Lecture 24   Weather Forecasting

- What should I wear today?
- How should the Forest Service fight a summer wildfire?
- Should Jack go skiing this weekend?
- Should Ace Hardware stock more umbrellas this fall?
- When should Paul Bunyan plant his wheat?
- How many snowplows does Seattle need?
- For what rate should Allstate insure homes on the North Carolina coast?
- Do we need to worry about global warming?

...require weather/climate forecasts for today, a few days, months, decades.

- How are forecasts made?
- How good are they?
- How good can they be?

We focus mainly on midlatitude weather forecasts out to a week ahead, where most progress has been made.

How are forecasts made?

1. Current weather conditions observed around the globe (balloons, satellites, surface, aircraft, etc.).
2. Observations sent over Global Telecommunications System to weather centers (In US, National Centers for Environmental Prediction, or NCEP, Camp Springs, MD).
3. Center quality controls and analyzes observations.
4. Computer model at center makes global or national weather forecast maps
5. Center disseminates observations and forecast information to public and private agencies, such as regional National Weather Service forecast offices (e.g. at Sand Point in Seattle).
6. Agencies use computer model maps and knowledge of local weather patterns to issue local and regional forecasts.
7. News media broadcast these forecasts.

Time is of the essence. In a miracle of technology and communication, 1-3 day forecasts are typically broadcast in US within 6 hours of the observations on which they are based.

Weather Observations

Weather is global, and requires global observations to forecast. Through the cooperation of 130 member countries, the UN World Meteorological Organization ensures uniform observation procedures and transmission protocols and free access to all available data.

<u>Data:</u>

Radiosondes -Wind, press.,temp., humidity profiles

Pilot Balloons -Wind profiles only

Satellites

- Geostationary - cloud track winds, cloud heights
- Polar orbiters - temperature profiles (1-2 km resolution)
  - humidity profiles (3-5 km resolution)
  - surface wind over ocean

Surface Observations

- Weather reporting stations over land
- Buoys
- Commercial ships and aircraft

Radiosondes (611)

Pilot Balloons (161)

James 1994

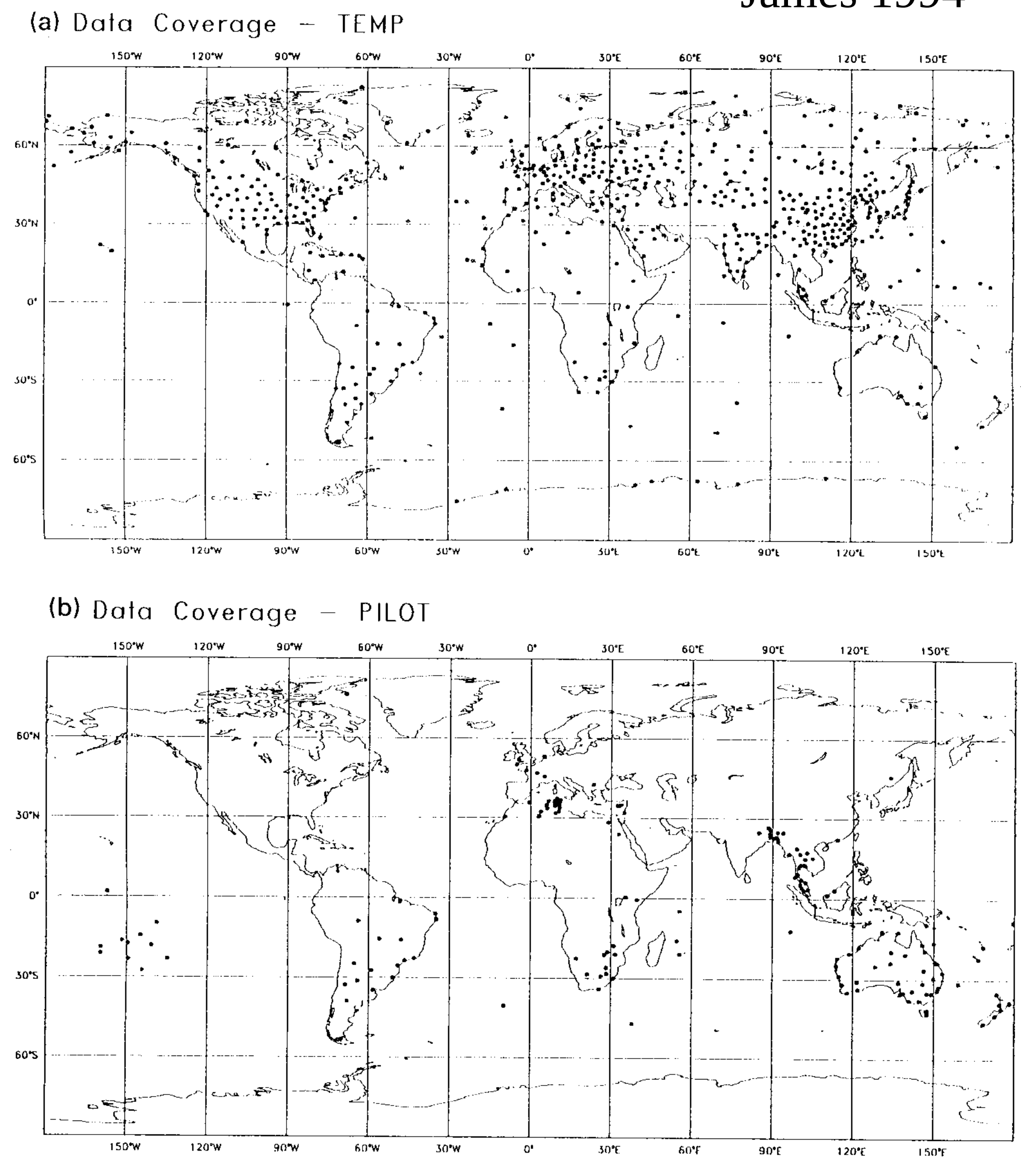


Fig. 2.1. Global distribution of (a) radiosonde (total number of observations = 611 (• 601 land, ∝ 10 ship)); and (b) pilot balloon ascents which were included in the routine analysis for 12.00 GMT on 29 October 1991 by the European Centre for Medium Range Forecasts (total number of observations = 161 (all land)). (Courtesy ECMWF.)

Land surface (6993), Ship (990), Buoy (369)

James 1994

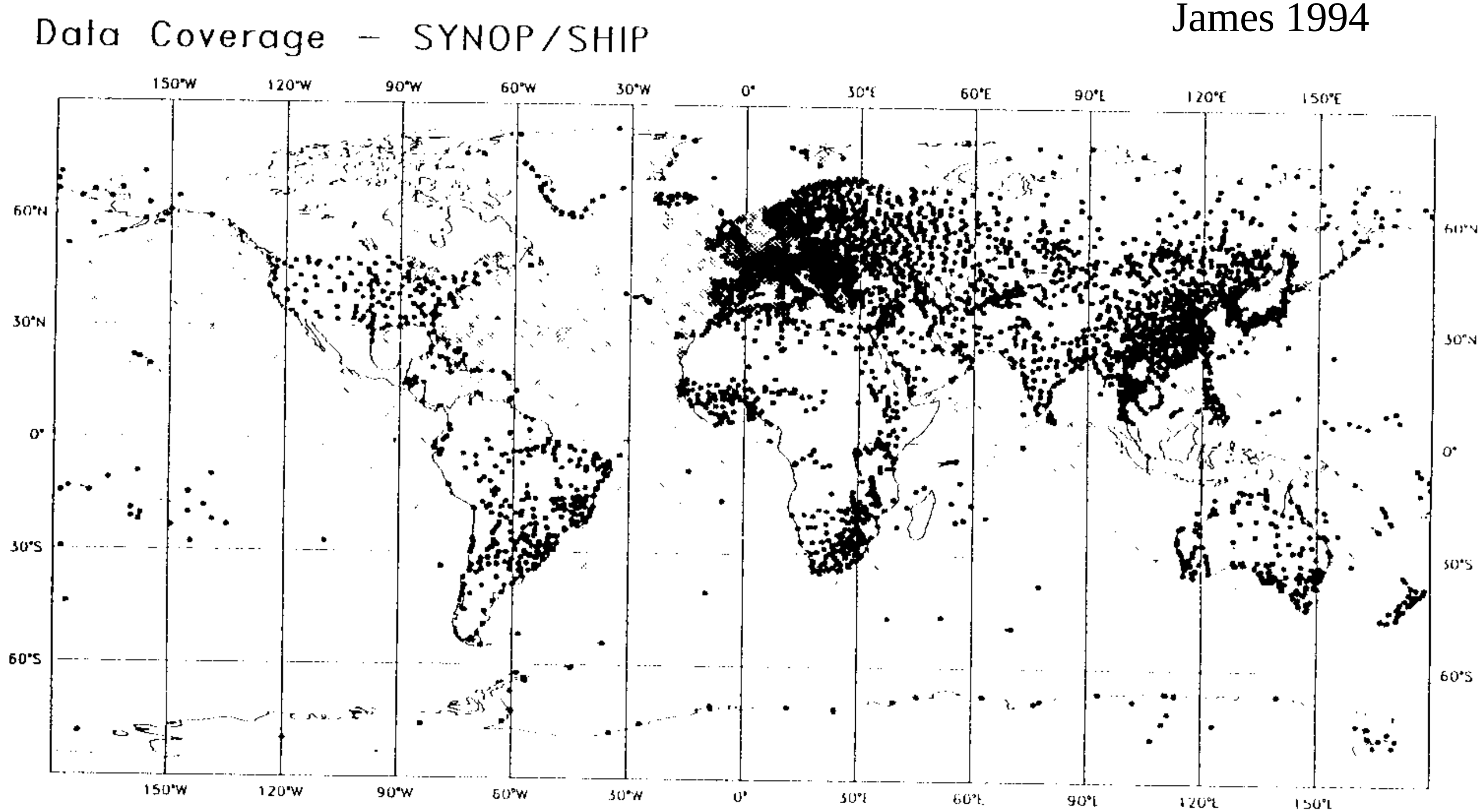
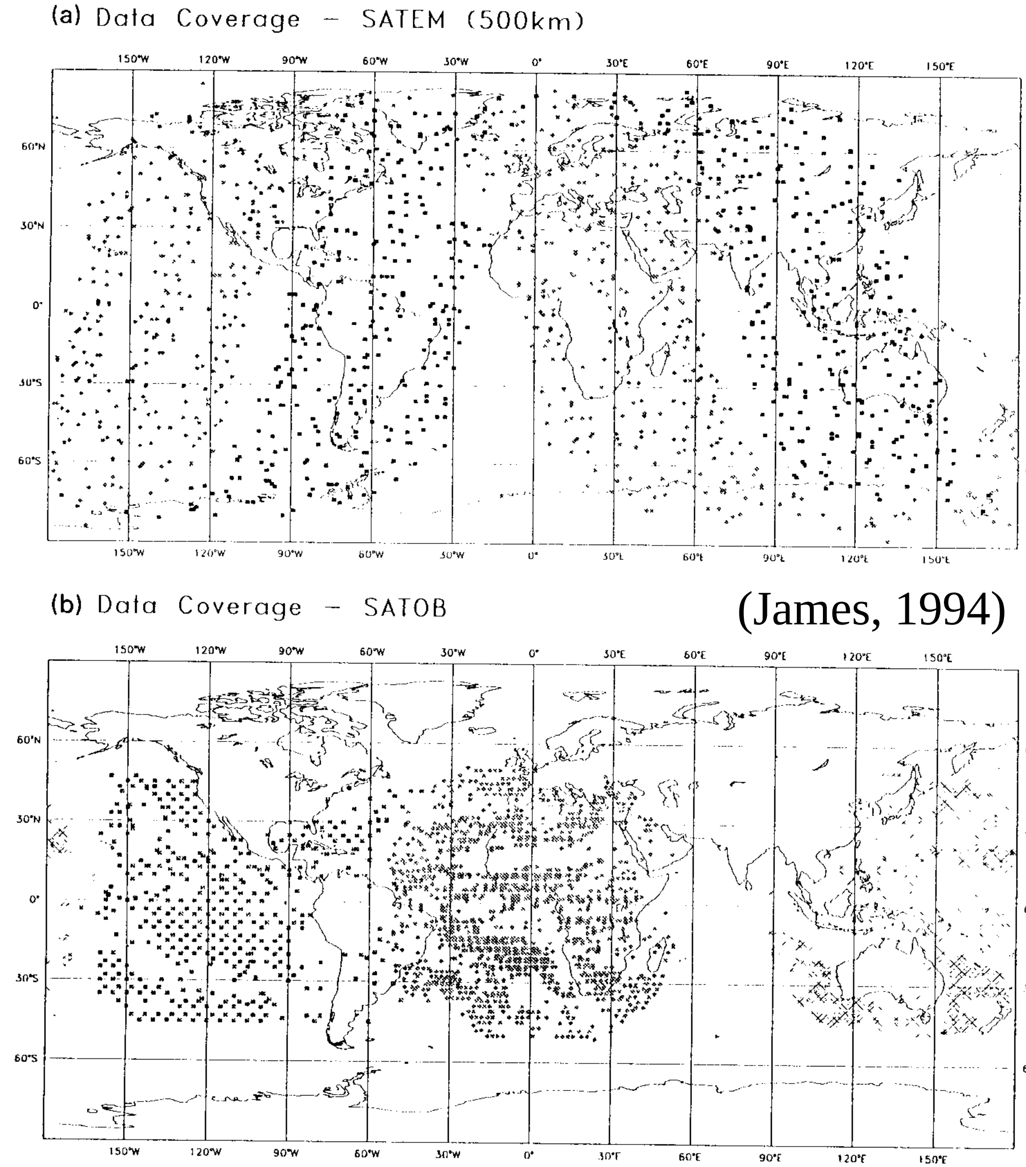


Fig. 2.2. The global distribution of surface observations, both on land and from ships, at 1200 GMT, 29 October 1991, used in the ECMWF analysis (total number of observations = 7983 (• 6993 SYNOP, × 990 ship)). (Courtesy ECMWF.)

Satellite temperature (1239)

Satellite winds (2414)



(James, 1994)

Fig. 2.4. Satellite data used in the 1200 GMT ECMWF analysis of 29 October 1991. (a) Temperature retrievals. Crosses indicate the NOAA 11 satellite and solid squares the NOAA 12 satellite (total number of observations = 1239 (× 674 NOAA11, ■ 565 NOAA12)). (b) Satellite winds from geostationary satellites (total number of observations = 2414 (■ 1472 METEOSTAT, × 522 HIMAWARI)). (Courtesy ECMWF.)

Aircraft (854)

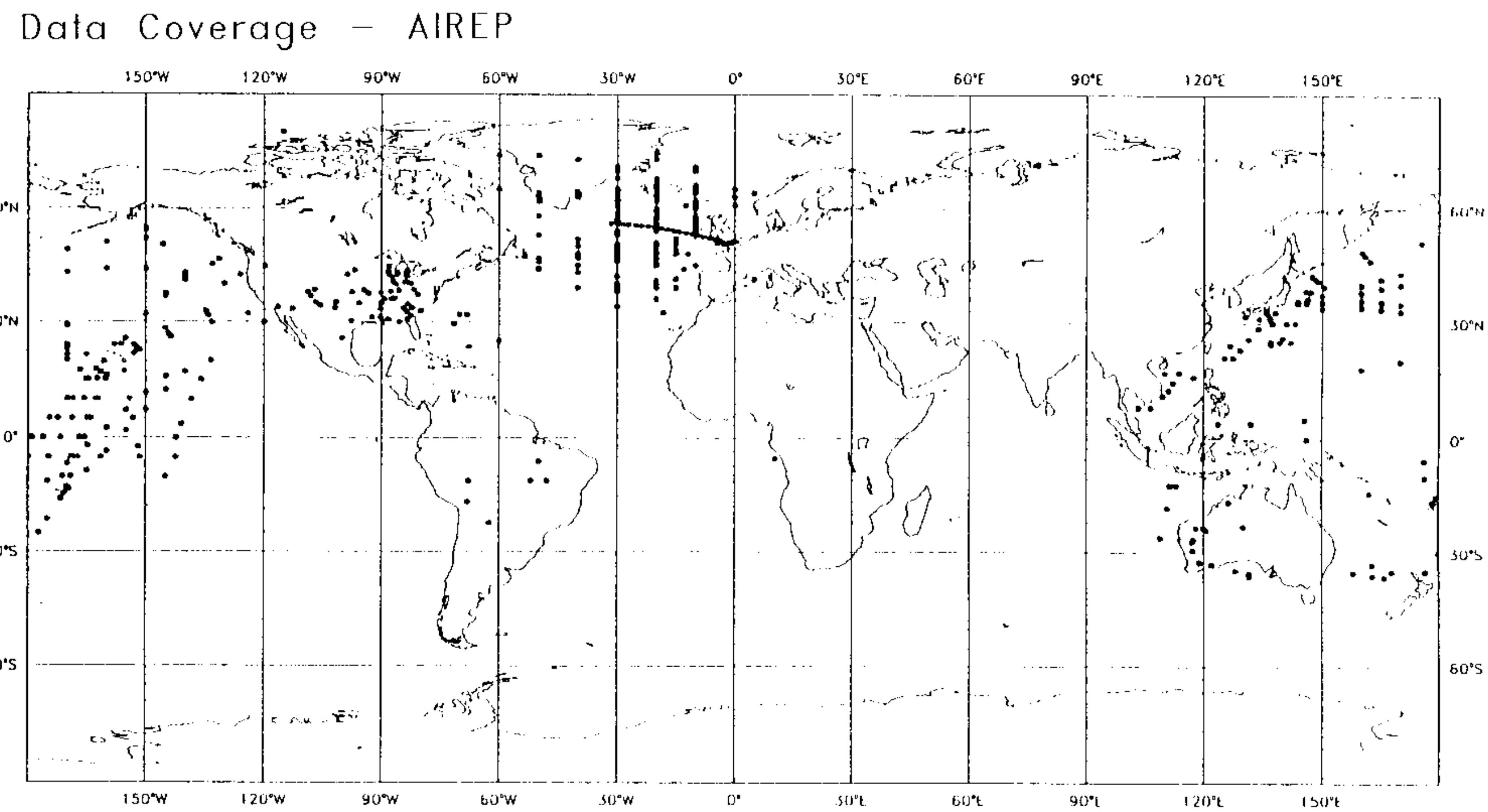


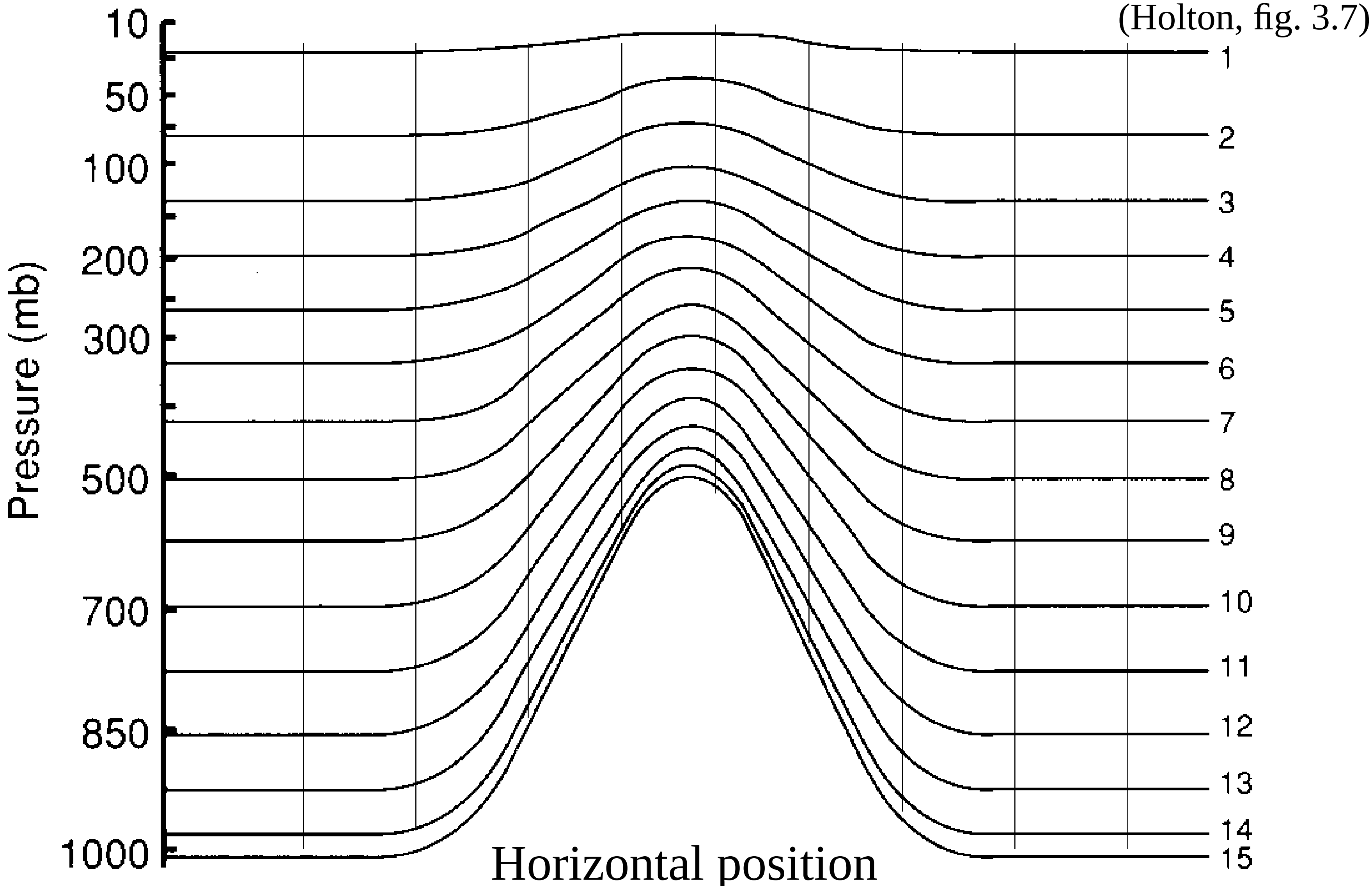
Fig. 2.5. Aircraft reports (AIREPs) included in the 1200 GMT ECMWF analysis of 29 October 1991 (total number of observations = 854 (all AIREP)). (Courtesy ECMWF.)

(James, 1994)

Numerical Forecast Model

- Atmospheric model uses mathematical equations to predict changes in temperature, humidity, pressure, winds, etc. due to airflow, precipitation, radiation, turbulence, friction, etc. These equations are *approximations* that represent to the best of our scientific knowledge the net effects of small-scale atmospheric motions on the larger scale motions that we can accurately observe.
- The model is formulated in terms of the atmospheric state at a set of grid points, typically at 15-50 height levels at up to 20,000 horizontal positions
- Using the observations, with the prior forecast to fill in gaps, the model starts with its best guess at the current atmospheric state at the grid points
- The model equations are solved, stepping the forecast atmospheric state 5-20 mins forward at a time.
- Billions of computations on the world's most powerful supercomputers go into a several day forecast.
- Forecast maps (500 mb height, 850 mb temp., precipitation, etc.) printed each 12 hours into forecast.

Forecast Model Grid



- Gridpoints are at box corners.
- Grid follows terrain.

Some Current Forecast Models

NCEP

Global Forecast System (GFS) model

global, run 4x daily out to 16 days. Grid points spaced at 50 km (distance from Seattle to Tacoma).

ETA model

Covers North America and adjacent regions, run out to 48 hours every 12 hours. Grid points spaced at 12 km; distance from Seattle-Bellevue. Runs in 2 hours.

UW/ Seattle NWS

Mesoscale Model (MM5)

Covers E Pacific, Western N America, run out to 72 hours every 12 hours. Grid points every 12 km across Pacific NW, 4 km over western WA.

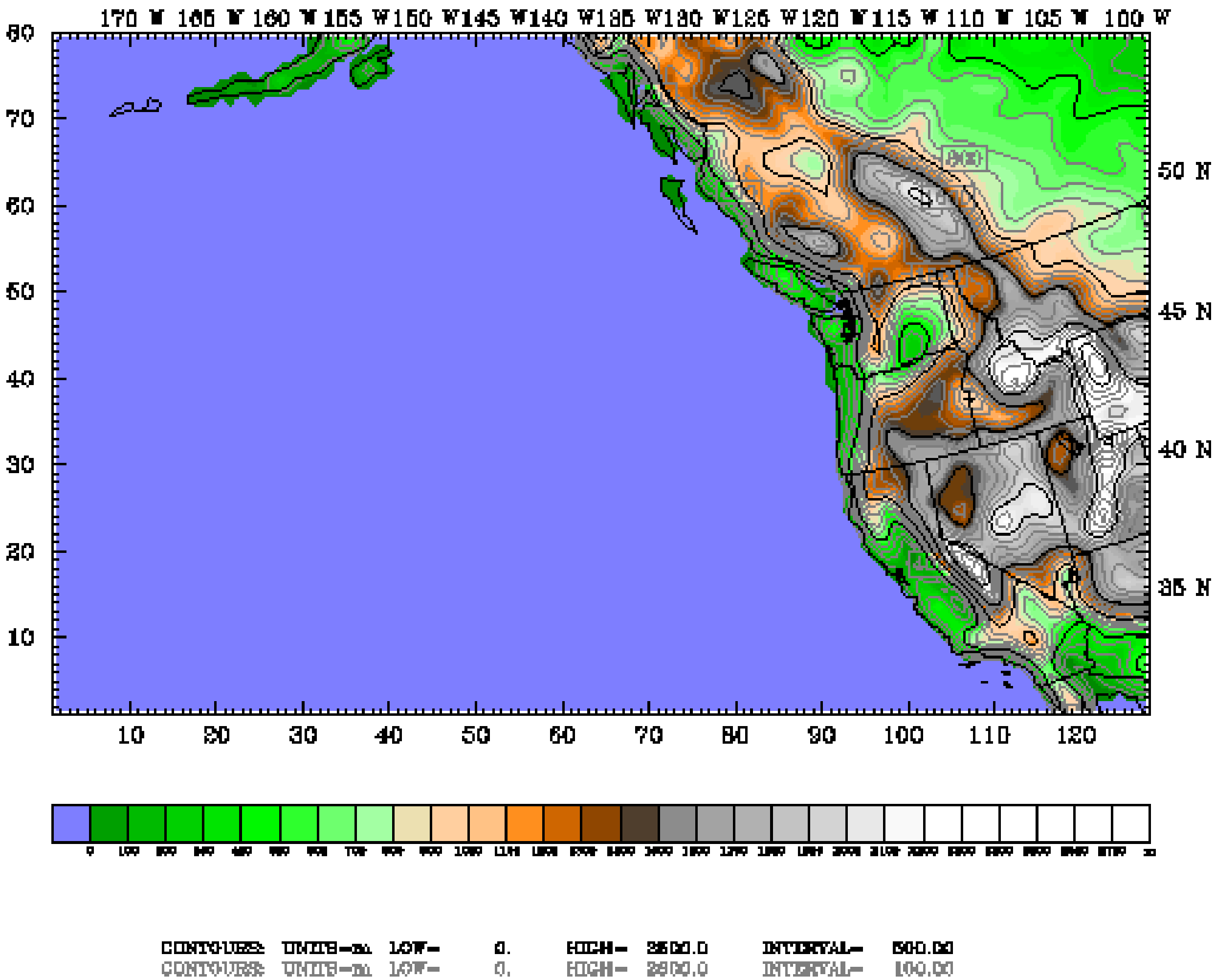
ECMWF

(European Centre for Medium-Range Weather Forecasts, England)

Like GFS model, run out to 20 days using data from 12 GMT daily

Pacific NW topography for 36 km grid spacing

(www.atmos.washington.edu under Weather/Climate Info: MM5)



- Olympic Mts., Puget Sound are smoothed over. 12 km resolution is required for these features, which are quite important to our local weather.

How does forecaster turn maps into a forecast?

- Local geography may be smeared out in model
- Model often has small biases (too low temperatures, too much rainfall W of Cascades but not enough E of Cascades).
- Model forecast not perfect; radar/satellite info may suggest improvement.

<u>The human forecaster has an important job:</u>

- Model-predicted surface temperatures must be adjusted, and local rainfall patterns and probability of precipitation predicted using experience and statistical models.
- Small-scale processes such as thunderstorms, valley fog or low cloud formation must be inferred from the maps based on forecaster experience.
- Forecaster must make forecasts, weather warnings intelligible to the public for many zones across Washington state.
- If forecast appears systematically off, forecaster must use updated current weather information from satellites, radar, surface obs. to correct it.