

Towards Ensemble Land Data Assimilation at ECMWF

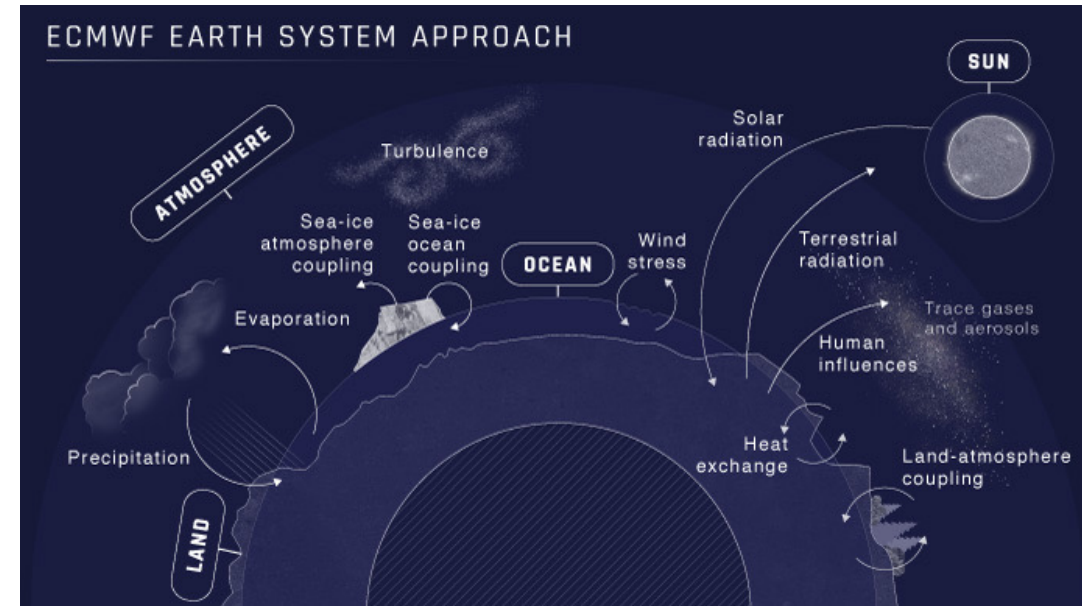
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Christoph Herbert, Kenta Ochi, Kirsti Salonen, Pete Weston,

With thanks to

Elias Holm, Simon Lang, Martin Leutbecher, Sarah-Jane Lock,
Aristofanis Tsiringakis, Gabriele Arduini, Gianpaolo Balsamo

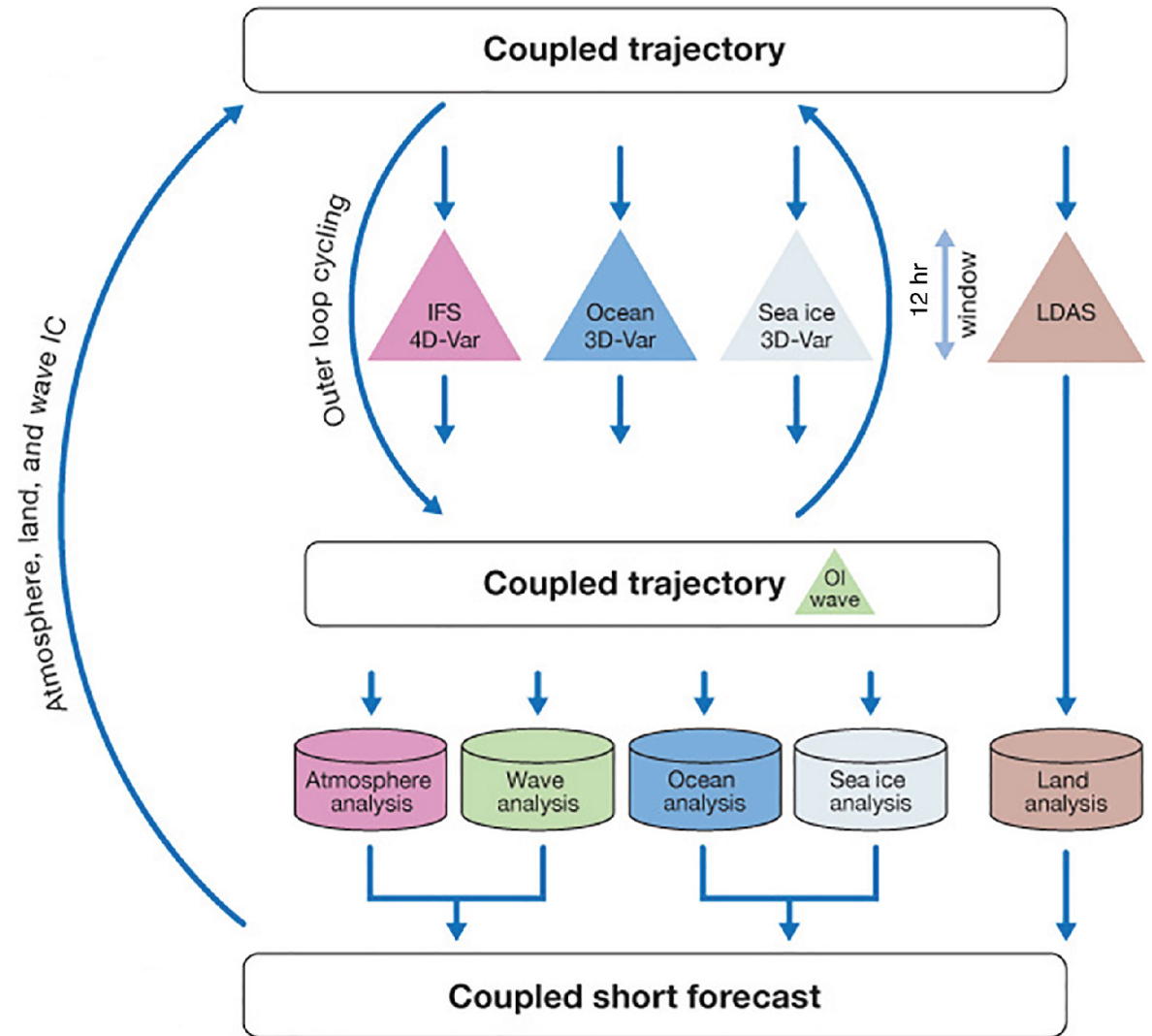
Talk Outline

- Overview of ECMWF Land Data Assimilation System (LDAS) activities
 - DA at ECMWF where does LDAS fit in
 - Land Data Assimilation System – Simplified Extended Kalman Filter (SEKF)
- Towards Ensemble Land DA at ECMWF
 - Status and results of using more ensemble information
 - Future perspectives - perturbed parameter ensembles
- Summary & Future Perspectives



DA at ECMWF... How Does LDAS Fit In?

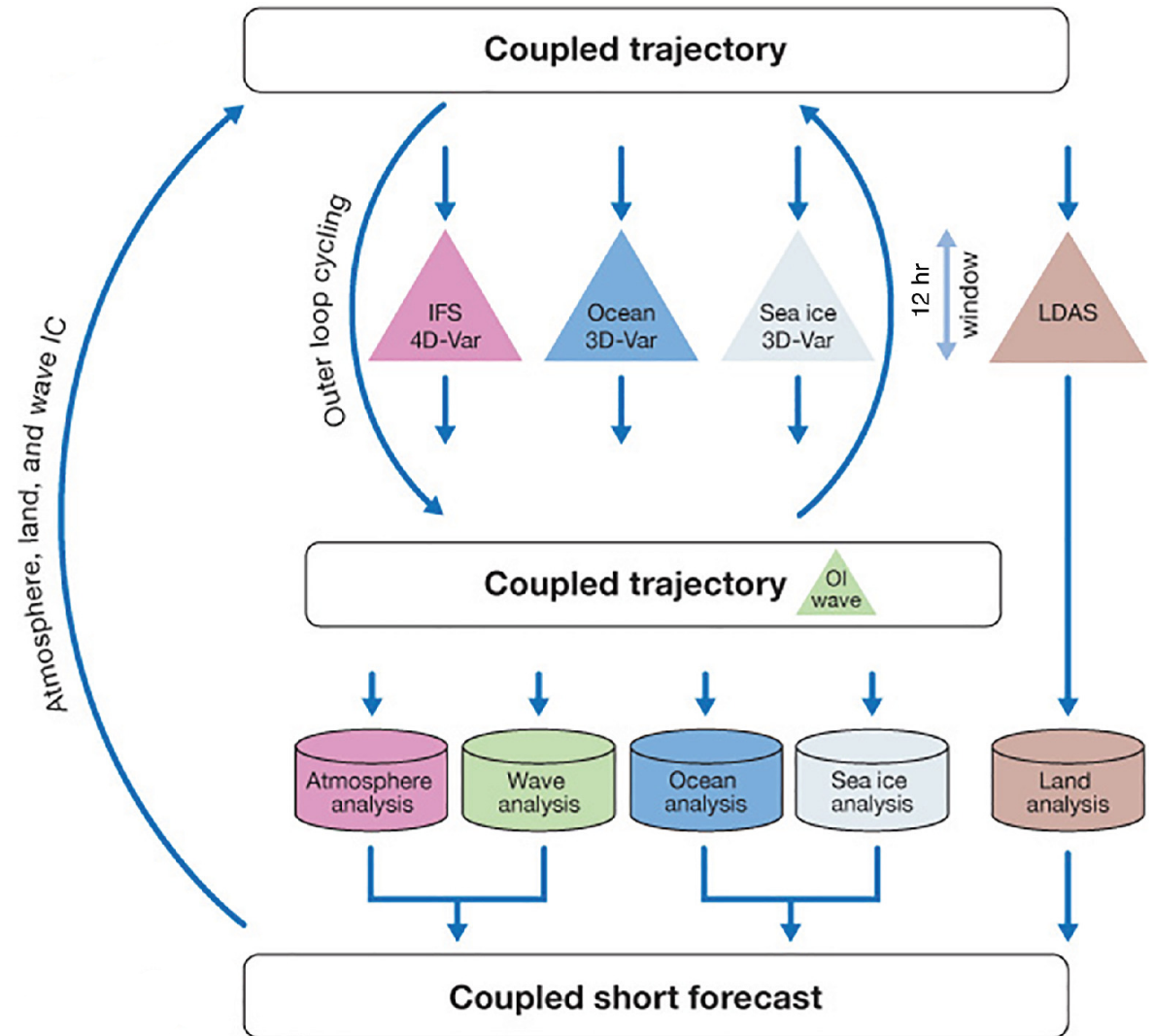
- LDAS currently weakly coupled
- Coupled trajectory analysis used as background in LDAS assimilation
- LDAS analysis used as initial state in subsequent coupled forecast
- Will be moved into “outer loop cycling” under the context of the CERISE project



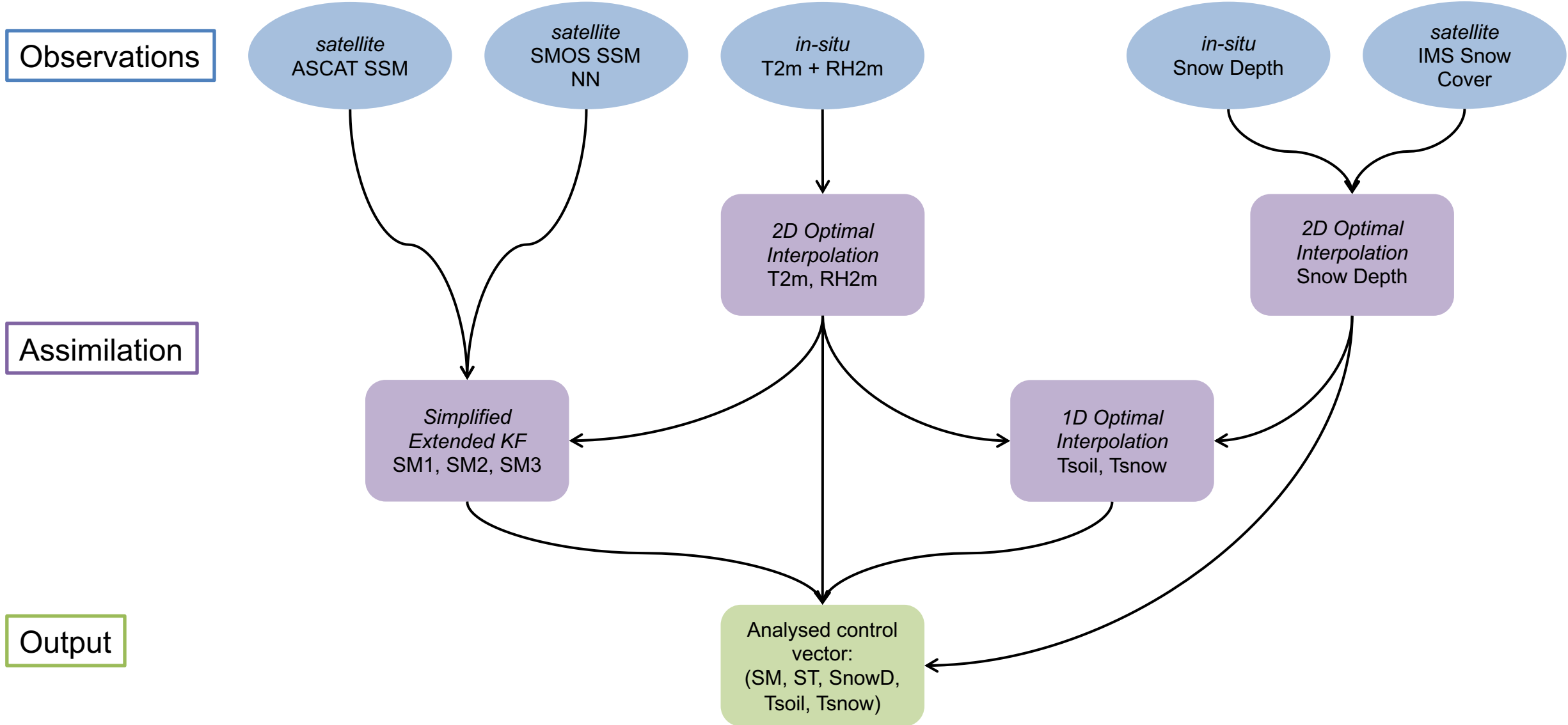
DA at ECMWF...

How Does LDAS Fit In?

- LDAS currently weakly coupled
- Coupled trajectory analysis used as background in LDAS assimilation
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- Will be moved into “outer loop cycling” under the context of the CERISE project
- More information in:
 - de Rosnay, P., et al. (2022) **Coupled data assimilation at ECMWF: current status, challenges and future developments**. *QJRMS*, <https://doi.org/10.1002/qj.4330>
- Special Collection at:
 - QJRMS “**Coupled Earth System Data Assimilation**” Submission deadline: 31 December 2023, [Special Collection Web Link](#)



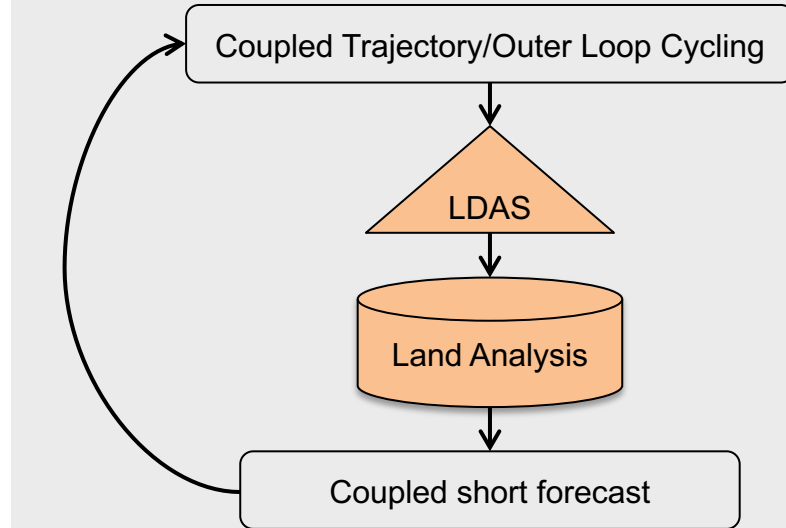
ECMWF's LDAS, What Does it Involve?



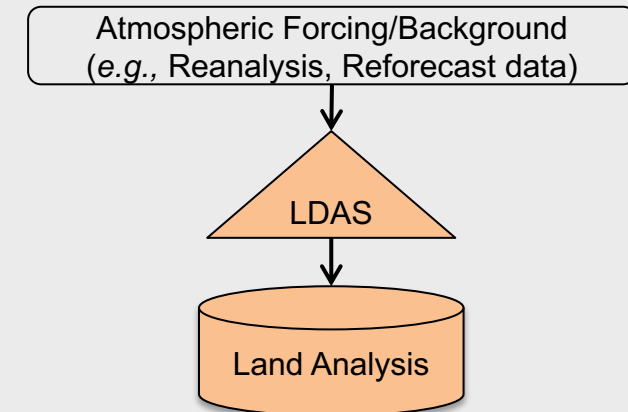
“Operational” vs “Offline” LDAS

- Previous slides show operational system used for forecast production
- Operational system coded in Fortran with no horizontal communication and parallelized per grid-cell
- Offline system used in generation of reanalysis products and seasonal forecast initialization
- Offline system coded in Python; problem solved globally with no parallelization
 - Parallelisation required as we move to higher resolutions for reanalysis

“Operational” System

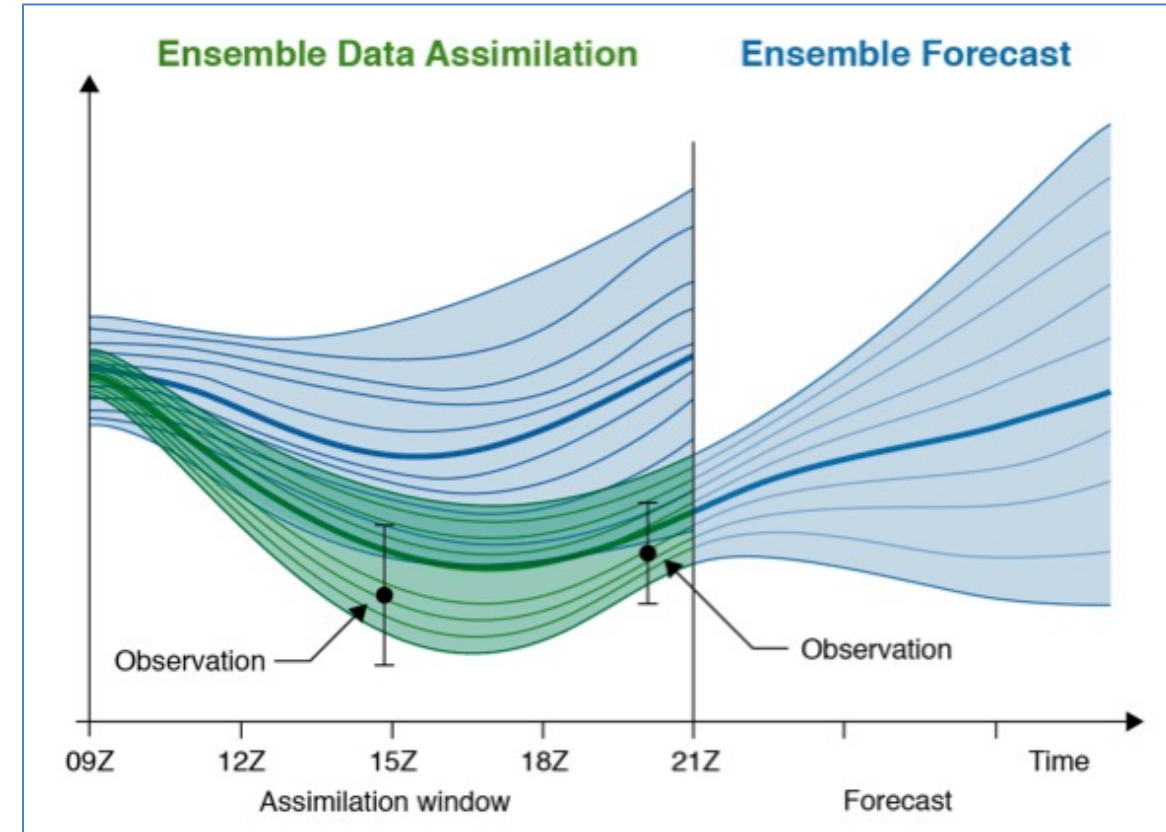


“Offline” System



Towards Ensemble Land DA...

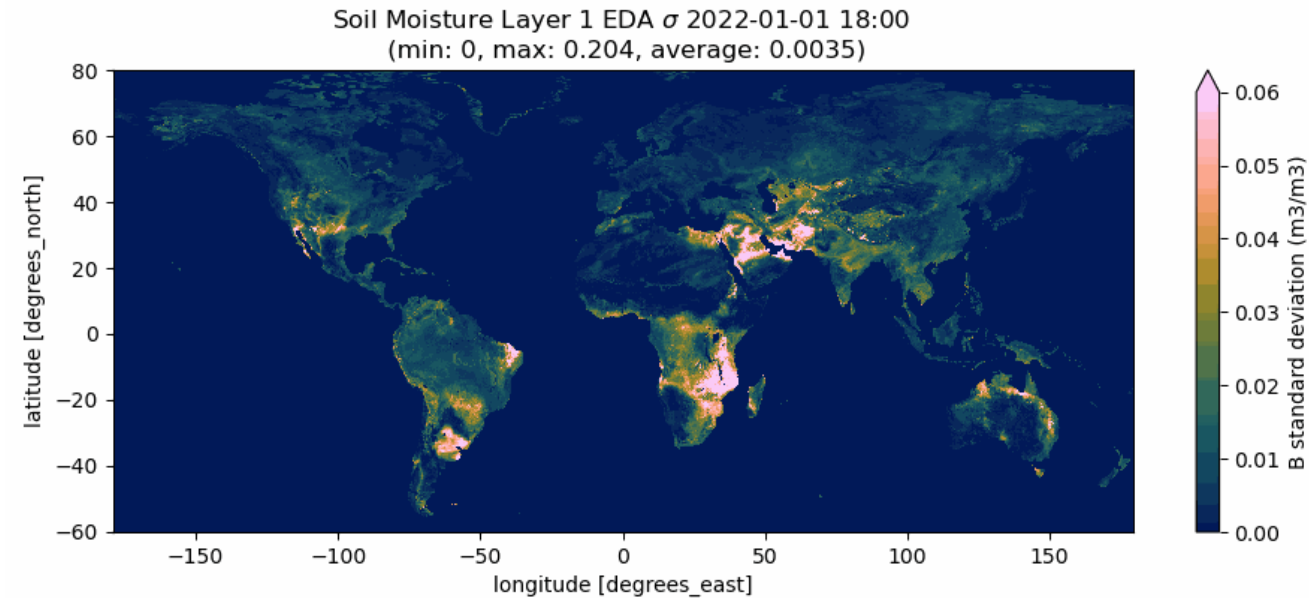
- 50-member Ensemble of atmospheric Data Assimilations (EDA) run in parallel to deterministic 4DVar
- Gives us information on model variable spread and sensitivities
- Outputs used in SEKF to construct linearized observation operator \mathbf{H} , in place of traditional finite-difference method
- Potential to use more information on land variable spread in ECMWF's LDAS...



Ensemble of Data Assimilations - Ensemble of atmospheric 4DVars with perturbed observations and forcing fields

Towards Ensemble Land DA...

- Currently assume static background error for Soil Moisture assimilation ($0.01 \text{ m}^3 \text{ m}^{-3}$)
- Ensemble of Data Assimilations (EDA) provides info on soil moisture spread
- Spread in EDA up to 20x larger than current specified Background error
- Experiments conducted on forecast impact of using EDA spread to construct flow-dependent B matrix



Towards Ensemble Land DA...

- Different specifications of **B**:

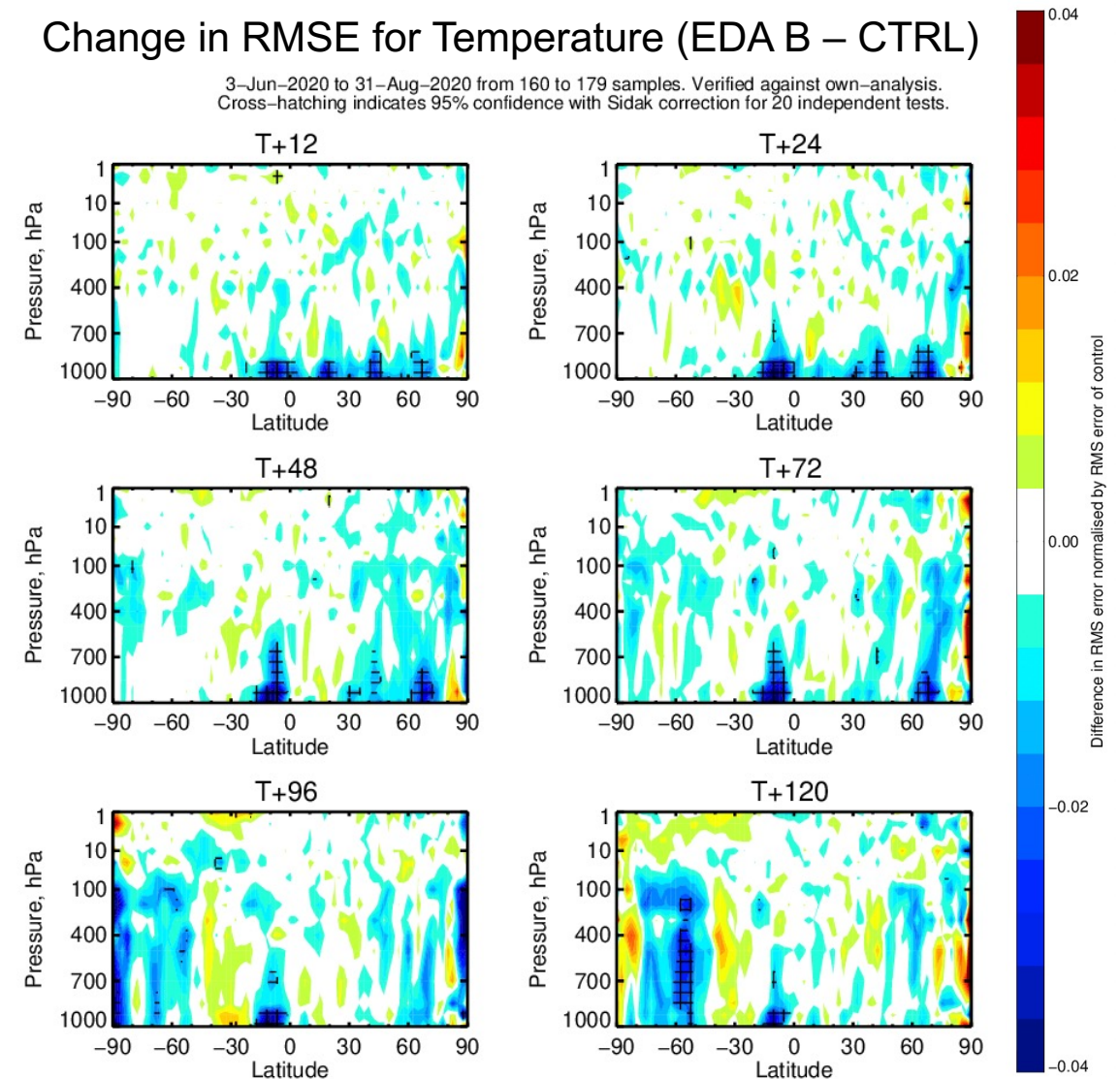
$$\mathbf{B} = \begin{pmatrix} 0.0001 & 0 & 0 \\ 0 & 0.0001 & 0 \\ 0 & 0 & 0.0001 \end{pmatrix}$$

$$\mathbf{B}_{EDA} = \begin{pmatrix} \sigma_{EDA,SM1}^2 & 0 & 0 \\ 0 & \sigma_{EDA,SM2}^2 & 0 \\ 0 & 0 & \sigma_{EDA,SM3}^2 \end{pmatrix}$$

- See good improvements to surface temperature in forecast from EDA B...

Change in RMSE for Temperature (EDA B – CTRL)

3–Jun–2020 to 31–Aug–2020 from 160 to 179 samples. Verified against own-analysis. Cross-hatching indicates 95% confidence with Sidak correction for 20 independent tests.



Towards Ensemble Land DA...

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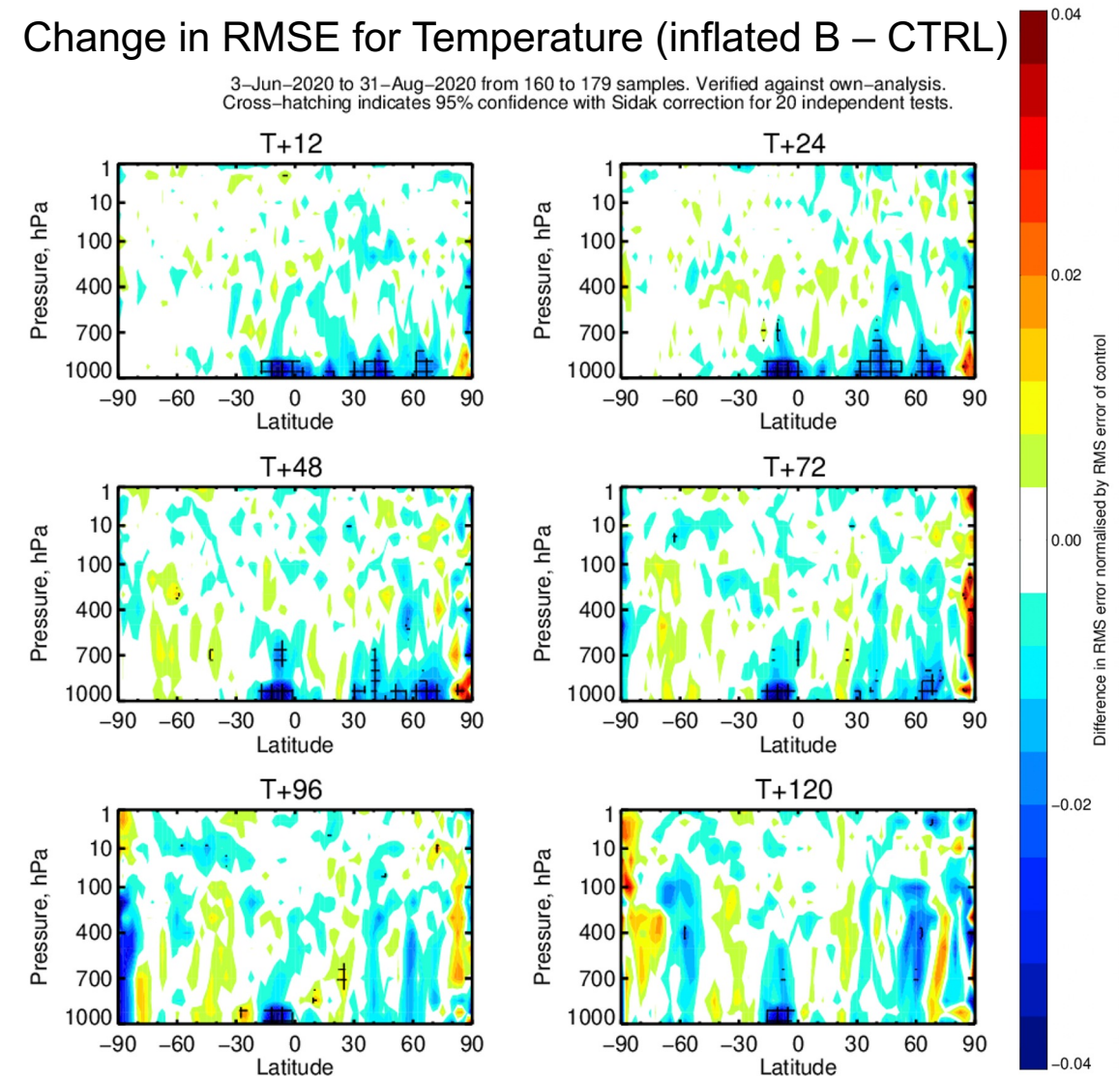
$$B = \begin{pmatrix} 0.0001 & 0 & 0 \\ 0 & 0.0001 & 0 \\ 0 & 0 & 0.0001 \end{pmatrix}$$

$$B_{inflated} = \begin{pmatrix} 0.0004 & 0 & 0 \\ 0 & 0.0004 & 0 \\ 0 & 0 & 0.0004 \end{pmatrix}$$

- See good improvements to surface temperature in forecast from EDA B...
- Also find improvements by just inflating background error
 - Putting this into operational cycle 49R1 (2024) merged with other Coupled Assimilation Team changes

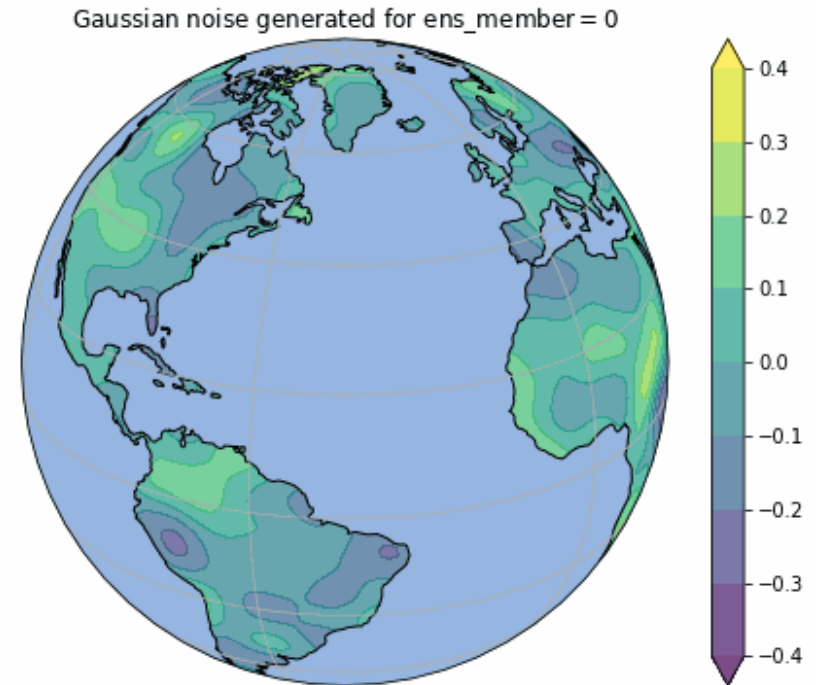
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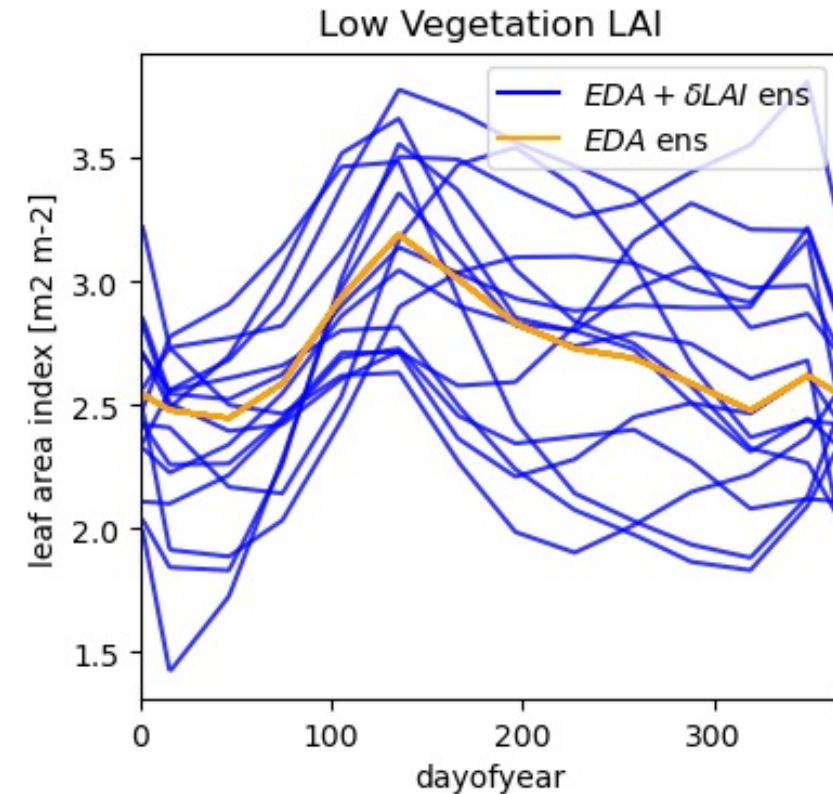
Towards Ensemble Land DA...

- Although the EDA provides a very good starting point it is under-spread at the surface
- We have applied Stochastic Parameter Perturbation approach for land surface model parameters (leaf area index, vegetation fraction) to see if this can increase spread at the surface in a set of “offline” experiments



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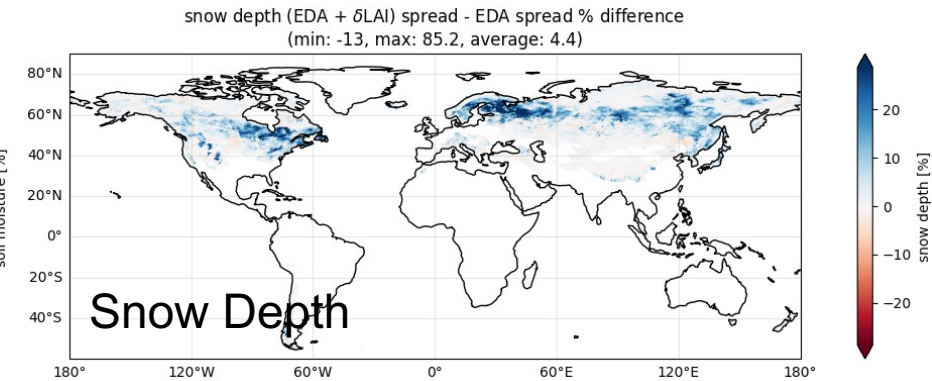
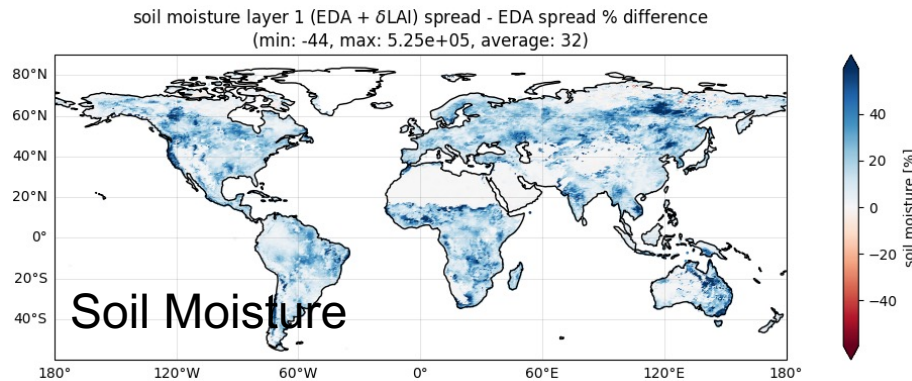
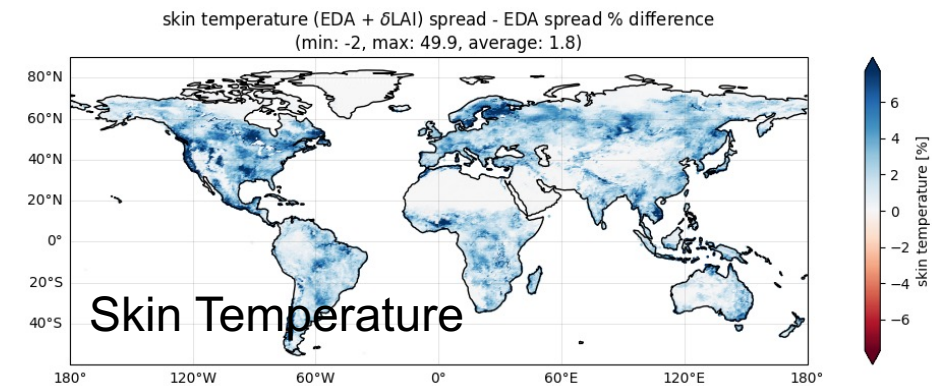
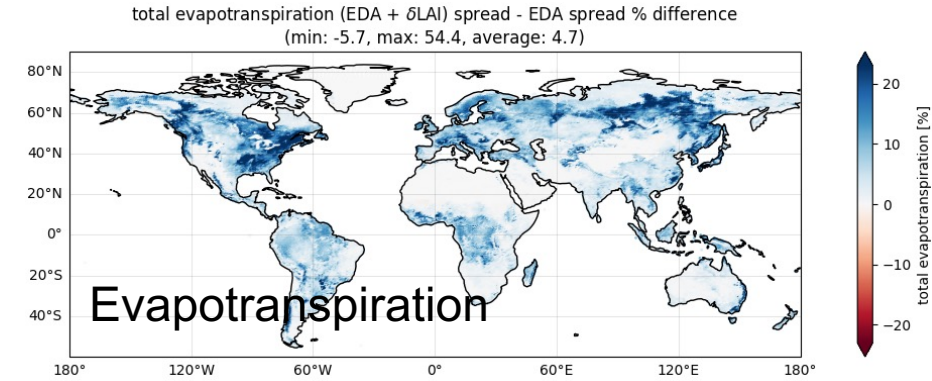
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Example Perturbations at single grid cell for Leaf Area Index

Towards Ensemble Land DA...

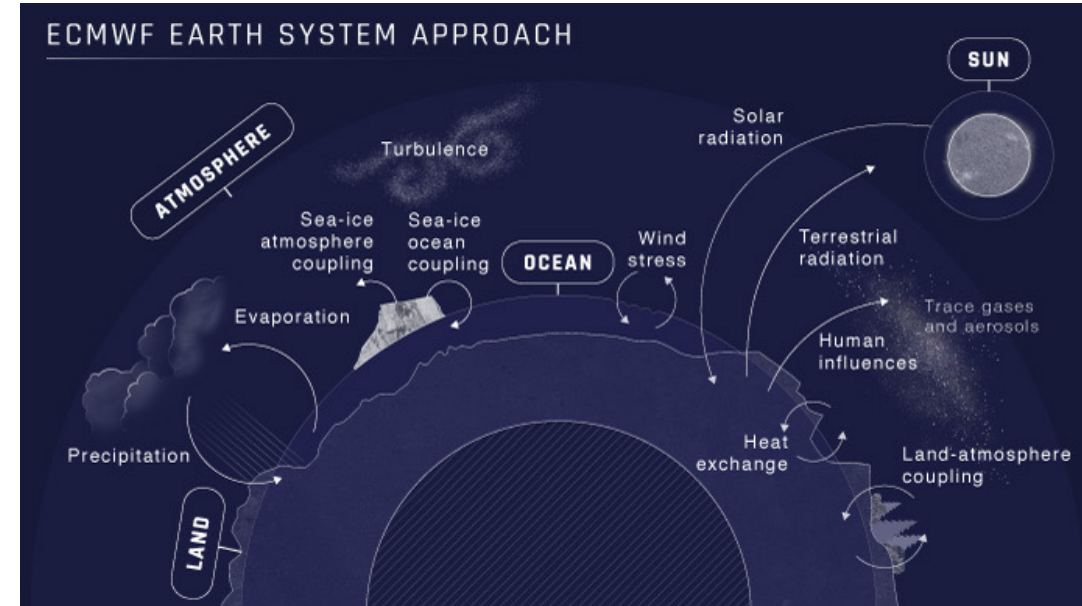
- Although the EDA provides a very good starting point it is under-spread at the surface
- We have applied Stochastic Parameter Perturbation approach for land surface model parameters (leaf area index, vegetation fraction) to see if this can increase spread at the surface in a set of “offline” experiments
- Results look promising for surface variable spread and future ensemble land surface data assimilation
- Potential to include these perturbations in EDA



Towards Ensemble Land DA...

Summary & Future Perspectives

- Adding more ensemble information to SEKF
 - Initial changes going into CY49R1 showing improvements to surface temperature forecasts
- Exploring ways to increase spread for land surface variables following SPP methodology
 - Find substantial increases in spread
 - Will be beneficial for future land surface ensemble DA (e.g., soil moisture, t2m, rh2m, fluxes, snow, leaf area index *etc.*)
- Future Perspectives
 - Building land surface parameter perturbations into the coupled EDA. Across Research Department collaboration
 - Testing different ensemble DA techniques with improved EDA spread



Thank You for Listening!