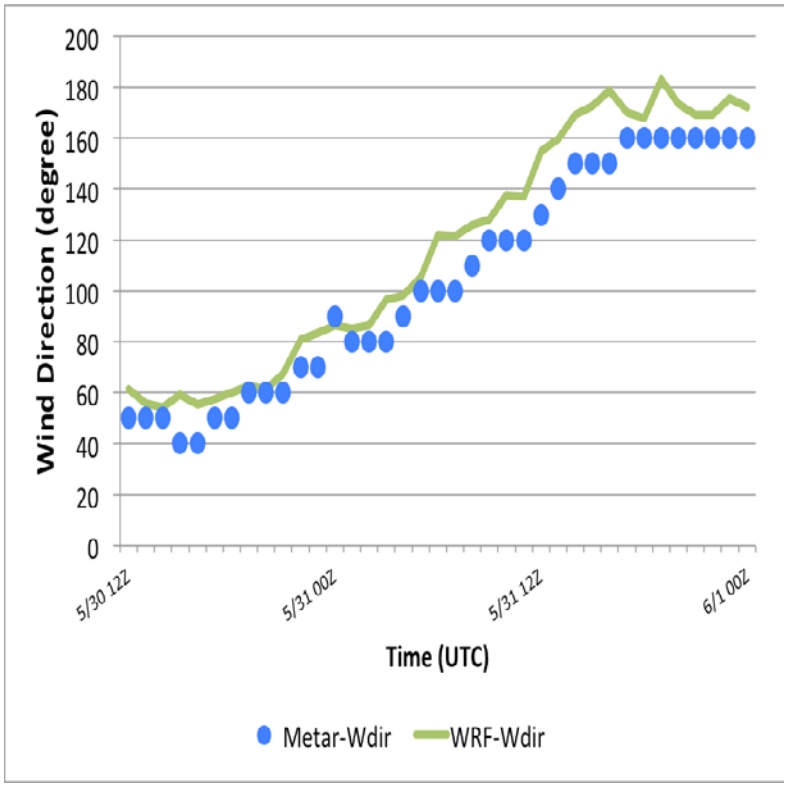
High Resolution WRF runs for May 31, 2021; 4 nests, with $z_{0c}$ = 0.01m, at 11Z, 31 May 2021
Temperature and Qc (g/kg) at 2 m height

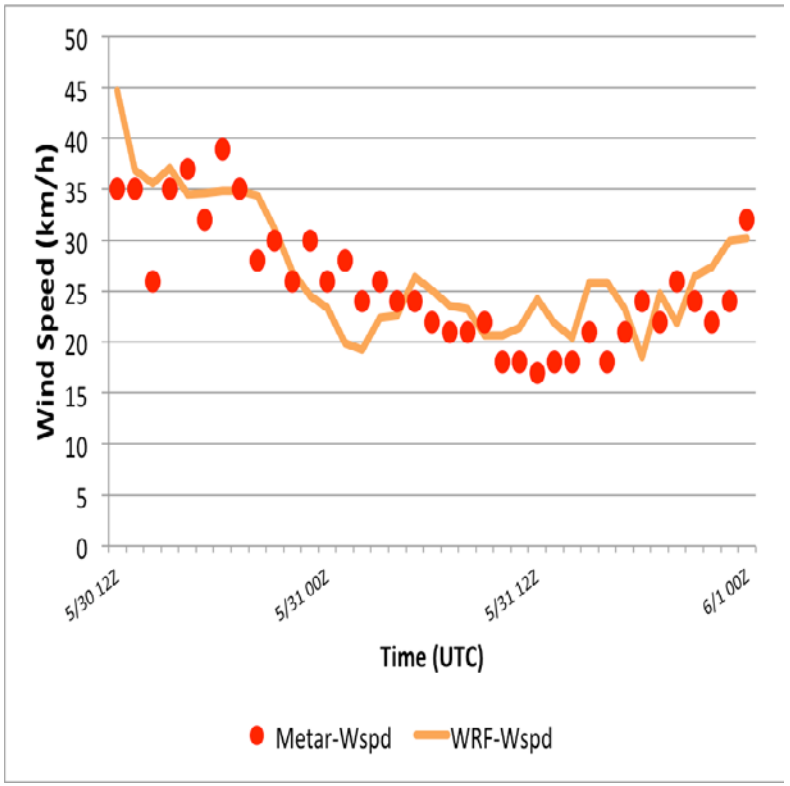


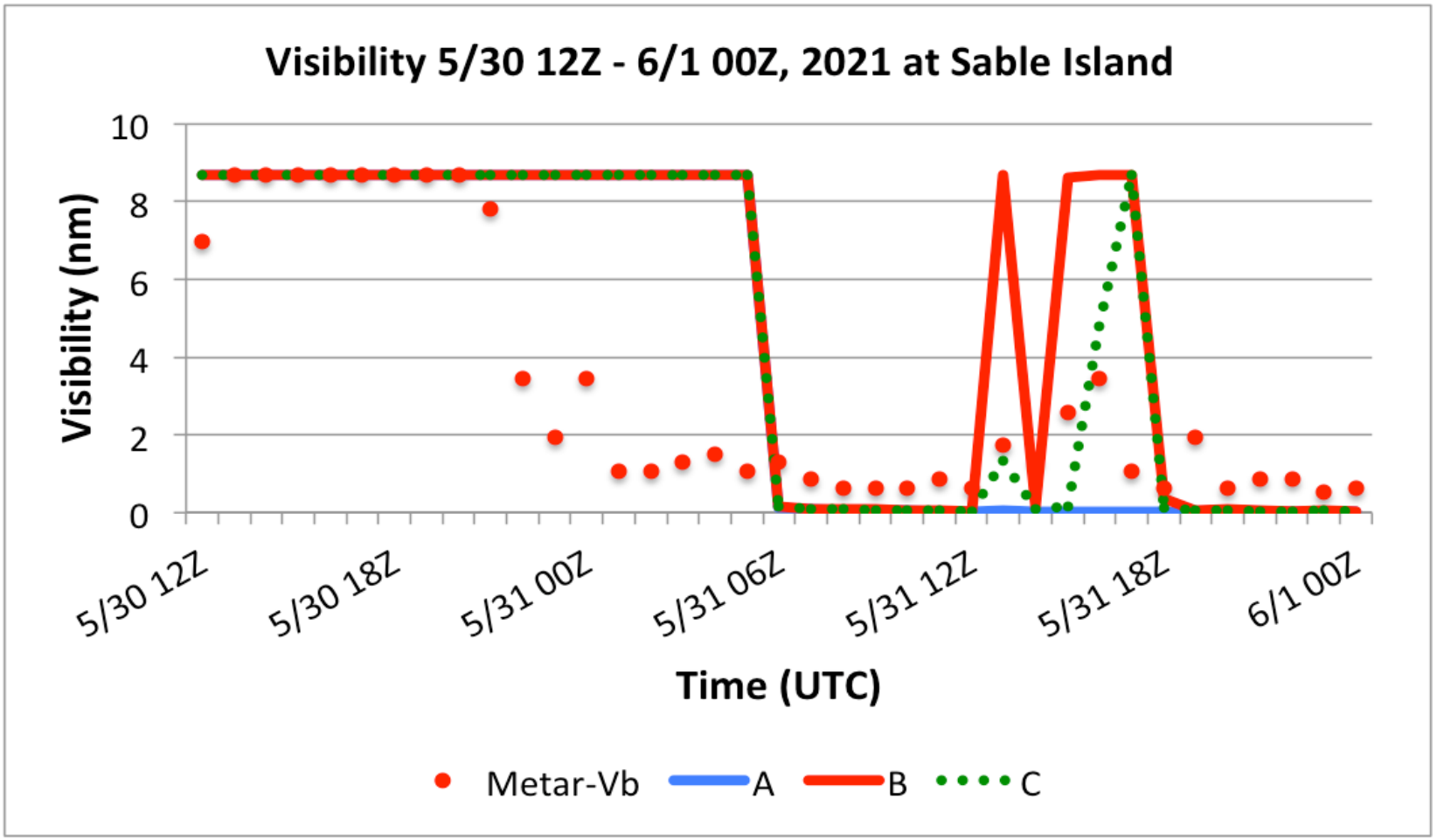




Winds from SW, Land Mask identifies Sable Island. Red dots are time series points A (in water S of island, B on Sable Island, close to YSA and C is North by 1 grid point.

# Wind on the Sable Island






The model run seems to miss fog 00Z-06Z on 31 May in Easterly winds, but tracks visibility increases on the island 12Z – 18Z in SE winds.

## Fatima – Sable Island 2022.

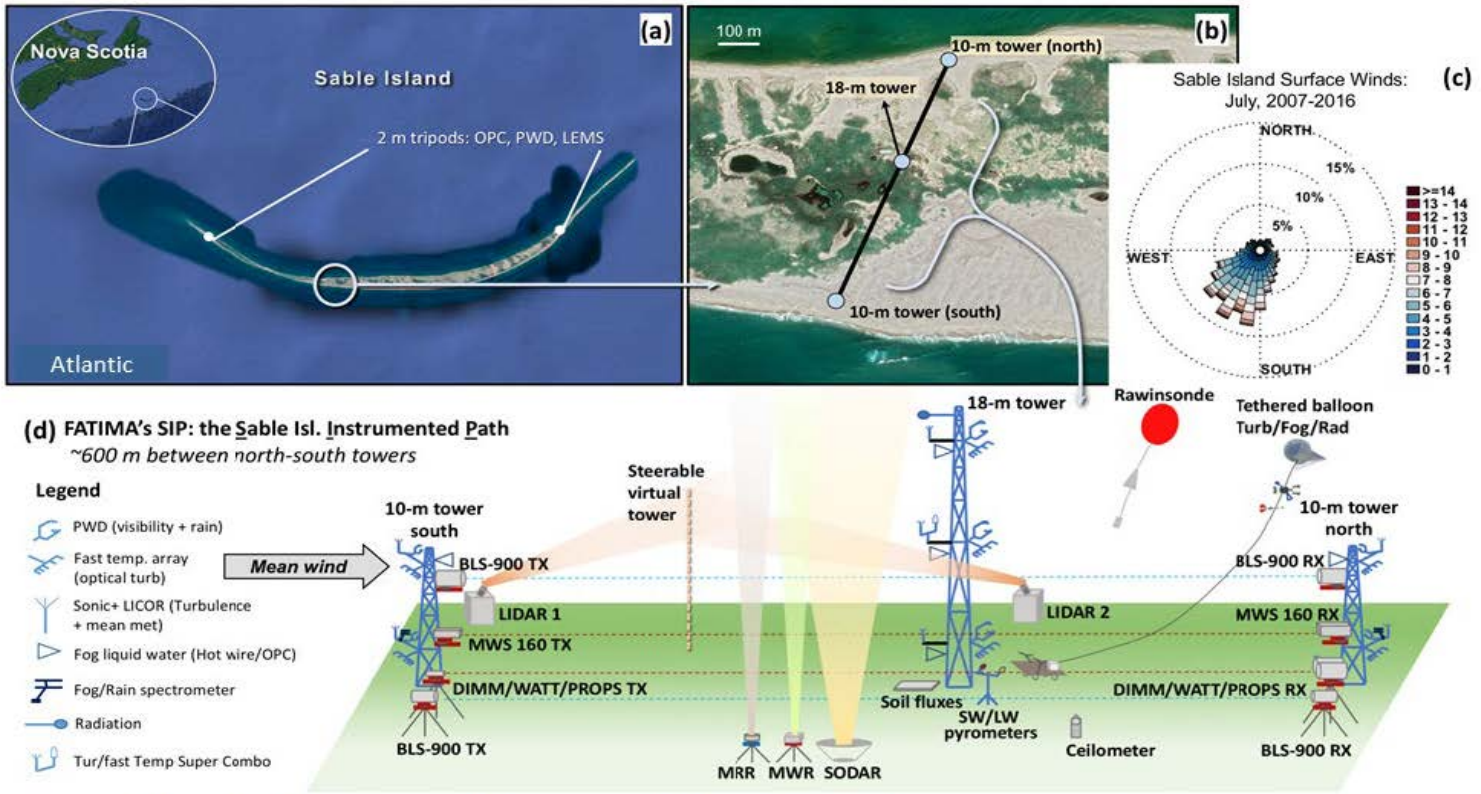
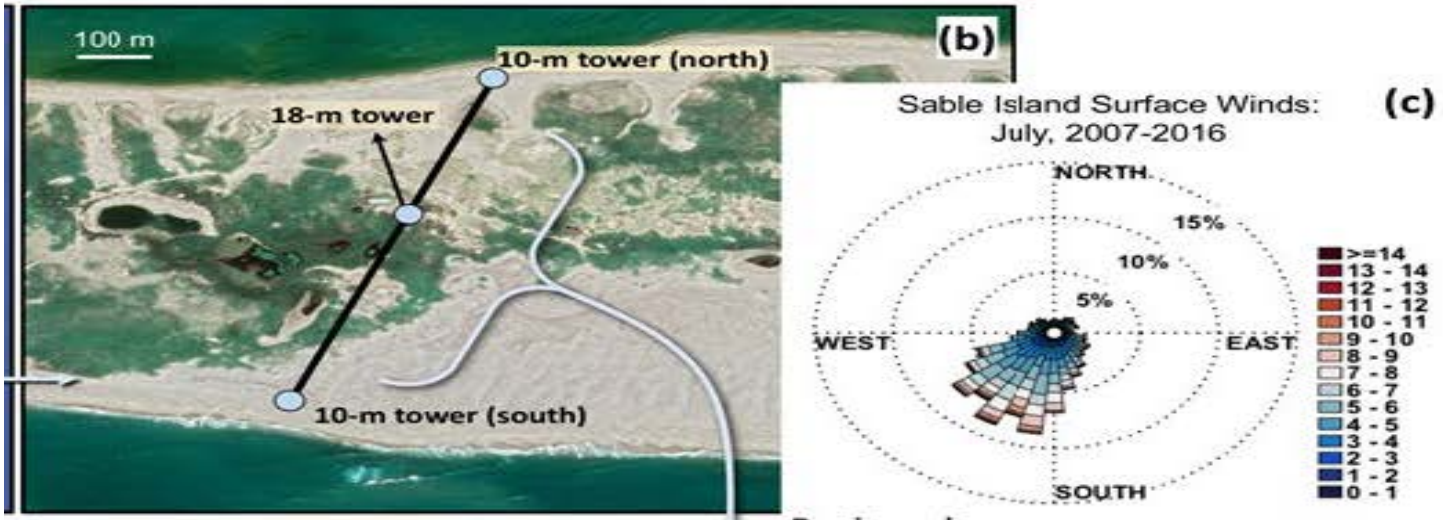


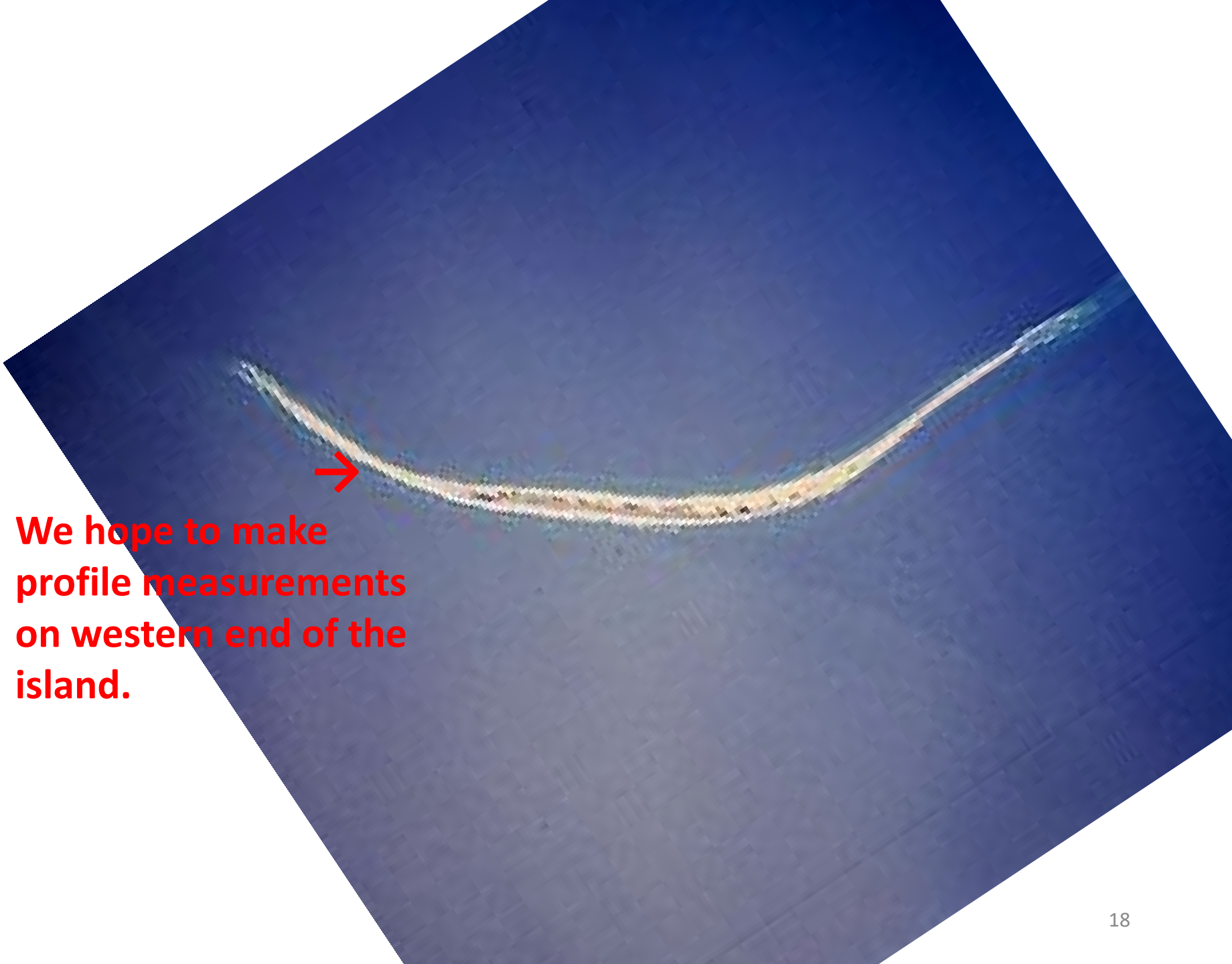

**Fig.11:** Sable Island instrument deployment during GB campaign. (a) Geography, (b) Measurement site and sensor line, (c) Surface wind climatology for July, and (d) Instrument placement and paths

The 18 m tower is roughly 400 m from the shoreline to the SSW and within the internal boundary layer associated with the change in underlying surface. Profile measurements from that mast will be difficult to interpret.

**A suggestion:**

**Switch locations of the 17 m tower and the shoreline south tower, but not the Scintillometer systems. Move the shoreline north tower and scintillometers to a south shore location so that measurements are made in the incoming onshore flow, and are representative of marine fog, less affected by the island. May need to be careful with landing strip logistics.**





**We hope to make profile measurements on western end of the island.**