RECOMMENDATIONS ON CATEGORIZING ARCTIC AIR MASS INTENSITY/COVERAGE AND IMPROVING THE MONITORING OF ARCTIC SOURCE REGIONS ACROSS THE NORTHERN HEMISPHERE

By Victor J. Nouhan

Who I am

- Presenter: Victor J. Nouhan
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- Current Position: Lead Forecaster
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Who I am

- Subsequently, I do not have much time or opportunity to access/use complex climatological tools with what is being presented here. Rather, I will be presenting ideas that full time climate researchers and powerful research tools can be utilized to display and research further in the future.

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I. Introduction

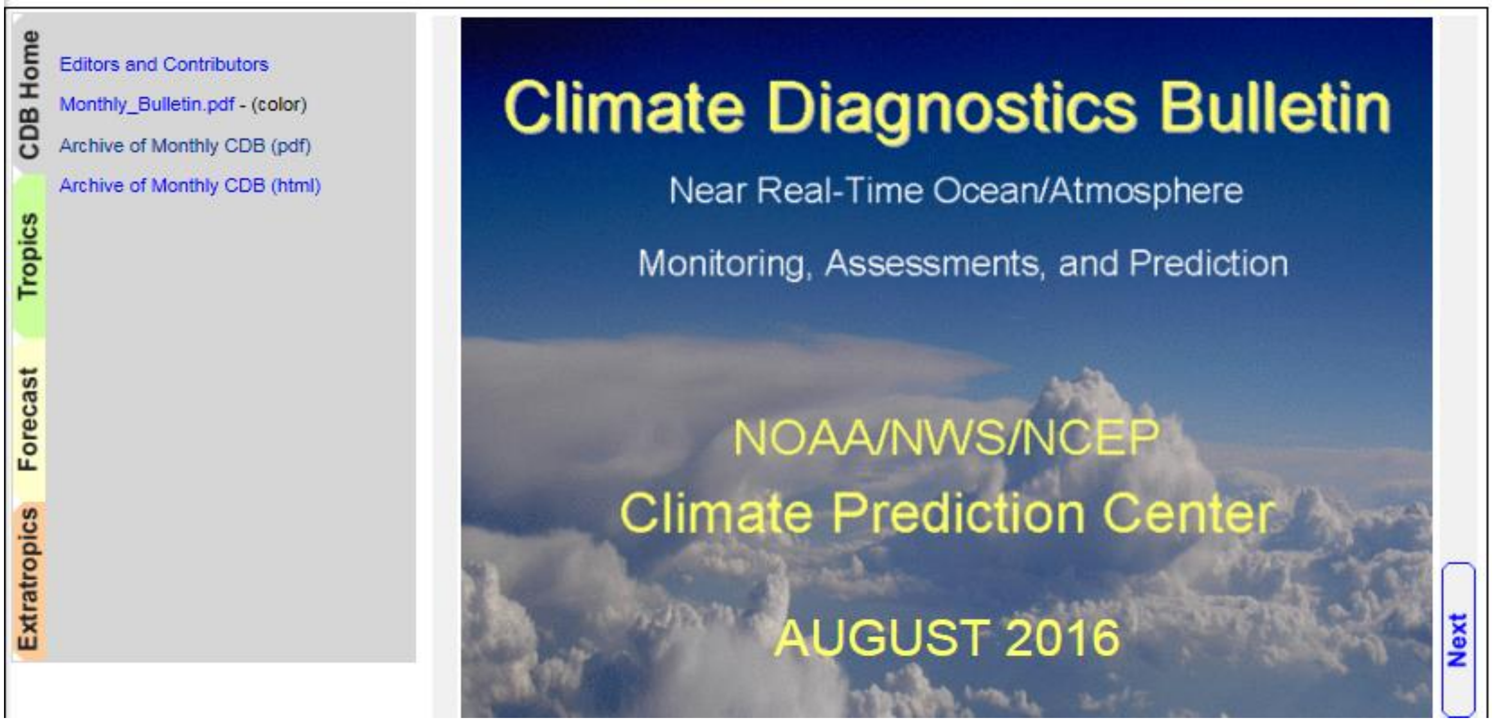
- During the last few decades, the science of meteorology/climatology regarding the discovery, categorizing, monitoring, and prediction of teleconnection patterns influencing atmospheric circulation across the northern hemisphere, originating from both the mid-latitudes and tropics, has been established. The science of categorizing, monitoring, and predicting of cold season arctic air masses over the continental source regions of the northern hemisphere and their advection into lower latitudes, unfortunately, has lagged behind knowledge gained by exploring teleconnections during the corresponding period.

I. Introduction

- In an effort to activate research in this mostly unexplored topic, this presentation will provide recommendations/ proposals regarding 1) defining arctic air masses by intensity and geographic coverage across northern hemispheric continents, 2) better utilizing the few existing established teleconnections that better correlate to arctic air mass formation and advection, especially over North America, and 3) new arctic (non-teleconnection) indices to better help forecast/monitor the development of arctic air masses over all known northern hemispheric source regions and the potential for advection of these air masses into adjacent lower latitudes.

I. Introduction

- Why: Note – no "Arctic Highlights" section in the Climate Diagnostics Bulletin, with the Extratropics section not containing much, if any specific info on arctic potential.



I. Introduction

- ***Acknowledgements***

- Dr. Martin - "**An examination of trends in both cold and warm pools over the Northern Hemisphere and North America" (2015)**, the climate forecast system re-analysis data was used to examine trends in both cold and warm pools over the Northern Hemisphere and North America from 1979-2010. The focus was pools of warm and cold air during the summer (June-July-August) and winter (December-January-February) months respectively. Winter cold pockets were defined as areas where the 850 hPa temperatures were -10, -20,-25, and -30C or colder. The corresponding 500 hPa height fields were examined to find the extant of the 5280 and 4980 m contours. During the warm season a similar examination was made of warm pools using the +20, +25 and +35C contours at 850 hPa and the 5880, 5940, and 6000 m contours at 500 hPa.

II. Defining Arctic Air Masses

- Arctic air masses over the Northern Hemisphere (NH) are Seasonal – Dependent on cold season snow pack for the development of strong surface-base inversions (usually greater than 10 degrees C from the surface to the inversion point – usually about 1000 to 1500 FT above flat surface).
- Air masses become arctic in character once temperatures at the top of the surface inversion reach -10 degrees C or less. Surface dew points (or frost points) significantly less than -10 degrees no longer represent a barrier (via latent heat release) to reduce the rate of fall of surface temps during long clear, cold season arctic/sub-arctic nights under positive (dry) hydro-lapse rate environments and light/calm winds.

II. Defining Arctic Air Masses

- Most meteorologists/climatologists infer arctic air masses using 850 hPa temps as a starting reference. For locations east of the Rockies over North America (NA), this to far above the surface inversion height. The use of 925 hPa is a better choice, but neither are very useful over western NA where there is much terrain above 850 hPa, models do not accurately depict arctic air infiltrating passes in the continental divide of NA.
- ***Recommendation 1) : Standardize monitoring arctic air (-10 deg C and colder) using a standard height of 1 KM above ground level (AGL). This would better show arctic air masses infiltrating complex terrain and splits the difference between 850 and 925 hPa for near mean sea level (MSL) locations.***

III. Defining Source Regions Across the NH

- What constitutes arctic air mass source regions across the NH?

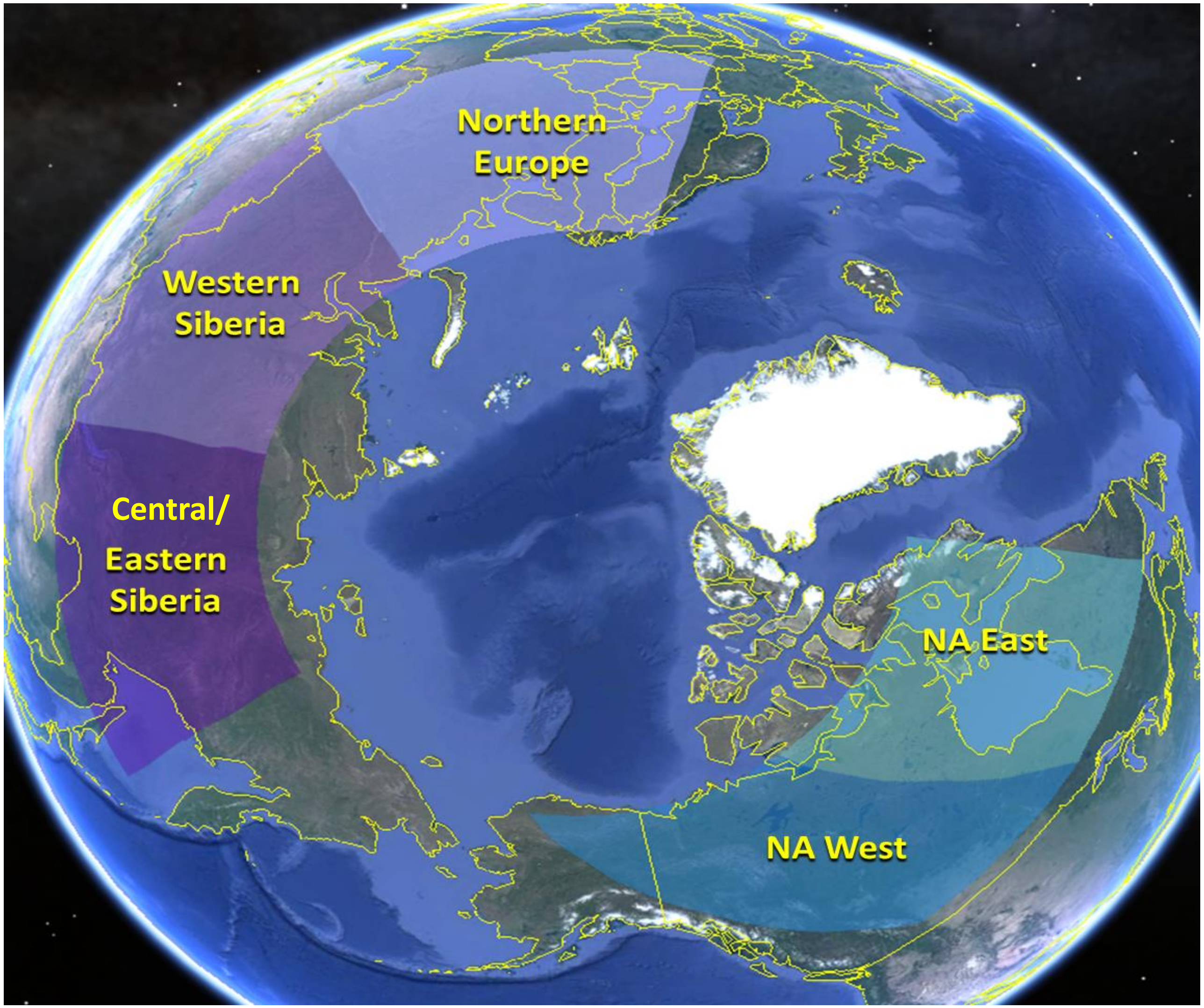
- ***Recommendation 2): Define Seasonal continental arctic source regions.***

- For the purpose of this presentation, we identify five source regions: 2 across NA and 3 across Eurasia (EA) based on frequency differences of loading and residence of arctic air masses and topography - limited to no greater than 45 degrees longitude wide generally from 50 to 70 degrees N latitude.

III. Defining Source Regions Across the NH

- 1) NA East- northeastern Canada (including Hudson Bay) – approximately between 65 degrees W and 100 degrees W longitude.
- 2) NA West - northwestern Canada (including the east central and northeast portions of Alaska) east of the Rockies – approximately between 100 degrees W and 135 degrees W longitude.
- 3) Central/Eastern Siberia – between 105 degrees E and 150 degrees E longitude.
- 4) Western Siberia – between 60 degrees E and 105 degrees E longitude.
- 5) Northern Europe (west of the Ural Mountains) – between 15 degrees E and 60 degrees E longitude.

III. Defining Source Regions Across the NH



IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Recommendation 3): Have descriptive arctic air mass intensity based on NA source region return frequencies per winter(s).***

Intensity	1KM AGL Core Temperature	Frequency
Marginal	-10.0 to -17.4 degrees C	Nearly Always
Moderate	-17.5 to -24.4 degrees C	Frequent
Deep	-24.5 to -29.4 degrees C	Occasional
Bitter	-29.5 to -34.4 degrees C	1 to 3 times
Very Bitter	-34.5 to -39.4 degrees C	1 every other winter
Pristine	-39.5 to -45.4 degrees C	1 every 3 to 5 winters
Glacial	≤ -45.5 degrees C	Greenland and Antarctica Winters

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Recommendation 4)*** – have a numerical arctic air mass index (ai) for public dissemination and historical ranking purposes that can be contoured daily and averaged on a hemispheric and/or continental basis ranging from less than 25 (non-existent arctic air) to 100+ (where 100 corresponds to the minimum threshold for a pristine arctic air mass). By definition:
-
- ai = 2.5 (0 degrees C – (1KM AGL Temperature))
-
- ami represents the maximum ai (coldest portion) of the air mass.

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Arctic Index vs. Air Mass Classification***

Arctic Index (ai)	Air Mass Classification
ai < 25	Polar Air Mass
25 ≤ ai ≤ 44	Marginal Arctic Air Mass
45 ≤ ai ≤ 59	Moderate Arctic Air Mass
60 ≤ ai ≤ 74	Deep Arctic Air Mass
75 ≤ ai ≤ 87	Bitter Arctic Air Mass
88 ≤ ai ≤ 99	Very Bitter Arctic Air Mass
100 ≤ ai ≤ 114	Pristine Arctic Air Mass
ai ≥ 115	Glacial Arctic Air Mass

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Recommendation 5A) -*** Arctic Area Indices
- ***Arctic Area Index (Aai)*** - The percentage amount of the entire NH, individual northern continents, or countries encompassed by the 1KM AGL -10 degrees C isotherm that can be calculated on a daily, monthly, or seasonal basis. For North America:
- Aai = Aa / 19.60 Mkm^2 * 100
- Where Aa represents the total area encompassed by the 1KM AGL -10 degrees C isotherm (at least marginal arctic air) in millions of square kilometers (Mkm^2) and 19.60 represents the total area of Canada and the United States (including Alaska, but excluding Hawaii) in Mkm^2.

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Deep Arctic Area Index (DAai)*** – The percentage amount of the NH, individual northern continents, or countries encompassed by the 1 KM AGL -25 degrees C isotherm that can be calculated on a daily, monthly, or seasonal basis. For North America:

- DAai = DAa / 19.60 Mkm^2 * 100

- Where DAa represents the total area encompassed by the 1KM AGL -25 degrees C isotherm (deep arctic air) in Mkm^2.

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Recommendation 5B) –*** Historical Reference Arctic Indices

- ***The Total Arctic Index (Tai)*** – A daily index combining the max Ai, Aai, and the DAai to provide historical comparison of arctic air masses encompassing large continental areas. A similar index for Tai can also be derived using the area coverage of the 1KM -10, -20, and -30 deg C isotherms (Martin 2015). For North America:
- $$TNai = \frac{ami + (x)\, ami\,(Aa/19.60) + (y)\, ami(DAa/19.60)}{3}$$
- The variables x and y are bias factors to weight the smaller DAa greater relative to the larger Aa with arctic air masses. For the purpose of this proposal, x and y are initially estimated at 1 and 2 respectfully, but is envisioned to vary month to month during the cold season with future use based on determination of normalized deep arctic to arctic air mass coverage ratio for each winter month.

IV. Proposed Arctic Air Mass Intensity Ratings and Area Measuring Parameters

- ***Recommendation 5C) –*** Arctic Air Mass (or simply Arctic) and Location Transport Efficiencies (ATE and LTE)

- ATE is the ratio (or percentage) of the ai core (closed maximum value) measured crossing more southern latitude bands to the maximum ai (ami) achieved prior to the air mass leaving the source region. This is a measure of how much of the air mass (core) remains refrigerated (or modifies) as it moves into middle latitudes. ATE is affected by factors such as the speed of the advection, the distance the air mass travels, and whether the underlying surface is snow/ice sheet covered. LTE is the ratio (percentage) of the max ai value experienced at an individual location by an air mass to the ami. By definition:

- ATE50 = ai (core max Lat 50) / ami * 100
- ATE45 = ai (core max Lat 45) / ami * 100
- ATE40 = ai (core max Lat 40) / ami * 100
- LTE = ai (location max) / ami * 100

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- What constitutes a good mid tropospheric (500 hPa) loading pattern over the NA arctic source region(s), especially using current teleconnection indices?

- A study of arctic air masses over the U.S plains and Midwest conducted by Nouhan over the winter of 1995/96 indicated that 1), both *anomalous amplitude and placement of the mean upper ridge along or just west of the NA west coast was a more reliable indicator for the development of arctic air over NA* then 2), the strength and position of a downstream upper trough/low over eastern and/or central NA, the second best indicator.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- And most importantly 3), that the production of arctic air across the NA source region during the cold season ***was proportional to the strength and fetch length of anomalous North to Northeast component mid-tropospheric flow over the NA arctic source region pointing toward the Canadian Rockies divide***. This pattern which favors confluent flow and deep layer cold advection aloft results in rapid formation of deep arctic air masses with strong surface base inversions, since strong and rapid surface anti-cyclogenesis is favored in the lee of the Canadian Rockies when combined with low level barrier blocking (Nouhan, CRARP Feb 1999).

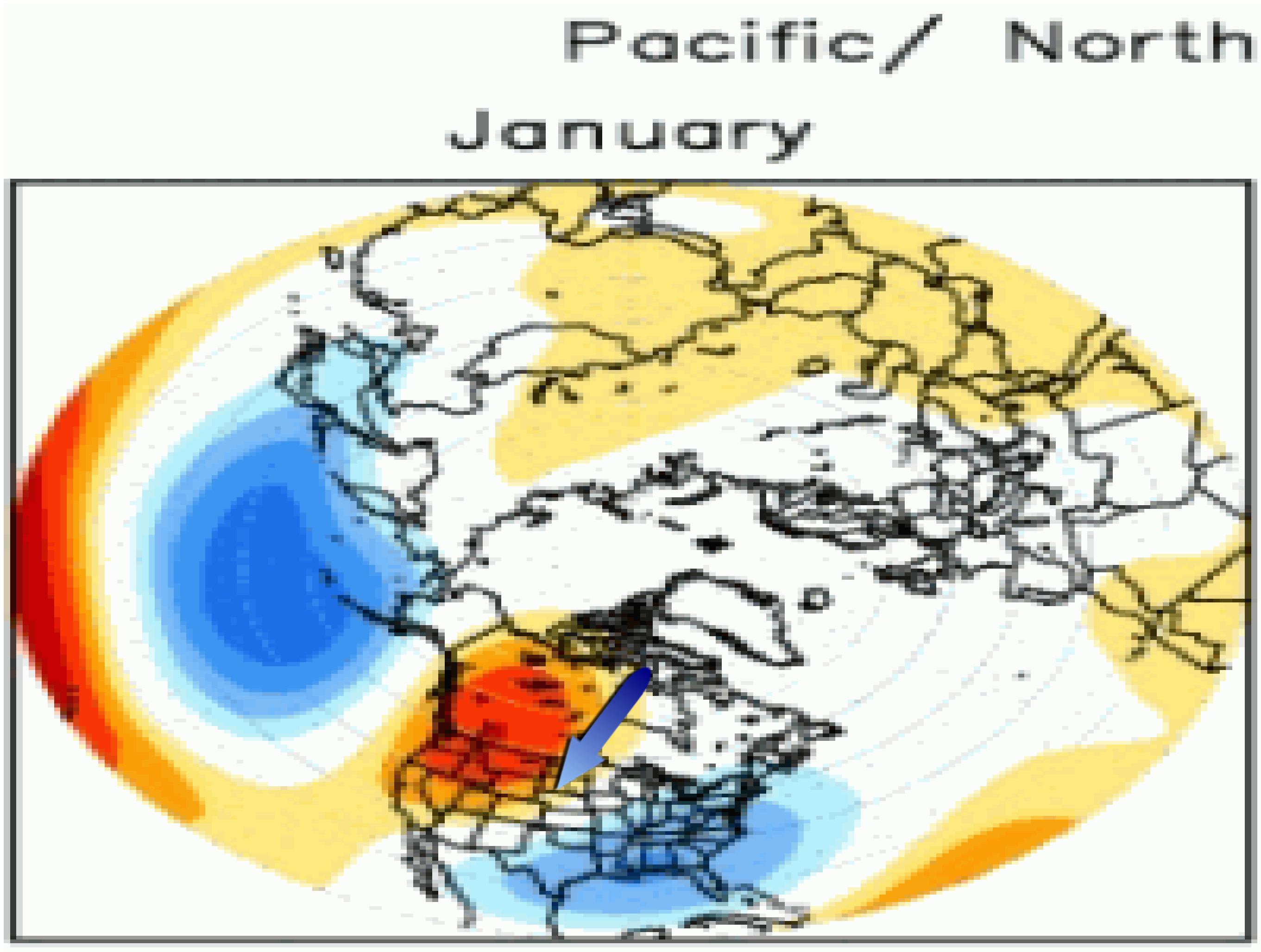
V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- How does this relate to well known, frequently used teleconnections over North America such as the PNA and NAO? It turns out, not consistently well, since the amount of northeast anomalous flow over the North America arctic source region(s) if either or both of these patterns dominate may be limited.

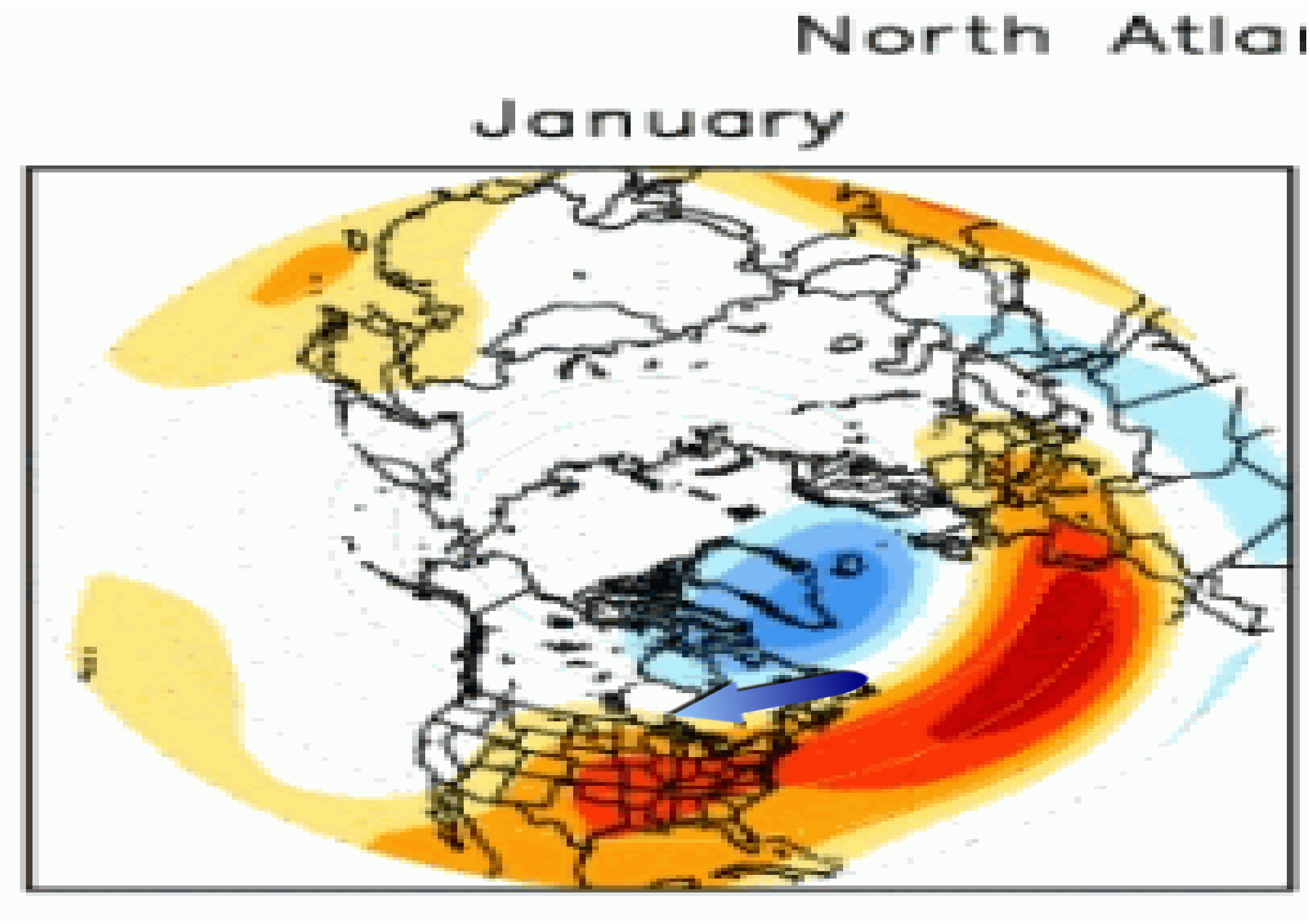
V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

Loading Patterns Follow

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections (PNA+)



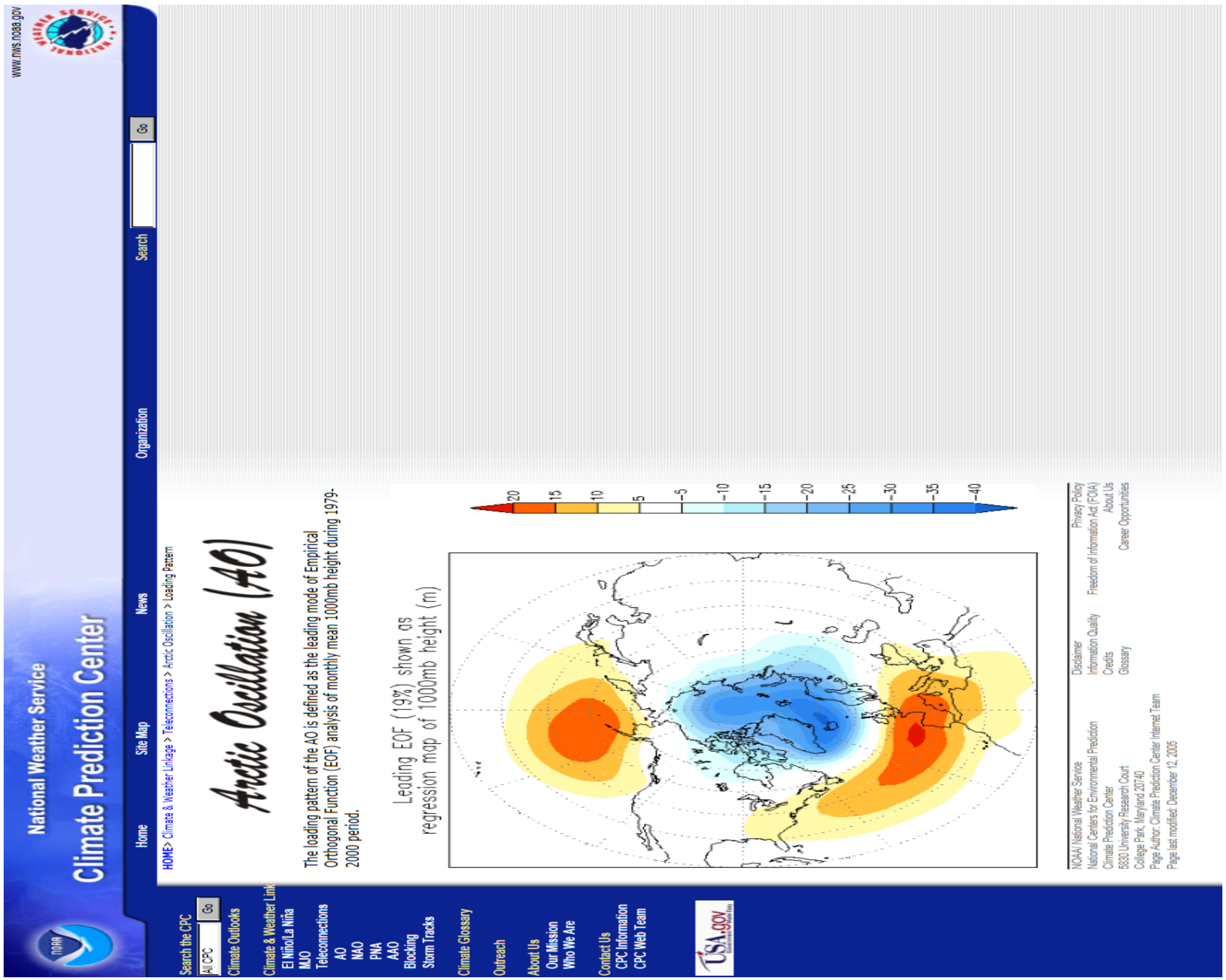
V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections (NAO)



V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- What about AO (fairly similar and related to NAO), especially since “arctic” is in the name of this teleconnection. It turns out, this index also is ***not*** consistent about relating favorable conditions for cold season arctic air formation over the NA source region. What this index (and NAO) does relate very well, however, *is the southward advection potential of air masses residing over the NA source region whether arctic, or not.*

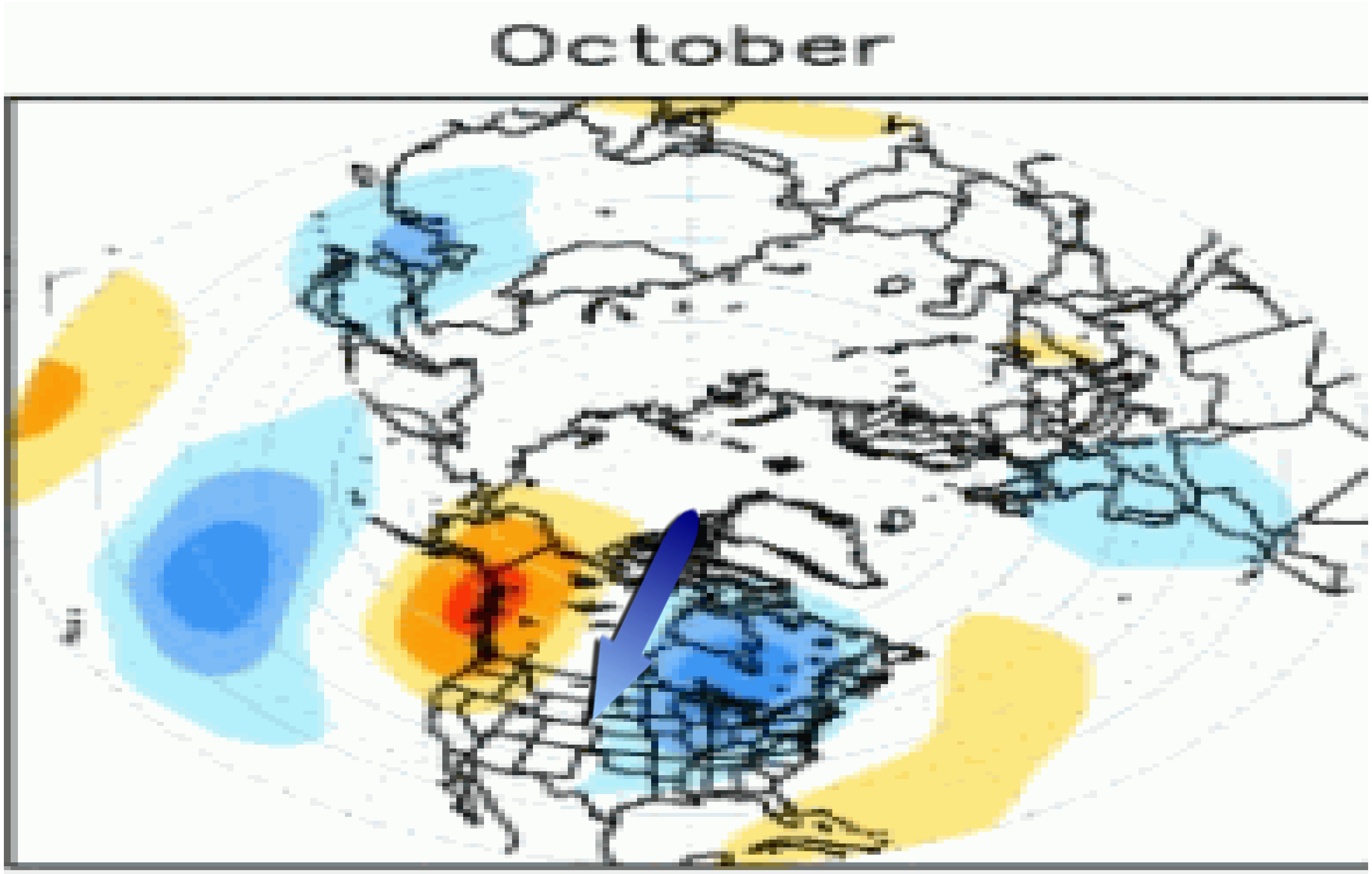
V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections



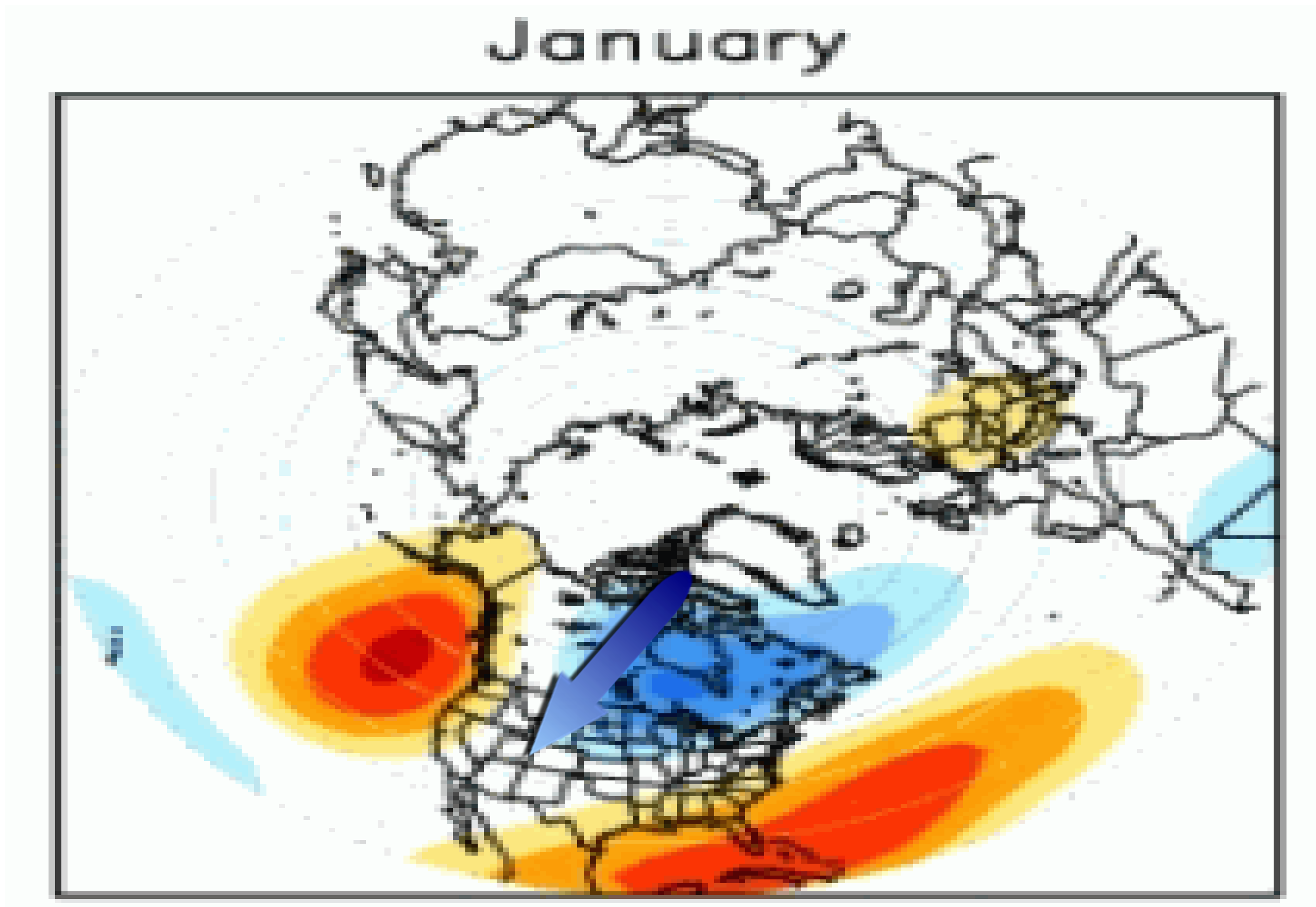
V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- So, are there any existing teleconnection patterns that better relate to cold season arctic air mass formation over the NA source region? ***Yes!*** It turns out that there are two, The EP-NP and the TNH. Both in their positive phase feature much more significant NE anomalous mid tropospheric flow over much larger portions of the NA arctic source region than the PNA index.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections (EP-NP +)



V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections (TNH+)



V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- Unfortunately, there are availability problems with EP-NP and TNH during the cold season. Based on the Rotated Principle Component Analysis (RPCA) methodology described and used by CPC, EP-NP is not a leading monthly mode of (8 to 9 indices listed) NH atmospheric variability to list for December and TNH is only a leading mode of atmospheric variability to list December thru February.
- ***Recommendation 6)*** **–** If possible, produce (list) monthly EP-NP for December and extend the listing of TNH indices from November through March (to encompass a greater portion of seasonal production time of arctic air), since both have leading roles of arctic variability for NA. Availability of listed daily values of each index are also needed.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- ***Recommendation 6A) –*** Rename the EP-NP teleconnection, since there is a significant center of tele-connectivity that impacts temperatures over both central and eastern Canada and U.S. How about, for example, NP-NA for North Pacific – North America. This would make it more relevant for users to want to interrogate this index.
- ***Recommendation 7) –*** If recommendation 6) were fulfilled, the EP-NP and TNH indices can be combined as a single index to monitor for arctic air mass formation and transport for all of North America (including both the NA East and NA West regions) at least from November through March.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- NAT = x(EP-NP) + y(TNH)
- x + y
- where NAT represents a proposed North American Arctic Transition Index (no longer a true teleconnection index, since this new index would cover additional area not fully in the domain of the constituent teleconnection indices for arctic variability). Variables x and y represent unknown weighting factors that may vary somewhat from 1, but could be determined more explicitly by correlation with the proposed ai or observed surface temperature anomalies. Note: positive values denote greater arctic air mass potential.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- Based on relatively few applications of past seasons for historical comparisons, it is estimated over the time scale of one month to a season that NAT values between 0.5 to 1.0 would potentially result in episodic cold season outbreaks, 1.0 to 1.5 in moderately high persistence of arctic outbreaks, and greater than 1.5, high persistence of arctic air across portions of the 48 contiguous U.S states.
- Over shorter time scales of 14 days and less, substantial arctic outbreaks will likely be associated with NAT values of 2.0 or more with NAT values of 3.0 or more potentially resulting in super arctic outbreaks and/or a logjam of arctic air over NA.

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

- Since the domain of the PNA index somewhat overlaps the EP-NP index (i.e. EP-NP appears to be like a westerly displaced PNA), during positive phases, NAT can be used in conjunction with contemporaneous PNA indices to determine what portion of the U.S. will have the greatest persistence (or at least be most affected) by arctic air mass regimes and observed temperature anomalies by utilizing the following table:

V. North America Arctic Source Region Loading vs. Current Mid Tropospheric Teleconnections

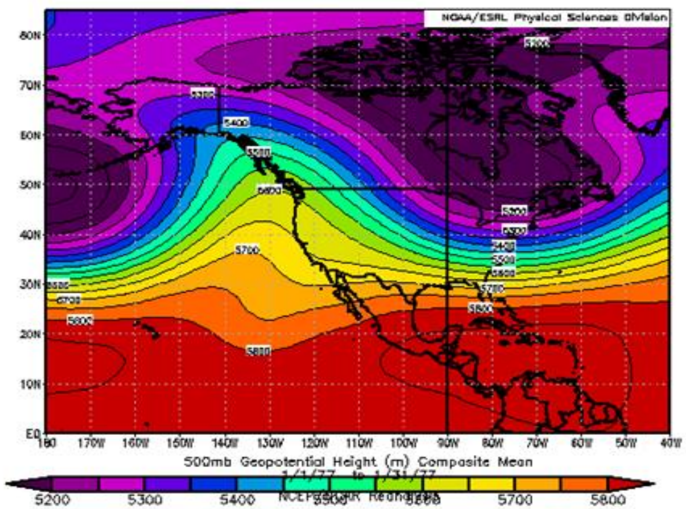
- ***U.S. Regional Persistence of Arctic Air Masses with Positive NAT vs. PNA***

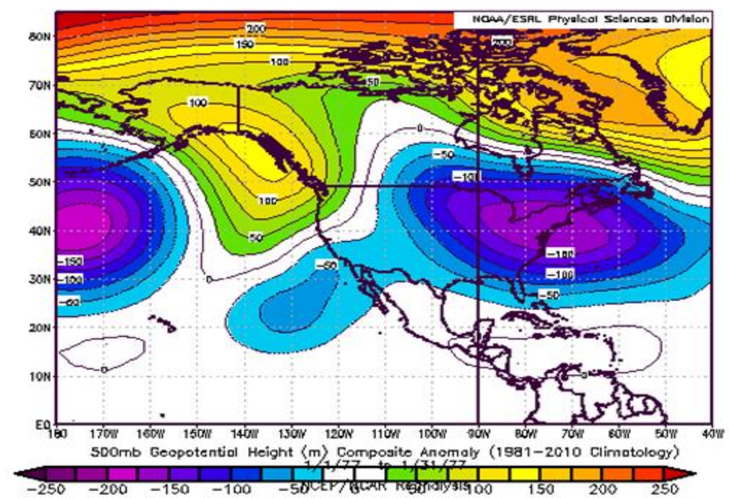
	PNA -	Amplified PNA Zero	PNA +
High Plains, Rockies, Inter-Mountain West	**Dominated**	**Affected**	**Peripheral**
Eastern Plains Midwest and Upper Great Lakes	**Affected**	**Dominated**	**Affected**
Eastern Great Lakes Ohio Valley and Northeast	**Peripheral**	**Affected**	**Dominated**

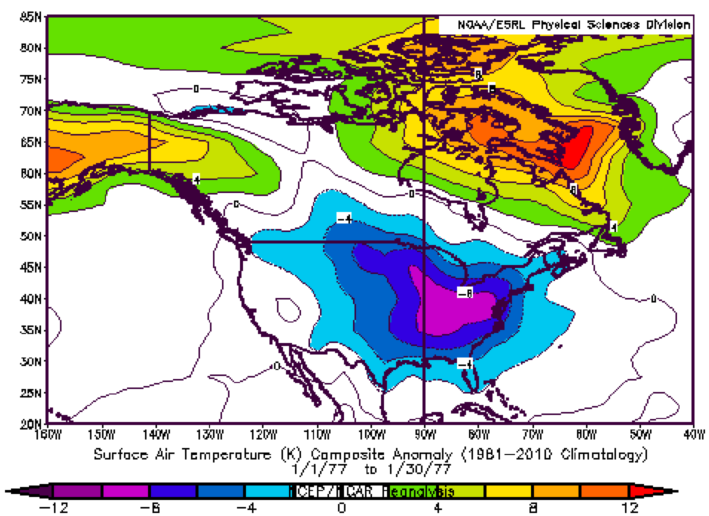
V. North America Arctic Source Region Loading (Example Winter Months Follow)

- 500 hPa Heights 500 hPa Ht. Anom.
- NCEP/NCAR Re-analyses
- Monthly Sfc Temp. Teleconnection Indices

V. North America Arctic Source Region Loading
January 1977

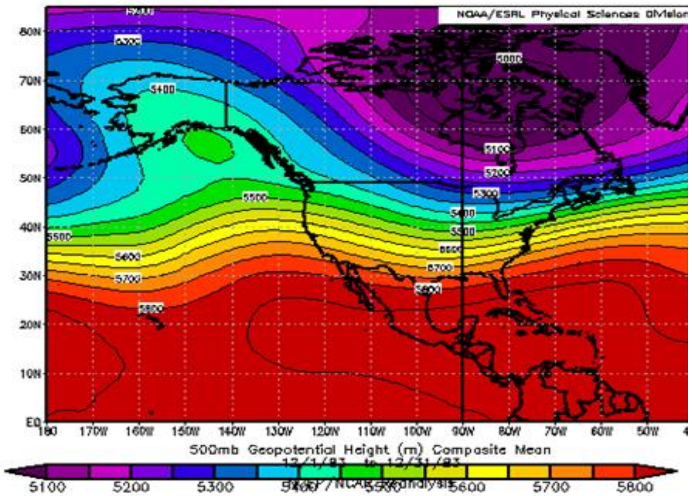


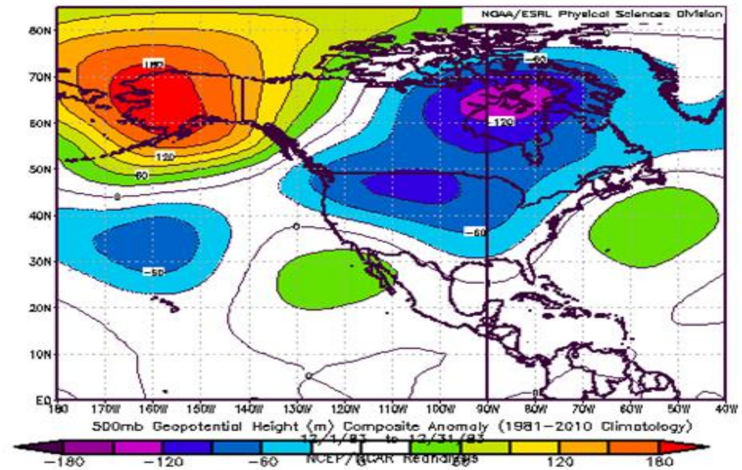


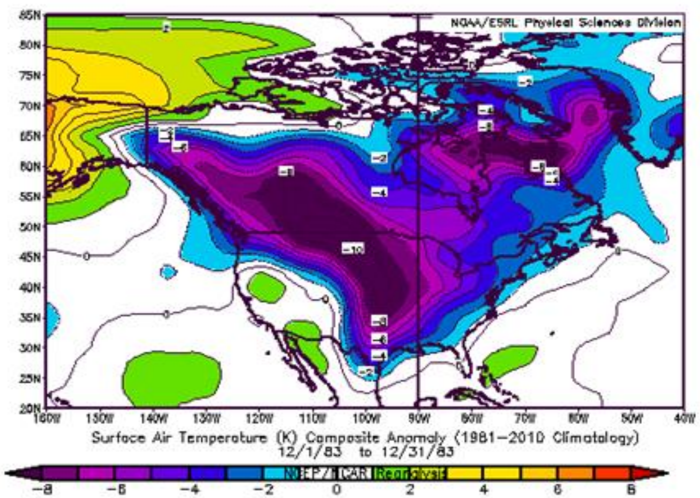


PNA = 1.60
NAO= -1.72
AO = -3.77
EP-NP = 0.75
TNH = 0.88
NAT = 0.82

V. North America Arctic Source Region Loading
December 1983

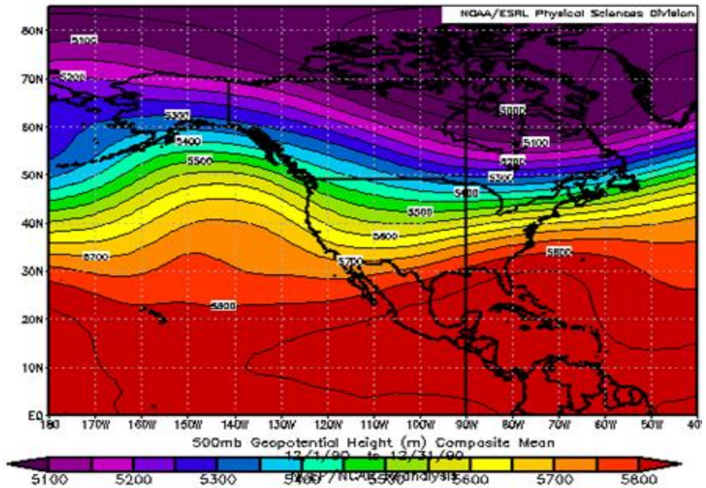


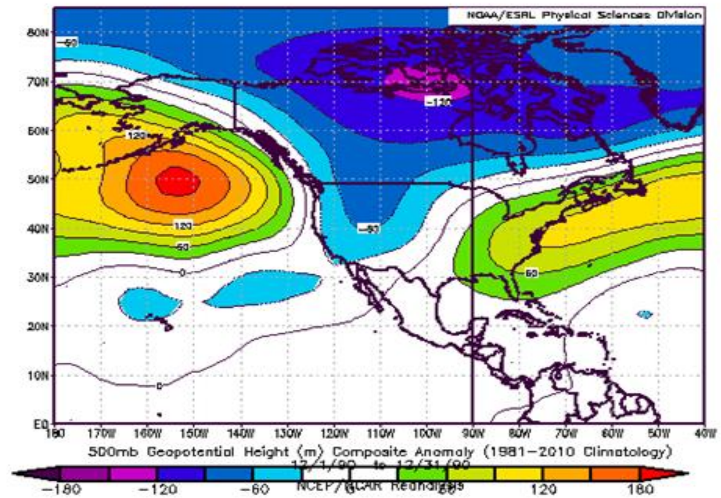


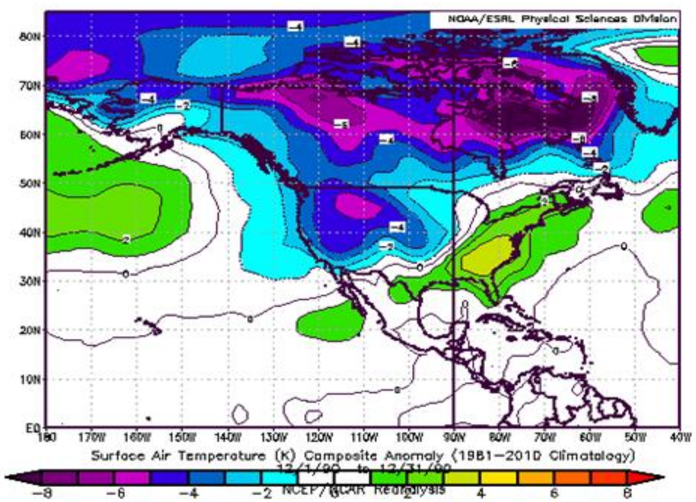


PNA = -0.61
NAO = 0.12
AO = 0.19
EP-NP = ?
TNH = 1.24
NAT = ?

V. North America Arctic Source Region Loading
December 1990

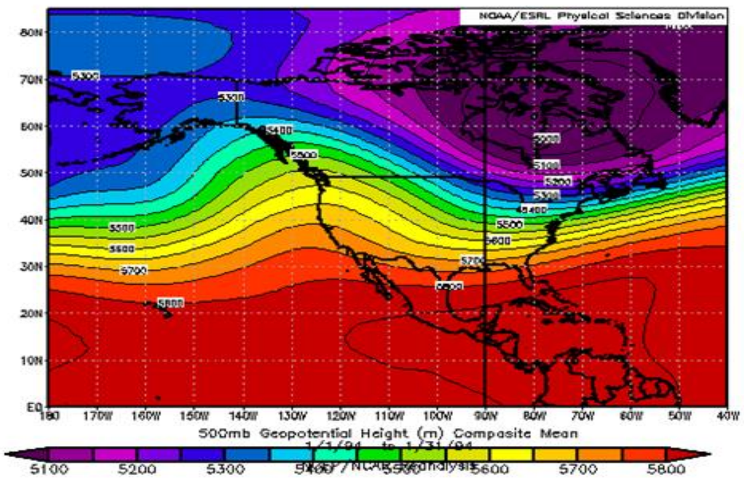


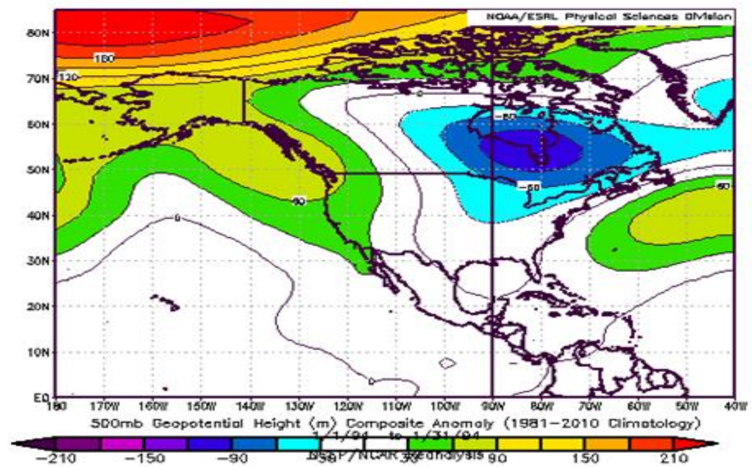


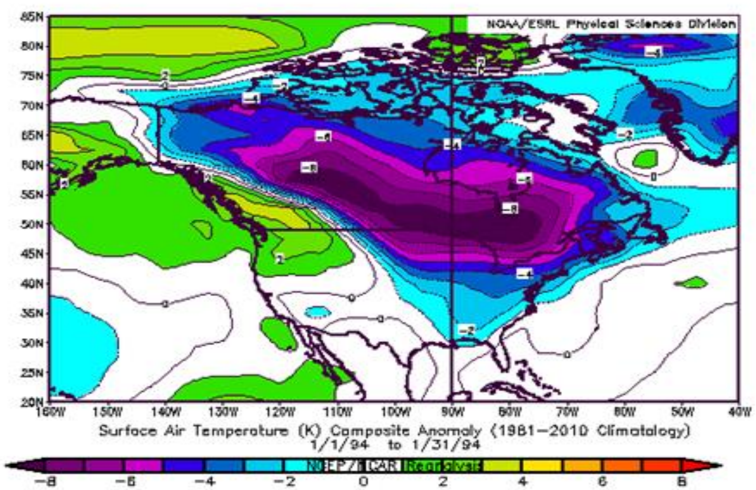


PNA = -1.62
NAO = 0.11
AO = 1.28
EP-NP = ?
TNH = 1.26
NAT = ?

V. North America Arctic Source Region Loading January 1994







PNA = -0.80

NAO = 0.70

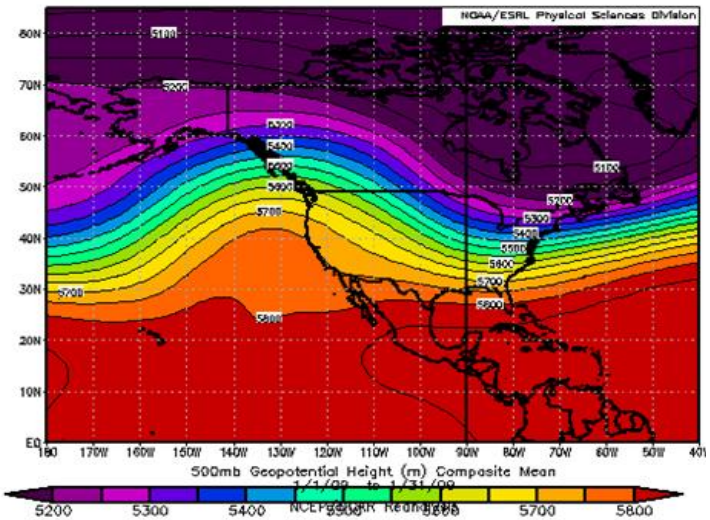
AO = -0.29

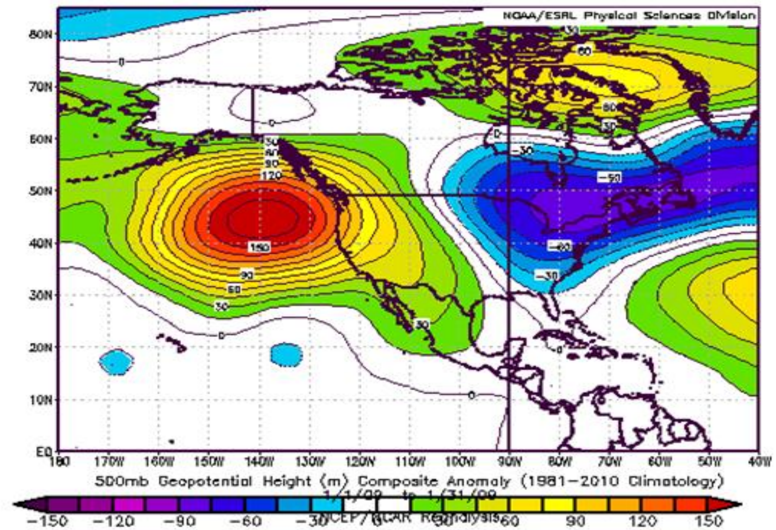
EP-NP = 2.38

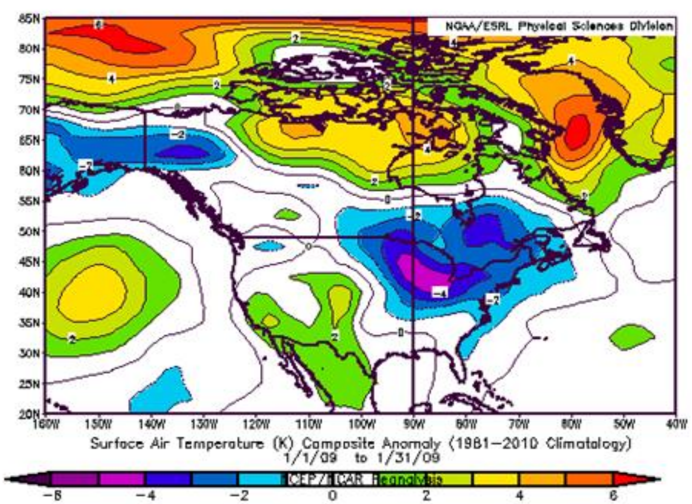
TNH = 0.78

NAT = 1.58

V. North America Arctic Source Region Loading January 2009

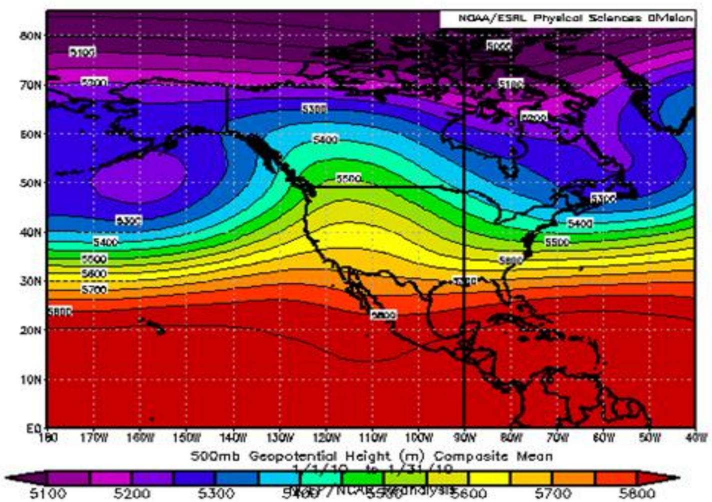


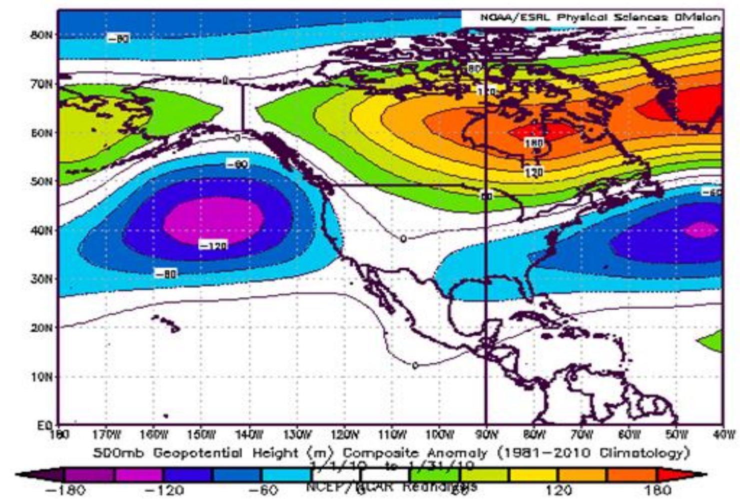


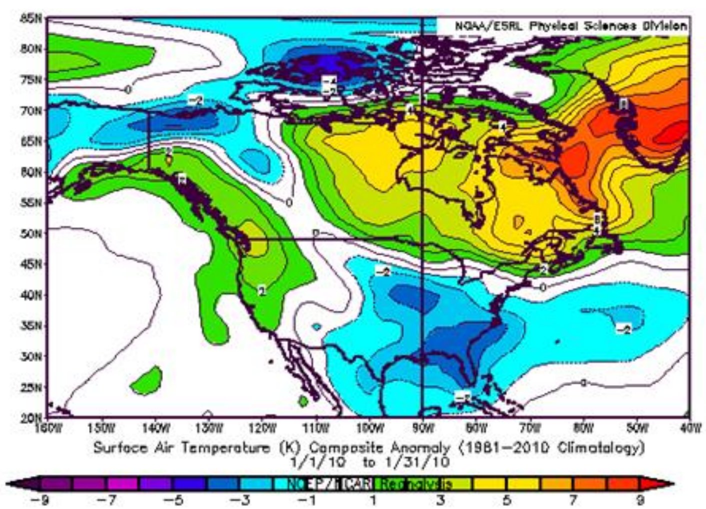


PNA = 0.13
NAO= -0.52
AO = 0.80
EP-NP = -0.18
TNH = 1.96
NAT = 0.89

V. North America Arctic Source Region Loading
January 2010

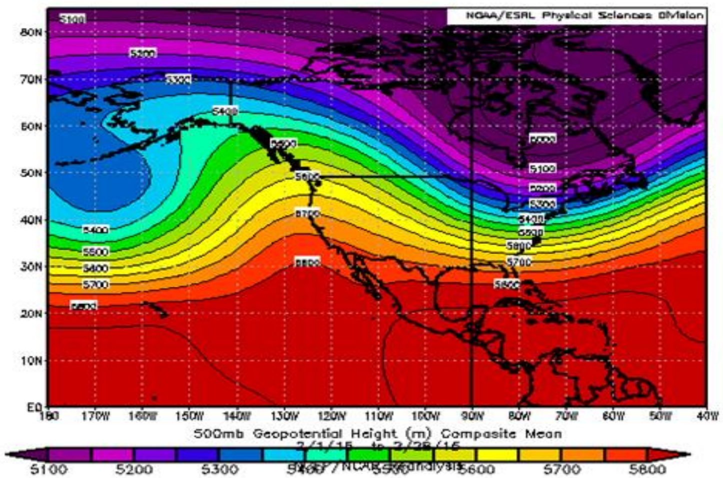


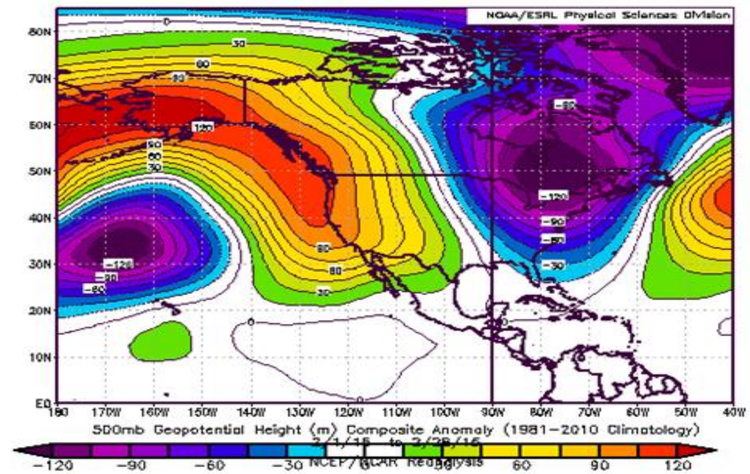


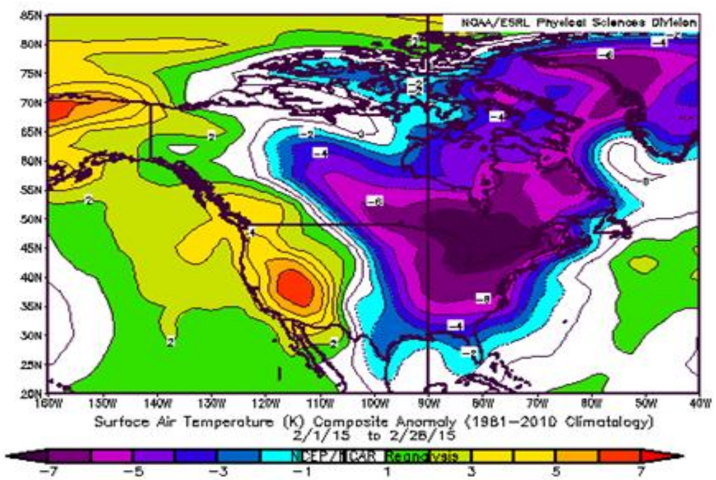


PNA = 0.96
NAO= -1.80
AO = -2.59
EP-NP = -0.58
TNH = -1.33
NAT = -0.96

V. North America Arctic Source Region Loading February 2015







PNA = 0.49

NAO = 1.05

AO = 1.04

EP-NP = 1.18

TNH = 0.66

NAT = 0.92

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- In addition to the NAT index, new non-teleconnection arctic indices can be created to monitor the potential of arctic air mass formation across all of the northern hemisphere (NH) by sectorizing AO for each continental source region. The major advantage of sectorizing AO specifically over each of the major NH continental source regions is that the affects of the ocean domain portions of AO can be minimized.

- Again we state that the NAT and following new mid tropospheric arctic indices, even though built on existing and/or portions of existing teleconnection indices , ***are not teleconnection indices in themselves***. These proposed arctic mid tropospheric circulation indices are geared to forecast the variability of arctic air mass potential/advection across N.H. source regions and adjacent temperate regions, ***not modes of explained N.H. mid tropospheric circulation variance via teleconnection patterns***.

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- Start with the current depiction of AO.

- CPC depicts AO using mean 1000-700 hPa height anomalies as an Empirical Orthogonal Function poleward from 20 deg N latitude across the entire NH (site-CPC website source).

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- However, since we are more interested in interactions between mid (rather than sub-tropical) and high latitudes and given arctic source regions over the NH land masses extend northward to 65+ N degrees, 500 hPa (for more lead time) standardized height anomalies (S) for the 40 N to 65N degree latitude and 65 to 90 degree latitude bands can be substituted so that AO can be modified and re-defined as:

$$AOm = \frac{500\ hPa(40\text{-}65N)S - 500\ hPa(65\text{-}90N)S}{2}$$

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- ***Recommendation 8) –*** Apply the AOm formula for each defined NH arctic source region to produce an overall NH arctic potential index.

- NAEi = <u>500 hPa[(40-65N)(60-92.5W)]S–500 hPa[(65-90N)(60-92.5W)]S</u>
- 2
-
- NAWi = <u>500 hPa[(40-65N)(92.5-117.5W)]S–500 hPa[(65-90N)(92.5-117.5W)]S</u>
- 2
-
- CESi = <u>500 hPa[(40-65N)(105-150E)]S–500 hPa[(65-90N)(105-150E)]S</u>
- 2
-
- WSi = <u>500 hPa[(40-65N)(60-105E]S–500 hPa[(65-90N)(60-105E)]S</u>
- 2
-
- NEi = <u>500 hPa[(40-65N)(15-60E)]S–500 hPa[(65-90N)(15-60E)]S</u>
- 2

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- Where NAEi and NAWi represents the North America East and west sectors, CESi and WSi the central/eastern and western Siberian sectors, and the NEi is the northern Europe sector of a modified land arctic index from the original AO. The total Northern Hemisphere arctic potential can then be expressed as follows:
- $$NHAi = \frac{NAEi + NAWi + CESi + WSi + NEi}{5}$$
- Given the same algebraic comparison of the latitude bands, the sign of NHAi and the individual source region sub-indices will be similar to AO, except increasing negative (positive) values will better anticipate greater (lesser) arctic air mass potential over source regions than AO.

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- Of course, it may be even more useful to separate NA indices from Eurasia, or from Siberia, to monitor different source regions contemporaneously:

$$NAi = \frac{NAEi + NAWi}{2}$$

$$EAi = \frac{CESi + WSi + NEi}{3}$$

$$Si = \frac{CESi + WSi}{2}$$

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- ***Important Note:*** Both subdivided source region indices and total NHAi would greatly reduce, but not completely eliminate impacts from oceans that the legacy AO frequently contains. Examples of potential error for the NAEi, for example, could occur when deep upper lows with strong to intense occluded surface lows east of the Canadian Maritimes and south of Greenland retrogrades westward back into northeast Canada due to high latitude North Atlantic blocking (- NAO pattern).

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- ***Recommendation 9):*** Enhance new source region indices to factor important topographical features:

- Certain of the newly derived source region indices can be modified to include important topographical factors. For example both the NAEi and NAWi can be modified to include standardized 500 hPa height anomalies between 40 and 65 N degrees latitude for approximately 15 to 30 degree slanted longitudinal parallelograms corresponding to the EP-NP and TNH index center of actions located along and just west the northern NA west coast, respectfully, to account for the impacts of the northwest-southeast orientated Rocky mountains on formation and southward transport of arctic air:

VI. Other Proposed Circulation Indices to Monitor Potential of Arctic Air Masses Across all NH Source Regions

- $NATe = \dfrac{x500\text{ hPa}[65N(150\text{-}130W),40N(130\text{-}115W)]S - y(NAEi)}{x + y}$

- $NATw = \dfrac{x500\text{ hPa}[65N(180\text{-}150W),40N(145\text{-}130W)]S - y(NAWi)}{x + y}$

- where NATe and NATw represent the North American arctic transition for the eastern (comprising the Midwest and eastern states) and western (intermountain west, Rockies and plains states) U.S. respectfully. So, unlike the single overall NAT presented in the last section where one would have to reference the corresponding value of PNA to infer what portions of the U.S. will be most dominated by arctic air for positive NAT values, positive NATe and NATw will have separate and more determinant values better corresponding what portion of the country that is being more greatly dominated by arctic air. Note: similar to NAT, positive values denote greater arctic air mass potential where initially x=1 and y=2.

VII. Possible Future Uses and Potential Refinement

- Use these (or similar) indices to provide a seasonal "Arctic Highlights" section in the Climate Diagnostics Bulletin.

- In addition to providing real time analyses and forecasting of arctic air masses and arctic air mass potential, these indices can be used via reanalysis of the radiosonde era to determine secular changes in arctic air mass source region loading frequencies since the mid 20th century.

- Can RCPA be used to refine proposed circulation indices by outputting mid-tropospheric circulation anomaly centers as a function of observed 1 KM AGL temps and/or observed surface temperatures anomalies for each arctic source region? ?

VIII. Summary

- In this presentation, we recommended the following:

- Define the limit of how we delineate seasonal arctic air masses from non-arctic air masses and standardize the height above ground we measure this (-10 deg C, 1KM AGL).

- Produce arctic air mass monitoring indices for intensity, area coverage, transport efficiency, and historical rating.

- Produce a new mid tropospheric circulation index for arctic air mass potential over NA by using lesser used existing mid tropospheric teleconnection indices.

VIII. Summary

- Sectorize AO by source region by compressing the latitude bands and eliminating ocean areas so to produce better mid tropospheric indices to gage arctic air mass potential across all NH land source regions and adjacent areas southward.

- Potential future uses of these new indices such as re-analyses of past data to examining changes of arctic source region loading.

VIII. Summary

The End

Appendix

- ***In realizing that no standardized set of definitions or terminology exist to describe arctic air mass source regions and transport, the following definitions and terminology are proposed:***

- ***A. Arctic source region*** – a portion of a continent that allows the formation of low level arctic air during the cold season, most frequently during the winter season.
- ***B. Source Region Loading*** – When arctic air forms over a source region or is imported over the region from an adjacent arctic source region.
- ***C. Transarctic*** – relating or connecting to more than one arctic source region.
- ***D. Transarctic Ridge/Block*** - an upper level ridge/closed blocking high (e.g., near or over Alaska), which often diverts mid-tropospheric flow and low level arctic air from one arctic source region to another (e.g., from eastern Siberia to north of, or through Alaska, into northern/central Canada).

Appendix

- ***E. Transarctic Advection (flow)*** - specifically, when arctic air formed over one arctic source region advects toward another source region via the mean low to mid tropospheric flow. Although this is roughly synonymous to the term cross polar flow, not all arctic air masses traverse from one source region to another by crossing over the North Pole. For example, some Siberian arctic air masses arrive into northern Canada from eastern Siberia in the vicinity of the Bering Strait by directly crossing through central Alaska. Another type of mostly land based trans-arctic advection occurs when Siberian air backs (moves westward) into northern and eastern Europe. Trans-arctic advection marks the beginning of the importation of arctic air into a second source region.

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- ***F. Transarctic (Source Region) Infusion*** - The arrival (loading) of arctic air into a second source region from another originating arctic source region. The completion of the infusion process usually marks a temporary break or end in trans-arctic advection. The infused arctic air mass may have higher refrigeration (residence) compared to an arctic air mass that begins forming over source region two, and may be able to more rapidly refrigerate into a colder (deeper) arctic air mass sooner as a result of this head start.

- ***G. Arctic Air Mass Residence (or simply, Residence)*** - The extent of spatial mid-tropospheric pattern favorability and temporal persistence of this pattern which allows for greater cold and depth of arctic air masses to form over source regions. For the purpose of this proposal, air mass residence is considered to be *low* with 1 KM AGL air mass core temperatures between -10.0 to -19.9 deg C, *moderate to high* between -20.0 to -29.9, *high to very high* between -30 to -39.9, and *extremely high* $\leq$ -40.0 deg C.

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- ***H. Source Region (Residence) Continuity*** - The ability of a deep, highly resident arctic air mass to remain quasi-continually through the cold season (especially the margins of the season) across a source region.
- ***I. Expanded Source Region*** - A geographic term relating to: 1) the ability of arctic air masses to expand and refrigerate over time across individual source regions greater than suggested by climatology (especially south of 60 degrees N lat), and 2) the ability of neighboring arctic source regions to link (or merge) in the production of arctic air.
- ***H. Super Arctic outbreak*** – advection (transport) of high residence arctic air into a large geographical region resulting in specific sites across a significant portion of this region experiencing coldest temperatures within 10 degrees of all time record lows sometime during the span (usually 2 to 3 days) the air mass occupies the region.

Appendix

- ***K. (North American) Arctic Logjam*** – a rare phenomena when most of the continent from northern Canada, to the U.S. southern plains, southeast, east coast, including the northern portions of the intermountain west is dominated by arctic air (likely a resultant of a succession of arctic air masses, rather than one large air mass) producing large negative temperature anomalies for up to weeks at a time. Examples of this include the arctic cold spells of January 1857, February 1899, February1936, January 1977, January 1982, and December 1983 with Aai $\geq$ 75 percent and DAai $\geq$ 40 percent.
- ***L. Source Region Tap-out*** – Over NA, this occurs when most, if not all, of an arctic air mass moves south and east of the source region(s) behind the passage of a mid-tropospheric short wave simultaneously with a major hemispheric mid-tropospheric flow regime change (often resulting from NH teleconnection index changes), not allowing arctic air to immediately re-form over the source region(s) for a time period afterwards. This is often marked by the anomalous component of 500 hPa flow over the arctic source regions of NA going from northeast to northwest or west. When this happens, thaw conditions usually follow the last surge of arctic air entering the continental U.S within days.