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- PARTICIPANTS: 18 in person, 26 Virtual
- ORGANISATION TYPE:
  - University/Academia
  - Research centres
  - Operational Forecasting centres

1. CURRENT MAIN ML APPLICATIONS IN THE THEMATIC AREA:

a) Emulation of NWP/Climate model parameterisations (hybrid models): ….

b) Estimation and correction of model error (hybrid models)

c) Emulation of full NWP/Climate/Ocean models: FourCastNet, Keisler, Pangu-Weather,…

d) “Weather” generators for eg EnDA and EnFO

e) Data-driven model discovery

f) Efficient retrieval models: $X=F^{-1}(Y)$

   a) Retrieval algorithms, forward operators, observation operators

g) Emulation of extreme events

h) Emulation of smaller scale models (e.g. boundary layer, LES)

i) Downscaling of NWP & climate models

j) NWP & climate model tuning

1. Full data-driven models: e.g. FourCastNet, Keisler Pangu-Weather
    a) Should components be learnt separately? e.g. ocean, land, atmosphere.
    b) How good are these models?
        a) RMSE
        b) Blurry, unrealistic spectrum, limited variability
        c) TC tracks & intensity
        d) Usefulness of a “ensemble-mean” like prediction
    c) How do we judge these models fairly?
        a) Scale aware metrics?
        b) Taking from existing verification, e.g. extreme event testing
        c) Would a forecaster use the product?
        d) Will people still buy ECMWF forecast?
    d) Probabilistic model & training as a route to overcome these difficulties?
    e) What should be our loss function?
        a) GANs or probabilistic skill scores?

2. LIMITATIONS, CHALLENGES and OPPORTUNITIES:

a) Stability
   a) Challenges both in ML training & inference if coupled to NWP.
   b) Application dependent.
   c) Good offline = good online? Convection model learning to use tropospheric humidity, correlation not causation.
b) Speedup
c) Improvement w.r.t. baseline
   a) Train on existing, or train on improved model or observations/hi res data.
   b) Superparametrisation?
d) Ability to generalise? (extrapolation vs interpolation, can we see the difference?)
   a) Is a pig sitting in an avocado chair an extrapolation or an interpolation?
   b) Can ML model uncertainty inform when generalisation failing?
   c) If ML model never shown cat-5 hurricane, can it generate one?
e) Embedding physical constraints, help with all of the above?
   a) Climate invariant scaling/normalisation?
f) Data-driven discovery: are we learning new science?
   a) Few tries/successes thus far.
   b) Can help identify correlations.
g) Probabilistic modelling – GANs, Diffusion, BNN, natural by-product of many ML techniques
h) Model calibration – under explored?
i) Online training.
j) One model to rule them all? Transfer learning or representation learning, will it be the future?
k) Cost of training, how can individuals contribute if large models are the answer? NWP, also true?