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The sensitivity of tree growth to air mass variability and the Pacific Decadal Oscillation in coastal Alabama

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Abstract This study investigates the relationship between tree growth and air mass type variability, using the spatial synoptic classification (SSC) in a bottomland slash pine forest in coastal Alabama (USA). The use of an air mass approach in dendroclimatology is somewhat unconventional and has not been fully explored. However, we believe that it may be useful because the air mass approach represents a holistic and comprehensive measure of surface conditions. Cores from 36 slash pines (*Pinus elliotti*) were extracted and ring widths were measured to the nearest 0.01 mm. The cores were then cross-dated and a standardized ring index series was established. Relationships were explored between the index series and several climate variables and teleconnections. The index series showed significant relationships with SSC air mass types and SSC air mass ratios, but insignificant results with teleconnections. Specifically the Dry Tropical air mass type was negatively correlated with tree growth while Moist Moderate was positively correlated. Concomitantly, Dry Tropical : Moist Moderate, Dry Tropical : Moist Tropical, and Dry Moderate : Moist Moderate air mass ratios also showed negative correlations. Positive Pacific Decadal Oscillation (PDO) sea surface temperatures were also associated with significant moisture and air mass variability in the region, although the PDO did not have a significant relationship with tree growth. The significance between SSC air mass variability and tree growth in the humid subtropical climate of coastal Alabama has favorable implications for dendroclimatological research in drier environments where trees are more sensitive to climatic variables.

Keywords Dendroclimatology · Spatial synoptic classification · Air mass · Alabama · Pacific Decadal Oscillation

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Introduction

Dendroclimate research has been used in climatic reconstructions since the early 1900s (Fritts 1976). For climatic reconstructions, chronologies are based on the principle that the width of annual growth rings is a function of the tree's environment. During more stressful years, trees exhibit less growth and rings are smaller. Conversely, during non-stressful years, tree growth is increased and rings are wider. Stressful years may result from many environmental variables for both the individual tree and the forest. Stress can also be attributed to climatic variation on seasonal to annual scales. A sizeable portion of dendroclimate literature is thus concentrated on the response of trees to seasonal and annual temperature, precipitation, and drought anomalies, e.g., Orwig and Abrams (1997), Cook et al. (2001), Fekedulegn et al. (2003), and Adams and Kolb (2005). Likewise, a comparable portion of dendroclimate research is concentrated on understanding the relationship between teleconnections and tree growth (Stahle et al. 1998); (Cleaveland et al. 2003). Dendroclimatologists have also investigated the influences of increased global CO_2 (West et al. 1993) and air pollution (Ashby and Fritts 1972) on tree growth. The humid subtropical climate of Coastal Alabama is not considered an ideal region for dendroclimate research. There are two primary reasons for the dearth of tree ring chronologies on the Alabama Coast. The first is the region's excessively moist climate and its modest range in annual temperature, which can produce complacent ring series (Stokes and Smiley 1968). The second reason is the scarcity of older trees due to extensive logging of original forests within the area. Few large and older trees are available for collecting tree cores, and this hampers the ability to investigate longer dendroclimate records.

Meldahl et al. (1999) is the one of the few dendroclimate studies within the region, and it discusses the affects of climatic variables on longleaf pine (*Pinus palustris*) in the Flomaton Natural Area, a track of old growth forest approximately 100 straight line km northeast of our study site. Their results indicate that soil moisture and precipitation are positively correlated with tree growth during peak evaporation months (Meldahl et al. 1999). In another study nearby, Rodgers et al. (2006) showed the presence of tropical cyclone signatures within tree rings from eastern Mobile Bay. Tree rings within this coastal forest were also significantly correlated to summer (June–August) Palmer Drought Severity Index (PDSI) (Palmer 1965) values and summer precipitation (Rodgers et al. 2006).

The marginal climatic characteristics of coastal Alabama combined with the lack of undisturbed forest poses questions regarding the practicality of dendroclimate research in this region. For example, on the eastern shore of Mobile Bay, seasonal mean climate division temperatures had no significant relationship with tree growth. Additionally, mean climate division annual precipitation and annual PDSI were only moderately correlated to tree growth (Rodgers et al. 2006). Thus, the use of seasonal climate variables may be of limited utility when evaluating cumulative growth throughout the entire growing season. Therefore, an alternative method is used in this research. The Spatial Synoptic Classification (SSC) is proposed as a new method to assess the sensitivity of tree growth to climatic variables via air mass variability in this region and possibly in other regions as well.

In this study, we use an air mass classification scheme, the (SSC; Sheridan 2002) to explore the sensitivity of current growing season tree growth to daily surface meteorological conditions in coastal Alabama. We believe the air mass approach may be well suited for dendroclimate studies because of the more comprehensive evaluation of surface conditions that the air mass classification scheme offers. Additionally, the SSC may improve upon traditional climate measures due to its synchronization with tree growth time scales. Should the SSC approach prove successful within the marginal climate of coastal Alabama, then it might have even greater utility within more environmentally limiting regions.

The SSC is a daily classification scheme based on the surface variables temperature, dew point, air pressure, wind speed, wind direction, and cloud cover. It was originally developed (Kalkstein et al. 1996) and later revised (SSC2; Sheridan 2002). It categorizes daily surface variables into one of seven different air mass types using a 6-h sampling interval. The SSC has been used for a variety of biometeorological purposes, most notably research involving heat and mortality (Tan et al. 2004), and pollution and mortality (Rainham et al. 2005). It has also been used for many other climatological topics including snow ablation (Leathers et al. 2004), and urban induced precipitation (Dixon and Mote 2003). It has not been previously used in any published dendroclimate research.

This article has two objectives. The first objective is to examine the sensitivity of tree growth to temporal changes in growing season (March–October) SSC air mass types. The second objective is to assess the impact of teleconnections on SSC air mass variability and growing season drought or surplus. Although several teleconnections were tested, only the Pacific Decadal Oscillation (PDO) was significant. The two phases of PDO (positive/negative) have been associated with climatic variability across the continental United States (Mauget 2003; Englehart and Douglas 2003), and increased streamflow and drought in the central and southwestern United States (Tootle et al. 2005; Tadesse et al. 2005). Therefore, it is likely that PDO exerts an influence on air mass variability in Coastal Alabama as well.

This article first proceeds by summarizing the background climate and environmental conditions of the study area in the Materials and methods section. This section also contains descriptions of the statistical procedures used to test for significance between the Index Series, SSC air mass types, climatic variables and teleconnections. The Results and discussion section is split into two parts paralleling the objectives mentioned above. The first part describes and summarizes the significant relationships between tree growth and air mass variability. The second part discusses teleconnective influences on drought and air mass variability.

Materials and methods

Study area and background climate

The Weeks Bay Reserve, located 10 km south of Fairhope, Alabama, is a National Estuary and Research Reserve (NERR). It consists of several tracks of wetland forest, estuaries, and upland forest that are proximal to Weeks Bay (Fig. 1). The Weeks Bay Reserve consists of 6.47 km^2 of subaerial land and 24.28 km^2 of water, all of which are managed by the Reserve (Weeks Bay NERR Reserve Management plan, September 2006). The "Swift Track" is one parcel in particular that borders the eastern shore of Mobile Bay (Fig. 1). This track is a swampy, bottomland forest that frequently floods. Soils are normally saturated and dry conditions may occur after 2–3 weeks without significant rainfall during the peak growing season. Drainage in the Swift Track is mostly in the form of sheet flow as there are very few organized stream channels that drain the bottomland forest. Several large slash pine (*Pinus elliotti*) exist in association with bald cypress (*Taxodium distichium*), water oak (*Quercus nigra*), and redbay (*Persea borbonia*). A significant portion of the ground cover consists of cinnamon fern (*Osmunda cinnamomea*) and royal fern (*Osmunda regalis*). The dense swampy environment and surrounding coastal marsh may have restricted wide-scale logging, which might explain why there are so many large (≥50 cm diameter at breast height) trees present at this location.

Coastal Alabama is a humid subtropical climate characterized by brief cold spells in winter and long, hot, muggy summers. Fall and spring are transitional periods subjected to the movement of polar and tropical air masses, but temperatures are generally very mild due to its proximity to the Gulf of Mexico. Average monthly temperatures range from a temperate 10°C in January to 28°C in July (Table 1) (National Climatic Data Center 2006). Using a 50% probability level, the average growing season is 280 days, and it can be initiated as early as mid-February. The average date of first and last 0°C freeze occurrence is 1 December to 22 February (National Climatic Data Center 2006). There is minimal temperature variation during the spring and fall months and almost none during the summer months. The region is very wet, averaging over 170 cm of annual precipitation at the nearest weather station and generally 165 cm across the coastal region. Mean monthly precipitation exceeds 8 cm in all months with 6 months exceeding 15 cm (See Table 1). For this research a more traditional March–October growing season is used to better gauge tree sensitivity to air mass variability during the peak growing season.

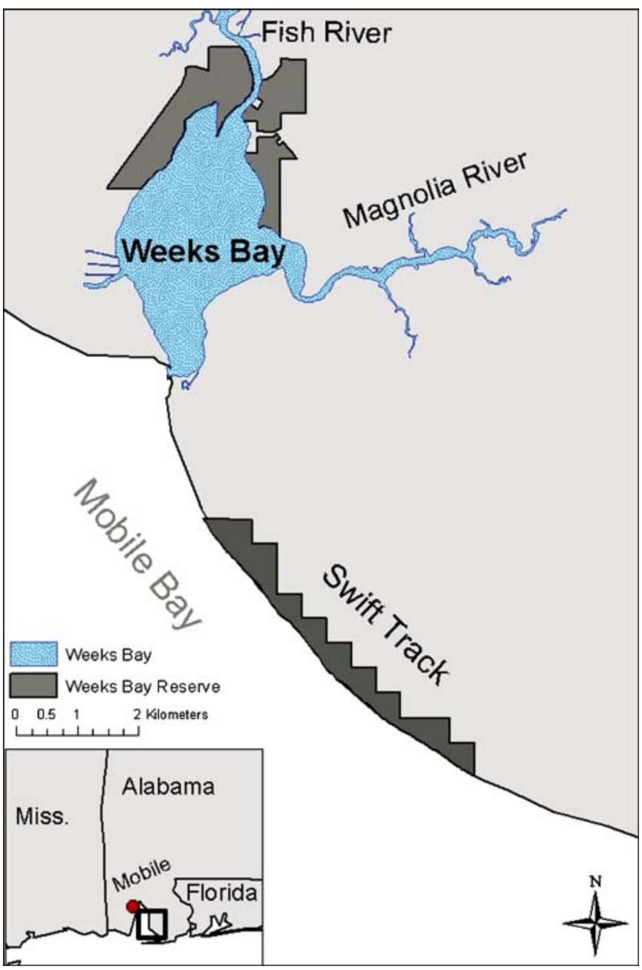

Fig. 1 The Weeks Bay Reserve and the Swift Track Forest

Field and laboratory analysis

Tree cores used in this study were extracted from 36 slash pines within the Swift Track area of the Weeks Bay Reserve. Larger trees were preferentially selected for coring because they would most likely be older and thus posses a longer climatic record. Two cores were collected from each tree at 90° angles to ensure consistency of growth rings around the trunk. Field sampling occurred at the end of the growing season during October and November of 1999 and January 2000. The tree cores used in this study are the same ones reported within Rodgers et al. (2006).

The tree core samples were prepared and sanded according to standard procedures (Phipps 1985; Stokes and Smiley 1968) and ring widths were measured to the nearest 0.01 mm with the aid of a Unislide "TA" Tree-Ring

Table 1 Fairhope, Alabama, mean monthly maximum, minimum temperature, and precipitation

	Max	Min	Precip. (cm)
January	16	4	15.5
February	18	6	13.9
March	21	10	17.0
April	25	13	11.5
May	29	17	14.2
June	31	21	15.1
July	32	23	20.3
August	32	22	15.8
September	30	20	15.2
October	26	14	9.1
November	21	9	13.2
December	17	6	11.2
Annual	25	14	172.0

1971–2000 climate normals

measurement System and Measure J2X software (Velmex 2005). Before the tree ring measurement could be used in an analysis they first needed to be crossdated and standardized. Crossdating helps identify false or missing rings and helps ensure that the proper calendar year has been given to each annual ring (Stokes and Smiley 1968). The software program COFECHA (Holmes 1986) was used to help crossdate the cores. The crossdating results from COFECHA showed an average mean sensitivity of 0.358 and a series inter-correlation of 0.371. After the cores were crossdated, the next step in the analysis was to create a ring-width chronology (master chronology) of the forest stand. The software program ARSTAN (Cook and Holmes 1986) was used to develop the master chronology. ARSTAN algorithms remove influences from endogenous growth factors, such as decreasing growth rates with age, by fitting negative exponential growth curves to the data (Cook and Holmes 1986). The ARSTAN output is a standardized ring index value that represents growth from all rings within the forest stand during that calendar year. The master chronology produced for the Swift Track trees spans from 1872 to 2000, but only the years 1950–1999 were used to correspond with the availability of SSC data.

Spatial synoptic classification

As described in the Introduction, the SSC classifies the daily surface values of temperature, dew point, pressure, wind speed, wind direction, and cloud cover into one of seven different air mass types. A description of each individual air mass type follows as well as the mean growing season air mass distribution for coastal Alabama (Fig. 2).

- **Dry Polar** (DP) air is largely synonymous with the traditional continental polar (cP) air mass classification. It is characterized by cool or cold dry air and northerly winds. Skies typically feature little or no cloud cover. This weather type has its source in northern Canada and Alaska, and is advected into Alabama by a cold-core anticyclone that emerges from the source region.
- **Dry Moderate** (DM) air is mild and dry. This weather type has no traditional source region. It is usually found in Alabama when polar air is advected around a surface anticyclone with a long trajectory over the Atlantic Ocean or Gulf of Mexico. In other cases, however, it may reflect a significantly modified DP weather type or the influence of more than one weather type.
- **Dry Tropical** (DT) air is associated with the hottest and driest conditions, and clear skies. It is analogous to the traditional continental tropical (cT) designation. Most commonly, it is present at, or advected from, its source region, which includes the deserts of the southwestern United States and northwestern Mexico. It can also be produced by moderate to severe drought periods when soil moisture is in deficit, resulting in high temperatures.
- **Moist Polar** (MP) air is a large subset of the traditional maritime polar (mP) air mass. Weather conditions are cool, cloudy, and humid, often with light precipitation. It is rarely encountered in coastal Alabama.

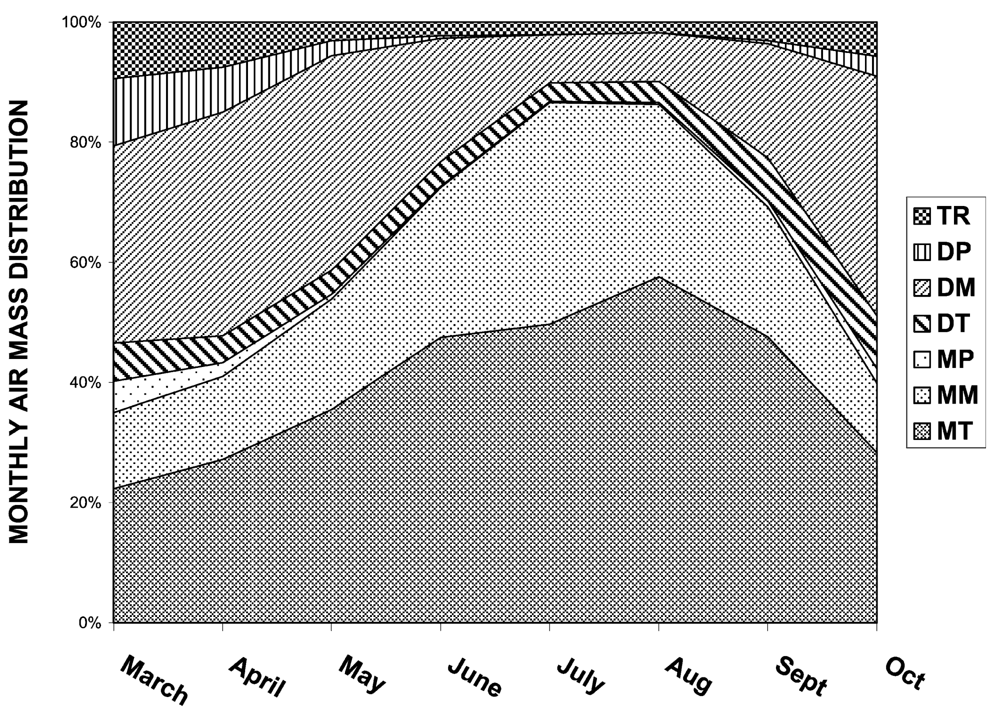

Fig. 2 Mean growing season distribution of SSC air mass types for Mobile, Alabama

- **Moist Moderate** (MM) air is warmer and more humid than MP air, though also cloudy. This can form either as a modified mP air mass, or independently, south of MP air nearer a warm front. During summer, it occurs under the influence of maritime tropical air masses on days with high cloud cover.
- **Moist Tropical** (MT) air is analogous to the traditional maritime tropical (mT) air mass. It arrives in coastal Alabama via the Gulf of Mexico. This weather type is warm and very humid and partly cloudy during the growing season. Convective precipitation is common.

These six weather types comprise the SSC catalog, along with a transitional (TR) situation, which represents a day in which one weather type yields to another, based on large diurnal changes in dew point temperature, pressure, and wind. Table 2 displays monthly mean conditions associated with each of these air mass types for the nearest first order station Mobile, Alabama. Additional information can be found on the SSC homepage (http://sheridan.geog.kent.edu/ssc.html).

Pearson Correlations

Pearson Correlations were evaluated in SPSS between the Index Series and several climate variables. A Kolmogorov-Smirnov test for normality resulted in all variables having p values>0.20. This indicated that the hypothesis of normality could be retained and the variables approximated normal distributions. Furthermore, Spearman correlations showed almost identical results to the Pearson results, so the Pearson results were retained. These variables include the following:

- **The number of growing season days that are categorized into each of the six SSC air mass types:** the number of growing season days within each air mass type are compared to determine if inter-annual variation of air mass types has either positive or negative impacts on tree growth.
- **The values of four growing season SSC air mass ratios:** four SSC air mass ratios were used to elucidate the relationships of one air mass type relative to another since potential impacts on tree growth may not be fully captured by the occurrence of individual air mass types. For this reason, the frequencies of the four most significant air masses of the growing season: MT, MM, DM, and DT, were directly compared for each year.
- **Standardized monthly Pacific Decadal Oscillation sea surface temperatures:** the positive/warm (negative/cold) phase of the PDO is characterized by warm (cold) equatorial waters in the east central pacific and cooler (warmer) waters over the mid latitude North Pacific and Gulf of Mexico (Mantua et al. 1997). PDO values were taken from the Climate Diagnostic Center website (2005). For the correlations, we averaged the monthly PDO index values for March–October and then correlated them with the ring index value of that same calendar year.

Table 2 Mean monthly temperature and dew point at Mobile, Alabama, for four most significant air mass types

	T		DP			T		DP	
	3 A.M. °C	3 P.M. °C	3 A.M. °C	3 P.M. °C		3 A.M. °C	3 P.M. °C	3 A.M. °C	3 P.M. °C
Dry Moderate					Dry Tropical				
March	9	21	6	7	March	13	25	9	3
April	13	25	11	10	April	17	29	14	9
May	17	29	14	14	May	20	32	18	14
June	20	31	17	16	June	23	35	20	18
July	22	32	19	19	July	25	36	22	19
August	21	31	18	18	August	24	35	21	18
September	18	28	14	14	September	21	33	18	17
October	13	25	10	10	October	16	29	13	11
Moist Moderate					Moist Tropical				
March	15	18	13	15	March	16	23	15	16
April	18	21	16	17	April	19	26	18	18
May	20	24	19	20	May	21	29	20	20
June	23	26	21	22	June	23	31	22	21
July	23	27	22	23	July	24	32	22	22
August	23	27	22	23	August	24	32	22	22
September	22	25	21	22	September	23	30	21	21
October	19	23	18	19	October	20	28	18	19

Table 3 Correlation coefficients, p values < 0.05 significance for growing season air mass type and tree growth, 1950–1999

Air mass	r	p
MM	0.45	0.001
DT	−0.51	0.000
DM:MM	−0.45	0.001
DT:MM	−0.52	0.000
DT:MT	−0.51	0.000

For explanation of abbreviations, see text

– **Palmer Drought Severity Index:** the ring index series and the PDO data were correlated to growing season Palmer Drought Severity Index (PDSI) values from Alabama Climate Division 8 (Mobile and Baldwin Counties). PDSI values were taken from the Climate Prediction Center website (2005).

Results and discussion

Tree growth and air mass variability

Tree growth is sensitive to the variability of SSC air mass types and SSC air mass ratios, but insensitive to teleconnections (Table 3). There was one significant negative correlation for the air mass types. The strongest air mass relationship is between DT days and the index series (r=−0.51, p=0.000). Coastal Alabama averages only 13 DT days during the 244-day March–October (M–O) growing season. It appears that an anomalous increase in DT days has an accelerated evaporation effect on the saturated bottomland soils of the Swift Track Forest possibly causing stressful conditions. DM days are more common during the growing season (See Fig. 2), but insignificant with tree growth (r=−0.21, p=0.147) further supporting the high evaporation DT assumptions. The ten lowest growth years are characterized by several anomalously high DT years, but this trend is not robust for all ten of the lowest growth years (Table 4).

A positive correlation is observed with MM (r=0.45, p=0.001). This complements the negative DT result. Since MT was not close to being significant, it appears that the cooler and moist MM days are less stressful, presumably due to minimized evaporative demand. Evaporative demand is likely higher during the warmer MT days (see Table 2) even though it is still a moist air mass. Therefore, when DT is anomalously high it inhibits tree growth in this moisture sensitive bottomland forest. Conversely, when MM is anomalously high it most likely promotes tree growth. If the DT and MM air mass types are both higher or lower than normal within the same growing season it is assumed

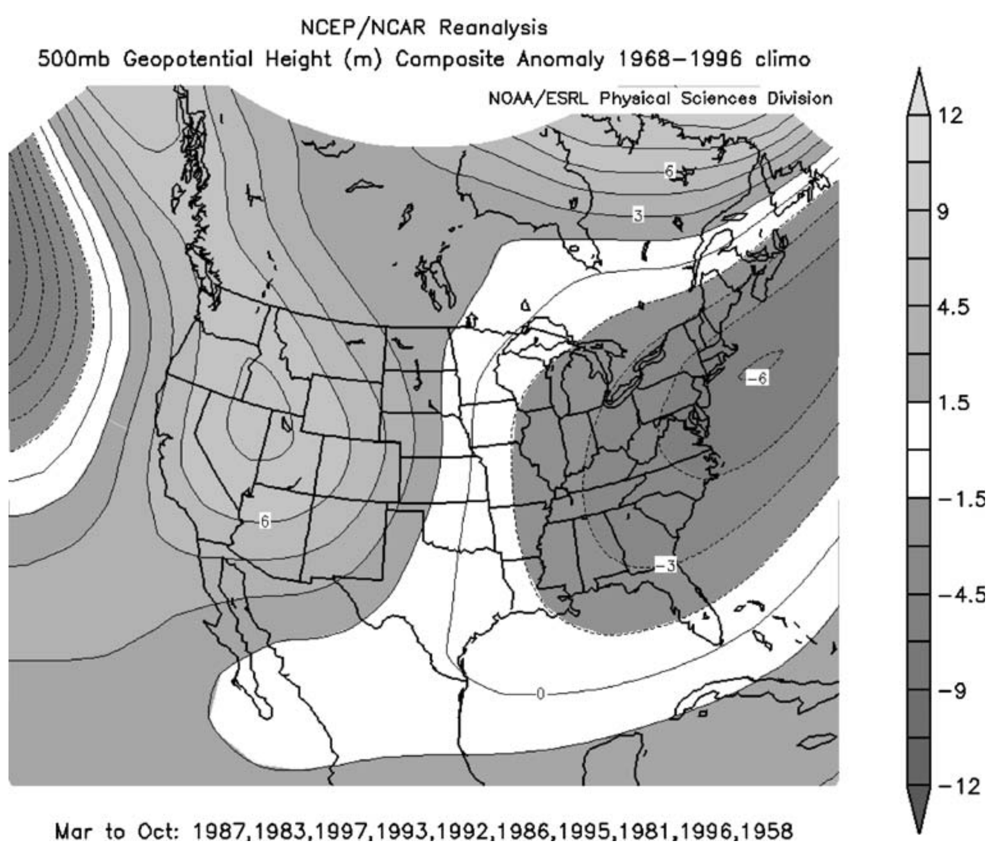

Fig. 3 Mean growing season 500 mb geopotential height anomalies for the ten most positive PDO years. Years are ranked by order of magnitude. Source: NOAA Climate Diagnostics Center, http://www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl

Table 4 Ten lowest growth years

Air mass	1981 (1)	1952 (2)	1953 (3)	1973 (4)	1984 (5)	1980 (6)	1978 (7)	1979 (8)	1954 (9)	1977 (10)
DM	6	0	−9	−22	48	−5	−14	19	−8	1
DP	−3	7	−3	−4	4	−5	−3	−2	5	−2
DT	2	16	18	11	−9	14	8	−2	10	−6
MM	−26	−7	4	−7	−14	−6	−15	−1	−28	−17
MP	0	−1	−3	−1	3	1	−3	−3	−2	−1
MT	15	−20	−12	24	−28	4	25	−11	16	28

Growing season air mass days, departure from 1950–1999 mean
Years are ranked by number in parentheses
1981 is the lowest growth year and 1977 is the 10th lowest growth year

the net effect is negligible on tree growth. In order to address these comparative issues ratios were established among the four most significant air masses of the M–O growing season: MT, MM, DM, and DT.

Four ratios were tested. The dry air masses were always the numerator of the ratio. The strongest results were again from DT. The DT:MM ratio has a strong negative correlation with the index series ($r=-0.52$, $p=0.000$), and the DT:MT ratio is almost as significant ($r=-0.51$, $p=0.000$) (see Table 3). When DT is anomalously high it is mostly at the expense of the usual entrenched MM and MT regime (Table 5). Additionally, DM:MM is also strong ($r=-0.45$, $p=0.001$) even though DM by itself is not significant. Recalling a point from earlier, the number of DT days for the ten lowest growth years is not always higher than normal (see Table 4), but in nine of the ten lowest growth years there is a ratio that is imbalanced by at least one standard deviation (Table 5). The ten highest growth years reflect the opposite of the above ratios. However, the number of standard deviations is not as strong (Table 6). This implies that growth is not necessarily influenced by anomalous occurrences of one particular air mass, but instead it is a complex relationship between the relative amounts of dry air mass days to moist air mass days.

The PDO, air mass variability, and PDSI

PDO values were not significantly directly correlated with tree growth. However, its influence may be exerted on the growing season circulation patterns over the study area as reflected by changes in air mass variability and its impacts on the PDSI (Table 7). The mean growing season PDO has a significant positive relationship with DM days ($r=0.32$, $p=0.025$). Additionally, the PDO has a positive relationship with growing season PDSI ($r=0.36$, $p=0.011$), a result similar to the positive correlation with PDSI and Nino 3.4 ($r=0.35$, $p=0.012$). Mean growing season climate division precipitation is insignificantly correlated with PDO. This suggests that the PDO may be partially responsible for both wetter growing seasons, evidenced by the PDSI results, and drier and less active growing seasons according to the DM results. An explanation is unclear at this time, but it is suggested that the cooler Gulf of Mexico SST during positive PDO years may be the likely cause for increased DM. The warmer tropical pacific SST during positive PDO mimics an El Nino episode, which has an established teleconnection with the region, albeit in the winter and early spring months (Green et al. 1997; Gershunov and Barnett 1998; Hansen et al. 1998; Wang et al. 1999). Since the growing season overlaps with early spring, a small

Table 5 Ten lowest growth years

Ratios	1981 (1)	1952 (2)	1953 (3)	1973 (4)	1984 (5)	1980 (6)	1978 (7)	1979 (8)	1954 (9)	1977 (10)
Ratio values										
DM:MM	2.68	1.39	0.95	0.89	2.95	1.24	1.31	1.60	2.30	1.82
DM:MT	0.60	0.80	0.60	0.33	1.60	0.60	0.39	0.94	0.47	0.50
DT:MM	0.60	0.66	0.60	0.55	0.11	0.60	0.58	0.22	1.00	0.21
DT:MT	0.14	0.38	0.37	0.20	0.06	0.27	0.17	0.13	0.21	0.06
Number of S.D.										
DM:MM	2.6	0.1	−0.7	−0.8	3.1	−0.2	0.0	0.5	1.9	1.0
DM:MT	−0.3	0.4	−0.3	−1.2	3.0	−0.3	−1.0	0.8	−0.7	−0.6
DT:MM	1.2	1.4	1.2	1.0	−0.7	1.0	1.1	−0.3	2.8	−0.4
DT:MT	0.0	2.9	2.7	0.7	−1.0	1.6	0.4	−0.1	0.8	−1.0

Growing season air mass ratio values and number of standard deviations
Years are ranked by number in parentheses
1981 is the lowest growth year and 1977 is the 10th lowest growth year

Table 6 Ten highest growth years

Ratios	1994 (1)	1991 (2)	1999 (3)	1995 (4)	1958 (5)	1966 (6)	1998 (7)	1993 (8)	1970 (9)	1996 (10)
Ratio values										
DM:MM	0.74	0.70	1.94	1.20	0.78	1.13	1.19	0.88	0.96	1.41
DM:MT	0.59	0.36	0.62	0.47	0.85	0.78	0.41	0.55	0.42	0.67
DT:MM	0.05	0.11	0.19	0.24	0.17	0.11	0.12	0.15	0.32	0.13
DT:MT	0.04	0.06	0.06	0.10	0.18	0.08	0.04	0.09	0.14	0.06
Number of S.D.										
DM:MM	−1.1	−1.2	1.2	−0.2	−1.0	−0.4	−0.3	−0.8	−0.7	0.2
DM:MT	−0.3	−1.1	−0.2	−0.7	0.5	0.3	−0.9	0.8	−0.9	1.2
DT:MM	−1.0	−0.8	−0.4	−0.2	−0.5	−0.8	−0.7	−0.6	0.1	−0.6
DT:MT	−1.3	−1.0	−1.0	−0.5	0.5	−0.8	−1.3	−0.6	0.0	−1.0

Growing season air mass ratio values and number of standard deviations
Years are ranked by number in parentheses
1994 is the highest growth year and 1996 is the 10th highest growth year

portion of the relationship between PDSI and PDO is probably attributed to moisture transport from the tropical Pacific in the early spring months. Thus, it is possible to have increased DM and positive PDSI in the same growing season. Although ENSO has significant impacts on annual and seasonal circulation patterns and precipitation across the northern coast of the Gulf of Mexico, it surprisingly appears to have little impact on tree growth or air mass variability during the growing season.

In order to investigate PDO influences on air mass variability, atmospheric circulation patterns were evaluated under positive PDO. Using the NCEP/NCAR Reanalysis, 500 mb geopotential height anomalies were analyzed during the ten strongest years of PDO. There was not a discernible trend in geopotential heights during these years, although the ten most positive PDO years favored lower heights over the Southeastern United States (Fig. 3). This complements cooler Gulf of Mexico SST under positive PDO.

Conclusions

Using the SSC, we explored the relationship between air mass variability and tree growth in a bottomland forest in Coastal Alabama. This particular air mass approach has not been used in dendroclimate research. Rodgers et al. (2006) found tree growth to be moderately related to seasonal precipitation and PDSI in this warm and moist climate. However, in this study, correlations with air mass variability were substantially higher. Tree growth was positively correlated with MM days and negatively correlated with DT days. It is suggested that DT (MM) days inhibit (promote) growth due to intense (relaxed) evaporative conditions. Upon further examination of subsets of the ten lowest and highest growth years, the anomalous occurrence of DT and MM is not robust across all ten lowest and highest growth years. Growing season ratios for the ten lowest and highest growth years reveal that the relationship between air mass variability and tree growth is better portrayed by the comparative growing season ratios of DT:MM, DT:MT, and DM:MM. The ratio results are more significant for the ten lowest growth years than the ten highest growth years.

Table 7 Correlation coefficients, p values < 0.05 significance

	PDO	
	r	p
DM	0.32	0.025
PDSI	0.36	0.011

DM air mass variability, PDSI, and PDO 1950–1999

A second objective of this article was to examine the influences of teleconnections on air mass variability in an attempt to explain some of the variation of growing season air mass type distribution. Although several teleconnections were tested, only the PDO was significant with air mass variability, but it was not significant with tree growth. The PDO was positively correlated with DM days and PDSI. Thus, the PDO may enhance or decrease the occurrences of DM which may indirectly influence tree growth. Furthermore, it may assist tree growth through its positive correlation with PDSI. It appears that the inter-annual air mass variability during the growing season is affected by teleconnected measures of sea surface temperature, albeit these correlations are weaker than the tree growth correlations.

Based on the results of this article, the SSC is considered to be a viable new method for conducting dendroclimate research. We believe its applicability is well suited for research involving climate and vegetation because of its holistic evaluation of surface conditions. Previous dendroclimate research using traditional climate variables in this region and other similar climatic regions has shown weak to moderate climatic significance on tree growth. Other influences on tree growth, such as environmental factors or increased CO2 (West et al. 1993), may explain much of the remaining variability in growth, but these influences were not evaluated in this study. Since the SSC was used successfully in the marginal climate of coastal Alabama, it is suggested that it will be even more useful in drier more traditional dendroclimate research areas. Further research will explore the applicability of the SSC in dendroclimate research across a greater variety of spatial scales and regions.

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