INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **21**: 355–369 (2001)
DOI: 10.1002/joc.612

THE RELATIONSHIP BETWEEN THE WINTERTIME NORTH ATLANTIC OSCILLATION AND BLOCKING EPISODES IN THE NORTH ATLANTIC

AMIR SHABBAR*, JIANPING HUANG and KAZ HIGUCHI
Meteorological Service of Canada, Environment Canada, Downsview, Ontario, Canada M3H 5T4

Received 22 September 1999
Revised 24 September 2000
Accepted 28 September 2000

ABSTRACT

A [illegible] (NAO) [illegible] North Atlantic [illegible] (1990), [illegible] North Atlantic [illegible] NAO. [illegible] NAO. [illegible] NAO. [illegible] NAO [illegible] 1 [illegible] 6-[illegible] NAO. The NAO [illegible] 30% [illegible] North Atlantic [illegible]

[illegible] NAO [illegible] North Atlantic [illegible] (1979) [illegible] North [illegible] NAO-[illegible] NAO. [illegible] NAO, [illegible] / [illegible] NAO, [illegible] / [illegible]

Copyright © 2001 Crown copyright of Canada. Published by John Wiley & Sons, Ltd.

KEY WORDS: [illegible] North Atlantic; North Atlantic Oscillation; [illegible]

1. INTRODUCTION

In the [illegible] 1950s [illegible] 1960s, [illegible] North Atlantic (Rex, 1950; [illegible] 1958; [illegible] *et al.*, 1981; [illegible] 1985). [illegible] North Atlantic Oscillation (NAO), [illegible] 1970s [illegible] NAO [illegible] (Hurrell [illegible] 1997), [illegible] North Atlantic (Knox and Hay, 1985). [illegible]

* Correspondence to: Meteorological Service of Canada, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4; e-mail: [illegible]

[illegible] 1960–1970 [illegible] 1980–1990 [illegible] N[illegible] A[illegible] In[illegible] [illegible] Pacific [illegible] A[illegible] NAO [illegible] N[illegible] A[illegible] [illegible] 0 [illegible] (K[illegible] H[illegible], 1984), [illegible] NAO [illegible] N[illegible] A[illegible]

- T[illegible] NAO [illegible] N[illegible] A[illegible]
- As [illegible] in Fig. 1, [illegible] N[illegible] A[illegible] 1960–1970 [illegible] 1980–1990? Is [illegible] NAO [illegible]

A [illegible] NAO [illegible] N[illegible] A[illegible]

T[illegible] (S[illegible] M[illegible], 1983; T[illegible] 1990). A [illegible] (GCMs) (T[illegible] M[illegible], 1990; T[illegible] *et al.*, 1997). R[illegible] D'A[illegible] *et al.* (1998) [illegible] A[illegible] M[illegible] I[illegible] P[illegible] (AMIP) [illegible] GCMs [illegible] N[illegible] H[illegible] T[illegible] [illegible] In[illegible] E[illegible] A[illegible]

A [illegible] (E[illegible] 1978; C[illegible] D[illegible] V[illegible], 1979; T[illegible] L[illegible], 1979; Ka[illegible], 1981). K[illegible] B[illegible] (1993) [illegible] N[illegible] H[illegible] T[illegible] U[illegible] T[illegible] L[illegible] (1979) [illegible] In[illegible] C[illegible] D[illegible] V[illegible] (1979) [illegible] T[illegible]

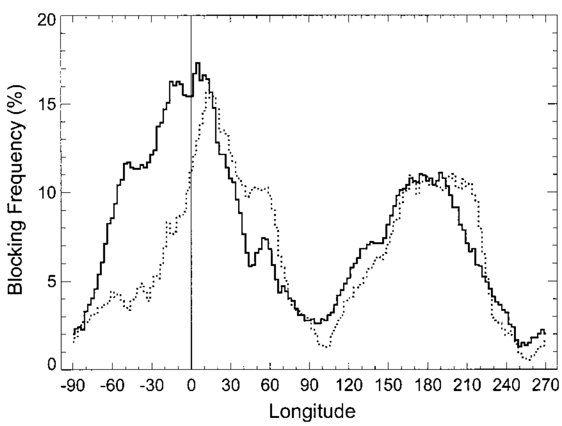


Fig. 1. D[illegible] S[illegible] 1960–1970 [illegible] 1980–1990 [illegible]

[illegible] It [illegible] a [illegible] [illegible] [illegible] N[illegible] A[illegible] F[illegible] NAO [illegible] NAO [illegible]

I[illegible] NAO, [illegible] N[illegible] A[illegible] T[illegible] NAO [illegible] N[illegible] A[illegible] N[illegible] A[illegible] E[illegible] (v[illegible] L[illegible] R[illegible] 1978; [illegible] N[illegible] 1998). C[illegible] NAO [illegible] N[illegible] A[illegible] T[illegible] NAO [illegible] (H[illegible] 1995), [illegible] N[illegible] A[illegible] E[illegible] (W[illegible] 1932; v[illegible] L[illegible] R[illegible] 1978; [illegible] C[illegible] NAO [illegible] C[illegible] D[illegible] (1979) [illegible] N[illegible] A[illegible]

S[illegible] NAO [illegible] N[illegible] A[illegible] I[illegible] NAO [illegible] C[illegible] /D[illegible]V[illegible] It [illegible] N[illegible] A[illegible]

I[illegible] T[illegible] NAO [illegible] A[illegible] C[illegible] /D[illegible]V[illegible] NAO [illegible] I[illegible] N[illegible] A[illegible] NAO.

2. DATA AND METHODOLOGY

T[illegible] N[illegible] C[illegible] E[illegible] P[illegible] (NCEP) [illegible] 500 [illegible] NCEP [illegible] 1000 [illegible] 2.5° [illegible] 2.5° [illegible] 1958 [illegible] D[illegible] 1996 (K[illegible] *et al.*, 1996). E[illegible] 1958–1959 [illegible] 1995–1996, [illegible] 1 D[illegible] 31 M[illegible]

T[illegible] NAO [illegible] W[illegible] (1932) [illegible] (SLP) [illegible] A[illegible] H[illegible] L[illegible] R[illegible] (1984) [illegible] NAO [illegible] 1894, [illegible] SLP [illegible] P[illegible] D[illegible] A[illegible] R[illegible] H[illegible] (1995) [illegible] P[illegible] S[illegible] I[illegible] 30 [illegible] A[illegible] NAO [illegible] NAO, [illegible] A[illegible] N[illegible] A[illegible] NAO [illegible] (EOF) [illegible] 500 [illegible] T[illegible] NAO [illegible] B[illegible] L[illegible] (1987) [illegible] A[illegible] A[illegible] W[illegible] G[illegible] (1981) [illegible]

The NAO [illegible] NAO [illegible] 35°N [illegible] 40°N. [illegible] NAO [illegible] United States [illegible] NAO [illegible] NAO [illegible] NAO.

A [illegible] (1990), [illegible] TM, [illegible] TM. [illegible]

The 500 hPa [illegible] GHGS [illegible] GHGN [illegible]

$$\mathrm{GHGS} = \frac{Z(\phi_0) - Z(\phi_s)}{\phi_0 - \phi_s} \quad (1)$$

$$\mathrm{GHGN} = \frac{Z(\phi_n) - Z(\phi_0)}{\phi_n - \phi_0} \quad (2)$$

[illegible] $\phi_n = 80°N + \Delta$, $\phi_0 = 60°N + \Delta$, $\phi_s = 40°N + \Delta$ [illegible] $\Delta = -2.5°, 0°, 2.5°$

A [illegible] 2.5° [illegible] 2.5° TM [illegible] 4°. A [illegible] Δ).

$$\mathrm{GHGS} > 0$$

$$\mathrm{GHGN} < -10 \text{ [illegible]}$$

As [illegible] TM, [illegible] *et al.* (1997) [illegible] 65 [illegible] TM [illegible] (1993) (KB), [illegible] KB [illegible] 5 [illegible] TM [illegible] TM [illegible] (e.g. D'A[illegible] *et al.*, 1998).

Table I. [illegible] NAO [illegible]

Negative NAO	1962	1963	1964	1965	1966	1969	1970	[illegible]		1996
Positive NAO	1973	[illegible]		1983	1989	1990	1992	1993	1994	1995

[illegible]

3. THE STATISTICAL RELATIONSHIP

A [illegible] NAO [illegible] a [illegible] NAO [illegible] T[illegible] N[illegible] A[illegible] (L[illegible] 1983; T[illegible] M[illegible] 1990; T[illegible] *et al.*, 1997). U[illegible] NCEP [illegible] N[illegible] A[illegible]

Fig. 1 [illegible] a [illegible] T[illegible] No [illegible] T[illegible] 1960–1970 [illegible] 1980–1990 [illegible] B[illegible] N[illegible] A[illegible] /E[illegible] N[illegible] P[illegible] H[illegible] N[illegible] A[illegible] /E[illegible] 10% [illegible] in [illegible] N[illegible] A[illegible] In [illegible] N[illegible] P[illegible] 2%. T[illegible] N[illegible] A[illegible]

Fig. 1 [illegible] (n[illegible]) [illegible] In [illegible] i [illegible] T[illegible] (5 [illegible]) [illegible] S[illegible] 2. In [illegible] a [illegible] S[illegible] 2. T[illegible] N[illegible] H[illegible] T[illegible]

- C[illegible] 130°–60°W
- A[illegible] 60°W–10°E;
- E[illegible] 10°–80°E.

[illegible] 1958–1996 [illegible] Fig. 2. E[illegible] (5 [illegible]) [illegible] D[illegible] M[illegible] T[illegible] N[illegible] A[illegible] E[illegible] In [illegible] N[illegible] A[illegible] 31.7 [illegible] 18.2, [illegible] E[illegible] 13.5 [illegible] 15.2 [illegible] T[illegible] NAO [illegible] NAO [illegible] D[illegible] M[illegible] (T[illegible] II). C[illegible] 38 $\times 4 = 152$ [illegible] (38 [illegible] 4 [illegible]). T[illegible] NAO [illegible] -0.45 [illegible] C[illegible] -0.54 [illegible] N[illegible] A[illegible] 1% [illegible] E[illegible] T[illegible] NAO [illegible] N[illegible] A[illegible] C[illegible] T[illegible] NAO [illegible]

B[illegible] Fig. 3 [illegible] (l[illegible]) [illegible] NAO. T[illegible] NAO [illegible] S[illegible] 2 (T[illegible] I). T[illegible] N[illegible] A[illegible] 67% [illegible] NAO [illegible] D[illegible] A[illegible] 52.8, [illegible]

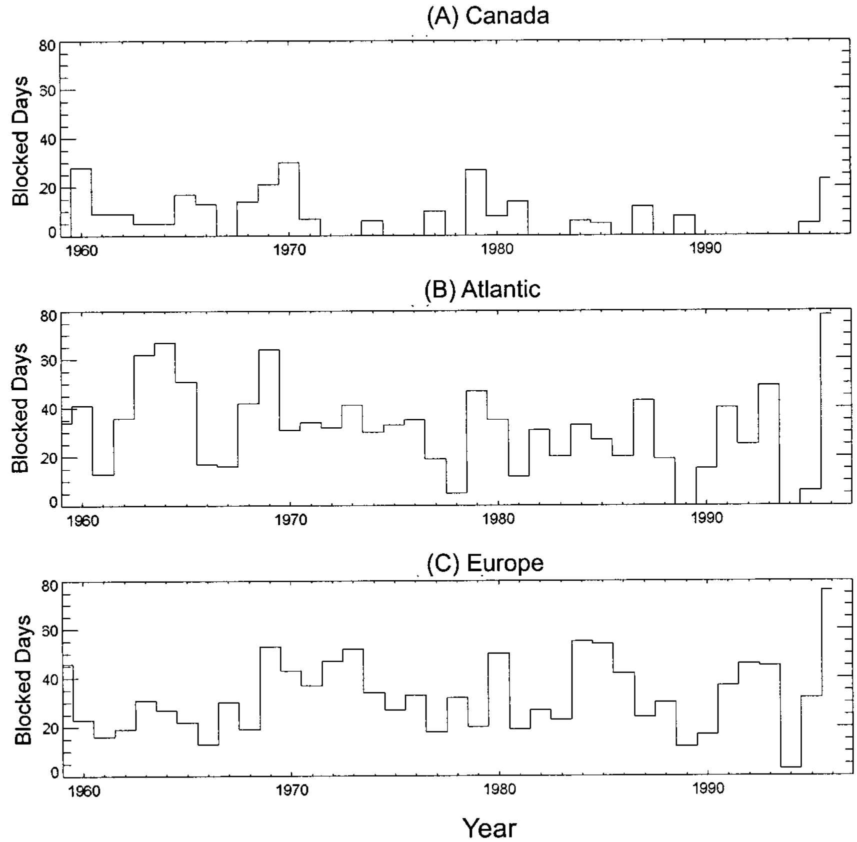


Fig. 2. [illegible] 1958–1996

Table II. [illegible] NAO [illegible]

[illegible]

R[illegible]	C[illegible]	A[illegible]	E[illegible]
C[illegible]	**−0.45**	**−0.54**	0.017

N[illegible] 1%.

5% [illegible] 31.7 [illegible] F[illegible] NAO [illegible] 19.4, [illegible] T[illegible] NAO [illegible] C[illegible] R[illegible] J[illegible] M[illegible] J[illegible] F[illegible] A[illegible] C[illegible] N[illegible] A[illegible] NAO [illegible] N[illegible] A[illegible]

T[illegible] NAO [illegible] NAO [illegible] (Fig. 3) [illegible] NAO [illegible] N[illegible] A[illegible] S[illegible] T[illegible] R^2, [illegible] NAO [illegible] 0.30. As a [illegible] 30% [illegible] N[illegible] A[illegible] NAO. A[illegible]

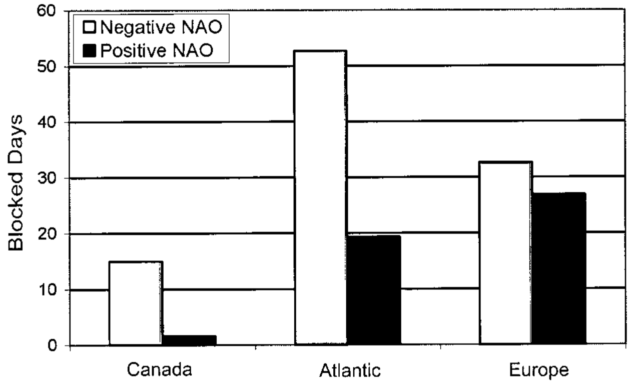


Fig. 3. [illegible] NAO ([illegible]) [illegible] NAO ([illegible]). Th[illegible] [illegible] NAO is [illegible] 5% [illegible] C[illegible] A[illegible]

[illegible] ie [illegible] F-[illegible] 55.5 [illegible] 1% [illegible] M[illegible] 6 [illegible] NAO [illegible] T[illegible] 1% [illegible] T[illegible] N[illegible] A[illegible] NAO [illegible]

Fig. 4 [illegible] NAO [illegible] A[illegible] T[illegible] NAO [illegible] (e.g. H[illegible] 1995, 1996). It [illegible] Fig. 4(B) [illegible] A[illegible] a [illegible] 39 [illegible] N[illegible] NAO [illegible] 1990s

T[illegible] NAO [illegible] Fig. 5, [illegible] NAO. [illegible] NAO [illegible] 5–6 [illegible] 70% [illegible]

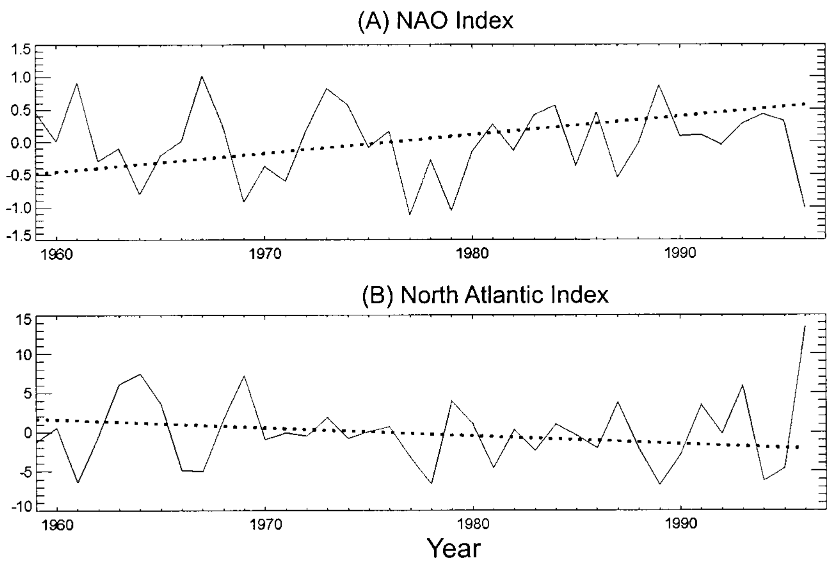


Fig. 4. A[illegible] (A) [illegible] NAO [illegible] (B) [illegible] A[illegible]

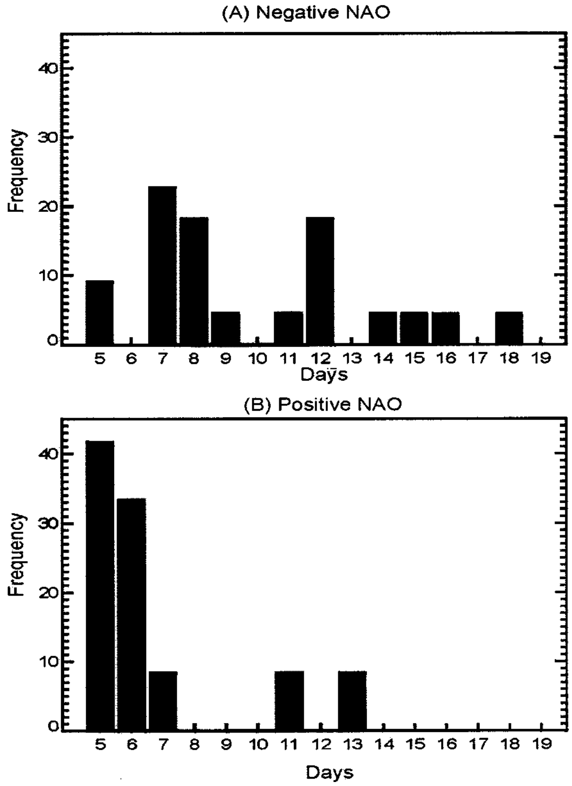


Fig. 5. [illegible] NAO

[illegible] 6 [illegible] NAO, [illegible] 5% [illegible] 6 [illegible] 5 to 18 [illegible] 1 [illegible] 6 [illegible] NAO ([illegible] 6 [illegible] (1989) [illegible] 10 [illegible] 6 [illegible] (Fig. 5) [illegible] 10 [illegible] 18 [illegible]

Fig. 6 [illegible] 500 [illegible] NAO. [illegible] (Th[illegible] *et al.*, 1997). [illegible] NAO. [illegible] 6 [illegible]

[illegible] NAO [illegible] 6 [illegible] NAO [illegible] NAO [illegible] NAO [illegible]

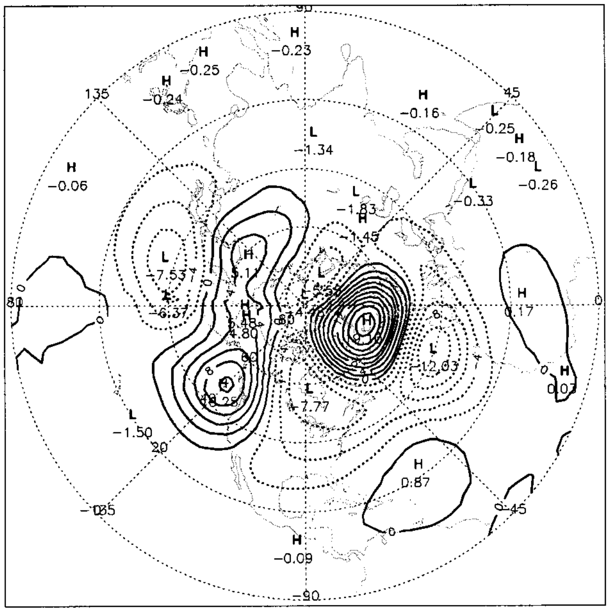


Fig. 6. [illegible] 500 [illegible] NAO [illegible] 2.0 [illegible]

4. THE IMPACT OF THE NAO ON BLOCKING

T[illegible] NAO [illegible] A[illegible] B[illegible] U[illegible] C[illegible] D[illegible] V[illegible] (1979) [illegible] (a[illegible]) [illegible] D[illegible] NAO [illegible] NAO [illegible] T[illegible] N[illegible] A[illegible] NAO.

F[illegible] C[illegible] D[illegible] V[illegible] (1979), [illegible]

$$\frac{\partial}{\partial t}\left(\nabla^2\psi - \frac{\psi}{\lambda^2}\right) + J(\psi, \nabla^2\psi + h) + \beta\,\frac{\partial\psi}{\partial x} = k\nabla^2(\psi^* - \psi) \qquad (3)$$

[illegible] ψ [illegible] h [illegible] ∇^2 [illegible] L[illegible] J [illegible] $\beta = L/a$ [illegible] ϕ_0, ϕ_0 [illegible] a [illegible] $k = D_E/2H$, D_E [illegible] E[illegible] H [illegible] ψ^* [illegible]

[illegible] ψ, ψ^* [illegible] h [illegible] L[illegible] T[illegible] C[illegible] D[illegible] V[illegible] (1979). T[illegible]

$$F_A = \sqrt{2}\cos y, \quad F_K = 2\cos nx \sin y, \quad F_L = 2\sin nx \sin y$$

[illegible] F_A [illegible] F_K [illegible] F_L [illegible]

$$\psi = \psi_A F_A + \psi_K F_K + \psi_L F_L$$
$$\psi^* = \psi_A^* F_A + \psi_K^* F_K$$
$$h = \frac{h_0}{2H} F_K$$

[illegible]

$$\dot{\psi}_A = -k(\psi_A - \psi_A^*) + h_{01}\psi_L \tag{4}$$
$$\dot{\psi}_K = -(\alpha_{n1}\psi_A - \beta_{n1})\psi_L - k(\psi_K - \psi_K^*) \tag{5}$$
$$\dot{\psi}_L = -(\alpha_{n1}\psi_A - \beta_{n1})\psi_K - k(\psi_K - h_{n1})\psi_A \tag{6}$$

[illegible]

$$\gamma_{n1} = \frac{8\sqrt{2}}{3\pi} n, \quad h_{01} = \gamma_{n1}\frac{h_0}{2H}, \quad h_{n1} = \frac{\gamma_{n1}}{n^2+1}\frac{h_0}{2H}, \quad \alpha_{n1} = \frac{n^2}{n^2+1}\gamma_{n1} \quad \text{[illegible]} \quad \beta_{n1} = \frac{n}{n^2+1}\beta$$

[illegible] Eqs (4)–(6), [illegible] $\overline{\psi_A}$ [illegible]

$$\overline{\psi_A^3} + v_1\overline{\psi_A^2} + v_2\overline{\psi_A} + v_3 = 0 \tag{7}$$

[illegible]

$$v_1 = -(2\beta_{n1}\alpha_{n1} + \alpha_{n1}^2\psi_A^*)/\alpha_{n1}^2,$$
$$v_2 = (\beta_{n1}^2 + k^2 + 2\beta_{n1}\alpha_{n1}\psi_A^* + h_{01}(h_{n1} - \alpha_{n1}\psi_K^*))/\alpha_{n1}^2$$

[illegible]

$$v_3 = ((\beta_{n1}^2 + k^2)\psi_A^* + h_{01}\beta_{n1}\psi_K^*)/\alpha_{n1}^2$$

T[illegible] (7) [illegible] Eqs (4)–(6) (C[illegible] and De V[illegible], 1979).

T[illegible] ψ_K^* [illegible] $k = 2*10^{-2}$, $h_0/H = 0.05$, $n = 2$, $\psi_A^* = 0.2$ [illegible] Fig. 7. [illegible]

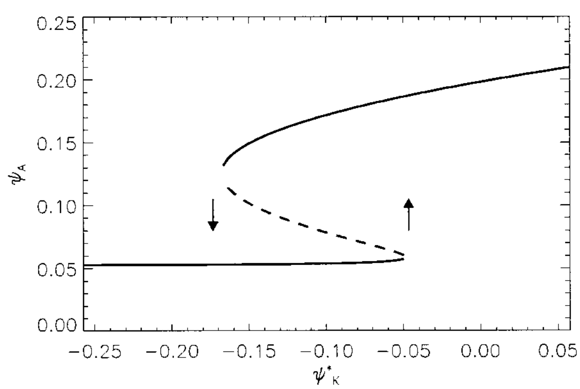


Fig. 7. T[illegible] $\overline{\psi_A}$. T[illegible] ψ_K^*. P[illegible] $k = 2*10^{-2}$, $h_0/H = 0.05$, $n = 2$, $\psi_A^* = 0.2$

[illegible] (ie $\psi^*_K > -0.05$), [illegible] $\overline{\psi_A}$. A [illegible]

[illegible] ($-0.17 < \psi^*_A < -0.05$), a [illegible] Fig. 7. In [illegible] W [illegible] O [illegible] (ie $\psi^*_K < -0.17$), [illegible]

T[illegible] ($\psi^*_K = -0.1$) [illegible] Fig. 8. T[illegible] (Fig. 8(A)) [illegible] Fig. 8(B) [illegible] (C[illegible] D[illegible], 1979). A[illegible] N[illegible] A[illegible] (Fig. 6), [illegible]

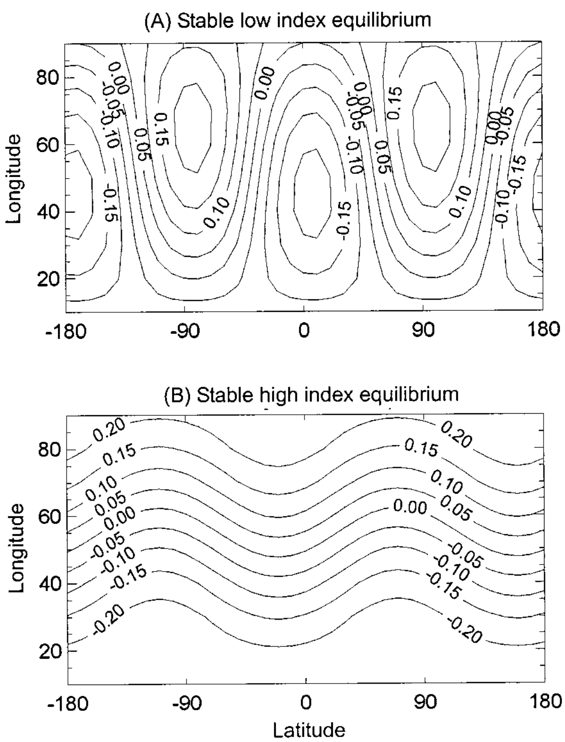


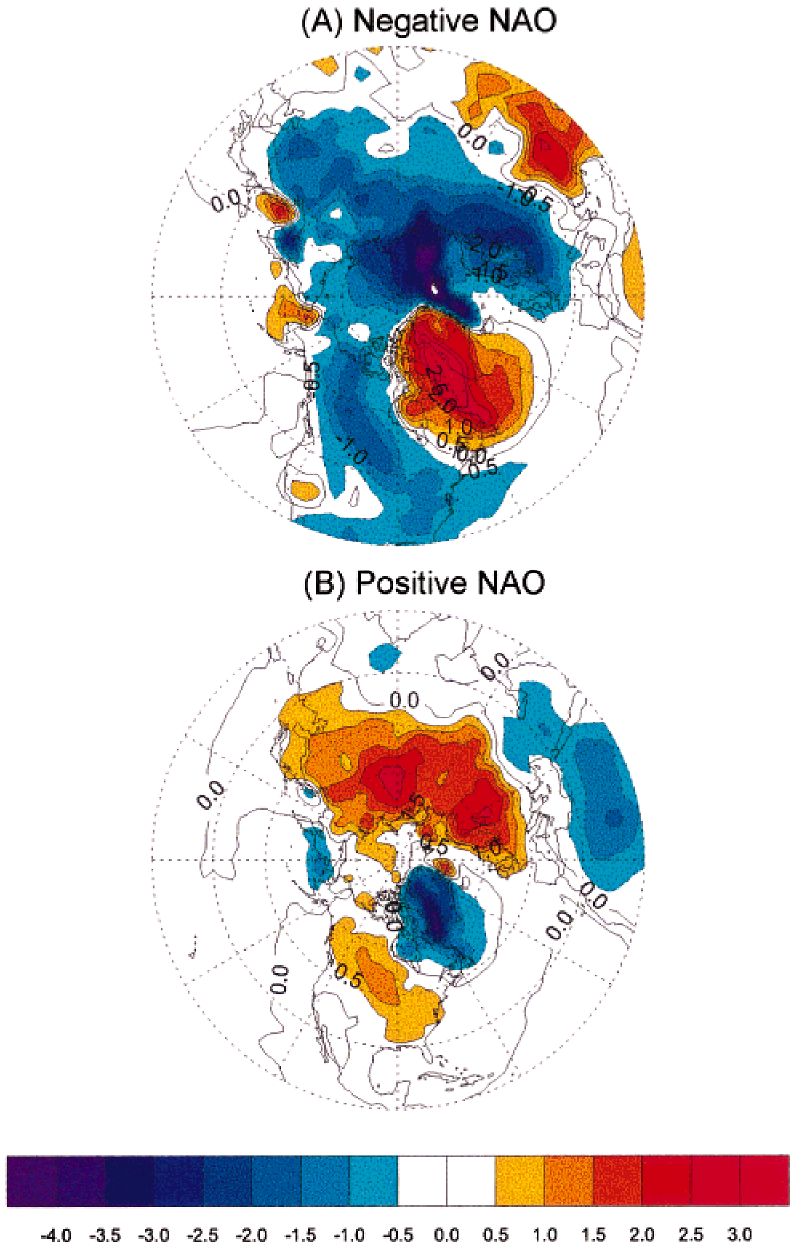
Fig. 8. S[illegible] $\psi^*_K = -0.1$ in Fig. 7 [illegible]

[illegible] NAO [illegible] N[illegible] A[illegible] C[illegible] /D[illegible] [illegible] (SATA) [illegible] NAO, [illegible] P[illegible] 1. F[illegible] NAO, [illegible] SATA [illegible] (P[illegible] 1(A)). [illegible] B[illegible] NAO, [illegible] C[illegible] [illegible] NAO, [illegible] SATA [illegible] (COL[illegible]' [illegible] (P[illegible] 1(B)) [illegible] NAO. [illegible]

N[illegible] NAO [illegible] SATA [illegible] P[illegible] 1. [illegible] (SST) [illegible] NAO [illegible] (R[illegible] *et al.*, 1999), [illegible] NAO (N[illegible] 1992, 1998). N[illegible] (1992) [illegible] NAO [illegible] SST [illegible] G[illegible] M[illegible] E[illegible] NAO [illegible] 1980s (H[illegible] 1995; [illegible] P[illegible] 1(B)). [illegible] H[illegible] (1996) [illegible] 1970s [illegible] NAO, [illegible] NAO [illegible] 60 [illegible] EOF [illegible] (1998) [illegible] NAO [illegible] (AO).

T[illegible] *et al.* (2000) [illegible] AO [illegible] SATA [illegible] COL[illegible] [illegible] AO [illegible] SATA [illegible] COL[illegible] AO-[illegible] 30% [illegible]

B[illegible] (1964) [illegible] K[illegible] (1994) [illegible] NAO [illegible] SST, [illegible] B[illegible] (1964). C[illegible] (1992), [illegible] NAO [illegible]



Pla1. Cispfitapthfi(DeMh) figiajsNAO. Cto

hinC

[illegible] NAO [illegible] N[illegible] A[illegible]. It [illegible] NAO [illegible] G[illegible] B[illegible] (B[illegible] 1995), [illegible] G[illegible] L[illegible] (R[illegible] *et al.*, 1997) [illegible] (M[illegible] *et al.*, 1997). V[illegible] M[illegible] (2000) [illegible] NAO, [illegible] G[illegible] T[illegible] SST [illegible] G[illegible] S[illegible]. T[illegible] NAO [illegible] N[illegible] A[illegible]

5. DISCUSSION AND CONCLUSIONS

T[illegible] NAO [illegible] N[illegible] A[illegible]. A[illegible] NAO [illegible] NAO [illegible] N[illegible] A[illegible]. By [illegible] C[illegible] D[illegible] V[illegible] (1979) [illegible] In [illegible] NAO, [illegible] NAO [illegible]

R[illegible] S[illegible] 3 [illegible] F[illegible] NAO [illegible] N[illegible] A[illegible] S[illegible] NAO [illegible] (Fig. 3). T[illegible] NAO. [illegible] NAO [illegible] 5–6 [illegible] NAO, [illegible] T[illegible] 11 [illegible] NAO (Fig. 5). L[illegible] 30% [illegible] N[illegible] A[illegible] NAO. M[illegible] T[illegible] I[illegible] NAO.

A[illegible] (C[illegible] D[illegible] V[illegible] 1979) [illegible] NAO-[illegible] N[illegible] (e.g. C[illegible] 1992; H[illegible] 1996, [illegible] (P[illegible] 1) [illegible] NAO) [illegible] NAO [illegible] N[illegible] A[illegible] F[illegible] NAO, [illegible] /[illegible] (P[illegible] 1(A) [illegible] Fig. 8(A)). F[illegible] NAO, [illegible] /[illegible] (P[illegible] 1(B) [illegible] Fig. 8(B)).

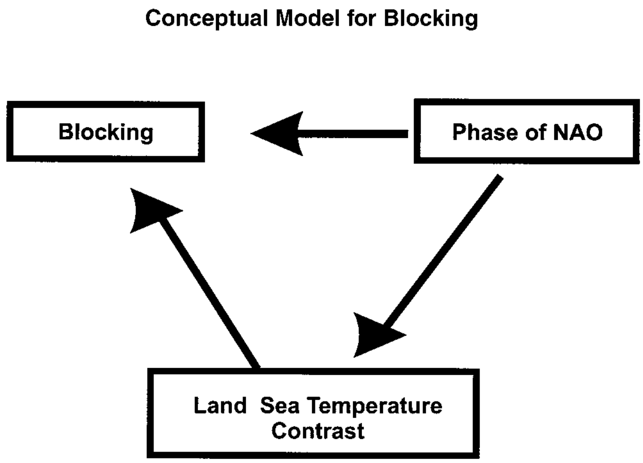


Fig. 9. A [illegible] NAO [illegible] N[illegible] A[illegible] /[illegible]

[illegible] /D[illegible] V[illegible] [illegible] NAO [illegible] NAO, [illegible] (Fig. 9). [illegible] NAO [illegible] NAO, [illegible] N[illegible] A[illegible] As [illegible] NAO [illegible] B[illegible] N[illegible] A[illegible] NAO; [illegible] NAO.

[illegible] NAO [illegible] N[illegible] A[illegible] A[illegible] NAO [illegible] NAO [illegible] NAO.

ACKNOWLEDGEMENTS

T[illegible]

REFERENCES

B[illegible] AG, L[illegible] RE. 1987. C[illegible] *Monthly Weather Review* **115**: 1083–1126.
B[illegible] J. 1964. A[illegible] In *Advances in Geophysics*, L[illegible] HE, M[illegible] V (ed). A[illegible] S[illegible] D[illegible] CA; 1–82.
B[illegible] E. 1995. A [illegible] G[illegible] R[illegible] D[illegible] A[illegible] N[illegible] H[illegible] C[illegible]

Ca[illegible]DR. 1992. L[illegible] [illegible] *Journal of Climate* **5**: 354–369.

C[illegible]J, D[illegible]J. 1979. M[illegible] *Journal of Atmospheric Science* **36**: 1205–1216.

D'A[illegible]F, T[illegible]S, B[illegible]M, B[illegible]G, D[illegible]M, D[illegible]MR, D[illegible]B, F[illegible]L, I[illegible]T, K[illegible]A, P[illegible]V, R[illegible]D, R[illegible]E, S[illegible]D, S[illegible]W[illegible]D[illegible]H, [illegible]D. 1998. N[illegible]H[illegible] [illegible]15 [illegible]1979–1988. *Climate Dynamics* **14**: 385–407.

D[illegible]RM. 1989. L[illegible]P[illegible]I: E[illegible]500 [illegible] *Monthly Weather Review* **117**: 177–211.

E[illegible]J. 1978. D[illegible] *Journal of Atmospheric Science* **35**: 1788–1801.

H[illegible]JW.1995. D[illegible]N[illegible]A[illegible]O[illegible] *Science* **269**: 676–679.

H[illegible]JW.1996. I[illegible]f[illegible]in[illegible]o[illegible]N[illegible]H[illegible] *Geophysical Research Letters* **23**: 665–668.

H[illegible]JW[illegible]L[illegible]H. 1997. D[illegible]N[illegible]A[illegible]O[illegible] *Climate Change* **36**: 301–326.

K[illegible]E, B[illegible]G. 1993. T[illegible] *Journal of Atmospheric Science* **50**: 3061–3077.

K[illegible]E. 1981. T[illegible] *Journal of Atmosphere Science* **38**: 2150–2163.

K[illegible]E, K[illegible]M, K[illegible]R, C[illegible]W[illegible]D, G[illegible]L, I[illegible]M, S[illegible]S, [illegible]G, [illegible]V, [illegible]C[illegible]M, E[illegible]W[illegible]W[illegible]J, MoKC, R[illegible]C, [illegible]V, L[illegible]A, R[illegible]R, J[illegible]R, J[illegible]D. 1996. T[illegible] NCEP/NCAR 40-[illegible] *Bulletin of the American Meteorological Society* **77**: 437–471.

K[illegible]JL, H[illegible]JE. 1984. B[illegible]N[illegible]H[illegible] *Atmosphere–Ocean* **22**(1): 36–47.

K[illegible]JL, H[illegible]JE. 1985. B[illegible]N[illegible]H[illegible] *Journal of Climatology* **5**: 1–16.

K[illegible]Y1994. I[illegible]N[illegible]A[illegible] *Journal of Climate* **7**: 142–157.

L[illegible]H, [illegible]H. 1983. C[illegible]N[illegible]H[illegible] *Tellus* **35A**: 350–362.

M[illegible]RL, M[illegible]DA, F[illegible]JF, B[illegible]HF. 1997. M[illegible] [illegible]N[illegible]A[illegible]O[illegible] *Journal of Geophysical Research* **102**: 3267–3278.

N[illegible]J. 1958. S[illegible]A[illegible] *Transactions of the American Geophysical Union* **39**(1): 45.

N[illegible]ES. 1992. I[illegible]N[illegible]A[illegible]O[illegible] *Soviet Meteorology and Hydrology* **5**: 46–50.

N[illegible]ES. 1998. C[illegible]N[illegible]A[illegible]O[illegible] *Russian Meteorology and Hydrology* **8**: 58–65.

R[illegible]DP. 1950. B[illegible](II). T[illegible] *Tellus* **2**: 275–301.

R[illegible]G, C[illegible]DR, K[illegible]Y1997. D[illegible]N[illegible]A[illegible]1948–1990. *Journal of Geophysical Research* **102**: 8505–8531.

R[illegible]MJ, R[illegible]DP, F[illegible]CK. 1999. O[illegible]N[illegible]A[illegible]O[illegible]E[illegible] *Nature* **398**: 320–323.

R[illegible]JC. 1984. T[illegible]N[illegible]A[illegible]O[illegible]S[illegible]O[illegible]N[illegible]H[illegible] *Monthly Weather Review* **112**: 1999–2015.

S[illegible]J, MoKC. 1983. S[illegible] *Monthly Weather Review* **111**: 388–402.

T[illegible]D[illegible]M. 1998. T[illegible]A[illegible]O[illegible] *Geophysical Research Letters* **25**: 1297–1300.

T[illegible]D[illegible]M, H[illegible]GC. 2000. A[illegible]P[illegible]II: T[illegible] *Journal of Climate* **13**: 1018–1036.

T[illegible]S, M[illegible]F. 1990. O[illegible] *Tellus* **42A**: 343–365.

T[illegible]S, D'A[illegible]F, T[illegible]E, R[illegible]E. 1997. C[illegible]N[illegible]H[illegible]ECHAM [illegible] *Climate Dynamics* **13**: 649–666.

T[illegible]MS. 1990. P[illegible] *Monthly Weather Review* **118**: 1666–1695.

T[illegible]RA, B[illegible]EC, S[illegible]P. 1981. B[illegible]N[illegible]H[illegible] *Atmosphere–Ocean* **19**: 1–23.

T[illegible]KK, L[illegible]RS. 1979. A [illegible]P[illegible]I: a[illegible] *Monthly Weather Review* **107**: 714–734.

[illegible]L[illegible]H, R[illegible]JC. 1978a T[illegible]G[illegible]E[illegible]P[illegible]I: [illegible] *Monthly Weather Review* **106**: 296–310.

[illegible]L[illegible]H, R[illegible]JC. 1978b T[illegible]S[illegible]O[illegible]P[illegible]II: [illegible] *Monthly Weather Review* **109**: 1163–1168.

V[illegible]S, M[illegible]L. 2000. I[illegible]A[illegible]? *Journal of Climate* **13**: 3412–3434.

[illegible]GT, B[illegible]EW.1932. [illegible]V. *Memoirs of the Royal Meteorological Society* **4**: 53–84.

[illegible]M, G[illegible]DS. 1981. T[illegible]N[illegible]H[illegible] *Monthly Weather Review* **109**: 784–812.