ECMWF WCB Workshop

Discussion Group on Predictability (12/3/2020)

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Q. What are the key aspects of WCBs which lead to enhanced forecast uncertainty?

Q. What are the implications for NWP development strategy?

Started discussion online with open questions raised by Heini in the opening talk:

- What determines WCB-jet stream interactions?
  "Sometimes WCBs promote ridge building, sometimes not."

- How often are WCBs involved in forecast busts? **And why?**

- How do WCBs affect ***ensemble reliability***?

- How can observations be used to reduce forecast uncertainty related to WCBs?
  Ensemble sharpness

plus a discussion centering on the dynamical processes behind the "butterflies"
(i.e., lower predictability in situations related to active WCBs)

… and phenomena where misrepresentation by models is expected.

Origins of atmospheric and model sensitivity: i) embedded convection

- Different **types of WCBs** (elevator/escalator, cyclonic/anticyclonic branches):
- Look at climatology of WCB types and diagnose how it relates to rate of ensemble spread.
- Is one WCB type less predictable than another?
- Is the ensemble of analyses greater on some types of WCBs?

- Typical finding *(e.g, Martinez-Alvarado, O., Joos, H. et al (2014), QJRMS):* trajectories entering anticyclonic branch more likely to:
  - Ascend early
  - Ascend rapidly in deep convection (above the cold front)
  - Reach higher altitude where anticyclonic wave breaking is dominant
- Therefore, sensitivity to representation of convection is expected to have large-scale effects

Uncertainty associated with embedded convection

- **Possible ways forward**: Look at what parametrizations are doing versus explicit motion in *several different* convection-permitting models.

- Different *types of convection* in WCBs & ARs. Skeptical if convection scheme captures this.

- What is the impact of resolution (both horizontal and vertical) on WCBs?

- The vertical level of WCB outflow is crucial to subsequent effects (C vs AC breaking as "bifurcation point" for ensemble sensitivity)

- Movement of the tropopause is more effective for amplifying uncertainty.

1. Studies emphasize influence of heating on divergence of outflow and advection of tropopause (ridge expansion)
2. PV dipoles from heating in vertical wind shear $\Rightarrow$ mesoscale jet streaks

- These arise by two distinct mechanisms: diabatic mass transport into outflow (large-scale) and non-advective PV flux (mesoscale and smaller)

Resolution sensitivity/ model numerics

- Non-advective flux creating PV dipoles is not robust across resolution.
- Dynamical core inconsistency is small within WCBs (based on Leo Saffin's work), physical parametrizations dominate.
- Dynamical core choices/numerical diffusion can dominate downstream PV changes.
- With different resolutions you get PV dipoles, but scale is very model dependent.
- Usual 300m-500m vertical resolution is not enough to represent very strong observed wind shears at tropopause (strongest shears occur in the region 1-3PVU).
- Does better resolving this shear have influence on downstream propagation?
- Case studies from NAWDEX: there are small scale (wavelength 20-50km), large amplitude oscillations present in vorticity (within the WCB) that we are not resolving (*e.g., Harvey et al, 2020, QJRMetS*).
- What are they? Have a role in predictability and upscale error growth?
- What is sensitivity to ad-hoc numerical aspects? E.g., the sequence of calls to physics parametrizations?

Ensemble spread and reliability

- Dynamics of error growth are **not** the same as system dynamics *(although the underlying mechanisms are the same – e.g., Baumgart, Riemer et al, 2019)*
- Cases where ensemble spread is higher tend to be linked to high WCB activity.
  - Poor initialization of ensembles or rapid early ensemble spread?
- Highest rate of ensemble spread (Z500) associated with ***diabatic influence on tropopause advection***
- Stochastic physics has a large impact in WCB outflow regions. Biggest analysis error (cf wind lidar obs, Schäfler talk) is also on the western side of WCBs.
- Need to be careful when tuning stochastic physics to spread-error relation (this is a very blunt tool).
- Might help to answer why there are **major differences in spatial distribution of ensemble spread growth rate** between different centres.

Analysis spread and forecast sharpness

- Initial condition sensitivity:
- Errors in the Atlantic can be traced to errors in the pacific (RW breaking).
- Can we distinguish errors that start at the tropopause vs those that propagate from below?
- WCBs with strong outflow at t=0 have much higher ensemble spread than those that do not. Why is this?

- NAWDEX **predictability barriers**. Events with greatest forecast error growth are often preceded by an event with stronger diabatic influence (e.g., Claudio Sanchez talk) (1st system pre-conditioning the state that the high impact system moves into?)
- Need to treat the two events as a pair?
- First storm can degrade background forecast used to create analysis before 2nd event?

New Activities

- **HRES inter-comparison**: to look at specific NAWDEX cases with well-observed WCBs and associated low predictability

- **Purpose** is to compare locations of embedded convection and mesoscale structure in convection-permitting simulations where there are sufficient **obs data resolving mesoscale in both the vertical and horizontal** in wind and humidity variables.
- What phenomena are observed? What is represented? Influence upscale identified?

  IOP3: Vladiana, IOP6-7: Stalactite Cyclone + subsequent frontal cyclone
- Need to get large enough domain in limited area models to capture WCB outflow. ICs same analysis.
- Conduct sensitivity experiments to model formulation (including resolution).
- Need ensembles (for global high res) – perhaps just EDA and short forecasts. Cf operational.
- Write experiment protocol specifying start dates, common diagnostics etc.

- **How is WCB activity expected to change in future climate (higher LHR and wind shear)?**
- Outliers in current ensembles might reflect some aspects of behaviour in the future?
- Statistical emulators for the occurrence of WCB inflow, ascent and outflow could be useful to address climate change question (provided present date climate is not baked into them):
- Learn about limitations of the technique from examination of S2S forecasts
- Could analyze change in WCB frequency and link it to cloud forcing.