PP-AWARE Task 3.5

LPI verification and correlation of convective events with microphysical and thermodynamical indices

F. Gofa, D.Boucouvala

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HELLENIC NATIONAL METEOROLOGICAL SERVICE

Lightning formation

- The microphysical processes that lead to the formation of precipitation particles are involved in charge separation and the buildup of electric fields in convective clouds.
- The noninductive mechanism, involves rebounding collisions between graupel particles and cloud ice crystals and requires the presence of **supercooled liquid water**
- While the connection between **cloud microphysics** and lightning seems apparent, the common indices used for the potential for lightning mostly rely on stability and **thermodynamical indices**.

Thermodynamical indices for lightning estimation

- **K index (KI)** was developed to assess the potential for severe thunderstorms. It is a combination of the lapse rate (T difference between 850 and 500 hPa), the lower-level moisture content (Td at 850 hPa level), and the moist layer depth, the difference between the T and Td at the 700 hPa level. or KI = 20–25, 50% potential or widely scattered thunderstorms for KI 26–29; 85% potential or numerous thunderstorms for KI =30–35; and 100% (certain) chance for values > 36

$$KI = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700}).$$

- **Lifted index (LI),** an air parcel is lifted from the surface with temperature and mixing ratios representative of the mean layer values of the lowest 100 hPa of the atmosphere. This hypothetical parcel is then lifted dry adiabatically to the lifting condensation level and pseudo-adiabatically to 500 hPa. The value of this index is the temperature of the environment minus the temperature of the parcel at 500hPa. -2 < LI < 0, thunder-storms possible; -4 < LI < -2, thunderstorms more probable, but few, if any severe; and LI <-4, severe thunderstorms possible.

- **Cloud Physics Thunder Parameter (CPTP),** based on evidence for the correlations between the presence of ice in the mixed phase region and the level of electrification. T_{EL} is the equilibrium temperature, $CAPE_{-20C}$ is the CAPE between the 0C isotherm to -20C, and K is a constant with a value of 100 J /kg

$$CPTP = (-19°C - T_{EL})(CAPE_{-20°} - K)/K,$$

- **CAPE (Convective available potential energy)** integrated amount of work that the upward (positive) buoyancy force would perform on a given mass of if it rose vertically through the entire atmosphere. CAPE above 400 J/kg is useful in predicting lightning (Friesbie et al, 2009)

Lightning Potential Index (J/Kg) (Yair et al.2010,JGR)

- Lightning Potential Index (LPI) is a **measure of the potential charge separation** that leads to lightning flashes in convective TSs.

- It is calculated from model simulated updraft and microphysical fields within the charge separation region of clouds between (0 °C and - 20 °C), where the non inductive mechanism involving collisions of ice and graupel particles in the presence of supercooled water is most effective (Saunders, 2008).

- *LPI is defined as the volume integral of the total mass flux of ice and liquid water within the "charging zone" in a developing thundercloud.* The LPI (J kg^{-1}) and is defined as,

$$LPI = \frac{1}{V} \iiint \epsilon\, \omega^2 dxdydz$$

- Where V is the volume of air in the layer between 0°C and -20°C, w is the vertical wind component (m s^{-1}), and q_s, q_i and q_g are the model-computed mass mixing ratios for snow, cloud ice, and graupel respectively (in kg kg^{-1}).€ is a dimensionless number that has a value between 0 and 1 and is defined by,

$$\epsilon = 2(Q_i Q_l)^{0.5} / (Q_i + Q_l)$$

- Where Q_l is the total liquid water mass mixing ratio (kg kg-1)and Qi is the ice fractional mixing ratio (kg kg-1) defined by,

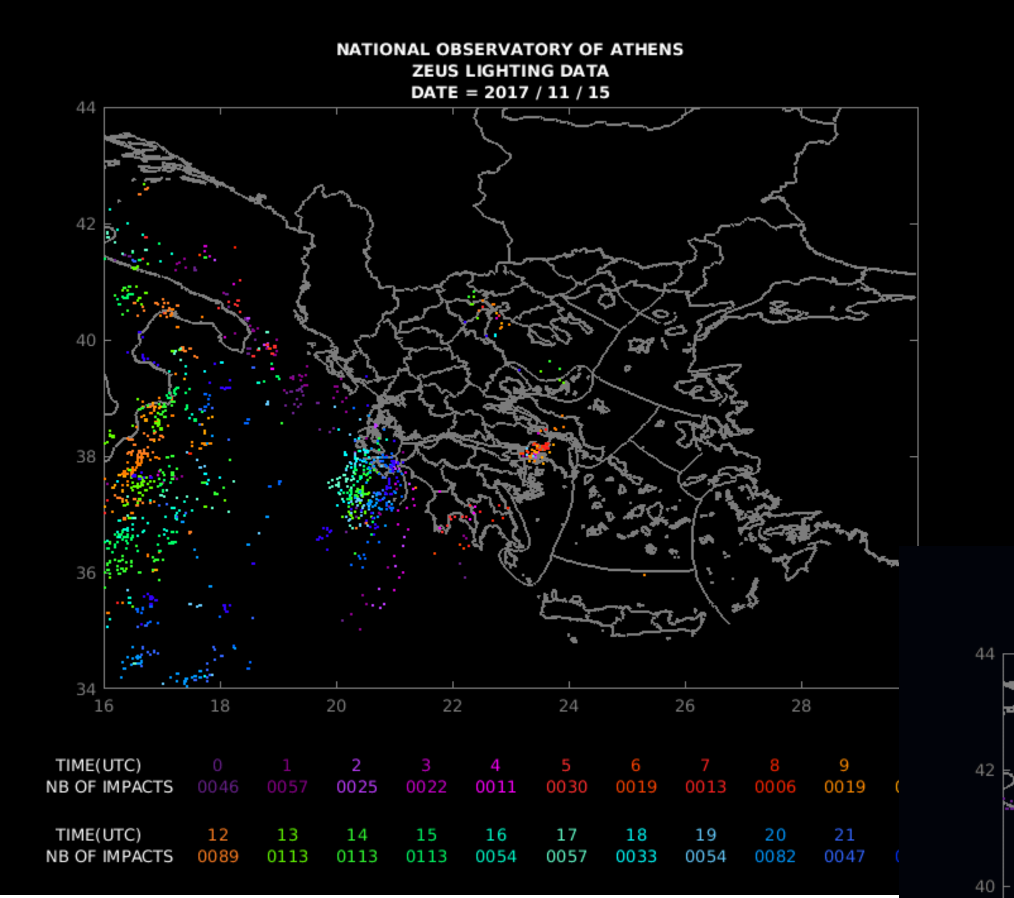
$$Q_i = q_g \left[\left((q_s q_g)^{0.5} / (q_s + q_g) \right) + \left((q_i q_g)^{0.5} / (q_i + q_g) \right) \right]$$

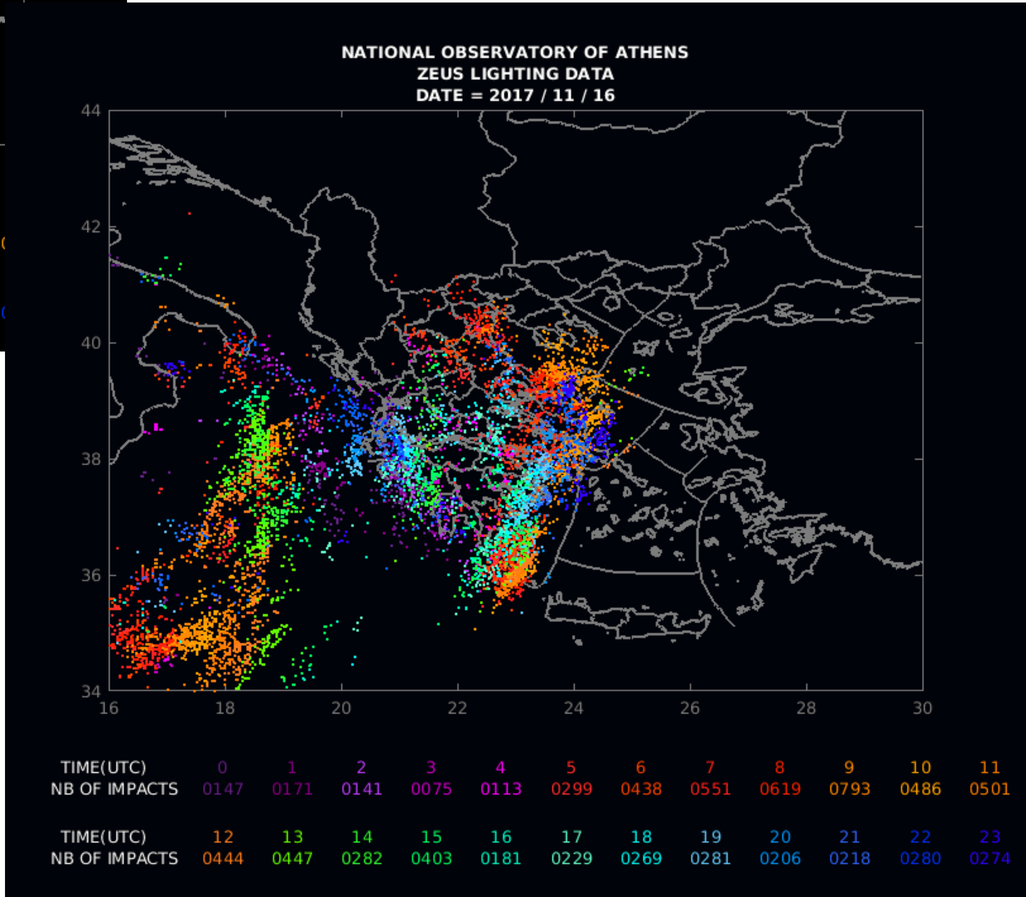
- € is a scaling factor for the cloud updraft and attains a maximal value when the mixing ratios of supercooled liquid water and of the combined ice species (the total of cloud ice, graupel, and snow) are equal.

- Calculation of the LPI from the cloud-resolving atmospheric model output fields can provide maps of the microphysics based potential for electrical activity and lightning flashes.

COSMO model setup

- LPI can only be calculated if you run with the graupel microphysics (itype_gscp=4) or the 2-moment microphysics.
- Results for LPI are only meaningful in convection resolving mode, i.e., deep convection parameterization switched
- off and grid spacing <= 3 km.
- LPI is a column integral involving the square of the vertical velocity and the presence of graupel (=riming process) and other ice hydrometeors at the same locations. It needs explicitly simulated convective cells with realistic updraft speeds.
- COSMO-GR1 simulations were performed with LPI (not a operational product), CAPE, preci_conv. KI to be calculated.





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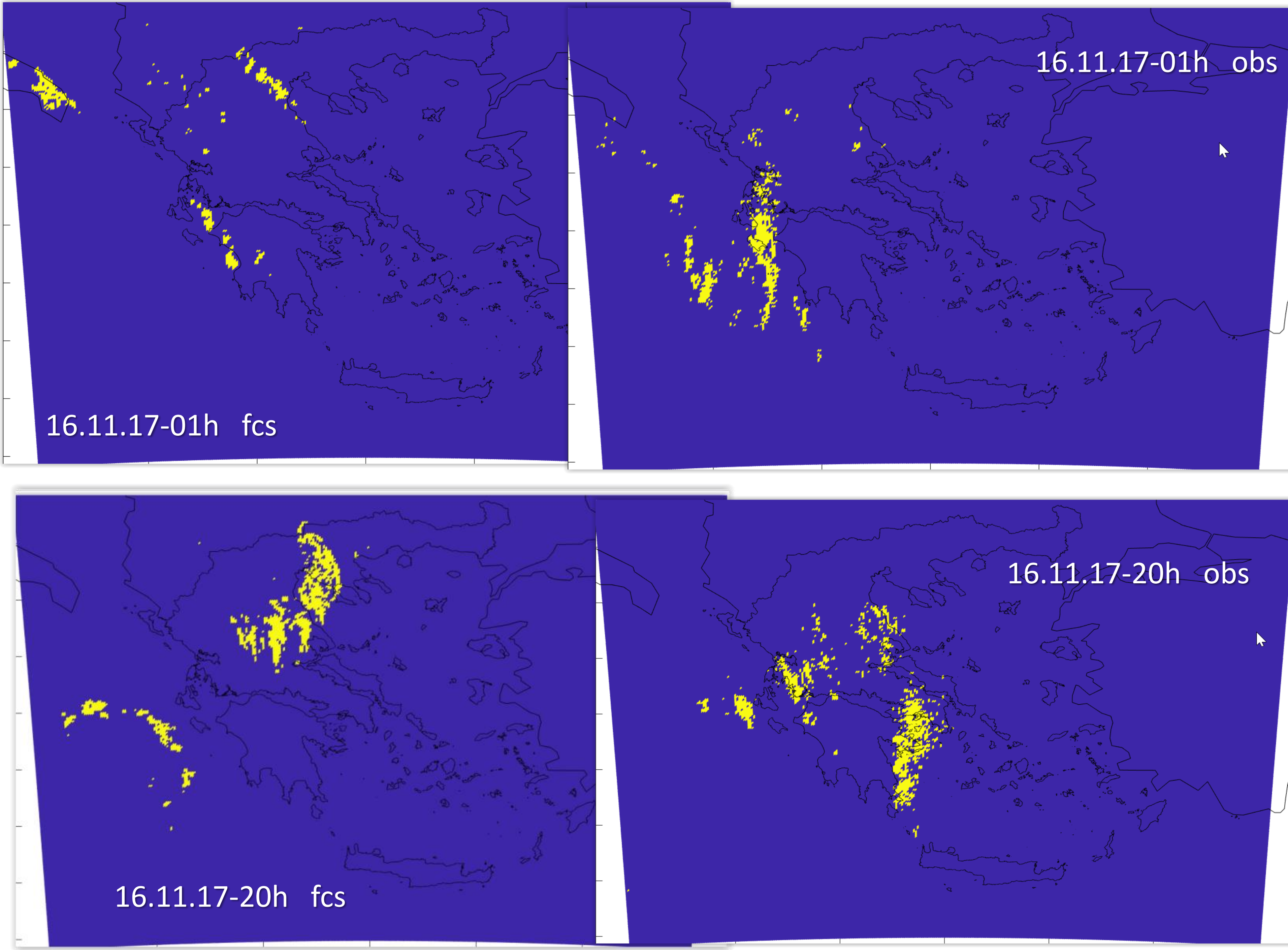
Methodology for fields (fcs-obs) adaptation

Aggregate in 3x3km

- A new grid 0.03x0.03° grid was adopted
- Observations gridding: In the derived 3x3 grid, in a radius of 2.5km around the centre of each grid point, all observations were checked and ia number of 1 was designated when strikes exist, or else a zero value was given.
- **Forecasts grid**: Each grid point of the grid was assigned the **mean** of the 9 grid points of the original grid. Then if the LPI>0.5, then the number 1 was assigned, else the zero.
- Traditional statistics for all grid points/hours (POD, FAR) or Object based methods (SAL?) on accumulated fields will be applied.

COSMO-D2

- LPI_MAX_{3x3} = LPI_MAX in einer 3x3 GP Umgebung
    - Mai – August: $LPI\_MAX_{3x3} > 10^{-3}$ J/kg und RG ≥ 0.0 mm/h
    - März, April, September: $LPI\_MAX_{3x3} > 0.2$ J/kg und RG ≥ 1.2 mm/h
    - Oktober – Februar: $LPI\_MAX_{3x3} > 0.5$ J/kg und RG ≥ 3.0 mm/h


16.11.17-01h fcs
16.11.17-01h obs
16.11.17-20h fcs
16.11.17-20h obs

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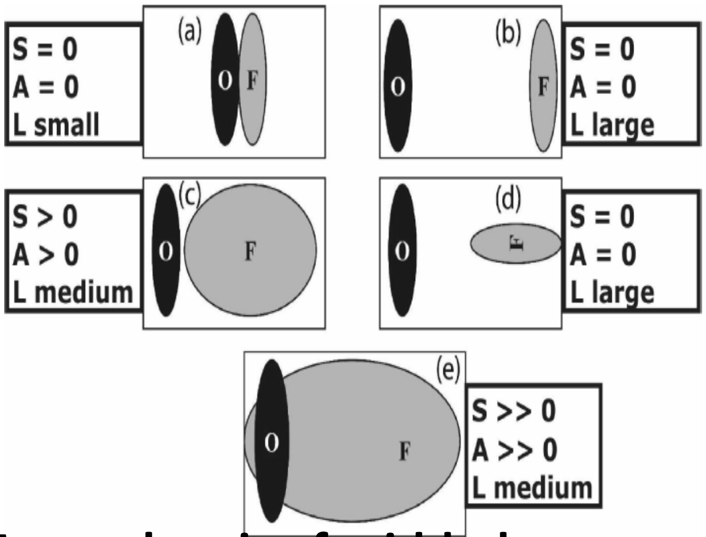
SAL:
Object based verification measure



SAL Method (Wernli et al. 2008, 2009) For each pair of gridded observations/forecast field 3 indexes are calculated.

S: Structure Component (Compares Total Volume of Normalized - Objects of obs/fcst . Captures size and shape of objects) (Values from -2 to 2) S=0 perfect, S >> 0 forecast predicts more widespread pcp , S<< 0 forecast predicts more peaked objects

A: Amplitude Component (Normalized difference of domain-averaged values of forecast and obs field) (Values from-2 to 2) A=0 perfect, A >> 0 forecast overpredicts pcp A<< 0 forecast underpredicts

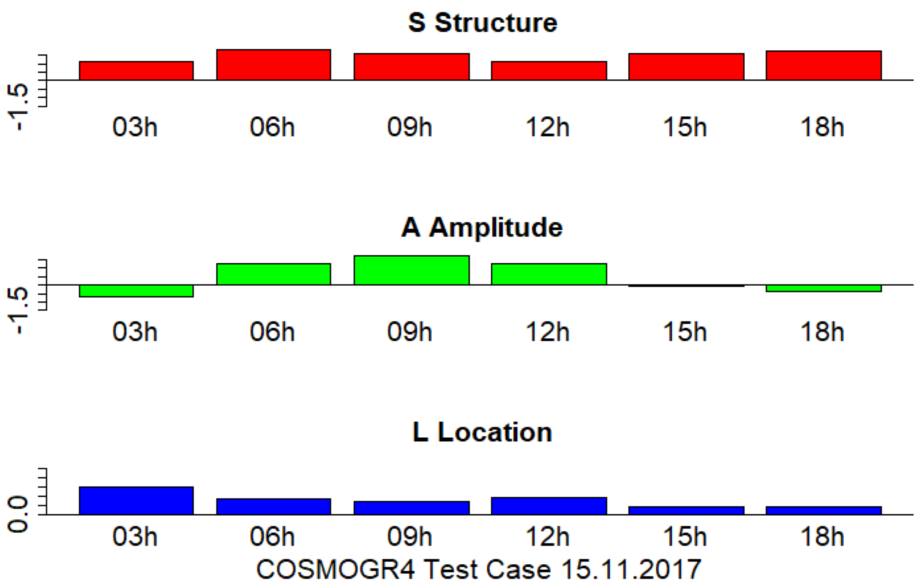
L: Location Component (Consists of L1+L2) (L Values from 0 to 2) (0 perfect)

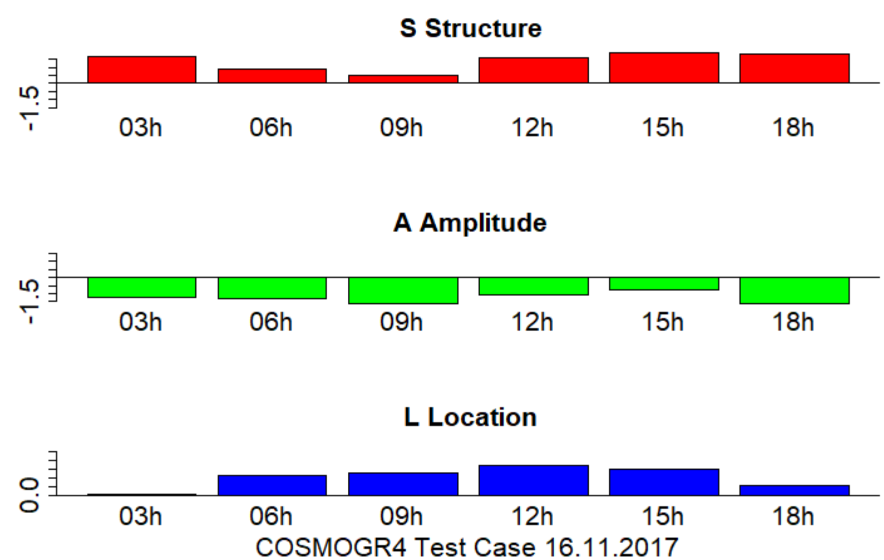
L1 : normalized distance between centers of mass of the obs/fcst fields

L2: difference of normalized distance between center of mass and individual objects over observed and forecast field. **Difference of Scattering of objects**

Preliminary analysis with SAL

Constant threshold R=1 in FeatureFinder





Important factors to reconsider

- Methodology for griding obs
- Methodology for re-griding fcs LPI
- Threshold for LPI that can lead to electricity discharge to be tested
- Verification methodology to apply?
- Calculate KI, CAPE and assess the correlation to lightning appearance
- Repeat steps to more convective cases

Summary of the evaluation of COSMO models at the ESSL Testbed 2016

European Severe Storms Laboratory

- ✓ The lightning potential index produces lightning in most stronger storms, much like observed in observational data. It seems to do what it is meant to do, and no big problems were noted.

- ✓ Forecasters would be able to anticipate lightning activity from other model fields such as modelled reflectivity, i.e. without the LPI. I.e., for forecasters the added value is very small, or not present at all.

- ✓ Probably, the LPI is somewhat better at distinguishing lightning-producing storms than a quantity like reflectivity and this may be of importance to some user groups. Whether this is the case cannot be determined from a small number of cases

VALUE OF LPI for IDENTIFYING LIGHTNING in STORMS?

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Thank you

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