File Revision Date:
September 20, 2019

This file to be modified as re-analysis or new analysis results are available

NDACC METAFILE FOR JPL STRATOSPHERIC OZONE LIDAR AT Mauna Loa Obs., Hawaii (MLO)

- Applies to instrument and data history from 17-Jul-1993 to 19-Sep-2019
- PLEASE READ IMPORTANT 2019 UPDATE AT THE BOTTOM OF THIS FILE
- The above period covers analyzed and (re-)analyzed data sets available at this time
- Applies to MLO stratospheric ozone data, temperature and aerosol data processed with LidAna version v5.15 or later, and GLASS v1.0 or later
- Does NOT apply to MLO data processed with older program versions, namely v5.00 or SO3ANL
- Applies to all Ames files cataloged on NDACC database with the following names:
  mla3YYMM.mdl (AEROSOL353)   (YYMM is for year and month)
  mla4YYMM.mdl (AEROSOL355)
  mlo3YYMM.mdl (OZONE)
  mlteYYMM.mdl (TEMPERATURE)
  mla4YYMM.tll (AEROSOL355)
  mlo3YYMM.tll (OZONE)
  mlteYYMM.tll (TEMPERATURE)
- Refer to "Reported Events" section for detailed report of unexpected problems
- This file to be modified as re-analysis or new analysis results are available

Data Set Description:

PI:	T. Leblanc (before 2013: I. Stuart McDermid)
Instrument:	Lidar
Site(s):	Mauna Loa Observatory, HI, USA
Measurement Quantities:	Ozone
	Temperature
	(Aerosols)

Contact Information:

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Reference Articles:
Please refer to the file named "jpl_publications_2000.txt" for publications list prior to 2000.
Note: A 2019-updated list of publications will be posted here soon

Instrument Description:

- DIAL stratospheric ozone lidar 4 Rayleigh channels (2 pairs at 308/353(355) nm) and 2 vibrational Raman channels (1 pair at 308-332/353-385(355-387) nm)
- Ozone profiles between 15-50 km
- Temperature profiles between 12-95 km
- Backscatter ratio profiles at 353 or 355 nm between 12-50 km
- Please refer to the above publications for more details

Description of Algorithms:

I - LidAna 5.xx and LidAna 6.xx (1993 - 2018)

Temperature/ozone/aerosol analysis program LidAna v5.xx, by Thierry Leblanc (TL) first released in June 1999. LidAna v5.00 (in IDL) replaced the old FORTRAN analysis program SO3ANL v4.62 by Eric Sirko. This v5.00 no longer used.
LidAna data processor is manual processingl, using 20+ keywords tailored for a specific type of science application. The results are quality-checked visually, manually, during analysis.

- Data set from beginning to December 2000 analyzed with versions 5.15.
- Data set from January to March 2001 analyzed with versions 5.2x.
- Data set from May 2001 to December 2004 analyzed with versions 5.40 or later.
- Data set from January 2005 to June 2018 analyzed with versions 6.2x or later.

An analysis overview is described below. Please refer to T. Leblanc for details.

a) For ozone, temperature and aerosol retrievals, raw signals are corrected for saturation, background noise, solid angle, Rayleigh extinction, and NO2 absorption if applicable.
b) For temperature and aerosol retrievals the signals are additionally corrected for ozone absorption.
c) Ozone Number Density calculation uses standard DIAL method: Calculating the derivative of the ratio of the slopes of the logarithm of the absorbed and non-absorbed corrected signals. Natural vertical grid is geometric altitude. Signal is smoothed to reduce statistical noise by applying a derivative filter. Raman channel is used below 30 km to avoid contamination by aerosols (systematically used since early 2001).
d) Aerosol primary information is the backscatter ratio profile: Ratio of the Rayleigh (353 or 355 nm) to the Raman (385 nm) corrected signals. An a priori density coming from radio-sounding or NCEP is used if Raman channel is not available.
e) Temperature calculation uses ideal gas law and hydrostatic equilibrium. Signal is normalized to a priori density coming from either radio-sounding or, if radio-sounding not available, from NCEP analysis. Temperature is tied-on at the top (near 85 km) using the a priori MSISE-90 daily mean climatology. Raman channel (385 nm) systematically used below ~30 km to avoid contamination by aerosols.
f) All results are output in NetCDF (native format), and then compiled into monthly data files in ASCII Ames format following NDACC requirements
g) In Ames files, the measured quantities are provided together with the following derived products: Ozone mixing ratio, ozone column from top of profile, potential temperature, and backscatter

coefficient. These products are usually obtained using either the density-pressure profiles measured by lidar, or a priori density-pressure profiles coming from NCEP or radio-sounding. Refer to "Ames description" section for more details.

Expected Precision/Accuracy of Instrument:

a) Ozone overall precision is calculated statistically during analysis and provided at 1-sigma in Ames files. The errors taken into account are the statistical error associated to photon counting, and systematic errors due to various corrections. The overall precision runs from 1-2% in ozone peak (near 24 km), to 15% at the bottom (near 16 km), and >40% at the top of the profiles (near 50 km).

b) Temperature overall error is calculated as for ozone, with additional systematic errors related to the use of a priori density normalization and tie-on temperature.

c) Unexpected - but identified - errors are issues in this metafile in the "Reported Events" section.

Ames description:

This section gives a few details on the Ames files content:

- All units are MKSA except pressure (in hPa), and mixing ratio (in ppmv).
- "Hour-Mean" and "Minute-Mean" is the averaged time of measurements
- "Hour-Stop" and "Minute-Stop" is the time at which the measurements stopped
- "Day of year (UT xxx.xx)" is the time at which the measurements started
- "pres/dens code" is the source of the "a priori" dens. and press. information
- "channel code" indicates which channels have been used:

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 *** On and before May 31, 2001 (MLO-1): code based on 3 ranges
 If Raman channel (or pair of channels) used alone,         then code=2**0 = 1
 If Low Rayleigh channel (or pair of channels) used alone,  then code=2**1 = 2
 If High Rayleigh channel (or pair of channels) used alone, then code=2**2 = 4
 If Low Rayleigh and High Rayleigh combined,        then code=2**1 + 2**2 = 6
 etc...
 *** On and after June 7, 2001 (MLO-2): Code redefined, based on 4 ranges
 If Raman channel (or pair of channels) used alone,         then code=2**0 = 1
 If Low Rayleigh channel (or pair of channels) used alone,  then code=2**1 = 2
 If Med Rayleigh channel (or pair of channels) used alone,  then code=2**2 = 4
 If High Rayleigh channel (or pair of channels) used alone, then code=2**3 = 8
 If Low Rayleigh and High Rayleigh combined,        then code=2**1 + 2**3 =10
 etc...
*** ATTENTION: The change in channel code definition reflects migration from
*** 6-channel (3 ranges) analysis in LidAna v5.2x to 12-channel (4 ranges)
*** analysis in LidAna v5.4x. The analysis version upgrade was implemented as
*** both TMF and MLO systems were upgraded in May and June 2001.
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II - GLASS 1.xx (2018 - Present)

Temperature/ozone/aerosol analysis program GLASS v1.xx, by Thierry Leblanc (TL) first released in early 2017. This program overrides all previous analysis programs (LidAna, SO3ANL, see section I above)

New GLASS data processor does not require manual processing. Analysis is automated, using 100+ keywords tailored for a specific type of science application.
The results are quality-checked visually, manually, after analysis is completed.
This new automation capbility allows for the re-analysis of a large number of measurements without user intervention.
- Data set from XXXXXX to present analyzed with versions 1.00, to be released in 2019.

An analysis overview is described below. Please refer to T. Leblanc for details.

a) For ozone, temperature and aerosol retrievals, raw signals are corrected for saturation, background noise, solid angle, Rayleigh extinction, NO2 and SO2 absorption if applicable.
b) For temperature and aerosol retrievals the signals are additionally corrected for ozone absorption.
c) Ozone Number Density calculation uses standard DIAL method: Calculating the derivative of the ratio of the slopes of the logarithm of the absorbed and non-absorbed corrected signals. Natural vertical grid is geometric altitude. Signal is smoothed to reduce statistical noise by applying a derivative filter. Raman channel is used below 30 km to avoid contamination by aerosols (systematically used since early 2001).
d) Aerosol primary information is the backscatter ratio profile: Ratio of the Rayleigh (353 or 355 nm) to the Raman (385 or 387 nm) corrected signals. An a priori density coming from radio-sounding or NCEP is used if Raman channel is not available.
e) Temperature calculation uses ideal gas law and hydrostatic equilibrium. Signal is normalized to a priori density coming from either radio-sounding or, if radio-sounding not available, from NCEP analysis. Temperature is tied-on at the top (near 85 km) using the a priori MSISE-90 daily mean climatology. Raman channel (385 nm) systematically used below ~30 km to avoid contamination by aerosols.
f) All results output in HDF-5 (native format), and HDF-4 (GEOMS template) following NDACC requirements
g) In the HDF files, the measured quantities are provided together with the Ozone mixing ratio. This product is obtained using either the density-pressure profiles measured by lidar, or a priori density-pressure profiles coming from NCEP or radio-sounding. Refer to "HDF description" section for more details.

Expected Precision/Accuracy of Instrument:

a) Ozone overall precision is calculated statistically during analysis and provided at 1-sigma in output files files. The uncertianty components taken into account include photon counting noise (random), and systematic terms due to various corrections. The overall precision runs from 1-2% in ozone peak (near 24 km), to 15% at the bottom (near 16 km), and >40% at the top of the profiles (near 50 km). The largest systematic uncertainty of 4% comes from the ozone absorption cross-sections uncertainty, and their temperature dependence
b) Temperature overall uncertainty comproses same uncertianty cmponents as in the ozone retrieval, with additional systematic components related to the use of a priori density, tie-on temperature uncertainty, and the acceleration of gravity.
c) Unexpected - but identified - errors are issues in this metafile in the "Reported Events" section.

HDF File description:

This section provides details on the HDF files content:
- All units are MKSA except pressure (in hPa), and mixing ratio (in ppmv).
***** Due to the novelty of the GLASS program and its HDF outputs, *****
***** this section is still under construction. It will be updated *****
***** as further documentation is available *****

Instrument History:

- Jun 1993 - lidar installed at MLO
- Jul 1993 - start of routine measurements (internally referred as MLO-1)
- Jul 1995 - MLO3 campaign
- Feb 2000 - Raman filters improved
- Mar-Apr 2001 - System relocation from JPL trailers to NDSC building
  New YAG implementation simultaneously with relocation
  End system referred as MLO-1. Start system referred as MLO-2.
- Aug 2002 - NDSC intercomparison campaign
- Oct 2003 - Historical excimer lasers replaced by new LambdaPhysics systems
- Oct 2012 - NDACC intercomparison campaign (part 1)
- Feb 2013 - NDACC intercomparison campaign (part 2)
- Jul 2017 - One new excimer laser replaced
- May 2019 - MCS data acqusition cards replaced by Licel Transient Recorders

Reported events 1993-2006:

Below is a chronological list of notes describing unexpected events affecting the result's quality. The notes are referenced in the comment section of the Ames files.

- 93-A Aerosol status in 1993: Moderately thick wide layer throughout 1993.
  Layer observable below 35 km. Rayleigh ozone and Rayleigh temperature significantly affected.
  Rayleigh channels never used below 33 km. Instead, systematic use of Raman channels.

- 93-B Rayleigh and/or Raman channels suspected misalignment.
  Misalignment suspected throughout 1993 but aerosol layer prevents from precisely identifying problem. Quantification impossible.
  PROBLEM definitely FIXED on August 20, 1998.

- 93-C Early measurements highly unstable (July 17 - November 1, 1993).
  Early stage of MLO system causing highly variable data quality from very bad to good.
  **** USE 1993 DATA WITH EXTREME CAUTION ****

- 93-D Data gain quality on and after November 3, 1993.
  **** USE 1993 DATA WITH EXTREME CAUTION ****

- 94-A Aerosol status in 1994: Moderately thick to thin wide layer.

Diminishing throughout 1994. Main layer observable below 25 km. Thick layer the first 6 months of 1994. Rayleigh ozone and Rayleigh temperature significantly affected.

- 94-B Misalignment suspected throughout early 1994 but aerosol layer prevents from precisely identifying problem. Quantification impossible.
PROBLEM definitely FIXED on August 20, 1998.
**** USE EARLY 1994 DATA WITH EXTREME CAUTION ****

- 95-A Aerosol status in 1995: Thin wide layer at and below 25-30 km.
Observable consistently throughout 1995. Main layer observable below 25 km. Only thin layer above 26 km during early 1995. Rayleigh ozone and Rayleigh temperature significantly affected.

- 95-B Raman filter 332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is too low, especially in ozone peak. Magnitude of bias unknown throughout 1995 due to lack of reliable Rayleigh measurements to compare with into aerosol layer. PROBLEM FIXED on February 25, 2000.

- 95-C Unexpected BSR>>1 below 28-30 km. Consequently, Low Rayleigh ozone slightly underestimated and low Rayleigh temperature significantly underestimated. However, several cases of too warm temperatures have also been observed. This BSR<<1 effect is mixing with the effect of the aerosol layer, making its quantitative evaluation impossible. PROBLEM definitely FIXED on August 20, 1998.

- 95-D Ozone severely overestimated and temperature critically overestimated below 20-25 km.

- 96-A Aerosol status in 1996: Thin wide layer at and below 30 km.
Observable consistently throughout 1996. Two diffuse layers observable BSR profile. Rayleigh ozone and Rayleigh temperature significantly affected.

- 96-B Raman filter 332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is to low, especially in ozone peak. Magnitude of bias unknown throughout 1996 due to lack of reliable Rayleigh measurements to compare with into aerosol layer. PROBLEM FIXED on February 25, 2000.

- 96-C Unexpected BSR>>1 below 28-30 km.
Consequently, Low Rayleigh ozone slightly underestimated and low Rayleigh temperature significantly underestimated. In 1996, this BSR<<1 effect is mixing with the effect of the aerosol layer, making its quantitative evaluation impossible. After November 21, 1996: Unexpected BSR<<1 below 23-27 km. Consequently, Low Rayleigh ozone slightly over-estimated and low Rayleigh temperature significantly over-estimated. During this period this BSR<<1 effect counteracts that caused by the aerosols.

- 97-A Aerosol status in 1997: Thin but wide layer at and below 30 km.

Observable consistently throughout 1997, slightly less observable in summer. Frequently two diffuse layers observable on BSR profile.
Rayleigh ozone slightly affected. Rayleigh temperature significantly affected (5-10 K too cold).

- 97-B Raman filter 332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is much to low, especially in ozone peak. Negative bias can reach 20%. PROBLEM FIXED on February 25, 2000.

- 97-C Unexpected BSR<<1 below 23-27 km. Consequently, Low Rayleigh ozone slightly overestimated and low Rayleigh temperature significantly overestimated. In 1997, this BSR<<1 trend counteracts the effect of the aerosol layer.
After May 20, 1997: Unexpected BSR>>1 below 23-27 km. Consequently, Low Rayleigh ozone significantly under-estimated and low Rayleigh temperature significantly under-estimated. In 1997 this BSR>>1 trend adds to that caused by the aerosols. PROBLEM definitely FIXED on August 20, 1998.

- 98-A Aerosol status in 1998: Diffuse mini-layer at and below 30 km.
Mostly observable between January and April, almost undetectable in summer observable in November-December. Sometimes two layers observable on BSR profile. Rayleigh ozone almost unaffected. Rayleigh temperature slightly to significantly affected (5-10 K too cold).

- 98-B Raman filter 332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is much to low, especially in ozone peak. Negative bias can reach 20%. PROBLEM FIXED on February 25, 2000.

- 98-C Before Feb 4, 1998: Unexpected BSR>>1 below 23-27 km. Consequently, Low Rayleigh ozone significantly under-estimated and low Rayleigh temperature significantly under-estimated.
After Feb 4, 1998: Unexpected BSR<<1 below 23-27 km. Consequently, Low Rayleigh ozone slightly overestimated and low Rayleigh temperature significantly overestimated. PROBLEM definitely FIXED on August 20, 1998.

- 98-D Tropopause aerosols event in September 98: Thin but sharp scattering layer observed near 17-18 km between Sep 9-Oct 17, 1998. Origin unknown (Asian dust?). Low-Rayleigh ozone and temperature affected. Additionally both low-Rayleigh and Raman channels give very warm troposphere between Sep 18-25. Origin of these warm temperatures unidentified.

- 99-A Aerosol status in 1999: Diffuse micro-layer below 30 km. Mostly observable between January and April, almost undetectable in summer, slightly observable in November-December. Sometimes two layers observable on BSR profile. Rayleigh ozone unaffected. Rayleigh temperature slightly affected.

- 99-B Raman filter 332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is much to low, especially in ozone peak. Negative bias can reach 20%. Problem fixed on February 25, 2000.

- 00-A Aerosol status as of January 2000: Micro-layer near and below 30 km
  Sometimes two layers observable on BSR profile. Rayleigh ozone almost unaffected. Rayleigh temperature slightly affected.

- 00-B Raman filter
  332 nm degraded causing residual Rayleigh signal polluting Raman channel 5. Consequently ozone calculated using Raman is much to low, especially in ozone peak. Negative bias can reach 20%. PROBLEM FIXED, filter replaced on February 25, 2000.

- 00-C Emerging Aerosol layer: Weak and diffuse aerosol detected in Summer 2000
  Low Rayleigh ozone and low Rayleigh temperature slightly affected.

- 01-A Aerosol status as of January 2001: Micro-layer near and below 30 km.
  Rayleigh ozone almost unaffected. Rayleigh temperature slightly affected

- 01-B System moved from trailer to new NDSC building starting March 21.
  No data from March 21 to May 4, 2001. New wavelength for temperature (355 nm), and receiving system slightly modified. First data on May 5.

*************************** END MLO-1 ******************************

**** ATTENTION: Channel code definition in Ames files modified as new system ***
**** configuration was set up. Changes reflect migration from 6-channel analysis
**** in LidAna v5.2x to 12-channel analysis in LidAna v5.4x. Refer to section
**** named "Ames description" for a re-definition of channel code **************

- 01-C New system configuration: First data on May 5. Test experiments until
  May 15, 2001. Fully operational in routine mode starting May 18, 2001.

*************************** START MLO-2 ******************************

- 01-D 2001 full night campaign on Oct 10-22: 8 long nights acquired.

- 02-A Aerosol status as of January 2002: Micro-layer near and below 30 km.
  Rayleigh ozone almost unaffected. Rayleigh temperature slightly affected

- 02-B July 2002: Suspect bias identified when running Osc or Amp side of laser
  BSR profile, and 355-L temperature seem affected by use of either laser side. Magnitude and exact effect of bias unknown at this date
  Major bias change identified between July 11 and 12, 2002.

- 02-C August 2002: NDSC Campaign. Numerous measurements and longer datasets.

Unfortunately, weather remained poor and many nights are contminated by high clouds.
Official start/end of the campaign: Aug 5-21, 2002

- 02-D October 2002: Chiller failure. No measurements from Oct 16 to Nov 10.

- 02-E November 2002: Service maintenance on YAG laser.
Power (and signals) up, using only 1 side of laser resulting in change in BSR bias at bottom (from slightly above 1 to slightly below 1)
Cause of bias thought to be related to polarization factors

**** ATTENTION: Change in LidAna processing version ****
**** Processing version 5.41 ends on 31 December 2002 ****
**** Processing version 5.50 starts on January 1, 2003 ****
**** No difference detected between the two versions ****

- 03-A Januay 2003: Quasi-permanent thin aerosol layer below 21 km.
Rayleigh temperature profiles cut-off above 21 km most of the time.
Raman temperature okay. However, measured tropopause temperatures found to be very cold. Source of the cold bias uncertain. Geophysical feature is not excluded.

- 03-B Januay 2003: Quasi-permanent thin aerosol layer below 21 km.
Rayleigh ozone profiles significantly affected most of the time.
Raman ozone okay. However the observed small ozone fluctuations may be an artefact of multiple scattering. Geophysical feature is not excluded.

- 03-C January-April 2003: Excimer laser multiple failures.
Failure on March 13 caused major drop in ozone quality until Apr 25 UT.
Temperature unaffected.

- 03-D May 2003: Excimer laser partially fixed.
Nominal power restored on May 5 UT.

- 03-E June 2003: Switching YAG laser operational firing side.
Temperature and ozone slightly affected at very bottom.
BSR profile negative bias now reversing to positive bias at very bottom.

- 03-F October 2003: Two week YAG interruption due to Excimer replacement
Major work in laser room resulting in YAG relocation.
No temperature measurement between Sep 30 and Oct 14, 2003.

- 03-G October 2003: Five week Excimer interruption due to Excimer replacement.
Historical MLO excimer lasers replaced by new lambda physics models.
No ozone measurement between Sep 30 and Nov 5, 2003.

- 03-H November 2003: New Excimer failure ("amplifier") on Nov 11.
  Running excimer "oscillator" only, resulting in weak 308/332 signals.
  between Nov 11 and Nov 17. Full power restored on November 18.

- 03-I November-December 2003: Strong saturation due to new high excimer power
  308 H and L strongly saturated, resulting in higher cut-off of both channels, and slight overestimation of ozone for 308-L below 20 km.
  Saturation effect present from November 18 to December 18.
  308-L signal reduction by ND filter on December 19, leading to less saturation and better cut-off conditions starting December 19, 2003.

- 04-A Januay 2004: Quasi-permanent ultrathin aerosol layer below 27 km.
  Ozone and Raman temperature profiles unaffected.

- 04-B April-May 2004: 355L filter displacement causing saturation below 20 km.
  Incident on channel 4 only (355L) between April 23 and May 5.
  Saturation correction cannot entirely remove additional pile-up effect.
  Rayleigh low ozone slightly overestimated below 20 km.
  Rayleigh low temperature cut-off above 20 km.
  NDSC archived ozone and temperature profiles unaffected.

- 05-A Januay 2005: Quasi-permanent ultrathin aerosol layer below 27 km.
  Ozone and Raman temperature profiles unaffected.

- 05-B September 2005: AMP side of YAG laser failed. Switched to OSC side.
  Resulting 355M transmission reduced. Additional smoothing applied to account for lower STNR. Ozone and temperature profiles almost unaffected
  Effect only on RayM O3 and T range between Sep 20 and Sep 28. Normal conditions re-established for October 5 measurement.

- 06-A January 2006: Quasi-permanent ultrathin aerosol layer below 27 km.
  Ozone and Raman temperature profiles unaffected.

- 06-B February 2006: Laser major failure. No measurements in February 2006.
  Last measurement before failure on January 31, 2006
  First measurement after repair on March 7, 2006

Reported events 2006-Present:

Below is a chronological list of notes describing major events affecting the results. These notes are retrospective, and are not included in any other data or meta data files.

Nov 2012 - Feb 2013: Suspicious, unexpected change of trigger settings Main impact is additional uncertainty in absolute altitude registration.

2013-2017: Incremental loss of STNR due to aging excimer lasers Most visible impact is reduced ozone precision at the top of profile, and a systematic change of up to 3% at 40 km due changing saturation correction parameters.

July 2017: Installation of a new Excimer laser
New laser replaces Oscillator. Amplifier remains in place.

December 2017: Nd:YAG laser "AMP" circuit failure, swapped to "OSC" circuit OSC side trigger setting and Q-switch delay slightly different from the AMP side. The use of OSC side required a change of ND filters in the 355 receiver units. Impact is mainly at bottom part of High-intensity temperature and ozone channels, either due to a change in beam-telescope overlap functon, or beam intensity, or both.

April 2019: New Licel recorders
Installation of new Licel Transient recorders, in replacement of the old MCS cards. Also, new data acquisition software. Main impact is an increase of sampling resolution from 300 m to 15 m, which allowed a 60-m (sub-bin) correction of altitude registration. This correction was applied retrospectively to the newest GLASS re-analysis (2001-present), improving the long-term consistency with Aura-MLS

************ CURRENT END OF LOG OF EVENTS, PENDING UPDATES *************