For submission to EOS
Our email address: terry@dao.gsfc.nasa.gov; phone: J. Otterman, 301-286-1312;
fax: 301-286-2323

February 1, 2001

The extremely warm early winter 2000 in Europe: what is the forcing?

J. Otterman[1], J. K. Angell[2], J. Ardizzone[3], R. Atlas[4], G. Demarée[5], J. C. Jusem[3],
D. Koslowsky[6], R. Przybylak[7], and J. Terry[3]

1. Land-Atmosphere-Ocean-Research at Data Assimilation Office, Code 910.3
   NASA GSFC, Greenbelt, MD, 20771
2. NOAA, Silver Spring, MD, Consultant
3. General Science Corp., Beltsville, MD
4. Data Assimilation Office, NASA GSFC, Greenbelt, MD
5. Royal Meteorological Institute, Brussels, Belgium
6. Free University of Berlin, Berlin, Germany
7. Nicholas Copernicus University, Torun, Poland

High variability characterizes the winter climate of central Europe: interannual fluctuations in the surface-air temperature as large as 18°C over large areas are fairly common. The extraordinary early-winter 2000 in Europe appears to be a departure to an unprecedented extreme of the existing climate patterns. Such anomalous events affect agriculture, forestry, fuel consumption, etc., and thus deserve in-depth analysis. Our analysis indicates that the high anomalies of the surface-air temperature are predominantly due to the southwesterly flow from the eastern North Atlantic, with a weak contribution by southerly flow from the western Mediterranean. Backward-trajectories based on the SSM/I and NCEP Reanalysis datasets traced from west-central Europe indicate that the warm air masses flowing into Europe originate in the southern North Atlantic, where the surface-air temperatures exceed by 15°C or more the climatic norms in Europe for late-November or early-December. Because such large ocean-to-continent temperature differences characterize the *winter* conditions, we refer to this episode which started in late November as occurring in the early winter. In this season, with the sun low over the horizon in Europe, absorption of insolation by the surface has little significance. The effect of cloudiness, a corollary to the low-level maritime-air advection, is a warming by a reduction of heat-loss (greenhouse effect). In contrast, in the summer, clouds, by reducing absorption of insolation, produce a cooling effect at the surface [Otterman et al., 2000].

At the end of November 2000, a low-level southwesterly current was firmly established over west central Europe, forced by a series of intense frontal cyclones, forming and migrating northward over the eastern North Atlantic, and by a blocking ridge over the western sector of the Mediterranean and eastern Europe. In response to this flow pattern, France, Belgium and the Netherlands were embedded during this period in an air mass of tropical origin that is cooled from below, and therefore shows weather manifestations consistent with low-level stability, such as low stratus and stratocumulus, fog, drizzle and continuous rain ahead of warm fronts.

The episode of elevated-temperatures shows up initially on the weather maps on November 22, 2000. See on Fig. 1 the rise in the temperature T_{max} at UCCLE meteorological station, Brussels, Belgium. After three days, the warm episode continues to be evident (T_{max} continues to have values higher than those before Nov. 22), in spite of strong cold fronts passing through for three days. Then, the full effect of the southwesterly flow is observed on November 28, 2000. On that day, following a shift in the surface-winds, T_{max} rose by 3.9° (to 12.7°C), and the daily minimum temperature, T_{min}, by 7.2°C (to 11.0°C), from the previous day. Southwesterly (SW) winds increased from 14 km/h on the 27th to 25 km/h on the 28th. In Middelkerke, the winds changed from S at 14 km/h to SW at 25 km/h. The daily pattern of T_{max}, presented in Fig. 1, depicts the rise in the temperatures at this UCCLE and the variations during this 18-day warm episode. We concentrate on T_{max} rather than on T_{min}, since T_{max} is representative of the airmass, whereas T_{min} often reflects strictly local conditions. The Diurnal Temperature Range, DTR = T_{max} - T_{min} , is rather small, consistent with the weak role of insolation and the sheltering role of cloudiness during this episode (see Crane and Barry 1984; Przybylak, 1999). The drop in the wind strength as well as in temperatures occurred on December 16.

This warm episode manifests itself clearly in the weather maps. However, real insight into the development of these extreme events can be gained by examining maps of near-surface streamlines, wind speed, and backward-traced trajectories, presented for November 29, 18Z, 2000, as Fig. 2. The three-day backward trajectory traced from the coastal point of France leads to the southeastern North Atlantic, establishes this area as the source of the airmass entering Europe. Note the length of the segments, which reflect the very large wind speeds, producing large 6-h displacement of air parcels. (However, we observe two short segments, crossing the streamlines in the vicinity of the cyclone. To some extent, these two segments introduce uncertainty how accurate is the direction of subsequent tracing). In contrast, the trajectory traced from a more easterly location, north central France, leading to the Mediterranean region as the source, consists of small segments, and furthermore forms a loop, indicating the advection from the south as not really significant when compared to the advection from the North Atlantic.

Quantitative relationship of the winter temperatures in Europe to the North Atlantic surface winds has been assessed by analyzing correlations for the 1988-1997 period of the SSM/I dataset available at that time (Atlas et al., 1996; 1997). For the month of February, the correlation of the specific Index I_{na} of surface southwesterlies over eastern North Atlantic, developed for quantifying the strength of maritime-air advection into Europe and the surface-air temperatures T_s in France was 0.82. Linear-best fit to T_s as a function of I_{na} established the sensitivity of T_s at about 1°C for 1 ms^{-1} variation in I_{na}. The variations in I_{na} are closely related to the phases of the North Atlantic Oscillation, but apparently I_{na} (as discussed in Otterman et al., 1999) is a more directly pertinent quantifier of the advection into Europe. The warmest February (T_s in France of 5°C) and the highest value of the Index (I_{na} of 8 ms^{-1}) occurred in 1990.

To continue the analysis of the strong maritime-air advection in that February, we traced backward trajectories from U.K. and France for February 26, 00Z – presented as Fig. 3. The three-day trajectories (as in Fig. 2, one segment represents a 6-h displacement) are superimposed on a map of the difference between the 2-m temperature and that of the surface (skin temperature). All along the trajectories across the Atlantic, this difference is negative, that is, the sources of the air advected lie in the very warm southwestern North Atlantic, in the vicinity of Gulf Stream, and the advected airmasses are *cooled* by the surface when crossing the ocean.

The investigation of this extreme-temperature episode, in which the surface-air temperature T_{max} rose to above 15°C from the normal values of 5-7°C (see Fig. 1 before November 22 and on December 16 and later), was based on weather maps and the SSM/I-NCEP Reanalysis surface wind data. We found the recently developed technique of trajectory tracing highly valuable in providing insight into the advection processes. Should this episode be placed in the framework of the global warming? We do not have an answer to this question; we do note that the global effects due to the greenhouse-factor increase are generally thought to enhance the variability of climate. Our study points to the strong ocean-surface southwesterlies over the North Atlantic as the direct cause of this episode. The winds are controlled by patterns of pressure and ocean-temperatures. Enhanced melting of the Greenland Icecap would strengthen the northerly cold currents flowing into the northwestern North Atlantic. This effect may be occurring already: the region of eastern Canada is the only region that exhibits regional surface cooling at these latitudes [Ross et al, 1996]. Will these cold currents reduce the ocean temperature in the regions which are the sources of the airmasses affecting Europe? Or, by enhancing the temperature gradients and the corollary cyclonic activity over the North Atlantic, will they reinforce the ocean-surface southwesterlies, producing even stronger positive anomalies of the surface-air temperatures? If such anomalies occur in February-March, by snow-albedo feedback the arrival of spring in central Europe can be significantly advanced. Is the enhanced cloud-cover during this winter 2000 warm episode related to the overall trend of increasing cloudiness (Angell, 1990; Karl and Teurer, 1990)? Thus, our analysis raises important questions, which deserve in-depth studies.

References

Angell, J. K., Variation in United States cloudiness and sunshine duration between 1950 and 1988, *J. Climate*, **3**, 296-308, 1990.

Atlas, R., R. N. Hoffman, S. C. Bloom, J. C. Jusem, and J. Ardizzone, A multiyear global surface wind velocity dataset using SSM/I wind observations, *Bull. Am. Meteorol. Soc.*, **77**, 869-882, 1996.

Atlas, R., J. Otterman, J. Terry, J. Ardizzone, and D. Starr, Surface wind velocity fields from SSM/I observations: Database update and applicability for neighboring land regions climatology, Eos Trans. AGU, 78(46), Fall Meet. Suppl. F285, 1997.

Crane, R. G., and R. G. Barry, The influence of clouds on climate with a focus on high latitude interactions, *J. Climatol.*, **4**, 71-93, 1984.

Karl, T. R., and P. M. Teurer, Increased cloudiness in the United States during the first half of the Twentieth Century: Facts or fiction? – *Geophys. Res. Lett.*, **17**, 1925-1928, 1990.

Otterman J., J. Ardizzone, R. Atlas, H. Hu, J. C. Jusem, and D. Starr, Winter-to-spring transition in Europe 48-54°N, from temperature control by advection to control by insolation, *Geophys. Res. Lett.*, **27**, 561-564, 2000.

Otterman, J., R. Atlas, J. Ardizzone, D. Starr, J. C. Jusem, and J. Terry, Relationship of late-winter temperatures in Europe to North Atlantic surface winds: A correlation analysis, *Theor. Appl. Climatol.* **64**, 201-211, 1999.

Przybylak, R., Influence of cloudiness on extreme air temperatures and diurnal temperature range in the Arctic in 1951-1990, *Polish Polar Research*, **20**, 149-173, 1999.

Rogers, J. C., and E. Mosley-Thompson, Atlantic arctic cyclones and the mild Siberian winters of the 1980s, *Geophys. Res. Lett.*, **22**, 799-802. 1995.

Ross, R. J., J. Otterman, D. O'C. Starr, W. P. Elliott, J. K. Angell, and J. Susskind, Regional trends of surface and tropospheric temperature and evening-morning temperature difference in northern latitudes, *Geophys. Res. Lett.*, **23**, 3179-3886, 1996.

Figure Captions

1. Temperature T_{max} and T_{min}, and wind speed observed at the UCCLE station, Brussels, Belgium.
2. 10 m streamlines over the eastern North Atlantic, Europe and the Mediterranean, for Nov. 29, 12Z, 2000, (from the SSM/I and NCEP data), with the backward-traced trajectories from coastal France and north central France.
3. Backward-traced trajectories from U.K and France for Feb. 26, 00Z, 1990, superimposed on the difference between the 2m temperature and that of the surface.

Daily maximum temperature (°C) at Uccle

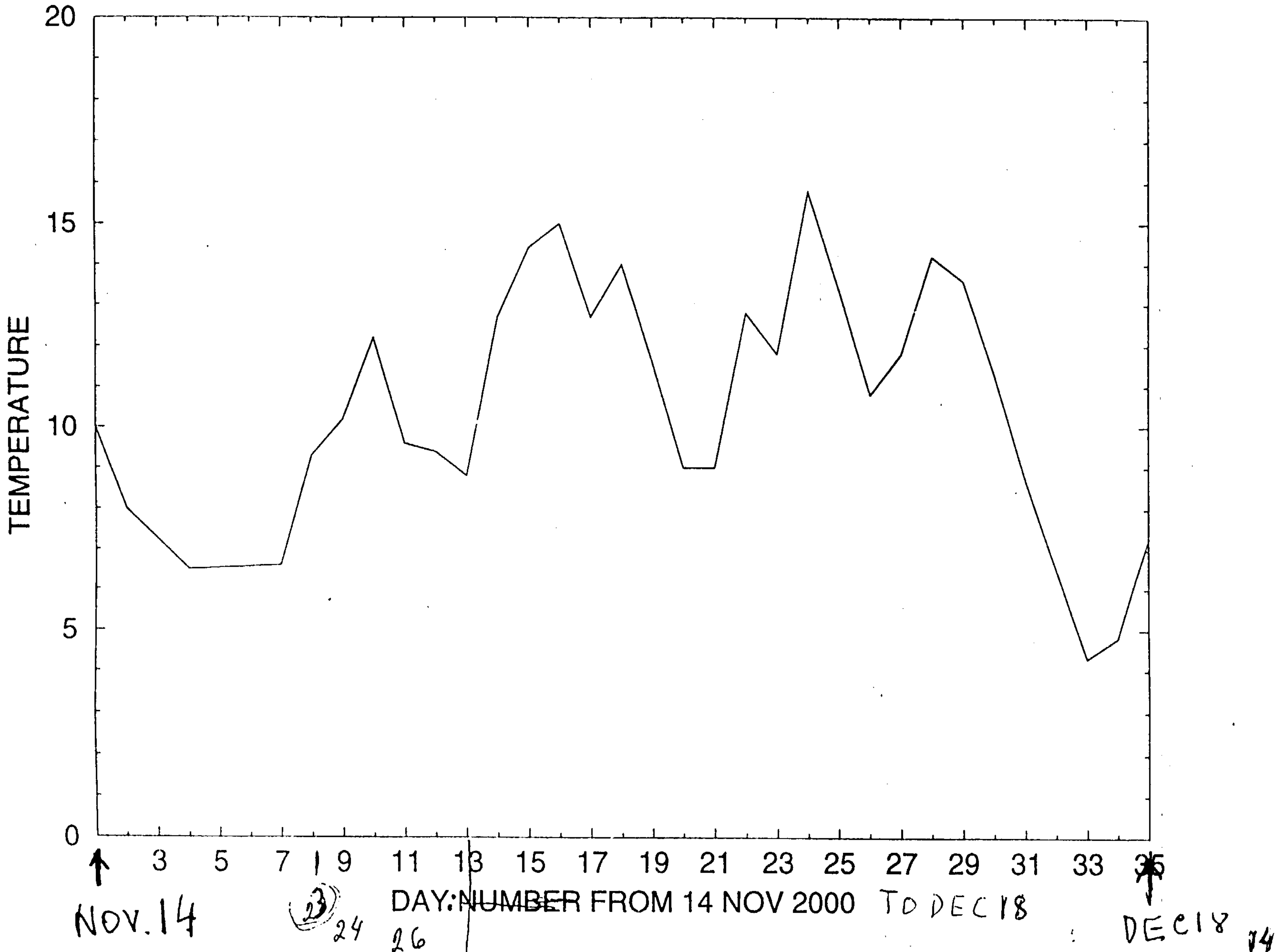

FIG. 1 PROVISORY

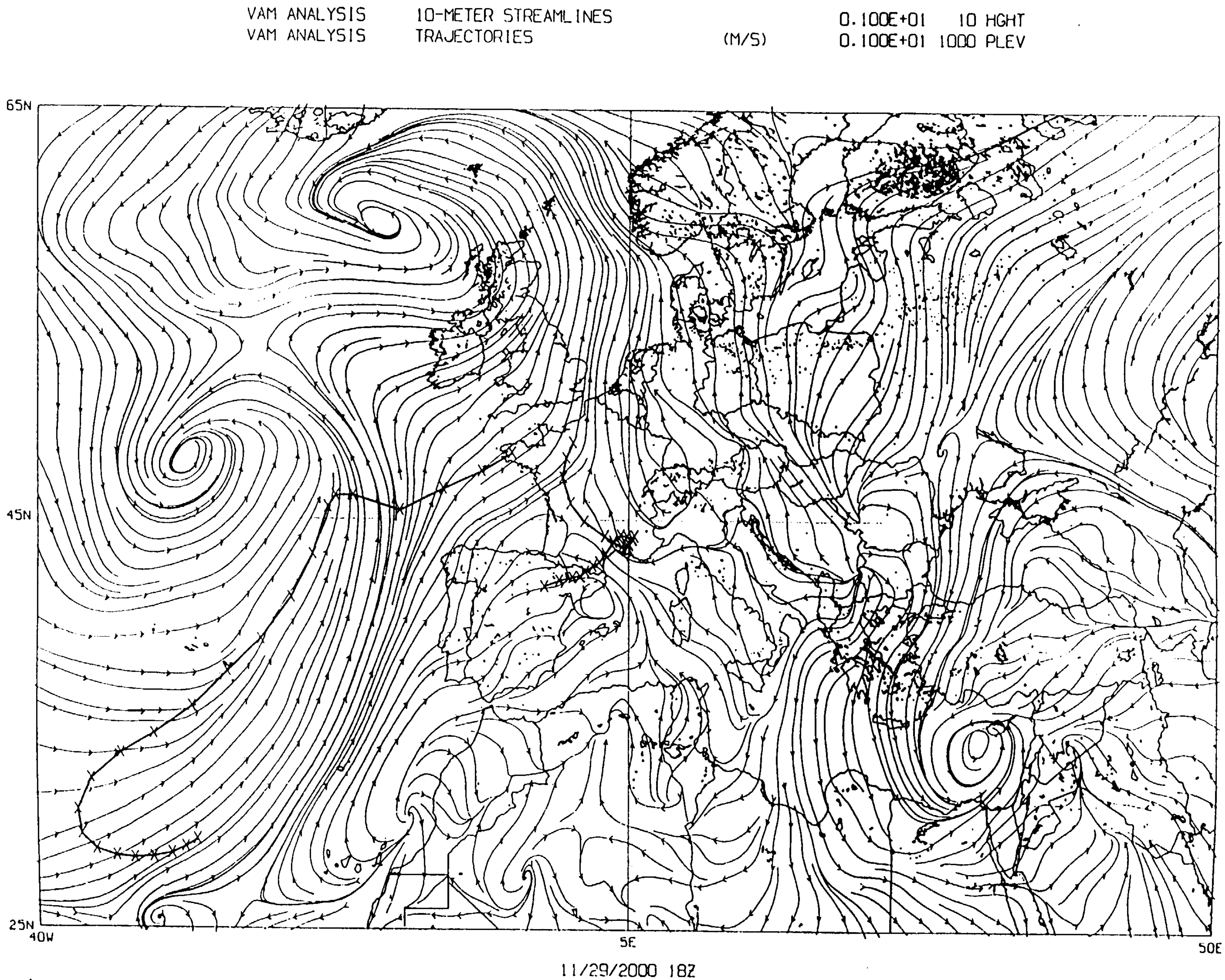
VAM ANALYSIS 10-METER STREAMLINES 0.100E+01 10 HGHT
VAM ANALYSIS TRAJECTORIES (M/S) 0.100E+01 1000 PLEV
65N
45N
25N
40W
5E
50E
11/29/2000 18Z

FIG 7

FIG. 3

NCEP 2 m Temperature Minus Surface Temperature with Trajectories
February 26, 1990 00Z

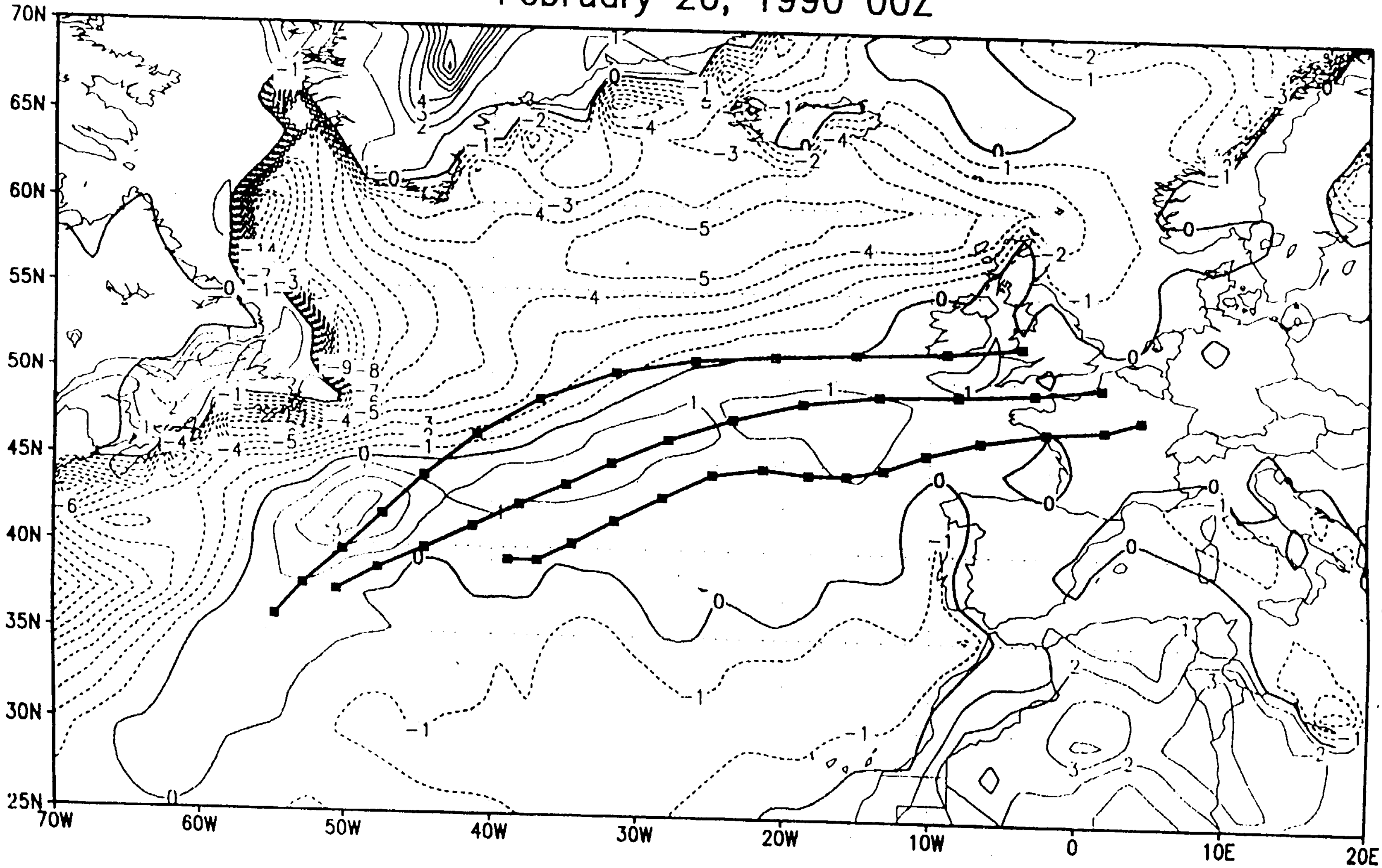

FIG 2

NCEP 2 m Temperature Minus Surface Temperature with Trajectories
February 26, 1990 00Z

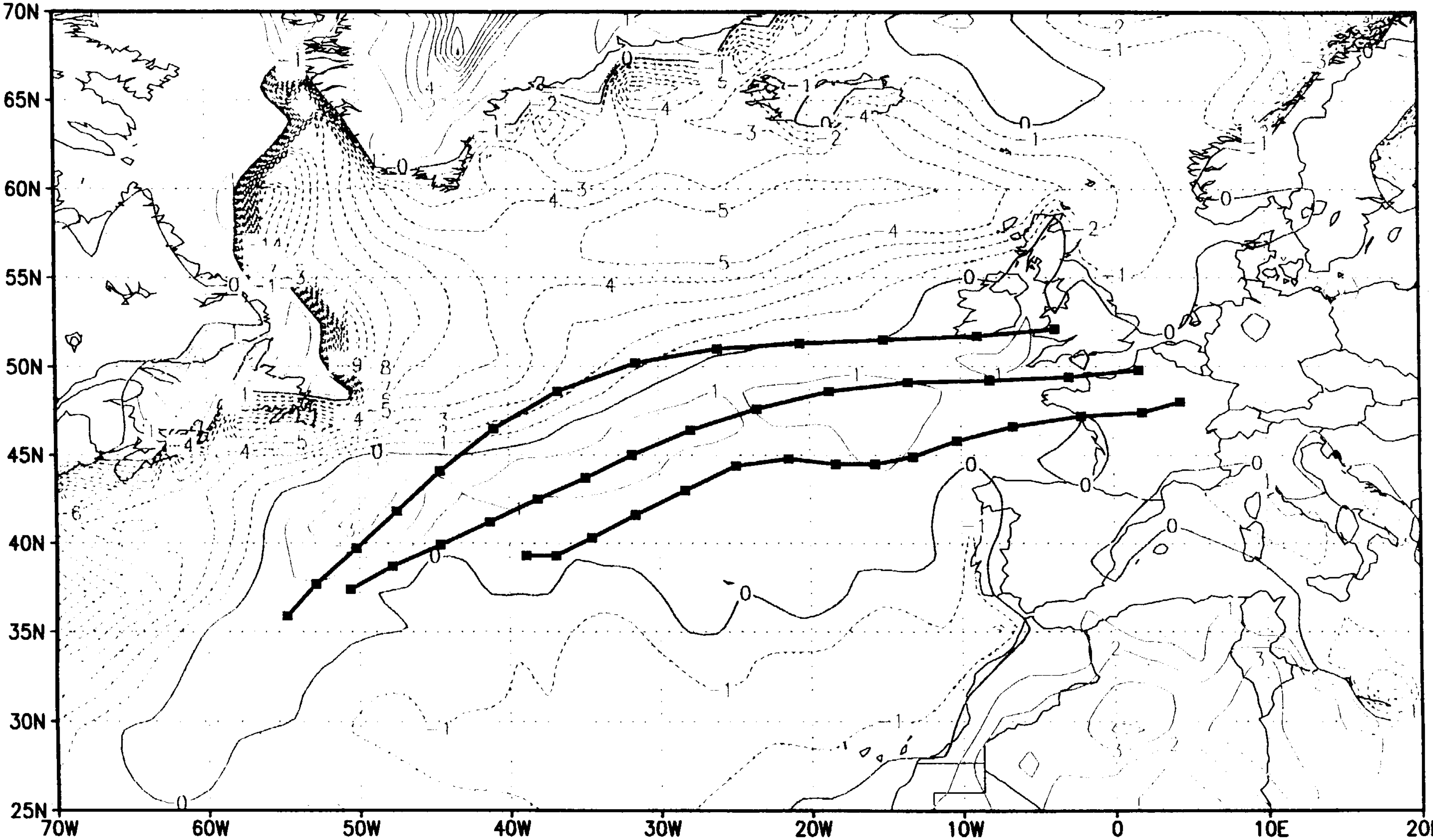

FIG. 3