Thoughts on a CALIPSO Level 3 Cloud Product

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- **Currently there are two Level 3 cloud products based on CALIOP data, produced for two specific projects:**
  - **GEWEX CA: 1x1 degree, H/M/L**
    - Produced for the GEWEX Cloud Assessment
  - **CALIPSO-ST: 2x2 deg x 480 meters**
    - Counterpart to CALIPSO-GOCCP produced for CMIP5
- **Both contain only information on cloud occurrence**
- **A full Level 3 product including cloud properties from both CALIOP and IIR is now being designed**

Design Principles

- **Ideally, the product emphasizes data strengths**
  - **guides the user in the proper way to use the data**
  - **minimize the weaknesses, or at least force users to confront weaknesses.**
- **Lidar strengths:**
  - **Accurate cloud top height, cloud phase, high spatial resolution (V & H: BL cloud), high sensitivity (optically thin cirrus and marine stratocumulus), most accurate OD and IWP for thin cirrus, multilayer clouds, Arctic clouds**
  - **Only partially penetrate optically thick clouds, don't see what's below**
  - **Mostly don't retrieve optical depth of water clouds**
- **Rather than frequency of occurrence, provide sample numbers to allow aggregation of statistics.**
  - **Not just means and variances: histograms, co-variation, …**
- **The product can't be all things to all people, try to anticipate the most common questions users will ask from the product.**
  - **Consider user communities and how they want to use data**
  - **Don't include parameters/features without identified users**
- **Grids for L3-Aerosol, L3-Cloud products should at least be consistent**

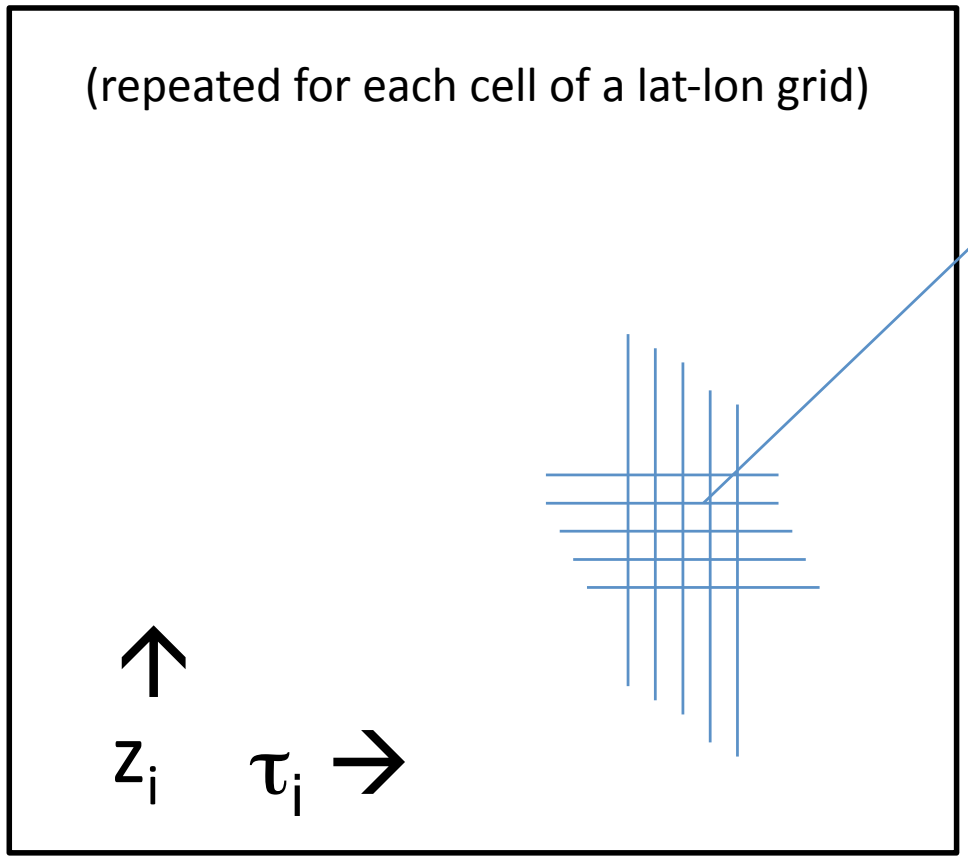
Primary Contents

- **CALIOP**
  - **Structure: cloud occurrence, cloud top height, cloud thickness, multi-layering,**
  - **Properties: OD (ice only?), IWP**
- **IIR:**
  - **Properties: emissivity, IR-OD, De, IWP**
- **Co-variations of lidar properties (examples):**
  - **OD vs. CTH**
  - **OD vs. cloud thickness**
  - **IWP vs. CTH**
- **Co-variations of IIR properties (examples):**
  - **ε vs. CTH**
  - **OD vs. De**
  - **ε vs. De**
  - **IWP vs. CTH**
  - **IWP vs De**

Proposing 3 basic ways to present CALIOP cloud data

(1) 3D Cloud Occurrence

Holds numbers of cloud samples in each of a number of (altitude, OD) bins
includes # clear air samples (τ =0) so that cloud fraction can be computed
user can compute cloud fraction for any desired OD threshold



Each element holds a vector **N**:

N = [N_1, N_2 …]

N_1: Number clouds at z_i with OD of τ_i

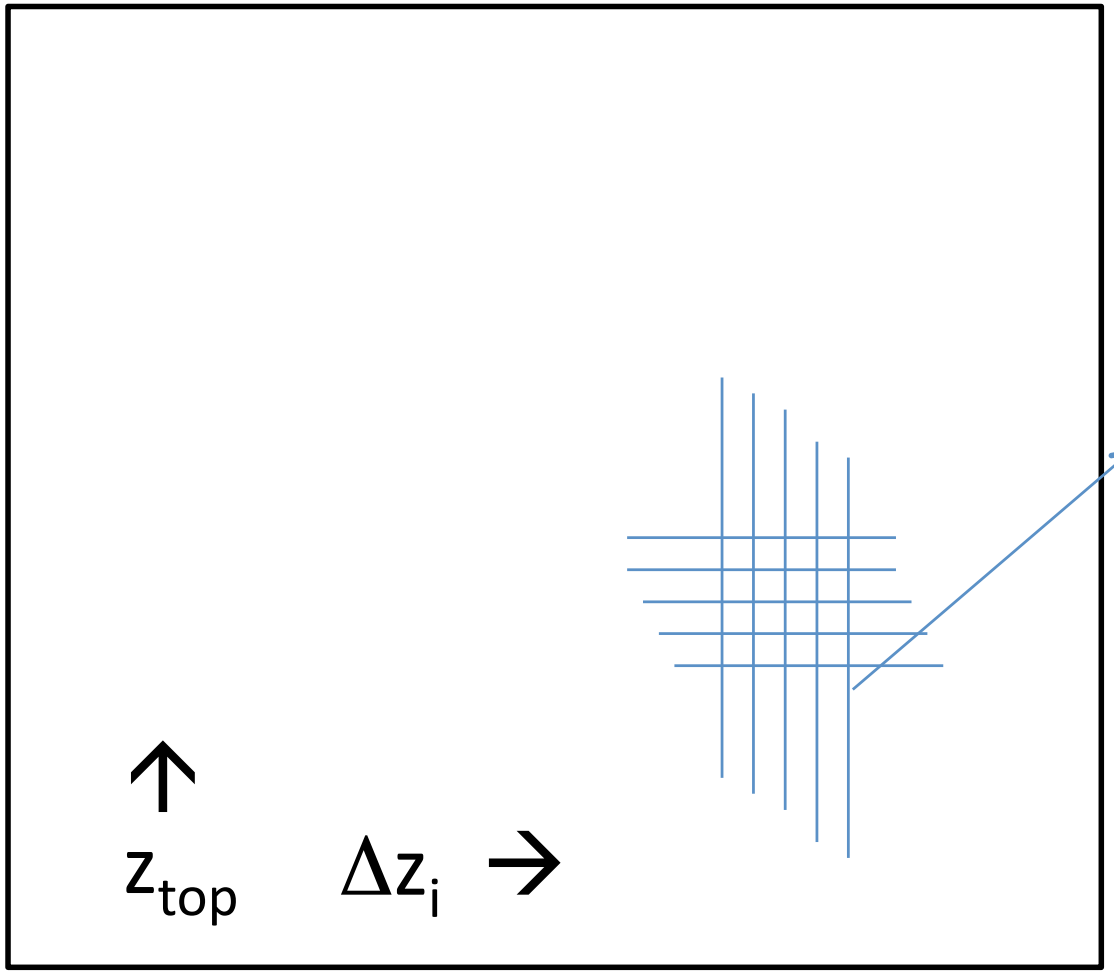
N_2: Number ice clouds at z_i with OD of τ_i

N_3: Number water clouds at z_i with OD of τ_i

$N_{total} = N_{water} + N_{ice} + N_{unknown}$

Do this also for z_i vs. IWP_i

(2) Cloud layer thickness statistics



Each element holds:

Number clouds w/ thickness Δz and cloud top at z_{top}

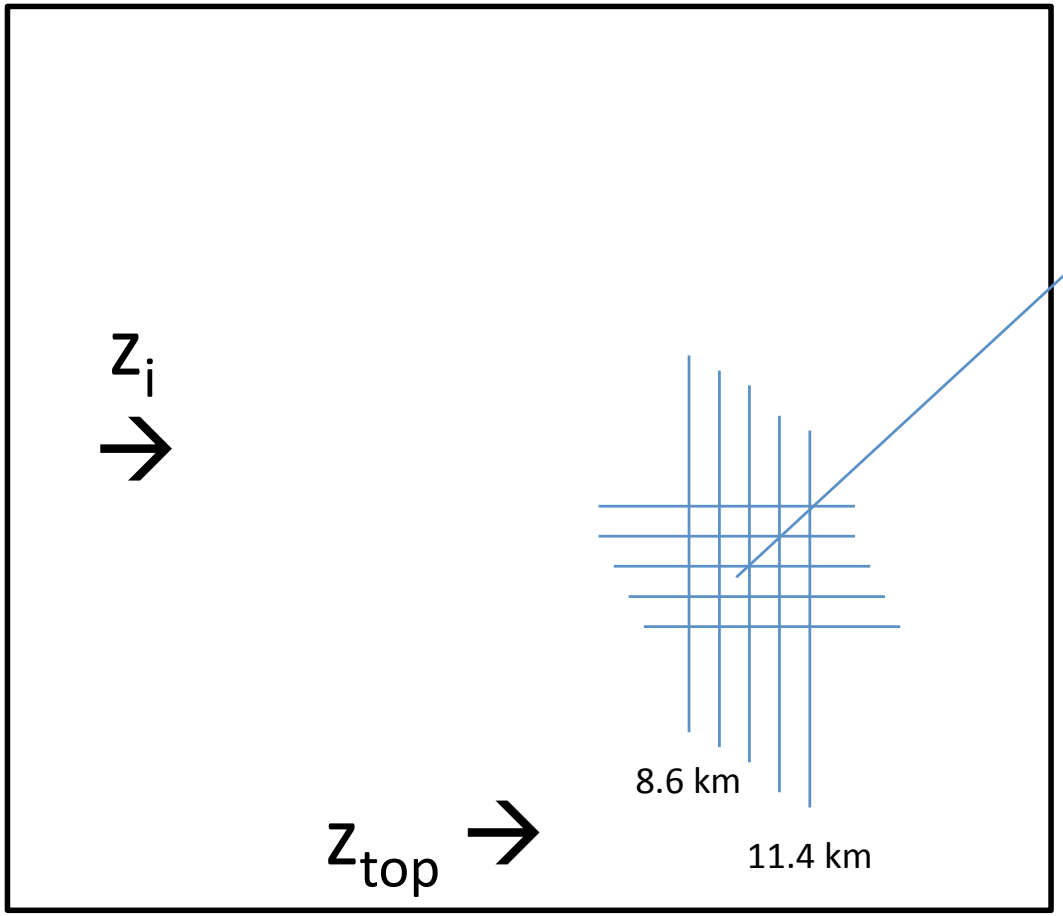
Number ice clouds w/ thickness Δz with cloud top at z_{top}

Number water clouds w/ thickness Δz with cloud top at z_{top}

Add optical depth or IWP to this? (3rd dimension)

How do we indicate opaque layers vs. layers with detected bases?

(3) Multi-layer occurrence



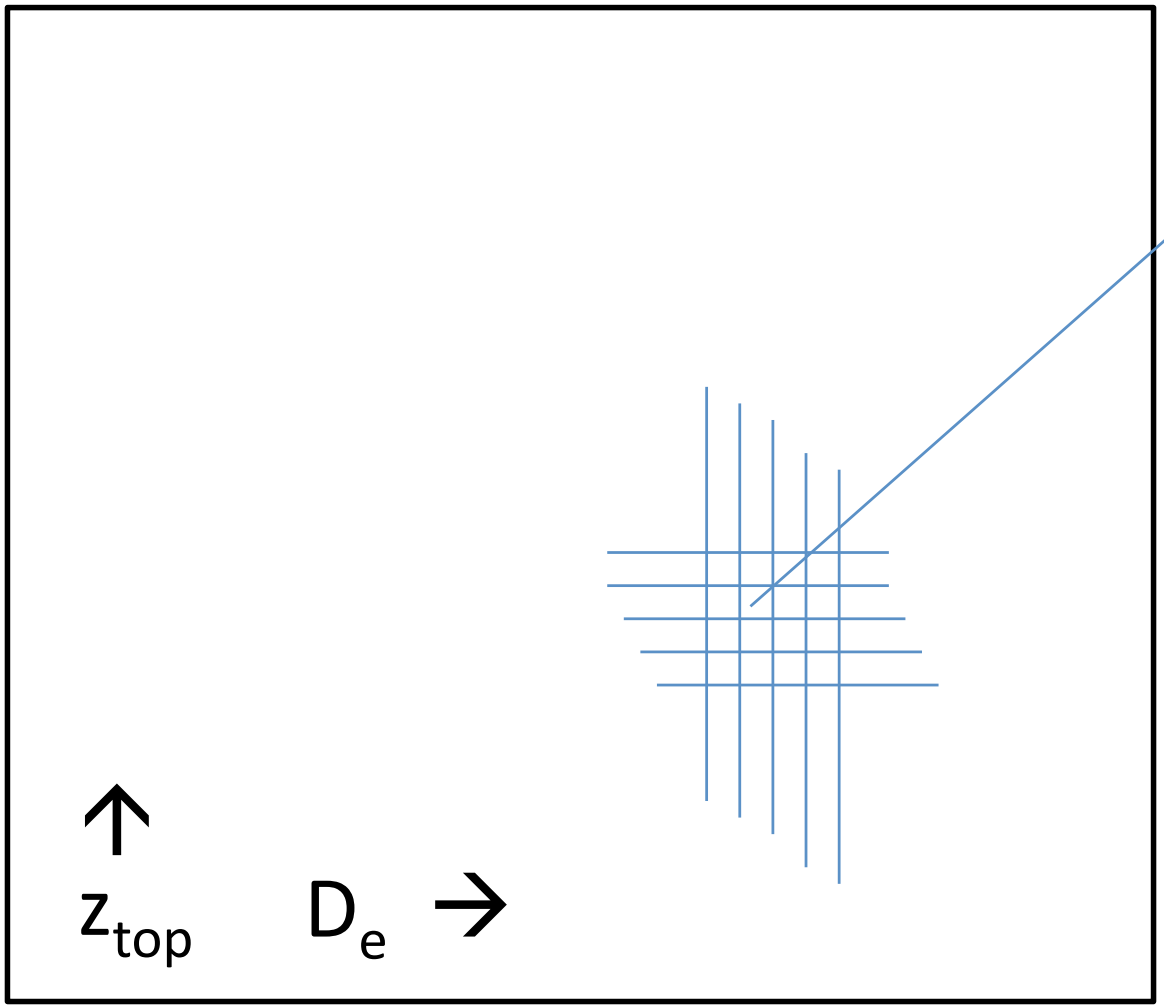
Number clouds at z_i
given cloud top at z_{top}

Number clouds at z_i
given cloud base at z_{base}

add OD of highest cloud layer as 3rd dimension?

Representing IR Properties

(Here, OD is the visible OD derived from 12 um IR channel)



Each element holds:

Number cloud layers with OD_i given De and z_t

Number cloud layers with ε_i given De and z_t

Number cloud layers with IWP_i given De and z_t

Number cloud layers with De_i at z_t

Thoughts on Implementation

- **There are other definitions of altitude:**
  - Some properties (cloud ice/water phase) should be reported vs. temperature as well as altitude
  - Report properties vs. pressure altitude?
- **Product will be monthly, but horizontal and vertical grids not defined yet**
  - **Leaning toward 2x2 degree lat-lon**
  - **Vertical resolution drives file size: 60 m (too small?), 480 m (too coarse?)**
- **Could have a "standard" and "research" versions**
  - **Standard version: statistical significance at grid-scale**
    - 10x10 monthly grid, for example
  - **Research version: high resolution for maximum flexibility in aggregation**
    - 1x1 daily grid, for example
- **Will provide the GEWEX Cloud Assessment statistics (CAH, CAL, etc.) either within these Level 3 files or as separate files**
  - **Oriented toward validation of passive cloud sensors**
  - **Can't be generated by from the high vertical resolution L3 cloud product**
  - **Include within L3-C, or only as a separate GEWEX product?**

- **Is there a need to represent profile parameters? (like IWC)**
  - **Aerosols are distributed (everywhere), clouds are objects**
  - **Who wants it? How do we represent profile parameters?**
- **Argument against:**
  - **Cloud extinction averaged over a grid cell (usually) not related to average radiative flux/cloud radiative effects for the grid cell**
  - **Aerosol extinction << cloud extinction (typically): still in the linear region**