Supplement

S1. Description of section in the model

The OVIDE section is collocated in the model as a continuous line between A and B defined by zonal (*y*) or meridional (*x*) grid segments. Horizontal velocities ($\vec{u}$ and $\vec{v}$) used to estimate mass transport across a section are towards the North (for $\vec{v}$) if orthogonal to grid segment x and towards the East (for $\vec{u}$) if orthogonal to grid segment y (Fig. S1).

Fig. S1: Schematic representation of the OVIDE section in the model

S2. Online computation of transport of Cant across a section

Fig. S2: Transport of Cant across (from top to bottom) 25° N, 36° N and OVIDE sections computed online by ORCA05-PISCES over the period 2003-2011 (monthly resolution). In the online approach, the transport of Cant (${}^{m}T_{Cant}^{online}$, black bold line) is the sum of the advection (${}^{m}T_{Cant}^{adv}$, red fine line), the diffusion (${}^{m}T_{Cant}^{lf}$, blue fine line) and the eddy (${}^{m}T_{Cant}^{eiv}$, green fine line) contribution. For each section, ${}^{m}T_{Cant}^{adv}$ is the major component of ${}^{m}T_{Cant}^{online}$.

Fig. S3. Smoothed time series.

S3. Evaluation of the proxy proposed by Zunino et al. (2014) in ORCA05-PISCES

Zunino et al. (2014) proposed a novel proxy to evaluate processes governing the long term variability of the transport of Cant in the northern Subpolar North Atlantic region. This proxy ($T_{Cant}°$) is computed from the magnitude of the meridional overturning circulation (MOC) times the difference of averaged-Cant concentration between the northward flow of warm and saline upper ocean waters, enriched in Cant, and the southward return flow of colder and fresher waters across the section (noted *Δ[Cant]*, Eq. (S1)). In this region, the MOC intensity is computed in density coordinates to remove depth overlaps between upper and lower limbs (Marsh et al., 2005; Lherminier et al., 2007). It is calculated as the integration of mass transport from Greenland to Portugal and from the bottom to each density level. As a consequence, the maximum negative value corresponds to the net southward transport in the lower limb of the overturning circulation; the absolute value of this estimate corresponds to the magnitude of the MOC (MOC_σ in Eq. (S1)). In the model, the proxy ($^{m}T_{Cant}°$) is evaluated from monthly simulations over the period 2002-2010.

$$^{m}T_{CANT}{}^{o} = MOC_{\sigma}\Delta[C_{ANT}] \qquad \text{(S1)}$$

$T_{Cant}°$ is defined by Zunino et al. (2014) as the proxy of the diapycnal component of the advective Cant transport across the OVIDE section. It could be used in the model if (i) the diapycnal transport of C_{ANT} ($^{m}T_{Cant}{}^{diap}$) is the major mechanism driving the variability of the advective C_{ant} transport across the OVIDE section and if (ii) $T_{Cant}°$ is a good estimator of $^{m}T_{Cant}{}^{diap}$.

S3.1. Is $^{m}T_{Cant}{}^{diap}$ the major mechanism driving the $^{m}T_{CANT}{}^{adv}$ variability?

In the model, the advective transport of Cant evaluated in an offline approach ($[^{m}T_{Cant}{}^{adv}]^{offline}$) has been decomposed in three additional components along the Greenland-Portugal OVIDE section (Eq. (S2)) to compare with results from Zunino et al. (2014). The approach was initially developed by Bryden and Imawaki (2001) to study the heat transport and has been recently adapted by Zunino et al. (2014) to the advective transport of Cant. ($^{m}T_{Cant}{}^{adv}=[^{m}T_{Cant}{}^{adv}]^{offline}$). Applying this approach to model output, allows to infer (i) the isopycnal transport of Cant across the OVIDE section, noted $^{m}T_{Cant}{}^{iso}$,), (ii) the diapycnal transport of Cant ($^{m}T_{Cant}{}^{diap}$), related to the overturning circulation and (iii) the net transport of Cant ($^{m}T_{Cant}{}^{net}$), related to the arctic mass balance (Lherminier et al., 2007).

$$\left[{}^{m}T_{Cant}^{adv}\right]^{offline} = {}^{m}T_{Cant}^{adv} = {}^{m}T_{Cant}^{net} + {}^{m}T_{Cant}^{diap} + {}^{m}T_{Cant}^{iso}$$

(S2)

The decomposition of the advective transport of Cant across the Greenland-Portugal OVIDE section yields 2002-2010 mean values of diapycnal, isopycnal and net transport of Cant of 178±42 kmol s^{-1}, -97±24 kmol s^{-1} and 13±9 kmol s^{-1} respectively. The sum is equal to $^{m}T_{Cant}{}^{adv}$ and amounts to 94±43 kmol s^{-1} obtained in offline mode (from monthly time frame). It's coherent with values computed online from 5 day averages (90±44 kmol s^{-1}). Both estimates (from online and offline mode) are strongly correlated (r=0.94, p-value = 0.00; r^2 = 0.89, Fig. S4a). In general, the model results are lower than those obtained from June observations (Table S1) but with a comparable relative contribution of individual terms to the total transport of Cant. The diapycnal component drives a large northward transport of Cant-rich waters across the section. It is partially compensated by the isopycnal component, yielding a negligible net transport (Fig. S4a). Moreover, the correlation between ${}^{m}T_{Cant}^{adv}$ and each transport component (${}^{m}T_{Cant}^{diap}$, ${}^{m}T_{Cant}^{iso}$ and ${}^{m}T_{Cant}^{net}$) is only significant with the diapycnal component (r = 0.75, p-value = 0.00 from all simulations; r= 0.89, p-value = 0.00 from June simulations; Fig.S4a). The diapycnal component explains between 60% (full model output over OVIDE period) to 78% (June outputs) of the variance of ${}^{m}T_{Cant}^{adv}$. These results attest that the variability of the ORCA05-PISCES advective transport of Cant is controlled by the variability of the diapycnal component and validates the first condition pertaining to the use of the estimator in the model.

S3.2. Is $T_{Cant}°$ a good estimator of ${}^{m}T_{Cant}^{diap}$?

Mean value of $T_{Cant}°$ derived from model output is higher by 155±57 kmol s^{-1} compared to ${}^{m}T_{Cant}^{diap}$, while the difference between the estimator and the diapycnal component in Zunino et al. (2014) is only 22 kmol s^{-1}. In other word, difference between average TCant° computed from model output and from OVIDE data set is smaller than those obtained for T_{Cant}^{diap} . This curiosity is probably due to their parametrizations. ${}^{m}T_{Cant}°$ is in fact a proxy of diapycnal transport of Cant based on MOCσ and ΔCant between both MOC limbs (Eq. (S1)) whereas ${}^{m}T_{Cant}^{diap}$ (Eq. (S2)) is a direct estimation using Cant concentration and velocity of each grid level. The underestimation of MOC magnitude and ΔCant by the model is not as large as those detected on transport (Fig. 5) and Cant concentration (Fig. 6), reducing thus the difference between TCant° from model output and TCant° from OVIDE data set (Table S1). $T°_{Cant}$ also presents a seasonal cycle with an amplitude higher than 100 kmol s^{-1}, in phase (opposite) with those observed on MOCσ (ΔCant; Figs. S4b to S4c). This seasonal organization is not detected on ${}^{m}T_{Cant}^{diap}$ and ${}^{m}T_{Cant}^{adv}$, which is confirmed by the small correlation observed between the estimator and ${}^{m}T_{Cant}^{diap}$ (r = 0.18, p-value = 0.04) or between the estimator and ${}^{m}T_{Cant}^{adv}$ (r = 0.33, p-value = 0.00) computed over the full period (2002-2010). The correlation is nevertheless correct between ${}^{m}T_{Cant}°$ and ${}^{m}T_{Cant}^{diap}$ from June simulations (r=0.66, p-value = 0.03), but not between ${}^{m}T_{Cant}°$ and ${}^{m}T_{Cant}^{adv}$ (r = 0.35, p-value = 0.29). These comments refute thus the second condition to use the estimator to disentangle the effect of both circulation and Cant accumulation variability on the Cant transport variability.

Table S1: Model-data comparison over the period covered by OVIDE cruises (2002-2010). Average and standard deviation (SD) for observation-based estimates (column 2) and model output (columns 3 to 5). Model output: (1) June average with SD being a measure of interannual variability, (2) average year with SD corresponding to the average seasonal variability, or (3) average over the full period with SD being representative of total variability (interannual + seasonnal).

	OVIDE data set	**ORCA05-PISCES**		
		June only	**Average year**	**Full period**
T_{Cant}^{0} (kmol s^{-1})	413.1±70.4	332.0±27.0	338.0±19.2	333.5±50.8
T_{Cant}^{diap} (kmol s^{-1})	391.2±79.2	201.5±30.9	178.2±9.2	178.1±41.8
T_{Cant}^{iso} (kmol s^{-1})	-164.5±16.2	-112.7±13.3	-97.0±7.8	-96.5±24.1
T_{Cant}^{net} (kmol s^{-1})	21.0±17.5	3.6±6.3	13.9±5.4	12.7±8.8
T_{Cant}^{adv} (kmol s^{-1})	247.7±77.3	92.4±32.4	95.1±13.48	94.3±42.6

Fig. S4 : Monthly evolution of (a) $T_{CANT}°$ (magenta) as well as the diapycnal (blue), isopycnal (red), net (green) and total (black) transport of C_{ANT} (kmol s^{-1}), (b) the maximal intensity of MOC (MOCσ, Sv), and (c) the C_{ANT} concentration in its upper (triangles) and the lower (inverse triangles) branches (µmol kg^{-1}) at the Greenland-Portugal OVIDE section computed offline from monthly averaged model output (continuous line) and compared to estimations derived from the OVIDE data set (dotted line) over the period 2002-2010. Colored dots symbolize the month June. The grey dashed line of panel (a) represents C_{ANT} transport across the OVIDE section computed in online by the model (includes advective, diffusive and eddies contributions).