SPECIAL ARTICLE

Alternate Ranging Methods for Cancer Mortality Maps

Dan J. Grauman, Robert E. Tarone, Susan S. Devesa, Joseph F. Fraumeni, Jr.

Background: **Mapping techniques can highlight the spatial or temporal variations in rates of cancer mortality. In mapping geographic patterns of cancer mortality, spatial units are grouped into categories defined by specified rate ranges, and then the units in each category are assigned a particular color in the map. We examined the consequences of using different ranging methods when comparing maps over several time intervals. *Methods:* Maps of mortality rates for cancers of the breast, lung (including the lung, trachea, bronchus, and pleura), and cervix uteri in the United States by county or state economic area are created for different time intervals between 1950 and 1994. Two ranging methods are employed: 1) Ranges are defined for individual time interval by the deciles of rates in that interval (ranging *within* intervals), and 2) constant ranges for all time intervals are defined by the deciles of rates for the entire 45-year period from 1950 through 1994 (ranging *across* intervals). The time intervals from 1950 through 1969 and from 1970 through 1994 were chosen to accommodate the availability of detailed county-level population estimates specifically for blacks starting in 1970. *Results:* The ranging method has little impact on maps for breast cancer mortality, which changed little over time. For lung cancer, which increased over time, and cervix uteri cancer, which decreased over time, ranging *within* time intervals shows the geographic variability but does not convey the temporal trends. Trends are evident when ranging *across* time intervals is employed; however, geographic variability is partially obscured by the predominance of spatial units in the highest rate categories in the recent time intervals for lung cancer and in the early time intervals for cervix uteri cancer. *Conclusions:* Ranging *within* time intervals displays geographic patterns and changes in geographic patterns, regardless of time trends in rates. Ranging *across* time intervals shows temporal changes in rates but with some loss of information about geographic variability. [J Natl Cancer Inst 2000;92:534–43]**

Mapping techniques can highlight the spatial or temporal variations in rates of cancer mortality. The new *Atlas of Cancer Mortality in the United States, 1950–94 (1)* includes more than 250 computer-generated, color-coded thematic maps showing mortality rates for 39 cancers during two time intervals, from 1950 through 1969 and from 1970 through 1994. For the period from 1950 through 1969, when detailed county-level population estimates were not available for blacks, maps are presented for whites only. In each map, the cancer mortality rates for 3055 counties or 508 state economic areas are divided into 10 equal categories, with ranges for the categories determined by the deciles of all mapped rates. The geographic units within each category are assigned a specific color in the creation of the map, and geographic variability in rates is conveyed by the resulting distribution of colors. In the published atlas, the deciles for each map are determined from the deciles of the rates for the particular time interval being considered; i.e., ranging takes place *within* time intervals. Thus, for each map, 10% of the geographic units have the color corresponding to the highest rate category (100% red), and 10% have the color corresponding to the lowest rate category (100% blue), so that regions of the country with particularly high or low rates can easily be identified by the presence of a particular color and its shades.

Page limitations impose constraints on an atlas published as a book, but an atlas on a Web site enables considerable flexibility. Accordingly, the National Cancer Institute (Bethesda, MD) is providing a dynamic Web site called *Customizable Maps* (URL: http://www.nci.nih.gov/atlas/) for U.S. cancer mortality maps that will allow the creation of maps by state, state economic area, or county, with several options available to the viewer. This Web site currently enables the user to view the maps for the entire time period, from 1950 through 1994, as well as the two time intervals considered in the published atlas. In the spring of 2000, the Web site will also allow the creation of one or more maps by 5- to 45-year intervals (in 5-year increments) for the period from 1950 through 1994. The user will be able to control certain mapping parameters from options available on drop-down menus. Among the parameters under user control will be the number of mortality rate categories, the percentiles used to define ranges for the categories, and the colors assigned to different categories. When more than one map is created, the user will also have the option of choosing categories defined by ranges determined from percentiles of rates for the entire time period being mapped. This method of ranging is termed ranging *across* time intervals. In this special article, maps of mortality for cancers of the breast, lung, and cervix uteri will be used to compare the interpretation of maps created by ranging within time intervals with those created by ranging across time intervals.

Materials and Methods

Data on all deaths among males and females from 1950 through 1994 with cancer as the underlying cause of death according to age, sex, and race were provided for the 3055 U.S. counties by the National Center for Health Statistics (Hyattsville, MD). For this analysis, we selected all deaths due to breast cancer or cervix uteri cancer for white women and lung cancer (including the lung, trachea, bronchus, and pleura) for white men. The International Classification of Diseases codes included were as follows: breast cancer—170 for the 6th and 7th Revisions (deaths occurring from 1950 through 1967) *(2,3)* and 174 for the 8th Revision (deaths from 1968 through 1978) *(4)* and the 9th Revision (deaths from 1979 through 1994) *(5);* cervix uteri cancer—171 for the 6th and 7th Revisions

Affiliation of authors: Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, MD.

Correspondence to: Dan J. Grauman, M.A., National Institutes of Health, 6120 Executive Blvd., MSC 7244, Rm. 8050, Bethesda, MD 20892 (e-mail: dan_grauman@nih.gov).

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and 180 for the 8th and 9th Revisions; and lung cancer—162–3 for the 6th and 7th Revisions, 162 and 163.0 for the 8th Revision, and 162–3 for the 9th Revision. Annual county-, age-, sex-, and race-specific mid-year population estimates on the basis of data from the U.S. Bureau of the Census (Suitland, MD) were aggregated to form the person-years at risk. Death counts and rates were produced at the county level and at the level of state economic areas, which are 508 individual counties or groups of counties defined by the U.S. Bureau of the Census to be relatively homogeneous in 1960 with respect to various demographic, economic, and cultural factors *(6).* Data for all 50 states and the District of Columbia are presented, with Alaska and Hawaii each being considered a single unit for both county- and state economic area-based maps.

The published atlas adopted rules for determining those rates for counties or state economic areas that were unstable on the basis of sparse data *(1,7).* Areas deemed to have unstable rates were shaded gray in the published maps. No stability criteria are utilized in creating the maps presented in this special article. The spring 2000 enhancement of *Customizable Maps* will allow the user to choose whether or not to invoke criteria for rate stability in creating cancer mortality maps.

All maps in this special article utilize 10 categories for mortality rates in each time interval. For each cancer being considered, maps are presented for the two time intervals considered in the published atlas (i.e., from 1950 through 1969 and from 1970 through 1994) as well as for nine consecutive 5-year time intervals (i.e., from 1950–1954 through 1990–1994). The time intervals from 1950 through 1969 and from 1970 through 1994 were chosen to accommodate the availability of detailed county-level population estimates specifically for blacks starting in 1970. Two methods are used to choose the ranges defining the 10 categories for each set of maps: 1) ranging within time intervals (i.e., for each time interval, the ranges are the deciles of rates for that particular interval) and 2) ranging across time intervals (i.e., the ranges are the same for all intervals and are equal to the deciles of rates for the entire 45-year time period [i.e., from 1950 through 1994]).

RESULTS

The temporal trends for the selected cancers varied considerably over the 45-year period (Table 1). Maps are presented for cancers with relatively stable mortality rates over time (female breast cancer), with dramatic increases over most of the period (male lung cancer), and with sharp decreases over most of the period (cervix uteri cancer).

The maps for breast cancer mortality are shown at the state economic area level for the two longer time intervals in Fig. 1, A, and for the nine 5-year time intervals in Fig. 1, B. The choice of ranging method has little effect on the overall appearance of the maps. With either method, the maps show high rates in northeast states, some north central states, and scattered areas of the far-western states as well as low rates across the south and in the Rocky Mountain states. Both sets of maps indicate that the regional pattern, like the magnitude of rates, has changed little over the 45-year period, although the north/south gradient has become less pronounced recently, especially in the maps with ranging across time intervals.

Table 1. U.S. mortality rates* and percent change in U.S. mortality rates for cancers of the breast, lung (lung, trachea, bronchus, and pleura), and cervix uteri

	Cancer (race, sex)†					
	Breast (W, F)		Lung (W, M)		Cervix uteri (W, F)	
Time interval	Mortality rate	% change‡	Mortality rate	% change	Mortality rate	% change
1950–1969	26.43	—	39.25	—	7.87	—
1970–1994	26.89	1.7	69.40	76.8	3.22	−59.1
1950–1954	26.42	—	25.51	—	9.56	—
1955–1959	26.47	0.2	34.07	33.6	8.67	−9.3
1960–1964	26.22	−0.9	42.15	23.7	7.62	−12.1
1965–1969	26.77	2.1	51.81	22.9	6.16	−19.2
1970–1974	26.92	0.6	60.79	17.3	4.74	−23.1
1975–1979	26.68	−0.9	67.11	10.4	3.60	−24.1
1980–1984	26.90	0.8	71.30	6.2	2.95	−18.1
1985–1989	27.39	1.8	73.05	2.5	2.60	−11.9
1990–1994	26.19	−4.4	71.71	−1.8	2.51	−3.5

*Age-adjusted (direct method, 1970 U.S. population standard) mortality rates per 100 000 person-years.

†W = white; F = female; M = male.

‡Compared with the preceding time interval.

Because of the availability of large numbers of deaths, the maps for lung cancer mortality are shown at the county level for the two longer time intervals in Fig. 2, A. Maps are shown at the state economic area level for the nine 5-year time intervals in Fig. 2, B. The choice of ranging method makes a dramatic difference in the appearance of the lung cancer mortality maps. The shift in geographic pattern leading to a concentration of the highest rates in the southeastern quadrant of the country is clearly apparent in the maps that use ranging within time intervals. These maps adjust for the increase in lung cancer rates over time, ensuring that approximately equal numbers of counties or state economic areas are represented in each category (note the counts in Fig. 2, A). Thus, ranging within time intervals reveals the changing geographic pattern but not the increase in rates over time.

The lung cancer mortality maps that use ranging across time intervals illustrate the large increase in rates over time, changing from predominantly blue in the early time intervals to predominantly red in later time intervals. The geographic patterns are not as apparent, however, in the maps using ranging across time intervals. The recent concentration of highest rates in the southeastern quadrant, for example, is largely obscured by the overall increase in lung cancer rates, resulting in a predominance of red in the northeastern, midwestern, and far-western states in maps for later time intervals. Nonetheless, extreme geographic variation is still evident, even when using ranging across time intervals. Despite the overwhelming predominance of blue in Fig. 2, A, for the period from 1950 through 1969 in the map with ranging across time intervals, there are indications of elevated rates for lung cancer, e.g., in the coastal regions of the southeast and in part of Montana. Similarly, the scarcity of blue in Fig. 2, B, in the later maps with ranging across time intervals accentuates the low rates observed in Utah, southern Texas, and in a diagonal band from northwestern New Mexico through southern Minnesota and central North Dakota.

The maps for cervix uteri cancer mortality are shown at the state economic area level for the two longer time intervals in Fig. 3, A, and for the nine 5-year time intervals in Fig. 3, B. Because of the striking decline in cervix uteri cancer rates over the 45-year period, the ranging method makes a dramatic difference in the appearance of the maps. The maps that use ranging within time intervals show regional patterns of elevated rates in southwestern Texas, in Appalachia, in the deep south, and in a northeastern area, including New York and northern New England. There is some change in the geographic pattern over time, with an increasing concentration of high rates in the Appalachian regions of Ohio, West Virginia, Kentucky, and Tennessee in later intervals and corresponding decreases in high-rate areas across the deep south.

The cervix uteri cancer mortality maps using ranging across time intervals illustrate a dramatic temporal decrease in rates,

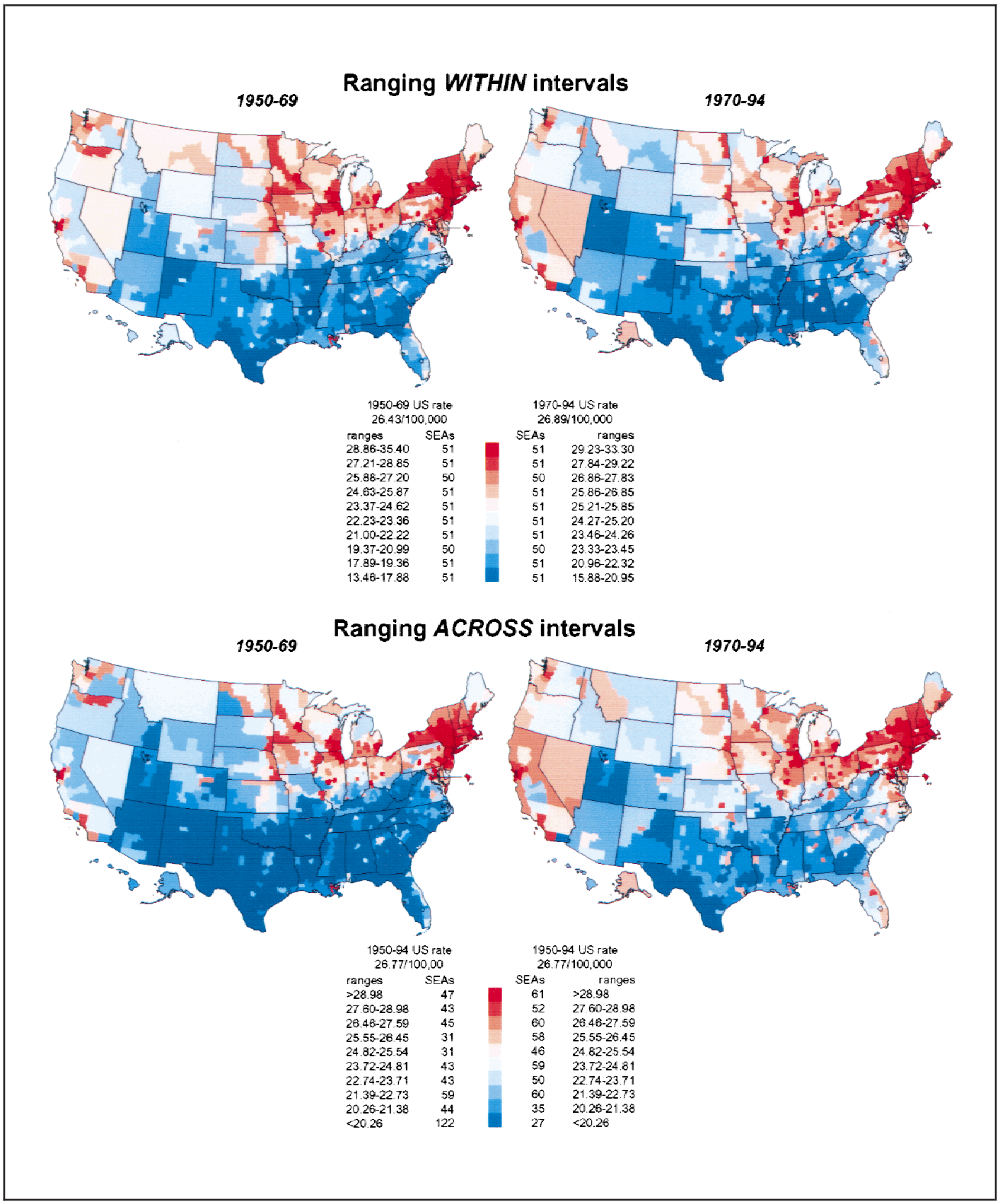

Fig. 1. A) Maps of breast cancer mortality rates (age-adjusted to 1970 U.S. population) by state economic areas (SEAs) for the two time intervals, from 1950 through 1969 and from 1970 through 1994. The **upper two maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower two maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The **keys** show the range for, and the number of state economic areas included in, each category.

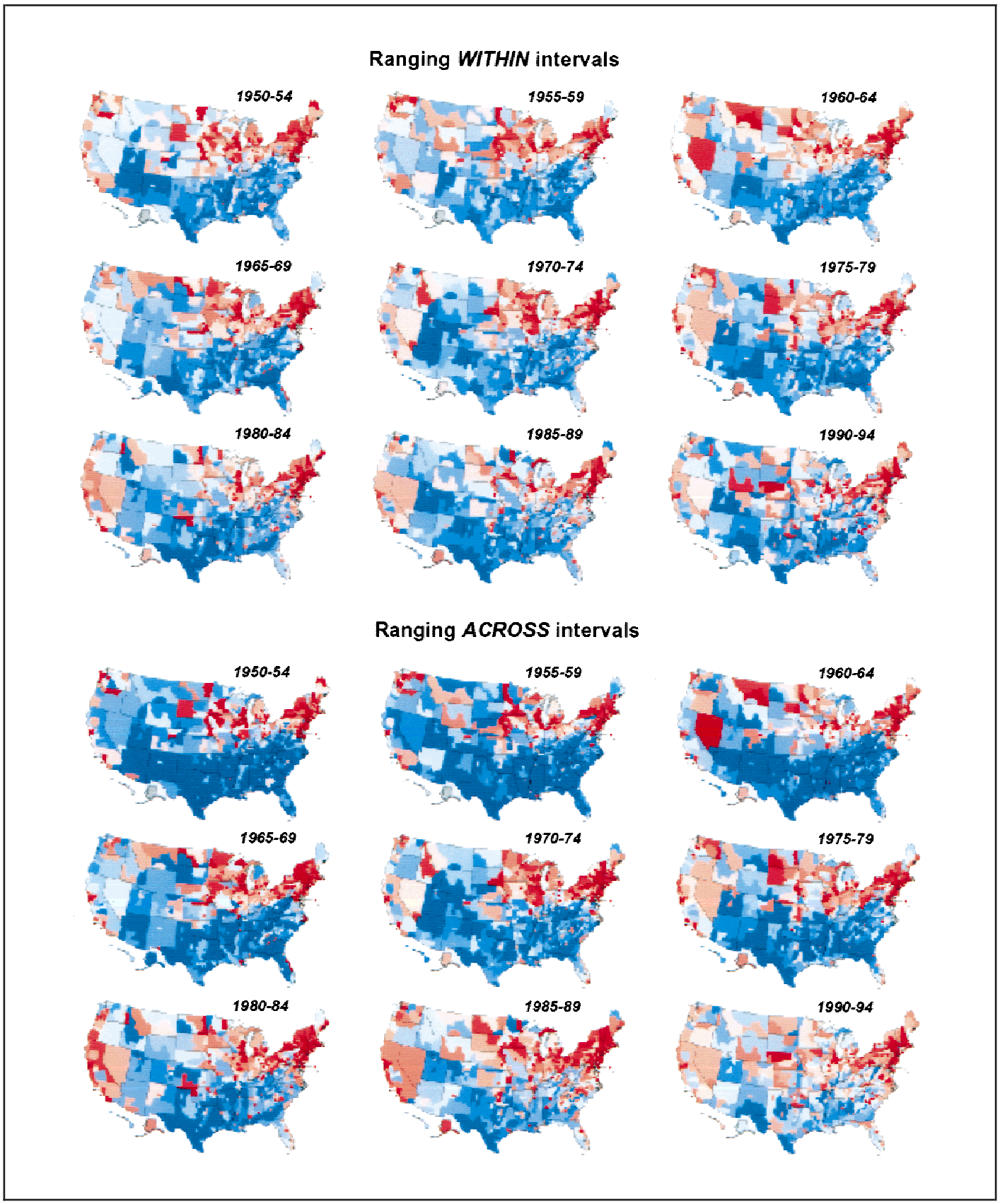

Fig. 1. B) Maps of breast cancer mortality rates (age-adjusted to 1970 U.S. population) by SEAs for the 5-year time intervals from 1950–1954 through 1990–1994. The **upper nine maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower nine maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The categories for the upper nine maps (not shown) are based on each map's specific 5-year time interval, while the categories for the lower nine maps (not shown) are based on the entire 45-year time period from 1950 through 1994 and are, therefore, identical to those of the lower two maps in A.

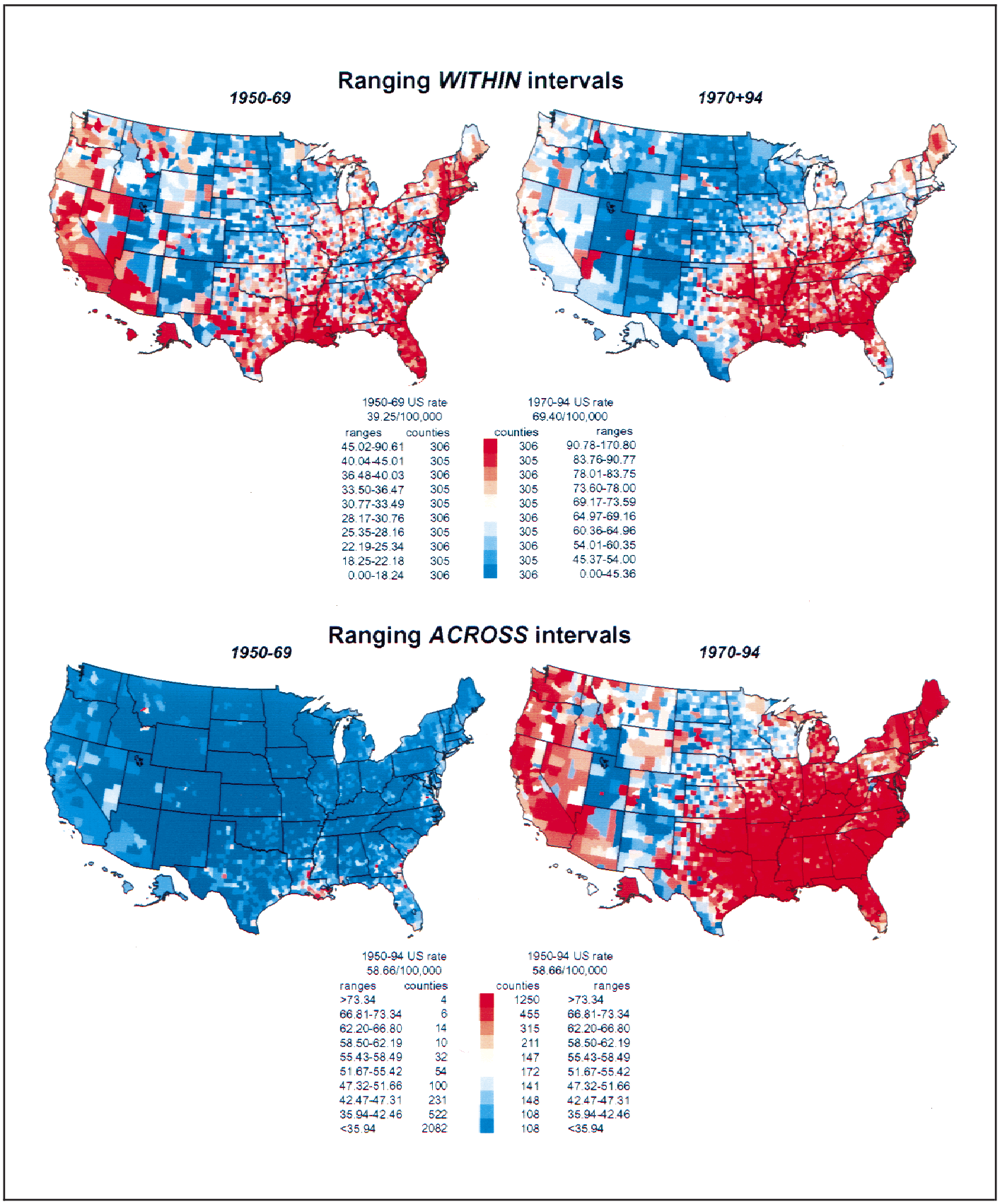

Fig. 2. A) Maps of lung (including the lung, trachea, bronchus, and pleura) cancer mortality rates (age-adjusted to 1970 U.S. population) by county for the two time intervals, from 1950 through 1969 and from 1970 through 1994. The **upper two maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower two maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The **keys** show the range for, and the number of counties included in, each category.

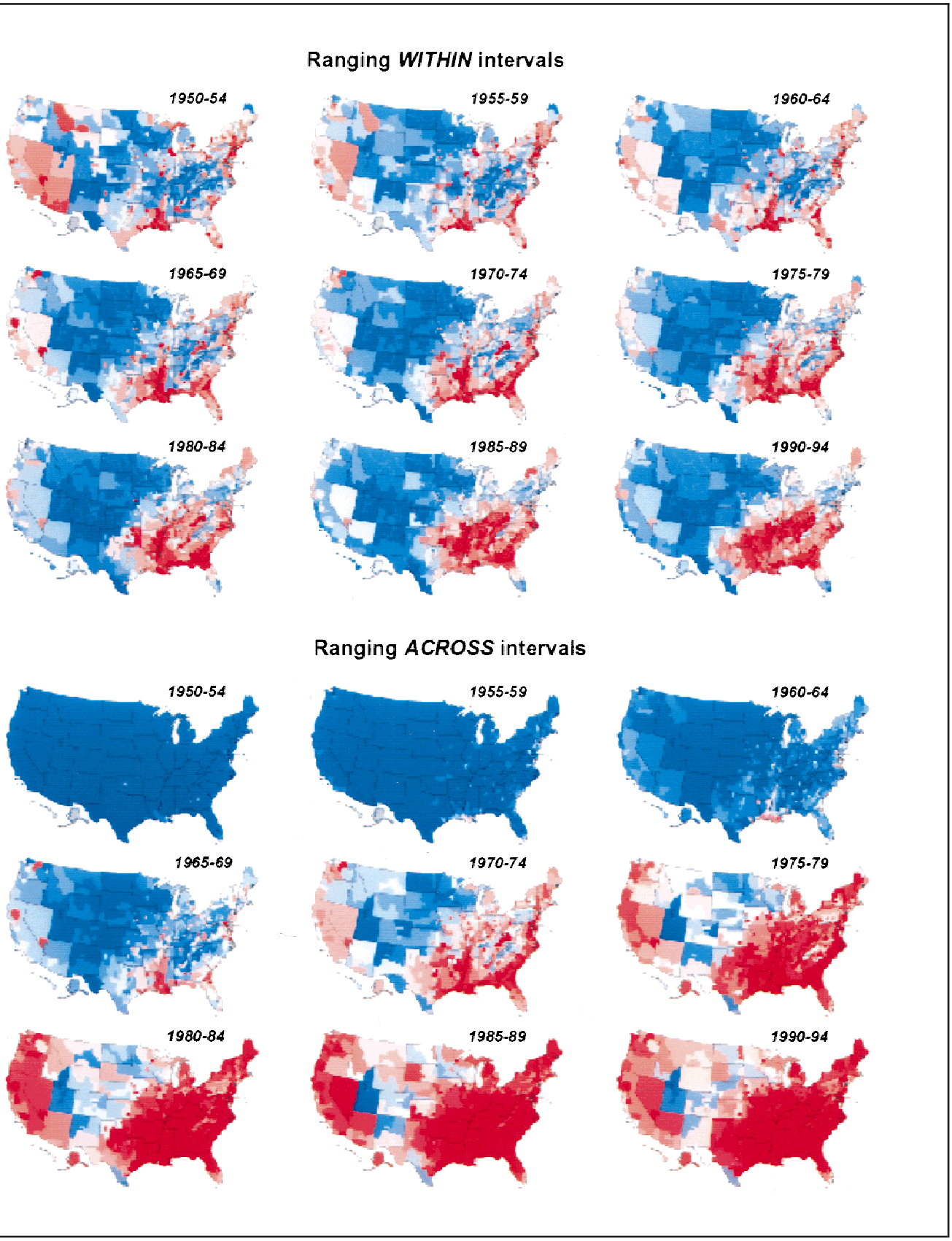

Fig 2. B) Maps of lung (including the lung, trachea, bronchus, and pleura) cancer mortality rates (age-adjusted to 1970 U.S. population) by state economic areas for the 5-year time intervals from 1950–1954 through 1990–1994. The **upper nine maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower nine maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The categories for the upper nine maps (not shown) are based on each map's specific 5-year time interval, while the categories for the lower nine maps (not shown) are based on the entire 45-year time period from 1950 through 1994 and are, therefore, identical to those of the lower two maps in A.

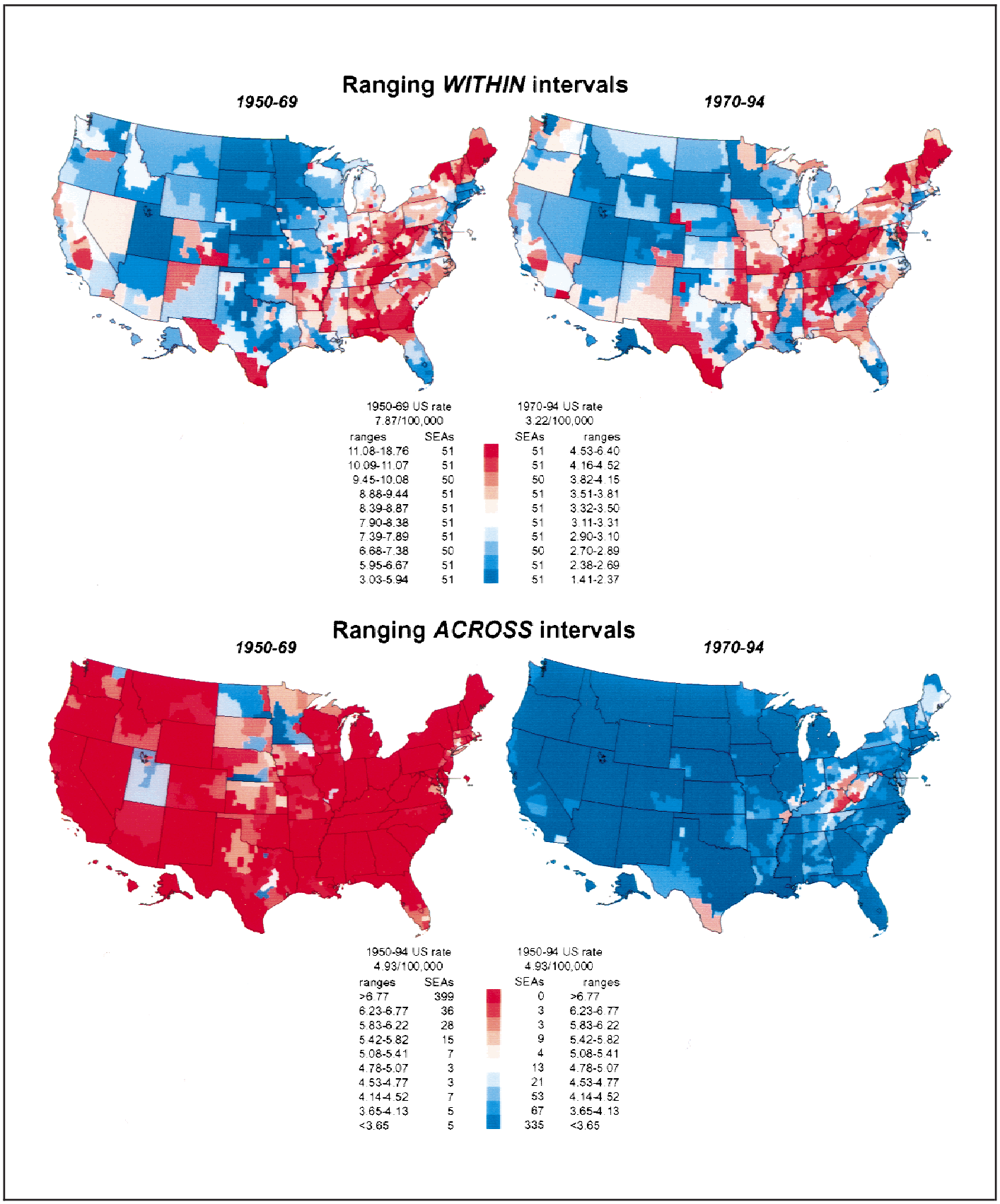

Fig. 3. A) Maps of cervix uteri cancer mortality rates (age-adjusted to 1970 U.S. population) by state economic areas (SEAs) for the two time intervals, from 1950 through 1969 and from 1970 through 1994. The **upper two maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower two maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The **keys** show the range for, and the number of SEAs included in, each category.

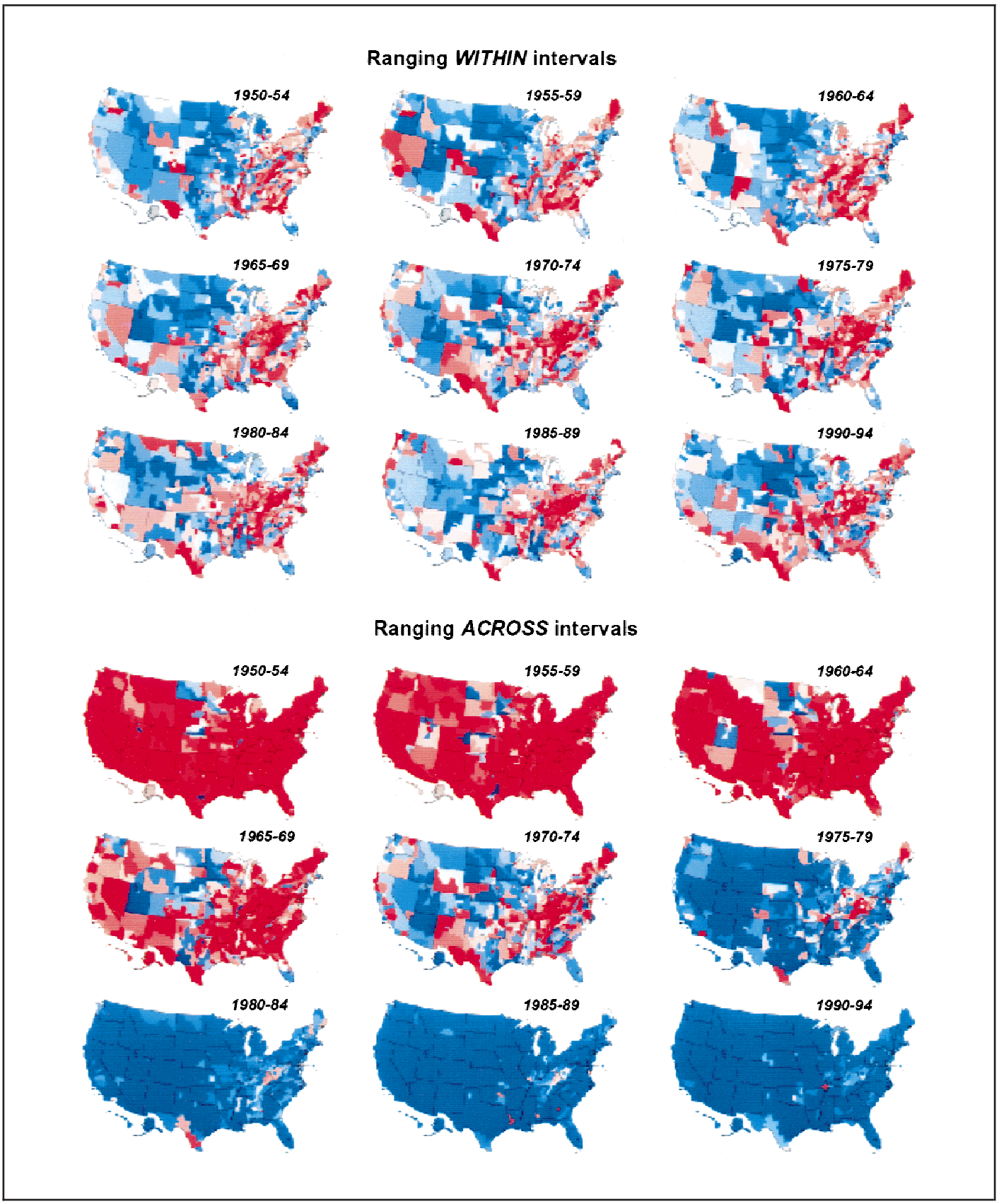

Fig. 3. B) Maps of cervix uteri cancer mortality rates (age-adjusted to 1970 U.S. population) by SEA for the 5-year time intervals from 1950–1954 through 1990–1994. The **upper nine maps** utilize ranging within time intervals, with categories for each map determined by the deciles of rates for the specific time interval indicated; the **lower nine maps** utilize ranging across time intervals, with categories for all maps determined by the deciles of rates for the time period from 1950 through 1994. The categories for the upper nine maps (not shown) are based on each map's specific 5-year time interval, while the categories for the lower nine maps (not shown) are based on the entire 45-year time period from 1950 through 1994 and are, therefore, identical to those of the lower two maps in A.

changing from predominantly red in the early time intervals to predominantly blue in later time intervals. An increase in the percentage of blue state economic areas is apparent in Fig. 3, B, beginning with the 1965 through 1969 map (compared with the maps for the three earlier 5-year time intervals) and continuing in the later intervals. On the other hand, regional variation in rates is largely obscured in the maps using ranging across time intervals. Nonetheless, areas with low rates are apparent in the northern plains states and in Utah, even in the early time intervals, while high-rate areas are seen in southern Texas, southeastern Missouri, and the Appalachian regions of Ohio, West Virginia, and Kentucky, even in the later time intervals.

DISCUSSION

As illustrated for breast, lung, and cervix uteri cancers, mapping techniques can highlight the spatial or temporal variations in the particular mortality rates, depending on the ranging method used. Maps that use ranges derived within time intervals provide no information about temporal changes in the magnitude of rates, but they are important in assessing spatial variability, including changes in the geographic pattern of rates over time. In contrast, maps that use ranges derived across time intervals can reveal temporal changes in the magnitude of rates. Maps with ranging across time intervals can also show spatial variability; however, in the presence of large increases or decreases in cancer mortality rates, such maps can only provide evidence of extreme geographic variation.

The breast cancer mortality maps demonstrate that, when rates are relatively stable, the choice of ranging method makes little difference in the appearance of the maps. Both ranging methods show the well-documented regional differentials in breast cancer mortality rates, notably the high rates in northeastern states and the low rates across the south *(8–10)*. Much of the regional pattern in breast cancer mortality can be explained by the geographic variation in known risk factors, such as age at first live birth *(11)*.

The geographic patterns for lung cancer shown by the maps using ranging within time intervals have provided important leads to the role of occupational carcinogens in certain high-risk areas *(12–14)*, although broader regional patterns appear to track regional shifts in the increasing prevalence of cigarette smoking across the United States *(7)*. Despite the enormous temporal increase at the national level of smoking-related lung cancer from 1950 through 1994, which resulted from the dramatic increase in cigarette smoking over the first half of the 20th century *(15)*, substantial geographic variation can be seen, even in the maps with ranging across time intervals. For example, the high rate in a Montana county resulting from arsenic exposure in a copper smelter *(16–20)* and high rates in southeastern coastal areas resulting from asbestos exposures in shipyards *(21–26)* are evident in the 1950 through 1969 county-based map that uses ranging across time intervals, despite the overall predominance of blue resulting from the lower rates in this interval compared with 1970 through 1994.

The cervix uteri cancer mortality maps with ranging across time intervals illustrate the marked national decline in mortality rates *(27)*, particularly after 1965. Rapid increases in the utilization of Pap smear testing were documented between 1961 and 1966 *(28)*, so it is likely that the decrease in cervix uteri cancer mortality after 1965 reflects the benefits of early detection. The concentration of elevated rates in Appalachia, which is evident in the maps using both ranging methods, appears to be associated with indices of poverty and reduced access to health care, including screening programs *(29)*. The low rates evident in Utah and in certain parts of the upper midwestern states in earlier time intervals, even for maps with ranging across time intervals, may reflect cultural or religious influences on sexual practices, resulting in reduced transmission of human papillomavirus *(30)*.

The variety of options available on the *Customizable Maps* Web site should provide investigators with increased flexibility in their use of cancer mortality maps. Among options currently or soon to be available are the following: choice of ranging method (within time intervals or across time intervals), maps for 5- to 45-year time intervals (in increments of 5 years), smoothed maps by use of Bayesian methods, and multiple maps on one screen with animation to display time trends. Data used for map creation will be available for downloading by the user. New mortality data will be added as they become available, and further enhancements will be made to the Web site as new methods are developed.

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NOTE

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