Exploring model uncertainty representation in the IFS transport scheme

Stochastic perturbations to the semi-Lagrangian scheme

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Exploring model uncertainty representation in the IFS transport scheme

Part I

- Including model uncertainty representations in ensemble forecasting systems: where / how / why?
- Current model uncertainty representation in the IFS
- Introducing a new model uncertainty scheme: STOCHDP

Part II

- STOCHDP: a case study
  - Typhoon Neoguri
  - Scheme sensitivities

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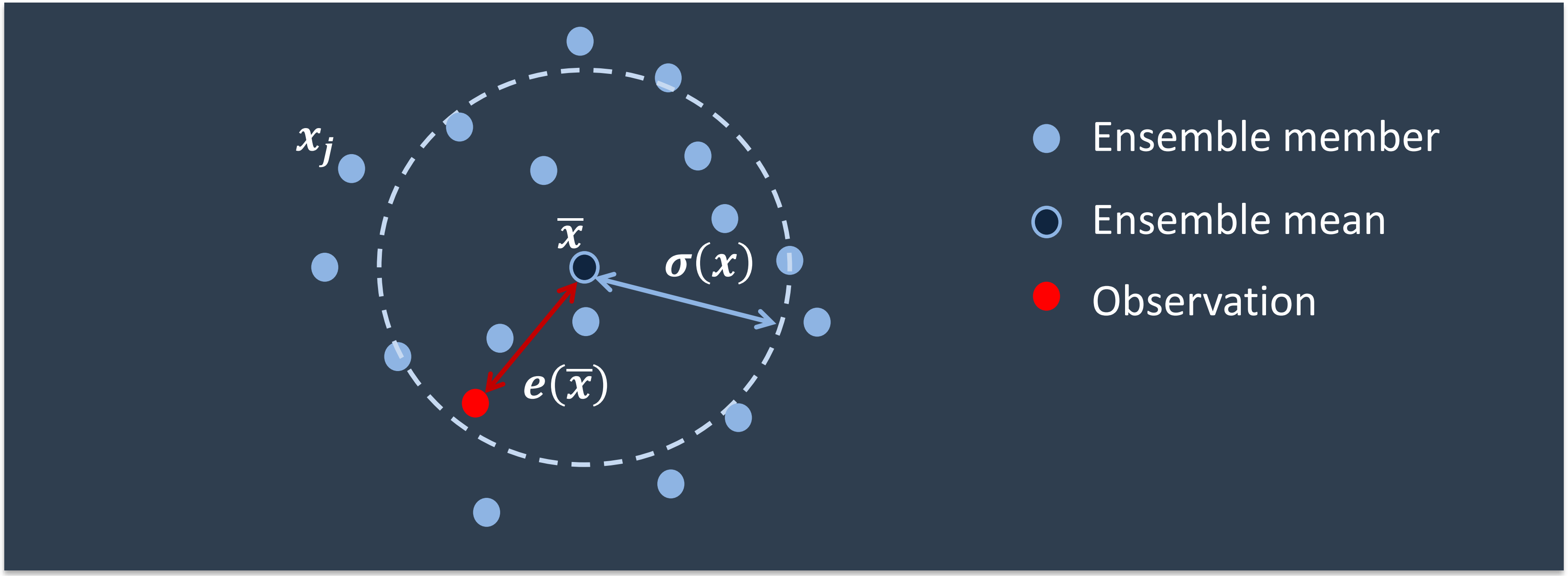
Background: building a reliable ensemble forecasting system

In a reliable ensemble, **ensemble spread** acts as a predictor of **ensemble error**

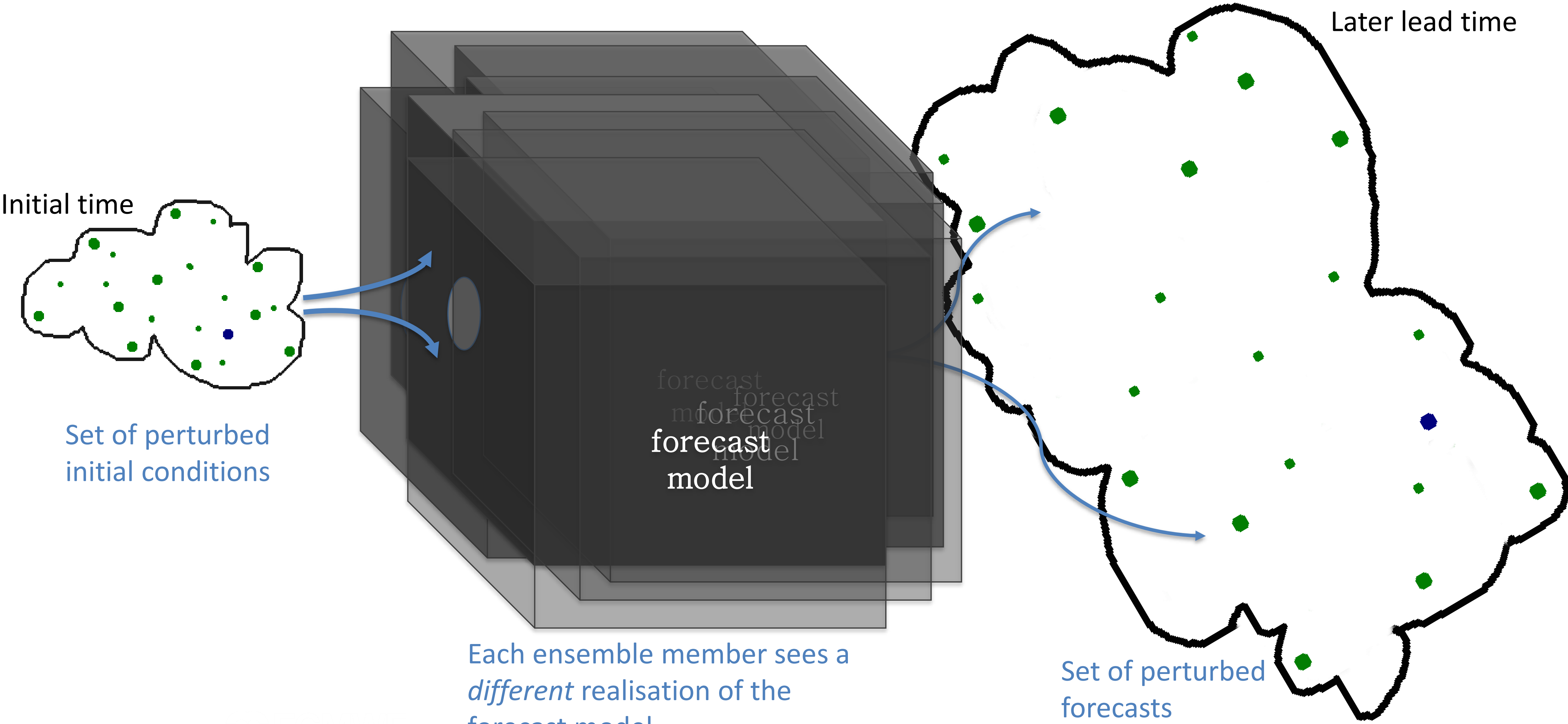


Averaged over many ensemble forecasts:

$$\sigma(x) \approx \left| e(\bar{x}) \right|$$

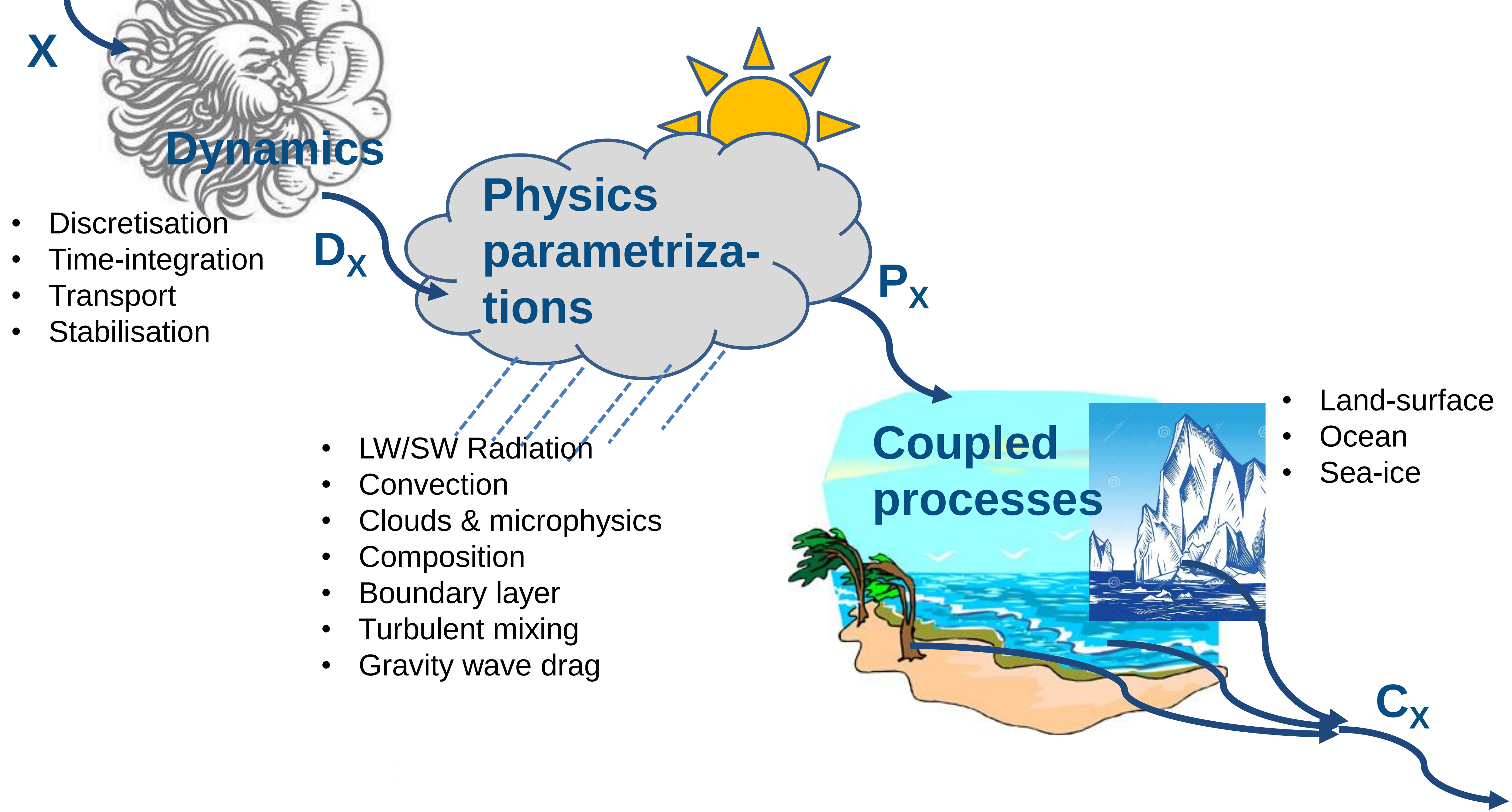
➔ Ensemble spread indicates the expected magnitude of the error of the ensemble mean

Background: representing model uncertainty in an ensemble forecast



Each ensemble member sees a *different* realisation of the forecast model

Background: model uncertainty representation in the IFS



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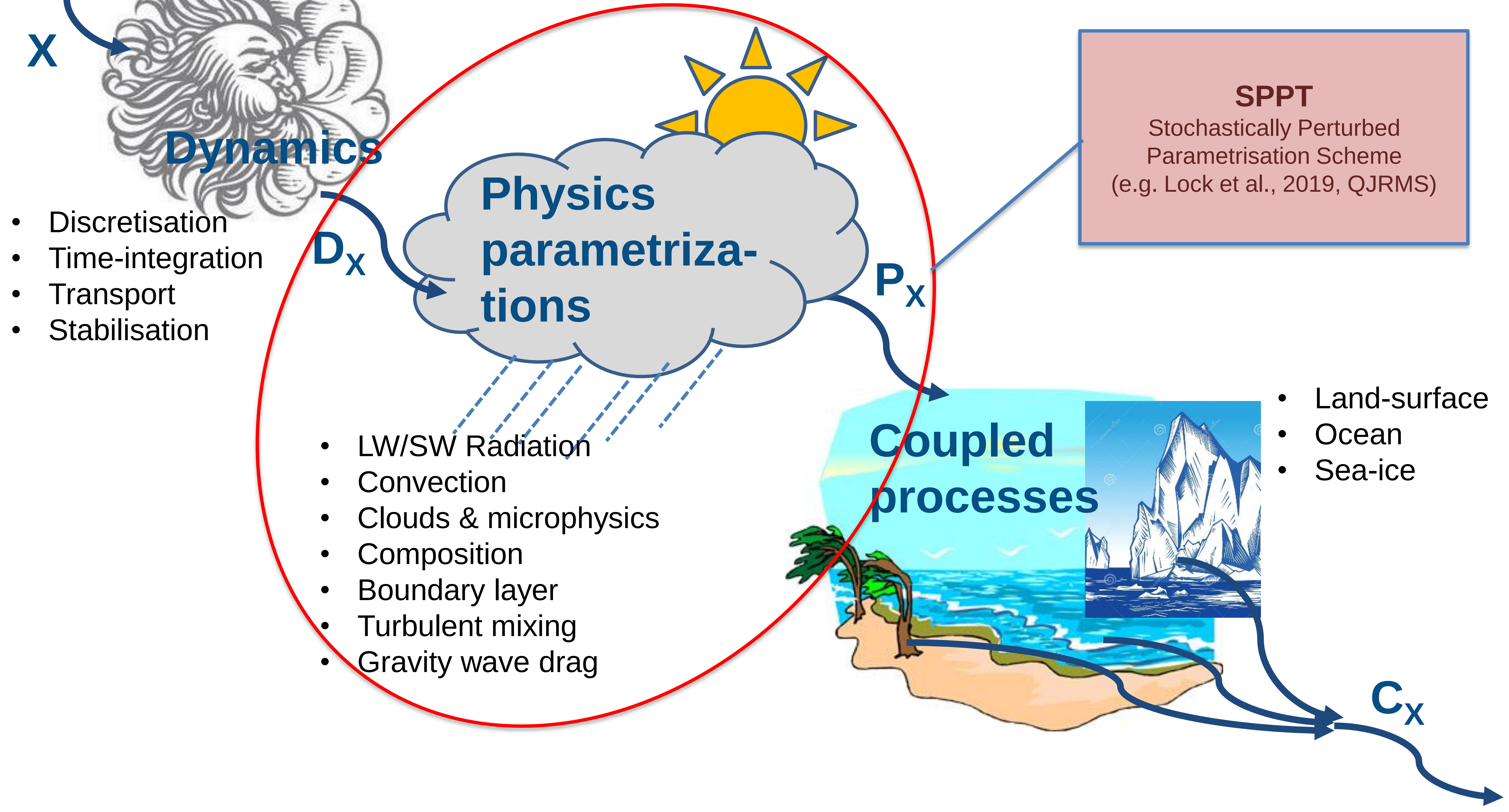
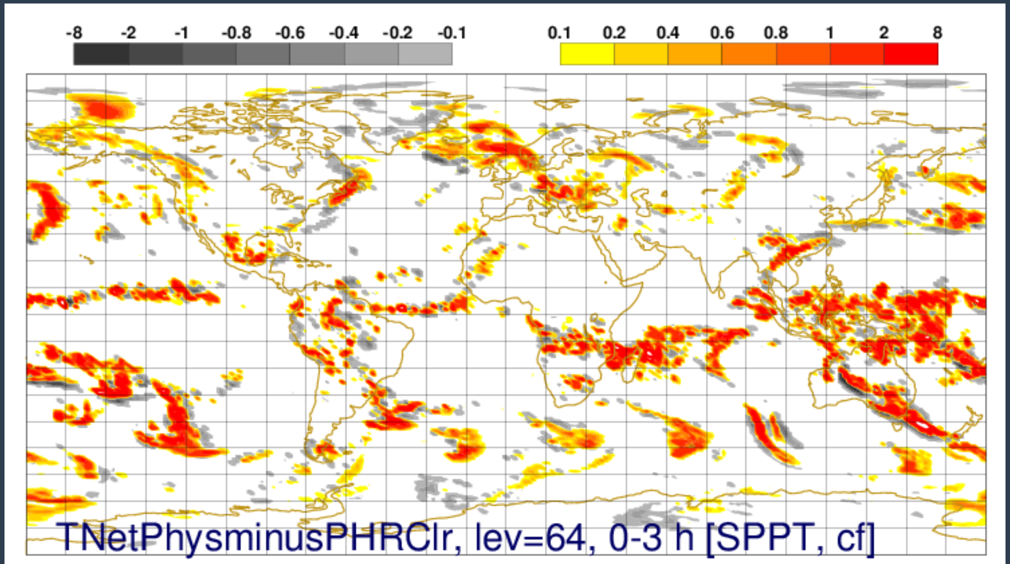


Background: how SPPT operates in the IFS

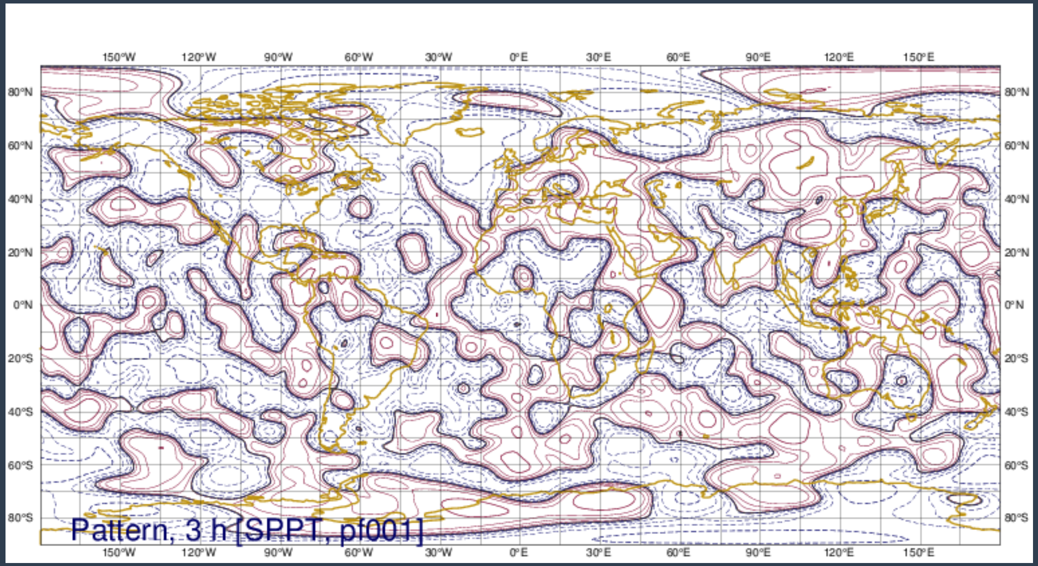
$$X' = (1 + r)X$$

Physics tendencies:
T tendencies (K/3h), 0-3h, model level 64



Unperturbed model

Random pattern:
r~*N*[0,0.44], time/spatial correlations



e.g. member #1

red, solid: 0<*r*<+1

blue, dash: -1<*r*<0

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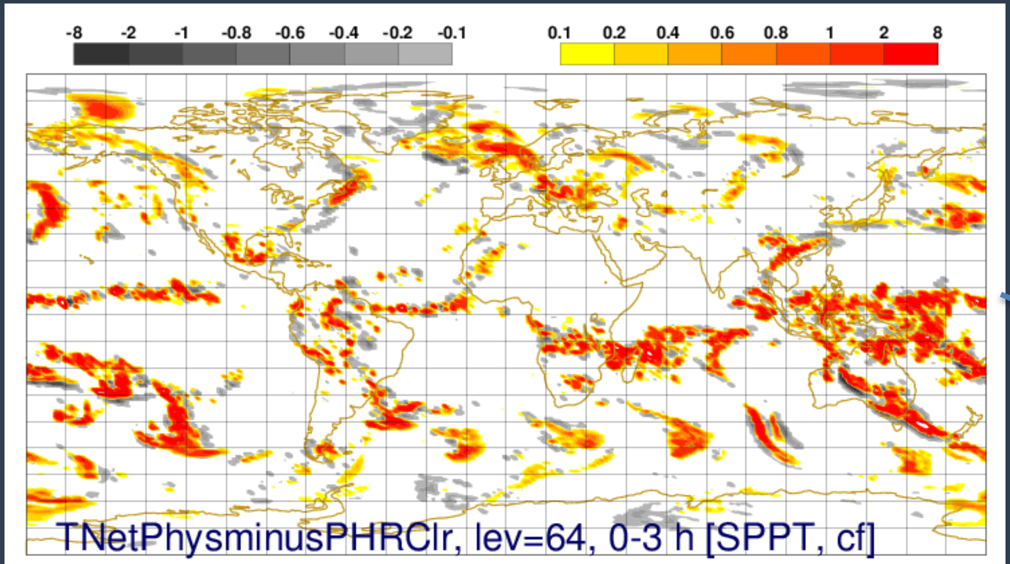

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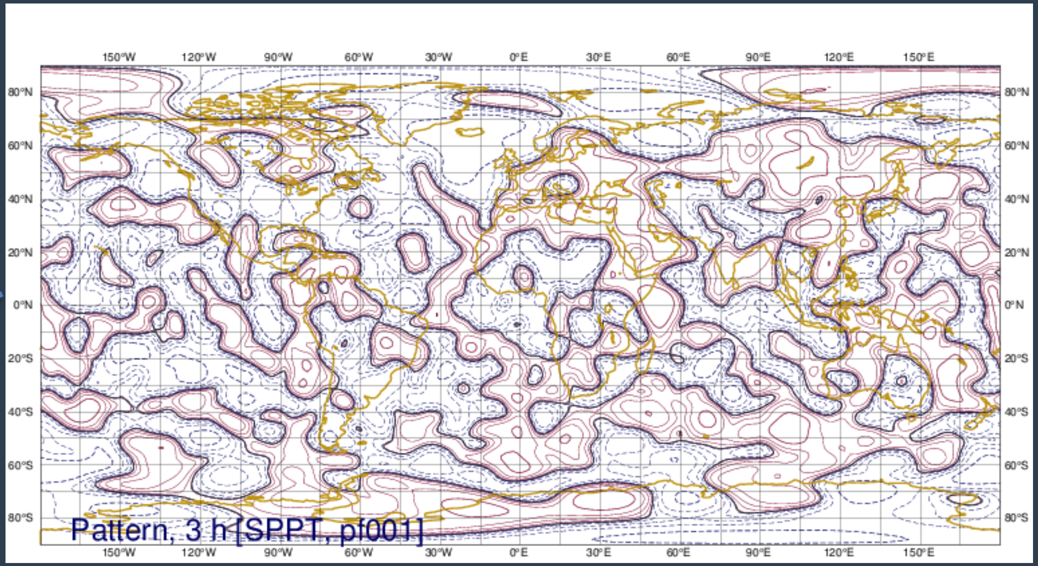

e.g. member #1
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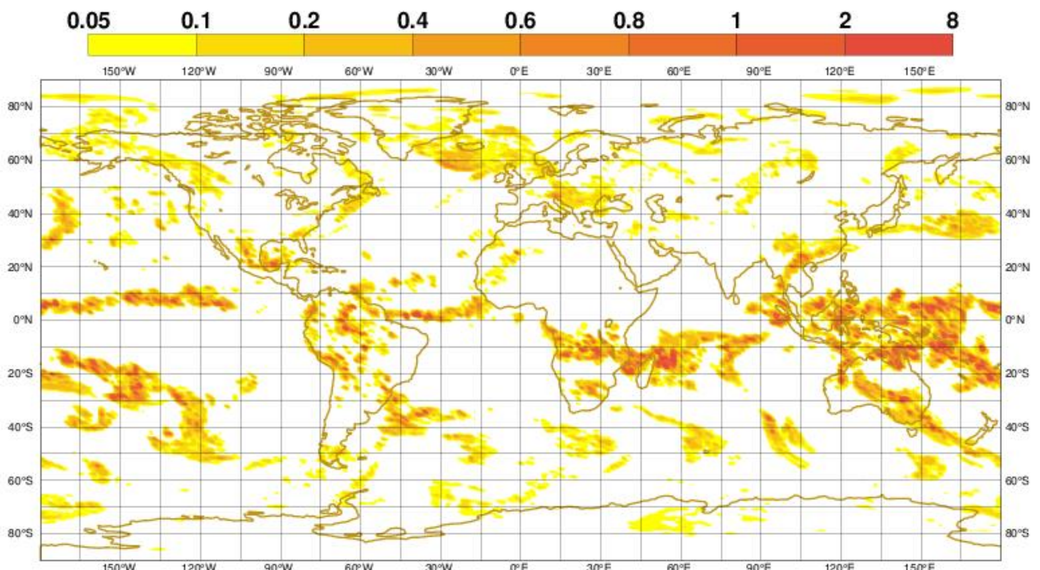

Ensemble standard deviation
(20 perturbed members)

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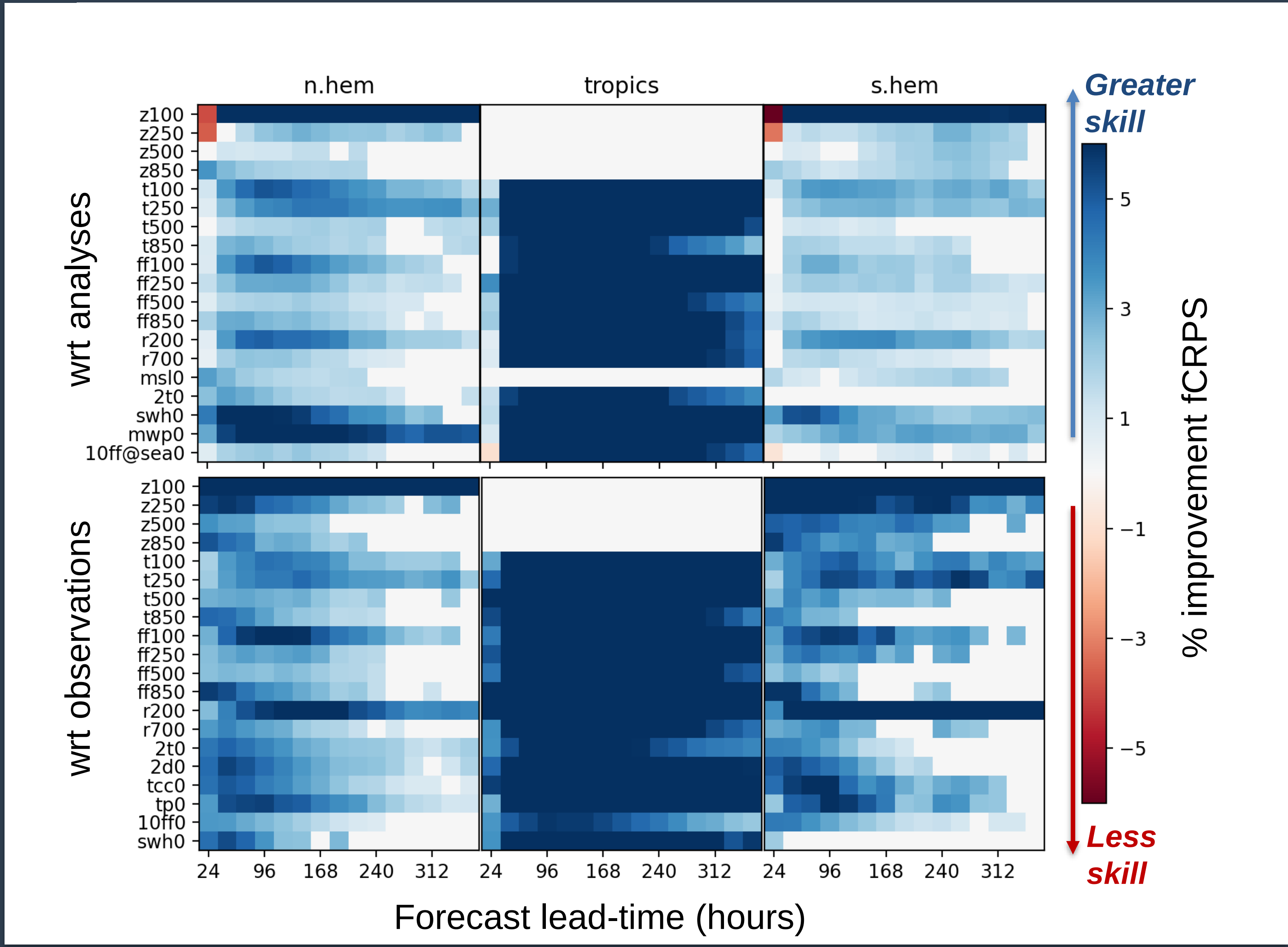
Background: how SPPT performs in the IFS



ENS:
Including SPPT vs **Excluding** SPPT

Fair CRPS (*see Leutbecher 2019, QJ*)

212 cases (*JJA2018 + NDJF2018/19*)
TCo399 L91 (*approx. 30km resol^n^*)
8+1 members

Colours => significance at 99.7%

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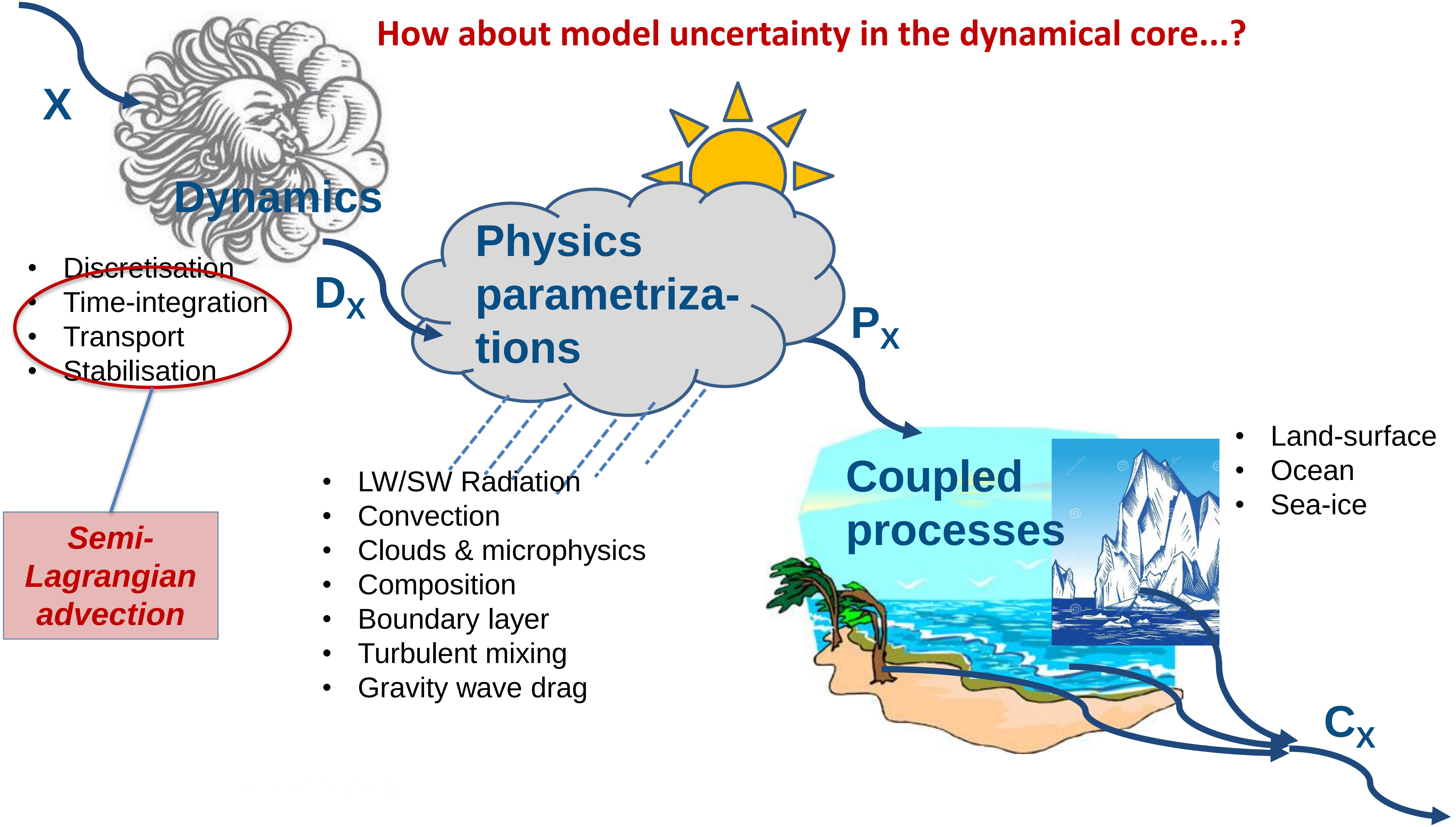
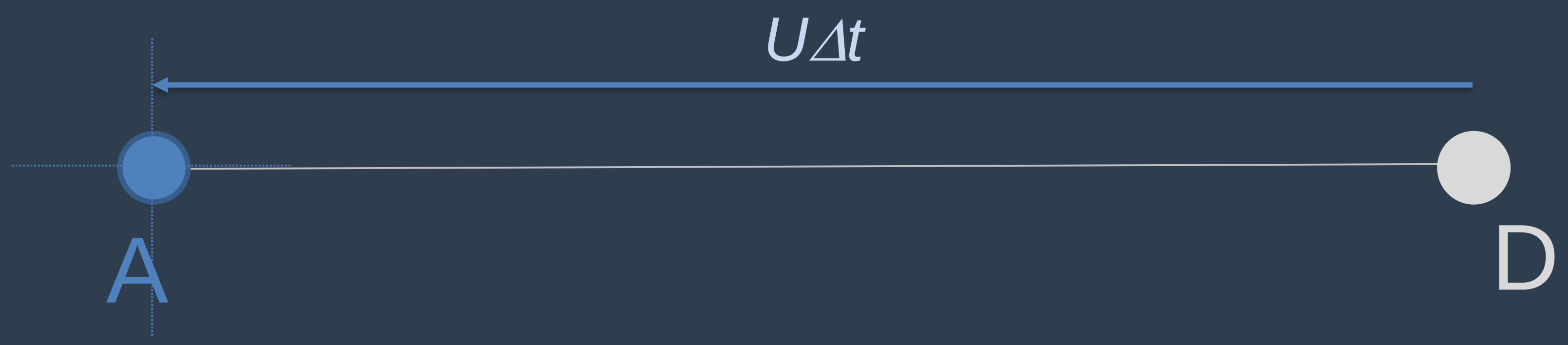
How about model uncertainty in the dynamical core...?



STOCHDP: stochastic departure points

- Semi-Lagrangian scheme: Departure Point (DP) estimates



STOCHDP: stochastic departure points

- Semi-Lagrangian scheme: Departure Point (DP) estimates
- Diamantakis & Magnusson (2016): slower convergence ⇔ strong shear/curvature

STOCHDP: stochastic departure points

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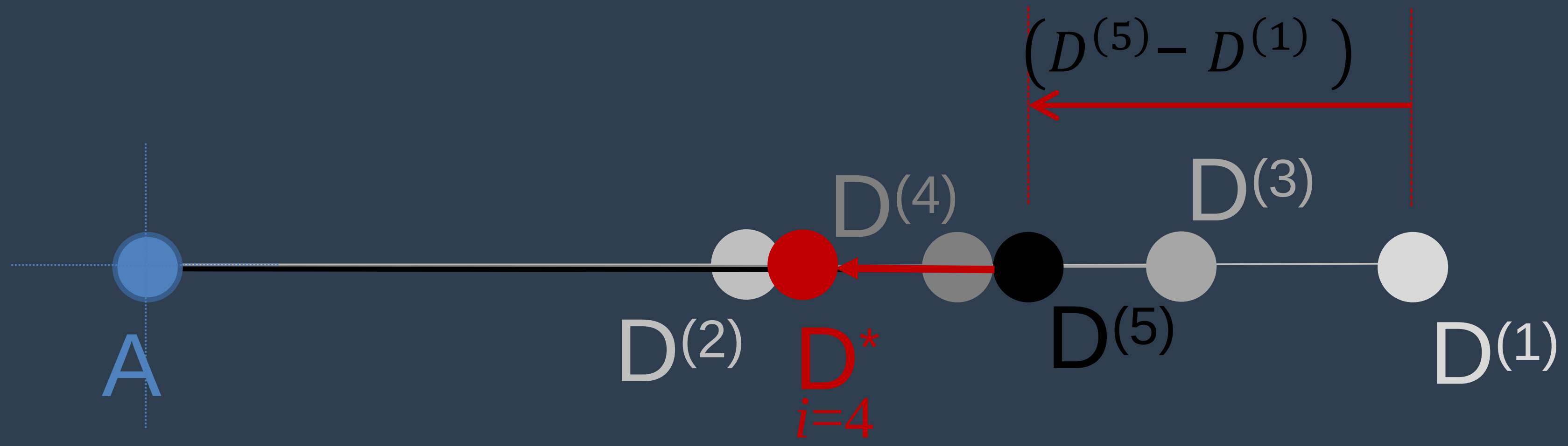
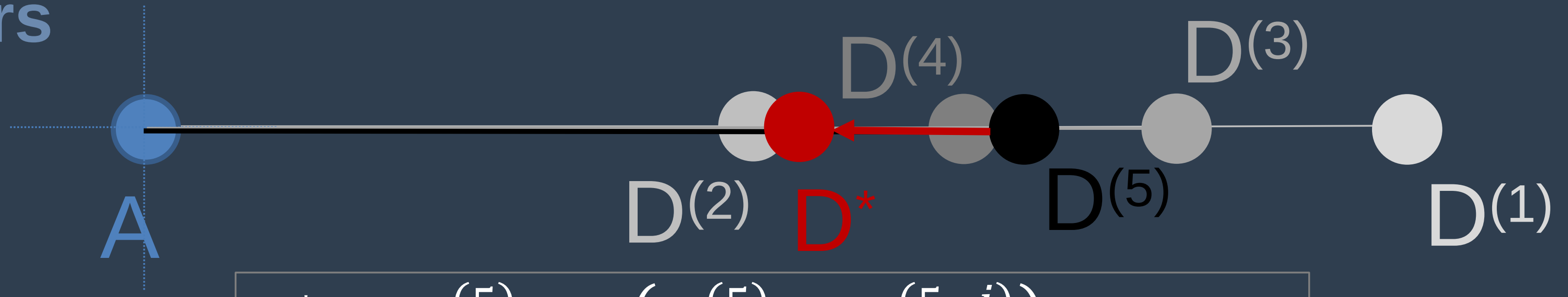


- Model uncertainty scheme: guided by the rate of convergence for the DP estimate

$$D^{*} = D^{(5)} + r\left(D^{(5)} - D^{(5-i)}\right), i = 1..4$$

where $D*$ is the perturbed DP and r is a random number

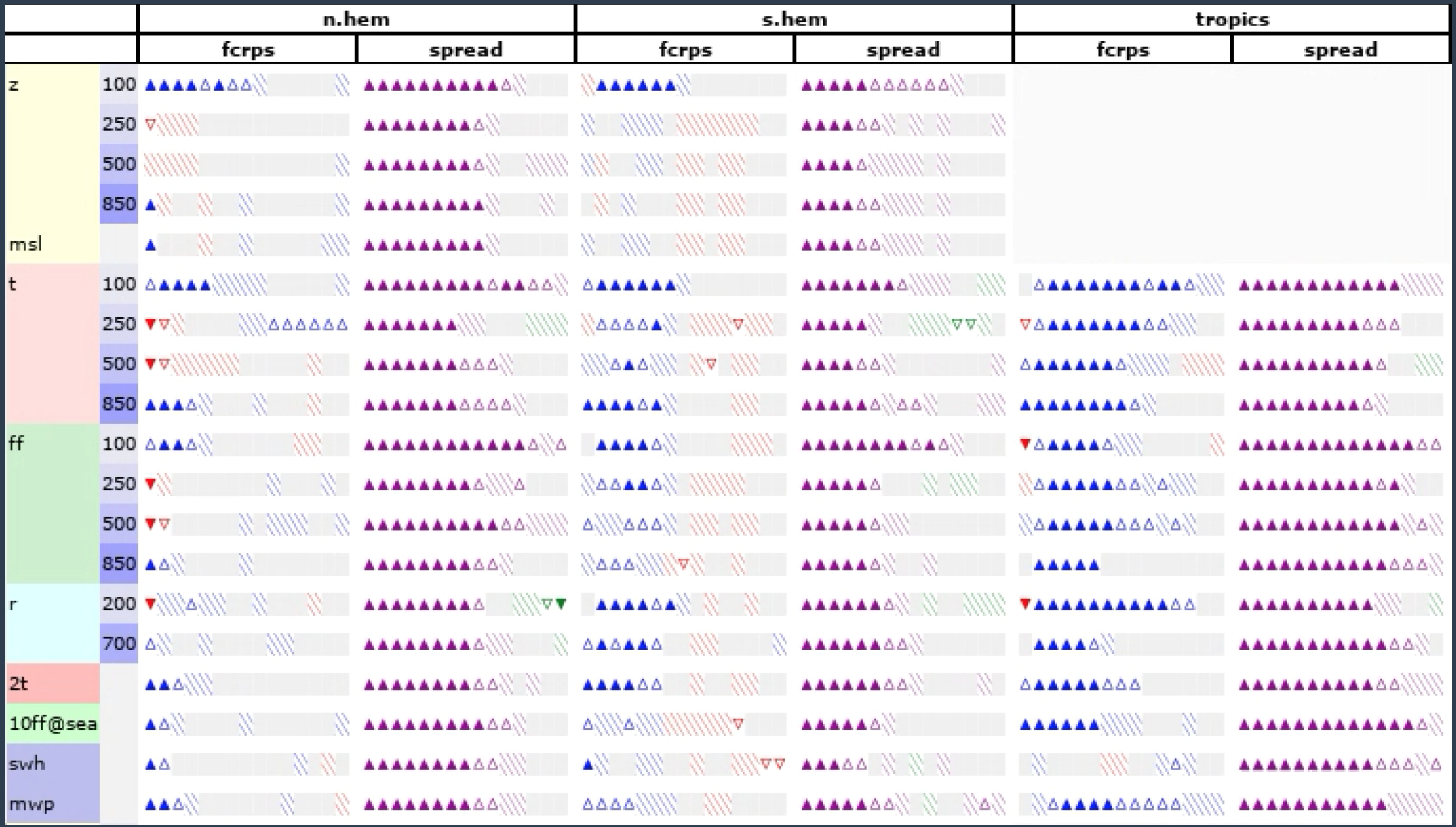
STOCHDP: parameters



$$D^* = D^{(5)} + r\left(D^{(5)} - D^{(5-i)}\right), i = 1..4$$

Parameter:		**Defaults:**
i	Perturb the difference btw 5th and (5-i)th DP estimate	3 *i.e.* $r(D^{(5)}-D^{(2)})$
r:	Random number:	
$N(\mu,\sigma)$	Normal distribution	$\mu=0,\sigma$
$\{x,\tau\}$	2D spectral pattern – correlation scales	{500km,6h} *(SPPT)*
r_j	Perturb LAT/LON/VER independently?	j=1 *i.e.* $r_{LAT}=r_{LON}=r_{VER}$
$r(\ldots)$	Apply a limiter to the perturbations: - Vertical: to prevent unphysical overturning - Horizontal: prevent U/V exceeding width of halos	max|$r(\ldots)$| = |$A-D^{(5)}$|

STOCHDP: early results (ENS scorecard)



ENS:
STOCHDP + Initial Perturbations
vs
Initial Perturbations only

42 cases (*Nov/Dec 2018*)
TCo399 L91, t+360h
8+1 members

=> improved skill (fCRPS)

=> degraded skill (fCRPS)

=> increased spread

=> decreased spread

Solid triangles => significance at 95%

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STOCHDP case study: TC Neoguri

Diamantakis & Magnusson (2016):

- TC Neoguri
- HRES forecast
- Initialised: 2014-07-05, 00UTC

- t+96h, 850hPa windspeeds (*Figure 1c*)

- DP estimate: slowest convergence in TC vicinity (*Figure 3*)

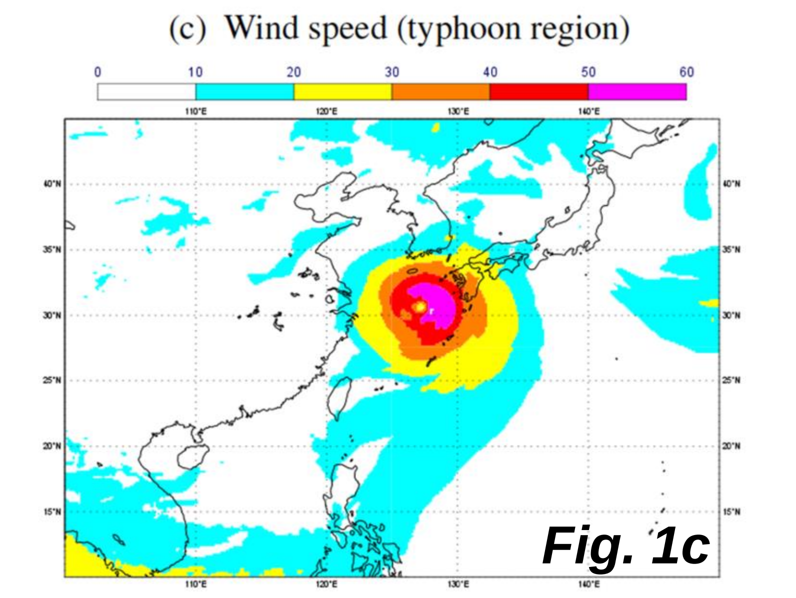
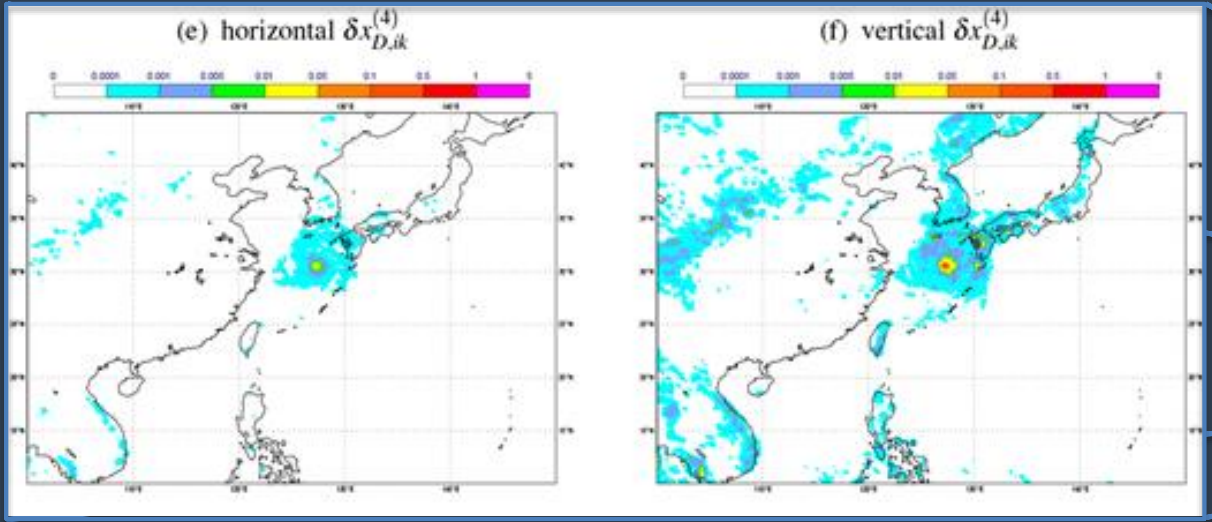


Fig. 1c



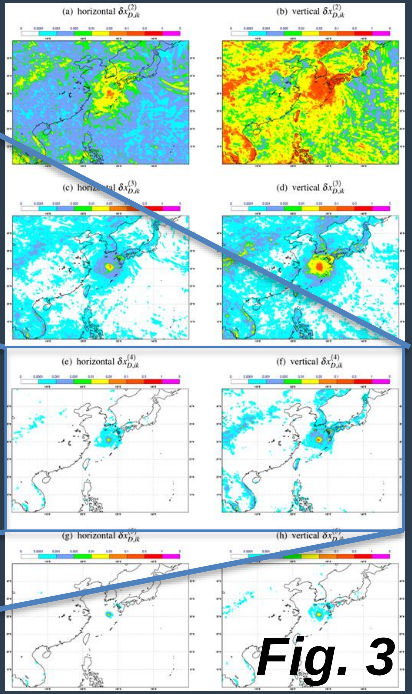


Fig. 3

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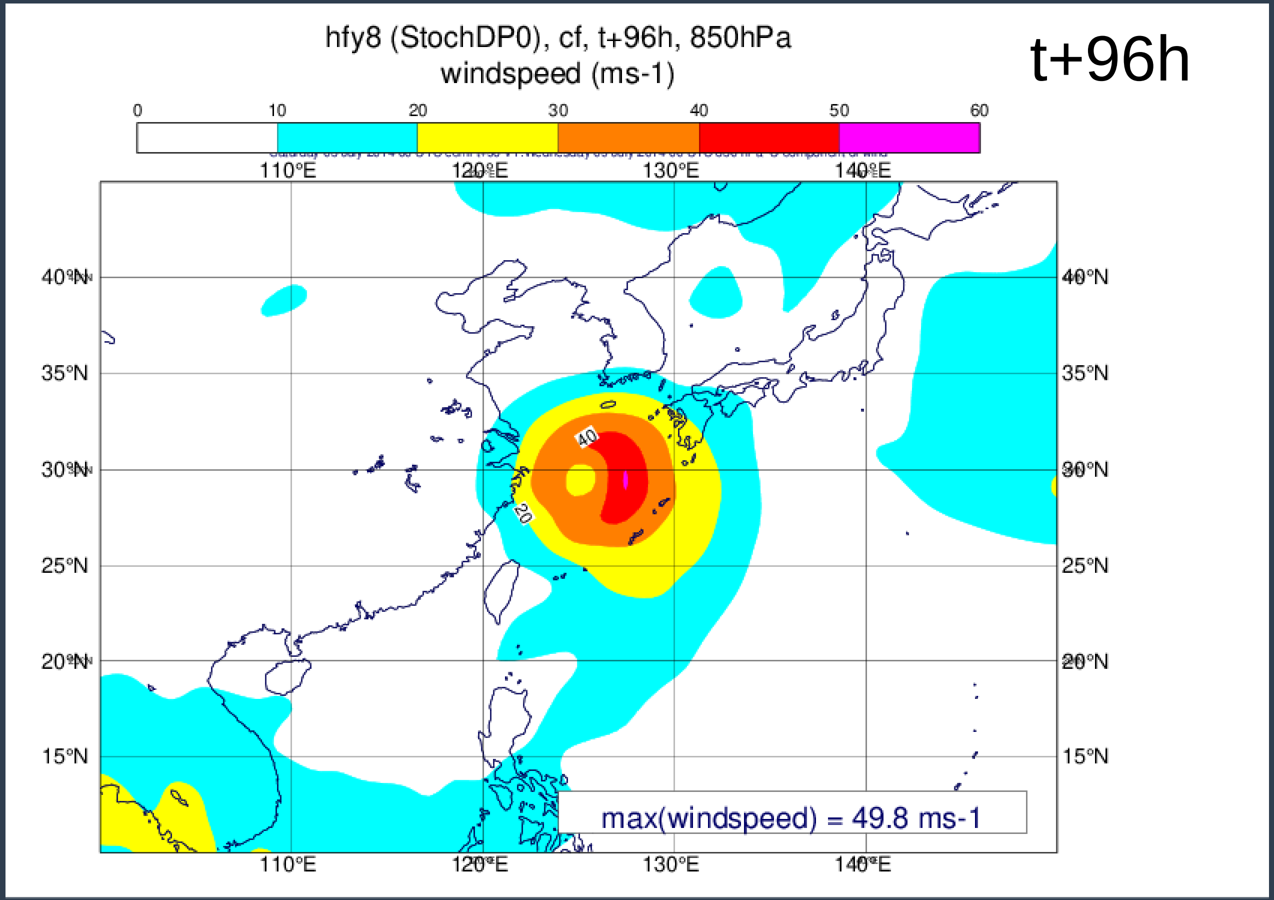
STOCHDP case study: TC Neoguri

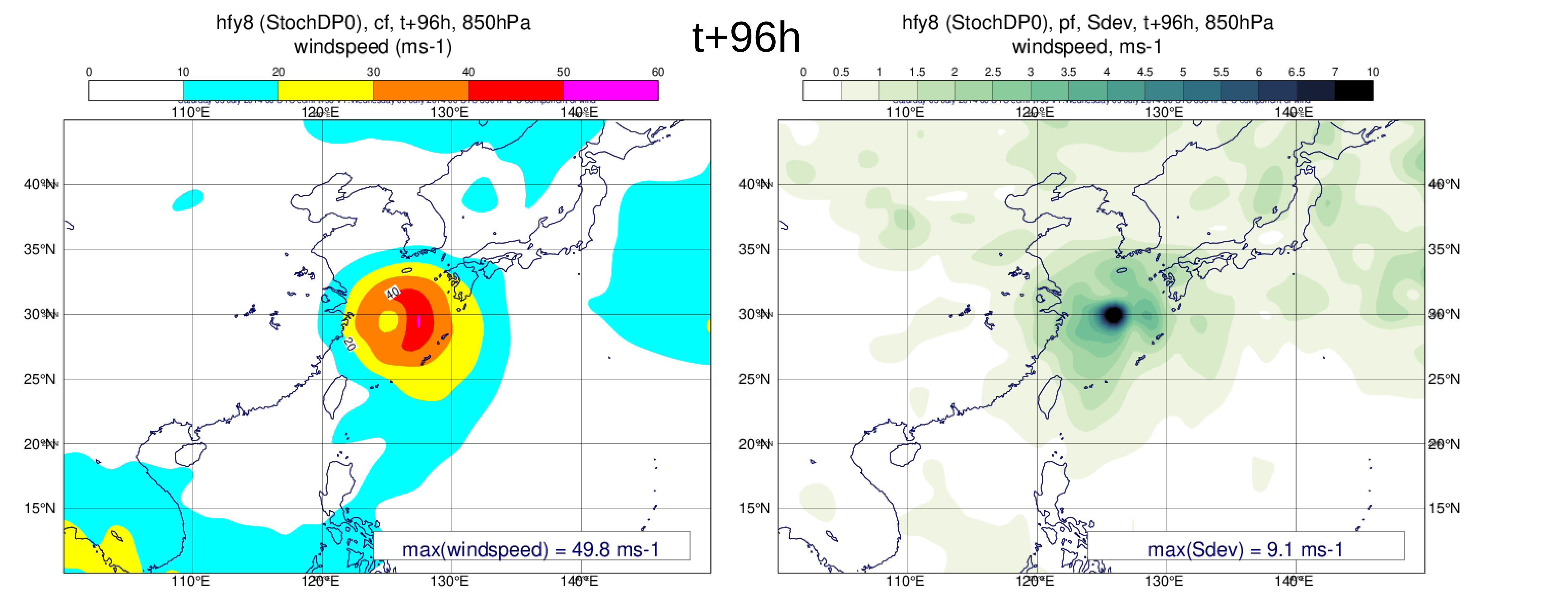


Control forecast

Windspeed

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

STOCHDP case study: TC Neoguri



Control forecast **Windspeed** **Ensemble stdev**

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TCo639L91, dt=720s
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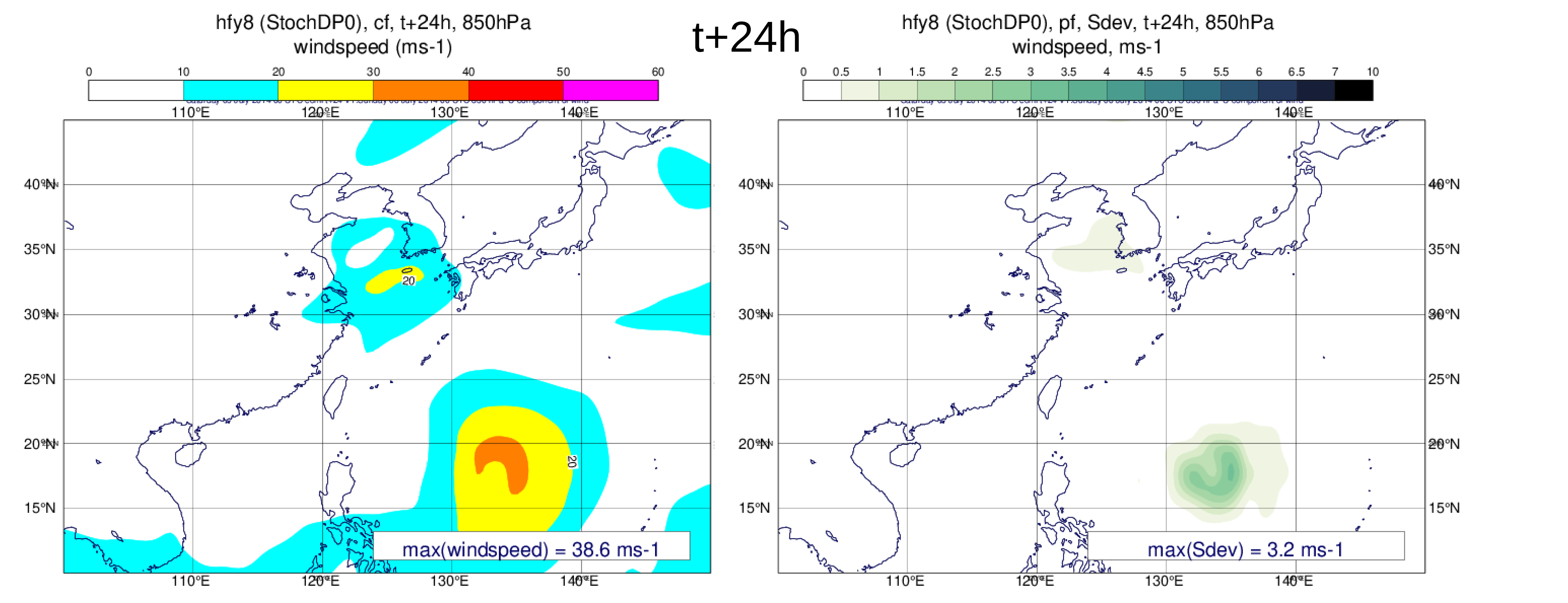
STOCHDP case study: TC Neoguri



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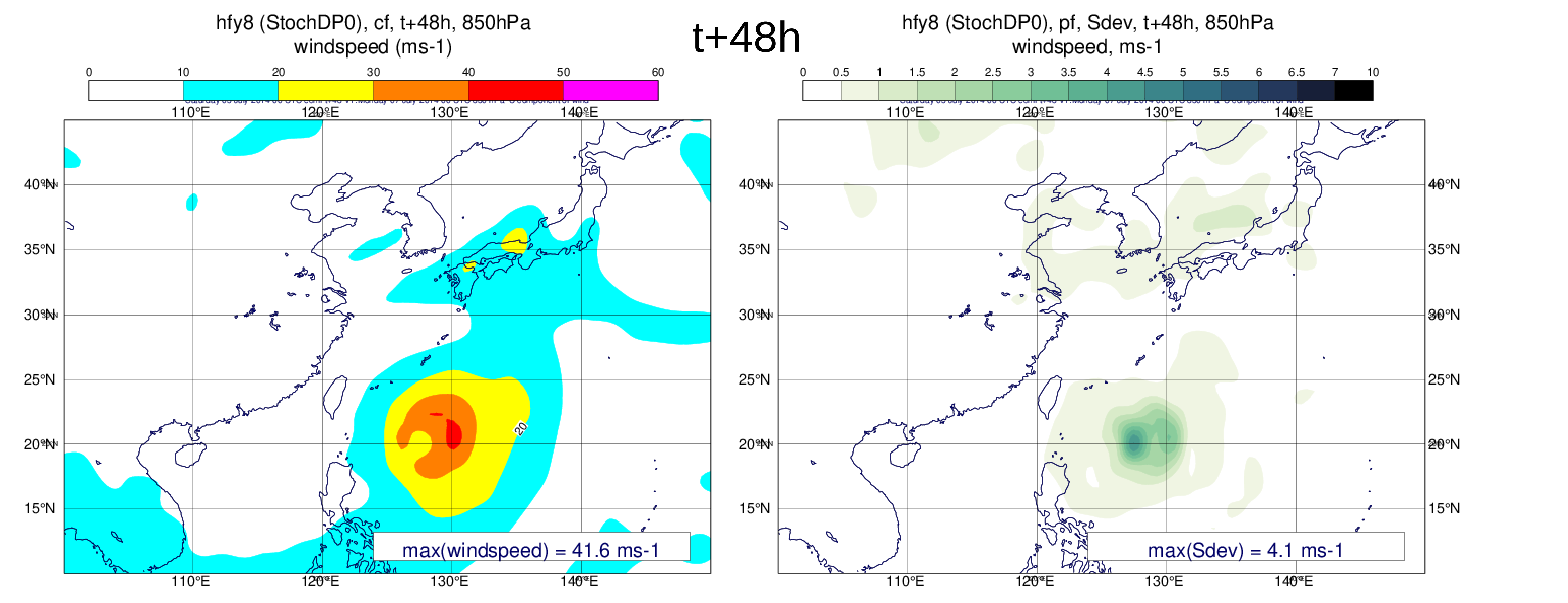

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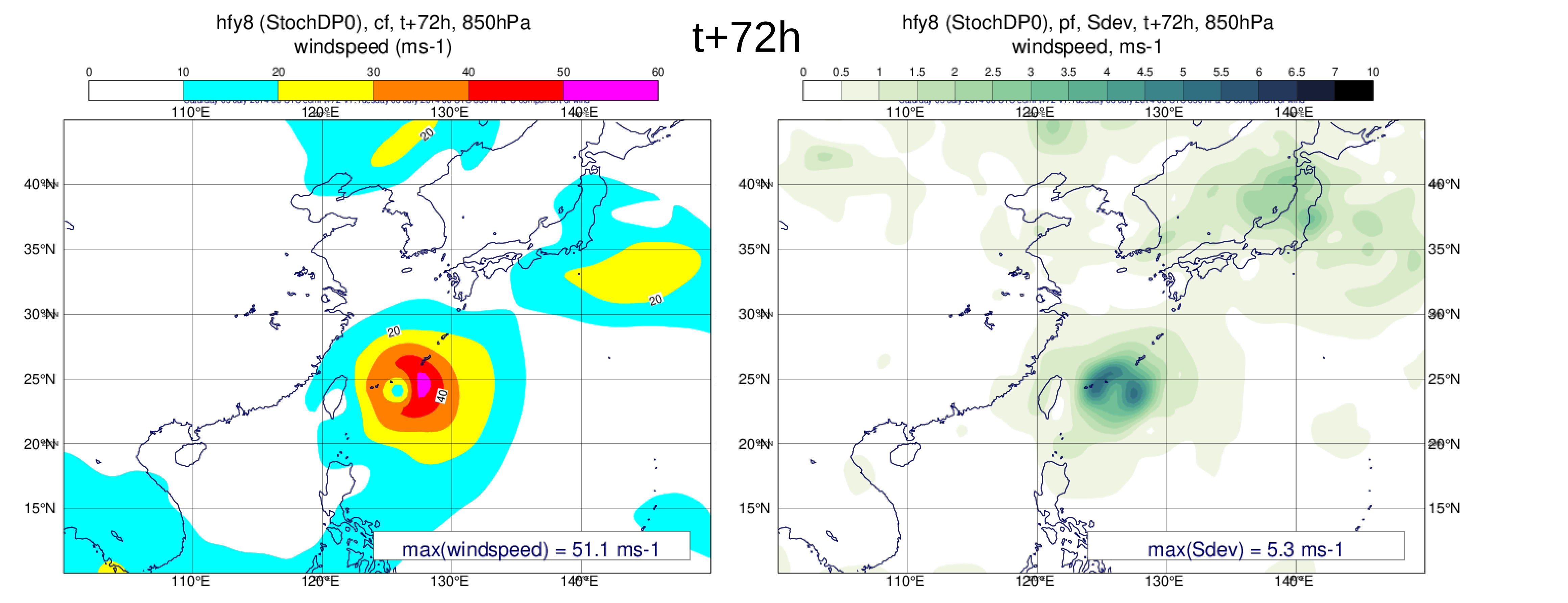

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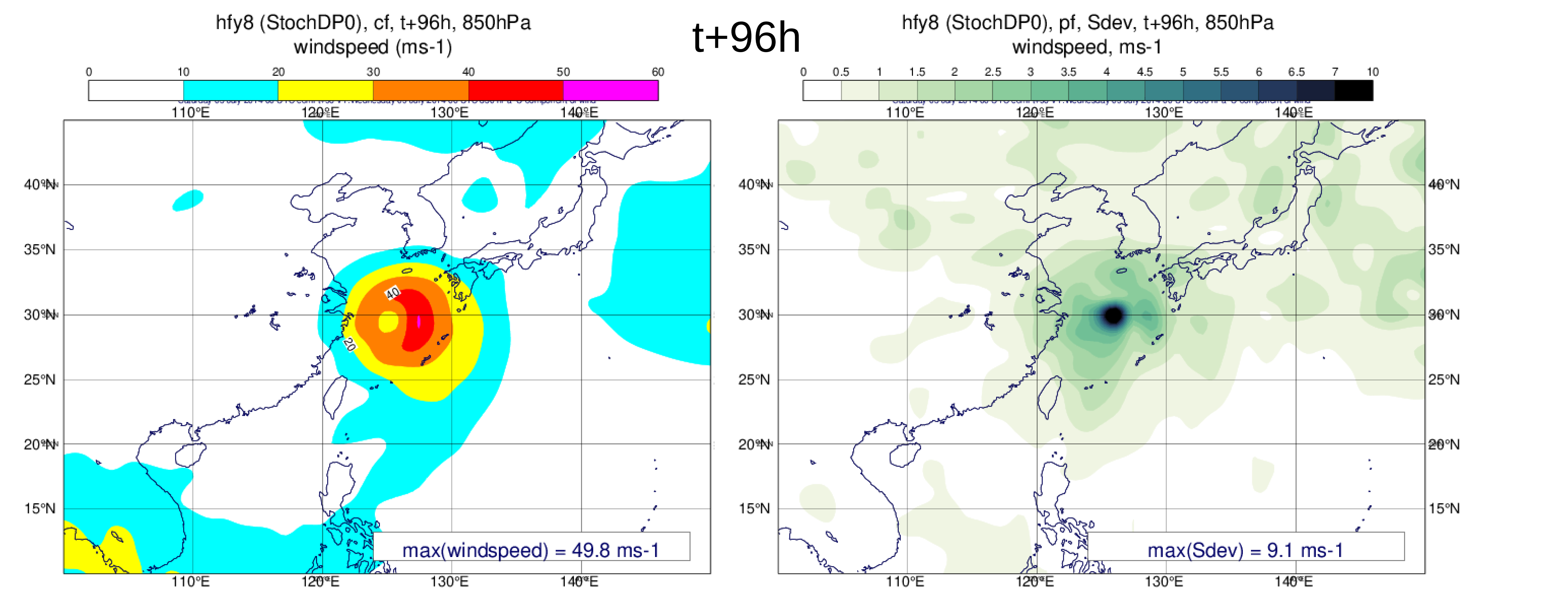

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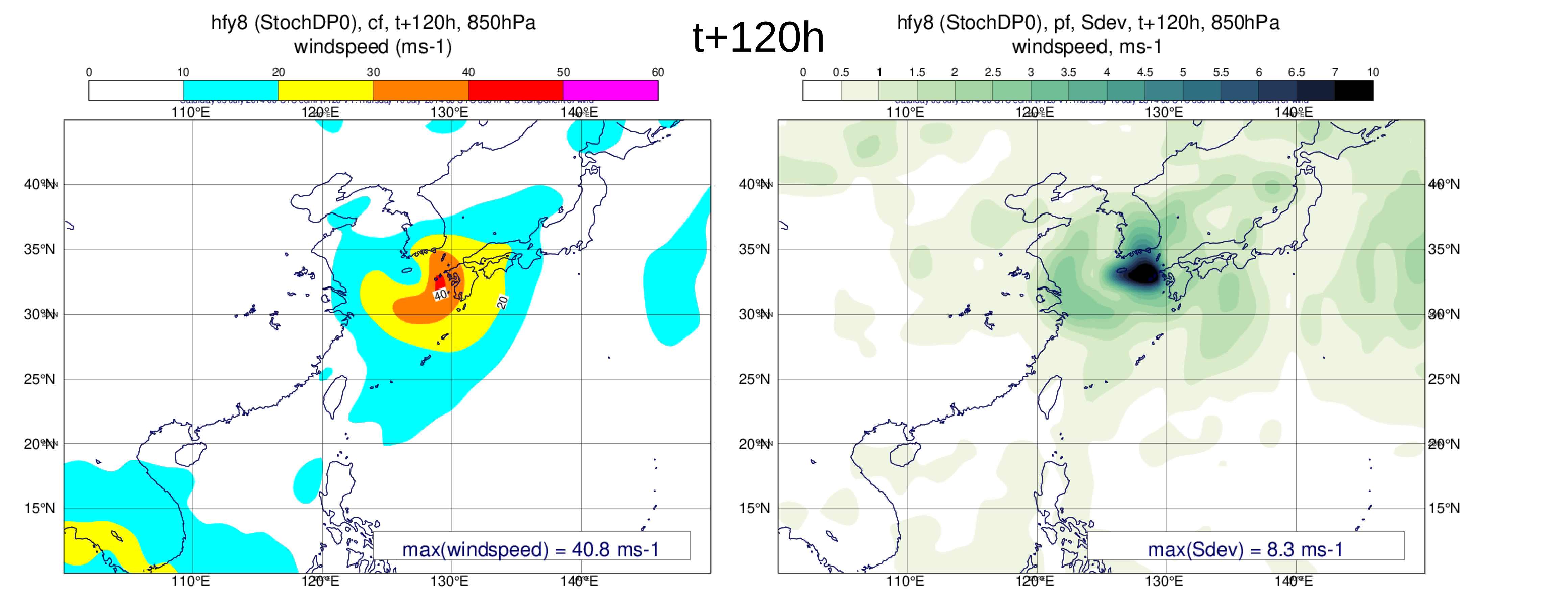


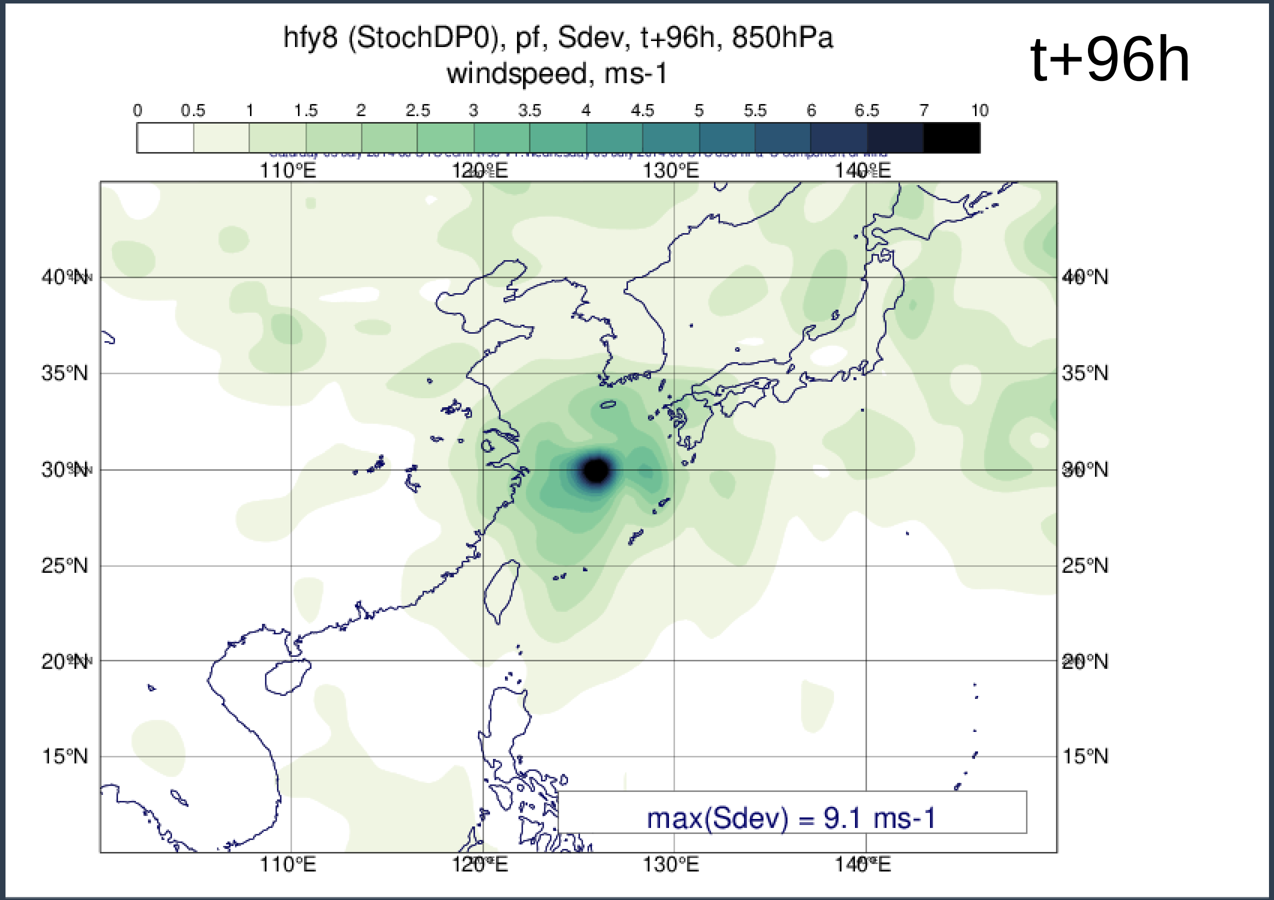
Control forecast

Windspeed

Ensemble stdev

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

STOCHDP case study: TC Neoguri --- sensitivities

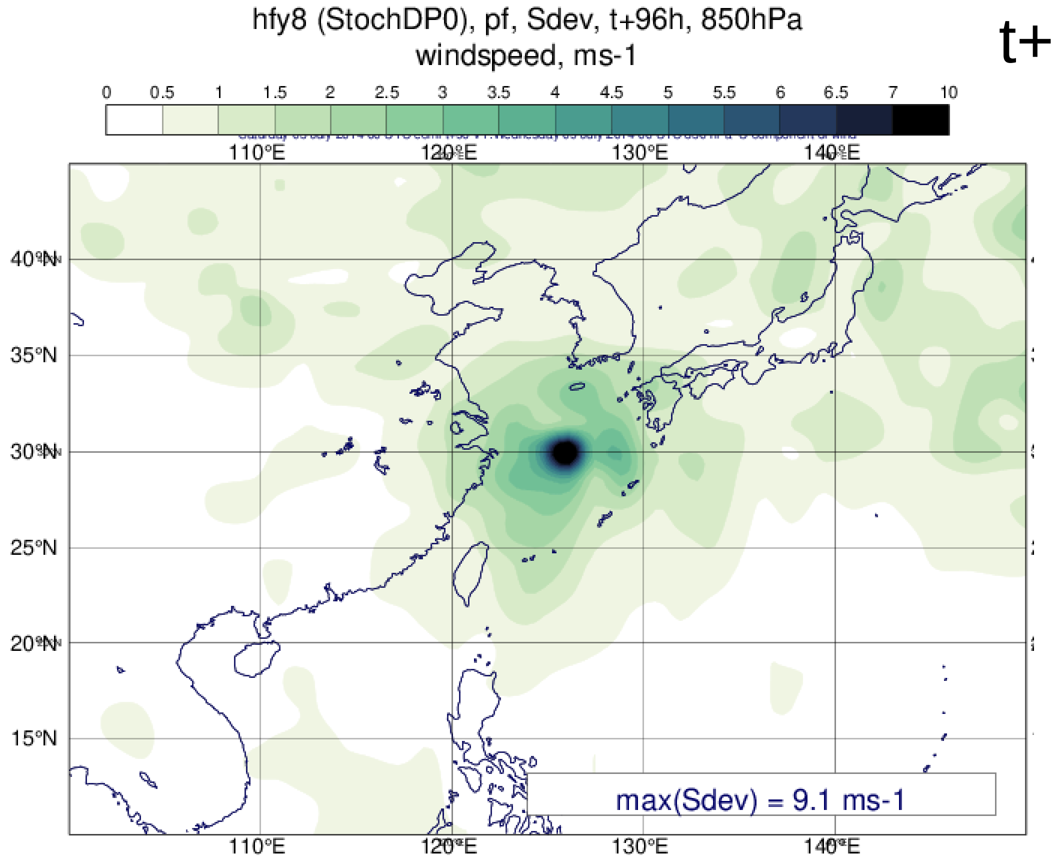


STOCHDP *(dt=720s)*

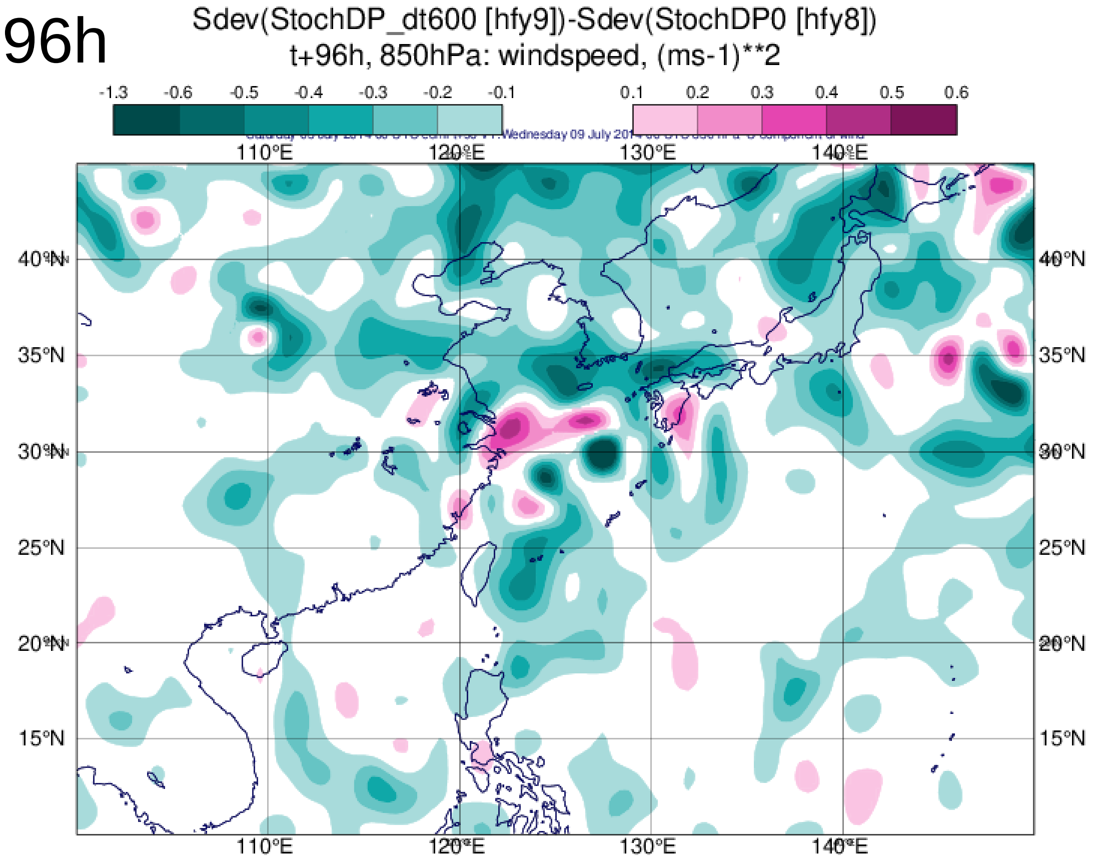
Ensemble stdev - windspeed

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

STOCHDP case study: TC Neoguri --- sensitivities



t+96h



STOCHDP *(dt=720s)*

Ensemble stdev - windspeed

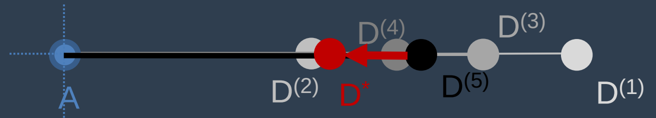
STOCHDP + dt=600s

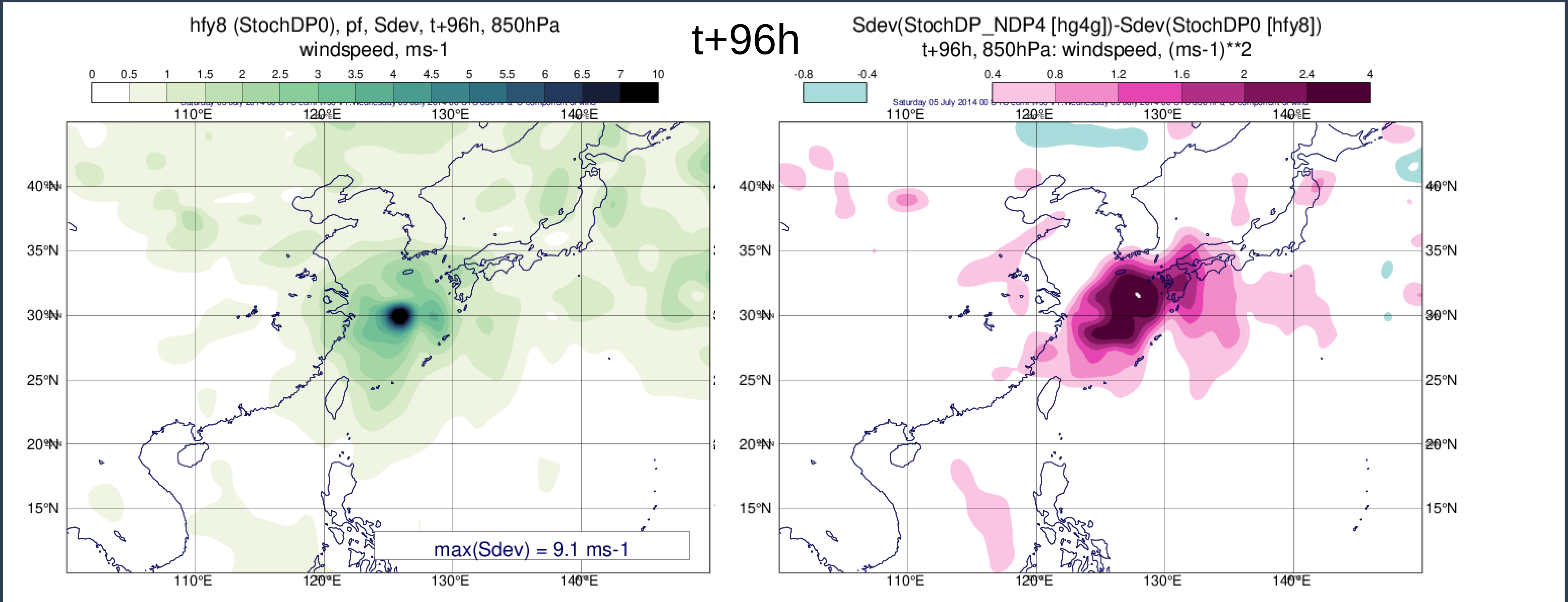
Shorter timestep:

- smaller spread (overall) ← *faster convergence of SL scheme*
- location of max spread differs ← *(reduced) phase speed errors*

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

STOCHDP case study: TC Neoguri --- sensitivities





STOCHDP ($D^{(5)}$-$D^{(2)}$) **Ensemble stdev - windspeed** **STOCHDP ($D^{(5)}$-$D^{(1)}$)**

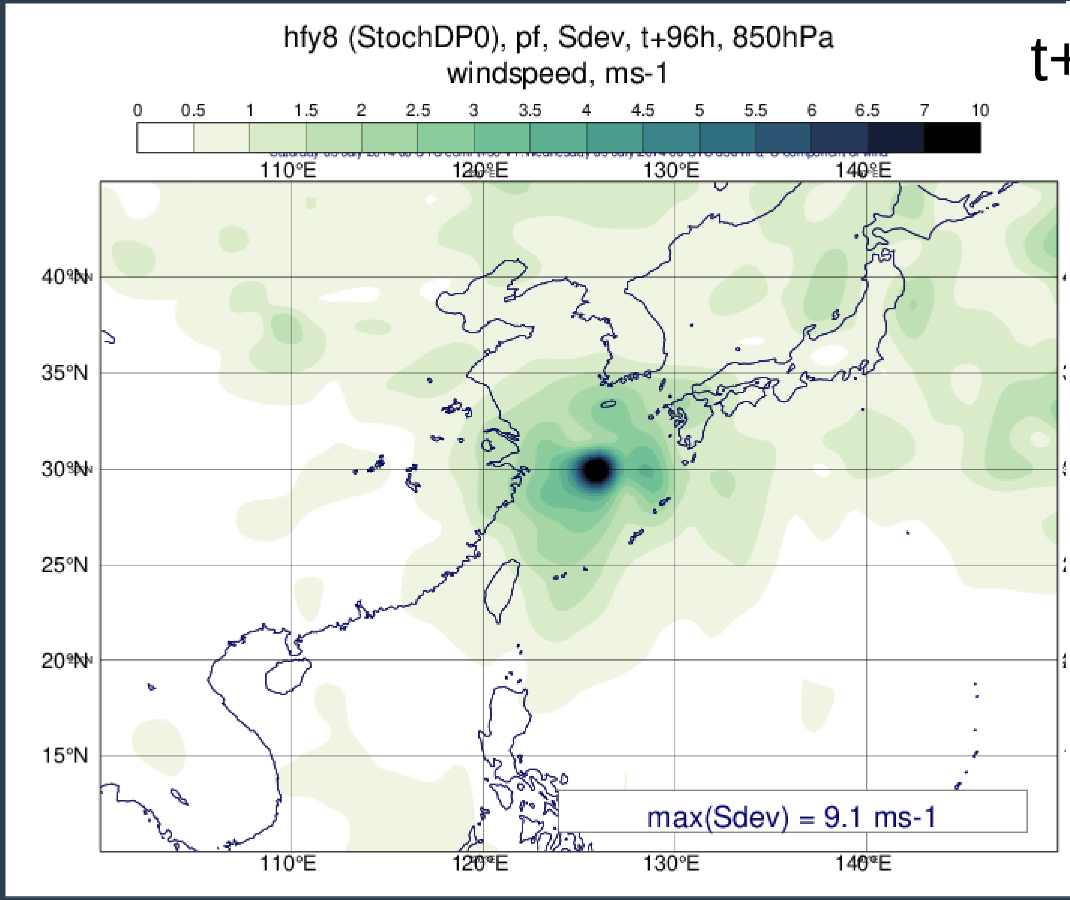
Using ($D^{(5)}$ - $D^{(1)}$) to construct the perturbation:

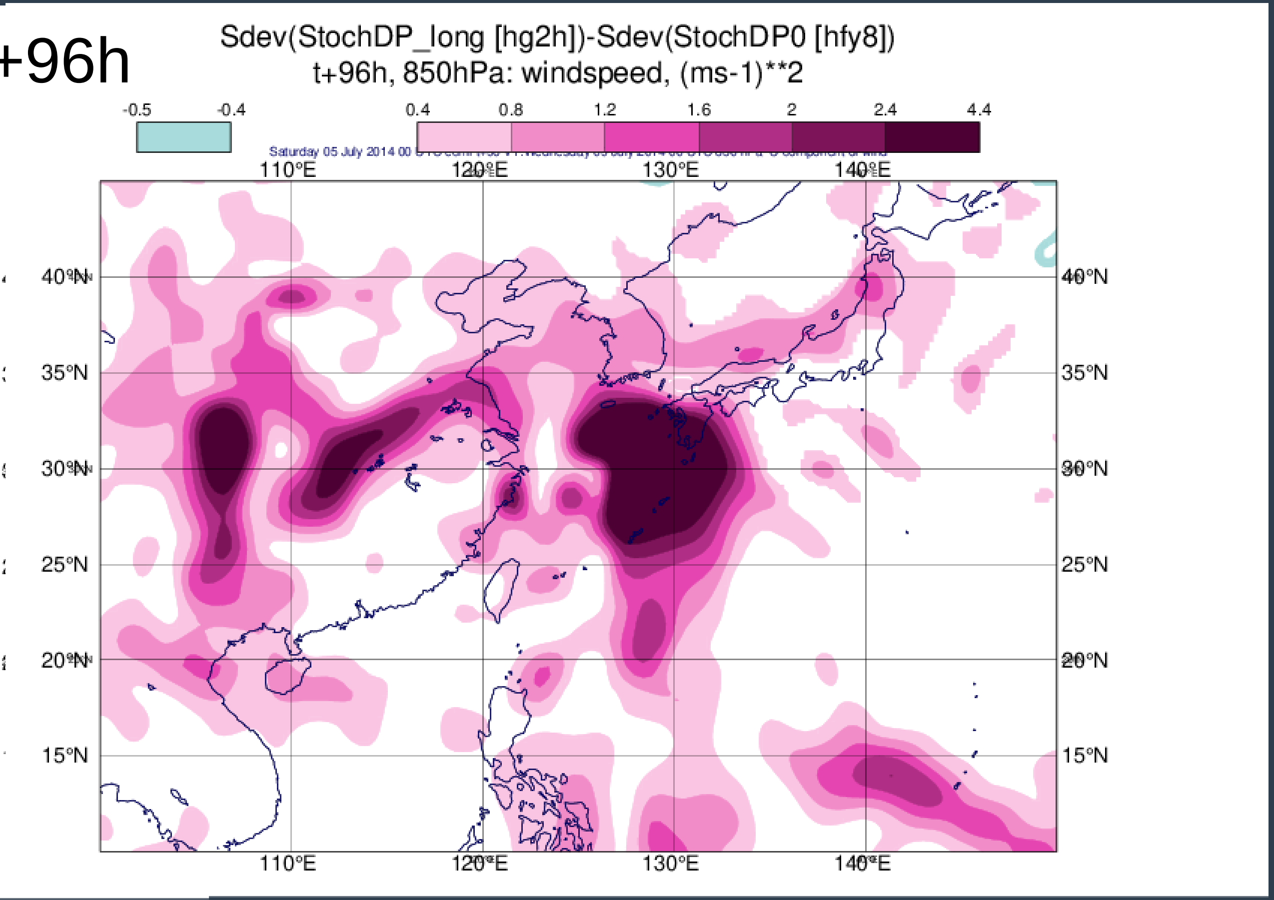
- amplitude of perturbations tuned for similar spread in global/regional analysis
- TC Neoguri: much greater spread ← *$D^{(1)}$ least accurate where flow most complex*

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

STOCHDP case study: TC Neoguri --- sensitivities

t+96h





STOCHDP *(6h, 500km)* **Ensemble stdev - windspeed** **STOCHDP + (72h, 2000km)**

Longer correlation scales in the random patterns:

- much greater spread
- extending over much larger area

ENS:
STOCHDP only
TCo639L91, dt=720s
20+1 members

Summary: Exploring model uncertainty representation in IFS transport scheme

Part I

STOCHDP:

- introduces stochastic perturbations to the SL departure point (DP) calculation in ENS
- uses convergence rate of unperturbed DP estimate to modulate size of perturbations
- ENS medium-range experiments show promise in terms of probabilistic skill

Part II

Typhoon Neoguri case study:

- STOCHDP generates ensemble spread close to the source of uncertainty
- Scheme sensitivities to timestep and DP calculation appear consistent with SL numerics

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Thank you for your attention!