# Numerics of scalar advection in ocean-sea ice models

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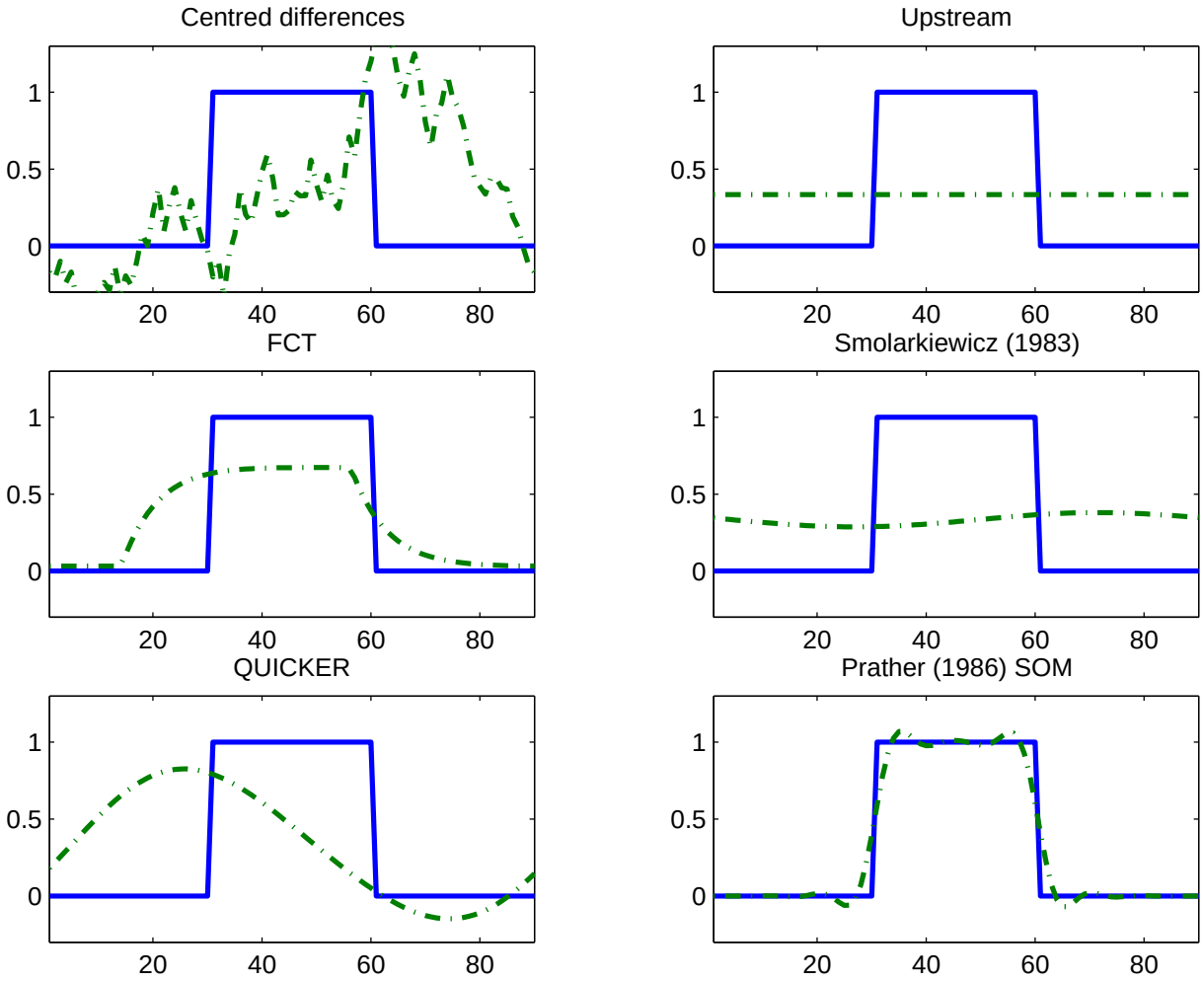
# Advection-diffusion of scalars

$$\frac{\partial T}{\partial t} = -\boldsymbol{\nabla} \cdot (\boldsymbol{u} T) - \boldsymbol{\nabla} \cdot (-\boldsymbol{K} \boldsymbol{\nabla} T)$$

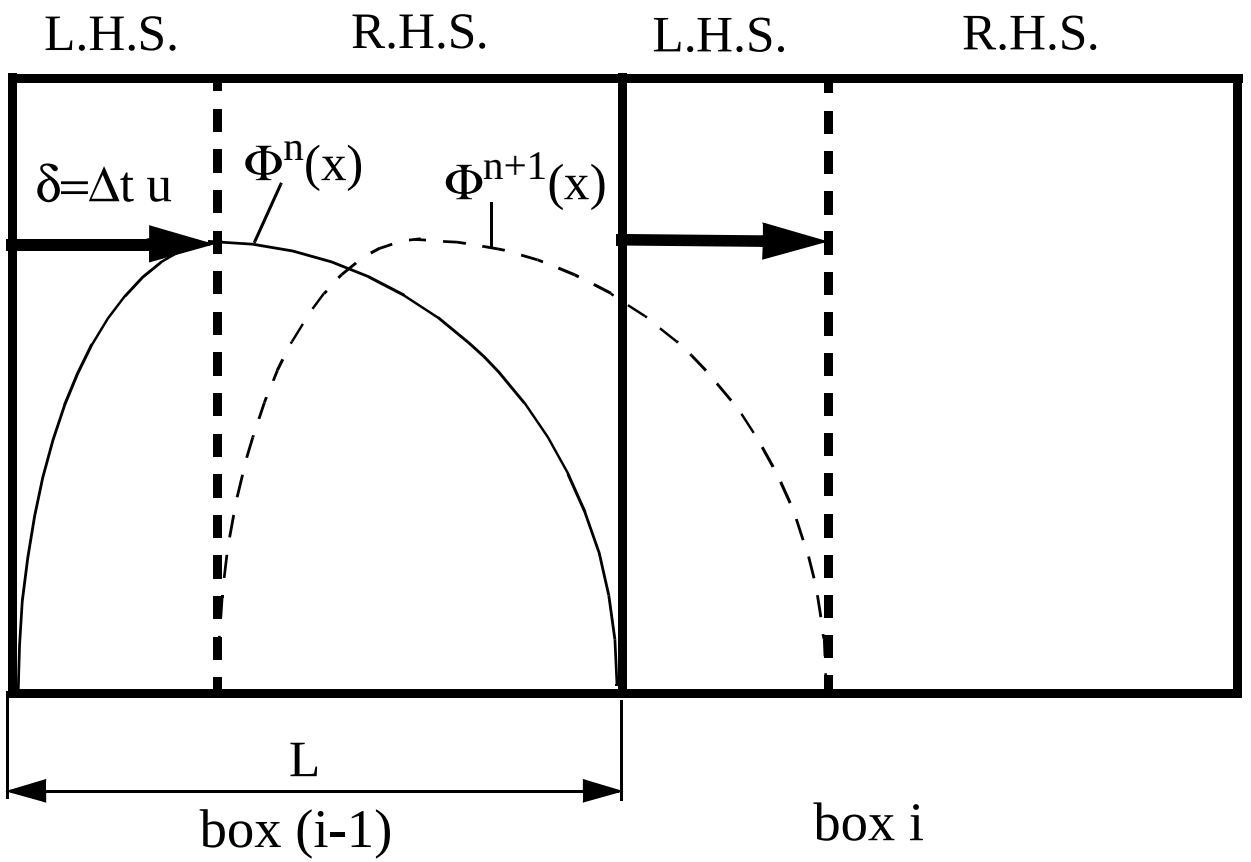
# Examples of advection-scheme performance

Square wave in a periodic domain ($10^3$ laps). $u = 0.1$ m s$^{-1}$, $\Delta x = 50$ km, $\Delta t = 25000$ s.

Key words: dispersion, diffusion, amplitude, phase.

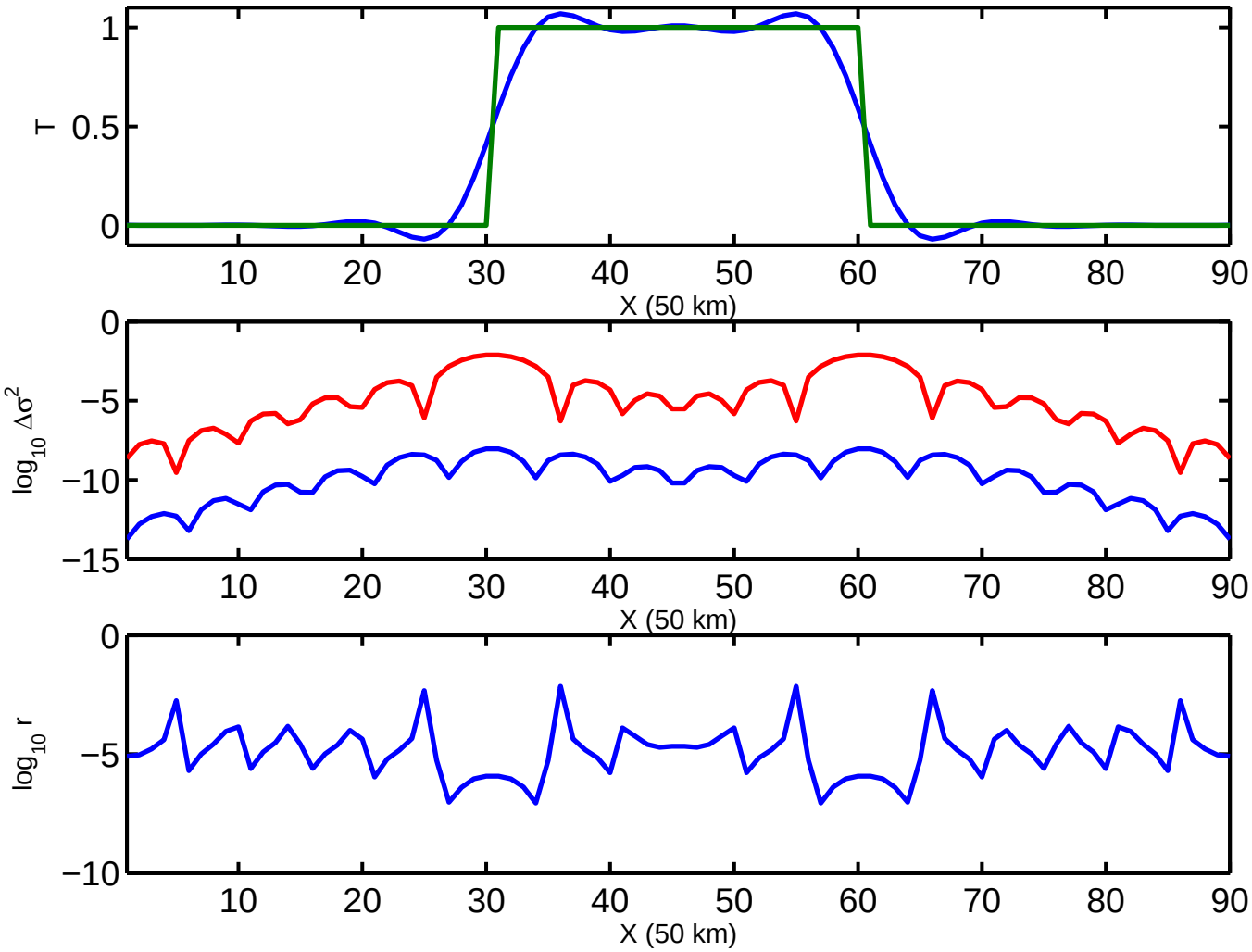


# SOM Method



# SOM Method

- $\Delta\sigma^2$ variance dissipated at each grid point by advection at a given time step
- $r = \Delta\sigma^2_{SOM}/\Delta\sigma^2_{upstream}$



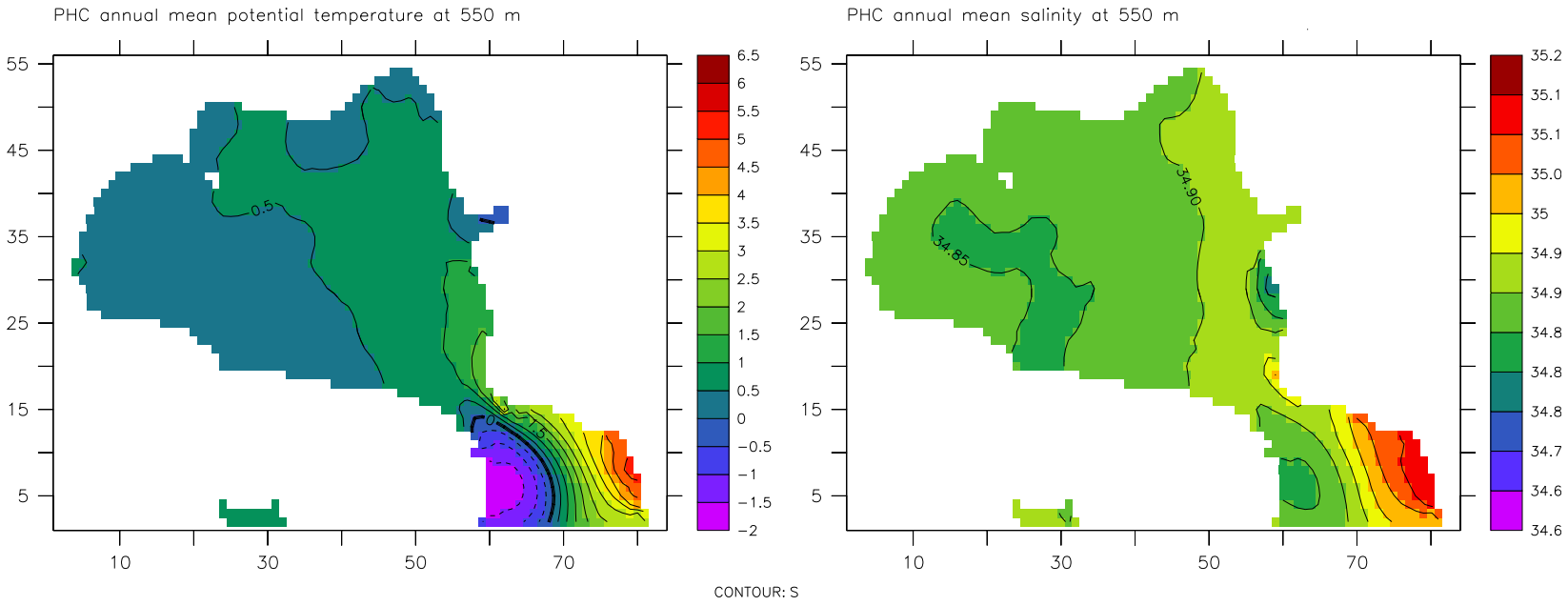
# Arctic ocean-sea ice model AIM (IOS)

- MOM-2
  - Boussinesq primitive equations in Z coordinates
  - Rigid lid
  - Stratification-dependent vertical mixing + tidal mixing
  - Second order moments advection scheme
  - Rotated grid, horizontal resolution: $5^\circ$
  - Vertical resolution: 29 levels (10-290 m)
- Sea ice model
  - 2 layers (snow + ice)
  - Visco-plastic rheology
- Forcing
  - Daily NCEP/NCAR reanalysis SAT and SLP ($\rightarrow$ geostrophic wind)
  - Climatological relative humidity, cloudiness, precipitation
  - Bulk heat, evaporation and momentum fluxes

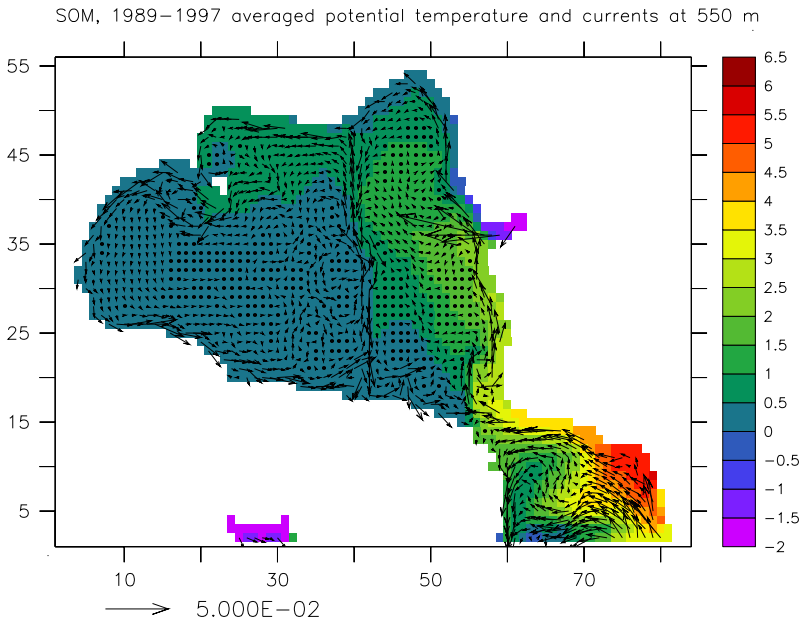
# Tests of advection schemes within the AOMIP Coordinated 1948-2000 Experiment

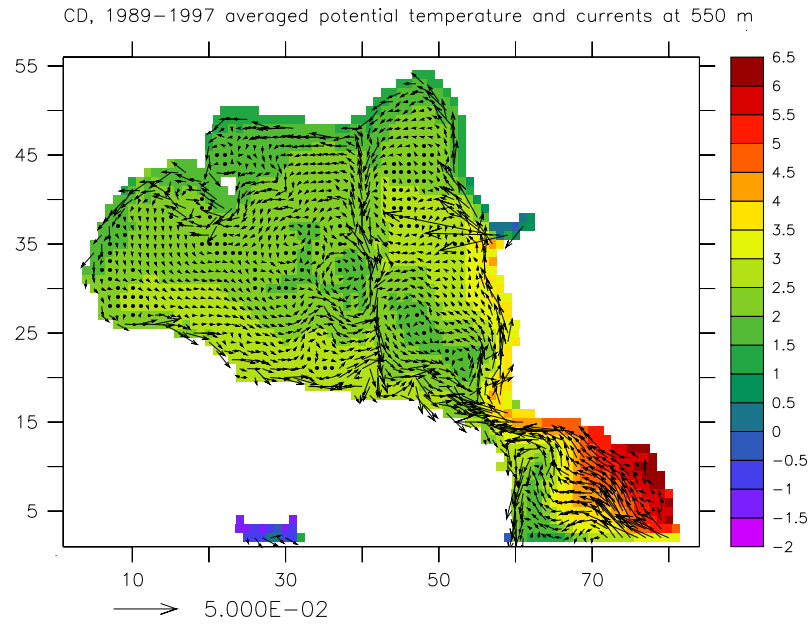
- Second order moments (SOM) in time-splitting mode –Prather (1986),
- Second order centred differences (CD)
- Flux corrected transport (FCT) –Gerdes, Koeberle and Willebrand (1991),
- Corrected upstream (SMOL83) in time-splitting mode –Smolarkiewicz (1983).

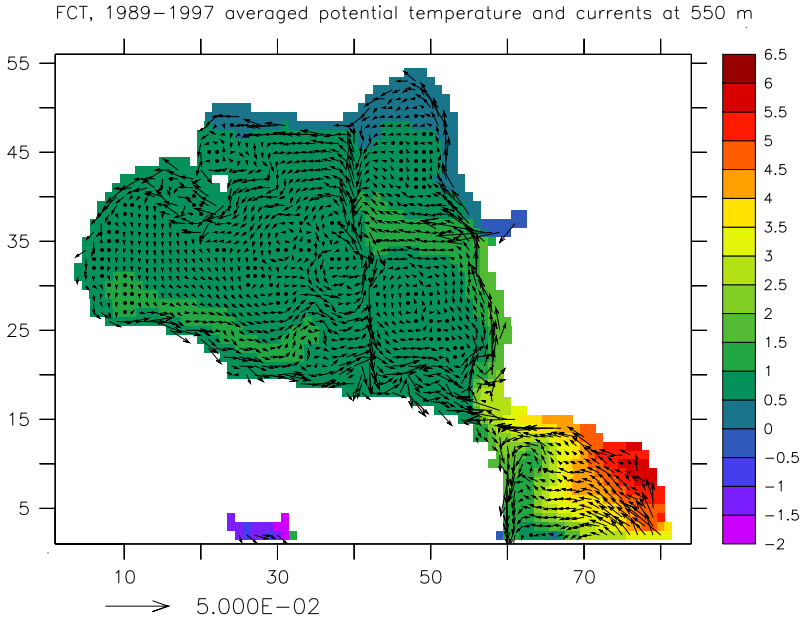
# PHC potential temperature and salinity at 550 m

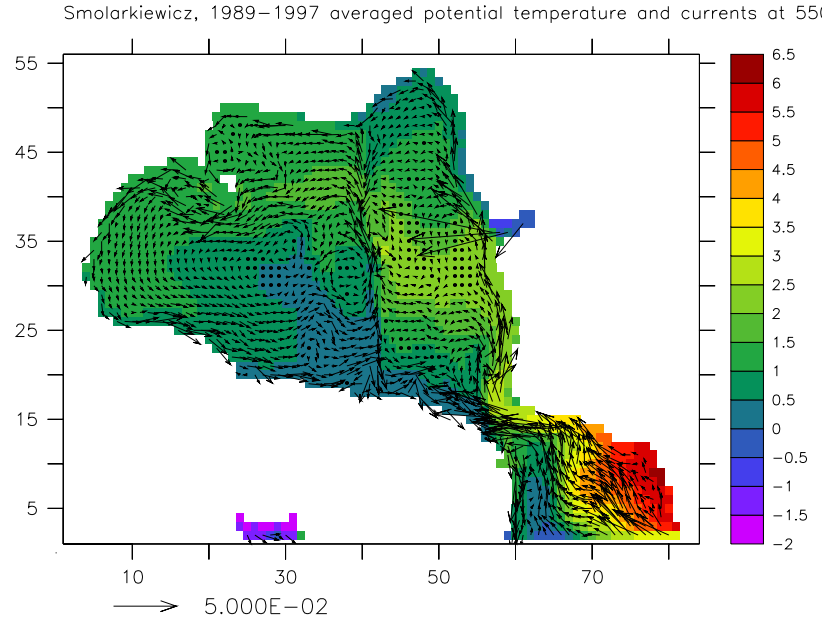


# 1988-1997 averaged potential density and currents at 550 m

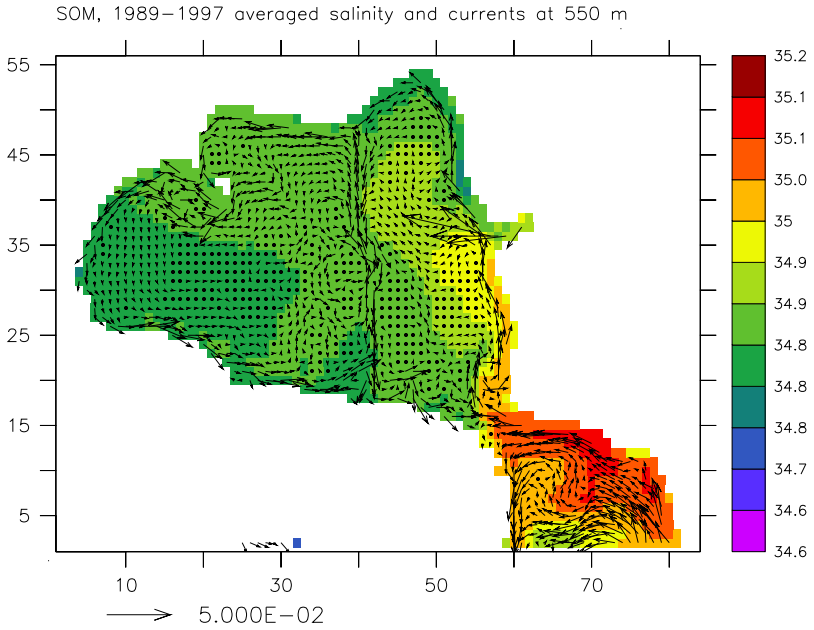


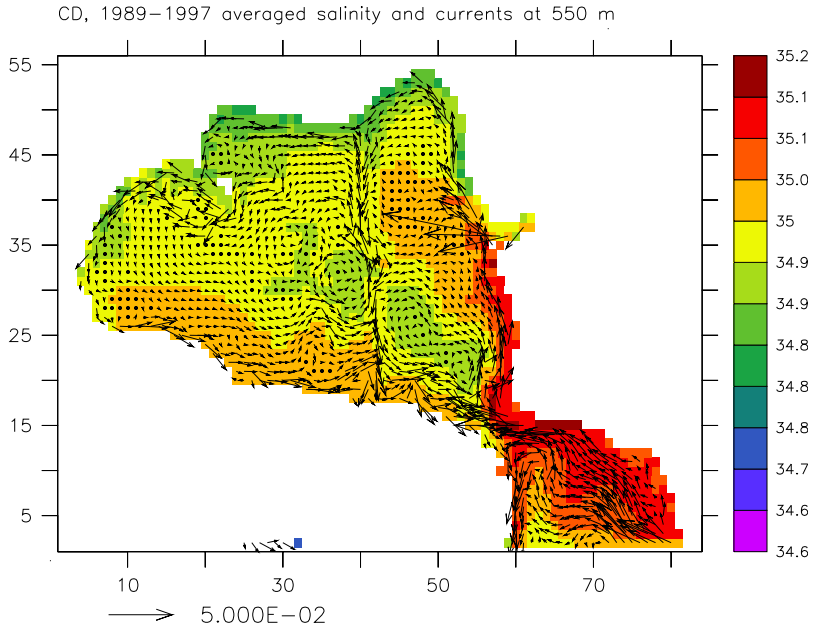



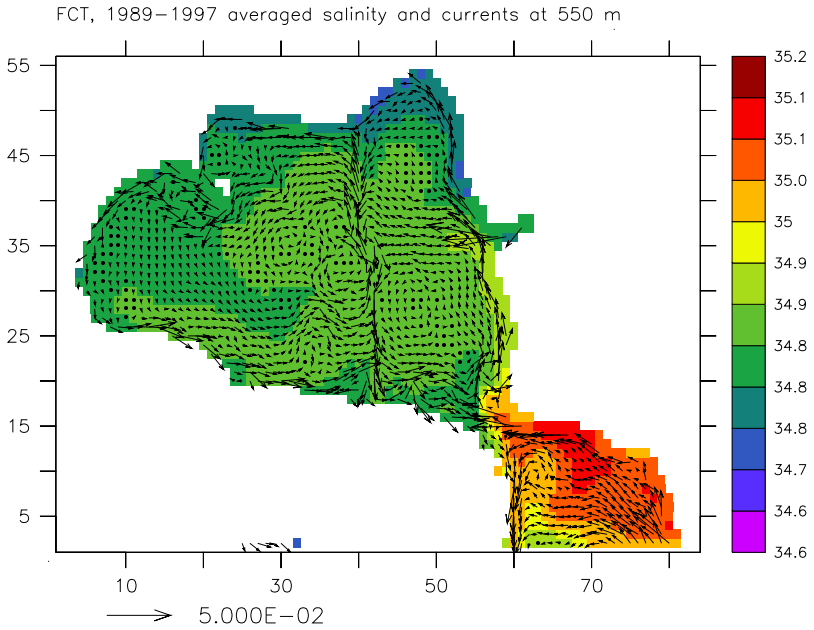



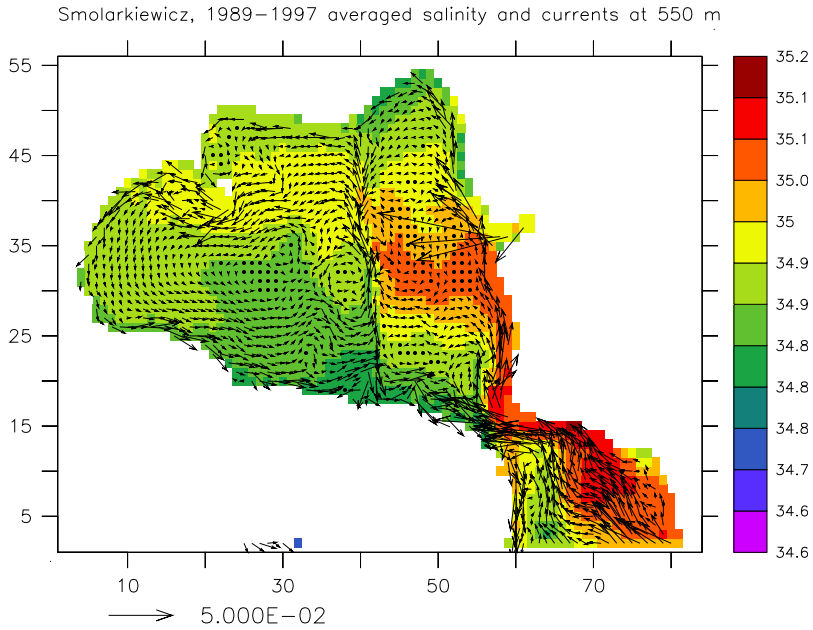



# 1988-1997 averaged salinity and currents at 550 m

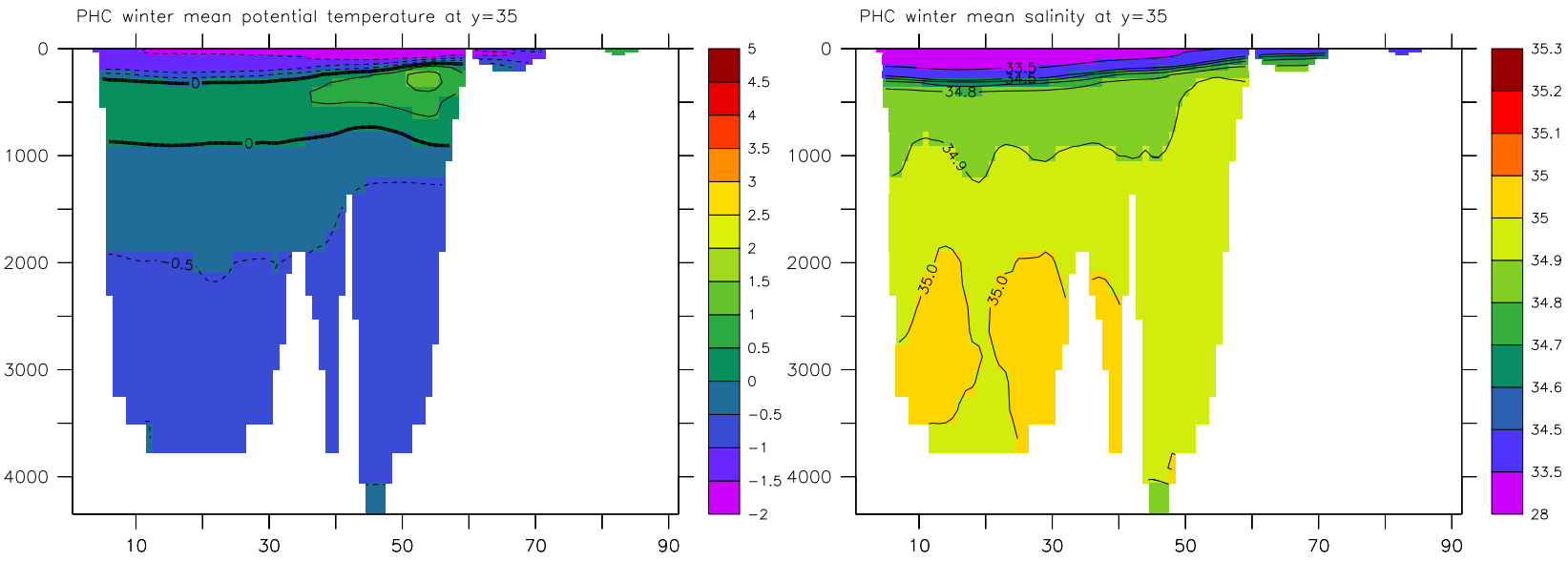


# PHC winter mean potential temperatures and salinities at $y = 35$



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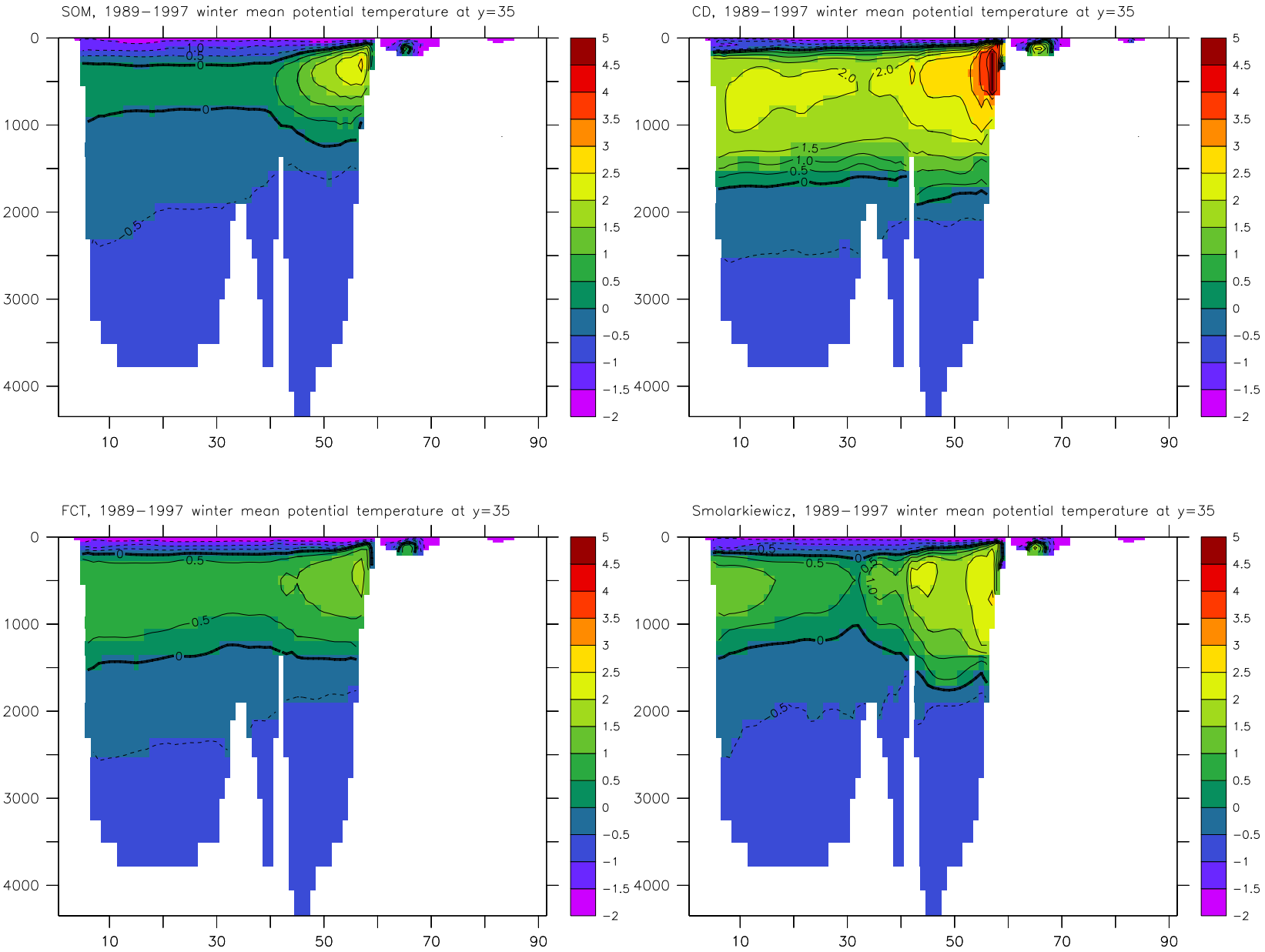
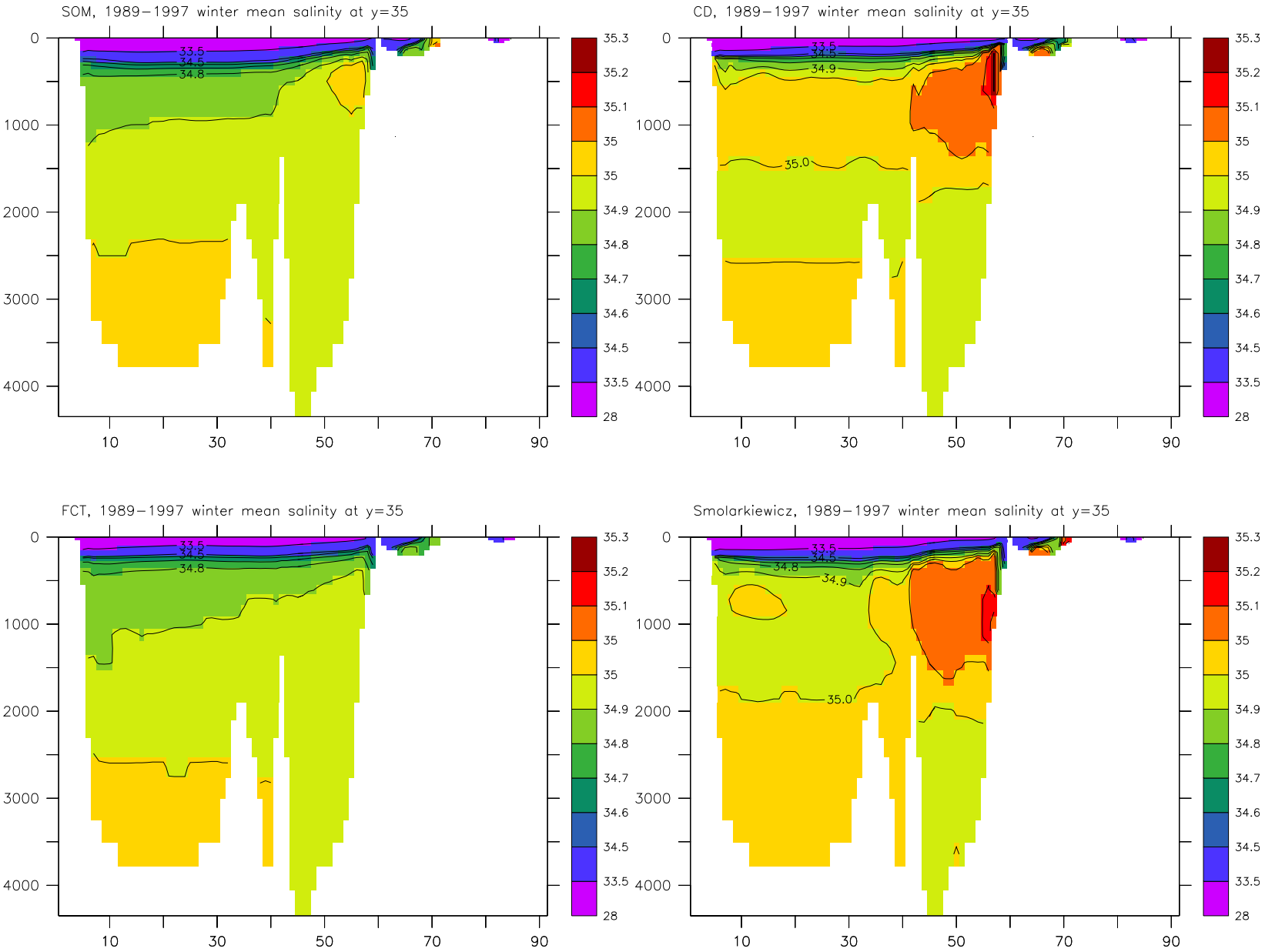


# 1988-1997 winter mean salinity at $y = 35$



# Conclusions and morality

- Different advection schemes produce very different distributions of water masses.
- Simple methods help computing the wrong solution very quickly...
- Complex methods are expensive, but probably preferable.