Subcolumns in CAM

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The CAM subcolumn infrastructure provides the ability to create fields with several elements within a single grid column.

- Rationale for subcolumns
- Introduction to subcolumn usage in CAM physics
- Introduction to infrastructure changes made to support subcolumns
- Current subcolumn development efforts
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Rationale for subcolumns

- Allow parameterizations finer granularity than the traditional grid box
- Use a statistical approach to sample within a single column or physically subdivide the column
- Don’t need to increase resolution on entire model to study one parameterization in detail

(Satellite view of earth)
Standardizing subcolumns

- Subcolumns already exist in CAM – radiation, SPCAM branch, etc.
- Each implementation is specialized – “shoehorned” into old existing static structures
- Not able to share subcolumns between parameterizations due to unique implementations
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The CAM Physics Package

- A collection of parameterized physics or chemistry processes (usually called parameterizations).
- A parameterization is handed a ‘chunk’ of grid columns to work on in one call.
- Each parameterization takes the model state and returns changes to the model state (‘tendencies’).
- `subcol_gen` creates a state with subcolumns which a subcolumn-aware parameterization will use to create a tendency with subcolumns.
The CAM Physics Package

Physics parameterizations with no subcolumns (simplified dataflow)

- **state**: The CAM physics state
- **tend**: The changes to variables used by the dynamical core (e.g., $\dot{u}, \dot{v}, \dot{t}$)
- **ptend**: The changes to state variables calculated by a parameterization
The CAM Physics Package

Adding subcolumn support (still simplified dataflow)

subcol_gen creates a state and tend with subcolumns
Physics parameterization B uses subcolumns
Parameterization tendency is averaged with subcol_ptend_avg
Physics Parameterization w/ Subcolumns
(subcolumn code not on CAM trunk)

- Retrieve needed fields from the physics buffer: `pbuf_get_field` (using the col_type optional input)
- Copy fields which are not defined on subcolumns: `subcol_field_copy`
- Operate on fields (math; involves loop over state%ncol)
- Update parameterization tendency fields
- Average subcolumn fields: `subcol_field_avg`
- Output grid fields to history: `outfld`
- Output subcolumn fields to history: `subcol_outfld`
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Features of changes

- \texttt{state\%ncol} is still the number of columns to loop over inside parameterizations
  - underlying physics parameterizations do not require code modifications - work the same whether grid or subcolumns
- Variable number of subcolumns per grid column
- Grid and/or subcolumn fields only allocated as requested
- \texttt{state} (for grid) and \texttt{state\_sc} (for subcolumns) may both exist at same time – synchronization occurs between parameterizations
- Several subcolumn generators may exist in CAM, but only one will be used per run
Dynamic state/tend/ptend changes

- Variables unchanged within new subcolumn framework
  - pcols - maximum number of grid columns
  - state%ncol - number of columns to loop over inside parameterizations
    - may be larger than pcols is using subcolumns
- New implementation to support subcolumns
  - psubcols - maximum number of subcolumns = 1 for grid
  - state%psetcols - maximum number of total columns
    - whether using grid or subcolumns = pcols*psubcols
    - replaces pcols in a lot of places
- state/tend/ptend are now dynamically allocated
New Fields to support subcolumns

**Subcolumnized data**

**Conceptual Layout**

<table>
<thead>
<tr>
<th>Grid columns</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcolumns</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

X = Data locations

**Internal Storage Layout - compressed**

<table>
<thead>
<tr>
<th>Grid Columns</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Subcolumns**

- pcols = 6
- ngrdcol = 5
- psubcols = 4
- nsubcol(6) = (2,1,3,1,1,0)
- psetcols = 24
- ncol = 8
- indcol(24) = (1,1,2,3,3,3,4,5,0,...)

**Grid data**

<table>
<thead>
<tr>
<th>Grid columns</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

- pcols = 6
- ngrdcol = 5
- psubcols = 1
- nsubcol(6) = (1,1,1,1,1,0)
- psetcols = 6
- ncol = 5
- indcol(6) = (1,2,3,4,5,0)
Physics buffer (pbuf) changes

pbuf structure contains:

(buffer_field_type):: bfg%data  – holds grid data
(buffer_field_type):: bfg_sc%data  – holds subcolumn data – NEW

- bfg%data and bfg_sc%data are only allocated as requested
- Each physics buffer field can have grid-only, subcolumn-only or both grid and subcolumn data
New control parameters

**col_type:** int  
- 0=grid, 1=subcolumns

Used to identify WHICH field (used in pbuf_get_field for example)

**grid_type:** int(bit_field_kind)  
- each bit is turned on/off to indicate which field(s) are required

<table>
<thead>
<tr>
<th>Grid and subcolumn</th>
<th>Grid only</th>
<th>Subcolumn only</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 0 0 0 0 ...</td>
<td>1 0 0 0 0 0 ...</td>
<td>0 1 0 0 0 0 ...</td>
</tr>
</tbody>
</table>

Used to identify ALL fields which are currently turned on (used in pbuf_add_field for example)
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Status

- Currently being implemented in CAM
- Infrastructure changes committed to CAM development trunk:
  - Part of CAM trunk since cam5_3_03
  - Note that this infrastructure is not in CESM 1.2 (except for the dynamic allocation of state/tend/ptend which was committed in cam5_2_09).
- Subcolumn support is being implemented in CAM microphysics (Gettelman, Craig)
Subcolumn Schemes

- Subcolumn generation/averaging is still under development (2 groups are currently prototyping subcolumn schemes).
  - SILHS and CLUBB: Improve the representation of sub-grid variability using an ensemble approach to microphysics driven by sampling the PDF output from CLUBB (Thayer-Calder, Larson, Bacmeister, Gettelman).
  - Cloud Model: Study extended cloud dynamics by creating subgrid-scale cloud objects which persist across time steps (Bacmeister, Goldhaber).
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Summary

- CAM now has a subcolumn infrastructure which introduces a standard method for working with a variable number of subcolumns.
- We are happy to support efforts to use subcolumns in CAM.

IF YOU PLAN ON IMPLEMENTING SUBCOLUMNS: CONTACT US – THIS IS A WORK IN PROGRESS

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