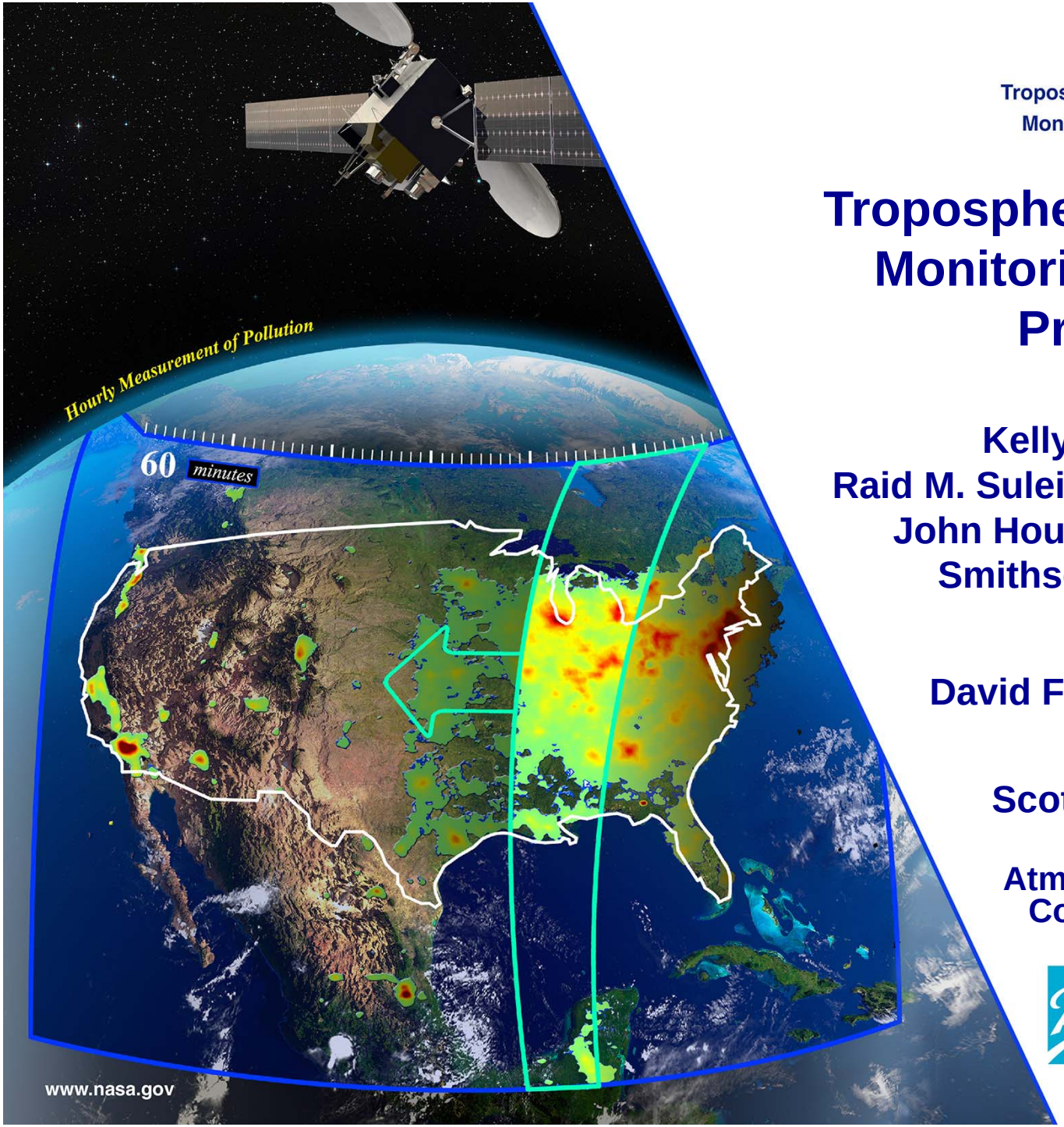


Tropospheric Emissions:
Monitoring of Pollution

TEMPO

Tropospheric Emissions: Monitoring of Pollution Pre-launch plans

Kelly Chance, Xiong Liu, Raid M. Suleiman, John E. Davis, John Houck, Ewan O'Sullivan
Smithsonian Astrophysical Observatory

David Flittner, Jay Al-Saadi,
NASA LaRC

Scott Janz, NASA GSFC

Atmospheric Composition Constellation Meeting 11
April 29, 2015

Ball

Smithsonian

NASA

TEMPO instrument specifications

1. **Spatial performance**
2. **Spectral performance**
3. **Radiometry**
4. **Alignment**

1. Spatial performance

- **Ground Sampling Distance (GSD)**
- **Spectral Co-Registration**
- **Spectral Alignment**
- **N-S Modulation Transfer Function (MTF)**
- **E-W (MTF)**

2. Spectral performance

- **Spectral Range**
- **Bandwidth**
- **Band Pass Symmetry**
- **Spectral Sampling**
- **Wavelength Mapping Uncertainty**

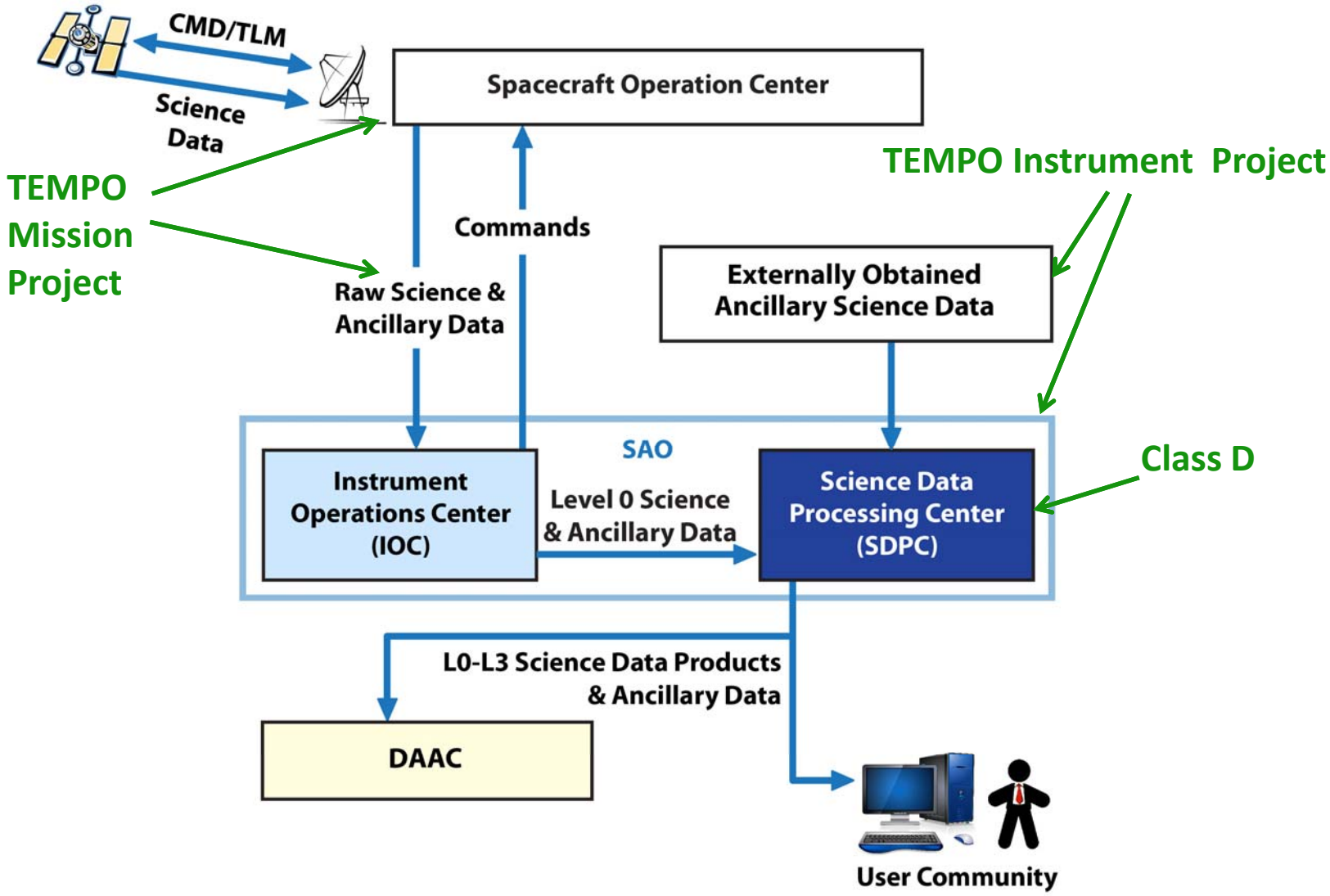
3. Radiometry

- **Linear Polarization Sensitivity**
- **Signal to Noise Ratio (SNR)**
- **Saturation**
- **Adjacent Pixel Saturation**
- **Non-Linearity**
- **Non-Linearity Knowledge**
- **Stray Light**
- **Radiance Stray Light**
- **Albedo Stray Light**
- **Structured Stray Light**
- **Spectral Features**

4. Alignment

- **Boresight East-West Stepping**
- **Boresight Knowledge Over the Full Field of Regard**
- **Boresight Knowledge – 0^{th} Order Terms**
- **Boresight Knowledge – 1^{st} Order Terms**
- **Boresight Knowledge – 2^{nd} Order Terms**
- **Boresight Knowledge – Higher Order Terms**
- **Alignment Over Two Adjacent N-S Swaths**

Ground systems overview



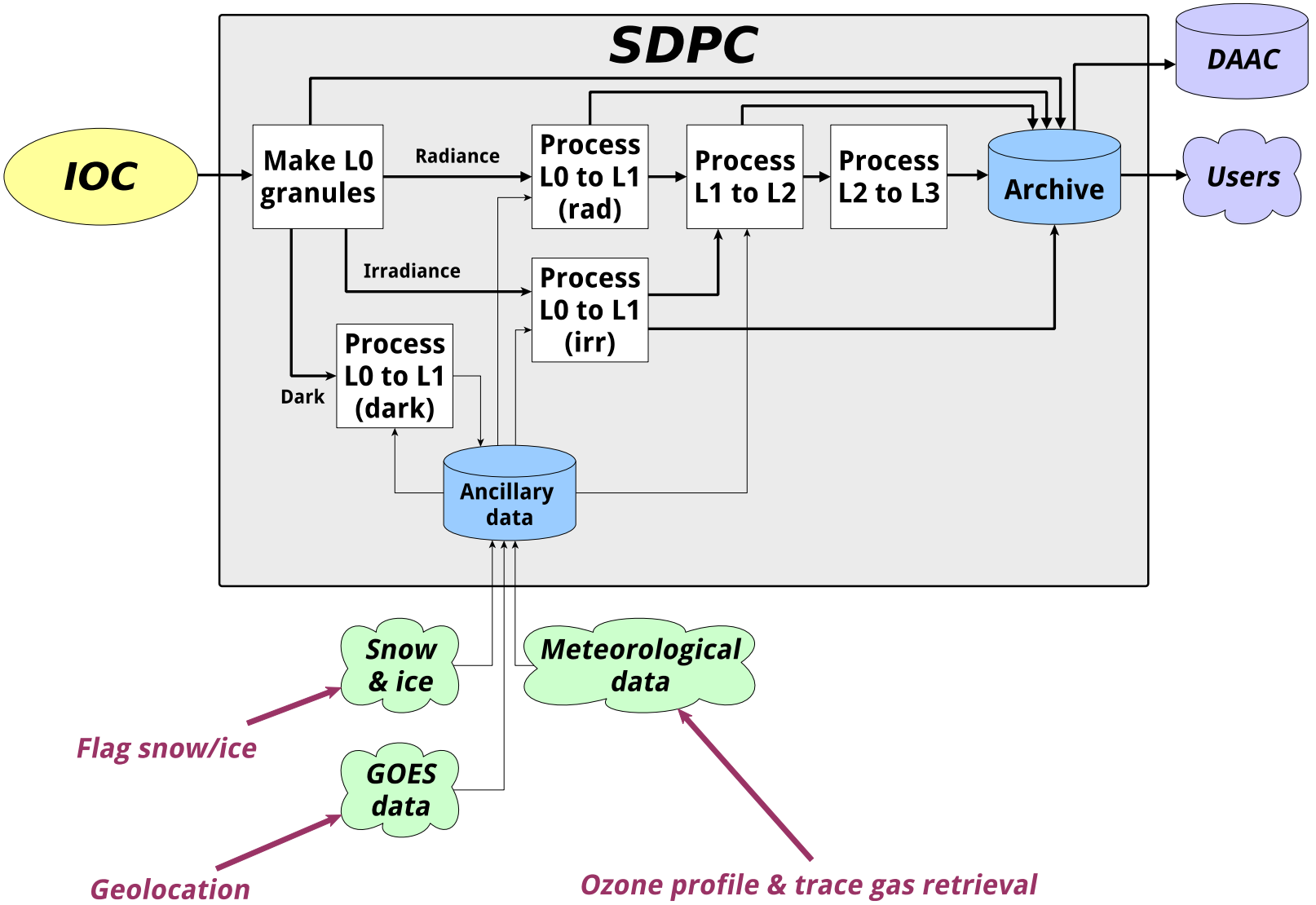
Requirements flowdown

- **24 Level 3 requirements (TEMPO-09-0003-SDPCRD) are derived from the PLRA and the SMRD**
- **223 Level 4 requirements are derived in the following categories:**

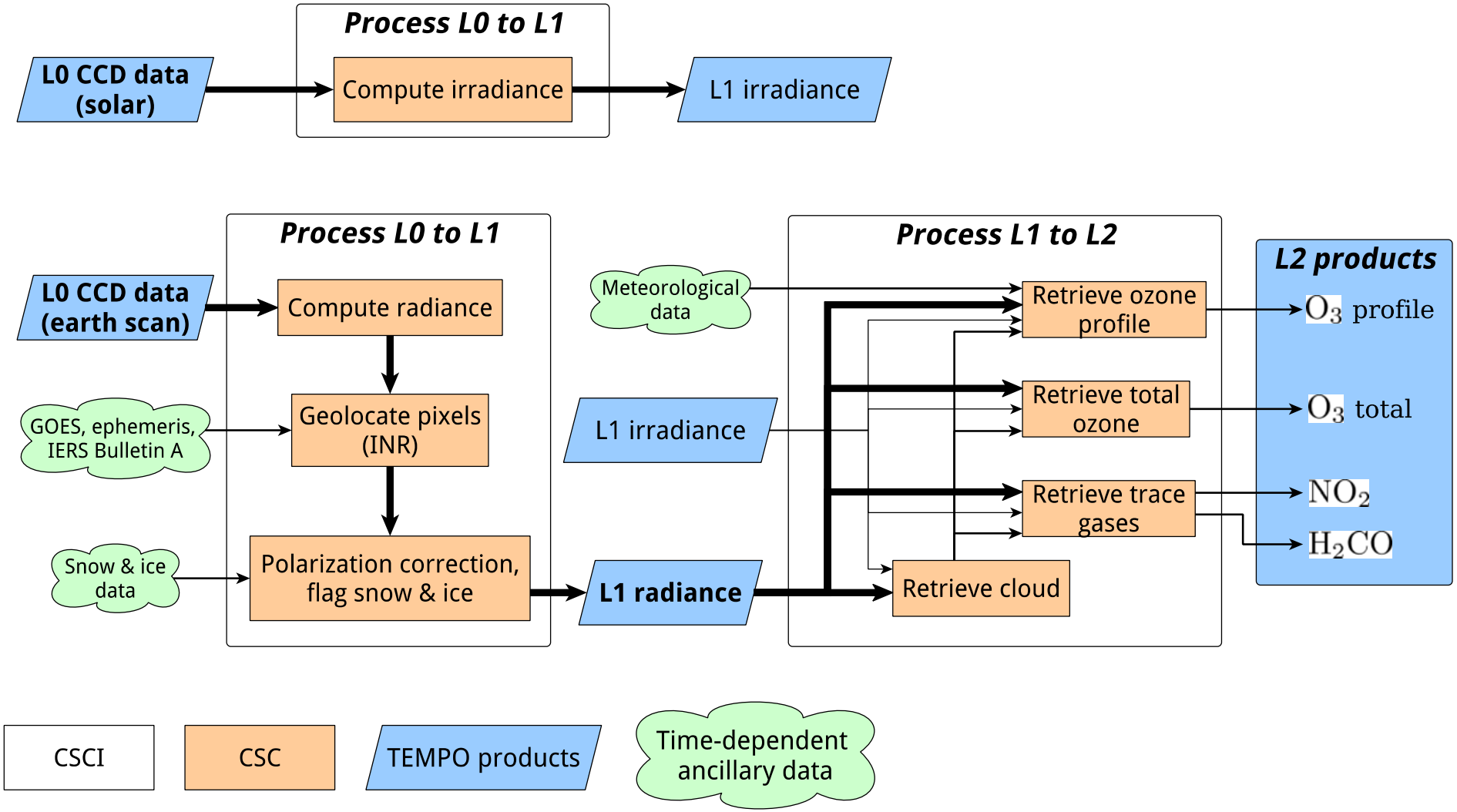
# of Reqs.	Requirement category
23	L0-L1 solar irradiance
26	L0-L1 radiance
26	L1-L2 clouds
51	L1-L2 trace gas
40	L1-L2 ozone profile
31	L1-L2 total ozone
22	L2-L3 gridding
4	Pipeline manager

- **85 Level 5 INR requirements are derived from one of the 26 L0-L1 radiance requirements**

Data & processing flow



Level 0 – Level 2 processing architecture

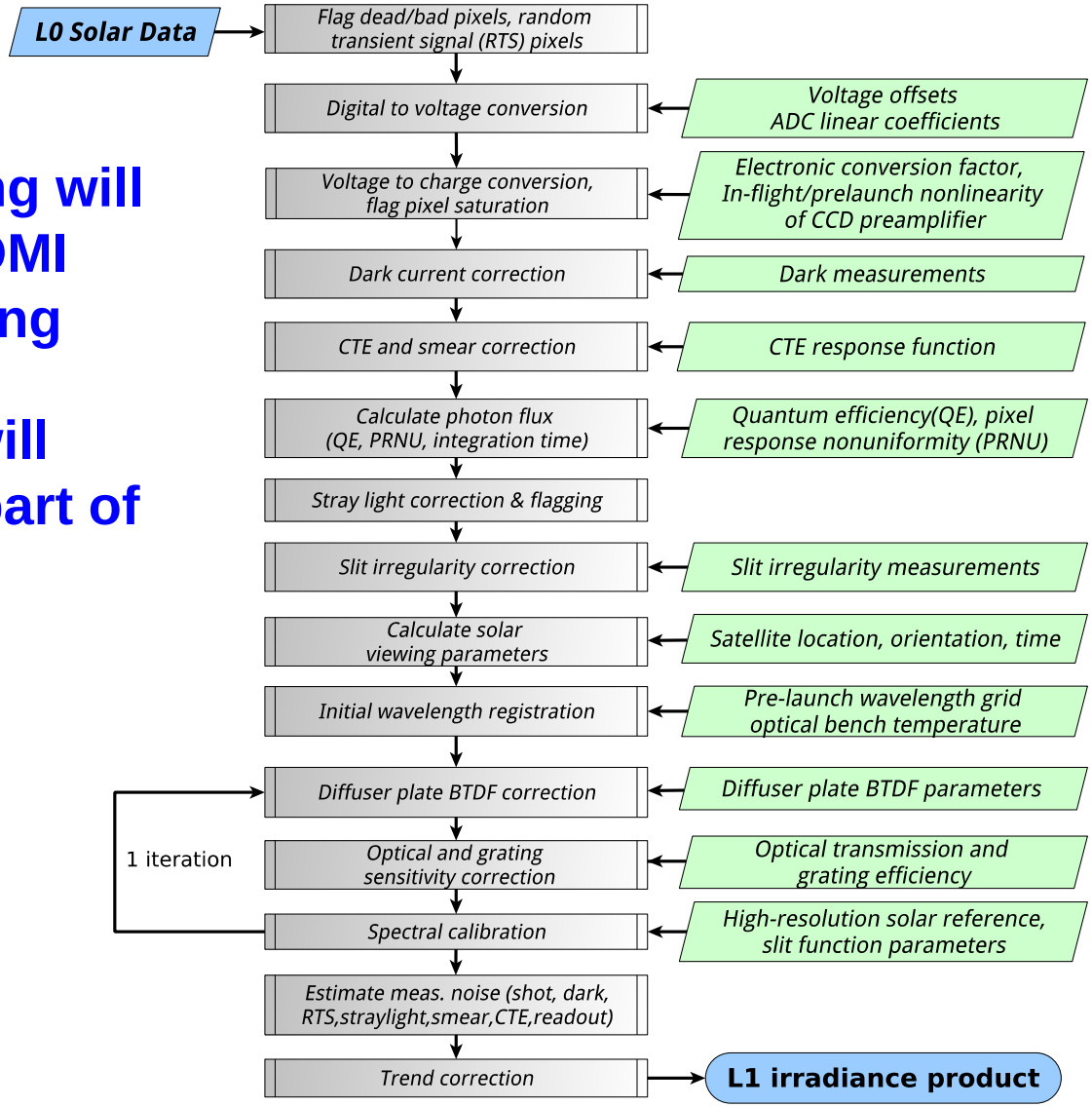


SDPCRD 4.5.2, 4.5.4, 4.5.5

CSC: Computer Software Component
CSCI: Computer Software Configuration Item

Level 0 – Level 1 irradiance processing detail

- **TEMPO L0-L1 processing will be similar to the TROPOMI and OMI L0-L1 processing**
- **Irradiance processing will occur once per day as part of calibration**

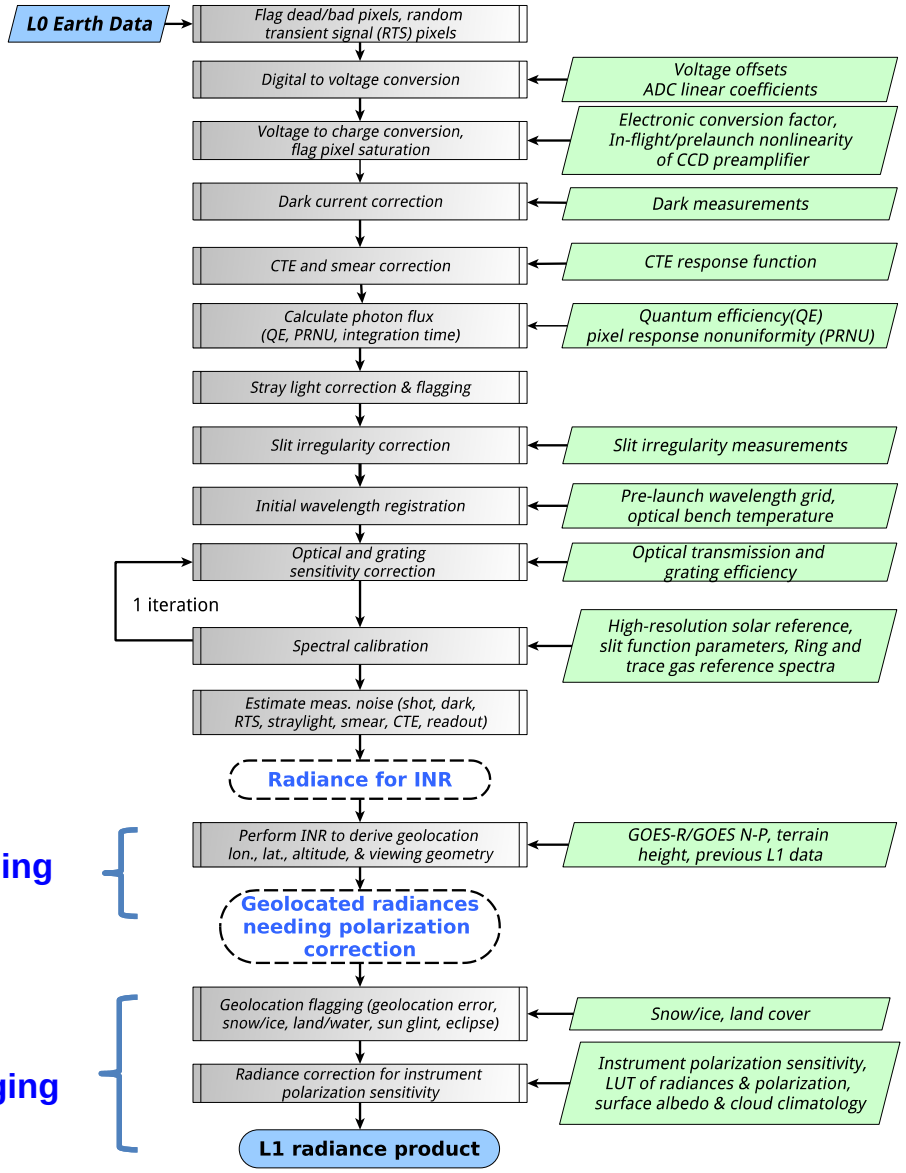


SPDCRD 4.5.2

Level 0 – Level 1 radiance processing detail

- **L0 – L1 radiance processing uses 3 CSCs**
- **TEMPO L0-L1 processing will be similar to the TROPOMI and OMI L0-L1 processing**
- **INR interface documented in SDPC/INR ICD**

SPDCRD 4.5.2, 4.5.4

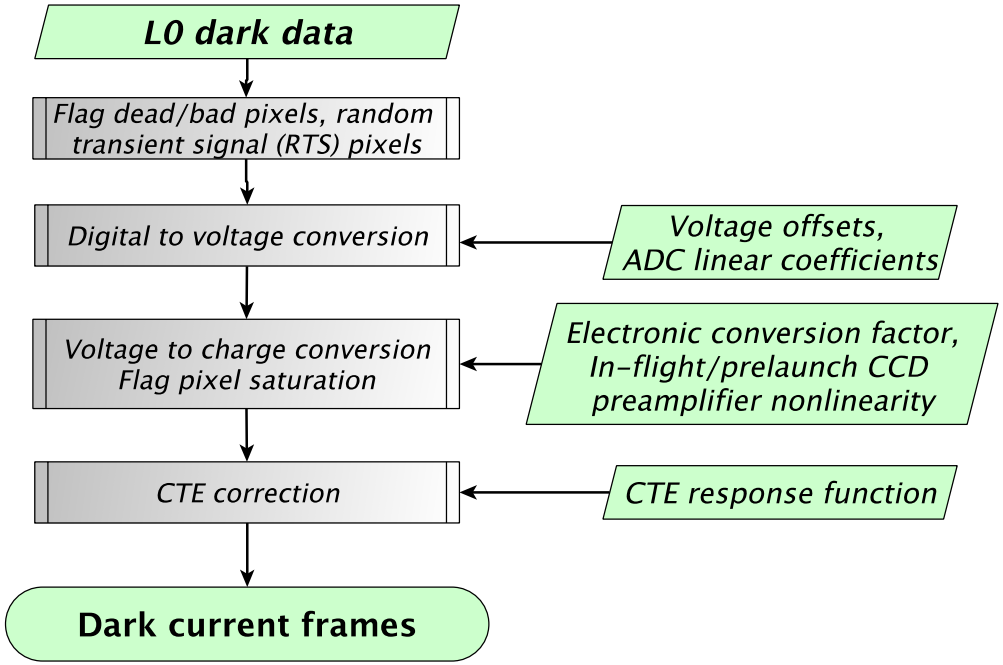


INR component of the L0 – L1 processing (Carr Astronautics)

Post-INR corrections and flagging

Level 0 – Level 1 processing detail

- **L0 – L1 dark processing generates dark current frames**



SPDCRD 4.5.2

Development timeline

PDR
7/14

Architecture Defⁿ

- Prelim ATBDs
- Assessment of existing OMI code

CDR
6/15

Detailed Design

- Adapt heritage code
- Archive layout
- Test planning and development
- Initial unit and integration testing

V1
6/16

Release 1

- Develop flight operational code
- Develop one product algorithm - expand to others
- Unit and integration testing
- Testing using SAO simulated instrument and retrieval proxy data
- Test IOC/SDPC interface

Instrument
First Look Data
11/16

Complete
12/16

Release 2

- Setup SDPC facility 9/16
- Test with Instrument first look data
- SDPC system test
- Acceptance testing
- IOC+SDPC end-to-end testing

The end!

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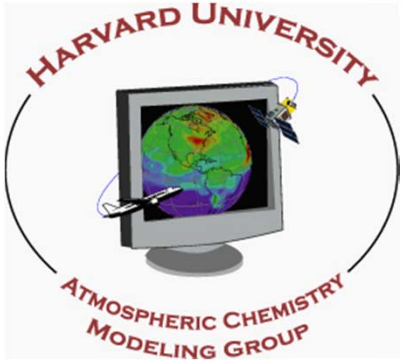
NCAR



Backups

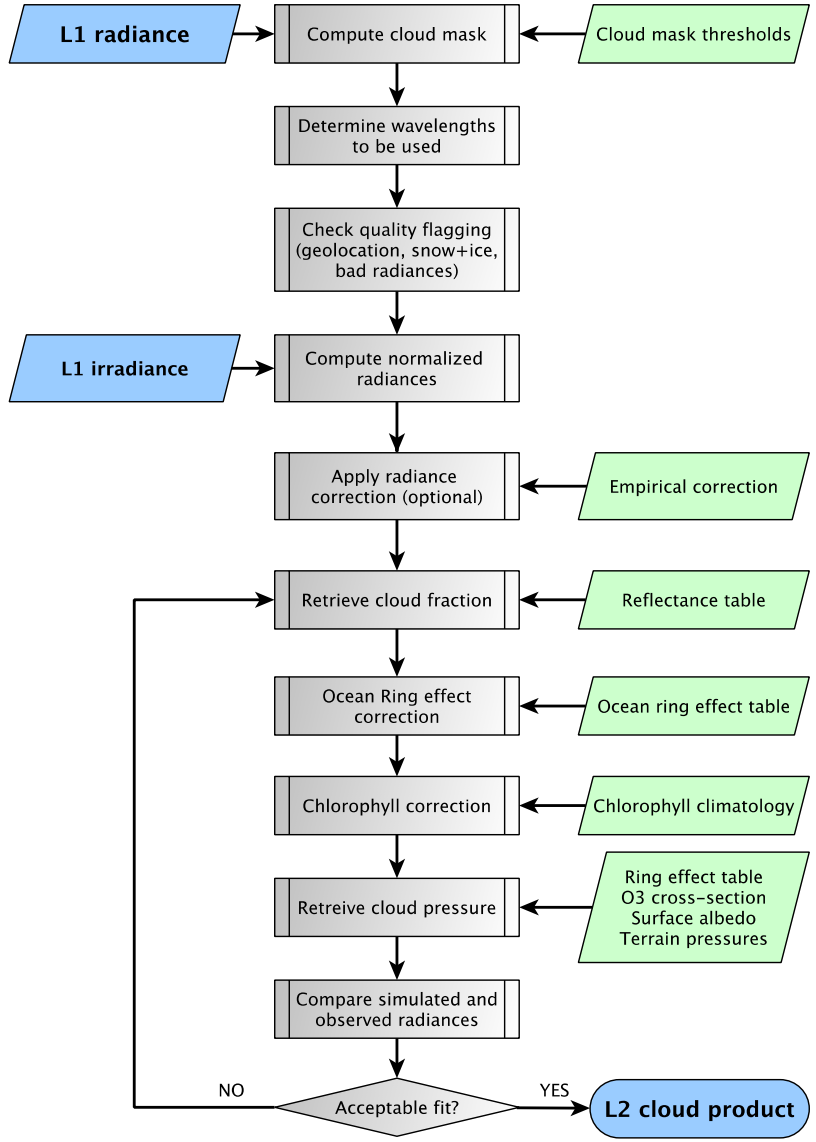
SNR

Driving Species	Wavelength (nm)	Nominal Radiance [Photons/(s·cm^2·sr·nm)]	Maximum Radiance [Photons/(s·cm^2·sr·nm)]	Signal to Noise Ratio
O_3	290	5.04×10^{10}	1.14×10^{11}	19.6
O_3	300	8.53×10^{10}	1.72×10^{11}	46.1
O_3	305	3.18×10^{11}	1.11×10^{12}	161.9
O_3	310	9.15×10^{11}	3.16×10^{12}	377
O_3	320	6.06×10^{12}	1.56×10^{13}	1220
H_2CO	330	1.48×10^{13}	3.33×10^{13}	2003
O_3	340	1.45×10^{13}	3.43×10^{13}	2013
Cloud	350	1.31×10^{13}	3.34×10^{13}	1414
NO_2	420	1.58×10^{13}	6.01×10^{13}	836
NO_2	430	1.22×10^{13}	4.85×10^{13}	675
NO_2	450	1.82×10^{13}	7.90×10^{13}	733
Cloud	490	1.65×10^{13}	8.30×10^{13}	1176
O_3	540	1.30×10^{13}	7.14×10^{13}	1109
O_3	600	1.15×10^{13}	7.11×10^{13}	987
O_3	650	1.08×10^{13}	7.02×10^{13}	898
Cloud	690	1.06×10^{13}	6.49×10^{13}	820

Level 2 cloud processing detail

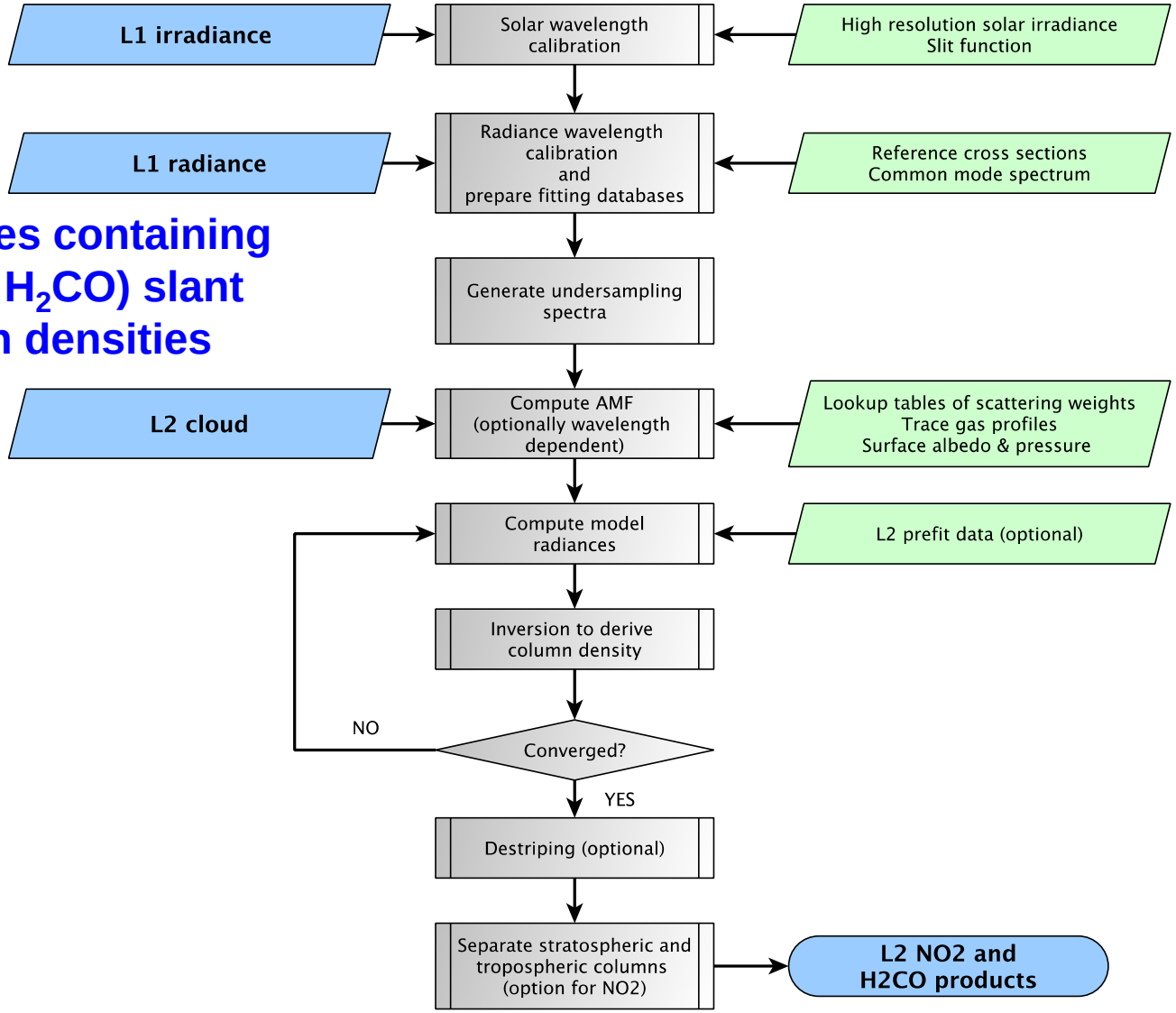
- **Cloud products are used to generate the standard L2 products**
- **Generates HDF5 files containing cloud optical centroid pressure, and effective cloud fraction**

SPDCRD 4.5.5



Level 2 trace gas processing detail

- **Generates HDF5 files containing trace gas (NO_2 and H_2CO) slant and vertical column densities and uncertainties**

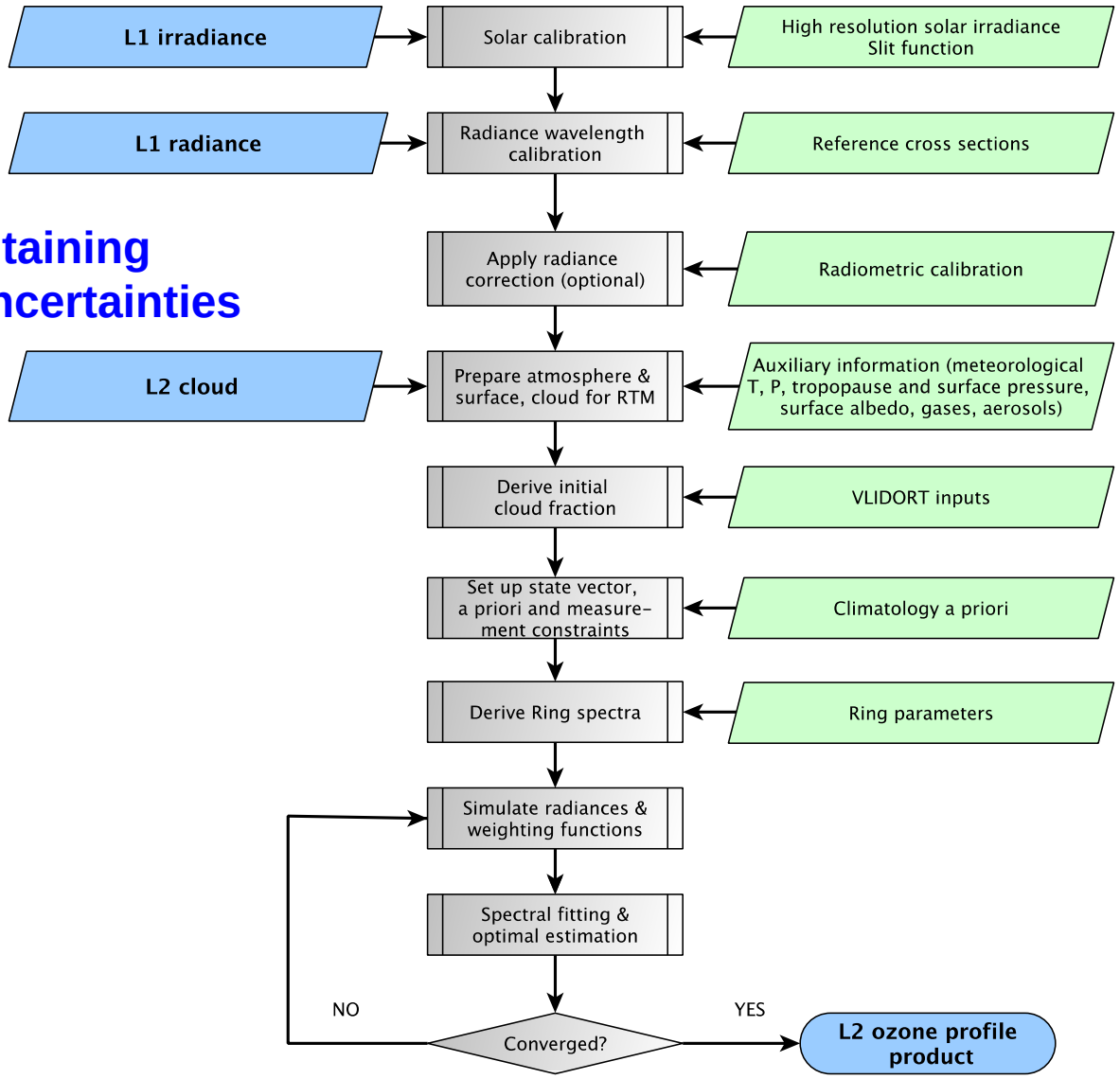


SPDCRD 4.5.5

Level 2 O_3 profile processing detail

- **Generates HDF5 files containing partial O_3 columns and uncertainties**

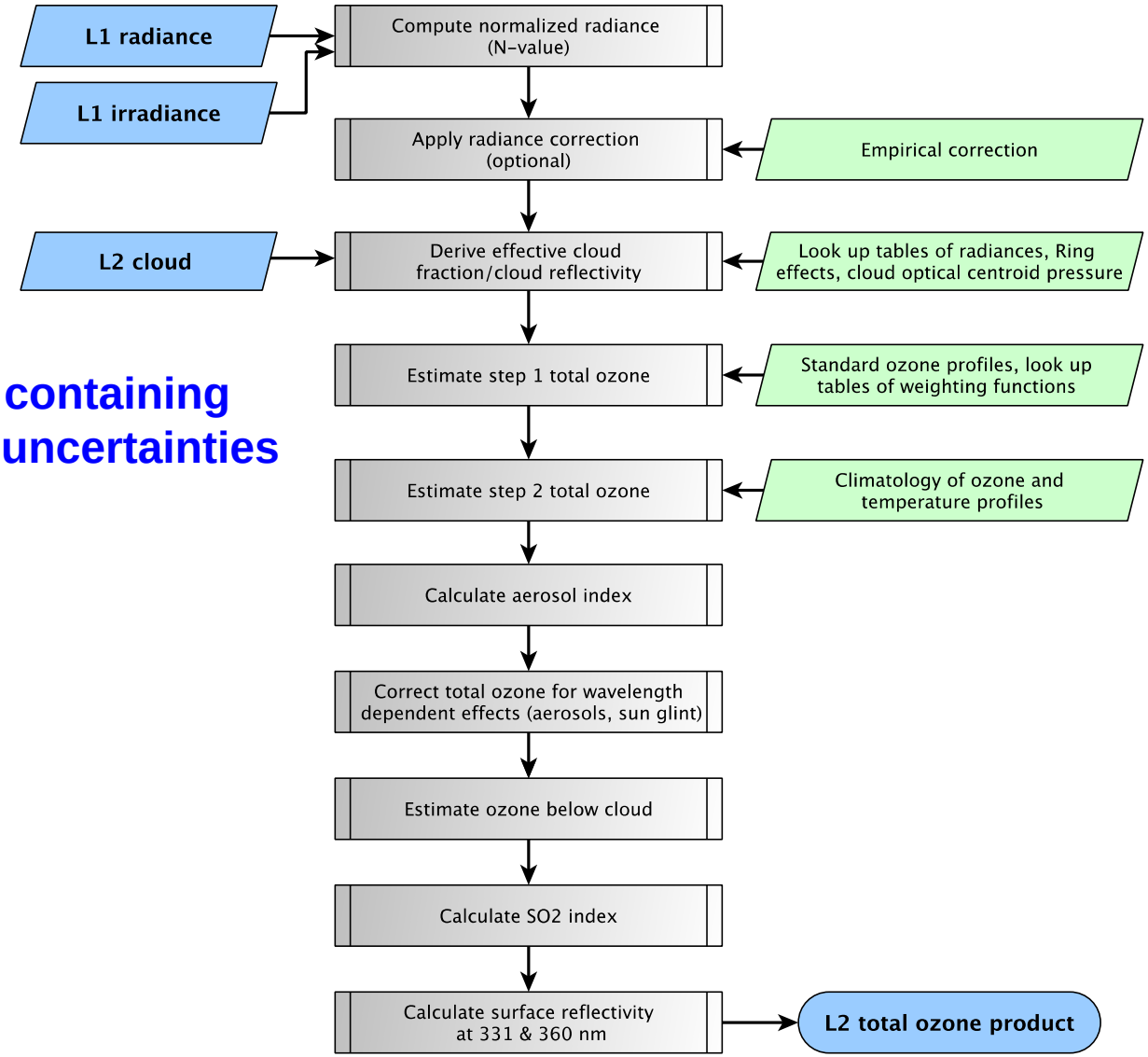
SPDCRD 4.5.5



Level 2 total O_3 processing detail

- **Generates HDF5 files containing total O_3 columns and uncertainties**

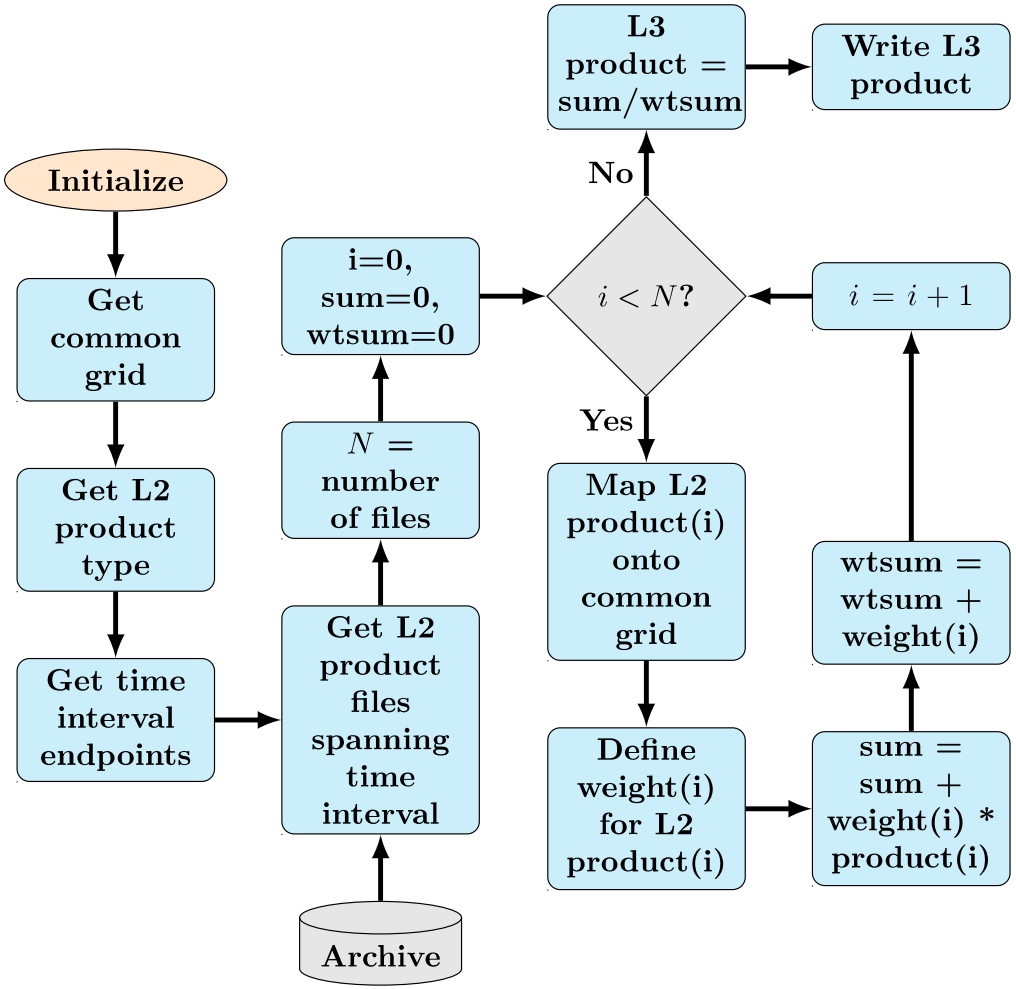
SPDCRD 4.5.5



TEMPO

Level 2 – Level 3 processing detail

- **Generates daily and monthly averages of L2 products in HDF5 format**



SPDCRD 4.5.7

Processing capacity

Baseline:

- Data volume in 1 TEMPO scan = 25 OMI orbits
- Using one core, processing time for a 6 minute TEMPO granule

= processing time for 2.5 OMI orbits

Derived estimates:

- 256 cores to keep up with incoming data
- 256 cores (additional) for reprocessing due to calibration changes, etc.
- 512 cores sufficient to meet SDPCRD performance requirements

Planning for 592 cores (15% overcapacity)

= 37 16-core servers

Spare machines will help ensure failure recovery time <96 hr

SPDCRD 4.3.2, 4.5.2, 4.5.3, 4.5.5, 4.5.6, 4.5.7, 4.5.8, 4.5.12

Storage capacity

Baseline:

15 hrs, 1278 steps/hr, 2048 N/S spatial pixel/step, 2048 spectral pixels/step, factor of 2 compression, 23 months of data-taking (713 days)

Derived estimates:

- **TL = 0.121 TB/day (from the IOC)**
- **L0 data = 0.121 TB/day**
- **L1 data = 0.202 TB/day**
- **L2 data = 0.093 TB/day**
- **L3 data = 0.093 TB/day**

- **Allow for archiving one additional reprocessing of early mission products**
- **Assume regular transfer to the DAAC**
- **Local backup of TL and L0 only**

	Rate (TB/day)	Duration (days)	Total (TB)
Archive all data products (TL+L0+L1+L2+L3)	0.630	713	449
Local backup (TL+L0)	0.242	713	173
Reprocessing (L1+L2+L3)	0.388	356	138
Total			760
+ 15% contingency			874

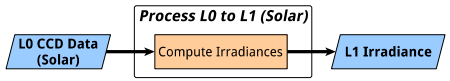
*** Storage will be purchased in phases (50 TB by 12/17, 400 TB by launch, the remainder 12 months after launch)**

SPDCRD 4.6.1, 4.9.1

Test planning

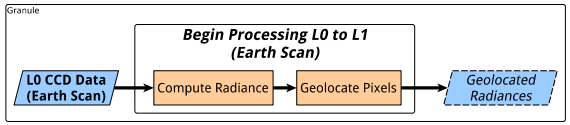
- **L0 to L1 radiance and irradiance computations will be tested using**
  - **synthetic data based on the expected instrument response and customized to test specific steps in the computation**
  - **archival data from prior missions as a proxy for TEMPO data**
- **L1 to L2 product retrieval computations will be tested using simulated radiances derived from radiation transport through a realistic model of Earth's atmosphere having known composition, accounting for the instrument slit function and measurement noise**

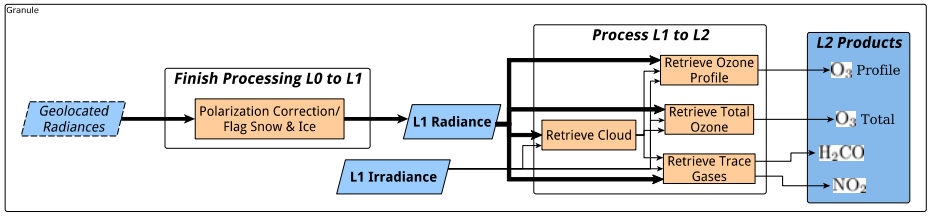
Parallel processing flow



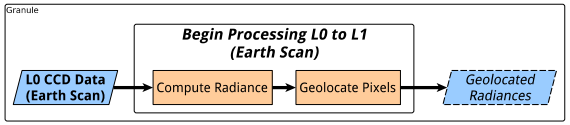
time →

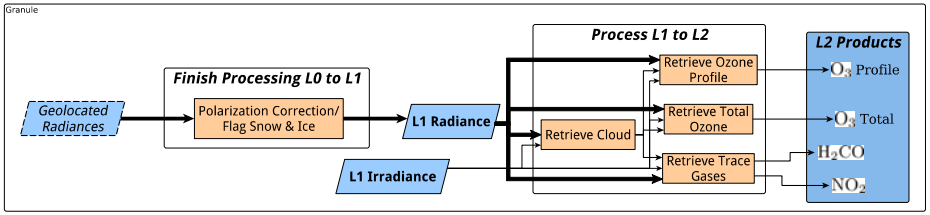
granule k



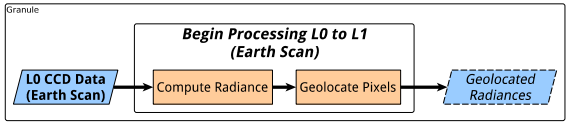


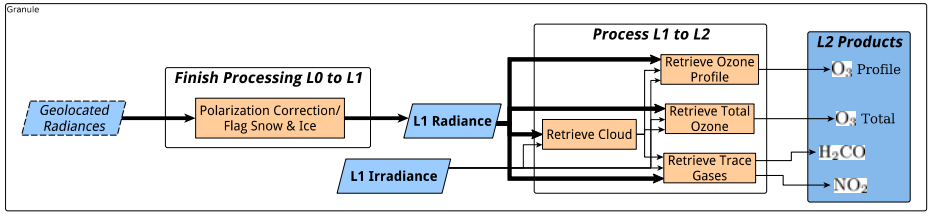
granule k+1





granule k+2





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