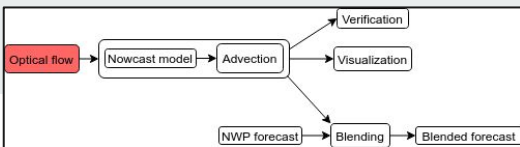# Hands-on session "users"

Introduction

Outline

- The purpose of this session is to give a "hands-on" experience of using pysteps.
- The session is divided into 5 exercise blocks + bonus exercises.
- In the following slides, we give an introduction to the basic pysteps workflow.

Optical flow → Nowcast model → Advection → Verification
Advection → Visualization
Advection → NWP forecast
NWP forecast → Blending → Blended forecast

Optical Flow and Extrapolation

- Advection (optical flow & extrapolation) is the key component of all pysteps nowcasting methods.
- All methods are based on the "Lagrangian persistence" nowcast shown on the right.
- Three different types of optical flow methods have been implemented in the **motion** module:
  - Feature tracking: Lucas-Kanade
  - Variational: VET and Proesmans
  - Spectral: DARTS
- For advection, pysteps implements the backward semi-Lagrangian scheme in the **extrapolation** module.


2016-09-28 15:50:00 +   5 min

Precipitation intensity [mm/h]

160
100
63
40
25
16
10
6.3
4
2.5
1.6
1
0.63
0.40
0.25
0.16
0.08
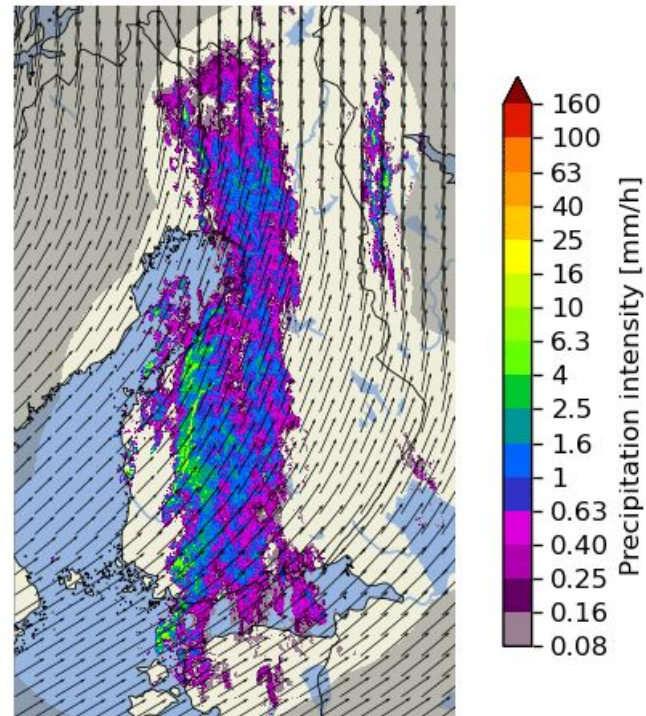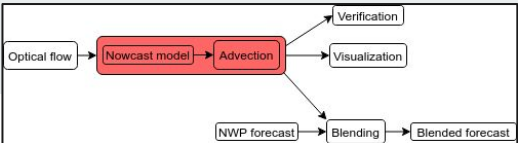
Deterministic Nowcasts

The main methods implemented in the **nowcasts** module:

Method	Pros	Cons	Typical computation time
Extrapolation	very fast	no prediction of growth or decay of precipitation	< 10 seconds
S-PROG	● for low-intensity precipitation (< 1-2 mm/h) has generally the best skill ● choose for stratiform events	inability to preserve the spatial structure of rainfall fields, and particularly convective cells	< 20 seconds
LINDA-D	● the most accurate method for intense precipitation (> 1-2 mm/h) ● choose for convective events	slow to compute	might take several minutes

Extrapolation


S-PROG
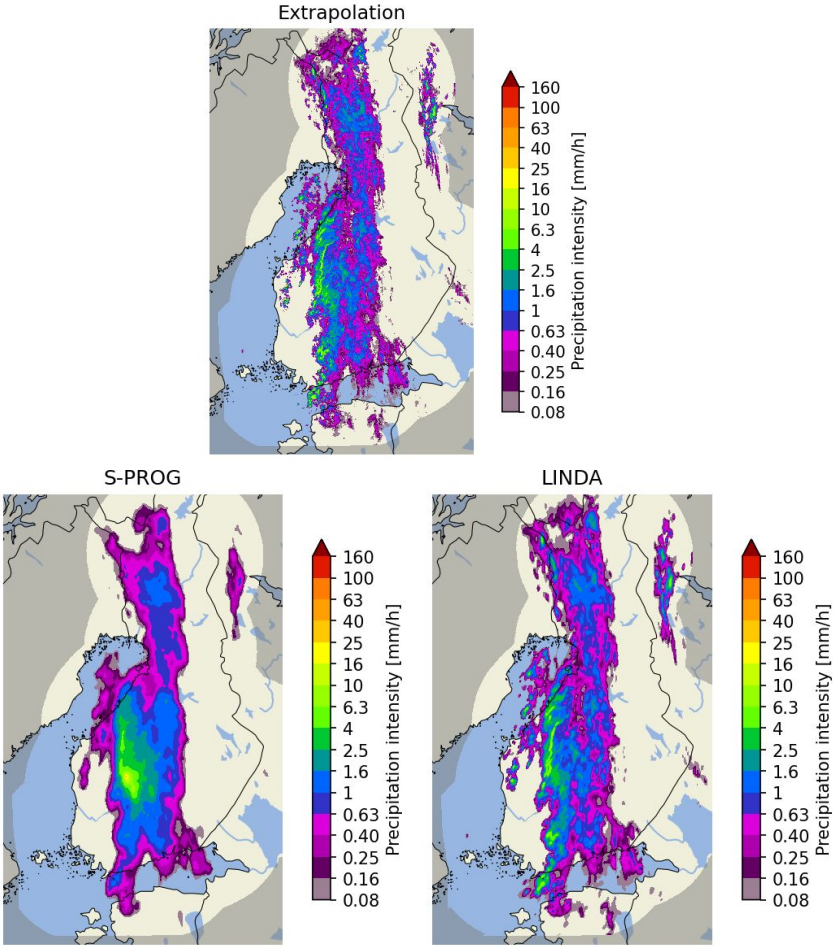
LINDA

Ensemble Nowcasts

- The main ensemble methods implemented in the **nowcasts** module are STEPS and LINDA-P.
- They model two sources of uncertainty: advection field estimation and Lagrangian growth and decay.
- The basic rule for choosing the method:
  - stratiform events: STEPS
  - convective events: LINDA-P
- LINDA-P generally produces more realistic ensemble members.
- Computation times for the 4-member ensembles shown on the right:
  - STEPS: ~20 seconds
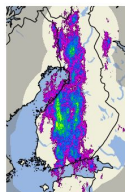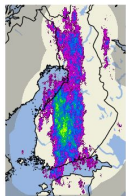 - LINDA-P: ~5 minutes

Observations at
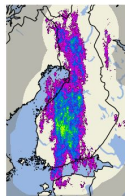2016-09-28 15:50 UTC
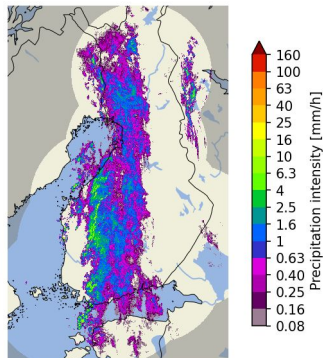
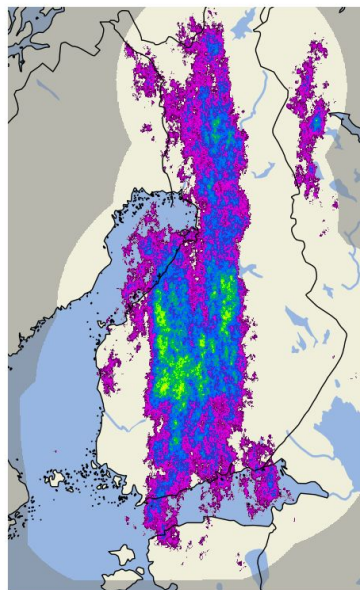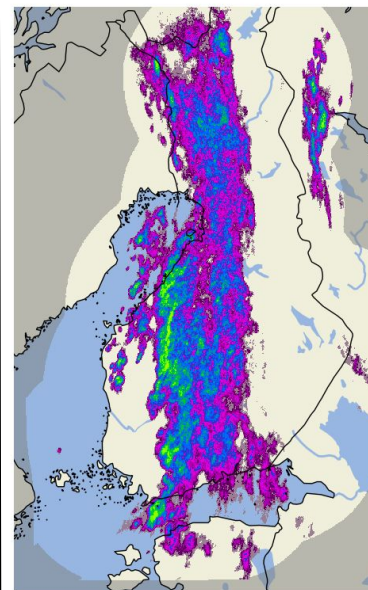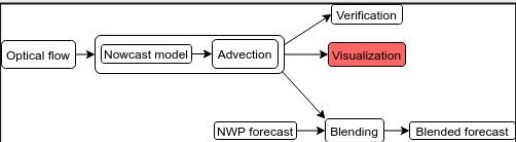Nowcast ensemble
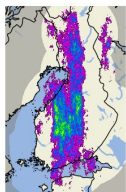
Member 1   Member 2

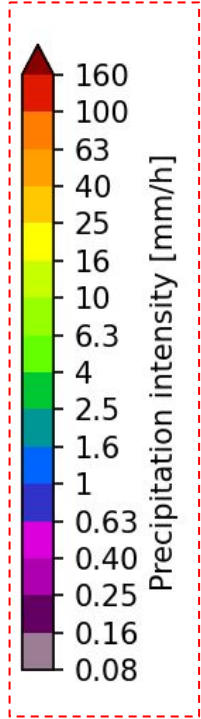Member 3   Member 4

First ensemble members

STEPS   LINDA-P
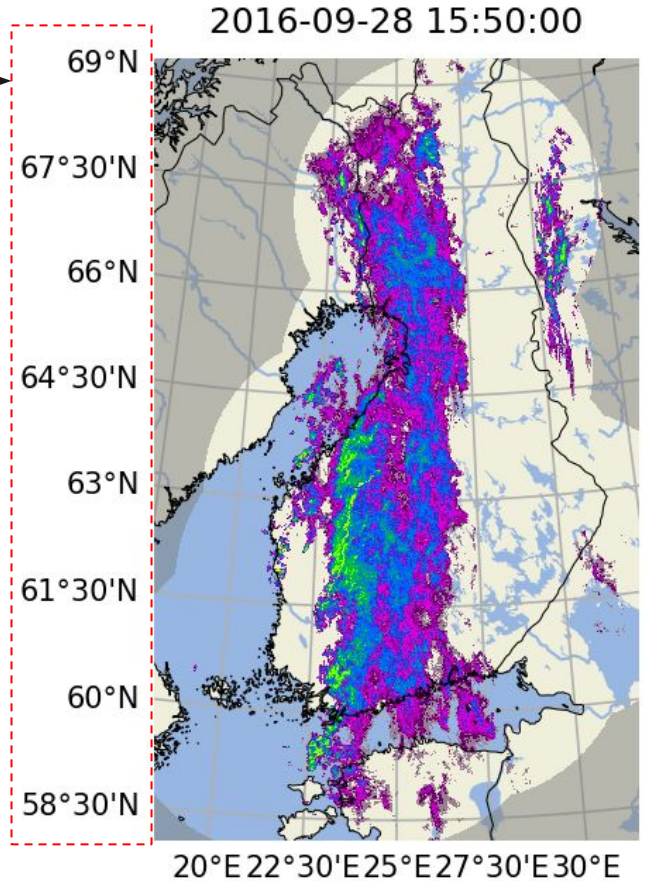
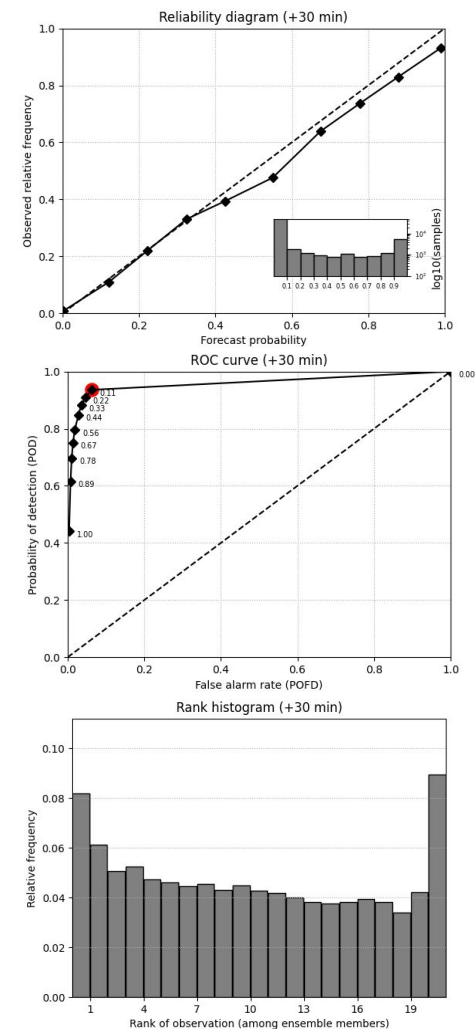Longitude-latitude lines with labels

Visualization tools

- Extensive set of visualization tools has been implemented in the **visualization** module
- Support for multiple layers: basemap, precipitation and motion field
  - Plotting of basemaps by using cartopy
  - Quivers and streamlines for advection fields

2016-09-28 15:50:00

Verification tools / metrics

- A large number of verification utilities and metrics have been implemented in the **verification** module
- Functionality
  - Creation of verification objects and aggregation from multiple nowcasts
  - Plotting of verification results

Metrics

- Deterministic
  - Categorical: CSI, ETS, POD, FAR
  - Continuous: MAE, ME
  - Scale/intensity-based metrics: FSS, intensity-scale
  - Radially averaged power spectral density (RAPSD)
- Probabilistic
  - CRPS
  - Reliability diagram
- Ensemble
  - Spread
  - Rank histogram

Examples of verification plots for 30-minute STEPS nowcasts

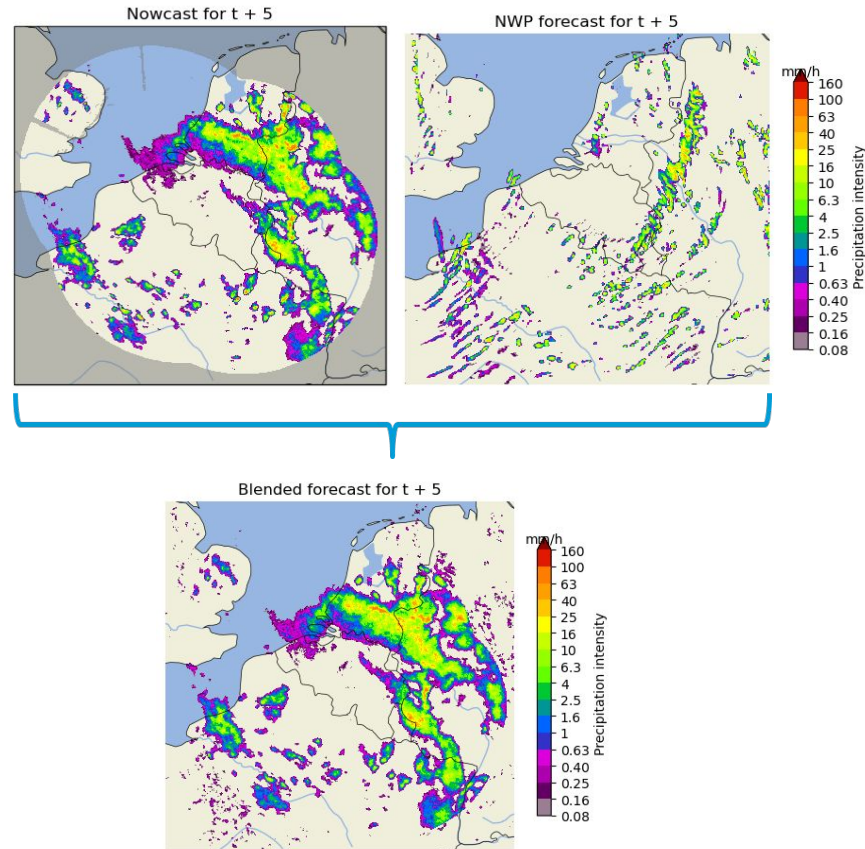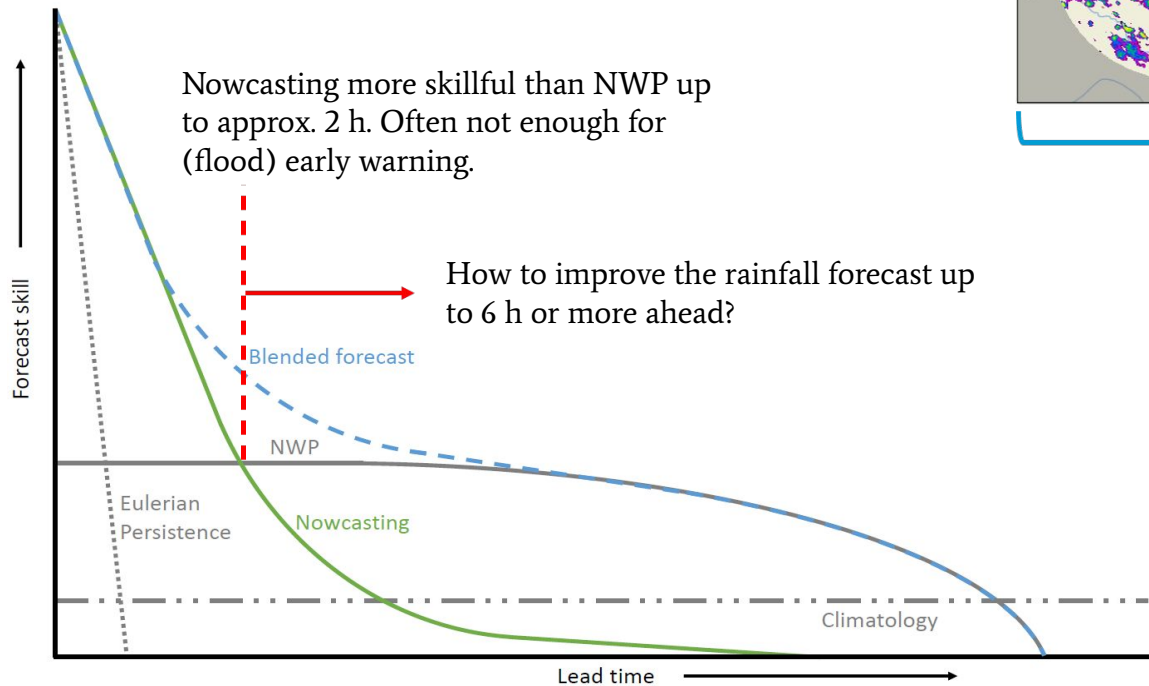Flowchart (top left): Optical flow → Nowcast model → Advection → Verification, Visualization; NWP forecast → Blending → Blended forecast
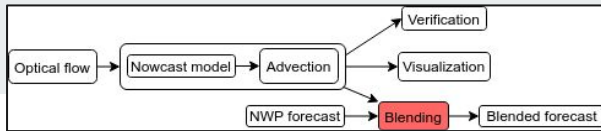
Blending with NWP

Nowcasting more skillful than NWP up to approx. 2 h. Often not enough for (flood) early warning.

How to improve the rainfall forecast up to 6 h or more ahead?

Nowcast for t + 5

NWP forecast for t + 5

Blended forecast for t + 5

Forecast skill vs Lead time graph labels:
- Blended forecast
- NWP
- Eulerian Persistence
- Nowcasting
- Climatology

Precipitation intensity scale (mm/h): 160, 100, 63, 40, 25, 16, 10, 6.3, 4, 2.5, 1.6, 1, 0.63, 0.40, 0.25, 0.16, 0.08
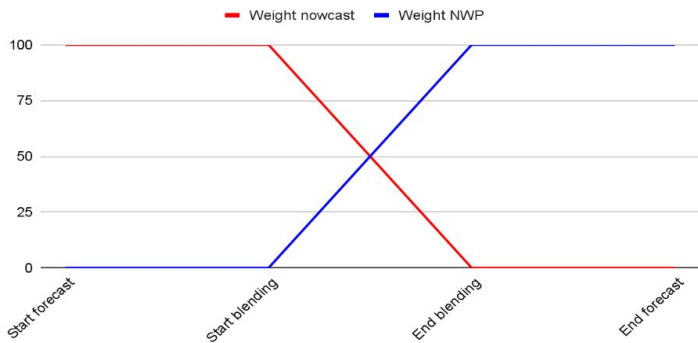
Blending with NWP: methods in pysteps

1. Linear blending

- Fixed start and end point of blending procedure
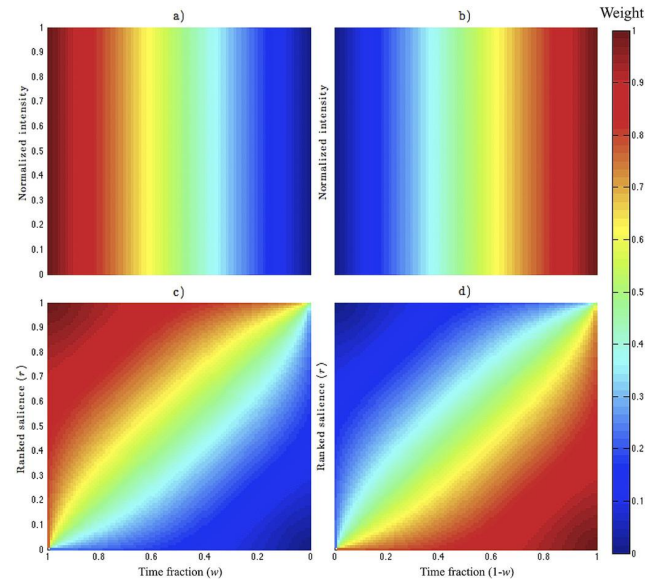- Weights go linearly from 1 to 0 and 0 to 1.

Linear blending weights

2. Saliency-based blending

- Similar to linear blending, but:
- Preserves pixel intensities over time if they are strong enough according to their ranked salience.
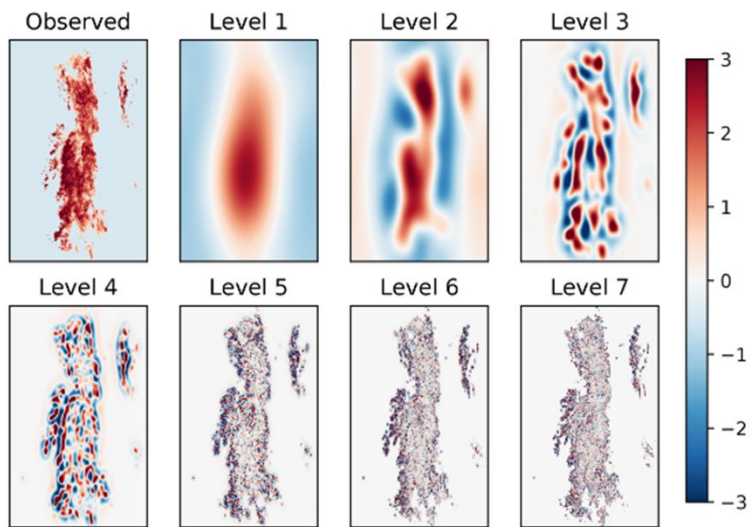
Hwang et al., 2015, Weather and Forecasting

3. STEPS blending (see next slide)

Per ensemble member:

The STEPS method

Pulkkinen et al., 2019

Level 1 **Level 2** **Level 7**

Extrapolated radar obs

$W_1^e \times$ $W_2^e \times$ [...] $W_7^e \times$

+   +   +

NWP

$W_1^n \times$ $+$ $W_2^n \times$ $+[...]+$ $W_7^n \times$

+   +   +

Correlated noise

$W_1^\varepsilon \times$ $W_2^\varepsilon \times$ [...] $W_7^\varepsilon \times$

Blending weights depend on initial and expected future skill