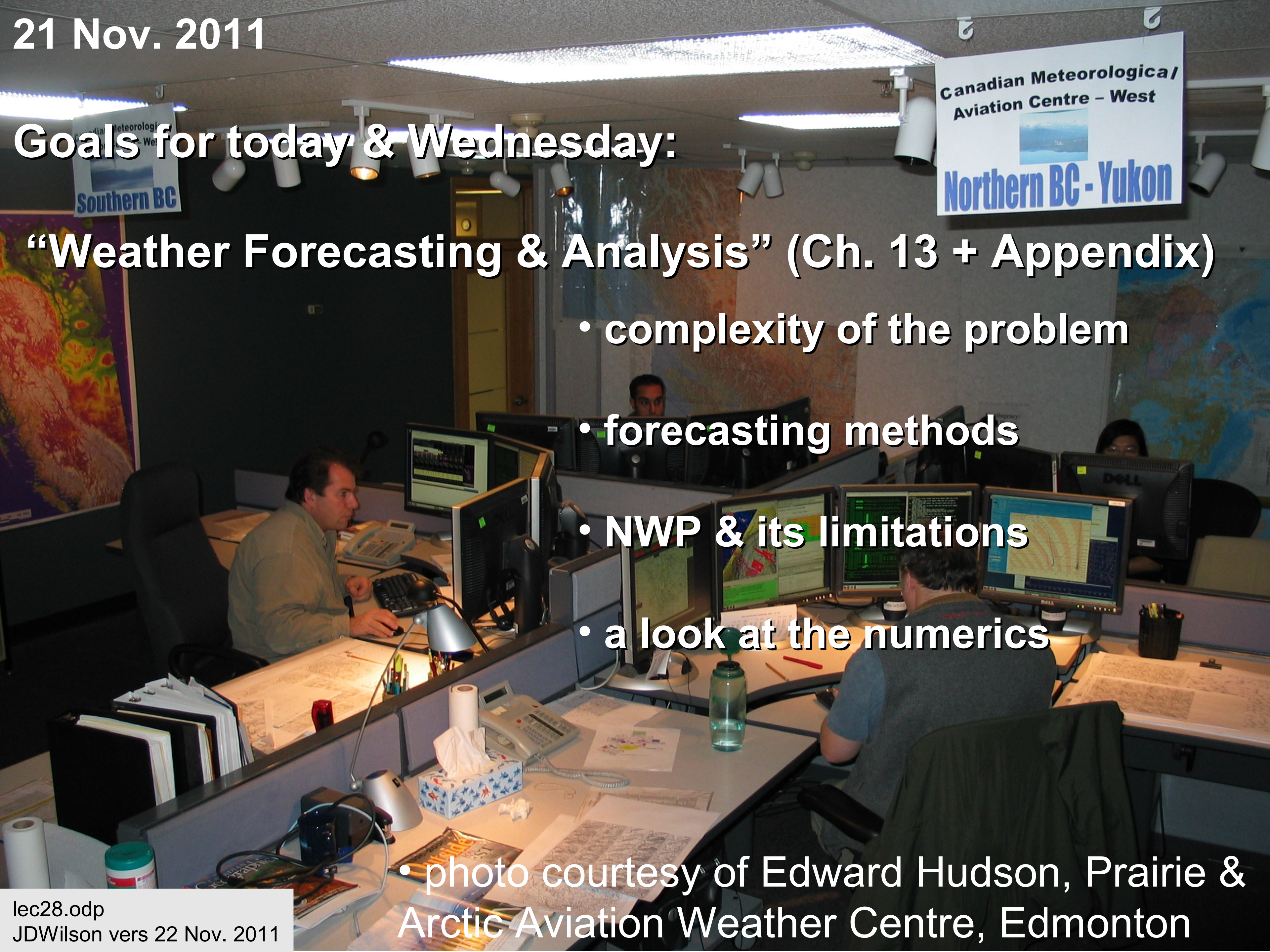
21 Nov. 2011

Goals for today & Wednesday:

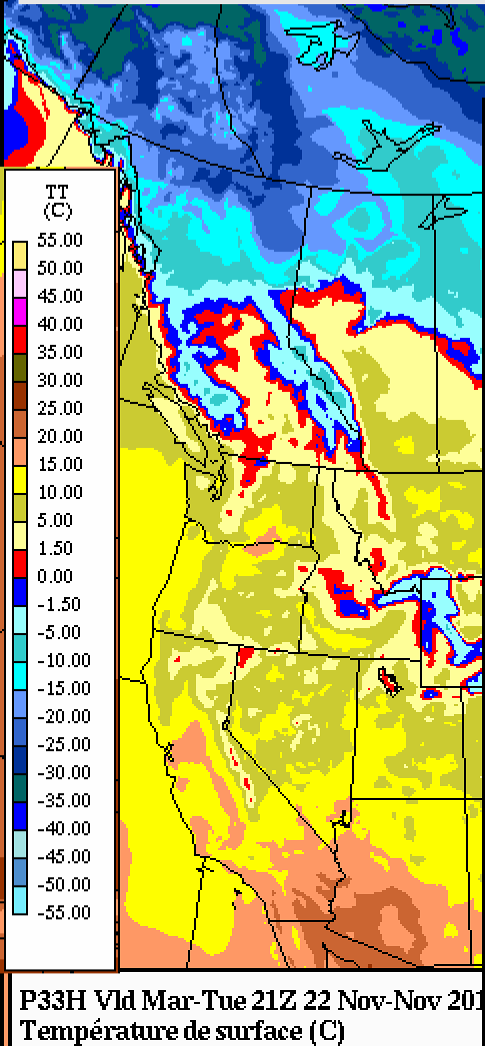
"Weather Forecasting & Analysis" (Ch. 13 + Appendix)

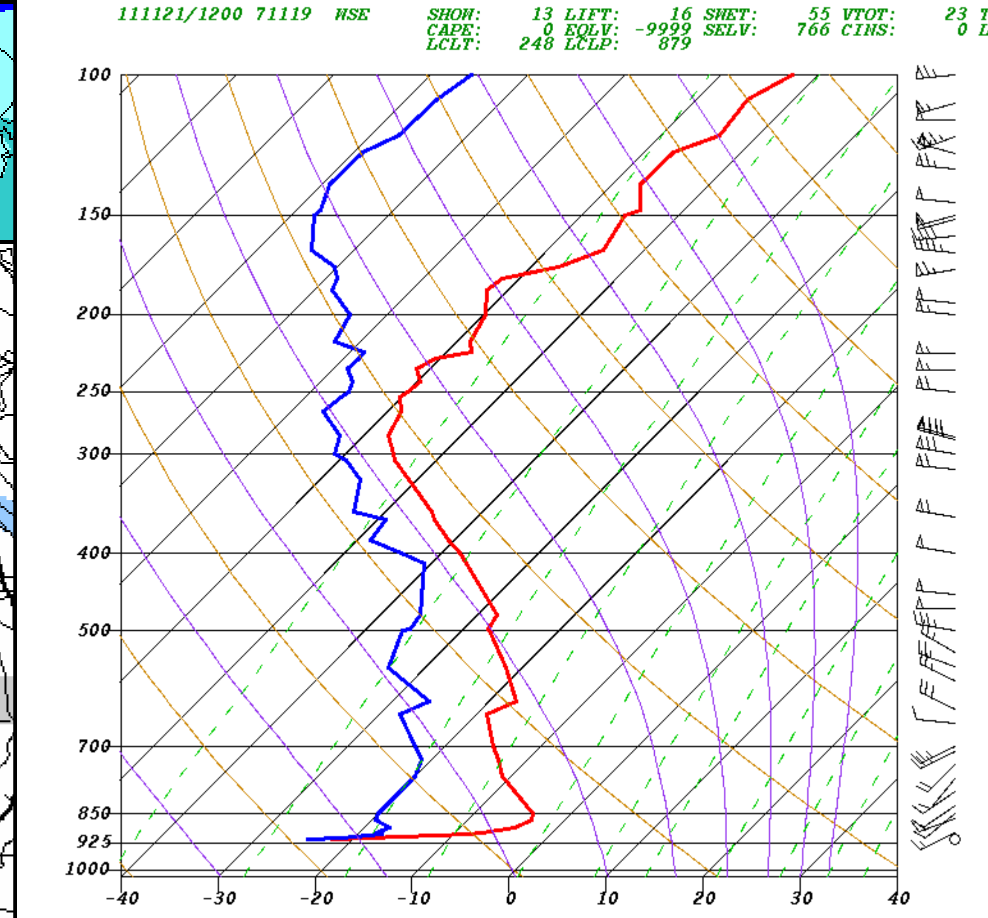
- complexity of the problem
- forecasting methods
- NWP & its limitations
- a look at the numerics

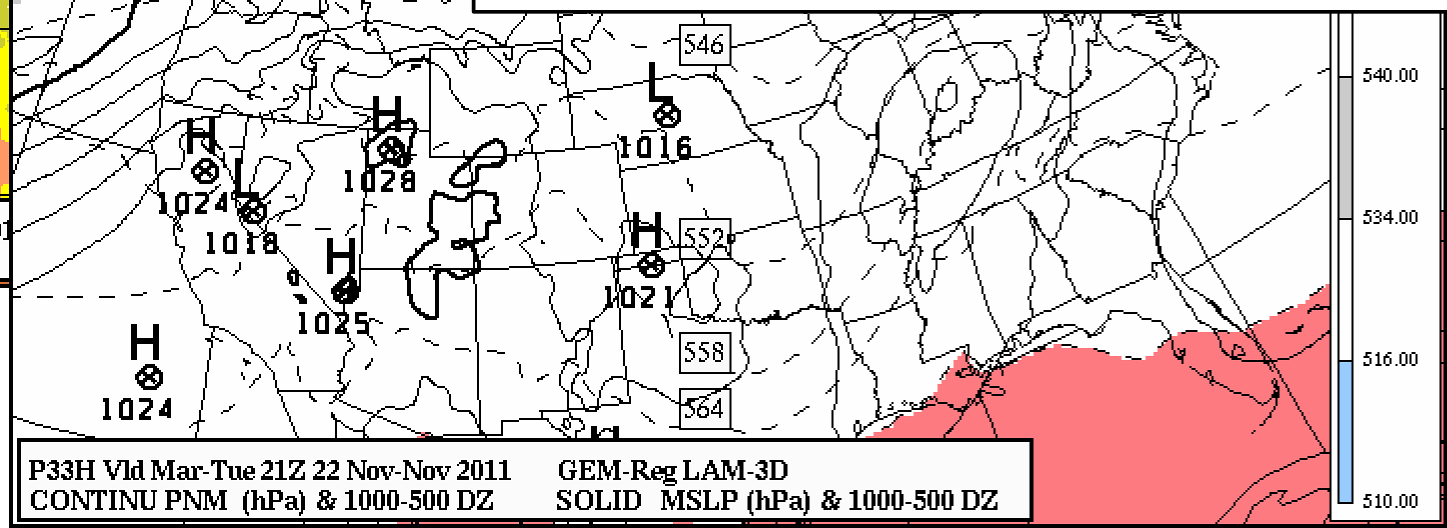


• photo courtesy of Edward Hudson, Prairie & Arctic Aviation Weather Centre, Edmonton

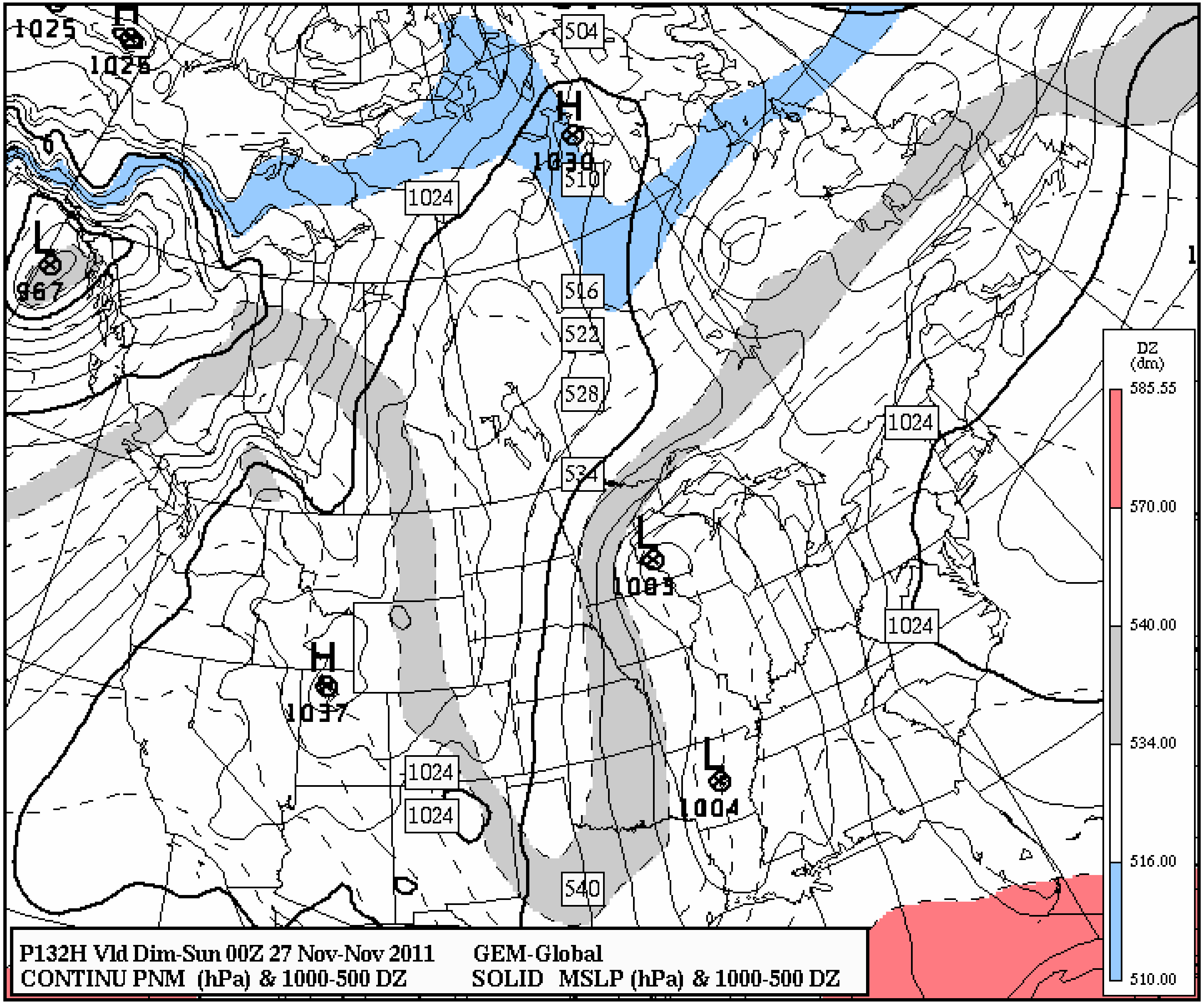
- much warmer air aloft
- warmer tomorrow (above frzg)







• another incursion of mild air forecast for next Saturday

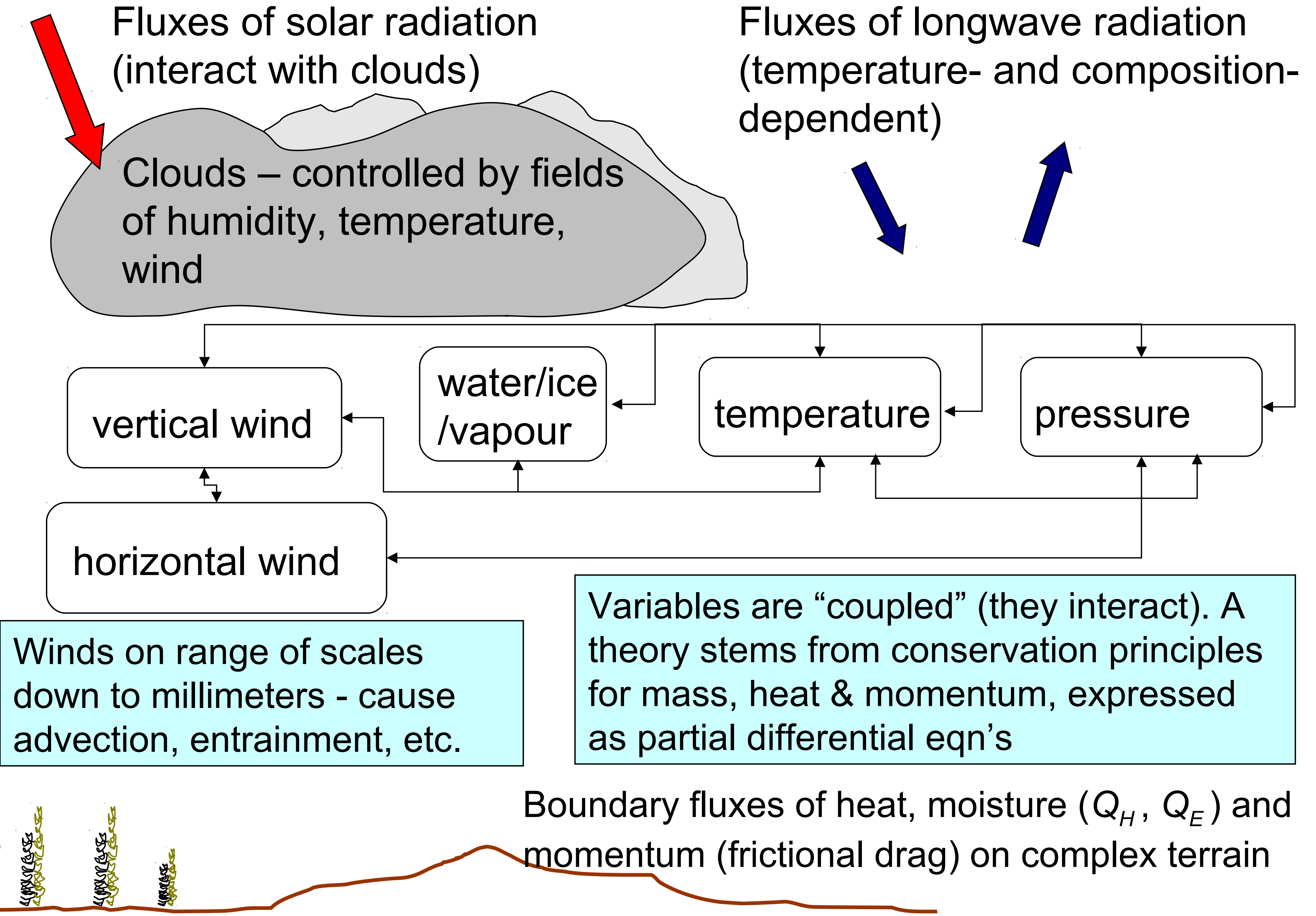


• lee trough – windy

RAIN FELL FROM overcast skies and gale force winds drove large waves on to the beaches of Normandy as dawn broke on Monday June 5, 1944. To the Germans watching their defences, there was nothing to show that this was the moment the Allied Armies had planned to invade Europe. In fact, the operation had been put on hold because the bad weather had been forecast 24 hours before. Had it gone ahead in these conditions, the invasion would have been a catastrophic disaster.

Nevertheless, the invasion had to occur on either the 5th, 6th or 7th of June to take advantage of the right conditions of moon and tide. Darkness was needed when the airborne troops went in, but moonlight once they were on the ground. Spring low tide was necessary to ensure extreme low sea level so that the landing craft could spot and avoid the thousands of mined obstacles that had been deployed on the beaches. If this narrow time slot was missed, the invasion would have to be delayed for two weeks.

From "The Most Important Forecast in History," by E. Brenstrum (N.Z. Meteorological Service). Published in *New Zealand Geographic*, pp11-16, Vol. 22, 1994. For modern NWP forecasts for the Normandy (D-day) landings – based on data available at the time – ecmwf.int/research/era/dday/



Slide 3 – Complexity of weather forecasting (p416)

Forecasting** methods

** also "nowcasting" & "hindcasting"

Value of a given technique depends on "range" of the forecast. For now, focus on "weather" forecast… ie. range of up to a couple of weeks

Climatology: hard to beat for f/c ranges beyond about 10 days.

• "The average." eg., this afternoon's weather in Edmonton will equal the average observed 1961-1990 for Nov. 26 in Edmonton

• or, (eg.) this afternoon's weather will be that associated with one of a set of "map types," ie. previously observed on an afternoon having similar maps. Called an "analog approach"... Ah! We've seen this before… in 1901 …

• or, forecast the anomaly associated with (eg.) Southern Oscillation Index

Persistence: hard to beat for f/c range of a few hours

- eg. This afternoon's weather same as this morning's, except for influence of local processes (eg. solar heating)

"Causal" weather prediction (pre-computer age)

- Detailed analysis of "initial state," using hand-plotted weather maps & charts

- Interpretation using rules and conceptual models (such as Polar Front theory, etc) having a physical basis, eg.
  - atmospheric stability
  - air-sea interaction
  - local diurnal cycle - surface energy balance

- Richardson's pioneering hand-computation

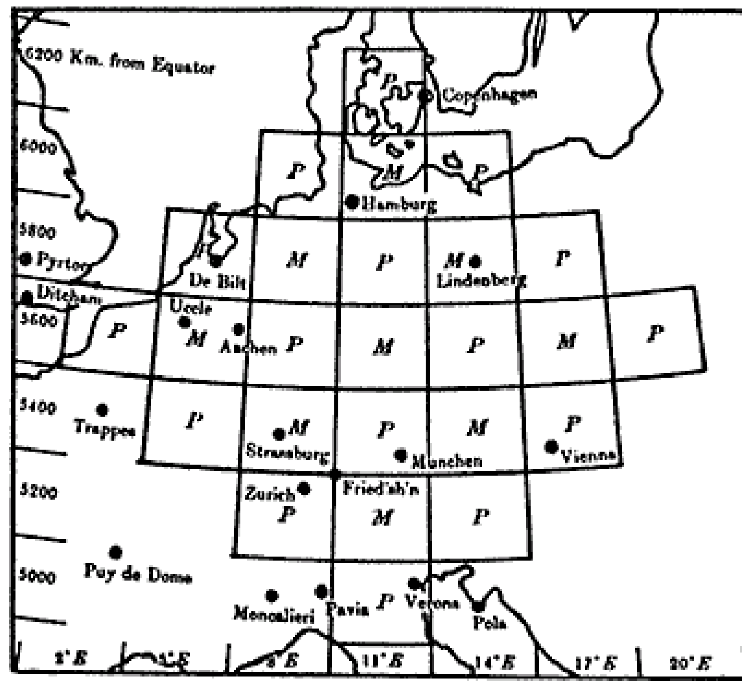
Lewis Fry Richardson (1881-1953)

- applied calculus to help Nat'l Peat Co. cut drains in peat
- 1913 joined Meteorol. Office (supervised an observatory)
- ambulance driver, WW1 France
- in off-duty time, embarked on test of his mathematical forecasting system… had taken with him to France observations for 7 a.m., 20 May 1910.
- by 1916, wrote *Weather Prediction by Arithmetic Finite Differences*… published 1922

"Causal" weather prediction (pre-computer age)

Richardson divided a map of Europe into squares… for each he tabulated atmospheric pressure… armed with a slide rule and mathematical tables, he began the laborious task of "forecasting" what was going to happen to the weather at 1 p.m. on his selected day… producing by hand a six-hour weather forecast which he could check against observations. For each square on his map, he applied his numerous equations, to calculate changes of pressure, wind and temperature… The six-hour forecast took him six weeks. And when he had finished, the forecast was horribly wrong.

Images and quotation from P. Holper, Australian Broadcasting Corp., www.abc.net.au/science/slab/forecast/story.htm



Numerical Weather Prediction

- based on the physics as expressed in equations… conservation of mass, momentum, energy + equations of state + (etc.)

- set of coupled "partial differential equations" for *U,V,W* (the three velocity components) and *T,Q* … versus *x,y,z,t* (or more typically latitude, longitude, pressure and time – 4 dimensions, "4D")

- these equations solved numerically given "initial" and "boundary" conditions (eg. sea surface temperature + much more)

- solution gives gridded fields of *U,V,W,T,Q*,…i.e. 3-dimensional view

- in order to produce a final forecast, numerical output is supplemented by rules of thumb, statistical packages, subjective guidance

Stages in NWP

Even the “regional run” has global domain. Ahren's (p391) is incorrect on this point (see Tech. note)

- Data acquisition
- Analysis phase
- Initialisation ($t = t_0$)
- Prediction phase (numerical integration)
- Post-processing phase

Canada’s “GEM” weather analysis/forecast model (“Global Environmental Multiscale”) developed and run by Cdn. Meteorol. Cntr. in Montreal on supercomputer

GEM is run 4 x daily in a “regional configuration” for which the grid spacing over N. America is 15 km. It is run 2 x daily in “global configuration” with a coarser 33 km resolution over N. America

The decision to postpone the invasion for 24 hours had been taken by Eisenhower and the Supreme Command at 0430 on Sunday June 4. It was not taken lightly, because so many ships were already converging on Normandy that the risk of detection was grave. Nor had the forecast which prompted the postponement been easily arrived at. Eisenhower's weather advice was provide by Group Captain Stagg, a forecaster seconded from the British Meteorological Office who was coordinating the advice of three forecasting teams: one from the Meteorological Office, one from the Admiralty and one from the United States Army Air Forces.

The advice of these groups was often diametrically opposed. The American team used an analog method, comparing the current map with maps from the past, and were often over-optimistic. The Meteorological Office, aided by the brilliant Norwegian theoretician Sverre Petterssen, had a more dynamic approach, using wind and temperature observations from high altitude provide by the air force, and were closer to the mark.

The decision to invade on Tuesday June 6, taken late on Sunday night and finally confirmed early Monday morning, was based on a forecast of a short period of improved weather caused by a strengthening ridge following the front that brought Monday's rain and strong winds. In the event, Monday's bad weather had already given the Allies a crucial advantage: it had put the Germans off guard.

From *New Zealand Geographic*, pp11-16, Vol. 22, 1994