From Particles to Priorities: Integrating Drift Modeling with Ecological Connectivity in the **Southern North Sea**

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Marine Plan Final Event – Day 2 – 30/09/2025

From Particles to Priorities – Part I

Structural and Functional Connectivity

PELETS-2D
Lagrangian Particle Drift

Southern North Sea
Planning Site Setup

From Ensemble Simulations to Probability Tables

From Particles to Priorities – Part II

Tasnim Patel

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Stuctural and Functional Connectivity

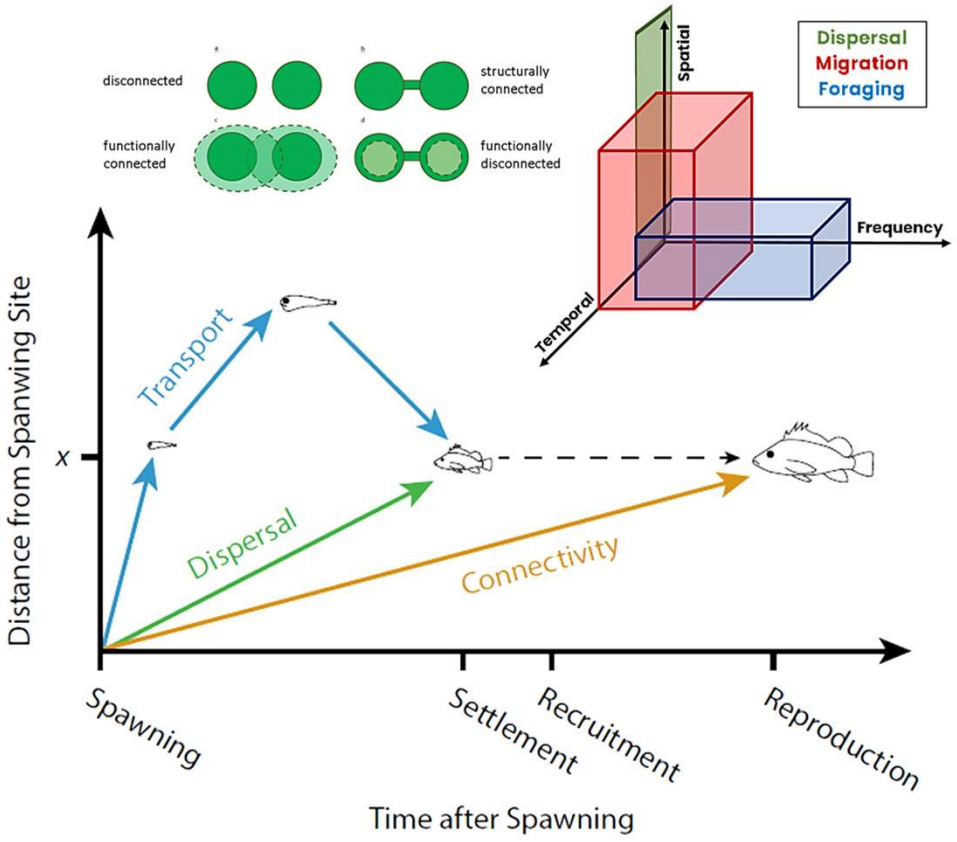
Within reach:

- **Passive transport** by ocean currents
- Spatio-temporal pattern of **potential disperal**

Beyond Scope:

- **Biological traits** (e.g., larval behavior, migration)
- Settlement & Recruitment
- Adult **movement & foraging**

Transport ≠ Connectivity



White et al. 2019. Connectivity, dispersal, and recruitment: Connecting benthic communities and the coastal ocean. *Oceanography* 32(3):50–59, https://doi.org/10.5670/oceanog.2019.310.

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PELETS-2D Lagrangian Engine

Triangulation
Topology
Boundaries

GRID

Currents, Winds
Elevation, Tides
Temp, Sal
Interpolation
2D-Averaging

PHYSICS

SETUP

Soures, Targets
Release time(s)
Ensemble Size
Trajectory Length
Forward / Backward

Offline
Hourly timesteps
Parallel MPI

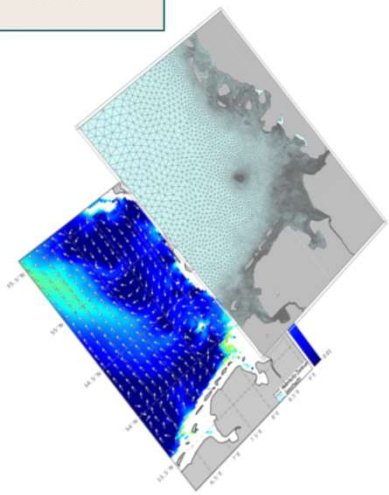
RUN

STORAGE

NetCDF
TSM Archive
Hierachical
Scalable

ANALYZE

Drift Climatology
Connectivity
Variability
Dispersion / Divergence
Coherence
Uncertainty



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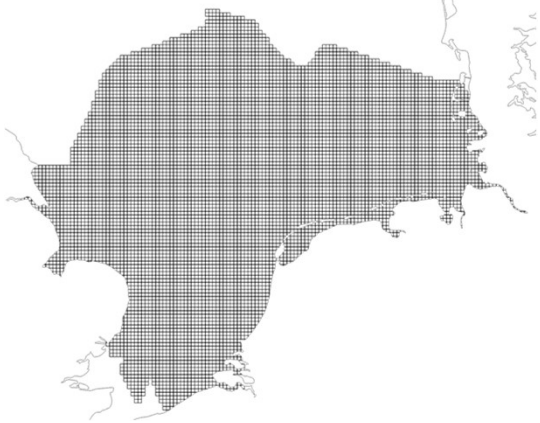

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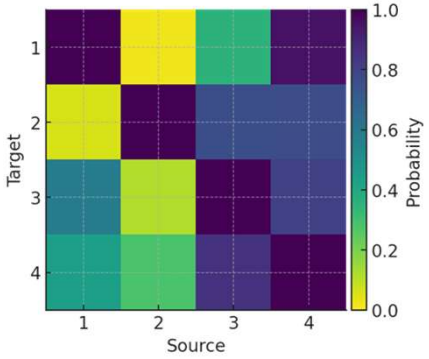

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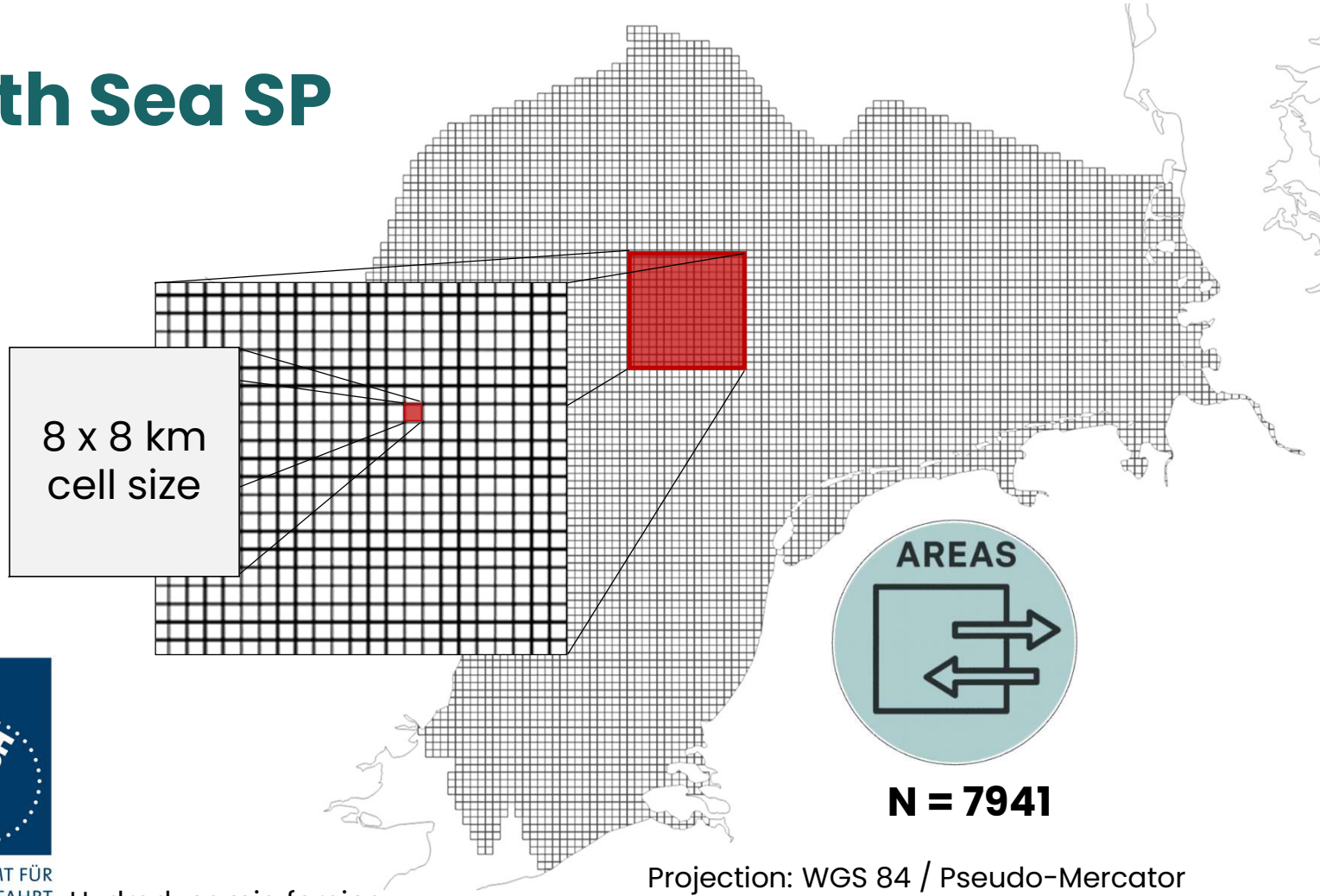
Southern North Sea SP

PARTICLES	100
DURATION	2160 h (90 d)
START	2010-01-01 01:00:00 UTC
END	2024-10-00 15:04:08 UTC
	~74.5 h
EVENTS	1737



BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Hydrodynamic forcing
BSHcmod_v4 hindcasts

Dick, Stephan, et al. 29: The Operational Circulation Model of BSH (BSHcmod). 2001, https://doi.org/10.57802/3xz5-gy93.

Projection: WGS 84 / Pseudo-Mercator
Total Area: 1,310,080 km^2

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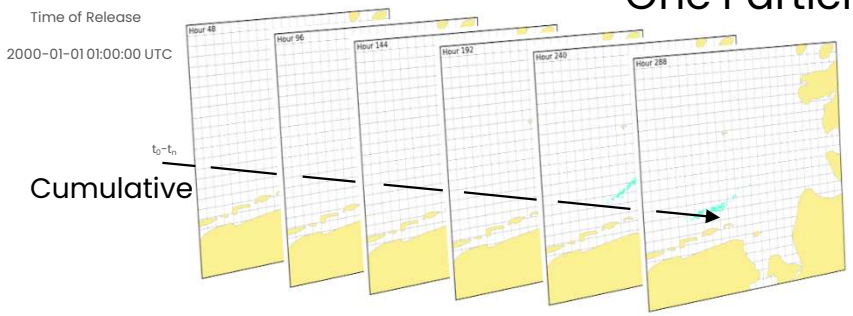
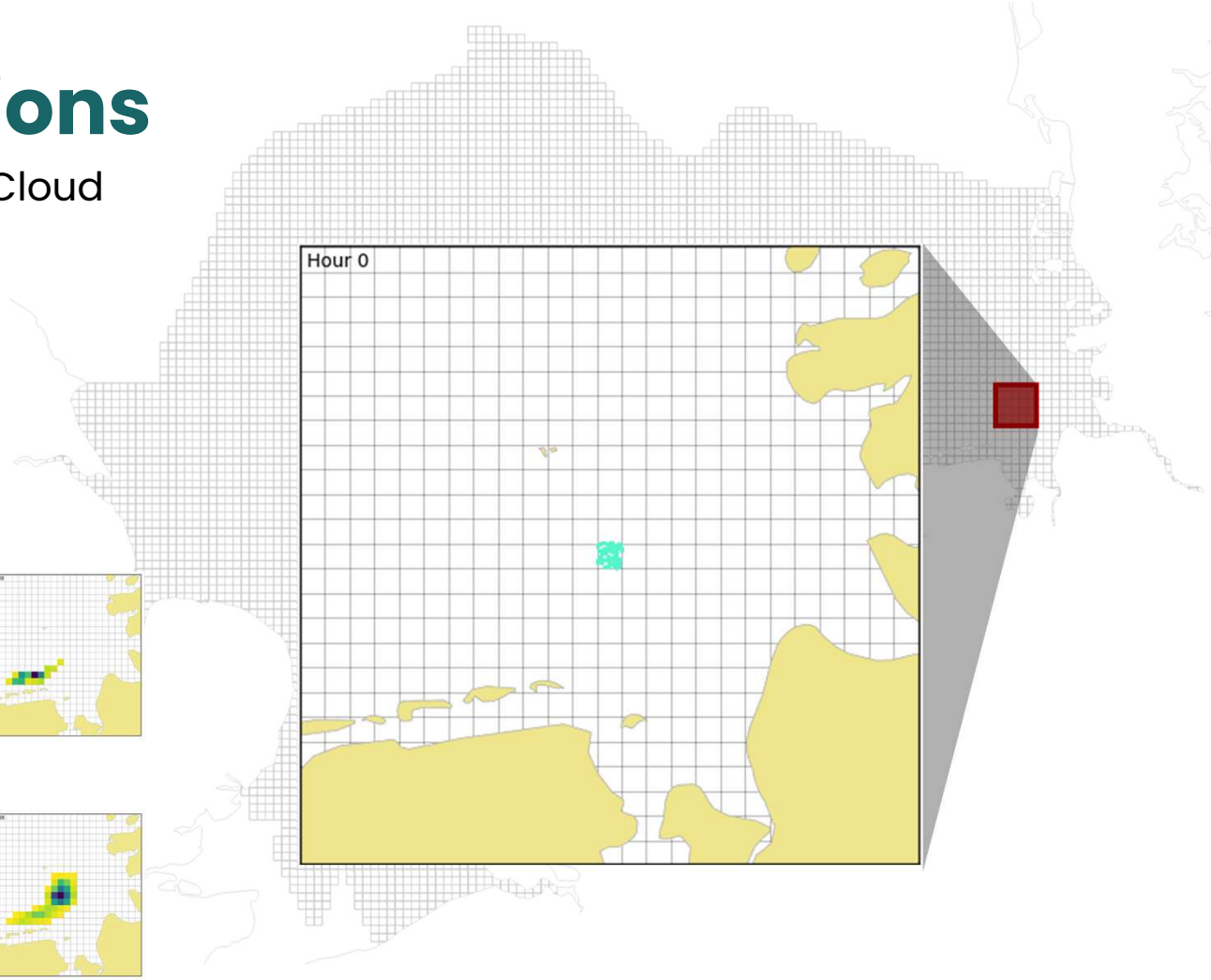
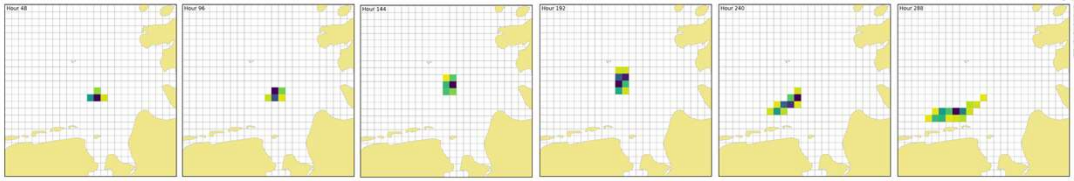
Ensemble Simulations

One Particle Cloud

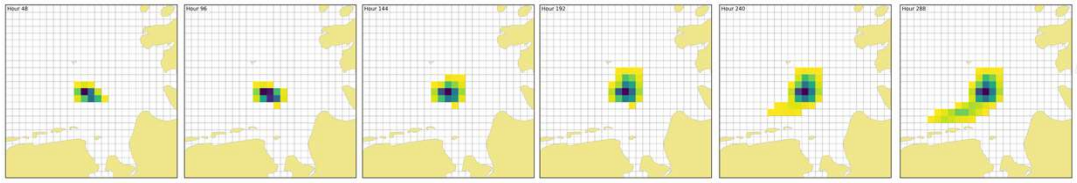




Cross Counts (instantaneous [t_x])



Cumulative Cross Counts (footprint [t_{0-n}])



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Trajectory => pathway information (single particle)

Ensembles => many realizations (variability snapshot)

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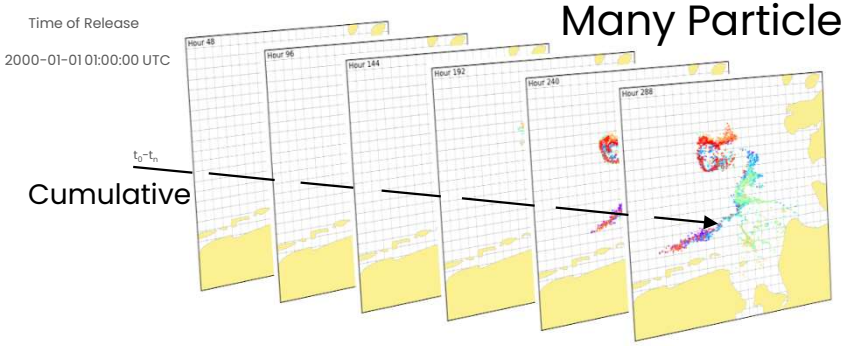
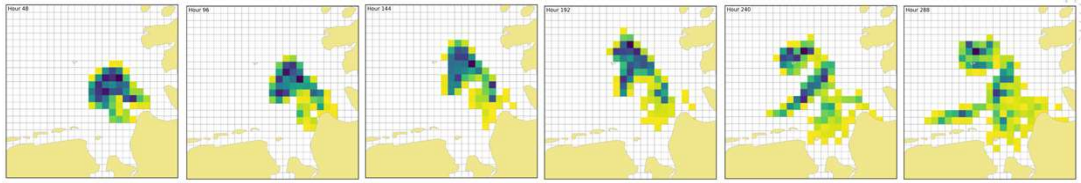
Ensemble Simulations



Cross Counts (instantaneous [t_x])



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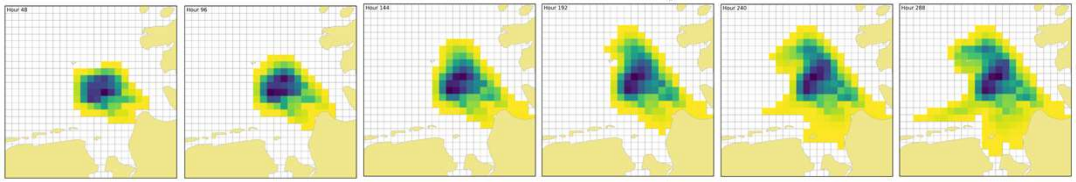

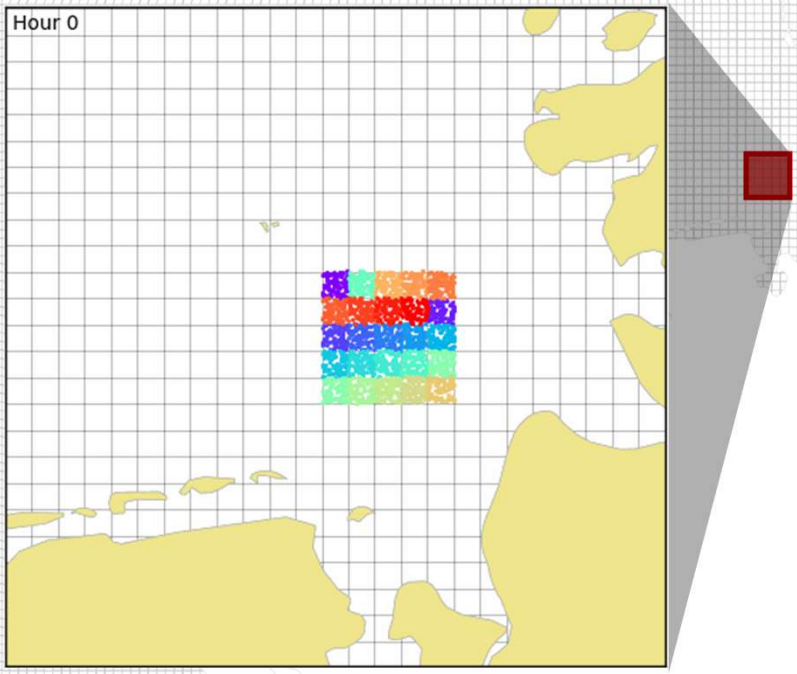

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Footprint => spatial pattern (transport history)

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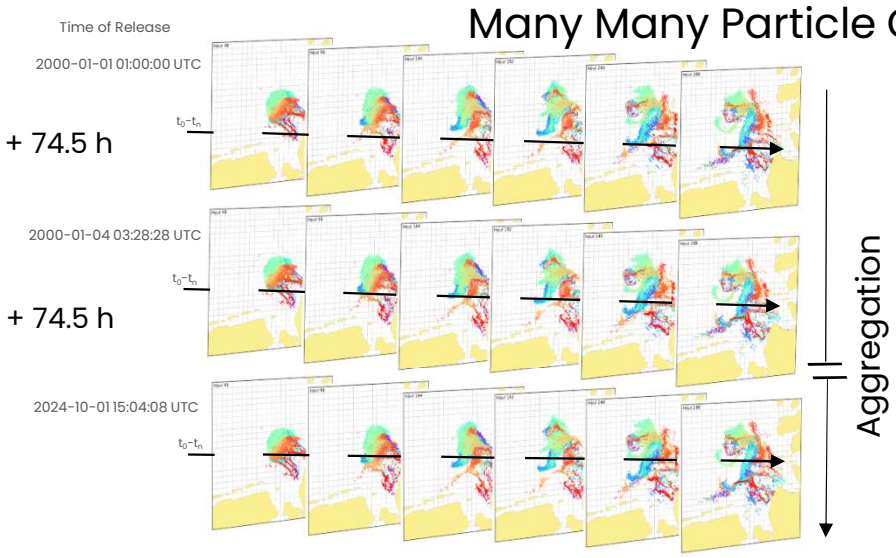
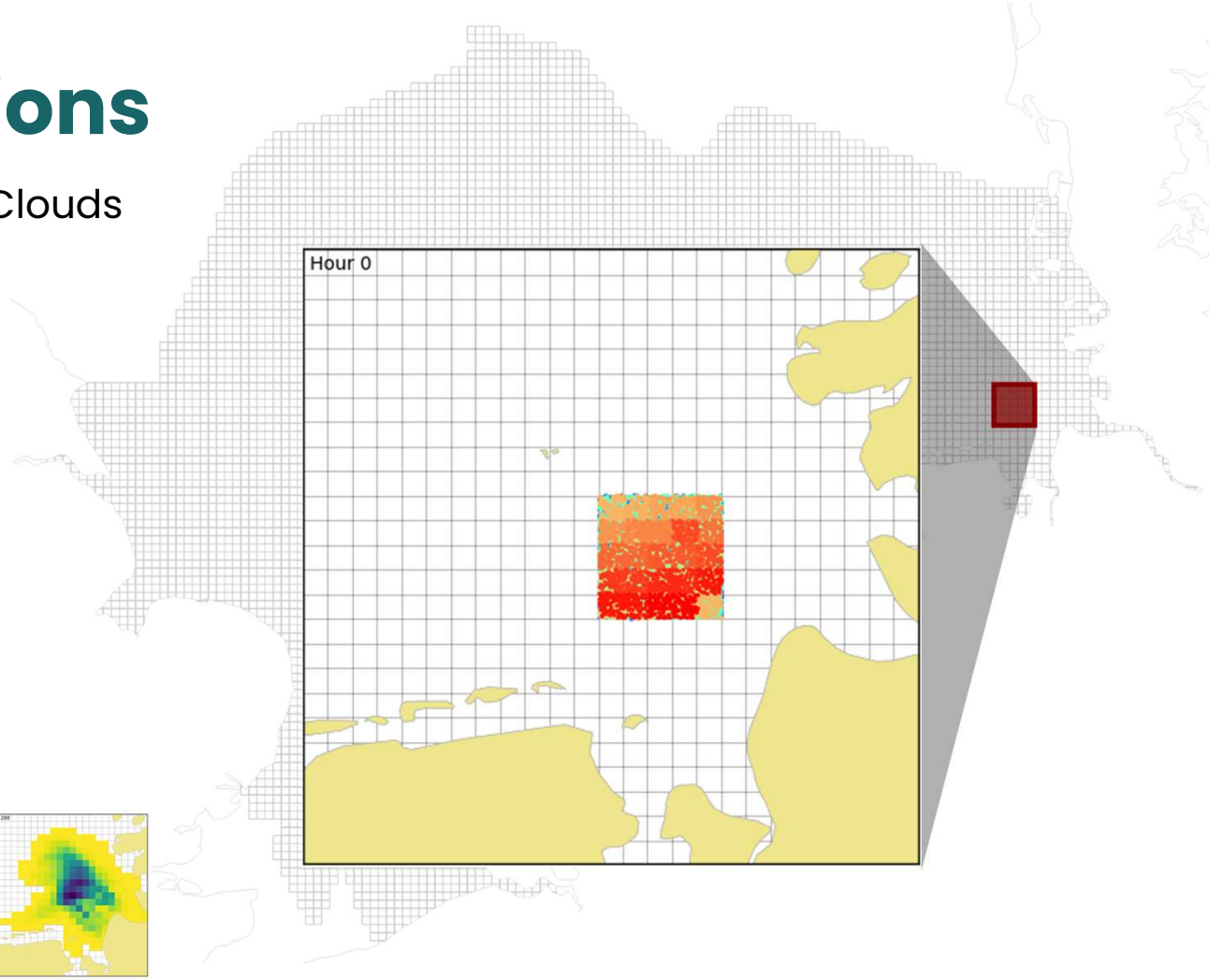
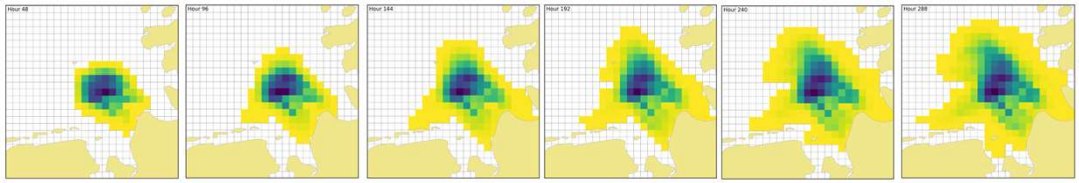
Ensemble Simulations



Many Many Particle Clouds



Cumulative Cross Counts (footprint [t_{0-n}])



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Climatology => baseline average (long-term)

Composite => condition-based average (short[er]-term)

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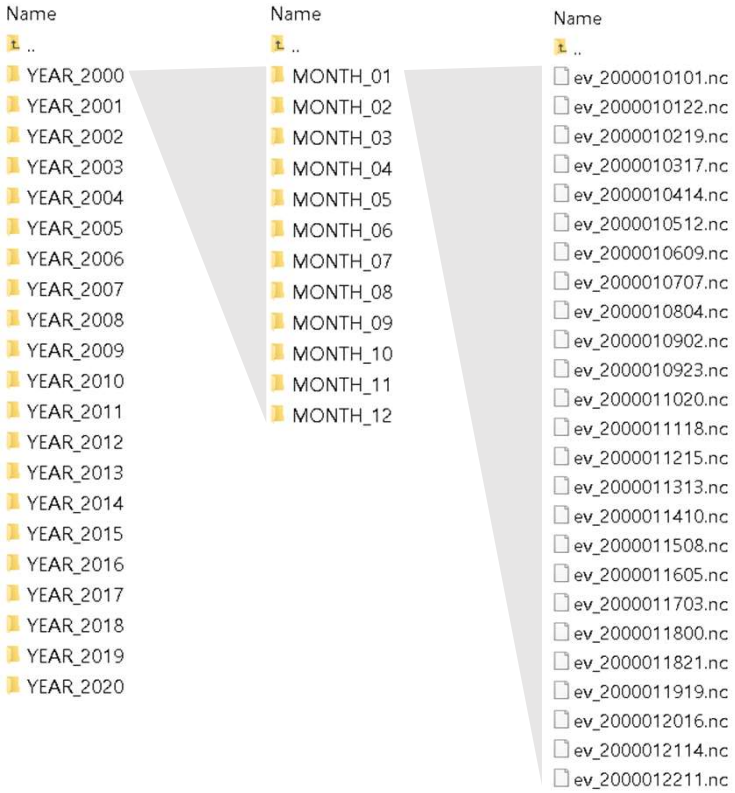
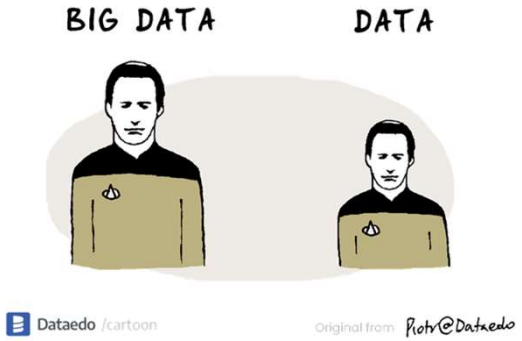
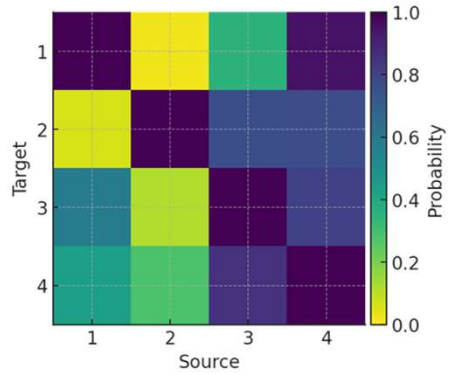
Probability Tables





Node-Edge-List (Netcdf Matrix)

Source	TARGET	Probability
57	57	1.00000000
57	58	0.74594712
57	59	0.45321587
57	60	0.24942732
57	235	0.50982380
57	236	0.45471364
57	237	0.32176211
57	238	0.19841410
57	239	0.10647577
57	240	0.05444934
57	241	0.02533040
57	414	0.14850220
57	415	0.13378854
57	416	0.09519824
57	417	0.05546255
...		



Network analysis

PriorCON, prioritizR, igraph

In-degree, out-degree, centrality,...

Some numbers

No. particles:	1.4x10^6
No. Points:	~ 3x10^12
Run Time:	~ 12 days on HP-Cluster
Parallelization:	> 200 nodes
Data Volume:	> 20 TerraByte

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Connectivity by ocean transport id **directed** (causal)!

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Thank you!

Next:
From Particles to Priorities – PART II

Tasnim Patel

"If you don't reveal some insights soon, I'm going to be forced to slice, dice, and drill!"

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