Refactoring of the SABER blocks

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JEDI Algorithms meeting

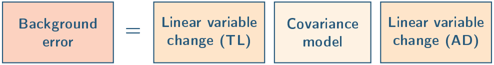
September 26, 2022

Background error covariance matrix

YAML template for background error:

```
background error:
  covariance model: CovarianceModel
    [... Covariance model parameters ...]
  linear variable change:
    [... Linear variable change parameters ...]
    input variables: [...]
    output variables: [...]
```

Block representation:



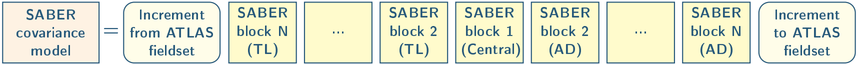
Background error = Linear variable change (TL) Covariance model Linear variable change (AD)

Options:

- Linear variable change (TL) and Linear variable change (AD) → model-specific or coming from VADER
- Covariance model → model-specific or coming from SABER

SABER blocks

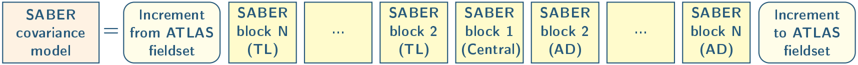
SABER covariance model:



SABER covariance model = Increment from ATLAS fieldset | SABER block N (TL) | ... | SABER block 2 (TL) | SABER block 1 (Central) | SABER block 2 (AD) | ... | SABER block N (AD) | Increment to ATLAS fieldset

SABER blocks

SABER covariance model:



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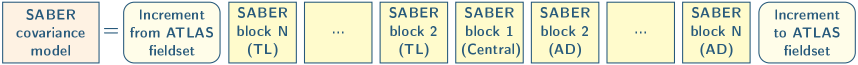
What is new in the branch `feature/refactor_saber_block`?

- Two different classes of blocks:
  - Central block, auto-adjoint.
  - Outer blocks, with forward and adjoint multiplications.
- Different constructors and methods.
- No more `<MODEL>` templating.
- Sequential construction of blocks to ensure geometry and variables consistency.

Sequential construction

SABER covariance model:



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Sequential construction requirements:

- For each block, the outer geometry and variables are provided as arguments in the constructor.
- For outer blocks, methods are available to return required inner geometry and variables.
- Blocks are successively constructed in reverse order: inner geometry and variables of block i are used as outer geometry and variables of block $i-1$.
- The outer geometry and variables of the block N must be consistent with the increment

Sequential construction

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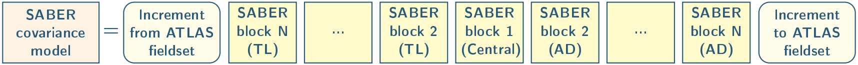

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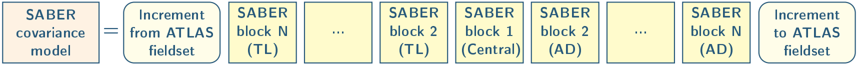

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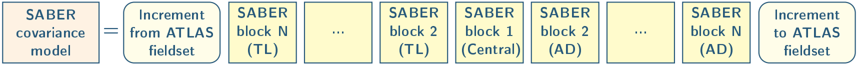

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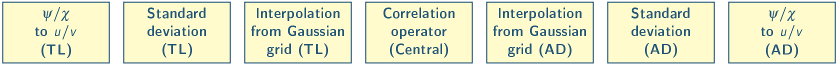
Sequential construction example

Basic wind covariance:



ψ/χ to u/v (TL)

Standard deviation (TL)

Interpolation from Gaussian grid (TL)

Correlation operator (Central)

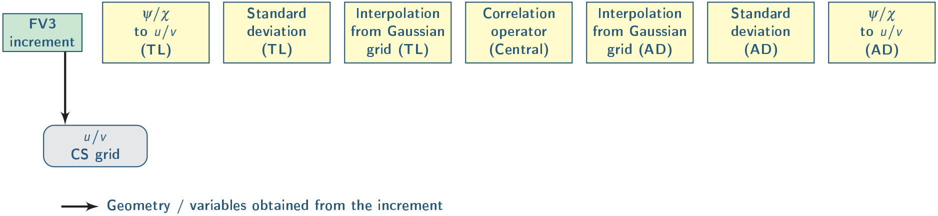
Interpolation from Gaussian grid (AD)

Standard deviation (AD)

ψ/χ to u/v (AD)

Sequential construction example

Basic wind covariance:



FV3 increment

ψ/χ to u/v (TL)

Standard deviation (TL)

Interpolation from Gaussian grid (TL)

Correlation operator (Central)

Interpolation from Gaussian grid (AD)

Standard deviation (AD)

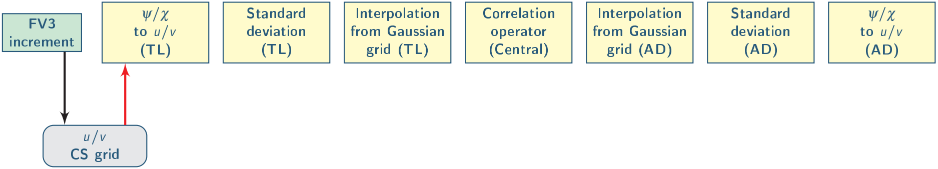
ψ/χ to u/v (AD)

u/v CS grid

→ Geometry / variables obtained from the increment

Sequential construction example

Basic wind covariance:



FV3 increment
ψ/χ to u/v (TL)
Standard deviation (TL)
Interpolation from Gaussian grid (TL)
Correlation operator (Central)
Interpolation from Gaussian grid (AD)
Standard deviation (AD)
ψ/χ to u/v (AD)
u/v CS grid

⟶ Geometry / variables obtained from the increment

⟶ Outer geometry / variables provided in the block constructor

Sequential construction example

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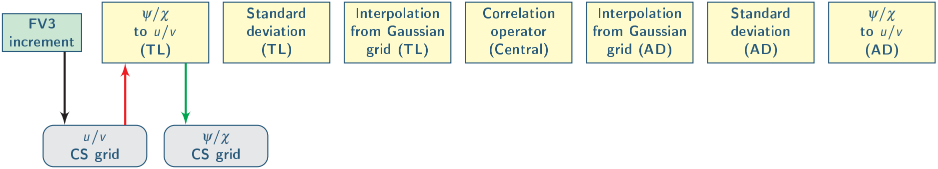
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Standard deviation (AD)
ψ/χ to u/v (AD)
u/v CS grid
ψ/χ CS grid

→ Geometry / variables obtained from the increment

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Sequential construction example

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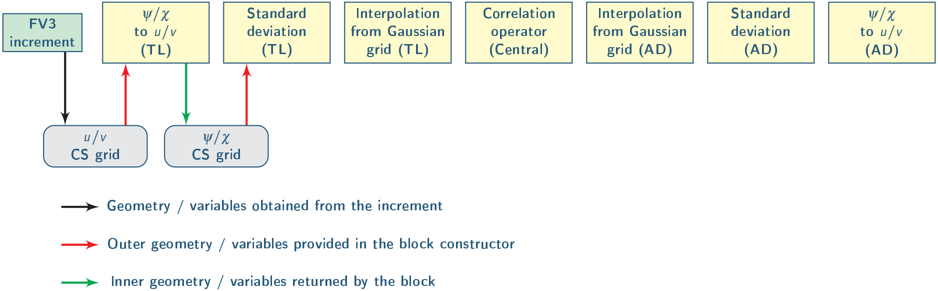

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Correlation operator (Central)

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ψ/χ to u/v (AD)

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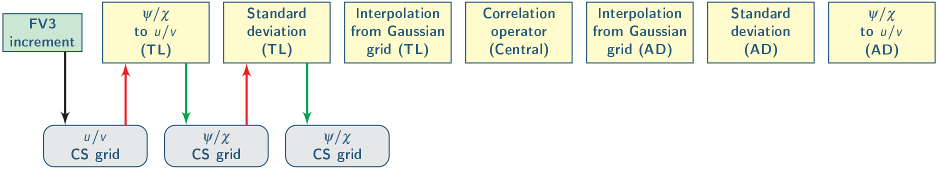

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Interpolation from Gaussian grid (AD)

Standard deviation (AD)

ψ/χ to u/v (AD)

u/v CS grid

ψ/χ CS grid

ψ/χ CS grid

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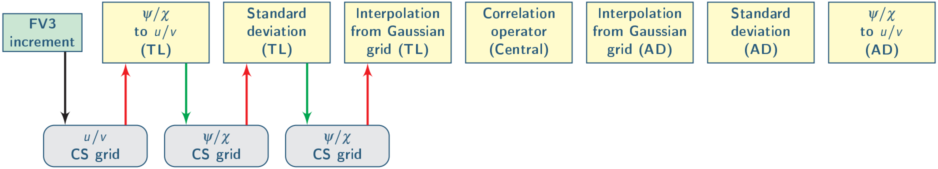

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Standard deviation (AD)

ψ/χ to u/v (AD)

u/v CS grid

ψ/χ CS grid

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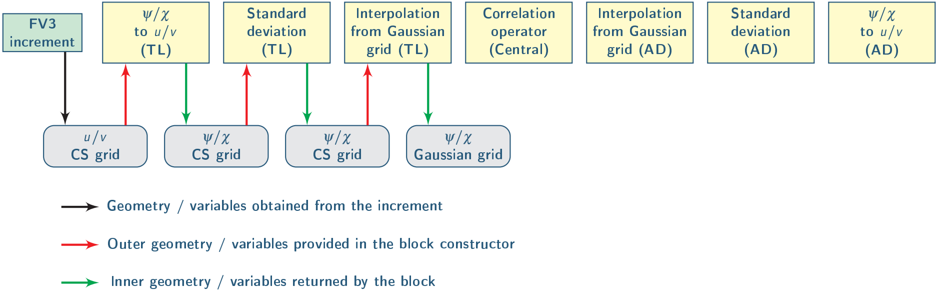

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ψ/χ to u/v (AD)

u/v CS grid

ψ/χ CS grid

ψ/χ CS grid

ψ/χ Gaussian grid

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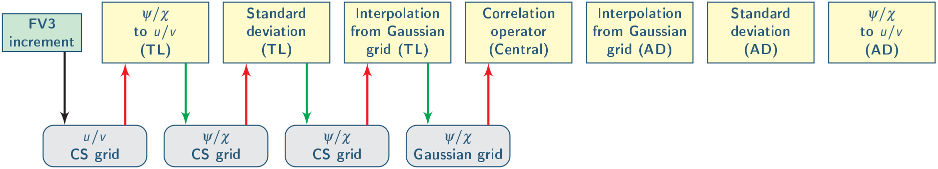

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ψ/χ to u/v (AD)

u/v CS grid

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ψ/χ CS grid

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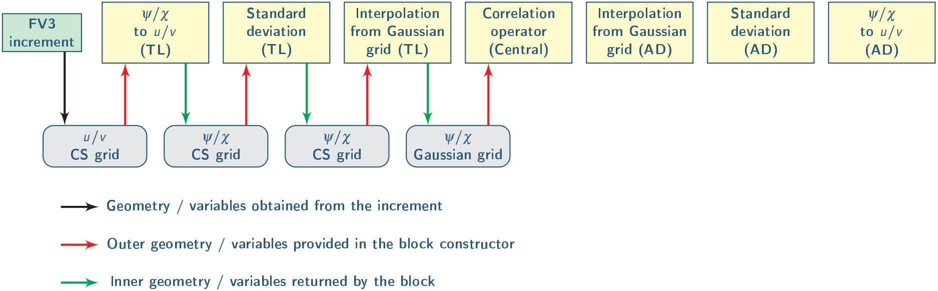

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ψ/χ CS grid

ψ/χ Gaussian grid

Geometry / variables obtained from the increment

Outer geometry / variables provided in the block constructor

Inner geometry / variables returned by the block

Remarks:

- For each block, internal checks can ensure that outer geometry and variables provided in the constructor are expected.
- For the central block, there is no such thing as “inner” or “outer” geometry and variables, just geometry and variables.

Methods

Central blocks methods:

- `randomize(atlas::FieldSet &)`
- `multiply(atlas::FieldSet &)`
- No more inverse: only an iterative inverse for the whole matrix is used. This might change "Nonlinear Jb" values in tests references.

Outer blocks methods:

- `multiply(atlas::FieldSet &)`
- `multiplyAD(atlas::FieldSet &)`
- `calibrationInverseMultiply(atlas::FieldSet &)`
- Accessors to inner geometry and variables

The calibration inverse is a (possibly approximate) left-inverse of the outer block.

YAML files update

Generic keys:

- `saber block name` [required]: block name
- `active variables` [optional]: potentially affected variables
- `input fields` [optional]: list of model-specific files to read

Old yaml

```
covariance model: SABER
saber blocks:
- saber block name: BUMP_NICAS
  saber central block: true
  input variables: &control_vars [...]
  output variables: *control_vars
  active variables: &active_vars [...]
  bump:
    # [BUMP parameters]
    universe radius:
      # [universe radius file parameters]
- saber block name: StdDev
  input variables: *control_vars
  output variables: *control_vars
  active variables: *active_vars
  file:
    # [standard-deviation file parameters]
```

New yaml

```
covariance model: SABER
saber central block:
  saber block name: BUMP_NICAS
  active variables: &active_vars [...]
  bump:
    # [BUMP parameters]
  input fields:
  - parameter: universe radius
    # [universe radius file parameters]
saber outer blocks:
- saber block name: StdDev
  active variables: *active_vars
  input fields:
  - parameter: StdDev
    # [standard-deviation file parameters]
```

Conclusions

Work in progress:

- Code is working, but not stable yet.
- Modifications are required in most repos:
  - OOPS: new template-free `GeometryData` class
  - SABER: full refactoring
  - All models: YAML and references
- YAML / references update for all models is ongoing. Some adjustments in the code might be needed depending on how tests will behave.
- Coordinated merge required once everything is ready.

Upcoming modifications:

- Generic SABER block to call VADER change of variables.
- Refactoring of the halo handling in B and H