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Data Mining:
Potential new observations for the CAMS validation activity

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1. Introduction and purpose of this document

The Copernicus Atmosphere Monitoring Service (CAMS, http://atmosphere. copernicus.eu) is a component of the European Earth Observation programme Copernicus. The CAMS system was developed by a series of MACC research projects (MACC I-II-III) until July 2015. CAMS has a subproject, CAMS-84, which is devoted to the validation of the CAMS service products made available to the users.

The validation activity makes use of an extended set of measurements. These measurements are discussed in the "Observations characterization and validation methods" document (Eskes et al., 2016) and the latest validation results for the global CAMS analyses and forecasts is found in Huijnen et al. (2016).

It is the purpose of this document to list a set potential new measurement datasets as well as extensions to the already used datasets which are not yet exploited for the validation activity. Such datasets will be considered to be used for the validation activity in the future.

This document is meant as a CAMS-internal document, and will be updated regularly during the CAMS project (living document). It serves as input for discussions on the evolution of the validation activity (in some cases depending on additional funding).

2. Observations to be considered for future extensions of the validation work

The tables below provide a list of sources of observations which will be considered for future validation work.

2.1 Aerosol observations

Observation source	Remarks
NRT Aeronet, level 1.5, version 3	AOD, fine&coarse mode AOD. Version 3 is free access, but not yet bundeled for mass import. Should improve NRT aerosol optical depth evaluation considerably. Improved cloud Screening in v3: • Improves removal of optically thin cirrus contamination • Preserves more highly variable smoke Quality Controls in v3: • Removes sensor temperature artifacts • Removes AOD affected by solar eclipses • Removes AOD impacted by window obstructions • Removes AOD with poor spectral dependence
NRT PM10 Europe (Airbase)	PM10 NRT data from Europe, not yet available to us (METNO), possibly useful, but may show the same bias as against climatology, incorporation is under investigation
EBAS NRT surface extinction	Data are free and are planned to be incorporated in 2017. Data dissemination via EBAS portal, ebas.nilu.no.
LIVAS, a National Observatory of Athens (NOA) product	Product web-page: http://lidar.space.noa.gr:8080/livas/. (Amiridis et al., 2015). The dataset is based on CALIPSO and will be available as a climatology (e.g. via SDS-WAS NAMEE) and not in NRT mode. AUTH uses LIVAS in different studies (Tsikerdekis et al., 2016, e.g. Fig 3 and Fig 10)
PANDONIA network of PANDORA observations; spectral AOD	Pandora-2S contains two spectrometers, capable of covering the full wavelength range up to 900 nm, and will capable to obtain spectral AOD over the entire range 300-900nm (SpecAOD) within ±0.05. At the moment, the Izaña Pandora-2S photometer has been absolutely calibrated in its full spectral range (September 2016) within ATMOZ campaign (Traceability for atmospheric total column ozone; September 12-30, 2016) as a TNA in ACTRIS-2. QA/QC will be assured for the PANDORA-2S triad reference against WRC-PFR and AERONET-Cimel at Izaña. Transference to station PANDORAS must be developed and protocolized by means of field intercomparisons and ad hoc absolute calibrations at Izaña. Centralized data processing is foreseen

	within ATMOZ project. Near-real time will be provided on a operational way, not before Autumn 2017.
Micropulse lidars and ceilometers	Vertical aerosol extinction retrieved from micropulse lidars and ceilometers using lidar/photometer synergy (AOD from photometers as constraint). Locations: M'Bour (Senegal), Tenerife (Canary Islands, Spain), Granada (Spain), Barcelona (Spain) and Lille (France). Pre-operational near-real time data are provided every 3 hours to be compared with dust model data. A preliminary qualitative comparison of vertical aerosol extinction between lidar/ceilometers and models. This process is centralized at the SDS-WAS NAMEE regional centre (http://sds-was.aemet.es/projects-research/evaluation-of-model-derived-dust-vertical-profiles).
Zenith-looking multi narrow-band radiometer based system (ZEN) AOD retrieval	The zenith-looking multi narrow-band radiometer based system (ZEN) ZEN system has been conceived to retrieve AOD by means of a simple operational technique, which involves zenithal measurements of downwelling sky radiance in four narrowband channels using the ZEN-R41 radiometer and a look up table (LUT) based methodology, especially designed to infer AOD for desert aerosols. The new ZEN-R41 instrument has been designed to operate without moving elements, such as tracking system or filter wheel. AOD at Izaña, Santa Cruz de Tenerife and Tamanrasset (Algeria) under validation process. Future instrument deployments are expected in Northern Africa. Near-real time is provided on pre-operational way. Not before Summer 2017 operational data delivery. QA/QC will be assured for ZEN AOD using WRC-PFR and AERONET-Cimel at Izaña. In a first stage all the instruments will be calibrated at Izaña. (Almansa et al., 2016)
AERONET lunar observations (night time)	AOD and Angstrom exponent during night-time is available for some stations in AERONET-Europe TNA (ACTRIS-2), based on the Cimel CE318-T photometer. 13 stations are now operating lunar photometer and producing NRT AOD within AERONET-Europe. They are located in Poland (Raciborz), Romania (Magurele Inoe), South Africa (Henties Bay), West Africa (Dakar), Spain (Izaña, Valladolid, Calibration sites + Granada, Burjassot anfd Huelva), Germany (MetObs Lindenberg, Leipzig, Munich), France (Lille and Carpentras, Calibration site), Cyprus (Nicosia, Field campaign), Norway (Andenes), in Italy (Leece, Napoli, Lamezia, Terme, Potenza), UK (Chilbolton, Bayfordbury), Norway (Andenes), Finland, France. NRT nocturnal AOD is provided for ACTRIS-2 data providers individually at the moment in this pre-operational phase. Nocturnal AOD has been validated with AEONET.

	Centralized data processing at LOA (University of Lille) (Barreto et al., 2016; Goloub et al., 2016)

2.2 GAW network surface ozone and CO

Observation source	Remarks
GAW stations	It is foreseen to enlarge the set of GAW stations. The growing need for NRT data and applications has been recognized by the WMO and an Advisory Group on near-real time modelling applications (SAG-APP) has been established, with a first meeting in June 2016. The institution of the SAG-APP is a great step forward towards the expansion of the GAW NRT station data provision.

2.3 NDACC extensions

Observation source	Remarks
NDACC network observations	The table below provides an overview of all NDACC stations that have promised to send data to NDACC RD in the coming months/years. (Of course this table is sensitive to errors. Some sites may not participate, or may send corrupt files. This should be seen as the best possible situation.) In the future some instruments will provide other data products of interets to CAMS (eg LIDAR tropospheric ozone & aerosol, LIDAR temperature, UVVIS offaxis tropospheric ozone, FTIR HNO3, HCL, …) . But it is too early at this point in time to say something about this.

Table: Overview of future NDACC products (green=RD already available, yellow=RD partly available)

site	no	targets	contact
athens/uvvis.doas	4	o3, no2, no2, hcho	richter@iup.physik.uni-bremen.de
bern/mwr	1	o3	klemens.hocke@iap.unibe.ch
bremen/uvvis.doas	4	o3, no2, no2, hcho	richter@iup.physik.uni-bremen.de
bujumbura/uvvis.doas	2	no2, h2co	francois.hendrick@aeronomie.be
cabauw/uvvis.doas	3	aerosol, no2, hcho	ankie.piters@knmi.nl
debilt/uvvis.doas	3	aerosol, no2, hcho	ankie.piters@knmi.nl
elisabeth/uvvis.doas	2	o3, no2	francois.hendrick@aeronomie.be
eureka/ftir	3	co, ch4, o3	strong@atmosp.physics.utoronto.ca
eureka/lidar	1	o3	alexey.tikhomirov@dal.ca
eureka/uvvis.doas	2	o3, no2	strong@atmosp.physics.utoronto.ca

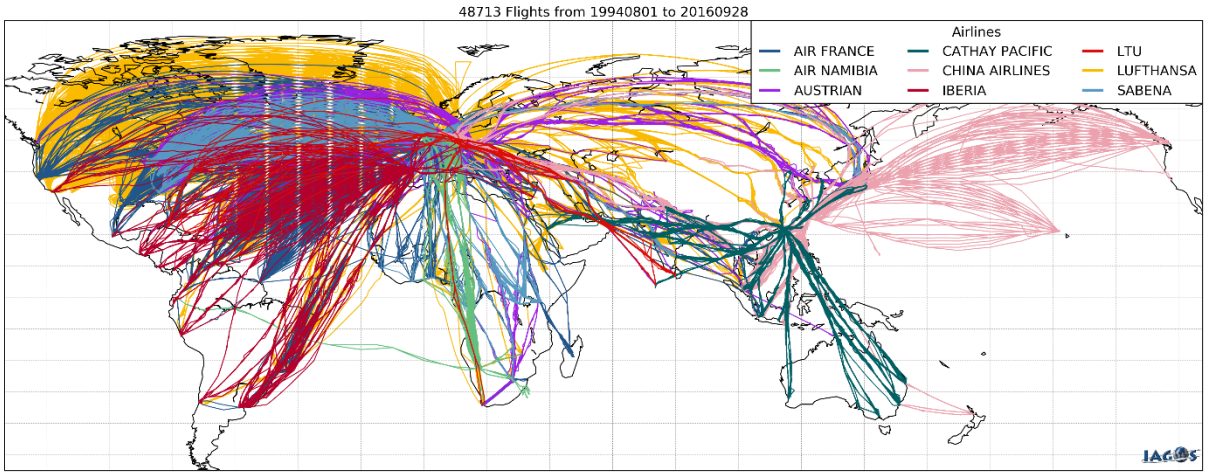
garmisch/ftir	4	co, ch4, no2, o3	ralf.sussmann@kit.edu
harestua/ftir	4	co, ch4, no2, o3	johan.mellqvist@chalmers.se
harestua/uvvis.doas	2	o3, no2	francois.hendrick@aeronomie.be
hohenpeissenberg/lidar	1	o3	wolfgang.steinbrecht@dwd.de
huntsville/lidar	1	o3	mike@nsstc.uah.edu
izana/uvvis.doas	3	o3, no2, aerosol	yelam@inta.es
jungfraujoch/ftir	4	co, ch4, no2, o3	emmanuel.mahieu@ulg.ac.be
jungfraujoch/uvvis.doas	5	o3, no2, aer, no2, h2co	francois.hendrick@aeronomie.be
lauder/ftir	4	co, ch4, no2, o3	dan.smale@niwa.co.nz
lauder/lidar	1	o3	daan.swart@rivm.nl
leport/uvvis.doas	3	aerosol, no2, h2co	francois.hendrick@aeronomie.be
maido/ftir	4	co, ch4, no2, o3	bavo.langerock@aeronomie.be
maido/lidar	1	o3	sophie.godin-beekmann@latmos.ipsl.fr
maunaloa/ftir	3	ch4, no2, o3	jamesw@ucar.edu
maunaloa/lidar	1	o3	thierry.leblanc@jpl.nasa.gov
maunaloa/uvvis.doas	5	o3, no2, aer, no2, hcho	rainer.volkamer@colorado.edu
melbourne/uvvis.doas	4	aer, no2, hcho, o3	m.tully@bom.gov.au
nyalesund/ftir	4	co, ch4, no2, o3	mathias@iup.physik.uni-bremen.de
nyalesund/mwr	1	o3	mathias@iup.physik.uni-bremen.de
nyalesund/uvvis.doas	2	o3, no2	richter@iup.physik.uni-bremen.de
ohp/lidar	1	o3	sophie.godin-beekmann@latmos.ipsl.fr
ohp/uvvis.doas	2	o3, no2	andrea.pazmino@latmos.ipsl.fr
paramaribo/ftir	4	co, ch4, no2, o3	mathias@iup.physik.uni-bremen.de
riogallegos/lidar	1	o3	jacosalvador@gmail.com
sodankyla/ftir	3	co, ch4, no2	bavo.langerock@aeronomie.be
spitzbergen/mwr	1	o3	klemens.hocke@iap.unibe.ch
st.petersburg/ftir	4	co, ch4, no2, o3	zaits@troll.phys.spbu.ru
stdenis/uvvis.doas	2	o3, no2	andrea.pazmino@latmos.ipsl.fr
tablemountain/ftir	3	ch4, no2, o3	jamesw@ucar.edu
tablemountain/lidar	1	o3	thierry.leblanc@jpl.nasa.gov
toronto/ftir	3	co, ch4, o3	strong@atmosp.physics.utoronto.ca
ushuaia/uvvis.doas	3	o3, no2, aerosol	yelam@inta.es
xianghe/uvvis.doas	3	aerosol, no2, h2co	francois.hendrick@aeronomie.be
zugspitze/ftir	4	co, ch4, no2, o3	ralf.sussmann@kit.edu

2.4 Aircraft

Observation source	Remarks
IAGOS water vapour	Water vapour is now available from IAGOS in NRT. Temporal and spatial coverage is the same as for the O3 and CO currently used. Data are stored every 4s throughout the

	flight, and are used either as tropospheric profiles taken during landing and take-off or as horizontal trajectories in the upper troposphere-lower stratosphere (UTLS) obtained during the cruise part of the flight.
CARIBIC	CARIBIC which is also part of IAGOS, also provides measurements of a large number of species in the atmosphere. These measurements are not available in NRT but may be useful in the validation of the re-analysis.

The IAGOS network is shown in the figure is constantly evolving. A new aircraft was equipped in summer 2016, which has served some destinations in Australia and New Zealand.
The website http://www.iagos.fr and links therein, give access to the database, details of the QA/QC procedures, the frequency and availability of flights, and details on the operation of the instruments.



2.5 Measurements in Asia

Observation source	Remarks
In-situ data in China from the PANDA project	The data cover China, it is surface observations and they are not validated. The data available for the cities: Dongguan, Chongqing, Harbin, Suzhou, Qingdao, Jinan, Zhengzhou, Dalian, Kunming, Wuxi, Xiamen, Changchun, Ningbo, Nanning, Taiyuan, Hefei, Changzhou, Tangshan, Changsha, Xuzhou, Wenzhou, Guiyang, Ürümqi, Zibo, Fuzhou, Shijiazhuang from January 2016; and for Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Tianjin, Chengdu, Nanjing, Xi'an, Wuhan, Shenyang from April 2015. The stations measure PM2.5, PM10, NO2, O3, SO2 and CO. The data are given as an average of the urban network, usually around 5-12 stations.

2.6 New datasets in the Eastern Mediterranean

Observation source	Remarks
Data from Cyprus Air Quality Network	As of winter 2015-2016 the surfase ozone validation analysis for the eastern Mediterranean is extended by using surfase ozone data from 3 background rural stations in Cyprus provided by the Department of Labour Inspection - Ministry of Labour and Social Insurance, of Cyprus (http://www.airquality.dli.mlsi.gov.cy/). The data are used only for the scope of CAMS-84 after an agreement between the Academy of Athens and the Cyprus Ministry. Currently there is not an automated way for data provision and the data are provided every week (by e-mail) to the Academy of Athens. The entire Cyprus reference lab belongs to the AQUILA network and has been accredited according to the standard CYS EN ISO/IEC 17025 (accreditation certificate) that dictates the general requirements for the competence of testing and calibration laboratories. Information about coordinates and species measured are given in Table 1 below. The stations measure PM2.5, PM10, NO2, O3, SO2 and CO. The data are given as an average of the urban network, usually around 5-12 stations.
Navarino Environmental Observatory (NEO) station	From the end of May 2016 a new fully automated instrument measuring surface ozone and CO was installed at the Navarino Environmental Observatory (NEO) in SE Peloponnese. The Navarino Environmental Observatory is located in the West Messenia which is in the crossroads of manmade and natural aerosols as well as reactive gases. The data are provided automatically every 10 min and will be freely available for the needs of the CAMS 84 project. Information about coordinates of Navarino Environmental Observatory are given in Table 2.

Table 1. List of Department of Labour Inspection - Ministry of Labour and Social Insurance, of Cyprus stations used for the validation.

Name	lat [°]	lon [°]	alt (m)	species measured	High Altitude	EMEP
Ayia Marina	35.04 N	33.06 E	532	O_3, NO_2, NO, CO, PM10, PM2.5	-	Yes
Inia	34.96 N	32.37 E	672	O_3, NO_2, NO	-	-
Troodos	34.95 N	32.86 E	1819	O_3, NO_2, NO	Yes	-

Table 2. Navarino Environmental Observatory (NEO) station coordinates and species measured.

Name	lat [°]	lon [°]	alt (m)	species measured	Country
Navarino Environmental Observatory (NEO)	37.00 N	21.67 E	50	O3, CO, PM10, PM2.5	Greece

It should be noted that an attempt to create a platform delivering near-to-real time data to CAMS-84 users is underway provided that the necessary funds are available.

2.7 New datasets in the Arctic

Observation source	**Remarks**
IASOA network	The IASOA network offers links to a number of databases which include long time series of atmospheric Arctic data that are freely available on the web. Links are set to various databases including Arctic gaseous or particulate parameters. Via personal contacts throughout this network we will get access to near-real time data on Arctic gaseous species. This will only be possible for a limited number of stations.

Table: Data availability of Arctic stations: long time series (green=RD already available, yellow=RD partly available)

site	no	targets	comment
ALERT	1	O3, CH4, CO, PM1, PM10	Also NRT data already available (O3)
BARROW	2	O3, CH4, CO, PM1, PM10	Also NRT data already available (O3)
CHERSKII	3	CH4	
EUREKA	4	CH4, CO, NOx, PM1, PM10	
NY-ÅLESUND	5	CH4, CO, NOx, PM1, PM10	
OLIKTOK	6	PM1, PM10	
PALLAS	7	O3, CH4, CO, NOx, PM1, PM10	
SUMMIT	8	O3, CH4, CO, NOx, PM1, PM10	Also NRT data already available (O3)
TIKSI	9	O3, CH4, CO, NOx, PM1, PM10	
VILLUM	10	O3, CH4, CO, NOx	Also NRT data already available (O3)

2.8 Surface remote sensing

Observation source	Remarks
MAX-DOAS	Extension of the number of sites, as well as inclusion of other species (HCHO, aerosol, ..) may be considered (Hönninger et al., 2004).
PANDONIA network of PANDORA observations	The PANDORA-2S instruments measure O3, NO2, SO2, CHCO, BrO. Centralised processing and near-real time delivery are planned. Some first preliminary NRT data are available, to be extended during 2017.

2.9 Stratosphere

Observation source	Remarks
OMPS-LP NO2	NO2 may be used when relevant.
ACE-FTS	The public dataset (v3.5) currently covers 200402-201306. I went to the latest PM of ESA O3-CCI to discuss with Kaley Walker (Univ. Toronto): ◦ *Potential for NRT validation:* Simon discussed with Kaley about the sustainability of ACE-FTS and the possibilities for more regular updates (e.g. 3-monthly with 1 month latency to allow ingestion into our WP1 reports). There is no hard time-limit with ACE-FTS: it can keep going for an indefinite period until some unexpected failure happens. So in theory ACE-FTS could be mentioned as a potential new source of data for WP1. (note that IMHO this requires ECMWF to start active negociations with University of Toronto). ◦ *Potential for reanalysis validation:* Kaley also informed Simon that a new version of the full mission dataset (200402-2016??) will be made public at the end of October. This schedule would match with the upcoming reanalysis validation in CAMS, in which Yves will of course update and use the nexer dataset.
OSIRIS	The public dataset (v5) currently covers 200110-201412. BIRA has no contact with this team, but the instrument is still active and still delivers data (as explained during a team presentation at latest ozone symposium).
ALTIUS	The ALTIUS mission (Fuessen et al., 2016) is designed by BIRA-IASB and approved by ESA for launch currently planned

	in 2020.

2.10 Satellite (UV-Vis)

Observation source	Remarks
GOME-2 NO2 and HCHO	In-house DOAS retrievals of NO_2 and HCHO from GOME-2/MetOp-B already exist at IUP-UB, but are not yet implemented in the validation chain of CAMS-84. (Callies et al., 2000; Munro et al., 2016; Richter et al., 2011; Vrekoussis et al., 2010)
GOME-2 SO2	SO_2 retrievals on GOME-2/MetOp-A and Metop-B are performed routinely at IUP-UB intended for investigation of volcanic SO_2 and could be used in CAMS-84.
OMI NO2, SO2	DOAS retrievals of NO_2 (whole dataset) and HCHO (available for specific months so far) are performed at IUP-UB based on level 1 data from NASA but not yet implemented in the validation chain of CAMS-84. DOAS retrievals of SO_2 are currently not performed at IUP-UB, but in plan and may then be used in CAMS-84 as well. (Levelt et el., 2006)
S5P	The Sentinel-5 Precursor launch is planned for early 2017. S5P will carry the TROPOspheric Monitoring Instrument (TROPOMI) UV-VIS-NIR-SWIR nadir spectrometer. It will provide data at high spatial resolution (3.5 x 7 km^2). DOAS retrievals of NO_2, HCHO and SO_2 are planned to be developed at IUP-UB once the S5P mission is launched and TROPOMI level 1 data has become available. (Veefkind et al., 2012)

NRT supply of validation results to CAMS is currently not available but in plan. QA/QCs/KPIs are planned for the future.

2.11 Satellite (IR)

Observation source	Remarks
Mopitt V7 CO	Since March 2016 Mopitt V7 CO data are available as a "beta" version. The data are not yet calibrated. V7 level 3 products are still in development. Featured improvements in the V7 retrieval product include: improved radiative transfer modeling, improved meteorological fields used in Level 2 processing, improved cloud detection, improved radiance bias correction. Compared to V6 validation results (not yet published), preliminary results for V7 indicate generally smaller retrieval biases and reduced bias variability.
IASI O3	No open access to IASI O3 NRT. This slows down the process.

	Natalia will contact retrieval team to get the access. Total amount of ozone under cloud-free conditions which is measured with a horizontal resolution of about 25 km.

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AERONET version 3: http://aeronet.gsfc.nasa.gov/new_web/Documents/AERONET_V3_AOD.pdf.

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PANDONIA network: http://www.pandonia.net.

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