Particle Tracking in the German Bight: Comparing Drift Climatologies from Different Numerical Models

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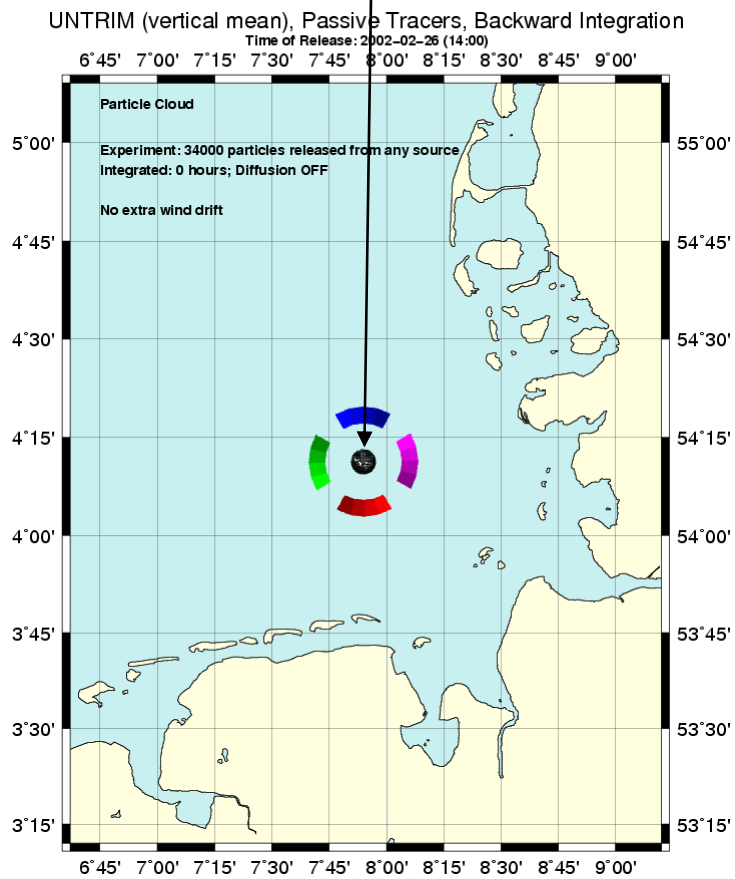
Outline:

1. Motivation
2. Summary of Models
3. Example Simulation
4. Cumulative Travel History (CTH), used for the
   - Description Mean Transports
   - Description of Transport Variability
5. Conclusions

Motivation

Long-term biological observations (since 1962) at the island of Helgoland in the German Bight (North Sea)



Question marine biologists ask:

- What is the history of water bodies analysed at the island of Helgoland?

Our objective:

- Compare Lagrangian transports based on the outputs of different hydrodynamic models

Approach:

- Particle releases from near the island and surrounding sectors at many different times (every 7h in 2002-2004)
- Integration 50 days backward (and also forward) in time.

Unstructured Grid

Regular Grids

3D, baroclinic

Grid:
irreg., 100m-5km
Dimension:
3D
Temp. / Salinity:
--- / yes
Atm. Forcing:
REMO

UnTRIM

Grid:
regular, ~10/1.8km
Dimension:
3D
Temp. / Salinity:
yes / yes
Atm. Forcing:
DWD

BSHcmod

Grid:
regular, 12.6 km
Dimension:
3D
Temp. / Salinity:
yes / yes
Atm. Forcing:
REMO

TRIM

2D

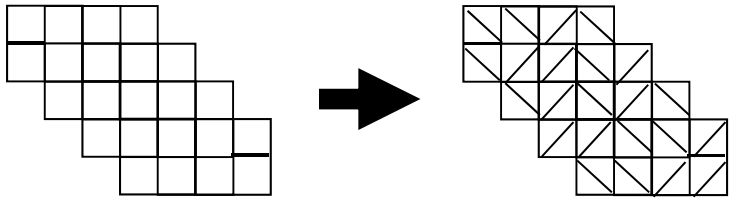
Grid:
irreg., 100m-5km
Dimension:
2D, finite element
Temp./ Salinity:
--- / ---
Atm. Forcing:
REMO

TELEMAC-2D

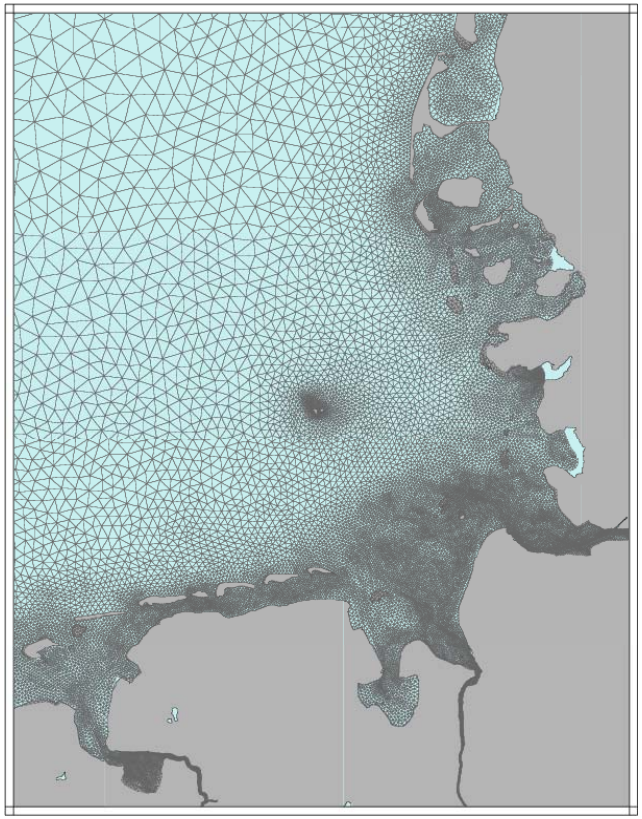
Offline particle tracking with PELETS-2D:

2D algorithm adapted to triangular grids

- for 3D models: take vertical averages
- for regular grids: introduce diagonals

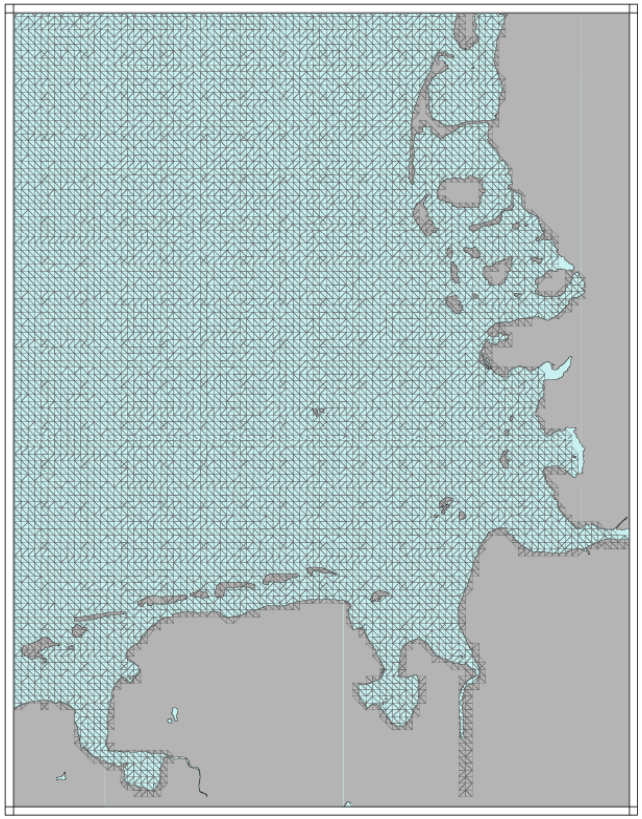


UnTRIM
TELEMAC-2D



100 m – 5 km

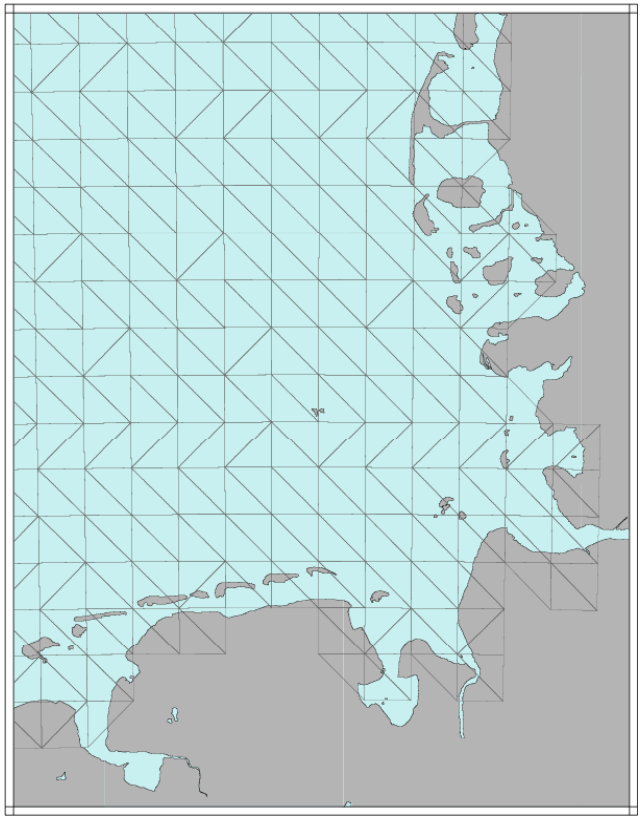
BSHcmod



1.8 km

TRIM

Helgoland not represented



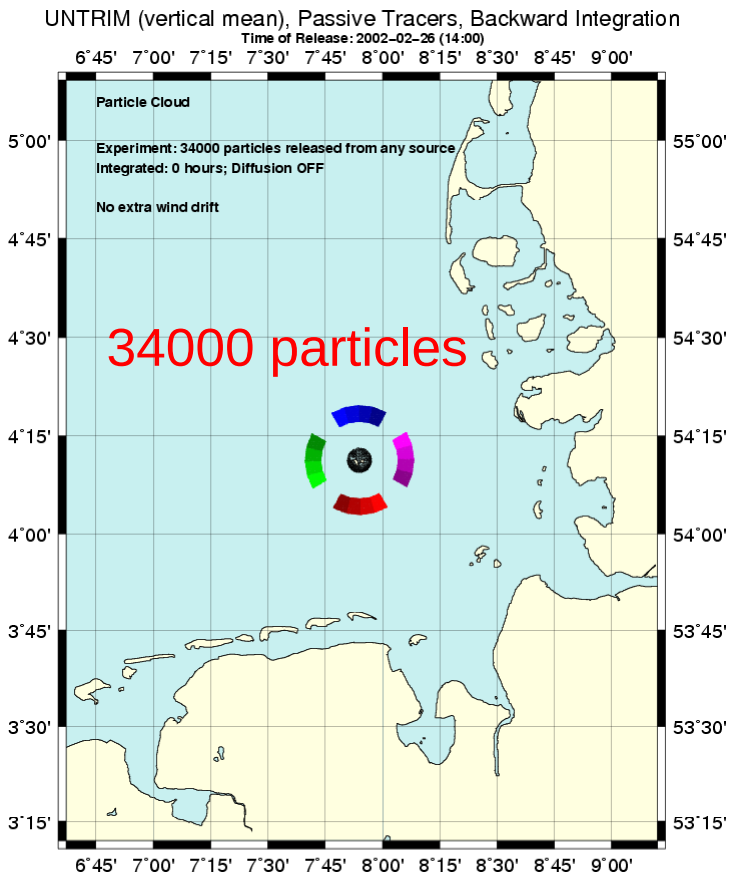
12.6 km

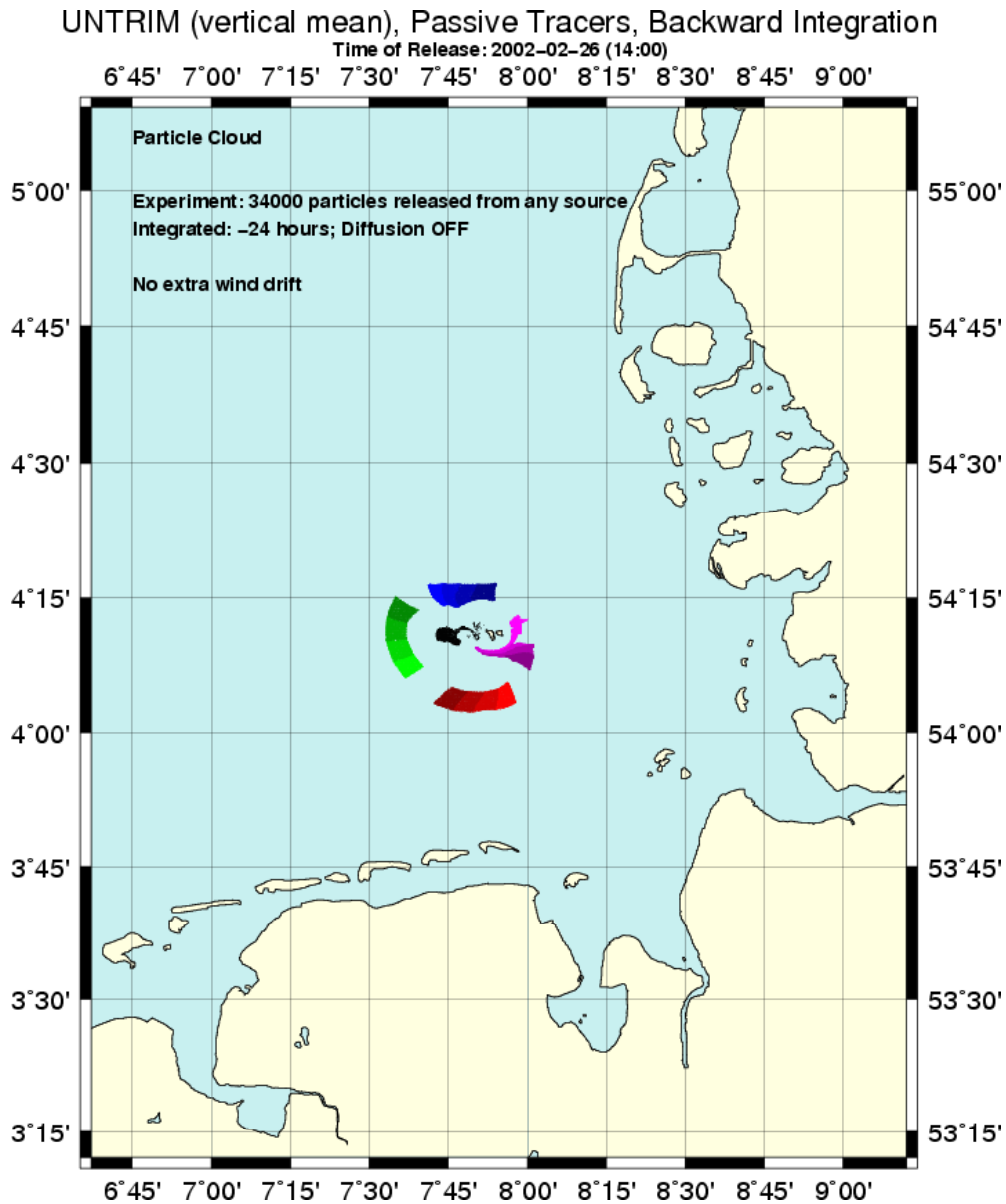
Example:

Backward Integration with UnTRIM

1 day back

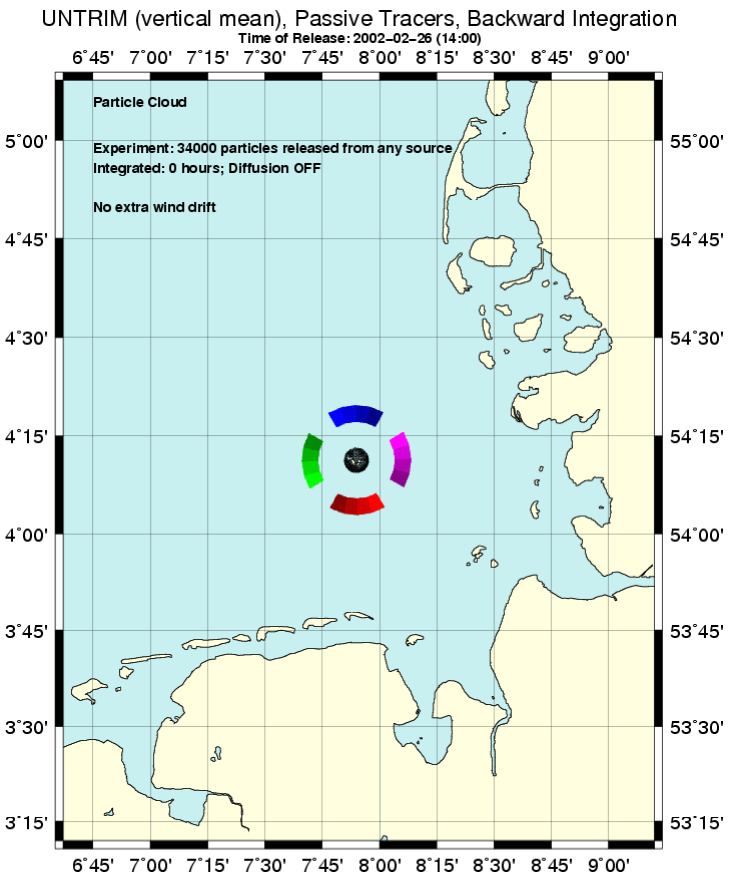
UnTRIM
3D, unstructured grid

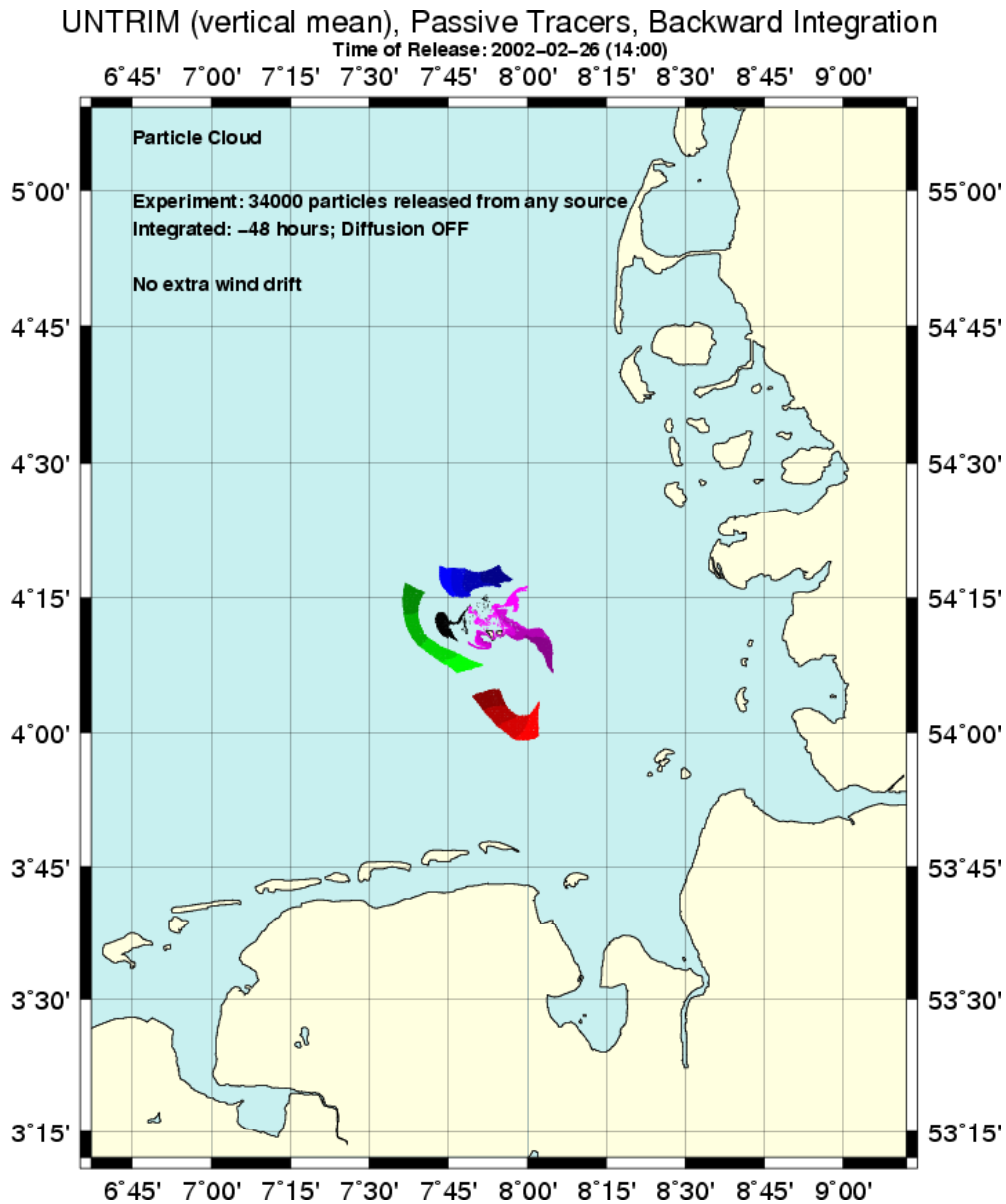




2 days back

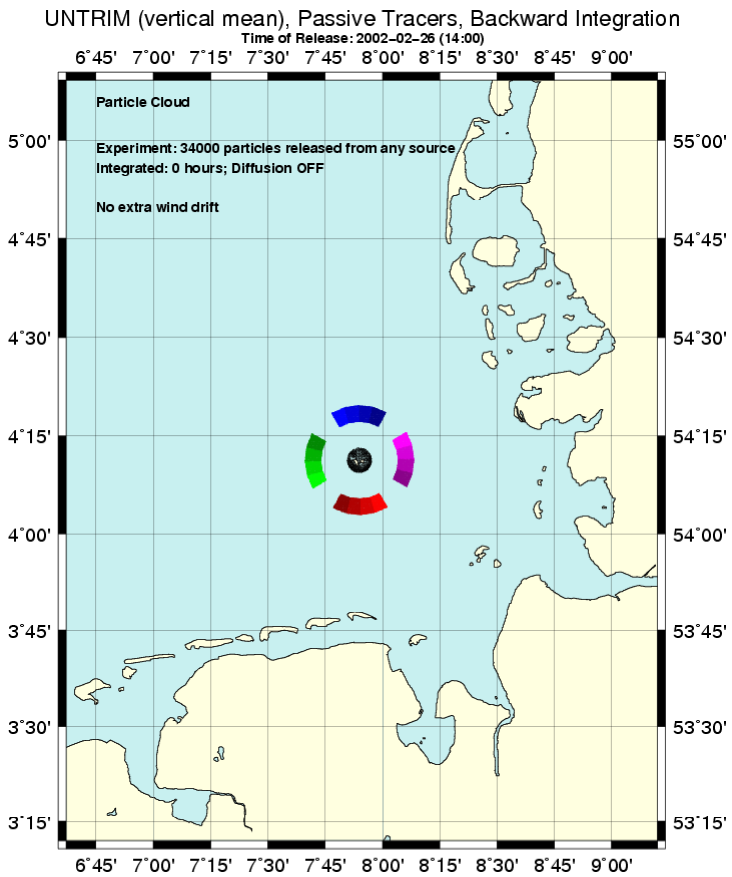
UnTRIM

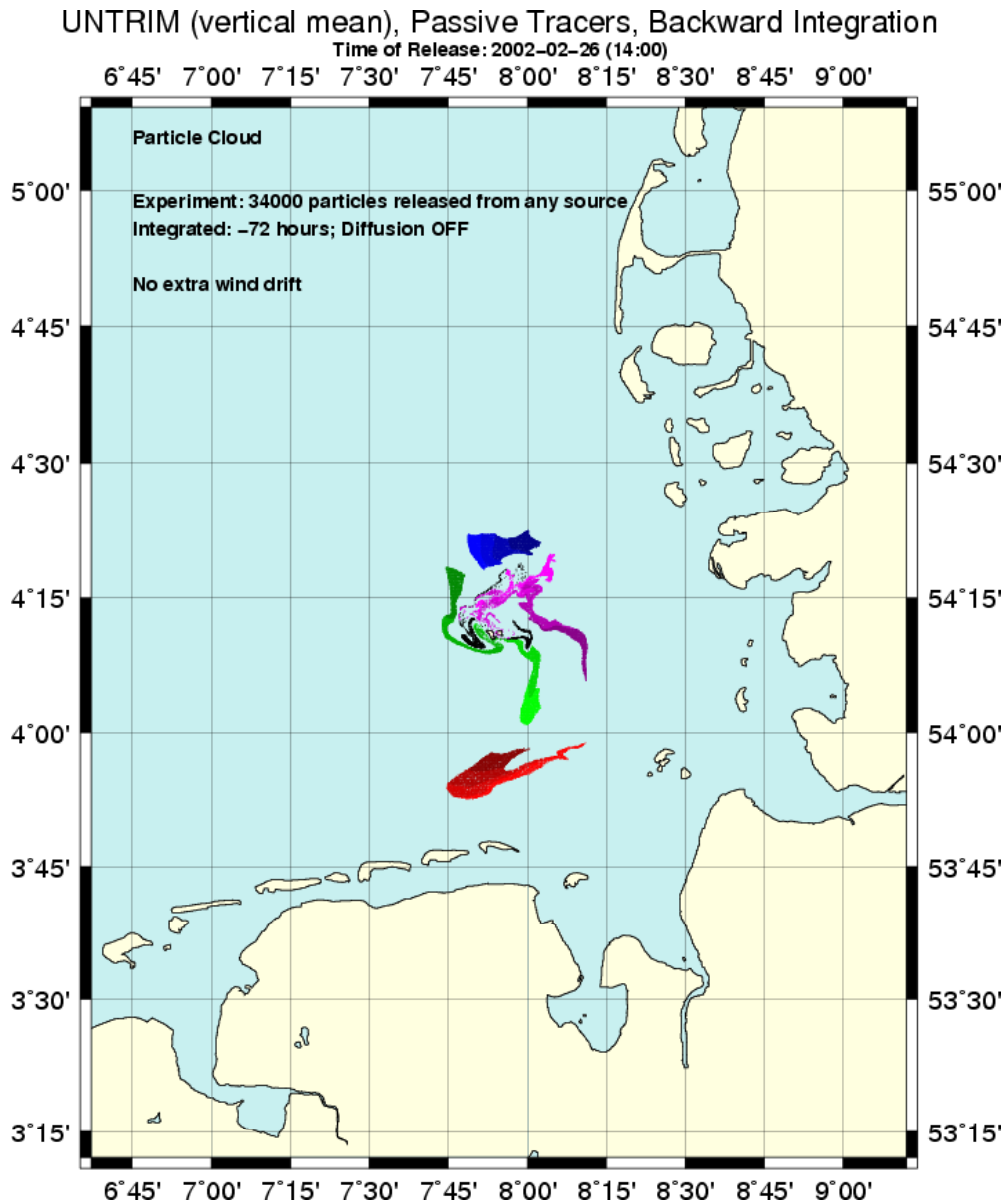




3 days back

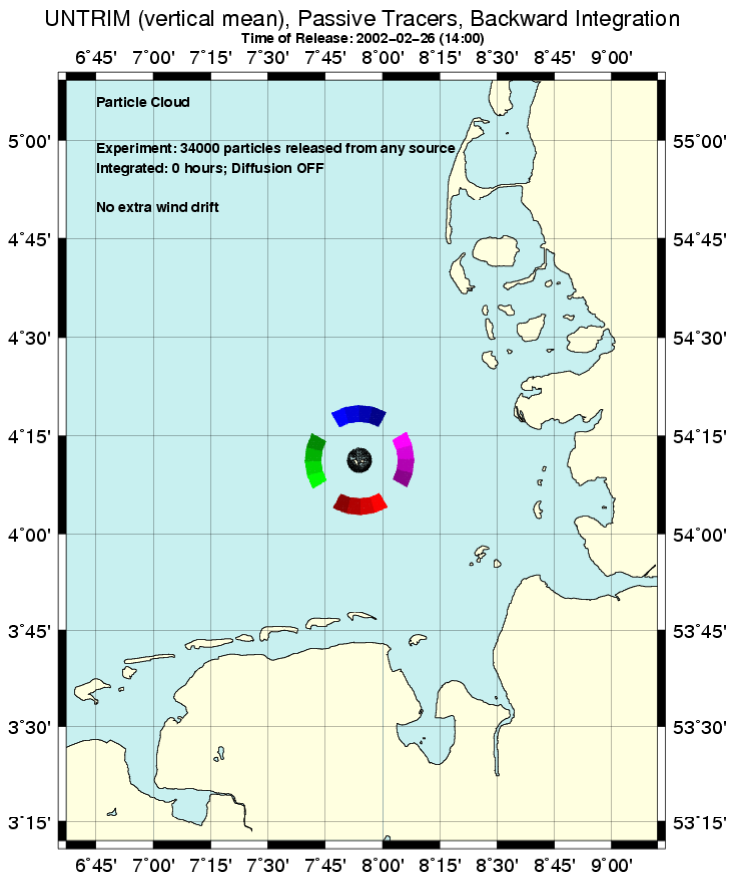
UnTRIM

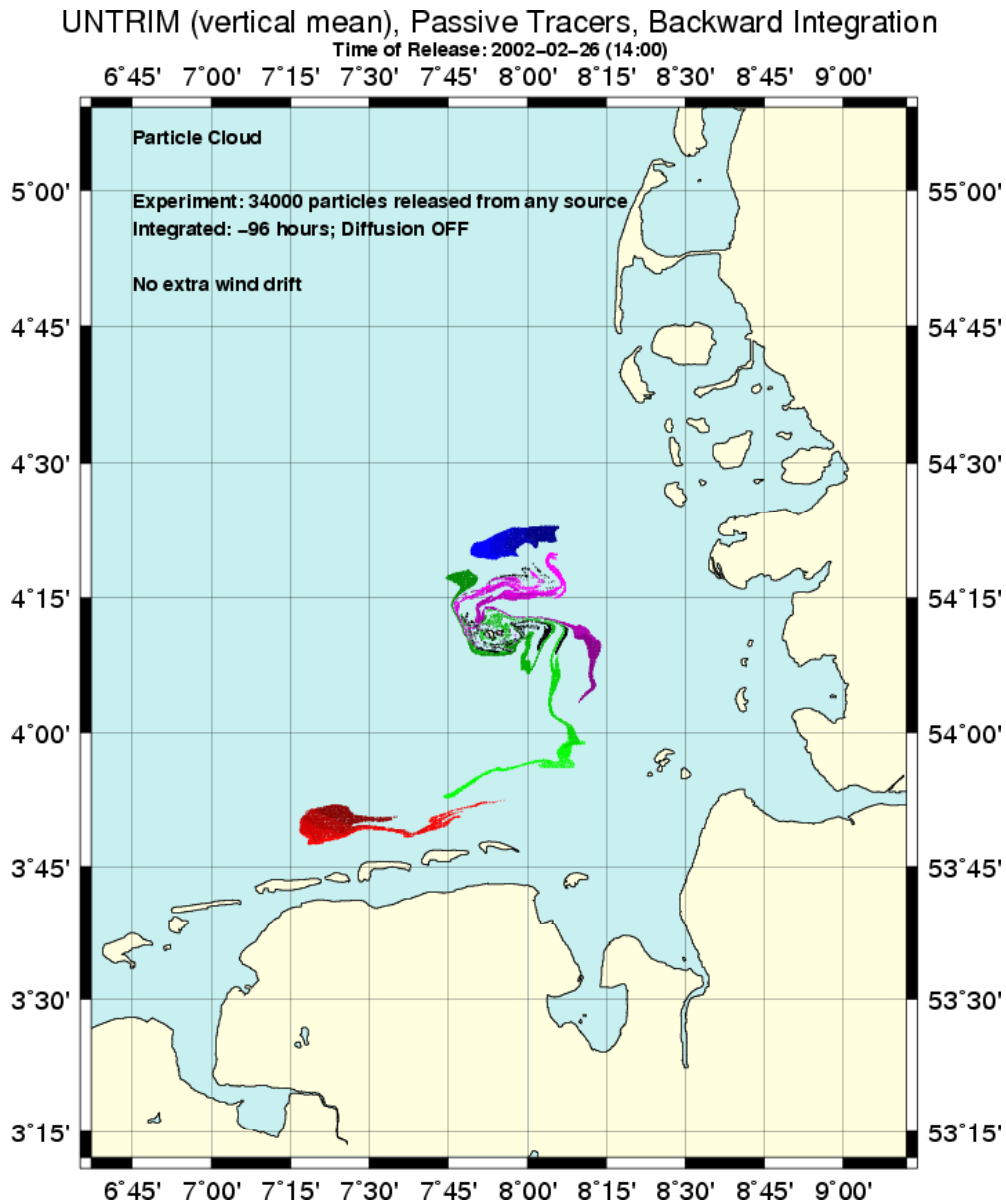




4 days back

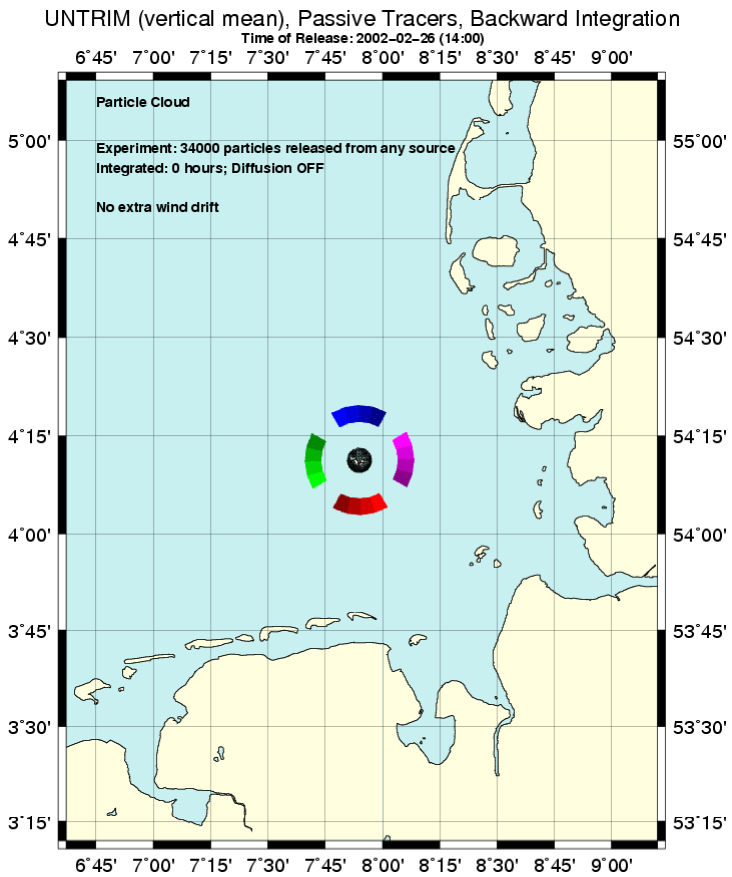
UnTRIM

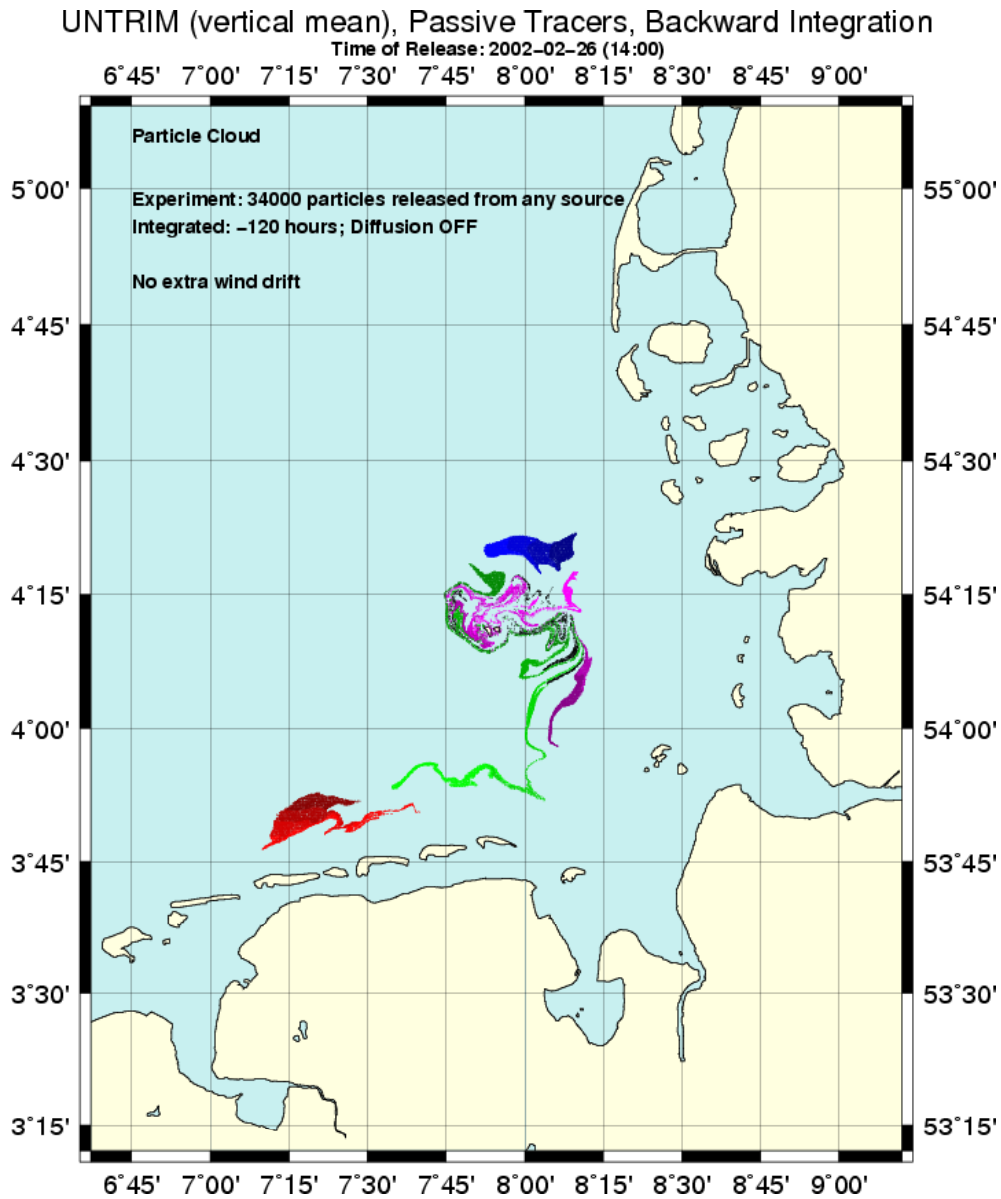




5 days back

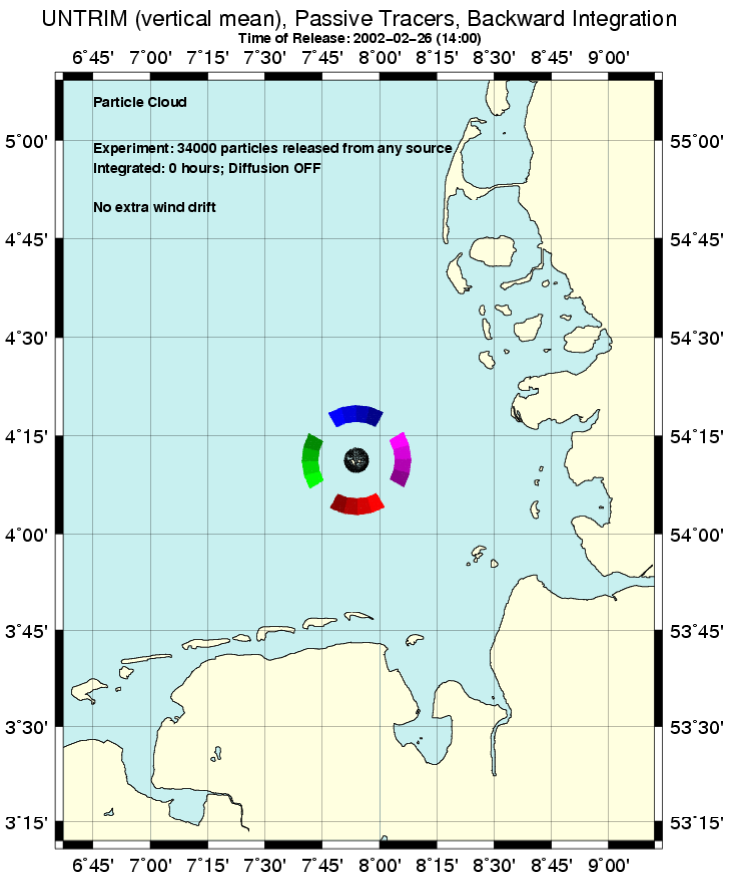
UnTRIM

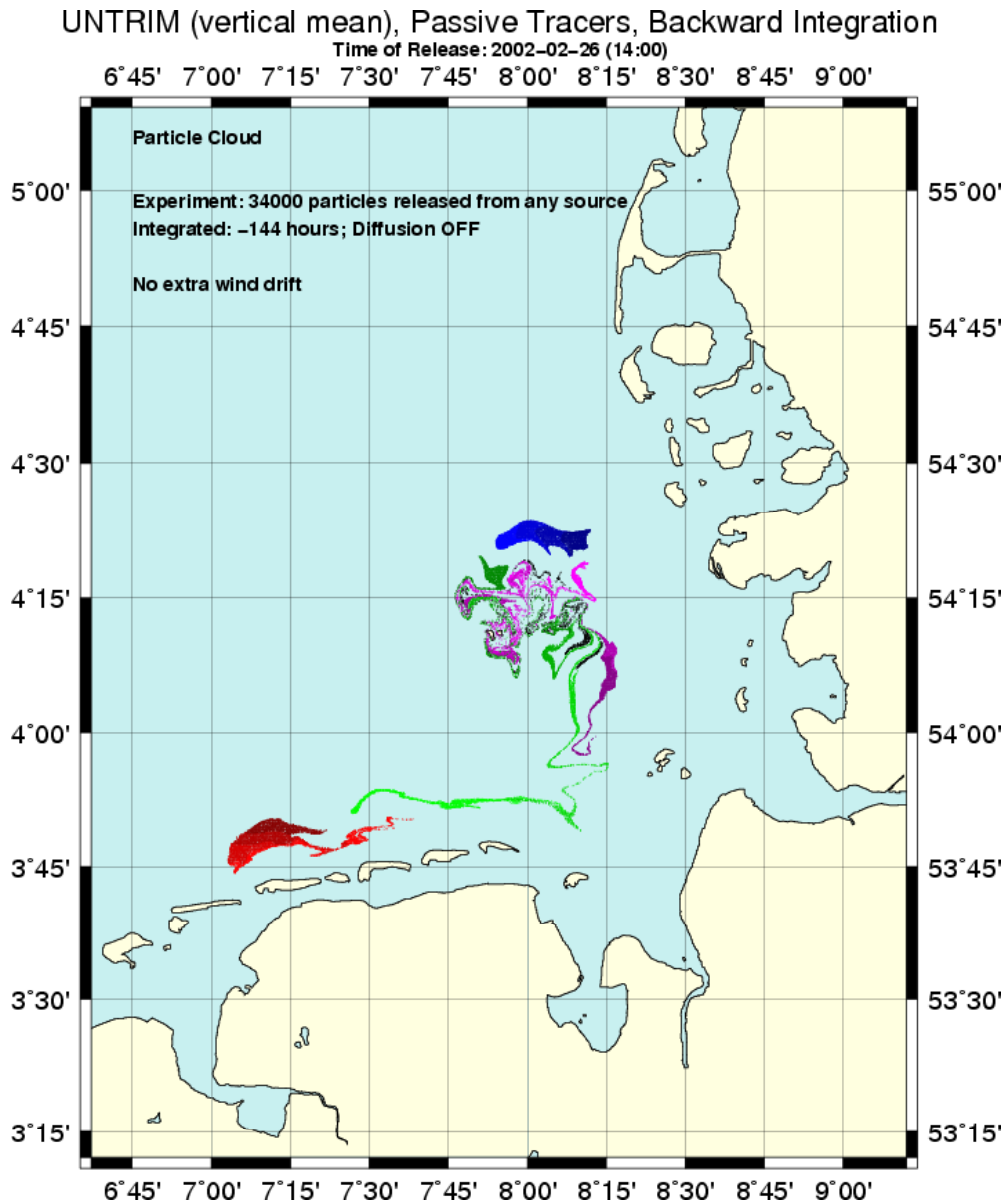




6 days back

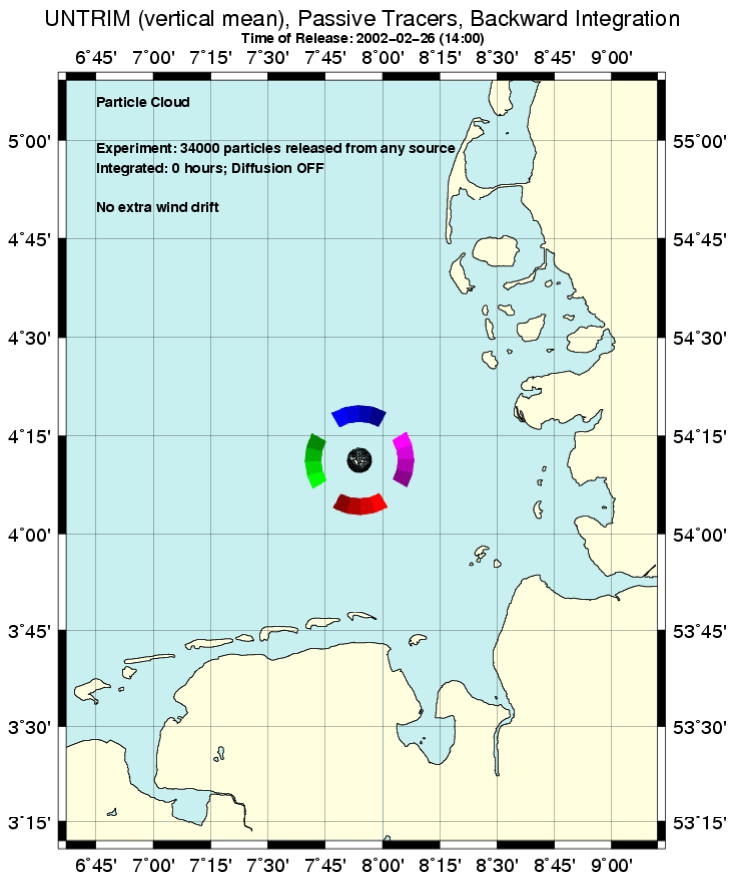
UnTRIM

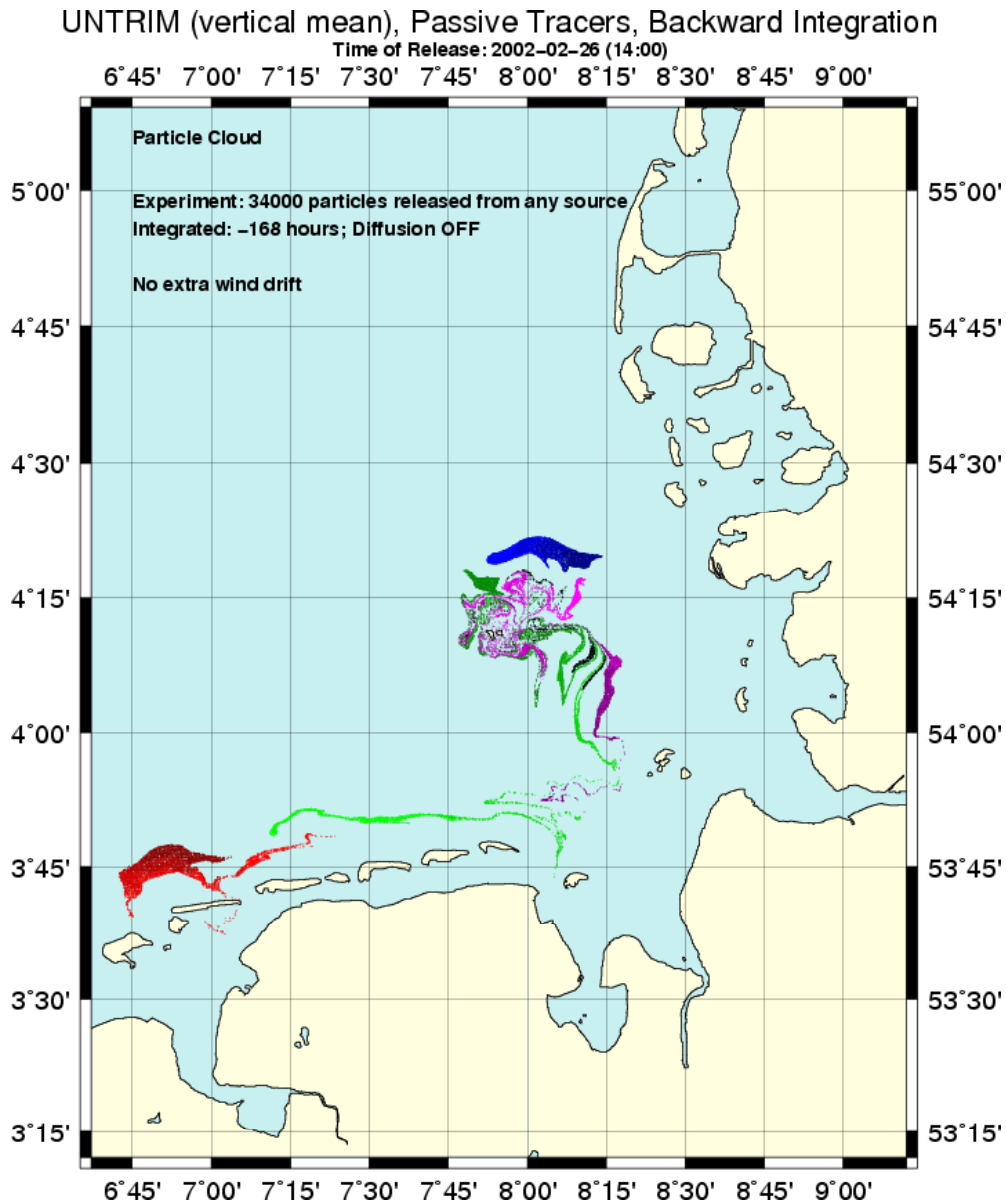




7 days back

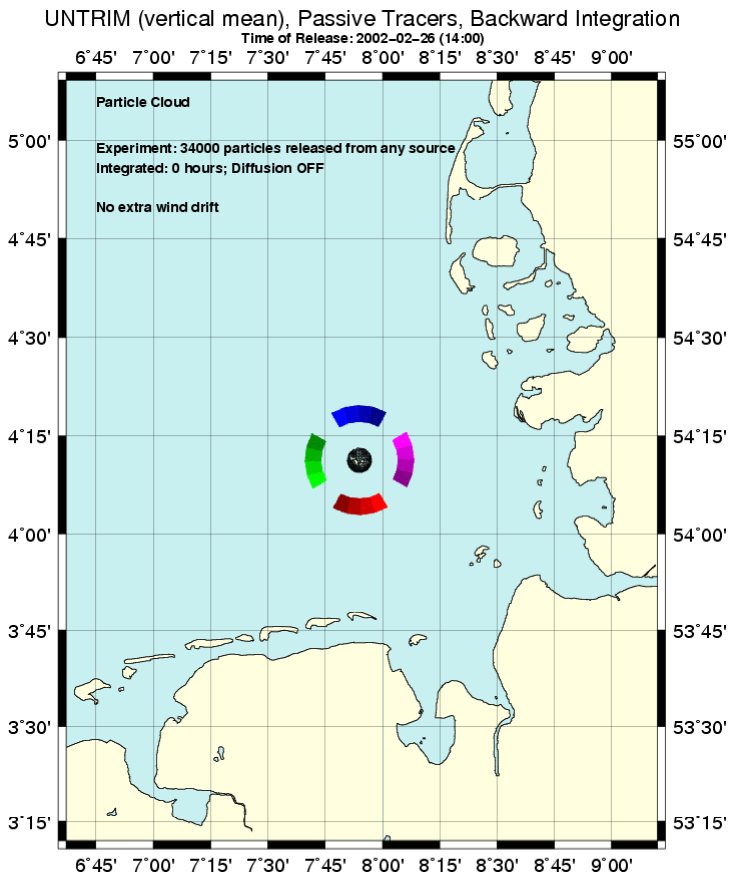
UnTRIM

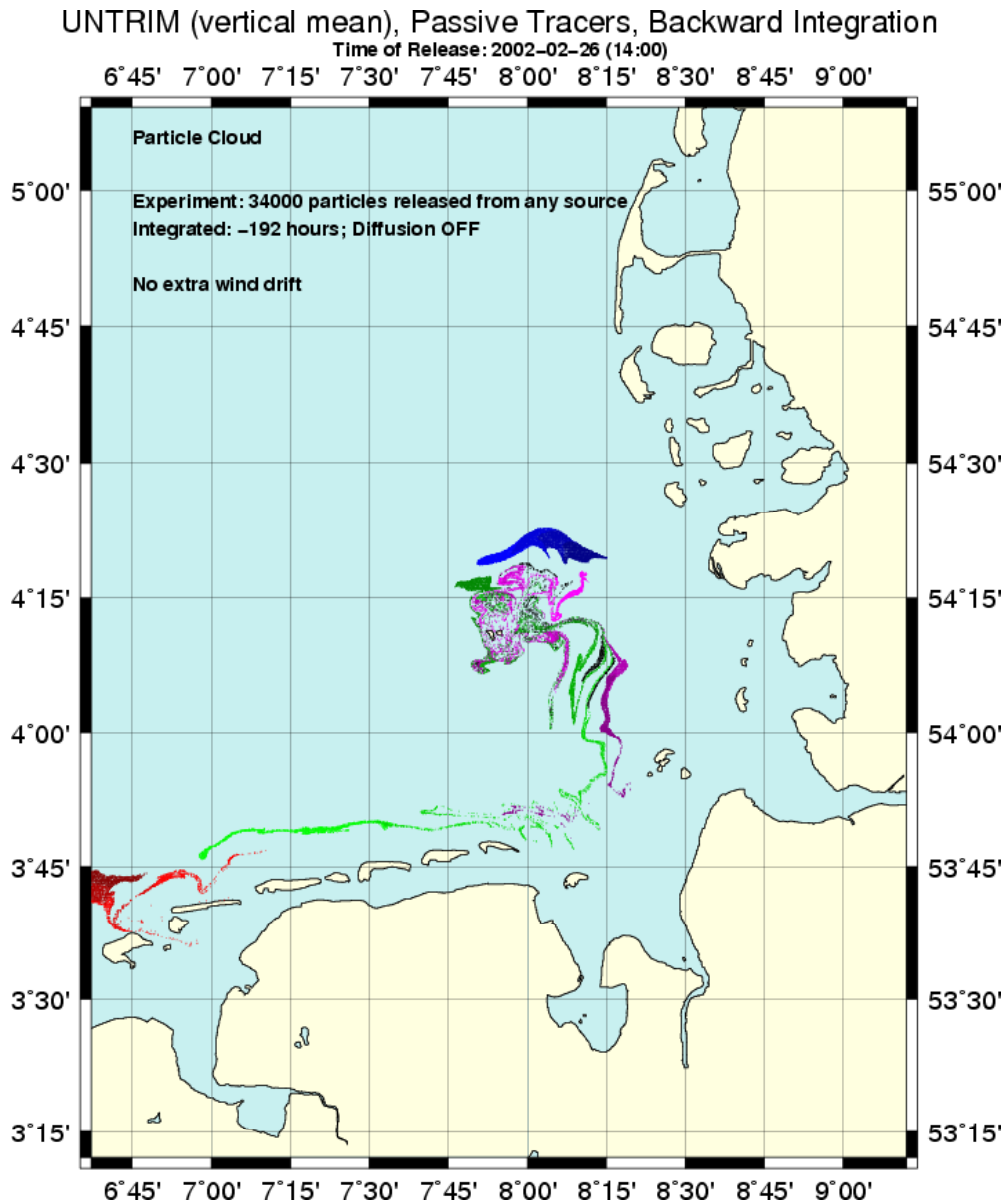




8 days back

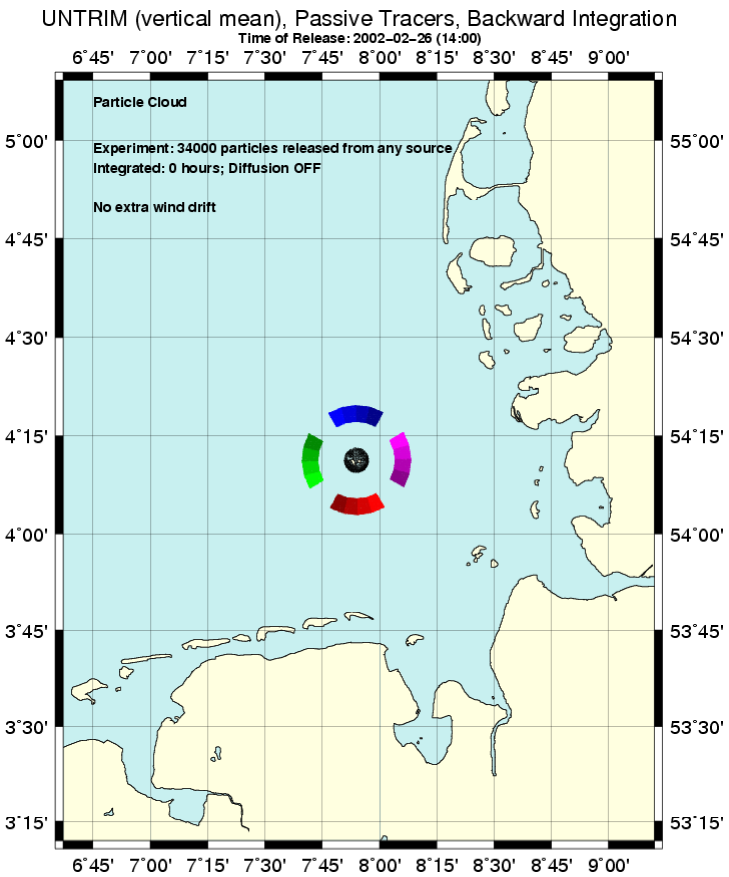
UnTRIM

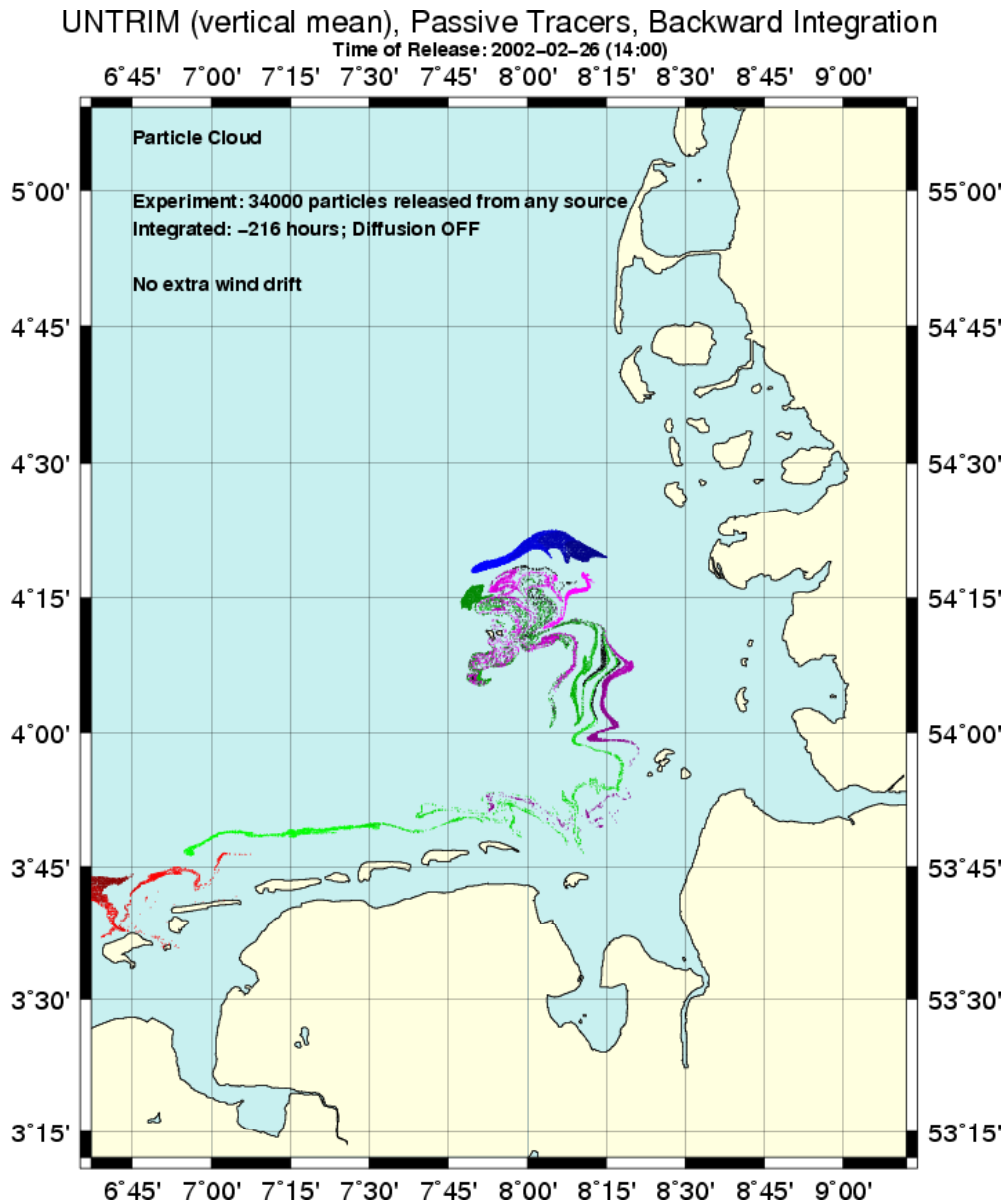




9 days back

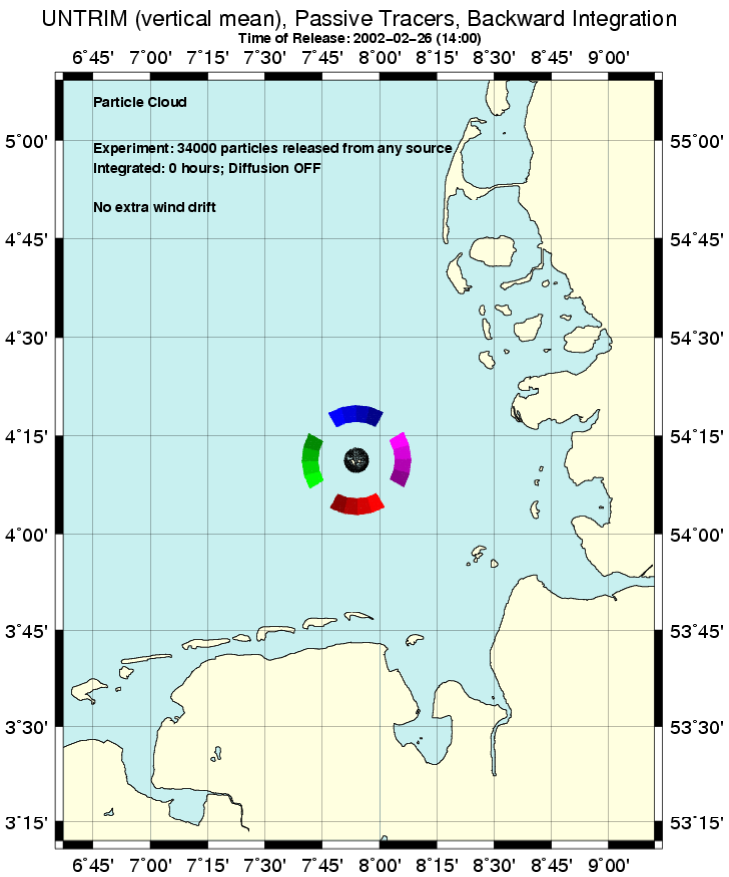
UnTRIM

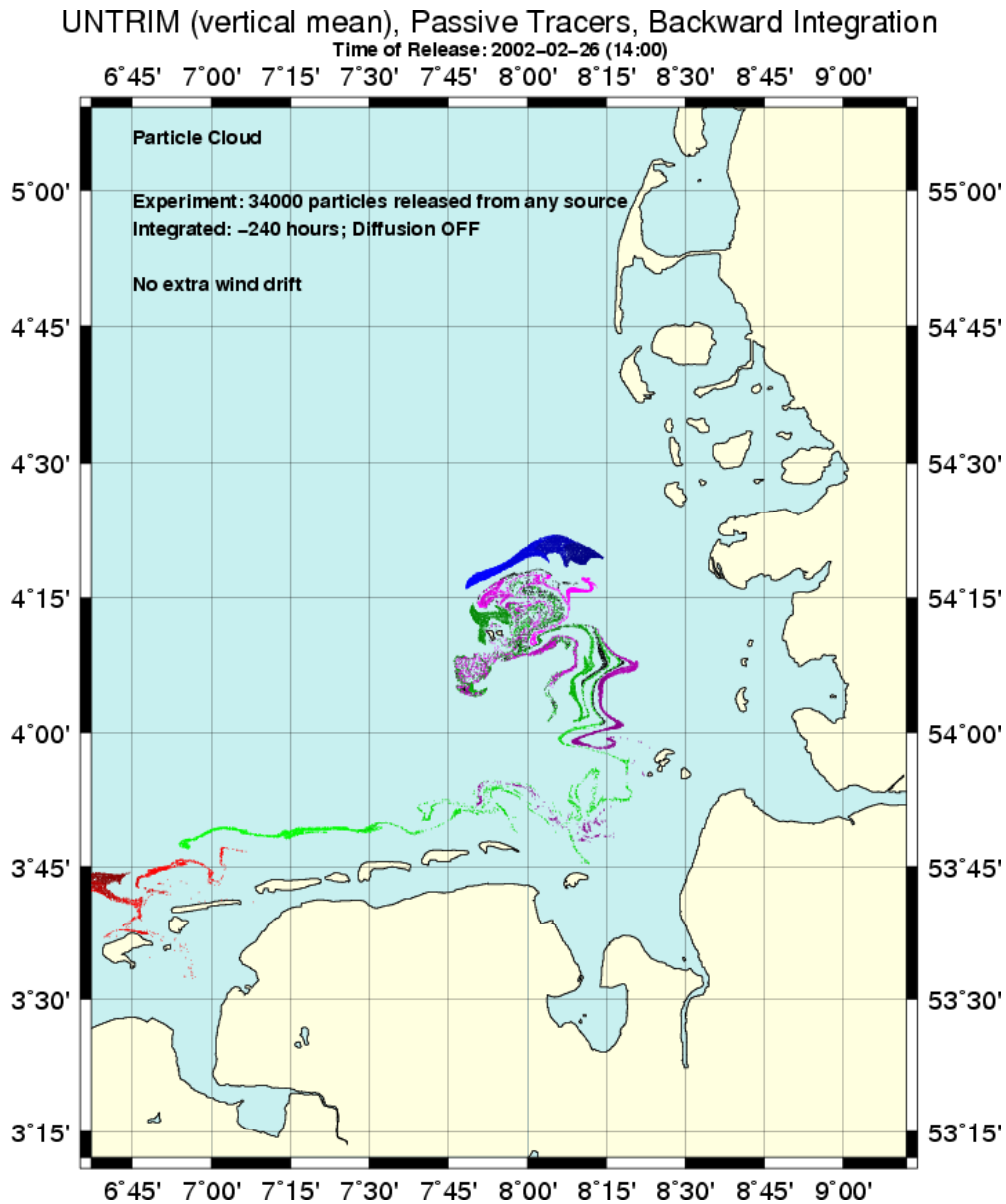




10 days back

UnTRIM





11 days back

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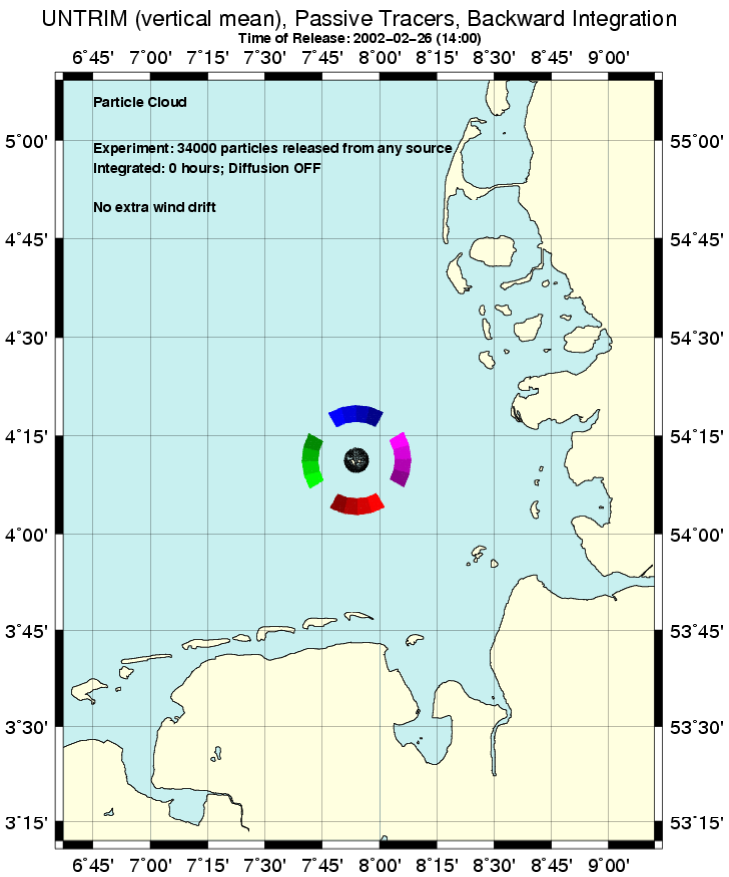

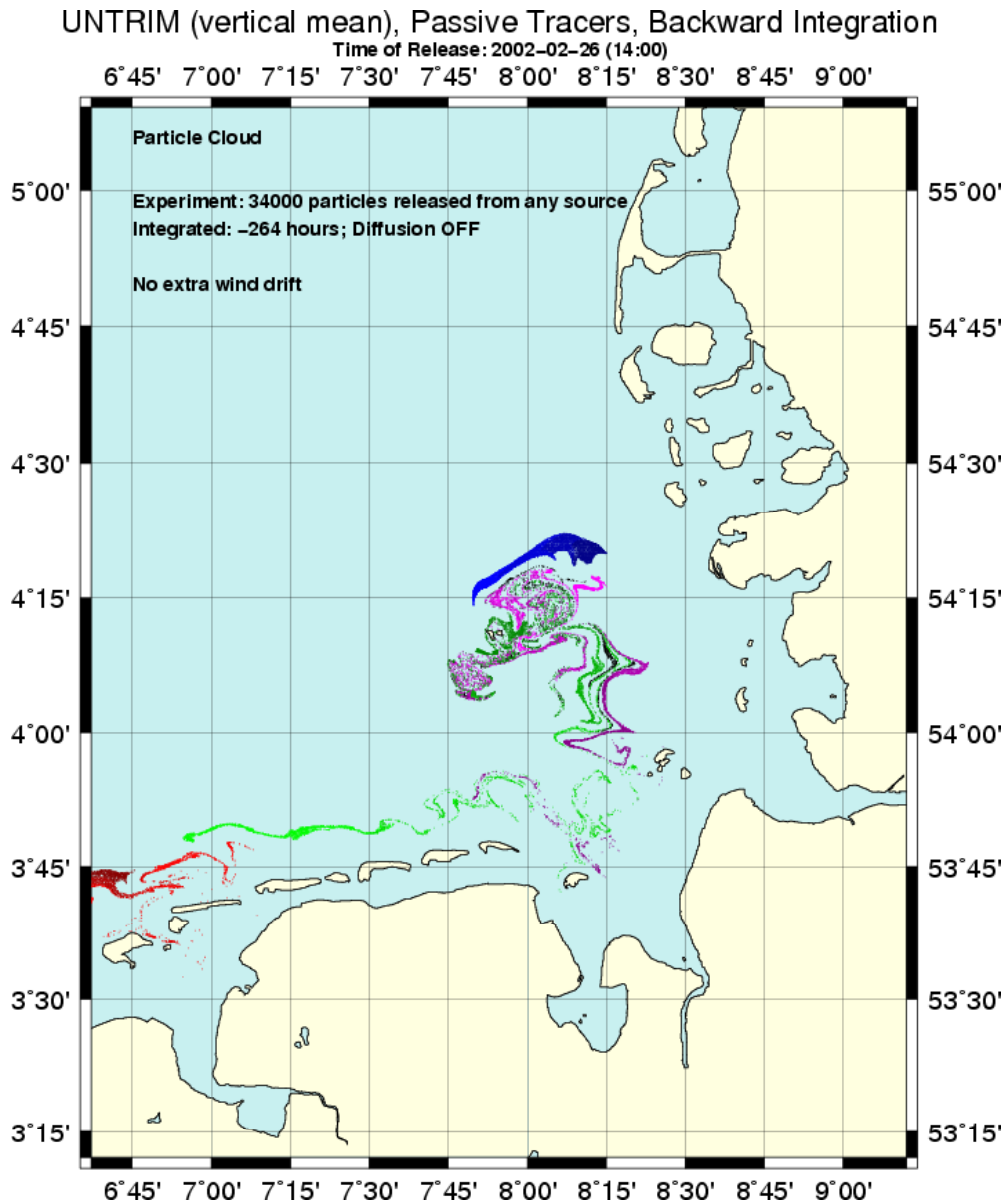

12 days back

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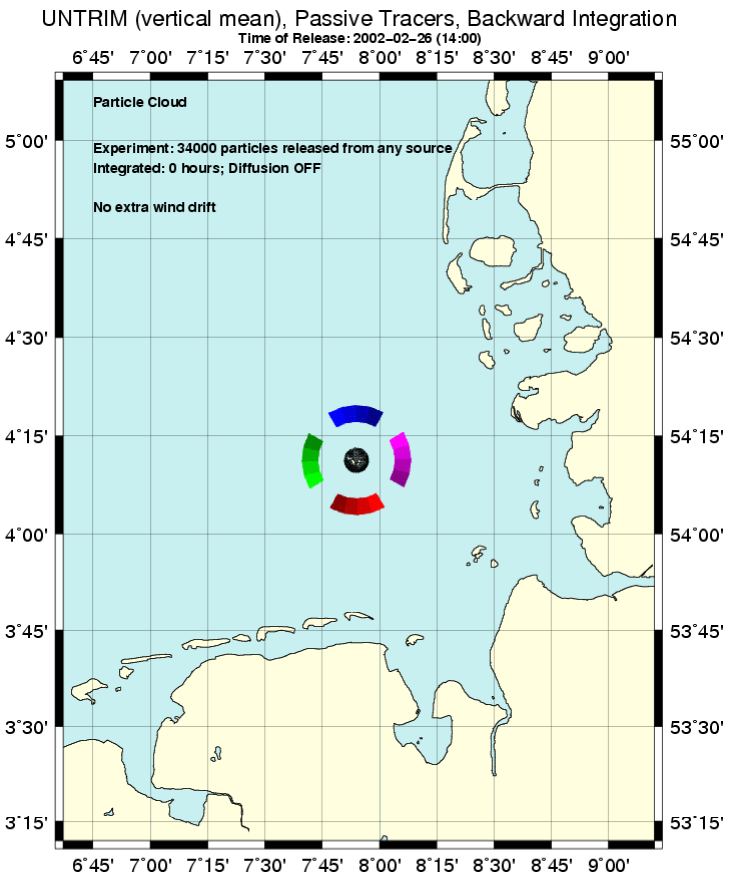

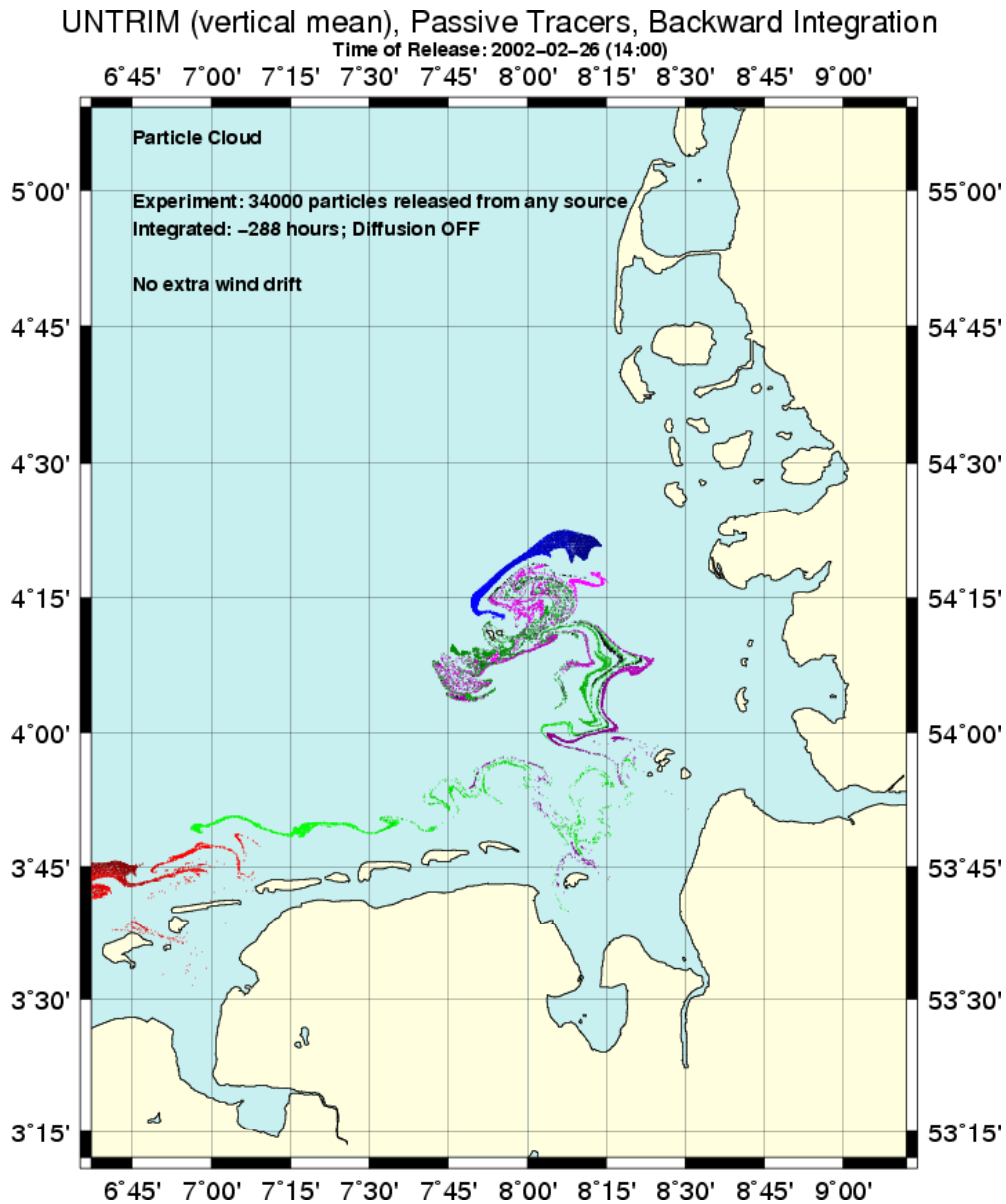

13 days back

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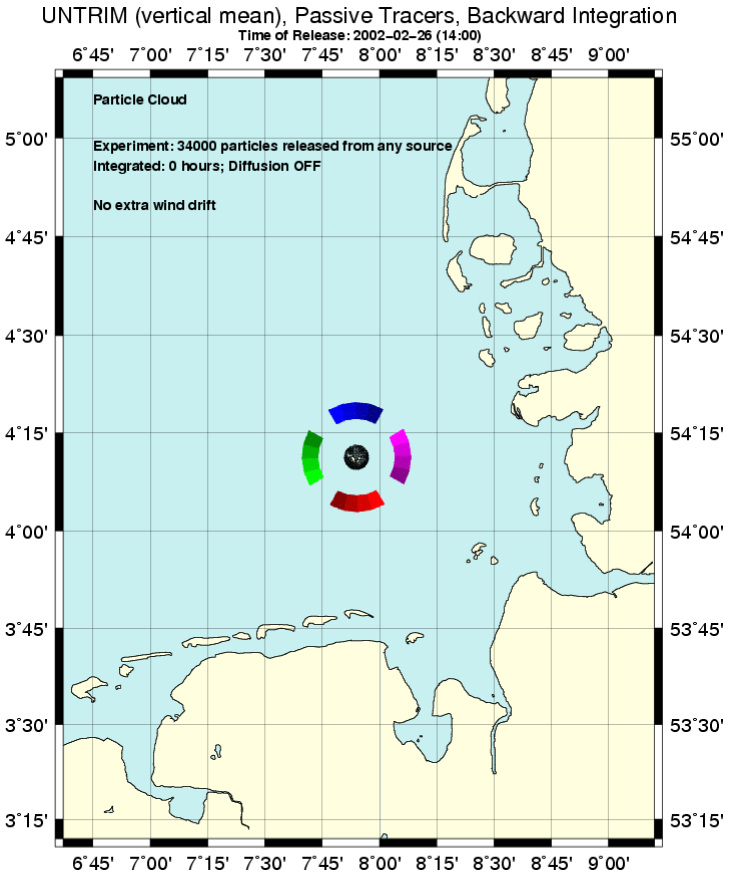
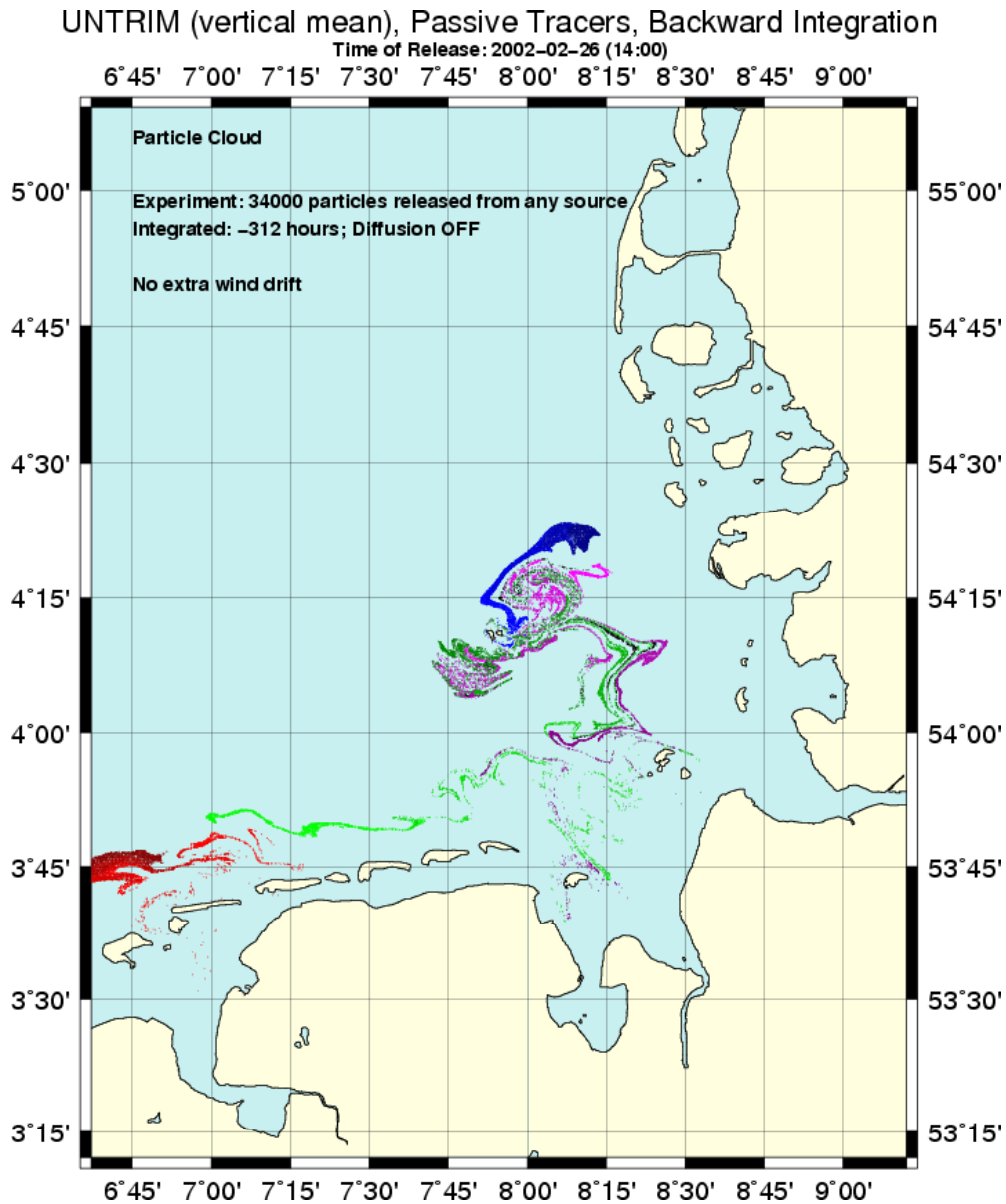
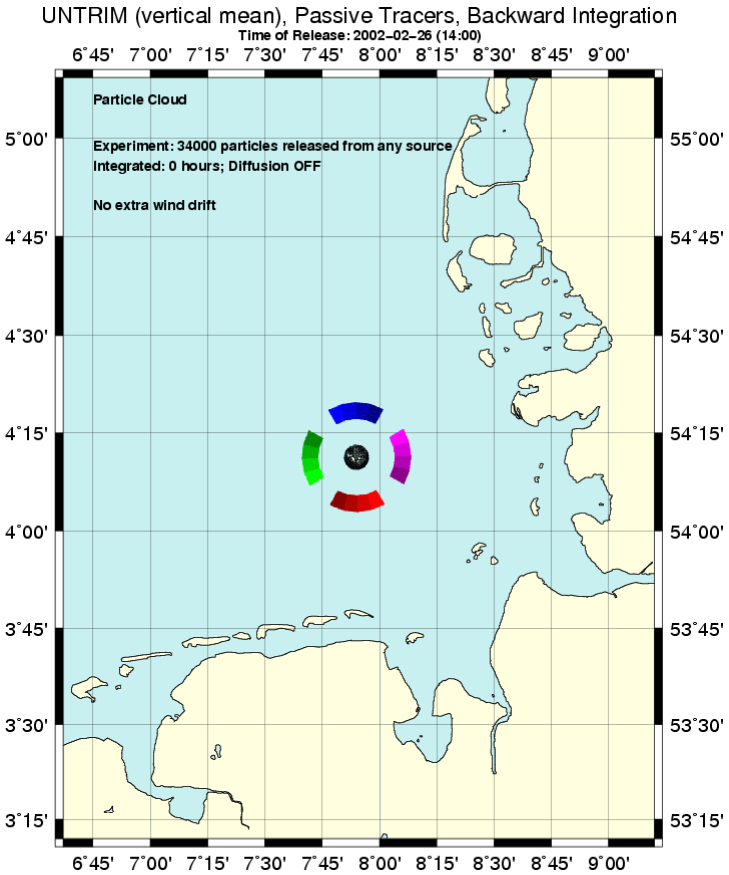
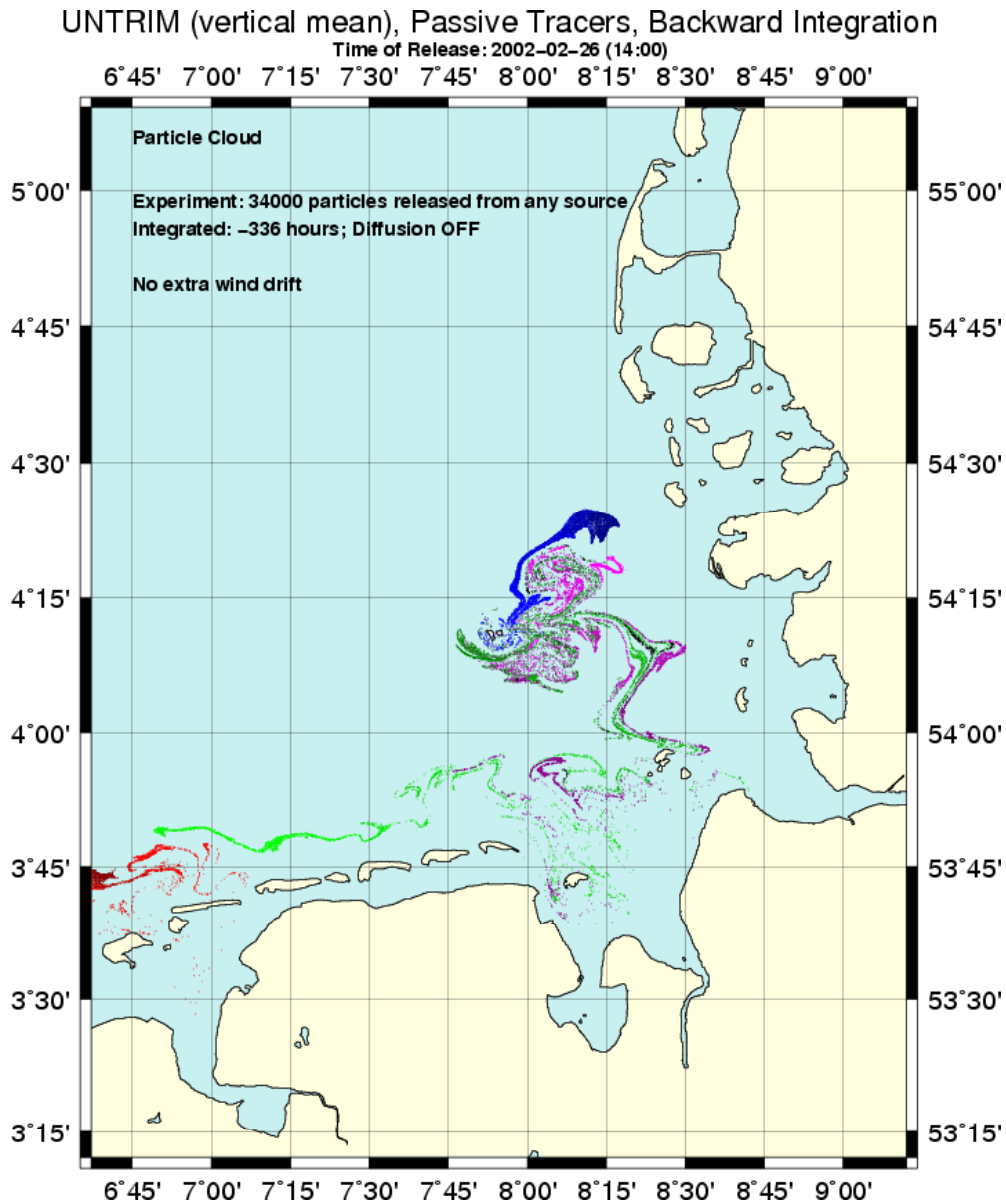




14 days back

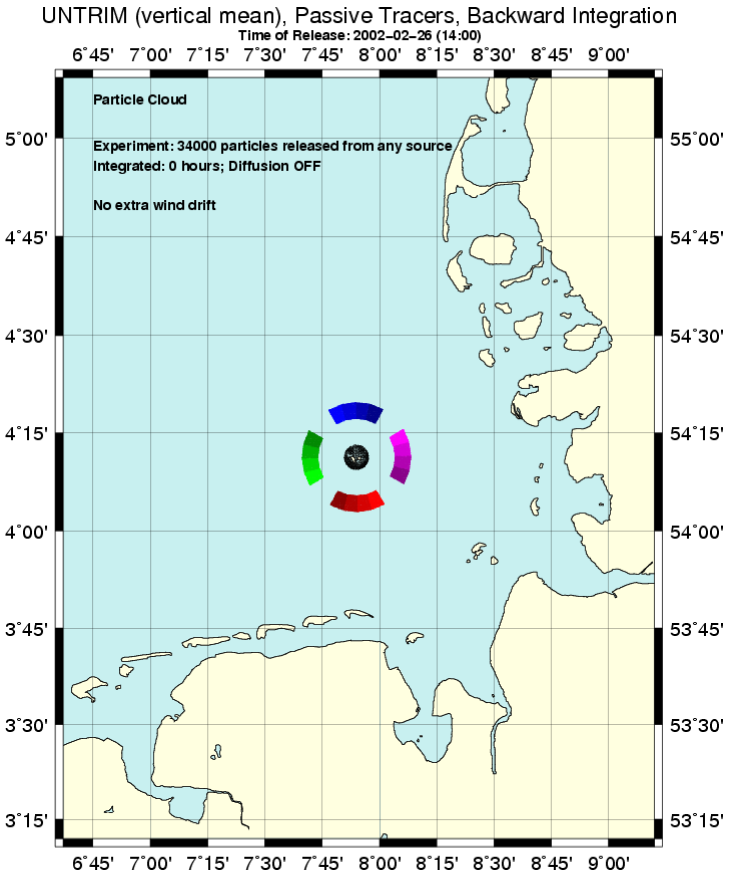
UnTRIM

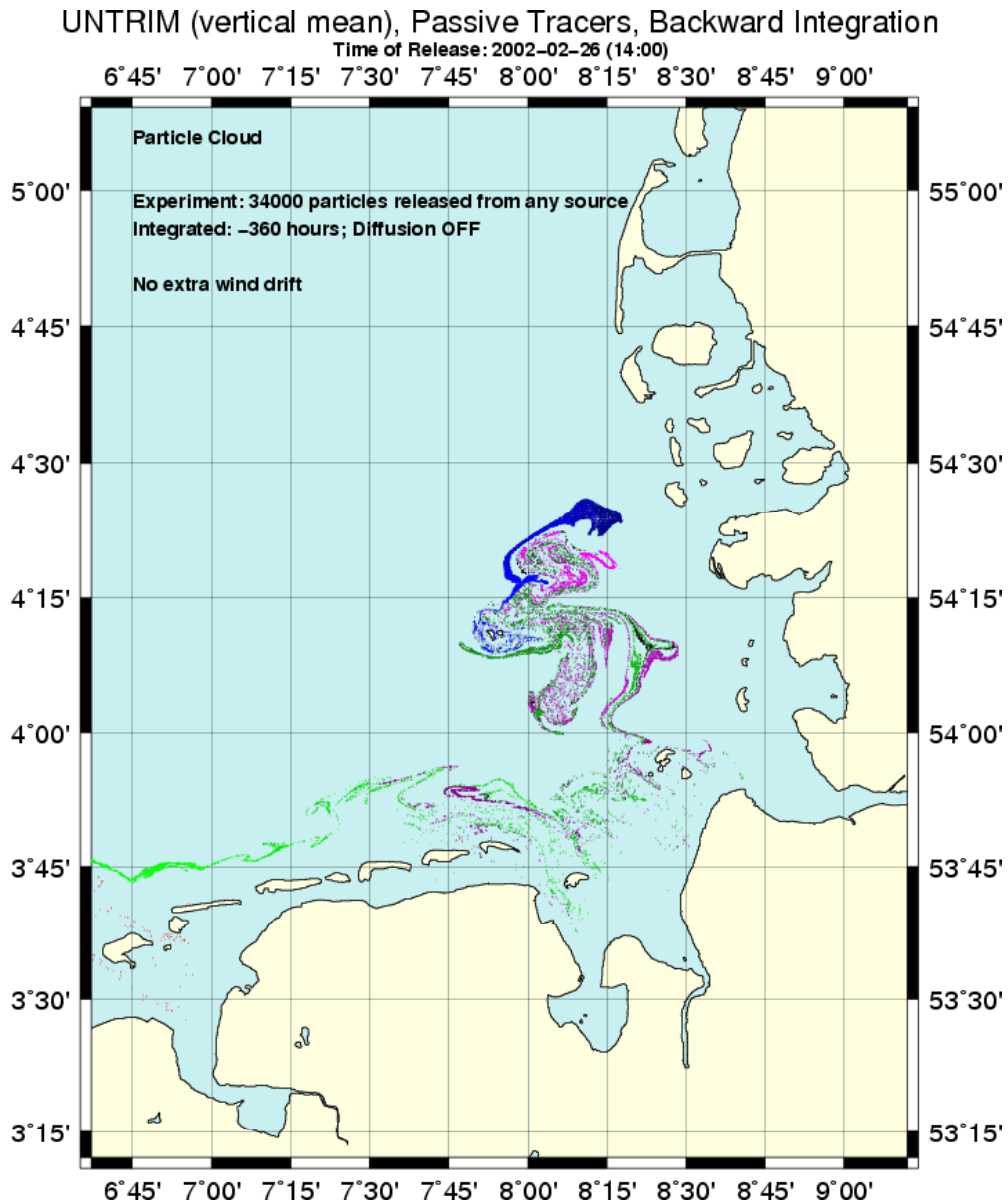




15 days back

UnTRIM

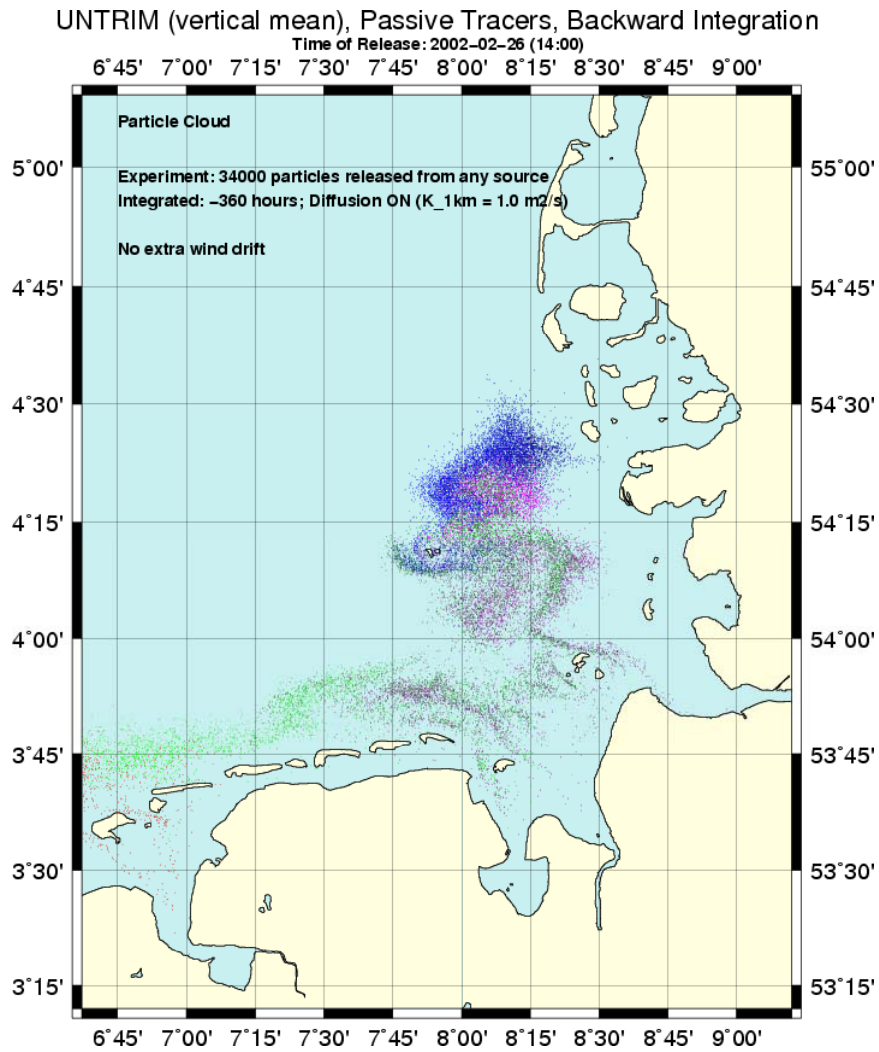




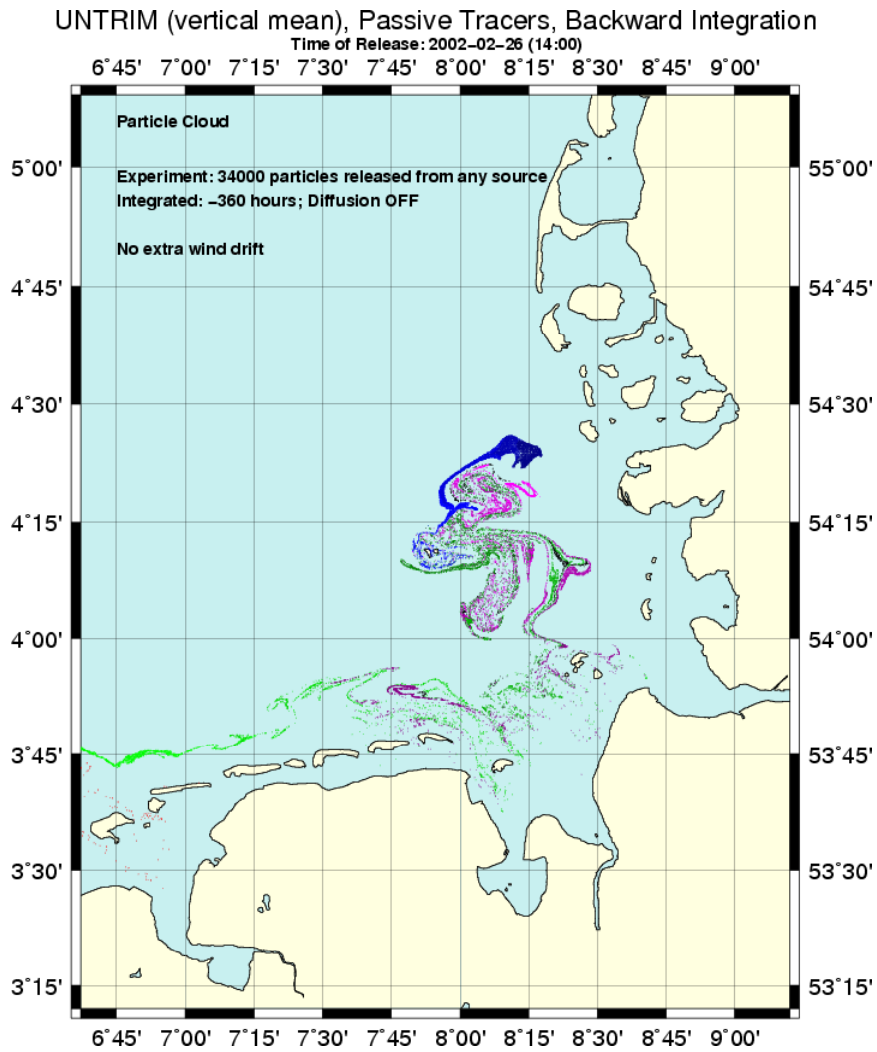
15 days back

UnTRIM

Diffusion on



Diffusion off



Horizontal eddy diffusivity A_{H} is assumed to depend on length scale l according to the following 4/3 law:

$$A_{\mathrm{H}}(l) = A_{\mathrm{H}}(l_0)\left(\frac{l}{l_0}\right)^{\frac{4}{3}}$$

Stommel (1949)
Schönfeld (1995)

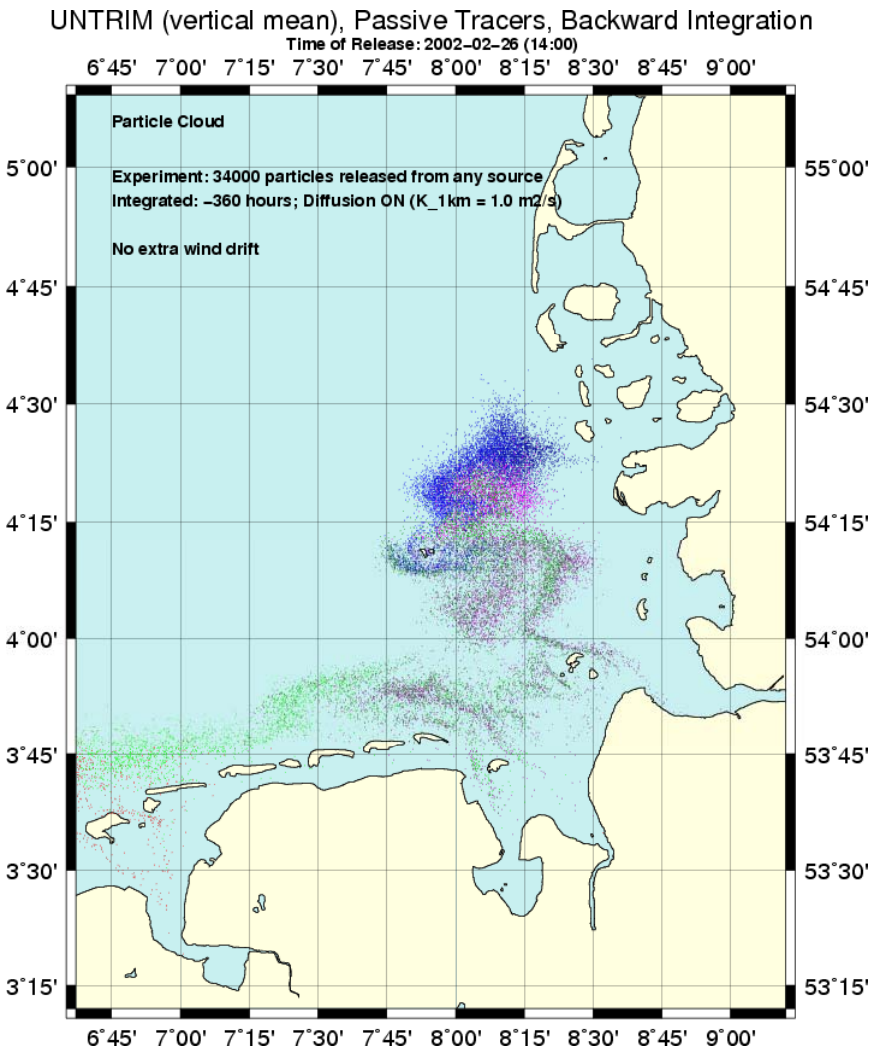
For reference length scale l_0=1 km we assume:

$$A_{\mathrm{H}}(l_0) = 1\ \mathrm{m}^2/\mathrm{s} \quad ; \quad l_0 = 1\mathrm{km}$$

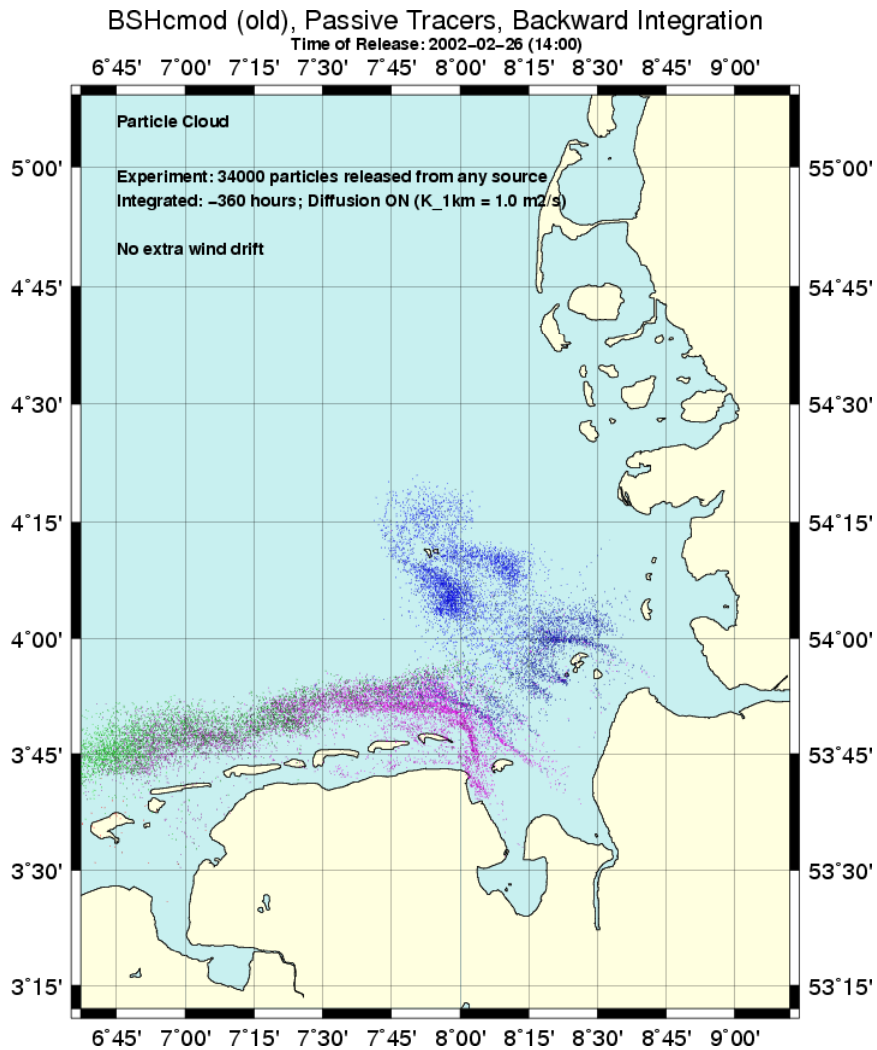
15 days back

Atmospheric forcing: different

UnTRIM
3D, unstructured grid

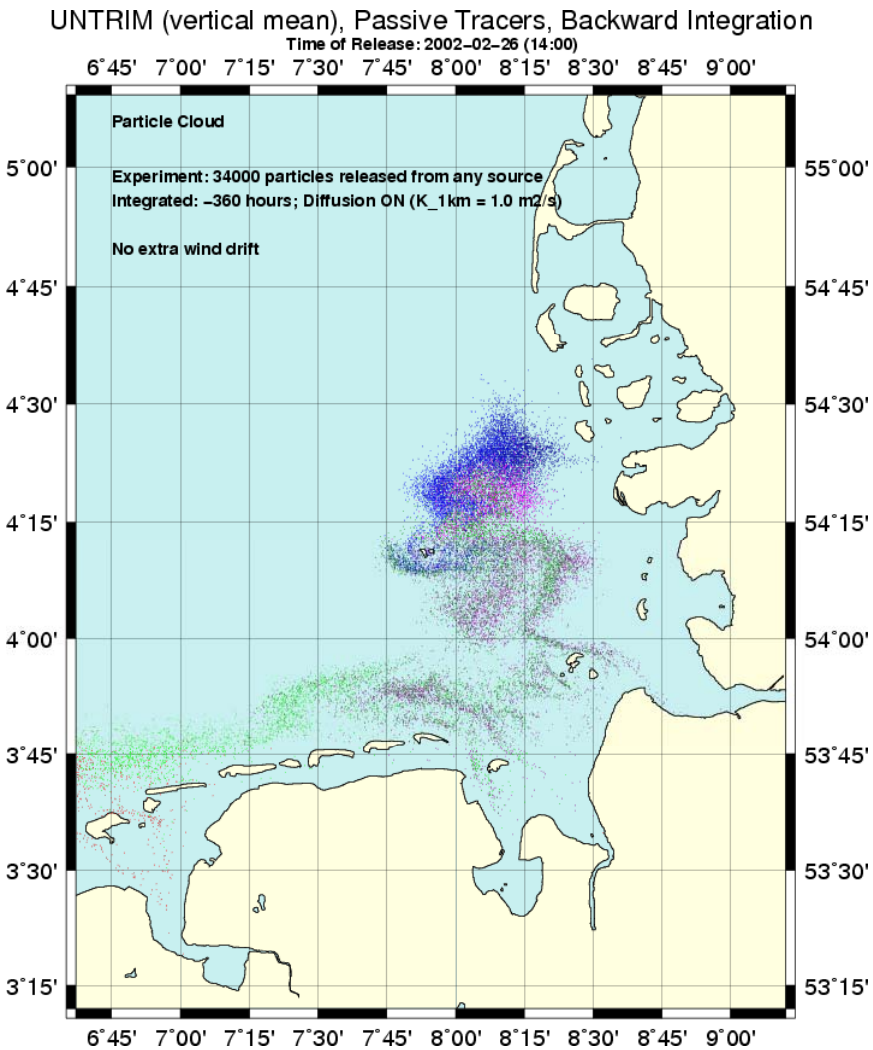


BSHcmod
3D, regular grid

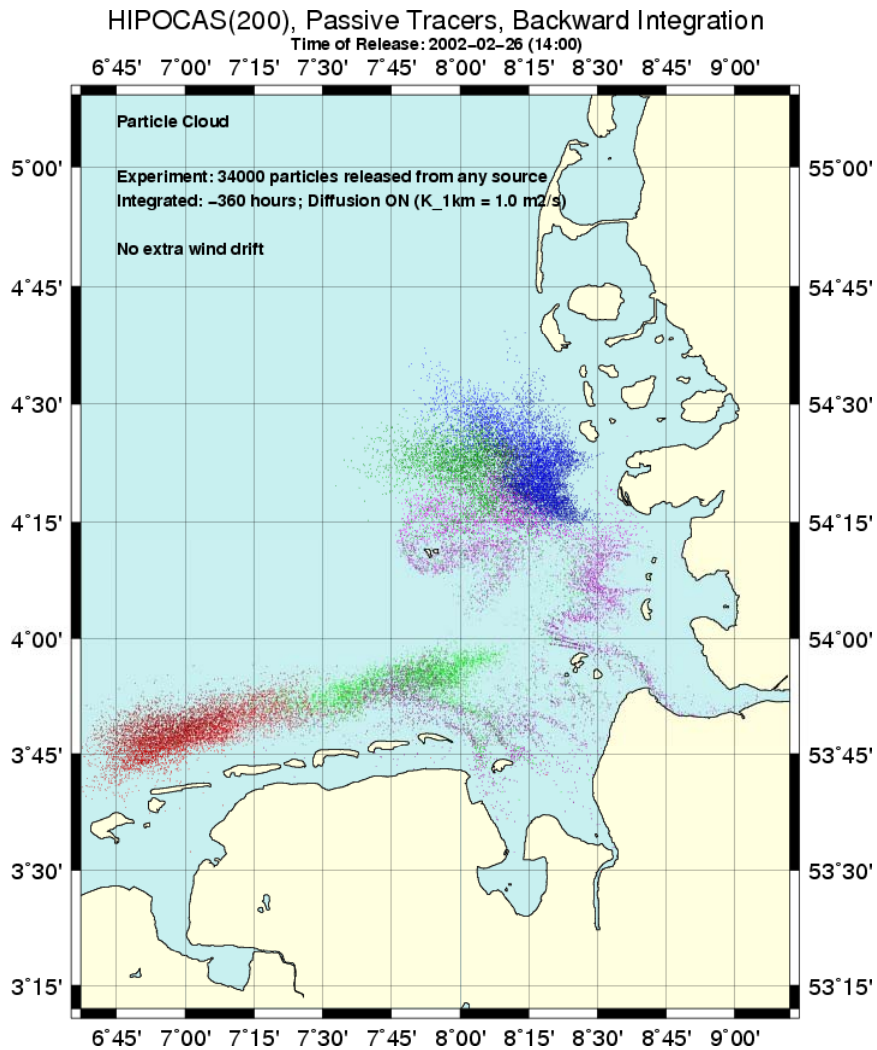


15 days back

UnTRIM
3D, unstructured grid

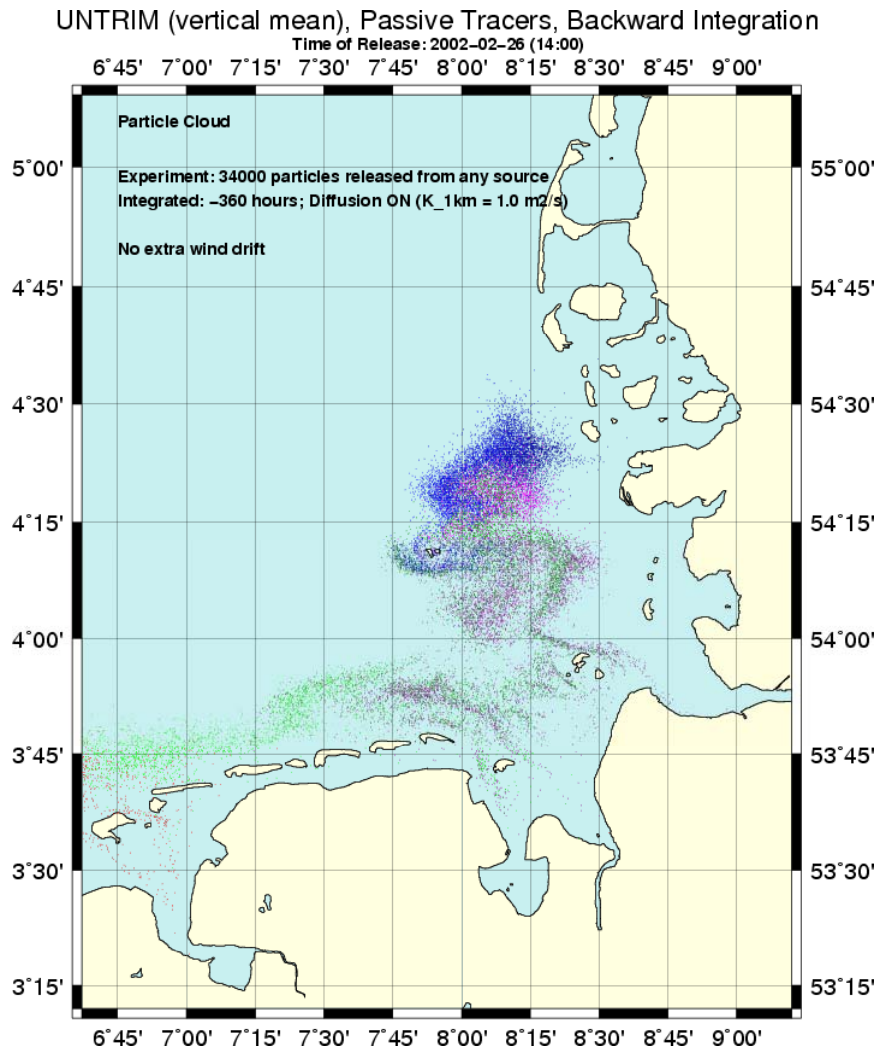


TELEMAC-2D
2D, same grid

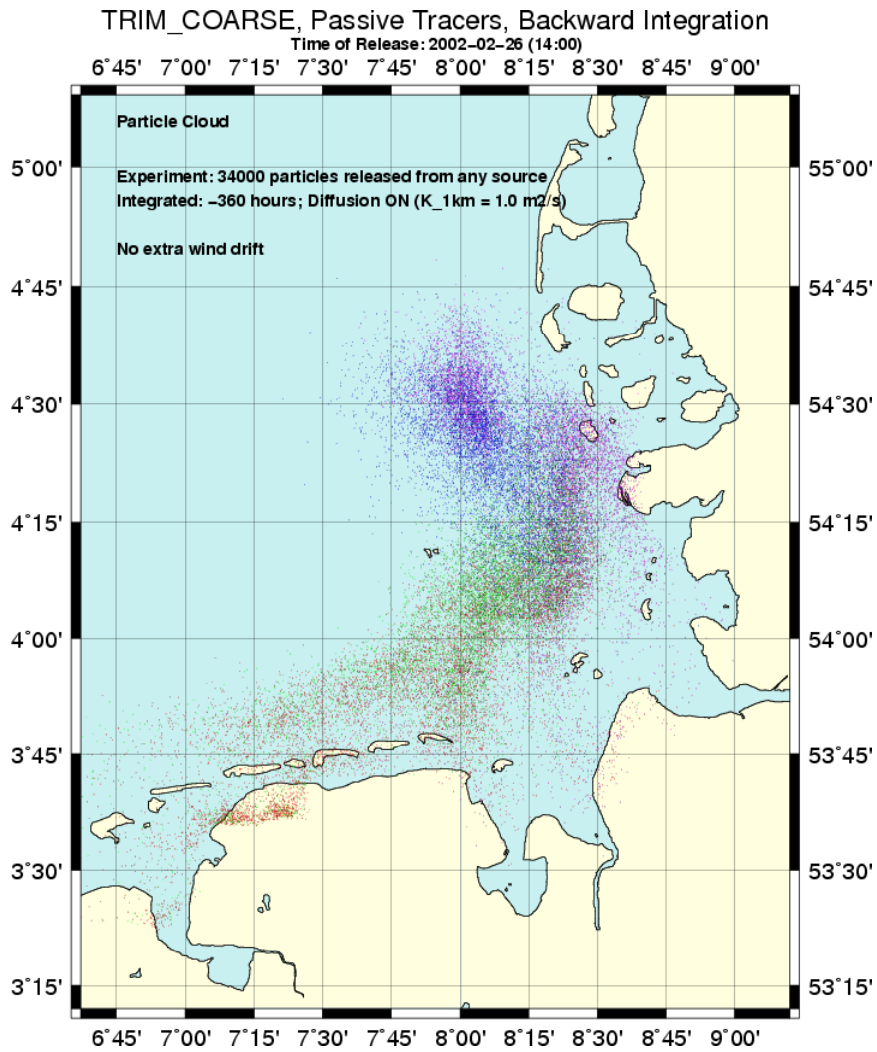


15 days back

UnTRIM
3D, unstructured grid



TRIM
3D, regular grid, 12.5 km



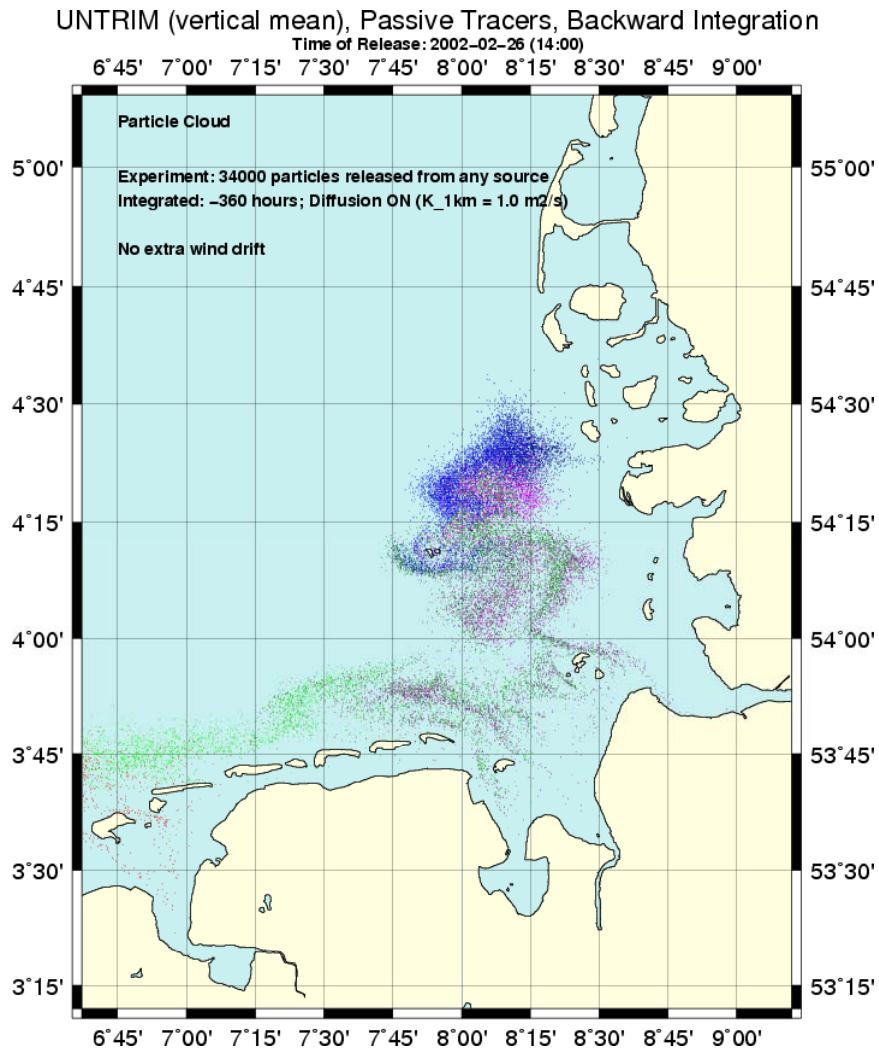
Summarizing Simultions in terms of grid cells visited

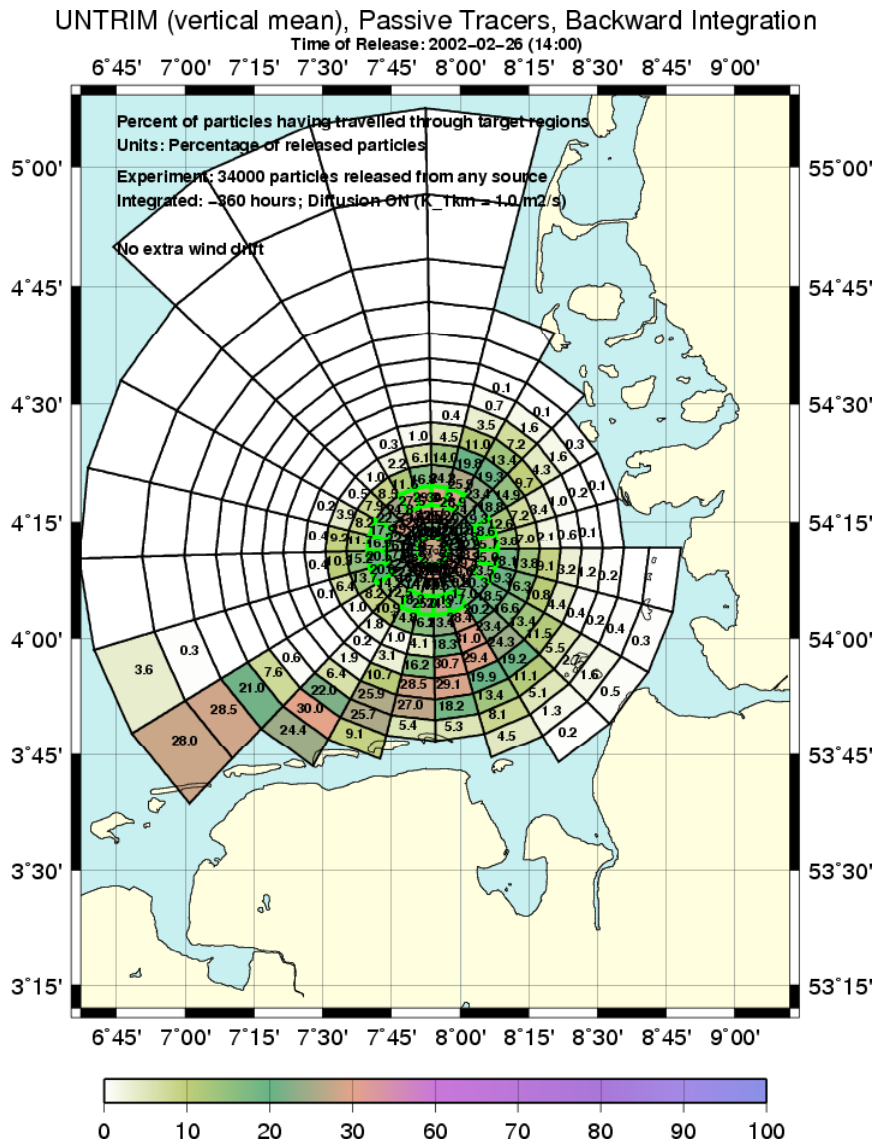
Cumulative Travel History (CTH)

15 days back

What is the status now? UnTRIM What happened so far?

Cumulative travel history (CTH)

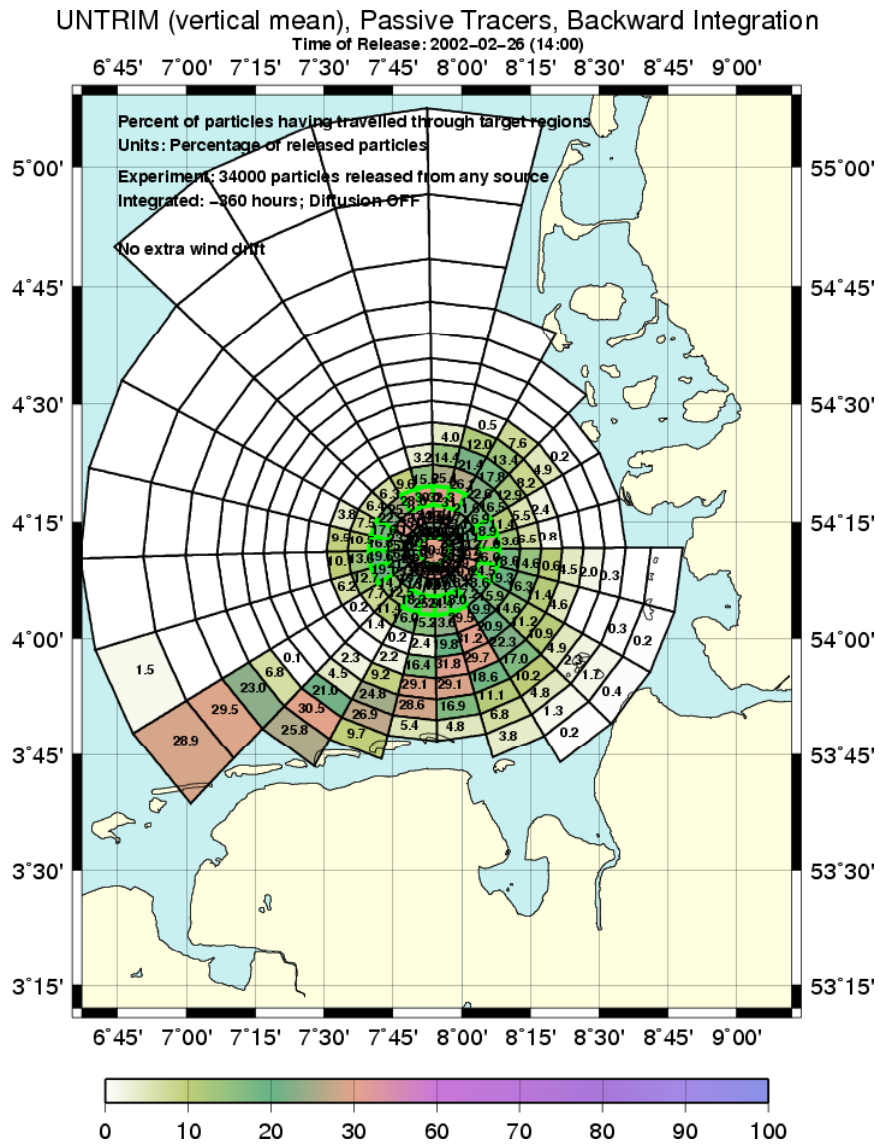




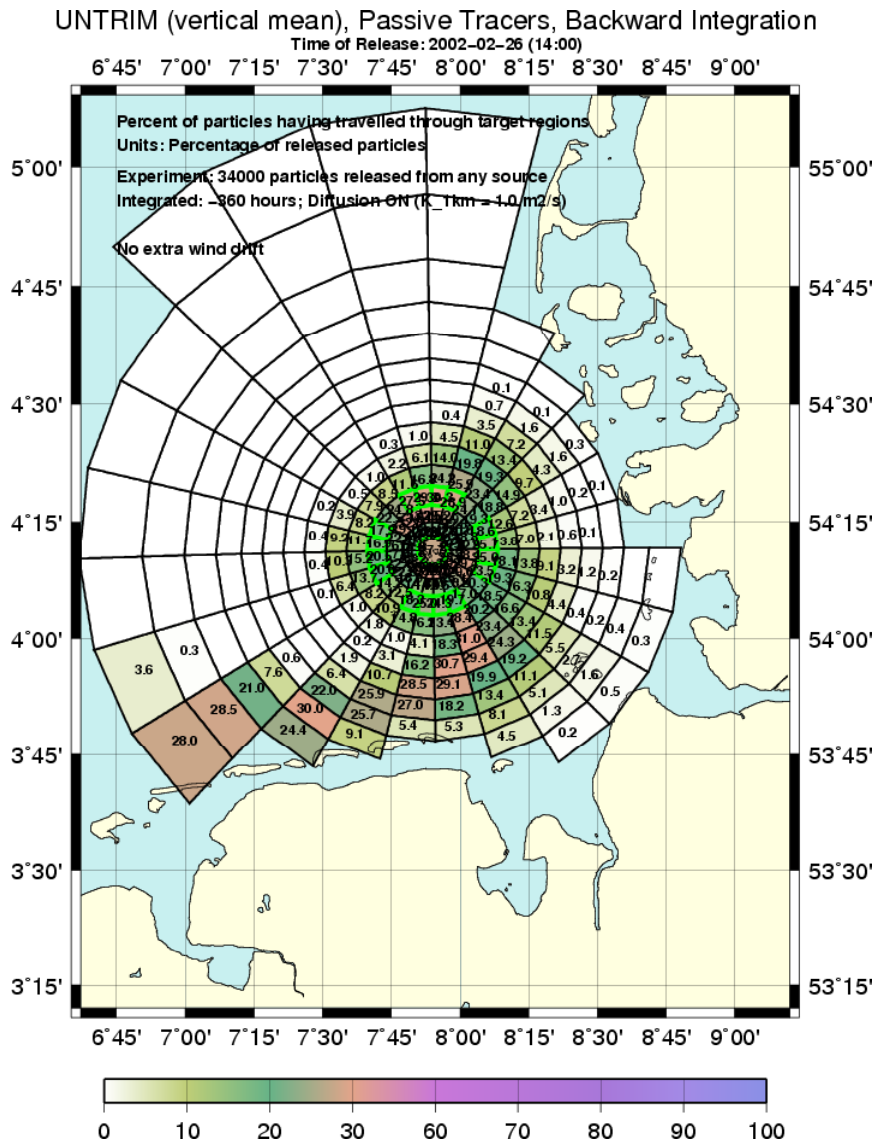
15 days back

UnTRIM

Diffusion off



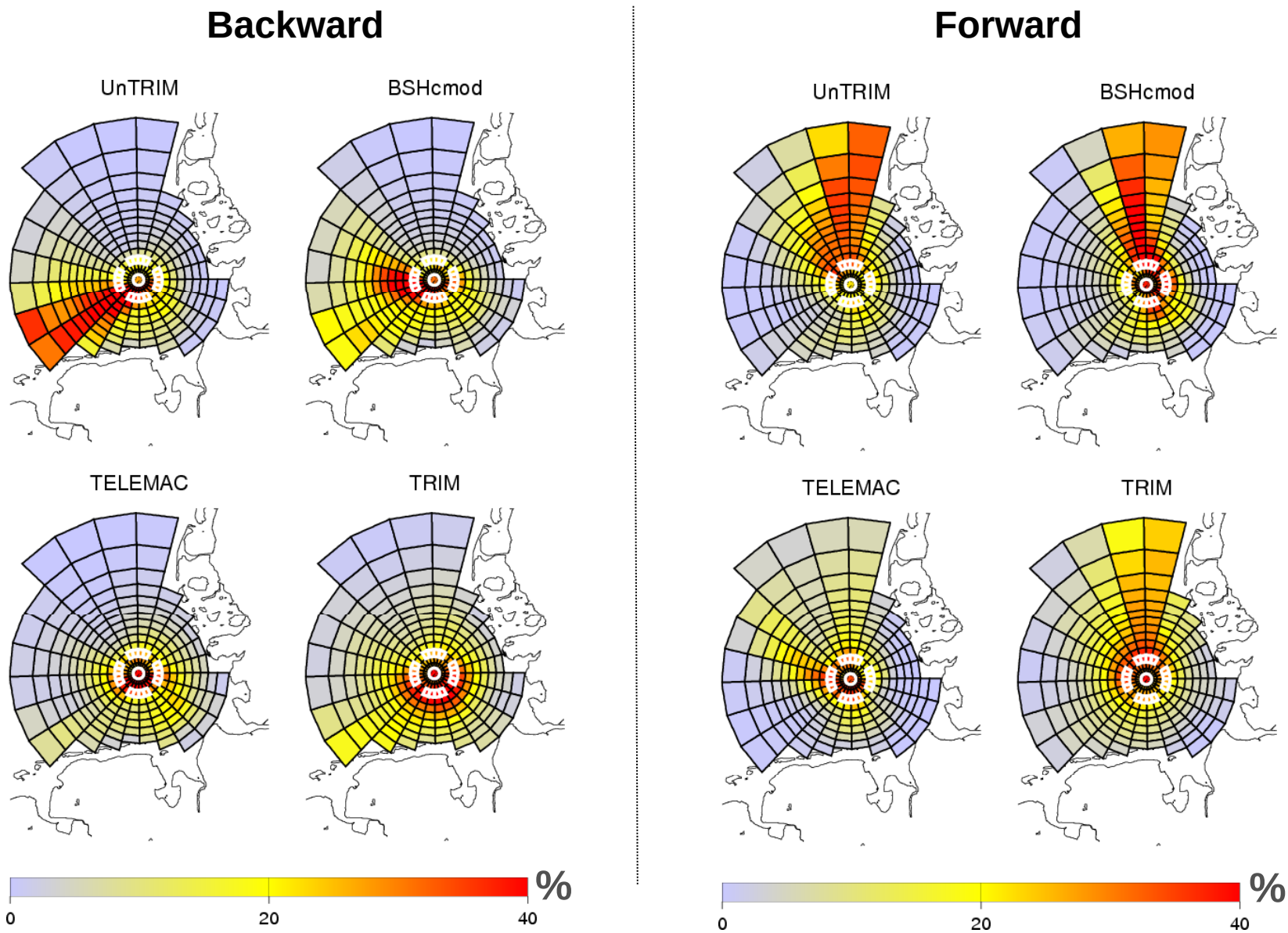
Diffusion on



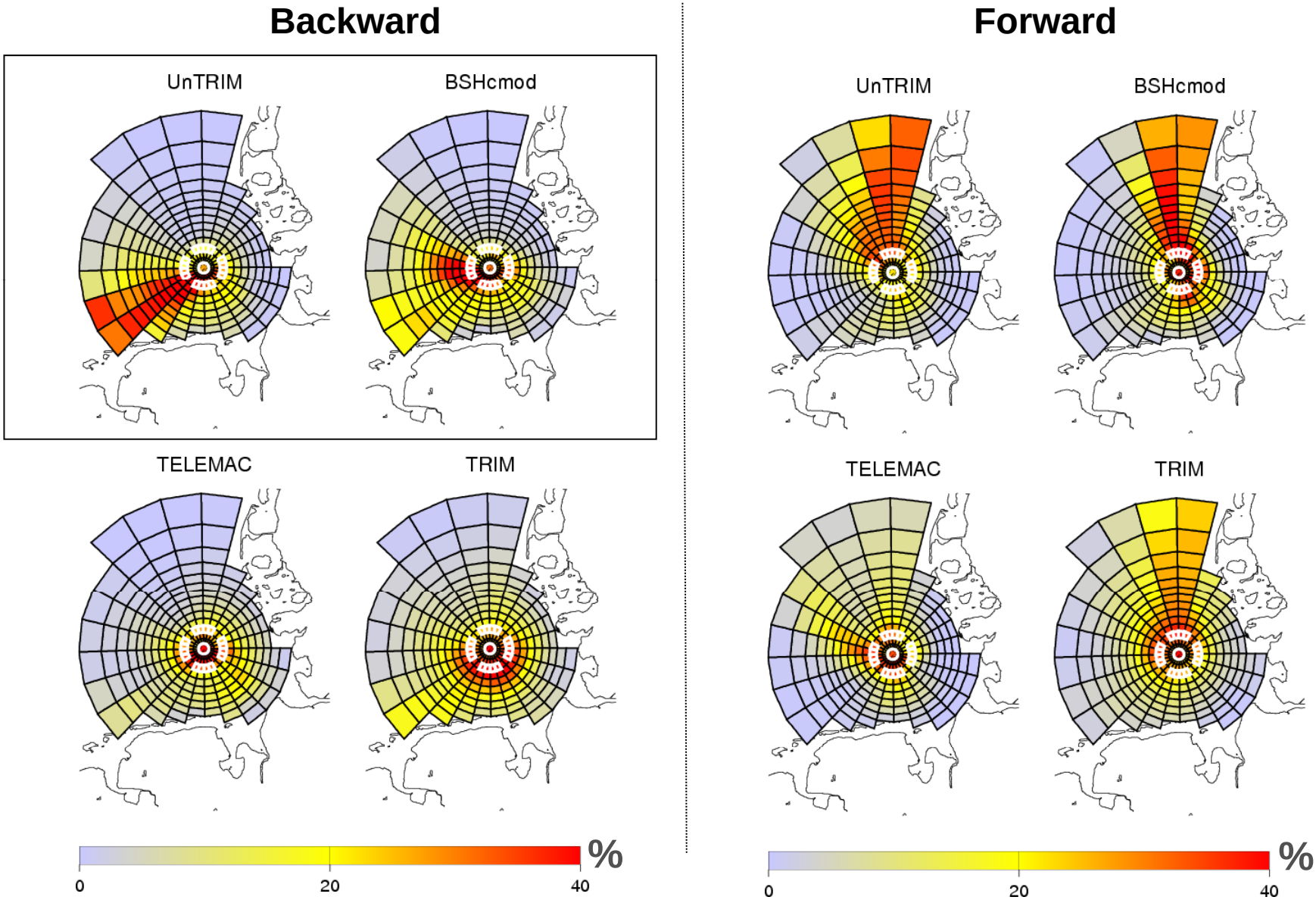
Mean Transport Conditions

3378 Simulations (2002-2004), time delay 7h
Integration time: 50 days
Diffusion on

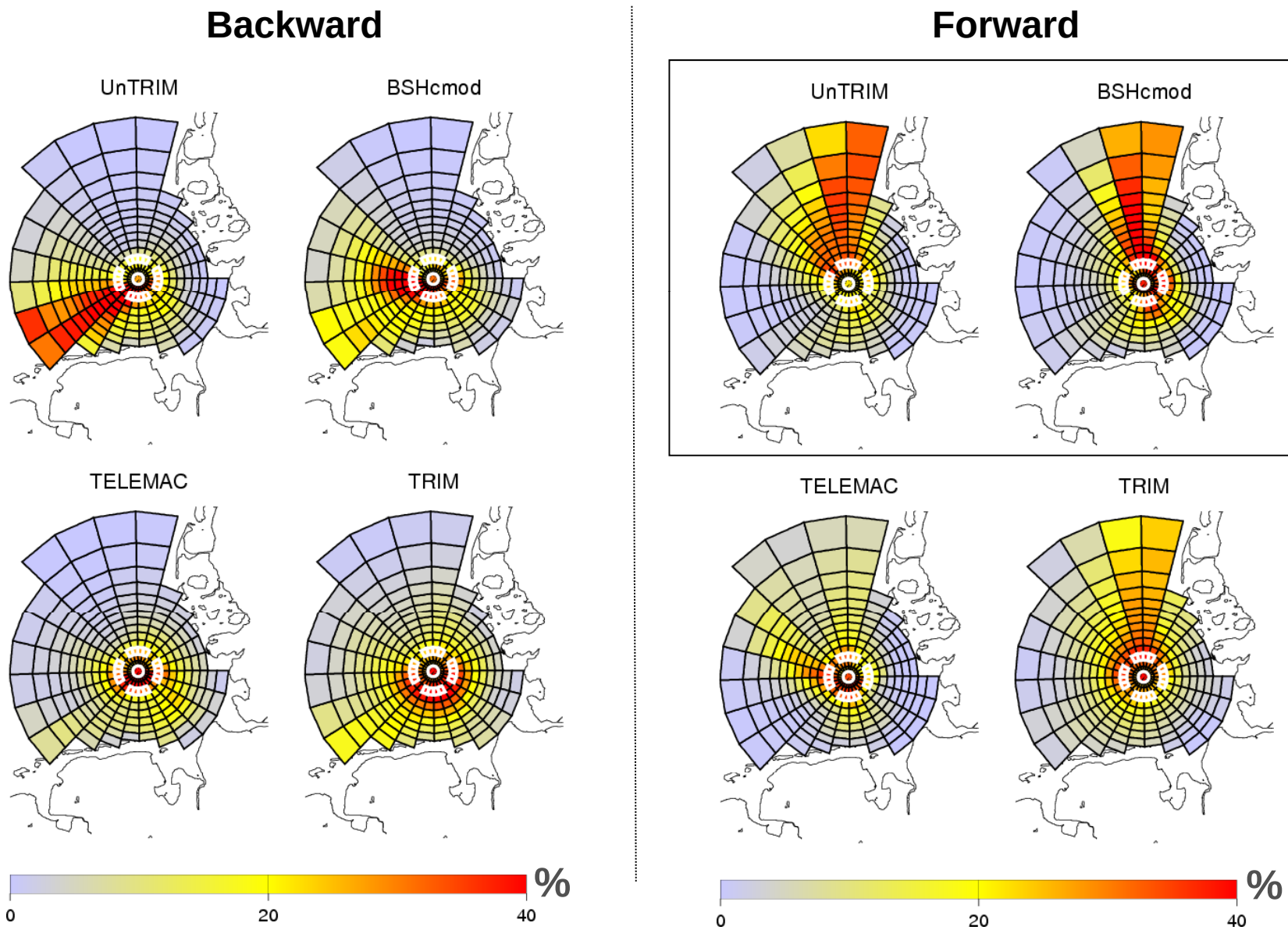
Percentage of Particles that Visited Grid Cell
Integration: 50 days (random diffusion on)
Averaging 3378 Simulations



Percentage of Particles that Visited Grid Cell
Integration: 50 days (random diffusion on)
Averaging 3378 Simulations



Percentage of Particles that Visited Grid Cell
Integration: 50 days (random diffusion on)
Averaging 3378 Simulations



Variability of Transport Conditions

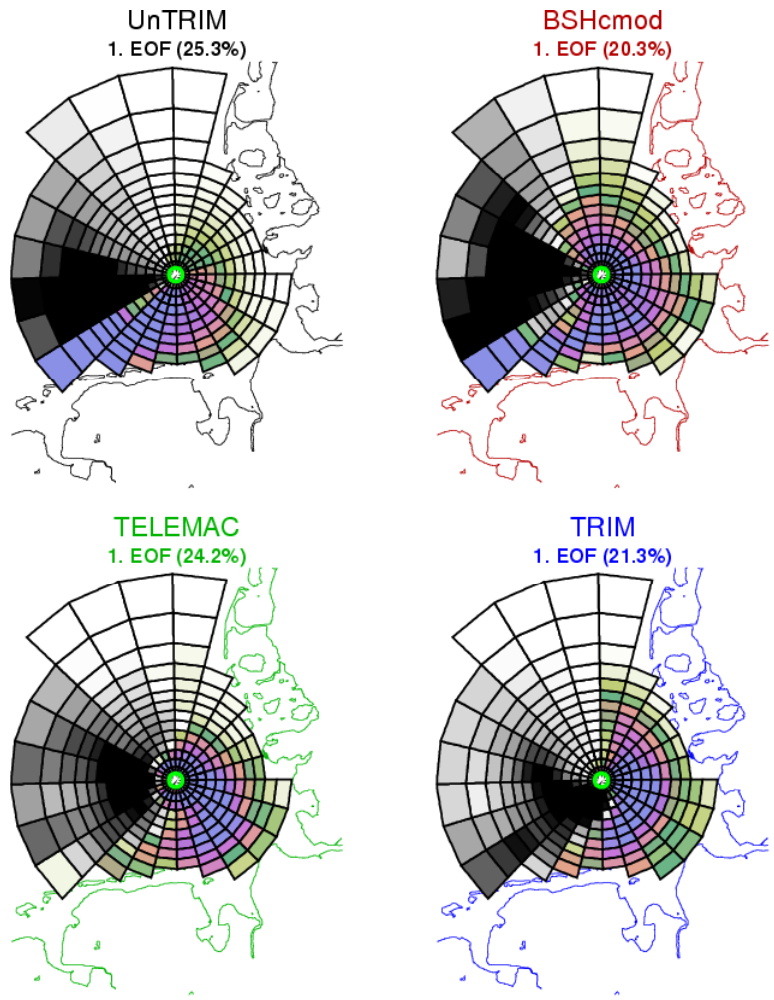
How do transports react to changing weather conditions?

(Principal Component Analysis)

3378 Simulations (2002-2004), time delay 7h
Integration time: 50 days
Diffusion off

Empirical Orthogonal Functions

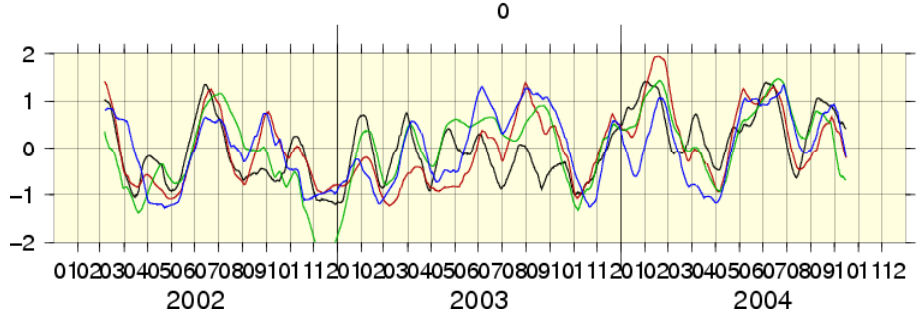
Leading EOFs for each of the four models



Backward Integration

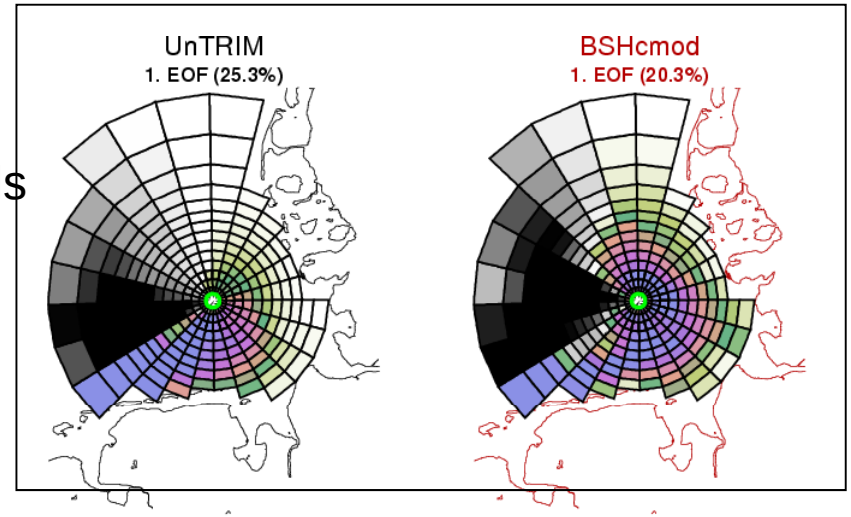
3378 Simulations (2002-2004)
Integration time: 50 days
Diffusion off

Principal Components:
(EOF time coefficients)
Monthly means



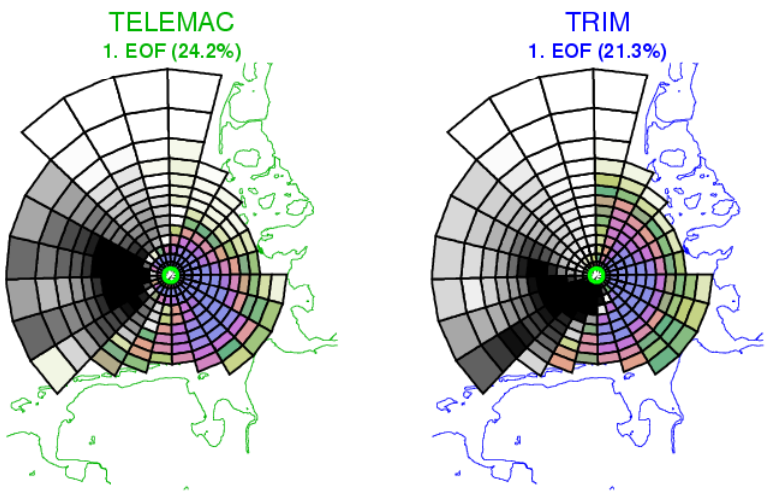
Empirical Orthogonal Functions

Leading EOFs for each of the four models

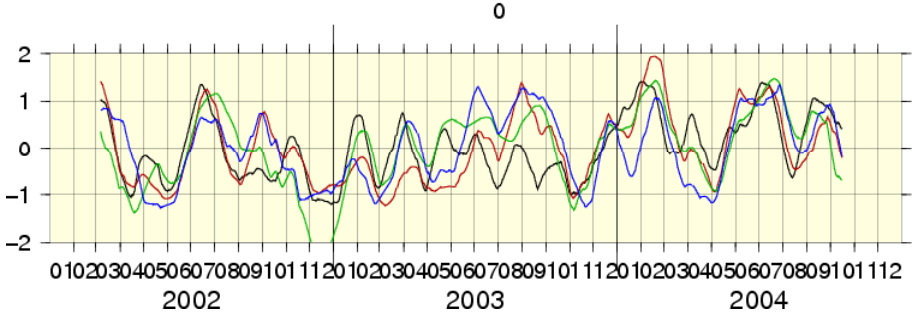


Backward Integration

3378 Simulations (2002-2004)
Integration time: 50 days
Diffusion off



Principal Components:
(EOF time coefficients)
Monthly means



Empirical Orthogonal Functions

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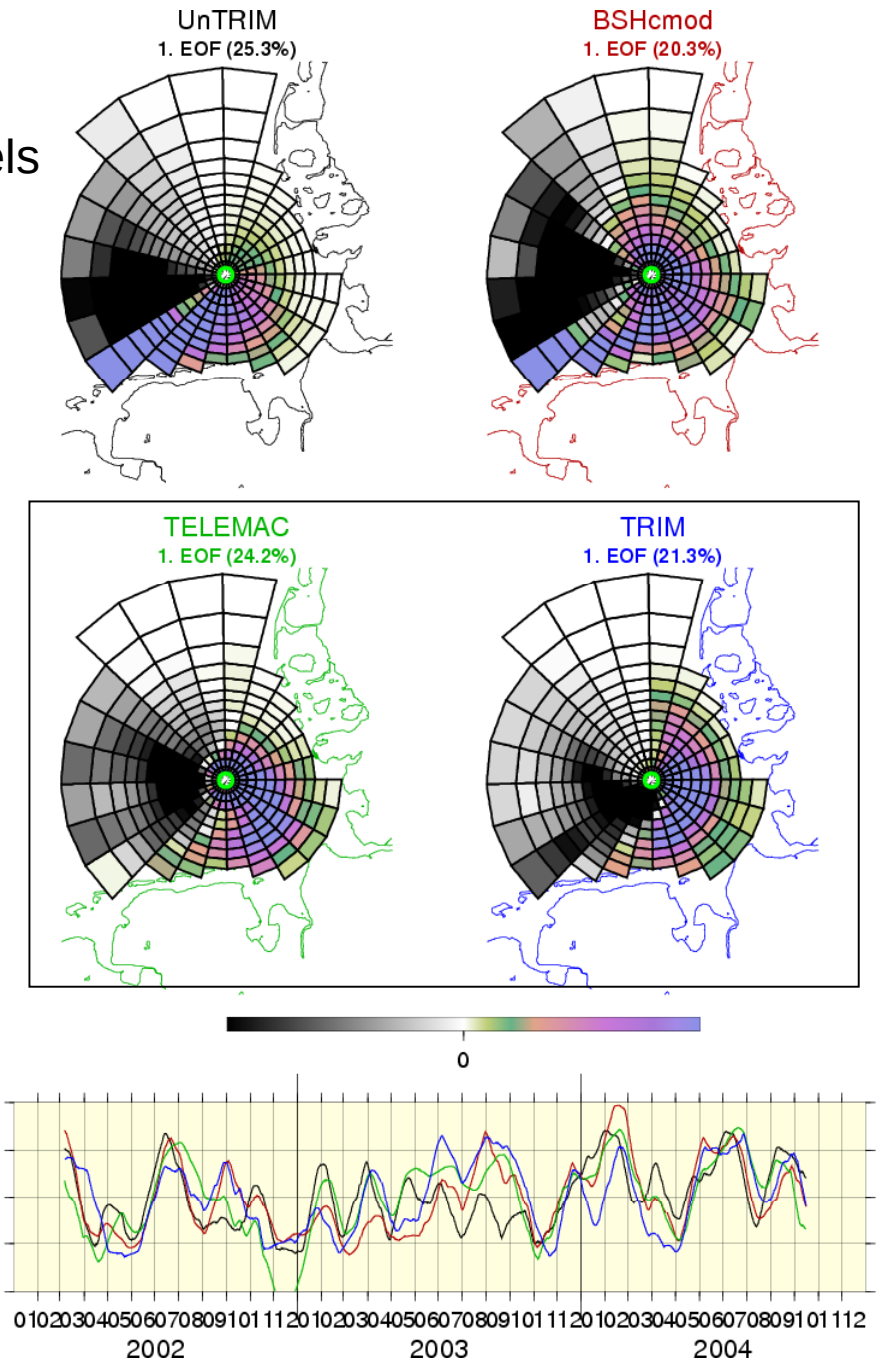

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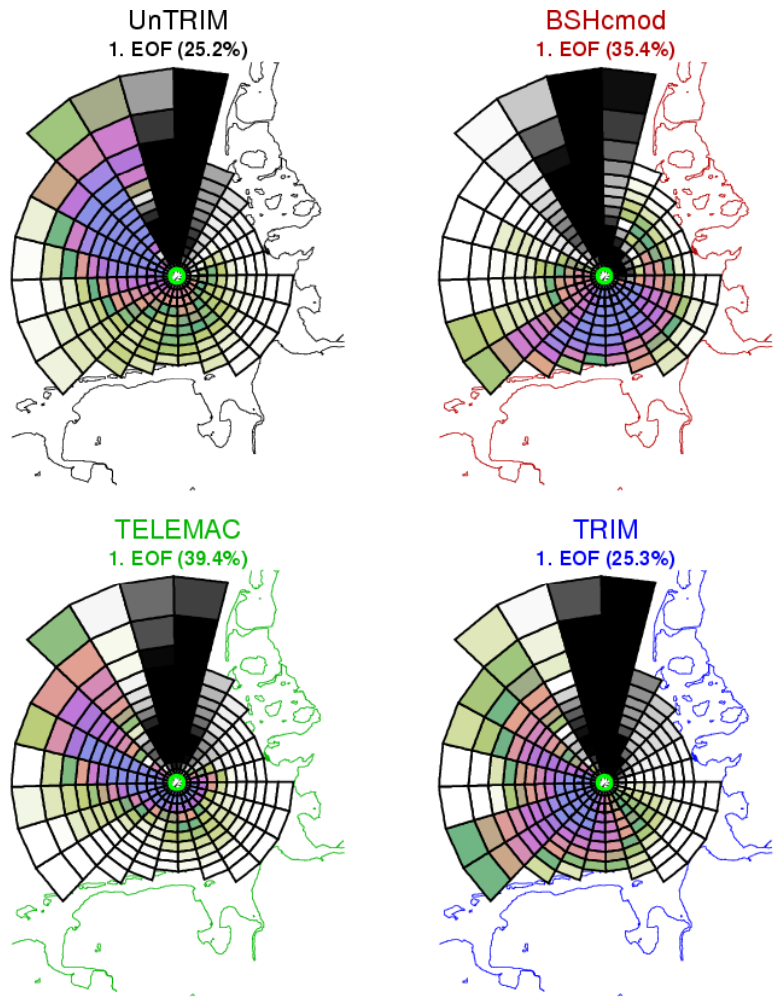

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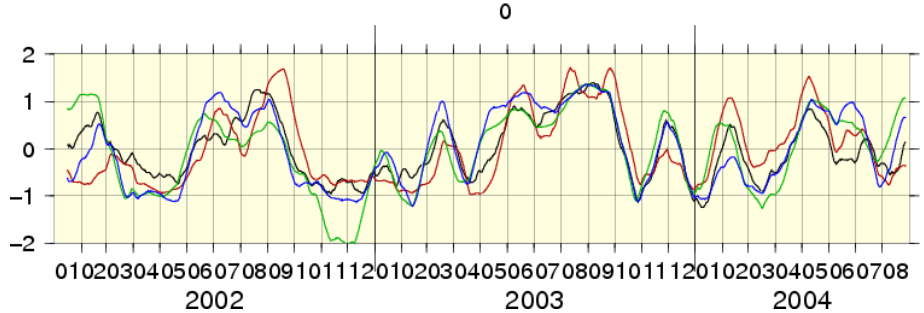

Empirical Orthogonal Functions

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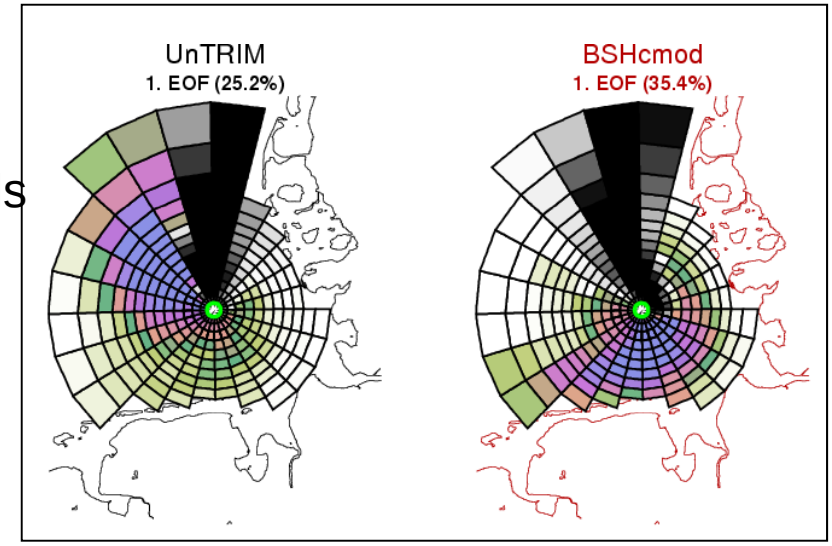

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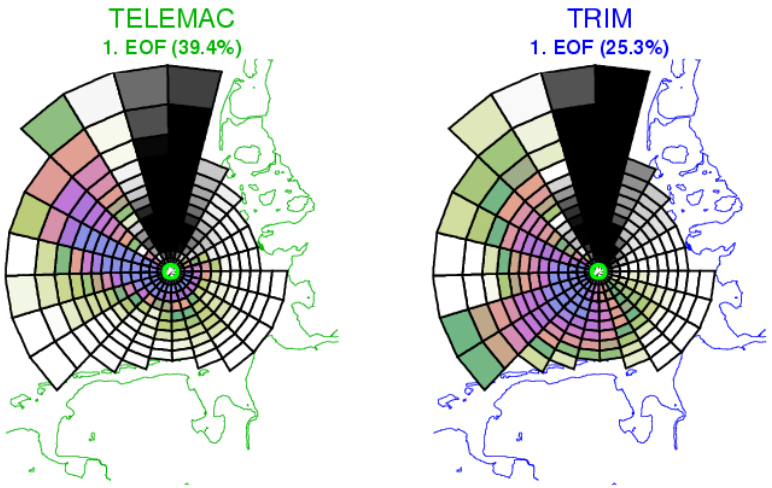

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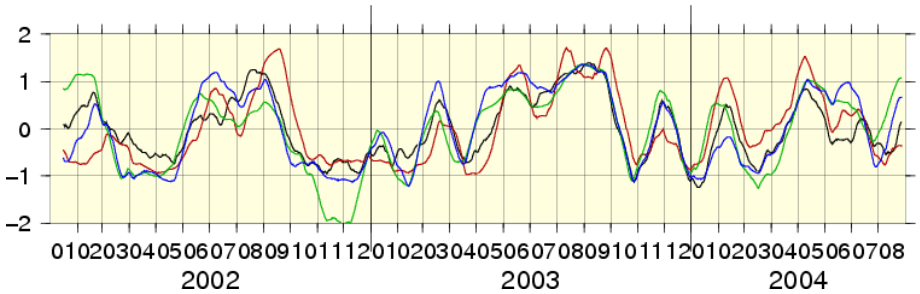

Empirical Orthogonal Functions

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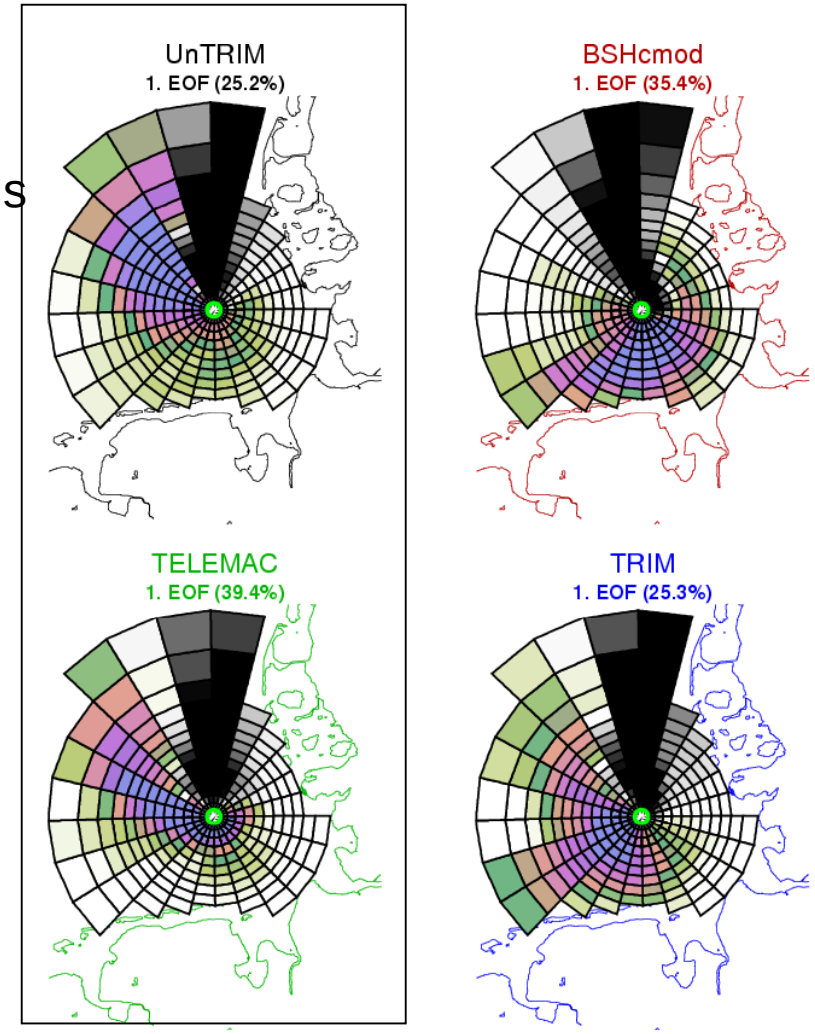

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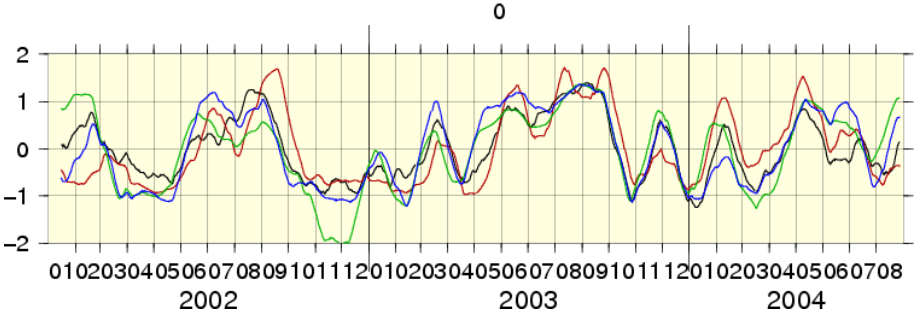

Conclusions

- Very complex drift behaviour near the island of Helgoland
- Therefore: Just few simulations are insufficient for an assessment of uncertainty
- A large number of simulations, however, reveals systematic differences even between 3D high resolution models:

  - Biases in transport strengths
  - Directional biases

- What about the passive tracer assumption?

  - Biases in mean transport paths will have effects on any simulation of non-passive substances as well.

THANK YOU FOR YOUR ATTENTION!