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Simple models for wind and boundary forced Arctic Ocean circulation

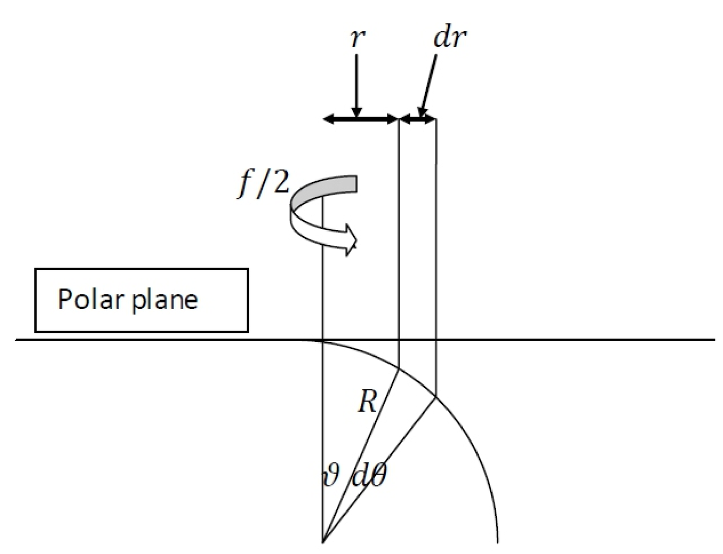
Andrew Willmott [1,2] and Maria Luneva [2]

ajwil@noc.ac.uk, mane1@noc.ac.uk,

(1)School of Physical and Geographical Sciences, Keele University, Keele , (2) National Oceanography Centre, Liverpool, L3 5DA

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL
Liverpool

Steady, barotropic wind and boundary forced circulation solutions in the presence of linear bottom friction are analytically derived in a circular basin of uniform depth on a polar tangent plane:



Polar plane approximation (Le Blond, 1964)

First order effects of the Earth curvature are retained:

$$\frac{df}{dr} = -\frac{2\Omega r}{R^2},$$

Approximate solutions: interior inviscid Sverdrup balance solution and the frictional wall boundary layer solution.

In contrast to the width of mid-latitude frictional western boundary layers that scale as $O(\mu)$, the width of the polar frictional boundary layer adjacent to the basin wall is wider, scaling as $O(\mu^{1/2})$ where μ is the bottom friction coefficient.

WIND-DRIVEN SOLUTIONS(EXACT SOLUTIONS):

$$\mu\nabla^2\Psi + \frac{rf}{R^2}\Psi_\varphi = r\mathbf{k}.\nabla_\wedge\left(\frac{\boldsymbol{\tau}}{\rho H}\right),$$

$$\Psi = 0 \quad on \quad r = a,$$

$$F(r,\varphi) = \mathbf{k}.\nabla_\wedge\left(\frac{\boldsymbol{\tau}}{\rho H}\right) = \frac{1}{\rho H a}W(r)sin\varphi,$$

1:Wind forsing is given by: $F(r,\varphi) = \frac{\tau_0}{\rho H a^2} r sin\varphi,$

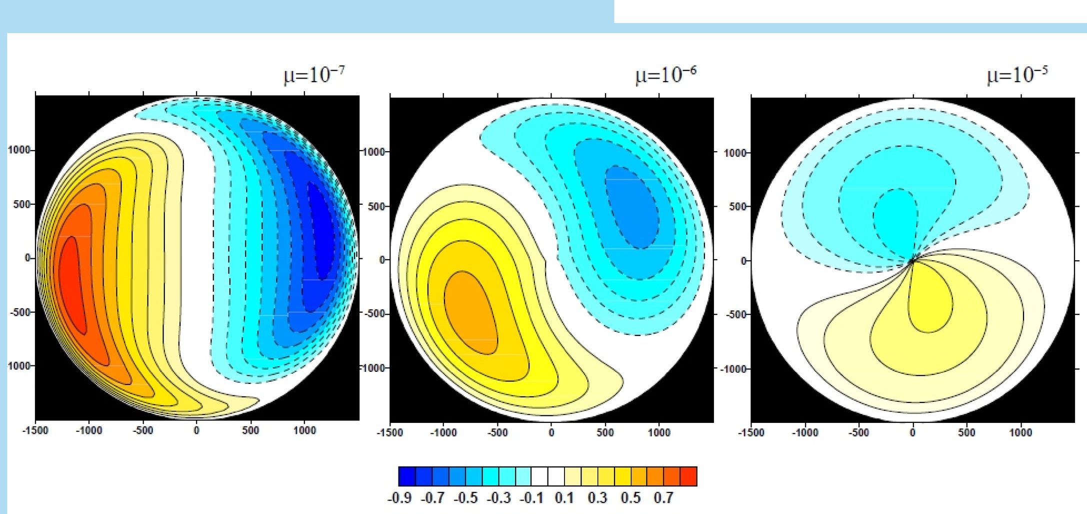
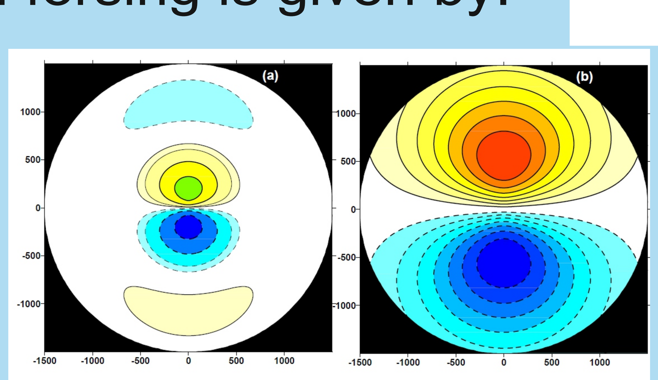
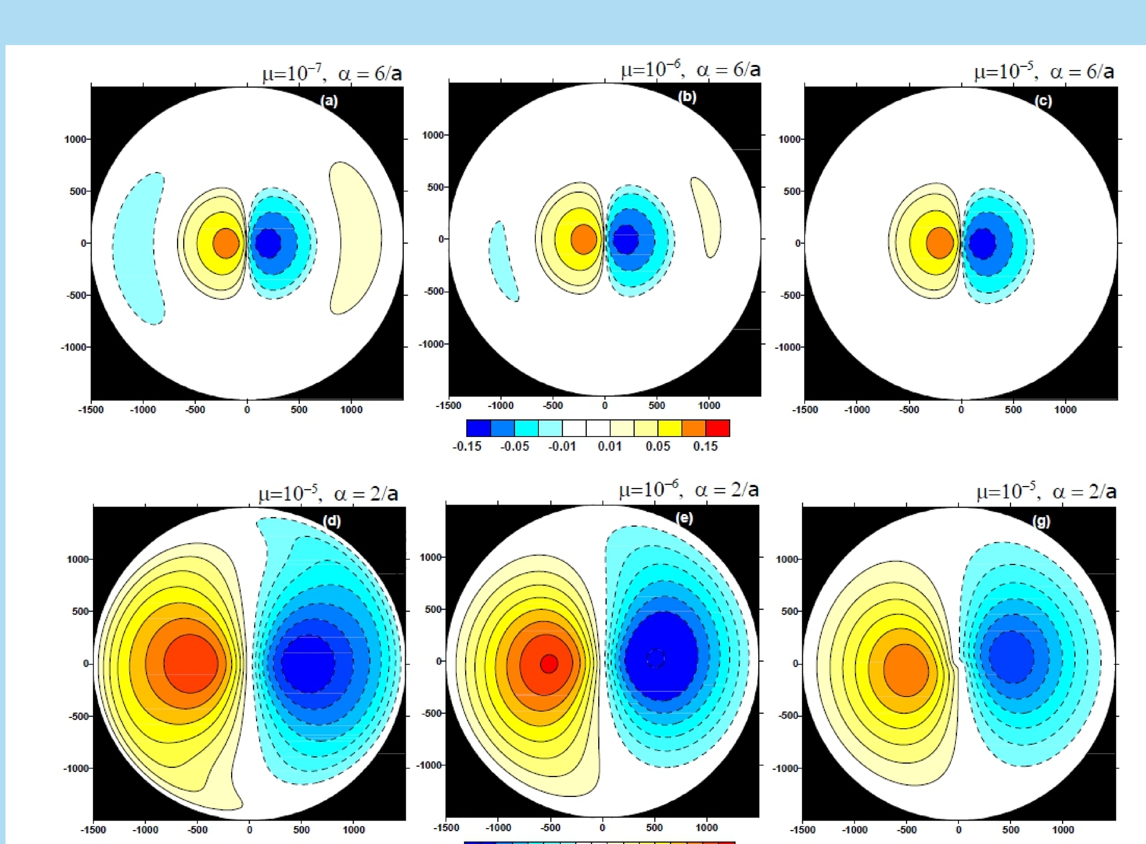


FIGURE 2

2:Wind forsing is given by: $W = \tau_0 \hat{r}^\beta e^{-\alpha r}$



solutions:



In this poster we elucidate, using simple analytical models, some of the processes that control the circulation of the Arctic. In the published literature there are numerous studies that employ coupled numerical

BOUNDARY FORCED SOLUTIONS:

$$\mu\nabla^2\Psi + \frac{rf}{R^2}\Psi_\varphi = 0,$$

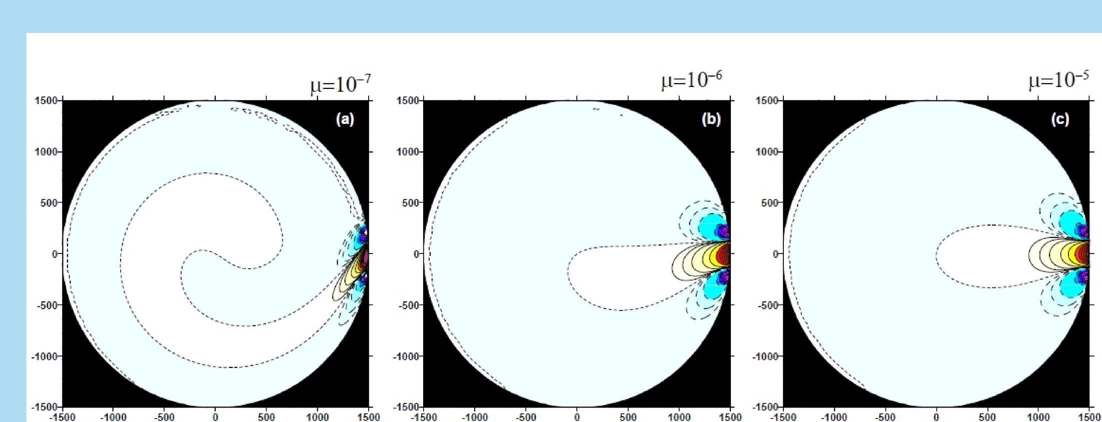
subject to

$$\Psi = \Psi_B(\varphi) \quad on \quad r = a$$

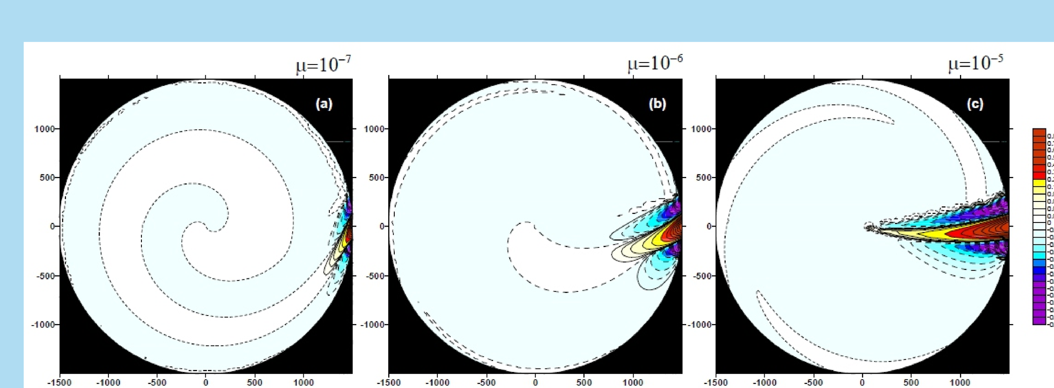
Specifically we consider

$$\Psi_B(\varphi) = \begin{cases} \frac{T}{2H}cos\left(\frac{\pi\varphi}{\hat{\varphi}}\right), & -\hat{\varphi} \le \varphi \le \hat{\varphi} \\ 0, & otherwise \end{cases}$$

An *exact* solution can be obtained, albeit in terms of Bessel functions with complex arguments.



An approximate *boundary layer solution* can also be obtained that captures, qualitatively, the structure of the exact solution.



In this poster we elucidate, using simple analytical models, some of the processes that control the circulation of the Arctic. In the published literature there are numerous studies that employ coupled numerical sea ice-ocean circulation models to address the factors controlling the dynamics of Arctic sea ice and the ocean circulation. Of particular note is the discovery by Proshutinsky and Johnson (1997) that there are two regimes of wind-forced circulation in this basin.

As the Arctic warms and its sea ice extent, volume and concentration decrease, especially during the summer months, and as the patterns of precipitation also change, is it possible to predict the resulting dominant changes in the circulation of the Arctic basin using relatively simple process models? There are relatively few published process models of vorticity wave dynamics and circulation of the Arctic which is no doubt linked to the fact that on a "polar plane" (the analogue of the mid-latitude b-plane the governing equations are less amenable to analytical treatment. For example, the linearised vorticity equation governing barotropic dynamics on a polar plane has non-constant coefficients. Nevertheless, the value of analytical solutions for Arctic wind and buoyancy driven dynamics in one and two layer models with simple topography is self-evident: solutions of this type are invaluable for interpreting the results from more "complete physics" coupled sea ice-ocean circulation models as well as providing insight on the design of worthwhile numerical experiments. For these reasons we are developing process models for Arctic Ocean circulation.

In developing a hierarchy of process models for the circulation of the Arctic the following factors must be considered:

- Relative role of wind and boundary forcing
- Major topographic features
- Wide shelves
- Quasi 2-layer stratification
- Adjustment via vorticity wave dynamics in near-closed basin on the polar plane
- Presence of land fast sea ice because it drastically alters the ice-ocean shear stress

The models developed below begin to address the first and third bullet points above....clearly further research is required.