DUST DETECTION ALGORITHM USING MODIS DATA AND HYDRA SOFTWARE

Marzia Boccone[1]

Abstract. Dust is part of natural aerosols quantity in air, with dimension from 1 to 10 microns, and could affect both human health, for breath disease, and local climate system, or global as well. Dust could reach Mediterranean and South European countries because of the local meteorology, the source points are often in the Sahara desert. Using Satellites Spectroradiometry we could detect and visualise dust over land and oceans. We used three Modis combination bands into the multispectral data analysis toolkit HYDRA (HYperspectral data viewer for Development in Research Application): a simple algorithm is showed with the help of HYDRA software, which help scientists to see dust easily without any other processed data. A case study is showed over the South West Mediterranean Area, near Tunisia and Libya, but could be used for any other case and area of the world.

Introduction

Dust is part of natural aerosols quantity in air, with dimension from 1 to 10 microns, and could affect human health, for breath disease, and local climate system, or global as well. The erosion, transport and deposition of this kind of particle matter creates hazards when it affects human activities. Locally, dust stormes result in a low visibility, creating dangers for road and air transport. There is also an environmental concern because of the severe dust erosion occurring, and also because has an impact on the nutrient budget of oceanic ecosystems by providing a source of Fe to fertilize ocean regions that would otherwise be nutrient-starved. It is well known that dust mineral particles influence the earth's radiation balance and the climatology mainly in two ways: first by reflecting and absorbing incoming and outgoing radiation and secondly by acting as cloud condensation nuclei, but the direction of that affected radiative forcing is unknown. It is important to remind that dust moves around in the atmosphere following meteorological conditions and patterns, in fact Eulerian-Lagrangean back-scatter

---

[1] Telegis Laboratory, University of Cagliari, 09100 Cagliari, Italy**,** boccone@unica.it

methods and Chemistry-Transport Parallel models use this information to develop trajectories for dust and other Particle Matter. The first is used to find centre of dust origin or Spot, the second is useful for air quality forecast or simulation, especially used around the most populated area. The Saharan desert is the world's most important natural source of dust. In the Mediterranean Sea we can detect between 10 to 20 dust cases per years. In the low Mediterranean region, nearby North African Dust Spots, cases are normally more frequent and more heavily than in the upper regions. Meteorological observations from space are made from the electromagnetic radiation leaving the atmosphere. Outgoing radiation from earth to space varies with wavelength for the Energy Planck function dependent on wavelength and for the absorption by atmospheric gases of differing molecular structures. Energy transfer from one place to another is accomplished by any of three processes. Conduction is the transfer of kinetic energy of atoms or molecules by contact among them travelling at varying speeds. Convection is the physical displacement of matter in gases or liquids. Radiation is the process whereby energy is transferred across space without the necessity of a medium. Remote sensing is the observation of a target by a device separated by some distance. With satellites for meteorological research has been largely confined to passive detection or radiation emanating from earth-atmosphere system. Satellite remote sensing can provide long time series of observations on atmospheric dust, which can help evaluating the importance of different sources. Using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) could be useful to combine different radiation bands, not only to identify specific dust sources. The measurements of aerosols, suspended particles in the atmosphere, such as dust from the Sahara desert, are an important element in describing energy transmission trough the atmosphere. Aerosols are a significant source of uncertainty in climate modelling because they affect cloud microphysics by acting as condensation nuclei, thereby affecting cloud radiative properties, the hydrological cycle and atmospheric dynamics. They also interact directly with solar radiation, thus affecting the radiative balance. Estimative emissivity of dust is 0.75 between 3.5-3.9 μm, 0.97 between 10.3-11.3 μm and 11.5-12.5μm, so the algorithm studied focuses on those bands. The purpose of this study is to use MODIS data and to develop an algorithm able to show dust by combining spectral bands into a scatter plot or RGB plot. The spectral bands were chosen between the emissivity bands of dust.

1. Study area

This kind of method could be applied over every part of the world, but to show the methodology we choose South West Mediterranean area because of the increase of mean seasonal temperature, desertification and frequent dust episodes

during rainfalls. In fact the presence of dust could increase mean seasonal temperature, but also sea surface temperature and general desertification. Tunisia and Libya and the nearby area consist of two climatic belts, with Mediterranean influences in the north and Saharan in the south. Temperatures are moderate along the coast, with an average annual reading of 18° C (64° F), and hot in the interior south. The summer season in the north, from May through September, is hot and dry; the winter, which extends from October to April, is mild and characterized by frequent rains. Temperatures at Tunis range from an average minimum of 6° C (43° F) and maximum of 14° C (57° F) in January, to an average minimum of 21° C (70° F) and maximum of 33° C (91° F) in August. Precipitation in the northern region reaches a high of 150 cm annually, while rainfall in the extreme south averages less than 20 cm a year. The Libya climate has marked seasonal variations influenced by both the Mediterranean Sea and the desert. Along the Tripolitanian coast, summer temperatures reach between 40 and 46° C (104– 115° F); further south, temperatures are even higher. Summers in the north of Cyrenaica range from 27 to 32° C (81–90° F). In Tobruk (Tubruq), the average January temperature is 13° C (55° F); July, 26° C (79° F). The ghibli, a hot, dry desert wind, can change temperatures by 17–22° C (30–40° F) in both summer and winter. Rainfall varies from region to region. Rain falls generally in a short winter period and frequently causes floods. Evaporation is high, and severe droughts are common. The Jabal Akhdar region of Cyrenaica receives a yearly average of 40 to 60 cm (16–24 in). Other regions have less than 20 cm (8 in), and the Sahara has less than 5 cm (2 in) a year.

2. Climatologic data

Here we present the general climatology of the Study Area, South West Mediterranean, choosing two local climatological data and nearby areas, Tripoli and Djerba (Libya and Tunisia). Tripoli lies at the western extremity of Libya close to the Tunisian border. The dominant climatic influences in Tripoli, a coastal lowland city, are Mediterranean. The city enjoys warm summers and mild winters with an average July temperature of between 22 °C (72 °F) and 29 °C (84 °F). In December temperatures have reached as low as 1 °C (34 °F), but the average remains at between 9 °C (48 °F) and 18 °C (64 °F). The average annual rainfall is less than 400 mm (15.7 inch). Here below in Table 1 you can see climatologic data for Tripoli.

Djerba is a beautiful island of Tunisia and it is well known for its mild Mediterranean climate. Average temperature is nearly the same of that of Tripoli, but precipitation is lower. Here below in Table 2 you can see climatologic data for Djerba and in Fig.1 the two precipitations related together.

Tab. 1 – Weather data for Tripoli

month	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	year
aver H °C (°F)	16 (61)	17 (63)	19 (66)	22 (72)	24 (75)	27 (81)	29 (84)	30 (86)	29 (84)	27 (81)	23 (73)	18 (64)	23 (73)
aver L °C (°F)	8 (46)	9 (48)	11 (52)	14 (57	16 (61)	19 (66)	22 (72)	22 (72)	22 (72)	18 (64)	14 (57)	9 (48)	15 (59)
precip mm (inch)	81 (3.2)	46 (1.8)	28 (1.1)	10 (0.4)	5 (0.2)	3 (0.1)	0 (0)	0 (0)	10 (0.4)	41 (1.6)	66 (2.6)	94 (3.7)	384 (15.1)

Tab. 2 – Weather data for Djerba

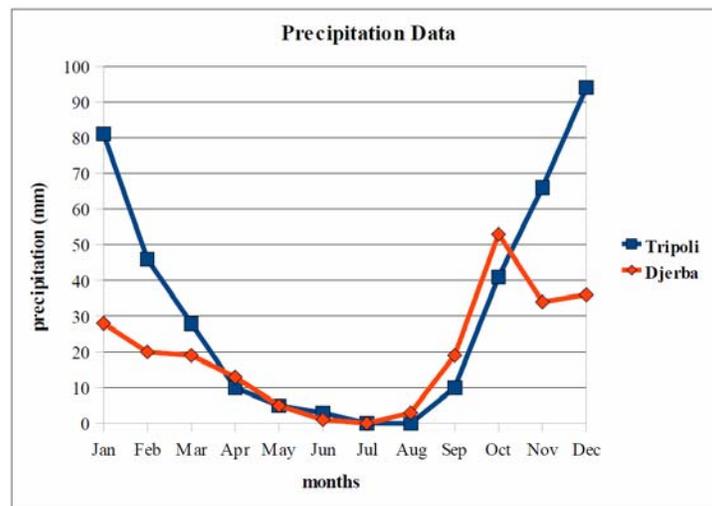| month	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	year
aver H °C (°F)	16 (61)	18 (64)	20 (67)	22 (72)	26 (78)	26 (83)	32 (89)	32 (90)	30 (86)	26 (79)	21 (70)	17 (63)	24 (75)
aver L °C (°F)	9 (48)	9 (49)	11 (52)	13 (56)	16 (62)	20 (67)	22 (71)	23 (73)	22 (71)	18 (65)	14 (57)	10 (50)	16 (60)
precip mm (inch)	28 (1.1)	20 (0.8)	19 (0.8)	13 (0.5)	5 (0.2)	1 (0)	0 (0)	3 (0.1)	19 (0.8)	53 (2.1)	34 (1.3)	36 (1.4)	231 (9.1)

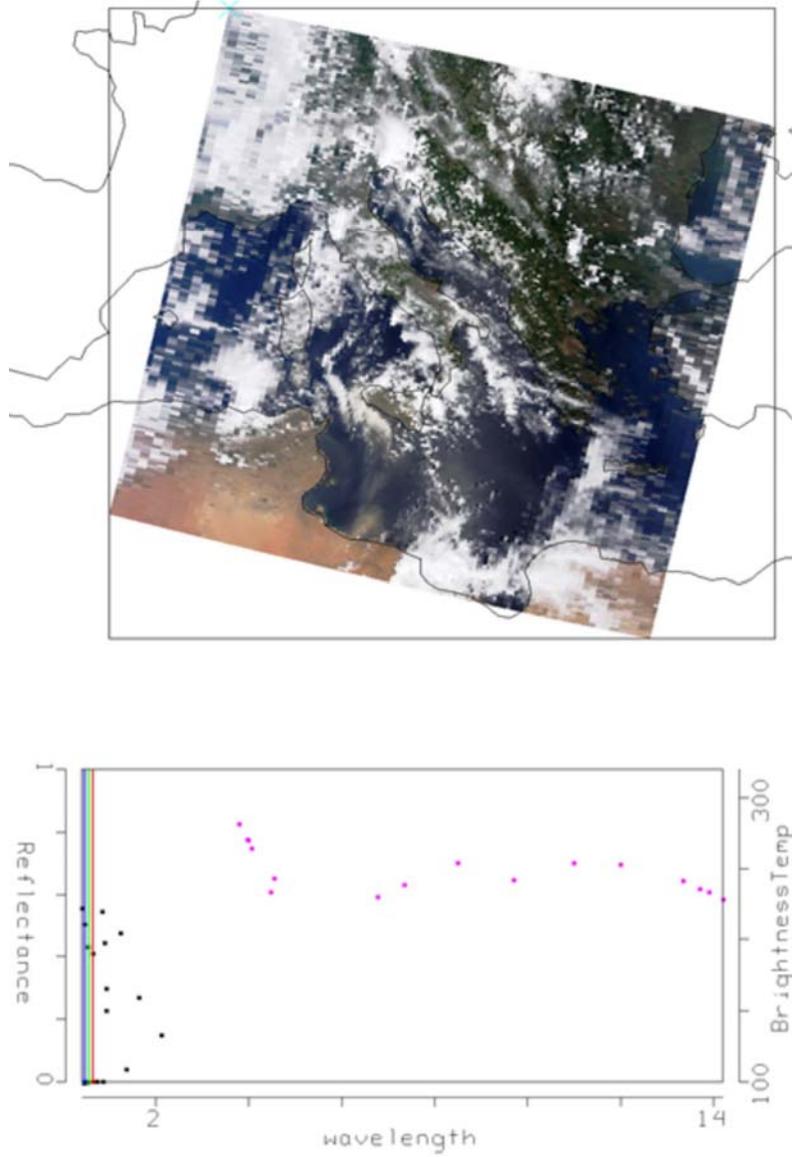Fig.1 - Monthly precipitation charts of Tripoli and Djerba

Fig. 2 - Up, RGB image of the Study Area, data: July 14, 2007, and down, the corresponding Reflectance/Brightness Temperature (BT) versus wavelength: the RGB bands are respectively the first, the second and the third by the left of the diagram

Here below is showed the general study area about 41N, 7W, 17E, 35S and the Reflectance/Brightness Temperature curve of the RGB combination bands versus wavelength.

3. Methods

3.1 Modis. The Moderate Resolution Imaging Spectroradiometer (MODIS) is an Earth Observing System (EOS) facility instrument that is currently flying, but in retirement age, aboard the Terra and Aqua spacecraft. Terra began collecting data on February 24, 2000, Aqua, a counterpart of Terra, was launched on May 4, 2002 and began collecting data on June 22, 2002. MODIS is a scanning spectro-radiometer with 36 spectral bands between 0.645 and 14.235 μm. Bands 1 – 2 are sensed with a spatial resolution of 250 m, bands 3 –7 at 500 m, and the remaining bands 8- 36 at 1 km. You can download rough data or processed data from some link to NASA institute or, if you have an Antenna, you can directly broadcast by your own. For this case we use MOD021KM level 1b data at 1km of spatial resolution and with calibrated radiances, from MODIS sensor on Terra. Our general programme focuses on Mediterranean Area, due to desertification and dust episodes. So the case study shows the image of Tunisia/Libya region on July 14, 2007.

3.2 Hydra. We used the freeware multispectral data analysis toolkit, HYDRA (HYperspectral data viewer for Development of Research Application). In fact various spectral channels combination were visualised to detect an algorithm for dust over Mediterranean region, and also multiple channel combinations and scatter plots that help to detect Particle Matter (PM). The software HYDRA can be used for such environmental studies but also for others, especially used to process and manage Meteorological Satellite Data, such as MODIS, SEVIRI and AIRS data.

3.3 Building the algorithm. Estimative emissivity of dust is 0.75 between 3.5-3.9 μm, 0.97 between 10.3-11.3 μm and 11.5-12.5μm, so the algorithm studied focuses on those bands combinations, that are 20 (3.7 μm), 29 (8.5 μm), 31 (11 μm) and 32 (12 μm) MODIS Channels.

We performed first three linear combination with the help of HYDRA, those linear combinations are X= 20 – 31 (3.7-11μm), Y= 29 – 31 (8.5-11 μm) and Z= 31 – 32 (11 - 12μm). In the next chapter is showed the methodology applied over the case study area and the entire algorithm based on the above mentioned linear combinations bands.
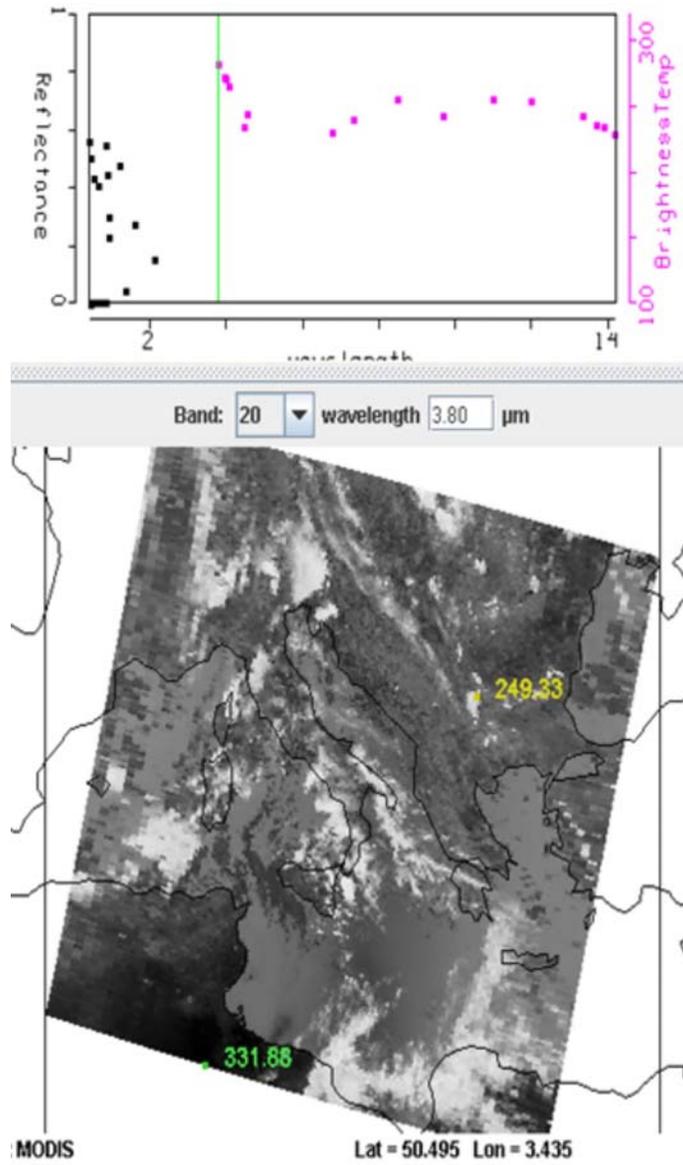
Fig 3.a - MODIS image of band: 3.a. 20 (3.7 μm), visualised using
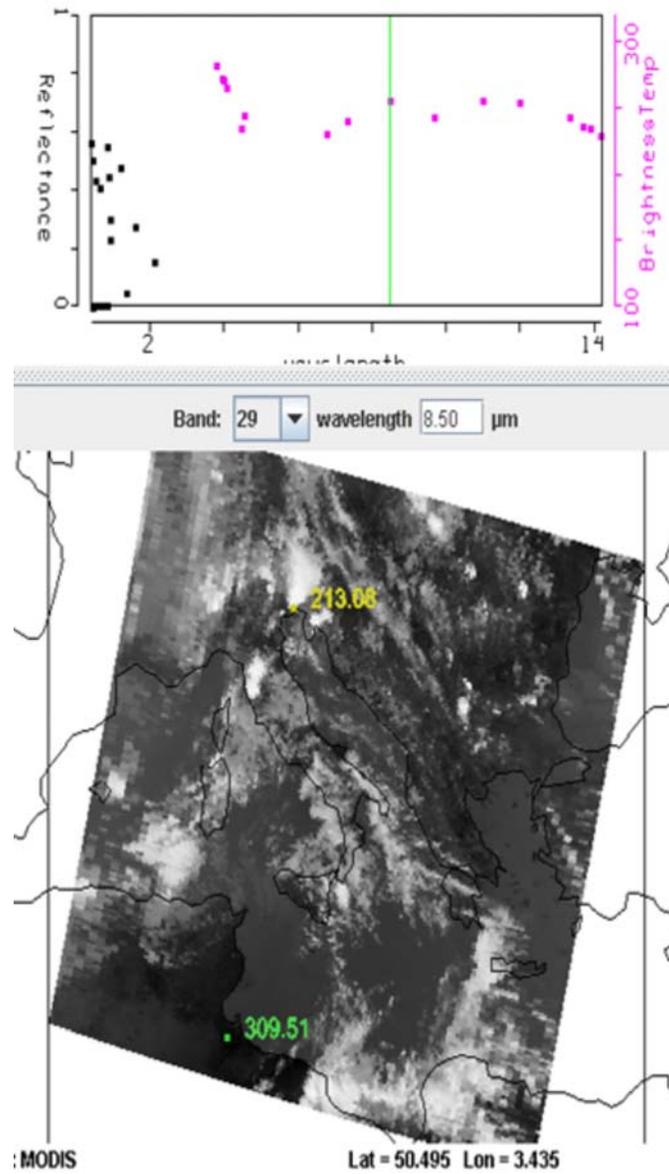HYDRA-Multichannel-Viewer

Fig 3.b MODIS image of band: 3.b. 29 (8.5 µm). Visualised using
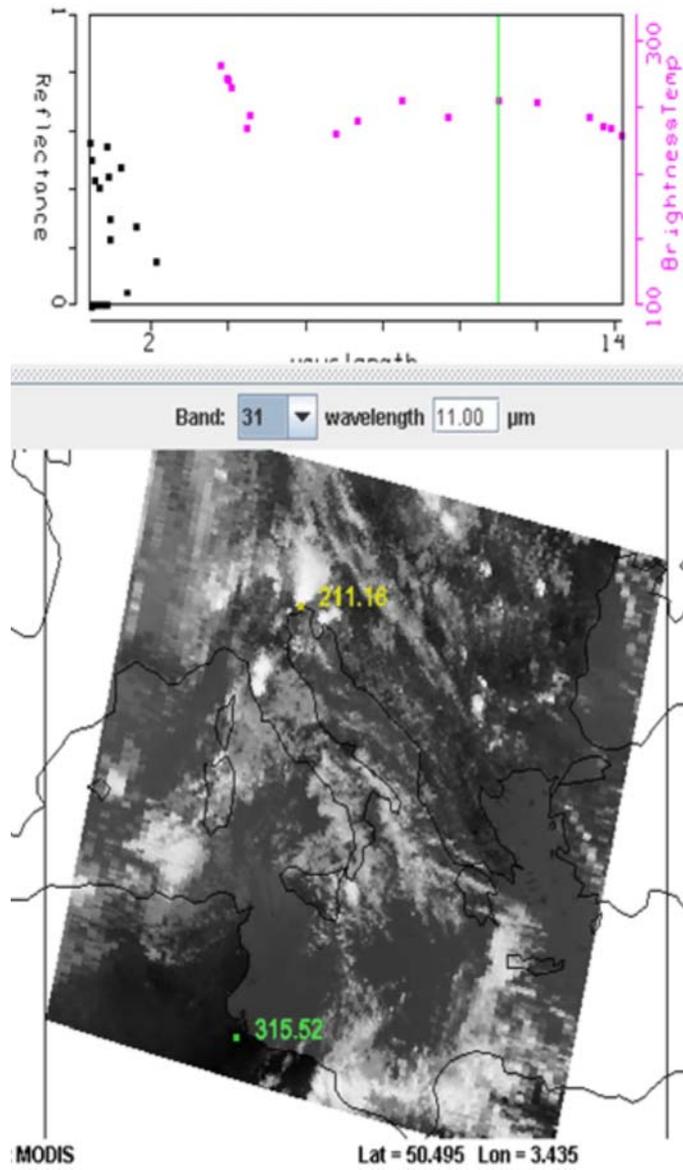HYDRA-Multichannel-Viewer

Fig. 3.c - MODIS image of band: 3.c. 31 (11 μm). Visualised using
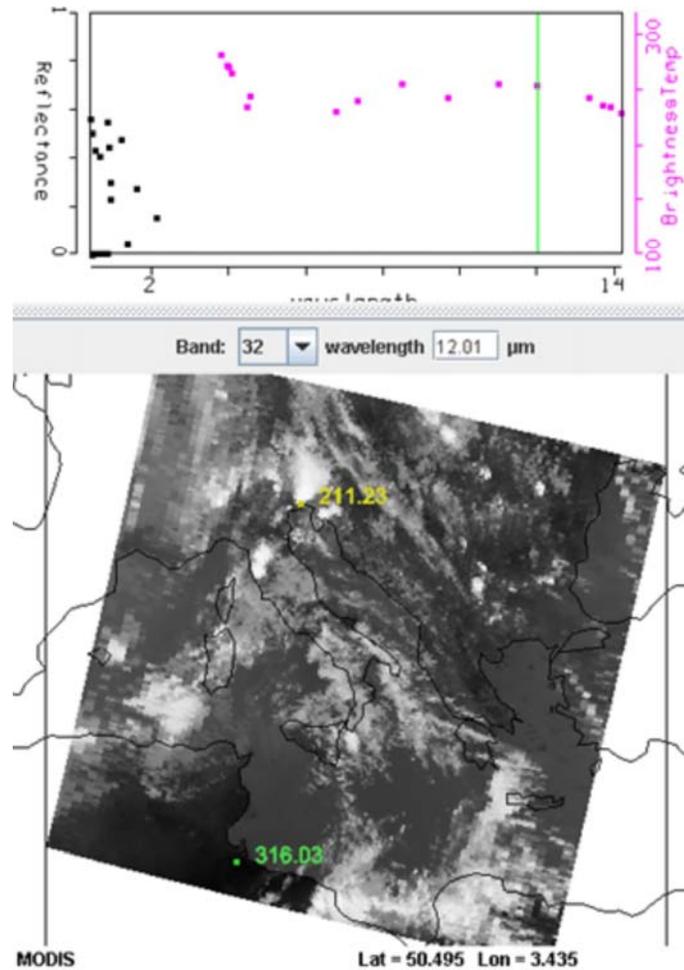HYDRA-Multichannel-Viewer

Fig. 3.d - MODIS image of band: 3.d. 32 (12 μm). Visualised using
HYDRA-Multichannel-Viewer

3.4 Methodology to the case study. The first linear combination bands
performed using HYDRA is X= 20 - 31 (3.7-11μm)- fig. 4.

Using HYDRA we also compare the first two linear combination bands,
X= 20 - 31 (3.7-11μm) and Y= 29 - 31 (8.5-11 μm) in a Scatter Plot in order to see
what happens in the dust area zone marked with the elliptic line (fig. 7).
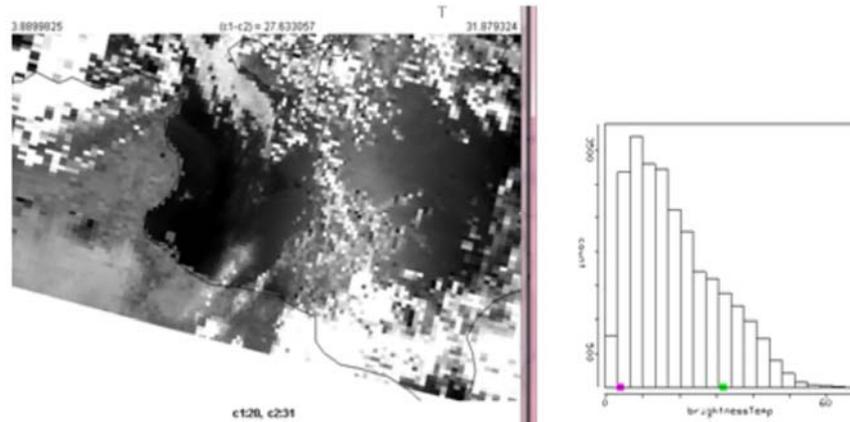
Fig. 4 – Image of the linear combination bands X=20-31 (3.7-11μm). Here the zone selected have the Brightness Temperature (BT) between 3.89 and 31.88. Dust, in the picture, have BT between 10-30, that correspond to 3000-3500 counts on the diagram (right), and very bright and white in the picture (left)

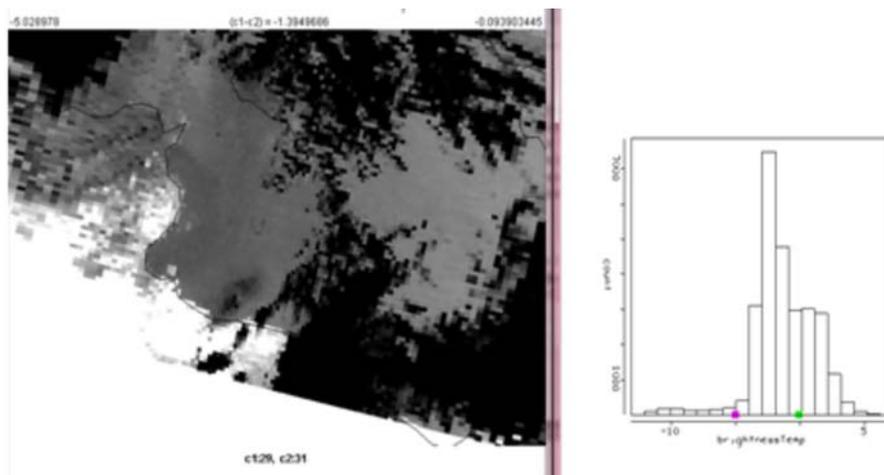The second linear combination bands performed is Y= 29 - 31 (8.5-11 μm) in the same area (fig. 5).

Fig. 5 – Image of the linear combination bands Y=29-31 (8.5-11 μm). Here the zone selected has Bright Temperature between - 5.03 and - 0.10. The picture shows the same dust area of the X combination in Fig. 4, here BT is between -5 and -1

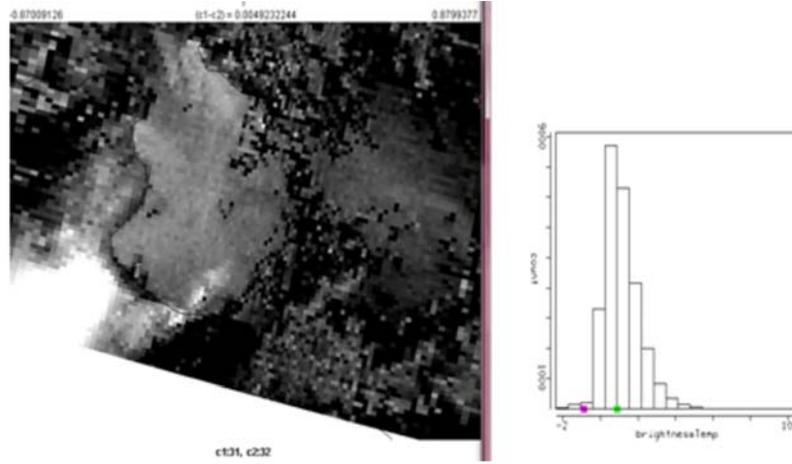The third linear combination bands performed is $Z = 31 - 32$ (11 - 12μm) - fig. 6.

Fig. 6 – Image of the linear combination bands Z=31-32 (11 - 12μm). Here the zone selected has Bright Temperature between - 0.87 and 0.88. The picture shows the same dust area of the combination X and Y (Fig. 4 and 5), here there is the point with highest BT, about -0.91
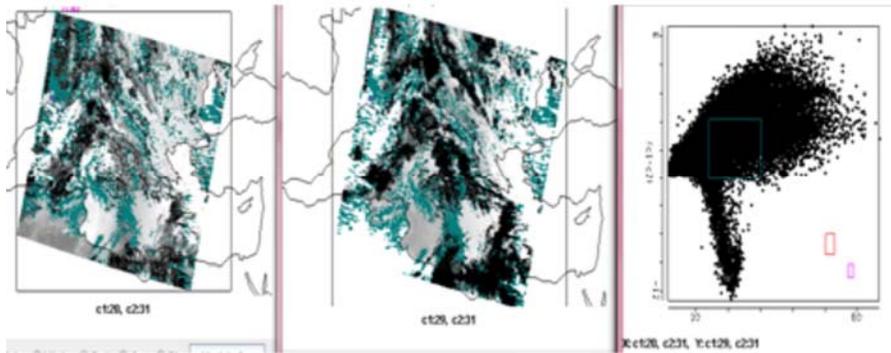

Fig. 7 - Image of the Scatter Plot of the two linear combination bands, X= 20 - 31 (3.7-11μm) and Y= 29 - 31 (8.5-11 μm). Here you see the dust area zone related to bands 20, 29 and 31. In the Scatter Plot on the left there are the corresponding values which contain also the dust area zone (see the square just about in the centre of the Plot)
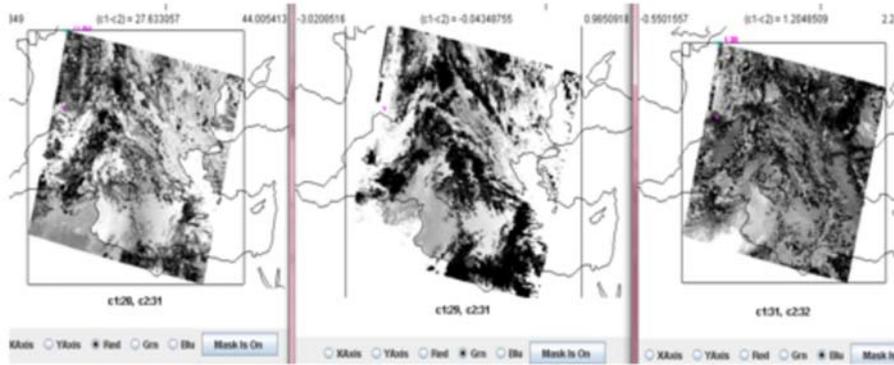
Fig. 8 - Image of the three linear combinations selected as X, R and Y, G and Z, B using HYDRA multichannel viewer
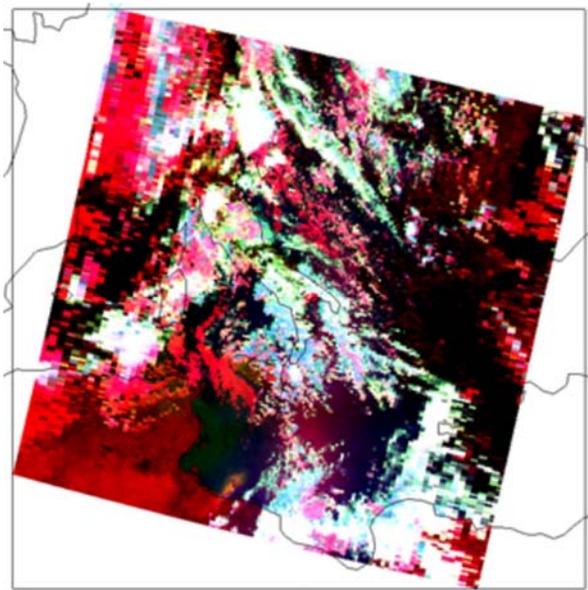

Fig. 9 – RGB Plot of the three combinations X, Y, Z. The picture shows the dust area. Here the lower and upper values of the colour scale were chosen as: 6.68 - 27.194 for Red [X= 20 – 31 (3.7-11μm)]; -2.10 - 1.26 for Green [Y= 29 – 31 (8.5-11 μm)]; -26.45 - 5.48 for Blue [Z= 31 – 32 (11 - 12μm)]

Using HYDRA we also compare all those combination bands X, Y and Z in a RGB plot, were the three combinations above are X, Y, Z like R, G, B (fig. 8, fig. 9).

The great concentration of dust leaving the land is following the weather conditions, the data image choose is well clear by high clouds, even thought there are some ice clouds on the right.

Conclusions

Now that we presented the algorithm performed, focused on the detection of dust of the Saharan desert, as already shown, estimative emissivity of dust is 0.75 between 3.5-3.9 μm, 0.97 between 10.3-11.3 μm and 11.5-12.5μm, so the algorithm presented focuses on combination of those bands. The location of anthropogenic aerosols is an important consideration in their impact on local climate, so the algorithm studied focuses on those MODIS bands 20 (3.7 μm), 29 (8.5 μm), 31 (11 μm) and 32 (12 μm), corresponding to the above mentioned emissivity bands of dust. Here there is the algorithm's summary:

- first of all the collection of data, images over the Mediterranean sea, from night and day from: http://ladsweb.nascom.nasa.gov/data/search.html or from direct broadcast from the Antenna (as we have at the University of Cagliari).

- we combined the MODIS bands 3.7-11, 8.5-11, 11-12, μm (fig. 4, 5, 6)

- we scatter those combination bands in a X,Y plot (fig. 7).

- we performed an RGB/XYZ Plot (fig. 8, 9).

It is a simple algorithm that helps scientists to detect dust easily without any other processed data only making some consideration about BT values and using HYDRA multichannel viewer toolkit. The same algorithm could be used to detect dust over other regions and study areas. With the final comparison between scatter plot, XYZ and the original RGB (Fig. 2) you can easily know where there is the largest amount of dust while the RGB give you an idea of the scatter of dust near and far the largest part of it. The next step of the Telegis laboratory research team is to compute the amount of dust detected, in order to compare the dust transported from desert/land to ocean/other land.

References:
Balis, D., Amiridis, V., Kazadzis, S., Papayannis, A., Tsaknakis, G., Tzortzakis, S., Kalivitis, N., Vrekoussis, M., Kanakidou, M., Mihalopoulos, N., Chourdakis,

G., Nickovic, S., Perez, C., Baldasano, J., Drakakis, M., (2006), O*ptical characteristics of desert dust over the east Mediterranean during summer: a case study.* Ann. Geophys., 24, 807-821

Duda, David P., Minnis, P., Trepte, Q., Sun-Mack, S. (2006), *The continuos monitoring of desert dust using an infrared based dust detection and retrieval   method.* Abstract for the 12th AMS Conference on atmospheric radiation, Madison

Goudie, AS., Middleton, NJ. (2001), *Saharan Dust storm: nature and consequences*. Earth Science Reviews 56, 179-204

Menzel, P. (2006), *Remote Sensing Applications with Meteorological Satellites.* NOAA Satellites and Information Services, University of Wisconsin, Madison WI National drought Mitigation Centre

Sodemann, H., Palmer, AS., Schwierz, C., Schwikowski, M., Wernli, H. (2006), *The transport history of two Saharan dust events achived in an Alpine ice core.* Atmos. Chem. Phys, 6, 667-688

White, K. (2007), *Remote Sensing of Aeolian Dust Production and Distribution*. Desertification and Risk Analysis Using high and medium Resolution Satellite Data. NATO Science for Peace and Security series - C: Environmental Security, 59-67.

http://www.nationsencyclopedia.com/Africa

http://www.ssec.wisc.edu/

HYDRA Project