Fire Danger Forecasts

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1. Introduction

Predicting the influence of weather on fire ignition and spread is an operational requirement for national and global fire planning by the National Interagency Coordination Center (NICC), which is the nation's support center for wildland firefighting. NICC is home to seven federal agencies including the Bureau of Land Management, National Park Service, Fish and Wildlife Service, and Bureau of Indian Affairs, all in the Department of the Interior; and the Forest Service, in the Department of Agriculture. NICC's Predictive Services produces national wildland fire outlook and assessment products at weekly to seasonal time scales. This is currently done by considering standard National Weather Service seasonal forecast products of temperature and precipitation (see Brown *et al.* 2003) along with other indicators, and carefully exercised human judgment.

By contrast, nowcasts of fire danger potential at individual locations have been carried out for decades at individual station locations using the US Forest Service (USFS) National Fire Danger Rating System (NFDRS; Deeming and others 1977). This process has been automated and implemented nationwide, resulting in web-based displays of the NFDRS indices. The NFDRS explicitly describes the effects of local topography, fuels and weather on fire potential. Fuel moisture models relate moisture content to cumulative precipitation, precipitation extent and variation, temperature, and relative humidity. These fire danger nowcasts are updated almost daily, but they only allow fire managers to react to the current weather and climate conditions, rather than plan for the upcoming fire season.

The goal of this work was to assess whether the NFDRS indices could also be forecast with a state of the art dynamical seasonal prediction model in the hopes that automatic seasonal forecasts could eventually be developed for NICC predictive services. Again, official NWS forecasts are only issued for temperature and precipitation. Forecasts for a number of more fire relevant variables, such as relative humidity, and wind speed, are still experimental and in many cases the fire community has had to empirically adapt to the official NWS forecasts of temperature and precipitation.

As described previously by Roads *et al.* (2001*a,b*, 2002, 2003*c,d*; Chen *et al.* 2001;), as part of this effort, the Scripps Experimental Climate Prediction Center (ECPC) has been routinely making experimental, near real-time, long-range dynamical forecasts since Sept. 27, 1997 of a number of additional variables relevant to fire danger forecasts. Images from these forecasts are regularly shown on the worldwide web (WWW) site (http://ecpc.ucsd.edu/; Roads *et al.* 2003*c*).

The global model is a version of the National Centers for Environmental Prediction's (NCEP's) global spectral model (GSM; Kalnay *et al.* 1996; Roads *et al.* 1999) used for the NCEP/NCAR reanalysis. With the GSM forecasts as boundary conditions a higher resolution regional spectral model (RSM; Juang *et al.* 1997) is also run for various regions (US, SW, CA, BZ; see e.g. Roads *et al.* 2003*a,b*) to provide increased geophysical detail. The initial conditions and SST boundary conditions for these experimental global forecasts come from the NCEP Global Data Assimilation (GDAS) 00UTC operational analysis, which is available nearly every day in near real time on NCEP rotating disk archives, to interested researchers. Transforming NCEP's higher-resolution operational global analyses to lower (vertical and horizontal) resolution initial conditions for the global model, 7-day global and regional forecasts are made every day and every weekend these global and regional forecasts are extended to 16 weeks.

ECPC's experimental forecasts are certainly not superior to official forecasts from NCEP, which use not only similar dynamical models (ECPC models are actually older fixed versions of NCEP's constantly improving models), but also take into account other climatic features that are not yet adequately represented in any dynamic model, (i.e. various climatic trends, tropical teleconnections, innate human forecast experience, etc.). However, the documented skill of our dynamical system (e.g. Roads *et al.* 2001) does seem to at least be comparable to official forecasts, which indicates that these experimental forecasts may at least be a useful research tool for developing various forecast applications.

We have therefore attempted to develop experimental forecasts of the National Fire Danger Rating System (NFDRS; Burgan 1988) in order to augment current USFS nowcasts from station observations and current seasonal forecast output of only temperature and precipitation. Basically, since our dynamical models have demonstrated some skill for forecasting various meteorological variables like temperature, relative humidity, and mean wind speed at seasonal time scales, we wish to determine whether the perceived meteorological forecast skill can carry over to forecasts of fire danger and whether the federal fire agencies should develop a more comprehensive seasonal fire danger forecasting capability. Encouragingly, Roads *et al.* (2001 *a,b*) did show that a simplified measure of fire danger, namely the Fosberg (1978) Fire Weather Index (FWI) was capable of being predicted at seasonal time scales, mainly because of the inherent predictability of relative humidity, which is a significant component of the FWI, and as we shall see, other NFDRS indices.

2. Results

As shown in **Fig. 1**, summertime (ensemble mean of seasonal forecasts initialized in May, June, July) fire danger is certainly greatest in the US West, with the ER emphasizing the Northwest forests, the IC and BI emphasizing the dry Southwest, and the SC emphasizing the Rocky Mountain Front Ranges. The FWI is similar to the SC, in part because of the wind speed influence, which is strong east of the Rocky Mountains and in part because the FWI assumes grass as the fuel model everywhere, which may result in greater fire spread. There is also some influence on the FWI by the relative dryness of the southwest. Again this dryness is also present in the IC, BI and KB although, variations in the KB and FWI are not well correlated. Presumably the higher resolution features of the standard NFDRS indices (IC, BI, ER, SC) are related to the higher resolution fuel characteristics embedded in these indices. In fact, the FWI can have remarkably high variations over the adjacent ocean (not shown), due to the higher wind speeds, which is another limitation associated with its use (a basic assumption of the FWI is an implicit grassland fuel model everywhere). Finally, as shown in **Figs. 1*g,h***, the NFDRS indices do have an overall relationship with fire counts, CN, and burned acres although it is clearly not a one to one relationship. Fire counts tend to be especially large over Oregon, northern Idaho, and Arizona, which are also related to the acres (log) burned.

The seasonal forecast has a number of seasonal biases (not shown). The SC forecasts tend to be too extreme in the region of Great Plains high wind speed, and this is also reflected in the FWI, which also has biases along the West coast. All indices have bias over Texas, which is presumably related to a bias in the forecast RH. For the most part the biases are positive but some negative biases do show up in the KB over the US West and East. The SC and FWI also have low biases over Montana and Wyoming. However, the biases are somewhat smaller than the climatological values and thus seasonal forecast climatologies have a high resemblance to the validating seasonal climatologies.

At seasonal time scales, the US West is relatively better predicted (**Fig. 2**). Unfortunately, since the seasonal biases are greater than the standard deviations of seasonal averages, it is mandatory that some bias correction must be made for the forecasts. Here, this bias correction was implicit since the correlations use only the anomalies from the forecasts or validations. Again, a separate climatology was developed for each forecast lag. Interestingly, the forecast correlations are not greatest where the means or SD are greatest and may be more related to where the skill in making the forecasts of basic meteorological variables, like relative humidity is greatest.

As shown in **Fig. 3** the correlation of the validation NFDRS indices with the acres burned (AC) is somewhat spotty but certainly significant in specific regions, which have their greatest skill in somewhat different regions. For example, the FWI tends to be most useful over Nevada and Idaho, whereas the KB is more useful over the 4 corners area. These correlations are substantially reduced for the forecast correlations (not shown), which have a tongue of high correlation over northern CA, NV, OR, and ID.

3. Summary

During the past decade seasonal forecasts have certainly become more commonplace, although making an explicit connection to the fire danger community has been typically lax. Instead it is commonly assumed that forecasts of standard monthly mean temperature and precipitation should be made and that applications communities would somehow adapt to using these monthly means. Here we have shown that it is quite possible to make the forecasts compatible with what the fire applications community needs (daily time series of a few critical variables (e.g. temperature, relative humidity, wind speed, precipitation) in order to drive fire danger models.

As was shown, there was probably significant seasonal forecast skill for all of the standard fire danger ratings (IC, BI, ER, KB, SC) as well as the FWI, which had previously been used to assess fire danger forecast skill. Persistence forecasts were also shown and while these forecasts are somewhat inferior to the dynamical forecasts, they did indicate that indices with longer persistence were better predicted at seasonal time scales. These seasonal fire danger forecasts had significant skill even for 1-month forecast leads (12 week averages of weeks 5-16). It would be of interest to determine the forecast skill for one season lead (e.g. out to 7 months), although this would mean a substantial increase in computer time and storage (almost double) in order to produce these ultra long-rang forecasts.

It was further shown that the fire danger indices are related to fire statistics such as fire counts and acres burned, especially when the validating rather than forecast output was used. Still, the relationships are weak and further improvements should be possible. In fact, fire danger indices are now evolving toward making use of more remotely sensed vegetation characteristics instead of trying to parameterize these relationships from complex averaging of meteorological input. In this regard, the experimental Fire Potential Index (FPI), first investigated in 1996 at the U.S. Forest Service (USFS) Intermountain Fire Sciences Laboratory, and then refined in collaboration with USGS EROS Data Center (EDC) is a major augmentation to standard USFS fire danger indices (Burgan and others 1998). The FPI model combines Relative Greenness derived from the normalized difference vegetation index (NDVI) data derived from NOAA AVHRR data to generate 1-km resolution fire potential maps on a daily basis. One potential advantage for this index is that fire danger could potentially be assessed for other regions, where good fuel models do not currently exist.

Finally, although NFDRS indices are widely used by the USFS and other agencies (NIFC) to guide decisions involving fire danger, it should be emphasized that the fire danger rating of an area is only one imperfect tool to assess “fire business” decisions. The emphasis is on imperfect because fire danger rating information is not a final answer by itself; it must be considered along with the manager’s local knowledge of the area and consequences of a decision when arriving at the best solution for a particular problem. Given the current low forecast skill, seasoned experienced judgment remains a critical aspect of fire danger forecasts.

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Further details are described in Roads *et al*. (2003*d*).

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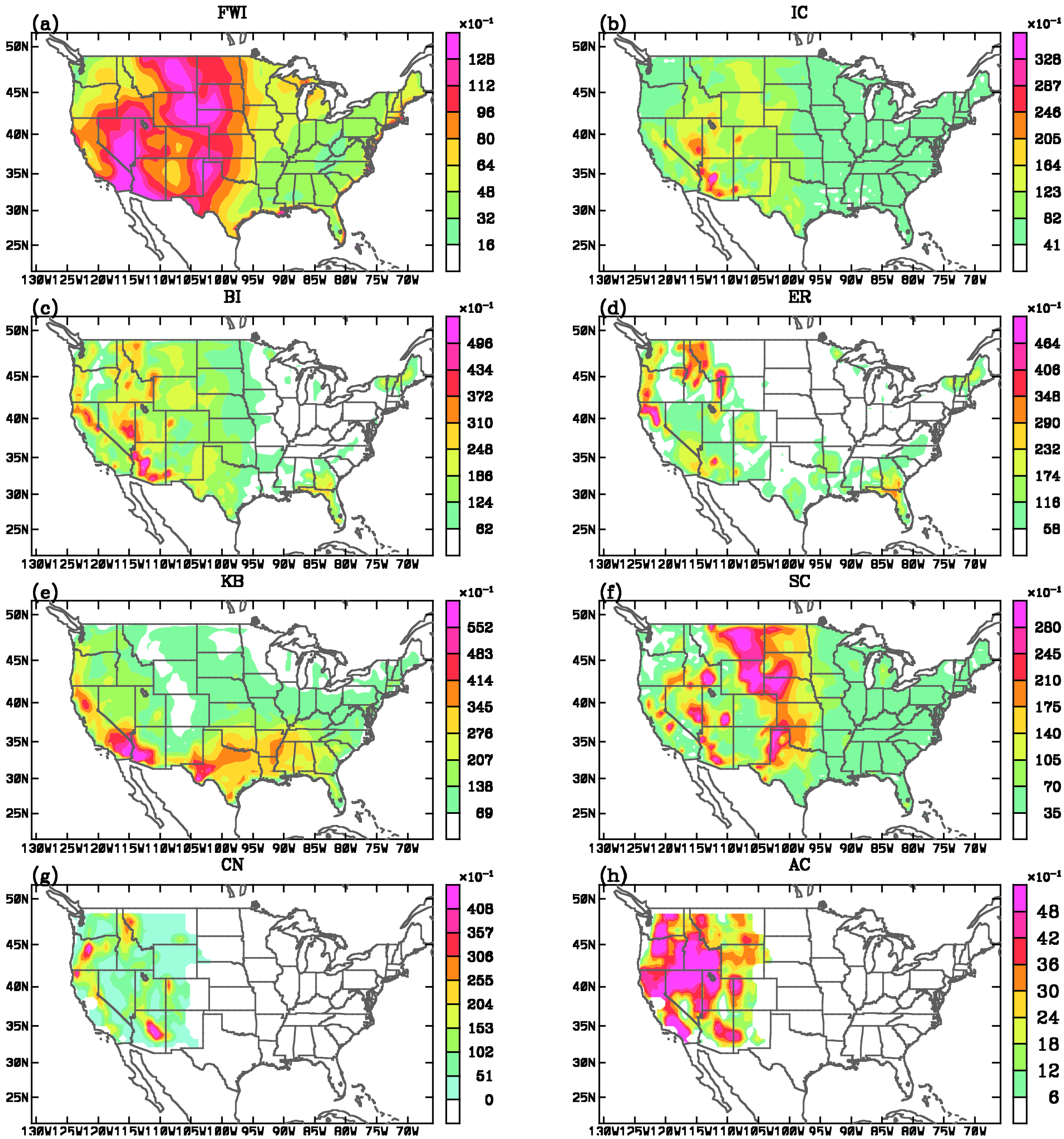

Fig. 1 Summer seasonal mean validation means: (a) FWI; (b) IC; (c) BI; (d) ER; (e) KB; (f) SC; (g) CN; (h) AC.

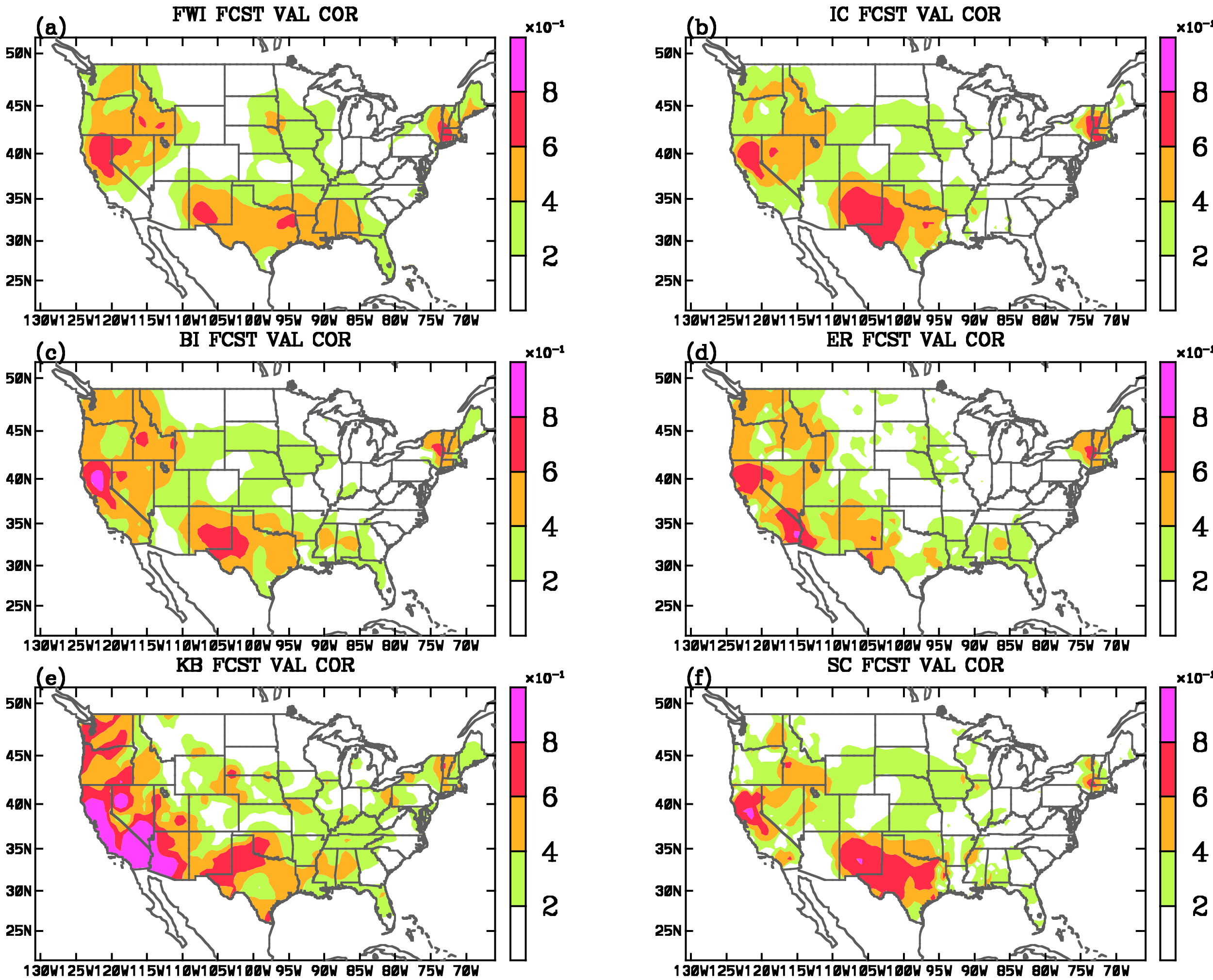

Fig. 2 Summer seasonal mean correlations between forecast and validation (a) FWI; (b) IC; (c) BI; (d) ER; (e) KB; (f) SC.

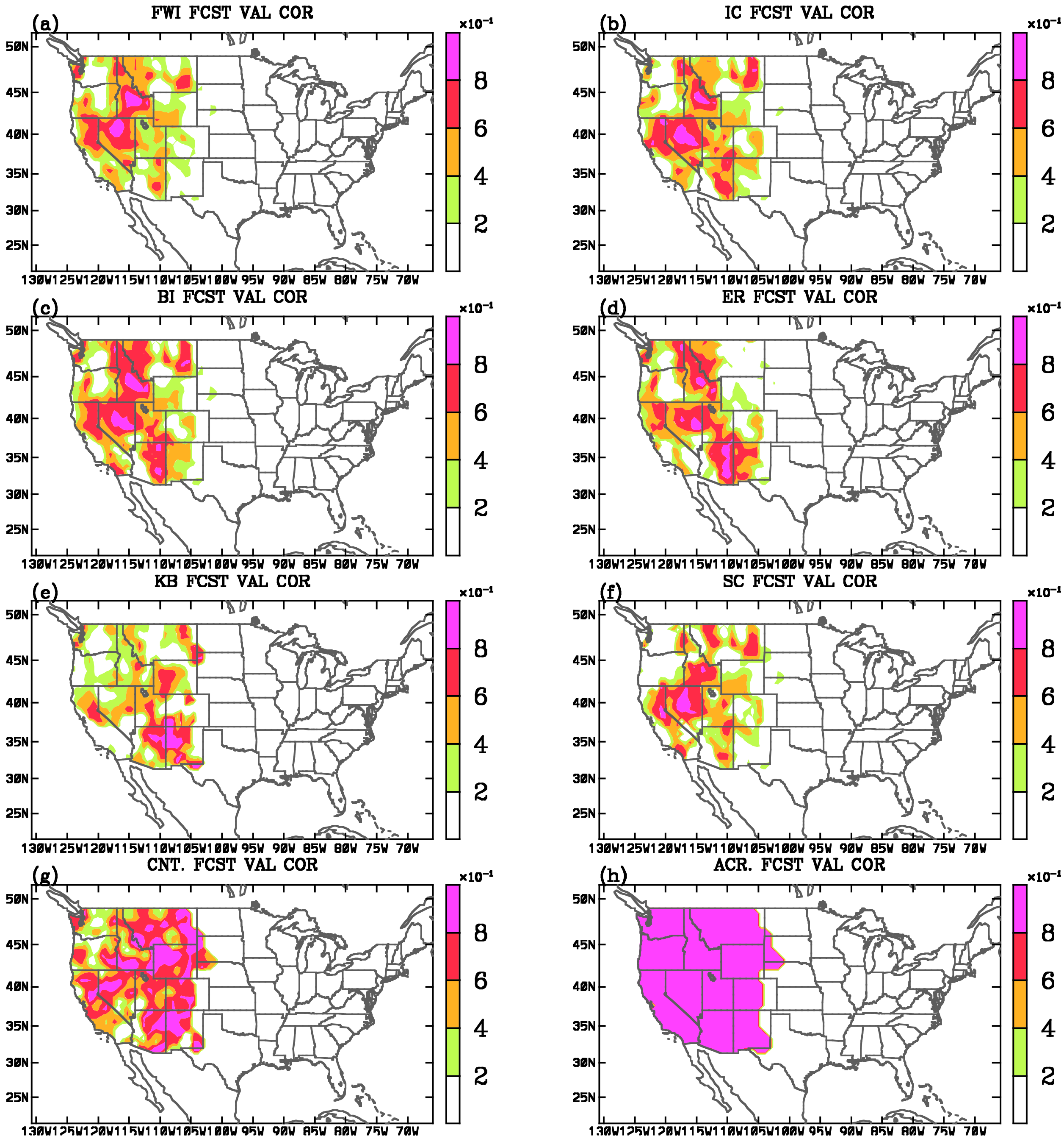

Fig. 3 Summer seasonal mean correlations between validation NFDRS indices, CN and AC, with AC: (a) FWI; (b) IC; (c) BI; (d) ER; (e) KB; (f) SC; (g) CN; (h) AC.