

Royal Meteorological Society: Australian Branch meetings

2 July 1981 — Oil under ice

G. Weller

The three great problems facing the world today are those concerned with the availability of energy — particularly liquid fossil fuel — fresh water and food. There is also rising concern with the need to protect the environment. A very good opportunity was provided at this Branch meeting for members to hear at first hand something of the problems, and the work being carried out in Alaska, where a 'super giant' oil field — believed to contain as much as 10 billion barrels — was first discovered in 1968 and is now in full-scale production. The oil field is located at Prudhoe Bay on the north coast of Alaska in latitude 70°N. Offshore exploration in this area has also discovered large reservoirs of petroleum. While this type of problem may not be of immediate concern to Australia, there is no doubt that because of the high probability of oil being found in offshore areas of the Antarctic continent — in sectors to which Australia makes territorial claims — it may well not be too long before Australian scientists become very directly concerned, given the pace of modern development.

The University of Alaska at Fairbanks carries out environmental research associated with the Alaskan offshore oil development under contract to the US National Oceanic and Atmospheric Administration (NOAA), and Professor Weller has been specifically involved in this for the past five years or so. He prefaced his talk by stressing the inter-disciplinary mix of activities and studies which are involved, e.g. in the fields of glaciology, oceanography, biology, engineering, as well as in meteorology.

The oil presently being recovered is piped via a 48-inch diameter pipeline over a distance of some 800 miles (1200 km), crossing three mountain ranges, to an ice-free port from which it is transported by super-tanker to the industrial centres in the eastern USA. Liquid natural gas, which is also recovered, is injected back into the wells to increase oil production, but there are plans to construct another pipeline across Canada so that the LNG would also be available for use. Also, plans are in existence for the development of ice-breaking super-tankers for the direct transport of oil and gas from the Canadian High Arctic.

Considerable environmental problems are presented by the nature of the terrain, a tundra

surface, north of the tree line, where the operation of vehicles causes considerable surface damage. This is overcome for roads by laying down a layer, or, for the operation of installations such as drill-rigs, a pad, of gravel 1 to 2 m thick to insulate the tundra from the effects of the industrial activity — which is carried on throughout the whole year — sometimes in air temperatures down to -50°C.

For exploratory oil drilling offshore, the engineering practice is to construct artificial-fill islands of gravel or sand on the continental shelf in water up to 25 m deep, or to use drilling ships. The latter must be given ample warning of storms, and good (ocean or atmospheric) ice-risk forecasts are vitally important. The depth of the ice masses requires the oil well-heads to be located in silos on the sea-bed. The problem of overriding ice is met by building gently sloping protective banks on which the ice rises and breaks up.

The environment is in a delicate state of balance, and contains diverse forms of flora and fauna. In addition the politically influential Eskimo populace demand that their life-style is not adversely affected. Any possible oil pollution has to be viewed in the context of an international — not simply a national — problem.

Against this general background, Professor Weller then proceeded to briefly examine the problems presented by ice, others which more directly concern oceanographers and meteorologists, and finally those that would have to be faced in the event of an oil spill.

Firstly for the Arctic Ocean area, the loss of the US ship *Jeanette* in 1881 was recalled, and the finding three years later of some of the wreckage near the southern-most tip of Greenland more than 3000 miles away which showed the steady oceanic drift across the Arctic Ocean. The oceanic work subsequently done by Nansen in the *Fram* has scarcely been equalled since. The continental shelf on the north coast of Alaska is only some 100 km wide, and the water in the Beaufort Sea is very deep. In all a reasonable picture has been built up of the large-scale oceanic circulation in the Arctic Ocean.

The Arctic sea ice varies in thickness, with a mean of 3 to 3.5 m. It is constantly in motion as shown during AIDJEX (Arctic Ice Dynamics

Joint Experiment) when leads opened up several times through established stations.

On the continental shelf there is a relatively stable fast ice layer close to shore but further out heavy ridges, some 10 m high and so deep as to be dragged across the sea-bed, are caused by the ice shearing past the coast. Outside this is the moving and heavily ridged pack ice zone. This is a difficult area in which to drill for oil, although the shore-based fast ice is relatively flat and provides a good platform. Airborne laser profilemeters are used to assess the ice roughness to determine the ridging intensity, which reaches a maximum some 50 to 60 km from the coast.

Satellite photographs and buoys deployed by aircraft are used to study the ice motion. The buoys also provide meteorological data which are collected via satellite. Radar transponders are used for smaller scale motion, and the combined information gives a good picture of the overall ice movement.

Overriding ice presents a particular problem. A combination of oceanic and meteorological events can lead to ice sheets overriding beaches, moving some hundreds of metres inland and causing significant damage. Similar behaviour over an artificial-fill island is obviously of major concern. Experiments have been carried out on the strength properties of ice.

Gouging of the sea-bed by ice can be as deep as 5 to 6 m, hence the well-head silos have to be positioned accordingly. Ocean currents, wind (or both), carry the ice in a wide range of directions. Sonar records permit assessment of the risk of gouging to a pipeline or underwater installation.

Permafrost on this section of the Arctic coast is about 800 m deep i.e. the temperature down to that depth is 0°C, and any water in the layer is frozen. Shallow seismic refraction techniques have been used to assess the wide variation in the structure of the permafrost layer — important for determining the position, say, of a pipeline where the transport of oil, hot from the well, would lead to melting in the permafrost layer.

The coastline in this area is highly dynamic and even a single storm shifts such a large volume of gravel or sand that any modelling involving the coast becomes most complicated. This problem demands extensive protection measures for any installations.

Oceanic studies are conducted by cutting large holes through the ice, through which current meters etc., can be lowered. Ice blocks extracted in this procedure can show extraordinarily large amounts of sediment embedded in the ice — the sediments being stirred up by the summer and autumn storms, becoming frozen-in when the ice

forms. In addition to affecting the strength of the ice itself, this behaviour is of biological interest because of the effects on the light transmitted through the ice. Vertical transport of material in this way would of course be relevant if oil were spilled.

In spring, melting occurs first in the foothills of the mountain range (Brooks Range) to the south, where the temperatures are higher than on the coast, and the fresh water overflows the sea ice and markedly affects the salinity conditions changing from super-saline to completely fresh water. Ocean drift is assessed by releasing cards over the ocean, and the dispersion of pollution would be entirely determined by the wind.

Beach debris provides useful guidance on storm surges — the maximum height of which is about 2 m.

Weather forecasting in this area is very difficult — there are only two first-class stations, Barrow and Barter Island, 500 to 600 miles apart. So far weather forecasting has not been a very significant factor, but later on, particularly when oil rigs are established in the ocean, ice forecasting will become particularly important.

Should oil leak or be spilled, it could collect or be trapped in pockets under the ice, and recovered by drilling. Trajectory modelling has been used to determine where spilled oil might go but there is no technology at present available for cleaning up an oil spill in moving pack ice.

In reply to questions, Professor Weller said that the work under discussion had been in progress for about the past five years — at an annual cost of some \$5 m — not a high amount having regard to the magnitude of the operation. US practice is for industry to lease an area or tract from which it seeks to maximise the return. The problem is to determine areas where activity should be prohibited or conditions imposed to eliminate any risk of adversely affecting the environment. The Secretary for the (US) Department of the Interior is the legal controlling authority — and decisions are made in the light of advice from NOAA which sub-contracts the work to organisations like the University of Alaska. So far Alaskan operations have been carried out with no serious or major catastrophes. The pipeline was very carefully engineered — costing some 9 billion (US) dollars.

Professor Weller used excellent slides and diagrams to illustrate his interesting and well-prepared address. Branch members are indeed fortunate to have had this opportunity of hearing something of the wide range of problems encountered in this type of field activity.

H.R.P.

6 August 1981 — What have general circulation models told us about the atmosphere?

B. G. Hunt

Mr Hunt began his well-attended talk by presenting a verbal sketch of general circulation models (GCM). He explained that they are based on the **precise** three-dimensional partial differential equations relevant to fluid flows and thermodynamics and include the effects of radiation, dissipation, convection, oceans, boundary layer processes and many other features. The speaker said that GCMs seem to excite strong support or violent dislike in the meteorological community. Three points often made by the detractors of GCMs are that they use a lot of computer resources, that they are not perfect and that they are considered to be 'monsters'. The speaker pointed out that GCMs are usually run in non-prime time when computers would be idle anyway. While conceding that the models are not perfect, Mr Hunt pointed out that the development of GCMs is still in its infancy. The models will be, and are getting, better. As for the fear of models, the speaker asserted that models, and their designers, are most approachable.

Many different aspects of the use of GCMs in the study of the atmosphere were mentioned and illustrated by research findings over the last two decades. Examples were shown of models predicting atmospheric structure in hard-to-observe areas (e.g. the upper atmosphere) which was at variance with accepted ideas at the time. Subsequent vindication of models by better observations led to a rethinking of some of the conventional meteorological wisdom.

Other examples were presented in which GCMs were used in controlled sensitivity studies. For many observed phenomena (e.g., sudden stratospheric warmings, drought) there may be a number of possible causes. Using observations or theoretical analyses it may be difficult or impossible to determine the relative importance of those possible causes. By systematically eliminating effects from a model it is usually easy to isolate the dominant mechanism.

The speaker also indicated that there is much to be gained by considering the output of a GCM as a (homogeneous and complete) data set. Sampling such 'sets' at points equivalent to the present data network gives much information of analysis errors made with the present observing stations and allows quantitative assessment of the value of adding new stations. Such sets can also give guidance to observational programs in advising where, when, how often and for how long to observe atmospheric quantities.

In conclusion, Mr Hunt spoke of the use of GCMs in climatic impact studies, such as the future response of the atmosphere to an increase in airborne CO₂. He asserted that the GCMs are the only quantitative predictive method so soundly based and that the only limitations to their use are the intellect and timidity of the people who run them.

I.S.

