

NOAA

#### Computing Precip Type and Snowfall in NCEP Models



#### Geoff Manikin MEG Webinar 18 November 2021



## Objectives



- Explain the history of precip type algorithms in the NCEP Production Suite
- Discuss the current state of precip type output in the guidance
- Provide overview of snow accumulation products
- Explain why snowfall and precip type products can be inconsistent
- Describe future plans

While this material will be a "refresher" for some of you, we get questions about precip type and snowfall every winter, so it's always good to revisit this





## The Original NCEP Precip Type Algorithm



- Used as the only operational precip type algorithm through 2005, this scheme had many strengths, but it had some very significant known issues
- This scheme predicts **ZR** for this sounding!
- The area check is based on a Tw of -4°C instead of 0, so a sounding with a deep saturated layer between 0 and -4 won't be identified as SN
- This was intentional, to have a high POD for ZR and IP



### **Alternatives**



- Work began ~17 years ago on a revised NCEP algorithm with an area check based on 0°C and a threshold for "warm area" in the profile to eliminate snow as the answer
- Scheme predicted a lot more snow, even too much snow
- There had been a lot of buzz about the well-tested Ramer scheme, so we decided to add that to our testing as well
- When used together with the NCEP algorithm, the two new schemes showed skill at identifying events for which the NCEP algorithm was displaying its high bias for IP/ZR



Low-Leve

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I Temps

#### **Alternatives**



VERIFICATION

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0131/10

0131/04

 In this example, a heavy wet snow fell in Philadelphia

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- The NCEP algorithm predicted ZR, even though the entire column, except for the surface, was below freezing (although it was just barely below freezing in the lower levels)
- The Revised NCEP and Ramer schemes correctly predicted snow

![](_page_5_Picture_0.jpeg)

#### **Dominant Precip Type**

![](_page_5_Picture_3.jpeg)

- Created a mini-ensemble in the post processor of precip type outcomes in 2005
- Used NCEP, revised NCEP, Ramer, Bourgouin all based on Tw profile
- For original NAM implementation, the methodology used "explicit" method based on microphysics as a 5<sup>th</sup> member of the ensemble
  - % of frozen precip first determines RA/ZR vs SN/IP
  - if < 50, determine RA or ZR with skin temperature
  - if > 50, determine IP or SN with ice density (rime factor): > 10 is IP
- Obtained 5 answers and picked the dominant precip type. Broke ties based on favoring "most dangerous" weather

ZR > SN > IP > RA

 Keep in mind that this ensemble approach is capturing the uncertainty associated with how different schemes handle Tw profiles; it does not account in any way for synoptic uncertainty

![](_page_6_Picture_0.jpeg)

**Dominant Precip Type** 

# Dominant Precip Type now used for NAM (including nests), GFS, HiResWs, SREF, and GEFS – not used for RAP/HRRR

 explicit algorithm not used for GFS, GEFS, and all HiResWs due to incompatibility with the microphysics, so those models have only 4 precip type algorithms comprising the dominant precip type

![](_page_7_Picture_0.jpeg)

### **RAP/HRRR**

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- Do not use precip type algorithms
- Determine precip type solely based on the explicit prediction of hydrometeors (snow, rain, graupel) reaching the surface from the Thompson bulk microphysics
- Can get 'yes' answers for multiple types

![](_page_7_Figure_7.jpeg)

![](_page_7_Figure_8.jpeg)

example of zone of multiple types (pink) predicted simultaneously in the RAP

![](_page_8_Picture_0.jpeg)

## **RAP/HRRR**

![](_page_8_Figure_3.jpeg)

Starts by computing snow fraction (fallen snow in past hour / total snow + rain over past hour) to determine potential for S/R/ZR, based on fall rates for rain and snow, amount of rain and snow over previous hour, and 2mT

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 Also checks fall rate for graupel to determine potential for IP, which is also dependent upon fall rates for rain and snow, max rain mixing ratio, and 2mT

![](_page_9_Picture_0.jpeg)

## SREF/GEFS/HREF

- Uses the dominant precip type for all members; all SREF members include the explicit algorithm, but all GEFS members do not
- Ends up with 26 (SREF) / 31 (GEFS) / ~10 (HREF) precip types and computes probs and mean precip type, with tiebreakers based on ZR>SN>IP>RA

![](_page_9_Figure_5.jpeg)

![](_page_9_Figure_6.jpeg)

51127/1800V027 SREF PROB of FRZ RAI 151127/1800V027 SREF PROB of SLEET

![](_page_10_Picture_0.jpeg)

#### **SREF/GEFS**

![](_page_10_Figure_3.jpeg)

![](_page_10_Figure_4.jpeg)

• These are <u>unconditional</u> probabilities

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 They don't add up to 100 at many points, because no type is computed at points at which precip is not falling at the valid time

![](_page_11_Picture_0.jpeg)

#### **HREF Precip Type Probabilities Example**

![](_page_11_Figure_3.jpeg)

![](_page_11_Figure_4.jpeg)

probability

Since the HRRR allows for multiple precip types to be selected at a given point, the HREF (with its HRRR members) can potentially have the sum of all four probabilities exceed 100 at a point

![](_page_12_Picture_0.jpeg)

- Cannot necessarily combine probabilities (probs) for QPF and probs for precip type
- For example, a 50% prob of ZR along with a 50% prob of QPF > 0.5" does not mean a 50% prob of ZR > 0.5"
  - considering the SREF, one could hypothetically have 13 members with 0.01" of ZR and 13 members with 0.55" of RA
  - need to look at individual members

![](_page_13_Picture_0.jpeg)

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#### 4 Main Issues with NCEP Winter Wx Output

- Most of the NCEP models have only a snow water equivalent field and not an actual snow accumulation in inches
- Snow and sleet are tallied together, and there is no attempt to determine whether the snow can actually accumulate
- The precip type and snow water equivalent / snow depth fields can be inconsistent
- Freezing rain (ZR) is the most dangerous winter precip type, and the models (other than RAP/HRRR) do not output a ZR accumulation

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### 4 Main Issues with NCEP Winter Wx Output

![](_page_14_Picture_2.jpeg)

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![](_page_15_Picture_0.jpeg)

- Snow water equivalent output forces the user to apply his/her own snow-to-liquid ratio (SLR) to obtain an actual number of inches of snow
- Many users apply a generic 10:1 ratio which is not representative in many cases
- This leads to overprediction in events with marginal temperatures and underprediction in events with very cold temperatures

![](_page_16_Picture_0.jpeg)

## **Snow Water Equivalent**

![](_page_16_Picture_3.jpeg)

 Complicating things further, the snow water equivalent is tallied by combining snow and sleet, so in an event with sleet as the primary precip type (which usually has a very low SLR), the 10:1 maps show massive totals where they shouldn't

![](_page_16_Figure_5.jpeg)

![](_page_16_Figure_6.jpeg)

![](_page_17_Picture_0.jpeg)

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![](_page_18_Picture_0.jpeg)

## **Snow Water Equivalent**

![](_page_18_Picture_3.jpeg)

- Also complicating things further, the snow water equivalent is computed by multiplying the precipitation by the % of frozen precip (snow ratio) and integrating through the period of interest
- This means that a storm that produces 1 inch of liquid in the model, comprised of 50% raindrops and 50% wet snowflakes, would have 0.5" as the snow water equivalent; this type of event would likely not involve accumulating snow, but a 10:1 map would show 5"
- Even an event with 1 inch of liquid in the model, comprised of 80% rain and 20% sleet, would show 0.2" of snow water equivalent and 2" of snow on a 10:1 map

![](_page_19_Picture_0.jpeg)

## Accumulated Snow Depth

![](_page_19_Picture_3.jpeg)

- The land-sfc model \*does\* determine how well snow can stick and how much it can accumulate; it uses an effective SLR based on snow density, and it accounts for warm ground as well as compacting and melting: product is an instantaneous snow depth
- The MEG has been advocating for users to view the change in accumulated snow depth (depth at forecast hour XX – depth at forecast hour 00) as an alternative to 10:1 map
- The accumulated snow depth works somewhat well, but it struggles in early and late season events with warmer ground; it's also complicated to use, since the value can decrease during the forecast period

![](_page_20_Picture_0.jpeg)

#### **Accumulated Snow Depth**

![](_page_20_Picture_3.jpeg)

#### ACCUMULATED SNOW 10:1

#### ACCUMULATED SNOW DEPTH

![](_page_20_Figure_6.jpeg)

![](_page_21_Picture_0.jpeg)

#### **Accumulated Snow Depth**

#### NAM Nest Example

#### ACCUMULATED SNOW 10:1

NAM) 36-h WEASD (10:1) Init: 0000 UTC 26 Oct 2020 | Fhrs: 12-48 | Val: 0000 UTC 28 Oct 2020

![](_page_21_Figure_6.jpeg)

#### ACCUMULATED SNOW DEPTH

![](_page_21_Figure_8.jpeg)

#### **NOHRSC ANALYSIS**

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36-h NOHRSC Snowfall Analysis (12Z 26 Oct 2020 - 00Z 28 Oct 2020)

![](_page_21_Figure_11.jpeg)

From 2-4-2021 MEG Recap of Southern Plains Ice Storm

![](_page_22_Figure_0.jpeg)

It's challenging to figure out when to examine accumulated snow depth. Here, F24 doesn't capture the full event. By F48, some of the snow has already compacted and melted. A lot of melting has occurred by the end of the run. F36 would be best time in this event to capture the actual snowfall.

#### Accumulated Snow Depth

![](_page_23_Picture_2.jpeg)

![](_page_23_Picture_3.jpeg)

![](_page_23_Picture_4.jpeg)

![](_page_23_Picture_5.jpeg)

![](_page_23_Figure_6.jpeg)

- Accumulated snow depth is available on Tropical Tidbits for several models (**it only tallies positive changes**), and there is a microphysics-based snow accum. plotted for the NAM
- Snow depth and the microphysics-based method nicely cut unrealistic 10:1 totals but can cut them too much
- There is some value in at least viewing them together to determine where the model effectively doesn't support anything close to 10:1 ratios

![](_page_24_Picture_0.jpeg)

#### **GFS Accumulated Snow Depth**

(gfsv16) 36-h SNOD Init: 1200 UTC 26 Oct 2020 | Fhrs: 0-36 | Val: 0000 UTC 28 Oct 2020

![](_page_24_Figure_4.jpeg)

From 2-4-2021 MEG Recap of Southern Plains Ice Storm

![](_page_24_Figure_6.jpeg)

 GFSv16 was running in parallel last winter, so the MEG monitored its snow products

nna

- The GFSv16 accumulated snow depth products tended to run high, compared to observations and compared to other models; the amounts also seemed inconsistent with forecasted vertical profiles
- Closer examination is needed this winter, now that GFSv16 is operational

![](_page_25_Picture_0.jpeg)

#### **HREF Snow Products**

- All HREF snow accumulation mean fields are based off the snow water equivalent field, so any SLR can be chosen in plotting (10:1 is common)
- There are no accumulated snow depth products

![](_page_25_Figure_5.jpeg)

![](_page_25_Figure_6.jpeg)

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![](_page_26_Picture_0.jpeg)

## **HREF Snow Probabilities**

- For snow accumulations, there are probabilities based on neighborhood maximum values (NBMAX - 15 km radius) and probabilities that use the Ensemble Agreement Scale (EAS) which uses a smaller radius when members agree closely and a larger one when they are less similar; the EAS acts as an intelligently-smoothed point probability
- The probabilities are based on water equivalent thresholds, so they're effectively using a 10:1 ratio (i.e. the prob of snow water equivalent > 2.54 mm is effectively the prob of > 1" of snow)

![](_page_26_Figure_5.jpeg)

HREF materials courtesy of Matthew Pyle

![](_page_26_Figure_7.jpeg)

![](_page_27_Picture_0.jpeg)

- Most of our models have only a snow water equivalent field and not an actual snow accumulation in inches
- Snow and sleet are tallied together, and there is no attempt to determine whether the snow can actually accumulate
- The precip type and snow water equivalent / snow depth fields can be inconsistent
- Freezing rain (ZR) is the most dangerous winter precip type, and most of our models do not output a ZR accumulation

![](_page_28_Picture_0.jpeg)

#### Inconsistencies

![](_page_28_Picture_3.jpeg)

![](_page_28_Figure_4.jpeg)

In this example, several inches of snow are predicted in parts of the northeast, even though the dominant precip type over the same period is mostly sleet or freezing rain; (this instantaneous precip type image is representative of the entire 3-hr period)

![](_page_29_Picture_0.jpeg)

#### Inconsistencies

![](_page_29_Picture_3.jpeg)

![](_page_29_Figure_4.jpeg)

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![](_page_29_Figure_6.jpeg)

The percent of frozen precip (right) is in the 40-60 range over NY and New England. That applied to the generally 0.25-0.5" of precip (left) results in snow water equivalent in the 0.10-0.30" range; a 10:1 ratio then becomes 1-3" of snow in 3 hours!

![](_page_30_Picture_0.jpeg)

#### Inconsistencies

![](_page_30_Picture_3.jpeg)

![](_page_30_Figure_4.jpeg)

The change in accumulated snow depth (right) is at least a huge improvement over the 10:1 map (left); actual snow accumulations ended up quite light

![](_page_31_Picture_0.jpeg)

#### **RAP/HRRR**

![](_page_31_Figure_3.jpeg)

The RAP/HRRR have an explicit snow accumulation field; the SLRs were "enhanced" in the last upgrade

![](_page_31_Figure_5.jpeg)

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The SLR can run high, so the RAP/HRRR amounts can often be considered a potential upper bound

![](_page_32_Picture_0.jpeg)

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#### 4 Main Issues with NCEP Winter Wx Output

![](_page_32_Picture_2.jpeg)

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![](_page_33_Picture_0.jpeg)

## **No ZR Accumulation**

![](_page_33_Picture_3.jpeg)

- Only the RAP/HRRR have an accumulated freezing rain and accumulated sleet (added in 2018)
- The field has been asking for these parameters in all of our models for years
- Some sites plot their own ZR accumulations, but they have to try to combine instantaneous precip type with longer-period QPF leading to large overpredictions

![](_page_33_Figure_7.jpeg)

![](_page_34_Picture_0.jpeg)

#### **HRRR Accumulations**

Example of HRRR output from the October 2020 Southern Plains ice storm

From 2-4-2021 MEG Recap of Southern Plains Ice Storm

![](_page_34_Figure_5.jpeg)

IRRR) 36-h ASNOW Init: 1200 UTC 26 Oct 2020 | Fhrs: 0-36 | Val: 0000 UTC 28 Oct 2020

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![](_page_34_Figure_7.jpeg)

![](_page_35_Picture_0.jpeg)

#### **Future Plans**

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- All of our models should have QPF outputs parsed into accumulations for snow (directly output in meters, not as a liquid equivalent), freezing rain, and sleet – we are moving in that direction
- There are plans to update the post processor to generate precip type from information in the model microphysics to make the snow fields and precip type information consistent
- These recommendations build upon existing capabilities of the RAP/HRRR system which will be exported into the RRFS, so the major effort here will be to expand these capabilities into the global system
- A potential move to Thompson microphysics in GFSv17/GEFSv13 would likely make the process even easier
- Product coordination will be complicated

![](_page_36_Picture_0.jpeg)

![](_page_36_Picture_2.jpeg)

## **THANK YOU!**

![](_page_36_Picture_4.jpeg)

geoffrey.manikin@noaa.gov