# On low cloud and fog over the Grand Banks - A comment on " The formation of fog and mist" by G.I. Taylor, 1917, Quart. J. Roy. Meteor. Soc. 43, 241–268.

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Sept 2022

Abstract

A simple 1-D RANS model of the time evolution of the Planetary Boundary Layer is extended to include water vapour and cloud droplets plus transfers between them. The underlying ocean surface is treated as a source of water vapour, and as a sink for cloud or fog droplets.  With the model we can simulate conditions reported in G.I. Taylor's classic 1917 paper "The formation of fog and mist" and our results are presented as "correspondence" related to that 1917 paper. The Grand Banks observations were from 1913.

Taylor, G. I.: 1917. The formation of fog and mist, Q. J. Roy. Meteor. Soc., 43, 241–268, https://doi.org/10.1002/qj.49704318302

# FOG AT SEA.

One of the foggiest regions on earth is the part of the Atlantic which stretches 300 miles east of Newfoundland. In this region the temperature of the water is very low, owing to the Arctic current which flows southward out of Baffin Bay along the east coast of the American continent. During the summer it is surrounded on three sides by warm regions. On the west is the American continent, while to the south and east lie the waters of the Gulf Stream. Winds, therefore, which blow from the East, South, and West are liable to be cooled by the Arctic water of the Banks, and fog is of very frequent occurrence.

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On July 25 I raised a kite in a light Southerly wind accompanied by thick fog. At the time of the ascent the *Scotia* was in latitude 46° 30′ N., long. 51° 41′ W. The temperature of the sea was 10° C. (50° F.), and the wind was blowing straight off the warm waters of the Gulf Stream. The position of the *Scotia* and the temperature of the sea are shown in Fig. 7. On that map the distribution of temperature in the sea is given by means of isotherms, or lines of equal temperature. These are drawn at the Meteorological Office by collecting together all the observations of sea-temperature taken by steamers during an interval of about a week. It will be seen that the isotherms of 50°, 60° and 70° F. are close together in the part of the sea we are considering.

ISOTHERMS OF SEA TEMPERATURE AND PATH OF THE SURFACE AIR FOR THE KITE ASCENT OF JULY 25TH

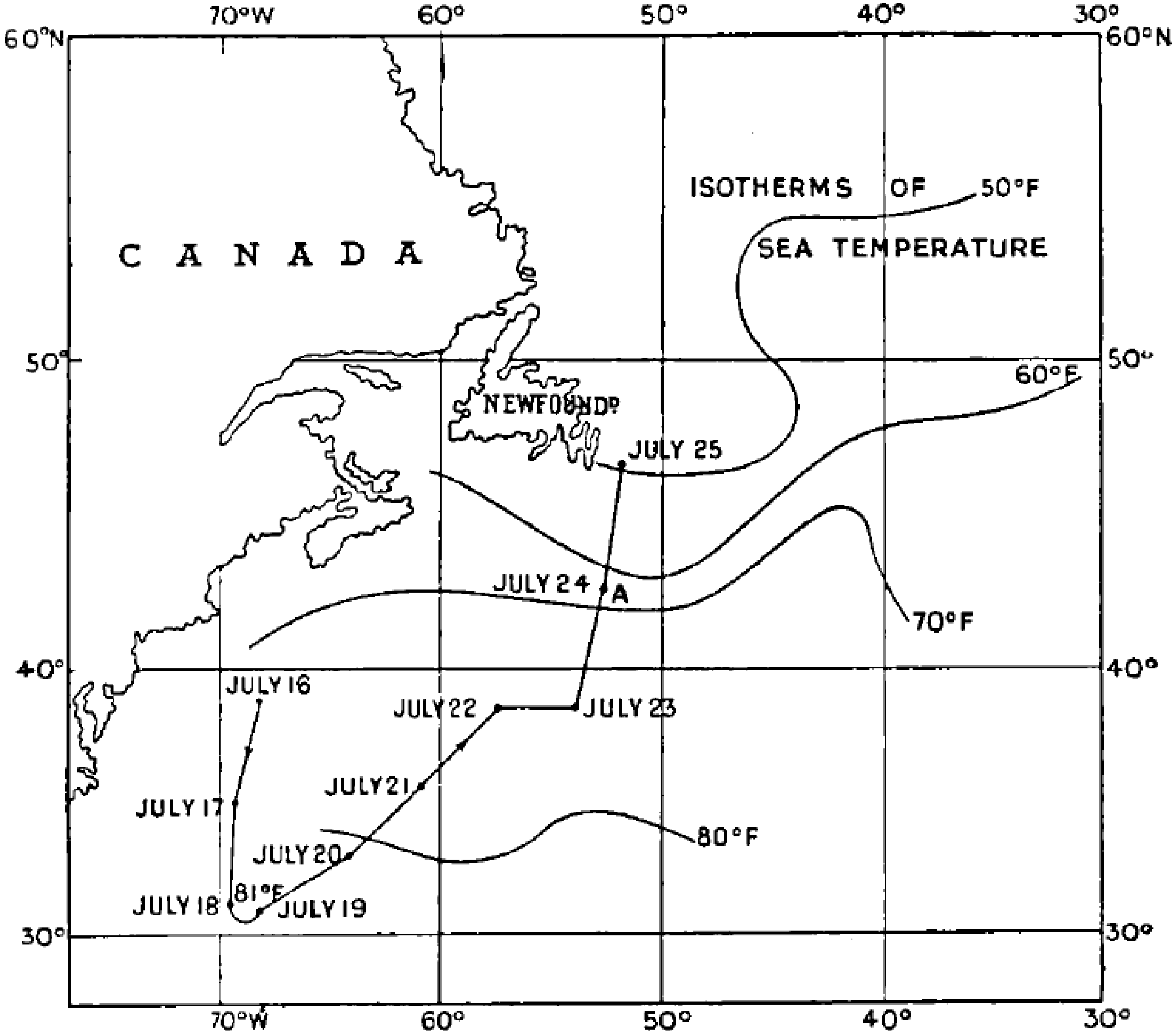
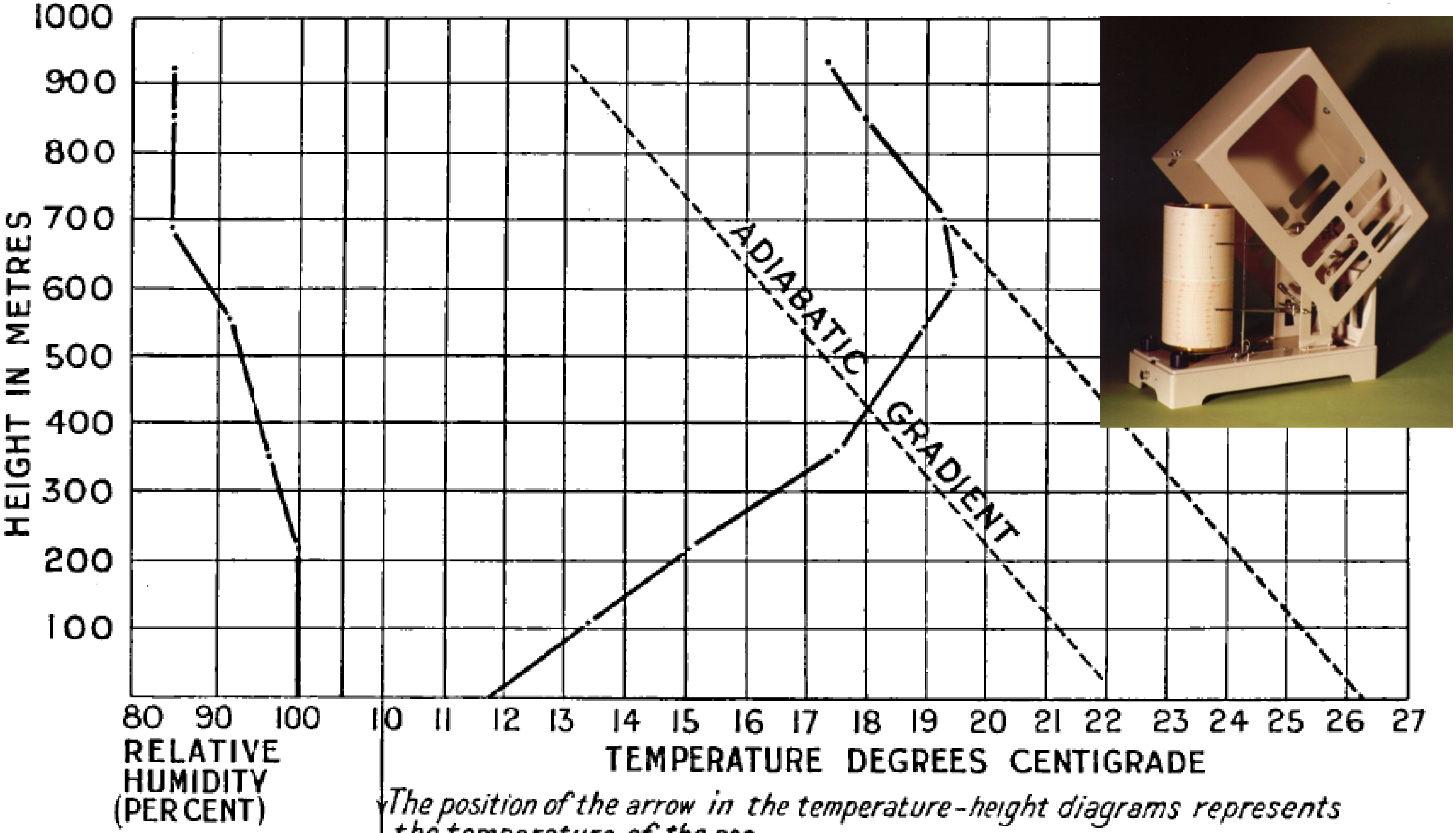


Fig. 7.

DISTRIBUTION OF TEMPERATURE AND HUMIDITY DURING KITE ASCENT ON JULY 25th



*The position of the arrow in the temperature-height diagrams represents the temperature of the sea.*

Fig. 8.

Measurements with hygrothermograph lifted by a kite and recovered. A 225-5020-A Hi-Q Hygrothermograph is shown.

# Concept and Model

Our relatively simple, time dependent, column (z,t), PBL model can simulate the formation of cloud and fog as a column of air moves over water with possibly varying sea surface temperature. It is based on Weng and Taylor (2003), using E-l closure in the 1-D Reynolds Averaged Navier-Stokes (RANS) equations. Equations for water vapour (Q) and liquid water (QL) mixing ratios were added to the basic equations for velocity (U,V), potential temperature (θ) and turbulent kinetic energy (TKE). The vertical coordinate (z) is stretched to give many points near the surface. Equations are represented in finite difference form and integrated forward simultaneously in time and implicitly, with a block-triagonal solver.

Our microphysics will simply be that condensation occurs instantaneously if the mixing ratio, Q > Qsat(T), the saturation value at air temperature, T. Then Q instantly reduces towards that saturation value with the excess becoming liquid water, QL. This releases latent heat, raises T and modifies $Q_{sat}$, requiring the process to be repeated in an iterative fashion until convergence is achieved. An adjustment is made in the opposite direction when liquid droplets diffuse into a sub-saturated layer. We can approximately solve directly if we assume that $\Delta Q_{sat} \alpha \Delta T$. Currently working on problems if QL becomes < 0.

We run our 1-D column model in 3 stages.

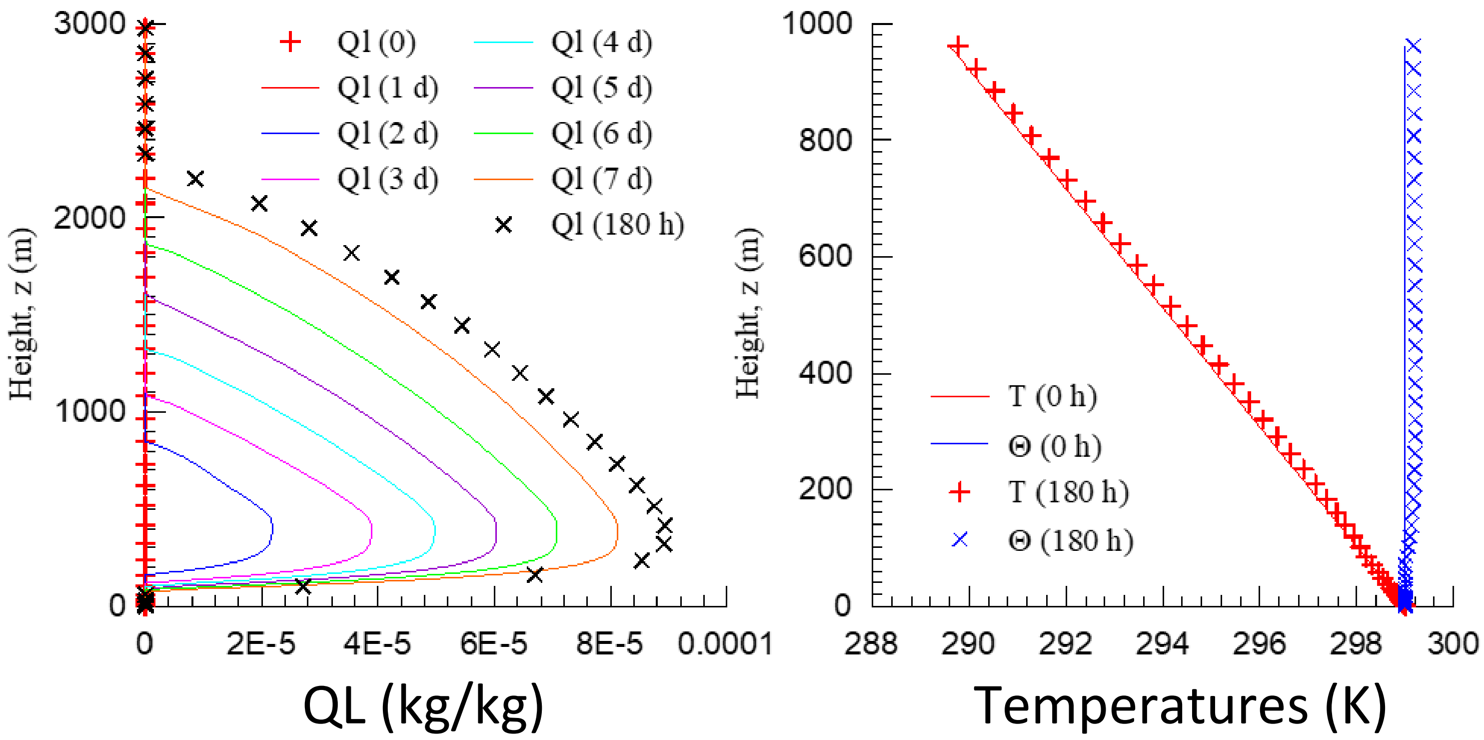
Stage 1 assumes neutral stratification and ignores any water vapor effects in order to establish initial velocity and turbulence profiles once the water surface becomes a potential source for water vapor.

We ran this with a geostrophic wind speed of 7 ms-1 for 5 days (120 h). This provides the initial conditions for ....

Stage 2 (180h) where water vapor and liquid water are added, with surface boundary conditions Q = Qsat (TW), so RH = 1, and QL = 0 at z = 0. We used constant TW = 299 K. After initial trials we re-ran stage 2 with an initial stable temperature gradient ($\partial\theta/\partial z = 4$ K/km above 600m and initial RH = 0.7), in general agreement with typical Atlantic Ocean conditions.

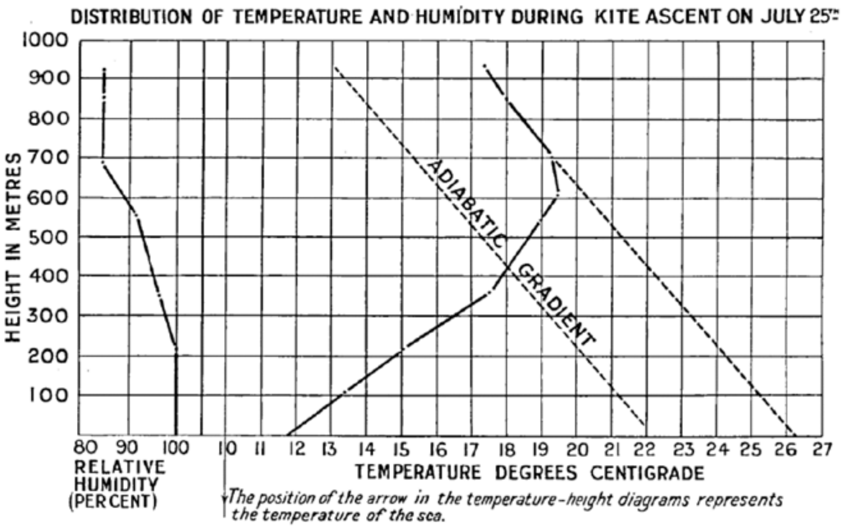
For Stage 3 (36h), we cool the underlying water surface (0.4 °/h), and also boost the geostrophic wind speed (up to 20 $\mathrm{ms}^{-1}$, typical conditions) to increase mixing.

# Initial Stage 2 runs.



Note no fog at surface.

Stratus cloud forms but maybe too deep in comparison with Taylor's 1914 RH profile.

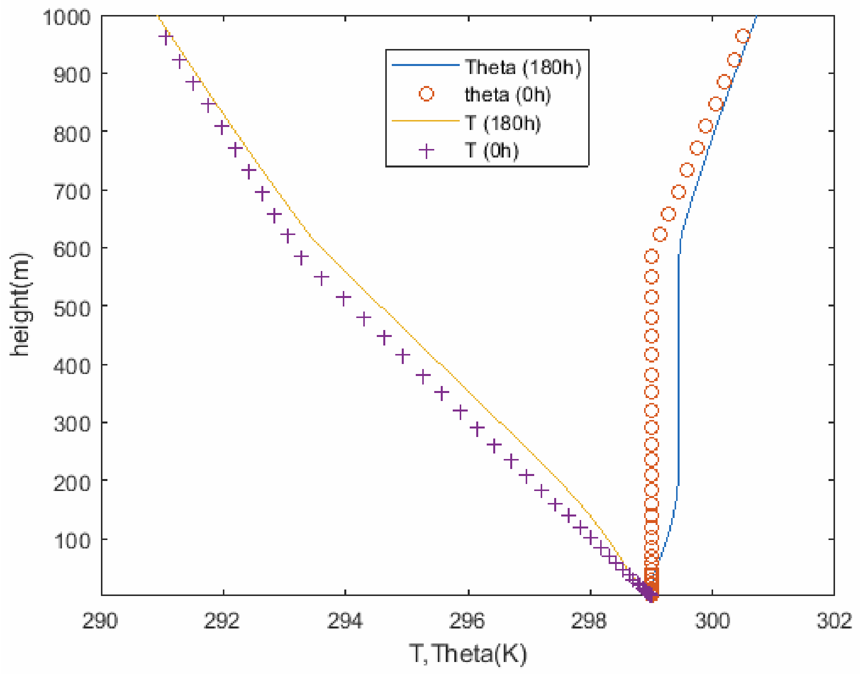


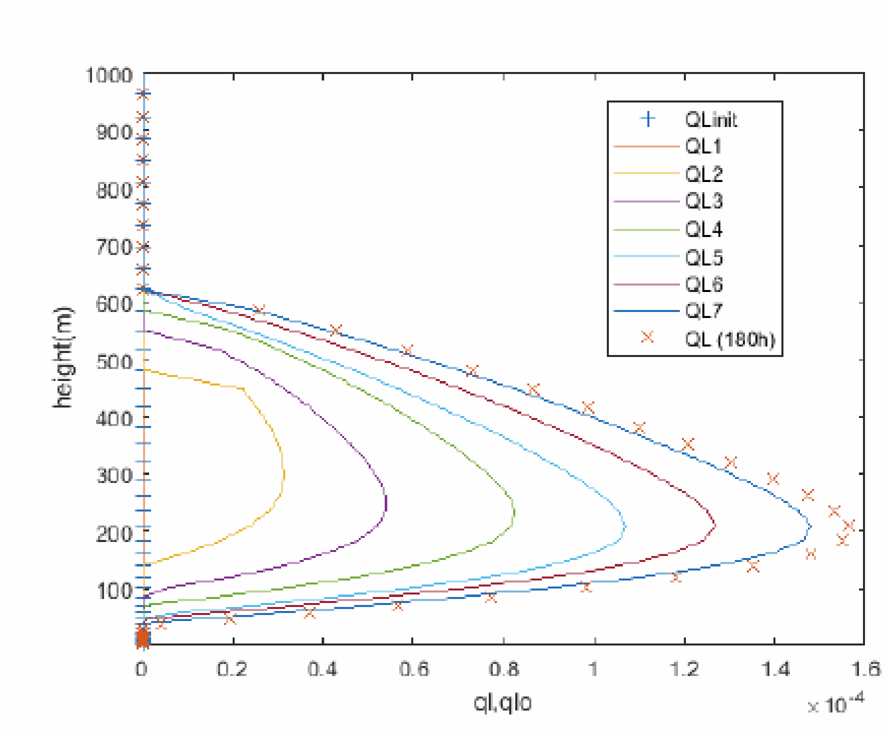
The position of the arrow in the temperature-height diagrams represents the temperature of the sea.

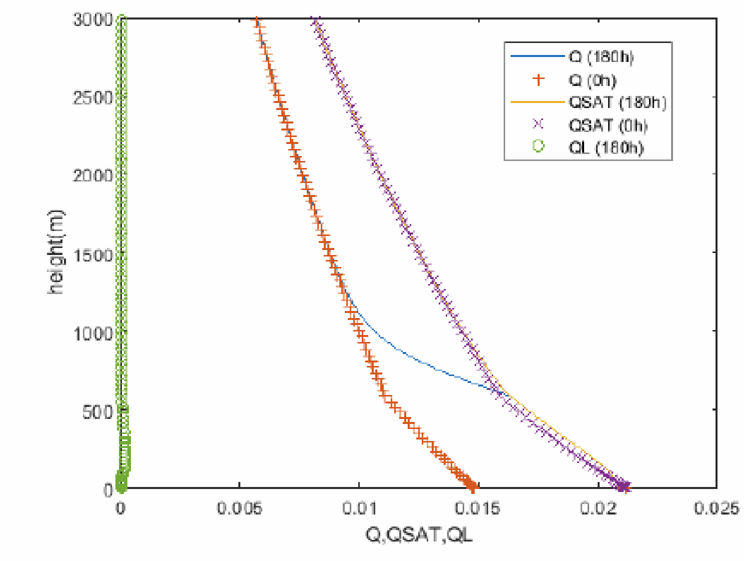
Fig. 8.

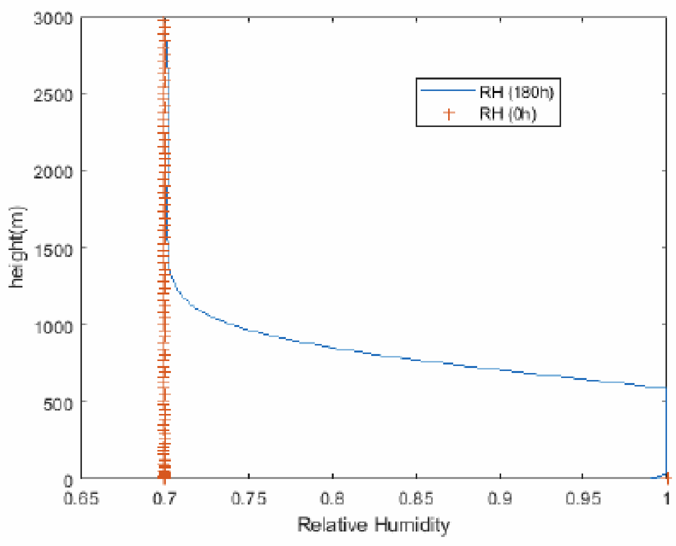
Typical profiles have saturated adiabatic T(z).

Revised Stage 2 runs. Stable temperature gradient above 600m. This limits vertical expansion of cloud and QL max increases. QLn is after n days.



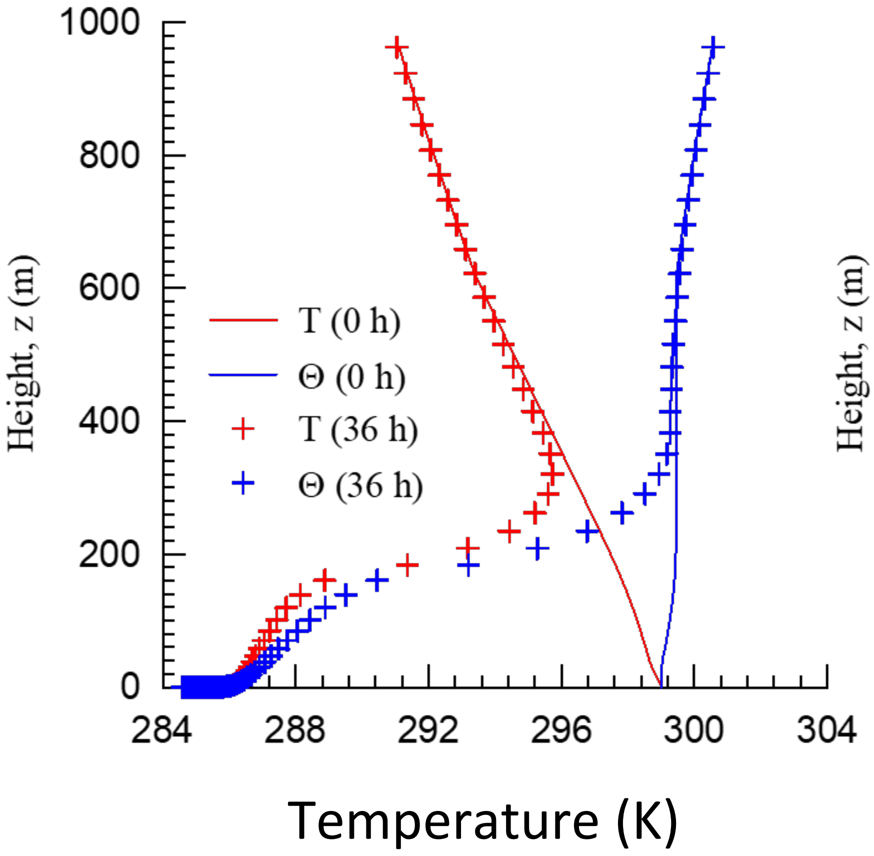


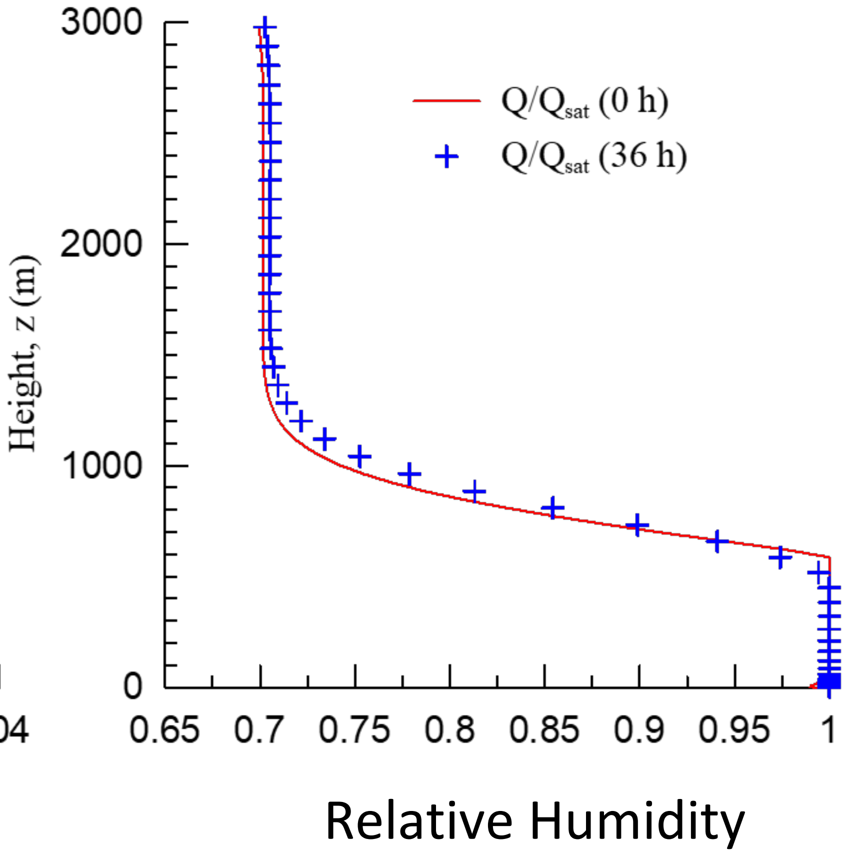


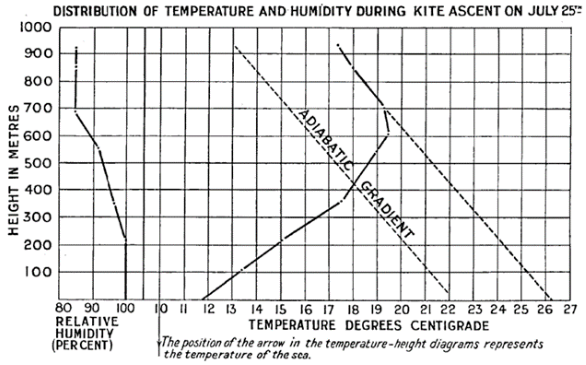


Can also look at Q, QL and RH. Note QL = 0 and RH < 1 in lowest 30m.

# Then move on to Stage 3 - cool the water surface to 284.4K (11.3°C).



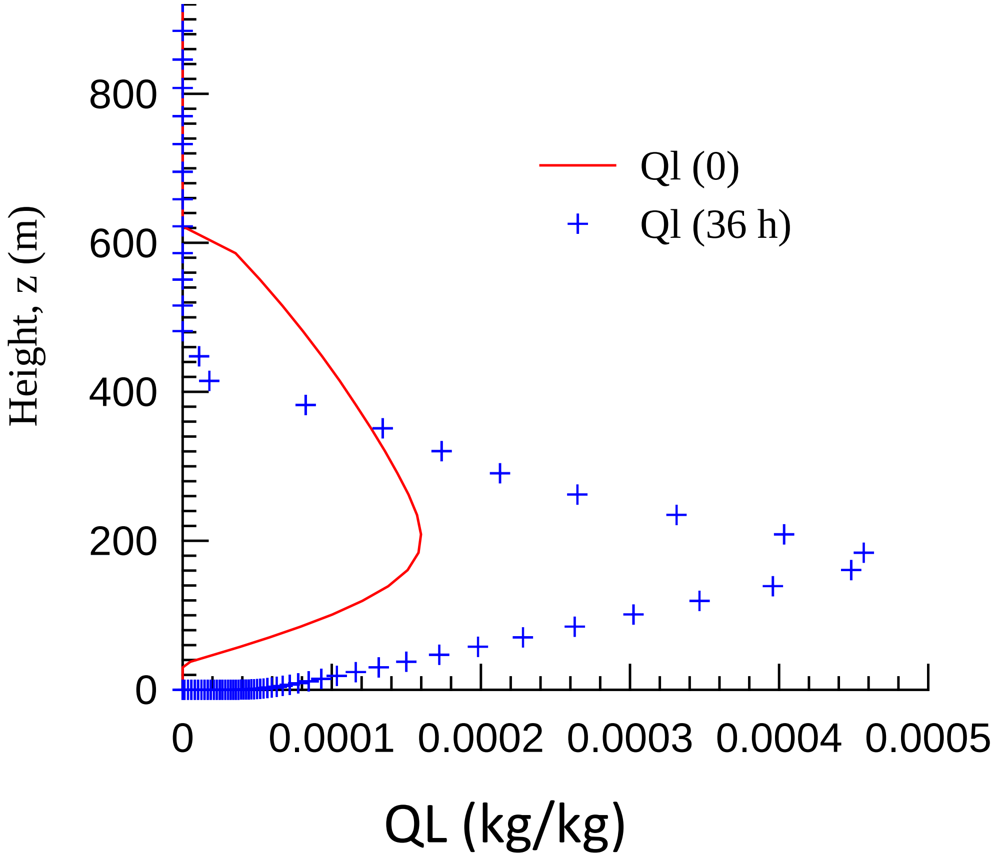


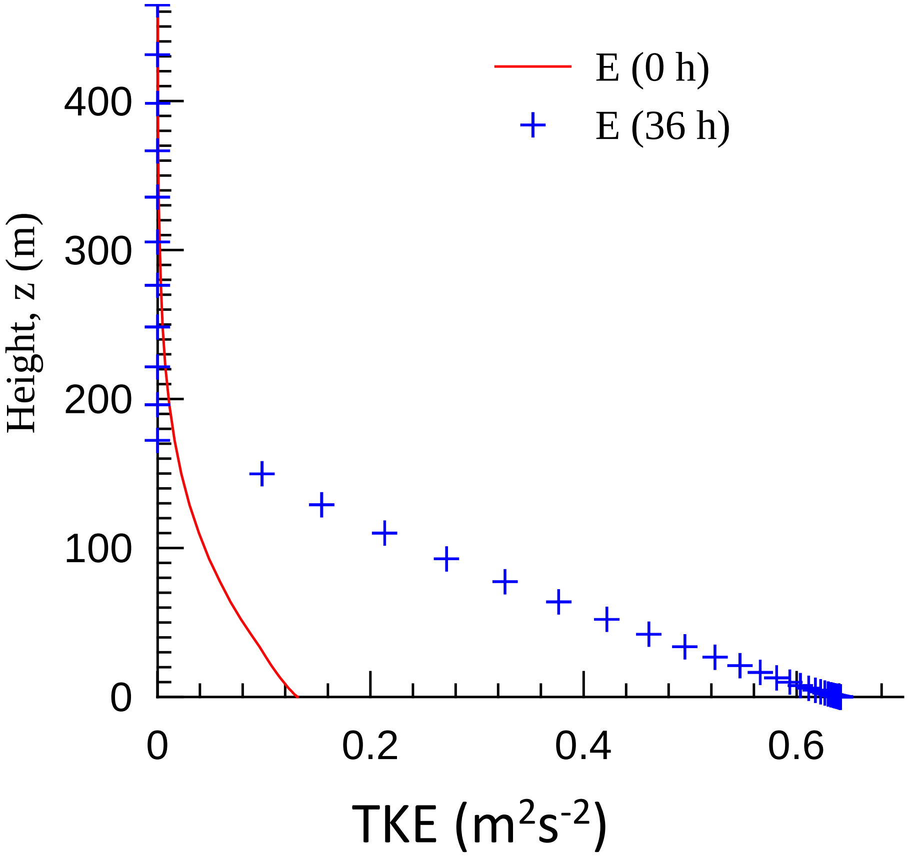


*The position of the arrow in the temperature-height diagrams represents the temperature of the sea.*

Fig. 8.

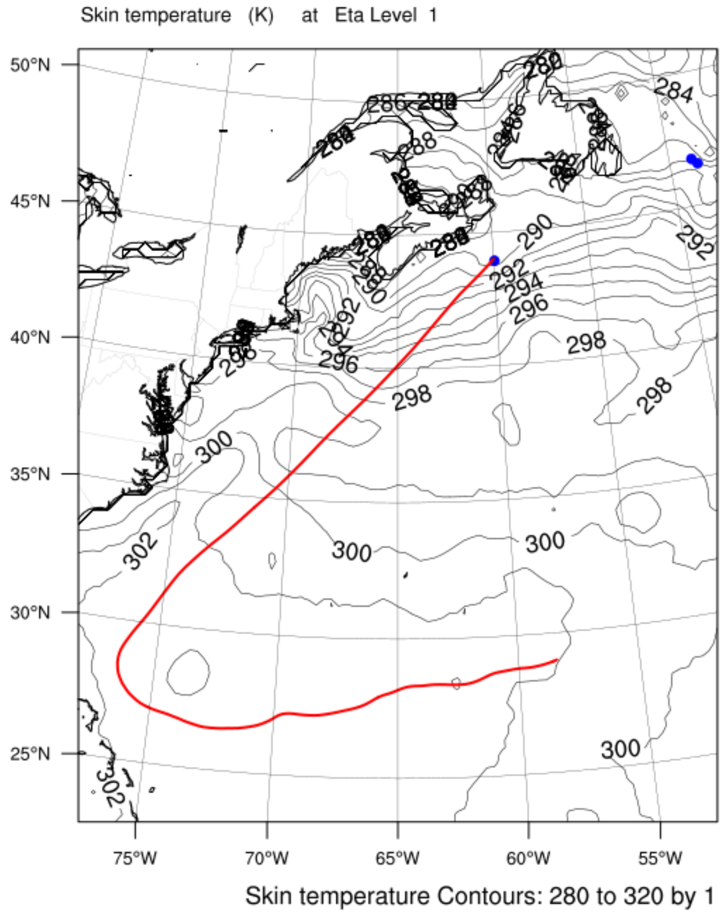
Note RH = 1 at surface and temperatures a reasonable match to G.I.Taylor profiles





Lower boundary condition is QL = 0 but fog down to the surface. QL mixing ratio shows considerable variation with height, from 0 at the surface to a peak of about 4.5 x 10-4 (0.45 g/kg) at approximately 200m and then dropping to 0 above 500m. Near surface values at 2m (the normal fog reporting height) are near 0.055 g/kg. Typical liquid water mixing ratios in fog are generally less than 0.1 g m-3, although clouds can have values of order 0.4 g/kg.

Next steps.


Skin temperature (K) at Eta Level 1

Skin temperature Contours: 280 to 320 by 1

1) Apply same methods to Fatima data. Zheqi and Clive Dorman have back trajectories and initial soundings could be from Bermuda. Also use Ug time series along the track. Compare with profile observations at Sable and from research vessel near Grand Banks.

Especially vertical profiles!

2a) Improve model Q/QL adjustment routine - risk of -ve QL! Could be a problem with a warming water surface.

2b) Add radiative flux divergences, especially at fog/cloud top.

3) For some situations consider Ud/dx rather than d/dt - steady state 2D model and look at the "fog shadow" downwind of Sable Island.

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