Developing and using JEDI for Earth system prediction

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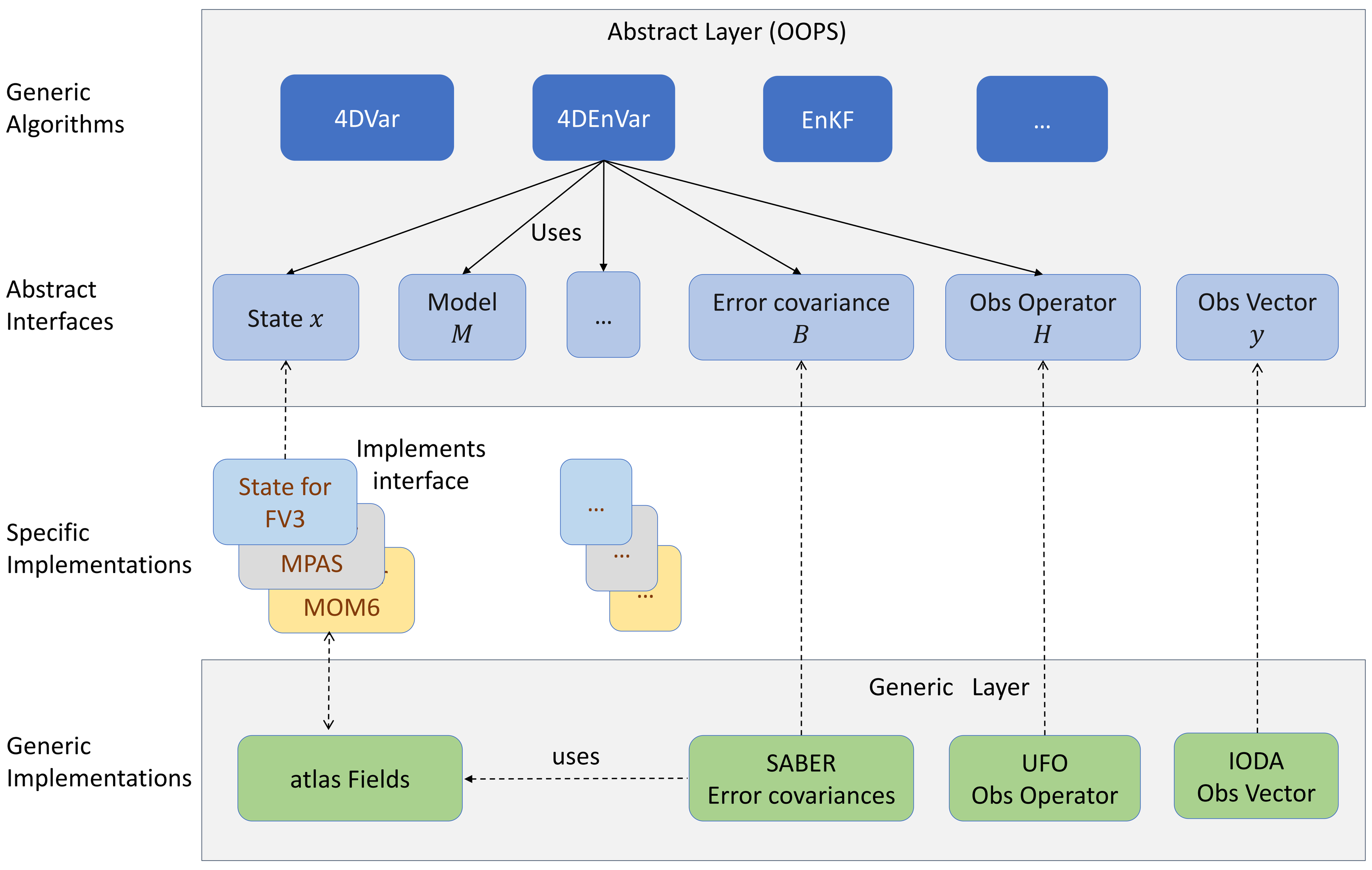
JEDI Overview

Joint Effort for Data assimilation Integration (JEDI): collaborative development of a unified DA system between the JCSDA partners (NOAA, NASA, Navy, Air Force; collaborations with UK Met Office and NCAR):

- From toy models to Earth system coupled models
- For research and operations (including O2R2O)
- Share as much as possible without imposing one approach

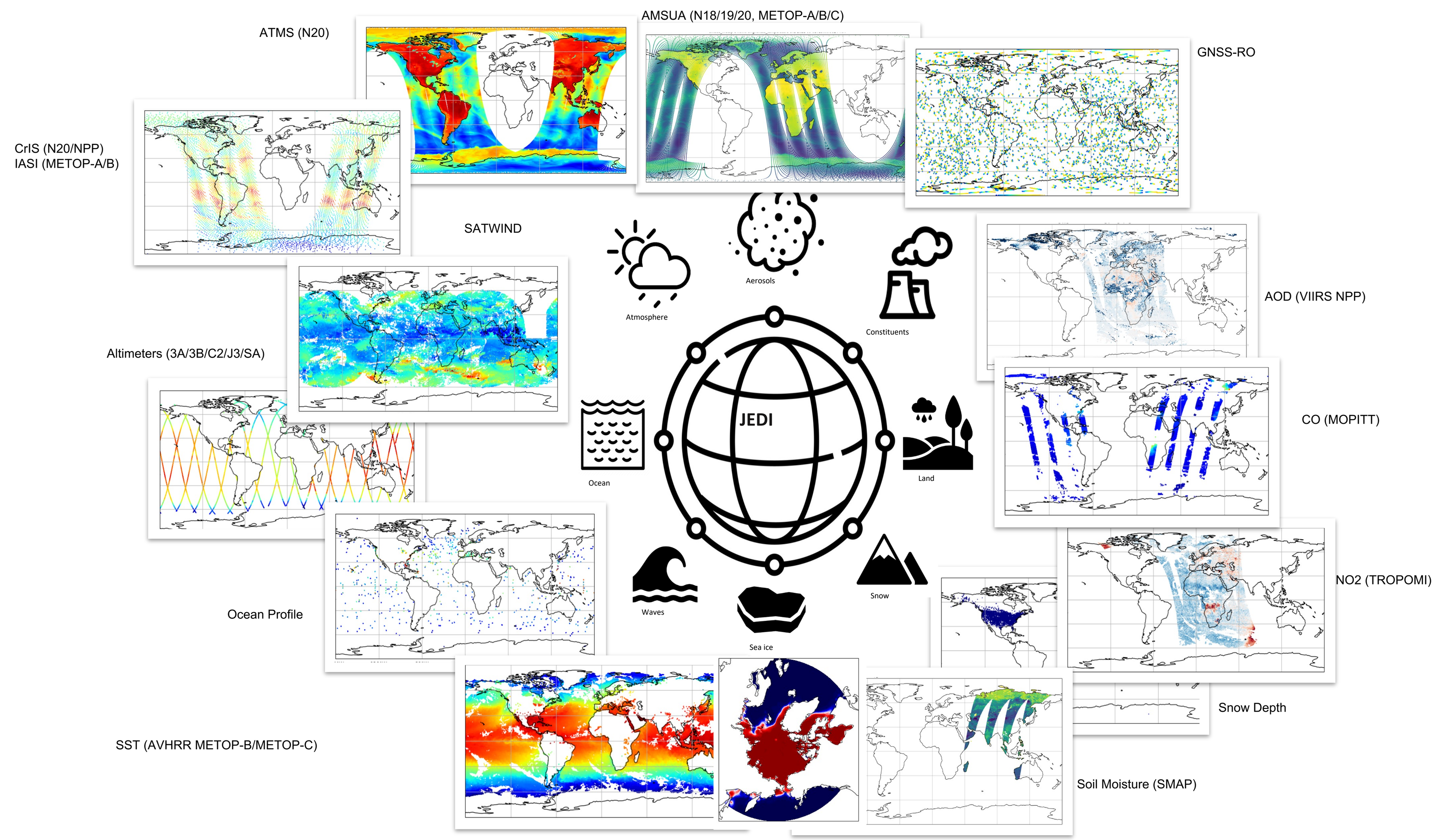
Most (Gaussian) DA algorithms can be written using concepts of x, y, H, M, B, R, without knowing what grid x is distributed on, how many different observed variables y may contain, and whether M is an atmospheric, a sea ice, or a multi-component coupled model.

The key of JEDI design is the "abstract interfaces" that are used by DA algorithms and implemented by specific models and specific observations.



JEDI: algorithms, models, observations

JEDI provides a variety of data assimilation algorithms; there are multiple observation operators and Earth system models interfaced to JEDI.



DA algorithms implemented in JEDI:

- **3DVar, 3DVar-FGAT, 4DEnVar, strong-constraint 4DVar** (all can be used with any of multiple choices of primal or dual minimizers), **weak-constraint 4DVar** (saddle point minimizer)
- **EDA** (with any Var from the above), **block-Lanczos EDA**, **control-pert EDA** (joint development with UK Met Office)
- **LETKF, LGETKF** (using modulated ensemble to emulate model-space vertical localization, joint development with NOAA/PSL)

Models interfaced to JEDI:

- Toy models: Lorenz95, QG
- Atmosphere: FV3 (NOAA GFS, NASA GEOS), MPAS (MMM/NCAR), Neptune (Navy), Lfric (UK MetOffice), UM (UK MetOffice)
- Ocean: MOM6 (SOCA), ROMS
- Sea ice: CICE5/6 (limited functionality)
- Land: Noah-MP, WRF-Hydro
- Composition: GFS with aerosols, GEOS-FP, GEOS-CF, GEOS-Chem

Observation operators interfaced to JEDI:

- Radiative transfer models: CRTM, RTTOV
- GNSSRO refractivity and bending angle operators, including interface to ROPP
- Conventional atmospheric and ocean obs
- In situ particulate matter
- Sea ice thickness

Generic implementations of data assimilation features in JEDI

JEDI allows for the flexibility in either implementing some data assimilation operations in the model interfaces, and/or using intermediate data structure (ECMWF's atlas library) to peruse the generic implementations of those operations that can be used with any model interface.

Some of the generic implementations include:

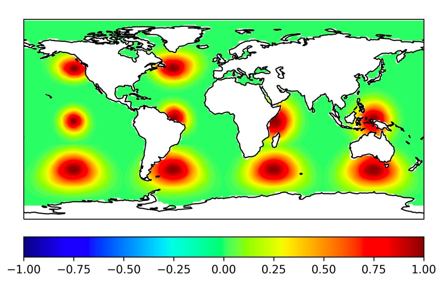
- Interpolations, including to/from observation locations for observation operators, between different grids for background error covariances (work in progress) and between different resolutions in outer loops (planned)
- Background error covariance implementations (SABER – System Agnostic Background Error Representation)
- Variable changes in model space (VADER – Variable Derivation Repository), including variable changes for observation operators and for background error covariance
- Implementation of the Ensemble Tangent Linear Model used in the Hybrid Tangent Linear Model (joint development with the UK Met Office)
- Planned: implementation of some of the linear algebra for the data assimilation

Background (and model) error covariances in JEDI (SABER)

A flexible framework for applying and estimating background (and model) error covariances: parametric, ensemble and hybrid, allowing for multiple components with ensembles on different grids.

$$B = \beta_1^2 B_{static} + \beta_2^2 L \circ B_{ensemble} + \cdots$$

Some of the background error covariances available in SABER:



- BUMP (Background error on an Unstructured Mesh Package), including NICAS (Normalized Interpolated Convolution on an Adaptive Subgrid)
- GSI covariance (developed by NASA/GMAO, see poster by Ricardo Todling)
- Spectral covariance (developed by UK MetOffice, see poster by Marek Wlasak)

Observation error covariances in JEDI

Some of the non-diagonal observation error covariance options:

- cross-channel (or cross-variable) correlations
- correlations among a group of observations (e.g. vertical correlations for the profile observations)

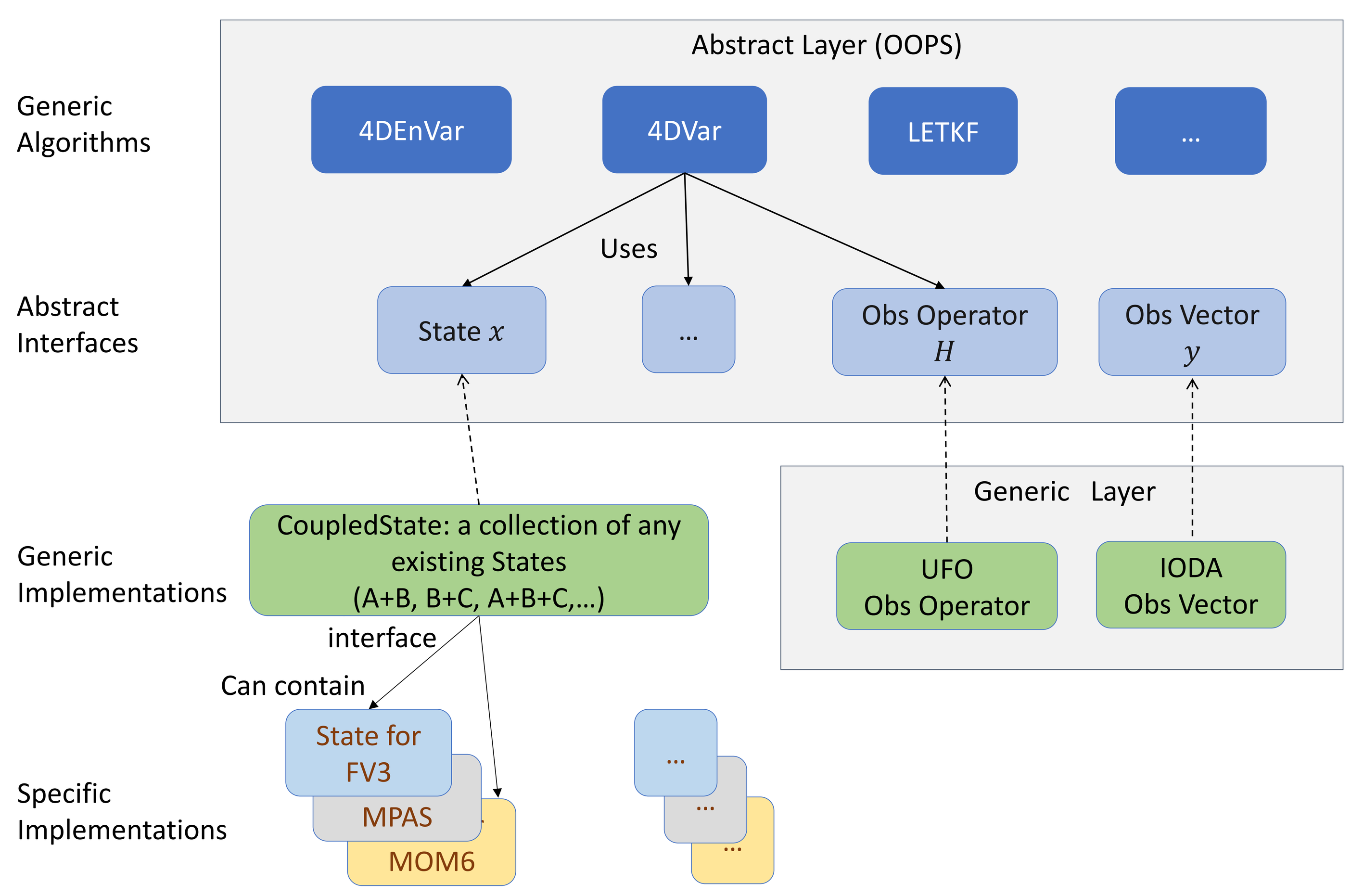
Development of coupled DA in JEDI

$$\Delta x_k^a = \mathbf{B}\mathbf{M}^\mathbf{T}\mathbf{H}^\mathbf{T}\left(\mathbf{H}\mathbf{M}\mathbf{B}\mathbf{M}^\mathbf{T}\mathbf{H}^\mathbf{T} + \mathbf{R}\right)^{-1}\left(y - H(M(x_{k-1}^a))\right)$$

Code design of JEDI simplifies technical aspects of coupled DA, but does not solve scientific questions.

Plans for coupling using JEDI:

- Coupling via M (outside of DA, use I/O in DA) - weakly coupled DA
- Coupling via H - use generic collection of states in observation operator (and its TL/AD for variational applications): work in progress for radiative transfer and ocean color observation operators
- Coupling via **B** – use cross-covariances between different components
- Coupling via M (inside a single DA executable without using I/O) – run coupled model within DA (e.g. for outer loop coupling)



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