Western Region Technical Attachment
No. 90-23
July 10, 1990

SOLAR-QBO-WEATHER RELATIONSHIP?

For several decades, meteorologists (and others) have pursued a physical relationship between variations in the Sun's output of radiation, magnetism, or particles and changes in the weather on Earth. Evidence supports climatological changes in tropospheric weather at time scales of a century or more, mainly from the coincidence of the Little Ice Age and the Maunder Minimum in sunspot activity. Variations at shorter time scales produced by the 11-year sunspot cycle or the 22-year magnetic variation, however, have been difficult to verify. To date, theories that explain a solar cycle-weather connection at the decennial time scale have been slow to develop as there is little evidence on which such theories may be grounded.

Recent studies by Labitzke and van Loon (1988, 1989), van Loon and Labitzke (1988), Venne and Dartt (1990), Tinsley (1988), Barnston and Livezey (1989), and others have postulated a new and more direct relationship between solar variations and weather. These investigators have calculated what they claim to be significant correlations between solar flux and Northern Hemisphere weather when data are stratified by the phase of the quasi-biennial oscillation (QBO) as well as the 11-year sunspot cycle (Fig. 1).

Holton and Tan (1980,1982) and van Loon and Labitzke (1987) have demonstrated that the phase of the QBO can affect middle and high latitude geopotential fields of the stratosphere. The proposed mechanism is the modification of the tropical wind field in the lower stratosphere, most likely by the shifting of the zero-wind line. This changes the refractivity of the tropical stratosphere to winter planetary-scale waves, and possibly results in the enhancement of wave propagation into the stratosphere, the reflection of waves out of the tropics, or the concentration of wave activity into the higher latitudes. The solar cycle-weather connection dependence on the QBO, therefore, may rest on the QBO-induced variations in planetary wave activity.

Investigators are presently defining a "composite solar cycle-QBO index" using the monthly mean 10.7 cm solar flux and the QBO phase as defined by the 40-50 mb monthly mean zonal wind component at Gan, Balboa, Singapore, and Canton. Upper-air data are available from about 1950 to the present.

Venne and Dartt used data from 176 Northern Hemisphere radiosonde stations for the period 1950-1973 and NMC gridded analyses for 1974-1988 in defining the geopotential fields tested. Labitzke and van Loon used sea level pressure patterns, NMC gridded data, and surface temperatures, including the Comprehensive Ocean Atmosphere Data Set (COADS) in their studies. Barnston and Livezey utilized a data set consisting of NMC gridded geopotential fields and monthly mean surface temperatures for 101 U.S. and 25 Canadian stations.

For tropospheric flow patterns Venne and Dartt reported that the summer data appear relatively insensitive to the QBO phase, with a weak positive correlation. There are stronger correlations in winter, with a positive correlation during westerly and negative correlation during the easterly QBO phase. Labitzke and van Loon report a correlation between the variation in the frequency of surface lows when the data are compared to the composite solar cycle-QBO index (see for example Fig. 2 from Labitzke and van Loon, 1989).

Barnston and Livezey found what they call "impressively strong" field significances for winter and "possibly" significant levels for autumn. They also point out that the 45 mb winds were chosen to define the QBO phase in their study a posteriori, and also there is a lack of a physical explanation for an association between the 11-year solar cycle-QBO modulated index. Thus, the validity of the statistical significance tests is questionable. However, they feel that the statistical results are strong enough to use in operational forecasting. At the Climate Analysis Center (CAC) the solar-QBO-atmosphere relationship is now being used in both solo mode to make U.S. temperature forecasts, and also as part of a predictive analog forecast system which uses numerous other climatic parameters to select similar or opposite past situations in the construction of the temperature forecast.

Barnston and Livezey also point out that the solar-QBO-atmosphere relationships are but one of at least two quasi-cyclical phenomena that affect U.S. temperatures, the second being the El Nino-Southern Oscillation (ENSO). Specifically, a warm ENSO episode tends to produce negative temperature anomalies in the eastern U.S. and positive anomalies in the western states. A cold ENSO tends to produce the opposite pattern. In January-February 1989, a cold ENSO episode occurred, tending to force the southeastern states to be warm, while the solar-QBO state, with the flux above its mean and the QBO nearing the end of its west phase, inclined this same region toward cold temperature anomalies. The outcome was mostly in accordance with the ENSO forcing. These authors boldly (but unofficially) call for below normal temperatures in the eastern two-thirds of the U.S. and normal to above normal temperatures in the western third for the January-February 1991 period since the QBO is expected to be in its west phase, the solar flux will be well above its mean, and the ENSO will likely be in a neutral or warm phase.

The above-cited investigations would seem to provide encouraging results for extended-range weather forecasting. However, these studies are all limited to only 3.5 solar cycles, the period from about 1950 onwards when the QBO phase can be determined from upper-air observations. Recently, there have been increasing discords to the apparent harmony of these investigations. Hamilton (1990) tested van Loon and Labitzke's results on historical data. Hamilton used the monthly "Zurich" sunspot numbers to construct the solar cycle and data from four stations near van Loon and Labitzke's "centers of action" for the period 1875 to 1936. If the phase of the tropical QBO were also known, it would be a very straightforward matter to test the reported results from the 1950 to 1988 data set. Since this cannot be done, Hamilton used the ensemble approach, i.e., he tried all plausible time series of QBO phases to see if even a single one duplicated the reported results. This amounted to several million possible sequences. Howard concluded that no reproduction of the 1950 to 1988 results seems possible and that either (i) the QBO behaved somewhat differently in the past, or (ii) that the solar-terrestrial relationship is not a stable feature of the data.

Thus, the jury is still out. At present, the evidence seems to be tipping in favor of Howard's conclusion ii. If insight cannot be provided by numerical model simulations, we will have to wait for many more years of upper-air data before a decision can be rendered.

References

Barnston, A.G., and R.E. Livezey, 1989: A closer look at the effect of the 11-year solar cycle and the quasi-biennial oscillation on Northern Hemisphere 700 mb heights and extratropical North American surface temperatures. *J. Climate,* **2**, 1295-1313

Hamilton, K., 1990: A look at the recently proposed solar-QBO-weather relationship. *J. Climate,* **3**, 497-503

Holton, J.R., and H.C. Tan, 1980: The influence of the equatorial quasi-biennial oscillation on the global circulation at 50 mb. *J. Atmos. Sci.,* **37**, 2200-2208

_______, and _______, 1982: The quasi-biennial oscillation in the Northern Hemisphere lower stratosphere. *J. Meteor. Soc. Japan,* **60**, 140-147

Labitzke, K., and H. van Loon, 1988: Association between the 11-year solar cycle, the QBO, and the atmosphere. Part I: The troposphere and stratosphere in the Northern Hemisphere in winter. *J. Atmos. Terr. Phys.,* **50**, 197-206

_______, and _______, 1989: Association between the 11-year solar cycle, the QBO, and the atmosphere. Part III: Aspects of the association. *J. Climate,* **2**, 554-565

Tinsley, B.A., 1988: Latitude variation of storm tracks in the North Atlantic; the solar cycle and the QBO influences. *Geophys. Res. Lett.,* **15**, 409-412

van Loon, H., and K. Labitzke, 1987: The southern oscillation. Part V: The anomalies in the lower stratosphere of the Northern Hemisphere in winter and a comparison with the quasi-biennial oscillation. *Mon. Wea. Rev.,* **115**, 357-369

_______, and _______, 1988: Association between the 11-year solar cycle, the QBO, and the atmosphere. Part II: Surface and 700 mb in the Northern Hemisphere in winter. *J. Climate,* **1**, 905-920

Venne, D.E., and D.G. Dartt, 1990: An examination of possible solar cycle-QBO effects in the Northern Hemisphere troposphere. *J. Climate,* **3**, 272-281

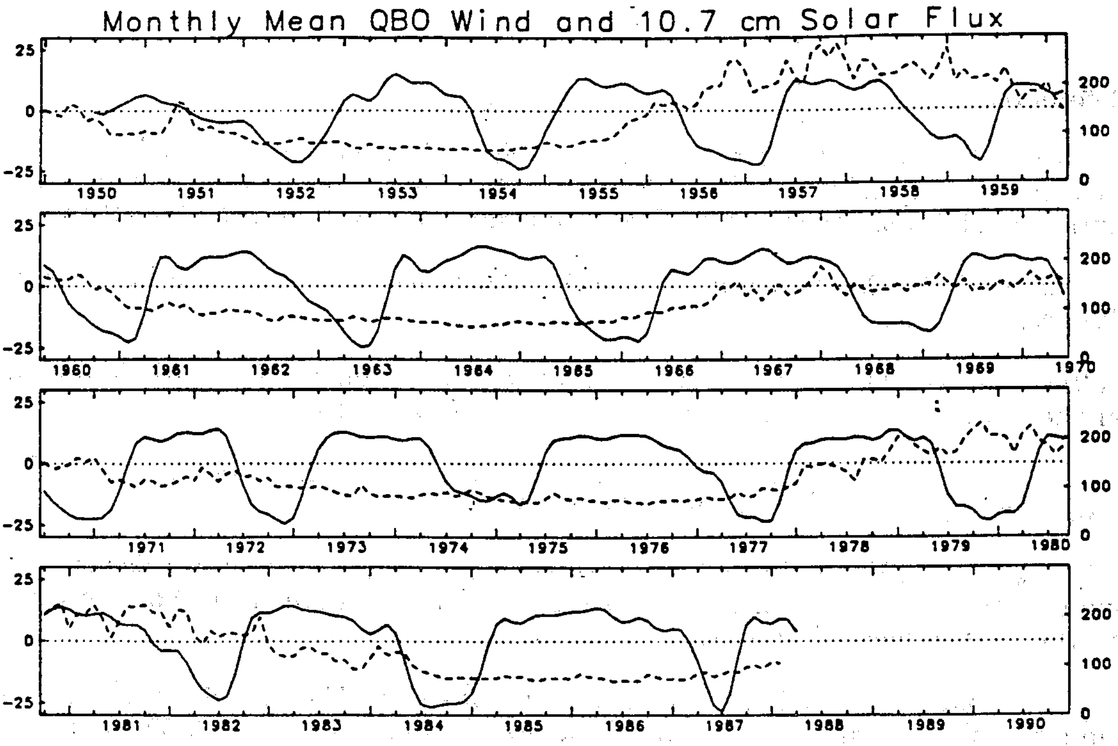

FIG. 1. The time series of monthly mean QBO wind (solid line) and 10.7 cm solar flux (dashed line). The QBO wind is the 5 kPa zonal wind component averaged from four stations near the equator. The wind scale is at the left and is in m s^{-1}, while the flux scale is on the right side of the diagram and has units of 10^{-22} W m^{-2} Hz^{-1}. The zero wind value is indicated by the dotted line.

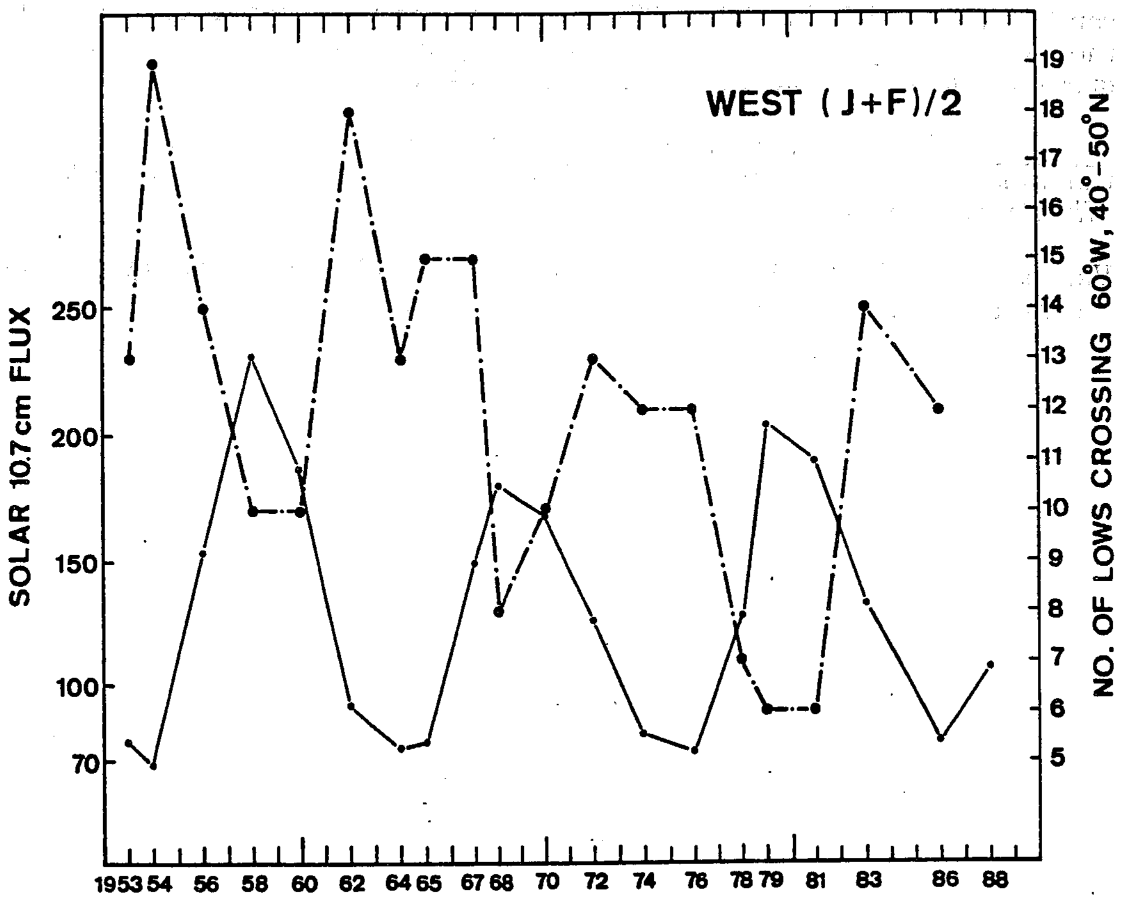

FIG. 2. Solid line: time series of the 10.7 cm solar flux. Broken line: time series of the number of low centers crossing 60°W between 40°N and 50°N. January–February for 19 yr of westerly QBO.