Remote sensing of the atmosphere from satellites

Jože Rakovec[1,2], Nedjeljka Žagar[1,2], Gregor Skok[1,2], Rahela Žabkar[1,2], Matic Šavli[1], Luka Honzak[2]

[1] University of Ljubljana, Faculty of Mathematics and Physics, Meteorological Group

[2] Centre of Excellence SPACE-SI

Methods

active – radars, lidars, backscatter measurement, GPS delays,…
passive – radiometers, spectrophotometers, scatterometers,…

Viewing

nadir – short optical path
limb – against cold background
limb – solar occultation

Satellites

geostationary – 36000 km high orbit
non-geostationary – low orbit 500-1000 km

Scientific background

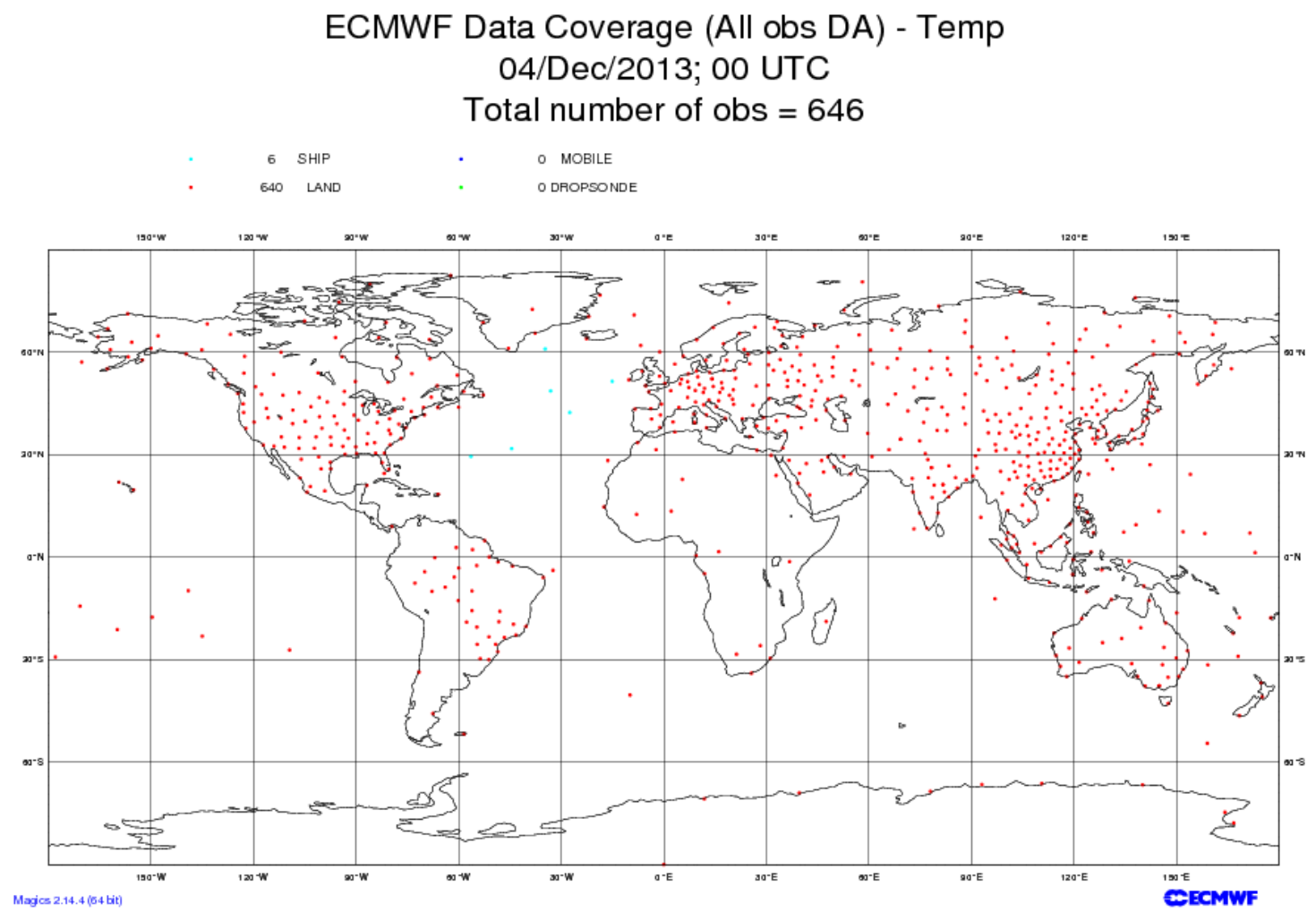
Radiative transfer equation (Schwartzschild)

$$L(\nu,s) = L(\nu,0)\, e^{-\chi(\nu;s)} + \int J[\nu,T(\chi')]\, e^{-[\chi(\nu;s)-\chi']} d\chi'$$

The most important measurements for meteorology

Thermal emission measurements (3D temperature sounding): e.g. HIRS, AIRS, IASI

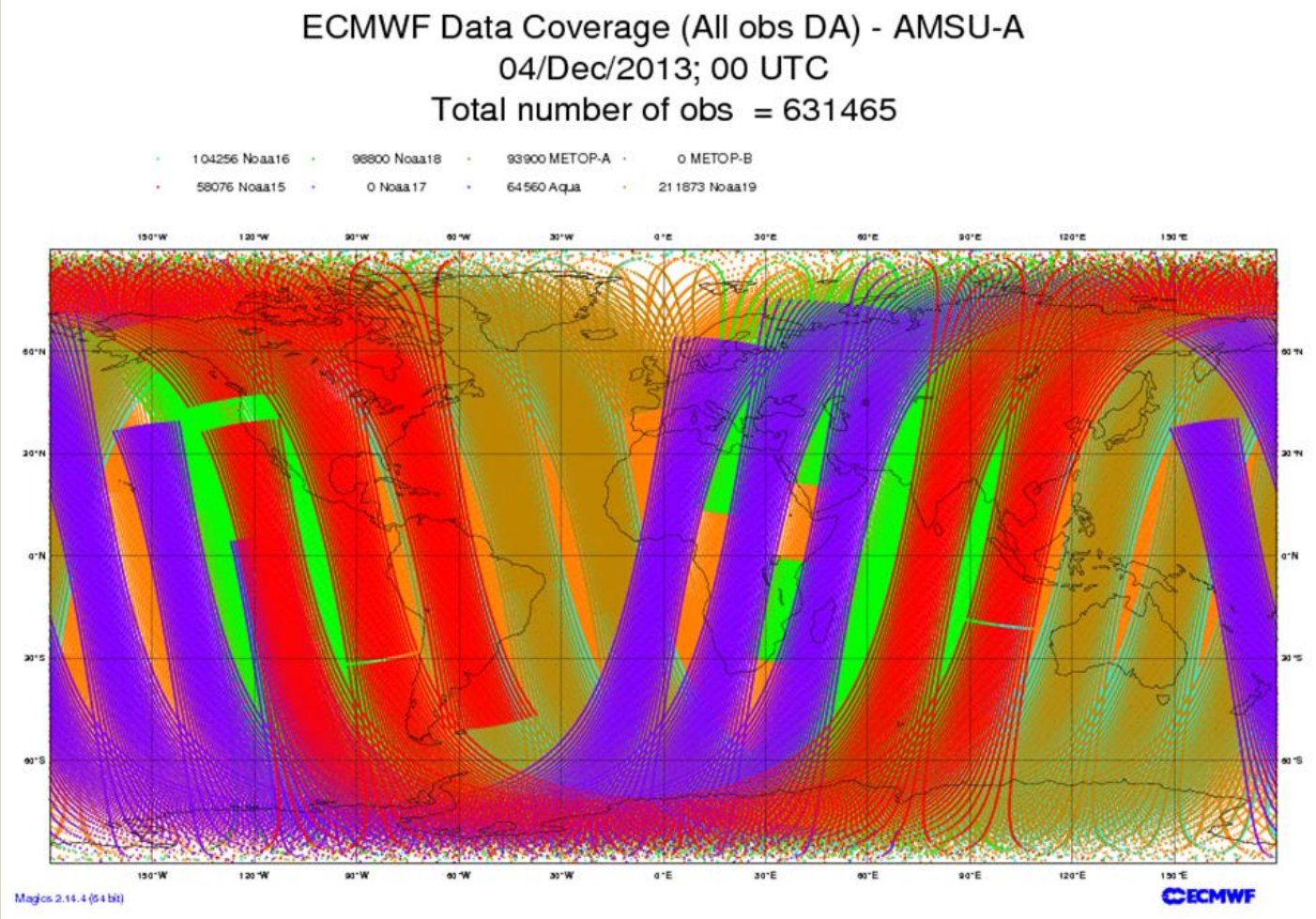
classical, from ground – balloon radiosoundings



ECMWF

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover!Temp!00!pop!od!mixed!w_coverage!latest!/

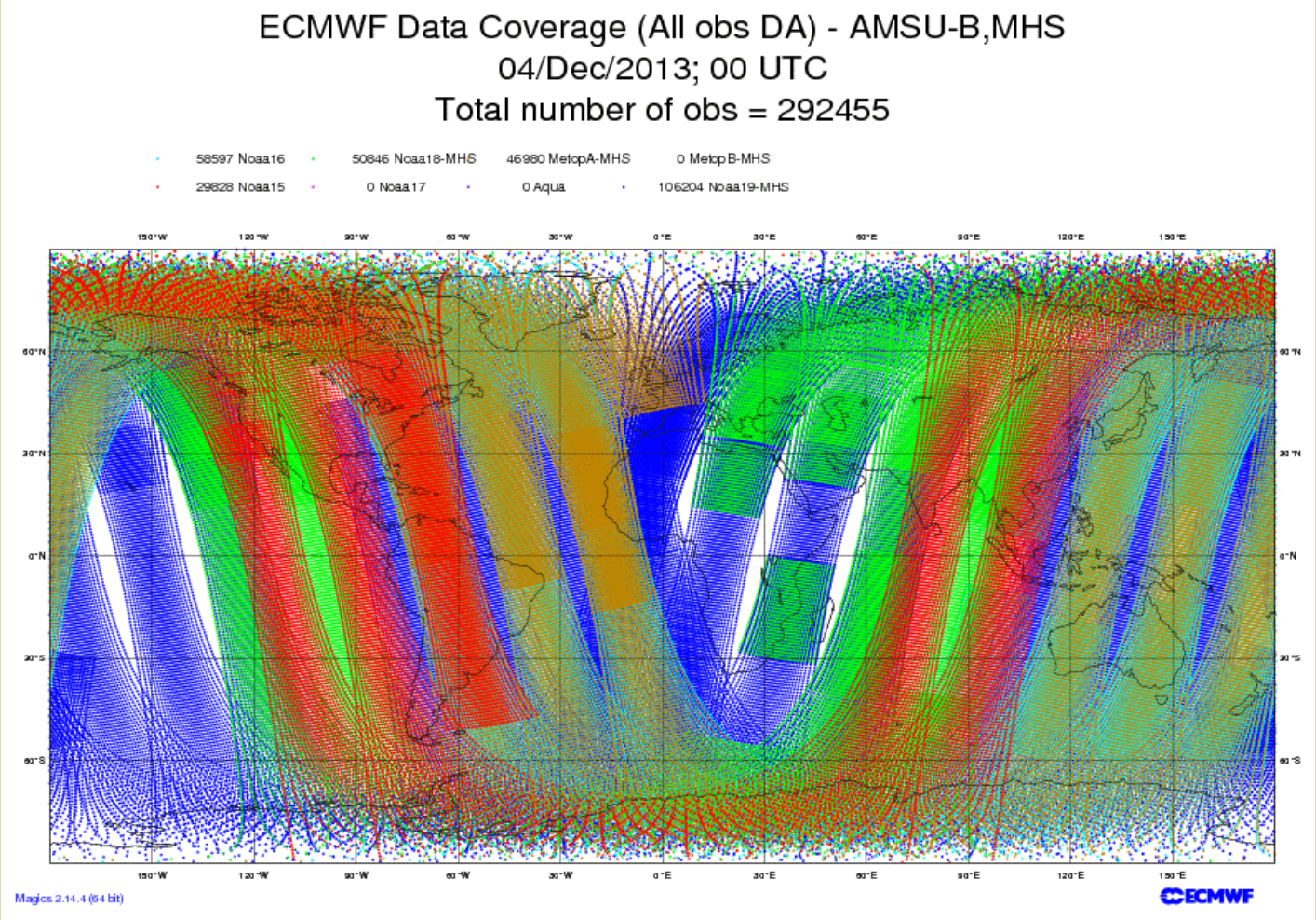
satellite data



ECMWF

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover!AMSUA!00!pop!od!mixed!w_coverage!latest!/

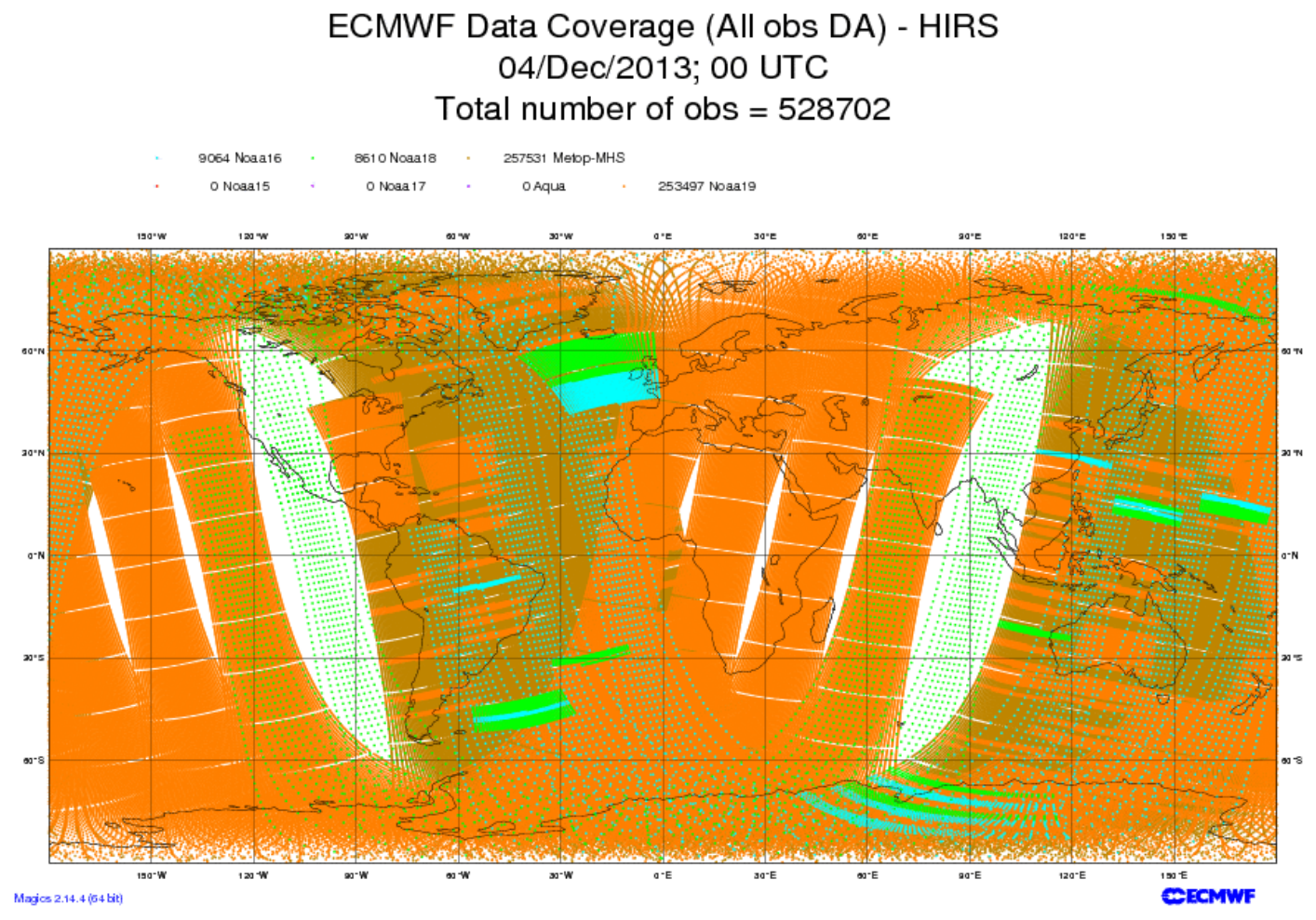
satellite data



ECMWF

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover!AMSUB-MHS!00!pop!od!mixed!w_coverage!latest!/

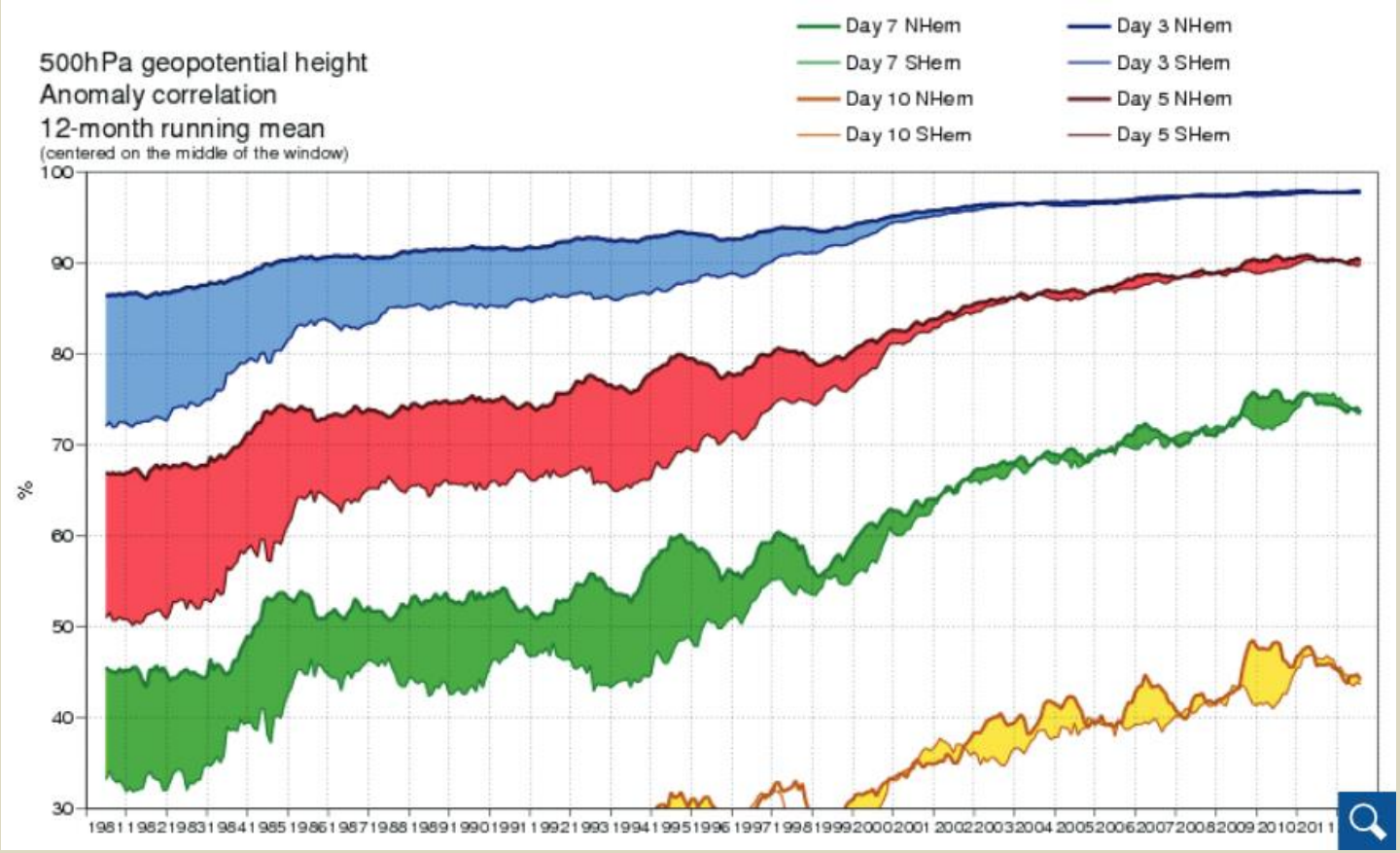
satellite data



ECMWF

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover!HIRS!00!pop!od!mixed!w_coverage!latest!/

final profit…
is essential!



ECWMF statistics of foracast quality
https://software.ecmwf.int/wiki/download/attachments/24317651/expansion-20130311.pdf?version=1&modificationDate=1363003246902&api=v2

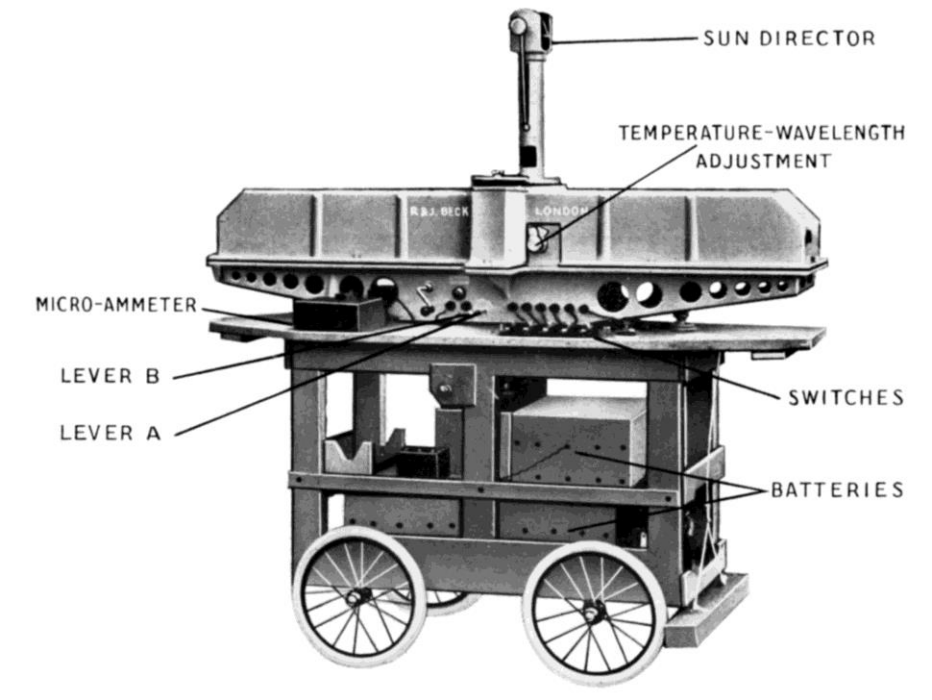
Ozone measurement

classical – from ground, Dobson…

the first Dobson's spectrophotometer, 1926

http://www.sciencemuseum.org.uk/objects/meteorology/1950-159.aspx

classical – from ground, Dobson…

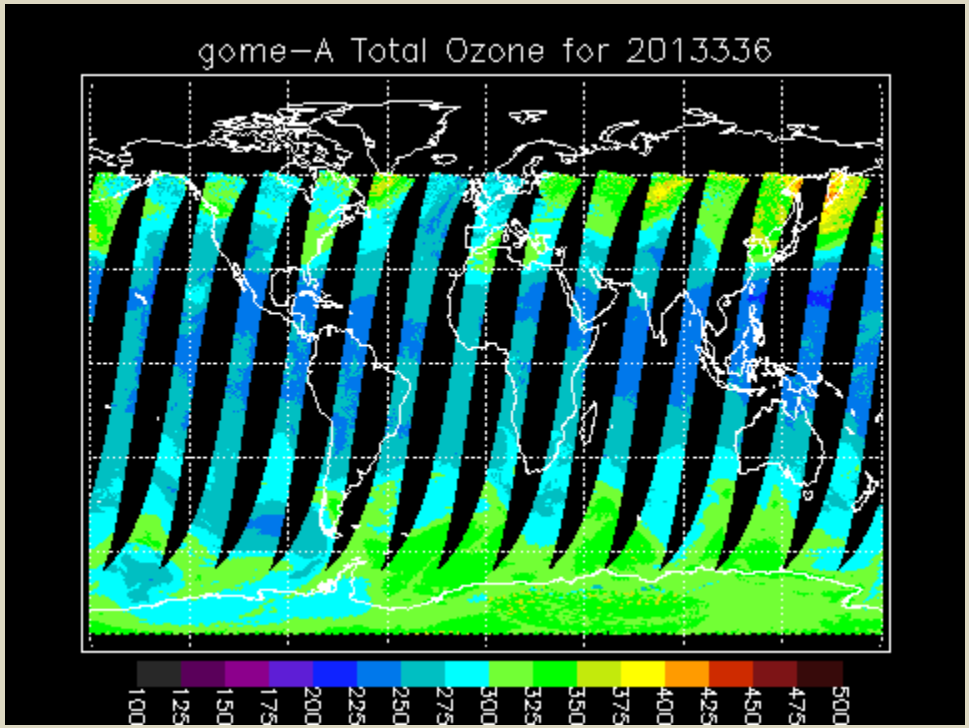


Dobson spectrofotometer from 1927/1928
http://www-atm.physics.ox.ac.uk/user/barnett/ozoneconference/dobson.htm

classical – from ground, modern Dobson…

NOAA - Modern Dobson spectrofotometer
http://www.ozonelayer.noaa.gov/action/dobson.htm

from satellite GOME-2 on satellite MetOp – backscatter of solar UV…



The GOME-2 designed by the European Space Agency (ESA), algorithm by DLR
http://www.ospo.noaa.gov/Products/atmosphere/gome.html

More

Wind close to the sea-surface via active scatterometer

Humidity sounding via emissions in IR and MW

Water vapor tomography via GPS delays

…
…

Future

Wind by light scattering along the line of sight

…

…

…

The use of satellite measured data in Slovenia

Geodesy – positioning system

Meteorology

ARSO
(next presentation by Mateja Iršič Žibert, ARSO)

University of Ljubljana, FMF
Meteorology group
in scope of
CE Space-SI,
the research program of FMF, funded by ARRS
and three ESA funded PECS projects

1. indirectly via boundary conditions
2. directly – satellite radar data
3. impact of new satellite wind observations
4. aerosol dynamics with 4D-var data assimilation
5. Slovenia from Space – Bora wind

1. **Research forecast with WRF and WRF/Chem**

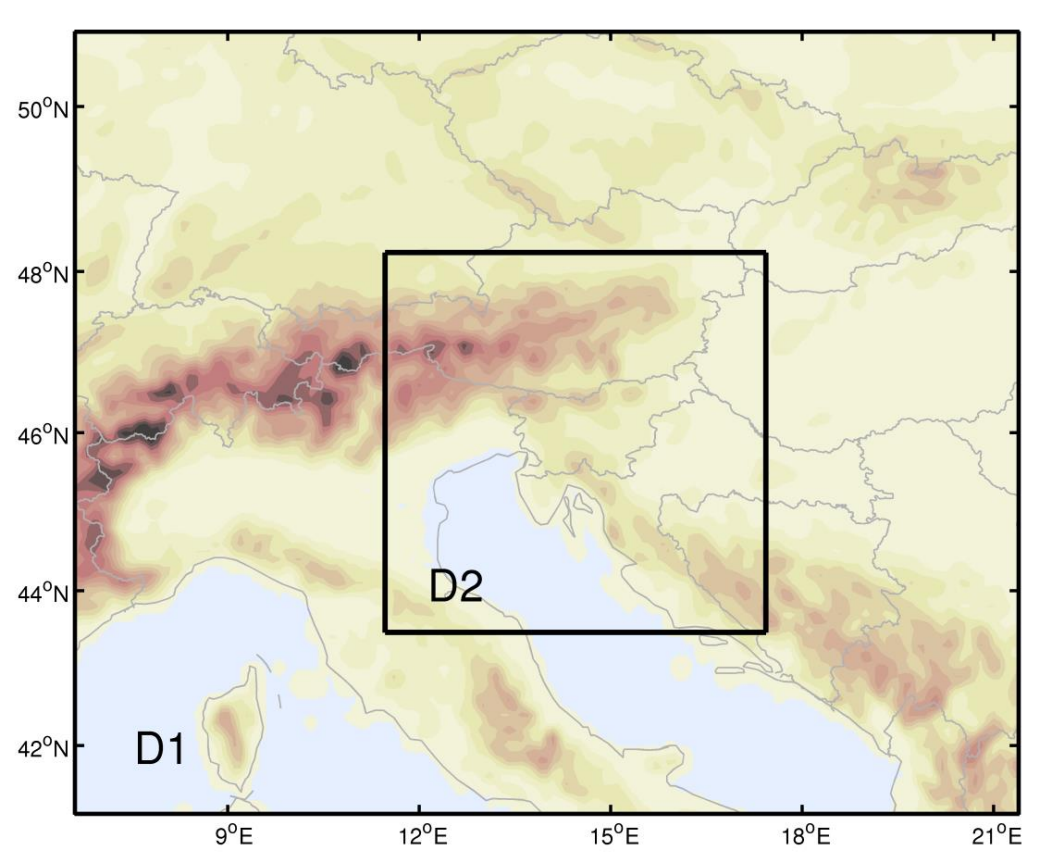
start of the forecast: initial and boundary conditions

4D structure of the atmospheric variables, obtained from the measured, initialized and analyzed data

The **most important** data source are the **satellite borne data!**

Boundary conditions $\Longrightarrow$ two nested domains:

11,12 km resolution (151x100 grid points)
and 3,7 km resolution (181x145 grid points)
42 vertical levels
48h forecast, once per day



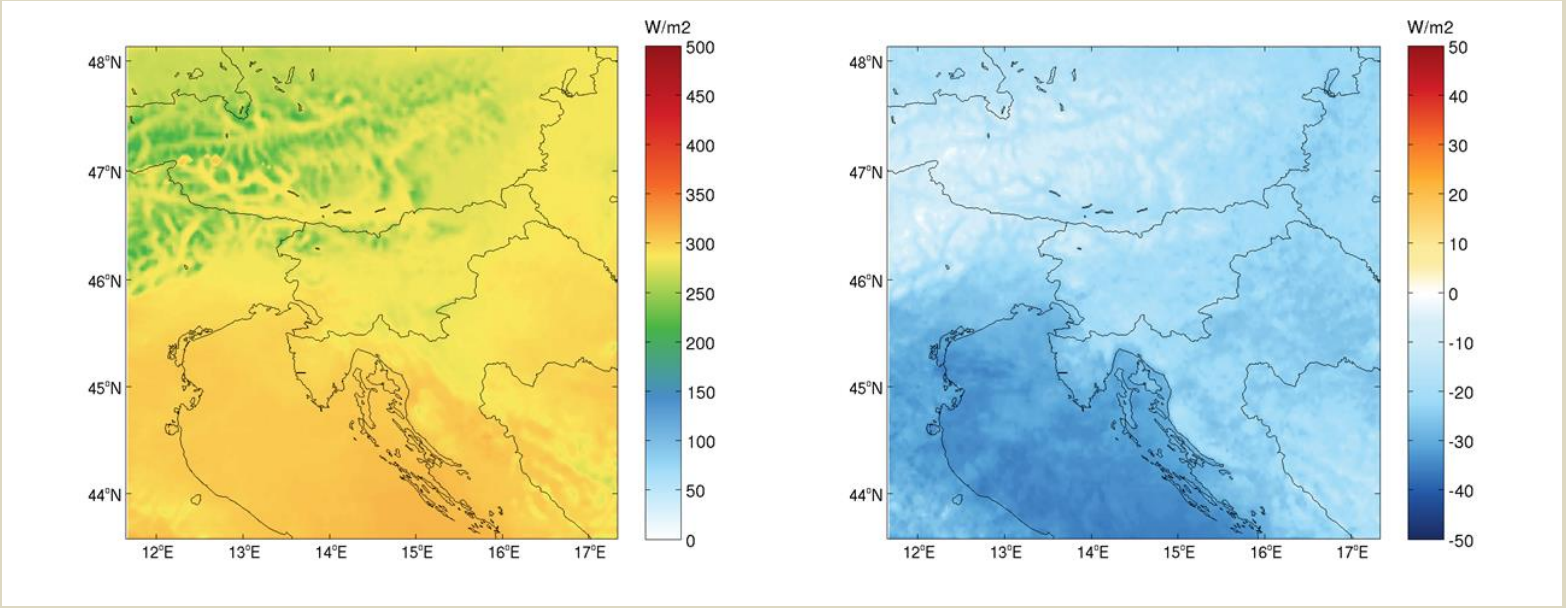
Impact of DIRECT EFFECT on weather

R. Žabkar[1,2] in L. Honzak[2], 2013: Napovedovanje kakovosti zraka z modelom WRF/Chem, Zbornik SZGG,
[1]Uni-Lj, FMF, [2]CE Space-SI

MEAN (WRF)

DIFF WRF/Chem –WRF

solar irradiation



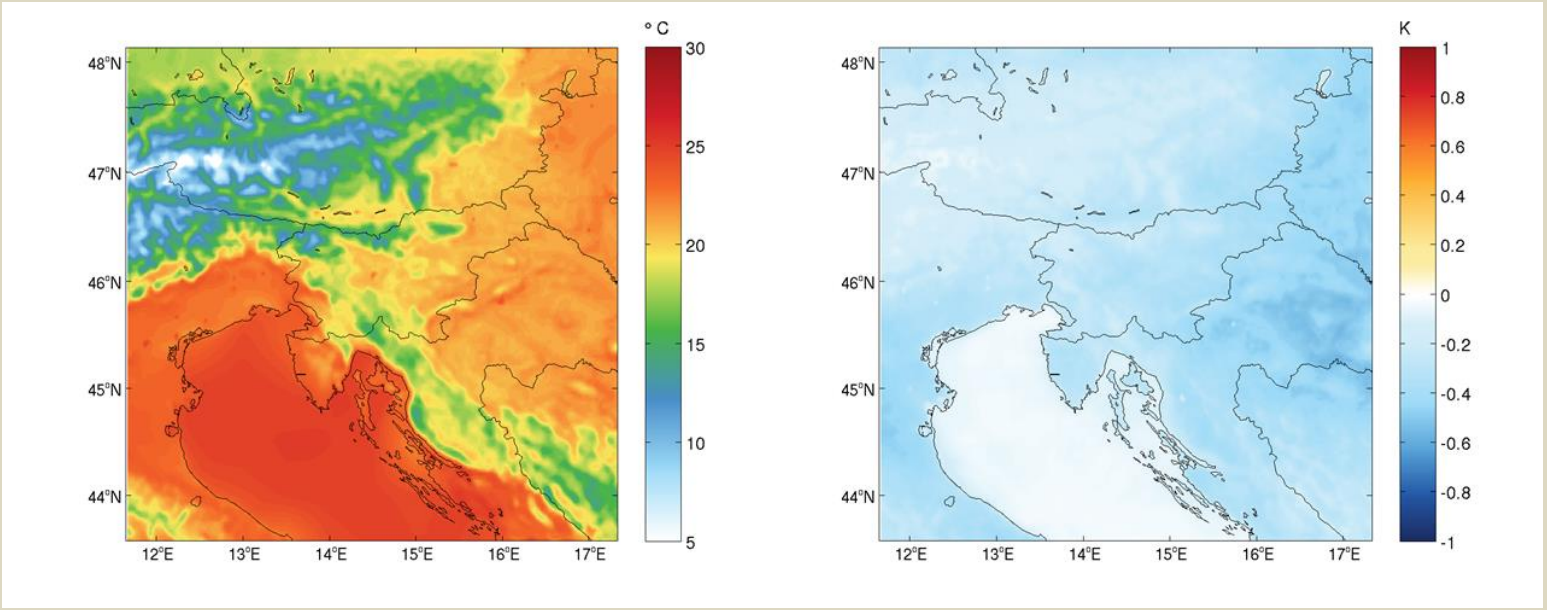
Impact of DIRECT EFFECT on weather

R. Žabkar[1,2] in L. Honzak[2], 2013: Napovedovanje kakovosti zraka z modelom WRF/Chem, Zbornik SZGG,
[1]Uni-Lj, FMF, [2]CE Space-SI

MEAN (WRF)

DIFF WRF/Chem –WRF

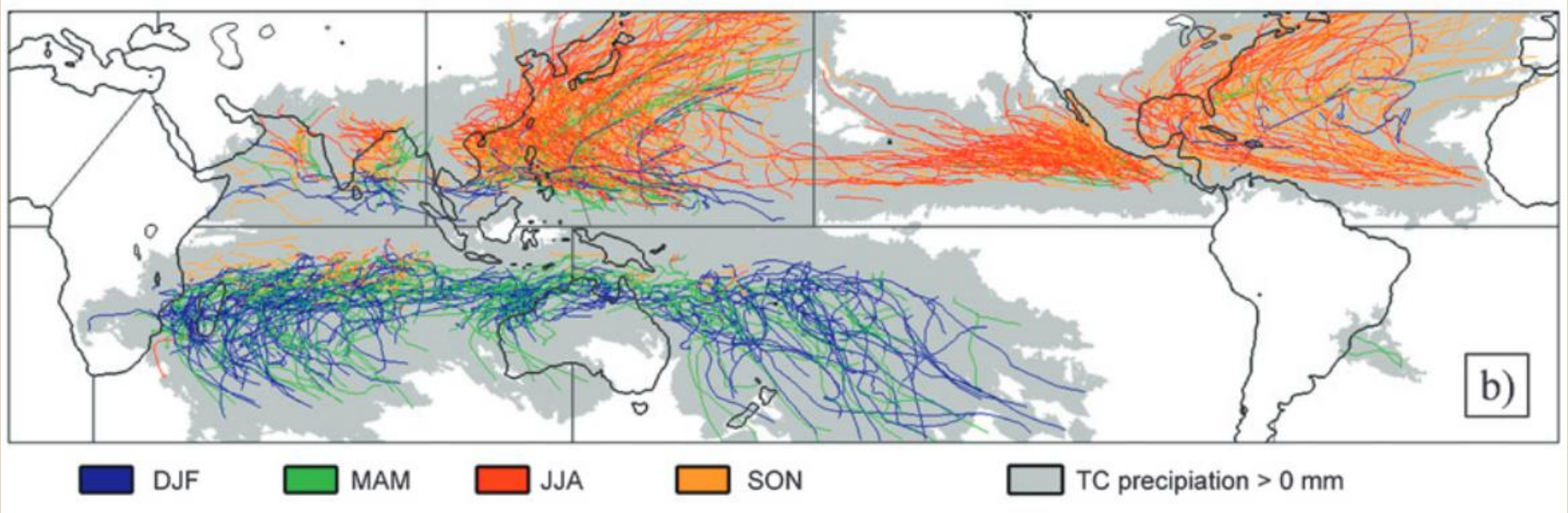
2 m temperature



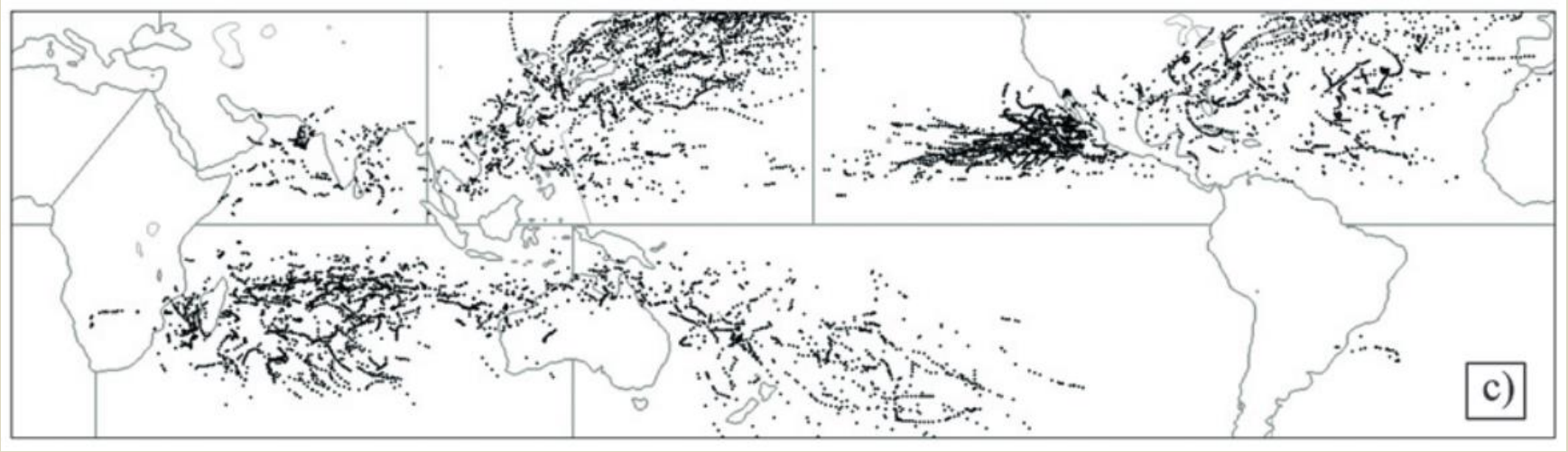
2. Precipitation in tropical cyclones
based on TRMM radar data

G. Skok[1,2], J. Bacmeister[3] and J. Tribbia[3], 2013:
Analysis of Tropical Cyclone Precipitation Using an Object-Based Algorithm,
J. Climate **26**, 2563-2579.
[1]Uni-Lj, FMF, [2]CE Space-SI, [3]NCAR, Boulder, Colorado

The TC trajectories from the IBTrACS dataset for the period 1998–2008. Colors represent seasons. Black lines represent domain borders. Light-gray shading indicates regions where any TC precipitation has been detected.



Locations of identified IBTrACS storm centers (1998–2008) that were not associated with any TRMM 3B42 precipitation object.



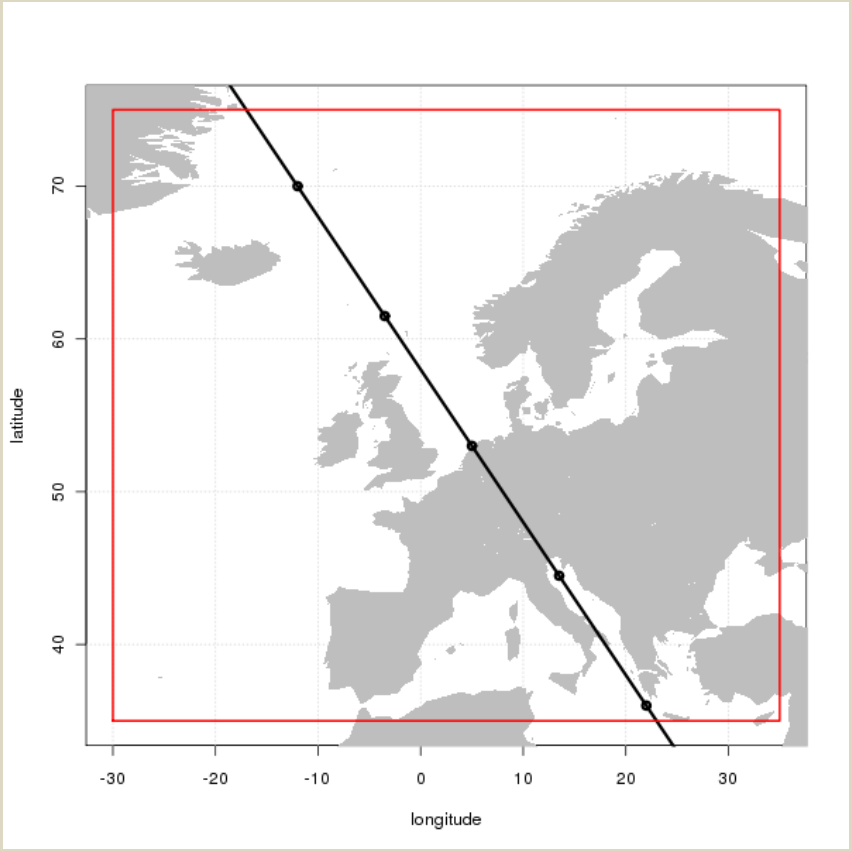
3. Impact of new satellite wind observations

Project ”Mesoscale wind profiles and data assimilation”
Funding: ESA-PECS

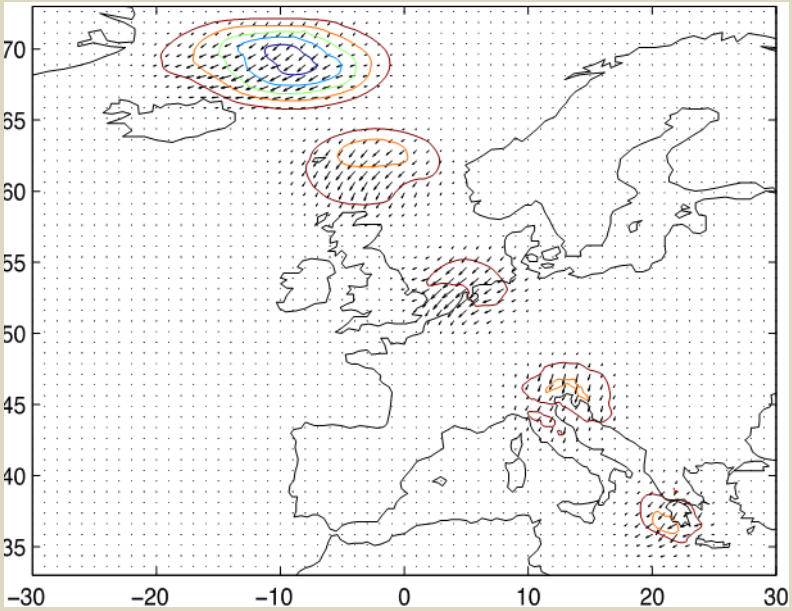
Polar-orbiting Doppler Wind Lidar providing global measurements of atmospheric wind profiles twice per day
Exploratory character mission measuring line-of-sight (LOS) winds
Expected launch in July 2015

http://www.esa.int/esaLP/LPadmaeolus.html

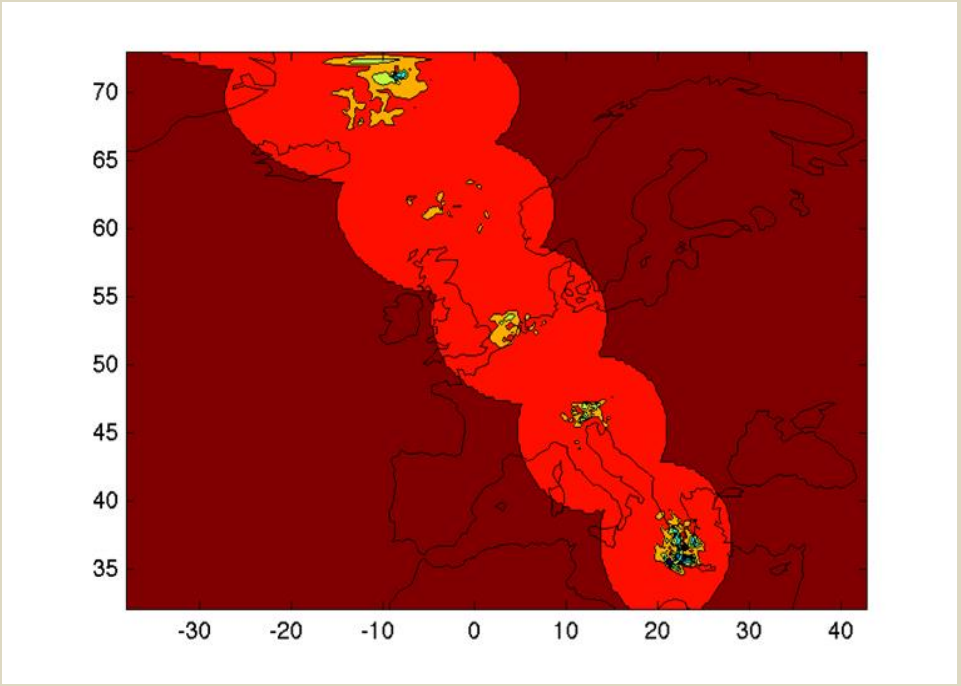
Data assimilation of LOS DWL winds



An example of analysis increments at a model level in the lower troposphere



v and T

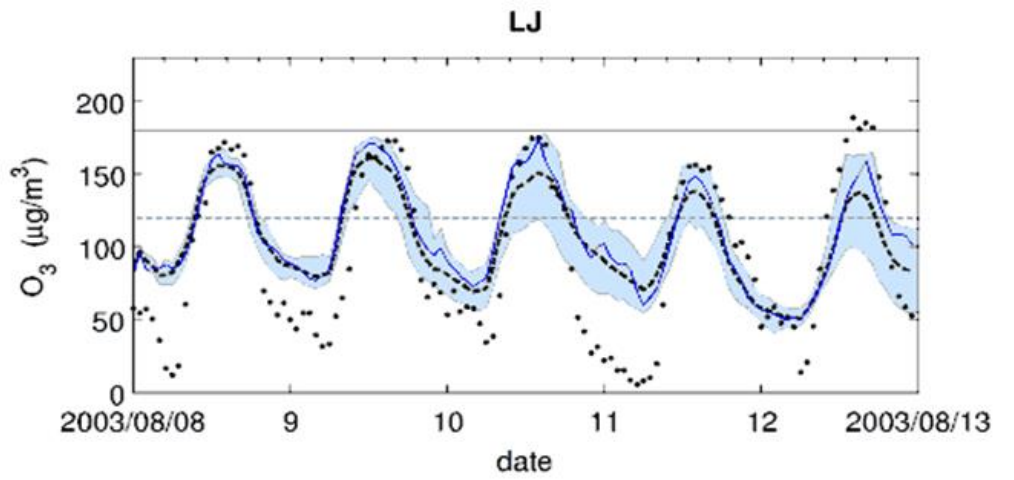


w

4. **Aerosol-dynamics coupling in 4D data assimilation**

Project ”Multivariate relationships between the aerosols, moisture and winds in four-dimensional data assimilation for the global monitoring for environment and security”
Funding: ESA-PECS
to start on 1 January 2014

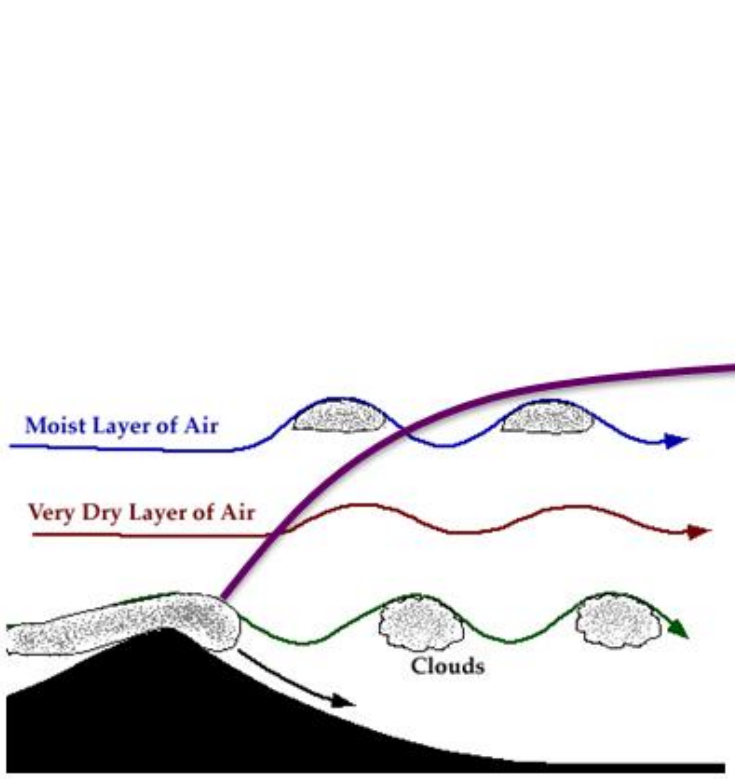
The project topic is highly relevant for the problem of data assimilation and forecasting of atmospheric composition.

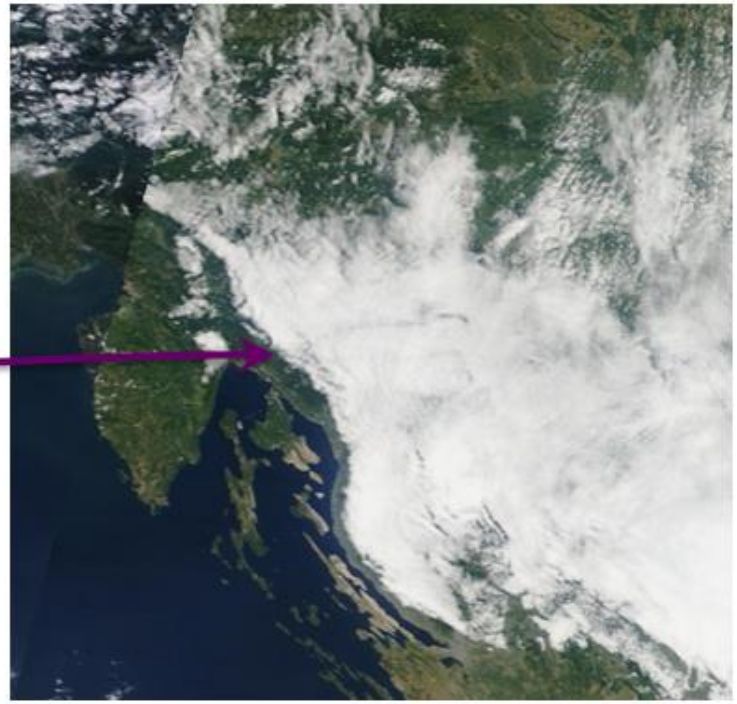


An example of the problem from R. Žabkar[1,2], D. Koračin[3] and J. Rakovec[1,2], 2013:
A WRF/Chem sensitivity study using ensemble modelling for a high ozone episode in Slovenia and the Northern Adriatic area.
Atmospheric Environment **77**, 990-1004
[1]Uni-Lj, FMF, [2]CE Space-SI, [3]DRI, Reno, Nevada

5. Slovenia from Space: Bora in the Vipava valley

http://www.space.si/slovenija-iz-vesolja/





Cloudiness accompanying the Adriatic bora

Together with the high-school students from the Vipava valley,
the area of strongest bora in Slovenia,
bora wind was measured and analyzed during the winter 2012