



3rd MedCyclones Training School

15–19 July 2024

Material and slides prepared by

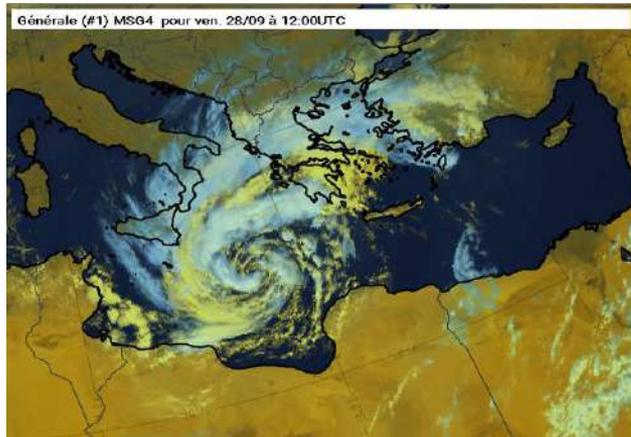
Michaël Kreitz & Frédéric Ferry, Météo-France – Ecole Nationale de la Météorologie (ENM)

Overview of the week

	MedCyclones Workshop			MedCyclones Summer school		
	Monday 15 July	Tuesday 16 July		Thursday 18 July	Friday 19 July	
09:30-10:30	Introduction (F. Pantillon and P. Patlakas) Magellan room	Oral session S3 (3 talks) Magellan room		Oral session S6 (3 talks) Magellan room	Practical session 1 Cook and Science Hub	Practical session 4 Cook and Science Hub
10:30-11:00	coffee break	coffee break		coffee break	coffee break	coffee break
11:00-11:45	Introduction (F. Pantillon and P. Patlakas) Magellan room	Oral session S4 (2 talks) Magellan room		Oral session S7 (7 talks) Magellan room	Practical session 2 Cook and Science Hub	Preparing presentations Cook and Science Hub
11:45-13:30	Lecture 1 Mesoscale dynamics (S. Gray) Magellan room	Visit ESA 1st group 11:45-12:15	Poster session Magellan room			
13:30-14:30	lunch break	lunch break		lunch break	lunch break	lunch break
14:30-16:15	Oral session S1 (5 talks) Magellan room	Oral session S5 (5 talks) Magellan room		Lecture 2 Medicanes (M. Miglietta) Magellan room	Practical session 3 Cook and Science Hub	Student presentations Magellan
16:15-16:45	coffee break	coffee break		coffee break	coffee break	
16:45-18:30	Oral session S2 (5 talks) Magellan room	Visit ESA 2nd group 16:45-17:15	Poster session Magellan room	Lecture 3 Climate change (D. Faranda) Magellan room	Lecture 4 D. Schultz (remote) Cook and Science Hub	

Outlook of the practical sessions

*Case study :
Medicane Zorbas
(september 2018)*



Session 1 : Monday 15 July morning

1. Dynamical study of the medicane

Session 2 : Thursday 18 July

1. Storm tracking in ERA5 reanalysis 
2. Cyclone Phase Space (CPS) diagrams 
3. Analysis and deterministic forecast 
4. Ensemble forecast 

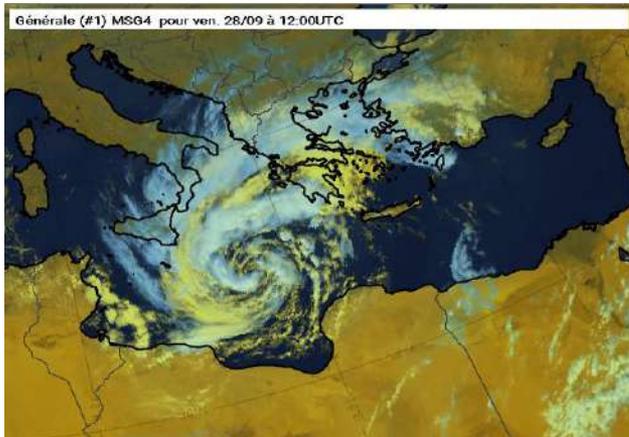
Session 3 : Friday 19 July morning

1. Preparation of the student presentations

Friday 19 July afternoon: student presentations

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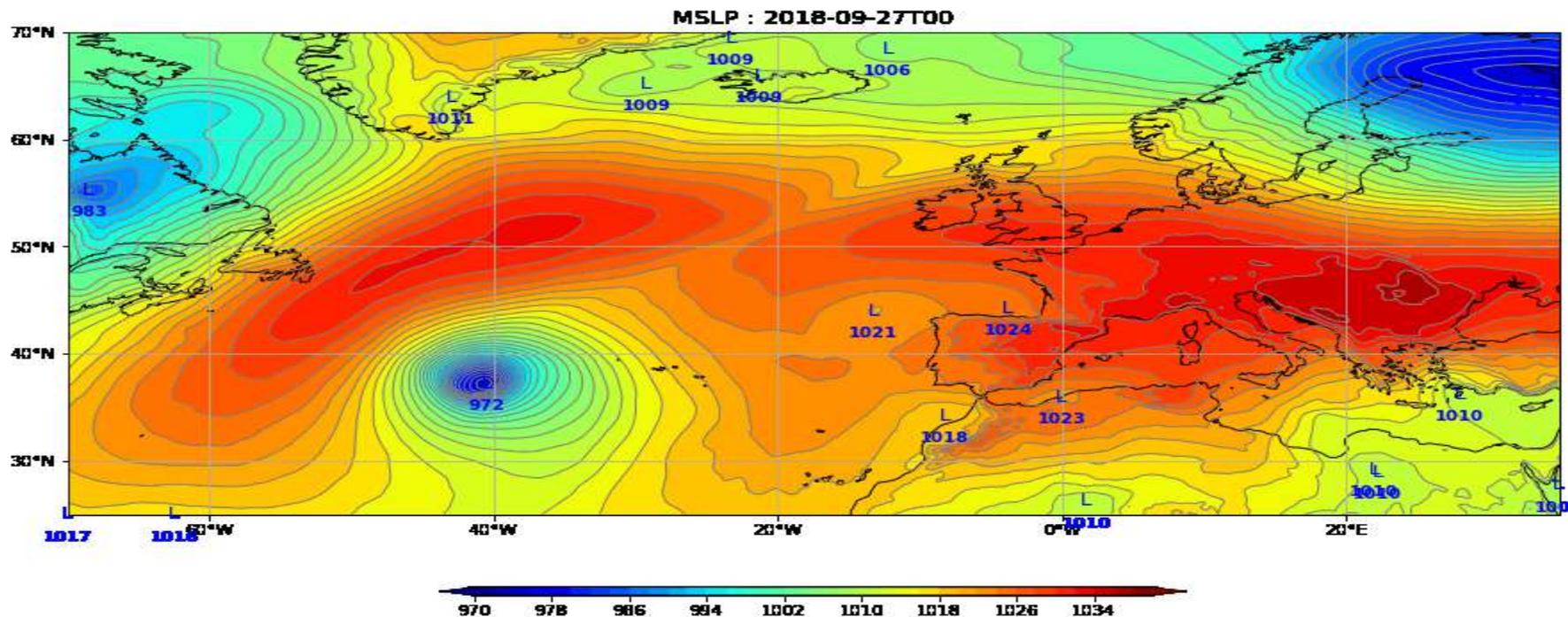
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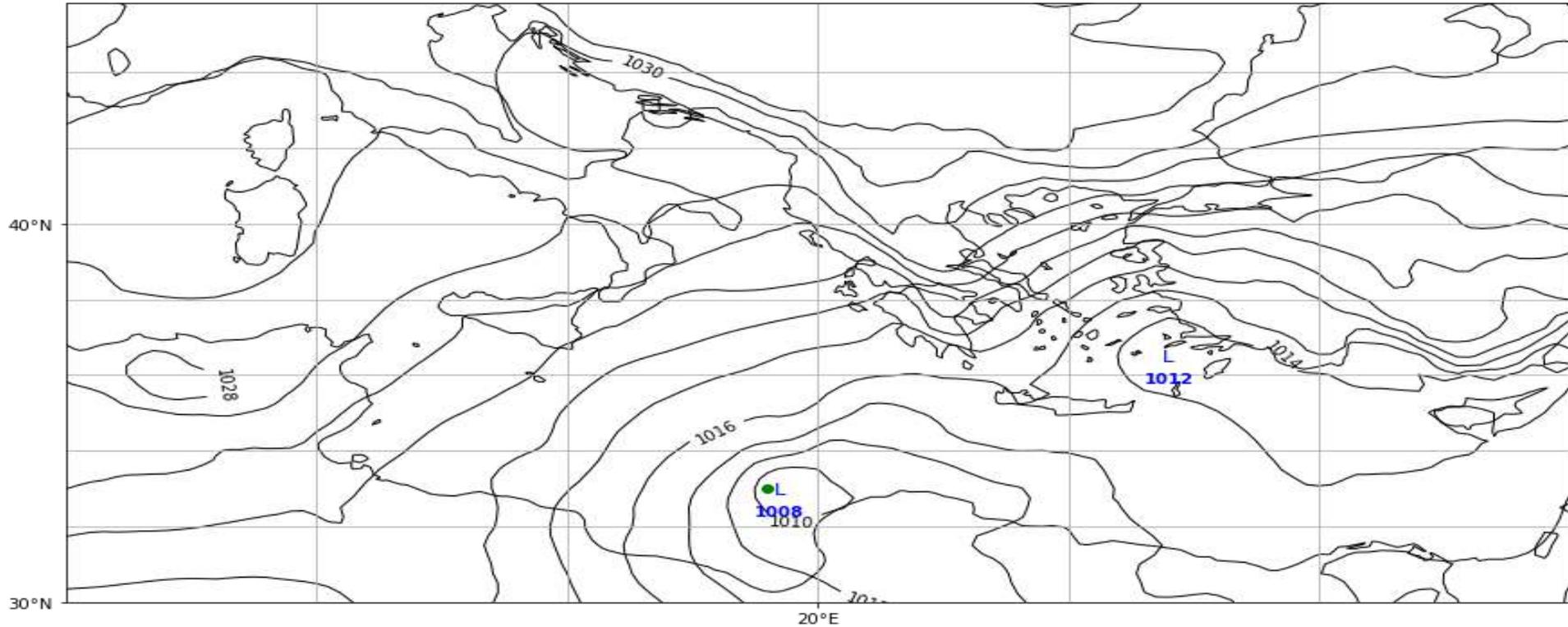
Friday 19 July afternoon: student presentations

MSLP : large domain



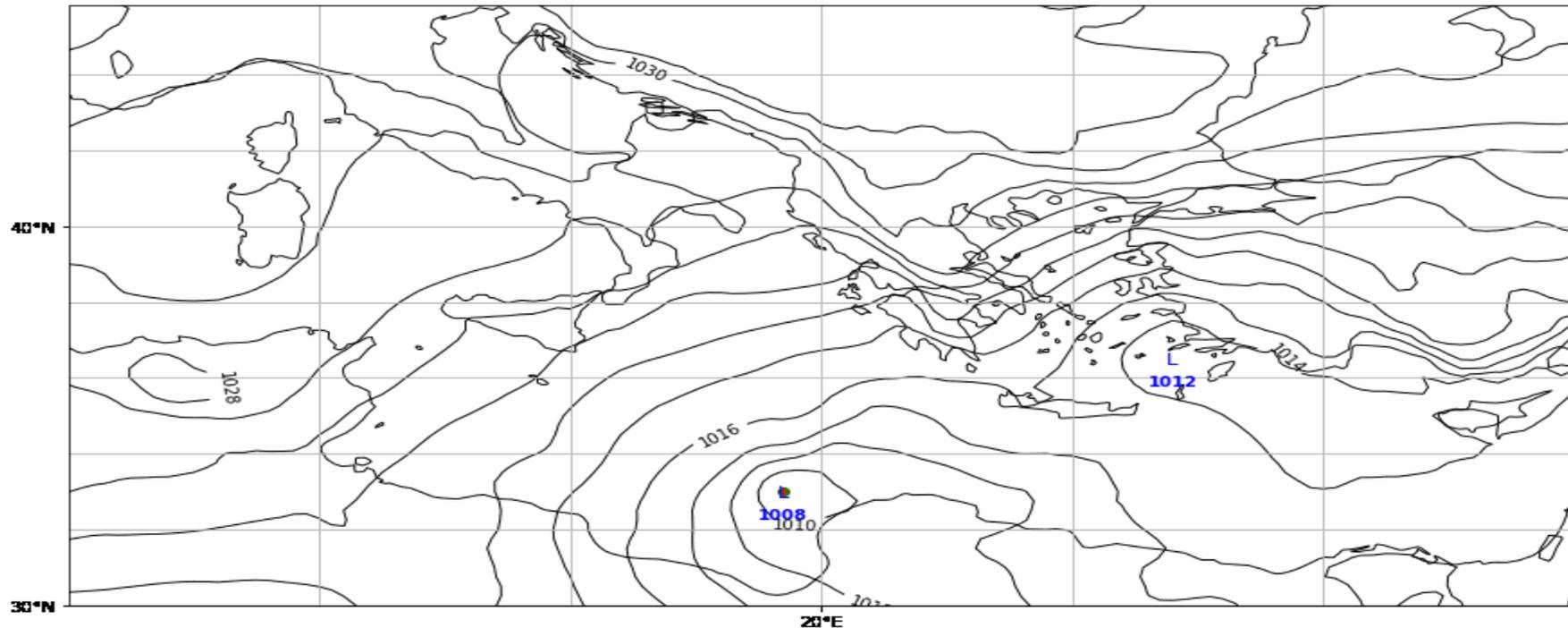
Medicane Zorbas : tracking

MSLP : 2018-09-27T09

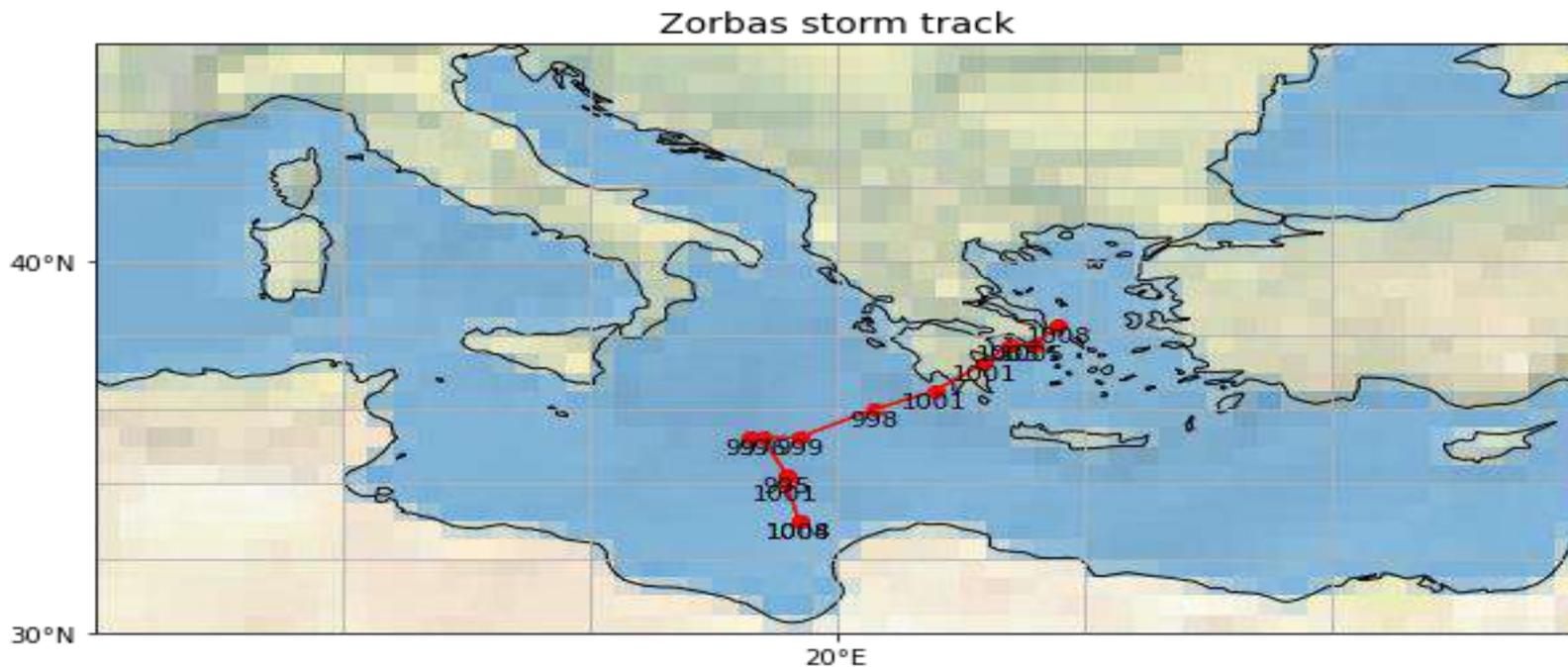


Medicane Zorbas : tracking

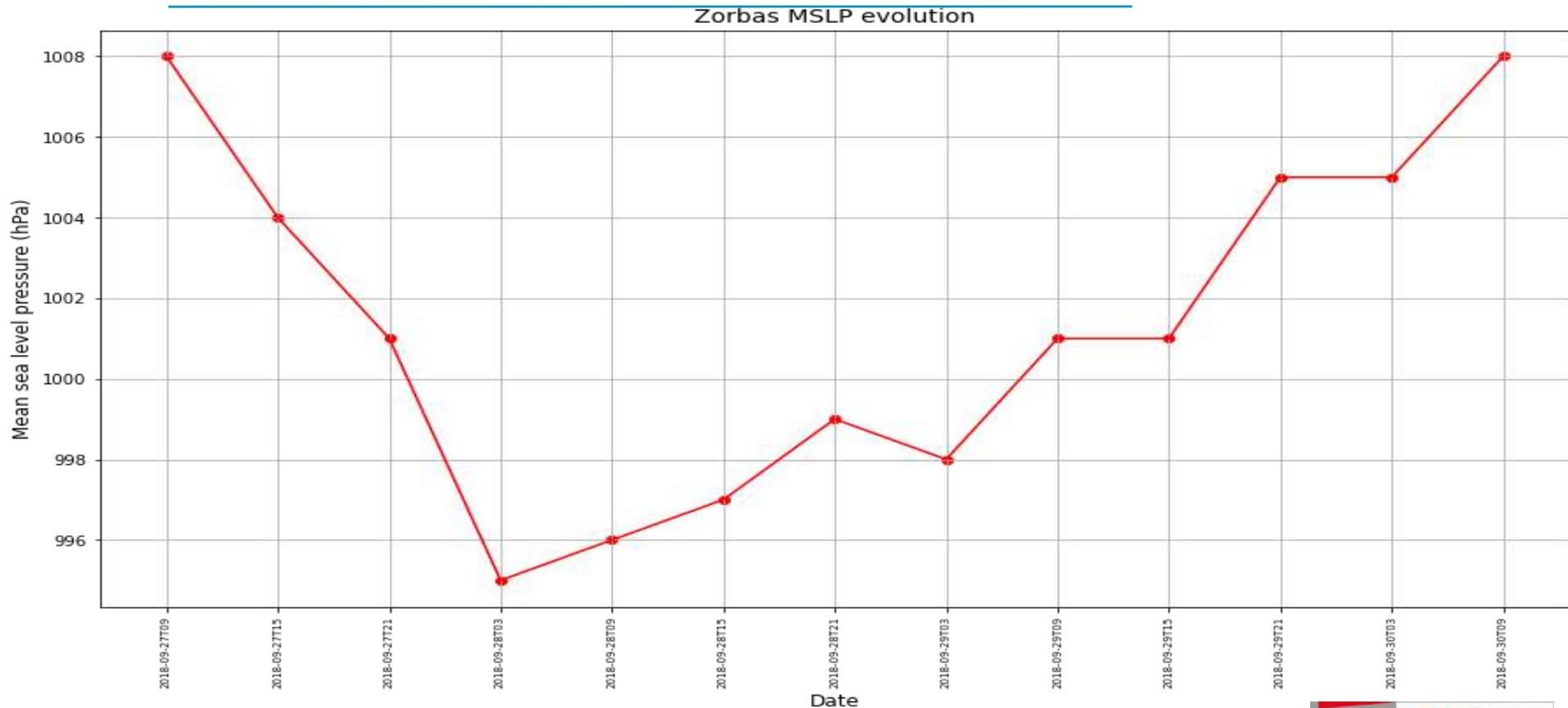
MSLP : 2018-09-27T09



Medicane Zorbas : tracking

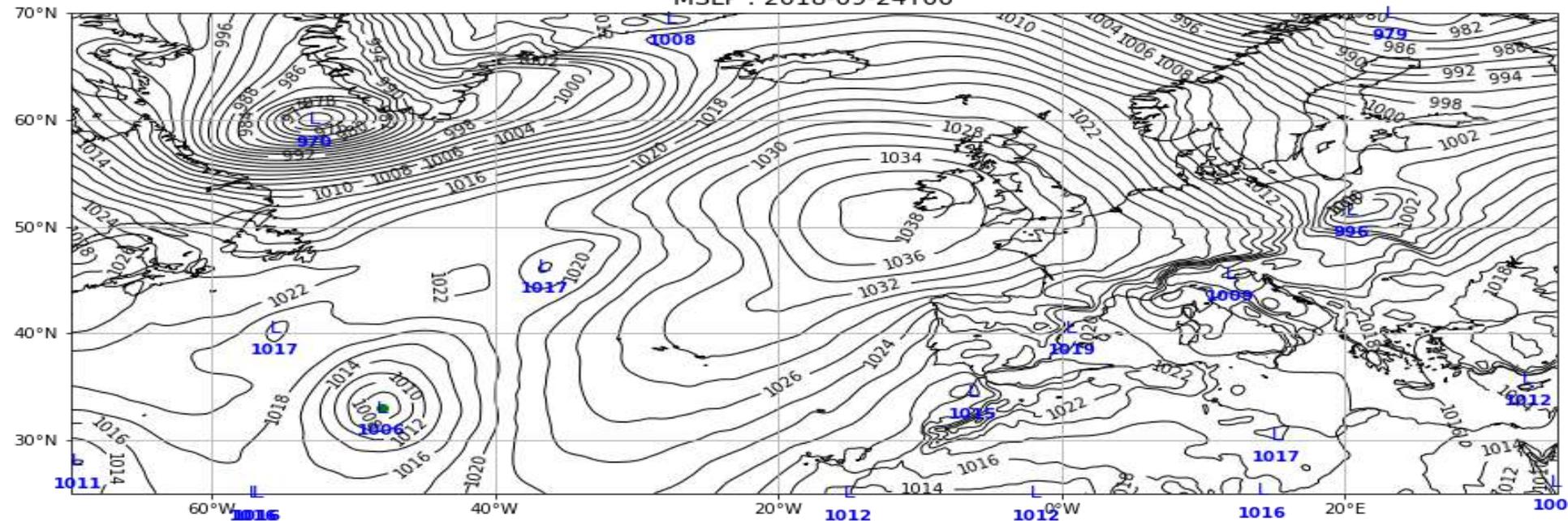


Medicane Zorbas : MSLP evolution



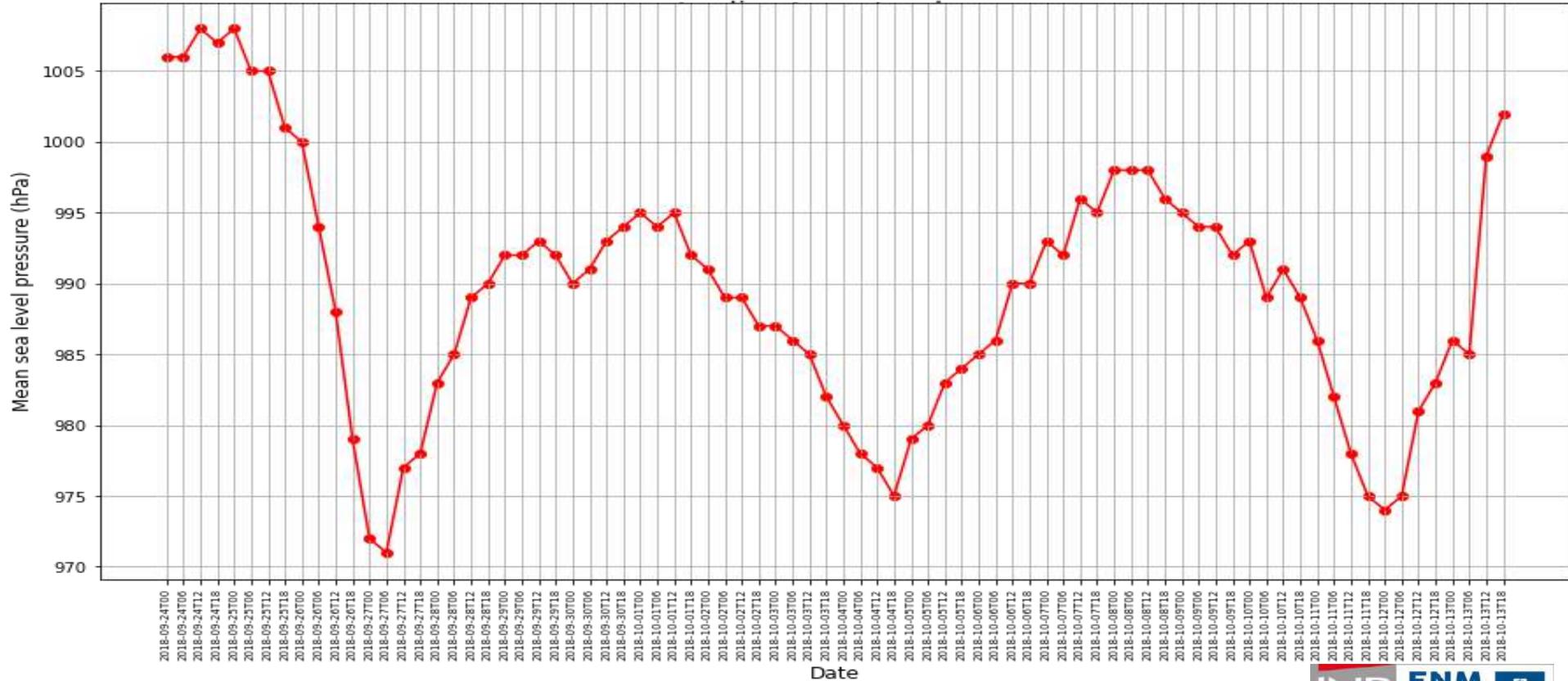
Tracking Hurricane Leslie

MSLP : 2018-09-24T00



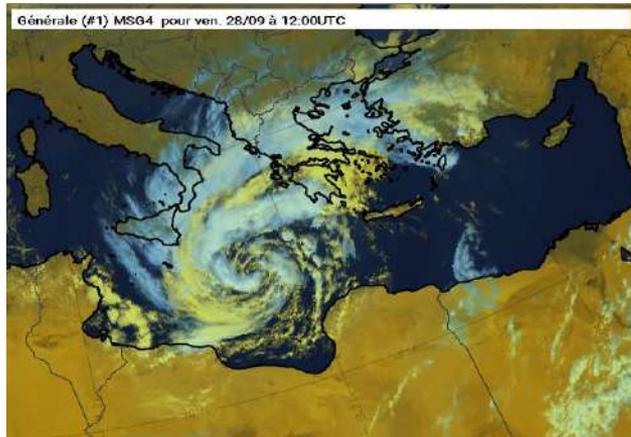
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Leslie MSLP evolution



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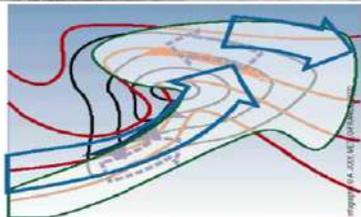
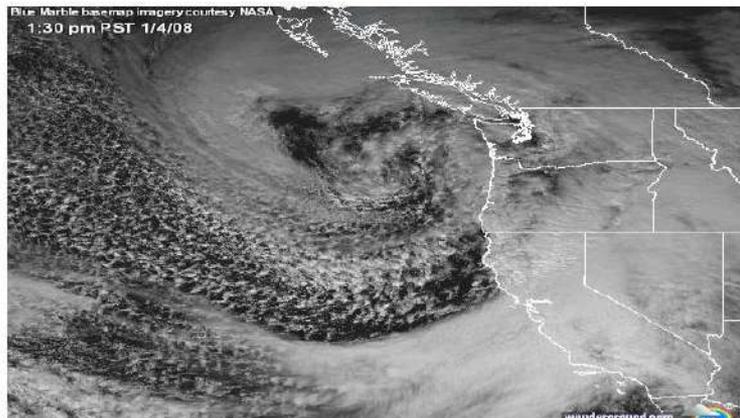
1. Storm tracking in ERA5 reanalysis 
2. **Cyclone Phase Space (CPS) diagrams** 
3. Analysis and deterministic forecast 
4. Ensemble forecast 

Session 3 : Friday 19 July morning

1. Preparation of the student presentations

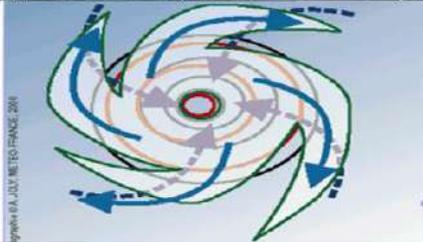
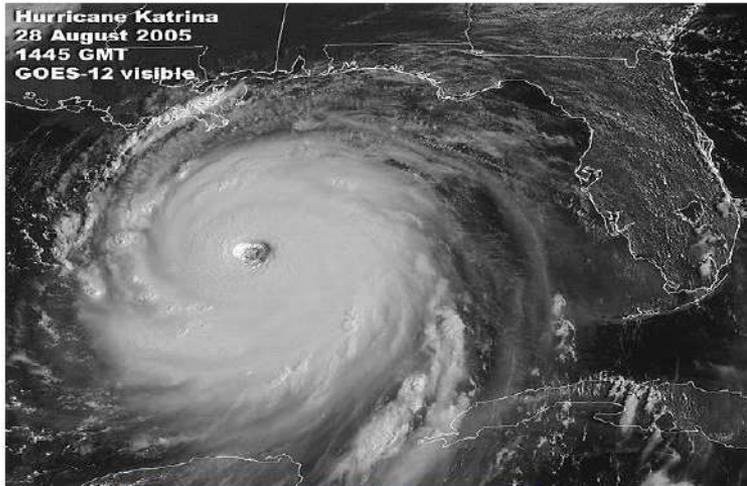
Friday 19 July afternoon: student presentations

Extratropical cyclone



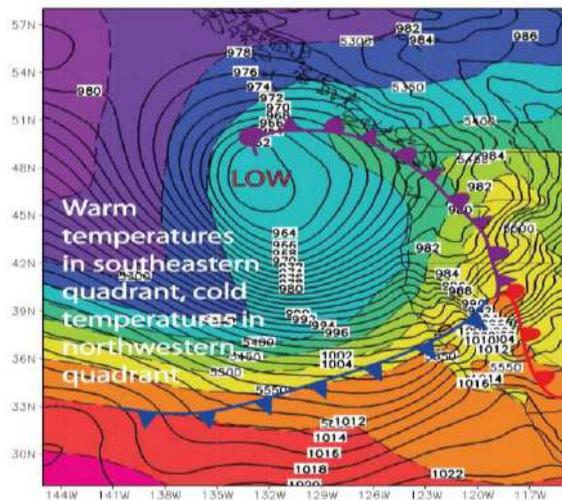
- Evolves at **mid latitudes**.
- Forms by the **interaction of and upper level disturbances and a surface disturbance**.
- Intensify via **baroclinic instability**.
- **Converts the available potential (APE) of the baroclinic zone into kinetic energy of the perturbation.**
- **Diabatic effects are of secondary importance.**

Tropical cyclone



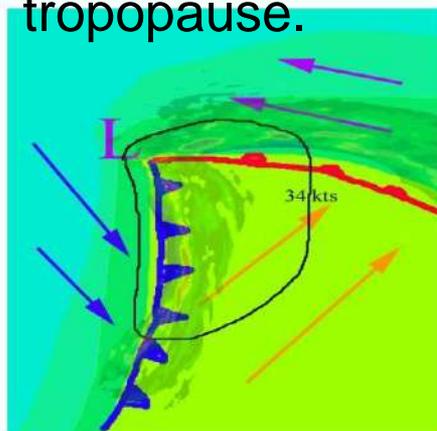
- Evolves at **tropical and subtropical latitudes**.
- Forms via several mechanisms of **convective organization**.
- Intensifies via **convective instability** (Conditionnal Instability of the **Second Kind**) or **feedback between circulation and surface heat fluxes** (Wind Induced **Surface Heat Exchange**).
- **Converts diabatic heating into potential the kinetic energy.**

Extratropical cyclone



MSLP and 1000-500hPa
mean temperature. West
USA depression
04/01/2008 18UTC

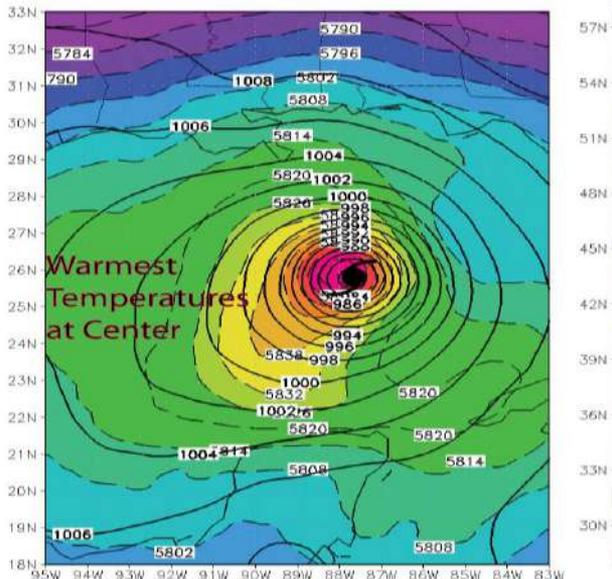
- **Frontal system** : warm, cold, occluded fronts (thermal asymmetry)
- **Tropospheric cold core system (cyclonic thermal wind)** → stronger winds are at the tropopause.



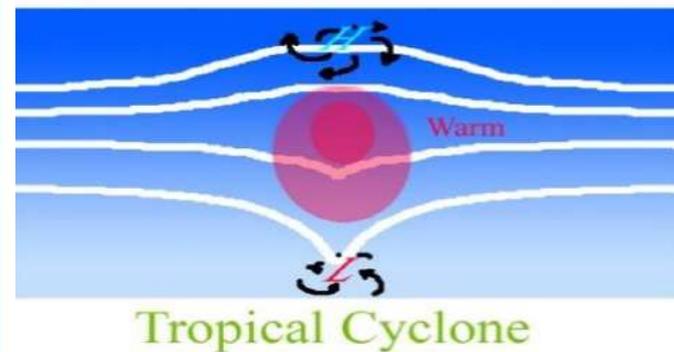
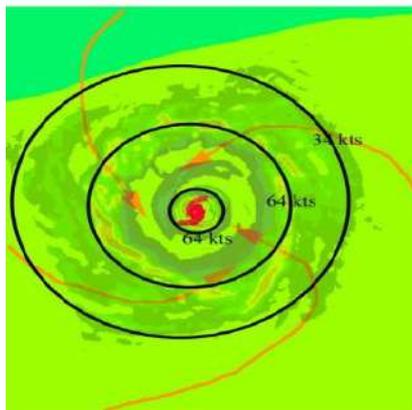
Merrill 1993

Tropical cyclone

- **Non frontal system** : no horizontal surface gradient (**thermal symmetry**)
- **Tropospheric warm core system** (anticyclonic thermal wind) → stronger winds (>33m/s) are near the surface.



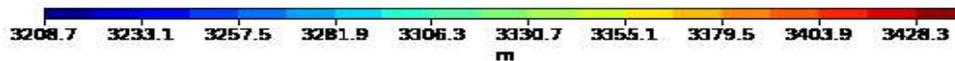
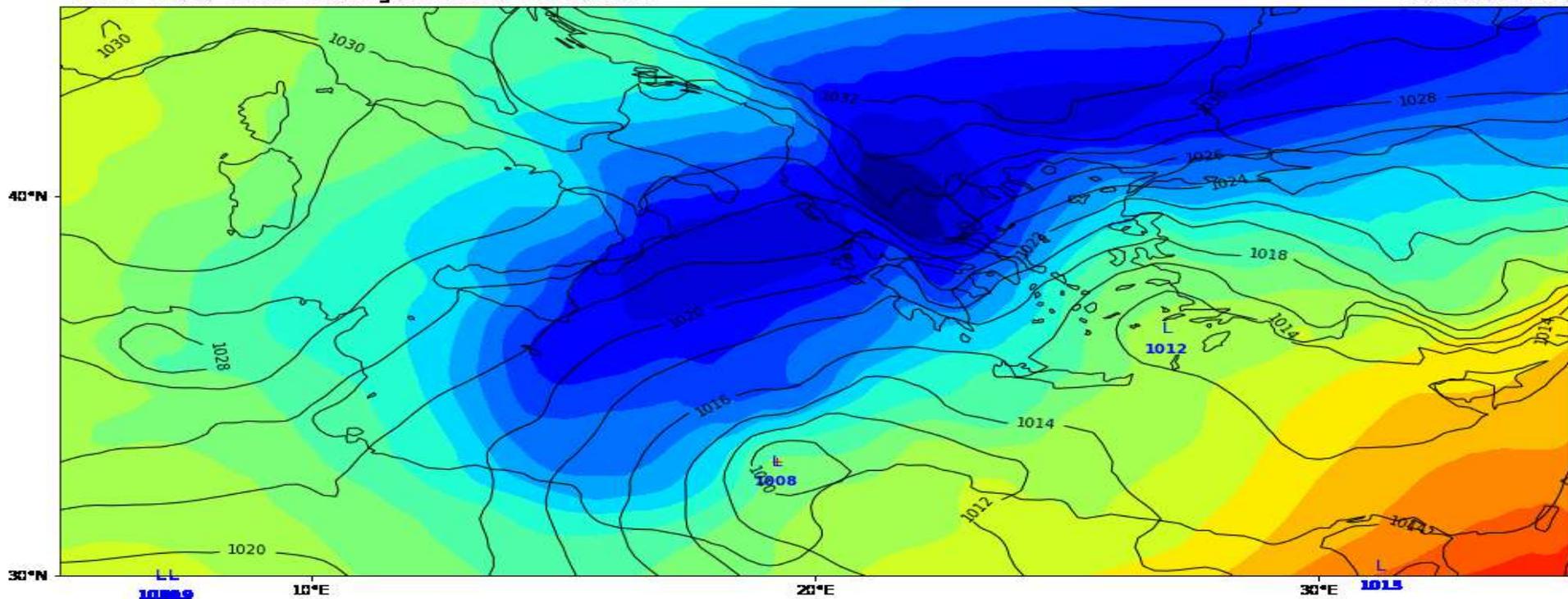
MSLP and 1000-500hPa
mean temperature.
Hurricane Katrina
28/08/2005, 12UTC



Medicane Zorbas : low-level thickness

Storm Zorbas - MSLP tracking and low level thickness

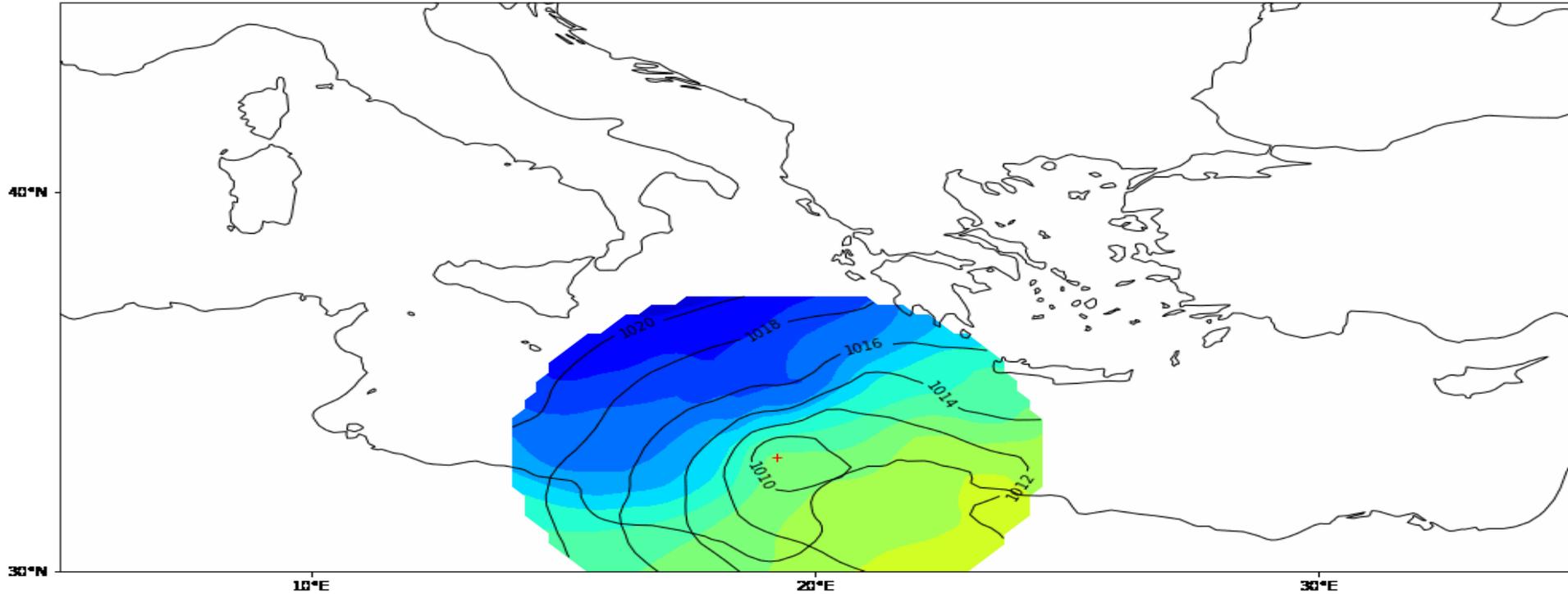
2018-09-27T09



Medicane Zorbas : choosing a radius

Storm Zorbas - MSLP tracking and low level thickness

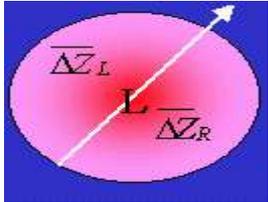
2018-09-27T09



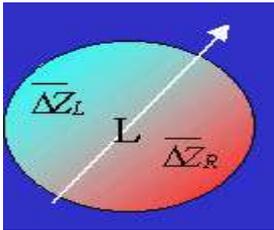
CPS diagram : thermal asymmetry parameter

$$B = h \left(\overline{Z_{600} - Z_{900}} \Big|_R - \overline{Z_{600} - Z_{900}} \Big|_L \right)$$

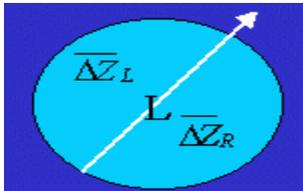
Source: http://www.cgd.cornell.edu/education/teaching/ENM/ENM101/ENM101_06_01_02_03_04_05_06_07_08_09_10_11_12_13_14_15_16_17_18_19_20_21_22_23_24_25_26_27_28_29_30_31_32_33_34_35_36_37_38_39_40_41_42_43_44_45_46_47_48_49_50_51_52_53_54_55_56_57_58_59_60_61_62_63_64_65_66_67_68_69_70_71_72_73_74_75_76_77_78_79_80_81_82_83_84_85_86_87_88_89_90_91_92_93_94_95_96_97_98_99_100_101_102_103_104_105_106_107_108_109_110_111_112_113_114_115_116_117_118_119_120_121_122_123_124_125_126_127_128_129_130_131_132_133_134_135_136_137_138_139_140_141_142_143_144_145_146_147_148_149_150_151_152_153_154_155_156_157_158_159_160_161_162_163_164_165_166_167_168_169_170_171_172_173_174_175_176_177_178_179_180_181_182_183_184_185_186_187_188_189_190_191_192_193_194_195_196_197_198_199_200_201_202_203_204_205_206_207_208_209_210_211_212_213_214_215_216_217_218_219_220_221_222_223_224_225_226_227_228_229_230_231_232_233_234_235_236_237_238_239_240_241_242_243_244_245_246_247_248_249_250_251_252_253_254_255_256_257_258_259_260_261_262_263_264_265_266_267_268_269_270_271_272_273_274_275_276_277_278_279_280_281_282_283_284_285_286_287_288_289_290_291_292_293_294_295_296_297_298_299_300_301_302_303_304_305_306_307_308_309_310_311_312_313_314_315_316_317_318_319_320_321_322_323_324_325_326_327_328_329_330_331_332_333_334_335_336_337_338_339_340_341_342_343_344_345_346_347_348_349_350_351_352_353_354_355_356_357_358_359_360_361_362_363_364_365_366_367_368_369_370_371_372_373_374_375_376_377_378_379_380_381_382_383_384_385_386_387_388_389_390_391_392_393_394_395_396_397_398_399_400_401_402_403_404_405_406_407_408_409_410_411_412_413_414_415_416_417_418_419_420_421_422_423_424_425_426_427_428_429_430_431_432_433_434_435_436_437_438_439_440_441_442_443_444_445_446_447_448_449_450_451_452_453_454_455_456_457_458_459_460_461_462_463_464_465_466_467_468_469_470_471_472_473_474_475_476_477_478_479_480_481_482_483_484_485_486_487_488_489_490_491_492_493_494_495_496_497_498_499_500_501_502_503_504_505_506_507_508_509_510_511_512_513_514_515_516_517_518_519_520_521_522_523_524_525_526_527_528_529_530_531_532_533_534_535_536_537_538_539_540_541_542_543_544_545_546_547_548_549_550_551_552_553_554_555_556_557_558_559_560_561_562_563_564_565_566_567_568_569_570_571_572_573_574_575_576_577_578_579_580_581_582_583_584_585_586_587_588_589_590_591_592_593_594_595_596_597_598_599_600_601_602_603_604_605_606_607_608_609_610_611_612_613_614_615_616_617_618_619_620_621_622_623_624_625_626_627_628_629_630_631_632_633_634_635_636_637_638_639_640_641_642_643_644_645_646_647_648_649_650_651_652_653_654_655_656_657_658_659_660_661_662_663_664_665_666_667_668_669_670_671_672_673_674_675_676_677_678_679_680_681_682_683_684_685_686_687_688_689_690_691_692_693_694_695_696_697_698_699_700_701_702_703_704_705_706_707_708_709_710_711_712_713_714_715_716_717_718_719_720_721_722_723_724_725_726_727_728_729_730_731_732_733_734_735_736_737_738_739_740_741_742_743_744_745_746_747_748_749_750_751_752_753_754_755_756_757_758_759_760_761_762_763_764_765_766_767_768_769_770_771_772_773_774_775_776_777_778_779_780_781_782_783_784_785_786_787_788_789_790_791_792_793_794_795_796_797_798_799_800_801_802_803_804_805_806_807_808_809_810_811_812_813_814_815_816_817_818_819_820_821_822_823_824_825_826_827_828_829_830_831_832_833_834_835_836_837_838_839_840_841_842_843_844_845_846_847_848_849_850_851_852_853_854_855_856_857_858_859_860_861_862_863_864_865_866_867_868_869_870_871_872_873_874_875_876_877_878_879_880_881_882_883_884_885_886_887_888_889_890_891_892_893_894_895_896_897_898_899_900_901_902_903_904_905_906_907_908_909_910_911_912_913_914_915_916_917_918_919_920_921_922_923_924_925_926_927_928_929_930_931_932_933_934_935_936_937_938_939_940_941_942_943_944_945_946_947_948_949_950_951_952_953_954_955_956_957_958_959_960_961_962_963_964_965_966_967_968_969_970_971_972_973_974_975_976_977_978_979_980_981_982_983_984_985_986_987_988_989_990_991_992_993_994_995_996_997_998_999_1000



- **Mature tropical cyclone : B=0 (symmetric non frontal)**



- **Intensifying extratropical cyclone : B>>0 (asymmetric frontal)**



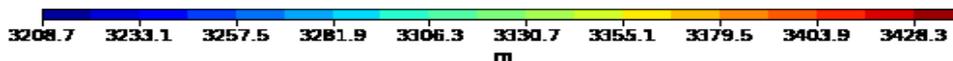
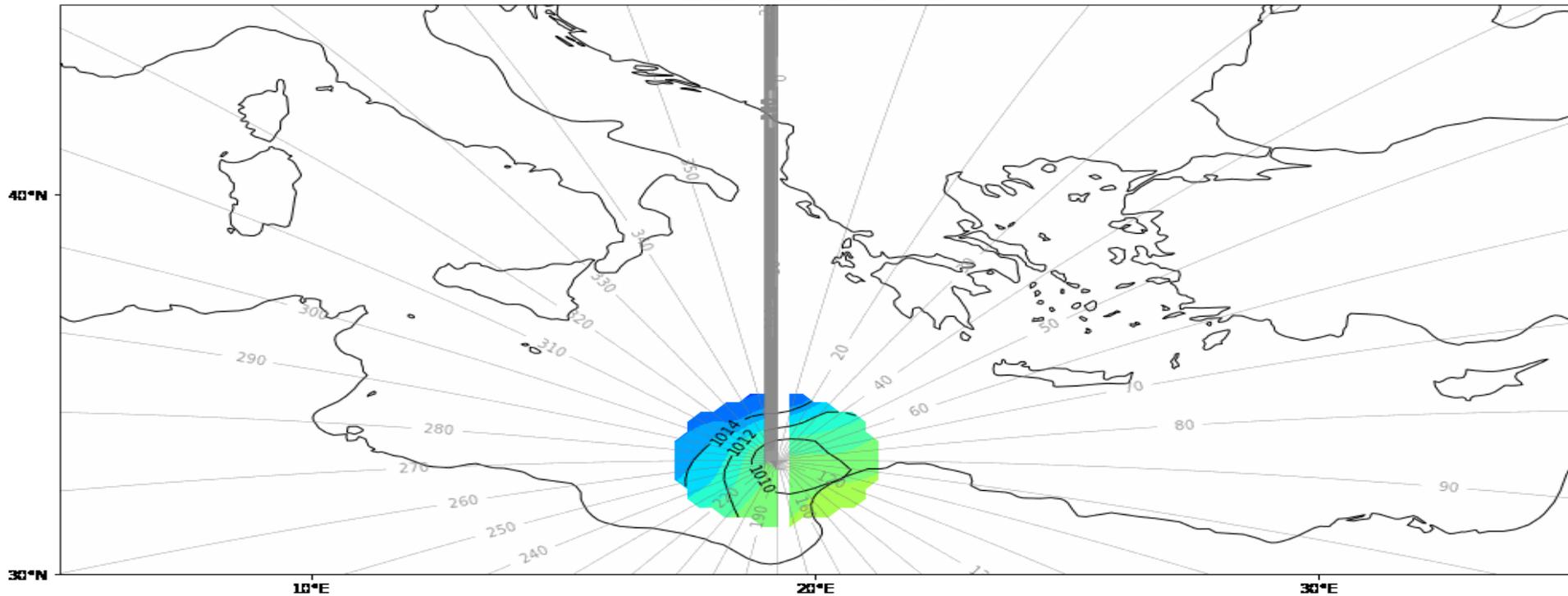
- **Occluded extratropical cyclone : B=0**

<http://mc.manuscriptcentral.com/mjor>

Storm Zorbas - MSLP, low level thickness and right/left quadrants

Medicane Zorbas : thermal asymmetry

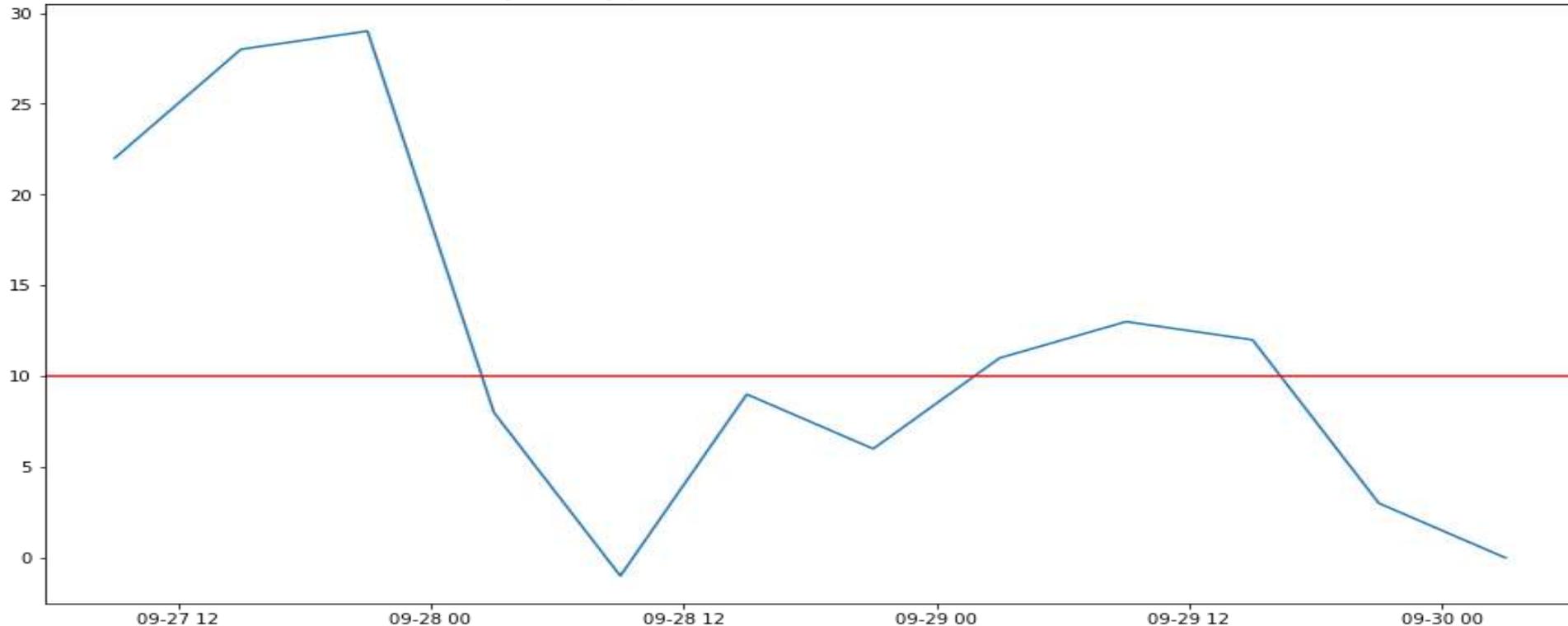
2018-09-27T09 : B = 22



Medicane Zorbas : thermal asymmetry

Storm Zorbas - low level thermal asymmetry parameter (B)

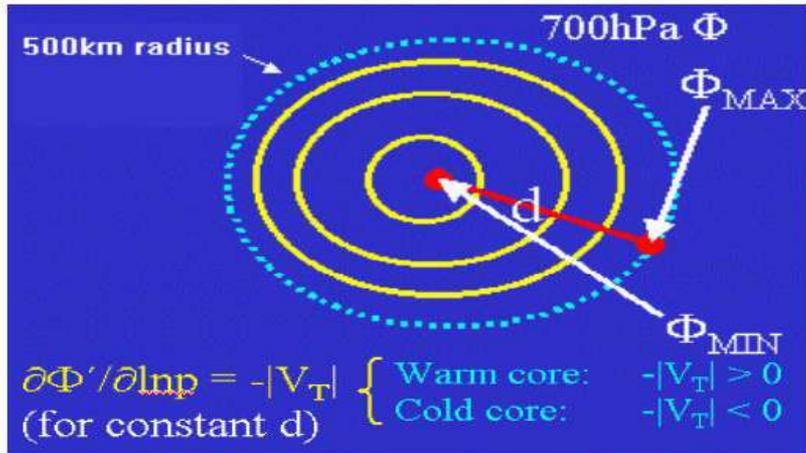
2018-09-27T09-2018-09-30T03



CPS diagram : -VT parameter

$$\Delta Z = Z_{\max} - Z_{\min}$$

$$\left. \frac{\partial(\Delta Z)}{\partial \ln p} \right|_{900}^{600} = -|V_T^L| \quad ; \quad \left. \frac{\partial(\Delta Z)}{\partial \ln p} \right|_{600}^{300} = -|V_T^U|$$

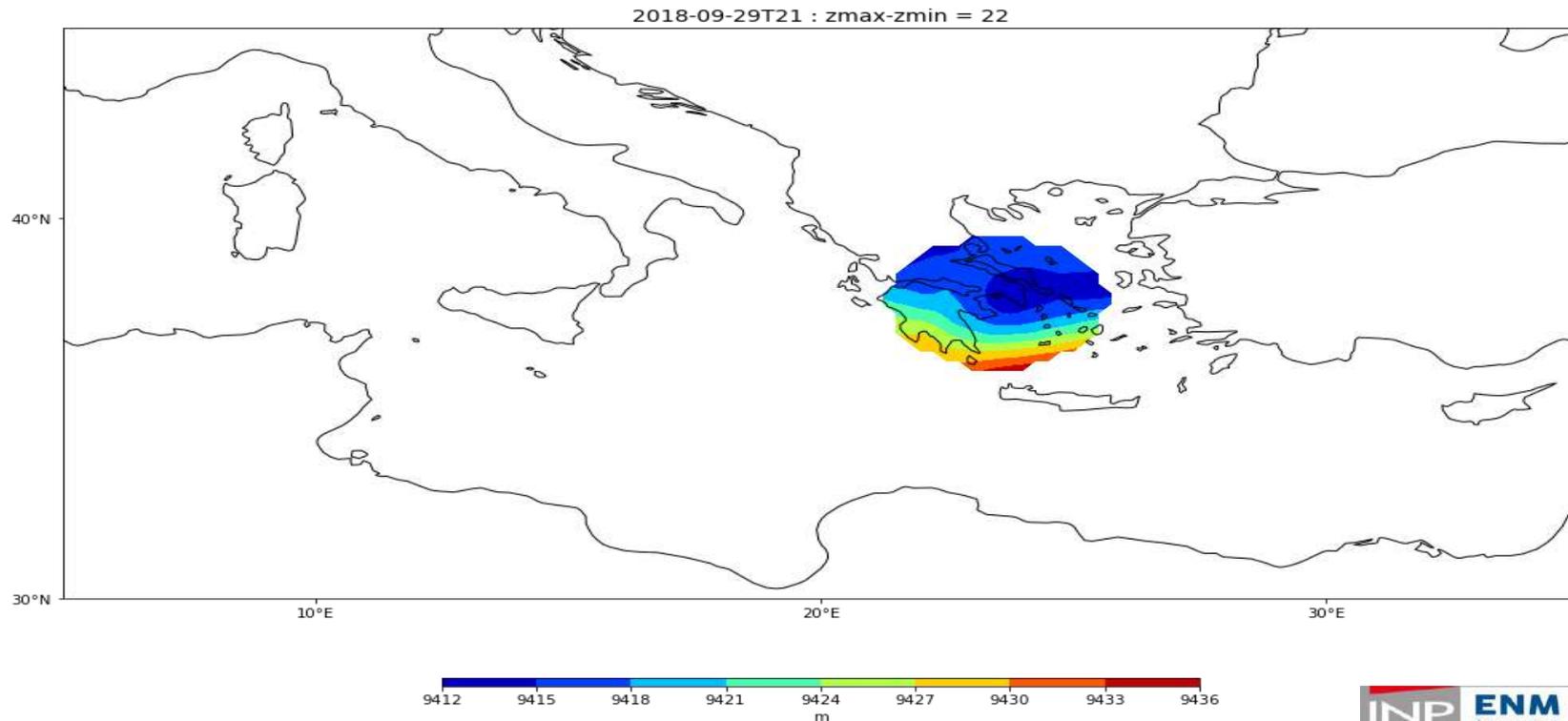


- Tropical cyclone = tropospheric warm core : the isobaric geopotential gradient decreases above the cyclone center : $-VT > 0$
- Extratropical cyclone = tropospheric cold core : the isobaric geopotential gradient creases above the cyclone center : $-VT < 0$

- Hybrid system : $-VTU \neq -VTI$

Medicane Zorbas : ΔZ

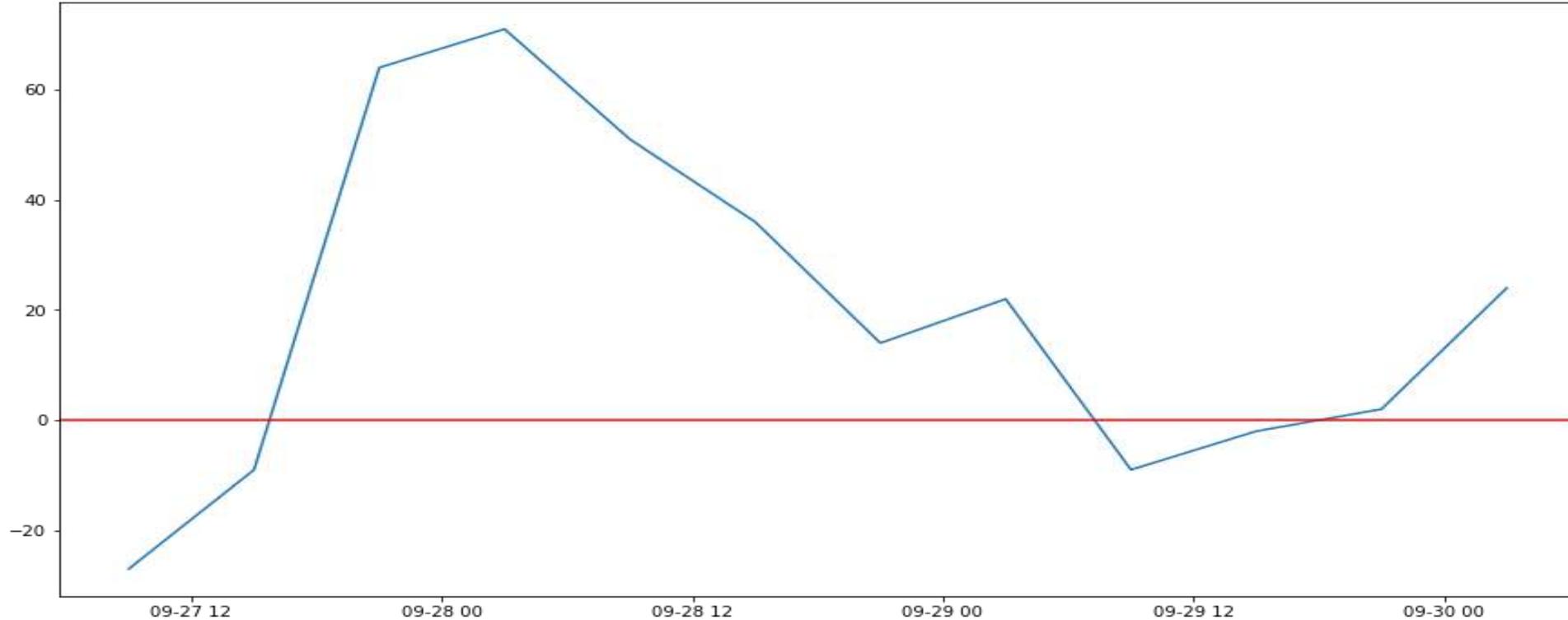
Storm Zorbas - Geopotential at 300hPa



Medicane Zorbas : low level cold core / warm core

Storm Zorbas - Low level thermal wind parameter

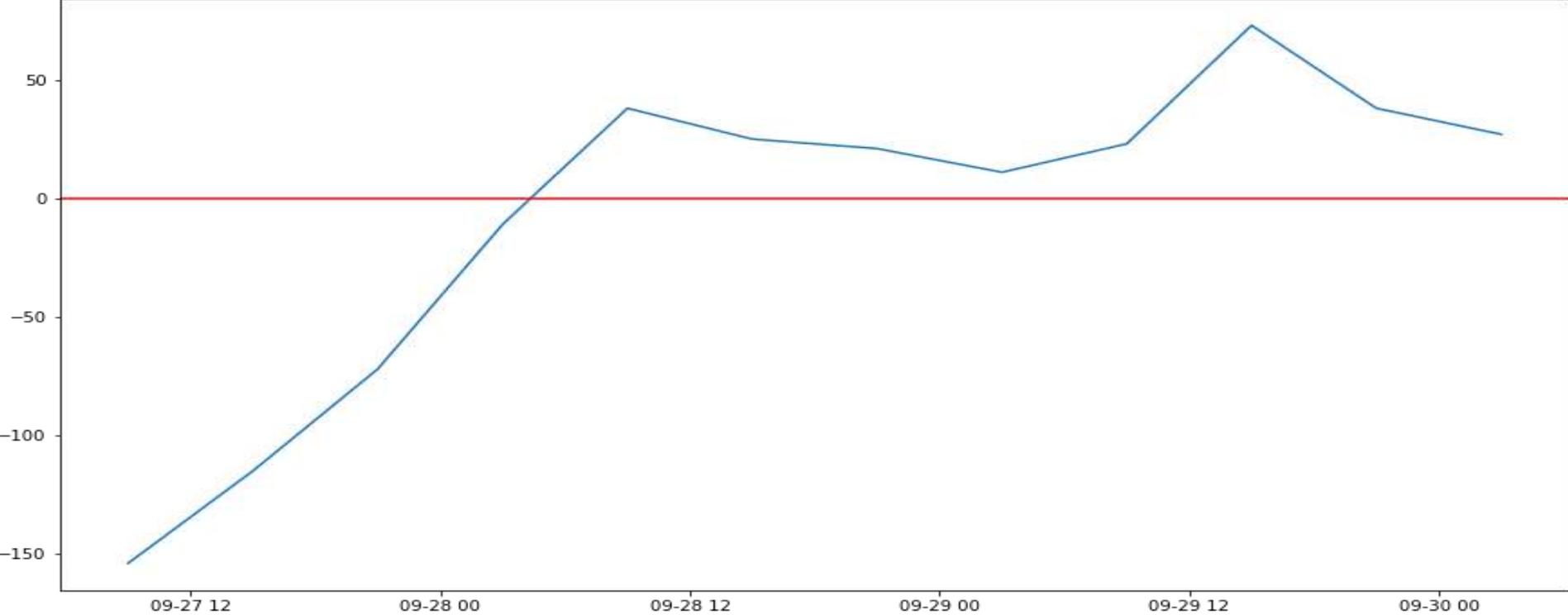
2018-09-27T09-2018-09-30T03



Medicane Zorbas : high level cold core / warm core

Storm Zorbas - High level thermal wind parameter

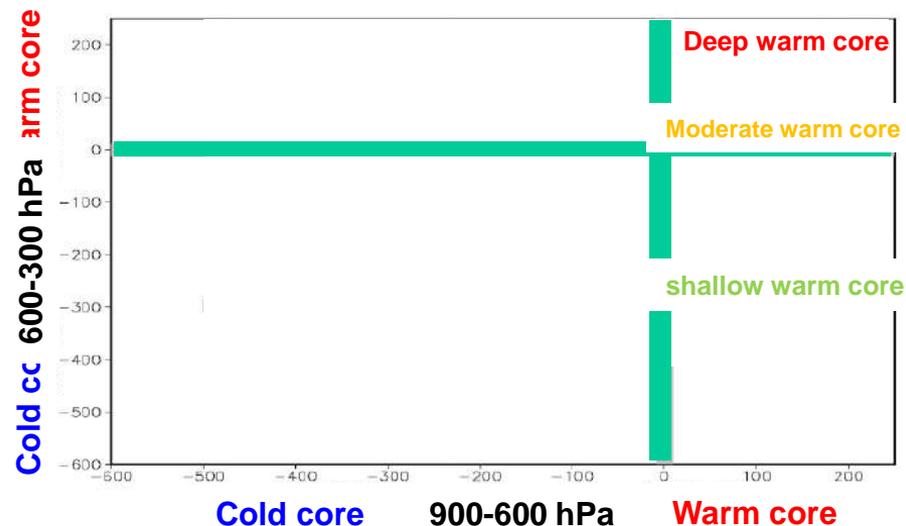
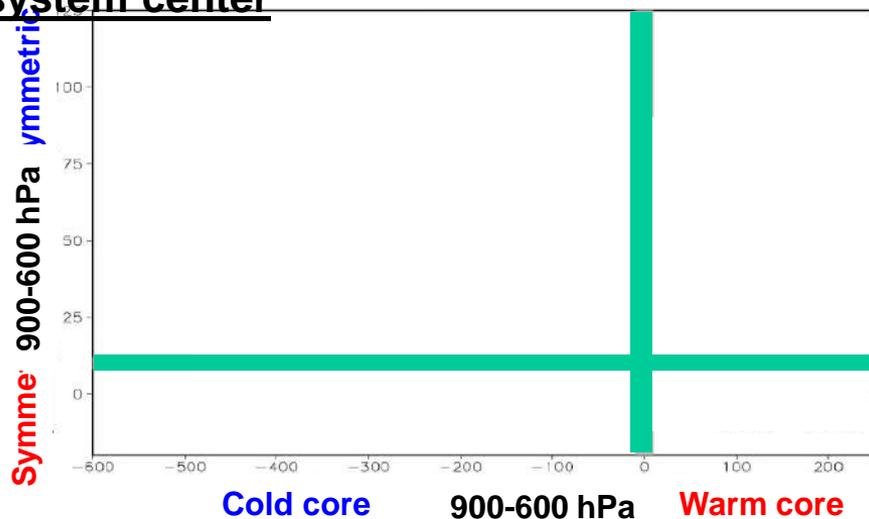
2018-09-27T09-2018-09-30T03



Cyclone Phase Space (CPS)

Analysis of the **thermal asymmetry** (symmetric /non frontal VS asymmetric/frontal) and the **vertical variation of the slope of the isobaric surfaces** (warm core VS cold core).

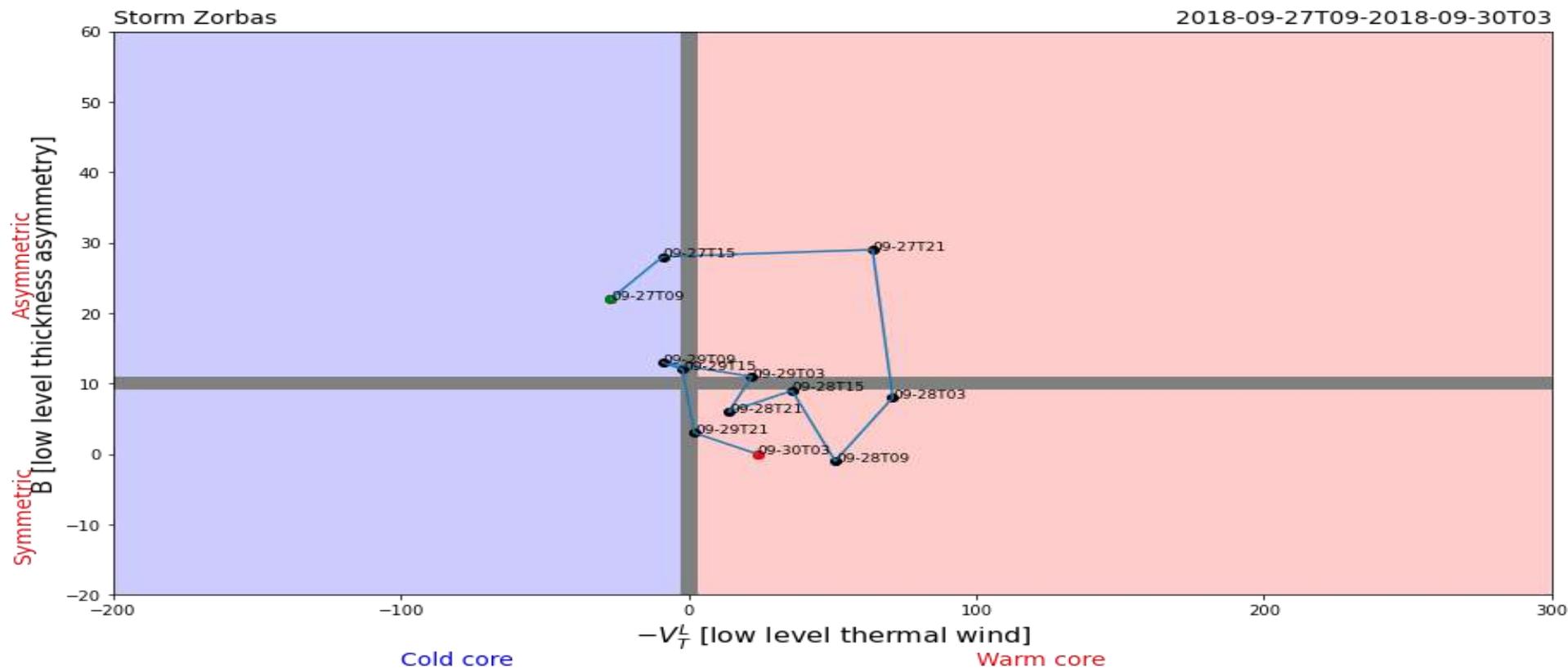
2 layers : **900-600hPa, 600-300hPa** . Parameters are computed within a **500km radius around the system center**



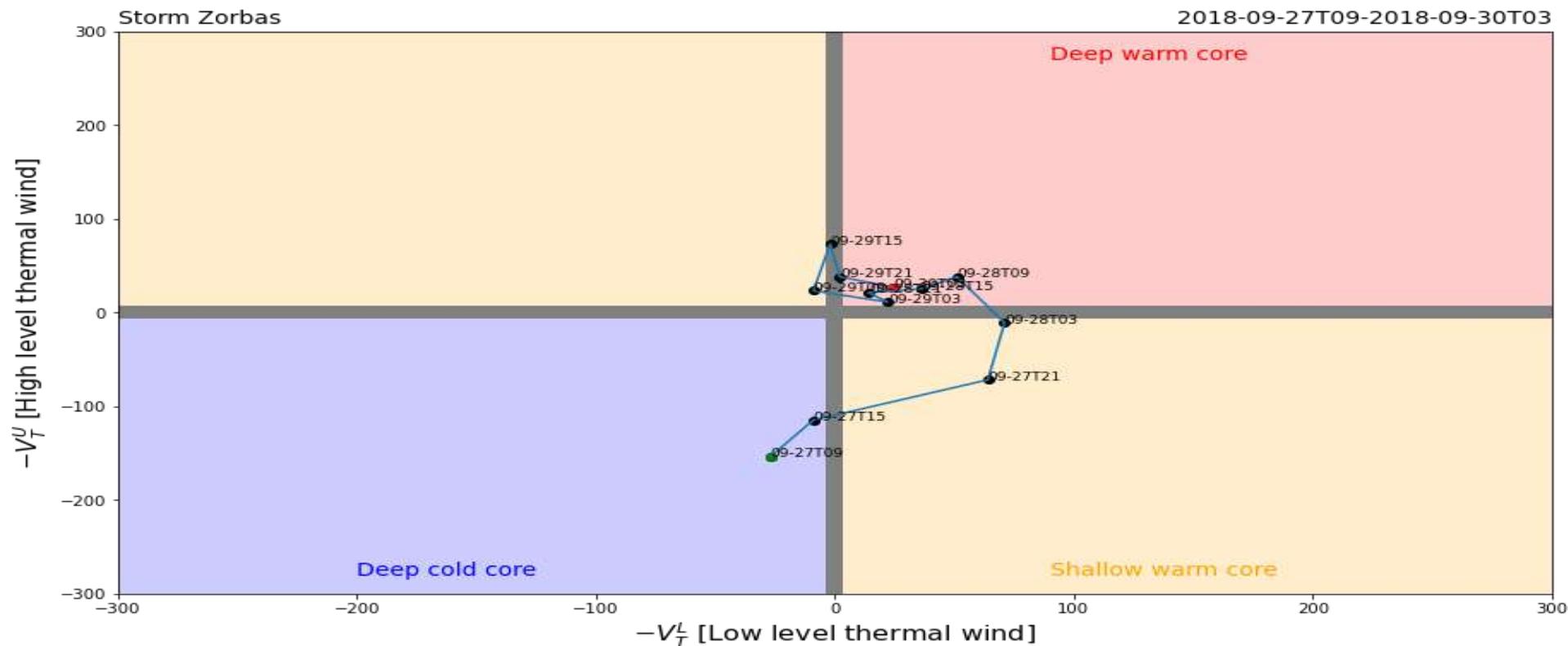
Hart, 2003 : a cyclone phase space derived from thermal wind and thermal asymmetry

<http://moe.met.fsu.edu/cyclonephase/>

Medicane Zorbas : CPS diagram

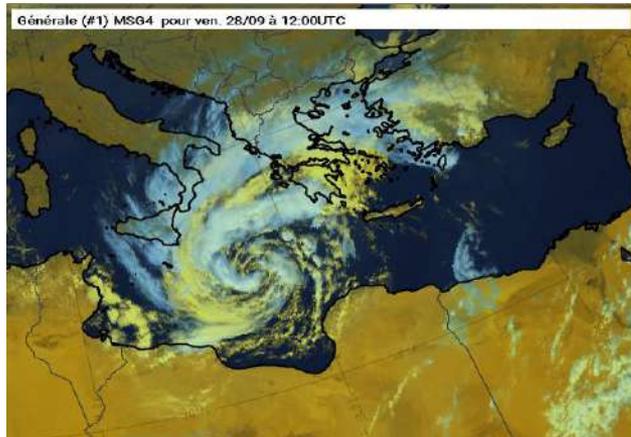


Medicane Zorbas : CPS diagram



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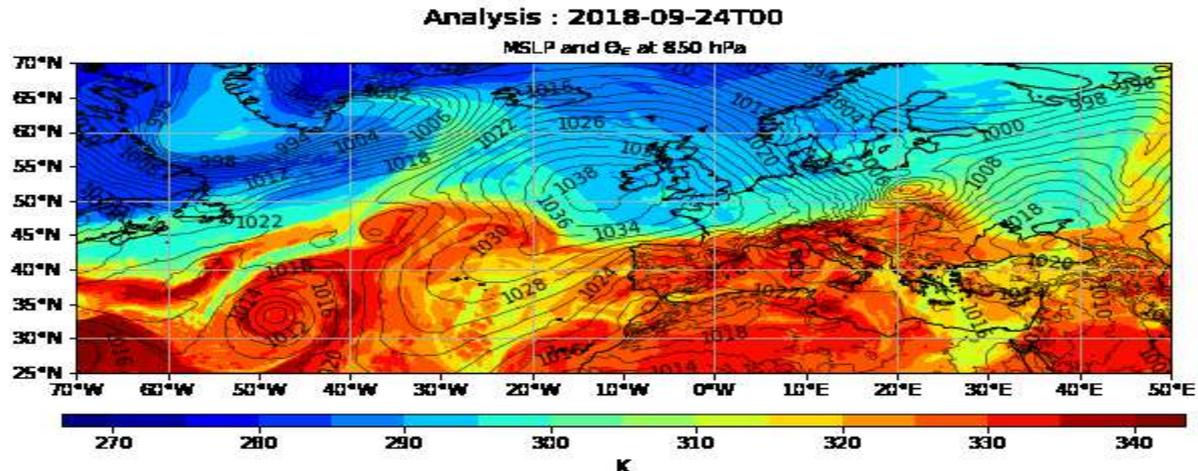
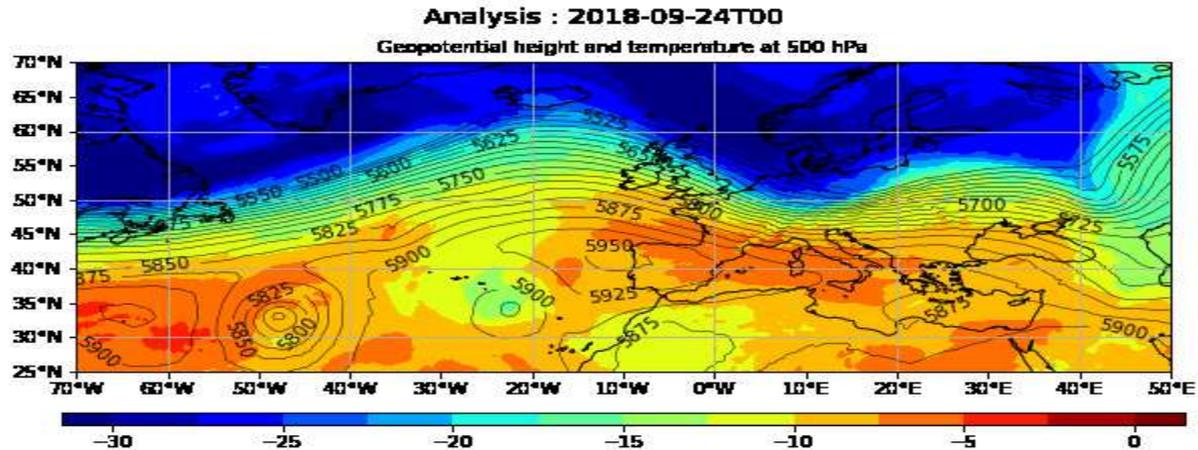
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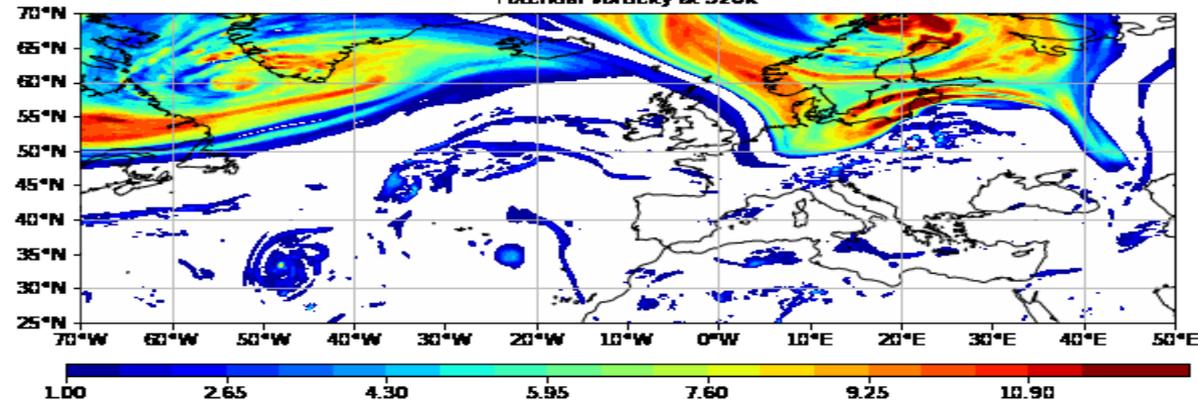
Medicane Zorbas : analysis



Medicane Zorbas : analysis

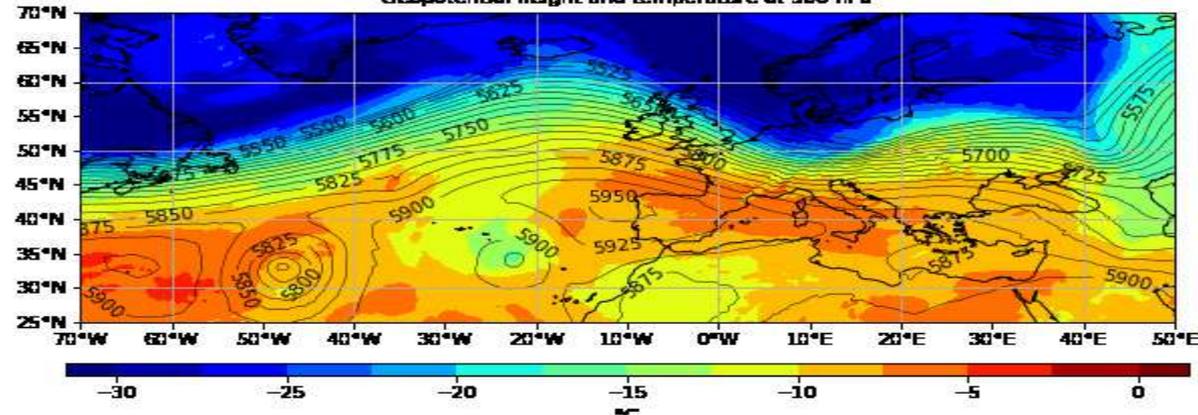
Analysis : 2018-09-24T00

Potential vorticity at 320K



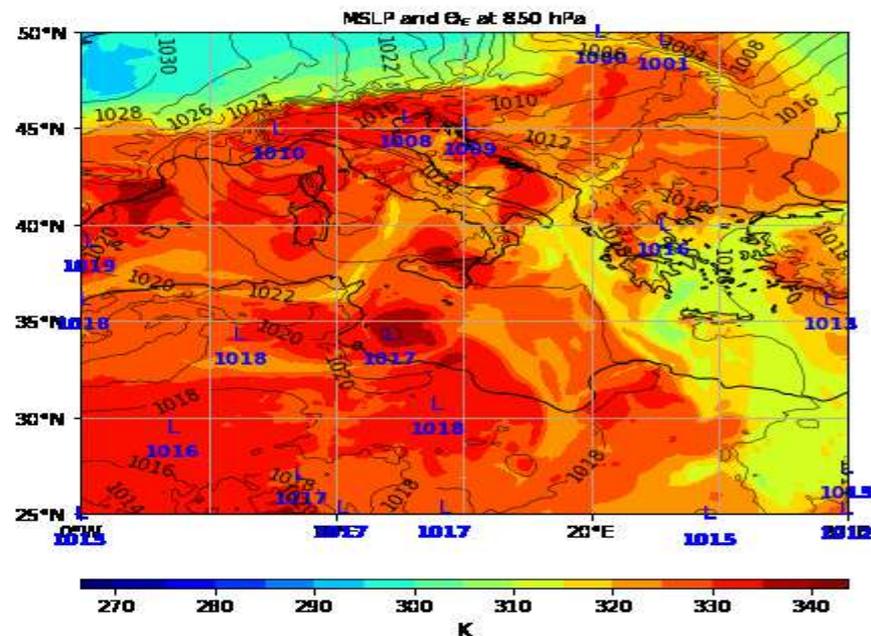
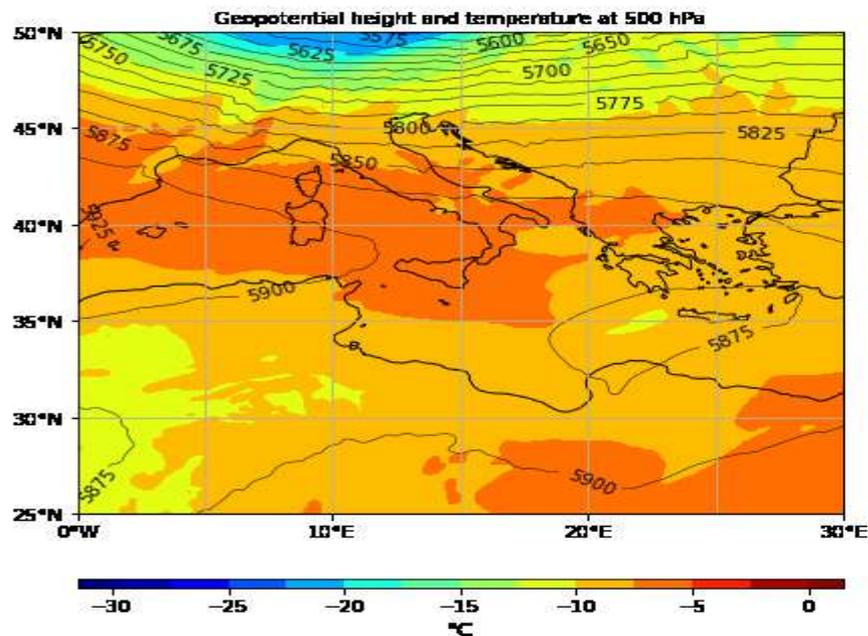
Analysis : 2018-09-24T00

Geopotential height and temperature at 500 hPa



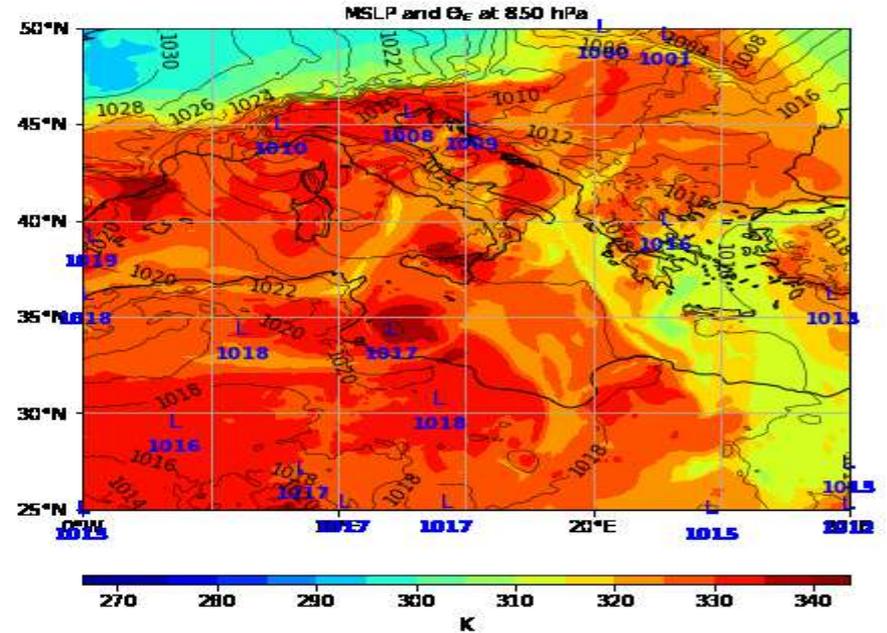
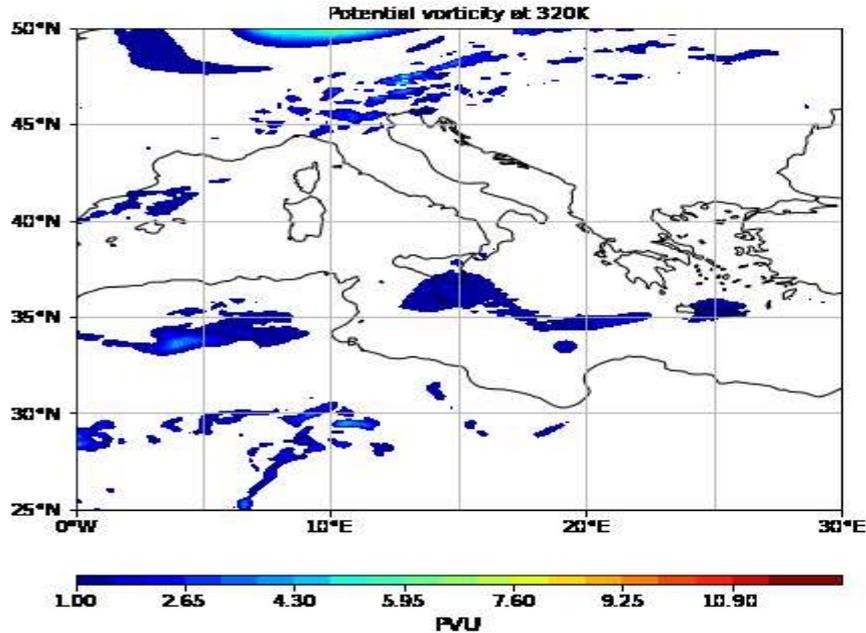
Medicane Zorbas : analysis

Analysis : 2018-09-24T00



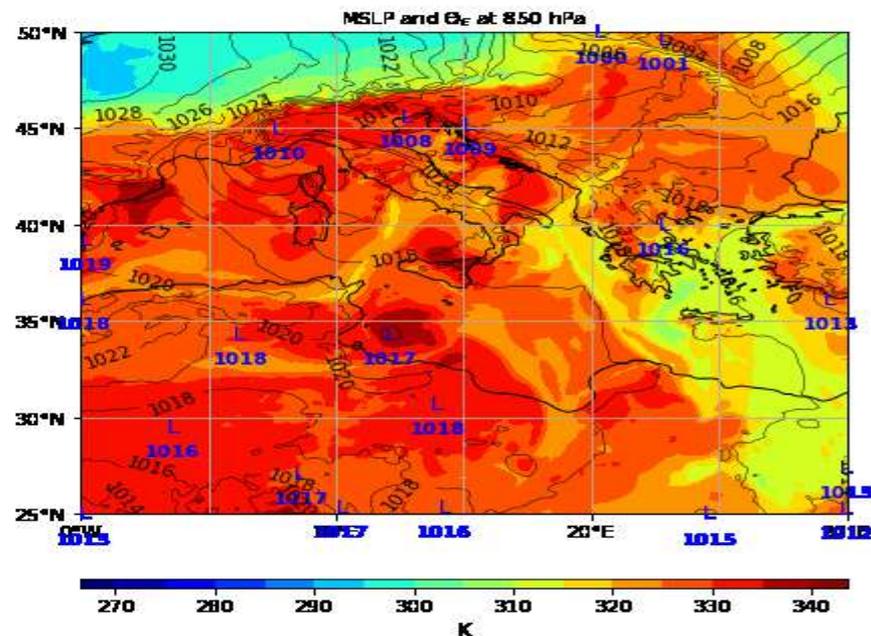
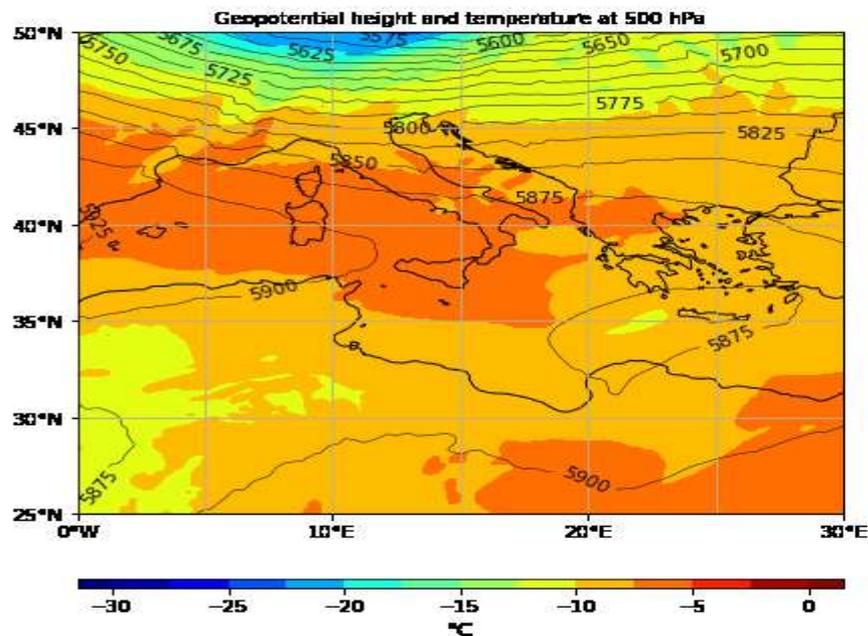
Medicane Zorbas : analysis

Analysis : 2018-09-24T00



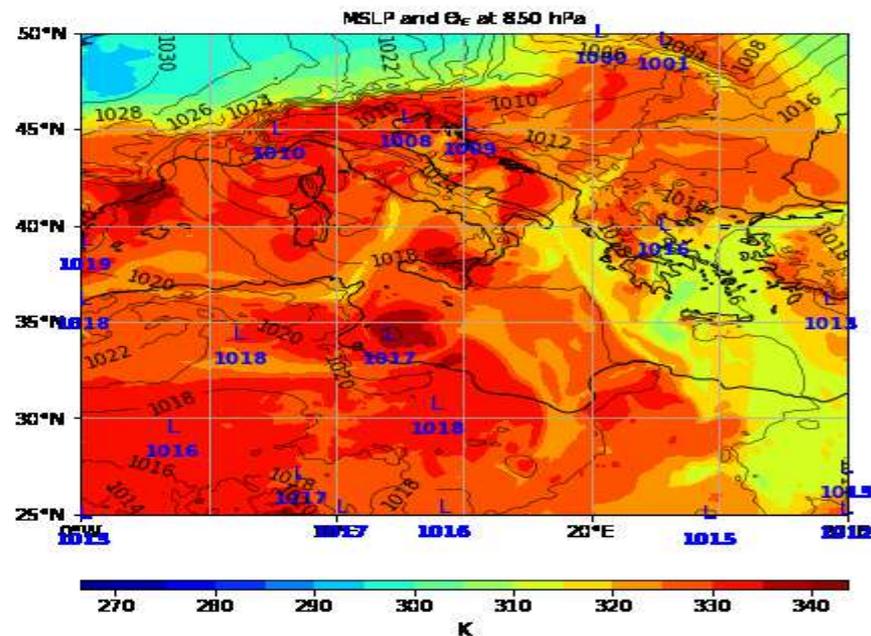
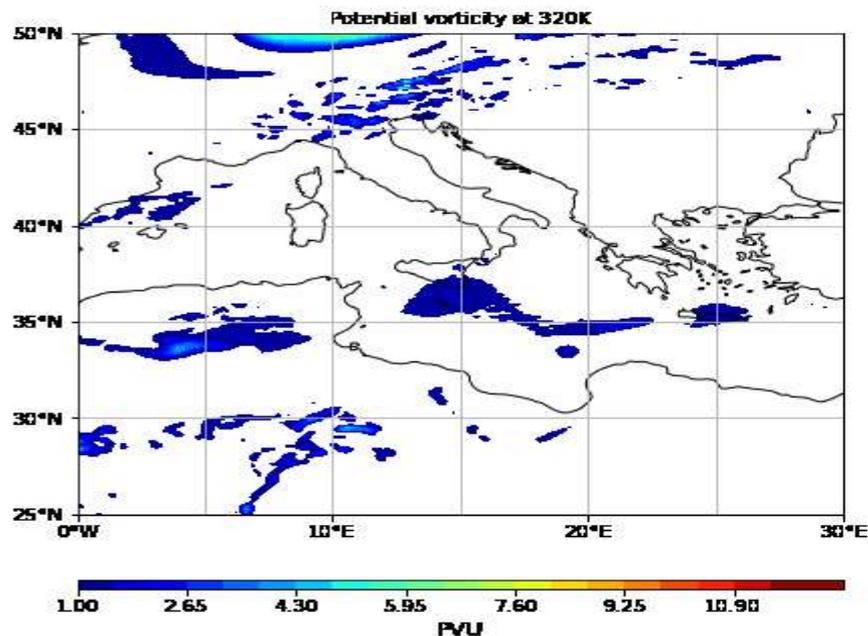
Medicane Zorbas : deterministic forecast

Analysis : 2018-09-24T00 - Forecast : 2018-09-24T00



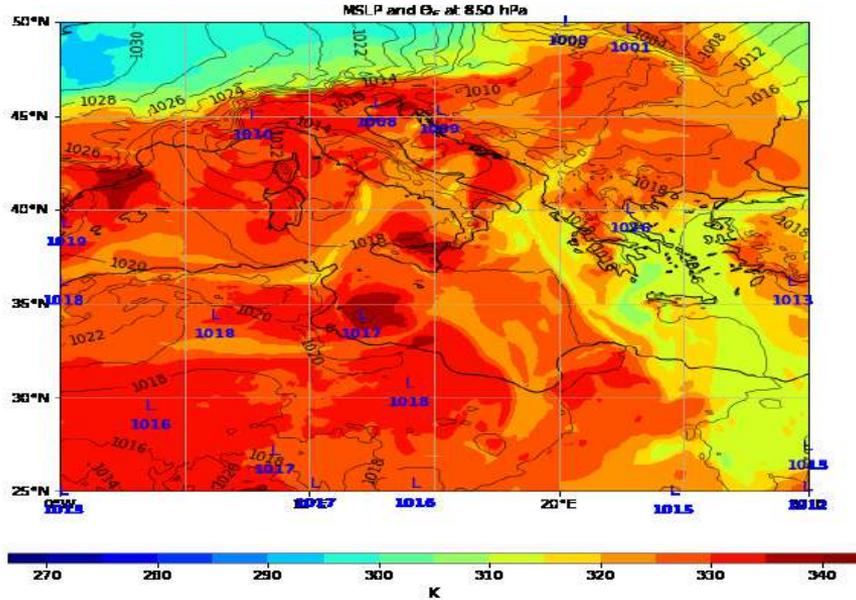
Medicane Zorbas : deterministic forecast

Analysis : 2018-09-24T00 - Forecast : 2018-09-24T00

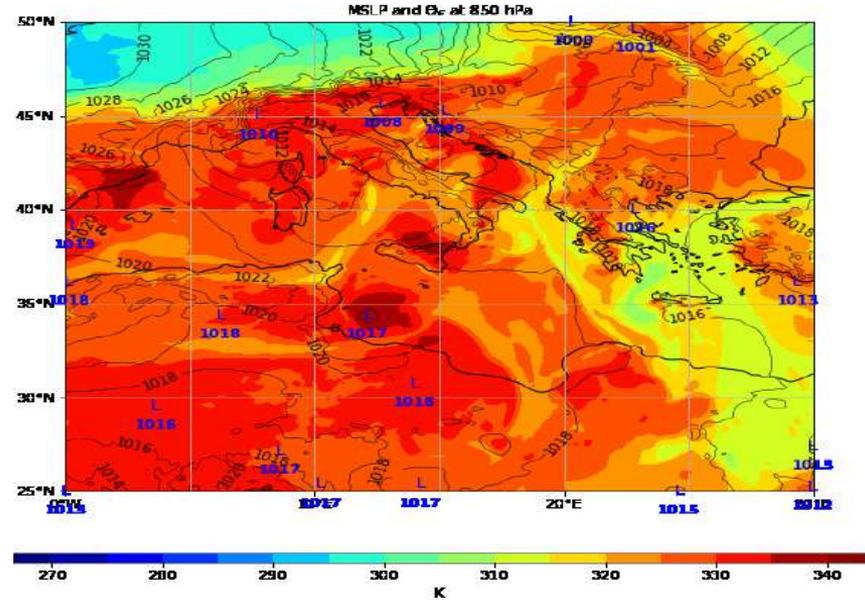


Medicane Zorbas : analysis VS forecast

Analysis : 2018-09-24T00 - Forecast : 2018-09-24T00



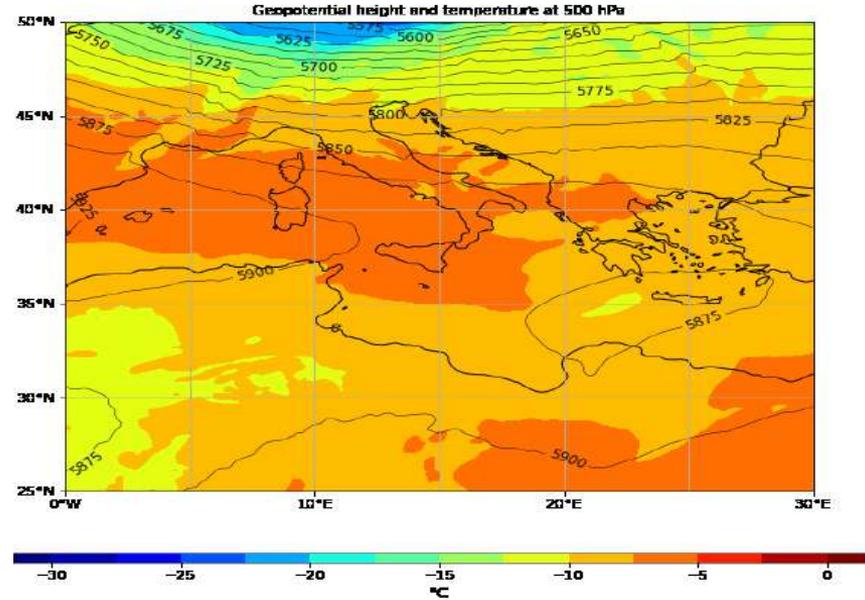
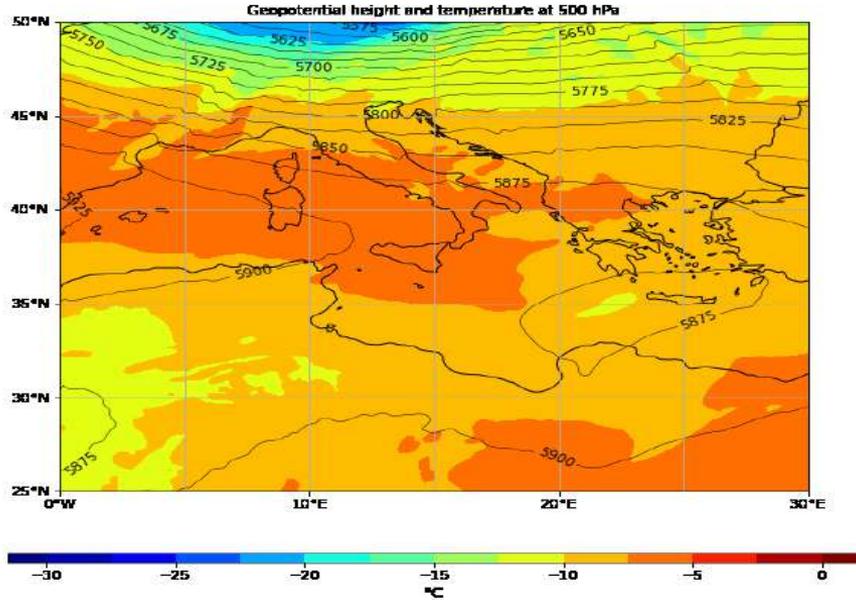
Analysis : 2018-09-24T00



Medicane Zorbas : analysis VS forecast

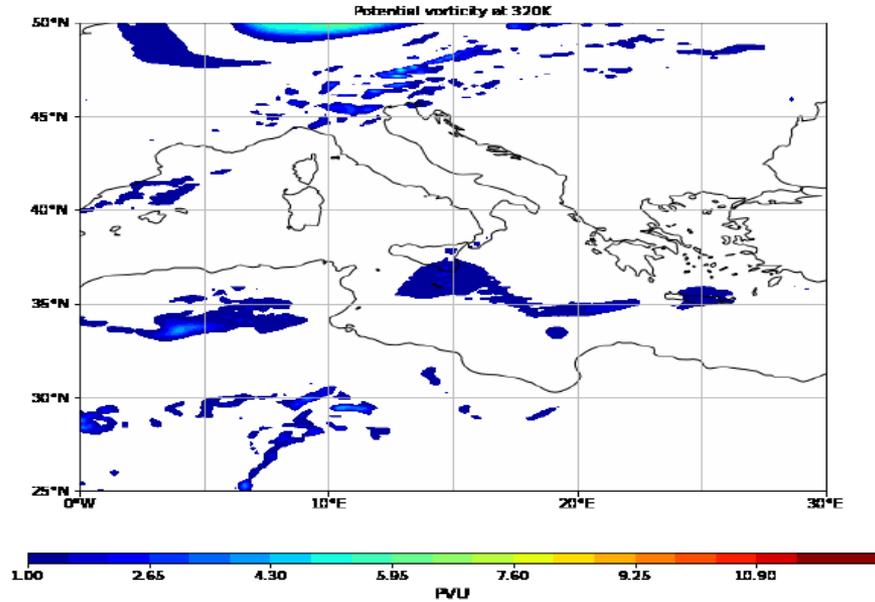
Analysis : 2018-09-24T00 - Forecast : 2018-09-24T00

Analysis : 2018-09-24T00

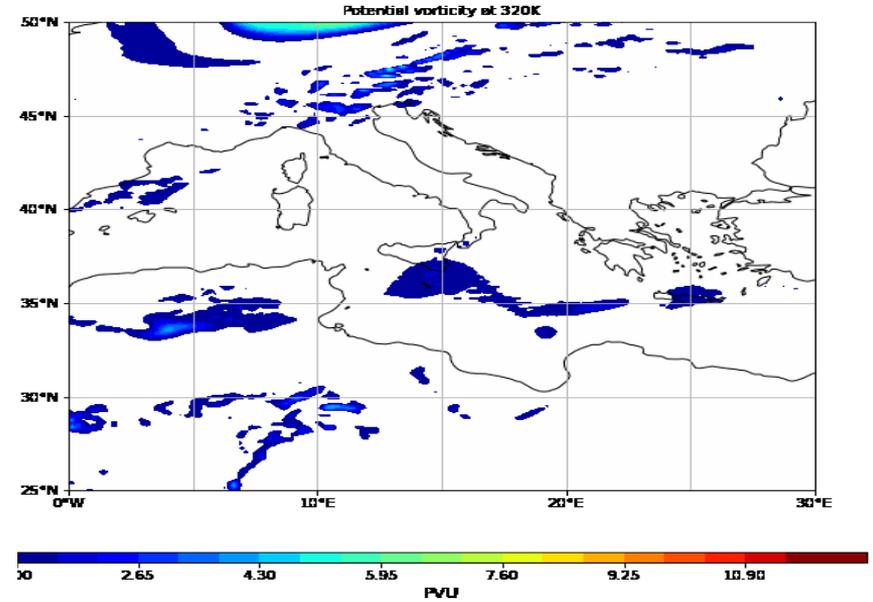


Medicane Zorbas : analysis VS forecast

Analysis : 2018-09-24T00 - Forecast : 2018-09-24T00

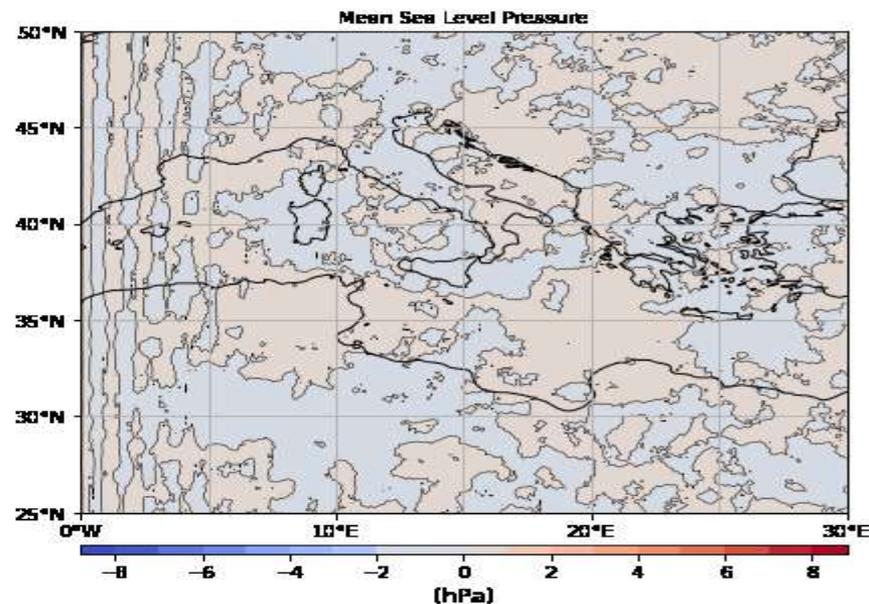
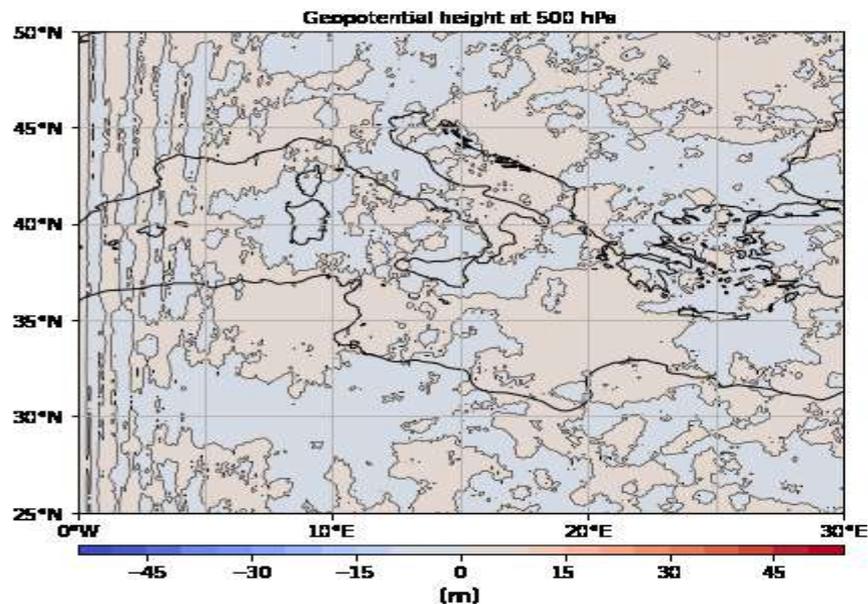


Analysis : 2018-09-24T00

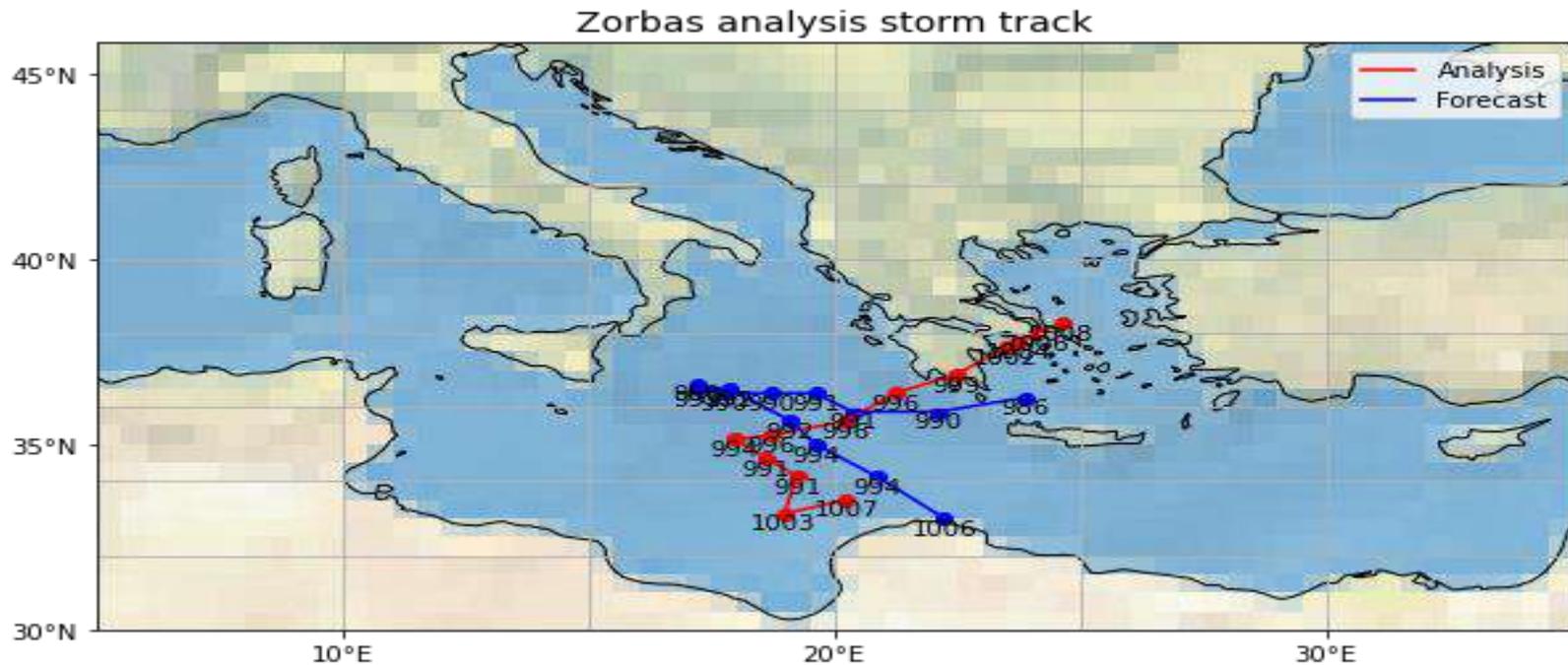


Medicane Zorbas : analysis VS forecast

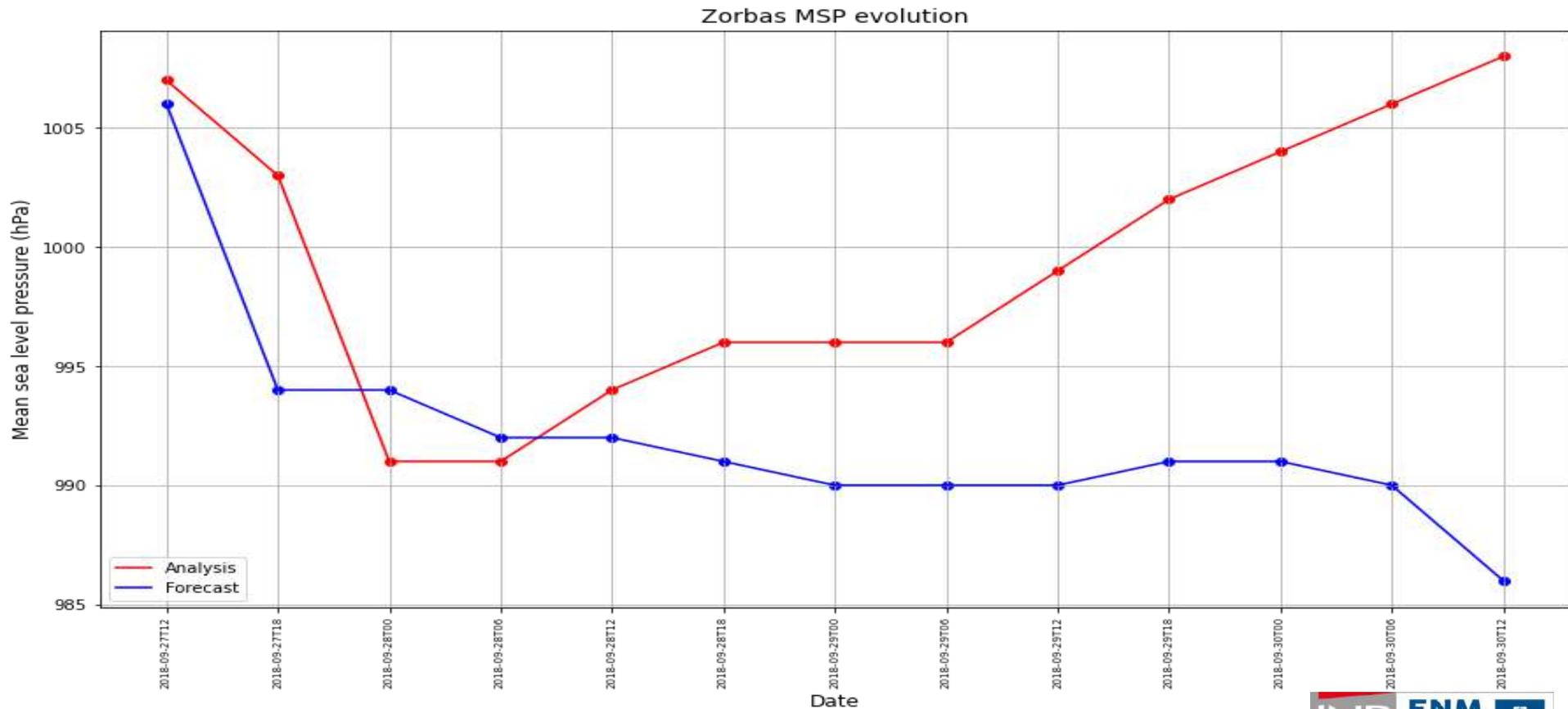
Analysis minus Forecast : 2018-09-24T00



Medicane Zorbas : analysis VS forecast

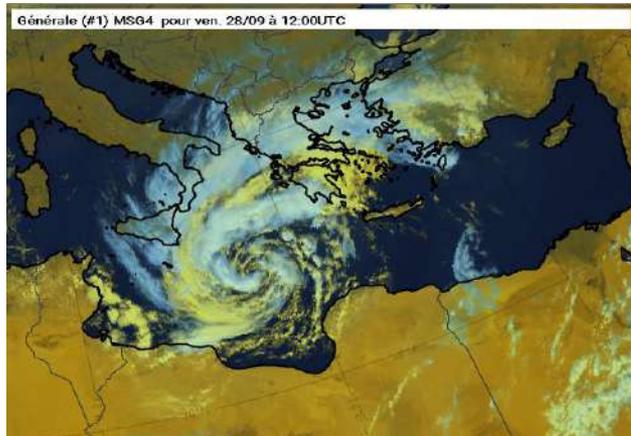


Medicane Zorbas : analysis VS forecast



Outlook of the practical sessions

*Case study :
Medicane Zorbas
(september 2018)*



Session 1 : Monday 15 July morning

1. Dynamical study of the medicane

Session 2 : Thursday 18 July

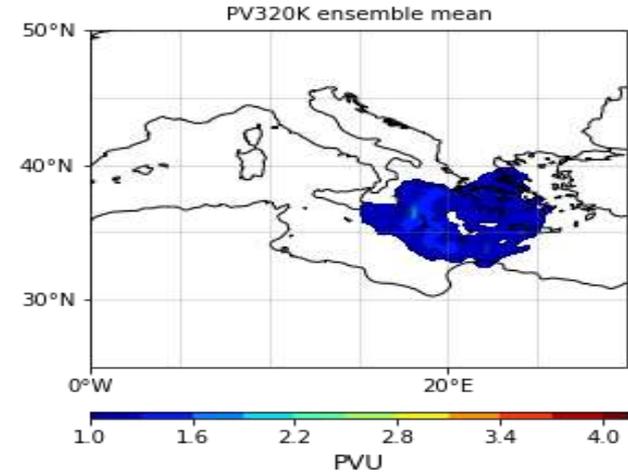
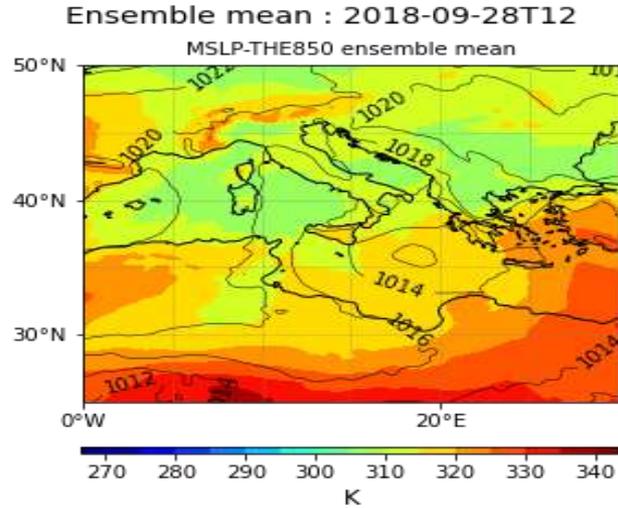
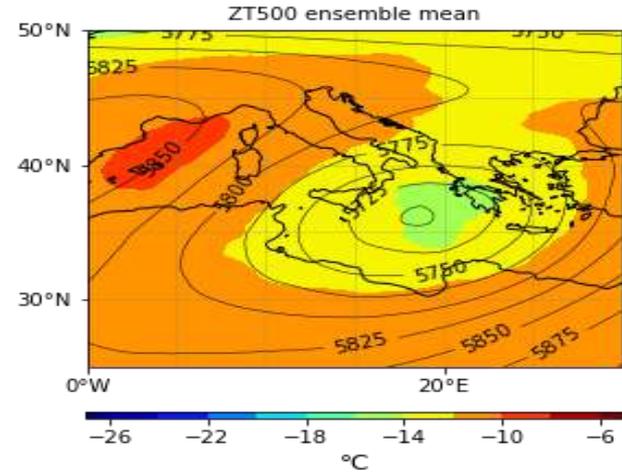
1. Storm tracking in ERA5 reanalysis 
2. Cyclone Phase Space (CPS) diagrams 
3. Analysis and deterministic forecast 
4. **Ensemble forecast** 

Session 3 : Friday 19 July morning

1. Preparation of the student presentations

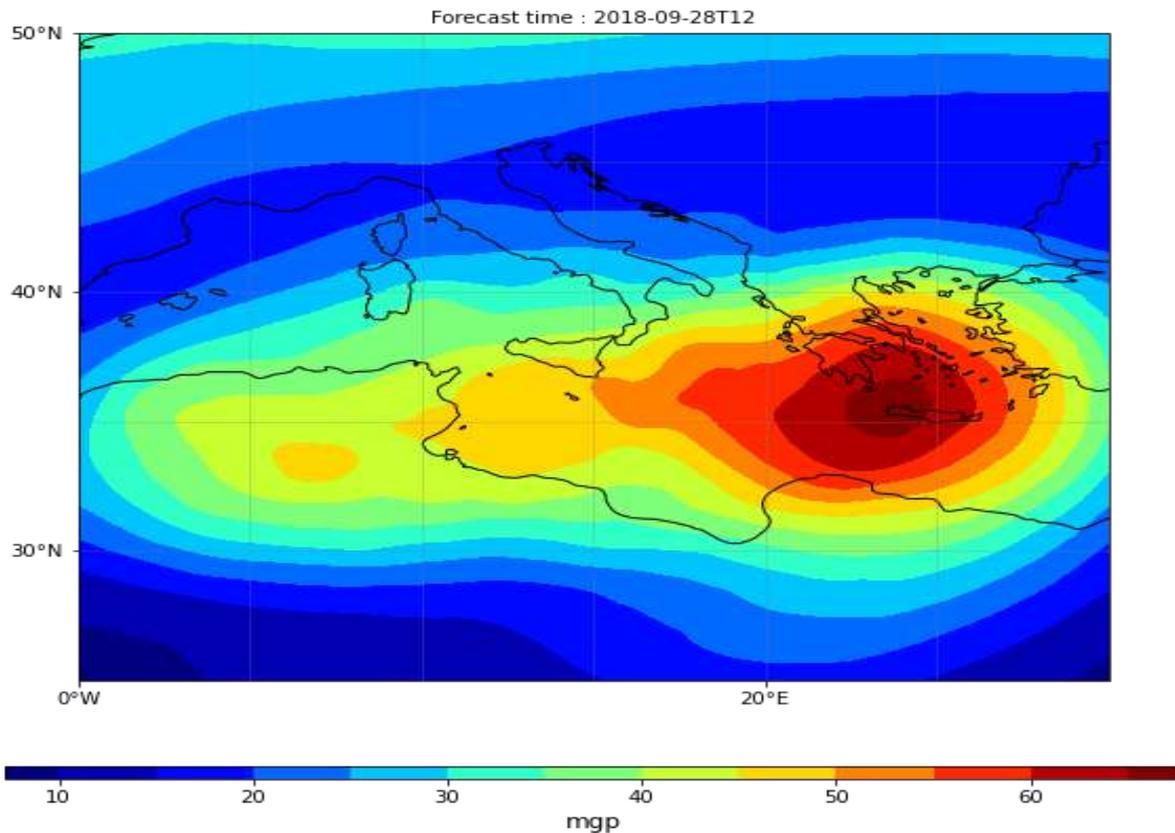
Friday 19 July afternoon: student presentations

Medicane Zorbas : ensemble mean



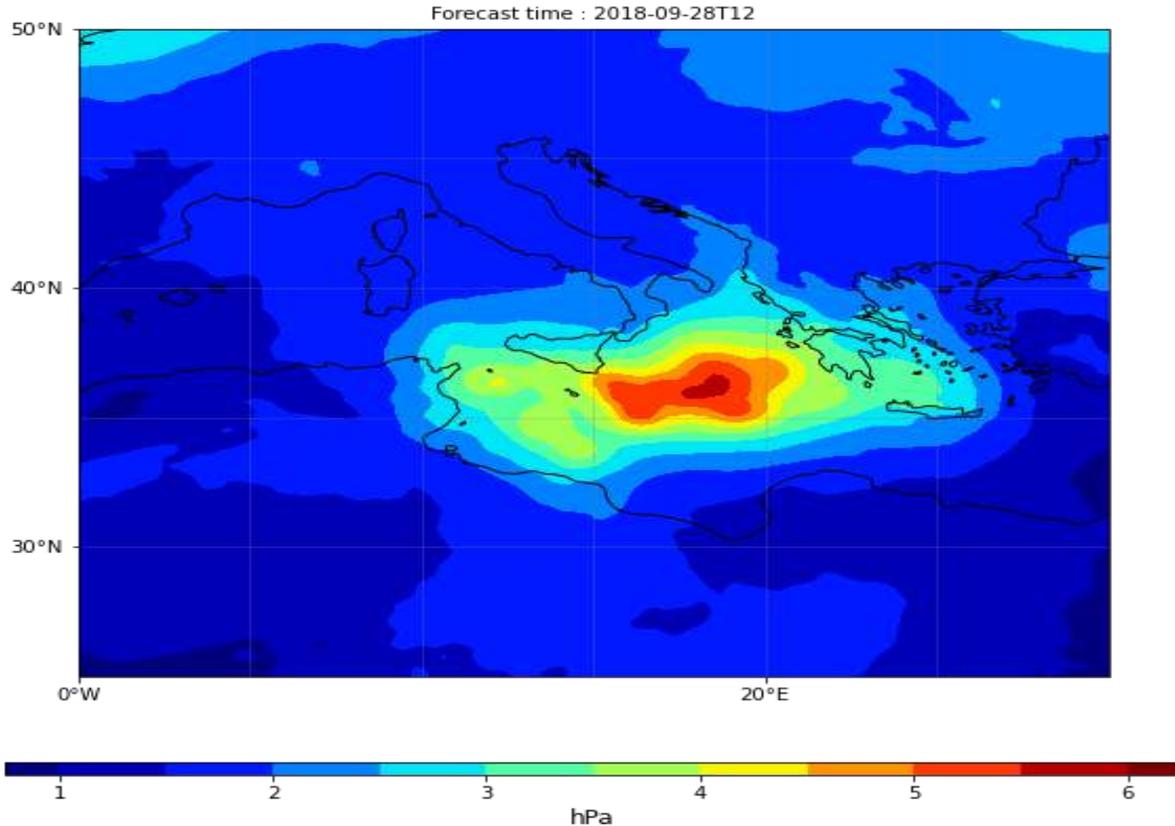
Medicane Zorbas : ensemble spread (Z500)

Geopotential height at 500hPa : ensemble spread



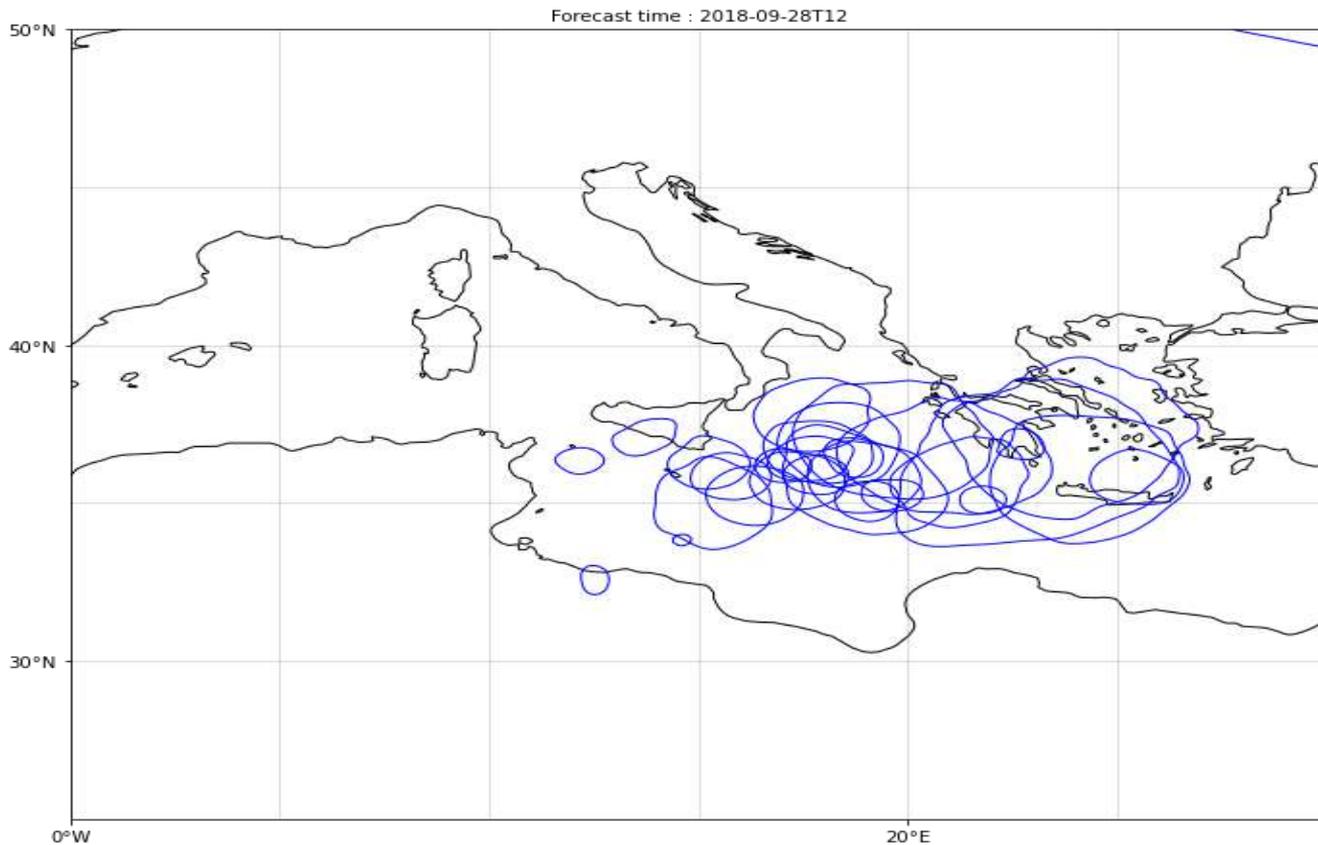
Medicane Zorbas : ensemble spread (MSLP)

Mean Sea Level Pressure : ensemble spread



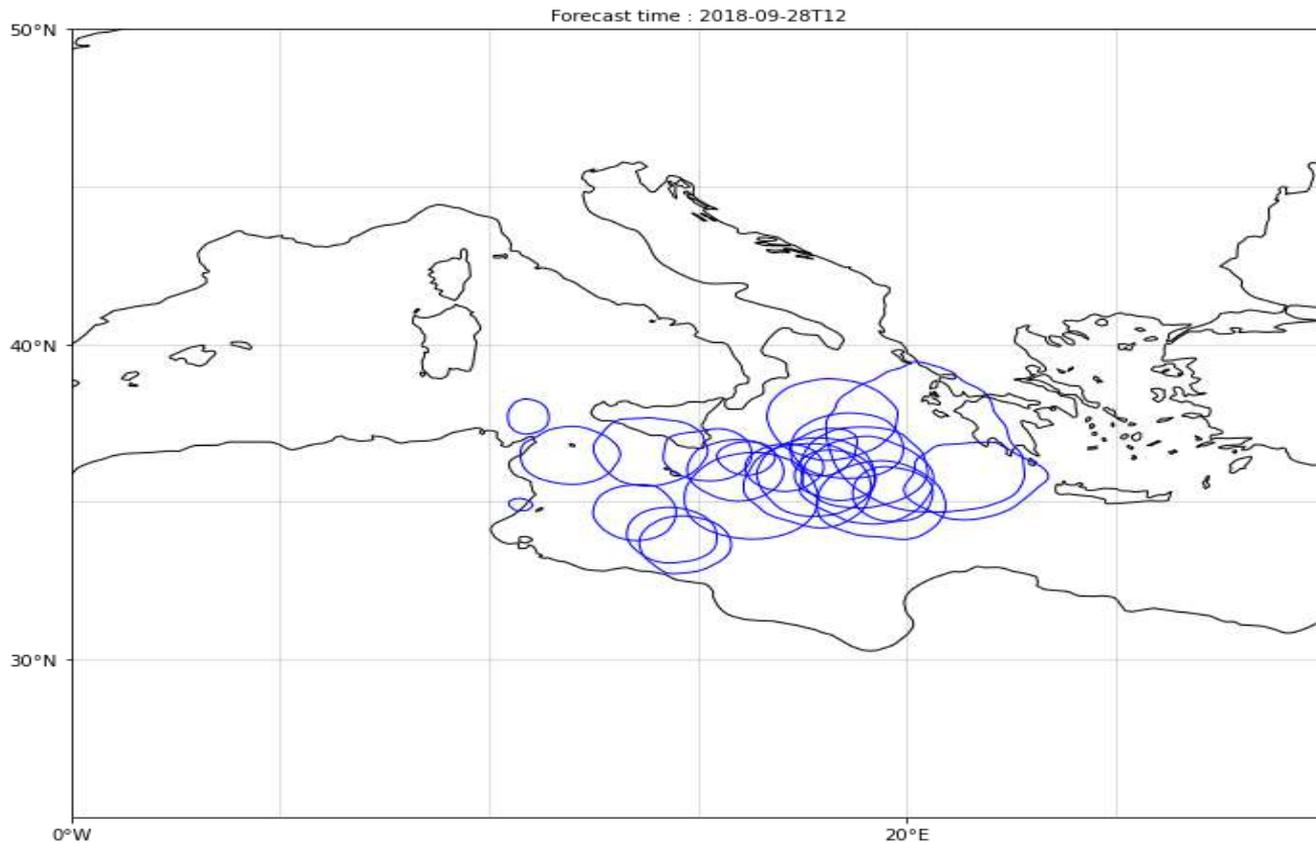
Medicane Zorbas : Z500 spaghetti

Geopotential height at 500hPa spaghetti : [5640] mgp contour



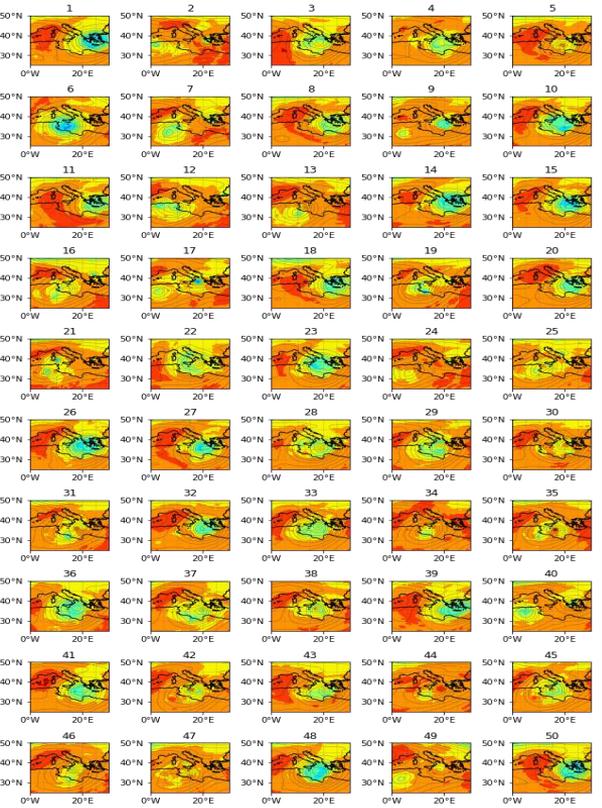
Medicane Zorbas : MSLP spaghetti

Mean Sea Level Pressure spaghetti : [1005] hPa contour

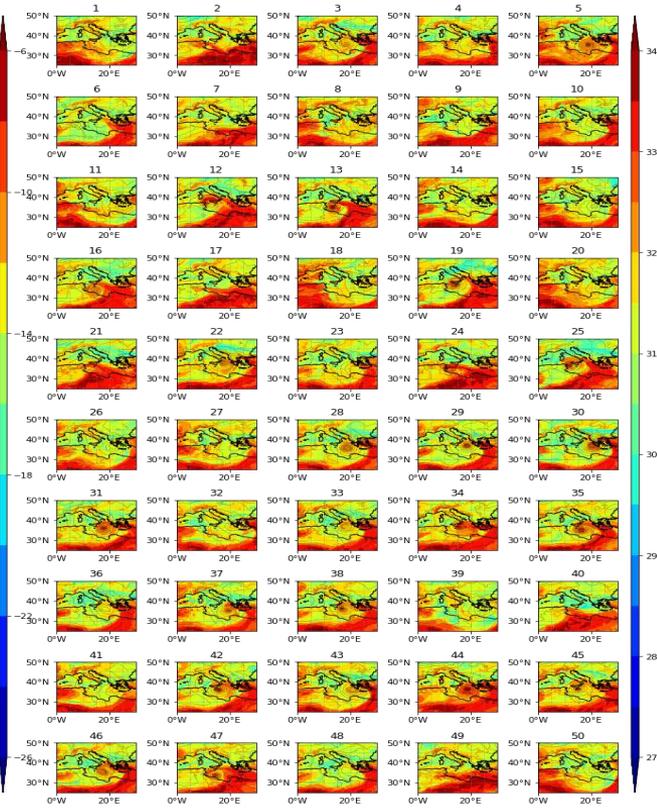


Medicane Zorbas : stamps

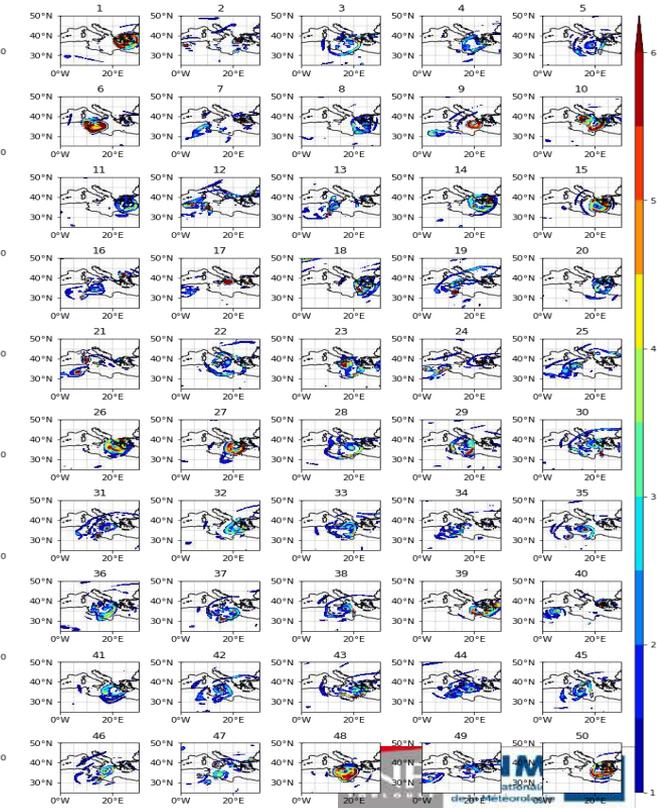
ECMWF ensemble members - ZT500. Forecast time : 2018-09-28T12



ECMWF ensemble members - MSLP and Θ_E at 850 hPa. Forecast time : 2018-09-28T12



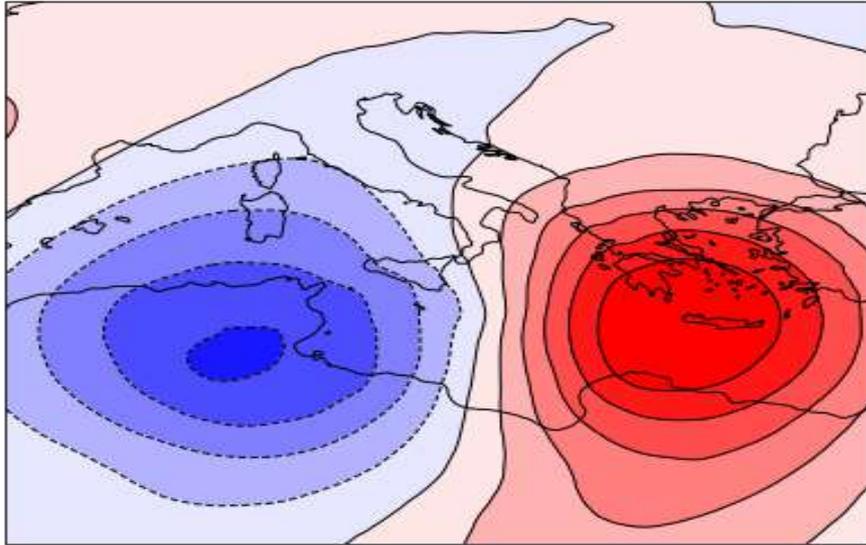
ECMWF ensemble members - PV320K. Forecast time : 2018-09-28T12



Medicane Zorbas : EOF analysis

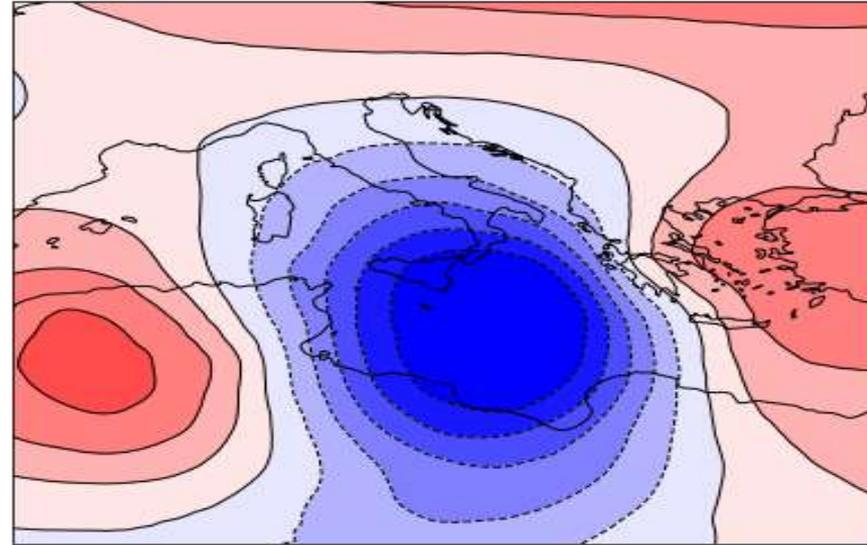
ECMWF ensemble members - EOF analysis : Z500 - 2018-09-28T12

EOF1 (explained variance : 51.38%)



-0.008 -0.004 0.000 0.004 0.008

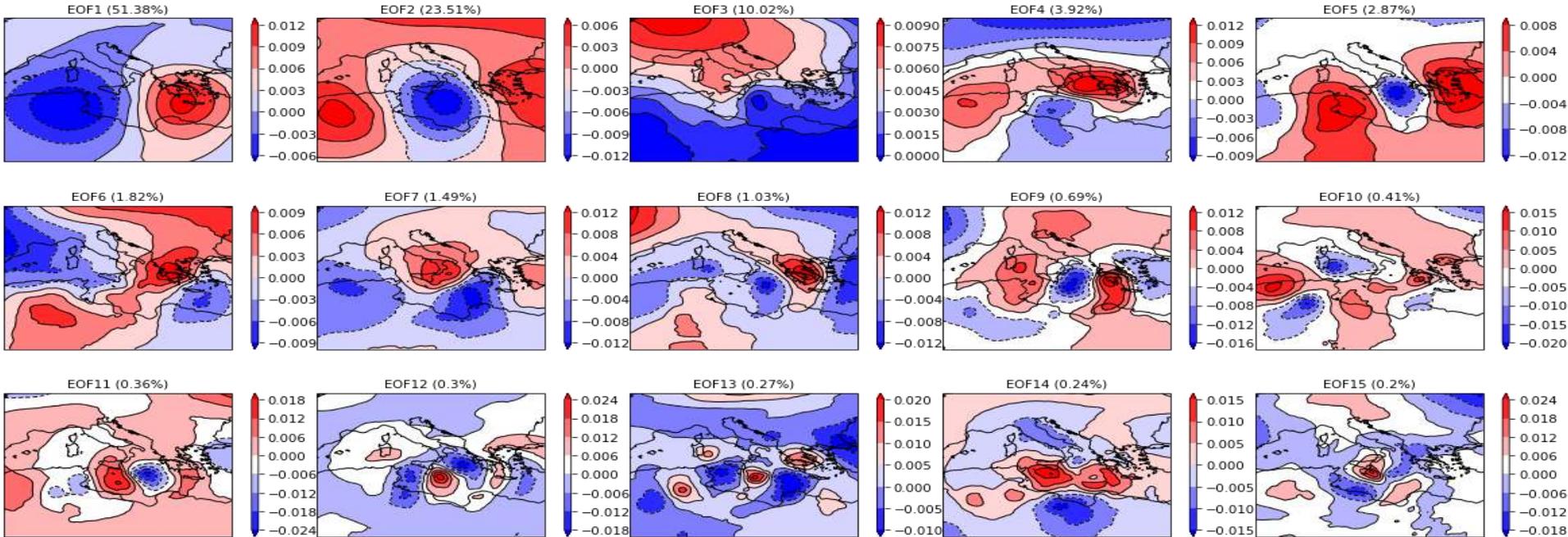
EOF1 (explained variance : 23.51%)



-0.008 -0.004 0.000 0.004 0.008

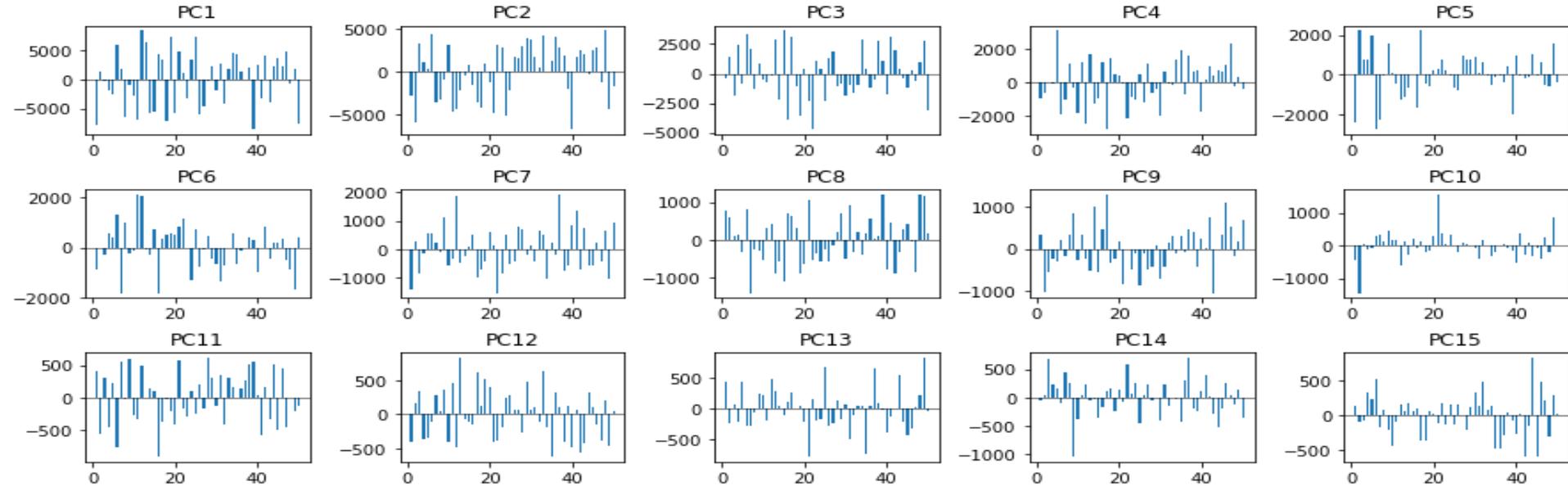
Medicane Zorbas : EOF analysis

EOFs



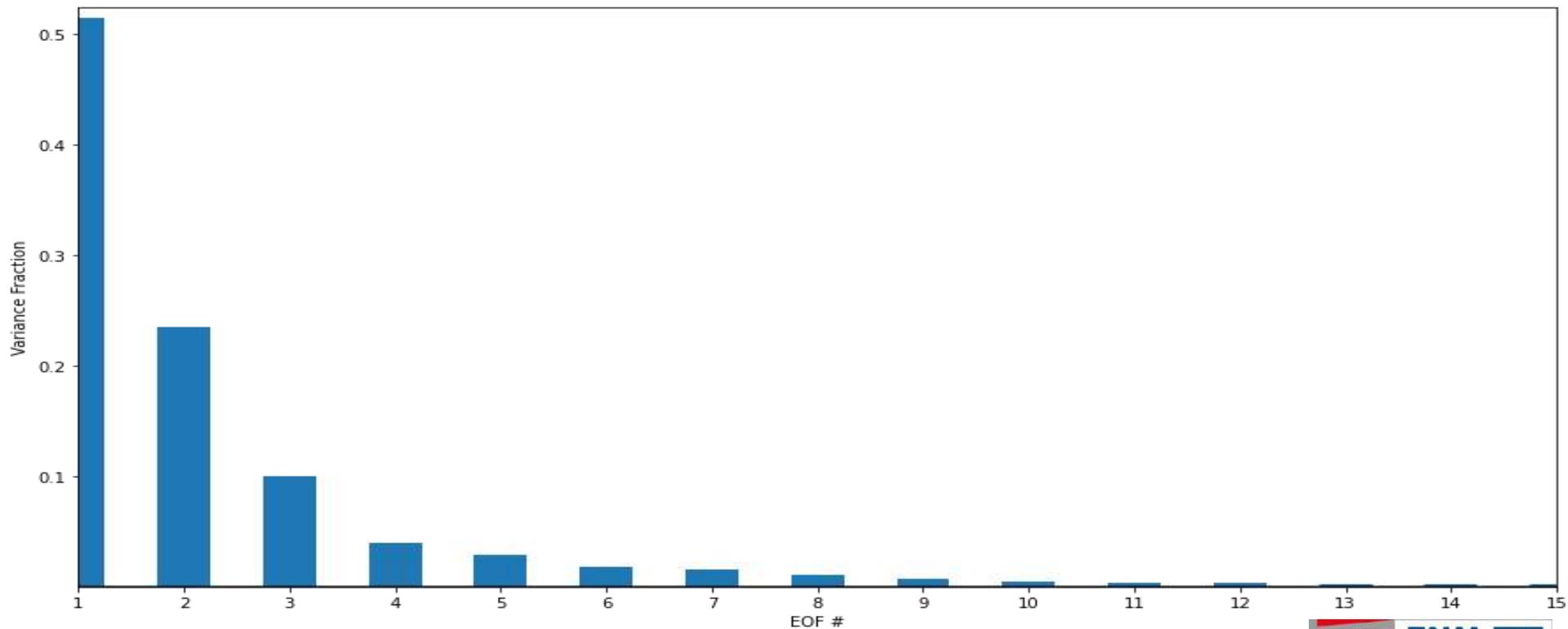
Medicane Zorbas : EOF analysis

PCs



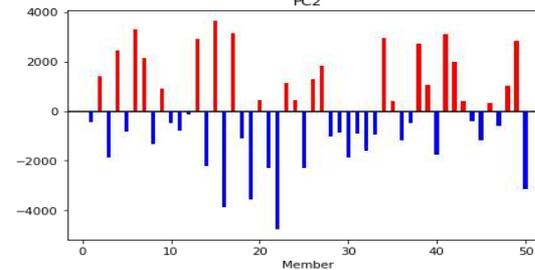
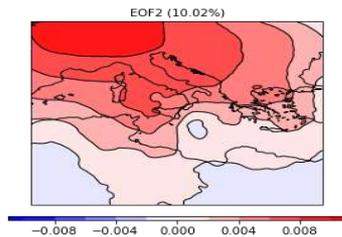
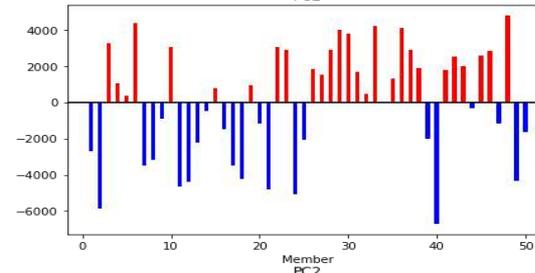
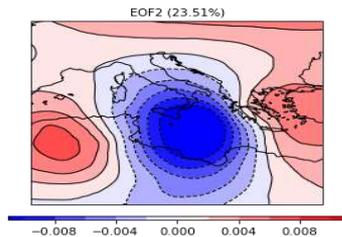
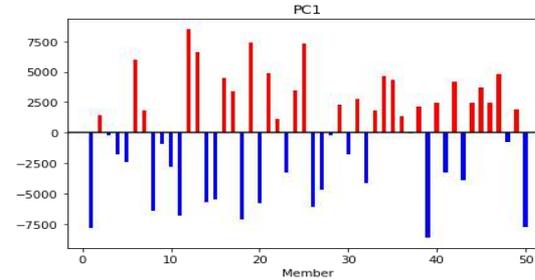
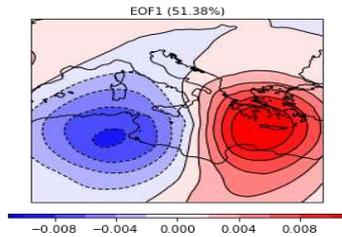
Medicane Zorbas : EOF analysis

Variance fraction



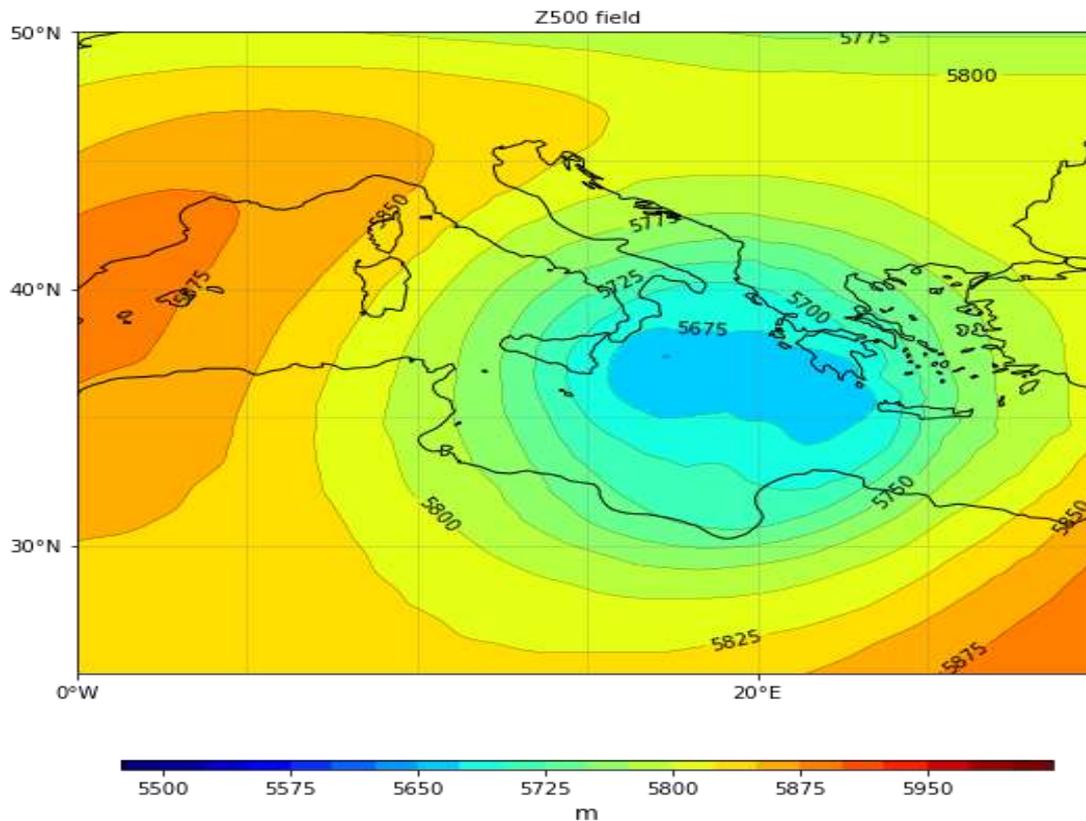
Medicane Zorbas : EOF analysis

ECMWF ensemble members - EOF analysis (Z500) : 2018-09-28T12



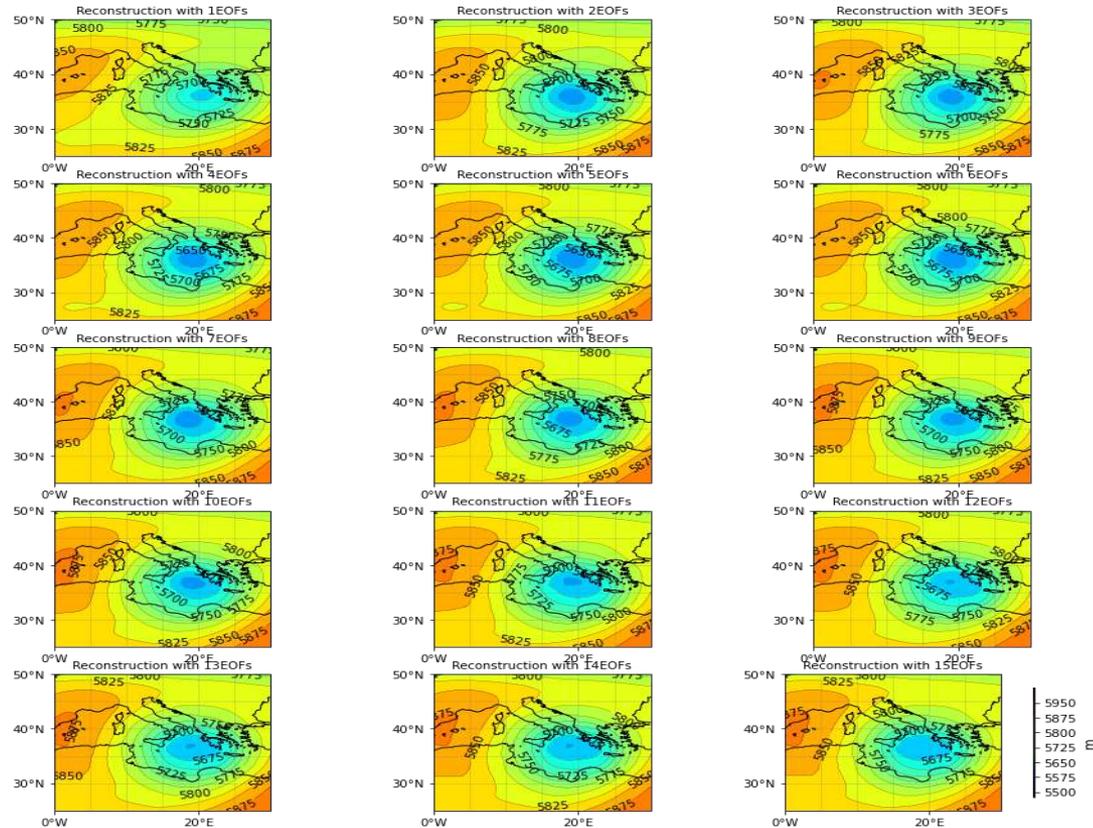
Medicane Zorbas : EOF analysis

Reconstruction of ensemble member 23 with the EOFs



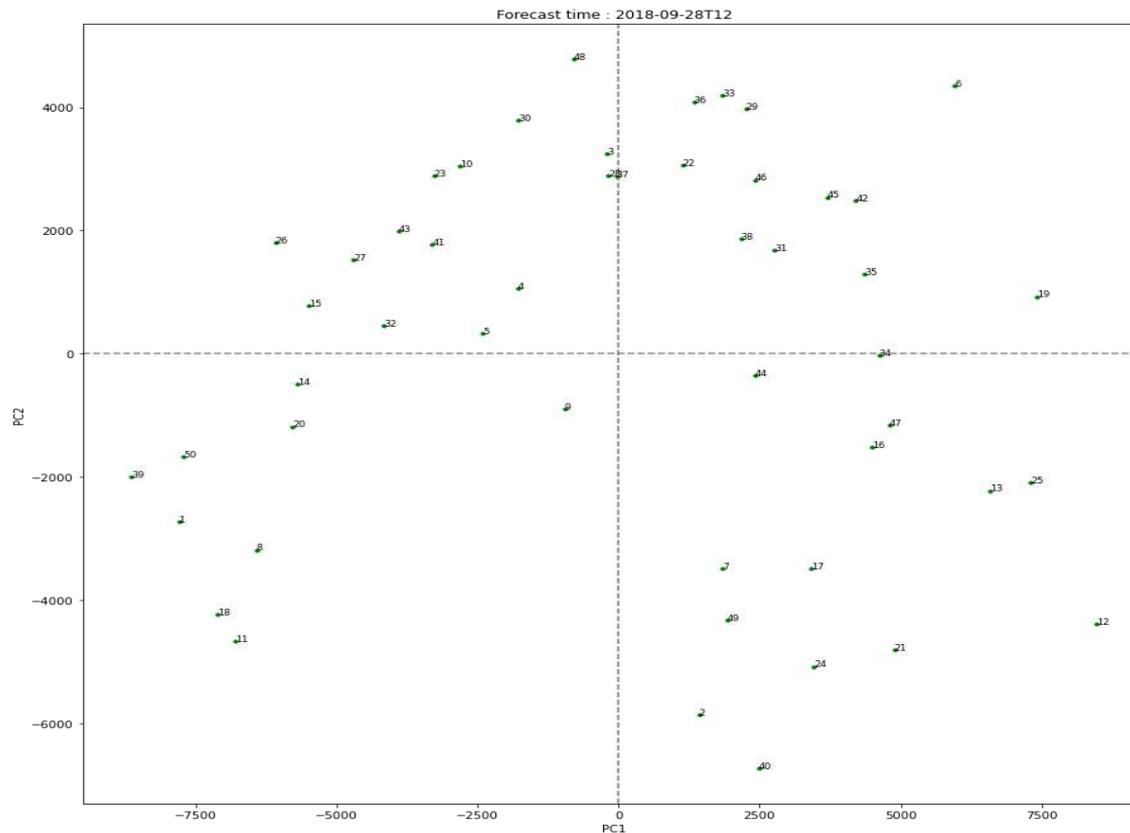
Medicane Zorbas : EOF analysis

Reconstruction of ensemble member 23 with the EOFs



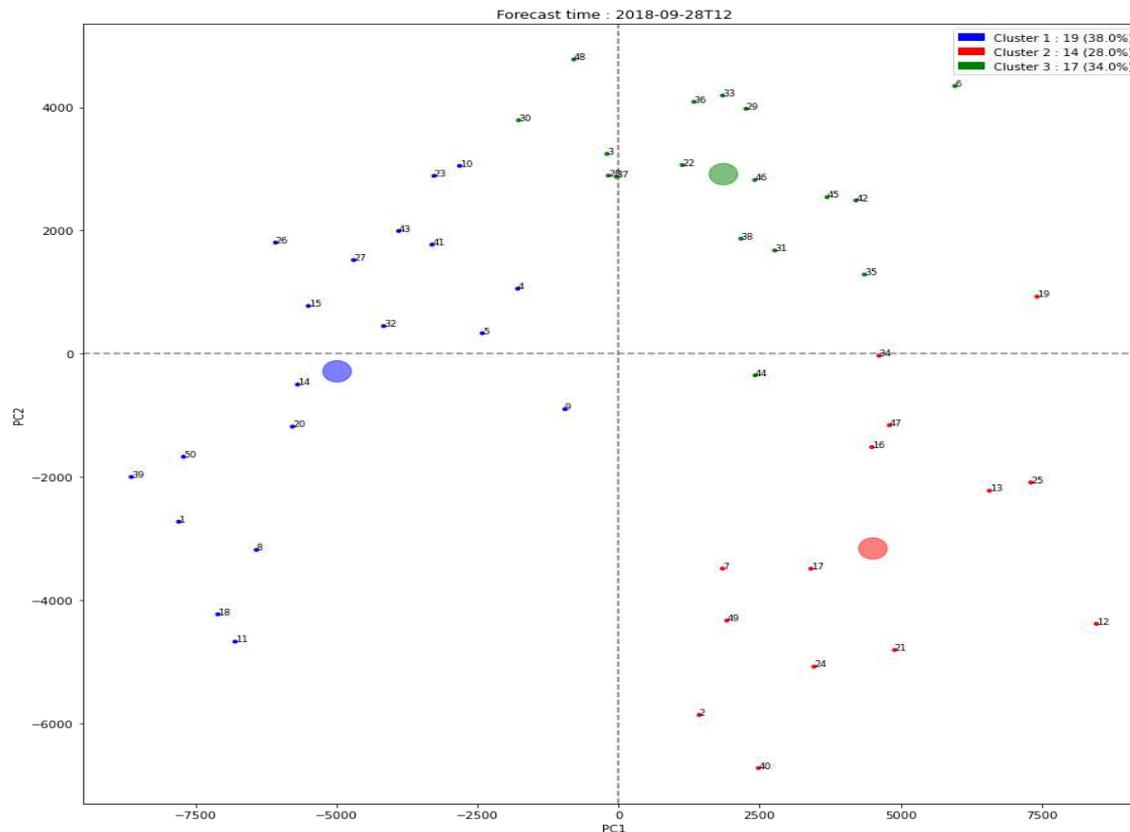
Medicane Zorbas : EOF analysis

Ensemble members in PC1 and PC2 phase space (Z500)



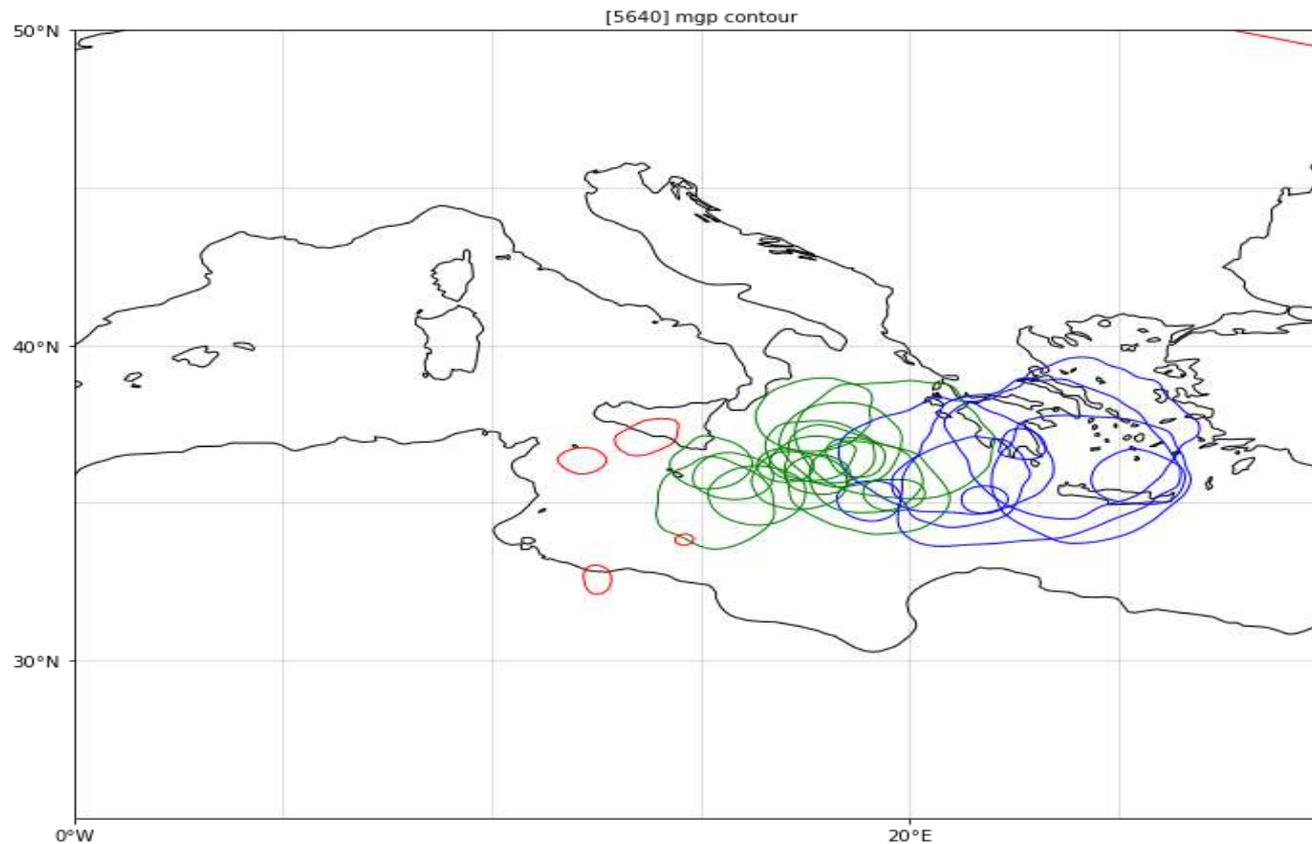
Medicane Zorbas : kmeans clustering

Ensemble members in PC1 and PC2 phase space - Z500 K-means clustering



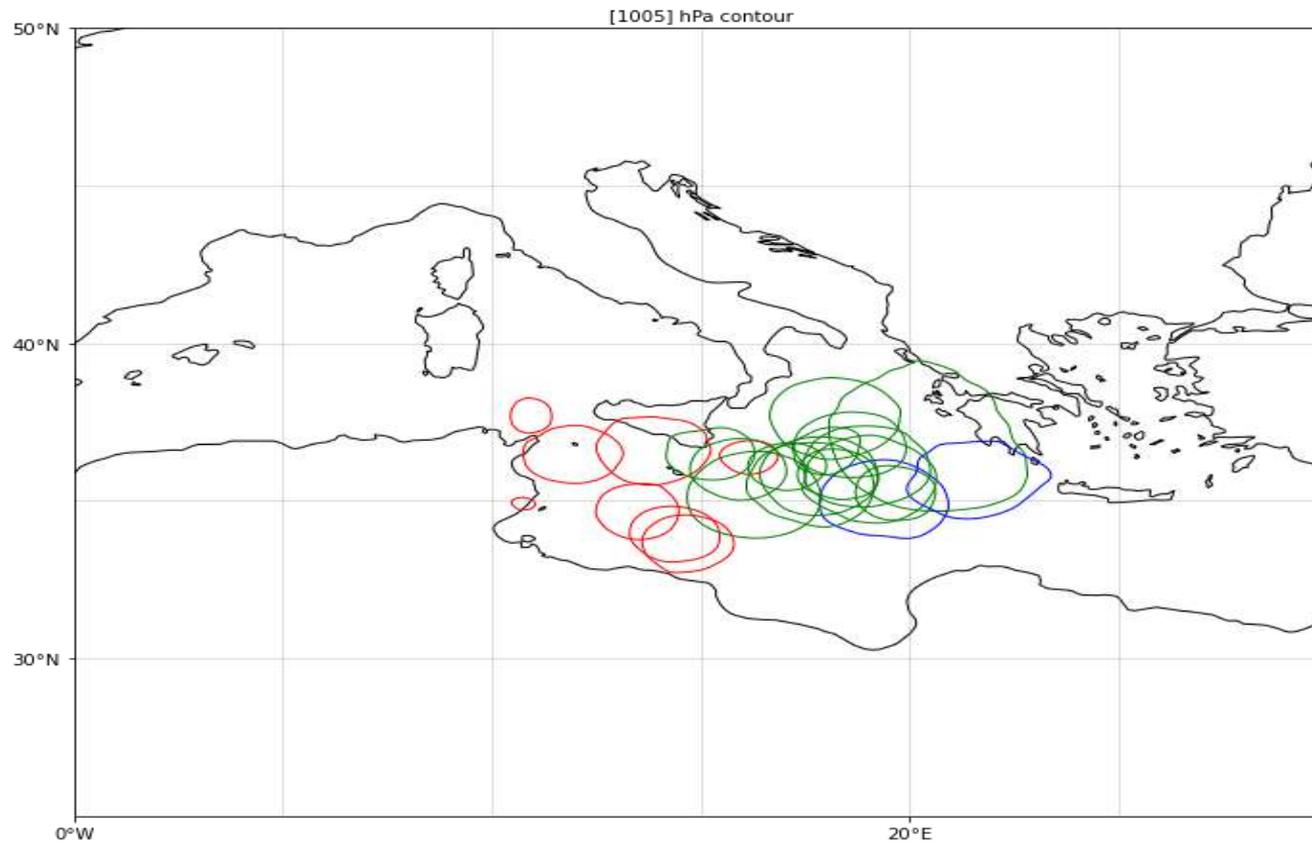
Medicane Zorbas : kmeans clustering

Geopotential height at 500hPa spaghetti with clustering. Forecast time : 2018-09-28T12



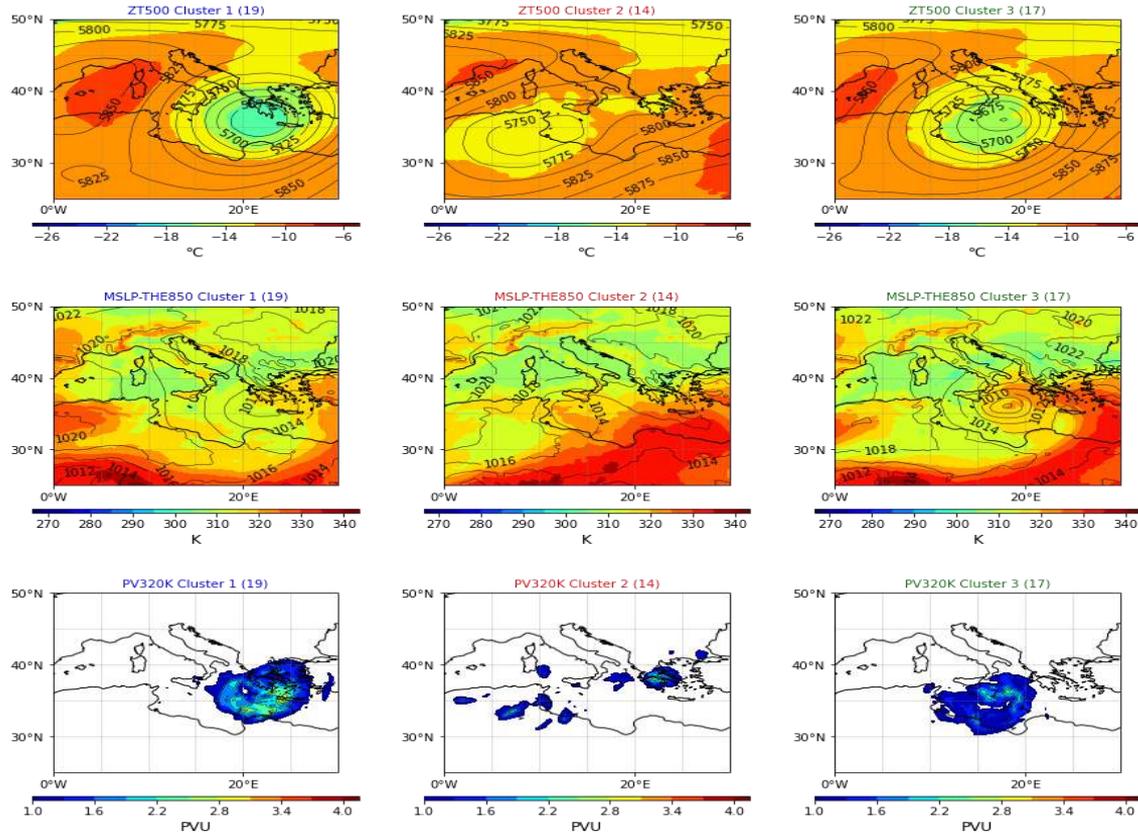
Medicane Zorbas : kmeans clustering

Mean Sea Level Pressure spaghetti. Forecast time : 2018-09-28T12



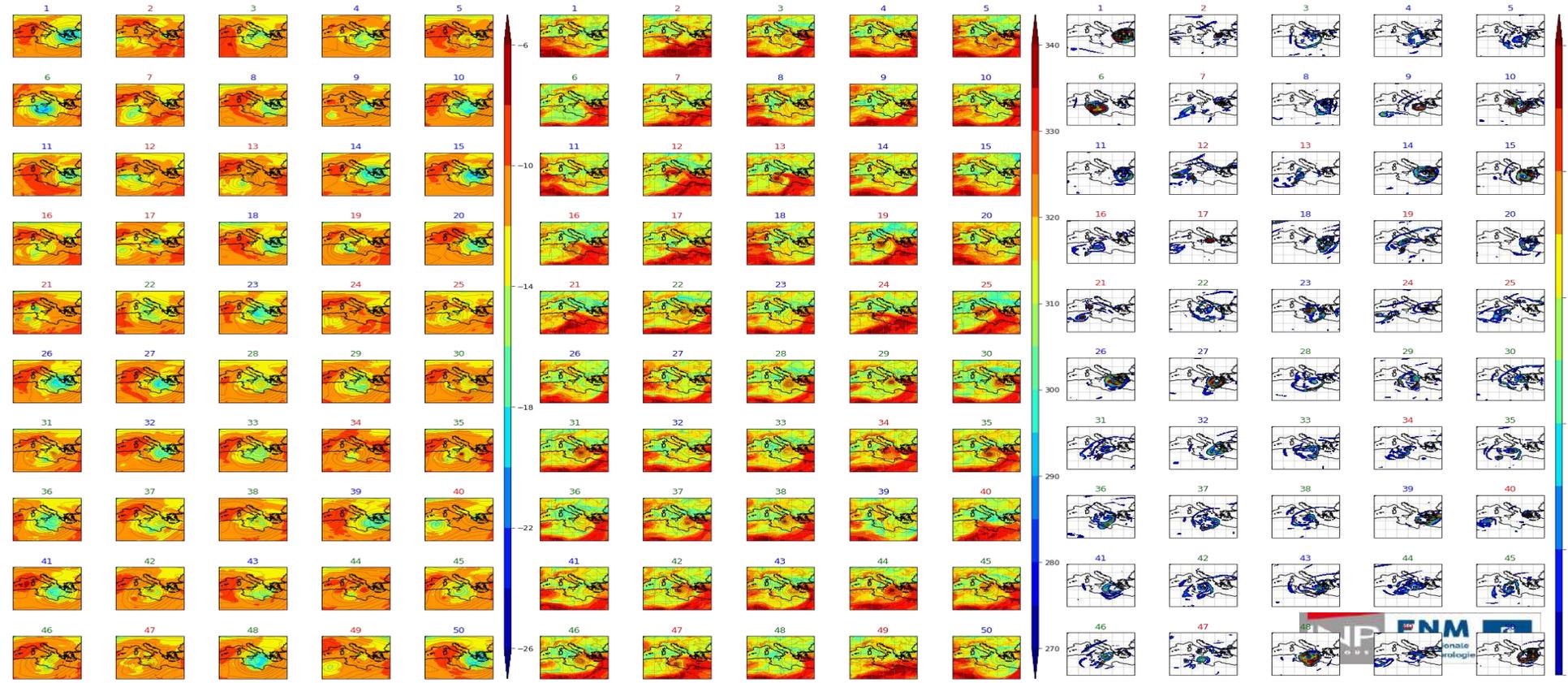
Medicane Zorbas : kmeans clustering

Cluster composites - Forecast time : 2018-09-28T12



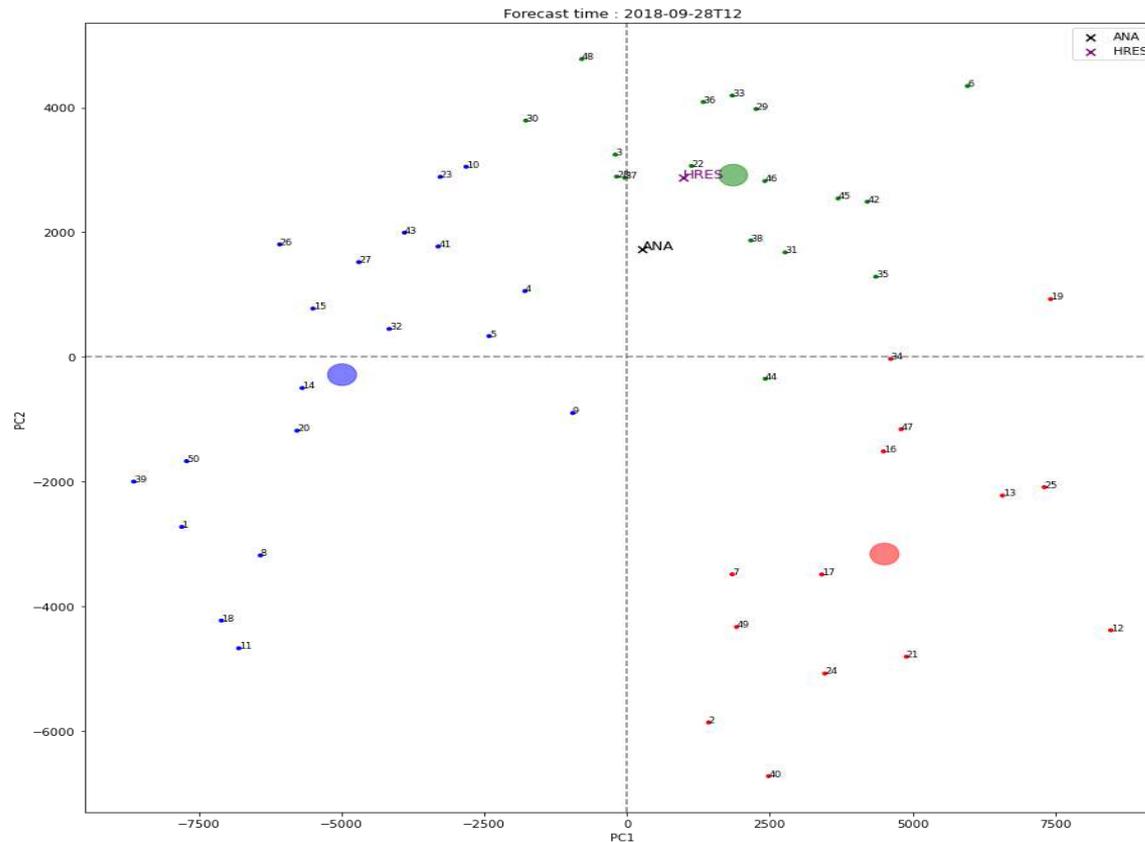
Medicane Zorbas : kmeans clustering

Left panel: 50 ensemble members with clustering - ZT500. Forecast time : 2018-09-28T12Z. Middle panel: 50 ensemble members with clustering - MSLP and Θ_E at 850 hPa. Forecast time : 2018-09-28T12Z. Right panel: 50 ensemble members with clustering - PV320K. Forecast time : 2018-09-28T12Z.



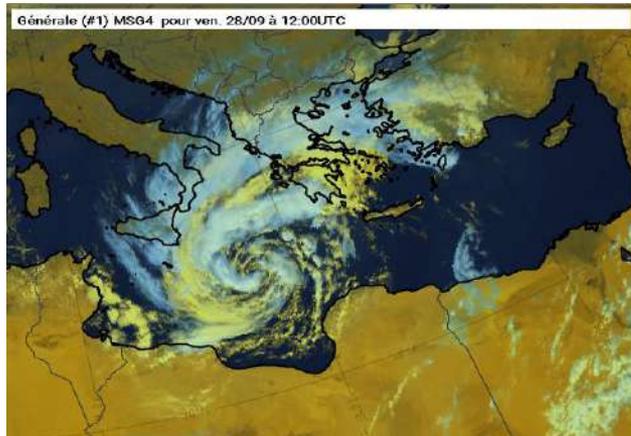
Medicane Zorbas : kmeans clustering

Ensemble members in PC1 and PC2 phase space - K-means clustering



Outlook of the practical sessions

*Case study :
Medicane Zorbas
(september 2018)*



Session 1 : Monday 15 July morning

1. Dynamical study of the medicane

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2. Cyclone Phase Space (CPS) diagrams 
3. Analysis and deterministic forecast 
4. Ensemble forecast 

Session 3 : Friday 19 July morning

1. Preparation of the student presentations

Friday 19 July afternoon: student presentations

Notebook extra tasks

1. Track hurricane Leslie over the Atlantic
2. Compute the CPS diagrams for hurricane Leslie
3. Compare tracks and MSLP evolutions (analysis VS deterministic forecast)
4. Classification of the ensemble (EOF and Kmeans clustering)
5. Projection of the analysis and deterministic forecast in the PC phase space
 - *To achieve extra task 2 you will need the tracking file from extra task 1*
 - *Extra task 4 is in fact an advanced task that may have been done in class*

Bibliography

- Portmann, R., González-Alemán, J. J., Sprenger, M., and Wernli, H.: How an uncertain short-wave perturbation on the North Atlantic wave guide affects the forecast of an intense Mediterranean cyclone (Medicane Zorbas), *Weather Clim. Dynam.*, 1, 597–615, <https://doi.org/10.5194/wcd-1-597-2020>, 2020.
- Kouroutzoglou, J.; Samos, I.; Flocas, H.A.; Hatzaki, M.; Lamaris, C.; Mamara, A.; Emmannouil, A. Analysis of the Transition of an Explosive Cyclone to a Mediterranean Tropical-like Cyclone. *Atmosphere* 2021, 12, 1438. <https://doi.org/10.3390/atmos12111438>